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Estimation of Water Vapor Attenuation Variations at Microwave Frequencies over Kolkata, India

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Abstract
The radiosonde data available from British Atmospheric Data Centre (BADC) over Kolkata, India (22.65°N) for two different season (winter season and rainy season) were analyzed to observe the variation of Water vapor attenuation in the frequency range 10 GHz -30 GHz. Zenith antenna temperatures at 10, 20, 22.235, 23.834, 26, 26.5 and 30 GHz have been determined for the different value of water vapor content during January-February and July-August. Antenna temperature, as expected, is less at 10 GHz, but increases with increase in frequency, thereafter, becoming maximum at the water vapor resonance line of 22.235 GHz, and then decreasing with further increase in frequency. The attenuation values in terms of dB have also been evaluated over this place.
Keywords: Water vapor, Attenuation, Antenna temperature

I. INTRODUCTION

When the signal transmitted higher in frequency, the clear atmosphere attenuates higher radio frequencies due to water vapor, oxygen, ozone, and other constituent gases. Because of the lower molecular densities of the other gases, only water vapor and oxygen contribute significantly in the millimeter band. The absorption of microwave signal by water vapor results from the coupling between the electric component of the radiation field and the electric dipole of the molecule, whereas absorption of microwave signal results from the interaction between the magnetic dipole and the magnetic field component.

The radiation field looses energy to the molecule in the case of absorption, but gains energy from the molecule in the case of emission. Water vapor has a single pure rotational line at 22.235 GHz and oxygen has a line at 60 GHz. Therefore, communication systems in the 10-30 GHz band are more affected by water vapor than by oxygen. Estimated theoretical calculations have been evolved based on the radiosonde data of Kolkata (22.265°N), to find the antenna temperature variation and attenuation variation.

The radiosonde data over the said places were made available to the authors by the British Atmospheric Data Centre (BADC), U.K.

II. ANALYSIS OF RADIOSONDE DATA

Radiosonde data, available from BADC (UK), is consisting of vertical profiles of temperature t (h) in degree centigrade, pressure P (mb), and dew point temperature (t_d) in degree. We have used the data for the month January-February and July – August for the year 2005 over this particular place of choice. One point to be mentioned here is that, there is a winter season during January-February and rainy season during July-august at Kolkata (Karmakar et al 2011). The radiosonde data of the chosen location is taken upto a height of 7.4 km from the surface 0.004 km, throughout the two month of each season and then took the average of two months data. These data set consisting of vertical profiles of average temperature, average pressure and average dew point temperature, are used for calculating antenna temperature and attenuation for the chosen location for the month of January-February and July-August. For the purpose of calculating antenna temperature and attenuation , the water vapour pressure e (mb) and saturation water vapour pressure e_s(mb) has been calculated using the following relations respectively (Moran and Rosen, 1981; Sen et al 1989),

$$e(z) = 6.105 \exp\{25.22\left(1-\frac{273}{T_d(z)}\right) - 5.31 Log_e\left(\frac{T_d(z)}{273}\right)\} \quad (1)$$

$$e_s(z) = 6.1121 \exp\{\frac{(17.502t)}{(t+240.97)}\} \quad (2)$$

Here, T_d is the dew point temperature in Kelvin and t is ambient temperature in degree centigrade.

Water vapour pressure, e and water vapour density, ρ(gm/m^3) are related by the relation

$$\rho_v(z) = 217\ \frac{e(z)}{T(z)} \quad (3)$$

The relative humidity, RH(%) is given by the relation(Karmakar et al 2011)

$$RH=(e/e_s)\times 100 \quad (4)$$

Now the total water vapor absorption co-efficient at frequencies below 100 GHz is given by (Ulaby et al 1986)

$$K_{H_2O_\gamma}(f,z) = 2f^2\rho_v(\tfrac{300}{T})^{3/2}\gamma_1 \times [\left(\tfrac{300}{T}\right) exp\left(-644/_T\right) \times \left(\frac{1}{(494.4-f^2)^2+4f^2\gamma_1^2}\right) + 1.2 \quad (5)$$

Where f is the frequency, z is the height in km , ρ_v is the water vapor density in gm/m^3, T is the temperature in ^{o} c, γ_1 is the line-width parameter and is given by

$$\gamma_1 = 2.85\left(\frac{P}{1013}\right)\left(\frac{300}{T}\right)^{0.626}\left(1+\frac{0.018\rho_v T}{P}\right) \quad GHz \quad (6)$$

Here p is the pressure in milibar.

The term opacity is the integrated attenuation of the microwave signal and mathematically it is given by

$$\tau_v(f,z) = \int_0^z K_{H_2O_\gamma}(f,z)\ dz' \quad (7)$$

That means the opacity which is a function of frequency and height, is the integration of the water vapor absorption co-efficient$K_{H_2O_\gamma}(f,z)$.

Using equation 5, 6, 7 and the average data of the chosen location for the year 2005, opacity is calculated during January-February and July-August. Knowing the value of $\tau_v(f,z)$, zenith temperature T_a can be determined by the equation (Raina, 1988)

$$T_a = (1-\exp(-0.23\ \tau_v(f,z)))T_m \quad (8)$$

Where T_m is the mean medium temperature of the atmosphere, taken to be 290 K. The antenna temperature so obtained is converted into attenuation A in dB, using the relation (Raina, 1988)

$$A = 10logT_m/(T_m - T_a) \quad (9)$$

III. RESULT AND CONCLUSION

Zenith antenna temperatures were calculated for the frequency range 10 GHz-30 GHz for various values of water vapor content over Kolkata.

Fig. 1 shows the Zenith antenna temperatures, calculated at 10, 20, 22.235, 23.834, 26, 26.5 and 30 GHz for the water vapor content of 18.2376, 20.4409, 22.2735 g/m3 during January-February and is tabulated in Table 1.Fig. 2 shows the Zenith antenna temperatures calculated at same frequencies for the water vapor content of 44.3243, 53.2666, 61.0478 g/m3 during July-August and is tabulated in Table 2.

Table 1: Showing the value of antenna temperature for different value of water vapour density at different frequency during January-February over Kolkata, India.

Freq. in GHz	Antenna temp. (K) at water vapour content 18.2376 g/m^2	Antenna temp. (K) at water vapour content 20.4409 g/m^2	Antenna temp. (K) at water vapour content 22.2735 g/m^2
10	1.3626	1.4918	1.5547
20	17.8052	19.8885	21.2826
22.235	29.3706	32.4032	37.8802
23.834	23.6481	26.415	28.9116
26	15.3615	16.9907	17.8689
26.5	14.2792	15.7577	16.5272
30	11.2668	12.3267	12.8647

Table 2: Showing the value of antenna temperature fordifferent value of water vapour density at different frequency during July-August over Kolkata, India.

Freq. in GHz	Antenna temp. (K) at water vapour content 44.3243 g/m^2	Antenna temp. (K) at water vapour content 53.2666 g/m^2	Antenna temp. (K) at water vapour content 61.0478 g/m^2
10	3.1549	3.4769	3.9857
20	41.0436	48.2592	54.1677
22.235	65.8803	84.7447	95.2143
23.834	53.9511	65.2945	72.9888
26	35.0654	39.7396	44.8559
26.5	32.562	36.645	41.4382
30	25.5093	28.214	32.0697

From the table 1 and Fig.1, it is clear that, during January-February, for water vapor content of 18.2376g/m3, the antenna temperature varies between 1.3 K and 29.3 k. Likewise, variations of antenna temperature for water vapor content at 20.4409 and 22.2735 g/m3 can be determined from Fig 1 or from Table 1. Similarly from the Table 2 and Fig.2, it is observed that, during July-August, for water vapor content of 44.3243 g/m3, the antenna temperature varies between 3.1 K and 65.8 k and the variations of antenna temperature for water vapor content at

53.2666 and 61.0478 g/m3 can be determined from Fig 2 or from Table 2.

The variation of antenna temperature with frequency for different value of water vapor content during January-February and July-august is shown in Fig. 3 and in Fig. 4 respectively. Antenna temperature is less at 10 GHz, but it increases with increase in frequency, thereafter becoming maximum at the water vapor resonance line of 22.235 GHz, and then decreasing with further increase in frequency. This phenomenon is occurring for both the season.

During January-February, at the water vapour resonance line(22.235 GHz),the maximum value of antenna temperature is found to be around 37.2 K for water vapor content of 22.2735 g/m3 and minimum around 29.3 K for water vapor content of 18.2376g/m3.Similarly, during July-August, the maximum value of antenna temperature is found to be around 95.2 K for water vapor content of 61.0478g/m3 and the minimum around 65.8 K at 44.3243 g/m3 , at the water vapour resonance line(22.235 GHz).

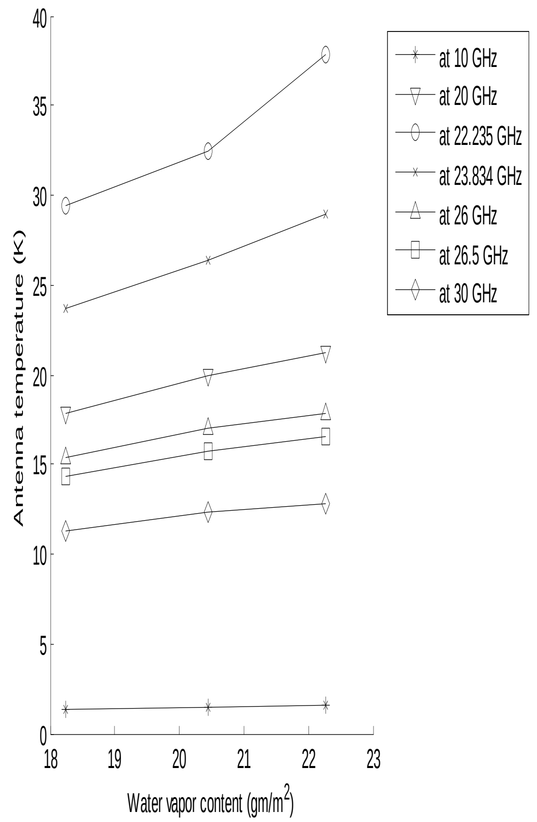

Fig. 1. Variation of Antenna Temperature with water vapor content during January-February over Kolkata, India.

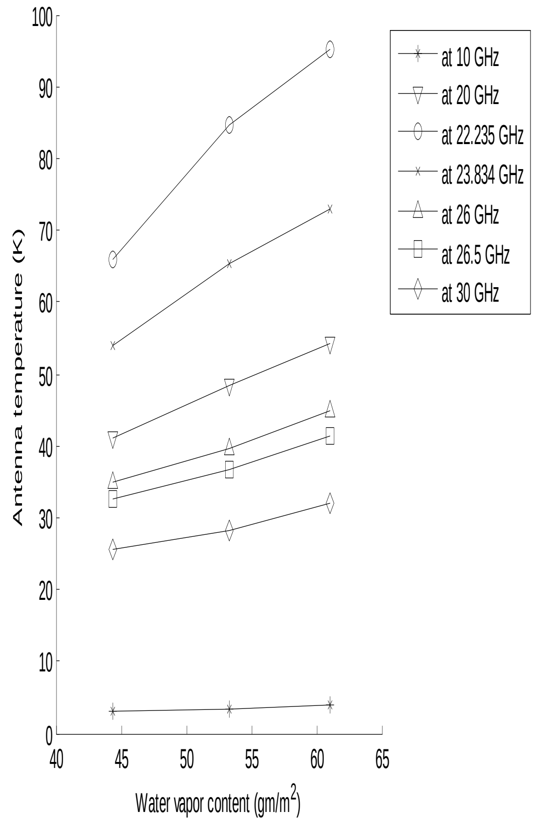

Fig. 2. Variation of Antenna Temperature with water vapor content during July-August over Kolkata,India.

Variation of attenuation with frequency for different values of water vapor content considered above during January-February and July-August is shown in Fig. 5 and Fig. 6 respectively. It is clear from these figures that the attenuation increases with increases of frequency and become maximum at the water vapour resonance line (22.235 GHz) and then the attenuation decreases with further increase of frequency. From these results, it is possible to predict the attenuation at a particular frequency for various values of water vapor content, for both the two season.

These results should be useful to those planning communication systems in the microwave and millimeter wave regions.

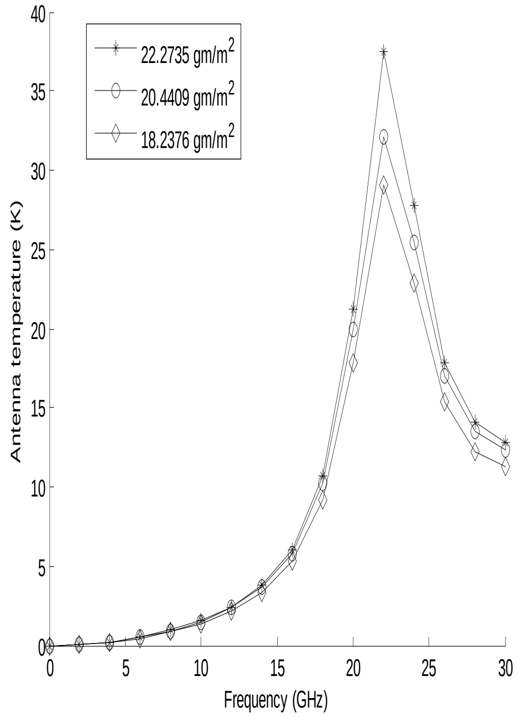

Fig. 3. Variation of Antenna Temperature with frequency during January-February over Kolkata, India.

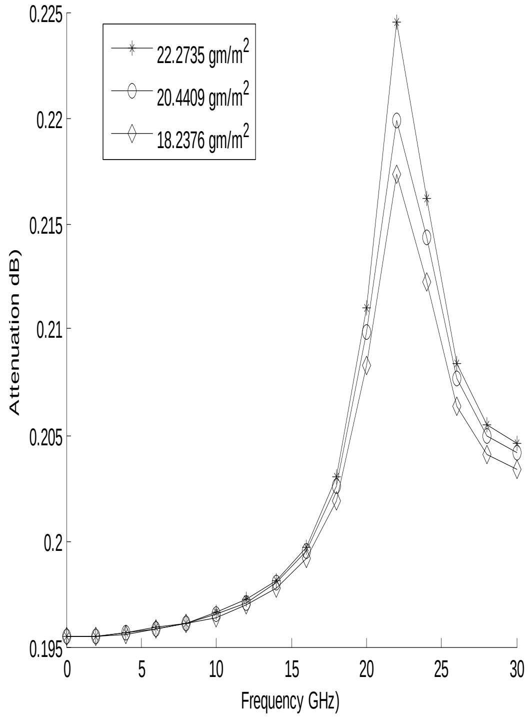

Fig. 5. Variation of Attenuation with frequency during January-February over Kolkata, India.

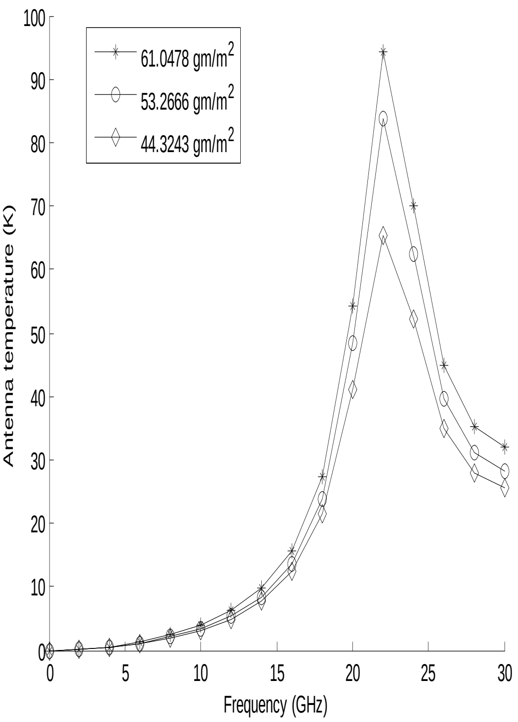

Fig. 4. Variation of Antenna Temperature with frequency during July-August over Kolkata, India.

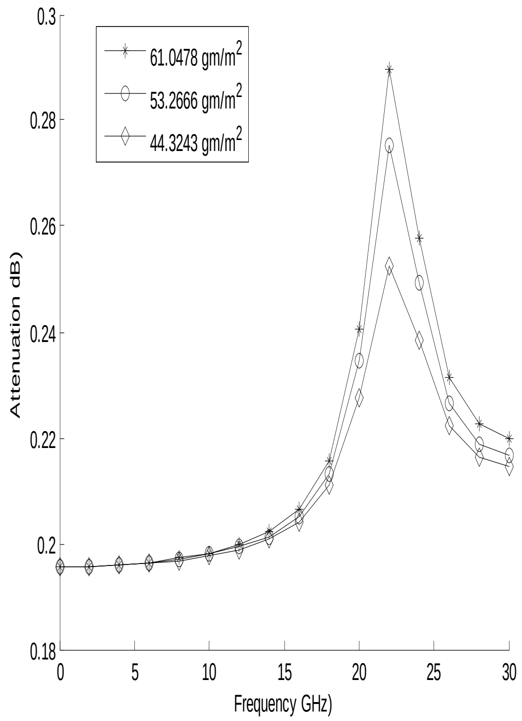

Fig. 6. Variation of Attenuation with frequency during July-August over Kolkata, India.

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