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The Performances of the SSC Combiner Output Signal in the Presence of Nakagami-m Fading

Mihajlo Č. Stefanović, Dragana S. Krstić, Petar Nikolić, Srdjan Jovković, and Dušan M. Stefanović

Abstract—It is notable that level crossing rate, outage probability and average time of fade duration of the combiner output signal are very important system performances. In this paper the level crossing rate, outage probability and fade duration of the SSC combiner output signal in the presence of the Nakagami-*m* fading are determined. The results are shown graphically for different variance values, decision threshold values and fading parameters values.

Keywords— Diversity reception, Fade Duration, Level Crossing Rate, Log-Normal fading, Outage Probability, SSC Combining.

I. Introduction

MANY of the wireless communication systems use some form of diversity combining to reduce multupath fading appeared in the channel [1]. Among the simpler diversity combining schemes, the two most popular are selection combining (SC) and switch and stay combining (SSC). SSC is an attempt at simplifying the complexity of the system but with loss in performance. In this case the receiver selects a particular antenna until its quality drops below a predetermined threshold. When this happens, the receiver switches to another antenna and stays with it for the next time slot, regardless of whether or not the channel quality of that antenna is above or below the predetermined threshold.

In the paper [2] Alouini and Simon develop, analyze and optimize a simple form of dual-branch switch and stay combining (SSC). The consideration of SSC systems in the literature has been restricted to low-complexity mobile units where the number of diversity antennas is typically limited to two ([3], [4] and [5]). Furthermore, in all these publications, only predetection SSC has thus far been considered wherein the switching of the receiver between the two receiving antennas is based on a comparison of the instantaneous SNR of the connected antenna with a predetermined threshold. This results in a reduction in complexity relative to SC in that the simultaneous and continuous monitoring of both branches SNRs is no longer necessary.

In [6] the moment generating function (MGF) of the signal power at the output of dual-branch switch-and-stay selection diversity (SSC) combiners is derived. Blanco consider diversity receiver performance in Nakagami fading in [7].

The joint probability density function of the SSS combiner output signal at two time instants in the presence of Rayleigh fading is determined in [10]. The level crossing rate, outage probability and average time of fade duration of the SSC combiner output signal in the presence of log-normal fading are calculated in [11]. In this paper level crossing rate, outage probability and average time of fade duration of the SSC combiner output signal in the presence of Nakagami-*m* fading will be determine. The results will be shown graphically for different variance values, decision threshold values and fading parameters values.

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Mihajlo Č. Stefanović is with Faculty of Electronic Engineering, University of Niš, Aleksandra Medvedeva 14, 18000 Niš, Serbia, (e-mail: misa@elfak.ni.ac.yu).

Dragana S. Krstić is with Faculty of Electronic Engineering, University of Niš, Aleksandra Medvedeva 14, 18000 Niš, Serbia, (e-mail: dragana@elfak.ni.ac.yu).

Petar Nikolić works as engineer in Tigar Tyres, Pirot (e-mail: p.nikolic@tigartyres.com).

Srdjan Jovković and Dušan M. Stefanović are with High Technical Scool in Niš, (e-mail: srbajovkovic@gmail.com and dusan.stefanovic@itcentar.co.yu)

II. System Model

The model of the SSC combiner with two inputs, considered in this paper, is shown in Fig. 1.

The signals at the combiner input are r_1 and r_2, and r is the combiner output signal. The predetection combining is observed.

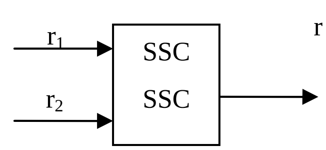

Fig. 1. Model of the SSC combiner with two inputs (input signals are r_1 and r_2, and output signal r)

The probability of the event that the combiner first examines the signal at the first input is P_1, and for the second input is P_2. If the combiner examines first the signal at the first input and if the value of the signal at the first input is above the treshold, r_T, SSC combiner forwards this signal to the circuit for the decision. If the value of the signal at the first input is below the treshold r_T, SSC combiner forwards the signal from the other input to the circuit for the decision, regardless it is above or below the predetermined threshold.

If the SSC combiner first examines the signal from the second combiner input it works in the similar way. The probability for the first input to be examined first is P_1 and for the second input to be examined first is P_2.

The determination of the probability density of the combiner output signal is very important for the system performances determination.

III. System Performances

Derivation of system performances we are starting with the probability density functions (PDFs) of the combiner input signals, r_1 and r_2, in the presence of Nakagami-m fading. The probability densities (PDFs) of the combiner input signals, r_1 and r_2 , are:

$$p_{r_1}(r_1) = \frac{2{m_1}^{m_1} {r_1}^{2m_1-1}}{{\Omega_1}^{m_1}\Gamma(m_1)} e^{-\frac{m_1 {r_1}^2}{\Omega_1}}, \quad r_1 \geq 0 \tag{1}$$

$$p_{r_2}(r_2) = \frac{2{m_2}^{m_2} {r_2}^{2m_2-1}}{{\Omega_2}^{m_2}\Gamma(m_2)} e^{-\frac{m_2 {r_2}^2}{\Omega_2}} \quad r_2 \geq 0 \tag{2}$$

The cumulative probability densities (CDFs) in the presence of Nakagami-m fading are given by:

$$F_{r_1}(r_T) = \int_0^{r_T} p_{r_1}(x)\,dx \tag{3}$$

$$F_{r_2}(r_T) = \int_0^{r_T} p_{r_2}(x)\,dx \tag{4}$$

r_T is the treshold of the decision.

In the presence of Nakagami-m fading CDFs are:

$$F_{r_1}(r_T) = \int_0^{r_T} \frac{2{m_1}^{m_1} x^{2m_1-1}}{{\Omega_1}^{m_1}\Gamma(m_1)} e^{-\frac{m_1 x^2}{\Omega_1}} dx = $$

$$= \gamma(\frac{m_1}{\Omega_1}{r_t}^2, m_1) \tag{5}$$

$$F_{r_2}(r_T) = \int_0^{r_T} \frac{2{m_2}^{m_2} x^{2m_2-1}}{{\Omega_2}^{m_1}\Gamma(m_2)} e^{-\frac{m_2 x^2}{\Omega_2}} dx = $$

$$= \gamma(\frac{m_2}{\Omega_2}{r_t}^2, m_2) \tag{6}$$

where $\gamma(x,a)$ is incomplete gamma function defined by [7]:

$$\gamma(x,a) = \frac{1}{\Gamma(a)} \int_0^x t^{a-1} e^{-t} dt .$$

The joint probability densities of the combiner input signals, r_1 and r_2, and their derivatives $\dot{r}_1$ and $\dot{r}_2$, in the presence of Nakagami-m fading, are:

$$p_{r_1 \dot{r}_1}(r_1, \dot{r}_1) = \frac{2{m_1}^{m_1} {r_1}^{2m_1-1}}{{\Omega_1}^{m_1}\Gamma(m_1)} e^{-\frac{m_1 {r_1}^2}{\Omega_1}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_1} e^{-\frac{\dot{r}_1^2}{2\beta_1^2}}, \quad r_1 \geq 0 \tag{7}$$

$$p_{r_2 \dot{r}_2}(r_2, \dot{r}_2) = \frac{2{m_2}^{m_2} {r_2}^{2m_2-1}}{{\Omega_2}^{m_2}\Gamma(m_2)} e^{-\frac{m_2 {r_2}^2}{\Omega_2}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_2} e^{-\frac{\dot{r}_2^2}{2\beta_2^2}} \quad r_2 \geq 0 \tag{8}$$

The probabilities P_1 and P_2 are:

$$P_1 = \frac{F_{r_2}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} =$$

$$= \frac{\gamma(\frac{m_2}{\Omega_2}{r_t}^2, m_2)}{\gamma(\frac{m_1}{\Omega_1}{r_t}^2, m_1) + \gamma(\frac{m_2}{\Omega_2}{r_t}^2, m_2)} \tag{9}$$

$$P_2 = \frac{F_{r_1}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} =$$

$$= \frac{\gamma(\frac{m_1}{\Omega_1}{r_t}^2, m_1)}{\gamma(\frac{m_1}{\Omega_1}{r_t}^2, m_1) + \gamma(\frac{m_2}{\Omega_2}{r_t}^2, m_2)} \tag{10}$$

The expression for the joint probability density function of the SSC combiner output signal and its derivative will be determined first for the case $r < r_T$:

$$p_{r\dot{r}}(r\dot{r}) = P_1 \cdot F_{r_1}(r_T) \cdot p_{r_2 \dot{r}_2}(r\dot{r}) +$$

$$+P_2 \cdot F_{r_2}(r_T) \cdot p_{r_1\dot{r}_1}(r\dot{r}) \tag{11}$$

and then for $r \geq r_T$:

$$p_{r\dot{r}}(r\dot{r}) = P_1 \cdot p_{r_1\dot{r}_1}(r\dot{r}) + P_1 \cdot F_{r_1}(r_T) \cdot p_{r_2\dot{r}_2}(r\dot{r}) +$$

$$+P_2 \cdot p_{r_2\dot{r}_2}(r\dot{r}) + P_2 \cdot F_{r_2}(r_T) \cdot p_{r_1\dot{r}_1}(r\dot{r}) \tag{12}$$

After substitution we have, for $r < r_T$:

$$p_{r\dot{r}}(r\dot{r}) = \frac{\gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) \cdot \frac{2{m_2}^{m_2} r^{2m_2 - 1}}{{\Omega_2}^{m_2} \Gamma(m_2)} e^{-\frac{m_2 r^2}{\Omega_2}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_2} e^{-\frac{\dot{r}^2}{2\beta_2^2}} +$$

$$+\frac{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2) \cdot \frac{2{m_1}^{m_1} r^{2m_1 - 1}}{{\Omega_1}^{m_1} \Gamma(m_1)} e^{-\frac{m_1 r^2}{\Omega_1}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_1} e^{-\frac{\dot{r}^2}{2\beta_1^2}} \tag{13}$$

and for $r \geq r_T$:

$$p_{r\dot{r}}(r\dot{r}) = \frac{\gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)} \cdot$$

$$\cdot \frac{2{m_1}^{m_1} r^{2m_1 - 1}}{{\Omega_1}^{m_1} \Gamma(m_1)} e^{-\frac{m_1 r^2}{\Omega_1}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_1} e^{-\frac{\dot{r}_1^2}{2\beta_1^2}} +$$

$$+\frac{\gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) \cdot \frac{2{m_2}^{m_2} r^{2m_2 - 1}}{{\Omega_2}^{m_2} \Gamma(m_2)} e^{-\frac{m_2 r^2}{\Omega_2}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_2} e^{-\frac{\dot{r}^2}{2\beta_2^2}} +$$

$$+\frac{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)} \cdot$$

$$\cdot \frac{2{m_2}^{m_2} r^{2m_2 - 1}}{{\Omega_2}^{m_2} \Gamma(m_2)} e^{-\frac{m_2 r^2}{\Omega_2}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_2} e^{-\frac{\dot{r}^2}{2\beta_2^2}} +$$

$$+\frac{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_2}{\Omega_2} r_t^2, m_2) \cdot \frac{2{m_1}^{m_1} r^{2m_1 - 1}}{{\Omega_1}^{m_1} \Gamma(m_1)} e^{-\frac{m_1 r^2}{\Omega_1}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta_1} e^{-\frac{\dot{r}^2}{2\beta_1^2}} \tag{14}$$

For the channels with identical parameters it is, for $r < r_T$:

$$p_{r\dot{r}}(r\dot{r}) = \gamma(\frac{m}{\Omega} r_t^2, m) \frac{2m^m r^{2m-1}}{\Omega^m \Gamma(m)} e^{-\frac{m r^2}{\Omega}} \cdot$$

$$\cdot \frac{1}{\sqrt{2\pi}\,\beta} e^{-\frac{\dot{r}^2}{2\beta^2}} \tag{15}$$

and for $r \geq r_T$:

$$p_{r\dot{r}}(r\dot{r}) = \left(1+\gamma(\frac{m}{\Omega}r_t^{\,2},m)\right)\cdot$$

$$\cdot\frac{2m^m r^{2m-1}}{\Omega^m\Gamma(m)}e^{-\frac{mr^2}{\Omega}}\cdot\frac{1}{\sqrt{2\pi}\,\beta}e^{-\frac{\dot{r}^2}{2\beta^2}} \tag{16}$$

The level crossing rate is:

$$N(r_{th}) = \int_0^\infty \dot{r}\, p_{r\dot{r}}(r_{th},\dot{r})\,d\dot{r} \tag{17}$$

for $r_{th} < r_T$:

$$N(r_{th}) = \frac{\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)+\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)\cdot$$

$$\cdot\frac{2m_2^{\,m_2}r_{th}^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_{th}^{\,2}}{\Omega_2}}\cdot\frac{\beta_2}{\sqrt{2\pi}}+$$

$$+\frac{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)}{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)+\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)\cdot$$

$$\cdot\frac{2m_1^{\,m_1}r_{th}^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_{th}^{\,2}}{\Omega_1}}\frac{\beta_1}{\sqrt{2\pi}} \tag{18}$$

and for $r_{th} \geq r_T$:

$$N(r_{th}) = \frac{\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)+\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}\cdot$$

$$\cdot\frac{2m_1^{\,m_1}r_{th}^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_{th}^{\,2}}{\Omega_1}}\frac{\beta_1}{\sqrt{2\pi}}+$$

$$+\frac{\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)+\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}\cdot$$

$$\cdot\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)\frac{2m_2^{\,m_2}r_{th}^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_{th}^{\,2}}{\Omega_2}}\cdot$$

$$\cdot\frac{\beta_2}{\sqrt{2\pi}}+\frac{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)}{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)+\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}\cdot$$

$$\cdot\frac{2m_2^{\,m_2}r_{th}^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}\cdot e^{-\frac{m_2 r_{th}^{\,2}}{\Omega_2}}\frac{\beta_2}{\sqrt{2\pi}}+$$

$$+\frac{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)}{\gamma(\frac{m_1}{\Omega_1}r_t^{\,2},m_1)+\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)}\cdot$$

$$\cdot\gamma(\frac{m_2}{\Omega_2}r_t^{\,2},m_2)\frac{2m_1^{\,m_1}r_{th}^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_{th}^{\,2}}{\Omega_1}}\frac{\beta_1}{\sqrt{2\pi}} \tag{19}$$

For the channels with identical parameters it is valid for $r_{th} < r_T$:

$$N(r_{th}) = \gamma(\frac{m}{\Omega}r_t^{\,2},m)\cdot\frac{2m^m r_{th}^{\,2m-1}}{\Omega^{m_1}\Gamma(m)}\cdot$$

$$\cdot e^{-\frac{m r_{th}^{\,2}}{\Omega}}\frac{\beta}{\sqrt{2\pi}} \tag{20}$$

and for $r_{th} \geq r_T$:

$$N(r_{th}) = \left(1+\gamma(\frac{m}{\Omega}r_t^{\,2},m)\right)\cdot$$

$$\cdot\frac{2m^m r_{th}^{\,2m-1}}{\Omega^{m_1}\Gamma(m)}e^{-\frac{m r_{th}^{\,2}}{\Omega}}\frac{\beta}{\sqrt{2\pi}} \tag{21}$$

The outage probabilty $P_{out}(r_{th})$ is defined as:

$$P_{out}(r_{th}) = \int_0^{r_{th}} p_r(r)\,dr \tag{22}$$

For $r < r_T$ probability density function is:

$$p_r(r) = P_1\cdot F_{r_1}(r_T)\cdot p_{r_2}(r)+P_2\cdot F_{r_2}(r_T)\cdot p_{r_1}(r) \tag{23}$$

and for $r \geq r_T$:

$$p_r(r) = P_1\cdot p_{r_1}(r)+P_1\cdot F_{r_1}(r_T)\cdot p_{r_2}(r)+$$

$$+P_2\cdot p_{r_2}(r)+P_2\cdot F_{r_2}(r_T)\cdot p_{r_1}(r) \tag{24}$$

In the presence of Nakagami-*m* fading and for $r < r_T$ probability density function is:

$$p_r(r) = \frac{\gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) \frac{2 m_2^{\,m_2} r^{\,2m_2 - 1}}{\Omega_2^{\,m_2} \Gamma(m_2)} e^{-\frac{m_2 r^2}{\Omega_2}} +$$

$$+ \frac{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2) \frac{2 m_1^{\,m_1} r_{th}^{\,2m_1 - 1}}{\Omega_1^{\,m_1} \Gamma(m_1)} e^{-\frac{m_1 r^2}{\Omega_1}} \quad (25)$$

for $r \geq r_T$:

$$p_r(r) = \frac{\gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \frac{2 m_1^{\,m_1} r^{\,2m_1 - 1}}{\Omega_1^{\,m_1} \Gamma(m_1)} e^{-\frac{m_1 r^2}{\Omega_1}} +$$

$$+ \frac{\gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) \frac{2 m_2^{\,m_2} r^{\,2m_2 - 1}}{\Omega_2^{\,m_2} \Gamma(m_2)} e^{-\frac{m_2 r^2}{\Omega_2}} +$$

$$+ \frac{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \frac{2 m_2^{\,m_2} r^{\,2m_2 - 1}}{\Omega_2^{\,m_2} \Gamma(m_2)} e^{-\frac{m_2 r^2}{\Omega_2}} +$$

$$+ \frac{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2) \frac{2 m_1^{\,m_1} r^{\,2m_1 - 1}}{\Omega_1^{\,m_1} \Gamma(m_1)} e^{-\frac{m_1 r^2}{\Omega_1}} \quad (26)$$

The outage probabilties $P_{out}(r_{th})$ are defined as, for $r_{th} < r_T$:

$$P_{out}(r_{th}) = \frac{\gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) \cdot \gamma(\frac{m_2}{\Omega_2} r_{th}^{\,2}, m_2) +$$

$$+ \frac{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2) \gamma(\frac{m_1}{\Omega_1} r_{th}^{\,2}, m_1) \quad (27)$$

and for $r_{th} \geq r_T$:

$$P_{out}(r_{th}) = \frac{\gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \left(\gamma(\frac{m_1}{\Omega_1} r_{th}^{\,2}, m_1) - \gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) \right) +$$

$$+ \frac{\gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) \cdot \gamma(\frac{m_2}{\Omega_2} r_{th}^{\,2}, m_2) +$$

$$+ \frac{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \left(\gamma(\frac{m_2}{\Omega_2} r_{th}^{\,2}, m_2) - \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2) \right) +$$

$$+ \frac{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t^{\,2}, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2)} \cdot$$

$$\cdot \gamma(\frac{m_2}{\Omega_2} r_t^{\,2}, m_2) \cdot \gamma(\frac{m_1}{\Omega_1} r_{th}^{\,2}, m_1) \quad (28)$$

For the channels with identical parameters we have, for $r_{th} < r_T$:

$$P_{out}(r_{th}) = \gamma(\frac{m}{\Omega} {r_t}^2, m)\gamma(\frac{m}{\Omega} {r_{th}}^2, m) \tag{29}$$

and for $r_{th} \geq r_T$:

$$P_{out}(r_{th}) = \gamma(\frac{m}{\Omega} {r_t}^2, m)\gamma(\frac{m}{\Omega} {r_{th}}^2, m) +$$

$$+\left(\gamma(\frac{m_2}{\Omega_2} {r_{th}}^2, m_2) - \gamma(\frac{m_2}{\Omega_2} {r_t}^2, m_2)\right) \tag{30}$$

Finnaly, fade duration is obtain from the expression:

$$T(r_{th}) = \frac{P_{out}(r_{th})}{N(r_{th})} \tag{31}$$

IV. NUMERICAL RESULTS

The joint probability density functions (PDFs) of the SSC combiner output signal are shown in Figs. 2. and 3. for diferent values of parameters r_T, m, Ω and β.

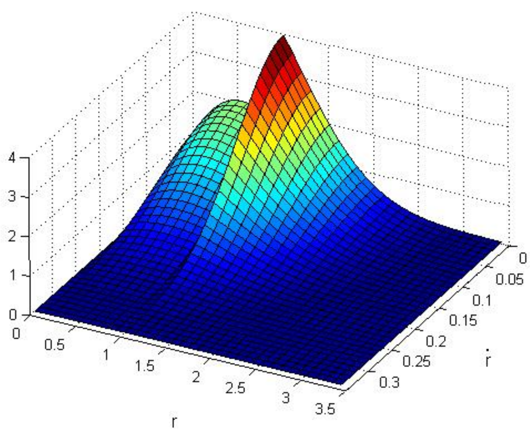

Fig.2. The joint probability density function (PDF), $p_{r\dot{r}}(r\dot{r})$ for r_T =1, m=0.7, Ω=1, β=0.1

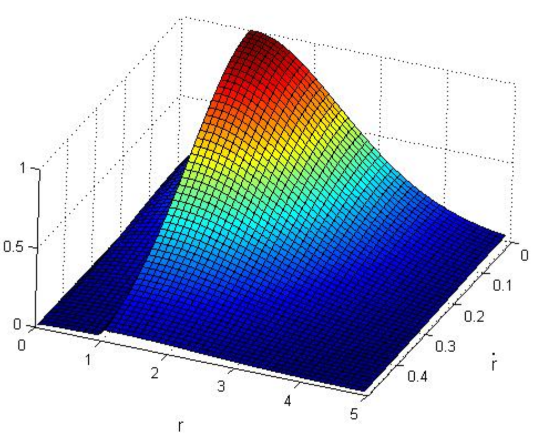

Fig.3. The joint probability density function (PDF), $p_{r\dot{r}}(r\dot{r})$ for r_T =1, m=0.7, Ω=4, β=0.2

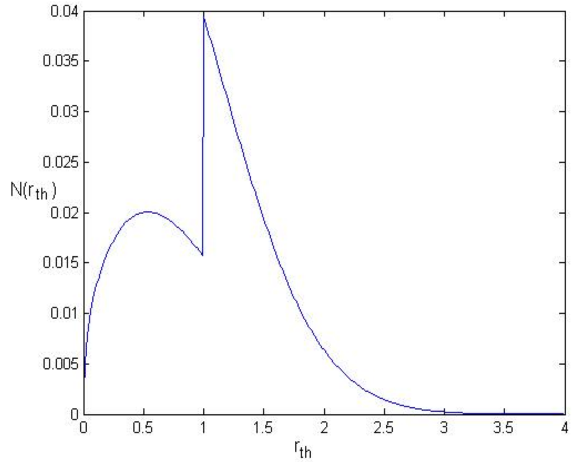

Fig. 4. Level crossing rate $N(r_{th})$ for r_T =1, m =0.7, Ω= 1, β=0.1

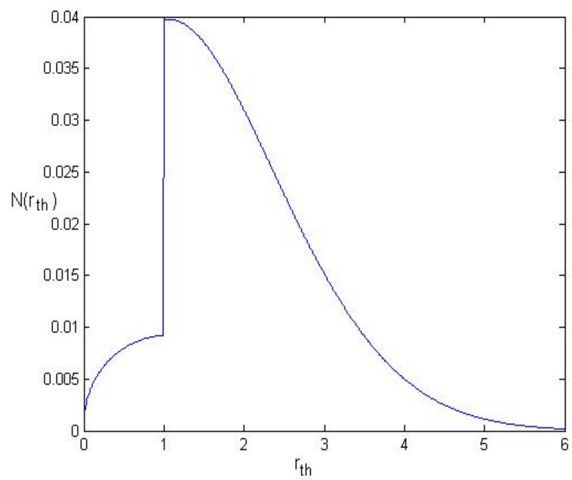

Fig. 5. Level crossing rate $N(r_{th})$ for r_T=1, m=0.7, Ω=4, β=0.2

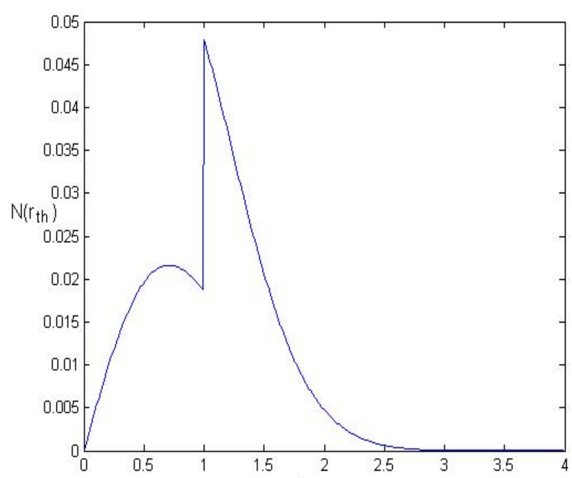

Fig. 6. Level crossing rate $N(r_{th})$ for r_T=1, m=1, Ω=1, β=0.1

The level crossing rate curves $N(r_{th})$ are given in Figs. 4. to 7. for diferent threshold values, Nakagami fading parameter m values, and other parameters.

We can see that in all cases curves have similar shape. Also, we can observe discontinuities on the level crossing rate curves versu threshold. Numerical values of threshold determine the discontinuity moment appearance.

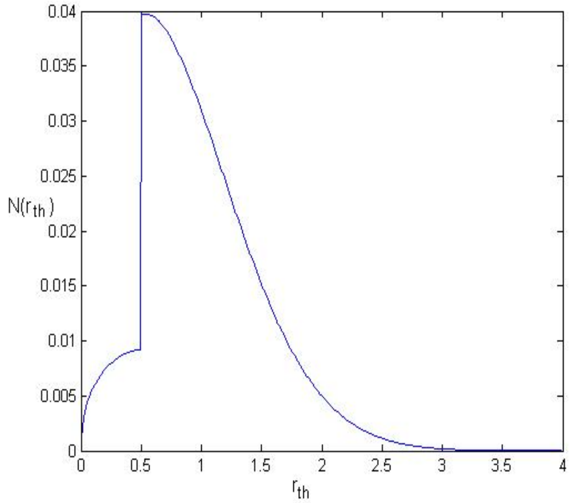

Fig. 7. Level crossing rate $N(r_{th})$ for r_T =0.5, m=0.7, Ω=1, β =0.1

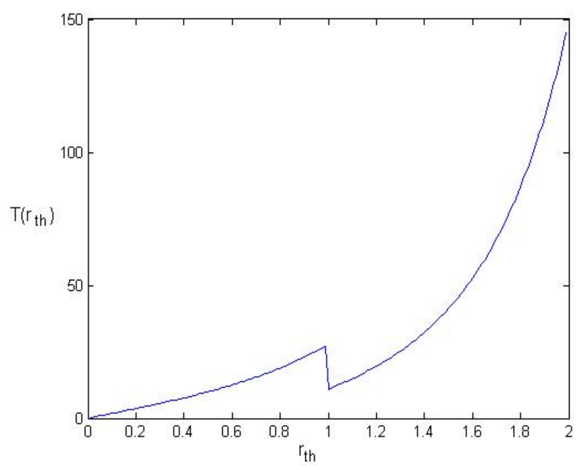

Fig.8. Fade duration $T(r_{th})$ for r_T = 1, m =0.7, Ω =1, β=0.1

Fade duration curves $T(r_{th})$ are shown in Figs. 8. to 11. for different parameter values. We can compare these figures now.

It can be observed that all curves, $T(r_{th})$ versu threshold, have similar shape, but threshold numerical value influence to the discontinuity moment appearance. Larger rise of fade duration corresponds to smaller threshold value.

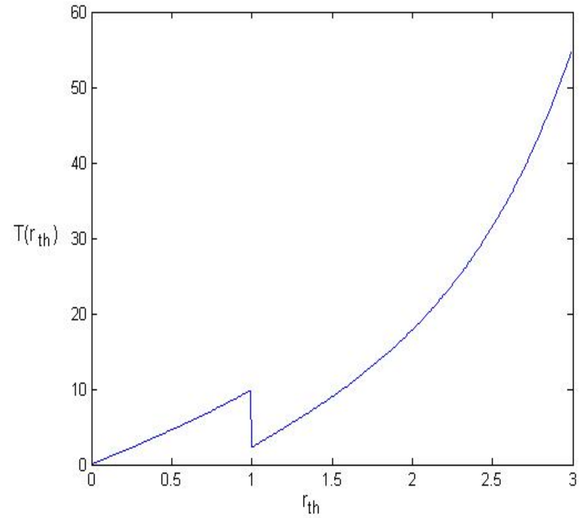

Fig.9. Fade duration $T(r_{th})$ for r_T = 1, m = 0.7, Ω = 4, β =0.2

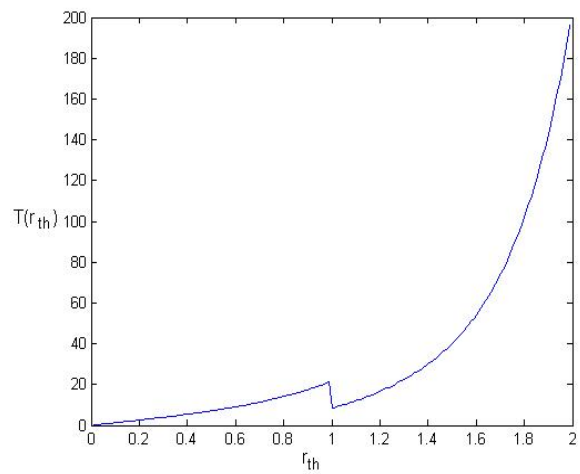

Fig. 10. Fade duration $T(r_{th})$ for r_T = 1, m = 1, Ω = 1, β = 0.1

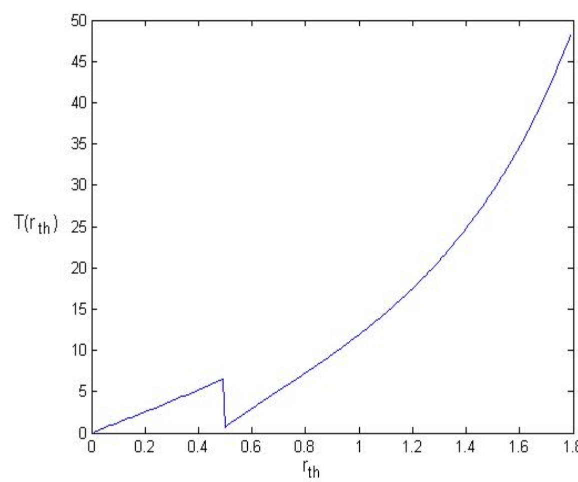

Fig. 11. Fade duration $T(r_{th})$ for r_T = 0.5, m =1, Ω = 1, β = 0.1

V. CONCLUSION

Diversity combining is good technique to reduce fading in wireless communication systems. The level crossing rate, outage probability and average time of fade duration of the SSC combiner output signal are important system performances.

We determine level crossing rate in order to obtain fade duration of SSC Combiner in the presence of log-normal fading in [14]. Level crossing rate, outage probability and fade duration of the SSC combiner output signal are determined in the presence of Nakagami-*m* fading in this paper. The results are shown graphically for different parameters values and some conclusions are given.

In our future work these system performances can be derived for correlated fading and for some other fading distributions.

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Mihajlo Č. Stefanović was born in Niš, Serbia, in 1947. He received the BSc, MSc and PhD degrees in electrical engineering from Faculty of Electronic Engineering (Department of Telecommunications), University of Niš, Serbia, in 1971, 1976 and 1979, respectively. His primary research interests are statistical communication theory, optical, satellite and wireless communication systems. His areas of interest also include applied probability theory, optimal receiver design and synchronization. He has written or co-authored a great number of journal publications. Dr Stefanović is a Professor at the Faculty of Electronic Engineering in Niš.

Dragana S. Krstić was born in Pirot, Serbia, in 1966. She received the BSc, MSc and PhD degrees in electrical engineering from Faculty of Electronic Engineering (Department of Telecommunications), University of Niš, Serbia, in 1990, 1998 and 2006, respectively. Her field of interest includes telecommunications theory, optical communication systems, wireless communication systems, etc. She works as Teaching Assistant at the Faculty of Electronic Engineering in Niš.

Petar B. Nikolić was born in Pirot, Serbia, in 1974. He received the BSc degree in electrical engineering from Faculty of Electronic Engineering, Niš, (Department of Telecommunications) in 2001. His field of interest includes telecommunications theory, wireless communication systems. He works as engineer in Tigar Tyres, Pirot.

Srdjan Jovković was born in 1971. He received the BSc and MSc degrees in electrical engineering from Faculty of Electronic Engineering (Department of Telecommunications), University of Niš, Serbia, in 1997. and 2006. His field of interest includes telecommunications theory, wireless communication systems. He works now as Teaching Assistant at High Technical Scool in Niš.

Dušan M. Stefanović was born in Niš, Serbia, in 1979. He received the BSc degrees in electrical engineering from Faculty of Electronic Engineering (Department of Telecommunications), University of Niš, Serbia, in 2005. He works as Teaching Assistant at High Technical Scool in Niš and he is post-graduated student at Faculty of Electronic Engineering in Ni š.