RESEARCH ARTICLE OPEN ACCESS

Analysis of Water Vapor Weighting Function in the range 58 degree North through 45 degree South over the Globe

S Mondal[1], N. Sk[2],P.K Karmakar[3]
[1]Asst. Prof.,Dumkal Institute of Engineering & Technology,P.O-Basantapur,Murshidabad-742406,India,
[2]PG student,Dumkal Institute of Engineering & Technology, P.O-Basantapur,Murshidabad-742406, India,
[3]Asst. Prof., Institute of Radiophysics and Electronics, University of Calcutta, Kolkata- 700 009,India,

Abstract
The radiosonde data available from the British Atmospheric Data Centre (BADC) for the latitudinal occupancy of 58 degree north through 45 degrees south were analyzed to observe the variation of water vapour absorption and water vapour Weighting Function to select the best frequency for retrieval of atmospheric variables such as water vapor density. It is seen that the vertical resolution of the retrieval of atmospheric parameter water vapour density will be better above a height of 2-3 km. It is also clear from these figures (figure 7 through 13) that the weighting function at 23.834 GHz, the curves are bending more above the height of 2-3 km comparison the to the weighting function calculated at 22.234 GHz,23.034 GHz, 25 GHz and 30 GHz.

I. INTRODUCTION

It is well known that the microwave and millimeter waves get attenuated while it propagates through the atmosphere. This attenuation largely depends on the prevailing meteorological condition of the atmosphere. The atmosphere is composed of several layers, namely, the troposphere, stratosphere, mesosphere, and thermosphere, in order of altitude. The tropopause is the thin layer that divides the troposphere and stratosphere. It occurs at about 8 km in the polar region and 16 km in the equatorial region. The temperature of the troposphere decreases by about 0.6 degree centigrade with every 100 m increase in altitude. The temperature in the polar region is low year-round and high near the equator. This temperature difference produces atmospheric circulation. The majority of the meteorological phenomena happen to be due to fluctuation of vapor and temperature as well. Convection is the phenomenon where the air at low altitude ascends when it is heated and becomes lighter, and air surrounding it descends to occupy the vacant space. Convection gives rise to ascending currents that from cloud and rain.

In this paper the author have tried to find out the water vapour absorption co-efficient and water vapor weighting function at the five frequencies 22.234 GHz, 23.034 GHz, 23.834 GHz, 25.00 GHz and 30.00 GHz for the various location of northern and southern latitude.

II. ANALYSIS OF RADIOSONDE DATA

We have used the radiosonde data available from the British Atmospheric data Center (BADC) for the latitudinal occupancy of 58 degree north through 45 degrees south. We took three places from the northern latitude region and three from the southern latitude region. Dumdum, India (22.65^{o}N); Chongging, China (29^{o} N) and Aldan, Russia (58 ^{o} N) are from the northern latitude whereas Lima Calla ,Peru(12^{o} S); Porto Alegre, Brazil (29^{o} S) and Commodore ,Argentina (45 ^{o} S)are belongs to the southern latitude. We took the radiosonde data of these places for the two months which are July and August. One interesting point may be mentioned here is that in the month of July and august, there is a rainy season over the places of northern latitude but winter season over the places of southern latitude (Karmakar et al. 2011). All these data are taken for the year 2005. These radiosonde data are consisting of vertical profiles of height, z; temperature, t (z), in degree centigrade; pressure, p (z), in milibar; and dew point temperature, t_d (z), in degree centigrade.

From the available data we computed the water vapor pressure, e (z) in bar using the relation (Moran and Rosen 1981):

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

water vapor pressure, e (z) and water vapor density, ρ_v (z) in gm/m^3 are related by the ideal gas law as

$$\rho_v(z) = 217\,\frac{e(z)}{T(z)} \quad (2)$$

here $T(z) = 273 + t(z)$ and $T_d(z) = 273 + t_d(z)$ are the ambient temperature and dew point temperature in Kelvin at a vertical height of z.

We calculated this $\rho_v(z)$ for each location for the month July and august and these value is used in the analysis of weighting function of each location for this two months.

III. WEIGHTING FUNCTION ANALYSIS

The water vapour weighting function gives an estimate of the sensitivity of a particular channel to changes of the atmospheric variable water vapor density and thus indicates the ability to retrieve this particular parameter from passive observations.
The water vapor absorption co-efficient at frequencies below 100 GHz is given by (Ulaby et al 1986)

$$K_{H_2O_\gamma}(f,z) = 2f^2\rho_v\left(\frac{300}{T}\right)^{3/2}\gamma_1 \times \left[\left(\frac{300}{T}\right) exp\left(-644/_T\right) \times \left(\frac{1}{(494.4-f^2)^2+4f^2\gamma_1^2}\right) + 1.2\times 10^{-6}\right] \quad (3)$$

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

$$\gamma_1 = 2.85\left(\frac{P}{1013}\right)\left(\frac{300}{T}\right)^{0.626}\left(1+\frac{0.018\rho_v T}{P}\right) \; GH \quad (4)$$

Here p is the pressure.

There is another formula for calculating the water vapor absorption for frequency above 100 GHz, but we have not used that formula because we are interested for analysis of weighting function at 22.234 GHz, 23.034 GHz, 23.834 GHz, 25.00 GHz, and 30.00 GHz, which are less than 100 GHz.

Now the following figures shows the variation of water vapor absorption coefficient with frequency (1 GHz-40 GHz) for the location of northern and southern latitude, for the month July and august.

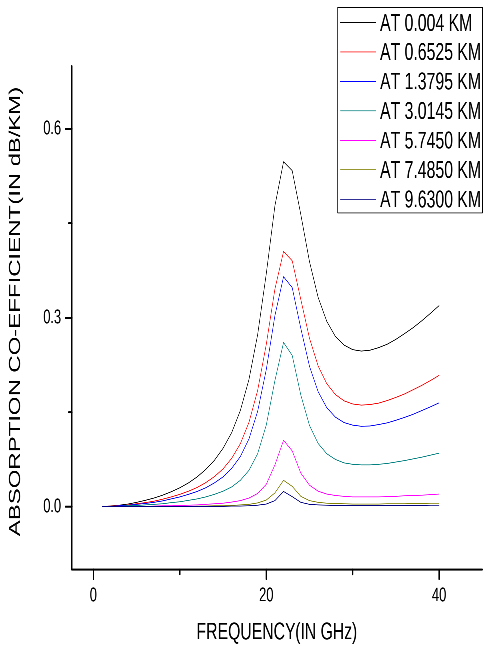

Fig. 1. Variation of water vapour Absorption co-efficient with frequency for Dumdum, India during July-August

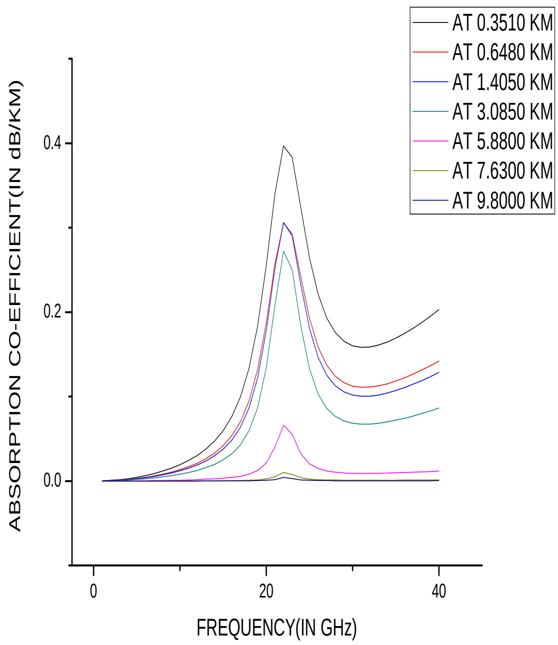

Fig. 2. Variation of water vapour Absorption co-efficient with frequency for Chongging,China during July-August

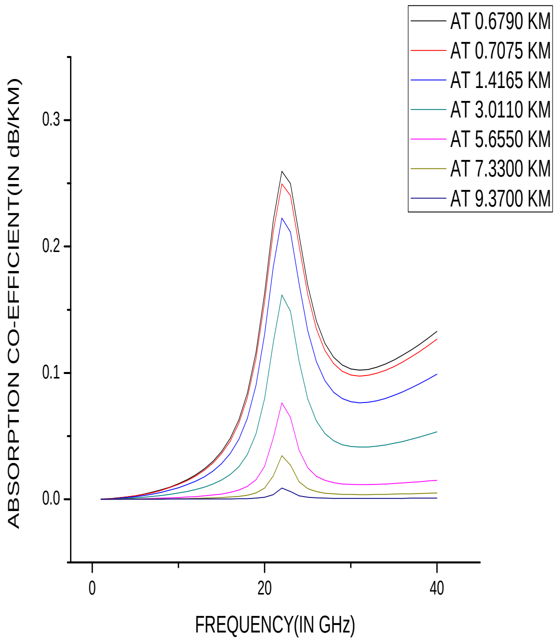

Fig. 3. Variation of water vapour Absorption co-efficient with frequencyfor Aldan, Russia during July-August

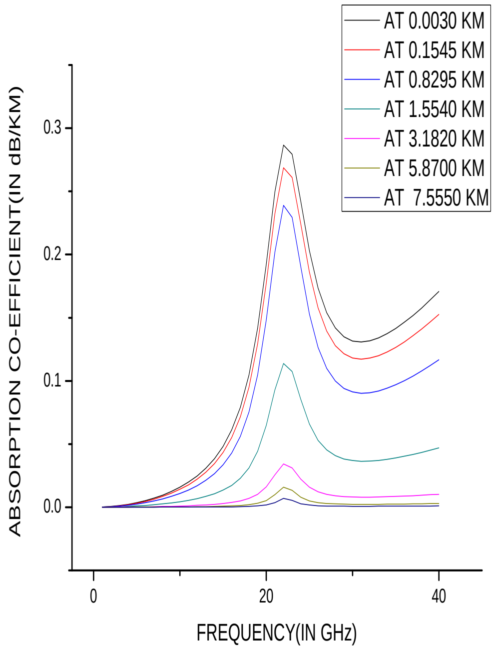

Fig. 5. Variation of water vapour Absorption co-efficient with frequencyfor Porto Alegre, Brazil during July-August

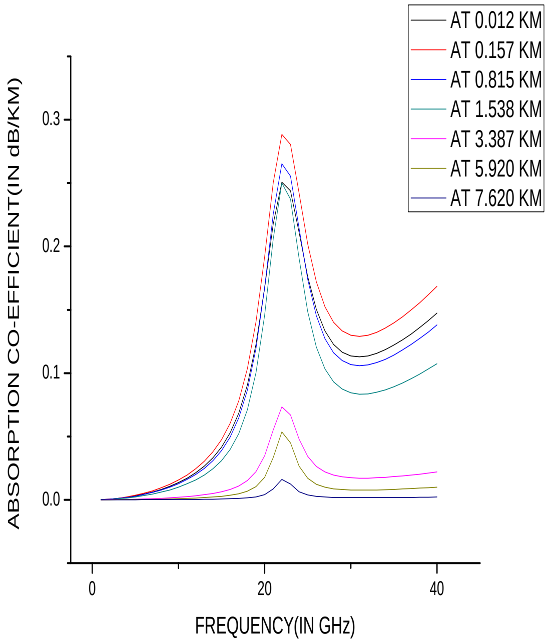

Fig. 4. Variation of water vapour Absorption co-efficient with frequencyfor Lima Callo, Peru during July-August

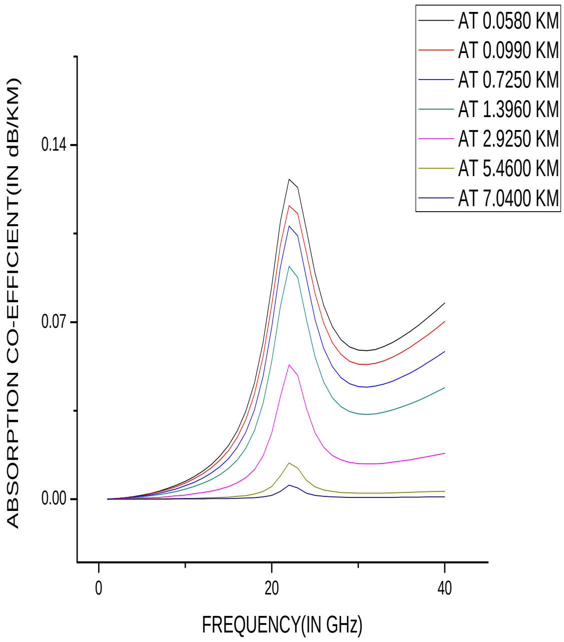

Fig. 6. Variation of water vapour Absorption co-efficient with frequencyfor Commodore, Argentina during July-August

It is clear from all the figure that in each figure, there are several curves that corresponds to several height and in each curves there is a peak of the absorption at 22.234 GHz i.e. at 22.234 GHz there is maximum water vapor absorption occurs for all the location of northern and southern latitude. So 22.234 GHz is the water vapor absorption spectra in our present study and it satisfies with the theoretical value because theoretically 22.235 GHz is considered as the water vapor absorption line.

The weighting Function for water vapor $W_\rho(\gamma,z)$ for the atmosphere extending between 0 to z km, is given by (Ulaby et al)

$$W_\rho(\gamma,z) = K_{H_2O_\gamma}(f,z)\left(\frac{T(z)}{\rho_v(z)}\right)exp(\tau_v(0,z)) \quad (8)$$

The figure 7 through 12 shows the height verses weighting function curve due to the presence of water vapor for the different places of northern and southern latitude. In each figure there are five curves for five selected frequency viz. 22.235 GHz, 23.034 GHz, 23.834 GHz, 25.00 GHz and 30.00 GHz.

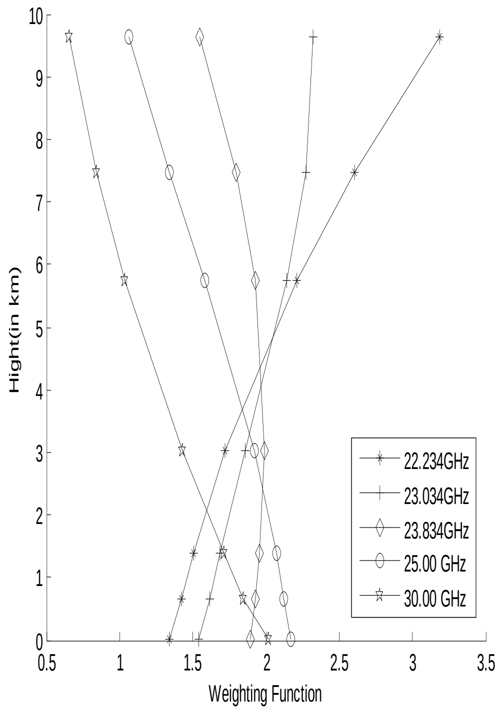

Fig. 7. Variation of Water Wapour Weighting function with Height for Dumdum, India during July-August.

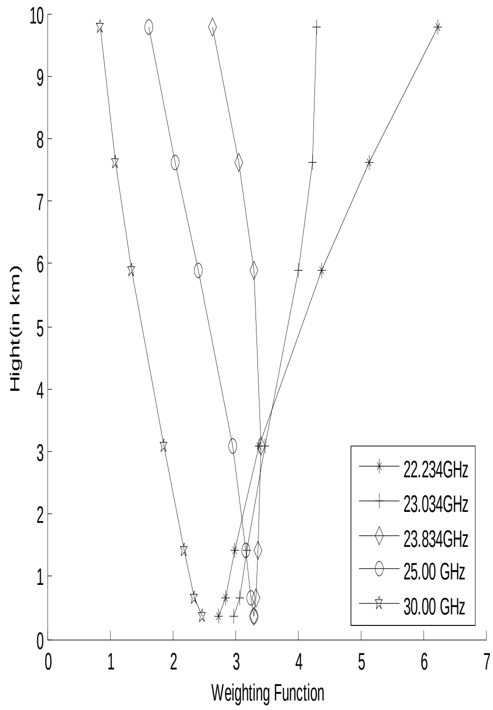

Fig. 8. Variation of Water Wapour Weighting function with Height for Chongging, China during July-August

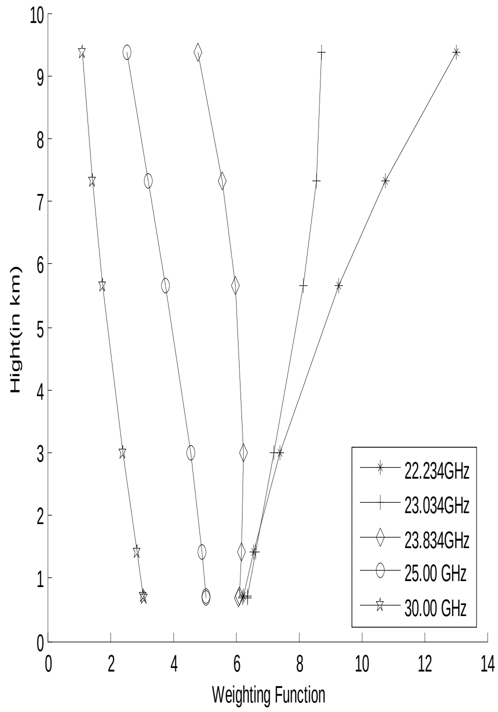

Fig. 9. Variation of Water Wapour Weighting function with Height forAldan, Russia during July-August.

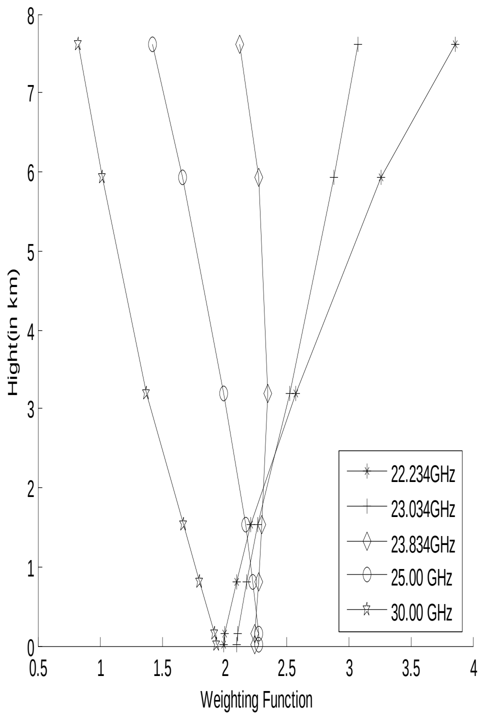

Fig. 10. Variation of Water Wapour Weighting function with Height for Lima callo, Peru during July-August

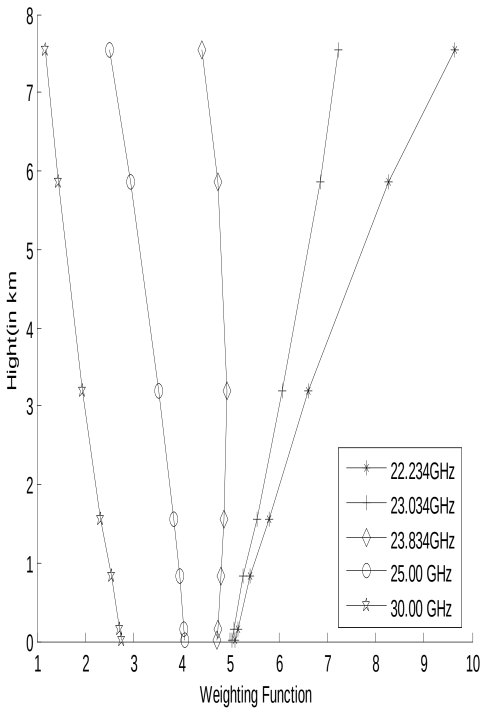

Fig. 11. Variation of Water Wapour Weighting function with Height for Porto Alegre, Brazil during July-August

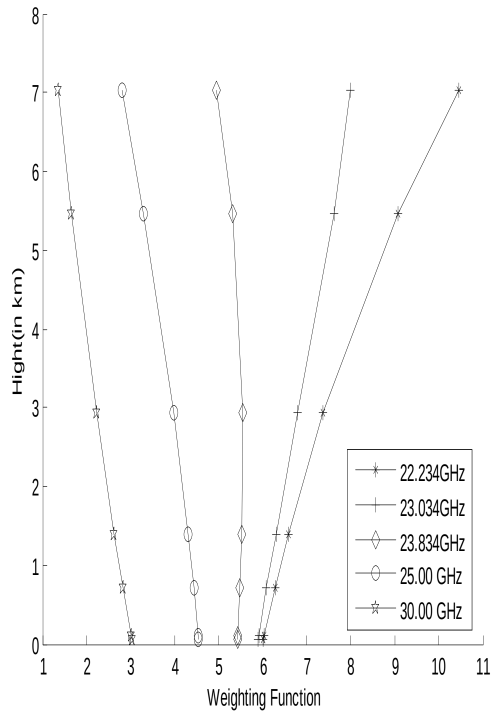

Fig. 12. Variation of Water Wapour Weighting function with Height for Commodore, China during July-August

IV. CONCLUSION

It is also clear from the figure 7 through 12 that, at the places of northern and southern latitude, the curves are steeper from the surface to a height of 2-3 km and the curves are bending in nature from a height of 3 km to the top of the height at each location of northern and southern latitude during July-August. This indicates that, from the surface to a height of 2-3 km, the sensitivity of the variation of atmospheric parameter (temperature, water vapor density etc.) is not so significant but from the height of 2-3 km to the top of the height, the sensitivity of the variation of atmospheric parameter is more significant. So it can be concluded that the vertical resolution of the retrieval of atmospheric parameter will be better above a height of 2-3 km. It is also clear from these figures (figure 7 through 13) that the weighting function at 23.834 GHz, the curves are bending more above the height of 2-3 km comparison the to the weighting function calculated at 22.234 GHz,23.034 GHz, 25 GHz and 30 GHz. So it can also be concluded that the vertical resolution for the retrieval of atmospheric variables will be better at frequency 22.834 GHz.

REFERENCES

[1] V. Mattioli, E. R. Westwater, D. Cimini, A. J. Gasiewski, M. Klein, and V. Y. Leuski,, “Microwave and millimeter-wave radiometric and radiosonde observations in an arctic environment,” J. Atmos.

Ocean.Technol ,Vol. 25, No. 10, pp. 1768–1777,2008.

[2] P. K. Karmakar, M. Maiti, Alan James P. Calheiros, Carlos Frederico Angelis, Luiz Augusto Toledo Machado and Simone Sievert da Costa, "Ground-based single-frequency microwave radiometric measurement of water vapour," International Journal of Remote Sensing, pp. 1–11, 2011.

[3] P.K. Karmakar, M. Maiti, S. Mondal and Carlos Frederico Angelis, "Determination of window frequency in the millimeter wave band in the range of 58 degreenorth through 45 degree south over the globe" Vol. 48, pp. 146–151,2011.

[4] J.M. Moran and B.R. Rosen, "Estimation of propagation delay through troposphere and microwave radiometer data" *Radio Science*, Vol. **16**, pp. 235–244.

[5] Liebe, J.Hans, "An updated model for millimeter wave propagation in moist air". Radio Science, Vol. 20, pp. 1069–1089, 1985.

[6] F.T. Ulaby, , R.K Moore. and A.K Fung, Microwave Remote Sensing: Active and Passive, Vol. 1: Fundamentals and Radiometry (Norwood: Artech House), 1986.

[7] G.M Resch, "Another look at the optimum frequencies for a water vapour radiometer." TDA progress report, pp. 42–76, 1983.

[8] F.T Ulaby, R.K. Moore and A.K Fung, "Microwave Remote Sensing: Active and Passive," vol. 1. Addison-Wesley Publishing Company, 1981, pp. 282–283.

[9] P.K. Karmakar, M. Maiti , S. Sett, C.F. Angelis and L.A.T. Machado, "Radiometric estimation of water vapor content over Brazil" Advances in Space Research, Vol. 48,pp. 1506–1514,2011.

[10] F. Solheim, J. R. Godwin, E.R. Westwater, Y Han, S. J. Keihm, K. Marsh, R. Ware, "Radiometric profiling of temperature, water vapor and cloud liquid water using various inversion methods" Radio Sci. 33(2), pp. 393-404, 1998.

[11] R. Ware, F. Solheim, R. Carpenter, J. Gueldner, J. Liljegren, T. Nehrkorn and F. Vandenberghe, "A multichannel radiometric profiler"of temperature, humidity and cloud liquid." Radio Sci. 38(4), 8079, pp. 4401-4413, 2003.

[12] E. R. Westwater, J. B. Snider and A. C. Carlson, "Experimental Determination of Temperature Profiles by Ground-Based Microwave Radiometry". J. Appl. Meteor. 14(4), pp. 524-539, 1975.

[13] E.R. Westwater. Ground-based Microwave Remote Sensing of Meteorological Variables, in: Michael A. Janssen (Eds.), Atmospheric Remote Sensing by Microwave Radiometry.J. Wiley & Sons, Inc., New York, pp.145-213, 1993

[14] ED R. Westwater, Y. Han, F.,Solheim . "Resolution and accuracy of a multi-frequency scanning radiometer for temperature profiling," in: P. Pampaloni and S. Paloscia (Eds.), Microwave Radiometry and Remote Sensing of the Earth's Surface and Atmosphere. VSP 2000, Netherland, pp. 129-135, 2000

[15] E. R. Westwater, S. Crewell and C. Matzler " A Review of Surface-based Microwave and Millimeter wave Radiometric Remote Sensing of the Troposphere." Radio Sci. Bull. 310, pp. 59-80, 2004.

[16] C. D.Rodgers, "Retrieval of Atmospheric Temperature and Composition from Remote Measurement of Thermal Radiation" .Rev. Geophys. 14(4), pp. 609-624. 1976.