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Performance of OFDM Systems: With Adaptive Modulation*

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Abstract: The traditional single carrier transmission schemes fail to give high data rate transmission with bandwidth efficiency and less power consumption. Hence multicarrier schemes like orthogonal frequency division multiplexing are available which are bandwidth efficient and also consumes less power as compared to single carrier system. But performance of OFDM with fixed modulation degrades under different channel scenario and it cannot achieve high data rate as well as reliable connectivity. So, in this paper OFDM system with adaptive modulation for different channel conditions is proposed. And its performance is analyzed using SNR VS BER Plots. Also comparative study of OFDM system with fixed modulation and adaptive modulation scheme is given.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Signal to noise ratio (SNR), Bit error rate (BER),

I. Introduction

Feature mobile communication must satisfies the growing demands of High data rate, reliable communication, low power consumption as well as spectral efficiency. As in traditional single carrier system the whole bandwidth is occupied by single carrier hence, it is necessary to increase the bandwidth or power of transmission to achieve the high data rate[1]. But there are some constraints on increasing the bandwidth or power. It should be below specific limit.

So, to fulfill the current requirements of wireless communication system the OFDM is the best option. OFDM is multicarrier transmission scheme in which the whole bandwidth is divided in to sub bands using multiple carriers. Each carrier occupies single sub band. And data is transmitted on each subcarrier. Hence bandwidth efficiency is achieved. Also, due to the use of FFT and IFFT the power requirement is less. Hence, now a day's OFDM is very useful technique in wireless communication. It is used in LTE, WIMAX, 4G technologies.

In OFDM as data is transmitted on each subcarrier of OFDM symbol. These subcarriers must remains orthogonal to each other during transmission to retrieve the data at receiver without error. If the orthogonality is not achieved then there may be problem of ISI an ICI which results in high bit error rate. To avoid these there is provision of cyclic prefix and guard interval insertion along with OFDM symbol. Also in vehicular communication due to mobility of devices various amount of individual path loss and varying Doppler spread due to individual velocities the ISI effects much to transmitted signal.[10].

OFDM perform better than single carrier system. But with fixed modulation scheme its performance degrades in fast fading channel due to quick change in channel conditions. The OFDM system in frequency selective channels gives different SNR values [9]. The system cannot achieve the high data rate as well as reliable connectivity at a time. Hence, this paper proposes an adaptive modulation scheme bases on different channel conditions for OFDM. In this technique the OFDM symbols are splits in to adjacent subcarrier and same modulation schemes is used for all subcarriers of same OFDM symbol [2]. Then for next symbols the channel is analyzed and SNR of the channel is computed. Based on this SNR value modulation schemes used are changed [3]. The channel conditions are in terms of SNR Values. So it can select the different modulations schemes like 8 QAM, 16 QAM, 32 QAM and 64QAM depending on the range of SNR values at the receiver.

The reminder of this paper is Organized as follows In section 1 .the Basic OFDM system is given. Section 2.gives the adaptive modulation technique with OFDM. Section 3. Gives performance comparison of fixed modulation and adaptive modulation of OFDM. Section 4. Concludes this paper.

II. OFDM SYSTEM MODEL

OFDM is multicarrier modulation technique. OFDM divides entire bandwidth B into N subcarriers. The basic block of an OFDM system is shown in fig1. Let's consider the multicarrier transmission scheme, where N no of subcarriers are transmitted using one OFDM symbol. Then i^{th} subcarrier is given as

$$i^{th} \text{ subcarrier} = i \frac{B}{N}, \text{ where } \frac{B}{N} \text{ is centre frequency of } i^{th} \text{ subcarrier}$$

$$\text{i.e } F(i) = i \frac{B}{N} \text{ where } -\frac{N}{2} \leq i \leq \frac{N}{2}$$

Let X_i be the data transmitted on i^{th} subcarrier then modulated signal on this subcarrier is given as

$$S_i(t) = X_i e^{j2\pi f_i t}$$

Where, $f_i = i \frac{B}{N}$ is the centre frequency of i^{th} subcarrier.

$$S_i(t) = X_i e^{j2\pi i \frac{B}{N} t} \quad (1)$$

As there are N subcarriers we can write it as

$$S(t) = \sum_i^N s_i(t) \quad (2)$$

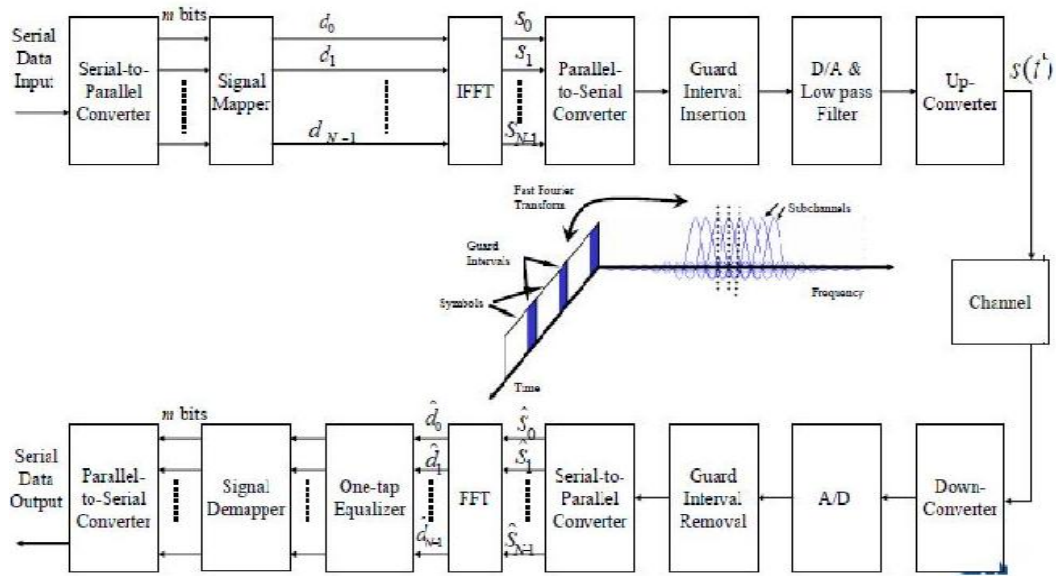
Where, $s(t)$ is composite transmit signal and $S_i(t)$ is i^{th} data stream on i^{th} subcarrier
From eq (1)

$$S(t) = \sum_i S_i(t) \quad (3)$$

$$S(t) = \sum_i X_i e^{j2\pi f_i t} \quad (4)$$

$$S(t) = \sum_i X_i e^{j2\pi i \frac{B}{N} t} \quad (5)$$

Figure 1: BASIC OFDM SYSTEM



Now multicarrier data detection at receiver (in absence of noise is given as follow
Let's, consider received signal as

$$y(t) = s(t) = \sum_i X_i e^{j2\pi f_i t} \quad (6)$$

Now, coherently demodulate each stream with corresponding subcarrier. At receiver the estimate of complex modulation symbol $X(m)$ is obtained by multiplying the received signal with $e^{-j2\pi f_i t}$ and integrating over an OFDM symbol duration,

$$y(t) = s(t) = \sum_i X_i e^{j2\pi f_i t} \quad (7)$$

$$= \sum_i X_i e^{j2\pi i \frac{B}{N} t} \quad (8)$$

We have, period of integration for orthogonality as

$$T = \frac{1}{f_0} = \frac{N}{B} \quad \text{where} \quad f_0 = \frac{B}{N}$$

$$y(t) = \frac{B}{N} \int_0^N y(t) (e^{j2\pi f_i t})^* dt \quad (9)$$

$$\mathbf{y}(\mathbf{t}) = \frac{B}{N} \int_0^{\frac{N}{B}} \left(\sum_i X_i e^{j2\pi i \frac{B}{N} t} \right) e^{-j2\pi l t} dt \quad (10)$$

$$y(t) = \frac{B}{N} \int_0^{\frac{N}{B}} \left(\sum_i X_i e^{j2\pi(i-l) \frac{B}{N} t} \right) dt \quad (11)$$

let (i-l)=k then

$$y(t) = \frac{B}{N} \int_0^{\frac{N}{B}} \left(\sum_i X_i e^{j2\pi k \frac{B}{N} t} \right) dt \quad (12)$$

$$\frac{B}{N} \int_0^{\frac{N}{B}} \left(\sum_i X_i e^{j2\pi k \frac{B}{N} t} \right) dt = \begin{cases} 0 & \text{if } i \neq l \\ \frac{N}{B} & \text{if } i = l \end{cases} \quad (13)$$

Hence eq (13) shows that all subcarriers except l^{th} subcarrier are orthogonal to i^{th} subcarrier. Hence individual subcarrier can be reconstructed at the receiver just using FFT operation. From above mathematical results it concludes that all subcarriers in an OFDM symbol are super imposed on each other and transmitted to receiver. Due to orthogonality it is possible to reconstruct them back. Hence OFDM is band width efficient technique. Although this is bandwidth efficient technique there is problem of inter carrier interference (ICI) and inter symbol interference (ISI)[4]. Because of which orthogonality of subcarriers losses and which will give error bits at the receiver. To minimize the effect of ICI and ISI there is provision of cyclic prefix and guard interval.

III. PROPOSED ADAPTIVE MODULATION SCHEME FOR OFDM

In OFDM system signal mapper is used in which the modulation scheme is applied on the input bit stream. The modulation schemes may be 4QAM, 8AQM,16QAM or 32QAM. The modulation scheme used in system decides the data rate and the reliability of the system. The lower modulation schemes like ,4QAM gives the reliable connectivity in more noisy channels but the data rates are lower. On the other hand the higher modulation schemes like 32QAM, 64QAM gives high data rates in the better channel condition but reliability of system decreases as channel become noisy.

In recent only fixed modulation scheme is adopted for the OFDM. Hence, due to this fixed modulation scheme it achieves either data rate or reliable connection. Hence, there is trade of between the data rate and reliability of system due to fix modulation scheme.

Now in proposed adaptive modulation technique instead of fixed modulation the different schemes are applied according to the SNR values estimated from channel at receiver [5]. These estimated SNR values are feed back to the transmitter and accordingly the modulation schemes are selected. The ranges of SNR values and corresponding modulation schemes used are given in the table (1)

The technique for SNR estimation at receiver is as follows

$$\bar{\gamma} = \gamma_0 \sum_{l=1}^L E\{\|H(l)\|_F^2\} \quad (13)$$

Where, $\|H(l)\|_F^2 = \text{Tr}(HH^*) = \text{Tr}(H_w^* \Lambda_R H_w \Lambda_T)$ is the frobenius norm [7], L is the no of paths per receive antenna and average SNR (γ_0) per receive antenna under unity channel gain is given as

$$\gamma_0 = \frac{P_T}{B \sigma_n^2}$$

Where, P_T is the total power transmitted and B is the utilized bandwidth[8] , $\sigma_n^2 = N_0$ and $\frac{N_0}{2}$ is the power spectral density of real and imaginary component of noise.

Table 1: Switching threshold for adaptive modulation

Threshold SNR in dB	Modulation scheme
SNR≤0.9	4QAM
0.9<SNR≤1.8	8QAM
1.8<SNR≤2.7	16QAM
2.7<SNR≤3.6	32QAM
3.6<SNR≤4.5	64QAM

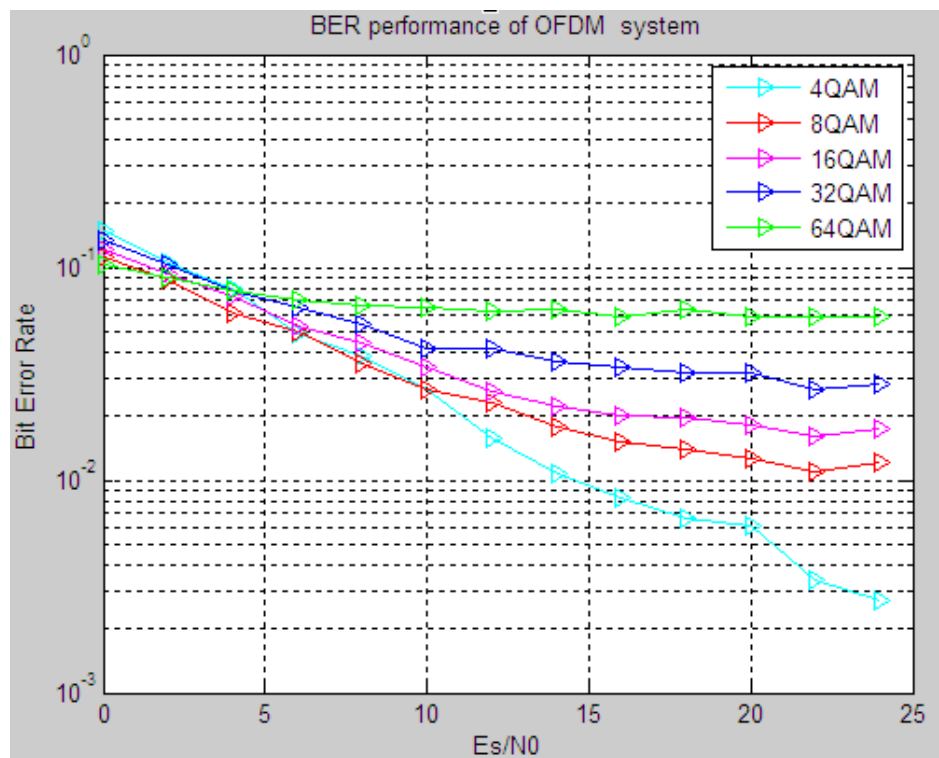
IV. Simulation result

In the simulation we are going to analyze the BER VS SNR plots. Table 2 gives the parameters used for simulation. The proposed OFDM system is simulated for frequency selective Raleigh fading channel. Two transmit and two receive antennas are used .Figure 2 shows the actual flow chart for simulation. Initial modulation scheme used is 64QAM.

From the table 3 gives the bit error rate values for corresponding SNR for different modulation schemes and also for adaptive modulation. Figure 2 gives the SNR VS BER plot of OFDM system under different modulation schemes. Figure 3 gives the SNR VS BER plot of OFDM system under proposed adaptive modulation.

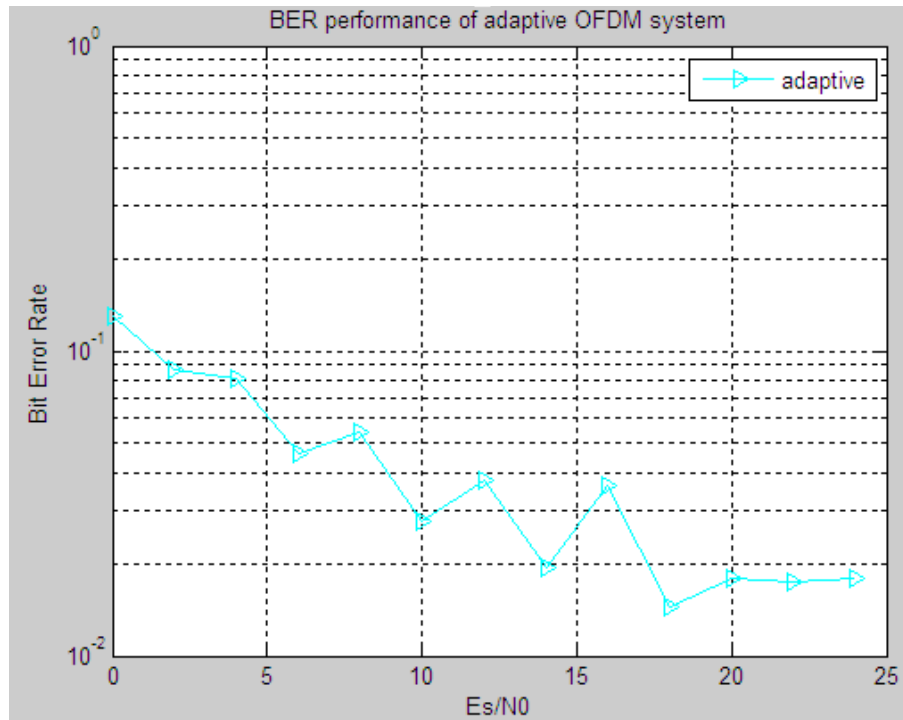
Table 2: Parameters for simulation

Parameters	Type
Modulation	M-QAM (M=4,8,16,32,64)
MIMO antenna configuration	2×2
Signal to noise ration	0:5:40 dB
Average transmit power	1db
Fading	Frequency selective Rayleigh fading
Carrier frequency	900 MHz
Bandwidth of signal(Bs)	200MHz
Symbol period	1/Bs
NO of paths	12
Threshold	0.9 dB

Figure 2 : SNR VS BER PLOT FOR N=128**Table 3: BER VS SNR VALUE FOR N=128**

FFT SIZE	N=128					
SNR	BER					
	4QAM	8QAM	16QAM	32QAM	64QAM	Adaptive
0	0.17	0.12	0.14	0.15	0.1	0.13
5	0.06	0.055	0.06	0.065	0.068	0.06
10	0.028	0.03	0.035	0.04	0.065	0.3
15	0.01	0.018	0.022	0.035	0.06	0.028
20	0.006	0.012	0.018	0.03	0.057	0.02
25	0.002	0.01	0.015	0.025	0.049	0.018
AVG BER	0.04	0.045	0.048	0.057	0.066	0.047

Figure 3 : SNR VS BER PLOT FOR N=128 for Adaptive Modulation



V. CONCLUSION

It is seen that as the SNR changes the BER is affected. In table 3 for 8QAM when the SNR is 5 then the BER value is 0.055, when SNR is 20 the BER is 0.012. Now for 64 QAM when SNR is 5 the corresponding BER is 0.68 and for SNR 20 the BER is 0.057. Similarly for adaptive modulation when SNR is 5 the BER is 0.06 and when SNR is 14 the BER is 0.02. which shows that for more noisy channel the SNR is low and lower modulation scheme works well giving low BER and For higher SNR values we can apply higher modulation scheme with considerable loss of BER performance. Table 3 shows that adaptive modulation gives average performance to maintain data rate as well as BER.

VI. REFERENCES

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