ADAPTIVE TURBO CODED OFDM

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ABSTRACT: *In this paper, the system throughput of an OFDM system is enhanced by adding turbo coding and adaptive modulation (AD). Simulation is done over a time varying Raleigh fading channel. Each OFDM block is individually modulated according to channel state information acquired during the previous burst. The system automatically switches from higher to lower order modulation in order to maintain a constant bit error rate. Turbo codes are added for forward error correction, in addition to adaptive modulation. The end goal is to increase the system throughput while maintaining a bit error rate (BER) of* 10^{-2}.

Categories and Subject Descriptors
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1. Introduction

Orthogonal frequency division multiplexing (OFDM) is a promising candidate for achieving high data rate transmission in mobile environment. OFDM transmission system offers possibilities for alleviating many of the problems encountered with single carrier systems [1]. It has the advantage of spreading out a frequency selective fade over many symbols. This effectively randomizes burst errors caused by fading or impulse interference so that instead of several adjacent symbols being completely destroyed; many symbols are only slightly distorted.

In 1995, W.T. Webb proposed an adaptive quadrature amplitude modulation (QAM) scheme, which had about 5dB improvement in the signal-noise-ratio (SNR) over fixed 16QAM [2]. Trellis codes can be superimposed on the adaptive modulation for a coding gain of around 5dB [3]. In 1993, powerful so-called turbo codes were introduced which achieve good bit-error-rate (BER) at low SNR [4]. They were originally proposed for binary phase keying (BPSK). Different approaches to combine binary turbo codes with high bandwidth efficiency modulation have been suggested in [5-8]. The least complicated scheme is proposed by S.L.Goff [5]. The idea is to map the encoded bits of a standard turbo code after puncturing some of the parity bits to obtain a desired spectral efficiency to a high order modulation constellation.

Adaptive modulation and coding (AMC) is a powerful technique to achieve high throughput in high speed wireless data transmission which requires robust and spectrally efficient communication techniques. The basic idea behind adaptive transmission is to improve spectral efficiency by varying the transmission power level, symbol transmission rate, constellation size, and coding rate scheme. In this paper adaptive modulation and turbo coding is applied to OFDM that can provide a lower bit error rate than adaptive OFDM [9]. This thesis analyzed the performance of a turbo-coded OFDM system and the results are simulated in Rayleigh fading channel. The performance is evaluated in terms of bit error rate.

2. Orthogonal Frequency Division Multiplexing (OFDM)

The basic principle of OFDM is to split a high rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of sub-carriers. Because the symbol duration increases for the lower rate parallel sub-carriers, the relative amount of dispersion in time caused by multi-path delay spread is decreased. Inter symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol. In the guard time, the OFDM symbol is cyclically extended to avoid inter-carrier interference.

Figure I show a block diagram of an OFDM system, where the upper path is the transmitted chain and the lower part corresponds to the receiver chain. The IFFT modulates a block of input modulated values onto a number of sub-carriers. In the receiver, the sub-carriers are modulated by an FFT, which perform a reverse operation of an IFFT. An interesting feature of IFFT/FFT is that FFT is almost identical to an IFFT. In fact, an IFFT can be made using an FFT by conjugating input and output of the FFT and dividing the output by the FFT size. This make it's possible to use the same hardware for both transmitter and receiver. Of course, this saving in complexity is only possible when the system does not have to transmit and receive simultaneously.

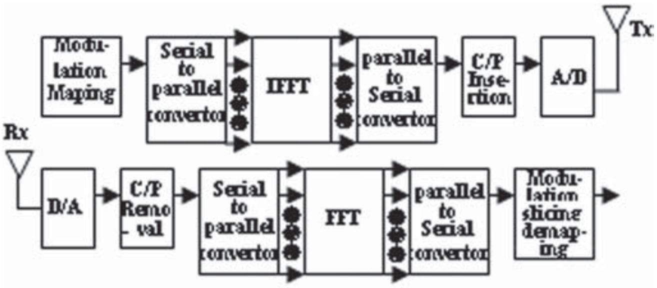

Figure 1. Block diagram of OFDM

The function before the IFFT is that binary input data is first encoded by a forward error correction code. The encoded data is than mapped into modulated signal. In the receiver path, after passing the RF part and the analog to digital conversion, the digital signal processing starts with a training phase to determine frequency offsets and symbol timings. An FFT is used to de-modulate all the sub-carriers. The output of the FFT contains N de-modulated values, which are mapped onto binary values and decode to produce the binary output data. To successful map the de-modulated values onto the binary values, first the reference phase and amplitudes of all the sub-carriers have to be acquired. Alternatively different differential techniques can be applied.

3. Turbo Coding

Coding theory has produced a number of different codes in an effort to improve the error-free transmission rate. Berrou, Glavieux, and Thitimajshima proposed a variation of concatenated codes that introduced a pseudo-random interleaver to reorder the input before passing it through the second coder [10]. They called these turbo codes, as an analogy to a turbo-charged engine, which uses feedback from the exhaust system to enhance system performance. Parallel concatenated codes, as they are also known, can be implemented by using either block codes or convolutional codes.The general structure used in turbo encoders is shown in Figure 2.

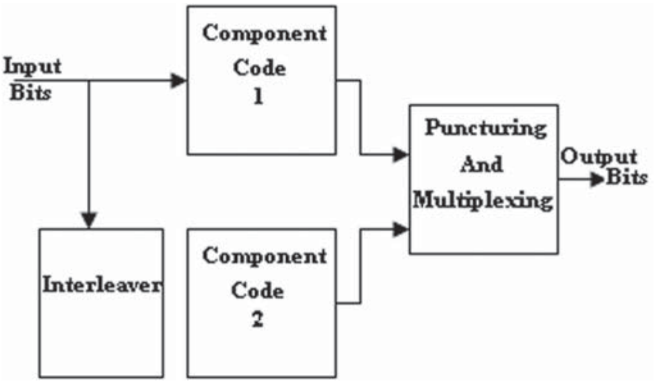

Figure 2. Block diagram of Turbo encoder

Two component codes are used to code the same input bits, but an interleaver is placed between the encoders. In this paper we concentrate entirely on the standard turbo encoder structure using two RSC codes. The outputs from the two component codes are then punctured and multiplexed. Usually both component RSC codes are half rate, giving one parity bit and one systematic bit output for every input bit. Than to give an overall coding rate of one half, half the output bits from the two encoders must be punctured. The arrangement that is often favored and that we have used in our work is to transmit all the systematic bits from the first RSC encoder, and half the parity bits from each encoder. Note that the systematic bits are rarely punctured, since this degrades the performance of the code more dramatically, than puncturing the parity bits.

The general structure of an iterative turbo decoder is shown in Figure 3. Two component decoders are linked by interleavers in a structure similar to that of the encoder. As seen in the Figure 3, each decoder takes three inputs i.e. the systematically encoded channel output bits, the parity bits transmitted from the associated component encoder, and the information from the other component decoder about the likely values of the bits concerned.

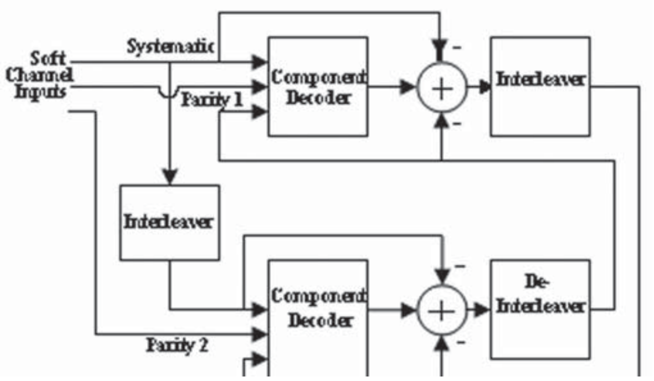

Figure 3. Block diagram of turbo decoder

The component decoders have to exploit both the inputs from the channel and a-priori information. They must also provide what are known as soft outputs for the decoded bits. The soft outputs are typically represented in terms of the so-called Log Likelihood Ratios (LLRs), the magnitude of which gives the sign of the bit, and the amplitude the probability of a correct decision.

The decoder operates iteratively, and in the first iteration the first component decoder produces a soft output as its estimate of the data bits. The soft output from the first encoder is then used as additional information for the second decoder, which uses this information along with the channel outputs to calculate its estimate of the data bits. The second iteration can begin, and the first decoder decodes the channel outputs again, but now with additional information about the value of the input bits provided by the output of the second decoder in the first iteration. This cycle is repeated, and with every iteration, the Bit Error Rate (BER) of the decoded bits tends to fall. However the improvement in performance obtained with increasing numbers of iterations decreases as the number of iterations increases.

4. Adaptive Modulation

Adaptive modulation is a promising technique to increase the data rate that can be reliably transmitted over fading channels. The basic premise of adaptive modulation is a real-time balancing of the link budget in flat fading through adaptive variation of the transmitted power level, symbol transmission rate, constellation size, BER, coding rate/scheme, or any combination of these parameters. Thus, without wasting power or sacrificing BER, these schemes provide a higher average link spectral efficiency (bps/Hz) by taking advantage of flat fading through adaptation. Good performance of adaptive modulation requires accurate channel estimation at the receiver and a reliable feedback path between the receiver and transmitter. Adaptive modulation provides many parameters that can be adjusted relative to the channel fading, including data rate, transmit power, instantaneous BER, symbol rate, and channel code rate or scheme.

5. Simulation Setup

The OFDM system used has 32 sub-carriers. The channel estimation is done by using decision feedback equalizer with a forward filter coefficient 3 and feedback filter coefficient 2. The recursive least square algorithm is used for channel estimation. The turbo encoder used in our simulation is of rate ½. The map algorithm is used for decoding with 12 iterations. The results are simulated in slow Rayleigh fading environment.

5.1 Simulation Result of OFDM

Firstly, the simulation of an OFDM system is presented. Figure 4 shows the simulation results and the performance of different modulation scheme in an AWGN channel. On the x-axis is the signal to noise ratio (SNR) and on the y-axis is the bit error rate (BER). The results show that the lower order modulation schemes has low bit error rate as compared to higher order modulation at a given SNR. The red, green and blue curves are for the QPSK, 8-PSK and 16-PSK modulation schemes and have the SNR threshold value of 10 dB, 15 dB and 25dB respectively. The OFDM system studied has 32 sub-carriers.

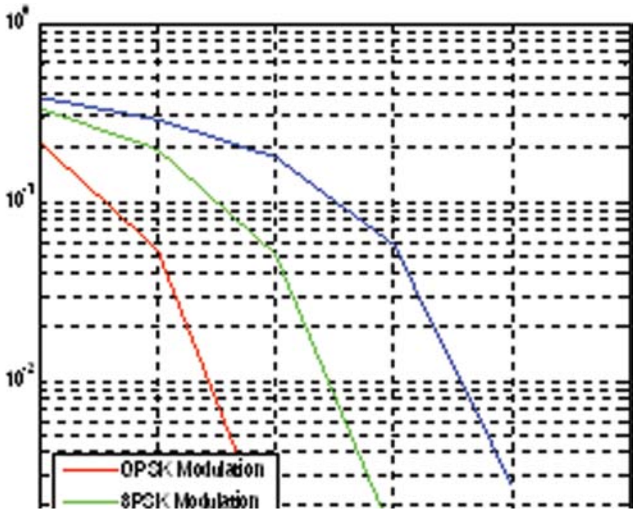

Figure 4. BER curves of different modulation schemes for OFDM system in AWGN channel

5.2 Simulation Result of Turbo codes

Figure 5, 6 and 7 below show the BER curves of turbo codes for one, four and eight iterations respectively. It is observed that as we increase the number of iterations for the same channel, the bit error rate decreases by increasing the signal to noise ratio. The simulation results show the significant increase in BER of the system by increasing the number of iterations.

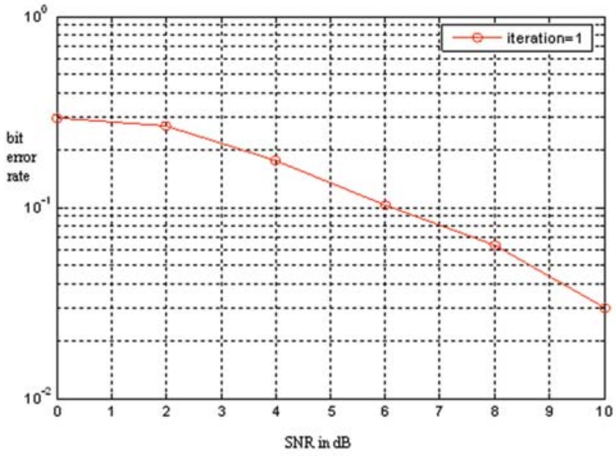

Figure 5. BER curve of turbo codes for 1 iteration

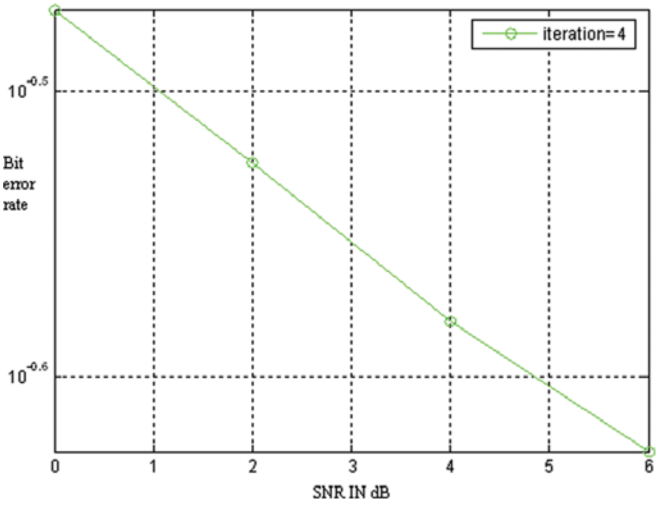

Figure 6. BER curve of turbo codes for 4 iteration

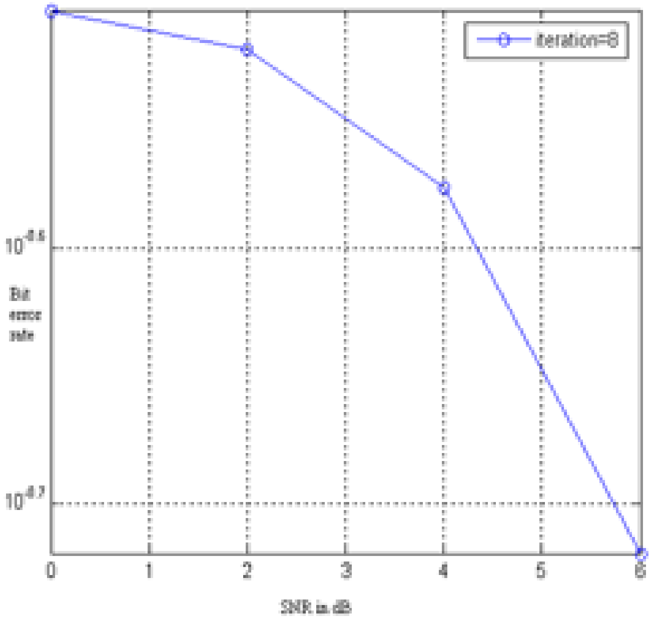

Figure 7. BER curve of turbo codes for 8 iteration

5.3 Simulation of Adaptive Turbo Coded OFDM

Figure 8 below shows the block diagram of adaptive turbo coded OFDM system. First the input stream is fed to the turbo encoder. The encoder output is than pass through the modulator which modulates the data. The modulated data is converted from serial to parallel and mapped on the subcarriers using an inverse Fast Fourier transform (FFT). Each OFDM block is prefixed by a cyclic copy of the last few samples in the same block, the convolution of the channel impulse response with the transmitted signal becomes a circular convolution. At the receiver the inverse operation is performed. After demodulating the data the bit error rate (BER) is calculated. If the BER increases the threshold value (10e-2) than a feedback is sent from the transmitter to the receiver and the transmitter shift to a lower modulation scheme.

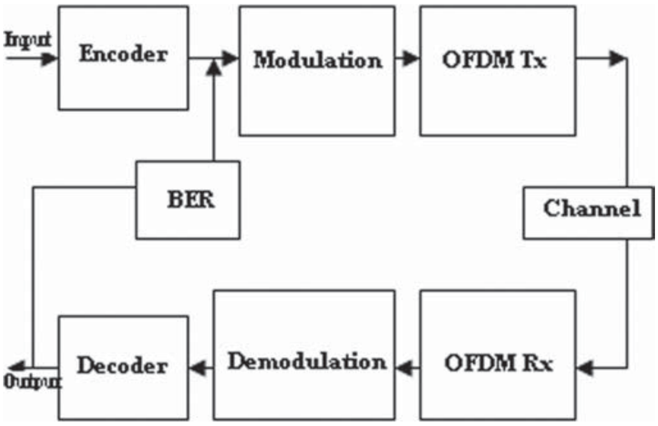

Figure 8. Block diagram of adaptive turbo coded OFDM system

The simulation result shown in Figure 9 shows the performance of adaptive turbo coded OFDM system in a slow Rayleigh fading channel. The enhancement in the system throughput of a working OFDM system is done by adding turbo coding and adaptive modulation (AD). The temporal variations in the simulated wireless channel are due to the presence of Doppler, a sign of relative motion between transmitter and receiver. The system has 32 data subcarriers; each OFDM block is individually modulated according to channel state information acquired during the previous burst. The end goal is to increase the system throughput while maintaining system performance under a bit error rate (BER) of 10-2.

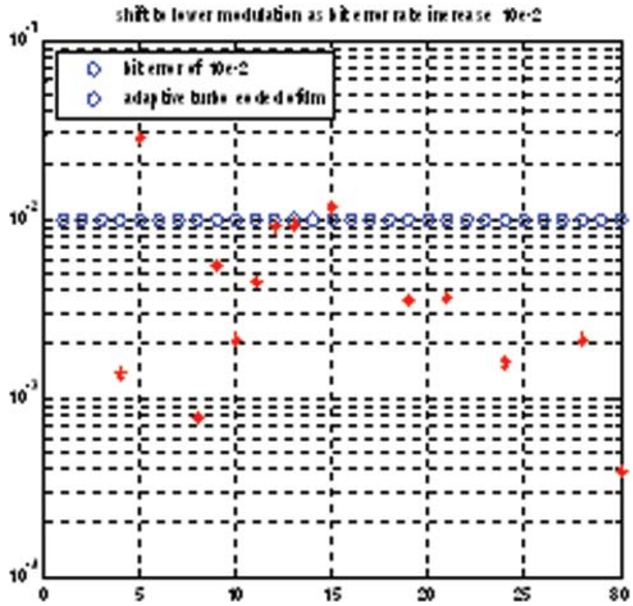

Figure 9. Adaptive OFDM in slow Rayleigh fading channel

6. Conclusion

For the most part, OFDM is the standard being used throughout the world to achieve high data rates necessary for data intensive applications. This thesis enhances the throughput of an existing OFDM system by implementing adaptive modulation and turbo coding. The new system guarantees to reach a target performance BER of 10-2 over a slow time-varying fading channel. The system automatically switches from higher to lower modulation schemes on individual OFDM symbol, when the bit error rate increases above 10e-2. The OFDM system simulated has 32 data subcarriers; each is individually modulated according to channel state information acquired during the previous burst. In conjunction with the adaptive design, forward error correction is performed by using turbo codes. The combination of parallel concatenation and recursive decoding allows these codes to achieve near Shannon's limit.

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