Prediction of Tropospheric Scintillation over some Selected Locations in Nigeria

Babatunde Adebo, Joseph Akindugbagbe

Department of Basic Sciences (Physics Unit), Lead City University Ibadan Nigeria.
adeboistalking@yahoo.com

Abstract: This paper discusses the prediction of tropospheric scintillation over some selected locations in Nigeria-Akure, Lagos, Port-Harcourt, Makurdi and Abuja, based on the ITUR scintillation prediction model. Tropospheric scintillation in this context means a rapid fluctuation of the amplitude or phase of radio wave caused by the changes in refractive index with altitude. Generally, scintillation occurs continually, regardless of whether the sky is clear or it is raining. Therefore, scintillation effects must be accounted for. This paper compares the result of the study locations, the findings show that for all the sites considered, the scintillation comes to peak in August, except at Makurdi. The highest value 0.06 dB, of scintillation was recorded at Akure in the month of August and the minimum 0.03 dB, at Abuja in the month of January. The result indicates that scintillation is higher in the wet season than in the dry season and that scintillation intensity is high in the coastal areas and decreases as one moves northward in the country. It is also observed that scintillation is higher in the raining season than in the dry season.

[Babatunde Adebo, Joseph Akindugbagbe. **Prediction of Tropospheric Scintillation over some Selected Locations in Nigeria.** *J Am Sci* 2019;15(3):72-77]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 11. doi:10.7537/marsjas150319.11.

Key Words: Scintillation, Nigeria, Tropical, Troposphere, Nwet

1. Introduction

Tropopheric scintillation can be defined as the rapid fluctuation of the amplitude or phase of radio wave caused by the changes in refractive index with altitude. The effect of tropospheric scintillation is seasonal and very from day to day with local climate (Mandeep and Yun Yang Ng, 2010). Now, in the field of satellite communications, the lower atmosphere meteorological conditions (relative humidity, temperature etc) influence the propagation of radio waves. The troposphere which is the atmosphere close to the ground is constantly in motion because energy from the sun warms the surface of the earth and the resultant convective activity agitates this layer. This disturbance results in the turbulent mixture of air mass, which results in variation in the refractive index. However, since scintillation occurs constantly regardless of the weather, its effect must then be accounted for in other to complete the link budget for design of low margin systems especially those at high frequency and low elevation angles. (Agunlejika e*t al;* 2012).

Methodology

The data used for this work were obtained from the ongoing propagation measurement of the Nigeria Environmental and Climatic Observatory Programme (NECOP) experiment. The data taken for this analysis were temperature, relative humidity and pressure. These were taken from 1st Jan2010 to 30^{th} Dec 2011. Table 1 shows the site characteristics of the study locations.

Theoretical Background

The long term tropospheric scintillation prediction model proposed by the ITU-R was used to calculate the standard deviation of the signal fluctuation due to scintillation. This model uses the wet term of earth refractivity N*wet*, a function of relative humidity, air temperature and pressure, averaged at least over one month, as the input parameter. The predicted meteorological factor and its relationship with the scintillation intensity and the earth satellite parameters dependence is given as:

$$AS(p) = a(p).\sigma \ (dB) \tag{1.0}$$

Where

$$a(p) = -61(log_{10}P)^3 + 0.072(\log_{10} p)^2 - 1.71log_{10}P + 3.0 \tag{2.0}$$

And

$$\rho = \rho_{ref} f^{7/12}\left[\frac{g(x)}{(sin\theta)^{1.2}}\right] dB \tag{3.0}$$

Where

σ = Standard deviation (dB), σ_{ref} = Normalized or reference standard deviation (dB), g (x) = antenna averaging factor, p = percentage of time (%), f = operational frequency (GHz), θ = antenna elevation angle
Reference standard deviation is given by:

$$\sigma_{ref} = 3.6 \times 10^{-3} + N_{wet} \text{ (dB)} \quad (4.0)$$

$$N_{wet} = 3.732 \times 10^{5} \frac{e}{T^2} \quad (5.0)$$

$$e = \frac{He_s}{100} \quad (6.0)$$

$$e_s = 6.1121 exp\left[\frac{17.502 \times t}{240.97+t}\right] \quad (7.0)$$

$$g(x) = \sqrt{3.86(x^2+1)^{11/12} sin\left[\frac{11}{6} arctan\frac{1}{x}\right] - 7.08x^{5/6}c} \quad (8.0)$$

$$x = 1.22\, D_{eff}^2 (f/L) \quad (9.0)$$

$$L = \frac{2h_L}{\sqrt{sin^2\theta + 2.35 \times 10^{-4}} + sin\theta}\ (m) \quad (10.0)$$

$$D_{eff} = \sqrt{\eta}\, D\ (m) \quad (11.0)$$

Where e = water vapour pressure (hPa), T = absolute temperature (K), t = Celsius temperature (°C), H = relative humidity (%), f = frequency (GHz) where 10 GHz ≤ f ≤ 20 GHz, p = percentage of time (%) where 0.01 ≤ p ≤ 10, θ = path elevation angle (intelsat), where =23°, θ = antenna elevation angle, where θ = 40°, D = physical diameter (m) of the earth-station antenna, D = 2.4m, = antenna efficiency; if unknown, 0.5, h_L= is the height of the turbulent layer, the value to used is h_L= 1000 m.

Result and Discussion

Figures 1 - 5 present the variations of amplitude scintillation at frequencies 10, 12, 16 and 20 GHz for Akure, Lagos, PH, Abuja and Makurdi respectively.

The result shows that amplitude scintillation decreases as the percentage of time increases. Amplitude scintillation also increases as frequency increases; it could also be observed that amplitude scintillation is higher at the coastal region as compared to the arid region of the country. Thus amplitude scintillation decreases as one move to the northern region of the country. This might be due to the fact that coastal region is highly humid, while arid region is hot and dry. For example, Lagos which is in the coastal region recorded about 0.4 dB while Makurdi which is at the arid part of the country recorded about 0.36 dB. Thus for all the sites considered, the scintillation comes to peak in August, except at Makurdi. The minimum value was observed in January, the highest value 0.06 dB of scintillation was recorded at Akure in the month of August and the minimum, 0.03 dB, at Abuja in the month of January. In conclusion, the result indicates that scintillation is higher in the wet season than in the dry season, because in the wet season the temperature is low and humidity is high. As a result, N_{wet} which is the wet term of the surface refractivity becomes high since the scintillation intensity depends on it.

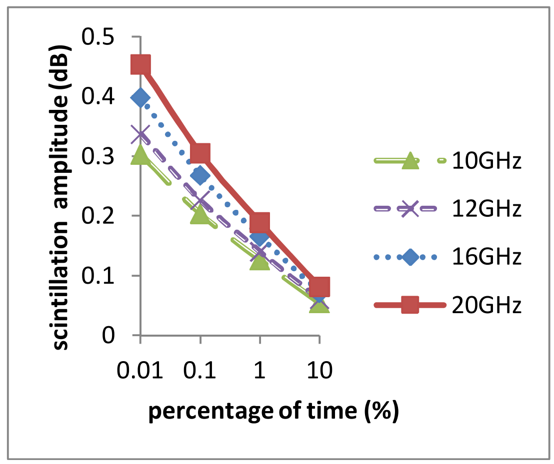


Figure.1: Amplitude Scintillation for Akure

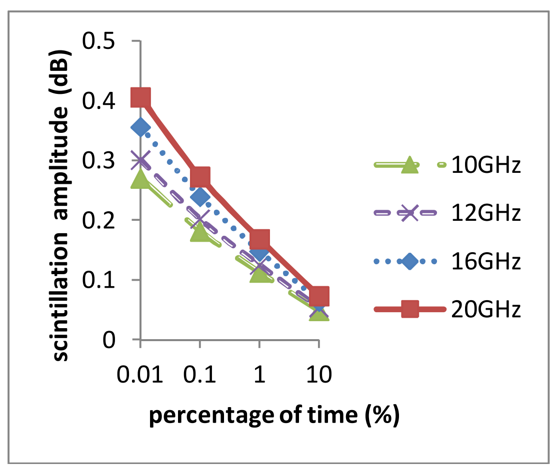


Figure.2: Amplitude Scintillation for Lagos

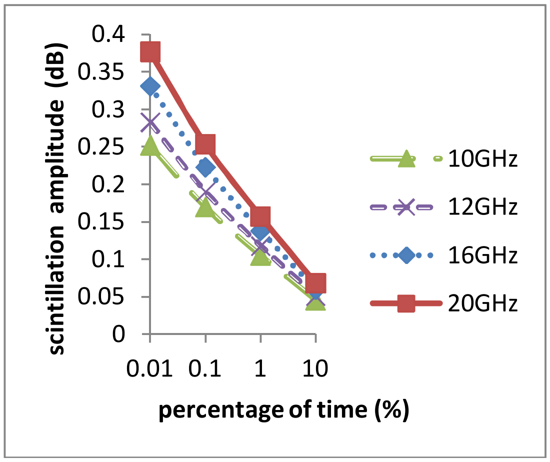


Figure 3: Amplitude Scintillation for Port Hacourt

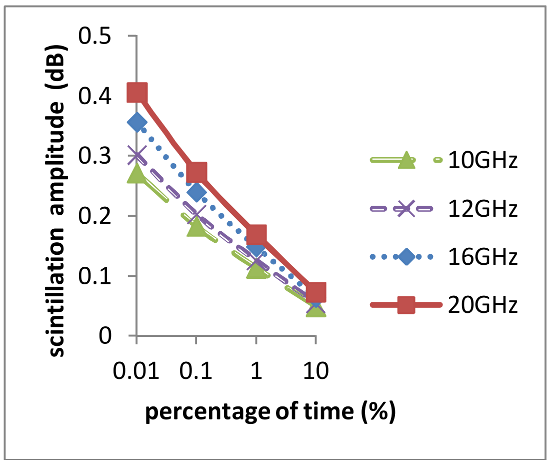


Figure 4: Amplitude Scintillation for Abuja

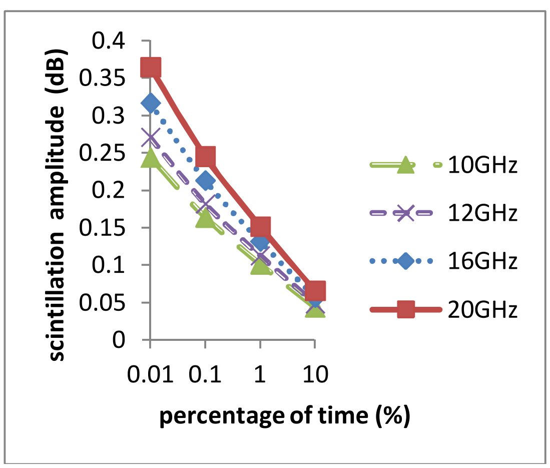


Figure 5: Amplitude Scintillation for Makurdi

Figures 6 - 10 also presents the monthly variability of standard deviation of scintillation at different frequencies for Akure, Lagos, PH, Abuja and Makurdi respectively. It could be observe that in all the sites considered; the standard deviation of scintillation intensity reaches the peak during the month of August except at Makurdi. This is due to the fact every other locations except Makurdi experiences little dryness in the month of August due to the movements of Intertropical Convergence Zone (ITCZ) that results into inter tropical discontinuity (ITD) that is commonly referred to as August break in the Southern part of the country and wetness in the Northern part. Therefore, it can be concluded that scintillation increases when the density of water vapour in the atmosphere is higher which explain why it is mostly marked around the month of August, with its high temperatures and high humidity.

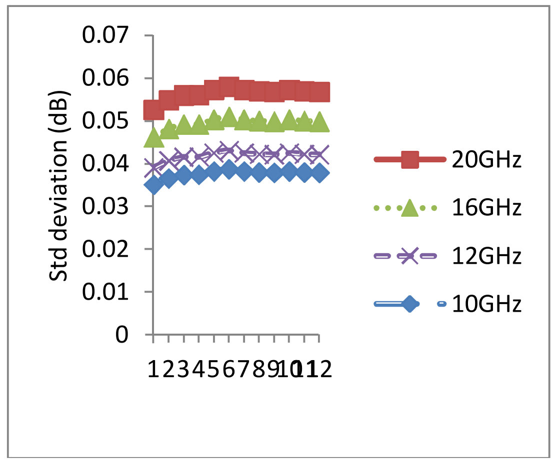


Figure 6: Monthly variability of standard deviation for Lagos

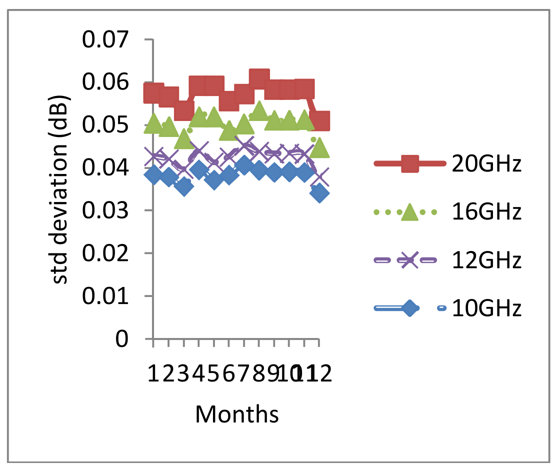


Figure 7: Monthly variability of standard deviation for Akure

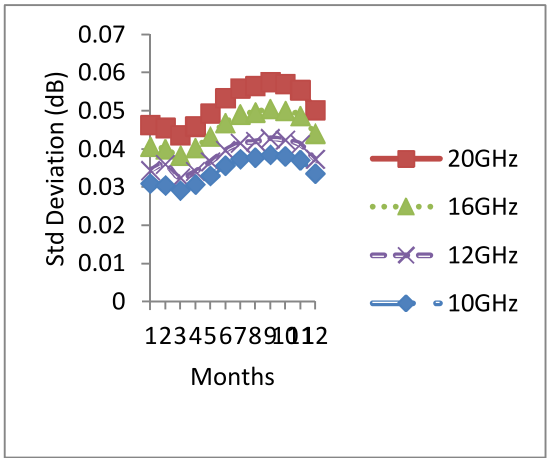


Figure 8: Monthly variability of standard deviation for Abuja

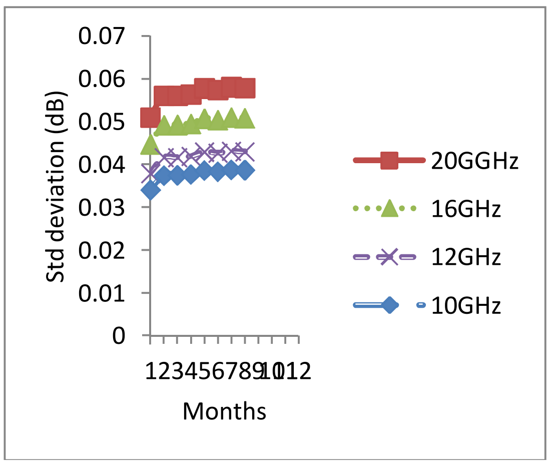


Figure 9: Monthly variability of standard deviation for Port Harcourt

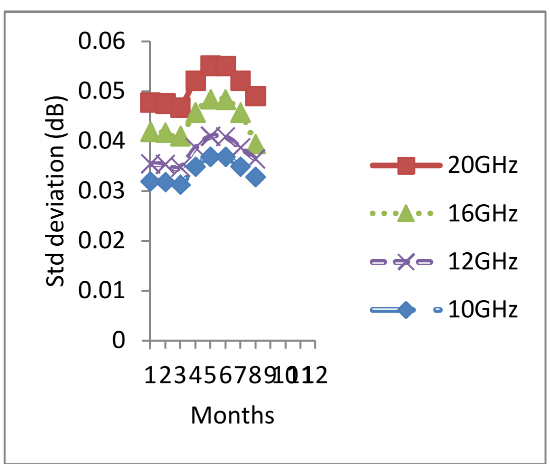


Figure 7: Monthly variability of standard deviation for Makurdi

Figures 11 – 20 show the peak to peak amplitude scintillation for the driest and the wettest month for Akure, Lagos, PH, Abuja and Makurdi respectively. The month of January has been chosen for the driest month while month of June was chosen for the wettest month. The result shows that during the driest month amplitude scintillations is 0.03dB except for Makurdi and Abuja which has 0.02 dB peak to peak values. Also, during the wettest month, the amplitude scintillations is 0.05dB except for Makurdi and Abuja which has 0.04 dB. This clearly shows that the scintillation is high during the raining months and low during the dry months because temperature is high and the humidity is low. Hence, the signal-level fluctuation caused by tropospheric scintillation will be low.

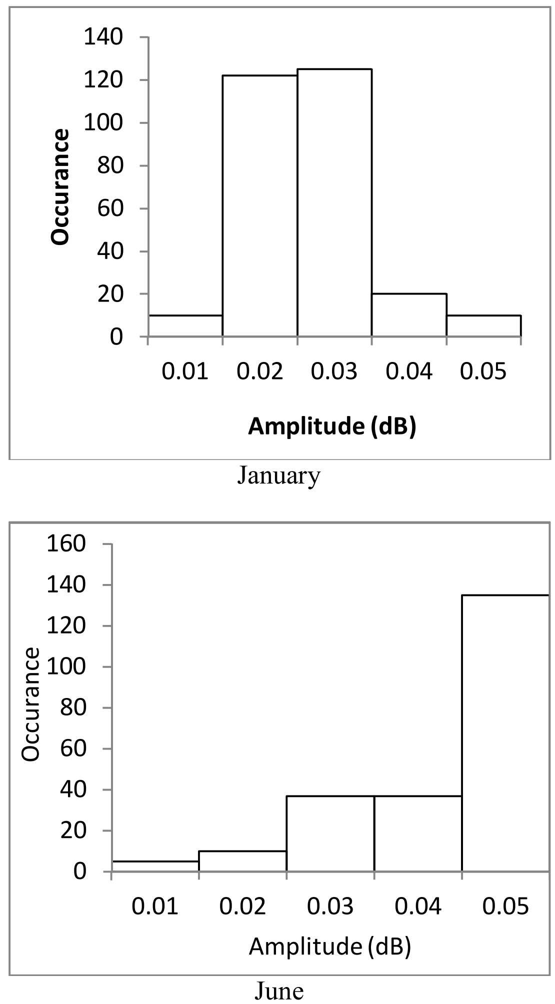
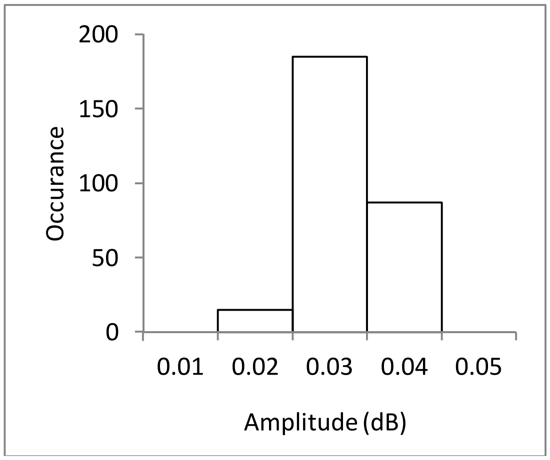
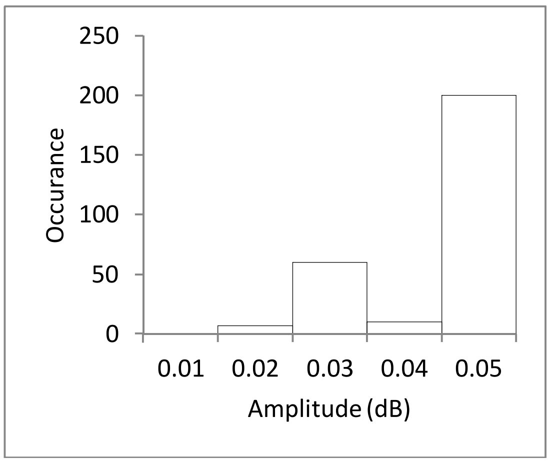


Figure 11: Peak to peak amplitude scintillation for the months of January and June in Akure

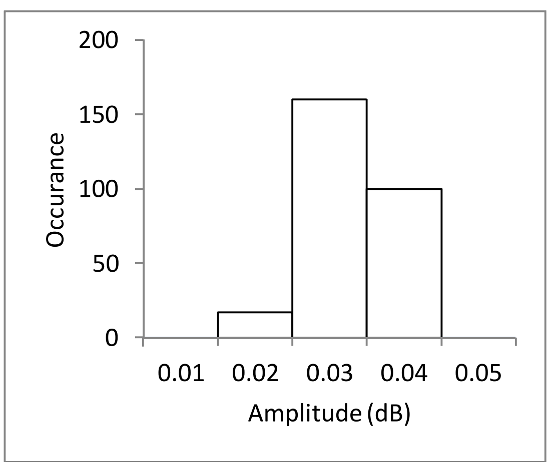


January

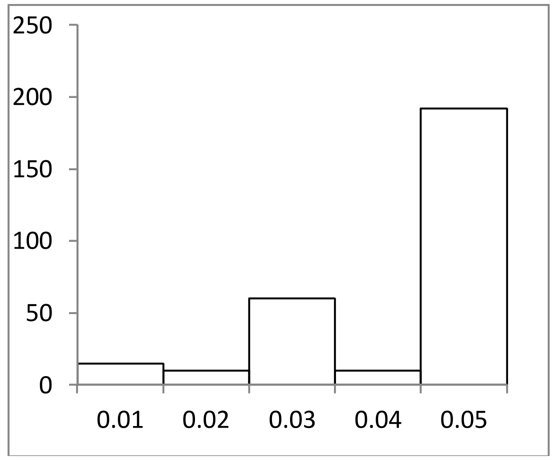


June

Figure12: Peak to peak amplitude scintillation for the months of January and June in Lagos

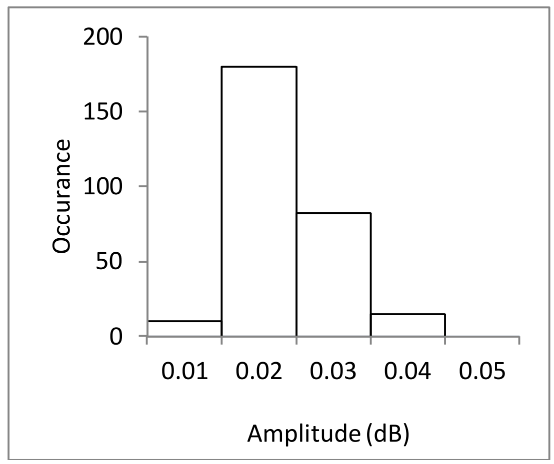


January

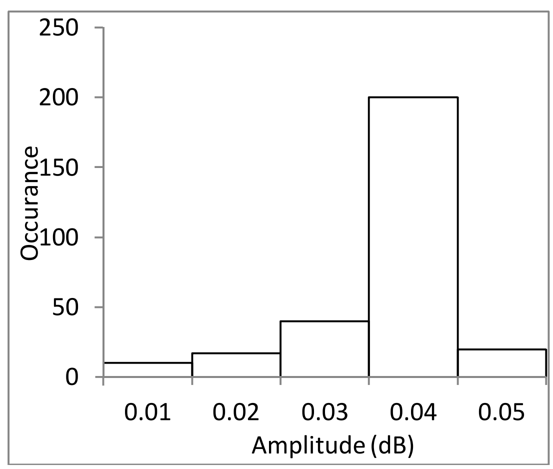


June

Figure. 13: Peak to peak amplitude scintillation for the months of January and June in Port Harcourt

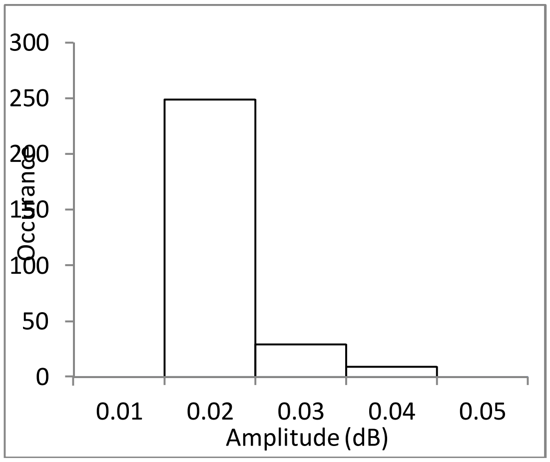


January

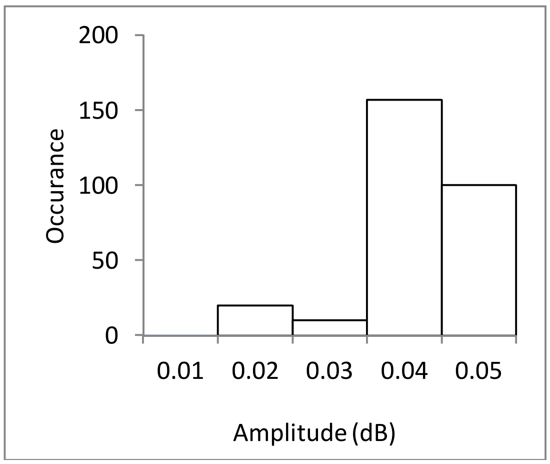


June

Figure14: Peak to peak amplitude scintillation for the months of January and June in Makurdi



January



June

Figure 15: Peak to peak amplitude scintillation for the months of January and June in Abuja

Conclusion

For all the sites considered, the scintillation comes to peak in August, except at Makurdi (Fig 10). The minimum value was observed in January. The highest value 0.06 dB, of scintillation was recorded at Akure in the month of August (Fig.6) and the minimum, 0.03 dB, at Abuja in the month of January (Fig 8). The result indicates that scintillation is higher in the wet season than in the dry season, because in the wet season the temperature is low and humidity is high. This shows that scintillation is dependent on seasons, regions and frequency. The scintillation intensity is high in the coastal areas and decreases as one moves northward in the country. It is also observed that scintillation is higher in the raining season than in the dry season, because in the raining season the temperature is low and the humidity is high.

References

1. Adediji and M. O. Ajewole., " Vertical profile of radio refractivity gradient in Akure South-west Nigeria ", Progress In Electromagnetics Research C, 2008; Vol. 4, 157–168.
2. Agunlejika O., Raji T. I, Adeleke O. A: " Tropospheric Scintillation prediction for some Selected cities in Nigeria's tropical climate", International Journal of Basic & Applied Sciences IJBAS Vol: 9 No: 10.
3. ITU-R (2003) "Propagation data and prediction methods required for the design of Earth- space telecommunication systems", Recommendation ITU-R. 618-8.
4. ITU-R (2007) "Propagation data and prediction methods required for the design of Earth- Space telecommunication systems", Recommendation ITU-R. 453-9.
5. J. S. Mandeep., " Experimental Analysis of Tropospheric Scintillation in Northern Equatorial West Malaysia ", International Journal of the Physical Sciences Vol. 6(7); 2011, pp. 1673-1676.
6. Jit Singh MANDEEP and Mohamad Tariqul ISLAM " Evaluation of Statistical Tropospheric Scintillation Models Using SUPERBIRD-C Satellite for Malaysia ", Acta Geophysica; 2012, vol. 60, no. 4, pp. 1180-1191 DOI: 10.2478/s11600-012-0024-x.
7. Mandeep Singh Jit Singh, Syed Idris Syed Hassan, Fadzil Ain Kiyoshi Igarashi, Kenji Tanaka and Mitsuyoshi Iida "measurement of tropospheric scintillation from satellite beacon at ku - band in South east asia", IJCSNS International Journal of Computer Science and Network Security; 2007, vol.7 No.2.
8. Mohammed Ali Hussein., "Scintillation Effect on Satellite Communications within Standard Atmosphere"; Anbar Journal of Engineering Sciences; 2009, vol. 2, no 2. Pp 17 - 27.
9. M. M. J. L. Van de Kamp., "Asymmetric signal level distribution due to tropospheric Scintillation", Electronic letter; 1998, Vol. 34 No. 71.
10. N. S. Murthysarma, C Mallikarjuna Rao*, K. Naga Chaitanya, Ch, Sai Rakesh, N. S. N. Lakshmi, Pathi Raju". Proposal on Troposphere Modeling one of the Parameters that affects the Satellite based Communication, Navigation and Surveillance Systems in Indian Sub continent", Journal of information, knowledge and research in electronics and Communication Engineering vol: 02, Issue - 02.

3/20/2019