Performance Comparison of DQPSK and QPSK in Two-Channel MC-CDMA Environment

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***Abstract* — MC-CDMA is a multiple access system. The multi-user access of MC-CDMA is accomplished by exploiting the advantages of both OFDM and CDMA. The purpose of this paper is to compare the performances of DQPSK and QPSK in a MC-CDMA environment. Each modulation is assigned to each of the two channels. Reed-Solomon coding is employed in both channels. The BER is performed considering AWGN.**

Keywords* — *MC-CDMA, DQPSK, QPSK, Reed-Solomon.

I. Introduction

The multi-user access in a communication system is a critical issue. It is important to consider the augment of simultaneous-users access and the fact that the mobile communications system is an integrated services set as a whole.

Presently, the services and applications in mobile communications need even more bandwidth and reliable channels. Hence, the allocation of the available resources of the channel bandwidth is of utmost importance.

MC-CDMA [1-4] is an OFDM-based multiple access scheme. The basic principle of MC-CDMA is to spread the original data stream over different subcarriers employing a given spreading code in the frequency domain. Additionally, it is noteworthy that MC-CDMA is strongly considered as a candidate for a next generation (4G) downlink system in a multi-cell environment.

Figure 1 shows a frequency spreading representation of MC-CDMA with two users. Also, the figure shows that the MC-CDMA scheme has a distance code c_d for orthogonality.

Moreover, in a downlink mobile radio communication channel is used the Hadamard-Walsh codes as an optimum orthogonal set.

The types of modulation used throughout this paper are DQPSK and QPSK. These modulation techniques are widely deploying e.g. in DVB, ISDB, and most wireless communications systems.

Some current related works have addressed different aspects about performance analysis of MC-CDMA, cf. [5-9].

The remainder of this paper is structured as follows. In Section II is presented a brief overview of Walsh codes and Reed-Solomon (RS) coding [10-12]. The performances of the simulations are provided in Section III. Finally, the main conclusions are drawn in Section IV.

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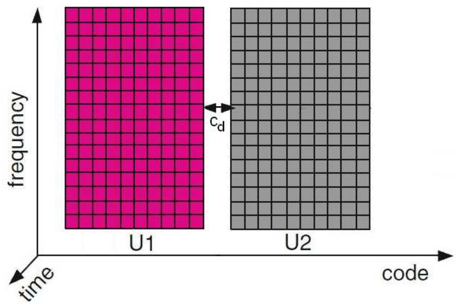

Figure 1. MC-CDMA scheme with two users (U).

II. Background

The block diagram of a transmitter using MC-CDMA is depicted in Fig. 2. The data bit streams of the users are RS encoded. With regard to the modulation alphabet, the bits are mapped to complex-valued data symbols. In the sub-carrier allocation block the mapped symbols are arranged for transmission. Besides, the data symbols are multiplied by a user-specific Walsh-Hadamard spreading sequence.

Finally, an OFDM modulation is performed which includes an inverse Fast Fourier Transformation (IFFT) and insertion of a guard interval (GI) to avoid inter-symbol (ISI) and inter-carrier (ICI) interference.

Additionally, MC-CDMA scheme makes possible mitigate ISI and also exploit the multipath channels. According to [4], MC-CDMA suffers only slightly in presence of interference as opposed to DS-CDMA, whose performance decreases significantly in presence of interference.

A. Hadamard-Walsh Codes

In the encryption process, CDMA employs Long and Short coding. Apart of those, Hadamard-Walsh coding is deployed. Walsh codes are created out of Hadamard matrices. Each row of a Hadamard matrix represents a Walsh code used for each channel. In CDMA-2000, 256 codes are used. The property of these Hadamard matrices is the fact

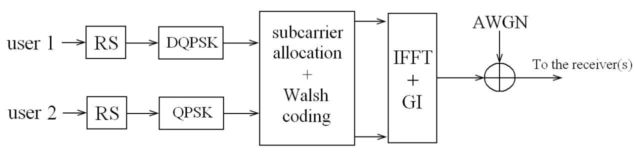

Figure 2. MC-CDMA environment diagram.

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that the rows of the matrix are orthogonal one each other.

The Hadamard matrix generation is as follows:

$$H_1 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (1)$$

$$H_{k+1} = \begin{bmatrix} H_k & H_k \\ H_k & \overline{H_k} \end{bmatrix} \quad (2)$$

B. *Reed-Solomon Coding*

Reed-Solomon codes [10-12] are a subset of BCH codes [13], [14]. RS codes constitute a class of linear, non-binary, cyclic codes. RS codes have the following parameters:

$$\begin{aligned} n &= q-1 = 2^m - 1 \\ k &= 1,3,\ldots,n-2 \\ d_{min} &= n-k+1 \\ R_C &= k/n \\ t &= (d_{min}-1)/2 \end{aligned} \quad (3)$$

From the above parameters, considering a RS code (n,k) over a Galois field $GF(q)$, n is the code length, k is the number of q-ary symbols mapped into n numbers of q-ary symbols, d_{min} is the minimum distance, R_C the code rate, and t is the error-correction capability.

In this paper, the Berlekamp-Massey (B-M) [15-18] algorithm is used to decode the RS encoding. The method, described by Berlekamp for evaluating error values, needs the following polynomial [11]:

$$Z(X) = 1 + (s_1 + \sigma_1)X^2 + \ldots + (s_\tau + \sigma_1 s_{\tau-1} + \sigma_2 s_{\tau-2} + \ldots + \sigma_\tau)X^\tau \quad (4)$$

From the above, s_k are the syndromes, $0 \le k \le \tau$, where τ is the number of errors occurred during a transmission, and the error-location polynomial coefficients are σ_k; the roots of this polynomial are β_i^{-1}, the inverses of the error-location numbers. Also, X is the variable that will be replaced in (4) with the roots of the error-location polynomial in order to calculate the error values.

Consequently, for $1 \le i \le \tau \le 2t$, the error values at position j_i, $\beta_i = \alpha^{j_i}$, are calculated as follows:

$$e_{j_i} = \frac{Z(\beta_i^{-1})}{\prod_{\substack{k=1 \\ k \ne i}}^{\tau} (1 + \beta_k \beta_i^{-1})} \quad (5)$$

III. Simulation and Analysis

The simulations are performed in this section. The computing tool used for this project was MATLAB®. Besides, the analysis of the outcomes is carried out.

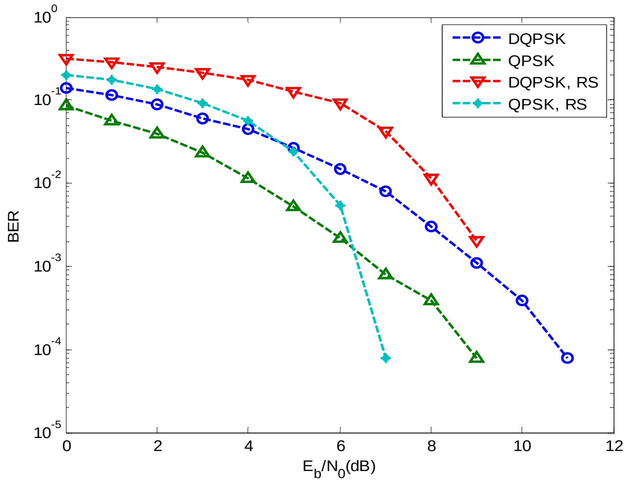

Figure 3. BER performance.

Figure 2 shows the MC-CDMA scheme. The two users are allocating in an OFDM scheme with 128 subcarriers. Each user has a Walsh code assigned and employs a modulation technique. The modulation techniques are DQPSK and QPSK for user 1 and user 2 respectively.

For the purpose of the simulations, each channel is assigned for each user. Also, we assume perfect synchronization between the transmitter and receiver.

In the first simulation, we use uncoded DQPSK and uncoded QPSK to transmit the data through the channel.

For the second simulation, the scenario considered has the following parameters:

$$\begin{aligned} (n,k,t) &= (15,5,5) \\ d_{min} &= 11 \\ R_C &= 1/3 \end{aligned}$$

Figure 3 depicts the simulation performances of DQPSK and QPSK under AWGN. Besides, in that figure it is shown the performances of these modulation techniques both with and without RS codes.

The plot shows that the BER performances of DQPSK and QPSK improve critically when RS codes are deployed.

Furthermore, according to Fig. 3, employing or not RS codes, the performance of QPSK is better than DQPSK, considering the BER performance plot.

The outcomes of the Fig. 3 are tabulated and summarized in the Table I.

TABLE I. Comparison of Performance

	E_b/N_0 (dB)			
BER	$10^{-1.09}$	10^{-2}	10^{-3}	$10^{-4.15}$
DQPSK	~ 2.3	~ 6.7	~ 9	~ 11
QPSK	~ 0	~ 4.2	~ 6.8	~ 9
DQPSK, RS	~ 6.2	~ 8.2	~ 9.1	~ 9.3
QPSK, RS	~ 3.5	~ 5.6	~ 6.4	~ 7

IV. Conclusion

In this paper, DQPSK and QPSK shared a MC-CDMA scheme under AWGN. Hence, under the same channel conditions, the BER plot displayed that QPSK has a better

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performance than DQPSK. Besides, the problems of ISI and ICI were overcome due to GI.

Now, when Reed-Solomon encoding was employed in the simulations, both modulation techniques showed an improvement regarding BER. Table I displays some tabulated outcomes to interpret the BER performance plot.

Therefore, considering a MC-CDMA environment under AWGN, we may conclude that DQPSK is more vulnerable than QPSK.

Many issues remain open yet. For example, an open issue is to analyze thoroughly the impact of the RS decoding algorithm. As it was mentioned, B-M was employed throughout this paper, however presently, many new proposals are arising.

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