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Effects of Rain on Scintillation Measured on Ku-Band Satellite Signals in Tropical Region

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Abstract—Analysis of the tropospheric scintillation from earth to space at Ku-band has been carried out in order to obtain the required cut off frequency for the scintillation. This paper presents a comparison of scintillation amplitude and scintillation intensity between rain and non-rain event using data measured in Kuala Lumpur in December 2011. The findings denote that the signal level of scintillation during rain is higher than during non-rain event. The findings also demonstrate that as the elevation angle is higher, the path length will be smaller. Therefore, the scintillation amplitude will be small.

1. Introduction

The rapid fluctuations of the signal parameters of a radio wave caused by time dependent irregularities in the transmission path are called scintillation[1]. The amplitude, phase, angle of arrival and polarization are the affected signal parameters [1]. The effects of scintillation can be recognized in both the ionosphere and troposphere layers. The electron density irregularities in the ionosphere layer can affect frequencies up to about 6 GHz. Furthermore, on line of site links up through 10 GHz, the tropospheric scintillation has been discovered and on earth-space paths at frequencies to above 50 GHz [1]. Also, the refractive index fluctuations in the first few kilometres of altitude yield tropospheric scintillation. And this is cause by high humidity and temperature. The scintillation effects are seasonally dependent and regularly change day to day with the local climate. Scintillation occurs continually regardless of whether the sky is clear or it is raining. But under raining condition, the signal-level fluctuations due to scintillation will be accompanied by signal-level attenuation caused by the rain. Hence, special attention must be given when analysing scintillation data during rain [2].

Table 1: Models Comparison According To the Location, Elevation Angle, Frequency and Data Sampling

Model	**Location**	**Elevation Angle(°)**	**Type of Antenna /Diameter (m)**	**Frequency (GHz)**	**Data Sampling**	**Satellite**
USM	Penang, Malaysia	40.1	Dish Antenna/2.4	12.255	1.0 s	Superbird C
Measured (IIUM)	Kuala Lumpur, Malaysia	77.5	Dish Antenna/2.4	10.982	0.1 s	MEASAT- 3

2. Experimental Setup

The Ku-band signal measurements of 10.982 GHz MEASAT3 TV broadcast signal are carried out recently using 2.4 m diameter dish antenna at the Satellite Communication Lab, Block E2, Faculty of Engineering, IIUM, Malaysia. The receive signal level has been sampled in 0.1-sec interval using a spectrum analyzer. The 2.4 m dish antenna is fixed on the rooftop of the IIUM Engineering Building. The dish antenna elevation angle is positioned at 77.5°. The rain gauge is placed near the dish antenna in order to measure the amount of liquid precipitation over a period of time.

3. Results and Discussion

In this paper, a total of 12 different average cut off frequencies (January 2011 till December 2011) were taken into account to study the scintillation. The power spectra of the raw data were processed during the rain event. Figure 1 depicts the average power spectral density. About 6000 samples of the signal level variation of sampling time 0.1 s has been focused on the power spectral analysis. In our analysis, it is proven that the scintillation has the power law spectrum defined by $f^{-8/3}$. This can be seen in Figure 1. Table 2 depicts the summary of the cut off frequencies during clear sky beginning from January 2011 till December 2011. From Table 2, it can be deduced that the cut off frequencies range from 0.12-0.14 Hz. Hence, the average of the cut off frequencies was calculated and it yields 0.13 Hz. Again, this cut off frequency was used to calculate the scintillation amplitude and scintillation intensity using high pass filter of order 10 [3]. The scintillation measurement in Kuala Lumpur agrees with the Tatarskii theory which indicates that as the elevation angle increases, the scintillation value tends to decrease as well.

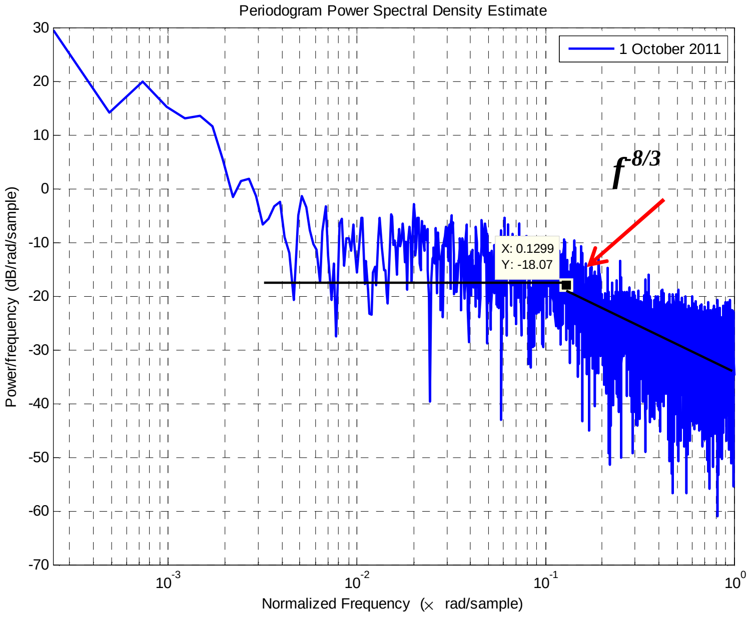

Figure 1: Average Power Spectral Density during Clear Sky

3.1 Seasonal Variations

Figure 2 and Figure 3 show the cumulative distribution for scintillation fades and enhancements on a monthly basis from January 2011 till December 2011 with annual plots. In both of the figures, the scintillation data were separated according to the scintillation fades (negative signals) and scintillation enhancements (positive signals) on a monthly basis. Subsequently, the cumulative distribution was calculated for the scintillation fades and enhancements. From Figure 2, it can be deduced that, the measured scintillation fades in January 2011 overestimated the rest of the months except at 0.5%; the measured scintillation fades in June 2011 overestimated the January 2011 plot. The severe fading can be observed at 0.01% in June 2011 and November 2011 with the same value of 0.38 dB. Meanwhile, in February 2011 till May 2011, the scintillation fades coincide which each other and are the weakest. In July 2011 till December, at 10%, the scintillation fades are merely the same, but those plots branched out at 1%. In November 2011, at 0.02%, the scintillation jumped further up till reached its maximum at 0.38 dB. The reason being is that, the temperature and humidity are the highest at this point of month if compared to other months. On the contrary, the measured average annual cumulative distribution of scintillation fades overestimated the individual month at 6%. But this is different in January 2011 and June 2011, where both of these plots overestimated the average annual plot at every percentage of time. From Figure 4, it can be deduced that the measured scintillation enhancements in January 2011 overestimated the rest of the months except at 2%, the measured scintillation enhancements in June 2011 exceeded the January 2011 plot. The highest measured scintillation enhancements occurred in June 2011 at 0.01% with the value of 0.37 dB.. In the meantime, in February 2011 till May 2011, the scintillation enhancements overlap which each other and have the weakest variations.

Table 2: Cut Off Frequencies during Clear Sky

Month	Jan	Feb	Mac	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Cut Off Frequency (Hz)	0.13	0.14	0.11	0.14	0.14	0.12	0.13	0.1	0.13	0.14	0.13	0.15

In July 2011 till December, at 10%, the scintillation fades are merely the same, but those plots branched out at 1%. In November 2011, at 0.02%, the scintillation enhancements jumped further up till reached its maximum at 0.37 dB. The reason being, the temperature and humidity are the highest at this point of month if compared to other months. On the contrary, the measured average annual cumulative distribution of scintillation enhancements overestimated the individual month at 5%. But this is different in January 2011 and June 2011, where both of these plots overestimated the average annual plot at every percentage of time.

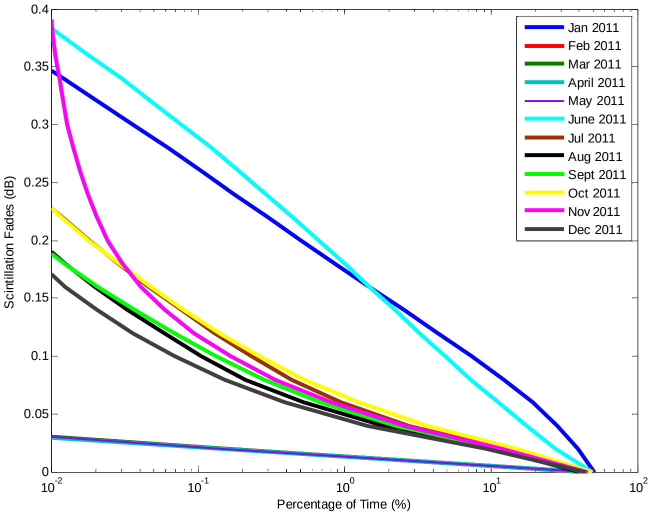

Figure 3: Measured Monthly Cumulative Distribution for Scintillation Fades

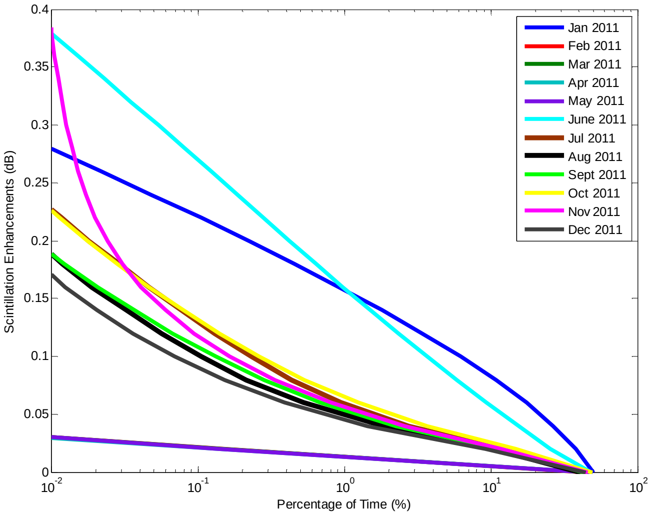

Figure 4: Measured Monthly Cumulative Distribution for Scintillation Enhancements

4. Conclusion

The scintillation data was measured on earth-to-satellite link at Ku-band in Malaysian tropical climate. The cut off frequency was evaluated to separate the scintillation event from rain. The suitable cut off frequency was calculated and it yielded 0.13 Hz. Seasonal variation of both scintillation fades and scintillation enhancements in January 2011 and June 2011 show some significant variations. A comparison of scintillation amplitude and scintillation intensity between rain and non-rain event was conducted using the data measured in December 2011. About five events were taken into account. It is found that the scintillation amplitude during rain is higher than during non-rain event. Also, the findings show that the scintillation intensity during rain is higher than during non-rain event.

References

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