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SYSTEM PERFORMANCES IN THE PRESENCE OF ONE FAST WEIBULL AND ONE SLOW GAMMA FADING

ODREĐIVANJE PERFORMANSI SISTEMA KORIŠĆENJEM VEJBULOVE RASPODELE I SPOROG GAMA FEDINGA

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Abstract:
This paper decribes the model of forming equivalent envelope of a signal at the entrance of the wireless digital telecommunication system in the presence of one fast Weibull and one slow Gamma fading. Probability density function (PDF) of random variable at the reception side has been determined for the described model. Dependence of the probability density function (PDF) of the parameters of fading (fading severity) and corresponding components power is analytically and graphically described. The influence of fading parameters on statistical characteristics of the received signal and quality of the signal detection in the entire communication system has been graphically presented.

Key words:
fading figure, Weibull fading, Gamma fading, probability density function (PDF), outage probability.

Apstrakt:
Ovaj rad prikazuje model formiranja ekvivalentnog omotača signala na ulazu u prijemnik bezičnog digitalnog telekomunikacionog sistema, kada je istovremeno prisutan parametar Vejbulove raspodele i spor gama feding. Za dati model utvrđuje se funkcija gustine verovatnoće (PDF) slučajne promenljive na strani prijemnika. Zavisnost funkcije gustine verovatnoće feding parametara i snage odgovarajućih komponenata prikazana je analitički i grafički. U radu je dat grafički prikaz uticaja parametara fedinga na statističke karakteristike primljenog signala i kvalitet detekcije signala u celokupnom sistemu komunikacije.

Key words:
dubina fedinga, Vejbulova raspodela, gama feding, funkcija gustine verovatnoće (PDF), verovatnoća prekida.

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1. INTRODUCTION

In wireless telecommunication systems, the signal is exposed to so many different environmental influences in which telecommunication channel is formed. The imperfections of electronic components, atmospheric conditions, electric discharge and other electromagnetic waves, as well as ground configuration influence the signal by degrading it. Every change in signal quality is treated as disturbance manifested on reception side. Disturbance might be noise, interference and fading.

Besides noise, fading has the biggest influence on radio signal. Fading occurs due to several reasons. In most cases, it is the consequence of different conditions in radio channel. The ideal case related to signal transfer is when there is a straight line between the transmitter and the receiver (Line Of Sight, LOS). However, that is not often the case, so signal on reception depends on signals arriving using different paths with different attenuation, phase shift and delays. By superposition of these radio signals at the reception, a signal is received with amplitude and phase changing in time. We say for such signal that it is influenced by fading (Simon et al, 2000; Goldsmith, 2005).

Since the conditions in channel significantly change during symbol duration, this fading is called fast fading (multipath, short-time fading) (Parsons, 1992; Stuber, 2000). On the other hand, in some cases receiver becomes interrupted, and signal power becomes attenuating or completely disappears at the reception. We say for such signal that it is influenced by shadowing effect (long-term fading). Since the conditions in channel occur more slowly, this fading is also called long-term fading (Simon et al, 2000). Hence, the signal at the entrance into the receiver is influenced by fast and slow fading, which change its amplitude and/or power.

Due to the relevance of fading influence on radio signal, this document will consider performances of wireless digital telecommunication system in the presence of fading. For the purpose of analyzing transmission characteristics of telecommunication systems, different distributions are used by which fading is modelled in different propagation environments.

For modelling of fast fading in most of the cases, Rayleigh, Rice, Nakagami-m and Weibull distribution is used, while for modelling of slow fading, Gamma distribution is used and it is significantly simpler from Lognormal distribution (Youssef et

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al, 1996; Panić et al, 2013). Rayleigh model is used for describing propagation conditions when there is no LOS. Rice or Rician model is used for description of propagation conditions when there is a dominant signal on LOS. Nakagami-m model represents the general channel model with fading that can be reduced to other models for different Nakagami distribution parameters (Nakagami, 1960). Weibull model is used to describe propagation conditions in cases when Rayleigh distribution is inadequate. It is empirically established that Weibull model gives extraordinary results in 2GHz system analysis.

Chapter II explains statistical characteristics of signal at the entrance of the wireless digital telecommunication system when one fast and one slow fading are simultaneously present. Fast fading will be modelled by Weibull distribution, while slow fading will be modelled by Gamma distribution. In such a way, general channel model with fading is obtained. Display of numeric results obtained for different fading severity and different ratio of signal power (Ω) at the entrance is given in chapter III. The analysis of obtained results and concluding considerations are given in chapter IV. The final part of the paper gives a preview of literature used.

2. RESULTS AND DISCUSSION

A case is considered when at the entrance into receiver of wireless communication system there are one fast and one slow fading. Fast fading influences the signal envelope, while slow fading influences the useful signal power. Indoor point to point model WiFi channel width 20MHz on 2.4GHz has been examined.

In that case conditional probability density of equivalent amplitude is equal to conditional probability density of fast Weibull fading:

$$p_x(x/y)=\frac{\alpha}{y}x^{\alpha-1}e^{-\frac{x^2}{y}} \quad ,x\geq o \tag{1}$$

The average square value of equivalent envelope, i.e. the power of equivalent envelope is a variable and it has probability density of slow Gamma fading.

$$p_y(y)=\frac{1}{\Gamma(c)}\left(\frac{c}{\Omega}\right)^c y^{c-1}e^{-\frac{c}{\Omega}y} \quad ,y\geq o \tag{2}$$

By transformations of probability densities and by appropriate averaging, we get PDF of equivalent envelope.

$$p_x(x)=\int_0^\infty dy\; p_x(x/y)\,p_y(y) \;=$$

$$=\int_0^\infty dy\;\frac{\alpha}{y}\,x^{\alpha-1}\,e^{-\frac{x^2}{y}}\;\frac{1}{\Gamma(c)}\left(\frac{c}{\Omega}\right)^c y^{c-1}\,e^{-\frac{c}{\Omega}y}\;=$$

$$=\;\alpha\,\frac{1}{\Gamma(c)}\left(\frac{c}{\Omega}\right)^c\int_0^\infty dy\;x^{\alpha-1}\,e^{-\frac{x^2}{y}}\;y^{c-1-1}\,e^{-\frac{c}{\Omega}y}\;=$$

$$=\;\alpha\,\frac{1}{\Gamma(c)}\left(\frac{c}{\Omega}\right)^c\int_0^\infty dy\;x^{\alpha-1}\;y^{c-2}\,e^{-\frac{c}{\Omega}y}\sum_{i=0}^{\infty}\frac{1}{i!}\,(-1)^i\;\frac{x^{2i}}{y^i}=$$

$$=\;\alpha\,\frac{1}{\Gamma(c)}\left(\frac{c}{\Omega}\right)^c\sum_{i=0}^{\infty}\frac{1}{i!}\,(-1)^i\;x^{2i+\alpha-1}\int_0^\infty dy\;\;y^{c-i-2}\,e^{-\frac{c}{\Omega}y}\;=$$

$$=\;\alpha\,\frac{1}{\Gamma(c)}\left(\frac{c}{\Omega}\right)^c\sum_{i=0}^{\infty}\frac{1}{i!}\,(-1)^i\;x^{2i+\alpha-1}\left(\frac{\Omega}{c}\right)^{c-i-1}\Gamma(c-i-1)$$

$$p_x(x)=\;\alpha\,\frac{1}{\Gamma(c)}\left(\frac{c}{\Omega}\right)^c\sum_{i=0}^{\infty}\frac{1}{i!}\,(-1)^i\;x^{2i+\alpha-1}\left(\frac{\Omega}{c}\right)^{c-i-1}\Gamma(c-i-1) \tag{3}$$

where Γ(...) - Gama function (Gradshteyn et al, 1994), α - Weibull fading severity, c - Gamma fading severity, and Ω average power of random process.

By using this PDF, it is possible to calculate outage probability (Po) and channel capacity (C).

Outage probability (OP), standard performance measure that defines the probability that received signal falls under QoS predetermined threshold can be determined according to (Panić et al, 2011; Spalević et al, 2010):

$$P_0=\int_0^{x_0}dx\;p_x(x)\;=\;F_x(x_0) \tag{4}$$

Channel capacity, which defines maximal rate of information at which reliably transmission could be performed, can be determined according to (Stefanović et al, 2012):

$$C=B\int_0^\infty dx\;(ln(1+x))\;p_x(x) \tag{5}$$

where B is bandwith expressed in Hz.

Influence of parameters of Weibull and Gamma fading, fading severity and signal power on PDF of random variable x at the entrance into receiver is displayed graphically on Figure 1 - Figure 3. Numeric results are obtained on basis of derived expression (3).

Figure 1 shows the dependency of PDF of resulting envelope x for different Weibull fading severity when Gamma fading severity and signal power are constant.

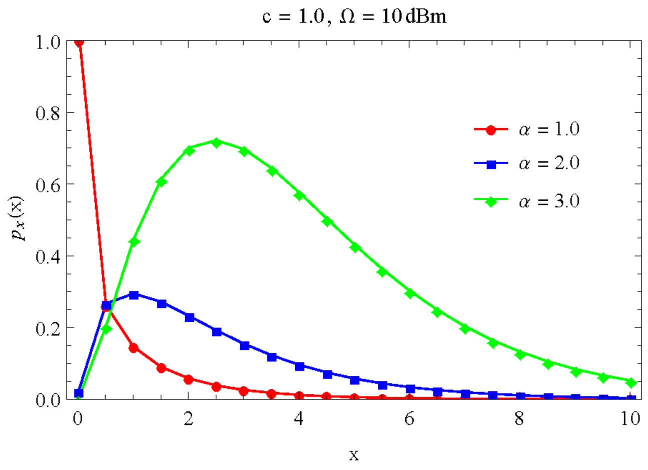

Figure 1. PDF of random variable x at the entrance into receiver for different Weibull fading severity when Gamma fading severity and signal power are constant

Figure 2 shows dependency of PDF of resulting envelope x for different Weibull fading severity when Gamma fading severity and signal power are constant.

Figure 3 shows dependency of PDF of resulting envelope x when signal powers under influence of fadings are variables,

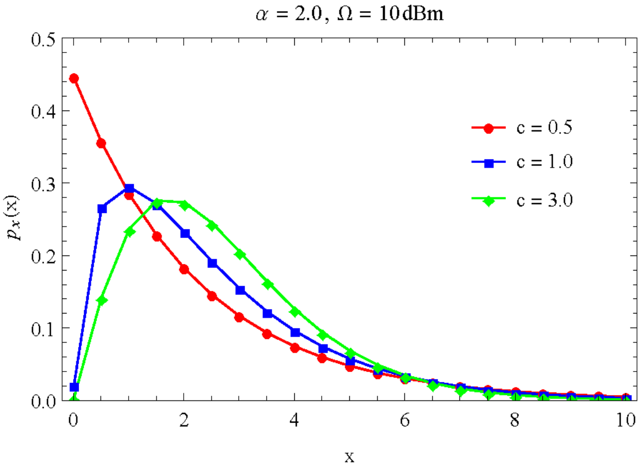

Figure 2. PDF of random variable x at the entrance into receiver for different Gamma fading severity when Weibull fading severity and signal power are constant

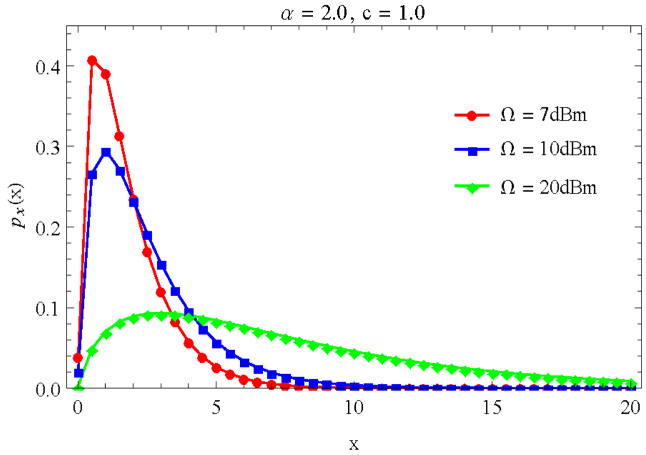

Figure 3. PDF of random variable x at the entrance to receiver for different signal powers when Weibull fading severity and Gamma fading severity are constant

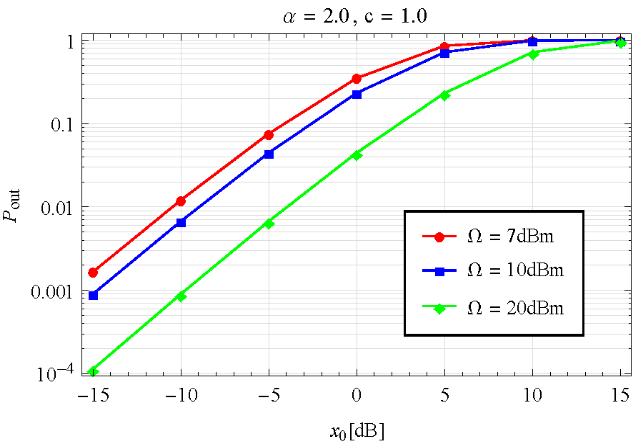

Figure 4. Outage probability depending on threshold for different Gamma fading severity parameter values

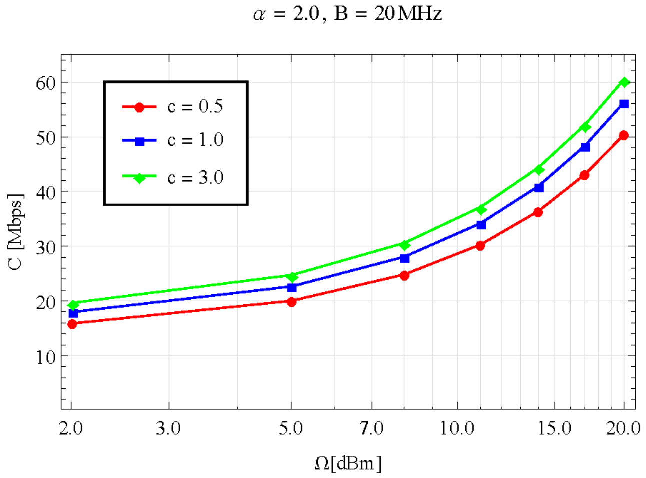

Figure 5. Channel capacity depending on signal power for different Gamma fading severity parameter values

and Weibull fading severity and Gamma fading severity are constant.

Figure 4 shows dependency of OP from threshold for different signal powers when Weibull fading severity and Gamma fading severity are constant. It can be seen that better system performances (lower OP values) could be reached in the area of higher values Ω, i.e. with the increase of signal power, Outage probability (OP) decreases.

Figure 5 shows dependency of channel capacity on signal power for different Gamma fading severity when Weibull fading severity are constant. It shows how channel capacity grows when c parameter values increase. As expected, with the increase of parameter c channel capacity slightly increases due to shadowing declining.

3. SUMMARY

This paper considers for the first time the case when wireless transmission is exposed to the simultaneous influence of fast fading process modeled by Weibull models and one shadowing process modeled with Gamma model. For this case, PDF of resulting envelope process is presented in the closed-form. Furthermore, the standard transmission performance criteria, such as outage probability and channel capacity, have been efficiently evaluated and observed in the function of fading and shadowing parameters.

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