Determination Of Bit Error Rate For Lora Transceiver Modulation Scheme Under Rician Fading Channel

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Abstract— In this paper, development of an online mineral In this paper, determination of bit error rate (BER) for LoRa transceiver modulation scheme under Rician fading channel is presented. Specifically, a closed form analytical model for the BEP of LoRa modulation in Rician fading channel was adopted and then used in the simulation conducted using ANYLOGIC software. Experimental setup was presented for the simulation of the BER as a function of signal-to-noise ratio SNR, γ for Lora modulation spreading factors, $SF \in \{7,8,9,10,11,12\}$ and the Rician factor or shape parameter, $k \in \{1,2,3\}$. The simulation was done with different random samples equal to 10^5 and this was done to ensure statistical convergence. The results show that for $SF = 7$, a BER of 10^{-05} required SNR of -6.2 dB for K=1, SNR of 1.8 dB for K=2 and SNR of 14 dB for K=3. Also, generally, for all the spreading factors, $SF \in \{7,8,9,10,11,12\}$, for a given BER value the K =1 scenario had the lowest SNR requirement while the K =3 scenario had the highest SNR requirement. In all, the results show that the BER decreases with SNR and for any given SNR, the BER increases with k.

Keywords— Bit Error rate, Transceiver, LoRa, Fading Channel, Modulation scheme, Rician Fading

I. INTRODUCTION

Wireless network technologies and applications have evolved over the years. The growing Internet of Things (IoT) and smart systems industries are based on wireless communication technologies [1,2,3,4,5,6,7,8,9,10,11,12,13,14]. Today, the world relies heavily on wireless technologies for both terrestrial and satellite applications [15,16,17, 18,19,20,21,22,23, 24,25,26, 27,28,29,30, 31,32,33,34,35,36]. Compared to the wired and fibre optic networks, wireless networks has gained more popularity even though is yet to offer as much bandwidth as the wired and fibre optic networks [37,38,39,40,41,42,43,44,45,46,47,48].

Notably, all wireless networks suffer various forms of attenuations or signal losses [49,50,51,52,53,54,55,56,57,58,59]. Among the top attenuation phenomenon is the path loss or propagation loss. Other loss factors include fading, multipath loss, atmospheric loss, rain fading, interference, among others [60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75]. In essence, wireless networks must be designed to deliver the required quality of service in the face of the diverse challenges in the system.

In any case, the major cause of the losses are obstructions in the signal path. The obstructions cause different forms of losses which can be modelled in various forms. One of the ways used to describe the condition and effect of the signal propagation channel is by the kind of fading it presents to the signal. In this case, fading is used to describe a situation where there is significant variation over time on the signal amplitude and phase. Among some notable fade channel categories, Rician fading channels is such channel where there is line of sight (LOS) signal that has dominant signal strength compared to the other received signals that experienced scattering and losses due to multipath effect [76,77,78].

In any case, the impact of fading on the signal are diverse. One the signal strength is negatively affected and also the probability of bit error is affected. As such, in this paper, the focus in this paper is to determine the bit error probability of a LoRa transceiver used in a Racian fading channel. The focus on LoRa transceiver is because Lora technology has proven to be the most preferred for wireless sensor applications requiring low power and long range transmission [79,80]. Remarkably, today, LoRa transceivers have been applied in many smart system, clustered networks and even on direct earth to satellite communication links. As such, a study of LoRa bit error performance is essential to ensure quality of service for the diverse applications requiring LoRa transceiver technologies.

I. II. METHODOLOGY

In Rician fading channel, the received signal strength is the summation of the line of sight (LOS) signal and the scattered signal components. Then, the Rician K factor denoted as k is used to capture the ratio of the line of sight (LOS) signal to the power of the power of the scattered signal components. The main focus of this paper is to present an approach for estimation of the bit error rate (BER) of LoRa transceiver modulator operating in a Racian fading channel. Specifically, a closed form analytical model presented in [77,78], is adopted and used in the simulation conducted using ANYLOGIC software. According to [Ferreira Dias], for Rician faded channel the demodulator output has a correlation output expressed as:

$$\sum_{n=0}^{2^{SF}-1} r_k\,(nT_s) \times \omega_i^*(nT_s) = \begin{cases} \sqrt{(\alpha + v)E_s} + \varsigma \\ \phi_i, \end{cases} \quad (1)$$

where, v relates to the direct path component. Based on this expression, a closed form expression for the average bit error probability for the Rice scenario is given as [77,78]:

$$P_b = \frac{2^{SF-1}}{2^{SF}-1} \sum_{q=1}^{2^{SF}-1} \frac{(-1)^{q+1}}{1+q+\frac{2^{SF} q\gamma\Omega}{1+k}} \binom{2^{SF}-1}{q} \times exp\left[-\right. \quad (2)$$

where the parameters used in Equations 1 and 2 are defined as follows;

- i SF is the LoRa modulator spreading factor,
- ii Es denotes the signal energy,
- iii T denotes the sampling period,
- iv ωk (nT) are the 2^{SF} orthonormal basis functions,
- v n denotes the sample index at time nT (where n = 0, 1, 2, . . . ,(2 SF − 1)),
- vi κ denotes the Rician factor or shape parameter (defined as the ratio of the power contributions from the line-of-sight path to power contributions from the remaining multi-paths where k ∈ {0, 1, . . . , 2^{SF} − 1})
- vii rk (·) denotes the received signal strength,
- viii φi denotes a complex Gaussian noise process,
- ix γ denotes the signal-to-noise ratio,
- x ω∗ i (nT) denotes the complex conjugate of the i-th basis function.
- xi Ω denotes the scale parameter which related with the total power that is received from all the paths

3. Results and Discussion

Experimental setup is presented for the simulation of the BER of Rician fading as a function of signal-to-noise ratio, γ for $SF \in \{7,8,9,10,11,12\}$ and $k \in \{1,2,3\}$. The simulation was done with different random samples equal to 10^5 and this was done to ensure statistical convergence.

The results of the BER of LoRa modulation under Rician fading based on γ for $k \in \{1,2,3\}$ and $SF \in \{7,8,9,10,11,12\}$ are shown in Figure 1 to Figure 6. From the graph in Figure 1 for $SF = 7$, it can be seen that for BER of 10^{-05} SNR of -6.2 dB is needed for K=1, SNR of 1.8 dB is needed for K=2 and SNR of 14 dB is needed for K=3. Also, generally, for all the spreading factors, $SF \in \{7,8,9,10,11,12\}$ for a given BER value the K =1 scenario has the lowest SNR requirement while the K =3 scenario has the highest SNR requirement.

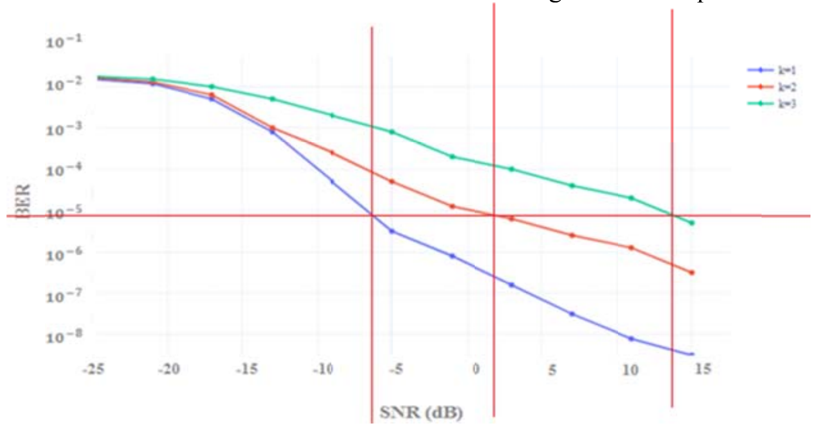

Figure 1: The graph of BER of LoRa Systems operating under Rician fading for $SF = 7$ and $k = 1,2$ and 3

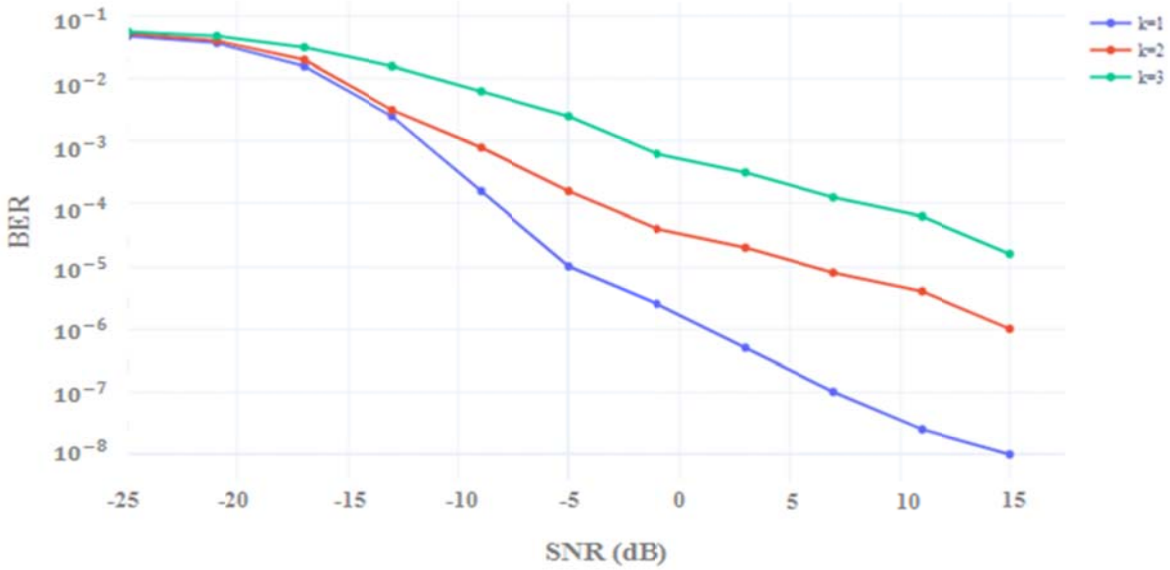

Figure 2: The graph of BER of LoRa Systems operating under Rician fading for $SF = 8$ and $k = 1,2$ and 3

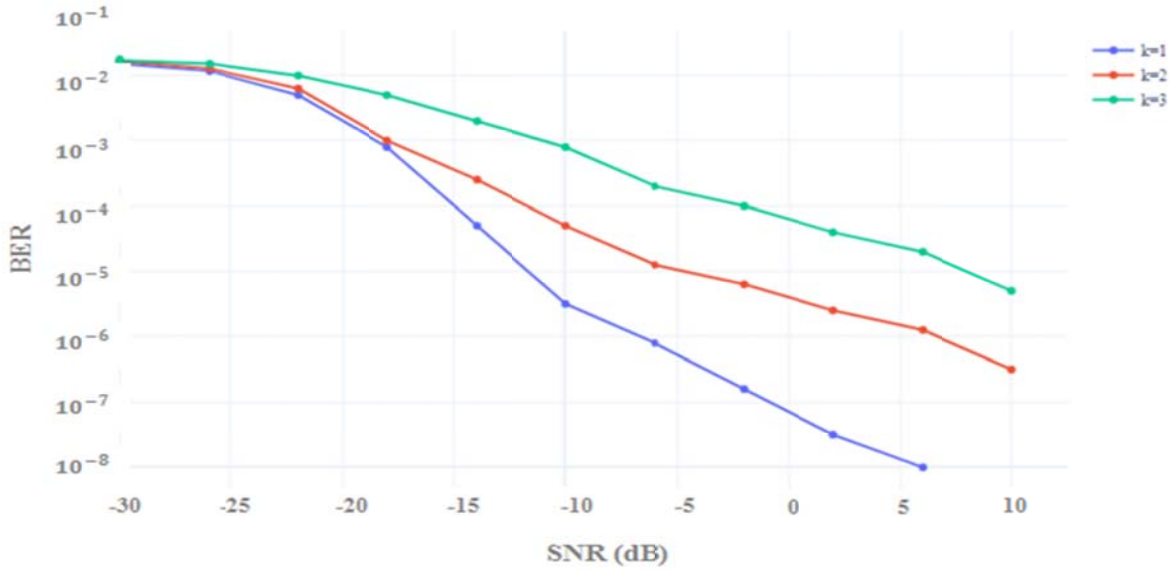

Figure 3: The graph of BER of LoRa Systems operating under Rician fading for $SF = 9$ and $k = 1,2$ and 3

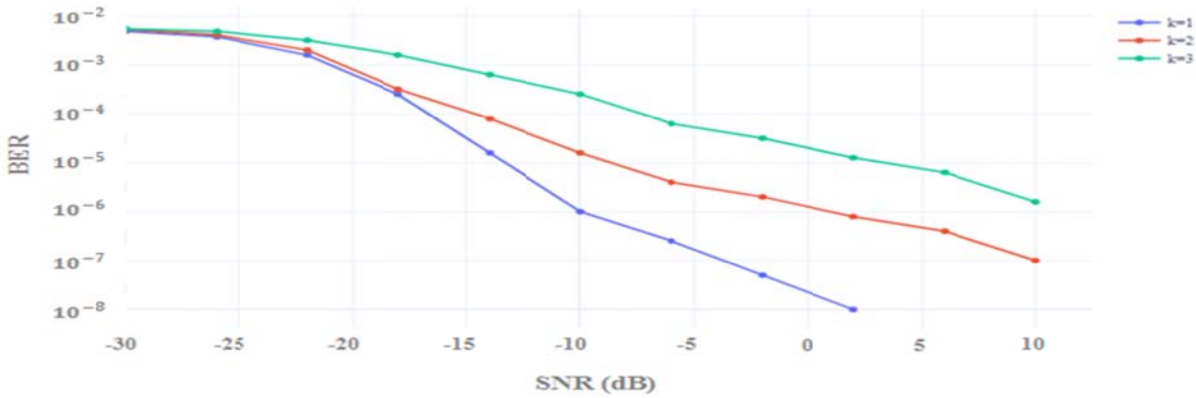

Figure 4: The graph of BER of LoRa Systems operating under Rician fading for $SF = 10$ and $k = 1,2$ and 3

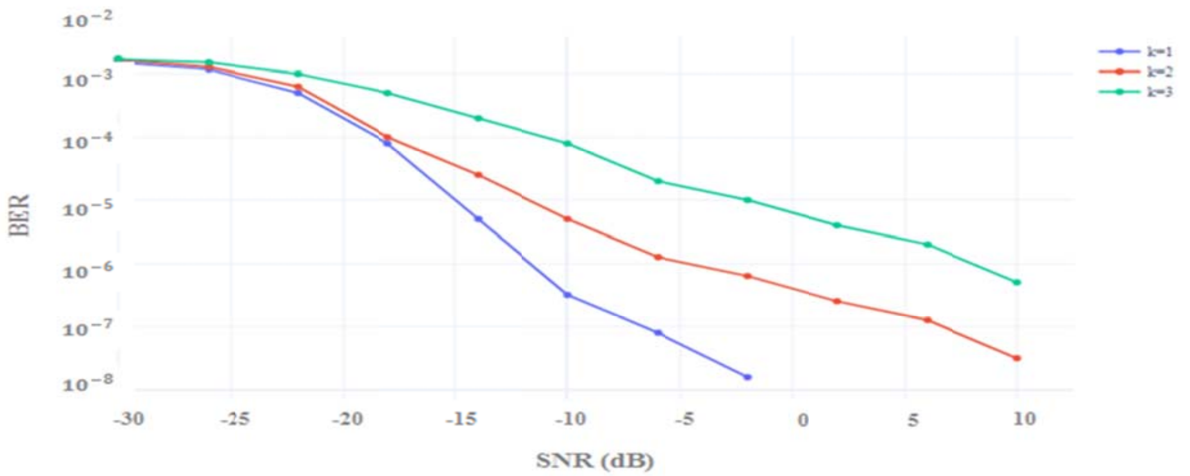

Figure 5: The graph of BER of LoRa Systems operating under Rician fading for $SF = 11$ and $k = 1,2$ and 3

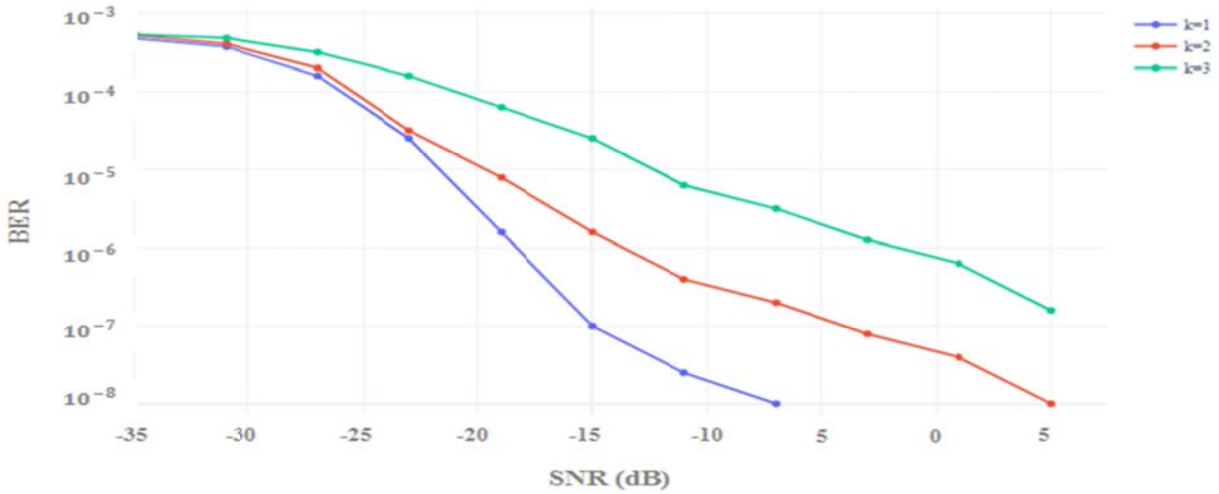

Figure 6: The graph of BER of LoRa Systems operating under Rician fading for $SF = \mathbf{1}2$ and $k = 1,2$ and 3

CONCLUSION

The bit error rate (BER) of LoRa modulator in Rician faded channel is presented. A closed-form expression of the BER for the modulator is presented and then simulated using ANYLOGIC software. The simulation was conducted for the six different spreading factors (SF) ranging from 7 to 12 and also for three different values of the shape parameter, k ranging from 1 to 3. The results of the BER versus signal to noise ratio were presented for the different SF and K values. In all, the results show that the BER decreases with SNR and for any given SNR, the BER increases with k.

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