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

Submission Title: [Power delay profiles for dynamic narrowband body area network channels]
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Abstract: [Power delay profile analysis for dynamic BAN channel measurements around 2400MHz, 900MHz and 400MHz]

Purpose: [To promote discussion of the dynamic channel model in 802.15.6.]

Power delay profiles for dynamic narrowband body area network channels

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NICTA
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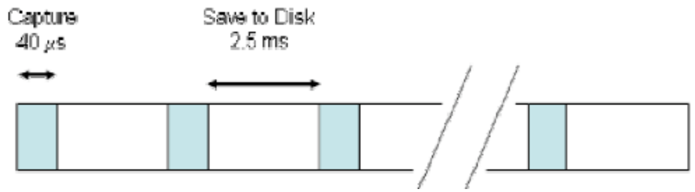
Introduction

- PDPs based on analysis of measurements of motion at 427 MHz and 820 MHz and 2360 MHz
- Aim: evaluate severity of multipath (ISI)
  - Absolute magnitude
  - Relative (to first arrival) magnitude

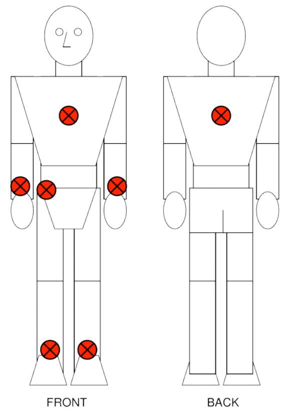
Experiment setup

- -10dBm Tx power,
- 63-symbol BPSK PN sequence at 12.5Mbps
- Modulated separately at 2360, 820 and 427MHz using National Instruments VSA
- Data capture:
  - Snapshot (40micro-sec)



- Antenna: (considered part of channel)
  - 2360MHz & 820MHz: Pharad wearable antenna for
  - 427MHz: Miracle Baby 1" stub
    - Miracle Baby substantially different to Pharad *(results are not comparable to 2360, 820)*

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



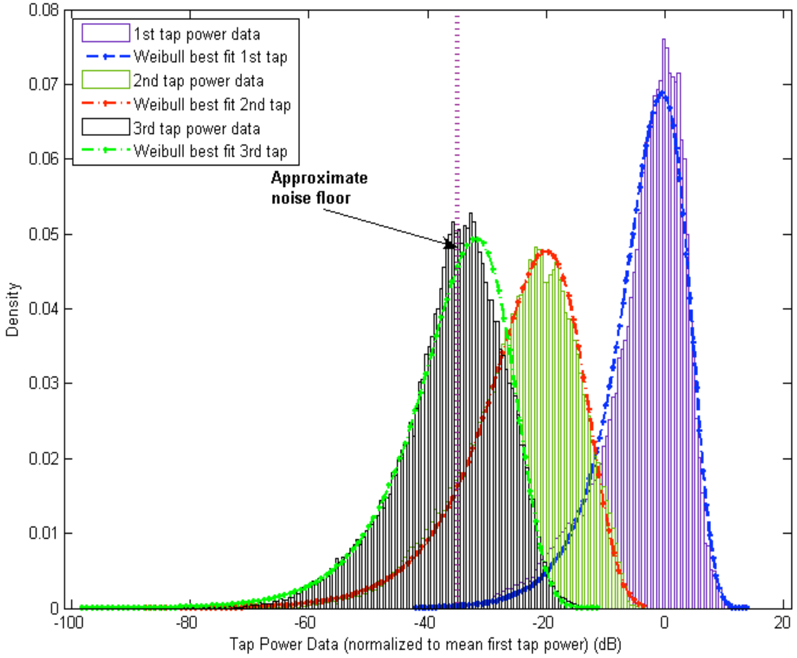
Estimation of power delay profiles

- transmitted waveform G
- Measured X

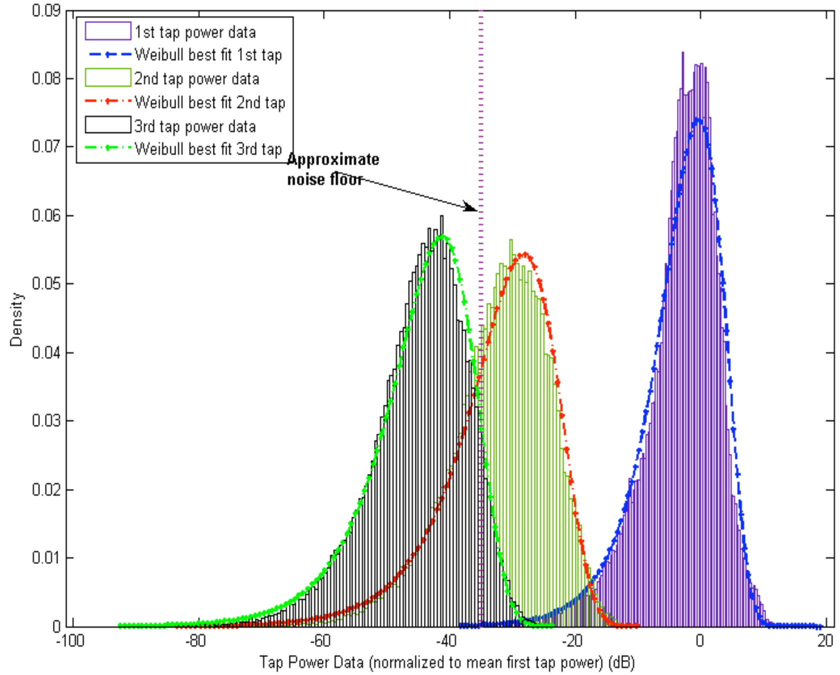
$$\text{taps ML estimates} = (\mathbf{G}^{\dagger}\mathbf{G})^{-1}\mathbf{G}^{\dagger}\mathbf{X}$$

Tap Power (absolute)

- To illustrate general magnitudes will first provide without ratios i.e. with subject moving (walking and running) all 9 Tx-Rx pair locations at 2360 MHz and 820 MHz – empirical pdf – normalization to mean first tap power over each scenario
- Note noise floor is approximately -35 dB (due to quantization noise of VSA)



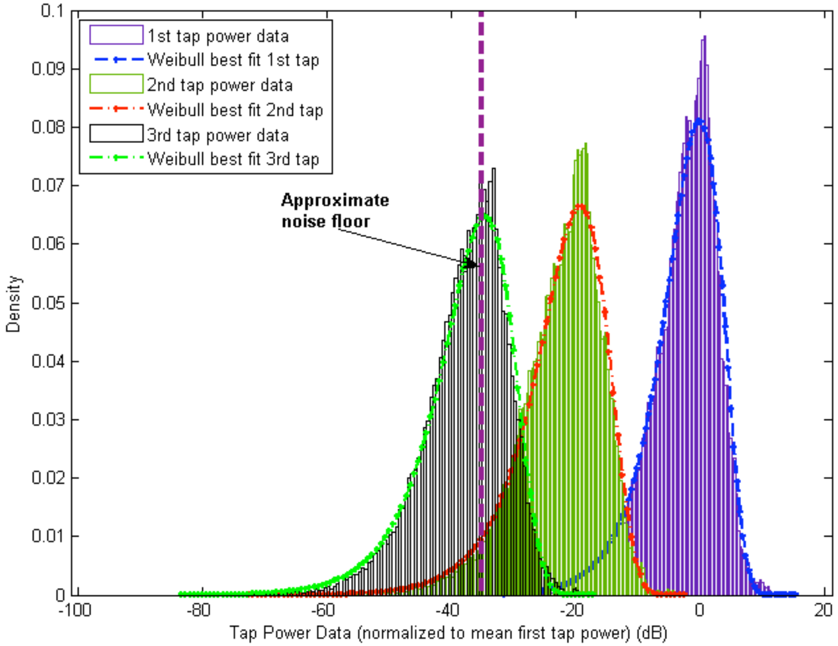
2360 MHz



820 MHz

Tap Power (absolute)

- 427 MHz non-ratios + table of fits – all for subject moving

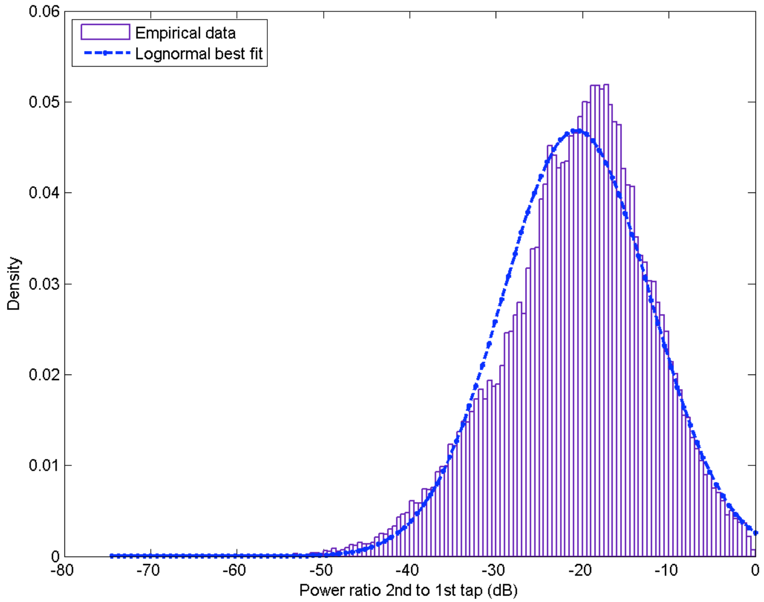


427 MHz

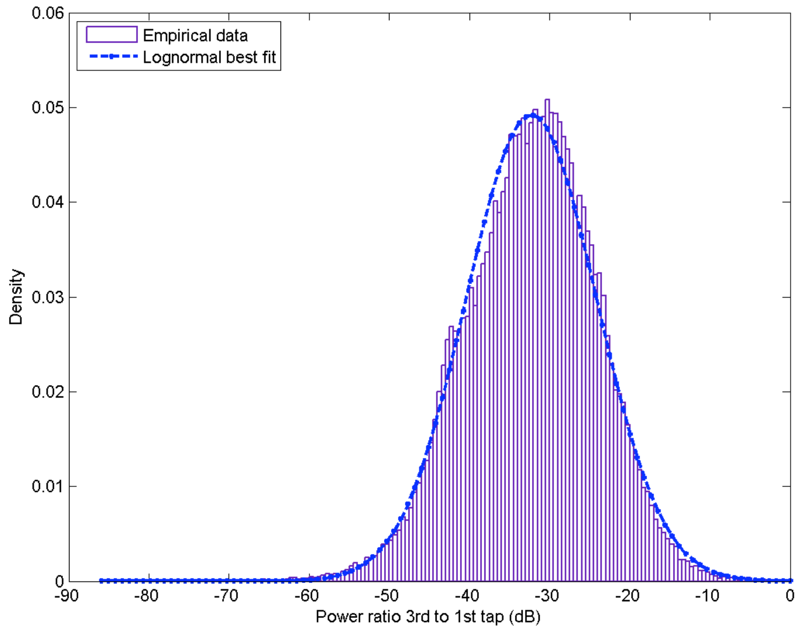
Frequency	Action	Tap number	Distribution of power in tap
427 MHz	Moving	1st tap	Weibull ($a = 0.979, b = 0.957$
427 MHz	Moving	2nd tap	Weibull ($a = 0.0118, b = 0.785$
427 MHz	Moving	3rd tap	Weibull ($a = 0.000348, b = 0.765$
820 MHz	Moving	1st tap	Weibull ($a = 0.928, b = 0.874$
820 MHz	Moving	2nd tap	Weibull ($a = 0.00151, b = 0.64$
820 MHz	Moving	3rd tap	Weibull ($a = 7.58e-005, b = 0.671$
2360 MHz	Moving	1st tap	Weibull ($a = 0.895, b = 0.811$
2360 MHz	Moving	2nd tap	Weibull ($a = 0.0101, b = 0.563$
2360 MHz	Moving	3rd tap	Weibull ($a = 0.000664, b = 0.583$

PDFs of power ratios (subject moving) 2360MHz

- Empirical pdfs of power ratios –all scenarios with movement/motion (walking and standing with best fit – guidelines – need conditional pdfs best indicator) (example a few slides time)
- [Note significant second tap at 2360 MHz]



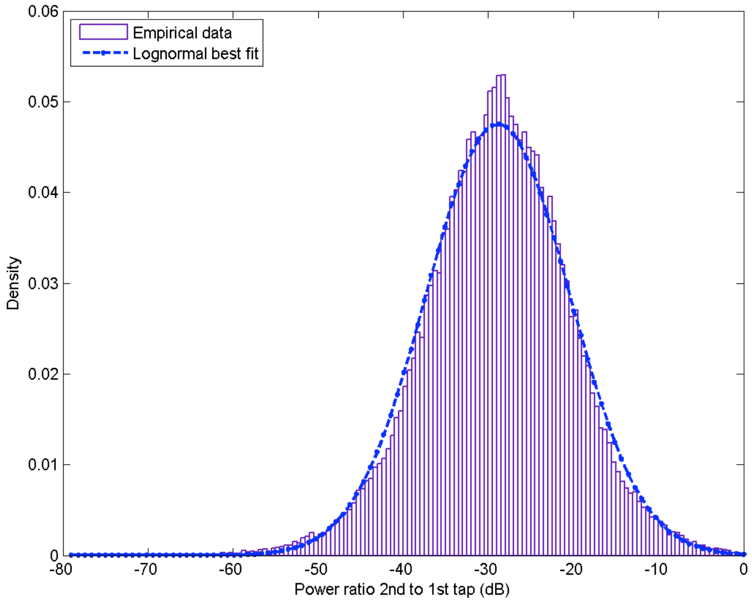
2360 MHz – 2nd to 1st tap



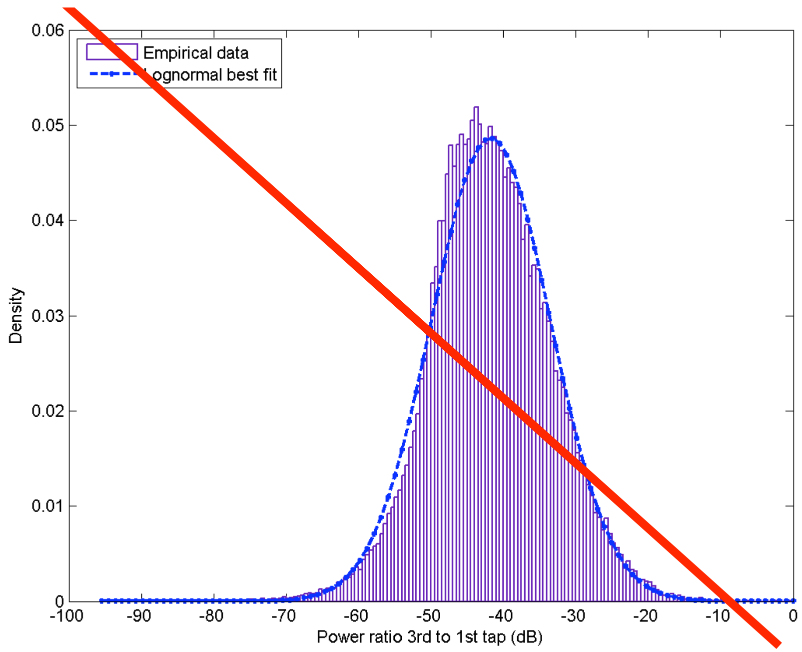
2360 MHz 3rd to 1st tap –

PDFs of power ratios (subject moving) 820MHz

3rd tap is below confidence region of measurements
Our processing gain allowed detection, but tap likely to be below a real receiver's sensitivity



820 MHz – 2nd to 1st

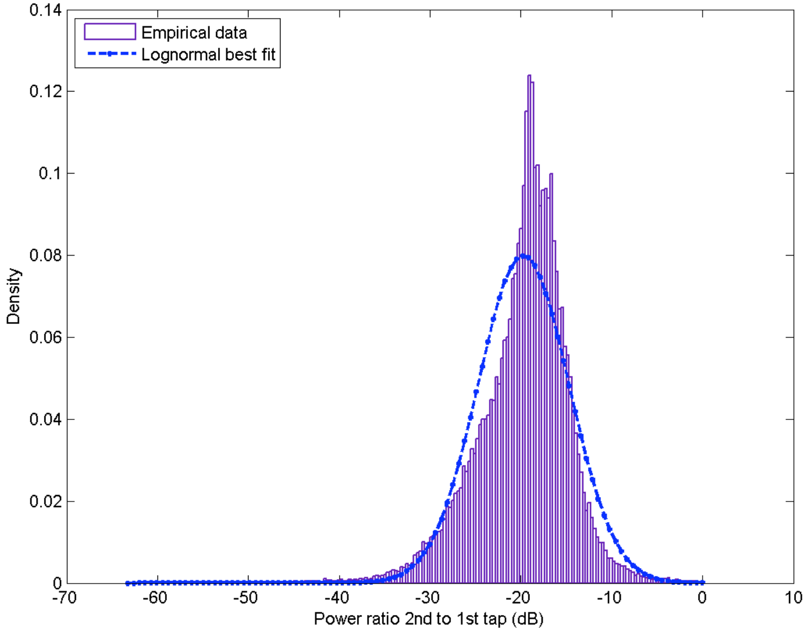


820 MHz 3rd to 1st tap –

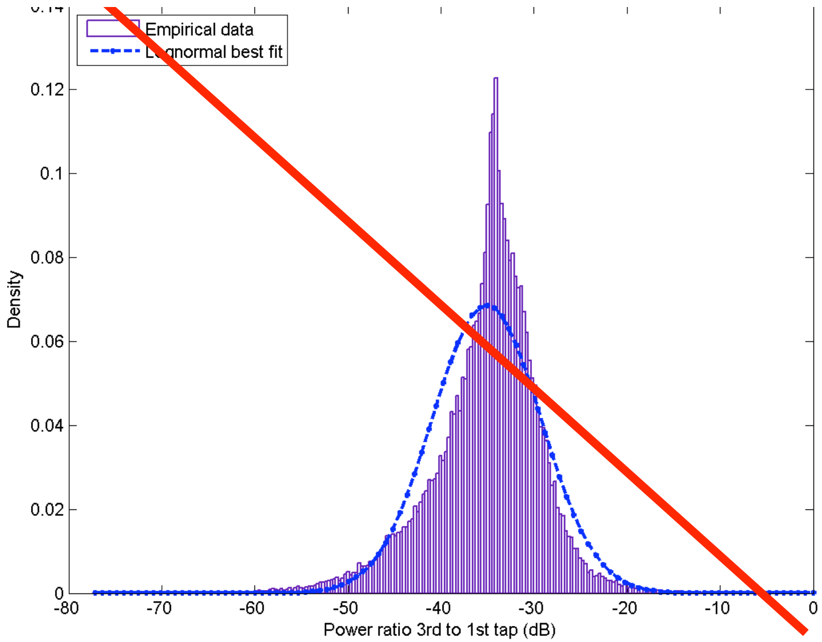
PDFs of power ratios 427MHz

3rd tap is below confidence region of measurements

Our processing gain allowed detection, but tap likely to be below a real receiver's sensitivity



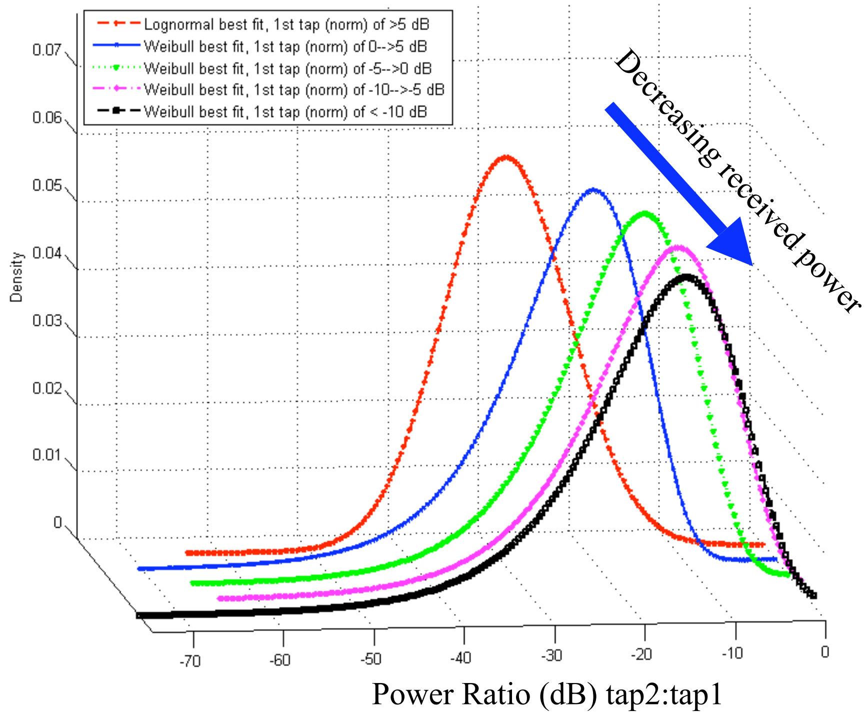
427 MHz – 2nd to 1st



427 MHz – 3rd to 1st

PDF of power ratios (conditional)

- Conditional PDF example, based on best fits, less first tap power → more relatively significant second taps (and also third tap), for 2360 MHz subject moving- i.e. reflections become stronger relative to first received ray



Summary

- Means over agglomerate moving data at 427, 820 and 2360 MHz, 2nd to 1st tap power ratio and 3rd to 1st tap power ratio

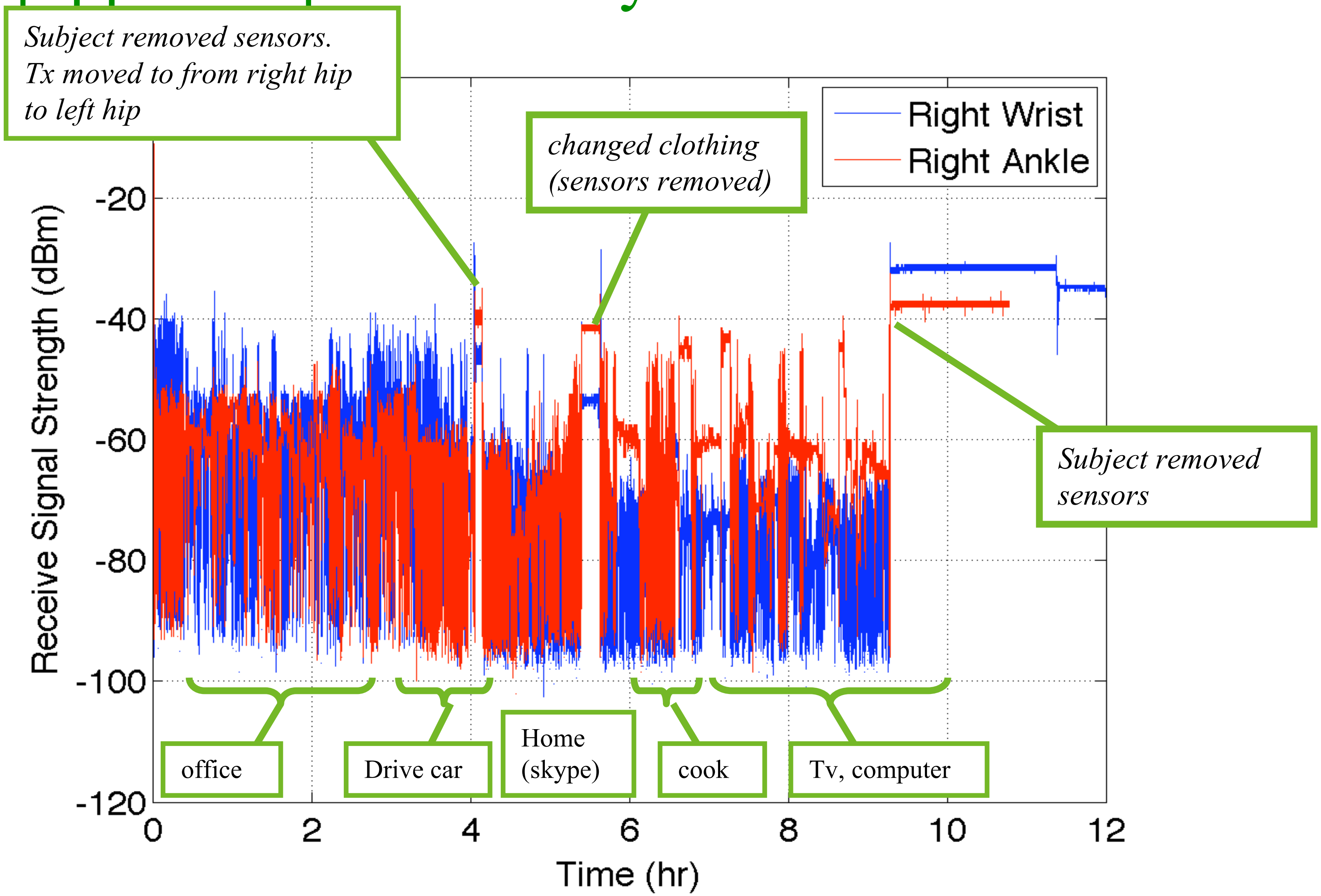
Frequency	Action	2nd to 1st tap mean power ratio	3rd to 1st tap mean power ratio
427 MHz	Moving	-17.1 dB	-31.4 dB
820 MHz	Moving	-20.9 dB	-33.3 dB
2360 MHz	Moving	-14.1 dB	-25.2 dB

Less than 0.1% main tap power

Summary

- PDP found for 427MHz, 820MHz, 2360MHz
- 2360MHz showed significant 2nd tap
  - *Different antenna for 427MHz -- not directly comparable*
- *Dynamics more significant than ISI*

[appendix] Channel dynamics over 10 hours



Appendix (more info), best fits conditional and overall

[*might be useful – shows comprehensiveness of analysis+measurements*]

Distributions of power ratios 2nd to 1st tap, 1st tap power norm. to mean of each scenario (0 dB), all Tx/Rx pair locations considered

Frequency	Action	1st tap power	Distribution of power ratio
427 MHz	Moving	> 5 dB	Nakagami-m ($m = 0.646, \omega = 0.000228$)
427 MHz	Moving	$0 \to 5$ dB	Weibull ($a = 0.0139, b = 1.35$)
427 MHz	Moving	$-5 \to 0$ dB	Weibull ($a = 0.016, b = 1.12$)
427 MHz	Moving	$-10 \to -5$ dB	Gamma ($a = 1.06, b = 0.0205$)
427 MHz	Moving	< -10 dB	Lognormal ($\mu = -3.88, \sigma = 1.52$)
427 MHz	Moving	All	Lognormal ($\mu = -4.54, \sigma = 1.15$)
820 MHz	Moving	> 5 dB	Weibull ($a = 0.000626, b = 0.71$)
820 MHz	Moving	$0 \to 5$ dB	Weibull ($a = 0.00128, b = 0.695$)
820 MHz	Moving	$-5 \to 0$ dB	Lognormal ($\mu = -6.71, \sigma = 1.64$)
820 MHz	Moving	$-10 \to -5$ dB	Weibull ($a = 0.00621, b = 0.606$)
820 MHz	Moving	< -10 dB	Lognormal ($\mu = -5.03, \sigma = 2.16$)
820 MHz	Moving	All	Lognormal ($\mu = -6.65, \sigma = 1.93$)
2360 MHz	Moving	> 5 dB	Lognormal ($\mu = -6.54, \sigma = 1.59$)
2360 MHz	Moving	$0 \to 5$ dB	Weibull ($a = 0.00987, b = 0.65$)
2360 MHz	Moving	$-5 \to 0$ dB	Weibull ($a = 0.026, b = 0.633$)
2360 MHz	Moving	$-10 \to -5$ dB	Weibull ($a = 0.0444, b = 0.599$)
2360 MHz	Moving	< -10 dB	Weibull ($a = 0.0392, b = 0.575$)
2360 MHz	Moving	All	Lognormal ($\mu = -4.77, \sigma = 1.98$)

Appendix cont. (more info), best fits conditional and overall

Distributions of power ratios 3rd to 1st tap, 1st tap power
norm. to mean of each scenario (0 dB), all Tx/Rx pair locations considered

Frequency	Action	1st tap power	Distribution of power ratio
427 MHz	Moving	$>$ 5 dB	Weibull ($a = 0.000385, b = 1.29$)
427 MHz	Moving	0 $\rightarrow$ 5 dB	Weibull ($a = 0.000386, b = 1.09$)
427 MHz	Moving	-5 $\rightarrow$ 0 dB	Weibull ($a = 0.000483, b = 0.972$)
427 MHz	Moving	-10 $\rightarrow$ -5 dB	Weibull ($a = 0.000775, b = 0.922$)
427 MHz	Moving	$<$ -10 dB	Lognormal ($\mu = -7.08, \sigma = 1.51$)
427 MHz	Moving	All	Lognormal ($\mu = -8.08, \sigma = 1.34$)
820 MHz	Moving	$>$ 5 dB	Lognormal ($\mu = -10.8, \sigma = 1.2$)
820 MHz	Moving	0 $\rightarrow$ 5 dB	Lognormal ($\mu = -10.5, \sigma = 1.52$)
820 MHz	Moving	-5 $\rightarrow$ 0 dB	Lognormal ($\mu = -9.71, \sigma = 1.59$)
820 MHz	Moving	-10 $\rightarrow$ -5 dB	Weibull ($a = 0.000353, b = 0.642$)
820 MHz	Moving	$<$ -10 dB	Lognormal ($\mu = -7.97, \sigma = 2.26$)
820 MHz	Moving	All	Lognormal ($\mu = -9.61, \sigma = 1.89$)
2360 MHz	Moving	$>$ 5 dB	Lognormal ($\mu = -8.99, \sigma = 1.39$)
2360 MHz	Moving	0 $\rightarrow$ 5 dB	Lognormal ($\mu = -8.15, \sigma = 1.62$)
2360 MHz	Moving	-5 $\rightarrow$ 0 dB	Lognormal ($\mu = -7.29, \sigma = 1.72$)
2360 MHz	Moving	-10 $\rightarrow$ -5 dB	Lognormal ($\mu = -6.66, \sigma = 1.81$)
2360 MHz	Moving	$<$ -10 dB	Lognormal ($\mu = -6.71, \sigma = 1.99$)
2360 MHz	Moving	All	Lognormal ($\mu = -7.43, \sigma = 1.87$)