UC San Diego
JACOBS SCHOOL OF ENGINEERING
Electrical and Computer Engineering

Morimoto Lab

WiForce: Wireless Sensing and Localization of Contact Forces on a Space Continuum

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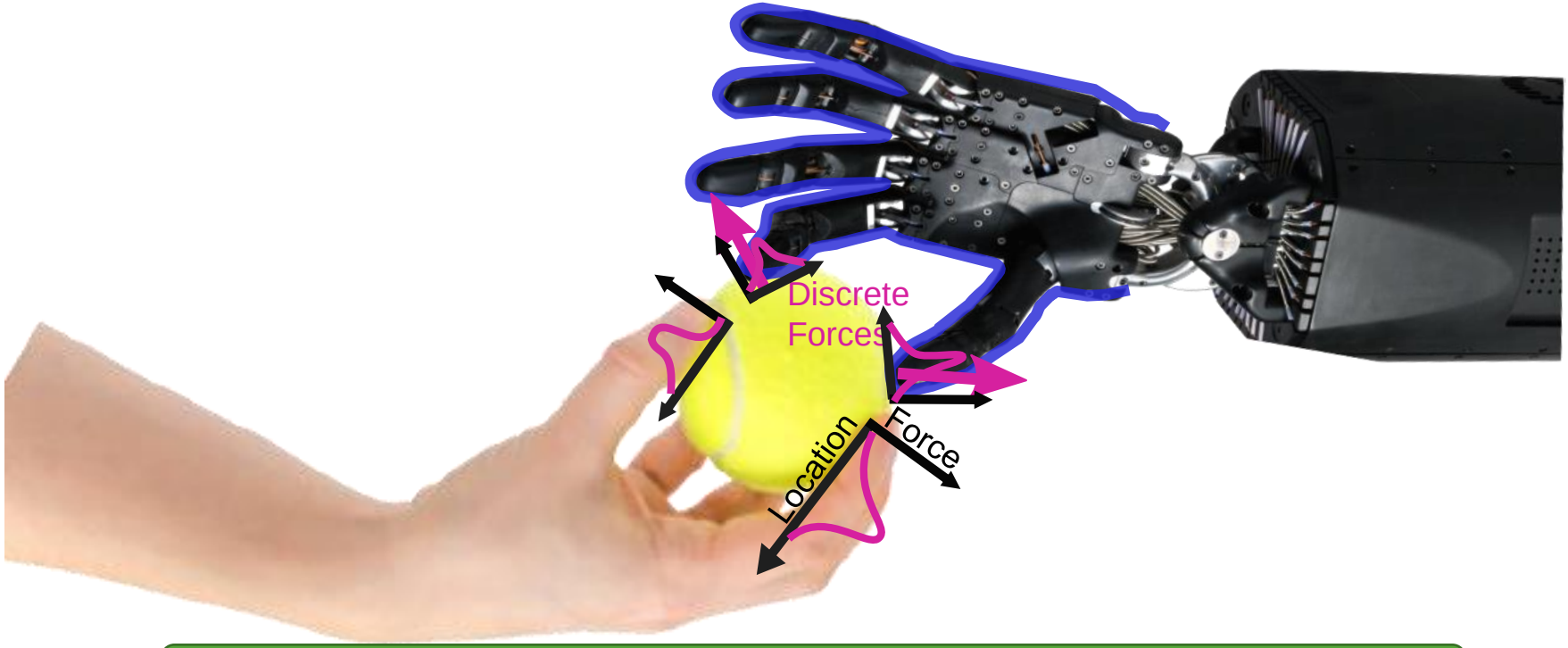
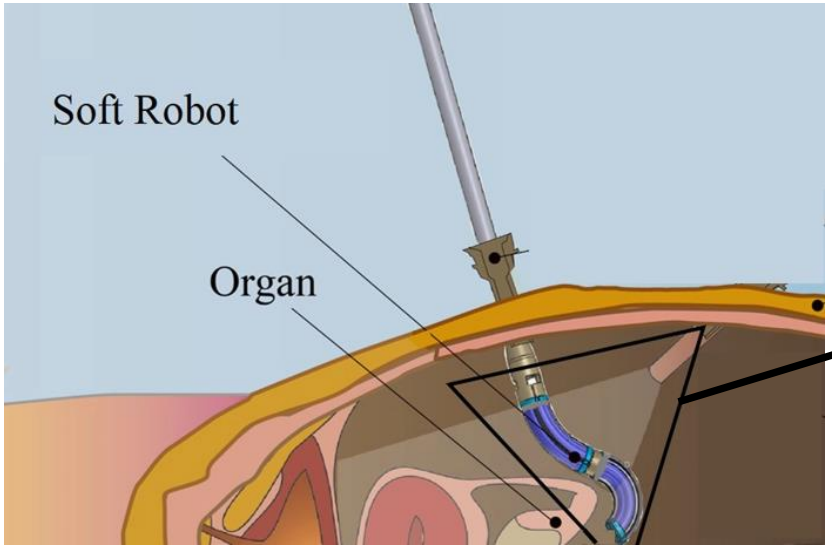
Need for a sensory layer like skin



Sensor Skins enable force sensing across the robot length

Emerging use-cases of sensor skins



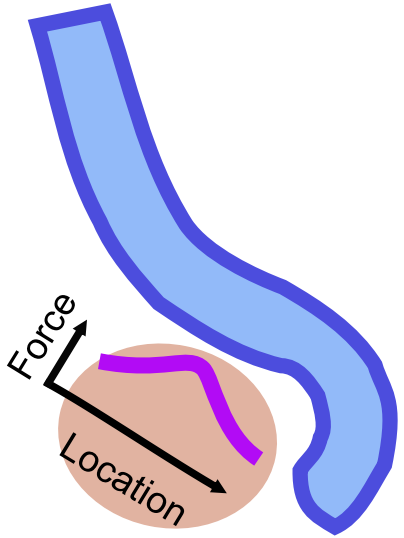
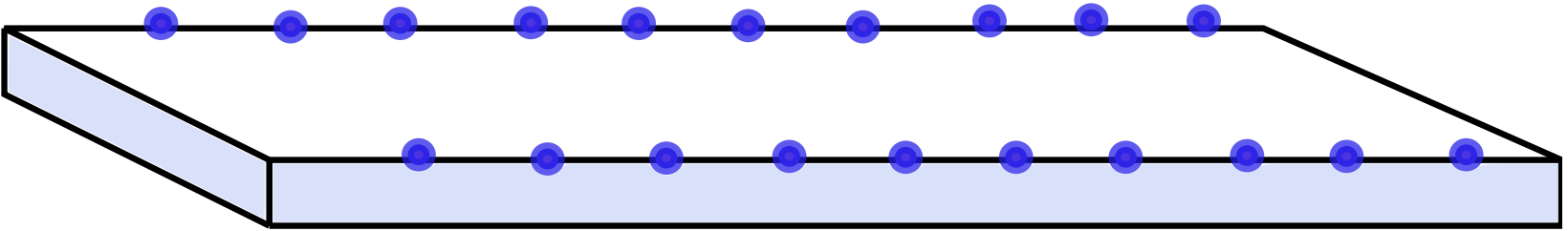


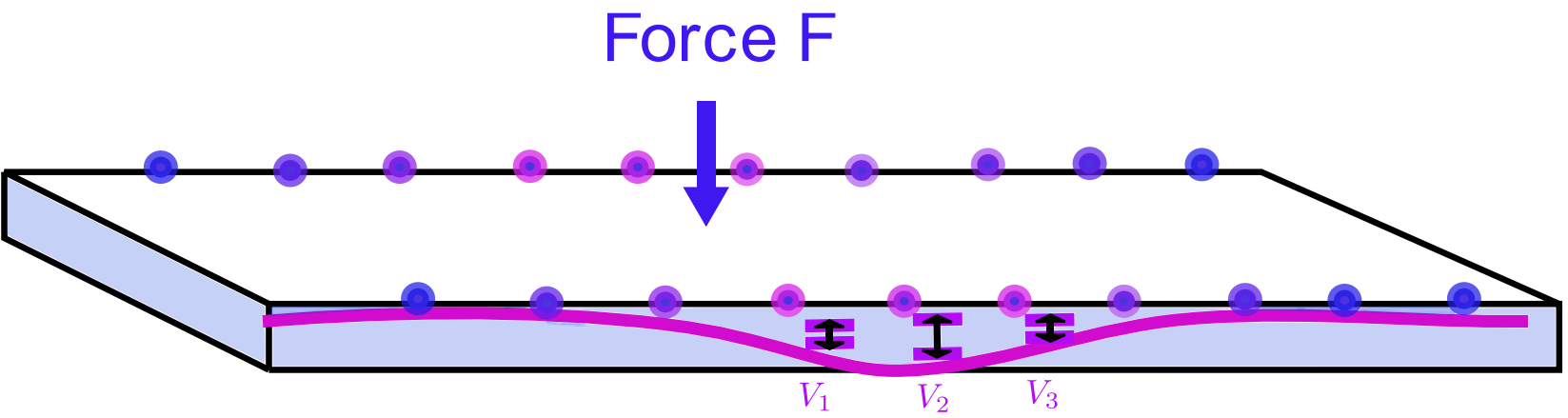
Image Source: **Highly dexterous 2-module soft robot for intra-organ navigation in minimally invasive surgery, Abidi et al.**

Wired sensing of force profile

Sensing surface covered with discrete force sensors

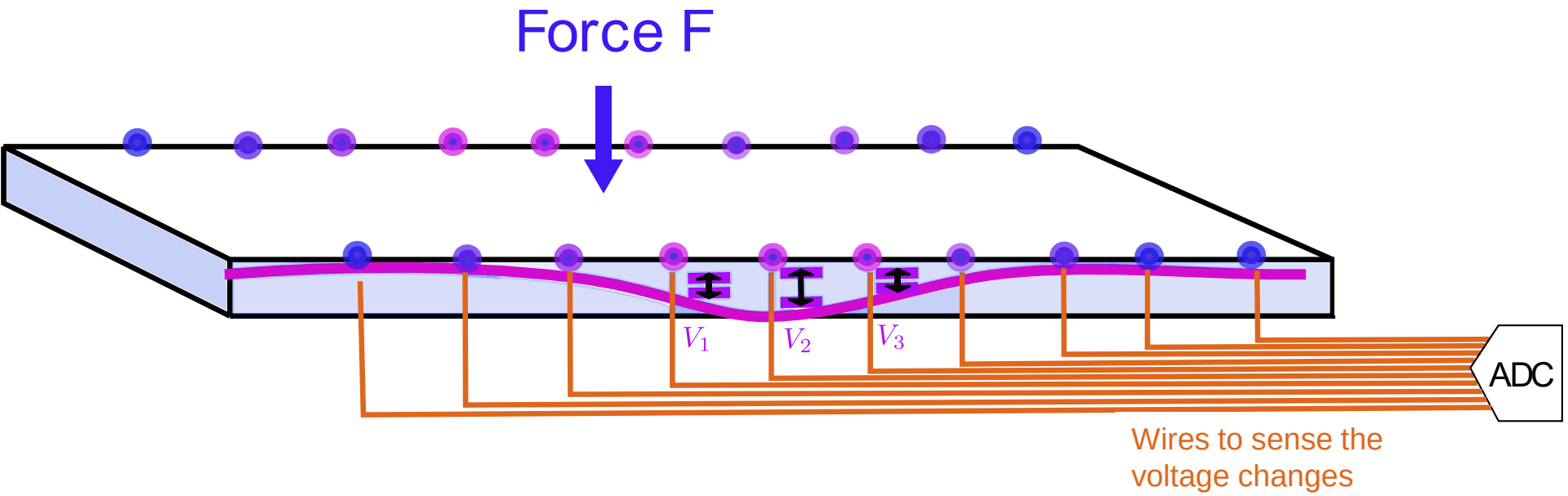


Wired sensing of force profile



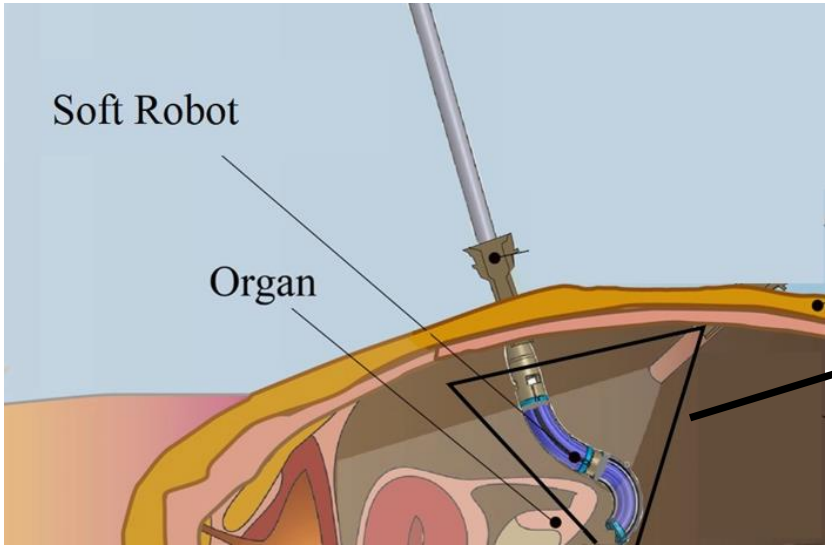
Voltage variation on sensors due to force F

Wired sensing of force profile



Current solutions have prohibitive wiring requirements

Problems with sensing wires



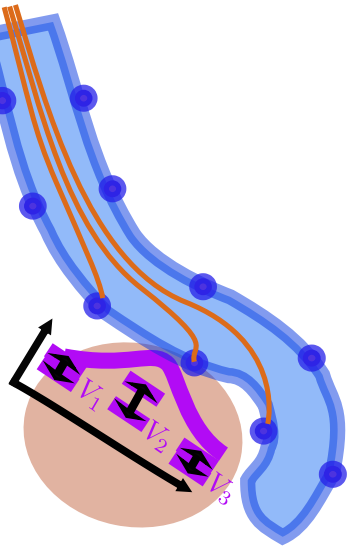
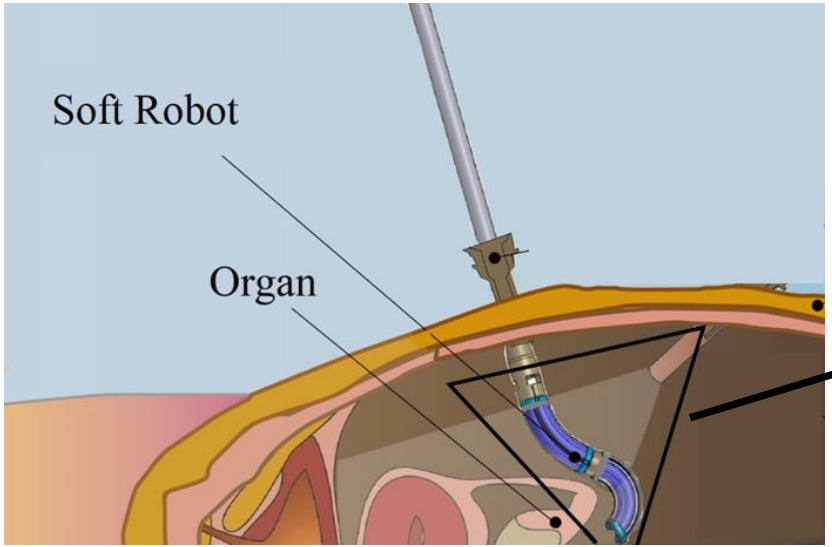


Image Source: **Highly dexterous 2-module soft robot for intra-organ navigation in minimally invasive surgery, Abidi et al.**

Need for wireless force sensing



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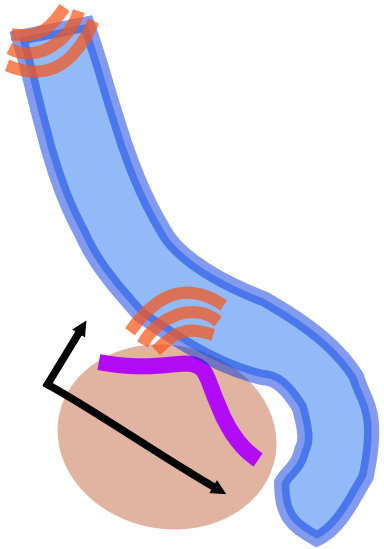
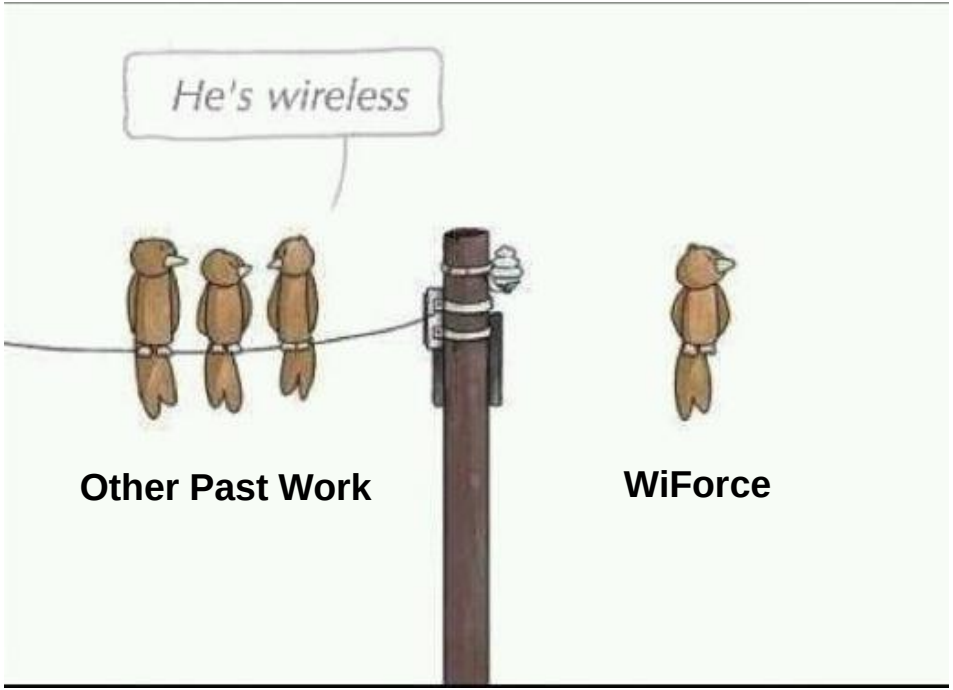
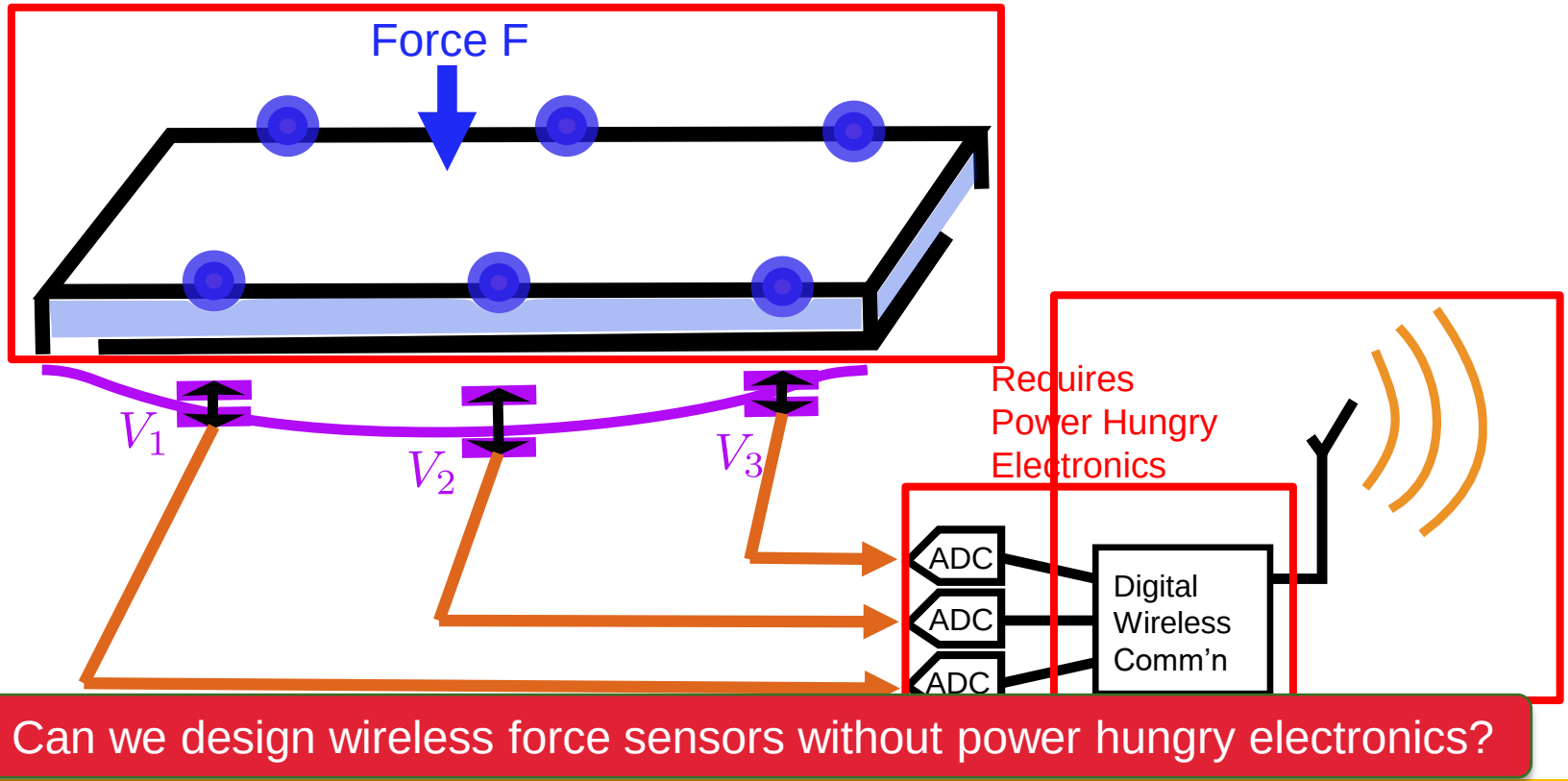


Emerging applications necessitate wireless force sensing



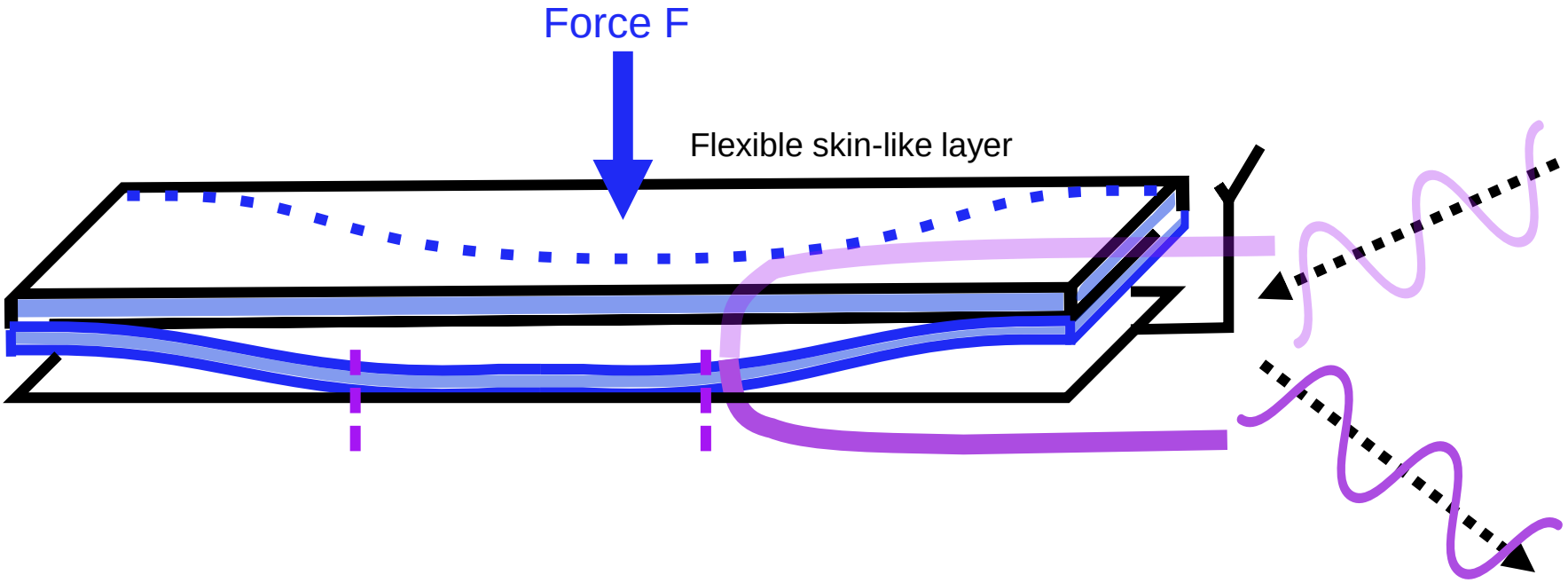
WiForce designs a wireless force sensor that achieves sub-Newton force accuracy and mm accurate localization

Naïve wireless feedback solution



Can we design wireless force sensors without power hungry electronics?

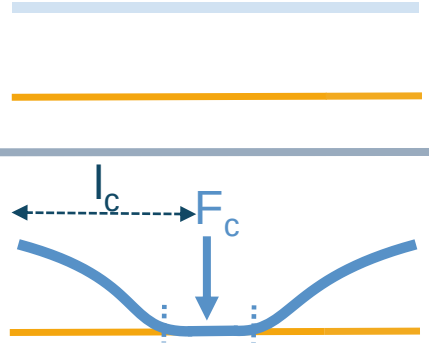
Combining sensing and communication



Encoding force onto the reflected signals doesn't require power hungry electronics

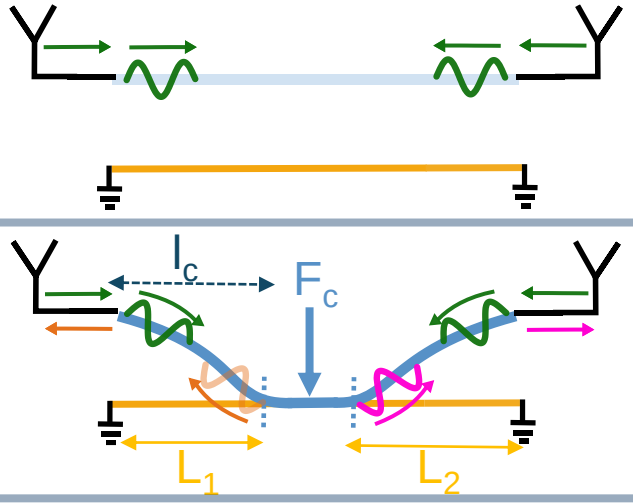
Encoding force into wireless signal reflections

Mechanical perspective: Two parallel air-separated beams



$F_c = f(L_1, L_2)$, $l_c = g(L_1, L_2)$

Connecting the beams to antennas

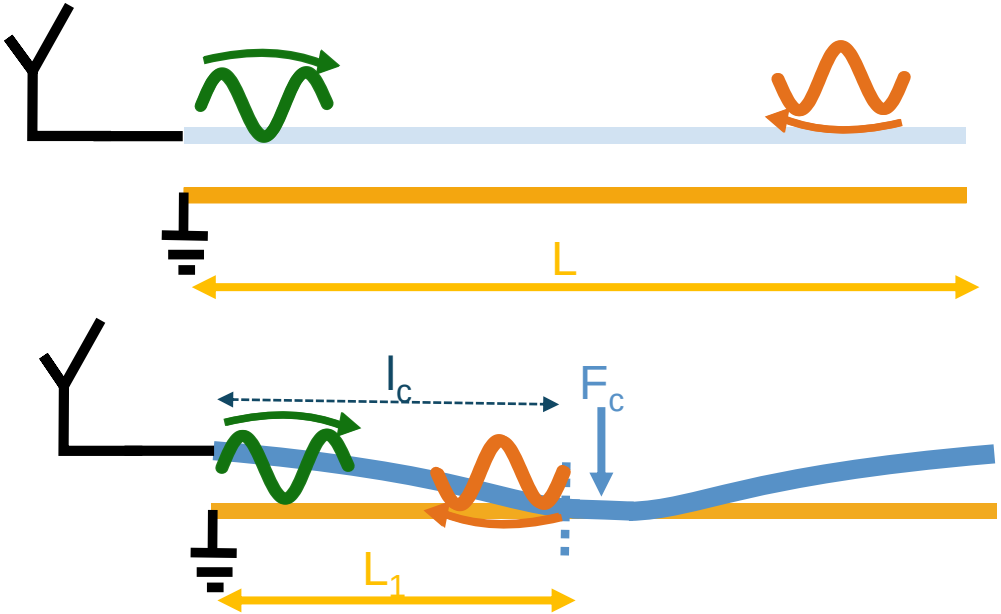


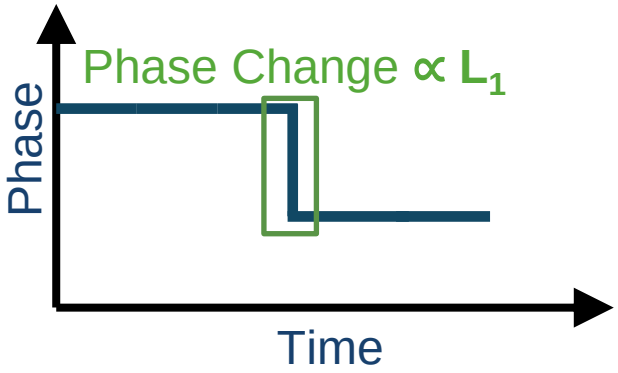
Travel back a distance of L1, L2 respectively

Contact lengths caused by applied force, gets encoded onto the reflected signals

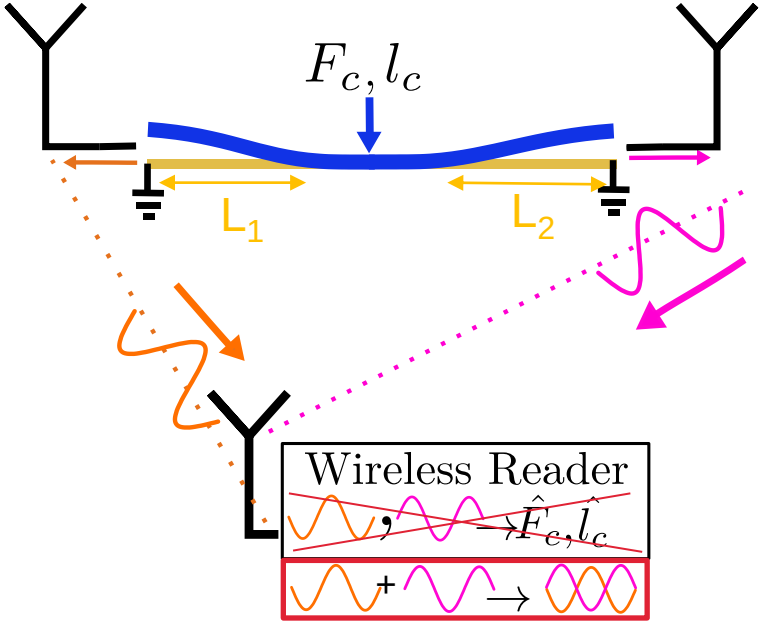
How are contact lengths measured wirelessly?

Phase Accumulated ∝ Travelled Length

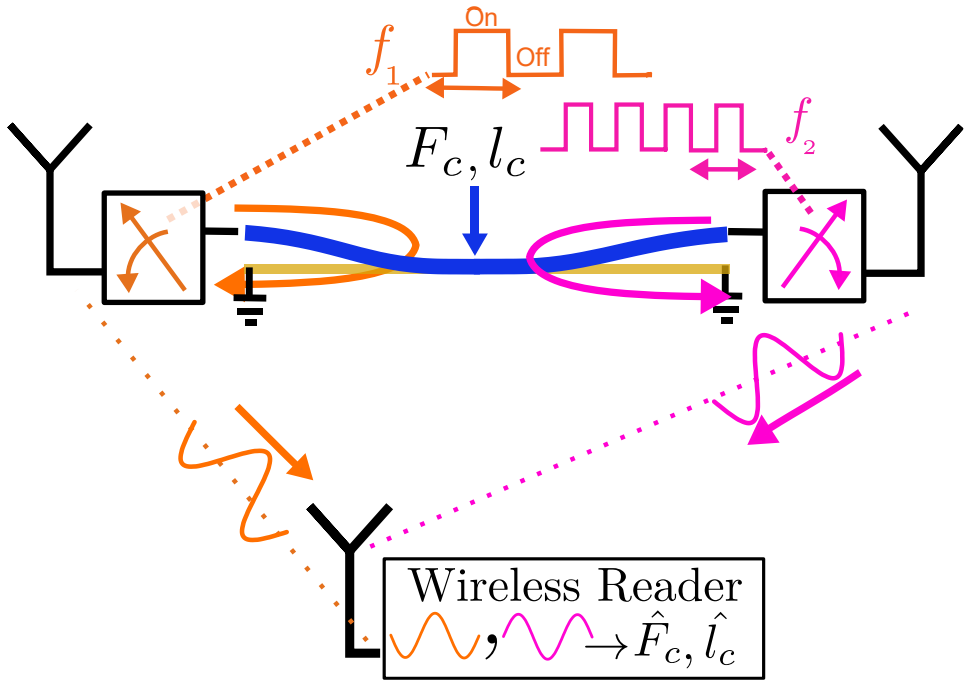




Handling interference caused by two-sided reflections

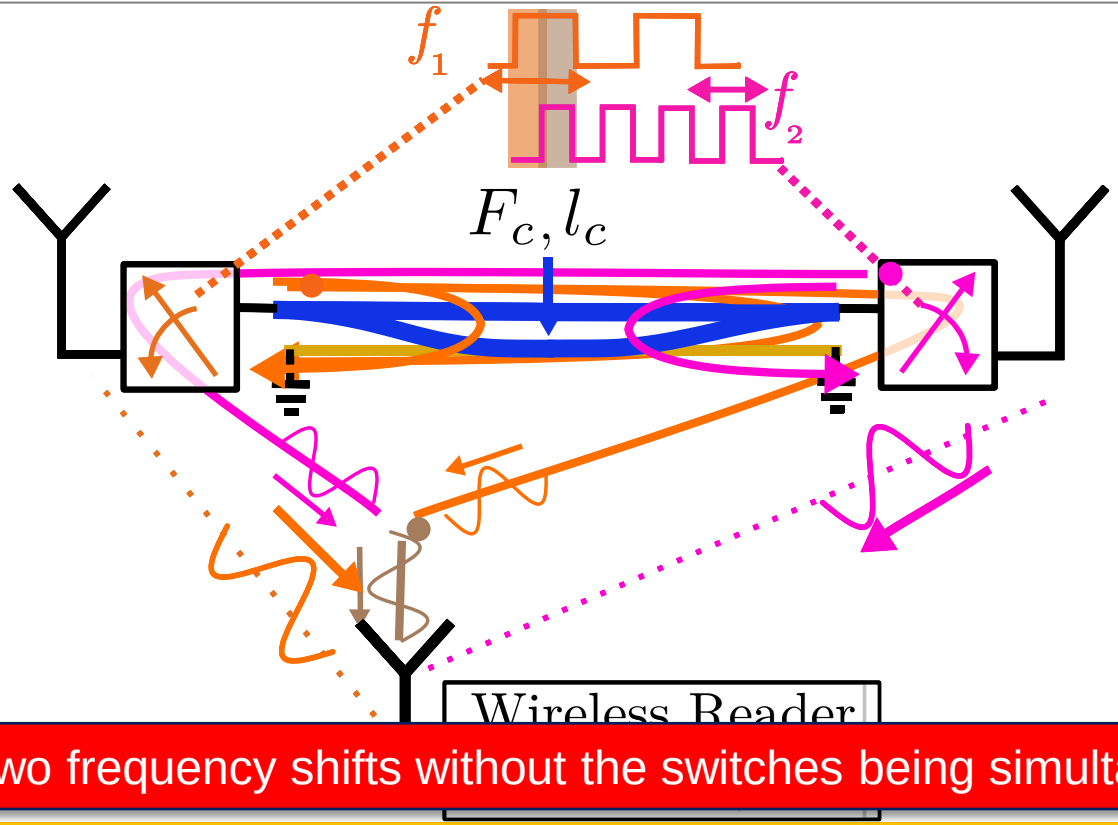


Without RF Switches



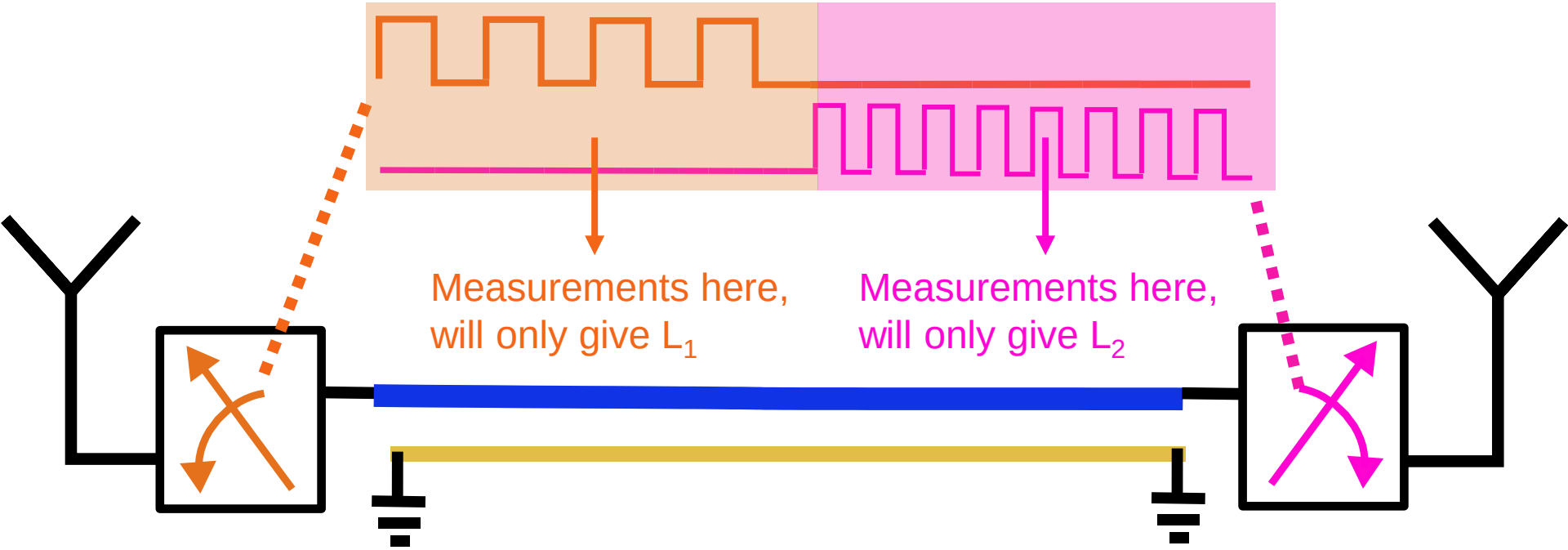
With RF Switches

Two swords in one sheath don't fit together



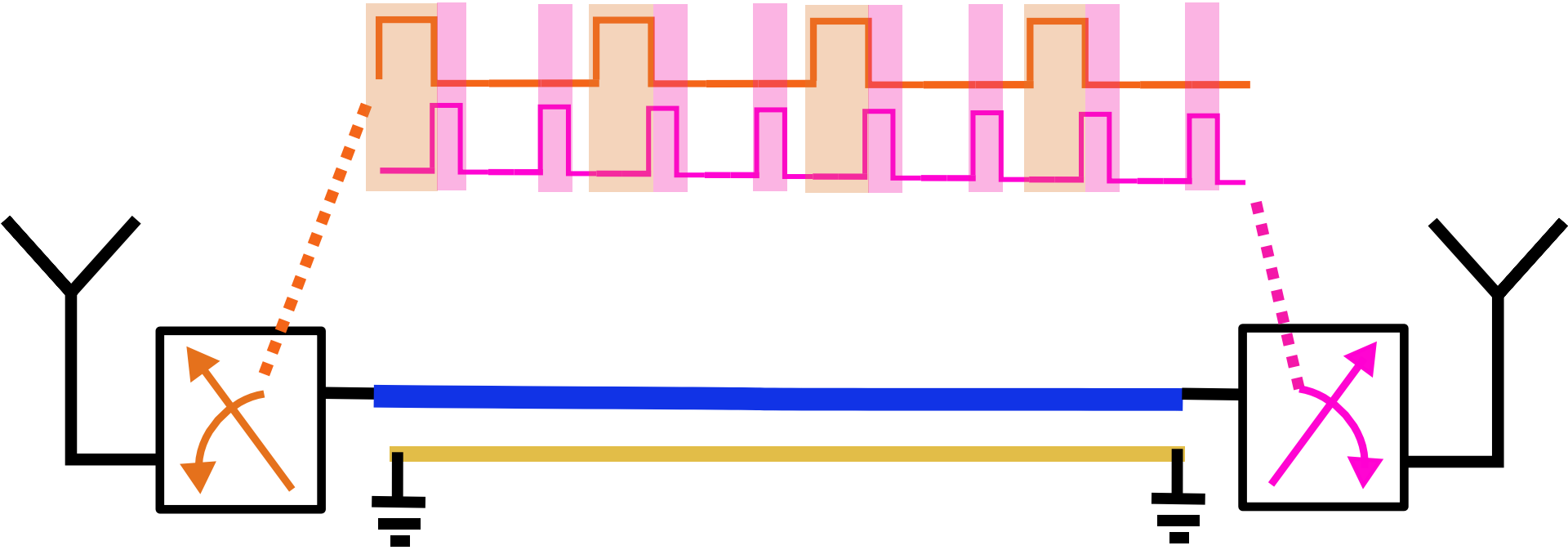
How to give two frequency shifts without the switches being simultaneously ON?

Doing one at a time toggling



We can not measure lengths from the two ends simultaneously with this solution

Interleaving the off times creates continuous modulation



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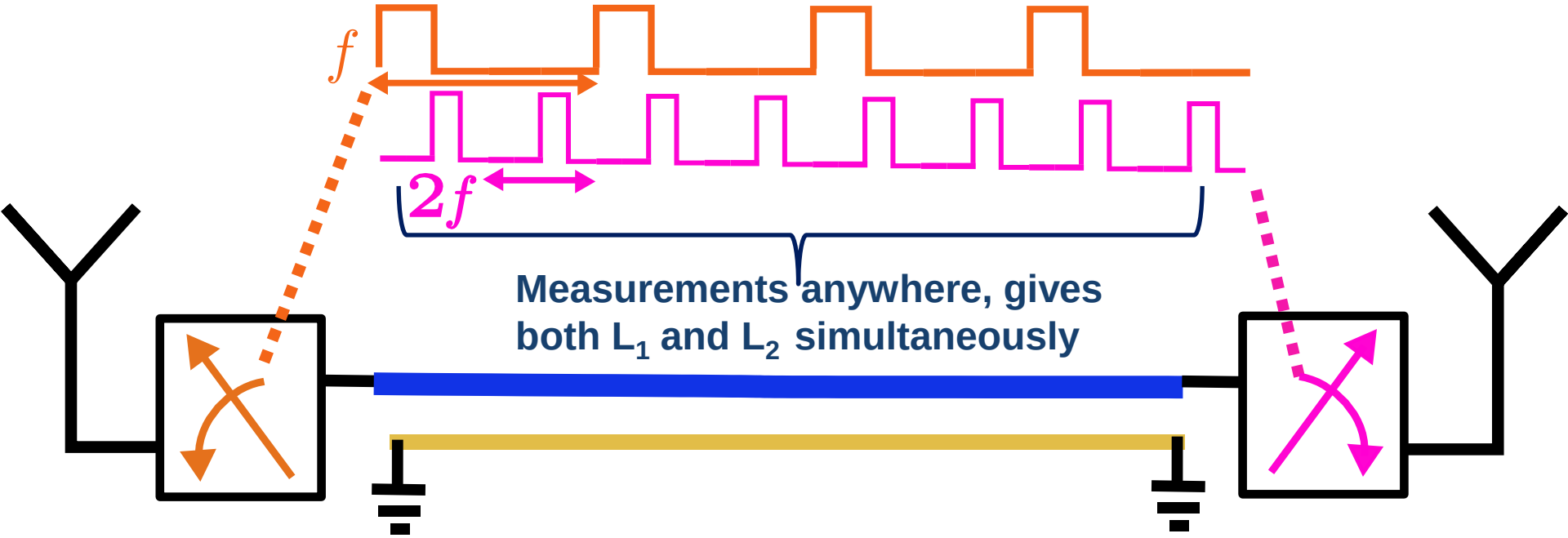
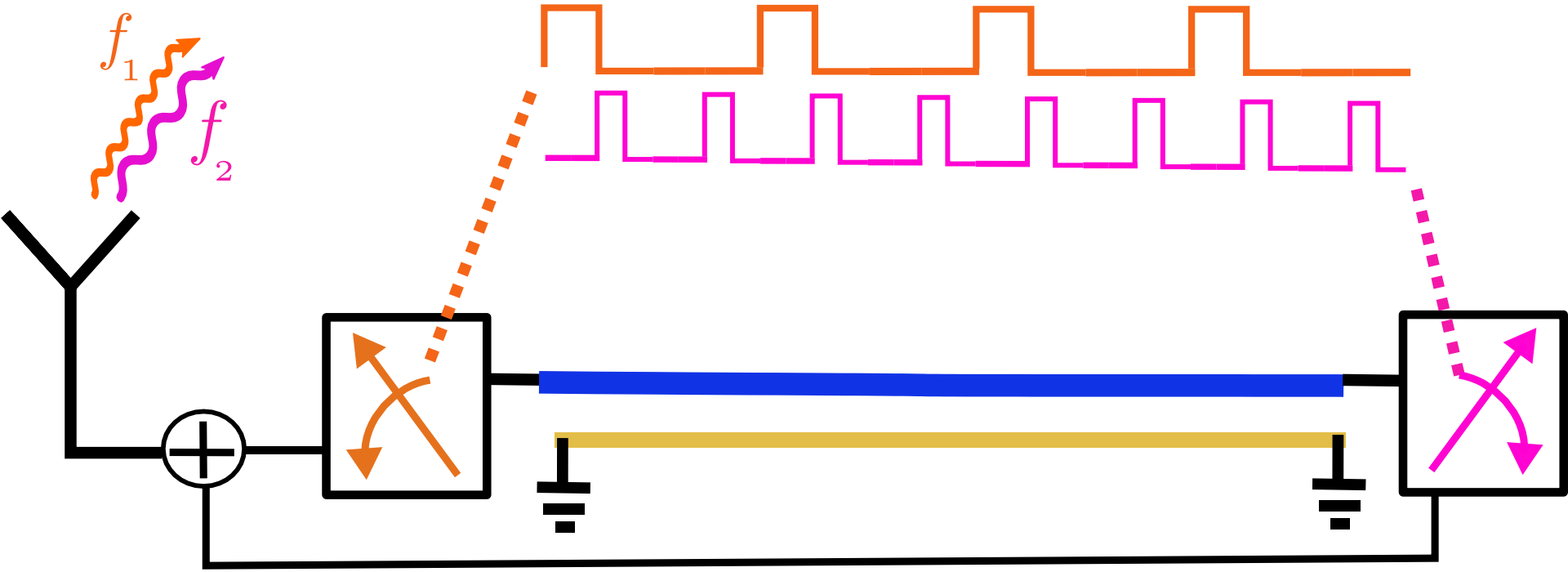
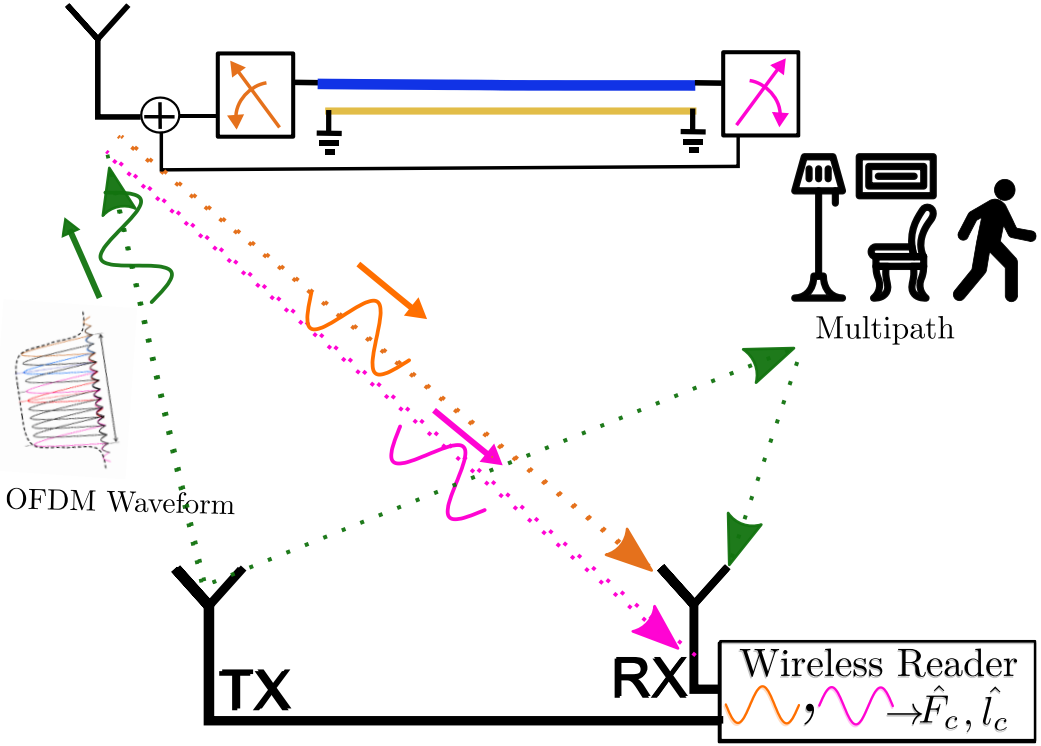


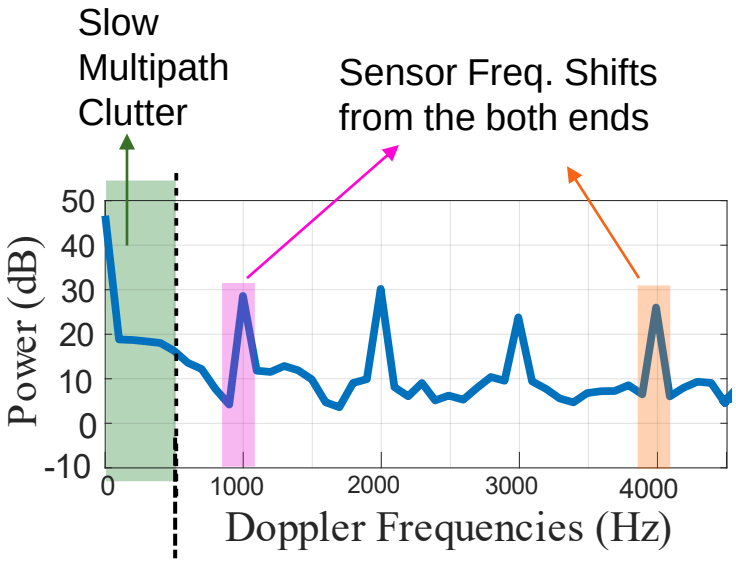
One antenna to sense them all



Two sided phases can be read with just one antenna reducing the form factor

Putting it all together: implementation of the reader

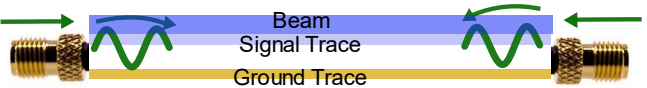


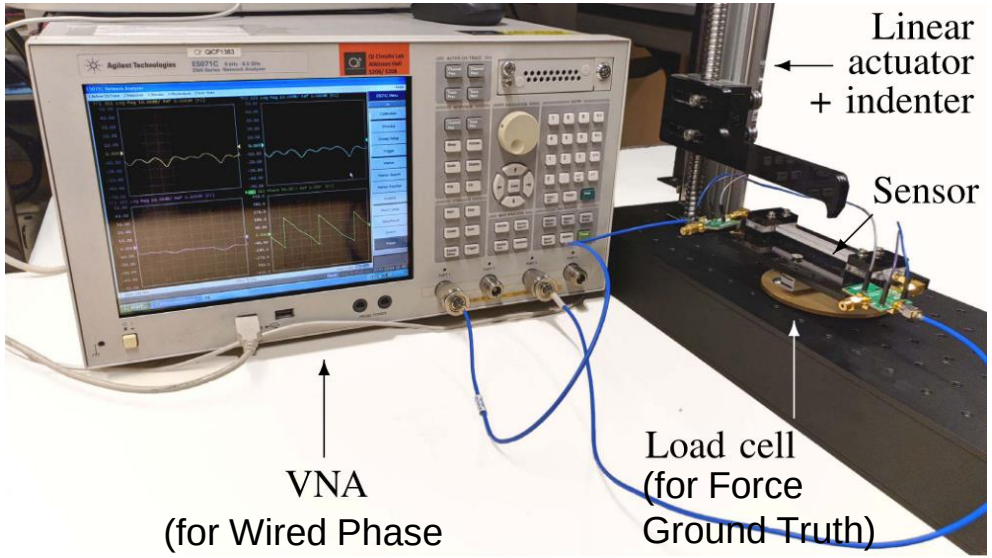


500 Hz ≈ 70 mph

Sensor implementation

Microstrip Line, with a soft polymer beam





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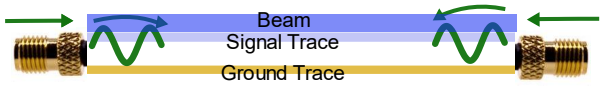
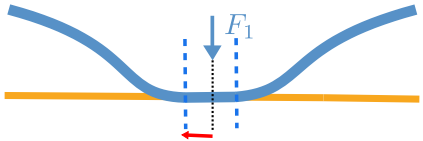
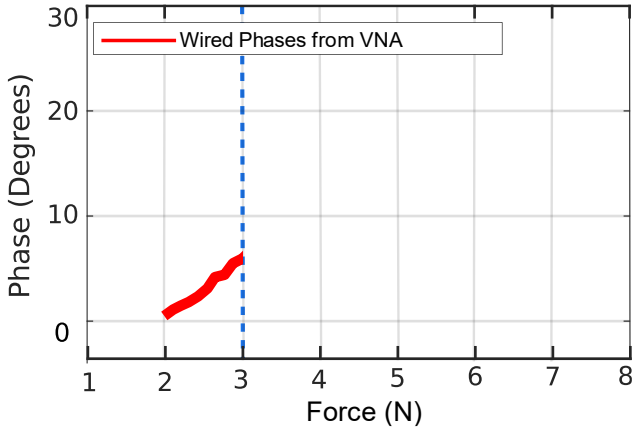
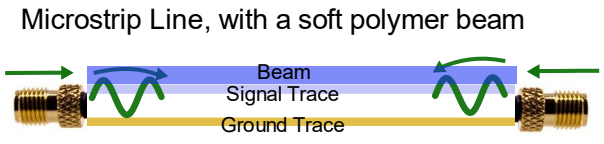
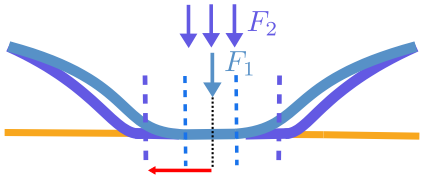


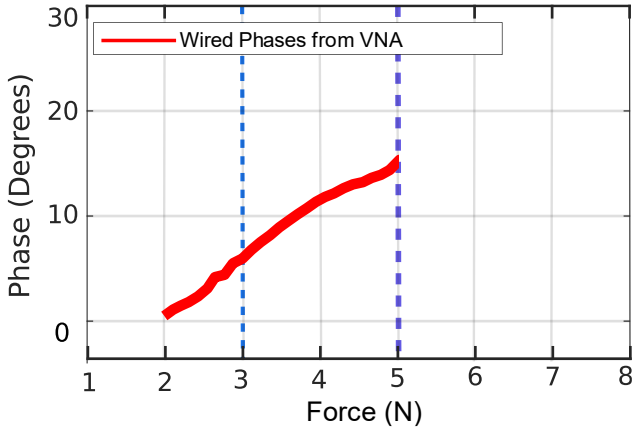




Sensor implementation







Sensor implementation

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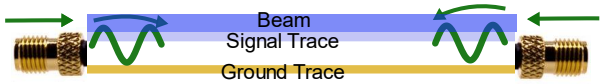
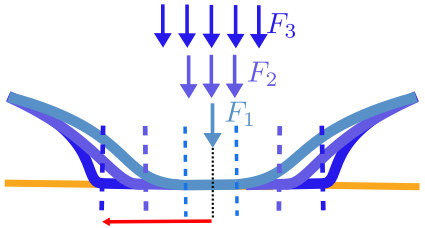
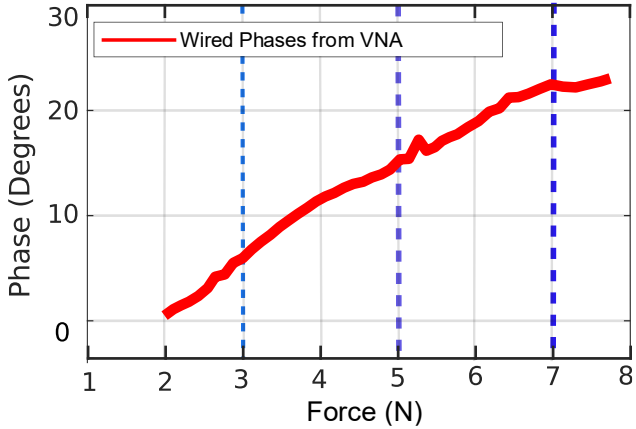
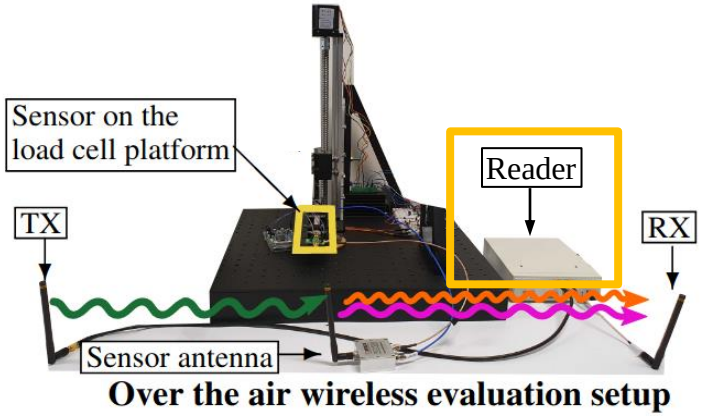


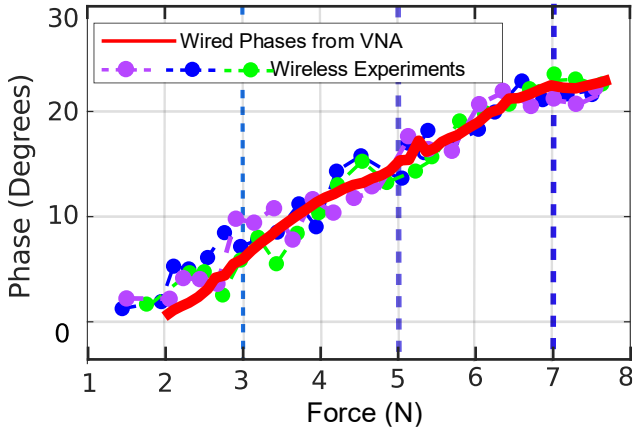




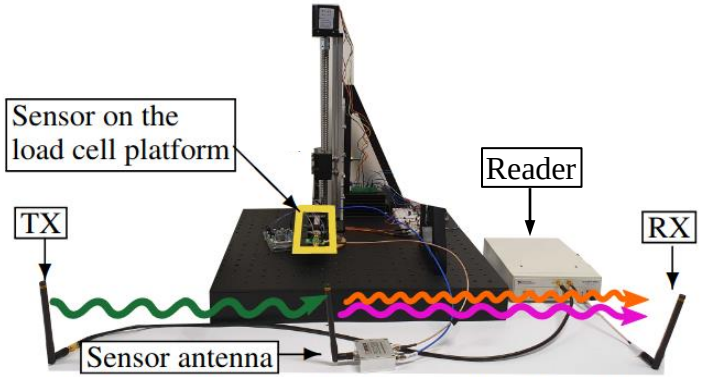
Wireless experimental setup



Over the air wireless evaluation setup



Force magnitude and location CDFs



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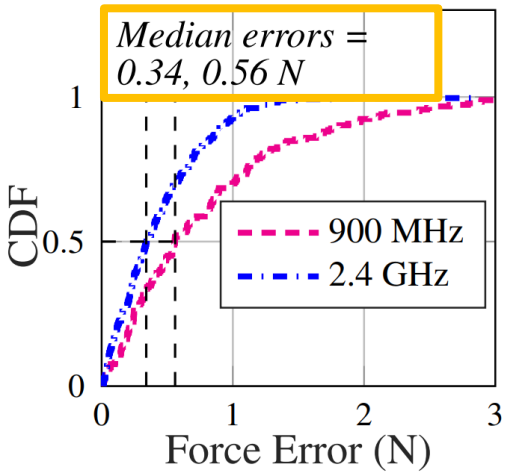
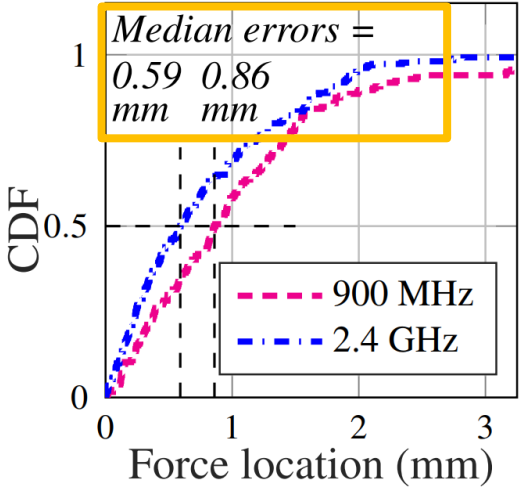
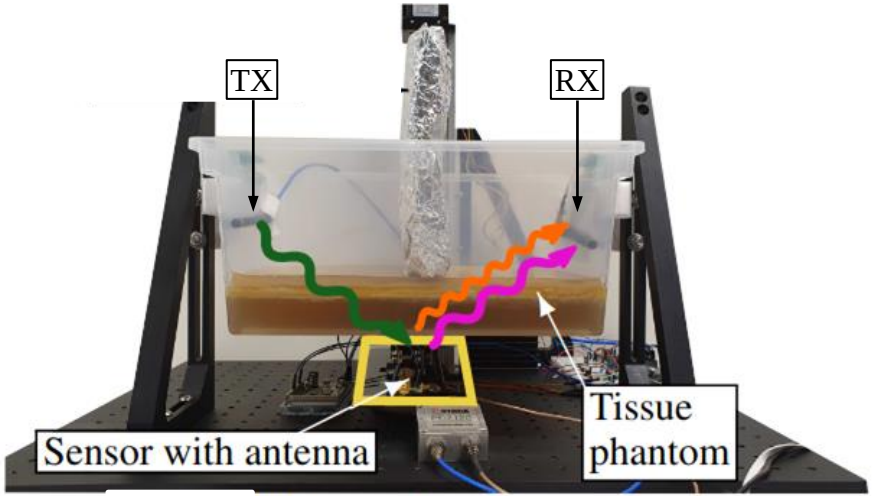
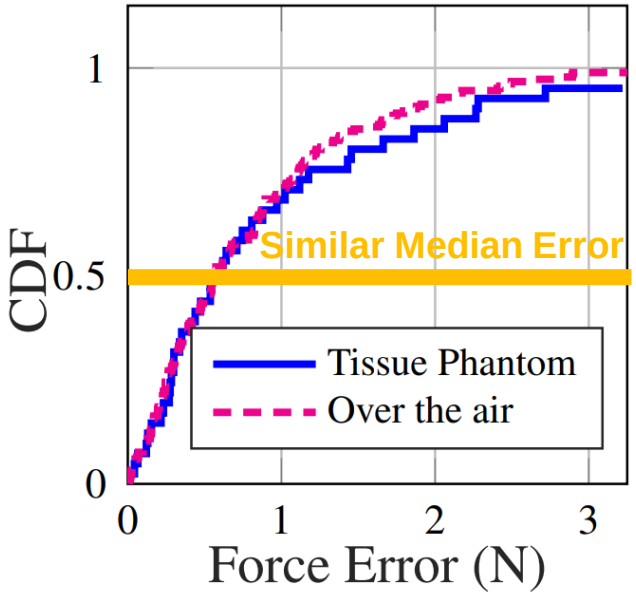




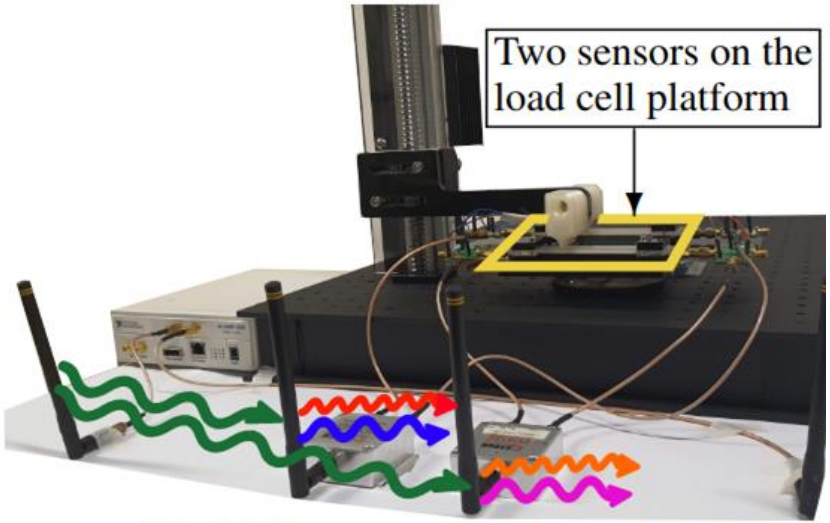
Tissue phantom testing setup



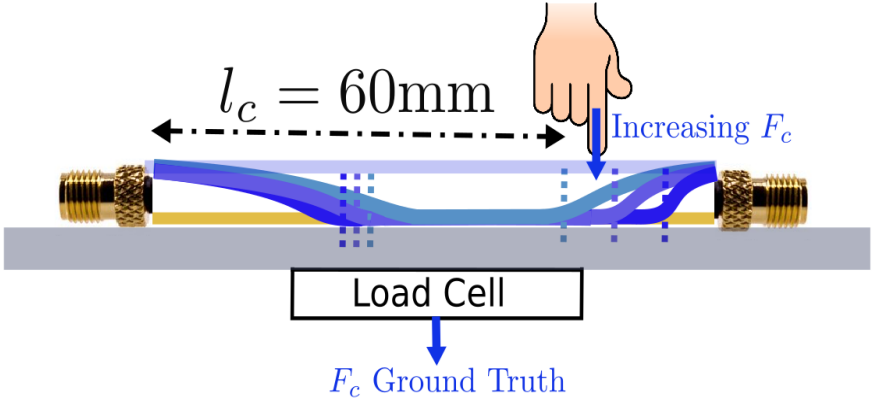
Tissue phantom setup



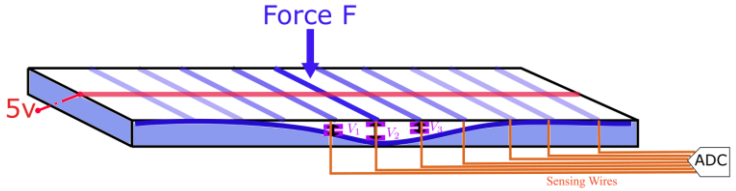
Multi-sensor and Fingertip touch force detection



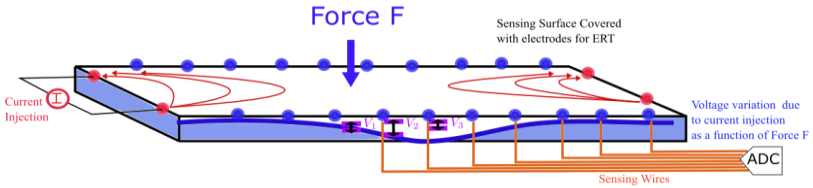
Multi Sensor experiment setup



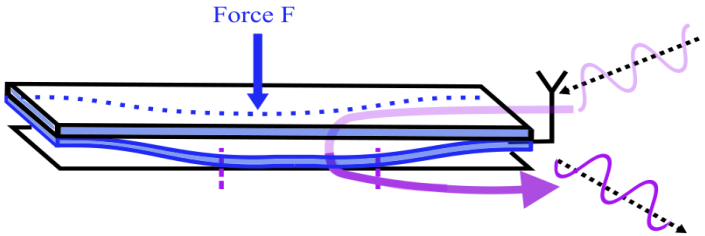
Related works



Force Sensitive Resistors,
Unmousepad: 2009



Electrode Resistance Tomography (ERT),
Hyosang Lee et al. 2018-20



WiForce

Future directions

WiForce achieves sub-N, mm level accuracy in sensing & localizing forces, fully wireless, multi-sensors scalable

1. Designing creative communication+sensing solutions for related quantities to force
2. Enabling new HCI usecases for AR/VR with WiForce
3. Combined wireless tracking with WiForce can enable a new robotics wireless sensor suite

Feel free to contact me at agg003@eng.ucsd.edu for more information about our research!

http://wcsng.ucsd.edu/force_sensing