Error Probability for Coherent Modulations in Rician Fading Channel

A. Chandra, N.I.T. Durgapur, India

C. Bose, Jadavpur University, India

ABSTRACT

Simple closed-form solutions for the average error rate of several coherent modulation schemes including square M-QAM, DBPSK and QPSK operating over slow flat Rician fading channel are derived. Starting from a novel unified expression of conditional error probability the error rates are analysed using PDF based approach. The derived end expressions composed of infinite series summations of Gauss hypergeometric function are accurate, free from any numerical integration and general enough, as it encompasses as special situations, some cases of non-diversity and Rayleigh fading. Error probabilities are graphically displayed for the modulation schemes for different values of the Rician parameter K. In addition, to examine the dependence of error rate performance of M-QAM on the constellation size, numerical results are plotted for various values of M. The generality of the analytical results presented offers valuable insight into the performance evaluation over a fading channel in a unified manner.. [Article copies are available for purchase from InfoSci-on-Demand.com]

Keywords: Bit Error Probability; M-QAM; Rayleigh Fading; Rician Fading; Symbol Error Probability

INTRODUCTION

Ubiquitous personal communication has become a reality with the rapid growth of cellular radio systems. To accommodate ever increasing subscribers, the geographical area covered by the cells are diminishing as we move from macrocell to microcell and further to picocellular architecture. In contrast to conventional cells, these micro or pico cells operate with low-power, low-height base station antennas, which provide line of sight (LOS) path between base station and mobile units even in urban areas characterized by many obstacles. In such a multipath environment, the fading amplitude of the received signal follows a Rician pdf rather than Rayleigh fading, often a feature of large cells with no direct LOS path (Sun & Reed, 1999; Hui, 2005). Rician fading may also be used to model long-range radio channels like

suburban land mobile system (Adachi, 1996), maritime satellite links (Hagenauer et al., 1987), inter-vehicular communications (Davis & Linnartz, 1994; Koike, Tanaka, & Yoshida, 2005), and satellite mobile channels (Divsalar & Simon, 1987). Land mobile satellite systems (LMSS) using constellations of low earth orbit (LEO) satellites in association with the concept of geographic reuse to every point on the globe are increasingly being considered as a valuable alternative to terrestrial links. Oestges et al. (1999) presented a model of the land mobile satellite channel based on a conditional Rician distribution, whose parameters are related to physical parameters such as building height, street width, azimuth and elevation angles of the satellite link. There are several other wireless applications using Rician model where mobility is not a big issue (Erceg et al., 2001). The fact is also supported by field data. In particular Greenstein et al. (1999) derived an empirical model from a 1.9 GHz experimental data set collected in typical suburban environments for transmitter antenna heights of approximately 20 m. An excellent agreement with the model was reported using an independent set of experimental data collected in San Francisco bay area at 2.4 GHz and similar antenna heights (Baum et. al., 2000). LMDS (local multipoint distribution services) is another promising fixed broadband wireless service introduced to deliver two-way high-speed data, broadcast video, video-on-demand and telephony to residential areas. When omni-directional antennas are used and the antennas are sufficiently high providing a LOS propagation path between the transmitter and receiver, LMDS channel statistics fits the Rician distribution (Zhang & Moayeri, 2000). In this connection, measurements by Kajiwara (2000) reveals that at LMDS frequency band of 29.5 GHz the attenuation level relatively fits a Rician distribution of $K = 4$.

Let us now steer our attention to low-mobility, low-coverage, and high-data rate fixed indoor wireless solutions. Unlike in mobile communications where the channel behaviour can be described by models that only consider wave propagation in the far field of the transmit antenna, the near field has to be taken into account for short range applications too. Because of the very fast decaying strong near field component in the close vicinity of the transmit antenna, conventional channel models are not able to describe the field within the whole range of operation sufficiently. However the suitability of Rician model is still valid for wireless local area network (WLAN) (Barbounakis & Papadakis, 2005), cordless telecommunication (CT) (Sun & Reed, 1999) and factory aisles (Rappaport, 1989). Experimental measurements performed for different applications, e.g. for terrestrial mobile systems at 900 MHz (Bultitude & Bedal, 1989), radio frequency identification (RFID) scenarios (Mayer, Wrulich & Caban, 2006) and for indoor wireless channels at 1.9GHz (Wijk et al., 1995), 2.4GHz (Walker et al., 1998) and 5GHz (Medbo et al., 1999) also confirm that the temporal envelope fading is best fit by Rician distribution.

Interestingly Rician pdf is also applicable to communication systems other than a wireless one. Yang & Yang (2006) measured the bit error probability (BEP) for *M*-ary frequency shift keying (MFSK) signals in an underwater acoustic channel. The BEP data is found to be significantly higher than that of a Rayleigh fading channel and is found to agree with that modelled with a *K*-distributed amplitude fading distribution. Moreover, the Rician fading channel model is widely used in the literature for infrared (IR) systems (Dubois & Abdul-Latif, 2005). Several other applications include medicine and image processing. The image intensity in magnetic resonance images (MRI) in the presence of noise is shown to be governed by a Rician distribution (Gudbjartsson & Patz, 1995), while Weldon & Higgins (1994) presented a Gabor filter design method using a Rician distribution to characterize the filtered textures.

Rician fading is characterized by the *K* factor, which is the power ratio of specular and diffused components. The value of the Rician factor is a measure of the severity of fading, with $K = 0$ being the most severe fading case

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