Addendum

List of connections

Reply to the 1st Expert

(i) "The candidate should use the rain drop size distribution as shown in figures 6.4 to 6.7 and compare to the attenuation measurements. This should probably give more information on the tropical rain mechanisms"

Reply

The measurements of rain rate, rain drop size distribution, rain attenuation from the drop size distribution measurement and Ku-band signal measurement for a single rain event has already been incorporated and discussed in the corrected Copy (Page 113-118) and pertinent comments are also been incorporated in the corrected Copy.

(ii) "I propose to the candidate to make such a comparison of the four measurements on a few events and to draw some conclusions"

Reply

The proposed comparisons of the four events have already been incorporated and the conclusions from them are also reported in the Corrected Copy.

(iii) "The candidate should also give more critical conclusions concerning what is new in his thesis, comparing to the existing results"

More critical conclusions as suggested by the Expert have been incorporated in the Corrected Copy at Page No. 129. The incorporated part is as follows:

"Thus on the whole, it can be said that the work presented above has four major contributions. Firstly, it provided a picture of rain rate and corresponding rain attenuation for Ku-band at a frequency greater than 10 GHz for a tropical location in the Indian region. Secondly a relation between annual and worst month occurrences of rain rate and rain attenuation has been depicted above. Correspondingly, these relations are compared with the globally accepted ITU-R Model. It has been found that in the ITU-R Model that the annual occurrence of rain rate and rain attenuation is given by $P_{yw} = 2.82 P_{yr}^{0.85}$ and $P_{aw} = 2.85 P_{ay}^{0.87}$ respectively, where $P_{yr}$ and $P_{yw}$ are respectively the annual and worst month time percentage of occurrences of rain rate, and $P_{ay}$ and $P_{aw}$ are the annual and worst month occurrences of attenuation respectively. The same relationship obtained on the basis of present experimental data for three years over Kolkata are as follows: $P_{yw} = 3.72 P_{yr}^{0.89}$ and $P_{aw} = 2.95 P_{ay}^{0.86}$. So it can be assumed that the present experimental data of Kolkata more-or-less matches the ITU-R Model. Thirdly, a new technique of sensing the rain induced depolarization effect of a low fade margin satellite signal by employing a simple experimental setup has been accomplished. The impact of
raindrop size distribution on the effect of depolarization has also been analyzed and reported in the above thesis. Forthly, the cross-polar degradation (XPD) against co-polar attenuation obtained during the year 2006 has been plotted and compared with the ITU-R model. The measured data on the whole shows a good matching with the ITU-R model. Finally, a picture of the evolution of drop size distribution of rain and its characteristics at the starting and ending phase of a rain event has been portrayed with the help of Disdrometer data”

(iv) “List of small corrections to be done in the text”

page 15 : “Chapter 4 contains a study of the effects of satellite signal for attenuation due to rain” ? what is the meaning?

The sentence has been replaced by “Chapter 4 contains a study on the attenuation of satellite signal due to rain.” [Corrected Copy, Pg. 15]

“At the same time, the measured attenuation are compared”

The sentence has been replaced by “At the same time, the measured attenuation is compared” [Corrected Copy, Pg. 15]

Page 19: COST projects are not funded by ESA! Only support for travel and secretariat are given by EEC

Under such circumstances, the statement “The COST projects, which is an intergovernmental framework for European Cooperation in Science and Technology is also funded by ESA” has been deleted in the Corrected Copy. [Corrected Copy, Pg. 19]

Page 22 line 11: “which can furnish a long term probably”

The sentence has been replaced by “which can furnish a long term probability” [Corrected Copy, Pg. 22]

Page 22 line 19 “experiment”

Replaced with “experiments” [Corrected Copy, Pg. 22]

Page 24 : “Analysis for 13 years rain rate and rain attenuation data also highlighted that though the Ku-band transmission is affected by rain, the link margin of Ku-band
exceeded for about 16 hours in a year (Ramachandran and Kumar, 2004).”— the phrase is not complete

The sentence has been replaced by “Although Ku-band transmission is affected by rain, the fade margin is exceeded for about 16 hours in a year (Ramachandran and Kumar, 2006)”. [Corrected Copy, Pg. 24]

Page 41 - line 3: “It was developed because statistically meaningful samples of raindrops could not be measured previously with a prohibitive amount of work.”
Meaning?

The sentence has been omitted from the corrected copy [Corrected Copy, Pg. 41]

“Line: 11 A cable 10 meters of long”

The sentence has been replaced by “A cable of 10 meters long”

Page 45 - “The ORG is vastly superior to traditional type of sensors and offer reliability and proven performance of the user's need”

The sentence has been replaced by “The ORG is vastly superior to traditional type of sensors and offers reliable and proven performance of the user’s need” [Corrected Copy, Pg. 45]

Page 49 - line 12: Fresnal’s

Replaced with “Fresnel’s” [Corrected Copy, Pg. 49]

Page 58 - line 17: Several models are available for the parameters, which needs to be tested”

The sentence has been replaced by “Several models are available for the parameters, which need to be tested” [Corrected Copy, Pg. 58]

Page 59 - line 14: “...the decay parameter γ. “ Has been used for another meaning on p54 'specific attenuation due to rain, please clarify.

The symbol has been replaced by Γ [Corrected Copy, Pg. 59]
Page 80 – formula 5.8: "V=23; 15≤f≤5 GHz", the last figure should not be 5 but maybe 50?

The last figure is 35, and as such the formula would be "V=23; 15≤f≤35 GHz" [Corrected Copy, Pg. 80]

Page 81 – line 12 “f being the in GHz”

The sentence has been replaced by “f being the frequency in GHz” [Corrected Copy, Pg. 81]

Page 84 - Rustburg and Brussard, 1993

Replaced by Rustburg and Brussaard, 1993 [Corrected Copy, Pg. 81]

Page 94 – line 17 (5.22) is not correct

It has been replaced by (5.15) [Corrected Copy, Pg. 96]

Page 95 – line 10 “Figute”

Replaced by “Figure” [Corrected Copy, Pg. 97]

Page 103 – line 7 “Weisner”

Replaced by “Wiesner” [Corrected Copy, Pg. 103]

Page 105 – line 1 “Although there are some limitations for theses models but these distributions are often used for the calculation of various propagation parameters that affects due to variations in drop size distributions”

The sentence has been omitted from the Corrected Copy

Page 108 “Several studies related to drop size distribution of rain could are made”

The sentence has replaced by “Several studies related to drop size distribution of rain are made” [Corrected Copy, Pg. 108]
Page 109, line 2 "the smaller drops are found to dominate in the eastern coast than in the western one.

The sentence has been replaced by "the smaller drops are found to dominate in the eastern coast with respect to the western one". [Corrected Copy, Pg. 109]
(i) Conclusion regarding ‘Worst Month’ is confusing and needs to be cleared by the Candidate

Reply

In Page 67, it is clearly mentioned in the definition of “Worst Month” that - the annual worst month for rain/attenuation is that month within a year that has the largest fraction of time during which the rain/attenuation exceeds a threshold value”. As such, the worst month attenuation does not depend on one observation of rain or attenuation value. It is the total attenuation for a month/year that exceeds certain percentage of time. Hence in Page 55-57 figures (4.3 to 4.7) represents only the rain rate and corresponding rain attenuation values for the point observation for the single rain events.

In Page 69, “the month of July experienced the highest occurrence of rain attenuation among all the months of 2006” signifies that the total attenuation for all the rain events in the month of July exceeding certain percentage of time which is higher among all the months of the year 2006.

In Page 125, The candidate concludes “pre monsoon months experiences higher rain”—There is no such conclusion in the mentioned page. The only thing, what we has been mentioned is that “it has been found that the pre-monsoon months experience a greater attenuation of signal than the other months for same rain rate in the three successive years”

(ii) Conclusion regarding ‘rain rate, attenuation and model evaluation’ needs to be substantiated

Reply:

The main aim of Fig. 4.8 and 4.9 is to compare the rain attenuation measured at Kolkata with the two well known global Models of rain attenuation i.e the SAM Model and the ITU-R Model. Correspondingly the factors responsible for the difference between the measured attenuation with the other two global models have also been considered. Hence in that case only the two rain rate has been considered in order to compare at higher rain rate and lower rain rate.

(iii) Conclusion regarding “Association of Rain drop size with onset of rain” is to be cleared and explained

In Page 113, “It is to be noted that the larger drops were relatively more abundant during the onset of the rain event in comparison to the later part. As the rain progressed, the fraction of smaller drops also increases”

Reply:
It has been already proved in the corresponding figures (Fig. 6.4-6.7) that the large rain drops dominate during the starting phase of the rain event while with progression, the smaller rain drops also comes into picture. Correspondingly in Fig. 5.4 to 5.7, my main intention is to show that the depolarization of the signal which has happened in presence of negligible attenuation is basically due to the presence of the larger rain drops. This becomes more evident in the Fig. 5.8 – 5.11, where the variation of rain drop size distribution has been shown for the same rain events as in the figures 5.4 to 5.7. Thus it is clear from the above figure that the large drops present at the initial or final stage of the rain events do affect the depolarization in presence of negligible attenuation. During the middle stage of rain events, both the attenuation and depolarization are present for which we cannot separate the impact of large drops in those events.

(B) Regarding other observations:

(i) **Page 64, Fig. 4.10** : For all seasons the rain rate was shown up to 60 mm/hr. But the attenuation should have been displayed for maximum rain condition for each season to understand the effect of total rain spectra on attenuation. Non linearity at the low rain rate is already noted in the curves

*Reply*

It has been found that the attenuation saturates at the higher rain rate. Hence in order to get the variation of rain attenuation, only the rain rate up to 60 mm/hr has been considered.

(ii) **Page 116/117, Fig. 6.8** : Figure legend and explanations in the text do not match

*Reply*

It has been rectified in the Corrected Copy.

(iii) **Page 118, Fig. 6.9** : The observation of the candidate i.e. “It is seen that log normal………and gamma distribution underestimates....” is not reflected in the figures

*Reply*

It has been rectified in the Corrected Copy.

(iv) **Page119-121, Figs. 6.10-6.15** : These figures are utilized by the candidate in an attempt of identifying type of rain (stratified/intermediate/convective). But this is not clear. The error bar may be shown if minor variations in such curves are significant.
Reply:

The main intension in these figures (Fig. 6.10 – 6.12) is to show the relations between the liquid water content, attenuation coefficient and radar reflectivity with rain rate for a single rain event and identify the different types of rain viz. convective, stratiform and transition based on the rain rate. The purpose is to identify the rain types rather than showing the error margin in quantitative estimates of rainfall parameters.

(v) Data points in most of the figures are missing

Reply:

They are incorporated in the respective figures.