IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 1, Issue 7, February 2013)

Study of Higher Order Statistics in Rayleigh Fading Channel

Nasiba Mandal nasiba_mandal@yahoo.com
Anjana Jain jain.anjana@gmail.com
Shekhar Sharma shekhar.sharma@rediffmail.com

Abstract —**Presented paper is the simulation and analysis of the statistical performances of the Rayleigh fading channel in wireless communication with MATLAB, including the higher order statics of complex envelop of received signal as the Level Crossing Rates and Average Fade Durations.**

Keywords — **Rayleigh Channel, Fading, random process, Level Crossing rate, Average Fade duration.**

I. Introduction

In the context of high-rate mobile communication systems, the received signal is often corrupted by a fading frequency selective channel. In this case, the coefficients of the equivalent discrete-time channel can be considered as highly low-pass time-varying centred Gaussian random variables.

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables.

Random processes associated with fading channels are usually characterized by their probability density function or cumulative distribution function. Second-order statistics of fading channels incorporate information related not only with the scattering environment but with the dynamics of the system. Level crossing rate which provides information about how often the envelope fading crosses a certain threshold and the Average fade duration which is related with the amount of time that the envelope remains below this threshold [1].

In the context of the performance evaluation of wireless communication systems over time-varying fading channels, the LCR has been introduced and used to provide the outage rate and the average outage duration (AOD) of these systems. As such, the LCR has been extensively studied for a variety of diversity combining techniques, over various fading channels in absence or presence of interference [2]. In this paper we are simulating Rayleigh fading channel and computing LCR and AFD by theoretically and practically.

II. Problem Formulation

Rayleigh fading channels are useful models of real-world phenomena in wireless communications. These phenomena include multipath scattering effects, time dispersion, and Doppler shifts that arise from relative motion between the receiver and transmitter. The requirement that there be many scatters present means that Rayleigh fading can be a useful model in heavily built-up city centers where there is no line of sight between the transmitter and receiver and many buildings and other objects attenuate, reflect, refract, and diffract the signal.

The impact of fading on the signal depends on the speed of transmitter and the receiver. If transmitter or receiver or both moving at faster speed the Doppler frequency shift is higher so signal fades on a higher rate. We showed this effect in this paper.

III. Methodology

When signal is passed through the Rayleigh fading environment the spectral broadening is given by jakes spectrum:

$$S(v) = \frac{1}{\pi f_d \sqrt{1 - \left(\frac{v}{f_d}\right)^2}} \tag{1}$$

Where,

v = the frequency shift relative to the carrier frequency.

Rayleigh fading channel can be generated by generating complex Gaussian distributed numbers. And then multiplying this complex signal to this jakes spectrum.

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 1, Issue 7, February 2013)

Now we will discuss the second order statics of this Rayleigh fading signal.

A. Level Crossing Rate

The level crossing rate is a measure of the rapidity of the fading. It quantifies how often the fading crosses some threshold, usually in the positive-going direction. For Rayleigh fading, the level crossing rate is given by:

$$LCR = \sqrt{2\pi} f_d \rho e^{-\rho^2} \tag{2}$$

The ρ is the threshold which is normalized to RMS value of signal.

The LCR of a sampled random process can be expressed in terms of the difference of its CDF and the bivariate CDF of the sampled envelope evaluated at the threshold level u. Note that this approach is general, and valid for arbitrary distributions of the envelope with arbitrary correlation. For a complex Rayleigh fading process its CDF can be given as:

On the basis of this F. Javier, Eduardo, F. Paris, Unai in their paper [3] presented LCR calculation in terms of bivariate CDF using Marcum Q function as:

$$F_r(x) = 1 - e^{-x^2/\sigma_g^2} \tag{3}$$

$$N_r(u) = \frac{e^{-u^2}}{T_s}\left[Q_1(k_\rho u, k_\rho u|\rho|) - Q_1(k_\rho u|\rho|, k_\rho u)\right] \tag{4}$$

B. Average Fade duration

The average fade duration quantifies how long the signal spends below the threshold ρ. For Rayleigh fading, the average fade duration is given as:

$$AFD = \frac{e^{\rho^2} - 1}{\rho f_d \sqrt{2\pi}} \tag{5}$$

In terms of CDF F. Javier, Eduardo, F. Paris, Unai in their paper [3] presented AFD calculation in terms of bivariate CDF using Marcum Q function as:

$$A_r(u) = T_s \frac{e^{u^2} - 1}{Q_1(k_\rho u, k_\rho u|\rho|) - Q_1(k_\rho u|\rho|, k_\rho u)} \tag{6}$$

IV. Simulation and Results

Rayleigh fading channel is constructed using the IFFT simulator method. Very first we generate two random complex signals which are Gaussian distributed. This signals are multiplied with jakes power spectral density as stated in equation 1. The square of two outputs are added together is envelop of Rayleigh faded signal. Below we are showing the impact of the speed of transmitter and receiver over the fading.

Figure below showing the Rayleigh faded signal for Doppler frequency of 10 Hz.

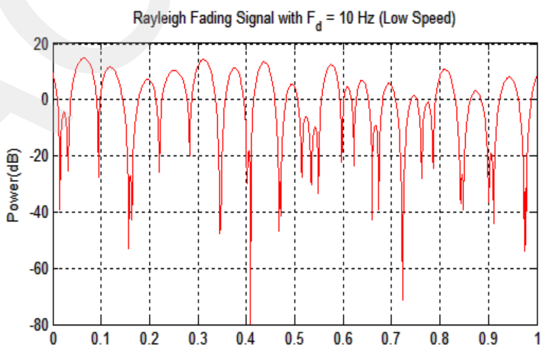

Figure 1: Rayleigh Fading Signal for F_d = 10 Hz

Figure below showing the Rayleigh faded signal for Doppler frequency of 100 Hz.

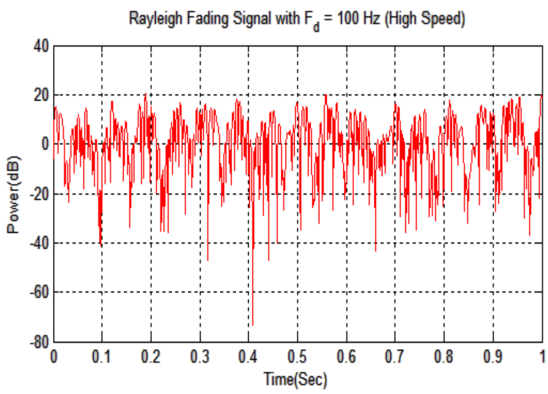

Figure 2: Rayleigh Fading Signal for F_d= 100 Hz

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 1, Issue 7, February 2013)

The figures show the power variation over 1 second of a constant signal after passing through a single-path Rayleigh fading channel with a maximum Doppler shift of 10 Hz and 100 Hz.

For this to scenario we calculated the LCR and AFD theoretically as stated before and practically by analysis full signal. To calculate LCR theoretically we used equation 2 and 4 and to calculate AFD theoretically we used equation 5 and 6.

Table 1: Theoretical and Practical LCR and AFD for F_d = 10 Hz

	LCR	AFD
Theoretical	2.578125	0.003836
Practical	2.481687	0.004009

Table 2: Theoretical and Practical LCR and AFD for F_d = 100 Hz

	LCR	AFD
Theoretical	21.875000	0.000435
Practical	24.816869	0.000401

Table 1 and 2 showing the difference theoretically and practically calculated values LCR and AFD of Rayleigh fading channel for different Doppler frequencies.

From the tables we analyse that value of LCR increases with the increment in Doppler frequency while AFD decreases. With the increment of Doppler frequency the difference between the theoretically and practically calculated values of LCR increases while it decreases for AFD as shown figure 3 and 4. For this we simulated the system for a range of Doppler frequency of 20 to 200 Hz.

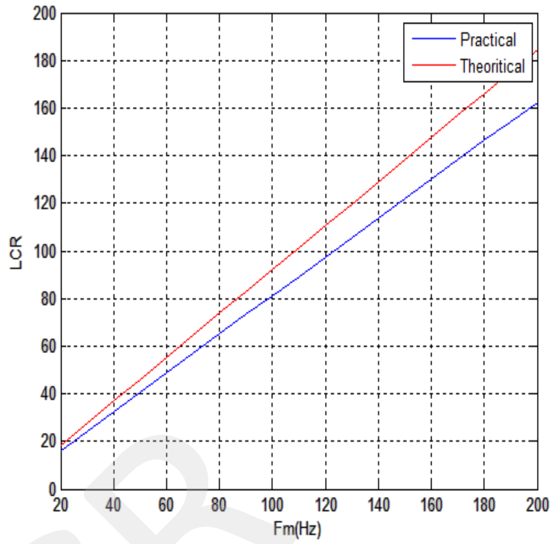

Figure 3: Difference between en the theoretical and practical values of LCR

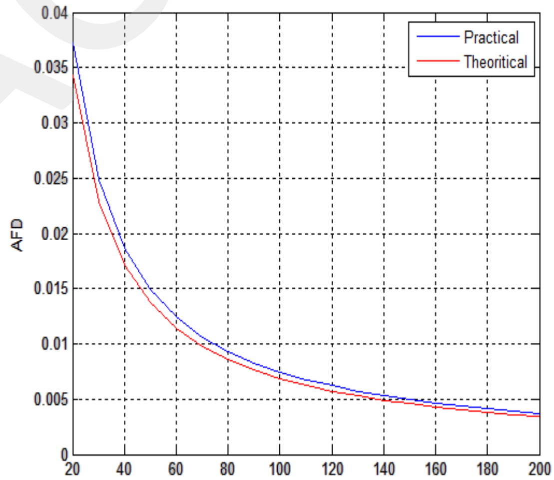

Figure 4: Difference between en the theoretical and practical values of AFD

V. CONCLUSION

In this paper we discussed the higher order statics of Rayleigh fading channel. We have analysis the effect of speed of source and destination of signal over the amount of fading. We simulated the Rayleigh fading channel in MATLAB environment and analysed the LCR and AFD of the received signal. From this study we can conclude that for a random process that the basic advantage of analytical and theoretical expressions is that they enable the derivation of necessary and sufficient conditions but these expressions make the often

IJDACR
ISSN: 2319-4863

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 1, Issue 7, February 2013)

time consuming and inaccurate estimation of the statistics from simulated channel output sequences superfluous.

REFERENCES

[1] W. Jakes, Microwave mobile communications. IEEE Press classic reissue, Wiley, 1974.

[2] X. Dong and N. C. Beaulieu, "Average level crossing rate and average fade duration of selection diversity," IEEE Commun. Lett., vol. 5, pp. 396–398, Oct. 2001.

[3] C. Loo, "A statistical model for a land mobile satellite link," IEEE Trans. Veh. Technol., vol. VT-34, pp. 122–127, Aug. 1985.

[4] M. P¨atzold, Y. Li, and F. Laue, "A study of a land mobile satellite channel model with asymmetrical Doppler power spectrum and lognormallydistributed line-of-sight component," IEEE Trans. Veh. Technol.,to be published.

[5] A. Krantzik and D. Wolf, "Distribution of the fading-intervals of modified Suzuki processes," in Signal Processing V: Theories and Applications, L. Torres, E. Masgrau, and M. A. Lagunas, Eds. Amsterdam, The Netherlands: Elsevier, 1990, pp. 361–364.

[6] M. P¨atzold, U. Killat, and F. Laue, "An extended Suzuki model for land mobile satellite channels and its statistical properties," IEEE Trans. Veh. Technol., to be published.

[7] L. Yang, M. O. Hasna, and M.-S. Alouini, "Average outage duration of multihop communication systems with regenerative relays," in Proc. IEEE 57th Veh. Tech. Conf. (VTC Spring 2003), pp. 171–175, April2003.

[8] K. W. Sowerby and A. G. Williamson, "Outage probability calculations for multiple cochannel interferers in cellular mobile radio systems," IEE Proc. (Pt. F), vol. 135, pp. 208–215, June 1988.

[9] A. A. Abu-Dayya and N. C. Beaulieu, "Outage probabilities of cellular mobile radio systems with multiple Nakagami interferers," IEEE Trans. Veh. Technol., vol. VT-40, pp. 757–768, Nov. 1991.

[10] Y.-D. Yao and A. U. H. Sheikh, "Investigation into cochannel interference in microcellular mobile radio systems," IEEE Trans. Veh. Technol., vol. VT-41, pp. 114–123, May 1992.