PERFORMANCE COMPARISON DCM VERSUS QPSK FOR HIGH DATA RATES IN THE MBOFDM UWB SYSTEM

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ABSTRACT

This paper presents the advantage of using a new modulation scheme called dual carrier Modulation (DCM) compared to classical Quadrature Phase Shift Keying (QPSK) modulation. This comparison is done at data transmission broadband in Multiband OFDM system (MBOFDM) based on Ultra Wide Band UWB. Simulation results show that the use of the modulation DCM for high data rates is more efficient compared with QPSK.

KEYWORDS

ECMA368, MBOFDM, WPAN, QPSK, DCM.

1. INTRODUCTION

UWB communication, accepted by the Federal Communications Commission (FCC) [1] in 2002, is characterized by its low cost for high data rates over wireless personal area networks WPAN. Recently, the UWB system based on MB-OFDM has been exploited in many fields such as wireless personal area networks offering broadband over 480 Mbps, low power multimedia capabilities for PCs, user electronics, mobile and automotive market [2].

In the MB-OFDM physical layer, DCM has been suggested as a new modulation scheme for high data rates [3].

QPSK and DCM are exploited as modulation schemes for MB-OFDM in ECMA-368. QPSK constellation is used for data rates 200 Mb/s and lower, while DCM is used as a multi-dimensional constellation for data rates 320 Mb/s and higher.

This paper compares the performance between DCM and QPSK modulation for high rates within the ECMA-368 standard using saleh and vanzuella channel.

The second section presents the studied system in general, the third one describes the two modulations QPSK and DCM, and then a performance comparison is discussed in section IV, and finally a conclusion in last Section.

2. MB-OFDM SYSTEM ARCHITECTURE

The architecture of the MB-OFDM transmitter is shown in Figure 1. An error correction code (FEC (Forward Error Correction)) is then applied to provide resilience against transmission errors. The punching step is essential to get high data rates.

The encoded sequence is interleaved in three consecutive steps as will be explained later, followed by the binary coding operation or symbol mapping of an OFDM symbol.
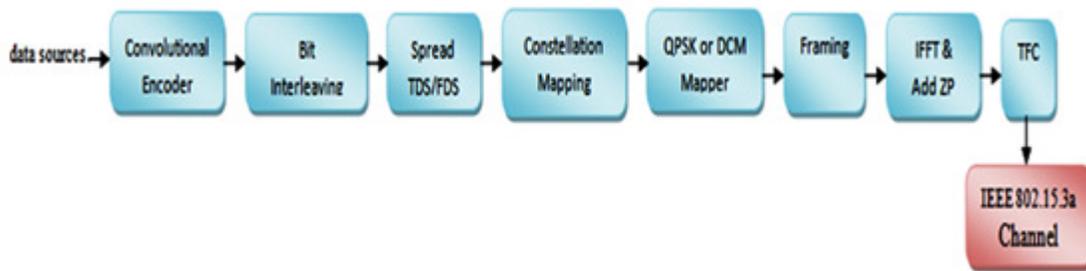
Figure 1: The transmitter architecture for the MB-OFDM system

The MB-OFDM system rates are summarized in Table 1 as they were defined in the ECMA-368 standard [4].

Tableau 1: Characteristics rates of MB-OFDM solution and number of bits per block

Data Rate (MB/s)	Modulation	Code rate (R)	FDS	TDS	Coded Bits/6 OFDM Symbol (N_{CBP6S})	Info Bits/6 OFDM Symbol (N_{IB6S})
53.3	QPSK	1/3	Yes	Yes	300	100
80	QPSK	1/2	Yes	Yes	300	150
106.7	QPSK	1/3	No	Yes	600	200
160	QPSK	1/2	No	Yes	600	300
200	QPSK	5/8	No	Yes	600	375
320	DCM	1/2	No	No	1200	600
400	DCM	5/8	No	No	1200	750
480	DCM	3/4	No	No	1200	900

3. QPSK AND DCM

3.1. QPSK

For rates below 200 Mb/s, the interleaved binary data is mapped to a constellation into QPSK Quadrature Phase.

$$d[k] = k_{MOD} \times [(2 \times b[2k] - 1) + j(2 \times b[2k+1] - 1)] \qquad (1)$$

Where $k = 0,1,2, ...,$

And $k_{MOD} = 1/\sqrt{2}$

3.2 DCM

For rates of 320 Mb/s and more, not using spreading (Tab. 1), the binary data is mapped to a multidimensional constellation using a dual-carrier modulation technique (DCM). Note that the first proposals MB-OFDM for IEEE 802.15.3a, including the proposal of September 2004, only consider a QPSK constellation for all data rates [6].

Indeed, the DCM modulation has been adopted by ECMA and recently amended in [7].

Passing from a QPSK constellation to a DCM scheme, an additional form of diversity may be obtained, which leads to an improvement in the overall range of the system.

This diversity is introduced by mapping four bits on two constellations of 16QAM (Quadrature Amplitude Modulation) shown in Figure 3.

The symbols obtained are then converted into bits which are separated by at least 200 MHz of bandwidth, which is approximately equivalent to 50 subcarriers.

The transmission of each obtained flow is carried out, respectively, by the first half and the second half of the subcarriers of the OFDM symbol. The different stages of the DCM modulation are listed as follows:

1. Binary input data coded and interleaved, b[i] where i = 0,1,2, ..., are divided into groups of 200 bits and converted into complex numbers 100 using a technique called double carrier modulation.

2. The 200 coded bits are grouped into 50 groups of 4 bits as shown in Table 2. Each group is represented as (b [g (k)], b [g (k) +1], b [g (k) + 50], b [g (k) 51]), where k ∈ [0, 49] and

$$g(k) = \begin{cases} 2k & k \in [0.24] \\ 2k + 50 & k \in [25.49] \end{cases} \qquad (2)$$

3. Each group of 4 bits (b [g (k)], b [g (k) +1], b [g (k) +50], b [g (k) 51]) must be mapped to a constellation four-dimensional, and converted into two complex numbers (d [k], d [k + 50]).

4. Complex numbers must be normalized using a normalization factor :

$$k_{MOD} = 1/\sqrt{10}$$

The use of non-adjacent subcarriers within this transmission makes it possible to increase the reliability of these high speeds modes towards the fading effect of the transmission channel.

The DCM technique is not applied to the low flow rates (200 Mb/s and below) as frequency diversity is better exploited through the use of FEC codes and TDS and FDS low flow techniques. Therefore, the expected diversity gain for these flows of DCM is minimal and the added complexity for DCM is not justified.
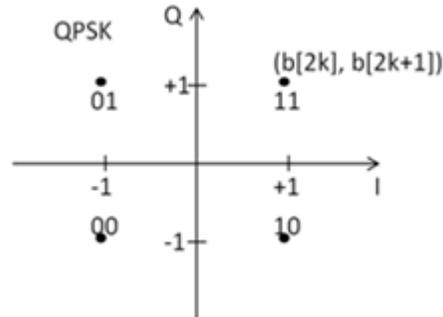


Figure 1: QPSK Constellation as standard ECM-368.
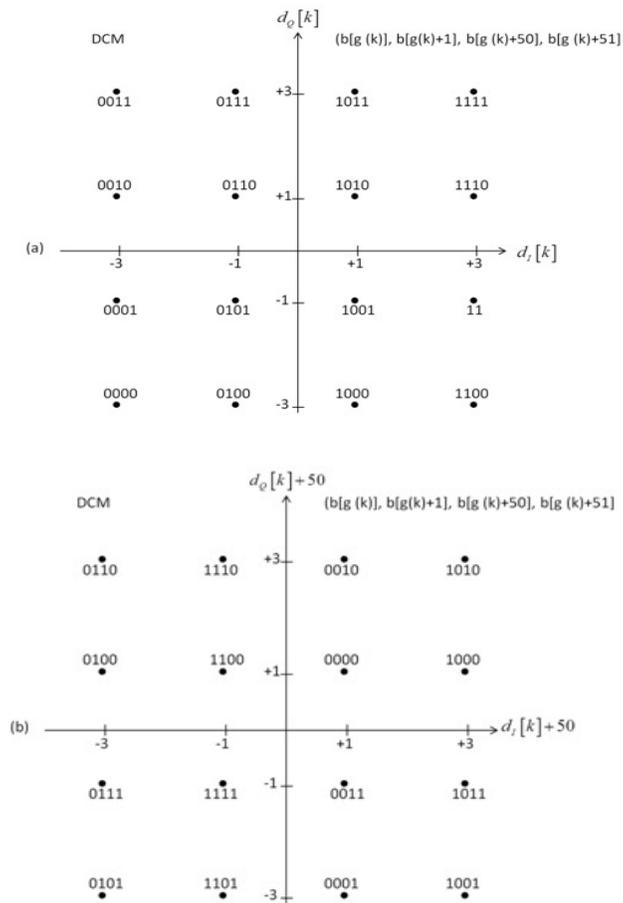
Figure 2: 16-QAM Constellations of the DCM modulation for MB-OFDM system.

Tableau 2: Encoding table of the dual carrier modulation (DCM).

Input bit (b[g(k)],b[g(k)+1], b[g(k)+50)], b[g(k)+51])	D[k] I-out	D[k] Q-out	D[k+50] I-out	D[k+50] Q-out
0000	-3	-3	1	1
0001	-3	-1	1	-3
0010	-3	1	1	3
0011	-3	3	1	-1
0100	-1	-3	-3	1
0101	-1	-1	-3	-3
0110	-1	1	-3	3
0111	-1	3	-3	-1
1000	1	-3	3	1
1001	1	-1	3	-3
1010	1	1	3	3
1011	1	3	3	-1
1100	3	-3	-1	1
1101	3	-1	-1	-3
1110	3	1	-1	3
1111	3	3	-1	-1

4. SIMULATION RESULTS

4.1. Parameters

In this section, we present some simulations results per-formed on the MB-OFDM system described above in or-der to analyse its performance.

In these simulations, we consider an indoor environment.

In the following, the performance evaluation of the MB-OFDM system is achieved by simulating the transmission chain for the CM1 channel model (channel models), adopted by the working group IEEE 802.15.3a, whose characteristics are shown in Table 3.

The results, expressed in terms of bit error rate (BER), were averaged over 100 iterations of distinct channels of each model CM. Each new transmitted frame of OFDM symbols employs a new channel realization. The stop conditions being themselves tested every 100 received frames, i.e., until all the channels achievements are proven.

The made TFC are those of group 1 (Tab. 4). Thus, the system works using the US regulations set by the FCC.

The simulation results are evaluated in terms of Eb / No, where Eb is the average energy per useful bit and No is the power density of AWGN (Additive white Gaussian noise), and perfect channel estimation is considered.

The performance of the MB-OFDM system is shown for various flow rates listed in Table 5. Note that the parameters considered here are those adopted in [5].

Replacing QPSK by DCM slightly improves the system performance to the detriment of the complexity of the higher-level system.

In reception, the used equalization technique is ZF. It is implemented from the coefficients obtained through a full assessment of the transmission channel.

Tableau 1: IEEE 802.15.3a Model Specifications for four distinct configurations.

	CM1	CM2	CM3	CM4
τ_m, Mean execs delay (ns)	5.05	10.38	14.18	27
τ_{RMS}, RMS (root-Mean-square) delay speed (ns)	5.28	8.03	14.28	25
$NP_{10\,dB}^{(a)}$	13	18	35	41
$NP_{85\%}^{(b)}$	24	36.1	61.54	123

(a) Number of paths above the threshold of -10 dB relative to the dominant path

(b) Number of paths containing 85% of the energy of the impulse response

Tableau 2: Time-Frequency codes (TFC) for the band group 1 [4].

TFC Number	TFC type	TFC code
1	TFI	123123
2		132132
3		112233
4		113322
5	FFI	111111
6		222222
7		333333
8	TFI2 (TFI over 2 sub-bands)	121212
9		131313
10		231231

Tableau 3: Rates of MB-OFDM system based on the ECMA-368 standard [4].

Rate (Mbit/s)	Modulation	Coding Efficiency (R)	FDS	TDS	Coded bits per symbol	useful bits per block
533	QPSK	1/3	Yes	Yes	200	100
80	QPSK	1/2	Yes	Yes	200	150
106.7	QPSK	1/3	No	Yes	200	200
160	QPSK	1/2	No	Yes	200	300
200	QPSK	5/8	No	Yes	200	375
320	DCM	1/2	No	No	200	600
400	DCM	5/8	No	No	200	750
480	DCM	3/4	No	No	200	900

4.2. DCM vs QPSK

Dual carrier modulation (DCM) is being studied as a potential improvement of the classic modulation QPSK. DCM provides not only a diversity gain, but also a coding gain. DCM results are compared with those using conventional QPSK.

Therefore, the simulation results show that the DCM achieves lower BER compared to conventional QPSK.

Figure 4 shows that for a BER value of 10-3 a gain of about 0.7 dB is observed with a 320 Mbit/s throughput for both cases with or without TFC (Time Frequency Code).

According to these results, the DCM method is more efficient than QPSK. The advantages of DCM are retained even when the channel coding is applied.

The use of DCM provides the selection of an increased return code. DCM is not only robust, but also offers improvements in speed for a signal to noise ratio (SNR (signal to noise ratio)) given.

This improvement in performance is related to the characteristics of DCM, which provides additional diversity gain, first by spreading the symbol on two independent sub-carriers and secondly by the use of coding gain with constellation rearrangement.
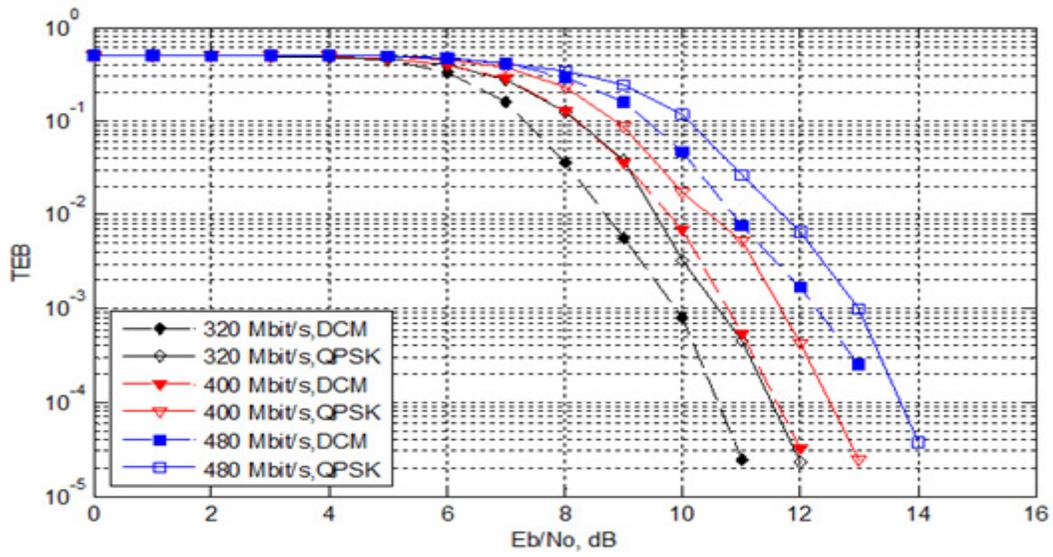
(a)   Without TFC
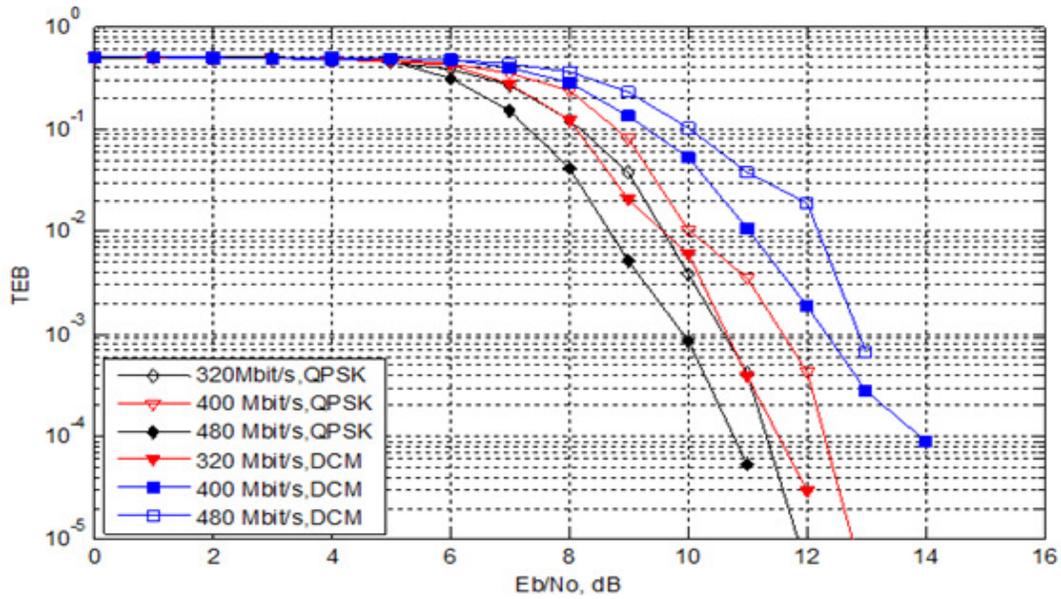

(b)   With TFC

Figure 3: DCM versus QPSK for high data rates of 320 Mb/s, 400 Mb/s and 480 Mb/s Simulation in the
case of CM1 (LOS) without TFC n°5 and with TFC n°1.

5. CONCLUSION

In this paper, a performance comparison between DCM and QPSK modulation was evaluated in a UWB system MBOFDM.

This evaluation shows the importance of using the new technology DCM only for high flow rates for both cases with and without TFC in MBOFDM system. Therefore, QPSK modulation is replaced by a multidimensional modulation DCM.

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