Precise Error Rate Analysis of MIMO System with Interference and Imperfect Channel State Information

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***Abstract*— In this paper, we derive closed-form solution for the bit error rate (BER) of multi-input multi-output (MIMO) system with maximum ratio combining (MRC). We consider binary PSK (BPSK) modulation suffering from cochannel interference(CCI) and imperfect channel state information (CSI). We assume a propagation model wherein the desired and interfering signals undergo independent and identically distributed (i.i.d.) Rayleigh fading channels. The numerical results presented in this paper demonstrate the system performance under very realistic propagation and detection conditions including MIMO system, CCI, imperfect CSI, generalized fading channels, and AWGN.**

I. Introduction

In the presence of CCI, optimum combining (OC) produces better performance than that of MRC since it maximizes the combiner signal-to-interference- plus-noise ratio (SINR) [1]. However, to implement OC, the knowledge of both the desired user's as well as the interferes' channel fading coefficients are needed at the receiver. This is basically a challenging task due to the time-variant characteristic of wireless channel which leads to dynamic interference environment. Hence, MRC is usually employed with MIMO combining, even in the presence of CCI and imperfect CSI, due to the simplicity of implementation. Therefore, it is of great interest to examine the ability of MIMO-MRC as a means for combating these impairments (CCI, imperfect CSI, multipath fading, etc.) all together.

In the absence of CCI and with perfect CSI, the performance of MIMO MRC systems is investigated in [2], [3], [4], [5], [6]. In [2], the average symbol error rate (SER) for M-ary systems under Rayleigh fading channel was analyzed for MIMO-MRC with arbitrary number of transmit and receive antennas. Closed-form solutions for the outage probability and the channel capacity for some MIMO-MRC systems were evaluated in [3]. The work in [4] took into account the system performance of two antennas, either in the transmitter side or the receiver side, in correlated-Rayleigh fading environment. As an extension to the work done in [4], the authors in [5] derived the SER and the outage probability of MIMO-MRC systems with arbitrary number of transmit and receive antennas. Moreover, in [6], the SER for several M-ary MIMO-MRC systems using the PDF based approach along with the distribution of the largest eigenvalue of $\mathbf{H}^H\mathbf{H}$ matrix were evaluated. We note that all the above results assume no CCI and perfect CSI.

Several authors have explored the performance of MIMO-MRC systems in the presence of CCI [7], [8], [9], [10], [11], [12], [13], [14]. The performance of MIMO-MRC systems in the presence of CCI was first handled for the special case of equal power interferers in [7]. In [8], the outage probability of MIMO-MRC systems with arbitrary numbers of transmit and receive antennas with unequal-power CCI was derived using the conventional PDF-based approach. Using the same PDF-based method, the outage probability of MIMO-MRC in the presence of both intracell and intercell interferences was derived in [9]. On the other hand, the error rate performance of MIMO-MRC under i.i.d. Rayleigh fading channels in the presence of CCI was investigated in [10]-[13]. The last four works are based on averaging the conditional BER (conditioned both on the desired user and the interference fading signals) over the distribution of the SINR or by using the moment generating function approach on the SINR. Such approaches yield to approximate solution since the distribution of the interference signals is approximated by normal RV using the central limit theorem. Recently, the author in [14] proposed an efficient analytical approach to calculate the error rate performance of MIMO-MRC systems suffers from CCI. Basri's approach in [14] is based on evaluating the conditional distribution of the MIMO combiner output conditioned only on the fading signal of the desired user. However, it is meaningful to note that the aforementioned works assume perfect CSI of the MIMO channel.

Few works that take into account the imperfect CSI scenario in the performance of MIMO-MRC systems can be found in [15], [16], [17], [18], [19]. The works in [15] and [16] have analyzed the performance of MIMO-MRC systems in the presence of Gaussian channel estimation errors in i.i.d. Rayleigh fading channels. The analysis in [15] and [16] assumes no CCI and including the evaluation of the conditional PDF of the output SNR for the case of two antenna at either the transmitter or the receiver side. On the other hand, the performance of MIMO-MRC with CCI and imperfect CSI is discussed in

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