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Efficient parallel interference cancellation algorithm for multiuser detection schemes in CDMA-based 20.48-Gb/s optical MIMO-OFDM system over 1200 km of SSMF

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ABSTRACT

This paper presents an efficient algorithm to cancel the parallel interference for multiuser detection (MUD) schemes in code division multiple access (CDMA) based 20.48 Gb/s optical multiple input multiple output orthogonal frequency division multiplexing (O-MIMO-OFDM) system over 1200 km of standard single mode fiber (SSMF). The performance of the system is compared by simulation results using the efficient algorithm and minimum mean square error (MMSE) schemes. It shows the superior performance of efficient algorithm.

1. Introduction

Spectral efficiency (SF) of any communication systems will be improved by applying multiple input multiple output (MIMO) technique [1]. A lot of study has been done by integrating MIMO systems into orthogonal frequency division multiplexing (OFDM). Optical MIMO-OFDM [2] is a multi-carrier modulation technology that has been proposed for fiber optic communication because it is an effective solution to inter symbol interference (ISI), when symbol period of each subcarrier is longer than the delay spread caused by group velocity dispersion (GVD) [3,4,6–10]. It has several advantages including efficient bandwidth usage, transformation of a frequency selective fading channel into a flat fading channel and simplified channel equalization.

On the other hand, CDMA technique is a promising method for MIMO-OFDM systems since it can conflict strong fading, eliminate the effect of narrowband interference and provide high capacity. However, to avoid reducing the capacity of CDMA-Based Optical MIMO-OFDM systems by multiple access interference (MAI), the use of MUD technique is necessary.

In order to overcome MAI in CDMA-Based Optical MIMO-OFDM systems, TURBO-BLAST is proposed.

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2. System model for CDMA-based O-MIMO-OFDM

By assuming the instance assigning spreading chips over the subcarriers, the relationship between input and output for the synchronous CDMA-Based O-MIMO-OFDM systems is given as:

$$y = ABx + n \tag{1}$$

where x, y and n are transmitted signal vector of all users, received signal vector of all antennas at the receiver and noise vector of all antennas at the receiver, respectively. x, y and n can be represented as:

$$x = \begin{bmatrix} x_1^T & x_2^T & x_3^T & \cdots & x_U^T \end{bmatrix}^T \tag{2}$$

$$y = \begin{bmatrix} y_1^T & y_2^T & y_3^T & \cdots & y_N^T \end{bmatrix}^T \tag{3}$$

$$n = \begin{bmatrix} n_1^T & n_2^T & n_3^T & \cdots & n_N^T \end{bmatrix}^T \tag{4}$$

where $x_u$is the transmitted signal vector for user number u, u = 1,2,3,. . .,U and U is the number of active users; y_j is the received signal vector for subcarrier number j, j = 1,2,3,. . .N and N is the number of subcarriers; n_j is the noise vector for subcarrier number j, j = 1,2,3,. . .N, respectively.

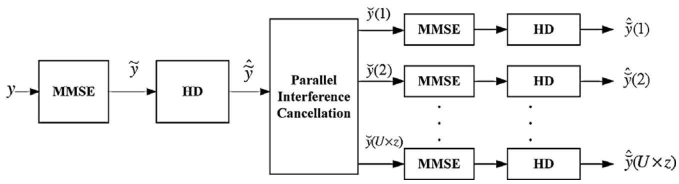

Fig. 1. Block diagram of HDMMSE.

By the way, A and B in Eq. (1) are defined as:

$$A = \begin{bmatrix} H_{1,1}s_{1,1}I_z & H_{1,2}s_{1,2}I_z & \dots & H_{1,U}s_{1,U}I_z \\ H_{2,1}s_{2,1}I_z & H_{2,2}s_{2,2}I_z & \dots & H_{2,U}s_{2,U}I_z \\ \vdots & \vdots & \ddots & \vdots \\ H_{N,1}s_{N,1}I_z & H_{N,2}s_{N,2}I_z & \dots & H_{N,U}s_{N,U}I_z \end{bmatrix} \quad (5)$$

$$B = diag\{\, diag(\, B_{1,1} \quad \dots \quad B_{z,1}\,)s \quad \dots \quad diag(\, B_{1,U} \quad \dots \quad B_{z,U}\,)\} \quad (6)$$

where $H_{j,u}$, $s_{j,u}$, $B_{i,u}$, i and I_Z are the channel coefficient matrix of the jth subcarrier of uth user, the jth chip of the Walsh code of uth user, symbol amplitude for corresponding transmit antenna, i = 1,2,3,. . .,z and $z \times z$ identity matrix, respectively.

To cancel the parallel interference efficiently for MUD schemes in CDMA-Based Optical MIMO-OFDM systems hard-decision MMSE (HDMMSE), soft-decision MMSE (SDMMSE) and weighted MMSE (WMMSE) are employed.

2.1. HDMMSE

By employing the MMSE algorithm at the beginning of the process, received signal will be modified as below:

$$\tilde{y} = (A^H A + \sigma^2 I_{U \times z})^{-1} A^H y \quad (7)$$

where $\tilde{y}$ and σ^2 are MMSE output and variance for each element of noise vector, respectively.

Then, the hard decision will be given as:

$$\hat{\tilde{y}} = HD(\tilde{y}) \quad (8)$$

Now, parallel interference cancellation algorithm can be shown as:

$$\breve{y}(j) = y - \sum_{\substack{l=1 \\ l \neq j}}^{U \times z} A(l)\hat{\tilde{y}}(l) \quad (9)$$

where $A(l)$ and l are the lth column of A and the symbol for all active users (l = 1,2,3,. . .,$U \times z$), respectively.

By employing the MMSE algorithm again and making hard decision of its output, the final decision result will be achieved as:

$$\hat{\breve{y}}(l) = HD((A(l)^H A(l) + \sigma^2)^{-1} A(l)^H \breve{y}(l)) \quad (10)$$

Fig. 1 demonstrates the HDMMSE algorithm.

2.2. SDMMSE

By employing the MMSE algorithm at the beginning of the process, received signal will be modified as Eq. (7).

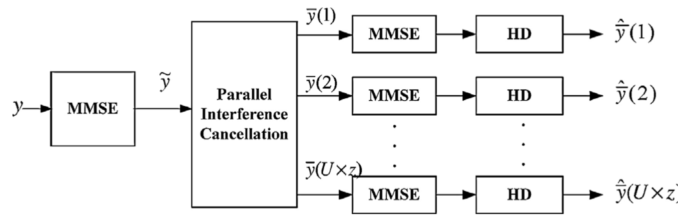

Fig. 2. Block diagram of SDMMSE.

Now, parallel interference cancellation algorithm can be shown as:

$$\bar{y}(j) = y - \sum_{\substack{l=1 \\ l \neq j}}^{U \times z} A(l)\tilde{y}(l) \quad (11)$$

By employing the MMSE algorithm again and making soft decision of its output, the final decision result will be achieved as:

$$\hat{\bar{y}}(l) = HD((A(l)^H A(l) + \sigma^2)^{-1} A(l)^H \bar{y}(l)) \quad (12)$$

Fig. 2 demonstrates the SDMMSE algorithm.

2.3. WMMSE

By employing the MMSE algorithm at the beginning of the process, received signal will be modified as Eq. (7).

The expected value of $\tilde{y}(j)$ can be obtained as:

$$E\,[\tilde{y}(j)] = \frac{1}{\sqrt{2\pi\sigma^2}} \sum_{i=1}^{P} \tilde{y}_i \exp\left(-\frac{(\tilde{y}(j) - \tilde{y}_i)^2}{2\sigma^2}\right) \quad (13)$$

where P and $\tilde{y}_i$ denote the number of constellation points and the constellation point, respectively.

The following algorithm can calculate the weight vector for $\tilde{y}(j)$:

$$w(j) = (r(j) + s(j) + \sigma^2 I)^{-1} A(j) \quad (14)$$

where $r(j)$ and $s(j)$ are given as below:

$$r(j) = A(j)A(j)^H \quad (15)$$

$$s(j) = \overleftrightarrow{A}_j \left(I - diag\left(E\left(\overleftrightarrow{\tilde{y}}_j\right) E\left(\overleftrightarrow{\tilde{y}}_j\right)^H \right) \right) \overleftrightarrow{A}_j^H \quad (16)$$

where $A(j)$, $\overleftrightarrow{A}(j)$ and $\overleftrightarrow{\tilde{y}}_j$ are the jth column of A, A after deleting the jth column and $\tilde{y}$ after deleting the jth column, respectively.

The final decision result will be achieved as:

$$\hat{\tilde{y}}(j) = HD\left(w(j)^H \left(\tilde{y} - \overleftrightarrow{A}_j E\left(\overleftrightarrow{\tilde{y}}_j\right) \right) \right) \quad (17)$$

Fig. 3 shows the WMMSE algorithm.

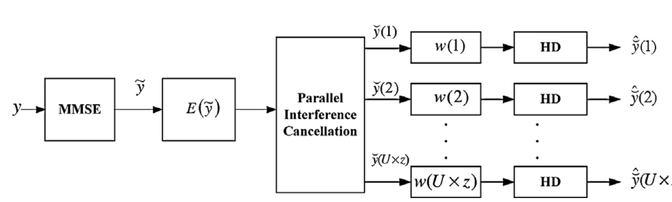

Fig. 3. Block diagram of WMMSE.