

Extreme Positioning for Billions of “Things”

Fadel Adib



Extreme Positioning for Billions of “Things”

Where are
my keys?



Robotic
Manipulation



Medicine
Adherence



Battery-Free UHF RFID Stickers

Each sticker costs few cents



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Each sticker costs few cents



Reply to wireless reader
with a unique identifier



This Talk: Enabling wide-area high-accuracy localization for billions of deployed RFID

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- Objects inside the box are tagged with RFIDs

**Board
eraser**

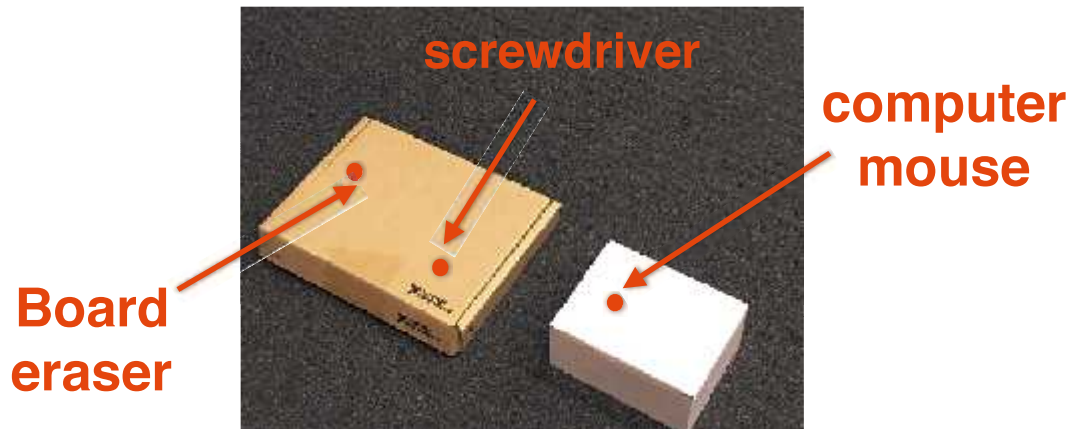
screwdriver

**computer
mouse**



This Talk: Enabling wide-area high-accuracy localization for billions of deployed RFID

- Objects inside the box are tagged with RFIDs



This Talk: Enabling wide-area high-accuracy localization for billions of deployed RFID

- Objects inside the box are tagged with RFIDs



Two Fundamental Challenges

Limited Bandwidth

Tens of kHz bandwidth →
poor localization accuracy



RFind

Ultra-wideband emulation
enables sub-cm localization
[MobiCom '17]

Ultra-Low Power

Battery-free nature →
Tens of cm to few meters range



RFly

Drone-based relay increases
coverage by 100x
[SIGCOMM '17]

RFind

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[MobiCom '17]

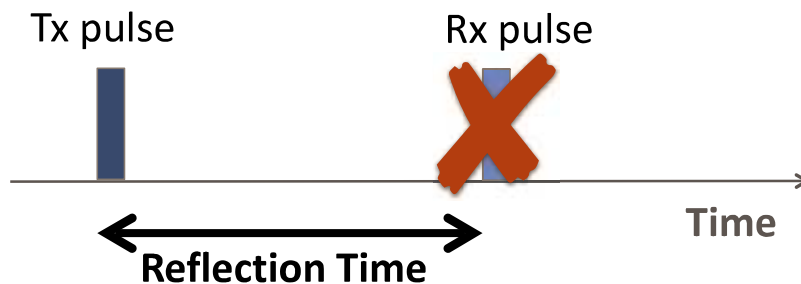
Localize by Measuring Distances



$$\text{Distance} = \text{Time-of-flight} \times \text{speed of light}$$

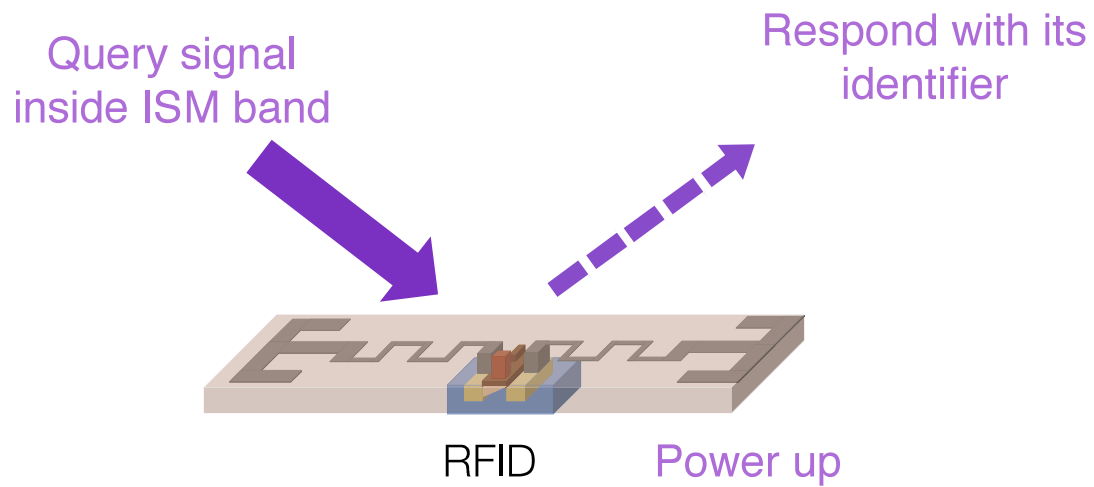
Measuring Time-of-Flight

Option1: Transmit short pulse and listen for RFID response

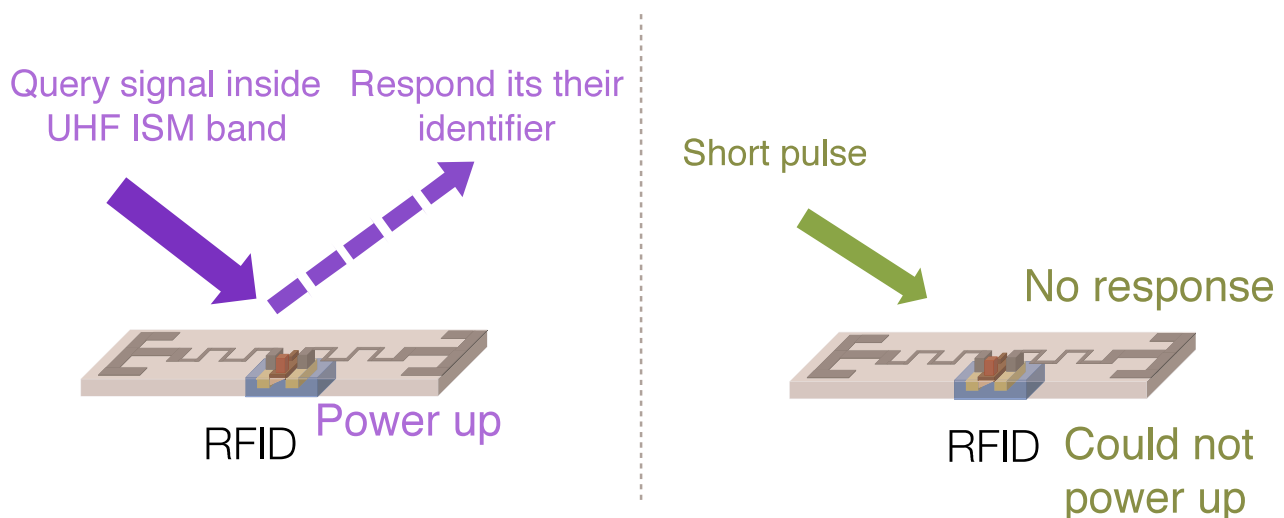


Problem: RFID does not respond!

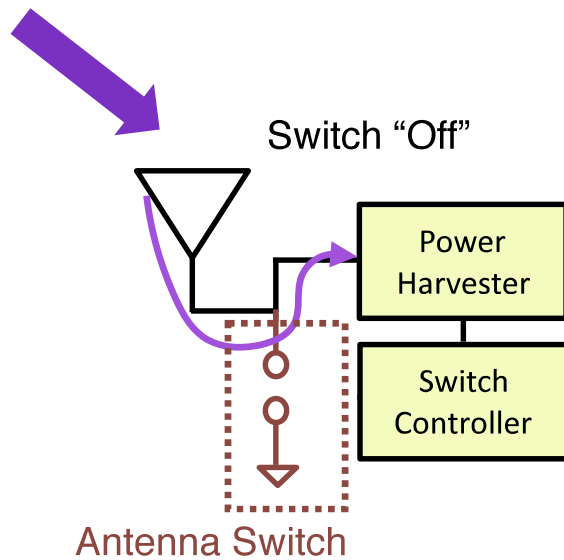
Problem: Battery-free UHF RFIDs are designed to respond to a reader's narrowband query signal



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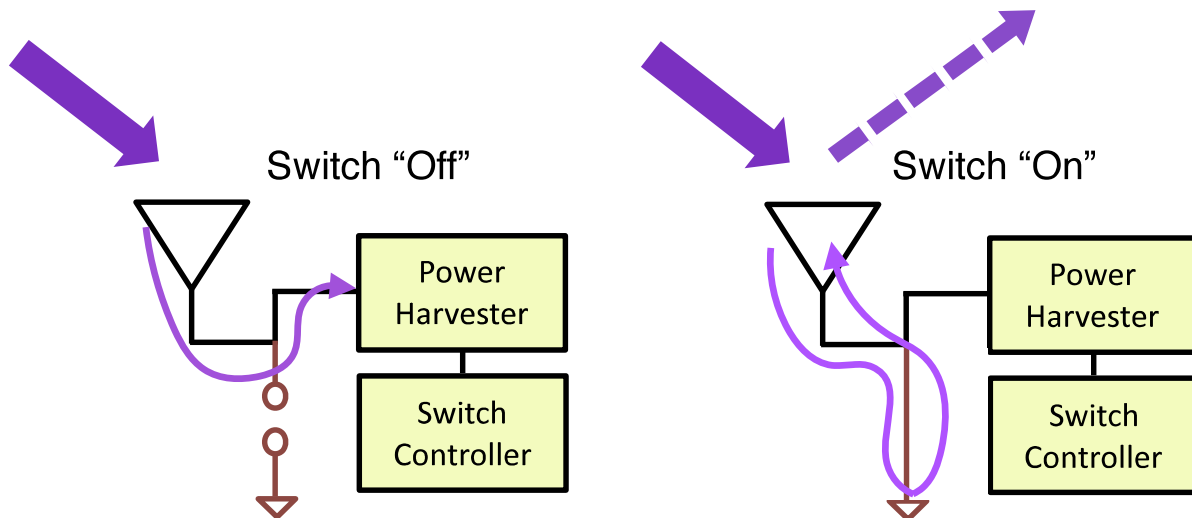


Key Realization:
RFID Modulation is Frequency Agnostic



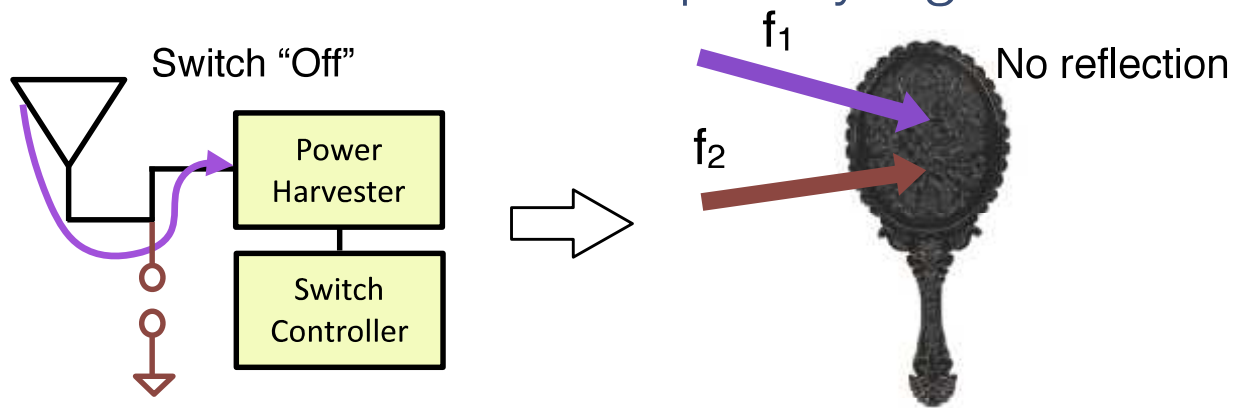
Simplified RFID schematic

Key Realization:
RFID Modulation is Frequency Agnostic

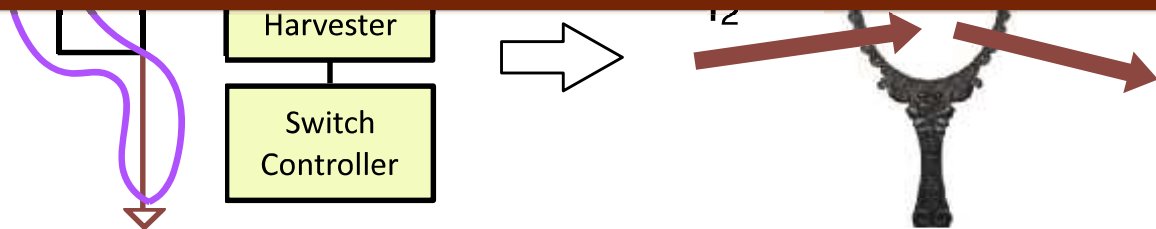


Key Realization:

RFID Modulation is Frequency Agnostic



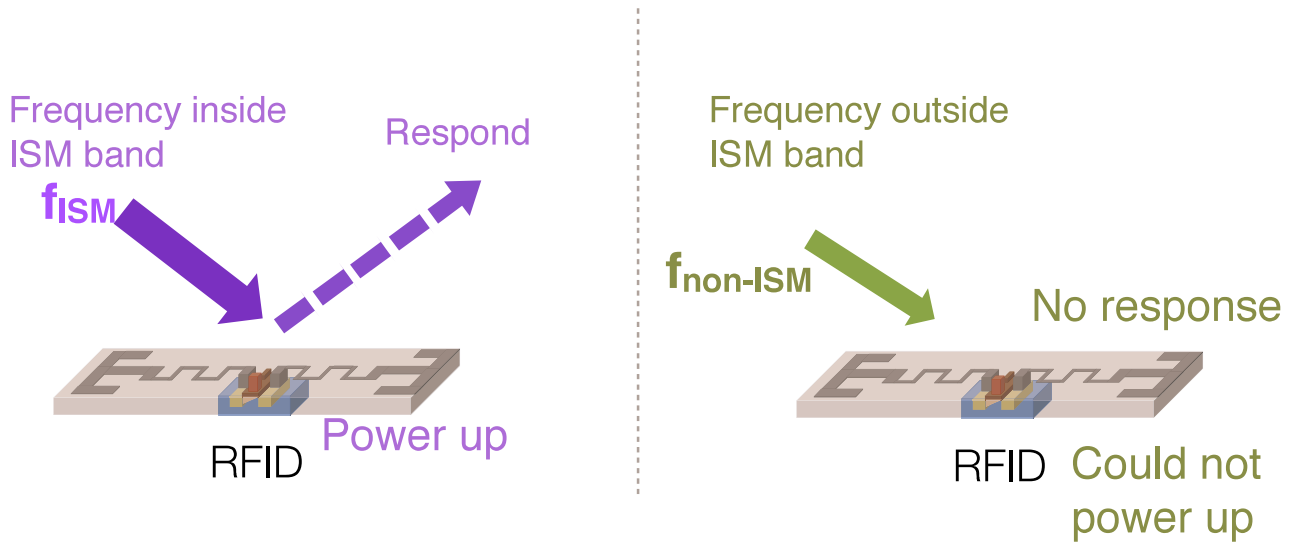
But we need to power up RFID in the first place



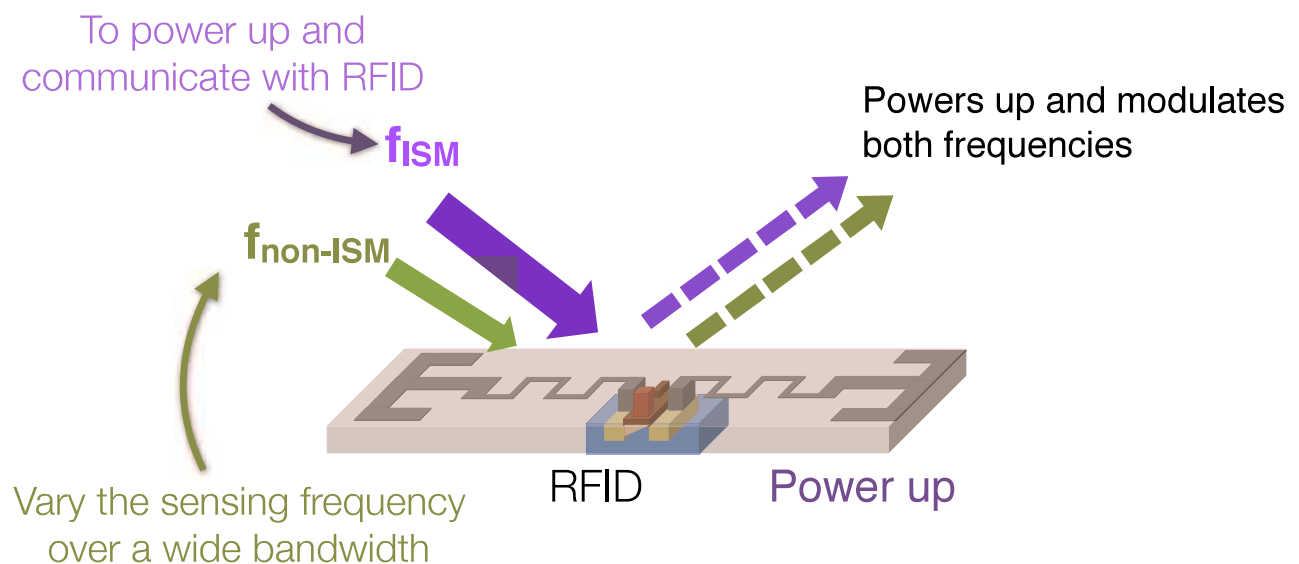
Dual-Frequency Excitation

a technique that decouples powering up from sensing in RFID localization

Dual-Frequency Excitation

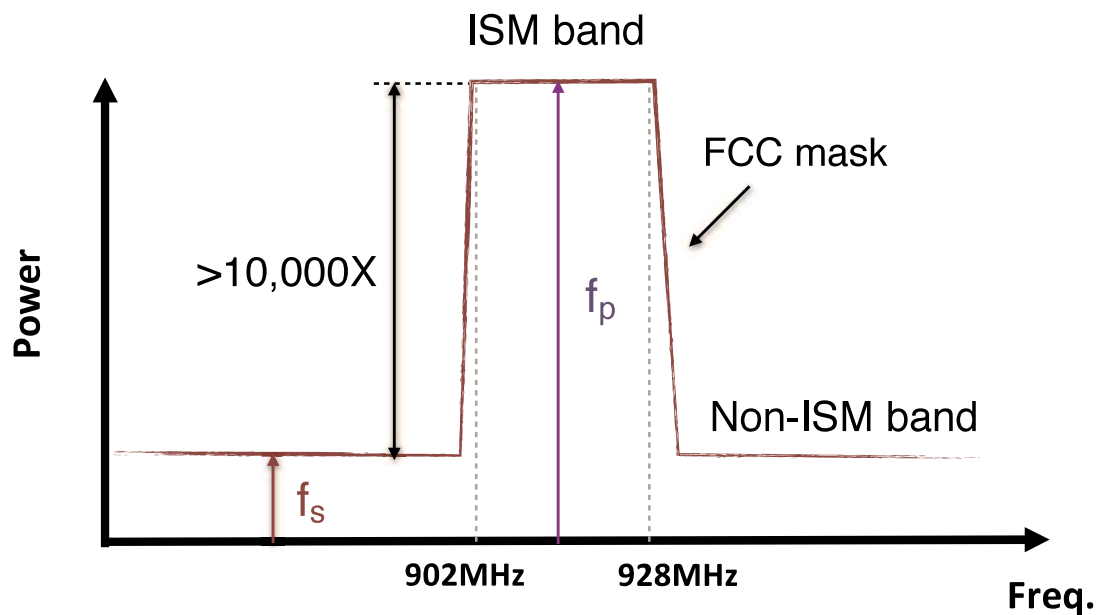


Dual-Frequency Excitation

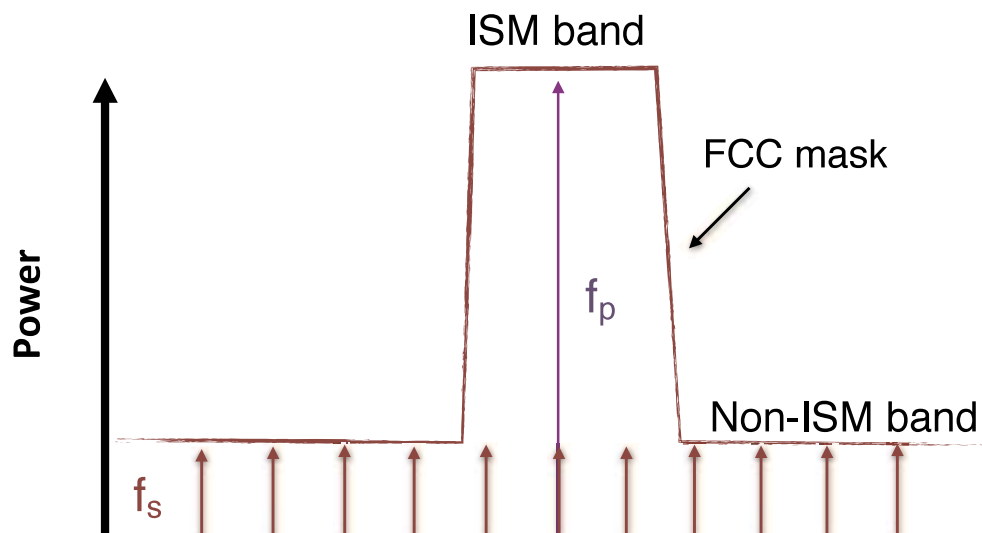


Wide Bandwidth → Time-of-flight → Accurate Localization

How can we perform wideband sensing despite FCC regulations?

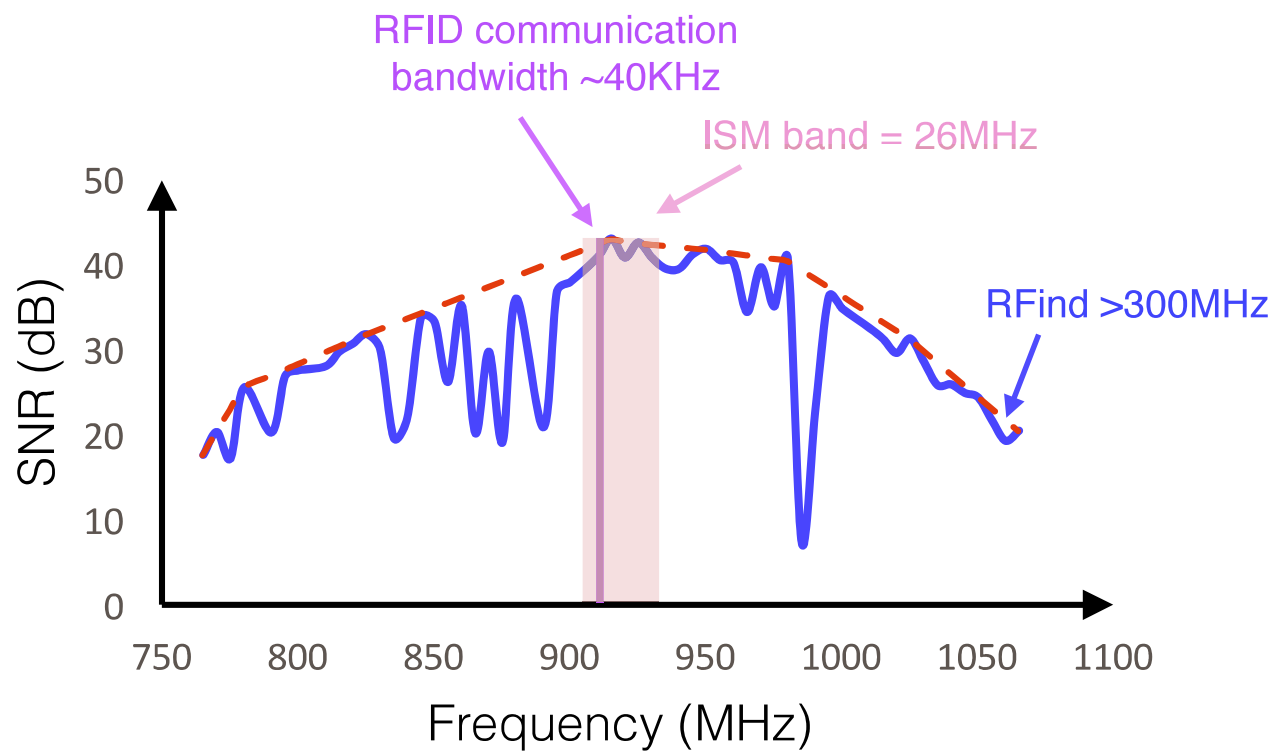


How can we perform wideband sensing despite FCC regulations?



Additional techniques to address multipath and achieve super-resolution accuracy

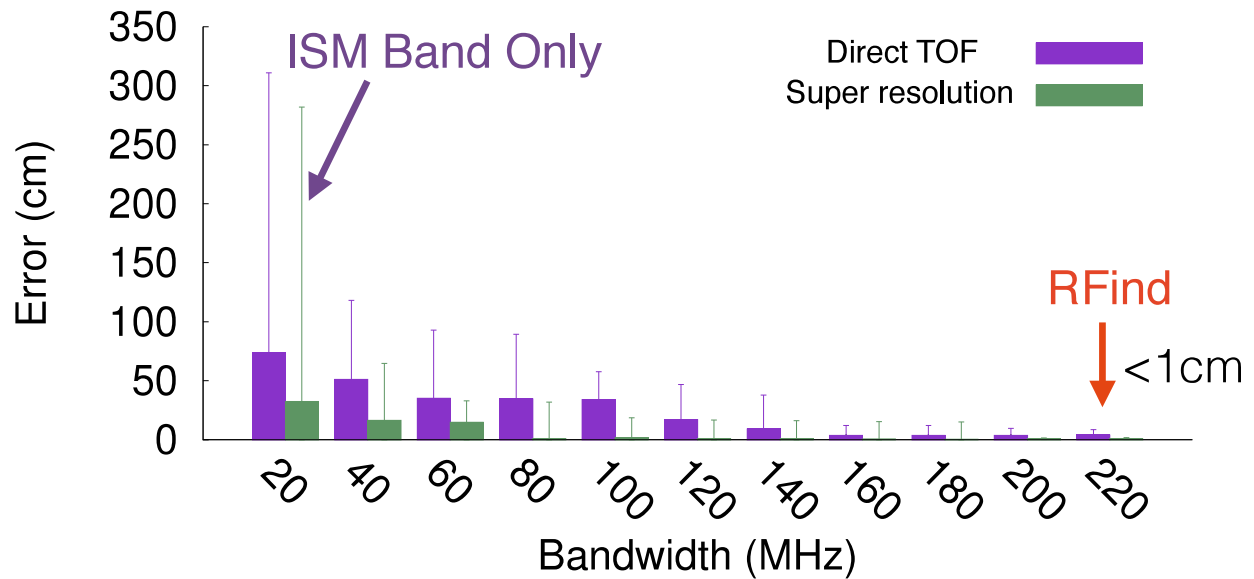
How much bandwidth can RFind emulate?



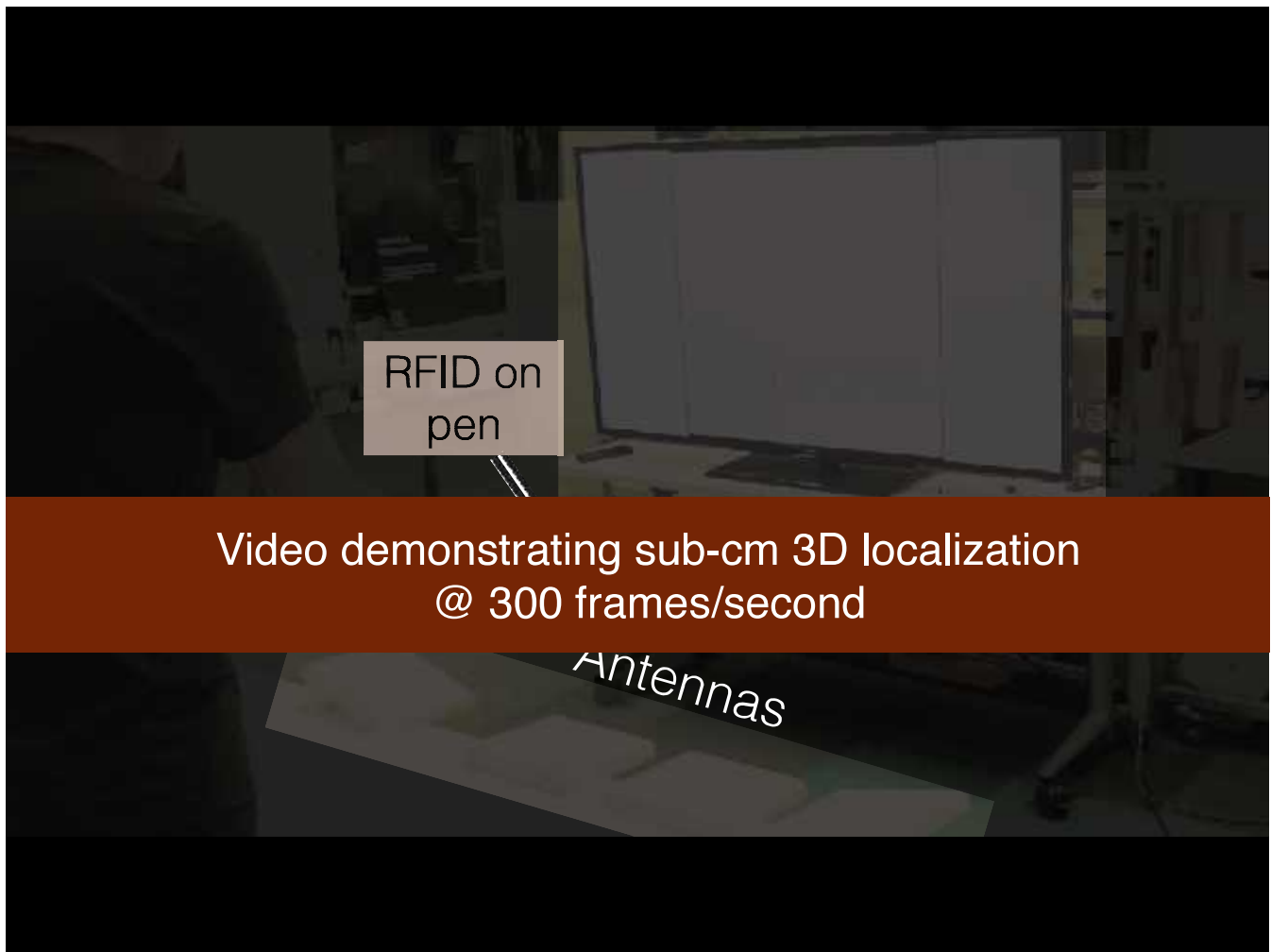
Video Demonstrating cm-scale Localization



Accuracy vs. Bandwidth



At What Speed Can We Track?



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[MobiCom '17]

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Warehouse Management

An inventory cycle in a single warehouse takes more than a month (NY Times)

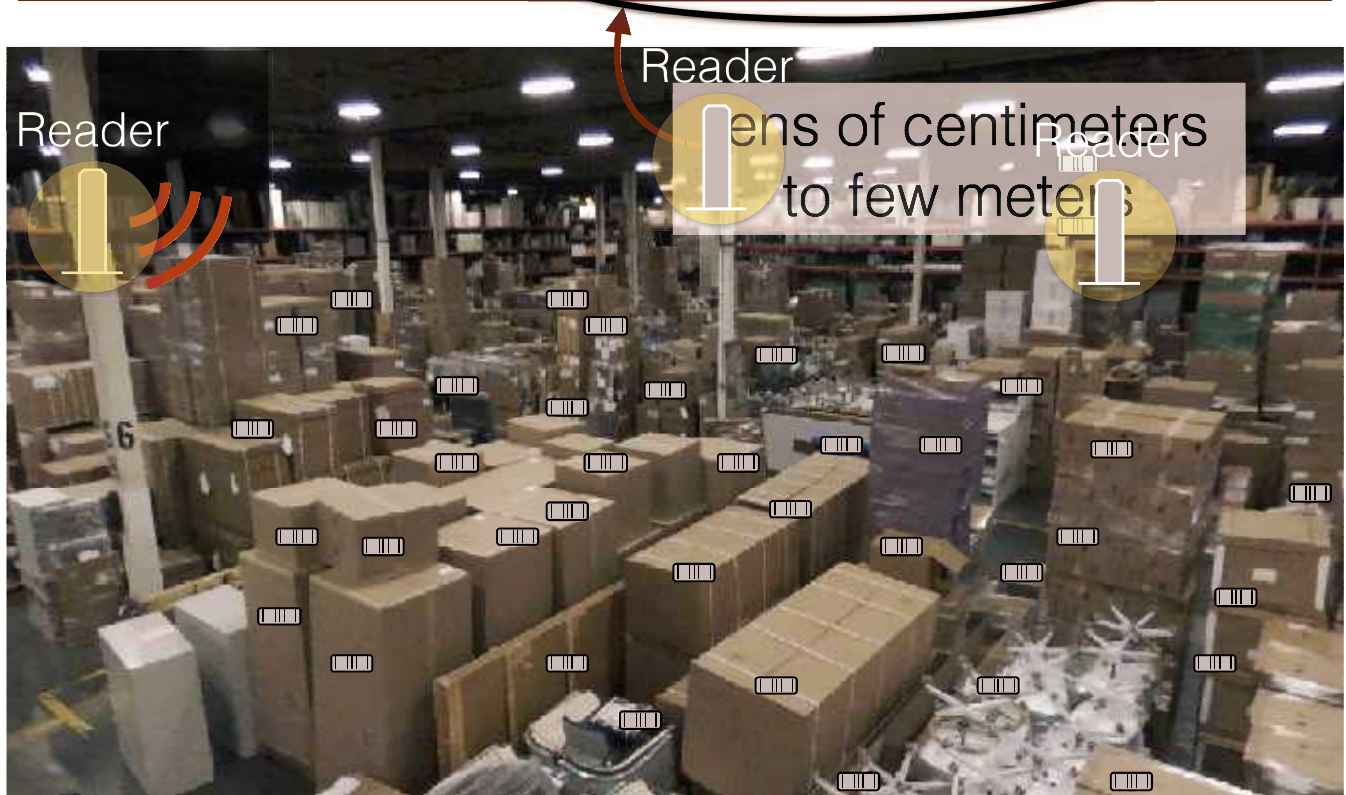
Walmart lost 3 billion dollars in a single year because of inventory mismatch (Fortune)

Battery-Free RFIDs for Inventory Control

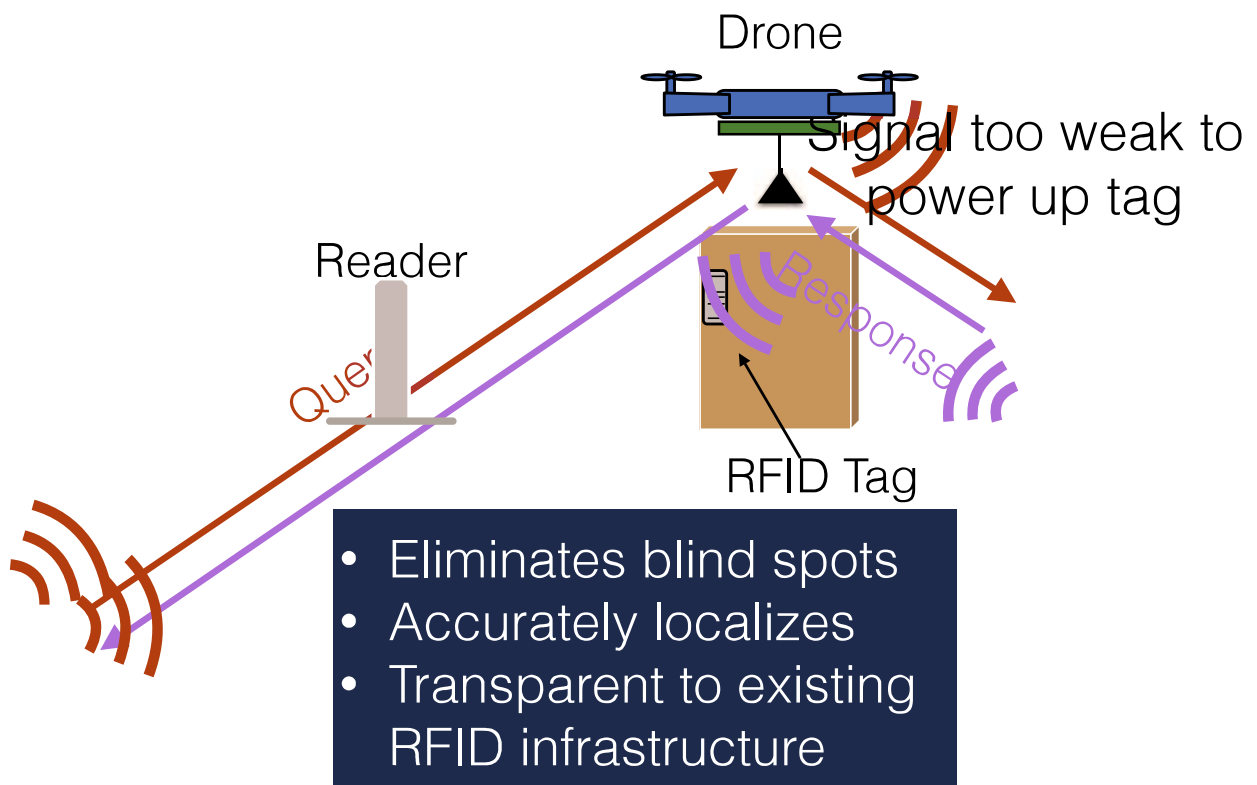


Read and uniquely identify it from a distance

Battery-free RFIDs are fundamentally crippled by their limited communication range



Warehouse-scale RFID inventory control and positioning using drone relays

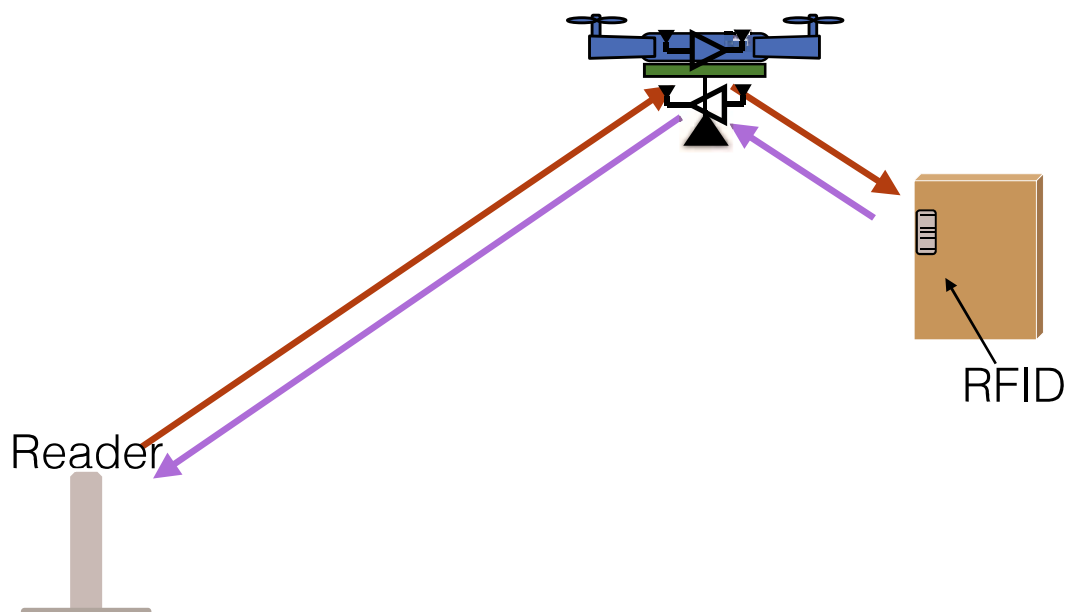


How Can We Design Relays for Localization?

Range extension requires amplifying the relayed signal

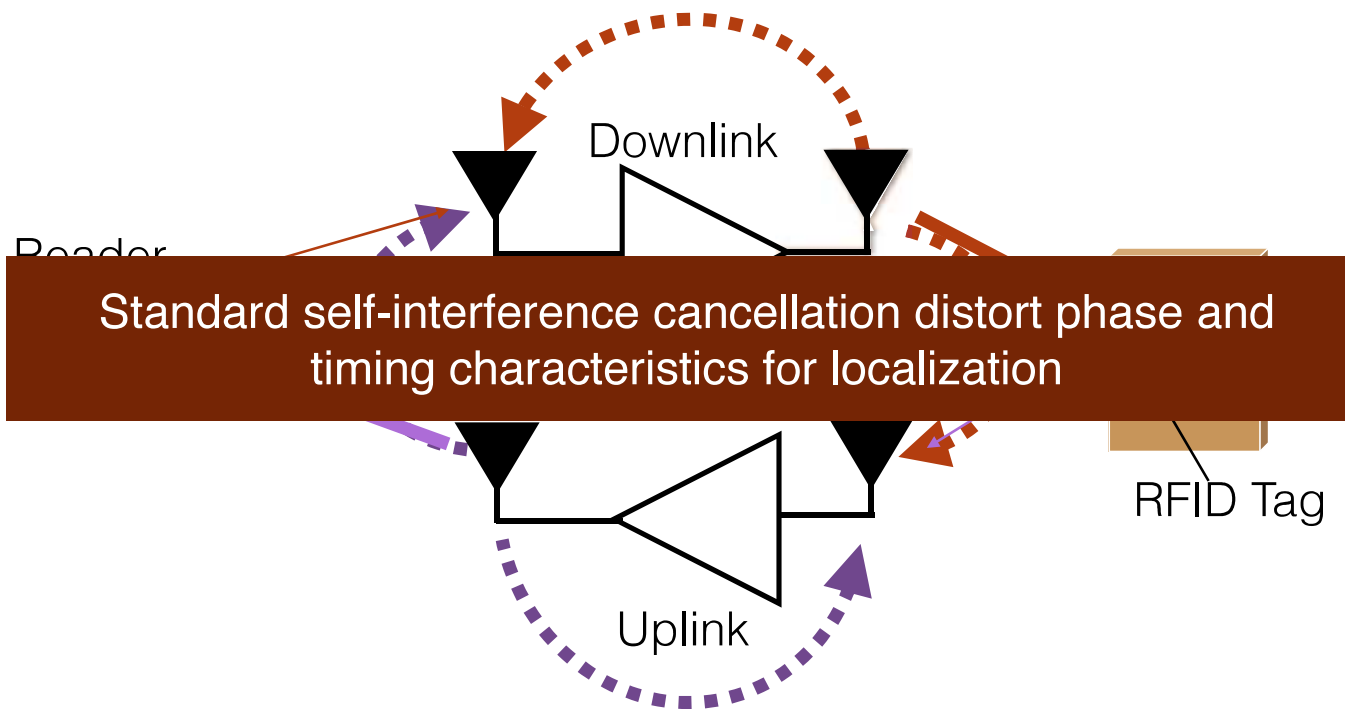
How Can We Design Relays for Localization?

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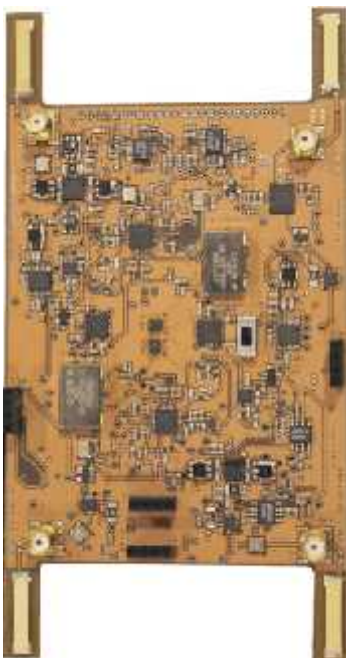


Problem: More amplification results in more self-interference

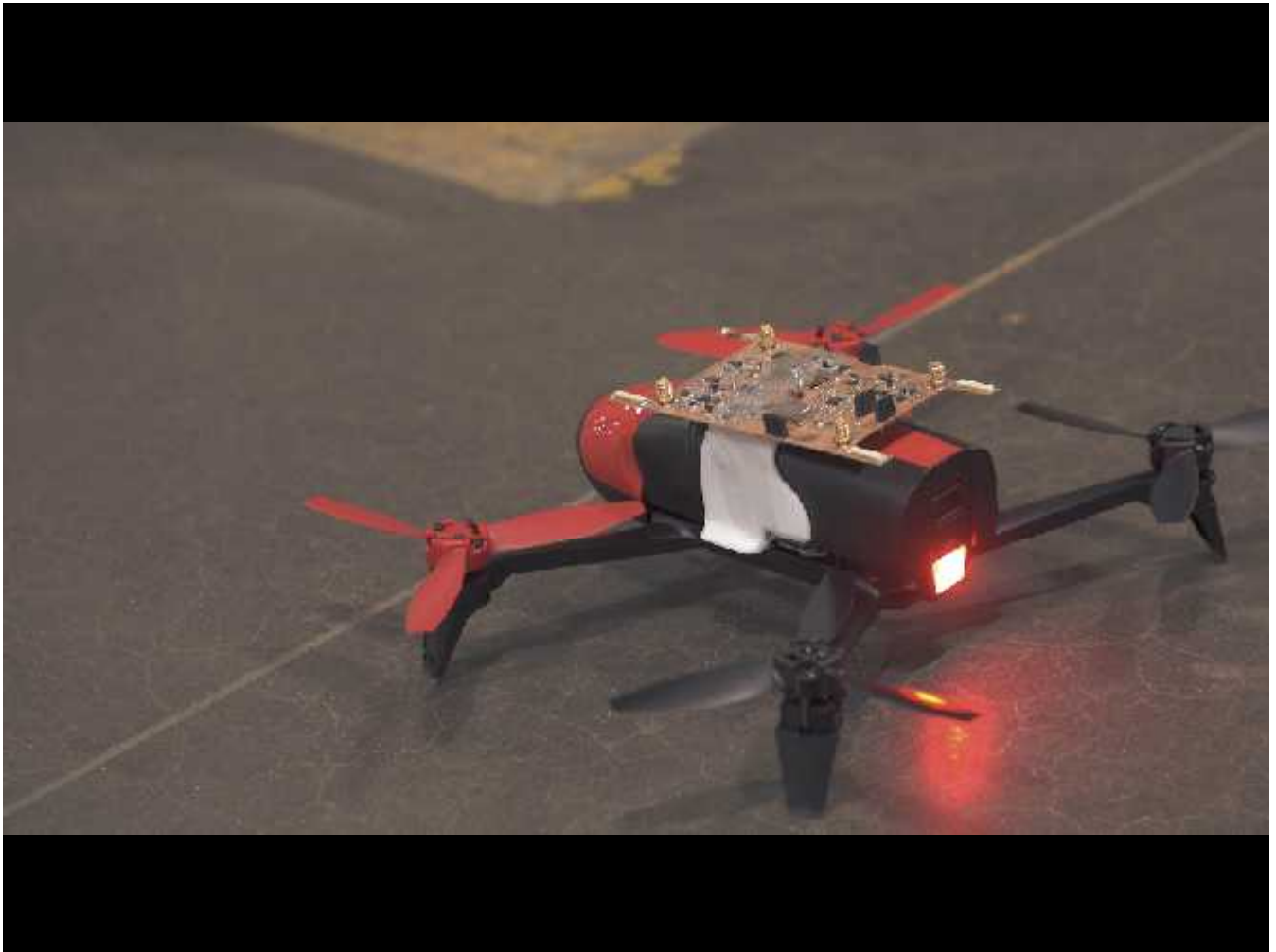
Four sources of self-interference



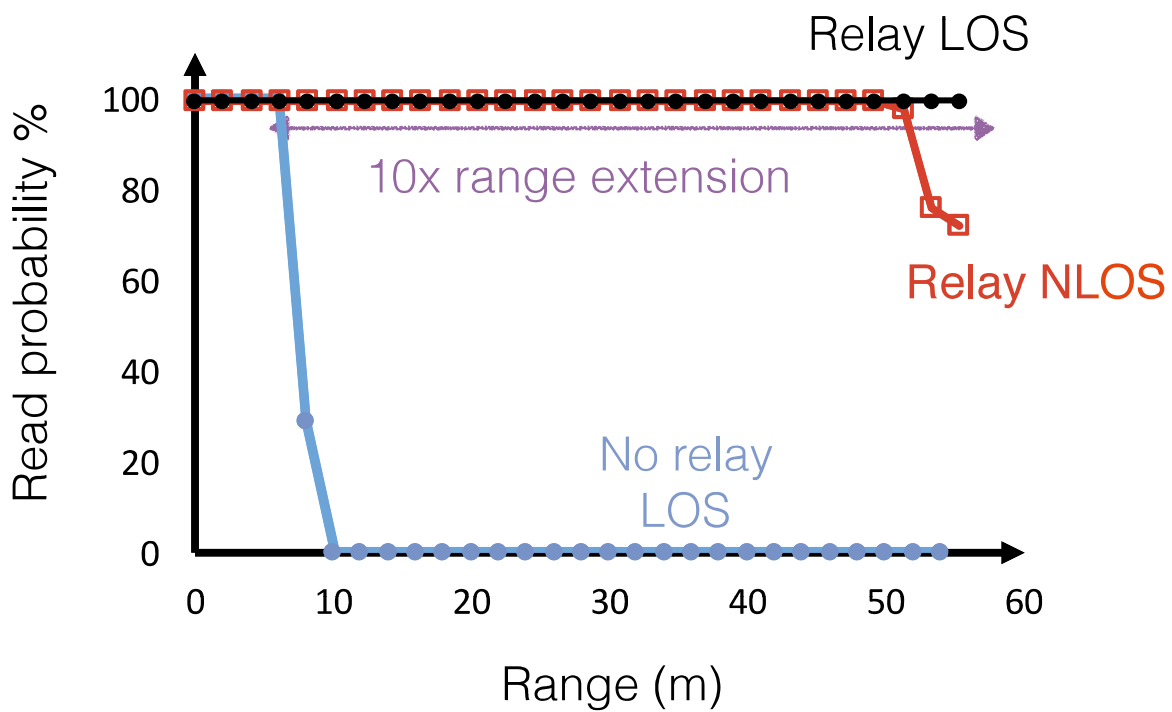
Solution: Bi-directional full-duplex relay with phase & timing preservation



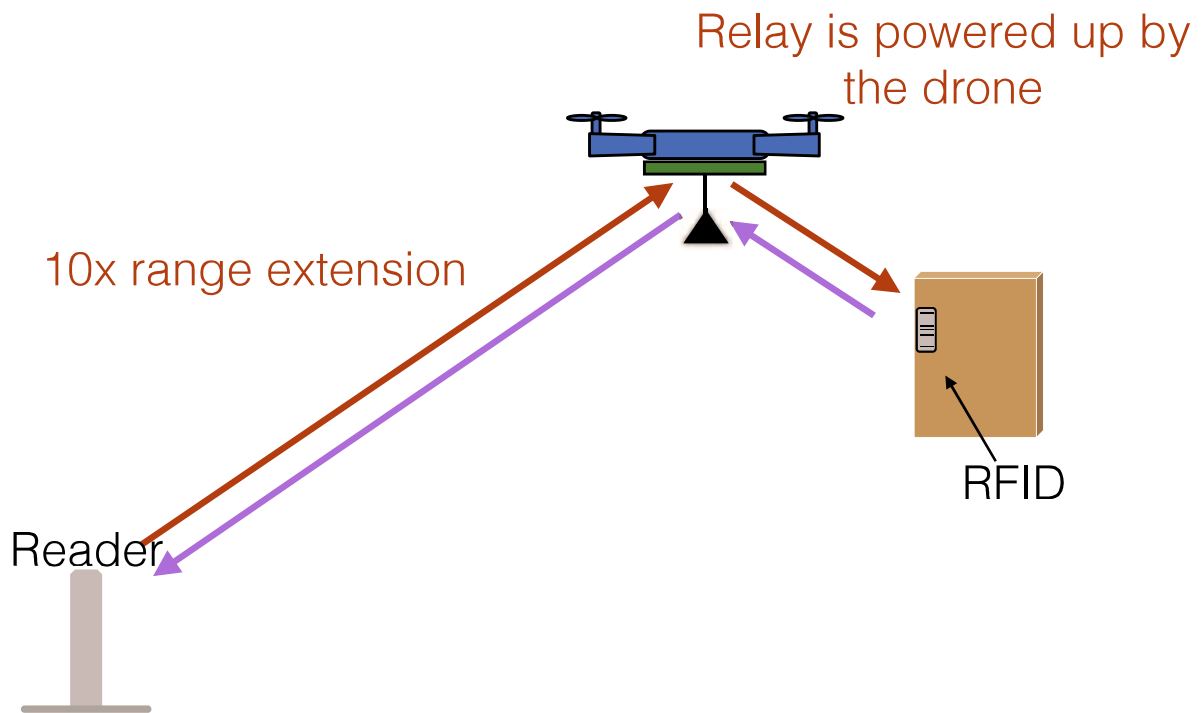
- Analog self-interference cancellation
 - 10 million times amplification (70dB)
- Highly accurate timing
 - Pico-second (10^{-12}) timing precision
- Small form factor & light weight
 - Size: 10 x 7.5 cm
 - Weight: 35 g
- Low Power
 - Consumes <3% drone's battery



How much can RFly extend reading range?



How much can Rfly extend reading range?



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[SIGCOMM '17]

RFind

[MobiCom '17]



- First technology that enables emulating ultra wide bandwidth on billions of deployed RFIDs
- Achieves sub-centimeter localization accuracy

RFly

[SIGCOMM '17]



- First systems that leverages drones as relays for battery-free systems
- Extends communication area by 100x with accurate localization

Can we sense humans without RFIDs?
using wireless reflections off their bodies

[SIGCOMM '13, NSDI '14, NSDI '15, SIGGRAPH '15, CHI '15, MobiCom '16]

