Chapter 7

Conclusion and Further Work

7.1 CONCLUSION

Radar reflectivity was used to estimate the rainfall rate using Battens and Marshall Palmer empirical relations. Battens relation deviates from the recorded data for any rain fall rate. Marshall Palmer estimates the appropriate rain fall for all events. The raindrop size distribution has been shown to have a considerable impact on variability of attenuation, which increases with frequency. The impact of the variability leads to significant problems in maintaining consistent availability of telecommunication systems. The results have shown that the traditional power-law relationship between attenuation and rainfall rate may result in significant errors in estimating attenuation at EHF due to increased variability caused by the DSD.

Analysis has shown that the mean raindrop diameter increases with rainfall rate, whilst the drop concentration reduces, and the shape parameter of the DSD shows considerable variability. The investigation also demonstrated that the DSD varied with season. Further analysis of the DSD in Chapter 4 showes some correlation with meteorological parameters, such as rain fall rate and time. Whilst these correlations are informative, they have little impact in attempts to account for the variability seen within the DSD. It has been concluded that there are too many unaccounted variables to recreate the DSD. Factors such as the local environment (i.e. buildings and trees) will cause large variance due to generated turbulence. Turbulence will severely impact the distribution of raindrops measured. Temperature and dew point may have some impact on the formation of raindrops but the resultant DSD seen at the ground is exposed to many other factors, such as drop collisions, break up, wind and pressure as the drop falls. Also one more investigation related to DSD is more informative i.e. DSD varies with disdrometer integration period because of the variation in mean drop diameter with observing interval.

Various prediction models are applied which are suitable for tropical environment for predicting the rain attenuation along with ITU-R. They are Rice Holmberg model, Moupfouma Martin method, Simple Attenuation models. They are clearly analyzed and final conformation with observation was made towards MM & RH models. MM model is the most suitable for (our region) vijayawada.ITU-R slightly underestimates the attenuation prediction.

Calculated attenuation from the beacon data for some rain events was more than the attenuation estimated from drop size using Mie scattering theory. Mie theory was implemented by assuming all rain drops are spherical in nature, attenuation obtained from the beacon data is super position of attenuation contributed by rain, scintillation, some contribution due to atmospheric gases and also including cable and system losses. scintillations are nothing but rapid fluctuations in signal data due to variations in tropospheric refractive index variations. But the scintillation variations are minor in the region where the elevation angles are more than 30^o . particularly in this region tropospaheric scintillation for Ku band signal is about 1dB.Especially for this location maximum attenuation offered by rain in the period of work is about 16.6dB, which was estimated from the point rain fall rate, that included the attenuation and scintillation effect also. As part of this work the amount of attenuation and amplitude scintillation are measured for some of the rainy days separately.

7.2 FURTHER WORK

This section briefly describes potential areas of research and methods that could be investigated leading on from this research. Potential work ranges from further investigation into the polarisation effects on attenuation using disdrometer measurements, the effect of the different time samples of disdrometer measurements, classification of stratiform and convective rain from a disdrometer and enhancing fade mitigation techniques such as spot beam satellites.

7.2.1 Polarisation

The effect of the raindrop size distribution on polarisation could be investigated further.The disdrometer could be used to calculate specific attenuation for different polarisations including circular and elliptical, as well as vertical and horizontal. Polarisation has been investigated within this thesis, however, the effects of different polarisations on attenuation and DSD could be further studied.

7.2.2 Disdrometer Time Samples

Disdrometers measure rainfall every ten seconds, which can be aggregated for longer periods. As previously discussed, an appropriate time interval was chosen to capture individual rain events whilst maintaining sufficient drop samples for comparison. The time period could be investigated further by aggregating over larger or smaller time periods and comparing the resultant rainfall rates and DSDs. Different time samples may be useful for other applications such as hydrology or comparison with other meteorological effects that could be recorded over longer or shorter time periods. Further it could be investigated with analytical distributions such as exponential or gamma, which are best suitable for the representation of DSD, for different time samples.

7.2.3 Classification of Stratiform and Convective Rain from a Disdrometer

The classification of stratiform and convective rain could potentially be achieved using a disdrometer. Atlas et al[133] use a combination of disdrometer and vertical radar data to determine the two types of rain from drop size Work by Capsoni et al[134] investigated the use of rain cells to determine stratiform and convective rain. Meteorological, radar and satellite data could be used to determine convective and stratiform rain. Combining this data with disdrometer data could potentially reveal a method to determine the type of rain from a single disdrometer. The synthetic rain cell technique could potentially lead to a method to determine the type of rain.

7.2.4 Fade Mitigation Techniques

Fade mitigation techniques are used to avoid or compensate for radio wave attenuation in order to maintain the availability of a communication system.

7.2.4.1 Implementation of Fade Mitigation

Services are expected to have a very high availability, which is defined as the percentage of the year where the signal bit-error-ratio is lower than a set boundary. This means the user will be able to maintain a usable service for a set percentage of time.

Traditionally, link budgets are used to compensate for fading on a communications link. The traditional link budget consists of a calculation of the power required to maintain a clear and quasi error free (QEF) link in clear sky conditions, only accounting for effective isotropic radiated power (EIRP), antenna gain and free space path loss (FSPL). A fade margin is then added to cover the excess variable attenuation from other sources. This excess attenuation is calculated from statistical models such as those provided by ITU-R recommendations.

At Ku-band frequencies and above, attenuation can no longer be mitigated using a static fade margin. The fade margin would need to be large, which would be inefficient during periods of clear sky or low attenuation. In order to efficiently counteract system fade to ensure that the quality of service is maintained, fade mitigation techniques (FMTs) can be implemented. FMTs can largely be grouped into three categories: power control, adaptive waveform and diversity.

Diversity approaches use a re-routeing strategy, either with multiple sites, satellites, frequencies or time to avoid a fade. Adaptive waveform techniques include changing signal code, modulation or data rate. Power control involves up-link and down-link power control or beam shaping. When choosing the most suitable technique the operating frequency, performance objectives (typically the quality-of-service) and system architecture must be taken into consideration.

7.2.4.2 Spot Beam Satellites

With the use of Ka-band frequencies and above, the antenna size can be reduced and directivity of a beam can be increased. These factors have allowed for the design of spot beam satellites. The technique uses multiple antennas to distribute signals over many areas.The separated beams allow for frequency reuse and higher system capacity. The techniques can be used to counteract attenuation by redistributing power between beams. It is easier to redistribute the power from travelling wave tube amplifiers (TWTAs) than to reduce its power. Excess power from several beams could be redistributed to another beam to overcome fade based on propagation predictions or real time information. The service area is covered by many overlapping spot beams to support two-way communications.