Experimental Analysis on Tropospheric Amplitude Scintillation on a Medium Antenna Elevation Angle in Malaysia

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Summary
This paper presents the result of measurement studies of amplitude scintillation on moderate-elevation satellite path at Ku-band. The prediction models for tropospheric scintillation on earth satellite paths from ITU and Gaussian are compared with measurement results from USM, Parit Buntar at frequency of 12.255 GHz and elevation angle of 40.1^0. The scintillation is here characterized by standard deviation of amplitude fluctuation and by the distribution of amplitude deviation from their mean. The ITU prediction model relates the average scintillation intensity to the wet term of refractivity at ground level.
Keywords:
Tropospheric Scintillation, Satellite Propagation, ITU

1. Introduction

One of the major problems in the link budget design of microwave and millimeter-wave communication systems is represented by tropospheric scintillation, i.e., rapid fluctuation of the signal amplitude and phase due to tropospheric turbulence [1]. Scintillation phenomena can cause a significant degradation of the signal-to-noise ratio (up to several decibels) and their effects increase with the increase of channel frequency and the decrease of the antenna aperture and elevation angle [2], [3]. Scintillation is normally refer to those fluctuations about the mean level of received signal power which occur continuously to varying degrees and which are distinguishable from gross fades due to rainfall on the basis of their spectra. They are distinguishable from deep fades due to low-angle fading on the basis of their probability density function (pdf) symmetry [4]. Tropospheric scintillation is rapid fluctuation of signal amplitude and phase due to turbulent irregularities in temperature, pressure and humidity, which translate into small-scale variations in refractive index which varies with altitude.

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Scintillation effects become a relevant noise source, which has to be considered and predicted for the optimum utilization of the channel capacity [4]. Table 1 show the ground station satellite specification for USM, Parit Buntar under POST-PARTNERS.

Table 1: Satellite specification

Ground station location	5.17^0N, 100.4^0E
Beacon frequency	12.255 GHz
Elevation angle	40.1^0
Polarisation	Horizontal
Antenna configuration	Offset parabolic
Antenna Diameter	2.4m
Satellite position	144^0E
Antenna height	57m above sea level

2. Prediction Model

It has been found from theory that the signal-level fluctuation due to turbulence (dB) on a short term basis (several minutes) 6 to 10 minutes can be described by a distribution around the mean signal level. This is the main factor why they can be characterized by standard deviation (σ). The long term average ITU-R [5] model is given as:

$$\sigma = \sigma_{ref}\, f^{7/12}[g(x)/(\sin\theta)^{1.2}] \quad \text{dB} \qquad (1)$$

where by
σ_{ref} standard deviation reference
$g(x)$ antenna averaging factor
f is the operating frequency and θ is the antenna elevation angle.
Where else for the short term amplitude fluctuation distribution, Gaussian

$$P(x, \sigma) = 1/(\sqrt{2\pi\sigma}\ \exp[-x^2 / 2\sigma^2] \qquad (2)$$

where P(x, σ) is the amplitude distribution function for given σ and x is the deviation of the amplitude from the 10 min mean value.

3. Data Analysis

Scintillation occurs continually, regardless of the weather whether the sky is clear or rainy. In rainy condition signal-level fluctuations due to scintillation will accompany signal-level attenuation caused by rain, special attention need to be paid when analyzing scintillation data during rainfall.

For this experiment we analyzed the scintillation data obtained during non-rain period. 12.255 GHz Superbird C beacon propagation data were recorded at USM (5.170N, 100.4^{0}E) at elevation angle of 40.1^0 using a sampling interval of 0.5s.The data was taken from January 2005 to September 2005, where the data were collected every. The raw data were inspected to exclude any spurious sample. The data without the suspicious jumps and errors were high pass filtered at a suitable cut-off frequency in order to obtain the scintillation amplitudes. The first three minutes of the output filter were excluded to avoid the start-up effect of the filter. The standard deviation was calculated over every ten minutes block of data and averaged over each month.

The PDF of amplitude scintillation was computed by dividing the histogram of the scintillation amplitude for a certain period by the sum of the histogram multiplied by the bin size. Histogram of amplitude scintillation was computed by grouping them according to their amplitude in bins of 0.03dB. For short-term distribution the scintillation amplitudes have Gaussian PDF. For long-term the PDF deviates from a Gaussian distribution especially in the tails if the distribution is above 05dB peak – to – peak.

4. Result Analysis

As the environmental conditions change with time the intensity of the scintillation also varies gradually with time. It has been reported that σ_x follows a logarithmic normal distribution [2] in the case of fairly weak scintillation ($\sigma_x \leq 0.1$dB).

Fig. 1 to 5 shows the probability density of amplitude deviation. There are months where the Gaussian distribution resulting from the mean value and standard deviation of the measured amplitudes follows the distribution of the measured data.

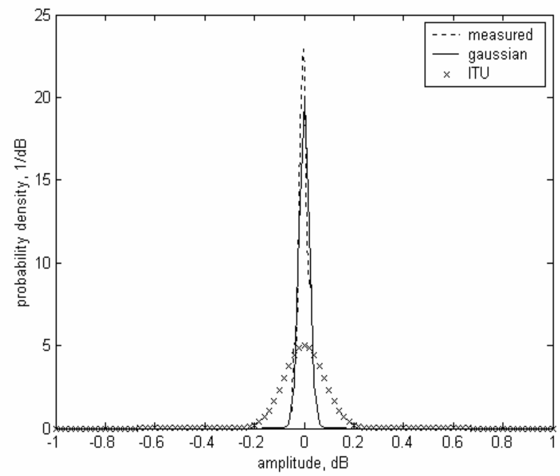

Fig.1 Probability density of amplitude deviation for the month of February

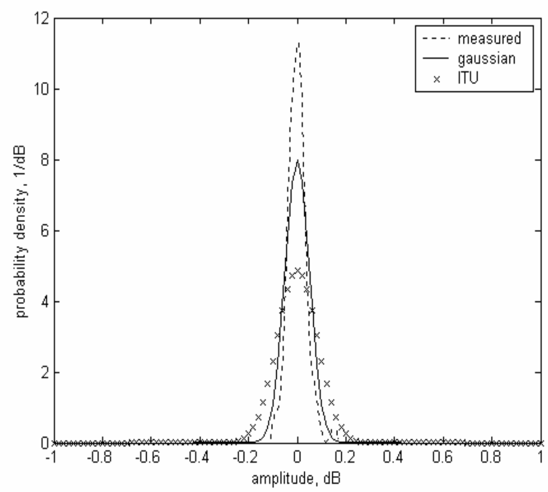

Fig.2 Probability density of amplitude deviation for the month of March

For example Fig. 1, 2, 3, 4 and 5 the Gaussian distribution follows the measured data where else in Fig. 3,4 and 5 the ITU distribution follows the measured data and figures 1 and 2 it doesn't. This is because the calculation of the model depends on the signal frequency, antenna diameter, and path elevation angle that are fixed with time. The humidity and temperature of the location varies with time. The variation of the average humidity and temperature is not much, so therefore the standard deviation will be around 0.08 to about 0.1dB thorough out the measuring time.

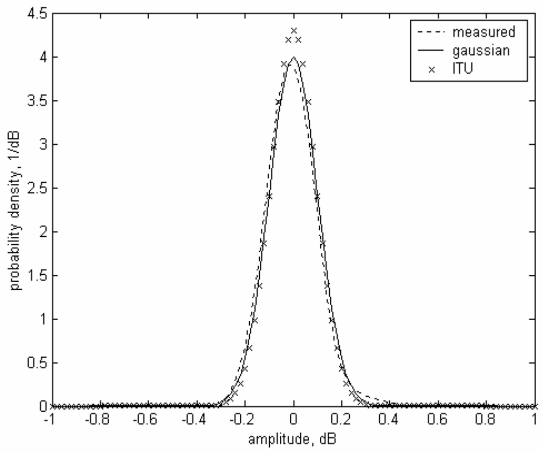

Fig.3 Probability density of amplitude deviation for the month of April

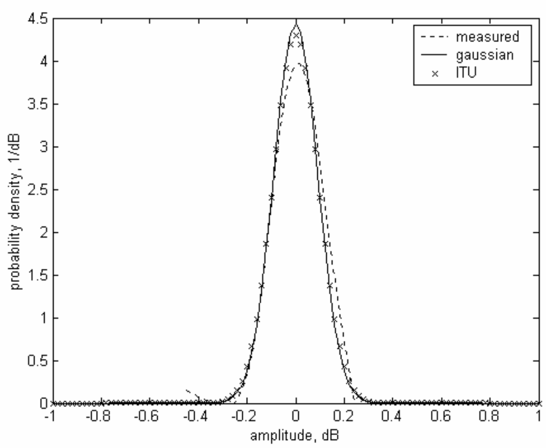

Fig. 4 Probability density of amplitude deviation for the month of May

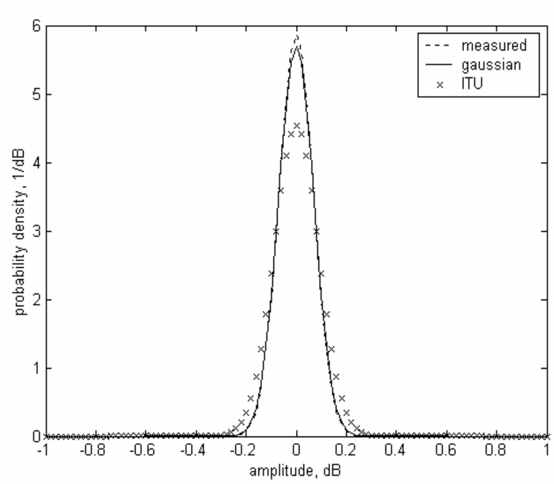

Fig. 5 Probability density of amplitude deviation form Jan to Sept 2005

Since ITU the amplitude deviation doesn't varies much this will effect on the measurement for the driest month where the scintillation is very low about 0.02 dB for example Fig. 1 and 0.05 dB in figure 2. Hence, the ITU model fails to predict the dependence of scintillation on temperature in dry months. This clearly shows that the ITU model needs to be revised for tropical countries with high temperature and humidity.

5. Conclusion

Based on the data analysis for USM tropospheric scintillation observed in the short and long term experiment on earth space paths with moderate elevation angle it has been found that the scintillation strength is at its lowest in February and highest in April. Over short periods, the probability function of signal level follows the normal the normal distribution very well. The model predicted by ITU is not suitable if the strength of the scintillation is low. This is due to the temperature and humidity that does not vary much in tropical countries where they are not seasonal dependence.

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