Influence of Fading Parameter on Performance of SC System over Rician Fading in the Presence of Interference

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Abstract – **Performance of dual selection sombining (SC) diversity system operating on correlated Rician fading channels in the presence of correlated Rayleigh distributed cochannel interference (CCI) is analyzed in this paper. The infinity–series representation for the probability density function (PDF) of output signal–to–interference ratio (SIR) at such SC receiver is used to study average symbol error probability (ASEP) for M-PSK modulation scheme. Numerical results presented in this paper point out effects of correlation and fading severity on the system performance.**

Keywords - **Selection combining, Correlated Rician fading, Cochannel interference, Average symbol error probability.**

I. INTRODUCTION

The mobile terrestrial and satellite communication channel is particularly dynamic due to multipath fading propagation, having a strong negative impact on the average bit error probability (ABEP) of any modulation scheme [1]. Diversity is a powerful communication receiver technique used to compensate for fading channel impairments. The most important and widely used diversity reception methods employed in digital communication receivers are maximal-ratio combining (MRC), equal-gain combining (EGC), selection combining (SC) and switch and stay combining (SSC) [2-3]. Among these diversity schemes, SC is the least complicated, since the processing is performed only on one of the diversity branches and no channel information is required. Traditionally, in SC the combiner chooses the branch with the highest signal-to-noise ratio (SNR), which corresponds to the strongest signal if equal noise power is assumed among the branches [2]. However, in interference-limited fading environments as in cellular communication systems where the level of the cochannel interference is sufficiently high as compared to the thermal noise [4–9], the most effective performance criterion is to select the highest signal-to-interference ratio (SIR) [10-11]. There are many methods providing viable solutions for real-time SIR estimations under various channel conditions. These solutions are based on either the method of moments or the histogram matching concept [12]. The circuits for measurement are composed of an envelope detector, an analog-to-digital converter and a microcomputer. They are described in [13].

Several statistical models are used in communications system analysis to describe fading in wireless environments. Rayleigh, Nakagami-m, Rice, and Weibull distributions are the most frequently used. Moreover, several problems in wireless communications theory involve bivariate and, in general case, multivariate distributions. Examples of such problems can be found in the performance analysis of correlative fading applications. Particularly, in practice due to insufficient spacing between antennas, when diversity system is applied on small terminals with multiple antennas, correlation arises between branches [11], [14-17]. Despite the usefulness of the Rice model, there are not so many papers studied bivariate Rician PDF. Complicated form of bivariate Rician PDF was the reason to use numerical integration for calculation ABEP in [18]. Infinite–series representation of this PDF, presented in [16], converges rapidly, and thus, it can be efficiently used to analytical study performance criteria of dual-diversity receivers. In this paper, we consider SC diversity system with two correlated Rician fading channels in the presence of Rayleigh distributed cochannel interference (CCI).

In order to study the effectivness of any modulation scheme and the type of diversity used, it is required to evaluate the performance of system over channel conditions. Well-known measures, commonly used in wireless communications systems, are the outage probability, channel capacity, the average output SIR or SNR, and average symbol error probability (ASEP). Capitalizing on formula for PDF of output SIR at the SC receiver determined in our previous paper, ASEP for M-ary-phase shift keying (M-PSK, M = 8) modulation scheme is obtained. Numerical results for ASEP are graphically presented.

II. AVERAGE SYMBOL ERROR PROBABILITY

The Rician distribution is often used to model propagation path consisting of one strong direct line-of-sight (LoS) signal and many randomly reflected and usually weaker signals. Such fading model may be used to model both the microcellular radio environments and the mobile satellite

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fading channel [2], [19-20]. The novel form of bivariate Rician PDF is given as [21]:

$$p_{r_1 r_2}(r_1, r_2) = \frac{r_1 r_2 (1+K)^2}{\beta^2 (1-r^2)} \exp\left(-\frac{(r_1^2 + r_2^2)(1+K) + 4K\beta(1-r)}{2\beta(1-r^2)} \right) \cdot$$
$$\cdot \sum_{k=0}^{+\infty} \varepsilon_k I_k \left(\frac{r_1 r_2 r (1+K)}{\beta(1-r^2)} \right) I_k \left(\frac{r_1}{(1+r)} \sqrt{\frac{2K(1+K)}{\beta}} \right) I_k \left(\frac{r_2}{(1+r)} \sqrt{\frac{2K(1+K)}{\beta}} \right) \quad (1)$$

where β is average power of r_1 and r_2 defined as $\beta = \overline{r_1^2}/2 = \overline{r_2^2}/2$, K is Rice factor, $\varepsilon_k = 1\,(k=0)$, i.e. $\varepsilon_k = 2\ (k \neq 0)$, $I_k(\cdot)$ is the modified Bessel function of the first kind and k-th order and r is correlation coefficient, which is assumed to be real, and is defined $r = \mathrm{cov}(r_1, r_2) \big/ \sqrt{\mathrm{var}(r_1)\mathrm{var}(r_2)}$.

The bivariate PDF of Rayleigh distributed CCI is [10]:

$$p_{A_1,A_2}(A_1, A_2) = \frac{A_1 A_2}{\sigma_A^4 (1-r_A^2)} \exp\left(-\frac{A_1^2 + A_2^2}{2\sigma_A^2 (1-r_A^2)} \right) I_0 \left(\frac{A_1 A_2 r_A}{\sigma_A^2 (1-r_A^2)} \right) \quad (2)$$

where r_A is correlation coefficient and $\sigma_A^2 = \overline{A_1^2}/2 = \overline{A_2^2}/2$.

Instantaneous values of SIR at the diversity branches can be defined as $\mu_1 = r_1/A_1$ and $\mu_2 = r_2/A_2$. In interference-limited environment the SC combiner chooses input branch with the largest SIR, i.e. $\mu_{SC} = \max\{\mu_1, \mu_2\}$. The PDF of μ_{SC}, $p_{\mu_{SC}}(\mu)$, is shown in Eq. (3) at the bottom of the page, where ${}_2F_1$ (a,b,c,d) is Gaussian hypergeometric function [21-22].

The average symbol error probability at the output of SC, $\overline{P}_{se}$, can be derived by averaging the conditional error probability, $P_{se}(\mu)$, over PDF of the SC output SIR, i.e. [21], [23]:

$$\overline{P}_{se} = \int_0^{\infty} P_{se}(\mu) p_{\mu_{sc}}(\mu) d\mu \quad (4)$$

$P_{se}(\mu)$ is defined, for great number of modulation schemes, as:

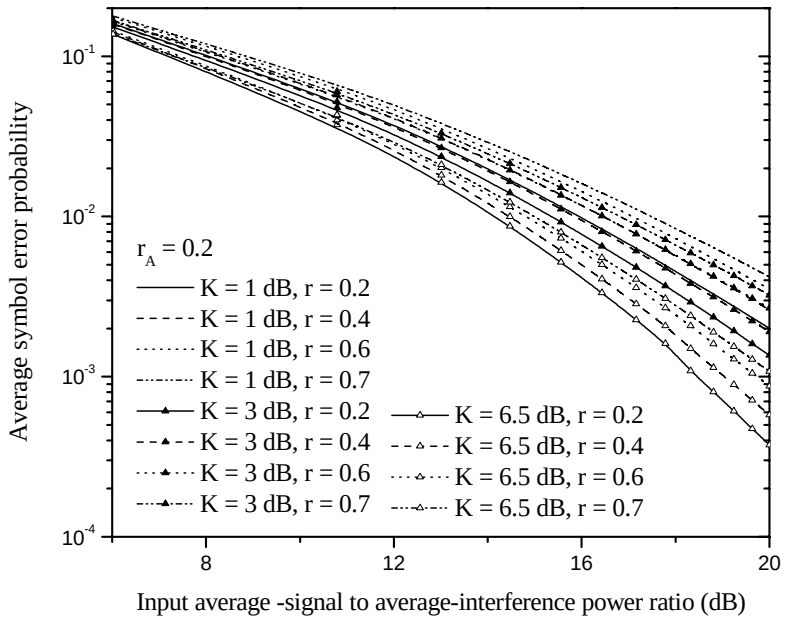
$$P_{se}(\mu) = A\,erfc\left(\sqrt{B\mu^2} \right) \quad (5)$$

where $erfc(\cdot)$ is the complementary error function and A, B are constants the values of which depend on the specific modulation scheme under consideration, i.e. $A = 1$ and $B = \sin^2(\pi/8)$ for 8-PSK [23].

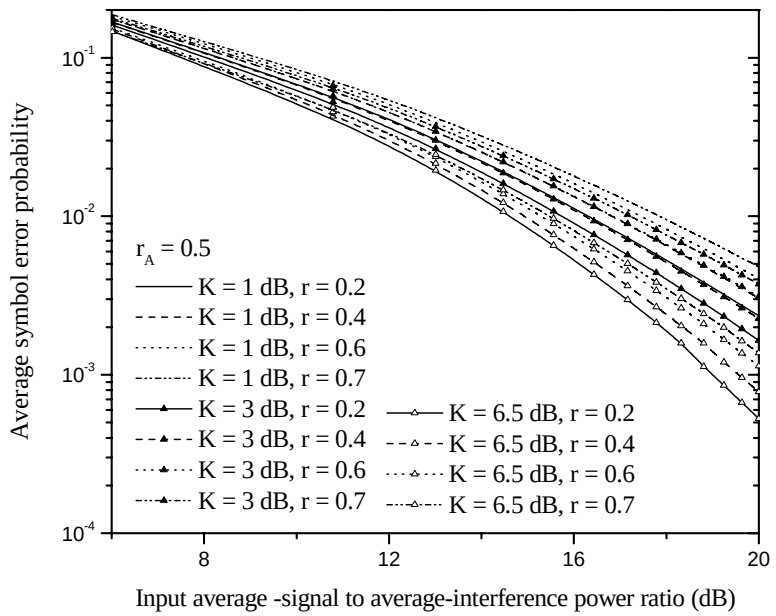
III. Numerical Results

In this section, using the mathematical analysis from Section II, numerical results are presented for the performance of dual SC receivers over correlated Rician fading in the presence of Reyleigh CCI. Using Eqs. (3), (4) and (5), the ASEP of 8-PSK is plotted in Fig. 1 as a function of input average-signal to average-interference power ratio for several values of Rice factor and correlation coefficient between r_1 and r_2. The obtained results show that error performance improves with the increase of K and decrease of r. These results have been expected because greater value of K means less fading severity, i.e. less influence of fading on system performance. Diversity reception have been applied to mitigate the effects of fading and CCI, but in small terminal with multiple antennas correlation arises between branches. In that case system shows the worst performance. Comparison of results from Figs. 1 (*a*) and 1 (*b*) shows the stronger

$$p_{\mu_{SC}}(\mu) = \exp\left(-\frac{2K}{1+r} \right) \sum_{k,\,p,\,n,\,l,\,m=0}^{+\infty} \frac{2\varepsilon_k K^{p+l+k} (1+K)^{2k+2n+p+l+2} \Gamma(n+p+k+m+2) \Gamma(n+l+k+m+2) r_A^{2m} r^{2n+k} \mu^{4n+4k+2p+2l+3}}{\beta^{2k+2n+p+l+2} (1+r)^{2p+2l+2n+3k+1} n!\,p!\,m!\,l! (1-r)^{2n+k+1} \Gamma(m+1) \Gamma(l+k+1) \Gamma(n+k+1) \Gamma(p+k+1)}$$
$$\cdot \left(\frac{(1-r_A^2)^{n+l+k+1-m} \sigma_A^{2n+2l+2k-2m} {}_2F_1\left[n+l+k+m+2, n+l+k+1, n+l+k+2, -\frac{\sigma_A^2 (1-r_A^2)(1+K)}{\beta(1-r^2)} \mu^2 \right]}{(n+l+k+1) \left(\frac{1}{\sigma_A^2 (1-r_A^2)} + \frac{\mu^2 (1+K)}{\beta(1-r^2)} \right)^{n+p+k+m+2}} + \right.$$
$$\left. + \frac{(1-r_A^2)^{n+p+k+1-m} \sigma_A^{2n+2p+2k-2m} {}_2F_1\left[n+p+k+m+2, n+p+k+1, n+p+k+2, -\frac{\sigma_A^2 (1-r_A^2)(1+K)}{\beta(1-r^2)} \mu^2 \right]}{(n+p+k+1) \left(\frac{1}{\sigma_A^2 (1-r_A^2)} + \frac{\mu^2 (1+K)}{\beta(1-r^2)} \right)^{n+l+k+m+2}} \right) \quad (3)$$



a)



b)

Fig 1. Average symbol error probability of 8-PSK versus input average-signal to average-interference power ratio: *a)* r_A = 0.2; *b*) r_A = 0.5.

immunity of M-PSK system from changing r_A than changing r. Obtained numerical results show that ASEP converges rapidly and the number of required terms to converges rapidly and the number of required terms to achieve its significant four-figure accuracy is about thirteen.

IV. CONCLUSION

ASEP, the important performance metric, of dual branch SC diversity system operating over correlated Rician fading channels in the presence of Rayleigh distributed CCI had been studied in this paper. Capitalizing on an previous extracted PDF formula of SC output SIR, the ASEP for 8-PSK modulation scheme is obtained for different values of correlation coefficients. Various performance evaluation results for different fading channel conditions have been also presented.

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