INFOTEH-JAHORINA Vol. 12, March 2013.

Performance Analysis of Wireless Communication System over α-η-μ Fading Channels in the Presence of CCI

Stefan R. Panić
Faculty of Natural Science and Mathematics
University of Pristina
Kosovska Mitrovica, Republic of Serbia
stefanpnc@yahoo.com

Dejan Jakšić
Faculty of Electrical Enginnering
University of Niš
Niš, Republic of Serbia
dejan.jaksic@etv.rs

Siniša Ninković
Radio TV Republika Srpska
Bosnia & Herzegovina
sinisa.ninkovic@rtrs.tv

Srđan Jovković / Borivoje Milošević
High Technical College
Niš, Republic of Serbia
srbajovkovic@gmail.com /
borivojemilosevic@yahoo.com

Abstract—**In this paper performance analysis of wireless communication over α-η-μ fading channels will be discussed. Analysis will be carried out for the case when communication is subjected to the influence of co-channel interference (CCI). Infinite series expressions will be derived for the probability density function (PDF) and cumulative distribution function (CDF) of the received signal-to-interference ratio (SIR). Outage probability (OP) has been obtained for this case, in the function of various values of system parameters, and also for the case when selection diversity (SC) is present at the reception. Capitalizing on obtained closed-form expressions, average bit error probability (ABER) has been efficiently evaluated, graphically presented and discussed in the function of system parameters.**

Keywords - α-η-μ distribution; Co-channel interference; Signal-to-interference ratio; Selection Combining; Average Bit Error probability.

I. INTRODUCTION

Every wireless communication system designing must take into account three major channel propagation impairments: short-time fading (multipath propagation), long-term fading (shadowing) and the corruptive effect of co-channel interference [1]. The nonlinear properties of propagation medium has been considered extensively recently. Namely, various short-time fading distributions like Nakgami-*m*, Ricean and Rayleigh assume a resultant homogenous diffuse scattering field, from randomly distributed scatters. However, surfaces are often spatially correlated and they characterize non-linear environment. Exploring the fact that resulting envelope would be a nonlinear function of the sum of multipath components, novel general α-η-μ distribution for short-time fading model was recently presented. Probability density function (PDF) is presented in the form of three parameters α, μ and η, which are related to the nonlinearity of the environment, the number of multipath clusters in the environment and the scattered wave power ratio between the in-phase and quadrature components of each cluster of multipath, respectively [2].

Since a general fading distribution, α-η-μ model includes as special cases other short-time fading distributions, like Rayleigh, Nakagami-*q* (Hoyt), Nakagami-*m*, η-μ, Weibull and One-Side Gaussian distribution. By setting parameter α to value α = 2, it reduces to η-μ distribution. Further, from the η-μ fading distribution Nakagami-*m* model could be obtained in two cases: first for η→1, with parameter *m* being expressed as *m* = μ/2, and second for η→0, with parameter *m* being expressed as *m* = μ. It is well-known that η-μ distribution reduces to Hoyt distribution, for the case when μ = 1, with parameter *b* defined as *b* = (1- η)/(1+ η). By equating the in-phase and quadrature components variances, namely by setting η = 1, Rayleigh distribution is derived from Hoyt. Also Weibull distribution could be obtained as special case of α-η-μ model by setting corresponding values to the parameters μ = 1 and η = 1. Major contribution of this analysis is then the above-mentioned generality.

Further, analytical framework for performance analysis of wireless communication system subjected to co-channel interference (CCI) over α-η-μ fading channels will be presented in this paper. Signal-to-interference (SIR) based analysis will be provided, and closed form expressions will be provided for received SIR PDF and CDF (cumulative distribution function). From this statistics, outage probability

(OP) values will be obtained in the function of system parameters. Even OP improvement will be observed trough a prism of space diversity reception techniques appliance, particularly selection combining (SC) reception appliance.

II. TRANSMISSION SUBJECTED TO CO-CHANNEL INTERFERENCE

In modern wireless communication systems, a tendency to preserve the available spectrum is present. Preserving of available spectrum could be obtained by reusing allocated frequency channels in areas, which are geographically close to each other as possible. However, distance for reusing channels is limited by level of CCI. CCI is defined as the interfering signal, that has the same carrier frequency as the desired information signal. Namely, two or more channels signals from different locations, but operating at the same carrier frequency, due to frequency reuse interfere. In this section we will analyze how CCI as a general distortion affects well-accepted criteria of wireless systems performances in the function of instantaneous and average signal-to-interference ratio's (SIR). SIR based performance analysis is very effective performance criterion, since SIR can be measured in real time both in base and mobile stations An interference-limited system will be discussed, so the effect of noise would be ignored.

Desired information signal with a α-η-μ distributed random amplitude process can be presented by [2]:

$$p_R(R)=\frac{\alpha(\eta_d-1)^{\frac{1}{2}-\mu_d}(\eta_d+1)^{\frac{1}{2}+\mu_d}\sqrt{\pi}\mu_d^{\frac{1}{2}+\mu_d}R^{\alpha\left(\frac{1}{2}+\mu_d\right)-1}}{\sqrt{\eta_d}\Gamma(\mu_d)\Omega_d^{\frac{1}{2}+\mu_d}} \times\exp\left(-\frac{(1+\eta_d)^2}{2\eta_d}\frac{R^\alpha}{\Omega_d}\right)I_{\mu_d-1/2}\left(\frac{(\eta_d^2-1)}{2\eta_d}\frac{R^\alpha}{\Omega_d}\right) \tag{1}$$

with Ω_d = E [R^2], denoting the desired signal average power, while I_n (x) is the n-th order modified Bessel function of the first kind Gamma function [6, eq. (8.406)].

In a similar manner, resultant interfering signal can be presented as:

$$p_r(r)=\frac{\alpha(\eta_c-1)^{\frac{1}{2}-\mu_c}(\eta_c+1)^{\frac{1}{2}+\mu_c}\sqrt{\pi}\mu_c^{\frac{1}{2}+\mu_c}r^{\alpha\left(\frac{1}{2}+\mu_c\right)-1}}{\sqrt{\eta_d}\Gamma(\mu_d)\Omega_d^{\frac{1}{2}+\mu_d}} \times\exp\left(-\frac{(1+\eta_c)^2}{2\eta_c}\frac{r^\alpha}{\Omega_c}\right)I_{\mu_c-1/2}\left(\frac{(\eta_c^2-1)}{2\eta_c}\frac{r^\alpha}{\Omega_c}\right) \tag{2}$$

with Ω_c = E [r^2], denoting the CCI signal average power, and parameters α, μ_c and η_c explained in [2]. If the instantaneous SIR, λ, is defined as $\lambda=R^2/r^2$, while average SIR, S, defined as $S=\Omega_d/\Omega_c$, then by using the relation [3]:

$$p_\lambda(\lambda)=\frac{1}{2\sqrt{\lambda}}\int_0^\infty p_R(r\sqrt{\lambda})\,p_r(r)\,dr \tag{3}$$

after performing similar mathematical transformations as ones already given in the literature, the PDF of instantaneous SIR can be presented in the form:

$$p_\lambda(\lambda)=\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\frac{\alpha\pi(\eta_d-1)^{2j}(\eta_d+1)^{2j+2\mu_d}}{2^{2j+2k-1}} \times\frac{(\eta_c-1)^{2k}(\eta_c+1)^{2k+2\mu_c}\mu_c^{2k+2\mu_c}\mu_d^{2j+2\mu_d}}{\Gamma(\mu_d)\Gamma(\mu_c)} \times\frac{\Gamma(2\mu_d+2\mu_c+2k+2j)}{\Gamma(\mu_d+j+1/2)\Gamma(\mu_c+k+1/2)\,j!k!} \times\frac{\lambda^{\frac{\alpha(2j+2\mu_d)}{2}-1}S^{2k+2\mu_c}\eta_d^{2k+2\mu_c+\mu_d}\eta_c^{2j+2\mu_d+\mu_c}}{\left(\mu_d(1+\eta_d)^2\eta_c\lambda^{\frac{\alpha}{2}}+\mu_c(1+\eta_c)^2\eta_d S\right)^{2\mu_d+2\mu_c+2k+2j}} \tag{4}$$

with $\Gamma(a)$ denoting the well-known Gamma function [6, eq. (8.310/1)].

The double infinity sum in (4) converge rapidly, since only about 20-30 terms should be summed in order to achieve accuracy at 5th significant digit for various values of corresponding system parameters. PDF of instantaneous SIR for various values of system parameters is presented at Fig. 1.

Capitalizing on (4), and by using the same mathematical transformations as in [4,5], closed-form expression for the cumulative distribution function (CDF) of the instantaneous SIR can be presented as:

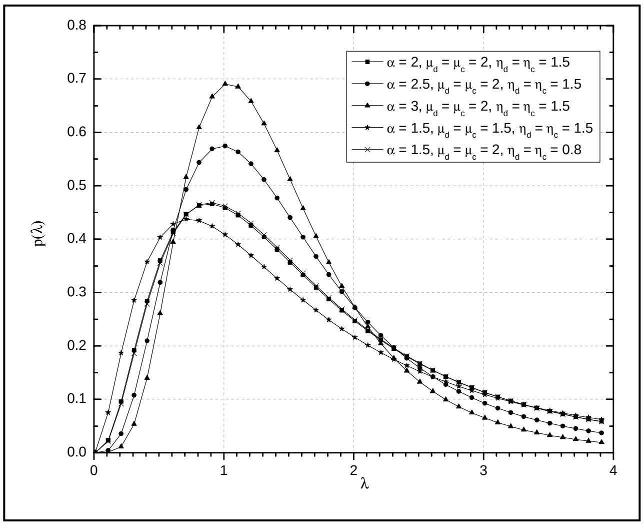

Figure 1. PDF of instantaneous SIR for various values of system parameters

$$F_{\lambda}(\lambda)=\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\frac{\pi(\eta_d-1)^{2j}(\eta_c-1)^{2k}}{2^{2j+2k-2}\Gamma(\mu_d)\Gamma(\mu_c)\Gamma(\mu_d+j+1/2)}$$

$$\times\frac{\eta_d^{\mu_d}\eta_c^{\mu_c}\Gamma(2\mu_d+2\mu_c+2k+2j)}{(\eta_d+1)^{2j+2\mu_d}(\eta_c+1)^{2k+2\mu_c}\Gamma(\mu_c+k+1/2)j!k!}$$

$$\times B\left(2j+2\mu_d,2k+2\mu_c,\frac{\lambda^{\frac{\alpha(2j+2\mu_d)}{2}-1}S^{2k+2\mu_c}\eta_d^{2k+2\mu_c+\mu_d}\eta_c^{2j+2\mu_d+\mu_c}}{\left(\mu_d(1+\eta_d)^2\eta_c\lambda^{\frac{\alpha}{2}}+\mu_c(1+\eta_c)^2\eta_d S\right)^{2\mu_d+2\mu_c+2k+2j}}\right) \tag{5}$$

with B(*a*,*b*,*z*) denoting the well-known incomplete Beta function [6, eq. (8.391)].

III. SYSTEM PERFORMANCES AND NUMERICAL RESULTS

In this section we will discuss some standard wireless transmission performance measures for observed scenarios. Considering interference limited system, outage probability (OP) has been efficiently evaluated for various values of transmission parameters and graphically presented at Fig.4. Namely, OP is standard measure often used for controlling the CCI level, in order to meet the QoS, and grade of service (GoS) demands. If the environment is interference limited, OP is defined as the probability, *y* that the output SIR of used combiner will fall below defined protection ratio, which depends on applied modulation technique and expected QoS [7]:

$$P_{out}=P_R(\xi<\gamma)=\int_0^{\gamma}p_{\xi}(t)dt=F_{\xi}(\gamma) \tag{6}$$

As one can see, in Fig.2, the influence of selection combining (SC) technique at the receiver, to the performance improvement, was also observed. various techniques for reducing fading effect and influence of co-channel interference are used. Multi-branch diversity reception is an efficient remedy, based on providing the receiver with multiple faded replicas of the same desired signal [7]. In that way transmission reliability is upgraded without transmission power and bandwidth increase. Simplest diversity reception, that process only one of the diversity branches is SC reception. It is well-known that SC diversity chooses and outputs the branch with the largest instantaneous SIR (or SNR), namely, $\lambda_{out} = \max(\lambda_1, \lambda_2 \ldots \lambda_N)$, with λ_i denoting the instantaneous value of SIR at *i*-th received branch. This means that in this case, for calculating OP we should take into account the CDF of *N*-branch SIR-based SC output determined from [8-9]:

$$F_{\lambda}(\lambda)=F_{\lambda_1}(\lambda)F_{\lambda_2}(\lambda)\cdots F_{\lambda_N}(\lambda)=\prod_{i=1}^{N}F_{\lambda_i}(\lambda); \tag{7}$$

where corresponding CDF's for the uncorrelated input branches are defined with (5).

General conclusion from Fig.2 is that higher OP values are achieved, in the areas where η, μ and α parameters obtain higher values. Performance improvement obtained with the usage of dual-branch SC diversity is visible, since for the same system parameter values, significantly lower OP values are reached. Capitalizing on (4) and (5) other well-known performance criterions could be efficiently evaluated for this scenario.

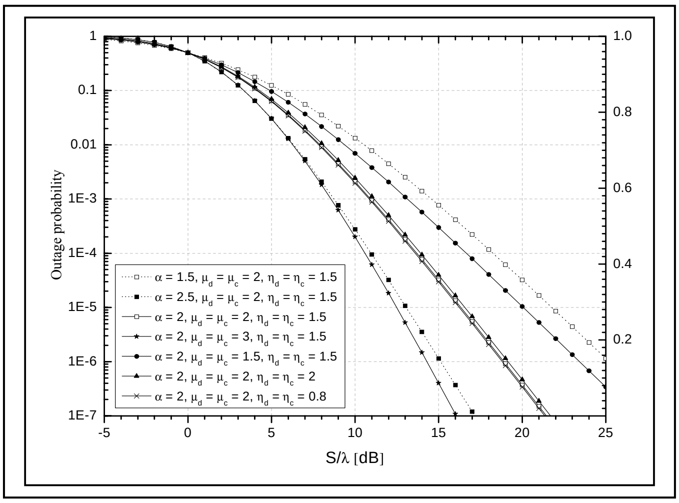

Figure 2. OP for various values of wireless communication parameters in the interference limited system

For the case when wireless communication is subjected to CCI, we will consider another important performance measure, the average bit error probability (ABER). Numerically, ABER values could be obtained by substituting (3) in [10]:

$$P_e=\int_0^{\infty}p_{\xi}(t)\frac{1}{2}\exp(-gt)dt \tag{8}$$

where *g* denotes modulation constant, i.e., *g* = 1 for BDPSK and *g* = 1/2 for NCFSK. In Fig. 3 some results are graphically presented in the function of corresponding parameters. It can be seen from Fig.3 that better performances (lower ABER) values are achieved, where parameters η and μ parameters obtain higher values.

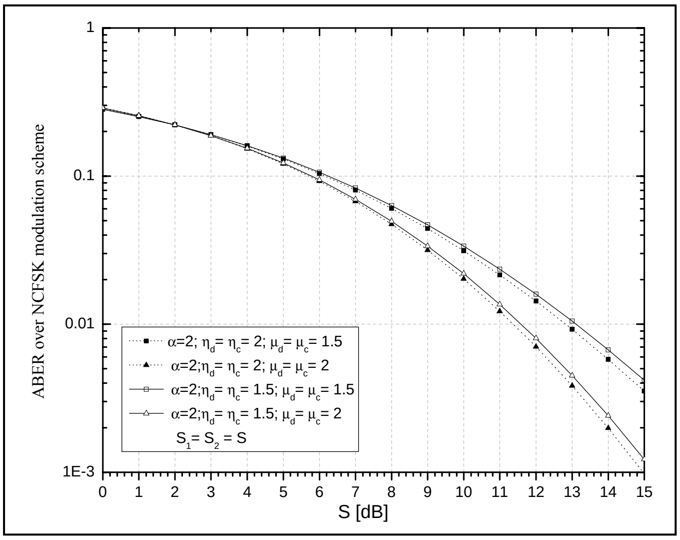

Figure 3. ABER over NCFSK modulation scheme for various values of system parameters

IV. CONCLUSION

This paper has considered wireless communication in general fading environment, which can be reduced to other types of fading environments like Rayleigh, Nakagami-*q* (Hoyt), Nakagami-*m*, η-μ, Weibull. Obtained closed form expressions for PDF and CDF of SIR for the interference-limited system case , allow simple unconstrained analysis, accurate wireless system planning and performance evaluation. Some of the performance measures are evaluated and discussed in the paper.

ACKNOWLEDGMENT

This work has been funded by the Serbian Ministry of Science under the project III 044006. Authors also thank Radio TV Republika Srpska on their financial support.

REFERENCES

[1] W. C. Y. Lee, (2001). Mobile communications engineering. New York, Mc-Graw-Hill.

[2] G. Fraidenraich and M. D. Yacoub, "The α-η-μ and α-κ-μ fading distributions," in Proc. IEEE Ninth International Symposium on Spread Spectrum Techniques and Applications, pp. 16--20, 2006.

[3] Trigui, I. et.al. (2009). "Performance Analysis of Mobile Radio Systems over Composite Fading/Shadowing Channels with Co-located Interferences", IEEE Transactions on Wireless Communications, vol. 8, no. 7 pp. 3449-3453.

[4] M. Stefanović, et al, "Performance analysis of system with L-branch selection combining over correlated Weibull fading channels in the presence of cochannel interference", *International Journal of Communication Systems*, vol. 23, no. 2, pp. 139-150, Feb. 2010,

[5] M. Matovic, S. Panic, Z. Popovic, M. Stefanovic, J. Zivanic, M. Peric, "Eta-Mu modeled multipath propagation of electromagnetic waves'', TTEM, 2012 vol. 7, no. 2, pp. 456-461.

[6] I. S. Gradshteyn and I. M. Ryzhik, Table of Integrals, Series, and Products, 6th ed. New York: Academic Press, 2000.

[7] M. Stefanović, et al. (2007). Performance analysis of system with selection combining over correlated Weibull fading channels in the presence of cochannel interference. Int J Electron Commun (AEU). 62 , pp 695-700.

[8] N. Sekulović, M. Stefanović, D. Drača, A. Panajotović, D. Stefanović "Performance Analysis of Microcellular Mobile Radio Systems with Selection Combining in the Presence of Arbitrary Number of Cochannel Interferences", *Advances in Electrical and Computer Engineering*, vol. 10, no. 4, pp. 3-8, Dec. 2010.

[9] D. Aleksić, N. Sekulović, M. Stefanović, "Outage Probability of System with Selection Combining over Correlated Weibull Fading Channels in the Presence of Rayleigh Cochannel Interference", *Electronics and Electrical Engineering*, vol. 90, no.2, pp. 7-10, 2009.

[10] A. Panajotović, M. Stefanović, D. Drača, "Cochannel Interference Effect on BEP Performance of SSC Receiver in Correlated Rician Fading", *Journal of the Franklin Institute*, published by Elsevier GmbH, Amsterdan, Netherlands vol. 347, no. 7, pp. 1242-1252, 2010

SAŽETAK

U ovom radu je izložena analiza performansi bežičnog komunikacionog sistema u prisustvu α-η-μ fedinga. Analiza je izvedena za slučaj kada je prenos izložen uticaju ko-kanalne interference (CCI). Izrazi u zatvorenom obliku su izvedeni za funkciju gustine verovatnoće (PDF) i kumulativnu funkciju raspodele (CDF) odnosa signal/interferencija (SIR) na prijemu. Verovatnoća otkaza sistema (OP) je za dati slučaj analizirana u zavisnosti od različitih vrednosti parametara sistema, kao i mogućnost njenog smanjena upotrebom tehnike prijama pomoću prostornog diverzitija (SC). Na osnovu dobijenih izraza u zatvorenom obliku, vrednosti sednje verovatnoće greške po bitu (ABER) su određene, grafički prikazane i ramatrane u funkciji parametara sistema.

ANALIZA PERFORMANSI BEŽIČNOG KOMUNIKACIONOG SISTEMA U PRISUSTVU α-η-μ FEDINGA I KO-KANALNE INTERFERENCIJE

Stefan R. Panić, Dejan Jakšić, Siniša Ninković, Srđan Jovković, Borivoje Milošević