Bit Error Rate for Complex SSC/MRC Combiner in the Presence of Nakagami-*m* Fading

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***Abstract*—The complex Switch and Stay Combining/Maximal Ratio Combining (SSC/MRC) combiner is considered in this paper. The system output signal at two time instants is observed in the presence of Nakagami-*m* fading at the input. Both of combiners, SSC and MRC, are with two branches. The probability density function (PDF) at the output of the complex combiner is obtained and the bit error rate (BER) for the case of binary phase swift keying (BPSK) modulation is determined. The obtained results are shown graphically. It was pointed out the improvement of using complex SSC/MRC combiner relative to classical MRC and SSC combiners at one time instant.**

Keywords-Bit error rate, Probability density function; Complex SSC/MRC combiner; Nakagami-m fading; two time instants

I. INTRODUCTION

The fading, the occurrence of variation of instantaneous value of the received signal envelope, is one of the very important factors of signal quality derogation at the reception. Many urban and vehicular communication systems are subjected to fading caused by multipath propagation due to reflection, refraction and scattering by buildings and other large structures [1]. The received signal is, thus, a sum of different signals that arrive via different propagation paths.

Several statistical models have been used in the literature to describe the fading envelope of the received signal [2]-[8]. The Rayleigh and Rician distributions are used to characterize the envelope of faded signals over small geographical areas or sort term fades, while the log-normal distribution is used when much wider geographical areas are involved. A more versatile statistical model, however, is Nakagami-*m*-distribution [7], which can model a variety of fading environments including those modelled by the Rayleigh and one-sided Gaussian distributions. Also the log-normal and Rician distributions may be closely approximated by the Nakagami distribution in some ranges of mean signal values [2]. The fit between Nakagami and Rician distributions may not be very good when the signal-noise ratio (SNR) is large, but is very accurate for low SNR values. Furthermore, the Nakagami distribution is more flexible and more accurately fit experimental data for many physical propagation channels then the log-normal and Rician distributions [2], [3]. Although the Nakagami model fits experimental data around the mean or median, it does not fit very well in the tails of the distribution. For this reason, some researchers question the use of the Nakagami model [4]; however, there is continued interest in modelling a variety of propagation channels with the Nakagami distribution [2], [3]. Moreover, in [9] Braun and Dersch give a detailed derivation of the Nakagami distribution and show that it is quite appropriate to model multipath fading in the mobile radio channel.

There are several ways to reduce the impact of fading on system performances. The goal is to achieve this without increasing the signal power and channel capacity. The diversity reception techniques are used extensively in fading radio channels to reduce the effects of fading on system performances [6], [10], and [11], including both fixed terminals and mobile communication systems.

In order to gain significantly from the use of diversity, there must be a sufficient degree of statistical independence in the fading of the received signal in each of the diversity branches. The assumption of statistical independence between the diversity channels is valid only if they are sufficiently separated [2]. In mobile radio systems the signals at the mobile station become decorrelated as the antenna separation (or frequency separation) increases, giving rise to diversity. If the antennas are crowded then such diversity conditions may be violated [8]. In space diversity systems an antenna separation of 30 to 50 wavelengths is typically required to obtain correlation coefficients strictly between zero and one-third, in which case, for a two-channel maximal-ratio system in a Rayleigh-fading environment, the effect of correlation may be ignored [10].

However, there are other cases of practical interest where the assumption of statistical independence is not valid. When the Nakagami channel is studied, the analysis is usually limited to the dual-branch diversity system [12]. A long time ago Al-Hussani and Al-Bassion studied the effect of correlation on the performance of a dual-branch maximal-ratio combiner for the correlated Nakagami-fading channel. They found that for the Nakagami-fading environment and for a worst case fading condition and identical signal-to-noise ratio (SNR) in each of the two branches, the performance difference between a single channel and the two channels system increases from 3 to 24 dB as the correlation coefficient decreases from unity to zero.

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II. RELATED WORK

In diversity systems multiple copies of the same signal are sending. They are combined in different ways in order to obtain as larger as possible signal to noise ratio. There are some kinds of diversity combining schemes.

Maximal-Ratio Combining (MRC) is the optimal combining scheme [13]. In this combiner signals from all inputs are summed. Because MRC requires cognition of the channel fading parameters, it is the most complicated and expensive combining model [14], [15].

Equal Gain Combining (EGC) is next and then Selection Combining (SC) and Switch and Stay Combining (SSC), with lower performances. These combining models are simpler and cheaper and they are very often implemented in practice whereas SC and SSC combining models do not require signal cophasing and fading envelope evaluation [16].

SSC is simplification of the system complexity, but with losing in quality. In this model, the receiver selects an antenna until its value drops below predetermined threshold. Then, the receiver switches to other antenna and remains for the next time slot, no matter the channel quality of that antenna is above or below the threshold. In the literature, mainly dual SSC schemes have been analyzed [17], [18].

By the authors' knowledge in the new open literature, except from papers published by this group of authors, there are no papers that treat these problems by sampling in the two time instants. We derived the expression for the joint probability density function of the SSC combiner output signal in the presence of different fading distributions (Nakagami, log-normal, Hoyt) in two time instants [19]-[21]. Based on these joint PDFs we made the performance analysis of SSC/SC combiner at two time instants in the presence of Rayleigh and log-normal fading in [22], [23]. The bit error rates for SSC/MRC combiner at two time instants in the presence of log-normal, Rayleigh and Hoyt fading we determined in [24]-[26], respectively.

In this paper the probability density function and the bit error rate of the SSC/MRC combiner output signal in the presence of Nakagami-*m* fading, with sampling signals at two time instants for one time slot, will be observed. The system is more complex then classical MRC and SSC systems at one time instant, but with better performances. That means that bit error rate can be increased and transmit power can be reduced comparing to classical systems.

This paper is organized as follows: II Section gives related works; III Section describes the complex SSC/MRC system model and the process of obtaining the probability density functions and the bit error rate of the SSC/MRC combiner output signal at two time instants. Sections IV presents numerical results obtained for performances introduced in previous section. Finally, the main results of the paper are presented in V Section as conclusions.

III. COMPLEX SSC/MRC COMBINER MODEL

The model of the SSC/MRC combiner with two inputs considering in this paper is shown in Fig. 1.

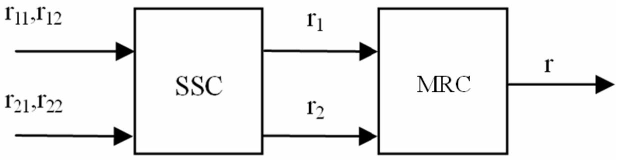

Figure 1. Complex dual SSC/MRC combiner.

We consider the SSC/MRC combiner with two branches at two time instants. The signals at the inputs at SSC combiner are r_{11} and r_{21} at first time moment and they are r_{12} and r_{22} at the second time moment. The output signals at SSC part are r_1 and r_2. The indexes for the input signals are: first index is the number of the branch and the other signs time instant observed. For the output signals, the index represents the time instant observed. After determining the output signals at SSC combiner r_1 and r_2, they become the inputs at MRC combiner and the overall output signal is r.

The joint probability density function of correlated signals r_1 and r_2 at the output of SSC combiner at two time inputs with Nakagami-*m* distribution and for the same parameters, is obtained in [19].

For $r_1 < r_T, r_2 < r_T$ it is:

$$p^1{}_{r_1 r_2}(r_1, r_2) =$$

$$= P_1 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_2^2}{\Omega_1(1-\rho)}} \gamma(\frac{m_1}{\Omega_1(1-\rho)} r_T{}^2, m_1+k) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_1^2}{\Omega_2(1-\rho)}} \gamma(\frac{m_2}{\Omega_2(1-\rho)} r_T{}^2, m_2+k) +$$

$$+ P_2 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_2^2}{\Omega_2(1-\rho)}} \gamma(\frac{m_2}{\Omega_2(1-\rho)} r_T{}^2, m_2+k) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_1^2}{\Omega_1(1-\rho)}} \gamma(\frac{m_1}{\Omega_1(1-\rho)} r_T{}^2, m_1+k) \tag{1}$$

For $r_1 \geq r_T, r_2 < r_T$:

$$p^2{}_{r_1 r_2}(r_1, r_2) = P_1 \frac{2{m_2}^{m_2} {r_2}^{2m_2-1}}{{\Omega_2}^{m_2}\Gamma(m_2)} e^{-\frac{m_2 {r_2}^2}{\Omega_2}} \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_1^2}{\Omega_1(1-\rho)}} \gamma(\frac{m_1}{\Omega_1(1-\rho)} r_T{}^2, m_1+k) +$$

$$+ P_1 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_2^2}{\Omega_1(1-\rho)}} \gamma(\frac{m_1}{\Omega_1(1-\rho)} r_T{}^2, m_1+k) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_1^2}{\Omega_2(1-\rho)}} \gamma(\frac{m_2}{\Omega_2(1-\rho)} r_T{}^2, m_2+k) +$$

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$$+P_2 \frac{2m_1^{m_1} r_2^{2m_1-1}}{\Omega_1^{m_1}\Gamma(m_1)} e^{-\frac{m_1 r_2^2}{\Omega_1}} \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_1^2}{\Omega_2(1-\rho)}} \gamma\left(\frac{m_2}{\Omega_2(1-\rho)} r_T^2, m_2+k\right) +$$

$$+P_2 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_2^2}{\Omega_2(1-\rho)}} \gamma\left(\frac{m_2}{\Omega_2(1-\rho)} r_T^2, m_2+k\right) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_1^2}{\Omega_1(1-\rho)}} \gamma\left(\frac{m_1}{\Omega_1(1-\rho)} r_T^2, m_1+k\right) \quad (2)$$

For $r_1 < r_T, r_2 \ge r_T$:

$$p^3_{r_1 r_2}(r_1, r_2) = P_1 \gamma\left(\frac{m_1}{\Omega_1} r_t^2, m_1\right) \cdot$$

$$\cdot \frac{4(r_1 r_2)^{m_2}}{\Gamma(m_2)(1-\rho)\rho^{(m_2-1)/2}} \left(\frac{m_2}{\Omega_2}\right)^{m_2+1} I_{m-1}\left(\frac{2m_2\sqrt{\rho}\, r_1 r_2}{\Omega_2(1-\rho)}\right) e^{-\frac{m_2(r_1^2+r_2^2)}{\Omega_2(1-\rho)}} +$$

$$+P_1 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_2^2}{\Omega_1(1-\rho)}} \gamma\left(\frac{m_1}{\Omega_1(1-\rho)} r_T^2, m_1+k\right) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_1^2}{\Omega_2(1-\rho)}} \gamma\left(\frac{m_2}{\Omega_2(1-\rho)} r_T^2, m_2+k\right) +$$

$$+P_2 \gamma\left(\frac{m_2}{\Omega_2} r_t^2, m_2\right) \cdot \frac{4(r_1 r_2)^{m_1}}{\Gamma(m_1)(1-\rho)\rho^{(m_1-1)/2}} \left(\frac{m_1}{\Omega_1}\right)^{m_1+1} \cdot$$

$$\cdot I_{m-1}\left(\frac{2m_1\sqrt{\rho}\, r_1 r_2}{\Omega_1(1-\rho)}\right) e^{-\frac{m_1(r_1^2+r_2^2)}{\Omega_1(1-\rho)}} +$$

$$+P_2 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_2^2}{\Omega_2(1-\rho)}} \gamma\left(\frac{m_2}{\Omega_2(1-\rho)} r_T^2, m_2+k\right) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_1^2}{\Omega_1(1-\rho)}} \gamma\left(\frac{m_1}{\Omega_1(1-\rho)} r_T^2, m_1+k\right) \quad (3)$$

For $r_1 \ge r_T, r_2 \ge r_T$:

$$p^4_{r_1 r_2}(r_1, r_2) = P_1 \frac{4(r_1 r_2)^{m_1}}{\Gamma(m_1)(1-\rho)\rho^{(m_1-1)/2}} \left(\frac{m_1}{\Omega_1}\right)^{m_1+1} \cdot$$

$$\cdot I_{m-1}\left(\frac{2m_1\sqrt{\rho}\, r_1 r_2}{\Omega_1(1-\rho)}\right) e^{-\frac{m_1(r_1^2+r_2^2)}{\Omega_1(1-\rho)}} + P_1 \frac{2m_2^{m_2} r_2^{2m_2-1}}{\Omega_2^{m_2}\Gamma(m_2)} e^{-\frac{m_2 r_2^2}{\Omega_2}} \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_1^2}{\Omega_1(1-\rho)}} \gamma\left(\frac{m_1}{\Omega_1(1-\rho)} r_T^2, m_1+k\right) +$$

$$+P_1 \gamma\left(\frac{m_1}{\Omega_1} r_t^2, m_1\right) \cdot \frac{4(r_1 r_2)^{m_2}}{\Gamma(m_2)(1-\rho)\rho^{(m_2-1)/2}} \left(\frac{m_2}{\Omega_2}\right)^{m_2+1} \cdot$$

$$\cdot I_{m-1}\left(\frac{2m_2\sqrt{\rho}\, r_1 r_2}{\Omega_2(1-\rho)}\right) e^{-\frac{m_2(r_1^2+r_2^2)}{\Omega_2(1-\rho)}} +$$

$$+P_1 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_2^2}{\Omega_1(1-\rho)}} \gamma\left(\frac{m_1}{\Omega_1(1-\rho)} r_T^2, m_1+k\right) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_1^2}{\Omega_2(1-\rho)}} \gamma\left(\frac{m_2}{\Omega_2(1-\rho)} r_T^2, m_2+k\right) +$$

$$+P_2 \frac{4(r_1 r_2)^{m_2}}{\Gamma(m_2)(1-\rho)\rho^{(m_2-1)/2}} \left(\frac{m_2}{\Omega_2}\right)^{m_2+1} I_{m-1}\left(\frac{2m_2\sqrt{\rho}\, r_1 r_2}{\Omega_2(1-\rho)}\right) e^{-\frac{m_2(r_1^2+r_2^2)}{\Omega_2(1-\rho)}} +$$

$$+P_2 \frac{2m_1^{m_1} r_2^{2m_1-1}}{\Omega_2^{m_1}\Gamma(m_1)} e^{-\frac{m_1 r_2^2}{\Omega_2}} \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_1}\right)^{m_2+k} e^{-\frac{m_2 r_1^2}{\Omega_1(1-\rho)}} \cdot \gamma\left(\frac{m_2}{\Omega_1(1-\rho)} r_T^2, m_2+k\right) +$$

$$+P_2 \gamma\left(\frac{m_2}{\Omega_2} r_t^2, m_2\right) \cdot \frac{4(r_1 r_2)^{m_1}}{\Gamma(m_1)(1-\rho)\rho^{(m_1-1)/2}} \left(\frac{m_1}{\Omega_1}\right)^{m_1+1} \cdot$$

$$\cdot I_{m-1}\left(\frac{2m_1\sqrt{\rho}\, r_1 r_2}{\Omega_1(1-\rho)}\right) e^{-\frac{m_1(r_1^2+r_2^2)}{\Omega_1(1-\rho)}} +$$

$$+P_2 \sum_{k=0}^{\infty} \frac{2(r_2)^{2m_2+2k-1}}{k!\Gamma(m_2)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_2}{\Omega_2}\right)^{m_2+k} e^{-\frac{m_2 r_2^2}{\Omega_2(1-\rho)}} \gamma\left(\frac{m_2}{\Omega_2(1-\rho)} r_T^2, m_2+k\right) \cdot$$

$$\cdot \sum_{k=0}^{\infty} \frac{2(r_1)^{2m_1+2k-1}}{k!\Gamma(m_1)} \left(\frac{\rho}{1-\rho}\right)^k \left(\frac{m_1}{\Omega_1}\right)^{m_1+k} e^{-\frac{m_1 r_1^2}{\Omega_1(1-\rho)}} \gamma\left(\frac{m_1}{\Omega_1(1-\rho)} r_T^2, m_1+k\right) \quad (4)$$

where m_i and Ω_i are parameters of Nakagami-*m* distribution, ρ is correlation coefficient and r_t is the threshold of the decision for SSC combiner.

Total conditional signal value at the MRC combiner output, for equally transmitted symbols of L branch MRC receiver, is given by

$$r = \sum_{l=1}^{L} r_l \quad (5)$$

For coherent binary signals the conditional BER $P_b(e|\{r_l\}_{l=1}^{L})$ is given by [13]:

$$P_b(e|\{r_l\}_{l=1}^{L}) = Q\left(\sqrt{2gr}\right) \quad (6)$$

where Q is the one-dimensional Gaussian Q-function [1]

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-t^2/2} dt \quad (7)$$

Gaussian Q-function is defined as [27]

$$Q(x) = \frac{1}{\pi} \int_0^{\pi/2} \exp\left(-\frac{x^2}{2\sin^2\phi}\right) d\phi \quad (8)$$

If alternative representation of Gaussian-Q function is used, the conditional BER can be expressed as

$$P_b(e|\{r_l\}_{l=1}^{L}) = \frac{1}{\pi} \int_0^{\pi/2} \exp\left(-\frac{gr}{\sin^2\phi}\right) d\phi = \frac{1}{\pi} \int_0^{\pi/2} \prod_{l=1}^{L} \left(-\frac{gr_l}{\sin^2\phi}\right) d\phi \quad (9)$$

The unconditional BER can be obtained by averaging the multichannel conditional BER over the joint PDF of the signals at the input of MRC combiner

$$P_b(e) = \underbrace{\int_0^{\infty}\int_0^{\infty} \cdots \int_0^{\infty}}_{L} P_b\left(\{r_l\}_{l=1}^{L}\right) \prod_{l=1}^{L} p_{r_1,r_2,\ldots r_L}(r_1, r_2, \ldots r_L) dr_1 dr_2 \ldots dr_L \quad (10)$$

Substituting (9) in (10), $P_b(e)$ is obtained as

$$P_b(e) = \underbrace{\int_0^{\infty}\int_0^{\infty} \cdots \int_0^{\infty} \frac{1}{\pi} \int_0^{\pi/2} \prod_{l=1}^{L} \left(-\frac{gr_l}{\sin^2\phi}\right) d\phi}_{L}\, p_{r_1,r_2,\ldots r_L}(r_1, r_2, \ldots r_L) dr_1 dr_2 \ldots dr_L \quad (11)$$

For dual branch MRC combiner, $P_b(e)$ is

$$P_b(e) = \underbrace{\int_0^{\infty}\int_0^{\infty} \cdots \int_0^{\infty} \frac{1}{\pi} \int_0^{\pi/2} \prod_{l=1}^{L} \left(-\frac{gr_l}{\sin^2\phi}\right) d\phi}_{L}\, p_{r_1,r_2,\ldots r_L}(r_1, r_2, \ldots r_L) dr_1 dr_2 \ldots dr_L \quad (12)$$

Substituting (1-4) in (12), $P_b(e)$ of SSC/MRC combiner can be obtained as:

$$P_b(e) = \frac{1}{\pi} \int_0^{r_t}\int_0^{r_t}\int_0^{\pi/2} dr_1 dr_2 d\phi \left(-\frac{gr_1}{\sin^2\phi}\right)\left(-\frac{gr_2}{\sin^2\phi}\right) p^1{}_{r_1 r_2}(r_1, r_2) +$$

$$+ \frac{1}{\pi} \int_{r_t}^{\infty}\int_0^{r_t}\int_0^{\pi/2} dr_1 dr_2 d\phi \left(-\frac{gr_1}{\sin^2\phi}\right)\left(-\frac{gr_2}{\sin^2\phi}\right) p^2{}_{r_1 r_2}(r_1, r_2) +$$

$$+ \frac{1}{\pi} \int_0^{r_t}\int_{r_t}^{\infty}\int_0^{\pi/2} dr_1 dr_2 d\phi \left(-\frac{gr_1}{\sin^2\phi}\right)\left(-\frac{gr_2}{\sin^2\phi}\right) p^3{}_{r_1 r_2}(r_1, r_2) +$$

$$+ \frac{1}{\pi} \int_{r_t}^{\infty}\int_{r_t}^{\infty}\int_0^{\pi/2} dr_1 dr_2 d\phi \left(-\frac{gr_1}{\sin^2\phi}\right)\left(-\frac{gr_2}{\sin^2\phi}\right) p^4{}_{r_1 r_2}(r_1, r_2) \quad (13)$$

IV. NUMERICAL RESULTS

The bit error rate curves, for different types of combiners and correlation parameters, are presented in Fig.2 and 3. It is assumed that both inputs have the same channel parameters. r_t is the optimal threshold for the SSC decision [8]:

$$r_t = \frac{\Gamma(m+1/2)}{\Gamma(m)} \left(\frac{\Omega}{m}\right)^{1/2} \quad (14)$$

The BER family curves for one channel receiver, for MRC combiner at one time instant and for SSC/MRC combiner at two time instants for uncorrelated case, and also for very strong correlation, are shown in Fig. 2 versus different distribution parameter.

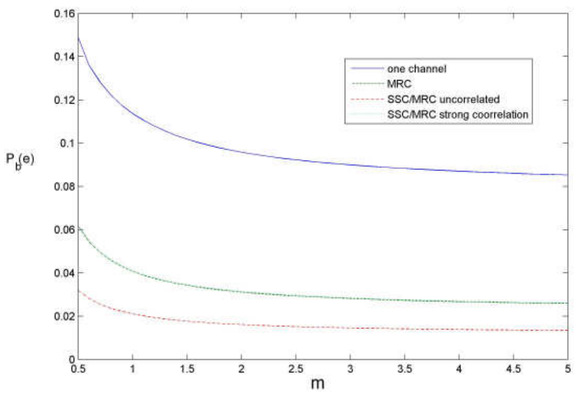

Figure 2. Bit error rate for different types of combiners versus parameter *m* , for *Ω=0.5*

One can see from this figure that SSC/MRC combiner has significant better performances for uncorrelated case then MRC combiner at one time instant. For $\rho = 1$ the BER of SSC/MRC combiner follows the results for MRC combiner.

It is obvious that using of complex SSC/MRC combiner results in better performance of the system because the BER for uncorrelated SSC/MRC combiner decrease for about 50% regarding MRC combiner.

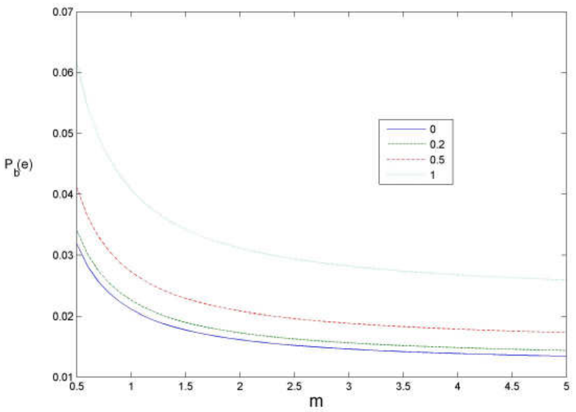

Figure 3. Bit error rate for SSC/MRC combiner versus parameter *m* for $\Omega=0.5$, for different values of ρ

The influence of correlation to the outage probability of complex SSC/MRC combiner is presented in Fig. 3. The benefits of using this type of combiner increases with decreasing of correlation between input signals. It is apparent that there is no economic justification for the use of complex SSC/MRC combiner in the case of strong correlations between input signals.

V. CONCLUSIONS

The SSC and MRC are simple and frequently used techniques for signal combining in diversity systems. The probability density function of complex dual SSC/MRC combiner output signal, at two time instants, is determined in this paper. The bit error probability is expressed based on it.

The system performances deciding by two samples can be determine by the joint probability density function of the SSC combiner output signal at two time instants and putting them as inputs of MRC combiner. The obtained results are shown graphically. The performance improvement of SSC/MRC combiner at two time instants, comparing with classical SSC and MRC combiners, is described.

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