BS4LIES: Backscatter 4 Low-power IoT Environmental Sensing

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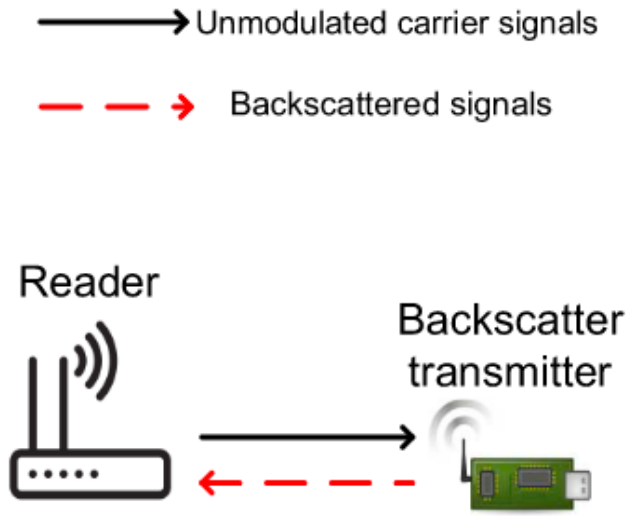
CS 8803 MCI

Background

Problem Statement

- Backscatter: low power (10s of microwatts) communications by piggybacking on existing signals
  - Energy harvesting
  - Persistent sensing
  - Low/no maintenance
- Current practical range: ~1 meter
  - Impractical for many outdoor applications
- Our goal:
  - a low-power backscatter system (<100 uW)
  - for IoT applications
  - with practical ranges (~100s+ meters)
  - by applying digital communications techniques
    - Forward error correction
    - Spread spectrum



Monostatic backscatter

Target Application

- Sensing temperature for Atlanta urban heat islands.

Graphic source: Van Huynh, Nguyen, et al. "Ambient backscatter communications: A contemporary survey." *IEEE Communications surveys & tutorials* 20.4 (2018): 2889-2922.

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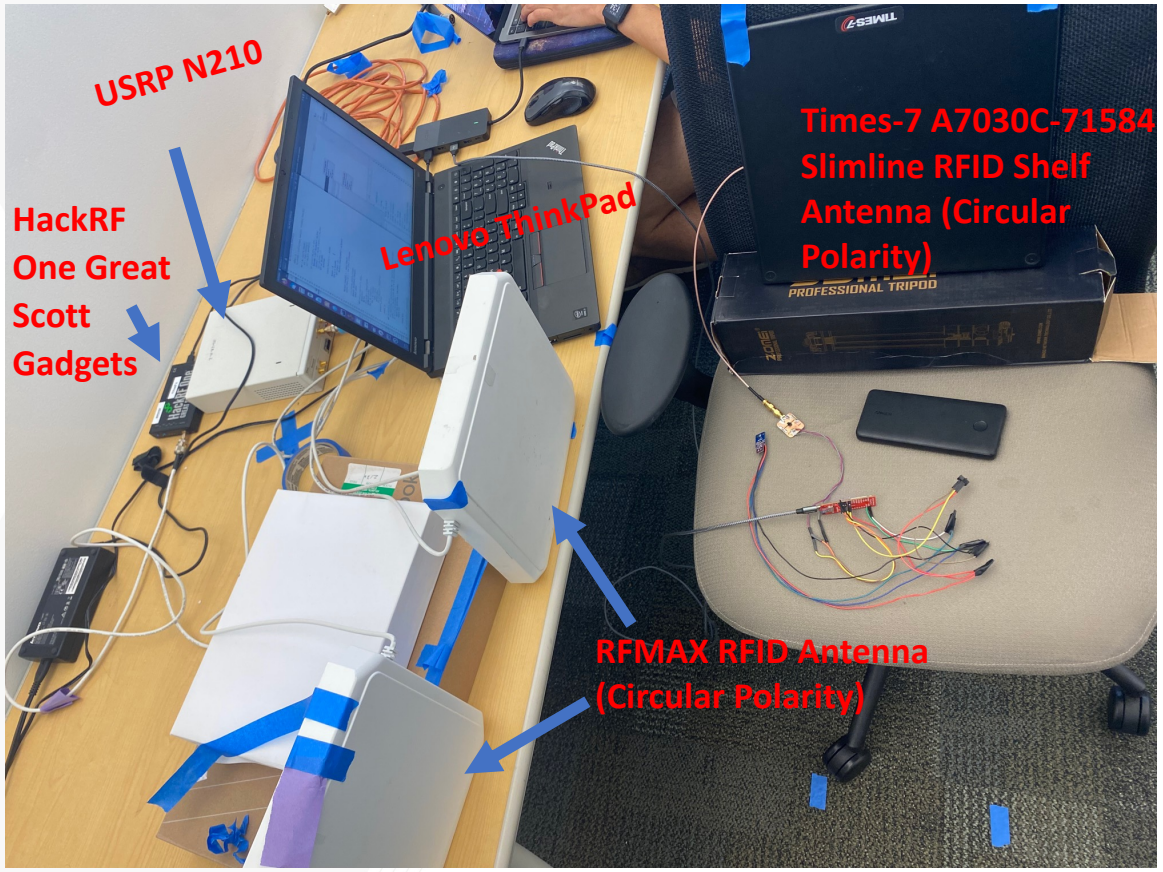
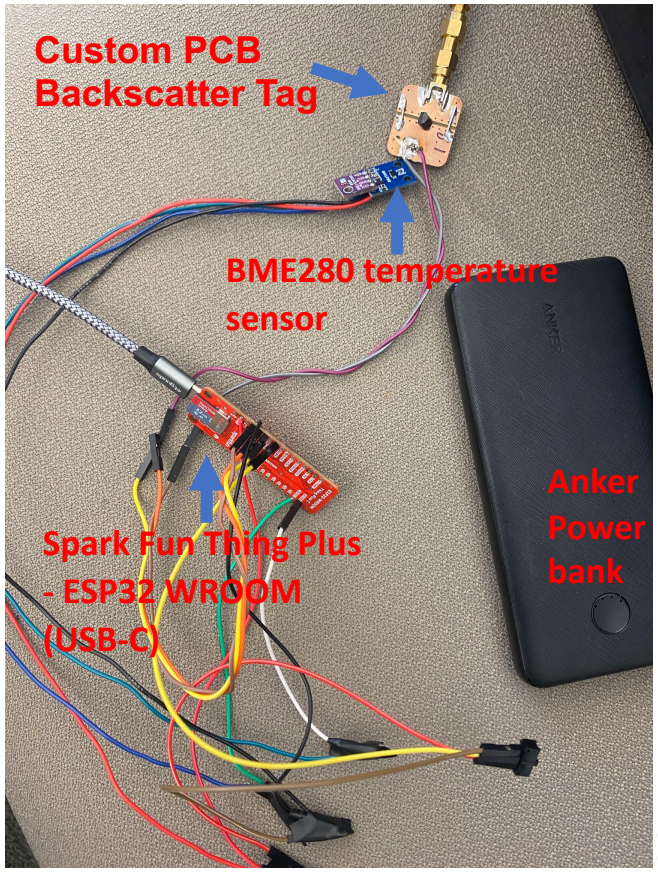
Hardware

Backscatter Full Setup



Backscatter Tag & Arduino Hardware



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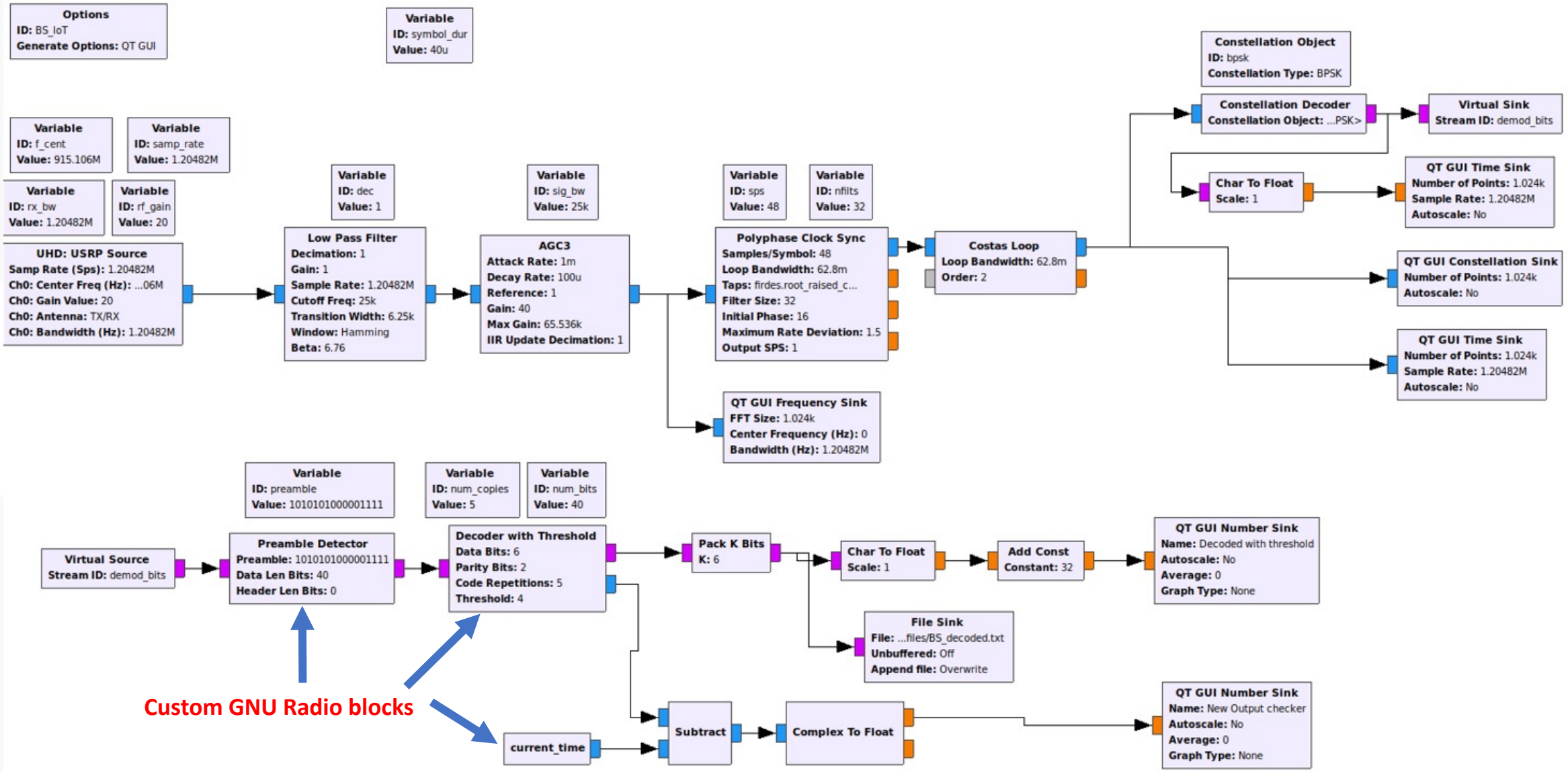
GNU Radio Flowchart for Demodulation



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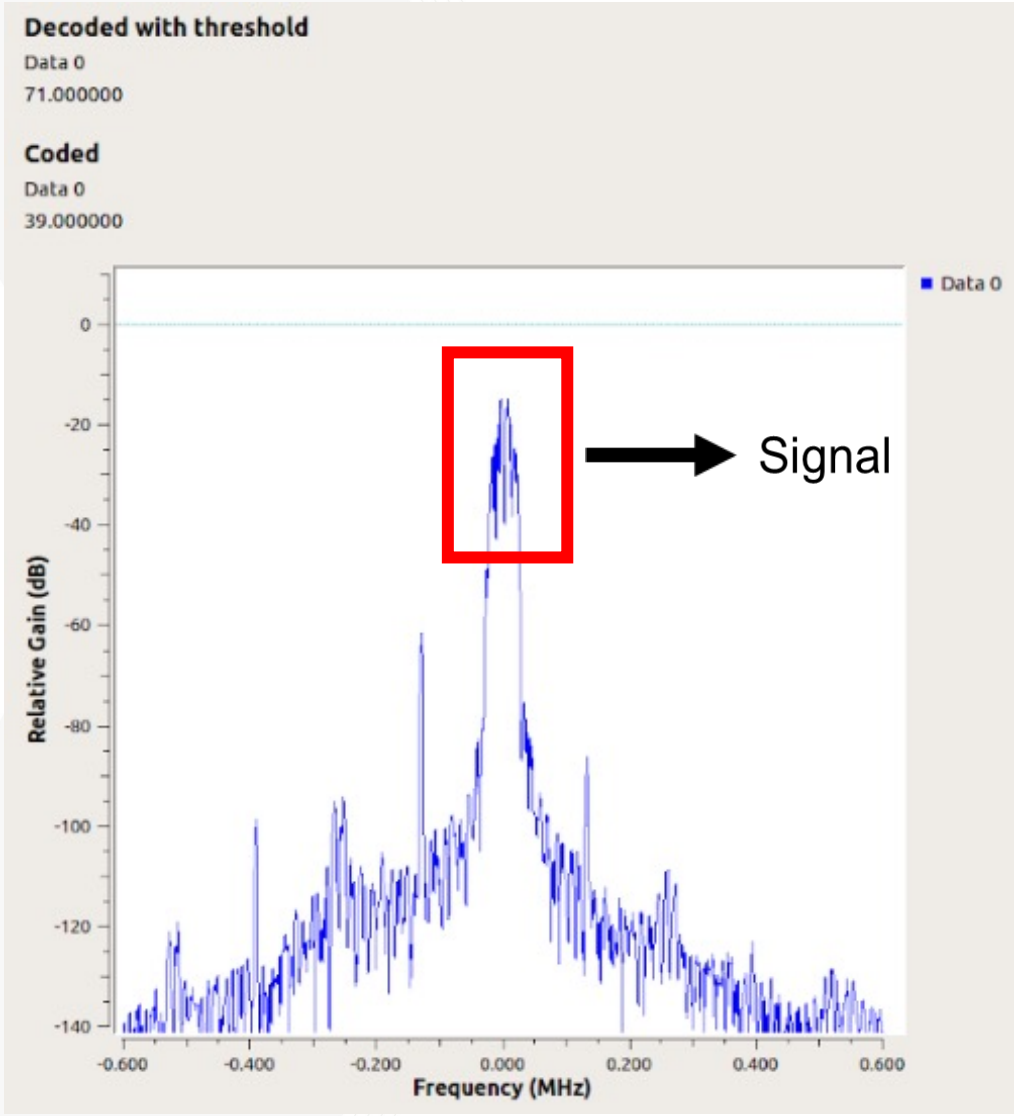
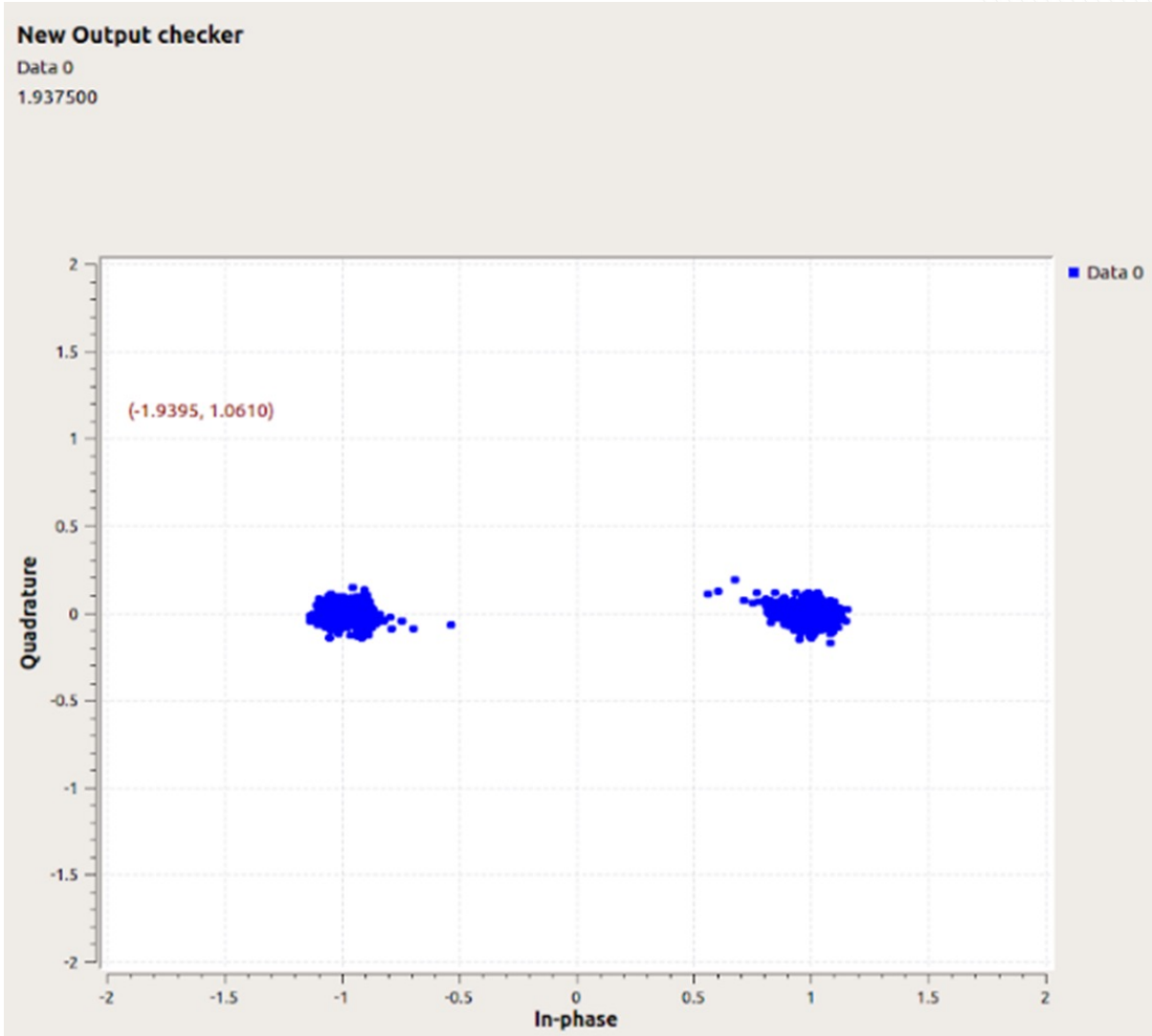
Results





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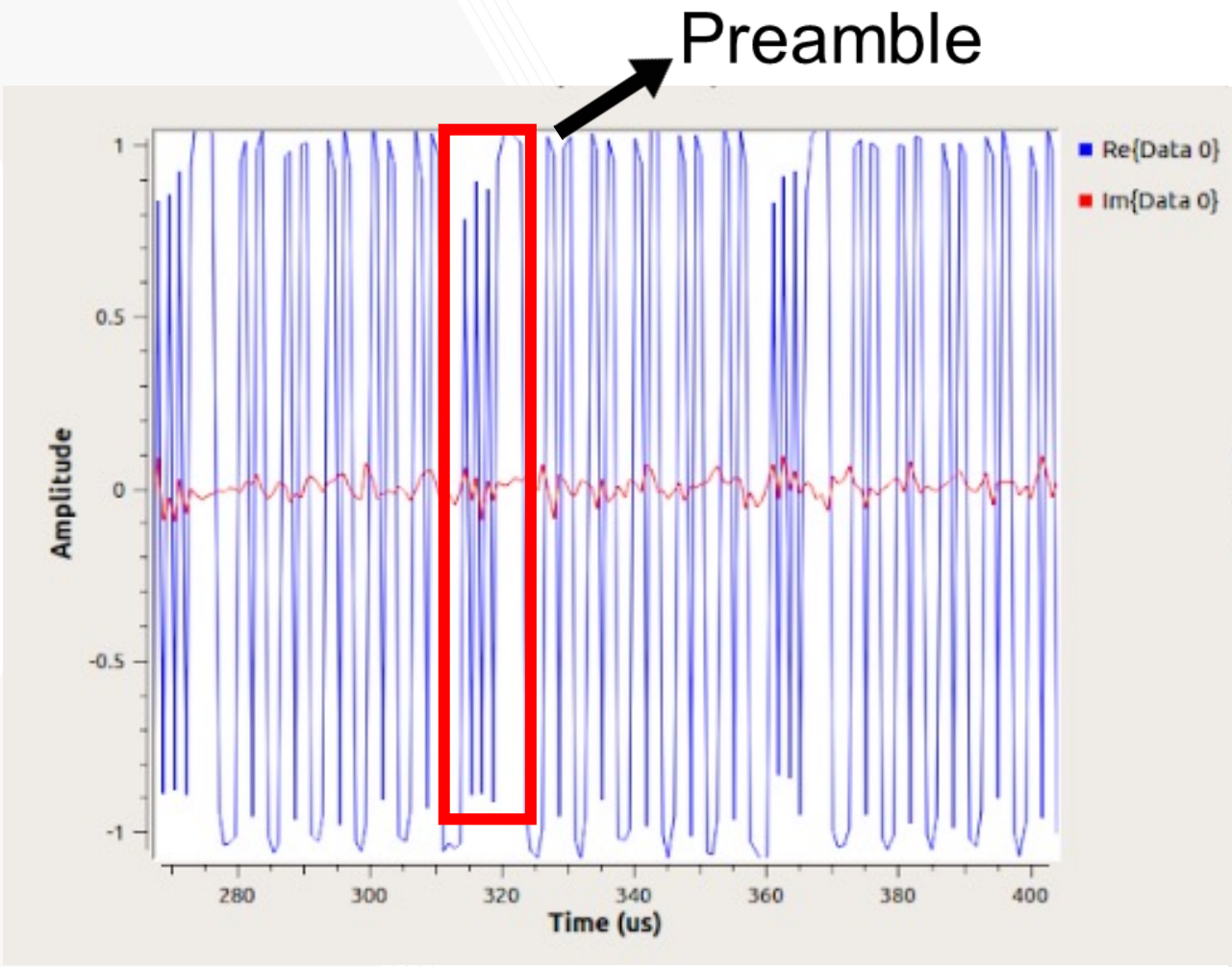
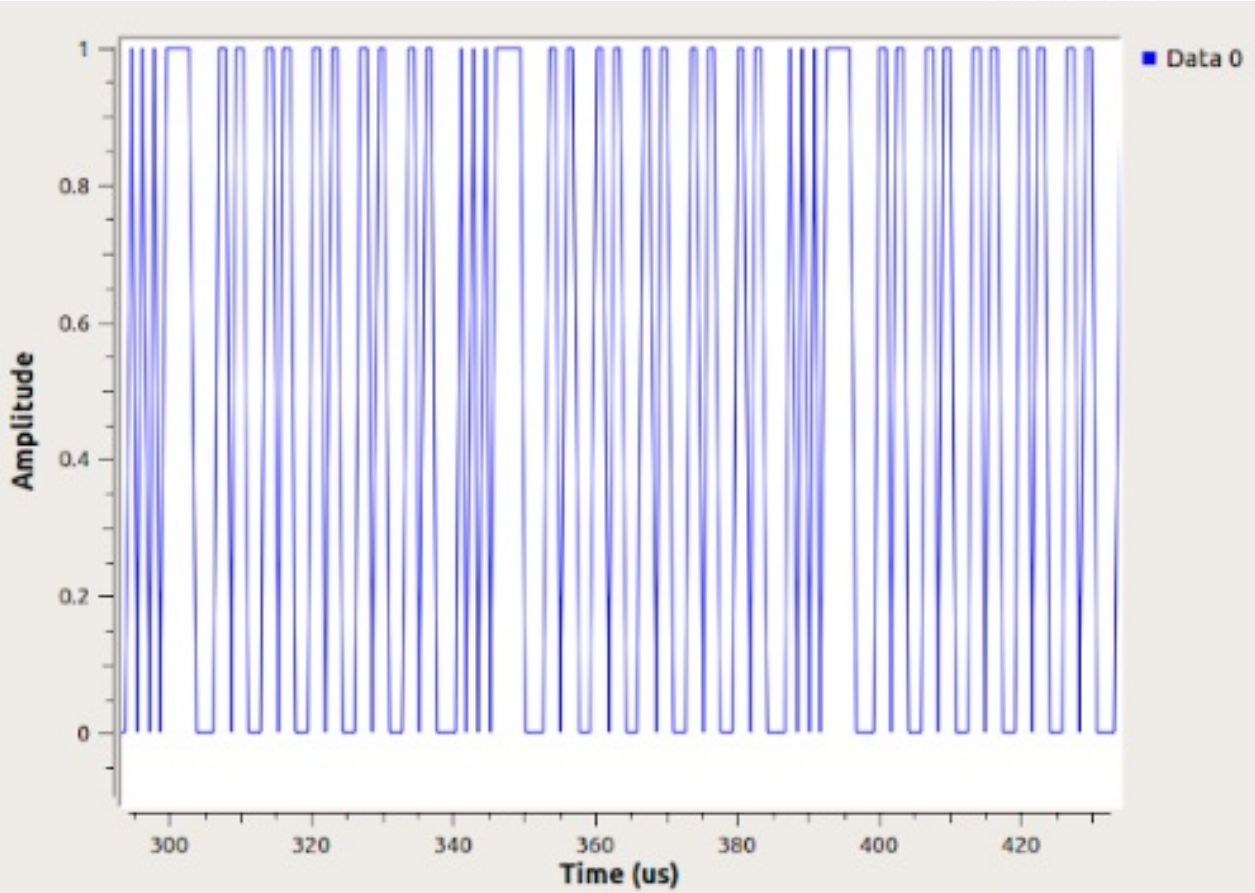
Results - Packets





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Results (Continued)

Throughput: 25kbps

Range: >7.65 meters (with line of sight)

Link Budget: $$P_R = \frac{P_T G_T G_R G_t^2 \lambda^4 X^2 M}{(4\pi r)^4 \Theta^2 B^2 F_\alpha}$$

	PT	GT	GR	Gt	λ	X	M	r	Θ	B	Fα	PR
Description	Transmitted power (W)	Transmitter antenna gain	Receiver antenna gain	Tag antenna g ain	Wavelength (m)	Antenna polarization mismatch	Modulation factor	Reader-to-tag separation	Tag's on-object gain penalty	Path-blockage loss	Fade margin for 1E-3 Error rate with 6 dB SNR	Received power
Raw value	0.03	3.98	3.98	3.98	0.33	1.00	1.00	7.65	1.23	1.00	6.31	8.69E-11
dB value	-16 dBW	6 dBi	6 dBi	6 dBi		0	0		0.9	0	8 dB	-100.5 dBW

*Link budget based on: Griffin, Joshua D., and Gregory D. Durgin. "Complete link budgets for backscatter-radio and RFID systems." *IEEE Antennas and Propagation Magazine* 51.2 (2009): 11-25.

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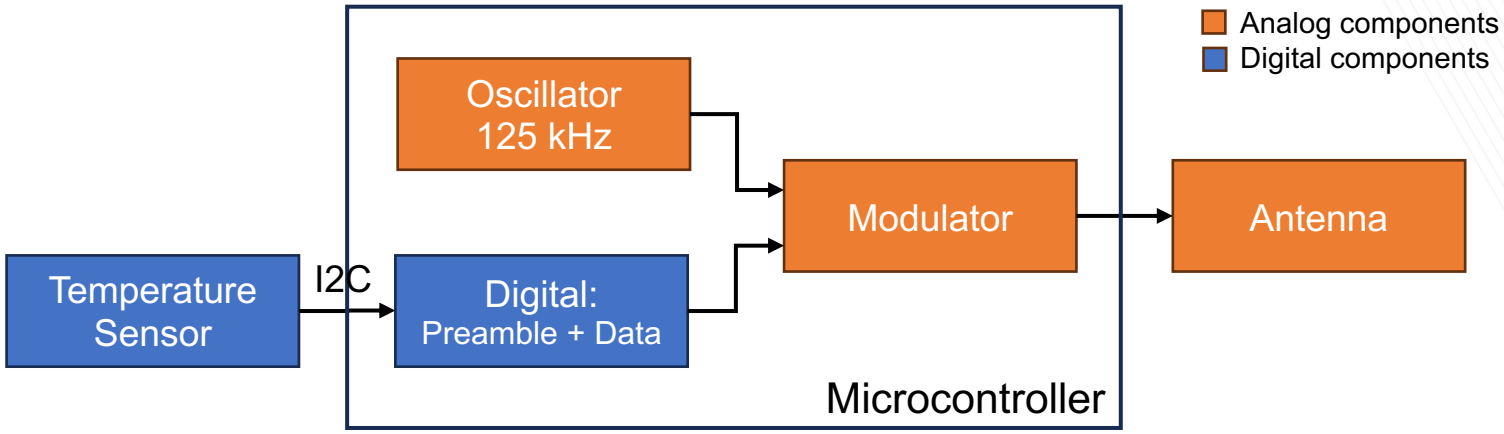
Power Budget Calculations

Tag Components:



Power Budget Calculation:

Temperature, Light Sensor	20 uW	→ Limited by existing hardware	Reasonable for low-power tag
Digital: Preamble + Data	< 5 uW		
Oscillator 125 kHz	500 uW	→ Change from BJT to MOSFET; Based on Clapp Osc. → 500 nW!	< 30 uW
Modulator	< 5 uW		

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Future Directions

- Extend range
  - Lower data rate -> Narrowing bandwidth
  - Power amplifier on transmitter
  - Interleave preamble for channel estimation
- Lower power
  - Build ASIC based on previous slide
- Improve usability
  - Spread spectrum
  - Deploy in the field

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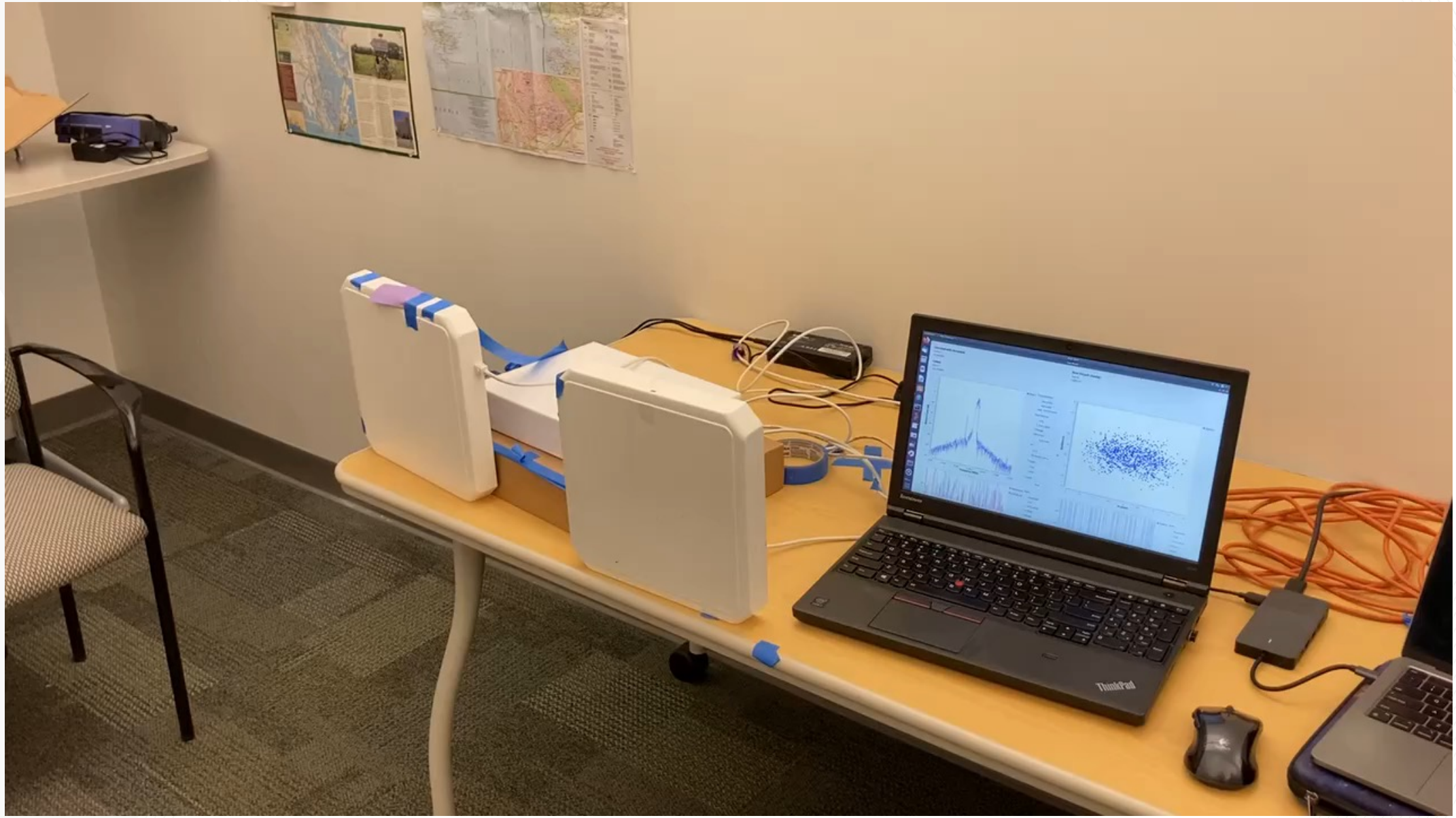
Video/Live Demo



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