Adaptive Modulation for Space-Time Block Code OFDM systems based on EVM

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Abstract: The Adaptive Modulation (AM) for Space-Time Block Code OFDM (STBC-OFDM) is addressed in this article as application for wireless systems. A new method was proposed, which is used the dispersion of Error Vector Magnitude (EVM) to represent the current channel condition in the following frames and to select the appropriate Modulation Scheme (MS) for the subsequent frame. In this method, the AM is not only compensated the channel variation, but also guaranteed the required Bit Error Rate (BER) performance and maximized the Spectral Efficiency (SE). The simulation shows that the proposed scheme outperforms in gaining performance the conventional scheme for all MS over a fading channel.

Keywords: AM, STBC-OFDM, selecting MS, EVM

Classification: Wireless Communication Technologies

References


1 Introduction

Fourth-Generation (4G) wireless systems require high-speed data rate service over wideband channels. To achieve the target data rate, the mobile system employs adaptive modulation and coding (AMC) besides a multiple antenna orthogonal frequency division multiplexing (OFDM) as successful techniques. The definition of AMC changes the modulation scheme and/or code rate instantaneously depending on the channel variations to maximize the SE as well as to overcome channels fading and other interference. The decision of selecting a useful modulation coding scheme (MCS) occurs in the receiver or transmitter depending on the system operating in frequency division duplex (FDD) or time division duplex (TDD) respectively for each frame.

Numerous researchers have been proposed in AM based on multiple antenna systems. In this system, the modulation scheme with or without coding is joining with two dimension code as space diversity combining with time, frequency and both [1]. In most previous works, the threshold method (TM) is used to choose a suitable MCS for the following frame. In this method after estimating Signal-to-Noise Ratio (SNR) of the channel divided to n sub-region by threshold values to maximize SE, these sub-regions are representing the n MCS which will be selected [2]. In our work, instead of estimating SNR in the receiver we estimate the dispersion of EVM to represent the channel condition and to select a suitable MS. The error vector is a vector which can be presented in the I-Q plane between the ideal constellation point and the data received by the receiver. In other words, it is defined as the difference between real received symbols and ideal symbols in terms of the root mean square value. There are two types of data transmitted from transmitter to receiver in modern systems; data-aided (DA) where the receiver has a priori knowledge of the transmitted symbols or transmits training sequences periodically such as (preamble or pilot symbol), and non-data-aided (NDA) where the receiver does not have any knowledge like (Information symbols).

Theoretically, the dispersion of EVM for the DA has the same value of all modulation schemes in different channel condition. This means that the EVM for any modulation can be predicted from EVM for another modulated signal [3, 4]. Then the relationship between SNR and EVM over large values of transmitted symbols for the DA and when SNR high (no inter symbol interference) is [5, 6].

\[
EVM_{\text{RMS}} = \sqrt{\frac{1}{\text{SNR}}} \quad (1)
\]
A number of studies on simulations and measurements of EVM for different application have been proposed. The EVM has been already used for adaptive modulation and coding OFDM system in [6], but based on the fixed thresholds only. Furthermore, this work will focus on discrete rate adaptation because it is more practical than continuous rate adaptation and it ignores the power adaptation because it has a little gain when mixing with rate adaptation. In addition, without coding that make the instantaneous BER more easily to obtain and there is no need to approximate the expressions of BER by curve fitting as in a coded system [7].

In this paper, a new method with the above considerations is proposed and named as Dispersion of Preamble Symbol (DPS). This method used a dispersion of Preamble symbol in the receiver for two purposes. The first one is to estimate the channel and the second one is to select a better MS. The simulation results show that our proposed method (PM) outperforms the conventional threshold method.

2 System model and proposed method

Fig. 1 shows the AM for STBC-OFDM in the wireless system in form of the block diagram. The system is considered in the ideal state, there is no delay or noise in the feedback bath from receiver to transmitter.

In this method the dispersion of EVM in Preamble symbol is computed at the receiver instead of estimation the SNR. The magnitude and phase of EVM for a received Preamble symbol position \( r(i) \) is calculated with respect to each ideal transmitted Preamble symbol position \( s(i) \) as shown in (2) and (3).

\[
\begin{align*}
    d_i &= \sqrt{(r_{Re}(i) - s_{Re}(i))^2 + (r_{Im}(i) - s_{Im}(i))^2}/|s(i)|^2 \quad (2) \\
    \varphi_i &= \frac{(r_{Im}(i) - s_{Im}(i))}{(r_{Re}(i) - s_{Re}(i)))} \quad (3)
\end{align*}
\]

Hence in the transmitter, if transmit \( k \) symbols of a Preamble, then the channel condition can be represented by dispersion vector \( D \) containing \( k \) dispersion symbols vector \( d_i \) as in (4) and (5).

Fig. 1. Block diagram for \( 2 \times 2 \) STBC-OFDM system model.
\[ D = \sum_{i=1}^{k} d_i \times e^{j\hat{\phi}_i} \]  \hspace{1cm} (4) \\
\[ \tilde{D} = \sum_{i=1}^{k} \tilde{d}_i \]  \hspace{1cm} (5)

The block diagram for the proposed method is shown in Fig. 2. It's depended on the fact that the dispersion due to channel fading is independent on the type of MS for the DA [3, 4]. Then the channel conditions can be represented by a sequence vector value \( \{d_1, d_2, \ldots, d_k\} \) of dispersion due to the \( k \) symbol of Preamble generated with the rate \( R \) (for example, BPSK) over a channel. In this block diagram, firstly, it generates random \( k \) symbol for different modulations (BPSK, QPSK, 16QAM and 64QAM). Secondly, these symbols added to the dispersion vector \( D \) separately in a parallel form after modulation. Then it is very easy to calculate the bit error rate \( (P_e) \) for all types of MS after demodulators. Hence, the \( P_e \) compared with target bit error rate \( (P_{tg}) \) is assumed for all the branches of modulator and demodulator. However, the selection of MS occurs for the highest MS rate, which has \( P_e \leq P_{tg} \) to maximize the SE of a system as in (6).

\[ \rho_{MS} = R_{MS}(1 - BER_{MS}) \]  \hspace{1cm} (6)

Where \( \rho_{MS} \) is the SE of MS whose selected, \( R_{MS} = \log_2(M) \) represent the rate of highest MS to be selected with constellation size of \( M \) when \( P_e(MS) \leq P_{tg} \), \( R_{MS} \in \text{MS Set (BPSK, QPSK, 16QAM and 64QAM)} \) and \( BER_{MS} \) is a bit error rate for selected MS.

### 3 Simulation model and results

In this paper, the results of SE for the conventional method (TM) and the proposed method (PM) are presented in STBC-OFDM by using the WiMax
Fig. 3. Performance of AM for STBC-OFDM $2 \times 2$. 
simulator. The Simulation model is implemented in Matlab 7. For clarification, the enhancement in SE is improved by using the proposed method over threshold method. We consider the system working with four MSs without coding like BPSK one bit per symbol, QPSK two bits per symbol, 16-QAM four bits per symbol and 64-QAM six bits per symbol through the fading channel. The PHY parameters which are used in simulation are 512 (FFT size), 360 (data subcarriers), 1/8 (cyclic prefix) and 5 MHz (Channel bandwidth) corresponding to the OFDMA. A carrier frequency of 2.4 GHz is also considered. The transmission matrix of the STBC scheme is \[\begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}\], where \(s_1\) and \(s_2\) represent the two consecutive OFDMA symbols. The SE is calculated from the BER as given by Eq. (6) as in the previous section. Furthermore, simulation results which are presented in this paper for Mobile WiMAX system based on the four tap pedestrian 3GPP channel model. The specified values of delay in (nsec) are 0, 110, 190 and 410, where the relative powers in (dB) are 0, -9.7, -19.2 and -22.8.

Fig. 3a displays the performance of 2 \(\times\) 2 STBC-OFDM systems. For comparison purposes, the SNR versus BER graph is plotted for different MSs showed respectively. The figure shows clearly that the QPSK modulation scheme is better suited for transmission in terms of BER performance from other modulation schemes. The gain performance of BPSK is over QPSK, 16QAM and 64QAM are 2.6, 9.12 and 15.65 dB respectively when the \(P_e\) equal to \(10^{-5}\).

Fig. 3b presents the SE versus SNR of 2 \(\times\) 2 STBC-OFDM for the threshold method (TM) and the proposed method (PM) with different modulation schemas. We observe that the PM for selection MS offers a significant performance gain up to 1, 0.8, 0.6 and 0.2 dB for 64QAM, 16QAM, QPSK and BPSK respectively. The exact values depend on the selected MS. As result, the PM improves the SE for each MS. However, at a given SNR the PM can provide a significant increase in SE when comparing with the TM. This means that for the same value of \(P_{tg}\) can achieve highest SE in lower SNR.

Fig. 3c shows the average SE envelope to all MS versus SNR based on switching method. The switching of the MS is implemented by a look-up table. To obtain this table, the SE performance curves are first generated for all the MSs as shown in Fig. 3b, then the switching table implemented. The MS can be chosen adaptively with fewer or more bits than the received frame, in result a better SE achieved. This envelope is assumed to be used in the PM for AM to maximize the expected SE.

4 Conclusion

In this paper, there are two AM for STBC-OFDM schemes which are presented with our great emphasis on the proposed method scheme. The simulation was aiming to compare these two schemes in the fading channel with different MS based on discrete rate adaptation without coding. The simulation result shows that the SE for the PM provides about 1, 0.8, 0.6 and 0.2 dB gaining over the TM for 64QAM, 16QAM, QPSK and BPSK respectively.