Rain attenuation of Ka-band signal over a Tropical station

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Abstract

This paper details the comparison of the microwave propagation at Ka-band frequencies (20.2 GHz and 30.5 GHz) during the typical rain events in two contrasting seasons over a Tropical station Thiruvananthapuram. The study uses the data received by Ka-band beacon receiver for GSAT-14 satellite installed at this location along with the collocated observations of rain using the laser precipitation monitor.

1. Introduction

Intensity and drop size distribution of precipitation is the major factor responsible for the attenuation of the Ka-band microwave signal. Both, Rain intensity and its drop size distribution varies greatly with region and season causing the regional dependence in the statistical variation of the Ka-band attenuation by rain [1]. The southern peninsular region of the Indian subcontinent experiences diverse type of rain including monsoon (both summer and retrieval) as well as convective systems. However, the characterization of Ka-band propagation has not yet been studied systematically over this region. This provides the need to characterize the microwave attenuation caused due to rain on regional basis over the Tropics.

The path integrated attenuation (PIA) or total attenuation of the Ka-band microwave signal is given by [2, 3]:

$$PIA = \int_0^r k(r)\,dr \qquad (1)$$

Where, k is the specific attenuation:

$$k = c \int \sigma_e(D) N(D) dD \qquad (2)$$

$\sigma_e(D)$ is the total extinction cross section in mm^2, N(D) is the drop size distribution in $mm^{-1}m^{-3}$ and c is the factor for accounting, when k is expressed in dB(km^{-1}). Hence, the attenuation of microwave signal depends on the rain intensity as well as the droplet size both. The total extinction cross section for typical rain is more for 30.5 GHz than 20.2 GHz, causing more attenuation at 30.5 GHz.

In this study, the propagation of Ka-band signal at 20.2 GHz and 30.5 GHz has been characterized over a Tropical station, Thiruvananthapuram (8.5°N, 77°E). This station receives significant amount of the rain during most period of the year. General characteristics of Ka-band attenuation for typical rain events in two contrasting seasons has been compared here based on collocated measurement of GSAT-14 Ka-band signal attenuation and rain intensity.

2. Experimental setup and data

Current study is based on the Ka-band beacon receiver for GSAT-14 satellite installed at Thiruvananthapuram. The GSAT-14 is located in geosynchronous orbit at 74°E. Collocated measurement of rain is carried out using laser precipitation monitor (LPM), which provides rain intensity and drop size distribution. Ka band signal is recorded at the interval of 1 sec and LPM data is recorded at the interval of 1 minute. The Ka-band receiver antenna and electronics modules for acquisition of data are shown in figure 1 and figure 2 respectively. The size of the antenna is 2.4m diameter. The details of the receiver setup can be obtained from [4].

Figure 1. Ka-band receiver antenna at Thiruvananthapuram

Figure 2. Ka-band receiver antenna at Thiruvananthapuram

3. Results and discussion

The attenuation of Ka band (H-pol) signal for a typical rain event on 8 May 2018 over Thiruvananthapuram is shown in figure 3. Over this location May month is dominated by spell of intense precipitation caused by convection. Also, on few occasion, the rain will be persisting for long period because of the large scale meteorological systems in Bay of Bengal and Arabian Sea. On 8 May 2018 it was isolated event of rain with very high intensity exceeding 100 mm/hr. During the peak rain intensity (>120 mm/hr) there was complete attenuation of the both 20.2 GHz and 30.5 GHz signal. The 20.2 GHz signal got completely attenuated when rain intensity was >120 mm/hr. The total attenuation for 20.2 GHz signal from rain free condition to 120 mm/hr rain was ~28 dB. However, 30.5 GHz signal was completely attenuated for the rain intensity >~ 40 mm/hr.

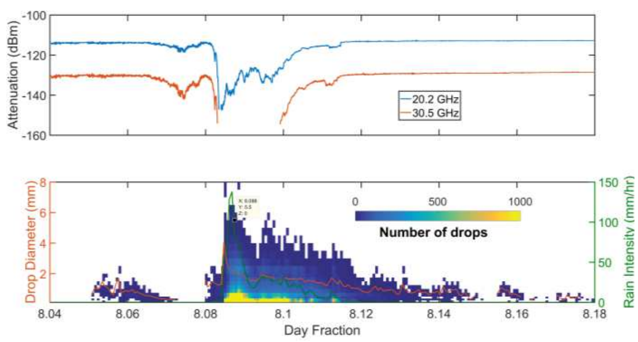

Figure 3. Attenuation of Ka-band (H-pol) signal for a typical rain event on 8 May 2018 over Thiruvanathapuram. Upper panel Shows the attenuation at 20.2 and 30.5 GHz. Lower panel, left Y axis shows the effective drop diameter and drop size distribution, right Y axis shows intensity of rain in mm/hr with time.

On 28 may 2018, it was persistent spells of precipitation throughout the day caused by widespread clouds because of the Monsoon onset. During most of the rain spells the rain intensity was less than 10mm/hr. However, for few events it exceeded 20 mm/hr. One such event is shown in figure 4. During this event the peak rain intensity was ~38 mm/hr causing an attenuation of ~10 dB and ~30 dB at 20.2 GHz and 30.5 GHz respectively. Also, it can be noted here that, two peak rain intensity cases are of the similar magnitude (~38 mm/hr) but they are causing different amount of attenuation because of the difference in drop size distribution in both the cases.

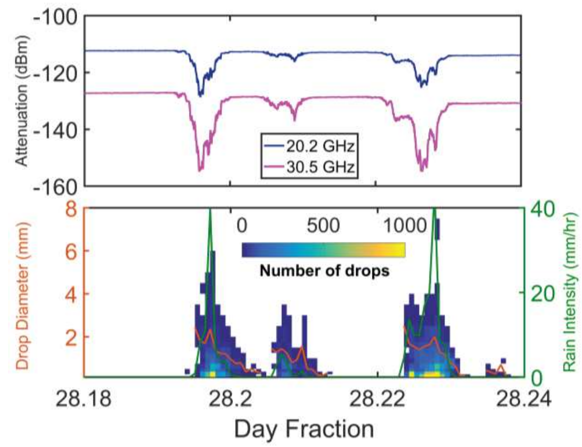

Figure 4: Attenuation of Ka-band (H-pol) signal for a typical rain event on 28 May 2018 over Thiruvanathapuram. Upper panel Shows the attenuation at 20.2 and 30.5 GHz. Lower panel, left Y axis shows the effective drop diameter and drop size distribution, right Y axis shows intensity of rain in mm/hr with time.

Similarly, one typical rain event on 14 August 2018 is shown in figure 5, which is the peak of the summer monsoon season. During this rain event, the peak rain intensity was ~ 37 mm/hr causing an attenuation of ~12 dB and ~28 dB at 20.2 GHz and 30.5 GHz respectively. This attenuation is comparable to that on 28 May 2018 because the rain drop size distribution and rain intensities are similar.

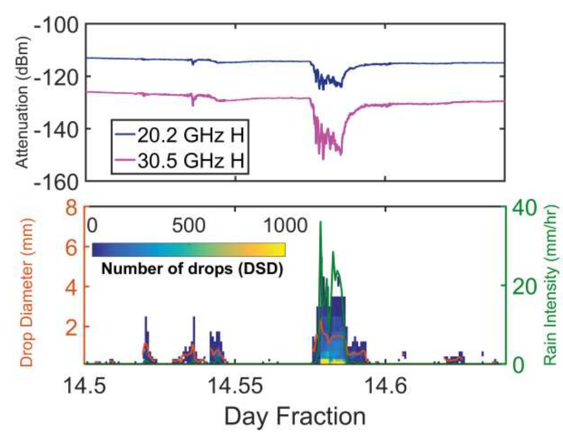

Figure 5. Attenuation of Ka-band (H-pol) signal for a typical rain event on 14 Aug 2018 over Thiruvanathapuram. Upper panel Shows the attenuation at 20.2 and 30.5 GHz. Lower panel, left Y axis shows the effective drop diameter and drop size distribution, right Y axis shows intensity of rain in mm/hr with time.

4. Acknowledgements

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5. References

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