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Analysis and comparison of tropospheric scintillation prediction models at Covenant University

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Abstract. Knowledge of tropospheric scintillation is an important phenomenon in the design of satellite communication system. One year (January 2015-December 2015) scintillation data extracted from Astra 2E/2F/2G Satellite link measurement installed at Covenant University, Ota (Lat: 6.7 oN, Long: 3.23 oE) southwest Nigeria, at an elevation angle of 59.9o and a frequency of 12.245 GHz was used in this study. The analysis and the result were compared with some reputable scintillation prediction models so as to obtain best performance model for Ota region. From the result, it was discovered that the Karasawa model gives the lowest percentage error rate for both fade and enhancement of about 0.57% at 0.1 percentage of time and 6.93% at 0.01 percentage of time respectively and therefore was best found fit for the prediction of propagation impairment for the region. However, the model should be tested further using higher frequency band such as Ka and V bands to confirm the accuracy of the model. The information provided in this study will help in fade margin for antenna sizing and performance needed for satellite communication link in the region.

Keywords: Tropospheric scintillation, Attenuation prediction, Satellite communication, Ku band, Performance evaluation

1. INTRODUCTION

Tropospheric scintillation occurrences transpires to be one of the key signal impairments that affect earth-satellite path [1-6] in modern earth-space communication systems, most importantly at higher frequency bands (both uplink and downlink). The influence of scintillation on radio wave signal transmission cannot be over highlighted due to its constant variation in phase and amplitude which affect signal power [7-8]. At short microwave or millimeter-wave bands, scintillation intensity increase with decrease in elevation angle, antenna size and with increase in frequencies [9]. Yet, the tropospheric scintillation is an intricate occurrence on earth-space transmission path, which includes the presence of gasses [10], and margin level up to altitudes of about 20 km within the tropical troposphere [11].
These disparities in turn transform the amplitude and phase of the received electric field. In actual fact scintillation intensity is a variable that can be influenced by atmospheric conditions [8], and the subsequent variability in tropospheric scintillation strength has a significant impact on the statistics of the scintillation process [12]. Also, tropospheric scintillation is acknowledged to show a robust correlation with some climatic parameters such as temperature, pressure and humidity [7].

2. METHODS AND DATA ANALYSIS

The tropospheric data site is located at the Covenant University, Ota from Astra 2E/2F/2G beacon satellite 12.245 GHz (Lat: 6.7 ^{o}N, Long: 3.23 ^{o}E, Elev. Angle: 59.9^{o}) at a sample rate of 1 second. The data for this study were measured from January 2015 to December 2015. However, the non-rainy days were separated from rainy days for the analysis by using Davis automatic weather station and spectrum analyser at rain rate 0 mm/h observed for non-rainy events, meanwhile the rain rate above 0 mm/h were removed from the corresponding days and time data within the period of observation because the rain rate above 0 mm/h indicate the presence of rain. A monthly average data were used as reference data signal level and was subtracted from daily measured received data signal level in other to obtained the non-rainy attenuation on every one minutes for each clear-sky day [1]. Subsequent filtering procedure result in data which consists of positive (enhancement) and negative (fade) scintillation amplitude that is above or below the mean level.

Also, the ground tropospheric scintillation measured data were compared with some of the existing scintillation prediction models. In this study, the considered models that predict the variance of signal log-amplitude are: ITU-R model [13], Karasawa model [14], Otung model [15], Van de Kamp model [16]. Finally, performance evaluation of each of the tropospheric scintillation was tested based on the fractional percentage error as presented in Eq. (1).

$$\text{Error } (\varepsilon) = \frac{predicted \ - measured}{measured} \ x \ 100\% \qquad (1)$$

Table 1: Percentage error of the models

% of time	ITU-R	Fade			Enhancement		
		Kasarawa	**Otung**	**Van de Kamp**	**Kasarawa**	**Otung**	**Van de Kamp**
0.01	55.77558	28.02516	190.9347	-39.1306	6.92731	71.48973	-31.7537
0.1	22.36777	0.570562	45.80179	-54.7107	-10.2135	1.607013	-50.2639
1	-2.97606	-20.2577	-25.8888	-66.6068	-24.1086	-51.4064	-64.6062
10	-33.2918	-51.3273	-56.6163	-78.5266	-44.9347	-98.2782	-77.5358

3. RESULT AND DISCUSSION

Table 1 shows the tropospheric scintillation prediction models with statistical comparison between fade (negative) and enhancement (positive). It can be observed that Karasawa model gave the lowest percentage error for fade of about 0.57% at 0.1% of time and 28.03% at 0.01% of time respectively. The next model to that of Karawasa is ITU-R, which is of about 22.37% at 0.1%. Same was observed for enhancement at 0.01% of time followed by ITU-R. However, at 1 and 10% of time, ITU-R is observed to have the least percentage error. Figure 1 demonstrates the assessment of the ground data in Ota and several models prediction for both fade and enhancement, in order to understand the limits of each predicted model and the degree of validity in Ota region.

For fade signal scintillation amplitude, Karasawa model (0.1%) and ITU-R model (1%) showed a very close agreement with the ground data values in Ota almost for all the percentage of time predicted. This was followed by Otung model, which slightly deviated from other models at 0.01%. The Van de Kamp model variance from other models may be attributed to the scintillation measurement during the presence of heavy clouds and rainfall. However, enhancement signal scintillation amplitude also shows a close relationship between measure data and Karasawa predicted model at all level of percentage of time (most especially at 0.1%). This closeness may be because the model was developed during non-rainy period with strong contribution from water vapour obtain from surface temperature and relative humidity [6]. No result for ITU-R model in enhancement because the model was only designed to yield result for signal fade.

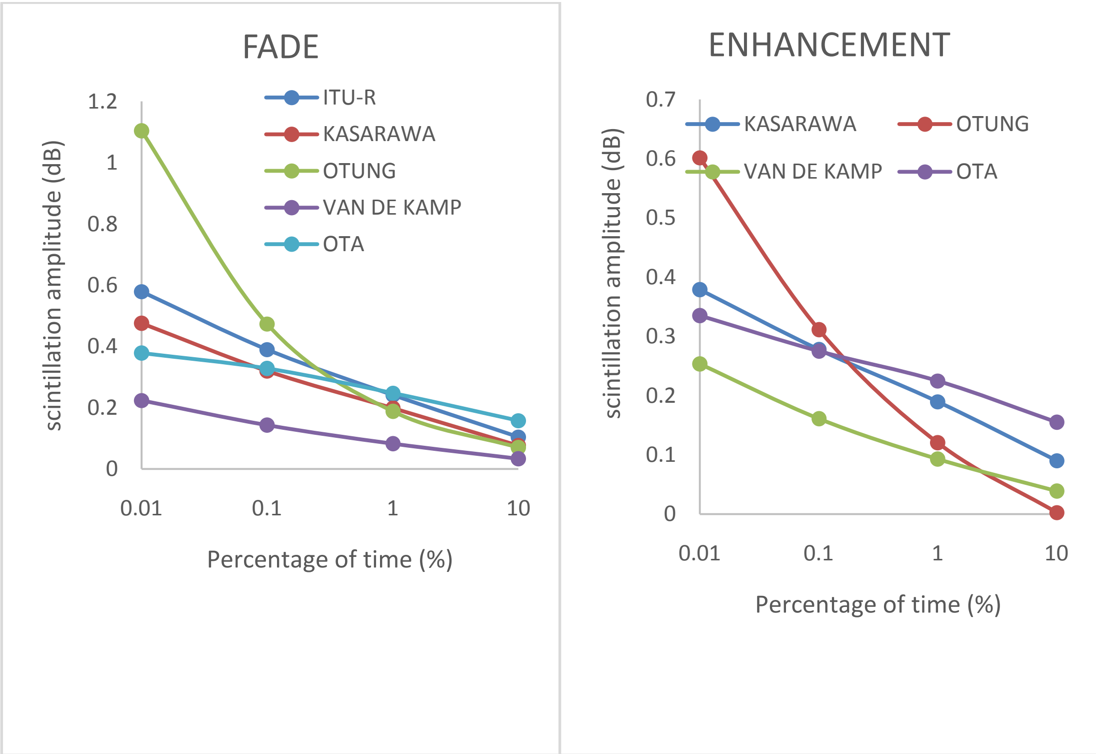

Fig. 1: Comparison of Ota data with Four existing models for fade and enhancement

4. CONCLUSION

Evaluation of four existing clear-sky scintillation models namely: ITU-R, Karasawa, Otung and Van de Kamp models have been presented in this study. This existing models were compared with the ground data in Ota obtained from Astra 2E/2F/2G satellite beacon at 12.245 GHz located at Covenant University. The ground measurements from Ota have confirmed that Karasawa model gave the best prediction for tropospheric scintillation intensity for Ota and its environment.

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