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FEC and DWT Guided Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM)-Enriched Quality

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Abstract: For high data rate wireless applications over short distances, multiband OFDM proves to be the right contender. The concatenation of error control code for multiband OFDM cognitive radio system is analysed. Reed Solomon code and convolutional code are taken in to account for analysis. From the simulation results it can be inferred that because of the improved coding gain concatenated codes prove to be superior to single codes. As a supplementary, the fast Fourier transform and Inverse fast Fourier transform portion of the multiband OFDM systems are exchanged with the discrete wavelet transform and inverse discrete wavelet transform blocks respectively thus reducing the interferences drastically and as a result the overall bit error rate (BER) gets improved.

Key words: Multiband OFDM, reed-solomon code, convolutional code, concatenated code, discrete wavelet transform

INTRODUCTION

The Federal Communications Commission announced a frequency spectrum as unlicensed spectrum called the Ultra Wide Band which is a wide band ranging from 3.1 to 10.6 GHz in the year 2002. Handling such a huge spectrum brought many difficulties and so a unique candidate named Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM) came into being (Balakrishnan *et al*., 2003).It's important features include high data rates, feeding little amount of power and silicon area. These features led to its popularity.

The frequency split up of UWB is as follows: there are five major divisions known as master groups. Each of the master groups possesses 3 sections and the final one has 2 sections. Totally there are 14 sections and 128 sub-carriers. Of the 128 subcarriers, 100 is allocated for transmission of data, 12 are for piloting purpose, 10 subcarriers are put to use as protecting tones and 6 are treated as unused tones. Spacing between the subcarrier is 4.125 MHZ. Multiband OFDM supports a high data rates ranging from 53 to 480 Mbps.

Figure 1 gives the block diagram of multiband OFDM system. In multiband OFDM system the input data is first randomized by the scrambler and a channel coder is used to encode the information sequence. The multipath fading that occurs in the communication channel is combated by error control codes (Praveenkumar *et al*., 2012). Compensation of heavy noise conditions can be done by concatenation of error controls which leads to

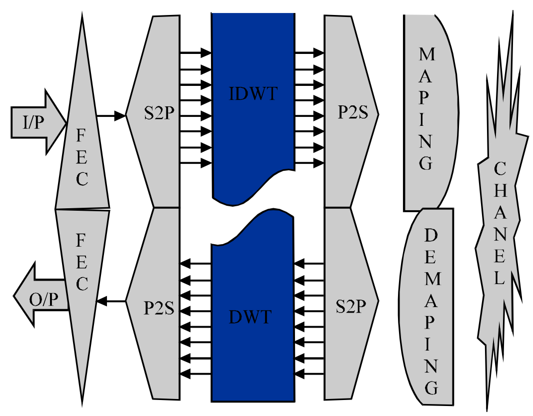

Fig. 1: Block diagram of -MBOFDM

improvement of coding gain (Avila *et al*., 2012b; Thenmozhi *et al*., 2012). The encoded bits are made to pass through an interleaver to confirm strength against burst error. A mapper is used to map into constellation symbols. This output is passed to IFFT block where OFDM symbols are generated (Avila *et al*., 2012c). The noise expected here is AWGN (Additive White Gaussian Noise). At the receiver the signal is made to pass through FFT block, demodulator and decoding take place to reclaim the sequence of information (Batra *et al*., 2006; Avila *et al*., 2012a).

This study aims at enhancing the performance of multiband OFDM system by combating the channel noise. Channel noise can be effectively mitigated by the use of

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error control codes. To offer better results in high noise conditions concatenation of error control codes is preferred. Here Reed Solomon code is concatenated with convolutional code and their performance is analysed.

Since Fast Fourier Transform is not suitable for non stationary signals, it is substituted with Wavelet transform in the multiband OFDM system. Four wavelet families namely Haar, Daubechie, Coiflet and Symlet which satisfy orthogonality property similar to FFT has been chosen.

LITERATURE

The channel coding is a process in which superfluous information is added to the data and this improves the capacity of the channel in which the data is transmitted. The forward error control codes implemented in the multiband OFDM of the proposed work are Reed Solomon code and convolutional code. Consisting of m binary bits, Reed Solomon Code is a technique where m can be any number exceeding 2. Hence for a known m, the range of the complete Reed-Solomon codes consisting of m-bit symbols is $2^m - 1 = 255$. Reed Solomon code has two parts: a data part and a parity part. In a code which contains n symbols, the data part is the initial k symbols. This is to improve security and safeguard information from intruders (Nyirongo *et al*., 2006). The rest (n-k) are parity symbols calculated with respect to the data part. This type of Reed Solomon Code is titled as an (n,k) code of RS(n,k) code. In this case, the (n-k) parity symbol is an even number and referred to as 2t. Therefore, an RS Code of 2t parity symbols has the ability to correct up to't' error symbols.

Convolutional code is the mechanism of adding surplus bits to the data to safeguard it. A k/n rate convolutional encoder, using binary shift registers, can work on an input of k bit information. This encoder processes the contents of the shift registers and computes on n bit output symbol. At the receiver side the Viterbi algorithm computes the path metrics (accumulated distances) from the input symbols to the possible transmitted output with the help of Trellis diagram (Viraktamath and Attimarad, 2010). Memory problems and complexity is caused when the stacked number of path metrics advances exponentially with the number of stages in the trellis. The number of paths in competition to have the smallest distance is limited to the number of states in one column of the trellis and this becomes a major advantage for the Viterbi algorithm.

The modulation scheme proposed in this study are Binary phase shift keying (BPSK) and Quadrature phase shift keying (QPSK).Binary phase shift keying is the technique in which phase of the carrier varies by 180 degree (Sanjeev and Swati, 2010). The probability of error of BPSK is given by:

$$p_b = \frac{1}{2}\,\text{effc}\sqrt{\frac{D}{J_o}} \tag{1}$$

Where:
D = Energy
J_0 = noise

QPSK supports high data rates because each symbol has two bits. The phase of the carrier is 90 degrees (Bernard and Ray, 2001). The probability of error of QPSK is given by:

$$p_b = \frac{1}{2}\,\text{effc}\sqrt{\frac{D_b}{2J_o}} \tag{2}$$

Where:
D = Energy
J_0 = noise

PROPOSED METHODOLOGY

To achieve high data rates and to make the multiband OFDM system error free Reed Solomon codes are combined with convolutional code with the former as outer code and the later as inner code. Here the rate of the convolutional code is fixed as ½. To boot, the IDWT and DWT blocks are used instead of IFFT and FFT blocks in the multiband OFDM system (Das *et al*., 2011). We use wavelet transform here because it offers lot of advantages. Wavelet transform gives accurate results both in the domains. Local information is not available in FFT (Zheng *et al*., 2005). Multi-resolution capability is also present. Thus wavelet transform is popularly used in image processing, information hiding, signal processing etc. (Al Wadi *et al*., 2011).

Filtering and scaling are the two basic steps in DWT. By means of passing the input signal into low pass and high pass filter we split it into two components. Of the two high pass filter gives accurate results whereas low pass filter gives approximate results. Scaling is improvised by passing through a decimator. To reach the target the process is repeated. Result is obtained by adding the coefficients. With many wavelet families existing, four wavelet transforms namely Haar, Daubechie, Symlet and Coiflet are implemented. Haar wavelet with its simplest nature, gains fame because of its rapid response (Idi and Kamarudin, 2012). But at the same time it is not suited for audio applications. The reason is since it is two elements wide the processing capacity is not good.

On the other hand Daubechie wavelet is complex and costly, has both linear and non linear phase response and also has large number of vanishing moments (Mahmoud *et al*., 2007). D2-D20 is the even index it has where index is nothing but the number of coefficients.

Initially the inner product of data and coefficients are obtained and then with its help the scaling and wavelet coefficients are obtained. A better version of Daubechie is the Symlet wavelet which is symmetric and has even index number. It has minimal phase (Chavan *et al*., 2011). The most symmetric wavelet is the coiflet wavelet and it has other properties similar to that of Daubechie wavelet.

RESULTS AND DISCUSSION

All graphs are obtained using MATLAB tool. The discussion is based on the bit error rate versus Eb/N_0 curve obtained for the multiband OFDM system. Figure 2 gives the evaluation amid multiband OFDM system without error control code and with error control code. Here Reed Solomon code is utilized. From the figure it is evident that coded system overrules the system without error control code.

Figure 3 gives the assessment between Reed Solomon code, Convolutional code and the concatenated output of both. The figure clearly shows that concatenated code yields better result than single codes. They have improved coding gain than single codes. The figure is plotted using Haar wavelet transform and with BPSK modulation scheme. BPSK is less prone to error because the distance between signal points is greater in this case. But since either binary one or binary zero is transmitted it is not suitable for high data rate scenarios.

Figure 4 gives the output of Reed Solomon code, convolutional code and the concatenation of the two with Daubechie as the wavelet transform and QPSK as the modulation scheme. For a given BER of 10^{-3} there is improvement in Eb/N_0 for the concatenated output than single codes.

Figure 5 gives the output for various orders of Symlet wavelet. As the order increases better results could be achieved. Figure 6 gives the output for various orders of Coiflet wavelet transform. With

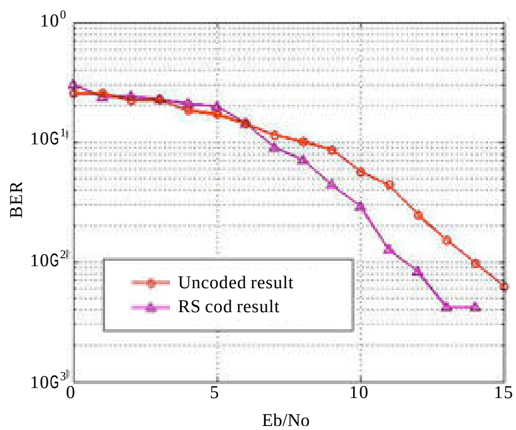

Fig. 2: Multiband OFDM system with and without FEC

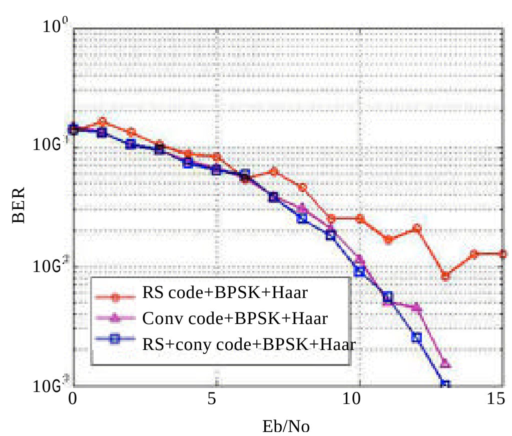

Fig. 3: RS-CC combination with Haar wavelet and BPSK modulation scheme

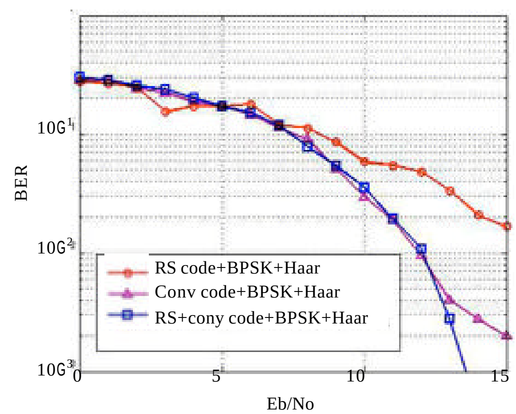

Fig. 4: CC-RS combination with Daubechie wavelet and QPSK modulation scheme

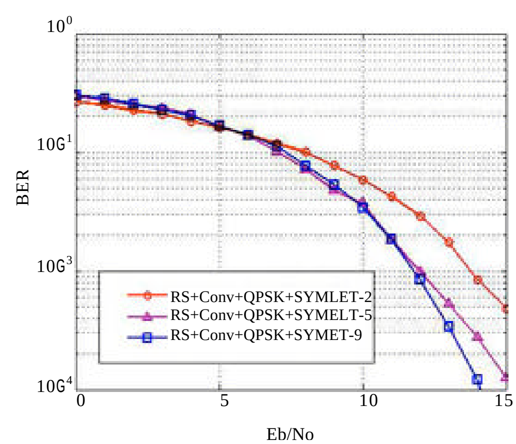

Fig. 5: Performance of RS-CC code for various order of Symlet

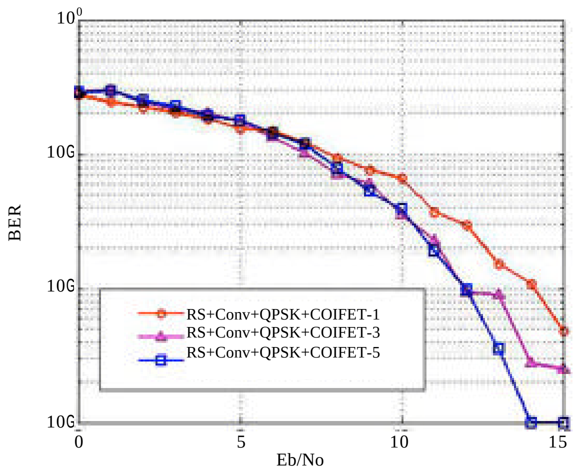

Fig. 6: Performance for various order of Coiflet transform

the increase in order more data is available for processing which in turn improves the accuracy of the system.

In the study proposed by Sato *et al*. (2007) Reed Solomon is concatenated with convolutional code in multiband OFDM system. In the study proposed by (Hussain *et al*., 2011) concatenated of Reed Solomon codes is done with convolutional code in OFDM system. (Jatoor *et al*., 2008) proposed the concatenation of convolutional with Alamouti code to achieve diversity. In the study proposed by Ahmed *et al*. (2009) the performance of OFDM is analysed in the presence of convolutional code. In the study proposed by (Leija-Hernandez *et al*., 2009) analysis of convolutional code in CDMA system is carried out.

CONCLUSION

In this research contribution the error analysis of the M ultiband OFDM system under concatenated coding scheme having convolutional code as inner code and Reed Solomon code as outer code is evaluated and it is found that concatenated code has better BER performance than single CC or single RS. In addition to enhance the system performance discrete wavelet transform is used as a substitute for FFT. Simulation is also carried out for various wavelet families and various modulation schemes. The results are also obtained for various orders of wavelet families. All this simulation proves that RS-CC combination has good error correcting capability which makes the multiband OFDM system a more powerful candidate.

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