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Stratiform and Convective Rain Intensity effects on Ka band Links

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Abstract*: *The four years rainfall accumulationsobservedwith respective rain rate has been presented for the location Lat 16.24 Lon 80.45. From the observations the maximum number of occurrences are below 60 mm/hr with an annual accumulation time less than 1.5% in a year. The stratiform and convective rainfall pattern and its effects on the link has been analyzed with respective rain event. The fine resolution rain rate obtained from Micro Rain Radar with 10 seconds integration time has been presented for a rain event. The observed rain attenuation on the20.2 GHz link has been presented for link design analysis.

Index Terms: **propagation studies, Rain Rate, GSAT-14, 20.2 GHz, Ka band.**

I. INTRODUCTION

With the rapid growth in technology and the demand for high data rate has pushed the satellite operators to utilize Ka band for communication links. Ka band links are subjected to atmospheric effects than Ku band. For effective design of the link the knowledge of local rainfall pattern is essential for link design.[1], [2] For long term analysis of atmospheric properties related to precipitation effects on the propagating signal above 10 GHz a propagation measurement campaign was carried under COST 205, COST 255, COST 280, ACTS, NAPEX, OPEX, OLYMPUS, ITALSAT F1, CEPIT and ALPHASAT groups across the world. Which formed a base for the formation of ITU- R and its database for estimation of rain attenuation on satellite-based communication links.[3]–[5][6], [7] The variations due to precipitation and its related effects on the propagating signal are analyzed to model the precipitation characteristics and its effects on the propagating signal. Researchers present the analysis in-terms of convective or stratiform rainfall effects on the signal. [8][9]–[12][13], [14] In this study we are presenting four years rainfall accumulationobservations with respective rain rate for the location Lat 16.24 Lon 80.45 and percentage time of accumulations in a year. The stratiform and convective rainfall pattern and its effects on the link has been analyzed. The fine resolution rain rate obtained from Micro Rain Radar with 10 seconds integration time has been analyzed. The observed rain attenuation on the 20.2 GHz link has been presented for effective link design analysis.

II. DATASET

For analyzing rain effects on the propagating signal above 10 GHz at K L University,

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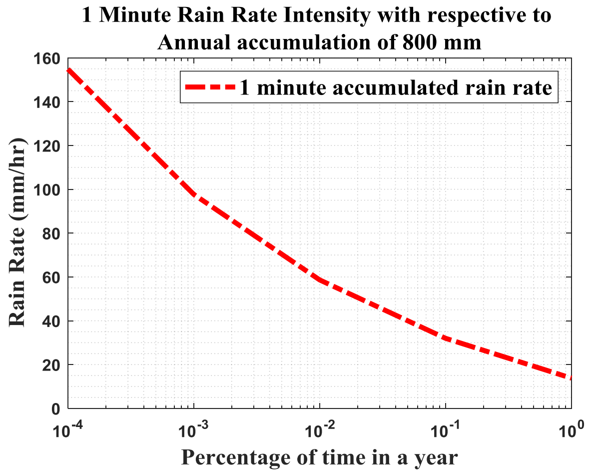
GHz signal from GSAT-14 were installed. OTT Pluvio is a weight-based rain gauge with accumulation time of 60 seconds for consecutive measurements, it can measure rain intensity as low as 0.1 mm it's been operating since 2014. MRR records the vertical profile of the rainfall structure and have an integration time of 10 seconds for consecutive measurements. It provides Rain Rate (RR), Liquid Water Content (LWC), Drop Size Distribution (DSD), Fall Velocity (W), Path Integrated Attenuation (PIA) derived from Radar Reflectivity (Z) and Attenuated Radar Reflectivity (z). it can measure rain intensity as low as 0.01 mm it's been operating since 2016. For analyzing rain effects on the propagating signal, Ka band antenna set-up is installed to receive 20.2 GHz signal from GSAT-14. It logs signal intensity of the beacon signal for every 300 ms and have a signal to noise ratio of 35 dBm, it's been operating since 2017. The 4 years accumulation pattern with respective yearly accumulations were presented. From the measurements stratiform and convective rain events are segregated, and their accumulation pattern is presented. The minute and 10 seconds observations from pluvio and MRR are presented for the respective rain event. The observed attenuation on GSAT-14 link at 20.2 GHz during a rain event is presented.

III. RESULTS

For link design at Ka band the possible rain intensities, its percentage of accumulations and its pattern in the yearly accumulation rainfall is vital. The rainfall accumulation and its pattern observed during the 4 years measurement campaign at KoneruLakshmaiah Education Foundation (KLEF) is presented with respective minute and 10 seconds accumulations in figure 1 to figure 6 for link design and analysis. From one minute and 10 seconds accumulations the possible yearly rainfall accumulation pattern can be estimated as well as the percentage of possible stratiform and convective rainfall occurrence in the yearly rainfall. The observations from OTT pluvio rain gauge during the 4 years measurement campaign has recorded yearly rainfall is in-between 800 mm to 1000 mm at KLEF. The observations from India Meteorological Department (IMD) during the two sun cycle events (24 years) have recorded the annual accumulation is in-between 600 mm to 1300 mm.From the observations presented in figure 1 (a) for an annual rainfall of 800 mm, the total rainfall accumulation time is observed to 1.18% in a year. The total time required for accumulation is observed to be 6231.2 minutes in a year.

The mean annual rainy days in a year is observed to be 61 days. The rain intensity for 0.1% of time in a year is observed to be 31.9 mm/hr, for 0.01% of time it is observed to be 58.64 mm/hr, for 0.001% of time it is observed to be 97.68 mm/hr,



for 0.0001% of time it is observed to be 154.88 mm/hr.

Figure 1(a). Rain rate intensity vs annual accumulation for 800 mm yearly rainfall

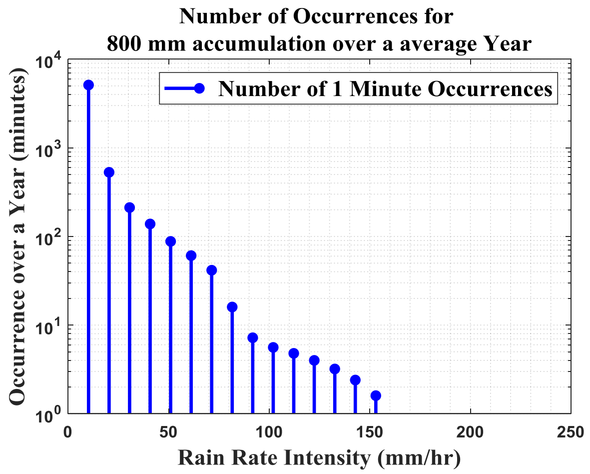


Figure 1(b) Number of occurrences vs rain rate for 800 mm yearly accumulation.

From figure 1 (b), for an annual 800 mm rainfall. It is observed upto 10 mm/hr a total of 5116 occurrences were recorded. With increasing intensity, the number of occurrences tends to decrease. Between 10 mm/hr to 20 mm/hr a total of 529 occurrences were recorded, whereas between 20 mm/hr to 30 mm/hr a total of 212 occurrences were recorded, between 30 mm/hr to 40 mm/hr a total of 138 occurrences were recorded, between 40 mm/hr to 50 mm/hr a total of 88 occurrences were recorded, between 50 mm/hr to 60 mm/hr a total of 60 occurrences were recorded, between 60 mm/hr to 70 mm/hr a total of 41 occurrences were recorded. Between 70 mm/hr to 80 mm/hr a total of 16 occurrences were recorded, between 80 mm/hr to 90 mm/hr a total of 7 occurrences were recorded, between 90 mm/hr to 100 mm/hr a total of 6 occurrences were recorded, between 100 mm/hr to 110 mm/hr a total of 5 occurrences were recorded, between 110 mm/hr to 120 mm/hr a total of 4 occurrences were recorded, between 120 mm/hr to 130 mm/hr a total of 3 occurrences were recorded, between 130 mm/hr to 140 mm/hr a total of 2 occurrences were recorded and above 150 mm/hr only 1 observation was recorded.

From the observations presented in figure 2 (a) for an annual rainfall of 900 mm, the total rainfall accumulation time is observed to 1.33% in a year. The total time required for accumulation is observed to be 7010.1 minutes in a year. The mean annual rainy days in a year is observed to be 65.61 days. The rain intensity for 0.1% of time in a year is observed to be 29.95 mm/hr, for 0.01% of time it is observed to be 62.47 mm/hr, for 0.001% of time it is observed to be 103.82 mm/hr, for 0.0001% of time it is observed to be 156.38 mm/hr.

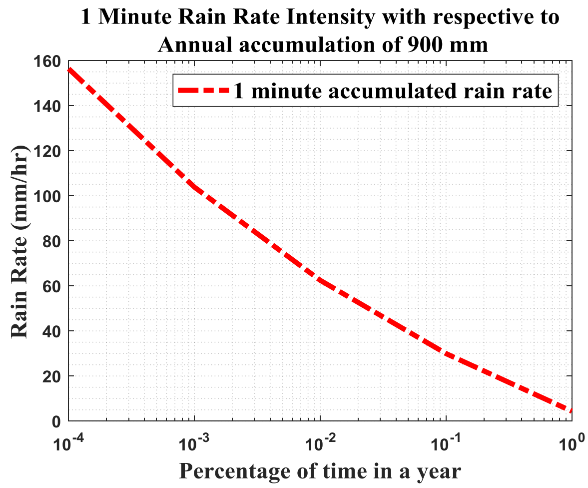


Figure 2(a). Rain rate intensity vs annual accumulation for 900 mm yearly rainfall

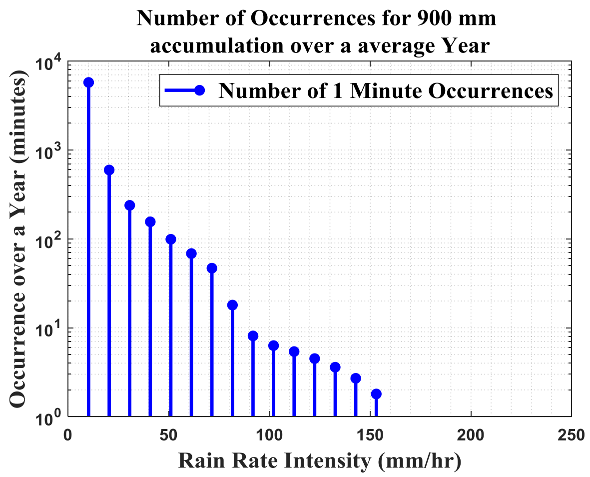


Figure 2(b) Number of occurrences vs rain rate for 900 mm yearly accumulation.

From figure 2 (b), for an annual 900 mm rainfall. It is observed upto 10 mm/hr a total of 5756 occurrences were recorded. With increasing intensity, the number of occurrences tends to decrease. Between 10 mm/hr to 20 mm/hr a total of 595 occurrences were recorded, whereas between 20 mm/hr to 30 mm/hr a total of 238 occurrences were recorded, between 30 mm/hr to 40 mm/hr a total of 155 occurrences were recorded, between 40 mm/hr to 50 mm/hr a total of 99 occurrences were recorded, between 50 mm/hr to 60 mm/hr a total of 68 occurrences were recorded, between 60 mm/hr to 70 mm/hr a total of 46 occurrences were recorded.

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Between 70 mm/hr to 80 mm/hr a total of 18 occurrences were recorded, between 80 mm/hr to 90 mm/hr a total of 8 occurrences were recorded, between 90 mm/hr to 100 mm/hr a total of 6 occurrences were recorded, between 100 mm/hr to 110 mm/hr a total of 5 occurrences were recorded, between 110 mm/hr to 120 mm/hr a total of 4 occurrences were recorded, between 120 mm/hr to 130 mm/hr a total of 3 occurrences were recorded, between 130 mm/hr to 140 mm/hr a total of 2 occurrences were recorded and above 150 mm/hr only 1 observation was recorded.

Figure 3 presents the four-year measurements from OTT Pluvio rain gauge with respective to number of occurrences. From the observations most of the accumulations would be less than 60 mm/hr (1 mm per minute). To evaluate rainfall effects on the propagation signal we need to analyze the accumulation pattern of rainfall during any event. For detailed analysis of rainfall accumulation pattern the observations was categorized into stratiform and convective rainfall. The stratiform rainfall has less than 10 mm per hour accumulations whereas the convective rainfall has more than 10 mm per hour accumulation.

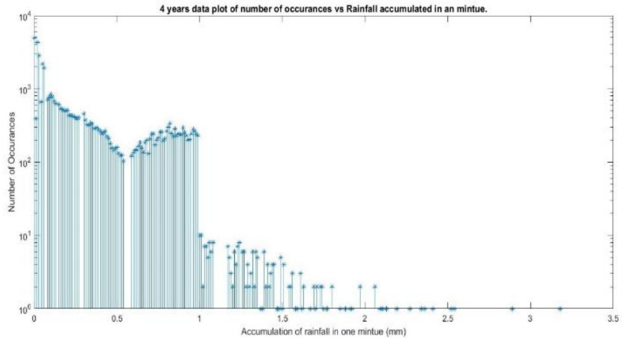

Figure 3: Four-year measurements from OTT Pluvio rain gauge.

Figure 4 presents the stratiform rainfall accumulation pattern. On 02/10/2018 highest one-minute accumulations of 3.2 mm (192 mm/hr) was recorded but the total rainfall accumulations are less than 10 mm. Similarly, during 17/09/2016 a high intensity accumulation of 1.45 mm was recorded during one-minute accumulations. It was observed stratiform rainfall have likely probability of high intensity occurrences than convective but the overall rainfall accumulation will be less than 10 mm per hour.

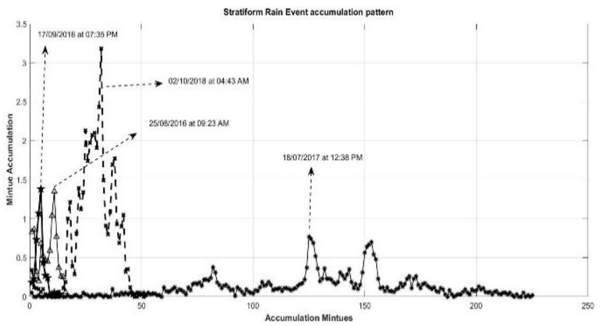

Figure 4: Stratiform rain event accumulation pattern.

Figure 5 presents convective rainfall accumulation pattern. It tends to accumulate for longer period with less intensity mostly in between 10 mm/hr to 60 mm/hr. On 25/09/2017 a high intensity accumulation of 2.4 mm (144 mm/hr) was recorded. Convective rainfall tends to have more effect on the communication link than stratiform rainfall.

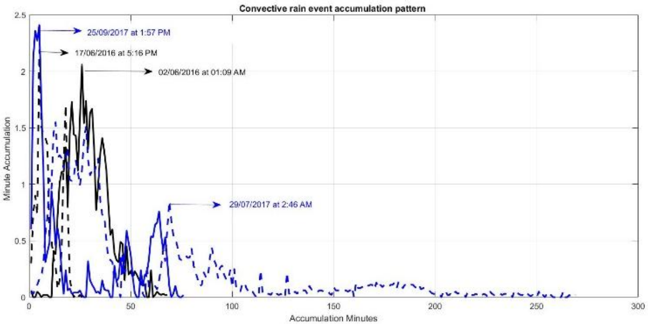

Figure 5: Convective rain event accumulation pattern.

To analyze fine resolution of rainfall accumulation pattern we have compared the accumulated rainfall from pluvio with Micro rain radar measurements. MRR have 10 seconds integration time whereas typical rain gauges have an integration time of 60 seconds. Integration of 6 measurements from MRR is equal to rainfall accumulated over 60 seconds by any rain gauge. MRR also measures rain rate in the vertical column which can used to analyze rainfall effects on the propagating signal. Figure 6 (a) to 6(d), presents the rainfall event on 25/09/2017. From the observations on 25[th] rain event the maximum rain rate is 219 mm/hr with fall velocity of 9 m/s and the respective attenuation for the rain rate is observed to 2.1 dB. The mean rain rate is 38 mm/hr with 5.3 m/s fall velocity and mean attenuation during the event is 0.14 dB at 200 m height.

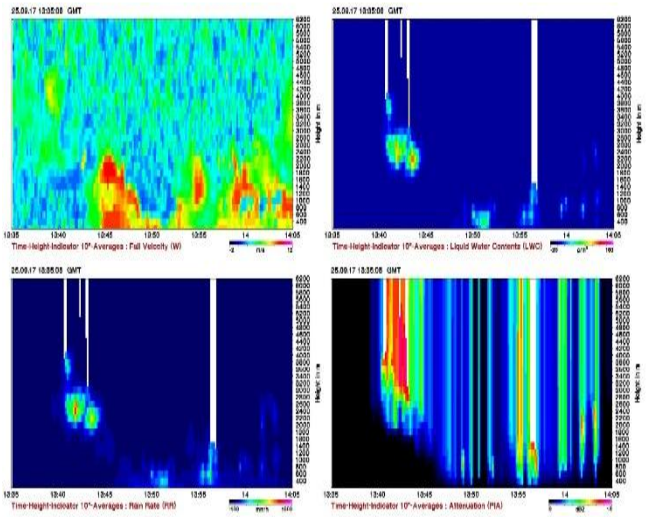

Figure 6: 6 (a) Fall velocity of the rainfall from the melting layer to ground with respective intensity near ground. (b) Liquid water content for the respective rain rate, 6 (c) Rain rate in the vertical column and 6 (d) Path Integrated Attenuation (PIA) observed for the respective intensity in the vertical column. Figure 7 presents the 20.2 GHz signal intensity from GSAT-14 and the respective rain rate intensity from Pluvio on 25/09/2017. From the observations the receiving signal intensity is observed to be around -65 dBm during no rain period. During the rain intensity of 20 mm/hr the received signal has been attenuated to -67 dBm. At 25 mm/hr, the received signal has been attenuated to -68 dBm. At 60 mm/hr, the received signal has been attenuated to -74 dBm.

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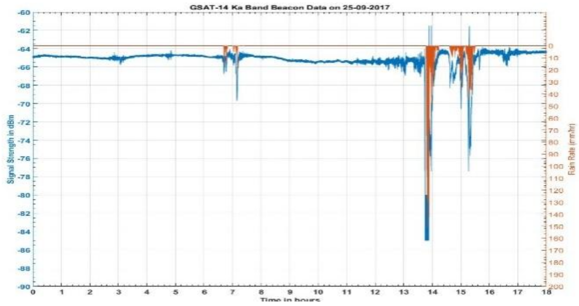

Figure 7: Ka band signal intensity (20.2 GHz) from GSAT-14 with respective rain rate from Pluvio.

IV. CONCLUSIONS

For effective communication link design at Ka band anaccumulation time required in a year has been analyzed and presented. To understand the effects on the 20.2 GHz link number of occurrences observed during the four years measurement campaign are been presented. The pattern and the rain intensity of stratiform and convective rainfall has been analyzed with respective accumulation time. The fine resolution observations for MRR has been analyzed with respective to link for the location Lat 16.24 Lon 80.45.

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