Outage Probability of SIR Based SC Macro-diversity Reception in Gamma Shadowed Rayleigh Multipath Fading Environment

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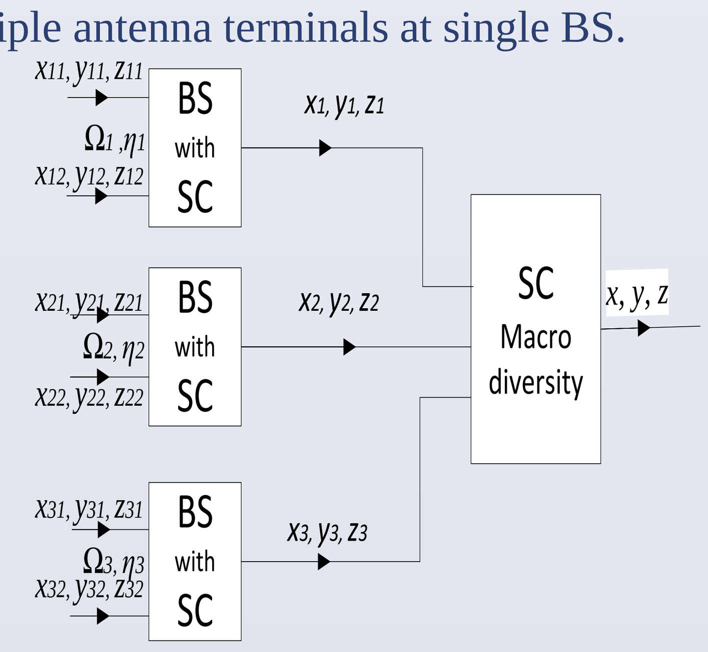
Abstract

The paper considers signal-to-interference ratio (SIR) based macro-diversity reception with macro level (MaL) selection combining (SC) diversity and three dual branch SC diversity receivers at micro level (MiL) in correlated Gamma shadowed Rayleigh multipath fading environment. Rapidly converging, infinite series expression for outage probability (OP) is obtained, graphically presented and analyzed regarding various system model parameters. Precisely, influence of Gamma long term fading severity parameter of desired signal as well as Gamma long term fading severity parameter of CCI on OP are examined and discussed. Further, MaL diversity system performance analysis also includes the effects of shadowing correlation parameter, average signal power of desired signal as well as average power of CCI.

System Model

Macro-diversity reception is one of the most effective technique which enables long term fading effects and short-term fading effects reductions, simultaneously. Thus, long term fading alleviation is provided by micro level (MiL) diversity at single base station (BS) while long-term fading alleviation is provided by macro level (MaL) diversity receiver processing signals from more BSs. Multipath propagation is caused by reflection, diffraction and scattering of radio waves causing signal envelope fluctuations, phenomena also known as short term fading. Shadowing is caused by obstacles between transmitter and receiver causing average signal power fluctuations, phenomena also known as long term fading.

The proposed Macrolevel diversity system consists of three dual branches MiL diversity SC structures routing the signals to the MaL diversity SC receiver as shown o 1 MaL diversity SC receiver process signal envelopes from BSs while MiL diversity SC receivers process signal envelopes from multiple antenna terminals at single BS.



Desired signal, x_{ij} has Rayleigh distribution [1]:

$$p_{x_{ij}}(x_{ij}) = \frac{2x_{ij}}{\Omega_i} e^{-\frac{x_{ij}^2}{\Omega_i}}, i = 1,2,3;\ j = 1,2; \quad (1)$$

where $\Omega_i = E\langle x_{ij}^2\rangle$, while the $E\langle\cdot\rangle$ denotes expectation.

Similarly, CCI denoted withy_{ij} has also Rayleigh distribution [1]:

$$p_{y_{ij}}(y_{ij}) = \frac{2y_{ij}}{\eta_i} e^{-\frac{y_{ij}^2}{\eta_i}}, i = 1,2,3;\ j = 1,2; \quad (2)$$

where $\eta_i = E\langle y_{ij}^2\rangle$, while the $E\langle\cdot\rangle$ denotes expectation.

In interference limited environment, such as cellular networks, level of interference is proposed to be significantly higher than level of Gaussian noise. Thus, the effect of Gaussian noise on system performances is negligible. The signal to interference ratio (SIR) is given as:

$$z_{ij} = \frac{x_{ij}}{y_{ij}}, i = 1,2,3;\ j = 1,2. \quad (3)$$

The probability density function (PDF) of z_{ij}, using [16, (3.478.1)] and some mathematical manipulations becomes:

$$p_{z_{ij}}(z_{ij}) = \int_0^\infty y_{ij} p_{x_{ij}}(y_{ij}z_{ij})\, p_{y_{ij}}(y_{ij}) dy_{ij}$$
$$= 2\Omega_i\eta_i \frac{z_{ij}}{(\Omega_i+\eta_i z_{ij}^2)^2}, i = 1,2,3;\ j = 1,2; \quad (4)$$

Cumulative density function (CDF) of SIR can be solved using [16, (3.381.4)]:

$$F_{z_{ij}}(z_{ij}) = \int_0^{z_{ij}} p_{z_{ij}}(t) dt$$
$$= \frac{\eta_i z_{ij}^2}{\Omega_i+\eta_i z_{ij}^2}, i = 1,2,3;\ j = 1,2. \quad (5)$$

CDF of SIR based MiL SC outputs signal envelopes are [1]:

$$F_{\mathrm{z_i}}(\mathrm{z_i}) = F_{\mathrm{z_{i1}}}(\mathrm{z_i}) F_{\mathrm{z_{i1}}}(\mathrm{z_i})$$
$$= \frac{\eta_i^2 z_i^4}{(\Omega_i+\eta_i z_i^2)^2}\, i = 1,2,3. \quad (6)$$

$$\mathrm{p}_{\Omega_1\Omega_2\Omega_3}(\Omega_1\Omega_2\Omega_3) =$$
$$\frac{(\Omega_1\Omega_3)^{\frac{c-1}{2}}}{\Gamma(c)(1-\rho)^2\rho^{(c-1)}\Omega_0^{c+2}} I_{c-1}\left(\frac{2}{\Omega_0(1-\rho)}(\rho\Omega_1\Omega_2)^{\frac{1}{2}}\right) I_{c-1}\left(\frac{2}{\Omega_0(1-\rho)}(\rho\Omega_2\Omega_3)^{\frac{1}{2}}\right) \mathrm{e}^{\frac{\Omega_1+\Omega_2(1+\rho)+\Omega_3}{\Omega_0(1-\rho)}} \quad (7)$$

$$p_{\eta_1\eta_2\eta_3}(\eta_1\eta_2\eta_3) = \frac{1}{\Gamma(c_1)\eta_0^{c_1}} \eta_1^{c_1-1} e^{-\frac{1}{\eta_0}\eta_1} \frac{1}{\Gamma(c_1)\eta_0^{c_1}} \eta_2^{c_1-1} e^{-\frac{1}{\eta_0}\eta_2} \frac{1}{\Gamma(c_1)\eta_0^{c_1}} \eta_3^{c_1-1} e^{-\frac{1}{\eta_0}\eta_3} \quad (8)$$

ρ is correlation parameter of the shadowing, c is shadowing severity parameter and Ω_0 is mean value of Ω_1, Ω_2 and Ω_3.

c_1 is Gamma interference severity parameter and η_0 is average power of η_1,$\eta_2$and η_3.

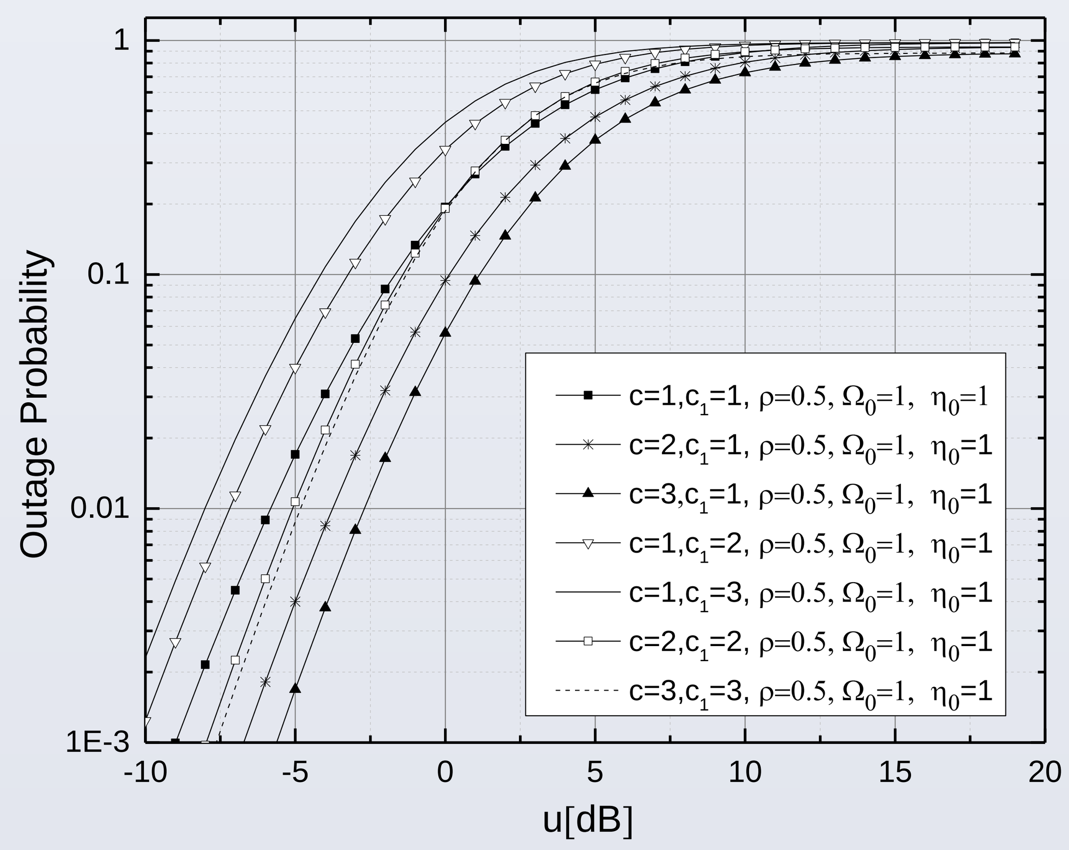
Numerical Results

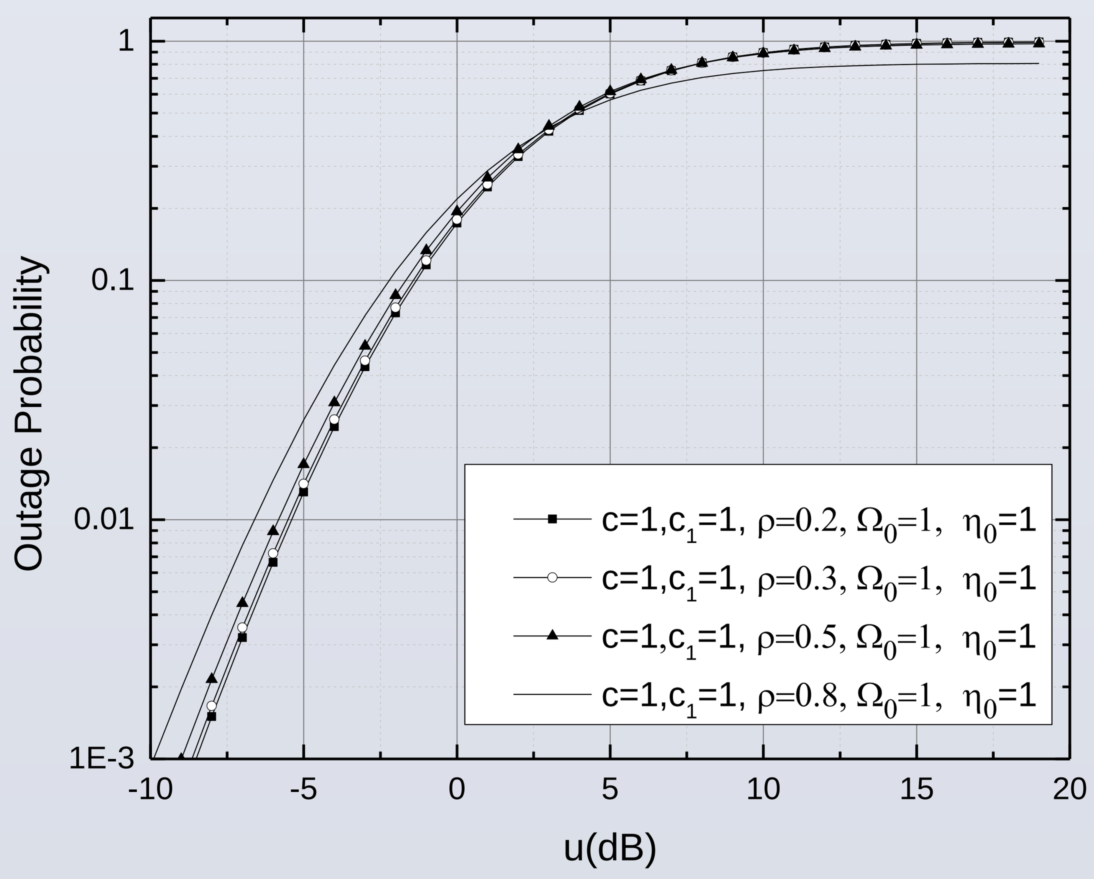
MaL SC receiver selects the MiL diversity SC structure to provide service to user with the highest $\Omega_{i.,}$ After some mathematical manipulation, CDF of SIR based MaL diversity SC receiver output can be obtain as:

$$F_z(z) = \int_0^\infty d\eta_1 \int_0^\infty d\Omega_1 \int_0^{\Omega_1} d\Omega_2 \int_0^{\Omega_1} F_{z_1}(z|\Omega_1\eta_1) p_{\Omega_1\Omega_2\Omega_3}(\Omega_1\Omega_2\Omega_3)\, p_{\eta_1}(\eta_1) d\Omega_3$$
$$+ \int_0^\infty d\eta_2 \int_0^\infty d\Omega_2 \int_0^{\Omega_2} d\Omega_1 \int_0^{\Omega_2} F_{z_2}(\eta|\Omega_2\eta_2) p_{\Omega_1\Omega_2\Omega_3}(\Omega_1\Omega_2\Omega_3)\, p_{\eta_2}(\eta_2) d\Omega_3$$
$$+ \int_0^\infty d\eta_3 \int_0^\infty d\Omega_3 \int_0^{\Omega_3} d\Omega_1 \int_0^{\Omega_3} F_{z_3}(z|\Omega_3\eta_3) p_{\Omega_1\Omega_2\Omega_3}(\Omega_1\Omega_2\Omega_3)\, p_{\eta_3}(\eta_3) d\Omega_2 \quad (9)$$

The outage probability (OP) of MaL diversity SC system is defined as the probability that the output signal falls below threshold u, given as:

$$OP = \int_0^{\mathrm{u}} p_z(t) dt = F_z(u), \quad (10)$$





Conclusion

In this paper, SIR based MaL diversity system with MaL SC reception and three dual MiL SCs in correlated Gamma shadowed Rayleigh multipath fading channel is considered. Novel, infinite series expressions for CDF of the output signal envelope is calculated and used for derivation of OP of SC MaL diversity system. The results are graphically presented regarding different system model parameters. In general the best possible outcome in theory is achievable for higher values of shadowing severity parameter and lower values of CCI fading severity parameter. It is shown, that obvious improvement is achievable with higher values of average desired signal power and lower values of CCI average power. Moreover, the impact of shadowing correlation on OP is more evident for higher values of ρ. The obtained analytical and numerical results can be of significance in designing wireless communication systems using MaL diversity technique to reduce short–term, long-term fading and CCI impacts on system performances.

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