Enhancement of Error Performance in OFDM System with Extended Hamming Code Under various Channels

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Abstract - Orthogonal Frequency Division Multiplexing (OFDM) is a high-data transmission technique for wireless applications. However, due to multipath fading the error performance of the OFDM system is condensed. Error controlling codes are used to enhance the error performance under fading channel. In this paper, Extended Hamming (EH) code is proposed to enhance the error performance in OFDM transmission. The performance has been evaluated for Additive white Gaussian Noise (AWGN) channel and Rician channel with Quadrature Phase shift Keying (QPSK) modulation. The simulation results confirm that the error performance of the proposed coded OFDM system is superior to that of un-coded OFDM system.

Index Terms - OFDM, QPSK, BER, EH Code, AWGN channel, Rician channel.

1. INTRODUCTION

The OFDM has been employed in 4G wireless standards such as IEEE 802.11a/g [1], HIPERLAN2 [2], digital audio and video broadcast (DAB/DVB) [3, 4]. OFDM has various benefits such as high spectral efficiency, robustness in frequency selective fading channels [5], immunity to Inter Symbol Interference (ISI) and capability of handling Fast Fourier Transform multipath fading.

OFDM makes use of competent spectrum utilization, in which data sequence modulates multiple carriers called as sub-carriers which are orthogonal to each other. However, owing to various obstacles in the signal path, the signal endures a multipath propagation, which sources several replicas of the transmitted signal. Some of the frequencies even get attenuated due to the reflections, diffraction and other such effects called as selective frequency fading [5]. The signal accompanied by its replicas is received at receiving antenna in a scattered manner. When transmitter and receiver are in motion the energy of the signal may vacillate, depend on the relative movement, which is called Doppler shift and it is mutually called as multipath fading [6]. When there is foremost line of sight, Rician fading is more appropriate. AWGN is every so often used as a channel model in which the only deficiency is a linear addition of white noise with a constant spectral density and a Gaussian distribution of amplitude [7-10]. So as to afford consistent communication, modern wireless systems must be able to provide high error performance [11].

In this paper, to enhance error performance in OFDM system (8, 4) EH code has been employed as single bit error correcting code. The performance is valued for both AWGN and Rician channel conditions.

This paper is organised as follows: Section II presents EH code and its error correction capability. Section III presents the BER of AWGN and Rician channels. The results are presented in section IV and section V concludes the paper.

2. EXTENDED HAMMING CODE

Hamming Code is a simple error controlling code invented by R. Hamming in 1950. The minimum Hamming distance is 3 and hence it can correct single bit error. For efficient Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) implementation, code word length of 2^n (n = any integer greater than 2) is utmost preferred. Henceforth (8, 4) EH code has been employed in this paper as channel coding technique. The Generator matrix G_{EH} for (8, 4) EH Code is given by [11]

$$G_{EH} = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 \end{bmatrix}$$

Then the code word [6]

$$[C]_{1X8} = [M]_{1X4}\,[G_{EH}]_{4X8} \qquad (1)$$

Where $[M]_{1X4}$ is the data matrix of length 4.

All possible code words are evaluated using equation (1) and presented in Table 1.

Table 1 EH Code words

Data sequence [M]				Code word [C]							
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1	0	1	1	1
0	0	1	0	0	0	1	0	1	0	1	1
0	0	1	1	0	0	1	1	1	1	0	0
0	1	0	0	0	1	0	0	1	1	0	1
0	1	0	1	0	1	0	1	1	0	1	0
0	1	1	0	0	1	1	0	0	1	1	0
0	1	1	1	0	1	1	1	0	0	0	1
1	0	0	0	1	0	0	0	1	1	1	1
1	0	0	1	1	0	0	1	1	0	0	0
1	0	1	0	1	0	1	0	0	1	0	0
1	0	1	1	1	0	1	1	0	0	1	1
1	1	0	0	1	1	0	0	0	0	1	0
1	1	0	1	1	1	0	1	0	1	0	1
1	1	1	0	1	1	1	0	1	0	0	1
1	1	1	1	1	1	1	1	1	1	1	0

Error Correction

Let [M] = [1011]

From the above table [C] = [1 0 1 1 0 0 1 1]

Let us assume error is introduced in 1st position, which makes the received code word, R = [0 0 1 1 0 0 1 1].

The parity check matrix for the G_{EH} can be derived as

$$H_{EH} = \begin{bmatrix} 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Then

$$H_{EH}{}^{T} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The syndrome for EH code is delineated as [6]

$$S_{EH} = R \bullet H_{EH}{}^{T} \qquad (2)$$

Substituting R and $H_{EH}{}^{T}$ in above equation, we get

$$S_{EH} = [1\ 1\ 1\ 1]$$

It is observed that, vector [1 1 1 1] is at first row in $H_{EH}{}^{T}$, hence the error position is admitted as first position.

BER for EH code is expressed as [6]

$$\text{BER} = 1 - [(1-p)^8 + 8p(1-p)^7] \qquad (3)$$

Where, p is BER without coding and presented in next section.

3. ERROR PERFORMANCE UNDER DIFFERENT CHANNELS

Figure 1 illustrates coded OFDM system architecture.

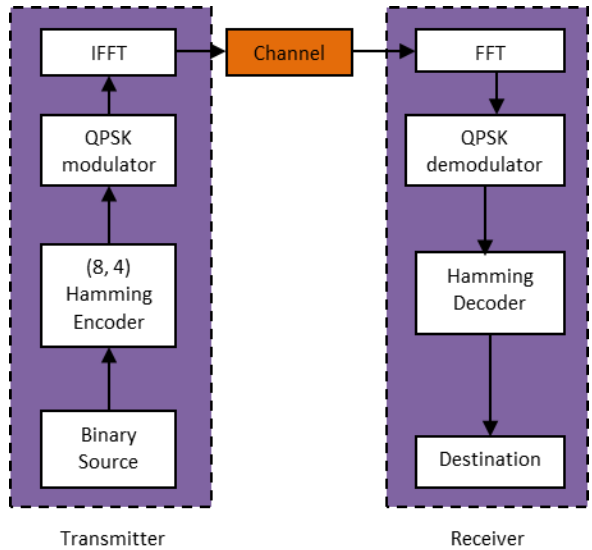

Figure 1 Coded OFDM system architecture

In OFDM system, N sub-carriers are employed to carry the data sequence, which requires N high frequency oscillators. Therefore, it necessitates huge computational complexity. This issue can be handled by implementing OFDM system with IFFT/FFT algorithms. The bandwidth performance of QPSK is superior to that of PSK [6]. However, the error performance point of view, QPSK is super to that of PSK. Hence to accomplish bandwidth efficiency and error performance simultaneously, a robust channel coding technique, (8, 4) EH code has been recommended in this paper. BER is a key metric to estimate error performance in communication system. BER can be expressed under AWGN channel and Raician channel, respectively as specified by [5, 6].

$$BER\ (AWGN) = p\ (AWGN) = erfc\left(\sqrt{\Omega}\right) \qquad (4)$$

$$BER\ (Rician) = p\ (Rician) = 1 - \sqrt{\frac{\alpha\Omega}{\alpha + \Omega}} \qquad (5)$$

Where

$$\Omega = \frac{Bit\ Energy}{Noise\ Power\ Spectral\ density} = \frac{E_b}{N_o}$$

α is the ratio between power in direct path to the power in other scattered paths

4. SIMULATION RESULT

In this section the simulation results using MATLAB are presented and the simulation has been done in order to investigate the performance of coded OFDM over un-coded OFDM. BER versus Ω of the proposed system under AWGN and Rician channel is presented in figure 2 and 3, respectively, with QPSK modulation.

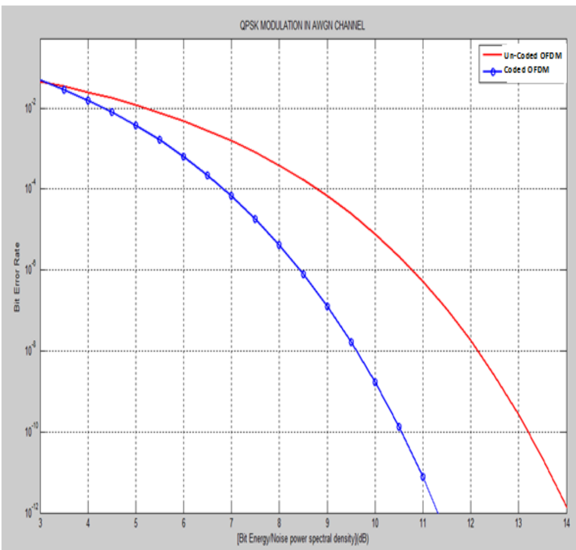

Figure 2 BER plot under AWGN channel

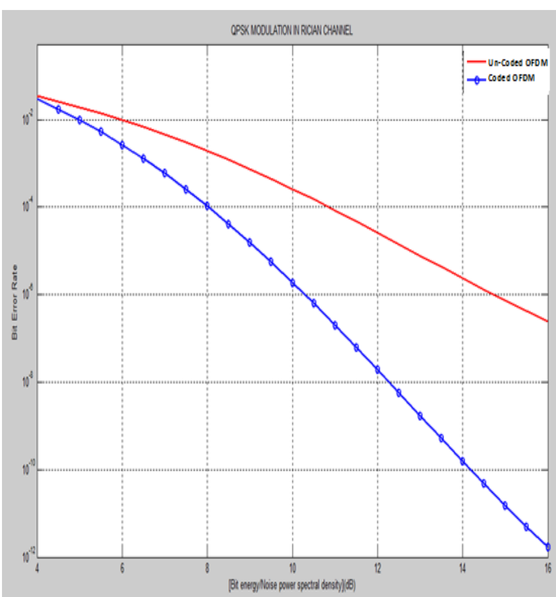

Figure 3 BER plot under Rician channel

From Figure 2 and 3, it perceived that the BER performance of the proposed system is superior to that of un-coded system. For instance, from figure 2, when the channel is AWGN, at BER = 10^{-4}, Ω of coded and un-coded system are 6.85 dB and 8.85 dB. In other words, over AWGN channel, the un-coded OFDM system requires Ω = 8.85 dB, while coded system requires just 6.85 dB to attain BER of 10^{-4}.

The coding gain (G_{dB}) of the system can be stated as

$$G_{dB} = \Omega_{un-coded}\, in\ dB - \Omega_{coded}\, in\ dB \quad (6)$$

Therefore, G_{dB} in AWGN channel is 2.00 dB. Similarly, from figure 3, G_{dB} under Rician channel is 2.85 dB.

5. CONCLUSION

In this paper, we recommended (8, 4) EH code to enhance the error performance in OFDM system. The error performance of the recommended technique is evaluated under AWGN and Rician channels with QPSK modulation. The simulation results confirmed that BER performance of coded OFDM system is superior to that of un-coded OFDM system. For instance, at BER = 10^{-4}, the coding gain of AWGN and Rician channel is 2.00 dB and 2.85 dB, respectively.

REFERENCES

[1] "IEEE 802.11 working group for wireless local area networks".
[2] ETS 300 652, "High performance radio local area networks (HIPERLAN) type 1", June 1996.
[3] ETSI EN 300 744 V1.5.1, "Radio broadcasting systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers".
[4] ETSI EN 300 744 V1.5.1, "Digital Video Broadcasting (DVB); framing structure, channel coding and modulation for digital terrestrial television".
[5] Marvin k. Simon, Mohamed-Slim Alouini, "Digital communication over fading channels", 2nd ed., John Wiley and Sons Publication, 2004.
[6] Bernard Sklar, "Digital Communications Fundamentals and Applications", 2nd ed., Pearson Education, 2001.
[7] T. May, H. Rohling, and V. Engels, "Performance analysis of Viterbi decoding for 64-DAPSK and 64-QAM modulated OFDM signals," IEEE Transactions on Communications, vol. 46, issue 2, 1998, pp. 182–190.
[8] M. Sandell, S. K. Wilson, and P. O. Borjesson, "Performance analysis of coded OFDM on fading channels with non-ideal interleaving and channel knowledge," proceedings of IEEE Vehicular Technology Conference, vol. 3, May 1997, pp. 1380-1384.
[9] A. Chini, M. S. EI-Tanany, and S. A. Mahmoud, "On the performance of a coded MCM over multipath Rayleigh fading channels," Proceedings of IEEE Conference, vol. 3, June 1995, pp. 1689-1694.
[10] T. S. Rappaport, "Wireless Communication Principles and Practice", IEEE Press, New York, Prentice Hall, 2002.
[11] Vandana B. Malode, Bhagwat P. Patil, "BER performance of LBC coded OFDM in Different Channels", proceedings of IEEE Conference on control and system graduate research colloquium, 2012, pp. 106-110.