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Title	**Closed-loop Power Allocation for Space-time Coding (STC) in Project 802.16m SDD**	
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Re:	IEEE 802.16m-07/040, "Call for Contributions on Project 802.16m System Description Document (SDD)"	
Abstract	This contribution proposes a section/sub-section to describe a space-time code scheme supporting closed-loop power allocation in the Table of Contents (ToC) of IEEE 802.16m SDD to further improve the performance of current space-time coding (STC) schemes in IEEE 802.16 system.	
Purpose	Propose to have a section/subsection "STC using closed-loop power allocation" in TGm SDD ToC.	
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Closed-loop Power Allocation for Space-time Coding (STC) in Project 802.16m SDD

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I. Introduction

Recently, multi-input multi-output (MIMO) systems through deploying multiple antennae at the transmitter and receiver now become a key technique for realizing various performance merits in wireless communication, e.g., spatial multiplexing gains via the V-BLAST architecture and diversity advantages based on space-time block encoding [1]. One important system configuration capable of achieving high-rate & high-reliability communication is to simultaneously transmit multiple groups of orthogonal space-time block coded (STBC) signals [3], [4], [5]. The double space-time transmit diversity (D-STTD) system [6], [7], which contains two co-channel Alamouti STBC streams, is the building block for such system category; it also serves as a transmit diversity mechanism for IEEE 802.16-2004 [8].

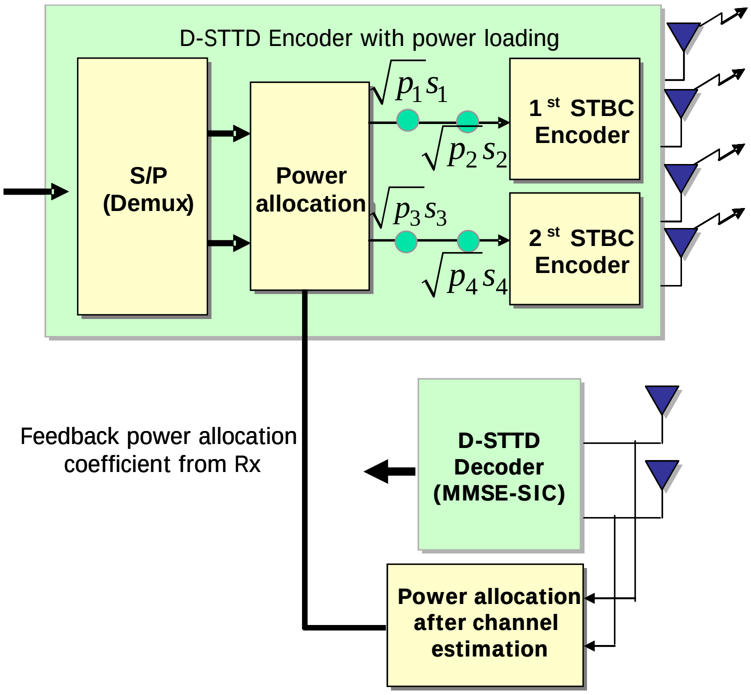

Figure 1. D-STTD transceiver structure with power loading strategy

While the multiplexing of multi-group STBC signals increases spectral efficiency, the induced co-channel interference then becomes the main detrimental factor dominating the overall system performance. Receiver design for mitigating co-channel STBC interferes, also capable of relieving algorithm complexity against the joint maximum-likelihood decoding, has recently drawn much attention [4], [7], [6], [13], [14]. For D-STTD systems, a popular solution is the QR-based successive interference cancellation scheme (SIC) [6], [7]. In [6] the decomposed channel matrix component is shown to exhibit a certain appealing structure which can further reduce computation; in [7] bit-error-rate analysis is investigated. It is well-known that through appropriate signal power loading the performance of the QR-SIC receiver can be improved [9], [10]. In this contribution, we propose a power allocation scheme for MMSE-SIC based D-STTD signal detection. In the proposed scheme (see Fig. 1) the transmit power is allocated so that all the four signal components are subject to an equal signal-to-interference- plus-noise (SINR) ratio. The main advantages of such an equal-SINR criterion are twofold. First of all, it can strike an optimal balance between channel capacity and the error-rate performance [10], [11]. Second, by exploiting a distinct channel matrix structure we proposed a closed-form expression of the power loading factors. Simulation results demonstrate the effectiveness of the proposed scheme: it outperforms most of the existing detecting schemes devised for the D-STTD system.

The rest of this contribution is organized as follows. The ensuing section describes the system model used and an algorithm for performance comparison. In Section III, we provide some numerical performance of the algorithms. Then, some concluding remarks are given in Section IV. Finally, proposed sections/subsections in the table of content (ToC) for IEEE 802.16m SDD are described in the last section.

II. System Model and Algorithm Description

A. D-STTD System Model

The signal model of D-STTD transmission can be expressed as [6] (see Fig.1)

$$\underbrace{\left[y_1\ y_2\, y_3\ y_4\right]^T}_{:=\mathrm{y}} = \mathrm{H}\underbrace{diag\left\{p_1^{1/2},\cdots,p_4^{1/2}\right\}}_{:=\mathrm{P}}\underbrace{\left[s_1\ s_2\, s_3\ s_4\right]^T}_{:=\mathrm{s}} + \mathrm{v} \tag{2.1}$$

where y_i, s_i, and p_i are, respectively, the *i*th received data sample, the *i*th source symbol and the associated power allocation factor, $\mathrm{v} \in \mathbb{C}^4$ is the complex Gaussian noise vector with zero mean and $E\mathrm{v}\mathrm{v}^H = \sigma_v^2 \mathrm{I}$, and the channel matrix **H** is defined by

$$\mathrm{H} := \begin{bmatrix} h_{1,1} & h_{1,2} & h_{1,3} & h_{1,4} \\ -h_{1,2}^* & h_{1,1}^* & -h_{1,4}^* & h_{1,3}^* \\ h_{2,1} & h_{2,2} & h_{2,3} & h_{2,4} \\ -h_{2,2}^* & h_{2,1}^* & h_{2,4}^* & h_{2,3}^* \end{bmatrix} \in \mathbb{C}^{4\times 4}, \tag{2.2}$$

in which h_{ij} denoting the channel gain with respect to *j*th transmit antenna to *i*th receive antenna. Let $\mathrm{H} = \mathrm{QR}$ be a QR decomposition of the channel matrix. Multiplying the signal model (2.1) from the left by Q^H we have [12]

$$\mathrm{z} := \mathrm{Q}^H \mathrm{y} = \mathrm{R}\mathrm{P}\mathrm{s} + \mathrm{Q}\mathrm{v} = \begin{bmatrix} r_1 \mathrm{I}_2 & \tilde{\mathrm{R}} \\ 0 & r_2 \mathrm{I}_2 \end{bmatrix} \mathrm{P}\mathrm{s} + \tilde{\mathrm{v}}, \tag{2.3}$$

with

$$\tilde{\mathrm{R}} := \begin{bmatrix} r_3 & -r_4^* \\ r_4 & r_3^* \end{bmatrix}.$$

We note that, for the upper triangular factor R in (2.3), the diagonal entries assume two distinct levels, whereas the upper off diagonal component $\tilde{\mathrm{R}}$ is essentially an Alamouti block [12]; such an appealing property will be exploited for power loading factor design.

B. Algorithm Description

The MMSE OSIC receiver detects received data symbols by multiplying a linear weight vector for each stage base on a MMSE criterion. At certain stage *j*, **the detection algorithm of the OSIC based MMSE receiver** can be summarized as follows [16]:

1). *Ordering:* Select the best substream *n* from all of the undetected ones in the MMSE sense: $\varepsilon_n = 1 - p_n \mathrm{r}_n^H \mathrm{R}_j^{-1} \mathrm{r}_n$, where ε_n is the MSE value corresponding to *n*th symbol; $\mathbf{r}_n$ denotes the *n*th column associated with the upper triangular channel matrix R in (2.3). $\mathrm{R}_j = \mathrm{R}\mathrm{P}^2\mathrm{R}^H - \sum_{i=1}^{j} p_i \mathrm{r}_i \mathrm{r}_i^H + \sigma_v^2 \mathrm{I}$ is the correlation matrix of the received vector after deleting the corresponding vectors.

2). *Weight calculation:* Determine the weight $\mathrm{w}_n \in \mathbb{C}^{4\times 1}$ of the *n*th substream in *j*th stage, and can be given by $\mathrm{w}_n = \sqrt{p_n} \mathrm{R}_j^{-1} \mathrm{r}_n$.

3). *Extraction:* Extract the *n*th substream: $y_n = \mathrm{w}_n^H \mathrm{z}_j$.

4). *Detection*: The estimated transmitted symbol $\hat{s}_n$ can be detected by y_n.

5). *Interference cancellation*: Remove the contribution of the *n*th substream $\hat{s}_n$ from the received signal $\mathrm{z}_{j+1} = \mathrm{z}_j - \mathrm{r}_n \hat{s}_n$, where $\mathbf{z}_0$=$\mathbf{z}$.

In particular, the power loading matrix **P** can be calculated by the following steps.

1). To attain equal MSE, the channel structure suggests that the power loading factors should be selected so that $p_1 = p_2$ and $p_3 = p_4$. As a result, only p_1 and p_3 need to be calculated.

2). $p_3 = p_4 = \left(-B + \sqrt{B^2 + 4AC}\right)(2A)^{-1}$, where $A = \left(|r_2|^2 + |r_3|^2 + |r_4|^2\right)^2 + |r_1|^2 |r_2|^2$, $C = \sigma_v^2 \frac{P_T}{2} |r_1|^2$ $B = \sigma_v^2 \left(|r_1|^2 + |r_2|^2 + |r_3|^2 + |r_4|^2\right) - \frac{P_T}{2} |r_1|^2 |r_2|^2$ and P_T is the total transmitted symbol power for those four symbols.

3). $p_1 = p_2 = \frac{P_T}{2} - p_3$. Hence, $\mathrm{P} = diag\left\{p_1^{1/2}, \cdots, p_4^{1/2}\right\}$ is determined.

By the detection algorithm of the OSIC MMSE detector described above (procedure 1)~5)), the estimated transmitted symbols using the D-STTD scheme can be decided. It is noteworthy that if p_1 is determined, p_3 can thus be determined and so do p_2 and p_4. As a result, only one parameter is needed to feedback from MS to BS to allocate the power in FDD system.

III. Simulation Result and Discussion

We consider a D-STTD system over a quasi-static channel environment; the channel gains are assumed to be zero-mean complex Gaussian with unit variance, and the source symbols are drawn from QPSK constellation. Also we assume that perfect channel knowledge is available at both transmitter and receiver. Figure 2 compares the bit-error-rate (BER) performances of the proposed scheme with the following receivers: linear ZF and MMSE equalizers, the Naguib's parallel interference cancellation scheme [13], the Stamoulis' group decoupled detector [14], the MMSE V-BLAST detector [1], the QR-based SIC with minimal BER power loading [9]. From the figure we can see that SIC based solutions can outperform Naguib's and Stamoulis' methods; this has been observed in [2], and is mainly due to the fact that SIC receivers tend to afford a layer-wise increase in the diversity gains. Among the SIC based solutions, the proposed detector with equal SINR power allocation is seen to yield the best performance.

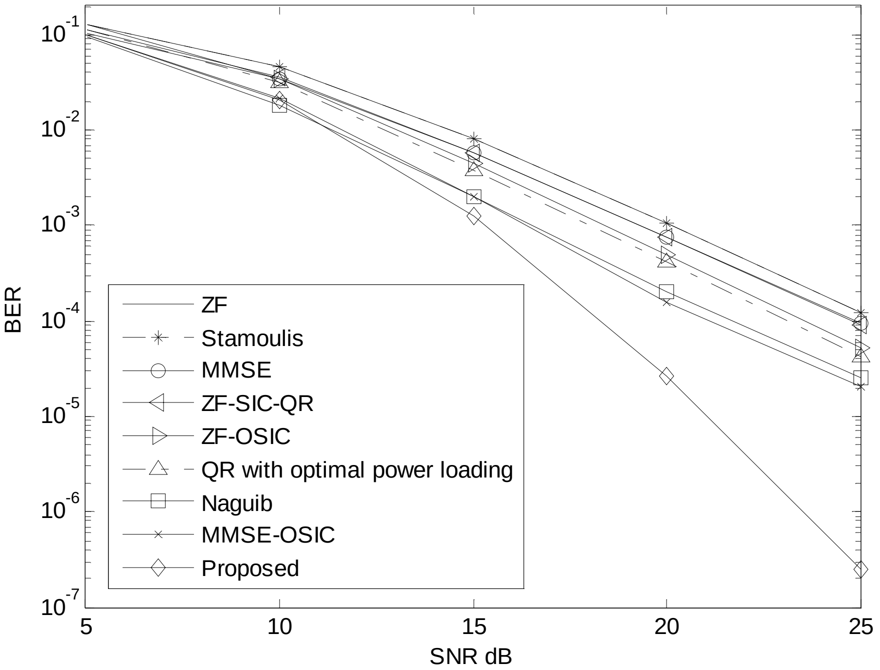

Figure 2. BER performance comparison

IV. Conclusion

A power loading scheme for MMSE OSIC receiver in the D-STTD system, which equalizes the SINR of each symbols with MMSE-OSIC receiver, is described and discussed in this contribution. Simulation results show that the D-STTD system using the proposed power loading strategy provides better SNR gain than the system using the power allocation used in ZF-OSIC and the MMSE-SIC without power loading strategy.

V. Proposed Sections/Subsections in the Table of Content (ToC)

This contribution is to present a scheme of STC using closed-loop power allocation and show that significant performance improvement can be achieved with this scheme. According to IEEE 802.16 documents, current system does not support the function of closed-loop power allocation for STC with two or above independent transmit data streams. This may degrade the system performance a lot if the transmission power is not adaptive to current channel status even with STC. It is suggested to include this functionality in IEEE 802.16m system. With closed-loop power allocation, the performance (BER) of STC with coding rate of 2 or above can be further improved by efficiently allocating transmission power over space and time domains. Required modifications to current system and proposed sections/subsections in ToC are shown as follows.

Proposed sections/subsections in ToC:

---Start of the Text---

[*Adopt the following text in the ToC of P802.16m System Description Document (SDD)*]

x.y Space-time coding (STC)

x.y.z STC using closed-loop power allocation

[*To support closed-loop power allocation, it is required to insert one functional block of power allocation immediately before STC encoder at the transmitter side and one functional block of power allocation coefficients estimation at the receiver side. It also requires a reliable feedback channel from receiver to transmitter. Therefore, the trade-off here is the system complexity and uplink bandwidth. Fig. 1 illustrates an example of the system architecture. However, the antenna combination is not limited to 4(Tx)x2(Rx). The only condition to support this scheme is that at least two antennas at receiver and four transmit antennas have to be applied in the system.*]

---End of the Text---

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