Implementation of OFDM Technique under the Influence of AWGN Channel for BER and PAPR Reduction

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***Abstract*— The past five decades have witnessed startling advances in digital communication technologies by the availability of faster, more reliable, and cheaper electronic components. The most drastic change is the multi-carrier transition with high SNR and low BER. In the last decade, a new transition technique has occurred i.e. OFDM by the means of ASK, FSK and PSK. In digital communications, the modulation is the process of transmitting time-domain message signals over channel in the bits form. In this paper, a digital data corresponding to a 2D Gray-scale image is used to estimate the overall performance of a modeled AWGN channel under the influence of modulation techniques such as BPSK, QPSK and 16-PSK.**

***Keywords:* OFDM, QPSK, 16-PSK, FFT, IFFT, AWGN, PAPR, Bit Error Rate, SNR.**

I. INTRODUCTION

The past five decades have witnessed startling advances in digital communication technologies by the availability of faster, more reliable, and cheaper electronic components. With the increasing complexity of these communication systems comes increasing complexity in the type of content being transmitted and received. In digital communication systems, the time-domain message signals are transformed to bits-form of different sizes by the means of IFFT bins allocator.

In single carrier communication system, the symbol period must be much greater than the delay time in order to avoid inter-symbol interference (ISI). Since data rate is inversely proportional to symbol period, having long symbol periods means low data rate and communication inefficiency. [1] While in a multicarrier system, such as OFDM (aka: Orthogonal Frequency Division Multiplexing), divides the total available bandwidth in the spectrum into sub-bands for multiple carriers to transmit in parallel [2]. An overall high data rate can be achieved by placing carriers closely in the spectrum techniques are continuously being developed to maximize data throughput and efficiency in these wireless communication systems while endeavouring to keep data loss and error to a minimum. The main aim in this paper is for reducing PAPR, by the means of QPSK and 16-PSK modulation techniques.

In this paper, basics of OFDM is discussed in section II, Gray-scale image in section III, OFDM Communication system in section IV,Peak-to-Average Power clipping as method of PAPR reduction technique has been proposed and simulated by QPSK and 16-PSK modulation schemes are discussed in section V, Results and Discussion in section VI and Conclusion in section VII.

II. OFDM BASICS

In digital communications, information is expressed in the form of bits. The term symbol refers to a collection of bits in various sizes, [6]. OFDM data are generated by taking symbols in the spectral space using QPSK, 16-PSK, etc., and convert the spectra to time domain by taking the Inverse Discrete Fourier Transform (IDFT). Since Inverse Fast Fourier Transform (IFFT) is more cost effective to implement, it is usually used instead [3]. A multi-carrier system, transmit more signals at the same time through separate channels, termed as sub-carriers. Due to sub-carriers, the signals do not interfere with the others and from each sub-carrier, the transmitted signals are recovered.

OFDM is a multi-carrier transmission scheme, in which a high-speed serial data stream is distributed into a set of low-speed sub-streams, each of which is modulated on a separate carrier frequency (FDM) by means of Phase Shift Keying. However, the bandwidth of the sub-carriers becomes small in compared to the coherence bandwidth of the entire channel; that is, the individual sub-carriers experiences flat-fading, which allows for equalization. This implies that the symbol period of the sub-carriers must be made long enough as compared to the delay spread of the time-domain dispersive radio channels.

III. GRAY-SCALE IMAGE

The message signal chosen for the estimation of OFDM system over an AWGN channel is Gray-scale bitmap image as shown in Fig. 1. It can be accessed by the name ‘guitar’. The description of this image is given in Table: 1. Each pixel value is represented in unsigned integer format of 8-bits (0-255). Initially, this image is not in suitable format for direct transmission over the digital communication systems. Firstly, the image to be sent is in 2-D format is to be converted into an array representation of linear form which is transmitted over the OFDM system after superimposing the modulation technique. For example, if use QPSK modulation, then we need to convert linear array data into binary data of 2-bits results in four signaling elements i.e. 00, 01, 10 and 11. Now, this data is used as source data for the OFDM transmitter.

At the receiver, after recovering the digital bits, the original test image can be reconstructed by performing the inverse operations corresponding to the operations as performed in the transmitter section.

Fig. 1: Original Test Image 'guitar.bmp'.

IV. OFDM COMMUNICATION SYSTEM

The OFDM System is a simple model of a digital communication system. This model comprises of several modules and each of these modules is defined in respect to its effect on the data and the system. As this model comprises the whole of the system within it. These include the source codes, equalization of the AWGN channel, Modulation/ Demodulation, and IFFT/FFT. The Digital Communication system utilizes the linear array source sequence of digital bits as an interface between the source and the input channel.

Fig.2 represents the simplified model of digital communication, on this basis the first three modules of the diagram (source encoder, modulator and channel encoder) together are termed as transmitter. The source represents the message signals to be transmitted over the AWGN channel, in this case a Gray-scale image. This time-domain message signal must be converted to digital bits, this conversion from analog to digital (ADC) is accomplished in the source encoder module. The digital sequence as an output from the source encoder is in the serial form is converted to parallel form(by the means of S/P convertor) so as to assign the data onto a multiple sub-carriers and further treated in the channel encoder(by the means of M-PSK techniques) for the transmission over the channel. After modulation, the N-point IFFT operation is performed and finally the message signal is transmitted over the sub-carriers.

The last three modules consisting of Detector/ Demodulator, a Channel decoder and a Source decoder are termed as receiver. At these modules, the corresponding inverse operations are performed so as to efficiently recover the transmitted image. The end-user waiting for the message is represented by the destination.

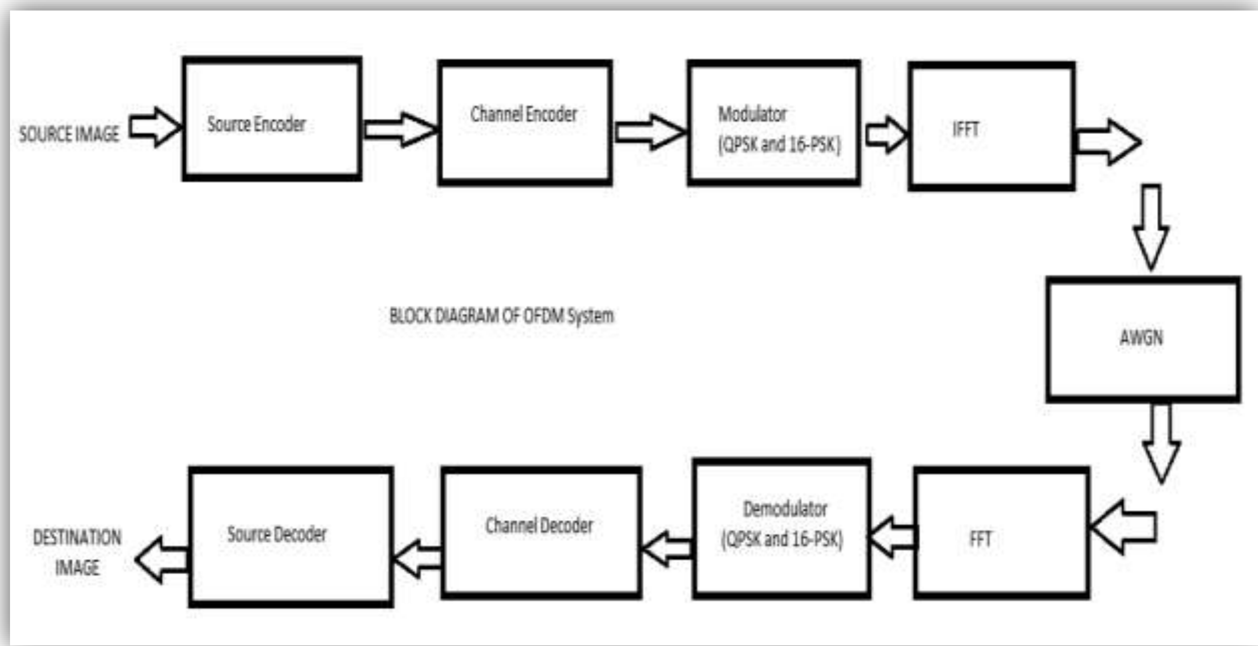

Fig.2: Block diagram of an OFDM Communication System

V. PAPR REDUCTION TECHNIQUE PROPOSED AND SIMULATED BY QPSK AND 16-PSK MODULATION SCHEMES

The mathematical modelling for image transmission through OFDM using QPSK and 16-PSK has been described by the methods of FFT (Fast Fourier transform) that has been employed for transmission of image. The aim of doing the simulations was to measure the performance of OFDM under different channel conditions, and to allow for different OFDM configurations to be tested. Four main criteria were used to assess the performance of the OFDM system. They are tolerance to multipath delay spread, peak power clipping, channel-noise and time synchronization errors. The OFDM system was modelled using MATLAB.

A brief description of the model is provided below:

a) RANDOM DATA GENERATOR

The input signal which we used is the random data generated by randn () function of the MATLAB.

b) Serial to Parallel Conversion

The input serial data stream is formatted into the word size required for transmission, e.g.2 bits/word for QPSK, and shifted into a parallel format. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

c) Modulation of Data

The data to be transmitted on each carrier is then differential encoded with previous symbols, then mapped into a Phase Shift Keying (PSK) format. Since differential encoding requires an initial phase reference an extra symbol is added at the start for this purpose. The data on each symbol is then mapped to a phase angle based on the modulation method. For example, for QPSK the phase angles used are 0^o, 90^o, 180^o, and 270^o. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading.

d) Inverse Fourier Transform

After the required spectrum is worked out, an inverse Fourier transform is used to find the corresponding time waveform. The guard period is then added to the start of each symbol.

e) Guard Period

The guard period used was made up of two sections. Half of the guard period time is a zero amplitude transmission. The other half of the guard period is a cyclic extension of the symbol to be transmitted. This was to allow for symbol timing to be easily recovered by envelope detection. However it was found that it was not required in any of the simulations as the timing could be accurately determined position of the samples. After the guard has been added, the symbols are then converted back to a serial time waveform. This is then the base band signal for the OFDM transmission.

f) Communication Channel

A channel model is then applied to the transmitted signal. The model allows for the signal to noise ratio, multipath, and peak power clipping to be controlled. The signal to noise ratio is set by adding a known amount of white noise to the transmitted signal. Multipath delay spread then added by simulating the delay spread using an FIR filter. The length of the FIR filter represents the maximum delay spread, while the coefficient amplitude represents the reflected signal magnitude.

g) PARALLEL TO SERIAL(P/S) CONVERTER

The parallel data is converted to the serial form to be passed through the channel.

h) AWGN NOISE

The serially transmitted data is corrupted by additive white Gaussian noise (zero mean) at a particular signal to noise ratio. As the SNR value increases, the chances of the bits being corrupted decreases.

i) RECEIVER

The receiver basically does the reverse operation to the transmitter. The serially received data is converted to parallel form and then guard period is removed. The FFT of each symbol is then taken to find the original transmitted spectrum. The OFDM symbols are then subjected to demodulation by using a bank of sub-carriers as those used in the transmitter. The words are combined back to produce the original data stream.

Problem associated with OFDM Systems is high Peak to Average Power Ratio:

Peak-to-average power ratio (PAPR) is a well-known issue with many communication systems that use the sum of many (N) un-modulated or identically modulated sinusoids in transmission. One particular system that employs this method in its transmission is OFDM with its N-orthogonal subcarriers used to multiplex together one OFDM symbol. The resulting high peak-to-average power ratio caused by this method is of particular concern when the signal needs to be passed through a high power amplifier for transmission.

Generally speaking the high power amplifiers used in wireless transmission systems have a linear response when used at low amplitude but for large amplitude input signals a non-linear response occurs in the amplifier, this means that for the amplification of OFDM symbols the occurrence of the high amplitude peaks will cause in-band and out-of band distortion to occur from the amplifier’s response.

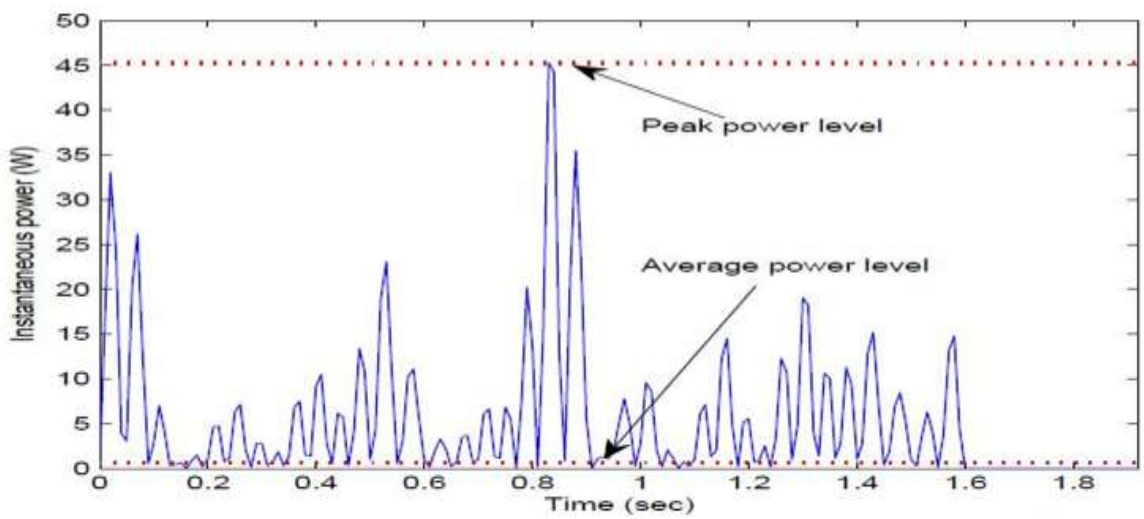

Figure 3: Power of an OFDM symbol with 16 carriers showing the large Peak-to- Average Power Ratio

Some of the work that has been performed to attempt to reduce the effect of high PAPR in OFDM includes the use of *clipping and filtering of the signal*, *block coding methods* and *clever constellation mapping technique.*

Clipping the high peaks of the OFDM signal is one of the easiest techniques employed to reduce the effect of a high peak-to-average power ratio, basically the amplitude peaks of the signal are clipped to a predetermined amplitude level using this method. This method does have the drawback of causing distortion to the signal due to clipping; this distortion can be considered as noise and affects both in- and out-of-band regions of the signal. Active constellation extension (ACE) is one method of reducing PAPR by altering the constellation map the data is being encoded onto. The concept behind this is presented in [5] and describes a method of extending the outer constellation points in M-PSK and QAM constellations and mapping the data onto these extended points.

j) Characteristics INPUT Test Image

PROPERTY	VALUE
Original Image Size	Dimensions = 600×800 = 469KB Width = 600 pixels Height = 800 pixels Bit depth =8
Total Pixels	480,000 pixels
Each Pixel Data Size	8-bits
Image type	Gray-scale (unit8) BMP file
For BPSK Transmission Size of Source Signal Data or Signal Elements	480,000*8 = 3,840,000
For QPSK Transmission Size of Source Signal Data or Signal Elements	480,000*8/2 = 1,920,000
For 16-PSK Transmission Size of Source Signal Data or Signal Elements	480,000*8/4 = 960,000

Table: 1 Characteristics INPUT Test Image

k) System Configurations and Parameters

A script file *ofdm_parameters.m* is invoked, which initializes all required OFDM parameters and program variables to start the simulation.

Some variables are entered by the user. The rest are either fixed or derived from the user-input and fixed variables. The user input variables are included in Table: 2.

PROPERTY	VALUE
IFFT size (must be at least 8 and power of 2)	512
Total Number of Sub-carriers & FFT size [must NOT be greater than ("IFFT size"/2 – 2)]	200
Type of Guard Interval inserted after IFFT at Transmitter	Cyclic Extension/Prefix
Modulation Schemes	1=BPSK, 2=QPSK, 3=16-PSK.
Channel	AWGN
Amplitude clipping introduced by Communication channel (in dB)	6 dB
Range of SNR(in dB) considered for evaluating BER	30 dB

Table: 2 MATLAB Simulation Parameters

VI. RESULTS AND DISCUSSION

The mathematical modelling of the system has been done for calculating the different values for parameters such as, Peak to average power ratio, Bit Error Rate, FFT and IFFT at different signal to noise ratio for investigating the performance of the system in terms of transmission time and reproducibility.The modulator 16-PSK modulates the pixel by pixel. The results show that using 16-PSK the transmission can tolerate a SNR of >25-30dB. The bit error rate BER gets rapidly worse as the SNR drops below 6dB. However, using QPSK allows the BER to be improved in a noisy channel, at the expense of transmission data capacity.

In Fig.3, The image transmission using various digital modulation techniques is shown.

BPSK	QPSK	16-PSK
		

Fig.3: Image Transmission using various Digital Modulation techniques

VII. CONCLUSION

The aim of this thesis was image transmission over digital communication system and examines various digital techniques such as BPSK, QPSK and 16-PSK using an Additive White Gaussian Noise channel and knows the best suitable modulation technique for image transmission over wireless digital communication system. Orthogonal Frequency Division Multiplexing (OFDM) has been used for image transmission of bitmap image (8-bit or 256 levels of grey-scale). The parameters for image transmission have been processed through MATLAB R2013a. The value of amplitude clipping in 9 dB has been used in plotting the transmitter and receiver plots of the image. The QPSK and 16-PSK modulation employed in the processing. Then the plot of received samples of the image at the output has been generated. The performance of the implemented method has been given in terms of Peak-to-Average Power Ratio (PAPR), Pixel Error, Bit Error Rate (BER) and bit rate capacity.

Like many of the other digital communication systems, the performance of this system is acceptable, up to certain level of noise from the critical channel. If the noise level is raised above this critical level, the performance of this system does not vary rapidly. The main advantage of this system is that, when the channel is under the condition of high noise i.e. SNR=0dB, the system generates a worse quality of image rather than lose the transmitted image completely. The simulation results are performed, when SNR is 9dB. The modulation technique 16-PSK provides better results than the other such as BPSK and QPSK.

REFERENCES

[1]. Ameya K. Naik and Nitin S. Nagori, "Optimal Modulation techniques for image transmission on a wireless OFDM system", *Proceedings of SPIT-IEEE Colloquium and International Conference, Mumbai, India, June 2008.*

[2]. Orlandos Grigoriadis, H. Srikanth Kamath, "BER Calculation Using MATLAB Simulation For OFDM Transmission", *International Multiconference of Engineers and Computer Scientists 2008, 19-21 March, 2008, Hong Kong.*

[3]. Prashant Tavde, Anupam Dubey, Dr.K.D. KULAT, "Performance Analysis of OFDM system", *International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 3, May-Jun 2012, pp.2550-2556 .*

[4]. Mehboob ul Amin, Randhir Singh, Javaid.A.Skeikh "Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) Based Image Transmission Using Hadamard Transform as PAPR Reduction Technique", *International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-4, April 2013.*

[5]. A. E. Jones, T. A. Wilkinson, and S. K. Barton, "Block Coding Scheme for Reduction of Peak to Mean Envelope Power Ratio of Multicarrier Transmission Schemes," *IEEE Electronic Letters, Vol. 30, No. 25, pp 2098-2099,Dec. 1994.*

[6]. D. R. Gimlin, and C. R. Patisaul, "On Minimizing the Peak-to-Average Power Ratio for the Sum of N Sinusoids," *IEEE Transactions on Communications, Vol. 41, No. 4, pp 631 - 635, Apr. 1993.*

[7]. S. H. Han, and J. H. Lee, "An Overview of Peak-to-Average Power Ratio Reduction Techniques for Multicarrier Transmission," *IEEE Wireless Communications, pp 56 - 65 , Apr. 2005.*

[8]. B. S. Krongold, and D. L. Jones, "PAR Reduction in OFDM via Active Constellation Extension," *IEEE Transactions on Broadcasting, Vol. 49, No.3, pp 258 - 268, Sep. 2003.*

[9]. D. Takahashi "An extended split-radix FFT algorithm IEEE Signal Processing", *Lett. vol. 8, no. 5, May 2001, pp. 145 – 147.*

[10]. Dharavathu Krishna and Dr. M.S. Anuradha, "Image Transmission through OFDM System under the Influence of AWGN Channel" *IOP Conf. Series: Materials Science and Engineering* ***225*** *(2017) 012217, ICMAEM-2017 IOP Publishing.*

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