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WIDEBAND LAND MOBILE SATELLITE CHANNEL MODELING FOR THE IMPROVED CHANNEL OUTAGES

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Abstract

Channels in satellite communication play a significant role in effective communication, determination of the quality of service, network availability and reduction in outages.It is paramount to analyze the behavioral features of satellite signal transmission to ensure that the limited assigned frequency is judiciously utilized in the envisioned service. Greater attention has been devoted on narrowband channeling with a view to ameliorate challenges associated with transmission links. However, due to advancements in modern technology, there is a need to focus on wideband channel modeling. This research proposes a modified land mobile satellite (LMS) channel built on two-state Latz's statistical model with the Markov chain state model applied on two transmission environments, which are shadowing and unshadowing conditions. The satellite diversity method was applied to cushion the challenge of outages. The effectiveness of the proposed method was verified and simulated using Matlab software. The results show that the satellite diversity improves channel outages and the concurrent channel availability is ensured with two satellites accessing mobile terminals compared to one satellite channel.

Keywords: Line of sight, Markov chain, mobile satellite, satellite channel, two-state model and wideband channel

1 Introduction

In today's growing world of modern technology, satellite communication has taken a driver's seat as one of the most used and reliable sources of communication in almost every part of the world. The usefulness of satellite communication covers a great while in the communication systems. Apart from providing communication across geographically separated great distances, and giving opportunity for live transmission and reception of programs (events such as sports, competitions, natural disasters: like an earthquake, tsunami, deadly erosions, wars, and weather forecasting, which is very important for travelers either through aviation and maritime industries). It is of necessity to think of better *quality of service* (QoS) that can ensure proper communication especially when there is urgent need. For a real-time event, QoS will be measured in line with speech quality and ability to watch and share streaming video without distortion. Some of the uses of satellite communication clearly make it advantageous over terrestrial services, and it also offers great advantages in delivering multicast and broadcast traffic; this cannot be done with terrestrial mobile communication due to network resource duplication that is, multiple base stations transmitting the same signal. However, implementing land mobile satellite(LMS) system still comes with challenges in connectivity, outages, inefficient communication and stability(Abo-Zeed *et al.*, 2019). According to (Yan, Xiao, Wang, *et al.*, 2018)(Yan, Xiao, An, *et al.*, 2018), the channel link between the satellite and the mobile client poses a significant challenge in communication reliability.

Different studies in the literature focus on the statistical distributive representation of fading and the impact of shadowing on the line of sight (LoS) and non-line of sight scenarios. In (Yoon, Lee and Kang, 2011), the authors applied Rayleigh and the lognormal distribution approach to analyze the effects of shadow and fading respectively. Authors in (Milojević *et al.*, 2009), presented an additive of Rayleigh and lognormal distribution model. It is assumed that the LoS constituents faded through shadowing and the multipath component behave independently to each other. The channel modeling in (Zhu *et al.*, 2011), adapted Nakagami-m and q distribution as a platform to investigate fading. This is because an extensive representation of diverse fading scenarios is ensured than Rayleigh distribution. The channel modeling in (Youssef, Wang and Pätzold, 2005) is examined as generalizations of Rayleigh-lognormal multipliers models. The models earlier mentioned come with application of double distributions that are not flexible in reflecting the features, considering different environment and weather conditions. In order to eradicate this shortcomings, Markov chain technique was widely applied in communication channels. In (Milojević *et al.*, 2009), the authors presented the propagation channels using hidden Markov 10 state models. However, the state number was extremely extensive to characterized the behavioral mechanism of all the states. Other researchers consider a higher degree Markov model while considering a satellite multiple broadcasting systems. Both the hidden Markov and higher degree Markov models yields a better performance in term of accuracy and complexity(Cid, Sanchez and Alejos, 2016).This paper proposes the modeling of complex behavior of Lutz's two-state model based LMS channel model. The Lutz's model is modified with Markov chain two-state to capture two separate transmission environments which are shadowing and unshadowing. An addition of satellite diversity is employed to cushion the effects associated with channel outages.

2 Material and Methods

With the application of two–state Gilbert-Elliot's equivalent to the Markov approach, the design assumption is made as follows: state transition is modeled in discrete-time first order of the Markov approach and each state signal variation is described by possible distribution such as Rayleigh and Rician. Markov's two state for LMS channel with unshadowed condition (Good state), and correspond with LoS condition. Also the bad state corresponds with non-line of sight (NLoS) or the blocked signal path by obstruction as shown in Figure 1. A mobile network user at speed v, with mean coverage (in m) of E_b and E_g as shadowed and unshadowed areas respectively. The mean translating time interval are D_b and D_g in which the channel oscillates between the good or bad state (Valenzuela, 2007).

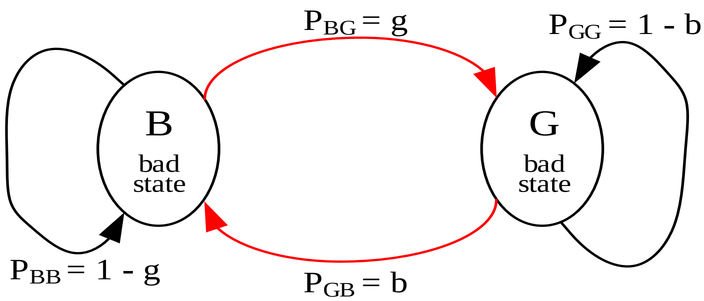

Figure 1: Markov two-state approach for LoS channel (Valenzuela, 2007)

For transmission rate R_T, the average state durations that is normalized to transition probabilities P_{BG} = g, and $P_{GB} = b$ with symbol duration yields(Lutz, 1998):

$$D_G = \frac{1}{P_{GB}} = \frac{1}{b} = \frac{R_T}{v} E_G \tag{1}$$

$$D_B = \frac{1}{P_{BG}} = \frac{1}{g} = \frac{R_T}{v} E_B \tag{2}$$

Where P_{GB} denotes the transition probability from good to bad state. P_{BG} denotes the transition probability from bad to good state.

$$P_b = (1-g)P_b + bP_g \tag{3}$$

Equation 3 translates to

$$gP_b = bP_g \tag{4}$$

Let $(1-g) = P_{BB}$ the probability such that the user moves from bad to bad state that is attributed to NLoS, such that $(1-b) = P_{GG}$ defines the probability of the users remaining in the good state based on availability of service in the state.

$$P_B = \frac{b}{g+b} = \frac{D_B}{D_G + D_B} = \mathrm{A} \tag{5}$$

$$P_G = \frac{\mathrm{g}}{\mathrm{g}+\mathrm{b}} = \frac{\mathrm{D}g}{\mathrm{D_G} + D_B} = 1 - \mathrm{A} \tag{6}$$

Where P_B is the probability of the sharing time during shadowing and A stands for the scenario in which service is unavailable. The sharing time during un-shadowing and service availability are P_G and $(1-\mathrm{A})$ respectively.

The two-state Markov chain with its associated parameters and transition matrices are calculated. Therefore, the absolute and transition probability matrices are used to model the duration and occurrences expressed as:

$$\sum_{i=1}^{2} P_i = 1 = P_{GOOD} + P_{BAD} \tag{7}$$

Where P_i meet the condition for equation 7 as the state probability. Also, the matrix for transition probability is made up of:

$$\sum_{i=1}^{2} P_{i|j} = 1 \tag{8}$$

Where $P_{i|j}$ is the transition probability from j to i state. The Markov chain convergence is expressed as:

$$[P][W] = [W] \quad \text{i.e} \quad \begin{pmatrix} P_{1|1} & P_{1|2} \\ P_{2|1} & P_{2`2} \end{pmatrix} \begin{pmatrix} P_1 \\ P_2 \end{pmatrix} = \begin{pmatrix} P_1 \\ P_2 \end{pmatrix} \tag{9}$$

Where [W] is the modulus of probability matrix, [P] is the matrix for transition probability. Another parameter for the modeling is the state duration which takes minimum and maximum value. The L_{Frame} takes the value of 1m, as a reasonable state duration frame-length. It is to be noted that both length of distance and time duration stands for duration. The two relates by terminal speed, that is taken to be constant. The state duration is a function of transition probabilities. Markov chain probability in assigned state i, while j is given for a number of consecutive frames and express as:

$$P_i \left(N = n\right) = P_{i|i}^{n-1} \left(1-P_{i|i}\right) \tag{10}$$

The cumulative distribution at each state duration is express as:

$$P_i \left(N \le n\right) = \left(1-P_{i|i}\right) \sum_{j=1}^{n} P_{i|i}^{j-1} \tag{11}$$

A random generator is employed for updating the current state, by framing each state random number. The disparity in good state is modeled using Rician distribution, Rayleigh distribution is assigned in the modeling of bad state. Figure 2 presents the diagram for modelling the whole channel scenario.

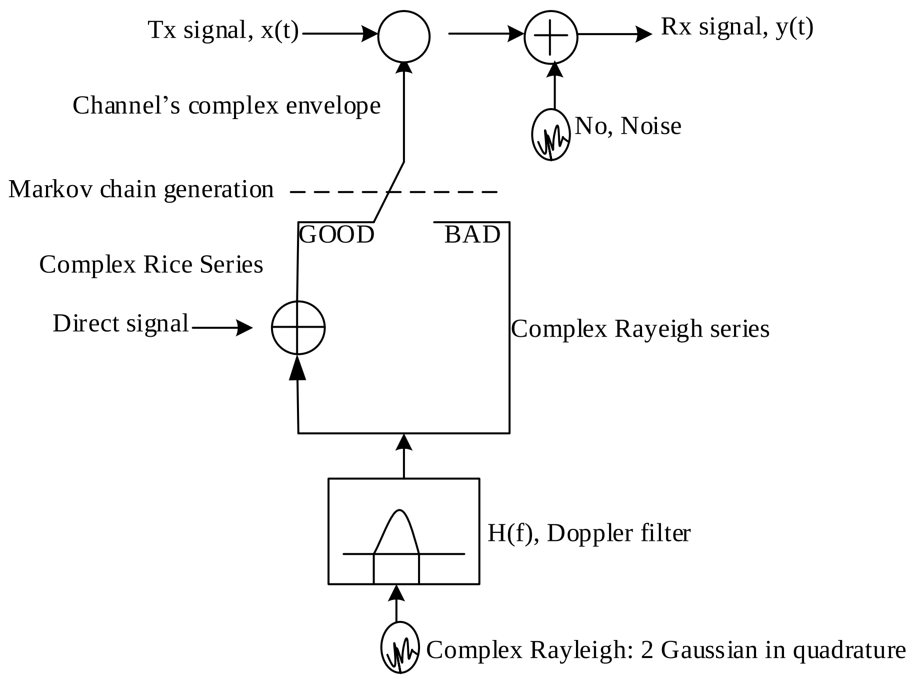

Figure 2. Two state combine Markov/Rayleigh channel simulator

2.1 Satellite Diversity

Transmission environment is highly significant and play a paramount role in communication between satellite stations. This model presents a condition in which mobile user transmits in built up areas where building, is a source of blockage to LoS and trees distort reflection of received signal. The parameter set for P is expressed as $P = \begin{pmatrix} 0.95 & 0.05 \\ 0.1 & 0.9 \end{pmatrix}$, with 200m distance. Here the user simultaneously gets signals through two satellite. Two satellites and two number of geostationary satellites are used while the transmission matrix $Q = \begin{pmatrix} 0.85 & 0.15 \\ 0.3 & 0.7 \end{pmatrix}$ is introduced for second satellite and uncorrelated with the first satellite. The expectation is that two satellite will not simultaneously shadowing.

3 Results and Discussion

For single satellite, with noisy channel and P $= \begin{pmatrix} 1 & 0 \\ 1 & 0 \end{pmatrix}$ as probability transition matrix, no transition in state occurred, the channel is unchanged all through the distance measured. The serial and multipath state parameters are shown in Figure 3 and 4 for the Rician and Rayleigh that can be compared to LoS condition.

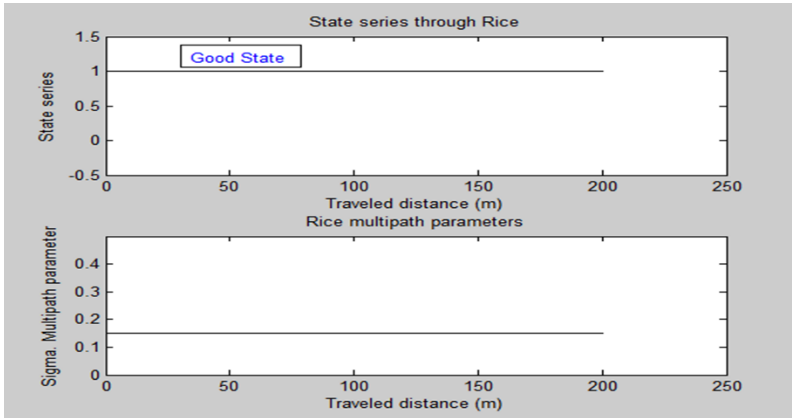

Figure 3: Series state and Rican distribution multipath parameters

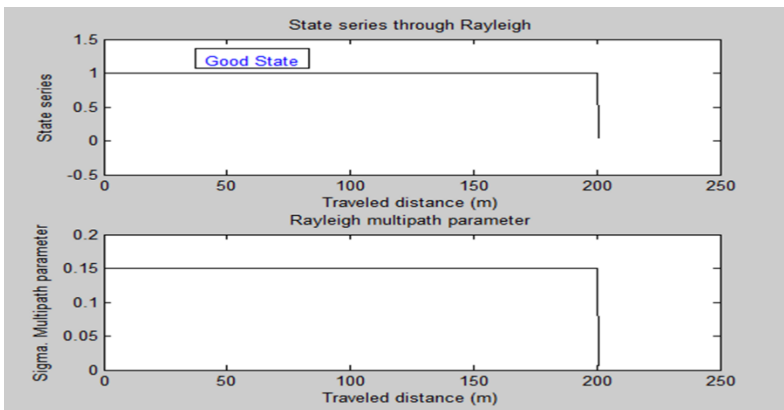

Figure 4: Series state and Rayleigh distribution multipath parameters

For the channel filter response and multipath parameter, it is unchanged all through the experiment because Butterworth filter parameter stay constant throughout as in Figure 5

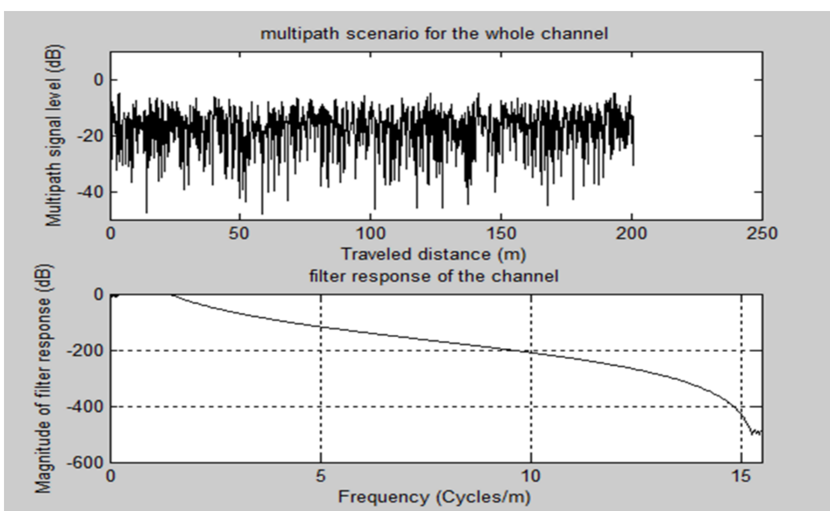

Figure 5: Effect of channel's multipath with filter response

Figure 6 presents the behavior of the channel, in decibel and linear forms and showing availability all times the channel response is more than the threshold value. This indicates the nature of the ideal channel.

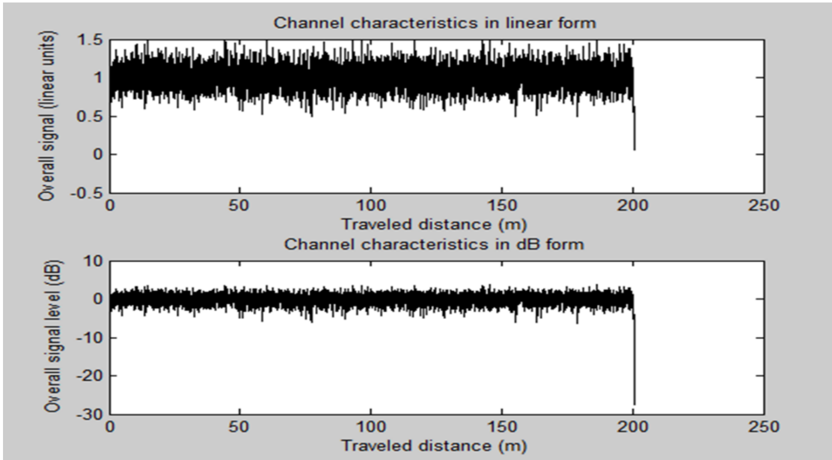

Figure 6: A noisy channel behaviour

For P = $\begin{pmatrix} 0 & 1 \\ 0 & 1 \end{pmatrix}$, it indicates a complete fading scenario occurred in the channel, a similar plot but opposite the response to Figure 3 to 6 as shown in Figure 7 to 9.

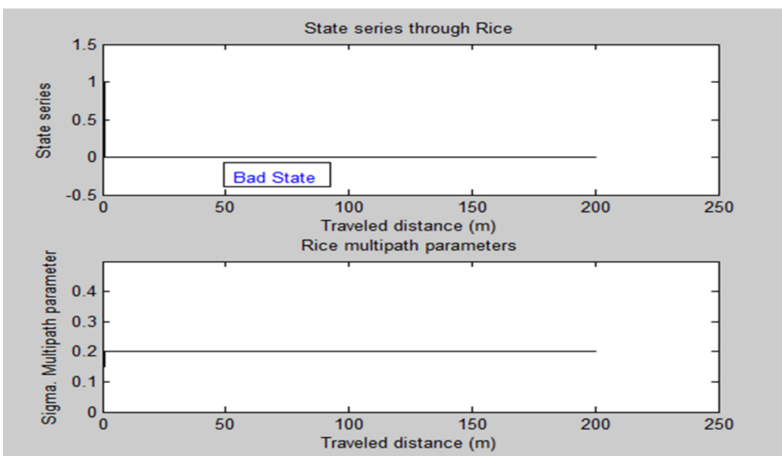

Figure 7: Series state and Rician distribution multipath parameters

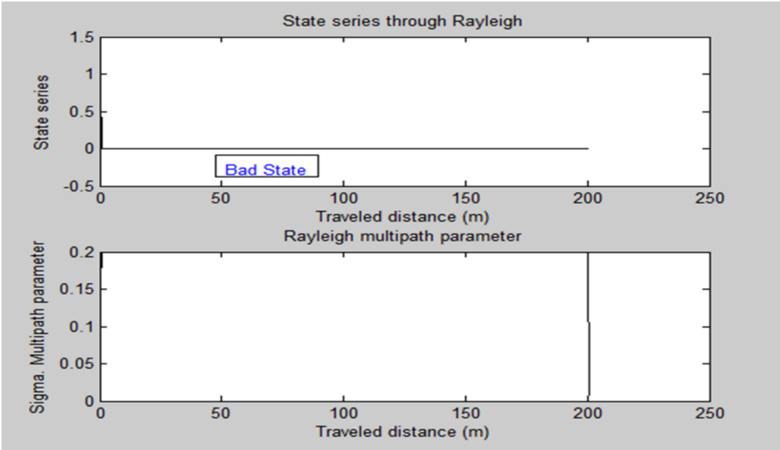

Figure 8: Series state and Rayleigh distribution multipath parameters

The filter response and multipath parameter is the same as Figure 5 and not replotted, there is no transition in the state because it is lower than the threshold value. It signifies attribute of channel fading with service unavailability.

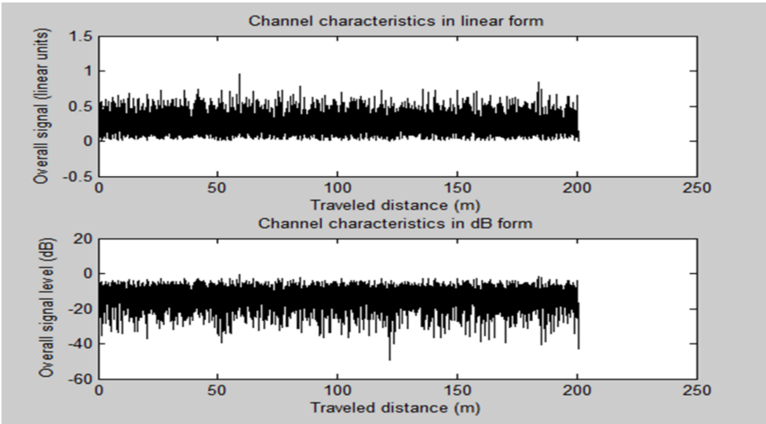

Figure 9:.A fading channel behaviour

In order to achieve a representation of realistic channel, P is adjusted to have $P = \begin{pmatrix} 0.95 & 0.05 \\ 0.1 & 0.9 \end{pmatrix}$ under a similar condition. Results show channel features in the same direction as series state for both Rayleigh and Rician distribution along with their multipath parameters. The whole channel multipath with the channel filter response and behavior in decibel and linear form are shown in Figure 10 to 13.

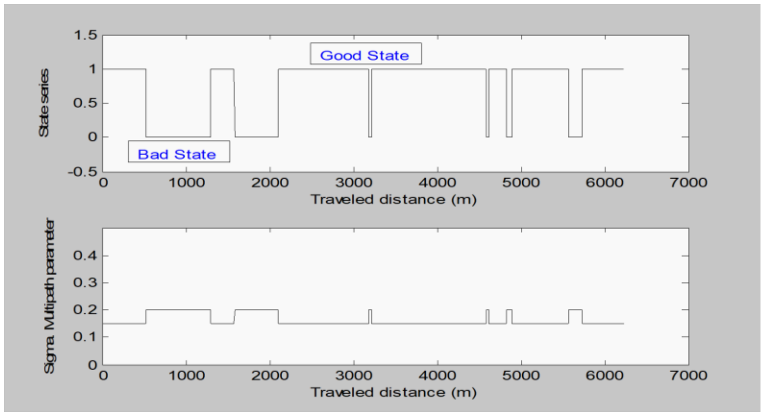

Figure 10: Series state and Rician distribution multipath parameters

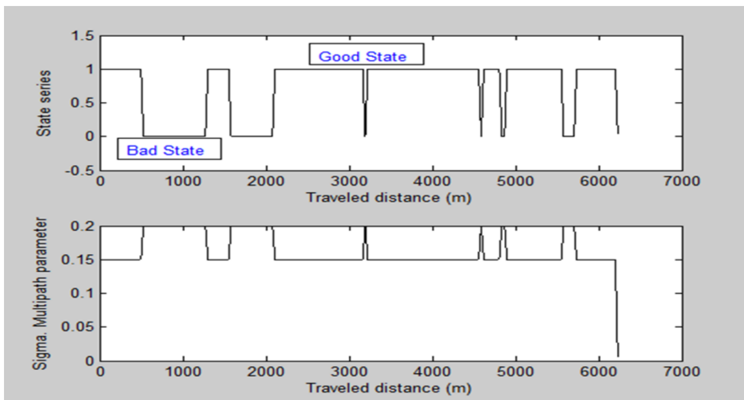

Figure 11: Series state and Rayleigh distribution multipath parameters

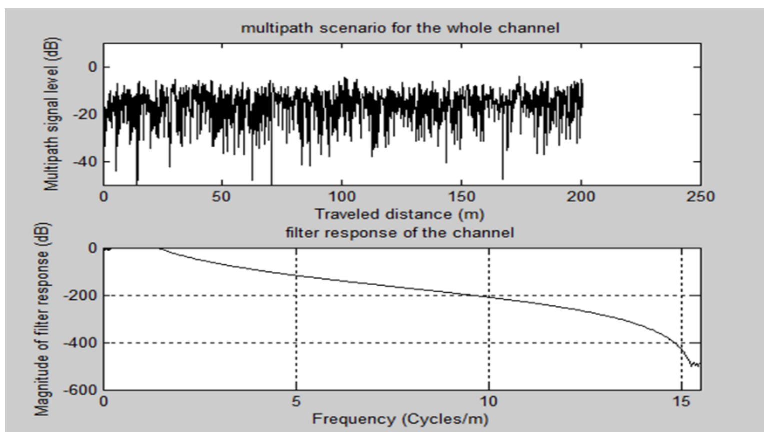

Figure 12: Effect of channel's multipath with filter response

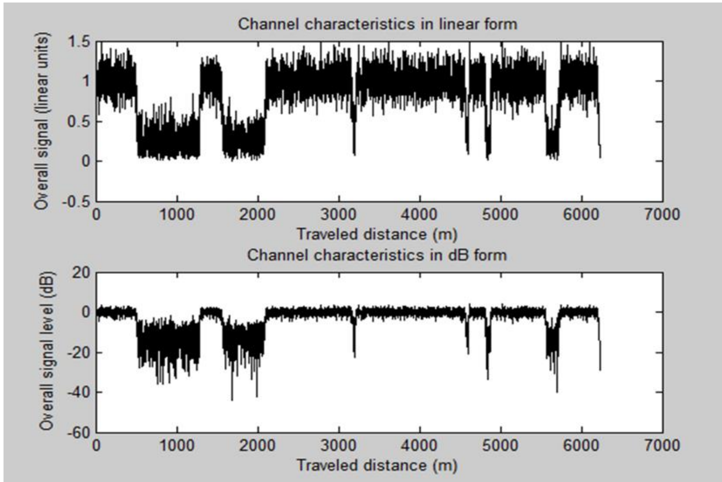

Figure 13: Linear/decibel representation for channel characteristics

For satellite diversity, outage on channel is noted in Figure 13, in which there would be service unavailability to mobile users. Satellite diversity is applied to ameliorate or overcome the challenge. The Rician series state for two satellites that show availability to mobile users stands for good and the unavailability stands for bad state as shown in Figure 14.

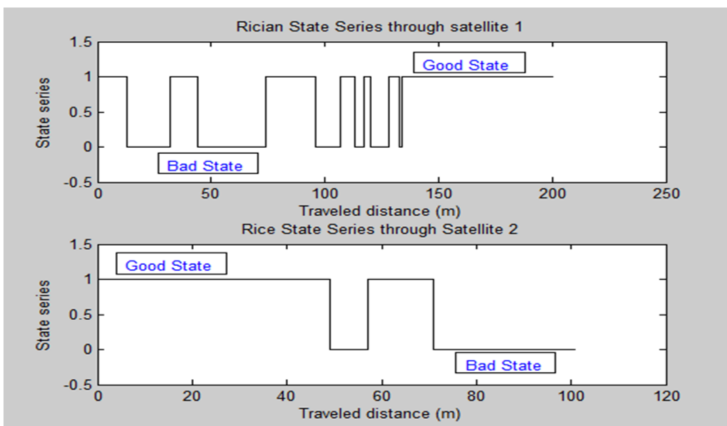

Figure 14: Rician series state that corresponds to satellites 1 and 2

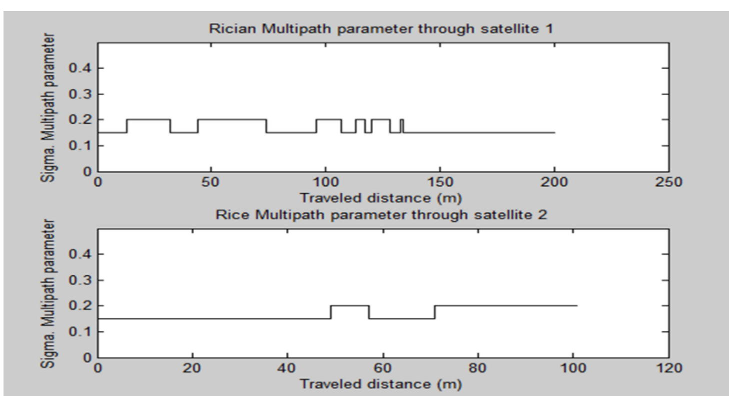

Figure 15: Satellite behaviour corresponds to Rician Multipath parameters

Similarly, the multipath parameters and Rayleigh series state from the satellite were presented in Figure 16 and Figure 17

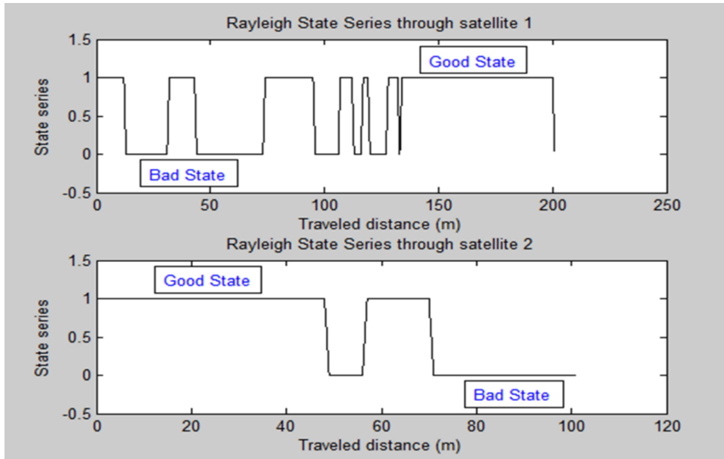

Figure 16: Rayleigh series state that corresponds to satellites

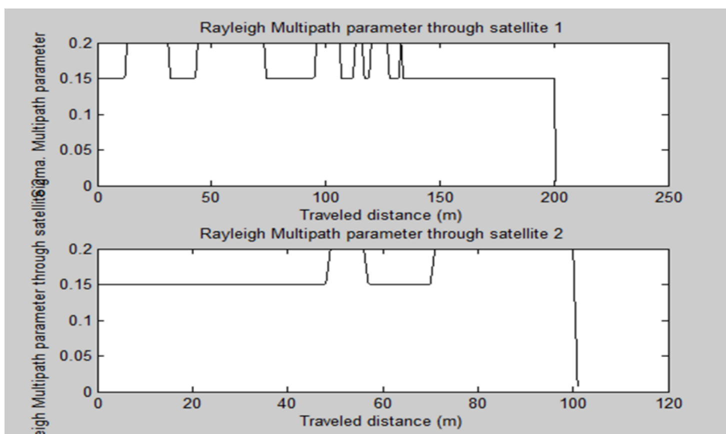

Figure 17: The satellites correspond to Rayleigh Multipath parameters.

An identical plot for the whole multipath parameters got by the mobile users from the satellite and the constant filter response were presented in Figure 18 and 19.

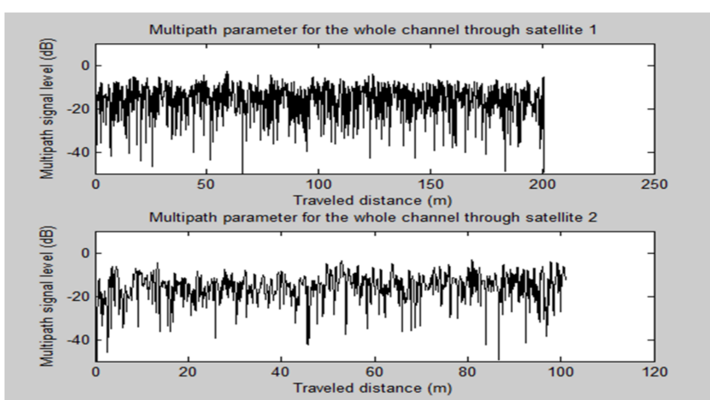

Figure 18: Effects of Multipath through the two satellites

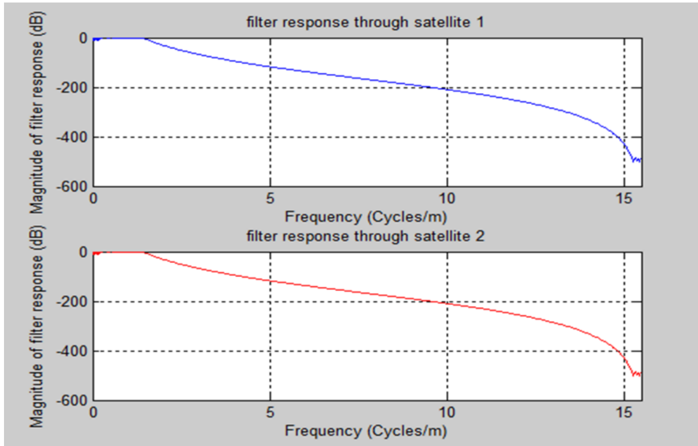

Figure 19: The constant filter responses from the satellites

Finally, the overall characteristics of the channel from the satellites are plotted and represented in both linear and decibel form as shown in Figure 20 and 21.

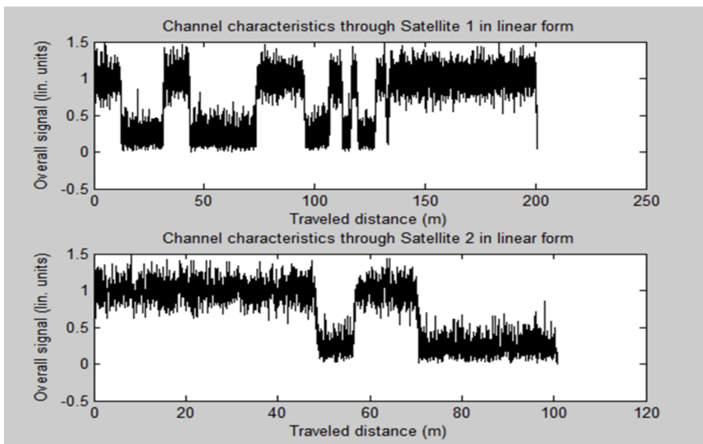

Figure 20: Linear form for channel characteristics from the satellites

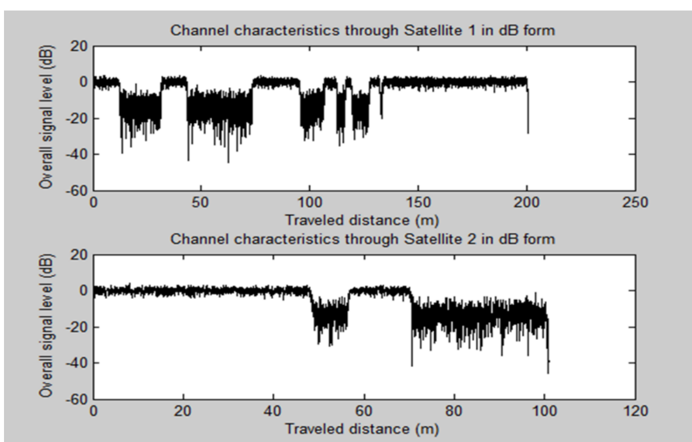

Figure 21: Decibel form for channel characteristics from the satellites

4 Conclusion

The significance of modeling LMS channel is clearly spelt out by its application in different modern technology where security of life is premium, and improved quality of service for mobile users. The availability of service to the terminal users is highly paramount. As a result of different environment in transmission for the mobile terminal operations, it is significantly difficult to achieve service availability at all moment to the mobile terminal using a single satellite. Therefore, the application of more than one satellite offer better advantages which is termed satellite diversity. Two satellite placed in geostationary orbits is employed for the provision of access to users by ensuring the mobile terminal could access the two satellites simultaneously. This in turn increased the service availability to the mobile users irrespective of their different location and transmission environment. The effects of fading experienced by the mobile user is also reduced in comparison to the usage of single satellite link

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