Security and Privacy in the Lifecycle of IoT for Consumer Environments

(SPLICE)

Detecting Battery Cells with Harmonic Radar

Cesar Arguello, Beatrice Perez[ǂ], Timothy Pierson, David Kotz

Dartmouth College

[ǂ]Riverside Research Institute

Agenda

- **Why detecting batteries?**
- Radar Basics
  - Traditional Radar
  - Harmonic Radar
- Advantages of Harmonic Radar
- Detecting Batteries with Harmonic Radar
- Experimental Setup
- Results
- Limitations + Future Work

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What is wrong with existing methods?

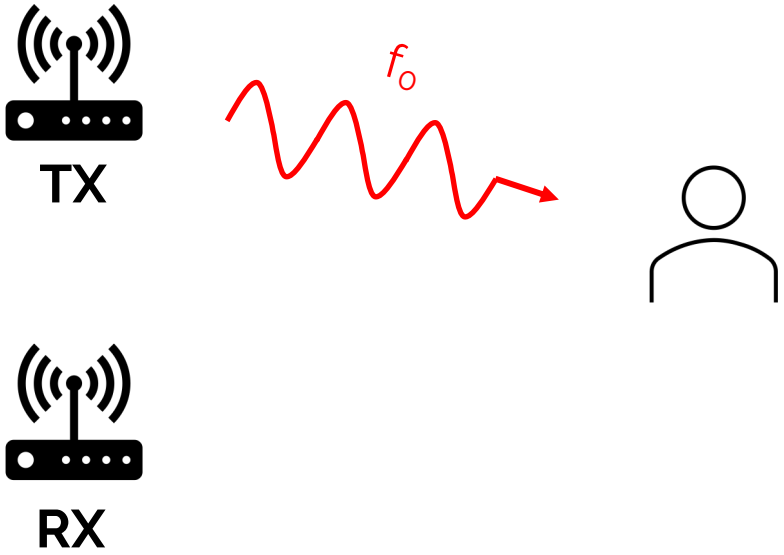
Expensive X-ray Machines

+

Computationally Intense ML

Radar Basics

Detection with Traditional Radars



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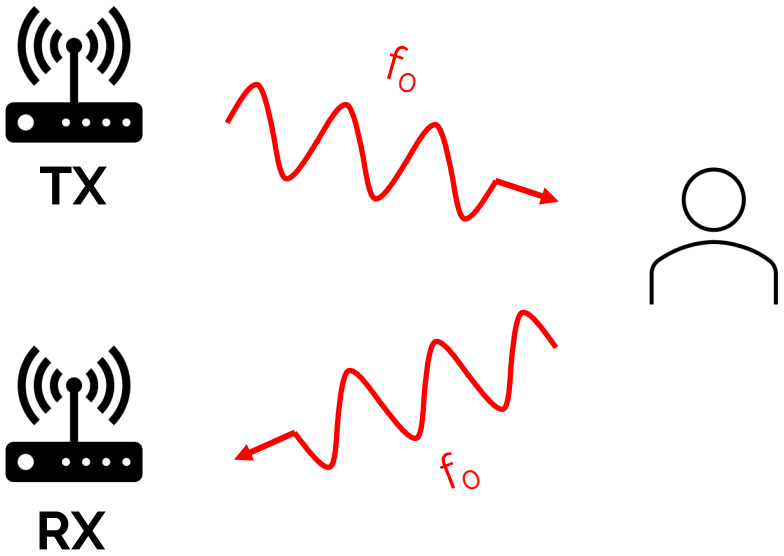

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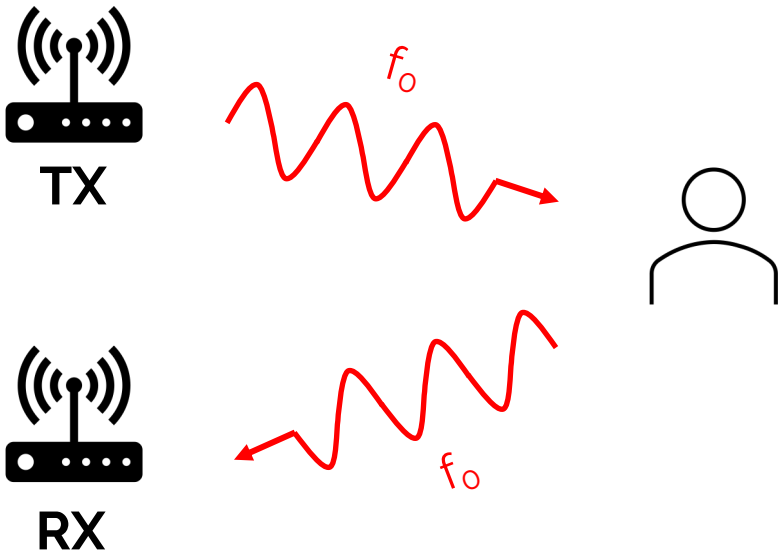

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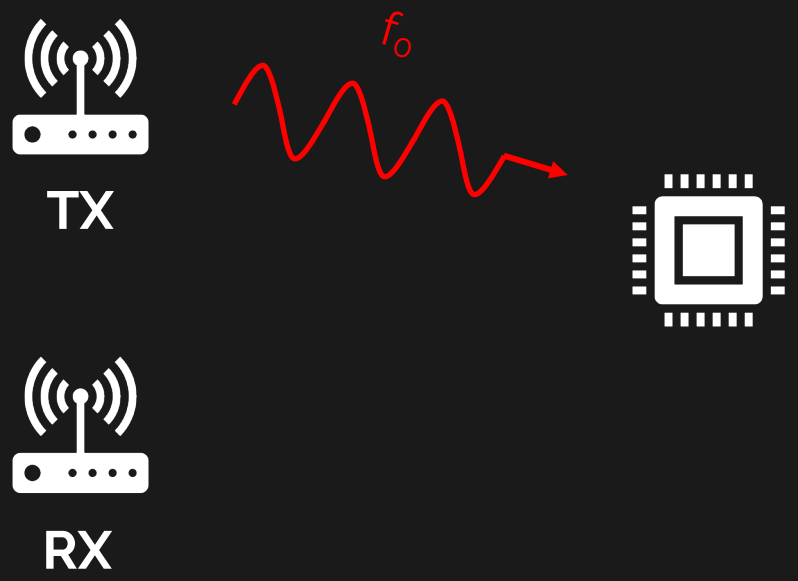

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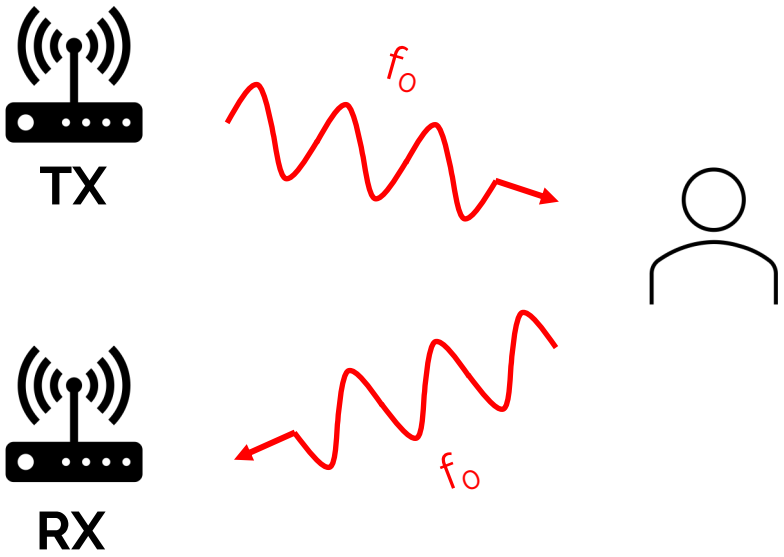

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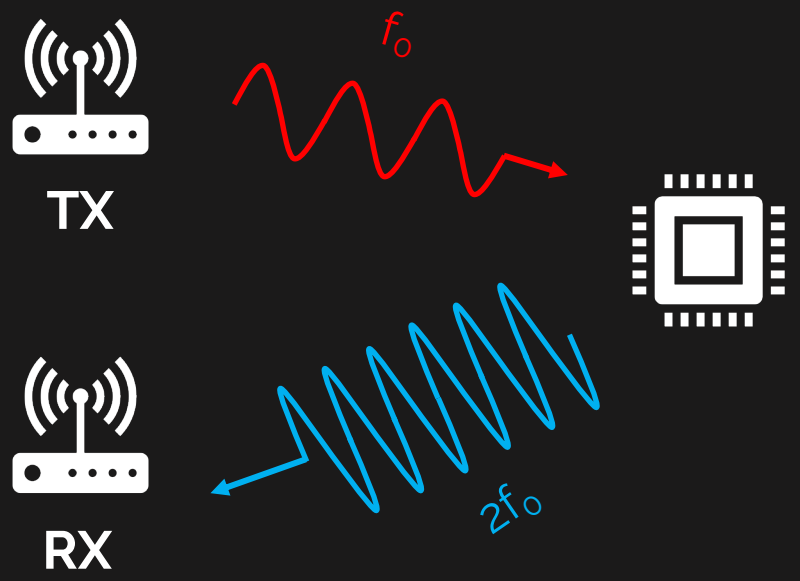

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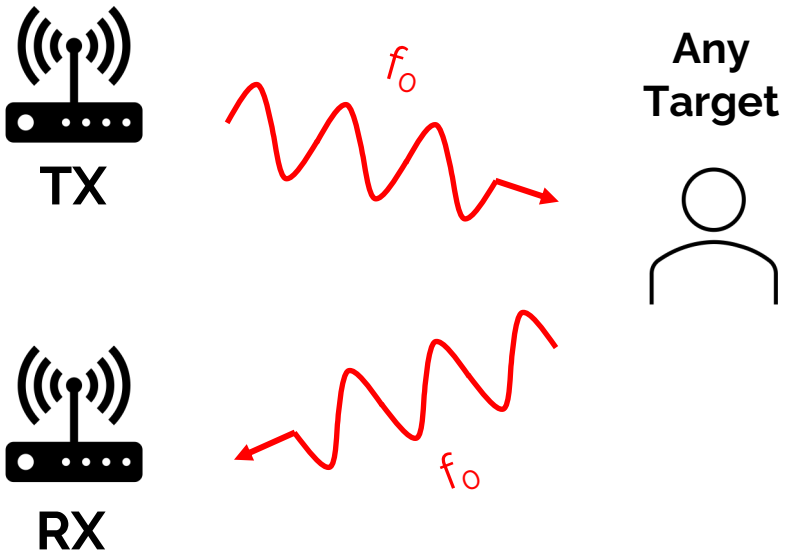

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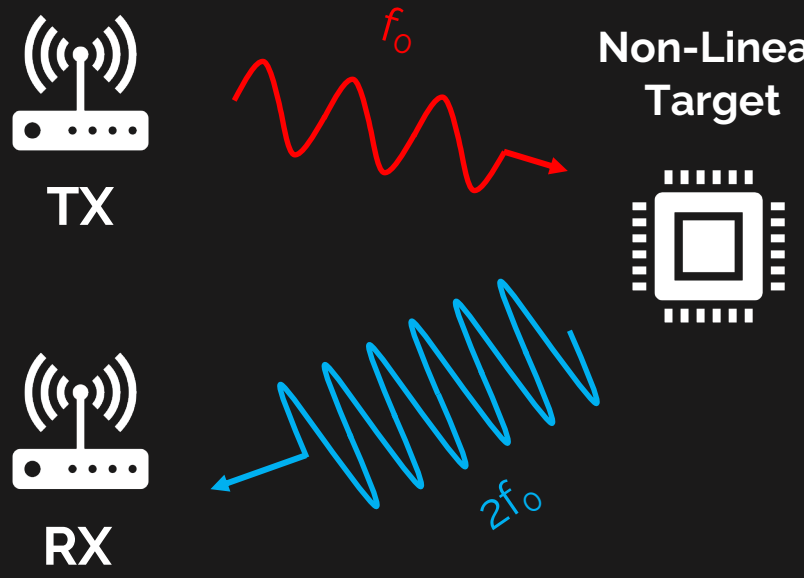
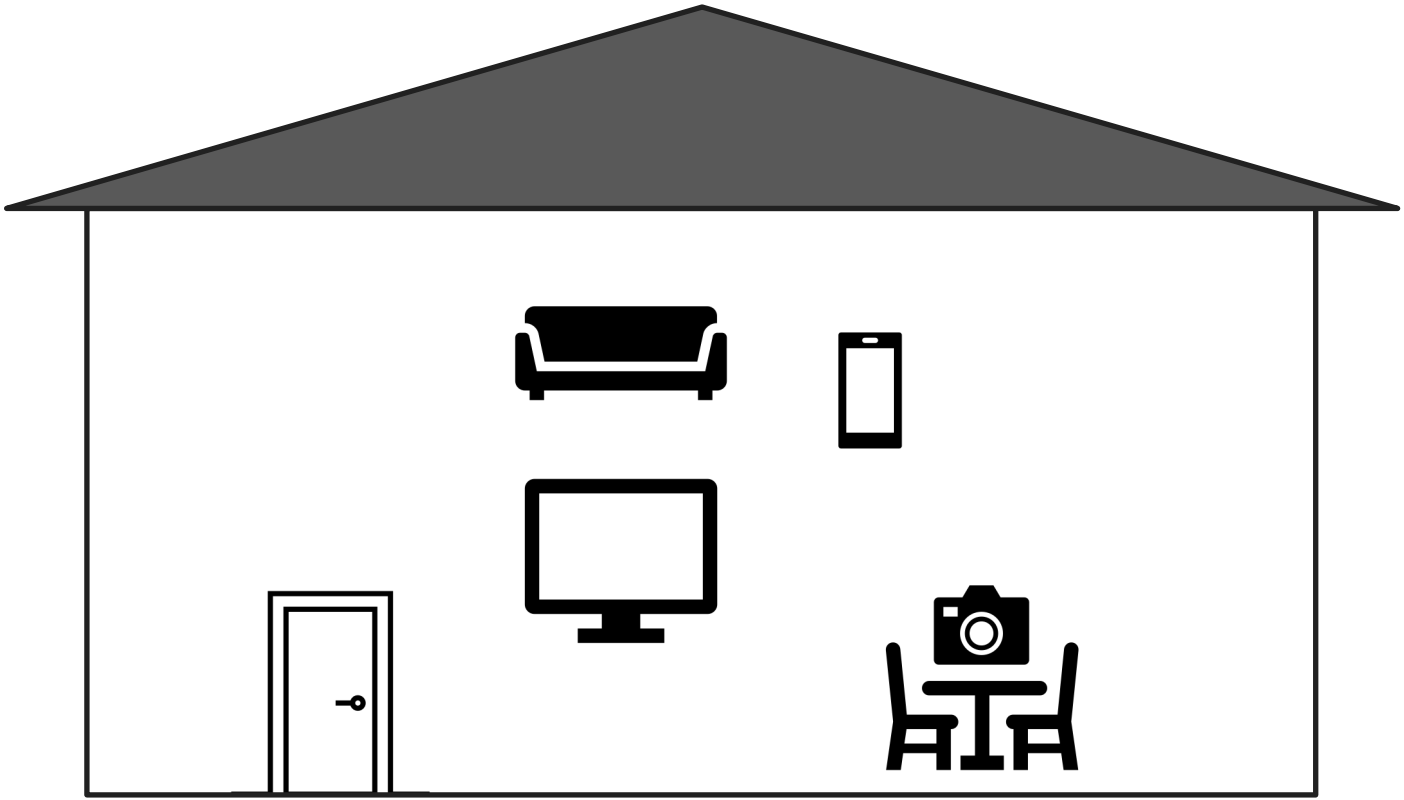


Advantages of Harmonic Radar

Task
Detect **ALL** electronic devices in a smart home



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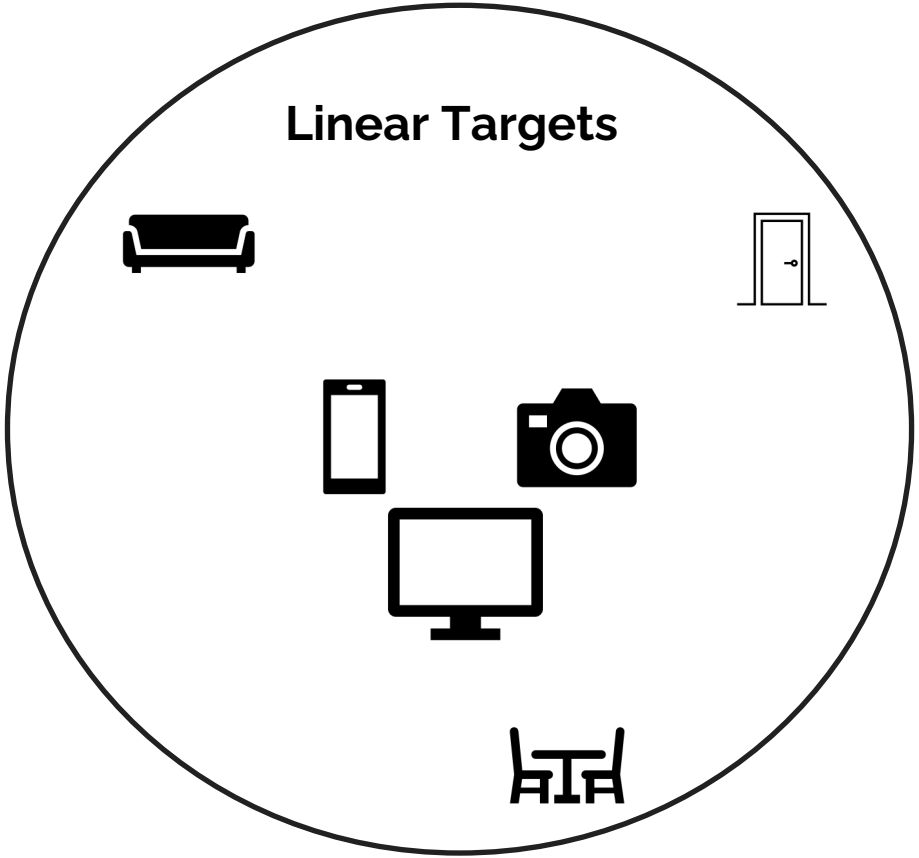

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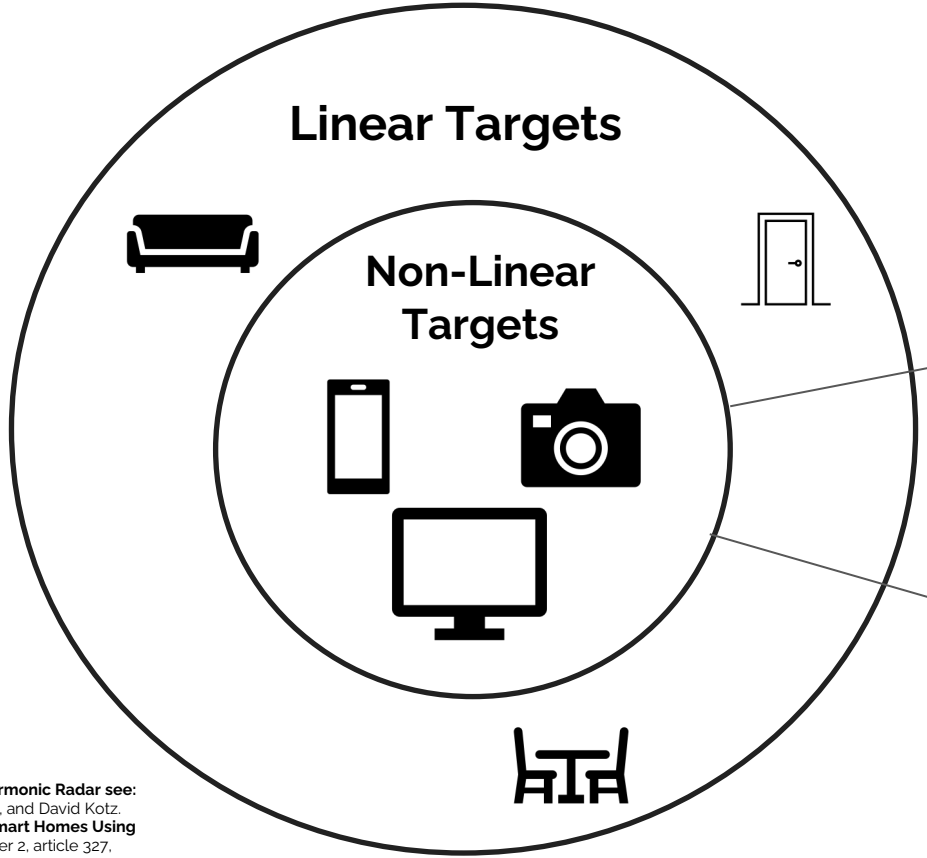
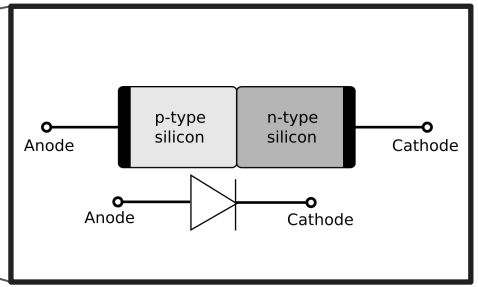
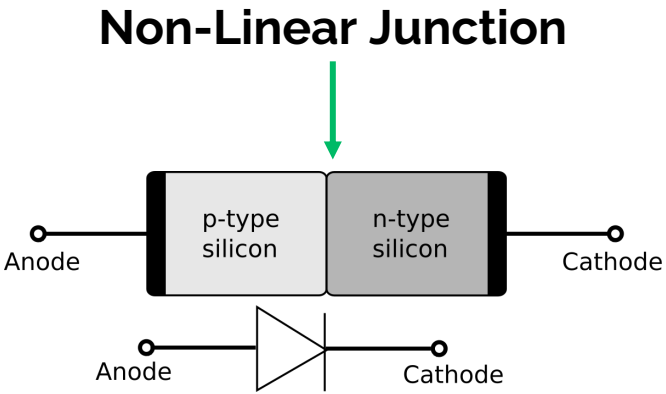




For more information on device detection with Harmonic Radar see:
Beatrice Perez, Gregory Mazzaro, Timothy J. Pierson, and David Kotz. **Detecting the Presence of Electronic Devices in Smart Homes Using Harmonic Radar.** *Remote Sensing*, volume 14, number 2, article 327, 18 pages. MDPI, January 2022. doi:10.3390/rs14020327. Special issue on Nonlinear Junction Detection and Harmonic Radar.

Detecting Batteries with Harmonic Radar



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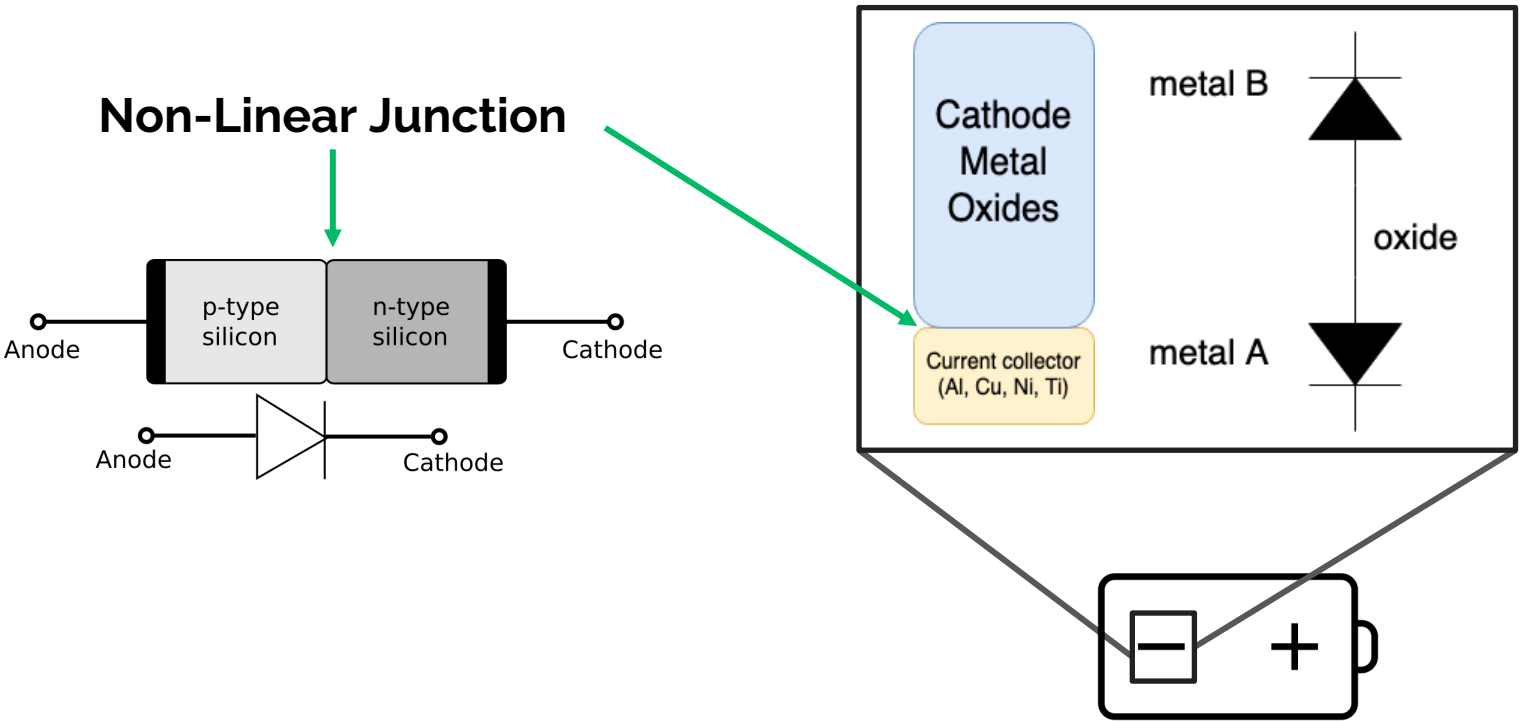

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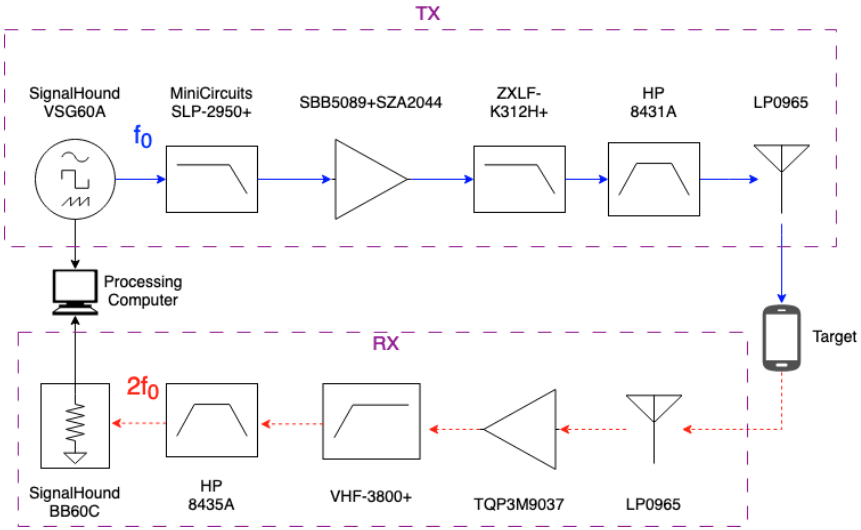
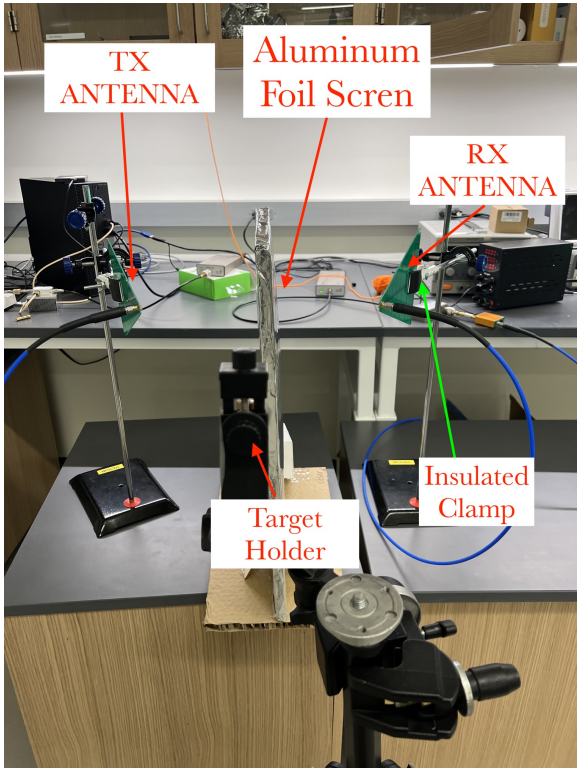


Block Diagram – Harmonic Radar Architecture

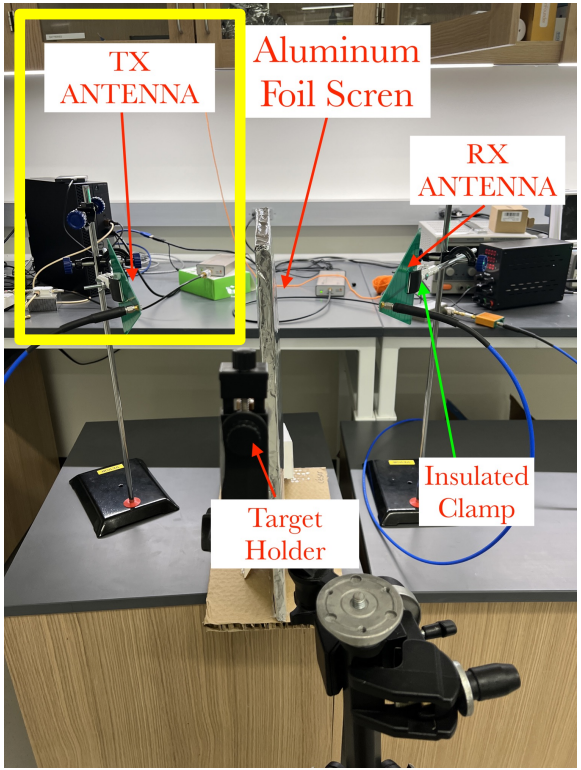


Lab Setup

For more information Harmonic Radar Architecture see:
Beatrice Perez, Cesar Arguello, Timothy J. Pierson, Gregory Mazzaro, and David Kotz. **Evaluating the practical range of harmonic radar to detect smart electronics.** *Proceedings of the IEEE Military Communications Conference (MILCOM)*, pages 528–535. IEEE, October 2023. doi:10.1109/MILCOM58377.2023.10356371.

Signal acquisition and processing

- **Set TX to f_0 at -20 dBm.**
- Set RX to $2f_0$ at 0 dBm.
- Place target on a tripod in line-of-sight.
- Set TX to emit a 0.6 ms CW pulse.
- Apply flat-top window to captured data and calculate DFT.



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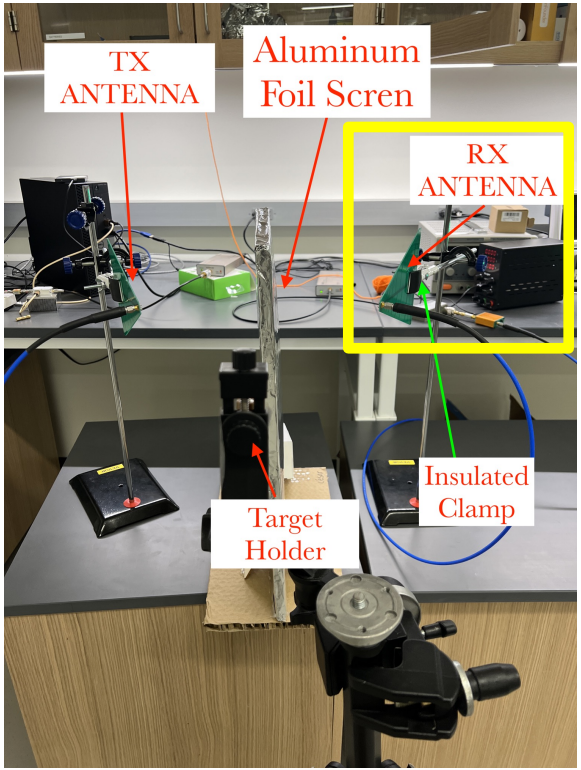

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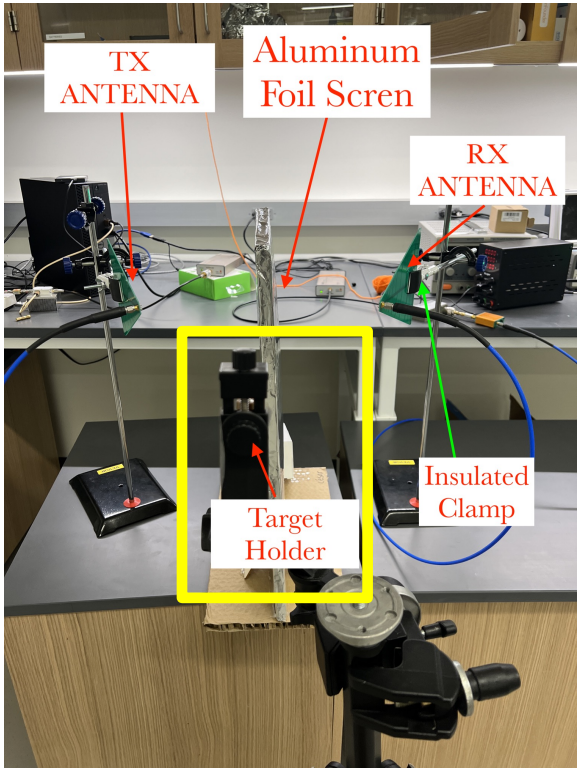

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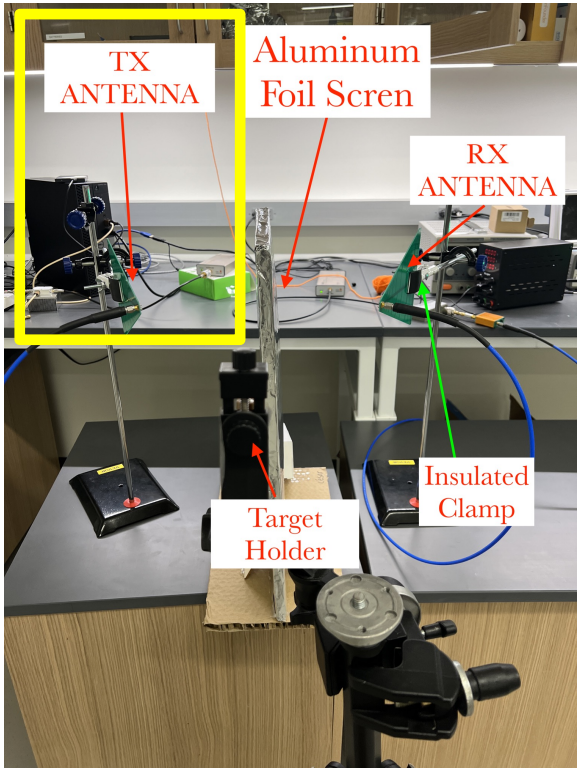

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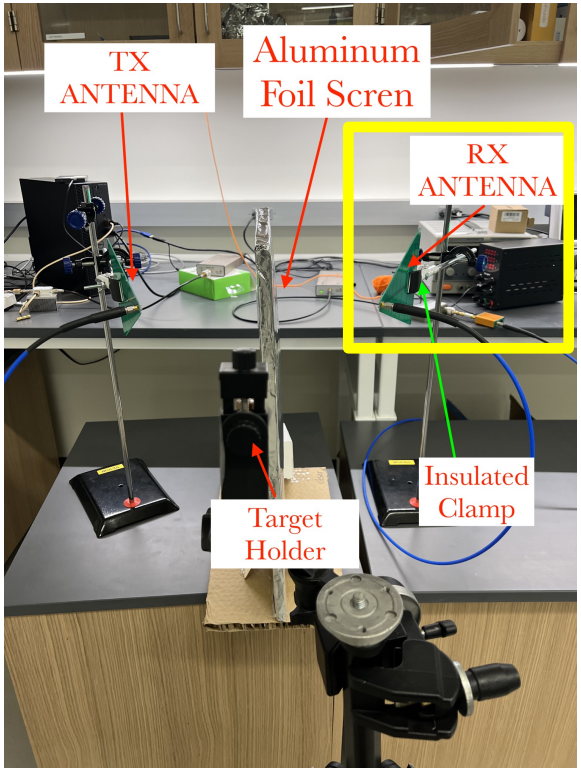

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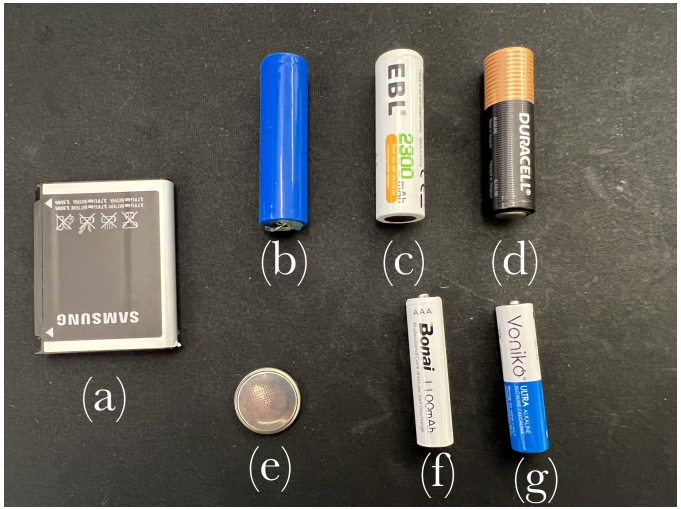
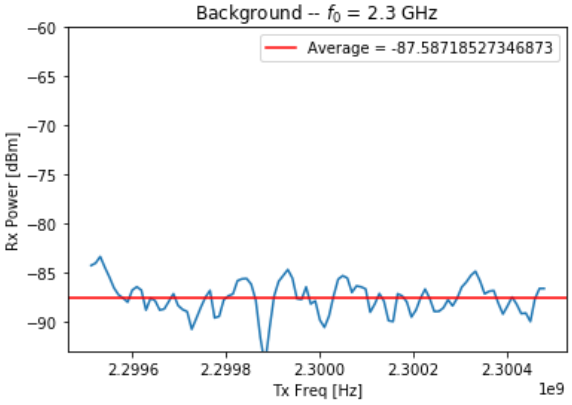
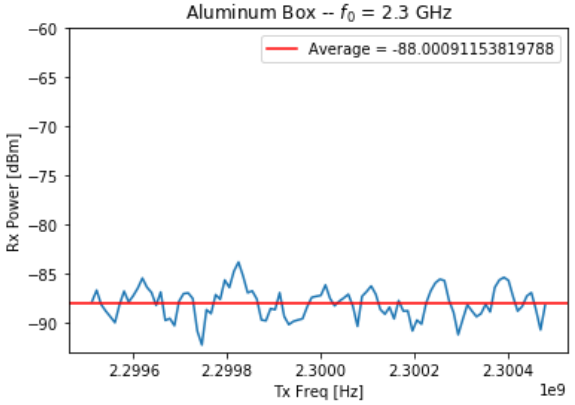
Targets

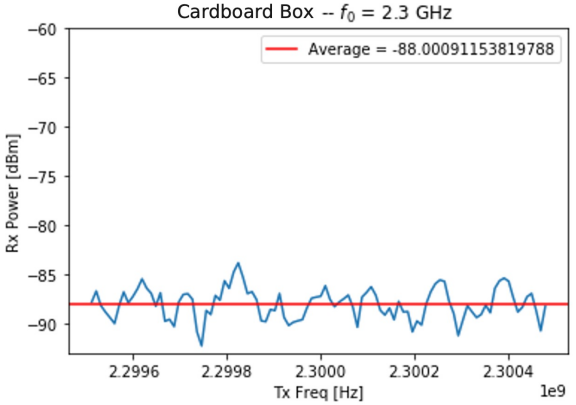


(a) Samsung Nexus S Li-Ion, (b) Li-Ion 1865, (c) NiMH AA, (d) Alkaline AA, (e) CR2032 coin cell, (f) NiMH AAA, (g) Alkaline AAA.

Results - Baseline







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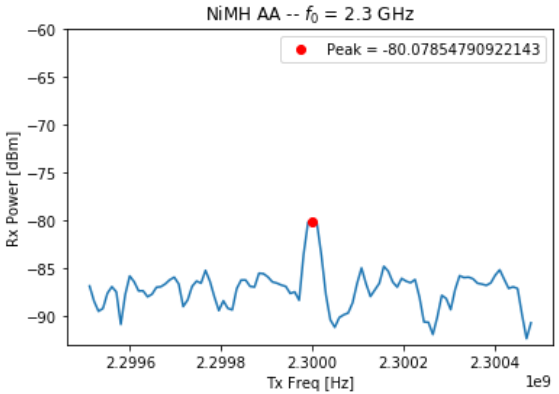

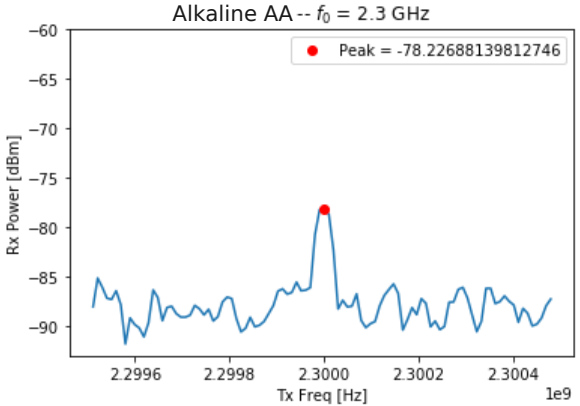

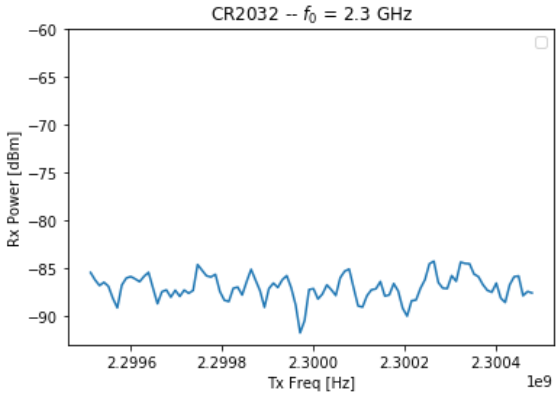

Results - Insights

- The harmonic radar detected the batteries in our testbed, except for the CR2032 coin cell.

Battery Type	Response (dBm)	Difference
Background	-87.6	0.0
NiMH AAA	-82.1	5.5
Alkaline AAA	-80.2	7.4
CR2032	**-86.1**	**1.5**
NiMH AA	-80.0	7.6
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Li-Ion 18650	-76.6	11.0
Nexus S Li-Ion	-80.6	7.0

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Results - Insights

- The harmonic radar detected the batteries in our testbed, except for the CR2032 coin cell.
- The larger the battery (e.g., AA vs. AAA), the higher the average response.
- Changing f_0 had no effect in detecting the presence of our test batteries.
  - Tested in the range: [2.0GHz-2.8GHz]

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- We had constraints in maximum detection range.
  - Target's radar cross section
  - Material covering it.
- We did not explore multi-target arrangements.
  - Batteries installed in electronics.
  - Multiple batteries in line-of-sight.

Contributions

- A theoretical discussion about why a harmonic radar should detect batteries.
- Laboratory experiments that confirm a harmonic radar does detect batteries.

Thank You! Questions?

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Contact : cesar.n.arguello.martinez.gr@dartmouth.edu

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