Capacity Enhancement for MIMO-OFDM Systems with Vertical and Horizontal Encoding Techniques

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***Abstract:*The capacity for the Multiple-Input Multiple-Output (MIMO) - Orthogonal Frequency Division Multiplexing (ODFM) systems can be increased by spatial multiplexing using Space-Time coding techniques. The spectral (bandwidth) efficiency can be improved by spatial multiplexing. In this paper, vertical and horizontal encoding techniques are implemented to enhance the capacity of MIMO-OFDM systems. The Rate-Compatible Punctured Convolutional (RCPC) code is used for channel encoding to reduce error rate. The most widely used Maximum likelihood (ML) receiver is used for symbol detection.**

***Keywords* - MIMO-OFDM, spatial multiplexing, Space-Time codes, Adaptive Modulation and Coding.**

I.INTRODUCTION

The Evolution of MIMO for recent wireless communication has various advantages like high data rate, throughput, capacity, link reliability and spectral efficiency. It is achieved by using the concept of increasing the number of antennas with same bandwidth and transmitter powers [1], [2]. The Spatial Multiplexing of MIMO is mostly to increase the capacity. Earlier days, higher data rate was achieved by transmitting data at higher modulation rates. Now-a-days, Spatial Multiplexing techniques are used where the data is de-multiplexed which increases the maximum achievable data rate.In wireless communication, the channel suffers from fading, noise and Interference. The space-time codes [3], [4] are used to improve transmission over fading channels [5]. The Inter symbol interference is eliminated by using OFDM systems without complex equalizers and it is mostly The link adaptation technique called "AdaptiveModulation and Coding (AMC)" is used can also increase the system capacity. The AMC automatically assigns the channel code rate and modulation levels to match the average channel conditions [7]. The Forward Error Correction (FEC) codes can easily detect and correct errors by adding redundant bits but at the cost of increased bandwidth and it can be overcome by puncturing concept. The different error protection to each channel is given by puncturing technique. The puncturing uses puncturing matrix to reduce the number of redundant data to be transmitted. The maximum likelihood detection gives better performance compared to others and it is the most widely used receiver algorithm [8].

In this paper, two bounds are used for ML receiver to find the capacity of MIMO-OFDM system. The vertical and horizontal encoding structures also called as vertical layered space-time code and horizontal layered space-time code are implemented to increase the capacity. The capacity is directly related to SNR and SNR is related to BER, therefore, capacity is inversely mapped to BER. In vertical encoding structure, all the data streams or antennas are connected to a single channel encoder, whereas in horizontal encoding structure, each data stream is connected to separate channel encoder [9], [10]. The RCPC codes [11] are implemented.

II.SYSTEM MODEL

The MIMO-OFDM system with N_t transmitter antennas and N_r receiver antennas are considered. The modulation levels and channel code rates are given by the MCS based on channel state information. The input bit is encoded vertically or horizontally as shown in Figure 1 and Figure 2. The RCPC code with octal polynomials (133,171) is used as FEC. The encoded value is bit–wise interleaved; QAM modulated [12] and signal is converted to time domain by Inverse Fast Fourier Transform (IFFT). The inter-symbol interference is prevented by adding cyclic prefix. The Rayleigh fading [2] channel is considered and is given by Jakes model. At receiver reverse operation of the transmitter is performed and the received signal vector at k^{th} subcarrier is represented as,

$$Y_k = H_k x_k + n_k \qquad \text{for } k = 1,\ldots, N_c \qquad (1)$$

Where x_k is the transmitted symbol vector, n_k denotes the

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Additive White Gaussian Noise (AWGN) vector with zero mean and covariance matrix $\sigma_n^2 I_{Nr}$ and H_k is the Rayleigh fading channel vector. The optimum detection of ML receiver is obtained by comparing all possible combinations of symbols which could have been transmitted and is given as,

$$x \arg\min \| Y - Hx \|$$

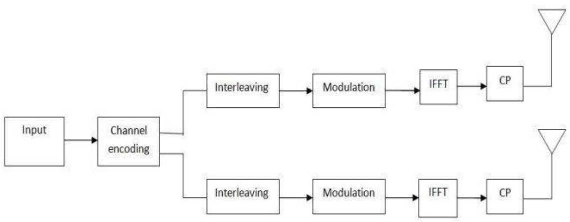

Fig. 1. Transmitter block diagram for Vertical Encoding Structure.

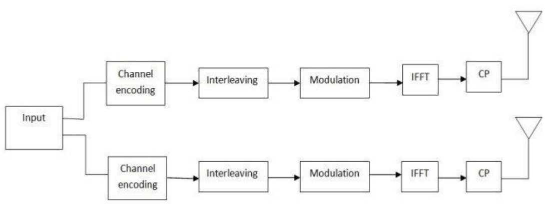

Fig. 2. Transmitter block diagram for Horizontal Encoding Structure.

III.VERTICAL ENCODING STRUCTURE

In Vertical Encoding (VE) case, all the de-multiplexed data streams are given the same modulation level and the

estimated assuming the symbol interference is perfectly cancelled which is known as Perfect Interference Cancellation (PIC) where the transmitter is also aware about the channel condition. The lower bound is derived assuming that there is an error and it is removed by minimum mean square error (MMSE) receiver.

code rate meaning a single MCS across all streams. The ML receiver performance is calculated by using two capacity bounds of linear receivers. The upper bound capacity is

The post detection of per stream SNR (γ_n^{ML}) of the ML receiver [9] [10] is given as

$$\gamma_n^{ML} = (1+\gamma_n^{PIC})^{\alpha\beta}(1+\gamma_n^{MMSE})^{1-\alpha\beta} -$$

where

$$\alpha \quad \frac{C_{Open} - C_{MMSE}}{C_{PIC} - C_{MMSE}} \quad 0 \le \quad \le 1$$

$C_{ML} - C_{MMSE}$

$C_{Open} - C_{MMSE}$ $, 0 \le \beta \le 1$

The capacities for PIC, MMSE, and Open-loop are given by

$$C_{PIC} \quad N_t \quad \log_2(1+\gamma_n^{PIC})$$

$$C_{OPEN} = \Sigma \log^n {}_2 \det(I_{Nr} + \rho HH^H)$$

where $\rho = p/(I_{Nt}\,\sigma_n^2)$

$$C_{MMSE} \quad \sum_{n}^{Nt} \log_2(1+\gamma_n^{MMSE}).$$

The SNR under conditions of PIC and MMSE is given by

$$\gamma_n^{PIC} = \rho \, \|h_n\|^2$$

$$\gamma_n^{MMSE} \quad \frac{}{[(I \quad \rho H^H H)^{-1}} \quad =N$$

$$C_{ML} = \quad N_t + \log_2(1+\gamma_n$$

The

$$C_{MMSE} \le C_{ML} \le C_{OPEN} \le C_{PIC}$$

The C_{ML} is the maximum achievable rate when ML receiver is used.

The optimal values of β for different MCS levels are complex calculation; the β value is taken directly from table. The β depends on the channel code rate. Here I_{Nt} is the identity matrix, ρ is the average SNR, H is a Rayleigh fading channel ,H^H is the Hermitian transpose, n is the n^{th} stream and *det* is the determinant.

IV.HORIZONTAL ENCODING STRUCTURE

In Horizontal Encoding (HE) case, all the de-multiplexed data streams are given different modulation levels and the code rates. The post detection of per stream SNR (γ_n^{ML}) of the ML receiver [9], [10] is obtained by modifying the equation (3) by

$$_n ML \quad (1+\gamma_n PIC)^{\alpha(\beta+\Delta\beta n)} (1+\gamma_n MMSE)^{1-\alpha(\beta+\Delta\beta n)} - 1. \quad (13)$$

Since there are non-identical modulation levels, we have a tuning parameter $\Delta\beta_n$ for each stream to adjust the value of β in (9). The $\Delta\beta_n$ is independent on channel code rate because detection performance is given by the minimum Euclidean distance of the symbol constellation. The tuning parameter $\Delta\beta_n$ for non identical MCS levels are given in Table.2 [9].

V.SIMULATION RESULTS

In this section, the simulation results of vertical and horizontal encoding technique for 2 x 2 MIMO-OFDM systems are analyzed. In Figure 4, the capacity of MIMO system is compared with different number of transmitter antennas and it shows that capacity increases with the increase in number of antennas.

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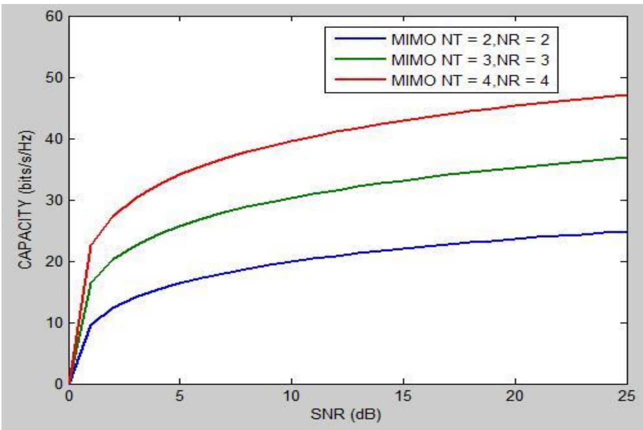
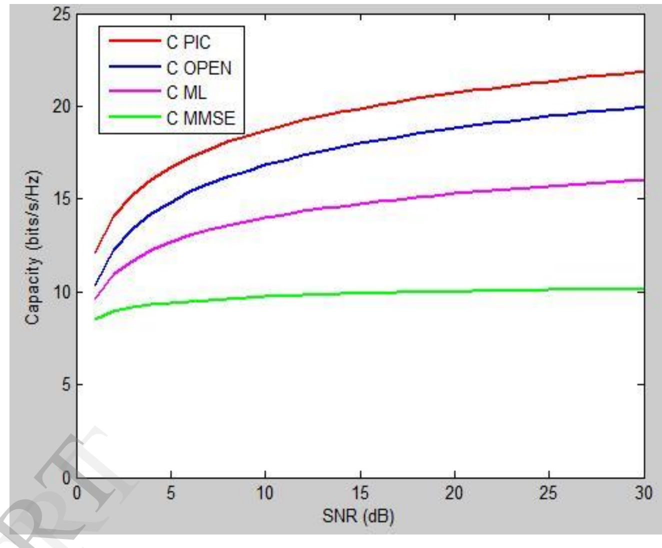
In Figure 5 and Figure 6 capacity conditions from equation (12) is proved for VE and HE structures. The capacity can be indirectly related to BER. The BER is reduced due to FEC by maximizing the possibility of detecting and receiving the corrupted data by adding redundancy to the transmitted data. It is concluded that when code rate is less, parity bits added are more so BER is reduced compared to higher order code rate from Figure 7.

Fig. 4. MIMO capacity



The Figure 8 concludes that when modulation level is low, BER is less. Whereas when modulation level increases, BER is increased. But higher modulation level has an advantage of transmitting more bits. Thus by reducing BER, the capacity is increased. Analyzes of the horizontal encoding structure for various non-identical MCS are shown in Figure 9 and Figure 10.

Fig. 5. VE capacity conditions proof



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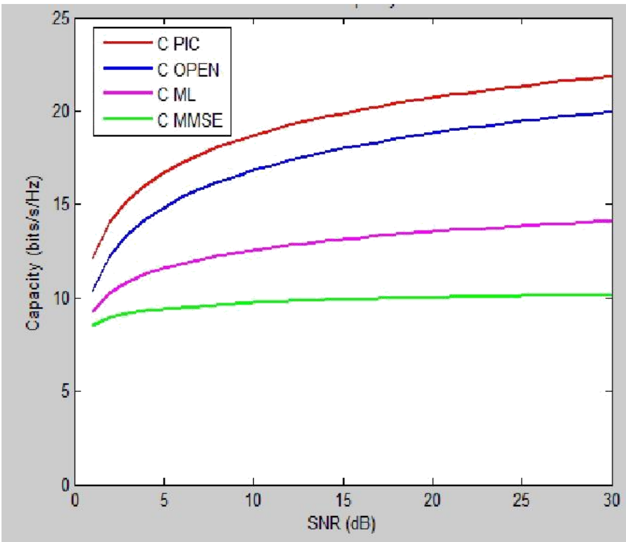

Fig. 6. HE capacity conditions proof

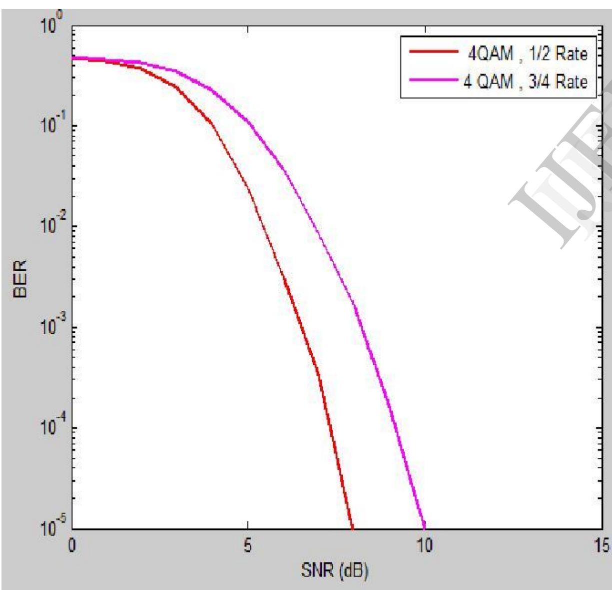

Fig. 7. VE Non-identical code rates.

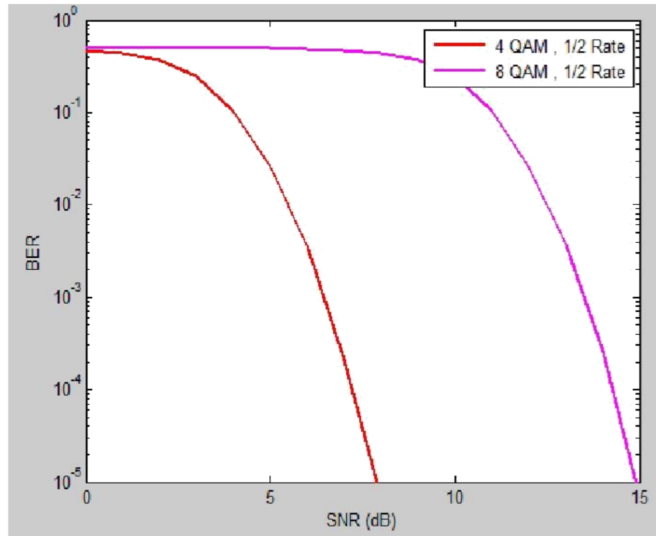

Fig. 8. VE Non-identical modulation levels.

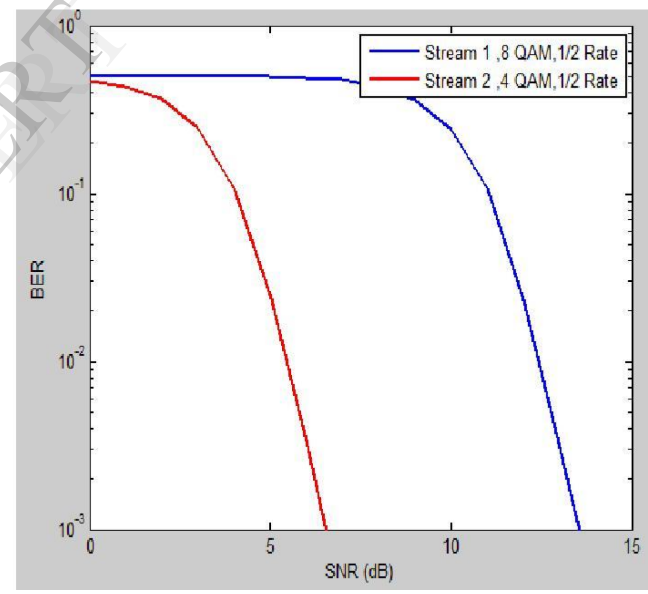

Fig. 9. HE Non-identical modulation levels.

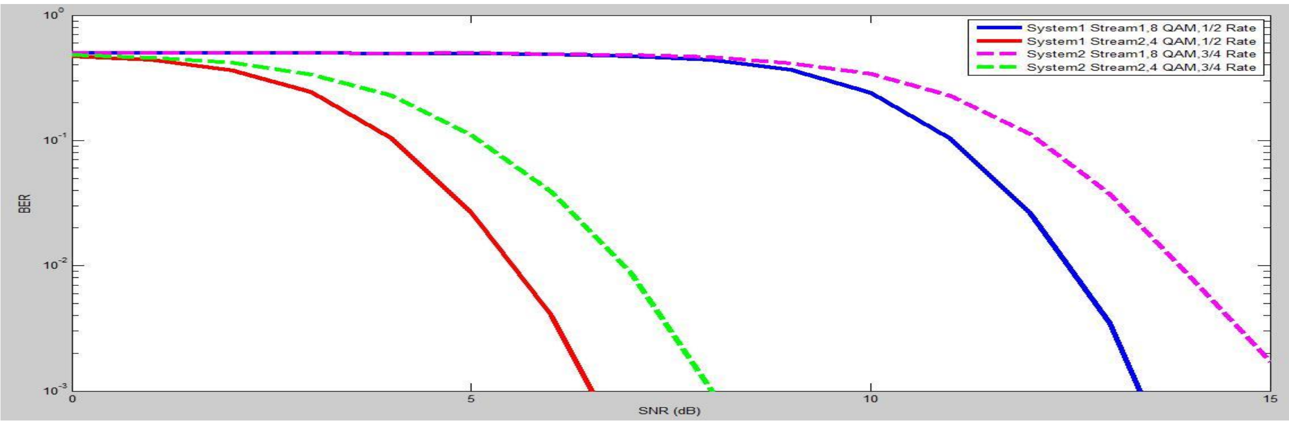

Fig. 10. HE Non-identical code rates.

VI. CONCLUSION

In this paper, capacity of MIMO-OFDM system is increased by using vertical and horizontal encoding technique. The RCPC codes give good error correction which can be used to improve capacity further. From simulation, it is concluded that, the optimal detection is given by ML receiver. Using vertical and horizontal encoding structures with ML receiver along with RCPC codes can give improved maximum data rate (capacity) for MIMO-OFDM systems.

REFERENCES

[1] I. E. Telatar, "Capacity of multi-antenna Gaussian channels," *Eur. Trans. Telecommun.*, vol. 10, pp. 585–595, Nov. 1999.

[2] G. J. Foschini and M. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," *Wireless PersonalCommun.*, vol. 6, pp. 311–335, Mar. 1998.

[3] M. Jankiraman, "Space time Codes and MIMO systems," published by Artech House.

[4] B. Vucetic, and J. Yuan, "Space Time Coding," published by John Wiley &Sons Inc,2003.

[4] I. Lee, A. Chan, and C.-E. W. Sundberg, "Space-time bit-interleaved coded modulation for OFDM systems," *IEEE Trans. Signal Process.*, vol. 52, pp. 820–825, Mar. 2004.

[5] K.-B. Song, A. Ekbal, S. T. Chung, and J. M. Cioffi, "Adaptive modulation and coding (AMC) for bit-interleaved coded OFDM (BICOFDM)," *IEEE Trans. Wireless Commun.*, vol. 5, pp. 1685–1694, July 2006.

[6]Sung-Hyun Moon, Kyoung-Jae Lee, Jihoon Kim, and Inkyu Lee, "Link Performance Estimation Techniques for MIMO-OFDM Systems with Maximum Likelihood Receiver," IEEE Transactions on wireless communications, vol. 11, pp. 1808 – 1816, no. 5, 2012.

[7] J. Kim, S.-H. Moon, C. K. Sung, and I. Lee, "A new SNR prediction method for MIMO-OFDM systems with maximum likelihood detector,"in *Proc. 2011 IEEE ICC*.

[8]J. Hagenauer, "Rate-compatible punctured convolutional codes (RCPC codes) and their applications," *IEEE Trans. Commun.*, vol. 36, pp. 389–400, Apr. 1988.

[9]W. T. Webb and R. Steele, "Variable rate QAM for mobile radio," *IEEE Trans. Commun.*, vol. 43, pp. 2223–2230, July 1995.