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# Ber Performance Analysis of Daubechies Wavelet In Dvb-T For Rayleigh Channel

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**ABSTRACT**:
*In today's scenario of communication technology, the demand for high speed data rate and bandwidth has increased to the extent, that it has become very difficult to manage the communication system. To increase the speed of operation, the data is transmitted parallel and for this purpose Orthogonal Frequency Division Multiplexing (OFDM) technique is used which also has high spectral containment required for wireless communication systems. The fundamental principle of OFDM is to decompose the high rate data stream (bandwidth W) into N parallel lower rate data streams or channels, one for each subcarrier. Each sub-carrier is modulated with a conventional modulation scheme (such as Quadrature Amplitude Modulation or Phase-Shift Keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. In OFDM, Fourier Transform (FT) is used as a modulation technique, but this concept creates an Inter Symbol Interference (ISI) because of the time dispersive nature of the channel. To reduce this effect, a Cyclic Prefix is used but this reduces its spectral efficiency too. Orthogonal Wavelet Division multiplexing (OWDM) scheme has been proposed in this paper for wireless (DVB-T) communication which outperforms OFDM and has a lower computational complexity and increased flexibility*.

**Key words**: OFDM, Bit Error Rate, FFT, DWT, AWGN, Rayleigh Channel, DVB-T.

## I. INTRODUCTION:

The scarcity of radio spectrum has become problem in many applications that utilize the higher Radio Frequencies (RF). It is therefore, important that this resource is carefully managed to avoid waste. To help optimize the RF spectrum, in 1997, The United Kingdom launched the world's first commercial digital terrestrial television service with the ultimate aim to switch off in the analogue services between 2008 and 2012 [] thus potentially freeing up a large number of RF channels for either more television services or for other applications. Because the UK was eager to release the analogue bandwidth as soon as possible (meaning the government had to start to migrate quickly), the UK adopted the 2K version of DVB-T due to commercial hardware restrictions at the time (the 8K system was too expensive for use in consumer devices). Those countries moving over to digital television recently have tended to go straight to the 8K system because the technology is now commercially viable and because of all the advantages the 8K system has to offer. OFDM is the underlying technology of the DVB-T standard and comprises of an Inverse Fast Fourier Transform (IFFT) at the transmitter (and an FFT at the receiver) which performs the frequency division multiplex (unlike wideband communications which tend to use time division multiple). It is the size of these IFFTs and FFTs that determines whether the system is in the 2K or 8K mode.

The implementation of such large FFT cores was the main cause for delay for implementing OFDM in Consumer devices although OFDM was used in military applications long before this time as there are minimal budget constraints in military hardware. In 1997, the 2K core was just becoming commercially viable with a Set-Top Box (STB) costing the consumer in the region of £200-300. Today, most STBs are dual core (implementing both systems) and can cost as little as £30 for a basic system. If the technology could be further simplified, then it would be of significant benefit to the Manufacturing community as it would contribute to a drop in production costs that impact on the consumer market. Even with its inherent advantages, there is a drawback to OFDM being the inflexibility of the system. With OFDM, there are a small number of parameters that can be changed to suit the channel but the choice has to apply across a whole OFDM symbol – it is not possible to code different parts of the symbol in different ways as it is in the Japanese Integrated Services Digital Broadcast (ISDB) standard. The use of filters in the wavelet domain has been predominantly used for multi-resolution analysis of time varying signals. An alternative, however, is to use the wavelet domain to separate the sub band components in the same way that OFDM does. This system is termed Orthogonal Wavelet Division Multiplex (OWDM). The big difference between OFDM and OWDM is that in OFDM, the FFT performs sub band decomposition with a specific number of sub bands at well defined intervals. With OWDM, it is possible to dynamically allocate the number of sub bands and the bandwidth of each. Of course, if there were sufficient levels, the OWDM would start to resemble the OFDM Symbol. With all this in mind, this paper will propose an alternative to using OFDM in DVB-T which employs a true time frequency division multiplex using wavelets which may provide a more flexible environment that can be tailored to suite signal and channel conditions and of lower financial and computational cost.

Standard DVB-T uses two modes of operation i.e. 2K and 8K. The 2K mode provides the best mobile reception conditions because of its larger inter career spacing.

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However, it is only suitable for small-size SFNs (Single Frequency Network) and DVB-H networks. The 8K mode can be used both in SFNs and MFNs (Multiple) networks. It provides a Doppler tolerance allowing for high-speed reception.
This paper is focussed on the implementation of OWDM (Orthogonal Wavelet Division Multiplexing) in place of OFDM (Orthogonal Frequency Division Multiplexing) in DVB-T. This paper also examine the performance of Wavelet Modulation (WM) in time varying channels. Results for Rayleigh fading channels are compared to the AWGN channel

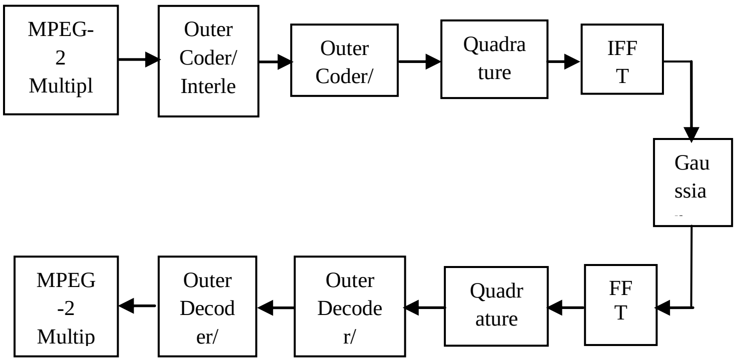



Figure.2. ETSI EN 300 744 DVB-T Block Diagram [2]

## II. DWT AND WAVELET MODULATION

A *wavelet* is a waveform of limited duration that has an average value of zero [4]. Unlike sinusoids that theoretically extend from minus to plus infinity, wavelets have a beginning and an end. The basic idea of the wavelet transform is to represent any arbitrary function "s" as a superposition of a set of such wavelets or basis functions. These basis functions or baby wavelets are obtained from a single prototype wavelet called the mother wavelet, by dilations or contractions (scaling) and translations (shifts). The Discrete Wavelet Transform of a finite length signal s(n) having N components, for example, is expressed by an N x N matrix. Wavelets are known to have compact support (localization) both in time and frequency domain, and possess better orthogonality. The DWT of a signal "s" is calculated by passing it through a series of filters.
The discrete wavelet transform (DWT) of a signal s is given by

$$S_{DWT}{}^{m}_{n} = \int_{-\infty}^{+\infty} S(t) 2^{m/2}\, \psi(2^m t - n) dt \qquad (1)$$

$$S_{IDWT}(t) = \int_{-\infty}^{+\infty} \sum_{m=-\infty}^{+\infty} \sum_{n=-\infty}^{+\infty} X_n^m\, 2^{m/2}\, \psi(2^m t - n) \qquad (2)$$

where $\psi(t)$ is the wavelet function [6]. Mallat's fast wavelet transform (FWT) provides a computationally efficient, practical, discrete time algorithm for computing the DWT. The scaling and wavelet coefficients at scales 'm' can be computed from the scaling coefficients at the next finer scale m+1, using

$$a_n^m = \sum_l h[l - 2n] a_l^{m+1} \qquad (3)$$

$$S_n^m = \sum_l g[l - 2n] a_l^{m+1} \qquad (4)$$

where $h[n]$ and $g[n]$ are the low-pass and high-pass filters.

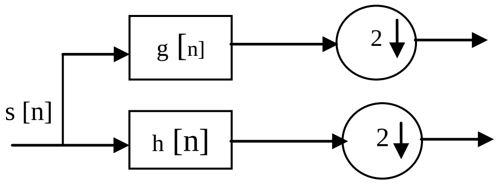


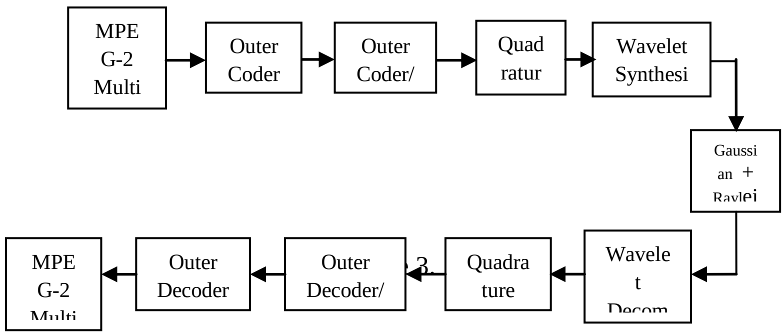

Figure 1: Block Diagram of Filter Analysis

First the samples are passed through a low pass filter (LPF) and high pass filter (HPF) with impulse response "g" and "h" respectively, resulting in a convolution of the two.

$$y_{low}[n] = (s * g)[n] = \sum_{n=-\infty} x[k] g[n - k] \qquad (5)$$

$$y_{high}[n] = (s * h)[n] = \sum_{n=-\infty} x[k] h[n - k] \qquad (6)$$

The output of the HPF gives the "detail coefficient" and the output of LPF gives the "approximation coefficient". The wavelet transform divides the signal into the approximation coefficient and detail coefficient.
The DWT analyses the signal at different frequency bands with different resolutions by decomposing the signal into an approximation containing coarse and detailed information. The original signal s[n] is first passed through a half-band high pass filter g [n] and a half-band low pass filter h [n]. A half-band low pass filter removes all frequencies that are above half of the highest frequency, while a half-band high pass filter removes all frequencies that are below half of the highest frequency of the signal. The low pass filtering halves the resolution, but leaves the scale unchanged. The signal is then sub-sampled by two since half of the number of samples is redundant, according to the Nyquist's rule.




Proposed System Block Diagram

The DWT based system replaces the IFFT and FFT blocks by IDWT (Inverse Discrete Wavelet Transformation) and DWT blocks respectively.

## III Wavelet Modulation

Wavelet modulation has a novel multi-rate diversity strategy that offers improved message recovery over conventional modulation techniques: if the message is not recovered at one rate due to channel disturbances, it can be received at another where the channel is clear.

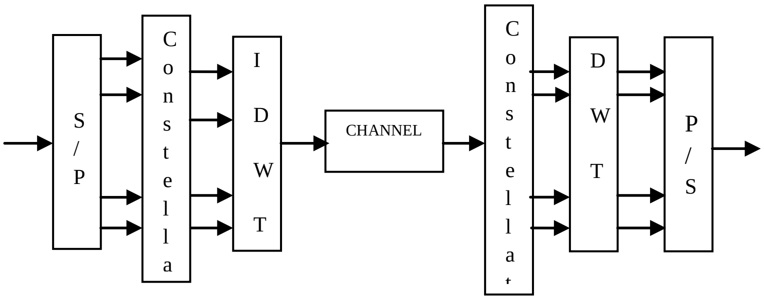



Figure.4 DWT-OFDM

One of the advantages of using wavelet transform is that due to the overlapping nature of wavelet properties, the wavelet based OFDM does not need cyclic prefix to deal with delay spreads of the channel. As a result, it has higher spectral containment than that of Fourier-based OFDM [6]. The input data is processed as per FFT-OFDM. However, the difference is that the system does not require CP to be added to the OFDM symbol.
The output of the inverse discrete wavelet transform (IDWT) can be represented as:

$$d(k) \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} D_m^n \, 2^{m/2} \, \psi\left(2_k^m - n\right) \qquad 7$$

Where $D_m^n$ are the wavelet coefficients and $\psi(t)$ is the wavelet function with compressed factor $m$ times and shifted $n$ times for each subcarrier (number $k$, $0 \le k \le N-1$). The wavelet coefficients are the representation of signals in scale and position or time. *Xm* At the receiver side, the process is inversed. The output of discrete wavelet transform (DWT) is

$$D_m^n = \sum_{k=0}^{N-1} d(k) \, 2^{m/2} \psi(2_k^m \quad - n) \qquad 8$$

Multi-resolution analysis of wavelet theory allows to represents wavelet and scaling functions by high and low pass filters (HPF and LPF), respectively with impulse responses $h[m]$ and $g[m]$. therefore the wavelet transformation can be easily implemented using discrete time filters.
In this Paper, The Wavelet of interest is Daubechies wavelet, because only this wavelet proves to be the wavelet of shortest duration during simulation.



## IV Fading and Multipath:

Fading occurs due to multipath components in a channel. In the wireless propagation channel there is no single direct link between the transmitter and the receiver; rather the transmitted signal undergoes multiple reflections, refractions, diffractions and scattering. The effect can cause time spreading of the signal and results in fluctuations in the received signal's amplitude,:phase, and angle of arrival, giving rise to the terminology multipath fading. It is possible that either or both the transmitter and receiver are moving. These moments cause Doppler shifts in the received signal and hence result in inter-carrier interference. The constructive (or destructive) interference results in random fluctuation in the received signal.

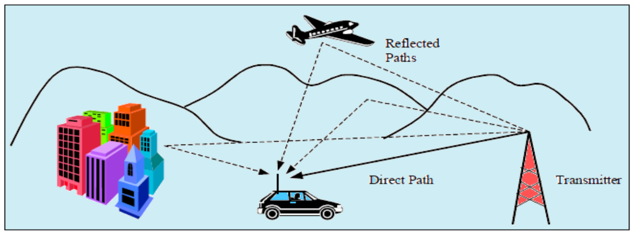



Figure 3: Multipath reception of a signal

## Rayleigh fading model:

The Rayleigh fading is primarily caused by multipath reception [6]. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal. It is a reasonable model for troposphere and ionospheres" signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading [7] is most applicable when there is no line of sight between the transmitter and receiver.

## V Simulation Parameter and Results:

In the OWDM system, the performance of BER as a function of $E_b/N_o$ (SNR) is examined. Simulation has been carried out to compare the performance of Daubechis (N= 2, 4,6,8,16,32) wavelet over Rayleigh fading channels. The study and comparisons are based on simulation done using MATLAB. The BER performance as a function of SNR is examined for Rayleigh fading and frequency selective fading with Doppler frequency ($f_d$ = 10Hz). Digital Video Broadcasting –Terrestrial (DVB-T) communication system with 16-QAM modulation is implemented using Matlab programming. The simulation time of different wavelets is also calculated and found that Daubechies wavelet is a wavelet of shortest duration.

Table1: Simulation Parameters[1]

| Parameter | 2K Mode | | | |
|---|---|---|---|---|
| Elementary Period *T* | 7/64 μs | | | |
| Number of carriers *K* | 1705 | | | |
| Value of carrier number $K_{min}$ | 0 | | | |
| Value of carrier number $K_{max}$ | 1704 | | | |
| Duration *Tu* | 224 μs | | | |
| Spacing between carriers $K_{min}$ and $K_{max}$ =*(K-1)/Tu* | 7.61 MHz | | | |
| Carrier Spacing *1/Tu* | 4464 Hz | | | |
| Allowed guard interval *Δ/Tu* | 1/4 | 1/8 | 1/16 | 1/32 |
| Duration of symbol part *Tu* | 2048xT<br>224 μs | | | |
| Duration of guard interval Δ | 512xT<br>56 μs | 256xT<br>28 μs | 128xT<br>14 μs | 64xT<br>7 μs |
| Symbol duration *Ts*= Δ+ *Tu* | 2048xT<br>280 μs | 2304xT<br>252 μs | 2176xT<br>238 μs | 2112xT<br>231 μs |



The choice of a suitable wavelet for digital wireless communication depends on its length and shape of the signal. The chosen wavelet must be of shortest duration and close to the analysed signal.

Table 2: Summary of the elapsed time in simulation.

| Wavelet | Gaussian Channel | Rayleigh Channel |
|---|---|---|
| Db2 | 39.057933 | 44.601987 |
| Sym2 | 40.678816 | 44.804060 |
| Coif2 | 46.71725 | 53.078534 |
| Db4 | 42.342866 | 48.086294 |
| Sym4 | 42.231923 | 48.302867 |
| Coif4 | 50.99034 | 56.72645 |

From the above table it is concluded that Daubechies (N = 2, 4) wavelets generate waveforms of shortest duration for both Gaussian and Rayleigh fading channels, that is why, BER performance of different Daubechies wavelets is analysed through MATLAB Code.

## VI. BER Vs EbNo plot of different Daubechies Wavelets for Gaussian and Rayleigh Channel in DVB-T.

Probability of reduced bit error rate (increased performance) is a very important key to measure the noise robustness of OWDM communication scheme. The relationship of BER as a function of $E_bN_o$ performance for different levels of noise is a useful performance tool. The wavelet family that results in a high performance gain is selected for optimum performance of the OWDM.

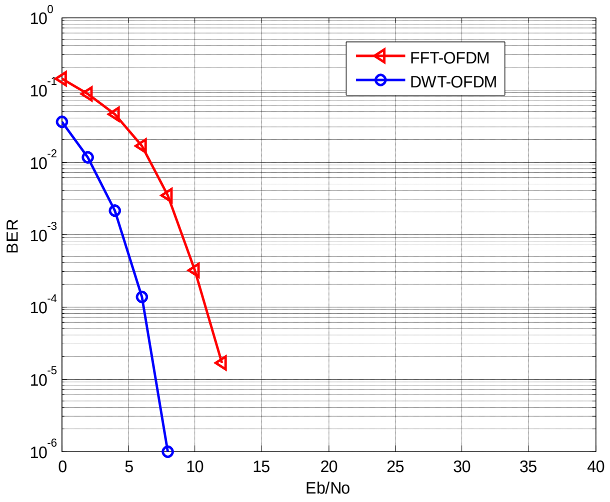



Figure 4: BER Performance Comparision of DWT- OFDM and FFT-OFDM in AWGN in 16-QAM Modulation

DWT based OFDM gives better performance than that of FFT based OFDM in Gaussian

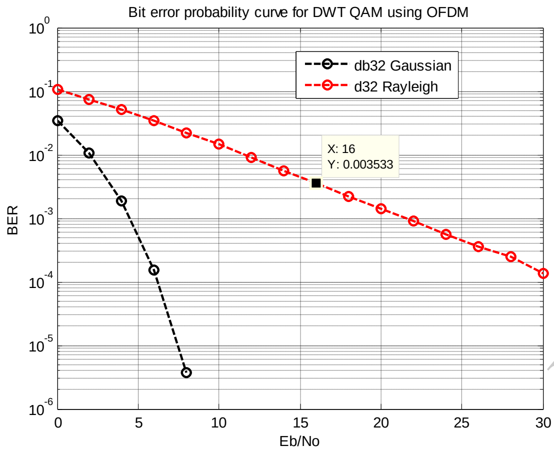



Figure 6: BER Vs $E_b/N_0$ for db4 in Gussian and Rayleigh fading channels

Channel. Wavelet based OFDM system was found having small bit error rate probability than that of the Fourier transform system.

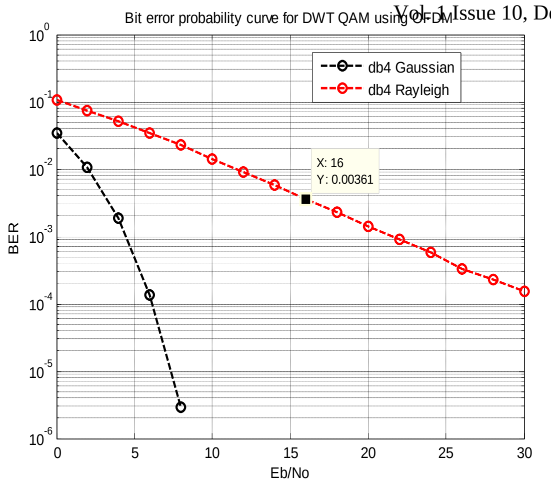



Figure 5:BER Vs $E_b/N_0$ for db4 in Gussian and Rayleigh fading channels

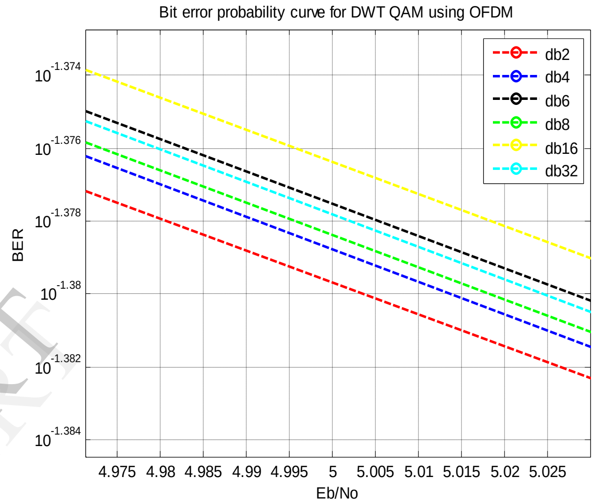



Figure 7: BER Vs $E_b/N_0$ at 5 Db for Daubechies in Gussian and Rayleigh fading channels

## VII. Performance Analysis

We analyze in this section the performance of OWDM in the propagation channels. The results have been obtained by simulations only, due to the fact that no analytical expressions are available for wavelet and wavelet filters. The different levels of decomposition of the Daubechies wavelet that are used, are (N= 2, 4,6,8,16,32). Wavelet Modulation (WM) performance in an AWGN channel is the best at all SNRs than that of Rayleigh channels.

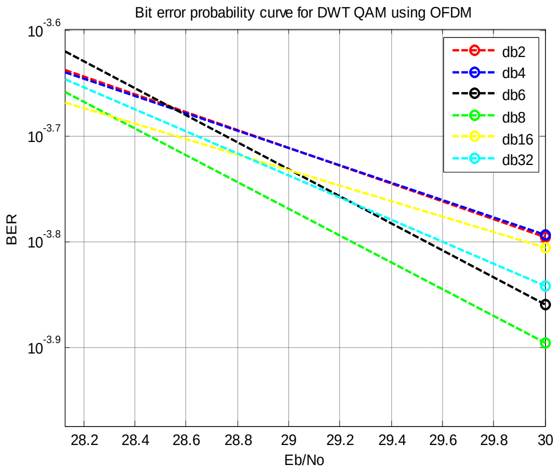



Figure 8 BER Vs $E_b/N_0$ at 30 Db for Daubechies in Gussian and Rayleigh fading channels

Table 4 values of min. BER at different EbNo of Daubechies Wavelets

| $E_bN_o$ (dB) | Minimum BER (dB) | Daubeccies Wavelet |
|---|---|---|
| 0 | 0.105 | db4 |
| 5 | 0.04172 | db2 |
| 10 | 0.01442 | db2 |
| 15 | 0.004529 | db6 |
| 20 | 0.00139 | db16 |
| 25 | 0.000444 | db16 |
| 30 | 0.000127 | db8 |

Table3: Values of BER at different EbNo of Daubechies Wavelet

| | BER | BER | BER | BER | BER | BER | min BER |
|---|---|---|---|---|---|---|---|
| EbNo | db2 | db4 | db6 | db8 | db16 | db32 | |
| 0 | 0.1056 | 0.105 | 0.1056 | 0.1056 | 0.1054 | 0.1052 | 0.105 |
| 5 | 0.04172 | 0.0418 | 0.04193 | 0.04184 | 0.04204 | 0.0419 | 0.04172 |
| 10 | 0.01442 | 0.01444 | 0.01454 | 0.01454 | 0.01442 | 0.01458 | 0.01442 |
| 15 | 0.004621 | o.oo4628 | 0.004529 | 0.004556 | 0.004537 | 0.004571 | 0.004529 |
| 20 | 0.001424 | 0.001462 | 0.001433 | 0.001431 | 0.00139 | 0.001473 | 0.00139 |
| 25 | 0.000461 | 0.000446 | 0.000444 | 0.000462 | 0.000444 | 0.000472 | 0.000444 |
| 30 | 0.000161 | 0.000161 | 0.001382 | 0.000127 | 0.000157 | 0.000144 | 0.000127 |



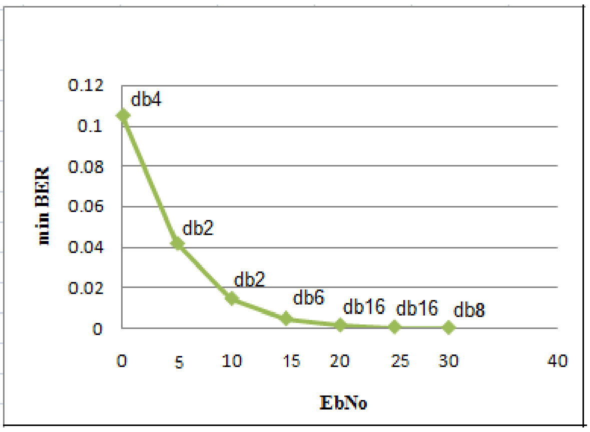



Figure 9: Performance of Daubechies Wavelet at different values of EbNo

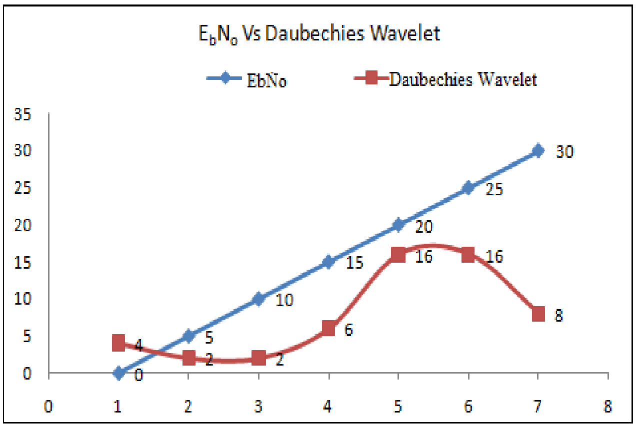



Figure 10: Graph between $E_bN_o$ Vs Daubechies wavelet in Rayleigh fading channel

## VIII. Results

Wavelets use to give improved message recovery over channel disturbances. This has become possible because of the multi-diversity behaviour of the wavelets. The results obtained above by simulation, justifies the multi-diversity behaviour if the wavelet, which means that if the message is not received at one rate due to channel disturbances, it can be received another rate where the channel is clear

BER performances of Daubechies N=2,4,6,8,16 and 32 in Rayleigh fading channel with Doppler spread of 10 Hz is analysed whose outcomes are.

(1) For EbNo of 0dB, db4 is more noise resilient, followed by db32.
(2) For EbNo of 5dB and 10 dB, db2 is more noise resilient, followed by db4 and db16 respectively.
(3) For EbNo at 15 dB, db6 is more noise resilient, followed by db16.
(4) For EbNo at 20dB and 25dB, db6 and db16 are equally noise resilient, followed by db4.
(5) For EbNo at 30 dB, db8 is more noise resilient, followed by db6.

The paper compares the performance of the system using 16-QAM only, whereas the future work may include the implementation of other modulation schemes and different channel scenarios for performance evaluation of any OFDM based system.

## Conclusion and Future works

Over all, the performance results of wavelet based OFDM and its ability to fulfil the wide range of requirements of tomorrow's ubiquitous wireless communications leads to a conclusion that this mew modulation technique is a viable alternative to conventional OFDM to be considered in future wireless communication systems

Because of the selective nature of wavelets, different order of the Daubechies wavelet should be selected for the enhanced performance of the system. Daubechies wavelet also generates a wave form of shortest duration. Short waveforms require less memory, limit the modulation-demodulation delay and require less computation which helps to implement fast wavelet transform less computational complex wavelet based OFDM scheme. This leads to conclude that Daubechies wavelet family can be a viable alternative suitable basis for OFDM to be considered for future OFDM communication scheme.

The paper compares the performance of the system using 16-QAM only, whereas the future work may include the implementation of other modulation schemes and different channel scenarios for performance evaluation of any OFDM based system. Diversity Scheme on Wavelet based OFDM: improved transmission integrity may be achieved with aid of diversity. Space, time, frequency diversities are the most physical diversities to be exploited.



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