

# Comparison of BER Performance of Various Adaptive Modulation Schemes in OFDM Systems

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## Abstract

**Objectives:** The aim of future generation in mobile communication system is impeccably to integrate different types of real time services such as e-mail, speedy communication, video streaming and multimedia applications. **Methods/Analysis:** The proposed method for future generation is Adaptive Modulation of Orthogonally Frequency Division Multiplexing (AM-Orthogonal FDM) technique. Orthogonal FDM modulation scheme provide maximum data rate, robustness against multipath fading and bandwidth saving up to fifty percentage compared to existing one. The performance of the system is improved according to the channel fading conditions, adaptive modulation is employed in AM-OFDM. **Findings:** We consider in this research work various adaptive digital modulation techniques and compare the received Bit Error Rate (BER) vs. Signal to Noise Ratio (SNR) of the system in various adaptive modulation techniques with the proposed one. The existing adaptive systems show the BER is  $10^{-3.9}$  for 18 dB SNR, however the proposed technique show the BER is  $10^{-5.7}$  for the same SNR value. The BER improvement of proposed one is 98 percentage compared with existing method. **Novelty/Improvement:** The novelty of proposed method is good modulation method of M-ary Phase Shift Keying is adapted, depending on the current channel conditions measured by channel estimator and this information is fed back to the input.

**Keywords:** AWGN, Adaptive Modulation, Bit Error Rate, Channel Fading, OFDM, Signal to Noise Ratio

## 1. Introduction

OFDM technique is a great digital modulation scheme being used in most of the new and advanced broadband communication systems. In OFDM system, a huge number of orthogonal closely-spaced subcarriers are used to transmit the data. The whole data stream is divided into multiple parallel small sub streams or channels and allocated a sub channel for each sub stream. After these sub carriers are modulated with appropriate modulation method such as Quadrature Amplitude Modulation and M-ary PSK method at low rate, continue the throughput similar to single carrier mapping technique. Though the sub carriers overlap in OFDM system, they do not interfere because of its orthogonal property and the peak of one sub carrier occurs when other sub carriers are at zero level. The OFDM system can successfully avoid the frequency-selective fading without using any complicated

equalization structure. The modulation and demodulation process provide fast and easy processing by including the Fast Fourier Transform and Inverse FFT.

In an Orthogonal FDM system, each one of the carrier is affected separately under fast fading channel conditions. The performance of the channel may be always changing of all sub carriers, also vary from one symbol to other symbol. If the fixed modulation method is applied for all carriers, the probability of error is increased with high signal attenuation during fast fading. So the overall system performance is very poor. Therefore, during frequency selective fading and fast fading, the error rate can be reduced gradually by increasing the average SNR value<sup>1</sup>.

### 1.1 Modulation Selection Algorithm

A signal takes multiple path to reach the destination in wireless communication however an obstruction between

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source and destination. Multipath fading occurs due to no line of sight between sender and receiver and intrusion between users, the Signal to Noise Ratio differ with time over the wireless channel. So adaptive and diversity methods are essential to improve the system performance and channel capacity. Adaptation method adjust the modulation in the transmitter section and choose the coding rates according to the users to increase the system throughput and improve the Bit Error Rate based on the current channel conditions<sup>2</sup>.

Figure 1 shows the modulation selection flow diagram of proposed method. It represents the need of continuous channel estimation in wireless communication and to make a decision about which one is suitable for communication from different digital modulation schemes. Also modulation selection depends on the coverage area or transmission range of base station. If the transmission range is high, then lower rate modulation scheme will be selected by using adaptive algorithm. Otherwise high rate modulation scheme is selected for low transmission range or near the base station. The Signal to Noise Ratio is very low during poor link stability or bad channel condition due to other internal or external disturbances. So the selection of low rate modulation is to boost the reliability of the system. The SNR is high for good channel conditions; at that time, we choose the high modulation rate to increase the target data rate. The goal of adaptive modulation based system is to enhance the system throughput and reduce the bit error rate and the sensitivity to surrounding disturbances.

The principle of adaptive algorithm is dynamically varying the modulation technique in an error free man-

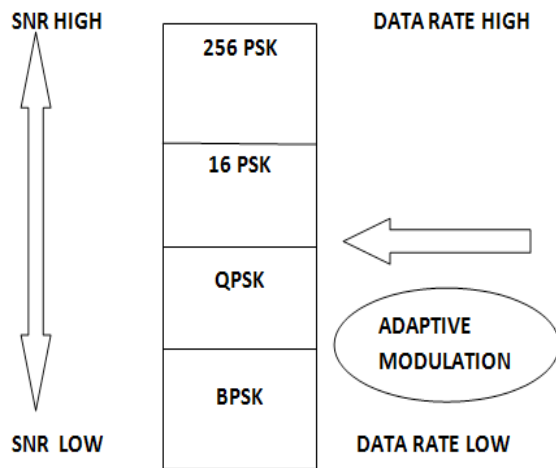


Figure 1. Modulation selection flow diagram.

ner during transmission to increase output data rate in multipath fading conditions.

The main aim of fourth generation communication system is to eliminate the ISI (Inter Symbol Interference) and increase the output data rates, with available limited spectrum bandwidth in a successful manner. To accomplish these parameters, need to use excellent modulation schemes: Orthogonal FDM and Multi Carrier - Code Division Multiple Access (MC-CDMA). The capacity of OFDM technique is to reduce the interference due to multiple path signals, in a bandwidth efficient manner without the help of local oscillators. Future mobile communication systems. The advanced communication techniques present in the future mobile systems, depends on combination of two or a hybrid technique uses multiple carrier OFDM and spread spectrum method called Code Division Multiple Access (CDMA) usually called as Multi carrier-CDMA. This method increases the average throughput when such a signal is applied to a wide-range transmission range. In addition to get better spectrum utilization of communication systems, various digital modulation schemes are proposed in paper<sup>3</sup>.

Chow<sup>3</sup> developed an adaptive modulation scheme called practical multiple tone transceiver algorithm for data communication over bandwidth shaped wireless channels. The necessary SNR for minimum BER target of  $10^{-3}$  can be decreased by 15dB to 5dB compare to fixed modulation based OFDM system based on the state of radio propagation<sup>4</sup>. The throughput performance of Turbo coding dynamic modulation is analyzed<sup>5</sup>.

## 1.2 Adaptive Modulation Scheme

In wireless communication, data transmission through a channel is continuously changing with time due to fast movement of the mobile users. During communication, the message signals takes different paths for reception. While doing this different speed of phase rotations caused by the Doppler spread results in quick variation in wireless channels.

These time varying transmission channels create different values of SNR at different time due to multiple path fading. While using fixed modulation, the system is to be designed as to handle poor channel condition to suggest suitable Bit Error Rate. Moreover, in fixed modulation based system is not bandwidth efficient because same modulation scheme is used for good and bad channel conditions. However, the adaptive modulation use differ-

ent types of modulation techniques based on the current channel situation to achieve reliable communication over-multipath fading channel. The adaptive system changes the modulation technique or coding or combination of these constraints according to the measurement of channel state information<sup>6</sup>.

### 1.3 Adaptive Modulation without Transmission Blocking

In reference<sup>7</sup> two types of adaptive techniques will be used to get better throughput performance of the communication system. In this method, the data are constantly transmitted through the channel for all time. If link stability is very poor then a high rate modulation mode is used, on the other hand when it is in good condition, a bandwidth efficient modulation technique will be used in the adaptive system. The result of Adaptive OFDM using Non-blocking method is shown in Figure 2.

### 1.4 Adaptive Modulation with Transmission Blocking

When the transmission channel is in deep fade at that time the data transmission will be stopped or blocked. This blocking mode is introduced because the link stability is very low to guarantee a required transmission. The information will be transmitted when the quality of the channel is better or improved. In this work, the performance of the system is analyzed in terms of throughput and BER parameters as mentioned in Figure 3. M-ary QAM, M-ary PSK modulation schemes are used in this simulation.

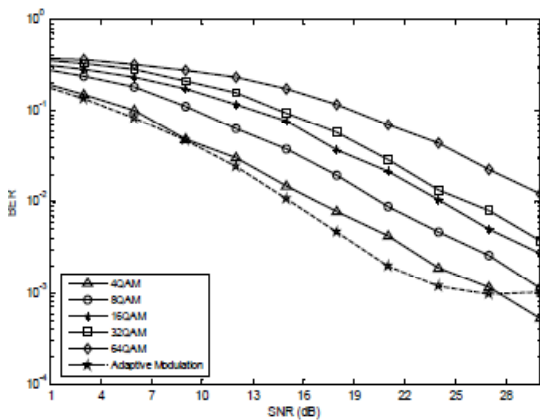


Figure 2. Adaptive OFDM using Non-blocking method.

To minimize the error probability of LTE system and to improve the spectrum efficiency, a process known as adaptive modulation and code rate in OFDM systems according to the channel condition, some pilot bits are generated and allowed to transmit in the modelled AWGN channel. The receiver measures the channel SNR, and decides suitable modulation and code rate. The simulation was done in MATLAB software and the result is shown in Figure 4. QPSK, 16- Quadrature AM, and 64- Quadrature AM modulation schemes are implemented, and the BER and spectral efficiency of these modulation schemes are compared for different code rates<sup>8</sup>.

Jejoria<sup>9</sup> has suggested an adaptive modulation based algorithm in order to combat the channel undergoes deep fading and effective in mitigating the effects of ICI (Inter Carrier Interference). This method uses

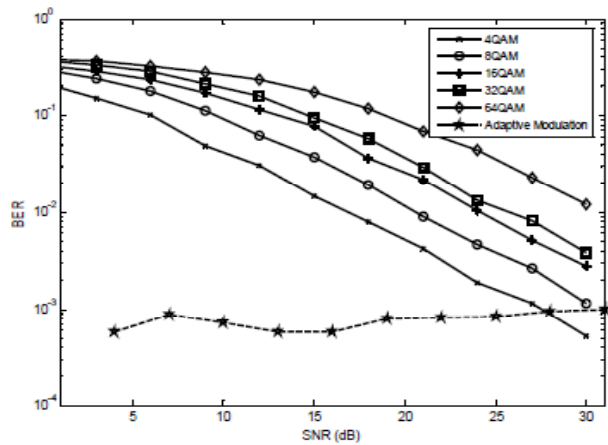


Figure 3. Adaptive OFDM using transmission blocking method.

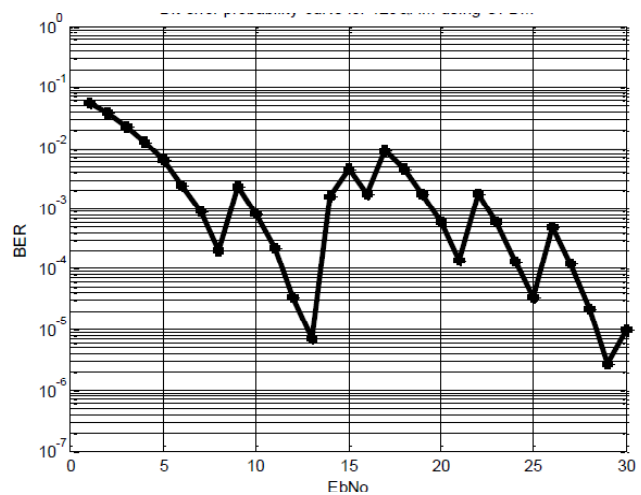


Figure 4. BER performance of adaptive OFDM using FIS.

ICI self-cancellation scheme for both modulation and demodulation. The output performance of the OFDM system in occurrence of frequency offset between the transmission and the reception has been studied or considered in terms of Carrier-to-Noise ratio and bit error rate. CNR is greatly increased by using ICI method and this enhancement will improve the power efficiency of the system. Hence, it reaches better results for BER. Adaptive algorithm assign input bits dynamically, so this method is effectively combat the channel with deep fading.

Peng HuinTan introduced a link adaptive algorithm during transmission for IEEE 802.11n multiple input multiple output OFDM system. This algorithm is compared with previous SNR based algorithm, and they achieved good system throughput<sup>10</sup>. In OFDM system, using low rate modulation scheme such as BPSK, 4-QAM and 8-QAM will improve better BER, but it reduces the bandwidth efficiency and speed of the system. Otherwise the higher rate modulation method such as 64-QAM, 128-QAM, 256-QAM and 512-QAM will improve the spectral efficiency and speed but results in poor bit error rate performance. To accomplish a good trade-off between spectrum efficiency and BER, adaptive modulation with Fuzzy Logic Interface (FIS) algorithm is proposed<sup>11</sup>. A role of FIS is decision making in channel estimation block used in adaptive modulation system. This is modelled in Matlab 7.4 in Fuzzy Interface editor. It takes current SNR value and present order of modulation technique as inputs and control the modulation and demodulation blocks. The BER and SNR performance of adaptive modulation with FIS is shown in Figure 4.

To design a new scheme using adaptive modulation technique to increase the required data rate in an OFDM system, a method is suggested using fuzzy logic Rule Based System (FRBS). The proposed system uses QAM modulation and the SNR algorithm is applied in fuzzy logic system. The input bits are passed through in different steps of modulation process. Then the channel applies the output to fuzzy logic block. The fuzzy block compares the present output which is coming from OFDM channel and the past one which is stored in fuzzy memory box. This method uses two functions, namely, "SNR" and "MOD" and this includes seven membership functions<sup>12</sup>.

Adaptive selection algorithm acting an important task in wireless communication because the channel conditions varies continuously. Therefore, the conventional fixed modulation method cannot be competent for all the channel conditions. A recent algorithm to estimate

the BER information at the receiver on Error Estimation Coding (EEC) to appreciate a simple modulation method. It prove that less complexity by using this algorithm and need fewer resources to get the similar error performance<sup>13</sup>.

Code Rate Control: When the rate of coding rate is applied to adaptive modulation schemes, however the necessary SNR value for a specific BER can be reduced, one can have additional chance to employ high user rates compare to non-coding controlled systems below the same received signal strength; thus, coding rate control improve the average system throughput<sup>14</sup>.

### 1.5 SNR Estimation

Mean and Variance of received data:

$$M = \frac{1}{N} \sum_{i=1}^N r_i \tag{A}$$

M=mean

r = received i<sup>th</sup> signal

N = number of symbols

$$\sigma^2 = \frac{1}{N-1} [\sum_{i=1}^N (r_i - M)^2] \tag{B}$$

$\sigma^2 = \text{variance}$

$$\text{SNR} = \left( \frac{N-3}{N-1} \right) \frac{|M|^2}{\sigma^2} - \frac{1}{N} \tag{C}$$

### 1.6 Adaptive Modulation Level

In Adaptive modulation system, we will select the appropriate modulation technique depending on the current channel conditions. This method uses the estimated SNR of the transmission link to select the suitable switching levels. A. Duel Hallen<sup>15</sup> has proposed that the receiver will provide a good channel estimation to select the switching level for modulation.

### 1.7 M-ary Modulation Techniques

In digital communication, the base band signal may be sent by changing the phase and envelope of a reference wave as it offers two degrees of freedom. The modulation scheme maps the input data in to two or many number of available reference signals. Such type of modulation is called M-ary modulation<sup>16</sup>. During pass band transmission these information signals are created by varying any one of parameter i.e. amplitude, phase, frequency of a carrier wave<sup>17</sup>.

## 2. Proposed Adaptive Modulated OFDM

The schematic illustration of the Adaptive modulation based OFDM technique is shown in Figure 5. The input data is encoded and go after by Serial-to-Parallel(S/P) converter to give low rate sub streams. Each user symbol is then modulated in parallel by suitable modulation techniques, such as Quadrature PSK, and M-PSK etc.

The Inverse FFT block converts frequency domain samples into time domain samples and still it maintains the orthogonality between subcarriers. The effect of ISI on symbol can be reduced by the adding guard period at the starting and ending of every frame. Guard band interval should be higher than the delay spread of the channel. After the guard interval has been included, the signals are changed into serial form. An AWGN model is then added with the transmitted signal. This model tolerates for the Signal to Noise Ratio variations. The receiver executes the reverse process of the transmitter.

The receiver section removes the guard band interval, FFT process and decoding of data. The adaptive OFDM

model consists of adaptive switch. The input information is formatted into word depends on the modulation method need for transmission. At the receiver section, the SNR value is calculated by using above formula and this value is directly applied to the mode selector block through the channel estimator. Based on this SNR value the mode selector switch chooses the correct modulation technique, which satisfy the threshold limit.

## 3. Result and Discussion

Figure 6 shows BER performance of the adaptive modulated signal using OFDM method which provides  $10^{-3}$  Bit Error Rate in support of 10 dB SNR range and  $10^{-5.7}$  BER for 18 dB SNR. From the result graph, we know that the proposed system gives the better Bit Error Rate for the 18 dB SNR.

Table 1 shows BER vs. SNR performance of adaptive modulation for OFDM scheme, which provides  $10^{-5.7}$  Bit Error Rate in support of 18 dB SNR value.

Table 2 illustrate the performance comparison of various adaptive modulation techniques. It shows the bit error

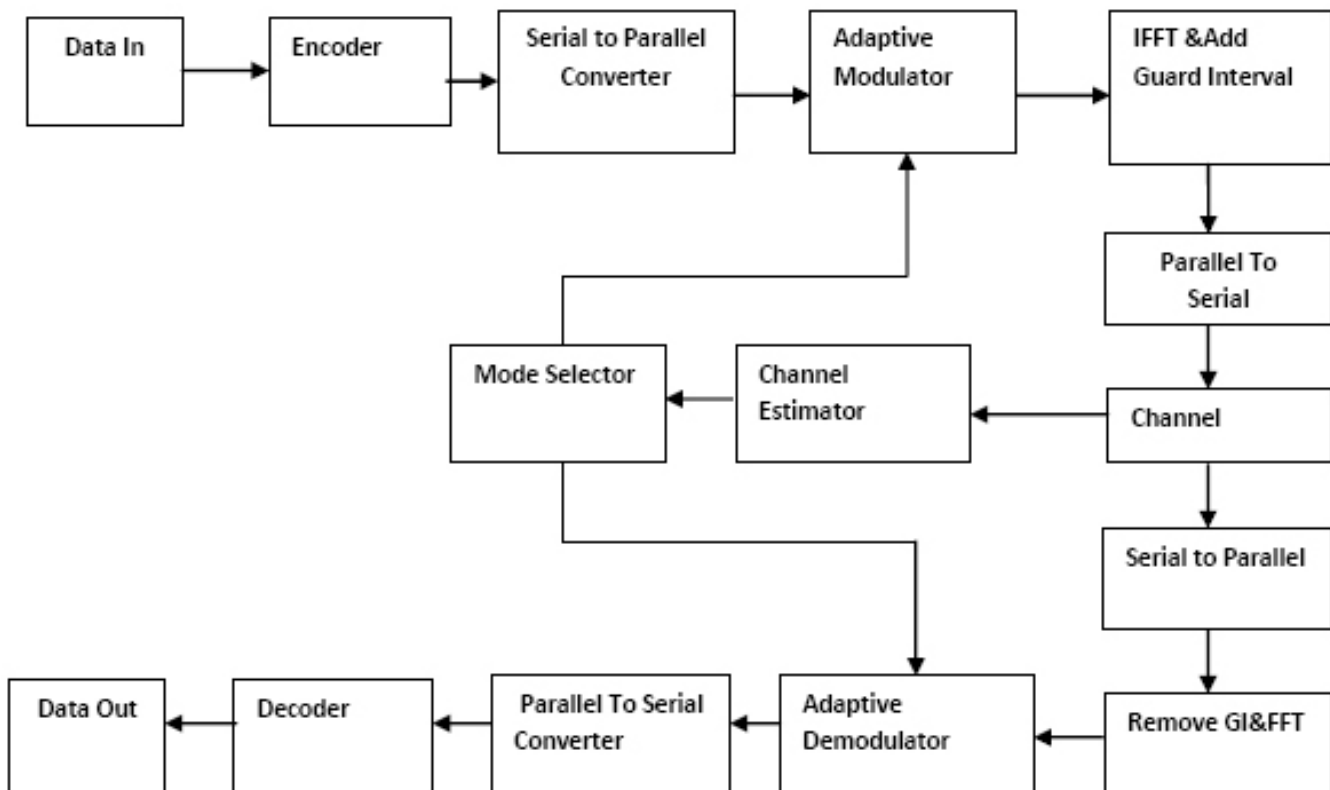


Figure 5. Schematic diagram of adaptive OFDM.

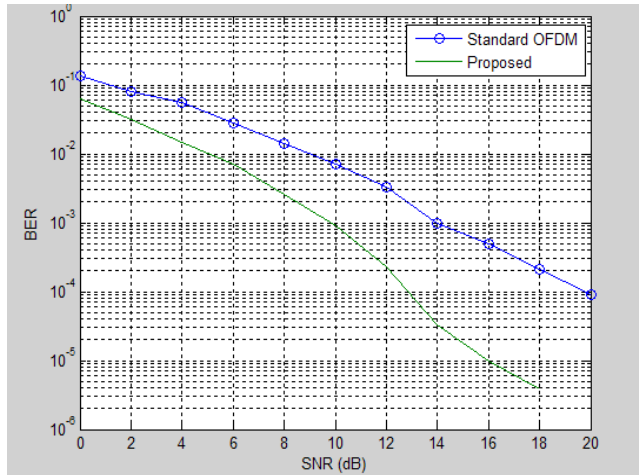


Figure 6. Adaptive modulation of OFDM system.

rate in support of different adaptive modulation methods using AWGN channel. From this table we conclude that the proposed adaptive method gives 10<sup>-5.7</sup> bit error rate for 18 dB SNR and it provides the performance improvement of 98 percentage compared to the existing one. Thus the proposed method reach the better BER performance compared with other method.

### 4. Conclusion

Thus we have proved that the proposed work of Adaptive Modulation of OFDM system gives better results by choos-

Table 1. Bit error rate for Adaptive modulation system

SL NO	CHANNEL	SNR (DB)	BER				
			CONVENTIONAL	ADAPTIVE	% BER IMPROVEMENT		
1	Additive White Gaussian Noise	0	10 <sup>0.9</sup>	0.12589	10 <sup>-1.4</sup>	0.03981	68.37
2		2	10 <sup>-1.3</sup>	0.05011	10 <sup>-1.8</sup>	0.01584	68.38
3		4	10 <sup>-1.4</sup>	0.03981	10 <sup>-1.9</sup>	0.01258	68.39
4		6	10 <sup>-1.6</sup>	0.02511	10 <sup>-2.3</sup>	0.00501	80.04
5		8	10 <sup>-1.9</sup>	0.01258	10 <sup>-2.8</sup>	0.00158	87.44
6		10	10 <sup>-2.3</sup>	0.00501	10 <sup>-3.2</sup>	0.00063	87.44
7		12	10 <sup>-2.8</sup>	0.00158	10 <sup>-3.9</sup>	0.00012	90.40
8		14	10 <sup>-3.2</sup>	0.00063	10 <sup>-4.8</sup>	0.000015	97.00
9		16	10 <sup>-3.5</sup>	0.00031	10 <sup>-5</sup>	0.00001	97.77
10		18	10 <sup>-3.9</sup>	0.00012	10 <sup>-5.7</sup>	0.0000019	98.41
11		20	10 <sup>-4</sup>	0.0001	-	-	-

Table 2. Comparison of different adaptive modulation techniques

SL. NO	VARIOUS ADAPTIVE MODULATION TECHNIQUES	BER	SNR	CHANNEL
	AM-QAM -Non Blocking method	10 <sup>-2.8</sup>	20dB	Additive White Gaussian Noise Channel
	AM-PSK -Non Blocking method	10 <sup>-2.6</sup>		
	Adaptive Modulation and Code rate	10 <sup>-1.8</sup>		
	Adaptive Modulated OFDM	10 <sup>-3.1</sup>		
	BER of Adaptive Modulated OFDM system	10 <sup>-0.3</sup>		
	Adaptive OFDM using FIS(Fuzzy Interface System)	10 <sup>-3.4</sup>		
	EEC-AMC Algorithm (Error Estimation Checking- Adaptive Modulation Coding selection )	10 <sup>-3.5</sup>		
	Proposed Adaptive Modulation method	10 <sup>-5.7</sup> (18 dB)		

ing appropriate modulation compared to other adaptive techniques as exposed in Table 2. The future scope is adaptive antenna with this proposed technique can be used to get better output performance.

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