Soft- and Hard-coded OFDM System over Diverse Environment

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Abstract

This work demonstrated a wireless OFDM system for various modulation schemes like BPSK, QPSK, 8PSK, 16PSK by viterbi decoding via soft- and hard-decision to achieve better BER evaluation over diverse environment. Further, the BER is reported at different channel conditions to recommend the suitable modulation scheme with suitable coding in OFDM system over Rayleigh- and Rician-channels. Under all channel conditions (Rayleigh channel), it is reported that soft coded OFDM system offers improved spectral efficiency than that of uncoded and hard coded wireless system. For good Rician channel conditions (Eb/No≤≤ 20 dB), hard coding may also be implemented as an alternative.

Index Terms— OFDM, Hard coding, Soft coding, Rayleigh channels, Rician channels

1. Introduction

High speed OFDM system with forward error correction (FEC) methods allowed WLANs, standardized as IEEE 802.11a at 5 GHz band and as IEEE 802.11g at 2.4 GHz band, to reach up to the rates of 54 Mbps [1-3]. In such wireless systems involving slow time-frequency hopping, the frequency nonselective fading channel model seems to be a realistic and convenient model [4-6]. Typically, for such frequency nonselective channels, a viterbi decoder is opted usually to decode the information sequence at the receiver for better BER. A conventional viterbi decoder uses hamming distance as a metric with soft decisions that lead to a high performance for frequency nonselective channel [7]. Further, in order to mitigate the inter-symbol interference (ISI) and inter-carrier interference (ICI) generated due to selective fading channels, a repeat of the OFDM symbol end i.e. cyclic prefix (CP), is inserted to the beginning of OFDM symbol [8]. This treatment helps in improving the performance and simplification of receiver structure at the cost of decreasing bandwidth efficiency. Addition to viterbi decoding, channel estimation and carrier frequency offset is also reported to design an OFDM receiver in flat fading environment [9]. However, recently BER performance of OFDM system in flat fading channel using BPSK modulation technique is also studied intensively [10]. Further, two efficient anti-jamming coding techniques have been demonstrated for lost transmitted packets recovery via parallel channels and the system’s throughput is analyzed [11-12]. To transmit information through a terrestrial channel with a high bit rate as in traditional wideband transmission approach, a number of lower bit rate channels were used in parallel in OFDM [13]. To improve the performance of the uncoded OFDM signal by convolution coding [14], viterbi decoding algorithm is mostly applied to convolution encoder and it uses maximum prospect decoding technique [15]. In this model, the hamming encoder block encodes the data before it is sent through the channel. The default code is the [7, 4] hamming code, which encodes message words of length 4 into codeword of length 7. The code can correct one error in each transmitted codeword. There are seven valid combinations of the three bit parity matrix excluding the all-zero combination. Hard decision decoding uses one bit quantization on the received channel to obtain the decoded signal by correct the error bits from the received information values while soft decision decoding use multi-bit quantization on the received channel values with the use of encoded bits from the transmitters side with the use of encoded bits with data from the transmitters side [16]. One

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bit precision is used to quantize the symbols with hard decision decoding while data bits are quantized to three or four bits of precision for soft decision decoding. For raising the performance of the link the selection of quantization levels is a significant design decision [17].

With the discovery of codes [18], coding theorists and practitioners have learned how to approach Shannon’s capacity with realistic codes. Later, low-density parity-check (LDPC) codes have been also recognized to be capacity approaching [19]. Some of them required Channel State Information (CSI) at the transmitter [20, 21], further research has investigated adaptation with imperfect CSI, compromised by noisy channel estimation [22], which may be unrealistic or too costly to acquire in wireless applications where the channel changes on a steady basis. Coding is a good substitute for enhance system performance rather than using channel state information in diverse channel circumstances. In this work demonstrated a wireless OFDM system for various modulation schemes like BPSK, QPSK, 8PSK, 16PSK by viterbi decoding via soft- and hard-decision to achieve better BER evaluation over Rayleigh- and Rician- channels. Section I covers the introductory and previous demonstrated work on OFDM wireless system. Section II describes the simulated work along with result discussion followed by the conclusions in Section III.

2. Simulation Description & Result Discussion

In our simulated OFDM back to back system, hamming encoded (7, 4) signal is multiplexed with minimum hamming distance codeword of 3. Error detection and correction capability of block code is 2 and 1 respectively. Priority check matrix is used to detect and correct error with the help of affected syndrome which sent from the transmitted side. Further, the subcarriers vary from 56 to 448 corresponding to FFT size from 64 to 512 with number of pilot insertion from 8 to 64. This OFDM signal is passed through Rayleigh- and Rician- fading channels having parameter specified in Table 1.

<table>
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<tr>
<th>Table 1 Channel Parameters</th>
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<tr>
<td>Number of bits per ofdm symbol</td>
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<tr>
<td>Sampling period</td>
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<tr>
<td>Maximum Doppler shift</td>
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<td>Rician K-factor</td>
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At receiver, after removing the cyclic extension, the signal is applied to a Fast Fourier transform (FFT) to recover the modulated signal which demodulated by Viterbi decoder. Forward error correction is done by hard and soft decision decoded on decoded binary data stream.

A full system model was implemented in MATLAB according to the above described system for different coding techniques. The BER, a significant FOM of wireless system to quantify the integrity of data transmitted through the system is evaluated with respect to normalized SNR over multipath fading channels along with AWGN noise. From Figs 1(a)–4(a), for 56 sub-carriers with FFT size of 64, it has been observed that soft hamming coded OFDM for different simulated modulation techniques such as BPSK, QPSK, 8PSK, 16PSK reports improved results at varied values of Eb/No over Rayleigh channels. For BPSK, soft coding reports an improvement of 5 dB in Eb/No than hard coded system and of 4 dB than conventional system at acceptable BER of 10–4. Under Rician channels conditions as shown in Figs 1(b)–4(b), for BPSK, soft- and hard-coding reports comparable results under worst channel i.e. Eb/No<10 dB) conditions but under good channel conditions i.e. Eb/No= 20 dB, soft coding looks well again. For QPSK and 8PSK, soft coding shows preeminent results for all the channel conditions while hard coding performs as an alternative under good channel conditions. For 16PSK, soft- and hard-coding reports similar results for good channel condition but for worst channel conditions, soft coding is recommended. It has been also reported that OFDM with BPSK modulation technique shows enhanced BER as compare to other simulated modulation techniques over both the simulated channels.

![Figure 1. BER vs. Eb/No (dB) for BPSK modulation techniques with 56 sub-carriers with FFT size of 64 over (a) Rayleigh channel, and (b) Rician channel.](image-url)
For QPSK, soft coding reports an improvement of 2 dB in Eb/No than hard coding and of 6 dB than conventional system at acceptable BER of $10^{-4}$ over Rayleigh channel. For Rician channel conditions, an improvement of 1.5 dB is reported for soft hamming than conventional system as shown in Fig 2. For 8PSK, soft coded system reports an improvement of 3 dB in Eb/No than hard coded and of 5 dB than conventional system at acceptable BER of $10^{-3}$ over Rayleigh channel. For Rician channel conditions, an improvement of 1 dB is reported for soft hamming than hard coding and 2 dB than conventional system as shown in Fig 3. For 16PSK, soft coded reports an enhancement of 2 dB in Eb/No than hard coded and of 4 dB than conventional system at acceptable BER of $10^{-3}$ over Rayleigh channel. For Rician channel conditions, an improvement of 1 dB is reported for soft -than hard-coded system and 4 dB than conventional system as shown in Fig 4. Further, the results are computed for higher number of sub-carriers as shown in Fig 5-8 and it is observed that increases sub-carriers leads to a diminutive SNR penalty to achieve acceptable BER of 10-4 in all the modulation techniques.
Figure 4. BER vs. Eb/No (dB) for 16PSK modulation techniques with 56 sub-carriers with FFT size of 64 over (a) Rayleigh channel, and (b) Rician channel.

Figure 5. BER vs. Eb/No (dB) for BPSK modulation techniques with 56 sub-carriers with FFT size of 512 over (a) Rayleigh channel, and (b) Rician channel.

Figure 6. BER vs. Eb/No (dB) for QPSK modulation techniques with 56 sub-carriers with FFT size of 512 over (a) Rayleigh channel, and (b) Rician channel.
3. Conclusions

From above discussion, it is concluded that for Rayleigh channel under all channel conditions, soft coded OFDM system offers best spectral efficiency than that of conventional/uncoded and hard hamming coded OFDM. For, Rician channels, soft hamming coding is recommended to use for poor- and good- channel conditions. For good channel conditions, hard coding may also be implemented as an alternative. For best channel conditions, soft coded OFDM system outperforms for BPSK, QPSK and 8PSK while hard hamming coded OFDM system is optional with 16PSK.

References

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Figure 7. BER vs. Eb/No (dB) for 8PSK modulation techniques with 56 sub-carriers with FFT size of 512 over (a) Rayleigh channel, and (b) Rician channel.

Figure 8. BER vs. Eb/No (dB) for 16PSK modulation techniques with 56 sub-carriers with FFT size of 512 over (a) Rayleigh channel, and (b) Rician channel.


