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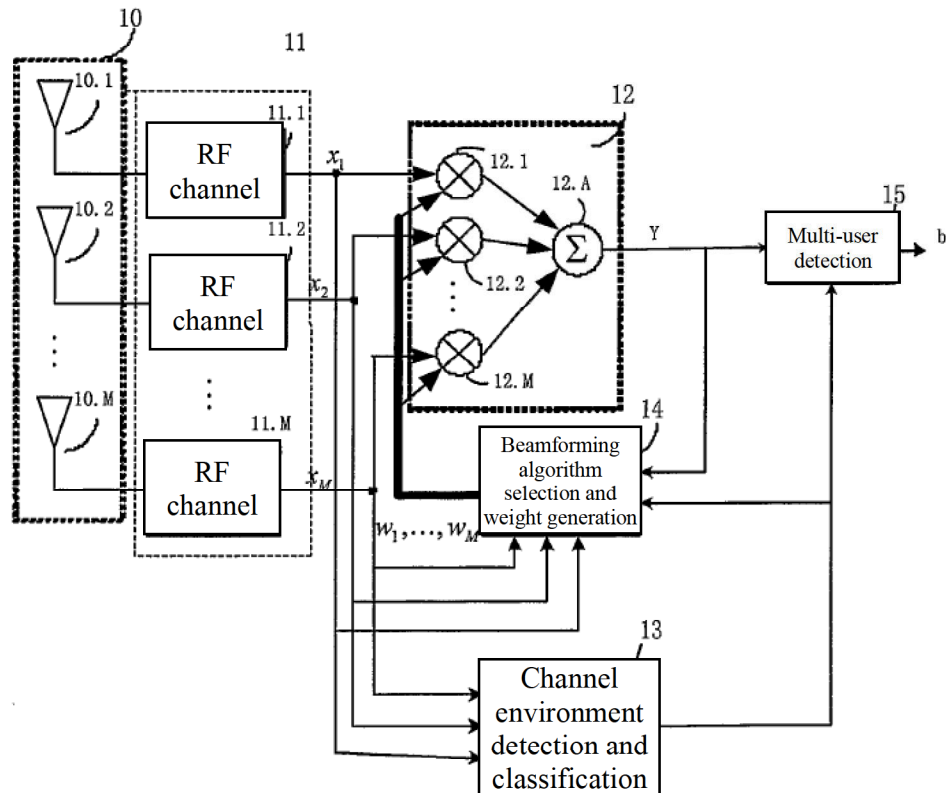
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(54) Title: A METHOD AND EQUIPMENT FOR REALIZING SMART ANTENNA IN WCDMA SYSTEM

(54) Title: METHOD AND DEVICE FOR REALIZING SMART ANTENNA OF WIDEBAND CODE DIVISION MULTIPLE ACCESS SYSTEM



(57) Abstract: A method and equipment for realizing smart antenna in WCDMA system are disclosed, the equipment comprises array antenna, RF channel module, beamforming module, channel environment detection and classification module, beamforming algorithm selection and weight generation module. After processing the signals received by the antenna in RF channels, the base-band array data X which contains multi-components is obtained, estimating and identifying the channel environment according to the features of said array data, and determining current channel type of the channel; selecting corresponding adaptive beamforming algorithm immediately based on the identification result of the channel type, so as to calculate up-link weight W containing multi-components; multiplying said array data X and weight W so as to form the beam Y . The invention could employ corresponding adaptive beamforming algorithm based on the channel environments, thus could restrain interference effectively under various channel environments.

(57) Abstract: The present invention discloses a method and device for realizing a smart antenna of a wideband code division multiple access system, comprising an array antenna, a radio frequency channel module, a beamforming module, a channel environment detection and classification module, and a beamforming algorithm selection and weight generation module. After processing a signal received by an antenna array in a radio frequency channel to obtain baseband array data X containing multiple components, a

channel environment is estimated and identified according to the characteristics of the array data to determine the channel type to which the channel currently belongs; next according to an identification result of the channel type, the corresponding adaptive beamforming algorithm is selected in real time to calculate an uplink weight W containing multiple components; the array data X and the weight W are multiplied and summed to form a beam Y . The present invention can adopt the corresponding adaptive beamforming algorithms according to different channel environments, and can effectively suppress interference in various channel environments.

**METHOD AND DEVICE FOR REALIZING SMART ANTENNA OF WIDEBAND CODE
DIVISION MULTIPLE ACCESS SYSTEM**

Technical Field

The present invention relates to a smart antenna technology for a Wideband Code Division Multiple Access (WCDMA) system in the field of communications, and more particularly to a method and device for realizing a smart antenna in a Wideband Code Division Multiple Access system.

Background Art

In a Wideband Code Division Multiple Access (WCDMA) communication channel, in addition to additive white Gaussian noise (AWGN), there exist various types of interference under different environments, and the design of the receiver must consider suppressing these interferences. In an ideal AWGN environment, a matched filter despreaders (or correlative despreaders) can be used. In the presence of multipath interference, the commonly used approach is the Rake multipath diversity despreading receiver, which requires estimation of multipath delays and amplitudes. In channels with narrowband interference, a common method is to add an adaptive prediction filter before the matched filter to estimate the narrowband interference and achieve separation from the wideband spread-spectrum signal. In a WCDMA system with multiple access interference, multi-user detection receivers have received significant attention. Such a receiver is composed of a set of matched filters combined with a multi-user detector, the most typical being the decorrelating multi-user detector, which has linear complexity and optimal near-far effect suppression capability. Its drawback is that it requires various information about all interfering users (such as pseudo-codes, timing, phase, etc.).

The aforementioned methods for suppressing various interferences are typically performed independently. However, in practice, we often encounter the following two situations: 1) We may not know which interference environment we will be in, and the parameters of the interference are unclear; 2) Sometimes multiple types of interference may coexist. In such cases, a receiver capable of suppressing one type of interference may not function properly when faced with another type of interference or a channel environment where multiple interferences exist simultaneously. There is also an approach that combines a narrowband interference notch filter, a

Rake receiver, and a decorrelating multi-user detector, but its drawback is that the receiver becomes extremely complex and may even be impractical to implement.

Herein we first discuss the baseband model of the received signal for BPSK-modulated DS/CDMA in a complex channel environment, where spread-spectrum modulation and multipath effects are modeled using FIR filters. The system experiences multiple access interference, multipath interference, narrowband interference, and additive white Gaussian noise.

There are k users in the system, with each user's data sequence being $d_k(n) \in \pm 1$, where c_k and h_k are the coefficients of the FIR filters. The filter c_k performs the spread-spectrum modulation function, with its input being $d_k(n)\delta(n-T_b)$, let $c_k = [c_{k,0}, c_{k,1}, \dots, c_{k,N-1}]^T$ represent the spread-spectrum pseudo-code sequence of the k -th user, with values of ± 1 , then the impulse response of the filter equals this spread-spectrum pseudo-code sequence c_k , h_k represents the effect of multipath interference. Assuming the multipath delay is an integer multiple of the chip period T_c , let $\tau_k T_c$ denote the direct path delay of the k -th user; suppose the maximum number of multipath components is L , the delays of each path for the k -th user are respectively:

$\tau_k T_c, (\tau_k + 1)T_c, \dots, (\tau_k + L - 1)T_c$, and the fading coefficient thereof is expressed as a vector

$h_k = [h_{k,0}, h_{k,1}, \dots, h_{k,L-1}]^T$. For users with fewer than L multipath numbers, some elements in h_k are zero.

Assume user 1 is the desired user, and $\tau_k > \tau_1, (k = 2, \dots, K)$, let

$$m_{k,l} = \text{int}[(\tau_k + l - \tau_1) / N]$$

$$q_{k,l} = \tau_k + l - \tau_1 - N \cdot m_{k,l}$$

The two equations above indicate how many data symbol periods the l -th path of the k -th user is delayed relative to the direct path of the 1st user, where $m_{k,l}$ is the integer part and $q_{k,l}$ is the remainder.

If narrowband interference is not considered, the received signal vector can be expressed as

$$\begin{aligned} x[n] = & h_{1,0}d_1(n)c_1 + \sum_{l=1}^{L-1} [h_{1,l}d_1(n-m_{1,l}-1)cf_{1,l} + h_{1,l}d_1(n-m_{1,l})cb_{1,l}] \\ & + \sum_{k=2}^K \sum_{l=0}^{L-1} [h_{k,l}d_k(n-m_{k,l}-1)cf_{k,l} + h_{k,l}d_k(n-m_{k,l})cb_{k,l}] + z(n) \end{aligned}$$

$$cf_{k,l} = [c_{k,N-q_{k,l}}, c_{k,N-q_{k,l}-1}, \dots, c_{k,N-1}, 0, \dots, 0]_{1 \times N}^T,$$

$$\text{Where } cb_{k,l} = [0, \dots, 0, c_{k,0}, c_{k,1}, \dots, c_{k,N-q_{k,l}-1}]_{1 \times N}^T$$

In the equation, the first term represents the direct path signal of the desired user, the second term represents the multipath interference caused by the desired user, the third term represents multiple access interference, and the multipath interference caused by multiple access users can be equivalently treated as multiple access interference, which is equivalent to (k-1) terms of multiple access interference. The fourth term represents additive white Gaussian noise interference.

Typically, in a WCDMA system base station, the receiver mainly employs correlation reception or Rake reception techniques, both of which are single-user processing methods. From an information theory perspective, the WCDMA system is a multiple-input multiple-output channel, and single-user detection cannot fully exploit the channel capacity. Multi-user detection can fully utilize the time-domain information of multiple user signals, such as codewords, amplitudes, timing, and delays, thereby significantly reducing multipath and multiple access interference. Smart antenna technology, based on adaptive antennas and high-resolution array signal processing techniques, makes it possible for the receiver to capture spatial-domain information of multi-user signals. This spatial-domain information includes parameters such as the angle of arrival of the signal, the number of signals, the polarization form of the signals, and the relative phase relationships of the signals.

To fully exploit the characteristics of the signal in both the spatial and temporal domains, it is necessary to perform joint space-time processing on the signal. Methods of joint space-time processing include those based on certain space-time optimization criteria and those based on certain structural characteristics. To make full use of various methods in different environments, space-time processing can be integrated into a software-defined radio architecture, where joint space-time signal processing is implemented through software, constructing a generalized joint space-time processing approach suitable for a variety of channel environments.

The currently adopted adaptive smart antennas, such as those disclosed in Chinese Patent 01132304 (A Fully Adaptive Smart Antenna Receiving Device) and Chinese Patent 01131993 (A Smart Antenna Receiving Method and Device), can continuously update weight according to certain criteria based on changes in the spatial distribution characteristics of the signal. Both the

1 amplitude and phase of the weight can be freely updated. When the update algorithm converges,
2 this method can fully exploit the spatial characteristics of the desired user signal and interference
3 signals, maximizing the signal-to-interference-plus-noise ratio of the received signal.

4 However, the practical application of adaptive smart antennas still faces several key
5 technical challenges that need to be addressed. Among them, the computational complexity and
6 robustness of adaptive beamforming algorithms are some of the difficulties constraining the
7 development of adaptive antennas. In real-world communications, channel conditions are highly
8 complex and time-varying. Relying on a single adaptive beamforming algorithm makes it
9 difficult to achieve good performance across various environments. In the aforementioned
10 patents related to adaptive smart antennas, some only propose the functional implementation of
11 the system without specific methods, while others propose algorithms with application
12 environments that have certain limitations. This is one of the fundamental reasons why, despite
13 numerous patents and studies in this field, no WCDMA adaptive smart antenna products have
14 emerged so far.

16 **Summary of the Invention**

17 The technical problem to be solved by the present invention is to propose an
18 implementation method for a broadband code division multiple access system smart antenna,
19 which can adopt a corresponding adaptive beamforming algorithm according to different channel
20 environments, and achieve effective suppression of interference in various channel
21 environments. The present invention also provides a smart antenna device that can implement the
22 method.

23 To solve the above technical problem, the present invention provides a method for
24 implementing a smart antenna in a wideband code division multiple access system, comprising
25 the following steps:

26 (a) processing a signal received by an antenna array in a radio frequency channel to
27 obtain baseband array data containing multiple components;

28 (b) estimating and identifying a channel environment based on characteristics of the array
29 data, and determining a current channel type to which the channel belongs according to a preset
30 channel type determination rule;

1 (c) selecting in real time a corresponding adaptive beamforming algorithm based on an
2 identification result of the channel type, and calculating an uplink weight; and

3 (d) multiplying and summing the array data with the uplink weight to form a beam.

4 Furthermore, the above implementation method may further have the following features:
5 in the channel type determination rule, the channel types are classified into the following three
6 types or any combination thereof: a first type, dominated by additive Gaussian white noise
7 interference, where the environment is far from a base station, a signal power is weak, and a
8 noise is strong; a second type, dominated by co-channel interference, where the environment is
9 affected by co-channel interference from other cells; and a third type, dominated by inter-symbol
10 interference, where the environment experiences severe inter-symbol interference due to large
11 delay differences among multipath components.

12 Furthermore, the above implementation method may further have the following features:
13 the channel type determination rule determines the channel type based on eigenvalues of a
14 correlation matrix of the array data and an in-band power spectrum deviation, and the
15 determination rule comprises the following three rules or any combination of at least two of the
16 following rules:

17 if the number of effective eigenvalues = 1 and the in-band power deviation is small, it is
18 the first channel type;

19 if the number of effective eigenvalues = 1 and the in-band power deviation is large, it is
20 the second channel type; and

21 if the number of effective eigenvalues > 1 and the in-band power deviation is small, it is
22 the third channel type.

23 Furthermore, the above implementation method may further have the following features:
24 in step (c), when selecting the corresponding adaptive beamforming algorithm based on the
25 identification result of the channel type, the following three rules or any combination of at least
26 two of the following rules are followed:

27 for the first channel type dominated by additive Gaussian white noise interference, a
28 maximum ratio combining beamforming algorithm is used;

29 for the second channel type dominated by co-channel interference, an improved constant
30 modulus beamforming algorithm is used; and

1 for the third channel type dominated by inter-symbol interference, an improved cascaded
2 feedback beamforming algorithm is used.

3 Furthermore, the above implementation method may further have the following features:
4 after step (d), the method further comprises step (e): selecting in real time, based on the
5 identification result of the channel type, the corresponding multi-user detection algorithm to
6 process data after beamforming, thereby completing differentiation of users.

7 Furthermore, the above implementation method may further have the following features:
8 in step (e), when selecting the corresponding multi-user detection algorithm based on the
9 identification result of the channel type, the following four rules or any combination of at least
10 two of the following rules are followed:

11 for the first channel type dominated by additive Gaussian white noise interference, a
12 multi-user detection method based on minimum mean square is used;

13 for the second channel type dominated by co-channel interference, a decorrelation
14 detection method is used; and

15 for the third channel type dominated by inter-symbol interference, a parallel interference
16 cancellation method is used.

17 Furthermore, the above implementation method may further have the following features:
18 in the channel type determination rule set in step (a), a fourth channel type is further determined:
19 the fourth channel type is characterized by multiple interferences and noise, where the
20 environment is a complex communication environment with strong noise, co-channel
21 interference, and inter-symbol interference, a corresponding determination condition is: the
22 number of effective eigenvalues > 1 , and the in-band power deviation is large; in step (c), when
23 selecting the corresponding adaptive beamforming algorithm based on the identification result of
24 the channel type, a pilot-assisted beamforming algorithm is used for the fourth channel type.

25 Furthermore, the above implementation method may further have the following features:
26 after step (d), the method further comprises step (e): selecting in real time, based on the
27 identification result of the channel type, the corresponding multi-user detection algorithm to
28 process the data after beamforming, thereby completing differentiation of users, and for the
29 fourth channel type characterized by multiple interferences and noise, a partial multiple access
30 interference cancellation method is used as the multi-user detection algorithm.

1 Furthermore, the above implementation method may further have the following features:
2 after step (e), the method further comprises step (f): calculating a downlink weight based on the
3 obtained uplink weight.

4 The present invention further provides a smart antenna device for a wideband code
5 division multiple access system, comprising: an array antenna, a radio frequency channel
6 module, and a beamforming module that weight and combines individual single-channel signals
7 to form a beam, characterized in that the smart antenna device further comprises a channel
8 environment detection and classification module and a beamforming algorithm selection and
9 weight generation module, where:

10 the channel environment detection and classification module is configured to estimate
11 and identify a channel environment based on characteristics of baseband array data output from a
12 radio frequency channel, determine a current type of the channel, and output a result to the
13 beamforming algorithm selection and weight generation module; and

14 the beamforming algorithm selection and weight generation module is configured to
15 select a corresponding beamforming algorithm based on an identification result of the channel
16 type, and calculate a new uplink weight based on a feedback of a beamforming signal and the
17 array data, and then send the new uplink weight to the beamforming module.

18 Furthermore, the above smart antenna device may further have the following features: the
19 smart antenna device further comprises a multi-user detection module configured to select a
20 corresponding multi-user detection algorithm based on the identification result of the channel
21 type, process the beamforming signal, and complete differentiation of users.

22 Furthermore, the above smart antenna device may further have the following features: the
23 channel environment detection and classification module further comprises: an eigenvalue
24 calculation unit, configured to calculate eigenvalues of a correlation matrix of the array data and
25 count the number of effective eigenvalues; an in-band power spectrum deviation calculation unit,
26 configured to estimate a power of each channel of array received signals and calculate an in-band
27 power spectrum deviation; and a channel type determination unit, configured to identify,
28 according to the set determination rule, the current type of the channel based on the number of
29 effective eigenvalues and the in-band power spectrum deviation.

30 Furthermore, the above smart antenna device may further have the following features: the
31 channel type determination unit, when identifying the current type of the channel based on the

number of effective eigenvalues and the in-band power spectrum deviation, follows any combination of the following 3 rules or at least 2 of the rules:

if the number of effective eigenvalues = 1 and the in-band power deviation is small, it is the first channel type, and this channel type is predominantly affected by additive Gaussian white noise interference, located in an environment far from the base station, with weak signal power and strong noise;

if the number of effective eigenvalues = 1 and the in-band power deviation is large, it is the second channel type, and this channel type is predominantly affected by co-channel interference, located in an environment subject to co-channel interference from other cells; and

if the number of effective eigenvalues > 1 and the in-band power deviation is small, it is the third channel type, and this channel type is predominantly affected by inter-symbol interference, located in an environment where severe inter-symbol interference exists due to large delay differences among multipath components.

Furthermore, the above smart antenna device may further have the following features: the multi-user detection module, when selecting the corresponding multi-user detection algorithm based on the identification result of the channel type, follows the following 3 rules or any combination of at least 2 of the rules:

for the first channel type predominantly affected by additive Gaussian white noise interference, a multi-user detection method based on minimum mean square is adopted;

for the second channel type predominantly affected by co-channel interference, a decorrelation detection method is adopted; and

for the third channel type predominantly affected by inter-symbol interference, a parallel interference cancellation method is adopted.

Furthermore, the above smart antenna device may further have the following features: the channel type determination unit, when identifying the current type of the channel based on the number of effective eigenvalues and the in-band power spectrum deviation, also follows the following rule:

if the number of effective eigenvalues > 1 and the in-band power deviation is large, it is the fourth channel type, and this channel type involves multiple types of interference and noise, located in a complex communication environment with strong noise, co-channel interference, and inter-symbol interference; and

1 the multi-user detection module, when selecting the corresponding multi-user detection
2 algorithm based on the identification result of the channel type, adopts a partial multiple access
3 interference cancellation method for the fourth channel type.

4 From the above description, it can be seen that the present invention adopts adaptive
5 beamforming algorithms of smart antennas suitable for different channel types, and compared
6 with existing adaptive beamforming algorithms, it has many advantages:

7 First, by analyzing the characteristics of the communication channel, a relatively suitable
8 beamforming algorithm is selected accordingly, thereby enabling the smart antenna base station
9 to have broader adaptability, avoiding the limitations of a single specific adaptive beamforming
10 algorithm.

11 Second, adopting beamforming algorithms and multi-user detection algorithms based on
12 software-defined radio technology, the algorithm switching is simple, the computation is fast, the
13 difficulty of hardware implementation is reduced, it is easy to engineer, and it facilitates the
14 upgrading and maintenance of the base station system.

15 Third, the algorithm can track the direction of arrival (DOA) of the user, adaptively
16 adjust the weight vector, form the maximum beam direction in the direction of arrival of the
17 desired user, and create a null in the direction of interfering users, effectively suppressing the
18 impact of interference.

19 Fourth, the use of partial multi-user interference cancellation reduces both the
20 computational load and buffer space of the system, while also avoiding system performance
21 degradation due to inaccurate estimation of weak multiple access interference components,
22 resulting in better system stability.

23 In summary, the smart antenna system implemented using the method provided by the
24 present invention, under the condition of relatively low hardware costs, greatly improves the
25 performance-to-price ratio of the smart antenna base station system, facilitates engineering
26 implementation, and significantly enhances the processing performance of the smart base station.

27 **Brief Description of the Drawings**

28 FIG. 1 is an example diagram of an actual communication environment.

29 FIG. 2 is a structural diagram of a smart antenna device according to an embodiment(s)
30 of the present invention.
31

1 FIG. 3 is a flowchart of a method according to an embodiment(s) of the present
2 invention.

3 FIG. 4 is a flowchart of the wireless communication environment detection and channel
4 identification shown in FIG. 3.

6 **Preferred Embodiments of the Present Invention**

7 This embodiment distinguishes four different channel types based on the varying wireless
8 communication environments, as shown in FIG. 1: The first type is dominated by additive white
9 Gaussian noise interference, where the environment is far from the base station, the signal power
10 is weak, and the noise is strong. The second type is dominated by co-channel interference, where
11 the environment is affected by co-channel interference from other cells, impacting system
12 performance. The third type is dominated by inter-symbol interference, where the environment
13 experiences severe inter-symbol interference due to large delay differences among multipath
14 components. The fourth type involves multiple interferences and noise, where the environment is
15 a complex communication setting with strong noise, co-channel interference, and inter-symbol
16 interference. Of course, other classifications can also be used, and the present invention is not
17 limited thereto.

18 This embodiment determines the channel type based on the eigenvalues of the correlation
19 matrix of the array-received signals and the in-band power spectrum deviation. For different
20 types of channels, it employs beamforming algorithms such as Maximal Ratio Combining
21 (MRC), Advanced Constant Modulus Algorithm (Advanced CAM), Advanced Wiener solution,
22 and partial multiple access interference cancellation, respectively. Subsequently, corresponding
23 multi-user detection is applied. This enables the smart antenna base station to achieve broader
24 adaptability.

25 The implementation of the technical solution(s) is further described in detail below with
26 reference to the accompanying drawings. Based on these structural diagrams, a person skilled in
27 the same field can easily implement these modules.

28 FIG. 2 is a structural diagram of the smart antenna device according to an embodiment of
29 the present invention, including an antenna array 10, a radio frequency channel module 11, a
30 beamforming module 12, a channel environment detection and classification module 13, a
31 beamforming algorithm selection and weight generation module 14, and a multi-user detection

1 module 15. Since the functions of modules such as scrambling code generation, spreading code
2 generation, code synchronization, descrambling and despreading, and clock control in the
3 software-defined radio smart antenna system are not the focus of the present invention, these
4 modules are generally not described in this embodiment. When needed, these modules or their
5 output signals are directly referenced.

6 The antenna array 10 is composed of M elements 10.1, 10.2 ... 10.M, used for receiving
7 wireless signals. Its output is connected to the input of the radio frequency channel module 11.
8 The radiation pattern of the antenna elements can be arbitrary, and the arrangement of the
9 antenna array can also be arbitrary. The adaptive method of the present invention will derive the
10 optimal array weight under specific criteria. However, the optimal signal reception quality
11 achievable varies depending on the specific antenna array configuration.

12 The radio frequency channel module 11 includes M radio frequency channels 11.1,
13 11.2 ... 11.M, which respectively perform low-noise amplification, automatic gain control,
14 channel correction, baseband conversion, A/D and D/A conversion, matched filtering, and other
15 processes on the signals output by the M antenna elements. In the radio frequency channels, the
16 signals have already been discretized, and the output is the M baseband signal $X = [x_1, x_2, \dots, x_M]$,
17 hereinafter also referred to as array data X. Subsequent processing involves digital signal
18 processing implemented via software. The array data X is output to the beamforming module 12,
19 the channel environment detection and classification module 13, and the beamforming algorithm
20 selection and weight generation module 14, respectively.

21 The channel environment detection and classification module 13 further includes: an
22 eigenvalue calculation unit, used to calculate the eigenvalues of the correlation matrix of the
23 array data X and count the number of effective eigenvalues; an in-band power spectrum
24 deviation calculation unit, used to estimate the power of each channel of the array-received
25 signals and calculate the in-band power spectrum deviation; and a channel type determination
26 unit, used to identify the current channel type based on the number of effective eigenvalues and
27 the in-band power spectrum deviation according to preset determination rules, with the result
28 being input to the beamforming algorithm selection and weight generation module 14. The
29 channel type is one of additive white Gaussian noise interference, co-channel interference, inter-
30 symbol interference, or a combination of multiple interferences and noise.

The beamforming algorithm selection and weight generation module 14 is used to select an appropriate beamforming algorithm based on the channel type result output by the channel environment detection and classification module 13. It processes the array data X from the radio frequency channel 11 and the feedback signal Y output by the beamforming module 12, calculates new weight W , and sends them to the beamforming module. The new weight $W = [w_1, w_2, \dots, w_M]$, which is composed of M components.

The beamforming module 12 is composed of M multipliers 12.1, 12.2 ... 12. M and one adder 12.A. It performs beamforming on the array data X from the radio frequency channel module 11 and the weight W output by the beamforming algorithm selection and weight generation module 14, by multiplying the array data X with the weight W and summing them to obtain the output signal Y .

The multi-user detection module 15 is used to select the appropriate multi-user detection algorithm based on the channel type result output by the channel environment detection and classification module 13. It processes the data Y output by the beamforming module 12 to perform user differentiation, ultimately outputting the demodulated output bits "b" to other subsequent conventional processing modules.

In this embodiment, the beamforming module 12, the channel environment detection and classification module 13, the beamforming algorithm selection and weight generation module 14, and the multi-user detection module 15 are implemented in software within a DSP. However, they can also be hardware modules, meaning these modules can be implemented in an Application-Specific Integrated Circuit (ASIC) or an FPGA.

FIG. 2 is a flowchart of the method according to an embodiment of the present invention. It includes the following steps:

Step 21: Process the signals received by the antenna array in the radio frequency channel to obtain the baseband array data $X = [x_1, x_2, \dots, x_M]$;

Step 22: Determine the current channel type based on the eigenvalues of the correlation matrix of the array-received signals and the in-band power spectrum deviation, using preset determination rules;

The detailed process of wireless communication environment detection and channel identification is shown in FIG. 3, including the following steps:

Step 31: Calculate the autocorrelation matrix $R = X \cdot X^H$ of the array-received signal;

Step 32: Calculate the eigenvalues λ corresponding to the eigenvectors V using the following equation:

$$R \cdot V = \lambda \cdot V$$

$\lambda_1 \geq \lambda_2 \geq \dots = \lambda_M = \sigma_N^2$, where σ_N^2 is noise power.

Step 33: Estimate the power of each channel of the array-received signals as $P_1, P_2, \dots, P_M$;

Step 34: Identify effective eigenvalues. Assume σ_N^2 is the noise power; if $\lambda \geq \sigma_N^2 + \delta_\lambda$, then λ is considered an effective eigenvalue, where δ_λ is a specific parameter determined based on the actual system;

Step 35: Perform in-band power deviation comparison, i.e., determine whether $|P_i - P_j| < \delta_p$ holds, where $i, j = 1, 2, \dots, M$, and $i \neq j$, δ_p is a threshold, a specific parameter determined based on the actual system. If it holds, the power deviation is considered small; otherwise, it is considered large;

Step 36: Based on the number of effective eigenvalues and the result of the in-band power deviation comparison, determine the current channel type according to the following rules:

If the number of effective eigenvalues = 1 and the in-band power deviation is small, then the channel contains only the desired signal and additive white Gaussian noise, with a small delay spread, corresponding to the first channel type;

If the number of effective eigenvalues = 1 and the in-band power deviation is large, then the channel contains both the desired signal and interference signals, with a small delay spread but some angular spread, primarily exhibiting co-channel interference, corresponding to the second channel type;

If the number of effective eigenvalues > 1 and the in-band power deviation is small, then the desired signal has a large delay spread and a small angular spread, primarily exhibiting inter-symbol interference, corresponding to the third channel type;

If the number of effective eigenvalues > 1 and the in-band power deviation is large, then both the desired signal and interference signals exhibit some delay spread and angular spread, corresponding to the fourth channel type.

The present invention can also adopt other suitable determination rules. For example, two or more of the above four rules can be selected for any combination, and accordingly, the channel types should be recombined as well.

Step 23: Based on the identification result of the channel type, select the corresponding adaptive algorithm to most effectively eliminate the interference under that channel type, and calculate the uplink weight W ;

For the first channel type, dominated by additive white Gaussian noise interference, this embodiment adopts the Maximal Ratio Combining (MRC) algorithm to calculate the uplink weight W . This method is widely applied and will not be described in detail herein.

For the second channel type, dominated by co-channel interference, this embodiment adopts an improved Constant Modulus (Advanced CAM) beamforming algorithm to calculate the uplink weight W .

The main process of the improved constant modulus beamforming algorithm adopted in this embodiment is as follows:

The initial weight of the constant modulus algorithm $W_0 = (X \cdot X^H)^{-1} \cdot X \cdot d^H$ is obtained according to the Wiener solution, where d is the reference signal, $X \cdot X^H = R$ is the autocorrelation matrix of the array received signal, where the R value has already been obtained during channel identification and can be directly referenced herein.

The cost function of the steepest descent implementation method of the constant modulus algorithm is as follows:

$$J = E\{\|w^H(n)x(n) - |\alpha|\|^2\}$$

Where $\alpha = W_0^H \cdot X(0)$, the update direction selection iterative equation is as follows:

$$w(n+1) = w(n) - \mu x(n) e^*(n)$$

In the above equation, $e(n) = 2[y(n) - \frac{y(n)}{|y(n)|}]$, where μ is the step size.

For other related contents, reference may be made to the improved constant modulus algorithm in "A combination of two adaptive algorithms SMI and CMA" by Rumiko YONEZAWA as published on IEICE TRANS. COMMUN., VOL. E84-B, NO. 7 JULY 2001. The present invention only makes the above-mentioned partial improvements to the disclosed algorithm.

For the third type of channel dominated by inter-symbol interference, this embodiment adopts an improved cascaded feedback beamforming algorithm. This method can be referred to the “Smart Antenna and Beamforming Algorithm thereof and Device” with the international patent application number PCT/CN2002/000946 and the international publication number W02004/030239A1, so as to calculate the uplink weight W .

For the fourth type of channel with various interferences and noise, this embodiment adopts the pilot-assisted LMS_DRMTA (Least-Mean-Squares De-spread Re-spread Multi-Target Array) beamforming algorithm to calculate the uplink weight W .

The main process of the pilot-assisted LMS_DRMTA beamforming algorithm is as follows:

Step I: Initialize the array receiving weight vector of the i -th user to $[1, 0, \dots, 0]^T$;

Step II: Update the weight according to equation (1) during the pilot bit (length is less than or equal to 8), and the reference signal is generated by equation (2).

$$\begin{cases} Y_i(j) = [W_i^H X(j)]^T = [y_i(1+jK), y_i(2+jK), \dots, y_i(K+jK)]^T; \\ \hat{b}_i(j) = \text{sgn}\left\{\text{Im}\left(\sum_{k=1+jK}^{(j+1)K} y_i(k) c_i(k)\right)\right\}; \\ r_i(j) = \hat{b}_i(j) [c_i(1+jK), c_i(2+jK), \dots, c_i(K+jK)] \\ W_i(j+1) = [X(j)X(j)^H]^{-1} X(j) r_i^*(j). \end{cases} \quad (1)$$

$$r_i(j) = \hat{b}_{\text{pilot}}(j) [c_i(1+jK), c_i(2+jK), \dots, c_i(K+jK)] \quad (2)$$

Where $K = N_c \cdot N_s$, N_c is the spreading spectrum gain, N_s is the oversampling multiple.

Step III, During the information code stream, use the weight vector generated in the above step as the initial value to generate the reference signal according to equation (1), and update it according to the following method:

$$W_i(j+1) = W_i(j) + \mu X(j) E_i(j+1)^H. \quad (3)$$

$$E_i(j) = r_i(j) - Y_i(j)$$

Where μ is the step size; $[X(j)]_{N \times P}$ represents the received vector of the array of current information bit; $[r_i(j)]_{1 \times P}$ is the reference signal generated according to equation (1); $[E_i(j)]_{1 \times P}$ represents the weight vector correction error vector of the current information bit; $[Y_i(j)]_{1 \times P}$ is the array output of P snapshots of the current information bit;

Step IV, repeat steps II to III until the algorithm converges.

For other related contents, reference may be made to the PCT international application entitled "Smart Antenna and Adaptive Beamforming Method thereof and Device," with the application number PCT/CN02/00947. The present invention only makes the above-mentioned partial improvements to the disclosed algorithm.

Step 24: Combine the weighted single-channel signals to form a beam $Y = W^H \cdot X$;

Step 25: Based on the identification result regarding the channel type, select the corresponding method for multi-user detection; the detected channel environment data is also used for the selection of the multi-user detection type to most effectively eliminate the interference of that channel type.

For the first type of channel, the multi-user detection method based on minimum mean square is used to resist the additive Gaussian white noise;

For the second type of channel, the decorrelation detection method is used to resist CCI;

For the third type of channel, the parallel interference cancellation method is used for multi-user detection.

If during a process of a call, the mobile station moves from the third type of channel through the second type of channel to the first type of channel, various corresponding aforementioned different methods can be used for multi-user detection in real-time based on the identification results.

The fourth type of channel is in a complex communication environment. In this embodiment, the method of partial multiple access interference cancellation is adopted to resist various interferences and noise.

The so-called partial multiple access interference cancellation method herein means that during array processing, the array receiving weight vector forms a directional beam with the main lobe pointing near the desired user, thereby greatly suppressing the interfering user signals

coming from other directions. It can be concluded that in $Y_i(j) = \sum_{k=1}^N w_{ik} x_k(j) = W_i^H X(j)$, only when the interfering user is near the desired user will there be a strong interfering user component, while the interfering user signal component far from the desired user is very weak. When $Y_i(j)$ is directly used for parallel interference cancellation for all active users, since a large number of interfering user signal components have been suppressed in advance, the estimation of the

regenerated signals for most interfering users becomes inaccurate. Consequently, the estimation of the multiple access interference for the desired user is also inaccurate, and in severe cases, it may even worsen the preliminary demodulation result of the desired user. Therefore, the partial multiple access interference suppression method can be adopted. On the one hand, it avoids the deterioration of system performance caused by erroneous interference estimation due to weak interference components. On the other hand, it greatly reduces the number of interfering users that need to be actually canceled, thereby reducing the system's computational load.

When distinguishing between strong and weak interfering users, the array outputting $Y_i(j)$ is first employed to perform matched filtering for all active users, obtaining the preliminary soft determination variables for all active users:

$$Z_i(j) = \sum_{l=1}^P c_l((j-1)P+l) \cdot Y_i(j), i=1, \dots, M$$

Assuming the k-th user is the desired user for the receiving channel, then it is strong

interference user upon satisfying $\frac{|Z_i(j)|}{|Z_k(j)|} \geq \rho, i \neq k$, which needs interference cancellation, where $0 < \rho < 1$ is a preset threshold value used to distinguish strong and weak interfering user signals.

Step 26: Calculate the downlink weight based on the obtained uplink weight.

For a CDMA system in the TDD duplex mode, the uplink and downlink signals operate at the same frequency point, pass through the same channel, and the transmission time interval is only a few milliseconds. It can be assumed that the uplink and downlink channel characteristics remain unchanged. Therefore, the uplink weight can be directly used for the downlink weight by simply taking the conjugate of the uplink weight and multiplying it by a correction weight, thereby converting the user's reception spatial information into the user's transmission spatial representation.

For a CDMA system in the FDD duplex mode, the uplink and downlink transmissions are separated by frequency, with the uplink and downlink occupying different frequencies. Due to multipath propagation, the fast fading caused depends on the frequency. Therefore, the fast fading coefficients corresponding to the FDD uplink and downlink are uncorrelated, and the uplink weight cannot be directly used for the downlink weight, requiring a certain conversion.

To further clarify the above processing, the following explains using a DS-CDMA system in an additive Gaussian white noise channel as an example. Consider the reception

processing of a sector within a cellular cell. Assume each sector uses a uniform linear array with M antenna elements, and there are N active users in the sector. The system's processing gain is G . All N users in the sector are far-field signal sources for the base station antenna array. The received signal at the k -th antenna element of the base station array at time t (the j -th source symbol) is as follows:

$$x_k = \sum_{i=1}^N \sqrt{2E_i} b_i(j) c_i((j-1)G+l) a_k(\theta_i) + n_k(t) \quad k=1, \dots, M$$

Where:

E_i represents the energy of each spreading code chip after the source symbol of the i -th user is spread;

$b_i(j)$ represents the value of the j -th source symbol of the i -th user, which is either +1 or -1;

$c_i((j-1)G+l), l=1, \dots, G$ represents the first spreading code chip of the j -th source symbol of the i -th user.

$a_k(\theta_i)$ represents the k -th component of the direction vector of the i -th user's signal with respect to the base station antenna array, where $\mathbf{a}(\theta_i) = [1, e^{j\phi}, e^{j2\phi}, \dots, e^{j(N-1)\phi}]^T, \phi = \frac{d \sin(\theta_i)}{\lambda} 2\pi$, d is the element spacing of the uniform linear array, λ is the carrier frequency, and $n_k(t)$ represents the additive Gaussian white noise at the k -th antenna element.

Thus, $X(j) = [x_1(j), x_2(j), \dots, x_M(j)]^T = \sum_{i=1}^N \sqrt{2E_i} b_i(j) c_i((j-1)G+l) \mathbf{a}_k + \mathbf{n}(j)$ represents the output of

a snapshot of the entire array. Let the receive weight vector of the i -th user be $\mathbf{W}_i = [w_{i1}, w_{i2}, \dots, w_{iM}]^T$, then the array output signal for the i -th user is:

$$Y_i(j) = \sum_{k=1}^M w_{ik} x_k(j) = \mathbf{W}_i^H X(j)$$

$Y_i(j)$ is used to demodulate and make determinations on the i -th user's signal. To perform matched filtering on $Y_i(j)$, the following can be obtained:

$$Z_i(j) = \sum_{l=1}^P c_i((j-1)G+l) \cdot Y_i(j) = D_i(j) + I_i(j) + n_i(j)$$

Where $D_i(j) = Pb_i(j)\sqrt{2E_i}\mathbf{a}_i$, which represents the desired signal component in the matched filter output.

$I_i(j) = \sum_{l=1}^P c_l((j-1)G+l) \cdot \sum_{k \neq i} \sqrt{2E_k} b_k(j) c_k((j-1)G+l) \mathbf{a}_k$, which represents the multi-user interference component in the i-th user's received channel. $n_i(j)$ represents the additive noise in the i-th user's received channel.

When performing array processing, the goal is to estimate $\mathbf{a}_i(j)$ as accurately as possible, so that the main lobe of the receiving array's directional pattern aligns with the direction of arrival of the desired user's signal, using relatively low sidelobes to suppress the interfering user signals. Parallel interference cancellation primarily aims to accurately estimate the value of $I_i(j)$ of the multiple access interference component in $Z_i(j)$, which can be subtracted from the received signal, thereby yielding a cleaner reception of the desired user's signal. The soft determination variable for the desired signal is $D_i(j) = Z_i(j) - \hat{I}_i(j)$, and the corresponding demodulated output bit is $\hat{b}_i(j) = \text{sign}(D_i(j))$.

Similarly, the above processing can easily be extended to other noise environments, and the array configuration is not limited to a uniform linear array. It is also applicable to other array types, such as non-uniform linear arrays, circular arrays, arc arrays, and other forms of arrays.

In summary, the present invention improves the limitations of applying a single adaptive beamforming algorithm, expanding the applicability of smart antennas to different communication environments. It can track users' rapid movement in real time and combat various interference environments. At the same time, if a software-defined radio-based system architecture is used, it does not require significantly higher hardware costs compared to conventional smart antennas, greatly improving the performance-to-cost ratio of the smart antenna system.

In conclusion, the smart antenna technology proposed in the present invention is an effective method for overcoming the time-varying characteristics of the channel. By discerning different channels and selecting the corresponding adaptive beamforming approach, or additionally using multi-user detection methods, it meets the communication requirements of various environments and improves communication quality.

Industrial Applicability

1 The method of the present invention can be used to implement a smart antenna system.
2 Under conditions of relatively low hardware costs, it greatly improves the performance-to-cost
3 ratio of the smart antenna base station system, making engineering implementation easier, while
4 significantly enhancing the performance of smart base station processing.

5

6

CLAIMS

1. A method for implementing a smart antenna in a wideband code division multiple access system, comprising the following steps:

(a) processing a signal received by an antenna array in a radio frequency channel to obtain baseband array data containing multiple components;

(b) estimating and identifying a channel environment based on characteristics of the array data, and determining a current channel type to which the channel belongs according to a preset channel type determination rule;

(c) selecting in real time a corresponding adaptive beamforming algorithm based on an identification result of the channel type, and calculating an uplink weight; and

(d) multiplying and summing the array data with the uplink weight to form a beam.

2. The method for implementing a smart antenna according to claim 1, characterized in that in the channel type determination rule, the channel types are classified into the following three types or any combination thereof:

a first type, dominated by additive Gaussian white noise interference, where the environment is far from a base station, a signal power is weak, and a noise is strong;

a second type, dominated by co-channel interference, where the environment is affected by co-channel interference from other cells; and

a third type, dominated by inter-symbol interference, where the environment experiences severe inter-symbol interference due to large delay differences among multipath components.

3. The method for implementing a smart antenna according to claim 2, characterized in that the channel type determination rule determines the channel type based on eigenvalues of a correlation matrix of the array data and an in-band power spectrum deviation, and the determination rule comprises the following three rules or any combination of at least two of the following rules:

if the number of effective eigenvalues = 1 and the in-band power deviation is small, it is the first channel type;

1 if the number of effective eigenvalues = 1 and the in-band power deviation is large, it is
2 the second channel type; and

3 if the number of effective eigenvalues > 1 and the in-band power deviation is small, it is
4 the third channel type.

5
6 4. The method for implementing a smart antenna according to claim 2, characterized in
7 that in step (c), when selecting the corresponding adaptive beamforming algorithm based on the
8 identification result of the channel type, the following three rules or any combination of at least
9 two of the following rules are followed:

10 for the first channel type dominated by additive Gaussian white noise interference, a
11 maximum ratio combining beamforming algorithm is used;

12 for the second channel type dominated by co-channel interference, an improved constant
13 modulus beamforming algorithm is used; and

14 for the third channel type dominated by inter-symbol interference, an improved cascaded
15 feedback beamforming algorithm is used.

16
17 5. The method for implementing a smart antenna according to any one of claims 1 to 4,
18 characterized in that after step (d), the method further comprises step (e):

19 selecting in real time, based on the identification result of the channel type, the
20 corresponding multi-user detection algorithm to process data after beamforming, thereby
21 completing differentiation of users.

22
23 6. The method for implementing a smart antenna according to claim 5, characterized in
24 that in step (e), when selecting the corresponding multi-user detection algorithm based on the
25 identification result of the channel type, the following four rules or any combination of at least
26 two of the following rules are followed:

27 for the first channel type dominated by additive Gaussian white noise interference, a
28 multi-user detection method based on minimum mean square is used;

29 for the second channel type dominated by co-channel interference, a decorrelation
30 detection method is used; and

1 for the third channel type dominated by inter-symbol interference, a parallel interference
2 cancellation method is used.

3
4 7. The method for implementing a smart antenna according to claim 2, 3 or 4,
5 characterized in that in the channel type determination rule set in step (a), a fourth channel type
6 is further determined: the fourth channel type is characterized by multiple interferences and
7 noise, where the environment is a complex communication environment with strong noise, co-
8 channel interference, and inter-symbol interference, a corresponding determination condition is:
9 the number of effective eigenvalues > 1 , and the in-band power deviation is large; in step (c),
10 when selecting the corresponding adaptive beamforming algorithm based on the identification
11 result of the channel type, a pilot-assisted beamforming algorithm is used for the fourth channel
12 type.

13
14 8. The method for implementing a smart antenna according to claim 7, characterized in
15 that after step (d), the method further comprises step (e): selecting in real time, based on the
16 identification result of the channel type, the corresponding multi-user detection algorithm to
17 process the data after beamforming, thereby completing differentiation of users, and for the
18 fourth channel type characterized by multiple interferences and noise, a partial multiple access
19 interference cancellation method is used as the multi-user detection algorithm.

20
21 9. The method for implementing a smart antenna according to claim 1, characterized in
22 that after step (e), the method further comprises step (f): calculating a downlink weight based on
23 the obtained uplink weight.

24
25 10. The method for implementing a smart antenna according to claim 3 or 7,
26 characterized in that when the in-band power deviation is greater than a set threshold, it is
27 considered a large in-band power deviation; otherwise, it is considered a small in-band power
28 deviation.

29
30 11. A smart antenna device for a wideband code division multiple access system,
31 comprising: an array antenna, a radio frequency channel module, and a beamforming module

1 that weight and combines individual single-channel signals to form a beam, characterized in that
2 the smart antenna device further comprises a channel environment detection and classification
3 module and a beamforming algorithm selection and weight generation module, wherein:
4

5 the channel environment detection and classification module is configured to estimate
6 and identify a channel environment based on characteristics of baseband array data output from a
7 radio frequency channel, determine a current type of the channel, and output a result to the
8 beamforming algorithm selection and weight generation module; and

9 the beamforming algorithm selection and weight generation module is configured to
10 select a corresponding beamforming algorithm based on an identification result of the channel
11 type, and calculate a new uplink weight based on a feedback of a beamforming signal and the
12 array data, and then send the new uplink weight to the beamforming module.
13

14 12. The smart antenna device according to claim 11, characterized in that the smart
15 antenna device further comprises a multi-user detection module configured to select a
16 corresponding multi-user detection algorithm based on the identification result of the channel
17 type, process the beamforming signal, and complete differentiation of users.
18

19 13. The smart antenna device according to claim 11 or 12, characterized in that the
20 channel environment detection and classification module further comprises: an eigenvalue
21 calculation unit, configured to calculate eigenvalues of a correlation matrix of the array data and
22 count the number of effective eigenvalues; an in-band power spectrum deviation calculation unit,
23 configured to estimate a power of each channel of array received signals and calculate an in-band
24 power spectrum deviation; and a channel type determination unit, configured to identify,
25 according to the set determination rule, the current type of the channel based on the number of
26 effective eigenvalues and the in-band power spectrum deviation.
27

28 14. The smart antenna device according to claim 13, characterized in that the channel
29 type determination unit, when identifying the current type of the channel based on the number of
30 effective eigenvalues and the in-band power spectrum deviation, follows any combination of the
31 following 3 rules or at least 2 of the rules:

1 if the number of effective eigenvalues = 1 and the in-band power deviation is small, it is
2 the first channel type, and this channel type is predominantly affected by additive Gaussian white
3 noise interference, located in an environment far from the base station, with weak signal power
4 and strong noise;

5 if the number of effective eigenvalues = 1 and the in-band power deviation is large, it is
6 the second channel type, and this channel type is predominantly affected by co-channel
7 interference, located in an environment subject to co-channel interference from other cells; and

8 if the number of effective eigenvalues > 1 and the in-band power deviation is small, it is
9 the third channel type, and this channel type is predominantly affected by inter-symbol
10 interference, located in an environment where severe inter-symbol interference exists due to
11 large delay differences among multipath components.

12
13 15. A method for implementing the smart antenna set forth in claim 14, characterized in
14 that the multi-user detection module, when selecting the corresponding multi-user detection
15 algorithm based on the identification result of the channel type, follows the following 3 rules or
16 any combination of at least 2 of the rules:

17 for the first channel type predominantly affected by additive Gaussian white noise
18 interference, a multi-user detection method based on minimum mean square is adopted;

19 for the second channel type predominantly affected by co-channel interference, a
20 decorrelation detection method is adopted; and

21 for the third channel type predominantly affected by inter-symbol interference, a parallel
22 interference cancellation method is adopted.

23
24 16. The method for implementing the smart antenna according to claim 15, characterized
25 in that the channel type determination unit, when identifying the current type of the channel
26 based on the number of effective eigenvalues and the in-band power spectrum deviation, also
27 follows the following rule:

28 if the number of effective eigenvalues > 1 and the in-band power deviation is large, it is
29 the fourth channel type, and this channel type involves multiple types of interference and noise,
30 located in a complex communication environment with strong noise, co-channel interference,
31 and inter-symbol interference; and

1 the multi-user detection module, when selecting the corresponding multi-user detection
2 algorithm based on the identification result of the channel type, adopts a partial multiple access
3 interference cancellation method for the fourth channel type.

4
5 17. The method for implementing the smart antenna according to claim 14 or 16,
6 characterized in that when the channel type determination unit determines that the in-band power
7 deviation is greater than a set threshold, it is considered that the in-band power deviation is large;
8 otherwise, it is considered that the in-band power deviation is small.

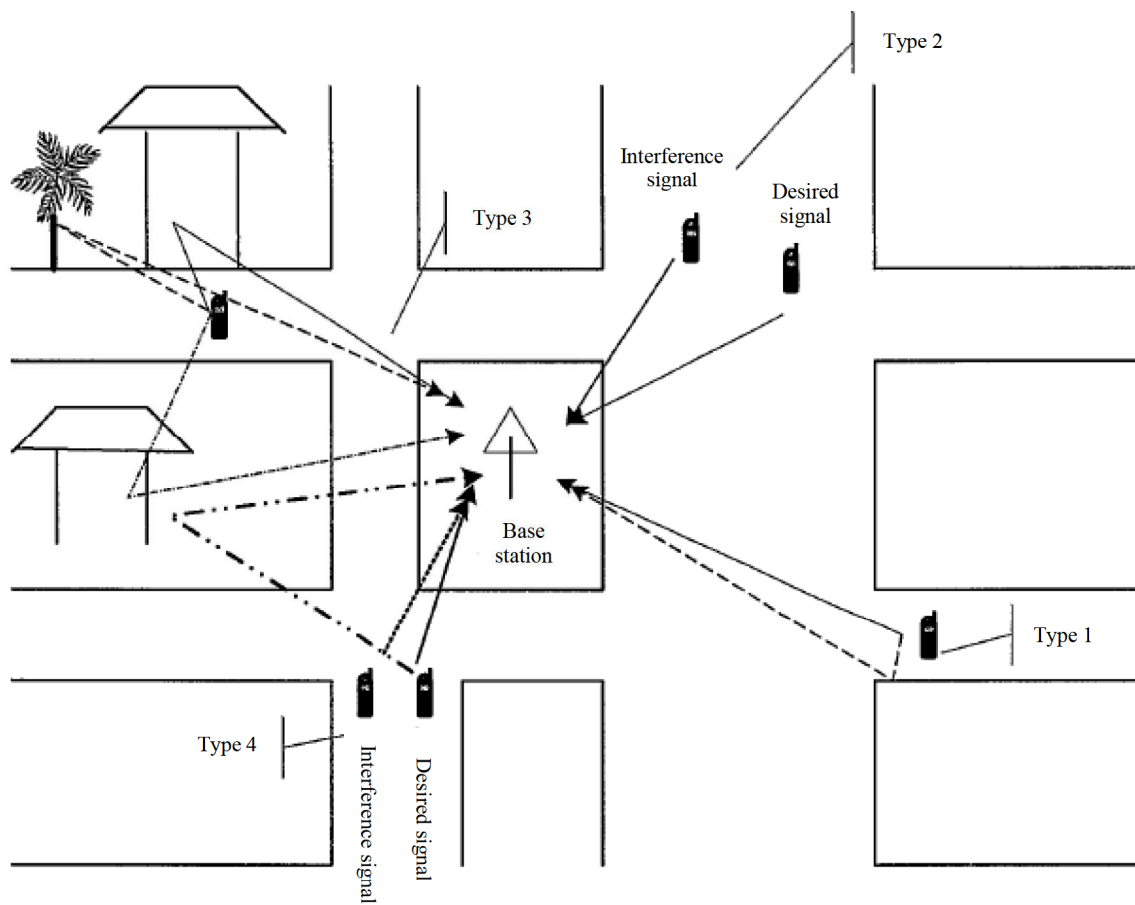


FIG. 1

1
2

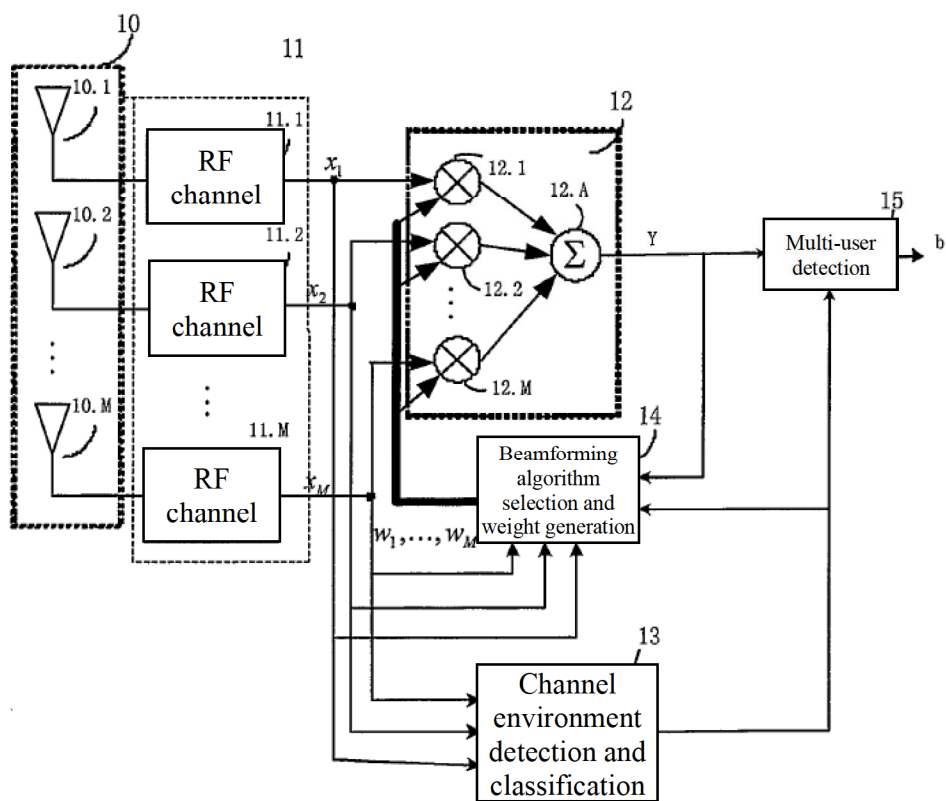


FIG. 2

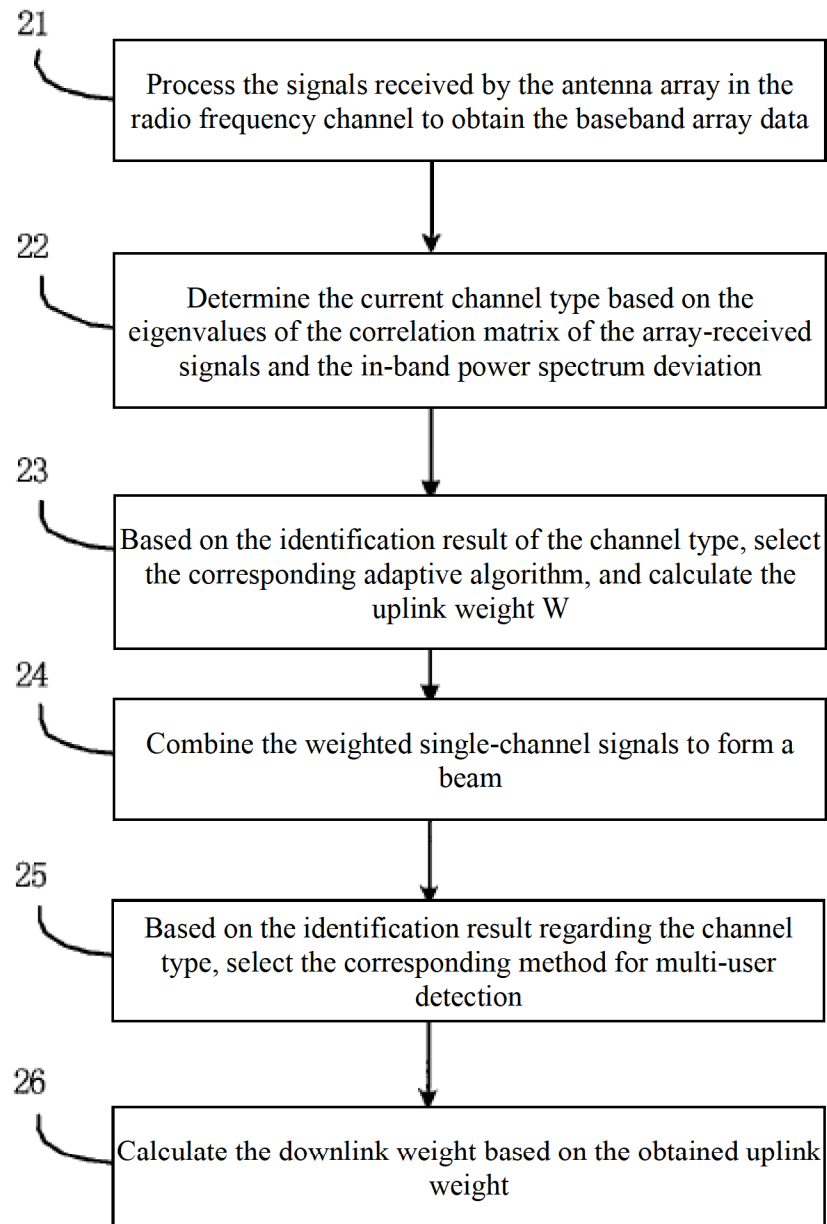


FIG. 3

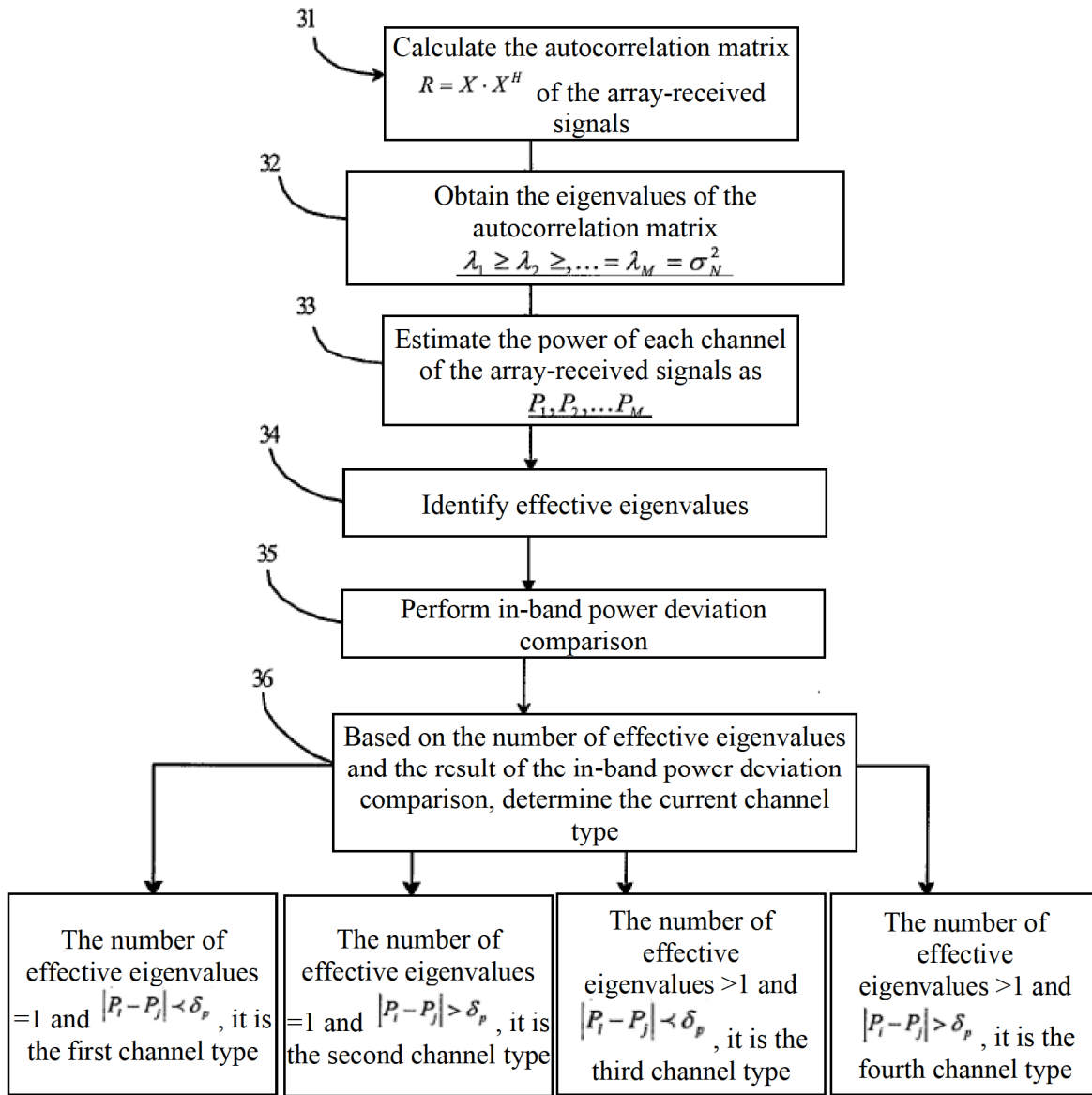


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2005/002361

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/02 (2006.01) i

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)

IPC8:H04B7/00,H04Q7/00,H01Q3/00

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)

WPI, PAJ, EPODOC: WPI, EPODOC, PAJ: antenna, beamform+, channel, WCDMA CNPAT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO A 03098837 (SAMSUNG ELECTRONICS CO LTD) 27.Nov. 2003 (27.11.2003) the whole document	1-17
A	CN A 1455473 (LG ELECTRONICS CO LTD) 12.Nov. 2003 (12.11.2003) the whole document	1-17
A	CN A 1352498 (HUAWEI TECH CO LTD) 05.Jun. 2002 (05.06.2002) the whole document	1-17

☐ 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

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"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.Mar. 2006(16.03.2006)

Date of mailing of the international search report

30 • MAR 2006 (30 • 03 • 2006)

Name and mailing address of the ISA/CN

The State Intellectual Property Office, the P.R.China
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100088

Facsimile No. 86-10-62019451

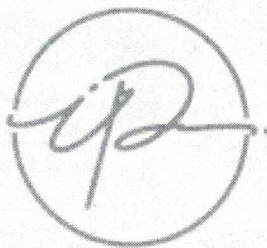
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Form PCT/ISA /210 (second sheet) (April 2005)



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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

The document is designated as:

#101705_WO2006092090A1 (Wang PCT)

Signature of Translator

March 1, 2025

Date