Channel Capacity of Dual SC Diversity System Based on Desired Signal Decision Algorithm in Microcell

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

Abstract – **Average channel capacity of selection combining (SC) diversity system based on desired signal decision algorithm operating in microcell interference-limited environment is evaluated in this paper. Numerical results are presented graphically and used to examine the effects of channel and systems parameters on concerned quantity. In addition, desired signal decision algorithm advantage to signal-to-interference ratio (SIR) decision algorithm is presented by way of obtained average channel capacity.**

Keywords – **Average channel capacity, Cochannel interference, Correlation, Fading, SC system.**

I. INTRODUCTION

In designing a cellular mobile system, a fundamental requirement is to provide specified quality-of-service (QoS) in combination with high system capacity. Cochannel interference (CCI), as a result of frequency reuse and multpath fading due to multipath propagation, are the main factors limiting system's performance [1]. Upgrading transmission reliability and increasing system's capacity without increasing transmission power and bandwidth can be achieved by using some of diversity techniques. Space diversity technique combines inputs signals from multiple receive antennas [2]. Three the most popular space diversity techniques are maximal ratio combining (MRC), equal gain combining (EGC) and selection combining (SC). Among them, SC is widely accepted because of its simple realization. Actually, it processes only one of the diversity branches, i.e. chooses the branch with largest signal-to-noise ratio (SNR) [3]. In interference-limited environment, environment where the level of CCI is much higher as compared to thermal 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 [4].

The continued rising of demands for multimedial services and products lead to increasing needs for radio channel spectrum and information data rate. Therefore, the channel capacity would be concerned in the future wireless systems as the primary performance metric. All of these is the reason for great number of the papers in the open technical literature that consider the channel capacity of diversity systems over the different fading channels [5-9].

Several statistical models are used in communication system analysis to describe fading. The most frequently used distributions are Nakagami, Rayleigh, Rician and Weibull. For example, in a microcellular environment, an undesired signal from distant cochannel cells may well be modeled by Rayleigh statistics, but Rayleigh fading is not good assumption for desired signal since a line-of-sight (LoS) path may exists within microcell. Actually, in such situation Rician statistic is acceptable solution for modeling desired signal. The channel capacity of dual SC diversity system over correlated fading channels is analyzed in this paper in the case when the receiver applies desired signal power decision algorithm. The influence of fading severity and branch correlation on the channel capacity are investigated through obtained results. Moreover, those results are compared with previous published [10] in order to reveal the best decision algorithm for SC system operating in the microcell environment.

II. CHANNEL AND SYSTEM MODEL

Due to insufficient antenna spacing, when diversity system is applied on small terminal, desired signal envelopes, r_1 and r_2, experience correlated Rician distribution whose probability density function (PDF) is given as [11]

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

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

The single dominant interference signal in microcell environment is subjected to Rayleigh fading [12]. The PDF of its envelope is expressed by

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

where $\sigma_a^{\,2}$ is average CCI power.

In this paper, SC diversity system applying desired signal decision algorithm is considered since it provides the same

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

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

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

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

performance as total signal decision algorithm, but it is easier to be modeled. Such diversity system selects the branch with the largest instantaneous desired signal power, i.e. $r^2 = \max\left\{r_1^2, r_2^2\right\}$. The instantaneous SIR at the output of SC receiver is given by $\eta = \max\left\{r_1^2, r_2^2\right\}/a^2 = r^2/a^2$. Applying [13, Eq. (4.10)] on [14, Eq. (6)], the PDF of output SIR is obtained in following form

$$p_\eta(\eta) = \exp\left(-\frac{2K}{1+\rho}\right) \sum_{k,p,n,l=0}^{\infty} \varepsilon_k \frac{\rho^{2p+k} K^{n+l+k} (1+K)^{p+k+1}}{n!\,l!\,p!\,\Gamma(p+k+1)\Gamma(l+k+1)}$$
$$\times \frac{S\eta^{p+k}}{\Gamma(n+k+1)(1-\rho)^p (1+\rho)^{2k+p+n+l}}$$
$$\times \left\{ \frac{(p+n+k)!(1+K)^l \eta^l (1-\rho)^n}{(1+\rho)^l} \left[\frac{(p+k+l+1)!}{\left(S + \frac{(1+K)\eta}{1-\rho^2}\right)^{p+k+l+2}} \right.\right.$$
$$\left. - \sum_{i=0}^{p+n+k} \frac{(p+l+k+i+1)!(1+K)^i \eta^i}{2^{p+k+l+i+2}\, i! \left(1-\rho^2\right)^i \left(\frac{S}{2} + \frac{(1+K)\eta}{1-\rho^2}\right)^{p+k+l+i+2}} \right]$$
$$+ \frac{(p+l+k)!(1+K)^n \eta^n (1-\rho)^l}{(1+\rho)^n} \left[\frac{(p+k+n+1)!}{\left(S + \frac{(1+K)\eta}{1-\rho^2}\right)^{p+k+n+2}} \right.$$
$$\left.\left. - \sum_{j=0}^{p+l+k} \frac{(p+n+k+j+1)!(1+K)^j \eta^j}{2^{p+k+l+j+2}\, j! \left(1-\rho^2\right)^j \left(\frac{S}{2} + \frac{(1+K)\eta}{1-\rho^2}\right)^{p+k+n+j+2}} \right] \right\}, \quad (3)$$

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

III. Channel capacity

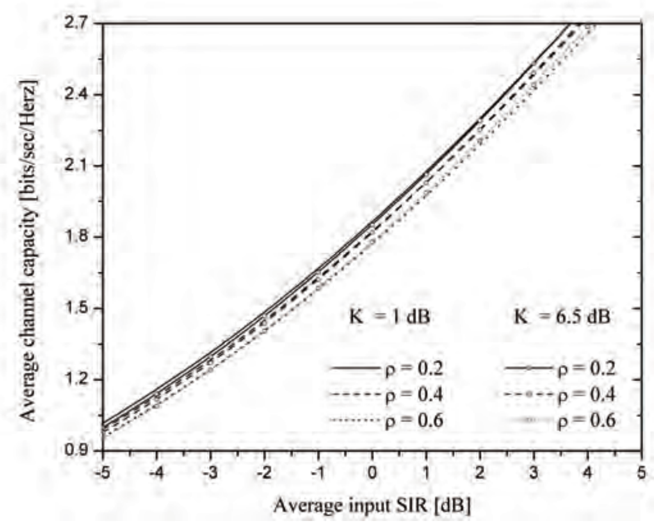
The channel capacity in fading environment has to be calculated in average sense due to variation of signal in time caused by the fading. The average channel capacity then, can be defined as [15]

$$\overline{C} = BW \int_0^\infty \log_2(1+\eta)\, p_\eta(\eta)\, d\eta , \quad (4)$$

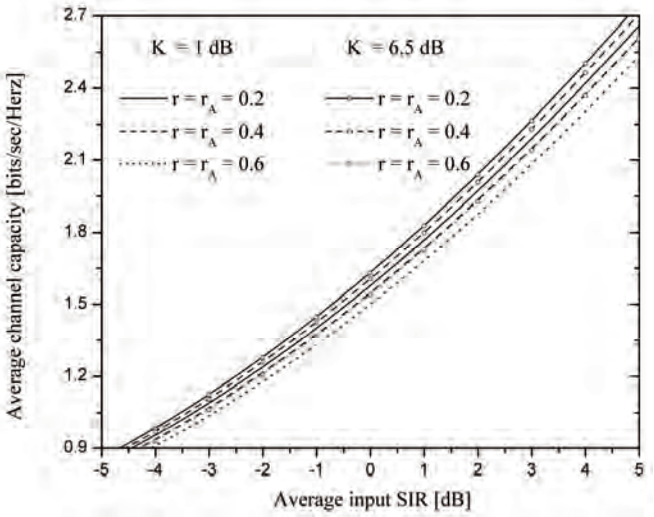
where BW is signal's transmission bandwidth. The program package *Mathematica 7* can be used for numerical evaluation of previous integral after substitution Eq. (3) into Eq. (4).

IV. Numerical results

Normalized to BW the average channel capacity of SC system ($\overline{C}/BW$) versus average input SIR is depicted in Fig. 1. Actually, channel capacity of two SC systems with different decision algorithms is analyzed in this Section. Results from Fig. 1 (*a*) are obtained solving integral in (4) and represent average channel capacity of diversity system applying desired signal decision algorithm. Results in Fig. 1 (*b*) have already been published in [10] and they are presented for comparison purpose. Namely, they present channel capacity of diversity system using SIR decision algorithm. As it is expected, regardless of applied decision algorithm channel capacity of SC system increases with increase of Rician factor (decrease of fading severity) and decrease of branch correlation coefficient (increase of distance between diversity branches). It can be concluded from comparison between Figs. 1 (*a*) and 1 (*b*), that for same system and channel parameters SC system considered in this paper guaranties higher channel capacity then SC system with SIR decision algorithm. Also, it shows greater resistance to variation of both Rician factor and correlation coefficient. Having in the mind previous exposed facts, it is obvious that SC system using desired signal decision algorithm has priority, especially if we know that it is easier to realize such SC system.



a)



b)

Fig. 1. Normilized channel capacity of SC systems with different decision algorithms
(*a*) desired signal decision algorithm; (*b*) SIR decision algorithm

V. Conclusion

In this paper, the performance of dual SC system operating in interference-limited microcell environment has been investigated. Actually, channel capacity, as widely accepted performance criterion, has been obtained 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 desired signal decision algorithm provides higher channel capacity regardless of working conditions.

Acknowledgement

This work has been funded by Serbian Ministry for Education and Science under the projects TR-32052, III-44006, TR-33035.

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