Dynamic Characteristics of Selection Combining Receiver with Different Decision Algorithms

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

Abstract – **In interference-limited environment, selection of appropriate antenna in diversity system plays crucial role in determining system performance. Therefore, in this paper, we simulate selection combining (SC) receiver with different decision algorithms which operates in Nakagami-*m* and Rayleigh fading environments in order to find out which decision algorithm and under which conditions provides the best system performance. Simulation results are obtained using sum-of-sinusoids Nakagami-*m* simulator.**

Keywords –**Average fade duration (AFD), Average level crossing rate (LCR), Nakagami-*m* fading, Rayleigh fading, Selection combining (SC).**

I. Introduction

Multipath fading due to multipath propagation caused by signal reflection and refraction and cochannel interference (CCI) as a result of frequency reuse aiming to increase cellular radio capacity are the main factors limiting system's performance [1]. Several statistical models are used to describe fading in wireless environments: Rayleigh, Nakagami-*m*, Rician, and Weibull. Among them, Nakagami-*m* distribution provides optimum fits to collected data in indoor and outdoor environments [2]. Moreover, it can model signal in severe, moderate, light and no fading environment via adjusting its parameter *m*. Thanks to those features, that distribution is very often used in open technical literature for modeling fading in wireless environment.

Receive diversity techniques, which combine input signals from multiple receive antennas, are the well known techniques that can be used to upgrade transmission reliability and increase channel capacity without increasing transmission power and bandwidth [3]. The most popular space diversity techniques are selection combining (SC), equal-gain combining (EGC), and maximal-ratio combining (MRC) [4]. The SC technique, the one considered in this paper, is the most practical for realization because it processes only one of the diversity branches, while MRC technique is the most difficult for implementation but it provides the best performance among these three techniques. So, it is evident that trade off between practical realization and system performance must be done. Traditionally, SC receiver selects the branch with the highest signal-to-noise ratio (SNR), or equivalently, with the strongest signal assuming equal noise power among the branches. However, in interference-limited environment, SC receiver can apply one of following decision algorithms: desired signal power algorithm, total signal power algorithm, and signal-to-interference ratio (SIR) algorithm.

In this paper, dynamic characteristics of three different types of *L*-branch SC diversity receiver operating over Nakagami-*m* and Rayleigh fading environment in the presence of CCI are modeled and simulated using program package Matlab. The Nakagami-*m* fading simulator incorporating Pop's architecture with Zhang decomposition algorithm is used [5]. In other words, a random phase into low-frequency oscillators for gaining the wide-sense stationary property is inserted, while decomposing a real number of the fading figure, *m*, into two parts, an integer and a fraction, is introduced to accomplish design [6]. The average level crossing rate (LCR) and average fade duration (AFD) of SC system are simulated to investigate a dynamic representation of the system outage performance depending on system and channel parameters and applied algorithm. The accuracy of the proposed simulation process was provided comparing simulated results with previous obtained numerical results for LCR [7] and AFD [8] of SC diversity system with desired signal power algorithm. Excellent agreement between results gives us idea to simulate, in this paper, dynamic characteristics of the other two SC systems.

II. Nakagami Simulator

The architecture of sum-of-sinusoids-based Nakagami-*m* simulator, used in this paper, is depicted in Fig. 1 [6].

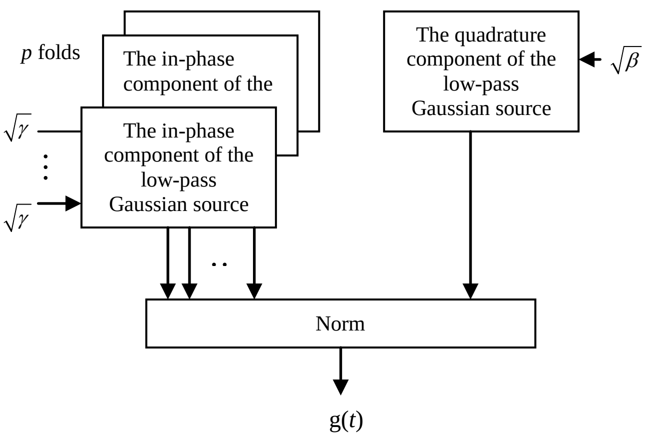

Fig. 1. The block diagram of sum-of-sinusoids-based Nakagami-*m* simulator

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The corresponding composite signal representing Nakagami-*m* envelope is

$$g(t)=\sqrt{\gamma\sum_{k=1}^{p}g_{I,k}{}^{2}(t)+\beta g_{Q}{}^{2}(t)}\,, \qquad (1)$$

where

$$g_I(t)=\sqrt{\frac{2}{N}}\times\left[2\sum_{n=1}^{M}\cos\Phi_n\cos(\omega_n t+\Psi_n)+\sqrt{2}\cos\Phi_N\cos(\omega_N t+\Psi_N)\right], \qquad (2)$$

$$g_Q(t)=\sqrt{\frac{2}{N}}\times\left[2\sum_{n=1}^{M}\sin\Phi_n\cos(\omega_n t+\Psi_n)+\sqrt{2}\sin\Phi_N\cos(\omega_N t+\Psi_N)\right], \qquad (3)$$

$$\gamma=\frac{2pm\pm\sqrt{2pm(1+p-2m)}}{p(1+p)}\,, \qquad (4)$$

and

$$\beta=2m-\gamma p\,, \qquad (5)$$

with p = [2*m*], N = 4*M*+2, $\omega_n=2\pi f_m\cos(2\pi n/N)$, $\Phi_n=n\pi/M$, $\Phi_N=0$. The parameter f_m is maximum Doppler shift and ψ_j is random phase uniformly distributed in the range (-π, π].

III. LCR AND AFD

The average LCR and AFD are metrics evaluating the dynamic performance of diversity system and therefore very important to get complete overview about system. Namely, they are used for proper selection of adaptive symbol rates, interleave depth, packet length and time slot duration in various wireless communications systems.

In interference-limited environment, where level of CCI is sufficiently high as compared to thermal noise, the average LCR of the ratio of desired signal and CCI, μ, at threshold μ_{th}, is defined as the rate at which a fading process crosses level μ_{th} in a positive (or negative) going direction, while the AFD presents average length of time in which envelope remains under threshold.

Figures 2 and 3 describe average LCR and AFD simulation processes for SC system operating in interference-limited Nakagami-*m* environment [7], [8].

Depending on applied selection decision algorithm of SC receiver, output signal-to-interference ratio (SIR), $\mu_{sc}(t)$, can be defined on one of following ways:

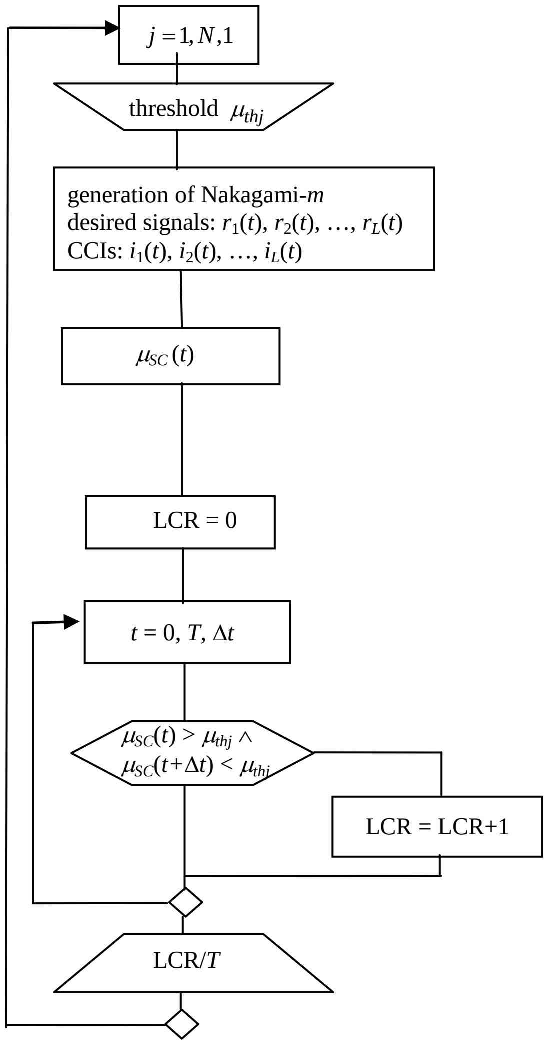

Fig. 2. The algorithm for simulation of average LCR of *L*-branch SC receiver.

$$\mu_{SC}=\frac{r_{SC}^2}{i_{SC}^2}=\begin{cases}\dfrac{\max\limits_{\substack{SC=l\\ l=1,L}}\left\{r_l^2\right\}}{i_{SC}^2}, & \textit{desired signal algorithm}\\[2ex] \max\limits_{\substack{SC=l\\ l=1,L}}\left\{\dfrac{r_l^2}{i_l^2}\right\}, & \textit{SIR algorithm}\\[2ex] \max\limits_{\substack{SC=l\\ l=1,L}}\left\{r_l^2+i_l^2\right\}, & \textit{total signal algorithm}\end{cases} \qquad (6)$$

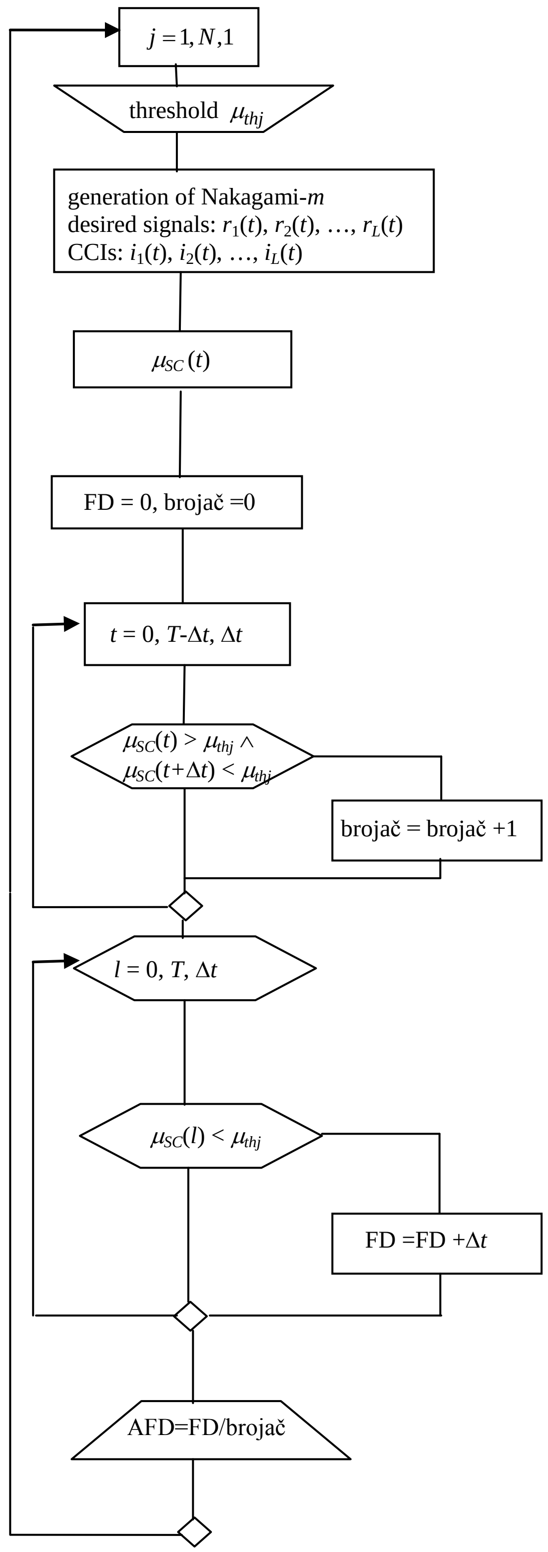

Fig. 3. The algorithm for simulation of AFD of L-branch SC receiver.

IV. Simulation Results

The simulation results for second order performance metrics of dual SC receiver operating in Nakagami-*m* fading environment are presented in following figure for three different decision algorithms aiming to show adventage each of them in comparison to other ones.

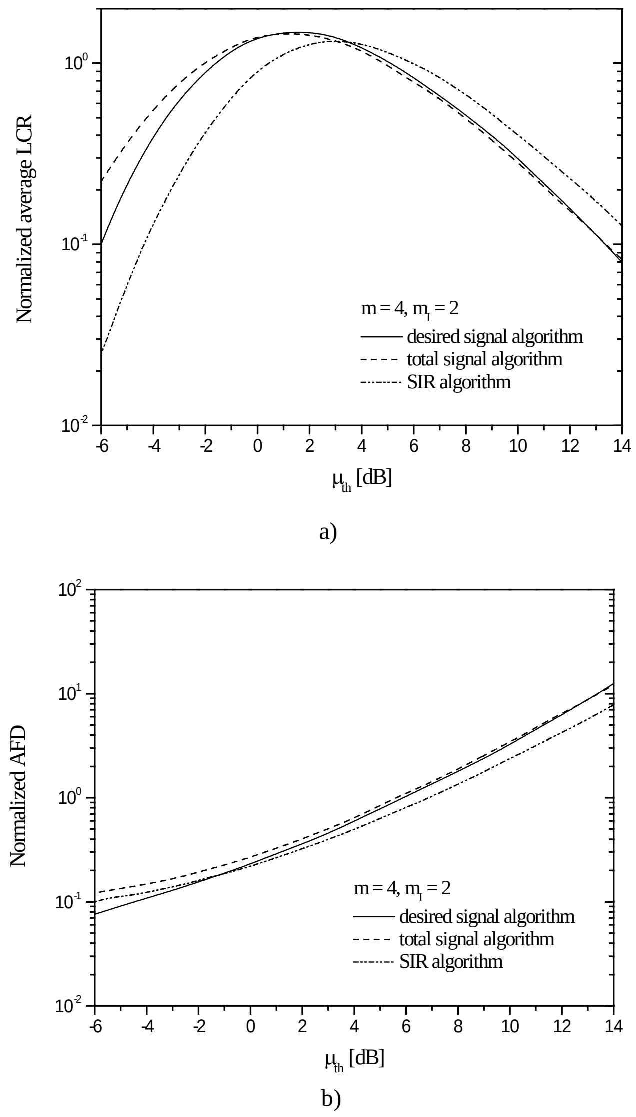

Fig. 4. Simulated second order performance metrics of dual SC receiver over Nakagami-*m* fading: a) Average LCR; b) AFD.

Note that in all considered range of threshold there is a great similarity in behavior of both performance curves for cases when receiver applies total signal and desired signal algorithms. Total signal algorithm requires the simplest realization since separation of CCI from desired signal is not needed. Otherwise, desired signal algorithm is easier for mathematical modeling and therefore very often performance of SC receiver with desired signal algorithm was studied [9-11]. When we speak about average LCR, it is obvious that it is better that system applies SIR algorithm for less threshold, i.e. total signal algorithm for greater threshold. In addition, almost for each threshold, SIR signal algorithm provides the best performance for AFD.

It is well known that Nakagami-*m* distribution contains a set of other distributions as special cases. For example, simulator presented in Fig. 1 becomes Rayleigh simulator for Nakagami parameters equal 1. Simulated results for that case are depicted in Fig. 5.

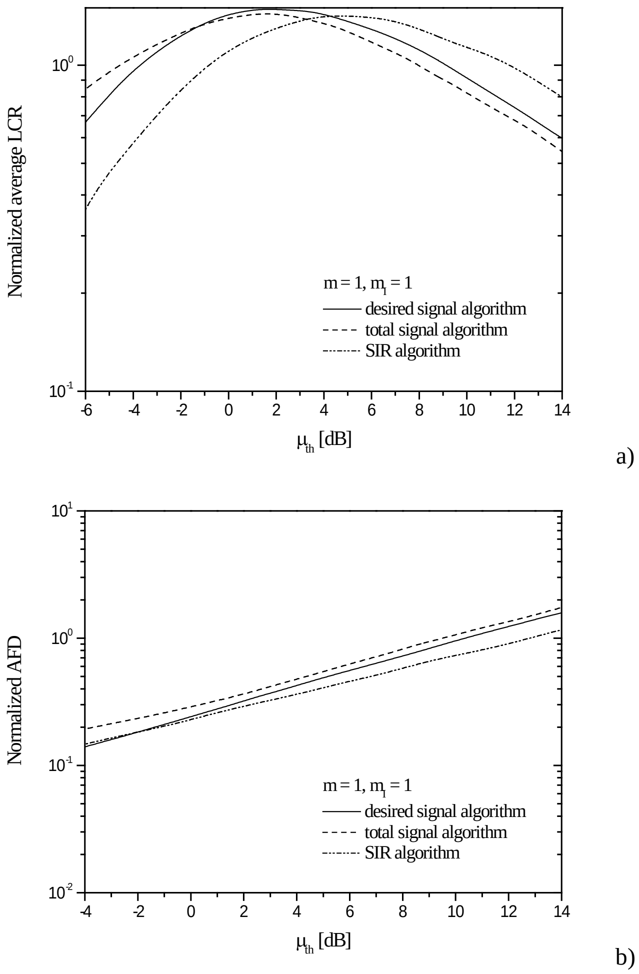

Fig. 5. Simulated second order performance metrics of dual SC receiver over Rayleigh fading: *a*) Average LCR; *b*) AFD.

Figure 5 confirms conclusions made from previous figure. Note that differences between decision algorithms are more expressed for more severe fading.

Accuracy of simulated results are confirmed through comparison with numerical results obtained for desired signal algorithm in [7], [8].

V. Conclusions

This work is result of an intention to compare different decision algorithms applied in SC receiver. Important and widely accepted performance indicators, average LCR and AFD, are choosen to be simulated. SC diversity system with arbitrary number of uncorrelated branches in Nakagami-*m* and Rayleigh fading environments in the presence of the strongest CCI is modeled. Simulation results obtained using program package Matlab give a slight advance to SC receiver with SIR decision algorithm.

Further work will concentrate on the simulation of the first order performance metrics of considered system in both correlated and uncorrelated environments.

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