Investigation of Gaseous Attenuation on a Ka-Band Propagation Link in Tropical Region

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***Abstract*—In this paper, gaseous attenuation along a Ka-band slant path link is investigated and analyzed for the tropical country of Singapore. The signal is chosen at a frequency of 18.9 GHz with an elevation angle 44.5°. In order to estimate the gaseous attenuation along this slant path, Recommendation ITU-R P.676-10 model is applied. Four-year gaseous attenuation is processed and analyzed. The results show that for Ka-band, the water vapor attenuation is much larger than the dry air attenuation and the total maximum gaseous attenuation can be up to 0.84 dB. The seasonal variation of gaseous attenuation is mainly due to the alteration of dry/wet and hot/cool phases. In addition, the gaseous attenuation is found to keep increasing from Year 2012 to 2015, which might be due to the global warming effect.**

Keywords—gaseous attenuation; Ka band; water vapor; radiowave propagation

I. INTRODUCTION

For Earth to Space communication systems, when the signal transmits through the atmosphere, it is attenuated by several fading impairments. They are primarily rain attenuation, cloud attenuation and gaseous absorption [1-3]. Although the contribution of gaseous absorption to the total attenuation is relatively small compared to the attenuation due to precipitation and cloud [4], for the system operating in high frequency band (V/W band) or in the case of low elevation angles, the gaseous attenuation should be taken into consideration.

The gaseous absorption [5] consists of dry air attenuation (oxygen, pressure-induced nitrogen and non-resonant Debye attenuation) and water vapor attenuation. For a tropical region like Singapore, the total gaseous attenuation especially the water vapor attenuation is relatively large since the temperature and relative humidity is quite high over the year comparing to subtropical and temperate regions.

Previously, the rain attenuation [1] and cloud attenuation [2, 6] along the slant path propagation link in tropical region have been investigated in Singapore. As a complementary research, the gaseous attenuation on Ka-band along the same propagation link is studied by applying ITU-R P.676-10 model [5] and surface meteorological data, and will be reported in this paper.

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II. PREDICTION MODEL AND DATA DESCRIPTION

A. Gaseous Attenuation Model

For the zenith gaseous attenuation, it is summation of the dry air attenuation A_o and the water vapor attenuation A_w. For Earth-Space path with an elevation angle, φ, between 5° and 90°, the total gaseous attenuation A based on surface meteorological data [5, 7] is,

$$A = \frac{A_o + A_w}{sin\varphi} \quad (1)$$

where $A_o = h_o \gamma_o$ and $A_w = h_w \gamma_w$. Here, γ_o (dB/km) and γ_w (dB/km) are the specific attenuations due to dry air and water vapor, and h_o and h_w are the equivalent height of dry air and water vapor respectively.

B. Weather Station Data

The Davis Vantage weather station is located at Nanyang Technological University (NTU). It continues measuring the surface meteorological data per minute. For this study, four-year (2012-2015) weather station data are processed. For the estimation of the gaseous attenuation, the surface pressure, relative humidity, and temperature are the key parameters.

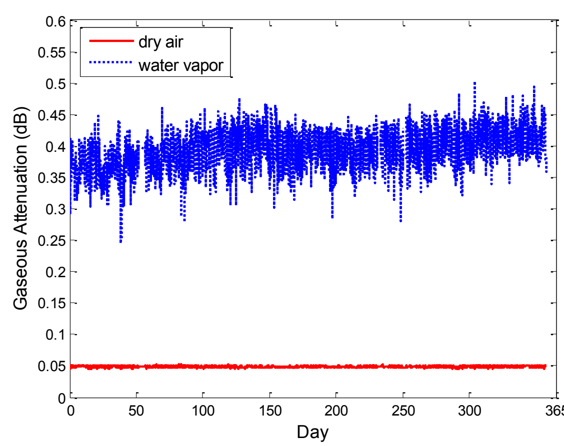

Fig. 1. The zenith gaseous attenuation due to dry air and water vapor in 2012.

III. Results and Analysis

A. Dry Air Attenuation and Water Vapor Attenuation

Fig. 1 shows an example of calculated zenith dry air attenuation and water vapor attenuation at 18.9 GHz in the year of 2012. From Fig. 1, it can be observed that the zenith dry air attenuation is around 0.05 dB with small variation (maximum variation of 0.007 dB) and the zenith water vapor attenuation fluctuates from 0.25 dB to 0.5 dB with large variation.

It can be also observed that, for Ka-band signal, the water vapor causes much larger attenuation comparing to the dry air and the seasonal variation of total gaseous attenuation is mainly due to the amount change of water vapor. It is noted that similar results are also observed for other years.

B. Seasonal Variation of Gaseous Attenuation

Fig. 2 shows the four-year slant path total gaseous attenuation calculated for 18.9 GHz with an elevation angle of 44.5°. The maximum total gaseous attenuation is found to around 0.84 dB and the minimum is around 0.42 dB. In order to study the trends of seasonal variation of total gaseous attenuation, moving average technique with sliding window of 30-day is applied.

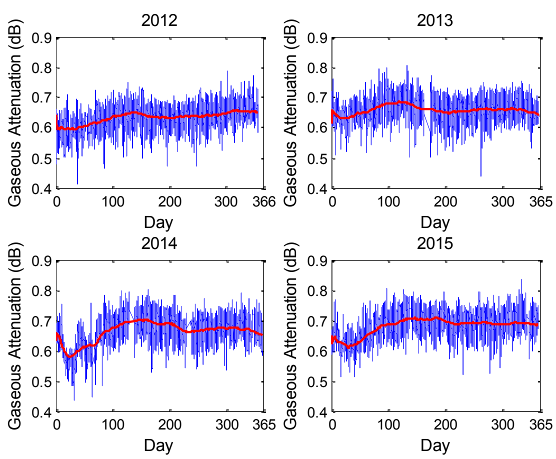

Fig. 2. Four-year (2012-2015) total gaseous attenuation with the slow trends.

It can be observed that the seasonal variation of gaseous attenuation has similar trend from 2012 to 2015. This is because for the tropical country of Singapore, there are two monsoon seasons (Northeast Monsoon and Southwest Monsoon) and two inter-monsoon seasons. This kind of variation is mainly due to the seasonal alteration of the dry/wet and hot/cool phases. The maximum gaseous attenuation happens at wet and hot phase (around May) and the minimum gaseous attenuation is observed at dry and cold phase (around February).

C. Gaseous Attenuation

Fig. 3 shows the four-year (2012-2015) cumulative distribution function of slant path gaseous attenuation at 18.9 GHz. It can be observed that at 0.01% of time, the gaseous attenuation can be up to 0.78 dB. In addition, the gaseous attenuation keeps increasing from 2012 to 2015, this might be due to the global warming effect. The difference between 2012 and 2015 is about 0.05 dB for Ka-band signal. Therefore, for the systems operating at higher frequency (e.g., V/W band), the gaseous attenuation is relatively large [7], and should be taken into consideration in system design.

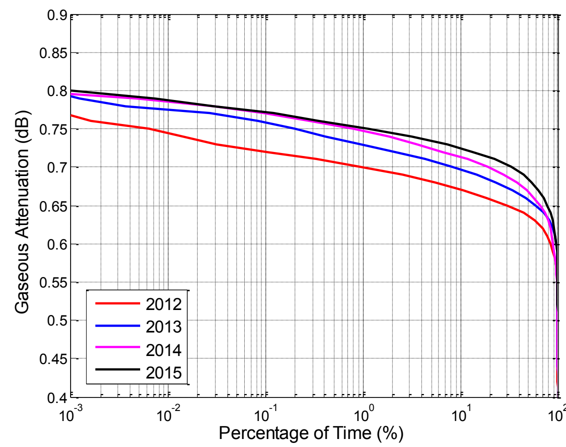

Fig. 3. Cumulative distribution function of gaseous attenuation for the year of 2012 to 2015.

IV. Conclusion

In this paper, four-year gaseous attenuation on a Ka-band slant path link was studied. ITU-R P.676-10 model and surface meteorological data are applied to calculate the gaseous attenuation.

The results indicate that for Ka-band signal, the water vapor attenuation is much larger than the dry air attenuation. The variation of gaseous attenuation is mainly due to the alternation of seasonal dry/wet and hot/cool phases. The maximum gaseous attenuation happens at wet and hot phase. It is also noted that the gaseous attenuation keeps increasing from 2012 to 2015, which might be due to the global warming effect.

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