PERFORMANCE EVALUATION OF M QAM-OFDM

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ABSTRACT

In wireless communication demand of high data rate transmission is increases rapidly on the other side limited amount of spectrum makes it difficult. For such cases signal modulation is a dominant method for transforming the information signal over the air and the choice of modulation scheme is crucial for wireless communication. In wireless communication, conventional FDM (Frequency Division Multiplexing) does not utilize the bandwidth because there is no frequency sub-band overlap. OFDM is a technique which provides the full bandwidth utilization by overlapping the sub carriers. In this paper the BER performance for QAM and PSK has been analyzed in the presence of AWGN noise. Further we will investigate the effect of QAM-OFDM for different orders in the presence of frequency selective Rayleigh fading channel through MATLAB simulation.

Keywords: OFDM, PSK, Multi carrier modulation, QAM, Bit error rate, fading

INTRODUCTION

The demand of high data rate is in wireless communication is growing rapidly; on the other side distortion in the received signal by multipath fading is a major problem. OFDM is a technique of solution for it. OFDM is a MCM (Multi Carrier Modulation) scheme in which multiple user symbols are transmitted in parallel using different orthogonal subcarriers [1]. Depending on the relation between the signal parameters (such as bandwidth, symbol period etc.) and the channel parameters (such as rms delay spread, Doppler spread), different transmit signals will undergo different types of fading [8]. The most significant reason for adopting OFDM is its ability to deal effectively with the most prevalent complicating factor in realistic wireless communication channel, ISI (Inter Symbol Interference) caused by multipath fading. Transmitting data on multiple carriers will reduce ISI [7].
MODULATION SCHEME

A) M-ary QAM modulation scheme in OFDM :
QAM is extensively used modulation scheme in which both amplitude and phase will carry information whereas in PSK and PAM only amplitude or phase carries the information [7]. In a QAM signal, two carriers each having the same frequencies but differing in phase by 90° are represented by,

\[ s(t) = R[I(t) + iQ(t)e^{j2\pi f_0 t}] \]

\[ = I(t) \cos(2\pi f_0 t) - Q(t) \sin(2\pi f_0 t) \]  \hspace{1cm} (1)

For 64-QAM, \( k = \log_2 64 = 6 \) bits/symbols

\( M = 2^b \), where \( b \) = no. of bits in each constellation symbol.

Gray coded bit mapping in M-QAM enhances its performance even more [5]. Also QAM has high spectral efficiency and robust to ICI and ISI occurred due to multipath fading channel [3]. Fig 1 shows the constellation plot for 64 – QAM.

![Fig. 1. Constellation plot for 64-QAM](image)

B) M-ary PSK modulation scheme in OFDM :
General expression for M-ary PSK signal is,

\[ S_i(t) = A \cos(\omega_c t + \varphi_i(t)) \]  \hspace{1cm} (3)

Where, \( A = \sqrt{\frac{2E_s}{T_s}} \), \( \varphi = \frac{2\pi m}{M} \). \hspace{1cm} (4)

In that \( E_s \) is the symbol energy and \( T_s \) is the symbol time duration. For BPSK modulation \( M=2 \) and for QPSK \( M=4 \) and data signal shifts the phase of the waveform \( S_i(t) \).

From the given comparison table it is clear that QAM is efficient in terms of bandwidth requirement compared to other modulation schemes. For high capacity data rate transmission, QAM modulation is better than PSK modulation. Because for higher order modulation BER is higher in M-ary PSK compared to M-ary QAM [6].
Many modulation techniques like BPSK, DPSK, MSK, GMSK, M-QAM, and M-PSK have been developed for faster communication with improved bit error rate and for that OFDM can be a good candidate over other digital modulation schemes. OFDM-QAM provides excellent bandwidth efficiency with lower bandwidth requirement [4]. Also spectral efficiency for higher order QAM is high at high SNR [3].

**OFDM TRANSCEIVER**

Fig. 2 illustrates the process of FFT based OFDM system. First the data is modulated by modulation schemes (QAM, PSK etc.). The output of modulator is then converted to parallel form. These signals are then transmitted through subcarriers which are orthogonal to each other. So, it will reduce the ISI. In mathematics, we can say that the inner product of two signals should be zero for orthogonality [7],

$$\int_0^T \cos(2\pi nf_0 t) dt \cdot \sin(2\pi mf_0 t)dt = 0$$  \hspace{1cm} (3)$$

The orthogonality requires that the subcarrier spacing is $$\Delta f = \frac{k}{T}$$ Hertz, where T seconds is the useful symbol duration and k is a positive integer, typically equal to 1. The risk of interference can be reduced by increasing the subcarrier spacing [2].

<table>
<thead>
<tr>
<th>Modulation Technique</th>
<th>Information capacity</th>
<th>Band-width required</th>
<th>Band-width efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASK</td>
<td>Poor</td>
<td>2R_b</td>
<td>Poor</td>
</tr>
<tr>
<td>BFSK</td>
<td>Better than BASK</td>
<td>2R_b</td>
<td>Not BW efficient</td>
</tr>
<tr>
<td>BPSK</td>
<td>Double to BFSK</td>
<td>2R_b</td>
<td>Used for high speed data transfer</td>
</tr>
<tr>
<td>QPSK</td>
<td>Double to BPSK</td>
<td>2R_b</td>
<td>Highly BW efficient</td>
</tr>
<tr>
<td>MSK</td>
<td>Same as QPSK</td>
<td>Less than QPSK</td>
<td>Higher than QPSK</td>
</tr>
<tr>
<td>64-QAM</td>
<td>Higher than above all</td>
<td>Less than other tech.</td>
<td>Excellent than above</td>
</tr>
</tbody>
</table>

**TABLE 1 COMPARISON OF DIFFERENT MODULATION SCHEME WITH THEIR PARAMETERS [4]**
Using IFFT at transmitter side, we can convert the spectral representation of data in time domain and it will also reduce the computations from $N^2$ DFT to $N \log N$. The IDFT can be calculated efficiently using IFFT algorithm [2]. To void ISI caused by multipath distortion a guard interval is inserted between symbols. The addition of cyclic prefix will solve the both problems, i.e. ISI & ICI [1]. Multicarrier modulation uses less bandwidth than single carrier modulation hence bandwidth efficiency (spectral efficiency) is larger than single carrier system. So, bandwidth can be saved using MCM with OFDM [9].

### TABLE 3 COMPARISON OF SINGLE-CARRIER AND MULTI-CARRIER TRANSMISSION

<table>
<thead>
<tr>
<th>Transmission Type</th>
<th>M in M-QAM</th>
<th>No. of Subcarriers</th>
<th>Band-width efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Carrier</td>
<td>64</td>
<td>1</td>
<td>6.0000</td>
</tr>
<tr>
<td>Multi Carrier</td>
<td>64</td>
<td>128</td>
<td>10.6022</td>
</tr>
</tbody>
</table>

In OFDM, multiple carriers having the frequency separtion of $1/T$ are used, where $T$ is the symbol period. The information sent on each subcarrier $k$ is $g_k$ and it is multiplied by its corresponding carrier, $g_k(t) = e^{\frac{j2\pi k t}{T}}$ and the sinusoidal used in OFDM is, $g_k(t) = \frac{1}{\sqrt{T}} e^{\frac{j2\pi k t}{T}} w(t)$, where $k = 0, 1, ..., N-1$ correspond to the frequency of the sinusoidal and $w(t) = y(t) - u(t-T)$ is a regular window over $[0, T]$.

Mathematically, transmit signal of OFDM defined as,

$$s(t) = a_0g_0(t) + a_1g_1(t) + ... + a_{N-1}g_{N-1}(t) \quad (4)$$

$$= \sum_{k=0}^{N-1} a_k g_k(t) \quad (5)$$

$$= \sum_{k=0}^{N-1} a_k e^{\frac{j2\pi k t}{T}} w(t) \quad (6)$$

Where $a_k$ is the $k^{th}$ symbol in message symbol in message symbol sequence and $N$ is number of carriers.

### FADING CHANNEL

The rayleigh probability density function is for prediction of BER in multipath environment, in which there is no Line of Sight (LOS) component. It is characterized as follows:

$$p_r(r) = \begin{cases} 
\frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} & \text{if } r \geq 0 \\
0 & \text{if } r < 0 
\end{cases} \quad (7)$$

Where $\sigma$ = rms value of the received signal before detection.

In frequency selective fading channel the coherence bandwidth is greater than the signal bandwidth [8]. So, it behaves like a multitap channel. OFDM technique is immune against the effect of frequency selectivity.
RESULTS AND SIMULATION

In this paper we have analysed the BER performance of OFDM systems with two digital modulation techniques like PSK and QAM over an AWGN channel. BER vs. Eb/No plot for higher order modulation M-QAM also shown in Fig. 5. Bit error rate performance for different modulation schemes shows that for higher values of SNR QAM performs better than PSK with AWGN noise as shown in Fig. 3 and Fig. 4.

![Figure 3](image)
**Figure 3**: BER curve for 16-PSK

![Figure 4](image)
**Figure 4**: BER curve for 16-QAM

From Fig. 3 and Fig. 4 it can be seen that for 10 db Eb/No value we get bit error rate of $2.028 \times 10^{-2}$ for 16 PSK while $1.705 \times 10^{-3}$ for 16 – QAM modulation. So, for further simulation our preferred scheme for modulation is QAM and simulation has been done for BER curve of different values of M – QAM where M = 64,128,512,256,512,1024.
After that we have investigated the effect of frequency selective fading channel for QAM modulation with two orders like 64-QAM & 512 - QAM using OFDM. From the simulation result it is clear that OFDM performs better with higher orders of QAM with reduced bit error rate.

**Figure 6**: BER curve for 64-QAM OFDM in Freq. selective Rayleigh channel
Figure 7: BER curve for 512-QAM OFDM in Freq. selective Rayleigh channel

FUTURE WORK

After the simulation of BER calculation for M-QAM OFDM in frequency selective Rayleigh channel it can be performed in the presence of frequency selective Rician fading channel. Same results can be simulated with different modulation techniques and with different fading effects.

CONCLUSION

OFDM has been proved an efficient method for transmitting high rates rates. In this paper we have simulated QAM-OFDM for the orders of 64 & 512 with Frequency selective Rayleigh fading channel. Our results show that the combination of M-QAM and OFDM will enhance the performance of communication system by decreasing the bit error rate for high SNR. So for high data rate transmission with OFDM, QAM is the better choice as a modulation scheme.

REFERENCES


http://en.wikipedia.org/wiki/Orthogonal_frequency_division_multiplexing

