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Effect of Gas Attenuation Prediction Models at Ota, Southwest Nigeria

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Abstract. The demand for satellite services is rapidly increasing on a daily basis. One of the major concern for satellite telecommunication designer is the impacts of gas attenuation on earth-space path link, most importantly in tropical areas. This research has been directed on the analysis and comparison of gas attenuation prediction models at Covenant University, Ota, southwest Nigeria (Lat: 6.7 °N, Long: 3.23 °E). Gas attenuation data were collected from spectrum analyzer and Davis automatic weather station for a period offive years (April 2012-December 2016) from Astra 2E/2F/2G Satellite link set at an elevation angle of 59.9° on 12.245 GHz. The monthly gas attenuation were analysed and compared with existing gas attenuation prediction models that could provide guide to microwave propagation engineers in the tropical region. The results suggest that even during clear-sky, gas attenuation still pose a threat to the design of satellite communication on earth-space path. Therefore, ITU-R model may be more accurate for modelling gas attenuation for the region. Hence, the statistics provided in this work will help engineers in planning and designing good telecommunication systems in the tropical region.

Keywords: Electromagnetic wave, Gas attenuation, Microwave propagation, Radiowave propagation, Satellite communication.

1. INTRODUCTION

The theory explaining the interaction between molecules and radiation of gases in telecommunication ascertained fact that microwave signals experience significant attenuation that can appreciably degrade the quality of signal transmissions [1]. Millimeter and sub-millimeter wave signals experience scattering and absorption while propagating through the atmosphere. The scattering is due to molecules of gases, water droplets and other atmospheric particles present in the atmosphere, while gases and solid particles (such as smoke and dust) cause absorption of the signal in the atmosphere. Certainly, trace gases become significant at higher frequencies [2, 3, 4]. Hence, the ability of the atmosphere to scatter and absorb transmitted signals depends on tropospheric parameters such as pressure, relative humidity and temperature [5].

Other atmospheric gases such as nitrogen and carbon dioxide only turn out to be problematic in very dry air circumstances at frequencies greater than 70 GHz. Hence, losses instigated by tropospheric absorption differ with frequency. Astronomy and remote sensing studied to more details effects of atmospheric losses such as a variety of nitrogen, minor gases components including stratospheric ozone, sulphur oxides or carbon, because their absorption rate is lower compare with oxygen and water vapour [6, 7]. The sun contribution to the movement of gases in the atmosphere; land and sea interactions are also very important. Solar radiations at ultra violet (UV), infrared and visible light wavelength frequently bombards the troposphere [8]. Moreover, few solar radiations are propagated back to space by vapours, while some attenuates back to planetary by gases through total or partial absorption of ozone and water vapour by atmospheric molecules [9].



In general, researcher's attention has been on rain attenuation because gaseous attenuation had little effect on radio signal than rain and clouds attenuation [10, 11, 12, 13] and Nigeria is no exception. Meanwhile, rain attenuation is restricted in space and time, whereas, clouds together with atmospheric gases (water vapour and oxygen) are constantly present nearly throughout the period of rain and no rain most especially at Ku band and above. Therefore, there is need for us to shift our focus from rain to clear-air (non-rainy) attenuation because knowledge of this impairment will increase exact performance of quality of signal for the period of a severe weather condition.

2. METHODS AND DATA ANALYSIS

Gas attenuation data were derived from a beacon set-up over a 12.245 GHz link located on ASTRA satellite (2E/2F/2G) orbited on 28.2 °E at an elevation angle 59.9° of the receiving antenna. The non-rainy attenuation measurement data were extracted from database record at a sample rate of 1 second integration time as reported by [6]. The five years observed data for this research is between April 2012 and December 2016. The rainy days were parted away from non-rainy days for this work by means of Davis automatic weather stations and spectrum analyser equipment at rain rate 0 mm/h measured for non-rainy events. On the other hand, rain rate directly above 0 mm/h were minus from the equivalent days and time data within the period of surveillance. A monthly average data were utilised as position data signal level and were minus from everyday observed established data signal level in way to acquire the gas attenuation on every single one minutes for each non-rainy day.

Furthermore, the measured attenuation due to gas data at Ota were compared with present gas attenuation models which are: [14, 15, 16] models.

3. RESULT AND DISCUSSION

The summary of the results of predicted gas attenuation models at 12.245 Hz frequency link at 59.9° elevation angle for Ota is presented in Figures 1 (a and b) and 2 (a - c) respectively. The measured data in Covenant University, Ota is considered for the period of three years from August, 2014 when Spectrum Analyser became available to December, 2016 for attenuation measurements. On the other hand, satellite data was used for the gas attenuation apart from ITU-R model which required ground input parameters for its measurements. The satellite data used for this study is between January, 2012 and September, 2016. The results of the total attenuation due to gas models using ground data and satellite as inputs parameters provided by the predicted models equations is given in Figures 1 (a and b) without the observed data in Ota. ITU-R and Salonen models were observed to be close to each other but Salonen model shows more dip and thus giving the lowest attenuation in the range of 0.056 dB to 0.070 dB in 2016. Liebe's model gave the highest attenuation at 0.126 dB in 2015 all through the year under this study.

Furthermore, Figure 2 (a - c) shows the inclusion of the observed data in Ota to the already predicted gas attenuation models and the results obviously revealed that the observed data of Ota is best predicted by the ITU-R model than other predicted models although Ota registered its presence in August 2014. This is because ITU-R model used database developed for the particular region. Whereas Liebe's used vertical profile of climatological data whose accuracy can be questioned and finally Salonen model was developed for temperate region. However, the results in 2014 show the inclusion of the measured data at Ota to the already predicted gas attenuation models and the results obviously revealed that the observed data of Ota is far lower than the predicted models, although Ota registered her presence in August. The monthly variation of attenuation in 2012, show that Salonen model recorded the lowest values between 0.076 to 0.095 dB followed by ITU-R model between 0.087 to 0.094 dB, Moreover, the highest observed attenuation was recorded in Leibe's model between 0.098 dB to 1.19 dB.

The uniqueness of all the models in this particular year was that they all witnessed low values of total gas attenuation in dry months and also recorded highest attenuation in wet months (especially April and October 2012). These surveillance have some thoughtful interpretation because the data

used for this research is strictly clear-sky data and yet the results confirmed high attenuation during rainy season. The results also suggest that even during clear-sky, gas attenuation still pose a threat to the design of satellite communication on earth-space path. Likewise, the same pattern was observed in 2013 to 2016 where Salonen's model was reported as the lowest model and Liebe's model gave the highest value as shown in Figures 1 (a and b) and 2 (a - c).

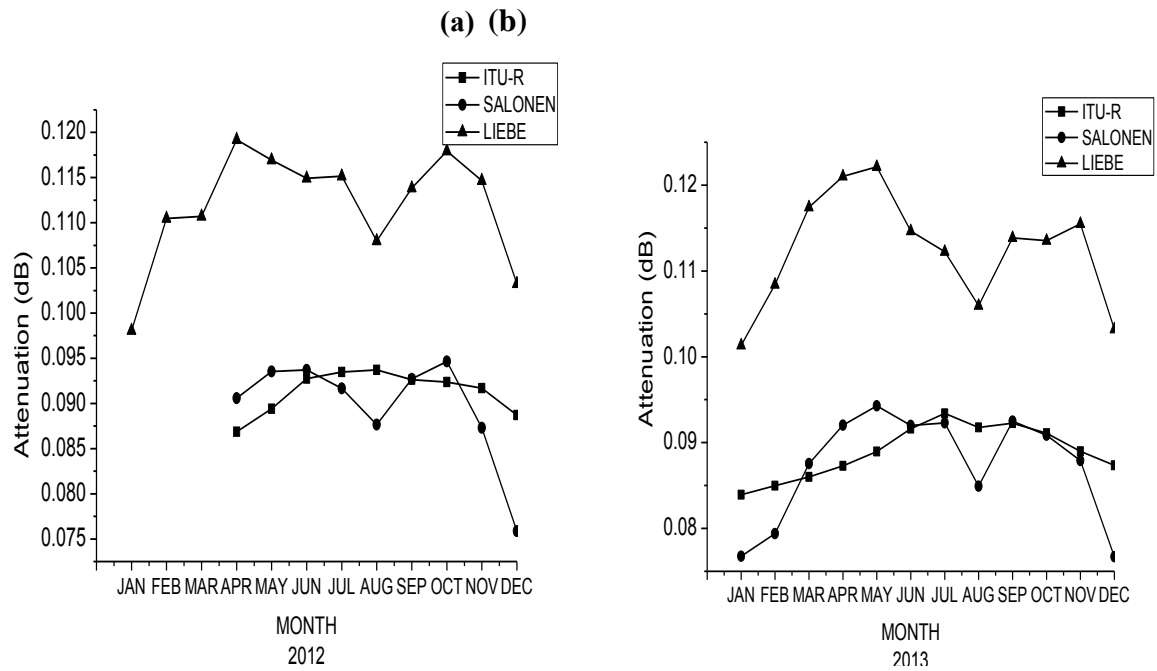
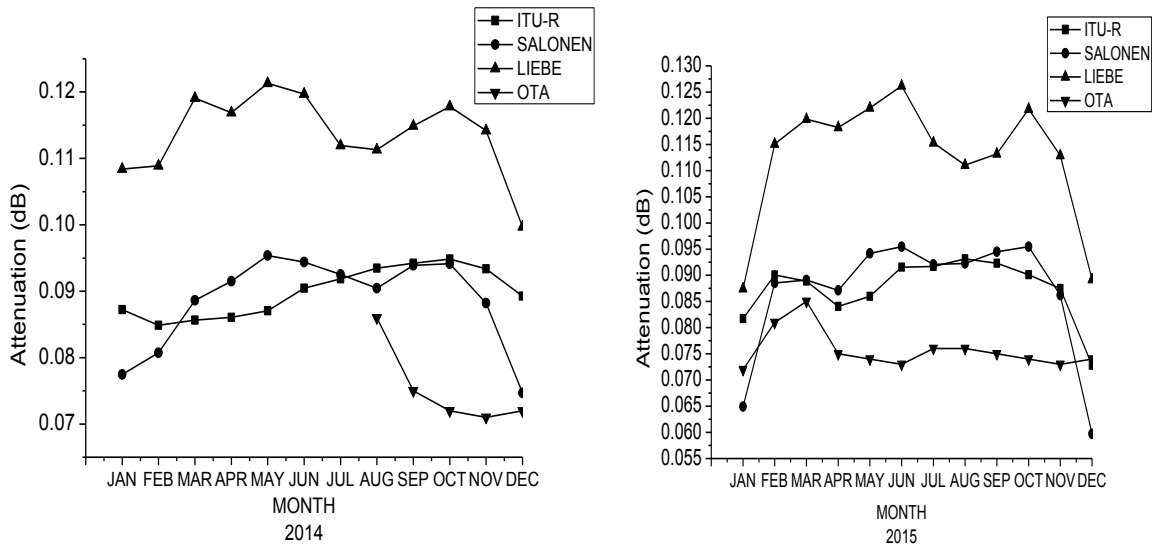


Figure 1: Comparison of predicted models of gas attenuation for: (a) 2012, and (b) 2013.

(a) (b)



(c)

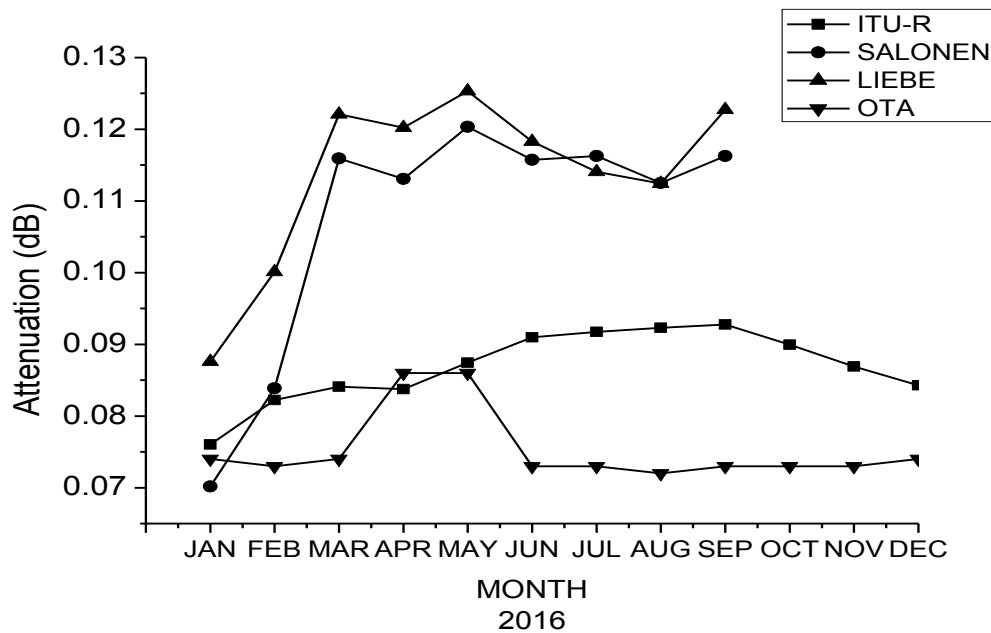


Figure 2: Comparison between ground data in Ota and predicted models of gas attenuation for: (a) 2014, (b) 2015, and (c) 2016.

4. CONCLUSION

The assessment of three prediction clear-sky gas attenuation models namely: ITU-R, Liebe's and Salonen models have been presented in this study. The three prediction models were compared with the observed ground data gathered from Astra satellite at Ku-band frequency located in Ota. The results also suggest that even during clear-sky, gas attenuation still pose a threat to the design of satellite communication on earth-space path. The results revealed that Ota is best fits ITU-R model than other models because the data were collected from the database from the region using ground data, same as Salonen model while Liebe's is distance from Ota values due to vertical profiles data requirements for its calculation for the input parameters.

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