Comparative Analysis of OFDM system with cyclic prefix and with different modulation techniques

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***Abstract*-Orthogonal frequency division multiplexing (OFDM) is a multi carrier transmission system. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, transmitted in parallel, divide the available transmission bandwidth. The objective of this paper is to demonstrate the flexibility of an OFDM system, and investigate how its performance is changed by varying some of its major parameters In a single carrier communication system, the symbol period must be much greater than the delay time in order to avoid inter-symbol interference (ISI). Therefore, OFDM scheme places a guard band at outer subcarriers. The technique of inserting a guard interval in the time domain, called cyclic prefix (CP), which mitigates the inter-symbol interference (ISI) between OFDM symbols. This paper analyzes effect of cyclic prefix on OFDM system. Also compare the different modulation technique with Bit Error Rate (BER) performance and the analysis of OFDM System utilizing different modulation techniques (QAM and BPSK) over Rayleigh and Additive White Gaussian Noise (AWGN) channels.**

Keywords: cyclic prefix, BER, Rayleigh and AWGN channels, OFDM.

I. INTRODUCTION

Using OFDM, terminals will be expected to handle a wide range of different applications, from pure voice communication to high-speed data transfers, with as little overhead in power consumption and protocol procedure as possible. To be able to adapt to different communication schemes and to have the possibility to fully utilize the ever-changing communication channels the OFDM transmitter must be flexible.

OFDM divides the high-rate stream into parallel lower rate data and hence prolongs the symbol duration, thus helping to eliminate Inter Symbol Interference (ISI). In an OFDM system the sub-channels overlap with each other to a certain extent as can be seen in figure.1-1in which leads to the reduced use of bandwidth and since these carriers are orthogonal to each other Inter Carrier Interference (ICI) is also reduced [5]. The input data sequence is mapped into symbols, which are distributed and sent over the N parallel sub-channels, one symbol per channel. To permit dense packing and still guarantee that a minimum of interference between the sub-channels is encountered, the carrier frequencies must be chosen carefully.

By using orthogonal carriers, which in the Frequency domain can be viewed so as the frequency distance between two sub-carriers is given by the distance to the first spectral null.

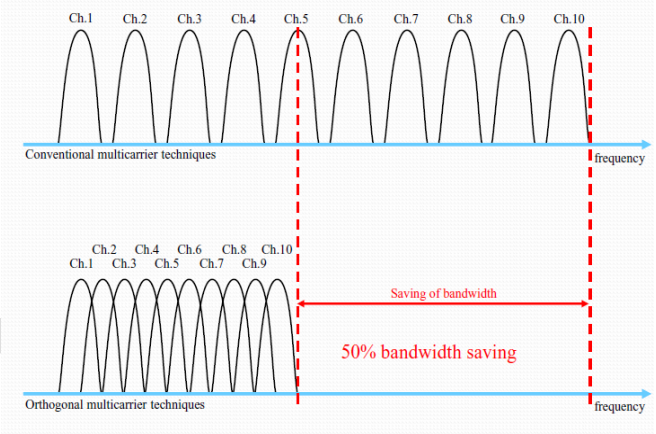


FIGURE 1-1: (A) Conventional multicarrier technique (FDM) (B) Orthogonal Frequency Division multiplexing Technique.

II. CYCLIC PREFIX OF OFDM

The OFDM guard interval can be inserted with cyclic prefix(CP). CP is to extend the OFDM symbol by copying the last samples of the OFDM symbol into its front[1]. To prevent ISI and maintain Orthogonality of sub-carriers is to create a cyclically extended guard interval, where each OFDM symbol is preceded by a periodic extension of the signal itself. The total symbol duration is Ttotal = Tg + T, where Tg is the guard interval and T is the useful symbol duration. ISI can be eliminated, when Tg is longer than the multi-path delay. Tg/T is application-dependent. Since the insertion of guard interval will reduce data throughput, Tg is usually less than T/4.

cyclic prefix (CP) is a copy of the last η samples from the IFFT, which are placed at the beginning of the OFDM symbol, see Figure 3.1. There are two reasons to insert a CP:

1. The convolution between the data and the channel impulse response will act like a circular convolution instead of a linear one. Circular convolution makes equalization easier.
2. Interference from the previous symbol will only affect the CP, which is discarded in the receiver.

Both reasons assume that the CP is longer than the channels impulse response. If the CP is shorter than the impulse response, the convolution will not be circular and

intersymbol interference will occur. However, if the number of samples in the CP is large, the data transmission rate will decrease significantly, since the CP does not carry any useful data. The data rate will decrease with the factor R as $R = N/(N + \eta)$. Thus, it is important to choose the minimum possible CP to maximize the systems efficiency.

Fig 1-2 shows an Effect of a multipath channel on the received signal without guard interval. In this ISI effect is occurring. When cyclic prefix is insert between two carriers ISI effect is eliminated that is shown in Fig 1-3 [7].

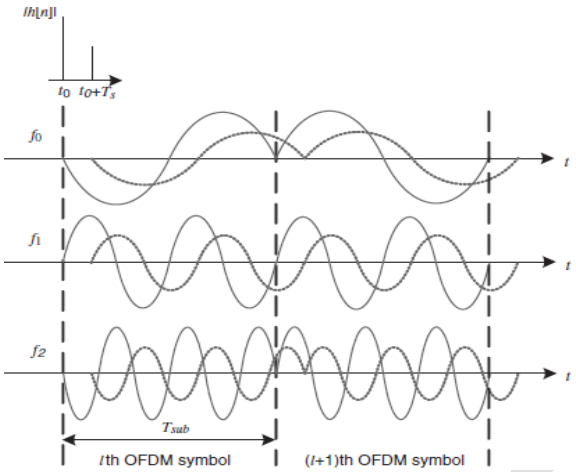


FIGURE1-2: Effect of a multipath channel on the received signal without guard interval.

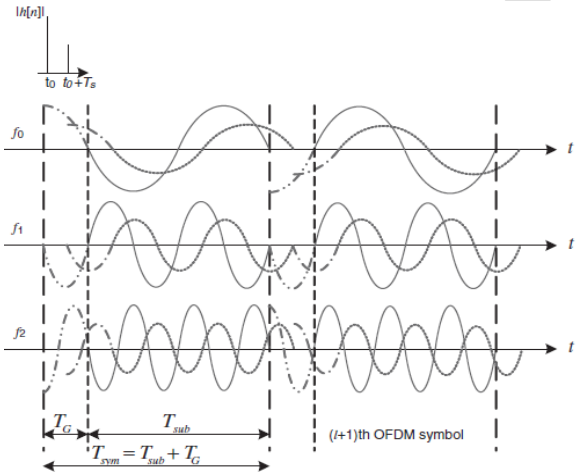


FIGURE1-3: Effect of a multipath channel on OFDM symbols with CP.

Cyclic prefix is more, and then the information content in one symbol would be less. So here also the trade off is needed between the transmission efficiency and the ISI effect. [3]

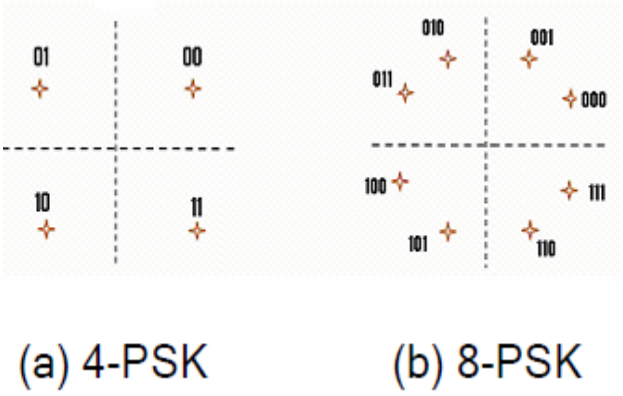
III. MODULATION TECHNIQUES

1. *M-PSK*
2. *M-QAM*

The input data stream is available serially, converted into parallel stream according to digital modulation scheme. The data is transmitted in parallel by assigning each data word to one carrier in the transmission. Once each subcarrier has been allocated symbols, they are phase mapped according to modulation scheme, which is then represented by a complex In-phase and Quadrature-phase (I-Q) vector. The amount of data transmitted on each subcarrier depends on the constellation. In an high interference channel a small constellation like BPSK is favorable, since the required signal to noise ratio (SNR) in the receiver is low, whereas in a low interference channel a larger constellation is more beneficial due to the higher bit rate.

The constellation diagrams of different M-PSK and M-QAM mapping are shown in Figure 1-5. Consider QPSK mapping in M-PSK block of proposed model, which maps 2 bits per symbol into phase, as shown in Figure1-5(a) [12]. Each combination of 2 bits of data corresponds to a unique I-Q vector. In M-PSK block, by changing bits per symbol, we can map the data for 8-PSK, 16-PSK etc. By moving to higher order constellation, it is possible to transmit more bits per symbol in parallel resulting in high speed communication. The use of phase shift keying produces constant amplitude signal and reduce problems with amplitude fluctuation due to fading.

M-QAM modulation can be considered as combination of ASK (Amplitude Shift Keying) and M-PSK. Digital M-PSK is a special case of M-QAM, where the amplitude of the signal is constant. In M-QAM, constellation points are usually arranged in a square grid with equal horizontal and vertical spacing as shown in Figure1-5(c) and Figure 4(d) [12]. If data rates beyond those offered by 8-PSK are required, it is more usual to move to M-QAM since it achieves a greater distance between adjacent points in the I-Q plane by distributing the points more evenly. In M-QAM the location of constellation points no longer indicate the same amplitude and so the demodulator must now correctly detect phase and amplitude, rather than just phase.



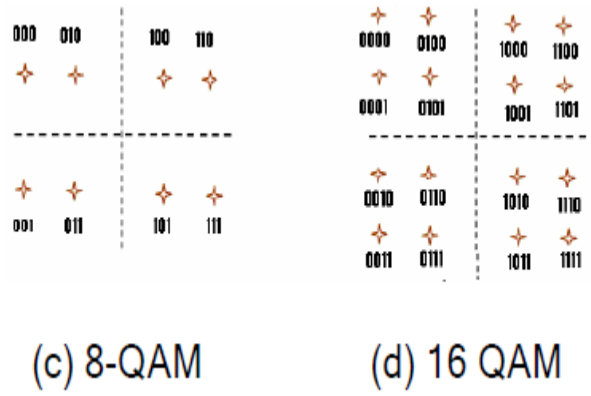


FIGURE1-5: Constellation diagrams 4/8-PSK and 8/16-QAM

If we go on increasing the Eb/No value, BER reduces. In comparison of BER performance for M-PSK, it is observed that use of a higher M-ary constellation is better for high capacity transmission but the drawback is that the points on constellation are closer which makes the transmission less robust to errors with same SNR.

IV. DIFFERENT CHANNELS FOR OFDM

1. AWGN channel

AWGN channel has only one path between the transmitter and the receiver and only a constant attenuation and noise is considered. Therefore no multipath effect is taken into account AWGN channel is not associated with either fading or any other system parameters. It is just the noise that is added to the OFDM modulated signal when it is travelling through the channel.

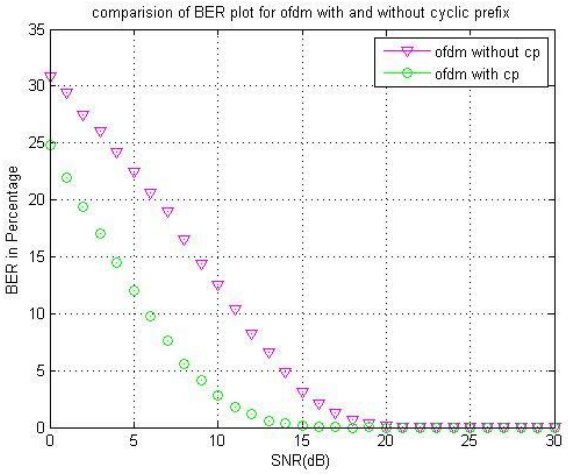
Cyclic Prefix and is not affecting on BER performance of AWGN channel. The BER performance in an AWGN channel is in consistence with the analytical results regardless of the length of CP because there is no multipath delay in the AWGN channel.

2. Rayleigh channel

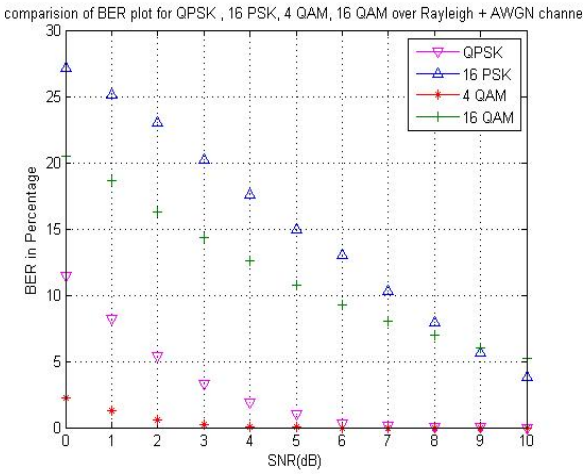
When no LOS path exists in between transmitter and receiver, but only have indirect path than the resultant signal received at the receiver will be the sum of all the reflected and scattered. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. This causes Rayleigh fading. Rayleigh fading channel has multipath between transmitter and receiver. Multipath signal produces the distortion. Cause inter-symbol interference (ISI) where adjacent symbols overlap with each other. This is prevented in OFDM by the insertion of a cyclic prefix between successive OFDM symbols. Cyclic prefix duration increases the BER decreases for Rayleigh fading channel. The effect of ISI on the BER performance becomes significant in the multipath Rayleigh fading channel as the length of CP decreases, which eventually leads to an error.[1]

By using higher order modulation scheme (like 16- QAM, 64-QAM, 16-PSK, 64-PSK) with OFDM technique in Rayleigh channel, we can transmit more data rate.[9] In both the cases QAM gives better performance under Rayleigh channel compared to other modulation scheme's and channels.[5]

V. SIMULATION RESULTS



This graph is comparison of OFDM with cyclic prefix and without cyclic prefix. from the graph we concluded that BER of OFDM with cyclic prefix is less than the BER of OFDM without cyclic prefix.



This graph is comparison of M-PSK and M-QAM. This graph shows that BER of 4-QAM is less than the BER of QPSK and BER of 16-QAM is less than the BER of 16-PSK.so in short M-QAM is perform better than the M-PSK in rayleigh and AWGN channel.

VI. CONCLUSION

From this simulation, I concluded that for AWGN and Rayleigh channel M-QAM performs better than M-PSK. Order of PSK increases BER is increases and Order of QAM increases BER is increases over AWGN and Rayleigh channel. And also BER of OFDM with cyclic

prefix is less than the BER of OFDM without cyclic prefix.

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