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Atmospheric Measurement Techniques Discussions

Interactive comment on "An urban microwave link rainfall measurement campaign" *by* Thomas C. van Leth et al.

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REVIEWER: The authors have put together an experimental campaign in order to explore in depth some aspects of rainfall measurement from microwave links attenuation and understand better the uncertainties, focusing an a relatively short links (2 km) and medium high frequencies (26/38 GHz). The experimental set up is impressive and thorough, with 2 microwaves links –one operating at 38 Ghz and the other one dual frequency 38/26 GHz and dual polarization- sharing the same (2 km long) path ; 5 disdrometers in order to analyze rainfall intensity and microphysical variability along the path and at both ends, and an additional rain gauge ; a near IR scintillometer, cameras and a met station complement the set up and provide additional information on visibility and other atmospheric variables that might influence or help understand-

ing the MWlinks signal fluctuations. This is an ideal setting to analyze and quantify – at least for the 2 frequencies and the path length that are available here – some of the uncertainties in MWlinks based Quantitative Precipitation Estimation : -variability and time/space scale issues in the k-R relationship -wet antenna attenuation -baseline derivation uncertainty and non-rain induced fluctuations of the signal

-Additionally the MWlink power level is sampled at 20 Hz and with a small quantization error - which could be used to investigate errors due to coarse quantization and to the subsampling of the signal typically provided by Commercial MWLinks network monitoring systems (only providing max and min power every 15 minutes is common).

-Also the dual-frequency and dual-pol capability, together with the 5 disdrometers will allow to go further than the simple k-R based retrieval.

First of all I would like to congratulate the authors for the experiment they have put together and acknowledge the amount of work and time which will be necessary to fully exploit such a data set !

RESPONSE: We thank the reviewer for the appreciation of our experiment and paper.

REVIEWER: The main objective of the present paper is to present the experimental setting itself and some preliminary results which illustrate -in a rather qualitative manner- some of the issues that could be further explored with the data set : the discrepancy between the rainfall retrieved by the links and the path average rainfall retrieved by the 5 disdrometers, illustrated with 3 rainfall events ; some illustration of measurement during mixed precipitation ; effects of temperature on the signal fluctuations; wet antenna attenuation and its sensitivity to the type of radom material ; effect of dew and fog ; effect of clutter. Altogether an interesting catalog that illustrates the complexity of mwlink based retrieval of precipitation is provided in section 5. However, the reader stands a bit frustrated by a somehow QUALITATIVE OVERVIEW OF VARIOUS CAUSES OF MW SIGNAL FLUCTUATIONS, WITH A LACK OF STATISTICAL AND QUANTITATIVE ASSESSMENT OF THEIR IMPACT ON I) DETECT-

ING/QUANTIFYING ATTENUATION DUE TO RAIN AND II) RETRIEVING RAIN RATE.

RESPONSE: As the reviewer acknowledges, the point of this paper was to provide a somewhat qualitative overview of the issues which could be explored with this dataset. An in-depth analysis of any one of these issues would merit it's own separate treatment and is beyond the scope of this paper. We do intend to explore several of these issues further and we encourage others to do so as well once we have published the accompanying dataset. However, as we have also admitted in our response to referee #1, some of our statements in the results section are needlessly qualitative and could easily be made more quantitative. We will remedy this in a revised manuscript.

REVIEWER: I would suggest that Sub-section 5.2, which has the most quantitative results and focus on the main objective of the MWlinks exploitation, i.e. rain retrieval, become a full section and be improved with some more quantitative results.

The other sub-sections in 5 should be lightened (5.3 and Fig9 which is essentially qualitative can be suppressed) and more focused on explaining some of the discrepancies observed in 5.2.

RESPONSE: We believe that following the recommendation in this comment would not serve to improve the manuscript as it would radically alter the focus of the paper. We will hence keep the structure as it was. However, we will add more quantitative results wherever possible, as also indicated in our response to reviewer #1.

REVIEWER: The text itself needs revising ; some expressions or comments are more subjective than scientific – and the authors sometimes overgeneralize their statements e.g. P4 L1 'the power law in the literature are ALL derived at point scale ' P 13 L12 'it is important to take into account that there will always be unexplained anomalies' P2 l 39 :' a relatively straightforward algorithm' P3 L31 'the relations ..... closely resemble power law' etc... see more below.

RESPONSE: We will revise the overgeneralized statements P4 L1 and P 13 L12. How-

ever, we do not believe that statements such as P2 L39 and P3 L31 are problematic. We will adapt the manuscript where applicable to make the wording less subjective.

REVIEWER: DETAILed SUGGESTIONS : Title/Introduction :

- The stress on urban in the title is misleading – the paper does not focus on an urban problem or urban hydromet scales specially. A tile like 'A multi-instrument microwave link measurement campaign' would be better. - The introduction also stresses a lot on urban scales which is not that relevant since a single link and not a dense network are studied here.

RESPONSE: The frequencies employed here are frequencies that are often used in operational networks in urban areas. Furthermore, although the experiment features a single link, the context for these research questions comes from the use of urban link networks. However, we acknowledge that the experiment itself is not necessarily only applicable to urban applications and we will adapt the title to reflect that.

REVIEWER: - P1 L33-L35 confusion between the space/time resolution of a single gauge and the problem of gauge network density versus scale of phenomenon.

RESPONSE: This text will be revised to make this distinction clearer.

REVIEWER: - P2l8 : modern radar also used propagation variables such as Kdp and not just Z....

RESPONSE: "radar" is now changed in the text to "traditional radar". Note that Kdp can only be used for rainfall estimation at high rain rates, so that even with dual-pol radar a relation between Z and R is needed for the lower rain rates.

REVIEWER: -P2 L25 : 'therefore further research... ... microphysical aspects' – Sentence not clear + microphysics is not really the focus of this paper....

RESPONSE: We will modify the text to read "Therefore, further research is needed regarding the physical aspects of the attenuation measurements themselves.".

REVIEWER: - P2 L 27 : relevance of urban? ‘ in order to help fine tune the existing retrieval algorithm’ - The sentence is clumsy and there is nothing about tuning the algorithm in the presented work anyway..... L 29: simulating links from radar data is not at all relevant to what is proposed here and to the local scale (one single 2 km path) studied.

RESPONSE: P2L27-29 will be completely revised in the updated manuscript, and the sentence related to "simulated links" will be removed.

REVIEWER: Section 2 – P3 L 29 ‘ the relations .... Resemble power laws’ – Paragraph to be revised – false or approximative statements.

RESPONSE: It is not clear to us what the referee means here. We see no false statements here. We will revise the wording of this paragraph to make it clearer.

REVIEWER: k-R relationship discussion : the discussion on k-R is spread in different parts of the manuscript with no consistency . The paragraph starting on P3 L35 is rather confused. There seem to be a confusion between DSD/rain type variability between rainfall events and k-R variability as a function of the scale considered (point versus path...). The concept of ‘control volum’ is unexplained and unclear. P3 Eq(6) insists on the problem of linearity of the relationship and the problem of point versus path average k-R relationship - but the fact that in this work the path average k-R relationship is effectively derived thanks to 5 disdrometers in not mentioned. ...Subsection 4.1.2-4.1.3 should be merged and with a more explicit title like ‘deriving path averaged k-R relationship’.

RESPONSE: We do not use path-averaged rain rate and attenuation to derive an R-k relationship, but the point scale data from all disdrometers are employed. This would not make much of a difference anyway. The importance of the near-linearity of the R-k relationship is related to the variability of raindrop concentration and size distribution along the path and not directly to variability between different events or as a function of the scale considered. Using a path-averaged relationship would not solve the ambiguity

unless one derives a new R-k relationship for every timestep for this particular path and rain field. This would defeat the point of doing a microwave retrieval in the first place! We admit that the phrasing used in P4L1 is misleading and we will revise it.

REVIEWER: Also note that k=aRËĘb is used in (5 and 6) while a and b in Table 2 are for R=a kËĘb most confusing

RESPONSE: Equation 5 and 6 are incorrect. Thank you for noting this. We will correct this.

REVIEWER: Section 3 : P4 L25 – please give the same precision for the frequency of the Nokia and RAL links.

RESPONSE: We will modify this.

REVIEWER: L24 : ‘representative of THE link systems that would be used ....‘ to be rephrased carefully – not all CMLs are Nokia and you dont use the NOKIA sampling/digitalization....

RESPONSE: "representative" is changed in the text to "a typical example".

REVIEWER: P4 L 31 : ‘roughly’ – unprecise L32-33 give the exact frequencies.

RESPONSE: See our response above.

REVIEWER: Section 4 4.1.2/4.1.3 – merge and improve. It seems that you are deriving a path-averaged k-R relationship based on weight values of both k and R derived from the 5 disdrometers with 30s long DSD spectra. Is this the case ? not very clear from the text. This very important point should stressed : most studies do not have access to the path average k-R and have to infer it from ponctual k-R and assumptions on rainfall variability . The differences between the single disdrometer and path averaged k-R should be discussed.

RESPONSE: This is not the case and that fact is mentioned in the text : P6L40. We will add an extra clarification to P6L29.

REVIEWER: P6L29-32 – earlier you mention that the disdrometer are evenly spread – so is this weighing really important ?

RESPONSE: They are not evenly spread so this is important. This can be seen in Fig 1a. They were only as evenly spread as the limitations of the underlying terrain allowed (mainly access to large flat rooftops). This is maybe not clear from the phrasing in P5L14 so we will add a clarification here.

REVIEWER: THE k-R (and not R-K otherwise do not use a and b as in (5 and 6)) relationships should be given here and the differences between previous studies and IUT discussed here and not introduced in conclusion. Also here is a good place to discuss point versus path k-R.... and your results on this with the 5 disdrometers.

RESPONSE: We welcome this suggestion. We moved some of the discussion from section 6 to here.

REVIEWER: P7 L 19 : the 24h centered window method is not applicable in RT (where you have access only to passed data - - and RT is mentioned in the introduction in the objectives of the work outcomes.....

RESPONSE: We do not believe this is relevant. We never suggest that the methods used in this paper are directly applicable to operational settings.

REVIEWER: Section 5 : P7 L 34 what is a 'relatively unambiguous event' ???

RESPONSE: An event that can be related a single type of attenuating phenomenon, such as rain or dew formation on the antennas. In contrast to the compound phenomena in section 5.8. We will rephrase the text to make this clearer.

REVIEWER: P7 L 35 : 'performance ... for detecting' : this is not done – there is no FAR/Miss study here – only analysis of the rainfall rate itself.

RESPONSE: changed "detecting" to "measuring"

REVIEWER: Section 5.2 : As mentioned, this could be enhanced and become the main

result section. As suggested by reviewer 1 the analysis in terms of attenuation should be done first and then the retrieved Rain rates can be compared. One of the major surprise is the discrepancy between the two 38GHz/Hpol links rain retrieval, which is not fully explained by the paper and should be further explored in dB first. -what is the correlation and consistency between the time series of attenuation for the 2 links ? - the variability of the 2 signal in dry/wet periods should be further quantified (variance for instance).

RESPONSE: As we mentioned above, making this section the main results section of this paper would greatly alter the focus of this paper, and we do not intend to do that. In our responses to reviewer #1, we have indicated that we will add comparisons in terms of specific attenuation. We have also indicated in our responses to reviewer #1 that we will quantify the signal fluctuations. We will also add an additional paragraph detailing the discrepancies between the links including their correlation.

REVIEWER: P8 – the analysis should be more objective and vocabulary such as 'visual inspection suggests' L35 ;' the magnitudes are similar' L15 ; 'loss seems almost entirely related to' L28 should be replaced by quantitative indicators.

RESPONSE: We will revise these phrases.

REVIEWER: P9 L1 : 'more spatially heterogeneous and probably convective' – please check and give some indicator of spatial heterogeneity – how is this affecting the path averaged versus punctual k-R on that day ?

RESPONSE: Spatial heterogeneity can be indicated by the spatial coefficient of variation. We will add these numbers to the text. The high rainfall variability in time and space and the high rainfall rates are all indicative of convective rainfall. It has been shown (e.g. Berne and Uijlenhoet, GRL, 2007, Leijnse et al., JHM, 2010) that the effect of spatial variability on the k-R relation is limited at the frequencies under consideration.

REVIEWER: P9 L17 to 25 : The discrepancies between links and between the link and disdro need to be further understood. What part can be explained by k-R variability ?; what comes from baseline error ? Comparison in DB first (with attenuations dervived from DSD spectra and your Tmatrix code) would help understanding.

RESPONSE: See our response to comment P9L17-20 by reviewer #1.

REVIEWER: Is a possible underestimation of rain rates by the DSD totally eliminated out ? What are the quantitative results of the gauge/DSD comparison for the 3 instruments that are gathered ?

RESPONSE: This is beyond the scope of this paper.

REVIEWER: The Conclusion will have to be adjusted when section 5 has been revised.

RESPONSE: We will modify conclusions based on the modifications made in this paper. Note that the modifications that we will make are less than what reviewer #2 suggests. Hence the necessary modifications to the conclusions will be minor.

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