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Multi Input Multi Output (MIMO) Multiband OFDM

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Abstract: Ever since the human mind gave birth to technology, adopted it and dedicated itself to enhance it for human ease, the need for an efficient technique that supports accelerated data rates is vital. To add on to the scenario, the spectrum utilization which has reached its pinnacle places before us a major challenge. Hence the need for an accomplished and unbiased use of the spectrum has become our main focus. After years of pondering over the above mentioned problems a solution has been arrived named Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM). Efficient error control codes form the basic building blocks of any system designed for a perfectionists requirement and it is these error control codes that enhances the data rate of MB-OFDM system. Rising demands have made single error control codes inefficient. This crisis can be overcome by concatenating error control codes which exhibit consequential improvement in coding gain. This study consolidates MB-OFDM system with following enhancement: the use of error control codes namely turbo codes, Reed Solomon codes and convolution codes in multiband-OFDM system. In addition improvement in spatial diversity is achieved by using Alamouti technique and finally Alamouti code is concatenated with error control codes and results are compared. As a supplement the fast Fourier transform of the multiband OFDM system is replaced by wavelet transform.

Keywords: Multiband OFDM, error control codes, turbo code, reed solomon code, convolutional code, concatenated codes, alamouti code

INTRODUCTION

The thirst for wireless technology is increasing drastically. To cope with the needs of the people, high data rate and efficient spectrum utilization become much more essential. Cognitive radio and Multiband-OFDM (Balakrishnan *et al*., 2003) are the two techniques that go hand in hand to meet this requirement. To improve the error rate performance of the system FEC are used (Praveenkumar *et al*., 2012). Concatenation of error control codes is done to compensate heavy error rates (Avila *et al*., 2012a).

The existing amplifiers and ADC become very complex in processing the huge UWB band. As a result the entire spectrum of UWB is divided into 14 sub bands. Each sub-band consists of 5 master groups and each master group contains 3 sub bands and 5th master group has 2 sub bands. So as a total there are 14 sub-bands. Each sub band occupies a bandwidth of 528 MHZ and comprises of 128 sub carriers. In 128 subcarriers 100 subcarriers are used for data transmission, 12 subcarriers are utilized for pilot tones, 10 subcarriers are applied for guard tones and 6 subcarriers are employed as null tones (Thenmozhi *et al*., 2012, 2011).

These subcarriers are placed 4.125MHz apart. Frequency hopping of the data is performed within the band. At the transmitter side given in Fig. 1, the data's are first scrambled and then encoded by the encoder. Error control codes are used to combat multipath fading in communication channel, then the coded bits are further interleaved by a bit interleaver and it is mapped into constellation symbols.

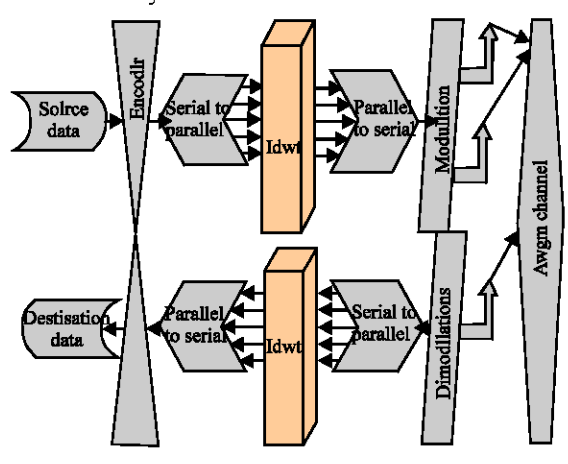

Fig. 1: Block diagram of Multiband OFDM

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The output of the mapper is then fed to IFFT block where they get converted to OFDM symbols by the OFDM modulator (Avila *et al*., 2012b). At the demodulator, the fast Fourier transform is performed. The output of FFT block is mapped into bits followed by de-interleaving and decoding to get back the information bits (Batra *et al*., 2006).

RELATED WORKS

In multiband OFDM system error control codes aims at removing the errors from the transmitted bit. These codes are concatenated to improve the performance of data transmission. Forward error correcting codes namely Reed-Solomon code, Turbo code and convolutional code are implemented in the multiband OFDM of the proposed work and are discussed in an exquisite manner.

Reed Solomon codes are basically non-binary error correcting codes. They are based on finite field know as Galois field. Parity bits are added to the blocks of data. The number of bits it can correct depends upon on the characteristics of the Reed Solomon code. It has the error correcting capability of x symbols in a code word where 2x = Y-l (Yar and Star, 2005). In this Y represents the total length of code word which includes message and parity bits, l represents the message and the parity bits is given by y-l = q. The maximum length of the code word is given by 2^c-1, where c represents the number of bits in the symbols.

Turbo codes could be obtained by the serial or parallel combination of either block codes or convolutional codes (Savitha *et al*., 2010). The most widely used code is convolutional code separated by an interleaver. The information sequence is first passed through the convolutional encoder. The output is passed through the interleaver. The interleaved output is given as input to second convolutional encoder (Gupta and Sharma, 2009). The performance of turbo codes in altered by many factors such as decoding algorithm, interleave size, constraint length of convolutional codes. Better performance could be achieved by proper choice of interleaver and interleaver size (Vafi *et al*., 2009). Soft decision decoding is performed at the receiver side to yield better results.

Convolutional encoder basically consist of shift registers and algebraic generators. The information sequence is processed bit by bit. It is basically convolutional operation of information with the impulse response (Nyirongo *et al*., 2006).The total code word which includes message bit and parity bit is denoted by n. Then the rate of convolutional code is given by k/n. The number of stages of the shift register denoted by K, known as constraint length determines the power and complexity of the code. At the receiver side Viterbi algorithm is used to decode the data. It makes use of the path metric to find the path that the transmit data has taken up (Gupta and Mehra, 2011).

The modulation scheme utilized in the multiband OFDM system is Quadrature phase shift keying (QPSK). Since QPSK gives moderate results in terms of error rate and data rate it is preferred in most of the digital communication applications (Bernard and Ray, 2001). Here one symbol is equal to two bits. The phase difference is 90 degrees. The probability of error is given by:

$$p_b = \text{erfc}\sqrt{\frac{E_d}{2I_o}} \quad (1)$$

where, E_d is the energy per bit and I_o is the noise.

PROPOSED METHODOLOGY

Since wavelet transforms offers lot of advantages than the fast Fourier transform the multiband OFDM system is worked out with wavelet transform. The wavelet transform in addition exhibit orthogonality property like FFT. So they are more suitable candidate to fill up the space of FFT. The wavelet transform proposed in this study is Daubechie. It is widely preferred because of maximum number of vanishing moments it has. This feature makes Daubechie wavelet to be utilized in many applications like signal discontinuities, signal trouble etc. The two parameters of Daubechie wavelet transform are scaling functions and wavelet functions (Avila and Thenmozhi, 2012) . Wavelet functions are obtained by inversing the scaling functions. Scaling functions are helpful in the analysis part and wavelet functions are used for synthesis purpose. Scaling functions represent the approximate values obtained y passing the signal through the low pass filter whereas, wavelet functions in turn denotes the accurate values obtained by passing the signal through high pass filter. The output of these filters are combined to get back the data.

Alamouti code: Space Time Block Coding (STBC) is a procedure in which, to improve the reliability of data transfer the information sequence is transmitted through many antennas and at the receiver the data are exploited to get the best signal to noise ratio (SNR) (Thenmozhi *et al*., 2012). Figure 2a and b gives the transmitter and receiver block diagram of Alamouti scheme. It is two transmitters and one receiver method. It is the simplest and less complex one in the STBC family which makes it more popular in wireless communication (Alamouti, 1998).

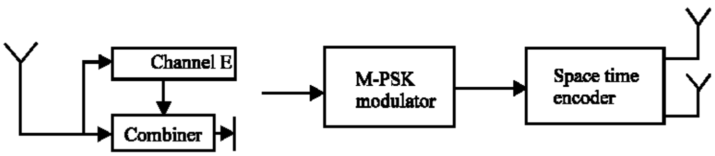

Fig. 2(a-b): Transmitter diagram of Alamouti system

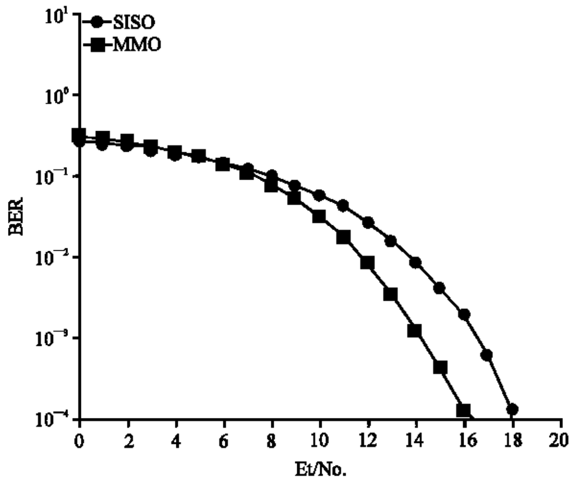

Fig. 3: SISO vs MIMO

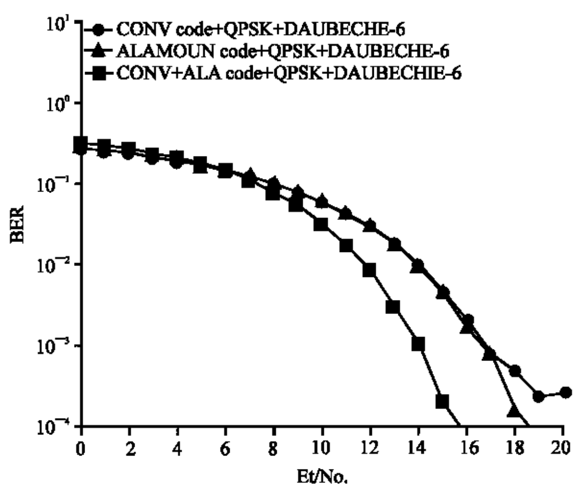

Fig. 4: Convolutional code combined with Alamouti code

The received signal at the input of the receiver is given as:

$$x^0 = a^0 b^0 + a^1 b^1 + c^0 \quad (2)$$

$$x^1 = -a^{1*} b^0 + a^{0*} b^1 + c^0 \quad (3)$$

Here α^0 and α^1 are the signals transmitted from the two antennas in time slot 1. α^{1*} and α^{0*} are the signals transmitted at time slot 2. C^0 and C^0 represents Additive White Gaussian noise (AWGN). At the receiver the Maximum likelihood decoding is performed and it is given as:

$$y^0 = b^{0*} x^0 + b^1 x^{1*} \quad (4)$$

$$y^1 = b^{1*} x^0 - b^0 x^{1*} \quad (5)$$

The received signals are given by:

$$y^0 = (|b^0|^2 + |b^1|^2) a^0 + b^{0*} c^0 + b^1 c^{1*} \quad (6)$$

$$y^1 = (|b^0|^2 + |b^1|^2) a^1 + b^{1*} c^0 - b^0 c^{1*} \quad (7)$$

where, b^0 and b^1 are the channel coefficients.

RESULTS AND DISCUSSION

The simulation results are obtained using MATLAB tool for the multiband OFDM system.In this study bit error rate (BER) versus Eb/N_0 is considered as the performance metric. In this study the results are plotted for QPSK modulation and using Daubechie wavelet transform. Figure 3 shows the comparison between single input single output (SISO) multiband OFDM system and multi input multi output OFDM(MIMO) system. From the Fig. 3, it is clear that MIMO system yields better performance that SISO because of improved diversity.

For a give BER of 10^{-3} there is at least 2 to 3 dB improvement. Figure 4 gives the evaluation between Alamouti code, convolutional code and the grouping of the two. It is clear that concatenated output is better than single codes. The rate of convolutional code is ½. For a given BER of 10^{-3} the is a significant improvement in Eb/N_0 which in turn indicates that with little amount of power data's are transmitted.

Figure 5 gives the comparison between Reed Solomon code, Alamouti code and the concatenated output of both. RS code is capable of correcting burst error and when combined with Alamouti code offers the best result. For a given BER of 10^{-3} there is a significant improvement in SNR.

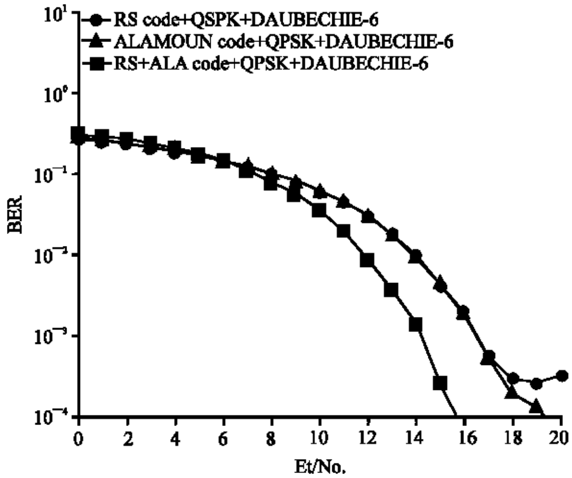

Fig. 5: Reed Solomon code concatenated with Alamouti

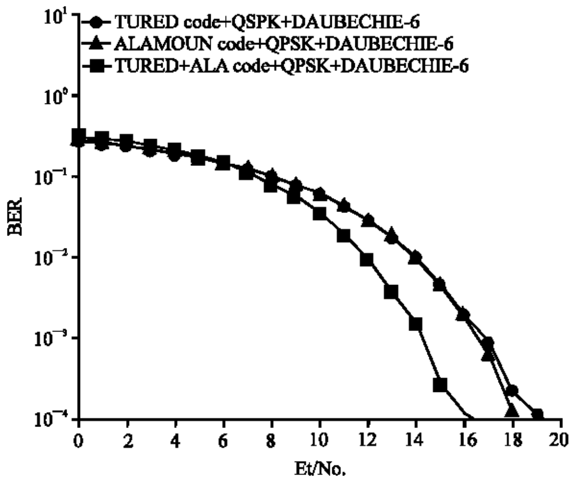

Fig. 6: Turbo code clubbed with Alamouti code

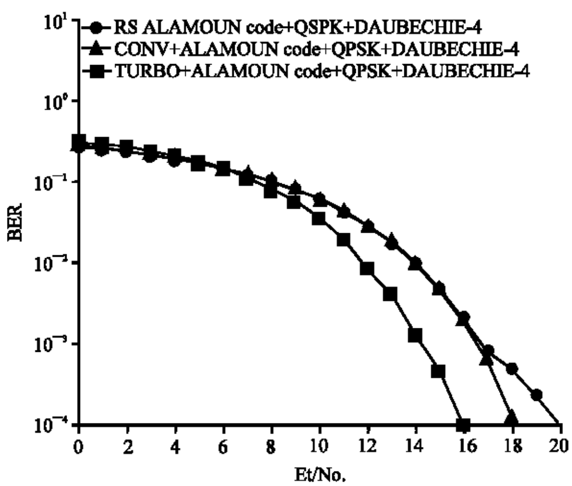

Fig. 7: Comparison between the concatenated scheme

Figure 6 shows the relationship between turbo codes, Alamouti codes and the combination of both. Concatenated code yields better results than the individual one. Figure 6 gives comparison between Turbo coded concatenated with Alamouti code, Reed Solomon code concatenated with Alamouti code and Convolutional code concatenated with Alamouti code. Turbo code offering the advantage of close to shanno's limit when combined with Alamouti which offers diversity proves to the better one among the three combinations. Figure 7 shows the comparison between the concatenated scheme.

CONCLUSION

This study mainly focussed on enhancing the performance of multiband OFDM system and make it more appropriate for short distance and high data rate applications. To make the system a successful candidate in high noise scenarios error control codes like turbo codes, convolutional code and Reed Solomon core are utilized. In addition, to enjoy the essence of MIMO technique the error control codes are concatenated with Alamouti code and it could be found that the combined scheme offers more advantage than the individual one. Since wavelet transform offers more advantages than the fast Fourier transform to further enhance the performance, the FFT is replaced by DWT in multiband OFDM system.

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