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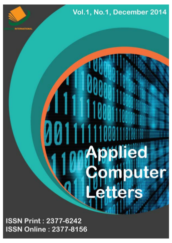

INTERFERENCE CANCELLATION SCHEME BASED ON INTERFERENCE ALIGNMENT FOR MULTIUSER FULL-DUPLEX COMMUNICATION

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ABSTRACT

Full-duplex systems have been proposed as a key technology of fifth generation (5G) mobile communications .For the first time this paper proposes an interference cancellation scheme by interference alignment to eliminate the self-interference and mutual interference of full-duplex interference channel. The majority of existing work focuses on the suppression of self-interference without considering the effect of mutual interference, so this paper presents an interference cancellation scheme to suppress the self-interference and mutual interference at the same time. In the scheme, the full-duplex channel with self-interference and mutual interference (the original model) is treated as a MIMO channel model with mutual interference (the equivalent model). Firstly, this paper introduces the channel matrix of the corresponding relationship between the equivalent model and the original model. Secondly, based on the corresponding relationship, iterative interference alignment algorithm and maximum signal to interference plus noise ratio algorithm are used to eliminate the self-interference and mutual interference. Finally, we simulate the capacity and average energy efficiency. The simulation results show that the capacity and average energy efficiency are more improved obviously by this scheme than other schemes.

KEYWORDS

Full-duplex, interference alignment, capacity, average energy efficiency

1. INTRODUCTION

With the growth of wireless communication users and the increase of the system bandwidth, the demand of the frequency spectrum resources is also increasing rapidly. Co-frequency and co-time full duplex (CCFD) wireless communication systems transmit and receive signals over the same frequency at the same time. Based on a study, as a potential key technology of 5G, compared with the currently deployed systems, such as frequency division duplex (FDD) and time division duplex (TDD), the maximum spectrum efficiency of the CCFD system can be doubled [1]. While the limiting factor in the performance of CCFD systems is the strong self-interference generated from a node's own transmitter to its receiver. Hence, effectively mitigating the self-interference in CCFD systems can result in a significant spectral efficiency increase over FDD and TDD systems.

In fact, in addition to in the CCFD systems, the self-interference and mutual interference also exist in small cellular network, wireless D2D (between the two user devices) communication environment etc. Some researches have been done for self-interference elimination of CCFD systems, which relates to three suppression techniques, namely the antenna interference cancellation, radio frequency (RF) interference cancellation and digital interference cancellation [2-8]. However, the current studies can't eliminate the mutual interference and self-interference of CCFD systems at the same. Furthermore, the above interference cancellation schemes don't involve interference alignment, so this paper uses interference alignment to eliminate the self-interference and mutual interference at the same time [9].

According to research, interference alignment is able to align interference from all other transmitters into the same interference subspace and keep the desired signal subspace and the interference subspace linearly independent [10]. In theory, interference alignment can completely suppress the self-interference and mutual interference. Thus, the system can achieve a larger freedom and total rate. Interference alignment is used to eliminate the self-interference and mutual interference of full duplex of the adjacent small cellular same frequency network, which is a kind of new mentality and has performance advantages [11].

The remainder of this paper is organized as follows. Section Ⅱ presents the model of CCFD system, and some definitions and assumptions are given. In Section Ⅲ ,the interference cancellation scheme based on interference alignment is presented. Section Ⅳ presents the simulation and results of different algorithms. Finally we conclude our paper in Section Ⅴ.

2.EQUIVALENT MODEL OF DUPLEX COMMUNICATION INTERFERENCE CHANNEL

2.1 Multiuser Full-Duplex Communication Interference Channel

We consider a multiuser CCFD communication channel of the adjacent small cellular same frequency network where users and base stations are working in full duplex mode. We suppose that user u_i (i = 1, 2) only expects to receive the signal from the base station (BS) b_i and transmit its signal to the base station bi , at the same time it considers the signals from other users and base stations as well as itself as interference signals. Conversely, it also causes interference to them. Similarly, BS b(i = 1, 2) only expects to receive the signal from the user ui and transmit its signal to the user ui , at the same time it considers the signals from other users and base stations as well as itself as interference signals. Conversely, it also causes interference to them. Figure 1 is a 2-user full-duplex interference channel example, in which the solid line corresponds to the desired channel, and the dotted line corresponds to the interference channel.

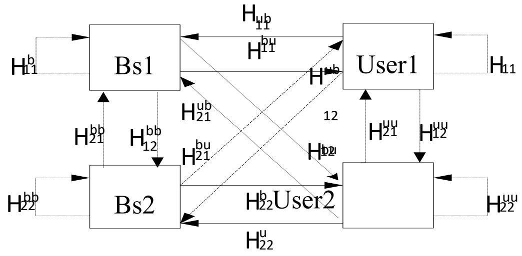

Figure 1: 2-user full-duplex interference channel.

Suppose we configure M antennas for the receiver and transmitter of all BS and users. For the receiver of user u_i (i = 1, 2) $\mathbf{H}^{bu}_{ji} \in \mathbb{C}^{M\times M}$ is the matrix channel coefficients between the transmitter of BS b_j (j = 1, 2) and the user u_i, and $\mathbf{H}^{uu}_{ji} \in \mathbb{C}^{M\times M}$ is channel matrix from user transmitter u_j to user receiver u_i. It is assumed that the channel is Rayleigh fading; hence, the coefficients in the channel matrices are complex independent identically Gaussian distributed random variables with zero mean and unit variance. So the received signal vector at user receiver is given by

$$\begin{aligned}\mathbf{y}^u_i &= \sum_{i=1}^{K}\mathbf{H}^{bu}_{ji}\mathbf{s}^b_j + \sum_{i=1}^{K}\mathbf{H}^{uu}_{ji}\mathbf{s}^u_j + \mathbf{n}^u_i \\ &= \mathbf{H}^{bu}_{ii}\mathbf{s}^b_i + \left(\sum_{j=1,j\neq i}^{K}\mathbf{H}^{bu}_{ji}\mathbf{s}^b_j + \sum_{j=1}^{K}\mathbf{H}^{uu}_{ji}\mathbf{s}^u_j\right) + \mathbf{n}^u_i\end{aligned} \tag{1}$$

where K is the number of users $\mathbf{s}^u_j \in \mathbb{C}^{M\times 1}$ is the data vector from user u_j($\forall$j ∈ K) , $\mathbf{s}^b_j \in \mathbb{C}^{M\times 1}$ is the data vector from BS b_j , and they are constrained by $E\{\|\mathbf{s}^u_j\|^2\} = P^u_j$, $E\{\|\mathbf{s}^b_j\|^2\} = P^b_j$ (P^b_j and P^u_j is the transmit power of BS b_j and user u_j, respectively). $\mathbf{n}^u \in \mathbb{C}^{M\times 1}$ is a zero mean unit variance circularly symmetric additive white Gaussian noise vector (AWGN) at user receiver u_i . In Equation (1), $\left(\sum_{j=1,j\neq i}^{k}\mathbf{H}^{bu}_{ji}\mathbf{s}^b_j + \sum_{j=1}^{k}\mathbf{H}^{uu}_{ji}\mathbf{s}^u_j\right)$ is the mutual interference and self-interference.

Similarly, for the receiver of BS b_i (i = 1, 2) , $\mathbf{H}^{ub}_{ji}$ is the M × M matrix of channel coefficients between the transmitter of user u_j (j = 1, 2) and the receiver of BS b_i (i = 1, 2) , and $\mathbf{H}^{bb}_{ji}$ is the M × M matrix of channel coefficients between the transmitter of BS b_j (j = 1, 2) and the receiver of BS b_i (i = 1, 2). It is assumed that the channel is Rayleigh fading; hence, the coefficients in the channel matrices are complex independent identically Gaussian distributed random variables with zero mean and unit variance. So the received signal vector at BS receiver is given by

$$\begin{aligned}\mathbf{y}^b_i &= \sum_{j=1}^{K}\mathbf{H}^{ub}_{ji}\mathbf{s}^u_j + \sum_{j=1}^{K}\mathbf{H}^{bb}_{ji}\mathbf{s}^b_j + \mathbf{n}^b_i \\ &= \mathbf{H}^{ub}_{ii}\mathbf{s}^u_i + \left(\sum_{j=1,j\neq i}^{K}\mathbf{H}^{ub}_{ji}\mathbf{s}^u_j + \sum_{j=1}^{K}\mathbf{H}^{bb}_{ji}\mathbf{s}^b_j\right) + \mathbf{n}^b_i\end{aligned} \tag{2}$$

where $\mathbf{n}^b_i \in \mathbb{C}^{M\times 1}$ is a zero mean unit variance circularly symmetric additive white Gaussian noise vector at the receiver b_i . In (2), $\mathbf{H}^{ub}\mathbf{s}^u$ is the desired signal and $\left(\sum_{j=1,j\neq i}^{k}\mathbf{H}^{ub}_{ji}\mathbf{s}^u_j + \sum_{j=1}^{k}\mathbf{H}^{bb}_{ji}\mathbf{s}^b_j\right)$ is denoted the interference.

2.2 Equivalent System Model

In Figure 1 the original model is complex, so we design the equivalent model of 2-user link full- duplex interference channel model which is a special 4-user link half-duplex interference channel model in Figure 2.

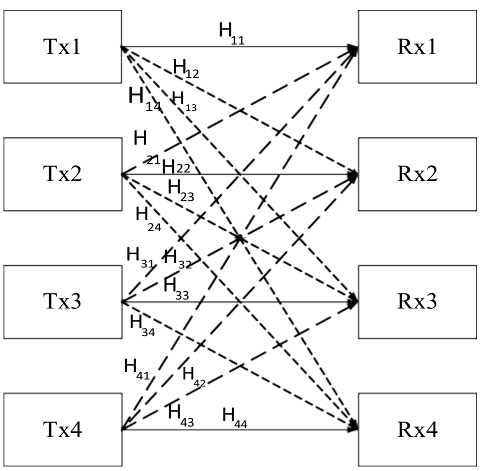

Figure 2: The equivalent model of 2-user full-duplex interference channel.

The equivalent model has a total of 4 transmitting ends and receiving ends. Each transmitting end T_j (j = 1, 2, 3, 4) only expects to transmit its signal to the corresponding receiving end R_i(i = 1, 2, 3, 4) , and causes interference to other three receiving ends at the same time. Conversely, each receiving end R_i only expects to receive the signal from the corresponding transmitting end T_j , meanwhile, other three transmitting end can also cause interference to the receiving end R_i .In this way, the interference (including self-interference and mutual interference) of the equivalent model in Figure 2 can be eliminated by interference alignment.

According to the equivalent model, the transmitting end Tx_1 and Tx_3 correspond to the transmitter of BS b_1 and BS b_2 , respectively. So we get the transmitted signal $\mathbf{s}_1 = \mathbf{s}^b_1$ $\mathbf{s}_3 = \mathbf{s}^b_2$. The transmitting end Tx_2 and Tx_4 correspond to the transmitter of user u1 and user u_2 , respectively. So we get the received signal vector $\mathbf{y}_1 = \mathbf{y}^u_1$, $\mathbf{y}_2 = \mathbf{y}^u_2$ The receiving end Rx_2 and Rx_4 correspond to the receiver of BS b_1 and BS b_2 , respectively. So we get the received signal $\mathbf{y}_2 = \mathbf{y}^b_1$,$\mathbf{y}_4 = \mathbf{y}^b_2$.

Suppose $\mathbf{H}_{ji}$ is the $M \times M$ matrix of channel between transmitting end Tx_i between transmitting end Tx_i and receiving end Rx_j($i, j \in${1, 2, 3, 4}) . $\mathbf{s}_i$ is the transmitted signal vector which satisfies $E[\mathbf{s}_j\mathbf{s}^H_j] = P(j)$ and $\mathbf{y}$ is the received signal. The corresponding relationship between the equivalent channel and the original channel is given by

$$\begin{aligned}
&\mathbf{H}_{11} = \mathbf{H}^{\mathbf{bu}}_{11}, \mathbf{H}_{12} = \mathbf{H}^{\mathbf{bb}}_{11}, \mathbf{H}_{13} = \mathbf{H}^{\mathbf{bu}}_{12}, \mathbf{H}_{14} = \mathbf{H}^{\mathbf{bb}}_{12} \\
&\mathbf{H}_{21} = \mathbf{H}^{\mathbf{uu}}_{11}, \mathbf{H}_{22} = \mathbf{H}^{\mathbf{ub}}_{11}, \mathbf{H}_{23} = \mathbf{H}^{\mathbf{uu}}_{12}, \mathbf{H}_{24} = \mathbf{H}^{\mathbf{ub}}_{12} \\
&\mathbf{H}_{31} = \mathbf{H}^{\mathbf{bu}}_{21}, \mathbf{H}_{32} = \mathbf{H}^{\mathbf{bb}}_{21}, \mathbf{H}_{33} = \mathbf{H}^{\mathbf{bu}}_{22}, \mathbf{H}_{34} = \mathbf{H}^{\mathbf{bb}}_{22} \\
&\mathbf{H}_{41} = \mathbf{H}^{\mathbf{uu}}_{21}, \mathbf{H}_{42} = \mathbf{H}^{\mathbf{ub}}_{21}, \mathbf{H}_{43} = \mathbf{H}^{\mathbf{uu}}_{22}, \mathbf{H}_{44} = \mathbf{H}^{\mathbf{ub}}_{22}
\end{aligned} \tag{3}$$

According to Equation (1), (2), and (3), the equivalent received signal vector is

$$\mathbf{y}_i = \sum_{j=1}^{K}\mathbf{H}_{ji}\mathbf{s}_j + \mathbf{n}_i = \mathbf{H}_{ii}\mathbf{s}_i + \sum_{j=1,j\neq i}\mathbf{H}_{ji}\mathbf{s}_j + \mathbf{n}_i \tag{4}$$

There is a substantial difference between the equivalent channel model and the general 4-user MIMO interference channel model. For the general 4- user MIMO interference channel model, the interference is the transmitted signal from other transmitters, and it is the mutual interference of 4 users. However, the equivalent model is similar to the general 4-user MIMO interference channel model, but it is the essence of the 2-user full-duplex interference channel. Because the interference in the equivalent model not only contains the mutual between different users, different base stations as well as the users and base stations, but also includes the self-interference of base stations and users in the full-duplex communication, i.e. Therefore the part of the channel in the equivalent channel reciprocal, according to the reciprocity of channel we can get the channel matrix which satisfies the following relations:

$$\begin{aligned}
&\mathbf{H}_{11} = \mathbf{H}_{22}, \mathbf{H}_{12} = \mathbf{H}_{12}, \mathbf{H}_{13} = \mathbf{H}_{42} \\
&\mathbf{H}_{14} = \mathbf{H}_{32}, \mathbf{H}_{21} = \mathbf{H}_{21}, \mathbf{H}_{23} = \mathbf{H}_{41} \\
&\mathbf{H}_{24} = \mathbf{H}_{31}, \mathbf{H}_{33} = \mathbf{H}_{44}, \mathbf{H}_{34} = \mathbf{H}_{34}\ \mathbf{H}_{43} = \mathbf{H}_{43}
\end{aligned} \tag{5}$$

3. INTERFERENCE ALIGNMENT ALGORITHM

3.1 Iterative Interference Alignment Algorithm

It is assumed that the link from BS to the user is called forward link and the link from user to the BS is called reverse link. In the forward link, the received signal vector at user u_i (i =1, 2) transmitter is given by

$$\begin{aligned}\mathbf{y}_i &= \sum_{j=1}^{K}\mathbf{H}_{ji}\mathbf{V}_j\mathbf{s}_j + \mathbf{n}_i \\ &= \mathbf{H}_{ii}\mathbf{V}_i\mathbf{s}_i + \sum_{j=1,j\neq i}^{K}\mathbf{H}_{ji}\mathbf{V}_j\mathbf{s}_j + \mathbf{n}_i\end{aligned} \tag{6}$$

where $\mathbf{y}_i \in \mathbb{C}^{N_r\times 1}$ is the received signal vector, $\mathbf{V}_i \in \mathbb{C}^{N_r\times d(i)}$ is the pre-coding matrix.

Therefore, in the reverse link, based on the reciprocity of channel the received signal vector at the transmitter of BS is given by

$$\overleftarrow{\mathbf{y}}_i = \sum_{j=1}^{K} \overleftarrow{\mathbf{H}}_{ji} \overleftarrow{\mathbf{V}}_j \overleftarrow{\mathbf{s}}_j + \overleftarrow{\mathbf{n}}_i = \overleftarrow{\mathbf{H}}_{ii} \overleftarrow{\mathbf{V}}_i \overleftarrow{\mathbf{s}}_i + \sum_{j=1, j\neq i}^{K} \overleftarrow{\mathbf{H}}_{ji} \overleftarrow{\mathbf{V}}_j \overleftarrow{\mathbf{s}}_j + \overleftarrow{\mathbf{n}}_i \tag{7}$$

where $\overleftarrow{\mathbf{y}}_i \in \mathbb{C}^{N_i \times 1}$ is the received signal vector, $\overleftarrow{\mathbf{V}}_i \in \mathbb{C}^{N_r \times d(i)}$ is the pre-coding matrix, $\overleftarrow{\mathbf{s}}_j \in \mathbb{C}^{d(i)\times 1}$ the transmitted signal vector which satisfies $E\{\|\overleftarrow{s}_j\|^2\} = P(j)$, $\overleftarrow{\mathbf{n}}_i \in \mathbb{C}^{N_r \times 1}$ is a zero mean unit variance circularly symmetric additive white Gaussian noise vector at receiver, $\overleftarrow{\mathbf{H}}_{ji} \in \mathbb{C}^{N_t \times N_r}$ is the channel matrix.

According to (5), the relationship between $\overleftarrow{\mathbf{H}}_{ji}$ and $\mathbf{H}_{ji}$ is given by

$$\begin{aligned}
&\overleftarrow{\mathbf{H}}_{11} = \mathbf{H}_{22}, \overleftarrow{\mathbf{H}}_{12} = \mathbf{H}_{21}, \overleftarrow{\mathbf{H}}_{13} = \mathbf{H}_{24}, \overleftarrow{\mathbf{H}}_{14} = \mathbf{H}_{23}\\
&\overleftarrow{\mathbf{H}}_{21} = \mathbf{H}_{12}, \overleftarrow{\mathbf{H}}_{22} = \mathbf{H}_{11}, \overleftarrow{\mathbf{H}}_{23} = \mathbf{H}_{14}, \overleftarrow{\mathbf{H}}_{24} = \mathbf{H}_{13}\\
&\overleftarrow{\mathbf{H}}_{31} = \mathbf{H}_{42}, \overleftarrow{\mathbf{H}}_{32} = \mathbf{H}_{41}, \overleftarrow{\mathbf{H}}_{33} = \mathbf{H}_{44}, \overleftarrow{\mathbf{H}}_{34} = \mathbf{H}_{43}\\
&\overleftarrow{\mathbf{H}}_{41} = \mathbf{H}_{32}, \overleftarrow{\mathbf{H}}_{42} = \mathbf{H}_{31}, \overleftarrow{\mathbf{H}}_{43} = \mathbf{H}_{34}, \overleftarrow{\mathbf{H}}_{44} = \mathbf{H}_{33}
\end{aligned} \tag{8}$$

In addition, for the reverse link, if interference is aligned into the null space of interference suppression matrix then the following condition must be satisfied

$$\overleftarrow{\mathbf{U}}_j^H \overleftarrow{\mathbf{H}}_{ji} \overleftarrow{\mathbf{V}}_i = 0, \forall j \neq i \tag{9}$$

$$rank(\overleftarrow{\mathbf{U}}_i^H \overleftarrow{\mathbf{H}}_{ii} \overleftarrow{\mathbf{V}}_i) = d(i) \tag{10}$$

According to the reciprocity, we can get $\overleftarrow{V}_i = U_i$, $\overleftarrow{U}_i = V_i$. For the equivalent model, we can use iterative interference alignment algorithm of to get the pre-coding matrix and interference suppression matrix [12]. The quality of iterative interference alignment is measured by the power in the leakage interference at each receiver i (BS receiver and user receiver). The goal is to minimize power in the leakage interference, eventually the leakage interference will be zero. Therefore, the total interference leakage at receiver i (BS receiver and user receiver) due to all undesired transmitters j(j ≠ i) (BS transmitter and user transmitter) is given by

$$I_i = Tr(\mathbf{U}_i^H \mathbf{Q}_i \mathbf{U}_i) \tag{11}$$

where Q_i is the interference covariance at receiver i which is given by

$$\mathbf{Q}_i = \sum_{j=i, j\neq i}^{K} \frac{P(j)}{d(j)} \mathbf{H}_{ji} \mathbf{V}_i \mathbf{V}_j^H \mathbf{H}_{ji}^H \tag{12}$$

Similarly, in the reverse link, the total interference leakage at receiver i (BS receiver and user receiver) is given by

$$\overleftarrow{I}_i = Tr(\overleftarrow{\mathbf{U}}_i^H \overleftarrow{\mathbf{Q}}_i \overleftarrow{\mathbf{U}}_i) \tag{13}$$

where Q_i is the interference covariance in the reverse link which is given by:

$$\overleftarrow{\mathbf{Q}}_i = \sum_{j=i, j\neq i}^{K} \frac{\overleftarrow{P}(j)}{d(j)} \overleftarrow{\mathbf{H}}_{ji} \overleftarrow{\mathbf{V}}_i \overleftarrow{\mathbf{V}}_j^H \overleftarrow{\mathbf{H}}_{ji}^H \tag{14}$$

The optimization problem in the forward link and the reverse link is to minimize I_i and $\overleftarrow{I}_i$ The algorithm process is describe as follows,

Algorithm 1: Iterative interference alignment algorithm (Minimum interference leakage: Min-IL)
Step 1: At the receivers, initialize the pre-coding matrix V_j randomly. Step 2: Start iteration, compute interference covariance matrix Q_i

$$\mathbf{Q}_i = \sum_{j=i, j\neq i}^{K} \frac{P(j)}{d(j)} \mathbf{H}_{ji} \mathbf{V}_i \mathbf{V}_j^H \mathbf{H}_{ji}^H$$

Step 3: Compute the interference suppression matrix: $\mathbf{U}_i = v_d^{\min}[\mathbf{Q}_i]$, where $v_d^{\min}[\mathbf{Q}_i]$ is denoted the eigenvector corresponding to the d^{th} smallest eigen value of the matrix Q_i.
Step 4: Reverse the communication direction and set $\overleftarrow{V}_i = U_i$.
Step 5: In the reverse link, compute interference covariance matrix at receiver i (BS receiver and user receiver):

$$\overleftarrow{\mathbf{Q}}_i = \sum_{j=i, j\neq i}^{K} \frac{\overleftarrow{P}(j)}{d(j)} \overleftarrow{\mathbf{H}}_{ji} \overleftarrow{\mathbf{V}}_i \overleftarrow{\mathbf{V}}_j^H \overleftarrow{\mathbf{H}}_{ji}^H$$

Step 6: In the reverse link, compute the interference suppression matrix at each receiver (that is, the pre-coding matrix in the forward link): $\overleftarrow{U}_i = vd[\overleftarrow{Q}_i]$.
Step 7: Reverse the communication direction and set $V_i = \overleftarrow{U}_i$.
Step 8: Continue iteration till convergence.

3.2 Maximum Signal to Interference plus Noise Ratio Algorithm

Above the iterative algorithm, because it does not consider the path of the desired signal, so the signal to interference plus noise ratio is not optimal at the receiver. In the case of high SNR, it almost doesn't affect the sum rate, but in small SNR causes a great influence. So we consider the SINR of the k^{th} stream of the i^{th} receiver is,

$$\mathbf{SINR}_{ki} = \frac{\mathbf{U}_{ki}^H \mathbf{H}_{ii} \mathbf{V}_{ki} \mathbf{V}_{ki}^H \mathbf{H}_{kk}^H \mathbf{U}_{ki}}{\mathbf{U}_{ki}^H \mathbf{B}_{ki} \mathbf{U}_{ki}} \frac{P(i)}{d(i)} \tag{15}$$

Where $\mathbf{B}_{ki}$ is the interference-plus-noise covariance matrix

$$\mathbf{B}_{ki} = \sum_{j=i}^{K} \frac{P(j)}{d(j)} \sum_{d=1}^{d(j)} \mathbf{H}_{ki} \mathbf{V}_{dj} \mathbf{V}_{dj}^H \mathbf{H}_{ki}^H - \frac{P(i)}{d(i)} \mathbf{H}_{ii} \mathbf{V}_{ki} \mathbf{V}_{ki}^H \mathbf{H}_{ii}^H + \mathbf{I}_{N_r} \tag{16}$$

Based on maximum signal to interference plus noise ratio algorithm, the interference suppression matrix of the k^{th} stream of the i^{th} receiver is

$$\mathbf{U}_{ki} = \frac{(\mathbf{B}_{ki})^{-1} \mathbf{H}_{ii} \mathbf{V}_{ki}}{\|(\mathbf{B}_{ki})^{-1} \mathbf{H}_{ii} \mathbf{V}_{ki}\|} \tag{17}$$

According to the reciprocity of channel, the algorithm process of maximum signal to interference plus noise ratio algorithm is described as follows,

Algorithm 2: maximum signal to interference plus noise ratio algorithm (Max-SINR)
Step 1: At the receivers, initialize the pre-coding matrix V_j randomly.
Step 2: Start iteration, compute covariance matrix B_{ki} of the k^{th} stream of the i^{th} receiver according to Equation (16), $1 \le i \le K, 1 \le k \le d(i)$.
Step 3: Computer interference suppression matrix of the k^{th} stream of the i^{th} receiver $\mathbf{U}_{ki}$ according to (17). $1 \le i \le K, 1 \le k \le d(i)$.

$$\mathbf{U}_{ki} = \frac{(\mathbf{B}_{ki})^{-1} \mathbf{H}_{ii} \mathbf{V}_{ki}}{\|(\mathbf{B}_{ki})^{-1} \mathbf{H}_{ii} \mathbf{V}_{ki}\|}$$

Step 4: Reverse the communication direction and set $\overleftarrow{V}_i = U_i$.
Step 5: In the reverse link, compute covariance matrix $\overleftarrow{\mathbf{B}}_{ki}$ of the k^{th} stream i^{th} receiver $1 \le i \le K$, $1 \le k \le d(i)$.
Step 6: Compute the interference suppression matrix $\overleftarrow{\mathbf{U}}_{ki}$.
Step 7: Reverse the communication direction and set $V_i = \overleftarrow{U}_i$.
Step 8: Continue iteration till convergence.

4. PERFORMANCE SIMULATION AND RESULTS

Consider 2 or 4 (K=2 or 4) user full-duplex interference channel where each node is equipped with 2 (M=2) antenna, all channel coefficients complex independent identically Gaussian distributed random variables with zero mean and unit variance. Each transmitter only transmits the target signal to the corresponding receiver, and the receiver treats the signals from other transmitters as interference. We imulate the capacity and energy efficiency of the two algorithms this paper, the antenna interference cancellation and radio frequency interference cancellation, respectively. The simulation results are shown in figures 3-5

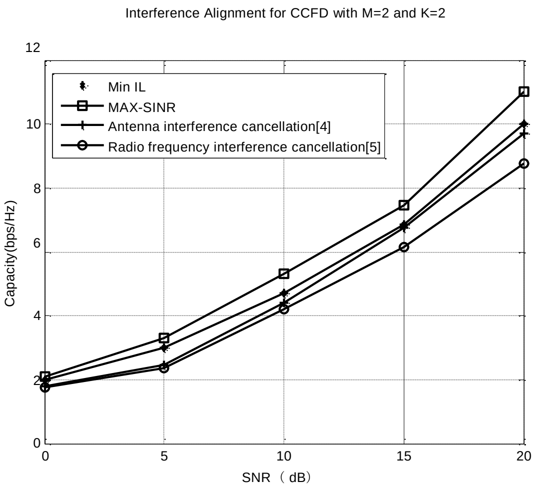

Figure 3: The capacity contrast curve of different algorithms for the two users two antenna case.

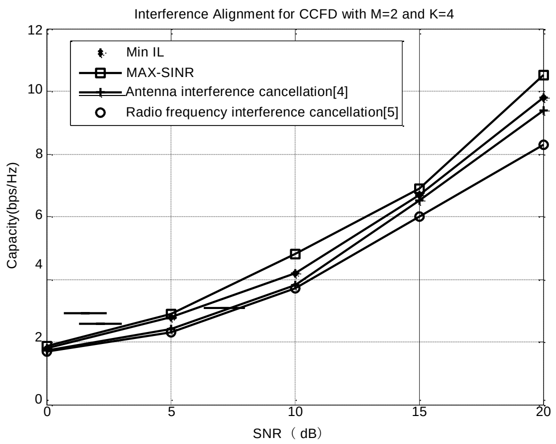

Figure 4: The capacity contrast curve of different algorithms for the four users two antenna case.

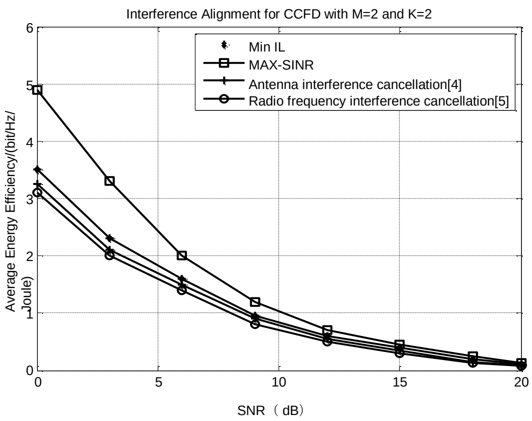

Figure 5: The Average Energy Efficiency Contrast curve of different algorithms.

In Figure 3 and 4, No matter what kind of the number of users and antenna configuration, in terms of improving the capacity, the interference cancellation algorithm in this paper is much better than the antenna interference cancellation in reference [4] and radio frequency interference cancellation in reference [5].

For the simulation of energy efficiency, we define the unit of average energy efficiency is the number of bits per joule, and the equation is given by $\eta = \log(1+ S/ N) / Eb$, where Eb is the unit bit energy. In Figure 5, the average energy efficiency in this paper is more greatly improved than that in references [4] and [5].

5. CONCLUSIONS

This paper applies interference alignment to suppress the self-interference and mutual interference of CCFD systems. Firstly, we treats the full-duplex interference channel as a one-way channel model, and then give the equivalent model of the system based on the reciprocity of full-duplex channel. After that, according to iterative interference alignment, the minimum interference leakage and Max-SINR are used to eliminate self-interference and mutual interference. Finally, the simulation results show that the capacity and average energy efficiency are more improved obviously by this scheme than other schemes.

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