Estimation and Comparison of Antenna Temperature and Water Vapor Attenuation at Microwave Frequencies over Northern and Southern Latitude

S.Mondal, N. Sk, P.K. Karmakar

Abstract— ***Radiosonde data available from British Atmospheric Data Centre (BADC) over Chongging, (29.0 N), China and Porto Alegre(29.0 S), Brazil were analyzed to determine the variation of antenna temperature and water vapor attenuation in the frequency range 5 GHz -40 GHz during two different season namely, winter season and rainy season. Antenna temperatures at 5, 10, 20, 22.235, 23.834, 30, 35 and 40 GHz have been determined for the different value of water vapor content during January-February and July-August over these two places. Antenna temperature and attenuation increases with increase in frequency, thereafter, becoming maximum at the water vapor resonance line of 22.235 GHz. With further increase of frequency beyond 22.235 GHz and up to 31 GHz, the antenna temperature and attenuation decreases. Again after 31 GHz, Antenna temperature and attenuation is increasing in nature.***

Keywords— ***Antenna temperature, Attenuation, Water vapor, Water vapor content.***

I. INTRODUCTION

The earth's atmosphere plays an important role in microwave remote sensing. Through an understanding of scattering, absorption and emission behavior of atmospheric constituents, microwave remote sensing techniques can be employed to monitor atmospheric parameters and weather conditions.Such an understanding also will provide the means to factor out the influence of the atmosphere on observations of land and ocean surfaces.The radio frequency signal is attenuated due to water vapor, oxygen, ozone, and other constituent gases of the atmosphere. Amongst these, only water vapor and oxygen contribute significant attenuation in the millimeter band. The coupling between the electric component of the radiation field and the electric dipole of the molecule is the cause of absorption due to water vapor, whereas the interaction between the magnetic dipole and the magnetic field component is the cause of absorption due to oxygen. It is well known that 22.235 GHz is the water vapor absorption line and 60 GHz is the oxygen absorption line,therefore, in the 5-40 GHz band, any communication system is more affected by water vapor than by oxygen.

In this paper author have tried to determine the variation of antenna temperature and water vapor attenuation of the two places of exactly same latitude but one place belongs to northern latitude and other place belongs to southern latitude. Chongging, (29.0 N), China of northern latitude and Porto Alegre(29.0 S),Brazil of southern latitude are the places of interest in this paper.

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II. ANALYSIS OF RADIOSONDE DATA

Radiosonde data consists 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 during January-February and July–August for the year 2005 over this two particular place of choice. One interesting point to be mentioned here is that, during January through February, winter season prevails at Chongging but rainy season at Porto Alegre and during July through August, rainy season prevails at Chongging but winter season at Porto Alegre [1]-[3]The radiosonde data of the chosen location is taken upto a height of approximately 7.5 km from the surface, throughout the two month of each season and then used the average of two months data of each season for the detremination of antenna temperature and attenuation due to water vapor.

The antenna temperature and water vaour attenuation is determined using the following relations [5].

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

$$A = 10 log T_m/(T_m - T_a) \quad (2)$$

Where T_a is the antenna temperature, T_m is the mean medium temperature of the atmosphere, taken to be 290 K, A is the attenuation in dB and $\tau_v(f,z)$, is the opacity or integrated attenuation of the atmosphere and is given by [7]-[8],

$$\tau_v(f,z) = \int_0^z K_{H_2O_v}(f,z)\,dz' \quad (3)$$

In equation (3) the term $K_{H_2O_v}(f,z)$ is the water vapor absorption and is given by

$$K_{H_2O_v}(f,z) = 2f^2\rho_v\left(\frac{300}{T}\right)^{3/2}\gamma_1 \times \left[\left(\frac{300}{T}\right)exp\left(-644/_T\right) \times \left(\frac{1}{(494.4-f^2)^2+4f^2\gamma_1^2}\right) + 1.2\times10^{-6}\right] \quad (4)$$

Here f is the frequency, z is the height, ρ_v is the water vapor density, T is the temperature, γ_1 is the line-width parameter and is given by

$$\gamma_1 = 2.85\left(\frac{P}{1013}\right)\left(\frac{300}{T}\right)^{0.626}\left(1+\frac{0.018\,\rho_v T}{P}\right) \quad GHz \quad (5)$$

Here p is the pressure.

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In equation (4) ρ_v is the water vapor density (gm/m^3) and is calculated using the relation [1]-[3]

$$\rho_v(z) = 217 \frac{e(z)}{T(z)} \qquad (6)$$

Where water vapor pressure e (z) is calculated using the relation [4],[6],

$$e(z) = 6.105 \exp\left\{25.22\left(1 - \frac{273}{T_d(z)}\right) - 5.31 Log_e\left(\frac{T_d(z)}{273}\right)\right\} \qquad (7)$$

III. RESULT AND DISCUSSION

Antenna temperatures were calculated for the frequency range 5GHz- 40 GHz for various values of water vapor content over Chongging, China and Porto Alegre, Brazil.

Fig. 1 shows the antenna temperatures, calculated at various frequencies for the water vapor content of 9.1642, 12.3861, 14.0468 g/m^2 during January-February and is tabulated in Table I where as Fig. 2 shows the antenna temperatures calculated at the same frequencies for the water vapor content of 34.1485, 33.9915, 47.5743 g/m^2 during July-August and is tabulated in Table II. This Fig. 1 and Fig. 2 are for the location Chongging, China.

On the other hand, for the location Porto Alegre, Brazil, Fig. 3 shows the antenna temperatures, calculated at the same frequencies for the water vapor content of 32.4012, 32.4838, and 37.4204 g/m3 during January-February and is tabulated in Table III where as Fig. 4 shows the antenna temperatures, calculated at same frequencies for the water vapor content of 17.2845, 20.7269, and 25.3793 g/m3 during July-August and is tabulated in Table IV.

From the Table I and Fig.1, it is observed that at the places of Chongging, China, during January-February, for water vapor content of 9.1642 g/m2, the antenna temperature varies between 0.6788 K and 15.946k. Likewise, variations for water vapor content at 12.3861 and 14.0468 g/m^3 can be determined from Fig 1 or from Table I. Similarly from the Table II and Fig.2, it is observed that, during July-August, for water vapor content of 33.9915 g/m^3, the antenna temperature varies between 1.8377 K and 63.3734 k and the variations for water vapor content at 34.1485 and 47.5743 g/m^3 can be determined from Fig 2 or from Table II.

From the Table III and Fig.3, it is observed that, during January-February, for water vapor content of 32.4012 g/m^3, the antenna temperature varies between 2.3 K and 50.0422k. Likewise, variations for water vapor content at 32.4838 and 37.4204 g/m^3 can be determined from Fig 3 or from Table III. Similarly from the Table IV and Fig.4, it is observed that, during July-August, for water vapor content of 17.2845 g/m^3, the antenna temperature varies between 1.2 K and 27.7049 k and the variations for water vapor content at 20.7269 and 25.3793 g/m^3 can be determined from Fig 4 or from Table IV.

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. With further increase of frequency beyond 22.235 GHz and up to 31 GHz, the antenna temperature decreases. Again after 31 GHz, Antenna temperature is increasing in nature.

This phenomenon is occurring at both the location and during both the season.

Table I. Summary of antenna temperature during January-February over Chongging, China.

Frequency In GHz	Antenna temperature (K) for water vapor content 9.1642 g/m^2	Antenna temperature (K) for water vapor content 12.3861 g/m^2	Antenna temperature (K) for water vapor content 14.0468 g/m^2
5	0.1529	0.183	0.2115
10	0.6788	0.8127	0.9387
20	9.2886	12.2285	13.7632
22.235	15.946	23.7855	26.8576
23.834	12.6153	17.2995	19.3962
30	5.7062	6.8764	7.9099
35	6.1411	7.3641	8.485
40	7.4201	8.8915	10.2427

Table II. Summary of antenna temperature during July-August over Chongging, China.

Frequency In GHz	Antenna temperature (K) for water vapor content 33.9915 g/m^2	Antenna temperature (K) for water vapor content 34.1485 g/m^2	Antenna temperature (K) for water vapor content 47.5743 g/m^2
5	0.4113	0.5088	0.6503
10	1.8377	2.2743	2.9021
20	31.2896	31.7807	42.7785
22.235	63.3734	53.5649	78.8983
23.834	44.8899	42.5849	58.8716
30	15.4761	18.6534	23.7711
35	16.1478	19.6123	24.9429
40	19.2937	23.3877	29.7049

Table III. Summary of antenna temperature during January-February over Porto Alegre, Brazil

Frequency In GHz	Antenna temperature (K) for water vapor content 32.4012 g/m^2	Antenna temperature (K) for water vapor content 32.4838 g/m^2	Antenna temperature (K) for water vapor content 37.4204 g/m^2
5	0.5269	0.5051	0.5771
10	2.3471	2.2494	2.5691
20	30.8497	30.6479	34.9217
22.235	50.0422	53.0197	60.7893
23.834	40.8054	41.3539	47.113
30	19.1898	18.4664	21.011
35	20.3894	19.6067	22.2969
40	24.3879	23.4632	26.6555

Table IV. Summary of antenna temperature July-August over Porto Alegre, Brazil.

Frequency In GHz	Antenna temperature (K) for water vapor content 17.2845 g/m^2	Antenna temperature (K) for water vapor content 20.7269 g/m^2	Antenna temperature (K) for water vapor content 25.3793 g/m^2
5	0.2821	0.3278	0.4048
10	1.2587	1.4624	1.8066
20	16.8627	19.9319	24.2598
22.235	27.7049	34.2641	40.0421
23.834	22.4637	26.8554	32.2648
30	10.4262	12.1014	14.8698
35	11.0873	12.8544	15.7559
40	13.3043	15.4141	18.8558

The variation of antenna temperature with frequency over Chongging ,China and Porto Alegre, Brazil at different value of water vapor content during January-February and July-august is shown in Fig. 5 and 6 respectively. It is seen that, during January-February, maximum value of antenna temperature is found to be around 26.8576 K for water vapor content of 14.0468 g/m^2 and minimum around 15.946K at 9.1642 g/m^2 over the place Chongging, China where as in the same duration maximum value of antenna temperature is found to be around 60.7 K for water vapor content of 37.4204g/m^2 and minimum around 50 K at 32.4012 g/m^2 over the place Porto Alegre, Brazil. On the other hand, during July-August, maximum value of antenna temperature is found to be around 78.8983K for water vapor content of 47.5743 g/m^2 and minimum around 53.5649K at 34.1485g/m^2 over Chongging, China but at the place Porto Alegre, Brazil maximum value of antenna temperature is found to be around 40 K for water vapor content of 25.3793 g/m^3 and minimum around 27.7 K at 17.2845 g/m^3.

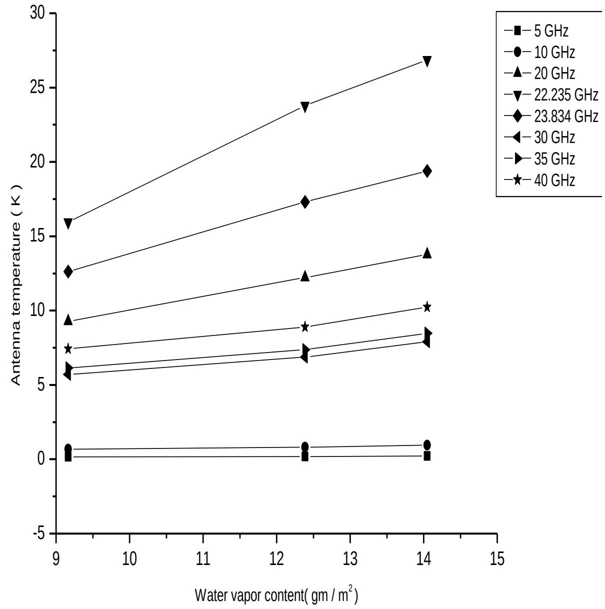

Fig. 1: Variation of Antenna Temperature with water vapor content during January-February over Chongging,china

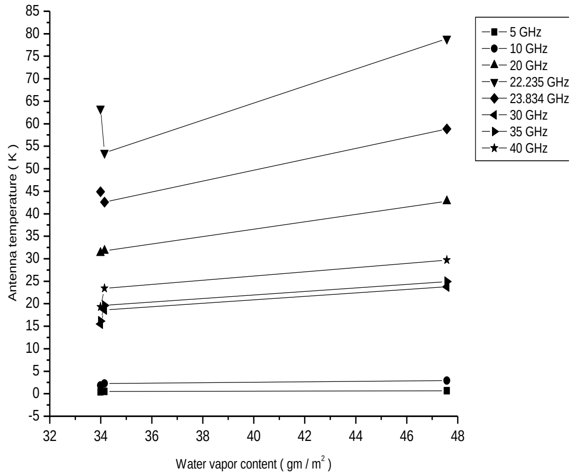

Fig. 2: Variation of Antenna Temperature with water vapor content during July-August over Chongging,china

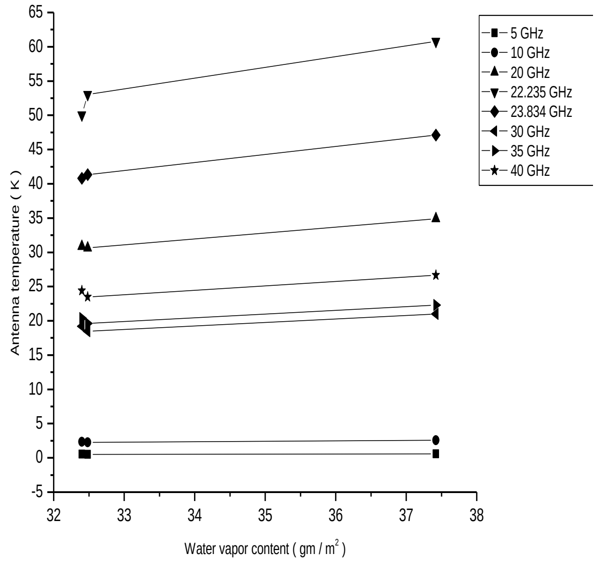

Fig. 3: Variation of Antenna Temperature with water vapor content during January-February Porto Alegre, Brazil.

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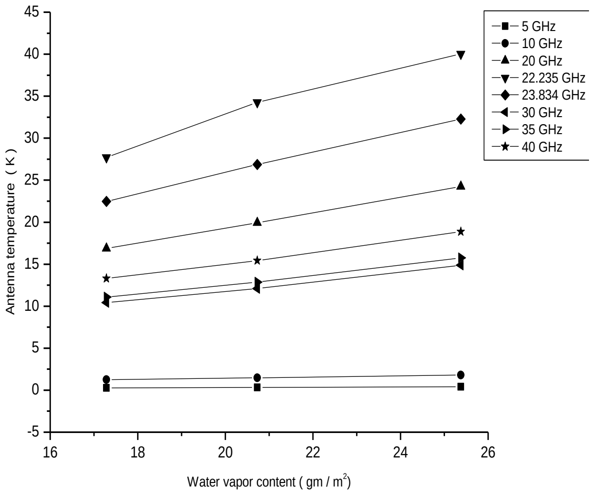

Fig. 4: Variation of Antenna Temperature with water vapor content during July-August Porto Alegre, Brazil.

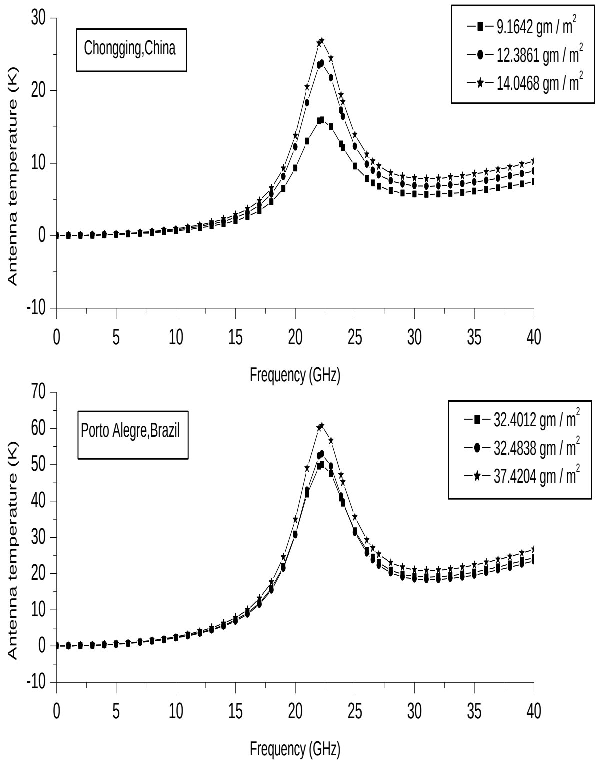

Fig. 5: Variation of Antenna Temperature with Frequency during January-February

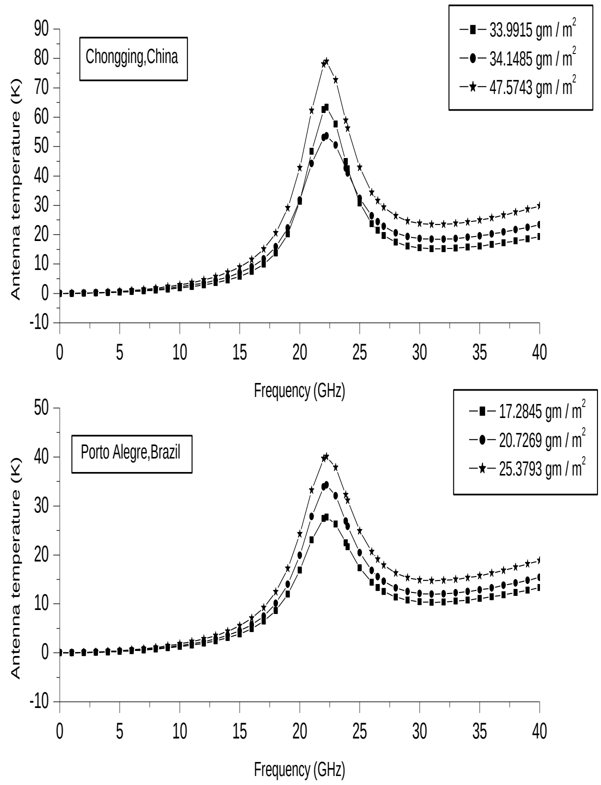

Fig. 6: Variation of Antenna Temperature with Frequency during July-August

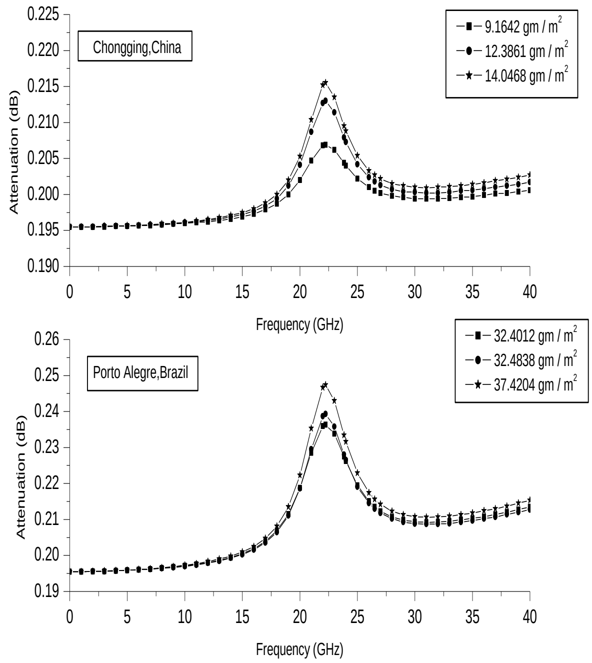

Fig. 7: Variation of Attenuation with Frequency during January-February

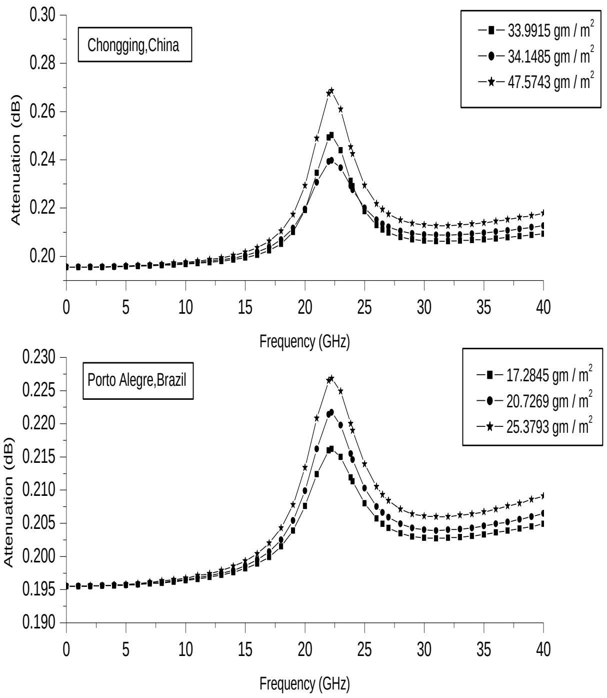

Fig. 8: Variation of Attenuation with Frequency during July-August

The variation of attenuation with frequency over Chongging, China and Porto Alegre for the different values of water vapor content considered above during January-February and July-August is shown in Fig. 7 and Fig. 8 respectively. It is clear that, attenuation also increases with increasing frequency, become maximum at 22.235 GHz and with further increase of frequency beyond 22.235 GHz and up to 31 GHz, attenuation decreases. Again after 31 GHz, water vapor attenuation is increasing in nature. From these results, it is possible to predict the expected attenuation at a particular frequency for various values of water vapor content.

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

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Since his joining in 1988 in the University of Calcutta, India, Dr. Karmakar published his noteworthy outcomes of researches over tropical locations in different international and national journals of repute. All these are culminated into a book entitled Microwave Propagation and Remote Sensing: Atmospheric Influences with models and Applications published by CRC Press in 2012.
He had been awarded the International Young Scientist award of URSI in 1990. Also, he had been awarded the South-South Fellowship of TWAS in 1997. He acted as visiting scientist in Remote Sensing Laboratory, University of Kansas, USA; Centre for Space Sciences, China, and National Institute for Space Sciences, Brazil.