Performance Analysis of MC-CDMA System using LDPC Codes and Turbo Codes

Santoshi Rani, Channabasappa Baligar, Dr Siva Yellampalli

Abstract: This paper presents the Performance Analysis of Multiple Carrier Code Division Multiple Access (MC-CDMA) system using different types of coding techniques such as LDPC Codes and Turbo Codes. MC-CDMA system is a combination of both CDMA and OFDM. This is a communication model where we are going to subject the image (data) to different levels of noises in the channel. By introducing AWGN Channel as the source of noise, the performances of the system are analysed with LDPC Codes and Turbo Codes. Finally from analysis, the Turbo codes provide a better decoding scheme with lower complexity and higher efficiency when compared with LDPC Codes. For both LDPC and Turbo code gives the similar results. If the input data is small, then turbo code works better, else LDPC code works better.

Keywords: MC-CDMA, LDPC, OFDM, TURBO CODE (TBC), AWGN, Rayleigh channel, sum-product decoding algorithm

1 INTRODUCTION

Wireless Mobile Communication systems present several design challenges resulting from the mobility of users throughout the system and the time-varying channel (multipath fading). There has been an increasing demand for efficient and reliable digital communication systems. To tackle these problems effectively, an efficient design of forward error coding (FEC) scheme is required for providing high coding gain. To obtain high coding gains with moderate Decoding complexity, concatenation of codes with iterative decoding algorithms has proved to be an attractive scheme. These codes are the TURBO CODE and the Low Density Parity Check (LDPC) codes.

MC-CDMA system is a combination of CDMA and OFDM. Hence MC-CDMA has the advantages of both CDMA and OFDM. The CDMA part increases spectrum utilization and the OFDM part reduces multipath fading and inters symbol interference (ISI). Even though MC-CDMA is more efficient when compare to other techniques, it has got some disadvantages like, high PAPR and Multiple Access Interference (MAI) which reduces BER performance of the system.

Santoshi Rani, M Tech, 4th Semester VLSI Design and Embedded Systems, VTU Extension Centre, UTL Technologies Bangalore -22, Karnataka, India.
santoshipatilit@gmail.com
Channabasappa Baligar, Professor, VTU Extension Centre, UTL Technologies Bangalore -22, Karnataka, India,
baligarc@yahoo.co.in

Several techniques were used to improve BER performance in MC-CDMA system, by reducing PAPR. Techniques like partial transmit sequence (PTS) [2], spreading code sharing M' ary PSK Multi-Carrier CDMA (SCS-MPSK-MCCDMA) system [3], a modified PTS scheme for uplink communications [4], optimum fixed sub carrier scrambling [5],cyclic shifted scramble code (CSSC) [6] were based on OFDM properties. These techniques used additional randomizing codes/sequences for reducing PAPR with additional computation at the IFFT Modulator. This increased the system complexity, which lead to the development of more efficient MC-CDMA system exploiting the spreading codes, viz., spreading code redistribution [7], modified variable code sets (VCS) [8], spreading code reallocation (SCR) [9] etc. with reduced PAPR. The spreading codes are re-allocated or phase-shifted to obtain low PAPR in the foresaid techniques. Another technique reduces PAPR with an aid of peak reduction signals, which "borrow" the spreading codes idle users [10]. Another technique used to improve BER performance of MC-CDMA systems was non linear companding [11], a technique that transforms the amplitude or power of the original signals into uniform distribution to reduce PAPR.

Coding techniques offers excellent performance on BER reduction owing to fact of increased coding gain [12]. By using efficient coding techniques with error correction capability and high coding gain, system performances can be enhanced in terms of BER. TBC is different from traditional coding techniques; TBC decoder iteratively decodes the received codes many times until required BER is obtained. Since decoding is done iteratively, BER performance can be

ISSN 2229-5518

improved without any additional hardware as error rate decreases further with iteration.

The paper is organized as follows: section 2 describes the signals generated by the proposed system. The details of LDPC Coding are explained in section 3. The simulation results are presented in section 4 and the conclusion is arrived at section 5.

2 MC-CDMA System using LDPC Code

The basic MC-CDMA signal is generated by a serial concatenation of classical DS-CDMA and OFDM [13]. Each chip of the direct sequence spread data symbol is mapped on to a different sub-carrier. Thus, with MC-CDMA the chips of a spread data symbol are transmitted in parallel on different sub-carriers, in contrast to a serial transmission with DS-CDMA. In MC-CDMA, the processing and spreading occurs in frequency domain, rather than in temporal domain. Different users transmit over the same set of sub-carriers but with a spreading code which maintains the orthogonality. The resulting signal has an orthogonal code structure in the frequency domain. If the number of and the spacing between sub-carriers is appropriately chosen, it is unlikely that all of the sub-carriers will be located in a deep fade and consequently frequency diversity is achieved. When the orthogonality of codes is disturbed while transmission, it results in MAI which will reduce the performance of the system. So to enhance the overall performance of the system the data is encoded using LDPC encoder at the transmitter and at the receiver it is decoded iteratively using a turbo decoder.

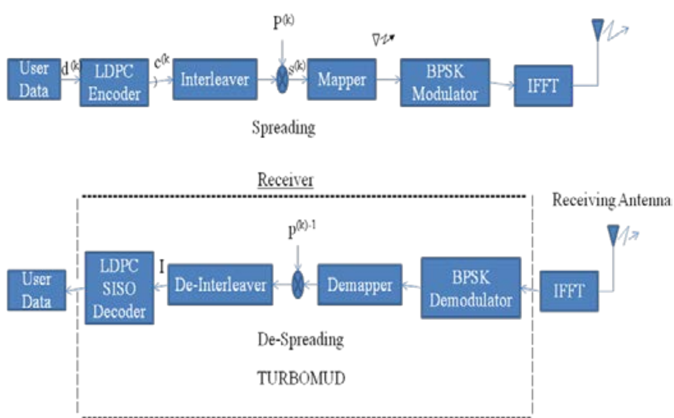

Fig 1 MC-CDMA System Using LDPC Code

MC-CDMA system with K active users is shown in Fig 1. Let d(k) be one complex-valued data symbol assigned to k^{th} user. At the transmitter side, the complex-valued data symbol d(k) is multiplied with the user specific spreading code of length: = PG (where PG is the processing gain) to spread the symbol.

The spreading code for k^{th} user, c(k) is given by,

$$p^{(k)}=(p_0^{(k)}, p_1^{(k)},\ldots p_{L-1}^{(k)})^T \quad (1)$$

The chip rate ($1/T_c$) of the serial spreading code $p^{(k)}$ before serial-to-parallel conversion is,

$$\frac{1}{T_c}=\frac{1}{T_d} \quad (2)$$

And is an L time higher than the data symbol rate 1/Td.

The complex-valued sequence obtained after spreading is given in vector notations by,

$$S^{(k)} = c^{(k)}\, p^{(k)} =(s_0^{(k)}, s_1^{(k)},\ldots s_{L-1}^{(k)})^T \quad (3)$$

A multicarrier spread spectrum signal is obtained after modulating the components; $s_l^{(k)}$, l=0,1,….L-1, in parallel on to L subcarriers. With multicarrier spread spectrum systems, each data symbol is spread over L subcarriers. In cases where the N number of subcarriers of one OFDM symbol is equal to the spreading code length L, the OFDM symbol duration with a multicarrier spread spectrum including a guard interval results in

$$T_s = T_g + LT_c$$

In this case one data symbol per user is transmitted for one OFDM symbol.

3 LOW DENSITY PARITY CHECK CODE

A LDPC code is a class of linear block codes [14] which can be defined in terms of a sparse parity check matrix, H. For an m x n parity check matrix H, m rows specify the number of parity message bits, and n represents the length of a codeword. H is also characterized by w_r and w_c which represent the number of 1's in the rows and columns respectively.

3.1 Construction of LDPC Codes

The parameters such as row and column weights, rate, girth and code length are considered in the construction process of LDPC Codes. The main objectives in code construction are good decoding performance and low implementation complexity. This is mostly achieved by having a code with regularly arranged row-column connections. But putting these kinds of constraints will limit decoding performance. So the main challenge in code construction is to obtain codes with required length and rates that have good decoding performance.

ISSN 2229-5518

3.2 Encoding LDPC Codes

The encoding efficiency has quadratic Complexity with respect to block length of the code, since it requires multiplication by the generator matrix which is not sparse. This complexity is in contrast to the turbo code case, which has linear encode complexity.

Steps involved in encoding a message ‘u’ are as detailed,

a. Let ‘u’ be the message block to be encoded and ‘H’ be the parity check matrix of order (m x n); where m and n are the number of message bits and code length respectively.

b. ‘H’ should be in the form of an augmented matrix given by,

$$H = [I/B] \quad (14)$$

Where I is the identity matrix of order (m x m) and B is a matrix of order (m x (n-m)) called parity.

a. Original message ‘u’ should be encoded to get the code word C (such that $C.H^T = 0$),

$$C = [c/s]. \quad (15)$$

Where c denotes check bits and s denotes the message bits.

b. To find c;

A code word, C is said to be valid, if it satisfy the condition,

$$C.H^T = 0 \quad (16)$$

From (14), (15) and (16); we have,

$$Ic + Bs = 0 \quad (17)$$

Therefore,

$$C = I^{-1} Bs \quad (18)$$

3.3 Random LDPC Code

The random constructions connect rows and columns of LDPC Code matrix without any structured or predefined connection patterns. Constructions could be made in tanner graph by connecting check nodes to variable nodes with edges or by replacing 0’s in check matrix with 1’s. Randomly adding edges to the tanner graph or adding 1’s to parity check matrix will not produce desired rate and may have cycles of four. The resulting code will be then optimized by either post processing or by putting constraints on random choices. Post processing exchanges or delete some connections in order to get a desired girth and rate. Random constructions with constraints add a connection in the code if it does not violate the desired girth or row column weights. Random codes have good performance especially at long code lengths.

Sum-product algorithm is used for decoding random LDPC code in this work. In sum-product decoding algorithm the values of the messages sent to each node are probabilistic denoted by a log likelihood ratio. What we receive are positive and negative values of a sequence. The signs of these values show the value of the bit suppose to be sent by the sender and the confidence in this decision is represented by a real value. For a positive sign it will send a 0 and for a negative sign it will represent a 1. Sum-product decoding algorithm use soft information and the nature of the channel to obtain the information about the transmitted signal.

4 SIMULATION RESULTS

The simulation results and comparisons of the proposed systems were executed and analysed using MATLAB version 7.14.0. BER performance of random LDPC Codes over AWGN channel and AWGN channel for different values of iterations were evaluated. The simulation parameters used for random LDPC Codes are shown in table 1.

TABLE 1: SIMULATION PARAMETERS FOR RANDOM LDPC CODES

Parameter	Specification
	Random LDPC
Code rate	½
SNR (in dB)	-30dB to 4dB
Number of iterations	50
Dimension of parity check matrix	32400x64800
Channel	AWGN
Modulation	BPSK

The code rate used is ½ for random LDPC Codes and performance of LDPC Codes is evaluated for different iterations. As the number of iteration increases performance also improves, since error count decreases with each iterations. In Rayleigh fading channel the performance varies as non clear line of site is considered, where as in AWGN Channel variations are negligible.

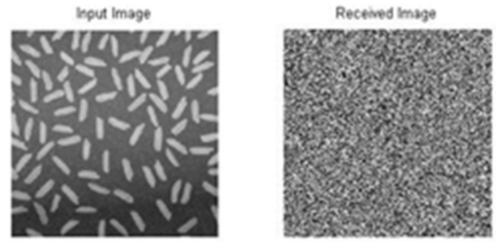

Fig 3: BER Performance Image for SNR = -30dB

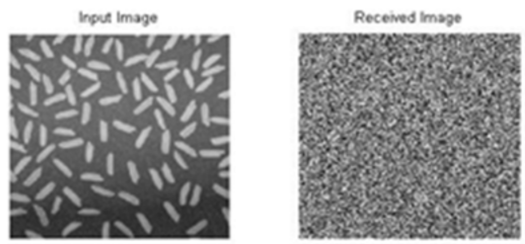

Fig 3: BER Performance Image for SNR = -20dB

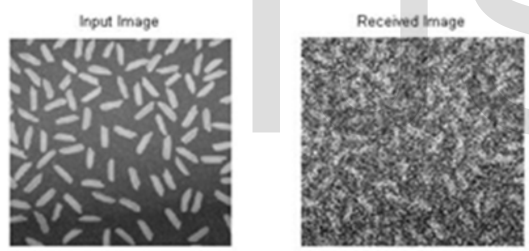

Fig 4: BER Performance Image for SNR = -10dB

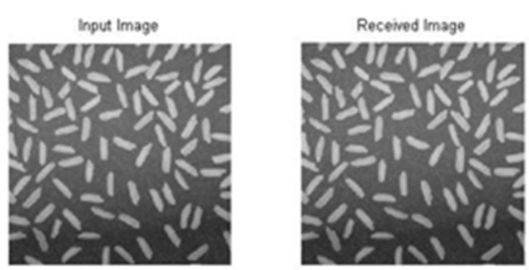

Fig 5: BER Performance Image for SNR = -4dB

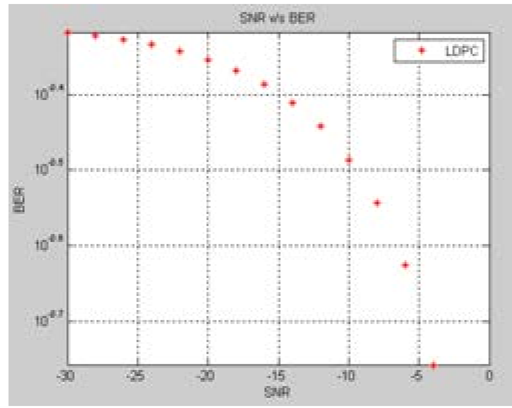

Fig 6: BER performance graph of MC-CDMA System using LDPC Code for different iterations of AWGN Channel.

The above image lists BER values of the system varying SNR values. It is observed that as the number of iterations increases the BER performance also increases: also the BER value decreases with increase in SNR value. The dimension of the parity check matrix used here is 32400 x 64800 with a code rate of ½.

Performance comparison of random LDPC codes for various values of iterations over AWGN channel is revealed in Fig 5. It is observed that as the number of iterations increases the BER performance also increases. Dimension of parity check matrix and code rate used here is the same used for random LDPC over AWGN channel. The performance of the system is degraded when channel used is Rayleigh fading channel, as channel introduced fading and more noise when compared to AWGN channel.

5 CONCLUSION

A TBC designed using LDPC code is proposed for MC-CDMA system to improve its system performance in terms of BER in this work. LDPC code enhances the BER performance with a quadratic encoding complexity and linear decoding complexity with respect to block length of the code. The simulation results and comparisons of the proposed systems were executed and analyzed using MATLAB. BER performance of MC-CDMA system using random LDPC codes over AWGN channel for constant and varying code rates were analyzed. It was observed that the BER performance of the system increases with an increase in the dimension of parity check matrix and a decrease in code rate.

Thus, one can observes from the results that the LDPC gives a better BER for the AWGN channel for low SNR and the difference in dB's increases for higher values of SNR.

ISSN 2229-5518

REFERENCES

[1] Aqiel N Almaamory and Husam Abduldaem Mohammed, "Performance Evaluation and Comparison Between LDPC and Turbo Coded MC-CDMA" in Journal of Engineering, vol. 18, no. 8, April

[2] N. Ruangsurat and R.M.A.P Rajatheva, " An Investigation of Peak to Average Power Ratio in MCCDMA Combined with Partial Transmit Sequence," Proc. IEEE VTC"01, pp. 761-765, Rhodes, May 2001.

[3] Ginige . T, Rajatheva. N and Ahmed. K.M, "Spreading Code sharing MPSK-MC-CDMA system for low PAPR in wireless communications", IEEE VTC –Fall, vol 2, pp. 666-670, Vaneouver, September 2002.

[4] Somchai Jitapunkul, Krittee Wutthipompong, Jirapa Songthanasak and Suwich Kunaruttanapruk, "peak to Average Power Ratio Reduction in MC-CDMA using Partial Transmit Sequences," Wireless Telecommunications Symposium, 2004, Pomona, May 2004, pp. 03-08.

[5] kwonhue Choi, Kunseok Kang and Sooyoung Kim, "Peak Power Reduction Scheme Based on Subcarrier Scrambling for MC-CDMA Systems", ISSSTA 2004, pp 326-329, Sydney, Aug-Sep 2004

[6] Masato SAITO, Akihiro OKUDA, Minoru OKADA, and Heiichi YAMAMOTO, "Performance Evaluations of Multi-Carrier CDMA System with cyclic shifted scramble code in Multi-path fading channel", 2006 IEEE 9th ISSSTA, pp 74-78, Manaus-Amazon, 2006.

[7] E Alsusa & L Yang, "MC-CDMA Specific PAPR Reduction Technique Utilising Spreading Code Redistribution", IEEE VTC/Fall 2006, pp 01-05, Montreal, Sept.2006.

[8] Sisi Liu, Lini Dan, Yue Xiao and Shaoqian Li, "PAPR Reduction Based on Improved VCS Scheme in MC-CDMA System", VTC 2007-Spring pp 2672-2676, Dublin, April 2007

[9] Lin Yang, Mingli You and Jun Li, "Optimized Spreading Code Reallocation Technique for PAPR Reduction in MC_CDMA Systems", IEEE "GLOBECOM" 2009 proceedings, Honolulu 2009, pp 01-06.

[10] Luis A. Paredes Harnandez and Mariano Garcia Otero, "User Reservation Approach for Peak-to-Average Power Ratio Reduction in MC-CDMA Systems". IEEE-VTC Spring 2009. Pp 01-05, Bracelona, April 2009.

[11] R. Manjith, S.C.Ramesh and M.Mohamed Ismail Majeed, "Papr Reduction In OFDM & MC-CDMA System Using Nonlinear Companding Technique", IEEE Region 8 SIBIRCON-2010, pp 274-278, Irkutsk Listvyanka, July 2010.

[12] Maryam Sabbaghian, Yongjun Kwak, Besma Smida and Vahid Tarokh, "Near Shannon Limit and Low Peak to Average Power Ratio Turbo Block Coded OFDM", in IEEE transactions on communications, volume.59, No. 8, August 2011, pp 2042-2045.

[13] K. Fazel and S. Kaiser, "Multi-Carrier and Spread Spectrum Systems form OFDM and MC-CDMA to LTE and WiMax", 2nd Edition. A John Wiley and Sons Ltd. Publication 2008.

[14] Todd K, Moon, "Error Correction Coding Mathematical Methods and Algorithms". John Wiley & Sons. Inc. Hoboken, New Jersey 2005.