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Performance Evaluation of a Wireless Orthogonal Frequency Division Multiplexing System under Various Concatenated Fec Channel-Coding Schemes

[1]Dulal Haque, [2]Shaikh Enayet Ullah and [1]Razu Ahmed
[1]Department of Computer and Communication Engineering,
International Islamic University Chittagong, Chittagong-4203, Bangladesh
[2]Department of Applied Physics and Electronic Engineering,
Rajshahi University, Rajshahi-6205, Bangladesh

Abstract: In this study, we study the effect of various concatenated Forward Error Correction (FEC) codes on the performance of a wireless Orthogonal Frequency Division Multiplexing (OFDM) system. In FEC concatenated channel code, the OFDM system incorporates Reed-Solomon (RS) encoder of (255, 239, 8), Cyclic Encoder of (15, 11), Bose-Chadhuri-Hocquenghem (BCH) encoder of (127, 64) with Convolution encoder of ⅔ and ¾ -rated codes under different combinations of digital modulation (QPSK,8PSK, 32-QAM and 64-QAM). The simulation study is made with the development of a computer program written in MATLAB source code on the processing of recorded audio signal under additive white Gaussian noise (AWGN) channel. The simulation results of estimated Bit error rate (BER) show that the implementation of concatenated RS(255, 239, 8) code with ¾ -rated Convolutional code under QPSK modulation technique is highly effective to combat inherent interference in the communication system. Due to constraint in data handling capability of the Matlab Editor, a segment of the recorded audio signal is used for analysis. The transmitted audio message is found to have retrieved effectively under noisy situation.

Key words: Orthogonal Frequency Division Multiplexing (OFDM), Cyclic encoding (CC), Reed-Solomon encoding (RS), Convolution encoding (CC), Bose-Chadhuri-Hocquenghem (BCH), Bit Error Rate (BER), Additive White Gaussian Noise (AWGN)

INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a multi-carrier modulation technique well suited to overcome adverse effects in hostile transmission environment. This technique provides a reliable reception of signals affected by multipath propagation and selective fading and has been used in broadcast media such as European terrestrial digital video broadcasting (DVB-T) and digital audio broadcasting (DAB) and in the IEEE 802.11a (local area network, LAN) and the IEEE 802.16a (metropolitan area network, MAN) standards. OFDM is also being pursued for dedicated short-range communications (DSRC) for roadside to vehicle communications. With the advent of next generation (4G) broadband wireless communications, the combination of multiple-input multiple-output (MIMO) wireless technology with orthogonal frequency division multiplexing (OFDM) has been recognized as one of the most promising techniques to achieve high data rate and provide more reliable reception compared with the traditional single antenna system (Gordon *et al*., 2004; Zhang *et al*., 2007). However, in the present study, an effort has been made merely to concatenate the various channel encoding codes to improve the reliable reception performance of an OFDM wireless communication system under different digital modulation schemes such as QPSK, 8PSK, 32-QAM, 64-QAM. In OFDM, generally, the transmitted bit stream is divided into many different sub streams and sent over many different sub channels. Typically the sub channels are orthogonal under ideal propagation conditions. The data rate on each of the sub-channels is much less than the total data rate and the corresponding sub-channel bandwidth is much less than the total system bandwidth. The number of sub-streams is chosen to insure that each sub-channel has a

Corresponding Author: Dulal Haque, Department of Computer and Communication Engineering, International Islamic University Chittagong, Chittagong-4203, Bangladesh

bandwidth less than the coherence bandwidth of the channel, so the sub-channels experience relatively flat fading with insignificant amount of ISI effect. In almost all applications of multi-carrier modulation, satisfactory performance cannot be achieved without the addition of some form of channel coding. In wireless systems subjected to fading, extremely high signal-to-noise ratios are required to achieve reasonable error probability. In addition, interference from other wireless channels is frequently severe. On wire-line systems, large constellation sizes are commonly employed to achieve high bit rates. Coding in this case is essential for achieving the highest possible rates in the presence of crosstalk and impulsive and other interference. Channel coding in OFDM systems can be implemented in time and frequency domain such that both dimensions are utilized to achieve better immunity against frequency and time selective fading. A concatenated coding scheme constituted from a combination of two 8-bit channel codes (block and convolution) along with proper time/frequency interleaving has been used in the present study (Goldsmith, 2005; Bahai and Burton, 2002).

TRANSMISSION SIMULATION MODEL

The block diagram of the simulated system model is shown in Fig. 1. The input binary data stream obtained from a segment of recoded audio signal is ensured against transmission errors with Forward Error Correction codes (FEC) and interleaved. A block Reed Solomon (255, 239, 8) code based on the Galois field $GF(2^8)$ with a symbol size of 8 bits is chosen that processes a block of 239 symbols and can correct up to 8 symbol errors calculating 16 redundant correction symbols.

The block formatted (Reed Solomon encoded) data stream is passed through a convolution interleaver of depth 12. A convolution code (CC) is applied to the interleaved symbols. Its rate R = m/n, where m is the number of input bits and n is the number of output bits- is equal to ⅔ and ¾ and the constraint length, K of 5 and 7. The convolutionally encoded bits are interleaved further prior to converted into each of the either four complex modulation symbols in QPSK 8PSK, 32-QAM and64-QAM modulation and fed to an OFDM modulator for transmission. The simulated coding and modulation schemes used in the present study are shown in Table 1.

In OFDM modulator, the digitally modulated information symbols are transmitted in parallel on sub carriers through implementation as an inverse discrete Fourier transform (IDFT) on a block of information symbols followed by an analog-to-digital converter (ADC). To mitigate the effects of intersymbol interference

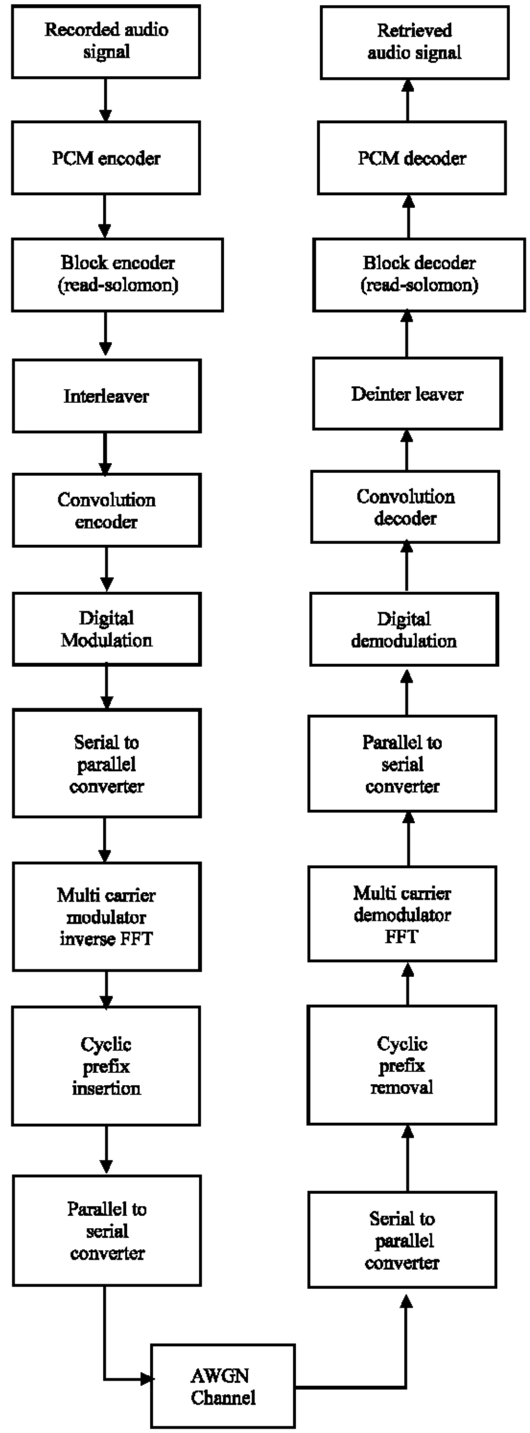

Fig. 1: A block diagram of an OFDM communication system with interleaved concatenated channel coding

(ISI) caused by channel time spread, each block of IDFT coefficients is typically preceded by a cyclic prefix (Kratochvil, 2003; Cimini, 1985). At the receiver side, the

Table 1: Simulated concatenated Coding and Modulation schemes

FEC #	Modulation	RS code	CC code rate	BCH code	Cyclic Code
1	QPSK	(255,239,8)	⅔		
2	8PSK	(255,239,8)	⅔		
3	32QAM	(255,239,8)	⅔		
4	64QAM	(255,239,8)	⅔		
5	QPSK	(255,239,8)	¾		
6	8PSK	(255,239,8)	¾		
7	32QAM	(255,239,8)	¾		
8	64QAM	(255,239,8)	¾		
9	QPSK		⅔	BCH(127,64)	
10	8PSK		⅔	BCH(127,64)	
11	32QAM		⅔	BCH(127,64)	
12	64QAM		⅔	BCH(127,64)	
13	QPSK		¾	BCH(127,64)	
14	8PSK		¾	BCH(127,64)	
15	32QAM		¾	BCH(127,64)	
16	64QAM		¾	BCH(127,64)	
17	QPSK		⅔		CC(15,11)
18	8PSK		⅔		CC(15,11)
19	32QAM		⅔		CC(15,11)
20	64QAM		⅔		CC(15,11)
21	QPSK		¾		CC(15,11)
22	8PSK		¾		CC(15,11)
23	32QAM		¾		CC(15,11)
24	64QAM		¾		CC(15,11)

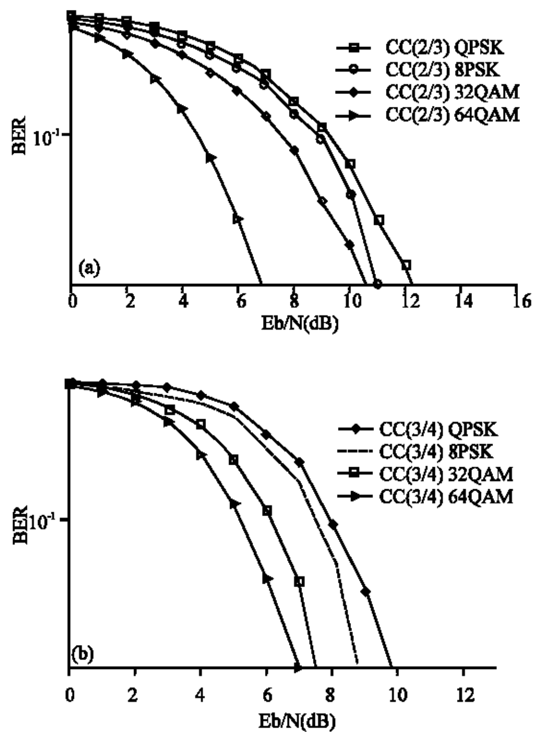

Fig. 2: System performance under different modulation schemes for Cyclic (15,11) concatenated with CC (code rate of ⅔ and ¾)

received signal is OFDM demodulated, de-mapped, de-interleaved and then de- decoded in order to recover the data transmitted.

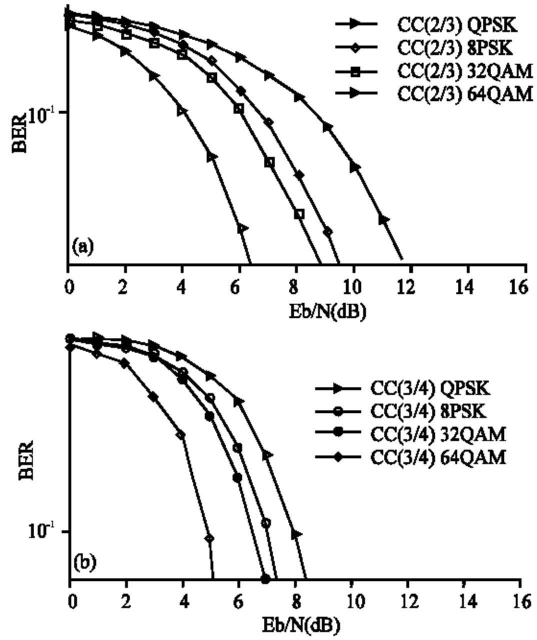

Fig. 3: System performance under different modulation schemes for RS (255, 239, 8) concatenated with CC (code rate of 2/3, 3/4)

RESULTS

BER performance of the wireless OFDM system under three concatenated FEC channel coding and different modulation schemes listed in the Table 1 have been evaluated. We first investigate the use of interleaved concatenated RS (255, 239, 8) and CC codes with code rates of ⅔ and ¾ under QPSK, 8PSK, 32-QAM and 64-QAM modulations. The BER performance is investigated and results are shown in Fig. 4. The use of concatenated RS((255, 239, 8) and CC with code rate ⅔ in 64-QAM modulation degrades the performance of the system. Next, we compare the BER performance of the OFDM system when channel coding is BCH and CC. The results are given in Fig. 3. Finally, we compare the BER performance of the OFDM system when channel coding is Cyclic and CC. The results are given in Fig. 4. The simulation study gives an insight into ways of concatenating 8 bit Reed Solomon Code with ⅔ and ¾ -rated Convolution code in 64-QAM modulation perform better than other concatenated codes and modulations. Figure 4 through Fig. 2 show the bit error rate (BER) for different values of energy per bit to noise ratio (E_b/N). Simulation results in Fig. 2 show the advantage of considering a low (2/3 and 3/4) convolution-coding rate for each of the four considered digital modulation schemes (QPSK, 8PSK, 32-QAM and 64-QAM). The performance of the system.

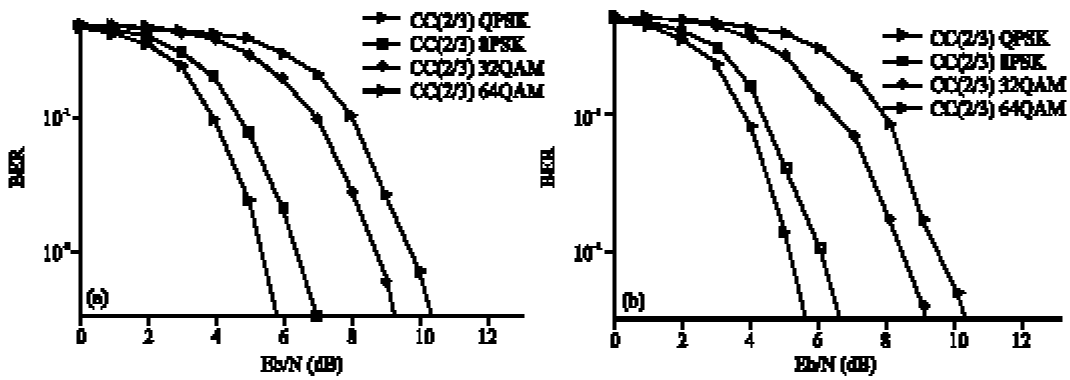

Fig. 4: System performance under different modulation schemes for BCH (127,64) concatenated with CC (code rate of ⅔ and ¾)

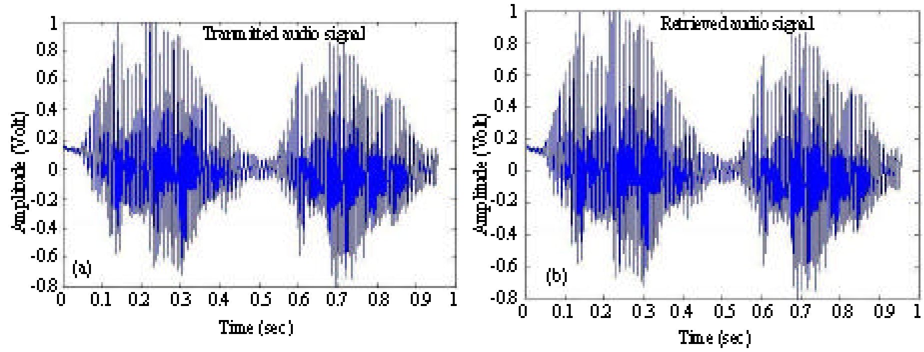

Fig. 5: Transmitted and retrieved signal

CONCLUSION

In this contribution, we have studied the performance of a wireless Orthogonal Frequency Division Multiplexing (OFDM) system adopting various concatenated FEC channel coding schemes and digital modulations. A range of system performance results highlights the impact of both digital modulation and concatenated channel coding schemes. In the context of system performance, it is observed that the implementation of interleaved Reed Solomon code with ¾ -rated Convolutional code under QPSK modulation technique provides satisfactory result among the three concatenated FEC channel coding schemes.

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