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PERFORMANCE EVALUATION OF WIMAX SYSTEM USING CONVOLUTIONAL PRODUCT CODE (CPC)

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Abstract—The WIMAX technology based on air interface standard 802-16 wireless MAN is configured in the same way as a traditional cellular network with base stations using point to multipoint architecture to drive a service over a radius up to several kilometers. The range and the Non Line of Sight (NLOS) ability of WIMAX make the system very attractive for users, but there will be slightly higher BER at low SNR.

In this paper, a comparison between the performance of WIMAX using convolutional code and convolutional product code (CPC) [1] is made. The CPC enables reducing BER at different SNR values compared to the convolutional code. For example, at BER equals 10^{-3} for 128 subcarriers, the amount of improvements in SNR is more than 2 dB. Several results are obtained at different modulating schemes (16QAM and 64QAM) and different numbers of sub-carriers (128 and 512).

1. INTRODUCTION

WIMAX [2, 3] is a new wireless technology that provides high throughput broadband connection over long distances based on IEEE.802.16 wireless MAN air interface standard. It is designed to accommodate both fixed and mobile broadband application. It can be used for many applications, including "last mile" broadband connections, cellular backhaul, and high-speed enterprise connectivity for business, due to its high spectrum efficiency and robustness in multi path propagation.

Comparing WIMAX to Wi-Fi and 3G, the WIMAX has an improved important characteristic, the throughput capabilities of WIMAX depends on the channel bandwidth used [4]. Unlike the

3G systems which have fixed channel bandwidth, WIMAX defines a selectable channel bandwidth from 1.25 MHz to 20 MHz. In WIMAX systems, there are many researches had been made for the different stages such as coding stage [5–9]. Our investigations are focused on studying the performance of WIMAX using convolutional product code (CPC) compared to convolutional code.

In the CPC coding method, a stream of bits, forming the message, is converted into a matrix (nxm). First each row will be coded by recursive systematic convolutional encoder. After interleaver each column will be coded by the other recursive systematic convolutional encoder. The same or different generator polynomials are used to code both rows and columns. CPC will be described in more details in Section 3.

In this paper, CPC method is studied for improving BER at different SNR of WIMAX system. The comparison between this method and convolutional code will be investigated. Moreover different modulation techniques are applied to both CPC and convolutional code. The coding stage of WIMAX system will be explained in details.

The paper is organized as follows: in Section 2, description of physical layer of the WIMAX is introduced. Detailed description of CPC scheme is presented in Section 3. Simulation results are given in Section 4. Finally conclusions are reflected in Section 5.

2. DESCRIPTION OF THE PHYSICAL LAYER OF A WIMAX SYSTEM

Here downlink transmission using the wireless Man is being considered. WIMAX system depends on OFDMA physical layer as specified in the IEEE.802.16 standard [10, 11]. A block diagram of the physical layer of WIMAX is depicted in Fig. 1.

The binary data bits after randomization are fed into the encoder. After interleaving, the sequence of binary bits, is fed into the modulator for mapping which means converting them to a sequence of complex values and modulate them by QPSK or 16QAM or 64QAM. The QAM symbols are allocated onto the appropriate data sub-carriers. Pilot symbol are allocated onto pilot sub-carriers which allow the receiver to estimate and track the Channel State Information (CSI). By this procedure the OFDM symbols are constructed in the frequency domain, then Inverse Fast Fourier Transform (IFFT) is used for converting the OFDM symbols into the time domain.

The channel coding scheme, IEEE 802-16e-2005, as shown in Fig. 2 is based on binary non-recursive Convolutional Coding (CC). The convolutional encoder uses a constituent encoder with constraint

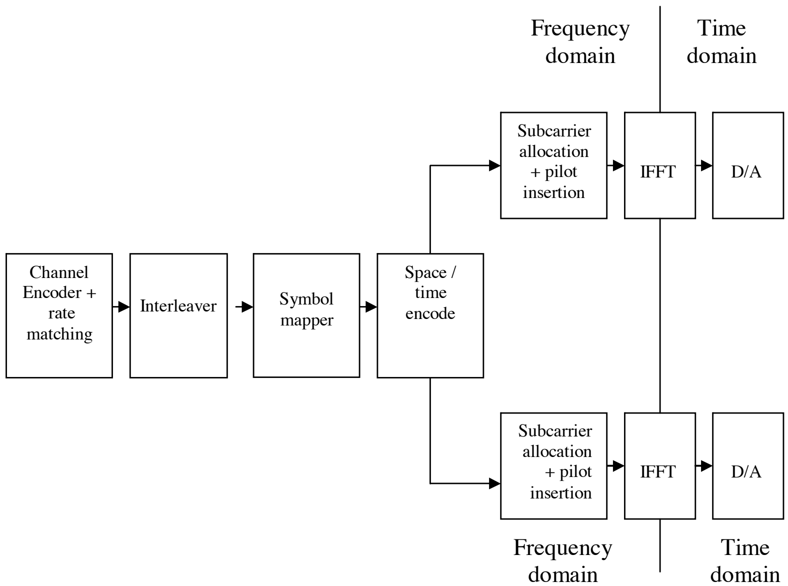

Figure 1. Physical layer of WIMAX system.

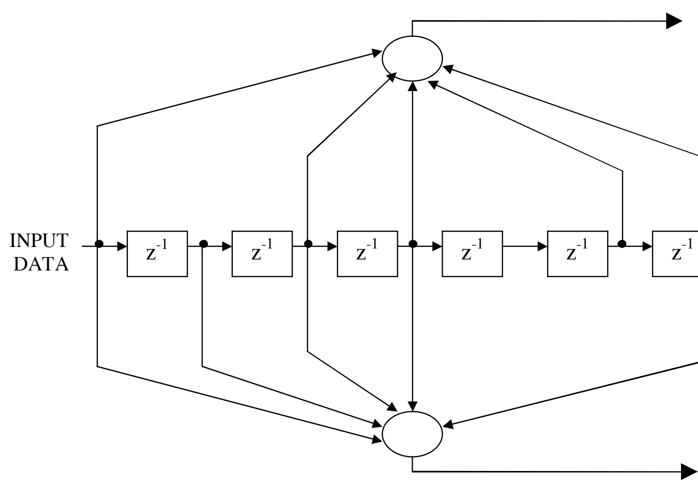

Figure 2. Convolutional encoder in IEEE 802.16e-2005.

length 7, code rate 1/2 and generator polynomials (133,171) octal. Tail-baiting is used to initialize the encoder by padding each FEC block with 6 zeros. In this stage, the CPC method will be applied for coding the message and this will be shown in the following section.

3. DETAILED DESCRIPTION OF CPC METHOD

CPC is a new coding method in which the information bits are placed into two dimensions (2D) matrix. The rows and the columns are encoded separately by using recursive systematic convolutional encoders. Each row of the matrix is encoded using a convolutional code, the same recursive systematic convolutional code is used to encode each row. Once all rows have been encoded, the matrix is sent, if desired, to an interleaver. Our original data matrix dimensions are $(n \times k)$, and the encoded data matrix dimensions will be $(2n \times k)$. The coded rows matrix is then recoded by column using the same or different recursive systematic convolutional encoder. CPC uses a recursive systematic convolutional code with rate 1/2 and generator polynomials $(1, 5/7)$ octal to encode each row and column. Hence, the overall code rate is 1/4.

In this work, the same technique is used for coding the message, except we use nonrecursive nonsystematic convolutional encoder instead of recursive systematic convolutional encoders for coding both rows and columns. The sequence of bits is fed into 2D matrix and fills it column by column. The size of this matrix will be $(n \times 4)$ for 16QAM and $(n \times 6)$ for 64QAM, to simplify the process of mapping, as the symbol size in 16QAM is 4 bits and in 64QAM is 6 bits. So each row will form one QAM symbol. The 'n' refers to the number of data subcarriers of OFDM, 128 or 512. The coding by CPC will be done in 2 stages. First each column will be independently coded, then each row of the resulting matrix will be coded by the same generator polynomials. The generator polynomials used for coding both rows and columns are $(5, 7)$ with constraint length 3, not following the standard of WIMAX, Fig. 3. Each column is padded with two zeros for terminating its

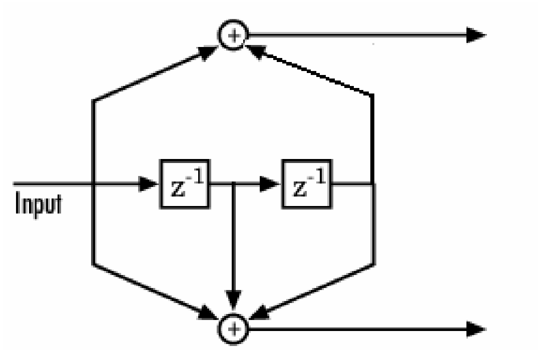

Figure 3. Convolutional coding [5, 7].

encoder but each row is padded with two or three zeros according to the number of used subcarriers, 128 or 512 receptively to form the suitable size of the overall matrix. Then that matrix is then divided into smaller matrices with sizes $(n \times 4)$ or $(n \times 6)$ as described later.

The reason for using nonrecursive nonsystematic convolutional encoder instead of recursive systematic convolutional encoders is simplifying the termination of the encoder,as RSC contains a feedback and its termination will be more difficult. Also using the generator polynomials $(5, 7)$ leads to a little increase in the complexity of the system because of a few number of zeros will be added to terminate the two encoders. After coding, the total number of bits will be more than the original message's bits as the overall code rate becomes 1/4, and zeros added to both column and rows for termination process. Therefore the following steps are done,

(1) Dividing the overall matrix produced from CPC into three matrices. Each one has a size $(n \times 4)$ or $(n \times 6)$ according to the type of QAM used as mentioned before. The reason for using three matrices only is to have a number of message bits equals to bits used in the convolutional code method, as a comparison between it and CPC is done.
(2) Applying symbol mapping for each one independently (16QAM or 64QAM).
(3) Inserting the pilot and DC subcarriers for each matrix.
(4) Performing the IFFT independently resulting in three OFDMA symbols.
(5) Applying (cyclic prefix) CP for each symbol.
(6) Sending each symbol independently.

At the receiver,the three OFDMA symbols are combined to form the original matrix which is decoded by Viterbi decoder,that uses the same generator polynomials (5,7)with hard decision for each row then for each column to obtain the results shown in figures 4,5,6 and 7. To match the CPC method,the number of data bits will be reduced.For example in OFDMA (128-16QAM)and (128-64QAM)the number of data bits was 144 and 216 but in CPC method it becomes 136 and 204 bits receptively due to the number of zero bits added to terminate the two encoders.

1. Do not need another interleaver after channel coding because of converting into matrix $(n \times 4)$ or $(n \times 6)$ do almost the same job as the overall matrix will be filled column by column and will be read row by row after coding processes (block interleaver) since each row is used for making QAM symbol.

2. Reducing the BER.

But on the other hand it causes more delay for obtaining the original message because the code rate becomes 1/4 not 1/2 as convolutional code so the system will be more complex. The performance of the system will be reduced and this is the price to be paid for the improvement obtained.

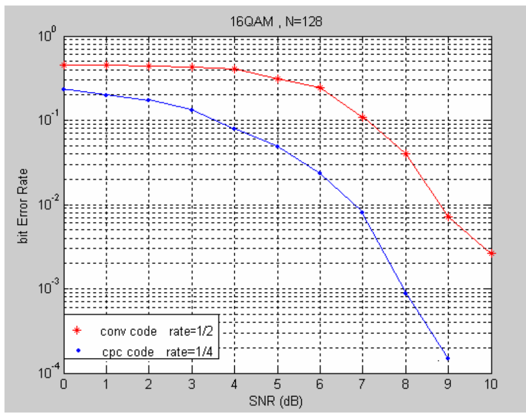

Figure 4. 16QAM, $N = 128$.

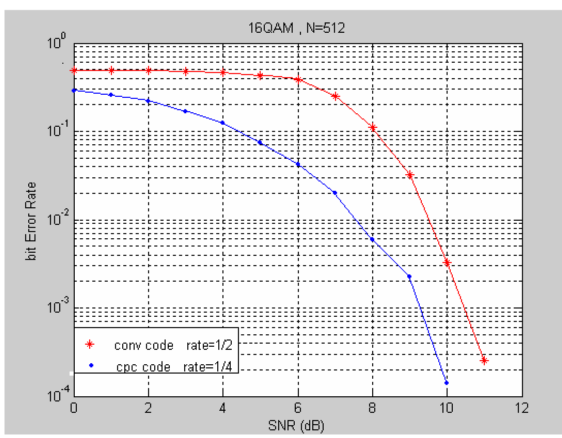

Figure 5. 16QAM, $N = 512$.

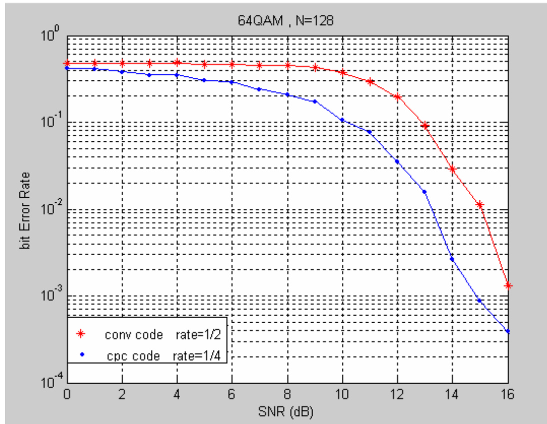

Figure 6. 64QAM, $N = 128$.

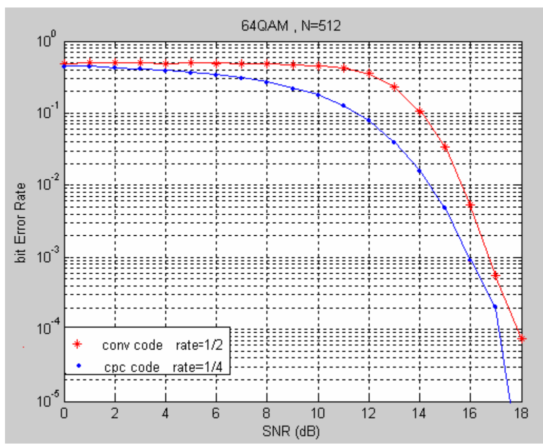

Figure 7. 64QAM, $N = 512$.

4. RESULTS

In this work, a simulation of physical layer of WIMAX was made as described in Section 2 by Matlab. AWGN will be assumed only. The Figures 4, 5, 6 and 7 show the BER versus the received SNR obtained at different modulation and different number of OFDMA sub-carriers.

Figure 4 shows the relation between SNR and BER at 16 QAM and 128 subcarriers. From this figure, we conclude that SNR will be improved by more than 2 dB at BER equals 10^{-3}. Also, an improvement will be obtained when the number of subcarriers is increased to 512 as shown in Figure 5. When different modulation is used, CPC still gives better results as shown in Figures 6 and 7.

5. CONCLUSIONS

In this paper, performance of WIMAX systems is studied under using CPC coding method. This method leads to reduce BER at any SNR. We investigated the effects of this method at different modulation schemes (16QAM-64QAM) and for different number of OFDMA subcarriers (128–512), it gives a good improvement, for example at BER equals 10^{-3} for 16QAM and 128 subcarriers, the amount of improvements in SNR is more than 2 dB.

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