Performance Analysis of OFDM-MIMO for Transmitting Medical Image

A Thesis Submitted to the Department

of

Electrical and Electronics Engineering

By

Shah Tabassum Bintu (09310001)

Shila Akter (09310031)

Sabikun Nahar (09310051)

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Declaration

We hereby declare that this thesis is based on the results we found by our work. Contents of work found by other researchers are mentioned by references. This thesis has never been previously submitted for any other degree neither in whole nor in part.

Date:

Signature of Supervisor: **Signature of authors:**

 Dr. Amitabha chakrabarty   Shah TabassumBintu

                                                                    (09310001)

Signature of Co-supervisor:

                                                                    Shila Akter

                                                                    (09310031)

MD. Zahangir Alom

                                                                    Sabikun Nahar

                                                                    (09310051)

Abstract:

In this project the impact of OFDM-MIMO combiner system using block codes and interleaver with FEC encoder and STTC code on RGB image in JPEG format has been investigated the performance of MIMO over orthogonal frequency division modulation technique. Additive white Gaussian noise and other fading like Rayleigh and Rician has an effective effect over two transmitters and two receivers. It implements maximum ratio combiner and minimum mean square error (MMSE) channel equalization technique is very much likely to combat interference and inter symbol interference. The transmitted color image is successfully received under noisy and fading condition. It has been proved that the performance of OFDM_MIMO is inversely related to the rate of error of the channel.

Chapter 1

Introduction

Chapter 1

Introduction:

In digital communication system, for progressive transmission of multimedia over wireless channel has create a center of attention because of increasing demand for upgrading wireless application. One of the constructive methods is OFDM-MIMO combined system for achieving extra ordinary data rates. It's a promising technique to support high data rates and high performance. It is widely believed that OFDM-MIMO combined system not only able to enhance the capacity of transmitting image but also able to combat the channel fading and interference effectively. Many researches regarding OFDM-MIMO already done by many scientist and researchers, such as, digital TV, digital audio broadcasting, digital video broadcasting ,high data rate wireless transmission ,4G wireless system etc.

Background:

Review:

Image transmission using OFDM provides a huge field to work on. All the paper we go through for our research purpose we get an immense idea of how orthogonal frequency division modulation technique provides a better network facility on various communication platforms. In addition with MIMO it becomes an unique idea for developing the process of image transmission in this modern communication based world. MIMO provides faster transmission facility combined with OFDM.

In paper [1] performance of MIMO_OFDM wireless system using block codes and interleaver with STTC has been investigated. Here two transmitter and receiver antenna was used based on QPSK and QAM over AWGN and fading channels and MMSE channel equalization technique is highly successful. It also provides very high potentiality for boosting up the diversity and mitigation of the detrimental effects due to multipath fading.

In paper [2] stated that, MIMO_OFDM is a promising technology for future broadband communication. MIMO_OFDM together with QAM is analyzed and a faster high speed communication can be possible under wide bandwidth and flexibility imposes the use of efficient transmission methods that would fit the characteristics of wideband channel.

In paper [3] the challenges for wireless communication designs come from the detrimental characteristics of wireless communication such as multipath fading, Doppler effect co channel interference and international jamming in military communication and ITS. Their objective is to provide new approaches to solve the problems mentioned above and enhance the transmission speed to 100 Mbps. For

example 4G mobile communication systems are projected to solve the remaining problems of 3G systems and to offer new services from high quality voice to high definition video to high data rate wireless channels.

In paper [4] JSCC is combined with STC_OFDM based multiple input multiple output systems for progressive image transmission. This design allows the measurement of the expected reconstruction of image quality. They proposed an adaptive modulation scheme for picking the constellation size that offers the best reconstructed image quality for each average SNR.

So our target of this work is based using OFDM_MIMO combined system increasing the speed of transmission and also improving the quality of the image minimizing the error at the output image. People of our country will benefited if this system actually implemented because this will reduces the tension of time of a critical patient as well expenses.

Thesis outline:

Previous chapter of this report was about the introduction of the whole paper, and literature review. The rest of the paper is organized as follows.

Chapter 2 discusses OFDM & MIMO and system implementation and discussion of the algorithm.

Chapter 3 will be aboutErrror calculation, test result and discussion with the graphs we get at the simulation using different modulation technique.

Chapter 4 will be about summery of the whole project

Chapter 5 will be conclusion and future work.

Chapter 2

Orthogonal frequency division modulation (OFDM)

Multiple inputs and multiple outputs (MIMO)

System implementation

Orthogonal frequency division multiplexing:

OFDM is a method of encoding digital data on multiple carrier frequency. OFDM takes several low data rate frequency channels and then combined them into one high data rate frequency channel. This multiplexing system is developed into wideband digital communication used for both wireless and copper wires communication. OFDM data are modulated to time signal. OFDM data can be generated using Q-PSK, 16-PSK, 256-PSK, B-PSK etc. Symbols are divided into frames so that data can be modulated frame by frame during modulation of the OFDM data. OFDM data has long symbol period by which we can minimize ISI but could not eliminate it properly. Cyclic extension can be a best solution for closely eliminating ISI. Cyclic extension or guard period is the amount of uncertainty which is permit able for the receiver to identify the header of the symbol period.

Orthogonality:

Having a sum of products of an integral that is zero or sometimes are under specified conditions are said to be orthogonality to each other. Multiple of two sinusoids signal with same frequencies can fulfill this condition

$$\int_0^T \cos(2\pi nft)\cos(2\pi mft)\,dt = 0 \,(n \neq m)$$

When n and m are two unequal integers, f is fundamental frequency and t is the time period.

Multiple-input and multiple-output:

Multiple-input and multiple-output or MIMO is a technology in which multiple antennas are used at both the transmitter and receiver. This method advances our communication performance. Now-a-days MIMO technology is widely used in wireless communication because the antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. Similarly it increases in data throughput and link range without additional bandwidth or increased transmit power. By using this technique, we extant the same total transmit power through the antennas. For example, if we have 100 bytes data then using MIMO technology we can use two transmitter and receiver where each transmitter can send 50 bytes data. If we use four transmitter and receiver then 25 bytes data will process. As we know that increasing the number of antennas can dramatically improve the performance. In our project, we use two transmitter and receiver. Also to develop spectral efficiency and link reliability for reducing fading.

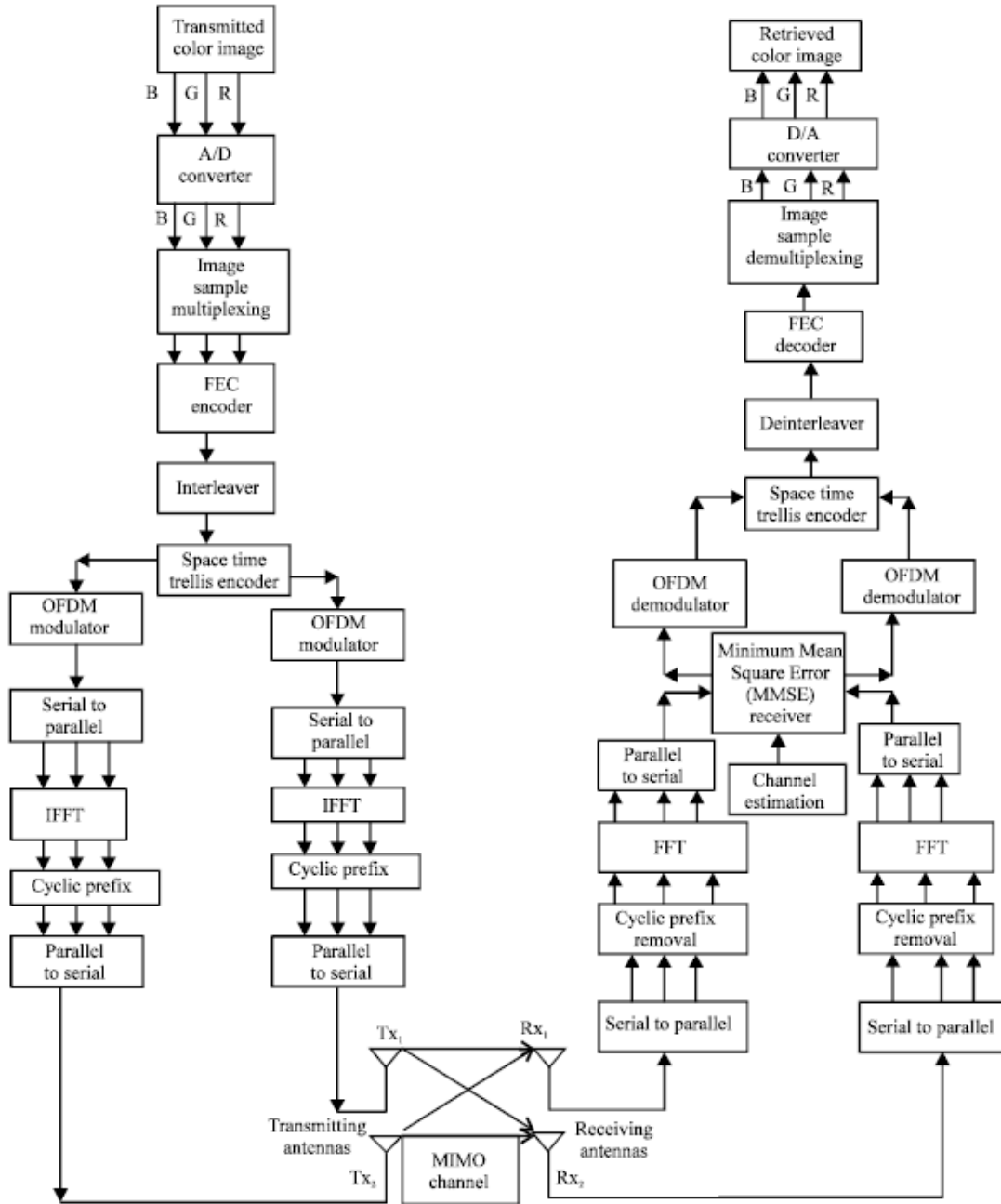# Implementation: MIMO OFDM combining system

Figure: OFDM-MIMO combining system

System configuration and parameters:

In our matlab program, a new script file "main_ofdm" is opened when the medical image and all script files saved in current directory. After initializing all the codes in the matlab program, we required some parameters to calculate errors separately for R,G and B.Here,parameters are given below.

1) Input file-medical image in jpeg format.

2) IFFT size –an integer of a power of two. For example, 1024, 2048 etc.

3) Numberofcarriers $\leq \frac{\text{IFFT\_size}}{2} - 2$

If IFFT is 1024 then number of carriers is 400.

 4) Digital modulation method method-BPSK, QPSK, 16-PSK, 256-PSK.

 5) Signal pick power clipping is 9 dB

 6) Signal to noise ratio is 12 dB

Input:

In OFDM-MIMO combined system a non-compressed digital color image (RGB) in joint photographic expert group (JPEG) format is used. Matlab simulation program obtain an matrix which is h by w. Here h represent the height of the image and w represents the width of the image and then matrix is reorganized into a serial data stream. Since the image is a medical related image RGB then converted to digital image component after passing through analog to digital conversion. Then each component of RGB image are multiplexed serially and then used as an input into FEC encoder.

Encoding:

In the FEC encoder various types of FEC codes such as RS BCH CC are used to protect data from being corrupted. FEC encoder is one of the special code where sender adds part of the data called redundancy which can be detect by the receiver. One of the advantage of the FEC encoder is there is no need for retransmission. FEC gives receiver the ability to do the correction without needing a reverse channel. But only higher bandwidth is required which sometimes become much costly in case of broadcasting to multiple receivers. A predetermined algorithom is used to set the redundancy for transmitting information. A redundant bit is a complex function of the original bits.

Interleaver:

It is a way to arrange memory to increase performance. Most of the time it is used in data transmission ,data storage or memory. Also it is frequently used in digital communication and storage to improve the performance of the FEC encoder. If the number of error in a code word of FEC encoder is exceeds interleaver can sort out the problem. After encoding the error in interleaver space time trail code is used in multiple antenna wireless communication.

Frame guard:

Header	Frame guard	Modulated signal	Frame guard	Header

Frame guard is used to minimize the interference between two signal. If the total number of data stream to be transmitted is less than total number of symbols per frame. The data would not be distributed into frames and would be modulated only once. Even if the data stream is not sufficiently long to be distributed into multiple number of frame. Two frame guards with all zero values and in a length of one symbol period are still added to both end of modulated time signal. This is to help the receiver to locate the beginning of the extensive portion of the time signal. A frame guard is inserted in between any neighboring frames, as well as both end of the concatenated time signal. To conclude a pair of header is padded to both end of the guarded series of frames.

Modulation technique:

Here we use QPSK modulation technique. In case of SISO (single input single output), we don't need to convert data stream from serial to parallel because single transmitter and receiver is used. But in case of MIMO (multiple input multiple output) we need to do the conversion. Padding is done in modulator. OFDM modulator pad a number of zeros to the end of the data stream just to adjust in the 2-D matrix. We use IFFT size 1024 or more than that, because a frame can carry 1024 or more than that data. Number of carriers also depend on the size of IFFT .number of carriers must be half less than IFFT size.

No of carriers $\leq \frac{\text{IFFT\_SIZE}}{2} - 2$

30       $\Big\{$ 404 | Data(400) | $\Big\}$
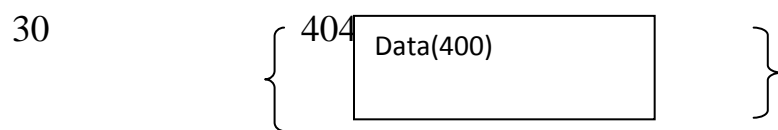
Figure: data transmitting matrix

400 carriers are used in this OFDM simulation. So 1024/400 symbols/carrier are being transmitted by 400 carrier with a capacity of 30 symbolls/carrier.

QPSK:

QPSK used to double the data rate compared to other modulation technique. It takes 2 bits per sumbol and four phases.

(symbol size= 2^2 = 4)

IFFT :

A Fourier transform convert a signal from time to frequency division or vice versa. The inverse fast Fourier just inverse the operation whatever is done by FFT. FFT is a computational algorithm, which is applied to the discrete data so that transform are done by summing instead of integration. In our project QPSK matrix represents a carrier which are saved in the column of IFFT. Both QPSK and IFFT carrier are aligned and their conjugate values are stored to the column corresponding to the locations of the conjugate carrier. To achieve the transmitting time signal matrix all other column in the IFFT of the matrix set to zero and IFFT of the matrix is taken. Real part of the IFFT is used for calculation and imaginary part is discarded.

Periodic time guard insertion: 1280

31   31
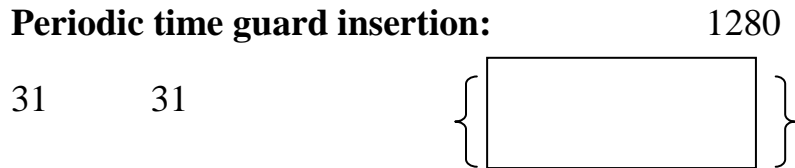
Figure: modulated matrix

After modulation, the final 25% accurate portion of each symbol period is inserted to the beginning. in the figure, the matrix is extra widened to a width of 1280.while demodulating each symbol period of the received signal, periodic time guard helps to synchronize the signal. The periodic time guard which is an matrix becomes a modulated matrix. In case of MIMO after converting to a serial form a modulated time signal is generated for one frame of data.

Communication Channel:

In MATLAB simulation, numbers of channels are set by the users. Two properties are used in communication channel which are peak power amplitude clipping and Signal-to-Noise Ratio. These properties are fixed by the user. We added white Gaussian noise (AWGN) at Alamouti scheme in the channel matrix. Channel noise of AWGN is defined by-

$$\sigma \text{ of AWGN} = \sqrt{\frac{variance of t\ hemodulatedsignal}{linearSNR}}$$

It has a mean of zero and standard deviation which is equal to square root of the proportion of the difference of the signal over the linear Signal-to-Noise Ratio (SNR). This value is set as dB value. Raleigh distribution channel matrix is created by adding Gaussian noise in the channel.

MIMO operation:

Multiple-input and multiple-output or MIMO is a technology in which multiple antennas are used at both the transmitter and receiver. This method advances our communication performance. Now-a-days MIMO technology is widely used in wireless communication because the antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. Similarly it increases in data throughput and link range without additional bandwidth or increased transmit power. By using this technique, we extant the same total transmit power through the antennas. For example, if we have 100 bytes data then using MIMO technology we can use two transmitter and receiver where each transmitter can send 50 bytes data. If we use four transmitter and receiver then 25 bytes data will process.As we know that increasing the number of antennas can dramatically improve the performance. In our project, we use two transmitter and receiver. After getting the encoded OFDM data we used MIMO in our simulation project.The total encoded data are equally divided to two transmitters. we used 100 frames for making data packets in the transmitter.These data frames are send from transmitter to receiver via channels.InMIMO,framelength,intilization variable like pre allocation for speed,per data length,channel matrix are need to set before running a code.Among different types of algorithm for transmitting image alamoti scheme is most preferable because both transmitting and receiving of image in MIMO are done by this method.

OFDM receiver:

At the receiver the frame detector detect the signal and then we received data packets from MIMO channel. At the beginning, the selective portion is relatively large because of taking header into account. Then the received signal is sampled to a shorter discrete signal with a sampling rate defined by the system. As we have done RGB in three different plates, another simulation technique is used to calculate the total sum which is taken over this sampled signal. After that frame detector will collect total moving sum of the input signal from about 10% of one symbol period. The moving sum is discarded because its length is less than a symbol period. The minimum moving sum is recognized as start of the signal frame.

Error calculation method:

Maximum ratio combiner: various techniques are used to add the signals from MIMO channel. In wireless communication system maximum ratio combining system is one of the useful techniques to compute error at the detector. In MRC signal is multiplied by weight factor which is proportional to the signal amplitudes. Different proportionality constants are used for each signal that coming out from MIMO channel. R B G values are calculated through this method and then plot a graph which almost same to the theoretical graph.

Demodulator:OFDM

OFDM demodulator is basically a reverse process of OFDM modulation which demodulates the received data frame by frame except in one condition of data length less than the designed total number of symbol per frame.
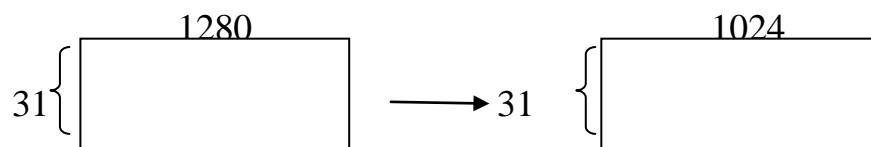
Time guard removal:

Figure: Time guard removal

This figure shows that after converting a frame of discrete time signal from serial to parallel 25% of symbol pried is discarded from all rows. The residual is then we get the parallel signal with the length of one symbol period.

FFT(fast Fourier transform):

1024

3131 | Data | conjugate |

400   400

400

| Reference row |
| data |
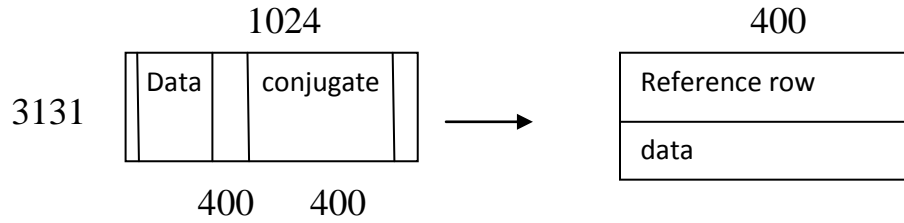
Figure: received data extracted from FFT bins

The column in the location of carrier is extracted to receive the complex matrix of the received data.

Chapter 3

Error Calculation, Test result, and discussion

Chapter 3

Error Calculation:

Data loss:

During transmission image may become distorted due to different kind of interference through the channel. For this reason, one or more of full rows of pixel may be missing at the output of the receiver.

Bit error rate:

Bit error is defined as the rate at which errors occur in a transmission system. There is a possibility of errors being introduced into the system during transmission as a result of noise, interference, distortion and bit synchronization error. Demodulated data is need to match up original baseband data to find the total number of error. This can be directly translated into a simple formula.

BER = (total number of error)/(total number of demodulated data)

When the medium between transmitter and receiver is good and SNR is high, then bit error will be small.

Phase Error:

Phase error is defined by the difference between the received phase and the translated phase corresponding symbol before transmission during OFDM demodulation. Before being converted into symbol values, the received phase matrix is store up to compute the average phase error.

Percentage error of pixel in the received image:

The percentage error can be get by comparing the received image and the original image pixel by pixel.

An 1024-by-768 image is transmitted by 400 carriers using an IFFT size of 1024 through a channel with 9dB peak power clipping and 30 dB SNR.

```
#**************** Summary of Errors in R Matrix ****************#
Total number of errors = 5878 (out of 3145728)
Bit Error Rate (BER) = 0.186857%
Average Phase Error = 11.270135 (degree)
Percent error of pixels of the received image = 0.744756%

##########################################
#******** END of OFDM Simulation ********#
##########################################
```

Fig: Error Calculation

Test result:

| Parameters	values
Source image size	1024×768
IFFT size	1024
Numbers of carriers	400
Modulation method	QPSK
Peak Power Clipping	9 dB
Signal to noise ratio	12 dB

Table: parameters of Simulation

After simulation we get bit error rate 0.18% when the percent error in output image pixels is 0.74%.here OFDM symbol size and word size of the data source are different.QPSK symbol is designed for one 8 bit word and when QPSK symbols are decoded incorrectly, the whole 8 bit word is mistranslated. In BER calculation our main target is to find out the accurateness of transmitter and receiver where only one QPSK symbols that are counted which is decoded incorrectly. We get average phase error of 11.27 which means that there is still a distance from the tolerance of 45 degree .when pixel per error is 0.74% the noise on the output image is recognizable. First graph in the transmitter plots shows IFFT bins are fully used by the carriers. As well as, second graph shows the collection of phases dispersed to 4 levels of QPSK and those values are scattered in the second graph of receiver plots. The amplitudes of the received data are not as flat as the original one in the first graph of transmitter plot but it still maintains the same pattern. The simulation runtime for both the transmitter and receiver don't appear to differ much if faking the number of carriers and IFFT size to about half while all other parameters remain the same. This is for the reason the simulation program monitors the total number of symbols to form one frame of data and thus total number of frames did not

differmuch. Additionally the runtime measured depends on the number of computer operation, which directly depends on the number of data needed to be modulated and demodulated for a fixed number of symbols per frame. In brief, this runtime measurement does not reflect the difference of the effectiveness based on varied number of carriers.
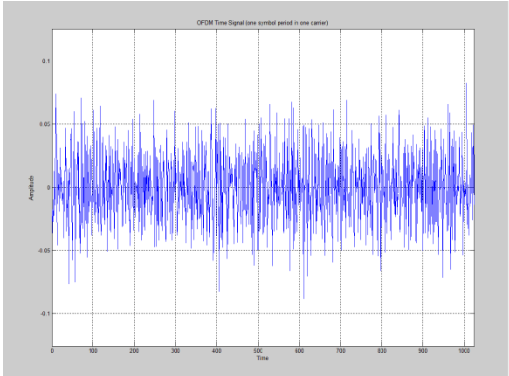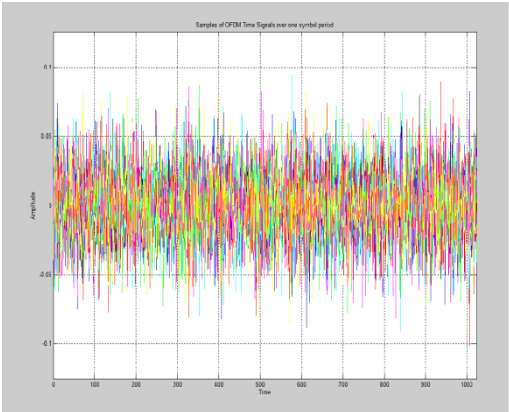
Transmitter plots:
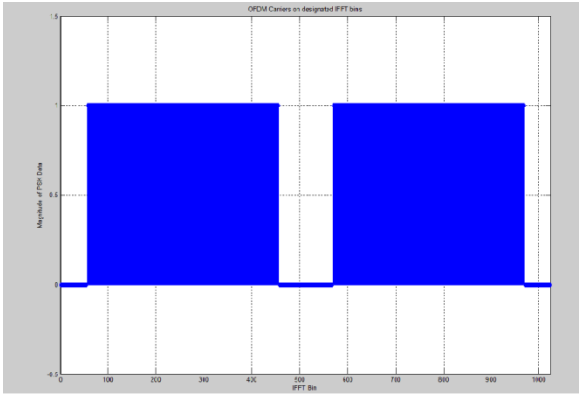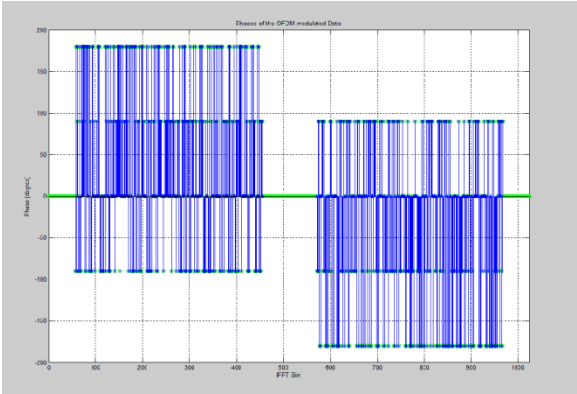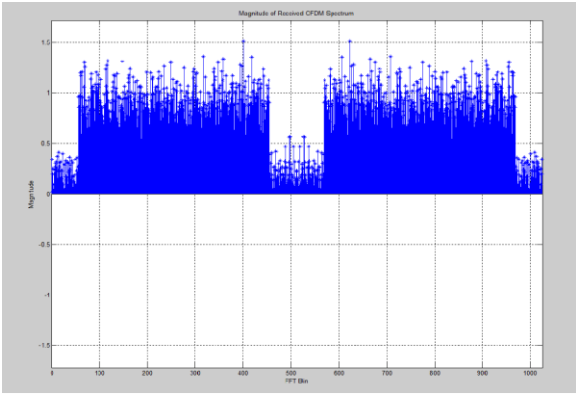

Plot 1   plot 2

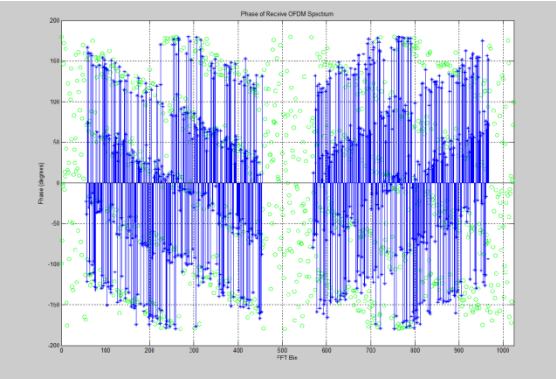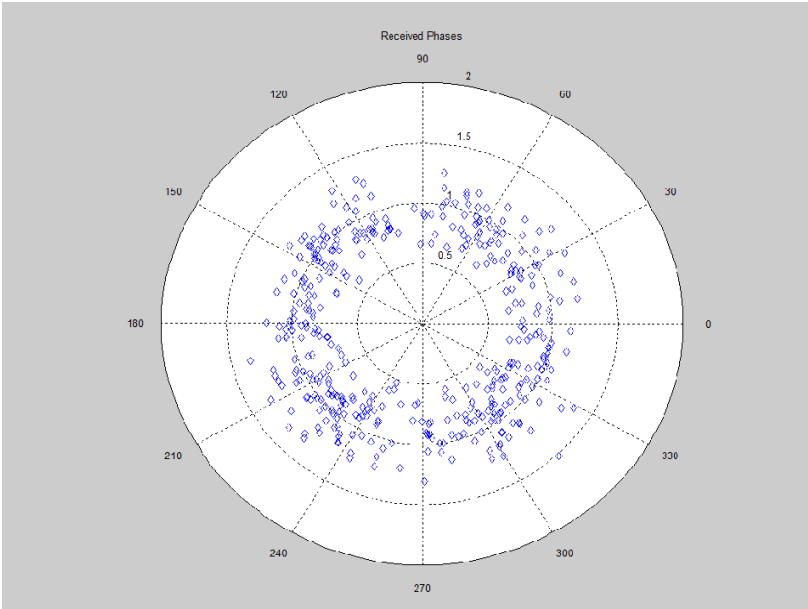Plot 3   plot

Figure: transmitter plots

Receiver plots:

Plot 5

plot 6

Plot 7

Figure: OFDM receiver plots

Plotting:

Seven graphs have been plotted during OFDM modulation.

First graph:

IFFT bins are fully utilized by the magnitude of the carrier. Here all magnitude are ONE and spread out in the IFFT bins.

2nd graph:

Total OFDM phase data are distributed to the total IFFT bin size. Phases are translated from the OFDM data and it is very simple to notice that original data has a number of possible levels equal to 2 raised to the power of symbol size.

3rd graph:

Shows the first symbol period of the modulated signal in the first frame of data.

4th graph:

Shows the modulated time signal up to the first six symbol periods in the first frame.

5th graph:

These are the magnitude of the received OFDM spectrum which will be compared to the first graph.

6th graph:

Phases of the received OFDM spectrum which need to compare to the second graph.

7th graph:

Shows the combination of the received phases into 2^symbol size constellation.OFDM transmission and reception should have this plot if the operation becomes successful.

The first and last segment of the modulated data has a probability of catching error as a result of imprecision in synchronization. Moreover, a sample of symbol period used by the fifth, sixth and seventh plots are from exact middle of a frame. On the other hand, the sample taken for the demodulation plots is still incorrect on certain trials of this matlab simulation.
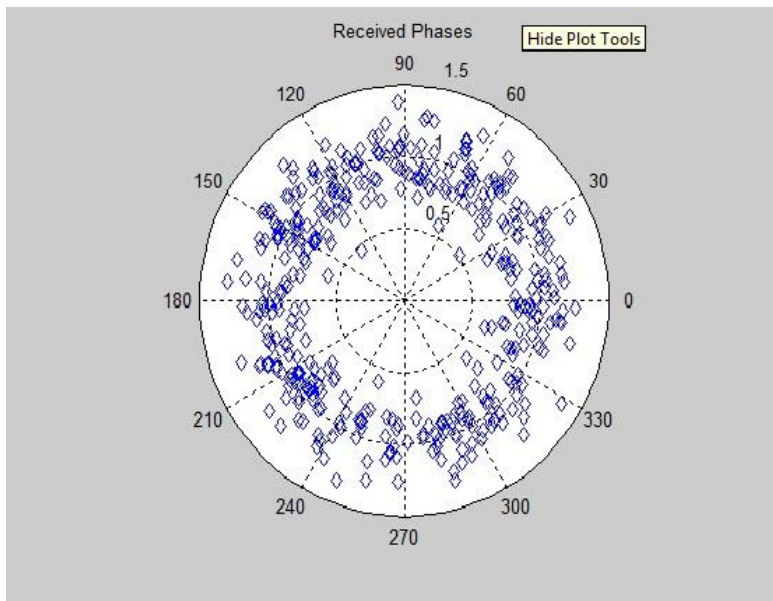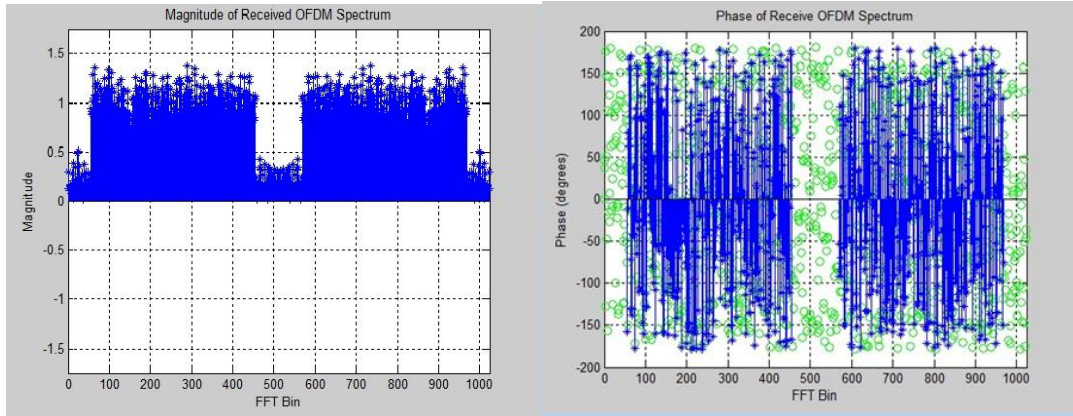
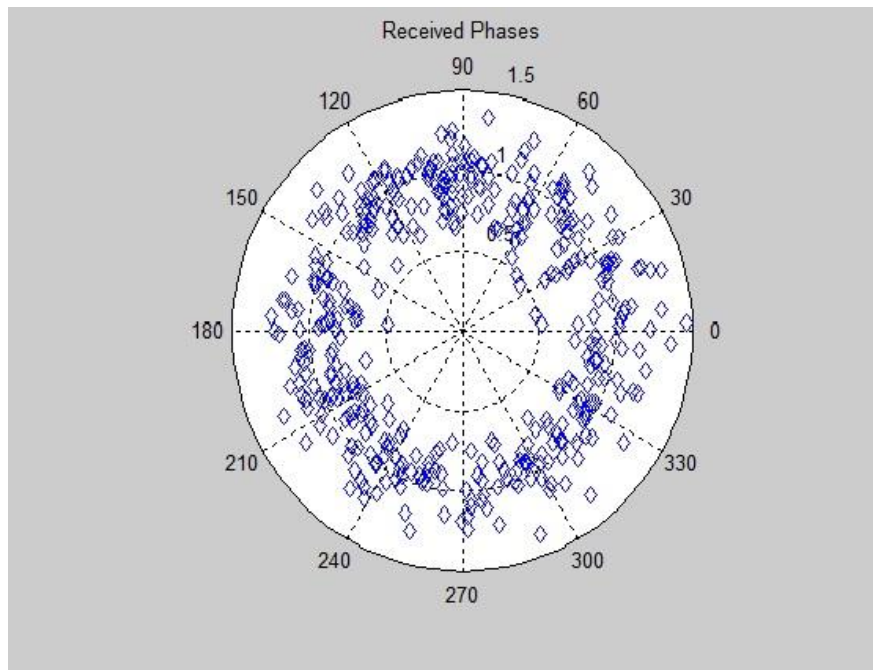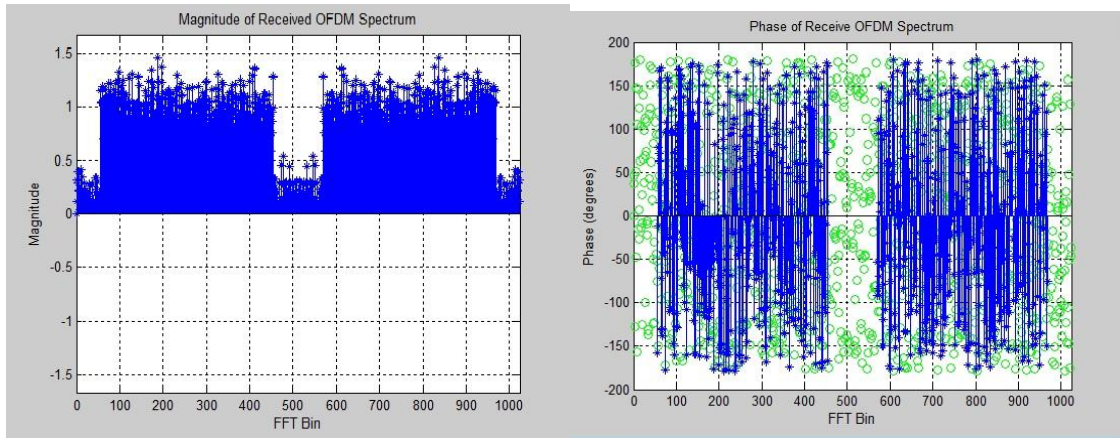Figure: Received plots using 16-PSK by using the same parameters

Figure: Received plots using 256-PSK by using same parameters.

Each modulation system has work on different BER and SNR using the same jpeg image but each has different results. Quality of the image differ from every modulation technique like BPSK,16-PSK,256-PSK.Hence,we keep the parameters same in every modulation system. We have found a balance trade off in all modulation technique.

Screen log

source data filename: cell.jpg

Output file will be: cell_OFDM.jpg

IFFT size: 1024

Number of carriers: 400

Modulation(1=BPSK, 2=QPSK, 4=16PSK, 8=256PSK): 2

Amplitude clipping introduced by communication channel (in dB):9

Signal-to-Noise Ratio (SNR) in dB: 12

Summary of the OFDM transmission and channel modeling:

Peak to RMS power ratio at entrance of channel is: 14.605877 dB

Peak to RMS power ratio at exit of channel is: 9.836256 dB

#****** OFDM data transmitted in 37.401486 seconds ********#**

Press any key to let OFDM RECEIVER proceed...

Demodulating Frame #1

Demodulating Frame #37

Demodulating Frame #74

Demodulating Frame #111

Demodulating Frame #148

Demodulating Frame #185

Demodulating Frame #222

Demodulating Frame #259

Demodulating Frame #296

Demodulating Frame #333

Demodulating Frame #370

Demodulating Frame #375

#******** OFDM data received in 14.690276 seconds *********#**

#************* Summary of Errors in R Matrix ***************#**

Total number of errors = 5878 (out of 3145728)

Bit Error Rate (BER) = 0.186857%

Average Phase Error = 11.270135 (degree)

Percent error of pixels of the received image = 0.744756%

###

#******* END of OFDM Simulation *********#**

###

Summary of the OFDM transmission and channel modeling:

Peak to RMS power ratio at entrance of channel is: 14.882200 dB

Peak to RMS power ratio at exit of channel is: 9.861563 dB

#******* OFDM data transmitted in 32.144298 seconds *********#**

Press any key to let OFDM RECEIVER proceed...

400

Chapter 4

Review of the paper

Summary:

This paper discussed a medical image of jpeg format which is transmitted by multiple transmitters. On the other hand, image is decoded from the multiple receivers through multiple channels. Inside the simulated code, various methods which are extremely fruitful like FEC encoder, interleaver, and most proficient modulation technique like OFDM has been introduce.MIMO associated with OFDM gives us a huge platform for developing communication system. At the receiver all methods are undoing and retrieve the color image. Different error calculation method like maximum ratio combiner, alamouti scheme is very effective in case of retrieving image with less error/close to original image.

Chapter 5

Conclusion and Future work

Chapter 5

Conclusion:

As a assured technology for future wireless communication OFDM-MIMO has gained more and more concentrations in recent year. In this paper, we have discussed Alamoutischeme, cyclic prefix and different type of modulation technique over an additive white Gaussian noise besides other fading like Raleigh for two transmitters and receiver antennas. Our OFDM-MIMO combiner system is effectively simulated in MATLAB. Simulation matching steps in modulator and demodulator, maintain the path of data format and data size in the whole simulation, planning a proper frame detector were our challenging issues for developing OFDM simulation program. When we simulate the program, we may face some problems in trials but may achieve for repeated trials with the same parameters because for random noise generated in every trial. After creating OFDM simulation we use multiple inputs and multiple outputs at both ends of a wireless link which minimize errors and increase data rate. The use of MIMO technology in combination with OFDM seems to be an attractive solution for future wireless system.

Future work:

In future we want to work on it get accuracy more close to 100%. And also want to develop it with newer technology like fastest modulation technique using multiple channels. Delay can be ignored in future by using other error calculation method.

Appendix A – Glossary and Acronyms

JPEG   Joint Photographic Expert Group

FEC   Forward Error Correction

STTC   Space Time Trellis Code

ISI   Inter Symbol Interference

MMSE   Minimum Mean Square Error

RS   Reed Solomon

BCH   Bose-Chadhuri-Hocquenghem

CC   Cyclic Code

QPSK   Quadrature Phase Shift Keying

OFDM   Orthogonal Frequency Division Multiplexing

MIMO   Multiple Input Multiple Output

FFT   Fast Fourier Transform

IFFT   Inverse Fast Fourier Transform

AWGN   Added White Gaussian Noise

MRC   Maximum Ratio Combiner

Symbol size   Number of bits per symbol to indicate number of levels represented by one Symbol.

Word size   Essentially the same as symbol size, but it's the "symbol size" of the file dataformat in this simulation.

References:

1).Haque,D.,Ullah,S.E.,Rahman,M. &Abadin,A.F.M.Z.(2010).Performance Evaluation of a FEC Encoded MIMO-OFDM Wireless Communication system on color image Transmission. Journal of Mobile Communication,3(4),62-67.http://www.medwelljournals.com/fulltext/?doi=jmcomm.2009.62.67

2)Jayakumari,J.(2010).MIMO-OFDM for 4G wireless systems. International journal of Engineering Science and Technology,2(7),2886-2889

3)Sinha,N.B.,Snai,M.C. &Mitra,M.(2010).Performance Enhancement of MIMO-OFDM Technology for high Data rate Wireless Networks. International journal of computer science and application issue.

4).Srikanth,N(2012).progressive image transmission over STC-OFDM based MIMO systems. International conference on computing and control Engineering,12&13 April,2012

5).DEEPA,R. &Baskaran,K.(2010).An adaptive power allocation scheme for robust transmission of jpeg compressed images over MIMO-OFDM systems. International journal of Engineering Science and technology,2(7),3120-3127.

6).Safar,W. Y. Z. & Ray Liu, K.J.Rate Efficient Wireless Image Transmission using MIMO-OFDM.Department of electrical and computer Engineering, University of Maryland, College Park,MD,20747.