International Journal of Emerging Engineering Research and Technology
Volume 3, Issue 12, December 2015, PP 60-66
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Performance Analysis of Adaptive MIMO OFDM Systems

[1]C.Padmaja, [2]Dr.B.L.Malleswari

[1]*Research Scholar, JNTUH, Hyderabad, India*
[2]*Principal, Sreedevi College of Engineering, Hyderabad, India*

ABSTRACT

In a wireless environment, the time varying and frequency selective channel distorts the transmitted signal, so that accurate and real time channel estimation is the challenging topic in the MIMO OFDM system. Channel state information from the receiver can be used for the detection of the signal and for improving the capacity of the system throughput by adjusting the modulation at the transmitter through the feedback.

The proposed channel estimation method based on pilot pattern arrangement by sending pilots at every sub carrier can eliminate the inter carrier interference (ICI). Signal to noise ratio is estimated at receiver and then transmitted to the transmitter through feedback channel. According to the estimated SNR, the transmitter select appropriate modulation scheme and coding rate which maintain constant bit error rate lower than the target BER. Simulation results show that better performance is confirmed for target bit error rate (BER) of (10-3) as compared to conventional modulation schemes. The convolution coded modulation offers a SNR gains of 5 dB compared to uncoded state at BER of 10-3. The proposed adaptive MIMO OFDM scheme maintains fixed BER under changing channel conditions.

Keywords: MIMO-OFDM; AMC block; CSI; M-QAM; BER; SNR; MRC.

INTRODUCTION

To balance the performance according to the signal's strength, adaptation of the coding rate and modulation allows for a higher degree of flexibility and is referred to as Adaptive Modulation and Coding (AMC).

The idea of adaptive modulation and coding (AMC) is to dynamically change the modulation and coding scheme in subsequent frames with the objective of adapting the overall throughput or power to the channel condition. In fact, when employing orthogonal frequency division multiplexing (OFDM) over a spectrally shaped channel the occurrence of bit errors is normally concentrated in a set of severely faded sub carriers, which should be excluded from data transmission. On the other hand, the frequency domain fading, while impairing the signal-to-noise ratio of some sub-carriers, may improve others above the average signal-to-noise ratio. Hence, the potential loss of throughput due to the exclusion of faded sub carriers can be mitigated by using higher order modulation modes on the sub-carriers exhibiting higher signal-to-noise ratio. In addition, other system parameters, such as the coding rate of error correction coding schemes, can be adapted at the transmitter according to the channel frequency response [Benvenuto and Tosato, 2004].

The multiple-input multiple-output (MIMO) technology is proven to be able to significantly increase the wireless system capacity for the same total transmission power [6] used in SISO. Its fundamental mechanism lies on the use of space-time frequency coding (STFC) [6]-[9]. In STFCs, signals are coded both in spatial, temporal and frequency domains, for example, using the Alamouti code [9] or other similar codes [7]-[9]. Alamouti code is designed for frequency flat fading and is capable of providing full rate and full diversity for up to two Tx and two Rx antennas. As a result, it enhances the diversity order and improves the link quality and capacity. The combination of ABICM with STF coding gives an additional improvement in the order of 1 to 3 dB can be achieved with this scheme. The improvement practically means a possible 12.5% to 50% further reduction of the total transmitted power, compared to the non-adaptive system. In other words, the adaptive scheme can significantly reduce the power consumption.

Address for correspondence:

padmaja.chennapragada@gmail.com

The rest of the paper is organized as follows. In section 2, a general ABICM-STFC-MIMO system structure is introduced. In section 3, the analytical performance measures are shown. In section 4, simulation results are discussed. In section 5, concluded the paper.

SYSTEM MODEL

The analytical approach is applied to evaluate the performance of MIMO schemes with delayed feedback, and to propose closed-form expressions for the adaptation thresholds.

Based on the modulation and coding applied, maximizes spectral efficiency, while maintaining a certain QoS measured over the probability of error.

As shown in Figure 1, the system combined with a MIMO and AMC blocks. The transmitter selects the appropriate M-QAM level to modulate data, and maps the symbols to the available antennas in the MIMO encoder. Assume the perfect channel estimation at the receiver. Then the terminal communicates the SNR in the CSI format via the feedback channel to the transmitter. Based of the CSI, the system selects the rate, i.e., the constellation size of the modulation to be transmitted.

Consider channel is characterized by a Rayleigh fading channel and the spatial links experience independent fading.

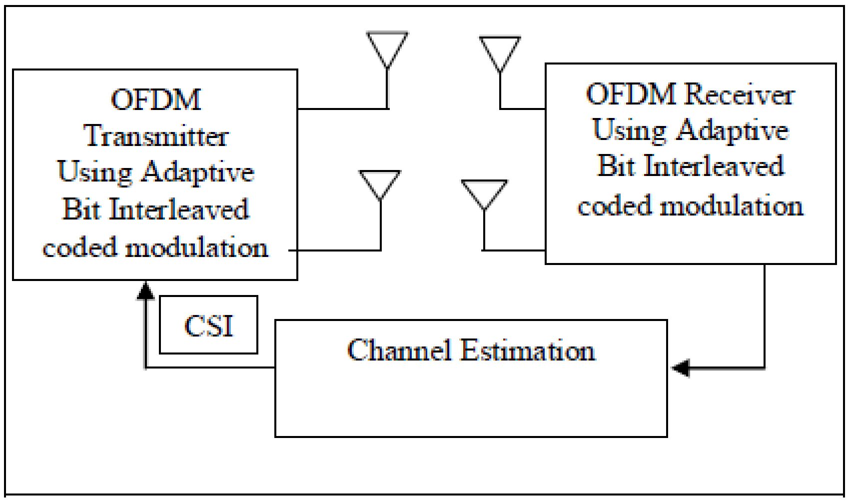

Figure1. *Block Diagram of ABICM-MIMO OFDM*

Channel Estimation

Consider a robust channel estimation algorithm such that the time-varying frequency response of the channel is modelled as a wide sense stationary (WSS) random process in both frequency and time.

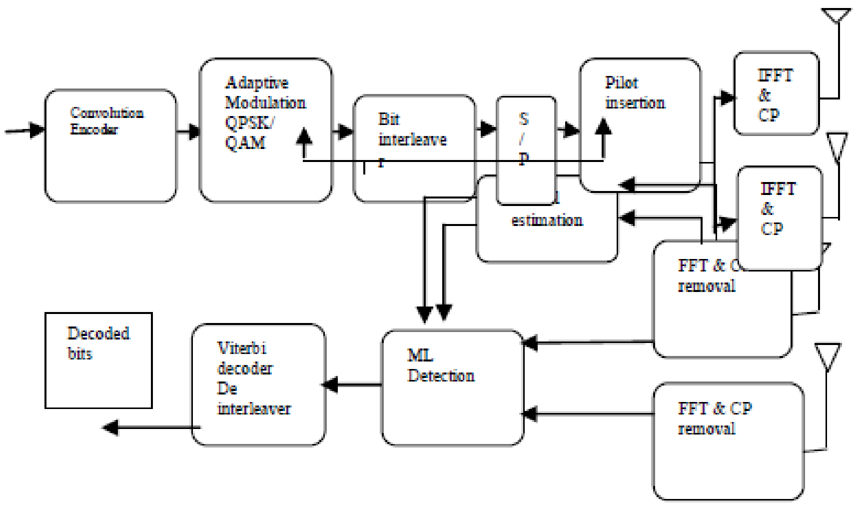

Figure2. *Channel estimation model of MIMO OFDM using ABICM*

The proposed adaptive OFDM system used in the test is shown in Figure (1). The transmitter codes the input data by the convolutional coder that is efficient in the multipath fading channel. The convolutional coder uses the code rate (R=1/2) and the constraint length (k=7). The encoded data are interleaved and modulated, the coded serial bit sequences are converted to the parallel bit sequences. The OFDM time signal is generated by an inverse FFT and is transmitted over the Rayleigh fading channel after the zero prefix extension has been inserted. Doppler frequency is assumed to be 5Hz (slow flat fading). In the receiver side, the received signal is serial to parallel converted and passed to a FFT operator, which converts the signal hack to the frequency domain. This frequency domain signal is coherently demodulated. Then the binary data is decoded by the Viterbi hard decoding algorithm.

The main concept of adaptive coding and modulation is to maintain a constant performance by varying transmitted power level, modulation scheme, coding rate or any combination of these schemes .This allows us to vary the data rate without sacrificing BER performance .Since in land mobile communication systems , the local mean value of the received signal level varies due to the fading channel, Adaptive coding and modulation is an effective way to achieve high data rates and it has proved to be a bandwidth efficient technology to transmit multimedia information over mobile wireless channels. It can be described as follows:

$$\text{Modulation mode} = \begin{cases} M_1 & cq < I_1 \\ M_2 & I_1 < cq < I_2 \\ \cdot & \\ \cdot & \\ \cdot & \\ M_n & I_{n-1} < cq \end{cases}$$

Where M_1, M_2... M_n, are n different modulation modes varying from lower multi-level modulation to higher multilevel modulation with increasing order. cq is the estimated channel quality expressed in terms of the signal-to-noise ratio SNR of the mobile wireless channel, I_1, I_2,….., I_{n-1} are the switching thresholds between different modulation modes.

The selection of modulation mode for the next transmission heavily depends on the current channel quality estimation. If the channel quality can be measured accurately, ideal switching between different modes is available. The system could have the highest performance under such circumstances, if the switching thresholds are selected carefully. In other words, in the scenario of no channel quality estimation error, the effectiveness of the adaptive modulation system will be decided mainly by the selection of the switching thresholds **[Long and Lo, 2003].** Modulation scheme and coding rate are the most common parameters used in adaptive modulation.

The MIMO system equation can be written as,

$$y_{k,l}^{j} = \sqrt{E_s}\sum_{i=1}^{N_t} H_{k,l}^{i,j} x_{k,l}^{i} + n_{k,l}^{j}$$

$$H_{k,l}^{i,j} = \sum_{n=1}^{K} \overline{h}^{i,j}(n) e^{\frac{-j2\pi k T_n}{FT}} = \overline{h}_{i,j}^{*} w_k$$

$$y_k = \sqrt{E_s} H_k X_k + N_k \tag{1}$$

Where $n_{k,l}^{j}$ denotes the AWGN with zero mean and variance σ_w^2, $H(i,k)$ is the frequency response of the radio channel at the k-th subcarrier of the i-th OFDM symbol. Then, the received pilot signal $Y_p(i,k)$ is extracted from $Y(i,k)$ to perform channel estimation.

The channel estimation in frequency domain at pilot subcarriers for i-th OFDM symbol can be given by

$$\tilde{\mathbf{H}}_{p,fast\,lmmse}(i) = \tilde{\mathbf{R}}_{\mathbf{H}_p\mathbf{H}_p}\left(\tilde{\mathbf{R}}_{\mathbf{H}_p\mathbf{H}_p} + \frac{\beta}{\widetilde{SNR}}\mathbf{I}\right)^{-1}\tilde{\mathbf{H}}_{p,ls}(i), i = 0,1,\ldots,N_{MST}-1.$$

System Capacity

It is well known that MIMO system capacity is defined by

$$C=\max I(X,Y)$$

Where $p(\mathbf{X})$ is the probability density function (PDF) of the transmitted signal $\mathbf{X}$, $I(\mathbf{X,Y})$ is the mutual information between $\mathbf{X}$ and $\mathbf{Y}$. The mutual information $I(\mathbf{X,Y})$ can be further written as

$$I(\mathbf{X,Y})=H(\mathbf{Y})-H(\mathbf{w})$$

where $H(\mathbf{Y})$ and $H(\mathbf{w})$ are the entropies of the received signal $\mathbf{Y}$ and AWGN noise $\mathbf{w}$. If σ^2 is the variance of the AWGN noise, **RXX** is the autocorrelation matrix of $\mathbf{X}$, $\mathbf{I}_{\mathbf{Nr}}$ is an N_R by N_R identity matrix, **(·)**H denotes the Hermitian transpose.

Then the mutual information can be further derived as

$$I(X,Y)=\log_2 \det\left[I_{Nr}+\frac{P}{N_T\sigma_w^2}HR_{xx}H^H\right]$$

Constellation size can be determined based on current channel condition and predefined BER, to approach the capacity.

$$C_{STFBC}=E\left\{\frac{N}{T}\log\left(1+\frac{P_T}{M_T\sigma^2}\|H\|_F^2\right)\right\} \tag{2}$$

Where N is the number of symbols transmitted in a block and T is the block length. $\|.\|_F$ is the Frobenius form. In 2X2 design N/T is 1.The relation of SNR (γ_i), BER (P_b)and constellation size (M_k) for coherent detection is approximated in [10]:

$$P_b \approx 0.2\exp\left(-1.5\frac{\gamma_i}{M_k-1}\right) \tag{3}$$

Where $M_k \geq 4$ and $P_b \leq 10^{-3}$

With a predefined P_b, the SNR thresholds can be easily found for every constellation size.

$$\tau_k=\frac{M_k-1}{1.5}\ln\frac{1}{5p_b} \tag{4}$$

The expression for uncoded BER performance of square M-QAM with Gray bit mapping over AWGN is approximated with [4]

$$BER(M,\gamma)\approx\frac{2}{\log_2 M}\left(1-\frac{1}{\sqrt{M}}\right)erfc\left(\sqrt{1.5\frac{\gamma}{M-1}}\right) \tag{5}$$

Where

$$erfc(z)=\frac{2}{\sqrt{\pi}}\int_Z^{\infty}e^{-t^2}\,dt$$

ANALYTICAL PERFORMANCE MEASURES

In an adaptive rate system based on predicted values of the SNR, the average BER for discrete rate adaptation with R constellations and the average spectral efficiency are

$$\overline{BER}=\frac{\sum_{i=0}^{R-1}\log_2(M_i)\int_{\gamma_i}^{\gamma_i+1}BER(\hat{\gamma})f(\hat{\gamma})d\hat{\gamma}}{\sum_{i=0}^{R-1}\log_2(M_i)\int_{\gamma_i}^{\gamma_i+1}f(\hat{\gamma})d\hat{\gamma}} \tag{6}$$

$$\eta_{eff}=\sum_{i=0}^{R-1}\log_2(M_i)\int_{\gamma_i}^{\gamma_i+1}f(\hat{\gamma})d\hat{\gamma}\left(1-\log_2(M_i)\int_{\gamma_i}^{\gamma_i+1}BER(\hat{\gamma})f(\hat{\gamma})d(\hat{\gamma})\right) \tag{7}$$

As used in [6], the probability of ith fading region in a Rayleigh channel can be expressed as follows:

$$\int_{\gamma_i}^{\gamma_i+1}f(\gamma)d\gamma=\frac{\Gamma\left(N_t,N_r,\frac{N_t}{\bar{\gamma}}\gamma_i\right)-\Gamma\left(N_t,N_r,\frac{N_t}{\bar{\gamma}}\gamma_{i+1}\right)}{\Gamma(N_t,N_r)} \tag{8}$$

where Γ (.) is the complete gamma function, and Γ(., .) is the incomplete gamma function.

From this closed-form expression, the average BER within a single fading region can be expressed for MIMO diversity scheme is

$$\overline{BER}_i = \begin{cases} \int_{\gamma_i}^{\gamma_i+1} BER(M_i,\gamma)\, f(\gamma) d\gamma \\ 0.2\left(\frac{N_t}{\bar{\gamma}}\frac{1}{b_i}\right)^{N_t N_r} \frac{\Gamma(N_t, N_r, b_i\gamma_i) - \Gamma(N_t, N_r, b_i\gamma_{i+1})}{\Gamma(N_t, N_r)} \end{cases} \quad (9)$$

SIMULATION RESULTS

The simulation parameters are listed in Table (1). The system is operating at a sampling rate of 20MHz. It uses 64-point FFT. The OFDM symbol duration worth's 66 sample where 64 is for data while 2 is ZP. Using different modulation schemes combined with interleaving of the convolution encoder, 5 different data rate are defined. The data rate is calculated using,

Data rate= ($bits_{carrier}$* $N_{carriers}$* CR)/ T_{OFDM} .

Table1. *Simulation Parameters*

Sampling rate	20 MHz
Number of FFT points	64
Number of carriers ($N_{carriers}$)	64
No. of input serial bits	100000 bits
OFDM symbol period (T_{OFDM})	3.3 μs
Coding	Convolution coding
FFT symbol period	3.2 μs
Data rate	19, 32,48,72,96 Mbps
Modulation scheme	QPSK, 16QAM, 64QAM, 256QAM
Demodulation	Coherent detection
Channel	Rayleigh

The theoretical required E_s/N_o to satisfy a BER_{req} under Rayleigh Conditions are shown in table 2.

Table2. *Theoretical SNR*

BER_{req}	BPSK	QPSK	16QAM	64QAM
10^{-2}	4.3dB	7.3 dB	13.9 dB	19.6 dB
10^{-3}	6.8 dB	9.8 dB	16.5 dB	22.6 dB
10^{-4}	8.4 dB	11.4 dB	18.2 dB	24.3 dB
10^{-5}	9.6 dB	12.6 dB	19.4 dB	25.6 dB

At an operating BER of (10^{-3}), there is no modulation scheme that gives the desired performance at an SNR below 6.8 dB. Therefore, 1/2 QPSK is chosen as it is the most robust. Between 6.8 and 12.5 dB, there is only one scheme that gives performance below (10^{-3}), and that is 1/2 QPSK. Between 12.5 and 15.5 dB, 1/2 16-QAM gives the desired BER at a better spectral efficiency than 1/2 QPSK. Between 15.5 and 23dB, 3/4 16- QAM gives the desired BER at a better spectral efficiency than 1/2 16- QAM. Between 23 and 30 dB, 3/4 64-QAM gives the desired BER at a better spectral efficiency than 3/4 16-QAM. And at SNR higher than 30dB, 256-QAM gives the best spectral efficiency while providing the desired BER performance.

The adapted transmission modes and rate based on channel estimation is given in table 3.

Table3. *Practical SNR to meet BER_{req}*

	M1	M2	M3	M4	M5
Modulation	QPSK	16QAM	16QAM	64QAM	256QAM
Coding rate	1/2	1/2	3/4	3/4	3/4
SNR(dB) at BER=10^{-3}	6.8	12.5	15.5	23	29

By considering the BER_t = 10^{-3}, the receiver tracks continuously the post processing SNR, and the M-QAM order is computed based on the SNR thresholds.

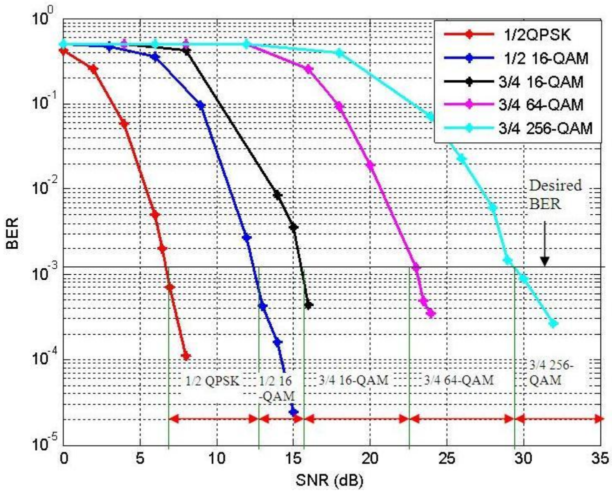

Figure2. *BER of adaptive OFDM system using STFC*

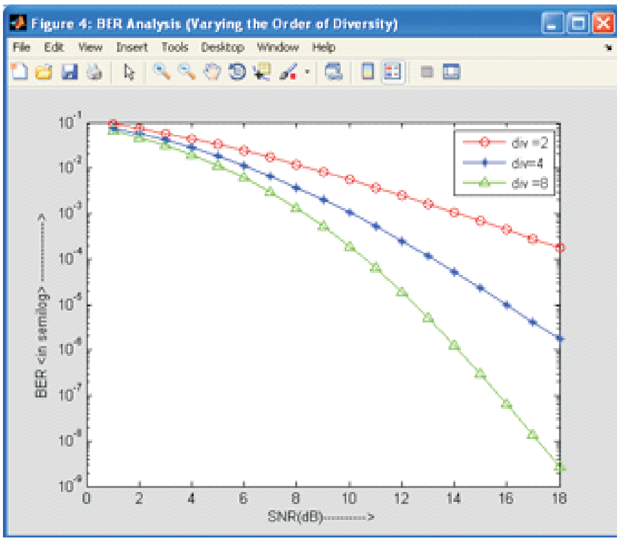

Figure3. *BER analysis (Varying the order diversity)*

If BER threshold is less, a lower-order QAM format is selected than the current modulation format to improve the SNR margin. For example, if BER of the 16QAM signal becomes worse than the upper limit of the BER threshold in the restoration path, 8QAM or QPSK is then chosen. On the other hand, if BER becomes better than the lower limit of the BER threshold, a higher-order QAM format is selected to provide the high spectral efficiency.

CONCLUSION

The ACM scheme enhances the performance of the OFDM wireless communication system. The results show that the ACM scheme adjusts effectively to the channel environment as it allocates (1/2 QPSK) to the decreasing SNR value and (1/2 16-QAM, 3/4 16-QAM, 3/4 64-QAM and 3/4 256-QAM) to the increasing SNR value. .

The ACM system provides better spectral efficiency. However, as the SNR increases, the throughput also improve steadily, which indicates that more spectrally efficient transmission mode is used without excessive complexity.

REFERENCES

[1] Antonis Phasouliotis and Daniel K.C, "Performance analysis and comparison of downlink MIMO MC-CDMA and MIMO-OFDMA systems", IEEE Communication Surveys &Tutorials, Vol.11, No.2, Second Quarter 2009.

[2] A.Moulisch, Wireless Communication. Wiley-IEEE Press,2005.

[3] D.G.Brennan, "Linear Diversity Combining Techniques", Proc. IRE, vol. 47, pp.1075-1102, June 1959, Reprint: Proc.IEEE, vol. 91, no. 2, pp. 331-356, Feb. 2003.

[4] Alamounti, S.M. (1998) A simple transmit diversity scheme for wireless communications. IEEE J. Select. Areas Commun., 16(8), 1451–1458.

[5] Tarokh, V., Jafrakhani, H., and Calderbank, A.R. (1999) Space-time block codes from orthogonal designs. IEEE Trans. Inform. Theory, 45(5), 1456–1467.

[6] Jan Mietzner, et.al, "Multiple-Antenna Techniques for Wireless Communication -A Comprehensive Literature Survey", IEEE Communication Surveys &Tutorials, Vol.11, No.2, Second Quarter 2009.

[7] Thesis of Eric Lawrey on OFDM modulation technique for wireless radio applications, submitted on October 1997.

[8] Bhasker gupta and Davinder S.Saini, "BER Analysis of Space-FrequencyBlock Coded MIMO-OFDM Systems Using Different Equalizers in Quasi-Static Mobile Radio Channel" Proc. of International Conference onCommunication Systems and Network Technologies (CSNT-11), pp. 520-524, 3-5 June 2011.

[9] Ankita Shukla and Prof. Abhishek Choubey, "Multi-Input Multi-Output Fading Channel Equalization with Constellation Selection and Space-Time Precoders," *International Journal of Advanced Computer Research (IJACR),* vol. 1, no. 1, September 2011.

[10] Ms. Sonal Sharma and Prof. Sumit Sharma, "An Analytical Approach for Efficient OFDM Modulator and Demodulator Communication Systems Based On Discrete Hartley Transform", *International Journal of Advanced Computer Research (IJACR),* vol. 1, no. 1, September 2011.

[11] Ms. Hema Singh and Mr. Aaditya Khare, "An Approach Based on MIMO and PN Sequence coding for Reduction of Peak to Average Power Ratio (PAPR) in Clipped OFDM", *International Journal of Advanced Computer Research (IJACR),* vol. 1, no. 1, September 2011.

[12] Zhang Jie, Liu Liang and Li Jin, "Performance Analysis of Space Time Block Code in MIMO-OFDM Systems", *IEEE* 2011.

[13] Manisha Rathore and Puspraj Tanwar, "Reduction of Co-Channel Interference in transmit/Receive diversity (TRD) in MIMO System", *International Journal of Advanced Computer Research (IJACR),* vol. 2, no. 3, Issue 5, September 2012.

[14] Saket kumar and Puspraj Tanwar, "Removal of cyclic prefix in Adaptive Non-Contiguous OFDM for Dynamic Spectrum Access using DWT and WT", *International Journal of Advanced Computer Research (IJACR),* vol. 2, no. 3, Issue 5, September 2012.

[15] Santanu Kumar Sahoo and Mihir Narayan Mohanty, "Effect of BER Performance in RLS Adaptive Equalizer", *International Journal of Advanced Computer Research (IJACR),* vol. 2, no. 4, Issue 6, December 2012.

[16] G. Bauch and J. Hagenauer, "Analytical evaluation of space-time transmit diversity with FEC-coding," in *Proc. IEEE Global Communications Conference(GLOBECOM), vol. 1, San Antonio, TX, USA, November 2001, pp.*435–439.

[17] L. T. Berger, T. E. Kolding, J. Ramiro-Moreno, P. Ameigeiras, L. Schumacher, and P. E. Mogensen, "Interaction of transmit diversity and proportional fair scheduling," in *Proc. IEEE Vehicular Technology Conference (VTC), vol. 4, Jeju, Korea, April 2003.*

[18] J. P. Burke, J. R. Zeidler, and B. D. Rao, "CINR difference analysis of optimal combining versus maximal ratio combining," *IEEE Transactions on Wireless Communications, vol. 4, no. 1, pp. 1–5, 2005.*

[19] C. Chayawan and V. A. Aalo, "Average error probability of digital cellular radio systems using MRC diversity in the presence of multiple interferers," *IEEE Transactions on Wireless Communications, vol. 2, no. 5, pp. 860–864,* 2003.

[20] S. Catreux, V. Erceg, D. Gesbert, and R. W. Heath Jr, "Adaptive modulation and MIMO coding for broadband wireless data networks," *IEEE Communications Magazine, vol. 40, no. 6, pp. 108–115, 2002.*