Enabling Connected Cities and Smart Fabrics

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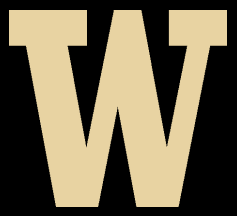
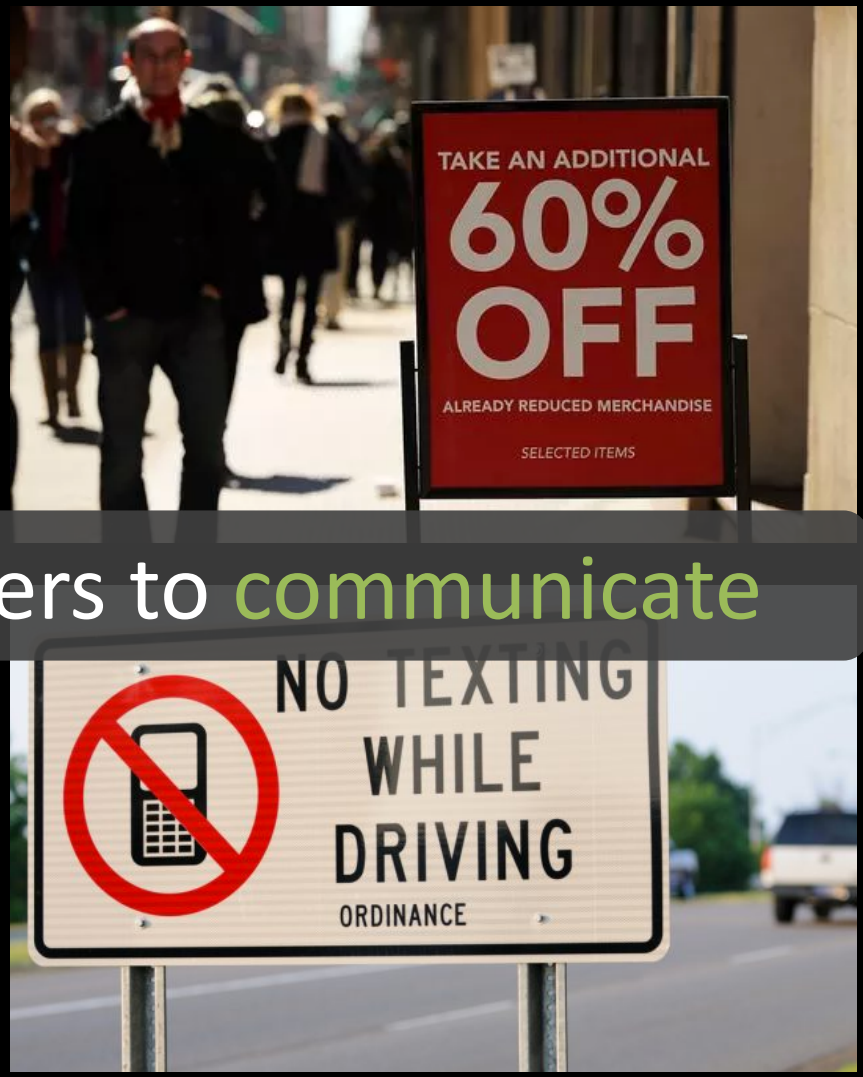


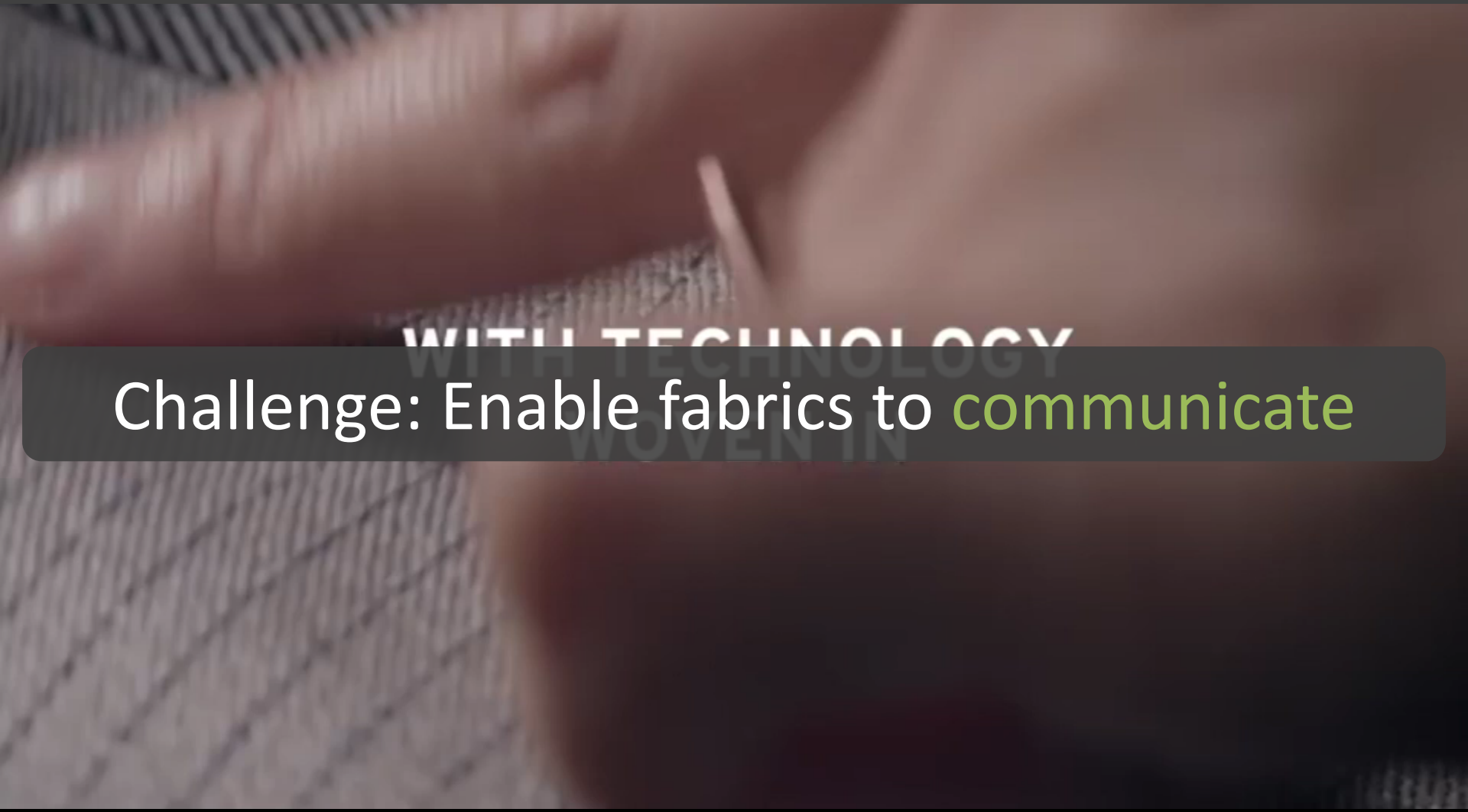
Vision: Connected Cities and Smart Fabrics





Challenge: Enable posters to communicate

Vision: Connected Cities and Smart Fabrics



Challenge: Enable fabrics to communicate

Source: Google Project Jacquard
Datacube

Radios are unsuitable for these applicaitons





<12 hours of battery life

Flexible batteries provide <10 mA

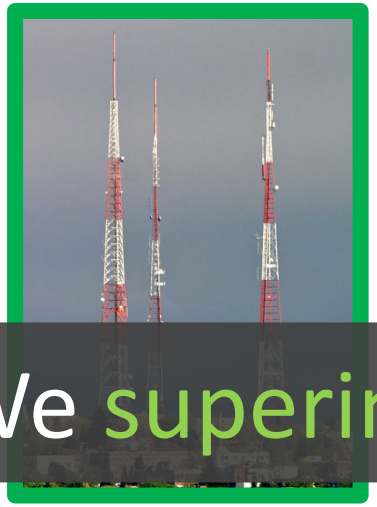
Our solution uses backscatter

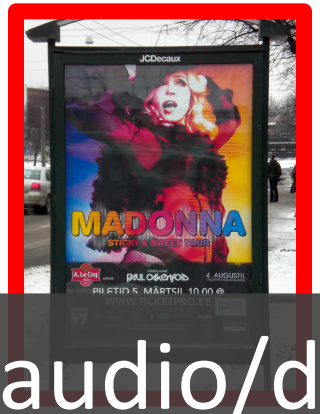


Solution: Backscatter FM radio signals

1. Use ambient radio signals
2. Available in outdoor environments
3. Compatible with phones and cars

FM Backscatter

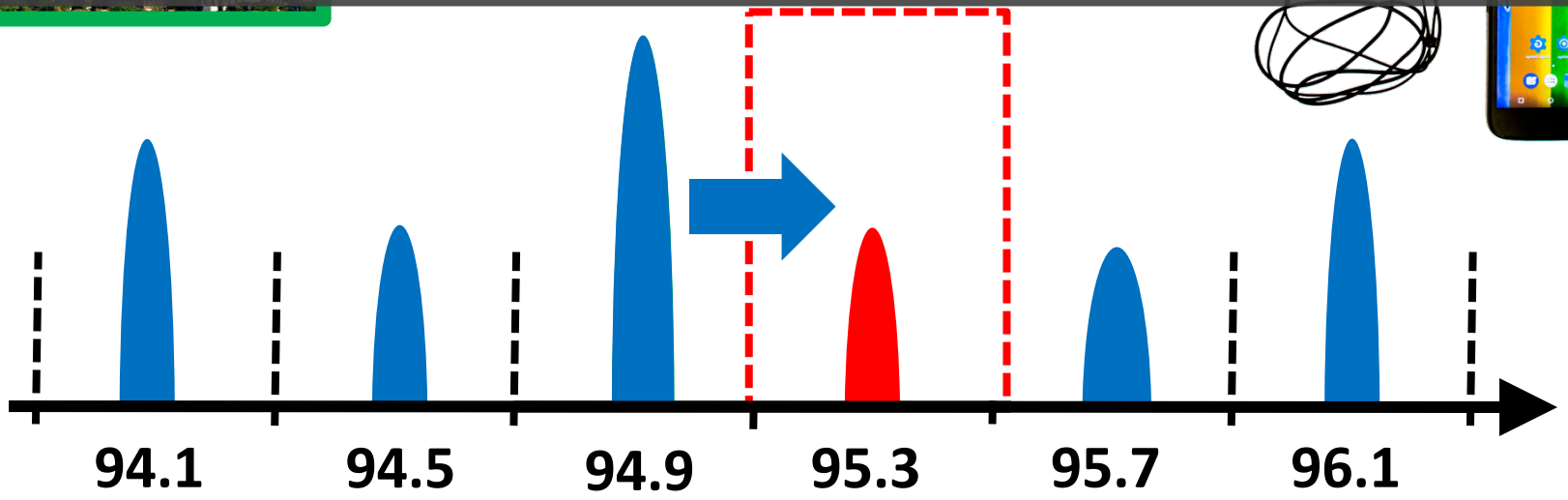








We superimpose audio/data on FM signals



Contributions

- First demonstration of backscatter with ambient FM
- Audio / data from everyday objects to phones or cars
  - Consumes only 12 µW
  - Compatible with flexible batteries



First posters and shirts that talk to phones and cars

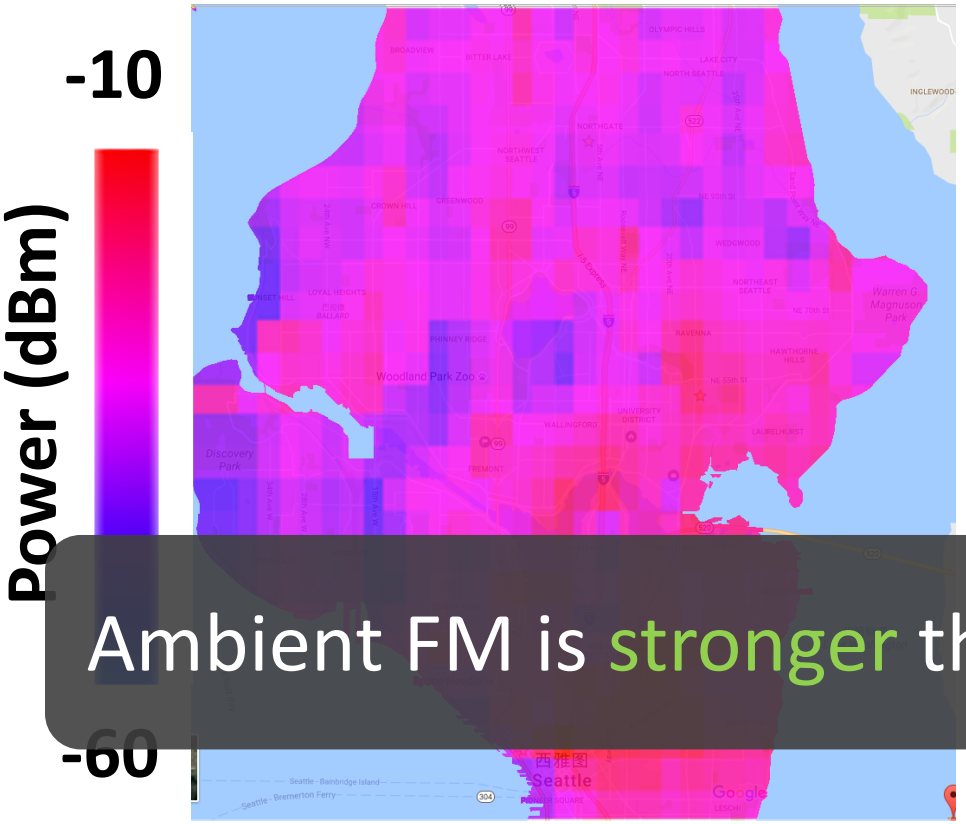
Live Demo

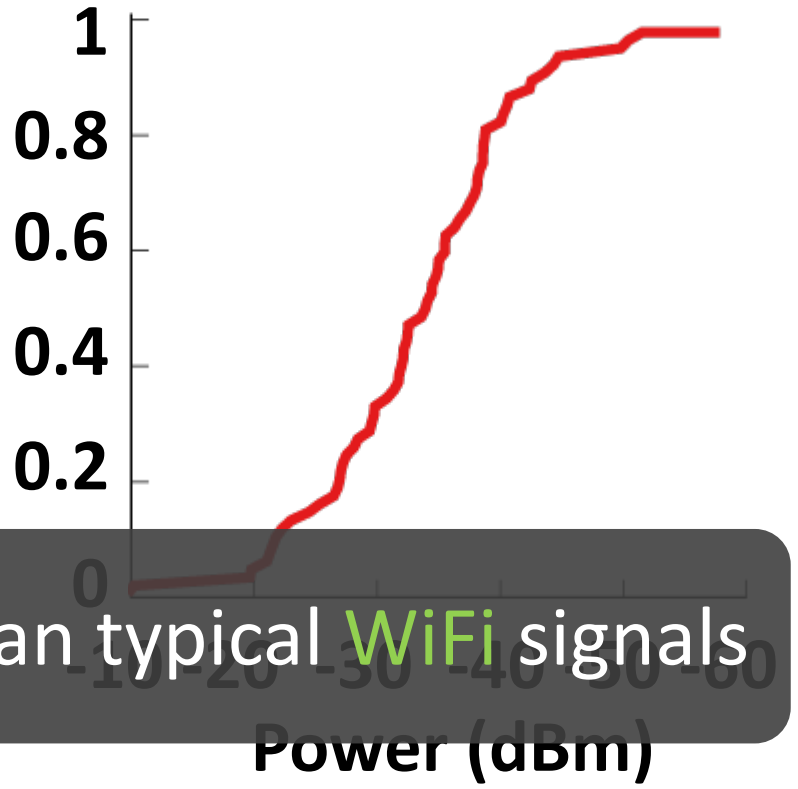
Outline

- How strong are ambient FM signals?

- How do we encode our own information?

How strong are ambient FM signals?





Ambient FM is stronger than typical WiFi signals

Measured: 0.6 mi^2 grid

Total: 40 mi^2

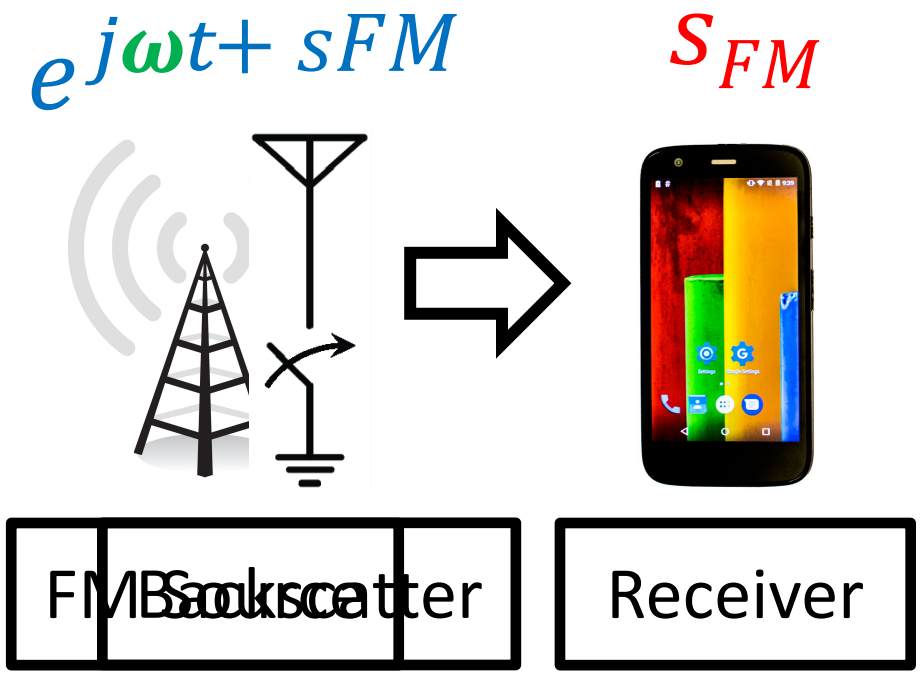
Median: -35 dbm

Min: -55 dBm

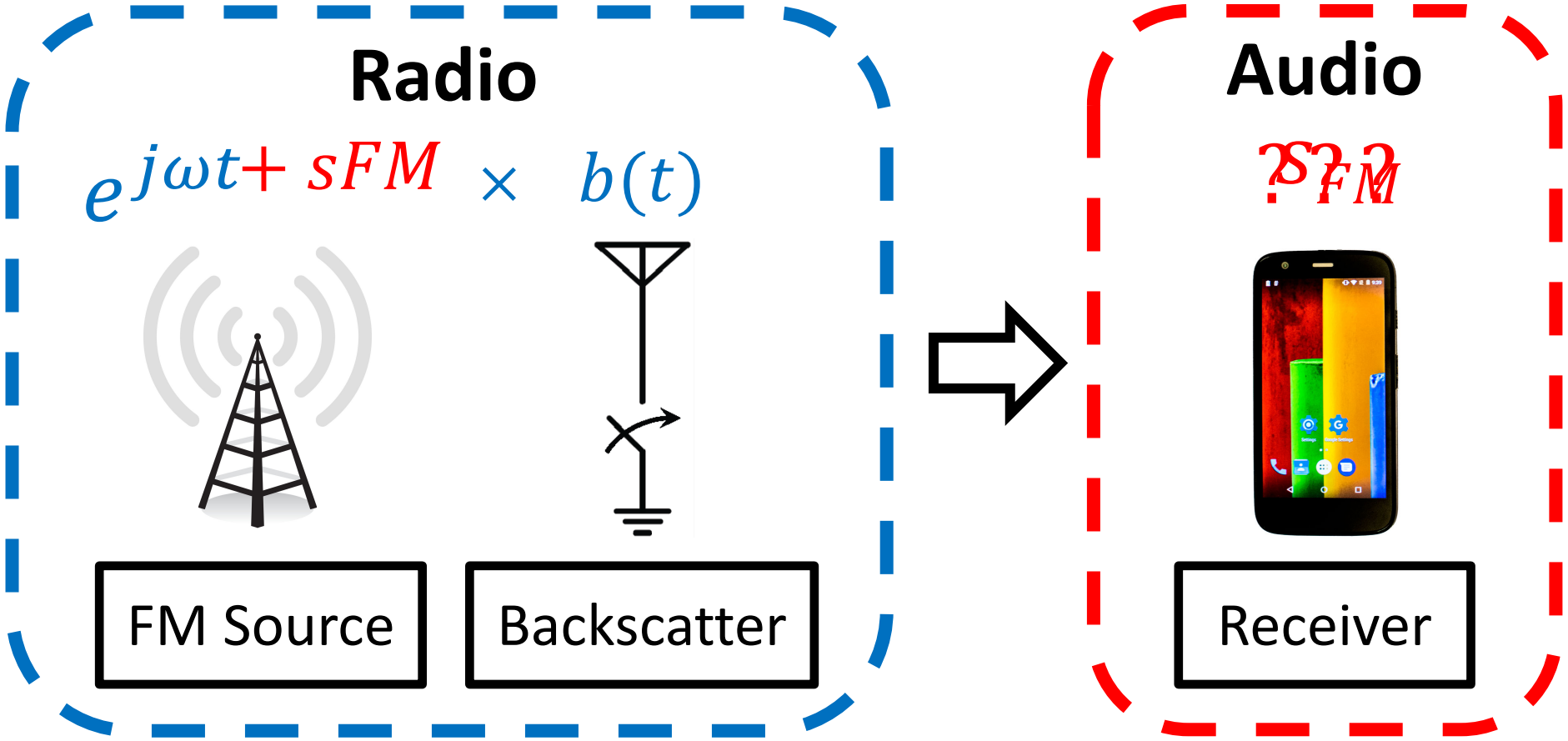
Outline

- How strong are ambient FM signals?
- How do we encode our own information?

How does FM backscatter work?



How does FM backscatter work?



Need to transform RF operations to audio

Solution: Imitate FM with Backscatter

Radio

$e^{j(\omega+\omega_B)t+(s_{FM}+sB)}$





FM Source

Backscatter

Audio

$s_{FM} + sB$



Receiver

Need to transform RF operations to audio

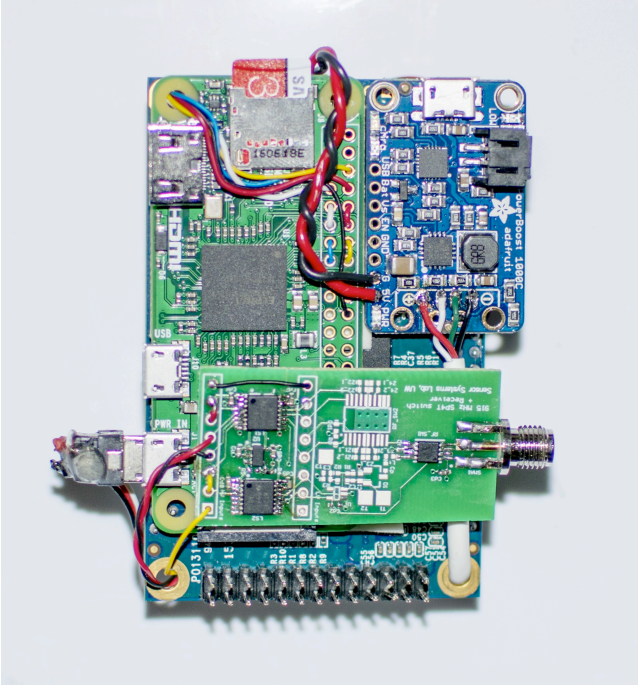
Further Enhancements

- Reducing the background sound
  - Leverage the stereo mode of FM radios
- Transmitting digital bits over audio
  - Use FSK modulation at 8-12 kHz

Works at distances of up to 12 ft

Implementation

Off-the-shelf Design



Current prototype

Custom IC



Consumes 12 uW

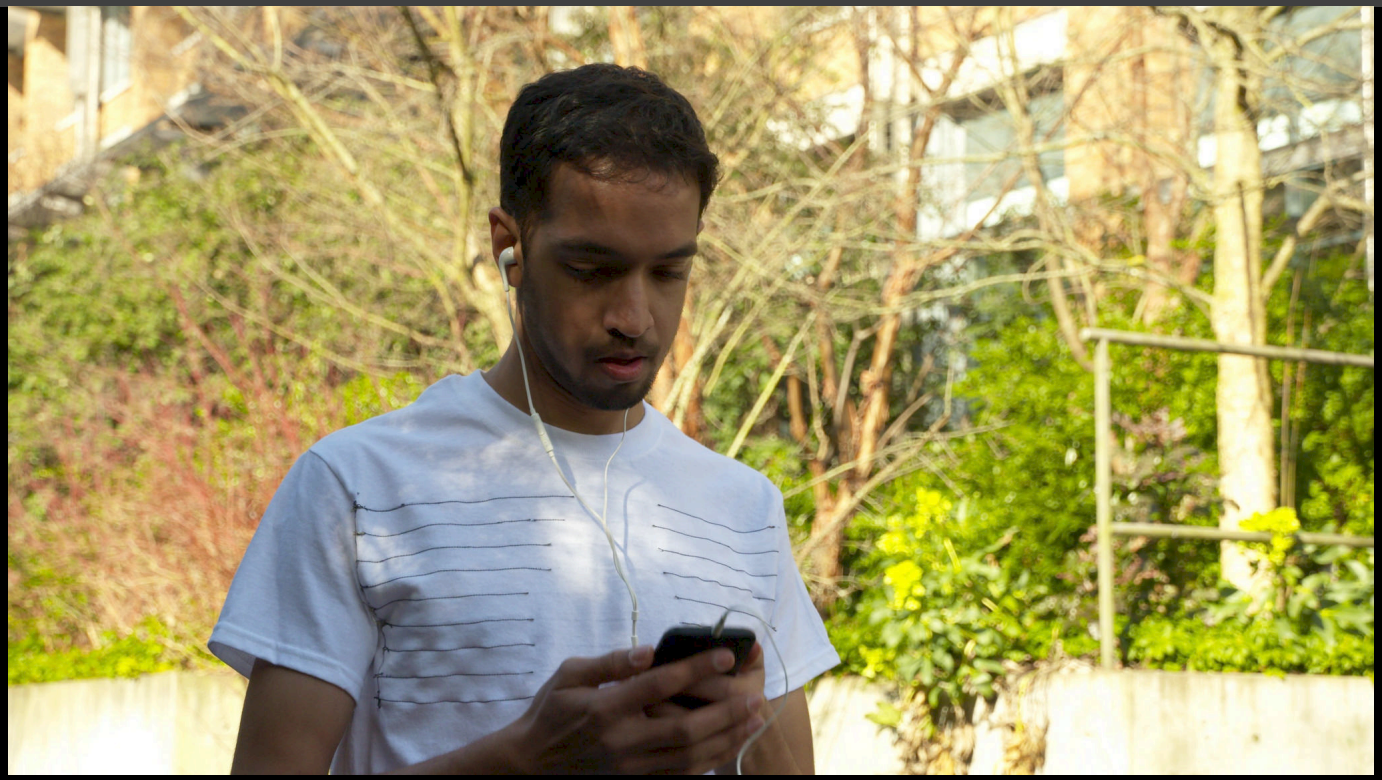
Proof of Concept Applications

Posters Talking to Cars



Works up to 60 ft

Shirt with Integrated Antenna



- Data rates up to 1.6 kbps
- Works while running and walking

Conclusion

First demonstration of backscatter with ambient FM

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