# Closed Form Expressions for Probability of Interference Free Reception in LMR System

Sonia Gupta[1], S.P. Singh[2], V.K.Pandey[3]
[1-3] *Assistant Professor, Dept. of Elec. & Comm., N.I.E.T., Greater Noida*
[2] *Assistant Professor, Dept. of Elec. & Comm., G.C.E.T., Greater Noida*
ec.sonia@yahoo.com

***Abstract*—The fast growth of wireless communication is based on the integration of different application. This integration needs increase in capacity or spectral efficiency, possible either by decreasing the fading effects or by spectral reuse. Number of diversity combining technique has been proposed in past to mitigate the fading effects. Either using diversity combining techniques or spectral reuse causes interference; moreover the spectral reuse is main reason for the co channel interference. So the Interference modeling has become a challenging research area for the performance analysis and improvement of wireless communication system. Closed form expressions for co-channel interference for Rayleigh distribution of received signal have been given in the literature. In this paper, we have given a simple analytical model for another important fading distribution namely Nakagami distribution giving a closed form solution for co-channel interference assuming that the interferer is linearly located.**

***Keywords*- co-channel interference; protection ratio; distribution**

## I. INTRODUCTION

Land mobile radio system are wireless communication system intended for use by terrestrial users in vehicles(mobile) or on foot(portables). LMR operators are faced with having to create highly reliable communications for noise limited systems while interference-limited systems are interspersed in the design service area. At this time users are seeing an increasing number of subscriber coverage holes when the LMR radios are in close proximity to high density cellular base station sites. As large number of radio systems are fielded with varying channel bandwidths and different types of modulation, it is becoming increasing important to model interference. The capacity of wireless communication systems is mainly limited by co-channel interference caused by frequency reuse. The acceptable co-channel interference at the receiver determines the minimum allowable distance between adjacent co-channel users and hence the system capacity. So, in order to increase the capacity we need to model co-channel interference. In the past years, mobile communications has become very popular and the demand for its services has increased significantly. The capacity of mobile communication systems is mainly limited by co-channel interference caused by frequency reuse. The acceptable co-channel interference at the receiver determines the minimum allowable distance between adjacent co-channel users and hence the system capacity. So, in order to increase the capacity we need to model co-channel interference.

A number of mathematical model of interference have been addressed in literature. The most common approach is to model the interference by a Gaussian random process [1]–[6]. In [7] a unifying framework has been developed to characterize the aggregate interference in wireless networks. It accounts for all the essential physical parameters that affect network interference, such as the wireless propagation effects, the transmission technology, the spatial density of interferers, and the transmitted power of the interferers. A new spatial-spectral interference model is introduced in [8], where interferers can be of any power spectral density and are distributed according to a Poisson process in space and frequency domains.

Acknowledging the need of interference modeling for increasing the capacity of the mobile communication system, we have achieved this aim in this research paper. A mathematical model was developed for co-channel and adjacent channel interference in land mobile radio system considering the received signal to be Rayleigh distributed in [9]. Here we have extended this work further to model co-channel interference for another important fading distribution namely Nakagami distribution and a closed form solution for probability of interference free reception is derived.

Considering a simple scenario where two base station Tx1 and Tx2, distance D from each other, and omnidirectionally radiating powers $W_1$ and $W_2$ respectively. A mobile receiver is considered to be located on the line joining Tx1 to Tx2 and distance x D ($0 < x < 1$) from Tx1. Supposing that the signal received at the mobile from Tx1 is $y_1$ and from Tx2 is $y_2$, if it is desired to receive the signal from Tx1 then it is necessary that

$$y_1 \geq a y_2 \qquad (1)$$

Here 'a' is a numerical constant known as the protection ratio. This ratio depends on the mode of modulation employed and technical characteristics of the receiver. For the present paper it will be assumed that a desired value of protection ratio has been selected for the system to be evaluated.

## II. INTERFERENCE ANALYSIS

Nakagami fading occurs for instances of multipath scattering with relatively large delay-time spread, with different clusters of reflected waves. Within any one cluster, the phases of individual reflected waves are random, but the delay times are approximately equal for all waves. The PDF of a Nakagami distributed signal is given as[10]:

$$p(y) = \frac{2m^m y^{2m-1}}{\Gamma(m)\Omega^m} \exp\left(-\frac{m}{\Omega} y^2\right) \tag{2}$$

where m is the shape parameter and Ω is scale parameter.

The probability Px that $y1 \geq ay^2$ at given $y^2$ is given by:

$$P_x = \int_{ay_2}^{\infty} p(y_1) dy_1 \tag{3}$$

$$P_x = \int_{ay_2}^{\infty} \frac{2m^m y_1^{2m-1}}{\Gamma(m)\Omega_1^m} \exp\left(-\frac{m}{\Omega_1} y_1^2\right) dy_1 \tag{4}$$

Based on table of integrals in [11], (4) can be simplified as:

$$P_x = \frac{\Gamma\left(m, \frac{ma^2 y_2^2}{\Omega_1}\right)}{\Gamma(m)} \tag{5}$$

The probability Pz that y1 > ay2 for all y2 can be obtained by integrating this function over all y2:

$$P_z = \int_0^{\infty} P_x . p(y_2) dy_2$$

$$P_z = \int_0^{\infty} \frac{\Gamma\left(m, \frac{ma^2 y_2^2}{\Omega_1}\right)}{\Gamma(m)} \frac{2m^m y_2^{2m-1}}{\Gamma(m)\Omega_2^m} \exp\left(-\frac{m}{\Omega_2} y_2^2\right) dy_2 \tag{6}$$

Based on table of integrals in [11], (6) can be simplified as:

$$P_z = \frac{1}{[\Gamma(m)]^2} \frac{\left(a^2 \frac{\Omega_2}{\Omega_1}\right)^m \Gamma(2m)}{m\left(a^2 \frac{\Omega_2}{\Omega_1} + 1\right)^{2m}} {}_2F_1\left(1, 2m, m+1; \frac{1}{1 + a^2 \frac{\Omega_2}{\Omega_1}}\right) \tag{7}$$

Equation (7) represents the probability that mobile station on line joining $BS_1$ and $BS_2$ will receive an acceptable signal.

By assuming inverse fourth power law for mean power we have:

$$\frac{\sigma_1}{\sigma_2} = \left(\frac{w_1}{w_2}\right)^{1/2} \left(\frac{1-x}{x}\right)^2 \tag{8}$$

Using the relation between λ and σ, (7) & (8) we get the Fig.1, Fig. 2 and Fig. 3.

## III. DISCUSSION

Equation (7) gives useful insights into the co-channel interference characteristics of a land mobile radio system in Nakagami distribution scenario. In what follows it will be convenient to assume, without real loss of generality, that $w_1 = w_2$. $P_z$ is the probability that the wanted signal $y_1$ will be received at a level above $y_2$ by the desired protection ratio, a. It also represents the probability of satisfactory operation.

Nakagami-m distribution of the received signal envelope, which models the radio transmission in urban areas [12] where the random fluctuations of the instantaneous received signal power are very frequent and fast. Such Nakagami-m distribution can model different propagation conditions, providing more flexibility and higher accuracy in matching some experimental data in comparison with the commonly adopted distributions [13][14]. For Nakagami distribution for higher values of coverage range the probability of interference free reception falls downs to 0 as shown in Fig 1, Fig. 2 and Fig.3. Increasing the value of protection ratio leds to decrease the rate of tending towards 0.

The results in Fig. 1 shows that for the case when fading parameter m=1, the Nakagami distribution interpolates to Rayleigh distribution and the amount of interference is moderate whereas in the case when m=0.5 i.e. it is less than unity the level of interference increases and worst case interference is experienced as shown in Fig.2. The situation changes drastically as we move to higher values of m i.e. greater than 1. Now, increasing the value of m from 1 to infinity the level of interference decreases.

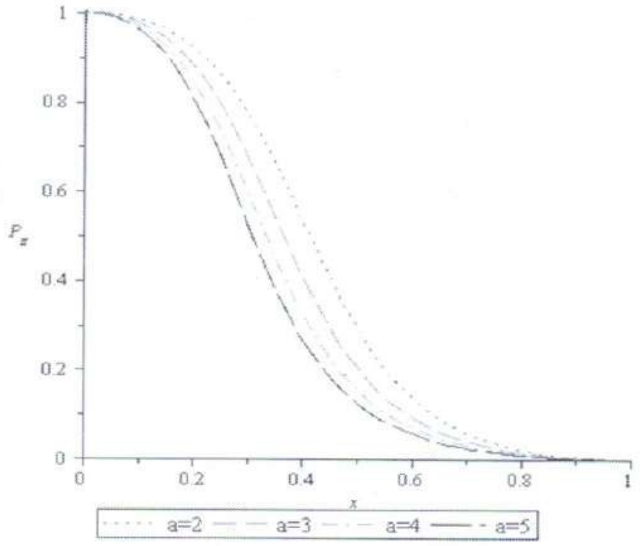


Figure 1: Probability of interference free reception (Pz) plotted as a function of coverage range (x) for different values of protection ratio for Nakagami Distribution(m=0.5).

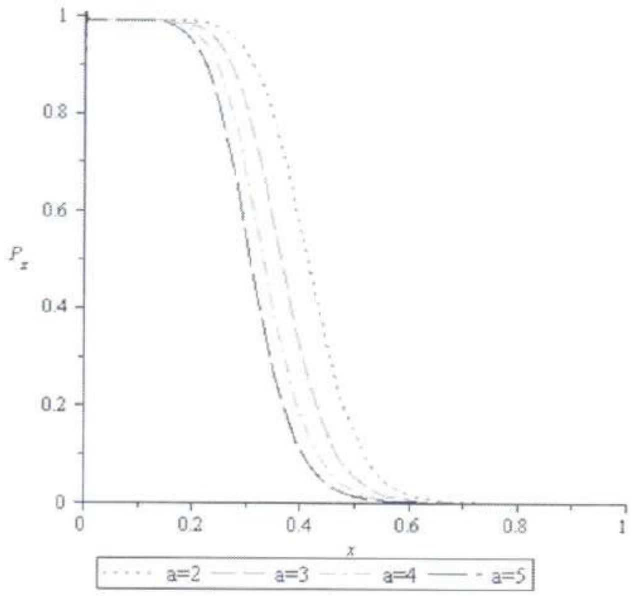


Figure 2: Probability of interference free reception (Pz) plotted as a function of coverage range (x) for different values of protection ratio for Nakagami Distribution(m=1.5).

## IV. CONCLUSION

It shows that a simple model of the dependence of mean signal on range and of its statistical distribution can yield useful insights into the design of land mobile radio systems. We have given relation between the probability of interference free reception, protection ratio and coverage range for Nakagami fading distribution of received signal. A comparison is also presented between the results of various fading distribution. This work could also be further extended to two dimensional case where the mobile is not on the line joining T1 to T2. Also here we have considered that the interferer and desired signal follow same channel whereas a situation could also be considered differently and worked in future.

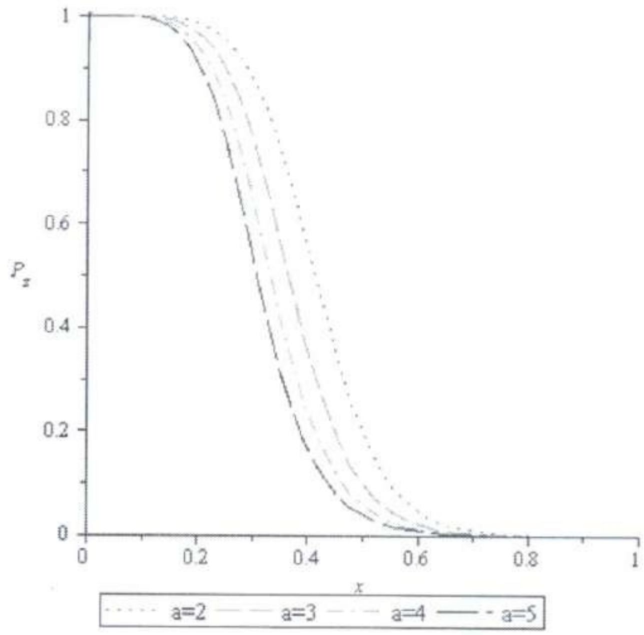


Figure 3: Probability of interference free reception (Pz ) as a function of coverage range (x), expressed as a fraction of the distance between wanted and co-channel interfering transmitter for different values of protection ratio (a) for Nakagami distribution(m=1)

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**Sonia Gupta** received her B.Tech. degree in 2008 in Electronics and Communication Engineering from IIMT Meerut, UPTU, Lucknow, M.Tech (2012) in Telecommunication from NIET Greater Noida, MTU Noida. She has total six year of teaching experience and is currently working as Asst. Prof at NIET Greater Noida. She has already published three research papers, one in IEEE conference and other two at international and national conference.

**S Pratap Singh** received his B.Tech. in (2003) in EC from MIT, MANDSAUR (A Semi Govt. College at that time), RGPV University, India. He received his M.Tech. degree in Wireless Communications in 2010 from Thapar University, Patiala, India and presently he is pursuing Ph.D. in Wireless Communication from Birla Institute of Technology, Ranchi, India. He has total Eleven year experience in teaching and research and is currently the Asst. Prof (Sr. Grade) at GCET Gr. Noida, India. He has total eight (08) research papers in IEEE proceeding (IEEE conferences) excluding various national and international journal and conferences. His research interests are in Statistical signal processing for medical applications, modeling and analysis of various impairments in Wireless communications. He is member of various professional bodies like IEEE and GISFI; he is also, member of Indus Quality Foundation (IQF).

**V K Pandey** graduated in Electronics Engineering from The University of Poona in 1990. He obtained M.E. (Control & Instrumentation) with honors from Delhi University in 1997. He received his Ph.D (Electronics Engineering) degree from I.T. BHU Varanasi in 2006. At present he is working as Professor in Electronics & Communication Engineering Department. He received a grant of Rs. 14.5 lacs under MODROB scheme from AICTE, New Delhi for establishing Project and Research laboratory in the Department of Electronics and Communication.

Prof. Pandey has around 23 years experience, teaching under graduate and post graduate classes. His field of research is Microwave Engineering. He has published around 25 research papers in International/National journals and conferences of repute.