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Analysis of Ka Band Inter-Fade Dynamics at an Indian Tropical Location

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Abstract

Inter-fade analysis and the physical phenomena behind it has been investigated for the data of GSAT-14 satellite beacon signal at 20.2 GHz for three years (2014–2016) over the tropical location Ahmedabad (23.02 ^{0} E, 72.51^0 N), India. As there is no such general model developed for interfade or inter event analysis till date, it is in great urgency to design a suitable model for that analysis of basic parameters of interfade is necessary so that in future it that can help system designers to design a suitable fade mitigation technique for signal in Ka band.

1. Introduction

Due to seasonal variation of tropical country like India, an efficient Radio Communication link is needed to be designed to achieve best reliability. Designing a suitable fade mitigation technique (FMT) is a challenge not only for tropical or equatorial region but also for a communication link above 10 GHz. . Rain attenuation and associated fade slope, fade duration, inter-fade dynamics work as the key parameter for FMT design as it provides information about the duration and number of times system outages can occur during unnatural condition of environment due to rain specially for tropical countries like India. As the long term duration and short term fade duration statics are important, the analysis of inter-fade and intra-fade and inter event analysis also plays a key role for proper SATCOM link design.

Various experimental studies have been done for tropical climate for understanding rain associated fade dynamics [1] and for finding suitable model to achieve best quality of service. An investigation has been reported at Madrid, Spain [2] with 50 GHz signal with 40 degree elevation angle and result shows short durations of interfades follow power law distribution while the long durations of interfades follow the log-normal distribution. The results also pointed out that till 5dB, the fade distribution is mainly due to the cloud attenuation or small rain events while for long interfade distribution rain events are only responsible. Using Eutelsat HB-6 satellite data of 19.7 GHz another study [3] on Interfade analysis has been performed for the same place. This experiment concludes that the nature of distribution of fade and interfade durations are same but considerable different in time. Another litreture at Malaysia [4] using SUPERBIRD-C2 satellite and becon signal at 12.255 GHz, shows that number of interfades decrease as attenuation threshold increases for a particular interfade duration. Though number of work done till date is very limited on dynamics of interfade durations, in the year 2004, ITU-R [5] has accepted a proposal on inclusion of interfade analysis on their recommendation ITU-R P.1623 –1 [6].

Fade and inter fade duration analysis has been done in this work to understand the physical phenomena behind the variation of fade duration so that FMT can be adjusted in a proper way by the SATCOM link design engineer.

2. Data Source and Pre-Processing

From Space Applications Center, Indian Space Research Organization at Ahmedabad (23.02 °E, 72.51°N) earth Station, beacon signal data of 20.2 GHz has been collected from GSAT-14 satellite with sampling rate of 1 Hz. Here earth station receives the signal with 2.3 m diameter antenna (height above mean sea level is 49.7 meter and station height is 48.7 meter) having 21.7° polarization angle and 63° elevation angle for consecutive three years (2014-2016). Collocated rainfall data was collected using a disdrometer and a tipping bucket rain gauge with 1 minute integration time.

The analog Ka band beacon receiver signals in volts are converted to dB by proper signal processing. The clear sky signal (Sum of Effective isotropic radiated power, satellite to receiver path loss, spectrum analyzer to low noise amplifier cable loss, Antenna Gain and Low noise amplifier Gain) level is the input to LNA (low noise amplifier). Calibration curve is plotted as input to LNA (dB versus voltage) with +/-0.5 dB accuracy. As for fade duration calculation both fast and slow fluctuations has been used here for inter-fade and inter- event calculation. For calculation, rainy and non-rainy days are separated first by visual inspection of received signal. In the process first non rain days are separated (approximately 12 days/month during monsoon) and later for a month all non rainy data are averaged and it is continued for consecutive three years for 20.2 GHz data. This unfiltered data is finally taken as reference signal level (dB) and the total attenuation is calculated considering reference signal level and measured signal level (dB) at the time rain. The total attenuation takes into account combination of rain

attenuation, gaseous attenuation and scintillation .

3. Result

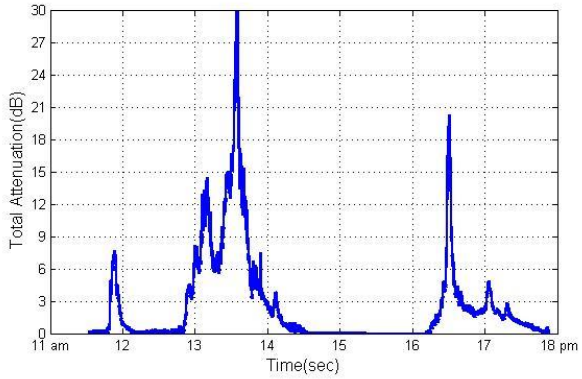

Figure 1. Total attenuation on 21st August, 2016, for 20.2 GHz received signal at Ahmedabad

In Figure 1, the total attenuation including scintillation that is unfiltered data is been plotted during rain events between 11 am morning to 6 pm evening on 21st august, 2016. It has been observed that the events are crossing several attenuation threshold where higher attenuation threshold had longer interfade durations than lower attenuation threshold but as fluctuations are more in lower attenuation threshold number of inter fade events are more for lower threshold value.

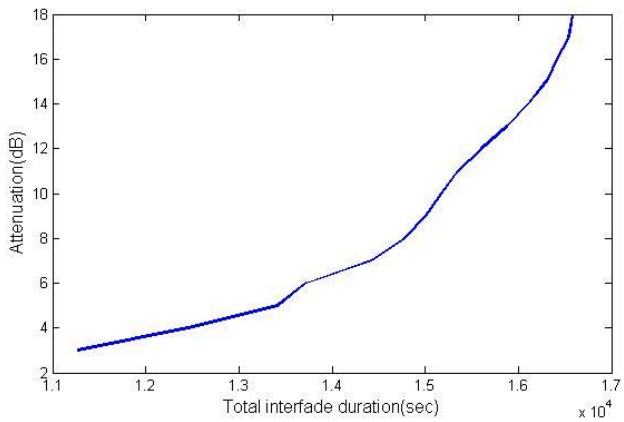

Figure 2. Attenuation (dB) versus total interfade duration (sec) for 21st August, 2016, for 20.2 GHz received signal at Ahmedabad

Figure 2 is actually plotted with the same data set, that is the data set of 21st August, 2016.Here the total inter-fade durations are plotted for each attenuation threshold starting for 3 dB to 18 dB and it is very clear that for lower attenuation the total fade duration is lesser and at higher attenuation the the total fade duration is higher for a single day where many interfade along with inter event fades are visible in Figure 1. For analyzing it further data for three years are taken for further anaylsis.

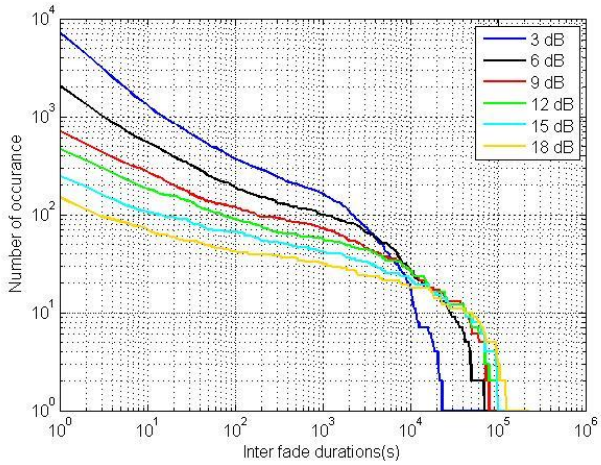

Figure 3. Interfade durations number of occurrence for different Attenuation threshold and time threshold.

In Figure 3, the number of interfade events are plotted for various attenuation threshold like 3 dB, 6 dB , 9 dB, 12 dB, 15 db and 18 dB for three consecutive years data for Ahmedabad and it is evident that number of occurrence of interfade events are more for lesser threshold but inter fade durations are more at higher threshold. For understanding the physical phenomena, the whole analysis is also divided based on time threshold. Till 10 sec there is rapid decrease of occurrence irrespective of attenuation threshold is observed mainly because of presence of rapid fluctuation caused by scintillation present irrespective of attenuation threshold due to rapid change of refractive index caused by turbulence in air. The thunderstorm which is frequent during monsoon at tropical location also causes rapid change in rain drop size. Therefore scattering of received signal is more and it causes rapid fluctuations lesser than 10 sec durations. Next till 1000 seconds time threshold rapid decrease of number of events irrespective of threshold values are observed as number inter-fades are more within a event which is also clear in Figure 1, due to drop size and rain intensity distribution. After 1000 seconds till 10,000 seconds the number almost same or very slowly deceasing sometime increasing also is observed. This may be due to transition between inter fade and inter-event fade and after these time threshold sudden decrease of number of events is observed depending on attenuation threshold value due to climate condition.

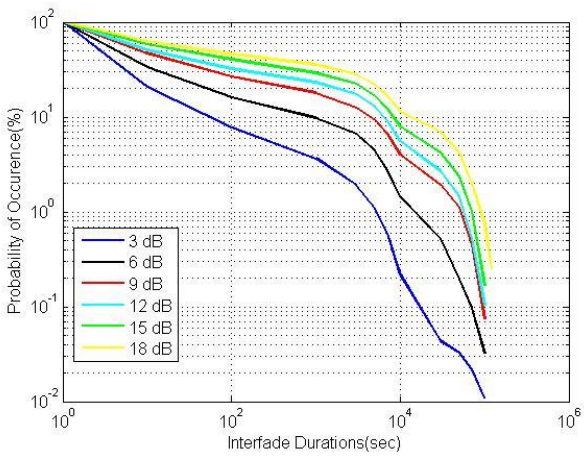

Figure 4. Interfade probability of occurrence (%) till 10^6 seconds for (2014-2016) , Ahmedabad

The Figure 4 is depicting the Probability of occurrence of interfade events and the nature of curve is supporting the same result that has been observed in Figure 3. It is easily visible that from initial (1sec) till 10000 second it is showing power law relation with time but for more than that and for inter events, log-normal relation is observed till 10^5 seconds.

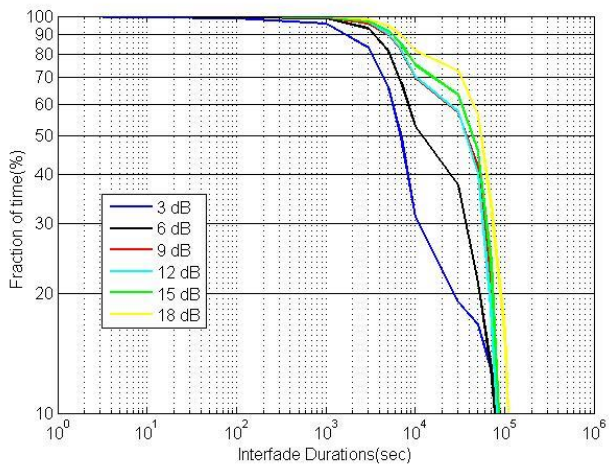

Figure 5. Cumulitive distribution of fraction of fading time (2014-2016) for 20.2 GHz.

The total fraction of inter-fade time due to interfades of duration $d > D$ for different attenuation threshold like 3 dB, 6dB, 9 dB, 12 dB, 15 dB and 18 dB are plotted in Figure. 5.The minimum duration is 100 seconds after which clear variation of fraction of fading time (%) for each attenuation threshold is observed and distribution shows that it is having lower slope at lower attenuation at same instant than the slope caused by distribution at higher attenuation.

4. Conclusion

The analysis of fade dynamics and its characteristics analysis is the most essential study for a suitable designing of FMT for received signal more than 10 GHz. An attempt has been made to make a classification of interfade durations based on time based threshold and its related physical phenomenon. First of all the whole duration is classified into four parts like mainly that is rapid fluctuation till 10 sec, next interfade events, followed by transition period between intefade and inter-event that lasts between 1000 to 10000 second and more than 10000 sections is purely due to climatic change or inter- events.

Finally the paper can be concluded that the work is having local data limitation and more data will help to reach to a strong conclusion .

5. Acknowledgements

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6. References

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