PERFORMANCE EVALUATION OF DWT BASED MULTICARRIER SYSTEM IN TIME VARYING CHANNELS

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Abstract—With an increase in user mobility, data rate and carrier frequencies we have to consider time variant channels. In order to overcome the impairments of the time varying channel on conventional OFDM system, a wavelet based OFDM system is investigated in place of FFT based system and its BER performance is analyzed for different Doppler frequencies. The results show that DWT based OFDM gives better performance compared to conventional OFDM system.

Keywords—OFDM, ICI, Time varying channel,DWT

I. INTRODUCTION

OFDM (Orthogonal frequency division multiplexing) is a multicarrier modulation technique, in which multiple carriers which are orthogonal to each other and are closely spaced, transmit data simultaneously over a narrow bandwidth. Compared to conventional single carrier modulation, OFDM is bandwidth efficient, robust to ISI and ICI, resistant to frequency selective fading and has higher data rate since more symbols can be transmitted. OFDM [1] finds its applications in digital television, audio broadcasting, and also in upcoming wireless technologies like 4G and 5G. OFDM system can also be DWT based.

Due to an increase in user mobility, data rates, and carrier frequencies the assumption of a time invariant channel will not hold good. Dispersive fading, timing and frequency offsets, sampling clock offset, and nonlinear distortion will cause various impairments in OFDM system. These impairments may lead to loss of orthogonality between the subcarriers and thus degrading the performance of the conventional OFDM system (using FFT). In this paper, we investigate an OFDM system implemented using DWT, which gives better performance in a time varying environment than the conventional system. If the transmitter or receiver is moving, the electromagnetic wave or signal experiences an apparent change in frequency or a shift in frequency. This shift is termed as Doppler shift. Thus Doppler shift can be considered as a time varying impairment [7] affecting the OFDM system. In this paper, we investigate a wavelet based method to combat the effect of time varying impairments on conventional OFDM [10] system. Here we have used different wavelets like Haar, Daubechies and Biorspline for simulating the results of DWT based OFDM system. In order to analyse the performance of wireless communication system, BER curves are plotted BER gives the number of bit errors per unit time. The paper is organised as follows, section I is the introduction , section II describes the impact of time varying channel on conventional OFDM system, section III explains the DWT based OFDM system and the wavelets employed for simulating the results. Results and observations are discussed in section IV and finally conclusion in section V.

II. IMPACT OF TIME VARYING CHANNEL

When the channel is time variant [2], each subcarrier undergoes a Doppler spreading effect that destroys the orthogonality of subcarriers as a result ICI is produced. We may assume that shortening of the OFDM blocks would reduce the ICI, but it cannot be made practical owing to the use of cyclic prefixing. So it needs some processing at the transmitter to nullify the effect of ICI and also other Doppler distortions [6].Frequency offset and Doppler spread [7] can be considered as major time varying impairments [3] which affects the conventional OFDM system. In general, an OFDM signal can be represented as,

$$s(t) = \sum_k s_k e^{-j2\pi f_k t}, 0 \le t \le T_s \quad (1)$$

Where, $s(t)$ is the transmitted signal and

$$f_k = f_0 + k\Delta f$$

If due to frequency offset or Doppler spread, there occurs a multiplicative time varying distortion then the received signal will become,

$$x(t) = s(t)\gamma(t) \tag{2}$$

Here, the multiplicative time varying distortion [5] is represented by $\gamma(t)$

The resulting demodulated signal can be expressed as,

$$X_m = a_0 + \sum_{k=m} a_{m-k} S_k \tag{3}$$

Where the first term in equation 3 is the desired signal part and the other one is ICI (Inter-carrier interference)

a. Effect of Frequency offset

If there is a frequency offset between the transmitter and receiver, then the resulting time varying multiplicative distortion is,

$$\gamma(t) = e^{j2\pi\delta ft} = e^{j2\pi\alpha\nabla ft} \tag{4}$$

And thus the demodulated signal will be,

$$a_l = -\frac{\sin(\pi\in)}{\pi(l - k_0 - \in)} e^{+j\pi\in} \tag{5}$$

where, k_o and $\in$ denotes an integer and a fractional number respectively. If the fractional part is zero, only simple tone shift occurs due to frequency offset, no ICI. If the integer part is zero, there is ICI. If both integer and fractional parts are present, there is phase shift, tone shift, ICI etc.

b. Effect of Doppler Shift

Here the multiplicative time varying distortion caused due to Doppler spread [8] is stochastic unlike frequency offset case, where it was deterministic.

$$F_d = \frac{v}{\lambda}\cos\theta \tag{6}$$

$\gamma(t)$ has a Power spectral density given by,

$$P_J(f) = \begin{cases} \dfrac{1}{\pi f_d \sqrt{1 - (\frac{f}{f_d})^2}}, if \left| f \right| < f \\ 0, otherwise \end{cases} \tag{7}$$

Where f_d denotes the maximum Doppler frequency.

power of ICI due to Doppler is given by,

$$P_{ICI} \le \frac{1}{12}(2\pi f_d T_s)^2 \tag{8}$$

FFT based OFDM system has severe degradation in its performance due to these impairments .Thus, we need to go for DWT based OFDM system where we can overcome this problem.

III. DWT BASED OFDM SYSTEMS

The advantage of using DWT [9] is that they are orthogonal for all translations and scales of the carriers so that the orthogonality is not lost even under adverse conditions. In DWT [6] based OFDM, modulation and demodulation is performed by DWT and IDWT unlike conventional OFDM. It gives better performance compared to FFT based OFDM. From the literature survey we observed that, in DWT based OFDM system cyclic prefixing is not mandatory and thus bandwidth efficiency can be improved. Also transmission power can be reduced by using Wavelet transform. Fig. 1 shows the block diagram representation of OFDM system using DWT. At the DWT-OFDM transmitter, random binary data is mapped on to corresponding constellation points by a QAM modulator to produce symbols. Then modulation is carried out by taking IDWT and demodulation by taking DWT. It is then passed through the channel. At the receiver side the reverse operations are carried out to retrieve the data back.

Wavelets [8] can be expressed as scaled and translated copies fast-decaying oscillating waveform, the mother wavelet. Wavelets [9] extract information from different kinds of data like image and audio signal [10],[11]. Different types of wavelets used in this paper for simulating the results are Haar, Daubechies and Biorsplines. The Haar wavelet is used since it is the simplest possible wavelet. A complete orthonormal system is formed on [0,1] by the Haar system. It forms an orthonormal basis, for the space $L^2([0, 1])$ of square integrable functions on the unit interval.

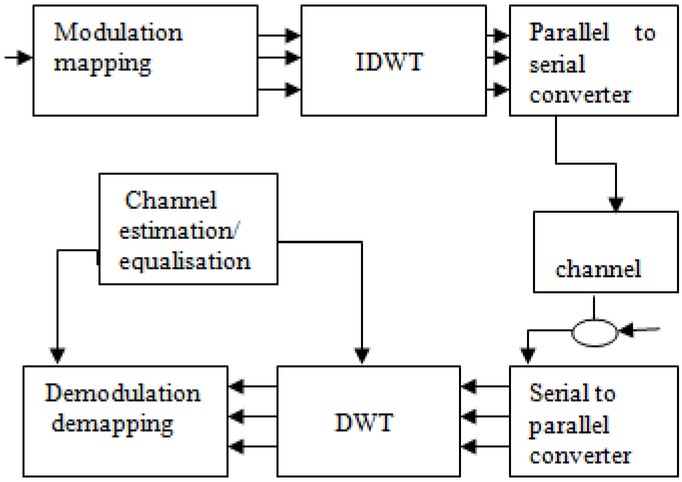


Fig. 1. Block diagram of Discrete wavelet based OFDM system

The Haar wavelet's mother wavelet function $\psi(t)$ can be described as,

$$\psi(t) = \begin{cases} 1, 0 \le t < \frac{1}{2} \\ -1, \frac{1}{2} \le t < 1 \\ 0, otherwise \end{cases}$$

the scaling function can be written as

$$\phi(t) = \begin{cases} 1, 0 \le t < 1 \\ 0, otherwise \end{cases}$$

Table1. Power delay profile of a channel model for a vehicular environment

Channel A			Channel B		
	Relative delay (ns)	Average power (dB)	Relative Delay (ns)	Average Power (dB)	Doppler spectrum
1	0	0	0	-2.5	Classic
2	310	-1.0	300	0	Classic
3	710	-9.0	8900	-12.8	Classic
4	1090	-10.0	12900	-10.0	Classic
5	1730	-15.0	17100	-25.2	Classic
6	2510	-20.0	20000	-16	Classic

A family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support is termed as Daubechies wavelet. The coefficients of scaling functions like D2, D4 and D6 are commonly used, where the index number indicates the number *N* of coefficients The ability of the wavelet to represent information in a signal as a polynomial is limited by the vanishing moment. For example, D2 encodes polynomials of one coefficient with one moment, which may be a constant signal component. D4 encodes two coefficient polynomials which includes a constant and linear signal component. Similarly, D6 encodes three coefficient polynomials, that is quadratic, linear and constant signal components. Biorspline wavelet is used in signal and image reconstruction. bior1.1, bior1.3,bior2.2 etc are different types of biorspline wavelets used in simulation of results.

IV. NUMERICAL RESULTS

In this paper, we investigate the DWT based OFDM system and compare its performance with that of FFT based system for different Doppler frequencies, fd= 6Hz, 50Hz and 30Hz. Among the different mother wavelets available for simulation purposes, we have used Haar, Daubechies and Biorspline mother wavelets for simulating the results of dwt based OFDM system. Here, 4-QAM modulator is used for constellation mapping, number of bits used is 10000.Number of subcarriers used in FFT based OFDM is eight and length of the channel used is three. Rayleigh channel in a vehicular environment is considered and SNR VS BER graphs are plotted for performance analysis.

Wavelets are constructed in such a way that their integer multiples are orthogonal to each other, therefore the impairments in conventional OFDM system can be avoided.

Fig. 2a, 2b and 2c indicates the performance comparison graph of conventional OFDM and DWT based OFDM system for varying Doppler frequencies fd=6Hz ,30Hz ,50Hz.Mother wavelet used for simulating the DWT plot is Haar. The figure depicts the BER (bit error rate) performance with respect to SNR (signal to noise ratio). In fig. 2a, it can be seen that at 10 dB SNR, for DWT based OFDM system, a BER slightly greater than 10^{-2} is obtained and for conventional OFDM a BER close to 10^{-1} is obtained. In fig. 2b, at 10 dB SNR, for DWT based OFDM a BER close to 10^{-2} is obtained and for conventional OFDM system, a BER almost equal to 10^{-1} is obtained and in fig. 2c, at 10 dB, for DWT based OFDM system, a BER of 10^{-3} is obtained and for conventional OFDM a BER close to 10^{-2}.Thus, it is clear that DWT based OFDM system gives better performance compared to conventional OFDM.

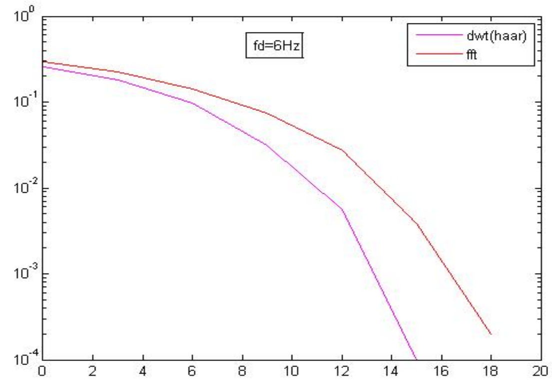
Fig. 3a, 3b, 3c indicates the BER performance comparison graph of conventional OFDM and DWT based OFDM system for varying Doppler frequencies fd=6Hz ,30Hz ,50Hz. Mother wavelet used for simulating the DWT plot is Daubechies. In fig. a, at 10 dB SNR, for DWT based OFDM system, a BER slightly greater than 10^{-2} is obtained and for FFT based OFDM, a BER between 10^{-1} and 10^{0} is obtained. In fig. b, at 10 dB SNR, for DWT based OFDM, a BER slightly greater than 10^{-3} is obtained and for conventional OFDM, a BER greater than 10^{-1} is obtained and in fig. c, at 10 dB SNR, for DWT based OFDM, a BER almost equal to 10^{-3} is obtained and for conventional OFDM, a BER almost equal to 10^{-1} is obtained. Thus the DWT based OFDM system gives better performance compared to FFT based OFDM system.

Fig. 4a, 4b and 4c indicates the performance comparison graph of conventional OFDM and DWT based OFDM for varying Doppler fd=6Hz ,30Hz ,50Hz.Mother wavelet used for simulating the DWT plot is Biorsplines. In fig. a , at 5 dB SNR, for DWT based OFDM, a BER close to 10^{-1} and for conventional OFDM, a BER greater than 10^{-1} is obtained. In fig. b, at 5dB SNR, for DWT based OFDM, a BER close to $10^{-1}$and for conventional OFDM, a BER greater than 10^{-1} is obtained. In fig. c, for DWT based OFDM, a BER slightly greater than 10^{-1} and for conventional OFDM, a BER between 10^{-1} and 10^{0} is obtained. Similarly for other SNR values DWT based OFDM system gives better performance compared to conventional OFDM.

Fig. 5a, 5b and 5c shows the BER performance comparison between various levels of DWT. In the figures 5a, 5b and 5c ,the wavelets used for simulating the results are dB1,bior1.1 and Haar respectively. We observed that at SNR equal to 6, the BER is lowest for level4 and highest for level1 with levels 2 and 3 in between. There is a possibility that performance may improve as level increases. Here we have considered only upto 4 levels and it was observed that level 4 gave the best performance compared to others.

DWT based OFDM system using Bior1.1 wavelet gives 9.8 % improvement compared to conventional OFDM system. DWT based OFDM using Daubechies and Haar wavelet also exhibited significant improvement in performance. Out of the wavelets used for simulating the results Bior 1.1 gives the best performance compared to all. Level 4 has the best performance when compared to the other three levels with levels 2 and 3 having performance in between them.

We analyse that when the doppler frequency is changed from 6Hz to 50Hz through 30Hz the DWT based OFDM system does not show a considerable improvement in the BER performance when compared to FFT based OFDM system. The BER performance graph was analysed for three different wavelets namely Haar, Daubechies and biorsplines by changing the doppler frequency.



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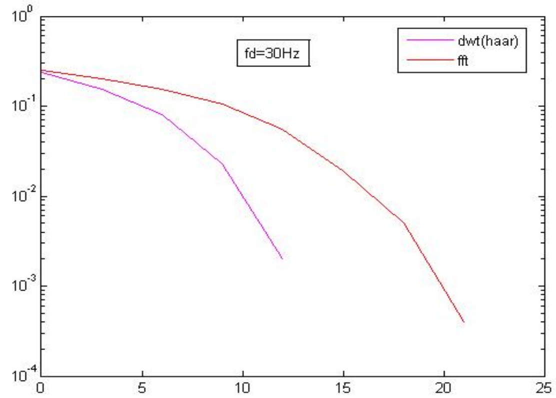

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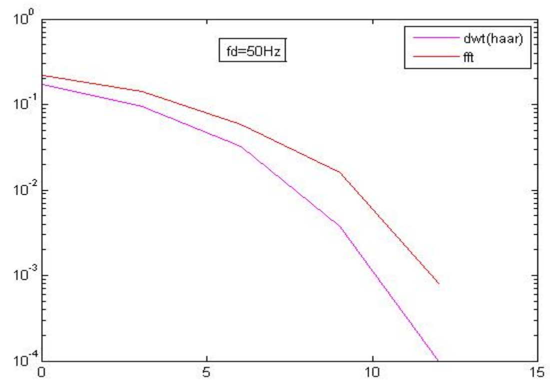

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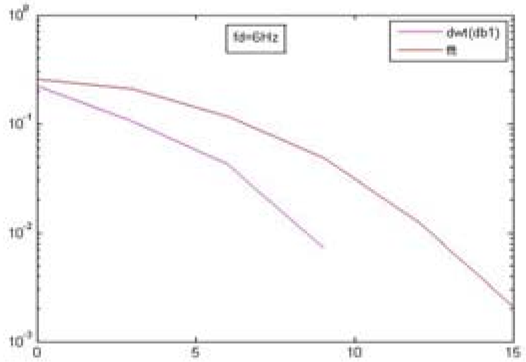
Fig. 2 represents the BER performance of Discrete wavelet transform based OFDM system of Discrete wavelet transform based OFDM(using Haar wavelet) system for varying Doppler frequencies like a)fd=6Hz b)fd= 30Hz



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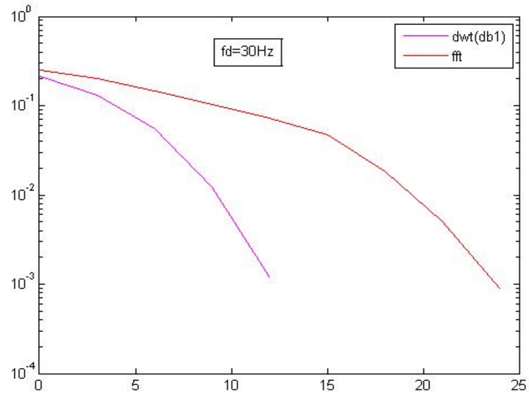

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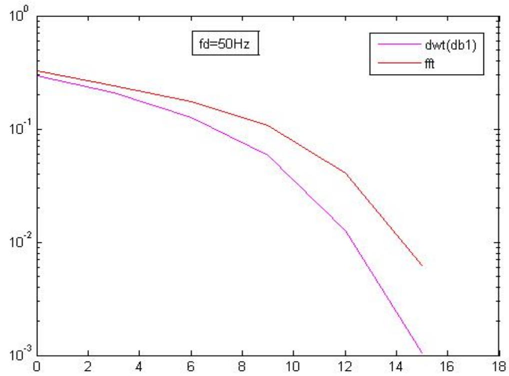

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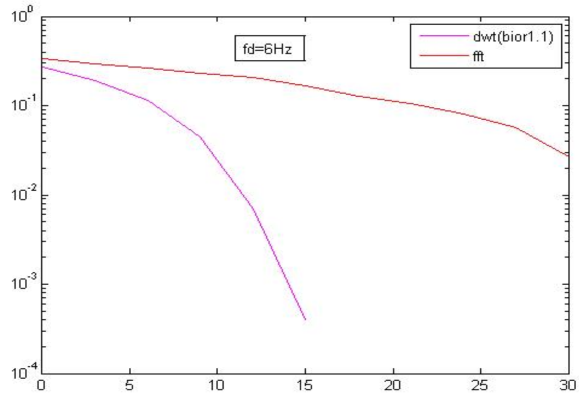
Fig. 3 represents the BER performance of Discrete wavelet transform based OFDM system of Discrete wavelet transform based OFDM(using Daubechies wavelet) system for varying Doppler frequencies like a)fd=6Hz b)fd= 30Hz



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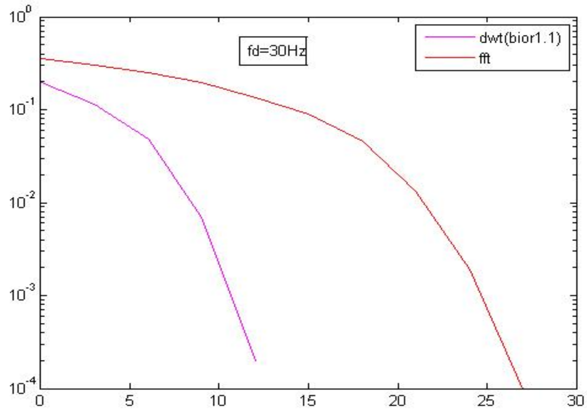

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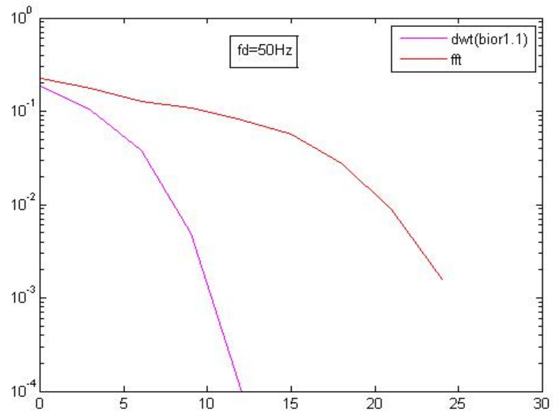

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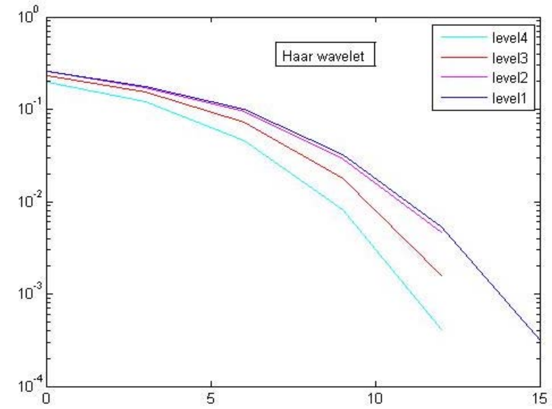
Fig. 4 represents the BER performance of Discrete wavelet transform based OFDM system of Discrete wavelet transform based OFDM(using Biorspline wavelet) system for varying Doppler frequencies like a)fd=6Hz b)fd= 30Hz



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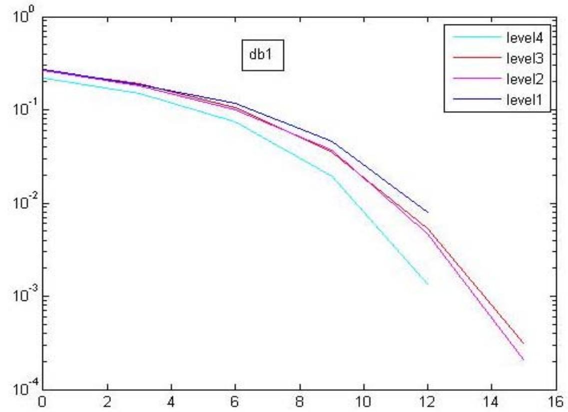

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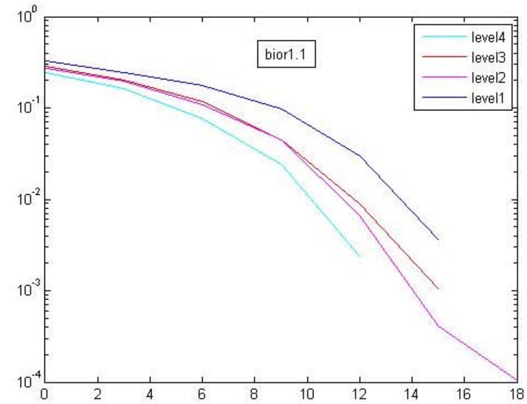

c)

Fig. 5 represents the BER performance of Discrete wavelet transform of different levels of wavelet a) Haar b) Daubechies and c) Biorsplines wavelet

V. CONCLUSION

In this paper, we analyzed the performance of DWT based OFDM system over conventional OFDM system under time varying channel. Simulation results show that wavelet based OFDM system gives better performance than the conventional OFDM system. We also observed the performance of various levels of wavelet and found that level 4 has a better performance compared to the others. Thus there is a possibility of improvement in performance with increase in levels. DWT based OFDM system, due to its ability to overcome time varying effects can be used in upcoming wireless technologies like 4G and 5G thereby enhancing the quality of communication.

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