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# LDPC encoding performances for fading suppression in MIMO-CDMA wireless networks

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## Abstract

In multiuser wireless communication systems, signal recovery, even at low BER is a relevant factor for ensuring a safe and reliable communication. Efforts for interference minimization include multiple analysis of source coding/decoding techniques, channel coding/decoding techniques and multiuser detection algorithms. This paper illustrates the improvement brought by LDPC technique in SS systems when AWGN and Rayleigh/Nakagami-m fading occur on communication channel. Performances are evaluated for different sets of spreading sequences (Walsh-Hadamard, Kasami and PN) and based on the simulation results several conclusions are highlighted and further improvement will be proposed for fading effects reduction and interference minimization.

**Keywords:** multiuser detection, LDPC, fading suppression, coding gain.

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## 1. Introduction

The performances of wireless communication system are significantly affected by the fading phenomena and co-channel interference, thus, over the years a large number of techniques have been developed in order to reduce those effects [1,2]. Numerous researches have been performed for high rate communications systems to find the optimum set of parameters that achieves the best results on the basis of certain preset metrics [3,4]. In [3] for a MIMO-CDMA system Minimum Mean Square Error (MMSE) multiuser detection provides lower Bit Error Rate (BER) in presence of Rayleigh fading channel using turbo technique. Transmitting information over a Rayleigh fading channel with Gaussian correlated interference in [4], the authors derive the necessary conditions for optimality and propose an iterative algorithm based on joint optimization between the encoder and the decoder.

To achieve significant performance improvement for each user in Spread Spectrum (SS) systems there should be determined the most appropriate multiuser detector algorithm, the best spreading sequence and the most efficient coding/decoding technique. It has been shown that a proper solution for efficient data recovery is MMSE estimator which takes into account the background noise into account [5]. Also the use of LDPC technique leads to better results than the classical convolutional codes [6] and closer to those achieved with turbo codes [7-9]. The implementation effort is considerable lowered in case of LDPC codes than in case of turbo technique.

In SS systems users' identification and separation can be efficiently achieved by an adequate selection of spreading codes. In [10] MMSE multiuser receiver using Walsh-Hadamard and PN sequences achieve very good performances if the codes are perfectly orthogonal while a small misalignment may lead to large cross-correlation coefficients and a significant degradation of the results obtained with respect to BER.

This paper investigates the effects of LDPC technique over fading transmission channel, the results being compared with the ones achieved in Additive White Gaussian Noise (AWGN). The paper is organized as follows: Section 2 contains the description of the implemented multiuser systems and the simulation parameters. In Section 3 the results are given as BER vs. SNR, while Section 4 highlights several conclusions and brings to attention future work.

## 2. System model and parameters

For evaluation purposes a four users baseband multiuser SS CDMA simulator is used, as shown in Fig. 1, each user transmitting binary data streams of 3000 bits length. The data are LDPC encoded with an irregular random LDPC code with rate 1/2. The encoded data are CDMA spread using several signature sequences: Walsh-Hadamard, PN and Kasami.

The communication channel is affected by AWGN, Rayleigh or Nakagami-*m* fading. For Rayleigh fading the parameters are: maximum Doppler frequency shift 50Hz, sampling frequency 1000Hz and noise generators have mean 0 and variance 0.25. For Nakagami-*m* fading the shape parameter $m$ was chosen 3 and the parameter controlling spread $\Omega$ is 0.5. After MMSE detector the LDPC decoder uses min-sum decoding algorithm which performs a suboptimal iterative decoding process [11].

In order to evaluate the performances of the implemented system BER has been evaluated for each user considering performance evaluation with/without LDPC coding with different signature sequences and types of communication channel. Monte Carlo technique has been used, with over 5000 trials for each data bit and performances are evaluated in terms of BERs versus SNRs.

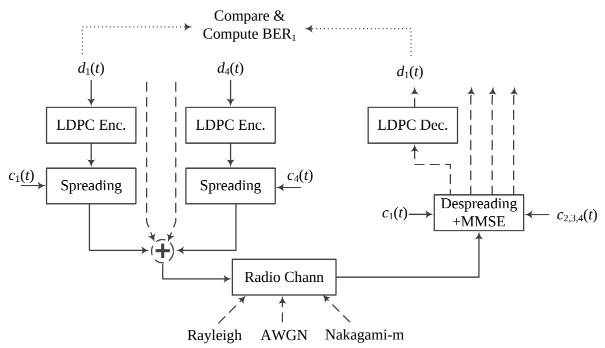



**Figure 1** – Tested LDPC-SS multiuser system

### 2.1. Walsh-Hadamard codes (WH codes)

Fig. 2 illustrates the behaviour of the multiuser system when WH codes signature are used. It can be noticed that BER results are improved when LDPC technique is involved, especially at high SNR. The performance of the system is acceptable when the channel is affected by AWGN only but, if Rayleigh or Nagakami-*m* fading occurs on the communication channel, its undesired effect can be overcome by using an efficient LDPC technique. Therefore, good Coding Gains (CGs) are achieved for these types of fading and their values are given in Table 1, for different values of BER.

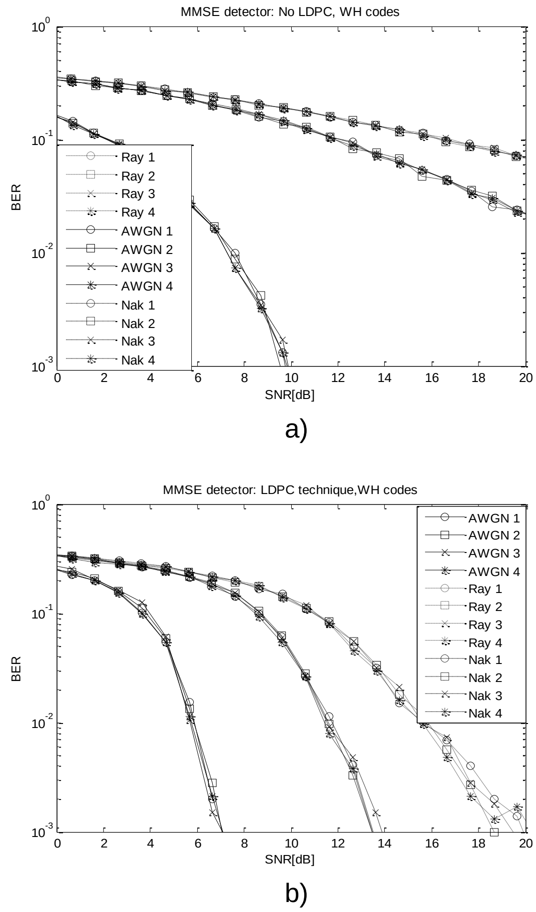



**Figure 2** – BER vs SNR: Walsh-Hadamard codes (a) No LDPC (b) LDPC technique

Table 1 shows that LDPC technique significantly reduces the degradation caused by the fading process, especially for high SNRs. While for AWGN channel the CG remains approx. 3dB, for Nakagami-*m* fading as BER decreases, performance gain reaches almost 18dB at BER=$10^{-3}$. For Rayleigh fading CG cannot be computed at BER=$10^{-3}$ since this value is not reached within the SNRs analysis interval (0 and 35dB) for the no-coding case. However, the highest CG achieved at BER=$10^{-2}$ (around 18 dB) shows that good improvement is possible in Rayleigh channels for high SNRs.

Table 1. CGs for WH/LDPC codes

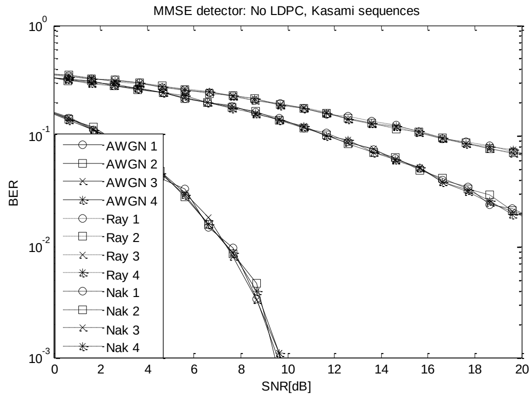
| BER | CGs (dB) | | |
|---|---|---|---|
| | **AWGN** | **Rayleigh** | **Nakagami-*m*** |
| $10^{-1}$ | 2,037 | 4,94 | 2,275 |
| $10^{-2}$ | 2,39 | 18 | 12,27 |
| $10^{-3}$ | 3 | - | 17,24 |

Table 2. CGs for Kasami sequences/LDPC codes

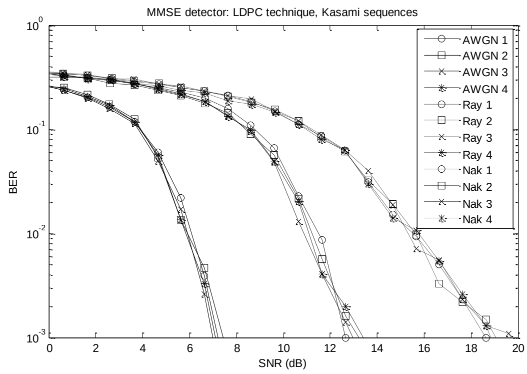
| BER | CGs (dB) | | |
|---|---|---|---|
| | **AWGN** | **Rayleigh** | **Nakagami-*m*** |
| $10^{-1}$ | 1,41 | 5 | 3,06 |
| $10^{-2}$ | 1,06 | 18,01 | 10,92 |
| $10^{-3}$ | 2,64 | - | 17,98 |

## 2.2. Kasami sequences

Fig. 3 illustrates the performance of the system when Kasami sequences are used for spectral spreading and user identification. For low SNRs the results obtained using Kasami sequences are not much different from the ones achieved with WH codes. Further, in both cases, the AWGN channel affects less the quality of the received signal while the Rayleigh fading proves to lead to the worst results, regardless if the LDPC codes are used or not. The CGs achieved in each case are shown in Table 2.




a)

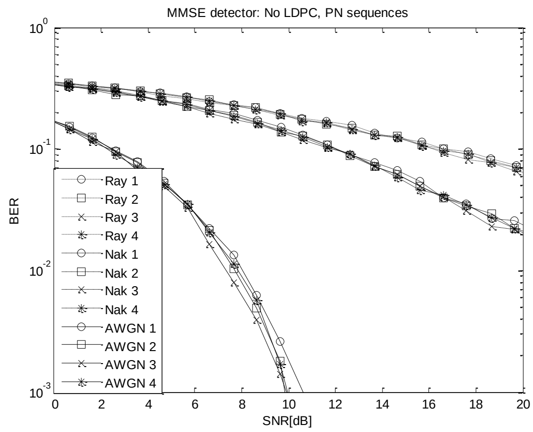



b)

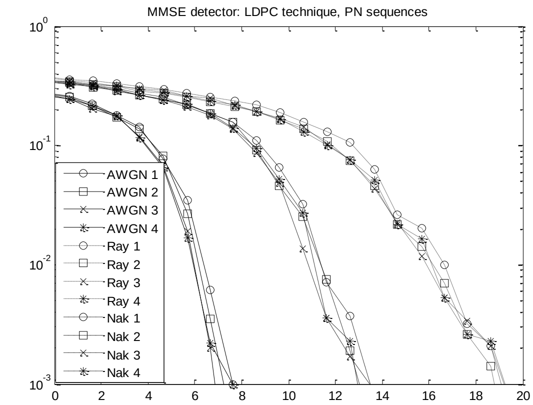
**Figure 3** – BER vs SNR: Kasami sequences (a) No LDPC (b) LDPC technique

## 2.3. PN sequences

In Fig. 4 are illustrated the results achieved with PN codes, while in Table 3 contains CGs are given for all types of noise/fading when LDPC codes are used. It can be noticed that this type of sequences are suitable for AWGN channel especially for low SNRs. For Rayleigh fading, the CGs achieved by LDPC are close to the ones achieved with Kasami sequences, increasing as SNR increases too.




a)




b)

**Figure 4 –** BER vs SNR: PN sequences (a) No LDPC (b) LDPC technique

For Nakagami-m channel using PN codes a CG of 20,23dB is achieved for BER=10-3 (almost 3dB higher compared to the one obtained with WH codes and approx. 2,3dB higher than the one obtained with Kasami sequences). Therefore PN sequences seem to be most efficient in Nakagami-m fading channels in combination with LDPC encoding, leading to better performances especially for high SNRs.

Table 3. CGs for PN sequences/LDPC codes

| BER | CGs (dB) | | |
|---|---|---|---|
| | **AWGN** | **Rayleigh** | **Nakagami-*m*** |
| $10^{-1}$ | 2,02 | 3,94 | 3,97 |
| $10^{-2}$ | 2,89 | 17 | 11,05 |
| $10^{-3}$ | 4 | - | 20,23 |

## 3. Conclusion and future work

The present paper illustrates the behaviour of SS systems when LDPC technique is involved in data recovery. The undesired effects of non-orthogonality of spreading sequences and fading can be partially controlled using LDPC technique. For AWGN channels WH codes lead to the best results in terms of CG while Kasami sequences proved to be more suitable in Rayleigh fading channels and PN sequences perform better with LDPC in Nakagami-*m* fading. By comparison with results from the existing literature [12], the present work implements a more complex system, covers a larger domain for SNR and achieves, at BER=$10^{-3}$, a significant larger CG.

Future work implies the change the random data sent on the communication channel to one that contains visual information (images or video streaming). The quality of the recovered data can be analysed using quality different metrics and the effect of LDPC technique in data recovery will also be analysed (Peak-Signal-to-Noise-Ratio, Video Quality Metric, Moving Pictures Quality Metric, etc).

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