

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

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**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

$$y_1 \geq ay_2 \quad (1)$$

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]:

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

where  $m$  is the shape parameter and  $\Omega$  is scale parameter.

The probability  $P_x$  that  $y_1 \geq ay^2$  at given  $y^2$  is given by:

$$P_x = \int_{ay^2}^{\infty} p(y_1) dy_1 \quad (3)$$

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

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

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

The probability  $P_z$  that  $y_1 > ay_2$  for all  $y_2$  can be obtained by integrating this function over all  $y_2$ :

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

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

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

$$P_z = \frac{1}{[\Gamma(m)]^2} \left(\frac{a^2 \Omega_2}{\Omega_1}\right)^m \Gamma(2m) \left(1.2m, m+1; \frac{1}{1+a^2 \frac{\Omega_2}{\Omega_1}}\right) \quad (7)$$

Equation (7) represents the probability that mobile station on line joining BS<sub>1</sub> and BS<sub>2</sub> will receive an acceptable signal.

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

$$\frac{\sigma_1}{\sigma_2} = \left(\frac{W_1}{W_2}\right)^{1/2} \left(\frac{1-x}{x}\right)^2 \quad (8)$$

Using the relation between  $\lambda$  and  $\sigma$ , (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 down to 0 as shown in Fig 1, Fig. 2 and Fig.3. Increasing the value of protection ratio leads 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.

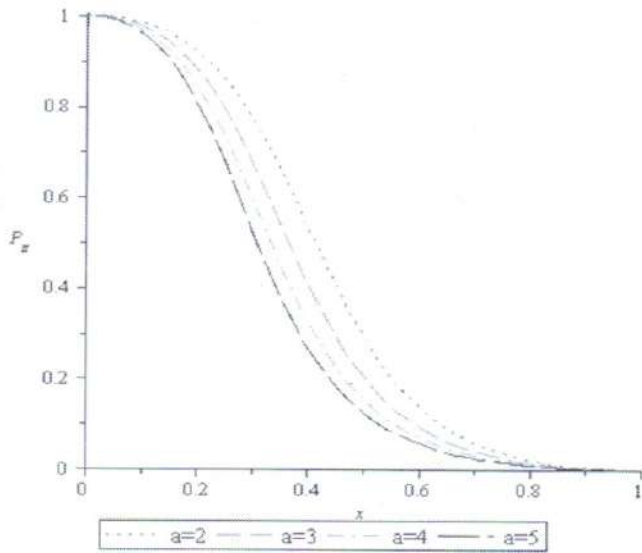


Figure 1: Probability of interference free reception ( $P_z$ ) plotted as a function of coverage range ( $x$ ) for different values of protection ratio for Nakagami Distribution ( $m=0.5$ ).

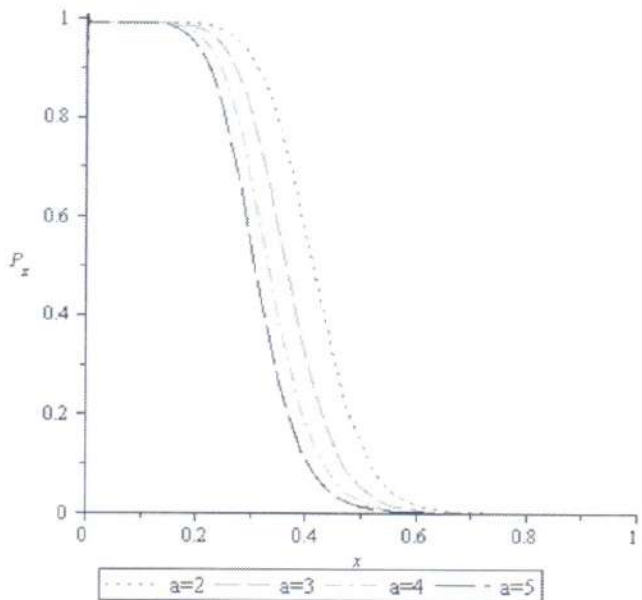


Figure 2: Probability of interference free reception ( $P_z$ ) plotted as a function of coverage range ( $x$ ) for different values of protection ratio for Nakagami Distribution ( $m=1.5$ ).

#### 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.

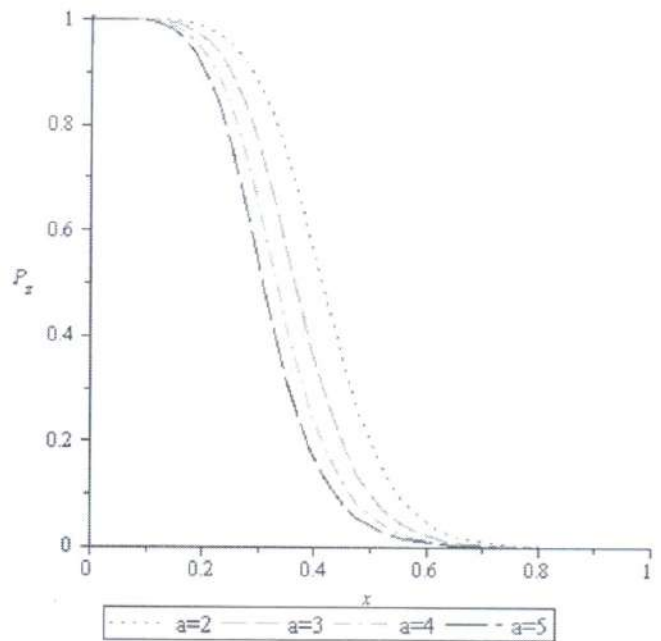


Figure 3: Probability of interference free reception ( $P_z$ ) as a function of coverage range ( $x$ ), expressed as a fraction of the distance between wanted and co-channel interfering transmitter for different values of protection ratio ( $a$ ) for Nakagami distribution ( $m=1$ )

#### REFERENCES

- [1] Viterbi, A. J. and Jacobs, I. M., 1975. Advances in coding and modulation for noncoherent channels affected by fading, partial band, and multiple-access interference, In *Advances in Communication Systems: Theory and Applications*, Vol. 4, pp. 279-308.
- [2] Habbab, M. I., Kavehrad, M. and Sundberg, C. E. W., 1989. ALOHA with capture over slow and fast fading radio channels with coding and diversity, *IEEE J. Sel. Areas Communication*, Vol. 7, pp. 79-88.
- [3] Zhang, K. and Pahlavan, K., A new approach for the analysis of the slotted ALOHA local packet radio networks, *Proceedings of IEEE International Conference on Communication*, Atlanta, GA, April 1990, pp. 1231-1235.
- [4] Linnartz, J., Goossen, H., Hekmat, R., Pahlavan, K., and Zhang, K., 1990. Comment on slotted ALOHA radio networks with PSK modulation in Rayleigh fading channels, *Electron. Letter*, Vol. 26, pp. 593-595.
- [5] Beaulieu, N. C. and Abu-Dayya, A. A., 1995. Bandwidth efficient QPSK in co-channel interference and fading, *IEEE Transactions on Communication*, Vol. 43, Issue 9, pp. 2464-2474.
- [6] Cheng, J. and Beaulieu, N. C., 2002. Accurate DS-CDMA bit-error probability calculation in Rayleigh fading, *IEEE Transactions on Wireless Communication*, Vol. 1, pp. 3-15.
- [7] Moe, Z. W. and Pedro, C.P., A mathematical theory of network interference and its applications, *IEEE*, Vol. 97, February 2009.
- [8] Cardieri, P., 2010. Modeling interference in wireless ad hoc networks, *IEEE Communications Surveys and Tutorials*, Vol. 12, Issue 4.
- [9] Gosling, W., 2010. A simple mathematical model of Co-Channel and adjacent channel interference in land mobile radio, *IEEE Transaction on Vehicular Technology*.
- [10] Simon, M. K., 2005. *Digital Communication over Fading Channels*. New Jersey, John Wiley and Sons.
- [11] Gradshteyn, I. S and Ryzhik, I. M., 2007. *Table of Integrals, Series, and Products*. New York, Academic Press.

- [12] Proakis, J., Digital Communications, 3rd ed., McGraw-Hill, New York, USA, 1999.
- [13] Suzuki, H., 1977. A statistical model for urban multipath propagation, IEEE Transactions on Communications.
- [14] Aulin, T., 1981. Characteristics of a digital mobile radio channel, IEEE Transactions on Vehicular Technology.



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