Proceedings of the 5th WSEAS Int. Conf. on Electronics, Hardware, Wireless and Optical Communications, Madrid, Spain, February 15-17, 2006 (pp20-25)

Multicarrier Interleave-Division Multiple Access Communication in Multipath Channels

Habib ur Rehman*, [1]Muhammad Naeem**, Imran Zaka*, Syed Ismail Shah**

* *Center for Advanced Studies in Engineering (CASE) Islamabad*
***Iqra University Islamabad Campus, H-9, Islamabad.*

Abstract

In this paper a simple multiuser Multicarrier system is proposed for multiuser communication, user separation and detection using Interleave Division Multiple Access (IDMA). The performance of IDMA is analyzed in Gaussian and Qausi Static channels. In multicarrier Interleave Division Multiple Access (MC-IDMA) users are separated and identified by interleaving instead of codes as in Code Division Multiple Access (CDMA). It employs chip-by-chip interleaving and detection. As a simpler form of Multicarrier Code Division Multiple Access (MC-CDMA), it also includes the benefits of MC-CDMA such as mitigation against fading, multipath effects and asynchronous transmission. The simulation results show that MC-IDMA not only improves the performance but also more efficient in these channels as compared to MC-CDMA.

Keywords*:* Multicarrier-CDMA, Multicarrier-IDMA Orthogonal Frequency Division Multiplexing (OFDM).

1. Introduction

Multicarrier-CDMA is a multicarrier multi-user technique, based on a combination of Orthogonal Frequency Division Multiplexing OFDM and CDMA [1-3]. The combination benefit from the features of both OFDM and CDMA. OFDM divides the total bandwidth into spectrally overlapping, narrow band sub-channels. The bandwidth of sub-channel is chosen much less than the coherent bandwidth of the channel. It transforms high rate serial data into low rate parallel data frames and maps these frames on orthogonal sub-carriers. OFDM transforms frequency selective fading into flat fading, has high spectrum efficiency and enhanced anti-multipath fading ability [2-3]. CDMA is a multi user communication technique based on spread spectrum. It assigns each user a unique spreading code; at the receiver the users are separated on the basis of low correlation of spreading codes. A drawback of CDMA is that its performance degrades rapidly as the number of users increases further it requires a complex receiver.

Multicarrier CDMA overcome these difficulties. A MC-CDMA system transmits N chips simultaneously by assigning each chip to a separate carrier so that each input symbol is transmitted on N carriers. Signal spreading in this scheme is performed in the frequency domain. The receiver extracts the transmitted symbol by correlating the signal samples at the OFDM output with the code sequence used for signal despreading. MC-CDMA system lowers the symbol rate in each subcarrier increasing the symbol durations, which minimize the multipath fading effects of the channel [4][6]. It uses multi-user capability of CDMA system, allowing multiple users to interact simultaneously with low BER using standard receiver techniques [2][8]. In MC-CDMA, modulation and demodulation is achieved by using Inverse Fast Fourier Transform and Fast Fourier Transform (IFFT/ FFT) algorithms [5].

The idea of IDMA was first proposed in [9]. The technique presented was a chip-by-chip iterative user detection based on chip interleaving. The interleaving was used to separate users and a semi analytical technique is proposed to estimate the BER, which provide fast and accurate method to predict the performance of the IDMA system [10-11]. Also [13] discuss the bit level and symbol level interleaving. A Multi User Interference (MUI) free, CDMA transceiver is presented in [14], which rely on Chip-Interleaving, and zero padded transmission, as a result multiuser separation is achieved with low complexity code-matching filter. In [14] an IDMA system in multipath fading channels is presented. It suggests the use of a rake receiver to separate the multiple paths and then apply the same algorithm to all the paths as in conventional CDMA.

In this we paper present the idea of MC-IDMA. MC-IDMA simplifies the receiver architecture in multipath channels by transforming the convolution of channel impulse response with the transmitted signal and recomputed it into multiplication with the channel frequency response with the frequency-transmitted signal. We analyze the chip-by-chip Interleaving scheme with multicarrier communication in Gaussian channel. We use Multi Carrier communication because it transforms frequency selective fading into flat fading and its convolutional effects of channel are converted into multiplication. By adding interleaving effects at the chip level excellent results are achieved.

Remainder of the paper is organized as follows. Next section describes the system model for IDMA. Section 3 describes the simulation results. The paper is concluded in Section 4.

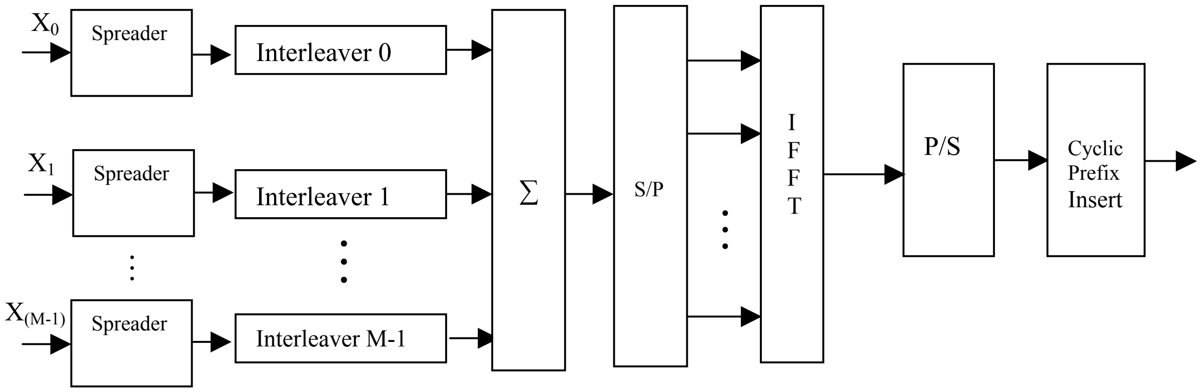

Figure 1: MC-IDMA Transmitter with spreader for multipath mitigation, user specific interleaver for User separation.

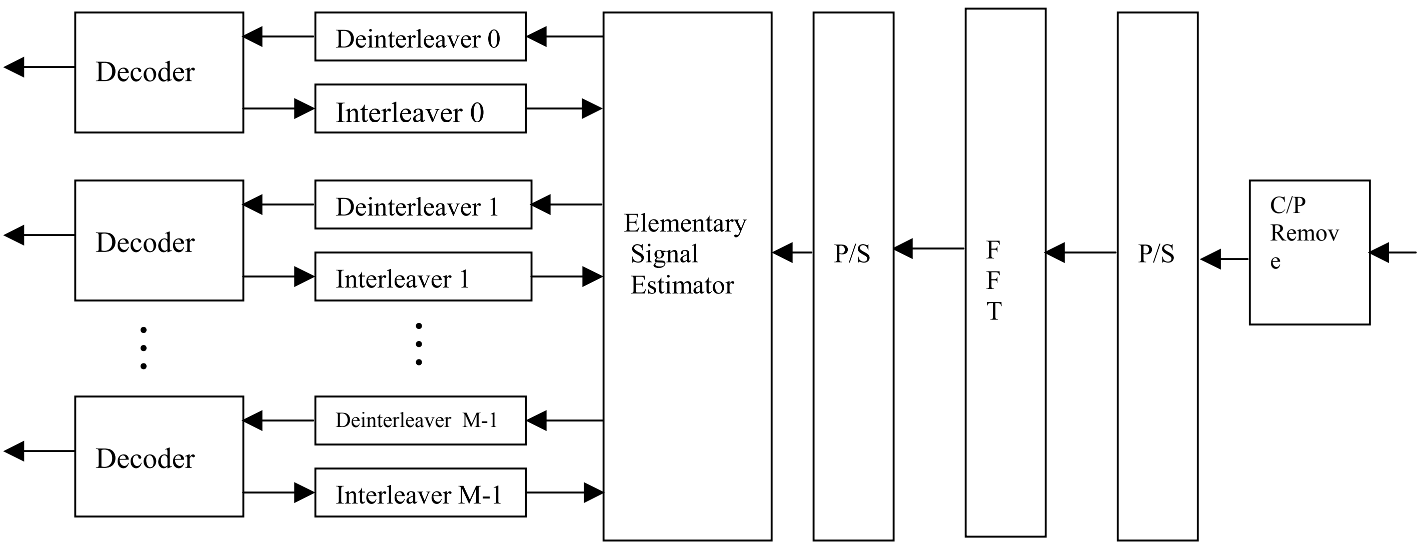

Figure 2: MC-IDMA receiver with decoder and deinterleaver

System Model

The transmitter model is shown in figure 1 for a MC-IDMA system, which has two parts. First part contains Spreader, Forward Error Correction (FEC) encoder and Interleaver [10] and the second part is multicarrier transmitter. We assume QPSK modulation. Same spreading code is used to spread data of M users opposed to DS-CDMA where each user requires a unique spreading code for identification. In the first part FEC encoder can be different for different users or it can be same for all users [10]. The user specific interleaver acts at the chip level, used to separate and identify each user. The interleaved FEC encoded chip data is the input of Multicarrier subsystem, which in first step converts the composite signal of all users from serial to parallel form followed by an IFFT operation. IFFT operation modulates each chip of data on a different subcarrier and provides frequency diversity. This modulated data is then reconverted to serial form and cyclic prefixes are added to each symbol. These prefixes are added to make symbols appear periodic so that convolution of the signal and the channel becomes circular [3]. The length of the cyclic prefix must be more than the expected delay spread so that when the signal passes through the multipath channel, it is circularly convolved with the channel impulse response.

The receiver structure of MC-IDMA is shown in figure 2. From the down-sampled signal, cyclic prefixes are removed and FFT coherently demodulates it. The signal is then fed to Elementary Signal Estimator (ESE). ESE algorithm is used to replace multiuser detector. ESE is a low complexity algorithm as compared to multiuser detection algorithms. Let $c(k)$ be the interleaved signal. Then the output of the FFT block is given by

$$x(t) = \sum_{i=-\infty}^{\infty}\sum_{n=0}^{N-1}\sum_{m=1}^{M} X_m(n)\, p(t-T_s)\, e^{j\frac{2\pi n(t-iT_s)}{(T_s-\Delta)}} \qquad (1)$$

Where $T_s = NT_c - \Delta$, T_c is the chip duration and Δ the duration of guard band. *p(t)* is pulse satisfying the following relations.

$$p(t) = \begin{cases} 1 & 0 \le t \le T \\ 0 & otherwise \end{cases} \quad (2)$$

The low pass equivalent impulse response of a time varying wide sense stationary uncorrelated scattering channel with L paths is given by

$$h(\tau;t) = \sum_{l=1}^{L} \varsigma_l(t)\delta(\tau - \tau_l) \quad (3)$$

Where t and τ are time and delay respectively. *L* is the number of multipath, τ_l is the delay in the j[th] path, $\varsigma_l(t)$ i[th] path gain which mutually independent qausi static Gaussian variable and δ is the dirac delta function.
The received signal y (t) is given by

$$y(t) = x(t) * h(\tau;t) \quad (4)$$

The received signal after down sampling is given by

$$r(j) = \sum_{m=1}^{K} H_m X_m(j) + N(j) \quad (5)$$

$$r(j) = H_k X_k(j) + \sum_{\substack{m=1 \\ m \ne k}}^{K} H_m X_m(j) + N(j) \quad (6)$$

$$r(j) = H_k X_k(j) + \zeta_k(j) \quad (7)$$

where $\zeta_k(j)$ is the distortion due to all other users except the user k plus the spectrum of noise. If data from all the users is independent then using central limit theorem $\zeta_k(j)$ can be approximated by a Gaussian random variable for large K. The ESE algorithm is executed on this sequence. In the first step we estimate mean and variance of *r(j)* using (6). Then estimate mean and variance of $\zeta_k(j)$ are estimated using (7). Now estimate $X_k(j)$ from *r(j)* using (2). This is the chip-by-chip ESE for a synchronized channel.

3. Simulation Results

In this section, we provide simulation results to illustrate the performance of newly proposed MC-IDMA on different channel conditions.

In figure 3 we compare the performance of an uncoded MC-IDMA in Gaussian channels with MC-CDMA. To illustrate the performance gain offered by newly proposed MC-IDMA in a Gaussian channel, we provide simulation results in term of bit error rate (BER) verses SNR with block length of B = 256 and spread length S = 64. The interleaver length is equal to Block length multiply by spread length (I = B * S = 256 * 64 = 16384). The performance compared by varying the number of users from 1 to 64. It is assume that all users are initially at the same power level and same spreading code. Simulation result show that at relatively high SNR performance of MC-IDMA is approached that of a single user. Also for high number of users, its performance is better than that of multicarrier CDMA.
Its potential for optimal performance is illustrated in figure 4 and figure 5 with BER plotted in multipath static and multipath Qausi static channels. Figure 4 shows the performance of MC-IDMA in multipath static channel. Block length is fixed at 256 and spread length is 64 and Interleaver length is 16384. Simulation result reveals that 2dB more SNR is required for MC-IDMA system to approach single user performance. Figure 5 shows the performance of MC-IDMA in multipath static channel. In last two simulations performance of new scheme is simulated against different spread length and block length. Figure 6 shows the performance of MC-IDMA as a function of spread length and figure 7 analyze the performance of MC-IDMA as a function of block length. For these two simulations number of users and SNR is fixed. The behavior of BER as a function of spread and block lengths is impressive.

4. Conclusions

In this paper we analyzed multicarrier multiuser communication technique MC-IDMA, in which interleaver is the only mean of user separation. It has been shown with simulation results that MC-IDMA has excellent BER performance for higher number of users and is more robust to multipath effects, and at a relatively high SNR, it approaches to the performance of single user. Also with increased interleaver length we can improve the performance of multiuser communication.

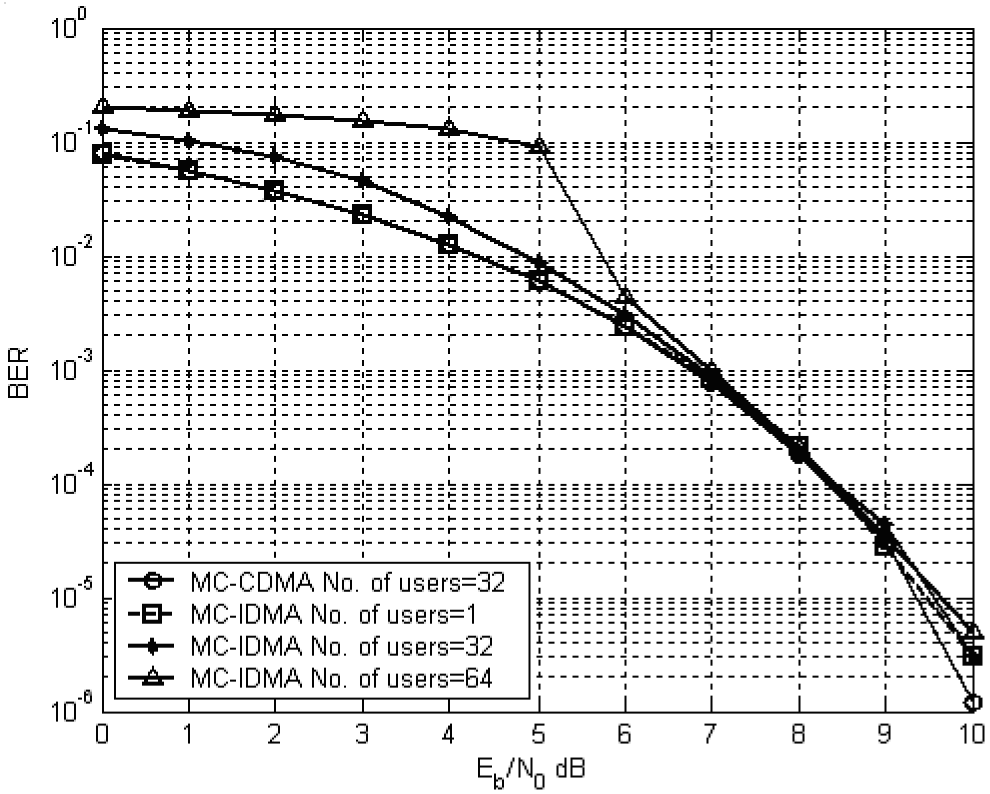

Figure 3. Performance of MC-IDMA in Gaussian Channels

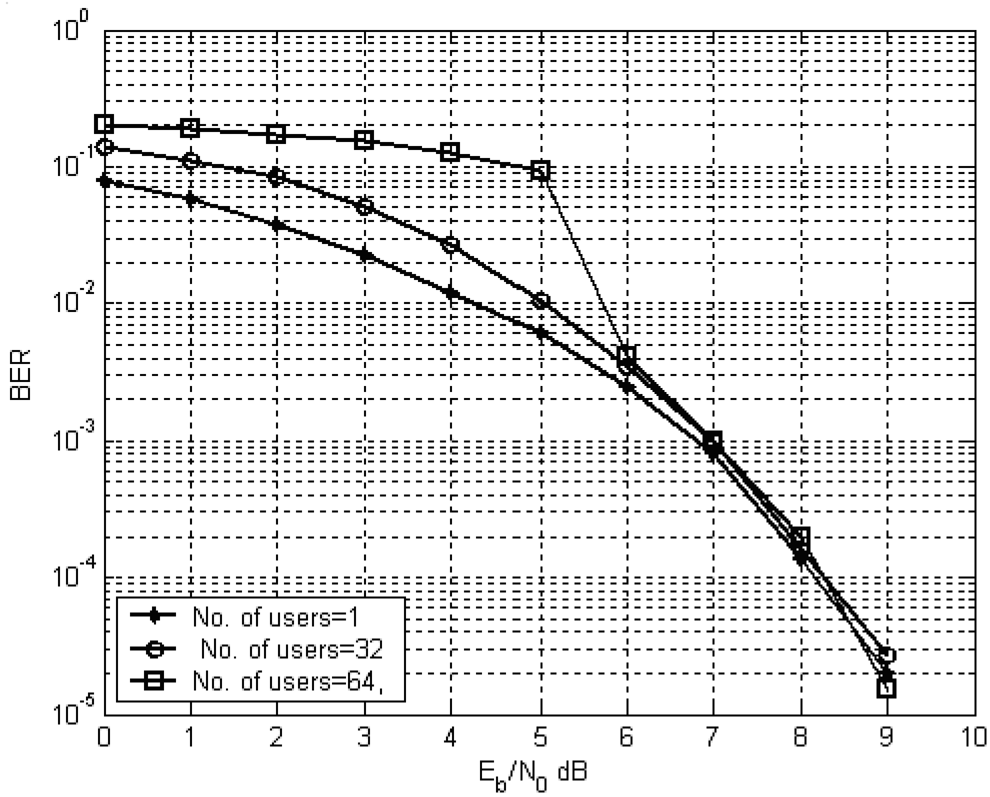

Figure 4. Performance of MC-IDMA in multipath static channels

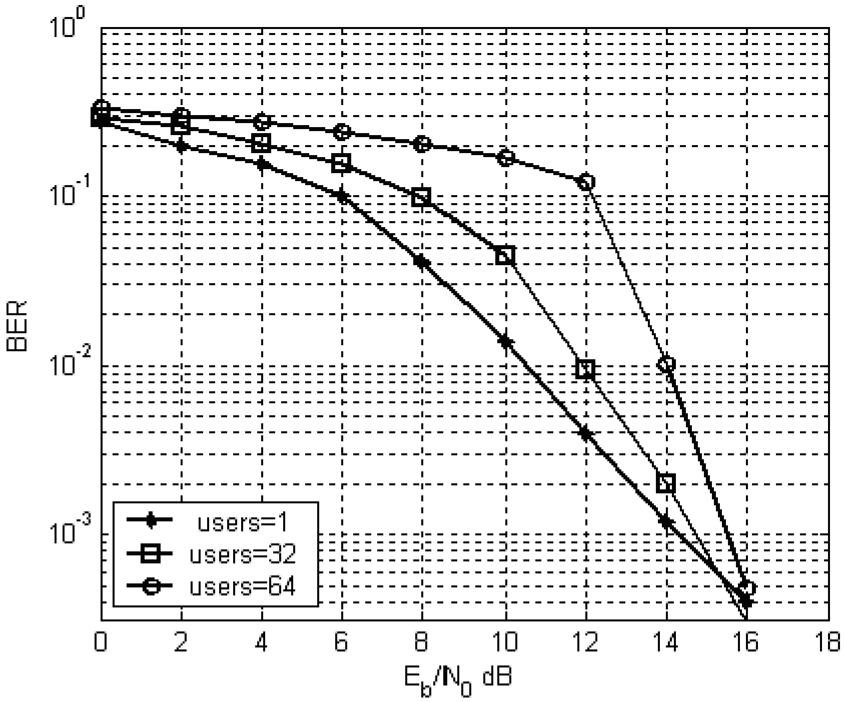

Figure 5. Performance of MC-IDMA in multipath Qausi static channels

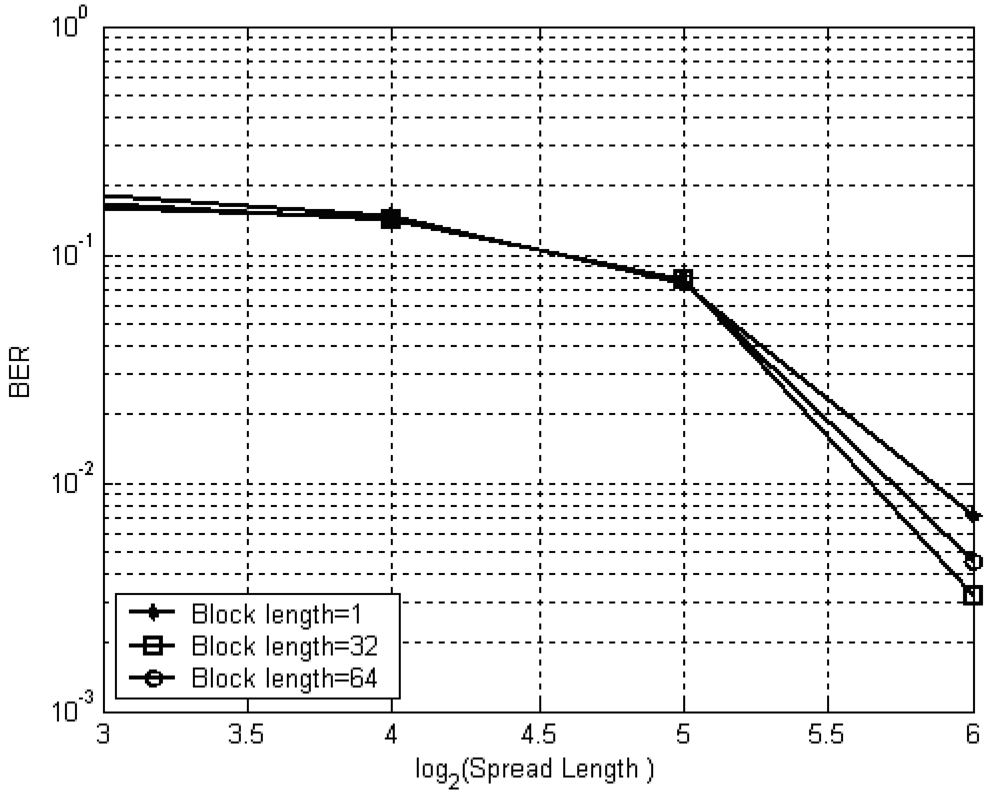

Figure 6. Performance of MC-IDMAas a function of spread length

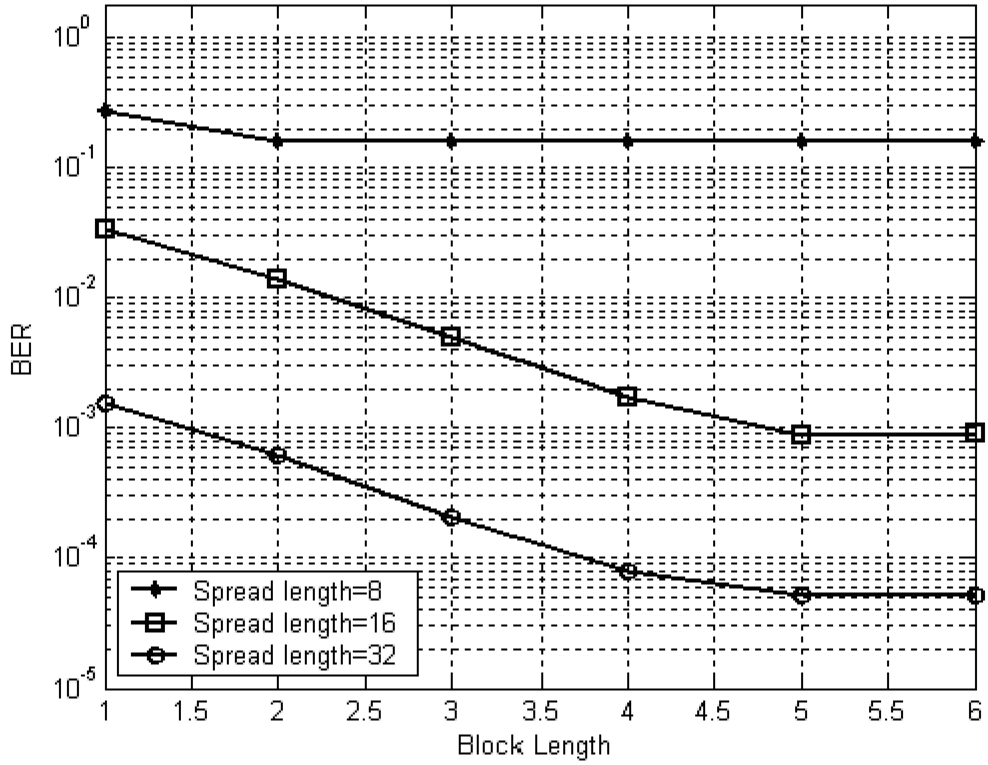

Figure 7. Performance of MC-IDMA as a function of block Length.

References

[1] S. Hara and R. Prasad, "Overview of multicarrier CDMA", IEEE Communications magazine, pp. 126-133 Dec. 1997.

[2] N. Yee, J.-P. Linnartz, and G. Fettweis, "Multicarrier CDMA for Indoor Wireless Radio Networks", Proc. PIMRC '93, Yokohama, pp. 109-113, September 1999.

[3] M. K. Simon and M. S Alouini, "Digital Communication over Fading Channels, A unified approach to performance Analysis", John Wiley & sons, inc., 2002.

[4] R. D. J. Van Nee and R. Prasad, OFDM for Wireless Multimedia Communications, Norwood, MA: Artech House, 2000.

[5] S. B. Weinstein and P. M. Ebert, "Data Transmission by Frequency-Division Multiplexing Using the Discrete Fourier Transform ", IEEE Trans. Commun. Tech., Vol. COM-19, pp. 628-634, Oct. 1971.

[6] J. A. C. Bingham, "Multicarrier Modulation for Data Transmission: An idea whose time has come", IEEE Comm. Mag, pp. 5-14, May 1990.

[7] G. L. Turin, "Introduction to Spread-Spectrum Antimultipath Techniques and Their Application to Urban Digital Radio," Proc. IEEE, Vol. 68, pp.328–353, Mar., 1980

[8] K. Fazel and L. Papke, "On the Performance of Convolutionally-Coded CDMA/OFDM for Mobile Communication Systems," Proc. PIMRC '93, Yokohama, pp. 468-472, September 1999.

[9] Li Ping, L. Liu, K. Y. Wu, and W. K. Leung, "A unified approach to multi-user detection and space-time coding with low complexity and nearly optimal performance," in Proc. 40th Allerton Conference, Allerton House, USA, pp. 170–179 Oct. 2002

[10] Li Ping, "Interleave-Division Multiple Access and Chip-by-Chip Iterative Multi-User Detection", IEEE Radio Communications • June 2005

[11] L. Ping., "On Interleave-division Multiple-Access," Proc. IEEE ICC '04, Paris, pp. 2869–73 June 2004

[12] R. Singh and L. B. Milstein, "Addaptive Interference Suppression for DS-CDMA", IEEE Trans. Comm. Vol. 50 No. 12, pp. 1902-1905, Dec. 2002.

[13] S. Zhou, G. B. Giannakis, and C. Le Martret, ``Chip-Interleaved Block-Spread Code Division Multiple Access," IEEE Transactions on Communications, Vol. 50, No. 2, pp. 235-248, February 2002.

[14] S. Zhou, P. Xia, G. Leus, and G. B. Giannakis, "Chip-Interleaved Block-Spread CDMA versus DS-CDMA for Cellular Downlink: A comparative study," IEEE Transactions on Wireless Communications, Vol. 3, No. 1, pp. 176–190, January 2004.

[15] J. Luo, K. Pattipati, P. Willett, and G. Levchuk, "Optimal grouping algorithm for a group decision feedback detector in synchronous CDMA communications", IEEE Trans. Comm. Vol. 51 No. 3, pp. 341-346, March 2003.