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Atmospheric observations with E-band microwave links – challenges and opportunities

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Data acquisition from commercial microwave links

The supplementary material describes features of data acquired from E-band commercial microwave links (CMLs) with a custom-made server-sided software. The data acquisition software polls selected E-band CMLs for transmitted (*tx*) and received signal power levels (*rx*) using SNMP protocol and stores the data in the PostgreSQL database. The software collects attenuation data at arbitrary sampling frequency, limited by the response time of the CML units only.

The data acquisition was tested on six CMLs (Table 1 in the manuscript) during the period between 21st June and 13th July 2018. The test was performed to understand limitations related to CML hardware and firmware and to verify that the data acquisition does not affect telecommunication function of the network, as the CMLs are part of telecommunication backhaul.

First, the influence of automatic power control (ATPC) on observed attenuation is investigated by analyzing raw *rx* and *tx* data. Second, the maximal sampling frequency is determined as the inverse of the response time of the devices. Finally, the frequency at which *tx* and *rx* values are updated by CML units (firmware), here referred to as 'the maximal efficient sampling frequency', is evaluated from raw data. The maximal efficient sampling frequency is assumed to be inverse of the period when *tx* and *rx* values polled at maximal frequency do not change. In general, all the periods where attenuation increases or decreases within a time step by more than the CML quantization are suitable periods for evaluating maximal efficient sampling frequency.

The quantization of *tx* and *rx* is 0.1 dBm. The ATPC is active on all the CMLs except one and maintains *rx* power in the range of ± 0.1 dBm. The width of *tx* range within which ATPC is active, however, differs from only 0.9 dBm by CML 6 to 10.8 dBm by CML 2 (Table S1).

Table S1: Range of observed *tx* power levels

ID	73 - 74 GHz *tx* (dBm)	83 – 84 GHz *tx* (dBm)
1	14.3–16	11.9–16
2	5–15	4.2–15
3	5.2–10	2.7–10
4	0–9.4	-1.3–8.8
5	-1.5–7	-1.2–7
6	11.1–12	12–12

The effect of ATPC and maximal sampling frequency is demonstrated on the readings of sub-link 5a shown in Figure S1. ATPC maintains *rx* approx. at a level of -35 dBm during the period with low attenuation. The ATPC is saturated when *tx* reaches 7 dBm and then *rx* starts to decrease. The detailed view shows *rx* and *tx* readings collected at maximal sampling frequency, approx. 5 Hz. Two sudden changes in *rx* level exceed by more than order of magnitude the quantization of *rx*, while the level of *rx* remains constant for approx. 10 s in between these changes. This indicates, that CML firmware updates *rx* readings only once per 10 s and maximal efficient sampling frequency is thus far lower than the frequency at which the server-sided software polls the data. Similar behavior is also encountered by the other CMLs where *rx* and *tx* readings are updated once per 9.7 – 10 s. It should be also noted, that updates of *rx* and *tx* readings are not perfectly synchronized, which possibly degrades temporal resolution of attenuation observations.

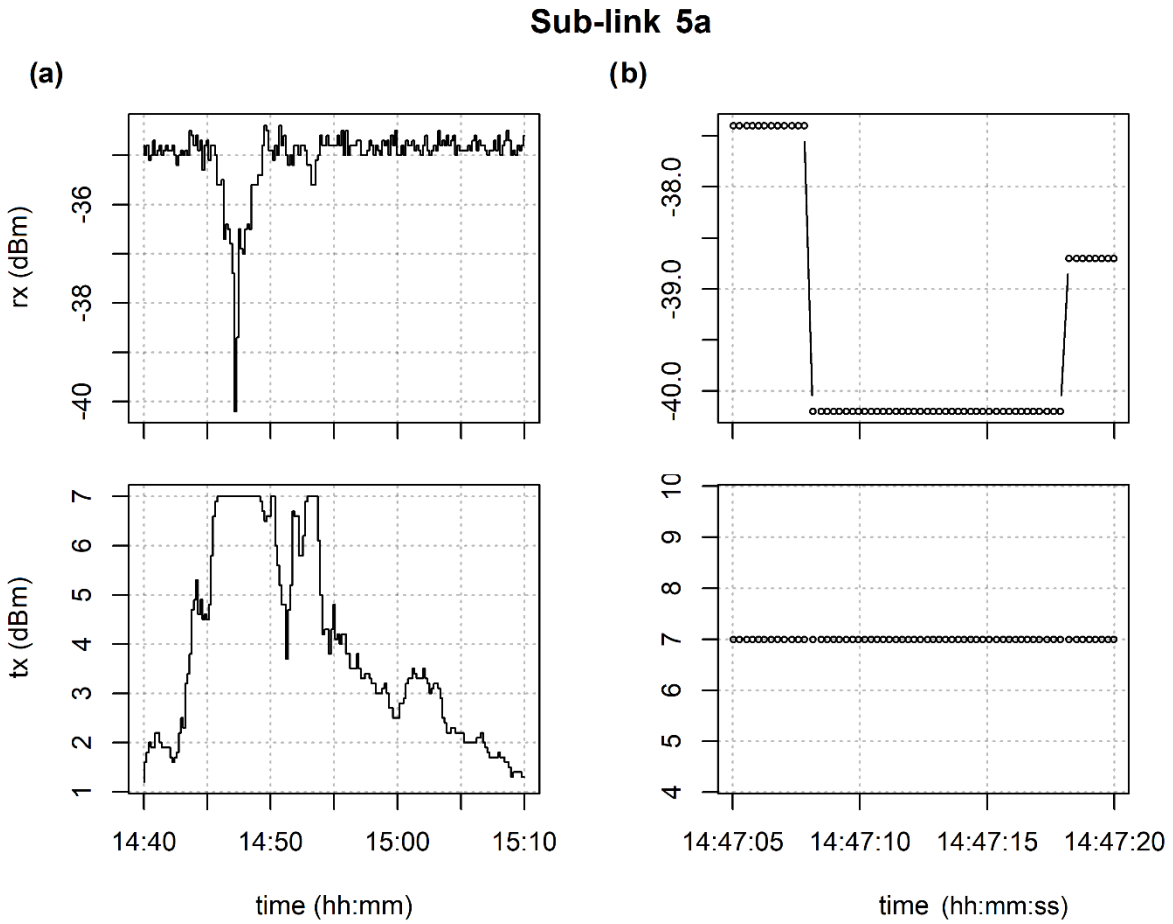

Figure S1: Rainfall event on 25th June as observed by sub-link 5a. (a) Effect of ATPC on *rx* and *tx* during rainfall. (b) Detail of attenuation peak showing difference between the frequency at which server-sided software polls the data (dots) and the frequency at which CML firmware updates the readings. Note that *tx* is constant because of the saturated ATPC.

In conclusion, the quantization of *tx* and *rx* at new E-band devices (Ericsson MINILINK) is currently 1/10 dBm, which reduces negative effect of ATPC on the precision of observed attenuation. The maximal efficient temporal resolution identified at studied CMLs is 10 s. The sampling frequency of the data acquisition software was therefore for further investigations adjusted to 10 s. Negative impacts of data acquisition on telecommunication function were not registered.