Implementation of MIMO-OFDM system using CORDIC based FFT for wireless applications

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Abstract: Orthogonal frequency division multiplexing based communication system is one of the modulation techniques for wireless communication. Multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) delivers a significant performance improvement in terms of many parameters like transmission rate, Bit error rate(BER),cyclic prefix, number of subcarriers, modulation types etc. In this paper, the study of an MIMO-OFDM system has been done using different modulation technique, forward error codes and channels. The simulation is done in two steps. The first step discusses the implementation issue of FFT in MIMO OFDM system, while in the second step the simulation of MIMO-OFDM has been done by implementing CORDIC algorithm based FFT receiver. The CORDIC based FFT block minimizes the hardware complexity because of the reducing of twiddle factors. The experimental result has been comparatively studied on the basis of normal mode and CORDIC mode. The main goal of the developed system is to improve the data rate and reliable channel capacity for efficient throughput. MIMO-OFDM system has several applications in wireless applications like IEEE 802.11a, digital video broadcasting. The project results have been provided by plotting graph of bit error rate versus $\boldsymbol{E_b/N_o}$ are simulated using MATLAB®. The statistical analysis has been implemented to provide benefits of the system over existing system.

Keywords **-Fast Fourier Transform (FFT), Coordinate Digital Computer (CORDIC), Multiple Input Multiple Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM).**

I. INTRODUCTION

In communication field, problem of high data rate has been increased day by day. So Orthogonal Frequency Division Multiplexing (OFDM) system has been implemented for efficient throughput in wireless system. The fundamental principle of OFDM is to split high streams of information into a number of data streams parallel usages of many orthogonal subcarriers. This system is used to remove inter symbol interference and bandwidth problems. Multiple Input Multiple Output scheme plays important role in the implementation of OFDM technology in wireless communication system. MIMO OFDM system offers high data rate and better performance by reducing inter symbol interference. MIMO OFDM with space time block coding system is mainly employed in 4G wireless technologies because of its decoding simplicity and overcoming multipath fading process. The Fast Fourier Transform is the important block in the OFDM system. It is used for reducing the complexity of computations in Discrete Fourier Transform (DFT) [1]. A FFT processor consists of control logic, memory storage, butterfly unit. In the FFT processor, generally single butterfly unit is used to perform all calculations iteratively. In this project, implementation of MIMO OFDM system using CORDIC based FFT architecture has been done. The Coordinate Digital Computer based butterfly can be twice faster than traditional multiplier-based butterflies. The design issues of FFT using CORDIC structure has been discussed in implementation of MIMO OFDM system. A MIMO OFDM system for two transmit and two receive antenna has been implemented to reduce the Bit Error Rate (BER) for wireless communication. The system has several applications in wireless applications i.e. WLAN, DVB etc. The system performance is simulated by using MATLAB software.

II. CORDIC BASED FFT IMPLEMENTATION

The N-point discrete Fourier transform can be defined as,

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-i2\pi nk/N} \quad k=0, 1, N-1$$

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) e^{2\pi ikn/N} \quad n=0,1,N-1$$

The twiddle factor is,

$$W_N^{kn} = e^{2\pi nk/N} = \cos(2\pi nk/N) - j \sin(2\pi nk/N)$$

W_N^{kn} is equivalent to roatate x(n) by $-\frac{2\pi kn}{N}$, which can be realized easily by the CORDIC algorithm.

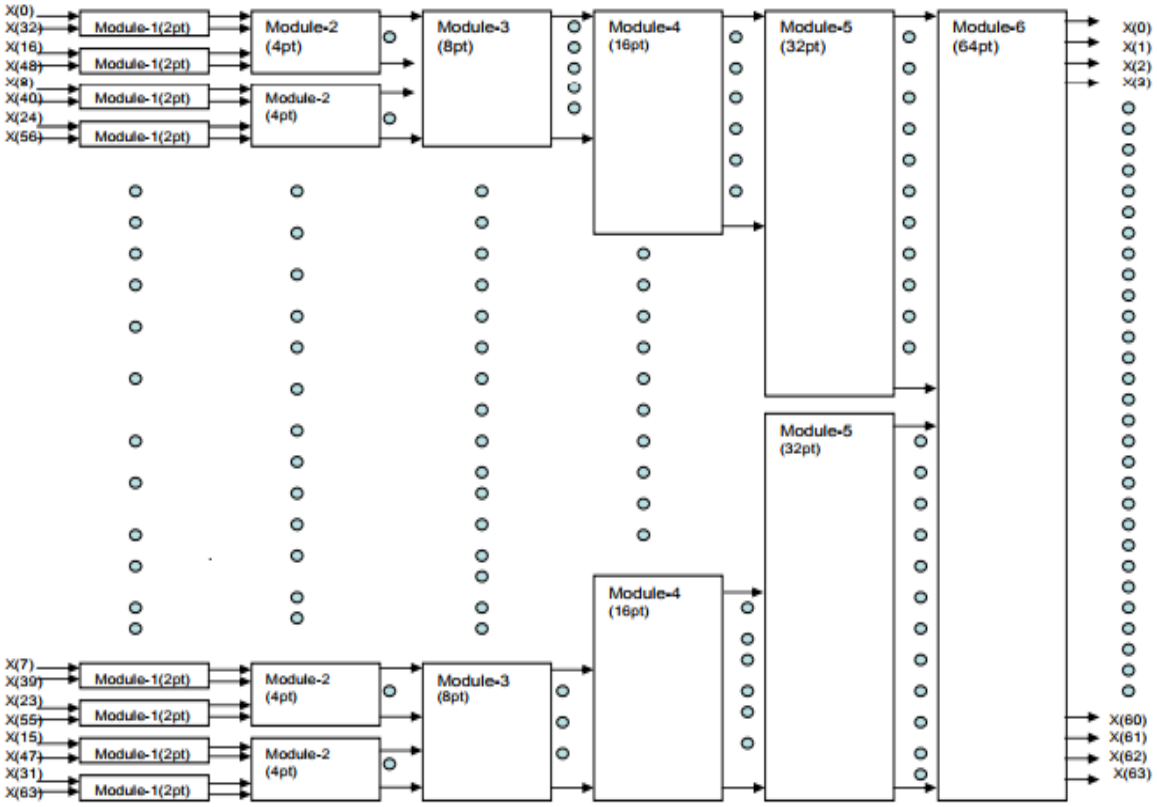

Figure 1: Block diagram of 64 point CORDIC based FFT

Figure1 shows the architecture of 64 point CORDIC based FFT implementation. Let, x (n) represents a sequence of N =64 values, where N is an integer power of 2 i.e., r=2.No of stages are L= log_2N =6. The input sequence is shuffled through bit reversal as in decimation in time algorithm [4]. The given sequence is decimated into two N/2 point sequences. Then each N/2 is divided into two N/4 point sequences. Then each N/4 point sequences are divided into two N/8 point sequences. Then each N/8 point sequences are divided into two N/16 point sequences. Then each N/16 point sequences are divided into two N/32 point sequences.

CORDIC algorithm:

Transforming complex twiddle factor multiplications into CORDIC operations can eliminate the complex multiplications. Therefore any complex multiplier based FFT architecture has its CORDIC based equivalent, which may provide a simpler implementation. In general, complex multiplications of the form given as,
Re(X) + j Im(X) = [Re(x) +j Im(x)].$e^{-j\theta}$ can be represented in matrix form as,

$$\begin{pmatrix} \text{Re(X)} \\ \text{Im(X)} \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \text{Re(X)} \\ \text{Im(X)} \end{pmatrix}$$

According to CORDIC algorithm,

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \text{Re(X)} \\ \text{Im(X)} \end{pmatrix}$$

The CORDIC algorithm can be realized as an iterative sequence of shift operation and addition/subtractions. This algorithm is generalized to evaluate a set of the arithmetic functions, which includes multiplication, division, sine, cosine, arctangent, and hyperbolic functions as shown in below equation.

$$x_n = x_0 cos\theta - y_0 sin\theta$$

$$y_n = y_0 cos\theta + x_0 sin\theta$$

This algorithm requires no dedicated multipliers or dividers. The CORDIC algorithm is well suited for FFT due to the simplicity of the operations involved.

III. MIMO OFDM IMPLEMENTATION

A] A 2 x 2 MIMO OFDM model:

In this model, there are two transmitters and two receivers to increase the data rate of the wireless communication system. MIMO scheme is used to transmit two or more data streams over the single channel. Hence the system can transmit the two or more data per channel without the need of extra bandwidth. A MIMO system with N_t transmit antennas and Nr receive antennas has a maximum diversity gain of $N_t N_r$ [2]. Space time block coding is used to transmit more than one copy of data stream across number of antennas. The given system is implemented by 2*2 antennas and it can support 64 point FFT, modulation may be BPSK or QPSK, channel type is Rayleigh.

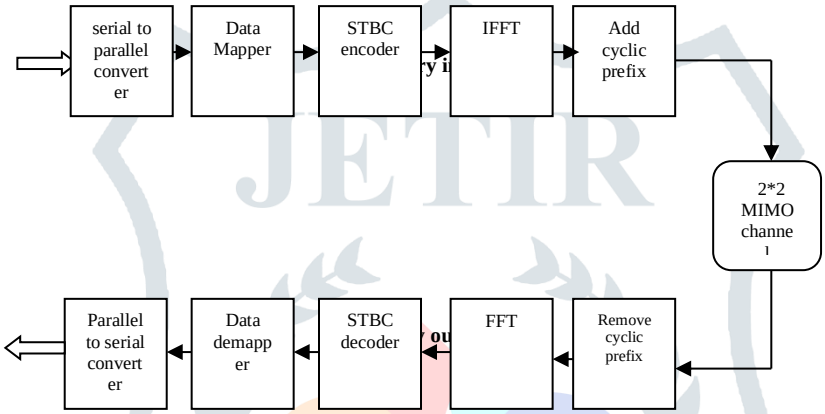

Figure 2: Block diagram of MIMO OFDM system

B] Algorithm for implementation of MIMO OFDM with STBC:

Step 1: The initialization parameters are set as shown in table 1.

Table 1: Parameters and its values

Parameter	Value
Antenna configuration	2x2 antennas
Noise	AWGN
SNR range	0 to 30
Cyclic prefix factor	1/4, 1/16
Modulation type	BPSK,QPSK

Step 2: The serial data are transformed into parallel information for OFDM. Then the mapped data are transmitted via the Space Time Block Coding.

Step 3: Pass the encoded sequences through IFFT and then add the Cyclic Prefix to the data in the frequency domain.

Step 4: The resultant data are transmitted using two transmitting antennas through an Additive White Gaussian Noise (AWGN) channel.

Step5: The information obtained by means of the two receiving antennas is applied to the FFT after removing the cyclic prefix and then passed to the STBC Decoder.

Step6: This parallel information is later transformed into serial form. The BER vs. E_b / N_0 plotted for various Modulations like BPSK, QPSK [3].

IV. SIMULATION RESULTS (MATLAB based)

Table 2: MIMO-OFDM System implementation simulation parameters

Sr. No.	Parameter	Rating
1	IFFT/FFT size	64 point
2	Modulation	BPSK,QPSK
3	Sampling frequency	312.5KHz
4	Carriers	4
5	Channel type	AWGN (Rayleigh fading)
6	Cyclic prefix	1 symbol
7	Cyclic prefix duration	0.8μS

For wireless application, we used forward error correcting code i.e. convolutional coding is used in the result. There are 2 transmitters and 2 receivers configuration so in comparison with simple OFDM it gives high throughput. So it is mainly used for wireless i.e. WLAN application. Figure shows 2*2 channel design OFDM simulation on the basis of FFT type having code length 1000.

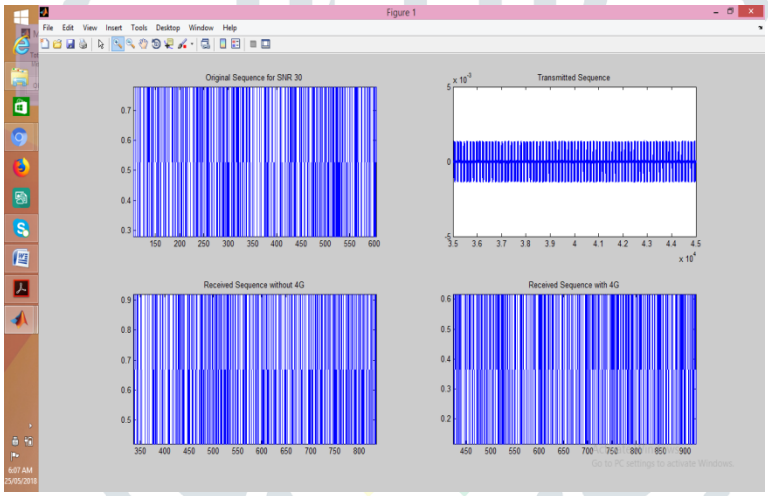

Figure 3(a) simulation of MIMO OFDM system for simple radix FFT algorithm

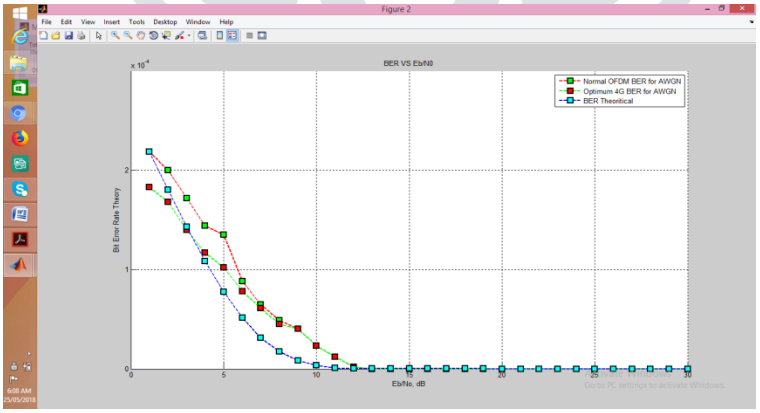

Figure 3(b) Plot of bit error rate versus E_b/N_o of MIMO OFDM system

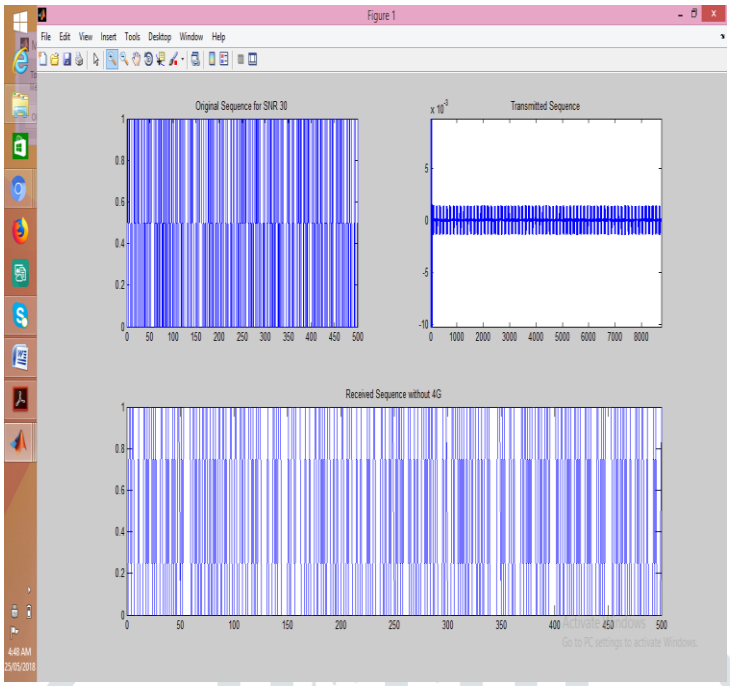

Figure 3(c) simulation of MIMO OFDM system

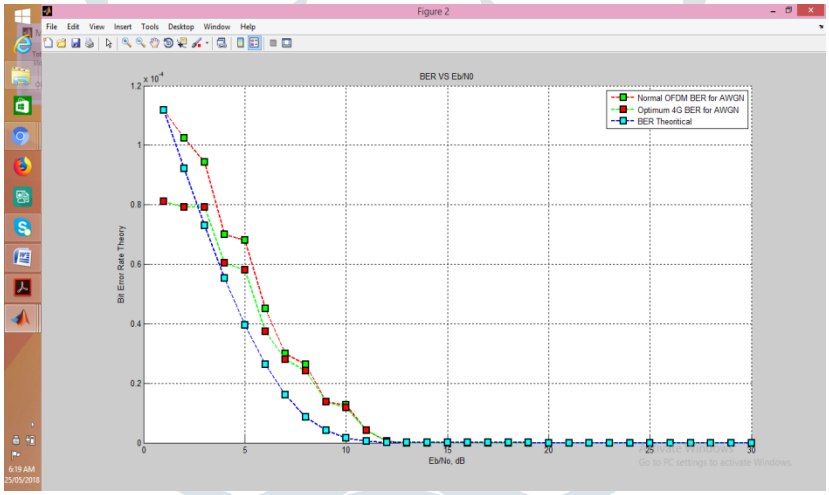

Figure 3(d) Plot of bit error rate versus E_b/N_ograph of MIMO OFDM system using CORDIC algorithm

From above simulation results, figure 3(a) to 3(d), shows the bit error rate is decreasing as E_b/N_o increases in MIMO OFDM system. Thus, CORDIC algorithm based FFT implementation gives higher throughput than normal MIMO OFDM system. Performance analysis is examined by changing modulations, number of carriers, cyclic prefix etc. By using these parameters analysis of the system has been done.

Comparison Results:

Table 3 Comparison between 2 x 2 OFDM normal and CORDIC FFT

Code length	**Data received time (seconds)**	
OFDM (2 x 2)	Normal FFT	CORDIC FFT
1000	85	60
800	70	43
500	421	30
400	35	23

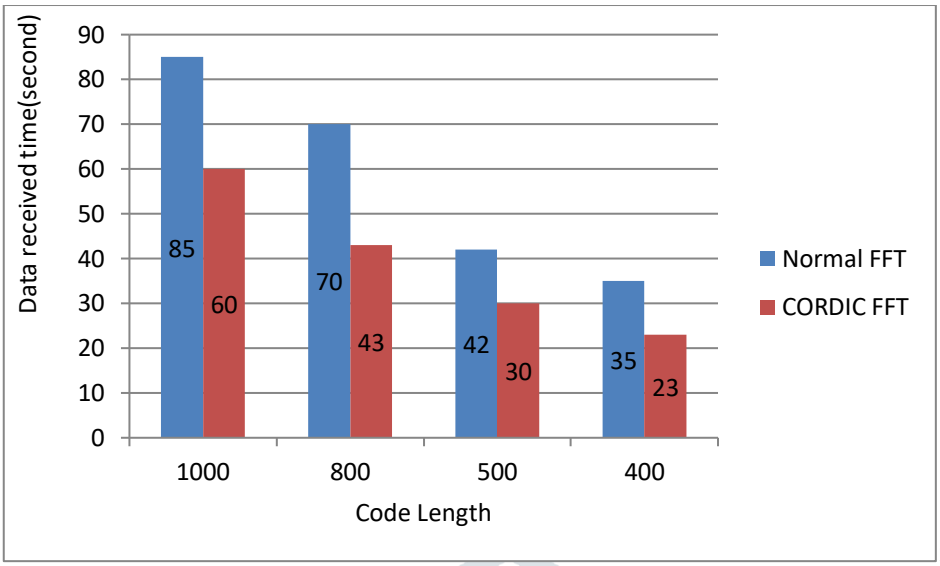

Figure 4: Statistical representation between Normal FFT and CORDIC FFT algorithm

V. CONCLUSION

In this project, 2 x 2 MIMO OFDM system has been implemented. The main focus of the system is to design FFT based receiver in OFDM system. For wireless applications, the CORDIC based FFT implementation has been done for designing MIMO-OFDM model to increase data rate. Using MATLAB®, the simulation of the system is done. The performance analysis was carried out by using plot of E_b/N_o versus Bit error rate. From the plot, it is concluded that as E_b/N_o increases bit error rate decreases. In conclusion, CORDIC simplifies life for FFT and proves boon to the orthogonal frequency division multiplexing technology.

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