Online ISSN 1848-3380, Print ISSN 0005-1144
ATKAFF 57(1), 261–267(2016)

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Outage probability of correlated SIR-based SSC diversity systems over composite K_G fading/shadowing channels

DOI 10.7305/automatika.2016.07.172
UDK 621.391.812:519.22; 621.371.3

Original scientific paper

In this paper, the effects of multipath fading and shadowing over the propagation channel are observed through the performance analysis of switch and stay selection combining (SSC) technique. The short term fading (multipath fading) in conjunction with the long term fading (shadowing) are both modeled by Generalized-*K* (K_G) distribution. The proposed system is considered as interference-limited system in correlated fading environment. The probability density function (PDF) of signal-to-interference ratio (SIR) at the output of SSC receiver is derived in form of Meijer G functions. According to this new expression, the outage probability is considered and the effects of fading and shadowing parameters and correlation coefficients on the performance gain are analyzed.

Key words: Composite fading channels, Generalized-*K* distribution, SSC combining method, Wireless communications

Vjerojatnost ispada koreliranih SIR prijemnika sa SSC raznolikosti putem kanala s kompozitnim K_G slabljenjem/zasjenjivanjem signala. U radu su razmatrana djelovanja višeputnog slabljenja i zasjenjivanja signala u propagacijskom kanalu pomoću analize SSC prijemnika raznolikosti (prekidački prostorni kombinator raznolikosti). Kompozitni utjecaj brzog (višeputnog) i sporog slabljenja signala (zasjenjivanja) modeliran je poopćenom-K (K_G) razdiobom. Predloženi sustav razmatran je kao sustav s ko-kanalnom interferencijom kao dominantnom smetnjom i koreliranim slabljenjem signala. Funkcija gustoće razdiobe (PDF) odnosa signal/smetnja (SIR) SSC izlaza prijemnika izvedena je u obliku Meijer G funkcija. Na osnovu ovog izraza, razmatra se vjerojatnost ispada te analiziraju učinci parametara i korelacijskih koeficijenata slabljenja i zasjenjivanja signala na unaprijeđenje performansi sustava.

Ključne riječi: Kompozitni kanali sa slabljenjem signala, poopćena-*K* razdioba, SSC metoda kombiniranja, bežični prijenos signala

In performance evaluation of wireless communication systems, the statistical characterization of signal propagation is frequently based on analysis of composite fading: large-scale fading due to multipath propagation and small-scale fading resulting from shadowing [1]. This destructive combination of obstacles often occurs simultaneously. The multipath fading can be modeled by Rice, Rayleigh and Nakagami-*m* distributions and shadowing by lognormal distribution. These lognormal based fading models are analyzed in few papers [1]-[3].

However, the analytical analysis of these models is very complicated, so in some other papers the Gamma distribution is employed as an useful solution for describing shadow fading phenomena [4]. Furthermore, based on Gamma distribution, several generalized distributions have been proposed as composite fading channel models, the generalized Gamma, the *G* [5], the *K* [6] and the Generalized-*K* (K_G) [7]-[11] channel models.

In an interference-limited system (the thermal noise is ignored), the effect of interference needs to be taken into consideration of performance analysis. The most effective performance criterion, in that case, is to select the signal-to-interference ratio [12]. Independently of the channel condition, the transmitted signals as well as the interfered ones could be correlated due to small distance between the diversity antennas.

In [8], the brief performance evaluations of the output signal-to-noise ratio (SNR) for the maximal-ratio combining (MRC), equal-gain combining (EGC), selection combining (SC) and switch and stay combining (SSC) operating over K_G fading channels are presented. The performance analysis of various diversity combining techniques, this time over the correlated K_G fading channels is considered in [9]. The infinite series expressions for the probability density function (PDF), cumulative distribution function (CDF) and joint moments of two correlated K_G vari-

ables are also derived in [9].

In [10], the uncorrelated composite fading channels in the presence of co-located interferers are considered. In this paper, the performance of SSC diversity receiver in interference-limited environment is analyzed. Considering the composite correlated fading channel condition, infinite series expressions for the performance evaluation are derived. The detailed analysis of outage probability is presented. Based on analytical results, required numerical results are also presented.

The paper is organized as follows. In the Section 2, we give the brief description of channel model and mathematical formulation of proposed problem. The switch and stay combining scheme is presented in Section 3. In Section 4 the derived expression for evaluating the outage probability is presented and in Section 5 numerical results are given.

1 CHANNEL MODEL

Assuming the composite fading channel model, the K_G distribution is convenient and mathematically tractable distribution for evaluating adequate performance criteria. The K_G distribution accurately approximates a great variety of fading and/or shadowing models. The received resultant of desired and interfering signal, considering K_G fading environment, can be presented as [13]:

$$y(t) = x(t) \exp\left[j(2\pi f_c t + \psi(t) + \theta(t))\right], \qquad (1)$$

where f_c is a carrier frequency, $\psi(t)$ is the information signal, $\theta(t)$ is the random phase and $x(t)$ is K_G distributed random envelope process, given by [8, eq. (1)]:

$$p(x) = \frac{4m^{(m+k)/2}}{\Gamma(m)\Gamma(k)\Omega^{(m+k)/2}} x^{m+k-1} K_{k-m}\left(2x\sqrt{\frac{m}{\Omega}}\right), \qquad (2)$$

where $K_{k-m}(.)$ is the $(k-m)^{\text{th}}$ order modified Bessel function of the second kind [14, eq. (8.407)], $G(.)$ is the Gamma function [14, eq. (8.310^7.1)] and $\Omega = \mathbb{E}(x^2)/k$ with $\mathbb{E}(.)$ being expectation operator. The parameter m is a fading severity parameter and k is a shadowing severity parameter. The two shaping parameters, m and k, can take different values ($m \geq \frac{1}{2}$ and $k \in (0, \infty)$). Therewith a great variety of short-term and long-term fading (shadowing) conditions can be described. For example Rayleigh-Gamma fading model can be obtained by setting parameter m value $m = 1$. In addition, more severe scenarios than Rayleigh-Gamma fading can be obtained by by setting parameter m value $m < 1$. Finally, for less severe scenarios by introducing $m > 1$, very good approximation of the Rician-Gamma fading model can be obtained. The shadowing level described by parameter k and the shadowing spread σ(dB) of Log-normal model, are related through the relation given in [19].

The proposed model refers to the case of a single co-channel interferer. We assume that the remaining interferers are combined and considered as uncorrelated interference between antennas. The fading amplitude of the desired signal $R(t)$ as well as of the interfering one $r(t)$ is K_G distributed. So, the PDF for instantaneous SIR, denoted by $z = R^2/r^2$, can be evaluated as (Appendix A):

$$p_z(z) = \frac{z^{(m_d+k_d)/(2-1)}}{\Gamma(m_d)\Gamma(k_d)\Gamma(m_c)\Gamma(k_c)} \left(\frac{m_d}{m_c S}\right)^{(m_d+k_d)/2} \times G_{2,2}^{2,2}\left[\frac{m_d z}{m_c S}\,\middle|\, \begin{matrix} 1-\frac{m_d+k_d+2k_c}{2}, 1-\frac{m_d+k_d+2m_c}{2} \\ \frac{(k_d-m_d)}{2}, -\frac{(k_d-m_d)}{2} \end{matrix}\right], \qquad (3)$$

where $G_{p,q}^{m,n}[.|.]$ is the Meijer's G-function [14, eq. (9.301^7)]; S is the average SIR at the two input branches defined as $S = \Omega_d/\Omega_c$, ($\Omega_d = \mathbb{E}(R^2)/k_d$, $\Omega_c = \mathbb{E}(r^2)/k_c$); m_d and k_d are the two shaping parameters for $R(t)$ and m_c and k_c are the two shaping parameters for $r(t)$. Also, the CDF of instantaneous SIR can be evaluated as (Appendix A):

$$F_z(z) = \frac{z^{(m_d+k_d)/2}}{\Gamma(m_d)\Gamma(k_d)\Gamma(m_c)\Gamma(k_c)} \left(\frac{m_d}{m_c S}\right)^{(m_d+k_d)/2} \times G_{3,3}^{2,3}\left[\frac{m_d z}{m_c S}\,\middle|\, \begin{matrix} 1-\frac{m_d+k_d+2k_c}{2}, 1-\frac{m_d+k_d+2m_c}{2}, \\ \frac{(k_d-m_d)}{2}, -\frac{(k_d-m_d)}{2}, \\ 1-\frac{m_d+k_d}{2} \\ -\frac{(m_d+k_d)}{2} \end{matrix}\right], \qquad (4)$$

Furthermore, due to a scenario with closely placed diversity antennas, both desired and interfering signal envelopes experience correlated K_G fading. In this paper, we analyze dual diversity system with balanced SIRs ($S_1 = S_2 = S$) at the input branches. The joint PDF for input balanced SIRs, denoted by $z_1 = R_1^2/r_1^2$ and $z_2 = R_2^2/r_2^2$, regarding $\Omega_{d_1} = \mathbb{E}\left(R_1^2\right)/k_d$, $\Omega_{c_1} = \mathbb{E}\left(r_1^2\right)/k_c$, $\Omega_{d_2} = \mathbb{E}\left(R_2^2\right)/k_d$, $\Omega_{c_2} = \mathbb{E}\left(r_2^2\right)/k_c$ and $S = \Omega_{d_1}/\Omega_{c_1} = \Omega_{d_2}/\Omega_{c_2}$, can be evaluated as (Appendix B):

$$p_{z_1 z_2}(z_1, z_2) = \sum_{a,b,c,d,=0}^{\infty} A \times z_1^{\varepsilon_d/2-1} z_2^{\varepsilon_d/2-1} \times G_{2,2}^{2,2}\left[\frac{m_d z_1 \sigma}{m_c S}\,\middle|\, \begin{matrix} 1-\frac{\varepsilon_d+\varepsilon_c+\psi_c}{2}, 1-\frac{\varepsilon_d+\varepsilon_c-\psi_c}{2} \\ \frac{\psi_d}{2}, -\frac{\psi_d}{2} \end{matrix}\right] \times G_{2,2}^{2,2}\left[\frac{m_d z_2 \sigma}{m_c S}\,\middle|\, \begin{matrix} 1-\frac{\varepsilon_d+\varepsilon_c+\psi_c}{2}, 1-\frac{\varepsilon_d+\varepsilon_c-\psi_c}{2} \\ \frac{\psi_d}{2}, -\frac{\psi_d}{2} \end{matrix}\right], \qquad (5)$$

with

$$A = \frac{m_d^{\varepsilon_d}\rho_{nd}^a\rho_{gd}^b\rho_{nc}^c\rho_{gc}^d}{\Gamma(m_d)\Gamma(k_d)\Gamma(m_c)\Gamma(k_c)m_c^{\varepsilon_d}\Gamma(m_d+a)\Gamma(k_d+b)} \cdot \frac{1}{\Gamma(m_c+c)\Gamma(k_c+d)S^{\varepsilon_d}a!b!c!d!(1-\rho_{nd})^{k_d+a+b}} \cdot \frac{1}{(1-\rho_{gd})^{n_d+a+b}(1-\rho_{nc})^{k_c+c+d-\varepsilon_d-\varepsilon_c}} \cdot \frac{1}{(1-\rho_{gc})^{m_c+c+d-\varepsilon_d-\varepsilon_c}},$$

$$\sigma = \frac{(1-\rho_{nc})(1-\rho_{gc})}{(1-\rho_{nd})(1-\rho_{gd})},$$

$$\varepsilon_d = k_d + m_d + a + b,$$

$$\varepsilon_c = k_c + m_c + c + d,$$

$$\psi_d = k_d + b - m_d - a,$$

$$\psi_c = k_c + d - m_c - c,$$

where ρ_{nd} and ρ_{nc} are the power correlation coefficients between the envelopes of the desired and interfering signals, and ρ_{gd} and ρ_{gc} are correlation coefficients between the average fading power of the desired and interfering signal, respectively.

2 SWITCH AND STAY COMBINING

The switched combining diversity technique is the less complex combining technique compared to the other space diversity combining methods. Because of its low complexity implementation requirements, SSC diversity systems are frequently used. The SSC combiner processes one branch unless the instantaneous SIR of that branch falls below the threshold when the combiner switches the treated branch with the other one:

$$F_{SSC}(z) = Pr(z_T \le z_1 \le z) + Pr(z_2 < z_T \wedge z_1 \le z). \tag{6}$$

The PDF of instantaneous SIR at the output of SSC, by differentiating equation (6), is given by [15, eq. (9)]:

$$p_{SSC}(z) = \begin{cases} f_{SSC}(z), & z \le z_T \\ f_{SSC}(z) + p(z), & z > z_T \end{cases}, \tag{7}$$

where $p_z(z)$ is defined as (3) and $f_{SSC}(z)$ is solved using [16, eq. (26)]:

$$f_{SSC}(z) = \int_0^{z_T} p_{z_1 z_2}(z, z_2)\mathrm{d}z_2 = \sum_{a,b,c,d,=0}^{\infty} A \times z^{\varepsilon_d/2-1} z_T^{\varepsilon_d/2} \times G_{2,2}^{2,2}\left[\frac{m_d z\sigma}{m_c S}\middle| \begin{matrix} 1-\frac{\varepsilon_d+\varepsilon_c+\psi_c}{2}, 1-\frac{\varepsilon_d+\varepsilon_c-\psi_c}{2} \\ \frac{\psi_d}{2}, -\frac{\psi_d}{2} \end{matrix}\right] \times G_{3,3}^{2,3}\left[\frac{m_d z_T\sigma}{m_c S}\middle| \begin{matrix} 1-\frac{\varepsilon_d+\varepsilon_c+\psi_c}{2}, 1-\frac{\varepsilon_d+\varepsilon_c-\psi_c}{2}, \frac{1-\varepsilon_d}{2} \\ \frac{\psi_d}{2}, -\frac{\psi_d}{2}, -\frac{\varepsilon_d}{2} \end{matrix}\right], \tag{8}$$

Moreover, after some manipulations of (6), the CDF of instantaneous output SIR can be expressed as [15, eq. 10]:

$$F_{SSC}(z) = \begin{cases} F_{z_1 z_2}(z, z_T), & z \le z_T \\ F_z(z) - F_z(z_T) + F_{z_1 z_2}(z, z_T), & z > z_T \end{cases}, \tag{9}$$

where $F_z(z)$ is given by (4) and $F_{z_1 z_2}(z, z_T)$ is evaluated as:

$$F_{z_1,z_2}(z, z_T) = \int_0^z \int_0^{z_T} p_{z_1 z_2}(z_1, z_2)\mathrm{d}z_1\mathrm{d}z_2 = = \sum_{a,b,c,d=0}^{\infty} A \times z^{\varepsilon_d/2} z_T^{\varepsilon_d/2} \times G_{2,3}^{3,3}\left[\frac{m_d z\sigma}{m_c S}\middle| \begin{matrix} 1-\frac{\varepsilon_d+\varepsilon_c+\psi_c}{2}, 1-\frac{\varepsilon_d+\varepsilon_c-\psi_c}{2}, \frac{1-\varepsilon_d}{2} \\ \frac{\psi_d}{2}, -\frac{\psi_d}{2}, -\frac{\varepsilon_d}{2} \end{matrix}\right] \times G_{2,3}^{3,3}\left[\frac{m_d z_T\sigma}{m_c S}\middle| \begin{matrix} 1-\frac{\varepsilon_d+\varepsilon_c+\psi_c}{2}, 1-\frac{\varepsilon_d+\varepsilon_c-\psi_c}{2}, \frac{1-\varepsilon_d}{2} \\ \frac{\psi_d}{2}, -\frac{\psi_d}{2}, -\frac{\varepsilon_d}{2} \end{matrix}\right]. \tag{10}$$

3 OUTAGE PROBABILITY

The outage probability P_{out} is a standard measure of the communication system performance and is commonly used to control the noise or co-channel interference level in wireless communication systems. In the interference-limited environment, outage probability P_{out} is defined as the probability that combined-SIR falls below a given outage threshold λ also known as a protection ratio:

$$P_{\text{out}} = \int_0^{\lambda} p_{SSC}(z)\mathrm{d}z = F_{SSC}(\lambda). \tag{11}$$

Protection ratio depends on modulation technique and expected quality-of-service (QoS).

4 NUMERICAL RESULTS

Figure 1 shows, P_{out}, versus the normalized switching threshold z_T/S for various correlation coefficient values. It is obvious that there is an optimal threshold that minimizes outage probability. For this threshold value, SSC combining can be observed as SC.

The outage probability, as a function of normalized average SIR for different values of shaping parameters is shown in Fig. 2. The influence of correlation between branches of desired, as well as interfering signal, is much more significant in the case of lower fading and shadowing severity. It is interesting to note here that, for pre-Rayleigh fading conditions ($m_d = 0.5$, $m_c = 0.5$), the

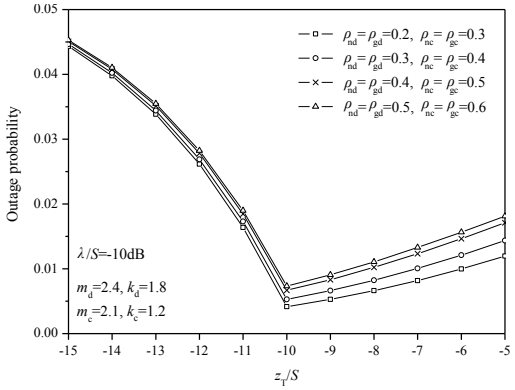

Fig. 1. Outage probability for various correlation coefficient values

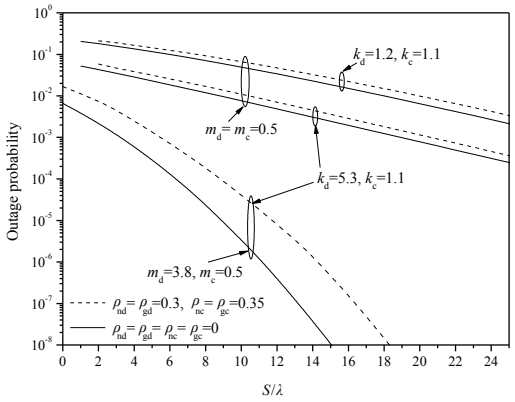

Fig. 2. Outage probability for different values of shaping parameters

system performance is not acceptable, even for light shadowing condition ($k_d = 5.3$, $k_c = 1.1$). The performance improves significantly when small scale fading effects decrease ($m_d = 3.8$, $m_c = 0.5$). In particular, the probability of outage is predominantly affected by the fading parameters of the desired user, rather than by the fading parameters of the interferers (Fig. 3). Figure 3 also shows the outage probability as a function of normalized average SIR for different fading and shadowing severity. In this figure the case of uncorrelated diversity system is observed. It is interesting to note here that shadowing k_c parameter of the interfering signal acts inversely. When parameter k_c increases the outage probability also increases, which means degradation in performance gain.

5 CONCLUSION

New expressions for PDF and CDF of SIR at the output of SSC receiver were derived. Major contribution of this paper is that analysis has been carried out for Generalized-K (K_G) fading model, which as general model includes

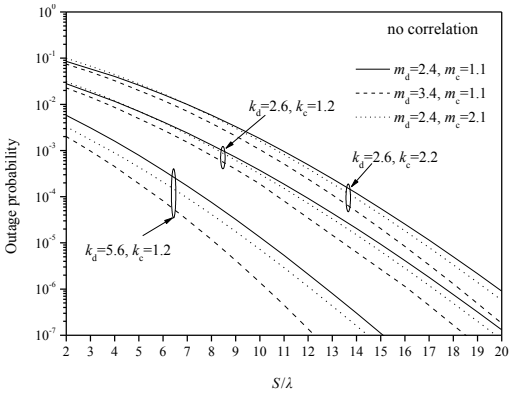

Fig. 3. Outage probability of uncorrelated system for different values of shaping parameters

in itself other important composite fading/shadowing models. Capitalizing on obtained expressions, important wireless transmission performance measure, OP was efficiently evaluated. The effects of various parameters, such as the fading and shadowing severity parameters and level of correlation of desired signal and interference to the system's performance were also examined. By taking into account these results, optimal values of link parameters could be chosen in the designing process of wireless communication system, for wide range of propagation environments.

APPENDIX A

The desired signal envelope and interfering one are both K_G random variables with the PDFs, respectively [8, eq. (1)]:

$$p_R(R) = \frac{4}{\Gamma(m_d)\Gamma(k_d)} \left(\frac{m_d}{\Omega_d}\right)^{\frac{m_d+k_d}{2}} R^{m_d+k_d-1} \cdot K_{k_d-m_d}\left(2R\sqrt{\frac{m_d}{\Omega_d}}\right), \tag{12}$$

$$p_r(r) = \frac{4}{\Gamma(m_c)\Gamma(k_c)} \left(\frac{m_c}{\Omega_c}\right)^{\frac{m_c+k_c}{2}} R^{m_c+k_c-1} \cdot K_{k_c-m_c}\left(2r\sqrt{\frac{m_c}{\Omega_c}}\right). \tag{13}$$

The PDF of input instantaneous SIR is given by [17]:

$$p_z(z) = \frac{1}{2\sqrt{(z)}} \int_0^\infty r p_R(r\sqrt{z}) p_r(r) \mathrm{d}r. \tag{14}$$

Substituting (12) and (13) in (14); representing $K_v(.)$ by Meijer G function as:

$$K_v(x) = \frac{1}{2} G_{0,2}^{2,0}\left(\begin{matrix} - \\ \frac{v}{2}, -\frac{v}{2} \end{matrix} \middle| \frac{x^2}{4} \right),$$

[18, eq. (03.04.26.0006.01)], and making change of variables $t = r^2 m_c/\Omega_c$ and $\mathrm{d}t = 2rm_c\mathrm{d}r/\Omega_c$ in integral, we get:

$$p_z(z) = \left(\frac{m_d}{m_c S}\right)^{(m_d+k_d)/2} \frac{z^{(m_d+k_d)/2-1}}{\Gamma(m_d)\Gamma(k_d)\Gamma(m_c)\Gamma(k_c)} \cdot \int_0^\infty t^{(m_d+k_d+m_c+k_c)/2-1} \times G_{0,2}^{2,0}\left[t \,\middle|\, \begin{matrix} - \\ \frac{k_c-m_c}{2}, -\frac{k_c-m_c}{2} \end{matrix}\right] \times G_{0,2}^{2,0}\left[\frac{m_d t}{m_c S} \,\middle|\, \begin{matrix} - \\ \frac{k_d-m_d}{2}, -\frac{k_d-m_d}{2} \end{matrix}\right] \mathrm{d}t. \quad (15)$$

Integral in (15) can be solved in closed form (3), using [18, eq. (07.34.21.0011.01)]. The CDF of input instantaneous SIR is given by [17]:

$$F_z(z) = \int_0^z p_z(u)\mathrm{d}u. \quad (16)$$

This integral can be solved, formula (4), using [16, eq. (26)].

APPENDIX B

Assuming [9, eq. (4)], the joint PDFs for both desired and interfering signal envelopes can be respectively expressed as:

$$p_{R_1R_2}(R_1,R_2) = \frac{16}{\Gamma(m_d)\Gamma(k_d)} \sum_{a,b=0}^{\infty} \frac{m_d^{\varepsilon_d}\rho_{nd}^a\rho_{gd}^b}{\Gamma(m_d+a)\Gamma(k_d+b)} \times \frac{\prod_{l=1}^{2}\left(\frac{R_l}{\sqrt{\Omega_l}}\right)^{\varepsilon_d} K_\psi\left(2R_l\sqrt{\frac{m_d}{(1-\rho_{nd})(1-\rho_{gd})\Omega_l}}\right)}{a!b!(1-\rho_{nd})^{k_d+a+b}(1-\rho_{gd})^{m_d+a+b}R_1R_2} \quad (17)$$

and

$$p_{r_1r_2}(r_1,r_2) = \frac{16}{\Gamma(m_c)\Gamma(k_c)} \sum_{c,d=0}^{\infty} \frac{m_c^{\varepsilon_c}\rho_{nc}^c\rho_{gc}^d}{\Gamma(m_c+c)\Gamma(k_c+d)} \times \frac{\prod_{l=1}^{2}\left(\frac{r_l}{\sqrt{\Omega_l}}\right)^{\varepsilon_c} K_\psi\left(2r_l\sqrt{\frac{m_c}{(1-\rho_{nc})(1-\rho_{gc})\Omega_l}}\right)}{c!d!(1-\rho_{nc})^{k_c+c+d}(1-\rho_{gc})^{m_c+c+d}r_1r_2}. \quad (18)$$

The joint PDF of the instantaneous SIRs at the two input branches of SSC, is given by [17]:

$$p_{z_1z_2}(z_1z_2) = \frac{1}{4\sqrt{z_1z_2}} \int_0^\infty\int_0^\infty p_{R_1R_2}(r_1\sqrt{z_1}, r_2\sqrt{z_2}) \cdot p_{r_1r_2}(r_1,r_2) r_1r_2\mathrm{d}r_1\mathrm{d}r_2. \quad (19)$$

Substituting (17) and (18) in (19), this double-fold integral is solved in the form of infinite series (5), using the same change of variables and the same equations as in solving integral in (14).

ACKNOWLEDGMENT

This work has been funded by the Serbian Ministry of Science under the projects TR32023 and III 044006.

REFERENCES

[1] M. K. Simon and M. S. Alouni, "Digital Communication over Fading Channels, " New York, StateNY: John Wiley & Sons Inc., 2nd ed., 2004.

[2] A. A. Abu-Dayya and N. C. Beaulieu, "Micro- and macrodiversity NCFSK (DPSK) on shadowed Nakagami-fading channels," *IEEE Trans. Comm.*, vol. 42, no. 9, pp. 2693-2702, Sept. 1994.

[3] M. J. Ho and G. L. Stuber, "Co-channel interference of microcellular systems on shadowed Nakagami fading channels," in *Proc. IEEE Veh. Technol. Conf. (VTC93)*, pp. 568-571, May 1993.

[4] A. Abdi and M. Kaveh, "On the utility of the gamma PDF modeling shadow fading (slow fading)," in *Proc. IEEE 49th VTC*, vol. 3, May 16-20, 1999, pp. 2308-2312.

[5] A. Laourine, M. S. Alouni, S. Affes and A. Stephenne, "On the performance analysis of composite multipath/shadowing channels using the *G*-distribution," in *Proc. IEEE ICC 2008*, pp. 1333-1338, Beijing, China, May 2008.

[6] A. Abdi and M. Kaveh, "*K* distribution: An appropriate substitute for Rayleigh-lognormal distribution in fading-shadowing wireless channels" *Electron. Lett.,* vol. 34, pp. 851-852, 1998.

[7] P. S. Bithas, N. C. Sagias, P. T. Mathiopoulos, G. K. Karagiannidis, A. A. Rontogiannis, "On the performance analysis of digital communications over Generalized-*K* fading channels," *IEEE Comm. Lett.*, vol. 5, no. 10, pp. 353-355, 2006.

[8] P. S. Bithas, P. T. Mathiopoulos and S. A. Kotsopoulos, "Diversity reception over Generalized-*K* (K_G) fading channels," *IEEE Trans. Comm.*, vol. 6, no. 12, pp. 4238-4243, 2007.

[9] P. S. Bithas, N. C. Sagias and P. T. Mathiopoulos, "The bivariate generalized-*K* (K_G) distribution and its application to diversity receivers," *IEEE Trans. Comm.*, vol. 57, no. 9, pp. 2655-2662, Sept. 2009.

[10] I. Trigui, A. Laourine, S. Affes and A. Stephenne, "Performance analysis of mobile radio systems over composite fading/shadowing channels with co-located interference," *IEEE Trans. Wireless Comm.*, vol. 8, no. 7, pp. 3448-3453, 2009.

[11] I. M. Kostić, "Analytical approach to performance analysis for channel subject to shadowing and fading," *IEE Proc.*, vol. 152, no. 6, pp. 821-827, Dec. 2005.

[12] S. Panić, M. Stefanović, A. Mosić, "Performance analysis of selection combining diversity receiver over α-μ fading channels in the presence of CCI", IET Communications, Volume 3, Issue 11, pp. 1769-1777, November 2009.

[13] A. A. Abu-Dayya and N. C. Beaulieu, "Outage probabilities of diversity cellular systems with cochannel interference in Nakagami fading," *IEEE Trans. on Vehicular Technology*, vol. 41, no. 4, pp. 343-355, Nov. 1992.

[14] I. S. Gradshteyn and I. M. Ryzhik, *Tables of Integrals, Series, and products*, 5th ed. New York: Academic Press, 1994.

[15] P. S. Bithas and P. T. Mathioppulos, "Performance analysis of SSC diversity receivers over correlated Ricean fading satellite channels," *EURASIP J. Wirel. Comm. and Networking*, vol. 2007, ID 25361, pp.1-9, 2007.

[16] V. S. Adamchik and O. I. Marichev, "The algorithm for calculating integrals of hypergeometric type functions and its realization in reduce system," in *Proc. Int. Conf. on Symbolic and Algebraic Computation,* Tokyo, Japan, 1990, pp. 212-224.

[17] C. W. Helstrom, *Probability and Stohastic Processes for Engineer*s, 2nd ed. New York: MakMillian, 1991.

[18] The Wolfram Functions Site, 2008. [Online] Available: http:/functions.wolfram.com

[19] P. Shankar, "Outage analysis in wireless channels with multiple interferers subject to shadowing and fading using a compound pdf model", *Int. Journal of Electronics and Communications (AEUE)*, vol. 61, no. 4, pp. 255-261., April 2007.

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Received: 2012-01-19
Accepted: 2015-06-19