wjert, 2020, Vol. 6, Issue 2, 198-212. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org SJIF Impact Factor: 5.924

ANALYSIS OF AWGN, FLAT FADING AND FREQUENCY SELECTIVE CHANNELS USING DAPSK MODULATION TECHNIQUE

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Article Received on 20/01/2020 **Article Revised on 10/02/2020** **Article Accepted on 02/03/2020**

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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.

KEYWORDS: Fading, OFDM, Flat Fading channel, Frequency selective channel, AWGN, Wireless Communications.

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.

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 binaryinformation data is obtained back after the demodulation and channel decoding.

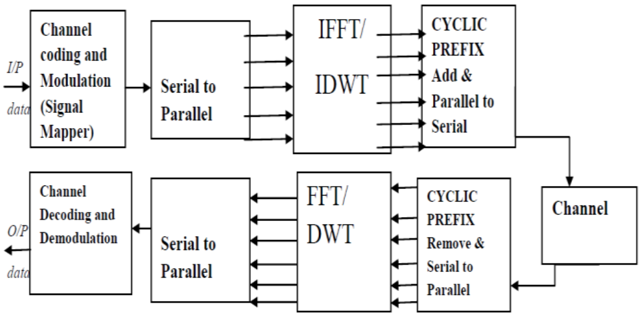

Figure 1: Block diagram of a OFDM system.

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 $a \in \{2^j: j \in Z\}$, and the position is sampled proportionally to the scale $b \in \{k2^j: (j, k) \in Z^2\}$.

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 $f(x) \in \mathbf{L}^2(R)$, the wavelet $\psi(x)$ has to be chosen such that $\{\psi(2^{-j}(x - 2^j k))\}$ $(j,k) \in Z^2$ is a basis of $\mathbf{L}^2(R)$. 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*Φ(x)*represents a scaling function and the coefficients h0, h1,….. 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 L2(0, 1), i.e., $<\Phi, \psi> = 0$.
- The wavelet function is localized in terms of space and frequency.
- The coefficients satisfies some constraints.

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

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

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

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:

$$S_{i,k} = B_{i,k}.S_{i-1,k}$$

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 work64-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_6. 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.

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

$$q = 0, ...3$$

$$n = 0, ...15$$

$$\Delta\varphi = 22.5$$

Wherea^qrepresents the four possible amplitude levels and $e^{j\pi\Delta\Psi}$represents the sixteen possible phase states as shown in the constellation diagram presented in figure 2. The four bits (b_0,.....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$|S_{i-1,k}|$.

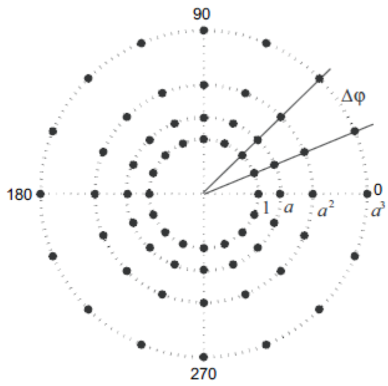

Figure 2: 64-DAPSK constellation diagram.

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.

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.

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.

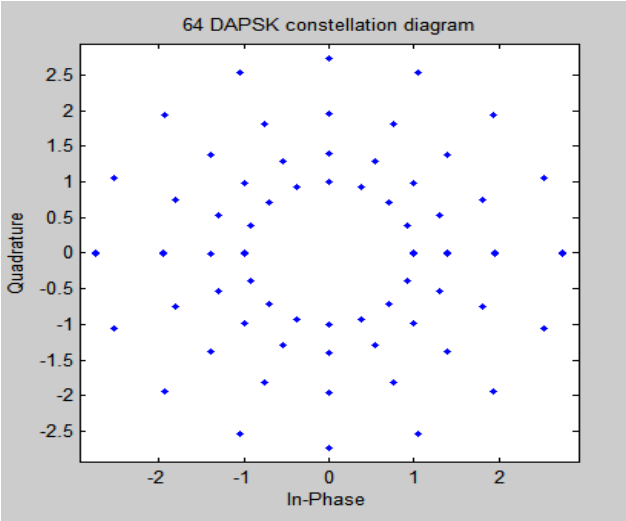

Figure 3: Simulated 64-DAPSK constellation diagram.

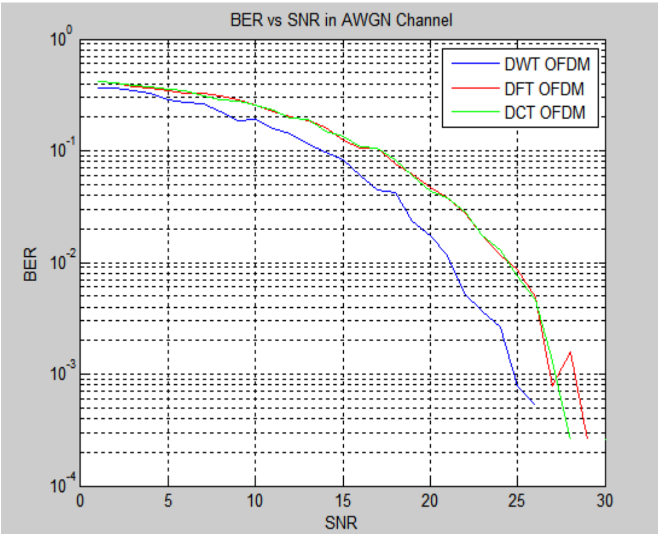

Figure 4: Performance of BER in the presence of AWGN at different SNR.

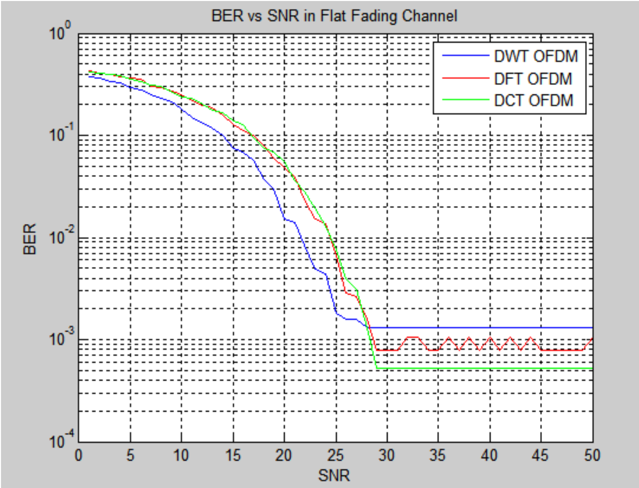

Figure 5: Performance of BER over Rayleigh flat fading channel in the presence of AWGN.

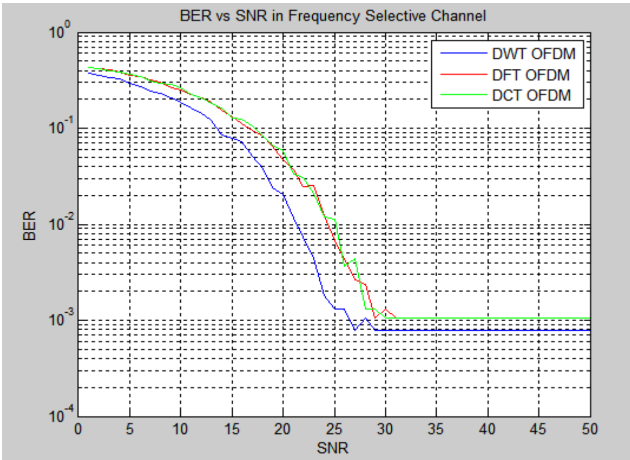

Figure 6: Performance of BER over a frequency selective channel in the presence of AWGN.

CONCLUSION

Theobjectiveofthis 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.

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