

DWT-OFDM Using DAPSK Modulation over AWGN, Flat Fading and Frequency Selective Channels

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Abstract – Orthogonal frequency division multiplexing (OFDM) is a modulation technique that is widely used in many wireless communication systems. Now-a-days the requirements of wireless communication are to have high voice quality, high data rates, multimedia features, lightweight communication devices etc. But the wireless communication channel suffers from much impairment. One of them is fading which is due to the effect of multiple propagation paths, and the rapid movement of mobile communication devices. In a typical wireless communication environment, multiple propagation paths often exist from a transmitter to a receiver due to scattering by different objects. So, this is necessary to reduce the problem of fading.

In traditional OFDM based on fast Fourier transform (FFT) and discrete cosine transform (DCT) high side lobes are created. Hence, OFDM based on discrete wavelet transform is used in this work. DWT is more flexible in terms of data rate and has much lower side lobes than traditional OFDM. In this work, the performance of OFDM based on DWT is compared with that of traditional OFDM based on FFT and OFDM based on discrete cosine transform (DCT) through the use of differential amplitude phase shift keying (DAPSK) as modulation scheme. These systems are simulated over additive white Gaussian noise (AWGN), flat fading, and frequency-selective channels through MATLAB software. Simulation results reveal that the performance of the proposed system is better than that of the other two systems over all types of channels.

Index Terms – Fading, OFDM, Flat Fading channel, Frequency selective channel, AWGN, Wireless Communications.

1. INTRODUCTION

In Today's communication environment, a demand for high data rate, reliable high speed is prevalent. These requirement place indicative challenges to the parallel data transmission scheme which removes the problems faced with serial systems. The Orthogonal Frequency Division Multiplexing (OFDM) is a wideband multicarrier wireless digital communication technique that is based on modulation. With the wireless multimedia applications becoming more and more popular, the required bit rate / high speed are achieved due to OFDM multicarrier transmissions.

The distribution of the data bits over many carriers means that fading will cause some bits to be received in error while others are received correctly. By using an error-correcting code, which adds extra bits at the transmitter, it is possible to correct many or all of the bits that were incorrectly received.

There is an ever-growing need for the communication systems that can provide high data rates. Modulation schemes characterized by these high data rate transmissions can in turn incur ISI which is usually caused by the channel delay spread and as a result, high performance equalizers are required. Solution to this problem involves using multicarrier modulations (MCM), which divides the high data rate serial streams into a number of parallel streams with low data rates. The number of sub-channels is selected so as to increase the symbol time as compared to the channel delay spread, and also to reduce the sub-stream bandwidth size than the size of the channel coherence bandwidth so the ISI can be bearable. An instance of such MCM is the OFDM which is an FFT- based multicarrier modulation (MCM) scheme. OFDM modulation is the main contender for the communication systems required for the next generation.

Wavelet Transform based multicarrier modulation is seriously being investigated as an alternative to the conventional Fast Fourier Transform for use in OFDM systems due to the fact that they can provide all the same benefits as of the FFT-OFDM with an added benefit of low BER and carrier frequency timing offset [5]. Unlike the conventional FFT-OFDM system wavelet scheme satisfies the condition for orthogonality and achieves perfect reconstruction (PR) using the orthogonal filters of the Quadrature mirror filter (QMF) banks [6]. Discrete wavelet transform has large power spectral density as compared to FFT-OFDM due to the fact that DWT produce well contained side lobes with the narrower side lobe having the contained energy with reduced out-of-band emissions. The BER performance of the WT-based systems is better. Besides all these benefits wavelets also use multi-resolution analysis of the signal in which by the applied functions, the signal is well localized

both in time and frequency domain and their resolution[7]. This multi-resolution- time-frequency signal representation is achieved by some shifting (translation) and scaling. Digital signal processing has played a very vital role in the advancement of the communication systems.

The basic principle of OFDM system is the division of the total frequency spectrum into many sub carriers to achieve high spectral efficiency, the frequency responses of the sub-carriers are overlapping and orthogonal, hence the name OFDM. Orthogonality between two signals means that the two coexisting signals are independent of each other in a specified time interval and do not interact with each other. The concept of orthogonal signals is essential for the understanding of Orthogonal Frequency Division Multiplexing (OFDM) system.

2. OFDM SYSTEM

A block diagram of a OFDM system is shown in figure 1. The binary information is first grouped, coded and mapped according to the modulation in a “signal mapper”. After the serial to parallel conversion, an N- point inverse fast Fourier transform (IFFT) block transforms the data sequence in to time domain. Following the IFFT block, a cyclic extension of time length, chosen to be larger than the expected delay spread, is inserted to avoid inter-symbol and intercarrier interferences. At the receiver side, after passing through analog-to-digital converter (ADC) and removing the CP, the FFT is used to transform the data back to frequency domain. Lastly, the binary information data is obtained back after the demodulation and channel decoding.

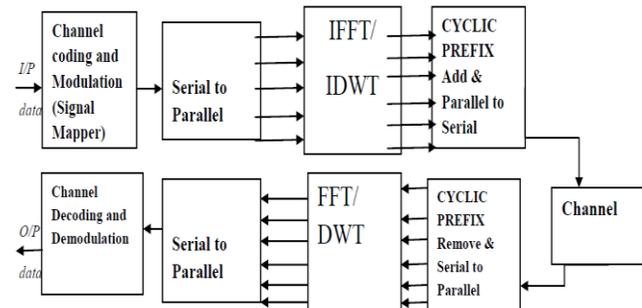


Figure 1: Block diagram of a OFDM system.

3. DISCRETE WAVELET TRANSFORM (DWT)

Discrete Wavelet Transform can be derived from the CWT. The discrete wavelet transform (DWT) is in literature commonly associated with signal expansion into (bi-) orthogonal wavelet bases. Thus, as opposed to the highly redundant CWT, there is no redundancy in the DWT of a signal; the scale is sampled at dyadic steps $a \in \{2^j : j \in \mathbb{Z}\}$, and the position is sampled proportionally to the scale $b \in \{k2^j : (j, k) \in \mathbb{Z}^2\}$.

By no means can a DWT be understood as a simple sampling from a CWT. In the first place, the choice of a wavelet is now far more restrictive: if we are dealing with finite-energy signals $f(x) \in L^2(\mathbb{R})$, the wavelet $\psi(x)$ has to be chosen such that $\{\psi(2^{-j}(x - 2^k))\} (j,k) \in \mathbb{Z}^2$ is a basis of $L^2(\mathbb{R})$. The systematic framework for constructing wavelet bases, known as the multiresolution analysis.

The orthogonal wavelets are rarely available as closed form expressions, but rather obtained through a computational procedure which uses discrete filters. The term “wavelets” refers to a orthonormal basis function that is generated by the translation and dilation of scaling function Φ and the mother wavelet ψ . A discrete wavelet transform is a finite scale multi resolution representation of a discrete function. Discrete wavelet transform is orthogonal and invertible where the inverse transform is expressed as the matrix is the transpose of the transform matrix. The wavelet function is localized in space, unlike sines and cosines in Fourier transform. Similar to sines and cosines the individual wavelet functions are localized in frequency. The wavelet basis is defined a

$$\psi_{(j,k)}(x) = 2^{j/2} \psi(2^j x - k)$$

The scaling function is mathematically given by

$$\phi_{(j,k)}(x) = 2^{j/2} \phi(2^j x - k)$$

Where ψ is the wavelet function and j and k are integers that scale and dilate the wavelet function. Factor ‘ j ’ in Equations is known as the scale index, which represents the width of the wavelet. The location index k gives the position. The wavelet function is dilated by powers of two and is translated by k which is an integer. In terms of the wavelet coefficients, the wavelet equation is

$$\psi(x) = \sum_k^{N-1} g_k \sqrt{2} \phi(2x - k)$$

function $\Phi(x)$ represents a scaling function and the coefficients h_0, h_1, \dots are low pass scaling coefficients. The wavelet and scaling coefficients are related by a quadrature mirror relationship which is given as

$$g_n = (-1)^n h_{1-n+N}$$

Where N is the number of vanishing moments.

3.2.1 Properties of DWT

Properties of a discrete wavelet transforms are given below.

- The wavelet coefficients of a fractional Brownian motion (fBm) support stationarity.
- Wavelet coefficients exhibit Gaussianity. This property aids wavelets in the removal of Gaussian noise from images.
- It provides a fast linear operation which can be efficiently applied on data vectors having length as integral power of 2.
- The wavelet coefficients are almost decorrelated.
- Discrete wavelet transform is invertible and orthogonal. The scaling function Φ and the wavelet function ψ are orthogonal to each other in $L_2(0, 1)$, i.e., $\langle \Phi, \psi \rangle = 0$.
- The wavelet function is localized in terms of space and frequency.
- The coefficients satisfies some constraints

$$\sum_{i=0}^{2N-1} h_i = \sqrt{2}$$

$$\sum_{i=0}^{2N-1} h_i h_{i+2l} = \delta_{l,0}$$

Here δ is the delta function and l is the location index.

4. DAPSK

In this section the mapping scheme or the modulation scheme that is used in this work is explained. DAPSK is a multilevel modulation technique. DAPSK is chosen as the modulation scheme as it doesn't require any channel estimation nor equalization at the receiver, which improves the complexity of the receiver compared to other modulation schemes. As any differential modulation technique DAPSK can be represented as follows:

$$S_{i,k} = B_{i,k} \cdot S_{i-1,k}$$

where $S_{i,k}$ is the complex symbol, $B_{i,k}$ is the bit sequence to be modulated and $S_{i-1,k}$ is the previous modulated complex symbol. In this work 64-DAPSK is employed. DAPSK uses both amplitude and phase for modulation. For 64-DAPSK the number of bits per modulated symbol or in other words the number of bits used to get $B_{i,k}$ is six. Those six bits are going to be referred to as b_0, b_1, b_2, b_3, b_4 and b_5 . The first four bits are responsible for the phase modulation while the last two bits will be responsible for the amplitude part along with the previous modulated symbol. $B_{i,k}$ in above equation can be represented as shown for 64-DAPSK.

$$B_{i,k} = a^q \cdot e^{j\pi\Delta\varphi}$$

$$q = 0, \dots, 3$$

$$n = 0, \dots, 15$$

$$\Delta\varphi = 22.5$$

where a^q represents the four possible amplitude levels and $e^{j\pi\Delta\varphi}$ represents the sixteen possible phase states as shown in the constellation diagram presented in figure 2. The four bits (b_0, \dots, b_3) that are responsible for the phase transition is applied to a normal 16-DPSK to satisfy the phase transitions shown in figure 2. To achieve the four amplitude circles as shown in the constellation diagram, bits b_4 and b_5 are used along with the amplitude of the previous modulated symbol $|S_{i-1,k}|$.

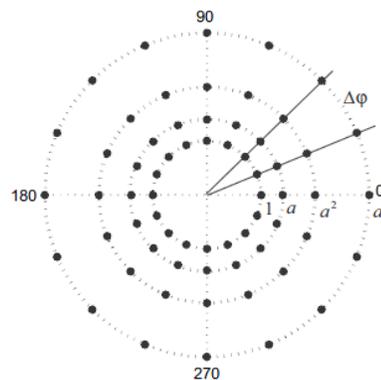


Figure 2: 64-DAPSK constellation diagram.

5. PERFORMANCE MEASURE OF COMMUNICATION SYSTEM

Some key measures of performance related to practical communication system design are as follows:

1. Signal to noise Ratio (SNR): It is a vital performance measure of a communication system. This performance measure is usually measured at the output of the receiver and indicates the overall quality of the system. For wireless communication system due to the presence of fading, the instantaneous SNR is a random variable.
2. Outage Probability: It is another important measure of performance to calculate the quality of service provided by wireless systems over fading channels and is defined as the probability that SINR falls below a certain threshold.
3. Average Bit Error Probability (BEP): It is one of the most informative indicators about the performance of the system. This measure can be obtained by averaging the conditional (on the fading) BEP over fading statistics.
4. Bit Error Rate (BER): In digital modulation techniques, due to some noise, interference, and distortion the received bits are

altered. So bit error rate is defined as the no of error bits divided by total no of bits transmitted.

$$\text{Bit Error Rate (BER)} = \frac{\text{No of bits in error}}{\text{Total no of transferred bits}}$$

The performance of modulation is calculated measuring BER with assumption that system is operating with Additive white Gaussian noise. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. Moreover, errors can be easily produced as the number of users is increased and the mobile terminal is subjected to mobility. Thus, it has driven many researches into the application of higher order modulations.

6. SYSTEM WORKING

The proposed system works as follows:

1. A random sequence of bits is generated and the number of bits is determined. For this simulation

Number of subcarriers=64

Message size=10

Bits per symbol for 64-DAPSK=6

2. Before the bits are modulated, they were divided into groups of six and put into a matrix form. The matrix consists of N rows which is the number of sub-carriers and S columns which is the number of OFDM symbols. The previous steps convert the signal from serial to parallel; each column in the matrix represents an OFDM symbol.
3. Evaluate the performance of a DWT based OFDM system adopting 64-DAPSK as the modulation scheme. A DFT based system and a DCT based system both adopting a 64-DAPSK modulation scheme are also implemented to compare the results with the DWT based system.
4. The performance of the DWT-OFDM system is evaluated over flat fading, frequency selective and AWGN channels. To evaluate the performance of the 64-DAPSK DWT-OFDM system and compare it to DFT-OFDM and DCT-OFDM systems, BER parameter is used. BER is measured at different SNRs.

7. SIMULATION RESULTS

Figure 3 shows the constellation diagram simulated for a sequence of randomly generated bits. BER is used to evaluate the performance DWT-OFDM system over different channel conditions, the results of the BER is presented. Figure 4 shows the BER at different SNRs for DWT-OFDM, DFT-OFDM and DCT-OFDM systems in the presence of AWGN only for the sake of comparison. It is clear that in case of the presence of AWGN the DWT-OFDM system outperforms the DFT-OFDM

and DCT-OFDM systems. The figure also demonstrates that both DFT-OFDM and DCT-OFDM systems have similar performance. The BER was also observed over a Rayleigh flat fading channel in the presence of AWGN in figure 5. The DWT-OFDM outperforms both the DFT-OFDM and the DCT-OFDM systems. Again DFT-OFDM and DCT-OFDM shows similar performance as each other. The performance over a Rayleigh multipath frequency selective channel in the presence of AWGN was also simulated. Figure 6 shows the performance curves in terms of BER for the DWT-OFDM, DFT-OFDM and DCT-OFDM systems over the frequency selective channel. It is observed that the DWT-OFDM system again outperforms both the DFT-OFDM and the DCT-OFDM systems. The performance curves of the DFT-OFDM and DCT-OFDM systems were almost the same at different SNRs.

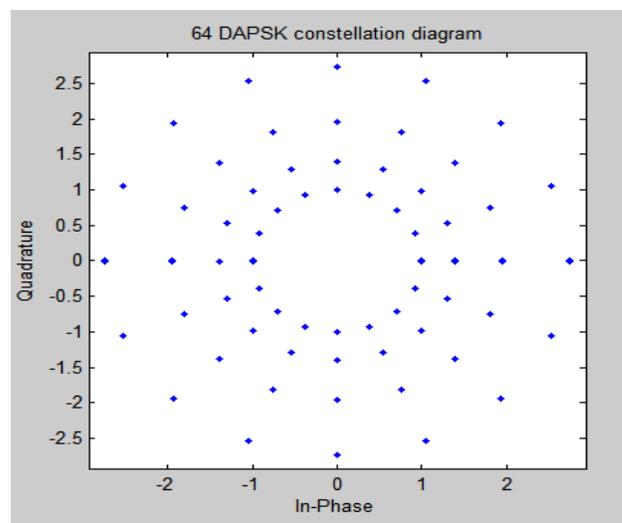


Figure 3: Simulated 64-DAPSK constellation diagram.

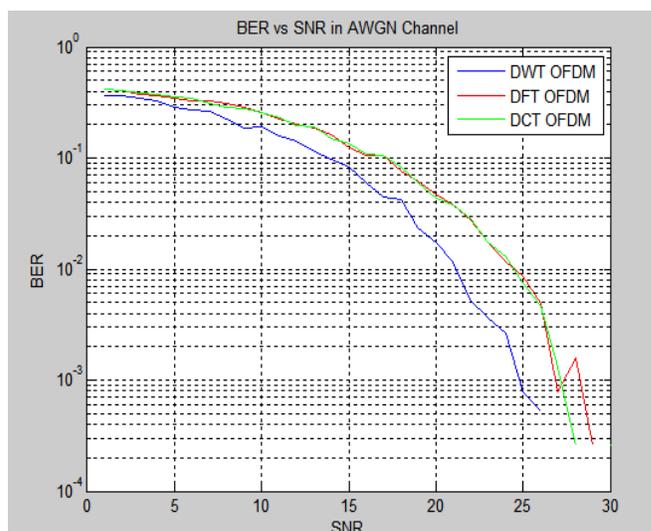


Figure 4: Performance of BER in the presence of AWGN at different SNR.

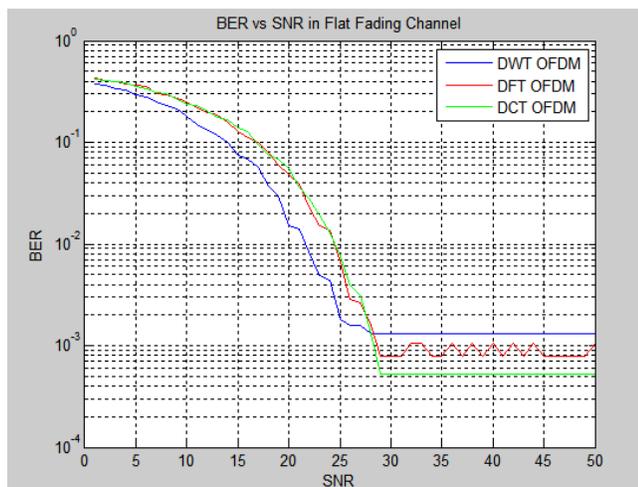


Figure 5: Performance of BER over Rayleigh flat fading channel in the presence of AWGN.

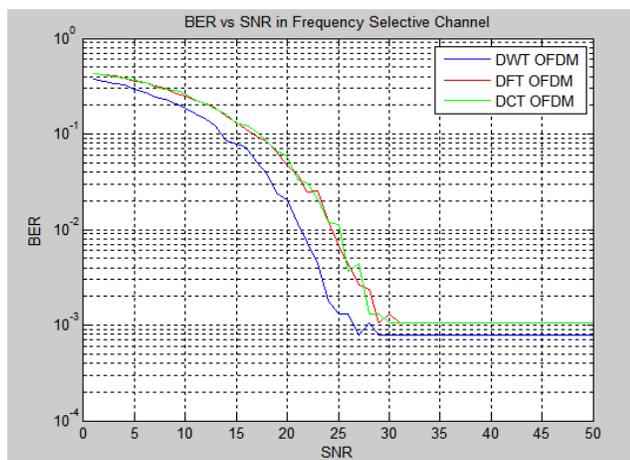


Figure 6: Performance of BER over a frequency selective channel in the presence of AWGN.

8. CONCLUSION

The objective of this dissertation work is to develop an efficient wireless system based on OFDM using 64-DAPSK modulation. The proposed system is analyzed on AWGN, flat fading channel and frequency selective channels. From the results it can be concluded that the proposed system has a better performance (reduced BER) over different types of channels at different SNR.

REFERENCES

[1] Mranali Joshi Amar Nath Dubey Debendra Kumar Panda, "Analysing various Fading channels using different Modulation Techniques under IEEE 802.16 Standard", IEEE Sponsored 2nd International Conference On Electronics And Communication System (ICECS 2015).
 [2] Mohd. Abuzer Khan¹, Sonu Pal², Ankita Jose³, "BER Performance of BPSK, QPSK & 16 QAM with and without using OFDM over AWGN, Rayleigh and Rician Fading Channel", International Journal of Advanced Research in Computer and Communication Engineering Vol.

4, Issue 7, July 2015.
 [3] Pratima Manhas, M.K.Soni, "Performance Analysis of DWT-OFDM and FFT-OFDM using Various Digital Modulation Techniques and Channel Coding", International Journal of Computer Applications (0975 – 8887) Volume 128 – No.11, October 2015.
 [4] Deepak K. Chyl, Md. Khaliluzzaman, "Evaluation of SNR for AWGN, Rayleigh and Rician Fading Channels Under DPSK Modulation Scheme with Constant BER", International Journal of Wireless Communications and Mobile Computing 2015; 3(1): 7-12 Published online February 6, 2015.
 [5] Deepak Bactor, Rajbir Kaur and Pankaj Bactor, "Diversity Techniques using BPSK and QPSK Modulation in MIMO system under fading environment", International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 4, Issue 5, May 2015.
 [6] S.Sowndeswari, Dr.C.V.Ravishankar, "Performance analysis of mobile & cellular communication system using M-ary modulation techniques by using PSK", International Journal of Application or Innovation in Engineering & Management (IJAIEM) Web Site: www.ijaiem.org Email: editor@ijaiem.org Volume 4, Issue 11, November 2015 ISSN 2319 – 4847.
 [7] Sachin Natasha Chandni, "Analyzing the BER Performance of OFDM-System with QPSK and BPSK Modulation Technique", International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Issue 6, Volume 2 (June 2015).
 [8] Karanpreet Kaur, Ankush Kansal, "Performance Analysis of Convolutional Interleaved DWT based OFDM system", International Journal of Advanced Research in Computer and Communication Engineering Vol. 3, Issue 5, May 2014.
 [9] Sutanu Ghosh, "Performance Analysis On The Basis of A Comparative Study Between Multipath Rayleigh Fading And AWGN Channel in the Presence Of Various Interference", International journal of Mobile Network Communications & Telematics (IJMNCT) Vol. 4, No.1, February 2014.
 [10] Prajyo Podder, T Zaman Khan, Mamdulul Haque Khan, M. Mukhtadir Rahman, "BER Performance Analysis of OFDM-BPSK, QPSK, QAM Over Rayleigh Fading Channel & AWGN Channel", International Journal of Industrial Electronics and Electrical Engineering, ISSN: 2347-6982 Volume-2, Issue-7, July-2014.
 [11] Pratima Sharma, Bhaskar Singh and Pushpraj Singh Tanwar, "A Review in Multiple Modulation Techniques 16 and 64 QAM MIMO-OFDM BPSK-QPSK-PSK system", International Journal of Electrical, Electronics ISSN No. (Online): 2277-2626 and Computer Engineering 3(1): 196-200(2014).
 [12] E kwe O. A., 2Abioye, A. E., 3Oluwe, M. O., 4Okoro, K.C, "Effective Fading Reduction Techniques in Wireless Communication System", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735. Volume 9, Issue 4, Ver. II (Jul - Aug. 2014), PP 35-43,w www.iosrjournals.org
 [13] Anurag Pandey, Sandeep Sharma, "BER Performance of OFDM System in AWGN and Rayleigh Fading Channel", International Journal of Engineering Trends and Technology (IJETT) – Volume 13 Number 3 – Jul 2014.
 [14] Mrityunjay Prasad Tripathi, Dr.Soni Changlani, Prof.Saiyed Tazin Ali, "Performance Comparison of M-PSK and M-QAM Modulations for WiMAX OFDM system under the Rayleigh Fading Channel", International Journal of Technological Exploration and Learning (IJTEL), ISSN: 2319-2135, vol.3, no.2, April 2014.
 [15] R. Asif, R. A. Abd-Alhameed, O.O. Anoh and Y.A.S. Dama, "Performance Evaluation of DWT-FDM and FFT-OFDM for Multicarrier Communications Systems using Time Domain Zero Forcing Equalization", Communications on Applied Electronics (CAE) Foundation of Computer Science FCS Volume 1–No.1, December 2014.
 [16] Abdul Haq N, Rajani Katiyar and Padmaja K V, "BER performance of BPSK and QPSK over rayleigh channel and AWGN channel", ISSN 2319 – 2518 www.ijeetc.com Vol. 3, No. 2, April 2014 © 2014 IJEETC.
 [17] Arpita Mishra¹, Stuti Rastogi, Ritu Saxena, Pankaj Sharma, Sachin

- Kumar "Performance analysis of MB-OFDM system with QPSK AND QAM for wireless communication", International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 2, February 2013.
- [18] G.Tharakanatha1, SK. Mahaboob kamal basha, Vijay Bhaskar chanda, I.Hemalatha, "Implementation and Bit Error Rate analysis of BPSK Modulation and Demodulation Technique using MATLAB", International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 9- Sep 2013.
- [19] Md. Mejbaul Haque, Mohammad Shaifur Rahman and Ki-Doo Kim, "Performance Analysis of MIMO-OFDM for 4G Wireless Systems under Rayleigh Fading Channel", International Journal of Multimedia and Ubiquitous Engineering Vol. 8, No. 1, January, 2013.
- [20] G. Mahesh Naidu, O. Sudhakar, V. Sailaja, "Simulation of BPSK Modulation and Demodulation on System Generator", International Journal of Scientific Engineering and Research (IJSER) www.ijser.in ISSN (Online): 2347-3878 Volume 1 Issue 2, October 2013.
- [21] Mr. Anshul Soni1, Mr. S.J. Basha, Mr. Ashok Chandra Tiwari, "Comparative Analysis of OFDM under FFT and DWT Based Image Transmission", International Journal of Innovative Research in Computer and Communication Engineering Vol. 1, Issue 2, April 2013.
- [22] M. Mirahmadi, Member, IEEE, A.Al-Dweik, Senior Member, IEEE, and A.Shami, Senior Member, IEEE, "BER Reduction of OFDM Based Broadband Communication Systems over Multipath Channels with Impulsive Noise", IEEE Transactions on Communications, vol.61, No.11, November 2013.
- [23] R. Asif, R. A. Abd-Alhameed, O.O. Anoh and Y.A.S. Dama, "Performance Evaluation of DWT-FDM and FFT-OFDM for Multicarrier Communications Systems using Time Domain Zero Forcing Equalization", International Journal of Computer Applications (0975 – 8887) Volume 51– No.4, August 2012.
- [24] Umesh Sharma, "Comparative Study of Digital Modulation Techniques in WIMAX", International Journal of Engineering and Innovative Technology (IJEIT), vol.2, No.2, August 2012.
- [25] Achala Deshmukh1 and Shrikant Bodhe, "Comparison of DCT and Wavelet Based OFDM System Working in 60 GHz Band", International Journal of Advancements in Technology, Vol. 3 No.2 (April 2012) © IJAT.
- [26] Anuradha.R.Kondelwar, and Dr.K.D.Kulat, "BER Analysis of Proposed Wimax System in different channel Environments", International Journal of Emerging Technology and Advanced Engineering (IJETA), vol.2, No.9, September 2012.
- [27] Khairi Ashour Hamdi, Senior Member, IEEE, "Analysis of OFDM over Nakagami-m Fading with Nonuniform Phase Distributions", IEEE Transactions on Wireless Communications, vol.11, No.2, February 2012.
- [28] Brian Krongold, Timo Pfau, Noriaki Kaneda and Sian Chong Jeffrey, "Comparison between PS-QPSK and PDM-QPSK with equal rate and bandwidth", IEEE photonics technology letters, vol.24, no. 3, February 1, pp 203-205 ,2012.
- [29] Suchita Varade, Kishore Kulat, "BER Comparison of Rayleigh Fading, Rician Fading and AWGN Channel using Chaotic Communication based MIMO-OFDM System", International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-1, Issue-6, January 2012.
- [30] Md. Sipon Miah, M. Mahbubur Rahman, T. K Godder, Bikash Chandra Singh and M. Tania Parvin, "Performance Comparison of AWGN, Flat Fading and Frequency Selective Fading Channel for Wireless Communication System using 4QPSK", Copyright © 2011 Ijcit, Issn 2078-5828 (Print), Issn 2218-5224 (Online), Volume 01, Issue 02, Manuscript Code: 110125.
- [31] A. Sudhir Babu Dr. K.V Sambasiva Rao, "Evaluation of BER for AWGN, Rayleigh and Rician Fading Channels under Various Modulation Schemes", International Journal of Computer Applications (0975 – 8887) Volume 26– No.9, July 2011
- [32] A. Omri and R. Bouallegue, "New Transmission Scheme for MIMO-OFDM System", International Journal of Next Generation Networks (IJNGN) Vol.3, No.1, March 2011.
- [33] Swati Sharma and Sanjeev Kumar, "BER Performance Evaluation of FFT-OFDM and DWT-OFDM", International Journal of Network and Mobile Technologies ISSN 2229-9114 Electronic Version VOL 2 / ISSUE 2 / MAY 2011.
- [34] Min, G., Yusheng, J., Han, H., and Xiaokang, L., "Two-Dimensional Demodulation for 64-DAPSK Modulated OFDM Signal", IEEE CCNC, proceedings (2010).
- [35] Jiang, Y., "New companding transform PAPR reduction in OFDM", IEEE Transaction on communications 14(4), 282-284(2010).
- [36] Xiaolong Li, "Simulink-based Simulation of Quadrature Amplitude Modulation (QAM) System", Indiana State University, Proceedings of The 2008 IAIC-IJME International Conference ISBN 978-1-60643-379-9.
- [37] Abdullah, K., and Hussain, Z. M., "Performance of Fourier-Based and Wavelet-Based OFDM for DVB-T Systems", Australasian Telecommunication Networks and Applications Conference, 475-479 (2007).
- [38] Y. Byungwook, H. L. Kyu and L. Chungyong, "Implementation of IEEE 802.16e MIMO-OFDMA Systems with K-BEST Lattice Decoding Algorithm", International Conference on Consumer Electronics. Las Vegas, NV, USA, 2007.
- [39] Tan and K.-C. Lin, "Performance of space-time block coded MB-OFDM UWB systems", in Proc.4th Annual Communication Networks and Services Research Conference (CNSR'06), pp.323-327, May 2006.
- [40] W.P. Siritwongpairat, W.Su, M. Olfat and K.J.R.Liu, "Multiband OFDM MIMO coding framework for UWB communication systems", IEEE Trans. Signal Processing , vol. 54 , no. 1, pp 214-224, Jan 2006.
- [41] Bing-Hung Chiang, Ding-Bing Lin, Jung-Lang Yu , "OFDM in Multipath Mobile Fading Channel", Institute of Computer, Communication and Control, National Taipei University of Technology, Taiwan, R.O.C.,
- [42] N. C. Beaulieu and C. Cheng, "Efficient Nakagami-M Fading Channel Simulation", IEEE Transactions on Vehicular Technology, vol. 54, no. 2, pp. 413-424, 2005
- [43] C.A. Corral, S. Emami and G. Rasor, "Model of MultiBand OFDM Interference on Broadband QPSK Receivers", IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP'05), vol. 3, March 18-23, pp 629-632, 2005.
- [44] Ben Lu, "Performance Analysis & design optimization LDPC coded MIMO OFDM systems", IEEE Trans. on signal processing vol. 52, No. 2, pp. 348-361, Feb. 2004.
- [45] R. Prasad. 2004, "OFDM for wireless communications systems", Artech House.
- [46] A. R. Bahai, B. R. Saltzberg and M. Ergen, "Multi-carrier digital communications: theory and applications of OFDM", Springer 2004.
- [47] Yahong Rosazheng and chengshanxiao, "Simulation model with correct statistical properties for Rayleigh fading channel", IEEE Trans. on Communications vol. 51, pp. 920-928, June 2003.
- [48] Ming xian chang, "Performance Analysis of Equalized OFDM system in Rayleigh fading channel", IEEE Trans. On Wireless Comm. Vol. 1 no. 4, pp 721-32 oct.-2002.
- [49] Xiaoyi tang, "Effect of channel estimation error on QAM, BER performance in Rayleigh fading", IEEE Trans. On Communications, vol. 47, pp. 1856-64, Dec 1999.
- [50] V. Strela, P. N. Heller, G. Strang, P. Topiwala and C. Heil, "The application of multiwavelet filterbanks to image processing", IEEE Transactions on Image Processing. 8: 548-563, 1999.
- [51] Y. Wu and W. Y. Zou, "Orthogonal frequency division multiplexing: A multi-carrier modulation scheme", IEEE Transaction. Consumer Electronics, vol.41, no.3, pp. 392 399, Aug. 1995.
- [52] L. J. Cimini, Jr., "Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing", IEEE Trans. on Communications., vol. 33, pp. 665-675, July 1985.