Towards Internet Connectivity for Implanted Devices

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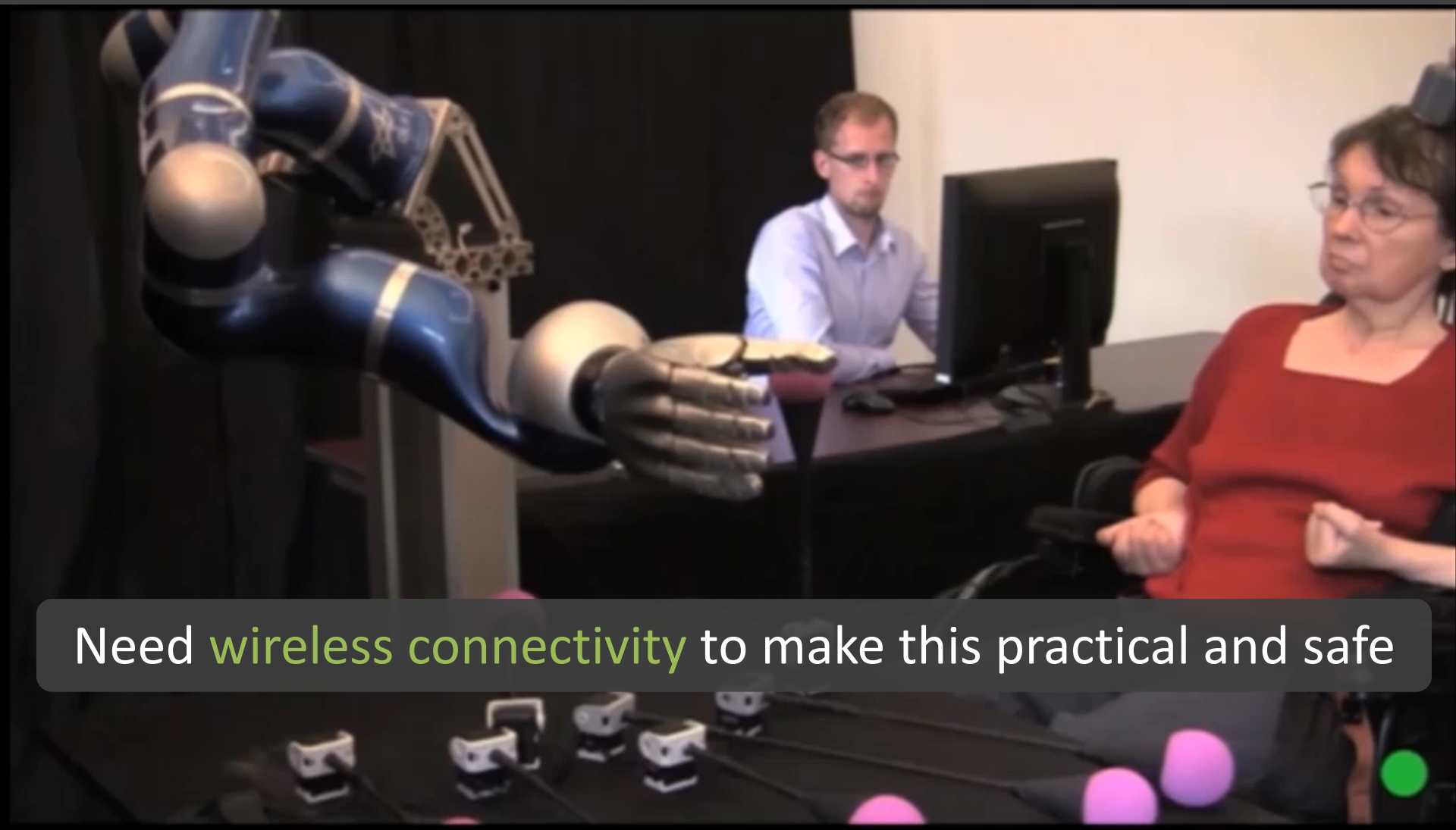
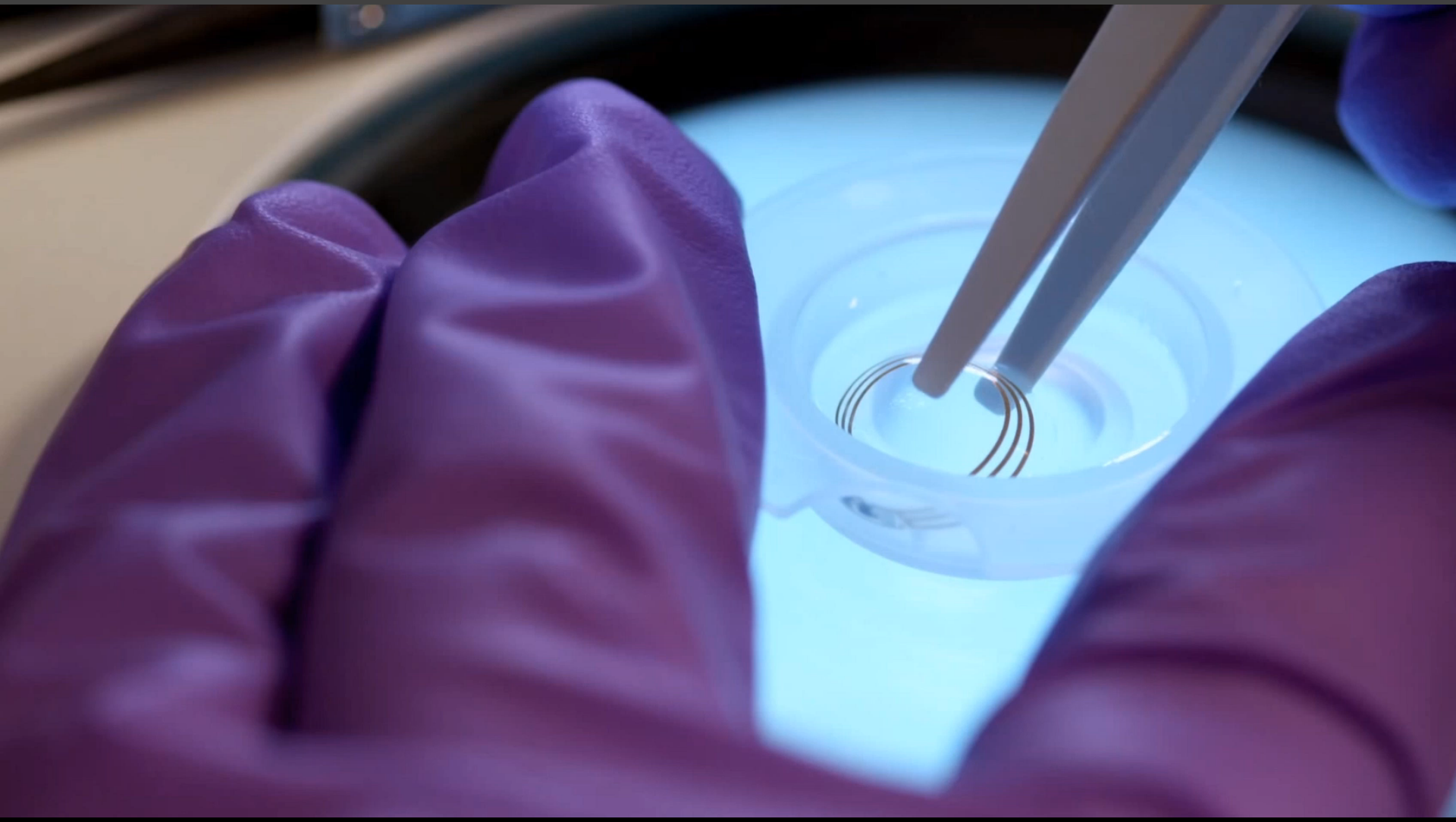
Brain implants for reanimation of limbs



Brown University - Guardian News & Media Ltd

Contact lenses that measure blood sugar

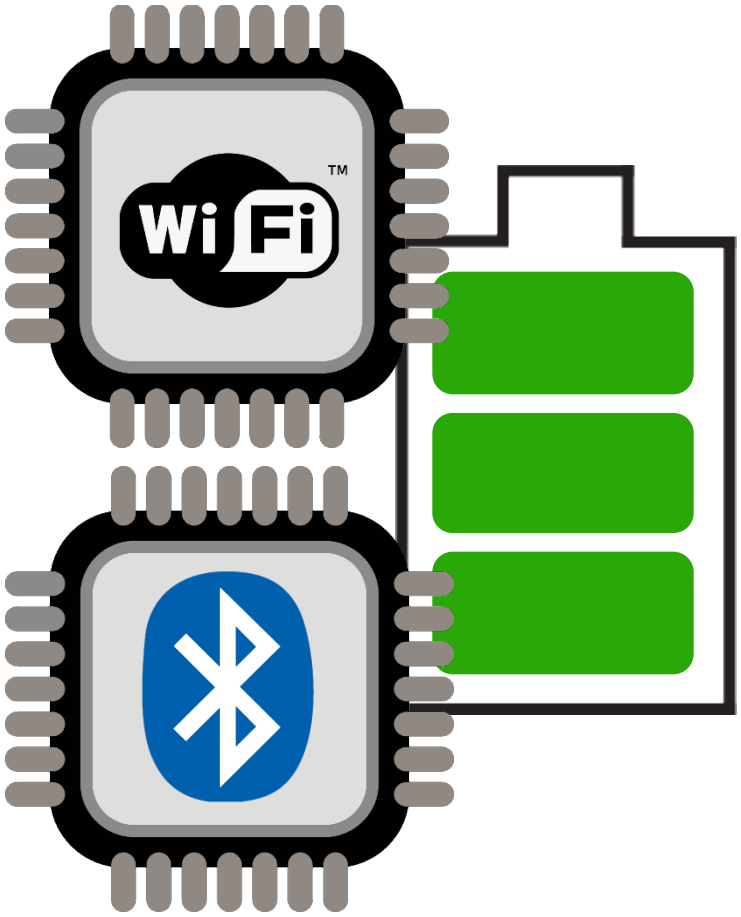


Google- Business Computing World

Contact lenses that measure blood sugar

Can implanted devices talk to smartphones?

Conventional radios consume too much power



Replacing implant batteries requires surgery

Problem: Creating RF signals is power expensive

Solution: Recycle RF signals from external devices

Interscatter Communication

Recycle Bluetooth signals to create WiFi

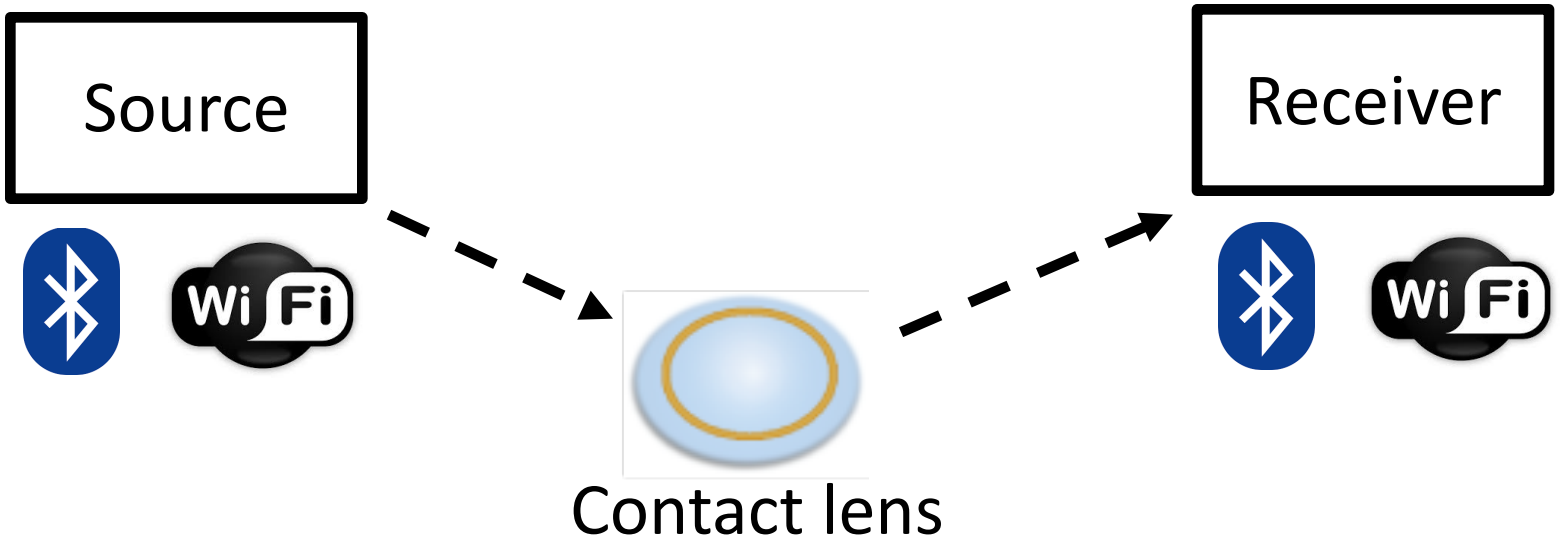
Creates WiFi packets for 28 µW of power

Our Contributions

- Build first Wi-Fi contact lens and brain implant proof of concepts

- Transform wireless transmissions from one technology to another, on the air
  - Bluetooth to 2-11Mbps Wi-Fi and ZigBee

System Requirements

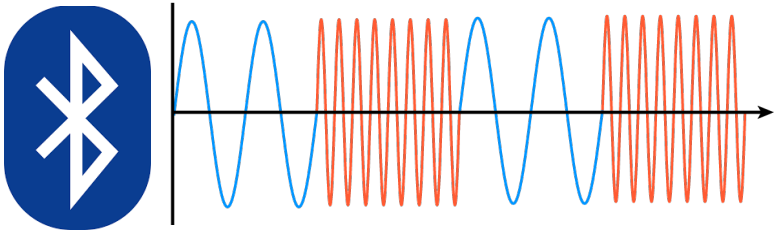


1. Commodity devices → Bluetooth/Wi-Fi
2. Minimize implant ON time → Send data at high rate
3. Source isn’t sending data → Minimize bandwidth

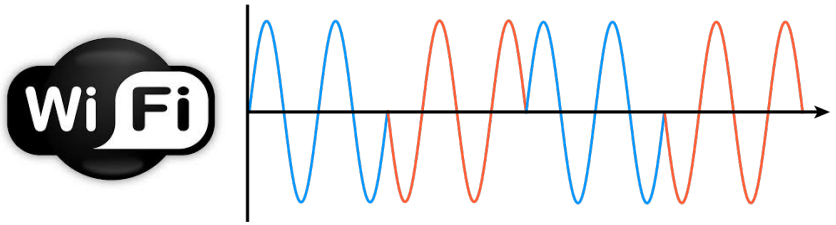
Problem: Bluetooth and WiFi are different protocols

Challenge 1: Different modulation

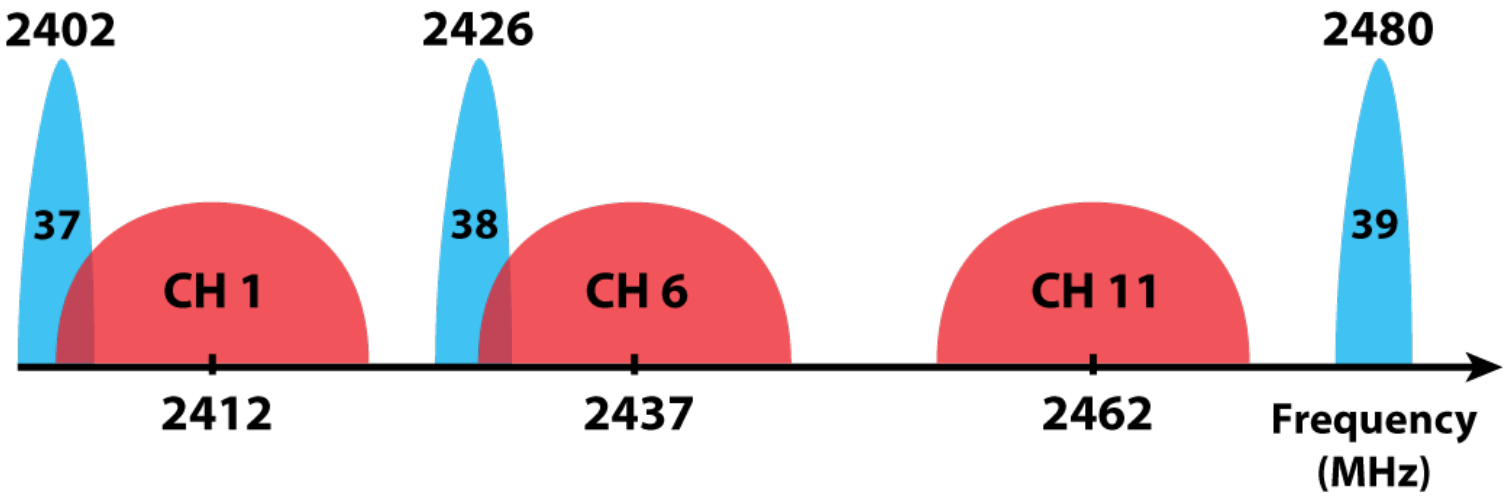
Frequency Shift Keying



Phase Shift Keying



Challenge 2: Different frequencies and bandwidth



Our Approach

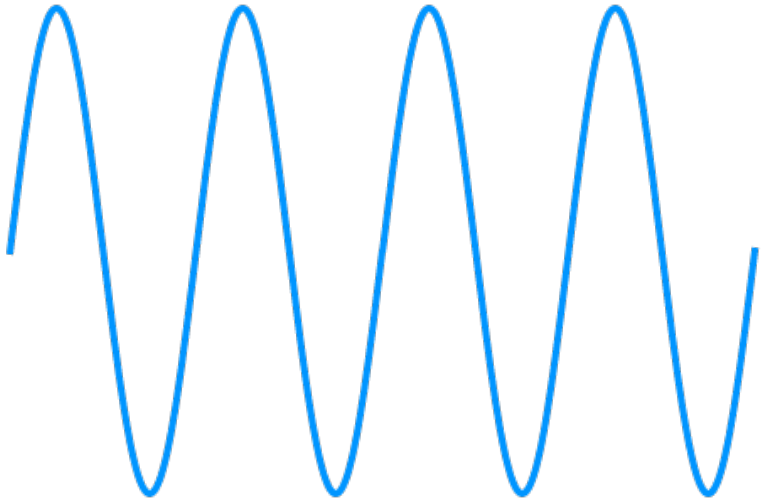
Step 1: Transform Bluetooth transmissions into single tone signals

Step 2: Reflect the single tone signal to create our own Wi-Fi packets

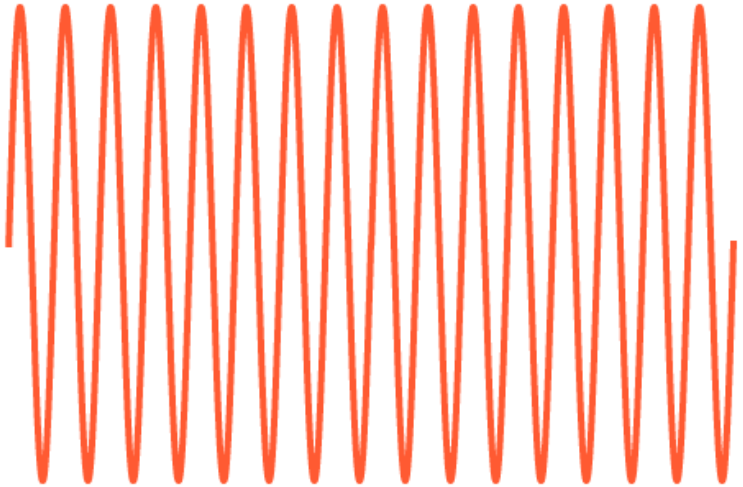
How do we create a single tone from Bluetooth?

Bluetooth uses frequency shift keying

$f_{low} = 0$

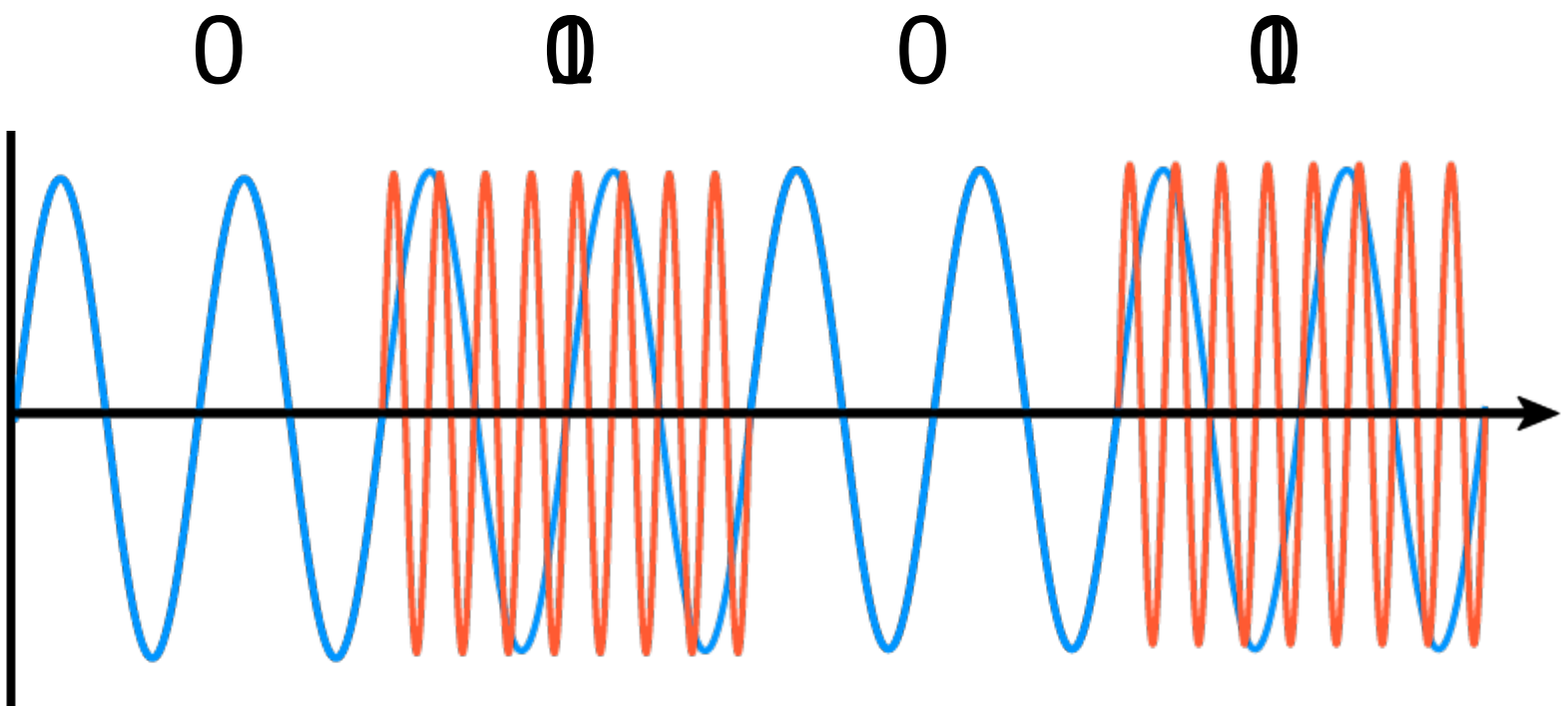


$f_{high} = 1$



How do we create a single tone from Bluetooth?

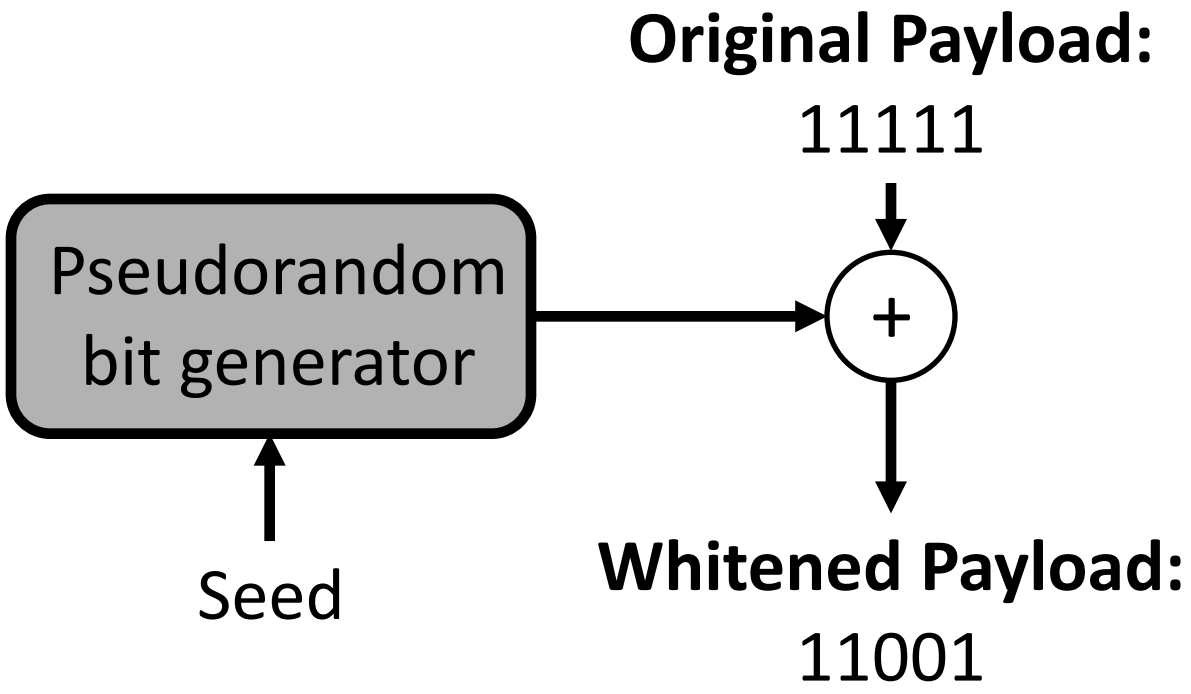
Bluetooth uses frequency shift keying



Transmitting all ‘0’ or ‘1’ bits creates a single tone

How do we create a single tone from Bluetooth?

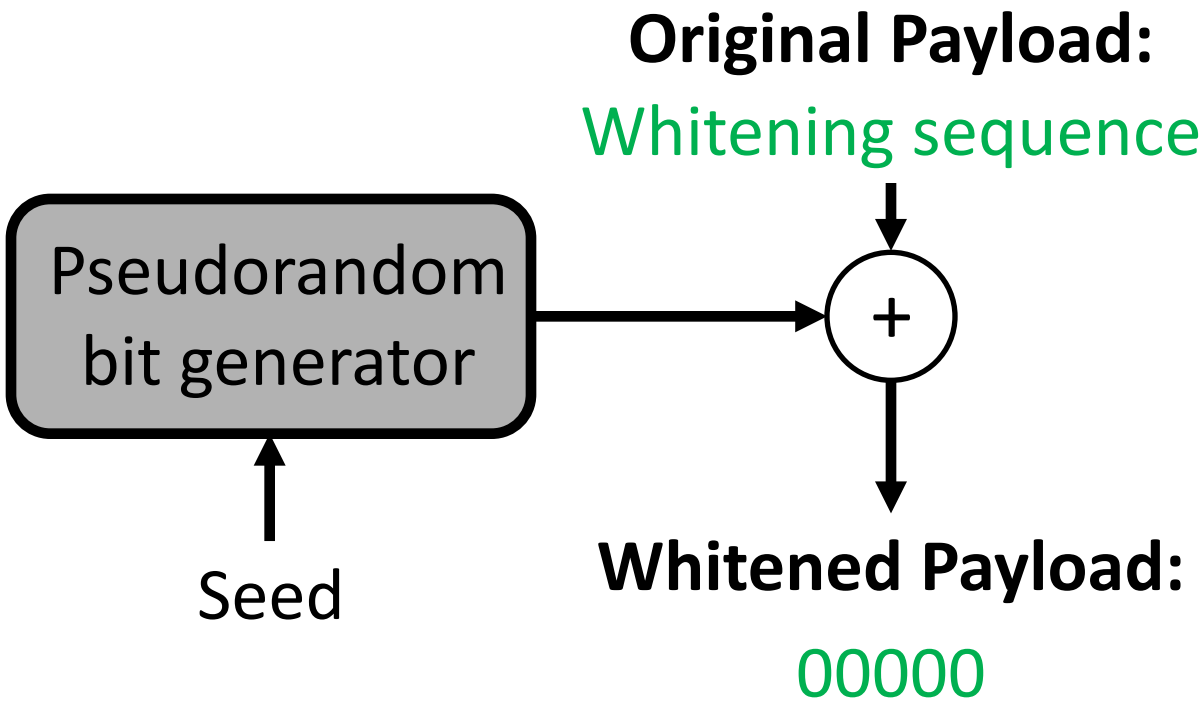
Problem: Bluetooth whitens the data



Seed is set to the channel number
→ Whitening sequence is constant

How do we create a single tone from Bluetooth?

Problem: Bluetooth whitens with a sequence



Transform Bluetooth to a single tone in user space

Seed is set to the channel number
→ Whitening sequence is constant

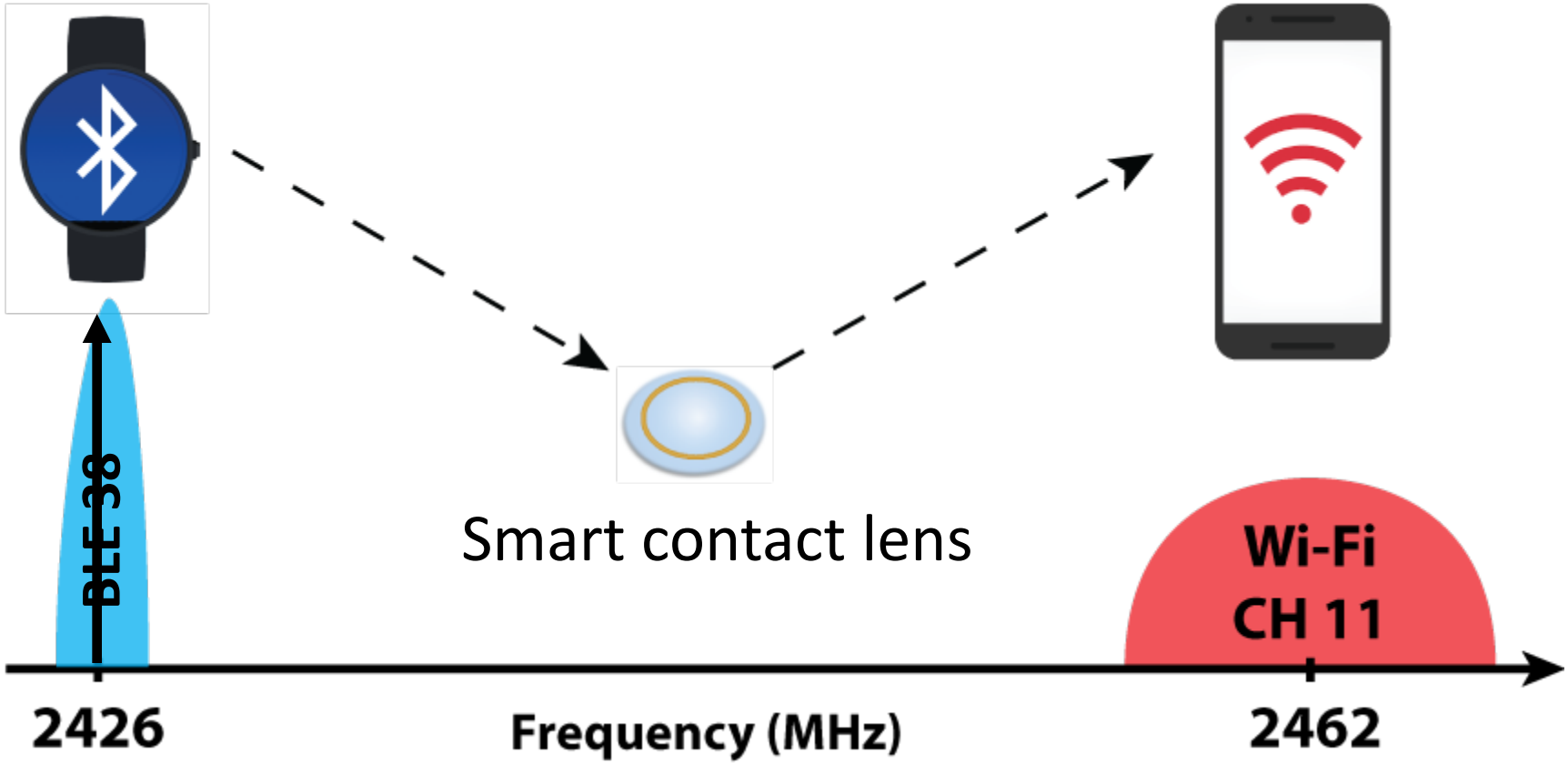
Our Approach

Step 1: Transform Bluetooth transmissions into single tone signals

Step 2: Reflect the single tone signal to create our own 802.11b packets

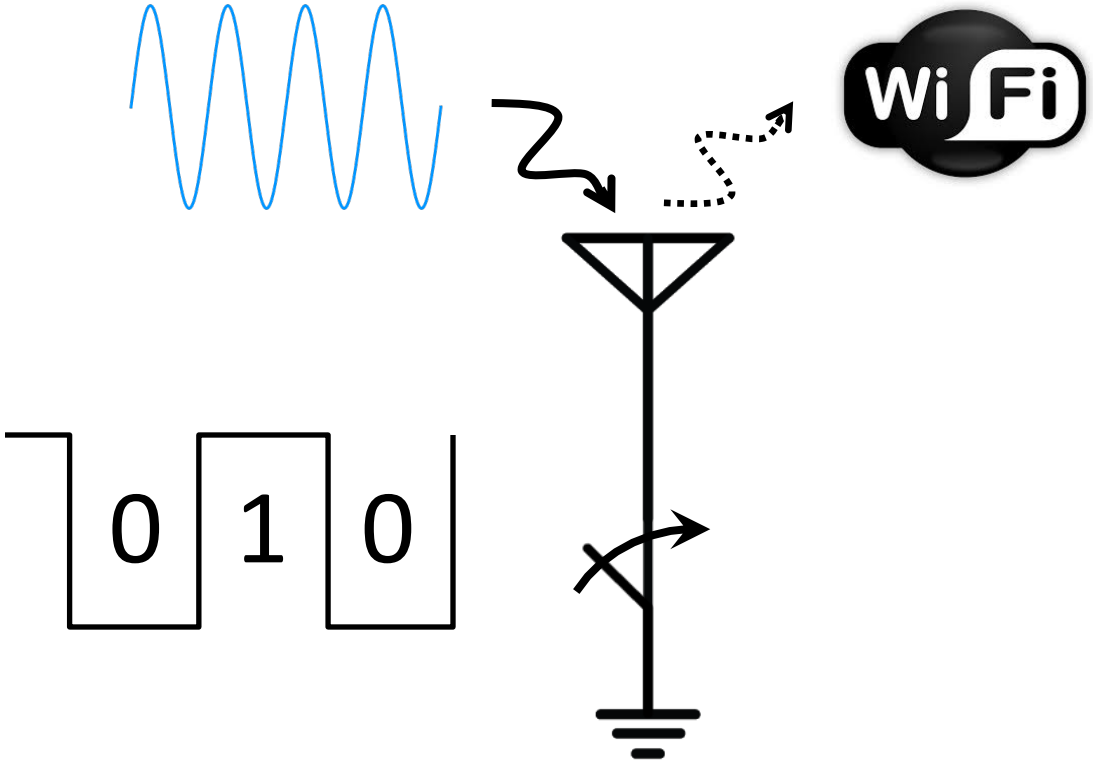
How do we create WiFi packets?

Problem: Bluetooth and WiFi use different frequencies

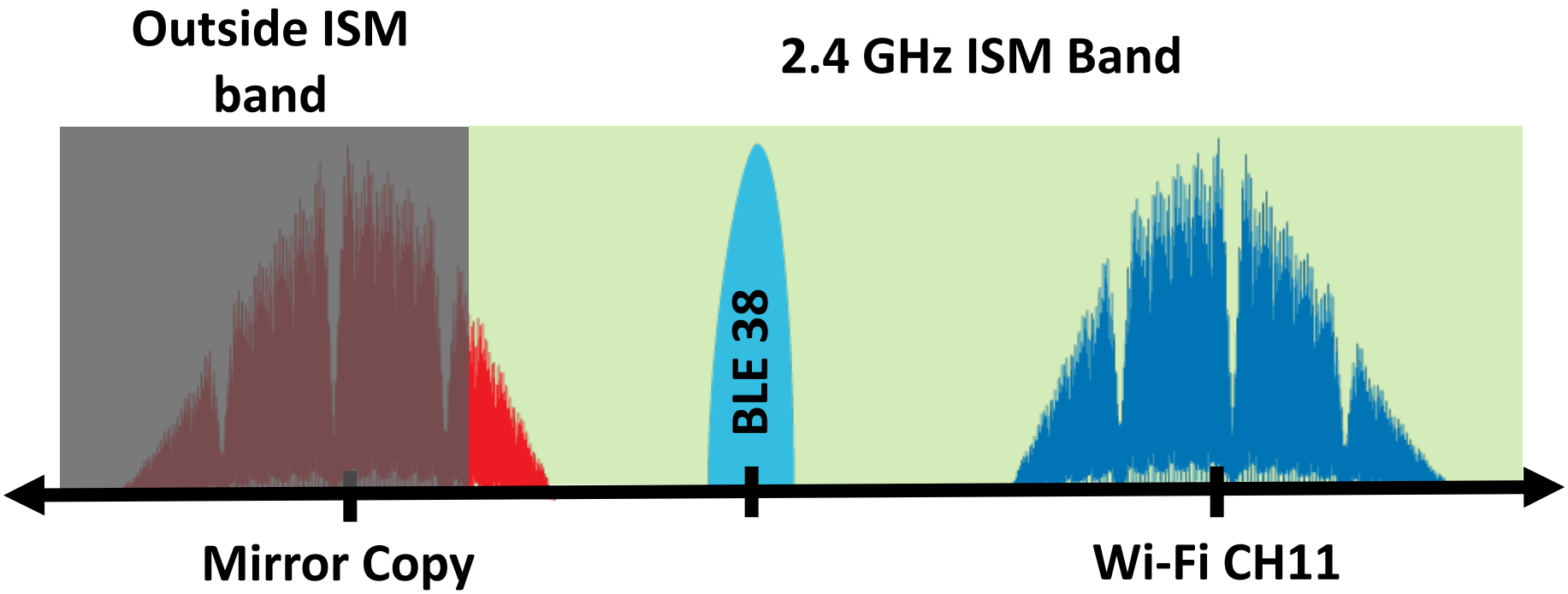


How do we create WiFi packets?

First-Order Solution: Use Passive WiFi (NSDI ‘16)

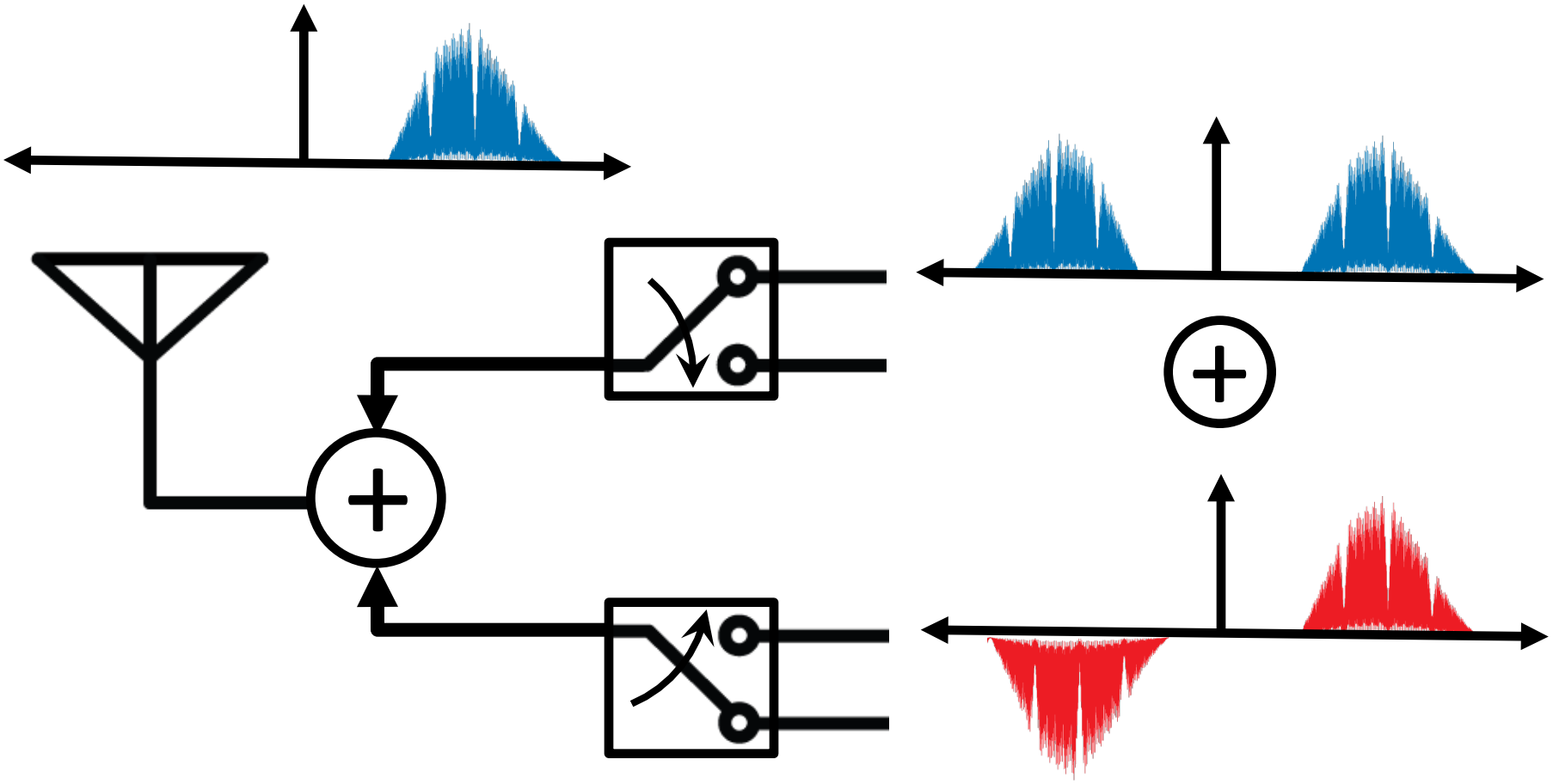


Problem: Passive WiFi creates mirror copy outside ISM band



Solution: First single sideband backscatter

Key Idea: Cancel mirror copy using two switches



Implementation

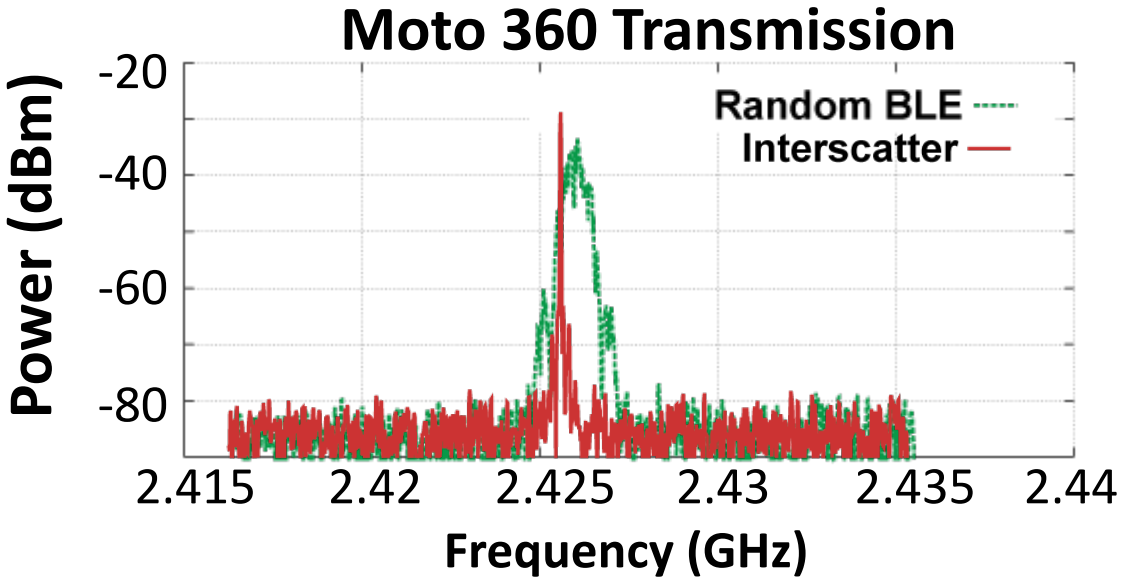
FPGA Prototype:

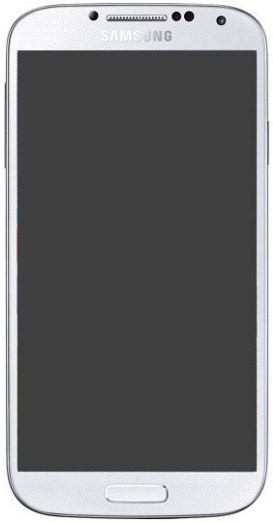
- Altera Cyclone II
- Custom backscatter switch
- 2-11 Mbps WiFi and 250 kbps Zigbee

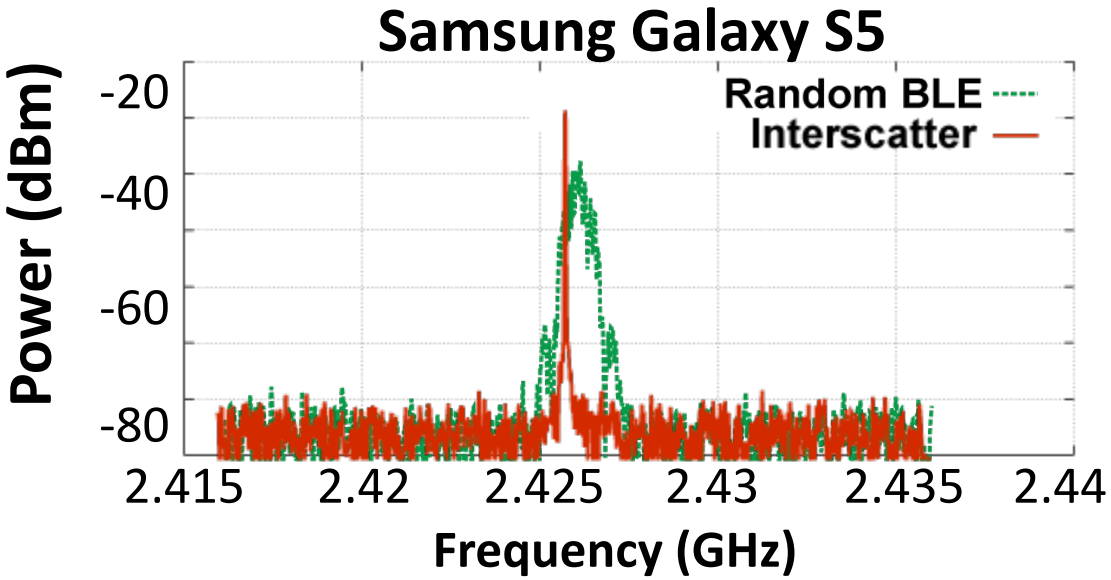
IC Implementation

- Verilog baseband, RF switch, & custom PLL
- TSMC 65nm LP Process
- 28 µW at 2 Mbps

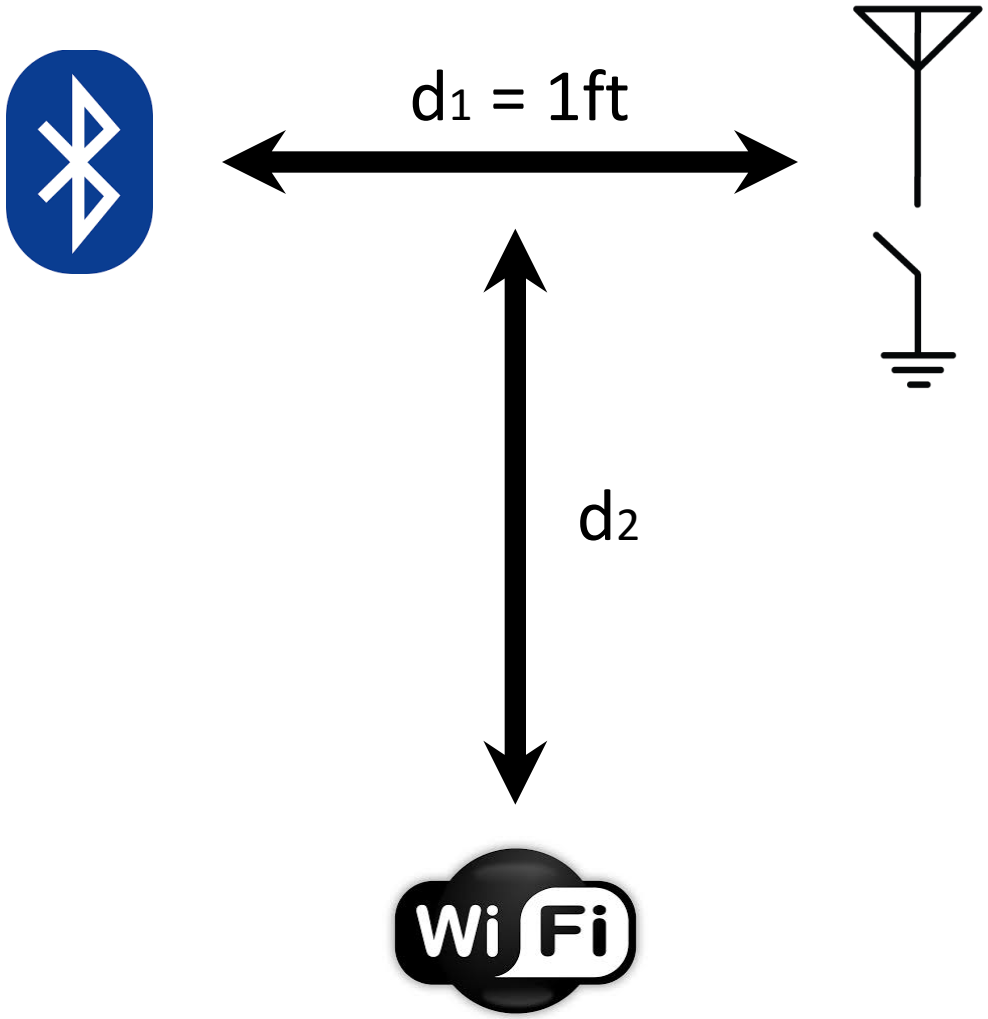
How well can we create a single tone from Bluetooth?







What is the range of our system?



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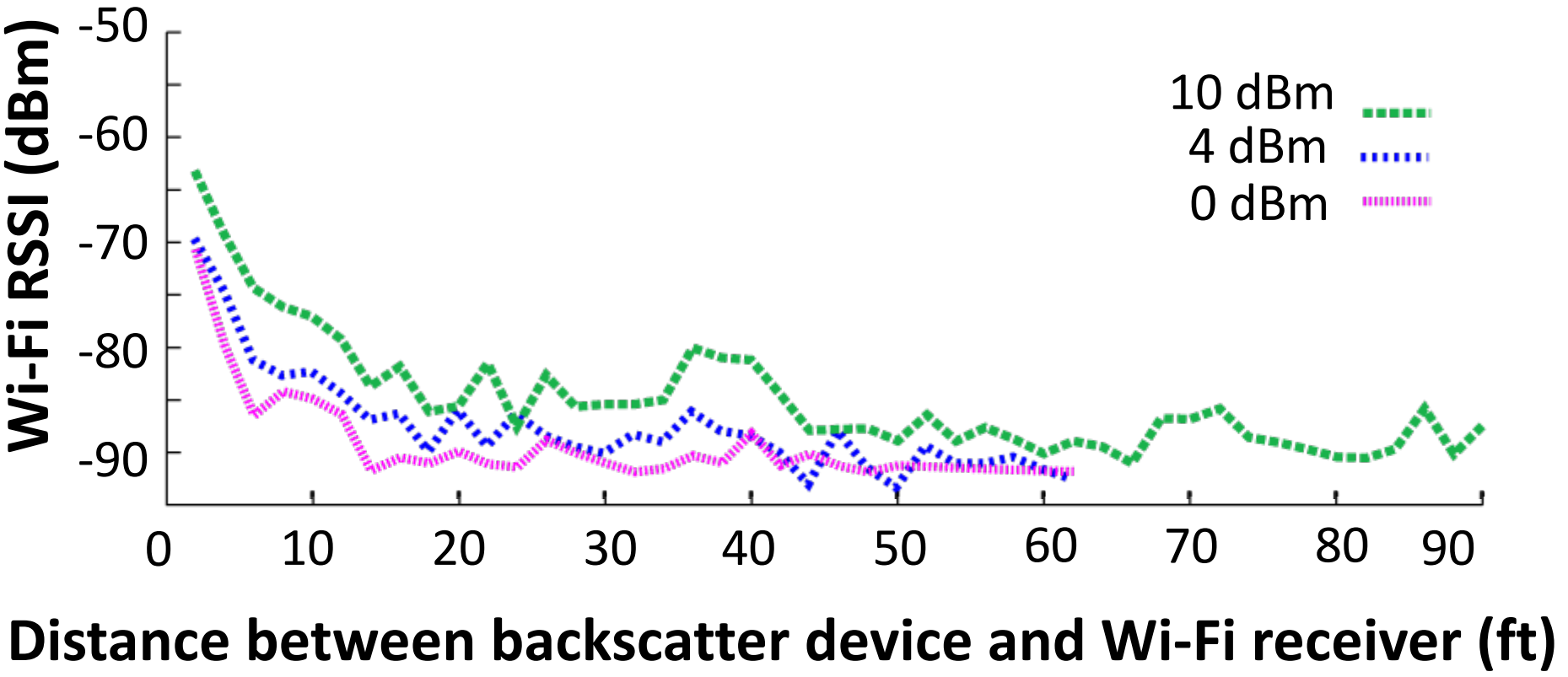
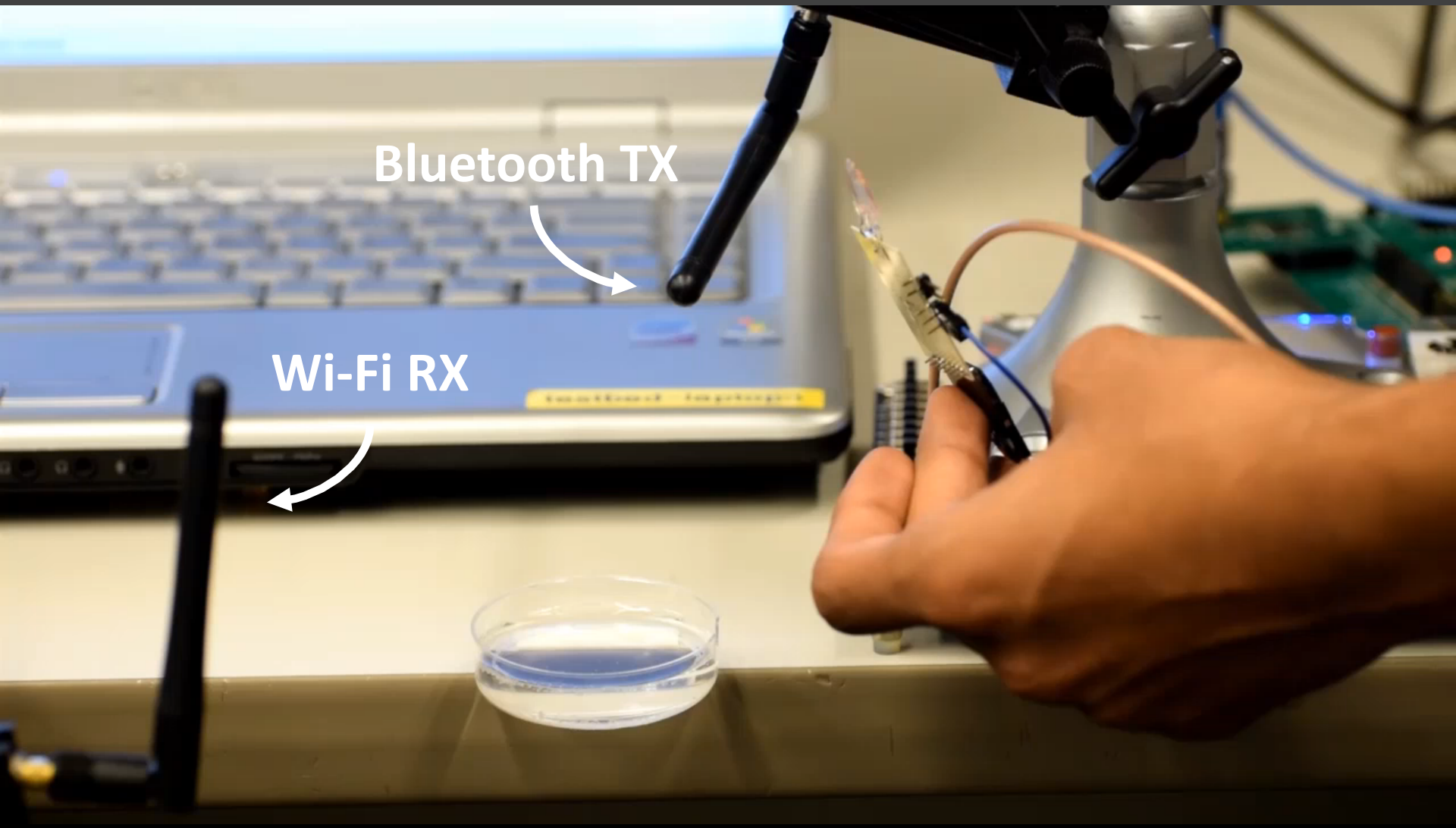
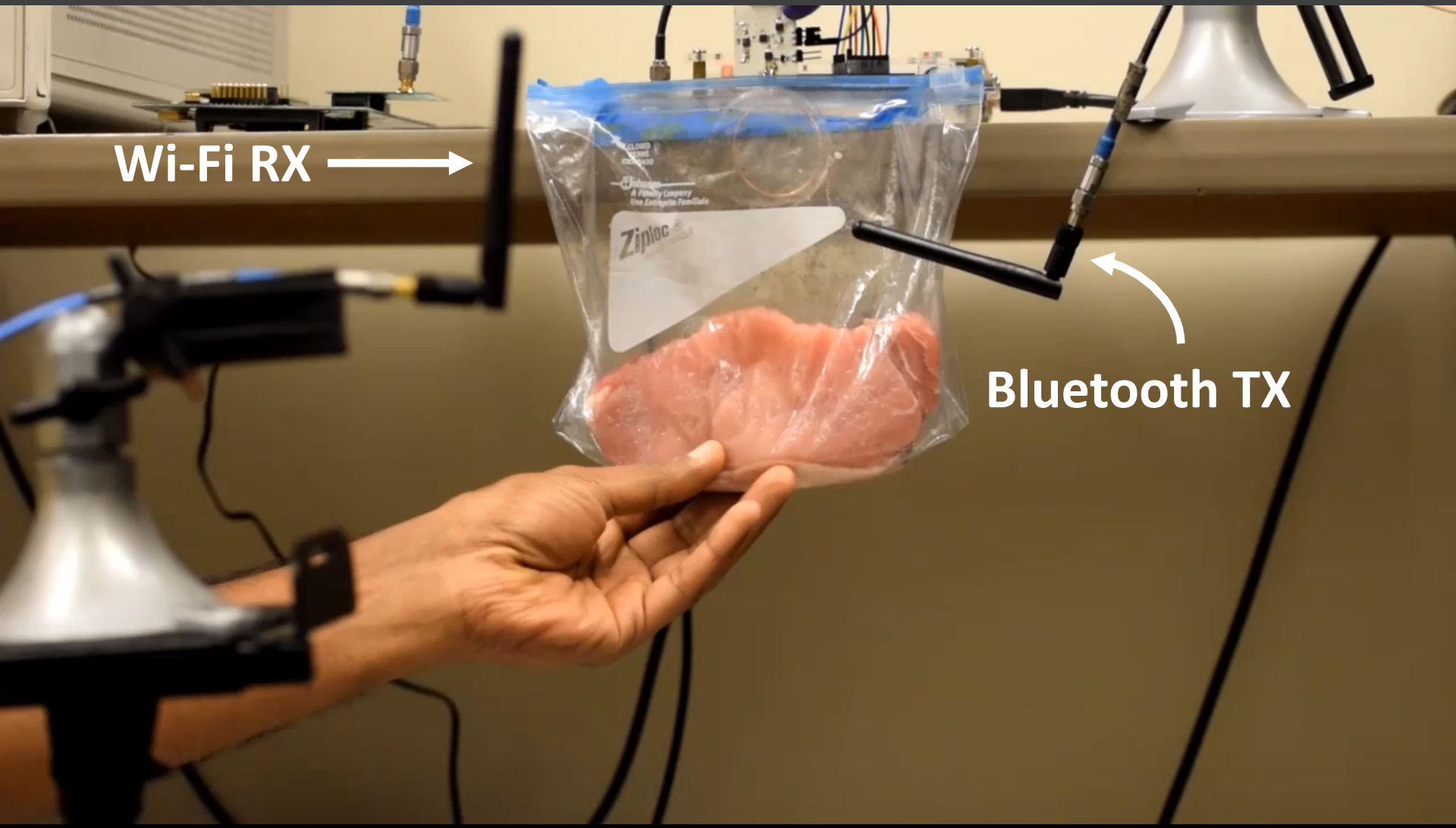


Proof of Concept Applications

Contact Lens Prototype



BMI Prototype



Conclusion

- Transform wireless transmissions from one technology to another, on the air
  - Bluetooth to 2-11Mbps Wi-Fi and ZigBee

- Opens up new opportunities for implanted devices

interscatter.cs.washington.edu