Optimize Adaptive Coding Technique to Improve Performance of OFDM System
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Abstract: In this paper, we have considered only adaptive modulation. First we have investigated the OFDM system performance of uncoded adaptive modulation using quadrature amplitude modulation (QAM) and phase shift keying (PSK). To further enhance the system, we employ convolutional coding to OFDM system. The obtained results show that a significant improvements in terms of bit error rate (BER) and throughput can be achieved demonstrating the Superiority of the adaptive modulation schemes compared to fixed transmission schemes [1]. Adaptive modulation and diversity combining represent very important adaptive solutions for the future generations of communication systems. In order to improve the performance and the efficiency of wireless communication systems these two techniques have been recently used jointly in new schemes named joint adaptive modulation and diversity combining. The highest spectral efficiency with the lowest possible combining complexity, given the fading channel conditions and the required error rate performance. Increase the spectral efficiency with a slight increase in the average number of combined path for the low signal to noise ratio (SNR) range while maintaining compliance with the bit error rate (BER) [6].

Keywords: Adaptive modulation, orthogonal frequency division multiplexing (OFDM), channel coding, bit error rate (BER), throughput.

1. INTRODUCTION

The name ‘OFDM’ is derived from the fact that the digital data is sent using many carriers, each of a different frequency (Frequency Division Multiplexing) and these carriers are orthogonal to each other, hence Orthogonal Frequency Division Multiplexing[6]. Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multi-carrier transmission technique in which a single high rate data stream is divided into multiple low rate data streams. These data streams are then modulated using subcarriers which are orthogonal to each other. In this way the symbol rate on each sub channel is greatly reduced, and hence the effect of inter symbol interference (ISI) due to channel dispersion in time caused by multipath delay spread is reduced [1]. The origins of OFDM development started in the late 1950’s with the introduction of Frequency Division Multiplexing (FDM) for data communications. In 1966 Chang patented the structure of OFDM and published the concept of using orthogonal overlapping multi-tone signals for data communications. In 1971 Weinstein introduced the idea of using a Discrete Fourier Transform (DFT) for implementation of the generation and reception of OFDM signals, eliminating the requirement for banks of analog subcarrier oscillators [6].

In an OFDM transmission system, each subcarrier is attenuated individually under the frequency-selective and fast fading channel. The channel performance may be highly fluctuating across the subcarriers and varies from symbol to symbol. If the same fixed transmission scheme is used for all OFDM subcarriers, the error probability is dominated by the OFDM subcarriers with highest attenuation resulting in a poor performance. Therefore, in case of frequency selective fading the error probability decreases very slowly with increasing average signal-to-noise ratio (SNR) [1].

This problem can be mitigated if different modulation schemes are employed for the individual OFDM subcarriers. Unlike adaptive serial systems, which employ the same set of parameters for all data symbols in a transmission frame, adaptive OFDM schemes have to be adapted to the SNR of the individual subcarriers. This will substantially improve the performance and data throughput of an OFDM system. For example if the subcarriers that will exhibit high bit error probabilities in the OFDM symbol to be transmitted can be identified and excluded from data transmission, the overall BER can be improved in exchange for a slight loss of system throughput. However the potential loss of throughput due to exclusion of faded subcarriers can be mitigated by employing higher order modulation modes on the subcarriers exhibiting high SNR values. Many adaptive transmission techniques have been presented in the literature. The combination of adaptive modulation with OFDM was proposed as early as 1989 by Kalet which was further developed by Chow and Czylikw. Specifically the results obtained by Czylikw showed that the required SNR for the BER target 10-3
can be reduced by 5dB to 15dB compared to fixed OFDM depending on the scenario of radio propagation [1].

2. EVALUATION OF OFDM

The evolution of OFDM [2] can be divided into three parts. These consist of Frequency Division Multiplexing (FDM), Multicarrier Communication (MC) and Orthogonal Frequency Division Multiplexing [2].

2.1 Frequency Division Multiplexing (FDM)

Frequency Division Multiplexing (FDM) has been used for a long time to carry more than one signal over a telephone line. FDM is the concept of using different frequency channels to carry the information of different users. Each channel is identified by the central frequency of transmission. To ensure that the signal of one channel does not overlap with the signal from an adjacent one, some gap or guard band is left between different channels. This guard band leads to inefficiencies which were exaggerated in the early days since the lack of digital filtering made it difficult to filter closely packed adjacent channels [2].

2.2 Multicarrier Communications (MC)

Multicarrier (MC) is actually the concept of splitting a signal into a number of signals, modulating each of these new signals over its own frequency channels; multiplexing these different frequency channels together in an FDM manner; feeding the received signal via a receiving antenna into a de-multiplexer that feeds the different frequency channels to different receivers and combining the data output of the receivers to form the received signal [2].

2.3 Orthogonal Frequency Division Multiplexing

OFDM is derived from the concept of MC where the different carriers are orthogonal to each other. Orthogonal in this respect means that the signals are totally independent. It is achieved by ensuring that the carriers are placed exactly at the nulls in the modulation spectra of each other [2].

3. SYSTEM MODEL

In this paper, sub band adaptive transmission schemes are employed to reduce the complexity. In sub band adaptive OFDM transmission, all subcarriers in an AOFDM symbol are split into blocks of adjacent subcarriers referred to as sub bands. The same mode is employed for all subcarriers of the same sub band. The choice of the modes to be used by the transmitter for its next OFDM symbol is determined by the channel quality estimate of the receiver based on the current OFDM symbol. Perfect channel estimation is assumed in this paper. In this simulation the instantaneous SNR of the subcarrier is measured at the receiver. The channels quality varies across the different subcarriers for frequency selective channels. The received signal at any subcarrier can be expressed as [1].

\[ R_n = H_n X_n + W_n \]  

(1)

Where \( H_n \) the channel coefficient at any subcarrier is, \( X_n \) is the transmitted symbol and \( W_n \) is the Gaussian noise sample. So the instantaneous SNR can be calculated using

\[ \text{SNR}_n = \frac{H_n^2}{N_0} \]  

(2)

The conservative approach in threshold based adaptation is by using the lowest quality subcarrier in each sub band for controlling the adaptation algorithm. It means that the lowest value of SNR will be used in mode selection. By using this method, the overall BER in one sub band is normally lower than the BER target. If the overall BER can be closer to the BER target by choosing a more suitable modulation mode or code rate, the throughput of the system will be higher [1].
Therefore a better adaptation algorithm is used in this paper to provide a better tradeoff between throughput and overall BER by choosing a more suitable scheme for each sub band. Instead of using the lowest SNR in each sub band, the average value of the SNR of the subcarriers in the sub band is going to be used [1].

![Figure 1. Adaptation Procedure](image)

4. **OFDM SYSTEM DETAILS**

The block diagram of this system is shown in Figure 2. The channel estimation and mode selection are done at the receiver side and the information is sent to the transmitter using a feedback channel. In this model the adaptation is done frame by frame. The channel estimator is used to estimate the instantaneous SNR of the received signal. Based on the instantaneous SNR calculated, the best mode will be chosen for the next transmission frame. This task is done by the mode selector block. At the transmitter the adaptive modulator block consists of different modulators which are used to provide different modulation modes. The switching between these modulators will depend on the instantaneous SNR. This block diagram is used to describe two types of adaptive modulation schemes which is based on MQAM and MPSK scheme. The goal of adaptive modulation is to choose the appropriate modulation mode for transmission in each sub band, given the local SNR, in order to achieve good trade-off between spectral efficiency and overall BER [1].

![Figure 2. Block diagram of OFDM system](image)

5. **OFDM SYSTEM ADVANTAGES**

The main advantages of OFDM are its multipath delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain. Another significant advantage is that the modulation and
demodulation can be done using inverse Fast Fourier Transformation (IFFT) and Fast Fourier Transformation (FFT) operations, which are computationally efficient [1].

Orthogonal Frequency Division Multiplexing (OFDM) has several advantages over single carrier modulation systems and these make it a viable alternative for CDMA in future wireless networks. In this section, these advantages are discussed [2].

5.1 Multipath Delay Spread Tolerance
OFDM is highly immune to multipath delay spread that causes inter-symbol interference in wireless channels. Since the symbol duration is made larger (by converting a high data rate signal into low rate signals), the effect of delay spread is reduced by the same factor. Also by introducing the concepts of guard time and cyclic extension, the effects of inter-symbol interference (ISI) and inter carrier interference (ICI) are removed completely [2].

5.2 Immunity to Frequency Selective Fading Channels
If the channel undergoes frequency selective fading, then complex equalization techniques are required at the receiver for single carrier modulation techniques. But in the case of OFDM the available bandwidth is split among many orthogonal narrowly spaced sub-carriers. Thus the available channel bandwidth is converted into many narrow flat fading sub-channels. Hence it can be assumed that the sub-carriers experience flat fading only, though the channel gain/phase associated with the sub-carriers may vary. In the receiver, each sub-carrier just needs to be weighted according to the channel gain/phase encountered by it. Even if some sub-carriers are completely lost due to fading, proper coding and interleaving at the transmitter can recover the user data [2].

5.3 High Spectral Efficiency
OFDM achieves high spectral efficiency by allowing the sub-carriers to overlap in frequency domain. At the same time, to facilitate inter-carrier interference free demodulation of the sub-carriers, the sub-carriers are made orthogonal to each other [2].

5.4 Efficient Modulation and Demodulation
Modulation and Demodulation of the sub-carriers are done using computationally efficient IFFT and FFT methods respectively. By performing the modulation and demodulation in the digital domain, the need for highly frequency stable oscillators is avoided [2].

5.5 Robust to Impulse Noise
The duration of OFDM symbols is much longer than that of single carrier system for a channel with strong impulse noise; the transmitted symbols can still be largely recovered since only a small fraction of each symbol is interfered by noise. Thus OFDM is more robust to impulse noise than single carrier systems [2].

6. APPLICATIONS OF OFDM SYSTEM

The primary applications of Orthogonal Frequency Division Multiplexing (OFDM) are discussed below [2].

6.1 Wireless LAN Applications
Data rates in wireless applications are mainly limited because of multipath fading channel. HiperLAN2 (European standard) and IEEE 802.11a pushes the performance of WLAN systems, allowing a data rate of 6Mbps to 54 Mbps. User location is achieved using TDM, and subcarriers are allocated using a range of modulation schemes, from BPSK up to 64 QAM, depending on the link quality[2].

6.2 Digital Subscriber Loop (xDSL)
In DSL can be transmitted data up to 52 Mbps using Discreet Multi tone (OFDM) on the same copper wire pair, which is used to transmit no more than 64 kbps using conventional PCM. In ADSL, DMT uses 249 channels in the frequency range of 26 kHz to 1.1 MHz in downstream and 25 channels between 26 kHz to 133.8 kHz in upstream [2].

6.3 Digital Audio Broadcasting (DAB)

DAB is a European standard for digital broadcasting that is intended to replace the current analog technologies such as A.M. and F.M. with a good sound quality and better spectrum efficiency even in multipath fading channel. DAB uses DQPSK modulation for subcarriers and has got four transmission nodes [2].

6.4 Digital Video Broadcasting (DVB-T)

DVB is also an ETSI standard for broadcasting digital television over satellites, cables and thorough terrestrial transmission. DVB-T receiver installed in a moving vehicle provides clear pictures and good music quality (as compared to analogue TV technology) and since the technology is digital, multiplex transmission of maps and other navigation information is possible as a supplementary data service [2].

7. ADAPTIVE MODULATION TECHNIQUE

Adaptive modulation is a powerful technique for maximizing the data throughput of subcarriers allocated to a user. Adaptive modulation involves measuring the SNR of each subcarrier in the transmission, then selecting a modulation scheme that will maximize the spectral efficiency, while maintaining an acceptable BER. This technique has been used in Asymmetric Digital Subscriber Line (ADSL), to maximize the system throughput. ADSL uses OFDM transmission over copper telephone cables. The channel frequency response of copper cables is relatively constant and so reallocation of the modulation scheme does not need to be performed very often, as a result the benefit greatly out ways the overhead required for measuring of the channel response. Using adaptive modulation in a wireless environment is much more difficult as the channel response and SNR can change very rapidly, requiring frequent updates to track these changes [4].

Adaptive modulation has not been used extensively in wireless applications due to the difficulty in tracking the radio channel effectively. Work has been done studying the use of adaptive modulation in single carrier systems [90] - [93], however not many works have been published on use of adaptive modulation in OFDM systems. Beam Reach is a new communications company that formed in March 2000. They are utilizing adaptive modulation in conjunction with OFDM and beam forming. Unfortunately little information has been released due to the propriety nature of the research. In [94] the effectiveness of a multiuser OFDM system using an adaptive subcarrier, bit and power allocation was investigated. Optimization of the transmission was achieved by minimizing the power requirement for a given transmission channel and user data rate. It was found that the use of adaptive modulation, and adaptive user allocation reduced the required transmitter power by 5 - 10 dB. The work in didn’t however investigate the effects of channel tracking errors on the BER performance [4].

8. SIMULATION AND RESULT

8.1 Adaptive Modulation-based OFDM System in AWGN Channel

In an OFDM system using lower order modulators such as BPSK, 4-QAM and 8-QAM will improve BER but decreases spectral efficiency, on the other hand employing higher order modulators such as 64 QAM, 128 QAM, 256QAM and 512 QAM will increase spectral efficiency but result in poor BER. So to achieve good trade-off between spectral efficiency and overall BER adaptive modulation is used.

Figure (3) shows the simulated BER performance of M-ary PSK, 16-QAM, 64-QAM and adaptive modulation scheme for an OFDM system over AWGN channel. The goal of the adaptive modulation
algorithm we used in our simulation is to reach and maintain a target BER irrespective of the SNR levels that each individual subcarrier experiences.

![Adaptive PSK & QAM over channel with convolutional coding](image)

**Figure 3. Adaptive PSK & QAM over channel with convolutional coding**

When the SNR of a specific subcarrier exceeds one of the switching thresholds, that carrier’s modulation scheme is updated. No signal transmission is performed at SNRs lower than 5 dB as that would put us above the target BER we want to achieve. The last two peaks shown in Figure (3) correspond to the algorithm switching to 16QAM and then 64QAM.

As clearly shown in Figure (3), the BER performance of adaptive modulation has a ripple phenomenon. This is because the BER of adaptive modulation scheme will rise up when the constellation is switched to one with larger constellation size as SNR increases and falls in the next SNR region. The BER will decrease when the SNR keeps increasing within the region boundaries. As the value of SNR increases, the BER decreases and the system will switch to the next higher modulation scheme and again the BER increases but it decreases for the chosen modulation scheme interval. But the adaptive modulation scheme keeps the value of the BER below the target BER.

9. **CONCLUSION**

The detail knowledge of a current key issue in the field of communications named Orthogonal Frequency Division Multiplexing (OFDM). We elaborated on the performance theory of the codes. First we developed an OFDM system model then try to improve the performance by applying forward error correcting codes to our uncoded system. From the study of the system, it can be concluded that we are able to improve the performance of uncoded OFDM by convolution coding scheme [6].

In this paper, the performances of adaptive transmission scheme for OFDM have been investigated. The advantage of employing adaptive transmission scheme is described by comparing their performance with fixed transmission system. A better adaptation algorithm is used to improve the throughput performance. This algorithm utilizes the average value of the instantaneous SNR of the subcarriers in the sub band as the switching parameter. The results show an improved throughput performance with considerable BER performance [1].
REFERENCES


