Influence of Cochannel Interference on SC Diversity System over Rician Fading

Aleksandra Panajotović[1], Mihajlo Stefanović[2], Dragan Drača[3], Daniela Milović[4], Nikola Sekulović[5], Dušan Stefanović[6]

Abstract – **Dual selection combining (SC) diversity system operating over correlated Rician fading channels is considered in this paper. It is assumed interference-limited environments where cochannel interference has Rayleigh statistic. Previous obtained probaility density functions (PDF) of SC output signal-to-interference ratio (SIR) have been used to analyse system peformance for different modulation schemes. Numerical results are presented to show effects of both fading severity and branch correlation.**

Keywords – **SC diversity system, Rician fading, Cochannel interference, Average symbol error probability.**

I. Introduction

In a mobile radio system, the received signal may suffer from both fading and shadowing. Fading is due to multipath propagation and shadowing is due to topographical variations of the transmission path. Microdiversity reception, such as spase diversity, is well known method used to combat multipath fading, while macrodiversity reception can be used to mitigate the effects of shadowing [1-3]. Microdiversity system with selection combining (SC) technique is considered in this paper, as technique having the least complexity. Traditionally, in SC the combiner chooses the branch with the highest signal-to-noise ratio, wich corresponds to the strongest signal if equal noise power is assumed among the branches [4]. Therefore, SC does not require all or some of the channel state informations from all the received signals.

In cellular land mobile radio, the received signal suffers cochannel interference (CCI), which also arises in mobile satellite communication channels. In some systems, where CCI is more significant than the front-end Gaussian noise [5], SC selects the branch with the highest signal–to-interference ratio (SIR) [6, 7].

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Rayleigh, Nakagami-m, Rice and Weibull statistical models are the most frequently used in communication system to describe the environment. There is assumption that, all signals, desired and undesired, have the same statistical characteristics. For example, in [8], both signals have Nakagami-m statistics, while in [9] they are subject to Weibull fading. In both papers, desired and undesired signals are correlated. Such assumption is quiet reasonable for medium to large cell systems. For instance, in a microcellular environment, an undesired signal from a distant cochannel cell may well be modeled by Rayleigh statistics, but Rayleigh fading may not be a good assumption for desired signal since a line-of-sight (LoS) path may exist within a microcell [10-12]. Therefore, different fading statistics are needed to characterize the desired and undesired signals in a microcellular radio system. Also in small-sized hand-hold terminal equipped with multiple antennas (space diversity), it is important to investigate the effects of branch correlation.

The performance of dual branch SC diversity receiver operating over correlated Rician fading channels in the presence of Rayleigh CCI had been studied in this paper. Actually, the average symbol error probability (ASEP), as important performance metric, is obtained for following modulation techniques binary phase shift keying (BPSK), binary frequency shift keying (BFSK) and M-ary quadrature amplitude modulation (M-QAM).

II. Average symbol error probability

The Rician distribution is often used to model propagation path consisting of one strong direct LoS signal and many randomly reflected and usually weaker signals. Such fading environments are typically encountered in some microcellular systems [10, 13]. For the case when diversity antennas are not placed sufficiently apart, correlation arises between diversity branches. Then, desired signal envelopes experience correlative Rician fading with joint PDF [14]

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

where r is branch correlation coefficient, 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 defined as the ratio of the signal power in the dominant component over the scattered power, $\varepsilon_k = 1\,(k = 0)$, i.e.

$\varepsilon_k = 2\ (k \neq 0)$ and $I_k(\cdot)$ is modified Bessel function of the first kind and k-th order.

The envelope of CCI on diversity branches is Rayleigh distributed because of its multipath propagation over large distance [6]. Its correlative bivariate PDF, due to insufficient antenna spacing, is expressed by

$$p_{A_1,A_2}(A_1,A_2) = \frac{A_1A_2}{\sigma_A^4(1-r^2)}\exp\left(-\frac{A_1^2+A_2^2}{2\sigma_A^2(1-r^2)}\right)I_0\left(\frac{A_1A_2r}{\sigma_A^2(1-r^2)}\right) \quad (2)$$

where average power of CCI is $\sigma_A^2 = \overline{A_1^2}/2 = \overline{A_2^2}/2$.

In interference-limited fading environments selection combiner chooses and outputs the branch with largest SIR, i.e. $\mu_{sc} = \max\{r_1/A_1, r_2/A_2\}$. Analytical expression of PDF of SC output SIR in the form of infinite series was obtain in [15]. Equation (3), shown at the bottom of the page, presents this PDF and it is substantional to study wireless performance criteria such as channel capacity, ASEP, average output SIR, etc.

The ASEP, $\overline{P}_{se}$, can be evaluated directly by averaging the conditional symbol error probability, $P_{se}(\mu)$, over PDF of μ_{SC} [8, 16]:

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

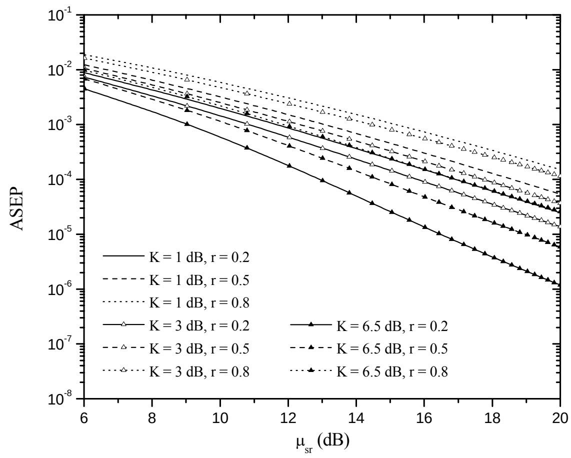
$P_{se}(\mu)$ is defined, for some modulation schemes, as:

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

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.

III. Numerical Results

Using the previous mathematical analysis, various performance evaluation results have been obtained by means of numerical techniques and will be presented in this section. Such results include ASEP performance for different modulation schemes presented for different channel conditions. The proposed infinite series representations of (3) can be efficiently used to study important performance criteria, such as ASEP. The main problem in these infinite series expressions may be their convergence. However, obtained numerical results show that $p_{\mu_{SC}}(\mu)$ converges rapidly and number of sum terms need to achieve significant accuracy of $p_{\mu_{SC}}(\mu)$ depend on both Rice factor and branch correlation coefficient.



. Fig. 1. Average symbol error probability for BPSK system versus input average signal-to-interference ratio.

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

The average symbol error probability defined by (3), (4) and (5) is evaluated via numerical integration using the well-known mathematical software package *Mathematica 5.2*. The numerical results present ASEP plotted against input average SIR ($\mu_{sr} = \beta / \sigma_A^2$) for some modulation schemes. Figs. 1, 2 and 3 depict the effect of both branch correlation and fading severity on the error performance of considered SC diversity system. From all these figures one can conclude that increase of branch correlation coefficient and/or fading severity deteriorate system performance. Moreover, proposed results show that BPSK system exhibits the best performance. Although M-ary modulation techniques is attractive for use in bandlimited channels, because these techniques achieve better bandwidth efficiency. However, M-ary signaling results in poorer error performance. It is evident if we compare Fig. 3 with Figs. 1 and 2. Also, comparison of results from these figures shows that BFSK system has the greatest immunity against changing of *K* and *r*.

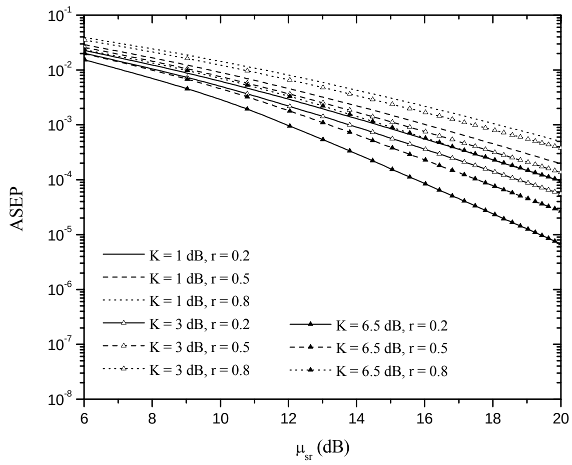


Fig. 2. Average symbol error probability for BFSK system versus input average signal-to-interference ratio.

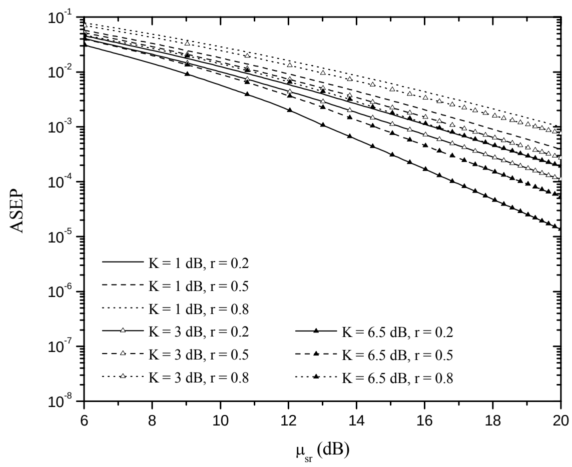


Fig. 3. Average symbol error probability for 4-QAM system versus input average signal-to-interference ratio.

IV. CONCLUSIONS

In summary, we presented a performance analysis of dual SC diversity system for various digital modulation schemes and over a fading channels encountered in real-life scenarios. Obtained results describe ASEP dependence on branch correlation coefficient and fading severity. They show that system's performance improves when Rice factor increases (fading severity decreases) and/or correlation coefficient decreases. The publication of these error system performance curves and comparisons will alow the diversity system designer to make the best choice in planing of wireless system.

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