ISART 2018 Panel Session:

"Driving Forward": Advances in Propagation Modelling

Evelyn Dohme, University of New Mexico

Katsuyuki Haneda, Aalto University

David Matolak, University of South Carolina

Paul McKenna, NTIA/ITS

Kevin Sowerby, University of Auckland (Moderator)

ISART 2018 Panel Session: "Driving Forward": Advances in Propagation Modelling

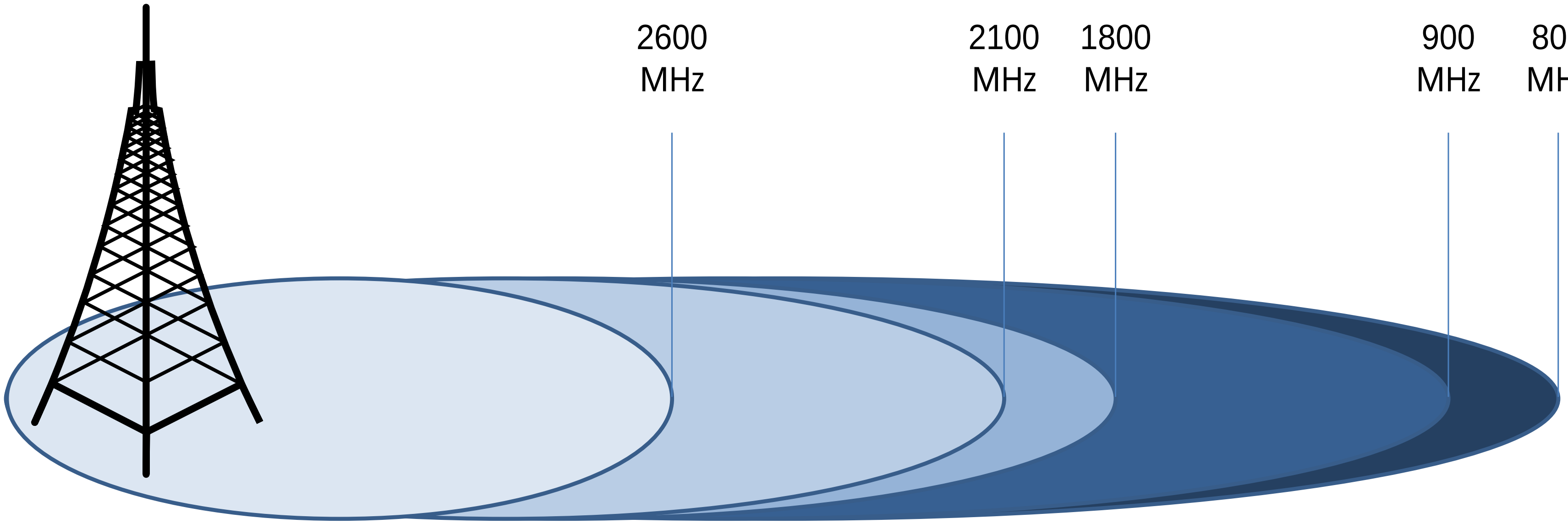
Kevin W Sowerby

Department of Electrical & Computer Engineering

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

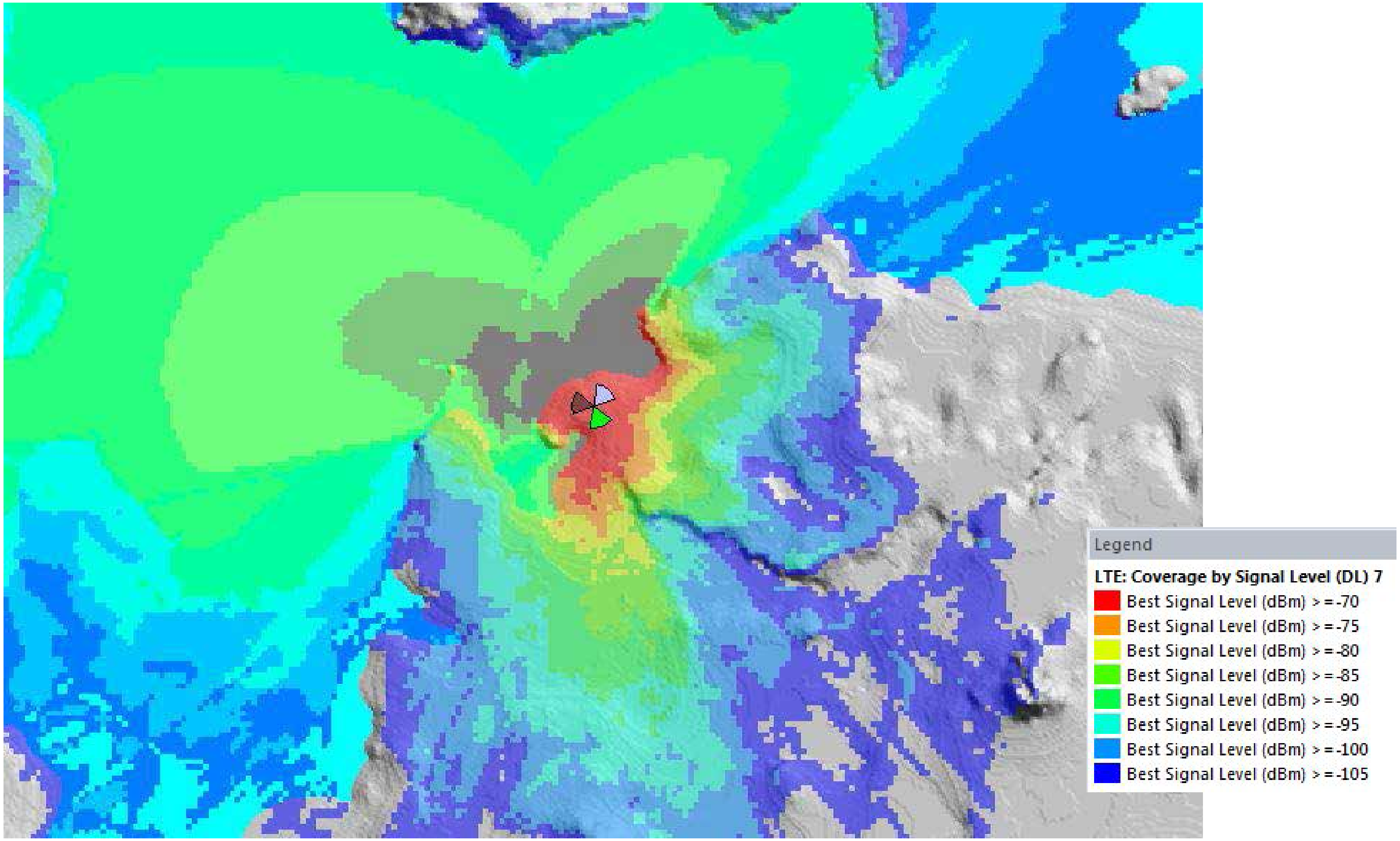
ENGINEERING

Cellular radio coverage



			3G	LTE	
	Data rate		128	128	kbps
	Available bandwidth		3840	1260	kHz
				7	# PRBs
	Frequency band		1800	1800	MHz
	Environment		urban	urban	
Tx (UE)	Max Tx power		23.0	23.0	dBm
	Tx antenna gain		0.0	0.0	dBi
	Body loss		0.0	0.0	dB
	EIRP		23.0	23.0	dBm
Rx ((e)NodeB)	Noise figure		2.0	2.0	dB
	Thermal noise		-108.1	-113.0	dBm
	Rx noise		-106.1	-111.0	dBm
	SINR		-10.5	-7.2	dB
	Rx sensitivity		-116.7	-118.1	dBm
	Interference margin		3.0	1.0	dB
	Cable loss		3.0	3.0	dB
	Rx antenna gain		18.0	18.0	dBi
	Fast fading margin		1.8	0.0	dB
	Soft handover gain		2.0	-	dB
	Coverage reliability		90%	90%	
	Shadowing plus penetration loss	mean	22.3	22.3	dB
		sigma	9.5	9.5	dB
		margin	34.5	34.5	dB
	Max. allowable path loss		117.4	120.7	dB
	Path loss model (COST 231 Hata)	fixed	134.8	134.8	dB
		distance	35.2	35.2	dB
	Max. allowable cell range		0.32	0.40	km

LTE 1800 MHz coverage



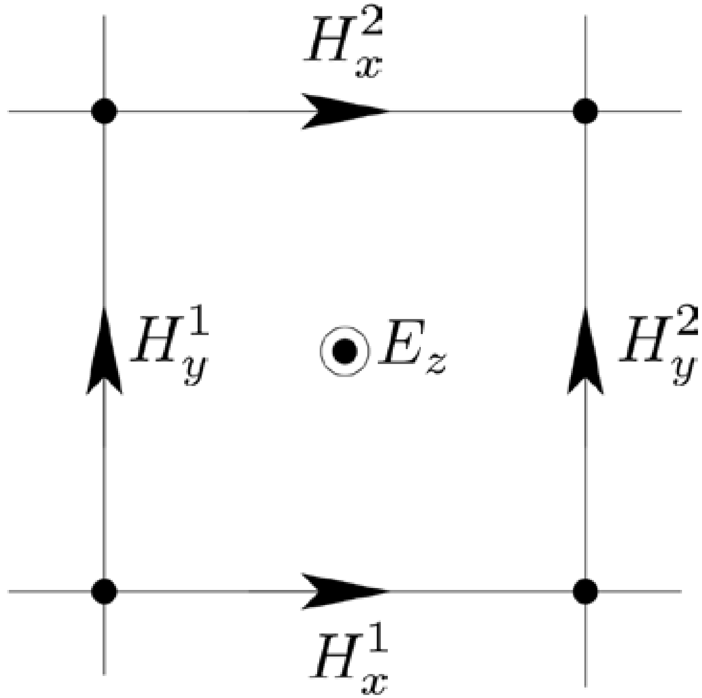
Actual LTE coverage from coastal site, using the UHF band (1800 MHz).

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

The Finite-Difference Time-Domain (FDTD) Method

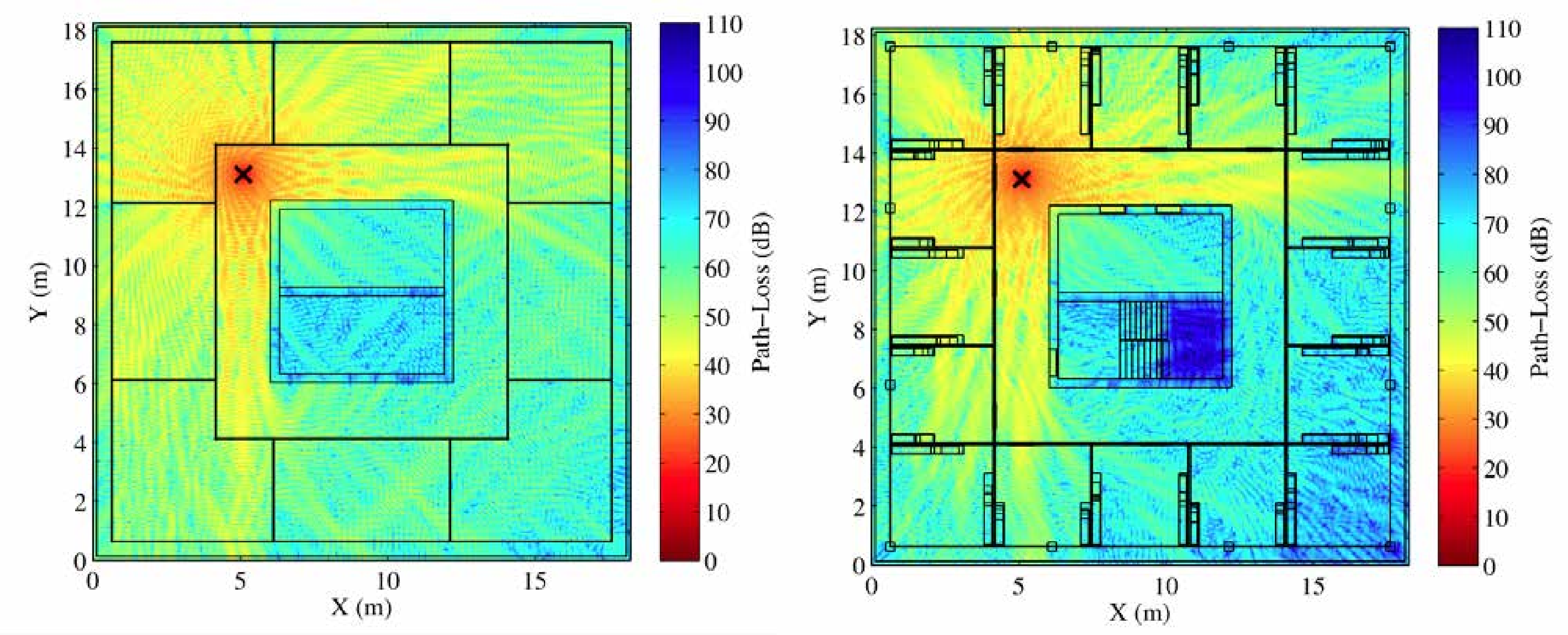
- Numerical solution of Maxwell's equations in the time domain
- Usually solved on regular cartesian lattice
- Spatial discretisation usually ~ wavelength/20
- Time step chosen to ensure stability – typically in ps
- Pulse excitation usually employed
- Simulation is run until transients die out
- Time harmonic response can be straightforwardly extracted

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING



$$E_z|_{\text{new}} = c_a E_z|_{\text{old}} + c_b (H_y^2|_{\text{old}} - H_y^1|_{\text{old}} + H_x^2|_{\text{old}} - H_x^1|_{\text{old}})$$

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING



(a) (b)

FDTD simulated path loss at 1GHz on a horizontal slice for (a) ‘basic’ and (b) ‘detailed’ internal geometries

Streamline Visualisation

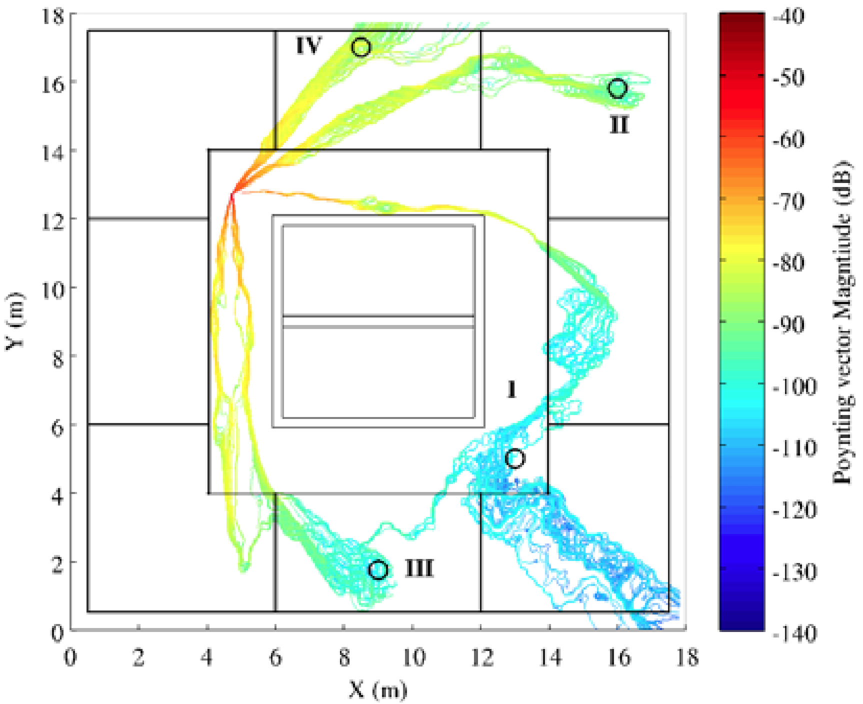
- Time-averaged Poynting vector

$$\mathbf{S} = \frac{1}{2}\Re\left[\mathbf{E} \times \mathbf{H}^*\right]$$

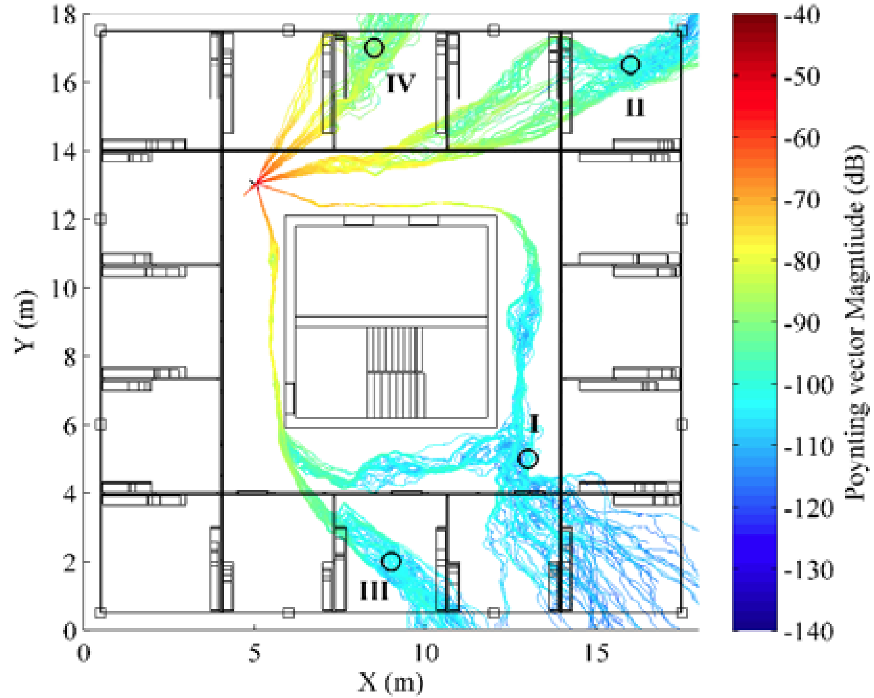
- Streamlines defined by

$$\frac{d\vec{p}(a)}{da} = \mathbf{S}(\vec{p}(a))$$

- Can be used to visualise energy flow



(a)



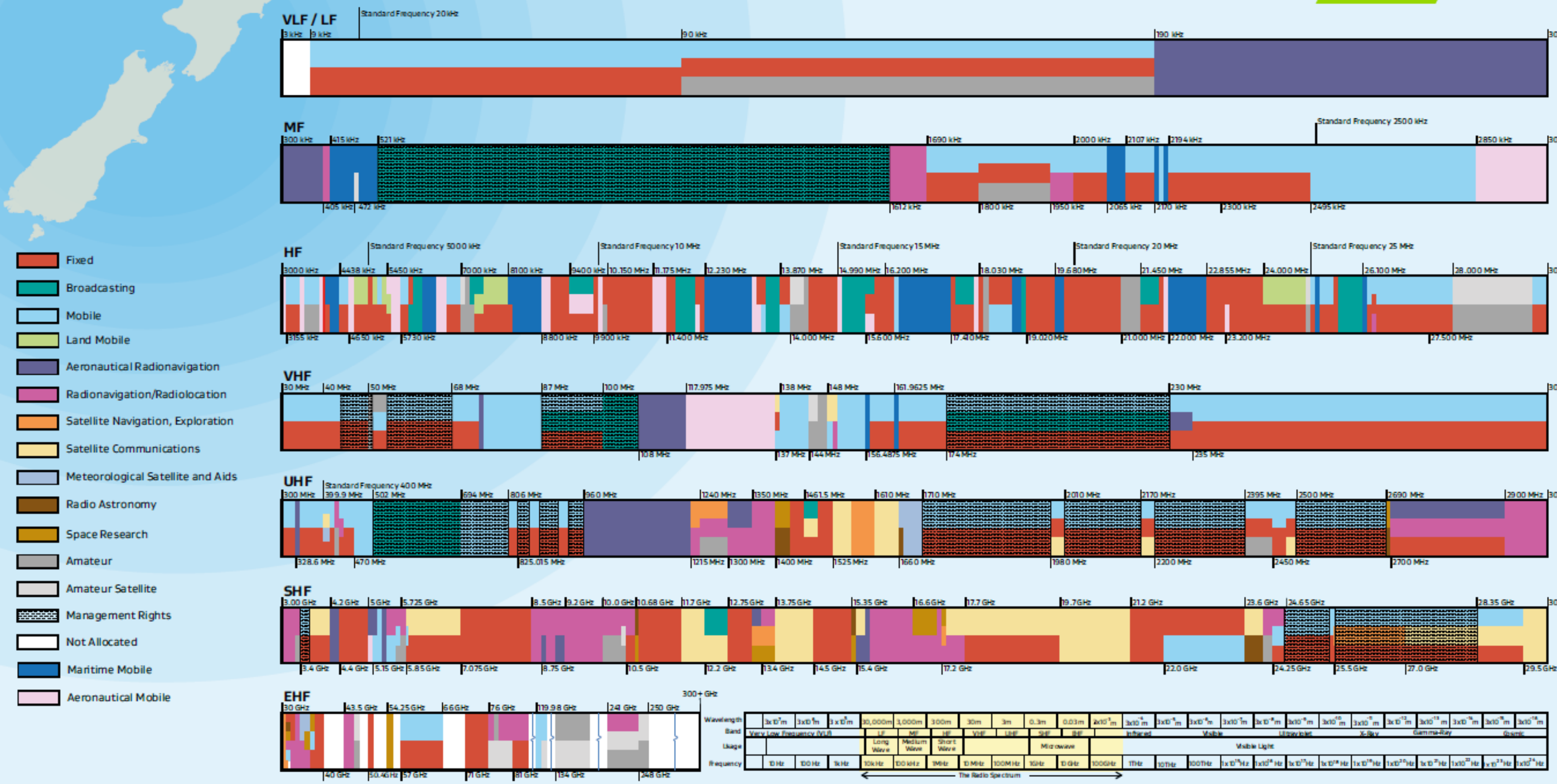
(b)

Streamlines of energy flow at 1GHz on a horizontal slice for (a) ‘basic’ and (b) ‘detailed’ internal geometries

Our Propagation Modelling Paradigm

- Semi-deterministic approach
- **'Exhaustive'** electromagnetic analysis of typical range of building environments
- Use results to derive simpler **'mechanistic'** models which capture the key effects which dominate propagation

Radio Spectrum Allocations in New Zealand



MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Enquiries are welcome and should be directed to:

Radio Spectrum Management
Ministry of Business, Innovation and Employment
PO Box 2847 Wellington 6140 New Zealand
Email: info@rsm.govt.nz
Fax: +64 4 978 3162 www.rsm.govt.nz

Radio spectrum is defined as electromagnetic energy of frequencies lower than 3000 gigahertz. It is managed by the Crown, through the Radio Spectrum Management (RSM) team within the Ministry of Business, Innovation and Employment, on behalf of the people of New Zealand. The efficient use of the radio spectrum to provide safety-of-life, telecommunications, broadcasting and other services is essential to the functioning of a modern economy.

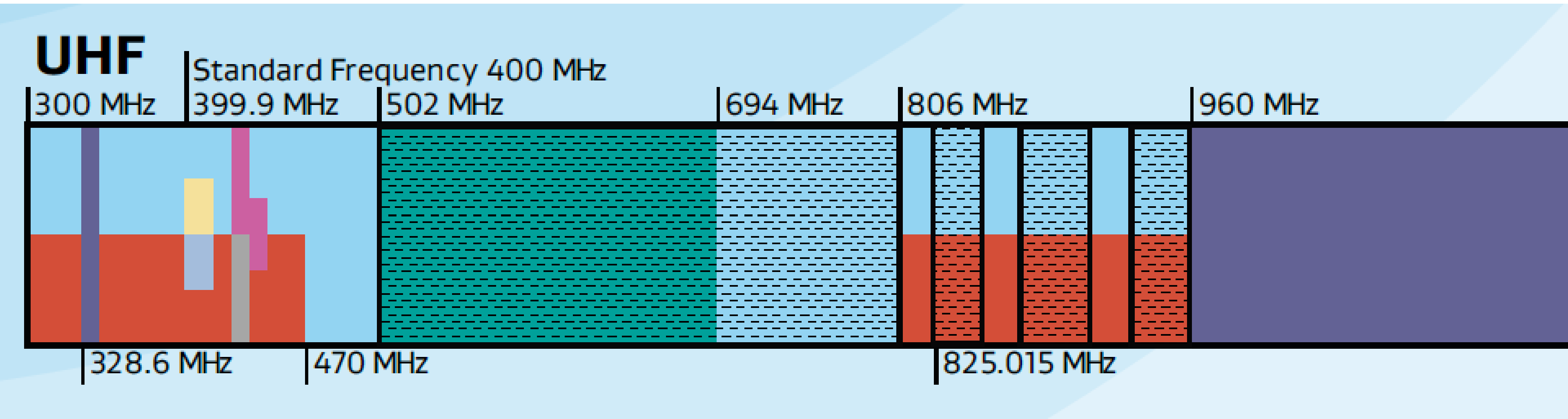
RSM is responsible for providing advice to Government on the allocation of radio frequencies to meet the demands of emerging technologies and services, in order to ensure radio spectrum provides the greatest economic and social benefit to New Zealand.

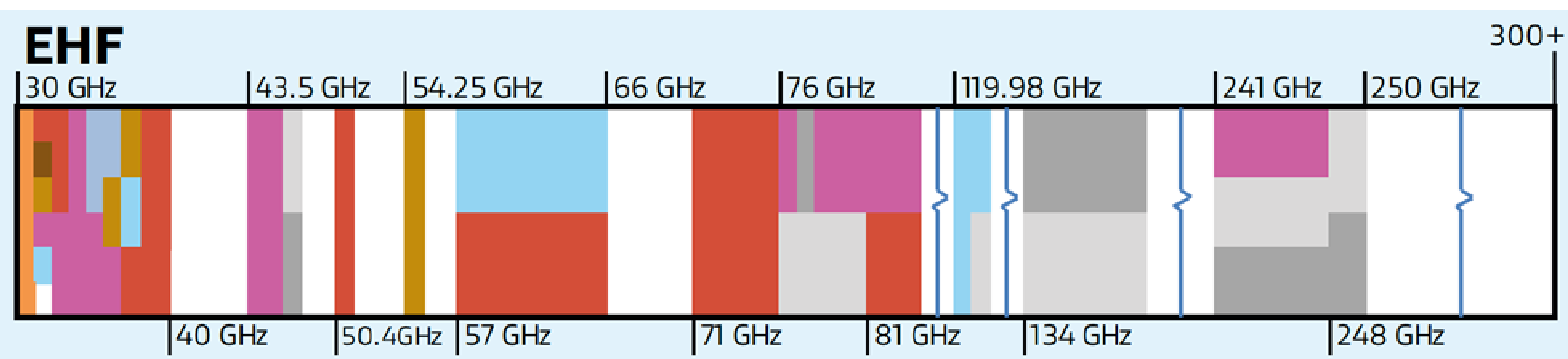
Frequency bands are planned for various services in accordance with Government policy directives, international practices, and technical standards. Persons wishing to utilise frequencies in accordance with these plans apply for a licence for which an annual fee is often charged.

This chart shows in simplified form the significant primary and secondary radio spectrum usage in New Zealand. Many frequency bands are also utilised for other secondary purposes, which may not be shown. Hence this chart must be regarded as indicative only and the Crown does not accept responsibility whether in contract, tort, equity or otherwise for any action taken, or reliance placed on the information in this chart or for any error or omission from this chart. For specific details of current allocations, please refer to *Table of Radio Spectrum Usage in New Zealand PIB 21*.

The Radiocommunications Act allows the Government to provide licences directly upon application but also allows the creation of a management right over particular frequencies for periods up to 20 years. These management rights can then be transferred to private entities, for example a company providing cellular services, thereby allowing that entity exclusive powers to create licences as required for their services.

VLF = Very Low Frequency
LF = Low Frequency
MF = Medium Frequency
HF = High Frequency
VHF = Very High Frequency
UHF = Ultra High Frequency
SHF = Super High Frequency
EHF = Extremely High Frequency


UHF
Standard Frequency 400 MHz
300 MHz
399.9 MHz
502 MHz
694 MHz
806 MHz
960 MHz
328.6 MHz
470 MHz
825.015 MHz


EHF
300+
30 GHz
43.5 GHz
54.25 GHz
66 GHz
76 GHz
119.98 GHz
241 GHz
250 GHz
40 GHz
50.4GHz
57 GHz
71 GHz
81 GHz
134 GHz
248 GHz

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Department of Electrical and Computer Engineering

2018 European Conference on Antennas and Propagation (EuCAP)

12 April 2018

Indoor Millimetre Wave Channel Measurements for 5G Wireless Systems

Dr Andrew Austin, Dr Michael Neve, and Ms Damla Guven

Background: *Current Thinking*

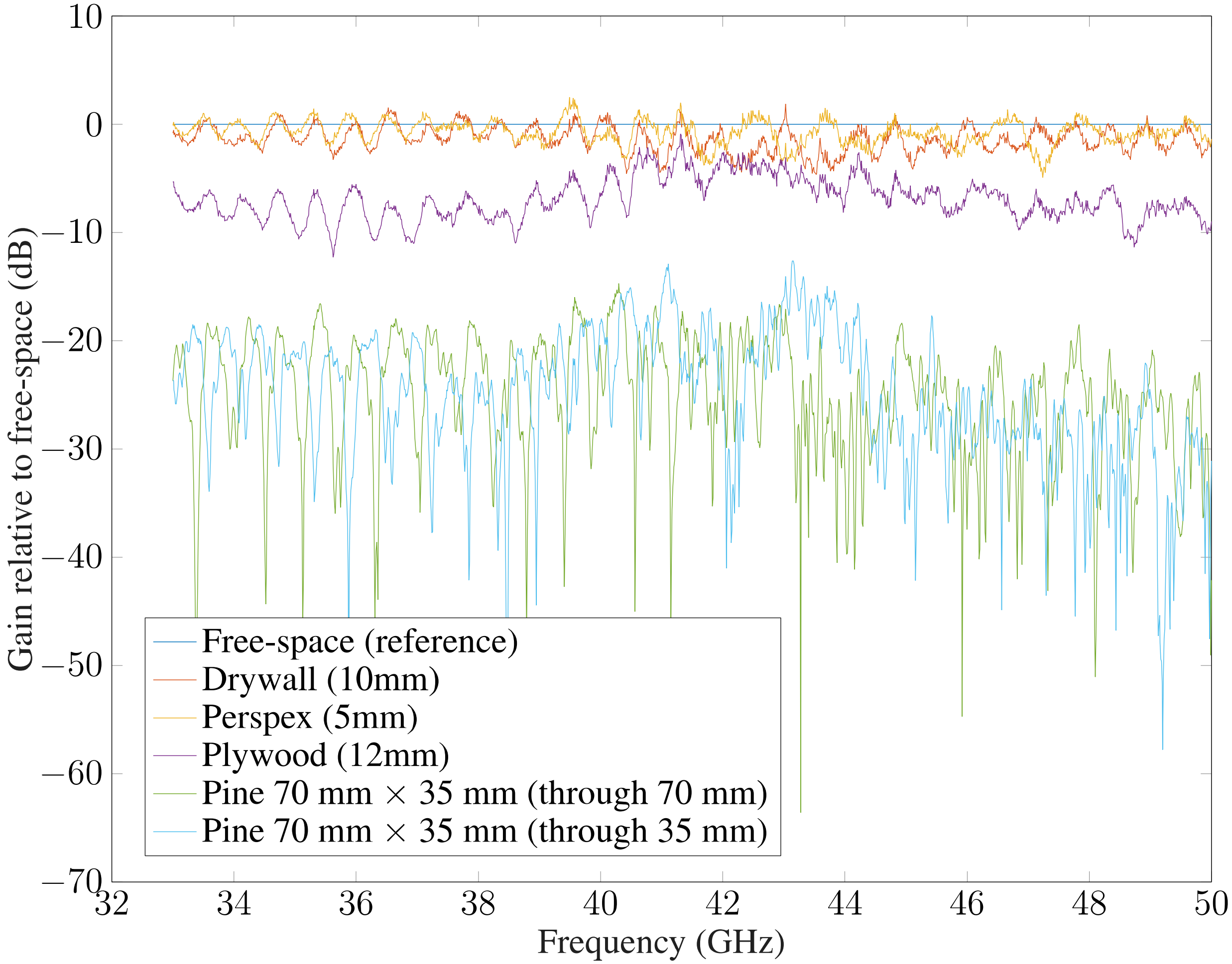
- System design is going to be easier at mmWave:
  - Steerable high-gain antennas to overcome increased pathloss
  - Accordingly, mostly LOS propagation
  - RXs don't need to worry (much) about multipath: **simple equalisers**

- High attenuation & beam-steering: indoor mmWave systems will be coverage limited, not interference limited
  - **Solution: put a mmWave access point in every office!**

- Need experimental measurements of the indoor channel:
  - How much scatter do we observe?
  - Impact of human shadowing?
  - Impact of co-channel interference? (from systems in adjacent offices)

mmWave Measurements of Common Building Materials

- “Insertion loss” for various material samples measured at Q-band (33-50 GHz) using network analyser

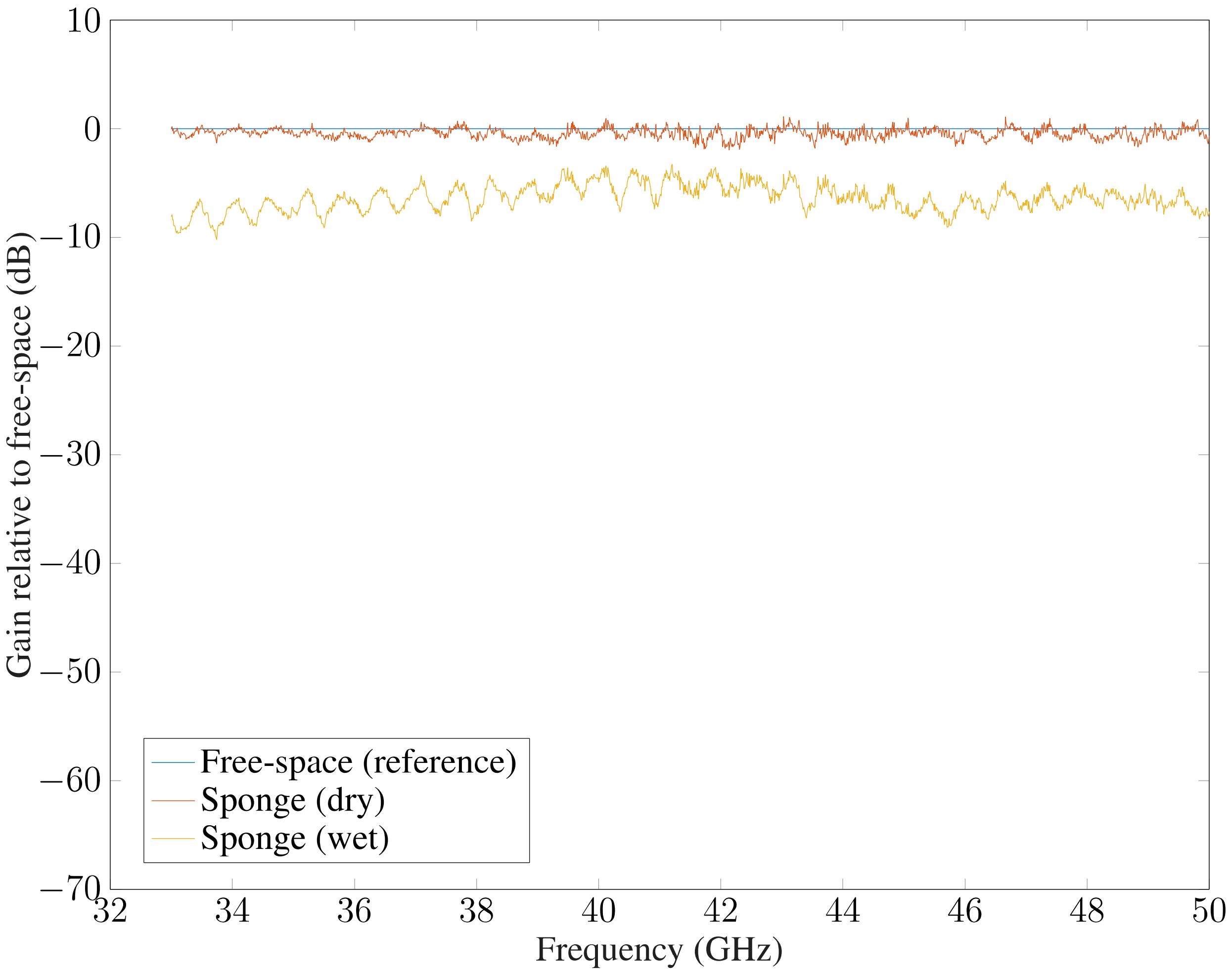


Drywall is practically invisible at mmWave bands

Water content is important!

Impact of Water Content

- Comparison between a dry and "wet" sponge



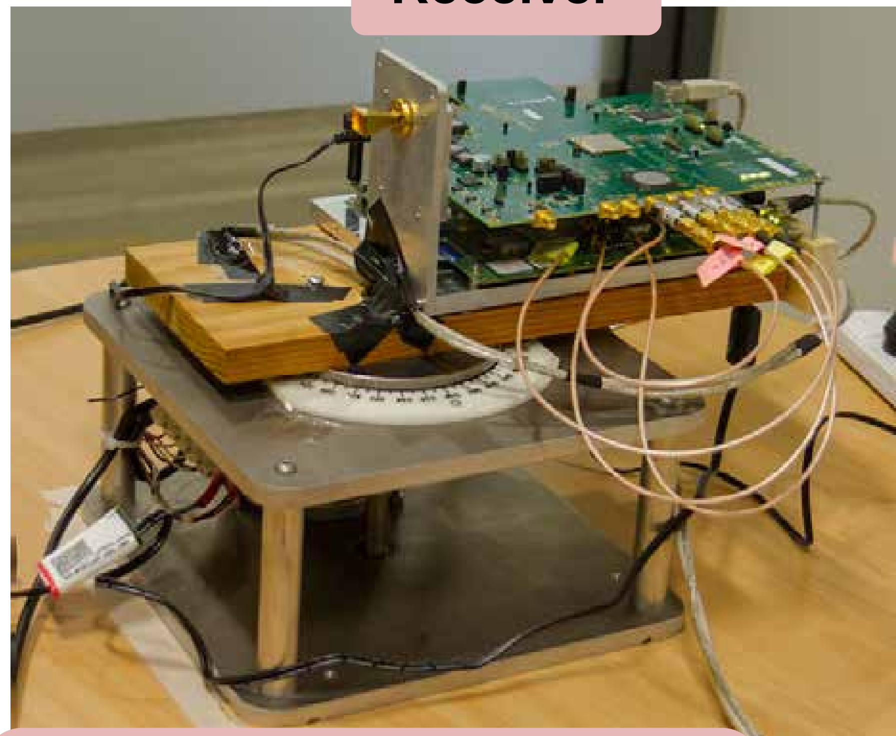
Approx. 10 dB additional attenuation due to water

60 GHz Indoor Channel Measurements

Transmitter

Directional horn antennas: azimuth/elevation and location varied

Receiver



Frequency sweep over 1 GHz bandwidth for 0º – 360º

- Frequency average to account for multipath

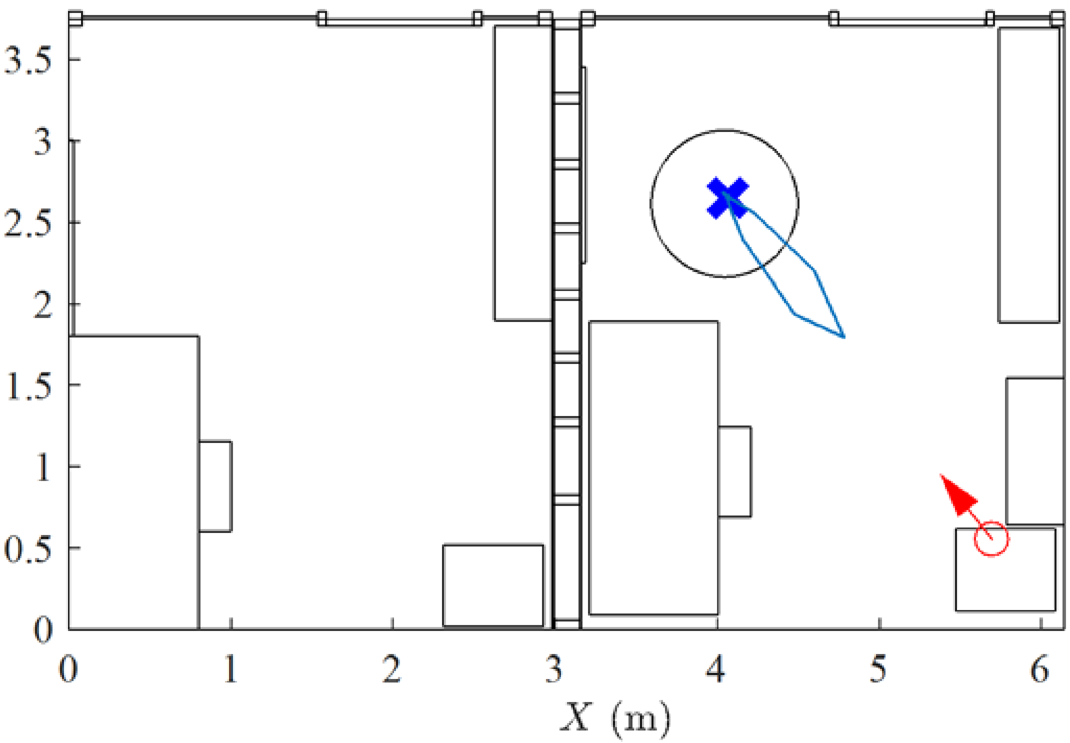
Environment Investigated

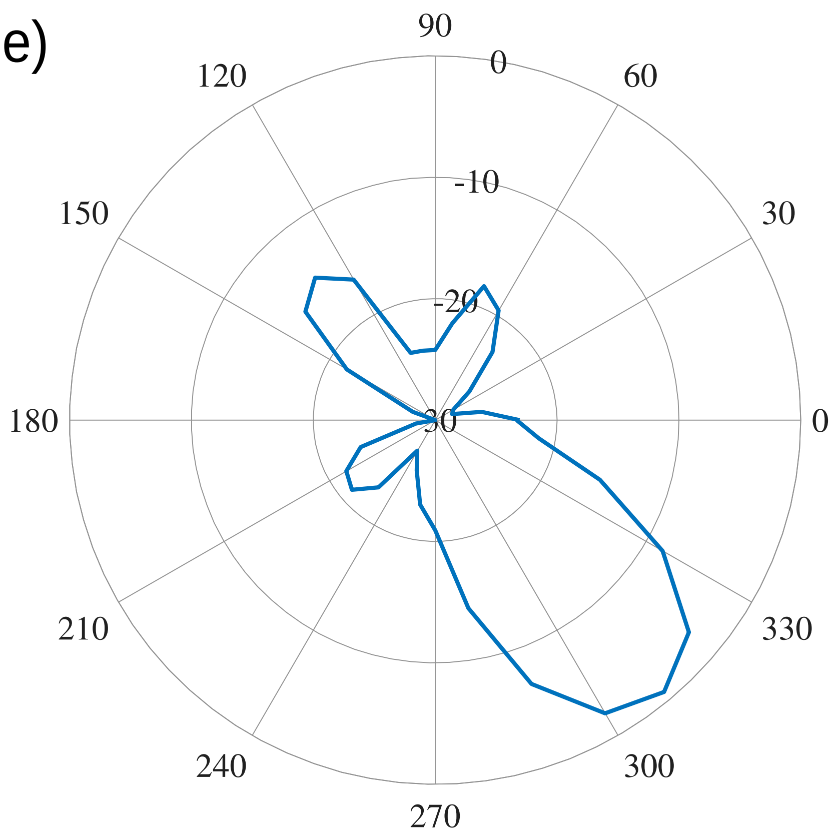
- Indoor interior office: no exterior windows!
  - Internal partitions: drywall/gib-board on timber frame

- Full of “academic clutter”: probably more books than a typical office

In-Office Deployments

Reference case (all results scaled to this one)



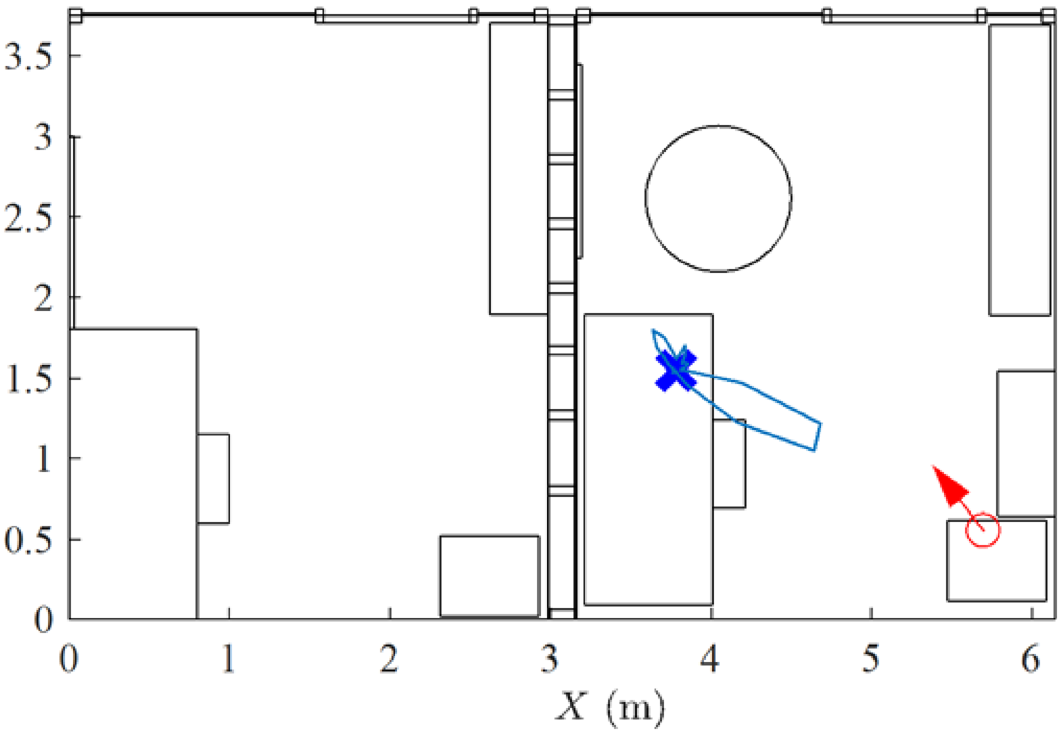


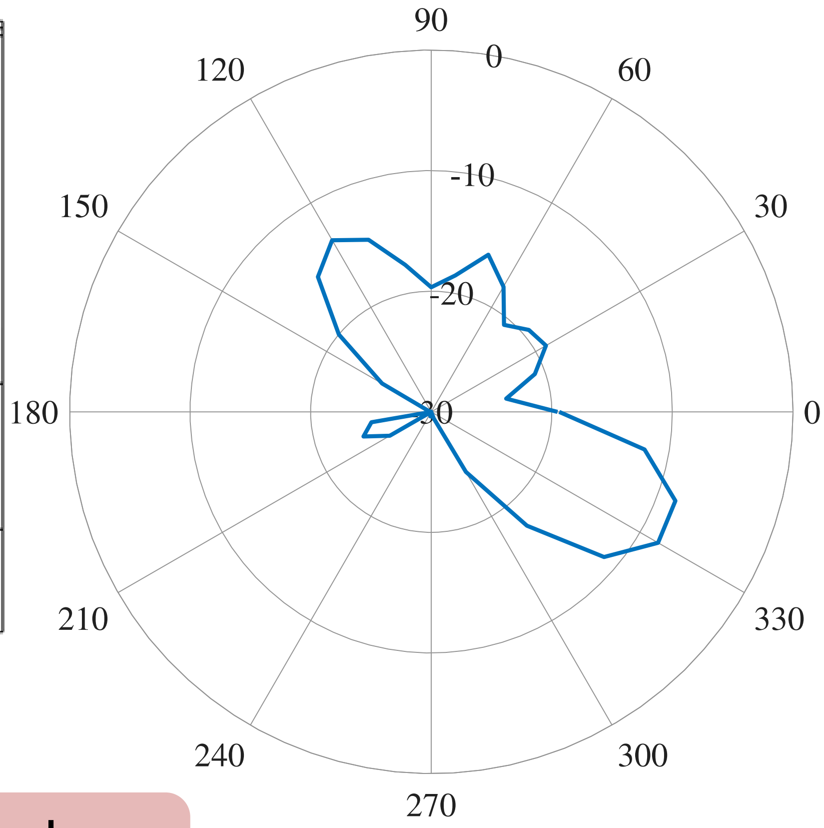
- Max. power when Tx and Rx antennas aligned (as expected)

- Reflected paths >15 dB down from main beam

In-Office Deployment

Reduction in power when moving off boresight (15° 3-dB beamwidth)

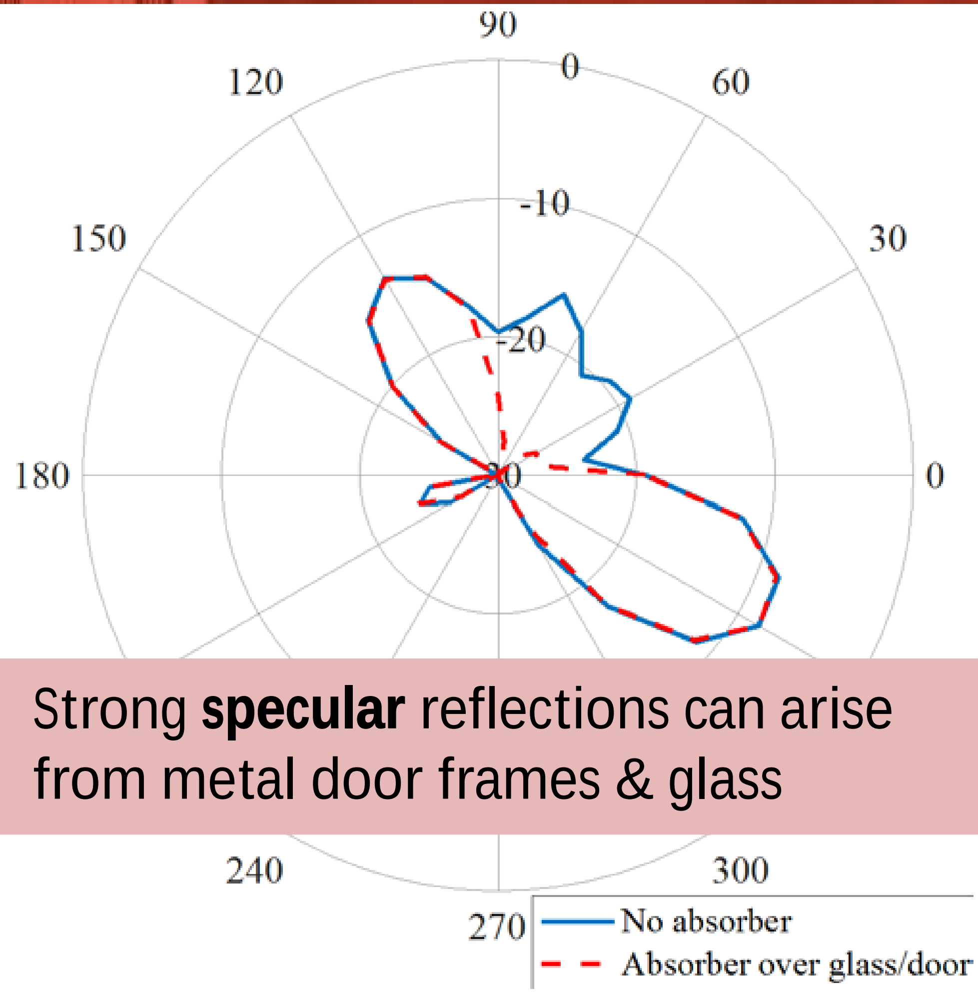




- Similar to previous RX location: reflected paths >15 dB down from main beam

Reflection Paths Within an Office

Block possible reflection points with absorbers

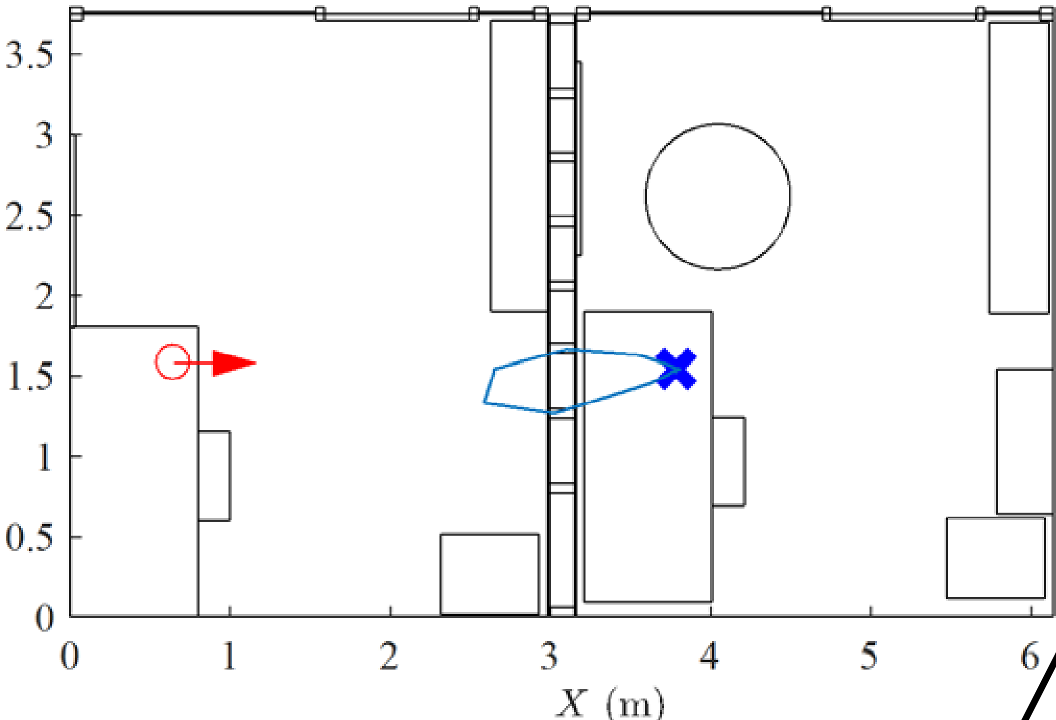


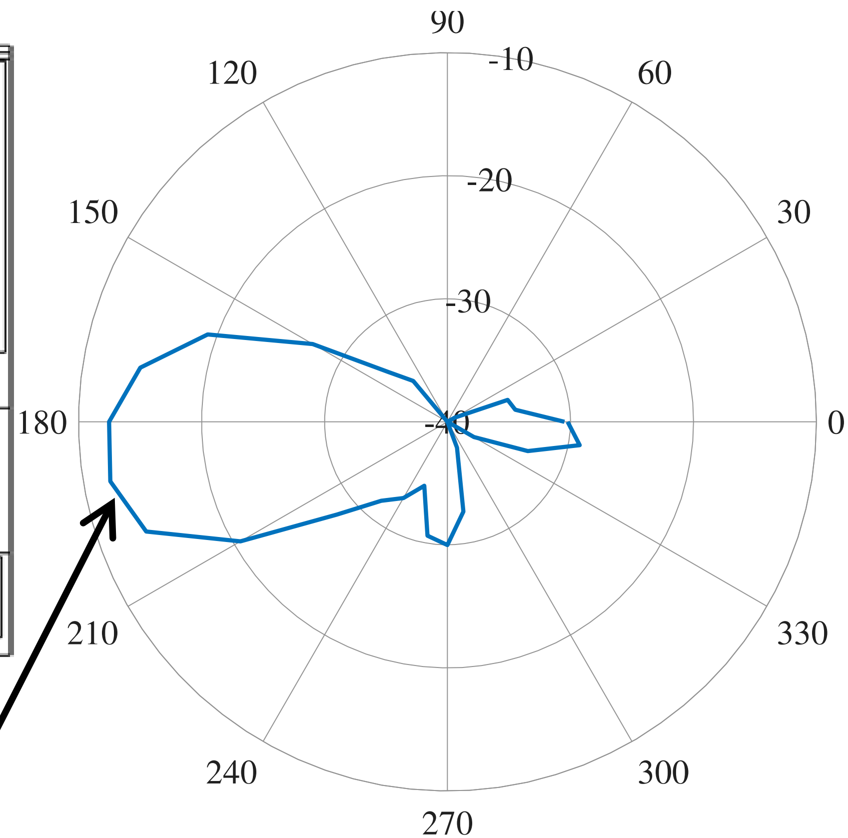
Strong **specular** reflections can arise from metal door frames & glass

Specular reflections are sensitive to position of RX/TX: easily “disappear”

Interference from Adjacent Offices

- TX placed in adjacent office: LOS path between wooden studs



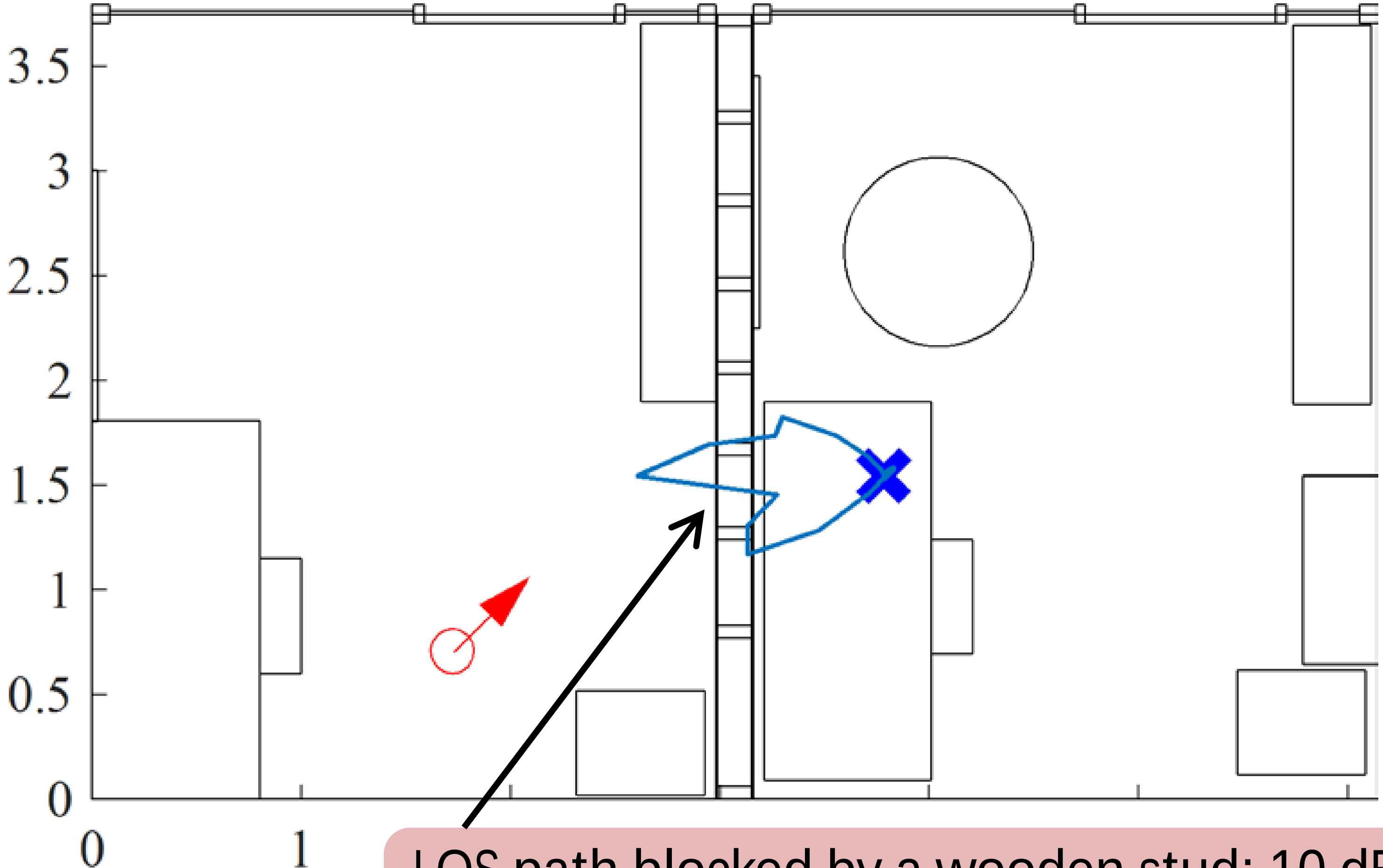


Approx. 12 dB attenuation through the wall

Potential for v. significant levels of inter-office interference!

Interference from Adjacent Offices

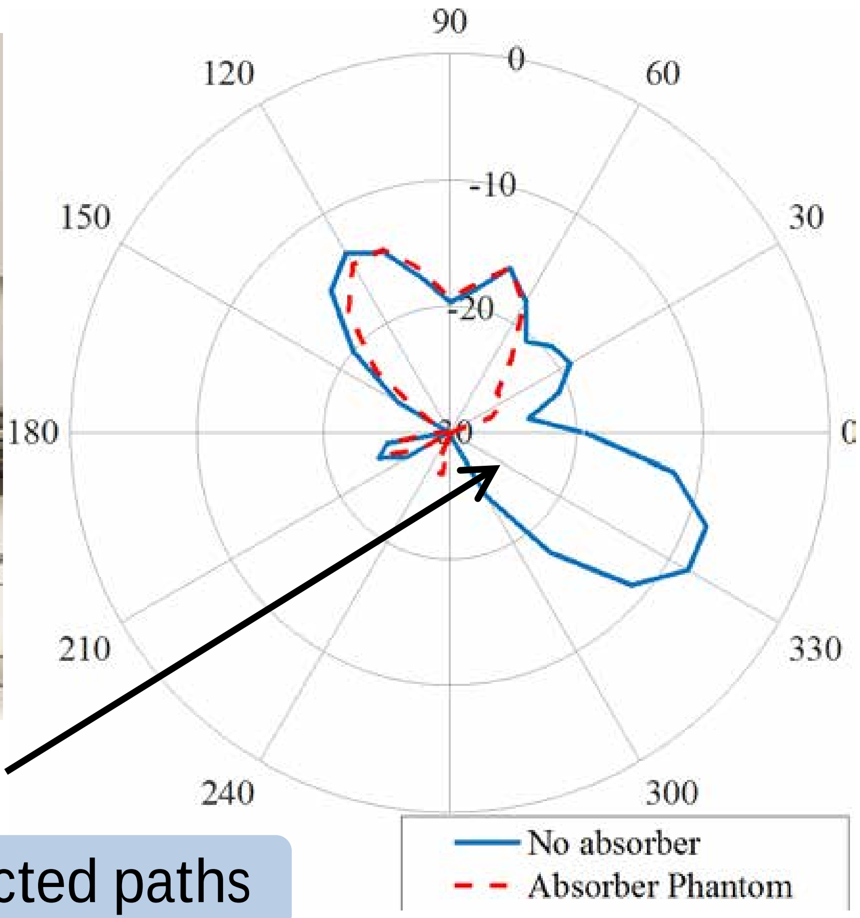
- Position of wooden studs matters: can shadow the through-wall signal



LOS path blocked by a wooden stud: 10 dB power reduction compared to LOS between studs

Blocking the LOS Path

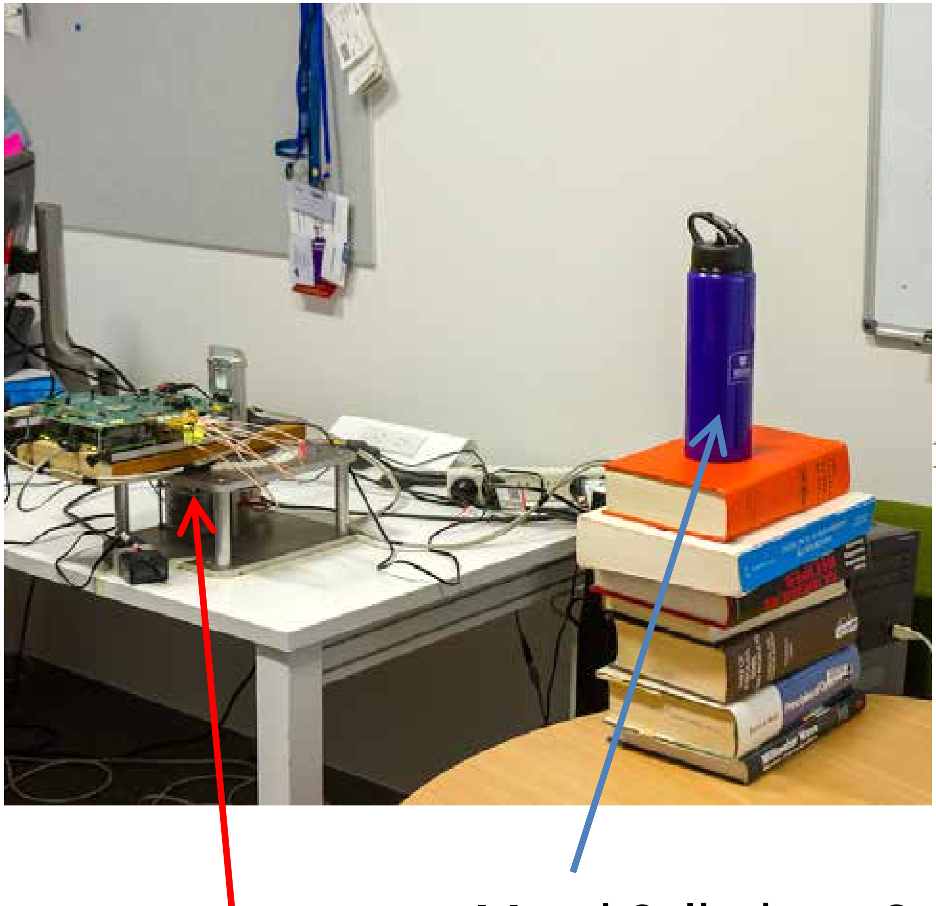
- 60 GHz signals are readily shadowed by the human body



Main beam attenuated by 20 dB

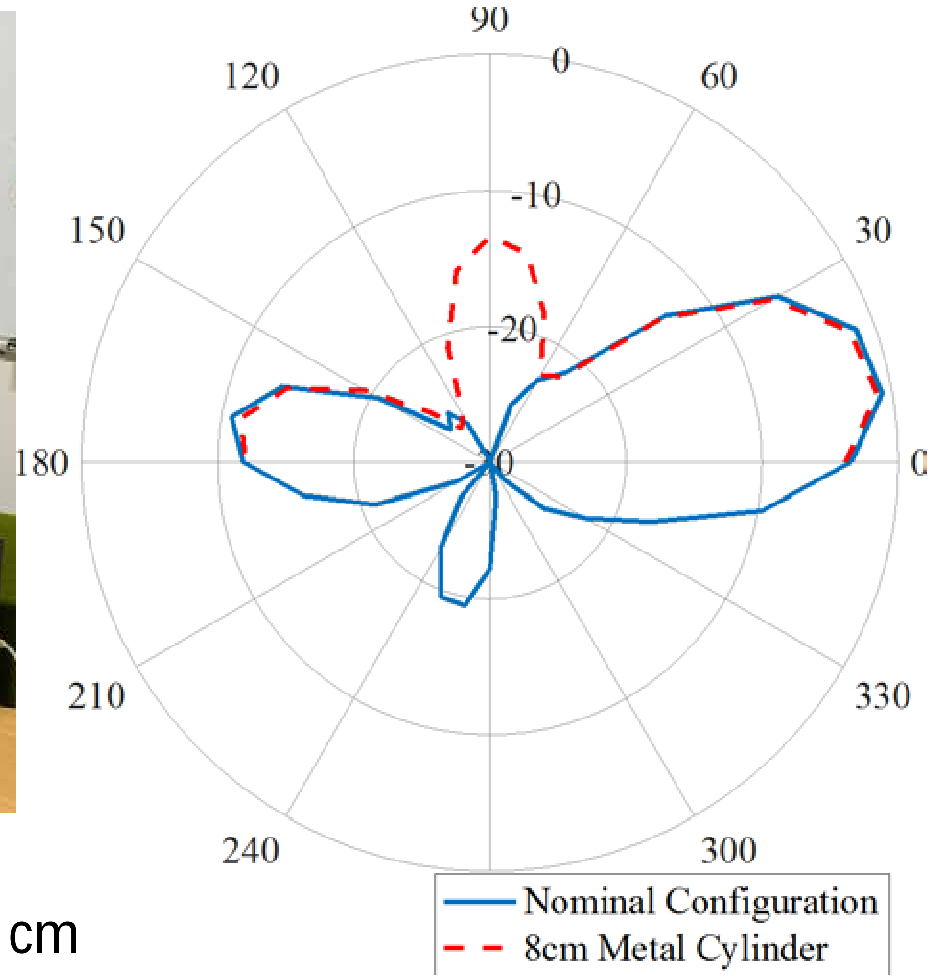
Desired signal is reaching user via reflected paths

Through-wall interference signal **3 dB stronger** than the reflections!



Receiver

Metal Cylinder: ⌀8 cm



Strong scattering is possible from curved surfaces

Conclusions

- Strong specular reflections (single, double and triple bounce) can exist at 60 GHz: **but sensitive to location**

- "Soft" internal partitions (gib on timber frame): 12 dB attenuation
  - **Comparable power levels to in-office specular reflections**

- LOS path readily shadowed by the human body
  - Interference from adjacent offices can **dominate**
  - **Difficult to improve desired signal levels via beam-steering**

- **Potentially**: introduce "*engineered scatter*" and combine with beam-steering to eliminate shadow regions

ENGINEERING