Prediction of Tropospheric Amplitude Scintillation on Earth-Space Paths with High-Elevation Angle

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Abstract: This paper presents the studies on prediction models of tropospheric scintillation. The prediction scintillation models are Karasawa and ITU-R , which can be improved for different locations and circumstances. In this paper, the investigation of average time between variance $\sigma_n{}^2$ and the wet part of refractivity N_{wet} under various conditions of meteorological parameters have been carried out at King Mongkut's Institute of Technology Lankrabang , Bangkok , Thailand , in the range of Ku-band (12.260 GHz) on high elevation angle from Thaicom2 satellite. From the studies results shows that average period of time of 30 days are best suitable for find out the relation between average time variance $\sigma_n{}^2$ and the wet part of refractivity N_{wet} according to Karasawa model, the average time variance is express as $\sigma_n{}^2 = (0.003N_{wet} - 0.1313)^2$, the appropriation model for occurrence of scintillation has been analyzed and experimental results are carried out.

Keywords: prediction model, scintillation, satellite communication

1. INTRODUCTION

Tropospheric scintillation is caused by variations of refractive index due to turbulence. Tropospheric scintillation prediction models have been described by Karasawa, yamada, and Allnult and ITU-R**.** Both of these models ultize the experiment data at low elevation angle in cool country. This paper is interested in finding out the model use for the experiment at high elevation in tropical zone such as Thailand, which located near equatorial region, where they have many effect from troposphere scintillation.

This paper examined by using model of Karasawa and ITU-R and improved model for use in tropical zone.

2. PREDICTION MODEL

2.1 Model of long-term correlation with meteorology

The prediction model of scintillation intensity presented by Karasawa [1] and ITU-R [2] , based on monthly mean values of the wet part of the refractivity N_{wet} , which is relation of relative humidity U in percent (%) , and temperature t in degrees centigrade (°C) , which is measured at ground level

$$N_{wet} = \frac{22790\ U\ e^{19.7t/(t+273)}}{(t+273)^2} \quad \text{ppm} \tag{1}$$

The prediction model of Karasawa [1] has derived following from

$$\sigma_{pre} = 0.0228\,\sigma_n f^{0.45}\sqrt{G(D_e)}\ /\sin^{1.3}\varepsilon \quad \text{dB} \tag{2}$$

where

$$\sigma_n = 0.15 + 5.2x10^{-3}\,N_{wet} \tag{3}$$

and f = frequency in gigaherz (GHz)

θ = elevation angle

$G(D_e)$ is antenna averaging function described by [3]

$$G^2(D_e) = \begin{cases} 1.0 - 0.7\left(\frac{D_e}{\sqrt{\lambda L}}\right) & ,0 \le \frac{D_e}{\sqrt{\lambda L}} \le 1.0 \\ 0.5 - 0.2\left(\frac{D_e}{\sqrt{\lambda L}}\right) & ,1.0 < D_e \le 2.0 \\ 0.1 & ,2.0 < \frac{D_e}{\sqrt{\lambda L}} \end{cases} \tag{4}$$

D_e is the effective antenna diameter given by

$$D_e = D\sqrt{\eta} \tag{5}$$

D is the geometrical antenna diameter and η is the antenna aperture efficiency, L is the distance to height of thin turbulent layer given by

$$L = \frac{2h}{\sqrt{\sin^2\varepsilon + 2h/R_e} + \sin\varepsilon} \tag{6}$$

For elevation angle $\varepsilon < 5°$, the $\sin\varepsilon$ in Eqs. (2) should be replaced by

$$\left(\sin\varepsilon + \sqrt{\sin\varepsilon^2 + 2\,h_w/R_e}\right) \tag{7}$$

h_w is the effective height of water vapour in atmosphere , Karasawa suggested a values for height h of the turbulent layer of 2000 m and R_e is the effective earth radius = $8.5x10^6$ m.

ITU-R [2] following the basic formulation technique was derived from Karasawa model, the resulting prediction has formula

$$\sigma_{pre} = \sigma_n f^{7/12}G(D_e)\ /\sin^{1.2}\varepsilon \quad \text{dB} \tag{8}$$

where

$$\sigma_n = 3.6x\,10^{-3} + 10^{-4}\,N_{wet} \quad (9)$$

$G(D_e)$ is antenna averaging function described by [4]

$$G(D_e) = \sqrt{3.8637\left(x^2+1\right)^{11/12}\sin\left[\frac{11}{6}\arctan\frac{1}{x}\right] - 7.0835\,x^{5/6}} \quad (10)$$

where $x = 0.0584k\,D_e^2 / L$, where k is the wave number = $2\pi / \lambda$, λ is the wavelength and h of the turbulent layer in the ITU-R model assumed to be 1000 m.

The Karasawa model is based upon measurements covering the elevation angle of 4° to 30° , frequency range of 7.3 to 14.2 GHz and antenna diameter between 3 to 36.6m , for ITU-R model can covering elevation angle of 4° to 32° , frequency range of 7-14 GHz and antenna diameter between 3 to 36 m.

2.2 Model for signal level distribution

Karasawa model [1] present the long-term distribution of signal level deviation due to scintillation y , expressed in terms of the predicted long-term standard. The estimation of this distribution cam be calculated by using the integration formula

$$p(y) = \int_0^\infty p(\sigma)p(y|\sigma)d\sigma \quad (11)$$

where $p(\sigma)$ is the distribution function of short-term standard deviations and $p(y|\sigma)$ is the short-term distribution function of signal level y for a given standard deviation σ , Karasawa assumed Gamma distribution for $p(\sigma)$ and Gaussian distribution for $p(y|\sigma)$. The resulting amplitude exceeded for a time percentage of P is given by

$$y = \left(-0.0597\log^3 P - 0.0835\log^2 P - 1.258\log P + 2.672\right)\sigma_{pre} \quad (12)$$

where σ_{pre} is the long-term signal standard deviation , which can be calculated from Eqs. (2) for Karasawa and Eqs. (6) for ITU-R , Eqs. (9) for signal enhancement . For signal fade , giving the relation

$$y = \left(-0.061\log^3 P + 0.072\log^2 P - 1.71\log P + 3.0\right)\sigma_{pre} \quad (13)$$

The ITU-R adopted only the Eqs. (12)

3. RESULT

3.1 Mesurement setup

The experimental data were carried out at King Mongkut's Institute of Technology Lankrabang , Bangkok , Thailand. The configuration of earth station is presented in Table1.

Table 1. Principal System Parameters

Receiving satellite	**Thaicom 2**
Location of ground station	13° 45′ 36″ N 100.8° 48′ 17″ E
Antenna Diameter	30 cm offset
Receiving frequency	12.260 GHz
Elevation angle	59.9°
Data sampling rate	100 ms

The results are presented have selected data from February, 2002 to January, 2003, consist of five minutes mean and standard deviation values of received signal. Fig1. and Fig 2. show the monthly mean temperature and relative humidity corresponding measurement data was recorded.

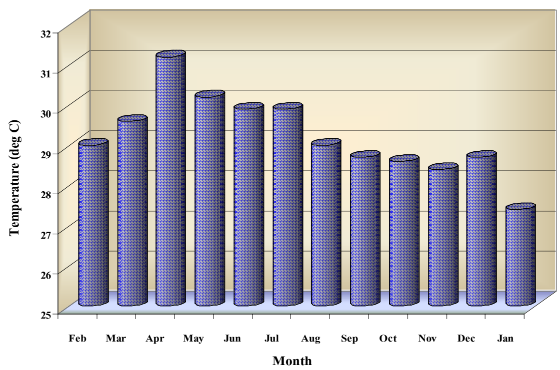

Fig. 1 Monthly mean temperature, Feb 02 - Jan 03.

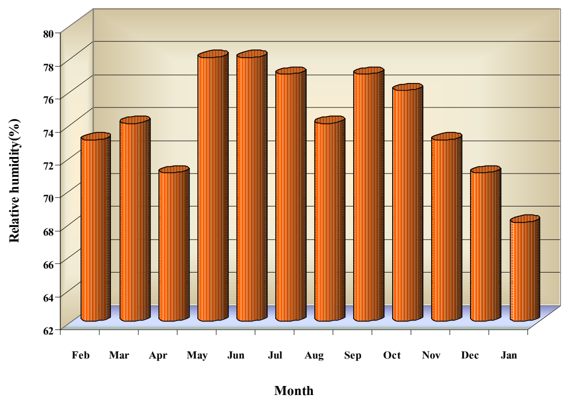

Fig. 2 Monthly mean relative humidity, Feb 02 - Jan 03.

3.2 Diurnal Variation

The main parameter to be studied in this paper is the scintillation intensity or variance (σ^2), calculated as the square of standard deviation of the signal amplitude (dB). Fig. 3 show the diurnal variable of scintillations variance of the hourly of day averaged over for a period of 1 year. The peak of variance occurs around the local noon, the highest found at the 13.00 and also found scintillations are highest in summer and lowest in winter.

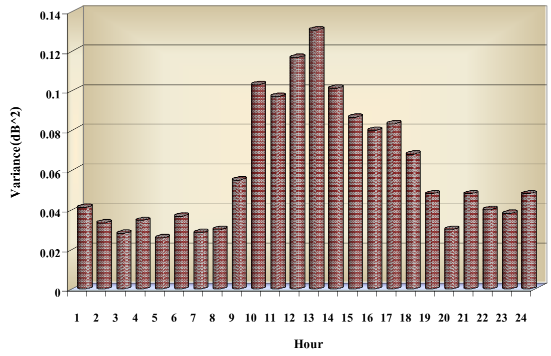

Fig. 3 Hourly variation of scintillation variance averaged for period 1 year.

3.3 Distribution of variance

[5] suggests the probability density function (PDF) are lognornal and gamma distribution for approximately measured signal. Fig. 4 and Fig. 5 show the sample plot of the lognornal and gamma distribution of measured variance. In Fig.4 show the measured distribution was lognormal distribution, which input parameters were the mean and standard deviation of $\log(\sigma^2)$.

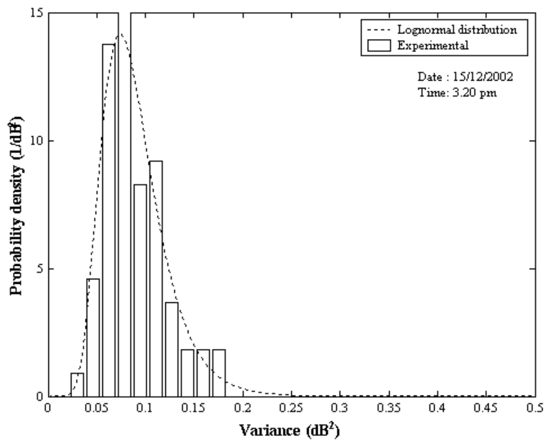

Fig. 4 The example of measured lognormal distribution of scintillation variance.

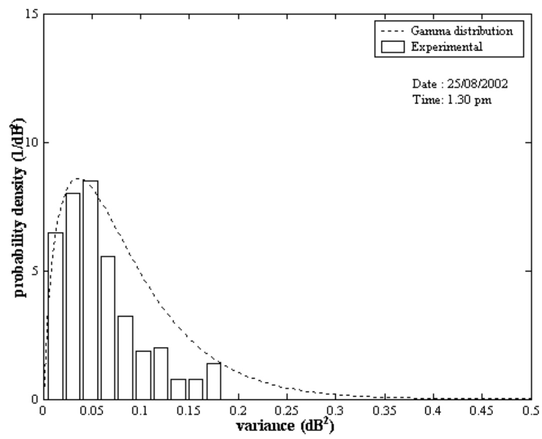

Fig. 5 The example of measured gamma distribution of scintillation variance.

Fig. 5 shows gamma distribution, which input parameter were mean and standard of σ. For the results found that the both distribution fits for data was recorded, sometimes found that measured data fits the lognormal distribution and sometimes fits the gamma distribution.

3.4 Comparison with models

Fig. 6 show the comparison of measured data and predicted values of monthly averaging variance by Karasawa model and ITU-R , the predicted by Karasawa used Eqs. (3) and ITU-R predicted by Eqs. (9) . It is found that the both of model overestimated the measured data, because the measurement data were carried out at high elevation and different climate , so we must be analyze some parameters for improve the prediction model , and we will described in next section.

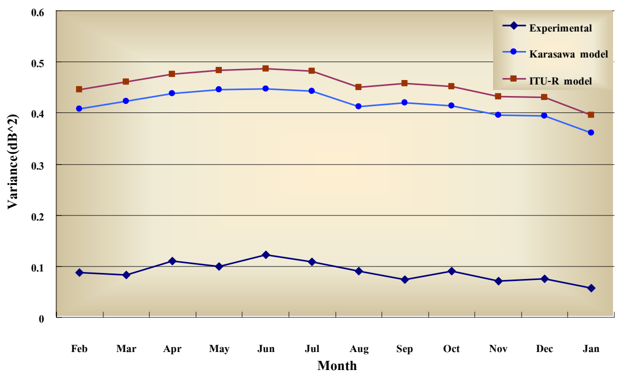

Fig. 6 Comparison between monthly variation of scintillation variance and predicted by Karasawa and ITU-R.

4. IMPROVEMENT AND ANALYSIS

The prediction models of Karasawa and ITU-R, which can be improved for different locations and climate, which refer to the wet part of refractivity N_{wet} relation with temperature and relative humidity at ground level , under various conditions of meteorological parameters have been carried out at King Mongkut's Institute of Technology Ladkrabang , Bangkok , Thailand , in the range of Ku-band (12.260 GHz) on high elevation angle (59°) from Thaicom2 satellite. The meteorological for analysis came from the measurement temperature and relative humidity. Fig. 7 show the wet part of refractivity N_{wet} is calculated by using Eqs. (1), which used the occurrence temperature and relative humidity.

The objective of this paper to find the averaging period for the good correlation between occurrence scintillation variance and wet part of refractivity N_{wet} in Thailand, the analysis by averaging over different periods showed in Table2.

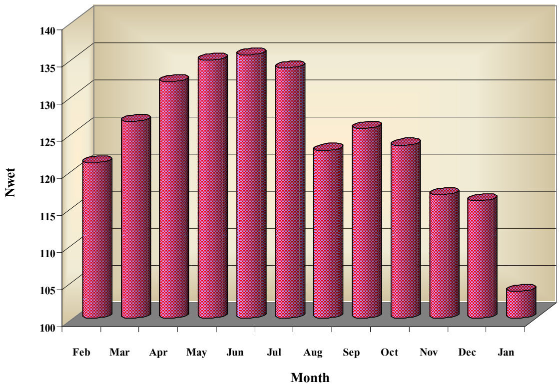

Fig. 7 The wet part of refractivity N_{wet} is calculated by Eqs. (1).

Table 2. Correlation between (σ^2) and N_{wet} have been averaged over different periods.

Averaged period	Correlation
7 day	0.660
15 day	0.853
30 day	0.903

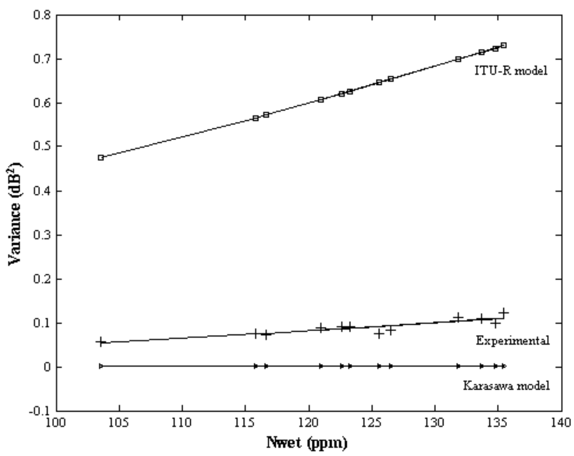

Fig. 8 Correlation between N_{wet} and (σ^2) on one month averaging.

The resulting of averaging periods, the correlation of N_{wet} and (σ^2) are very high for an averaging one month, it can be fitted show in Fig 8. The resulting can expression from the curve fitting is

$$\sigma_n{}^2 = (0.003 N_{wet} - 0.1313)^2 \quad \mathrm{dB}^2 \qquad (12)$$

From Fig.8, it is found that the predicted curve is closer experimental than the model of Karasawa and ITU-R , and then using the Eqs. (12) to plot the predicted monthly variance curve compare with the Karasawa model in the Eqs. (3) and ITU-R model in the Eqs. (7) , it is found that the predicted by Eqs. (12) closer than the predicted by Karasawa and ITR-U model show the result in Fig 9.

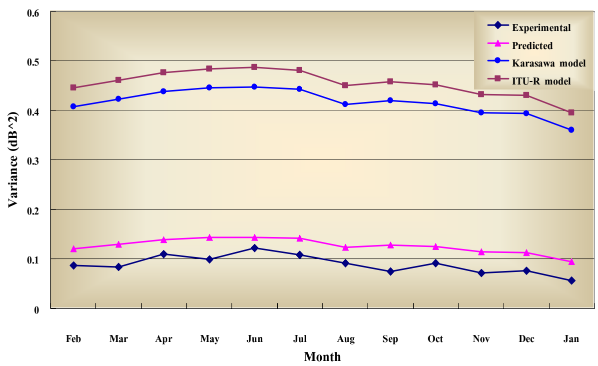

Fig. 9 Monthly variation of scintillation variance comparison with predicted by Karasawa , ITU-R and improvement.

5. CONCLUSSION

A scintillation prediction model was proposed based on the measurement of scintillation in 12.260 GHz band, high elevation angle in the hot country.

This model include metrological parameters in Thailand which have not been covered in existing models and expected to be applied hot region. This model is always necessary for unifications over long period of time and another parameter such as the intensity of sunlight.

6. REFERENCE

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