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Seasonal and Diurnal Variation on Tropospheric Scintillation at K_u-band in Tropical Climate

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ABSTRACT

Tropospheric scintillation is a rapid fluctuation of the received signal amplitude which can cause propagation impairments that affect satellite communication systems operating above 10 GHz. Scintillation data was collected in Equatorial Johor Bahru, Malaysia, based on a one-year K_u-band propagation measurement campaign, utilizing MEASAT-1 Satellite with an antenna elevation angle of 75.61°. This work concentrates on the probability density function (PDF) of diurnal variations of clear sky scintillation variance analyzed on an hourly basis. Besides, seasonal variation of scintillation amplitude has been presented in this paper. From the results, it is concluded that clear sky scintillation variance is likely to occur during morning and afternoon periods. Moreover, clear sky scintillation amplitude of the South-West monsoon shows a relatively higher comparing with others monsoon seasons. Hence, signal attenuation based on seasonal and diurnal information is of great interest for the system designers to appropriately design fade margin.

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1. INTRODUCTION

Satellite communication systems operating at low fade margins with a frequency above 10 GHz are exposed to the turbulent fluctuations of the refractive index, which causes random fading (negative amplitude) and enhancement (positive amplitude) of the received signal. In fact, these fluctuations are mainly influenced by the peculiarities of the local climatology and topography, characterized by high humidity; uniform temperature and excessive rainfall. In fact, such characteristics could lead to different characteristics of radiowave propagation [1]. Hence, the impact of the behaviour or features of those parameters on scintillation is of key importance, particularly in the equatorial region that is often dominated by local climatic peculiarities.

Scintillation characteristics in Southeast Asia depend on the monsoon season that is caused by a seasonal shift in wind direction. In Malaysia, wind flow patterns can be categorized into four yearly seasons, namely pre-Northeast (pre-NE), Northeast (NE), pre-Southwest (pre-SW) and Southwest (SW). These correspond to October-November, December-March, April-May and June-September [2],[3]. A few previous researchers studied the effect of seasonal variation on clear sky scintillation in Asian monsoon region [4],[5].

In addition to the seasonal variation, diurnal variation plays a significant role in in designing mechanisms to ensure the high performance of satellite systems. Various studies had been carried out to predict the clear sky tropospheric scintillation, using, in particular, diurnal behaviour related to the hour of the day [6]-[12]. Similar studies that focus on this aspect in heavy rain regions are still very rare, with the exception of [13],[14]. Hence, it is worthwhile to further investigate the seasonal and diurnal variations of scintillation in this heavy rain region.

2. EXPERIMENTAL SETUP AND DATA PROCESSING

The experimental station installed in the premises of Universiti Teknologi Malaysia, Johor Bahru. The experimental setup was collected for one year (from March 2001 to February 2002), situated at 103.64˚ E and 1.55˚ N consist of one direct broadcast receiving antenna with a diameter of 60 cm, pointed toward MEASAT-1, broadcasting satellite at the elevation angle of 75.61°. The broadcasting signal at 11.075 GHz is monitored and recorded through spectrum analyzer and data logger. The experimental setup is illustrated in Figure1and the details of experimental setup can be found in [13]. The experimental data set was processed and separated into rain periods and clear sky periods based on data from a tipping bucket rain gauge located near the receiver antenna [15]. After the separated between two phenomena, monthly cumulative distribution functions (CDF) of scintillation amplitude were discussed in next section. Thus, the probability density function (PDF) of scintillation variance for all clear sky periods were investigated within four non-overlapping times of day intervals: 00:00-06:00, 06:00-12:00, 12:00-18:00 and 18:00-24:00. In addition, seasonal variations of clear sky scintillation amplitude were determined in particular Malaysian monsoon climate.

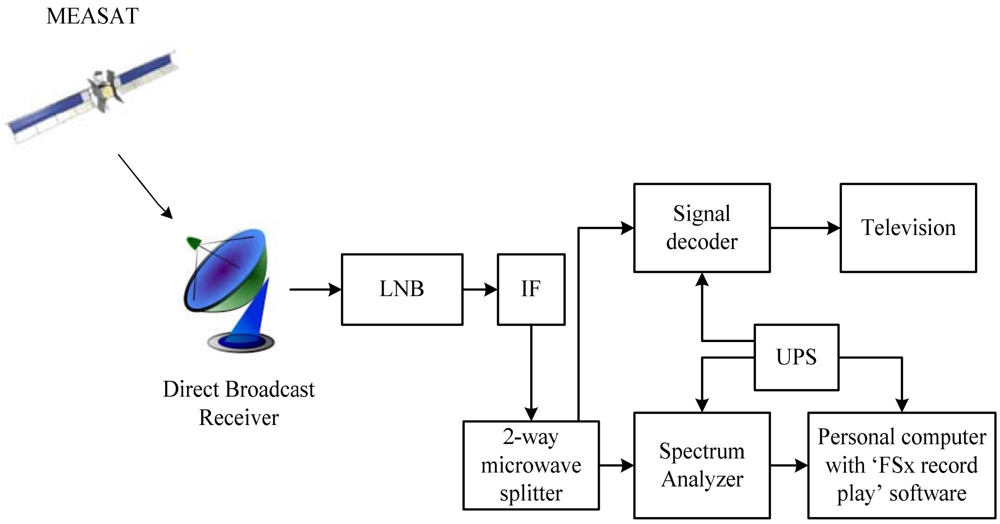
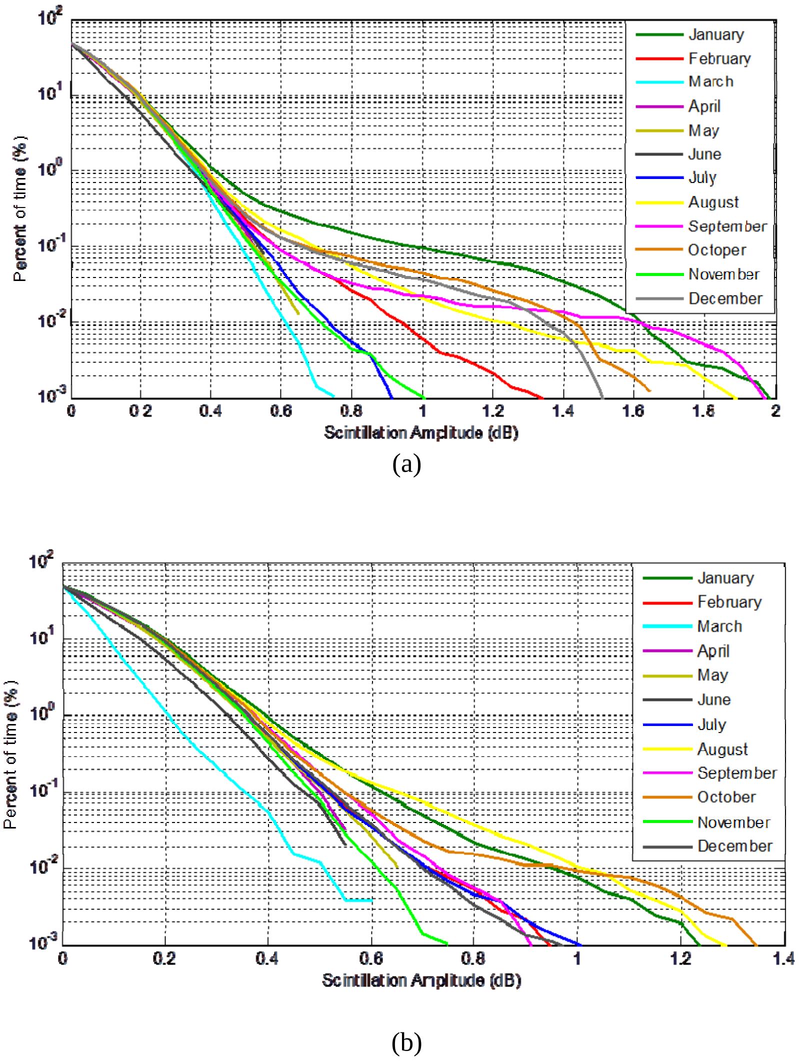


Figure 1. Block diagram of MEASAT satellite receiving system

3. ANALYSIS OF SCINTILLATION AMPLITUDE

The cumulative distribution functions (CDF) of scintillation amplitude statistic is processed for clear-sky events. The results present monthly scintillation data in both fade and enhancement scintillations in the equatorial region. Figure 2(a) and (b) shows that CDF of fade scintillation is higher than enhancement scintillation for all months. Moreover, the signal fade and enhancement are highest in January and August, which exceeded about 0.01% of time range from 1.6 dB to 1 dB, respectively. It is evident that scintillation fade and enhancement at 0.01% of time varied in a range between 0.5 to 1.6 dB all the months. As a consequence, tropospheric scintillation at K_u-band system for high elevation angle links is significant for low fade margin systems.



(a)

(b)

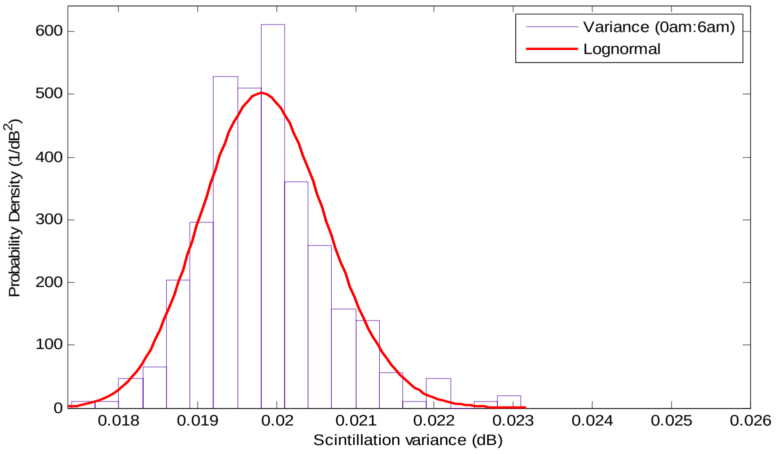
Figure 2. Monthly cumulative distribution function (CDF) for one year measurement; (a) scintillation fade, b) scintillation enhancement

4. STATISTICAL DISTRIBUTION OF DIURNAL SCINTILLATION VARIANCE

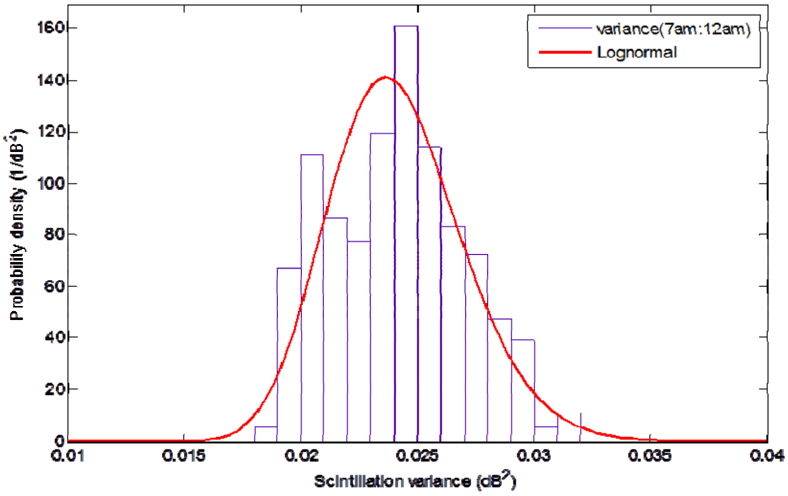
Karasawa and the ITU-R models assume a Gamma PDF distribution forσ_x, Ortgies model proposes a log-normal PDF for σ_x^2 and others use the Rice-Nagakami for σ_x^2.The distributions as shown in Figure 3, as well as distributions for each different time intervals of the day, had been compared to the lognormal distributions. The input parameters for these model distributions were the mean and standard deviation of $\log(\sigma_x^2)$ for the lognormal distribution, which were all calculated from the measured distributions. From the analysis as shown in Figure 3, we can conclude that the best-fitting long-term pdf of σ_x^2 is lognormal on year time period analyzed in hourly basis. As well as, the results clearly showed that higher scintillation variance are more likely to occur during the morning and afternoon periods. The lognormal distribution can be expressed as (1) [16],[17]:

$$p(\sigma_x{}^2) = \frac{1}{\ln 10\sqrt{2\pi}\sigma_{12}\sigma_x{}^2}\exp\left(-\frac{(\log\sigma_x{}^2 - m_{12})^2}{2\sigma_{12}^2}\right) \qquad (1)$$

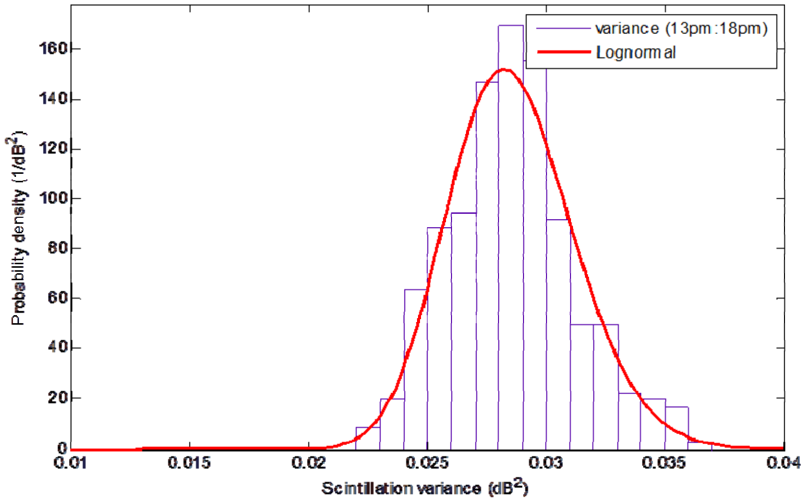
where m_{12}= the mean of $\log \sigma_x^2 = 2m_1$; σ_{12}= the standard deviation of $\log \sigma_x^2 = 2\sigma_1$. Where m_1= the mean value of logσ_x; σ_1= the standard deviation of log σ_x (with σ_x in dB).


Variance (0am:6am)
Lognormal
Probability Density (1/dB^2)
0
100
200
300
400
500
600
0.018
0.019
0.02
0.021
0.022
0.023
0.024
0.025
0.026
Scintillation variance (dB)

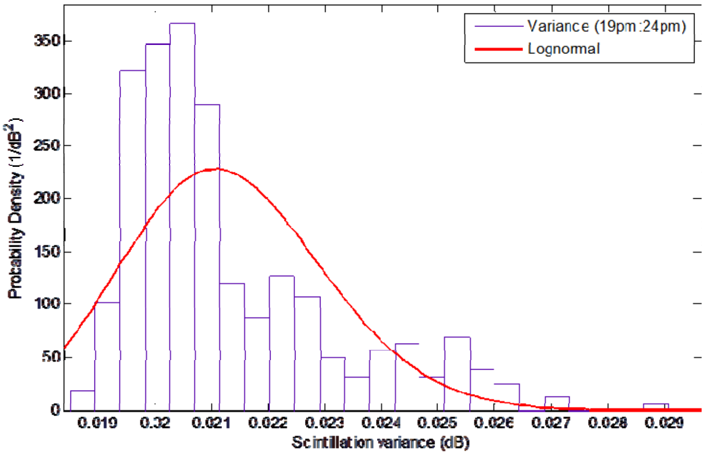
(a)


variance(7am:12am)
Lognormal
Probability density (1/dB^2)
0
20
40
60
80
100
120
140
160
0.01
0.015
0.02
0.025
0.03
0.035
0.04
Scintillation variance (dB^2)

(b)


variance (13pm:18pm)
Lognormal
Probability density (1/dB^2)
0
20
40
60
80
100
120
140
160
0.01
0.015
0.02
0.025
0.03
0.035
0.04
Scintillation variance (dB^2)

(c)

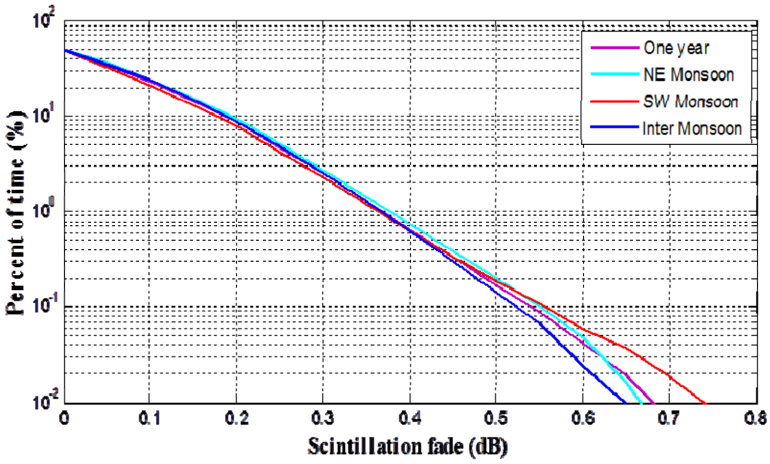


(d)

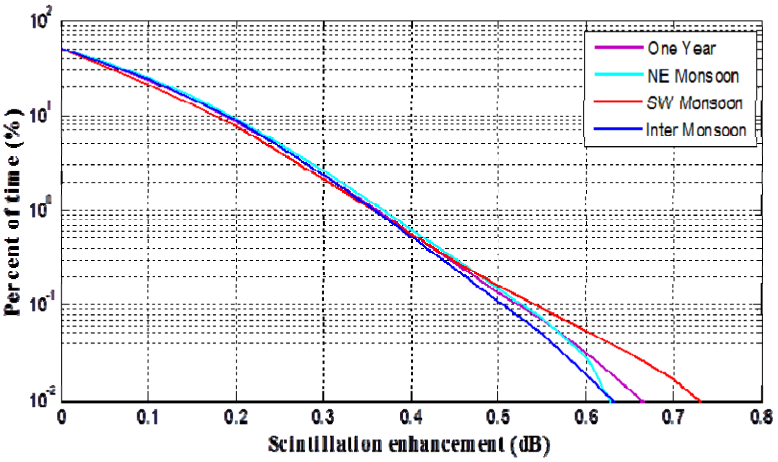
Figure 3. Measured probability distributions of scintillation variance at 11.075 GHz, for the whole year of 2001, and lognormal distributions with the input parameters taken from the measurements

5. SEASONAL VARIATIONS

Seasonal variations of clear sky scintillation were investigated by considering three different seasons: i) North-East (NE) (December to March), ii) South- West (SW) (June to September) and iii) Inter-monsoon (April to May and October to November). Figure 4(a) and (b) shows the cumulative distribution of annual and seasonal scintillation amplitude. The results demonstrate that the South-West monsoon appeared as the season with higher scintillation fade and scintillation enhancement compared to the Inter-monsoon and North-East seasons. For instance, SW monsoon appeared with the highest scintillation of 0.74 dB at 0.01 % of the time for scintillation fade and 0.725 dB at 0.01 % of the time for scintillation enhancement. Meanwhile, inter-monsoon exhibited the lowest scintillation of 0.65 dB at 0.01 % of the time for scintillation fade and 0.625 dB at 0.01 % of the time for scintillation enhancement.



(a)



(b)

Figure 4. Annual and seasonal cumulative distributions of scintillation amplitude extracted from the MEASAT-1 broadcasting satellite signal; a) scintillation fade, b) scintillation enhancement

6. CONCLUSION.

This study was mainly based on one year of data collected from a measurement campaign carried out in UTM, Johor Bahru. The statistics of diurnal variations of clear sky scintillation is presented in Equatorial Johor, Malaysia (a heavy rain region), by using probability density function (PDF) of clear sky scintillation variance. It was found that the lognormal distributions were symmetric to the data during different time intervals of the day. Furthermore, the highest value of the scintillation variance was observed at midday, while the lowest value of scintillation variance defined at midnight. This consequence shows that high temperatures and low relative humidity are the main factors of scintillation. Besides, clear sky scintillation amplitude of the South-West monsoon shows a relatively higher scintillation fade and scintillation enhancement compared to the Inter-monsoon and North-East seasons. This outcome appears scintillation strength in the dry season which provides the highest temperature and lowest rain attenuation. The results can provide significant information on the fluctuations of seasonal and diurnal tropospheric scintillation at K_u-band earth space link in tropical regions.

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