ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 7, July 2015

Improvement of BER Performance in OFDM under various Channels with EH Code

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is a very efficient high speed data transmission technique in wireless communication technology. In this paper, we present Bit Error Rate (BER) performance of OFDM system using BPSK and DPSK modulation schemes, operating under various channel conditions. To imitate the practical applications in the real world Rayleigh channel, Rician channels are also considered in addition to the AWGN channel. The simulation is done to investigate the performance of the coded OFDM system over the uncoded OFDM system. It is seen that coding improves BER performance of OFDM system and hence in this work, Extended Hamming Code (EH Code) is used as Single Error Correcting Code (SEC).

Keywords: OFDM, BER, EH Code, SEC, AWGN, Rayleigh and Rician channels.

I. INTRODUCTION

Mobile communication systems demand high data rate for multimedia applications. OFDM has been applied in mobile wireless communication by Cimini back since 1985 [1]. It has many advantages such as high spectral efficiency, robustness in frequency selective fading channels [2], immunity to Inter Symbol Interference (ISI) and capability of handling strong multipath fading. However, in OFDM the bit error occurs in the presence of Doppler frequency shift because of the Inter Carrier Interference (ICI). OFDM has been adopted as a standard for various wireless communication systems; it includes Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN), Digital Audio Broadcasting (DAB) [3] and Digital Video Broadcasting (DVB).

OFDM makes use of efficient spectrum utilization, in which message signal is modulated with multiple carriers called as subcarriers which are orthogonal to each other. It divides the total available bandwidth into a number of sub-channels and each subcarrier has a null at the centre frequency of the adjacent carrier, which results in zero interference among the carriers. OFDM is preferred to implement due to efficient FFT (Fast Fourier Transform) algorithm. The implementation of FFT is proportional to the number of input bit size. OFDM characteristics and advantages over a single carrier system were described in [4] and [5]. However in real life application the data transmitted by the OFDM system will be distorted and attenuated by noisy channel and the receiver may experience some difficulties to recover back the original data. There are several types of communication channels which are AWGN, Rayleigh and Rician channels [2]. Hence modern mobile radio transceiver systems must be able to provide high capacity and variable bit rate information with high bandwidth efficiency, efficient signal power as such [6]. This paper aims to show that the BER performance of OFDM system improves with the help of EH Code for BPSK and DPSK modulation schemes under various channels.

This paper is organised as follows: Section II introduces channels viz., AWGN, Rayleigh and Rician. Section III presents Simulink model. Section IV considers Generator matrix and Parity check matrix of EH Code. Section V presents simulation results and Section VI concludes the paper.

II. FADING CHANNELS

Due to various natural or manmade obstacles in the signal path, the signal undergoes a multipath propagation, which causes more number of replicas of the transmitted signal. At receiving antenna the signal reaches as superimposition of the signal which may be constructive or destructive. Some of the frequencies even get attenuated due to the reflections, diffraction and other such effects called as selective frequency fading [7].

The signal along with its replicas is received at receiving antenna in a scattered manner. In a condition where transmitter and receiver are in motion the radio frequency of the signal may increase or decrease depending on the relative movement. This is called Doppler shift and it is collectively called as multipath fading [8]. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is dominant line of sight, Rician fading may be more applicable. AWGN is often used as a channel model in which the only impairment to communication is a linear addition of white band or white noise with a constant spectral density and a Gaussian distribution of amplitude [9]. This model does not account for fading, frequency selectivity, interference, non linearity or dispersion. AWGN channel is a good model for many satellite and deep space communication links.

III. SIMULINK MODEL

Fig. 1 shows the basic OFDM system architecture explaining how the modulation is being done and then it is being transmitted. During the period of transmission the

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 7, July 2015

Generator matrix G_e is adopted [10]. In this work BPSK and DPSK modulation schemes are used under various channels viz., AWGN, Rayleigh and Rician.

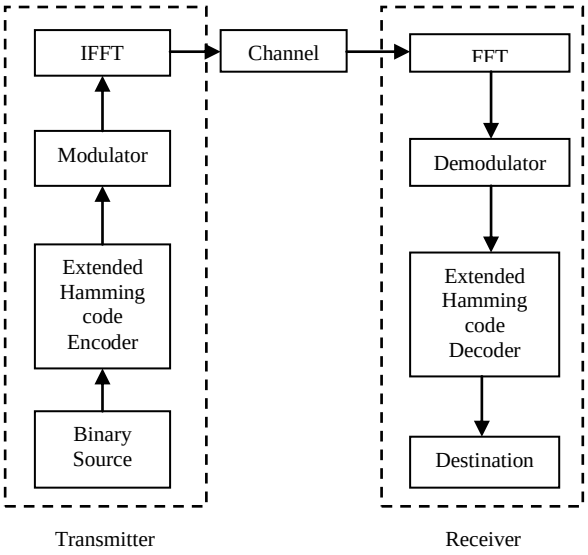

Fig. 1. Basic OFDM system Architecture

There are two key steps in the transmitter, one is to include (8,4) EH Code into information and the other one is to modulate the encoded sequence by the appropriate modulation techniques.

The Theoretical expressions of Probability error (P_e) for various uncoded OFDM schemes are given in TABLE 1.

TABLE 1 : THE PROBABILITY ERROR FOR BPSK AND DPSK MODULATION SCHEMES UNDER VARIOUS CHANNELS

Channel	Modulation	Probability of error (P_e)
AWGN	BPSK	$\frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{N_o}}\right)$
	DPSK	$\frac{1}{2}\exp\left(-\frac{E_b}{N_o}\right)$
Rayleigh	BPSK	$\frac{1}{2}\left(1-\sqrt{\frac{E_b/N_o}{1+E_b/N_o}}\right)$
	DPSK	$\frac{1}{2}\left(1+\frac{E_b}{N_o}\right)^{-1}$
Rician	BPSK	$\frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{k(E_b/N_o)}{k+E_b/N_o}}\right)$
	DPSK	$\frac{k+1}{2(k+1+E_b/N_o)}\exp\left(-\frac{k\,E_b/N_o}{k+1+E_b/N_o}\right)$

Where
E_b is the energy per bit
N_o is Noise power spectral density and
k is the ratio between power in direct path to the power in other scattered paths

IV. EXTENDED HAMMING CODE

Hamming Code is one type of Block coding, invented by R. Hamming in 1950. However Hamming Code is being used in many applications due to their simplicity and efficiency. The minimum Hamming distance d_{min} is 3 and hence it can correct single bit error. For efficient FFT/IFFT algorithm (8,4) EH Code was used in this paper for the encoding process. Suppose that C which is 7 bits by a [7,4]. Let C_e be the code obtained by adding an extra bit to the end of each word in C in such a way that every word in C_e has even parity. The Generator matrix G_e for (8,4) EH Code is given by [10]

$$G_e = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 \end{bmatrix}$$

Then the code word $[C_e]_{1xn}=[M]_{1xk}[G_e]_{kxn}$ (1)
Where
[M] is the information matrix

The Parity check matrix of (8,4) EH Code C_e is H_e:

$$H_e = \begin{bmatrix} 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

According to the formula syndrome matrix is

$$S = eH_e^T \quad (2)$$

The syndromes which are corresponding to the non-error and one error patterns could be obtained.

The probability of error with EH Code is evaluated as

$$P = 1 - [(1-P_e)^8 + 8P_e(1-P_e)^7] \quad (3)$$

Where
P_e is probability of error with modulation only

From (2) one can estimate exact error bit and correct error bit when error occurs. This point improves the BER performance.

V. SIMULATION AND RESULT ANALYSIS

In this section the simulation result using MATLAB is presented and the simulation has been done in order to investigate the performance of coded OFDM over uncoded OFDM. The tested error controlling coding scheme is EH Code.

First, the OFDM system was tested with different channel conditions. The data stream has been modulated using BPSK and DPSK modulation to show how the modulation will affect the system performance.

The results are illustrated in Fig. 2, Fig. 3 and Fig. 4

DOI 10.17148/IJARCCE.2015.4729

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
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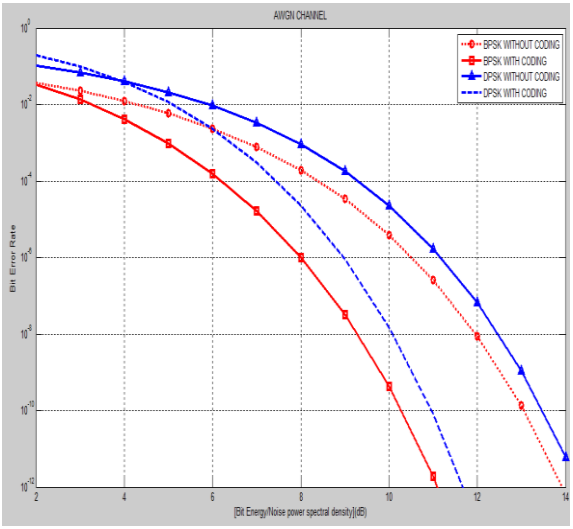

Fig. 2. Comparison of BER performance for BPSK and DPSK modulation schemes under AWGN channel

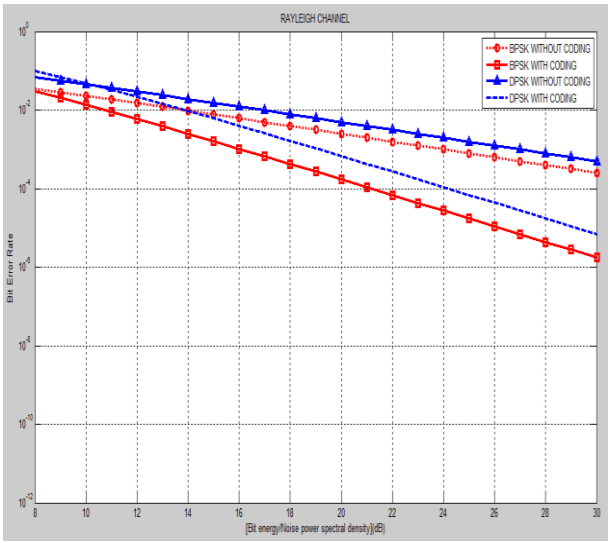

Fig. 3. Comparison of BER performance for BPSK and DPSK modulation schemes under Rayleigh channel

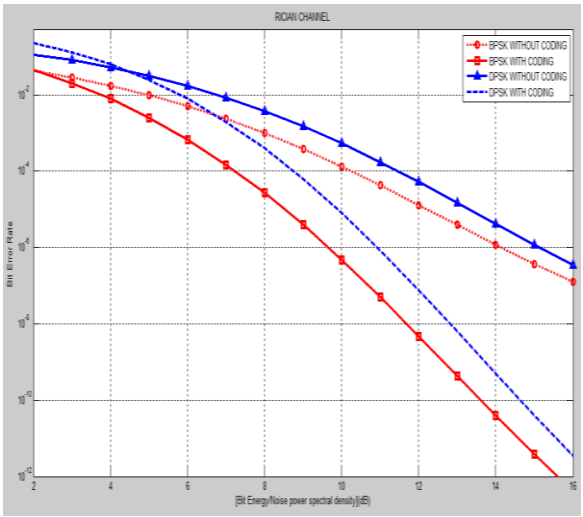

Fig. 4. Comparison of BER performance for BPSK and DPSK modulation schemes under Rician channel

Over AWGN channel, the DPSK-OFDM system requires E_b/N_o of 11dB at BER of $1.7x10^{-6}$ while the same E_b/N_o is sufficient in BPSK for achieving BER of $0.261x10^{-6}$.

The comparison result between BPSK and DPSK in AWGN, Rayleigh and Rician channels are summarised in TABLE 2.

TABLE. 2 : COMPARISON OF BER VALUES FOR BPSK AND DPSK MODULATION SCHEMES UNDER VARIOUS CHANNELS AT E_b/N_o OF 11dB

Channels	Modulation Schemes	Without coding	With coding
AWGN	BPSK	$0.261x10^{-6}$	$0.191x10^{-11}$
	DPSK	$1.7x10^{-6}$	$8.13x10^{-11}$
Rayleigh	BPSK	$1.87x10^{-2}$	$0.912x10^{-2}$
	DPSK	$3.67x10^{-2}$	$3.27x10^{-2}$
Rician	BPSK	$0.0423x10^{-3}$	$0.501x10^{-7}$
	DPSK	$0.173x10^{-3}$	$8.43x10^{-7}$

Next, the investigation regarding the affect of EH Code towards the SNR performance of OFDM system was conducted. It is shown that in Fig. 5, the SNR performance can be improved by using EH Code.

Over the Rician channel the EH Code in DPSK of OFDM system achieves a coding gain of 1.96dB at BER of 10^{-3} where as the BPSK of OFDM system can achieve coding gain of 2.25dB at same BER.

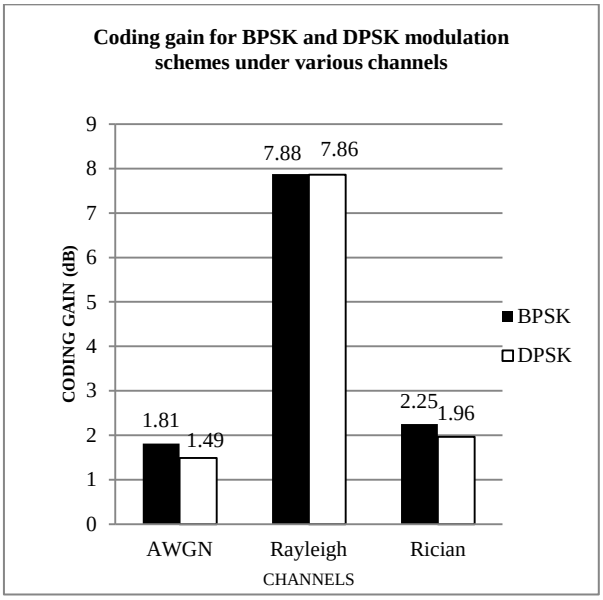

Fig. 5 Coding gain for BPSK and DPSK modulation schemes under various channels at 10^{-3} BER

VI. CONCLUSION

In this paper, a comparative performance between BPSK and DPSK modulation schemes under AWGN, Rayleigh and Rician fading channels have been conducted. It has been found that the significance BER performance of OFDM system can be improved by using EH Code.

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ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 7, July 2015

The simulation results show that, OFDM system with BPSK modulation gives better performance under AWGN channel with EH Code.

ACKNOWLEDGMENT

The authors would like to take this opportunity to thank **Dr.N.Bala Subrahmanyam** (Professor & HOD) and **Prof.G.T. Rao** for their valuable suggestion and advice for smooth progress of this work.

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