

PAPR Performance of Dual Carrier Modulation using Improved Data Allocation Scheme

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Abstract—The dual carrier modulation (DCM) has been proposed for use in the multi-band orthogonal frequency division multiplexing (MB-OFDM) ultra-wideband (UWB). The DCM has a significant diversity improvement in multi-path fading channel, but it suffers from a high peak-to-average power ratio (PAPR). Many PAPR reduction schemes have been introduced for solving the PAPR problem. However, general PAPR reduction schemes cause increasing computational burden, signal distortion or side information problem. In this paper, improved data allocation scheme is proposed as PAPR reduction method. The PAPR performance of proposed method is compared with that of conventional data allocation of the dual carrier modulation

Keywords— DCM, MB-OFDM, PAPR, UWB

I. INTRODUCTION

Ultra-wideband (UWB) technology was proposed to standardize wireless personal area network (WPAN). The fundamental issue of UWB is that the transmitted signal can be spread over large bandwidth with a very low power spectral density. In 2002, the USA federal communications commission (FCC) agreed to allocate 7.5 GHz spectrum in the 3.1~10.6 GHz band for unlicensed use for UWB devices and limited the UWB effective isotropic radiation power (EIRP) to -41.3 dBm/MHz [1]. In 2005, the WiMedia alliance announced the establishment of the multi-band orthogonal frequency division multiplexing (MB-OFDM) UWB as global UWB standard.

Quadrature phase shift keying (QPSK) and dual carrier modulation (DCM) are exploited as modulation schemes for MB-OFDM in ECMA-368 [2]. QPSK modulation is used for data rates 200 Mbps and DCM is used for higher data rates mode. However, 480 Mbps mode in a practical environment cannot be achieved due to poor radio channel conditions causing dropped packets, resulting in a lower throughput and needing to retransmit the dropped packets. However, this poor radio channel can be overcome by frequency diversity of DCM.

All systems based on OFDM have the high PAPR, which is a serious drawback. The high PAPR causes poor power efficiency and system performance. Therefore, this paper proposes PAPR reduction method using improved data allocation in DCM.

The following sections of this paper are organized as

follows: In section II, the DCM is described in the MB-OFDM. Section III represents the improved data allocation scheme of DCM. Section IV demonstrates the simulation results. Finally, section V offers our conclusions.

II. DCM

DCM has been proposed in MB-OFDM system, where the successive two QPSK modulated symbols are mapped into the two 16 - quadrature amplitude modulation (QAM) symbols onto two subcarriers of OFDM system so as to exploit the frequency/ time diversity gain.

Channel diversity can be exploited in the MB-OFDM system by adding an alternative form of redundancy for the higher data rate modes. This additional diversity will result in an improvement in the overall range of the system. The additional redundancy can be introduced by mapping 4 bits onto two 16-point constellations. The symbols from the two 16-point constellations are then mapped onto tones that are separated. This technique is referred to as DCM [4]. A block diagram of the DCM technique is shown in figure 1 and the mapping of bits onto the two 16-point constellations is shown in figure 2.

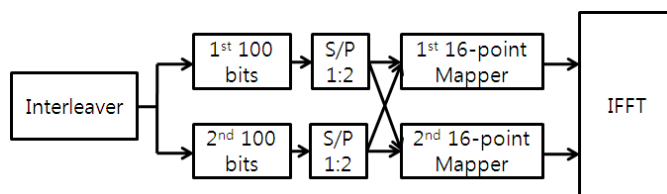


Figure 1. Block diagram of DCM

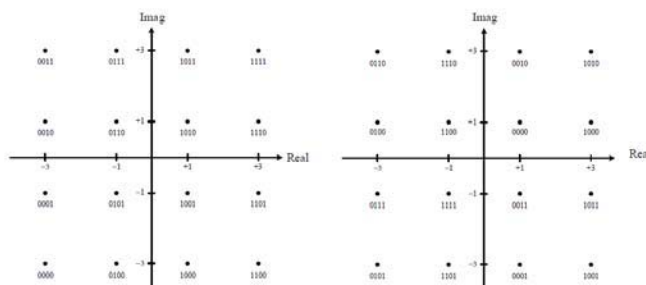


Figure 2. Two 16-point constellations use for DCM technique

Figure 3 shows bit error rate (BER) performance of DCM in Rayleigh fading channel.

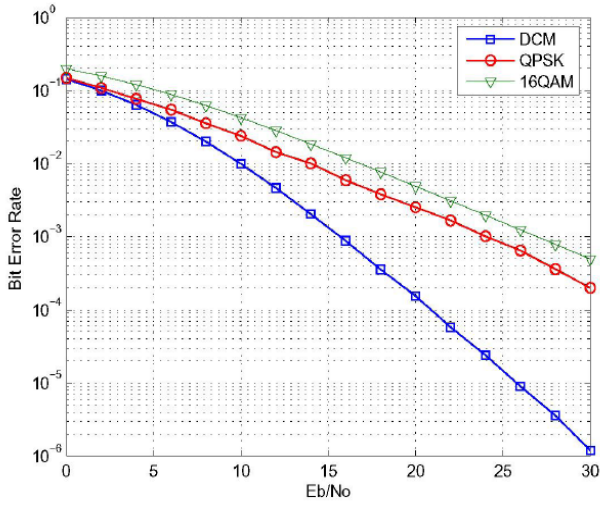


Figure 3. BER performance of DCM in Rayleigh fading channel

Figure 4 shows the PAPR performance of conventional OFDM and DCM. DCM shows higher PAPR performance than conventional OFDM because data allocation pattern is changed.

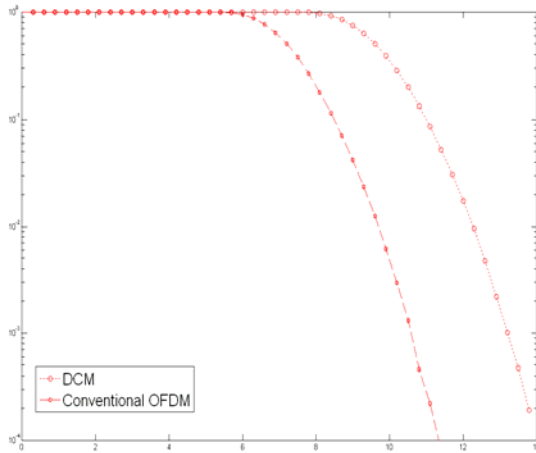


Figure 4. PAPR performance of conventional OFDM and DCM

III. PROPOSED METHOD

MB-OFDM UWB has been proposed as a physical layer for high bit rate and short range communications networks. In the MB-OFDM system, the 3.1 to 10.6 GHz band is divided into 14 bands. These bands are then grouped into five band groups. The first four band groups contain three sub-bands each and the fifth one contains two sub-bands. Transmitted signal hops over the three sub-bands group [3]. The block diagram for the MB-OFDM transmitter is shown in figure 5.

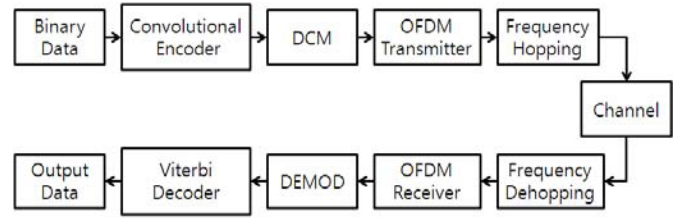


Figure 5. MB-OFDM transmitter and receiver

For high data rate transmission in the MB-OFDM, the coded and interleaved binary serial input data are divided into groups of 200bits, which is $B_p, p = 0, 1, \dots, 199$ and converted into 100 QPSK data, which are $Y_q, q = 0, 1, \dots, 99$. And then, 100 QPSK data are converted into 50 16-QAM data, which are $X_k, k = 0, 1, \dots, 49$, by using the DCM. The DCM data are allocated as ascending order k and figure 6 represents overall DCM procedure [4].

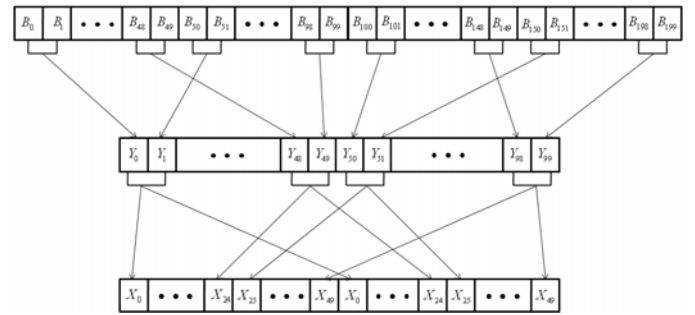


Figure 6. DCM procedure

The 200 coded bits are grouped as $(B_{g(k)}, B_{g(k)+1}, B_{g(k)+50}, B_{g(k)+51})$ where $k \in [0, 49]$ and

$$g(k) = \begin{cases} 2k & , k \in [0, 24] \\ 2k + 50 & , k \in [25, 49] \end{cases} \quad (1)$$

Each group of 4 bits $(B_{g(k)}, B_{g(k)+1}, B_{g(k)+50}, B_{g(k)+51})$ are mapped onto a four-dimensional constellation and converted into 16-QAM symbol.

The MB-OFDM uses multiple subcarriers to carry data which is divided into several parallel data stream. When the number of subcarrier is N , the baseband signal of MB-OFDM is represented as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi n \Delta f t}, \quad 0 \leq t \leq T \quad (2)$$

where X_n is the data symbol carried by the n_{th} subcarrier, Δf is the frequency difference between each subcarrier, and T is the MB-OFDM symbol duration which must be $1/\Delta f$ to satisfy the orthogonal condition of each subcarrier. With

these notations the sampling period of the time-domain transmitted signal can be expressed by $T_s = T / N$.

Although multicarrier techniques, which include OFDM technique, have good properties in multipath fading channel, these techniques have high PAPR problem because of coherent parts of each subcarriers. The PAPR of the transmitted MB-OFDM signal can be defined as

$$\text{PAPR} \equiv 10 \log_{10} \frac{P_{\text{peak}}}{P_{\text{av}}} [\text{dB}] \quad (3)$$

where $P_{\text{peak}} = \max |x(t)|^2$ is the peak power and

$$P_{\text{av}} = \frac{1}{T} \int_0^T [x(t)]^2 dt$$

is the average power of the transmitted

MB-OFDM signal [5].

The cumulative distribution function (CDF) of the PAPR is one of the most frequently used performance measures for PAPR reduction techniques. In the literature, the complementary CDF (CCDF) is commonly used instead of the CDF itself. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold. A simple approximate expression is derived for the CCDF of the PAPR of a multicarrier signal with Nyquist rate sampling. From the central limit theorem, the real and imaginary parts of the time domain signal samples follow Gaussian distribution, each with a mean of zero and a variance of 0.5 for a multicarrier signal with a large number of subcarriers. Hence, the amplitude of a multicarrier signal has a Rayleigh distribution, while the power distribution becomes a central chi-square distribution with two degrees of freedom. The CDF of the amplitude of a signal sample is given by

$$F(z) = 1 - \exp(-z) . \quad (4)$$

What we want to derive is the CCDF of the PAPR of a data block. The CCDF of the PAPR of a data block with Nyquist rate sampling is derived as

$$\begin{aligned} P(\text{PAPR} > z) &= 1 - p(\text{PAPR} \leq z) \\ &= 1 - F(z)^N \\ &= 1 - (1 - \exp(-z))^N \end{aligned} \quad (5)$$

This expression assumes that the N time domain signal samples are mutually independent and uncorrelated. This is not true, however, when oversampling is applied. Also, this expression is not accurate distribution of PAPR.

The paper proposes different data allocation pattern in inverse data allocation order of the DCM to reduce PAPR. The 200 input data bits are converted into Y_q . And then, Y_q

are converted into X_k . The converted data, X_k , are allocated descend order k between 51th subcarrier and 100th subcarrier. Figure 7 shows overall data allocation procedure of proposed method.

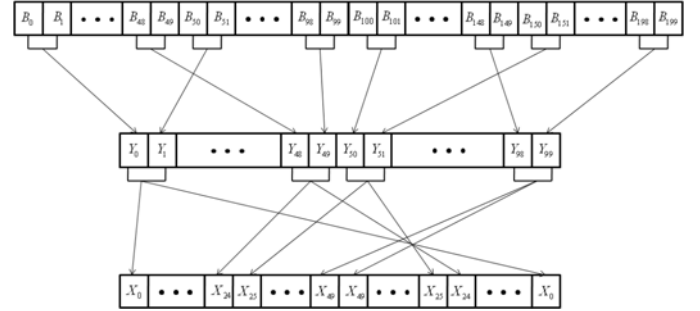


Figure 7. Data allocation procedure of proposed method

IV. SIMULATION RESULT

Figure 8 shows PAPR performance of the DCM and proposed method. 16QAM modulation technique and 16, 32, 64 and 128 subcarriers are used for the simulation.

The PAPR performance is represented as a CCDF curve. Proposed method shows 2dB better PAPR performance than that of DCM in 128 subcarriers. Besides, proposed data allocation scheme has lower PAPR when other subcarriers are used.

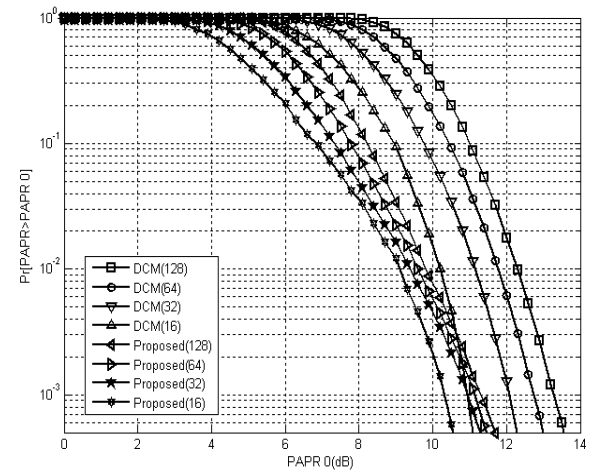


Figure 8. The PAPR performance of DCM and proposed method

V. CONCLUSIONS

This paper has proposed the improved data allocation as a PAPR reduction scheme. Proposed method shows lower PAPR characteristic than that of DCM with the same number of subcarriers. And as a result, a considerable PAPR reduction has been obtained.

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