Average SIR Comparison for SC Systems Using Different Decision Algorithms in the Presence of Interference

Aleksandra Panajotović[1], Dragan Drača[2] and Nikola Sekulović[3]

Abstract – **Ascertaining the importance of the selection combining (SC) as the most efficient diversity technique, average signal-to-interference ratio (SIR) at the output of dual SC receiver is investigated in the paper as important performance criterion. The diversity system operates in microcell environment and applies desired signal power algorithm. Numerical results are presented to show effects of fading severity and level of correlation. Moreover, they are used to compare performance of dual SC systems using different decision power algorithms.**

Keywords – **Cochannel interference, Fading, Selection combining.**

I. INTRODUCTION

The performance of wireless system is severely affected by fading and cochannel interference (CCI). Fading is result of multipath propagation, and CCI is result of frequency reuse [1]. Space diversity techniques, which combine input signals from multiple receive antennas (diversity branches), are the well known techniques that alleviate the deleterious effects of fading and CCI. The most popular diversity techniques are maximal-ratio combining (MRC), equal-gain combining (EGC) and selection combining (SC). Among of these types of diversity technique, SC has the least implementation complexity since it processes only one of diversity branches [2]. Usually, SC receiver chooses the branch with the highest signal-to-noise ratio (SNR), which corresponds to the strongest signal if equal noise is assumed among the diversity branches. In some systems, where CCI is more significant than noise, SC receiver can employ one of following decision power algorithms: the desired signal power algorithm, the total signal power algorithm and the signal-to-interference power ratio (SIR) algorithm [3].

There are few statistical models used to describe fading in wireless environment. Rician statistical model is typically observed in the line-of-sight (LoS) path of microcellular urban and suburban land mobile environment [4]. In such environment, CCI experiences significantly deeper fading than the desired signal. Therefore, the different fading models for the desired signal and CCI have to be used. Cochannel interference from distant microcell may be modelled by Rayleigh statistics [5,6].

There is set of performance criteria that allow the system designer to evaluate the performance of wireless systems and investigate influence of key system parameters. The most popular first order performance criteria are outage probability (OP), average bit error probability (ABEP), channel capacity, average output SNR/SIR, etc [7-11]. In this paper, analytical expression for average SIR at the output of dual SC receiver operating over correlated Rician fading channels in the presence of Rayleigh CCI is derived for the case when receiver applies desired signal power algorithm. Numerical results illustrate the influence of system and channel parameters on the system performance. Moreover, our previous published result [12] is used to compare average output SIR of considered SC system with SC system applying SIR decision algorithm.

II. SYSTEM AND CHANNEL MODEL

If diversity system is applied in small terminal, correlation arises between diversity branches due to insufficient antenna spacing. In that case, desired signal envelope, r_1 and r_2, on two diversity branches follow correlated Rician distribution whose probability density function (PDF) is given by [13]

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

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

We assume that there is a single dominant interferer, independent of the desired signal, subjected to Rayleigh fading [14]. PDF of its envelope is expressed by

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

where σ_a^2 is average CCI power.

The considered dual SC receiver uses the desired signal power decision algorithm. Actually, it selects the branch with the largest instantaneous desired signal power, i.e.

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

[2] Dragan Drača is with the Faculty of Electronic Engineering at University of Niš, Aleksandra Medvedeva 14, Niš 18000, Serbia, E-mail: dragan.drača@elfak.ni.ac.rs.

[3] Nikola Sekulović is with the School of Higher Technical Professional Education, Aleksandra Medvedeva 20, Niš 18000, Serbia, E-mail: sekulani@gmail.com.

$r^2 = \max\left\{r_1^2, r_2^2\right\}$. The instantaneous SIR at its output is given by $\eta = \max\left\{r_1^2, r_2^2\right\} / a^2 = r^2 / a^2$.

III. AVERAGE OUTPUT SIR

Average output SIR is important performance criterion for wireless system operating in interference-limited environment. The average SIR envelope, $\overline{\mu}$, at the output of SC system can be obtained by averaging the instantaneous SIR envelope, $\mu = \sqrt{\eta} = r/a$, over its PDF [15]

$$\overline{\mu} = \int_0^\infty \mu p_\mu(\mu) d\mu , \tag{3}$$

where p_μ (μ) for SC system with desired signal power decision algorithm was derived in [16] as

$$\begin{aligned} p_\mu(\mu) &= \exp\left(-\frac{2K}{1+\rho}\right) \sum_{k,p,n,l=0}^{\infty} \varepsilon_k \frac{\rho^{2p+k} K^{n+l+k} (1+K)^{p+k+1}}{n!\,l!\,p!\,\Gamma(p+k+1)\Gamma(l+k+1)} \\ &\times \frac{S\mu^{2p+2k+1}}{\Gamma(n+k+1)(1-\rho)^p (1+\rho)^{2k+p+n+l}} \\ &\times \left\{ \frac{(p+n+k)!(1+K)^l \mu^{2l} (1-\rho)^n}{(1+\rho)^l} \left[\frac{2(p+k+l+1)!}{\left(S + \frac{(1+K)\mu^2}{1-\rho^2}\right)^{p+k+l+2}} \right. \right. \\ &\left. - \sum_{i=0}^{p+n+k} \frac{(p+l+k+i+1)!(1+K)^i \mu^{2i}}{2^{p+k+l+i+1} i!\left(1-\rho^2\right)^i \left(\frac{S}{2} + \frac{(1+K)\mu^2}{1-\rho^2}\right)^{p+k+l+i+2}} \right] \\ &+ \frac{(p+l+k)!(1+K)^n \mu^{2n} (1-\rho)^l}{(1+\rho)^n} \left[\frac{2(p+k+n+1)!}{\left(S + \frac{(1+K)\mu^2}{1-\rho^2}\right)^{p+k+n+2}} \right. \\ &\left. \left. - \sum_{j=0}^{p+l+k} \frac{(p+n+k+j+1)!(1+K)^j \mu^{2j}}{2^{p+k+l+j+1} j!\left(1-\rho^2\right)^j \left(\frac{S}{2} + \frac{(1+K)\mu^2}{1-\rho^2}\right)^{p+k+n+j+2}} \right] \right\}. \end{aligned} \tag{4}$$

Substituting Eq. (4) into Eq. (3), the average output SIR envelope is obtained in the analytical form using [17, Eq. (3.194(3))]

$$\begin{aligned} \overline{\mu} &= \exp\left(-\frac{2K}{1+\rho}\right) \sum_{k,p,n,l=0}^{\infty} \varepsilon_k \frac{\rho^{2p+k} K^{n+l+k} \Gamma(0.5)}{n!\,l!\,p!\,\Gamma(p+k+1)\Gamma(l+k+1)} \\ &\times \frac{\sqrt{S}(1-\rho)^{k+n+l+1.5}}{\Gamma(n+k+1)\sqrt{1+K}(1+\rho)^{k+n+l-1.5}} \\ &\times \left\{ (p+n+k)! \left[\Gamma(p+k+l+1.5) - \sum_{i=0}^{p+n+k} \frac{\Gamma(p+k+l+i+1.5)}{2^{p+k+l+i+2} i!} \right] \right. \\ &\left. + (p+l+k)! \left[\Gamma(p+k+n+1.5) - \sum_{j=0}^{p+l+k} \frac{\Gamma(p+k+n+j+1.5)}{2^{p+k+n+j+2} j!} \right] \right\}, \end{aligned} \tag{5}$$

where S is average input SIR defined as $S = \beta / \sigma_a{}^2$.

The average SIR envelope at the output of SC system applying SIR decision algorithm can be evaluated using Numerical Integration in program package Mathematics after substitution p_μ (μ) [12]

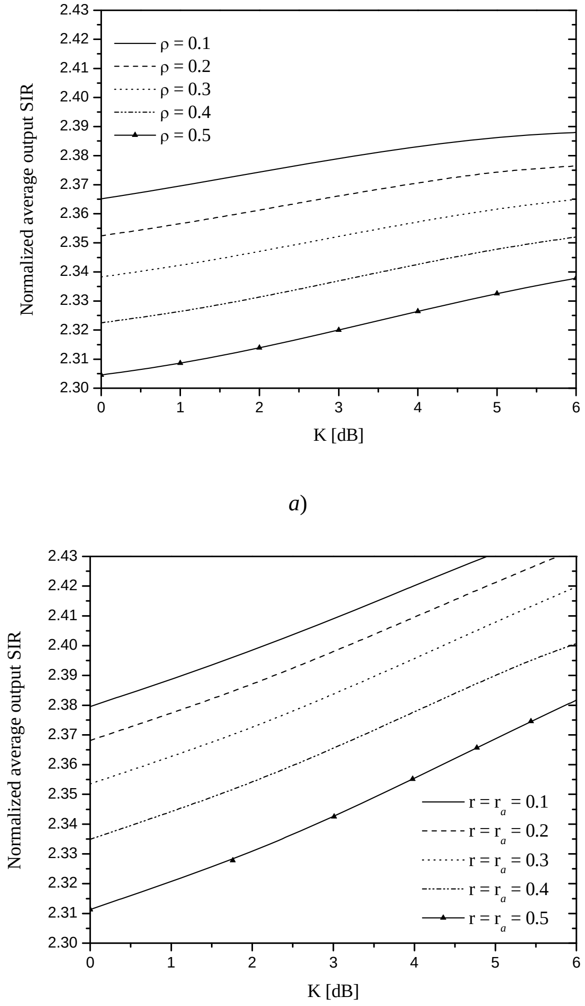
$$\begin{aligned} p_\mu(\mu) &= \exp\left(-\frac{2K}{1+r}\right) \sum_{k,\,p,\,n,\,l,\,m=0}^{+\infty} \frac{2\varepsilon_k K^{p+l+k}}{\beta^{2k+2n+p+l+2}} \\ &\cdot \frac{\Gamma(n+l+m+k+2) r_a^{2m} r^{2n+k} \mu^{4n+4k+2p+2l+3}}{\Gamma(m+1)\Gamma(l+k+1)\Gamma(n+k+1)\Gamma(p+k+1)} \\ &\cdot \frac{(K+1)^{2k+2n+p+l+2} \Gamma(n+p+m+k+2)}{n!\,p!\,m!\,l!(1-r)^{2n+k+1}(1+r)^{2p+2l+2n+3k+1}} \\ &\cdot \left(\frac{\left(1-r_a^2\right)^{n+l+k+1-m} \sigma_a^{2n+2l+2k-2m}}{\left(\frac{1}{\sigma_a^2\left(1-r_a^2\right)} + \frac{\mu^2(K+1)}{\beta\left(1-r^2\right)}\right)^{n+p+k+m+2}} \right. \\ &\cdot \frac{{}_2F_1\left[n+l+k+m+2, n+l+k+1, n+l+k+2, -\alpha\mu^2\right]}{(n+l+k+1)} \\ &+ \frac{{}_2F_1\left[n+p+k+m+2, n+p+k+1, n+p+k+2, -\alpha\mu^2\right]}{(n+p+k+1)} \\ &\left. \cdot \frac{\left(1-r_a^2\right)^{n+p+k+1-m} \sigma_a^{2n+2p+2k-2m}}{\left(\frac{1}{\sigma_a^2\left(1-r_a^2\right)} + \frac{\mu^2(K+1)}{\beta\left(1-r^2\right)}\right)^{n+l+k+m+2}} \right), \end{aligned} \tag{6}$$

in (3). The parameters r_a and r are branch correlation coefficients and $\alpha = \frac{\sigma_a^2\left(1-r_a^2\right)(K+1)}{\beta\left(1-r^2\right)}$.

IV. NUMERICAL RESULTS

Previous proposed mathematical analysis is complemented in this section through illustration of influence of system and channel parameters on the average output SIR as important system performance criterion.

Figure 1 shows normalized average SIR ($\overline{\mu} / \sqrt{S}$) at the output of dual SC system applying different decision algorithms in function of Rice factor. The performance curves are evaluated for different values of correlation coefficient in order to show influence of distance between diversity branches on considered performance criterion. Regardless of applied decision algorithm, diversity gain decreases with increase of branch correlation coefficient. Also diversity gain is greater for environment with light fading than for environment with severe fading. Comparison of Fig.1 (*a*) and Fig. 1 (*b*) shows advantage of SIR signal power decision algorithm because it provides better diversity gain. That advantage is more noticeable for greater values of Rice factor. In environment with severe fading it is better to use SC system with desired signal power algorithm because it requires less complicate receiver and gives almost the same diversity gain as SC system with SIR decision algorithm.



a)

b)

Fig.1. Average output SIR versus Rice factor for several values of correlation coefficient:
a) desired signal power algorithm; *b*) SIR power algorithm

The main problem in the infinite series expression of the average output SIR is its convergence. The nested infinite sums in (5) and (6) converge for any values of branch correlation coefficient and Rice factor. As is shown in Table I, the number of terms that need to be summed to achieve the desired accuracy strongly depends on branch correlation.

TABLE I
NUMBER OF TERMS SUMMED TO ACHIEVE THREE-SIGNIFICANT-FIGURE ACCURACY OF AVERAGE OUTPUT SIR (DESIRED SIGNAL/SIR ALGORITHM)

$\rho = 0.1$	10/11
$\rho = 0.2$	9/13
$\rho = 0.3$	9/12
$\rho = 0.4$	10/9
$\rho = 0.5$	11/16

V. CONCLUSION

In this paper the performance of dual SC system operating in interference-limited microcell environment has been studied. Actually, average output SIR as important performance criterion has been derived in infinite series form for the case when SC system using desired signal power decision algorithm. Presented numerical results have described influence of fading severity and correlation coefficient on considered performance criterion. Moreover, evaluated results have been compared with results obtained for SIR decision algorithm. The general conclusion of this paper is that SC diversity system with SIR algorithm provides better diversity gain regardless of working conditions.

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