TELEPROBE

Near-zero-power Contactless Probing for Implantable Medical Devices

Woosuk Lee[1]

Applied Sciences Lab
Microsoft Corporation

Younghyun Kim[2]

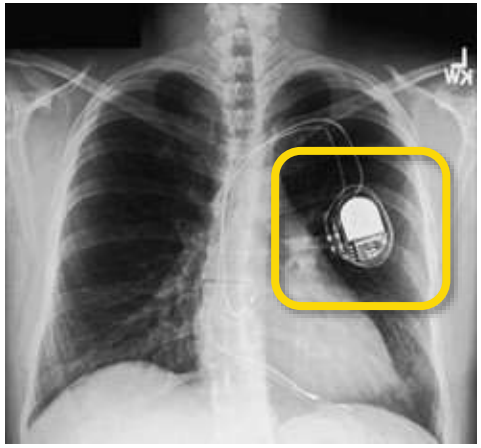
Department of ECE
UW-Madison

Vijay Raghunathan

School of ECE
Purdue University

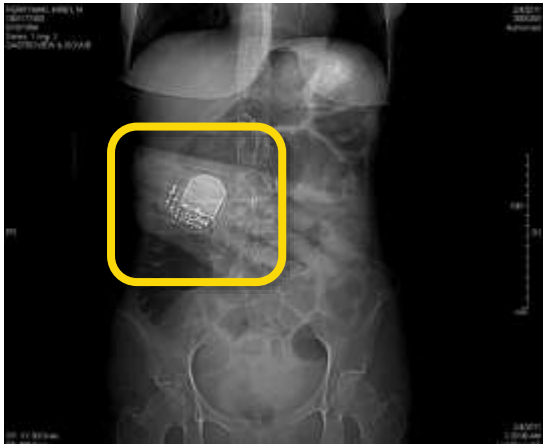
[1,2] *The authors were at Purdue University while doing this work*

Implantable Medical Devices



Pacemaker

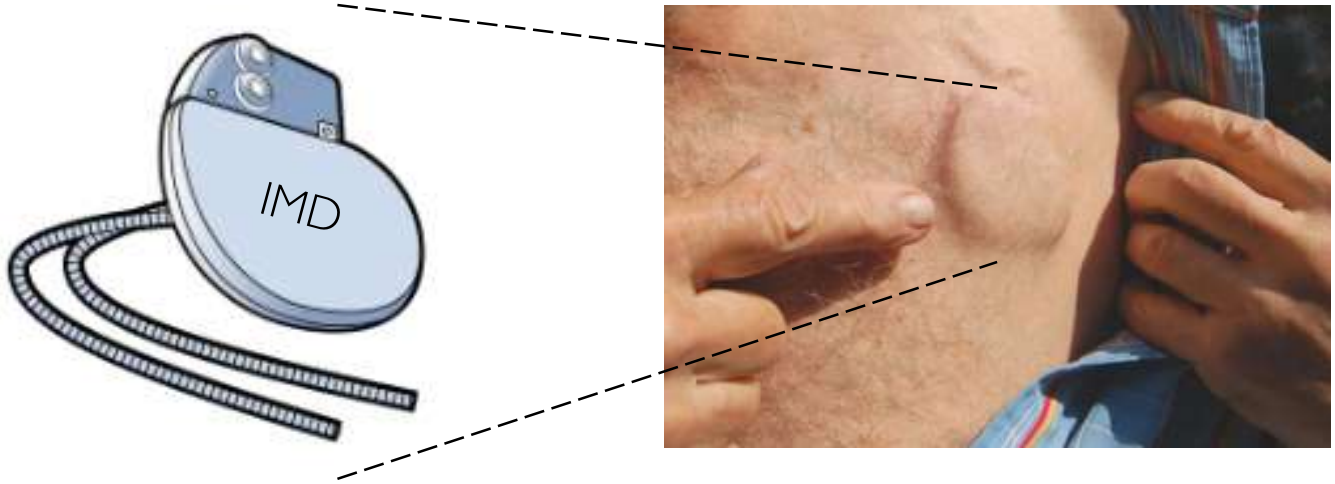
Neurostimulator



Gastric Stimulator

How can we monitor if an IMD is working correctly?

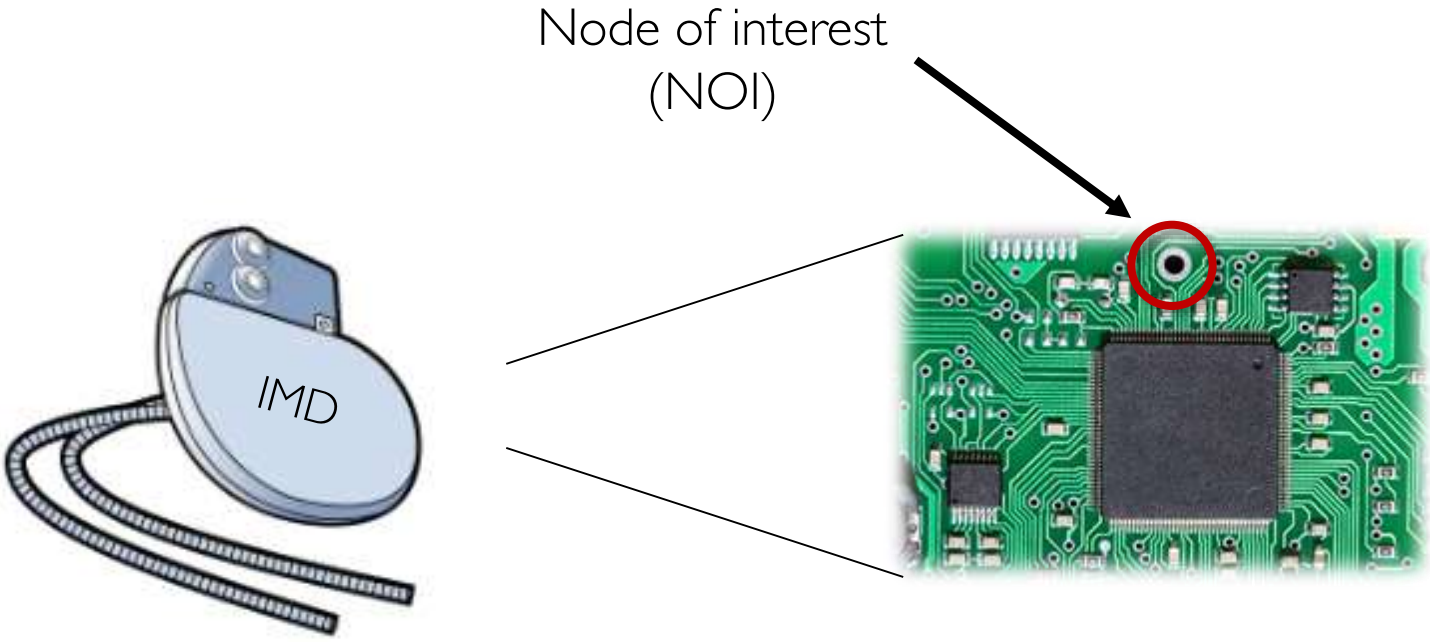
Implantable Medical Devices



- Physically inaccessible
- Extremely energy/size-constrained

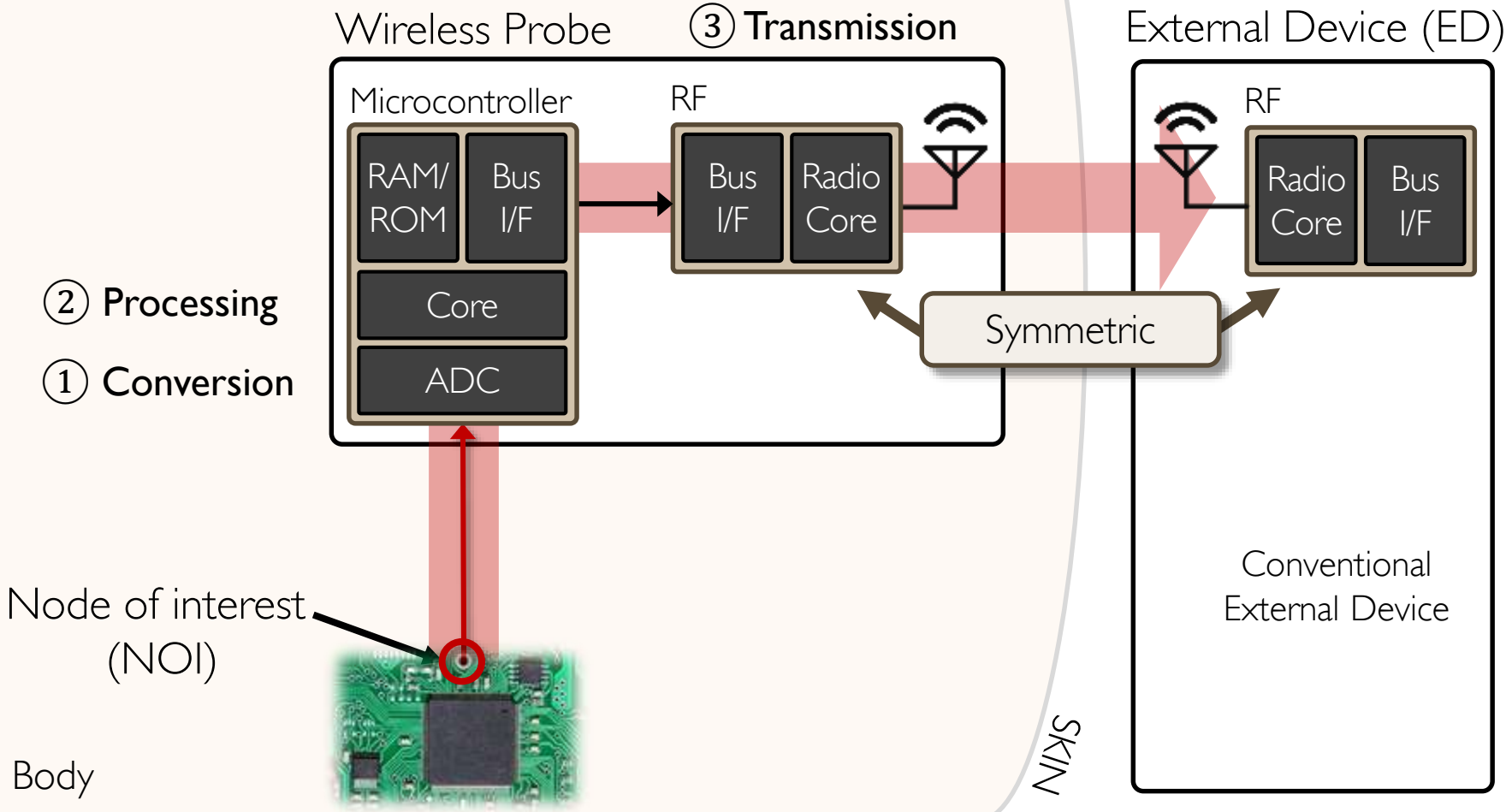
➡ Requires power/size-efficient wireless channel to monitor

Implantable Medical Devices



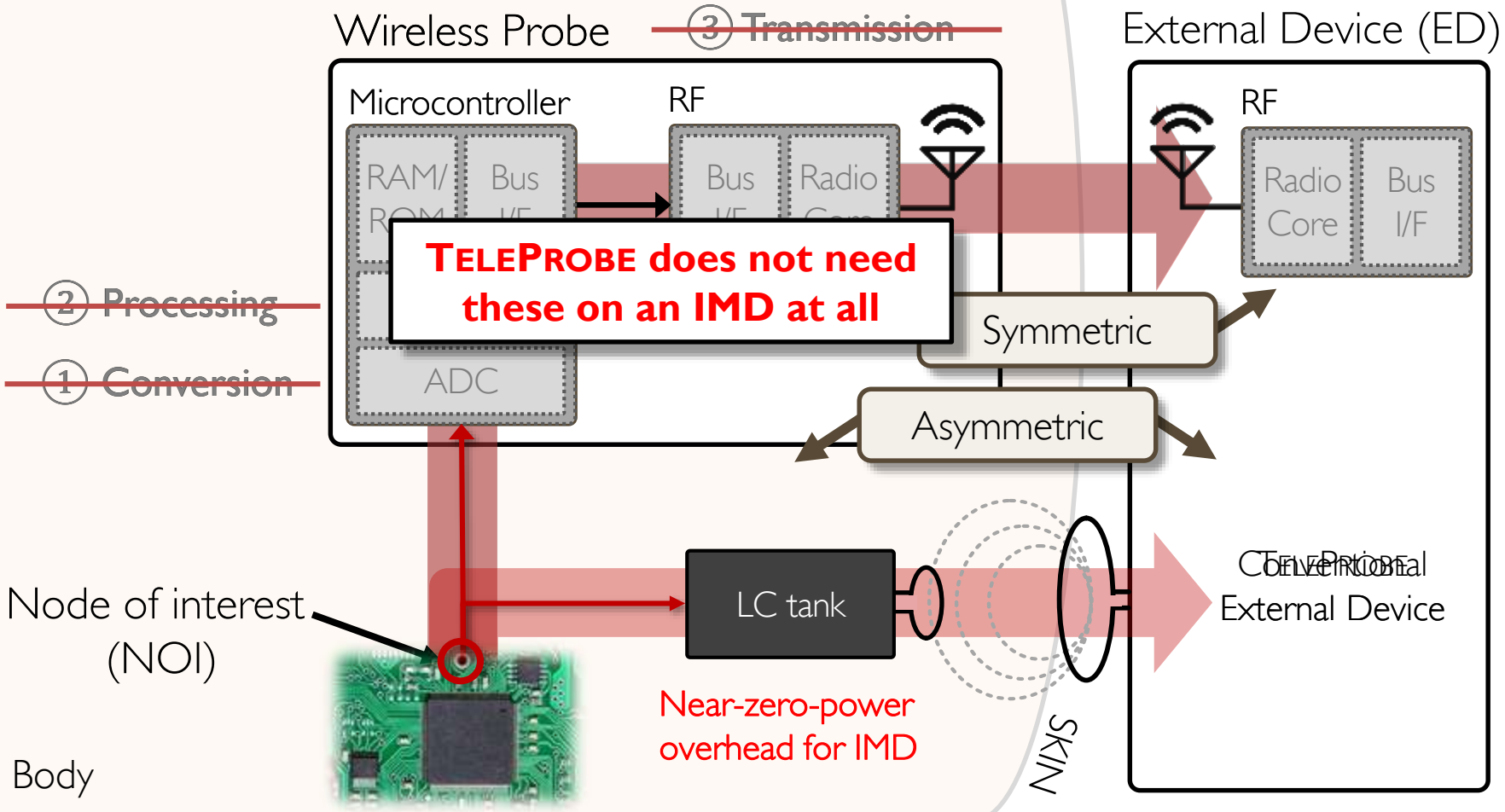
Wireless Probe – Naïve Approach

- Excessive power consumption makes the traditional radio inapplicable



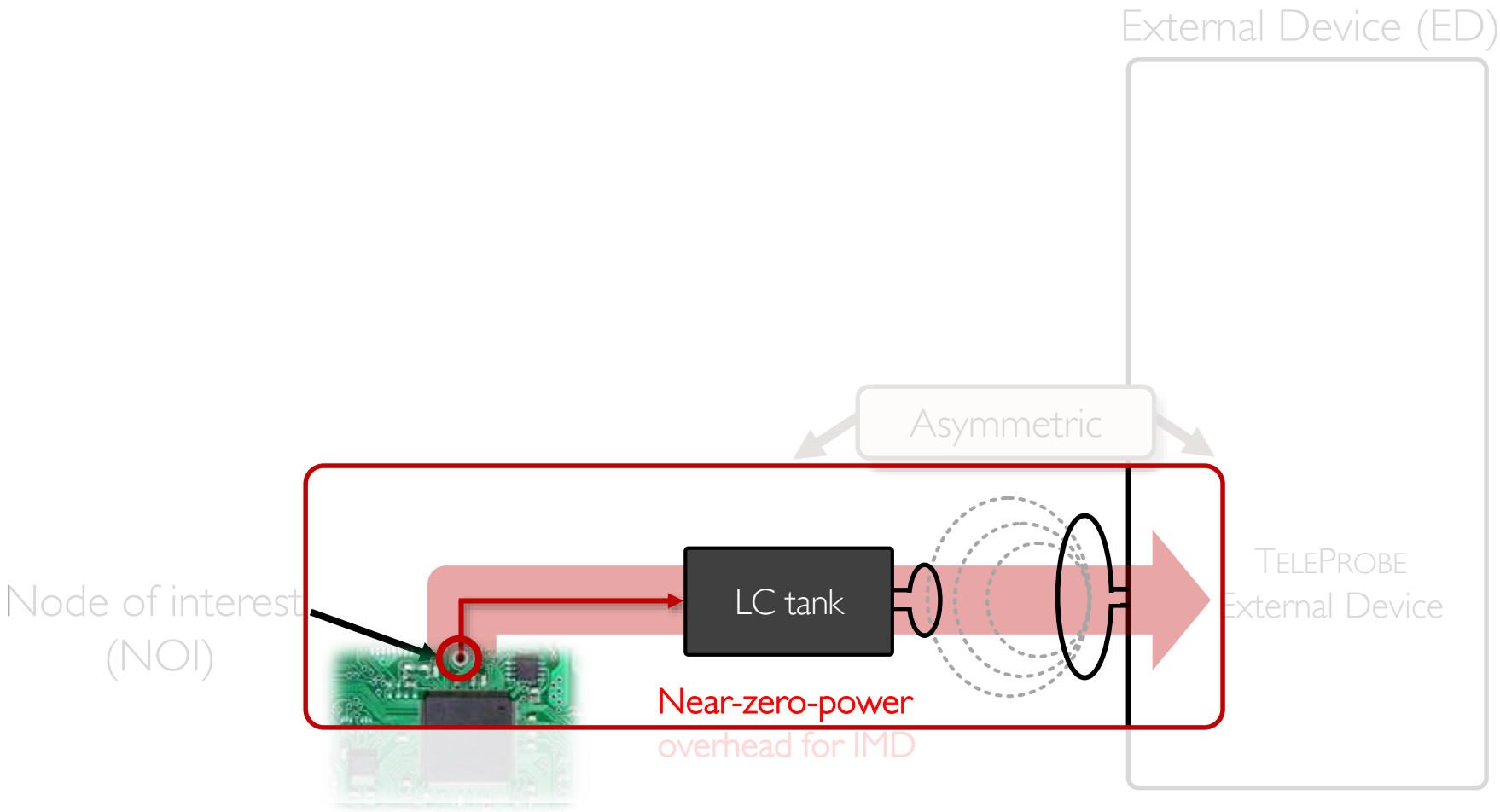
Wireless Probe – TELEPROBE Approach

- Near-zero-power wireless direct readout of an electrical signal



Wireless Probe – TELEPROBE Approach

- Near-zero-power wireless direct readout of an electrical signal

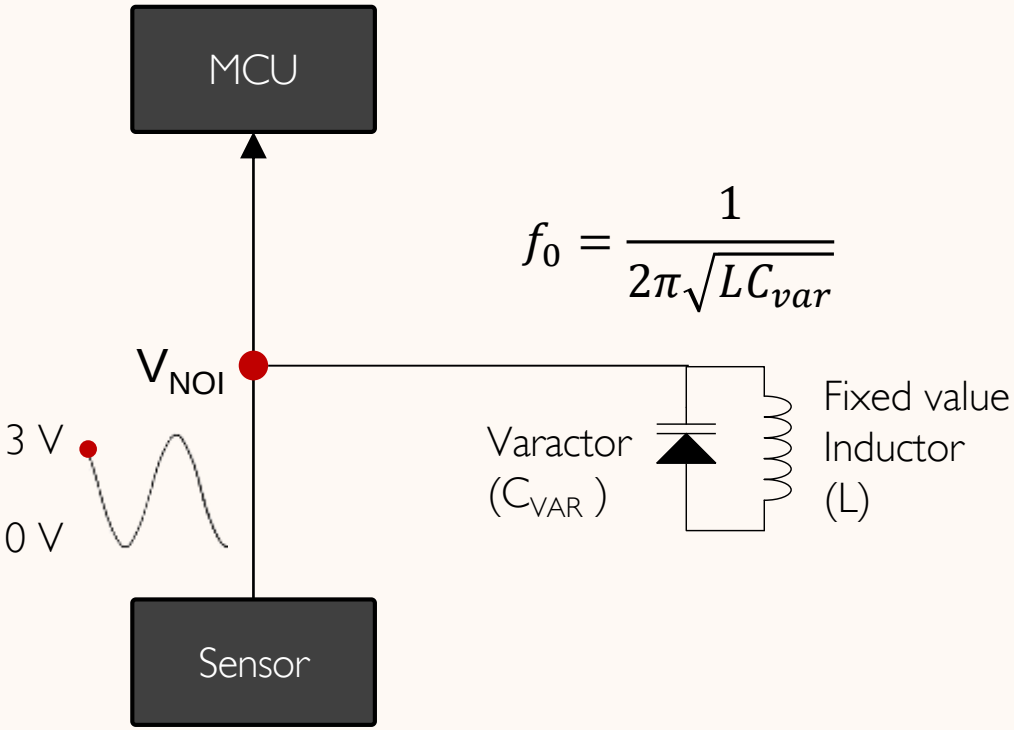


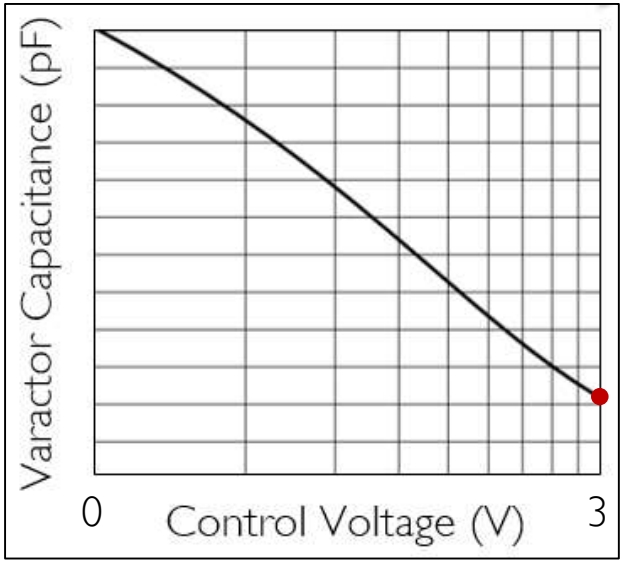
Wireless Probe – TELEPROBE Approach

Body

SKIN

Air



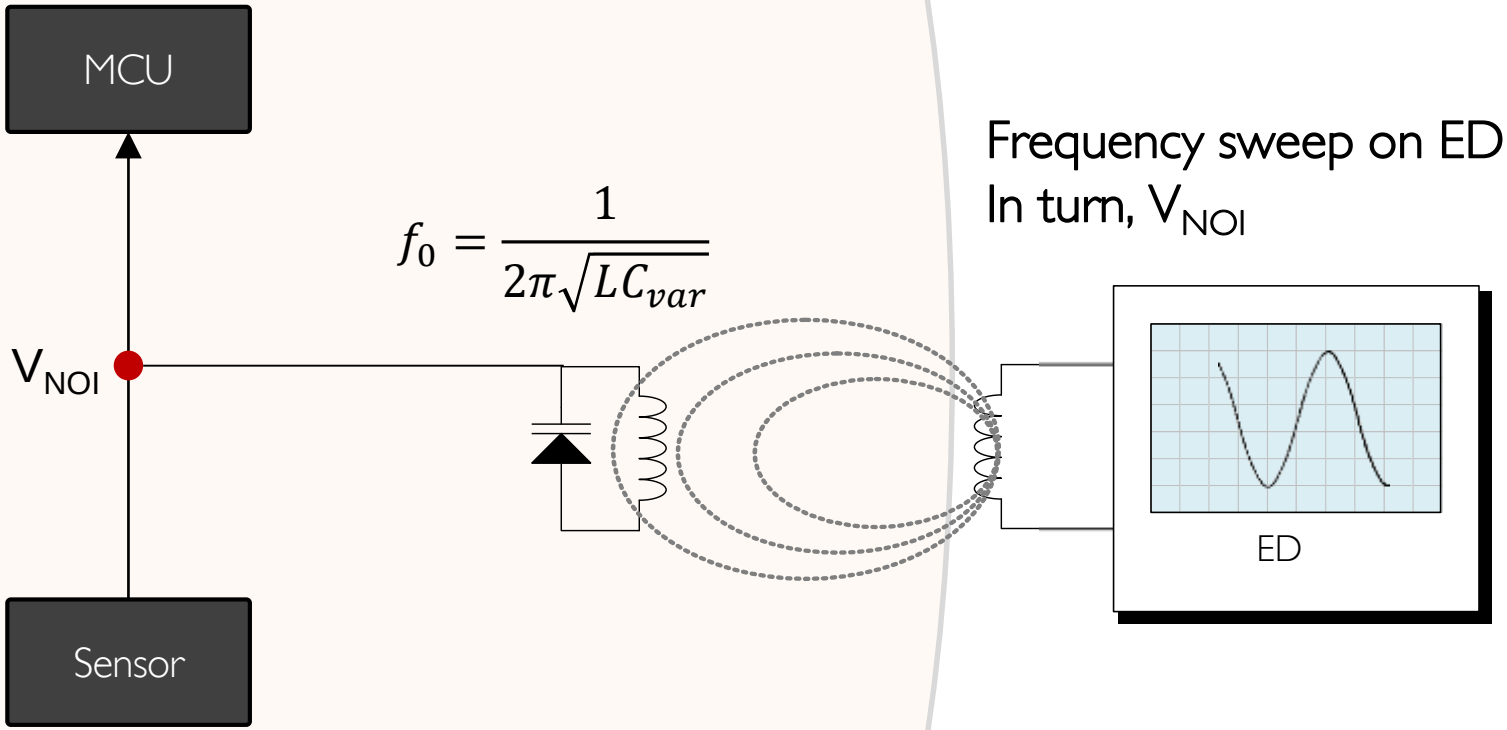


Wireless Probe – TELEPROBE Approach

Body

SKIN

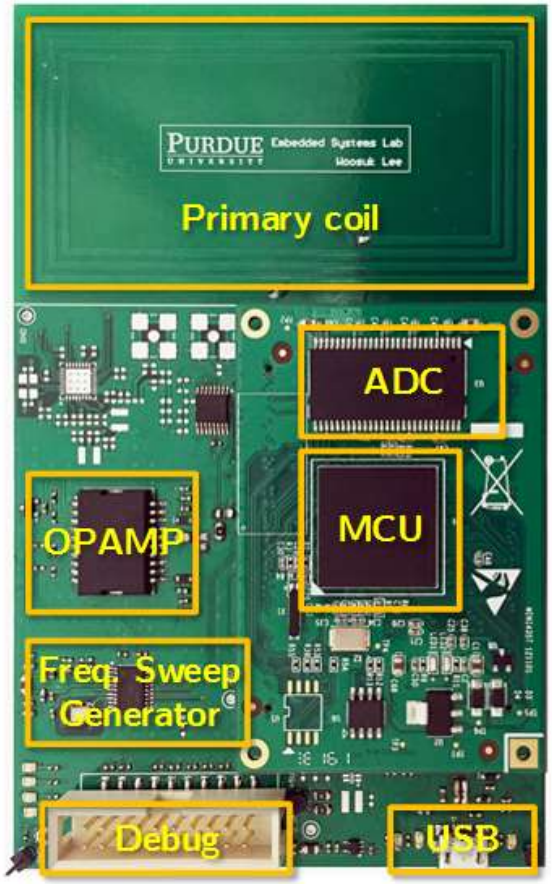
Air



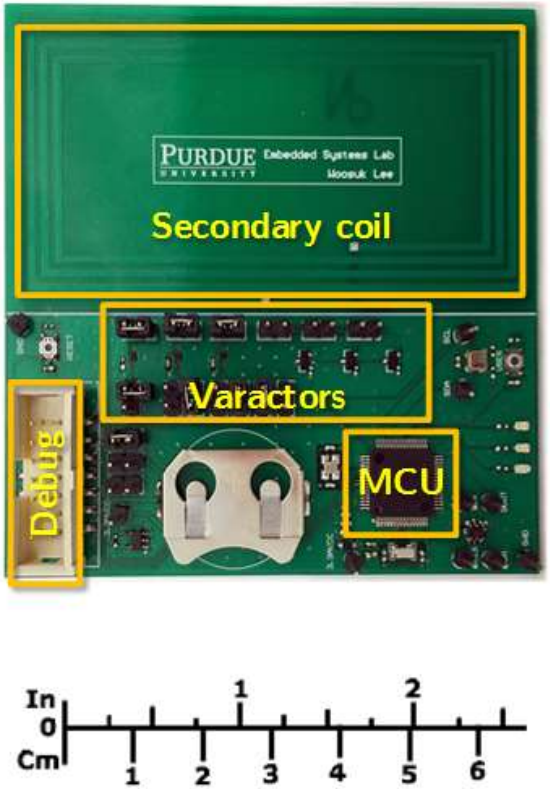
Frequency sweep on ED reveals f_0, In turn, V_{NOI}

Implementation

- Prototypes with only off-the-shelf components



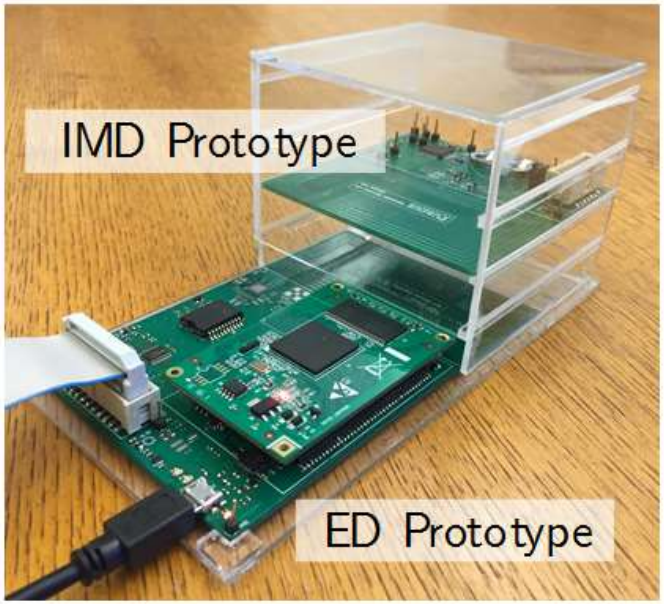
TELEPROBE ED prototype

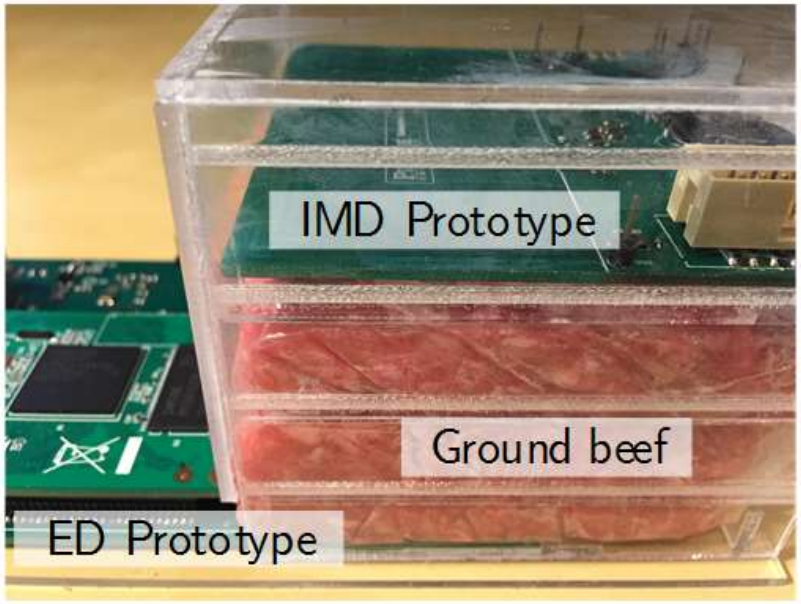


TELEPROBE IMD prototype

Experimental Setup

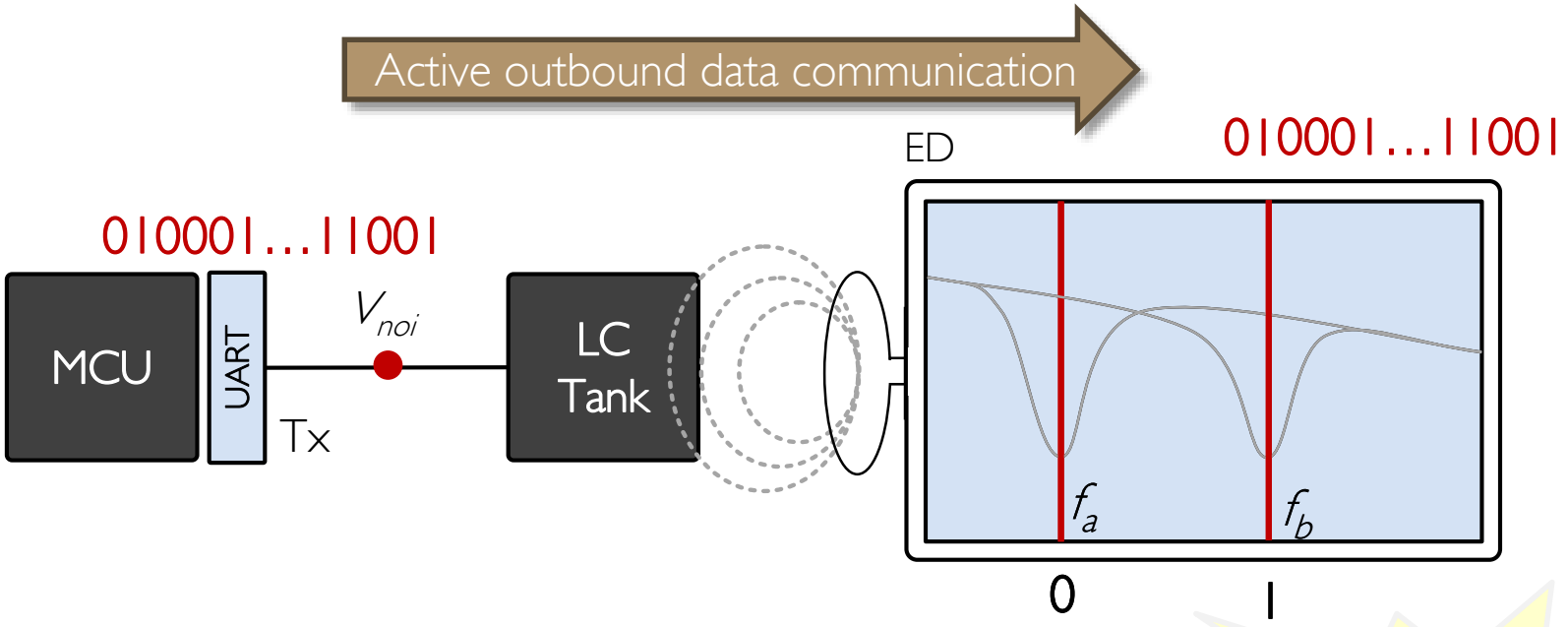
- Distance between the two coils was varied while perfectly aligned
- In-vitro experiment with ground beef





Active Data Transmission

- IMD actively controls a digital line equipped with LC tank circuit
  → Achieves an active outbound data communication



Energy per bit: 95 fJ/bit

163x improvement‡

‡ S. J. Thomas and M. S. Reynolds, "A 96 Mbit/sec, 15.5 pJ/bit 16-QAM modulator for UHF backscatter communication," in *IEEE RFID*, 2012, pp. 185–190.