Performance Analysis of OFDM for Ultra Wideband System using BPSK Modulation Scheme

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Abstract - Orthogonal Frequency Division Multiplexing (OFDM) has become a popular modulation method in high speed wireless communications. By partitioning a wideband fading channel into flat narrowband channels, OFDM is able to mitigate the detrimental effects of multipath fading using a simple one-tap equalizer. There is a growing need to quickly transmit information wirelessly and accurately. OFDM is a suitable candidate for high data rate transmission over wireless channels. Coded-OFDM eliminates ISI and is robust to radio fading channels impairments. Thus OFDM offers higher data throughput with increased reliability in data transmission. Multiband OFDM based Ultra Wideband (UWB) system uses OFDM modulation technique with a multiple banding approach, which divides the spectrum into several sub-bands, whose bandwidth is approximately 490MHz. OFDM based system is very sensitive to timing and frequency offsets, the received constellation is slightly different from transmitted constellation due to processing delay and additional delay introduced from the channel. This paper provides the analysis of block coding on OFDM based UWB system and also comparing system BER and SNR performance over different modulation techniques.

Keywords: BER performance, Block codes, OFDM, Ultra wideband.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other [1]. Some of the main advantages of OFDM are its multi-path delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain. Also one other significant advantage is that the modulation and demodulation can be done using inverse fast fourier transmission (IFFT) and fast fourier transmission (FFT) operations, which are computationally efficient.

Generally the radio spectrum can be divided into two categories: licensed and unlicensed bands. In 2002, FCC approved the deployment of UWB on an unlicensed basis in the 3.1–10.6 GHz band[2]. This was done to limit the power spectral density (PSD) measured in a 1 MHz bandwidth at the output of an isotropic transmit antenna to a spectrum mask. However, in order to avoid impairments to other users' communications, the amount of interference introduced by a transmission system operating in those bands must be limited. Hence some limitations on the power spectral density were introduced.

Shannon-Hartley theorem shows that higher data rate can be achieved at a faster rate by increasing the bandwidth rather than the received SNR according to

$$C = B\log_2(1 + SNR) \qquad (1)$$

Channel capacity of UWB system operating at 7.5GHz BW is 7.5GB/S for SNR of 0dB. So, UWB falls in the power limited region.

Multiband UWB (MB-UWB) signalling is simply the division in the frequency domain of a single UWB signal into multiple sub-bands. These sub-bands may be transmitted in parallel or sequentially and may be received by separate receive paths or one single frequency-agile receiver.

II. MULTI-BAND ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is a type of multi channel modulation that divides a given channel into many parallel sub-channels or sub-carriers, so that multiple symbols are sent in parallel so that each sub-carrier experiences a flat channel. An OFDM signal consists of N orthogonal sub-carriers modulated by N parallel data streams. Each baseband sub-carrier is of the form given by

$$\emptyset_k(t) = e^{j2\pi f_k t} \qquad (2)$$

Where, f_k is the frequency of k_{th} sub-carrier. $\emptyset_k(t)$ forms an orthonormal basis function. One baseband OFDM symbol multiplexes N modulated subcarriers as given by

$$s(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k \emptyset_k(t) \quad (3)$$

$$0 < t < Ts$$

where, x_k is the k_{th} complex data symbol taken usually from a QPSK constellation and T_s is the length of the OFDM symbol, $T_s = NT$ where N is the number of sub-carriers and T is the base band elementary period. The subcarrier frequencies f_k are equally spaced as $f_k = k/T_s$ which makes the subcarriers. $\emptyset_k(t)$ on $0 < t < Ts$ orthogonal.

OFDM System Implementation:

For continuous time implementation as in equation-3 it needs N oscillators and DACs, which is of very high complexity. So, discrete time implementation of equation-3 is commonly used in practice, which is achieved by T spaced sampling as given by

$$s(nT) = IDFT(x_k) \quad (4)$$

IDFT is implemented by using IFFT and the frequencies are orthogonal because the basis function of Fourier transform is orthonormal. The modulation and demodulation of OFDM using FFT's is shown in Fig 1.

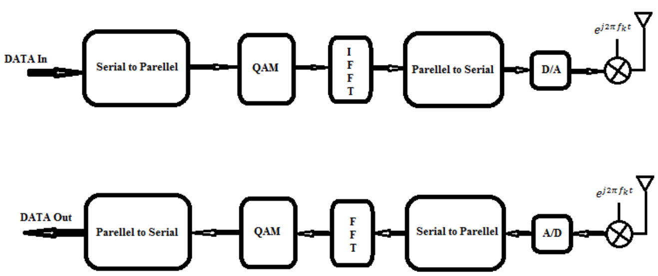


Fig 1: OFDM Modulator and Demodulator using FFT

Multi Band OFDM :

In MB approach the transmission of data for a given user occurs on different sub-bands (each of at least 500MHz) in subsequent periods of time. Different types of modulation schemes can be adopted for data modulation within each sub-band. The most popular is OFDM so the name MB-OFDM UWB. In each sub-band, OFDM is applied. Frequency hopping between different bands is supported, so for every symbol duration the transmitted signal hops between sub-bands. In MB approach, the spectrum is divided into 14 bands (each with a bandwidth equal to 528 MHz), and devices are allowed to statically or dynamically select which bands to use for transmission. The entire spectrum is divided into 4 distinct groups. Only Group A is intended for first generation devices because of current technology limitations. Other groups have been reserved for future use. Fig 2 shows time-frequency coding for the MB-OFDM system, where the first OFDM symbol is transmitted on sub-band 1, the second OFDM symbol is transmitted on sub-band 3, the third OFDM symbol is transmitted on sub-band 2, the fourth OFDM symbol is transmitted on sub-band

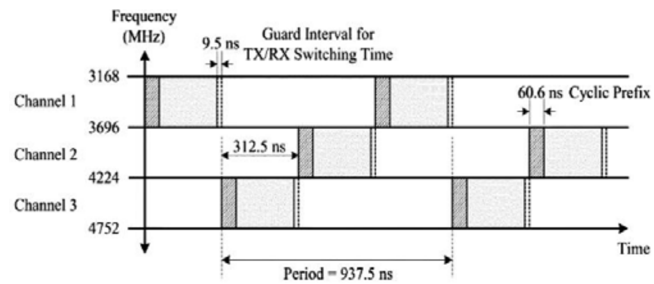
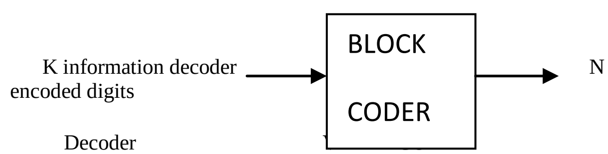


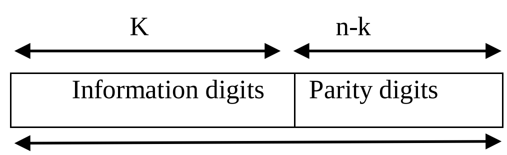
Fig. 2: T-F coding for MB OFDM

III. LINEAR BLOCK CODES

We assume that the output of an information source is a sequence of binary digits "0" or "1." In block coding, this binary information sequence is segmented into message blocks of fixed length; each message block, denoted by **u,** consists of K information digits. There are a total There are a total of 2k distinct messages. The encoder, according to certain rules, transforms each input message **u** into a binary n-tuple **v** with n> k. This binary n-tuple **v** is referred to as the code word (or code vector) of the message **u ,** as shown in Figure.



Rate ,R= k/n



N digit code word

Therefore, corresponding to the 2k possible messages, there are 2k code words. This set of 2k code words is called a block code. For a block code to be useful, the 2k code words must be distinct. Therefore, there should be a one-to-one correspondence between a message **u** and its code word **v.**

IV. SYSTEM MODELING

Since the main goal of this research paper was to simulate the OFDM system by utilizing block codes and BPSK, QPSK and Different versions of QAM Modulation. The block diagram of the entire system is shown in "Fig. 3".

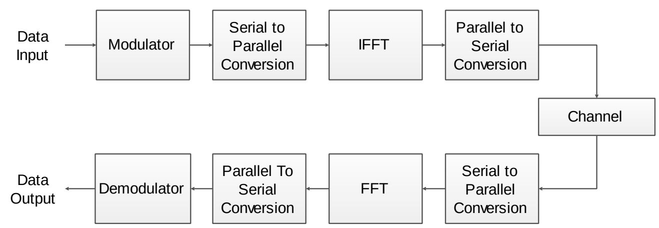


Fig. 3: System Block Diagram

The system is equipped with the BPSK, QPSK or m-QAM modulation techniques so that the signal can be processed in protected manner at transmitter itself. The modulated signal is further encoded with the block codes which is an added security to the signal. The following system arrangement recover signal significant lower error at the output because of modulation with OFDM system. The block diagram is shown in the Fig. 3.

The above mentioned system is executed on the simulation tool and its flow of execution is shown with the help of flow chart of the algorithm in Fig. 3.2. The flow of information through various stages and changes briefly mentioned in the chart.

The steps are as follows:

a. *Start of simulation*
b. *Create simulation environment with the help of variable declaration and system variables*
c. *Generate data to transmit through system (to evaluate system)*
d. *Modulate data either with BPSK or with m-QAM technique (for different performance)*
e. *Convert signal from serial to parallel (OFDM Symbol conversion)*
f. *Perform IFFT operation(OFDM Modulation)*
g. *Convert parallel signal to serial (OFDM symbol to data stream)*
h. *Transmit through AWGN channel which is encountered with the noises during transmission*
i. *Convert signal from serial to parallel (OFDM Symbol conversion)*
j. *Perform FFT operation (OFDM Demodulation)*
k. *Demodulate signal with BPSK or m-QAM respectively*
l. *Convert parallel signal to serial (OFDM symbol to data stream)*
m. *Calculate Bit Error Rate(BER)*
n. *Compare results of different modulation techniques as well as making changes in system parameter like FFT size subcarrier length, and symbol length(shown in the result section)*
o. *End of simulation process*

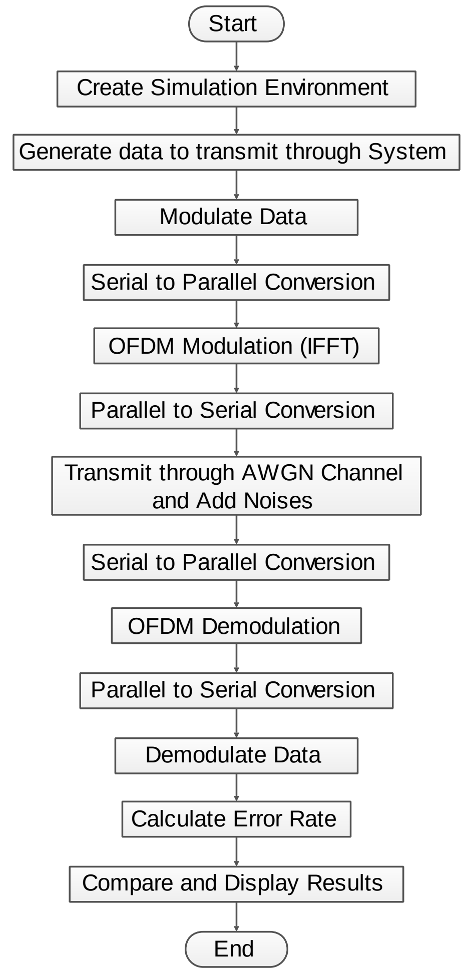


Fig. 4 Flow chart of Proposed System Model

V. SIMULATION & RESULTS

The system proposed in this paper is explained in the previous section with the implementation algorithm shown in flowchart.

The simulation is done and the Bit Error Rate(BER) is analysed of the system. In Fig. 5 the BER vs SNR curve of the system using 32-FFT with three different modulation techniques 16-QAM, 64-QAM and 256-QAM. The optimum BER achieved on 16-QAM, because of the 16-QAM is lower complex than other modulation techniques. As the complexity of the modulation technique increases the performance of the system decreases.

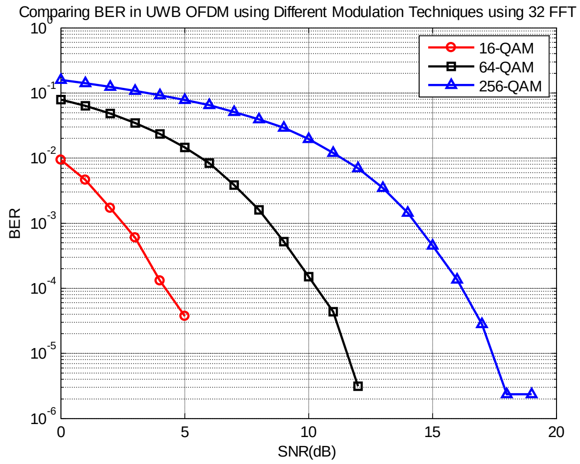


Fig. 5: BER comparison of OFDM with 16, 64 and 256-QAM using 32 FFT Points

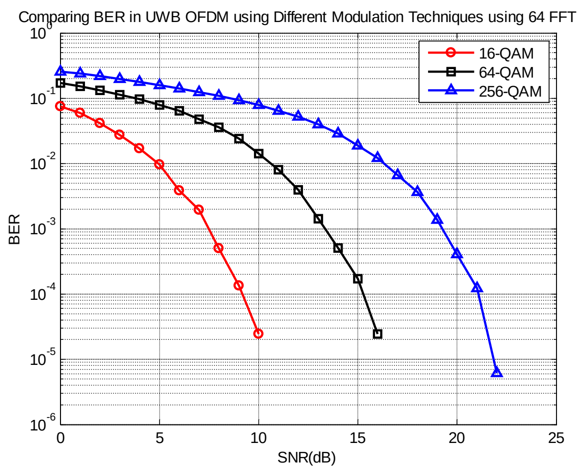


Fig. 6: BER comparison of OFDM with 16, 64 and 256-QAM using 64 FFT Points

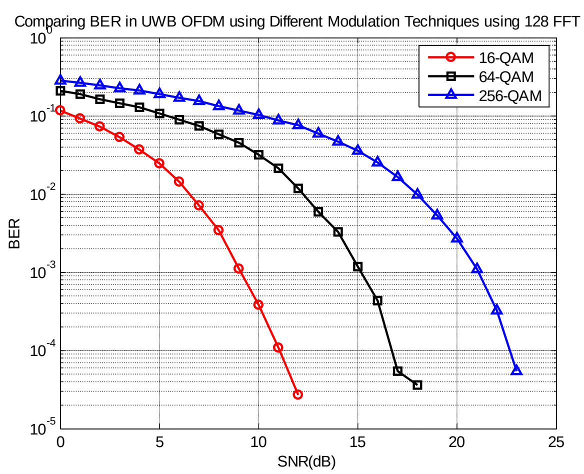


Fig. 7: BER comparison of OFDM with 16, 64 and 256-QAM using 128 FFT Points

In Fig. 6 the BER vs SNR curve of the system using 64-FFT with three different modulation techniques 16-QAM, 64-QAM and 256-QAM. The optimum BER achieved on 16-QAM, because of the 16-QAM is lower complex than other modulation techniques. As the complexity of the modulation technique increases the performance of the system decreases.

In Fig.7 the BER vs SNR curve of the system using 128-FFT with three different modulation techniques 16-QAM, 64-QAM and 256-QAM. The optimum BER achieved on 16-QAM, because of the 16-QAM is lower complex than other modulation techniques. As the complexity of the modulation technique increases the performance of the system decreases.

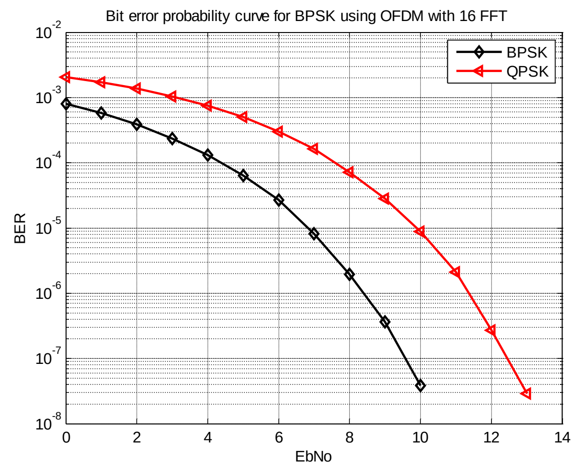


Fig. 8: BER comparison of OFDM with BPSK and QPSK using 16 FFT Points

In Fig.8 the BER vs SNR curve of the system using 16-FFT with two different modulation techniques BPSK and QPSK. The optimum BER achieved on BPSK, because of the BPSK is lower complex than QPSK modulation techniques. As the complexity of the modulation technique increases the performance of the system decreases.

In Fig.9 the BER vs SNR curve of the system using 32-FFT with two different modulation techniques BPSK and QPSK. The optimum BER achieved on BPSK, because of the BPSK is lower complex than QPSK modulation techniques. As the complexity of the modulation technique increases the performance of the system decreases.

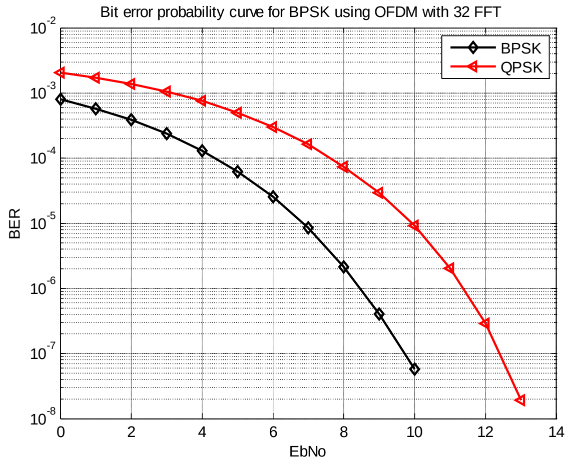


Fig. 9: BER comparison of OFDM with BPSK and QPSK using 32 FFT Points

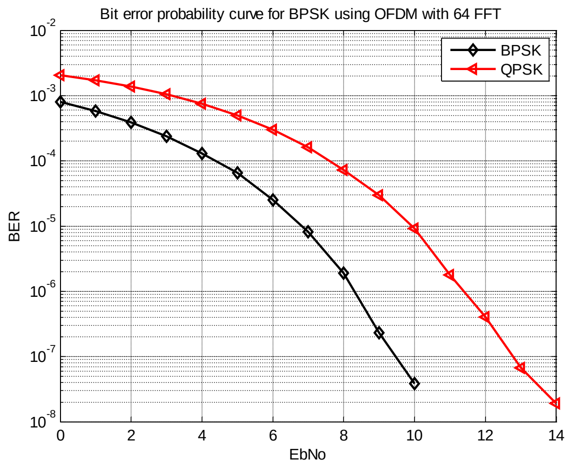


Fig. 10: BER comparison of OFDM with BPSK and QPSK using 64 FFT Points

In Fig. 10 the BER vs SNR curve of the system using 64-FFT with two different modulation techniques BPSK and QPSK. The optimum BER achieved on BPSK, because of the BPSK is lower complex than QPSK modulation techniques. As the complexity of the modulation technique increases the performance of the system decreases.

Table 1: Simulation Parameters

Parameters	Types/Values
Modulation Techniques	BPSK, QPSK, 16, 64, 256-QAM
No. Of Bits	1024
FFT size	16, 32, 64, 128
Bits per Symbol	52
Sampling Frequency	20 MHz
PSD	-55 to -35

The comparison of BER for various modulation technique is given below in Table.

Table 2: BER vs SNR comparison for various modulation technique in proposed system

SNR	BPSK	QPSK	16-QAM	64-QAM	256-QAM
0	0.8042	0.002	0.127	0.2902	0.3447
1	0.5769	0.0017	0.1047	0.2679	0.3296
2	0.3858	0.0014	0.0836	0.2461	0.3128
3	0.2349	0.0011	0.0638	0.223	0.2958
4	0.1277	0.0007	0.047	0.2003	0.2783
5	0.0623	0.0005	0.0317	0.1794	0.2612
6	0.0264	0.0003	0.0207	0.1586	0.2421
7	0.0086	0.0002	0.0112	0.138	0.2234
8	0.0019	0.0001	0.0056	0.119	0.2047
9	0.0004	0	0.0023	0.101	0.1841
10	0.0001	0	0.0007	0.0841	0.1644
11	0	0	0.0002	0.0682	0.1455
12	0	0	0	0.0525	0.1289
13	0	0	0	0.0391	0.1128
14	0	0	0	0.0272	0.0978
15	0	0	0	0.0172	0.083
16	0	0	0	0.01	0.0695
17	0	0	0	0.0052	0.0564
18	0	0	0	0.0023	0.0428
19	0	0	0	0.0008	0.0321
20	0	0	0	0.0002	0.0225
21	0	0	0	0	0.0144
22	0	0	0	0	0.0085
23	0	0	0	0	0.0044
24	0	0	0	0	0.002
25	0	0	0	0	0.0007
26	0	0	0	0	0.0002
27	0	0	0	0	0.0001
28	0	0	0	0	0
29	0	0	0	0	0
30	0	0	0	0	0

The BER performance of block coded OFDM system is analysed at different modulation techniques over noisy channel. Recursive Systematic Convolution encoding and decoding are considered in this paper as the iterative decoding scheme easily outperforms conventional codes, or in other words non-iterative decoded codes. The burst errors can happen either by impulsive noise or by deep frequency fades.

BPSK modulation techniques showing best BER performance as in Fig. 9. While QAM-256 showing worst BER performance as compared to BPSK, QPSK, 16-QAM and 64- QAM.

VI. CONCLUSION

In this paper we analyses BER performance with respect to signal to noise ratio and improved BER using block coding. In OFDM there are some factors included inter symbol interference (ISI) caused by a dispersive channel, inter channel interference (ICI) and its deleterious effects. Exploration of techniques to combat some of these problems such as the use of a cyclic prefix (longer than the channel delay spread), and equalization made easy thanks to the wideband nature of the OFDM. As long as the subcarrier spacing is kept smaller than the coherence bandwidth, taking advantage of the high correlation between adjacent sub carriers. Presentation of a few results in both AWGN and Raleigh environments, as we needed to validate our modified, simplified simulator. The concept of OFDM and block coding with a target-based, modulation scheme by introducing the noises, which occurs in communication networks is done by analyzing the performance of networks. The simulation of the entire work is done on MATLAB 2013. First developing an OFDM system model then try to improve the performance by applying block codes to our uncoded system. From the study of the system, it can be concluded that improving the performance of uncoded OFDM by block coding scheme and BPSK modulation techniques.

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