A Review of Adaptive QAM Modulation Technique for OFDM

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Abstract—With the advancement of communications technology comes with the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links. New modulation schemes are required which must be able to adapt to different requirements of individual services in terms of their data rate, allowable Bit Error Rate (BER), and maximum delay. To improve the BER performance, modulation scheme which is used these days is Adaptive Modulation. In this paper, we present review adaptive modulation scheme with channel conditions being varied.

Key words: OFDM, SNR, Adaptive Quadrature Amplitude Modulation, Bit Error Rate

I. INTRODUCTION

One new modulation scheme which has received significant attention over the last few years is a form of multicarrier modulation called as Orthogonal Frequency Division Multiplexing (OFDM). OFDM has also been standardized as the physical layer for the wireless networking standard “HIPERLAN2” in Europe and as the IEEE 802.11a, g standard in the US, promising raw data rates of between 6 and 54Mbps. Despite the many advantages of OFDM it still suffers from some limitations such as sensitivity to carrier frequency offset, large Peak to Average Power Ratio (PAPR) and fixed modulation scheme leading to poor BER performance. To improve the BER performance, modulation scheme which is used these days is Adaptive Modulation. In this modulation scheme used by the transmitter is changed in response to the changing channel conditions. In essence, it is a way to optimize the transmission scheme according to the state of the channel for a required fidelity. For example, when the channel is in a poor state (i.e., low SNR), the signal constellation size is reduced. Conversely, when the channel is in a good state (high SNR), the signal constellation size is increased in order to increase the data rate achievable. The problem now becomes: How to decide what ranges of SNR will be used for which modulation scheme? The answer lies in the AWGN performance of each modulation scheme. Adaptive modulation for wireless communications has received significant interest in the past five years. It has long been recognized that adaptive modulation provides more efficient use of the channel than fixed modulation schemes. Specifically, change in bit error rate performance will be improved while using adaptive modulation scheme with channel conditions being varied. In this paper, the main aim is to survey the theory of OFDM system using adaptive modulation techniques.

II. PREVIOUS WORK

R W Chang presented the principle of orthogonal frequency division multiplexing. In which the transmission medium used is linear band limited in nature and a number of data message send together. The data transmit is at maximum data rate without any type of interference like interchannel and intersymbol interference in “Synthesis of Band Limited Orthogonal Signals For Multichannel Data Transmission. The system proposed by Chang was analog in nature, and implementation was very complex[1].

John A. C Bingham published paper on “Multicarrier Modulation for data transmission: An Idea Whose time has come” in an IEEE communication magazine. This paper discusses the core of OFDM system Multicarrier modulation and multiplexing in detail. Echo cancellation and adaptive loading were also discussed. In the end the author has explained GSTN system for duplex application of MCM[2].

S. B. Weinstein He proposed a communication system using Fourier transform that is based on frequency division multiplexing (FDM) in that system discrete Fourier transform are computed as a part of modulation and demodulation process. Hence in OFDM the design of complex bank of modulators and demodulators can be replaced by digital fast Fourier transform (FFT) processing chips. The use of FFT blocks improved the speed of the system and reduces the complexity. The null carriers were used as guard band for reducing interference but the cyclic prefix was introduced by Peled and Ruiz as discussed in next review[3].

Peled and Ruiz: Introduced Cyclic prefix (CP) for OFDM systems. In this model cyclic extension of OFDM symbol is used instead of null guard interval and this new scheme can reduce ISI (Inter Symbol Interference) to a great extent in flat fading channels. Hence present IEEE standards are adopting this scheme. The AWGN channel was used for data transmission which is less sensitive to frequency. The work was done for flat channels i.e. frequency insensitive, in next paper Rayleigh multipath channel was used with pilot insertion for multipath propagation[4].

Leonard J. Cimini: Proposed pilot-based correction, for combating the effects of multipath propagation and co-channel interference on narrow band digital mobile channel. With this proposed scheme, flat Rayleigh fading can be reduced significantly. Using this scheme signal to noise ratio increment obtained is approximately 6 dB in a bursty Rayleigh environment. In order to avoid co channel interference a frequency offset scheme is proposed[5].

Yuping Zhao and Sven-Gustav Häggman: Proposed a scheme named as self cancellation scheme. This scheme is very simple and given the working on bases of transmitter and receiver side. At the transmitter side, adjacent subcarriers have a weighting coefficient and data symbol is modulated according to adjacent subcarrier. The role of weighting coefficient is to minimize the channel frequency error due to ICI. In the second part i.e receiver side for ICI level indicator used a parameter named as average carrier to interference power ratio. At this side subcarrier have their proposed coefficient which are used the received signal in linear manner. The main aim is to give the theoretical value of CIR[6].

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T.P. Surekha, T. Ananthapadmanabha, C. Puttamadappa: Implemented a simulink based simulation. It show the performance between bit error rate and signal to noise ratio for this the channel used is additive white Gaussian noise in “Modeling and Performance Analysis of QAM-OFDM System with AWGN Channel” in IEEE conference in 2011 and compared the BER performance with theoretical BER Tool curves by varying Eb/No and constellation diagrams. The simulation setup used does not include pilot insertion and cyclic prefix block which can improve the system[7].

Yuan-Pei Lin and See-May Phoong work on OFDM system which is preceded to analyzed the performance and it is different from others because it is used zero forcing and error received in this system is minimum mean square in “BER Minimized OFDM Systems With Channel Independent Precoders” published in IEEE transactions in Signal Processing. Optical Precoders are used which are not depend on channel are discussed with examples of this class including the discrete Fourier transform (DFT) matrix[8].

Andreas Czyliwik compared two modulation schemes one is multicarrier and other is single carrier modulation schemes for radio communication systems as in “Comparison Between Adaptive OFDM and Single Carrier Modulation with Frequency Domain Equalization”. In case of OFDM at transmitter side individual subcarriers are transform by using inverse FFT in time domain and at the receiver side inverse operation is done. Because of slow variance of transfer function of channel it is assumed that the instantaneous transfer function of the radio channel can be estimated at the receiver and can be communicated back to the transmitter via signaling channels for adaptive modulation[9].

Andrea J. Goldsmith and Soon-Ghee Chua superimposed trellis and lattice codes designed for additive white Gaussian noise (AWGN) channels on adaptive modulation for fading channel as in “Adaptive Coded Modulation for Fading Channels”. The above said methodology is applied to obtain trellis-coded adaptive MQAM by using adaptive M-ary quadrature amplitude modulation (MQAM) and show that Adaptive Scheme save 20dB power. The channel considered in this paper was slow fading in nature [10].

Ahmed Sohail and M.N. Jafri carried out a study for mobile communication systems in which he consider the channel to be used is frequency selective and fast fading. As in “Adaptive OFDM over Frequency Selective and Fast Fading Channel using Blockwise Bit Loading Algorithm”. When change in loading algorithm is noticed it is found that computational complexity is reduced without affecting the performance as compared to so called loading algorithm and the information collected from the receiver [11].

J.Faezah1, and K.Sabira discussed the enhancement in the OFDM system, by employing convolution coding to OFDM system and Applying adaptive modulation as in “Adaptive Modulation for OFDM Systems”. First, they investigated the OFDM system performance of uncoded adaptive modulation using quadrature amplitude modulation (QAM) and phase shift keying (PSK) and then compare its BER performance with adaptive modulation and convolution encoding implemented OFDM system showing improvement in BER. All the hardware circuits were used for decision making and changing modulation scheme which makes the system slow and inefficient[12].

K. SeshadrSastry and Dr.M.S.PrasadBabu proposed an OFDM system to improve the system capacity for this, it consider adaptive modulation and using the concept of fuzzy logic interference and it also provide better error performance as in “Adaptive Modulation for OFDM system using Fuzzy logic interface”. They comes to a conclusion that if adaptive modulation is used it is difficult to take decision according to given conditions because it is based on hardware decision making circuit. Besides this if fuzzy logic is used it show better performance [13].

Nita J.Borkar and Dattatray.S. Bormane introduced the adaptive modulation to know the basic difference between two modulation schemes one is fixed and other is adaptive modulations schemes in “BER Performance of OFDM System with Adaptive Modulation” presented in IEEE conference in 2012. First whole subcarriers are divided into blocks of adjacent subcarriers and then adaptive modulation is implemented that depends on calculated average instantaneous signal to noise (SNR) by applying same modulation scheme to all subcarriers of same block. For all values of IFFT sizes, average BER of Adaptive modulation is approximately 0.203568 and for higher order fixed modulation it is approximately 0.913545 concluding that BER performance of adaptive modulation is better than fixed modulation with the cost of more execution time [14].

III. METHODOLOGY

An OFDM signal consists of a number of independently modulated sub-carriers, each having a different frequency. When N signals are added with the same phase, they produce an OFDM signal. When this signal is passed through AWGN channel, its different frequency parts experience different noise variance resulting into poor performance of the OFDM system. Each QAM technique used in OFDM also experience different noise variance as the number of data bits encoded in technique change. So for every SNR value of AWGN channel experienced by OFDM symbol, there is a QAM technique which results into minimum BER for those environmental conditions. Here the methodology is designed the same way, first BER performance of each QAM technique is analyzed with changes in SNR values.

A. QAM Modulation Scheme

Many different fixed modulation methods have been designed for various channels and applications. M-QAM is the main modulation scheme that is used in an OFDM system. Quadrature Amplitude Modulation (QAM) is a communication scheme used in both an analog and a digital. It carries either two message signals or two digital bit streams. If change in the amplitudes of two carrier waves is done then use either one modulation scheme Amplitude Shift Keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves used in QAM is generally sinusoids. They are out of phase with each other by 90° and are so this is called quadrature carriers or quadrature components. After the modulation waves are summed and the waveform obtained
is a combination of both phase shift keying (PSK) and amplitude shift keying (ASK). QAM is different from other modulation scheme because it has higher order form of modulation. QAM can carry more bits of information per symbol. If the data rate is to be increased then higher order format of QAM are used. For faster data rates higher order modulation can be used in case of QAM modulation and for the radio communications system spectral efficiency is of higher levels. The higher order modulation schemes have some advantages like it is less immune to noise and inter

B. OFDM

OFDM is type of multi-carrier modulation scheme in which spacing between sub carriers is selected so that they are orthogonal to the other sub carriers. Carrier spacing is reciprocally related to the symbol period. The purpose of carrier spacing is to minimize the interference between the carriers.

Mathematically, orthogonality of two signals can be written as:

\[ \int_{0}^{\pi} X_a(t)X^*_b(t) = k \]

Where \( X_a \) and \( X_b \) are \( a_{ib} \) and \( b_{ib} \) elements in the symbol set, \( T \) is the symbol period and \(*\) indicates the complex conjugate.

Step edges become Ramp edges and Line Edges become Roof edges, where intensity changes are not instantaneous but occur over a finite distance. Edge detection contains three steps namely filtering, enhancement and detection.

C. Adaptive QAM Modulation

The methodology of adaptive can be implemented in various ways. Instead of changing the modulation scheme of transmitter, other parameters can also be changed depending on the channel conditions. These parameters with their brief descriptions are listed in Table 1.1.

<table>
<thead>
<tr>
<th>Adaptive parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td>Modulation index</td>
<td>Changing the modulation scheme affecting the data rate of the system</td>
</tr>
<tr>
<td>Coding scheme</td>
<td>Changing the encoding scheme of the message bits resulting into the number of encoded bits to be transmitted per symbol and per second</td>
</tr>
<tr>
<td>Input power</td>
<td>Changing the signal power resulting into a signal having multiple power levels</td>
</tr>
<tr>
<td>Cyclic prefix</td>
<td>Changing the length of the cyclic prefix reducing ICI depending upon the SNR if the channel</td>
</tr>
<tr>
<td>Data Rate</td>
<td>Changing the input data rate depending upon channel environment</td>
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</tbody>
</table>

Table 1.1: List of Adaptive parameters

IV. CONCLUSIONS AND FUTURE SCOPE

This paper presents a review about the optimum design of an adaptive modulation scheme implemented on an OFDM system based on M-QAM modulation is investigated. This work deals with the implementation of OFDM with various QAM techniques implemented on it. However the performance of the system is greatly affected by the SNR of the AWGN channel. The traditional QAM techniques used in OFDM were studied. The employed Adaptive methodology offered significance improvement in average BER of the system. It can provide better BER values than that of traditional QAM techniques by changing modulation index of QAM modulator depending on the SNR of the channel. A lot of research is going on in the field of cognitive radio technology which is an example of intelligent and efficient system. The proposed adaptive scheme can be implemented in a cognitive radio and further design improvement can be done using channel estimation techniques. Instead of the QAM modulation number, the encoding scheme can also be made adaptive in accordance with SNR of the channel. Higher values of data rates with lower BER values can also be achieved changing the cyclic prefix length in accordance with the data rate and SNR simultaneously leading to Adaptive Cyclic Prefix which reduces the ISI of the OFDM system.

REFERENCES
