OP Comparison of Dual SC Systems using Desired and SIR Power Algorithm in Presence of Interference

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

***Abstract* – An analytical expression for evaluation outage performance of dual selection combining (SC) diversity system employing desired signal power decision algorithm is presented in the paper. The diversity system operates over correlated Rician fading channels in the presence of Rayleigh cochannel interference (CCI). Numerical results are presented to show influence of fading severity and branch correlation on outage probability (OP). Moreover, they are used to compare performance of dual SC systems applying two different decision power algorithms, i.e. desired and signal-to-interference ratio (SIR) power algorithm.**

***Keywords* – Cochannel interference, Outage probability, Selection combining, Rayleigh fading, Rician fading.**

I. Introduction

In wireless system, the main causes of the performance degradation are fading due to multipath propagation and cochannel interference (CCI) due to frequency reuse [1]. Space diversity techniques, which combine input signals from multiple receive antennas, are the well known techniques that can be used to alleviate the effects of these degradations [2]. The most popular diversity techniques are maximal-ratio combining (MRC), equal-gain combining (EGC) and selection combining (SC). The last one has the least implementation complexity since it processes only one of the diversity branches. Traditionally, SC receiver chooses the branch with the highest signal-to-noise ratio (SNR), or equivalently, with the strongest signal assuming equal noise power among the branches. In interference limited environment where the level of CCI is sufficiently high as compared with noise, SC receiver can employ one of decision power algorithms: the desired signal power algorithm, the total signal power algorithm and the signal-to-interference (SIR) power algorithm.

Several statistical models are used in communication systems to describe fading in wireless environment. For example, in microcellular environment, an undesired signal from distant cochannel cell may well be modelled by Rayleigh statistics, but Rayleigh fading may not be good assumption for desired signal since line-of-sight (LoS) path may exist within a microcell. Then, the Rician distribution is often used to model a propagation path consisting of one strong direct LoS signal and many randomly reflected and usually weaker signals. Therefore, different fading statistics are needed to characterize the desired signal and CCI in microcell systems [3].

There is set of performance measures that allow the system designer to compute the performance of different digital communication systems characterized by variety of modulation/detection types and fading channel models. Performance measures not only allow easy yet accurate performance evaluation but at the same time provide insight into the manner in which this performance depends on the key system parameter [2]. One of the most important performance measures is outage probability (OP). It is also essential to determine some other performance measures. OP for various diversity techniques with/without CCI and over independent and correlated channels can be found in [4]-[8]. In this paper, analytical expression for OP of dual SC system which applies desired signal power decision algorithm and operates over correlated Rician fading channels in the presence of Rayleigh distributed CCI is presented. Numerical results illustrate the proposed mathematical analysis and show the influence of system and channel parameters on the system performance. Moreover, presented numerical results are compared with results from [8] in order to compare performance of SC systems which apply different decision algorithms.

II. System and Channel Model

Instead of simple case of the channels being independent, channels are correlated due to insufficient distance between diversity antennas. In that case, desired signal envelopes, r_1 and r_2, on two diversity branches follow correlated Rician distribution whose probability density function (PDF) is given in [9, Eq. (3.13)]. For identically distributed case, [9, Eq. (3.13)] simplifies to

[1]Aleksandra Panajotovic is with the Faculty of Electronic Engineering, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: aleksandra.panajotovic@elfak.ni.ac.rs.

[2]Nikola Sekulovic is with the Faculty of Electronic Engineering, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: nikola.sekulovic@elfak.rs.

[3]Mihajlo Stefanovic is with the Faculty of Electronic Engineering, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: mihajlo.stefanovic@elfak.ni.ac.rs.

[4]Dragan Draca is with the Faculty of Electronic Engineering, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: dragan.draca@elfak.ni.ac.rs.

[5]Dusan Stefanovic is with the High Technical School, Aleksandra Medvedeva 20, 18000 Nis, Serbia, E-mail: dusan.stefanovic@itcentar.rs.

$$p_{r_1r_2}(r_1,r_2)=\frac{r_1r_2}{\sigma^4(1-\rho^2)}\exp\left(-\frac{r_1^2+r_2^2+2b^2(1-\rho)}{2\sigma^2(1-\rho^2)}\right)$$
$$\times\sum_{k=0}^{\infty}\varepsilon_k I_k\left(\frac{r_1r_2\rho}{\sigma^2(1-\rho^2)}\right)I_k\left(\frac{br_1}{\sigma^2(1+\rho)}\right)I_k\left(\frac{br_2}{\sigma^2(1+\rho)}\right), \quad (1)$$
$$\varepsilon_k=\begin{cases}1, & k=0\\ 2, & k\neq 0\end{cases}$$

where ρ is branch correlation coefficient and $I_k(\cdot)$ is modified Bessel function of the first kind and k-th order. Rice factor, K, and average desired signal power, β, are defined as $K=b^2/(2\sigma^2)$, $\beta=\sigma^2(1+K)$.

In cellular mobile radio system with fading, an exact performance analysis is usually quiet complicated, and approximations are sometimes used to simplify the analysis. As in [6], [8] and [10], we consider the effect only of the strongest CCI and its envelope follows Rayleigh PDF expressed by

$$p_a(a)=\frac{a}{\sigma_a^2}\exp\left(-\frac{a^2}{2\sigma_a^2}\right), \quad (2)$$

where σ_a^2 is average CCI power.

The considered SC receiver uses the desired signal power decision algorithm. Actually, it selects the branch with the largest instantaneous desired signal power, i.e. $r^2=\max\{r_1^2,r_2^2\}$. The instantaneous SIR at the output of such interference-limited SC system is given by $\eta=\max\{r_1^2,r_2^2\}/a^2=r^2/a^2=R/A$.

III. OUTAGE PROBABILITY

In cellular mobile communications systems subject to CCI, OP is defined as the probability that SIR being less than their respective predetermined threshold values. Mathematically speaking, the OP of dual SC system applying desired signal power algorithm, P_{out}, is given by [11]

$$P_{out}=1-\int_0^{\infty}\int_0^{R/\eta}p_A(A)\,p_R(R)\,dA\,dR, \quad (3)$$

where $p_R(R)$ and $p_A(A)$ are the PDFs of desired and interference signal power, respectively.

The PDF of desired signal envelope at considered dual SC receiver output can be obtained as [2]

$$p_r(r)=\int_0^{r}p_{r_1r_2}(r,r_2)\,dr_2+\int_0^{r}p_{r_1r_2}(r_1,r)\,dr_1\,. \quad (4)$$

Solving integrals in previous equation after substituting Eq. (1) into Eq. (4), the PDF of desired signal power at the SC receiver output is expressed in the form of following infinite-series [12]

$$p_R(R)=\sum_{k,p,n,l=0}^{\infty}\varepsilon_k\frac{\rho^{2p+k}K^{n+l+k}(1+K)^{p+k+1}}{(1-\rho)^p(1+\rho)^{2k+p+n+l}\beta^{p+k+1}}$$
$$\times\frac{R^{p+k}}{2^{p+k+1}n!\,p!\,l!\,\Gamma(n+k+1)\Gamma(p+k+1)\Gamma(l+k+1)}$$
$$\times\left\{(p+n+k)!(1-\rho)^n\left(\frac{(1+K)R}{2\beta(1+\rho)}\right)^l\right. \quad (5)$$
$$\times\left[\alpha_2-\alpha_1\sum_{i=0}^{p+n+k}\frac{1}{i!}\left(\frac{(1+K)R}{2\beta(1-\rho^2)}\right)^i\right]+(p+l+k)!(1-\rho)^l$$
$$\left.\times\left(\frac{(1+K)R}{2\beta(1+\rho)}\right)^n\left[\alpha_2-\alpha_1\sum_{j=0}^{p+l+k}\frac{1}{j!}\left(\frac{(1+K)R}{2\beta(1-\rho^2)}\right)^j\right]\right\},$$

where $\Gamma(\cdot)$ is Gamma function and $\alpha_i=\exp\left(-\frac{R(1+K)}{i\beta(1-\rho^2)}-\frac{2K}{1+\rho}\right), i=1,2$.

Substituting PDF of interference signal power at the SC receiver output, derived applying [13, Eq. (4.10)] on Eq. (2), and Eq. (5) into Eq. (3), outage probability of SIR at the output of considered SC receiver is derived in the following form [12]

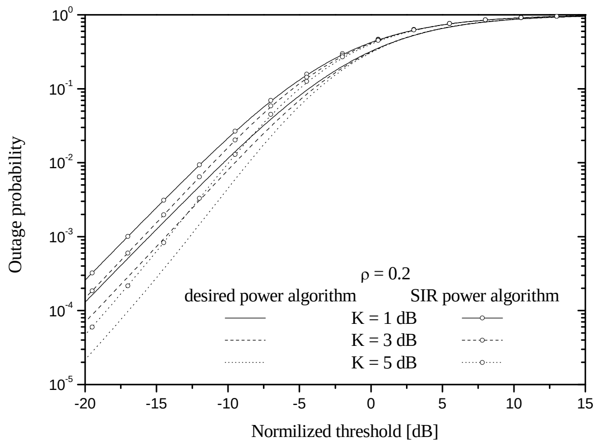
$$P_{out}=1-\exp\left(-\frac{2K}{1+\rho}\right)\sum_{k,p,n,l=0}^{\infty}\varepsilon_k\frac{\rho^{2p+k}(1-\rho)^{n+l+k+1}}{(1+\rho)^{n+l+k-1}}$$
$$\times\frac{K^{n+l+k}}{n!\,p!\,l!\,\Gamma(n+k+1)\Gamma(p+k+1)\Gamma(l+k+1)}$$
$$\times\left\{(p+n+k)!\left[(p+l+k)!\left(1-\frac{1}{\chi^{p+l+k+1}}\right)\right.\right.$$
$$\left.-\sum_{i=0}^{p+n+k}\frac{(p+l+k+i)!}{i!}\left(\frac{1}{2^{p+l+k+i+1}}-\frac{1}{(1+\chi)^{p+l+k+i+1}}\right)\right] \quad (6)$$
$$+(p+l+k)!\left[(p+n+k)!\left(1-\frac{1}{\chi^{p+n+k+1}}\right)\right.$$
$$\left.\left.-\sum_{j=0}^{p+l+k}\frac{(p+n+k+j)!}{j!}\left(\frac{1}{2^{p+n+k+j+1}}-\frac{1}{(1+\chi)^{p+n+k+j+1}}\right)\right]\right\},$$

where average input SIR is defined as $S=\beta/\sigma_a^2$ and $\chi=1+\frac{(1-\rho^2)S}{(1+K)\eta}$.

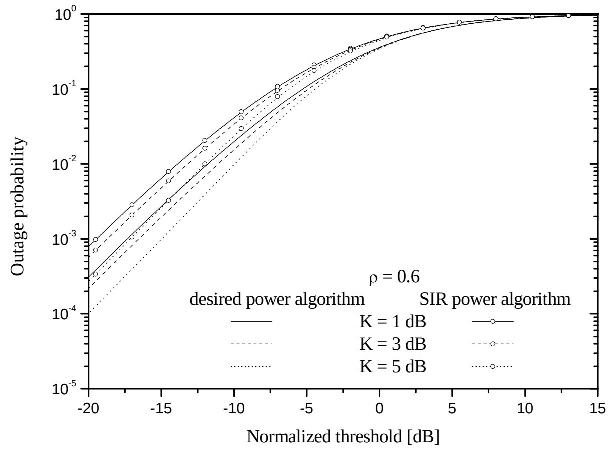
IV. NUMERICAL RESULTS

In this section, we present illustrative examples for the outage probability of spatially correlated dual SC system which applies different decision algorithms and which is exposed to the influence of Rayleigh CCI in Rician fading channels in order to both complement mathematical analysis provided in the previous section and compare outage performance of different SC systems.

All figures show outage probability in function of normalized threshold (η/S). The influence of Rice factor on outage system performance is presented in Fig.1, while



a)



b)

Fig. 1. Outage probability versus normalized threshold for dual SC receiver for several values of Rice factor: *a*) $\rho = 0.2$; *b*) $\rho = 0.6$.

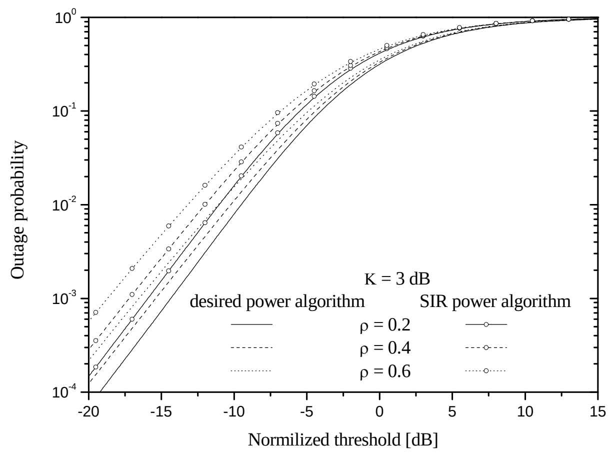


Fig. 2. Outage probability versus normalized threshold for dual SC receiver for several values of branch correlation coefficients.

influence of distance between diversity antennas is proposed in Fig. 2. The signal-to-interference power ratio decision algorithm requires more complex design of SC receiver and shows worst system performance than desired power algorithm. Presented results illustrate that. Regardless of applying decision algorithm system performance improves with increase of Rice factor. Decrease distance between diversity antennas produces increase of outage probability. Advantage of desired power decision algorithm is more evident for small value of Rice factor and great value of branch correlation coefficient.

V. CONCLUSION

In cellular land mobile radio, the received signal suffers from CCI, which also arises in mobile satellite communication channels. With the increasing demand for wireless systems and services, microcell and picocell structures have been proposed to increase system capacity. Propagation measurements in such environments have shown that the received signal envelope has a Rician distribution, but the interference envelope has Rayleigh distribution. In this paper, the performance of a dual SC system, operating over correlated Rician fading channels in the presence of Rayleigh distributed CCI, with desired signal power algorithm, i.e. SIR power algorithm has been studied. Numerical results for the outage probability are presented, describing its dependence on correlation coefficient and fading severity. They show that system's performance improves when the Rice factor increases (fading severity decreases) and/or correlation coefficient decreases. Moreover, presented results point out better outage system performance in case of applying desired power decision algorithm.

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