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Research Article

Amended (Wavelet) Multiband OFDM Cognitive Radio System

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Abstract: This study focuses on improving the functioning of multiband Orthogonal Frequency Division Multiplexing (OFDM) system by utilizing wavelet transform as a substitute to Fast Fourier Transform (FFT). The performance is further refined by apt inclusion of modulation technique. Error control codes are utilized which aims at the removal of error from the transmitted bits. In addition to attain diversity Alamouti code is concatenated with error control codes. OFDM is the best fit for cognitive radio and sensing the free holes is the key task of any cognitive system. This study additionally also analyses the performance of energy detection based spectrum sensing in the presence of various noise models.

Keywords: Alamouti code, cognitive radio, energy detection, error control codes, noise models, wavelet transform

INTRODUCTION

The wide spectral width of ultra wide band spectrum extending from 3.1 to 10.6 GHz makes it difficult to handle. To overcome these challenges multiband OFDM came into existence by virtue of its high data rates, less power consumption and need of less silicon space (Balakrishnan *et al*., 2003). The multiband OFDM divides the spectrum into numerous sub-bands (Praveenkumar *et al*., 2012), among which the 128 available sub-carriers with sub-carrier spacing of 4.125 MHz, 100 is used for data transmission, 12 as the pilot carriers, 10 as guard tones and 6 as null tones. In ultra wide band the entire spectrum is divided into 5 major groups, consisting of 3 sub-bands with an exception of the last group with 2 sub-bands making a total of 14 (Avila *et al*., 2012).

The block diagram depicting the MB-OFDM is shown in Fig. 1. A random sequence of input data generated by a scrambler followed by encoding the channel using an encoder. The error control codes are used to correct multipath fading of the communication channel, concatenation of such codes is implemented to increase the coding gain and efficiency of the system in noisy environment. The encoded bits are then fed into a 3-stage interleaver which provides stability against burst error and are mapped into constellation samples. An OFDM modulator converts the mapped output from the IFFT block into OFDM symbols. The demodulation and decoding of retrieving the original sequence is administered by the receiver (Thenmozhi *et al*., 2012; Batra *et al*., 2006).

For reliable communication, error control codes are added along with the message Reed Solomon codes, which are non-binary and depends on Galois field. The relation $2x = Y^{-1}$ signifies its error correcting capability, here Y represents the length of the code and 1 represents the message. The maximum length of the code is given by 2^c-1 where c is the number of bits (Viraktamath and Attimarad, 2010). The performance of the convolutional codes depends on the constraint length which is nothing but the number of stages of shift register. With the increase in constraint length the accuracy increases.

The turbo codes are implemented by serial or parallel connections with convolutional codes and its recital is influenced by the decoding algorithm, interleaver size and constraint length (Hoosier *et al*., 2000).

The binary phase shift keying is preferred due to its simplicity and durability and has 180° phase change between binary one and binary zero. The transmitted signal is given by Sanjeev and Swati (2010):

$$K(t) = p(x)\sqrt{2D}\cos(2\pi bt) \quad (1)$$

where,
$p(x)$ = ±1
D = Power
b = The carrier frequency

The probability of error is given by:

$$P = 1/2\text{erfc}\sqrt{D_b / M_0} \quad (2)$$

where, M_0 = Power spectral density of noise

Quadrature Amplitude Modulation (QAM) has both amplitude change and phase change. QAM supports M-ary signaling and the type of QAM to be

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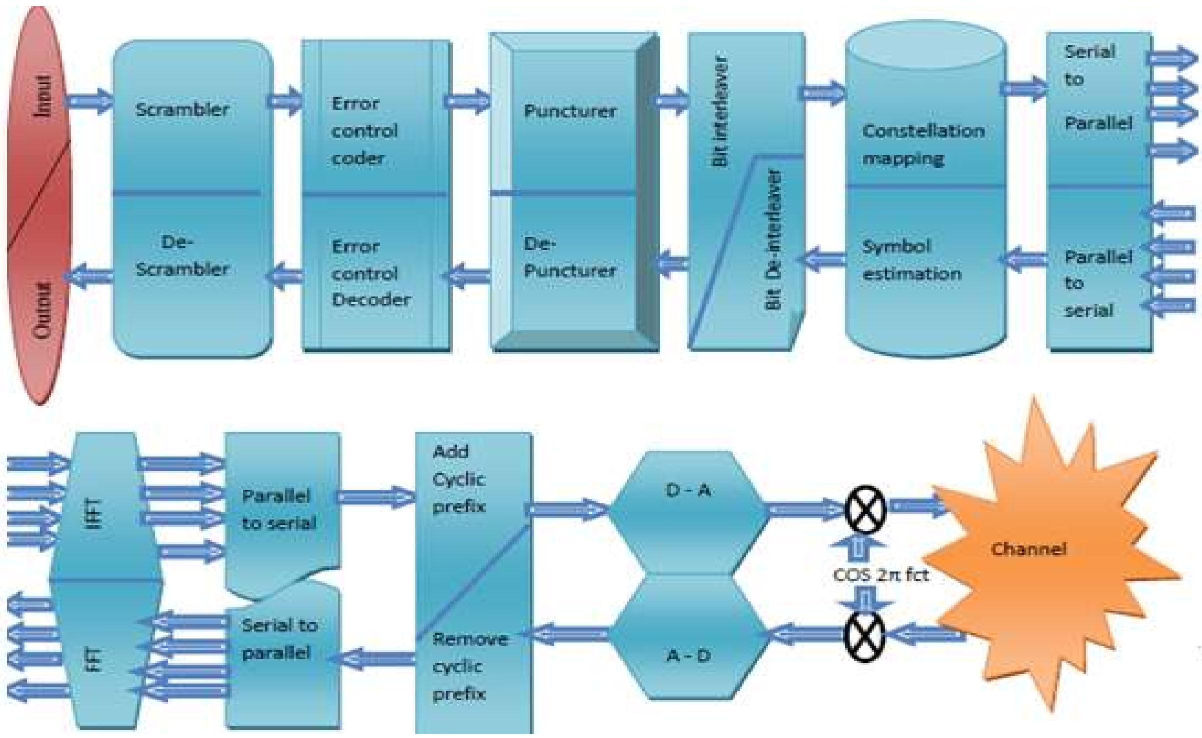


Fig. 1: Block diagram of multiband OFDM system

used is chosen based on the application (Bernard and Pabitra, 2001):

$$Z(t) = d_o(t)\sqrt{E}\cos(2\pi f_0 t) + d_e(t)\sqrt{E}\sin(2\pi f_0 t) \quad (3)$$

where,
E = Amplitude of the signal
$d_o(t)$ = Odd number sequence
$d_e(t)$ = Even number sequence

Quadrature phase shift keying introduces a phase change of 45° between the bits in the symbol and 90° phase shift between symbols. It supports two bits at a time .The probability of error is given by:

$$\text{P} = \text{erfc}\sqrt{D_b / M_0} \quad (4)$$

METHODOLOGY

Wavelet transform: The IDWT and DWT blocks replace the IFFT and FFT blocks respectively in the transmitter and receiver of Fig. 1. The time and frequency domain both support the wavelet transformation, which plays key role in wide range of applications in many fields like image processing, signal processing etc. The primary operation of wavelet transform is filtering. In the wavelet tree the incoming signal is portioned into low and high frequency components. High frequency components provide precise outcome while low frequency components provide approximate output (Gupta *et al*., 2008; Das *et al*., 2011).

Haar wavelet gains popularity because of ease and simplicity (Mahmoud *et al*., 2007). Wavelet coefficients are generated by reversal of order of scaling coefficients and sign change of the second term. From the inner product of data and coefficients the scaling and wavelet functions could be obtained. Symlet wavelet (Chavan *et al*., 2011) transform, a modified version of Daubechie is more symmetric having even index number and minimal phase. Yet the most efficient and symmetric wavelet than the above wavelets is the Coiflet wavelet.

Cognitive radio: Cognitive radio is an artificial intelligence (Haykin, 2005) based device that changes its parameters according to the environment. Spectrum sensing is the basic step in cognitive radio from which it comes to know about the free spectrum. The main focus is on the performance of energy detection based spectrum sensing under various noise models like AWGN, Rayleigh fading, Rician fading and lognormal fading.

The block diagram of the energy detector method is as shown in Fig. 2. In energy detection method the Power Spectral Density (PSD) of the incoming signal is found out and it is compared with the threshold. Based on the following hypothesis the decisions are made:

H_o = Noise - Primary user absent

H_1 = Signal + noise - primary user present

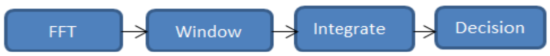


Fig. 2: Energy detector method

Additive White Gaussian Noise (AWGN) can be conceived as a channel model that has a constant power spectral density. Thus, it is obtained through several natural sources and is called so due to the addition of white noise. It is suitable for satellites and has applications in deep space communication links though not been much used for terrestrial links. The received signal is the signal additively combined with noise. The PSD is given as:

$$F(x) = 1/2\sigma \exp(-x^2)/2\sigma^2) \tag{5}$$

where, σ is the variance of noise.

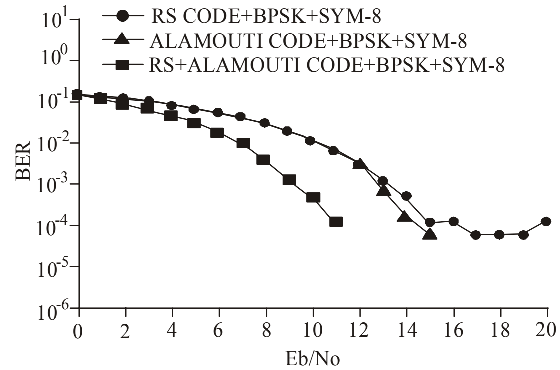
Rician noise model assumes that there is at least one Line of Sight (LOS) path between transmitter and receiver. The noise model is based on the parameter known as Rican factor K. It is defines as the power in the LOS path to the power in the other paths. Hence as the value of K increases the signal strength increases which in turn reduces the error. Rayleigh noise model assumes that is no line of sight communication between the transmitter and the receiver. The signal gets attenuated following the Rayleigh distribution (Rasheed *et al*., 2010).

In this study Haar and Symlet wavelet transforms are exchanged in the place of FFT. To battle with the channel noise Reed Solomon code, Turbo code and convolutional code are utilized. To achieve diversity Alamouti code is concatenated with the error control codes and the act of the multiband OFDM system is analyzed in the presence of BPSK, QPSK and QAM. Further with the multiband OFDM acting as cognitive radio its performance is analyzed in the occurrence of various noises.

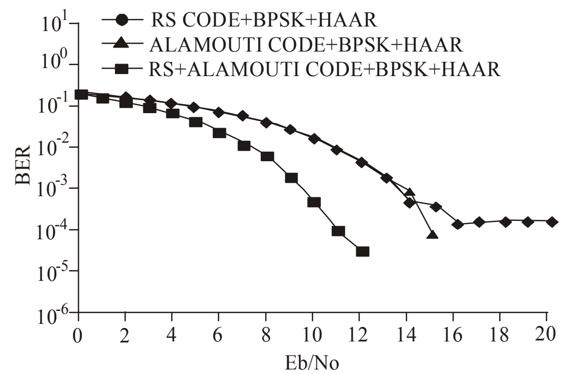
RESULTS AND DISCUSSION

The outputs are obtained by means of MATLAB tool. The performance metric is Bit Error Rate (BER) versus Eb/N_0 curve plotted for the multiband OFDM system

Figure 3a and b displays the result of Alamouti code combined with Reed Solomon code.Here the traditional Fast Fourier Transform is modified with wavelet families namely Symlet and Haar respectively. Since these wavelet families satisfy orthogonality property they become best choice for the replacement of FFT with BPSK as the modulation scheme. It is highly desired because it is fewerfaultscheme when compared with other schemes. In both the cases due to better coding gain and diversity for a given BER of 10^{-4} the concatenated code domineers the individual ones.



(a)



(b)

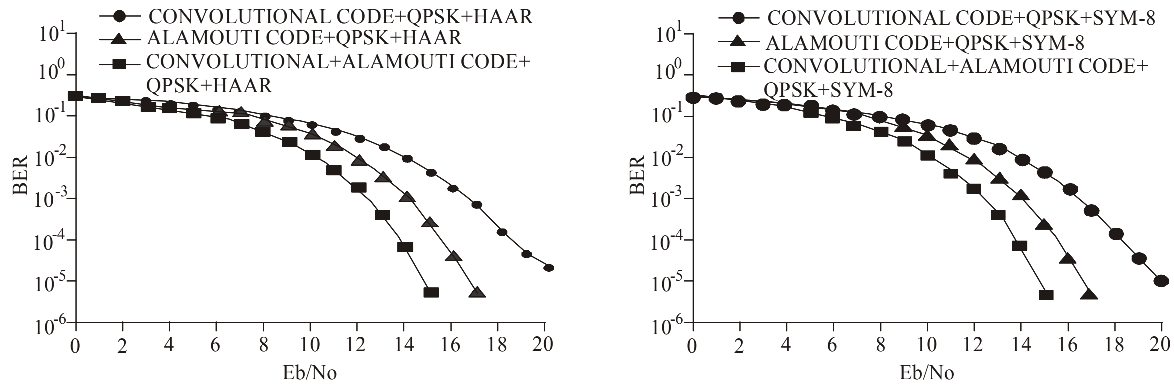
Fig. 3: Alamouti code concatenated with reed solomon code

Figure 4a and b displays the output of Alamouti code combined with convolutional code with FFT substituted by Haar and Symlet wavelet transform respectively. The order of symlet transform is set as 8 and QPSK modulation technique is used. There is atleast 1 dB change between concatenated code and the individual one for a given BER of 10^{-5}.

Figure 5a and b shows the output of the turbo concatenated with Alamouti code with FFT being replaced with wavelet family Haar and Symlet respectively. The concatenated code offers better results when compared with individual code for a given BER of 10^{-5}. The results are plotted for QAM modulation techniqe. When compared with other concatenated schemes this method provides better output in terms of BER.

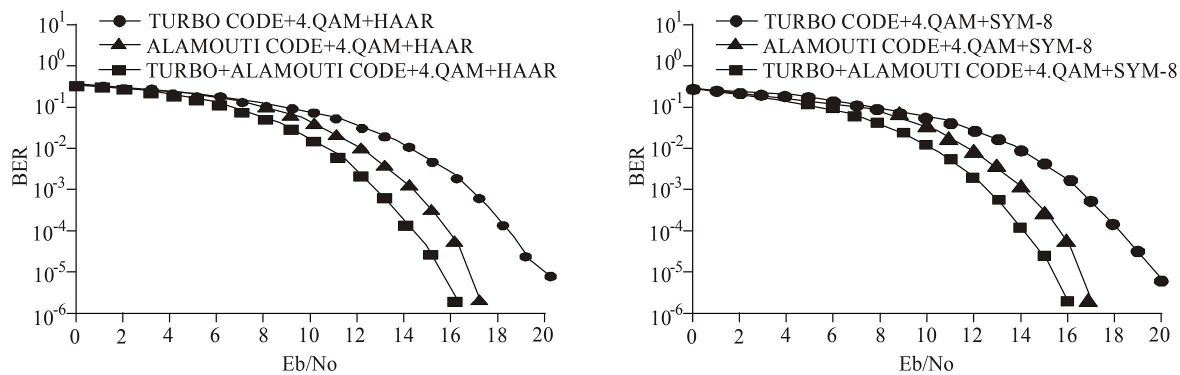
Figure 6 gives the comparison between for various values of Rician factor which is denoted by K. As the K value increases the line of sight communication dominates and the probability of encountering deep fade decreases and it approaches the AWGN performance.

Figure 7 gives the comparison between probability of false alarm (p_f) and probability of missed detection



(a) (b)

Fig. 4: Alamouti code combined with convolutional code



(a) (b)

Fig. 5: Turbo code concatenated with alamouti code

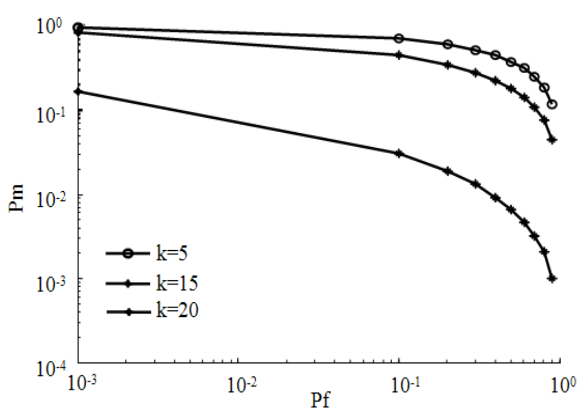


Fig. 6: Comparison between various values of K

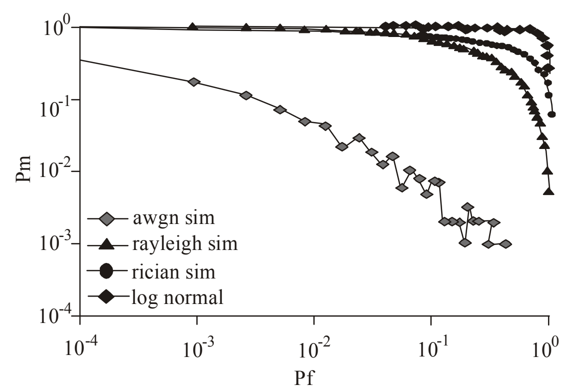


Fig. 7: Comparison between various noise models

(p_d) for various noise models. The probability of false alarm is greater to achieve the probability of missed detection of 0.01. This results in poor utilization of spectrum. From the graph it is clear that the performance of energy detector is better in case of AWGN noise when compared to other noise models. Other fading models degrade the performance of energy detector.

CONCLUSION

The performance of DWT based MB-OFDM is monitored for Symlet and Haar wavelet families. Convolutional code, Turbo code and Reed Solomon codes are used as channel coding to counteract the channel noise and further to improve the diversity they are combined with Alamouti code. The performance is also analyzed in the presence of BPSK, QPSK and

QAM modulation technique. Simulation results prove that with proper choice of modulation technique, FEC and wavelet family the presentation of the multiband OFDM can be significantly improved. In addition when treated as cognitive radio is analyzed in the presence of various noise models.

REFERENCES

Avila, J., E. Vinoth, E. Praveen and K. Thenmozhi, 2012. Performance augment of Multiband OFDM system with ANN assisted concatenated codes. Proceeding of the IEEE International Conference on Computing, Electronics and Electrical Technologies, pp: 76-80.

Balakrishnan, J., A. Batra and A. Dabak, 2003. A multi-band OFDM system for UWB communication. Proceeding of the IEEE Conference on Ultra Wideband Systems and Technologies, pp: 354-358.

Batra, A., S. Lingam and J. Balakrishnan, 2006. Multi-band OFDM: A cognitive radio for UWB. Proceeding of the International Symposium on Circuits and Systems, pp: 4094-4097.

Bernard, S. and K.R. Pabitra, 2001. Digital Communication: Fundamentals and Applications. 2nd Edn., Pearson Education.

Chavan, M.S., N. Mastorakis, M.N. Chavan and M.S. Gaikwad, 2011. Implementation of symlet wavelets to removal of gaussian additive noise from speech signal. Proceeding of the 10th International Conference on Recent Researches in Communications, Automation and Signal Processing, pp: 37-41.

Das, B., S. Tiwari and S. Das, 2011. Performance study of discrete wavelet packet based MB-OFDM system for short range indoor wireless environment. Proceeding of the IEEE International Conference on Devices and Communication, pp: 1-5.

Gupta, D., V.B. Vats and K.K. Garg, 2008. Performance analysis of DFT-OFDM, DCT-OFDM, and DWT-OFDM systems in AWGN channel. Proceeding of the 4th International Conference on Wireless and Mobile Communications, pp: 214-216.

Haykin, S., 2005. Cognitive radio: Brain-empowered wireless communications. IEEE J. Sel. Area Comm., 23(2): 201-220.

Hoosier, R., S.H. Jamali and A.R.S. Bahai, 2000. Turbo coding performance in OFDM packet transmission. Proceeding of the IEEE Vehicular Technology Conference, pp: 805-810.

Mahmoud, M.I., M.I.M. Dessouky, S. Deyab and F.H. Elfouly, 2007. Comparison between haar and daubechies wavelet transformations on FPGA technology. Int. J. Elec. Comput. Electr. Commun. Eng., 1(2): 133-137.

Praveenkumar, P., R. Amirtharajan, K. Thenmozhi and J.B.B. Rayappan, 2012. Regulated OFDM-role of ECC and ANN: A review. J. Appl. Sci., 12(4): 301-314.

Rasheed, H., N. Rajatheva and F. Haroon, 2010. Spectrum sensing with energy detection undershadow-fading condition. Proceeding of the 5th IEEE International Symposium on Wireless Pervasive Computing, pp: 104-109.

Sanjeev, K. and S. Swati, 2010. Error probability of different modulation schemes for OFDM based WLAN standard IEEE 802.11a. Int. J. Eng., 4: 262-267.

Thenmozhi, K., P. Padmapriya, R. Amirtharajan, V. Prithiviraj, R. Varadarajan and J.B.B. Rayappan, 2012. OFDM+CDMA+Stego = Secure communication: A review. Res. J. Inform. Technol., 4(2): 31-46.

Viraktamath, S.V. and G.V. Attimarad, 2010. Impact of constraint length on performance of convolutional CODEC in AWGN channel for image application. Int. J. Eng. Sci. Technol., 2(9): 4696-4700.