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*Full Length Research Paper*

# Experimental analysis of tropospheric scintillation in Northern Equatorial West Malaysia

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**This paper compares predicted monthly scintillation means of nine scintillation prediction models to the monthly mean of the empirical data collected from the beacon receiver located at Universiti Sains Malaysia (USM). Tropospheric scintillation is a phenomenon where a rapid fluctuation of signal happens due to the turbulence at the atmosphere. The tropospheric scintillation models which use to compare to the actual scintillation data are Ortigies T, DPSP, MPSP and KVS. The ground station of the satellite system has a frequency of 12.255 GHz and elevation angle of 40.1° and the data is gathered from January 2002 till December 2007. The scintillation amplitude of each prediction model is plotted into graph and the percentage of error is calculated to analyze the different between the actual scintillation data and prediction model in Northern Malaysia. The findings show the Ortgies-T gives the best fit result among the others in Northern Malaysia.**

**Key words:** Tropospheric scintillation, satellite, Ku-band.

## INTRODUCTION

The rapid development of telecommunication and the increasing demands for larger channel capacity is forcing the use of beacon frequencies in the K band (Vasseur, 1999). At frequencies above 10 GHz, tropospheric scintillation is an important source of signal degradation in satellite communication systems and it may cause as much attenuation as rain, especially for time percentage lager than 1% depending on its operational frequency and elevation angle (Marzano and ’Auria, 1999; Vasseur, 1999). Therefore in the past years many microwave propagation experiments have been carried out to evaluate the impact of tropospheric scintillation on the budget design of satellite link. Predicting tropospheric scintillation then became a growing interest by many researchers to develop statistical methods based directly from meteorological data (Karasawa et al., 1988; ITU-R P.618-7, 2009; Van-de Kamp et al., 1999; Mayer, 2002; Mandeep et al., 2011).

This prediction models are separated into two categories. Firstly the scintillation variance prediction models which are KVS (Tervonen et al., 1998). Secondly the lognormal scintillation prediction models which are Ortgies-T, DPSP and MPSP (Geoffory et al., 1997). Table 1 shows information about the scintillation model including the year it was proposed, parameters such as frequency dependence exponent, the angle dependence exponent, the surface meteorological parameter, the turbulent layer height H and empirical data which the scintillation model is based. Each scintillation model has at least four components to its model. The basic scintillation model, which also applies to the lognormal model, is formulated as (Mayer, 2002).

$$\sigma^2_\chi = G\ (R_p, f, \eta, \theta, H)\ P(\textit{weather})\ f^{\alpha} \sin^{b} \theta\ (\mathrm{dB}^2) \qquad (1)$$

where $\sigma^2_\chi$ is the scintillation variance, G ($R_p$, *f*, η, θ, *H*) is the antenna aperture averaging factor, *f* is the frequency in GHz, η is the total antenna efficiency, θ elevation angle, *H* is the turbulent layer height (m) and P(*weather*) is the meteorological factor usually temperature (t), wet term refractive index ($N_{wet}$), cumulus cloud cover, P(Cu) or average water content of heavy clouds, $W_{hc}$. α and *b*

**Table 1.** Parameters of the pre-existing tropospheric scintillation models.

| Scintillation model | Year | Freq. depend. | Sinθ dep. | Par | H (m) | Data source | Model restrictions |
|---|---|---|---|---|---|---|---|
| **KVS** | 1998 | 0.45 | -1.3 | $N_{wet}$ P(Cu) | 2000 | Kirkkonummi | 7-14 GHz ($4 < \theta < 30^0$) |
| **Ortgies-T** | 1993 | 0.605 | -1.2 | T | 1000 | Darmstadt, Germany | $6.5 < \theta < 30^0$ |
| **DPSP** | 1997 | 0.583 | -1.2 | T | 2058 + 94.5T | Louvain-la-N, Belgium and Milan, Italy | T > -5 C |
| **MPSP** | 1997 | 0.583 | -0.92 | T | 2058 + 94.5T | Louvain-la-N, Belgium and Milan, Italy | T > -5 C |

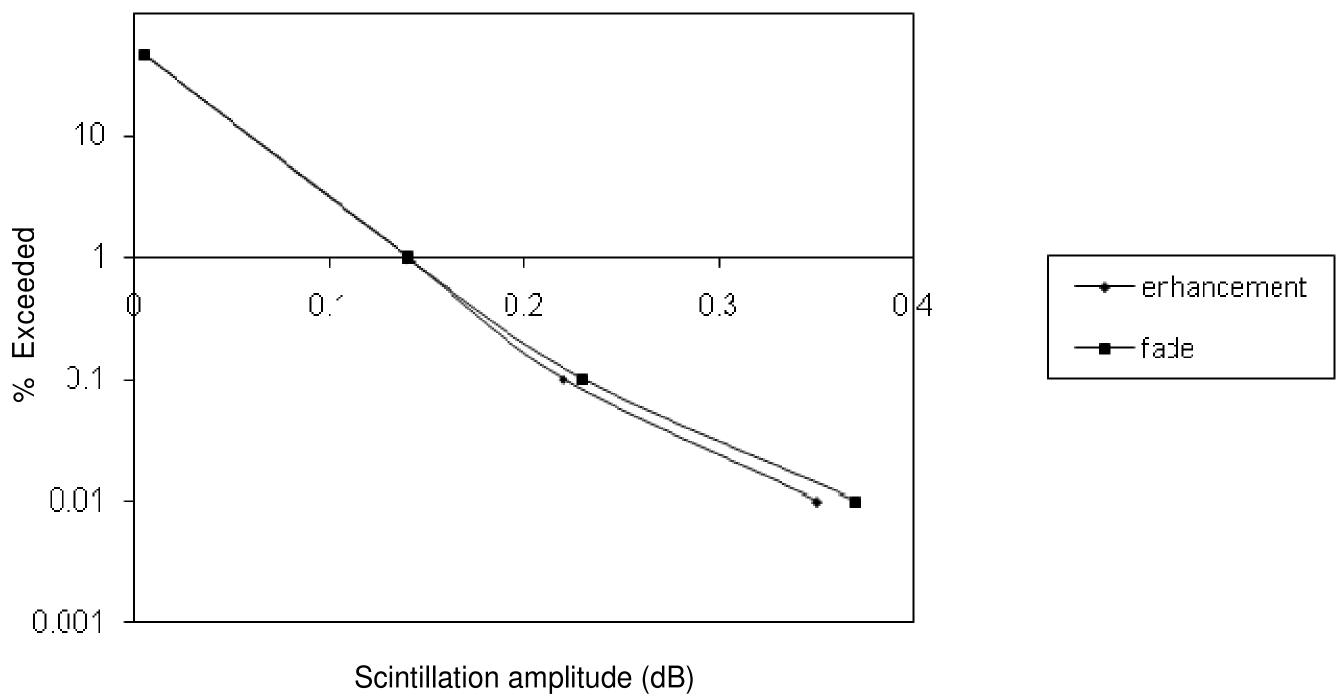


**Figure 1.** Cumulative distribution of scintillation amplitude form 2002 to 2010.

are the frequency and angle dependence exponent.

**METHODOLOGY**

To evaluate the extent of this variability, analysis of measurement was performed of signal magnitude from the 12.255 GHz beacon receiver using a Superbird-C satellite. This measurement was carried out between January 2002 to December 2010 at a sampling rate of 1 Hz and an elevation angle of 40.10 using a receiver antenna of 2.4m diameter. The scintillation amplitude calculation was done during clear sky (absent of rain and spurious spikes) (Figure 1). Spurious and invalid data have been eliminated by visual inspection of all data sequences. Before using the measured raw beacon propagation data for scintillation studies, contribution to data fluctuations by other propagation factors must be excluded.

## RESULTS AND DISCUSSION

Scintillation, which consists of enhancement above, and fades below the clear sky un-faded signal level are shown in Figure 2 for USM. The negative signal deviations or fade is on average larger than the positive or enhancement due to large signal fluctuations caused by the refractive index inhomogeneities induced by strong

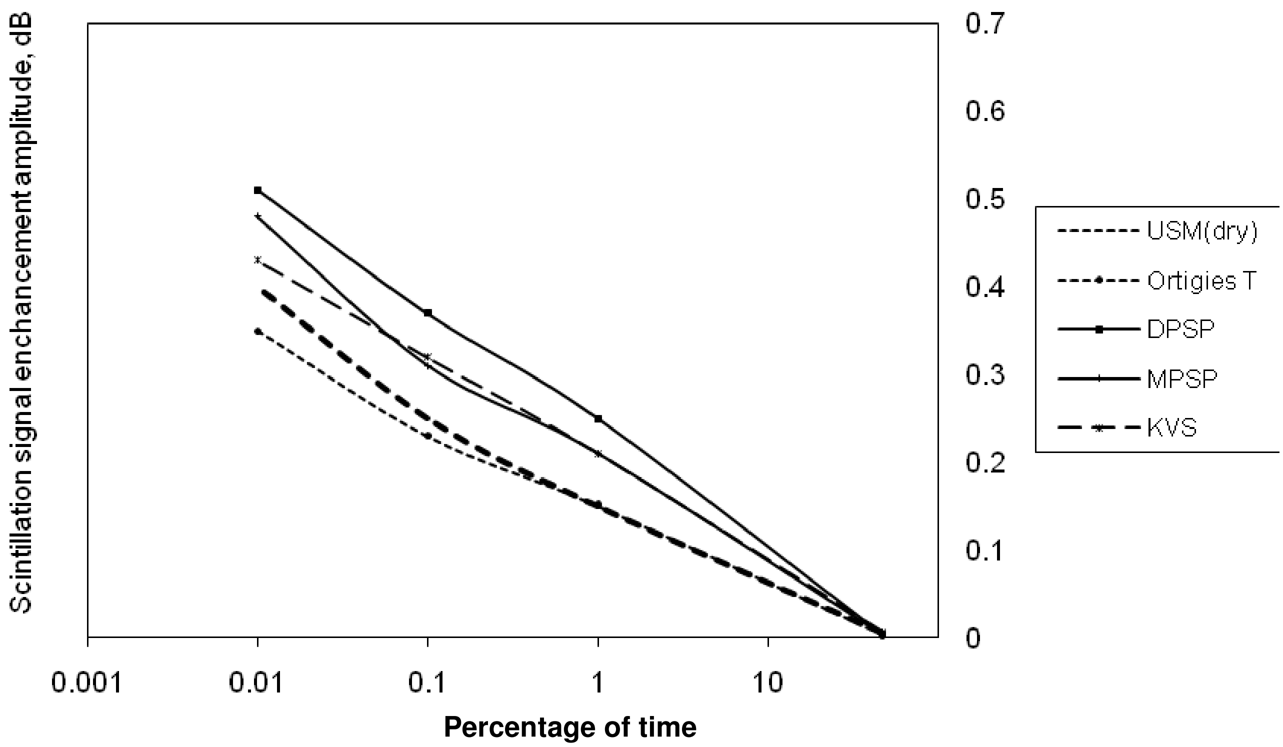


**Figure 2.** Comparison of measured annual scintillation signal enhancement amplitude with prediction models.

atmospheric turbulence in the clouds passing along the propagation path. Signal enhancement and fade levels are overall higher compare to year 2002 from 0.1% percentage of time to 0.01% percentage of time, because of the increase on the liquid water density of the clouds by 0.1 g/m$^3$ (annually).

Figure 2 shows the comparison of the measured data with the predicted model. The Ortigies T model approximates closely the measured signal enhancement scintillation amplitude values for the entire prediction percentage time. This is because the model depends closely on the ground temperature. The model was developed based on higher elevation angles and temperature. The DPSP model overestimates the measured signal enhancement scintillation amplitude values for the entire prediction time because the height of the turbulent layer varies with the ground temperature it should vary with the sky or cloud temperature. The MPSP model overestimates the measured signal enhancement scintillation amplitude values for the entire prediction time This model performed better compared to the DPSP model is because the model includes a thin layer of homogeneous turbulent atmosphere equation that is directly correlated with the surface temperature and the vertically integrated water vapour content. The KVS model overestimates the measured signal enhancement scintillation amplitude values for the entire prediction time. This is because the model was developed based very low temperature, high humidity and long hours of cumulus clouds present.

Figure 3 shows the comparison of the signal fade measurement with the predicted models. The Ortigies T, DPSP and MPSP model has the same result of cumulative distribution for the fading signal as to the enhancement signal because the researchers have assumed the signal level for both fade and enhancement to be symmetrical. KVS overestimates the measured signal fade scintillation amplitude values for the entire prediction time followed back by Ortigies-T and VTSB until December.

## Conclusions

The evaluations of existing tropospheric scintillation prediction model have been done with comparism to the measured scintillation data obtain from Superbird-C satellite. Overall the Ortigies-T model is the best scintillation prediction model and it found to be suitable to be used in USM location. Model based in $N_{wet}$ underestimate the measured scintillation data. Some of the prediction model has percentage of error higher than 100% hence they are not suitable to use to predict tropospheric scintillation in tropical country. Ortigies-T

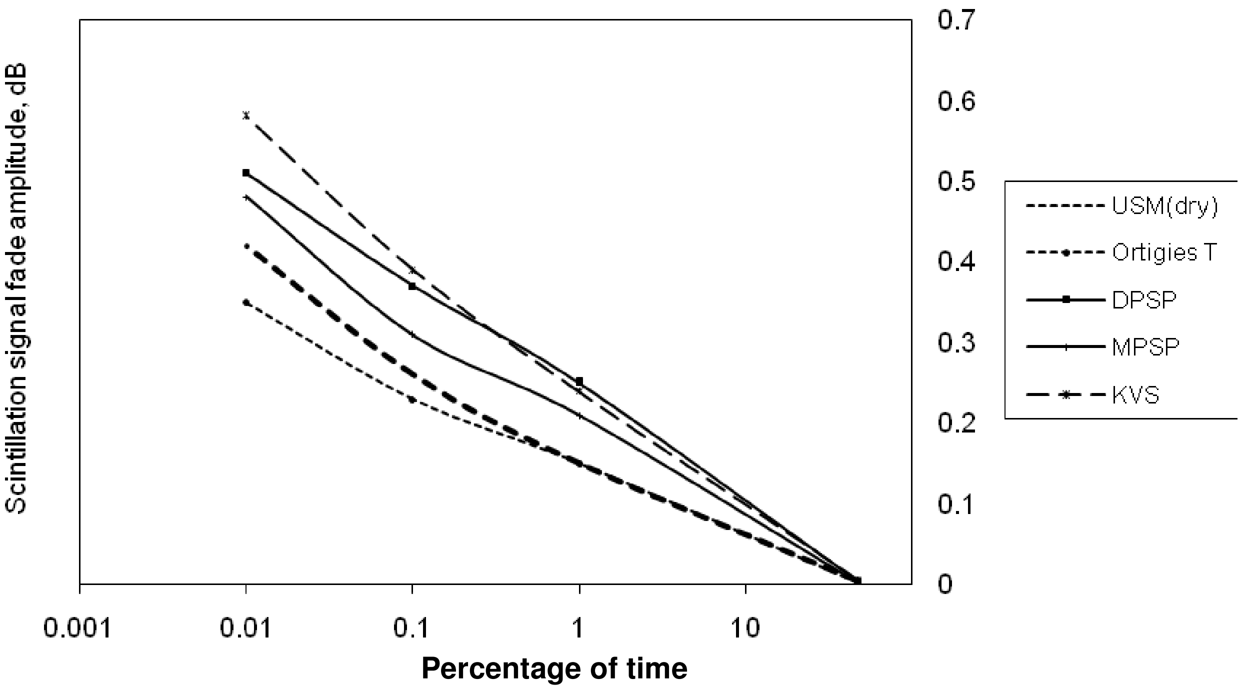


**Figure 3.** Comparison of measured annual scintillation signal fade amplitude with prediction models

scintillation models can be improved introducing elevation and frequency parameters that are function of climate conditions, either wet term refractive index or temperature.

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