Research Paper Presentation

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June 16, 2021

Performance Analysis of Signal Pattern Reducing Techniques for Low probability of Detection

Abstract

1. We will talk about the communication system based on Quasi Synchronous(QS)CDMA.
2. Disturbing those recurring patterns can reduce the probability of detection measured in terms of the Degree of Cyclostationarity (DCS).
3. We aim to achieve that by employing some techniques that will perturb the signal structure by randomly selecting spreading sequences, random time dithering or a combination of the two.
4. We study and compare the performance of all the above techniques.

Keywords and some definitions

Code Dimensional Multiple access (CDMA)

CDMA is an example of multiple access, where several transmitters can send information simultaneously over a single communication channel.

Bit Error Rate (BER)

The BER is the number of bit errors per unit time.that can be caused due to noise,interference or bit synchronization errors

System Model

Introduction

1. Normally in QS-DS-CDMA each user spreads all their symbols using the same (unique) spreading sequence.

LS Code

A LS code is defined by the triplet (M, L_c, Z)

1. M is Family Size.
2. L_c is code length.
3. Z is the size of the code's ZCZ.
4. Fundamental orthogonal bond ,i.e $L_c = M.Z$

System Model

The transmitted signal model

The transmitted signal of a user in a Quasi Synchronous (QS)-DS-CDMA system is modeled as

$$x(t) = \sum_{n=0}^{N-1} b_n \sum_{l=0}^{L-1} a_l p(t - lT_c - nT - \Delta t) \quad (1)$$

spreading sequence is $\{a_0, a_1, ...a_{L-1}\}$ of length L

System Model

Parameters

Parameter	Parameter Denotes
N	Number of data symbols transmitted per packet
T	Symbol duration
b_n	The nth symbol which is spread by sequence of length L
T_c	Chip duration
Δt	Time uncertainty due to imperfect synchronization

Table: Parameters

Pattern Reducing Schemes

Pattern Reducing Schemes :

1. Random Spreading Sequence Selection (RS-MECS).
2. Random Time Dithering (DITH).
3. Random Selection with Dithering (RS-DITH).

Random Spreading Sequence Selection

RS-MECS

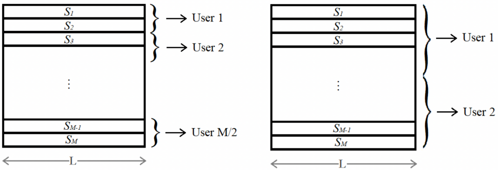
In this , we describe and analyze a scheme for spreading sequence assignment and random selection which we call Random Selection from Mutually Exclusive Code Subsets (RS-MECS).

1. In this scheme, We instead propose a system where each user is assigned a set of sequences; spreading is then performed by picking one of those sequences randomly in a per-symbol basis.

Note

It is not necessary to make a ‘symmetric’ sequence assignment, as shown in the following example.

Example for RS-MECS



(a) $c = 2$ sequences per user (b) $c = M/2$ sequences per user

Figure: RS-MECS Examples

Random Spreading Sequence Selection

The transmitted signal model

The transmitted signal model then becomes

$$x(t) = \sum_{n=0}^{N-1} b_n \sum_{l=0}^{L-1} a_{l,n} p(t - lT_c - nT - \Delta t) \tag{2}$$

In this case , Spreading sequence is additionally indexed by data symbol number ,When compared to equation (1);

Random Time Dithering

DITH

1. In this technique each user is assigned a unique sequence to spread their data.
2. Given the time uncertainty requirement of the system, one could choose a longer ZCZ i.e Z than the one required for weak synchronization in order to introduce an additional random delay (dither)

Random Time Dithering

The transmitted signal model

The transmitted signal model then becomes

$$x(t) = \sum_{n=0}^{N-1} b_n \sum_{l=0}^{L-1} a_l p(t - lT_c - nT - \Delta t - \epsilon_n T_c) \quad (3)$$

In this case ,Additional Term $(\epsilon_n T_c)$ accounts for random time dithering on a per-symbol basis. When compared to (1) ;

Random Selection with Dithering

RS-DITH

In this scheme, that we will refer to as Random Selection with Dithering (RS-DITH), each user is assigned a set of spreading sequences and is also allowed to perform dithering within the ZCZ .

The transmitted signal model

The transmitted signal model then becomes

$$x(t) = \sum_{n=0}^{N-1} b_n \sum_{l=0}^{L-1} a_{l,n} p(t - lT_c - nT - \Delta t - \epsilon_n T_c) \tag{4}$$

In this case ,both dithering and a symbol-dependent terms get included, When compared to (1) ;

Auto correlation function (ACF)

ACF

The autocorrelation function is the correlation between the random variables corresponding to two time instants of the random signal,or

$$R_x(t_1, t_2) = E[x(t_1).x^*(t_2)] \tag{5}$$

To see how the autocorrelation varies with some particular central time t, we can use a more convenient parameterization of the two time instants t_1 and t_2, such as

$$R_x(t, \tau) = E[x(t + \tau/2).x^*(t - \tau/2)] \tag{6}$$

LPD Evaluation - Cyclic Spectral Analysis

LPD

Cyclostationary signals have either a periodic or an almost periodic autocorrelation function which, for a signal $x(t)$, can be represented by a Fourier series as

$$R_x(t,\tau) = \sum_{\alpha} R_x^{\alpha}(\tau) e^{i2\pi\alpha t} \tag{7}$$

The coefficient $R_x^{\alpha}(\tau)$ is Cyclic Autocorrelation Function (CAF)

$$R_x^{\alpha}(\tau) = \lim_{T\to\infty} \int_{-T/2}^{T/2} x(t-\tau/2)x^*(t+\tau/2)e^{-i2\pi\alpha t}dt \tag{8}$$

LPD

Parameters

Parameter	Parameter Denotes
τ	lag parameter
α	Cycle frequency
T	fundamental period of signal

Table: Parameters

LPD Evaluation

DCS

DCS ,Which can be computed either in time or frequency domain.Here we will compute using time domain.By Defining temporal coreal coefficient as

$$\gamma_x^\alpha(\tau) = \frac{R_x^\alpha(\tau)}{R_x(0)} \tag{9}$$

we can then write time decomposed degree of cyclostationarity as

$$DCS_\tau^\alpha = |\gamma_x^\alpha(\tau)|^2 \tag{10}$$

LPD Evaluation

DCS

Frequency decomposed degree of cyclostationarity as

$$DCS^{\alpha} = \frac{\int_{-\infty}^{\infty} DCS_{\tau}^{\alpha} d\tau}{\int_{-\infty}^{\infty} DCS_{\tau}^{0} d\tau} \tag{11}$$

Signal's degree of cyclostationarity over all values of α as

$$DCS = \sum_{\alpha \neq 0} DCS^{\alpha} \tag{12}$$

We define DCS ratio ,which will help in computing DCS Reduction, as

$$\text{DCS ratio} = \frac{DCS \text{ of signal using selected technique}}{DCS \text{ of original signal}} \tag{13}$$

Bit Error Rate(BER)

BER

1. Communication performance is measured in terms of Bit Error Rate (BER) for various values of signal to noise ratio (SNR).
2. We introduce additive white Gaussian noise(AWGN) of various power levels .

Simulation and Results

Parameters

Scheme	RS-MECS	DITH	RS-DITH
C	$1 \leq C \leq 32$	$C = 1$	$1 \leq C \leq 32$
D	$D = 0$	$0 \leq D \leq 32$	$0 \leq D \leq 32$
L_c	64	64	64

Table: Simulation Parameters

DCS Reduction for RS-MECS and RS-DITH

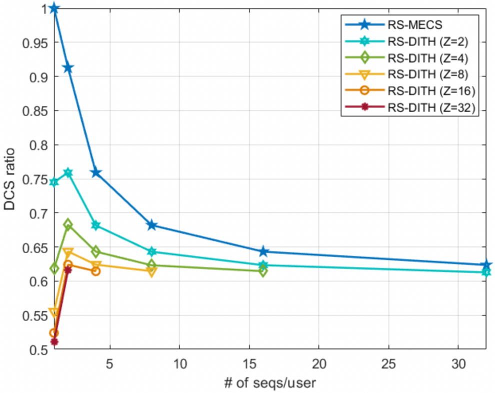


Figure: DCS Reduction for RS-MECS and RS-DITH

Results

Results

From Figure 2 :

1. RS-MECS,The DCS reduction depends only on number of sequences assigned for each user,C.
2. RS-DITH achieves higher DCS reduction for codes with longer ZCZ and performs better than RS-MECS for a fixed value of C .

BER Performance of DITH, RS-MECS and RS-DITH

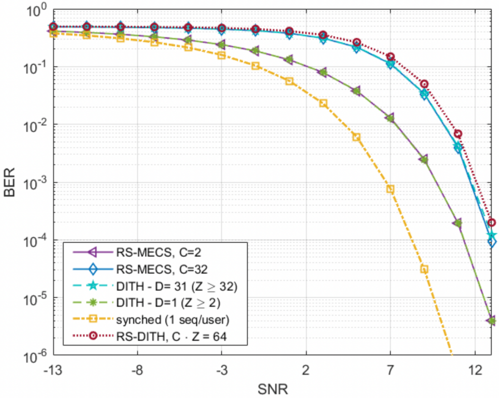


Figure: SNR vs BER Performance of DITH, RS-MECS and RS-DITH

Results

Results

From Figure 3 :

1. BER curves of DITH when only 1 chip of dithering is allowed coincides with BER curves of RS-MECS,when utilizing 2 sequences per user.
2. The BER performance of RS-DITH is lower than both DITH and RS-MECS for the same codes and depends on the product $C.Z$.

parameters

RS-MECS		DITH / RS-DITH		
$\Delta t \leq T_c$	$\Delta t = 7T_c$	$\Delta t = 0$	$\Delta t = T_c$	$\Delta t = 7T_c$
$C = 2$, $(M \geq 2)$	$C = 2$ $(M \geq 2)$	$D = 1$, $(Z \geq 2)$	$D = 0$, $(Z \geq 2)$	
$C = 4$, $(M \geq 4)$	$C = 4$, $(M \geq 4)$	$D = 3$, $(Z \geq 4)$	$D = 2$, $(Z \geq 4)$	
$C = 8$, $(M \geq 8)$	$C = 8$ $(M \geq 8)$	$D = 7$, $(Z \geq 8)$	$D = 6$, $(Z \geq 8)$	$D = 0$ $(Z \geq 8)$
$C = 16$, $(M \geq 16)$		$D = 15$, $(Z \geq 16)$	$D = 14$, $(Z \geq 16)$	$D = 8$ $(Z \geq 16)$
$C = 32$, $(M \geq 32)$		$D = 31$, $(Z \geq 32)$	$D = 30$, $(Z \geq 32)$	$D = 24$ $(Z \geq 32)$

TABLE II: Dither-Seqs/User Given Sync Requirement

DCS / BER Trade-off for DITH and RS-MECS

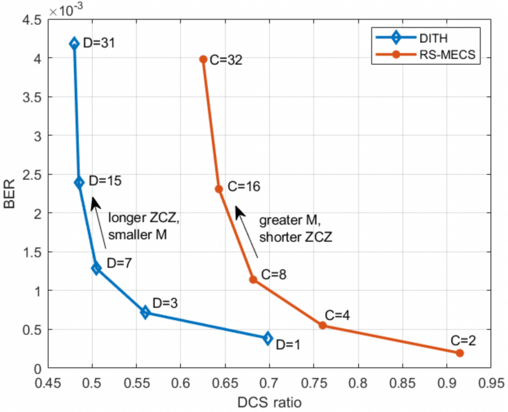


Figure: DCS / BER Trade-off for DITH and RS-MECS

Results

Results

From Figure 4(Above Figure) :

1. DCS reduction offered by DITH or RS-DITH diminishes as the time uncertainty increases due to the fact that ZCZ chips are allocated to both sync requirement and dithering.
2. DCS reduction offered by RS-MECS, it doesn't change, as long as the code can satisfy the time uncertainty requirement.

Conclusion

Conclusions and Inference

1. The employment of pattern reducing techniques in the context of QS-DS-CDMA is investigated aiming to reduce the Degree of Cyclostationarity leading to a lower probability of detection
2. We have seen that the DCS reduction is better for DITH, RS-DITH follows and RS-MECS offers the smallest reduction among the methods discussed
3. Even though combining random sequence selection with dithering seemed like a promising direction, the BER performance drops further due to the need to correlate both for the delay and the spreading sequence.