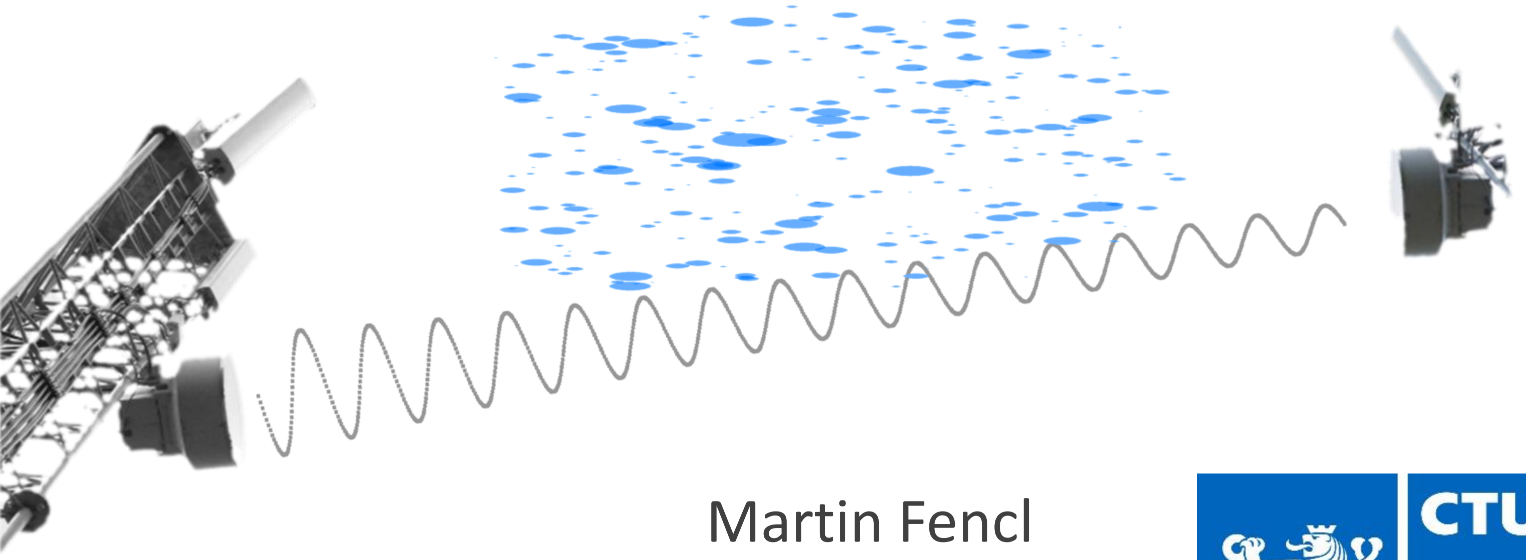
Effect of drop size distribution on rainfall retrieval from E-band commercial microwave links

Is the new generation of commercial microwave links (CMLs) which operate at E-band suitable for rainfall retrieval?

Highlights:

- E-band CMLs can accurately observe light rainfalls
- E-band rainfall retrieval is sensitive to drop size distribution
- E-band performance is improved by adapting parameters of rainfall retrieval model to the rainfall type



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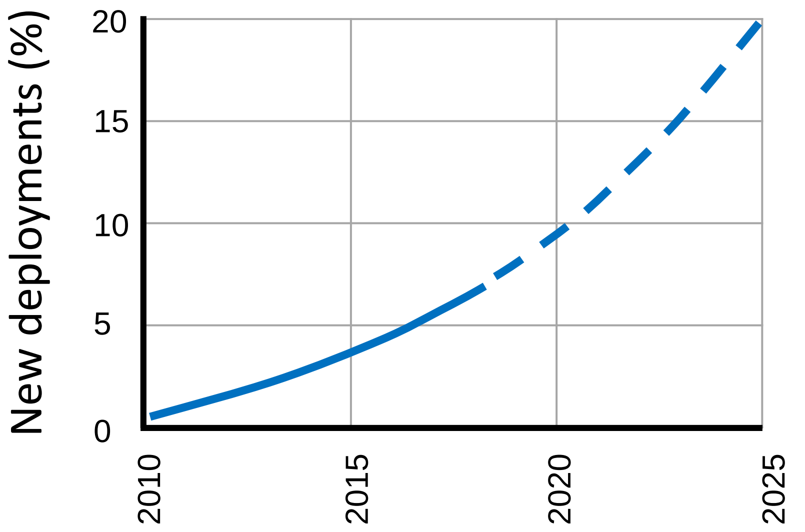
Motivation & Goal

- Rainfall retrieval from commercial microwave links (CMLs) has been proposed and tested for old generation of CMLs operating typically at frequencies 15 – 40 GHz
- CMLs operating at E-band (71 – 86 GHz) rapidly complete and often replace older devices in cellular backhaul. E-band CMLs are acknowledged as essential for the backhaul of 5G networks.
- Variable drop size distribution is expected to affect attenuation-rainfall relation at E-band substantially more than at 15 – 40 GHz



New deployments of E-band CMLs globally
Ericsson Microwave Outlook (2019)

This contribution evaluates how variable drop size distribution (DSD) affects rainfall retrieval from E-band CMLs

Methods

Numerical experiment:

1. Model attenuation-rainfall (*k*-*R*) relation from DSD:

$$k = \frac{1}{ln\ 10} \int_{D_{min}}^{D_{max}} C_{ext}(D,\lambda)\ N(D) dD \qquad (1)$$

$$R = 0.6\ 10^{-3}\ \pi \int_{D_{min}}^{D_{max}} D^3\ v(D)\ N(D) dD \qquad (2)$$

2. Classify rainfall types based on mass-weighted diameter

$$D_m = \frac{\int_{D_{min}}^{D_{max}} N(D) D^4 dD}{\int_{D_{min}}^{D_{max}} N(D) D^3 dD} \qquad (3)$$

3. Fit approximate power-law attenuation-rainfall model:
   - for all rainfalls
   - separately for stratiform and convective rainfalls

$$R \approx \alpha k^{\beta} \qquad (4)$$

4. Compare rainfall intensity estimated by power-law model (1, 4) and obtained directly from DSD (2)
   - Quantify RMSE separately for light, moderate, and heavy rainfall

Demonstration on a real CML:

1. Collect attenuation data from E-band CML
   - CML processing as described in Fencl et. al (2020), Atmospheric Observations with E-Band Microwave Links - Challenges and Opportunities, *AMTD*, 1–29. https://doi.org/10.5194/amt-2020-28.

2. Apply power-law attenuation rainfall model with:
   - ITU parameters
   - parameters from virtual experiment obtained for stratiform rainfall

3. Compare estimated rainfall to rain gauges
   - Compare 15-min average rainfall intensities obtained when using rainfall retrieval model with ITU parameters and parameters for stratiform rainfalls obtained from numerical experiment

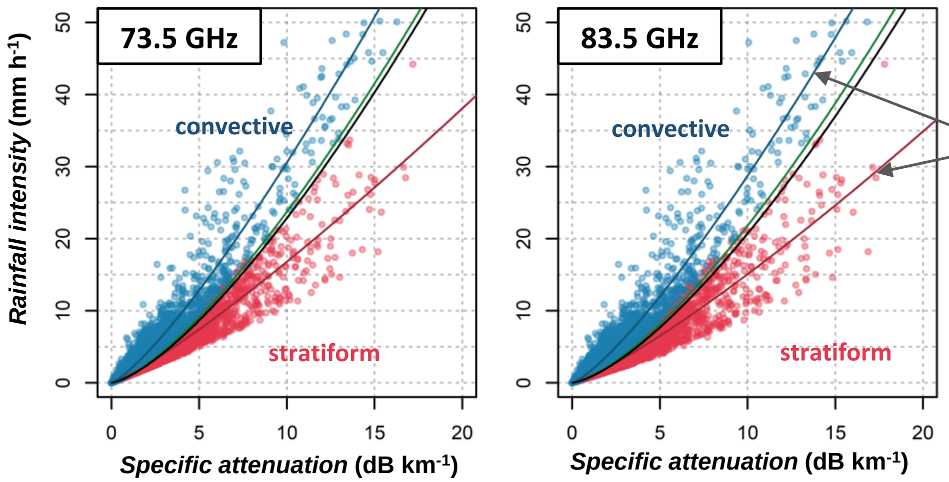
Datasets

Dataset	Type of obserevation & Instrumentation	Observation period	Other features
Numerical experiment	Drop size distribution from PARSIVEL OTT, 1st generation	03/2011 – 04/2012	Quality-checked data
Demonstration on a real CML	• CML (Ericsson MINILINK), dual frequency 73.5 and 83.5 GHz, vertically polarized • 3 tipping bucket rain gauges	11/2018 – 12/2018 *(predominant occurrence of stratiform rainfalls)*	• Data acquisition by SNMP protocol • dt = 10 sec

Observation layout with a real CML:

Results

Numerical experiment



Fits for convective and stratiform rainfalls differ markedly

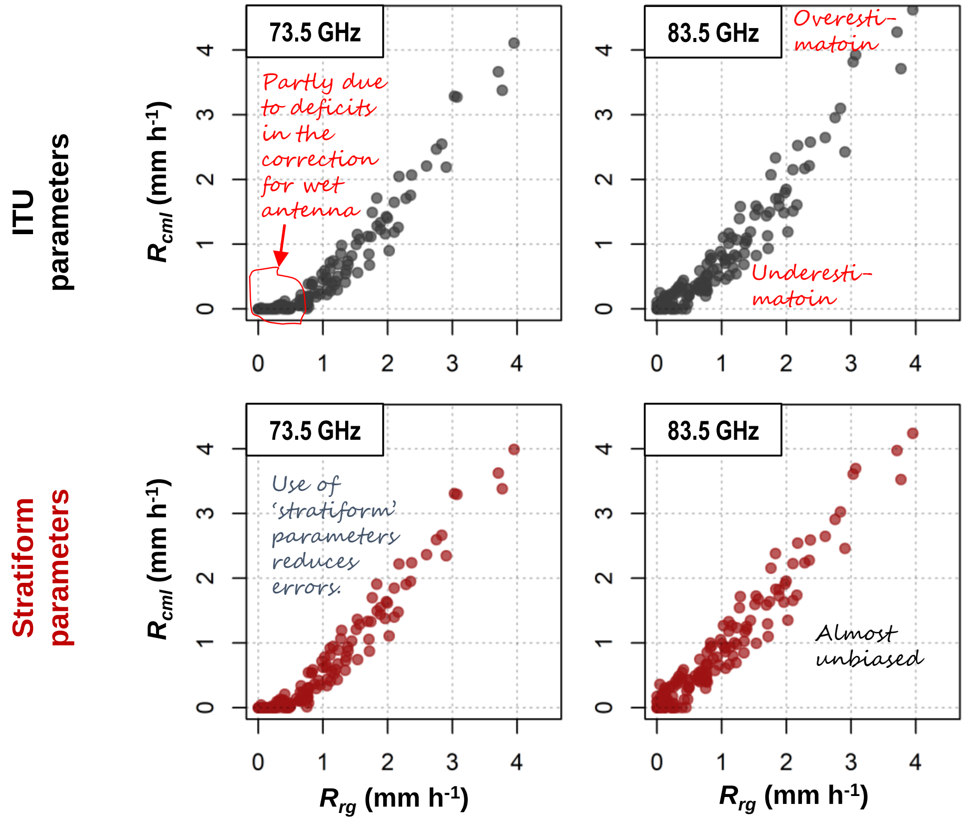
stratiform fit:	$R = 1.11\ k^{1.18}$	$R = 1.11\ k^{1.18}$
convective fit:	$R = 1.72\ k^{1.25}$	$R = 1.72\ k^{1.25}$
Joined fit:	$R = 0.99\ k^{1.38}$	$R = 0.99\ k^{1.38}$
ITU:	$R = 0.91\ k^{1.40}$	$R = 0.91\ k^{1.40}$

Parameter set	Freq. (GHz)	RMSE (mm h^{-1})			
		R ∈ ⟨0,50⟩	R < 4	4 < R ≤ 12	R > 12
Conv./ strat. fits*	73.5	0.67	0.20	1.34	4.75
	83.5	0.73	0.24	1.48	5.08
Joined fit	73.5	1.17	0.43	2.46	8.03
	83.5	1.26	0.41	2.73	8.43
ITU	73.5	1.18	0.41	2.39	8.17
	83.5	1.27	0.45	2.63	8.74

Joint fit results in parameters similar to the ITU and thus also to the similar RMSE

* Respective set of parameters used for convective and stratiform rainfalls

Rainfall estimated from a real CML



Sub-link	ITU parameters			Stratiform parameters		
Frequency (GHz)	r (-)	rel. error (-)	RMSE (mm h^{-1})	r (-)	rel. error (-)	RMSE (mm h^{-1})
73.5	0.95	-0.44	0.49	0.96	-0.35	0.39
83.5	0.96	-0.17	0.31	0.97	-0.08	0.24

Conclusions & Research outlook

- E-band CMLs can accurately observe light rainfalls (unlike 15 – 40 GHz CMLs)
- Rainfall retrieval from E-band CMLs is substantially more sensitive to drop size distribution than older CMLs operating at frequencies 15 – 40 GHz
- E-band rainfall estimation performance is improved by adapting parameters of attenuation-rainfall model to the rainfall type

Further research will concentrate on:

- Investigating performance on real E-band CMLs during periods with heavy rainfalls
- Adapting parameters of attenuation-rainfall model to the rainfall type in operational settings
- Inferring drop size distribution from joint observations of E-band and 15 – 40 GHz CMLs

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