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PAPR and Bandwidth Analysis of SISO-OFDM/WOFDM and MIMO OFDM/WOFDM (Wimax) for Multi-Path Fading Channels

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ABSTRACT
In today's wireless communication, the efficient utilization of resources is the main concentration of engineers and spectrum of the most significant resources. So the aim is to exploit the bandwidth in a competent manner. From the report of FCC it is known that the 70% of spectrum occupied by several mobile operators is not fully utilized that leaded to motive new developments of spectrum efficient communication technologies. Therefore, the present work, investigates the performances of several systems such as SISO, MISO and MIMO OFDM and wavelet based OFDM systems to reflect the expected improvements can be made in terms of BER versus SNR and PAPR in Multipath Rayleigh fading channel. The performance analysis over the modulation impact using BPSK, 4QAM, 16QAM and 64QAM are discussed. In addition, Orthonormal- wavelets Haar, Daubechies, Coiflet and Biorthogonal are used instead of the conventional Fourier-based carriers. It is concluded that WOFDM outperforms OFDM with 25% bandwidth efficiency.

Index Terms
Wavelet based OFDM, Bandwidth efficiency, PAPR, Orthonormal Wavelets, Multipath Rayleigh fading channel, BER, Multiple-Input Multiple-Output communications (MIMO).

I. INTRODUCTION
The efficient utilization of resources is one of the major attentions of engineers. So the aim is to exploit the bandwidth in a competent manner, additionally reduce peak to average power ratio (PAPR) that is one of the main problem in OFDM scheme [1, 2]. In addition, the wavelet based OFDM has been proved its importance to operate better than traditional OFDM because of its unique properties of wavelets as compared to sinusoids [3, 4], as demosnstrated by the Lab View simulation of SISO-OFDM, SISO-WOFDM and MIMO-OFDM, MIMO-WOFDM in terms of PAPR, bandwidth efficiency and BER results.

Reliability of today's deployed IEEE 802.16e WiMAX wireless communication system which is based on OFDM is limited; inaccuracies produced by ICI are avoided by the use of guard band/cyclic prefix insertions that decreases the spectral efficiency correspondingly [5]. In this work a WOFDM scheme is offered and investigated which is based on Haar-orthonormal wavelets and perfect reconstruction QMF bank that helps to reduce the ISI and ICI, in addition increases the system performance in terms of BER and lower PAPR [6, 7].

II. SYSTEM MODEL
OFDM and Wavelet based OFDM systems (SISO, MISO, MIMO) are implemented with and without Alamouti coding as shown in Figures 1, 2 and 3 [6]. Implementation of both OFDM and WOFDM systems are same instead wavelet based systems are implemented without cyclic prefix insertion, therefore increases the bandwidth efficiency up to 25% [8].

Fig. 4 is illustrating the orthogonal wavelet division multiplexing, in which a 3-level inverse discrete wavelet transform at transmitter with Lowpass and highpass filters of synthesis side and a 3-level discrete wavelet transform at receiver with Lowpass and highpass filters of analysis side, are used in WOFDM systems for multiplexing instead of OFDM [9].

On receiving the symbol r(n) on the analysis side, the discrete wavelet transform is performed to decompose the signal in terms of approximate and detail coefficients with the help of a conjugate high pass filter h*(-n) and a low pass filter g*(-n) as shown in Fig. 4(b).

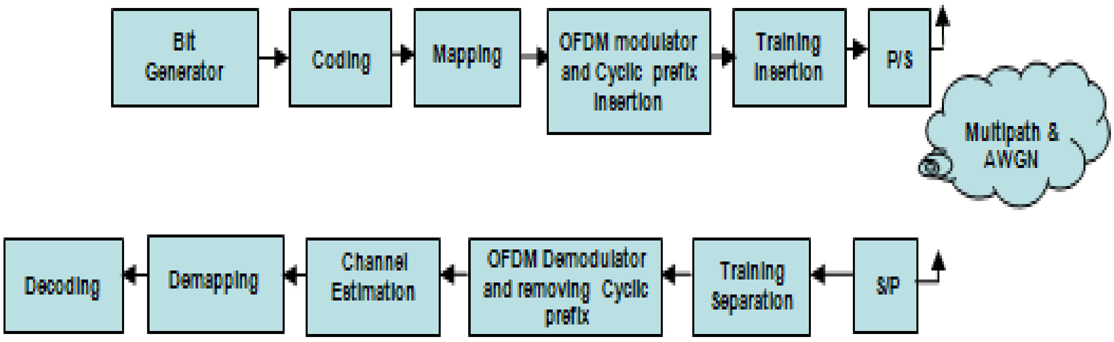
The relationship between the high and the low pass filters applying a quadrature mirror filter (QMF) bank is given by:

h(n) = (-1)n g(U-1-n) (1)

Where U = length of filter, that defines the number of filter coefficients

A. Lowpass and Highpass Filters Of Synthesis Side
Low pass filter coefficients for synthesis side of quadrature mirror filter bank are given as {0.707, 0.707}, the following procedure is used in order to find the high pass filter coefficients:

$$H_H(\mathrm{n}) = (-1)^{n+1} H_L(z^{-1}) = -0.707 + 0.707z^{-1} \quad (2)$$



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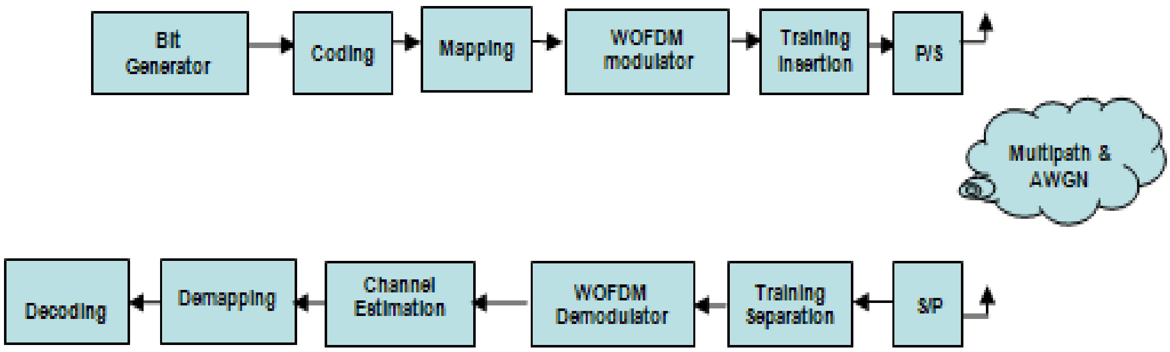


(b)

Fig. 1: Transceivers Block Diagrams;
(a) SISO-OFDM
(b) SISO-WOFDM

B. Lowpass and Highpass Filters of Analysis Side

Similarly, following are the formulas used to find out the low and high pass conjugate mirror filter respectively, for analysis side:

$$F_L(\mathrm{z}) = H_L(z^{-1}) = 0.707 + 0.707z \quad (3)$$
$$F_H(\mathrm{z}) = H_H(z^{-1}) = -0.707 + 0.707z^{+1} \quad (4)$$

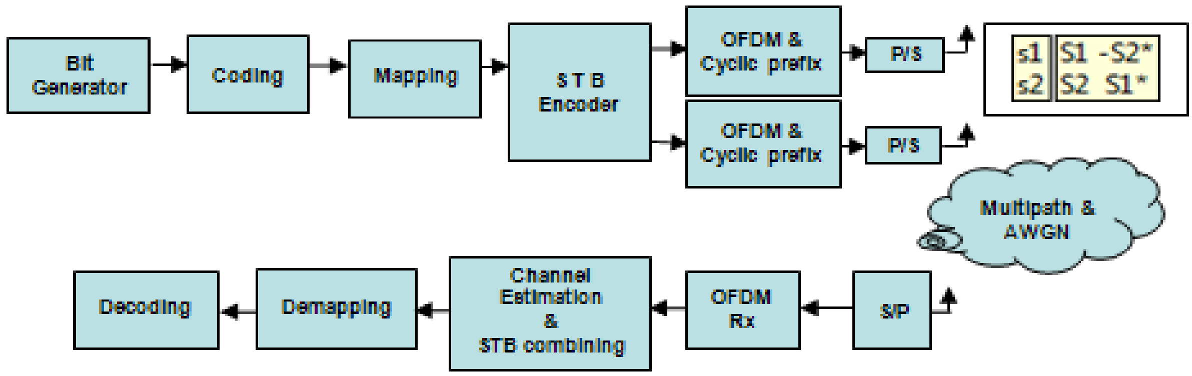
In Equ. (3) and (4) there are positive delays and in real time these kinds of delays doesn't exists, therefore these delays have been compensated by adding padded zeros. The filters after padding some zeros are given by the following:

$$F_L(\mathrm{z}) = -0.707z^{-1} + 0.707z^{-2} \quad (5)$$
$$F_H(\mathrm{z}) = 0.707z^{-1} - 0.707z^{-2} \quad (6)$$

At transmitter side of MISO and MIMO systems, Space Time Block Coding (STBC) has been applied, and at receiver STB combining is used [10]. Channel estimations are done with pilot and preambles insertions. In addition, two Rayleigh fading channels with exponential power delay profiles are modelled through which symbols will be navigated as well as AWGN channel is used [11].

III. SIMULATION RESULTS

Multicarrier transmissions involving the use of cyclic extension to mitigate multipath influence and inter-carrier interference follow with some cost. For instance, if L is the length of OFDM blocks, cyclic extension is usually appended to this symbol thus increasing the length of the symbol by a fraction µ. This will cost a transmit power value of L/ (L+ µ) and an added noise of (L+ µ)/L [Goldsmith, 2005] [12]. If however that zero is transmitted in this period instead of copied part of the OFDM symbol, transmit power shall have been optimized because the guard period will cost zero-transmit power but ICI prevails. Now, consider a case where no cyclic prefix is required, the bandwidth, the noise and the power penalties shall have been gained. These are the merits WOFDM offers [13].



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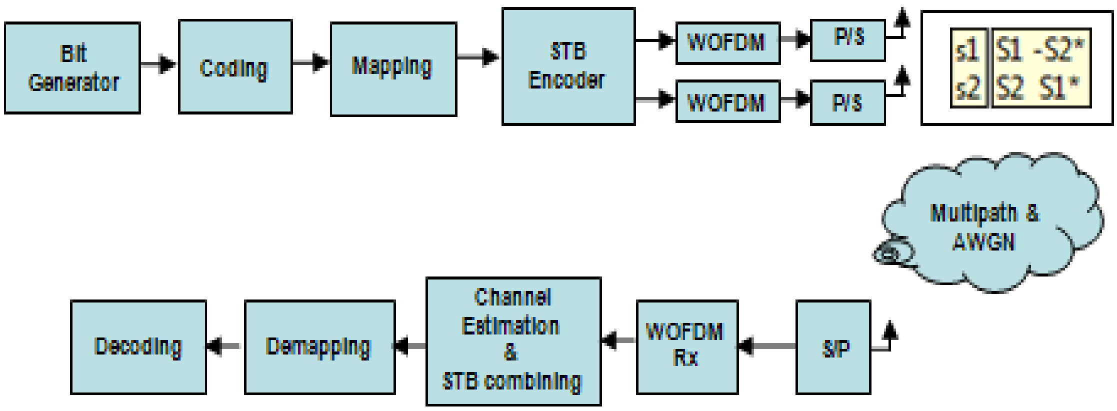


(b)

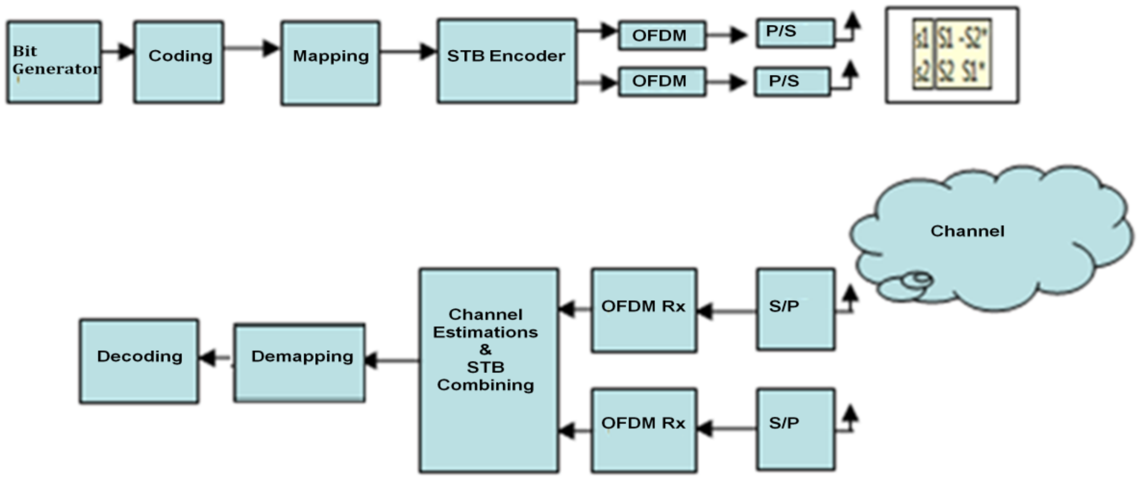
Fig. 2: Block diagrams of considered systems;
(a) MISO-OFDM (2×1 Alamouti) System,
(b) MISO-WOFDM (2×1 Alamouti) System.

PAPR evaluation has been widely studied for improved performance in systems that are conventionally OFDM-based. The PAPR can be computed in dB as follows;

$$PAPR = 10\log\left(\frac{\text{Peak Power}}{\text{Average Power}}\right) \quad (7)$$

Fig. 5 is demonstrating the PAPR of both OFDM and Wavelet based OFDM for BPSK, 4QAM, 16QAM and 64QAM. Reduction in peak to average power ratio can be seen clearly using the User-defined wavelet coefficients (Haar & Daubechies). It is to be noted that the WOFDM signals peaks are lesser than that of the OFDM signal.

BER versus SNR of SISO for OFDM and WOFDM and BER versus SNR of MISO (2×1Alamouti) for OFDM and WOFDM in AWGN plus Multipath channel are illustrated in Figs 6 and 7. The implementation of 2×2 Alamouti both with OFDM and WOFDM for BPSK and 4QAM in AWGN channel is also shown in Figs. 8 and 9. Performance increase in terms of BER can be seen evidently with the increase in diversity branch. The parallel effect of OFDM/WOFDM as in all other implementation is found in this implementation as well.



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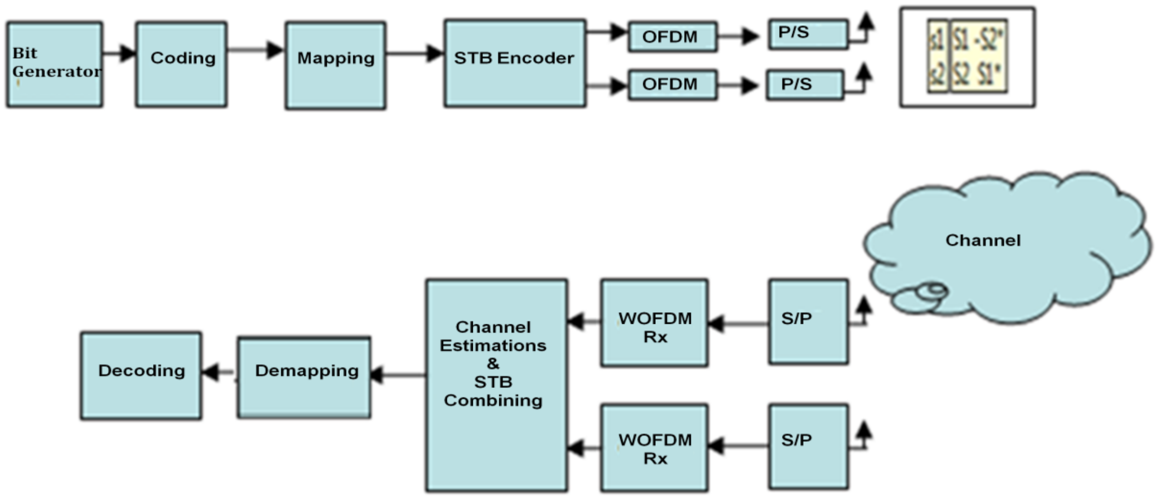


(b)

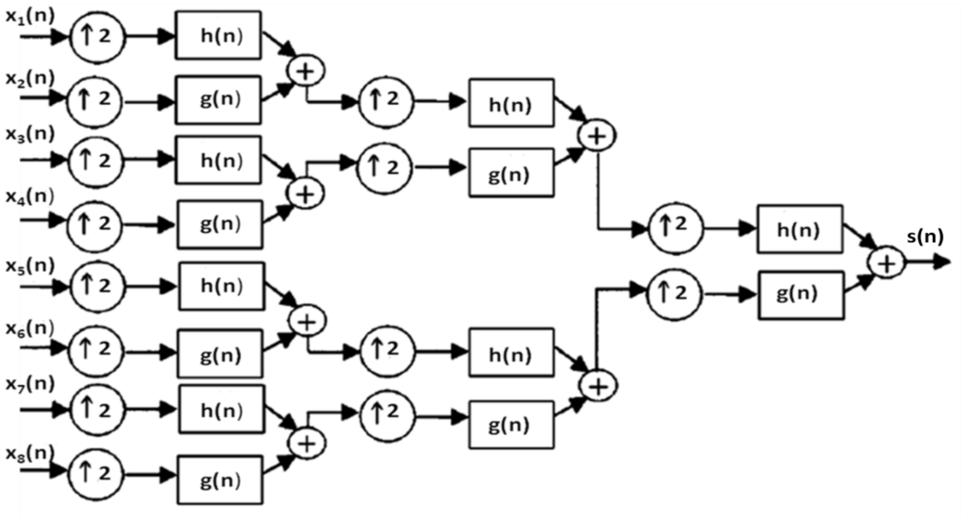
Fig. 3: Block diagrams of MIMO systems:
(a) MIMO-OFDM (2x2 Alamouti) System,
(b) MIMO-WOFDM (2x2 Alamouti) System.

In all the figures shown it is well worth to notice that the BER curves of all the modulation schemes for OFDM/WOFDM having exactly the same variations and besides increasing the symbol rate or going to higher modulation schemes proportionally influence the BER and makes the scheme less tolerant to bit error rate. Lower modulation schemes like BPSK provides better performance with less SNR because of the reason, that increasing signal energy establishes the larger distance between adjacent symbols that can endure large noise and augment the boundary margins.

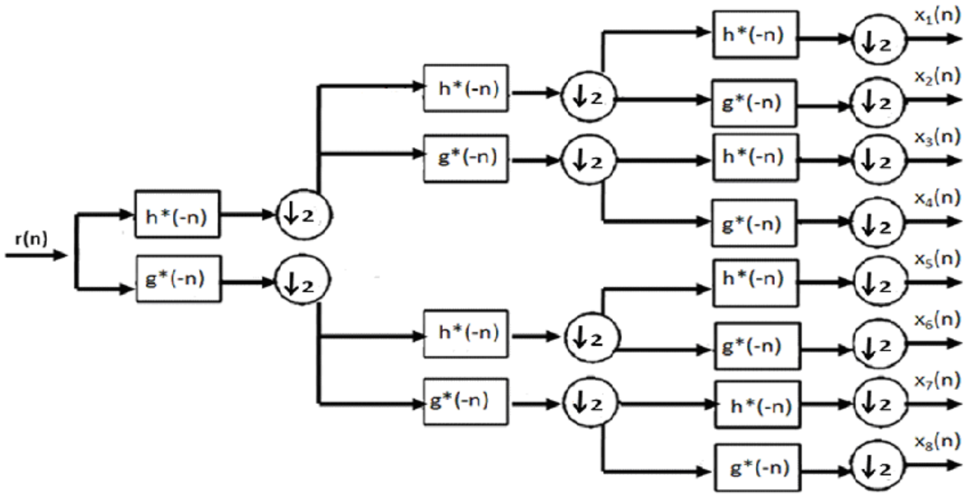
Even though we have a trade-off between the complexity, delay and QoS, but there is one more compromise that is between BER and Bandwidth efficiency. As it is stated that without insertion of cyclic prefix we have achieved 25% bandwidth efficiency but what if we do insert the cyclic prefix and increase the length of WOFDM symbol by 25% than the performance of WOFDM in terms of BER might be much better than traditional OFDM but the opportunity of achieving higher bandwidth efficiency would be lost so we have to state either we want to have good QoS or more bandwidth saving.

Beside the purpose of proving the bandwidth efficiency, BER and PAPR improvements, it can also be verified that making use of diversity principle and increasing number of diversity branches, leaded us to more stabilized system and better QOS in terms of BER that is clearly proved by the results.

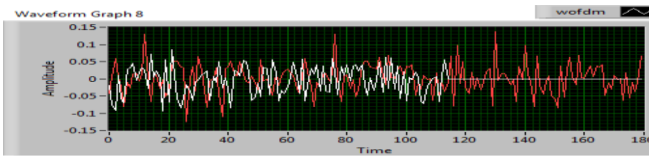
We have also demonstrated the simulation and importance of different wavelet families with respect to different applications and it may be suggested that Haar/db1 wavelet is most suited for WOFDM implementations because of better performance and more resilience to noise



(a)



(b)
Fig. 4: WOFDM transceiver;
(a) Modulator,
(b) Demodulator.



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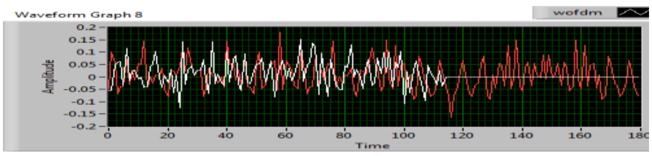

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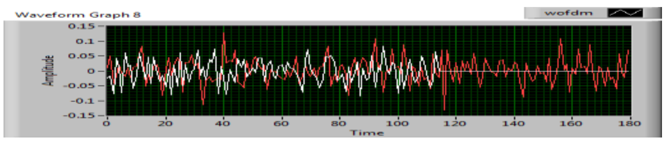

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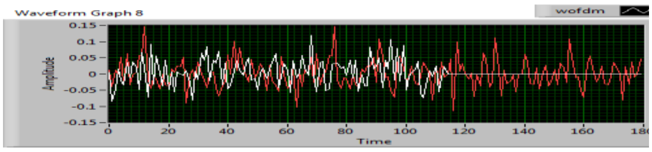

(d)

Fig. 4: Peak reduction assessment of OFDM (red line) and WOFDM (white line);
(a) BPSK
(b) 4QAM
(c) 16 QAM
(d) 64 QAM.

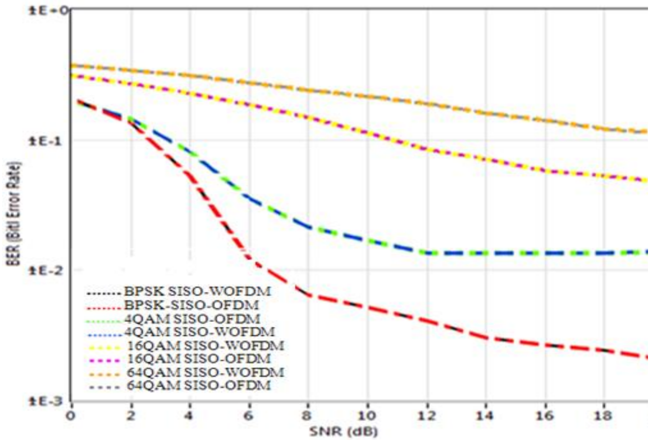

Fig. 5: BER versus SNR of SISO OFDM and WOFDM in AWGN and Multipath.

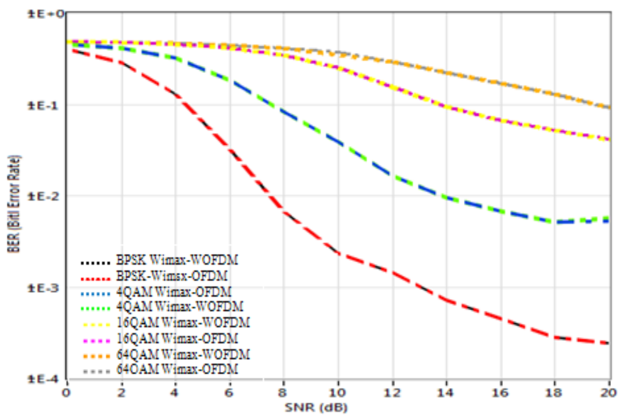

Fig. 6: BER versus SNR of MISO (2×1Alamouti) OFDM and WOFDM in AWGN and Multipath.

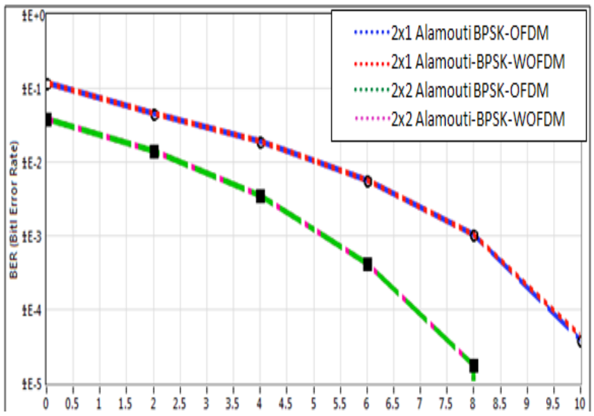

Fig. 7: BER versus SNR of MISO and MIMO (2×1 and 2×2 Alamouti: BPSK) OFDM and WOFDM in AWGN.

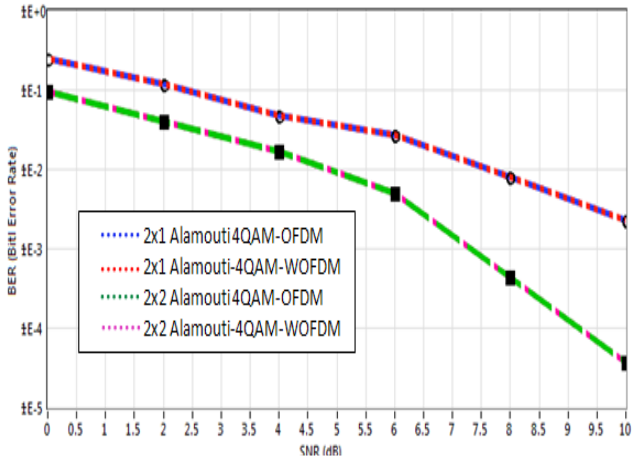

Fig. 8 BER versus SNR of MISO and MIMO (2×1 and 2×2 Alamouti: 4 QAM) OFDM and WOFDM in AWGN.

IV. CONCLUSIONS

Proposed WOFDM scheme is investigated and compared with OFDM system in terms of BER, PAPR, bandwidth efficiency and Considerable improvements have been seen. Of course, there are many other aspects where the performance of WOFDM needs to be compared with OFDM in order to show its significance but they may be considered for future work Overall we conclude that the WOFDM scheme can be a better alternative to OFDM scheme.

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