Propagation measurements and models in the mmWave band

Sana Salous
Department of Engineering
Durham University, UK
Sana.salous@durham.ac.uk

Durham University

Outline

1. Frequency bands for 5G

2. Propagation measurements and models for 5G: updated and new ITU recommendations

3. Future plans for 6G frequency bands and propagation studies

Durham
University

WRC15/WRC19 frequency bands

WRC15 Band (GHz)	Bandwidth (GHz)
24.25-27.5	3.25
31.8-33.4	1.6
37-43.5	6.5
45.5-50.2 45.5-47, 47.2-48.2	4.7 1.5, 1
50.4-52.6	2.4
66-76 66-71	10 5
81-86	5

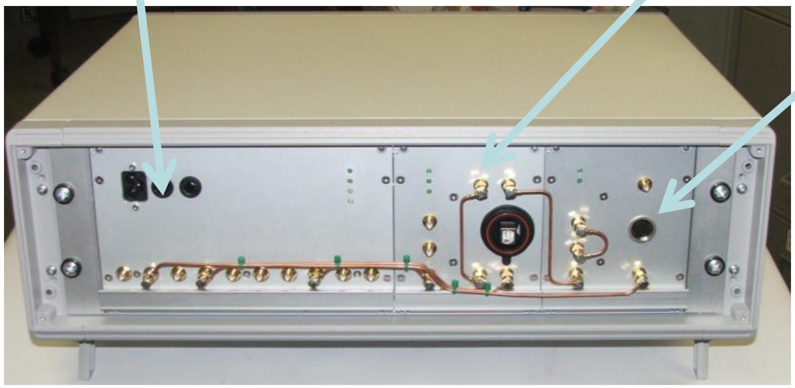
With 14.75 GHz harmonized worldwide, ~ 85% of global harmonization

Durham University

Durham Channel Sounder

Rubidium unit

DDS and 2.2-2.95 GHz



4.4-5.9 GHz and

14.5-16 GHz

25-30 GHz,
36-41 GHz
50-75 GHz
60-90 GHz

Durham University

5G Use Scenarios:

Outdoor:

LoS/NLoS: ITU-R P. 1411

Clutter loss: ITU-R P. 2108

Outdoor fixed links: ITU-R P. 530

Indoor: ITU-R P. 1238

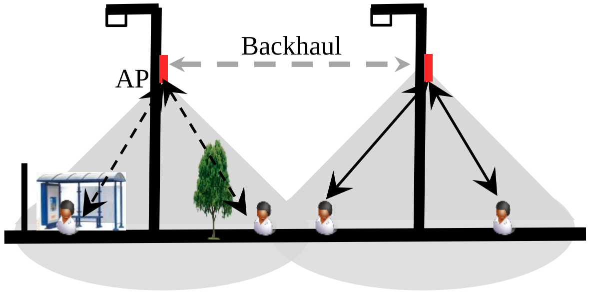
Outdoor to indoor: ITU-R P. 2109

Durham University

Use Scenarios: outdoor/indoor

Street canyon

Open square



Backhaul

Shopping mall

Exhibition

Conference room

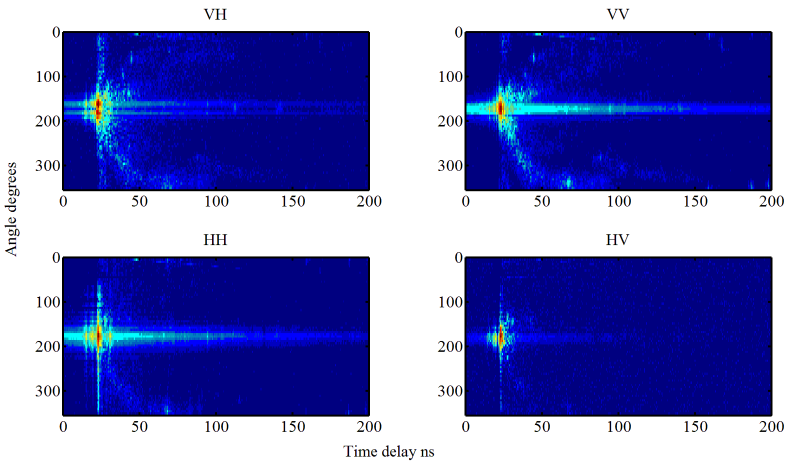
Durham University

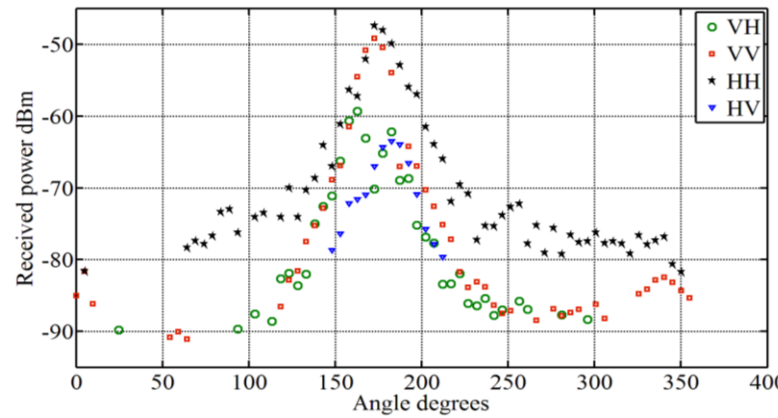
Measurements approach

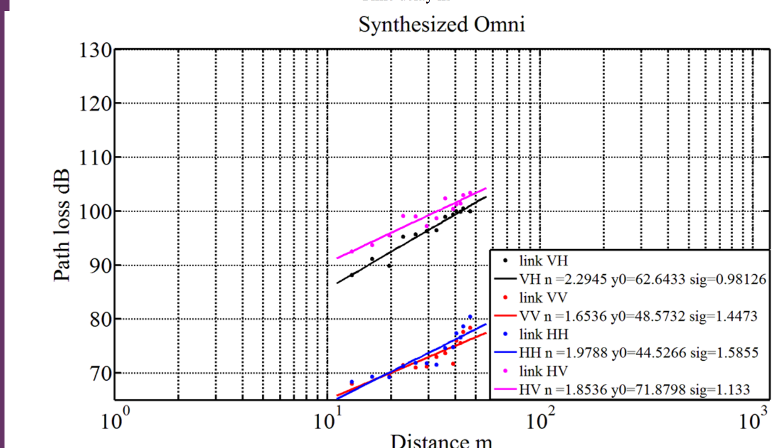
1. Directional vs omni-directional
2. Spatial distance for samples
3. Minimum acceptable SNR
4. Path loss model: single frequency or multiple frequency

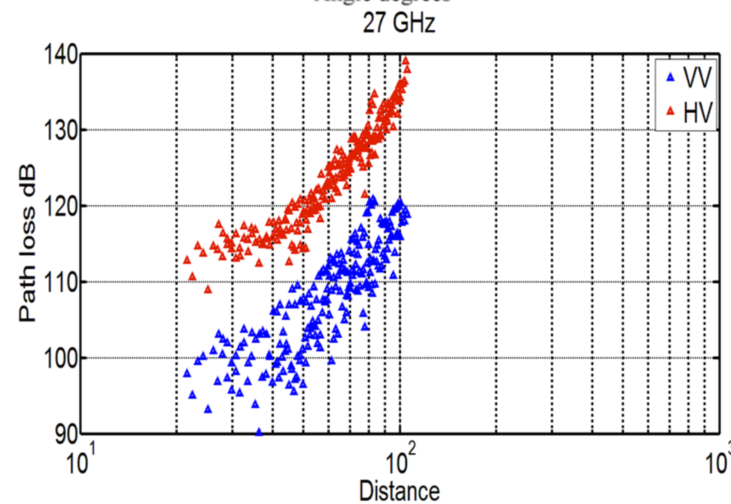
Durham University

Directional vs omni measurements



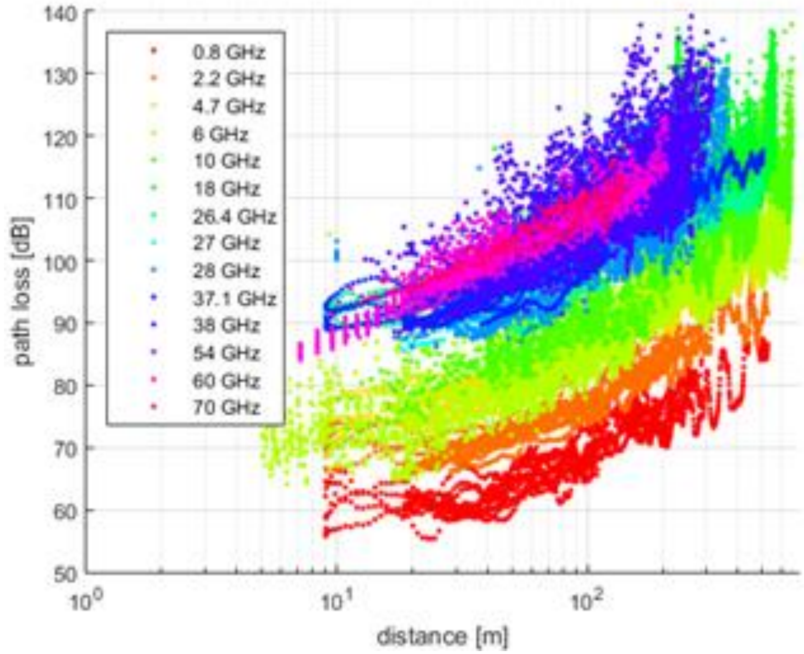




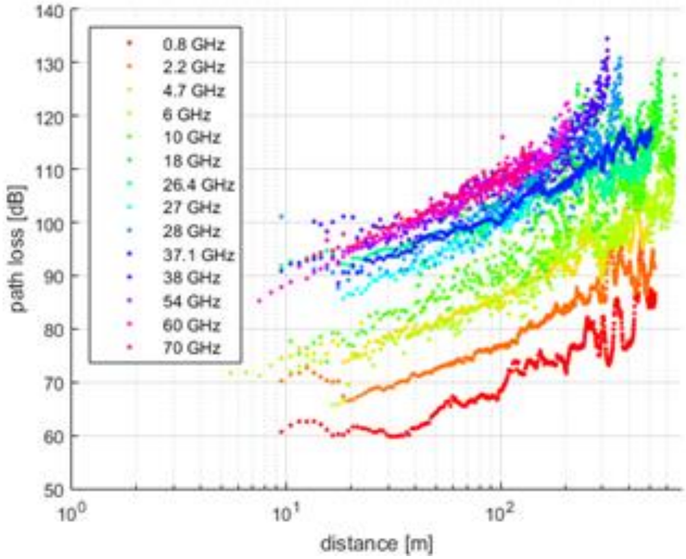


Durham University

Spatial distance



Raw data



Decimated data over 1 m

Path loss model

Single frequency vs multiple frequency

$$PL_{logDist}(d) = 10\alpha\log_{10}(d) + \beta \ dB$$

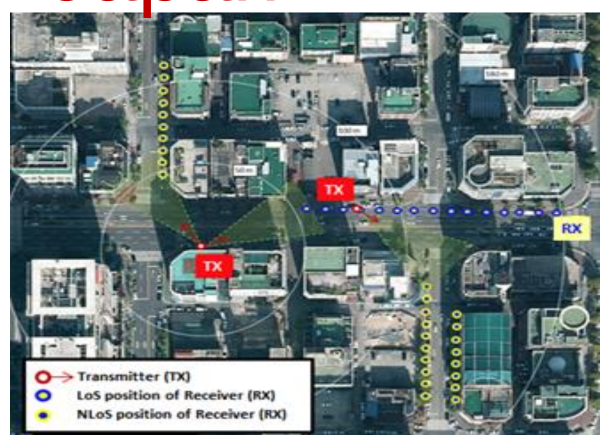
$$PL(d,f) = 10\alpha\log_{10}(d) + \beta + 10\gamma\log_{10}(f) \ dB$$

with an additive zero mean Gaussian random variable $N(0,\sigma)$ with a standard deviation σ (dB)

ITU-R P. 1411 measurements , Japan, Korea

Japan

UK

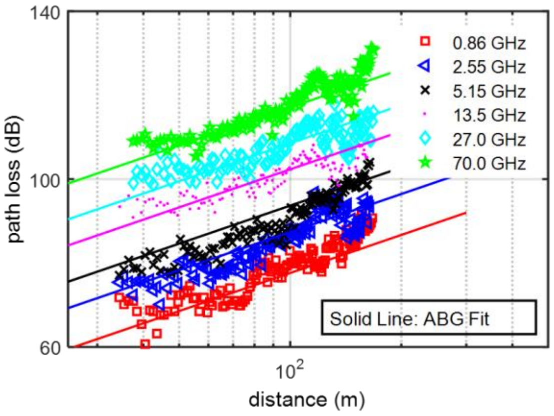


Korea

Durham University

Adopted model for below rooftop

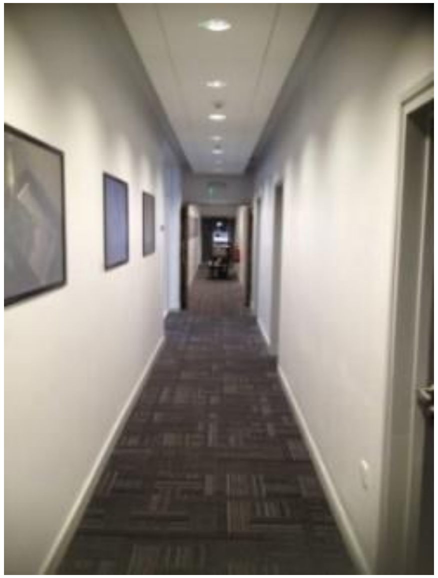
Frequency range (GHz)	Distance range (m)	Type of environment	LoS/ NLoS	α	β	γ	σ
0.8-73	**5-660**	**Urban high-rise, Urban low-rise/ Suburban**	**LoS**	**2.12**	**29.2**	**2.11**	**5.06**
0.8-38	30-715	Urban high-rise	NLoS	4.00	10.2	2.36	**7.60**
10-73	**30-250**	**Urban low-rise/ Suburban**	**NLoS**	**5.06**	**-4.68**	**2.02**	**9.33**
0.8-73	**30-170**	**Residential**	**NLoS**	**3.01**	**18.8**	**2.07**	**3.07**



AGB
(α, β, γ, σ)
3.01, 18.8, 2.07, 3.07

Durham University

ITU-R P. 1238 measurement scenarios



Indoor Ceiling height to user,
Tx=2.35 m, Rx=1.5 m

Durham University

Adopted model ITU-R 1238-11

Environment	LoS/NLoS	Frequency range (GHz)	Distance range (m)	α	β	γ	σ
Office	LoS	**0.3–83.5**	2–27	1.46	34.62	2.03	3.76
	NLoS	**0.3–82.0**	4–30	2.46	29.53	2.38	5.04
Corridor	LoS	**0.3–83.5**	2–160	1.63	28.12	2.25	4.07
	NLoS	**0.625–83.5**	4–94	2.77	29.27	2.48	7.63
Industrial	LoS	**0.625–70.28**	2–101	2.31	24.52	2.06	2.69
	NLoS	**0.625–70.28**	5–108	3.79	21.01	1.34	9.05

Durham University

ITU-R P. 2109-1 Building entry loss model

Building classification

- Thermally-efficient: metallised glass, foil-backed panels
- Traditional’ buildings without such materials

Durham University

Type of properties measured

Traditional

Modern

Victorian House

80s build

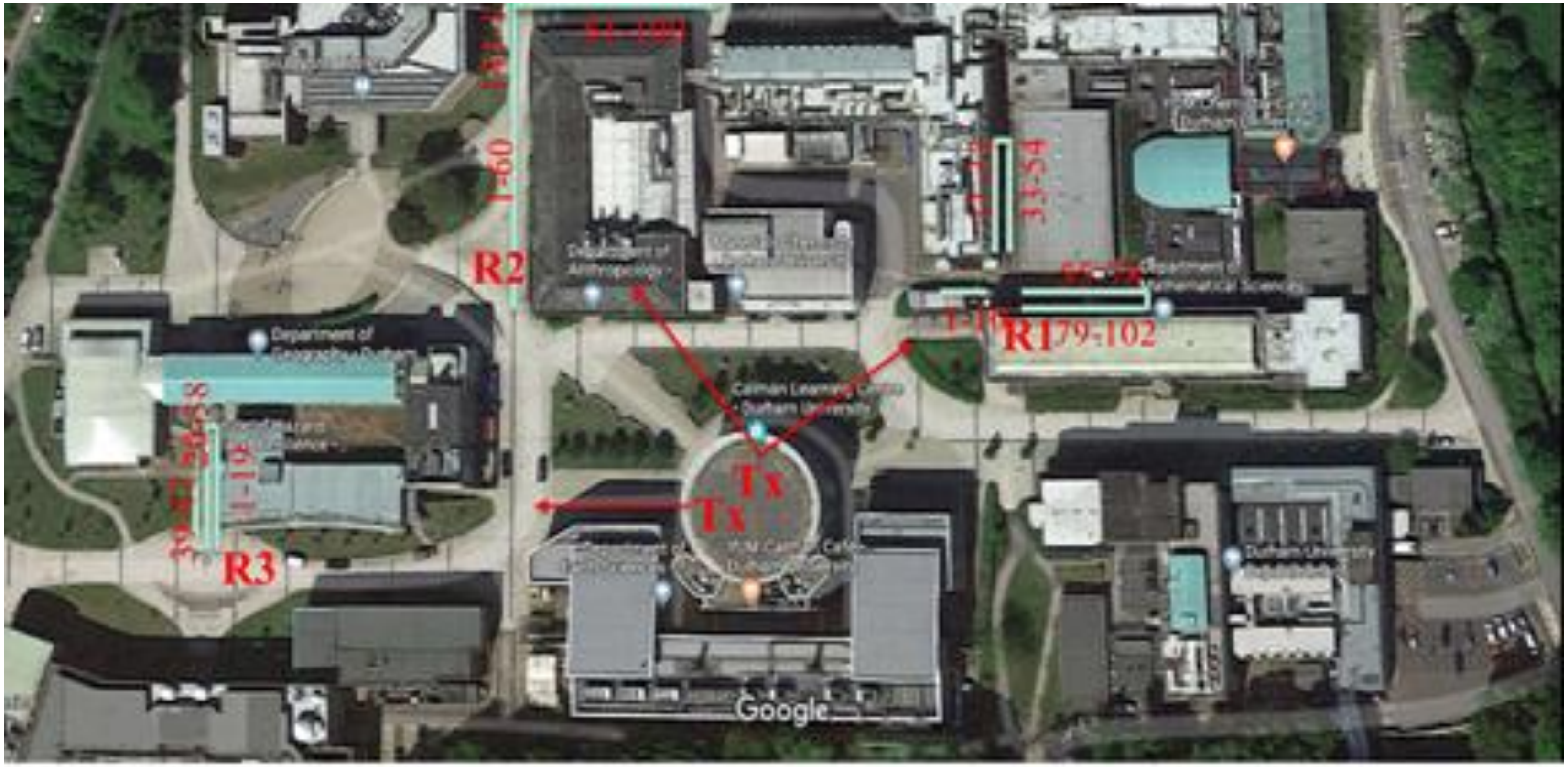
Üserhuus

Weinerberger-E4

Building Research Establishment (BRE) in Watford, UK

Durham University

ITU-R P. 2108: Clutter loss prediction
Clutter Loss Measurements UK

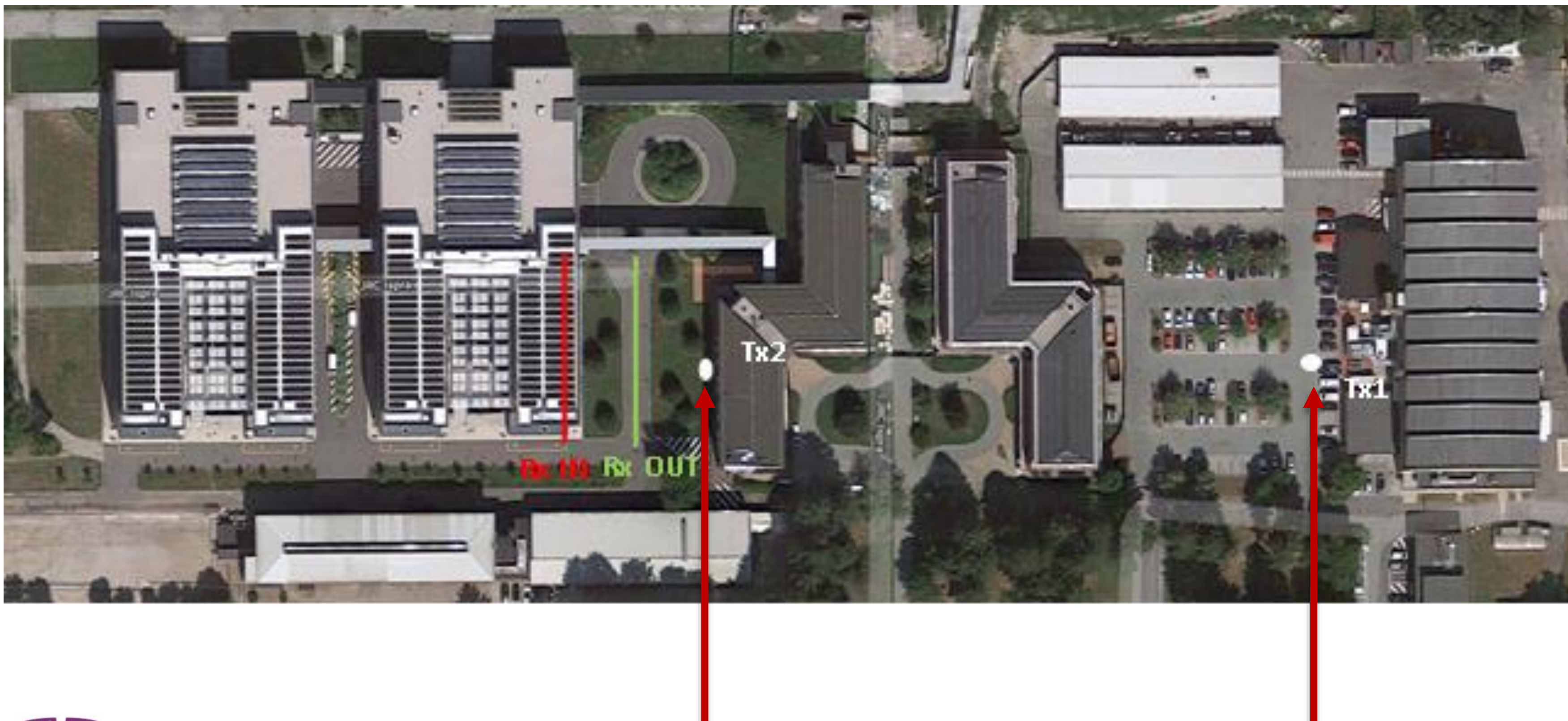


Durham
University

Combined Clutter Loss and BEL

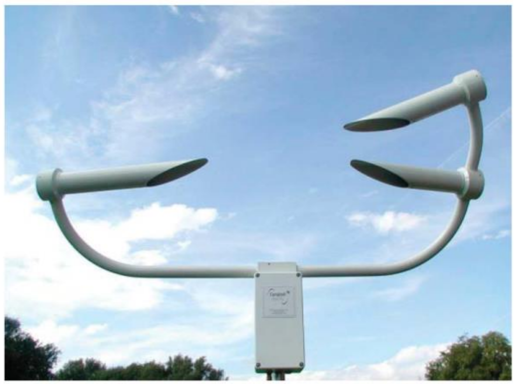
Durham University

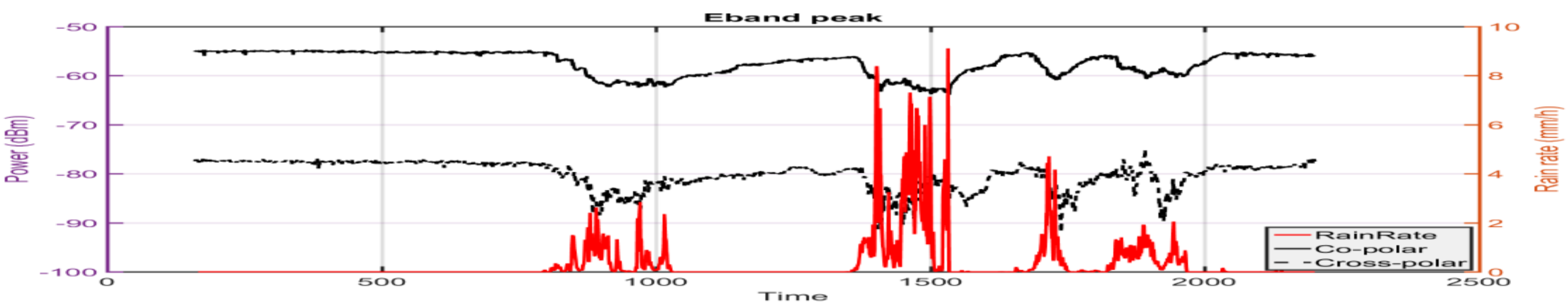
Combined Clutter Loss and BEL: Measurement Scenario



Durham University

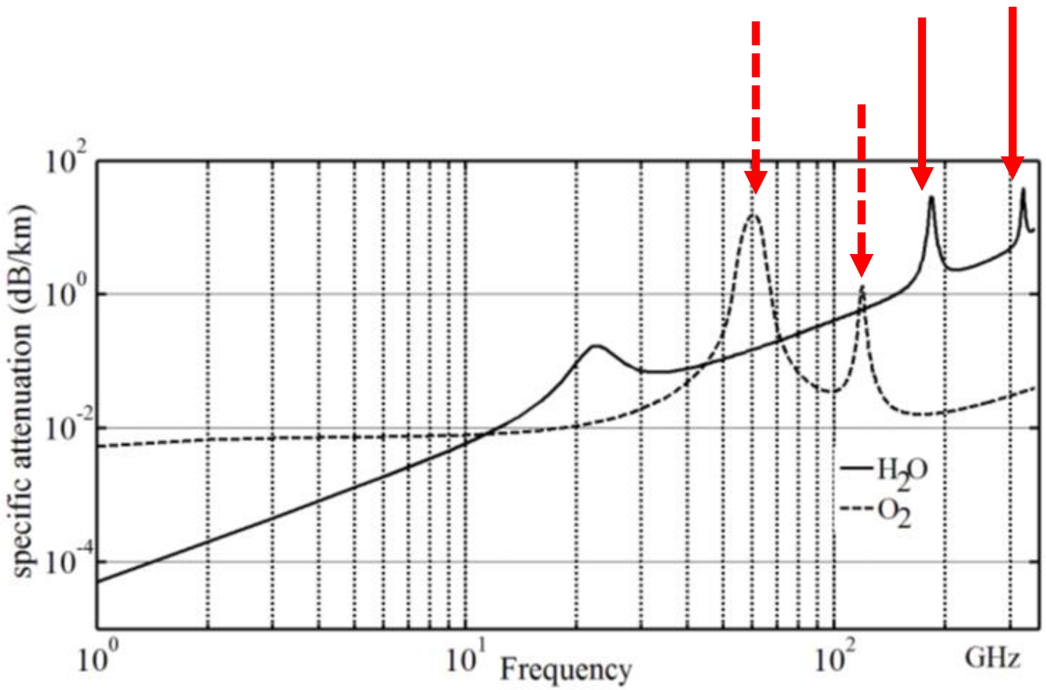
ITU-R P. 530: Impact of precipitation





Durham University

6 G bands in EHF (30-300 GHz)



Oxygen peaks:

60 GHz and 118 GHz

Water vapour peaks:

184 GHz and 325 GHz

- **WRC23:** 140-170 GHz, and 235-300 GHz

- **Models**: Indoor, outdoor, Precipitation measurements

Durham University

Plans for 6 G measurements: WRC 2023 frequency bands

Extend/update the models

1. Outdoor mobile: ITU-R P. 1411
2. Indoor: ITU-R P. 1238 revisit the models above 100 GHz
3. Fixed links: ITU-R P.530 study impact of precipitation

Durham University

References

Salous, S., Lee, J., Kim, M.-D., Sasaki, M., Yamada, W., Raimundo, X. & Cheema, A.A. (2020). Radio propagation measurements and modeling for standardization of the site general path loss model in International Telecommunications Union recommendations for 5G wireless networks. Radio Science 55(1): e2019RS006924.

Huang, Jie, Cao, Yusheng, Raimundo, Xavier, Cheema, Adnan & Salous, Sana (2019). Rain Statistics Investigation and Rain Attenuation Modeling for Millimeter Wave Short-range Fixed Links. IEEE Access 7: 156110-156120.

Salous, Sana, Feeney, Stuart, Raimundo, Xavier & Cheema, Adnan (2016). Wideband MIMO channel sounder for radio measurements in the 60 GHz band. IEEE Transactions on Wireless Communications 15(4): 2825-2832.

Durham University