

Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Summary of NICTA channel measurement results]

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Abstract: [This document summarizes the NICTA wireless on-body channel measurement results at 820 and 2360 MHz presented in document 15-08-0421-00-0006.]

Purpose: [To promote discussion of channel dynamics within 802.15.6.]

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Summary of NICTA channel measurement results

(NICTA & The Australian National University)

Dino Miniutti, Leif Hanlen, David Smith, Andrew Zhang

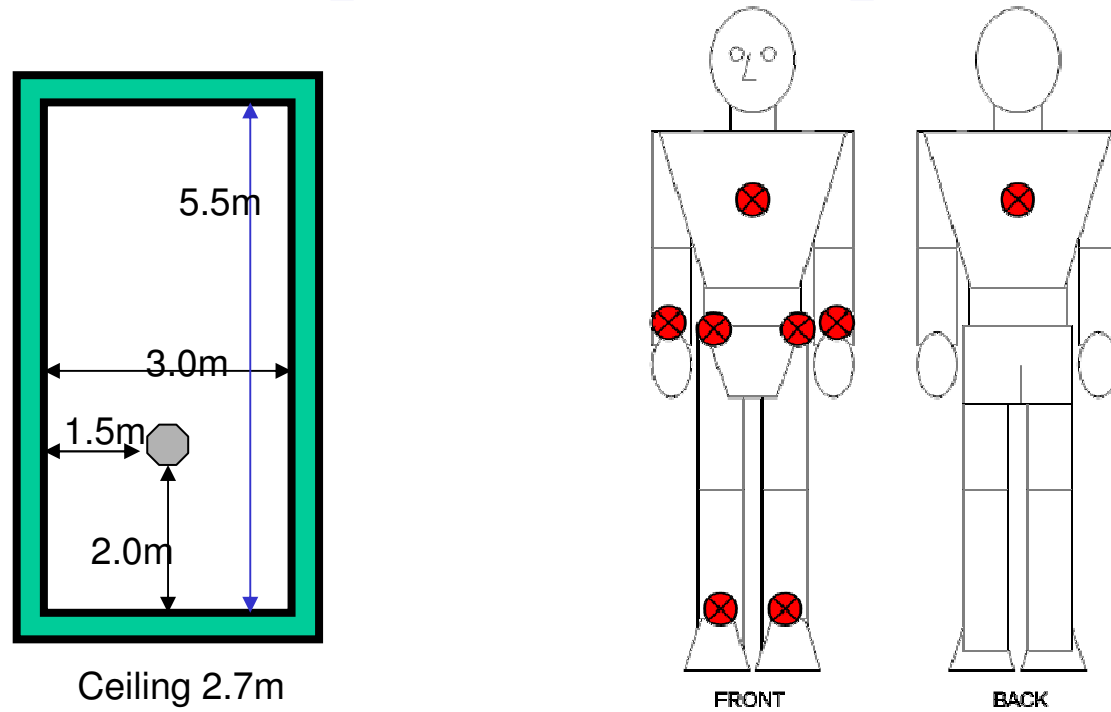
(NICTA)

Daniel Lewis, David Rodda, Ben Gilbert

Outline

- May 08 – Preliminary measurement results [15-08-0354-01-006]
- July 08 – Measurement report [15-08-0421-00-0006]
 - Extended duration of trials
 - Two frequencies
 - No more single-tap assumptions
 - All measurement results presented
- This presentation
 - Summary only
 - On-body wireless channels around 900 and 2400 MHz ISM bands
 - Channel dynamics; movement of test subject is important

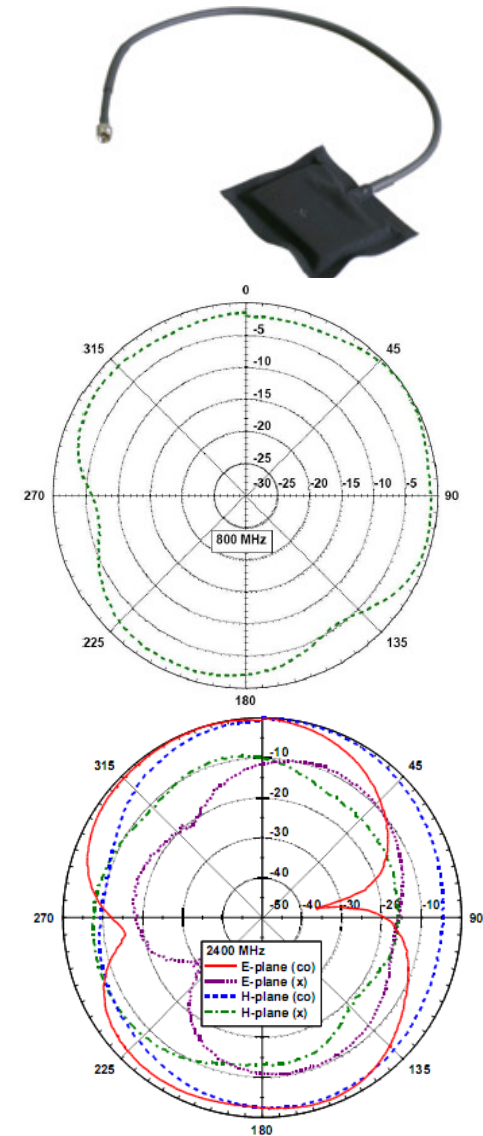
Experiment setup



Receiver location	Transmitter location					
	Chest	Right wrist	Left wrist	Right ankle	Left ankle	Back
Right hip	×	×	×	×	×	×
Chest		×		×		×

Equipment

- National Instruments NI PXIe-1065 (chassis)
 - 30 dB amplifier
- Mini-Circuits LNAs
 - 800 MHz: ZEL-0812LN
 - 2.36 GHz: ZQL-2700MLNW
- Octane Wireless wearable flexible antennas
 - BW-800-900, BW-2400-2500
 - Near Omni directional, vertical polarisation

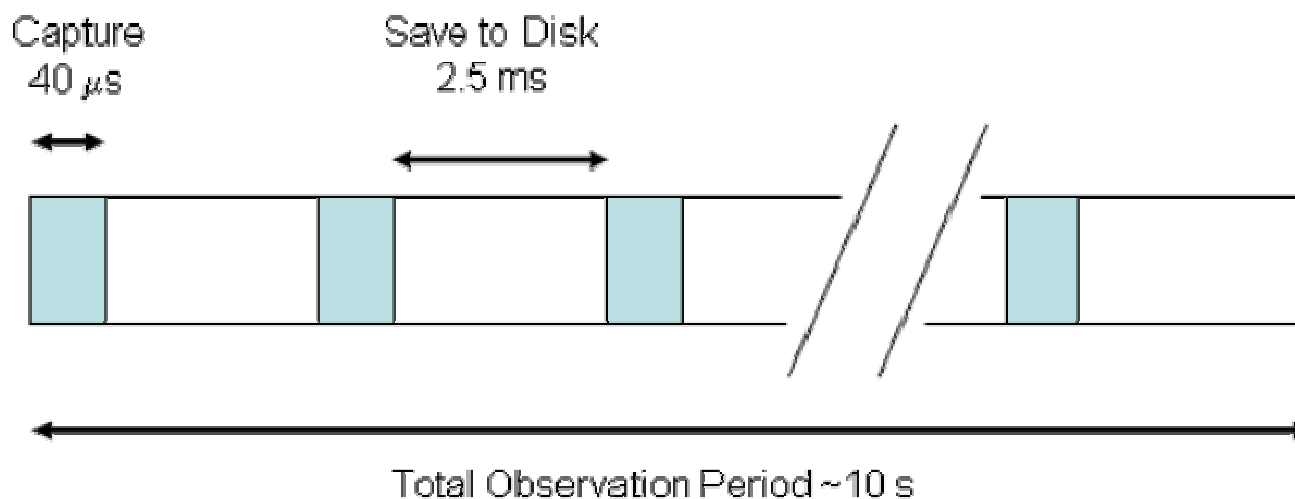


Some details

- On-body channel only (S4 & S5, CM3 in CMD)
- Measurements done at 820 MHz and 2360 MHz
 - Close to 900 and 2400 MHz ISM bands
 - Least experimentally measured interference
- Movements: Standing, walking, running
- -10 dBm transmit power
- 63-symbol BPSK PN sequence at 12.5 Mbps
- Time domain sampling

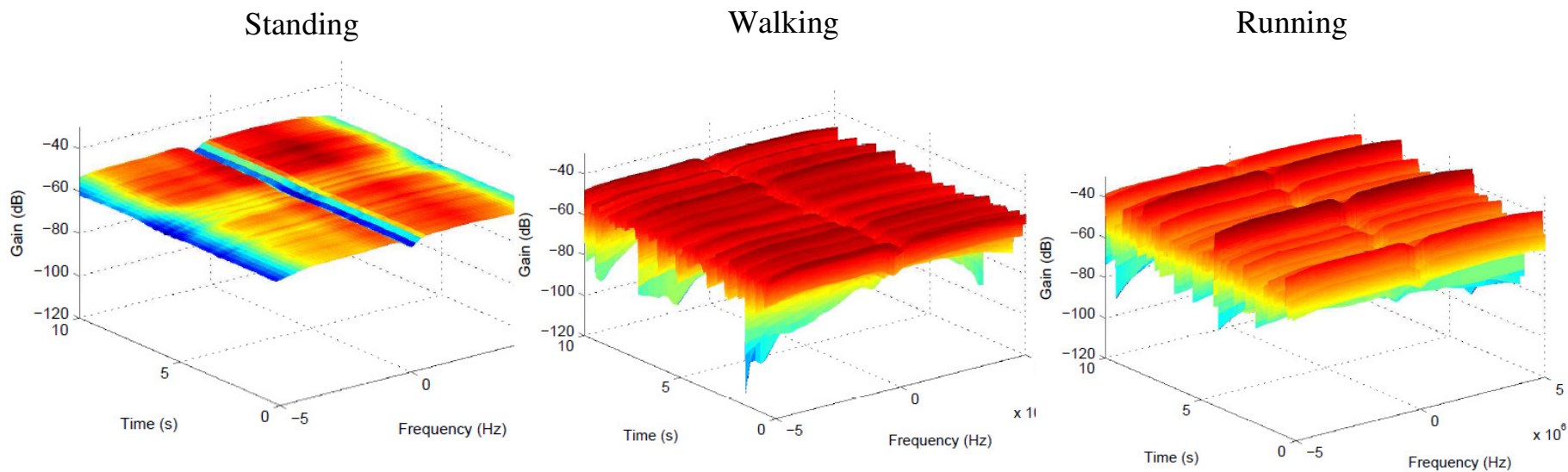
Data capture

- Hardware doesn't allow continuous capture of 10 seconds of data
- Capture snapshots (40 microseconds at a time)
 - Assume channel is static during this time



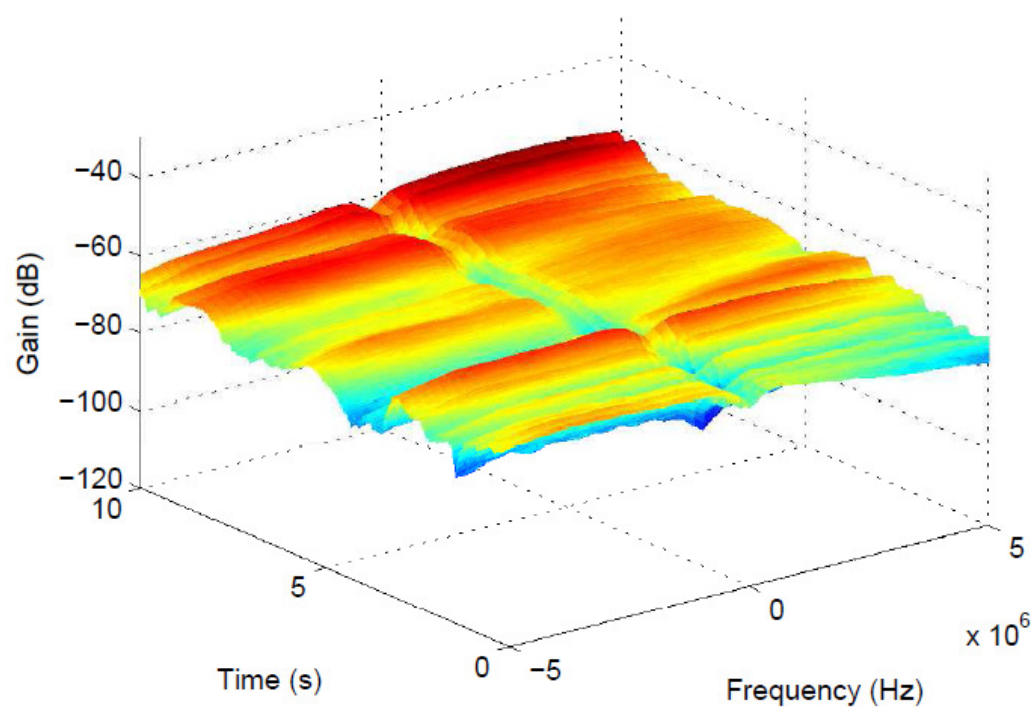
Power spectral density over time

- Chest → Right hip @ 820 MHz
- Movement induced flat fading



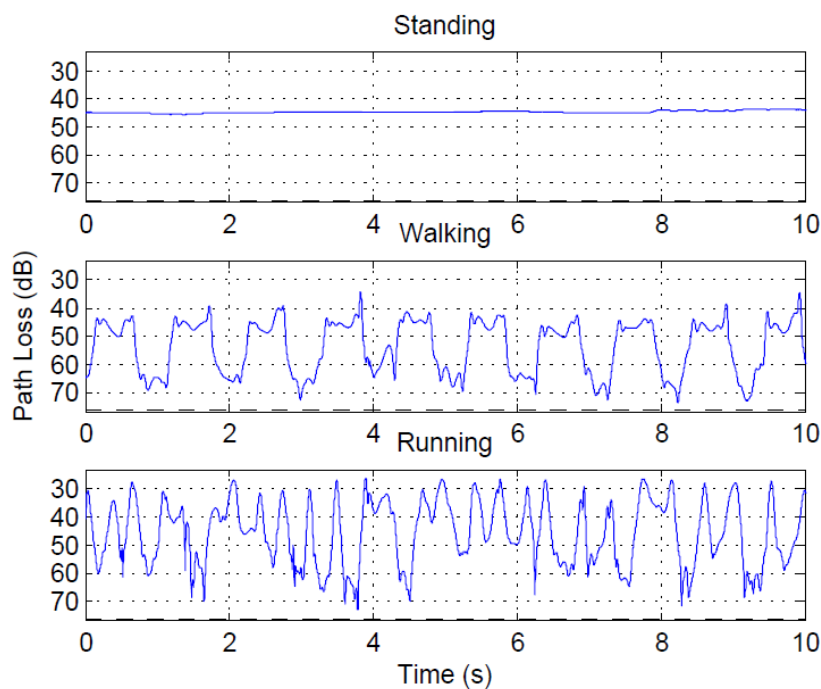
Fading types

- Right ankle → Chest @ 2.36 GHz (standing still)
- Most obvious example of frequency selective fading
- But... Flat fading > freq. selective fading



Path loss over time

- Right wrist → Right hip @ 2.36 GHz
- Variation consistent with movement



Average path loss

(a) 820 MHz

Action	Receiver at Right Hip; Transmitter at:						Receiver at chest; Transmitter at:		
	Chest	Right Wrist	Left Wrist	Right Ankle	Left Ankle	Back	Back	Right Wrist	Right Ankle
Standing	57.4	50.2	59.8	54.3	68.7	61.8	66.3	54.5	54.3
Walking	52.9	38.4	63.6	48.1	55.5	57.1	63.8	51.3	56.9
Running	44.1	37.2	60.2	48.9	54.2	62.3	66.3	49.4	54.1

Path loss variation

(b) 2.36 GHz

Action	Receiver at Right Hip; Transmitter at:						Receiver at chest; Transmitter at:		
	Chest	Right Wrist	Left Wrist	Right Ankle	Left Ankle	Back	Back	Right Wrist	Right Ankle
Standing	65.3	44.5	74.7	60.9	70.7	75.3	73.0	70.5	66.3
Walking	59.1	47.3	59.8	53.9	58.5	67.4	72.0	64.9	62.4
Running	55.9	36.3	52.5	55.0	59.0	68.5	71.7	57.4	63.3

(a) 820 MHz

Action	Receiver at Right Hip; Transmitter at:						Receiver at chest; Transmitter at:		
	Chest	Right Wrist	Left Wrist	Right Ankle	Left Ankle	Back	Back	Right Wrist	Right Ankle
Standing	1.6	0.7	2.2	5.1	1.8	5.1	3.0	2.2	0.7
Walking	30.0	35.1	24.4	24.4	26.5	13.5	23.7	34.0	17.2
Running	38.0	45.6	28.0	32.8	27.9	23.8	30.9	27.8	32.5

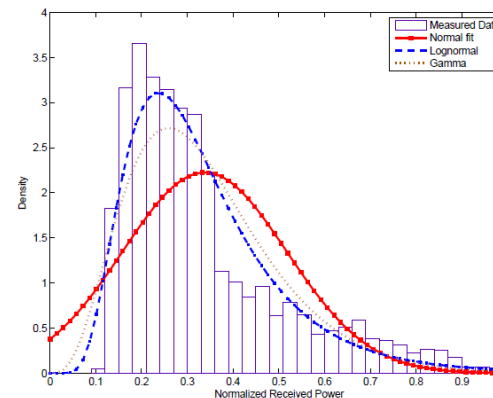
(b) 2.36 GHz

Action	Receiver at Right Hip; Transmitter at:						Receiver at chest; Transmitter at:		
	Chest	Right Wrist	Left Wrist	Right Ankle	Left Ankle	Back	Back	Right Wrist	Right Ankle
Standing	3.3	2.0	1.8	2.4	7.1	1.4	4.2	1.3	11.3
Walking	20.0	39.6	24.5	22.5	21.1	14.1	8.6	21.2	20.4
Running	30.3	46.8	33.7	28.4	24.1	16.3	9.3	29.4	19.5

Statistical analysis of received power

- Find best fit for received signal power
 - Normal, Lognormal, Gamma
 - Tried other distributions

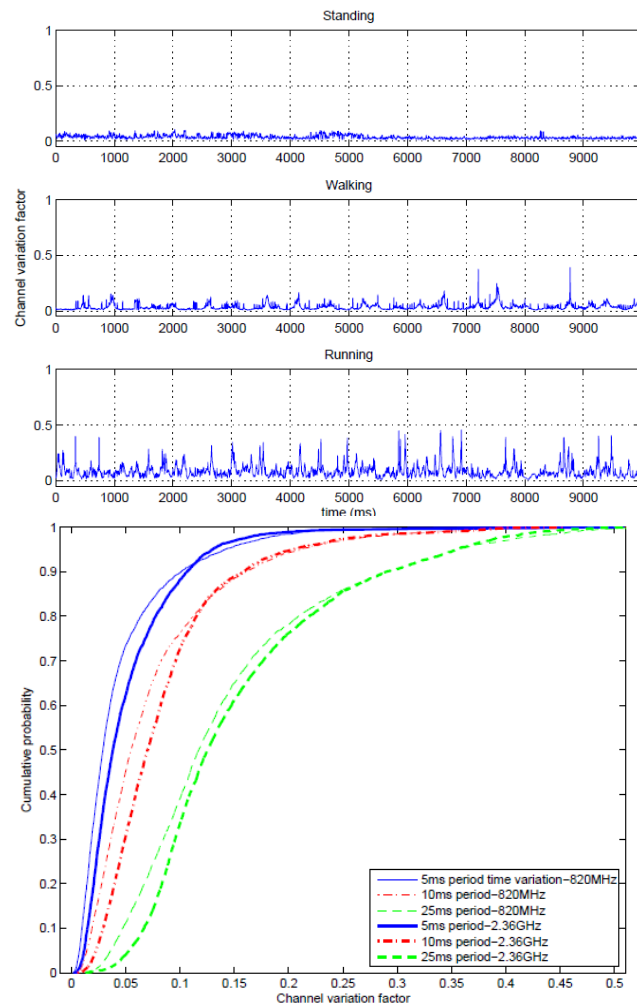
- Motion → Lognormal or Gamma
- No motion → Normal
 - Not a good fit



Tx Antenna	Rx Antenna	Action	Distribution	
			820 MHz	2.36 GHz
Chest	Right Hip	Standing	Normal	Normal
Chest	Right Hip	Walking	Normal	Normal
Chest	Right Hip	Running	Gamma	Lognormal
Right Wrist	Right Hip	Standing	Normal	Normal
Right Wrist	Right Hip	Walking	Lognormal	Gamma
Right Wrist	Right Hip	Running	Lognormal	Lognormal
Left Wrist	Right Hip	Standing	Normal	Normal
Left Wrist	Right Hip	Walking	Lognormal	Lognormal
Left Wrist	Right Hip	Running	Lognormal	Gamma
Right Ankle	Right Hip	Standing	Lognormal	Normal
Right Ankle	Right Hip	Walking	Gamma	Gamma
Right Ankle	Right Hip	Running	Gamma	Gamma
Left Ankle	Right Hip	Standing	Lognormal	Normal
Left Ankle	Right Hip	Walking	Gamma	Gamma
Left Ankle	Right Hip	Running	Gamma	Gamma
Back	Right Hip	Standing	Normal	Normal
Back	Right Hip	Walking	Lognormal	Lognormal
Back	Right Hip	Running	Lognormal	Lognormal
Back	Chest	Standing	Normal	Normal
Back	Chest	Walking	Lognormal	Lognormal
Back	Chest	Running	Gamma	Lognormal
Right Wrist	Chest	Standing	Normal	Normal
Right Wrist	Chest	Walking	Lognormal	Lognormal
Right Wrist	Chest	Running	Lognormal	Gamma
Right Ankle	Chest	Standing	Lognormal	Lognormal
Right Ankle	Chest	Walking	Lognormal	Lognormal
Right ankle	Chest	Running	Lognormal	Lognormal

Channel coherence

- Own coherence measurement factor
 - Variance of channel impulse response over time
 - Indicates periods of time where channel is stable (low = stable)
- Channel stability consistent with movement
- Channel more stable at 820 MHz than at 2.36 GHz (longer wavelength)



Summary

- Human movement → more variation in the channel (as expected)
- Human movement is the dominant fading effect (flat fading)
- Lognormal and Gamma distributions best match received power distribution for moving subject
- Channel more stable at 820 MHz than at 2.36 GHz