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Performance evaluation of OFDM using various modulation subcarriers in AWGN

Charu Srivastava, Shweta Bhardwaj

Abstract— OFDM is based on parallel data transmission scheme that reduces the effects of multipath fading and renders complex equalizers unnecessary so it is used in wireless LAN (WLAN) systems. Other applications are Asymmetric Digital Subscriber line (ADSL), Digital Audio Video Broadcasting, Power line communication. In this paper, I have studied and simulated the Orthogonal Frequency Division Multiplexing (OFDM) technology that compares theoretical and practical values of OFDM for various subcarriers under AWGN channel using BPSK and QPSK modulation techniques separately using SIMULINK model. Essentially, comparison study is carried out to obtain the performance for OFDM under the number of sub carriers as well as modulation techniques for AWGN channel to identify which modulation technique is better for different number of sub carriers.

Key words—OFDM, SIMULINK, Modulation techniques, No of Channels (N), BER, SNR, AWGN

1 Introduction

The name 'OFDM'[1,7,8] is derived from the fact that the digital data is sent using many carriers, each of a different frequency (Frequency Division Multiplexing) and these carriers are orthogonal to each other, hence Orthogonal Frequency Division Multiplexing. It is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multi-path environments. OFDM transmits data by using a large number of narrow bandwidth carriers. These carriers are regularly spaced in frequency, forming a block of spectrum. The frequency spacing and time synchronization of the carriers are chosen in such a way that the carriers are orthogonal.

The basic principle [7, 8] of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over the number of sub carriers [3]. The relative amount of dispersion in time caused by multipath delay spread is decreased because the symbol duration increases for lower rate parallel sub carriers. The inter symbol interference is being eliminated completely by introducing a guard time in every OFDM symbol.

The purpose of this project is to investigate how OFDM performs in AWGN channels with different number of subcarriers under different modulation techniques. The number of subcarriers varies from 64 to 1024.

The modulation techniques used for each channel are BPSK and QPSK.

2. Problem Identification

In 1971, Weinstein and Ebert proposed a modified OFDM system in which the discrete Fourier Transform (DFT) was applied to generate the orthogonal sub-carriers waveforms instead of the banks of sinusoidal generators. Cyclic prefix (CP) or cyclic extension was first introduced by Peled and Ruiz in 1980 for OFDM systems. As a result, the orthogonality among the sub-carriers was guaranteed. With the trade-off of the transmitting energy efficiency, this new scheme can result in a phenomenal ISI (Inter Symbol Interference) reduction. In 1980, Hirosaki introduced an equalization algorithm to suppress both inter symbol interference (ISI) and ICI, which may have resulted from a channel distortion, synchronization error, or phase error. In 1985, Cimini introduced a pilot-based method to reduce the interference emanating from the multi-path and co-channels. Chang shows in 1966 that multi-carrier modulation can solve the multi-path problem without reducing data rate.

In this paper, study and simulation of Orthogonal Frequency Division Multiplexing (OFDM) technology has been carried out which gives the best SER performance in AWGN channel for different subcarriers

Using different modulation techniques namely, BPSK, and QPSK.The work was accomplished by designing a simulator in SIMULINK. Also R-S (15/11, Double error correcting) Code is done and a training based channel estimator is implemented [2]. Basically, comparison has been done to evaluate the performance of OFDM under the different sub carriers in AWGN channel using different modulation techniques to identify which modulation technique gives the best BER performance for different subcarriers.

3. Experimental Setup Parameters

3.1. OFDM Simulation Flowchart

The transmitter first converts the input data from a serial stream to parallel sets which are then modulated or mapped into signal mapper using modulation technique: 1) BPSK and 2) QPSK , one after the other on AWGN, Channel, for various subcarriers.

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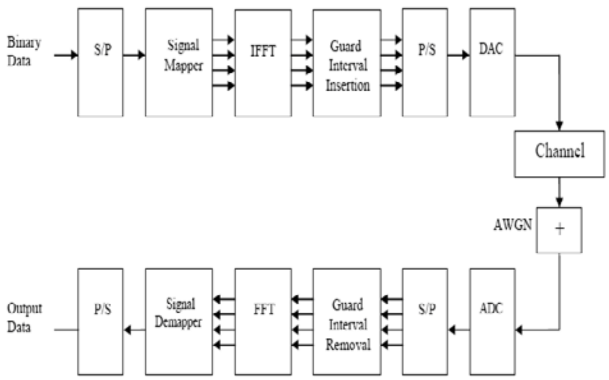

Figure 1 OFDM Simulation Flow chart

As shown in Figure 1, an inverse Fourier transform converts the frequency domain data set into samples of the corresponding time domain representation of this data. Specifically, the IFFT is useful for OFDM because it generates samples of a waveform with orthogonal frequency components.

Then, the guard interval is inserted to remove inter symbol interference. The parallel to serial block creates the OFDM signal by sequentially outputting the time domain samples [4]. The channel simulation will allow examination of the effects of noise. By adding random data to the transmitted signal, simple noise can be simulated. The receiver performs the inverse of the transmitter. First, the OFDM data are split from a serial stream into parallel sets. Then guard intervals are removed. The Fast Fourier Transform (FFT) converts the time domain samples back into a frequency domain representation. Demodulation is performed in the signal demapper. Finally, the parallel to serial block converts this parallel data into a serial stream to recover the original input data.

3.2 Results

3.2.1 OFDM using BPSK

(a) For N = 64

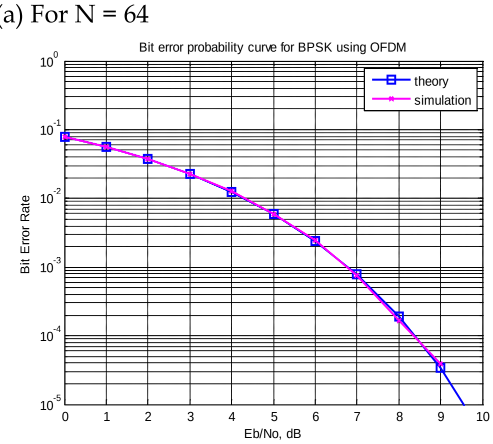

Figure 2 OFDM using BPSK for 64 subcarriers

As shown in the Figure 2, **For N = 64:-** After 7db, simulated E_b/No decreases than theory and then increases very little bit after 8.5db till 9db. After 9 db there is no error.

(b) For N = 128

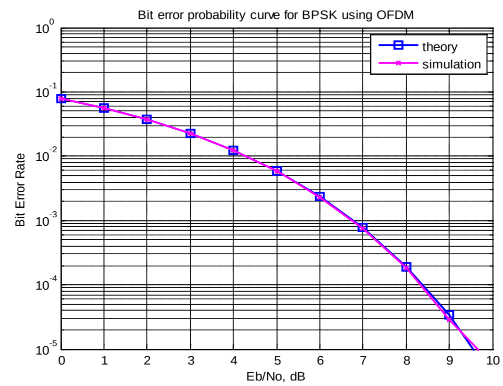

Figure 3 OFDM using BPSK for 128 subcarriers

For N = 128:- After 8db, simulated E_b/No decreases than theory till 9.3db and then increases very little bit after 9.3db till 9.7db as shown in the Figure 3.

(c) For N = 256

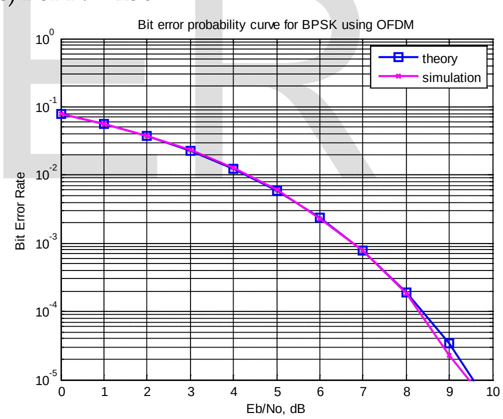

Figure 4 OFDM using BPSK for 256 subcarriers

For N = 256:- After 8db, simulated E_b/No decreases than theory as shown in the Figure 4.

(d) For N = 512

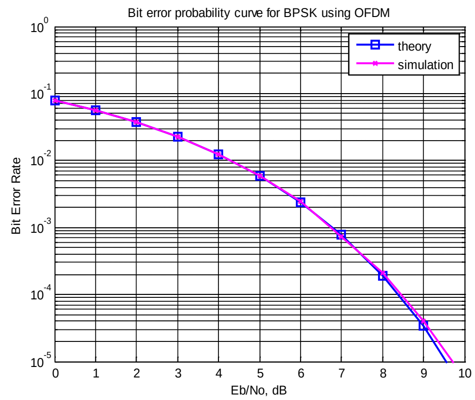

Figure 5 OFDM using BPSK for 512 subcarriers

For N = 512:- After 7.6db, simulated E_b/No increases than theory with same BER as shown in the Figure 5.

(e) For N = 1024

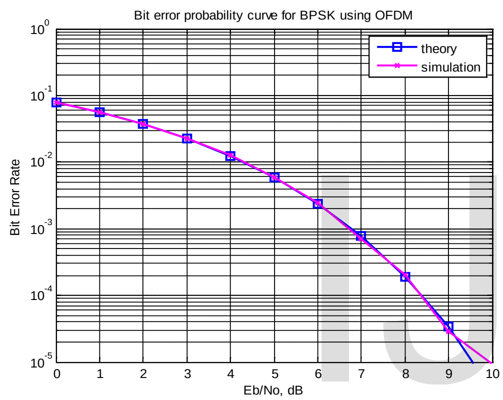

Figure 6 OFDM using BPSK for 1024 subcarriers

For N = 1024:- After 9db, simulated E_b/No increases drastically than theory with the same BER as shown in the Figure 6.

If we compare the Figures 2, 3, 4, 5 & 6, it is seen that the BER is changing for theoretical and simulated values. The difference value of BER (theory – simulated) is varying for all the subcarriers in the case of BPSK.
3.2.2 OFDM using QPSK.

(a) For N = 64

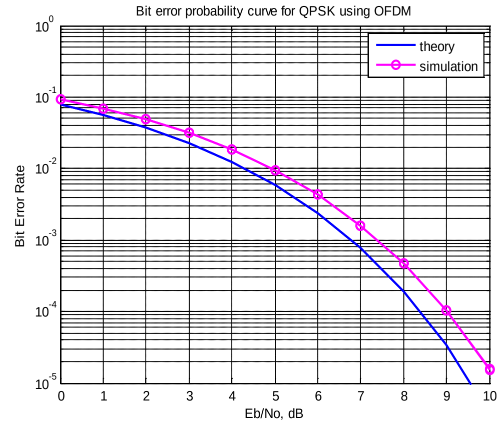

Figure 7 OFDM using QPSK for 64 subcarriers

As shown in the Figure 7, **For N = 64:-** The simulated E_b/No is greater than theory from 0 db showing that there is error from the very beginning.

(b) For N = 128

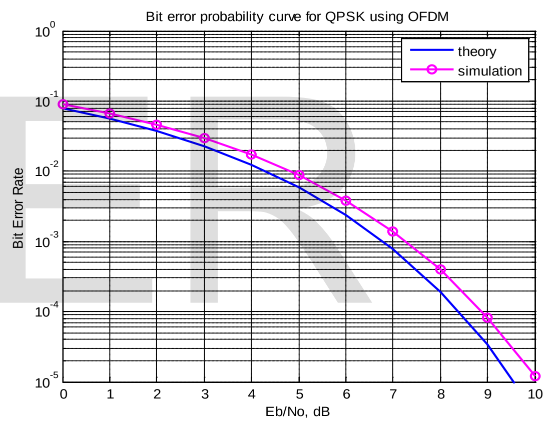

Figure 8 OFDM using QPSK for 128 subcarriers

For N = 128:- As clearly seen from the above figure i.e. Figure 8, it clearly shows that the simulated E_b/No is greater than theory from beginning till end

(c) For N = 256

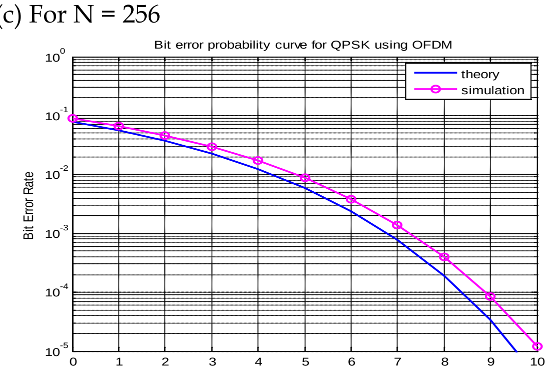

Figure 9 OFDM using for 256 subcarriers

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QPSK

For N = 256:- In the above Figure 9 also, the simulated E_b/No is greater than theory from beginning till end.

(d) For N = 512

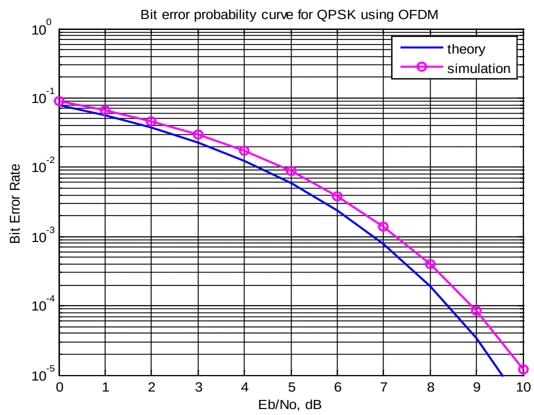

Figure 10 OFDM using QPSK for 512 subcarriers

For N = 512:- In the above Figure 10 also, the simulated E_b/No is greater than theory from beginning till end.

(e) For N = 1024

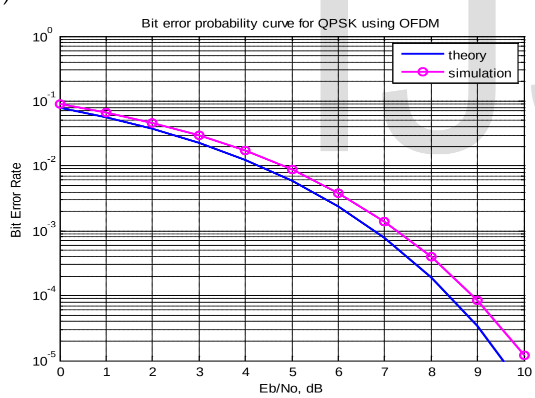

Figure 11 OFDM using QPSK for 1024 subcarriers

For N = 1024 :- In the above Figure 11, the simulated E_b/No is greater than theory from beginning till end.

Comparing all the above figures from Figure 7 to 11, there is constant difference of simulated and theoretical value of BER for almost all subcarriers whether it is 128 or 1024 except for 64. There is hardly any change in the difference value of BER (simulated – theoretical) for QPSK.

The result has shown that AWGN under simulation gives 0.9691 db shifts from the theoretical value. This shift was caused by the cutting off of the guard interval power from the received signal. It can be calculated as follows:

shift value(dB) = -10log 10 (gilen/fftlen2)

4. Conclusion

For more number of carriers QPSK is better than BPSK as the BER is same for both but there is hardly any change in theoretical and simulated QPSK OFDM after 128 channels where as incase of BPSK there is change in SNR for corresponding BER in all above cases (different no of parallel subcarriers, N) .

From the performed simulations, it was found that in AWGN channel, QPSK performs best as it shows the least bit error rate requiring the least SNR while BPSK is the worst for the same value of no of parallel channels.

In future, study can be carried out to obtain the performance for Orthogonal Frequency Division Multiplexing (OFDM) under different types of communications channels as well as modulation techniques. Also different types of channel estimation techniques can be used to study the performance of OFDM. Its performance can also be studied in wireless applications i.e. WLAN. Real time hardware can be implemented to coded-OFDM with RS code to enhance the performance of the OFDM system. Also the number of bits used in modulation can be changed to study.

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