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Analysis of non-rainy attenuation on earth-space path in Ota, Southwest Nigeria

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Abstract. Propagation effects due to atmospheric gases and tropospheric scintillation requires accurate modelling in the design of satellite communication systems. The combination of the two attenuation phenomena was observed within the period of August 2014 to December 2015. The result of this paper presents the on-going observation and data analysis of non-rainy attenuation on earth-space path in Ota, Southwest Nigeria. Results of clear-sky attenuation vary between 0 dBm and 4.85 dBm in January and February 2015 respectively. While a value of 4.23 dBm and 4.75 dBm were observed in October 2014 and 2015 respectively. The results will be useful for satellite communication system design and will be submitted to ITU-R Study group 3 Databank.

1. Introduction

As demand for satellite, services are increasing especially at higher frequencies, under the influence of microwave propagation. Earth-space path link is a major concerned in the design of satellite communication systems. Major propagation factors that might impair the signal quality and also affect availability of satellite communication service includes rain attenuation, gaseous attenuation, tropospheric scintillation, cloud attenuation, melting layer attenuation, and rain and ice depolarization. Particularly, at Ku-band (14/12 GHz) and above [1, 2].

Rain attenuation is the main impairment effect for millimetre wave signals propagating through the troposphere. Interestingly, communication satellite operating in Ku and Ka bands links only requires small size of antennas that reduce or eliminate the use of tracking method and mostly cheaper cost of earth stations with the use of Very Small Aperture Terminals (VSATs). Therefore, rain may only form a little effect of the total propagation link margin [2]. However, the frequent presence of atmospheric gases and tropospheric scintillation may cause significant fades in these higher frequency bands for a large portion of the time.

Atmospheric gases, such as nitrogen (78.09%) and oxygen (20.95%) are predominantly present in the atmosphere. Water vapour (0.25%) though very small, is the most important in gaseous attenuation and it's has a major effect on propagation of electromagnetic wave. However, absorption caused by oxygen and water vapour is fundamental in understanding how attenuation due to gases depends on electromagnetic radiation [3]. Scintillation is caused by absorption and scattering of signal in the transmission link between the earth station and satellite station. Scintillation phenomena in earth satellite link is characterised at low elevation angles and high frequencies [4].

Little or no non-rainy attenuation ground measurements has been carried out in Nigeria up till now, most of the previous works on gaseous attenuation prediction model was based on theoretical model developed for the temperate region [5, 6, 7, 8].

In tropical countries, accurate performance of signal quality has turn into a growing demand due to the fact that modern satellite communication technology applications are being increasingly demanded for during highly tropical weather impairments and there is a scarcity of information as regards the non-rainy attenuation such as tropospheric scintillation analysis particularly in tropical region [9,10,11,12,13]. Therefore, the prediction, measurement and modelling of atmospheric gases and tropospheric scintillation on earth-satellite path links at Ku band and above in Southwest, Nigeria during clear-sky is essential, hence form the basis of this research.

2. Non-Rainy Attenuation Measurement

The ground data experimental measurement system at our laboratory incorporates Very Small Aperture Terminal (VSAT) with 0.9 m diameter. This satellite dish VSAT antenna was installed at the rooftop of a building at College of Science and Technology (CST) of Covenant University (CU), Ota, for approximately 52 m above the ground level. On the point of latitude 6.7˚ N and longitude 3.23˚ E and is directed toward Astra satellites (Astra 2E/2F/2G) on the geostationary orbit of longitude 28.2 ° E and the elevation angle of the receiver antenna is 59.9˚.

The measurement setup at CU in Figure 1 shows VSAT transmitting data and simultaneously receiving returned data from Astra satellite. The beacon fixed-frequency of 12.245 GHz is transmitted by the satellite for reception on the ground and is vertically polarized. The output signal of the low noise block (LNB), at the dish was connected to a spectrum analyzer, which was interface to a computer at CU, Ota as shown in Fig. 2.

The 9103 handheld Spectrum Analyser (Aeroflex) is a multi-channel remote sensing active device that has many applications such as logging of attenuation received signal level data frequency every seconds in decibel meters (dBm), troubleshooting of antenna and cable installations among others. The averaged channel power attenuation (in dBm) at one-minute interval is recorded and stored on a personnel computer.

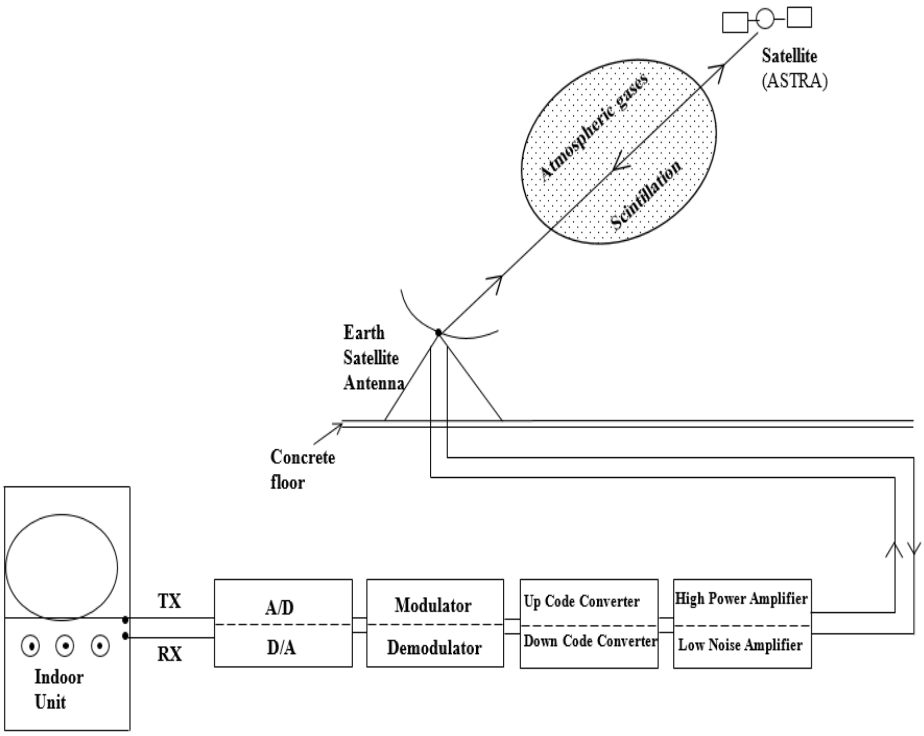

Figure 1. Experimental setup and illustration

The separation of gaseous attenuation and scintillation and other attenuation phenomena were done by filtering. Although, scintillation occur during rainy as well as non-rainy periods but rain events are excluded in this report. Also, from Davis weather station the rain rate at 0 mm/h were observed for non-rainy days while rain rate above 0 mm/h were filtered away from the corresponding days and time data from spectrum analyser within the period of August 2014 to December 2015.

The non-rainy attenuation is obtained by subtracting a reference signal level data from measured received signal level data on every one minutes for each clear-sky day. The reference level data is therefore, obtained by averaging the entire received signal level data on each month and at each place during non-rainy term.

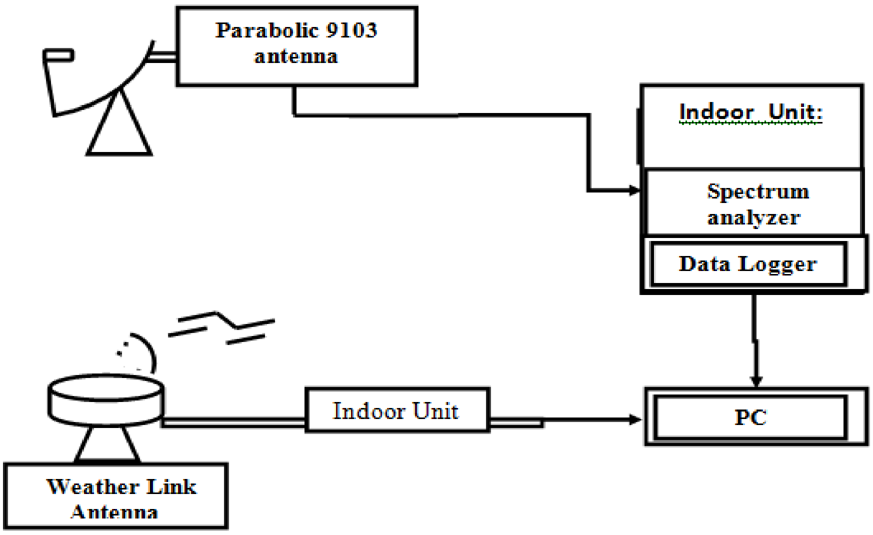

Figure 2. Block diagram of the VSAT setup in CU

3. Results and Discussion

Gaseous attenuation and tropospheric scintillation fade distributions were predicted using Spectrum Analyser and Davis weather station for a period of two years (August, 2014 to December, 2015). The non-rainy attenuation for different percent (0.001%, 0.01%, 0.1% and 1%) of time of the year determined by percentage of ordinate exceedance curves is shown in Figures 3 to 6 for the year 2014 and 2015 respectively. The results obtained showed the time portion gets smaller with an increase received clear-sky attenuation distribution, the reason for this is attributed to little effects of gases and scintillation on the total attenuation at small percentage of time.

Table 1 show summary of results of clear-sky attenuation minimum values of 0 dBm experience in January and March, 2015 respectively. While, Maximum value of 4.85 dBm was observed in February 2015 been a dry month, this may be due to the presence of cumulonimbus cloud which cause scintillation (presence of high water vapour density) contribute to the results. However, maximum values of 4.23 dBm and 4.75 dBm was recorded in October of 2014 and 2015 respectively, this is in conformity with high attenuation during rainy season.

Table 1: Summary of the result

YEAR	2014		2015	
MONTH	Min. (dBm)	Max. (dBm)	Min. (dBm)	Max. (dBm)
JAN	-	-	0	4.00
FEB	-	-	0.05	4.85
MAR	-	-	0	4.50

APR	-	-	0.02	3.92
MAY	-	-	0.05	3.85
JUN	-	-	0.04	4.06
JUL	-	-	0.05	4.75
AUG	0.03	3.63	0.02	4.48
SEP	0.04	4.04	0.05	3.65
OCT	0.03	4.23	0.05	4.75
NOV	0.03	3.77	0.01	3.91
DEC	0.05	3.95	0.03	4.23

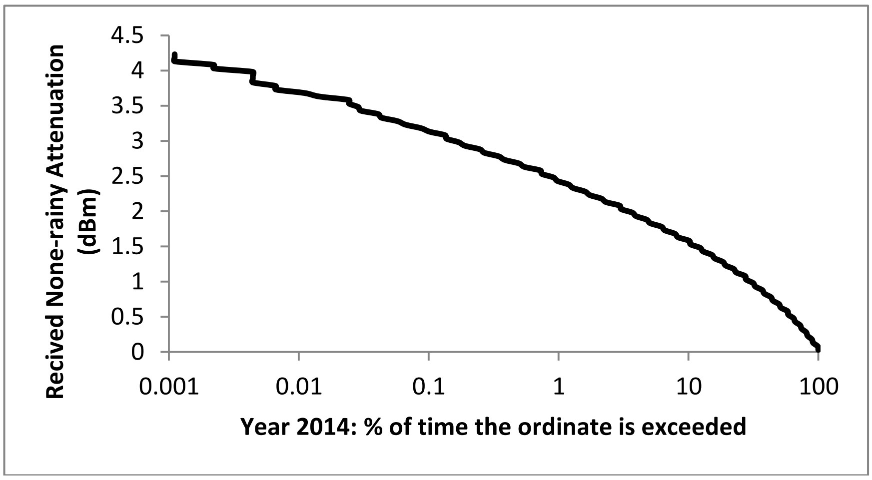

Figure 3. Total measured cumulative distributions for non-rainy Attenuation in 2014

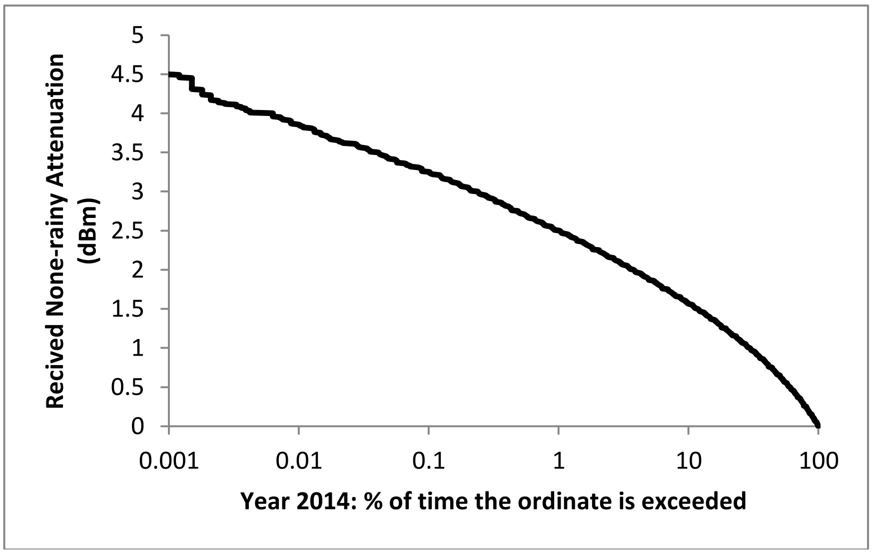

Figure 4. Total measured cumulative distributions for non-rainy Attenuation in 2015

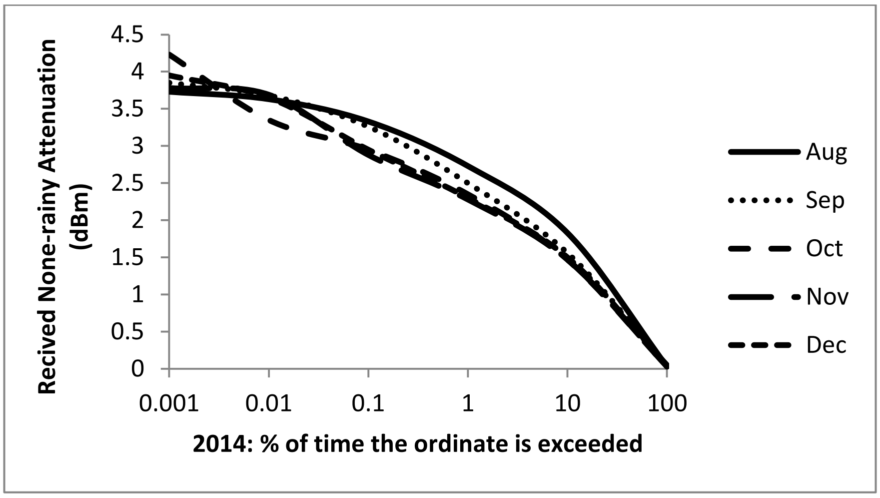

Figure 5. Cumulative distributions of non-rainy Attenuation in CU, Ota from August to December 2014

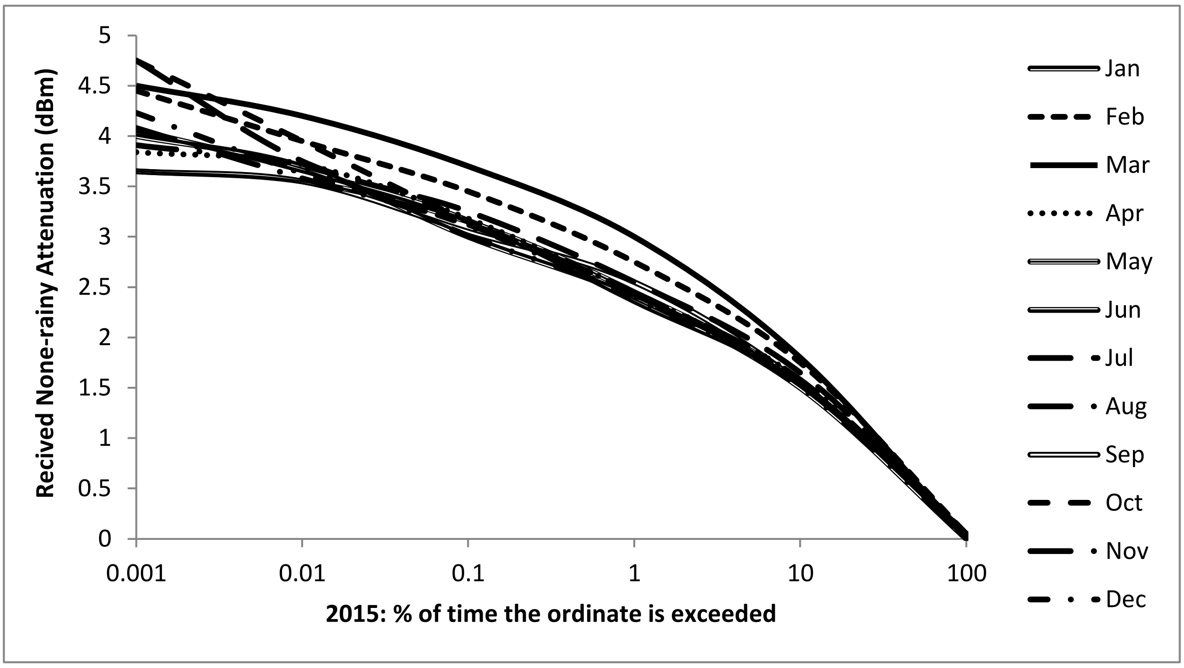

Figure 6. Cumulative distributions of non-rainy Attenuation in CU, Ota from August to December 2015

4. Conclusion

The results from Covenant University show that atmospheric gases and tropospheric scintillation can be combined accurately with the fact that is statistically independent of each other. However, the results non-rainy attenuation may be significant for low fade margin system designs at higher frequency bands. The model and data analysis process is ongoing in the study area and the results may be useful for satellite communication system design and submitted to ITU-R for future recommendations.

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