International Journal of Engineering & Technology, 7 (2.21) (2018) 131-134

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Performance improvement of 4G OFDM systems using CTSTC techniques

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Abstract

The concatenation of channel coding and diversity schemes are essential in the 4G communication systems to improve the reliable data rate transmission. To address Bit Error Rate performance enhancement, the paper presents the coding gain and diversity gain benefits using the proposed CTSTC scheme by adding modified Turbo features and Space Time encoding features. Simulation results of are provided using MATLAB and compared the results with convolutional coded Space Time Coding technique.

Keywords: *Bit error rate, convolutional coded space time coding, turbo coded Space time coding.*

1. Introduction

The next generation 4G communication systems are to fulfill communication at all times and by anybody. The BER performance against multipath fading makes a challenge for error free high speed data transmission. The wireless channel often suffers from fading. Fading reduction can be done by using channel coding, diversity technique and equalization process [1-2]. Channel coding can effectively reduce the bit errors by forward error correction techniques to improve the link performance of wireless systems under deep fading environment [3-4]. Diversity technique used to overcome fading and is implemented using multi input multi output antenna at either end (MIMO) [5-9].
The channel induced distortion at the receiver can be corrected by Equalization process [10]. Few core technologies enables the performance of the 4th generation (4G) mobile broadband wireless communication system using a multi carrier multiplexing and modulation technique called Orthogonal FDM and multi input multi output antennas. The combination of these two techniques provides spectral efficiency through extended channels by multiple array antennas [11] and an ISI free high data rate transmission over multipath channel [12].
The Spatial Diversity and Spatial Multiplexing are two basic MIMO techniques used to improve the wireless link reliability. Spatial Diversity is used to transmit more copies of the same signal through multiple antennas which reduces the fading effect [13]. The enhanced spectral efficiency can be achieved by means of spatial multiplexing by transmitting multiple data streams over multiple antennas simultaneously called [14].Maximum diversity gain can be achieved through Space Time Codes. At low SNR, STBC gives better performance with low decoding complexity than SM. But at high SNR, SM can provide double throughput with minimal error rate [15]. By concatenating Convolution Turbo Code (CTC) with STBC, proposed technique CTSTC is developed. The simulation results of the proposed scheme are also presented using MATLAB. The rest of the paper is organized as follows. Section II describes the OSTBC based Turbo coded MIMO OFDM system model. Section III lists the implementation procedure for the proposed scheme the CTSTC systems. Simulation results are plotted in Section IV and concluded the paper in section V.

2. System model

Consider a frequency selective fading channel with number of transmitting antennas M_T, and receiving antennas M_R. Let the average energy E_S is distributed evenly across antennas the transmitting antennas. Then the input and output relation for the multi antenna OFDM channel can be written as,

$$Y = \sqrt{\frac{E_S}{M_T}} H.S + W \tag{1}$$

Where, E_s is the average energy allocated evenly to MIMO antennas, H is channel matrix with the size M_R X M_T and the received and transmitted symbol vector from MIMO antennas with Additive White Gaussian noise vector is given as,

$$Y = \begin{bmatrix} y[0]^T \\ y[1]^T \\ . \\ y[M_R]^T \end{bmatrix} \tag{2}$$

$$S = \begin{bmatrix} s[0]^T \\ s[1]^T \\ . \\ s[M_T]^T \end{bmatrix} and W = \begin{bmatrix} w[0]^T \\ w[1]^T \\ . \\ w[M_R]^T \end{bmatrix}$$

The Maximum Likelihood decoding of equation (1) is used to find a design criterion for MIMO-OFDM systems.The first step is to calculate the conditional pairwise error probability of transmitting S1 but decoding it as S2can be given as,

$$P(S_1 \to S_2) \leq \frac{1}{2}\exp\left(-\frac{\gamma}{4} d^2(S_1, S_2)\right)$$

$where$

$$d^2(S_1, S_2) = \|[S_2 - S_1].H\|^2 \quad (3)$$

where, ‘d’ is the Euclidian distance between S1 and S2.
The CTSTC MIMO-OFDM proposed system model is given in figure 1.

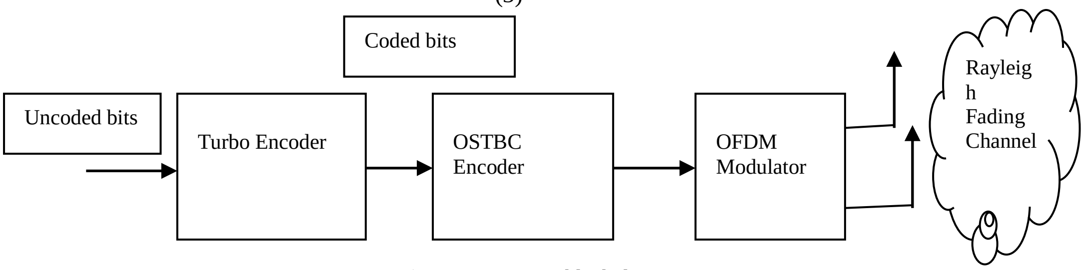

Fig. 1: Transmitter block diagram

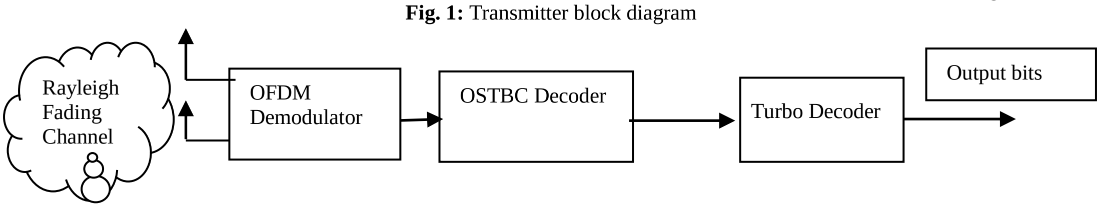

Fig. 2: Receiver block diagram

From figure 1, the information uncoded bits are encoded by channel Turbo encoder and then mapped by digital modulation. The mapped data symbols are encoded by Orthogonal STBC encoder. The independent parallel data symbols are sending through OFDM modulators, which perform IFFT and add Cyclic Prefix (CP) then it, is passing through MIMO channel.
The receiver performs the removal of cyclic prefix and N-point FFT through the OFDM demodulators. The OFDM demodulator output are finally separated and passed through OSTBC decoder. This data is demodulated and then Turbo decoded using log MAP algorithm.

3. Proposed scheme

Turbo codes can be used for serial or parallel concatenation. Turbo codes are available in two kinds namely Convolution Turbo Code (CTC) and Block Turbo Code (BTC). CTC shows superior performance when compared to BTC.

Convolution turbo code (CTC)

The CTC which is specified by the 3GPP UMTS standard which is a 2D code, i.e, it uses parallel concatenated two similar recursive systematic convolution (RSC) coders known as component encoders with ½ rate which are separated by an inter leaver to provide randomness to the input sequences and to increase the weights of the code words.
The turbo encoder uses built-in inter leavers which are pseudo random inter leavers whose length varies from 40 to 5114. As block fading assumption is made and inter leaver size is a multiple of spectral efficiency(r_c) of the system and the block length (L). Thus, channel coding across consecutive differently faded blocks is performed. The basic turbo encoder is shown in Figure 3.

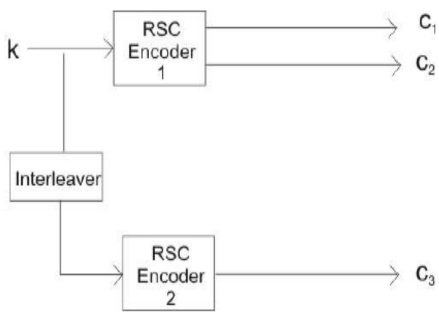

Fig.3: The Turbo code encoder, rate r=1/3.

Figure 4 shows a 1/3 rate turbo code encoder. RSC encoder 1 output the systematic sequence c1 and parity sequence c2 whereas RSC encoder 2 only output the parity sequence c3.

RSC encoder

The RSC encoder is formed by feeding back one of its encoded outputs to its input of the non-systematic convolutional (NSC) encoder.

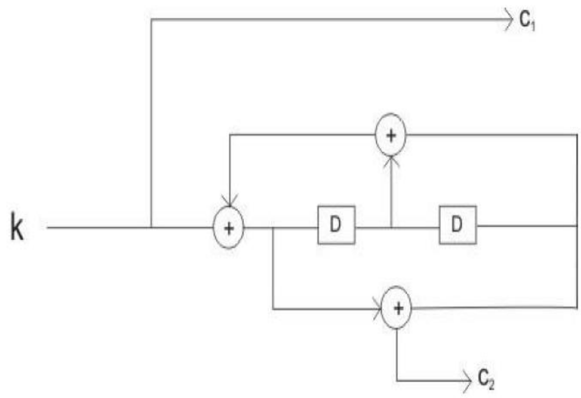

Fig. 4: The RSC encoder with rate r=1/2, K=3

Puncturing

The turbo encoder is 1/3, it can be increased to1/2 or other higher rates such as 2/3 or 4/5, by puncturing the parity check bits ofthe recursive convolution encoders. The first puncture output is the information sequence.
The second output is either odd check bits from RSC_1 or even check bits from RSC_2. These outputs are multiplexed using a parallel-to-serial multiplexer and fed as inputs to the STBC encoder.

Proposed concatenated space time block turbo model

The turbo decoder consists of two MAP decoders that are interleaved and the soft information is exchanged iteratively. The hard decision is made on the transmitted symbol. These decoders are serially concatenated via an inter leaver as shown in Figure 5.

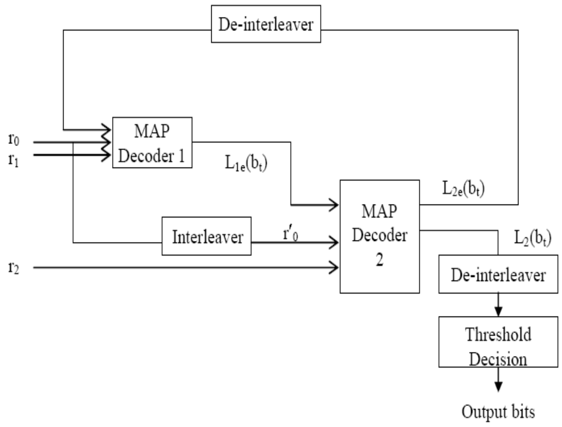

Fig.5: Turbo Decoder

The use of iterative decoding using log-MAP algorithm results in the good performance of turbo codes. In log-MAP decoding, soft decision values are formed using log-likelihood ratios (LLRs) and are based on minimizing the bit error probability, given a transmitted sequence.
The outputs represented by L_{1e}(bt) and L_{2e}(bt) refer to the extrinsic information of the input bit b_t, defined as the information obtained at the output of each decoder, considering only the parity bits of the encoder. Part of the encoded sequence refers to the original message and is decoded by the first decoder and the second part refers to the interleaved version of the original message and is decoded by the second decoder.
At the beginning of the decoding process, the apriori probability of the original bits are equal and given by

$$Pr(1)= Pr(0)=1/2 \quad (4)$$

These apriori probabilities are improved by the two decoders during the iteration process and soft output estimates or LLRs are obtained. The symbols to be decoded are passed through decoder1 and the outputs are interleaved and the extrinsic information thus extracted is then passed through decoder 2.
These estimates are mutually fed back and are interleaved by the same interleaving pattern that was used at the transmitter.
By using MAP algorithm, the second decoder obtains the LLR $L_2(b_t)$ as:

$$b = \begin{Bmatrix} 1, L_2(b_t) \geq 0 \\ 0, otherwise \end{Bmatrix} \quad (5)$$

Thus the LLR equation can be broken into three terms as,

$$L\ (bt) = Lapriori + Lchannel + Lextrinsic \quad (6)$$

The STBC employed in the turbo concatenation scheme is the Alamouti's two transmit and one receives antenna encoder. The Alamouti STBC is a well knowntwo transmit diversity antenna scheme. This is attractive for its simple decoding and full diversity ($2M_R$),where M_R is the number of receive antennas. The channel coefficients h1 and h2 at the receiverare assumed to be perfectly estimated. The combiner combines the received signals and these combined signals are the soft input values that are fed into the outer turbo decoder. Diversity advantage is derived from the STBC and coding advantage from the turbo code.

4. Simulation results

Performance results for the Turbo Concatenated Space Time Block Code are provided in this section. The parameters considered for simulation are listed in table 1.

Table 1: Simulation Parameters

Parameter	Value
Spectral efficiency	2bps/Hz
Block length	40 symbols
Frame size	10 blocks
Inter leaver size	80
Channel	Rayleigh fading
Channel code rate	1/2
Mapper	QPSK,16 QAM, 64 QAM
FFT length	512
Number of info Subcarriers	360
Diversity Schemes	2×2,4x2 and 4×4 antennas
Noise	AWGN
Number of Pilot Subcarriers	60
Cyclic prefix	1/8

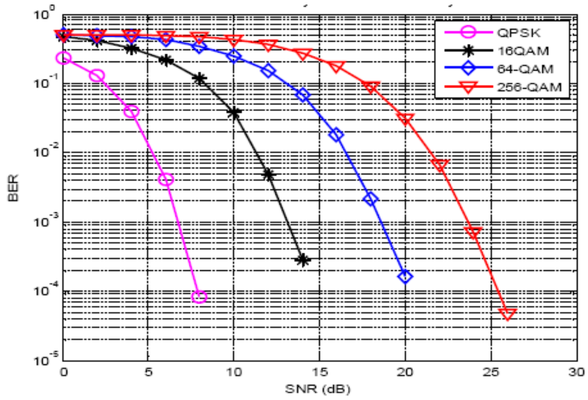

Fig.6: BER performance of 4x2 OSTBC MIMO OFDM

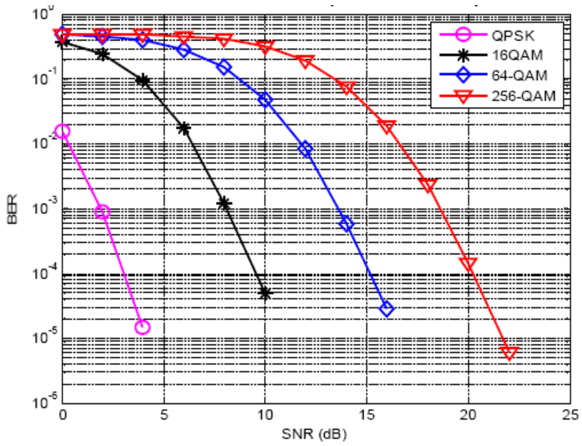

Fig.7: BER performance of 4x4 OSTBC MIMO OFDM

From figure 6& 7, it is clear that OSTBC MIMO-OFDM 4x4 system outperforms than 4x2 system with SNR gain of 6 to 10 dB.

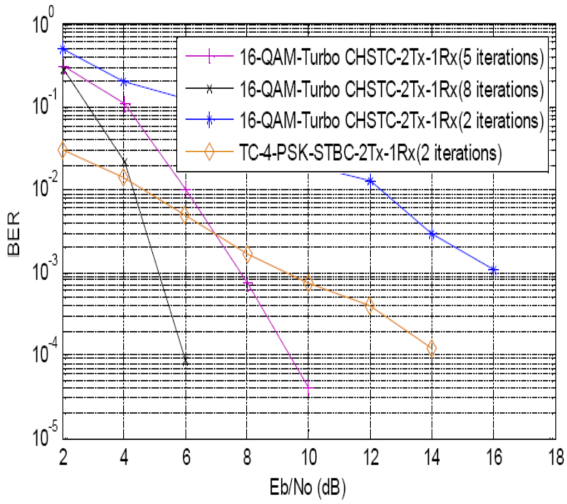

Fig.8: BER Performance Comparison of with and without CTSTC

From Figure 8, the concatenated STBC performance is better than the concatenated CHSTC with two iterations. At a BER of 10^{-3}, when the iterations are increased from five to eight, concatenated CHSTC outperforms concatenated STBC by providing a coding gain of 1.4 dB and 4 dB, respectively. Both the schemes offer diversity order of two and spectral efficiency of 2 bps/Hz.

5. Conclusions

From the simulation results, it is seen that the performance of Turbo coded CTSTC scheme is better than that of the un-coded schemes in terms of error reduction. By varying the block sizes and by increasing the number of iterations, different performance results achieved.

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