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Multiple Antenna Interference Alignment Method in Cognitive Radio Networks

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Abstract

This paper studies the multiple antenna system is a kind of cognitive radio can achieve full interference alignment method of multiplexing gain, sender in multiple users and multiple users topology results at the receiving end, the user system interference to primary user system to produce at the same time, also cause interference between each other, which reduces the primary user system and the size of user system, also can affect the user's system can't normal communication; This method is based on the interference to primary user system under the condition of limited power, maximize user system capacity; Through the analysis can see, interference alignment method through alignment interference subspace, can spare the relative number of signal subspace, the subspace can be used to transport the user system information and useful information of user's system, so as to eliminate the interference effect; The simulation results show that this method is compared with the previous beam forming algorithm, and can get more transfer rate, improve the capacity of second user's system.

Keywords: *Cognitive radio; Multipoint transmission; Interference alignment; Beam forming*

1. Introduction

Wireless communication system, with its convenient way of accessing, become a modern way of communication is the most sought-after access. However in the traditional wireless communication, wireless spectrum is well defined in advance, and authorization to a particular user; this way of distribution can effectively reduce the interference, but from a long-term point of the development of wireless communications, it is the bottleneck of development. First of all, the radio spectrum resources are fixed, non-renewable, the fixed allocation will inevitably cause authorized users in time, geography, space and a series of dimensions will not be able to make full use of spectrum resources, resulting in waste of precious resources. It is based on this reason, the research of wireless communication scholars on the basis of software radio, and puts forward the concept of cognitive radio. Cognitive radio technology's thought is authorized users under the premise of without affecting the main user communication, can transmit information about themselves, so as to achieve the aim of make full use of resources. This technique is based on software radio transceiver hardware can be reached on the basis of. Once the idea is put forward, get the extensive concern of the academia, became a hot issue of research. In the cognitive radio system, generally experienced two steps, you can achieve the purpose of time users transmit information; First, first of all must carry on the spectrum detection, detection of primary user is in the occupied spectrum, spectrum detection accurate or not is not only related to cognitive radio users transmission, but also determines the amount of interference to

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primary users. Second, on the basis of the detection and transmission strategy, complete user information transmission. This paper mainly studies the second step, that is, determine the transmission strategy, user information transmission time. In this, this research is based on the first step is ready.

In traditional research, most of the transmission strategies were not given the time users and users configure multiple antennas, multiple antenna technology since the date of put forward, however, is widely attention. Multi-antenna technology without any increase in power and spectrum occupied, on the basis of multiple increase the transmission rate of the system. So many antenna cognitive radio network as transmission of the optimal solution. From another perspective, multi-antenna configuration to the main user and client, can provide more freedom of space, which can effectively avoid the interference from each other, improve the transmission rate of primary user system and the user system, achieve better transmission effect, it is based on this, this article will study the foothold on the multiple antenna cognitive radio system.

Interference alignment technology has been widely studied in the multiple antenna systems, it can achieve full taking gain and maximum improve system capacity and the basic idea is to interfere with the signal transform, make its alignment to the same height space, so as to reduce interference subspace, will make the subspace of useful signal transmission. This technique in other multiple antenna system is superior to other beam forming algorithm. Less application in cognitive radio network, however, in this paper, it is in this study, under the situation of received multiple antenna interference alignment schemes of the cognitive radio network, through the derivation and simulation, proved that the proposed interference alignment schemes of beam forming algorithm is superior to the other.

2. System Model

Interference alignment schemes proposed in this paper, which is based on the following topology, as shown in Figure 1, the system includes a primary user transceiver, transmission of information to K pairs of users. Which sent by the time the user record, for users to send, receive the user records for second user receiver. Suppose time user to the main user using the same spectrum (*i.e.*, the same amount of time - frequency block), with dotted lines represent the interference signal, is the need to eliminate, solid lines represent the need to transmit signal. Primary user configuration M receiving antenna, at the same time, each second user N_r antenna configuration, second user base station N_t antenna configuration.

As shown in Figure 1 has K pairs of second users to the interference of multiple input multiple output channels, Each second user of i sending end users of the receiver i and its corresponding for the communication of information, But for other interference of the receiving end j ($j \neq i$), and each second user of the transmission i can send d_i data to receiver of second user i , to meet $d_i \leq \min(N_t, N_r)$, in this paper, in order to simplify the calculation, so every second user configure the sender and the receiver in the same way on the number of antenna, also can be extended to the users to the sender and the receiver configuration different antenna number of topology. Under the same time-frequency block, second users sending end i to second receiver j channel model $\mathbf{H}_{j,i} = \left[\mathbf{h}_{j,i}^{(1)} \cdots \mathbf{h}_{j,i}^{(N_t)}\right]$, The dimensions of the matrix $N_r \times N_t$, where $\mathbf{h}_{j,i}^{(l)} \in \mathbb{C}^{N_r \times 1}$ is the l -

th column vector. In this article, $\mathbf{H}_{j,i}$ is independent identically distributed gaussian random variables, the mean to 0, variance of 1. Similarly, second users sending end i to the primary user receiver channel model $\mathbf{G}_i = \left[\mathbf{g}_i^{(1)} \cdots \mathbf{g}_i^{(N_t)}\right]$, at the receiving end of matrix dimension $M \times N_t$ for $\mathbf{g}_i^{(l)} \in \mathbb{C}^{M\times 1}$ represent $\mathbf{G}_i$ the l -th column. $\mathbf{G}_i$ independent, complex gaussian random variable with the distribution, the mean to 0, variance of 1.

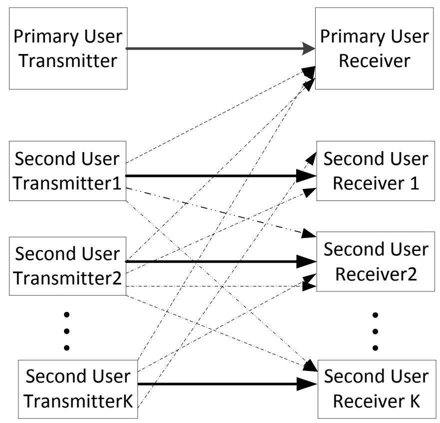

Figure 1. Multiple Antenna Cognitive Radio System

Second users the receiver i , the received signal vector $\mathbf{y}_i \in \mathbb{C}^{N_r\times 1}$ can be given

$$\mathbf{y}_i = \mathbf{H}_{i,i}\mathbf{T}_i\mathbf{x}_i + \sum_{j=1,\, j\neq i}^{K} \mathbf{H}_{i,j}\mathbf{T}_j\mathbf{x}_j + \mathbf{n}_i \tag{1}$$

The $\mathbf{x}_i \in \mathbb{C}^{d_i\times 1}$ is transmitting symbol vectors from second users i and $\mathbf{T}_i$ is transmitting beamforming matrix, the matrix model of 1 a combination of the columns; $\mathbf{n}_i \in \mathbb{C}^{N_r\times 1}$ is second users additive white gaussian noise at the receiving end. In this paper, $\mathbf{x}_i$ and $\mathbf{n}_i$ are mutually independent, and its variance 1 and N_0 respectively. User receiver in time space equilibrium, use the receive combined matrix vector $\hat{\mathbf{x}}_i$ can be represented as received signal processing

$$\hat{\mathbf{x}}_i = \mathbf{R}_i^{\mathrm{H}}\mathbf{y}_i = \mathbf{R}_i^{\mathrm{H}}\mathbf{H}_{i,i}\mathbf{T}_i x_i + \mathbf{R}_i^{\mathrm{H}} \sum_{j=1,\, j\neq i}^{K} \mathbf{H}_{i,j}\mathbf{T}_j x_j + \mathbf{R}_i^{\mathrm{H}}\mathbf{n}_i \tag{2}$$

Where $(\bullet)^{\mathrm{H}}$ is on behalf of the conjugate transpose matrix, it is assumed that each second user receiver i know completely the channel status information $\mathbf{H}_{i,1}$, $\cdots$, $\mathbf{H}_{i,K}$ .The channel state information is K second user independent pilot signal sent by a second user sending. At the same time, the assumption for the other $j \neq i$ channel, the receiver can through the radio channel transmission. Therefore algorithm used in the TDD system.

Similarly, in primary user receiver, the received signal vector $\mathbf{y}_P \in \mathbb{C}^{M\times 1}$ is represented as

$$\mathbf{y}_P = \mathbf{G}_P\mathbf{T}_P\mathbf{x}_P + \sum_{j=1}^{K} \mathbf{G}_j\mathbf{T}_j\mathbf{x}_j + \mathbf{n}_P \tag{3}$$

The $\mathbf{x}_P \in \mathbb{C}^{d\times 1}$ is the sending symbol vectors for users from primary user and give priority to the user send the $\mathbf{T}_P$ beam forming matrix and the matrix model of 1 a combination of the columns; $\mathbf{n}_P \in \mathbb{C}^{M\times 1}$ is the primary user additive white gaussian noise at the receiving end. In this paper, $\mathbf{x}_P$ and $\mathbf{n}_P$ are mutually independent, and its variance N_0 and 1 respectively. In the primary user receiver receive combined matrix is adopted to improve the spatial equilibrium, receiving signal processing vector $\hat{\mathbf{x}}_P$ can be expressed as

$$\hat{\mathbf{x}}_P = \mathbf{R}_P^{\mathrm{H}}\mathbf{y}_P = \mathbf{R}_P^{\mathrm{H}}\mathbf{G}_P\mathbf{T}_P\mathbf{x}_P + \mathbf{R}_P^{\mathrm{H}}\sum_{j=1}^{K}\mathbf{G}_j\mathbf{T}_j\mathbf{x}_j + \mathbf{R}_P^{\mathrm{H}}\mathbf{n}_P \tag{4}$$

Assume that each user primary user receiver know completely $\mathbf{G}_1$, $\cdots$, $\mathbf{G}_K$ channel state information. The channel state information is time independent pilot signal sent by K pair of second user sending, primary user receiver to pilot the estimated results.

Assumes that $\mathbf{x}_i$ the average energy per unit of energy, *i.e.*, $E\left[\mathbf{x}_i\mathbf{x}_i^{\mathrm{H}}\right] = \mathbf{I}_{N_r/2}$, the separate second users can achieve the transfer rate of the receiver

$$R_i = \sum_{k=1}^{K}\sum_{i=1}^{N_t/2}\log_2\left(1+\frac{\left|\mathbf{r}_i^{(k)}\mathbf{H}_{i,i}\mathbf{t}_i^{(k)}\right|^2}{\sum_{(l,j)\neq(k,i)}\left|\mathbf{r}_i^{(k)}\mathbf{H}_{i,i}\mathbf{t}_i^{(k)}\right|^2 + N_0\left\|\mathbf{r}_i^{(k)}\right\|^2}\right) \tag{5}$$

$\mathbf{r}_i^{(k)}$ and $\mathbf{t}_i^{(k)}$ respectively, $\mathbf{T}_i$ and $\mathbf{R}_i^{\mathrm{H}}$ i -th column vector. And sending power is

$$\sum_{k=1}^{K} Tr\left(\mathbf{T}_i\mathbf{T}_i^{\mathrm{H}}\right) = P \tag{6}$$

At the same time, its interference to primary user power must be smaller than a fixed value η can be represented as

$$\sum_{j=1}^{K} Tr\left(\mathbf{T}_j\mathbf{G}_j\mathbf{G}_j\mathbf{T}_j^{\mathrm{H}}\right) \leq \eta \tag{7}$$

3. Improve interference alignment method

For interference alignment conditions, can be given

$$\mathrm{span}\left(\mathbf{H}_{i,j}\mathbf{T}_j\right) = \mathrm{span}\left(\mathbf{H}_{i,k}\mathbf{T}_k\right) \quad \text{for all } j \neq i, \quad k \neq i \tag{8}$$

According to force zero criterion, all interference alignment schemes to meet the criteria of type (8), and still need to meet

$$\mathrm{span}\left(\mathbf{G}_i\mathbf{T}_j\right) = \mathrm{span}\left(\mathbf{H}_{i,k}\mathbf{T}_k\right) \quad \text{for all } j \neq i, \quad k \neq i \tag{9}$$

They give you can eliminate interference to primary users, also can eliminate the interference between users. The beam forming method can be divided into two steps, the first step is encoding, the second step is to decode, its formula is

$$\mathbf{T}_i = \mathbf{T}_{iSU}\mathbf{T}_{iPU} \tag{10}$$

$$\mathbf{R}_i = \mathbf{R}_{iSU}\mathbf{R}_{iPU} \tag{11}$$

Among them $\mathbf{T}_{iSU} \in \mathbb{C}^{N_t \times N_t/2}$ is to eliminate matrix interference between users send the beam forming; $\mathbf{R}_{iSU} \in \mathbb{C}^{N_r \times N_r/2}$ is to avoid the interference from the user receiving beam forming matrix; In the same way $\mathbf{T}_{iPU} \in \mathbb{C}^{N_t/2 \times N_t/2}$ in order to avoid the interference from the primary user to send a beam forming matrix, $\mathbf{R}_{iPU} \in \square^{N_r/2\times N_r/2}$ to eliminate the main user interference matrix receive beam forming. At first, how to decide $\mathbf{T}_{iSU}$ and $\mathbf{R}_{iSU}$ interference alignment schemes, $\mathbf{T}_{iSU} = \square(\mathbf{M}_i)$ and among them $\square(\bullet)$ as an orthogonal basis, define three matrix, $\mathbf{E}$, $\mathbf{F}$ and $\mathbf{G}$ for

$$\mathbf{E} = \left(\mathbf{H}^{(31)}\right)^{-1}\mathbf{H}^{(32)}\left(\mathbf{H}^{(12)}\right)^{-1}\mathbf{H}^{(13)}\left(\mathbf{H}^{(23)}\right)^{-1}\mathbf{H}^{(21)} \tag{12}$$

$$\mathbf{F} = \left(\mathbf{H}^{(32)}\right)^{-1}\mathbf{H}^{(31)} \tag{13}$$

$$\mathbf{G} = \left(\mathbf{H}^{(23)}\right)^{-1}\mathbf{H}^{(21)} \tag{14}$$

Through setting $\mathbf{M}_i$, to meet their interference alignment can be achieved.

$$\mathbf{M}_1 = \left[e_{i_1}\cdots e_{i_{\frac{M}{2}}}\right], \text{ for } 1 \le i_1 < \cdots < i_{\frac{N_t}{2}} \le N_t \tag{15}$$

$$\mathbf{M}_2 = \mathbf{F}\mathbf{M}_1 \tag{16}$$

$$\mathbf{M}_3 = \mathbf{G}\mathbf{M}_1 \tag{17}$$

Once $e_{i_1}\cdots e_{i_{\frac{M}{2}}}$ is the eigenvector matrix $\mathbf{E}$, respectively interference alignment condition is met, $\mathbf{R}_{iSU}$ can be used as a front $N_t/2$ left singular value vector $\mathbf{H}_{i,j}\mathbf{T}_{iSU}$. Aligned to $1 \le i_1 < \cdots < i_{\frac{N_t}{2}} \le N_t$ meet disturbance conditions, can choose to maximize the total transmission rate, the number of its search for $\begin{pmatrix} N_t \\ N_t/2 \end{pmatrix}$.

For a given user, after eliminating interference $\mathbf{R}_{iSU}$ and $\mathbf{T}_{iSU}$ the optimal matrix and avoid the interference from the primary user beam forming can be got easily

$$\mathbf{T}_{iPU} = \bar{\mathbf{T}}_{iPU}\Theta_i \tag{18}$$

$$\mathbf{R}_{iPU} = \bar{\mathbf{R}}_{iPU} \tag{19}$$

Among them, $\bar{\mathbf{T}}_{iPU}$ and $\bar{\mathbf{R}}_{iPU}$ is $\mathbf{R}_i^{\mathrm{H}}\mathbf{H}_{i,i}\mathbf{T}$ of right and the left singular matrix singular matrix respectively; As Θ_i real diagonal matrix, including its diagonal elements can be water flooding algorithm to optimization, is the power allocation matrix. The total power limitation $\sum_i Tr\left(\Theta_i^2\right) = P$.

4. Optimize the Interference of the Alignment Method

Can be seen by the third part, the proposed interference alignment schemes did not put forward the plan with maximum total transmission rate, this section is based on the third part, on the basis of further determine how to choose $N_t/2$ a singular vectors from N_t, to maximize the total transmission rate. From (12), (13), (14) can be seen that, if $(\mathbf{T}_1, \mathbf{T}_2, \mathbf{T}_1) \in S$ is forced to meet zero interference alignment condition matrix set S, beam forming, $\mathbf{M}_1$、 $\mathbf{M}_2$ and $\mathbf{M}_3$ need to meet

$$\square(\mathbf{M}_1) = \square\left(\left[e_{i_1}\cdots e_{i_{\frac{M}{2}}}\right]\right) \text{ for } 1 \le i_1 < \cdots < i_{\frac{N_t}{2}} \le N_t \tag{20}$$

$$\square(\mathbf{M}_2) = \square(\mathbf{F}\mathbf{M}_1) \text{ and } \square(\mathbf{M}_3) = \square(\mathbf{G}\mathbf{M}_1) \tag{21}$$

By the above type (20) and (21) can be seen that type (20) can be easily, the key is type (21) how to prove it.

Due to the $\mathbf{H}_{i,j}$ is irreversible, so if you can get $(\mathbf{T}_1, \mathbf{T}_2, \mathbf{T}_1) \in S$, $\Box(\mathbf{M}_2) = \Box(\mathbf{FM}_1)$, so you can get

$$\Box\left(\mathbf{E}\left[e_{i_1} \cdots e_{i_{\frac{M}{2}}}\right]\mathbf{C}\right) = \Box\left(\left[e_{i_1} \cdots e_{i_{\frac{M}{2}}}\right]\mathbf{C}\right) \tag{22}$$

With $\lambda_1, \cdots, \lambda_M$ representatives of characteristic value $\mathbf{E}$, type (22) can be expressed as the left side of the calculation

$$\mathbf{E}\left[e_{i_1} \cdots e_{i_{\frac{M}{2}}}\right] = \left[e_{i_1} \cdots e_{i_{\frac{M}{2}}}\right] diag\left(\lambda_1, \cdots, \lambda_M\right) \tag{23}$$

We can find that, $\Box(\mathbf{M}_2) = \Box(\mathbf{FM}_1)$ and $\Box(\mathbf{M}_3) = \Box(\mathbf{GM}_1)$ proved.

5. Improve Interference Alignment Algorithm

Interference alignment by above method can know that its using is based on the rule of forced to zero, but interference alignment method based on the rule of forced to zero under the condition of low SNR performance is poorer, therefore, this paper puts forward optimization based on minimum mean square error criterion, can be defined as the standards

$$\sum_{k=1}^{K} E\left[\left\|\mathbf{T}_{\Lambda}^{i}\mathbf{s}_i - \hat{\mathbf{s}}_i\right\|^2\right] \tag{24}$$

Gain matrix $\mathbf{T}_{\Lambda}^{i} = \mathbf{R}_i^{\mathrm{H}}\mathbf{H}_{i,i}\mathbf{T}_i$, which is an effective channel and respectively send matrix $\mathbf{R}_i^{\mathrm{H}}$ and $\mathbf{T}_i$ receiving matrix of beam forming beam forming, due to the introduction of the poor $\mathbf{T}_{\Lambda}^{i}$ can prevent sub-channel allocation more power. In fact, if according to the poor searching method, can get the optimal method, but the complexity is higher, so the minimum mean square error can improve performance with less computational complexity.

Order $\mathbf{R}_i^{\mathrm{H}} = \mu^{-1}\mathbf{R}_i^{\mathrm{H}}$, the minimum mean square error problem can be expressed as

$$\begin{aligned} &\min_{\mathbf{R}_i^{\mathrm{H}}, \mathbf{T}_i} E\left[\left\|\mathbf{T}_{\Lambda}^{i}\mathbf{s}_i - \mu^{-1}\hat{\mathbf{s}}_i\right\|^2\right] \\ &s.t. \quad \sum_{k=1}^{K} Tr\left(\mathbf{T}_i\mathbf{T}_i^{\mathrm{H}}\right) = P \\ &\qquad\ \sum_{j=1}^{K} Tr\left(\mathbf{T}_j\mathbf{G}_j\mathbf{G}_j\mathbf{T}_j^{\mathrm{H}}\right) \le \eta \end{aligned} \tag{25}$$

$\hat{\mathbf{s}}_i = \mathbf{R}_i^{\mathrm{H}}\left(\sum_{j=1, j\neq i}^{K} \mathbf{H}_{i,j}\mathbf{T}_j x_j + \mathbf{n}_i\right)$, among them, the introduction of a real number μ , send the gain to increase, in order to solve this problem, can use the Lagrange algorithm to optimize functions

$$F\left(\mathbf{T}_i;\mathbf{R}_i^{\mathrm{H}};\mu;\lambda;\kappa\right)=\sum_{k=1}^{K}Tr\left\{\left(\mathbf{T}_{\Lambda}^{i}-\mu^{-1}\mathbf{R}_i^{\mathrm{H}}\mathbf{H}_{i,i}\mathbf{T}_i\right)\left(\mathbf{T}_{\Lambda}^{i\,\mathrm{H}}-\mu^{-1}\mathbf{T}_i^{\mathrm{H}}\mathbf{H}_{i,i}^{\mathrm{H}}\mathbf{R}_i\right)\right\}+\mu^{-2}N_0^2\sum_{k=1}^{K}Tr\left(\mathbf{R}_i^{\mathrm{H}}\mathbf{R}_i\right)+ \lambda\left(\sum_{k=1}^{K}Tr\left(\mathbf{T}_i\mathbf{T}_i^{\mathrm{H}}\right)-P\right)+\kappa\left(\sum_{j=1}^{K}Tr\left(\mathbf{T}_j\mathbf{G}_j\mathbf{G}_j\mathbf{T}_j^{\mathrm{H}}\right)-\eta\right)+\Xi \tag{26}$$

Among them, the change $\Xi=\mu^{-2}\sum_{k=1}^{K}Tr\left\{\mathbf{T}_k^{\mathrm{H}}\left(\sum_{l\neq k}\mathbf{H}_{l,k}^{\mathrm{H}}\mathbf{H}_{l,k}\right)\mathbf{T}_k\right\}$ can get by

$$\Xi=\mu^{-2}\sum_{k=1}^{K}Tr\left\{\mathbf{R}_k^{\mathrm{H}}\left(\sum_{l\neq k}\mathbf{H}_{l,k}^{\mathrm{H}}\mathbf{H}_{l,k}\right)\mathbf{R}_k\right\} \tag{27}$$

In (26) investigated $\mathbf{T}_k$ and $\mathbf{R}_k^{\mathrm{H}}$ derivation, and set it to zero, so as to get and for

$$\mathbf{T}_k=\mu\left(\sum_{k}\mathbf{H}_{l,k}^{\mathrm{H}}\mathbf{H}_{l,k}+\omega\mathbf{I}_{N_t/2}\right)^{-1}\mathbf{H}_{i,i}^{\mathrm{H}}\mathbf{T}_{\Lambda}^{i} \tag{28}$$

$$\mathbf{R}_k=\mu\left(\sum_{k}\mathbf{H}_{l,k}^{\mathrm{H}}\mathbf{H}_{l,k}+\omega\mathbf{I}_{N_t/2}\right)^{-1}\mathbf{H}_{i,i}\mathbf{T}_{\Lambda}^{i} \tag{29}$$

Among them, ω to say the product $\omega=\lambda^2\mu$ of the number of daily, because type (28), (29), which contains unknown variables respectively, so can only use iterative method to gradually improve the optimization performance. The optimization procedure is as follows

The first step, the fixed $\mathbf{T}_k$, optimization $\mathbf{R}_k$ 、 μ 、 κ.

The second step, the fixed $\mathbf{R}_k$ and optimize the $\mathbf{T}_k$ 、 μ 、 κ 、 ω.

After a series of iterations, get $\mathbf{T}_k=\kappa\tilde{\mathbf{T}}_k$, which $\tilde{\mathbf{T}}_k$ can be defined as

$$\tilde{\mathbf{T}}_k=\mu\left(\sum_{k}\mathbf{H}_{l,k}^{\mathrm{H}}\mathbf{H}_{l,k}+\omega\mathbf{I}_{N_t/2}\right)^{-1}\mathbf{H}_{i,i}^{\mathrm{H}}\mathbf{T}_{\Lambda}^{i} \tag{30}$$

estrictions related to daily (elm) number μ and total power κ, so it can get

$$\mu=\sqrt{\frac{P}{\sum_{k=1}^{K}Tr\mathbf{T}_k^{\mathrm{H}}\left(\sum_{l\neq k}\mathbf{H}_{l,k}^{\mathrm{H}}\mathbf{H}_{l,k}\right)\mathbf{T}_k}} \tag{31}$$

Results of fixed $\mathbf{R}_k$ optimization $\mathbf{T}_k$, get a function κ is on

$$\min_{\omega}\sum_{k=1}^{K}E\left[\left\|\mathbf{T}_{\Lambda}^{k}\mathbf{s}_k-\sum_{l=1}^{K}\mathbf{H}_{l,k}^{\mathrm{H}}\mathbf{T}_l^{\mathrm{H}}\left(\kappa\right)\mathbf{s}_l-\mu\mathbf{R}_k\mathbf{n}_i\right\|^2\right] \tag{32}$$

Which μ depends on κ and through the derivation, and set to zero, it can be optimal κ for

$$\kappa=\frac{N_0^2\sum_{k=1}^{K}Tr\left\{\mathbf{R}_k^{\mathrm{H}}\mathbf{R}_k\right\}}{P} \tag{33}$$

Thus, you can perform the calculation of step 1, the whole calculation process can be summarized as follows

1) computing $\mathbf{T}_{\Lambda}^{i}$ and $\mathbf{T}_{\Lambda}^{i}$, for any i;

2) For $\mathbf{R}_i$ that $\mathbf{R}_{\Lambda}$, for the arbitrary i;

3) By type (33)calculate κ ;

4) calculated $\mathbf{T}_k$ by multiplying the type (28), (30);

5) By type (29)calculate $\mathbf{R}_k$

Iterative process, further optimize performance, but at the cost of increased computational complexity.

6. Simulation Results

In this part, using the computer simulation to show the advanced nature of the proposed scheme; In order to simplify the simulation, this paper argues that time user to the main user distance is equal at the receiving end. General, do not lose time users sending side and time the receiver to the main user distance is at the receiving end users the sender to the primary user receiver distance of two times and three times. In this simulation $N_t = 8$, $N_r = 2$, $K = 8$, User and set a time equal to the maximum power of the relay sends, *i.e.*, P . In the simulation, set up different stages of boundaries are the primary user interference η . In order to compare the feedback scheme under the condition of superiority, this paper simulated five iterations. In order to compare convenience, this article proposed solutions respectively compared with the following three schemes:

Solution 1: optimal power allocation scheme, the legend of Figure 2 and Figure 3 recorded as "[9]";

Solution 2: to maximize user system transmission rate, Figure 2 and Figure 3 in the legend of recorded as "[10] plan";

Solution 3: to maximize user system transmission rate and the optimal power allocation optimization, the legend of Figure 2 and Figure 3 as a "joint".

Figure 2 in the user's average signal-to-noise ratio (), the maximum mutual information of the user's system, left feedback bits for the 6 bit is the case, as can be seen from the left, the proposed scheme and optimal scheme 3, 2 db gain, the main reason for CSI scheme 3 is based on the RS obtain complete under the condition of the optimal solution, without considering quantization error exists, from another Angle and you can see, quantitative error affect user transmission rate. Time for users to send end of CSI is more accurate, the proposed scheme advantages are more obvious, you can see there is a gain of 2.5 dB. As can be seen from the two figure of Figure 2, the proposed scheme is effective to overcome the influence of quantization error to the user transmission rate.

Figure 3 in the same time the user's average signal-to-noise ratio ($0 \sim 30dB$), the bit error performance of four kinds of schemes are compared, left for feedback bits for 6 bit, the BER curves, we can find that, due to the optimization criteria for the MMSE, so its BER performance advantage is more obvious, the other three kinds of solution with the increase of SNR, the BER curve does not decline, while the proposed scheme has a good BER and convergence with the convergence of mean square error (MSE) have equivalence, from the perspective of the simulation prove that the convergence of the algorithm.

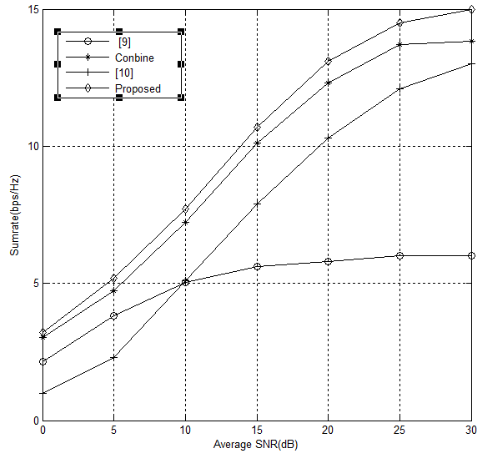

Figure 2. Sum Rate Simulation

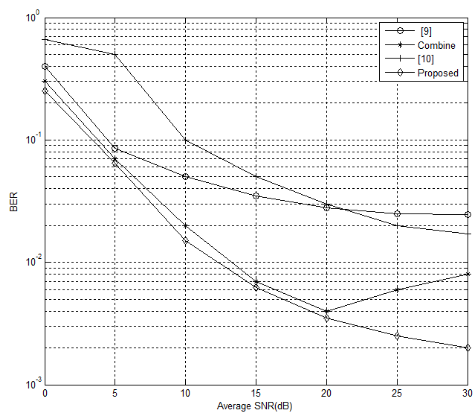

Figure 3. BER Simulation

7. Conclusion

We studied in several times the sending end and receiving end user case, how to use communication interference alignment beam forming algorithm, the scheme based on multiple cognitive radio antenna system, according to this plan, you can get the maximum system capacity of the beam forming algorithm, simulation shows the effectiveness of the method, of course, the FDD system, CSI's gain and interference alignment schemes to explore further in the future.

References

[1] V. Chakravarthy, X. Li and R. L. Zhou, "A Novel Hybrid Overlay/Underlay Cognitive Radio Waveform in Frequency Selective Fading Channels," in Proc. 4th International Conference on Cognitive Radio Oriented Wireless Networks and Communications, **(2009)**, pp. 1-6.

[2] V. Chakravarthy, Z. Q. Wu and M. Temple, "Cognitive Radio Centric Overlay/Underlay Waveform," in Proc. 3rd IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks, **(2008)**, pp. 1-10.

[3] V. Chakravarthy, Z. Q. Wu and A. Shaw, "A General Overlay/Underlay Analytic Expression Representing Cognitive Radio Waveform," in Proc. International Waveform Diversity and Design Conference, **(2007)**, pp. 69-73.

[4] F. F. Digham, M. S. Alouini and M. K. Simon, "On the Energy Detection of Unknown Signals over Fading Channels," in Proc. IEEE International Conference on Communications (ICC'03), **(2003)** May, pp. 3575-3579.
[5] A. Ghasemi and E. S. Sousa, "Collaborative Spectrum Sensing for Opportunistic Access in Fading Environments," in First IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN 2005), **(2005)**, pp. 131-136.
[6] S. P. Chen, W. B. Wang and X. Zhang, "Performance Analysis of Multiuser Diversity in Cooperative Multi-Relay Networks under Rayleigh-Fading Channels," IEEE Trans. on Wireless Commun., vol. 8, no. 8, **(2009)**, pp. 3415-3419.
[7] J. Oh and W. Choi, "A Hybrid Cognitive Radio System: A Combination of Underlay and Overlay Approaches," in IEEE Vehicular Technology Conference Fall (VTC 2010-Fall), **(2010)**, pp. 1-5.
[8] S. Sriram, S. Vishwanath and S. Jafar, "On the Capacity of Cognitive Relay Assisted Gaussian Interference Channel," in proc. of 2008 International Symposium on Information Theory, **(2008)** July, pp. 1-5.
[9] A. Ben Letaifa and S. Tabbane Mediatron, "Dynamic Reconfiguration of Radio Mobile Multimedia Services Platforms of 3rd and 4th Generations", IJAST, vol. 12, **(2009)** November, pp. 11-24.
[10] M. M. Alkhawlani and A. M. Mohsen, "Hybrid Approach for Radio Network Selection in Heterogeneous Wireless Networks", IJAST, vol. 44, **(2012)** July, pp. 33-48.
[11] J. Chen, S. Li and S. Deng, "Route Selection Strategy Combined with Spectrum Characteristic in Cognitive Radio Networks", IJSEIA, vol. 2, no. 2, **(2008)** April, pp. 119-128.
[12] C. Song, K. Kim, W. Park and J. Kim, "Performance Analysis of Signal feature detection using Spectral Correlation Function for Cognitive Radio Environments", IJMUE, vol. 1, no. 3, **(2006)** September, pp. 32-36.

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