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PERFORMANCE OF MACRO DIVERSITY WIRELESS COMMUNICATION SYSTEM OPERATING IN WEIBULL MULTIPATH FADING ENVIRONMENT

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Abstract. *In this paper, we consider wireless mobile radio communication system with macro diversity reception. Signal is subject to Weibull small scale fading and Gamma large scale fading resulting in system performance degradation. Receiver uses macro diversity selection combining (SC) technique in order to reduce the impact of long term fading effects, and two micro diversity SC branches are used to mitigate Weibull short term fading effects on system performance. Probability density function (PDF), and cumulative distribution function (CDF), as well as level crossing rate (LCR) and average fade duration (AFD) of the SC receiver output signal envelope are evaluated. The obtained expressions converge rapidly for all considered values of Weibull fading parameter and Gamma shadowing severity parameter. Mathematical results are studied in order to analyze the influence of Weibull fading parameter and Gamma shadowing severity parameter on statistical properties of the SC receiver output signal.*

Key words: *Weibull short term fading, probability density function, cumulative distribution function, level crossing rate, average fade duration.*

1. INTRODUCTION

Long term fading and short term fading degrade outage probability and limit channel capacity of wireless communication systems in general, and different techniques can be used to lessen the impact of the fading effects. One of the strategies for mitigating both effects: long term fading (shadowing), as well as short term fading, is the use of macro diversity combining reception. In general, macro diversity receiver features two or more micro diversity combiners, and it then combines their outputs in order to avoid the possibility of deep fades.

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Such system reduces the influence of simultaneously long term fading effects and short term fading effects on system performance. There are a number of statistical distributions that can be used to describe small scale signal envelope variation in multipath fading channels, depending on propagation environment and communication scenario. Rayleigh and Nakagami-m distributions can be used to describe signal envelope in small scale non line-of-sight multipath fading environments, while Rician distribution can model signal envelope in line-of-sight multipath fading environments. Signal envelope variation in nonlinear multipath fading environments can also be well described by using Weibull model [1].

Samples of a Weibull random process can easily be obtained by taking the samples of a Rayleigh random process and raising them to a power. Weibull distribution therefore has a parameter related to nonlinearity of environment. When this Weibull parameter tends to infinity, Weibull multipath fading channel becomes a channel without fading effects. When Weibull parameter goes to two, Weibull channel reduces to Rayleigh channel, and when Weibull parameter goes to one, Weibull channel becomes exponential fading channel. First order performance measures of a communication system include: outage probability, bit error probability and channel capacity. These performance measures can be calculated by using probability density function of receiver output signal. Second order performance measures of a wireless communication system usually encompass average level crossing rate and average fade duration. These performance measures can be evaluated by using joint probability density function of the receiver output signal and the first derivate of output signal.

Log-normal distribution and Gamma distribution can be used to describe variations of signal average power in shadowed channels. When log-normal model is used to describe long term fading, the expression for probability density function and cumulative distribution function of received output signal cannot be evaluated in the closed form. Application of Gamma distribution enables tractable calculation of system performance of the wireless communications system in shadowing environment [2].

There are a number of papers in open technical literature considering outage probability, bit error probability and average level crossing rate of macro diversity system with two or more micro diversity receivers operating over shadowed multipath fading channels. In [3], [4], [5] macro diversity system with two micro diversity branches operating over Gamma shadowed Nakagami-m multipath fading channels is considered. Communication channel is described by the use of compound model [6].

System performance of macro diversity system in the presence of log-normal shadowing and Rayleigh multipath fading are presented in [7]. Average level crossing rate and average fade duration of macro diversity system operating over Gamma shadowed multipath fading channel are evaluated in [8], where macro diversity reception in cellular system is considered and its outage probability is calculated.

In this paper, we analyze macro diversity selection combining receiver, with two micro diversity SC branches, operating over Gamma shadowed Weibull multipath fading channel. Macro diversity SC receiver serves to reduce considered Gamma shadowing effects and micro diversity SC branches mitigate Weibull multipath fading effects on system performance. Analytical expressions can be obtained for calculation of important performance parameters such as outage probability and bit error probability. To the best author’s knowledge system performance of macro diversity system in Weibull fading channel is not reported in technical literature.

2. WEIBULL RANDOM VARIABLE

Probability density function of Weibull random variable is [9]:

$$p_x(x) = \frac{\alpha}{\Omega} x^{\alpha-1} e^{-\frac{1}{\Omega}x^{\alpha}} \tag{1}$$

where α is Weibull fading parameter and Ω is average power of *x*.

Cumulative distribution function of Weibull random variable is [10,11]:

$$F_x(x) = \int_0^x dt p_x(t) = 1 - e^{-\frac{1}{\Omega}x^{\alpha}} \tag{2}$$

Weibull random variable *x*, and its first derivative $\dot{x}$, are:

$$x = y^{\frac{2}{\alpha}}, \quad y = x^{\frac{\alpha}{2}}, \quad \dot{x} = \frac{2}{\alpha} y^{\frac{2}{\alpha}-1}\dot{y}, \quad \dot{y} = \frac{\alpha}{2} x^{\frac{\alpha}{2}-1}\dot{x} \ , \tag{3}$$

where *y* is Rayleigh random variable.

Joint probability density function (JPDF) of *x* and $\dot{x}$ is [12]:

$$p_{x\dot{x}}(x,\dot{x}) = |J|\, p_{y\dot{y}}\left(x^{\alpha/2}, \frac{\alpha}{2} x^{\frac{\alpha}{2}-1}\dot{x} \right) \tag{4}$$

where the Jacobian of the coordinate transform is:

$$J = \begin{vmatrix} \frac{\partial y}{\partial x} & \frac{\partial y}{\partial \dot{x}} \\ \frac{\partial \dot{y}}{\partial y} & \frac{\partial \dot{y}}{\partial \dot{x}} \end{vmatrix} = \begin{vmatrix} \frac{\alpha}{2} x^{\frac{\alpha}{2}-1} & 0 \\ 0 & \frac{\alpha}{2} x^{\frac{\alpha}{2}-1} \end{vmatrix} = \frac{\alpha^2}{4} x^{\alpha-2} \tag{5}$$

Joint probability density function of Rayleigh random variable *y* and its first derivative $\dot{y}$ is [12]:

$$p_{y\dot{y}}(y,\dot{y}) = p(y)p(\dot{y}) = \frac{2y}{\Omega} e^{-\frac{y^2}{\Omega}} \frac{1}{\sqrt{2\pi}\beta} e^{-\frac{\dot{y}^2}{2\beta^2}}, \quad \beta^2 = \pi^2 f_m{}^2 \Omega, \tag{6}$$

where f_m is maximal Doppler frequency, and $\dot{y}$ is Gaussian random variable [13, 14], with variance β.

After substituting (5) and (6) into (4), the expression for JPDF of Weibull random variable and its first derivative becomes:

$$p_{x\dot{x}}(x,\dot{x}) = |J|\, p_{y\dot{y}}(y,\dot{y}) = |J|\, p_{y\dot{y}}\left(x^{\alpha/2}, \frac{\alpha}{2} x^{\frac{\alpha}{2}-1}\dot{x} \right) = \frac{\alpha^2 x^{\frac{3\alpha-4}{2}}}{2\sqrt{2\pi}\beta\Omega} e^{-\frac{1}{\Omega}x^{\alpha} - \frac{\alpha^2}{8\beta^2}x^{\alpha-2}\dot{x}^2} \tag{7}$$

The average level crossing rate of Weibull random processes is [15]:

$$N_x = \int_0^{\infty} d\dot{x}\dot{x} p_{x\dot{x}}(x\dot{x}) = \sqrt{\frac{2\pi}{\Omega}} f_m x^{\alpha/2} e^{-\frac{1}{\Omega}x^{\alpha}} \tag{8}$$

The selection combining diversity receiver with inputs operating over identical, independent Weibull multipath fading channel is considered next. Signal envelopes at inputs of a SC receiver are denoted with x_1 and x_2, and the SC receiver output signal envelope is denoted with x. PDF of SC receiver output signal envelope is [16]:

$$p_x(x) = p_{x_1}(x)F_{x_2}(x) + p_{x_2}(x)F_{x_1}(x) = 2p_{x_1}(x)F_{x_2}(x) = \frac{2\alpha}{\Omega}x^{\alpha-1}e^{-\frac{1}{\Omega}x^{\alpha}}\left(1-e^{-\frac{1}{\Omega}x^{\alpha}}\right) \quad (9)$$

Cumulative distribution function of SC receiver output signal envelope is [17]:

$$F_x(x) = F_{x_1}(x)F_{x_2}(x) = \left(1-e^{-\frac{1}{\Omega}x^{\alpha}}\right)^2 \quad (10)$$

The JPDF of SC receiver output signal and its first derivative is [17]:

$$p_{x\dot{x}}(x,\dot{x}) = 2p_{x_1\dot{x}_1}(x,\dot{x})F_{x_2}(x) = \frac{\alpha^2 x^{\frac{3\alpha-4}{2}}}{\sqrt{2\pi}\,\beta\Omega}e^{-\frac{1}{\Omega}x^{\alpha}-\frac{\alpha^2}{8\beta^2}x^{\alpha-2}\dot{x}^2}\left(1-e^{-\frac{1}{\Omega}x^{\alpha}}\right) \quad (11)$$

where the SC receiver output signal envelope is denoted with x.

Using the previous expression (11), level crossing rate of the process x is [17]:

$$N_x = \int_0^{\infty} d\dot{x}\dot{x}p_{x\dot{x}}(x\dot{x}) = 2F_{x_2}(x)\int_0^{\infty} d\dot{x}\dot{x}p_{x\dot{x}}(x\dot{x}) = 2F_{x_2}(x)N_{x_1} = 2\sqrt{\frac{2\pi}{\Omega}}f_m x^{\alpha/2}e^{-\frac{1}{\Omega}x^{\alpha}}\left(1-e^{-\frac{1}{\Omega}x^{\alpha}}\right) \quad (12)$$

This expression can be used for calculation of average level crossing rate of wireless communication system with SC receiver operating over Weibull multipath fading channel.

3. Macro Diversity System with Two Micro Diversity Branches

Macro diversity system with two micro diversity SC branches is considered next. Received signal experiences Gamma correlated long term fading and Weibull short term fading resulting in signal envelope and average power variation. Model of the system considered in this paper is shown in figure 1. Signal envelopes at inputs of the first micro diversity SC combiner are denoted with x_{11} and x_{12} and at input of the second micro diversity SC combiner with x_{21} and x_{22}. Signal envelopes at the outputs of micro diversity SC combiners are denoted with x_1 and x_2, and ultimately, at the output of macro diversity SC combiner with x.

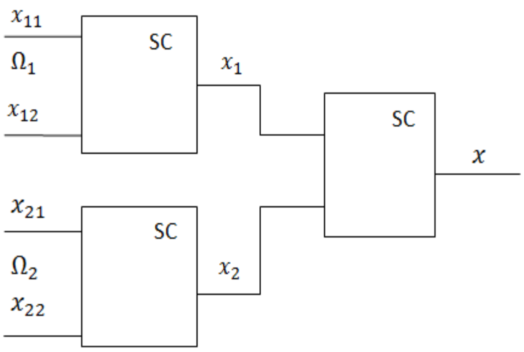

Fig. 1 Model of a macro diversity system, featuring two front-end micro diversity combiners

Average signal powers at the inputs of micro diversity SC combiners are denoted with Ω_1 and Ω_2, and they follow correlated Gamma distribution [18]:

$$p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2)=\frac{(\Omega_1\Omega_2)^{\frac{c-1}{2}}}{\Gamma(c)(1-\rho^2)\rho^{c-1}\Omega_0^{\ c+1}}e^{-\frac{\Omega_1+\Omega_2}{\Omega_0(1-\rho^2)}}\left(I_{c-1}\frac{2\rho}{\Omega_0(1-\rho^2)}\cdot\Omega_1^{\ 1/2}\Omega_2^{\ 1/2}\right)= \\ =\frac{1}{\Gamma(c)}e^{-\frac{\Omega_1+\Omega_2}{\Omega_0(1-\rho^2)}}\sum_{i=0}^{\infty}\frac{\rho^{2i}\Omega_1^{\ i+c-1}\Omega_2^{\ i+c-1}}{\Omega_0^{\ 2i+2c}(1-\rho^2)^{2i+c}i!\Gamma(i+c)} \quad (13)$$

where $\Gamma(a)$ denotes the well-known Gamma function [19, eq.(8.310)], ρ is correlation coefficient, Ω_0 is the scaling factor proportional to mean value of Ω_1 and Ω_2, $c \geq 1/2$ is Gamma shadowing parameter, and $In(\cdot)$ is the n-th order modified Bessel function of the first kind [19, eq. (8.406)]. Macro diversity SC receiver selects the branch with the highest signal power.

Therefore, using the expression (9), probability density function of x can be written as [16]:

$$p_x(x)=\int_0^{\infty}d\Omega_1\int_0^{\Omega_1}d\Omega_2\,p_{x_1}(x|\Omega_1)p_{\Omega_1\Omega_2}(\Omega_1\Omega_2)+\int_0^{\infty}d\Omega_2\int_0^{\Omega_2}d\Omega_1\,p_{x_2}(x|\Omega_2)p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2)=$$

$$=2\int_0^{\infty}d\Omega_1\int_0^{\Omega_1}d\Omega_2\,p_{x_1}(x|\Omega_1)p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2)=\frac{4\alpha x^{\alpha-1}}{\Gamma(c)}\sum_{i=0}^{\infty}\frac{\rho^{2i}}{\Omega_0^{i+c}(1-\rho^2)^i i!\Gamma(i+c)}\cdot$$

$$\cdot\left(\int_0^{\infty}d\Omega_1\Omega_1^{i+c-2}e^{-\frac{1}{\Omega_1}x^{\alpha}-\frac{\Omega_1}{\Omega_0(1-\rho^2)}}\left(1-e^{-\frac{1}{\Omega_1}x^{\alpha}}\right)\right)\gamma\left(i+c,\frac{\Omega_1}{\Omega_0(1-\rho^2)}\right)=$$

$$=\frac{8\alpha}{\Gamma(c)}\cdot\sum_{i_1=0}^{\infty}\sum_{i_2=0}^{\infty}\frac{\rho^{2i_1}x^{\frac{2\alpha i_1+\alpha i_2+2\alpha c+\alpha-2}{2}}}{\Omega_0^{\ i_1+\frac{i_2}{2}+c+\frac{1}{2}}(1-\rho^2)^{i_1+\frac{i_2}{2}+\frac{1}{2}}i_1!\Gamma(i_1+c)(i_1+c)(1+i_1+c)_{i_2}}\cdot \\ \cdot\left(2^{\frac{1-2i_1-i_2-2c}{2}}K_{2i_1+i_2+2c-1}\left(2\sqrt{\frac{2x^{\alpha}}{\Omega_0(1-\rho^2)}}\right)-K_{2i_1+i_2+2c-1}\left(4\sqrt{\frac{x^{\alpha}}{\Omega_0(1-\rho^2)}}\right)\right) \quad (14)$$

where $\gamma(a, x)$ is incomplete lower Gamma function, $(a)_n$ is Pochhammer symbol [19] and $K_v(\cdot)$ is the second kind of the modified Bessel function of order v [19, eq. (8.407)].

Using the expression (12), the level crossing rate of macro-diversity SC receiver output signal envelope of x can be written in the form [20]:

$$N_x(x)=\int_0^{\infty}d\Omega_1\int_0^{\Omega_1}d\Omega_2 N_{x_1}(x|\Omega_1)p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2)+\int_0^{\infty}d\Omega_2\int_0^{\Omega_2}d\Omega_1 N_{x_2}(x|\Omega_2)p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2)=$$

$$=2\int_0^{\infty}d\Omega_1\int_0^{\Omega_1}d\Omega_1 N_{x_1}(x|\Omega_1)p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2)=\frac{8f_m\sqrt{2\pi}}{\Gamma(c)}\sum_{i_1=0}^{\infty}\sum_{i_2=0}^{\infty}\frac{\rho^{2i_1}}{i_1!\Gamma(i_1+c)(i_1+c)(1+i_1+c)_{i_2}}\cdot$$

$$\cdot\left(\frac{x^{\alpha}}{\Omega_0(1-\rho^2)}\right)^{i_1+\frac{i_2}{2}+c+\frac{1}{4}}\left(2^{\frac{1}{4}-i_1-\frac{i_2}{2}-c}K_{2i_1+i_2+2c-\frac{1}{2}}\left(2\sqrt{\frac{2x^{\alpha}}{\Omega_0(1-\rho^2)}}\right)-K_{2i_1+i_2+2c-\frac{1}{2}}\left(4\sqrt{\frac{x^{\alpha}}{\Omega_0(1-\rho^2)}}\right)\right) \quad (15)$$

Using the expression (10), cumulative distribution function of macro diversity SC receiver can be written in the form [21]:

$$F_x(x) = \int_0^{\infty} d\Omega_1 \int_0^{\Omega_1} d\Omega_2 F_{x_1}(x|\Omega_1) p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2) + \int_0^{\infty} d\Omega_2 \int_0^{\Omega_1} d\Omega_1 F_{x_2}(x|\Omega_2) p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2) =$$

$$= 2\int_0^{\infty} d\Omega_1 \int_0^{\Omega_1} d\Omega_2 F_{x_1}(x|\Omega_1) p_{\Omega_1\Omega_2}(\Omega_1,\Omega_2) = \frac{2}{\Gamma(c)} \sum_{i_1=0}^{\infty}\sum_{i_2=0}^{\infty} \frac{\rho^{2i_1}}{\Omega_0^{2i_1+i_2+2c}(1-\rho^2)^{2i_1+i_2+c} i_1! \Gamma(i_1+c)} \cdot$$

$$\cdot \frac{1}{(i_1+c)(1+i_1+c)_{i_2}} \left[\Gamma(2i_1+i_2+2c) \left(\frac{\Omega_0(1-\rho^2)}{2} \right)^{2i_1+i_2+2c} - 4 \left(\frac{x^{\alpha}\Omega_0(1-\rho^2)}{2} \right)^{i_1+\frac{i_2}{2}+c} \cdot \right. \quad (16)$$

$$\left. \cdot K_{2i_1+i_2+2c}\left(2\sqrt{\frac{2x^{\alpha}}{\Omega_0(1-\rho^2)}} \right) + 2(x^{\alpha}\Omega_0(1-\rho^2))^{i_1+\frac{i_2}{2}+c} K_{2i_1+i_2+2c}\left(4\sqrt{\frac{x^{\alpha}}{\Omega_0(1-\rho^2)}} \right) \right]$$

Using expressions (16) and (15), we can easily obtain AFD. The AFD is defined as the average time over which the signal envelope ratio remains below the specified level after crossing that level in a downward direction, and is determined as [12,15]:

$$T_x(x) = \frac{F_x(x)}{N_x(x)} = \frac{\displaystyle\sum_{i_1=0}^{\infty}\sum_{i_2=0}^{\infty} \frac{\rho^{2i_1}}{i_1!\Gamma(i_1+c)(i_1+c)(1+i_1+c)_{i_2}(\Omega_0(1-\rho^2))^{i_1+\frac{i_2}{2}}}}{\displaystyle 4\sqrt{2\pi}\, f_m x^{\alpha c} \sum_{j_1=0}^{\infty}\sum_{j_2=0}^{\infty} \frac{\rho^{2j_1}}{j_1!\Gamma(j_1+c)(j_1+c)(1+j_1+c)_{j_2}} \cdot \left(\frac{x^{\alpha}}{\Omega_0(1-\rho^2)} \right)^{j_1+\frac{j_2}{2}+\frac{1}{4}}} \cdot$$

$$\cdot \frac{\dfrac{(\Omega_0(1-\rho^2))^{i_1+\frac{i_2}{2}+c}\Gamma(2i_1+i_2+2c)}{2^{2i_1+i_2+2c}} - 2x^{\alpha\left(i_1+\frac{i_2}{2}+c\right)}\left(2^{1-i_1-\frac{i_2}{2}-c} K_{2i_1+i_2+2c}\left(2\sqrt{\frac{2x^{\alpha}}{\Omega_0(1-\rho^2)}} \right) - K_{2i_1+i_2+2c}\left(4\sqrt{\frac{x^{\alpha}}{\Omega_0(1-\rho^2)}} \right) \right)}{2^{\frac{1}{4}-j_1-\frac{j_2}{2}-c} K_{2j_1+j_2+2c-\frac{1}{2}}\left(2\sqrt{\frac{2x^{\alpha}}{\Omega_0(1-\rho^2)}} \right) - K_{2j_1+j_2+2c-\frac{1}{2}}\left(4\sqrt{\frac{x^{\alpha}}{\Omega_0(1-\rho^2)}} \right)} \quad (17)$$

4. NUMERICAL RESULTS

Numerically obtained results are presented graphically in order to examine the influence of shadowing and fading severity on the concerned quantities. Probability density function of macro diversity SC receiver output signal is given in Fig. 2. It is evident that the probability density function shifts to the right due to the increase of α, while the change of correlation coefficient ρ causes only slight changes of general PDF behavior.

Level crossing rate values normalized by maximal Doppler shift frequency f_m, versus SC receiver output signal, are presented in Fig. 3, for several values of Weibull fading parameter α, Gamma shadowing severity parameter c and correlation coefficient. In Fig. 3, abscissa represents arbitrary crossing level, relative to scaling factor Ω_0.

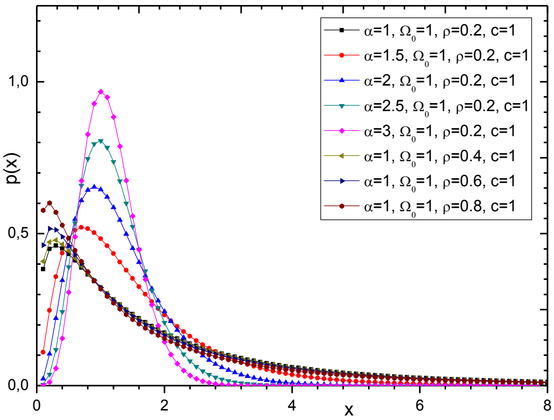

Fig. 2 PDF of macro diversity SC receiver output signal

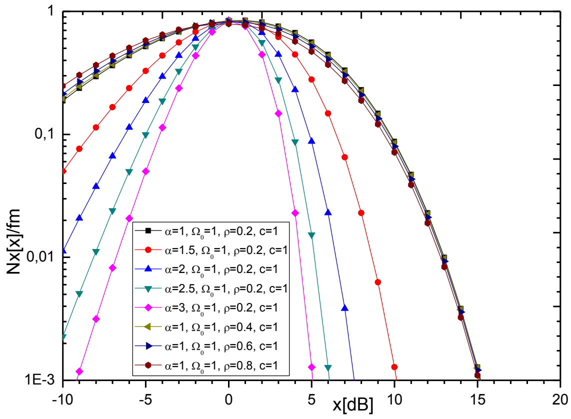

Fig. 3 LCR for different fading severity and correlation parameter

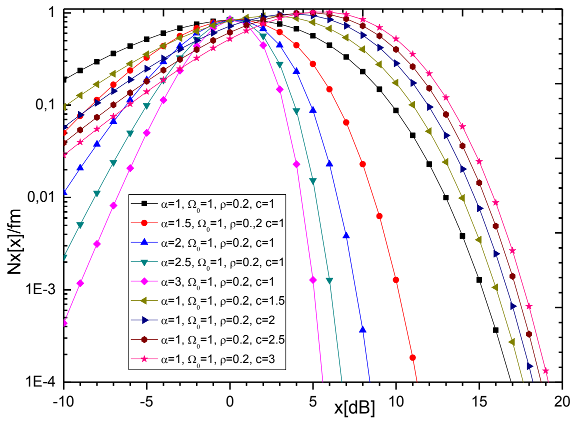

Fig. 4 LCR for different fading and shadowing severity

Average level crossing rate increases as the crossing level increases towards the mean signal level. Close to mean signal level, LCR achieves its maximum and then decreases again with increasing the crossing level. Sharpness of the peak near the maximum is closely related to Weibull fading severity parameter. While the higher values of Weibull parameter α correspond to less severe fading conditions, increasing of correlation parameter slightly worsens the effectiveness of diversity reception.

It is evident from Fig. 3. that, for severe fading conditions, higher correlation increases probabilities that signal passes lower threshold levels. General influence of correlation is the same for lower fading severity, but this is not shown in figures. When correlation coefficient tends to one, the same signal is present simultaneously on both antenna ports and system will not be able to achieve any diversity gain.

Fig. 4 shows LCR when shadowing severity parameter increases. This increases the mean signal level, identified by the peak LCR, and it is the consequence of normalization by the scaling factor Ω_0, which we chose previously. Going back to (13), we see that averaging over Ω_1, mean value of Ω_2 is $c{\cdot}\Omega_0$, and vice versa. This higher mean value is clearly seen as LCR curves shift to the right in Fig. 4. By increasing parameter *c*, shadowing severity decreases, which is analogous to behavior due to Weibull parameter α.

Cumulative distribution function of macro diversity SC receiver output signal for different system parameters is presented in Fig. 5. From the figure, we can conclude that changes of the parameter α show significant influence on the outage probability. Due to an increase in the parameter α, the outage probability becomes lower, and the system is more stable at lower threshold levels. Cumulative distribution clearly shows that probability of signal staying below the threshold level is lower. An increase of parameter ρ affects the stability of the system also. If ρ rises, the outage probability is greater and the system operation becomes less stable.

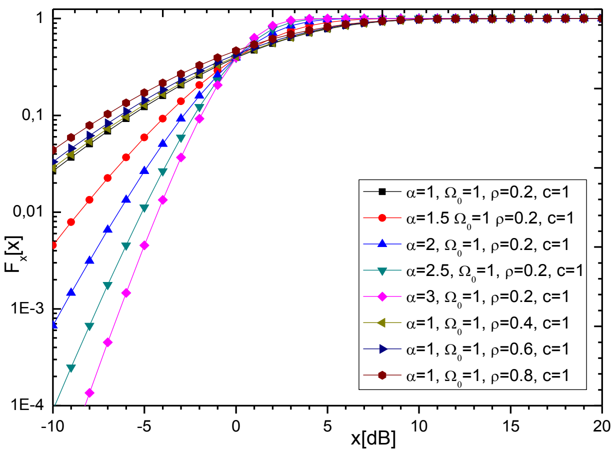

Fig. 5 CDF for different system parameters

Table 1 represents the table of convergence for the expression (16) in reliance on the variable x. The table shows number of terms needed to be included in (16), in order for the accuracy of the resulting expression to achieve 6 accurate decimal positions, for the given parameter values. It is evident that the expression converges rapidly for the given parameters. We can conclude from the table 1 that due to increase of the coefficient α, the number of terms that have to be summed is slightly lower, while for the greater values of correlation coefficient ρ, the required number of terms increase.

Table 1 Number of terms that should be added in expression (16) in order to reach 6 accurate decimal positions, when parameters *α* and *ρ* change.

	x= -10 dB	x=0 dB	x=10 dB
$\alpha=1$, $\Omega_0=1$, $\rho=0.2$, $c=1$	8	13	19
$\alpha=1.5$, $\Omega_0=1$, $\rho=0.2$, $c=1$	6	13	19
$\alpha=2$, $\Omega_0=1$, $\rho=0.2$, $c=1$	5	13	19
$\alpha=2.5$, $\Omega_0=1$, $\rho=0.2$, $c=1$	5	13	19
$\alpha=3$, $\Omega_0=1$, $\rho=0.2$, $c=1$	5	13	19
$\alpha=1$, $\Omega_0=1$, $\rho=0.4$, $c=1$	9	15	19
$\alpha=1$, $\Omega_0=1$, $\rho=0.6$, $c=1$	9	15	21
$\alpha=1$, $\Omega_0=1$, $\rho=0.8$, $c=1$	13	20	29

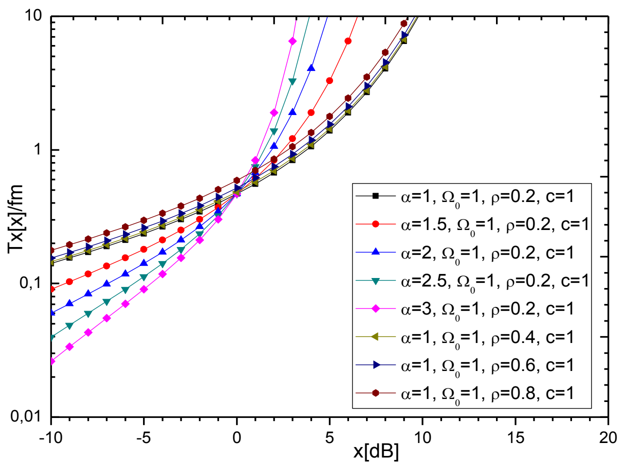

Fig. 6 AFD for different system parameters

Fig. 6 presents normalized values for average fade duration for various system parameters. When the crossing threshold level *x* is below the average signal level, AFD stays low, and it is the main mode in which the system is operates normally. Better performance is expected in cases where the value of Weibull parameter α is higher, and correlation coefficient ρ is lower, resulting in lower AFD.

4. CONCLUSION

Macro diversity receiver with macro diversity SC combiner and two micro diversity SC combiners operating over Gamma shadowed multipath fading environment is considered in this paper. Received signal experiences combined effects of Gamma long term fading and Weibull short term fading resulting in system performance degradation. When shadowing severity parameter tends to infinity the composite channel approaches a simple Weibull multipath channel, and when Weibull fading parameter tends to infinity the channel tends to a Gamma shadowing channel. When Weibull fading parameter equals two, the composite fading channel reduces to Gamma shadowed Rayleigh multipath channel.

Closed form expressions for probability density function, cumulative distribution function and average level crossing rate of macro diversity SC receiver output signal envelope are calculated. For special case when Weibull parameter is equal to two, we can easily evaluate PDF, CDF and average level crossing rate for the resulting Rayleigh signal envelope. Infinity series expressions converge for any values of Gamma shadowing severity parameter, Weibull fading parameter, and shadowing correlation coefficient. Number of terms that need to be summed in order to achieve desired accuracy depends on Gamma severity parameter, Weibull fading parameter and correlation coefficient. The number of terms increases as Gamma severity parameter and Weibull parameter deceases, and correlation coefficient increases.

Level crossing rate and average fade duration are presented graphically to show the influence of Gamma severity parameter, Weibull fading parameter, and correlation coefficient. on average level crossing rate of SC receiver output signal. As expected, system performance is better when the fading and shadowing severity is lower, and correlation between the diversity branches is relatively low. When the correlation of shadowing effects on the two macro branches is substantial, macro diversity system gains are minimal, and the receiver performance reduces to performance of a micro diversity receiver.

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