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PERFORMANCE COMPARISON OF SPACE TIME BLOCK CODE AND SPACE FREQUENCY BLOCK CODE WITH ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING IN WIRELESS COMMUNICATION SYSTEMS

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ABSTRACT : *Orthogonal Frequency Division Multiplexing (OFDM) in combination with Multiple Input Multiple Output (MIMO) is an attractive air interface solution for next generation wireless local area networks (WLANs), wireless metropolitan area networks (WMANs), and fourth-generation mobile cellular wireless systems. This article provides an overview of the basics of MIMO-OFDM technology and focuses on space-frequency coding and receiver design aspects. Due to its We conclude with a discussion of relevant open areas for further research. Use of space-frequency block coded (SFBC) OFDM signals is advantageous in high-mobility broadband wireless access, where the channel is highly time- as well as frequency-selective because of which the receiver experiences both inter-symbol interference (ISI) as well as inter-carrier interference (ICI). ISI occurs due to the violation of the `quasi-static' fading assumption caused due to frequency- and/or time-selectivity of the channel. In addition, ICI occurs due to time-selectivity of the channel which results in loss of orthogonality among the subcarriers. In this paper, we are concerned with the detection of SFBC-OFDM signals on time- and frequency-selective MIMO channels. Specifically, we propose and evaluate the performance of an interference cancelling receiver for SFBC-OFDM which effectively alleviates the effects of ISI and ICI.*

INTRODUCTION

The design of the LTE physical layer (PHY) is heavily influenced by the requirements for high peak transmission rate(100 Mbps DL/50 Mbps UL), spectral efficiency, and multiple channel bandwidths (1.25-20 MHz). To fulfill theserequirements, orthogonal frequency division multiplex (OFDM) was selected as the basis for the PHY layer. OFDMis a technology that dates back to the 1960's. It was considered for 3G systems in the mid-1990s before beingdetermined too immature. Developments in electronics and signal processing since that time has made OFDM amature technology widely used in other access systems like 802.11 (WiFi)[1] and 802.16 (WiMAX)[2] and broadcastsystems (Digital Audio/Video Broadcast – DAB/DVB).In addition to OFDM, LTE implements multiple-antenna techniques such as MIMO (multiple input multiple output)which can either increase channel capacity (spatial multiplexing) or enhance signal robustness (spacefrequency/time coding).Space Time Codes (STC) are designed to achieve the diversity gains of MIMO. Space-Time Codes (STC) were first introduced by Tarokh et al. from AT&T research labs [3]in 1998 as a novel means of providing transmit diversity for the multiple-antenna fading channel.Previously, multipath fading in multiple antenna wireless systems was mostly dealt with by otherdiversity techniques, such as temporal diversity, frequency diversity and receive antenna diversity,with receive antenna diversity being the most widely applied technique. However, it is hard to efficiently use receive antenna diversity at the remote units because of the need for them to remainrelatively simple, inexpensive and small. Therefore, for commercial reasons, multiple antennas arepreferred at the base stations, and transmit diversity schemes are growing increasingly popularas they promise high data rate transmission over wireless fading channels in both the uplink anddownlink while putting the diversity burden on the base station.

The space-time coding scheme by Tarokh et al. [3][4][5], is essentially a joint design of coding, modulation,transmit and receive diversity, and has been shown to be a generalization of other transmitdiversity schemes, such as the bandwidth efficient transmit diversity scheme by Witneben [6] andthe delay diversity scheme by Seshadri and Winters [7].

There are two main types of STCs, namely space-time block codes (STBC) and space-time trelliscodes (STTC). Space-time block codes operate on a block of input symbols, producing a matrixoutput whose columns represent time and rows represent antennas. In contrast to single-antennablock codes for the AWGN channel, space-time block codes do not generally provide coding gain,unless concatenated with an outer code. Their main feature is the provision of full diversity witha very simple decoding scheme. On the other hand, space-time trellis codes operate on one inputsymbol at a time, producing a sequence of vector symbols whose length represents antennas. Liketraditional TCM (trellis coded modulation) for a single-antenna channel, space-time trellis codesprovide coding gain. Since they also provide full diversity gain, their key advantage over space-timeblock codes is the provision of coding gain. Their disadvantage is that they are extremely hard todesign and generally require high complexity encoders and decoders.

We start with a model of the multiple antenna system as shown in Figure 1. This is followed by a discussion ofAlamouti's two-antenna transmit diversity scheme in relation to maximum ratio combining (MRC) scheme.

SPACE TIME CODE SYSTEM

Historically, the first STBC to provide full diversity with full rate matrix and simple decoding algorithm was proposed by Alamouti in [8]. A block diagram of Alamouti STBC encoder can be found in figure below.

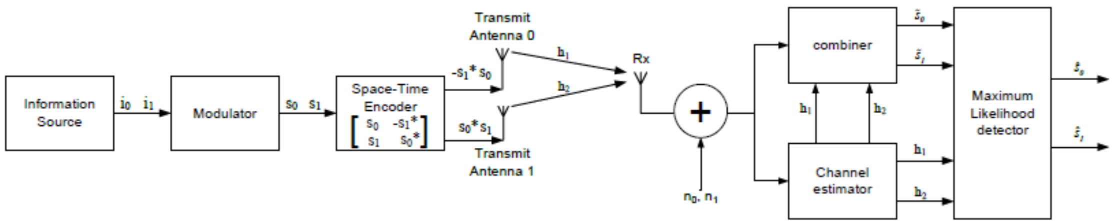

Figure 1 A Block diagram of Alamouti's STBC system

As it can be seen from Figure 1, *M*-ary modulated symbols $x_0$and x_1 are passed through the STBC encoder and complex matrix Xis generated such that symbols $x_0$and x_1 are coded through space and time. Indeed, replicas of $x_0$and x_1 for Alamouti coding are sent through two transmit antennas and over two time slots. Complex matrix X can be expressed as

$$X_2^C = \begin{bmatrix} x_0 & x_1 \\ -x_1^* & x_0^* \end{bmatrix} \qquad (1)$$

Here, the number of columns corresponds to the number of transmit antennas N_T and the number of rows to the number of time slots or number of symbols transmitted per antenna n_t. It can be seen from the matrix in equation 1 that at time *t*, x_0 and x_1 are sent simultaneously from antenna 1 and 2 respectively and at time $t+T$, where *T* is the symbol duration, $x_0$is transmitted from antenna 1 and $x_1$is simultaneously transmitted from antenna 2. Moreover, from equation 1, it can be seen that full diversity is accomplished as one symbol is transmitted from each antenna during each time slot. Finally, the rate (*R*) of STBC achieved by Alamouti's code defined as the number of different symbols transmitted per antenna n_s (here n_s=2 because of the two symbols x_0 and x_1) divided by the number of time slots n_t (here n_t=2), for 2 × 2 antenna it is giving the full rate of one.

An interesting key feature of Alamouti's scheme is that the sequence transmitted from the different antennas are orthogonal since the matrix of *X* times the Hermitian matrix *X* is equal to the identity matrix such as:

$$\begin{aligned} X_2^c X_2^{cH} &= \begin{bmatrix} x_0 & x_1 \\ -x_1^* & x_0^* \end{bmatrix} \begin{bmatrix} x_0^* & -x_1 \\ x_1^* & x_0 \end{bmatrix} \\ &= |x_0|^2 + |x_1|^2 I \end{aligned} \qquad (2)$$

Assuming that the channel parameters are constant over two consecutive symbols, thus:

$$\begin{aligned} h_1(t) = h_1(t+T) = h_1 &= |h_1|e^{j\theta_1} \\ h_2(t) = h_2(t+T) = h_2 &= |h_2|e^{j\theta_2} \end{aligned} \qquad (3)$$

where$|h_i|$ and θ_i, with i=1,2 are the amplitude and phase shift respectively. At the receiver, the received signals at time *t* and $t+T$ can be expressed as in equation 4. The received signal will be denoted by r_1 and r_2 at time *t* and $t+T$ respectively.[9]

$$\begin{aligned} r_1 = r(t) = &\quad h_1x_1 + h_2x_1 + w_1 \\ r_2 = r(t+T) = &\quad -h_1x_1^* + h_2x_0^* + w_2 \end{aligned} \qquad (4)$$

wherew_1 and w_2 represent the white Gaussian noise samples. Originally, STBC channel parameters were assumed known at the receiver. Therefore, transmitted symbols x_0 and x_1 can be recovered by combining the received signal r_1 and r_2 as:

$$\begin{aligned} \tilde{x}_0 &= r_1 h_1^* + r_2^* h_2 &&= (|h_1|^2 + |h_2|^2)x_0 + h_1^* w_1 + h_2 w_1^* \\ \tilde{x}_1 &= h_2^* r_1 - h_1 r_2^* &&= (|h_1|^2 + |h_2|^2)x_1 + h_2^* w_1 - h_1 w_1^* \end{aligned} \quad (5)$$

As it can be seen from equations 4 and 5, and due to the orthogonality of the transmitted matrix, cancellation of the unwanted signal x_1 to recover x_0 and x_0 to recover x_1 is possible. This is attributed to complex orthogonality of the Alamouti code in Equation (1). Both signals are then passed through the maximum likelihood (ML) detector as described in Figure 1 to determine the most likely transmitted symbols.

The decision rule is based on choosing si if and only if:

$$h_1^2 + h_2^2 - 1|x_i|^2 + d^2(\tilde{x}_0, x_i) \leq h_1^2 + h_2^2 - 1|x_k|^2 + d^2(\tilde{x}_0, x_k) \quad (6)$$

wherei≠k and d^2(.) represents the Euclidean distance between the two signals. From equation (6), it can be seen that the transmitted symbol is the one with the minimum Euclidean distance from the combined output signal.

GENERALIZED STBC

STBC is generally regarded as a generalization of the Alamouti coding. Based on the previous Subsection where simple ML can be achieved due to the orthogonality of the design scheme, Tarokh et al generalized STBC to an arbitrary number of transmit and receive antennas in [8]. STBC can achieve full rate and full diversity which as stated earlier is specified by the number of different symbols to transmit and the number of time slots required to transmit the entire STBC block. In addition, STBC allows a very simple decoding algorithm based on the ML decoding described in the previous Subsection.

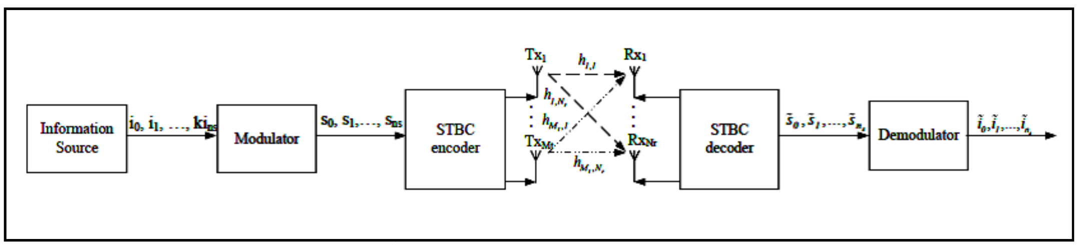

Figure 2 Generalized block diagram of STBC Communication System

Figure 2 shows a block diagram of the generalized STBC communication link. Like Alamouti case, data is first mapped by a 2^k points modulator resulting in $n_s$data symbols passed to the STBC encoder. At the receiver, the data is decoded with the STBC decoder including channel estimation, combiner and ML detector.

Based on the type of modulation used, STBC can be classified in two categories known as real and complex constellations. STBC with real constellation can be found when Pulse Amplitude Modulation (PAM) or Binary Phase Shift Keying (BPSK) modulation is applied to the information signal, while STBC with complex-constellation is used with M-PSK or M-QAM modulation.

REAL CONSTELLATION OF STBC

For STBC with real-constellations, if an N_T x n_t transmission matrix with variables $x_0, x_1, \ldots, x_{n_s}$ satisfies [8]:

$$X_{N_T} \cdot X_{N_T}^T = c|x_0|^2 + |x_1|^2 + \cdots + |x_{n_s}|^2 I_{N_T} \quad (7)$$

where$c$ is a constant and I_{N_T} is a $N_T \times N_T$identity matrix. Two main objectives of orthogonal STBC design are to achieve the full diversity order of $N_T N_R$ and to implement computationally efficient per-symbol detection at the receiver that achieves the ML performance.. Square STBC matrix X_{N_T} with real-constellation exist if and only if the number of transmit antennas N_T=2, 4 or 8 [3]. These codes offer full transmit diversity of N_T due to their full rate R=1. The real transmission matrices for 2, 4 and 8 transmit antennas are given by:

$$X_2 = \begin{bmatrix} x_0 & x_1 \\ -x_1 & x_0 \end{bmatrix} X_4 = \begin{bmatrix} x_0 & x_1 & x_2 & x_3 \\ -x_1 & x_0 & -x_3 & x_2 \\ -x_2 & x_3 & x_0 & -x_1 \\ -x_3 & -x_2 & x_1 & x_0 \end{bmatrix}$$

$$X_8 = \begin{bmatrix} x_0 & x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 \\ -x_1 & x_0 & x_3 & -x_2 & x_5 & -x_4 & -x_7 & x_6 \\ -x_2 & -x_3 & x_0 & x_1 & x_6 & x_7 & -x_4 & -x_5 \\ -x_3 & x_2 & -x_1 & x_0 & x_7 & -x_6 & x_5 & -x_4 \\ -x_4 & -x_5 & -x_6 & -x_7 & x_0 & x_1 & x_2 & x_3 \\ -x_5 & x_4 & -x_7 & x_6 & -x_1 & x_0 & -x_3 & x_2 \\ -x_6 & x_7 & x_4 & -x_5 & -x_2 & x_3 & x_0 & -x_1 \\ -x_7 & -x_6 & x_5 & x_4 & -x_3 & -x_2 & x_1 & x_0 \end{bmatrix}$$

At the receiver side, the received equations are based on Alamouti's model with the simplicity of having only real symbols and therefore no conjugate symbolin the equations. Thus, the received equations for two and four transmit antennas and any number of received antennas can be found in equations (8) and (9) respectively.

$$\begin{aligned} r_{1,j} = r_j(t) &= h_{1,j}x_0 + h_{2,j}x_1 + w_{1,j} \\ r_{2,j} = r_j(t+T) &= -h_{1,j}x_1 + h_{2,j}x_0 + w_{2,j} \end{aligned} \qquad (8)$$

$$\begin{aligned} r_{1,j} = r_j(t) &= h_{1,j}x_0 + h_{2,j}x_1 + h_{3,j}x_2 + h_{4,j}x_3 + w_{1,j} \\ r_{2,j} = r_j(t+T) &= -h_{1,j}x_1 + h_{2,j}x_0 - h_{3,j}x_3 + h_{4,j}x_2 + w_{2,j} \\ r_{3,j} = r_j(t+2T) &= -h_{1,j}x_2 + h_{2,j}x_3 + h_{3,j}x_0 - h_{4,j}x_1 + w_{3,j} \\ r_{4,j} = r_j(t+3T) &= -h_{1,j}x_3 - h_{2,j}x_2 + h_{3,j}x_1 + h_{4,j}x_0 + w_{4,j} \end{aligned} \qquad (9)$$

where $w_{1,j}$, $w_{2,j}$, $w_{3,j}$ and $w_{4,j}$ are independent noise samples and j denotes the j-th receive antenna.
Received signals are then combined for two and four transmit antennas as given in equations (10) and (11) respectively.

$$\begin{aligned} \tilde{x}_0 &= \sum_{j=1}^{N_R} r_{1,j}h_{1,j} + r_{2,j}h_{2,j} \\ \tilde{x}_1 &= \sum_{j=1}^{N_R} r_{1,j}h_{2,j} - r_{2,j}h_{1,j} \end{aligned} \qquad (10)$$

$$\begin{aligned} \tilde{x}_0 &= \sum_{j=1}^{N_R} r_{1,j}h_{1,j} + r_{2,j}h_{2,j} + r_{3,j}h_{3,j} + r_{4,j}h_{4,j} \\ \tilde{x}_1 &= \sum_{j=1}^{N_R} r_{1,j}h_{2,j} - r_{2,j}h_{1,j} - r_{3,j}h_{4,j} + r_{3,j}h_{3,j} \\ \tilde{x}_2 &= \sum_{j=1}^{N_R} r_{1,j}h_{3,j} + r_{2,j}h_{4,j} - r_{3,j}h_{1,j} - r_{4,j}h_{2,j} \\ \tilde{x}_3 &= \sum_{j=1}^{N_R} r_{1,j}h_{4,j} - r_{2,j}h_{3,j} + r_{3,j}h_{2,j} - r_{4,j}h_{1,j} \end{aligned} \qquad (11)$$

Finally, the combined signals are sent to the ML detection in order to recover the transmitted signal.

Complex Constellation of STBC
In general, for STBC with complex-constellations, if an $N_T \times n_t$ transmission matrix with variables $x_0, x_1, \ldots, x_{n_s}$satisfies [8]:

$$X_{N_T} \cdot X_{N_T}^T = c|x_0|^2 + |x_1|^2 + \cdots + \left|x_{n_s}\right|^2 I_{N_T} \qquad (12)$$

where c is a constant and I_{N_T} is a $N_T \times N_T$ identity matrix, STBC can achieve a full diversity order of N_T.
The introduced by Alamouti is considered as the simplest STBC with complex constellation and it is also the only $N_T \times N_T$ STBC code with complex-constellations. In addition, Alamouti code is the only STBC achieving full rate of 1 for a full diversity of 2. The aim of using higher number of transmit antennas on generalised STBC is to achieve high rate with full diversity, minimum coding delay (minimize T_s) and minimum decoding complexity.
Examples of full rate and rate half complex transmission matrices achieving full diversity for three ($N_T = 3$)and four ($N_T = 4$) transmit antennas are given in [8].

MIMO OFDM System using STBC
Application of STBC to MIMO systems using OFDM modulation is made in a similar way to conventional OFDM modulation. However, instead of sending one STBC block over $n_t$time slots, $N_s$blocks are simultaneously transmitted over the $N_s$subcarriers over n_tOFDM symbols. Similar to STBC-OFDM, another coding technique known as SFBC-OFDM where symbols are coded through frequency over multiple subcarriers within only one OFDM symbol, has been proposed in [9, 10, 11]. In SFBC-OFDM, N_s/ n_tblock coded symbols are simultaneously sent from the transmit antennas instead of one block of length n_t.

In this Section, data transmission is considered using *Ns* subcarriers over N_T transmit and $N_R$receive antennas. The channel parameters are assumed known at the receiver. We will provide brief discussion of 2 and 4 transmit antennas.

STBC-OFDM for 2 Transmit Antennas

In this Section, data transmission is considered using *Ns* subcarriers over two transmit and $N_r$receive antennas. The channel parameters are assumed known at the receiver. As described in previous section, data is encoded through space, time and frequency with the help of the space time encoder and OFDM modulation. From equation (1), it can be seen that two time slots are required to transmit the matrix X_2^C. Therefore, each antenna of the STBC-OFDM system is fed with a data stream of length $2N_S$transmitted over $n_t=2$ OFDM symbols.

For a two transmit antenna STBC-OFDM, vectors $X_1(n)$ and $X_1(n+1)$ are transmitted alternatively form antenna 1. Simultaneously, $X_2(n)$ and $X_2(n+1)$ are similarly transmitted from antenna 2. Each vector is composed of symbols coded according to STBC rules described equation (2) and (3).

Assuming $h_{i,j,k}(n) = h_{i,j,k}(n+1)$ the received equations at the output of the FFT, for the case of two transmit and $N_R$receive antenna can be expressed as:

$$\begin{aligned} R_j(n) &= \sum_{j=1}^{N_R} H_{1,j}(n)X_1(n) + H_{2,j}(n)X_2(n) + W_j(n) \\ R_j(n+1) &= \sum_{j=1}^{N_R} H_{1,j}(n+1)X_1(n+1) + H_{2,j}(n+1)X_2(n+1) + W_j(n+1) \\ &= \sum_{j=1}^{N_R} -H_{1,j}(n)X_2^*(n) + H_{2,j}(n)X_1^*(n) + W_j(n+1) \end{aligned} \tag{13}$$

where$R_j(n)$, $X_j(n)$ and $W_j(n)$ are the received symbols, transmitted vector symbols and the Gaussian noise sample respectively; *n* refers to the *n*-th OFDM symbol and *j* to the *j*-th receive antenna.

In addition, $X_1(n)$ and $X_2(n)$ are the vectors given after the serial to parallel operation at transmit antennas 1 and 2 respectively and given for the OFDM symbol *n* and *n*+1 by the following equations:

$$\begin{aligned} X_1(n) &= [x_0, x_2, \dots, x_{2k}, \dots, x_{2N_S-4}, x_{2N_S-2}]^T \\ X_2(n) &= [x_1, x_3, \dots, x_{2k+1}, \dots, x_{2N_S-3}, x_{2N_S-1}]^T \\ X_1(n+1) &= [-x_1^*, -x_3^*, \dots, -x_{2k+1}^*, \dots, -x_{2N_S}^*, x_{2N_S}^*]^T = -X_2^*(n) \\ X_2(n+1) &= [x_0^*, x_2^*, \dots, x_{2k}^*, \dots, x_{2N_S-4}^*, x_{2N_S-2}^*]^T = X_1^*(n) \end{aligned} \tag{14}$$

with$k$=0, 1, …, N_S-1 and *n* represent the *n*-th OFDM symbols.

With the help of above equation (14), it can be seen that at OFDM symbol *n*, and are transmitted simultaneously at subcarrier *k* from antenna 1 and 2 respectively and in the second OFDM symbol *n*+1 at the same subcarrier *k*, is transmitted from antenna 1 while simultaneously, is transmitted from antenna 2.

At the receiver, the signal is first demodulated by an FFT demodulator and data is recovered by the space time decoder. For an ideal transmission where the channel is known at the receiver and according to the equations given in [8] for single carrier system, the following can be derived for multicarrier systems:

$$\begin{aligned} \tilde{X}_{1,k}(n) &= \sum_{j=1}^{N_R} \left(H_{1,j,k}(n)R_{j,k}(n) + H_{2,j,k}(n)R_{j,k}(n+1) \right) \\ &= \tilde{s}_{2k} = \sum_{j=1}^{N_R} \left(h_{1,j,k}^* r_{j,2k} + h_{2,j,k} r_{j,2k+1}^* \right) \\ \tilde{X}_{2,k}(n) &= \sum_{j=1}^{N_R} \left(H_{2,j,k}^*(n)R_{j,k}(n) + H_{1,j,k}(n)R_{j,k}^*(n+1) \right) \\ &= \tilde{s}_{2k+1} = \sum_{j=1}^{N_R} \left(h_{2,j,k}^* r_{j,2k} - h_{1,j,k} r_{j,2k+1}^* \right) \end{aligned} \tag{15}$$

with$k$=1, 2, ...,N_S, representing the symbol number, j represent the j-th receive antenna and $\tilde{X}_{i,k}$, $\tilde{x}_{2k}$and $\tilde{x}_{2k+1}$ are the decoded signal and symbols respectively.

SFBC-OFDM for 2 Transmit Antennas

Similar to STBC-OFDM presented in previous section, SFBC-OFDM for two transmit antennas requires two time slots to transmit the X_2^C matrix. However, in contrast with STBC-OFDM, only one OFDM symbol is required as data is coded across subcarriers.

SFBC consists of symbol $x_k$and $-x_{k+1}^*$are transmitted alternatively from antenna 1 while $x_{k+1}$and $x_k^*$are transmitted in a similar way from antenna 2.

Due to the fact that data symbols are transmitted within one OFDM symbol, the received signal can be expressed as:

$$R_j(n) = \sum_{j=1}^{N_R} H_{1,j}(n)X_1(n) + H_{2,j}(n)X_2(n) + W_j(n) \qquad (16)$$

where$Wj(n)$ is the white Gaussian noise. Data vector $X_1(n)$and $X_2(n)$can also be expressed as:

$$X_1 = [x_0, -x_1^*, \dots, x_k, -x_{k+1}^*, \dots, x_{N-2}, -x_{N-1}^*]^T$$
$$X_2 = [x_1, x_0^*, \dots, x_{k+1}, x_k^*, \dots, x_{N-1}, x_{N-2}^*]^T \qquad (17)$$

where k = 0, 2, …, N – 1.

Data symbols can be recovered using only one OFDM symbol, therefore, n has been omitted and will be omitted for the rest of this Section.

Assuming that channel parameters remain constant over two consecutive subcarriers and that channel parameters are known at the receiver. After FFT operation is performed, received data is sent to the SFBC decoder. Following the derivation of the single carrier STBC case, it can be derived that:

$$\begin{aligned}\tilde{x}_k &= \sum_{j=1}^{N_R}\left(h_{1,j,k}^* r_{j,k} + h_{2,j,k} r_{j,k+1}^*\right)\\ \tilde{x}_{k+1} &= \sum_{j=1}^{N_R}\left(h_{2,j,k}^* r_{j,k} - h_{1,j,k} r_{j,k+1}^*\right)\end{aligned} \qquad (18)$$

Data is then sent to the ML decoder and to the demapper to recover the transmitted stream.

STBC Vs SFBC in Performance

Several researchers have evaluated the performances of STBC and SFBC with ML decoder at the speed of 30kmph in ITU vehicular B channel.[10]On base of the result carried out, it can be concluded that STBC achieves satisfactory performance in time fading channel, SFBC suffers from severe ISI. In the channel with large delay spread, the performance degradation of SFBC mainly comes from the ISI due to the frequency selectivity of the channel in an Alamouti code block. The residual ISI of MMSE decoder results in nearly 1.4dB performance degradation of SFBC over STBC.

SFBC-OFDM is compared with the STBC-OFDM in this survey. It is found that SFBC-OFDM is more sensitive to channel gain variation over frequency. Since STBC-OFDM is more sensitive to channel gain variation over time.

CONCLUSION

Preliminary performance evaluation of Alamouti code in OFDM simulation chain is discussed here. Using ML decoder, both STBC/SFBC achieve satisfy performance with slight difference at low mobility with small delay spread; at high mobility, SFBC often outperforms STBC, while with large delay spread, SFBC has worse performance than STBC.[10] The performance difference between STBC and SFBC mainly comes from the sensitivity of the used ML decoder to the channel selectivity in an Alamouti code block. MMSE decoder can improve the performance of Alamouti code in the selective channel at cost of complexity, but has still some performance degradation due to residual ISI of MMSE decoder. Therefore, for high spatial diversity gain and low decoding complexity, this contribution recommends both STBC and SFBC should be supported to adapt to various application environments in IEEE802.16m system.

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