Wavelet Entropy Algorithm to Allocate the Extreme Power Peaks in WiMax Systems

http://dx.doi.org/10.3991/ijim.v8i4.3766

Qardi Hamarsheh, Omar Daoud, and Saleh Saraireh
Philadelphia University, Amman, Jordan

Abstract—**This work proposes a solution to overcome the effect for one of the main drawbacks of these days' wireless systems, where Multiple-Input Multiple-Output (MIMO)-Orthogonal Frequency Division Multiplexing (OFDM) combinations has been used. High peak-to-average power ratio (PAPR) arises after the OFDM stage and reduces the performance of the used nonlinear devices. Therefore, a new stage has been imposed between the MIMO and OFDM block. It is based on the entropy meaning of the wavelet transformation to trigger a proposed thresholding criterion and reconstruct the OFDM signal. As a result, the probability of high PAPR appearance will be limited and reduced; a promising result over our recently published work has been conducted; 15-25% extra reduction. This work could be denoted by MIMO-OFDM based on Entropy Wavelet Transform (MO-EWT) systems.**

The MO-EWT validity has been checked based on either numerical analysis or conducted simulation based on MATLAB; where 80% improvement of reducing the high PAPR has been achieved over the literature. These results have been reached using the same environment conditions and at additional cost and complexity of the transceivers structure.

Index Terms—**Thresholding, Wavelet Entropy, MIMO, OFDM, PAPR**

I. INTRODUCTION

The transmission capacity and spectrum efficiency are considered as vital parameters for enhancing the performance and the multimedia quality of the wireless communication systems during the past decades. Increasing both of users and market demand for the best quality was the challenge for the scholars to propose rigid systems to meet these demands. Therefore, combination between two powerful techniques has been found in the literature to offer such services with high quality and adequate spectrum allocation; Multiple-Input Multiple-Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) systems. As a result of such combination, they making use of the multipath to enhance the system capacity instead of consider it as a deficiency. Furthermore, it is using the diversity gain to enhance the system robustness to the noise and then improving the system link reliability. Moreover, a good utilization of the frequency spectrum has been offered by using the parallel transmission of the sequential one. There are several ways to implement the MIMO systems to enhance either the spatial diversity or the diversity gain, where the OFDM is easily implemented using the fast Fourier transforms (FFT) and its inverse [1-8]. However, the wireless system performance will be affected by a main deficiency that is resulted after the inverse-FFT (IFFT) stage in the transmitter; namely, Peak-to-Average Power Ratio (PAPR). Due to the unexpected resultant large peaks, the dynamic range of the used nonlinear devices in the transceiver should be enlarged otherwise the output will be distorted and will limit the work performance of such devices. This distortion will cause some vital deficiencies that will affect the system performance, such as spectral spreading, intermodulation, effect the signal constellation. This will cause an increasing in the system cost and complexity [6,8,9].

For such problem, utilizing the PAPR will result an improvement of the overall signal to noise ratio. Various methods, techniques and algorithms have been found in the literature to ease this bottleneck problem and utilize the PAPR problem to improve the overall link budget [10-16].

As a conclusion, MIMO-OFDM technology is considered as a powerful one that is proposed to be used in the next generation of the wireless communications systems.

Imposing some other technologies to this combination has been found in the literature to improve and enhance the system characteristics, such as the wavelet transform technology. It has been used in order to improve and enhance the OFDM system under the multipath fading channel characteristics. Furthermore, the wavelet packet has been proposed to be used instead of the FFT block to enhance the both of SNR and BER, improve the spectral efficiency, the same time reduces the transmitted power, and finally can manage the frequency offset and phase noise, then reduces the inter symbol interference (ISI) and inter carrier interference (ICI) [17-23]. Furthermore, OFDM based wavelet has been found in the literature as a solution of combating the PAPR problem and then providing better transmission quality [24].

This work details a proposed work as a new usage of the wavelet transform to deal with the PAPR problem. Here, the wavelet entropies have been used to trigger a thresholding criterion to deal with the affected OFDM symbol by large PAPR values. This is in addition to give a reconstruction criterion to enhance the BER of the system. This proposition has been compared to our previously published work in [10, 24] and to some techniques in the literature such as partial transmit sequence (PTS) and the clipping algorithms.

The rest paper is organized as follows; the introduced structure of the WiMax system based on the wavelet entropy is defined in Section 2, the simulation results that validated the numerical model are presented in Section 3, while the last section summarizes the conclusion.

II. WI-MAX SYSTEM DESIGN BASED ON WAVELET PEAK DETECTION

As a radio resource management solution, the IEEE 802.16 standard, WiMAX, is considered these days. It offers the facility of describing the traffic profile for the users and there service need. Thus, the quality of service requirements (QoS) and the traffic characteristics could be determined to support various data transmissions scenarios [25].

The structure of the modified WiMax systems after imposing the MO-EWT is shown below in Figure 1. Here, we can divide the system block diagram into three main parts; OFDM part, the proposed algorithm and the MIMO part. For the MIMO part; Convolutional encoder is used, in addition to Quadrature Shift Keying (QPSK), and 256 IFFT points. After, the FFT block the high power peaks could be appeared due to the coherence addition at the same phase. Therefore, the proposed work has been placed at this stage to overcome the effect of the resultant high PAPR. Finally and before the transmission stage the signals will pass through Vertical-Bell Laboratories Layered Space-Time (V-BLAST) MIMO system, where it's used to enhance the system capacity/throughput expressed in terms of bits/symbol.

Not like the proposed work in the literature, the wavelet entropy has been proposed to trigger an adaptive clipping criterion in order to overcome the high PAPR effect. Furthermore, there are no overload resulted since there is no need for redundant data to be transmitted.

The proposed work is clearly explained by the depicted flowchart in Figure 2. As a start, wavelets could be defined by a small wavy function of proficiently limited duration over an average of zero. It deals with signal based on power of two and it can decompose it based on its high and low frequency bands at each level. This will be attained by using a pair of low and high pass filters to be decimated by a factor of two. For capturing different features during the temporal information detection, this process is repeated to get smaller frequency bands. Secondly, as a general, the entropy of the wavelet could be defined as:

$$P_j = \frac{E_j}{E_{total}} \quad (1)$$

E_j is the energy at each j resolution level, E_{total} is the sum of E_js where j is in the same interval; j=-N,….,-1.

The equation in (3) could be easily applied on the discrete wavelet decomposition of any signal $S(t)$ that is found in as:

$$S(t) = \sum_{j=-N}^{-1} \sum_k C_j(k)\psi_{j,k}(t) \quad (2)$$

$C_j(k)$ is the wavelet coefficient and limited to following frequency interval $2^{j-1}\omega_s \leq |\omega| \leq 2^j\omega_s$ [26-28].

The depicted flowchart in Figure 2 is used to ease the understanding of the process of the proposed work. It starts with scanning the resultant signal after the IFFT block, where a high peak power occasionally appears and defined mathematically as in [8]

$$\text{PAPR} = NT \times \frac{\left(\left|\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X_n e^{j2\pi f_0 n t}\right|^2\right)}{\left(\int_0^{NT}\left|\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X_n e^{j2\pi f_0 n t}\right|^2 dt\right)} \quad (3)$$

X_n is the data modulating the n-th is sub carrier and f_o is the nominal subcarrier frequency spacing, N is the length of FFT stage, T is the symbol duration, t is in the range of $0 \leq t \leq NT$.

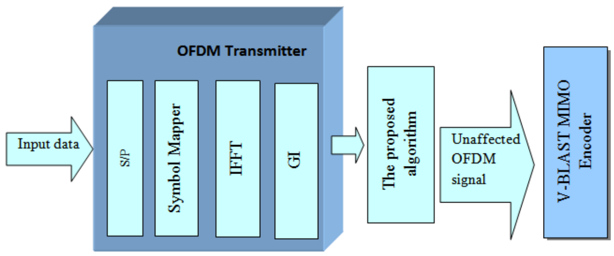

Figure 1. WiMax based MO-EWT system block diagram

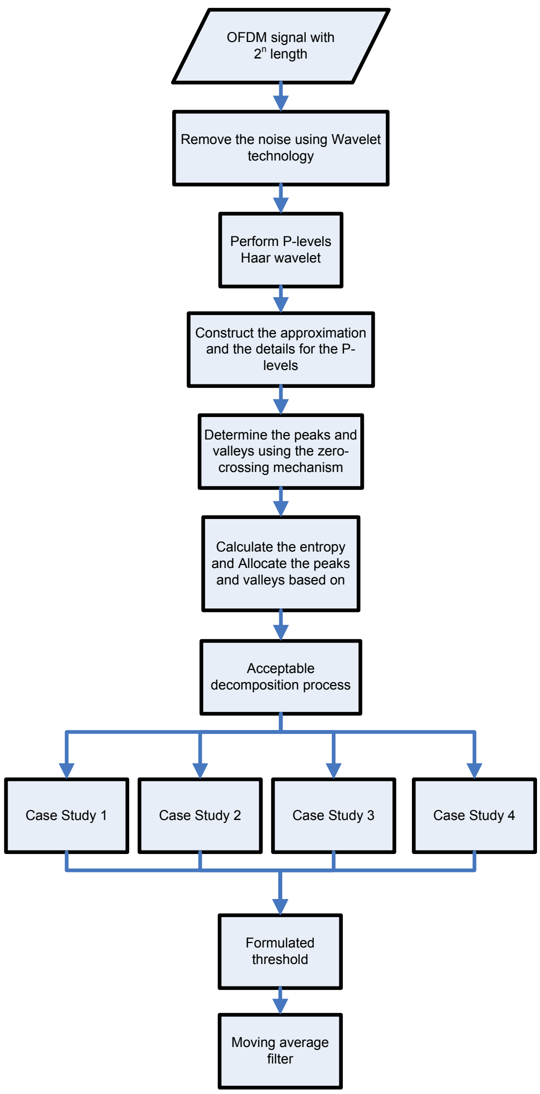

Figure 2. Flowchart of the proposed algorithm

Then the scanned signal will pass through 5 different stages as follows:

1) *The preprocess stage:*

In this stage, the signal will be treated from the noise using the wavelet technology, it will be decomposed into *P*-levels, and then approximates and details will be generated. This will be accomplished using Haar wavelet decomposition of a signal with *P*=8.

2) *Dealing with extreme Peaks and Valleys Stage:*

- In this part, the zero crossing mechanism is used to find the extreme peaks values for the founded details coefficients. This is true for local peaks and valleys detection.
- Finding the locations of such peaks in the original OFDM signal, and then store them into a different decomposition level matrix. This projection will be based on an adaptive proposed classification formula:

$$2^n * j + s \qquad (4)$$

n is the index of the decomposition level, and s value is an adaptive factor changed with changing the decomposition level.

3) *Entropy calculation Stage:*

Based on Shannon method, Table 1 shows the calculated entropies for both of the preprocessed OFDM signal and the decomposed P-Levels. 4 different case studies have been studied to show the proposed work powerfulness. This is in addition to check the peak detection error ratio as a factor of the comparison as shown in Figure 3.

First Case Study: This case study will take into account the details of each level to detect the True and False local extremes points.

Second Case Study: Based on achieved results in Table 1, where the decomposition acceptance shows that the decomposition is not accepted after the second level. Thus, the first two decomposition levels will be used.

Third Case Study: Using all decomposition levels that satisfy the decomposition acceptance stage.

Fourth Case Study: Based on the results found in Table 2, the peaks allocations will be based on each decomposition level separately. The error ratio plays vital role in the allocation process, as an example the false peaks in higher level with good error ratio can be excluded. For that the sharing peaks for the given packet with previous level can be detected and declared as true peaks as shown in Figure 4 for the lowest level ($P = 8$).

4) *Thresholding Stage:*

An adaptive thresholding formula is proposed to remove low amplitude peaks, while only the significant ones will be taken into consideration. These results are depicted clearly in Figure 5. The adaptive thresholding formula is given as:

$$\mathbf{T} = \frac{(\mathbf{max} + \mathbf{abs\_avg} + \mathbf{abs\_dev})}{\mathbf{K}} \qquad (5)$$

max defines the OFDM signal maximum value, **abs_avg** stands for the OFDM signal average value, **abs_dev** is the mean absolute deviation, and **K** is the adaptive constant that defines the type of thresholding criteria. Thus, the predetermined threshold is used as an adaptive criterion to be attuned with the different wireless systems.

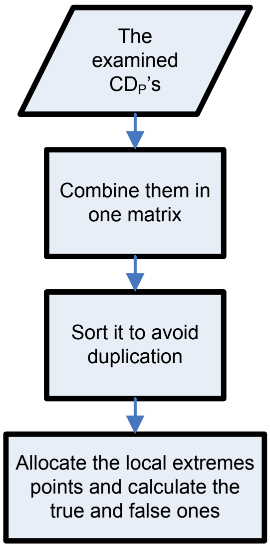

Figure 3. Flowchart of the used procedure

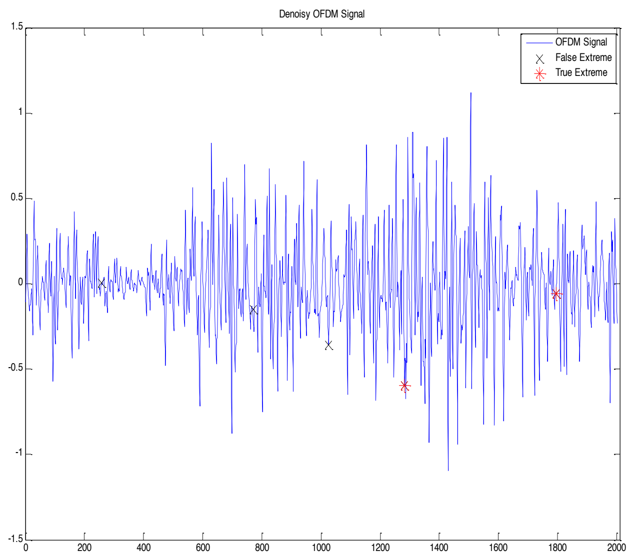

Figure 4. sharing peaks detection for decomposition level P=8

TABLE I.
PACKETS' ENTORPY VALUE

P level	Entropy				Decomposition Acceptance*
	CDp	CAp	Summation	Original Signal	
1	13.3924	60.8508	74.2432		**Accepted**
2	26.5319	32.917	59.4489		**Accepted**
3	16.3553	20.7162	37.0715		Not Accepted
4	8.2519	9.7128	17.9647		**Accepted**
5	6.3765	3.2822	9.6587	**100.4268**	**Accepted**
6	1.6068	0.93369	2.5405		**Accepted**
7	1.541	0.54864	2.0897		Not Accepted
8	0.62314	0.059486	0.68262		Not Accepted

(*)Acceptable for Decomposition when the sum of entropies of the given level (approximations and details) is less than the entropy of the level above the given.

5) *Saving the original values Stage:*

Figure 6 shows the results of using the moving average (MA) filter to save the original peak values to be compared with the transmitted amended ones. The suffered OFDM symbols with high peaks will be treated according to their surrounding neighbors and then replaced them to avoid the deficiencies caused by the transmission of high power peaks.

The proposed five stages algorithm shows that the wavelet entropy could be used to allocate and overcome the effect of the high peaks powers. It is clearly shown that calculated entropies in Table 1 acting as a thresholding role and gives varies results depending on the used decomposition level and on the use case study. Among the four case studies, case study number 4 gives the best results where the lowest error ratio is found and equals to 4% and 414 allocated peaks.

TABLE II.
TOTAL, TRUE AND FALSE LOCAL EXTREMES POINTS' NUMBER

Case Study Number		Number of peaks			Error Ratio %
		Total	True	False	
1		461	389	72	16
2		408	383	25	6
3		424	390	34	9
4	P-level				
	CD1	398	389	9	2
	CD2	353	347	6	2
	CD3	139	92	47	34
	CD4	53	40	13	25
	CD5	33	25	8	24
	CD6	8	7	1	13
	CD7	8	5	3	38
	CD8	5	2	3	60
Peaks Clustering		414	395	18	4

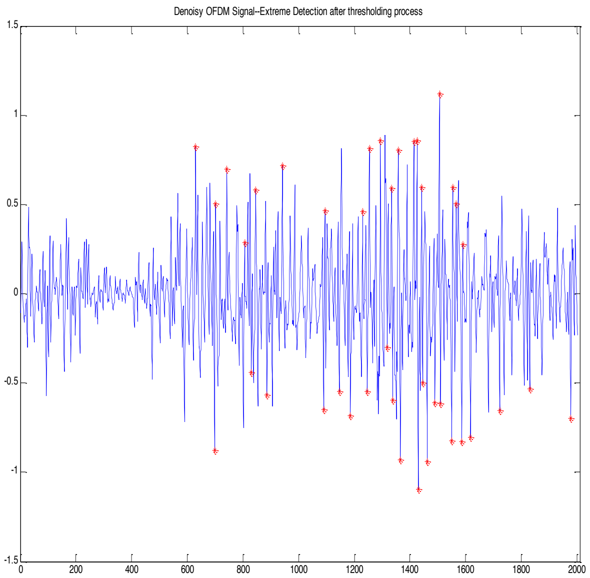

Figure 5. Extremes detection after thresholding process.

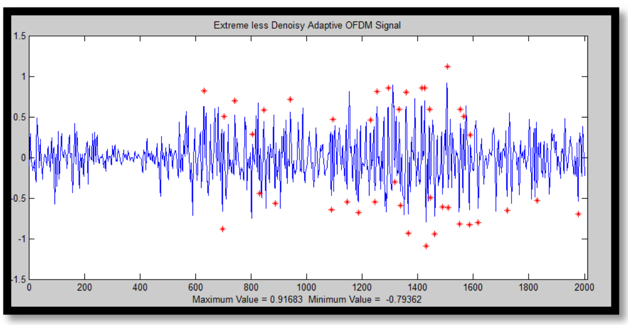

Figure 6. MA Filter result.

TABLE III.
SHARING PEAKS DETECTION AND ERROR RATIO FOR ALL DECOMPOSITION LEVELS.

P-level	Total number of local extremes points	NSEP	NRTE	$Error\ Ratio_{TE}$ % (*)
CD8	5	2	1	50
CD7	8	3	2	33
CD6	8	3	2	33
CD5	33	13	8	38
CD4	53	29	19	34
CD3	139	79	73	8
CD2	353	343	336	2
CD1	398		First level (stop sharing process)	

III. SIMULATION RESULTS AND DISCUSSION

Two main factors have been taken into consideration to check the proposed work performance; the bit error rate (BER) and the complementary cumulative distribution function (CCDF) curves. The work in defines the BER formula as

$$\text{BER}= BER_{WGN}\left(-\lambda \ln\left(\frac{1}{NQ}\sum_{q=1}^{Q}\sum_{n=1}^{N}\exp\left(\left(\frac{-SNR_q}{\lambda}\right)\right)\right)\right) \quad (6)$$

N is the total point's number of the FFT block, n is the n-th taking the values between 1 and N, Q is the amended data that passes through certain number of antennas, and λ is a system level simulation based parameter. The CCDF curves gives the system performance based on the probability of such peaks that are higher than a reference level.

A conducted MATLAB simulation limited to the following factors has been made. The results have been compared with both of the conventional techniques and our previously published work [10,22,23] under equivalent conditions.

- To be compatible with the WiMAx systems:
  - 20 MHz channel bandwidth
  - 1.152 oversampling ratio
  - 256 FFT points (200 data points)
  - QPSK modulation technique
- 2s duration real input data
- Convolutional encoder with coding rate of 1/2, and

WiMax system's performance has been checked based onto two main categories, where depicted in Figure 7 and 8; the CCDF curves and the BER curves. It is clearly shown that the proposed work has better performance than either some techniques found in the literature such as clipping technique and partial transmit sequence (PTS) or our previously published work found in [10]. This is in addition to that the MO-EW**T** enhances the probability that the PAPR exceeds 14dB from 2.5×10^{-2} to 1.9×10^{-1}, when the modulation technique has been change to 64QAM.

Moreover, it is observed through from Figures 8 and 10 that the use of higher order modulation techniques gives better BER than the lower order ones; the BER has been improved to be 7.5×10^{-1} while it was 1.8×10^{-1}. Thus, using MO-EW**T** gives extra 15% reduction of the CCDF value at 20dB threshold over our previously published work in [9].

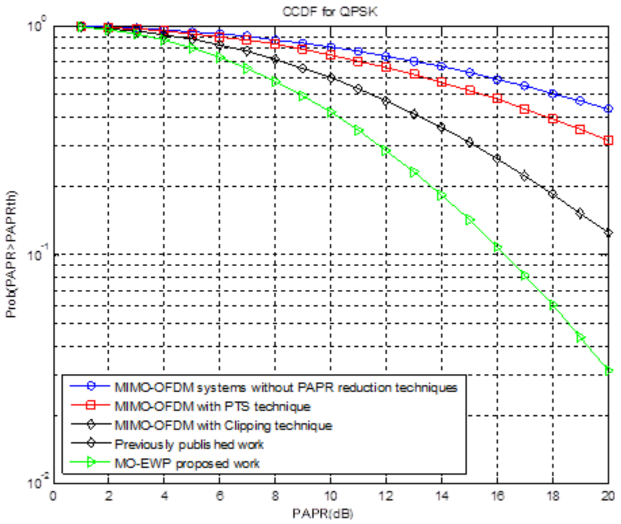

Figure 7. CCDF comparison among the MO-EWT and the work in the literature and our previously published ones using QPSK modulation Technique

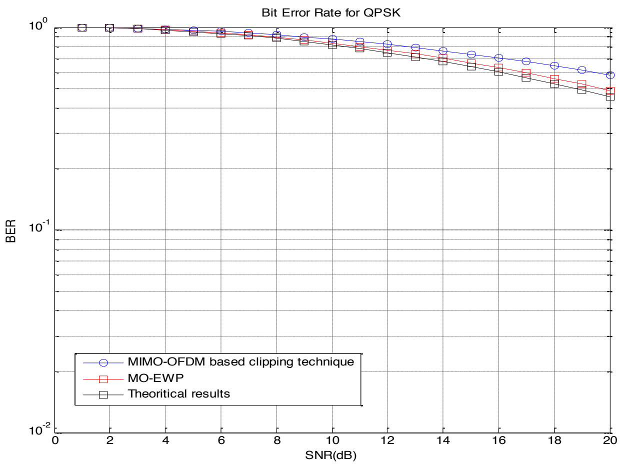

Figure 8. BER results comparing the MO-EWT performance with our previously published work using QPSK modulation Technique

IV. CONCLUSION

In this paper a new algorithm has been proposed not only to detect the extreme peaks but also to overcome their effects in WiMax systems, namely MO-EWT. This proposition making use of the wavelet entropy and the moving average filters to fulfill the procedure. In order to validate this proposition, a simulation has been conducted and checked the validity of the analytical derivation. As a result, it shows that a noticeable performance enhancement has been achieved over the work found in the literature. This enhancement has been shown based on both of BER and CCDF curves of the amended transmitted signals.

MO-EWT enhancement has been exposed clearly in the previous section, where the BER has been enhanced for around 60%. Based on the CCDF curves, extra 15% enhancement has been accomplished over our previously published work. This enhancement has been enlarged to reach around 80% over the work in the literature.

REFERENCES

[1] Peijian Zhang, "A new scheme of space division multiplexing and its analysis", *IEEE 2nd International Conference on Power Electronics and Intelligent Transportation system*, vol. 2, pp. 407-410, 2009.

[2] Raghavendra, M.R. ; Juntti, M. ; Myllyla, M., "Co-Channel Interference Mitigation for 3G LTE MIMO-OFDMSystems", *IEEE International Conference on Communications*, pp 1-9, 2009

[3] P. Bender, *et al.*,"CDMA/HDR: a bandwidth efficient high speed wireless data service for nomadic users," *IEEE Commun. Mag.*, vol. 38, pp. 70–77, July 2000. http://dx.doi.org/10.1109/35.852034

[4] B. Lu, X. Wang, and K. R. Narayanan, "LDPC-based space-time coded OFDM systems over correlated fading channels," *IEEE Trans. Commun.*, vol. 50, pp.74–88, Jan. 2002. http://dx.doi.org/10.1109/26.975756

[5] Mishra, H.B. ; Mishra, M. ; Patra, S.K., Selected mapping based PAPR reduction in WiMAX without sending the side information", *IEEE 1st International Conference on* Recent Advances in Information Technology (RAIT), pp. 182 – 184, 2012.

[6] Vitenberg, R.M., "Single Carrier Multi-Tone modulation scheme", *16th IEEE International Conference on Advanced Communication Technology (ICACT)*,pp. 568 – 574, 2014. http://dx.doi.org/10.1109/ICACT.2014.6779024

[7] [7]Yang, X.D. , et. al., "PERFORMANCE ANALYSIS OF THE OFDM SCHEME IN DVB-T", *PROCEEDINGS OF THE IEEE 6TH CIRCUITS AND SYSTEMS SYMPOSIUM ON EMERGING TECHNOLOGIES: FRONTIERS OF MOBILE AND WIRELESS COMMUNICATION*, VOL. 2, PP. 489-492, 2004.

[8] NEE V. AND PRASAD R., "OFDM WIRELESS MULTIMEDIA COMMUNICATIONS", *ARTECH HOUSE, BOSTON LONDON* 2000.

[9] *Yao Cheng, et al., " An Efficient Transmission Strategy for the MulticarrierMultiuser MIMO Downlink", IEEE Transaction on Vehicular Technology, vol. 63 , no. 2 , pp. 628–642, 2014.* http://dx.doi.org/10.1109/TVT.2013.2280951

[10] Al-Akaidi M., Daoud O. and Gow J., "MIMO-OFDM-based DVB-H systems: A Hardware design for a PAPR reducing technique", *IEEE Transaction on Consumer Electronics*, vol. 52, issue 4, pp. 1201-1206, Nov 2006. http://dx.doi.org/10.1109/TCE.2006.273134

[11] Hung, Ying-Che ; Tsai, Shang-Ho Lawrence," PAPR Analysis and Mitigation Algorithms for BeamformingMIMO OFDM Systems" *IEEE Transaction on Wireless Communications*, vol. 13, no. 5, pp. 2588-2600, 2014. http://dx.doi.org/10.1109/TWC.2014.031914.130347

[12] European Telecommunication Standards Institute (ETSI), "Digital Video Broadcasting; Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications", TR 102 376, V 1.1.1, 2005

[13] Digital Video Broadcasting Group, "DVB-T2 Call for Technologies", SB1644 r1, April 2007.

[14] Mansour M. M., and Shanbhag N. R., "A Novel Design Methodology for High-Performance Programmable Decoder Cores for AA-LDPC codes," in IEEE Workshop on Signal Processing Systems (SiPS), Seoul, Korea, August 2003.

[15] Hocevar D. E., "LDPC Code Construction with Flexible Hardware Implementation," in IEEE International Conference on Communications, pp. 2708 –2712, 2003.

[16] Chen Y. and Hocevar D., "An FPGA and ASIC Implementation of Rate 1/2 8088-b Irregular Low Density Parity Check Decoder", Global Telecommunications Conference, vol. 1, pp. 113-117, 2003.

[17] Han S. and Lee J., "An overview of Peak-to-Average Power Ratio reduction techniques for Multicarrier Transmission", *IEEE Wireless Communications*, pp. 56-65, Apr. 2005 http://dx.doi.org/10.1109/MWC.2005.1421929

[18] Tarokh V. and Jafarkhani H., "On the Computation and Reduction of the Peak-to- Average Power Ratio in Multicarrier Communications," *IEEE Transaction Communications*, vol. 48, no.1, pp.37–44, 2000. http://dx.doi.org/10.1109/26.818871

[19] Prema, G. ; Amrutha, E., "A new MIMO-OFDM transmit preprocessing using pilot symbol assisted rateless codes to mitigate fading and wavelet based OFDM for PAPR reduction", IEEE International conference on *Signal Processing, Communication, Computing and Networking Technologies (ICSCCN)*, pp. 679 – 684, 2011

[20] Krongold S., and Jones L., "PAR Reduction in OFDM via Active Constellation Extension," *IEEE Transactions on Broadcast,* vol. 49, no. 3, pp. 258–68, Sept. 2003. http://dx.doi.org/10.1109/TBC.2003.817088

[21] Jiang T. and Zhu G., "OFDM Peak-to-Average power Ratio reduction by Complement Block Coding Scheme and Its Modified Version," Vehicular Technology Conference, vol. 1, pp. 448 – 51, 2004.

[22] Al-Akaidi M., Daoud O., and Linfoot S., "A new Turbo Coding Approach to reduce the Peak-to-Average Power Ratio of a Multi-Antenna-OFDM", International Journal of Mobile Communications, vol. 5, no.3, pp. 357-369 ,2007. http://dx.doi.org/10.1504/IJMC.2007.012399

[23] Al-Akaidi M. and Daoud O., "Reducing the Peak-to-Average Power Ratio Using Turbo Coding ", IEE Proceeding Communications, vol. 153, no. 6, pp. 818-821, Dec. 2006http://dx.doi.org/10.1049/ip-com:20060061

[24] Zhang T. and Parhi K. K., "Joint (3, k)-regular LDPC Code and Decoder/Encoder Design," *IEEE Transactions on Signal Processing*, vol. 52, no. 4, pp. 1065-1079, 2004. http://dx.doi.org/10.1109/TSP.2004.823508

[25] G. Nair, *et. al.*, "IEEE 802.16 Medium Access Control and Service Provisioning," Intel Technology Journal, vol.8, no.3, pp.213-228, August 2004.

[26] Xuyuan Zheng; Mingui Sun; Xin Tian, " Wavelet Entropy Analysis of Neural Spike Train", *IEEE Congress on Image and Signal Processing,* pp. 225-227, Tianjain, 2008.

[27] S.-Y.Lung, "Applied multi-wavelet feature to text independent speaker identification", IEICE Trans. Fundam. E87-A (4) 944–945, 2004.

[28] R. Gray, *Entrom and Infirmation theorv.* New York: Springer, 1990. http://dx.doi.org/10.1007/978-1-4757-3982-4

[29] 3GPP TSG-RAN-1, "TR 25.892: feasibility study of OFDM for UTRAN enhancement", March 2004.

AUTHORS

Qardi Hamarsheh is with the Dept. of Computer Engineering, Philadelphia University, Amman, Jordan.

Omar Daoud is with the Dept. of Communications and Electronics Engineering, Philadelphia University, Amman, Jordan (odaoud@philadelphia.edu.jo).

Saleh Saraireh is with the Dept. of Communications and Electronics Engineering, Philadelphia University, Amman, Jordan.

Submitted 29 April 2014. Published as resubmitted by the authors 14 October 2014.