A Comparative Analysis of Atmospheric Attenuation between Coastal and Inland Stations of India For A Ka-Band Cloud Radar

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Abstract:
Precise computation of atmospheric attenuation for Millimeter wavelength radars is quite important for accurate probing of the cloud hydrometeors. Hence in the present study the atmospheric attenuation for 35GHz zenith looking experimental prototype cloud radar developed by Society for Applied Microwave Electronics Engineering and Research (SAMEER) is computed for three tropical stations (Mumbai, Delhi and Jodhpur). Coastal station Mumbai has shown higher and dry inland station Jodhpur has shown lowest values of attenuation. Peak month to month variation in the attenuation was observed in the respective months of monsoon onset (Mumbai-June; Delhi and Jodhpur -July) of the three stations. Minimum values of attenuation occur in January (Dry month) and maximum values occur in the August or September month, when the air is saturated with monsoon rains over the station.

Keywords: *Atmospheric attenuation, Millimeter wave length radar, Absorption model*

I. INTRODUCTION

The application of radars in meteorology is initially started for the detection and understanding of precipitation structures. However with the advancement of radar electronics and understanding the importance of clouds in the radiation budget, the scope of radar meteorology has expanded for the analysis of cloud properties and structure. Early studies of these cloud properties are operated at 1.25 cm wave length (Marshall 1953; Plank et al. 1955; Wexler 1955; Wexler and Atlas 1959). These studies suggested that the precipitating clouds (cumulonimbus and nimbo-stratus) were always detected at this wavelength, while thin clouds with low liquid water content (cumulus humilis, thin stratocumulus and thin cirrus) were virtually never detected. In the further stage, the Millimeter wave length radars were recognized as potential to provide a more sensitive probe of cloud particles ranging from few micrometers in diameters to precipitating drops. The utility of making cloud observations with radars operating at 8.6 mm (35 GHz) was first demonstrated by Harper (1966) and Petrocchi and Paulson (1966). In the later stage, the Doppler systems operating at 8.6 mm are described by Pasqualucci et al. (1983) and Hobbs et al. (1985). Improvements in technology during the past few decades have enabled the cost-effective development of radar systems operating at even shorter wavelengths. A radar operating at 3 mm (94 GHz) is described in Lhermitte (1987a,b), and Pazmany et al. (1994) used an airborne 94-GHz radar to study orographic clouds. Mead et al. (1989) describe a radar system operating at 1.4 mm (215 GHz). These cloud radar studies clearly demonstrate the benefit of shorter wavelength radars for defining the vertical structure of cloud reflectivity and velocity.

These Millimeter-wavelength radars, however, had to overcome the relatively strong attenuation in the microwave window regions due to water vapor and oxygen, which required large power-aperture products and sensitive receivers with low noise figures. Hence quantifying the attenuation due to atmospheric gases, clouds, and precipitation is quite important at these frequencies to derive the micro physical properties (Heike Kalesse et al. 2012). This atmospheric attenuation varies from place to place based on the seasonal variation of the atmospheric gases (oxygen and watervapor), clouds and precipitation over the respective station. In the present article an inter comparison of 35 GHz atmospheric attenuation between the regions like Mumbai (coastal climatic conditions), Delhi (inland climatic conditions) and Jodhpur (dry climatic conditions) with different tropical atmospheric conditions of India was studied using a well proved Millimeter wave Propagation Model (MPM) of Liebe et al.1993.

II. DATA AND METHODOLOGY

To calculate atmospheric attenuation at different atmospheric height levels using MPM model, the meteorological variables provided by Radiosonde (RS) data from the Wyoming University (http://weather.uwyo.edu/upperair/sounding.html) for the station Mumbai, Delhi and Jodhpur from 1st Jan. 2010 to 31st Dec. 2011 are used. Since this RS data may not be providing same height data for all the days, it is difficult to make monthly means from the daily RS data. To make monthly means of pressure, temperature and humidity (PTU) data from daily RS, each day data is averaged to a common height up to 20km, with height resolution of 100m up to 1km, 200m from 1-5km, 500m from 5-10km and 1000m from 10-20km. At these height intervals monthly mean profiles of PTU data was used as input for attenuation calculation at the respective heights. From these attenuation values at different levels total attenuation over a 20 km radar range is computed to quantify the cumulative attenuation.

III. RESULTS AND DISCUSSION

Atmospheric attenuation for radar looking at different elevation angles will vary as the experiencing atmospheric layers for one elevation angle to other elevation angle varies. Hence attenuation computation for a 20 km radial range of 90^0(Zenith)-10^0 elevation angles with an interval of 10^0 was made at all the three stations. Due to un-availability of radiosonde data for the months January, April, May and June of 2010 at Jodhpur, a comparison between only Mumbai and Delhi was made for these months.

1. Comparison for the year 2010

In the month of January cumulative attenuation at coastal station Mumbai varies between 0.29 - 1.26 dB at 900-100 elevation angle respectively and that of Delhi and Jodhpur varies between 0.24-0.91 dB and 0.22-0.77 dB respectively. In February the range of attenuation increases slightly, with values between 0.37-1.64 dB at Mumbai, 0.29-1.16 dB at Delhi and 0.29-1.13 dB at Jodhpur. March month attenuation range varies between 0.36-1.46 dB at Mumbai, 0.34-1.45 dB at Delhi and 0.27-1.02 dB at Jodhpur (Figure.1). For the month of April it varies between 0.40-1.68 dB & 0.35-1.45 dB at Mumbai and Delhi respectively. In the month of May slight increase of attenuation from previous month was observed with 0.47-2.16 dB at Mumbai and 0.43-1.90 dB at Delhi. June month has shown good increment in the attenuation from previous month at Mumbai, where huge amount of moisture transport from Arabian ocean takes place through the onset of South-West (SW) monsoon, and the values ranges between 0.67-2.96 dB that of Delhi was 0.48-2.05 dB. Similar peak jump in attenuation was seen at Delhi in the month of July when the monsoon activity starts over that station, with the values 0.76-3.38 dB and at Mumbai and Jodhpur it varies between 0.69-3.03 dB and 0.68-3.00 dB respectively (Figure. 2). In the month of August, Mumbai has shown little increment in the attenuation where as Delhi and Jodhpur values are nearly same as July. In Mumbai the peak values were reached in September with attenuation range 0.74-3.36 dB whereas in Delhi and Jodhpur the attenuation range started decreasing as the withdrawal of monsoon starts in this month. At the three stations in the months of October, November and December the range of attenuation values were further decreasing and reaching minimum in the month of December with value ranges 0.41-1.80 dB at Mumbai, 0.25-0.98 dB at Delhi and 0.22-0.83 dB at Jodhpur. The monthly range of this attenuation at all the three stations for the year 2010 is presented in Table 1.

2. Comparison for the year 2011

In the continuation, January 2011 the values further decreased from December and ranging from 0.29-1.26 dB at Mumbai, 0.24-0.91 dB at Delhi and 0.22-0.77 dB at Jodhpur (Figure 3). From February to August months, this cumulative attenuation increases gradually and reaches to peak in the August month with the values ranging in 0.69-3.05 dB, 0.71-3.20 dB, 0.63-2.88 dB at Mumbai, Delhi and Jodhpur respectively (Figure 4). Further from August to December the attenuation comes down and reaches near to the values of January. The attenuation for each month is given in Table 2.

As a whole, the coastal station Mumbai has shown higher attenuation values and Jodhpur with dry climate condition has shown lower values of attenuation in almost all the months. Month to month variation of attenuation has shown peak variation in the monsoon onset months of the respective stations i.e June at Mumbai and July at Delhi and Jodhpur. Attenuation is strong in lower elevation angles where the radar looks more number of lower atmospheric layers with high attenuation. The variation of attenuation is large in 10-40^0 elevation angles and is almost negligible amount between 50-90^0 angles.

IV. SUMMARY AND CONCLUSIONS

In the present paper a comparison of 35 GHz atmospheric attenuation between three tropical stations with different climatic conditions namely Mumbai (coastal), Delhi (inland) and Jodhpur (dry inland) is made for different months of the years 2010 and 2011. For all these computations the radiosonde data from Wyoming University was used and the MPM atmospheric absorption model was applied. The analysis of the results reveals that as a coastal station Mumbai has shown higher attenuation than that of Delhi and Jodhpur in most of the months. And as a dry land Jodhpur has shown lowest values in all the months. Month to month attenuation variations were drastic in Delhi and Jodhpur compared to gradual varying Mumbai station. Peak variation in the attenuation was observed in the respective months of monsoon onset (Mumbai in June, Delhi and Jodhpur in July) of the three stations. Minimum values of attenuation occur in January (dry month) and maximum values occur in the August or September month, when the air is saturated with monsoon rains over the station. The variation of attenuation with scan angle was less or negligible between 90^0-50^0 and high between 40^0-10^0 elevation angles. This can be attributed to the experiencing of more number of lower atmospheric layers in the lower elevation angles. This study on attenuation would help the radar system designer to optimize the key radar parameters in order to achieve the desired sensitivity for a given radial range required by the scientific community to achieve their scientific goal.

ACKNOWLEDGMENT

The authors are grateful to authorities of Department of Electronics and Information Technology (Deity) and Society for Applied Microwave Electronics Engineering & Research (SAMEER) for providing the facilities to carry out this work. They convey their thanks to Atmospheric Radar and Instrumentation Division (ARID) team members for their support during the work. They highly acknowledged the authorities of University of Wyoming website for providing radiosonde data in the public domain.

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BIODATA

S Rambabu received his M.Sc in Meteorology and M.Tech in Atmospheric science from Andhra University in 2007 and 2008 respectively. He worked as Senior Research Fellow in Satish Dhawan Space Centre, ISRO of India from 2008-2011. Presently he is working as Scientist-B in SAMEER in the area of retrieving the atmospheric products from ground based atmospheric remote sensing measurements.

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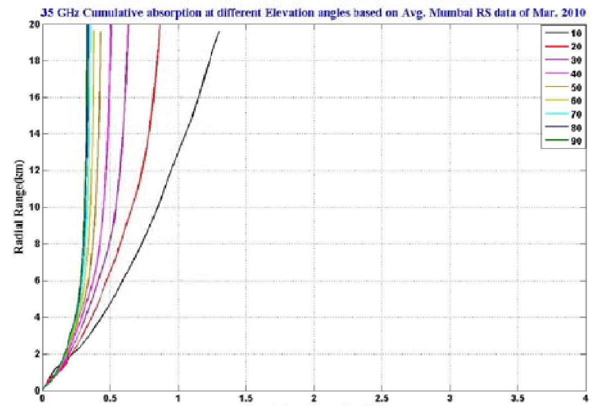
J S Pillai received M.Tech in Solid State Technology from IIT, Madras in 1987. He has been working in the field of development of atmospheric instrumentation including SODAR, wind profiler, RASS and Microwave Radiometer. His field of interest includes atmospheric instrumentation, virtual instrumentation, signal processing and data processing.

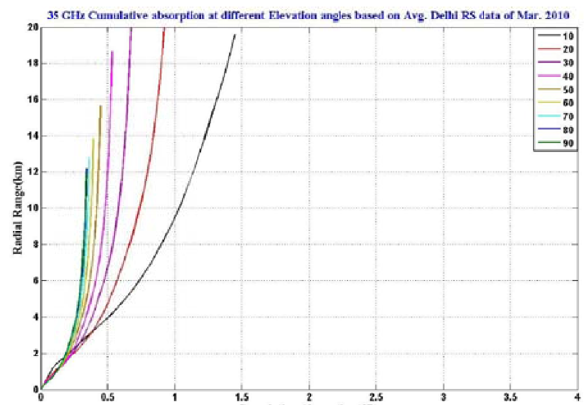
FIGURES

a)



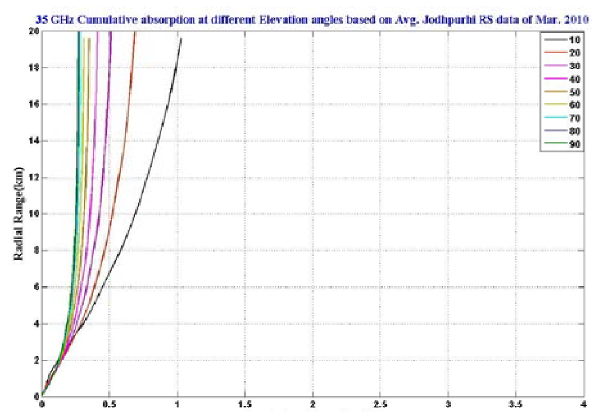
Cumulative attenuation (dB)

b)



Cumulative attenuation (dB)

c)



Cumulative attenuation (dB)

Fig.1. Mean Cumulative attenuation of March 2010 over Mumbai (a), Delhi (b) and Jodhpur (c) at different elevation angles.

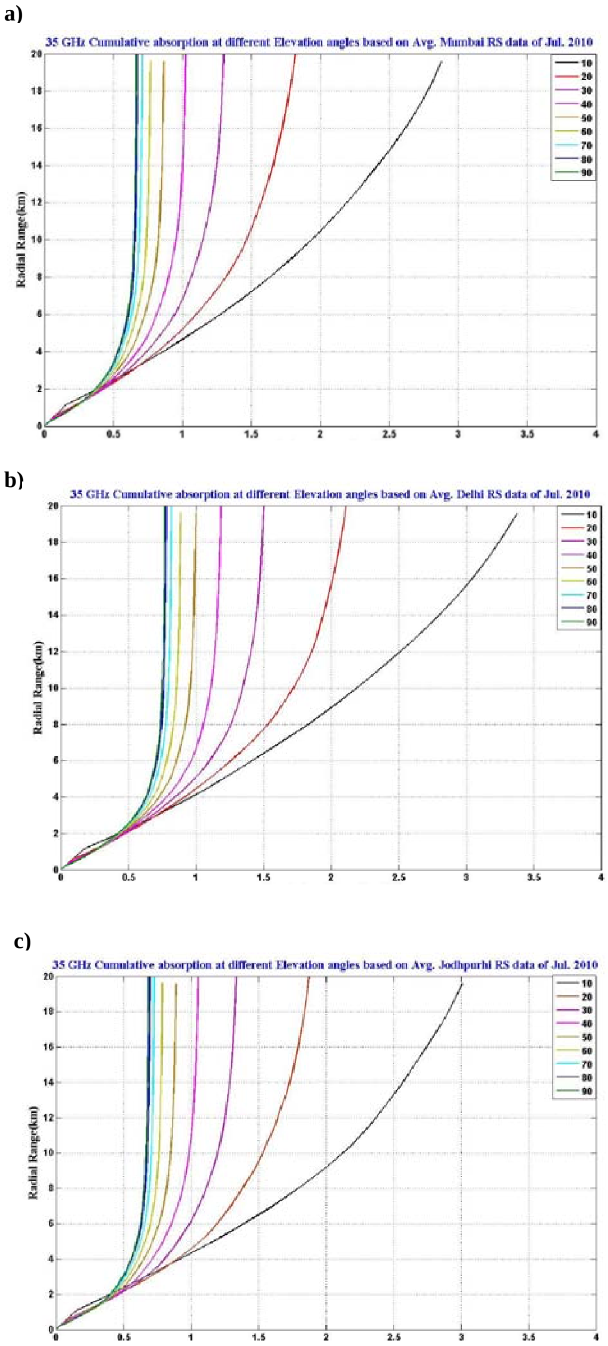


Fig.2. Mean Cumulative attenuation of July 2010 over Mumbai (a), Delhi (b) and Jodhpur (c) at different elevation angles.

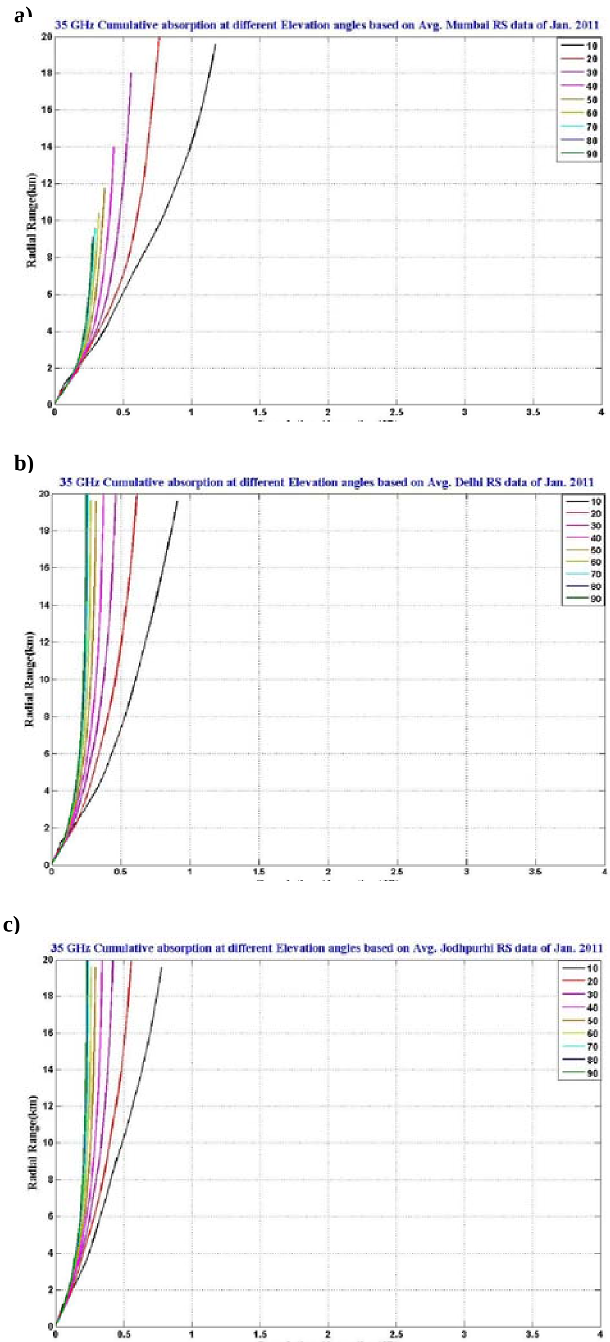


Fig.3. Mean Cumulative attenuation of January 2011 over Mumbai (a), Delhi (b) and Jodhpur (c) at different elevation angles.

a) b) c)

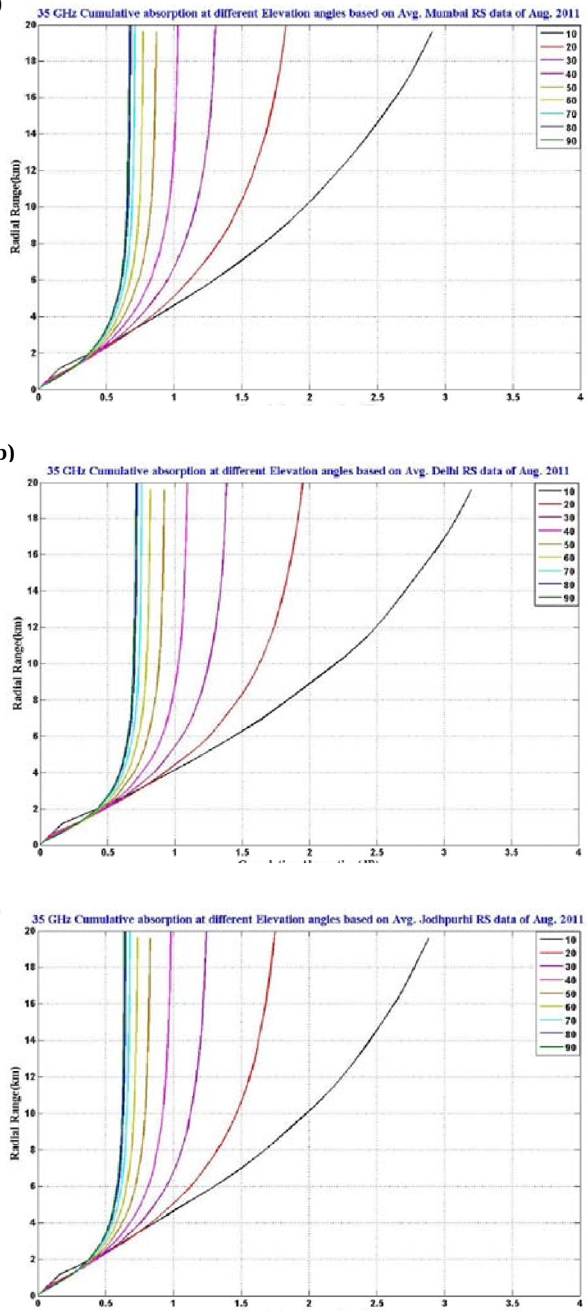


Fig.4. Mean Cumulative attenuation of August 2011 over Mumbai (a), Delhi (b) and Jodhpur (c) at different elevation angles.

TABLES

Table 1. Range of variation of Cumulative attenuation (dB) between $90^0$and 10^0 elevation angles for the year 2010.

Month/Station	Mumbai	Delhi	Jodhpur
January	0.32-1.35	0.29-1.16	-
February	0.33-1.43	0.29-1.17	0.23-0.85
March	0.36-1.46	0.34-1.45	0.27-1.02
April	0.40-1.68	0.35-1.45	-
May	0.47-2.16	0.43-1.90	-
June	0.67-2.96	0.48-2.05	-
July	0.69-3.03	0.76-3.38	0.68-3.00
August	0.73-3.33	0.78-3.37	0.67-3.08
September	0.74-3.36	0.60-2.61	0.50-2.20
October	0.53-2.38	0.36-1.57	0.31-1.28
November	0.61-2.74	0.34-1.43	0.35-1.42
December	0.41-1.80	0.25-0.98	0.22-0.83

Table 2. Range of variation of Cumulative attenuation (dB) between $90^0$and 10^0 elevation angles for the year 2011.

Month/Station	Mumbai	Delhi	Jodhpur
January	0.32-1.35	0.29-1.16	-
February	0.33-1.43	0.29-1.17	0.23-0.85
March	0.36-1.46	0.34-1.45	0.27-1.02
April	0.40-1.68	0.35-1.45	-
May	0.47-2.16	0.43-1.90	-
June	0.67-2.96	0.48-2.05	-
July	0.69-3.03	0.76-3.38	0.68-3.00
August	0.73-3.33	0.78-3.37	0.67-3.08
September	0.74-3.36	0.60-2.61	0.50-2.20
October	0.53-2.38	0.36-1.57	0.31-1.28
November	0.61-2.74	0.34-1.43	0.35-1.42
December	0.41-1.80	0.25-0.98	0.22-0.83