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BER Performance of Multilevel Linear Block Codes with Error Correction on RICIAN Fading Channel

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ABSTRACT
Linear block codes (LBCs) generally provide good error detection and correction capability, but only transmit one data symbol per time slot. Using higher order modulations incurs high decoding complexity and lengthy code searches. Multi-layer schemes using multiple LBCs over sub-groups of antennas provide higher throughput, but require as many receive as transmit antennas and have reduced diversity gains. Here, development of multilevel LBCs that can provide the high throughput of multi-layered schemes while realizing larger diversity gains. Any number of receive antennas can be used. An example is shown that achieves 4 bits/sec/Hz using 16-QAM and 2 transmit antennas.

Keywords-Linear block code, MIMO, Multilevel code, Rician fading channel

I. INTRODUCTION

Linear block codes are a class of parity check codes that can be characterized by the (n, k) notation. The encoder transforms a block of k message digits (a message vector) into [1] a longer block of n codeword digits (a code vector) constructed from a given alphabet of elements. When the alphabet consists of two elements (0 and 1), the code is a binary code comprising binary digits (bits). The k-bit messages form 2^k distinct message sequences, referred to as k-tuples [1] (sequences of k digits). The n-bit blocks can form as many as 2^n distinct sequences, referred to as n-tuples. The encoding procedure assigns to each of the 2^k message k-tuples *one* of the 2^n n-tuples.

The code rate $\mathbf{R} = k/n$. For a binary code, $\mathbf{R} \leq 1$, so after encoding a k-digit message or information block, there [2] are $n - k$ remaining redundant digits in the code word. The redundant digits give the code words the ability to reduce the effect of channel noise, which could introduce errors during the transmission of the message.

Multilevel coding allows [3] the construction of a high complexity coded signal constellation using simple component codes. Multilevel coding utilizes, antenna grouping and linear block codes to develop *multilevel linear block codes* (MLLBCs), capable of simultaneouslyproviding coding gain, diversity improvement and increasedspectral efficiency. A key advantage of the MLLBCstructure is that, by using multistage decoding, instead of a fixed number of receive antennas any number ofreceive antennas can be used. Decoding complexity remainsmanageable even for high [3] order modulations.

II. SYSTEM MODEL

MIMO wireless system is shown in Fig. 1, with n_T transmit antennas and $n_R$receive antennas. The symbol transmitted at time t by the i^{th} transmit antenna is denoted byQ_t^i, $1 \leq i \leq n_T$. The channel exhibits [4] Rician fading over the frame duration. This means that fading is constant only for one frame duration and varies independentlybetween frames from one frame to the other. Also, perfect channel state information (CSI) is available at the receiver only.

The received signal at time t, at the j^{th} receive antenna is a noisy superposition of independently faded versions of the n_T transmitted signals and is denoted byr_t^j, $1 \leq j \leq n_R$. The discrete complex baseband output [5] of the j^{th} receive antenna at time t is given by:

$$r_t^j = \sum_{i=1}^{n_T} h_{j,i}^t Q_t^i + \eta_t^j \quad (1)$$

where, $h_{j,i}^t$is the path gain between the i^{th} transmit andj^{th}receive antennas; and η_t^j is the noise associated with the j^{th} receive antenna at time t. Multilevel codes are usually decoded by a staged decoder which [5] operates in a sequential manner. First the decoder at level L makes a decision on the code C_L and outputs the corresponding data bits, $\mathbf{b}_L$. This decision information is then passed on from stage L to stage $L-1$ and the decoder at level $L-1$ operates in a similar way, giving$\mathbf{b}_{L-1}$ at the output and the corresponding co-subset information. The process continues down the partition chain until the received sequence is completely decoded [6].In this LBCs are used as the component codes and accordingly we can decode them at each level. Also identical linear block codes are used at each of the 2 used levels.

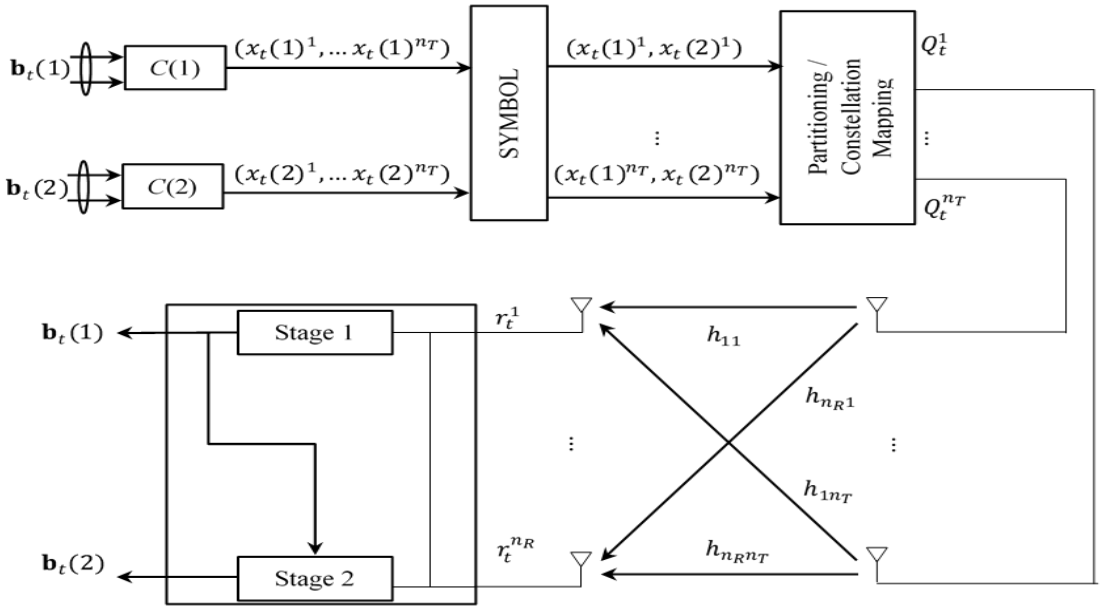

Figure 1: Multilevel MIMO System.

The Rician distribution degenerates to a Rayleigh distribution when the dominant component fades away. The Rician distribution is given by:

$$p(r) = \begin{cases} \frac{r}{\sigma^2} e^{-\frac{r^2+A^2}{2\sigma^2}} I_0\left(\frac{Ar}{\sigma^2}\right) & \text{for}(A \geq 0, r \geq 0) \\ 0 & \text{for}(r < 0) \end{cases} \quad (2)$$

The parameter A denotes the peak amplitude of the dominant signaland $I_0(\bullet)$ is the modified Bessel function of the first kind and zero-order.The Rician distribution is often described in terms of a parameter K which is [7] defined as the ratio betweenthe deterministic signal power and the variance of the multipath.It is given by$K = A^2/(2\sigma^2)$) or, in terms of dB:

$$K(\text{dB}) = 10 \log \frac{A^2}{2\sigma^2} \,\text{dB} \quad (3)$$

The parameter K is [8, 9] known as the Rician factor and completely specifies the Rician distribution. As$A \rightarrow 0, K \rightarrow -\infty$ dB, and as the dominant path decreases in amplitude, the Rician distribution degenerates to a Rayleigh distribution [10].

III. RESULTS AND DISCUSSION

The effect of error correction on the bit error rate (BER) performance of the code is considered in this section. Performance is evaluated using 2 transmit and different number of receive antennas. The BER performance of a system described as shown in the subsequent figures below. The spectral efficiency is 4 bits/sec/Hz and the underlying constellation is 16-QAM. Two identical (6, 3) Linear Block Codes were used as component codes. Assumed perfect CSI at the receiver only.

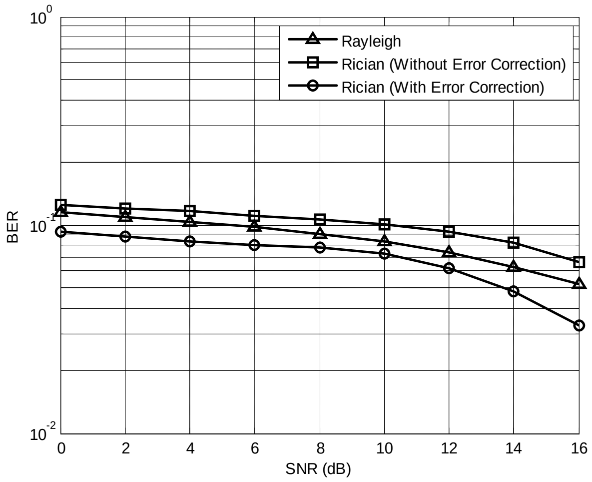

Figure 2: BER for one receive antenna.

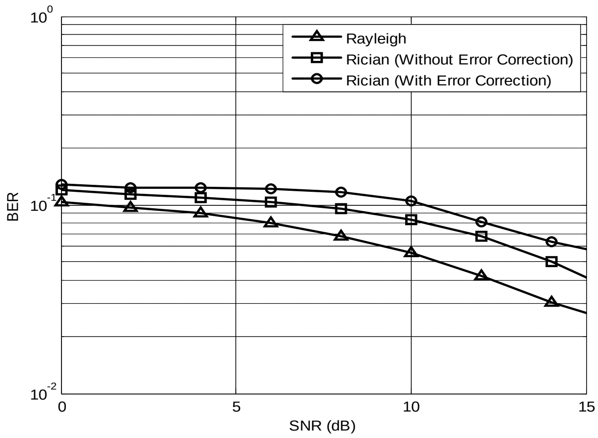

Figure 3: BER for two receive antennas.

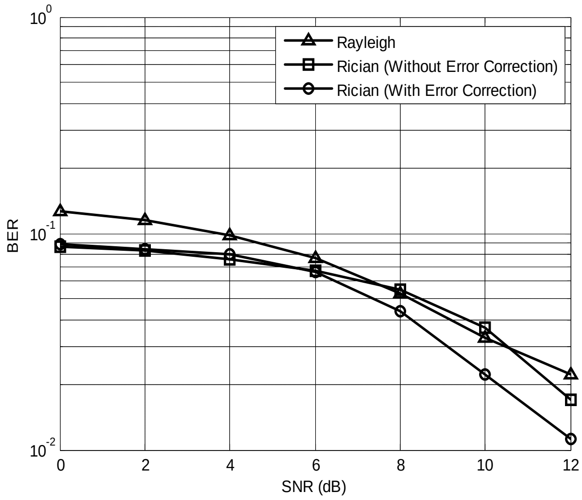

Figure 4: BER for four receive antennas.

Above results shows that there is a significant improvement in the BER performance of the multilevel system using linear block codes with error correction as compared with the same system but without error correction.

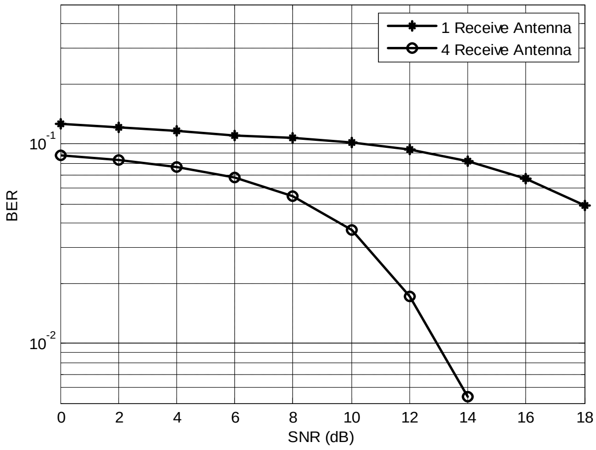

Figure 5: BER without Error Correction.

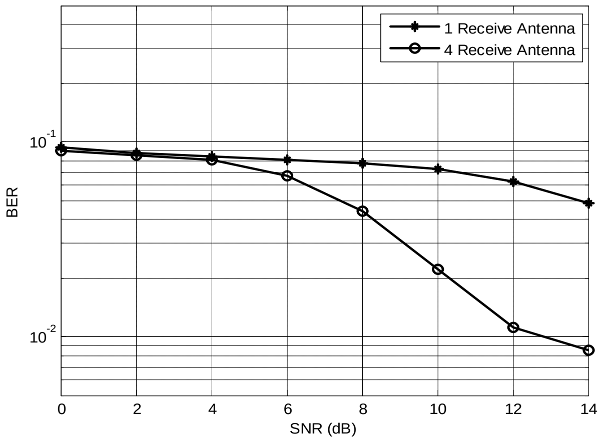

Figure 6: BER with Error Correction.

Fig. 2 demonstrates the error performance comparison for two transmit and one receive antenna, both with error correction and without error correction. It can be seen that with error correction the system is superior by about 4.1 dB at the BER of $10^{-1.2}$ in Rician fading channel. Fig. 3 shows that with error correction the system is superior by about 1.7 dB at the BER of 10^{-1} when compared with the system without error correction. Fig. 4 shows that with error correction the system is superior by about 1.7 dB at the BER of $10^{-1.4}$when compared with the system without error correction.

Next, consider the effect of receive diversity on the bit error rate performance of the system. The results shown in Fig. 5 and Fig. 6 reflect the fact that with an increase in the number of receive antennas we get a significant error performance gain.

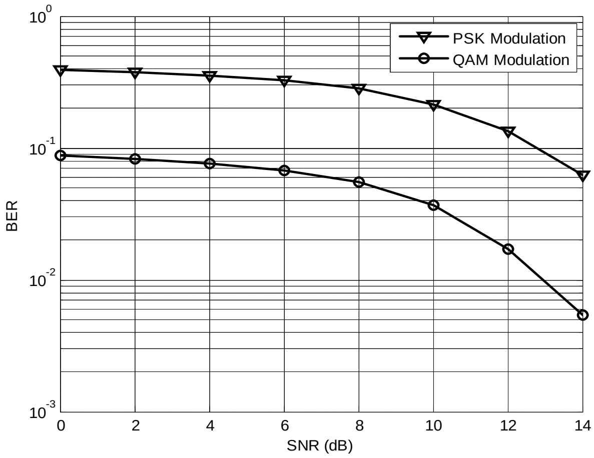

Figure 7: BER without Error Correction.

Fig. 7 and Fig. 8, shows the BER performance for 4 receive antennas, using QAM modulation and PSK modulation, without and with error correction, respectively. It can be seen that, with QAM modulation better BER performance achieved as compared to PSK modulation, in both cases (with and without error correction). Without error correction, the QAM modulation based system is superior as compared to the PSK modulation based system by about 5.7 dB at the BER of $10^{-1.5}$, whereas with error correction, it is superior by about 6.1 dB at the BER of $10^{-1.5}$.

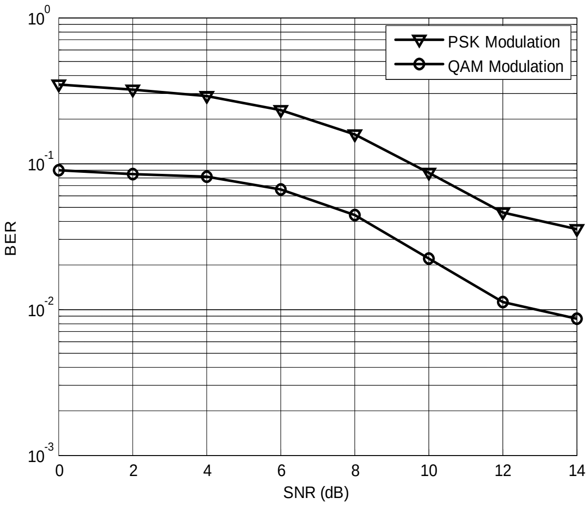

Figure 8: BER with Error Correction.

IV. CONCLUSION

Linear Block Codes perform up to mark in case error detection and correction problems. This capability of error detection and correction of the linear block codes in a multilevel environment then higher throughput achieved along with a reliable and less error prone wireless communication.

As expected, by comparing the performance of the linear block codes with and without error detection and error correction capability, the codes with error detection and error correction performed better at each and every point in terms of bit error rate.

As shown in the simulation results, significant improvement obtained in the BER performance with error correction. The system with 4 receive antennas performed better than the system with 1 and 2 receive antennas. Also if we changed the modulation from PSK to QAM, BER performance became better by huge margins.

REFERENCES

[1] G. J. Pottie, and D. P. Taylor, Multilevel codes based on partitioning, *IEEE Transactions on Information Theory, 35*, 1989, 387-98.

[2] U. Waschmann, R. F. Fischer, and J. B. Huber, Multilevel codes: Theoretical concepts and practical design rules, *IEEE Transactions on Information Theory, 45*, 1999, 1361-1391.

[3] P. A. Martin, D. M. Rankin, and D. P. Taylor, Multi-dimensional space-time multilevel codes, *IEEE Transactions on Wireless Communications, 5*, 2006, 2569-2577.

[4] M. Isaka, H. Imai, Z. Morelos and L. Shu, Multilevel codes and multistage decoding for unequal error protection, *Wireless Communication IEEE International Conference*, 1999, 249-254.

[5] M. Grossi, M. Lanzoni, and B. Ricco, A novel algorithm for high-throughput programming of multilevel flash memories, *IEEE Transactions, 50(5)*, 2003, 1290-1296.

[6] A. R. Calderbank, and N. Seshadri, Multilevel codes for unequal error protection, *IEEE Transactions on Information Theory, 39(4)*, 1993, 1234-1248.

[7] L. Huan-Bang, Y. Iwanami, T. Ikeda, Performance of a multidimensional BCM scheme with fading estimation based on time correlation, *Communications, 1993. ICC '93 Geneva. Technical Program, Conference Record, IEEE International Conference on, 1*, 1993, 443-447.

[8] M. Godavarti, A.O. Hero, Training in multiple-antenna Rician fading wireless channels with deterministic specular component, *Wireless Communications IEEE Transactions, 6(1*), 2007, 110-119.

[9] L. Gu-Rong, S.M. Moser, The Fading Number of a Multiple-Access Rician Fading Channel, *IEEE Transactions, 57(8)*, 2011, 4983-4991.

[10] Y. Xiangming, K. Yanmin, Y. Dongfeng, Performance analysis of turbo codes in wireless Rician fading channel with low Rician factor, *12th IEEE International Conference*, 2010, 48-51.