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COMMUNICATIONS

MOMENTS OF MICRODIVERSITY EGC RECEIVERS AND MACRODIVERSITY SC RECEIVER OUTPUT SIGNAL OVER GAMMA SHADOWED NAKAGAMI–m MULTIPATH FADING CHANNEL

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A system with macrodiversity selection combining (SC) receiver and for microdiversity equal gain combining (EGC) receivers is considered. Received signal is subjected, simultaneously to multipath fading and shadowing, resulting in signal envelope and signal power variation. Closed form expressions for moments of macrodiversity SC receiver output signal envelope are calculated. Numerical expressions are plotted to present the influences of Gamma shadowing severity and Nakagami-m severity on moments of proposed system output signal.

Keywords: moments, selection combining (SC) receiver, equal gain combining (EGC) receiver, gamma shadowing severity, Nakagami-m severity

1 INTRODUCTION

Short term fading and long term fading degrade and limit performance and channel capacity of wireless communication system. Reflection and refraction cause short term fading and large obstacles cause long term fading. Signal envelope variation is result of multipath fading and signal envelope power variation is result of shadowing. There are more statistical models which can be applied to describe signal envelope variation and signal envelope power variation in fading channels depend on communication scenario on propagation environment [1-2]. Rayleigh distribution can be used to describe small scale signal envelope variation in linear, non line-of-sight multipath fading environment and Rician distribution can good describe signal envelope variation in linear line-of-sight multipath fading environment. Nakagami-m model describe small scale signal envelope variation when more clusters are presented in propagation environment [3-5].

Macrodiversity system can be applied to reduce long term fading effects and short term fading effects on system performance. Macrodiversity system has macrodiversity receiver and two or more microdiversity receivers. Macrodiversity receiver mitigates long term fading effects and microdiversity receivers mitigate short term fading effects [6-7]. When large obstacles and large deviation of terrain profile are presented in propagation environment shadowing correlation are arises between microdiversity receivers resulting in diversity gain degradation.

There are more works in open technical literature considering performance analysis of macrodiversity systems. In paper [8] macrodiversity system with macrodiversity SC receiver and two microdiversity MRC receivers is analyzed. Received signal experiences Nakagami-m multipath fading and Gamma shadowing. Microdiversity MRC receivers reduces Nakagami-m multipath fading and macrodiversity SC receiver reduces Gamma shadowing effects. Closed form expressions for level crossing rate and average fade duration of proposed macrodiversity system are evaluated. In [9], average fade duration and level crossing rate of macrodiversity system with macrodiversity SC receiver and two microdiversity MRC receivers operating over Gamma shadowed Rician multipath fading channel are calculated. In [10] moment generating function of macrodiversity system with macrodiversity SC receiver and two microdiversity MRC receivers operating over correlated Gamma shadowed Nakagami-m multipath fading environment is calculated.

In this paper, macrodiversity system with macrodiversity SC receiver with two equal gain combining (EGC) receivers is considered. Received signal suffer simultaneously Nakagami-m multipath fading and Gamma shadowing resulting in system performance degradation. Nakagami-m multipath fading causes received signal envelope variation and Gamma shadowing causes received signal envelope power variation. Macrodiversity SC receiver reduces the influence of Gamma shadowing on system performance and microdiversity EGC receivers reduces the influence of Nakagami-m multipath fading on system performance. Closed form expression for moment of nth order of macro SC receiver output signal envelope is derived. To the best authors knowledge moments

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of macrodiversity SC receiver output signal envelope operating over Gamma shadowed Nakagami-m multipath fading environment are not calculated. Obtained results can be used in performance analysis and designing wireless macrodiversity systems operating over Gamma shadowed Nakagami-m multipath fading environment.

2 MOMENT OF EGC RECEIVER OUTPUT SIGNAL ENVELOPE

Equal gain combining (EGC) receiver with two branches is considered. Received signal is affected to identical and independent Nakagami-m fading. Signal envelopes at inputs of EGC receiver are denoted with x_1 and x_2 and EGC receiver output signal envelope is denoted with x. Random variables x_1 and x_2 follow Nakagami-m distribution

$$p_{x_i}(x_i) = \frac{2}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m x_i^{2m-1} e^{-\frac{m}{\Omega}x_i^2},\ i=1,2,\ x_i \geqslant 0 \tag{1}$$

The moment of n-th order $x_i, i=1,2$ is

$$m_{nx_i} = \overline{x_i^n} = \int_0^\infty dx_i x_i^n p_{x_i}(x_i) = = \frac{1}{\Gamma(m)}\left(\frac{\Omega}{m}\right)^{\frac{n}{2}} \Gamma\left(m+\frac{n}{2}\right) \tag{2}$$

EGC receiver output signal envelope can be written as sum of signals envelope at inputs of EGC receiver $x = x_1 + x_2$. Moment n-th order of EGC receiver output signal envelope is

$$m_{nx_i} = \overline{x_i^n} = \overline{(x_1+x_2)^n} = \sum_{i=0}^n \binom{n}{i} \overline{x_1^{n-i}}\,\overline{x_2^i} \tag{3}$$

After substituting (2) into (4), moment of nth order of EGC receiver output signal envelope becomes

$$m_{nx} = \frac{1}{\Gamma(m)^2}\left(\frac{\Omega}{m}\right)^{\frac{n}{2}} \sum_{i=0}^n \binom{n}{i} \Gamma\left(m+\frac{n-i}{2}\right) \times \Gamma\left(m+\frac{i}{2}\right) \tag{4}$$

The mean of EGC receiver output signal envelope is

$$m_{1x} = \overline{x} = \frac{2}{\Gamma(m)}\left(\frac{\Omega}{m}\right)^{\frac{1}{2}} \Gamma\left(m+\frac{n}{2}\right) \tag{5}$$

The average square value of x is

$$m_{2x} = \overline{x^2} = \frac{1}{\Gamma(m)^2}\left(\frac{\Omega}{m}\right)^{\frac{n}{2}} [\Gamma(m+1)\Gamma(m) +\Gamma(m+\frac{n}{2})^2] \tag{6}$$

3 MOMENTS OF MACRODIVERSITY SC RECEIVER OUTPUT SIGNAL ENVELOPE

Macrodiversity system with macrodiversity SC receiver and two microdiversity EGC receivers operating over Gamma shadowed is analyzed. Nakagami-m multipath fading environment is considered. Macrodiversity SC receiver output signal envelope is equal to microdiversity EGC receiver output signal envelope with greater signal envelope power at inputs. Signals envelopes at outputs of microdiversity EGC receivers are denoted with y_1 and y_2 and macrodiversity SC receiver output signal envelope is denoted with y. Moments nth order of $y_j, j=1,2$ is

$$m_{ny_j} = \frac{1}{\Gamma(m)^2}\left(\frac{\Omega_j}{m}\right)^{\frac{n}{2}} \sum_{i=0}^n \binom{n}{i} \Gamma\left(m+\frac{n-i}{2}\right) \times \Gamma\left(m+\frac{i}{2}\right),\quad \text{for} j=1,2, \tag{7}$$

where Ω_1 and Ω_2 are signal envelope power at inputs of microdiversity EGC receivers. Signal envelope powers Ω_1 and Ω_2 experience correlated Gamma long term fading.

$$p_{\Omega_1\Omega_2}(\Omega_1\Omega_2) = \frac{(\Omega_1\Omega_2)^{\frac{c-1}{2}}}{\Gamma(c)(1-\rho^2)\rho^{\frac{c-1}{2}}\Omega_0^{c+1}} e^{-\frac{\Omega_1+\Omega_2}{\Omega_0(1-\rho^2)}} \times I_{c-1}\left(\frac{2\rho}{\Omega_0(1-\rho^2)}(\Omega_1\Omega_2)^{\frac{1}{2}}\right), \tag{8}$$

where $\Omega_1 \geqslant 0, \quad \Omega_2 \geqslant 0$. Moment n-th order of macrodiversity SC receiver output signal envelope is equal to moment n-th order of microdiversity EGC receiver output signal envelope with greater signal envelope power at inputs. Therefore, moment nth order of signal envelope at output of macrodiversity SC receiver is

$$m_{ny} = 2\int_0^\infty \mathrm{d}\Omega_1 \int_0^{\Omega_1} \mathrm{d}\Omega_2 m_{ny_1} p_{\Omega_1\Omega_2}(\Omega_1\Omega_2) = =\Phi(n,m,c,\rho,\Omega_0)\times \times \int_0^\infty \mathrm{d}\Omega_1 \Omega_1^{c+j+\frac{n}{2}-1} e^{-\frac{\Omega_1}{\Omega_0(1-\rho^2)}} \gamma\left(c+j, \frac{\Omega_1}{\Omega_0(1-\rho^2)}\right) \tag{9}$$

$$\text{where} \qquad \Phi(n,m,c,\rho,\Omega_0) = = \frac{2\sum_{i=0}^n \binom{n}{i} \Gamma\left(m+\frac{n-i}{2}\right)\Gamma\left(m+\frac{i}{2}\right)}{m^{\frac{n}{2}}\Gamma(m)^2\Gamma(c)(1-\rho^2)\rho^{\frac{c-1}{2}}\Omega_0^{c+1}} \times \times \sum_{j=0}^\infty \frac{\rho^{c+2j-1}\left[\Omega_0(1-\rho^2)\right]^{1-j}}{\Gamma(c+j)j!} \tag{10}$$

Using of the incomplete Gamma function $\gamma(n,x)$, [11]

$$\gamma(n,x) = \Gamma(n) - \frac{1}{n}x^n e_1^{-x} F_1(1,n+1,x) = = \Gamma(n) - \frac{1}{n}x^n e^{-x} \sum_{i=0}^\infty \frac{x^i}{(n+1)_i} \tag{11}$$

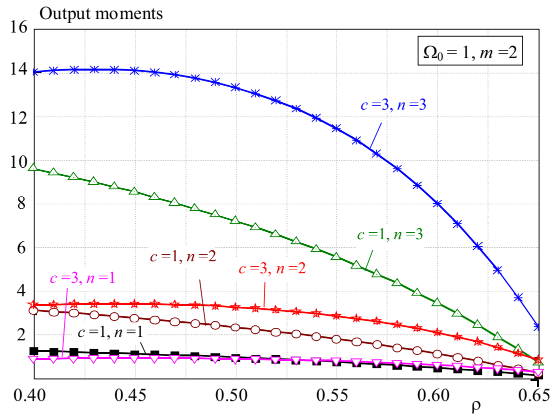

Fig. 1. Macrodiversity moments versus gamma fading correlation coefficient for different values of shadowing severity c

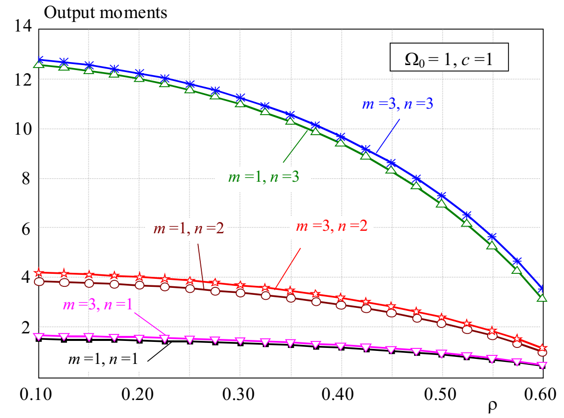

Fig. 2. Macrodiversity moments versus gamma fading correlation coefficient for different values of severity parameter m

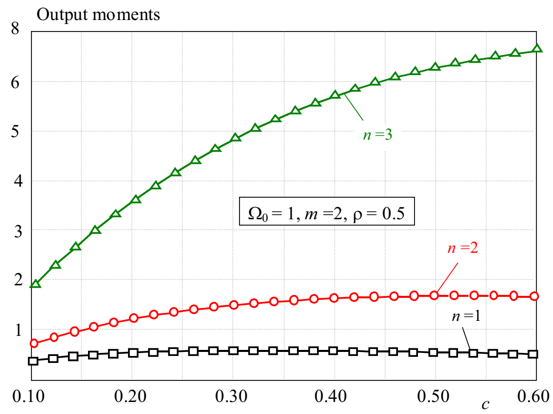

Fig. 3. SC receiver output signal versus shadowing severity c

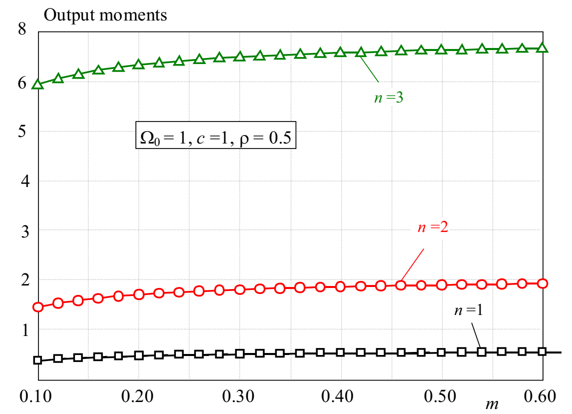

Fig. 4. SC receiver output signal versus parameter m

with $(a)_n$ being the Pocchammer symbol, the expression for moment n-th order at signal envelope at output of macrodiversity SC receiver can be written as $m_{ny} = \Phi(n,m,c,\rho,\Omega_0)(I_1 - I_2)$ where

$$I_1 = \int_0^\infty d\Omega_1 \Omega_1^{c+j+\frac{n}{2}-1} e^{-\frac{\Omega_1}{\Omega_0(1-\rho^2)}} \Gamma(c+j) \quad (12)$$

$$I_2 = \int_0^\infty d\Omega_1 \Omega_1^{c+j+\frac{n}{2}-1} \frac{e^{-\frac{2\Omega_1}{\Omega_0(1-\rho^2)}}}{c+j} \left(\frac{\Omega_1}{\Omega_0(1-\rho^2)}\right)^{c+j} \times \\ \times \sum_{k=0}^\infty \frac{\left(\frac{\Omega_1}{\Omega_0(1-\rho^2)}\right)^k}{(c+j+1)_k} \quad (13)$$

After solving integrals (12) and (13) and some manipulation, the result becomes

$$m_{ny} = \Phi(n,m,c,\rho,\Omega_0)\Big[\Gamma(c+j)\Gamma(c+j+\frac{n}{2})\times \\ \times \left(\Omega_0(1-\rho^2)\right)^{c+j+\frac{n}{2}} - \frac{1}{c+j}\sum_{k=0}^\infty \frac{\Gamma(2c+2j+k+\frac{n}{2})}{(c+j+1)_k}\times \\ \left(\frac{\Omega_0(1-\rho^2)}{2}\right)^{2c+2j+k+\frac{n}{2}}\Big] \quad (14)$$

3 NUMERICAL RESULTS

The first moment, the second moment and the third moment versus correlation coefficient of long term Gamma fading is plotted on Fig. 1 and Fig. 2 for some values of Gamma shadowing severity parameter c, Nakagami-m multipath fading severity m and average power of Gamma shadowing Ω_0. The first moment and the second moment are important performance measures of wireless communication systems. The system performance is better for higher values of the first moment and the second moment. The second moment decreases as the correlation coefficient increases. The best values for outage probability are obtained when correlation coefficient goes to zero. The worst values for outage probability are obtained for the case when correlation coefficient goes to 1. In this case, the least value for signal envelope occurs, simultaneously, at each antennas of diversity system

In Fig. 3, moments are shown in terms of Gamma shadowing severity c. The second moment increases as Gamma shadowing severity c increases. The system performance is better for higher values of shadowing severity c. The fading is more severity for lower values of c.

Moments of macrodiversity SC receiver versus Nakagami-m multipath fading severity m is plotted at Fig. 4. Moments increases as parameter m increases. When parameters c and m go to infinity, composite shadowed multipath fading channel becomes no fading channel.

5 CONCLUSION

Macrodiversity system with macrodiversity SC receiver and two microdiversity EGC receivers operating over shadowed multipath fading environment is considered. Microdiversity EGC received signal experience Nakagami-m multipath fading resulting in signal envelope variation. Macrodiversity SC received signal experiences correlated Gamma long term fading resulting in signal envelope power variation. Macrodiversity SC receiver reduces long term fading effects on system performance and microdiversity EGC receivers reduce short term fading effects on system performance. EGC receivers enable better performance than SC receivers but SC receivers have lower implementation complexity.

In this paper, closed form expression for nth moment of macrodiversity SC receiver output signal is calculated. The mean, average square value and variance of output signal are important performance measures of wireless communication systems. These performance measures are presented graphically to show influence Gamma shadowing severity and Nakagami-m multipath severity on average values of macrodiversity SC receiver output signal envelope. System performance is better for higher values of average values. Average values increases as Gamma fading severity increases. Diversity gain and average values decrease as correlation of shadowing increases. The influence of Gamma shadowing severity and Nakagami-m multipath fading severity on average value of macrodiversity SC output signal envelope is greater for lower values of correlation coefficient.

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