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Performance Evaluation of a Concatenated Interleaved Forward Error Correction Scheme Based Orthogonal Frequency Division Multiplexing System

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Abstract: In this study, the performance of an Orthogonal Frequency Division Multiplexing (OFDM) system under different combination of digital modulations(BPSK, QPSK, 8-QAM and 16-QAM) and a concatenated interleaved Forward Error Correction (FEC) scheme on the transmission of an audio signal has been evaluated. The OFDM system incorporates Reed-Solomon (RS) encoder of (255,239,8) with Convolution encoder with ½, ⅔ and ¾ -rated codes in FEC channel coding. A computer program written in the MATLAB source code is developed and the simulation study is made with the acquisition of recorded audio signal and its processing under Additive White Gaussian Noise (AWGN) channel. The simulation results of estimated Bit Error Rate (BER) show that the implementation of interleaved RS (255,239,8) code with ¾-rated Convolution code under BPSK modulation technique is highly effective to combat inherent interference in the communication system. It is anticipated that the performance of the communication system degrades with the increasing of noise power. 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, block encoding, convolutional encoding, bit error rate, additive white gaussian noise

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier 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 road side 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; Wei 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 BPSK, QPSK, 8-QAM and 16-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 bandwidth less than the coherence bandwidth of the channel, so the sub channels experience relatively flat fading with insignificant amount of ISI effect.

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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; Ahmad *et al*., 2002).

SYSTEM 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 (FECs) 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 convolutional interleaver of depth 12. A convolutional 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 ½, ⅔ and ¾ the constraint length , K is of 3,5 and 7.The convolutionally encoded bits are interleaved further prior to converted into each of the either four complex modulation symbols in BPSK, QPSK, 8QAM and 16-QAM modulation and fed to an OFDM modulator for transmission. The simulated coding and modulation schemes used in the present study is shown in Table 1.

Table 1: Simulated Coding and Modualtion schemes

FEC #	Modulation	RS code	CC code rate
1	BPSK	(255,239,8)	½
2	QPSK	(255,239,8)	½
3	8-QAM	(255,239,8)	½
4	16-QAM	(255,239,8)	½
5	BPSK	(255,239,8)	⅔
6	QPSK	(255,239,8)	⅔
7	8-QAM	(255,239,8)	⅔
8	16-QAM	(255,239,8)	⅔
9	BPSK	(255,239,8)	¾
10	QPSK	(255,239,8)	¾
11	8-QAM	(255,239,8)	¾
12	16-QAM	(255,239,8)	¾

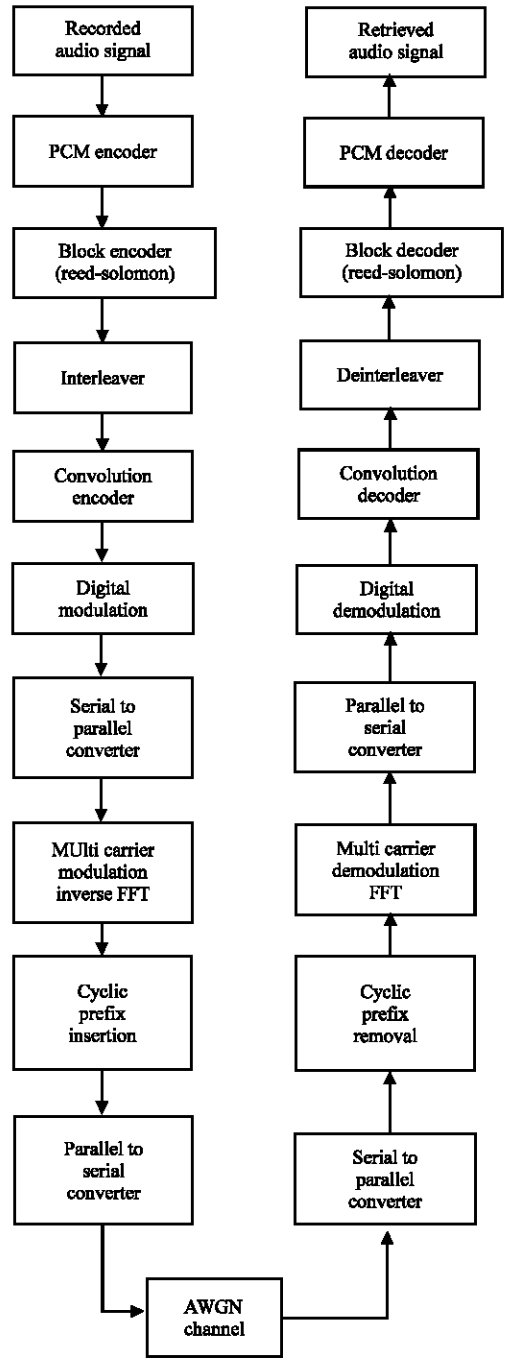

Fig. 1: A block diagram of an OFDM communication system with interleaved concatenated channel coding

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

SIMULATION RESULTS

BER performance of the OFDM system under 8-bit RS-CC codes and different modulation schemes listed in the Table 1 have been evaluated. Figure 2 and 3 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 (½) convolutional coding rate for each of the four considered digital modulation schemes (BPSK, QPSK, 8-QAM and 16-QAM). The performance of the system under BPSK modulation is quite satisfactory as compared to other modulation techniques. In ½ convolutional code rate, a signification improvement of signal to noise ratio (SNR) is observed in case of 8-QAM modulation. The bit error rate under such a modulation technique for a typical SNR value of 11 dB is 0.000212 which is 100 times smaller than that of 16QAM modulation.

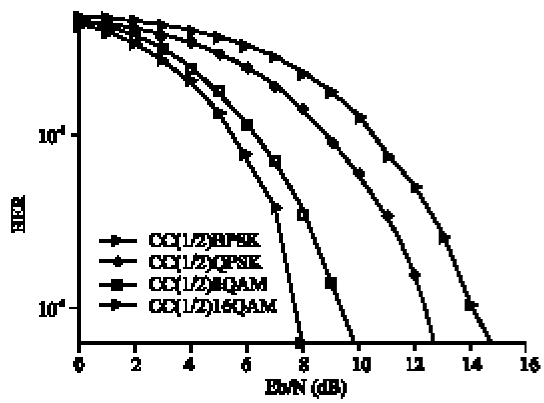

Fig. 2: System performance under different modulation schemes for a Convolutional Encoder with a ½ code rate

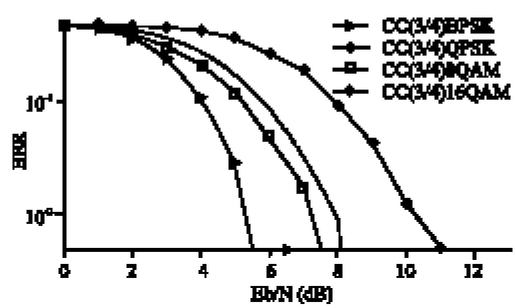

Fig. 3: System performance under different modulation schemes for a Convolutional Encoder with a 3/4 code rate

In Fig. 4, BER performance in case of 64-QAM modulation is found to be not suitable for OFDM transmission for a ⅔ convolutional code rate and better

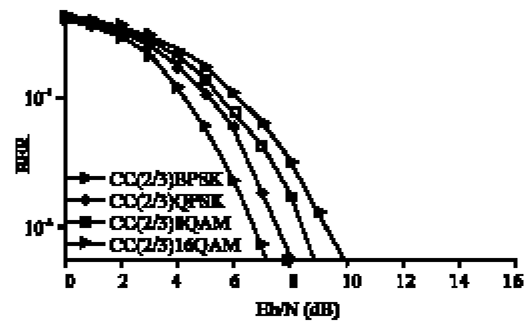

Fig. 4: System performance under different modulation schemes for a Convolutional Encoder with a 2/3 code rate

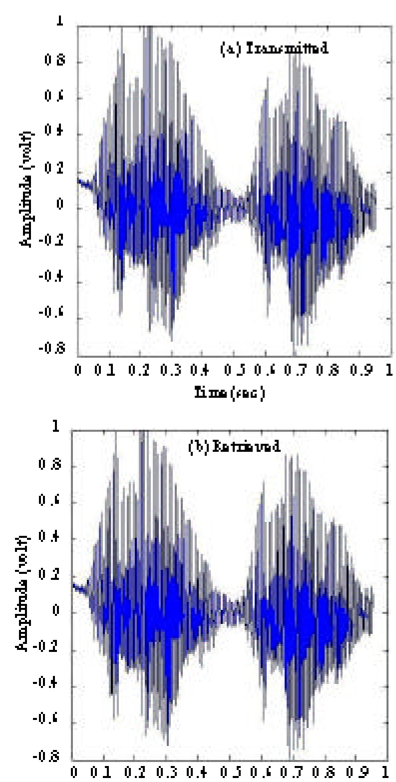

Fig. 5: A segment of an audio signal, (a) Transmitted, (b) retrieved

performance is shown for BPSK modulation. The bit error rate under such a modulation technique for a low SNR value of 8 dB is 0.00094. In Fig. 3, BER performance in case of 64-QAM modulation is not satisfactory for a ¾ convolutional code rate. The better performance is observed for BPSK modulation. The bit error rate under such a modulation technique for a low SNR value of 6 dB is 0. The transmitted and received audio signal for such a case is shown in Fig. 5.

CONCLUSION

A performance analysis of an Orthogonal Frequency Division Multiplexing (OFDM) system adopting concatenated Reed Solomon and Convolution encoding with block interleaver has been carried out. Performance results highlight the impact of modulation scheme and show that the implementation of an interleaved Reed Solomon with ¾ -rated Convolutional code under BPSK modulation technique provides satisfactory performance among the four considered modulations.

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