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Effect of Scintillations on Ka-band Frequency Satellite signals

R.Prabhakar[1], Dr.T.Venkata Ramana[2]

Research Scholar[1], Assoc..Professor[2]
.GITAM University,
Visakhapatnam,A.P,India

Abstract:

Scintillation is a transmission impairment. The Received Satellite signals degradation due to the scintillation on space to earth link in tropical region. This proposed work goal is to find the performance evaluation of scintillation in clear sky conditions. To estimate and compare the statistic of atmospheric scintillation based on the parameters in ITU-R model. To evaluate Atmospheric Amplitude scintillation, the parameters required are scintillation intensity, standard deviation of predicted signal, frequency, elevation angle, antenna averaging, effective, diameter of antenna, geometrical diameter of antenna and antenna aperture efficiency.

To observe the relationship between the scintillation intensity and the local environmental parameters. An experimental satellite signal measurements need to analyse and to be compare with meteorological parameters. New prediction model for the scintillation effect could be develop and need to specify the improvements to existing models in Ka band.

Index Terms— Scintillation, Amplitude ,Angle, Ka-Band frequency, ITU-R and other Prediction Models .

Introduction

In telecommunications , Satellite Communications provide high bandwidth and data. Signal degradation due to solar radiation the ground surface heats up, boundary layer of atmosphere excites, causing refractive index to be varied slightly generates as the atmosphere turbulent. When signals travels through this turbulent mixing atmosphere, it will experience alternation and scattering which received and called as scintillation, Components are due to turbulence, pure scattering and apparent scintillation. Several models are applied to calculate the tropospheric scintillation such as ITU-R Model, Karasawa Yamada Allnutt model, Ounting model, Ortgies model, DPSP model and Van de Kamp model etc. Scintillation also changes diurnally. And also present the effect of diurnal variation on tropospheric scintillation.

SC operates Ka-band frequency in low elevation angle 10º and low margin <3 to 4dB are vulnerable to tropospheric scintillation. The prediction and modeling of Tropospheric scintillation effect to be important for high degradation in scintillation. Scintillation models needed to be accurate for designing systems like Karasawa and the ITU-R model that will be presented are only considering the clear sky scintillation. Analysis of measurements at Ka band frequency and elevation angle. The impact of scintillation on satellite communication systems to be developed for applying scintillation measurements on a satellite downlink to remote sensing of the atmosphere. To evaluate Atmospheric Amplitude scintillation, the parameters required are scintillation intensity, standard deviation of predicted signal, frequency, elevation angle, antenna averaging, effective, diameter of antenna, geometrical diameter of antenna and antenna aperture efficiency.

Model	**Specifications**
ITU-R	DBSG5 database
Otung	19.8-GHz satellite link, elevation angle of 28.7, diameter 7.6 m, Sparsholt, UK,and 1 year of data (1996)

DPSP	18.7, 39.6, and 49.5-GHz satellite link, elevation angle of 30.6, diameter of 1.8 m, Milan, Italy, 1 year of data (1998)
Ortgies	20 and 30-GHz satellite link; diameter of 0.6, 1.8, and 3.7 m; Darmstadt, Germany, and 1 year of data (1993)
Van de Kamp	19.8- and 29.7-GHz satellite link, elevation angle of 12.7, diameter of 1.8 m, Helsinki, Finland, 1 year of data (1998)

ITU-R Model

Tropospheric Scintillation prediction model proposed by the International Telecommunication Union-Radio communication sector was used for calculating the standard deviation of signal fluctuation due to scintillation. This model uses the wet term of earth refractivity *wet* N, regarding relative humidity and temperature, averaged at least once a month as input. This model is applicable for frequencies ranging from 7GHz to 20 GHz and 4 to 32 elevation angles. In this model statistic of scintillation can be estimated from the parameters of environment. ITU-R model determine the parameter of σ, of signal amplitude in dB, referred as scintillation intensity.

The parameters are:

n=antenna efficiency,
,θ=elevation angle of antenna,
f = frequency
t= average monthly temperature
H =average relative humidity,

Scintillation intensity: The value of es(hPa):

es=EF.a.exp[(b-t/d).t/(t+c)], the saturation water vapour pressure.

Nwet= 3732 H es /(273+t), The wet term and radio refractivity,

σref=3.6x10^-3 +10^-4 Nwet, standard deviation of the signal amplitude:

$$L = \frac{2h_L}{\sqrt{\sin^2\theta + 2.35\times10^{-4}} + \sin\theta}$$

The value of effective path length L, hL =1000m.

Deff=√(η).D m,The value of the effective antenna diameter *Deff* and *D* is geometrical diameter, η is antenna efficiency.

g(x)=√(3.86(x^2+1)^11/12.sin(11/6arctan1/x)-7.08x^5/6), Antenna averaging factor g(x),
where x=1.22Deff^2(f/L),
σ = σref f^7/12 g(x) /(sinθ)^1.2, standard deviation
a(p)=0.0061(log10p)^3+0.072 (log10p)^2-1.71log10p+3.0
where a(p) is the time percentage factor for time percentage p ,0.01<p<50.
As(p)=σ(p).σ dB,fade depth.

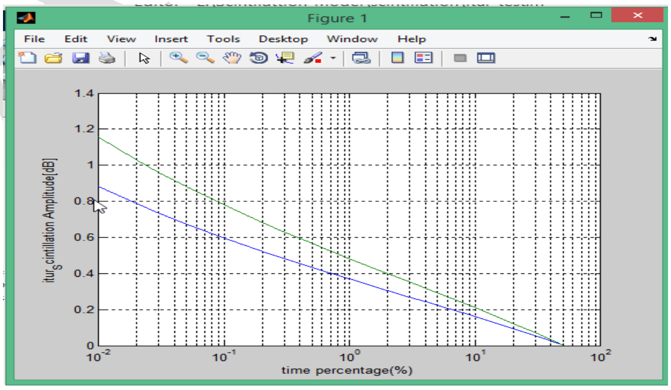

Fig1.ITU-R model

Van de Kamp Model

The model development was done at four different places which are Finland, United Kingdom, Japan, and Texas. For both Karasawa and ITU-R model, scintillation was measured based on only monthly average of wet part of refractivity Nwet at ground level. So, Van de Kamp model proposed to extend Karasawa and ITU-R model which cloud scintillation also taken into consideration. Diurnal variation in scintillation was also introduced in this model. With diurnal variation, could be seen that effect of scintillation is different at morning, midday, evening and night. [2]

$$\sigma_{pre}=\sigma_{reff}{}^{0.45}g(x)(\sin\theta)^{1.3}\sigma pre=\sigma reff0.45gx\sin\theta1.3$$

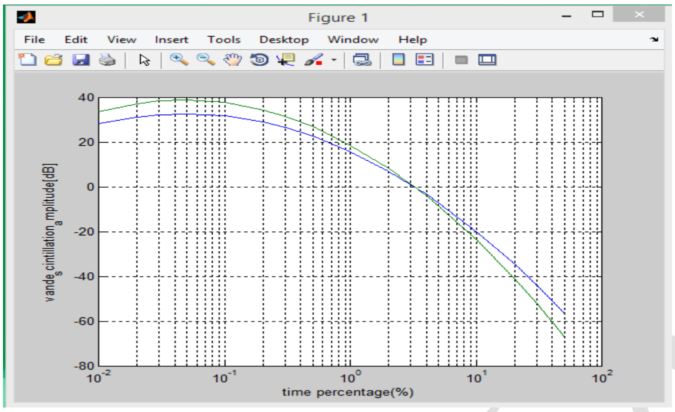

Fig2.Van de Kamp model

DPSP Model

The Direct Physical Statistical Prediction (DPSP) model was developed using the measurement data for 1 year from Louvain-la-Neuve in Belgium and Milan in Italy. The data were collected by the Olympus satellite beacon at frequencies of 29.7, and 19.77 GHz. The antenna diameters for the antennas in Belgium and Italy are 1.8 and 1.5 m, respectively.

The elevation angles of the antennas are 27.60° and 30.60°, with a post-processing sampling rate of 1Hz. A threshold value was imposed on the scintillation data because of the noise of the equipment, and any scintillation intensity above 0.04 dB was considered a scintillation event. For both models, the wet term refractive index was not considered because of the lack of humidity data. The DPSP model.

$$\mathrm{In}\sigma^{2}_{pre}=\ln[g(x)\cdot f^{1.166}(\sin\theta)^{-2.4}]+[-16.95+0.1235T].$$

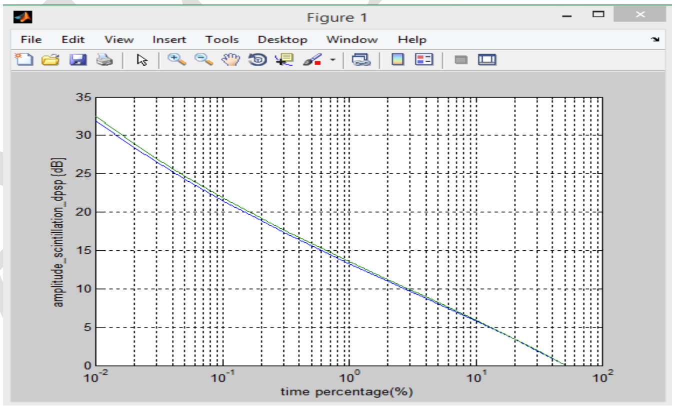

Fig3.DPSP Model

Otung Model

This is perceived in the receiver as scintillation superimposed on the mean fade depth. Theoretical expressions are obtained for the variance of each component of scintillation. Experimental measurements of scintillation at three sites in the United Kingdom using the European Space Agency's Olympus satellite are described. The experiments also included a concurrent distrometer measurement of rain drop size distribution in one site. A digital processing method is devised for extracting scintillation-induced fluctuations and rain attenuation time series from the jumble of fluctuations in raw propagation data. Results of an extensive analysis of measurements on the Olympus-Sparsholdt ownlink at 20 GHz and path elevation of 29.2° are presented. Peak-to-peak scintillation amplitude exceeded 1.35 dB during 1% of one-minute intervals in the year. The mean corner frequency of scintillation power spectral density was 0.27 Hz. The variation of hourly scintillation intensity was well approximated by a lognormal distribution, although a Gamma distribution was followed as well in some months. Scintillation amplitude followed a normal distribution over short term intervals of weak-to-moderate turbulence. The Moulsley-Vilar model gave good prediction of scintillation fade for annual time percentages above 0.01%, but consistently overestimated scintillation enhancements. Semi-empirical models are developed which give the annual cumulative probability distribution of scintillation fade and enhancement. These new models gave excellent agreement with our measurements and are applicable to any satellite link. The Scintillation is polarisation sensitive, being more pronounced on vertically polarised signals than on signals transmitted with horizontal polarisation. The impact of scintillation on satellite communication systems is discussed and a scheme is developed for applying scintillation measurements on a satellite downlink to remote sensing of the atmosphere.There was good agreement with the ITU-R prediction of seasonal and annual average scintillation intensity and with their prediction of scintillation fade distributions at annual time percentages above 0.4%.

Σpre=σreff7/12g(x)(sinθ)1112/.σpre=σreff7/12gxsinθ1112.

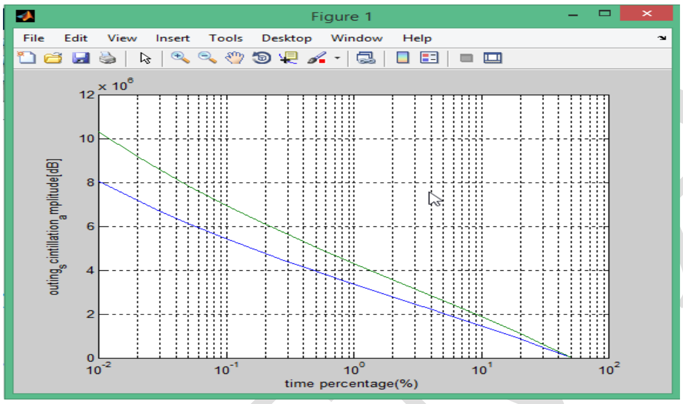

Fig4.Otung model

Marzano's model

The Marzano statistical temperature and humidity 2 (STH2) and statistical temperature and refractivity 2 (STN2) models are developed using the statistical multivariate regression method. The models are developed based on 10-year conventional radio-sounding observation (RAOB) and compared with 19.8-GHz microwave slant link at an elevation angle of 30.6°. The models predict monthly mean logarithm of log-signal variance by scaling a normalized mean logarithm of log-signal variance.

⟨ln(σpre2)⟩=ln[g2(x)·k1.166(sinθ)−116]+⟨ln(σχn2)⟩.lnσpre2=lng2x·k1.166sinθ-116+lnσχn2.

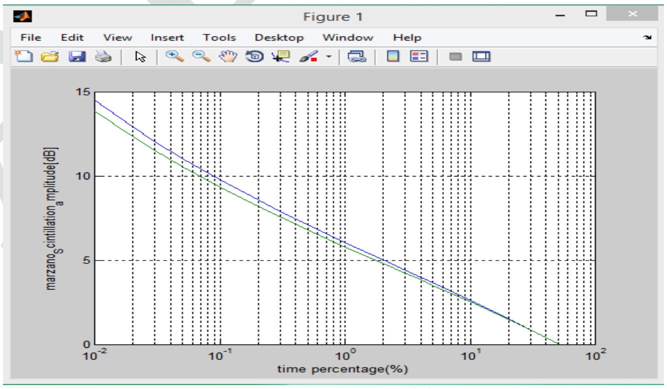

Fig5. Marzano’s Model

Ortgies scintillation model

This model is based in the Research Centre of Deutsche Bundespost Telekom with the scintillation data obtained since October 1989 at 12.5, 20, and 30 GHz by using the Olympus satellite. The attenuation obtained was based on two antennas: the first was at 12.5 GHz (1.8 m in diameter) and the second was for the B1 and B2 beacons at 20 and 30 GHz, which were captured at Darmstadt. The signal fluctuations caused by tropospheric attenuation due to gases, clouds, and rain were separated with appropriate filtering. Variances in 1-min increments were calculated to represent the signal fluctuations known as scintillations. In σ2x , the Ortgies model assumed that short-term scintillation fluctuations follow a normal probability density function (pdf) and long-term scintillation follows lognormal pdf (Ortgies 1993).The models that were used in this paper are the Ortgies-N model that utilizes the mean wet component of the surface refractivity.

$$\text{In}\sigma_{2pre}=\ln[g(x)\cdot f_{1.21}(\sin\theta)_{-2.4}]-13.45+0.0462N_{wet}$$

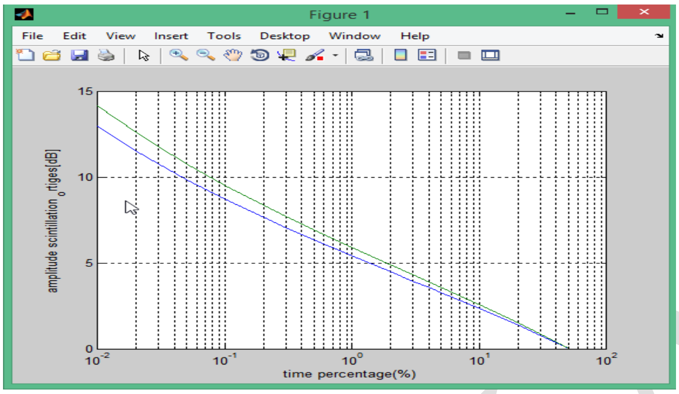

Fig6. Ortgies model

RESULTS

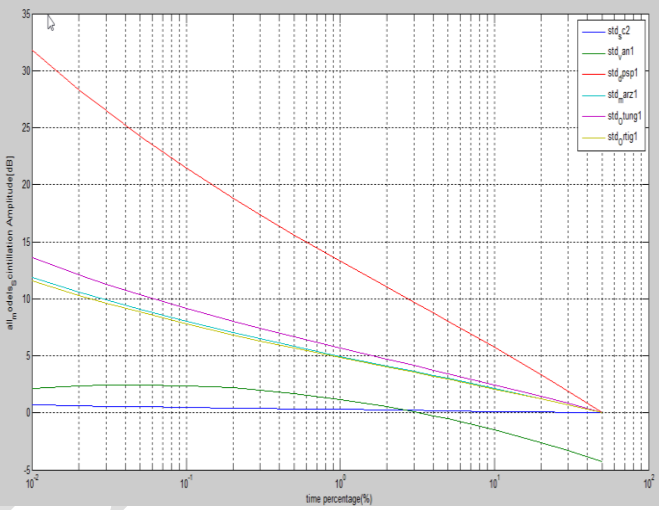

Fig7.Comparison of Atmospheric Scintillation Models on Earth-Space Paths in Tropical Region

CONCLUSION

Five models namely , ITU-R, Van de Kamp, DPSP, Otung and Ortgies models were compared with the measured scintillation data The ITU-R model does not provide any equation for the scintillation enhancement. The measured fades stretch upto 0.30 dB at 0.01% of time. The measured enhancements stretch upto 0.27 dB at 0.01% of time. The highest RMS error for scintillation fades is the ITU-R. The best model for scintillation fades is the Ortgies. While for the scintillation enhancements, the best model is ITU-R Model. In a nutshell, both of these models are not suitable to predict scintillation data in India because both gave high rms errors. Therefore, need to innovate a new scintillation prediction model that fits with the India's tropical climate. Estimated the scintillation intensity based on the input parameter in the ITU-R scintillation. the meteorological parameter is the mean for one years weather data. The scintillation intensity will increase with frequency. This is proven with the simulation. scintillation static was estimated at different attenuation levels for Ka band frequency. Since the effect of scintillation is strongly frequency dependent, signal with shorter wavelength will encounter more severe variation. It can be said that Ka band communication link are more affected by scintillation phenomenon in communication link.

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