VOL. 10, NO. 4, MARCH 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MEASUREMENT OF TROPOSPHERIC SCINTILLATION USING KU BAND SATELLITE BEACON DATA IN TROPICAL REGION

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ABSTRACT

The down Link signal travelling from satellite to the earth surface need to pass through the layers of the atmosphere situated at an altitude above the earth surface. While passing through these layers the radio wave undergoes some changes in its characteristics .These fluctuations are observed in the troposphere (0 to 12 km containing nitrogen (78 percent) and oxygen (21 percent), with the remaining 1- percent consisting of argon, (0.9 percent) and traces of hydrogen ozone (a form of oxygen)), very close to earth surface, so they are called as tropospheric scintillations. There are two types of scintillations called amplitude and phase scintillations. In this paper we are concentrating on estimation of trosposheric amplitude scintillation. While considering lower frequencies (<3GHz) we take the effects of ionosphere into consideration. For higher order frequencies (>10GHz) ionosphere acts as a transparent layer, so only tropospheric scintillations are taken into consideration. Tropospheric amplitude scintillation can be defined as rapid fluctuations in the amplitude of the radio wave caused by changes of refractive index at the altitude. It is caused by humidity and temperature of the atmosphere. The effects of tropospheric scintillation are seasonal and vary from day to day with local climate. In this paper we are estimating the tropospheric amplitude scintillation for ku-band down link signals using RECOMMENDATION ITU-R P.618-8(Propagation data and prediction methods required for the design of Earth-space telecommunication systems) [4].

Keywords: tropospheric scintillations, amplitude, Ku-band, beacon signals.

1. INTRODUCTION

Communication system plays a major role present day human life. Every communication system like satellite, radar communication systems etc. should be designed with at most care considering all the effects that disturb the system. Scintillation is one of the adverse effects caused in the signals propagating through the atmosphere. While considering lower frequencies (<3GHz) we take the effects of ionosphere into consideration. For higher order frequencies (>10GHz) ionosphere acts as a transparent layer, so only tropospheric scintillations are taken into consideration. Tropospheric scintillation can be described as fast fluctuation in amplitude and phase of the millimeter-wave satellite signal. It is caused due to turbulence in the atmosphere. The effect due to scintillation in the frequency ranges less than 4GHz is very little. The degradation of the signal increases with increase in frequencies. It also depends on physical and meteorological parameters such as temperature, humidity, elevation angle, location and refractive index variations of propagation media. So calculation of scintillation is an important factor to be estimated before designing any efficient communication system. In this paper we are concentrating on amplitude scintillation caused in the troposphere layer by using the received beacon signal using experimental set up at KLUniversity, Vijayawada (16.44^{o}E, 80.62^{o}N).Ku band beacon data was received by using a parabolic dish antenna with size 90cm, elevation angle 65^{o} and offset angle 25^{o}. Received beacon applied to LNBF which as two oscillator frequencies 9.75 and 10.5 GHz to down convert the received spectrum in the range of 9 KHz to 2.7GHz which was monitored by using spectrum analyzer .with aid of data logging module and GPIB cable spectrum amplitudes (dBm) recorded in computer/laptop was clearly shown in Figure-5.

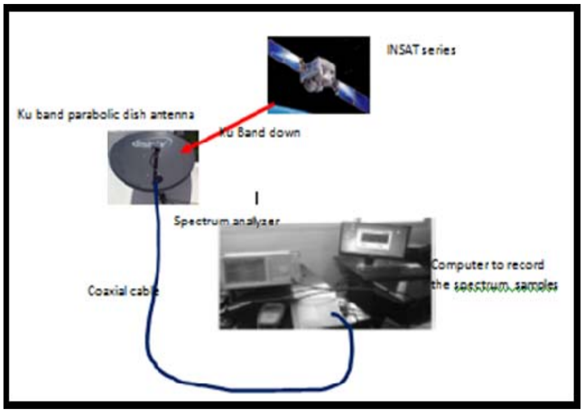

Figure-1. Experimental set up in KLUniversity to measure Ku band beacon data.

2. OBTAINING SCINTILLATION AMPLITUDE VECTORS FROM THE RECEIVED BEACON SIGNALS

Scintillation amplitudes were calculated from the received beacon data at K L University (AP) at an elevation angle of 65.6 degrees using a parabolic dish antenna with a diameter of 90 Centimeters .The longitude and latitude values of the receiving station are 16.44 and 80.62 respectively. The receiving antenna is operated at a frequency of 11.7GHz. The scintillation amplitude was calculated during clear sky and invalid or erroneous data has been eliminated. The raw data was converted from quantization levels to relative signal level, using a fifth order polynomial. A total of 8192 samples were obtained after quantization. The power spectral density , dB^2 /Hz, of each signal was computed on a block of 4096 samples by breaking the block into seven half-overlapping segments of 1024 samples[3]. Then the mean was calculated and removed from each segment and then multiplied with hanning window and finally averaging the period grams (square magnitude FFT) of the modified segments. The PSD was then smoothed with a third order median filter with a cut off frequency f_c ranging between 2 to 500 MHz[2].

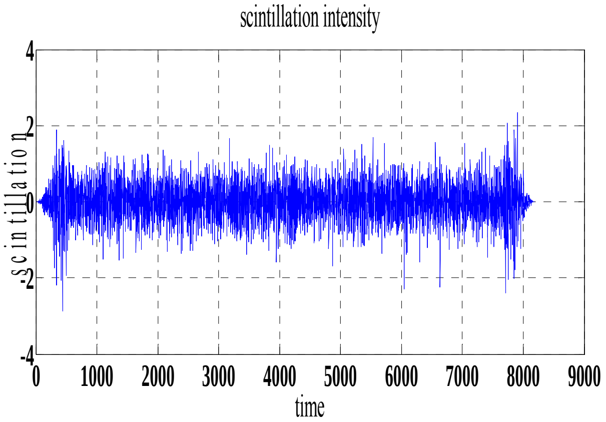

Figure-2. Scintillation amplitude variations of Ku band beacon data on 2nd February.

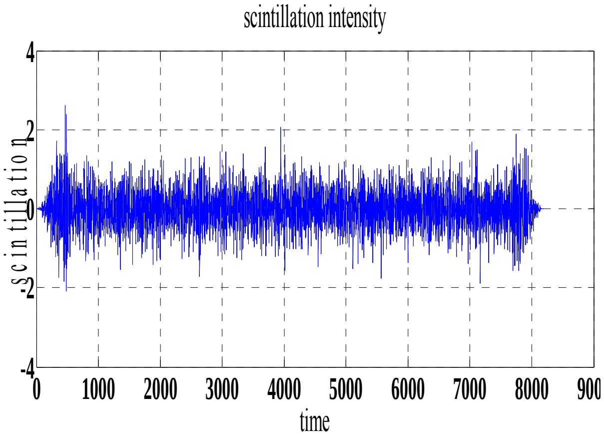

Figure-3. Scintillation amplitude variations of Ku band beacon data on 5th February**.**

From the above graphs the Scintillation Intensity which is calculated with respect to the time varies nearly around 0dB. The maximum and minimum value on 2nd FEB ranges from -2.1 to 2.5 dB whereas that on 3rd FEB 2012 varies from -2.9 to 2.3 dB. The variation between the two days is only 0.2 dB. This small variation is due to the collection of data only on dry conditions (absence of rain and spurious spikes).

3. SCINTILLATION INTENSITY CALCULATION USING ITU-R

The ITU-R has proposed a model with frequencies between 7-14 GHz and theoretical frequency dependence and aperture averaging effects, estimates the average scintillation intensity σ_{per} over a minimum period of one month. The required input parameters needed for this model are signal frequency f (GHz), antenna diameter D (m), path elevation angle θ, average temperature, and average relative humidity which are readily available. The elevation angles used here is in the range from 4° to 32° and the antenna diameters used is between 3 and 36 m. In ITU-R scintillation model, the long-term scintillation variance is expressed as corresponded to N_{ewt}, which is a function of relative humidity U (%) and temperature t (ºC), measured at ground level[4].

Parameters required for the method include:

f = frequency (GHz), where 4 GHz $\leq f \leq$ 20 GHz

θ = path elevation angle, where $\theta \geq 4°$

D = physical diameter (m) of the earth-station antenna

η = antenna efficiency; if unknown, $\eta = 0.5$ is a conservative estimate.

Step-1: Compute the wet term of the radio refractivity, $N_{wet.}$

Step-2: Calculate the standard deviation of the signal amplitude, σ_{ref}, used as reference

$$\sigma_{ref} = 3.6\times10^{-3} + 10^{-4}\times N_{wet} \qquad \text{dE}$$

Step-3: Calculate the effective path length L according to:

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

Where h_L is the height of the turbulent layer; the value to be used is h_L = 1 000 m.

Step-4: Estimate the effective antenna diameter, D_{eff}, from the geometrical diameter, D, and the antenna efficiency η:

$$D_{eff} = \sqrt{\eta}\, D \qquad \text{m}$$

Step-5: Calculate the antenna averaging factor:

$$g(x) = \sqrt{3.86(x^2+1)^{11/12}\cdot\sin\left[\frac{11}{6}\arctan\frac{1}{x}\right] - 7.08x^{5/6}}$$

$$\text{With} \quad x = 1.22\, D_{eff}^2\,(f/L)$$

Where f is the carrier frequency (GHz).

If the argument of the square root is negative (i.e. when $x \geq 7.0$), the predicted scintillation fade depth for any time percentage is zero and the following steps are not required.

Step-6: Calculate the standard deviation of the signal for the considered period and propagation path:

$$\sigma = \sigma_{ref} \; f^{7/12} \frac{g(x)}{(\sin\theta)^{1.2}}$$

Step-7: Calculate the time percentage factor, a(p), for the time percentage, p, of concern in the range

$0.01 < p \leq 50$

$$a(p) = -0.061\,(\log_{10} p)^3 + 0.072\,(\log_{10} p)^2 - 1.71 \log_{10} p + 3.0 \#$$

Step-8: Calculate the scintillation fade depth for the time percentage p by:

$$A_s(p) = a(p) \cdot \sigma \qquad \text{dB}$$

The antenna averaging factor (g(x)) is calculated. Then the standard deviation, σ of the signal and the time percentage factor a(p), for the time percentage p, of concern in the range 0.01 < p < 50 are computed. Finally the scintillation fade depth for the corresponding time percentage p is calculated. The scintillation enhancement formula is not available in ITU-R model [4].

4. PROBABILITY DENSITY FUNCTION

The probability density function plots for scintillation intensity on 2nd and 3rd falls in the range of -1.5 to - 1.3 dB.

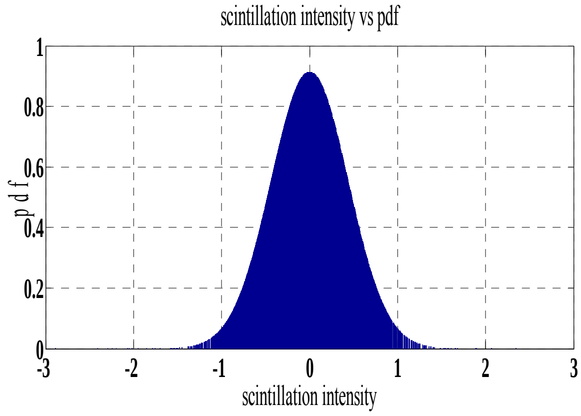

Figure-4. Probability density function of scintillation intensity on 2nd February.

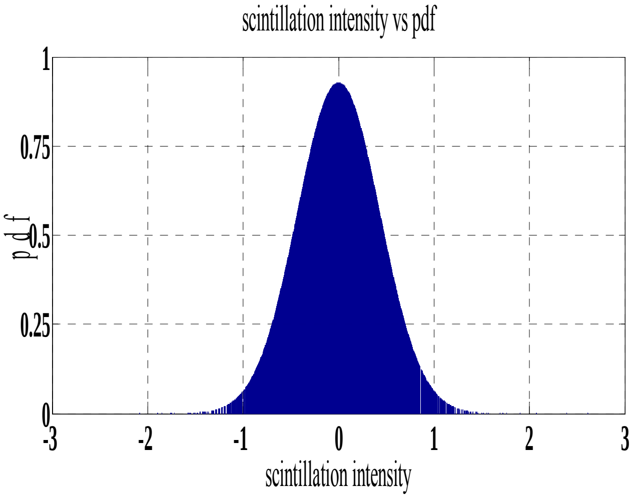

Figure-5. Probability density function of scintillation intensity on 3rd February.

Scintillation intensity for the two graphs plotted on 2nd and 3rd FEB 2012. The maximum probability is 0.92 on 2nd FEB whereas it is 0.91 on 3rd FEB. There is a slight difference of 0.01 in the probabilities for the recorded two days [1].

5. POWER SPECTRAL DENSITY

The power spectral density is calculated with respect to the frequency from 2nd to 6th February 2012.

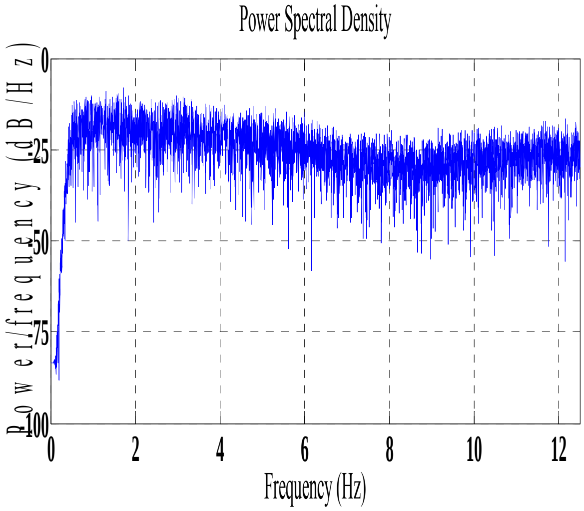

Figure-6. Power spectral density of scintillation intensity on 2nd February.

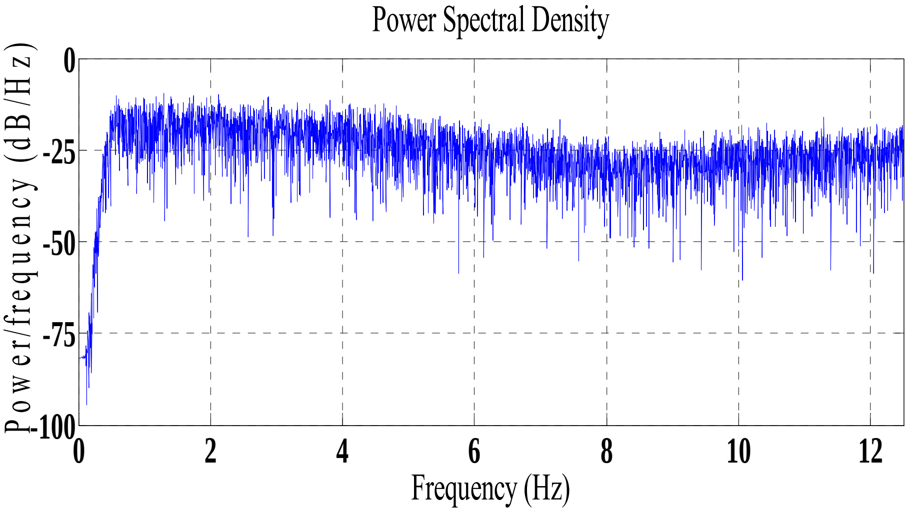

Figure-7. Power spectral density of scintillation intensity on 3rd February.

From the two graphs it is evident that the power is very less at low frequencies and as frequency increases the power also increases steadily up to a certain value and from then it maintains a constant value which is fluctuating slightly. The minimum power at 0Hz frequency on 2nd FEB 2012 is -88.2 dB/Hz and on 3rd FEB 2012 it is -92.5 dB/Hz.

6. RESULTS AND CONCLUSIONS

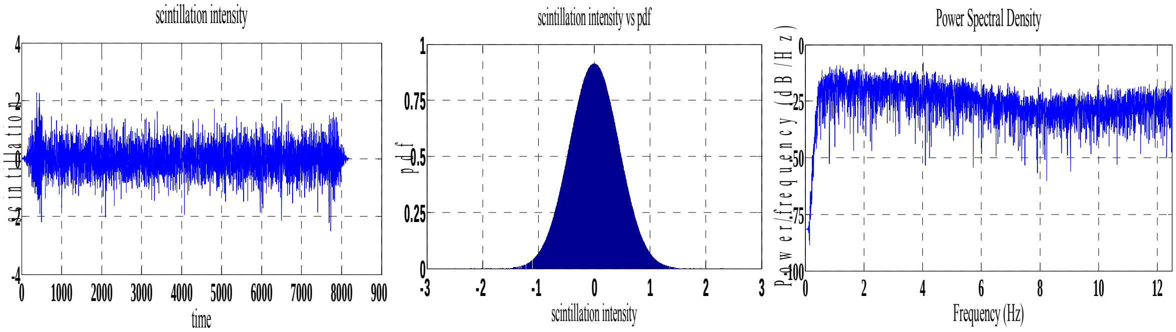

Figure-8. Figure shows scintillation intensity, pdf of scintillation, power spectra density on 4th February.

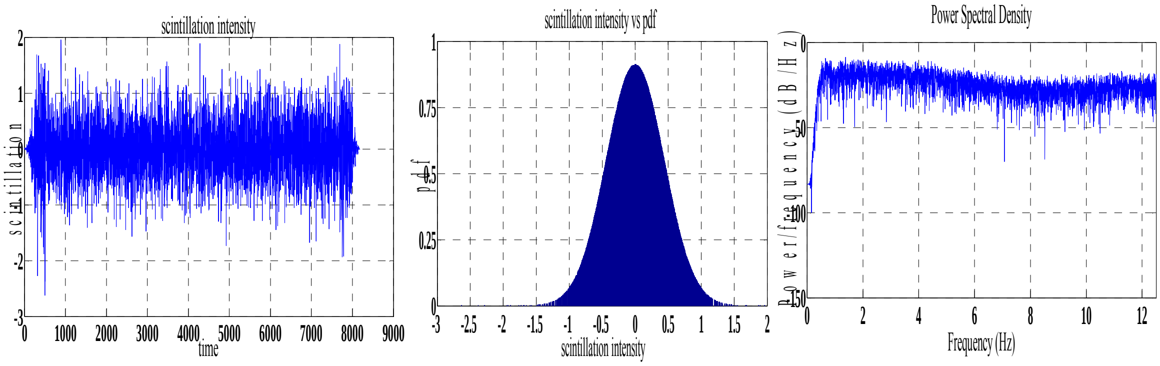

Figure-9. Figure shows scintillation intensity, pdf of scintillation, power spectra density on 5th February.

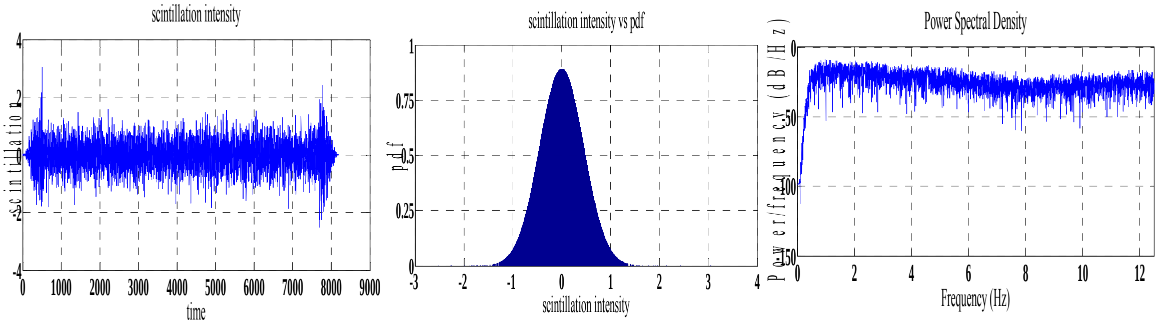

Figure-10. Figure shows scintillation intensity, pdf of scintillation, power spectra density on 6th February.

Scintillation depends on meteorological parameters, especially temperature, humidity and wet-term refractivity. Scintillation amplitude intensity distributions are measured using hanning windoe technique, analyzed and presented in details. Scintillation in dry season is stronger than wet season for both clear air and rainy conditions.

7. ACKNOWLEDGEMENTS

Author acknowledges greatly to the Department of Science and Technology for giving financial support to carry out this work under WOS and SERB Schemes file No: SR/WOS-A/ET-81/ 2011, SR/S4/AS-82/2011, and also acknowledges management of KL University for giving constant encouragement and for providing all necessary facilities to fulfill the objectives of the work.

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