Performance Analysis of MIMO Equalization Techniques with Highly Efficient Channel Coding Schemes

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ABSTRACT

To combat the wireless fading impairment in the high network demand environment, various coding schemes have been implemented. MIMO techniques are still the powerful techniques along with source coding. This paper focuses on coherent implementation of high performance turbo codes with MIMO equalization techniques. It is proposed to achieve optimum BER value at very low values of SNR in a noisy environment.

KEYWORDS: *Turbo Codes, MIMO, Maximal Likelihood Technique, Minimum Mean Square Error Technique*

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Abbreviations Used:
MIMO- Multi-Input Multi-Output
ML- Maximal Likelihood
MMSE- Minimum Mean Square Error
BER- Bit Error Rate
SNR- Signal to Noise Ratio

I. INTRODUCTION

The quality of a wireless link can be described by three basic parameters, namely the transmission rate, the transmission range and the transmission reliability. The transmission reliability may be improved by reducing the transmission rate and range [1]. However, with the advent of multiple transmit and receive antenna (MIMO) techniques, the above-mentioned three parameters may simultaneously be improved. An increased capacity, coverage and reliability are achievable with the aid of MIMO techniques [2]. Furthermore, although MIMOs can potentially be combined with any modulation or multiple access technique, recent research suggests that the implementation of MIMO with channel coding schemes is more efficient. Multi-antenna implementation such as MIMO scheme enhances the coverage and capacity in even the most challenging environments [3]. Considering advantages of various MIMO techniques, there is a need to integrate them so that the whole system can get benefit from these technologies. In this paper, it is demonstrated that the combination of MIMO equalization techniques and channel coding techniques is a promising scheme for future multimedia wireless communication systems and other applications of MIMO like LTE, WIMAX, WLAN etc.

Some of these MIMO equalization techniques and Turbo codes are explained in the subsequent sections.

A. MIMO Schemes

Multiple transmit and receive antennas (MIMO) are used to increase the capacity of the channel and to fulfil the requirement of information rate [4]. MIMO equalization techniques are:

a) Maximum likelihood technique (ML):

The Maximum Likelihood receiver minimizes,

$$J=|y - H\hat{x}|^{2} \quad (1)$$

It computes the transmitted signal estimation. This is generally easy to derive.

b) Minimum Mean Square Error (MMSE):

An MMSE estimator is a method which reduces the mean square error (MSE). MMSE equalizer does not completely exclude Inter Symbol Interference (ISI) but minimizes the total power of the noise and ISI components in the output.

B. Turbo codes

Turbo codes are high-performance Forward Error Correction Codes (FEC) developed in 1993. Turbo codes uses Recursive Systematic Convolution (RSC) Encoder and Iterative BCJR (Bahl Cocke Jelinek Raviv) decoder. Turbo encoder is constituted of two rate 1/2 RSC encoders combined in parallel to form Turbo coded signal with rate 1/3 [5]. The message signal is encoded with the RSC turbo encoder. Secondly, the message signal is interleaved with random interleaver and encoded again [6]. Then these two encoded signals are multiplexed with the original message signal to form rate 1/3 turbo encoded signal. Then after channel transmission, decoding is done with BCJR algorithm where Log likelihood ratio is evaluated and the output is retrieved.

II. Methodology

In this paper, a reliable transmission channel has been designed comprising of digital data synthesiser, encoder, modulator, MIMO transmitter and receiver antennas, wireless channel, demodulator, turbo decoder and the digital data output. The (1, 15/13, 15/13) RSC turbo encoder along with BCJR decoder in algorithm Max-Log-MAP has been used for encoding and decoding purposes respectively [7]. Various MIMO equalization schemes like ML and MMSE have been simulated with iterative turbo coding schemes [8]. Thermal noise has been modelled as Additive white Gaussian noise (AWGN) and fading as Rayleigh fading [9, 10].

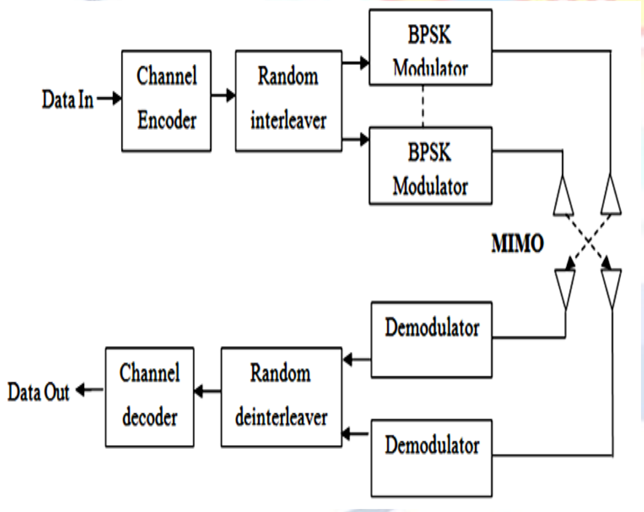

Fig.1 Simulation model

III. Simulation Results

The details of the simulated work have been given in the following section:

Table I: Simulated Parameters

PARAMETER	VALUE
No. of bits	10^6
Turbo Encoder	RSC [1, 15/13, 15/13] Encoder
Decoder	BCJR
Wireless channel	AWGN, Rayleigh Fading
Antenna diversity	MIMO
Modulation	BPSK
MIMO Equalization scheme	ML, MMSE
Signal to Noise Ratio (SNR)	-6 to 25 (dB)
No. of iterations	4
Algorithm for BCJR decoder	Max-Log-Map
No. of Transmitter-Receivers	2X2, 2X3, 2X4

IV. Results

Initially, the variation of Bit Error Rate (BER) with respect to SNR (in dB) for Turbo Decoder implemented with AWGN channel and BPSK modulation is shown.

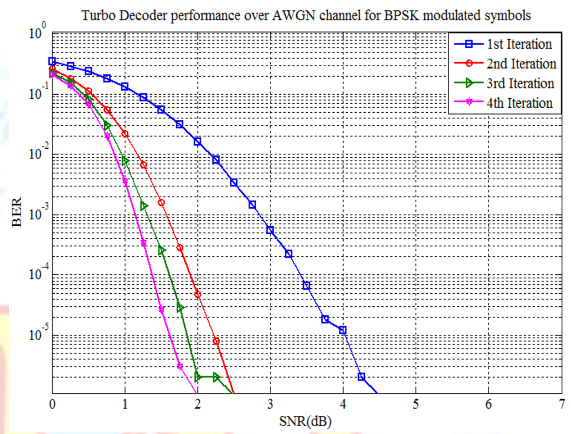

Fig.2 Simple Turbo Performance without MIMO scheme

From fig.2, it has been observed that the performance of Turbo codes improved with the number of increasing iterations. It is noted that BER becomes 10^{-6} at 2.5 dB of SNR after 3 iterations and at 2 dB of SNR after 4th iteration.

MIMO-ML equalization performance with Turbo Coding

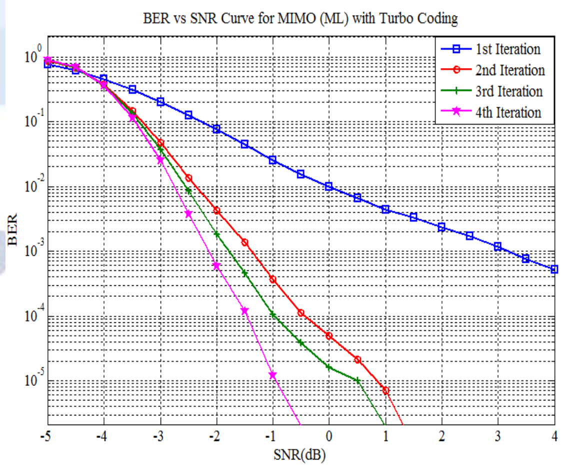

Fig.3 Turbo Coded Performance with 2X2 MIMO ML equalization scheme

In fig.3, the variation of BER Vs SNR for the combination of ML equalization technique with turbo coding scheme in a wireless communication channel for 2 transmitters and 2 receivers is shown. The performance improved with the number of receiver antennas even with less number of iterations. The achieved value of BER is 10^{-6} after 1.5 dB of SNR for 2nd iteration and at -0.5 dB of SNR for 4th iteration. This implementation has further been done for more number of receiver antennas and the results have been summarized in the subsequent sections.

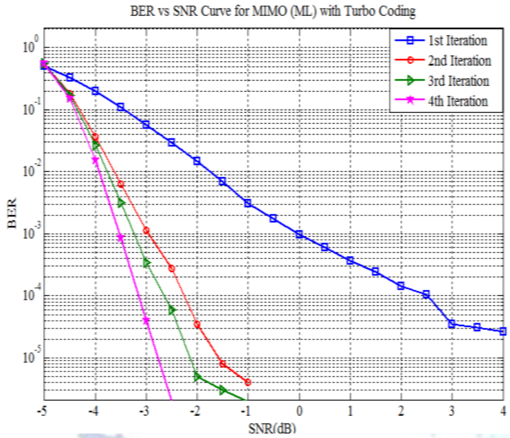

Fig.4 Turbo Coded Performance with 2X3 MIMO ML equalization scheme

In fig.4, the results of ML equalization technique simulated with turbo codes have been discussed taking two transmitters and three receiver antennas. In this case, the performance of BER is enhanced. The achieved value of BER is 10^{-6} at -2.5 dB of SNR for 4th iteration where signal strength is very low so this technique is suitable for challenging noisy environments.

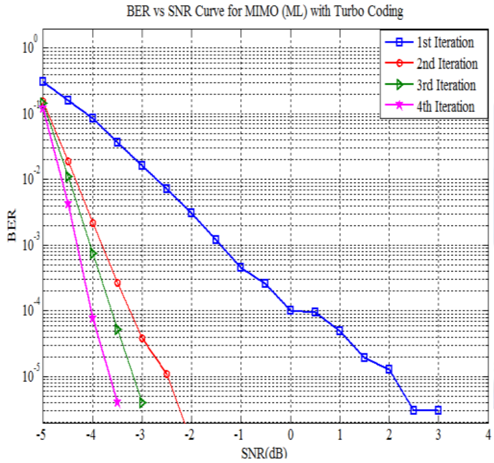

Fig.5 Turbo Coded Performance with 2X4 MIMO ML equalization scheme

Fig.5 shows the variation of BER vs. SNR for 2X4 MIMO-ML scheme implemented with turbo codes. Here BER is 10^{-6}at very low value of SNR i.e. -3.5 dB after four decoding iterations only. This takes very less time to send the data reliably to the receiving side without any error or if any, that is also negligible.

MIMO-MMSE equalization performance with Turbo Coding

In this section, MMSE equalization MIMO scheme has been implemented with channel coding schemes.

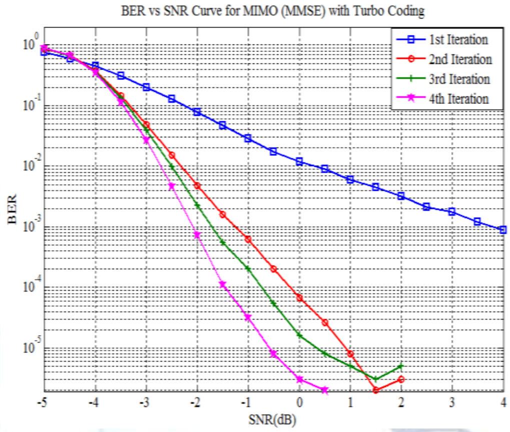

Fig.6 Turbo Coded Performance with 2X2 MIMO MMSE equalization scheme

In fig.6, the performance improved rapidly with number of increasing iterations. The achieved value of BER is 10^{-6} at 0.5 dB of SNR after 4th iteration in 2X2 MIMO scheme.

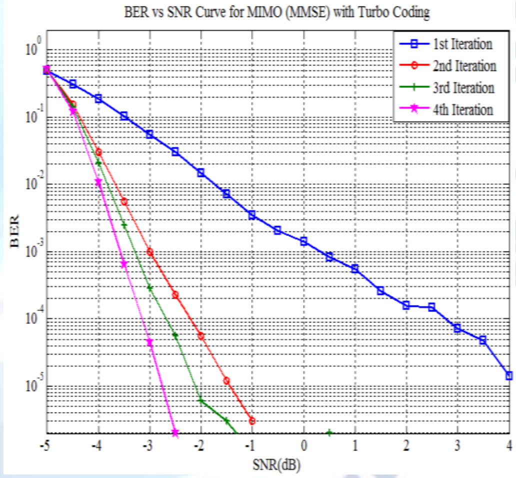

Fig.7 Turbo Coded Performance with 2X3 MIMO MMSE equalization scheme

When 2X3 MIMO scheme is implemented in fig.7, it takes less number of iterations to converge the BER at same rate as that of 2X2 MIMO scheme. Now BER is approximately 10^{-6} at -2.5 dB of SNR after 4th iteration.

The best performance is given by 2X4 MIMO scheme implemented with turbo codes as shown in fig.8. Here BER is equal to 10^{-6} at -3 dB of SNR after 4th iteration. This is very low signal strength and t can be efficiently applied in challenging situations. The number of receivers is not increased beyond this as it can affect the cost and complexity constraints. It can also lead to wastage of bandwidth which is not acceptable in the design of communication channel.

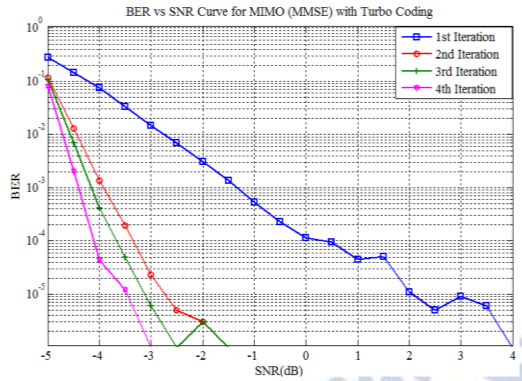

Fig.8 Turbo Coded Performance with 2X4 MIMO MMSE equalization scheme

BER Performance after 4th Iteration

In this section, various MIMO equalization techniques have been compared on the basis of BER values achieved after 4th iteration of turbo encoding and decoding process for 2X4 MIMO scheme. In Fig.9 and Fig.10, the results are presented for the variation of BER with respect to SNR for ML and MMSE techniques respectively with varying number of transmitter and receiver antennas.

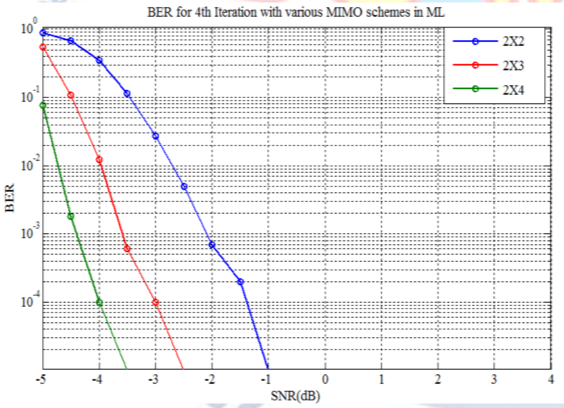

Fig.9 BER plot for various MIMO schemes for ML after 4th Iteration

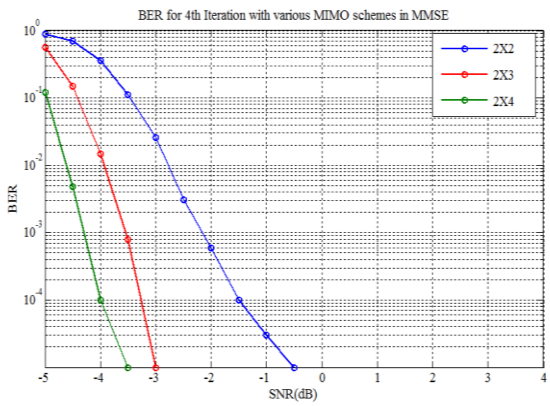

Fig.10 BER plot for various MIMO schemes for MMSE after 4th Iteration

From fig.9 and fig.10, it is clearly inferred that with change in number of transmitting and receiving antennas, the performance upgrades to acceptable levels. 2X4 MIMO system gives the best performance as compared to corresponding 2X3 and 2X2 MIMO systems. In all types of MIMO simulations, ML equalization performs better than MMSE equalization and provides superior results. ML needs less number of decoding iterations as compared to that of MMSE for same value of Bit error rate (BER).

V. Conclusion

From the Results explained above, it is concluded that the performance of MIMO equalization techniques implemented with channel coding is superior to the MIMO techniques implemented without coding. BER achieved is 10^{-6} in the range of 10-20 dB of SNR without coding and is in the range of -3 to 5 dB of SNR with the use of channel coding. The simulated model can be applied in GPS signals, Radar applications etc. In near future, the performance can be enhanced further by increasing number of antennas and by using other equalization techniques.

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