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BER Performance Evaluation of Turbo Coded MIMO System in Nakagami Channel

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Abstract: ***Wireless technologies are aiming to improve data rates along with reliability using Multiple Input and Multiple Output(MIMO) systems. The major performance parameter for advanced systems is Bit Error rate (BER). Researchers are working for minimizing the BER for data communication. This paper presents the BER performance of turbo coded Multiple Input Multiple Output (MIMO) system in Nakagami channel. MIMO system is realized using Space Time Block Codes. System performance is analyzed for M-ary Quadrature Amplitude Modulation (QAM) in Nakagami channel. System is implemented using MATLAB code. 4QAM system performs better as far as BER is concerned. The implemented turbo coded system outperforms the uncoded system in case of BER performance. This system can be used for improved performance of data communication in LTE and WiMax.***

Keywords: ***BER, MIMO, Turbo Coded, MQAM, Nakagami Channel***

I. INTRODUCTION

The MIMO systems use multiple antennas for transmission and reception. They improve data rates. MIMO uses less transmit power providing bandwidth efficient solution. Space-Time Block Code (STBC) is methods to implement MIMO giving high transmit diversity for improved reliability. MIMO system creates multiple independent channels from transmitter to receiver.

STBC scheme is proposed for multiple transmit antennas [1] for coded orthogonal and quasi orthogonal STBC and their BER performances are evaluated. Coded and uncoded systems are compared based on BER performance for two transmit and one receive antennas [2]. Out of coded systems, orthogonal scheme executes better performance. Authors [3] developed group-decodable code structure for reducing the decoding complexity. Different Channels results in better BER reduction efficiencies. Full diversity is offered by STBC with the Partial Interference Cancellation (PIC) group decoding proposed [4]. Performance is improved in M-ary systems for small M values. 4x2 , 4x1 and 2x2 MIMO systems are discussed and evaluated for their BER performances [5].

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4x2 system gives better results as compared with other two. Jiliang Zhang et. al. [6] discussed and compared spatial modulation scheme with STBC and Vertical Bell Labs Layered Space Time (V-BLAST) system for four transmit antennas. BER performance of SM system is better over STBC and V-BLAST schemes. Performance of m x n system are compared for maximum likelihood (ML) and minimum mean square error (MMSE) reception [7]. Muhammad Sana Ullah et al [8] implemented 2x2 Alamouti scheme and 1x4 Maximum Ratio Combining (MRC) scheme. 2x1 and 1x2 schemes are showing degradation in BER over 2x2 scheme in Additive White Gaussian Noise (AWGN) channel. MIMO system with MPSK and MQAM is analyzed and evaluated [9]. MIMO-OSTBC is implemented over Rayleigh Fading Channel [10]. BER and Spectral efficiencies for different SNR are compared. It is observed that 2 x2 system gives better bandwidth efficiency with full coding rate. Increase in number of antennas show improvement in BER. BER performance of space time coded system with 4x2 and 4x4 antenna dimensions are evaluated over measured indoor radio channels [11]. BER is improved for indoor channel for 4x4 scheme.

Authors of this paper have compared the BER performance of (STBC SM) with V-BLAST and Diagonal-BLAST STBC [12]. BER for STBC-SM is improved over BLAST systems. However increases decoding complexity. Authors research contributions are presented in [13], [14] and [15]. A prototype model of MIMO is developed to evaluate BER performance of 2x2 system [13]. Algorithm is developed for evaluating BER performance of convolutionally Coded MIMO System with MPSK in Rayleigh Channel [14]. Algorithm is also developed for convolutionally coded 4XN MIMO system with MQAM and BER performance is evaluated in Rayleigh Channel [15]. BER is observed to be improved over uncoded systems.

MIMO systems are under research for improvement in BER. Authors have proposed turbo coded 2x2 STBC system for BER improvement in Nakagami distribution environment. BER performances are evaluated for MQAM M =4 to 16 in Nakagami channel. System model and method of implementation are shown in Section 2 and 3 respectively. Simulation results are presented in Section 4. Performance is concluded in Section 5.

II. SYSTEM MODEL FOR STBC MIMO SYSTEM WITH MQAM

The Turbo coded 2x2 STBC MIMO system with MQAM is shown in Fig. 1.

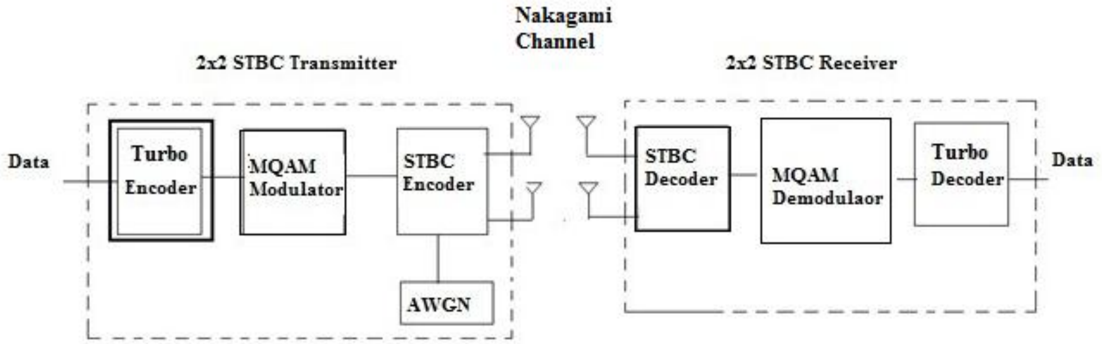

Fig. 1 : Turbo coded 2x2 STBC MIMO system concatenated with MQAM

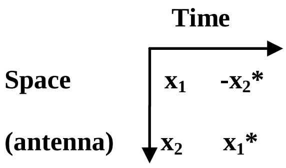

Fig 2: Space time representation for 2×2 STBC System

The data is first Turbo encoded and then given to MQAM modulator. Modulated output is shown in equation (1)

$$x(t) = A_{mi}\, s(t) \cos 2\,\pi f_c t + s\,(t) \sin 2\pi f_c\, t \qquad (1)$$

where s(t) is turbo encoded data and f_c is carrier frequency.A_{mi}= carrier in phase component, A_{mq} = carrier quadrature phase component. A_{mi} and A_{mq} in (1) are represented by $\log_2$ M level. M taking the values 4,8,16.

The symbols x(t) from equation (1) are then transmitted via 2x2 system. Space time representation for 2x2system is shown in Fig 2.

x_1 and x_2 represent signals transmitted in first and second time slots respectively. The channel is modeled as Nakagami channel.

Scattering due to multipath and delay spreading causes Nakagami fading. Its distribution is presented by pdf in equation (2).

$$f(r) = \frac{2}{\Gamma(m)}\left(\frac{m}{2\sigma^2}\right) r^{2m-1} e^{-\frac{mr^2}{2\sigma^2}} \qquad (2)$$

where $2\sigma^2 = E\{r^2\}$, Γ is gamma distribution function and $m \geq 1/2$ is fading depth parameter..

In case of m = 1, it gives rise to Rayleigh. For m > 1, envelope becomes same as Rician distribution. For m =0.5, this represents one sided Gaussian distribution

Considering x as signal transmitted via antennas , h_{mn} represent the path gain from m^{th} transmitting antenna to n^{th} receiving antenna. y(t) is representing received signal and n(t) is AWGN. The received signal at n^{th} antenna is given in equation (3)

$$y_{n,t} = \sum_{m=1}^{N} h_{m,n} x_{m,t} + n_{n,t} \qquad (3)$$

The space time decoder decision metric is mentioned in (4),

$$\sum_{t=1}^{l} \sum_{n=1}^{N} \left| y_{n,t} - \sum_{m=1}^{N} h_{m,n} x_{m,t} \right|^2 \qquad (4)$$

This metric is computed over all possible code words. The decision is made in favor of codeword providing minimized sum. Space time decoder output y giving smallest sum of equation (4) is given to demodulator. The demodulated output is expressed in equation (5)

$$z(t) = \int_0^T y(t) \cos\,(2\pi f c t + \theta_m)\, dt$$

(5)

This z(t) is then decoded with turbo decoder.

The algorithm is developed based on this model for BER performance evaluation of turbo coded 2x2 MIMO system with MQAM.

III. METHOD OF SYSTEM IMPLEMENTATION

Authors have developed a turbo encoded MIMO system with MQAM using MATLAB. Flowchart for the same is given in Fig. 3.

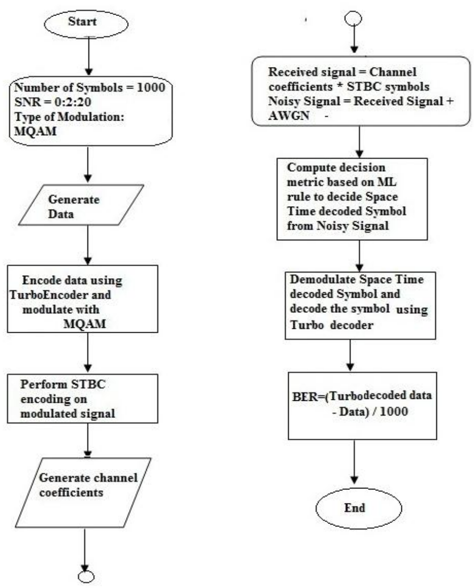

Fig. 3: Flowchart of developed Turbo coded STBC MIMO system

As shown in Fig. 3, for developed system, number of symbols is defined along with SNR. Binary data is generated and turbo encoded. Turbo encoded signal is further given to MQAM modulator. The modulated signal is then Space Time Block Coded. Channel coefficients for Nakagami channel are generated. Noise and channel fading effect is added to get the received signal. Noisy signal is then STBC decoded, demodulated and Turbo decoded. The decoded data is compared with input to calculate BER.BER Vs SNR is plotted.

Similar procedure is followed excluding Turbo encoding and decoding block.

IV. SIMULATION RESULTS AND DISCUSSION

Performance in terms of BER for MIMO concatenated with MQAM for M= 4,8,16 and for M = 32, 64 in Nakagami channel for m = 0.5, 1 and 1.5 are obtained.

BER Vs SNR is plotted for Turbo coded and uncoded systems as shown in Fig. 4 , Fig. 5 and Fig. 6 respectively. Fig 4 shows BER vs SNR plot for m = 0.5. This m represents unilateral Gaussian distribution. Fig. 5 shows BER Vs SNR plot for m = 1 which gives Rayleigh distribution. Fig. 6 shows BER Vs SNR plot for m = 1.5 which yields Rician distribution.

Plotted graph shows BER performance of MQAM system for different shaping factor in Nakagami fading distribution. 4QAM turbo coded System performs better than other systems in terms of BER performance.

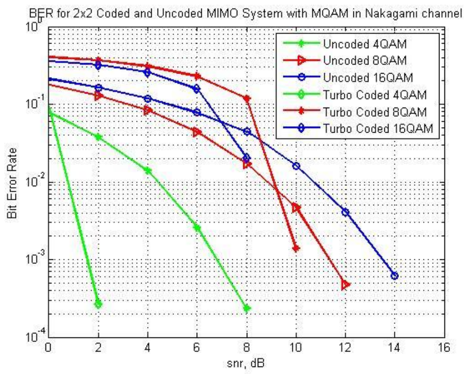

Fig 4: BER Vs SNR of Coded and Uncoded MIMO concatenated with MQAM in Nakagami channel for m=0.5

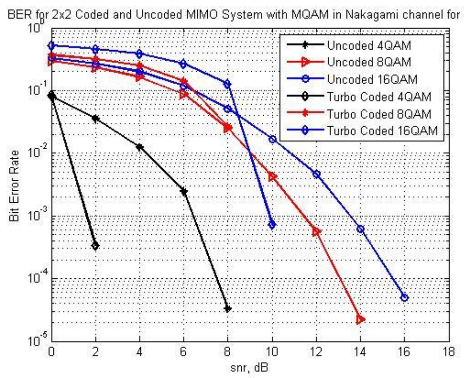

Fig 5: BER Vs SNR of Coded and Uncoded MIMO concatenated with MQAM in Nakagami channel for m=1

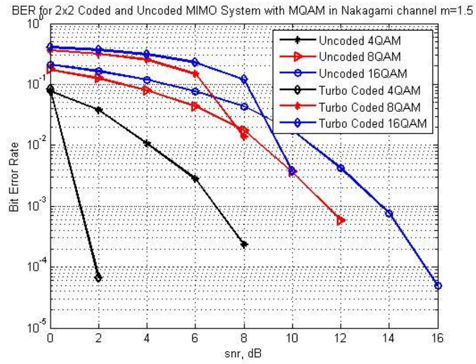

Fig 6: BER Vs SNR for Coded and Uncoded MIMO concatenated with MQAM in Nakagami channel for m=1.5

Table[I]: BER Improvement of Turbo Coded MIMO with MQAM over Uncoded System in Nakagami-m channel for m=0.5

System	Percentage BER improvement over uncoded system at SNR =4 dB	Percentage BER improvement over uncoded system at SNR =12 dB
4QAM	80	81
8QAM	80	87
16QAM	-52	83

The simulation results are presented in Table [I], [II] and [III] at low SNR=4dB and high SNR =12 dB in Nakagami-m channel for m = 0.5, 1 and 1.5 respectively.

Table[II]: BER Improvement of Turbo Coded MQAM STBC MIMO over Uncoded System in Nakagami-m channel for m=1

System	Percentage BER improvement over uncoded system at SNR =4 dB	Percentage BER improvement over uncoded system at SNR =12 dB
4QAM	83	91
8QAM	-6.5	87
16QAM	-51	91

As shown in table[I], for m=0.5 channel, turbo coded MQAM systems show minimum 81% improvement over uncoded systems at SNR = 12 dB and 80% at 4 dB. BER improvement of 83% and 80 % is observed for m=1 and m= 1.5 respectively over uncoded system at 4 dB as per table [II] and [III].

Table[III]: BER Improvement of Turbo Coded MQAM STBC MIMO over Uncoded System in Nakagami-m channel for m=1.5

System	Percentage BER improvement over uncoded system at SNR =4 dB	Percentage BER improvement over uncoded system at SNR =12 dB
4QAM	80	88
8QAM	-68	87
16QAM	-52	77

Table IV: BER of developed Turbo Coded System and Existing System at 4 dB in Nakagami Channel

2x2 system	MIMO system with ML decoding at receiver [6]	MIMO system with ML decoding at receiver [17]	Developed Turbo Coded system with ML Equalization at receiver
4QAM, m=0.5	-	0.5E-1	0.3E-4
4QAM, m=1	-	0.1E-1	1E-2
8QAM, m=0.5	-	0.4E-1	0.8E-2
8QAM, m=1	-	0.6E-1	0.3E-1
16QAM, m=0.5	0.1	-	0.1
16QAM, m=1	0.6	-	0.3E-1

Table V: BER of developed Turbo Coded System and Existing System at 12 dB in Nakagami Channel

2x2 system	MIMO system with ML decoding at receiver [6]	MIMO system with ML decoding at receiver [17]	Developed Turbo Coded system with ML Equalization at receiver
4QAM, m=0.5	-	0.1E-2	1E-5
4QAM, m=0.5	-	0.8E-3	0.3E-5
8QAM, m=0.5	-	0.9E-3	0.5E-4
8QAM, m=1	-	0.1E-2	0.2E-4
16QAM,m=0.5	0.1	-	0.3E-3
16QAM, m=1	0.5	-	0.8E-5

BER improvement is of 87% and 77% for m=1 and m=1.5 respectively at 4 dB as depicted in table [II] and [III]. However 8QAM and 16QAM turbo coded system shows BER degradation at 4 dB at m=1 and m=1.5.

Results of developed system are also compared with existing system in Nakagami channel and tabulated in Table IV and V. BER improvement is observed at 4dB and 12 dB for 4QAM, 8QAM and 16QAM systems. 4QAM turbo coded system performs better than other MQAM systems in Nakagami channel.

V. CONCLUSION

The Turbo Coded MQAM STBC MIMO system is presented. The MATLAB code is developed as per model and BER performance is evaluated in Nakagami-m channel for m =0.5, 1 and 1.5. Turbo coded systems are compared with uncoded systems on basis of BER performance. It is observed that coded MIMO system with 4QAM performs better as compared 8QAM and 16QAM. Implemented turbo coded system shows BER improvement by minimum 77% at 4dB and 83% improvement at 12dB over uncoded system. This BER improvement at low as well as high SNR makes the turbo coded system useful in data communication for LTE and WiMax.

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