RSS Step Size: 1 dB is not Enough!

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HotWireless’16
Applications of RF Sensing


**Future:** Ubiquitous RF Sensing
Standard RF Sensors

RSS Step Size: 1 dB is not Enough!

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RF Sensing Tradeoff Space

Performance vs. Cost (BW & $)

- 1 dB RSS
- Multi-Channel RSS
- WiFi
- UWB

RSS Step Size: 1 dB is not Enough!
RF Sensing: sub-dB

Performance

Cost (BW & $)

- sub-dB
- WiFi
- UWB
- Multi-Channel RSS
- 1 dB RSS

RSS Step Size: 1 dB is not Enough!
Outline

1. sub-dB
2. Breathing Monitoring
3. Gesture Recognition
4. Conclusion
sub-dB CC1200 Prototype

Processor:
- CC1200 Evaluation Board
- Beaglebone Black (BBB)

Datasheet:
- 12 bits / 0.0625 dB

Empirical study:
- 4 least significant bits / 1 dB

IQ Sample
- 17 bits Magnitude

Programable Real-time processing Unit (PRU)
- 348 samples per sec
RSS Calculation and Verification

- \[ RSS = \frac{1}{K} \sum_{n=0}^{K} |Magnitude_n|^2 - G \]
  with \( K \) samples, \( G \) amp gain
- Test with known generated signal
sub-dB Errors

![Graph showing sub-dB Errors]

- sub-dB MME: 0.013 dB
- 1dB: 0.25dB
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Breathing Monitoring

Experimental Setup:

- CC1200 TX 434 MHz, sub-dB RX
- Ground truth via respiratory inductance plethysmography (RIP) belt
Breathing Monitoring Algorithm

$s_n \rightarrow \sum |s_n|^2 \rightarrow \text{Filter} \rightarrow \text{FIFO} \rightarrow \text{DFT} \rightarrow \text{Peak} \rightarrow \hat{f}$
Oversampling & Quantization for Breathing

For breathing monitoring, high accuracy requires:

\[ \text{Sampling rate} \geq 29 \text{ Hz} \]

\[ \text{Quantization step size} \leq 1/16 \text{ dB} \]

\[ (\geq 12 \text{ bits}) \]
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Gestures Recognition

Office Room
8.4m x 6.7m

- 6.7m
- 2.4m

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Gesture Recognition Evaluation

Features:

- Variance
- Skewness
- 8 percentiles (5th to 95th)
- PSD for 3 different bands
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Recommendations

- **Chip Designer:**
  - smaller step size
    - (1/16 dB or 0.0625 dB)
- **Application Designer:**
  - Pick IC with 12 bits RSSI
  - IQ Sample
Conclusion

Ubiquitous RF Sensing

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Thank you

This material is based upon work supported by the U.S. National Science Foundation under Grant Nos. #1329755 and #1407949.

Visit span.ece.utah.edu for more information

Breathing Monitoring Code is available at: https://github.com/SPAN-UofU/rub

PRU Code is available at: https://bitbucket.org/anh_luong/pru