# The Performance of Macrodiversity System in the Presence of Long-term and Short-term Fading

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*Abstract*: - Probability density function (PDF), moments of signal and amount of fading (AF) at the output of macrodiversity system in closed form are obtained. Moreover, level crossing rate (LCR) of signal at output of macro diversity system is analytically derived and used to study average fade duration (AFD) of the proposed system. Dual maximal-ratio combining (MRC) is implemented at the micro level (single base station) and selection combining (SC) with two base stations (dual diversity) is implemented at the macro level. This model assumes a Nakagami-m density function for the envelope of the received signal and a gamma distribution to model the average power to account for the shadowing. The results are shown graphically for different signal and fading parameters values.

*Key-Words:-* Shadowing, Nakagami-*m* Fading, Microdiversity, Macrodiversity, Probability Density Function, Amount of Fading

## 1 Introduction

Transmissions in wireless communications systems are influenced by various effects such as multipath and shadowing. Short-term fading is the result of multipath propagation while shadowing is the result of large obstacles between transmitter and receiver.

The reliability of communication over the wireless channels can be improved using diversity techniques, such as space diversity [1], [2]. Diversity techniques at single base station (microdiversity) reduce the effects of short-term fading. Impairments due to shadowing can be mitigated using macrodiversity techniques which employ the processing of signals from multiple base stations. The use of composite micro- and macrodiversity has recently received considerable interest due to the fact that it simultaneously combats the both short-term fading as well as shadowing. A composite multipath/shadowed fading environment modeled either as Rayleigh-lognormal, Rician-lognormal or Nakagami-lognormal is considered in [3], [4].

The use of lognormal distribution to model the average power which is random variable due to shadowing doesn't lead to a closed form solution for the probability density function (PDF) of the signal-to-noise ratio (SNR) at the receiver. A compound fading model uses a gamma distribution to account for shadowing instead of the lognormal distribution [6], [7]. This model incorporates short-term fading and shadowing and provides an analytical solution for the PDF of the SNR facilitating the analysis of wireless systems.

In this paper, system following micro- and macrodiversity reception in correlated gamma shadowed Nakagami-m fading channels is considered. Microdiversity system was used to reduce the effects of short-term fading to the system performance. Macrodiversity system was used to reduce the effects of long-term fading to system performance. Closed form expressions for probability density function (PDF) at

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the output of macrodiversity system is obtained and used to derive moments and amount of fading (AF) of the proposed system. Furthermore, analytical expressions for cumulative density function (CDF), the joint probability density function of signal envelopes and its derivatives, and average level crossing rate (LCR) at the output of the system are obtained and used to study probability outage and the average fading duration (AFD). Numerical results are shown graphically.

## 2 Model of the System

The model of the macrodiversity system is shown in the Fig. 1.

Dual-branch maximal-ratio combining (MRC) is implemented at the micro level (single base station) and selection combining (SC) with two base stations (dual diversity) is implemented at the macro level. Signals at antennas in single base station are independent. The two base stations are treated to have nonzero correlation.

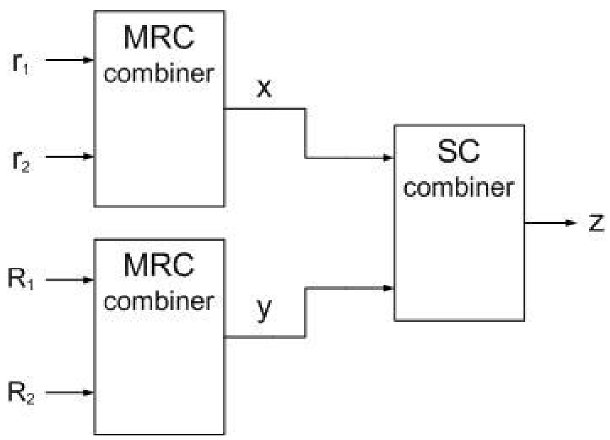


Fig.1. Macrodiversity system model

The probability density functions (PDFs) of the combiner input signals, $r_1$, $r_2$ and signals $R_1$, $R_2$ in the presence of Nakagami-*m* fading, are [5]:

$$p_{r_i}(r_i)=\frac{2}{\Gamma(m)}\left(\frac{m}{\Omega_1}\right)^m r_i^{2m-1}\exp\left(-\frac{m}{\Omega_1}r_i^2\right),$$

$$r_i\geq 0 \quad for \quad i=1,2$$

$$p_{R_i}(R_i)=\frac{2}{\Gamma(m)}\left(\frac{m}{\Omega_2}\right)^m R_i^{2m-1}\exp\left(-\frac{m}{\Omega_2}R_i^2\right),$$

$$R_i\geq 0 \quad for \quad i=1,2 \qquad (1)$$

where $\Omega_1$, $\Omega_2$ are signals power, on the first and second dual MRC receiver respectively, m is Nakagami-*m* fading parameter (m≥0.5). After replacement $x_i=r_i^2$ and $y_i=R_i^2$, $i=1,2$ in (1), the following expression can be obtained by transformation of random variables:

$$p_{x_i}(x_i)=\frac{2}{\Gamma(m)}\left(\frac{m}{\Omega_1}\right)^m x_i^{m-1}\exp\left(-\frac{m}{\Omega_1}x\right),$$

$$for \quad i=1,2$$

$$p_{y_i}(y_i)=\frac{2}{\Gamma(m)}\left(\frac{m}{\Omega_2}\right)^m y_i^{m-1}\exp\left(-\frac{m}{\Omega_2}y\right),$$

$$for \quad i=1,2 \qquad (2)$$

The probability density functions (PDFs) at the outputs of MRC receivers are respectivly:

$$p_x(x)=\int_0^x p_{x_1}(x-x_2)p_{x_2}(x_2)\,dx_2$$

$$p_y(y)=\int_0^y p_{y_1}(y-y_2)p_{y_2}(y_2)\,dy_2 \qquad (3)$$

Furthermore, the probability density functions (PDFs) at the output of the macro diversity system is:

$$p_z(z)=\int_0^\infty d\Omega_1\int_0^{\Omega_1} d\Omega_2 p_x(z/\Omega_1)p_{\Omega_1\Omega_2}(\Omega_1\Omega_2)$$

$$+\int_0^\infty d\Omega_1\int_{\Omega_1}^\infty d\Omega_2 p_y(z/\Omega_2)p_{\Omega_1\Omega_2}(\Omega_1\Omega_2) \qquad (4)$$

where $p_{\Omega_1\Omega_2}(\Omega_1\Omega_2)$ is the joint probability density function of $\Omega_1$ and $\Omega_2$ which has gamma density distribution and can be expressed as [7], [8]:

$$p_{\Omega_1\Omega_2}(\Omega_1\Omega_2)=\frac{\rho^{-\frac{c-1}{2}}}{\Gamma(c)(1-\rho)s_0^{c+1}}(\Omega_1\Omega_2)^{\frac{c-1}{2}}\cdot$$

$$\cdot\exp\left(-\frac{\Omega_1+\Omega_2}{(1-\rho)s_0}\right)I_{c-1}\left(\frac{2\sqrt{\rho\Omega_1\Omega_2}}{(1-\rho)s_0}\right) \qquad (5)$$

where $\rho$ is the correlation between $\Omega_1$ and $\Omega_2$, $c$ is the order of gamma distribution and integer, $s_0$ is related to the average power of $\Omega_1$ and $\Omega_2$, $I_{c-1}(\cdot)$ is the modified Bessel function of the first kind of order (c-1), where $c$ is integer, and $\Gamma(\cdot)$ is gamma function.

## 3 System Performances and Numerical Results

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

The integral (4) can be evaluated in closed form using Eq. (2), (3), (5) and using [9, Eqs (3.381/2) and (3.471/9)] with the result:

$$p_z(z) = \frac{4m^{2m}}{\Gamma(m)^2} \cdot \frac{1}{\Gamma(c)(1-\rho) s_0^{c+1}} z^{2m-1} \cdot$$

$$\cdot \sum_{i=0}^{m-1} \sum_{p=0}^{\infty} \sum_{k=0}^{\infty} \left( (-1)^i \binom{m-1}{i} \frac{1}{m+i} \right) \cdot$$

$$\cdot P \left( \frac{1}{(1-\rho) s_0} \right)^{p-1} \left( \frac{m z s_0 (1-\rho)}{2} \right)^{\frac{2c+2p-2m+k}{2}} \cdot$$

$$\rho^p \frac{1}{p! \Gamma(p+c)} \left( \frac{1}{(1-\rho) s_0} \right)^{p+c+k} \cdot$$

$$\cdot K_{2c+2p-2m+k} \left( 2 \sqrt{\frac{2mz}{(1-\rho) s_0}} \right) \tag{6}$$

where $P = \frac{1}{\prod_{j=0}^{k} (c+p+j)}$ and $K_n(\cdot)$ is modified Bessel function of the second kind of order $n$.

Expression (6) requires summation of an infinite number of terms. Table I summarize the number of terms for both sums (p=k), needed for PDF, in order to achieve an accuracy better then ±2% after the truncation of the infinite series.

| z | ρ = 0.1 | ρ = 0.3 | ρ = 0.5 | ρ = 0.7 |
|---|---|---|---|---|
| 5 | 2 | 3 | 4 | 6 |
| 10 | 4 | 5 | 6 | 9 |
| 15 | 5 | 6 | 7 | 11 |
| 20 | 6 | 7 | 8 | 13 |
| 25 | 7 | 8 | 9 | 15 |
| 35 | 8 | 9 | 11 | 17 |

Table 1 Number of terms for both sums for convergence of the PDF of macrodiversity system in range of ±2% (PDF, $m$=3, $c$ =2, $s_0$= 4, $p$=$k$)

As table 1 indicates, an increase in ρ leads to an increase of the number of terms that are needed to be summed in order to achieve the target accuracy. Furthermore, an increase of $z$ increases the number of terms that are required to be summed.

The probability density functions (PDFs) at the output of the macrodiversity system are given in Figs. 2-5 for diferent parameters m,ρ,c and $s_0$.

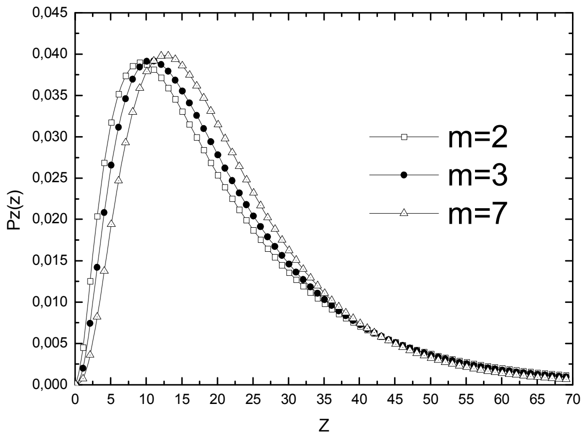


Fig.2. Probability density function at the output of macrodiversity system for different integer $m$ parametars and constant following parametars: $c$ = 2, $\rho$ = 0.2, $s_0$ = 4

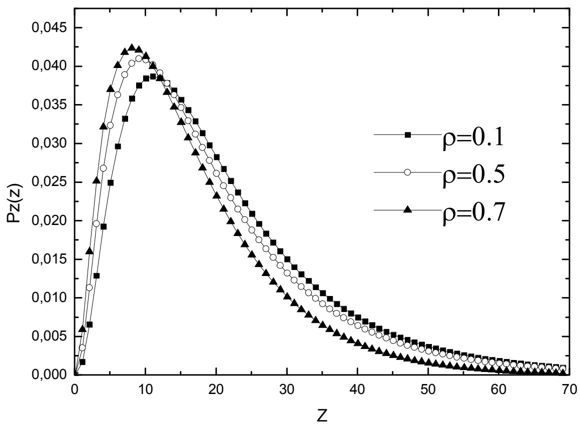


Fig.3. Probability density function at the output of macro diversity system for different ρ parametars and constant following parametars: $c$ = 2, $m$ = 3, $s_0$ = 4

The moments at the output of the macrodiversity system can be obtained by following expression :

$$m_n = \int_0^{\infty} z^n p_z(z) dz \tag{7}$$

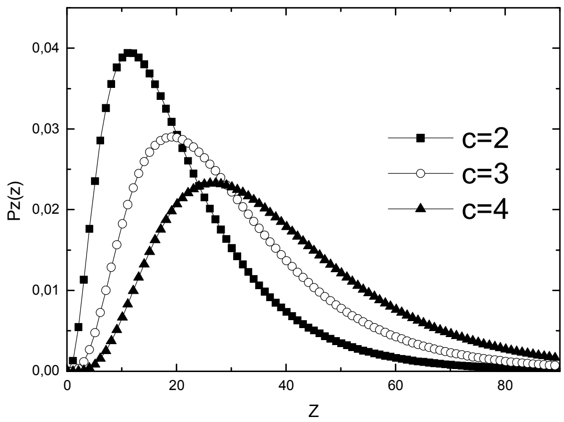


Fig.4. Probability density function at the output of macro diversity system for different *c* parametars and constant following parametars: $\rho = 0.2$, $m = 4$, $s_0 = 4$

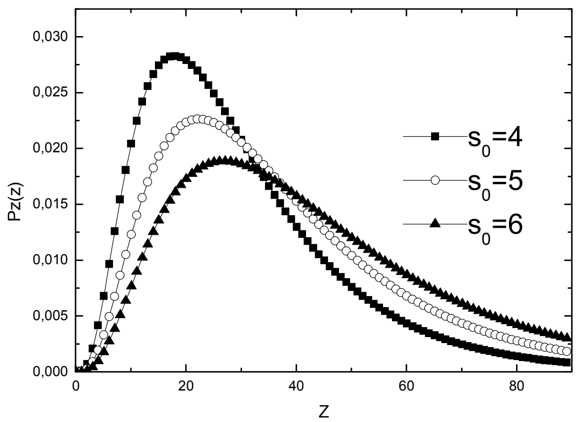


Fig.5. Probability density function at the output of macrodiversity system for different $s_0$ parametars and constant following parametars: $\rho = 0.2$, $m = 3$, $c = 3$

Combining expression (6) and (7) and using [9, Eqs (6.561/16)], the moment expression at the output of macrodiversity system is derived as:

$$m_n = \frac{4m^{2m}}{\Gamma(m)^2} \cdot \frac{1}{\Gamma(c)(1-\rho)s_0^{c+1}} \cdot$$

$$\cdot \sum_{i=0}^{m-1} \sum_{p=0}^{\infty} \sum_{k=0}^{\infty} \left( (-1)^i \binom{m-1}{i} \frac{1}{m+i} \right) \left( \frac{1}{(1-\rho)s_0} \right)^{p-1} P \cdot$$

$$\cdot \rho^p \frac{1}{p!\Gamma(p+c)} \left( \frac{1}{(1-\rho)s_0} \right)^{p+c+k} 2^{2c+2p+2m+k+2n-2} \cdot$$

$$\cdot 2 \left( \frac{ms_0(1-\rho)}{2} \right)^{\frac{2c+2p-2m+k}{2}} \Gamma(2c+2p+k+n) \cdot$$

$$\cdot \left( 2\sqrt{\frac{2m}{(1-\rho)s_0}} \right)^{-2c-2p-2m-k-2n} \Gamma(2m+n) \qquad (8)$$

Expression (8) also requires summation of an infinite number of terms. Table 2 and 3 are derived for $n$=1 and $n$=2 respectively. Tables indicate that an increase in ρ leads to an increase of the number of terms, and an increase of $s_0$ increases the number of terms that are required to be summed.

| $S_0$ [dB] | ρ = 0.1 | ρ = 0.3 | ρ = 0.5 | ρ = 0.7 |
|---|---|---|---|---|
| -5 | 6 | 10 | 13 | 23 |
| 0 | 9 | 11 | 13 | 23 |
| 5 | 9 | 11 | 13 | 23 |
| 10 | 9 | 11 | 13 | 23 |

Table 2. Number of terms for both sums for convergence of the first moment of macrodiversity system in range of ±2% (First moment, m=3, c=3, p=k)

| $S_0$ [dB] | ρ = 0.1 | ρ = 0.3 | ρ = 0.5 | ρ = 0.7 |
|---|---|---|---|---|
| 0 | 2 | 3 | 4 | 6 |
| 5 | 4 | 5 | 6 | 9 |
| 10 | 5 | 6 | 7 | 11 |

Table 3. Number of terms for both sums for convergence of the second moment of macrodiversity system in range of ±2% (Second moment, m=3, c=3, p=k)

Moments for $n$=1 and $n$=2 have particular significance, where $m_1$ represents average value of the signal at the output of macrodiversity system and $m_2$ represent average square value of the signal at the output of macrodiversity system. Moments $m_1$ and $m_2$ are shown in Figs. 6. and 7. for different parameter values.

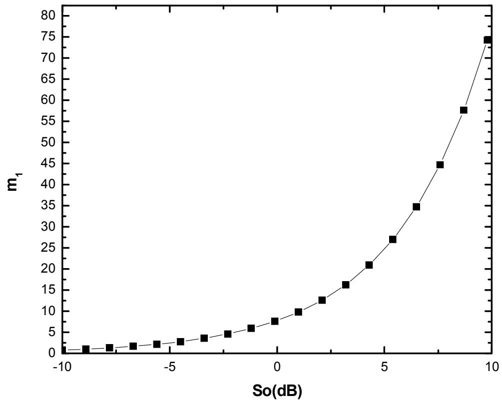


Fig.6. First moment at the output of macrodiversity system for constant following parametar values: $\rho = 0.1$, $m = 3$, $c = 3$

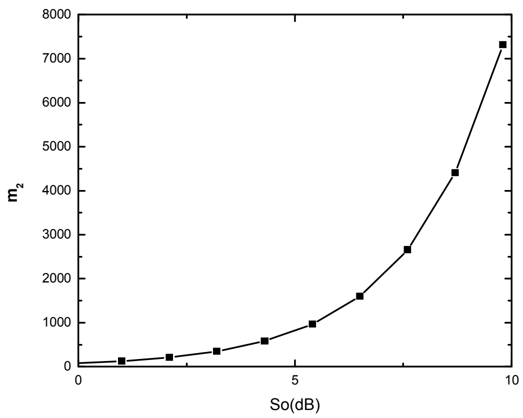


Fig.7. Second moment at the output of macrodiversity system for constant following parametars: $\rho = 0.1$, $m = 5$, $c = 3$

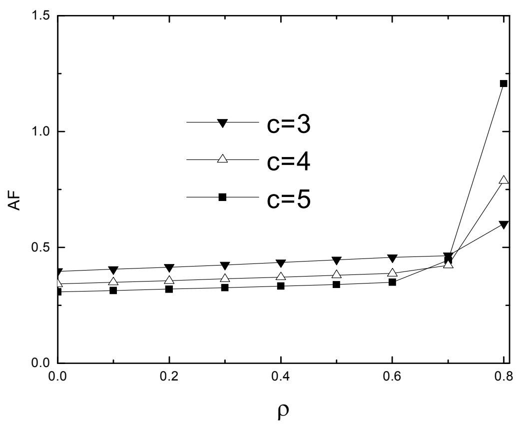


Fig.8. Amount of fading at the output of macro diversity system for differnet $c$ parametars and constant following parametars: $m = 3$, $s_0 = 4$

Amount of fading (AF), which is a measure of the performance of the entire system, can be obtained by following expression:

$$AF = \frac{m_2}{m_1^2} - 1 \tag{9}$$

Amount of fading (AF), at the output of the macrodiversity system are given in Figs. 8-9 for different parameters. It is evident that system performance is improved as $m$ and $c$ increase and $\rho$ decreases.

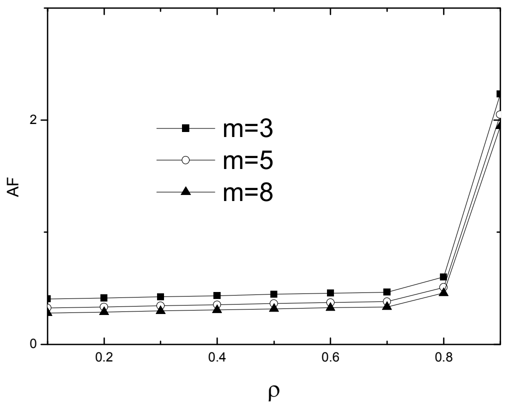


Fig.9. Amount of fading at the output of macro diversity system for differnet integer $m$ parametars and constant following parametars: $c = 3$, $s_0 = 4$

The CDF at the base station output is

$$F(x/\Omega_1) = \int_0^x p_x(x/\Omega_1)dx$$

$$F(y/\Omega_2) = \int_0^y p_y(y/\Omega_2)dy \tag{10}$$

The CDF of the SNR at the output of a dual-port selection based macrodiversity can be obtained as

$$F(z) = \int_0^\infty d\Omega_1 \int_0^{\Omega_1} d\Omega_2 F(z/\Omega_1) p_{\Omega_1\Omega_2}(\Omega_1\Omega_2) +$$

$$+ \int_0^\infty d\Omega_1 \int_{\Omega_1}^\infty d\Omega_2 F(z/\Omega_2) p_{\Omega_1\Omega_2}(\Omega_1\Omega_2) \tag{11}$$

which by substituting (5) and (10) in (11) and using [9, Eqs (3.351/1) and (3.471/9)], becomes

$$F_z(z)=\frac{2m^{2m}}{\Gamma(m)^2}\sum_{i=0}^{\infty}(-1)^i\binom{m-1}{i}\frac{1}{m+i}\cdot$$

$$\cdot\frac{1}{\Gamma(c)s_0^{c+1}(1-\rho)}\sum_{p=0}^{\infty}\frac{\rho^p}{p!\Gamma(p+c)}\left(\frac{1}{(1-\rho)s_0}\right)^{2p+c-1}\cdot$$

$$\cdot\Bigg[\frac{(2m-1)!}{m^{2m}}\big((p+c-1)!\big)^2\big((1-\rho)s_0\big)^{2p+2c}-$$

$$-\frac{(2m-1)!}{m^{2m}}\sum_{j=0}^{p+c-1}\frac{(p+c-1)!}{j!}(p+c+j-1)!\cdot$$

$$\cdot\left(\frac{2}{(1-\rho)s_0}\right)^{-p-c-j}\big((1-\rho)s_0\big)^{p+c-j}-$$

$$-\sum_{k=0}^{2m-1}\frac{(2m-1)!}{m^{2m-k}}\frac{z^k}{k!}(p+c-1)!\;2\big(zm(1-\rho)s_0\big)^{\frac{p+c-k}{2}}\cdot$$

$$\cdot\big((1-\rho)s_0\big)^{p+c}K_{p+c-k}\left(2\sqrt{\frac{mz}{(1-\rho)s_0}}\right)+$$

$$+\sum_{k=0}^{2m-1}\frac{(2m-1)!}{m^{2m-k}}\frac{z^k}{k!}\sum_{j=0}^{p+c-1}\frac{(p+c-1)!}{j!}\big((1-\rho)s_0\big)^{p+c-j}\cdot$$

$$\cdot 2\left(\frac{zm(1-\rho)s_0}{2}\right)^{\frac{p+c+j-k}{2}}K_{p+c-k+j}\left(2\sqrt{\frac{2zm}{(1-\rho)s_0}}\right)\Bigg] \tag{12}$$

As table 4 indicates, the number of the required terms depends strongly on correlation cofficient $\rho$. The number of terms increases as the correlation cofficient increases. Furthermore, an increase of $z$ increases the number of terms that are required to be summed.

| Z[dB] | ρ = 0.1 | ρ = 0.3 | ρ = 0.5 | ρ = 0.7 |
|---|---|---|---|---|
| -5 | 1 | 1 | 2 | 2 |
| 0 | 1 | 1 | 2 | 3 |
| 5 | 1 | 2 | 3 | 5 |
| 10 | 1 | 2 | 4 | 9 |
| 15 | 2 | 4 | 7 | 14 |

Table 4. Number of terms for both sums for convergence of the CDF of macrodiversity system in range of ±2% (CDF, m=3, c=3, $s_0$ = 4, p=k)

The outage probability $P_{out}$ is defined as probability that the output SNR falls bellow outage threshold $\lambda_{th}$. The outage threshold is protected value of the SNR, above which the quality of service (QoS) is satisfactory. The outage can be obtained by replacing z with $\lambda_{th}$ in (), i.e.,

$$P_{out}(\lambda_{th})=F_z(\lambda_{th}) \tag{13}$$

Based on (12) and (13), in Fig. 10-12, the outage probability is plotted versus outage treshold for several values of $m$, $\rho$ and $s_0$. As expected, the system performance for outage probability are improved as $\rho$ decreases and $s_0$ and $m$ increase.

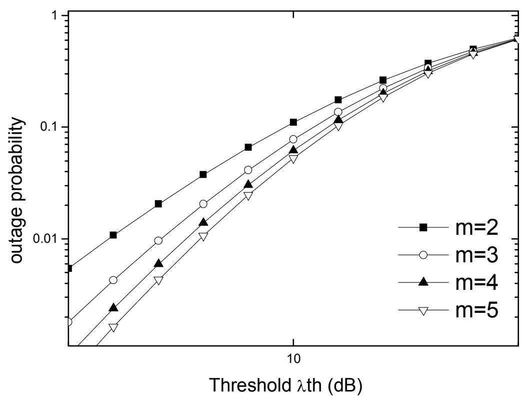


Fig.10. Outage probabilityat the output of macro diversity system for differnet integer $m$ parametars and constant following parametars: $c$ = 3, $\rho$ = 0.2, $s_0$ = 4

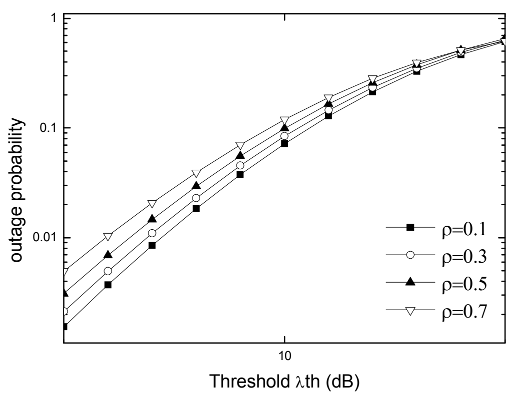


Fig.11. Outage probabilityat the output of macro diversity system for differnet integer $\rho$ parametars and constant following parametars: $c$ = 3, m = 3, $s_0$ = 4

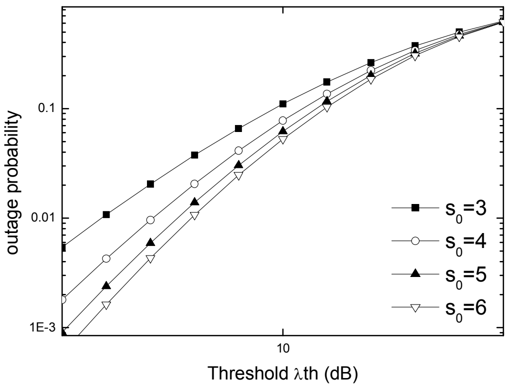


Fig.12. Outage probabilityat the output of macro diversity system for differnet integer $s_0$ parametars and constant following parametars: $c = 3$, $m = 3$, $\rho = 0.2$

The level crossing rate (LCR) is very important measure of the wireless systems. The LCR at envelope level, is defined as the rate at which a fading signal envelope crosses level in a positive-(or negative-) going direction. The probability density functions of random variables and its derivatives at the outputs of MRC are

$$p_{z\dot{z}}\left(z\dot{z}/\Omega_i\right)=\frac{1}{\sqrt{8\pi\frac{\pi^2 f_m^2}{m}\Omega_i}}e^{-\frac{\dot{z}^2}{8\frac{\pi^2 f_m^2}{m}\Omega_i}}\left(\frac{m}{\Omega}\right)^{2m}\cdot$$

$$\cdot\frac{z^{2m-1}}{\Gamma(m)^2}e^{-\frac{m}{\Omega_i}z}\sum_{i=0}^{\infty}(-1)^i\binom{m-1}{i}\frac{1}{m+i}, \qquad i=1,2 \tag{14}$$

where $f_m$ is maximal Doppler frequency

The joint probability density function of signal envelope $Z$ and its derivatives $Z$ *at* the output of macro-diversity is

$$p_{z\dot{z}}\left(z\dot{z}\right)=\int_0^{\infty}d\Omega_1\int_0^{\Omega_1}d\Omega_2\, p_{z\dot{z}}\left(z\dot{z}/\Omega_1\right)p_{\Omega_1\Omega_2}\left(\Omega_1\Omega_2\right)+$$

$$+\int_0^{\infty}d\Omega_1\int_{\Omega_1}^{\infty}d\Omega_2\, p_{z\dot{z}}\left(z\dot{z}/\Omega_2\right)p_{\Omega_1\Omega_2}\left(\Omega_1\Omega_2\right) \tag{15}$$

The joint PDF can be evaluated by substituting (5) and (14) in (15) and using [9, eq. (8.445), (3.381/9) and (3.471/9)], resulting in

$$p_{z\dot{z}}\left(z\dot{z}\right)=\frac{z^{2m-\frac{3}{2}}}{\sqrt{2\pi\frac{\pi^2 f_m^2}{m}}}\frac{m^{2m}}{\Gamma(m)^2}\sum_{i=0}^{\infty}(-1)^i\binom{m-1}{i}\cdot$$

$$\cdot\frac{1}{m+i}\frac{1}{\Gamma(c)s_0^{c+1}(1-\rho)}\sum_{p=0}^{\infty}\frac{\rho^p}{p!\Gamma(p+c)}\cdot$$

$$\cdot\left(\frac{1}{(1-\rho)s_0}\right)^{2p+c-1}\sum_{k=0}^{\infty}\left(\frac{1}{(1-\rho)s_0}\right)^k\frac{1}{\prod_{j=0}^{k}(p+c+j)}\cdot$$

$$\cdot 2\left(\left(\frac{mz}{2}+\frac{\dot{z}^2}{16\frac{\pi^2 f_m^2}{m}z}\right)(1-\rho)s_0\right)^{p+c-m+\frac{k}{2}-\frac{1}{4}}\cdot$$

$$\cdot K_{2c+2p+k-2m-\frac{1}{2}}\left(2\sqrt{\frac{2}{s_0(1-\rho)}\left(mz+\frac{\dot{z}^2}{2\sqrt{2\pi\pi^2 f_m^2}}\right)}\right) \tag{16}$$

The average level crossing rate, is obtained by

$$N=\int_0^{\infty}\dot{z}p_{z\dot{z}}\left(z\dot{z}\right)d\dot{z} \tag{17}$$

which, by substituting (16) in (17) and using [9, eq. (8.445), (3.381/9) and (3.471/9)], yields

$$N=4\frac{z^{2m-\frac{3}{2}}}{\sqrt{2\pi\frac{\pi^2 f_m^2}{m}}}\frac{m^{2m}}{\Gamma(m)^2}\sum_{i=0}^{\infty}(-1)^i\binom{m-1}{i}\frac{1}{m+i}\cdot$$

$$\cdot\frac{1}{\Gamma(c)s_0^{c+1}(1-\rho)}\sum_{p=0}^{\infty}\frac{\rho^p}{p!\Gamma(p+c)}\left(\frac{1}{(1-\rho)s_0}\right)^{2p+c-1}\cdot$$

$$\cdot\sum_{k=0}^{\infty}\left(\frac{1}{(1-\rho)s_0}\right)^k 2\left(mz(1-\rho)s_0\right)^{p+c-m+\frac{k}{2}+\frac{1}{4}}.$$

$$\cdot \frac{1}{\prod_{j=0}^{k}\left(p+c+j\right)} K_{2c+2p+k-2m+\frac{1}{2}}\left(2\sqrt{\frac{2}{s_0\left(1-\rho\right)}mz}\right) \qquad (18)$$

In table 5, the number of the required terms depends on correlation cofficient $\rho$ and $z$

| Z[dB] | ρ = 0.1 | ρ = 0.3 | ρ = 0.5 | ρ = 0.7 |
|---|---|---|---|---|
| -5 | 2 | 2 | 3 | 3 |
| 0 | 2 | 3 | 4 | 5 |
| 5 | 3 | 4 | 5 | 7 |
| 10 | 5 | 6 | 7 | 11 |
| 15 | 8 | 9 | 11 | 19 |
| 20 | 13 | 15 | 17 | 31 |

Table 5. Number of terms for both sums for convergence of the N of macrodiversity system in range of ±2% (N, m=3, c=3, $s_0$ = 4, p=k)

Based on (16), the LCR normalized by *fm* as a function of *z* for different system parameters is plotted in Fig. 13-15.

It is observed that LCR increases as *c* and *m* increase and $\rho$ decreases.

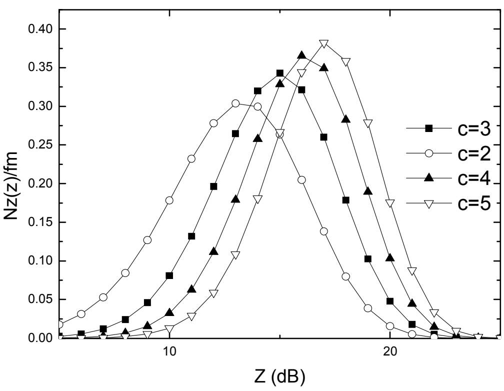


Fig.13. LCR the output of macro diversity system for differnet integer c parametars and constant following parametars: m = 3, $\rho$ = 0.1, $s_0$ = 5

The more accurate view on the system performance is given by the average fading duration (AFD). The average fading duration is obtained as

$$AFD = \frac{P_{out}\left(\lambda_{th}\right)}{N\left(\lambda_{th}\right)}. \qquad (19)$$

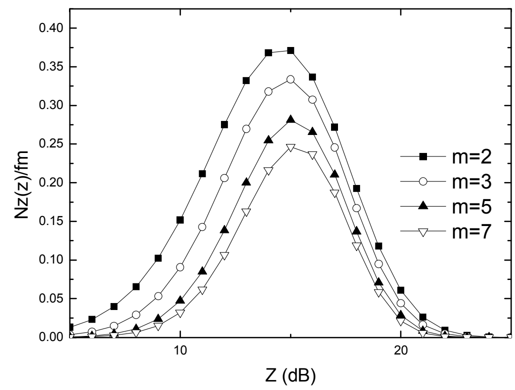


Fig.14. LCR the output of macro diversity system for differnet integer m parametars and constant following parametars: $c$ = 3, $s_0$ = 5, $\rho$ = 0.3

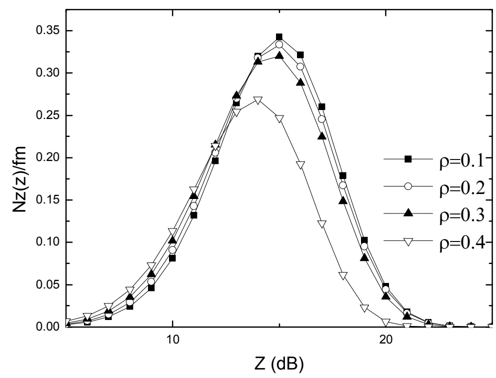


Fig.15. LCR the output of macro diversity system for differnet integer $\rho$ parametars and constant following parametars: $c$ = 3, m = 3, $s_0$ = 5

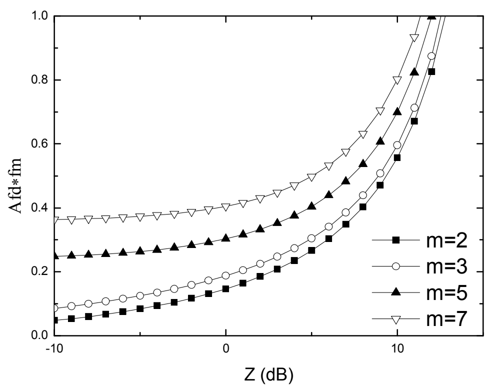


Fig.16. AFD the output of macro diversity system for differnet integer m parametars and constant following parametars: $c$ = 3, $s_0$ = 4, $\rho$ = 0.3

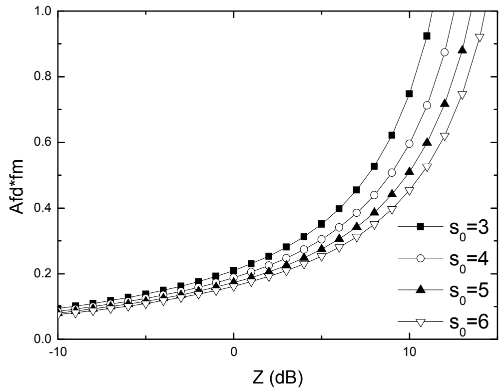


Fig.17. AFD the output of macro diversity system for differnet integer $s_0$ parametars and constant following parametars: $c = 3$, m = 3, $\rho = 0.3$

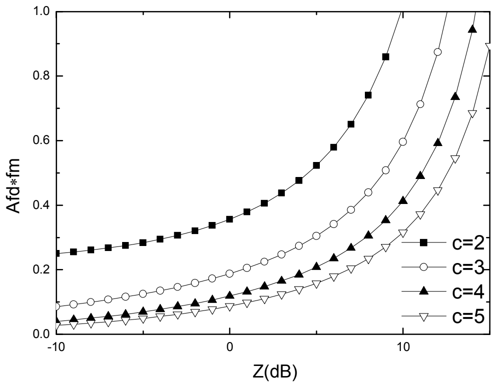


Fig.18. AFD the output of macro diversity system for differnet integer c parametars and constant following parametars: $s_0 = 4$, m = 3, $\rho = 0.3$

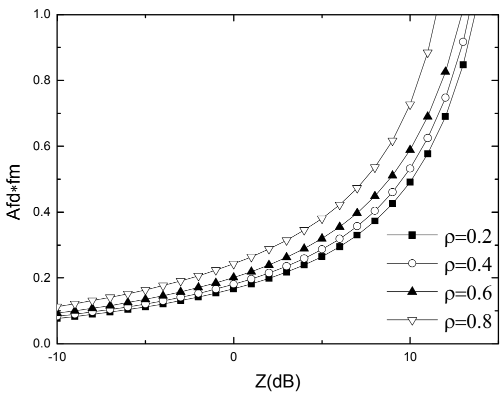


Fig.19. AFD the output of macro diversity system for differnet integer $\rho$ parametars and constant following parametars: $c = 3$, m = 3, $s_0 = 5$

By using (19), in Fig. 16-19. the AFD normalized by *fm* is plotted versus outage treshold. It is evident that system performance is improved as $m$, $s_0$ and $c$ increase and $\rho$ decreases.

# 4 Conclusion

Using a compound PDF model, system with micro- and macrodiversity reception in gamma shadowed Nakagami-m fading channels has been analyzed. Closed form expression for the PDF, CDF and LCR after diversity combining at the micro and macro level are obtained. Several performance criteria, such as outage probability, AF and AFD were considered. These expressions require the summation of an infinite number of terms. However, the presented infinite series representations converge for any value of the parameters and accordingly, they enable great accuracy of the evaluated and graphically presented results. They show that system performance improves with an increase of the Nakagami-m factor, average power and order of gamma distribution, while an increase of correlation parameter leads to deterioration of system performance. It was also shown that composite micro- and macrodiversity provides significantly performance improvement which was the main task of this paper.

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