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

Submission Title: [Dynamic narrowband channel measurements around 2.4 GHz for body area networks]
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Source: [Dino Miniutti[12], Leif Hanlen[12], David Smith[12], Andrew Zhang[12], Daniel Lewis[1], David Rodda[1], Ben Gilbert[1]] Company [NICTA[1], The Australian National University[2]]
Address [7 London Circuit, Canberra, ACT, 2600, Australia]
Voice:[+61-2-6267-6256], FAX: [+61-2-6267-6220], E-Mail:[dino.miniutti@nicta.com.au]

Abstract: [This document presents preliminary real-time measurements of the dynamic nature of 10 MHz bandwidth radio channels around the human body at 2.4 GHz.]

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

Dynamic narrowband channel measurements around 2.4 GHz for body area networks

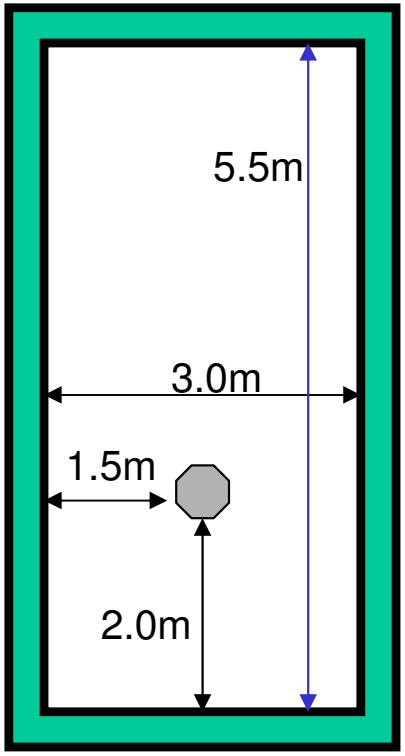
(NICTA & The Australian National University)
Dino Miniutti, Leif Hanlen, David Smith, Andrew Zhang

(NICTA)
Daniel Lewis, David Rodda, Ben Gilbert

Aim

- To present preliminary measurements of the time-variable dynamics of a BAN channel
  - On-body to on-body channels studied
  - Assist the design of BAN systems & standard
- This presentation is a summary
  - Further results to be disseminated to TG6 in the near future

Experiment Setup (1)

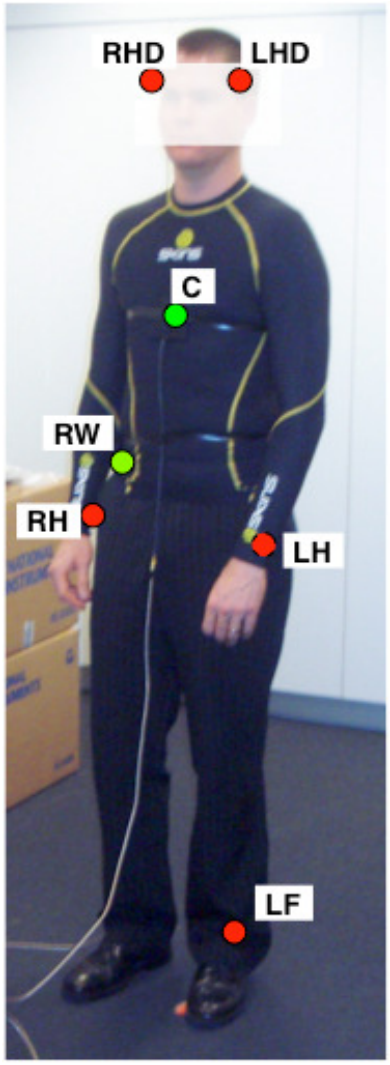


Ceiling 2.7m

Enclosed office

Transmitter

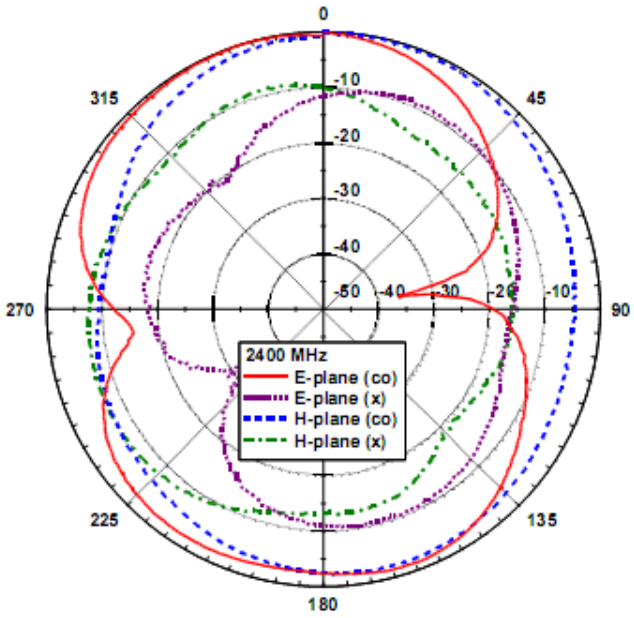
Receiver



Clothing tight to torso
Standing position shown

Experiment Setup (2)

- National Instruments NI PXIe-1065 (chassis)
  - 30 dB amplifier
- Mini-circuits 15542 ZQL-2700MLNW (LNA)
  - 25 dB amplifier (receiver side)
- Pharad BW-2400—2500 wearable antenna
  - Near Omni directional, vertical polarisation
- -10 dBm transmit power
- 255 chip PN sequence at 12.5Mcps
  - 36.3ms between slices (long-average)
  - 285.6us sampling period (short-average)



Formation of results

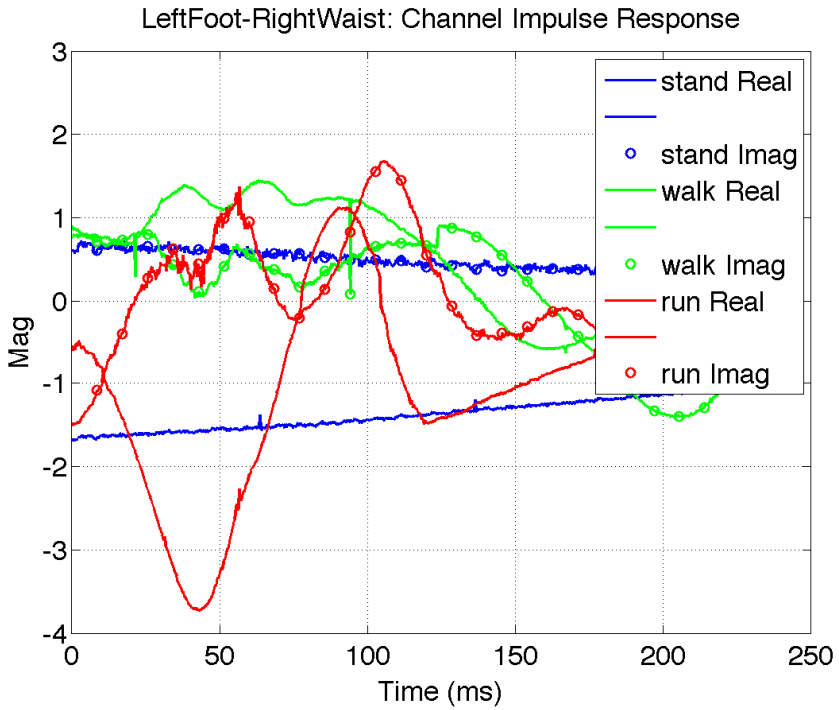
- Transmit 255 chip PN sequence, repeated 4 or 14 times (for fast or slow measurements, respectively).
- Received signal averaged to improve SNR

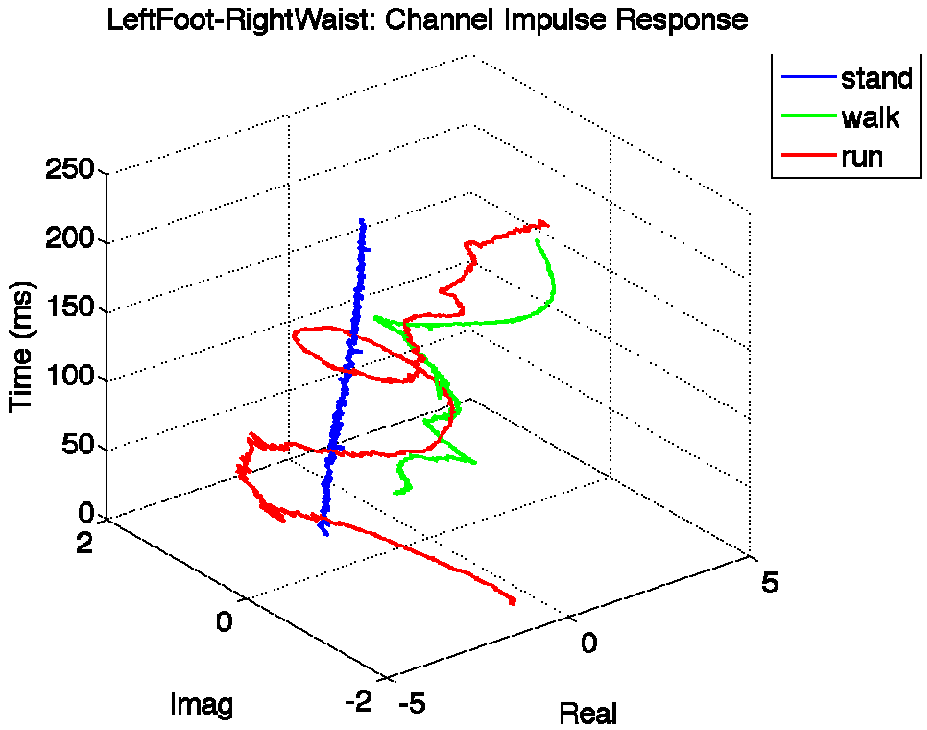
Block correlation, for block length τ

$$c(\tau) = \frac{x\left[t : t+\tau\right] \cdot x\left[(t+1) : (t+\tau+1)\right]^*}{\|x\left[t : t+\tau\right]\| \cdot \|x\left[(t+1) : (t+\tau+1)\right]\|}$$

- Used 5ms, 20ms and 35ms for block size
  - Channels with correlation above 98% considered static
  - $F_{carrier}$ = ~ 2.4 GHz, 10MHz bandwidth
- Various Antenna points, each with activities
  - Standing (stationary)
  - Walking (slowly)
  - Running (fast)

Left foot to right waist

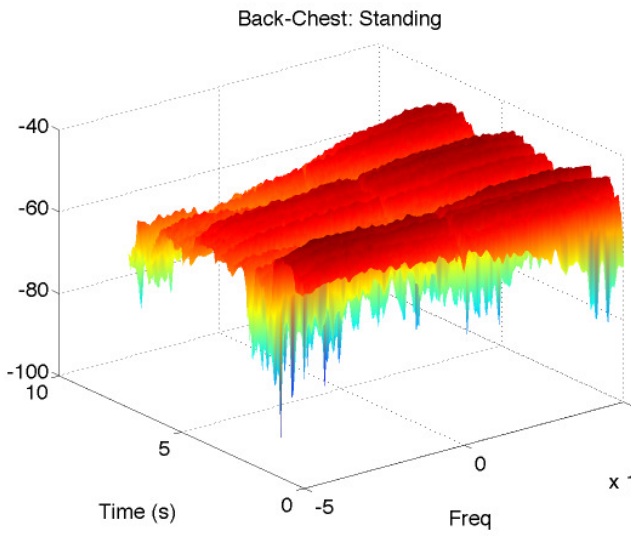




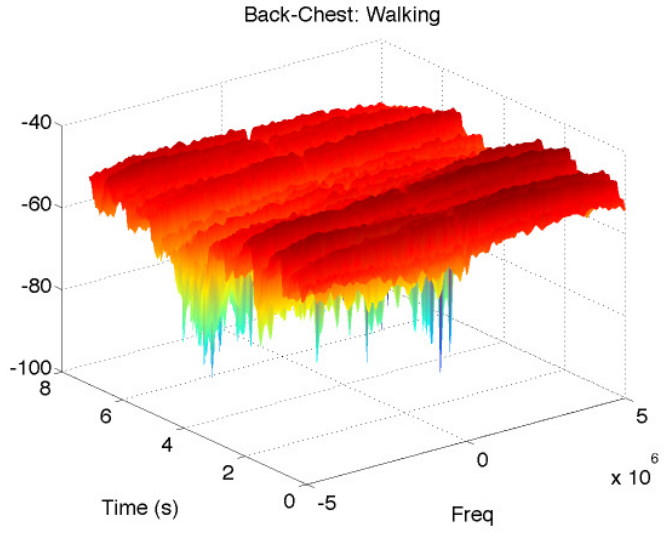
The more energetic the movement (standing < walking < running), the more variable is the channel

Back to chest (1)

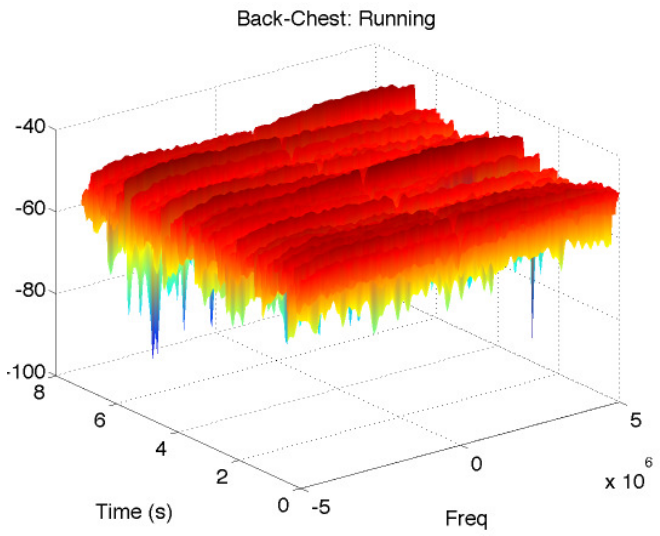
- Periodic channel soundings with ~36 ms between measurements → PSD over time



Standing

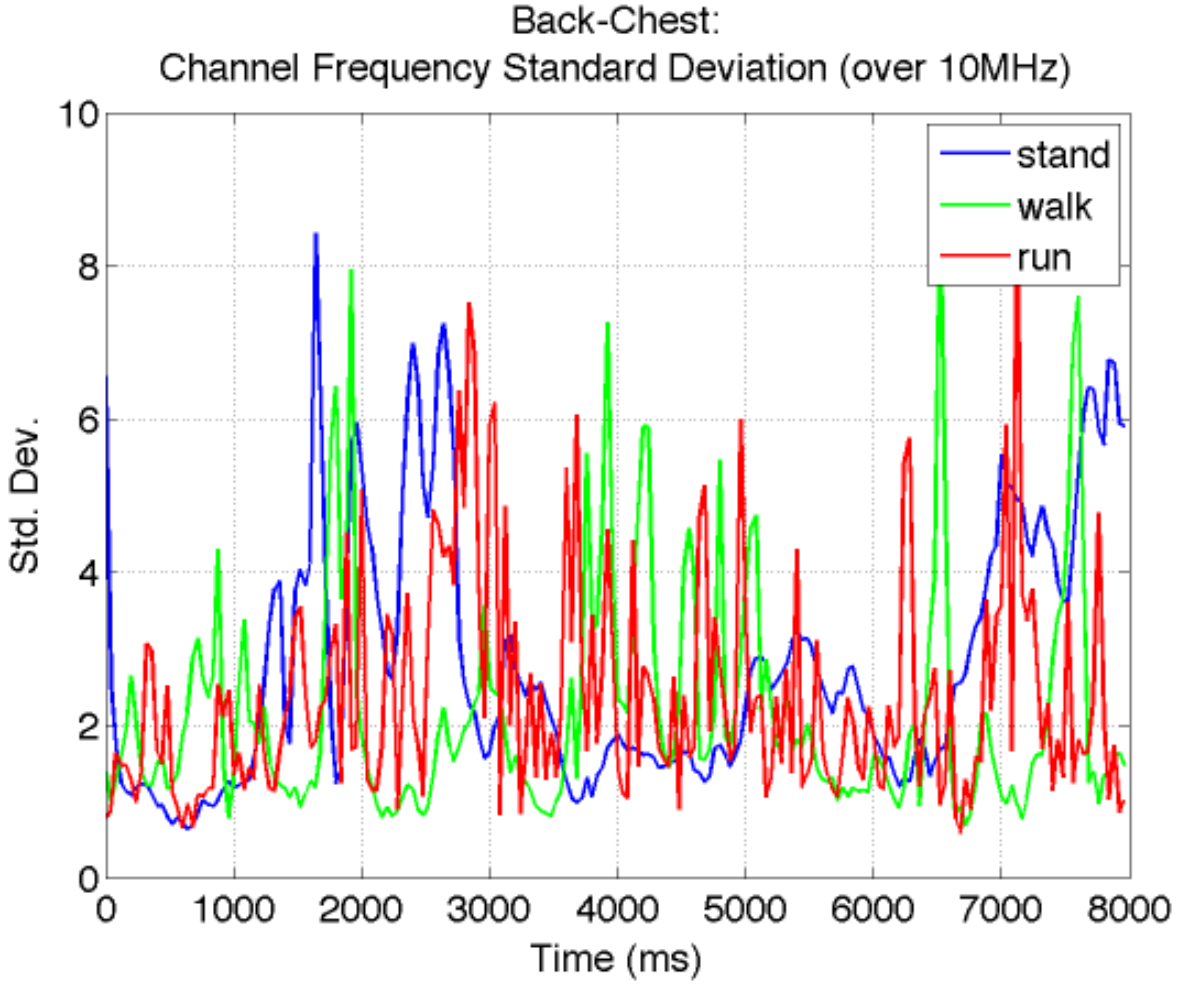


Walking



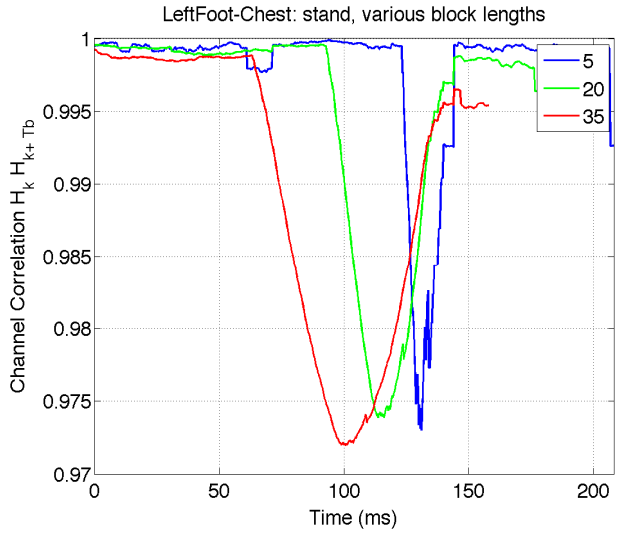
Running

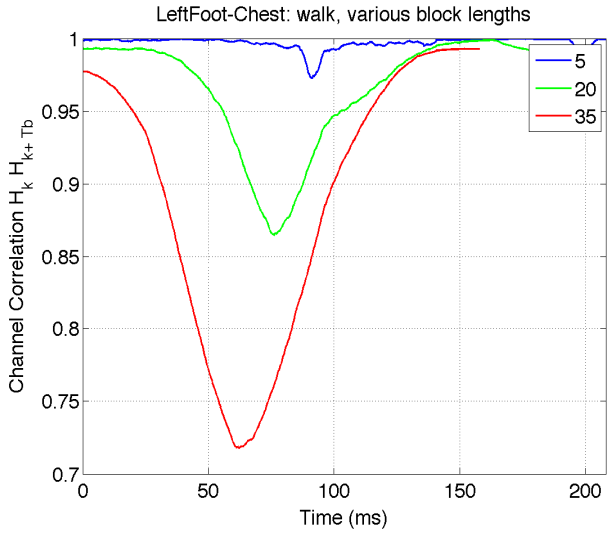
Back to chest (2)

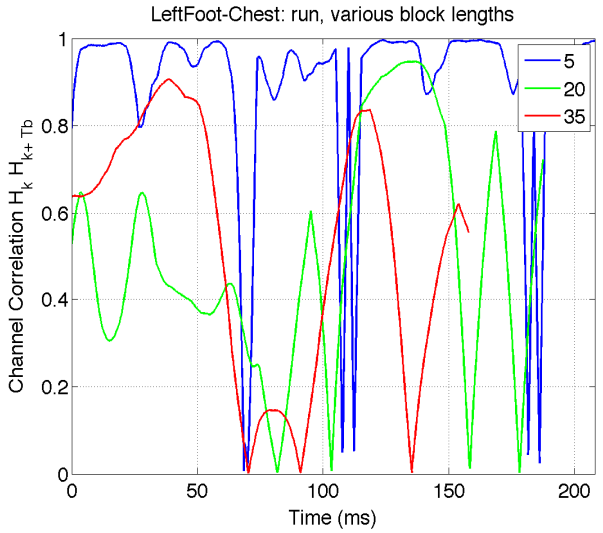


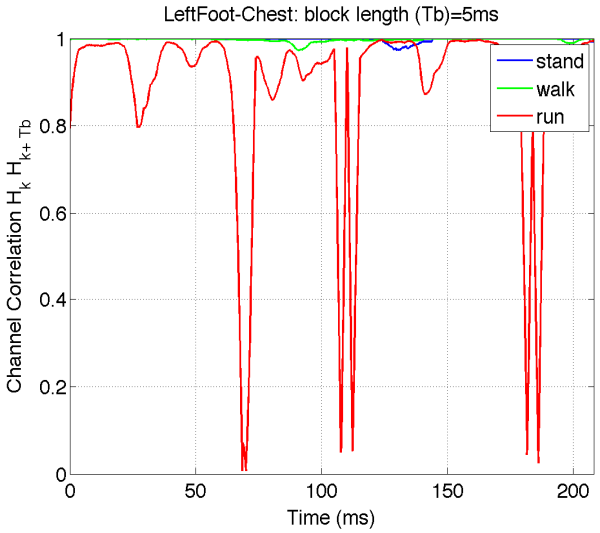
- Standard deviation of power (dB) in frequency bins of PSD for each channel sounding
  - No resolved multi-path in room

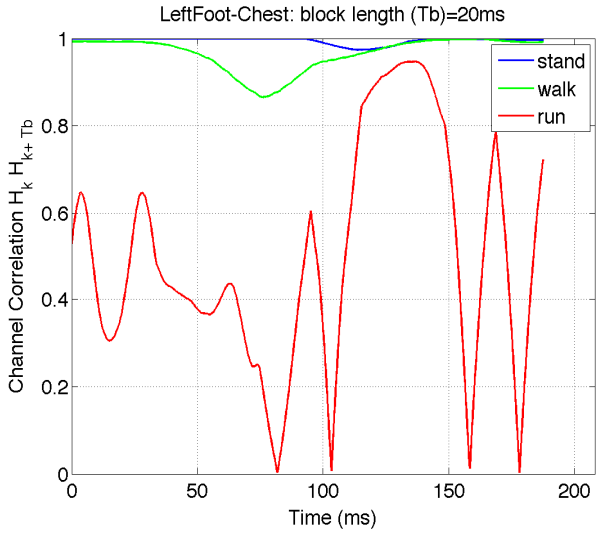
Standing, walking, running vs. block length

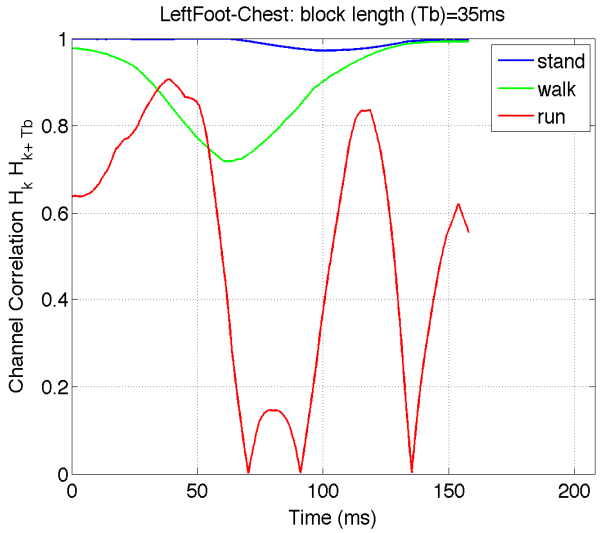






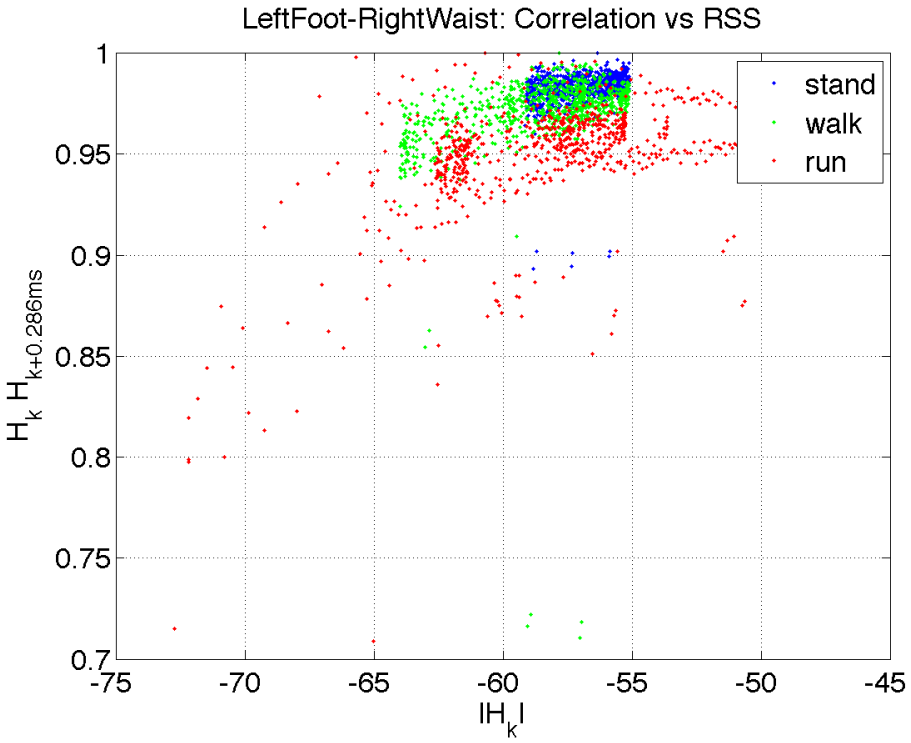


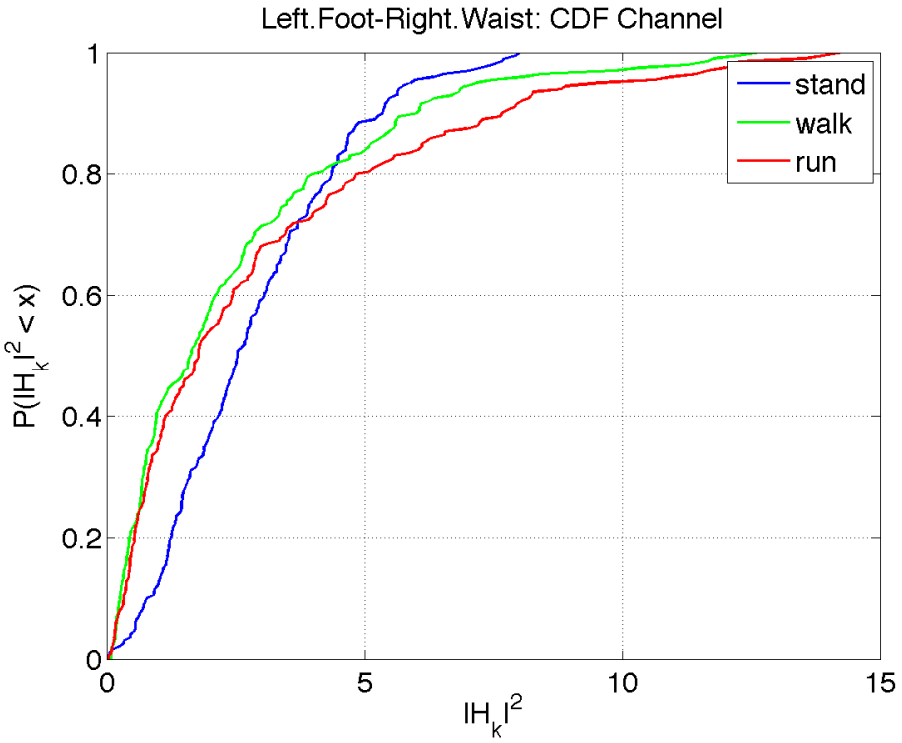




All measurements used 285.6us sampling rate

Left foot to right waist

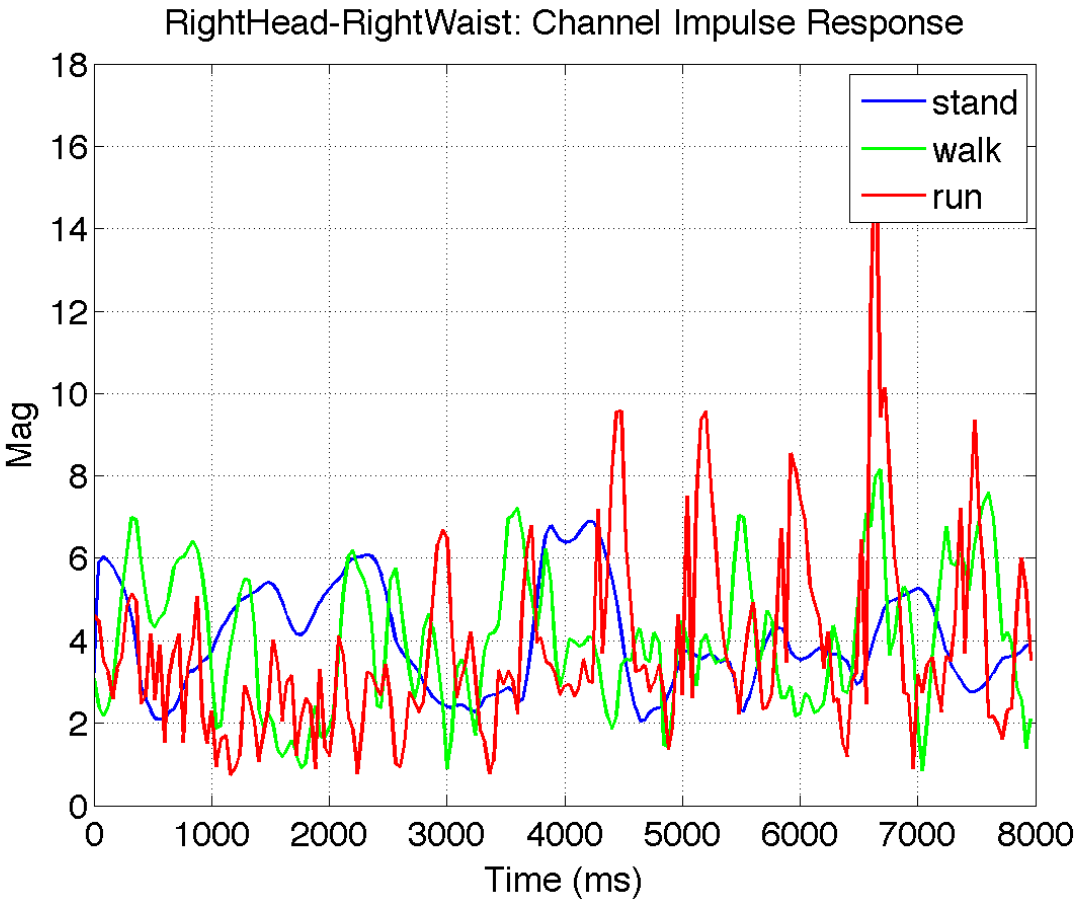


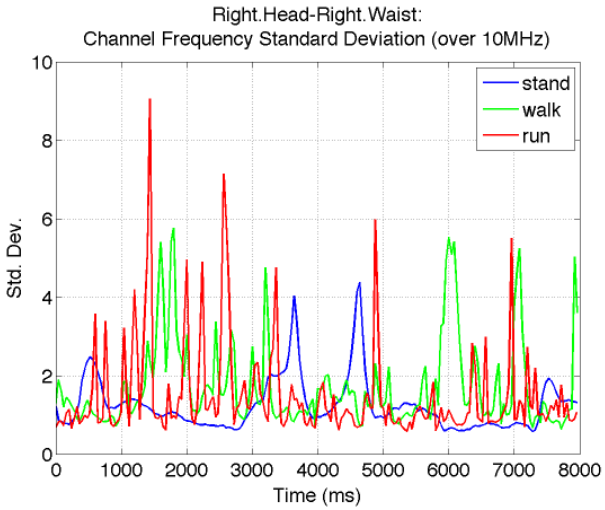


No clear relation between "strong" channels and "correlated" channels.

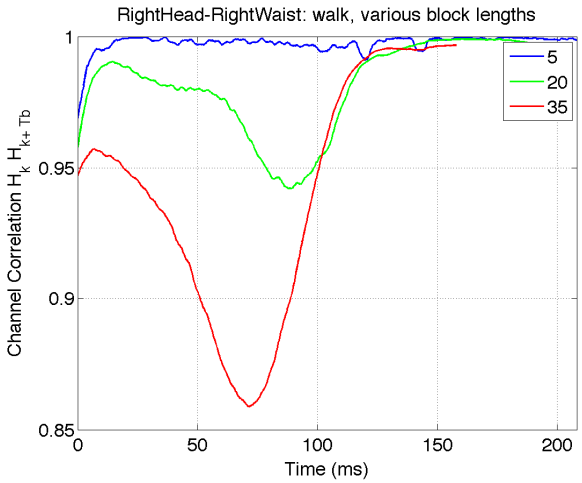
Channel CDF moves toward log-normal for high-movement (running) and normal for standing.

Right head to right waist





Frequency variation



Correlation for walking

Impulse response CDF

Probability distribution (best match) of channel gain

	R.Waist to Chest	R.Head to L.Waist	L.Foot to L.Waist	L.Foot to Chest	Back to Chest	R.Hand to Chest
Stand (Impulse)	normal	normal	normal	normal	normal	log-normal
Walk (Impulse)	normal	normal	log-normal	normal	normal	log-normal
Run (Impulse)	normal	log-normal	log-normal	log-normal	normal	log-normal

Summary

- Channels stable within 5-15ms period
  - Stationary body gives 100's ms stability
  - Time-varying results consistent with physical movement of subject
  - Channel strength characterised statistically
    - Single-tap time-domain result for 10MHz band

Further contributions

- Presentation is a summary of technical report we will send to Channel Modeling sub-committee
  - Will consider frequencies other than 2.4GHz
- Emphasis on real-time, dynamic channel model