Peak to Average Power Ratio Analysis for OWDM-IDMA system

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***Abstract*- A major drawback of orthogonal frequency division multiplexing interleave division multiple access (OFDM-IDMA) is the high peak to average power ratio (PAPR) of the transmitted signal. In this paper, the basic principle of Orthogonal Wavelength-Division Multiplexing-Interleave Division Multiple Access (OWDM-IDMA) technique is outlines. The PAPR for multicarrier systems with different pulse shapes is studies, and comparison between OWDM-IDMA and OFDM-IDMA techniques in terms of PAPR by estimating the complementary cumulative distribution function (CCDF) of system is provided.**

***Keywords*- PAPR, OWDM-IDMA, OFDM-IDMA, DWPT, IDWPT.**

I. INTRODUCTION

The next generation of wireless systems will require higher data quality than current cellular mobile radio systems. In other words, the next generation of wireless systems are supposed to have a better quality and coverage, be more powerful and bandwidth efficient, and be deployed in diverse environments. The fundamental phenomenon which makes reliable wireless transmission difficult is time-varying multipath fading.

Recently, it has been shown that OFDM-IDMA [1], [2] is a promising approach for resolving the two main obstacles in wireless communications, namely, the inter-symbol interference (ISI) and the multiple access interference (MAI). This technique can alleviate ISI by the OFDM operation and suppress MAI by very low-cost IDMA-type multiuser detection (MUD) [3], [4], [5]. However, a major drawback in the OFDM signal is its large envelope fluctuation, which may degrade the efficiency of power amplifiers of the transmitters by forcing them to operate at lower average power. This phenomenon is quantified by the PAPR, and it results from the superposition of a large number of usually statistically independent sub-channels that can constructively sum up to high peaks. The power consumption of a power amplifier depends largely on the peak power than the average power. Thus, occasional large peaks lead to low power efficiency.

In this contribution, we propose to study the performance of a new multiple access technique, called OWDM-IDMA which is the combination of OWDM and IDMA techniques. OWDM-IDMA technique based on the pulse shaping characteristics of multicarrier modulation can be a novel PAPR solution. We show that the PAPR decreases with an appropriate choice of the pulse shaping. In fact, through the formalism of wavelets and their application to wavelet packets and filter banks, it is possible to construct orthogonal basis in time and frequency whose properties will develop a Multicarrier communication system which uses more accurately the radio-electric spectrum. Moreover, the use of IDMA technique can make the system more robust against MAI, and lead to a significant performance enhancement [2].

The system performance is analyzed. It is shown from numerical results that significant PAPR reduction is achieved by the proposed technique.

The rest of this paper is organized as follows. In section 2, we present the transceiver architecture of OWDM-IDMA. In section 3, the basics of OFDM-IDMA are discussed. Afterwards, we present a definition of PAPR. Comparison between OFDM-IDMA and OWDM-IDMA and Simulation results are given in section 5. Finally, section 6 is dedicated to the conclusion.

II. OWDM-IDMA PRINCIPLE

In this paper, we propose to study a new technique, called OWDM-IDMA, which is the combination of the OWDM and IDMA techniques. The use of OWDM technology in this scheme offers better properties.

The first idea of using wavelet transform in communication was made in multidimensional signaling techniques. Wavelet packet waveforms have the property of localization in both frequency and time domains. Using the time domain localization property of wavelet packet waveforms, a multi-carrier IDMA system based on wavelet packets can be designed to achieve both frequency and time domain diversity. Moreover, it can alleviate ISI by the OWDM technique and

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cancel multiple access interference (MAI) by the IDMA technique [6], [7].

A. Transmitter Structure

Figure.1 shows the transmitter structure of the OWDM-IDMA scheme under consideration with K simultaneous users. The input data sequence d_k of the k^{th} user is encoded basically on a low-rate code C, generating a coded sequence $b_k = \{b_k(j); j = 1......J\}$ where J is the frame length (Here, "chip" is used instead of "bit" as the FEC encoding may include spreading or repetition coding.). Then b_k is permutated by an interleaver π_k, producing $X_k = X_k(j)$.

The interleavers π_k, are not similar for different users. We assume that the interleavers are generated independently and randomly.

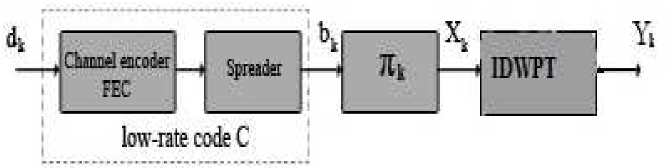


Fig.1: Transmitter structure for OWDM- IDMA system

The resultant signals, again denoted by $X_k(n)$, are modulated by using IDWPT producing $Y_k(n)$, The received signal equals the sum of the signals received from all transmitters [9]. The multiuser received signal can be written as:

$$r(n) = \sum_{k=1}^{K} h_k(n) Y_k(n) + z(n) \quad (1)$$

With:

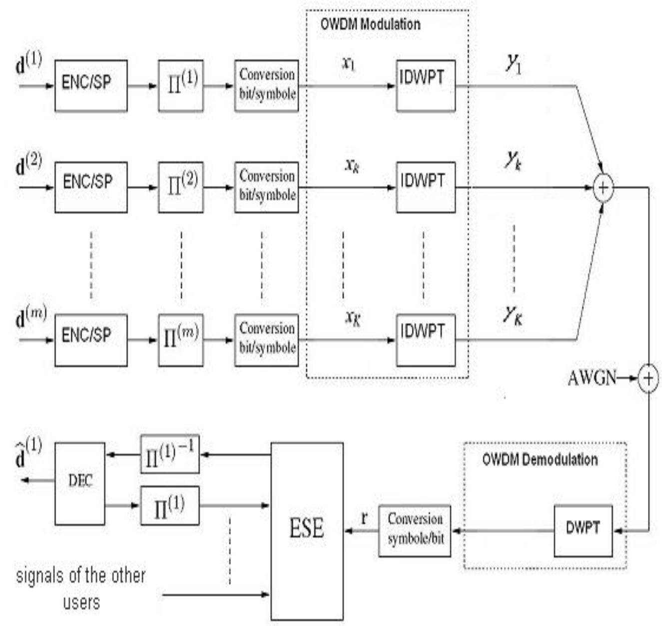
$$Y_k(n) = \sum_{n=-\infty}^{+\infty} \sum_{m=0}^{M-1} x_k(n) \psi_{m,n}(t) \quad (2)$$

Where h_k is the channel coefficient for user-k, $\{z(n)\}$ are samples of an AWGN with variance $\sigma^2 = N_0/2$, $Y_k(n)$ a chip sequence for user k after OWDM modulation, M the number of sub-channels associated with the transmission, $\varphi(t)$ is the set of orthogonal wavelet pulses assembled in the form of a vector and n denotes the transmission time.

B. Reciever Structure

As shown in figure.2, the core of the OWDM-IDMA receiver consists of DWPT for demodulation OWDM, an elementary signal estimator (ESE) and K a posteriori probability decoders (APP DECs). After OWDM demodulation by using DWPT, the iterative processes for receiver IDMA can be applied in the receiver signal r(n) to detect the information data of users. The multiple access and coding constraints are considered separately in the ESE and DECs. In the iterative detection process, the ESE and DECs exchange extrinsic information in a turbo-type iterative manner [2]. The ESE operation can be carried out in a chip-by-chip way [8]. Thus, the iterative process does not include the OWDM demodulation.

If the number of paths L is large, this structure reduces significantly the calculation complexity of the receiver.



III. OFDM-IDMA PRINCIPLE

The transmitter/receiver structure of an OFDM-IDMA system with K active users is shown in figure.3. At transmitter, for user-k, the information data is forward-error-correction (FEC)-encoded into C_k. Each coded bit $C_k \in \{+1, 1\}$ is spread using a length-S repetition code, interleaved by a user-specific interleaver. Then the resultant signals, again denoted by $\{x_k(n)\}$, are modulated onto subcarriers by using IDFT. Each subcarrier can be occupied by several users, so users are solely distinguished by their interleavers. The received signal after DFT can be represented by [1]:

$$R(n) = \sum_{k=1}^{K} H_k\, x_k(n) + Z(n) \quad (3)$$

At the receiver, the signal R(n) is demodulated by using DWPT, then the ESE and DECs exchanges extrinsic information in a turbo-type manner [8][9]. The multiple access and coding constraints are considered separately in the ESE and DECs.

IV. PEAK TO AVERAGE POWER RATIO

A main defect of OFDM-IDMA signals is that they have a large envelope fluctuation. The reason behind this phenomenon is simple. Since an OFDM-IDMA signal consists of independently modulated subcarriers number, when the sub-symbols for each subcarrier are added up coherently, the maximum instantaneous power of the OFDM-IDMA signal could be larger than its average power. Typically, PAPR is used to quantify the envelope excursions of OFDM-IDMA signals.

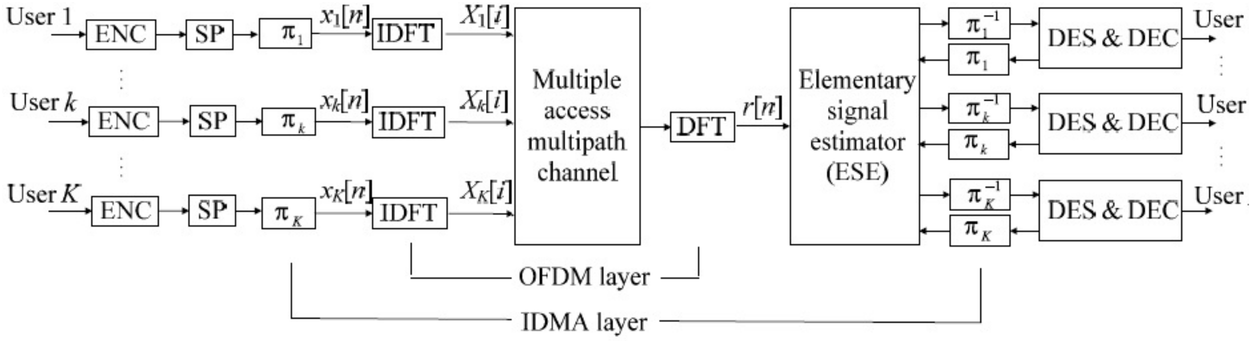


Fig.3 Transmitter /Receiver structure for OFDM-IDMA

The PAPR of any continuous signal y(t) is defined as the ratio between the peak envelope power and the average envelope power, i.e [10].

$$PAPR\big(y(t)\big) = \frac{max_{0\le t\le T}|y(t)|^2}{\frac{1}{T}\int_0^T |y(t)|^2 dt} \qquad (4)$$

High PAPR directly translates into high peak power which may exceed the linear dynamic range of the power amplifier. To overcome this problem, we must resort to either high quality linear amplifier or backing off the operating point of the non linear amplifier. This leads to inefficient amplification, excess battery consumption and very expensive transmitter.

V. SIMULATIONS AND RESULTS

In what follows, we demonstrate the advantages of OWDM-IDMA using numerical results.

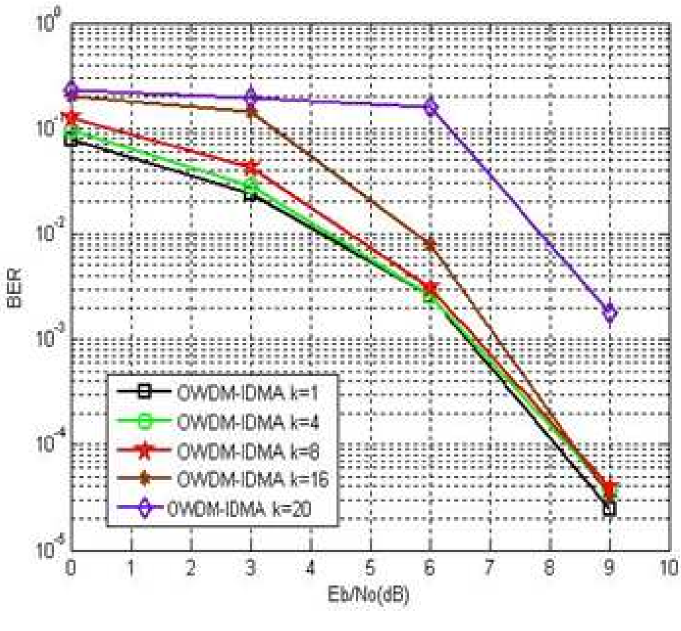


Fig.4: The simulated performance curves for OWDM-IDMA .In this example, we assume that Information bit length = 3072, iteration number =10, number of users=1,4,8,16,20

We consider the uplink scenario. Only AWGN channel is assumed in all figures. For simplicity, we only consider uncoded systems. K is the number of simultaneous users in the system. Figure.4 shows the performance of the OWDM-IDMA system (with randomly generated interleavers and a common length-16 spreading sequence for all users) using BPSK modulation, iteration number is equal to 10, length of the information block is N = 3072 bits per user, All channel coefficients are set to $h_k = 1$, the number of Haar wavelets pulses is 16, and number of users k = 1, 2, …, K. The unique constraint used in selecting the spreading sequence for OWDM-IDMA is that it should contain a balanced number of +1 and –1 (so as to ensure randomness).

It is observed from Figure.4 that near single-user performance is achievable for large K values and the performance of OWDM-IDMA degrades slightly when K>16. On the other side, the OWDM-IDMA system support more users than spreading factor (K > S) and the loading rate can reach 125% for K=20 users. The convergence system trigger point with a number of users approximately twice as large as the spreading code length is located at 6 dB. The above OWDM-IDMA system convergence with K=20 is generally achieved within fourteen iterations [6].

As a performance measure for the proposed technique, we use the complementary cumulative distribution function (CCDF) of the PAPR, which is defined as:

$$CCDF(PAPR_0) = Prob\,[PAPR > PAPR_0] \quad (5)$$

Where:

$PAPR_0$ is the given threshold

Performances of the proposed system are compared to OFDM-IDMA system with 4-QAM symbols modulated on M=128 subcarriers as shown in Figure.6 and Figure.7 depict the CCDF of the proposed technique for Haar, Coifelet, Daubechies and Symlet wavelets.

It is shown that the OFDM-IDMA signal has a PAPR which exceeds 12.4 dB for less than 0.4 probability; in contrast to 10dB in the proposed technique using Haar wavelets for the same probability, 9.8dB when 3th Coiflet wavelets is used, 11.3dB when 4th Symlet wavelet is used and 7.5dB when 8th Daubechies wavelet is used.

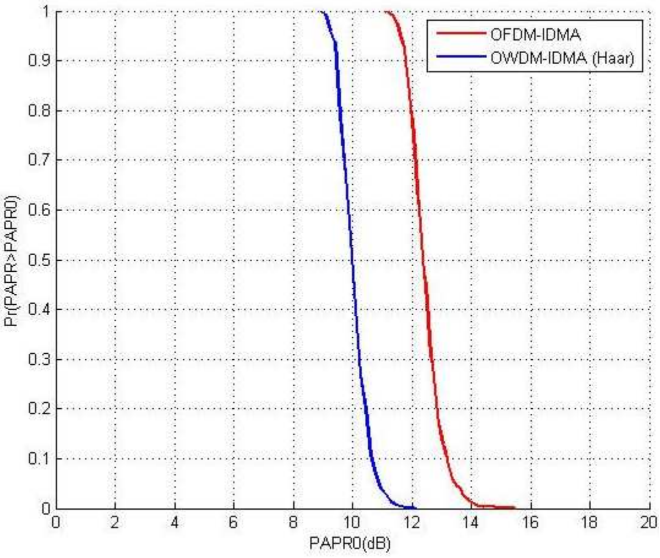


Fig.6: CCDF of PAPR comparison between OFDM-IDMA an OWDM-IDMA

The performance gain with Haar wavelet is in the range of 2.4dB over the original OFDM-IDMA signal.

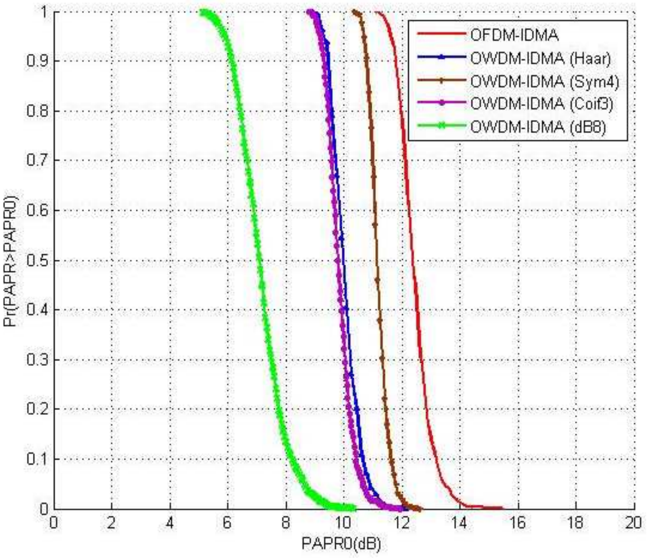


Fig.7: CCDF of PAPR for OWDM-IDMA system with different wavelets families

A 4.9 dB reduction is reached with the 8th Daubechies wavelet; this result is very interesting but, the complexity of this system is higher than the complexity of OFDM-IDMA modulation.

VI. Conclusion

In this paper, we have outlined the basic principles of OWDM-IDMA and OFDM-IDMA techniques. The proposed technique is compared to OFDM-IDMA modulation and achieves a significant reduction in PAPR for a low number of channels.

Furthermore, it is possible to trade-off the amount of PAPR reduction and the complexity by using different versions of wavelet. The main advantage of using OWDM-IDMA relies in the fact as it represents a very high loading, and is that wavelets allow flexibility in the system's design and their choice depends on the transmission environment. We have used simulation results to demonstrate these features of OWDM-IDMA.

References

[1] I. Mahafeno, C. Langlais, and C. Jego, "OFDM-IDMA versus IDMA with ISI cancellation for quasi-static Rayleigh fading multipath channels," in Proc. 4th Int. Symp. on Turbo Codes & Related Topics, Munich, Germany, Apr. 3–7, 2006.

[2] S. Zhou, Y. Li, M. Zhao, X. Xu, J. Wang, and Y. Yao, "Novel techniques to improve downlink multiple access capacity for beyond 3G, " IEEE Commun. Mag., vol. 43, pp. 61–69, Jan. 2005.

[3] P. Wang, J. Xiao, and Li Ping, "Comparison of Orthogonal and Non-Othogonal Approaches to Future Wireless Cellular Systems," IEEE Vehic. Tech. Mag., vol. 1, no. 3, Sept. 2006, pp. 4–11.

[4] H. Schoeneich and P. A. Hoeher, "Adaptive interleave-division multiple access-A potential air interference for 4G bearer services and wireless LANs," in Proc. WOCN 2004, Muscat, Oman, June 2004, pp. 179–182.

[5] Li Ping, L. Liu, K. Y. Wu, and W. K. Leung, "Interleave-division ultiple-access," IEEE Trans. Wireless Commun. Vol. 4, pp. 938–947, Apr. 2006.

[6] A. ROUIJEL, B. NSIRI, A. FAQIHI, D. ABOUTAJDINE, "A new approach for wireless communication systems based on idma technique " ISIVC'2010 , 30-2 Oct 2010 , Rabat MAROC

[7] A. ROUIJEL, B. NSIRI, M. ET.TOLBA, "Performance of iterative multiuser detection in owdm-idma system" ISIVC'2010 , 30-2 Oct 2010 , Rabat MAROC

[8] Li Ping, K. Y. Wu, Lihai Liu et W. K. Leung, .A simple, unified approach to nearly optimal multiuser detection and space-time coding, Information Theory Workshop, ITW'02, (pp. 53-56),Inde, Oct. 2002.

[9] Li Ping, L. Liu, K. Y. Wu, and W. K. Leung, "A unified approach to multi-user detection and spacetime coding with low complexity and nearly optimal performance," in Proc. 40th Allerton Conference, Allerton House, USA, Oct. 2002, pp.170-179.

[10] J. Tellado, *Multicarrier modulation with low PAR: Applications to DSL and Wireless*. Massachusetts, USA: Kluwer Academic Publishers, 2000.