

Performance Analysis of OFDM Modem Based on Mapping Techniques & Use of Pilot Carriers

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Abstract- Orthogonal frequency division multiplexing (OFDM) is a combination of modulation & multiplexing. It is multi-carrier high transmission scheme which supports 4G and has tremendous scope in the field of wireless communication. This paper presents an analytical framework to calculate the data rate that can be achieved by using different mapping techniques viz. BPSK, QPSK, 16QAM, 64QAM in an OFDM system overcoming the challenges faced by this system. The concept of pilot carrier that has been used in OFDM is a way to combat the intrasymbol interferences. In this paper a study is performed that, which mapping technique should be used for a particular channel that exist as the communication medium. The trade off between error performance & high data rate must be chosen as per requirement.

Keywords - Pilot carriers, Mapping Techniques, FEC rate, Cyclic Prefix, LOS (Line of Sight) dominant multipath rician fading channel.

I. INTRODUCTION

Multiplexing generally refers to independent signals those produced by different sources so it is a question of how to share spectrum with these signals. In OFDM (Orthogonal frequency division multiplexing) the question of multiplexing applies to these independent signals which are a subset of a main signal. The signal is first split into independent channels modulated by data and then re-multiplexed to create the OFDM carrier [1]. The need to switch to OFDM from conventional system is that the high bit rates that are prohibited by obstacle-course of communication channels, multipath propagation effects that forbid increase in transmission rates and, higher data rate are required for DAB (Digital Audio Broadcasting), DVB(Digital Video Broadcasting), WLAN (Wireless LAN) applications which have not been achieved by conventional 2G, 2.5G & 3G technologies so far. Higher data rates will be achieved by trying different mapping techniques & analysing its performance depending upon the conditions of channel that are available in nature.

II. SYSTEM DESCRIPTION

A. OFDM Modem

OFDM modem has transmitter & receiver at both ends as shown in Fig. 1 & 2 for transmitting & receiving the signals [8].

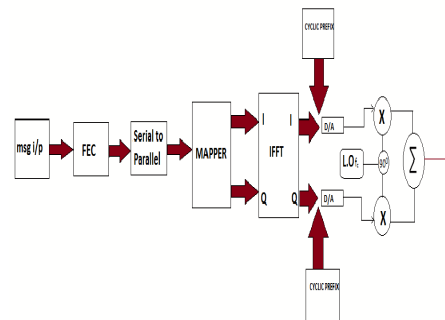


Figure 1. OFDM Transmitter

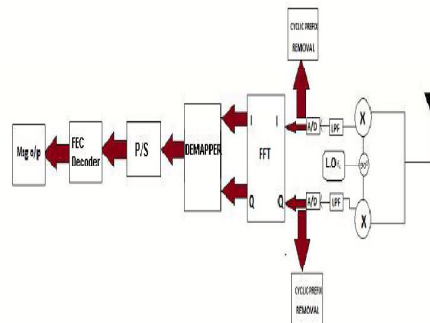


Figure 2. OFDM Receiver

1) *Pilot carriers:* A pilot signal is a signal, usually a single frequency, transmitted over a communication system for supervisory, control, equalization, continuity, synchronization and reference purposes. The number of pilot carriers depend upon modulation schemes and the type of channel used in the system [2].

B. Mapping Techniques Used:

The mapper includes the modulation technique that is used to modulate the signal. Different mapping techniques are used on the basis of which mapping technique provides the best in terms of data rate & also considering its error performance. These mapping techniques that are used in our OFDM Modem are:-

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a) *BPSK* : (Binary Phase Shift Keying) uses alternative sine wave phases as shown in Fig.3 to encode bits[5]. The bits are separated by a phase of 180° . It is very easy to use BPSK however leads to inefficient use of available bandwidth. It is very robust and is used extensively in satellite communication.

$$S_1(t) = A_c \cos(2\pi f_c t + \theta_c) \quad \text{binary 1} \quad (1)$$

$$S_2(t) = A_c \cos(2\pi f_c t + \theta_c + \pi) \quad \text{binary 0} \quad (2)$$

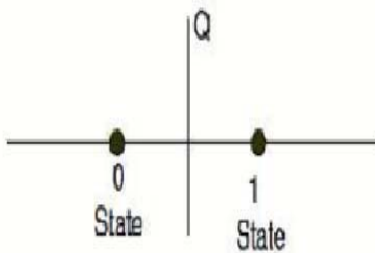


Figure 3. BPSK modulation technique

b) *QPSK* (*Quadrature Phase Shift Keying*)

Fig. 4 shows constellation diagram & phasor equation [5] of QPSK where the two bits show four combination of 0s & 1s. It is a multilevel modulation technique in which two bits are used at a time and hence twice more bandwidth efficient than BPSK.

$$S(t) = A \cos(2\pi f_c t + n\pi/4) \quad (3)$$

Where $n=1,3$ for 11, 01

$n=-1,-3$ for 10, 00

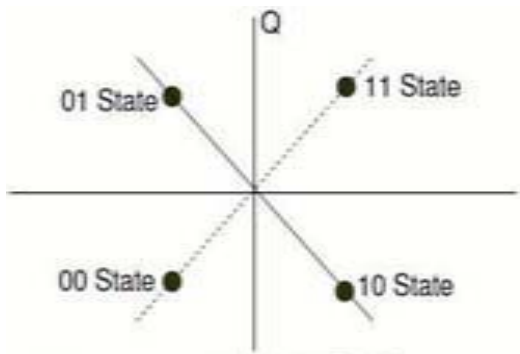


Figure 4. Constellation diagram & Phasor Equation

c) *QAM* (*Quadrature Amplitude Modulation*)

In Fig. 5 16 QAM, 4 data bits are used at a time and have three varying amplitudes represented by 16 different points in the I-Q phases. Constellation points show the combination of bits that can be encoded to transmit. Two types of QAM that we have used are 16 QAM & 64 QAM. The 64 QAM mapping provides the highest achieved data rate in a wireless LAN IEEE 802.11.a modem at 54 mbps. It maps 6

bits at a time into a 64-point constellation map as shown in Fig. 6

a) *16 QAM*

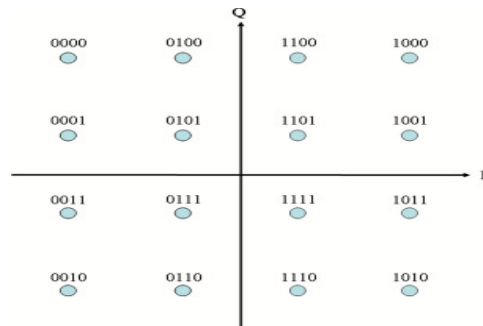


Figure 5. Constellation diagram of 16 QAM

b) *64 QAM*

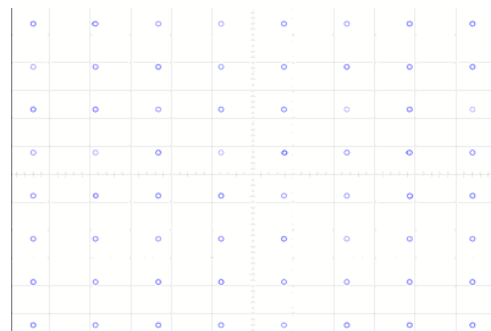


Figure 6. Constellation diagram of 64 QAM

III. MODEM DESIGN CONTENT & SPECIFICATIONS:

TABLE I. MODEM CONTENTS & THEIR SPECIFICATION

MAIN PART	SUB PART	SPECIFICATIO NS
Data source	Random integer	No. of bits/integer = 4
IQ mapper	General QAM	No. of constellation points=16
AWGN channel	--	SNR = 10 dB, Input Signal Power = 0.01 watts
IQ demapper	16 QAM demodulator	No. of bits/integer = 4
Data sink	Bit to integer converter	No. of bits/integer = 4
OFDM modulation	Matrix constellation ,IFFT & padder	No. of inputs = 4
OFDM demodulation	Cyclic prefix & zero prefix remover, FFT	No. of input dimensions = 1

A. Key Notes In Understanding

1) Simulation Diagrams:

Frequency Response: At transmitting end it shows the spectra which the transmitting signal have before exposure to channel as shown in Fig.8 .At the receiver end it shows the spectra which the receiving signal have after exposure to channel . If the spectra gets spread out or is moved from the bandwidth chosen then the moved out portion will not be received at the receiver.

2) Constellation Diagram:
At transmitter & receiver end it shows the no. of symbols that is being transmitted & received from transmitter & receiver. The rapid movement depicts highly error producing channel. Constellation points stability shows the reliability of channel being used.

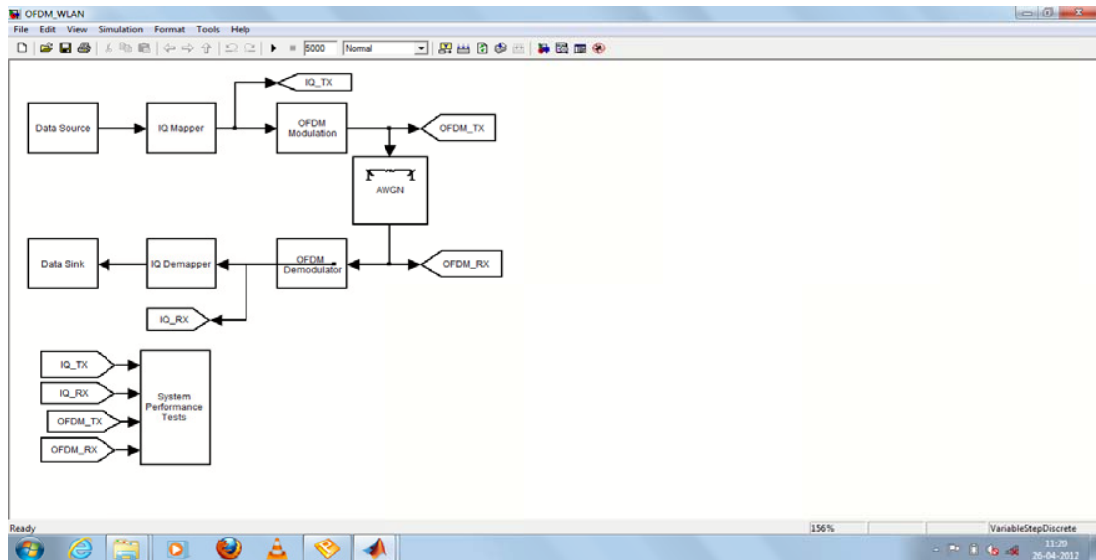


Figure 7. OFDM modem with AWGN channel

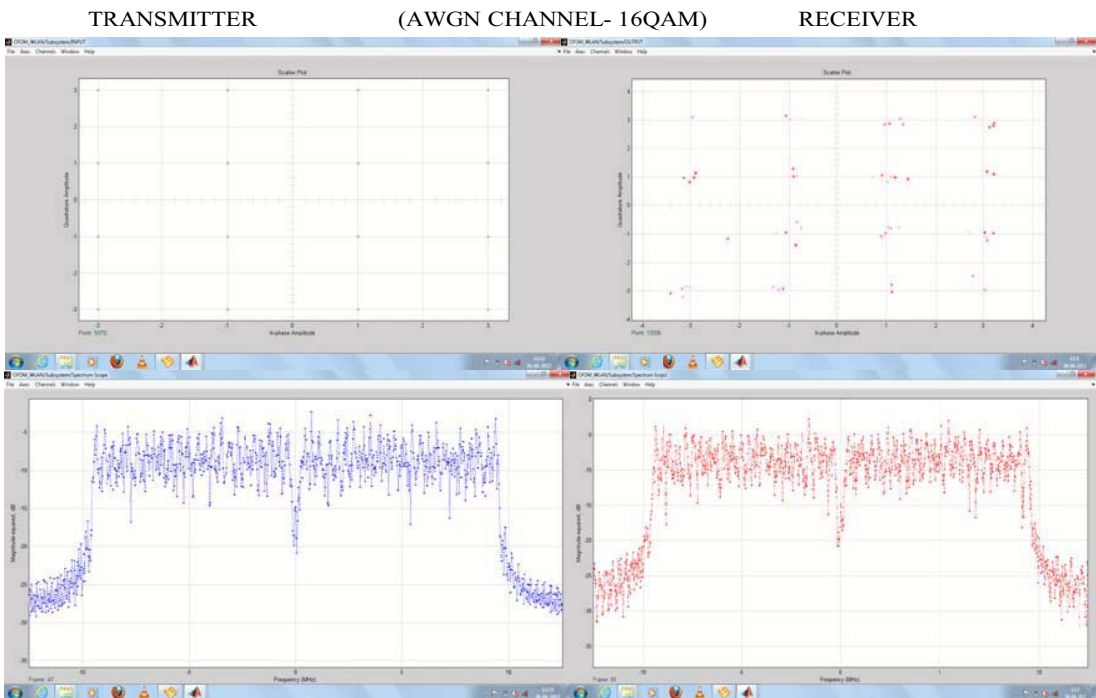


Figure 8. Simulation Response of OFDM Modem

IV. DESIGN PARAMETERS FOR WLAN MODEM:

A. Design Parametes Used

TABLE II. DESIGN PARAMETERS

Bandwidth used (MHz)	20
Total no. of subcarriers	64
Carrier separation (KHz)	20/64=312.5
OFDM symbol time duration (ms)	1/321.5=3.2
Cyclic prefix (ms)	0.25*3.2=0.8
Total symbol duration (ms)	3.2+0.8=4
No. of data carrier used	48

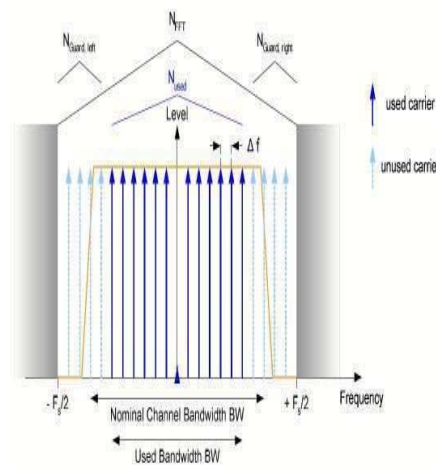


Figure 9. Concept of used & unused(Pilot)Carriers

B. Calculation Of Net Data Rate

a) Number of sub carriers used (N used):

Due to the shape of the outer carriers that may gets attenuated and thus be disturbed. Also the d.c. carriers cannot be used. Consequently the outer carriers do not carry any modulation data. Hence we use 48 subcarriers as shown in Fig.9, out of available 64 and 16 being pilot carriers [2].

b) Modulation technique used:

We can use BPSK, QPSK, 16 QAM or 64QAM depending upon the data rate required. BPSK provides the least data rate using 1 bit at a time while 64 QAM is highly spectral efficient and uses 6 bits to provide the maximum data rate.

c) Forward error correction rate 'FEC' (minimum, maximum): 0.5 – 0.75

d) Total symbol duration (Ts): It is the duration of complete OFDM symbol including the useful symbol time and the cyclic prefix $T = T_s + T_g$ (3.2+0.8 = 4 us)

e) Data rate:

Is the data in (bits/second) that can be transmitted using the given specification for OFDM transmitter.

C. Calculations:

TABLE III. CALCULATION OF DATA RATE

BPSK	QPSK
No. of bits =1	No. of bits=2
Total bits=48	Total bits =96
Data Rate=48/4 = 12 Mbps	Data Rate=96/4=24 Mbps
16QAM	64QAM
No. of bits=4	No. of bits=6
Total bits=192	Total bits=288
Data Rate = 192/4 =48 Mbps	Data Rate = 288/4 =72 Mbps

V. COMPARITIVE ANALYSIS

A multipath channel will cause two problems for an OFDM system. The first problem is intersymbol interference. This problem occurs when the received OFDM symbol is distorted by the previously transmitted OFDM symbol. The effect is similar to the intersymbol interference that occurs in a single-carrier system. However, in such systems, the interference is typically due to several other symbols instead of just the previous symbol; the symbol period in single carrier systems is typically much shorter than the time span of the channel, whereas the typical OFDM symbol period is much longer than the time span of the channel. The second problem is unique to multicarrier systems and is called Intrasymbol Interference. It is the result of interference amongst a given OFDM symbol's own subcarriers.

TABLE IV. COMPARATIVE DATA RATES

Mod.	BPSK	QPSK	16QAM	64QAM
FEC rate 1/3	4Mbps	8Mbps	16Mbps	24Mbps
1/2	6Mbps	12Mbps	24Mbps	36Mbps
2/3	8Mbps	16Mbps	32Mbps	48Mbps
3/4	9Mbps	18Mbps	36Mbps	54Mbps

A comparative analysis of these four mapping techniques shows which mapping technique is providing the better data rate when seen with FEC rate .Our comparison shows that 64 QAM using six bits at a time is the most efficient in terms of high speed data transmission. Though 64 QAM might be the best choice in terms of data rate but it will be the most susceptible by noise since error in a single bit will degrade all the symbols. So, for choosing an OFDM modem both, error performance & higher data rate requirement must be consider for a reliable service.

VI. RESULTS AND DISCUSSION:

We have design & discussed important concepts of OFDM modem & analysed our modem for different mapping techniques which affect the data rates. But there is a trade off between number of bits used & its error performance. So using the concept of pilot carriers in OFDM Modem we have reached a maximum data rate of 72 mbps before considering FEC rate and 54 mbps after considering FEC rate. Thus, this paper presents an analysis that which modem (with particular mapper configuration) should be used based on the channel that is present viz. Multipath Rician & Rayleigh fading channel considering error performance. In the presence of LOS (Line of Sight) dominant multipath rician fading channel 64 QAM will be best choice..

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