



METHOD FOR SIGNAL PROCESSING IN USER EQUIPMENT OF CDMA MOBILE COMMUNICATION SYSTEM

Field of the Technology

The present invention relates generally to CDMA cellular mobile communication technology, and more particularly to a method for signal detection and processing of user equipment (UE) in a CDMA spread spectrum cellular mobile communication system. The method is a combination of time diversity and joint detection.

Background of the Invention

In a CDMA spread spectrum cellular mobile communication system, especially a Time Division Duplex (TDD) code division multiple access mobile communication system, in order to overcome multipath and multiple access interference, in principle a base transceiver station (BTS) and a user equipment can all deploy time diversity method to raise system performance; and deploy joint detection algorithm as a basic signal detection method to suppress Multiple Access Interference (MAI) and Inter-Symbol Interference (ISI). Specifically, BTS side can deploy smart antenna technology. In this case, by using multiple antenna units, spatial diversity gain is obtained, and with corresponding beam synthesized algorithm receiving sensitivity is raised (it can be understood as decreasing interference and suppressing white noise at the same time). Nevertheless, at UE side in order to decreasing cost and size, usually only one antenna is used for receiving. In this case, as multiple antennas receiving technology cannot be used, i.e. same frequency interference and hot noise cannot be suppressed by spatial diversity, so uplink and downlink receiving gain is unmatched.

Especially in a CDMA spread spectrum cellular mobile communication system applying joint detection algorithm, as joint detection algorithm can estimate multipath and multiple access interference coming from all users in this cell, so at the BTS, the multipath and multiple access interference can be suppressed at a maximum degree. Nevertheless, at the UE, although multipath and multiple access interference coming from the cell user can be suppressed in a maximum degree by using joint detection algorithm, but for those users at the cell edge, joint detection algorithm cannot estimate and suppress the signal, which comes from neighbor cell with same



frequency and adds to the system as a noise. This signal decreases system performance greatly, and noise coefficient of the receiver limits the receiving sensitivity. In this case, if there is no appropriate signal processing method, error rate of receiving signal will be greatly increased and the communication will be even interrupted.

Although, power control and smart antenna algorithm can suppress interference coming from neighbor cells in a maximum degree, but without appropriate method to raise UE receiving gain, communication quality will be seriously decreased and communication will be even interrupted. For the purpose of same frequency multiplexing in a CDMA spread spectrum cellular mobile communication system, the only way to do is to decrease the working channels activated at the same time to guarantee the UE communication quality in the cells overlap area. Nevertheless, this will decrease system capacity.

Summary of the Invention

In order to solve the problem mentioned above, it is necessary to propose a baseband processing method, which is appropriate to UE.

The purpose of the invention is to provide a signal processing method for UE in a CDMA spread spectrum cellular mobile communication system. The method will increase UE (receiver) diversity gain, and when used in a mobile terminal, the method will solve the uplink and downlink unmatched problem. The method will reach same frequency multiplexing purpose without increasing calculation amount greatly, and when it is used in a BTS, receiving gain is increased also.

The implementation of the invention is as follow: a signal processing method of user equipment in a CDMA spread spectrum cellular mobile communication system, is characterized that the method is a combination of time diversity and joint detection.

The method of combining time diversity and joint detection comprises the following steps:

A. sample a received signal in M times on time domain, then M sampled data e_i are obtained;

B. make spatial channel impulse response estimate for each sampled data e_i obtained at each sampling, then obtain M spatial channel impulse response estimated values h_i ;

C. obtain M matrixes A_i from the obtained each spatial channel impulse response estimated value h_i ;

D. constitute a system matrix A from the M matrixes A_i ;

E. perform joint detection algorithm according to the system matrix A , and obtain an original sending data estimated value d_{est} , $i = 1 \dots M$.

The spatial channel impulse response estimated value h_i is obtained by first using formula $e_{mid} = \sum_i m_i \otimes h_i + n_m$, then formula $h_i = G^{-1} e_{mid}$. Wherein e_{mid} is a training sequence midamble received by user equipment, G is a coefficient matrix generated by the training sequence midamble of user equipment, m_i is a training sequence midamble sent by the i^{th} user equipment, and n_m represents noise interference at training sequence midamble.

The original sending data estimated value d_{est} is estimated according to sampled data e and system matrix A , including using formulas:

$$d_{est} = (diag(A *^T A))^{-1} A *^T e,$$

$$\text{or } d_{est} = (A *^T A)^{-1} A *^T e.$$

To constitute a system matrix A from M matrixes A_i uses formulas:

$$A_{sum} = (A_1^T, A_2^T \dots A_M^T)^T \text{ and } e_{sum} = (e_1^T, e_2^T \dots e_M^T)^T;$$

and also uses formula

$$d_{est} = \left(\sum_{i=1}^M A *^T_i A_i \right)^{-1} A_{sum} *^T e_{sum},$$

or when M being larger, uses formula

$$d_{est} = (diag(\sum_{i=1}^M A_i *^T A_i))^{-1} A_{sum} *^T e_{sum}$$

The invention method, combining time diversity and joint detection algorithm, applies an optimal algorithm, which uses diversity gain obtained on time domain, to raise signal noise ratio of receiving signal of user equipment.

A signal processing method for user equipment of the invention is a method combining time diversity and joint detection. Without greatly increasing calculation complexity, user equipment in CDMA spread spectrum cellular mobile communication system can obtain diversity gain, so receiver sensitivity is raised, system capacity is increased and uplink and downlink performance unmatched problem is solved. Again, as taking time diversity, a relatively simple algorithm of joint detection can be used, so without increasing total calculation amount the method has stronger anti-interference performance comparing with only using joint detection algorithm. The method of the invention also can be used in BTS to raise receiving gain.

Brief Description of the Drawings

Figure1 is a block diagram of the joint detection algorithm.

Figure2 is a burst data structure diagram in a TDD CDMA mobile communication system.

Figure3 is a block diagram of the invention method combining time diversity and joint detection.

Embodiments of the Invention

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

The embodiment takes Time Division Synchronized CDMA (TD-SCDMA) system as an example. The TD-SCDMA system is proposed by CWTS and is one of the IMT-2000 Radio Transmission Technologies.

Figure1 shows implementation steps of joint detection algorithm in a TD-SCDMA system. Suppose a sent original data is d , a system matrix A represents

spread spectrum, scrambling and spatial channel functions, n represents same frequency interference between neighbor cells and hot noise, then data e received by user equipment (receiver) can be expressed by the following formula (1):

$$e = Ad + n \quad (1)$$

Step1 of Figure1 represents solving an impulse response estimated value h_i from the received sample data e_i . In a TD-SCDMA system, burst data structure defines training sequence midamble for channel estimation is shown in Figure2. The training sequence midamble is located in a time slot width (usually, it is several hundreds microsecond, and it is 675 μ s in the Figure). Before and after the training sequence Midamble (it is 144 chips length in the Figure), there are Data Symbols (the length is 352 chips in the Figure). When m_i represents a training sequence midamble sent by a user i , e_{mid} represents a training sequence midamble received, and n_m represents noise interference at training sequence midamble, then there is the following formula:

$$e_{mid} = \sum_i m_i \otimes h_i + n_m \quad (2)$$

Wherein $\otimes$ symbol represents convolution.

The channel impulse response estimated value h_i in UE receiving end can be solved by formula (3):

$$h_i = G^{-1} e_{mid} \quad (3)$$

The G matrix in formula (3) is a coefficient matrix generated by every user training sequence midamble.

In Figure1, steps 1 and 2 represents procedure for obtaining impulse response estimated value h_i at UE side and procedure for generating system matrix A_i by the obtained h_i and the UE user spread spectrum code, respectively. (The generating technology of system matrix A_i is in another invention patent of the inventor.)

Purpose of joint detection is to estimate d according to e and A . Step3 in Figure1 is an implementation of joint detection, i.e. estimating sending signal. There are various algorithms to implement estimating d_{est} , includes:

$$d_{est} = (diag(A *^T A))^{-1} A *^T e \quad (4)$$

$$\text{or} \quad d_{est} = (A *^T A)^{-1} A *^T e \quad (5)$$

etc., wherein T is an inverse matrix symbol, $*$ is a solving conjugation symbol and $diag$ is a diagonal matrix symbol.

Taking formula (5) as a specific algorithm example describes the combination method of time diversity and joint detection.

Refer to Figure3, the method of the invention, which combines time diversity and joint detection, comprises the following steps:

- 1) UE makes i^{th} sample of received signal e on time domain and obtains sampled data e_i ;
- 2) make impulse response estimate of a spatial channel according to sampled data e_i and obtain the spatial channel impulse response estimated value h_i ;
- 3) obtain matrix A_i from the obtained spatial channel impulse response estimated value h_i ;
- 4) repeat steps 1), 2), 3) M times in total, i.e. after M times sampling of a received signal, the sampled data can be expressed by $e_i, i = 1, \dots, M$. In the received signal, the part corresponding to the training sequence midamble can be expressed as $e_{mid-i}, i = 1, \dots, M$. According to formula (3), after sampling the received signal with M times, M spatial channel impulse response estimated values $h_i, i = 1, \dots, M$ can be obtained. Then, according to the M spatial channel impulse response estimated values h_i, M matrixes A_i can be obtained;
- 5) constitute a system matrix A by the M matrixes A_i ;
- 6) perform joint detection algorithm based on the system matrix A and obtain estimated value of the original sending data. If simply using formula (4) for calculation, M estimated values of the original sending data $d_i, i = 1, \dots, M$ can be obtained. Then, process these M estimated values d_i with the following formula:

$$d_{sum} = \sum_{i=1}^M d_i = \sum_{i=1}^M (A_i *^T A_i)^{-1} A_i *^T e_i \quad (6)$$

Making a decision according to the sign of d_{sum} , then an original sending data is recovered. With formula (6), diversity gain is raised, but at the same time, the operation amount is increased by M times. In order to raise diversity gain and without increasing operation amount, the invention applies the following method:

$$\text{Suppose: } A_{sum} = (A_1^T, A_2^T \dots A_M^T)^T \quad (7)$$

$$e_{sum} = (e_1^T, e_2^T \dots e_M^T)^T \quad (8)$$

Then, an estimated value of original sending data can be expressed as:

$$d_{est} = \left(\sum_{i=1}^M A_i^{*T} A_i \right)^{-1} A_{sum}^{*T} e_{sum} \quad (9)$$

Comparing formulas (6) and (9), it is seen that formula (9) greatly decreases matrix inverse calculation, which has bigger operation amount. Therefore, the total operation amount of formula (9) is greater decreased comparing with formula (6).

When sampling times M is larger, formula (4) combining time diversity and joint detection algorithm can be used, i.e.

$$d_{est} = \left(\text{diag} \left(\sum_{i=1}^M A_i^{*T} A_i \right) \right)^{-1} A_{sum}^{*T} e_{sum} \quad (10)$$

Operation amount of formula (10) is lower then formula (9). When M takes an appropriate value, the operation amount of formula (10) is that near the operation amount of formula (5), but the performance of formula (10) is better than formula (5).

From the above analysis, it is seen that using the method, proposed by the invention, for combining time diversity and joint detection algorithm, the unmatched problem of uplink and downlink receiving gain can be solved and the UE receiving signal noise ratio can be raise without increasing operation amount. Consequently, in a CDMA spread spectrum cellular mobile communication system, same frequency multiplexing of neighbor cells is implemented without decreasing communication quality.

Although the embodiment of the invention is designed for a UE based on a TD-SCDMA system, but it can be directly used in other CDMA systems with TDD mode, such as UTRA TDD, another CDMA TDD system in IMT-2000. The invention also can be directly used in BTS of CDMA TDD system. After appropriate revision, the invention can be thoroughly used in UE and BTS of other CDMA mobile communication system applying joint detection algorithm.

Claims

1. A signal processing method for user equipment (UE) in a code division multiple access mobile communication system, comprising:

combining time diversity method and joint detection algorithm.

2. The method according to Claim1, the combination of time diversity method and joint detection algorithm comprising the steps of:

A. sampling a received signal in M times on time domain, then getting M sampled data e_i ;

B. estimating spatial channel impulse response for each sampled data e_i obtained at each sampling, then getting M spatial channel impulse response estimated values h_i ;

C. getting M matrixes A_i from the obtained each spatial channel impulse response estimated value h_i ;

D. constituting a system matrix A from the M matrixes A_i ;

E. performing joint detection algorithm according to the system matrix A , and getting original sending data estimated value d_{est} , $i = 1 \dots M$.

3. The method according to Claim2, wherein the spatial channel impulse response estimated value h_i is got by first using formula $e_{mid} = \sum_i m_i \otimes h_i + n_m$, then formula $h_i = G^{-1} e_{mid}$; wherein e_{mid} is training sequence midamble received by user equipment, G is coefficient matrix generated by the training sequence midamble of user equipment, m_i is a training sequence midamble sent by the i^{th} user equipment, and n_m represents noise interference at training sequence midamble.

4. The method according to Claim2, wherein the original sending data estimated value d_{est} is estimated according to sampled data e and system matrix A .

5. The method according to Claim4, wherein the original sending data estimated value d_{est} is estimated by using formulas:

$$d_{est} = (diag(A *^T A))^{-1} A *^T e, \text{ or}$$

$$d_{est} = (A *^T A)^{-1} A *^T e$$

6. The method according to Claim4, wherein the original sending data estimated value d_{est} is estimated by using formulas:

$A_{sum} = (A_1^T, A_2^T \cdots A_M^T)^T$, $e_{sum} = (e_1^T, e_2^T \cdots e_M^T)^T$; and then

$d_{est} = (\sum_{i=1}^M A_i^* A_i)^{-1} A_{sum}^* e_{sum}$, or when M being larger,

$$d_{est} = (diag(\sum_{i=1}^M A_i^* A_i))^{-1} A_{sum}^* e_{sum}.$$

7. The method according to Claim2, wherein constituting a system matrix A from M matrixes A_i uses formulas:

$$A_{sum} = (A_1^T, A_2^T \cdots A_M^T)^T \text{ and } e_{sum} = (e_1^T, e_2^T \cdots e_M^T)^T;$$

and also uses formula

$$d_{est} = (\sum_{i=1}^M A_i^* A_i)^{-1} A_{sum}^* e_{sum},$$

or when M being larger, uses formula

$$d_{est} = (diag(\sum_{i=1}^M A_i^* A_i))^{-1} A_{sum}^* e_{sum} \text{ to get original sending data estimated value.}$$