Approximating Shadowed Rician Model to Other Simpler Models

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ABSTRACT

Shadowed Rician model is considered to be the most appropriate that is used to characterize the impairments seen in wireless channels, which suffer Line-Of-Sight (LOS) shadowing and small-scale fading. In this model, the Probability Density Function (PDF) of the Signal to Noise Ratio (SNR) per symbol needs numerical solutions to be evaluated. More than that, for some values of the fading parameters, the numerical solution converging too slowly, and so needs too much time to be evaluated. This is considered as a problem in real time applications where delay is a critical issue. In this paper, the authors present and prove approximations for Shadowed Rician model according to the values of the fading parameters, which are the Rice factor and the Shadowing standard deviation. With the proposed approximation, the required PDF could be written in intervals which make it easier to calculate at parameters values that causes slow converging.

KEYWORDS

Lognormal Shadowing, Loo’s Model, LOS Shadowing, Nakagami-m Shadowing, Rayleigh Fading, Rician Fading, Shadowed Rician Model

1. INTRODUCTION

Wireless communication channels suffer two main impairments: Shadowing and small scale fading (DU & SWAMY, 2010). The main reason behind small scale fading is the multipath. We can distinguish between two main situations: channels where we have LOS between the transmitter and the receiver, and channels where no LOS exists between them. Considering no shadowing in the channel, the first case is mostly modeled as a Rician channel, where the second case is modeled as a Rayleigh channel (Goldsmith, 2005).

Shadowing exists almost in most applications; caused by the dynamic nature of the channel between the communicating devices. This nature is inherently related to the non-uniform scatters found within different paths in the channel (Vadda & Rao, 2016). Two types of shadowing could be found in Rician channels: LOS shadowing, and multiplicative shadowing (Abdi, Lau, Alouini & Kaveh, 2003). With LOS shadowing, only the LOS direct component will be affected by shadowing. This type of shadowing could be found in applications such as Land Mobile Systems (LMS) (Bhatnagar & Arti, 2014; Zhang, Guo & Yang, 2013), UAV networks (Aljuneidi, Jaamour & Khorzom, 2015; Simunek, 2013), water acoustic channels (Ruiz-Vega, Clemente, Otero & Paris, 2011), spectrum sensing (Bomfin, Souza & Guimaraes, 2014), and Body-centric communications channels (Cotton, 2014). In multiplicative shadowing, both direct and multipath components will suffer the shadowing effects. In this paper, the authors are interested only with LOS shadowing.

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Shadowed Rician model with LOS shadowing was firstly proposed by Loo in (Loo, 1985). This model is widely used in wireless communication as it describes the statistical fluctuations of the received signal caused by fading and shadowing occurring separately and concurrently in rural environments, and thus, it mostly models the real situations we can find in several mobile applications within rural areas (Simon & Alouini, 2005). Shadowed Rician model was validated in the standardization activity of Digital Video Broadcasting for Satellite Services to Handheld “DVB-SH” (ETSI, 2008). A comparison of the model in (Loo, 1985) with experimental data at 870MHz and 1542MHz had been given in (Loo, 1987), and other results of the model at 1542MHz had been given in (Loo, 1991). The analytical derivation of the probability of bit error of non-coherent Phase Shift Keying (PSK) signals transmitted through the LOS shadowed Rician channel had been described in (Loo, 1990). Several researches had been made in order to modify the model of (Loo, 1985). In (Corazza & Vatalaro, 1994) Loo’s model was modified by assuming multiplicative shadowing instead of LOS shadowing. In (Hwang, Kim, Ahn & Whang, 1997) another extension of (Loo, 1985) had been made where the authors assumed the scattered component as a lognormal variable. A generalization of the model of (Corazza & Vatalaro, 1994) is made in (Vatalaro, 1995) by adding an extra scatter component. Other researches proved that we can use this model in different frequency bands (Castro, Buonomo, Baptista & Rastburg, 1998; Loo & Butterworth, 1998; Vucetic & Du, 1992). The same model had been expanded in (Hwang, Kim, Ahn & Whang, 1997) towards multiplicative shadowing, but the authors considered independent shadowing effects on multipath and LOS components.

The problem with Loo’s model is in its complexity. Until now, there is no closed form formula for the PDF of the received signal envelope (Konig, Amdt, Ihlow & Heuberger, 2012). Even if we use numerical solutions to calculate required quantities, such as Symbol Error Rate (SER), it will take a lot of time to get results, even with accepted tolerance. This problem makes it difficult to be used especially in real time applications. Because of that, most researches try to find another model to describe this type of wireless communication channels. In (Abdi, Barger & Kaveh, 2001), the authors used Gamma distribution to model shadowing effects in the channel; they proved their findings and used them in (Abdi, Lau, Alouini & Kaveh, 2003) to get an acceptable approximated shadowed Rician model. They also proved identical results with Loo’s model. The model in (Abdi, Lau, Alouini & Kaveh, 2003) is very popular due to significantly less computation compared to other channel models, and thus its convenience to calculate closed-form mathematical expressions of channel statistics such as the Cumulative Distribution Function (CDF) (Paris, 2010) and the sum of the squared shadowed Rician random variables (Alfano & De Maio, 2007; Clemente & Paris, 2014).

Unfortunately, the approximated shadowed Rician model of (Abdi, Lau, Alouini & Kaveh, 2003), which is used until now (Bu, Lin, An, Ouyang, & Yuan, 2016; Javed, He, & Liu, 2016), has some complexity that also makes it difficult to be used in real time applications, especially for some fading parameters values, which are the Rice factor mean and the shadowing standard deviation, that make required calculations progress slowly. In this paper, according to the state of the channel, the authors found acceptable approximations for Loo’s model with other models which are more efficient in real time situations.

The rest of this paper is organized as follows: In section 2 the authors present the general form for the PDF of the SNR per symbol in shadowed Rician channels. In section 3, the authors found fading parameters intervals that allow approximating the shadowed Rician model with Rayleigh model. Fading parameters intervals that allow the approximation with lognormal model, Nakagami-m model and Rice model is found in the fourth and fifth section, respectively. The final PDF formula is given in the sixth section. Discussion of numerical and simulation results is shown in the seventh section. Finally, the authors finish this paper with some concluding remarks and future aspects.
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