Measurement of Tropospheric Scintillation from Satellite Beacon at Ku-Band In South East Asia

Mandeep Singh Jit Singh[1], Syed Idris Syed Hassan[1], Fadzil Ain[1]
Kiyoshi Igarashi[2], Kenji Tanaka[2] and Mitsuyoshi Iida[3]

[1]School of Electrical and Electronic Engineering
Universiti Sains Malaysia, Engineering Campus
14300 Nibong Tebal, Seberang Perai Selatan, Pulau Pinang, Malaysia
[2]National Institute of Information and Communications Technology 4-2-1, Nukui-kita , Koganei, Tokyo , Japan
[3]Association of Radio Industries and Businesses 1-4-1,Kasumigaseki, Chiyoda, Tokyo, Japan

Summary

This paper presents the results of beacon measurements on a moderate elevation satellite link at 12.255 GHz during the present of scintillation were analyzed. The spectra of the beacon signal were extracted from the raw beacon data using high pass filter with suitable cutoff frequency where the scintillation here are characterized by standard deviation of the amplitude fluctuations and by the distribution of amplitude deviations from their mean. The mean of the power spectra that's been displayed by two asymptotic with the values was found to be close to the slope of the Kolmogorov spectra.

Keywords:

Scintillation, Microwave propagation, satellite beacon

1. Introduction

Scintillation arising from scattering atmospheric refractive index discontinuities and resulting in random fades and enhancements of the received signals amplitude about a mean level is an important source of degradation especially on low-availability satellite communication systems operating at frequencies above 10 GHz [1]. The mathematical complexity of the problem of turbulent scattering and the randomness of its occurrence necessitate a strong dependence on satellite beacon measurement to develop empirical models for scintillation prediction. Before using the measured raw beacon propagation data for scintillation studies, contributions to data fluctuations by other propagation factors must be excluded [2]. As these other causes introduce fluctuations at a lower rate than those due to scintillation, it follows that scintillation-induced fluctuations in the raw data can be separated by passing the raw data through a high-pass filter at a suitable cutoff frequency f_c. The value of f_c must be carefully set. If f_c is too low, then nonscintillation effects are inadvertently included in the signal fades and enhancements about the mean level. On the other hand , if f_c is too high, then the legitimate contributions to scintillation at Fourier components lower than the set value of f_c are excluded [3].

Generally , scintillation occurs continually, regardless of whether the sky is clear or rainy. In rainy conditions, however, signal-level fluctuations due to scintillation will accompany signal-level attenuation caused by the rain, so that careful attention should be given when analyzing scintillation data during rainfall [4]. In this paper scintillation were analyzed during a no-rain period at noon for 10 minutes. Comparison of short term and long term prediction results are shown and discussed.

2. Background Studies

Studies to determine the distribution of scintillation amplitude have been carried by many researchers. Over relatively short time periods it was found that the probability density function (PDF) of amplitude fluctuations (in dB) due to tropospheric scintillation is Gaussian [2]. Karasawa, Yamada and Allnut [5] obtained similar results. A Gaussian distribution of scintillation amplitude over short time period was also reported in [6].

Moulsley and Vilar [7] found that the PDF of scintillation measured over sufficiently long period must be expected to deviate from normal distribution because for long-term data the standard deviation which is a parameter of a normal distribution varies with the change of the local weather. The PDF of scintillation intensity, obtained by calculating the standard deviation of the amplitude scintillation in the ten-minute interval was found to follow the lognormal distribution for long term period and the hourly value of scintillation intensity appeared to follow a Gamma distribution over monthly periods [4].

Theoretically, the power spectrum of amplitude scintillation has a low pass filter shape. It has a well

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defined flat region followed by a region with high frequency roll off slope defined as f^s where s is referred to as the spectral slope. The two regions intersect at a point referred to as the corner frequency f_c .

3. Approach and Methods

The scintillation measurement was carried out at Universiti Sains Malaysia (USM) from January to July 2002. The signals from the Superbird C satellite at 12.255 GHz were received with an elevation angle of 40.1^0 and a sampling rate of 2 Hz using an offset parabolic antenna of diameter 2.4m. The signal polarization is horizontal from the Superbird C satellite, which is at 144^0 E.

The raw data was converted from quantization levels to relative signal level, A in dB using a fifth-order calibration polynomial and inspected to exclude any spurious samples. Then the scintillation amplitude was extracted from A and it was pass through a Butterworth digital high-pass filter of sixth order with a cutoff frequency of 0.06 Hz. The first two minutes of the output of the filter were excluded to avoid the start-up effect of the filter. To examine the effect on the scintillation statistics of the cutoff frequency f_c used for data filtering, 14 different values of f_c between 2 to 500 mHz were used. For each scintillation data set (obtained using a particular value of f_c) a chi-square goodness-of-fit test was performed to determine whether the 1 min distribution of the amplitude scintillation followed a Gaussian pdf with statistical significance [3].

The power spectral density (psd), dB/Hz, of each signal was computed on a block of 4096 samples by breaking the block into seven half-overlapping segments of 1024 samples, removing the mean from each segment before multiplying by a Hanning window,

$$w(k) = 0.5[1-\cos(2\pi k/1025)] \quad (1)$$

where k = 1, 2, 3, ………. 1024. Finally averaging the periodograms (square magnitude of FFT) of the modified segments. The psd was then smoothed using a third-order median filter[3].

4. Results and Discussion

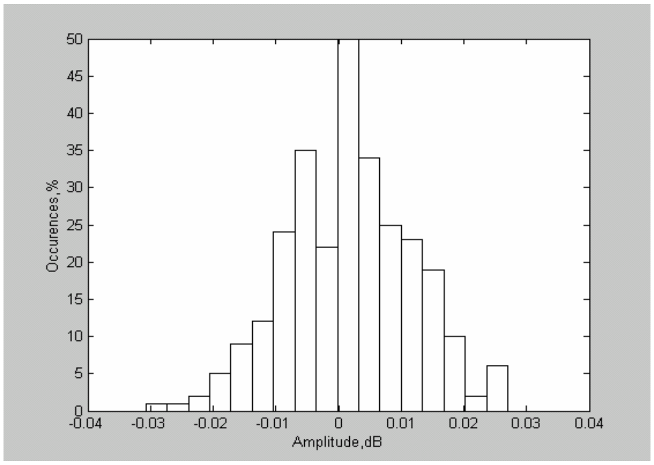

Fig.1: Peak to peak amplitude scintillation for February

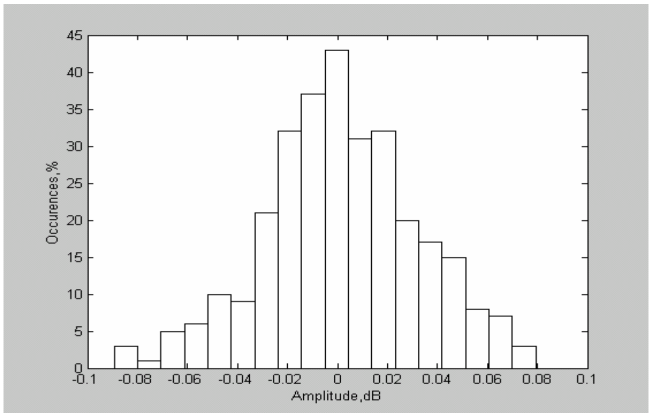

Fig.2: Peak to peak amplitude scintillation for March

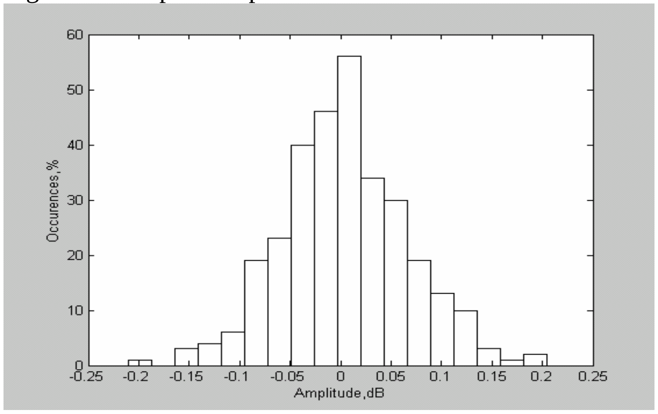

Fig.3: Peak to peak amplitude scintillation for April

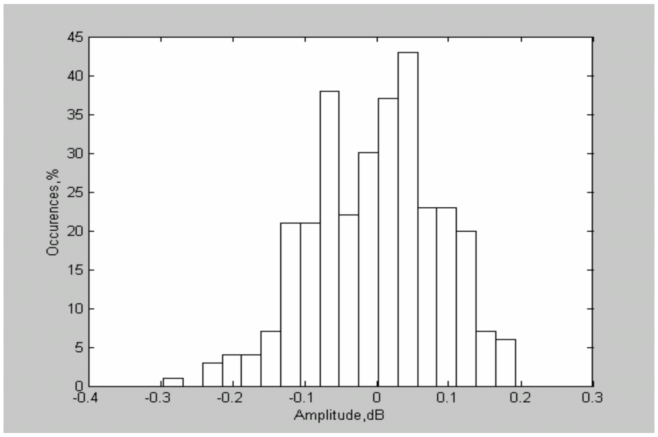

Fig. 4: Peak to peak amplitude scintillation for May

Fig.1 to Fig.4 shows the peak to peak amplitude scintillation for the driest and wettest month from January to July 2002.The peak to peak for the month of February is 0.06 dB_{p-p} and for the month of March is 0.18 dB_{p-p} compare to the wettest month of April is 0.6 dB_{p-p} and May 0.5 dB_{p-p}. This clearly shows that the scintillation is high during the raining month with clear sky and huge clouds. During the dry months when the temperature is high and the humidity is low, the signal-level fluctuation caused by tropospheric scintillation will be low.

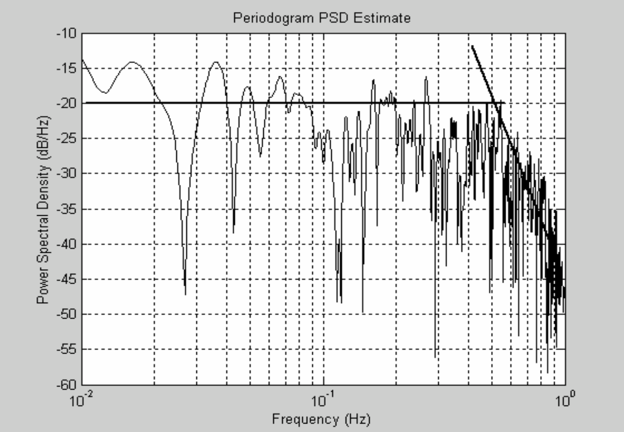

Fig.5: Power spectral density of beacon signal

Fig.5 shows the power spectra density of the signal –level fluctuations from the month of January to July. The shape of the spectra are similar to the theoretically one predicted by assuming a Kolmogorov spectrum of atmospheric refractivity fluctuations [8]. A flat portion occurs between 0.02 Hz to 0.5 Hz followed by a slope of approximately $f^{-8/3}$ above 0.5 Hz.

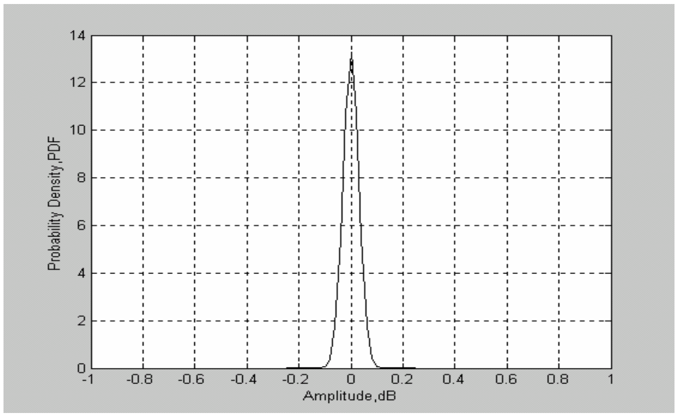

Fig. 6: Measured short-term amplitude scintillation, pdf

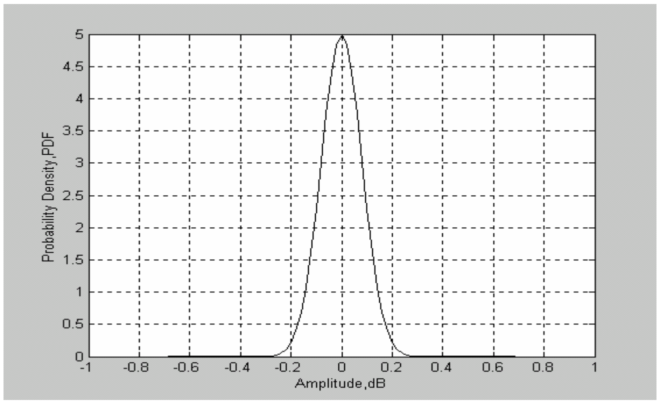

Fig. 7: Measured long-term amplitude scintillation, pdf

Fig. 6 shows the measured short-term amplitude scintillation, probability density function (pdf) for short-term that's about a month long period and Fig. 7 shows the measured long-term amplitude scintillation pdf for the whole month of January to July. The short-term pdf has a standard deviation of 0.01 and the long-term has a standard deviation of 0.08. This clearly shows that the scintillation for this experiment does not effect the degradation of signal-to-noise ratio.

5. Conclusion

The main objective of this paper is to analyzed the long-term and short-term statistic of the scintillation , confirm it with the theoretical studies for satellite broadcasting communication and to check whether are there any degradation in the signal-level satellite beacon . It has been confirmed that the slope $f^{-8/3}$ achieved during experiment and comparing it with the Kolmogorov spectrum clearly show that the scintillation that occurred was without any rain attenuation. The scintillation level is moderately during the raining season and very low during the dry season. This clearly shows that the signal – level fluctuation caused by tropospheric scintillation does not effect the radio wave transmission.

6. Acknowledgment

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