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ANALYSIS OF DIFFERENT HIGH LEVEL MODULATION TECHNIQUES FOR OFDM SYSTEM

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Abstract

In an OFDM system, typical sub-carrier modulation schemes include Binary Phase Shift Keying (BPSK), Quadrate Phase Shift Keying (QPSK), and Quadrature Amplitude Modulation (QAM). High level of modulation is used in order to increase the data rate of the OFDM system.

In this paper the analysis of high level of modulations (16-PSK, 32-PSK,64-PSK,128-PSK,16-QAM, 64-QAM) on OFDM system is presented. Here AWGN and Rayleigh channels have been used for analysis purpose and their effect on BER for high data rates have been presented.

Key words: OFDM, M-PSK, M-QAM, BER (Bit Error Rate)

I. Introduction

OFDM (Orthogonal Frequency Division Multiplexing) is a multi-carrier modulation technique where data symbols modulate a sub-carrier which is taken from orthogonally separated sub-carriers with a separation of 'f_k' within each sub-carrier [1]. Here, the spectra of sub-carrier are overlapping; but the sub-carrier signals are mutually orthogonal, which is utilizing the bandwidth very efficiently [2]. To maintain the orthogonality, the minimum separation between the sub-carriers should be 'f_k' to avoid ICI (Inter Carrier Interference) [3].

By choosing the sub-carrier spacing properly in relation to the channel coherence bandwidth, OFDM can be used to convert a frequency selective channel into a parallel collection of frequency flat sub-channels. Techniques that are appropriate for flat fading channels can then be applied in a straight forward fashion [3] .

OFDM is similar to FDM technique except that the 'N' sub-carriers are made orthogonal to each other over the OFDM symbol (frame) duration T_s. By orthogonality of the carriers, we mean that the carrier frequencies satisfy the following requirement:

$$f_k = f_0 + \frac{k}{T_s}, \qquad k=1,2,3,\ldots,N-1 \qquad (1.1)$$

T_s = OFDM symbol duration
K = an integer
f_k = frequency of k^{th} carrier
f_0 = fundamental frequency

In section A the effect of ISI (Inter Symbol Interference) and ICI on OFDM system have been discussed and the solutions to mitigate these effects are also discussed. In section 1.2 the advantage of using of guard interval to prevent the effects of ISI is discussed. The length of the cyclic prefix should be greater than the length of the channel response. In section 2 different modulation techniques that are commonly used in OFDM system are discussed. M-PSK and M-QAM are the most widely used techniques. In section 3 different channels are discussed. In this paper we have discussed only AWGN and Rayleigh channels. Finally in section 4 the simulated results based on the performance of OFDM system in AWGN and Rayleigh channels have been shown in the form of plots of BER vs SNR for M-PSK and M-QAM modulation.

A. Effects of ISI & ICI on OFDM system

The orthogonality of sub channels in OFDM can be maintained and individual sub channels can be completely separated at the receiver when there is no ISI and ICI introduced by transmission channel distortion. Practically these conditions cannot be governed. Since the spectra of an OFDM signal is not strictly band limited (sinc(f) function), linear distortions such as multipath causes each sub-channel to spread energy into the adjacent channels and consequently cause ICI [3].

A simple solution to this problem is to increase the symbol duration or the number of carriers so that the distortion becomes insignificant. However, this method may be difficult to implement in terms of carrier stability, Doppler shift, FFT size and latency.

B. Use of Guard Interval in OFDM

To prevent IS1 is to create a cyclically extended guard interval, where each OFDM symbol is preceded by a periodic extension of the signal itself. Considering the discrete time implementation of the Multi Carrier system, sampling the transmitted Multi Carrier signal at a rate equal to the data rate one obtains a frame structure composed of the IFFT of the data symbols and of cyclic prefix, as shown in figure 1, and where the OFDM frame will contain N_{total} = L + N samples. Here L is the number of samples copied from the end of N sample IFFT frame and glued at the start of each IFFT frame called as cyclic prefix [4].

At the receiver, removing the guard interval becomes equivalent to removing the cyclic prefix, while the effect of the channel transforms into the periodic convolution of the discrete time channel with the IFFT of the data symbols. Performing a FFT on the received samples after the cyclic prefix is discarded, the periodic convolution is transformed into multiplication, as it was the case for the analog Multi Carrier receiver. Therefore, a discrete time implementation of the Multi Carrier transmitter will use a cyclic prefix to emulate the guard interval from the analog transmission [5][6][7].

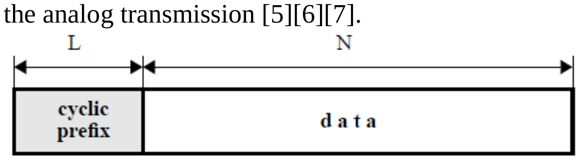

Fig. 1 Cyclic Prefix in OFDM Transmission [5]

II. Different Modulations Techniques used in OFDM system

Modulation is the process of mapping the digital information to analog form so it can be transmitted over the channel. Consequently every digital communication system has a *modulator* that performs this task. Closely related to modulation is the inverse process, called *demodulation,* done by the receiver to recover the transmitted digital information [8].

Modulation of a signal changes binary bits into an analog waveform. Modulation can be done by changing the amplitude, phase, and frequency of a sinusoidal carrier. There are several digital modulation techniques used for data transmission. We will review the ones that are basic or frequently used and appropriate for OFDM. The nature of OFDM only allows the signal to modulate in amplitude and phase.

There can be coherent or non-coherent modulation techniques. Unlike non-coherent modulation, coherent modulation uses a reference phase between the transmitter and the receiver which brings accurate demodulation together with receiver complexity [9].

A. Phase Shift Keying

Phase-shift keying (M-PSK) for which the signal set is:

$$S_i(t)=\sqrt{\frac{2E_S}{T_S}}*(\cos(2\pi*f_c+2\frac{(i-1)}{M})) \qquad (1.2)$$

$$i=1,2,\ldots..M \;\; \& \; 0<t<T_s$$

Where E_s the signal energy per symbol T_s is the symbol duration, and f_c is the carrier frequency.

This phase of the carrier takes on one of the M possible values, namely

$$\theta_i = 2(i-1)^{\pi/M}$$

where i=1,2,…,M

An example of signal-space diagram for 8-PSK is shown in figure 2.

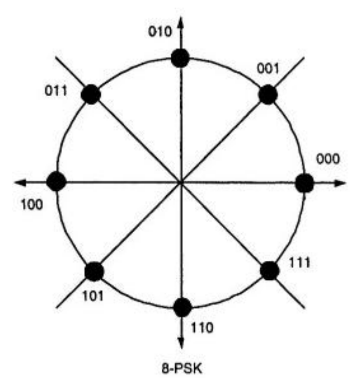

Fig 2. signal-space diagram for 8-PSK [9]

B. Quadrature Amplitude Modulation

In M-ary PSK modulation, the amplitude of the transmitted signals was constrained to remain constant, thereby yielding a circular constellation. By allowing the amplitude to vary with the phase, a new modulation scheme called quadrature amplitude modulation (QAM) is obtained[10] as shown in figure 1.3.

The transmitted M-aray QAM symbol i can be expressed as

$$S_i(t) = \sqrt{\frac{2}{T_s}} *a_{n*} \cos(2\pi*f_c) - \sqrt{\frac{2}{T_s}} *b_n *\cos(2\pi*f_c)$$

$$i = 1,2,\ldots.M \;\; \& \;\; 0 < t < T_s \qquad (1.3)$$

Where a_n and b_n are amplitudes taking on the values and

$$a_n , b_n = \pm a, \pm 3a, \ldots\ldots\ldots\ldots \pm(\log_2 * M\text{-}1)a \qquad (1.4)$$

Where M is assumed to be a power of 4 for M-QAM modulation.

The parameter a can be related to the average signal energy (E_s) by

$$a = \sqrt{\frac{3E_s}{2}} *(M\text{-}1) \qquad (1.5)$$

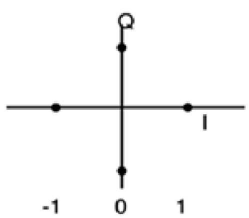

Fig. 1.3 QAM Constellations [9]

III. CHANNELS

Wireless transmission uses air or space for its transmission medium. The radio propagation is not as smooth as in wire transmission since the received signal is not only coming directly from the transmitter, but the combination of reflected, diffracted, and scattered copies of the transmitted signal.

Reflection occurs when the signal hits a surface where partial energy is reflected and the remaining is transmitted into the surface. Reflection coefficient, the coefficient that determines the ratio of reflection and transmission, depends on the material properties.

Diffraction occurs when the signal is obstructed by a sharp object which derives secondary waves. Scattering occurs when the signal impinges upon rough surfaces, or small objects. Received signal is sometimes stronger than the reflected and diffracted signal since scattering spreads out the energy in all directions and consequently provides additional energy for the receiver which can receive more than one copies of the signal in multiple paths with different phases and powers. Reflection, diffraction and scattering in combination give birth to multipath fading [11].

A. AWGN Channel

Additive white Gaussian noise (AWGN) channel is a universal channel model for analyzing modulation schemes. In this model, the channel does nothing but add a white Gaussian noise to the signal passing through it. This implies that the channel's amplitude frequency response is flat (thus with unlimited or infinite bandwidth) and phase frequency response is linear for all frequencies so that modulated signals pass through it without any amplitude loss and phase distortion of frequency components. Fading does not exist. The only distortion is introduced by the AWGN. AWGN channel is a theoretical channel used for analysis purpose only.

The received signal is simplified to

$$r(t) = s(t) + n(t) \qquad (1.6)$$

where n(t) is the additive white Gaussian noise[11].

B. Rayleigh Fading Channel

Constructive and destructive nature of multipath components in flat fading channels can be approximated by Rayleigh distribution if there is no line of sight which means when there is no direct path between transmitter and receiver. The Rayleigh distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function (pdf) given by:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} \qquad 0 \leq r \leq \infty \qquad (1.7)$$

where σ^2 is the time-average power of the received signal.[12][13].

IV. SIMULATED RESULTS

The system discussed above has been designed using MATLAB 9.0 and results are shown in the form of SNR vs BER plot for different modulations and different channels.

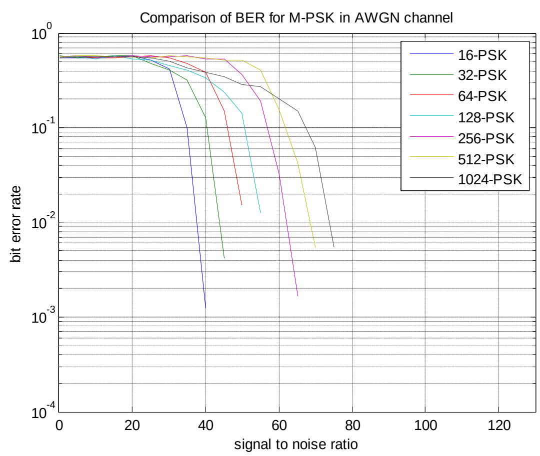

Fig 4 SNR vs BER for M-PSK over AWGN channel

Figure 4 shows the comparison of the behavior of the OFDM system using M-PSK modulation for the AWGN channel. Here the graph depicts that as the order of the modulation increases the BER of the OFDM system keeps on increasing

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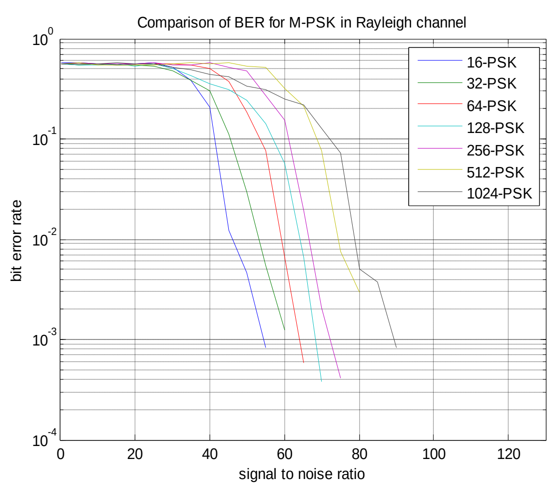

Fig 5 SNR vs BER for M-PSK over Rayleigh channel

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Figure 5 shows the comparison of the behavior of the OFDM system using M-PSK modulation for the Rayleigh channel. . Here the graph depicts that as the order of the modulation increases the BER of the OFDM system keeps on increasing. But here BER is greater than the AWGN channel.

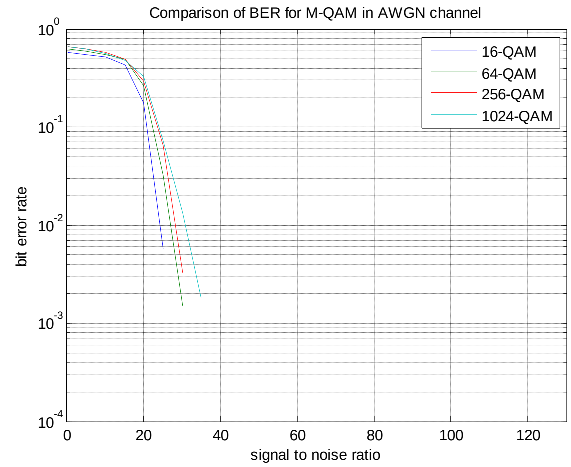

Fig 6 SNR vs BER for M-QAM over AWGN channel

Figure 6 shows the comparison of the behavior of the OFDM system using M-QAM modulation for the AWGN channel. Here the graph depicts that as the order of the modulation increases the BER of the OFDM system keeps on increasing. But here the BER is less than the M-PSK modulated signal, because of the spacing of the constellation points.

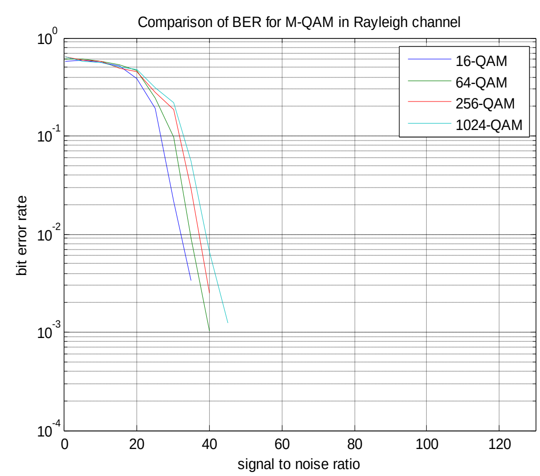

Fig 7 SNR vs BER for M-QAM over Rayleigh channel

Figure 7 shows the comparison of the behavior of the OFDM system using M-QAM modulation for the Rayleigh channel. Here the graph depicts that as the order of the modulation increases the BER of the OFDM system keeps on increasing. But here the BER is less than the M-PSK modulated signal, because of the spacing of the constellation points. But here BER is greater than the AWGN channel.

V. CONCLUSION

In this paper, an idea about the performance of the OFDM systems at higher modulation levels is presented using. OFDM system can be implemented using higher order modulations to achieve large data capacity. But there is a problem of BER (bit error rate) which increases as we increase the order of the modulation. The solution to this problem is to increase the value of the SNR so, that the effect of the distortions introduced by the channel will also goes on decreasing, as a result of this, the BER will also decreases at higher values of the SNR for high order modulations.

As it can be concluded from the graphs, that M-QAM modulation gives better performance than M-PSK modulation in any environment (AWGN or Rayleigh).

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