ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 3, September 2013

Turbo coded MIMO-OFDM systems

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Abstract*—Increasing demand for high-performance 4G broadband wireless is done by the use of multiple antennas at both sides transmitting and receiving. Multiple antenna technologies allow high capacities suited for Internet and multimedia services, and also increase range and reliability of communication systems. Orthogonal frequency-division multi-plexing (OFDM) is a popular method for high-data-rate wireless transmission over multipath fading. OFDM may be combined with multiple antennas at both the access point and mobile terminal to increase diversity gain and to enhance system capacity on a time-varying multipath fading channel, resulting a multiple-input multiple-output OFDM system. In this article, we describe a multiple input multiple output OFDM wireless communication system, with compressed technique i.e. Turbo Code. By this, increased capacity, coverage, and reliability of communication systems are clearly evident from the results presented in this article. Thus, the simulation results of BER plot show the effectiveness of our proposed practical image transmission system.

***Index Terms*— OFDM, MIMO, Turbo Code, STBC.**

I. INTRODUCTION

This design is motivated by the growing demand for broadband Internet access. The challenge for wireless broadband access lies in providing a comparable quality of service (QoS) for similar cost as competing wire line technologies. The target frequency band for this system is 2–5 GHz due to favorable propagation characteristics and low radio frequency (RF) equipment cost. The broadband channel is typically non-LOS channel and includes impairments such as time-selective fading and frequency-selective fading. This article describes the physical layer design of a fourth generation (4G) wireless broadband system that is, motivated from technical requirements of the broadband cellular channel, and from practical requirements of hardware and RF. The key objectives of the system are to provide good coverage in a non-line-of-sight (LOS) environment (>90 percent of the users within a cell), reliable transmission (>99.9 percent reliability), high peak data rates (>1 Mb/s), and high spectrum efficiency (>4 b/s/Hz/sector). These system requirements can be met by the combination of two powerful technologies in the physical layer design: multi-input and multi-output (MIMO) antennas and orthogonal frequency division multiplexing (OFDM) modulation. [6]

OFDM (Orthogonal Frequency Division Multiplexing) is most popular method for high data rate transmission in wireless communication, robustness to multipath fading, high spectral efficiency and high flexibility in resource allocation. MIMO-OFDM system is very attractive for future 4G wireless communication systems. MIMO boost the capacity and diversity and OFDM suitable for high data rate transmission over multipath fading channels. [1]

OFDM systems may suffer from deep fading, in which the received SNR (Signal-to-Noise Ratio) is below the required SNR level. Gray scale image is a two dimensional data set using 8-bit data to represent each pixel. An image contains huge data and transmitting this data over wireless medium is a difficult task. For this, image compression used to reduce the data. This compressed image is always interfered by channel noises. The suitable robust channel coding and transmission system design compensates at the cost of additional complexity. The specific application of image transmission over wireless channel poses a challenging research problem. In order to deal with deep fading in multi-carrier, it is essential to use FEC (Forward Error Correction) codes. The popular FEC code used in OFDM is Turbo Code. Turbo codes employing iterative decoding are channel codes that have been shown to yield remarkable coding gains and showing a performance close to the Shannon limit and are specified as FEC schemes for most of the future wireless systems. [3]

Spectral efficiency is increase by MIMO (Multiple Input Multiple Output) systems is based on utilization of space (or antenna) diversity technique at both the transmitter and the receiver. Due to utilization of space diversity, MIMO systems are also known by Multiple-Element Antenna systems (MEAs).The advantage of MIMO techniques is linear growth in transmission rate with the number of antennas, enhance coverage and reliability, efficient use of bandwidth, are all obtained without additional radio resource requirements. [1]

In MIMO systems, the data stream from a single user is demultiplexed into number of transmit antennas separate sub-streams. Each sub-stream is then encoded into channel symbols. It is common to impose the same data rate on all transmitters, but adaptive modulation rate can also be utilized on each sub streams. The signal are received by receive antennas. [2] The behind MIMO is that the transmit antennas at one end and the other end are connected in such a way so that BER (Bit Error Rate) or data rate for used can improved.

STBC (Space-Time Block Codes) are used for MIMO systems to enable the transmission of multiple copies of data stream across a number of antennas at transmitter to improve reliability of data transfer at receiver. STBC combines all copies of received signal in such a way to extract as much as information as possible. This help in reducing channel fading problems.

In the paper Turbo Codes are used to improve the performance of MIMO-OFDM systems. In Section II, Literature view and In Section III, MIMO_OFDM is introduced. In Section IV, System model is presented. Turbo Code is described in Section V with necessary diagrams. Section VI STBC is introduced. Section VII

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ISO 9001:2008 Certified
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simulation results for performance verification of coded systems. Finally, conclusion and future work in Section VIII.

II. LITERATURE REVIEW

The concept of using parallel data transmission by frequency division multiplexing (FDM) was published in mid 60's. Some early development with this can be traced back to the 50s. A U.S. patent was filled and issued in January 1970. The idea was to use parallel data streams and FDM with overlapping sub channels to avoid the use of high speed equalization, reduce noise and multipath distortion as well as to fully use the available bandwidth. The initial applications were in the military communications. Weinstein and Ebert applied the discrete Fourier transform (DFT) to parallel data transmission system as part of the modulation and demodulation process. In the 1980s, OFDM has been studied for high speed modems and for digital mobile communications. In 1990s, OFDM has found its applications in wideband data communications over mobile radio FM channels, wireless LAN, wireless multimedia communication, high-bit-rate digital subscriber lines (HDSL), asymmetric digital subscriber lines (ADSL), digital audio broadcasting (DAB), digital video broadcasting (DVB). OFDM has been chosen as the modulation technique for the new Fourth Generation (4G) standard as well as High-Performance LAN (HIPERLAN). For the reduction of the error rate in transmitting digital data we use forward error correcting Codes in design of digital transmission systems. The IEEE 802.16e standard incorporates with MIMO-OFDM. The IEEE 802.11n standard, October 2009, recommends MIMO-OFDM. MIMO is used in Mobile radio telephone standards such as recent 3GPP and 3GPP2. In 3GPP, High-Speed Packet Access plus (HSPA+) and Long Term Evolution (LTE) standards take MIMO into account. Turbo Codes proposed by Berrou, Glavieux and Thitimajshima in 1993 ("*Near Shannon Limit Error-correcting Coding and Decoding: Turbo-codes*" paper published in IEEE International Communications Conference) have been widely considered to be the most powerful error control code of practical importance. Turbo codes have error correcting capability very close to the theoretical performance limits. Turbo codes are finding use in 4G mobile communications and as well as other applications where need to achieve reliable information transfer over bandwidth or latency-constrained communication links in the presence of data-corrupting noise. Turbo codes are nowadays competing with LDPC codes. [7]

III. MIMO-OFDM

OFDM is a multicarrier digital communication scheme. It combines a large numbers of low data rate carriers to build a high rate communication system. Orthogonally gives carriers to be closely spaced, even overlapped without iter- carrier interference. Low data rate of each carrier will removes inter-symbol interference.

Advantages of OFDM systems are:

- High spectral efficiency.
- Simple implementation by fast Fourier Transform.
- Low receiver complexity.
- Suitability for high-data-rate transmission over a multipath fading channel.
- High flexibility in terms of link adaptation.
- Low-complexity multiple access schemes such as orthogonal frequency-division multiple access (OFDMA).

Disadvantages of OFDM systems are:

- Higher peak-to-average power ratio (PAPR). compared to single-carrier modulation.
- Sensitivity to time and frequency synchronization errors.

OFDM signals have high peak-to-average ratio, therefore it has high tolerance of peak power clipping due to transmission limitation.

MIMO system provide high data rate, low error rate, easy to implement, low power consummation, low cost and efficient use of resources. In a wireless communication system due to multipath interference the signal level at the receiver never remains constant; it fluctuates or fades. For that, transmit multiple copies of the same signal then the probability that the signal goes into deep fade is decreased. It may happen that a copy of the signal goes into deep fade while others may be accurate may not go into fading at all. The number of copies is named as diversity technique. If increasing the independent copies of the same signal then error decreases. A MIMO system has n_T transmit antennas at the transmitter and n_R number of receiving antennas at the receiver.

By Shannon's theorem the rate of transmission is always less than or equal to the capacity. Practically, it is less than capacity. The capacity depends on the bandwidth and SNR of the channel. The SNR can be improved either by reducing noise power or by increasing signal power. Reduction in noise power is not possible while increase in signal power requires more power for transmission which should be avoided for a good design. The improvement of bandwidth is not possible. However there are techniques like OFDM (orthogonal frequency division multiplexing) which solves this problem by efficient use of the channel i.e. spectral efficiency. But however the use of multiple antennas at the transmitter and at the receiver that is use of MIMO meets the ongoing requirements in 4G technology. The bit error rate in MIMO is very less as compared to conventional SISO (Single Input Single Output), SIMO (Single input Multiple Output), MISO (Multiple Input Single Output) systems.

MIMO-OFDM is most attractive technique in new wireless communication for high data rate. [2]

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IV. SYSTEM MODEL

The general system used in this paper is shown in figure 1. At transmitter, the data bit streams are encoded by a FEC encoder.FEC encoder used in this is Turbo encoder. The coded bit streams are mapped to a constellation by digital modulator, and are encoded by MIMO encoder. PSK (Phase Shift Keying) or QAM (Quadrature Amplitude Modulation) is used to transmit symbol streams which will converted into parallel output. First, pilot symbol are inserted according to pilot patterns then symbol sequence in frequency is modulated by inverse FFT (IFFT) to an OFDM symbol sequence. IFFT is used to transmitter to generate sum of orthogonal sub carrier signals. The key to OFDM is to maintain orthogonally of the carriers. If the integral of the product of two signals is zero over a time period, then these two signals are said to be orthogonal to each other. A cyclic prefix (CP) is attached to every OFDM symbol to protect from channel delay spread, and a preamble is inserted in every slot for timing.

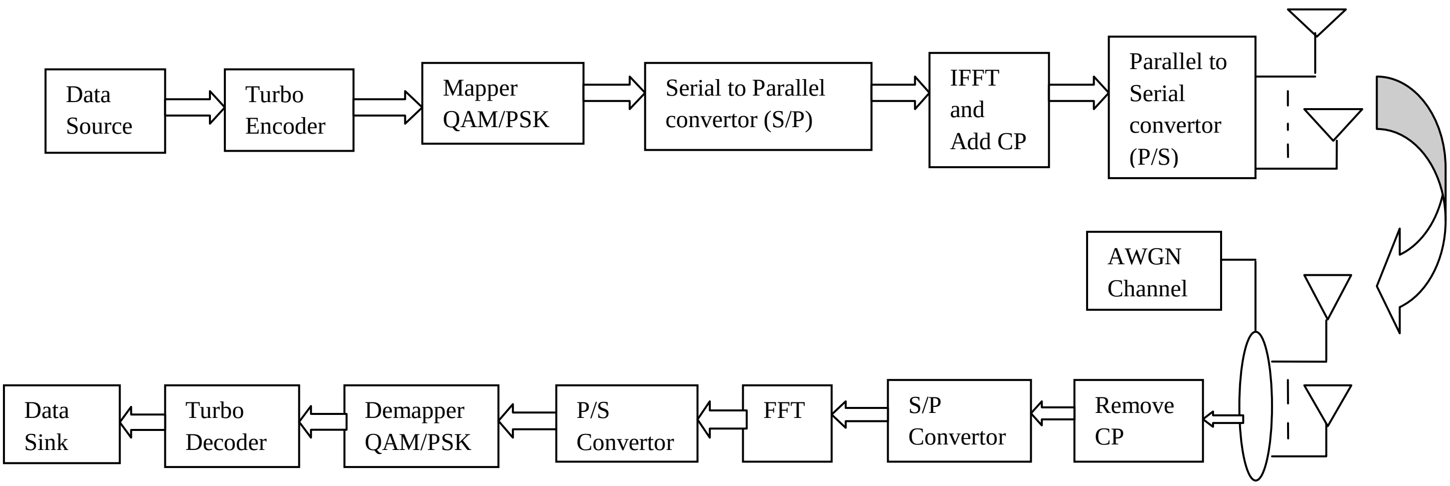

Fig 1: Block diagram of transmitter and receiver of MIMO-OFDM with Turbo code. [3]

CP is to use to extend the OFDM symbol by copying the last samples of OFDM symbol into its front. Finally, the data is transferred.

At receiver, the received symbol streams are first synchronized, including frequency synchronization and time aided by preamble. After that, preamble and CP are removed from received symbol streams and remaining OFDM symbol is demodulated by FFT. Frequency pilots are extracted from the demodulated OFDM symbol in frequency domain, and fine frequency synchronization and timing are carried out to extract pilots and data symbols accurately. The refined frequency pilots from all the receive antennas are used for channel estimation. The estimated channel matrix aids the MIMO decoder in decoding the refined OFDM symbols. The estimated transmit symbols are then demodulated and decoded. For decoder, turbo decoder is used. Finally, the decoded source bit streams are received in data sink. [2]

V. TURBO CODE

(a) Turbo encoder:- Turbo code is based on convolutional encoding, was introduced by Berrou et al in 1993. The idea behind encoders and interleaver is –

- If two encoders are used should be normally identical.
- The code should be in a systematic form. The input bits occur in output (shown in figure 2).
- The interleaver reads the bits in a pseudo-random order.

The bits are scramble in a pseudo-random fashion by interleaver because for two reasons. First, if the input to the second encoder is interleaved, its output is usually quite different from the output of first encoder. One of the output code words has low weight, then the other doesn't, and there is a smaller change of producing an output with very low weight.

Higher weight is beneficial for good performance of the decoder.

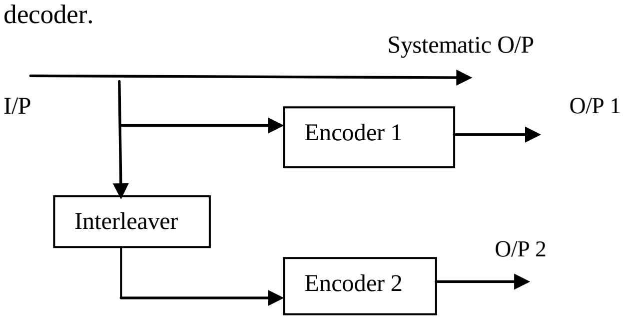

Fig 2: The Turbo Code encoder. [4]

Secondly, the code is parallel concentration of two codes; the divide-and-conquer strategy can be employed for decoding. If the input of second decoder is scrambled, its output will be different and uncorrelated from first encoder. The corresponding two decoders will gain more information exchange. For short block sizes, the odd-even

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ISO 9001:2008 Certified
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interleaver has been found to outperform the pseudo-random interleaver and vice-versa. The choice of interleaver is important part in the success of the code. [4]

(b) Turbo decoder: - The first requirement of decoder is decoder should able to use soft input and produce soft output. Number of decoder work in a pair to estimate original information bits. The decoder work on Maximum A posteriori Probability (MAP) and output soft decision information from noisy parity bits.

The MAP algorithm minimizes the probability of bit error by using the entire received sequence to identify the most probable bit at each stage. The MAP algorithm does not constrain the set of bit estimates to necessarily correspond to a valid path. So the results can differ from those generated by a Viterbi decoder which identifies the most probable valid path.

A soft-in-soft out (SISO) decoder receives as input a 'soft' valve of signal. The decoder then outputs for each data bit an estimate expressing the probability that the transmitted data bit was equal to one. The number of decoders equal to number of encoders. Each decoder provides estimates of same set of data bits all in a different order. In decoding process all intermediate valves are soft valves, the decoder can gain more from exchanging information, after appropriate record of valves. Initially, first decoder starts estimating information (are set to 0). After that in subsequent iterations, the soft decision information of one decoder is used to initialize the other decoder and so on. The decoder information is cyclic around in a loop until soft decision can't come on a stable set of values. Number of time information can be iterated to enhance the system performance. After every round, decoder re-calculate their estimates.

Only in final stage will hard decisions be made, each bit is assigned by 1or 0. The turbo code uses three simple ideas: parallel concatenation of codes to allow simpler decoding; interleaving to provide better weight distribution; and soft decoding to enhance decoder decisions and maximize the gain from decoder interaction. But turbo code is difficult to implement. [5]

VI. STBC

The Alamouti code is the first STBC that provide full diversity at full data rate for number of transmit antennas. Number of multiple copies of same signal is send via two or more number of different antennas by doing this error decreases. In Alamouti code, in first time slot x1 and x2 data are transmitted from antenna 1 and 2 respectively. In next time slot –x2* and x1* are transmitted from 1 and 2 antennas respectively.

$$X = \begin{bmatrix} x1 & -x \\ x2 & x1 \end{bmatrix}$$

(1)

Now the Alamouti code word X in equation (1) is a complex-orthogonal matrix that is

$$X = \begin{bmatrix} |x1|^2 + |x2|^2 & 0 \\ 0 & |x1|^2 + |x \end{bmatrix}$$

(2)

$$= (\quad |x1|^2 + |x)$$

(3)

Denotes the 2*2 identity matrix.

Let Y1 and Y2 are received signals at time t and t + now:-

Y1 = h1x1 + h2x2 +z1

(4) Y2 = -h1x2* + h2x1* +z2

(5)

H1 and h2 are channel and z1 and z2 are additive noise at time t and t + . Taking complex conjugation of second received signal, have following matrix:-

$$(= \begin{bmatrix} h1 & h2 \\ h2 * & -h1 * \end{bmatrix} (+ \quad ($$

(6)

In course of time, from time t and t + , the estimates for channels and are provided by channel estimator. If assume an ideal situation in which the channel gains, h1 and h2 are exactly known by receiver. Then the transmit symbols are two unknown variables in matrix now by multiplying both side equation (6) by Hermitian transpose of channel matrix, the output will be:-

$$(= \quad [|h1|^2 + |h2|^2] (+ \quad ($$

(7)

Equation (7) , other antenna interference does not exist anymore, that is, unwanted symbol x2 dropped out of Y1,while the unwanted symbol x1 dropped ut of Y2. This is attributed to complex orthogonality of the Alamouti code in Equation (1). [3]

VII. SIMULATION RESULTS

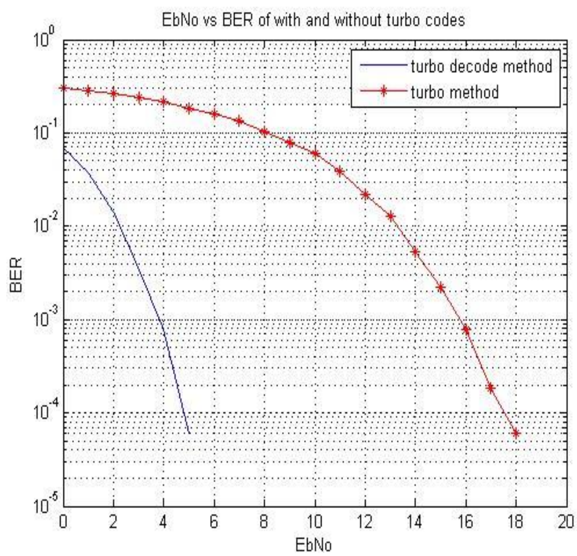

Fig 3: SISO-OFDM with and without turbo code

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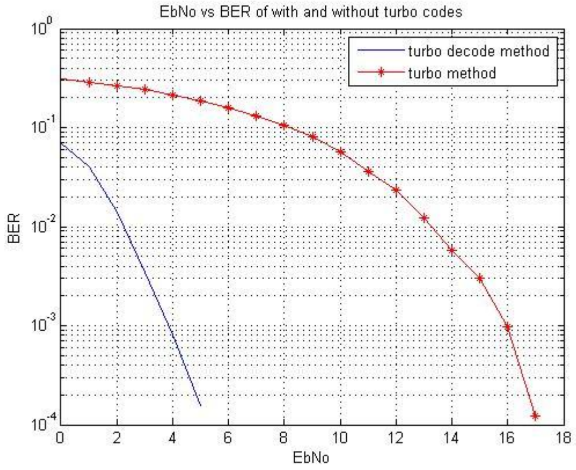

Fig 4: SISO-OFDM with and without turbo code.

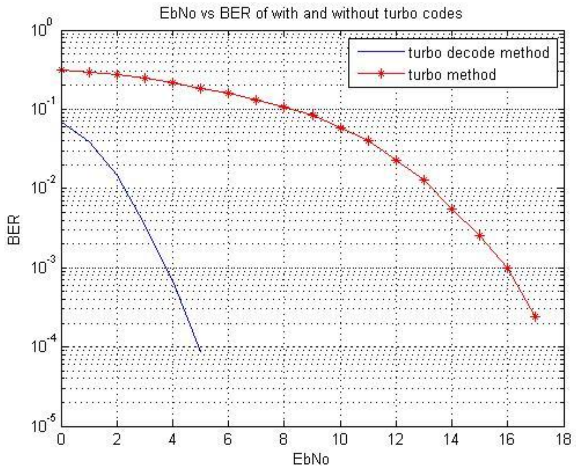

Fig 5: MISO-OFDM with and without turbo code.

The simulation results of BER performances of both un-coded and coded systems are presented in this section. The signal is modulated by using 16 QAM. The turbo code used is 2/3. It is observed that turbo-code MIMO-OFDM provides a gain of 4 dB times the un-coded MIMO-OFDM at BER of 10^{-3}.

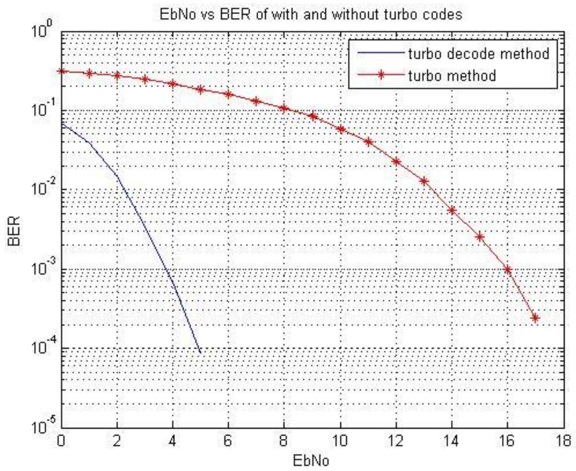

Fig 6: MIMO-OFDM with and without turbo code.

VII. CONCLUSION

This paper, we proposed an approach for high data rate wireless communication systems. Our approach incorporates the turbo coding approaches. The results for higher modulation schemes show that as the modulation order increases, a higher SNR is required to obtain the same BER performance at a lower order. They also demonstrate that the iterative gain is greater for higher modulation orders. In result we found a better performance of MIMO OFDM system using turbo code approach with higher modulation order. Simulation results demonstrate that the proposed sy-stem not only has good ability of suppressing interference, but also significantly improves the bit-error rate (BER) performance of the system. Experimental results show that an adaptive beam-forming gives the optimum performance on AWGN channels. This system will also be optimum on fading channels when combined with space–time turbo codes.

Future work, Set Partitioning In Hierarchical Trees (SPIHT) is an image compression algorithm that exploits the inherent similarities across the sub-bands in a wavelet decomposition of an image. The algorithm codes the most important wavelet transform coefficients first, and transmits the bits so that an increasingly refined copy of the original image can be obtained at receiver. By this algorithm we achieve a better image over a noisy channel.

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