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# Estimation in OFDM Based Cognitive Radio Systems BER Analysis for Fourier and Wavelet Transform Process

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**Abstract:** ***In this correspondence, sparse channel estimation is first introduced in orthogonal frequency-division multiplexing (OFDM)-based cognitive radio systems. Based on the results of spectrum sensing, the pilot design is studied by minimizing the coherence of the dictionary matrix used for sparse recovery. Then, it is formulated as an optimal column selection problem where a table is generated and the indexes of the selected columns of the table form a pilot pattern. A novel scheme using constrained cross-entropy optimization is proposed to obtain an optimized pilot pattern, where it is modeled as an independent Bernoulli random process. Comparison between the conventional FFT based OFDM systems with DWT based OFDM system have been made according to some conventional and non-conventional modulation methods over AWGN and Rayleigh fading channel. The different wavelet families have been used and compared with FFT based OFDM system and found that DWT based OFDM system is better than FFT based OFDM system with regards to the bit error rate (BER) performance. Finally, we provide numerical results in terms of both MSE estimation performance and Bit Error Rate (BER) of a coded OFDM system using the proposed channel estimators, to show that they indeed approach MMSE performance.***

**Keywords:** Cognitive radio (CR), cognitive radio networks(CRNs), dynamic resource management, dynamic spectrum access

## 1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multi carrier transmission which has found its application in a number of wireless and wire-line systems. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, transmitted in parallel, divide the available transmission bandwidth. The separation of the subcarriers is theoretically minimal such that there is a very compact spectral utilization. Multicarrier Modulation schemes divide the computer file into bands upon that modulation is performed and multiplexed into the channel at totally different carrier frequencies so info is transmitted on every of the sub carriers, specified the sub channels area unit nearly distortion less. In typical OFDM system, IFFT/IDCT (Inverse quick Fourier Transform) and FFT/DCT area unit accustomed multiplex the signals along and rewrite the signal at the receiver severally. during this system, the Cyclic Prefix is added before transmittal the signal to channel.

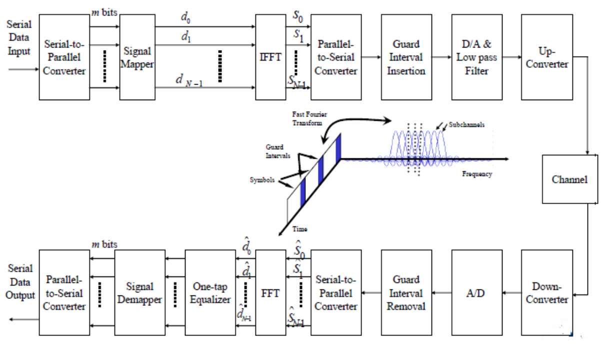



**Figure:** OFDM Block Diagram Process

In this paper that is typical and non-convention modulation schemes. BPSK, QPSK and QAM area unit the elements of typical modulation schemes whereas Differential BPSK and Differential QPSK area unit the non-conventional modulation schemes. BPSK (also sometimes called PRK, phase reversal keying, or 2PSK) is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis, at 0° and 180°. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol (as seen in the figure) and so is unsuitable for high data-rate applications.

The QPSK could be a construction modulation technique; it uses a pair of bits per image to represent every part. Compared to BPSKSometimes this is known as *quadriphase PSK*, 4-PSK, or 4-QAM. (Although the root concepts of QPSK and 4-QAM are different, the resulting modulated radio waves are exactly the same.) QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with Gray coding to minimize the bit error rate (BER) — sometimes misperceived as twice the BER of BPSK. QAM is that the technique of mixing 2 amplitude modulated signals into one channel. it\'s going to be Associate in Nursing analogy QAM or a digital QAM. During this paper channel impulse response has been calculable and compared victimisation LS, MMSE and DFT/DCT /DWT based mostly estimation techniques. The paper is organized as follows. In Section two, MIMO system and channel estimation is delineated . Section three discusses coaching DFT/DCT/DWT based mostly channel estimation. Simulation and results for the performance of BPSK, QPSK, and QAM, LS, MMSE and DFT/DCT/DWT primarily based techniques ar given in section four and Section five concludes the paper

## 2. DFT/FFT Based Channel Estimation

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is gen erated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically differential BPSK, QPSK, or QAM). The multiple orthogonal subcarrier signals, which are overlapped in spectrum, need to be produced at the transmitter side. In practice, Discrete Fourier Transform (DFT) and Inverse DFT (IDFT) processes are useful for implementing these orthogonal signals. DFT and IDFT can be implemented efficiently by using fast Fourier transform (FFT) and inverse fast Fourier transform (IFFT), respectively. In the OFDM transmission system N point IFFT is taken for the transmitted symbols so as to generate, the samples for the sum of N orthogonal subcarrier signals. The receiver will receive a sample corrupted by additive noise. Taking the N-point FFT of the received samples the noisy version of transmitted symbols can be obtained in the receiver. The spectrum of the OFDM signal can be considered as the sum of the frequency shifted sinc functions in the frequency domain because all subcarriers are of the finite duration. The OFDM scheme also inserts a guard interval in the time domain, called cyclic prefix (CP), which mitigates the inter-symbol interference (ISI) between OFDM symbols Fig. 1 shows the configuration for a basic OFDM transmitter and receiver. The signal generated is at baseband and so to generate an RF signal the signal must be filtered and mixed to the desired transmission frequency [3]. The sequence of N complex numbers x0... xN−1 is transformed into the sequence of N complex numbers X0... XN−1 by the DFT according to the equation below

$$X_k = \sum_{n=0}^{N-1} x_n \frac{-2\pi i}{N} kn$$

Where i is the imaginary unit and is a primitive Nth root of unity and k = 0... N 1. The Inverse Discrete Fourier Transform (IDFT) is given by Equation

$$X_n = \frac{1}{N} \sum_{n=0}^{N-1} x_K \frac{-2\pi i}{N} kn$$

Where n = 0... N-1.
A simple description of these equations is that the complex numbers Xk represent the amplitude and phase of the different sinusoidal c omponents of the input signal xn . The DFT computes the Xk from the xn, while the IDFT shows how to compute the xn as a sum of sinusoidal components found with frequency k/N cycles per sample. A key enabling factor for these applications is the fact that the DFT can be computed efficiently in practice using a Fast Fourier Transform (FFT) algorithm. "DFT" refers to a mathematical transformation or function, regardless of how it is computed, whereas "FFT" refers to a specific family of algorithms for computing DFTs.

## 3. DWT Based Channel Estimation

Wavelets are an extension Fourier analysis. The mathematics of Fourier analysis dates back to the nineteen century but it wasn't until the mid twentieth century, with the advent of fast algorithms and computers that Fourier analysis began to make an impact on the world. Widely used in signal analysis, hardly a scientific field hasn't been impacted by this technique. Wavelet analysis uses a similar approach but instead of sinusoids, waves of limited duration, termed basis function or mother wavelets, are used [Figure ].

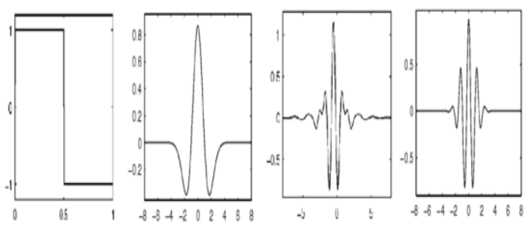


**Figure:** Wavelet family examples, from left to right: Haar, Mexican Hat, Daubechies and Morlet

A riffle may be a little piece of a wave. wherever a curved wave as is employed by Fourier transforms carries on continuance itself for eternity, a riffle exists solely inside a finite domain, and is zero-valued elsewhere.

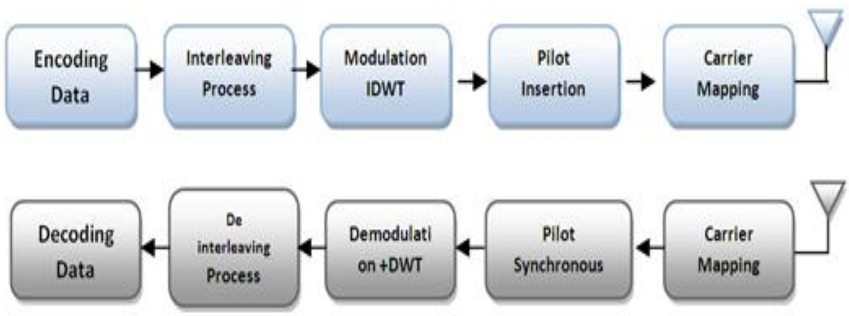


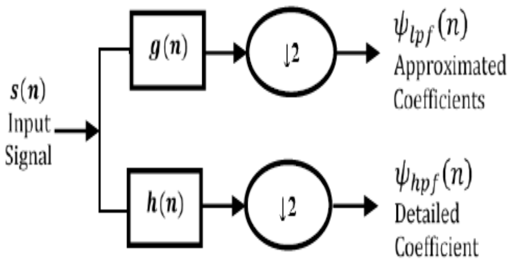

**Figure:** Block Diagram: DWT Based OFDM

A riffle rework involves convolving the signal against explicit instances of the riffle at varied time scales and positions. Hence, riffle rework as a joint time-frequency domain. the everyday application fields of wavelets area unit like physical science, acoustics, engineering science, sub-band secret writing, signal and image process. There area unit some sample applications characteristic pure frequencies, De-noising signals, detective work discontinuities and breakdown points, detective work self similarity and pressing samples.

**DFT/FFT vs. DWT Based OFDM**

Fourier based Conventional OFDM system has been a popular choice for wireless transmission over a long time for its transmission performances. In Fourier analysis we break up a signal into a set of an infinite sum of Sines and Cosines to exploit the Orthogonality relationship between them. On the other hand, using wavelet transform the signal is first decomposed by a low-pass (LP) and a high-pass (HP) filter. Half of the frequency components have been filtered out at filter outputs and hence can be down-sampled.

We get approximation (1) and detail coefficients (2) from and filters respectively. Where and are the wavelet's half-band low pass filter and high pass filter impulse responses. In wavelet decomposition the details as well as the approximations can be split into a second level details and approximations. These two sets of coefficients are obtained by performing convolution between the input signals and wavelet filter coefficients.




Decomposition process is repeated by a series of high and low pass filters until we are left with a coefficient sequence of wavelets that are orthogonal in nature, the original signal is then reconstructed by performing the reverse operation of this decomposition.

$$\Psi_{lpf}(n) = \sum_{k=-\infty}^{k=+\infty} s(k)g(2n-k)$$
$$\Psi_{hpf}(n) = \sum_{k=-\infty}^{k=+\infty} s(k)h(2n-k)$$

One thing about wavelet packet analysis that attracts communication system is ―accurate reconstruction" using wavelet coefficients.

**Least Square Estimation**

Least Squaresis a standard approach to the approximate solution of over determined systems, i.e., sets of equations in which there are more equations than unknowns. "Least squares" means that the overall solution minimizes the sum of the squares of the errors made in the results of every single equation. The most important application is in data fitting. The best fit in the least-squares sense minimizes the sum of squared residuals, a residual being the difference between an observed value and the fitted value provided by a model. When the problem has substantial uncertainties in the independent variable(the 'x' variable), then simple regression and least squares methods have problems; in such cases, the methodology required for fitting errors-in-variables models may be considered instead of that for least squares. Least squares problems fall into two categories: linear or ordinary least squares and non-linear least squares, depending on whether or not the residuals are linear in all unknowns. A regression model is a linear one when the model comprises a linear combination of the parameters, i.e.,

$$f(x, \beta) = \sum_{j=1}^{m} \beta_j \Phi_j(x)$$

where the function, $\phi_j$, is a function of $x$.
Let

$$X_{ij} = \frac{\partial f(x_i,\beta)}{\partial \beta_j} = \Phi_j(x_i)$$

we can then see that in that case the least square estimate (or estimator, in the context of a random sample), β is given by
$\beta = (X^T X)^{-1} X^T y$

For a derivation of this estimate see Linear least squares (mathematics).

**MMSE Estimation:**

Minimum Mean Square Error (**MMSE**) estimator is an estimation method which minimizes the mean square error (MSE) of the fitted values of a dependent variable, which is a common measure of estimator quality.
Let x be a n x 1 a hidden random vector variable, and let y be a m x 1 known random vector variable (the measurement or observation), both of them not necessarily of the same dimension. An estimator ẋ(y) of x is any function of the measurement y. The estimation error vector is given by e=ẋ-x and its mean squared error (MSE) is given by the trace of error covariance matrix

$$MSE = tr\{E\{(\dot{x}-x)(\dot{x}-x)^T\}\}$$

where the expectation E is taken over both x and y . When x is a scalar variable, then MSE expression simplifies to$E\{(\dot{x}-x)^2\}$ . Note that MSE can equivalently be defined in other ways, since

$$tr\{E\{ee^T\}\} = E\{tr\{ee^T\}\} = E\{e^Te\} = \sum_{i=1}^{n} E\{e_i^2\}$$

The MMSE estimator is then defined as the estimator achieving minimal MSE.

## 4. Result Analysis

By victimization MATLAB performance characteristic of DFT {based mostly primarily based mostly} OFDM and riffle based OFDM area unit obtained for various modulations that area unit used for the LTE, as shown in figures. Modulations that might be used for LTE area unit QPSK, sixteen QAM and sixty four QAM (Uplink and downlink).

**MSE v/s SNR**

Signal to noise ratios and Eb/No figures are parameters that are more associated with radio links and radio communications systems. In terms of this, the mean square error(MSE), can also be defined in terms of the probability of error or POE. The determine this, three other variables are used. They are the error function, erf, the energy in one bit, Eb, and the noise power spectral density (which is the noise power in a 1 Hz bandwidth), No.

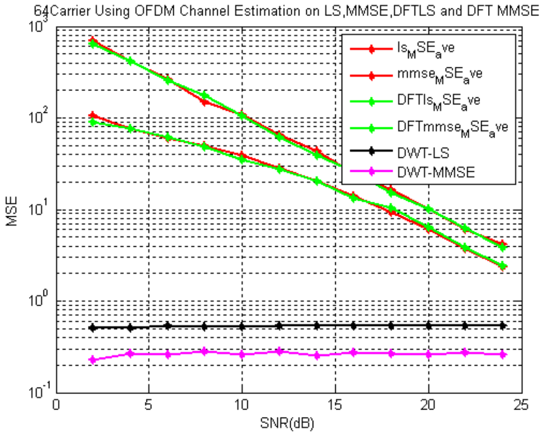



**Figure:** Comparison Analysis of DFT Vs. DWT Process Using 64QAM

It should be noted that each different type of modulation has its own value for the error function. This is because each type of modulation performs differently in the presence of noise. In particular, higher order modulation schemes (e.g. 64QAM, etc) that are able to carry higher data rates are not as robust in the presence of noise. Lower order modulation formats (e.g. BPSK, QPSK, etc.) offer lower data rates but are more robust.

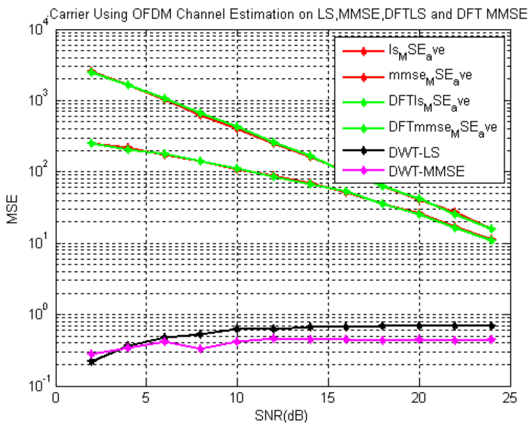



**Figure:** Comparison Analysis of DFT Vs. DWT Process Using 128QAM

The energy per bit, Eb, can be determined by dividing the carrier power by the bit rate and is a measure of energy with the dimensions of Joules. No is a power per Hertz and therefore this has the dimensions of power (joules per second) divided by seconds). Looking at the dimensions of the ratio Eb/No all the dimensions cancel out to give a dimensionless ratio. It is important to note that POE is proportional to Eb/No and is a form of signal to noise ratio.

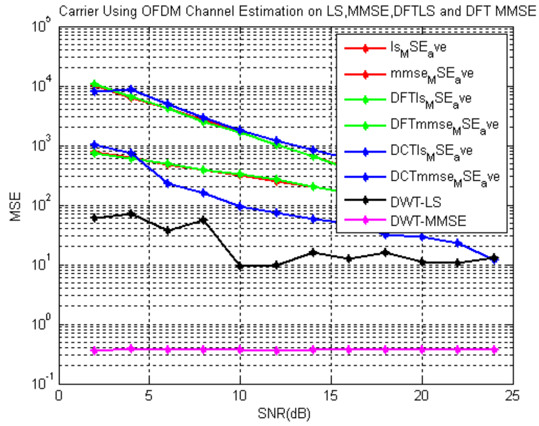



**Figure:** Comparison Analysis of DFT Vs DCT Vs. DWT Process Using 256QAM

**BER v/s SNR**

For the aim of simulation, signal to noise quantitative relation (SNR) of various values area unit introduced through AWGN channel. information of 9600 bits is shipped within the variety of one hundred symbols, thus one image is of ninety six bits. Averaging for a selected price of SNR for all the symbols is finished and BER is obtained and same method is continual for all the values of SNR and final BERs area unit obtained. foremost the performance of DFT {based based mostl primarily based mostly} OFDM and riffle based OFDM area unit obtained for various modulation techniques. totally different riffle varieties biorthogonal, daubechies2 and haar is employed in riffle based mostly OFDM for 64-QAM, 256QAM.

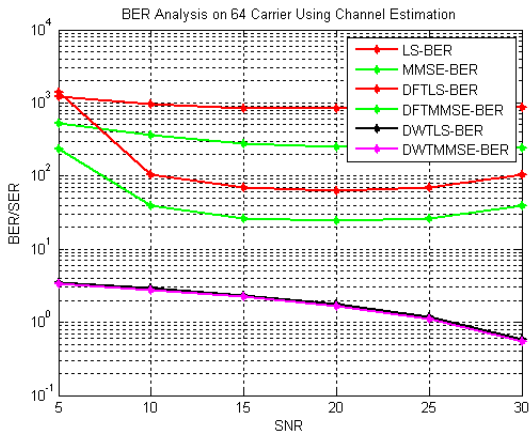



**Figure:** Comparison Analysis of DFT Vs DCT Vs. DWT Process Using 64QAM

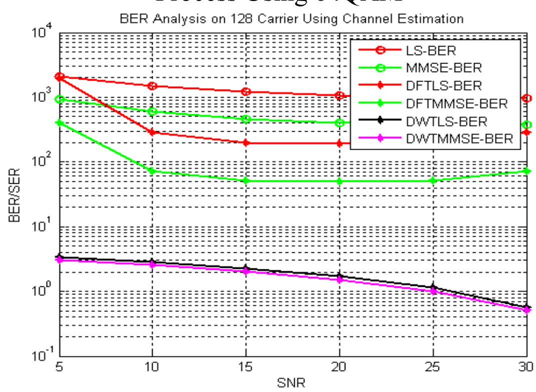



**Figure:** Comparison Analysis of DFT Vs. DWT Process Using 128QAM

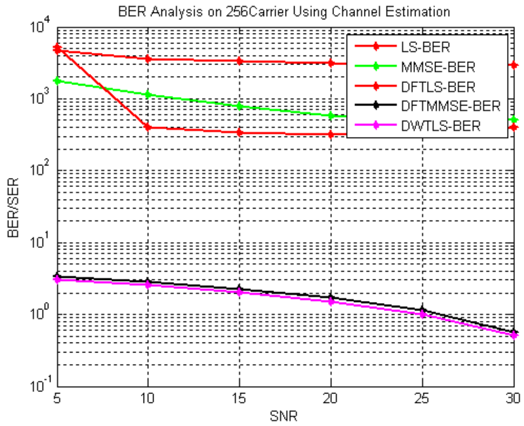



**Figure:** Comparison Analysis of DFT Vs DCT Vs. DWT Process Using 256QAM

## 5. Conclusion

In this paper we have a tendency to analyzed the performance of rippling based mostly OFDM system and compared it with the performance ofDFT based mostly OFDM system. From the performance curve we\'ve got determined that the BER curves obtained from rippling OFDM are higher than that of DFT based OFDM. we have a tendency to used 3 modulation techniques for implementation that ar QPSK, sixteen QAM and sixty four QAM, that ar employed in LTE. In rippling based mostly OFDM differing types of filters may be used with the assistance of various wavelets out there. we\'ve got used daubechies2 and haar and biorthogonal wavelets, each offer their best performances at totally different intervals of SNR.

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