

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

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REVIEWER: Summary: This manuscript presents results from a comprehensive field experiment studying error sources for rainfall retrieval with microwave links. The paper is well structured and well written, except for some places where the writing should be made less monotonous. The conclusion are a bit vague, though. However, in my opinion, this is more a shortcoming of the writing and less of the experimental setup or the analysis. In summary, this manuscript provides an important contribution and should undergo a minor revision to be published in AMT.

RESPONSE: We thank the referee for the appreciative words. We will reformulate some of the vagueness in the text. See the specific comments for details.

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REVIEWER: General comment: The discussion of the causes, implications and possible mitigation strategies for the different effects should be more detailed in section 5. In particular the consequences when using data from a large number of operational microwave links from a cell phone network, where no ground truth is available to detect and accurately mitigate the caused errors, should be addressed. It would be important to, at least, estimate the magnitude of the different effects on rainfall retrieval from typical operational microwave link networks.

RESPONSE: Extension of the analysis to link networks is outside the scope of this work. However, we will provide a more thorough discussion of the causes, implications, and possible mitigation strategies for the different effects that we encounter in our data. This includes a discussion of the magnitude of the effects of the different phenomena.

REVIEWER: The title and the abstract do not hold much information about the main goal and findings of this study, the search for explanations of the fluctuations of the received signal level. I recommend that the findings, which are a bit vague, but nevertheless very important for the community of researchers that derive rainfall information from microwave links, are presented clearer already in the abstract.

RESPONSE: The Abstract will be adapted to include more of the findings.

REVIEWER: Specific comments: Title: The title should reflect the actual topic, investigation of the microwave links errors, a bit more.

RESPONSE: The title will be replaced by one more appropriate to the contents of the paper.

REVIEWER: page1, Line 18: With all the "and"s this sentence is a bit hard to understand

RESPONSE: This sentence will be modified to improve its readability.

REVIEWER: Page1, Line 25: Why not start a new paragraph here (instead of one sentence before) for the part of the abstract which summarizes the results.

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RESPONSE: We will implement this suggestion.

REVIEWER: Page1, Line 27: I would not call "temperature" an "attenuating phenomena". As you show in the manuscript, it can have a big effect on the RSL, but not by adding attenuation. It is more likely to be bias from the electronics. Maybe you could reformulate here.

RESPONSE: "attenuating phenomena" will be changed to "phenomena affecting received signal level".

REVIEWER: Page1, Line 28: The summary of the conclusions should be more detailed. What is the order of magnitude of the different error sources, etc?

RESPONSE: We agree with the reviewer that adding details about the magnitude of the effects of the different error sources will improve the paper. We will hence add general quantitative results.

REVIEWER: Page 1, Line 36: Instead of "regional" precipitation distribution, writing "local" or just "spatial" fits better here.

RESPONSE: Thank you for the suggestion. We will use "spatial".

REVIEWER: Page 1, Line 38: Since the height of the radar observation above ground is very close to the ground near the radar, and can be a lot higher than 1000 meters far from the radar, I would not write "roughly 1000 meters" but maybe mention that it can be more than 1000 meters far from the radar or in complex terrain

RESPONSE: We will change the text following the recommendation of the referee.

REVIEWER: Page 2, Line 1: "arsenal" sounds a bit colloquial.

RESPONSE: We will replace "arsenal" by "range"

REVIEWER: Page 2, Line 10: Do you mean "back then" instead of "since then"

RESPONSE: We do mean "since then", but we agree that the way it is used in this

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sentence is confusing. We will rewrite the sentence to become: "Despite these advantages, microwave links have not been deployed at a large scale for the purpose of precipitation monitoring, for the cost of setting up such a network would still have been quite severe."

REVIEWER: Page 2, Line 13: A bit monotonous: "This ... This ... This.."

RESPONSE: We will some variation in the wording.

REVIEWER: Page 2, Line 25: Add a comma after "Therefore ..."

RESPONSE: We will add a comma.

REVIEWER: Page 2, Line 25: Is "research ... into ... " correct english?

RESPONSE: We will rewrite this to become: "Therefore, further research is needed regarding the physical aspects of the attenuation measurements themselves."

REVIEWER: Page 2, Line 25: When speaking about "microphysical aspects" of the "retrieval algorithm" I would think more towards the em-wave scattering of individual drops and not the error sources you are investigating here. Hence, I feel the term "microphysical" is misleading here.

RESPONSE: See our response to the comment about this to reviewer #2. We will modify the text to read "Therefore, further research is needed regarding the physical aspects of the attenuation measurements themselves."

REVIEWER: Page 3, Line 31: Add comma after "on the other"

RESPONSE: We will add a comma here.

REVIEWER: Page 4, Line 24: Is the Nokia link working in both directions? If yes, what is the frequency difference?

RESPONSE: The Nokia link is bidirectional, but only the received signal level at one end was recorded. The frequency of the reverse carrier wave is 39.436250 GHz.

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REVIEWER: Page 4, Line 32: Is the difference of only 176 MHz between the Nokia and the dual-pol RAL link really enough to make sure they do not interfere? To be more precise, do you know the band-pass filtering characteristics of both systems?

RESPONSE: The bandwidth of the RAL receiver is 4 KHz, and the bandwidth of the Nokia receiver is 0.9 MHz. The bandwidth of the RAL transmitter is « 1 KHz and the bandwidth of the Nokia transmitter is 3.5 MHz. The difference of 176 MHz should therefore be enough to avoid interference. We will add additional information to the description of the links in section 3.2.

REVIEWER: Question regarding the systems: Multipath effects can also cause large fluctuations in the received signal level. This effect will be different for different propagation settings, i.e. different frequencies and different antennas. What is the antenna size, beam width and gain for the used systems? Maybe a table with the details of the systems would be good.

RESPONSE: We will provide additional information on the antenna characteristics.

REVIEWER: Page 4, Line 35: "This provides for comparison in the case of, ... ". Is the term, "to provide for comparison" correct English?

RESPONSE: We believe it is. However, understand that the sentence may be difficult to read. We will alter this sentence to improve its readability: "This provides information about, for example, fog and other visibility-affecting phenomena."

REVIEWER: Page5, Line 7: Since you did not monitor the TX power, how about (temperature) drifts of the transmitter?

RESPONSE: We do not make a distinction between temperature dependencies in the transmitter or the receiver.

REVIEWER: Page 5, Line 11: Is "in this way" correct english?

RESPONSE: We will modify this part of the sentence to become: "This information can

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be used to, for example, identify solid precipitation in the..."

REVIEWER: Page 6, line 27: You use temperature observations for deriving the terminal velocity (as stated in section 4.1.1), but here you use a constant temperature of 15 degree Celsius. Why? In particular for 38 GHz, temperature difference e.g. between summer and winter, will impact the extinction cross section and hence the k-R relation.

RESPONSE: This was done due to pragmatic reasons. However, the temperature dependence of the extinction cross section is very slight within the used temperature range and will not effect the R-K relation to a significant degree. See e.g. Olsen et al. (1978).

REVIEWER: Page 7, Line 4: You should discuss how do the derived k-R parameters compare to the ones from the literature here.

RESPONSE: We have moved the relevant parts of section 6 to section 4.1.3, so that this section now also includes a comparison with values from the literature.

REVIEWER: Page 7, Line 6: It is a bit misleading that you write that you are "closely following" Overeem et al., but some sentences later write that you use a completely different way (which is fine for this experiment) to detect rain events.

RESPONSE: This sentence is indeed misleading and an unfortunate remnant of earlier drafts. We will remove it.

REVIEWER: Page 7, Line 13: "would not be relevant here", maybe better write "is not applicable here"

RESPONSE: Agreed. We will rephrase this according to the reviewer's suggestion.

REVIEWER: Page 8, Line 10: Are you sure this is "background noise", hence stemming from the electronics? It could also stem from propagation differences of the systems, e.g. because of different beam widths or slightly different alignments. Both of these could result in different propagation conditions resulting from diffraction/refraction from

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the ground (buildings, trees, etc.).

RESPONSE: By using the term "background noise" we did not wish to imply that the source is with the electronics, but rather that the source is unknown and not related to the quantity of interest. Moreover, we are not talking about the "dry" received power level per se, but rather the variability within this power level for a single receiver as represented by the 5th and 95th percentile over the moving window. We will clarify what we mean by the "background noise level".

REVIEWER: Page 9, Line 1: Add a "a" after "probably"

RESPONSE: That does not seem right to us, as we have an "a" between "is" and "more".

REVIEWER: General question: Doesn't the additive bias mainly stem from the very simple baseline determination?

RESPONSE: Yes. We will expand upon this in the revised text.

REVIEWER: General question: What is the correlation and bias of the disdrometer and the gauge next to it?

RESPONSE: We will add this information to the manuscript.

REVIEWER: Page 10, Line 4: The precipitation intensities should not only be "taken with a grain of salt". Their absolute values are, as you explain a little later, completely unusable. Maybe the dynamics indicate a little the dynamics of the precipitation event. But the problem most likely is that your 30-second disdrometer aggregations are too short and only contain a very small number of drops. Hence there is a lot of sharp isolated peaks which might probably stem from individual large snowflakes the disdrometer detected during on 30-second period.

RESPONSE: We agree with the reviewer that the absolute values are incorrect. However, the dynamics of the intensity and the precipitation type are useful information,

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which is why we stated that they should be taken with "a grain of salt". We will rephrase this subjective sentence to clarify this.

REVIEWER: Page 10, line 16: Maybe, if available, you could add possible explanations for this effect if, as you write, the snow deposit alone cannot explain it.

RESPONSE: One possible explanation is antenna wetting due to the partial melting of the snow deposits on top of the antenna cover. However, at this point that is no more than speculation and we would need more research to confirm it.

REVIEWER: Page 11, line 15: It is not clear from the text whether the periods with high humidity are also removed for the calculation of correlation including rainy periods.

RESPONSE: We have not removed periods with high humidity for the computation of correlation coefficients in rain. We will clarify this in the text.

REVIEWER: Page 11, line 15: "temperature dependence ... is still roughly consistent ...". First of all, the term "still roughly consistent" is a bit vague and should be rephrased. However, judging from table 1, there is a clear decrease of the correlation if rainy periods are included and a further decrease when only considering rainy period. I think, this should be reflected in the text. Nevertheless, the correlation of, e.g. -0.4 for rainy periods only, is surprisingly high.

RESPONSE: We will revise the text accordingly.

REVIEWER: Page 11, line 26: Does dew really build up a thin layer on the antenna or does it also form small droplets, as shown for the spraying of the antennas?

RESPONSE: The effect is the same as for the artificial spraying. So, a nearly uniform layer on the Nokia and large drops on the RAL links. This can be observed in the time lapse camera footage.

REVIEWER: Page 11, line 41: Fog cannot generate an attenuation of 3 dB for such short links at frequencies of 38 GHz and below (please check the references you cited).

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Hence, I do not understand why the you consider fog as a possible source in this sentence.

RESPONSE: We agree with the reviewer that fog cannot generate an attenuation of 3dB for these links. However, part of the attenuation (up to 1.5 dB) can be caused by fog on the path, so this is why we do mention this here. We agree that the sentence can benefit from rewording to clarify what we mean: "However, both wetting of the antennas and the attenuation by the fog droplets themselves can contribute to this attenuation, and it is difficult to estimate their respective relative contributions to the total attenuation."

REVIEWER: Page 13, line 19: "... no lingering attenuation, ..." This comma should be moved after "...in both cases ...".

RESPONSE: We will move this comma.

REVIEWER: Page 14, line 2: The comparison of the different parameters would fit better in section 4.1.3 where the actual analysis is explained. In the conclusion section I would not expect the presentation of new results or data.

RESPONSE: This section will be moved.

REVIEWER: Page 14, line 43: Will the data of the experiment be made available after publication?

RESPONSE: Yes! We believe is is very important that others can also use this dataset. The raw data will be published as soon as we have made final quality control checks. In the mean time, the data will be available upon request from the corresponding author.

REVIEWER: Fig 5: "RAL 38 V" appears two times in the legend. Colors of RAL 38H and RAL 26 change between plot "a" and "b"

RESPONSE: This is unfortunate. The graphs will be fixed.

REVIEWER: Fig 7: Why not use the same color for the different microwave links as in

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the time series plots, e.g. Fig 6.

RESPONSE: This is a welcome suggestion. We will do so.

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