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Research paper

Performance Analysis of Uncoded and Coded 4XN Space Time Block Coded MIMO System Concatenated with MQAM in Rayleigh Channel

M. H. Belsare[1]*, Dr. P. B. Mane[2]

[1] Research Scholar, Department of E &TC, AISSMS's Institute of Information and Technology, Kennedy Road, Near R.T.O., Pune: 411001,Maharashtra, India
Assistant Professor, PVG's College Of Engineering and Technology, Pune
[2]Research Guide, Principal and Professor AISSMS's Institute of Information and Technology, Kennedy Road, Near R.T.O., Pune: 411001,Maharashtra, India
**Corresponding author E-mail:madhavi.belsare@gmail.com*

Abstract

Wireless Communication using Multiple input and multiple output(MIMO) systems are achieving high data rates with increased diversity. This paper presents the performance analysis of half rate convolutionally coded 4x4, 4x3 and 4x2 STBC MIMO system concatenated with MQAM. System performance is analyzed for 4QAM, 8QAM and 16QAM in Rayleigh channel. It is observed that BER performance is better for 4x4 system as compared with other schemes. Results show that BER performances of employed coded 4x4 system is improved over uncoded system in Rayleigh channel.

Keywords: BER; MIMO; MQAM; Rayleigh Channel; Rician Channel; STBC.

1. Introduction

Number of antennas are used at transmitter and receiver side in MIMO systems. They provide high data rates limited bandwidth with minimum transmit power. Space-Time Block Coding (STBC) is a MIMO transmit approach that gives high reliability and good transmit diversity. MIMO system generates many independent channels between transmitter and receiver. Space Time Block Codes (STBC) are used to assure the diversity gain.
Tarokh et al [1] derived STBC scheme for number of transmit antenna = 2, 3, 4. Coded orthogonal and quasi orthogonal STBC performance is compared with uncoded scheme for two transmit and one receive antennas[2]. Orthogonal scheme outperforms the other two schemes. *Ming Yang Chen et al [3] presented quasi orthogonal STBC with symbol by symbol ML detection for 4x4 scheme in Rayleigh channel. Improvement in BER is observed over simple quasi orthogonal STBC . BER is evaluated for different modulation schemes such as BPSK, QPSK, 16QAM and 64 QAM in [4]. Performance improvement is observed for increase in number of antennas as well as decrease in value of M. 4x2 , 4x1 and 2x2 schemes with 4QAM, 16QAM and 8PSK are discussed and their BER performances are evaluated in [5]. 4x2 scheme is giving 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) code for 4x4, 4x2, 4x1 schemes with BPSK, QPSK and 16QAM. SM scheme shows better BER performance over STBC and V-BLAST schemes. Performance comparison of m x n equalizer based maximum likelihood (ML) and minimum mean square error (MMSE) MIMO receiver is done for wireless channel [7]. BER performance is improved with increase in value of M and N. BER performance of space-time coded transmission using four transmit antennas and two and four receive antennas are evaluated over measured indoor radio channels [8]. BER is observed to be improved for 4x4 indoor as well as i.i.d channels.

From the literature survey it is observed that, MIMO systems are under lot of research for reducing Bit Error Rate (BER). Authors have proposed half rate Convolutionally encoded 4x4, 4x3 and 4x2 STBC scheme concatenated with MPSK for improvement of BER in fading environment. BER performances of these systems are analyzed for QPSK, 8PSK, 16PSK in Rayleigh and Rician channels. System model is presented in Section 2 and simulation results are discussed in Section 3. Conclusion based on simulation results is presented in Section 4.

2. System Model for STBC MIMO System Concatenated with MQAM

The half rate Convolutionally coded 4xN (N =2,3,4) STBC MIMO system concatenated with MPSK is considered to develop the system model.

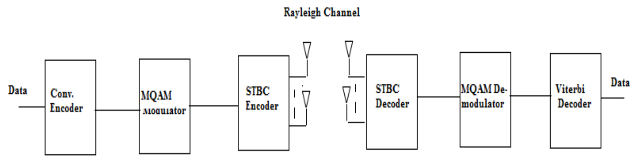

Fig. 1 : Half rate Convolutionally coded 4XN STBC MIMO system concatenated with MQAM

Convolutional encoded data is given to MQAM modulator. Modulated output is obtained as shown in equation (1)

$$x(t) = A_{mi}\, v(t)\cos 2\,\pi f_c t + A_{mq}\, v(t)\sin 2\pi f_c\, t \quad ---- \quad -----(1)$$

where,
Am = {(2m-1-M), m=1,2,...M} represents amplitude of carrier,
M = 4,8,16,
i= in phase carrier component,
q = quadrature phase carrier component,
v(t) = output of Convolutional encoder and
fc = the carrier frequency.
The symbols obtained from equations (1) are then transmitted via four antennas. Space time representation for transmitted symbols is shown in fig. 2

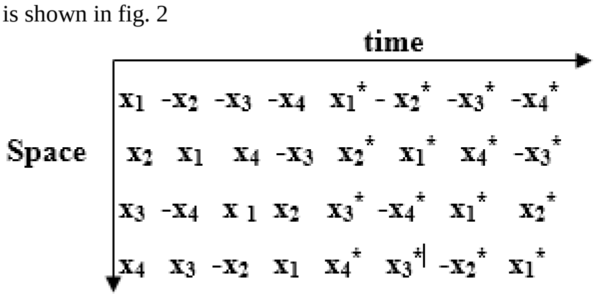

Fig. 2 : Space Time Representation for four transmit antenna system

Channels under consideration are Rayleigh and Rician channels . Rayleigh channel is modeled by mixing two random signals with Gaussian distribution. Resulting Rayleigh channel is represented by following equation:

$$p(r) = \frac{r}{\sigma 2}\exp(-r/\sigma 2) \quad -------(2)$$

where r represents envelope of received signal and σ2 is its variance. p represents pdf. Channel Coefficients for Rayleigh channels are modeled as independent and identically distributed (i.i.d.) complex Gaussian random variables with variance 1/2 in each dimension.
Rician channel can be modeled considering presence of a strong line of sight component. It can be described by probability distribution function given below,

$$\left[\frac{r}{s,\sigma}\right] = \frac{r}{\sigma^2}\exp\left[\frac{-r^2}{2\sigma^2}+\frac{r^2}{2\sigma^2}\right]\ln\left[\frac{s^2}{\sigma^2}\right] \quad --- \quad --------(3)$$

If x is transmitted signal, hi,j is the path gain from ith transmitting antenna to jth receiving antenna, n(t) is AWGN and y(t) is received signal, then received signal at jth antenna is given as

$$y_{j,t} = \sum_{i=1}^{N} h_{i,j}x_{i,t} + n_{j,t} \quad ----- \quad ---------(4)$$

The space time decoder decision metric is mentioned below,

$$\hat{s_l} = \sum_{t=1}^{l}\sum_{j=1}^{N}\left|y_{j,t} - \sum_{i=1}^{N} h_{i,j}x_{i,t}\right|^2 - \quad ----------(5)$$

Space time decoded symbols s given by equation (5) are used to demodulate the carrier. The demodulated output is given in equation (6)

$$z(t) = \int_0^T s(t)\cos(2\pi fct + \theta_m)dt - \quad ----------(6)$$

where T is symbol duration.
This demodulated output is decoded with Viterbi decoder that makes decision of decoded symbol based on Maximum Likelihood(ML) Decision rule as shown in equation (7)

$$\hat{d} = \arg\min \|z - Hx_j\| \quad ----------- \quad ---(7)$$

where j=1,2,...n, for n possible symbols.

Based on system model discussed above, an algorithm is developed for BER performance evaluation of half rate Convolutionally coded 4x4, 4x3, 4x2 STBC MIMO system concatenated with MPSK.

3. Simulation Results and Performance Analysis

Bit error performances of 4xN (N=2,3,4) STBC MIMO concatenated with MQAM (M= 4,8,16) in Rayleigh channel are obtained as shown in fig 3, 4 and 5 respectively.

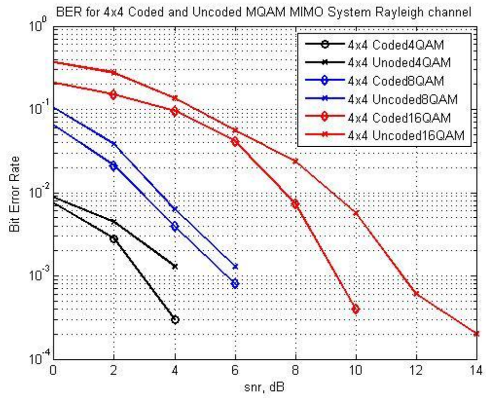

Fig 3: BER Vs SNR of 4x4 Coded and Uncoded STBC MIMO concatenated with 4QAM, 8QAM and 16QAM in Rayleigh channel

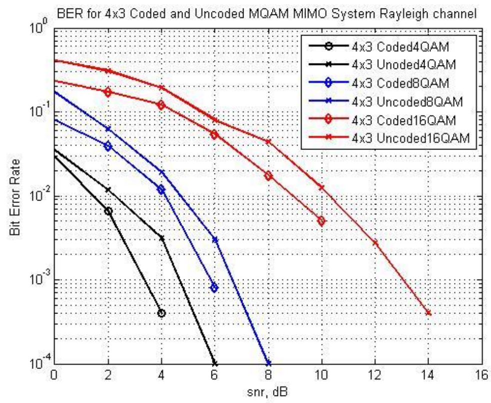

Fig 4: BER Vs SNR of 4x3 Coded and Uncoded STBC MIMO concatenated with 4QAM, 8QAM and 16QAM in Rayleigh channel

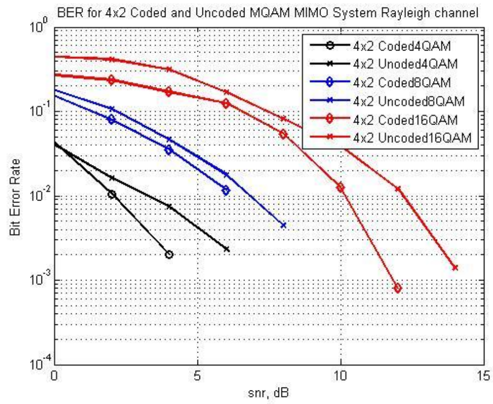

Fig 5: BER Vs SNR of 4x2 Coded and Uncoded STBC MIMO concatenated with 4QAM, 8QAM and 16QAM in Rayleigh channel

Plotted BER and channel signal to noise ratio (SNR) plane shows behavior of different constellation order for different spatial diversity. It is observed that as number of receive antennas increases bit error performance improves. 4x4 system outperforms other schemes as far as BER is concerned. The simulation results of these systems are tabulated in Table [1] at low SNR=4dB and high SNR =12 dB for Rayleigh channel

Table[1]: BER Improvement of 4x4, 4x3, 4x2 Coded MQAM STBC MIMO over Uncoded System in Rayleigh channel

Systems	4x4			4x3			4x2		
	4QAM	8QAM	16QAM	4QAM	8QAM	16QAM	4QAM	8QAM	16QAM
Improvement in BER over Uncoded System at low SNR (< 5dB)	76%	38%	29%	87%	37%	36%	72%	24%	45%
Improvement in BER over Uncoded System at high SNR(>10 dB)	90%	92%	95%	92%	93%	95%	89%	92%	96%

As shown in table[1], for Rayleigh channel, 4x4 systems with MQAM gives 24% to 87% improvement in BER over uncoded systems at low SNR and 89% to 96% improvement in BER over uncoded systems at high SNR for M= 4, 8, 16. 4x4 system with 4QAM is showing maximum improvement in BER as compared with other M-ary schemes.

Simulation results from fig. 5,6 and 7 and percentage improvement in BER as given in table [1] shows that BER deteriorates as M increases. However as increase in M minimizes bandwidth requirement, authors have proposed system to get improvement in BER with less bandwidth requirement. It is also observed that as spatial diversity increases, system's performance improves by minimum 24% at low SNR (<5dB) to approaching 96% improvement at high SNR (>10dB) as far as BER is concerned. Practically for larger bit length, it will not be possible to get zero BER. Half rate convolutionally coded system minimizes BER in every 4XN scheme.

4. Conclusion

The half Rate Convolutionally Coded 4XN(N=2,3,4) MQAM (M=4,8, 16) STBC MIMO system is presented. Reliability for 4 x 4 system is better as compared with 4x2 and 4x3. 4QAM MIMO performs better as compared with other M-ary schemes for N =2,3,4. Implemented half rate Convolutionally coded systems improves BER performance by minimum 24% at low SNR(<5dB) and 96% improvement at high SNR(>10dB) over uncoded systems which is appreciable in data communication systems such as 4G, LTE, WLAN and WiMAX. 4x4 half rate convolutionally coded 16QAM system exhibits significant improvement in BER with minimum bandwidth requirement as compared with other systems.

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