A Comparative Study of Integrated Water Vapor (IWV) and of Attenuation of 94 GHz Signal from Radiometer and Radiosonde Observations during Monsoon Period over Kolkata, India.

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ABSTRACT

Millimeter wave propagation technology now plays an important role in exploring new communication channels in the higher microwave bands. In this paper, a 94 GHz Dicke Radiometer is employed in zenith looking mode from the ground to collect atmospheric radio noise over the passband of the receiver. This instrument was set on the roof of the Institute of Radio Physics and Electronics, University of Calcutta. Simultaneously, the meteorological parameters like pressure, temperature, and dew point temperature are collected from the Radiosonde observation over Kolkata during monsoon period for some specific dates of 1991. The results shows that the atmospheric radio noise that has been calculated from the Radiosonde data is highly correlated with that obtained from 94 GHz Radiometer output. Also the water vapor content of the atmosphere during the course of Radiometer observation is also found to be highly correlated.

(Keywords: wave propagation, radiometer, meteorological parameters, water vapor)

INTRODUCTION

Distribution of water vapor density within the troposphere is an important parameter from the viewpoint of millimeter wave propagation. Different thermodynamic processes within the atmosphere are controlled by water vapor distribution both spatial and temporal. The measurement of atmospheric water vapor is still difficult under all weather conditions. Hence the measurement of atmospheric water vapor is very much important for the advance of atmospheric science[1]. Moreover, for the remote sensing purposes the nature of 'ground truth' could be measured from onboard sensors in the millimeter wave frequencies. The radio-wave propagation scientists need to understand the mechanism of radio wave propagation through the atmosphere. In fact, it is well understood that the atmosphere plays a vital role in propagation effect. Before going into measurements of attenuation, delay, scintillation, scattering, etc., in these higher frequencies, it is essential for the designer to look into the effects of different gaseous molecules including water vapor present in the atmosphere. For passive remote sensing where Radiometer acts as a sensor for collecting radio noise emitted from the ground as well as atmosphere, such studies of different parameters are essential.

The use of ground based microwave radiometric measurement of tropospheric temperature and columnar amount of water vapor is well established[2-4]. The useful accuracy can be achieved in temperature profiling and in the measurement of columnar water vapor by deploying a comparative study between the Radiometric measurement and the Radiosonde data analysis[5-8].

Studies regarding the accuracy of radiosonde soundings have been reported[9]. Radiosonde balloon datasets are taken at discrete pressure levels or at discrete heights. Also the spatial and temporal humidity profile as obtained from radiosonde differ from that obtained from the zenith looking radiometer as the ascending balloon follows a random path due to wind during telemetry. Hence the balloon experiment cannot be performed during the period of severe storm or during the time of thunderstorm or squall event. On the contrary, by means of radiometric technique we can measure the integrated water vapor profile in the atmosphere in all weather conditions.

In clear weather conditions, the propagation of millimeter wave is affected by several rotational absorption lines and bands arise out of the existence of a large number of different gaseous molecules in the atmosphere which are not so severe at microwave bands. A sizeable attenuation is experienced, in and around such frequencies of resonance absorption lines or bands of molecular oxygen and water vapor of the atmosphere in the propagation path. The microwave/millimeter wave absorption spectra show the existence of severe maxima due to water vapor and oxygen molecules which are prevalent in the atmosphere. The water vapor maxima occur at 22.235 and 183.31 GHz and those due to oxygen at 60 and 118.75 GHz[10]. However, a sizeable attenuation occurs in and around of such frequencies of absorption maxima.

It is observed that there lies the minima at or around 35 and 94 GHz which are normally known as 'windows' in millimeter wave band. The 'so called' 94 GHz valley lies in between the two absorption lines of water vapor at 22.235 GHz and 183.31 GHz. The frequency dependence of the absorption is a function of line-width parameter, pressure, temperature, and absolute humidity of atmosphere[11].

At the conventional window at or around 94 GHz the atmospheric attenuation due to oxygen exhibits a minimum and while due to atmospheric water vapor dominates. In the neighbor of 94 GHz, the absorption due to water vapor is not only contributed by the distinct rotational lines at 22.235 and 183.31 GHz, but also is contributed by non – resonant absorption processes.

DATA AND METHODOLOGY

We have collected the Radiosonde data for the year 1991 during the monsoon period for some specific dates from the India Meteorological Department, Kolkata. We have also collected the Radio Meter data at 94 GHZ operated in the Institute of the Radio-physics & Electronics department, University of Calcutta for the same year and for same specific dates. From the Radiosonde data we have calculated the water vapor content at different heights for the specific dates of 1991 -1992 using following equations.

Water vapor density in gm/m^3 = 216.7 * e / T ;

Where e = Partial vapor pressure and T = Atmospheric temperature in Kelvin.

Now e = 6.1078 * exp [5369 (1/273 – 1/ T_d)] ;

where T_d = Dew point temperature in Kelvin

Then from the curve fitting equation (height vs. water vapor density) we calculated the integrated water vapor density or I.V.D (in gm/m^3) up to 10 km height for some specific dates of 1991.

Although the concentration of water vapor in the atmosphere beyond 8 Km height is negligible, yet the computation is done for the height up to 10 Km. Using millimeter wave propagation model (MPM) of Liebe[12] and Radiosonde data we also calculated the attenuation (db/km) of millimeter wave at 94 GHz due to water vapor content for different heights in Km. Then using curve fitting equation we calculated the integrated attenuation (db) up to 10 Km height for the specific dates of 1991.

Also at the same time we have also calculated the integrated attenuation in db from our Radiometer data at 94 GHz during the same period of 1991 and during the same specific dates of Radiosonde observation in the following way:

Attenuation α (in db) = 10 log (T_m /(T_m – T_A) .

where T_m = Mean atmospheric temperature in Kelvin which is taken as 290 Kelvin.

and T_A = Measured antenna temperature in Kelvin

We then plotted the integrated water vapor density (gm/m^3) vs. total zenith attenuation (db) from both 94 GHz Radiometer data and Radiosonde observation which is shown in Figure 1 and Figure 2, respectively.

Also we have plotted the integrated attenuation (in db) from 94 GHz Radiometer vs. integrated attenuation (in db) from Radiosonde which is shown in Figure 3.

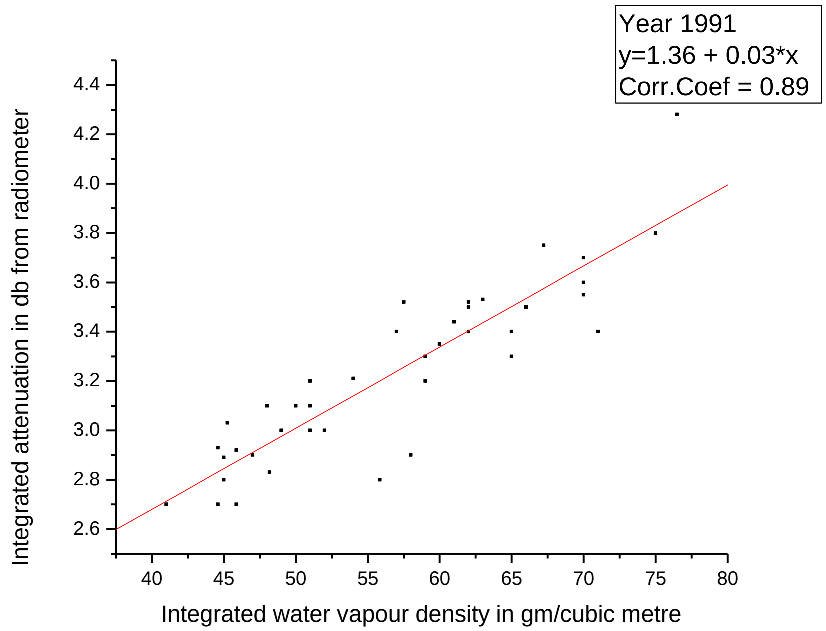

Figure 1: Variation of Integrated Water Vapor Density in gm/m^3 with Integrated Attenuation Measured in db from 94 GHz Radiometer.

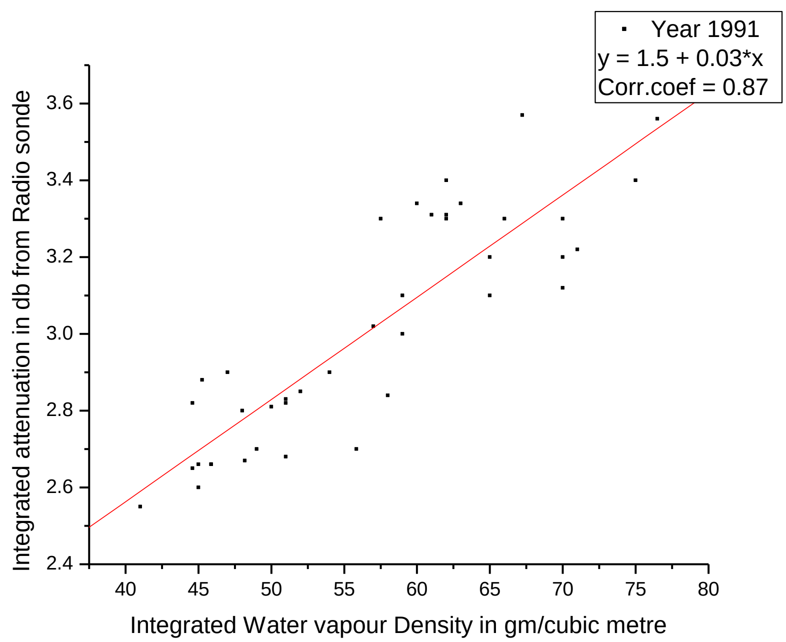

Figure 2: Variation of Integrated Water Vapor Density in gm/m^3 with Integrated Attenuation Measured from Radiosonde Data.

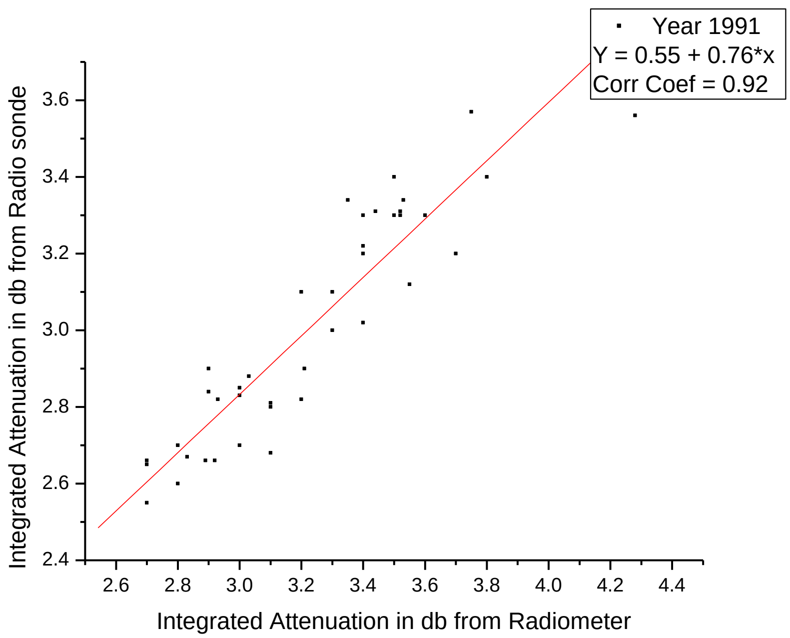

Figure 3: Variation of Integrated Attenuation in db from 94 Ghz Radiometer with Integrated Attenuation from Radiosonde Data.

RESULTS AND DISCUSSION

From the curve fitting equation of integrated attenuation in db from 94 GHz Radiometer (as X axes) vs. integrated attenuation in db from Radiosonde (as Y axes) which is shown in Figure 3 is a straight line having curve fitting equation is:

$Y = 0.761*X + 0.549$,

and having very high correlation coefficient 0.92. So we can conclude that during the low wind condition which is observed during the monsoon period the use of Radiosonde data shows a very high correlation coefficient with that observed from Radiometer observation.

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