

Performance Analysis of OFDM for Different Digital Modulation Schemes using Matlab Simulation

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Abstract

In this Paper, proposed OFDM system design is simulated using Matlab simulink toolbox. The digital modulation schemes such as M-PSK (M-ary Phase Shift Keying) and M-QAM (M-ary Quadrature Amplitude Modulation), which provide way of parallel transmission, are compared to analyze the BER performance of designed OFDM system. Mentioned schemes used in OFDM system can be selected on the basis of the requirement of power or spectrum efficiency and BER analysis. In wireless communication, concept of parallel transmission of symbols is applied to achieve high throughput and better transmission quality. OFDM is one of the techniques for parallel transmission.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Bit Error Rate (BER), Wireless communications.

INTRODUCTION

Many methods are proposed to combat the multipath effects in wireless communication. One of the solutions to combat Inter Symbol Interference (ISI) is multicarrier modulation for data transmission [1], [3], [11], that is Orthogonal Frequency Division Multiplexing (OFDM). The analysis of Bit Error Rate (BER) performance suggests, OFDM is better than Code Division Multiple Access (CDMA) which is mostly incorporated in existing 3G systems [3], [11]. The aim of OFDM is to divide the wide frequency selectivity of fading channels into multiple flat fading channels [1], [11]. The idea of using a Discrete Fourier Transform (DFT) for the generation and reception of OFDM signals eliminates the requirement of banks of analog sub carrier oscillators [5] [10]. Orthogonality property allows multiple information signals to be transmitted in parallel over a common channel and detected, without interference. In OFDM spectrum each subchannel has a peak at the subcarrier frequency and nulls evenly spaced with a frequency gap equal to the carrier spacing $\Delta f = 1/T_s$, where T_s is OFDM symbol duration [1], [2], [5]. Another characteristic of orthogonality is that each carrier has an integer number of sine wave cycles in one bit period [8]. Although OFDM enables simple equalization, it is sensitive to carrier frequency offset [2], [7]. The peak to average ratio (PAR) of the transmitted signal power is large [4], [5], [7], [8]. OFDM system performance can be improved by channel coding [1], [6].

Model Design of OFDM Transceiver Using MATLAB/SIMULINK

The OFDM system is modeled using MATLAB/SIMULINK to allow various parameters of the system to be varied and tested. The following OFDM system parameters are considered for the simulation.

Bit rate $R = 1/T$:	1 Mbps
Data mapping	:	M-PSK and M-QAM
IFFT, FFT size	:	64-poi
Channel used	:	AWGN
Guard Interval size	:	IFFT size/4 = 16 samples
OFDM transmitted frame size	:	64+16 = 80

The system model for OFDM with M-PSK mapping is shown in Figure 1, representing the following blocks. M-PSK block can be replaced by M-QAM block for further comparison.

Binary source: The random Bernoulli binary generator generates binary data that is frame based. In data output, 48 samples per frame are used, and data rate is 1 Mbps.

Data mapping: 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 constellation diagrams of different M-PSK and M-QAM mapping are shown in Figure 2. Consider QPSK mapping in M-PSK block of proposed model, which maps 2 bits per symbol into phase, as shown in Figure 2(a). 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 modulated signal is constant. In M-QAM, constellation points are usually arranged in a square grid with equal horizontal and vertical spacing as shown in Figure 2(c) and Figure 2(d), although other configurations are also possible [9]. 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.

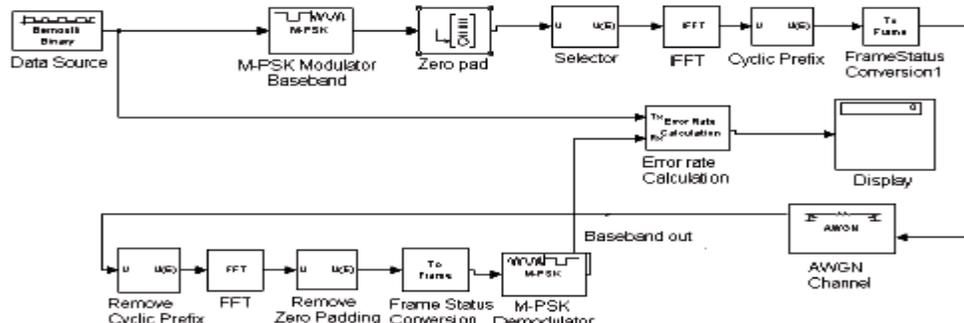


Figure 1: Block diagram of OFDM transceiver

In general, the selection of modulation scheme applied to each subchannel depends solely on the compromise between the data rate requirement and transmission robustness.

IFFT-Frequency domain to time domain conversion: The IFFT converts frequency domain data into time domain signal and at the same time maintains the orthogonality of subcarriers. The real signal output can be generated by arranging conjugate subcarriers [4] as shown in Figure 3(b). In this stage, IFFT mapping, zero pad, and selector blocks are included. Zero pad blocks adds zeros to adjust the IFFT bin size of length L , as the number of subcarriers may be less than bin size. Selector block reorders the subcarriers. The IFFT bin setting, for complex OFDM signal for the given design, is shown in Figure 3(a). The IFFT block computes the Inverse Fast Fourier Transform (IFFT) of length L points, where L must be a power of 2 [8].

Guard period: The effect of ISI on an OFDM signal can be eliminated by the addition of a guard period at the start of each symbol [5]. This guard period is a cyclic copy that extends the length of the symbol waveform. The guard period adds time overhead, decreasing the overall spectral efficiency of the system. Guard duration should be longer than channel delay spread [5]. After

the guard band has been added, the symbols are converted into serial form. One frame length duration $T = T_s + T_g$, where $T_s = NT$, $N =$ number of carriers. This is the OFDM base band signal, which can be up converted to required transmission frequency. An AWGN channel model is then applied to transmitted signal. The model allows for the Signal to Noise Ratio (SNR) variation. The receiver performs the reverse operation of then transmitter. The receiver consists of removal of guard band, FFT, removal of zero padding and demapping of data.

SIMULATION RESULT

The performance of a data transmission system is usually analyzed and measured in terms of the probability of error at given bit rate and SNR. The parameter E_b/N_0 , where E_b is bit energy and N_0 is noise energy, is adjusted every time by changing noise in the designed channel.

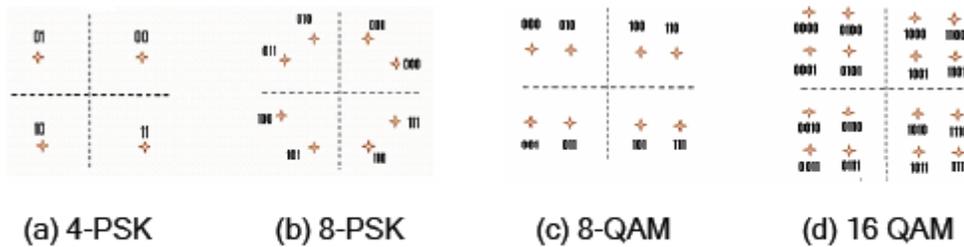


Figure 2. Constellation diagrams 4/8-PSK and 8/16-QAM

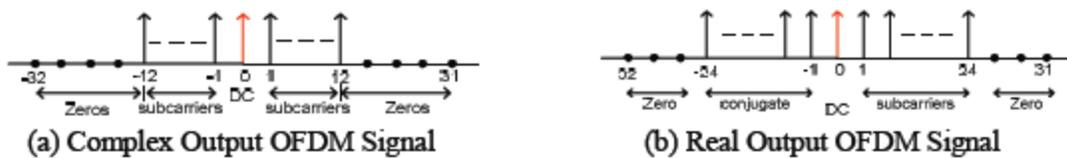


Figure 3. Concept of IFFT bin setting used in the simulation

For particular E_b/N_0 value, system is simulated and corresponding probability of error is noted. The proposed design is simulated with necessary parameter changes for QPSK, 8-PSK and 16-PSK. As shown in Figure 4, if we go on increasing the E_b/N_0 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. For OFDM with QPSK simulation, constellation diagram of transmitted signal and received signal is shown in Figure 5. The OFDM with 8-QAM and 16-QAM mapping simulation are analyzed for BER performance and compared with 8-PSK and 16-PSK systems simulation as shown in Figure 6.

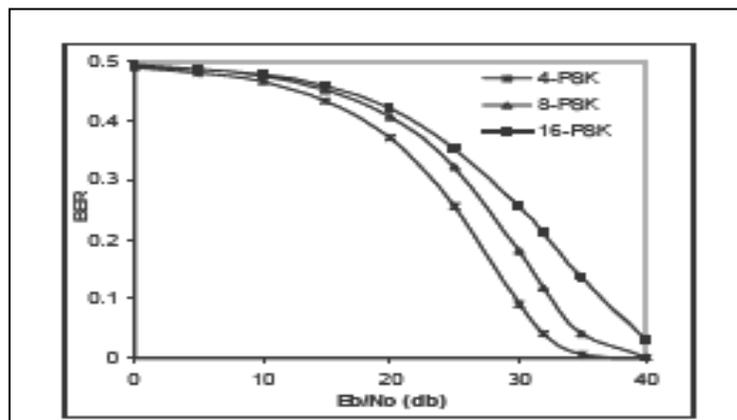


Figure 4. BER performance comparison of 4/8/16-PSK

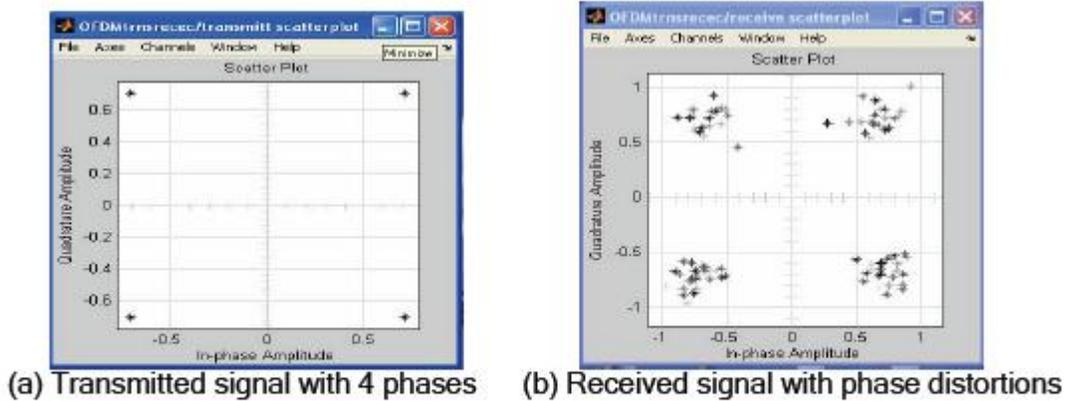


Figure 5. Constellation diagrams for QPSK mapped simulation

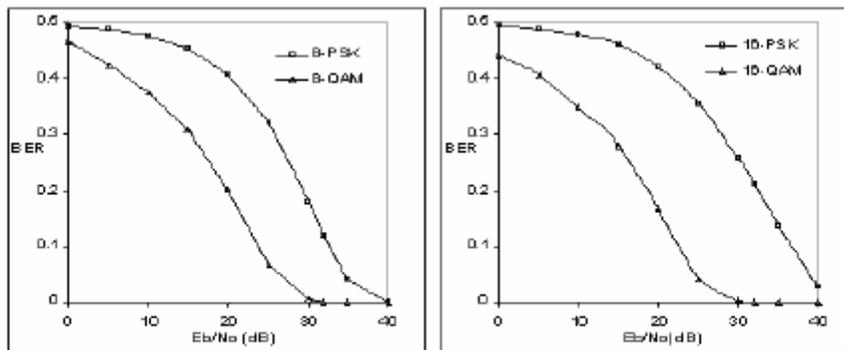


Figure 6. BER performance comparisons of 8/16-PSK and 8/16-QAM

Conclusion

OFDM is a powerful modulation technique used for high data rate, and is able to eliminate ISI. It is computationally efficient due to the use of FFT techniques to implement modulation and demodulation functions. The performance of OFDM is tested for two digital modulation techniques namely M-PSK and M-QAM using MATLAB/SIMULINK toolbox. It is observed from M-PSK BER plot that BER is less in case of 4-PSK for low E_b/N_0 as compared to 8-PSK and 16-PSK. Hence, high value of M-ary increases spectrum efficiency, but easily affected by noise. So OFDM system with QPSK scheme is suitable for low capacity, short distance application. While the OFDM with higher M-ary modulation scheme is used for large capacity, long distance application at the cost of slight increase in E_b/N_0 . The comparison of M-PSK and M-QAM indicates that, BER is large in M-PSK as compared to M-QAM and it generally depends on applications. For higher value of M that is for $M > 16$, QAM modulation scheme is used in OFDM. Similarly, results can be tested with addition of channel coding block in the model design.

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