

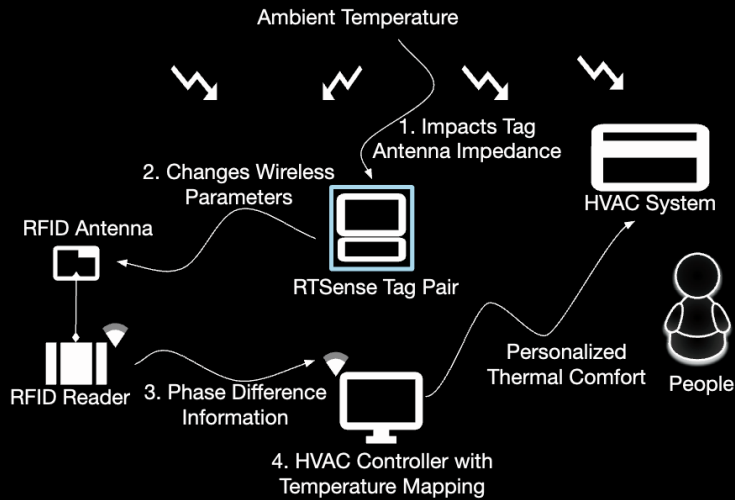


From Signal-based to Impedance-based Sensing: A Paradigm Shift for Plug-and-play, Mobile, and Sensitive Battery-free Sensing

Liyao Li¹, Yun Wu², Minsung Kim³, Bozhao Shang², Jie Xiong⁴, Wenyao Xu¹,
Xiaojiang Chen², Yaxiong Xie¹

¹University at Buffalo, SUNY, ²Northwest University
³Rutgers University, ⁴Nanyang Technological University

Battery free Wireless sensing



RTSense [SenSys '20]:
Temperature sensing

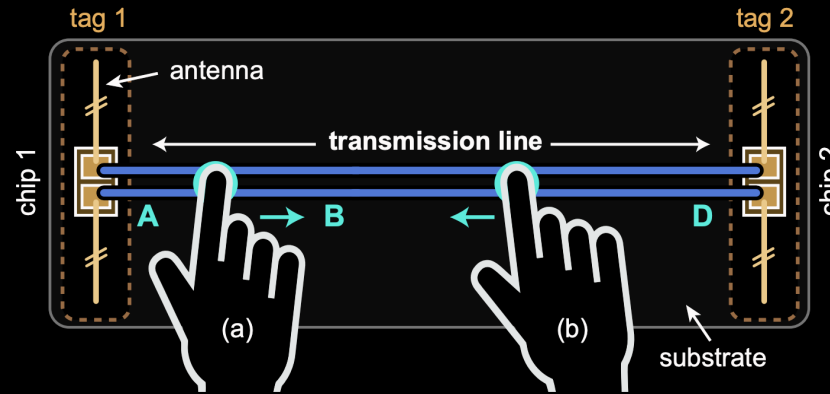
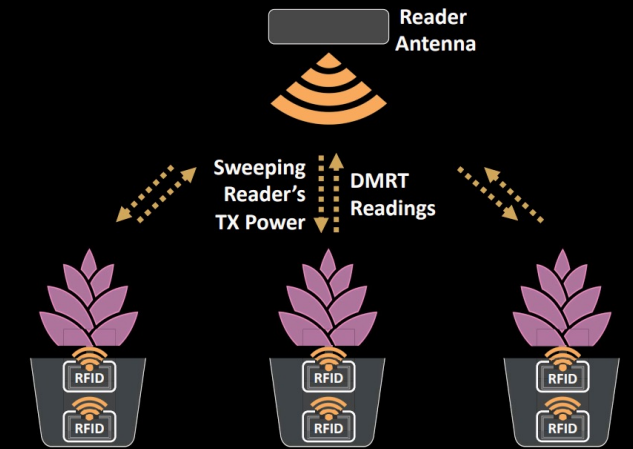
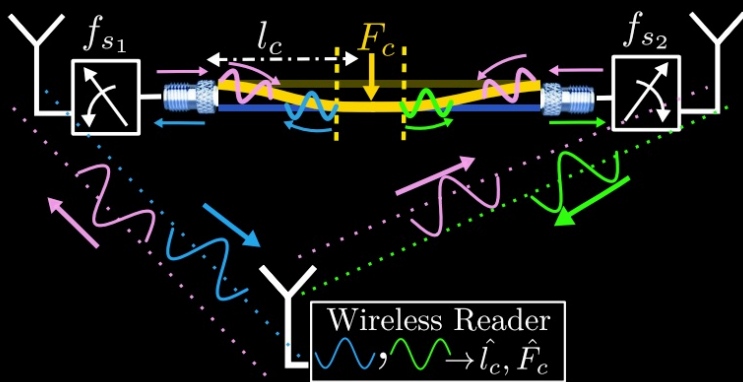


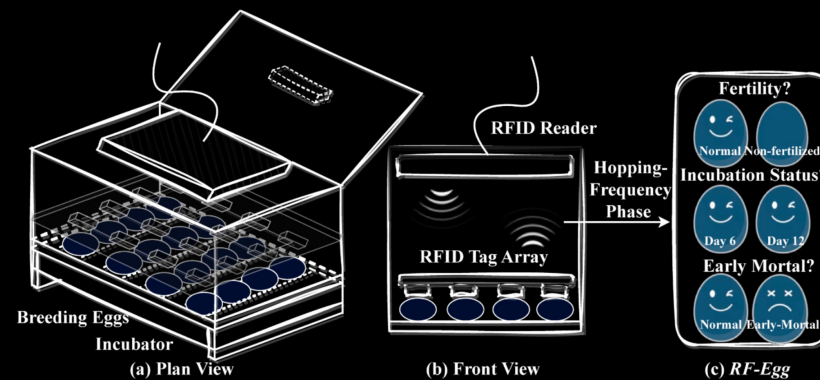
Figure Input sensing [Sensys '20]



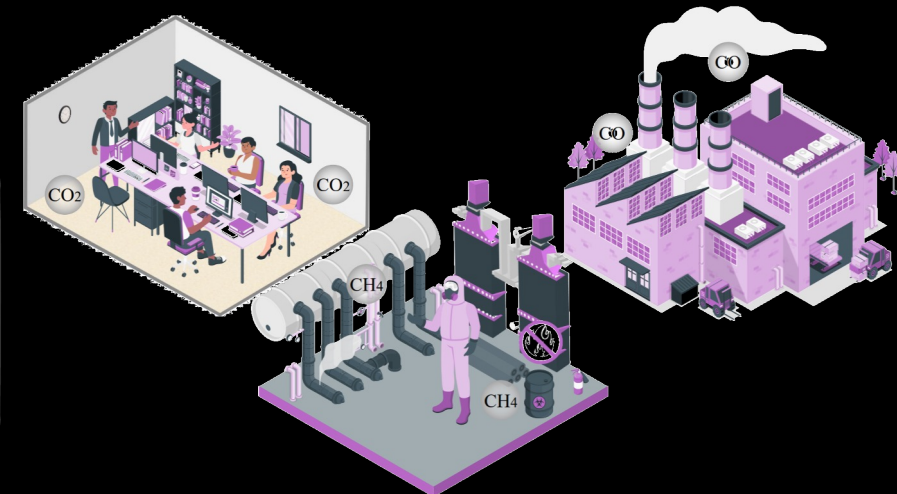
Soil Moisture sensing [MobiSys '20]



WiForce [NSDI '22]: Tracking and
measuring force

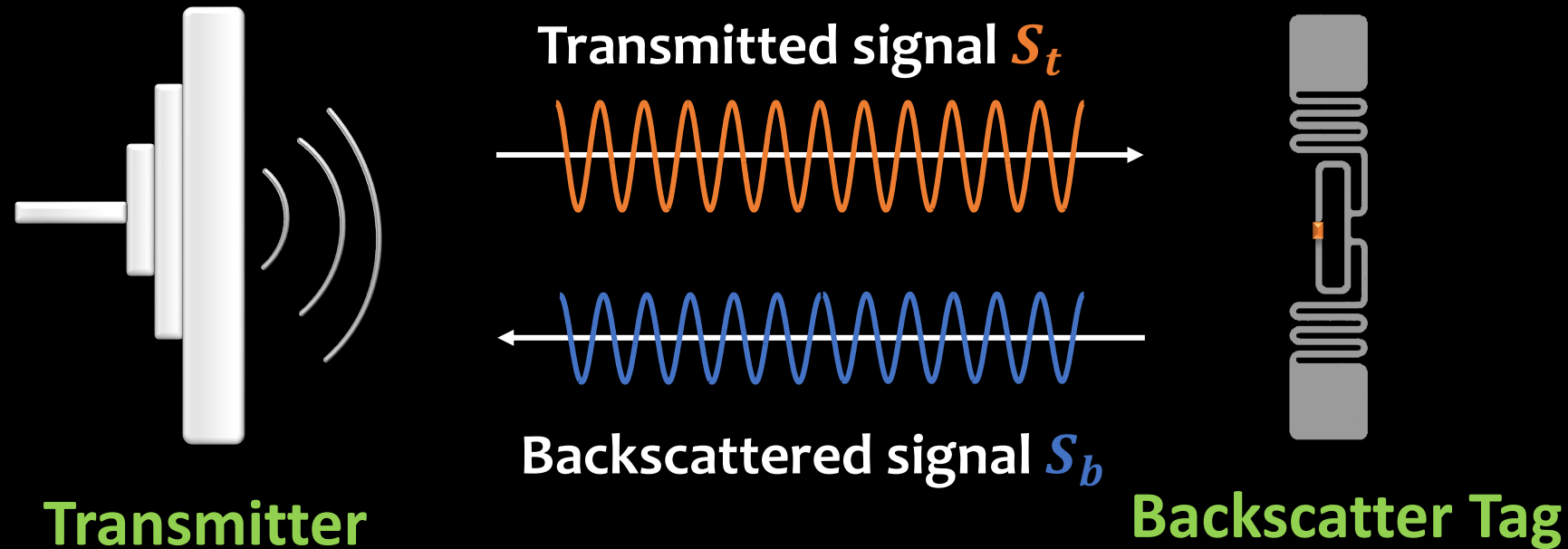


RF-Egg [Mobicom '25]: Egg incubation
sensing

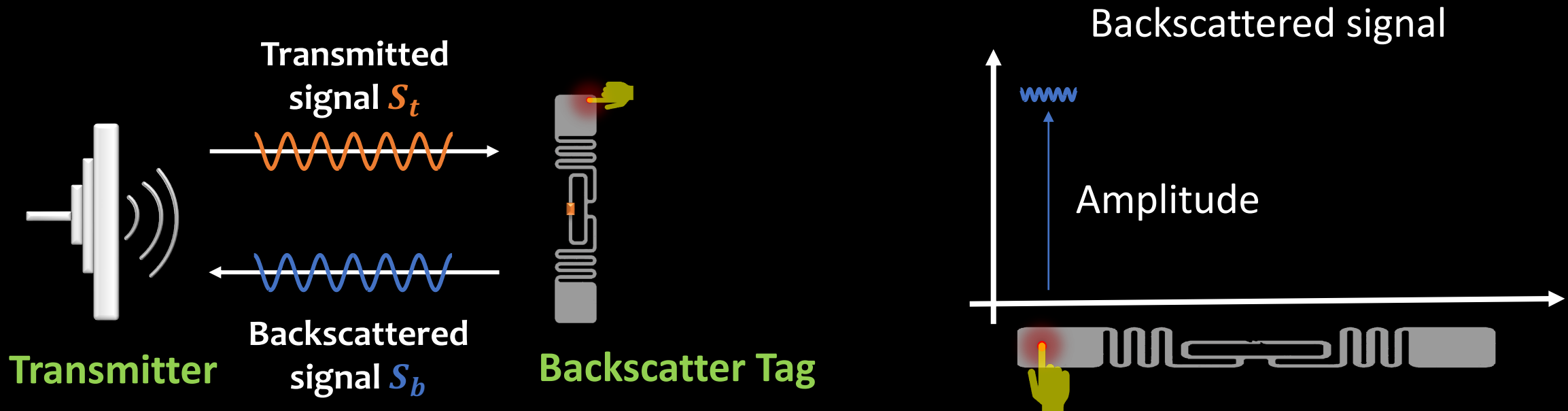


Gastag [Mobicom '25]: Sensing gas
concentration

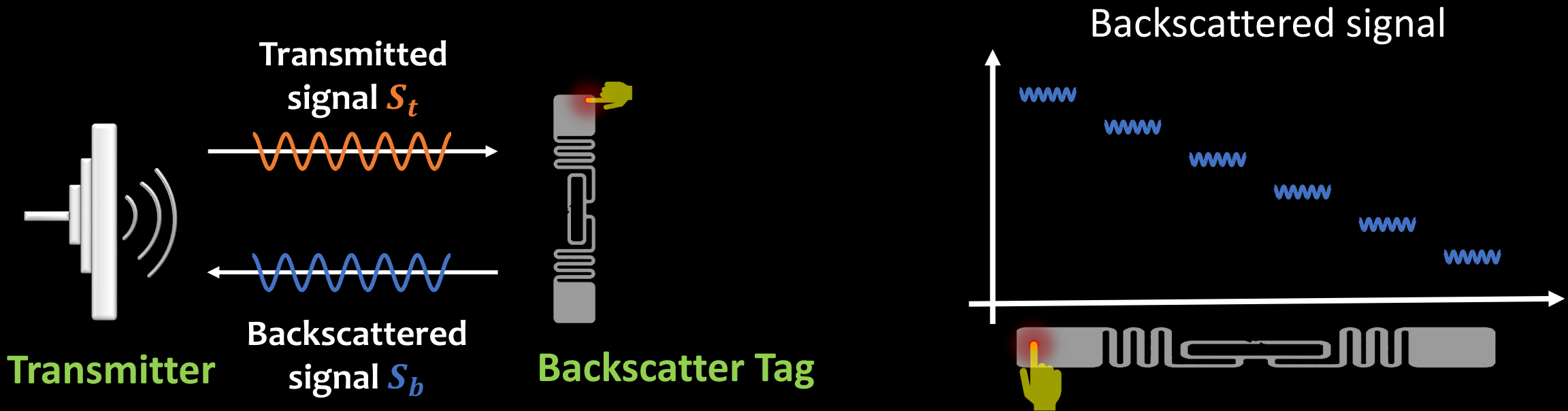
Battery-free Communication: Backscatter



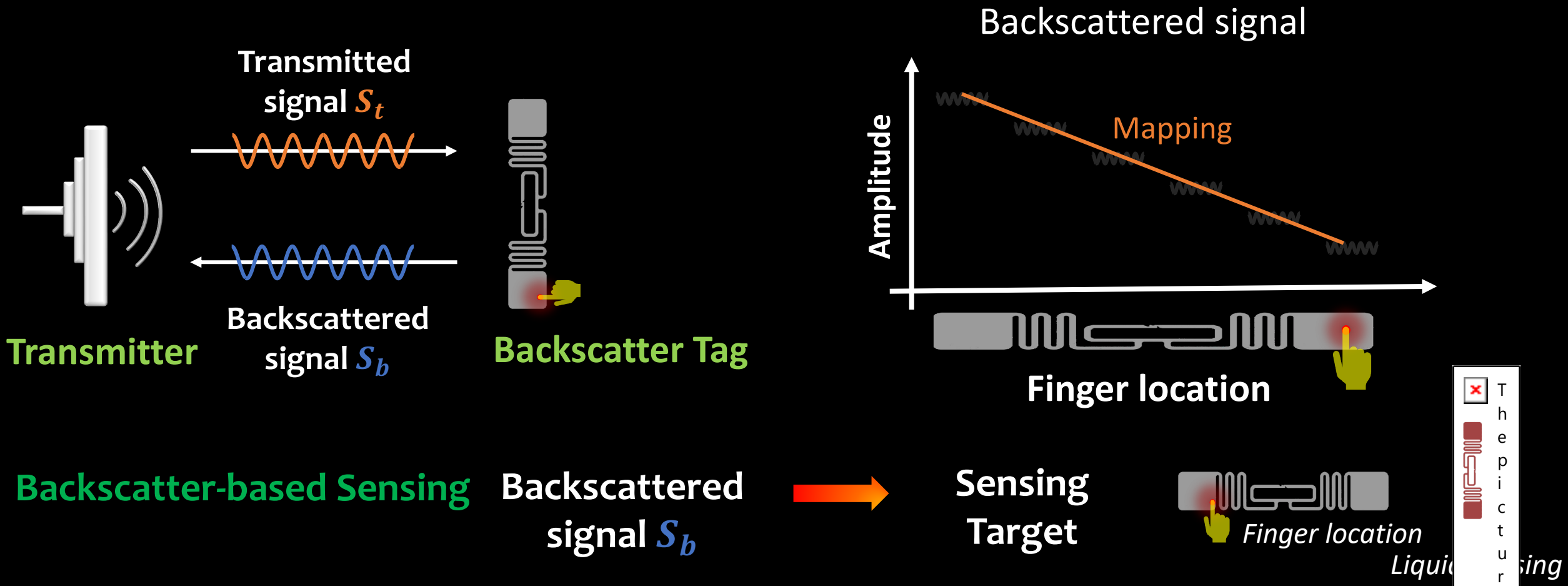
Backscatter-based Sensing



Backscatter-based Sensing

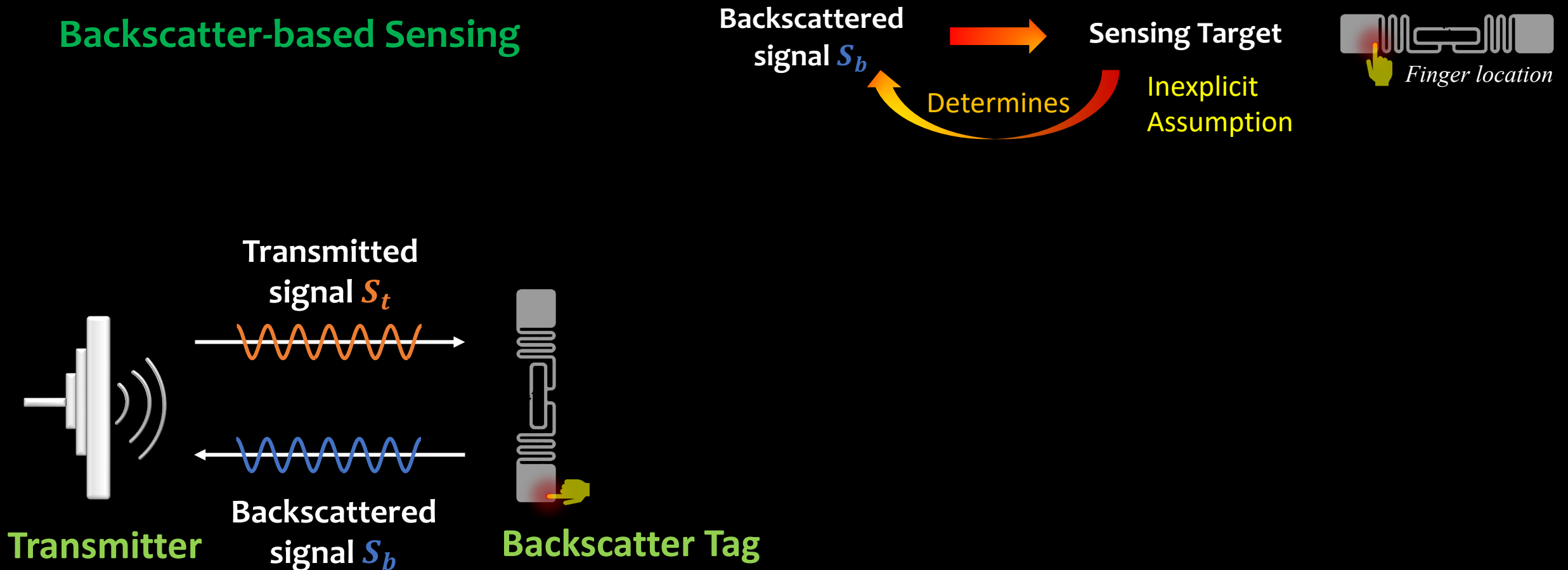


Backscatter-based Sensing



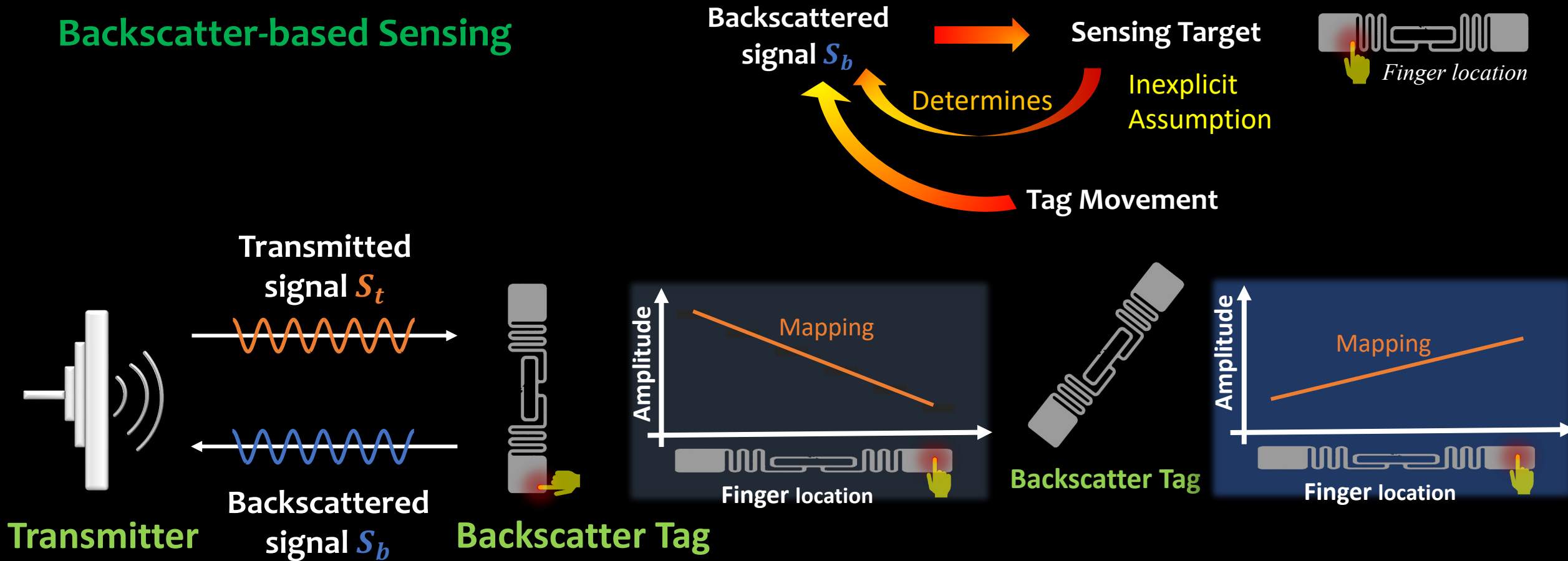
Challenges of Backscatter-based Sensing: *Interference*

Backscatter-based Sensing



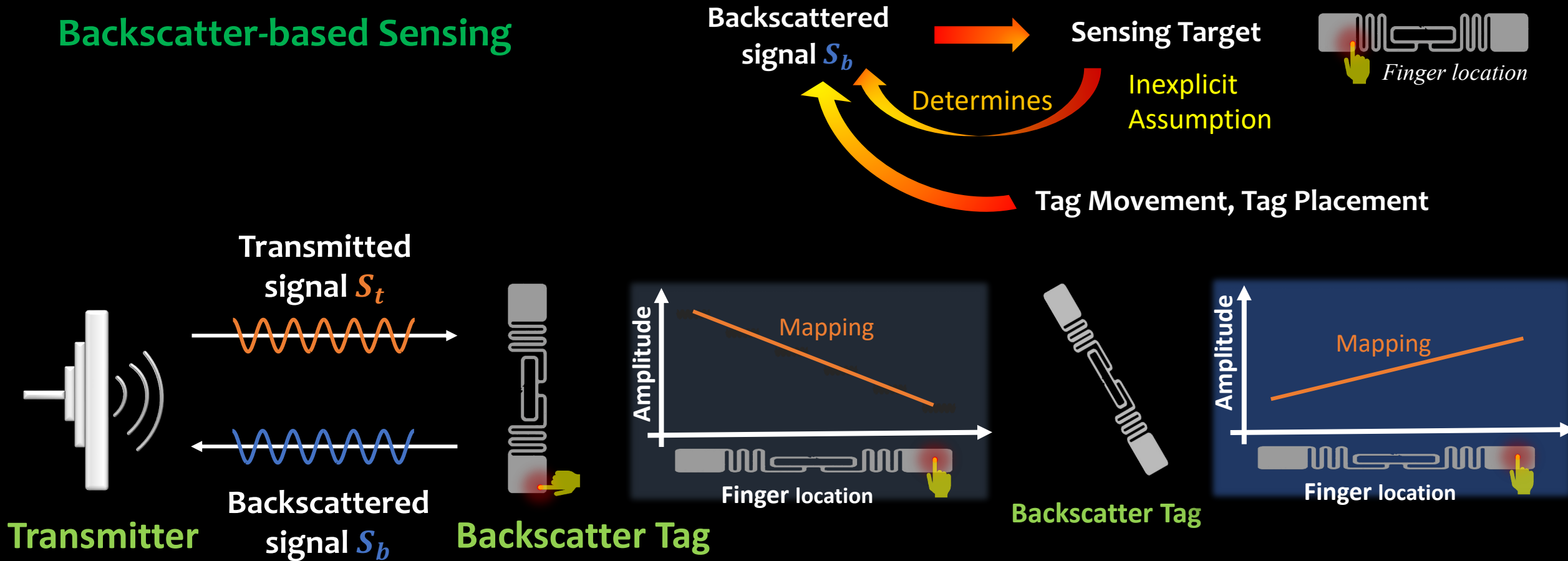
Challenges of Backscatter-based Sensing: *Interference*

Backscatter-based Sensing



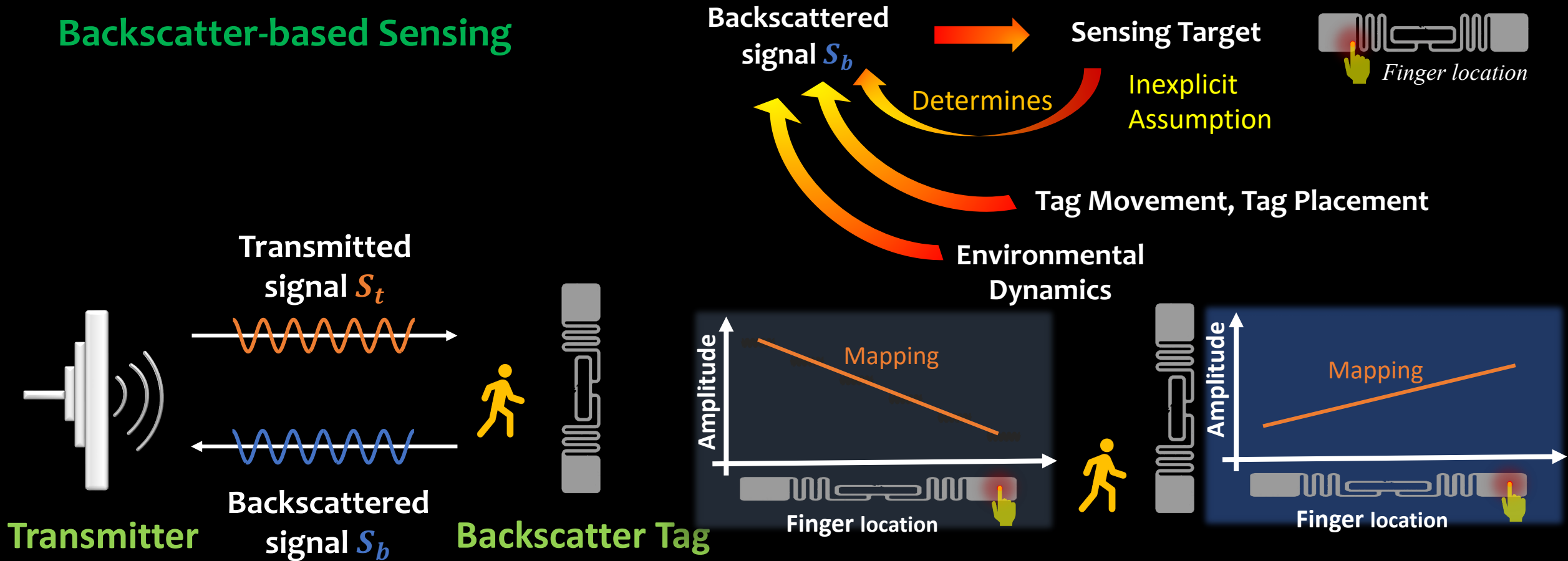
Challenges of Backscatter-based Sensing: *Interference*

Backscatter-based Sensing



Challenges of Backscatter-based Sensing: *Interference*

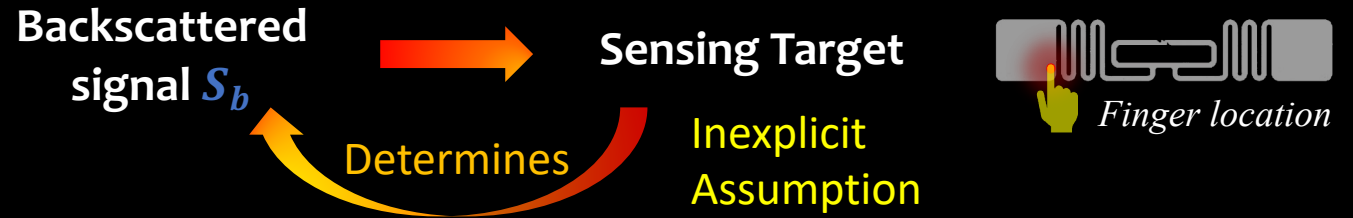
Backscatter-based Sensing



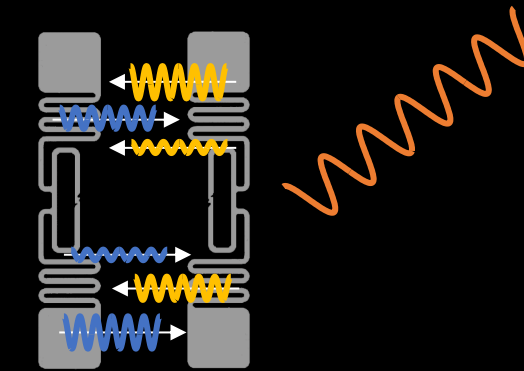
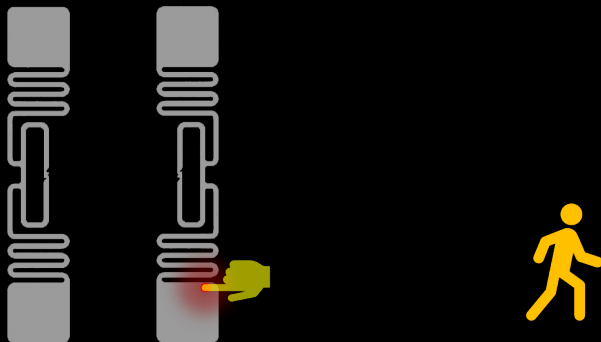
Challenges of Backscatter-based Sensing: *Interference*

→ *Existing Solutions : Reference tag*

Backscatter-based Sensing



Reference Tag



Mutual Coupling

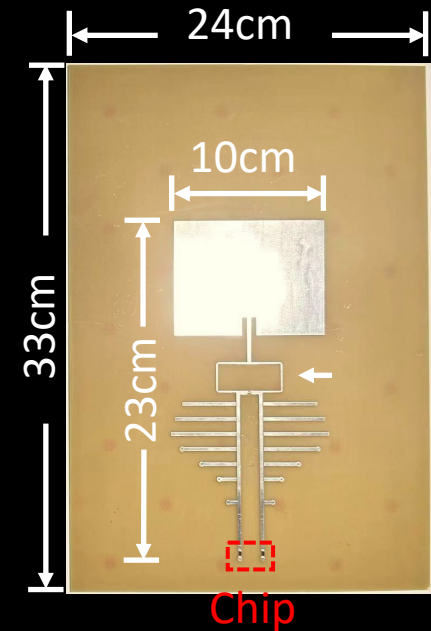
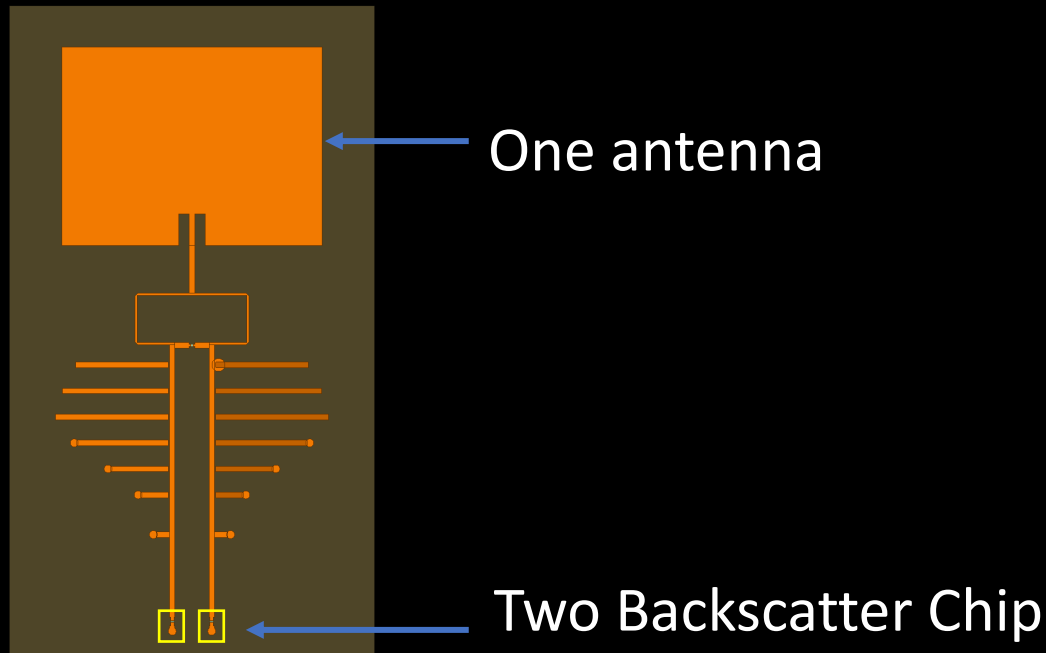
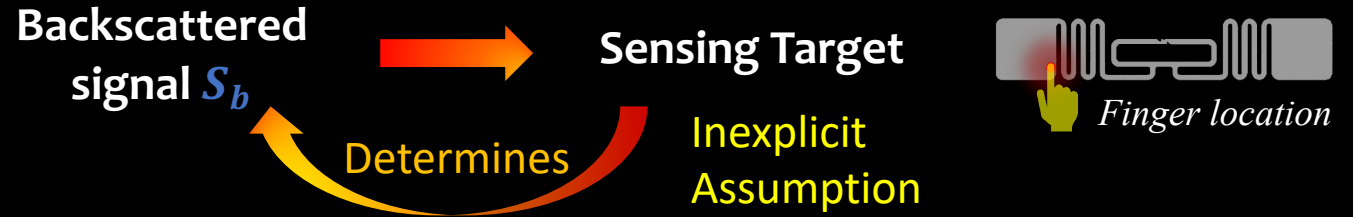
- Mutual coupling changes the signal and thus signal difference
- Mutual coupling varies with tag motion, placement and channel dynamics

Measure the signal difference

Challenges of Backscatter-based Sensing : *Interference*

→ *Existing Solutions: Power divider*

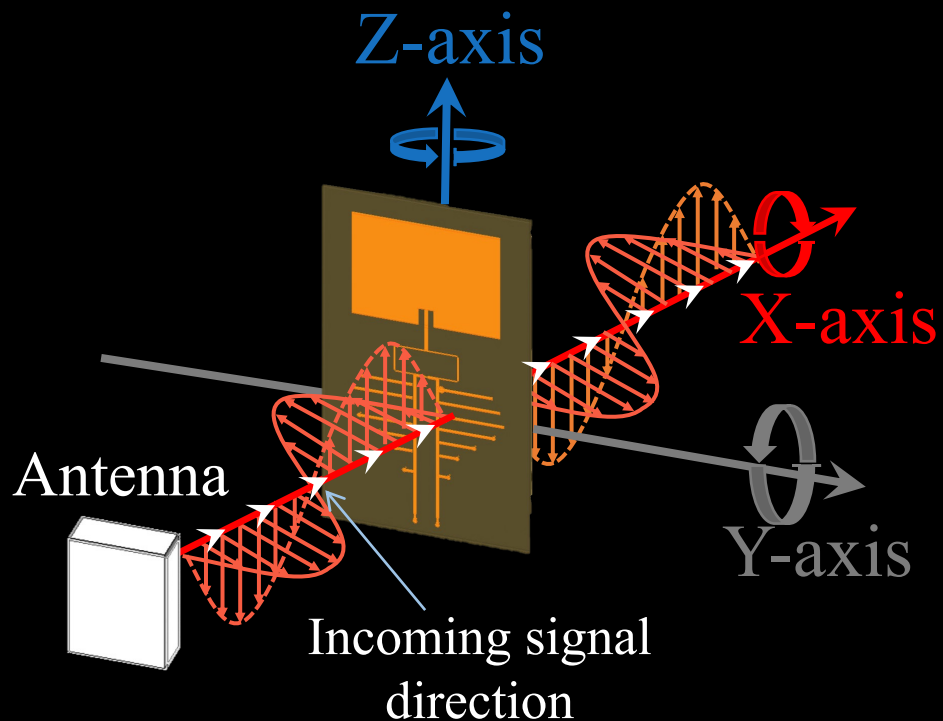
Backscatter-based Sensing



Challenges of Backscatter-based Sensing : *Interference*

→ *Existing Solutions : Power divider*

Backscatter-based Sensing



Backscattered signal S_b



Sensing Target

Determines

Inexplicit Assumption

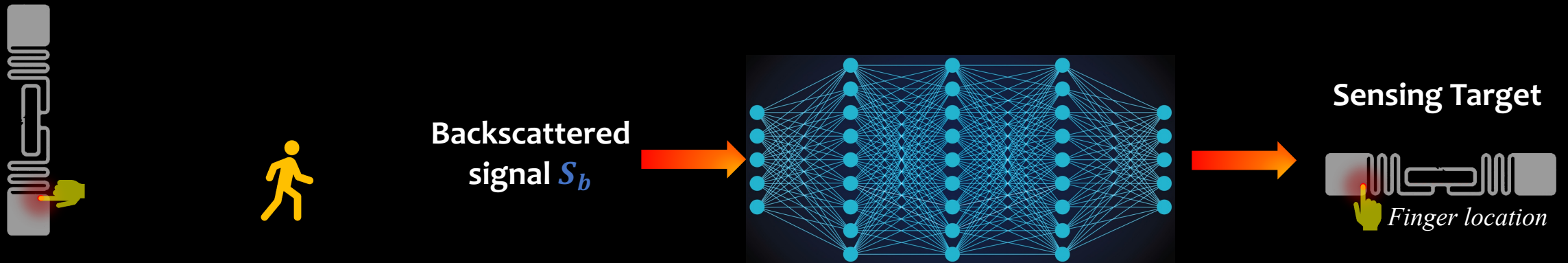
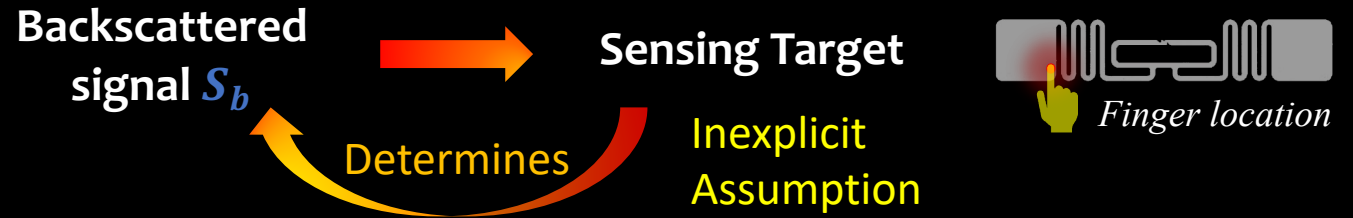


- Bulky Tag
- Sensitive to Tag Orientation
- Reading Rates Drop with Distance & Rotation

Challenges of Backscatter-based Sensing: *Interference*

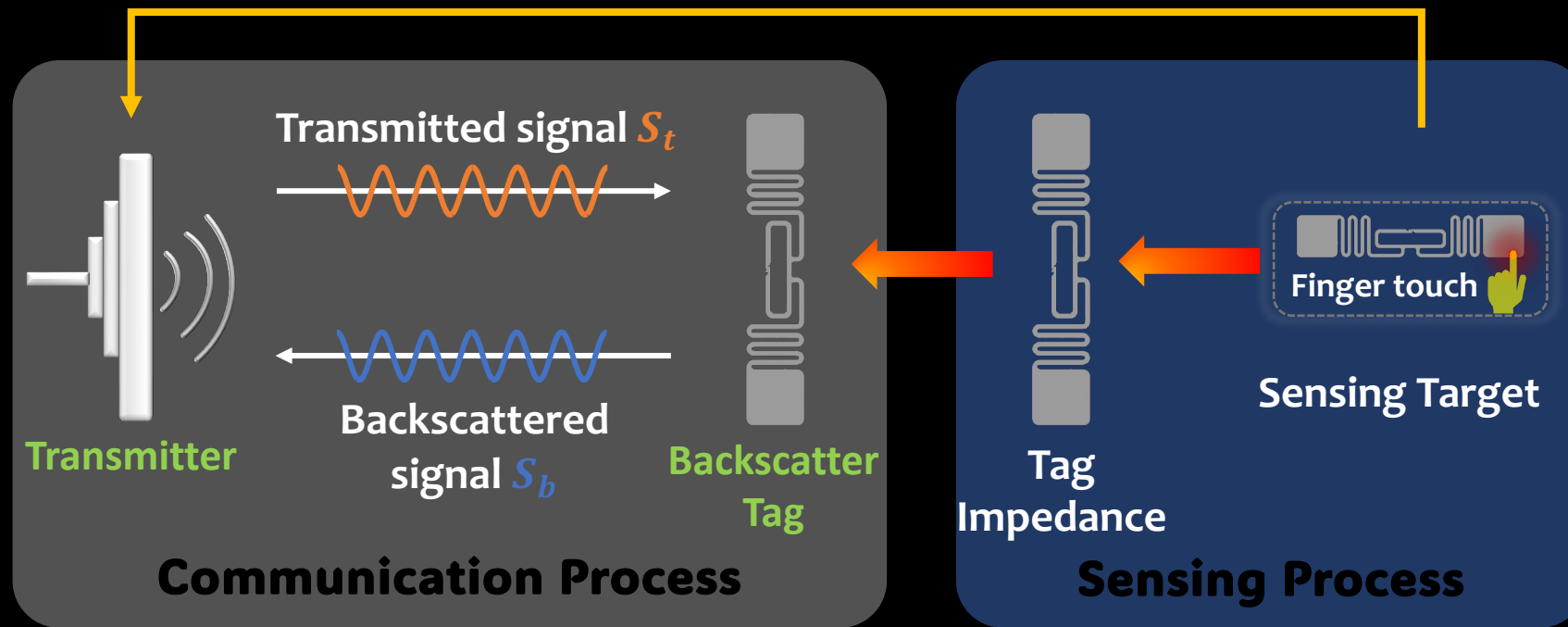
→ *Existing Solutions : Machine learning based*

Backscatter-based Sensing

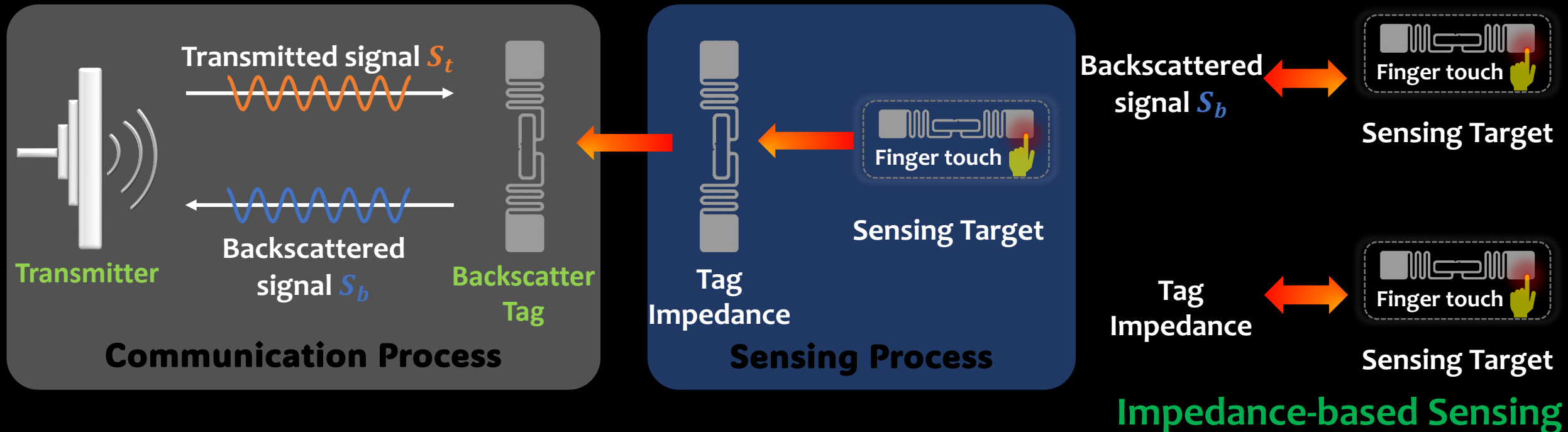


Paradigm-Shift: Impedance-based Sensing

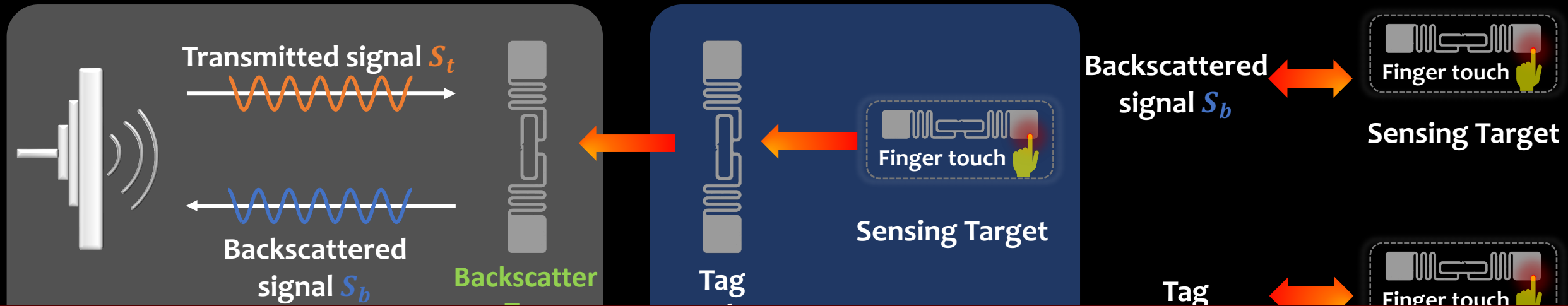
Traditional Scheme



Paradigm-Shift: Impedance-based Sensing

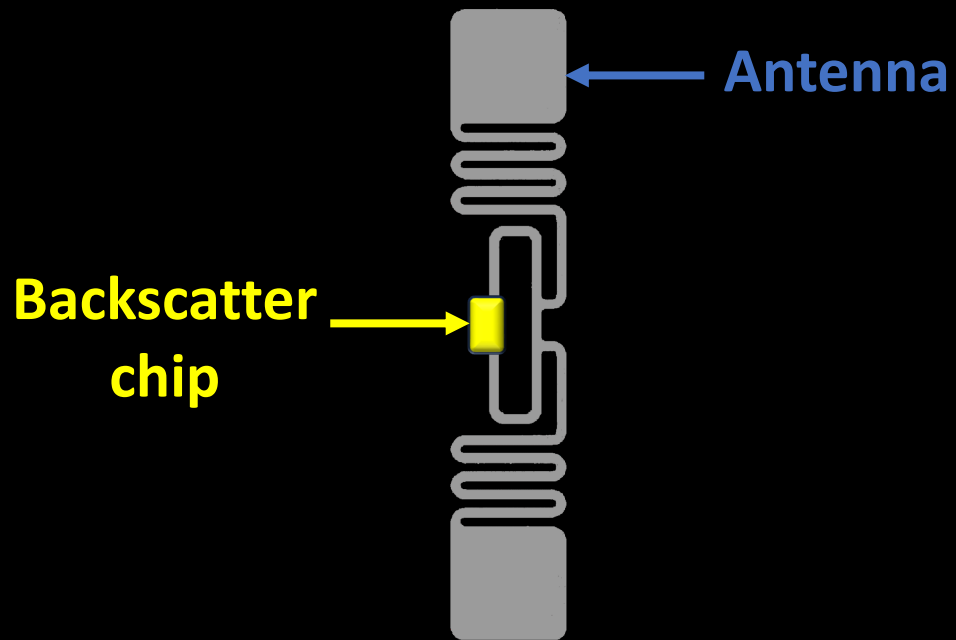


Paradigm-Shift: Impedance-based Sensing

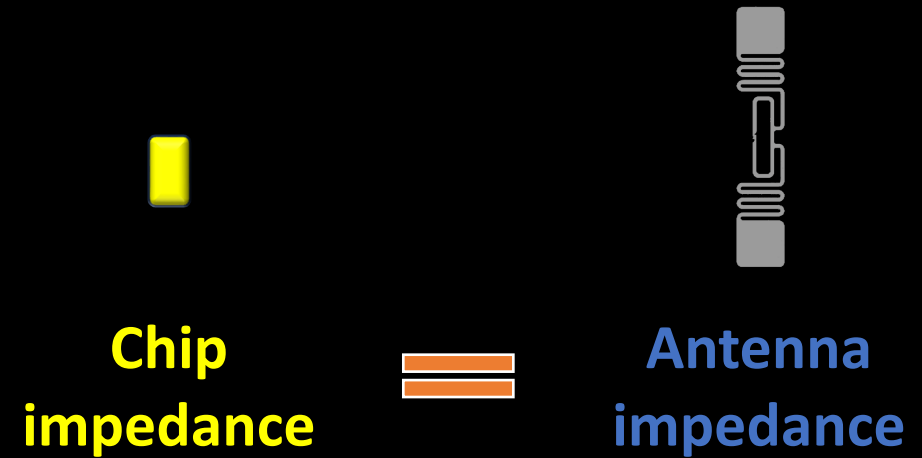


How can we **accurately measure** the impedance of the backscatter tag?

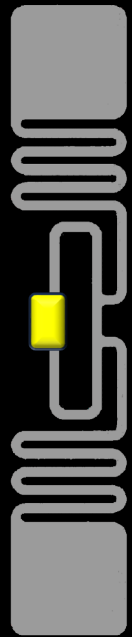
Impedance Matching



Wireless Communication Theory



Antenna Impedance Varies with Sensing Targets



Wireless Communication Theory

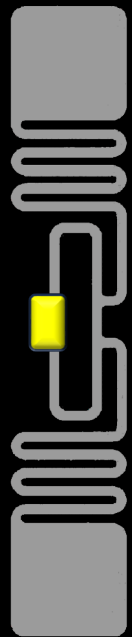
**Chip
impedance**



**Antenna
impedance**

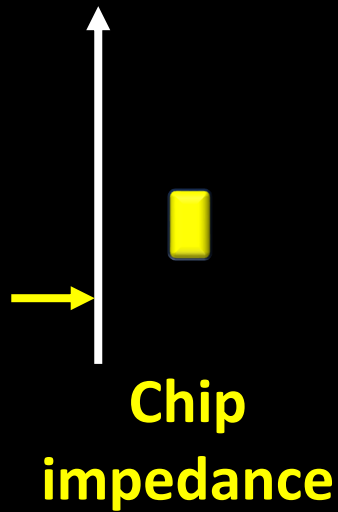
**Antenna
Impedance**

Dynamic Impedance Matching



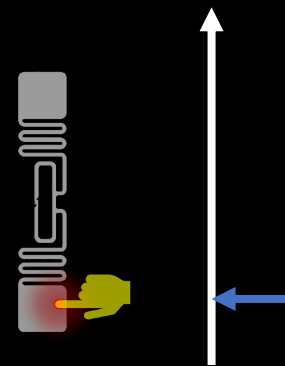
Wireless Communication Theory

Chip impedance



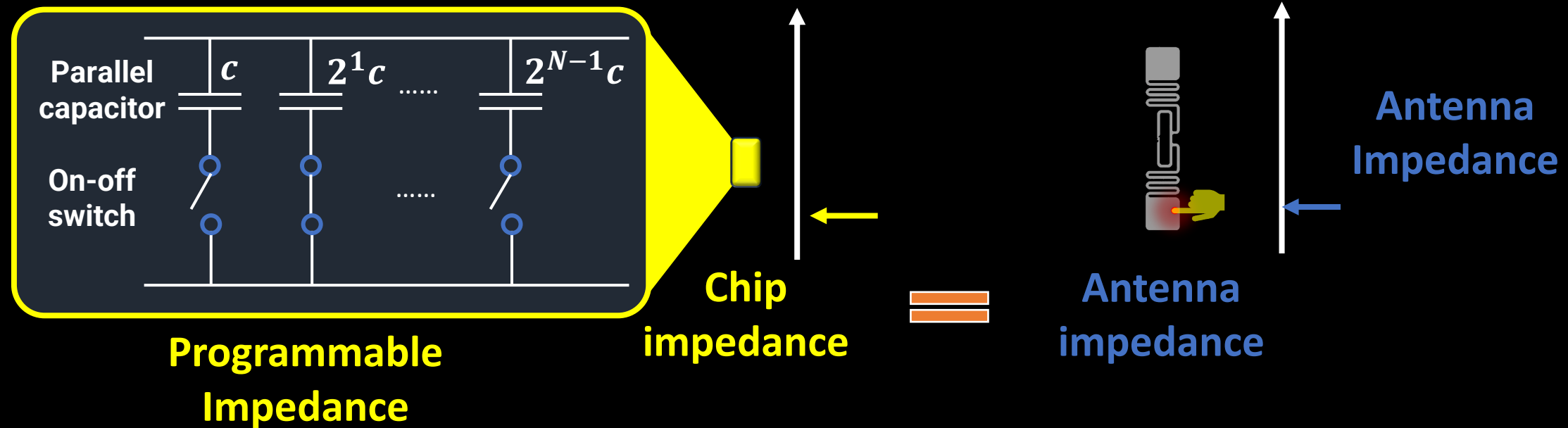
Antenna impedance

Antenna Impedance



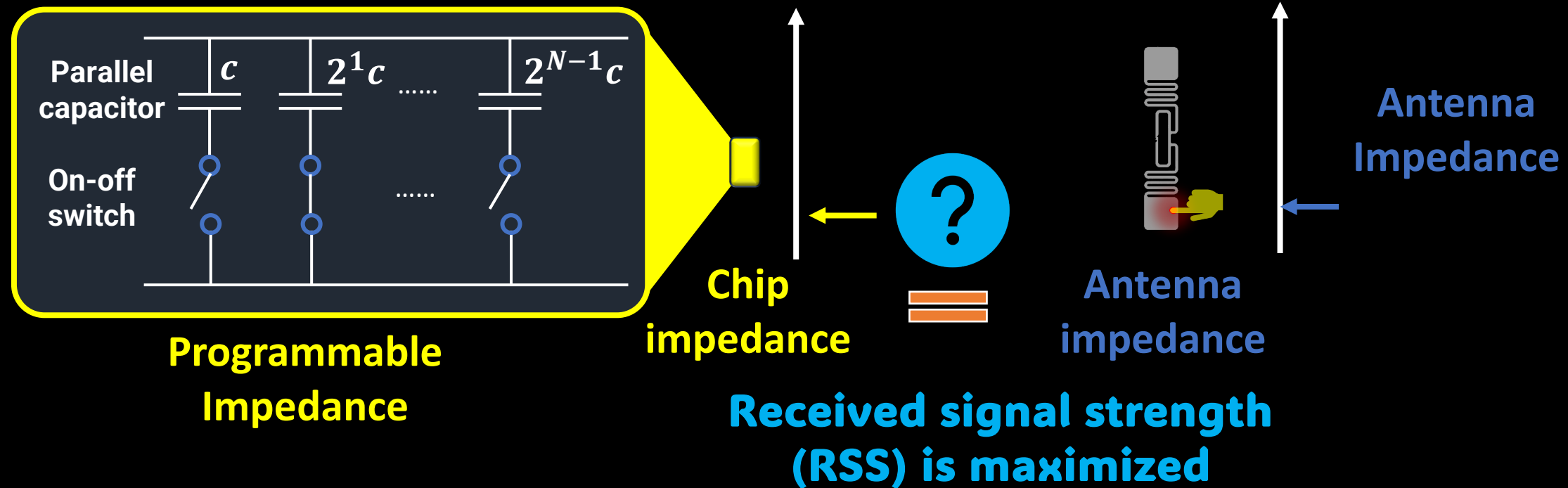
Dynamic Impedance Matching

Wireless Communication Theory

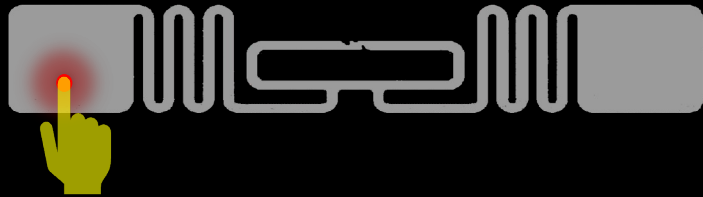


Dynamic Impedance Matching : OhmScanner

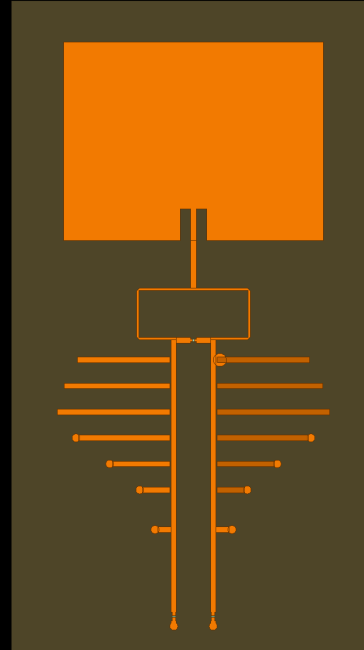
Wireless Communication Theory



Comparing with Existing Application



Tracking finger location

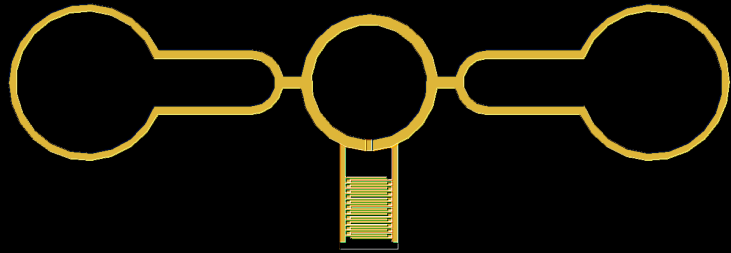


Keyboard

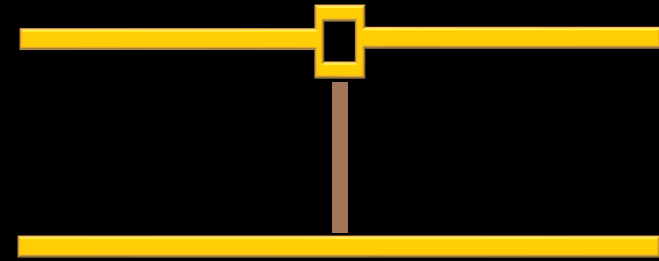


Liquid Sensing

New Applications



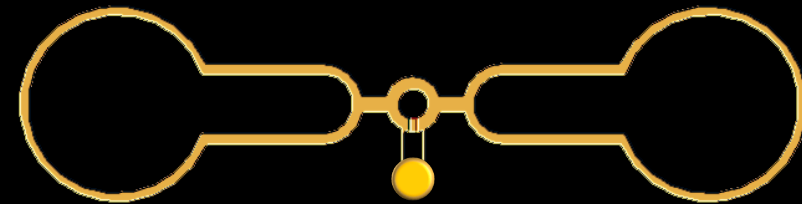
Liquid Concentration Sensing



UV-Light Sensing



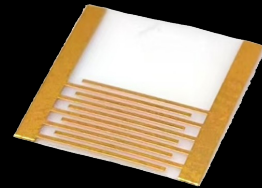
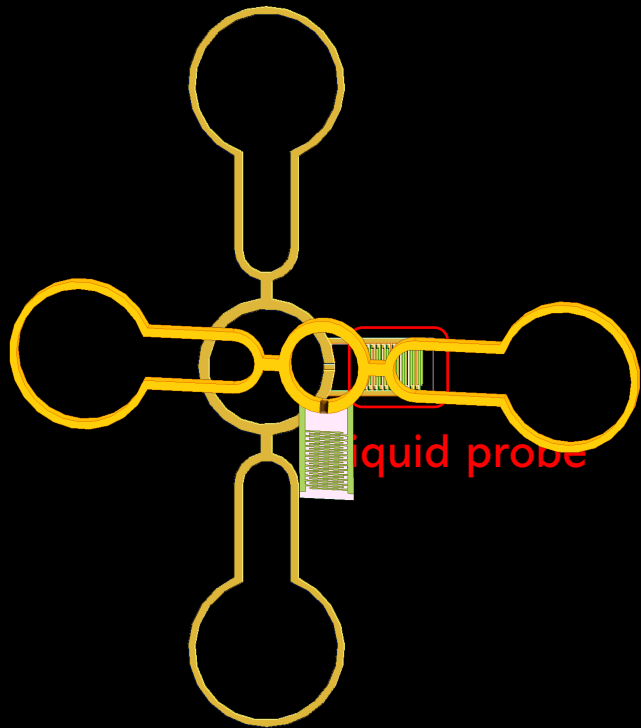
Pressure Sensing



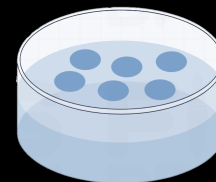
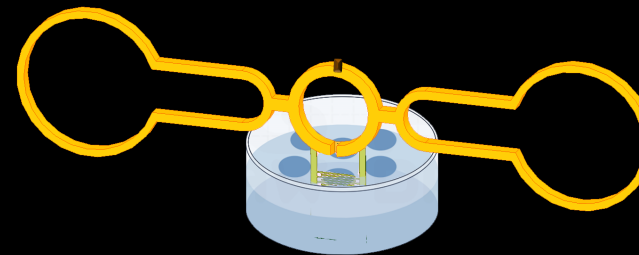
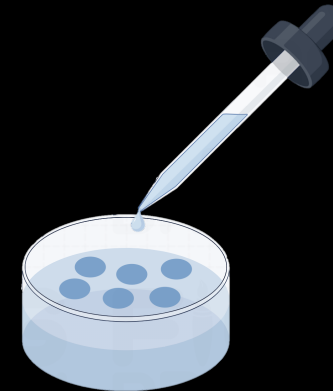
Temperature Sensing

New APP: Liquid Concentration Sensing

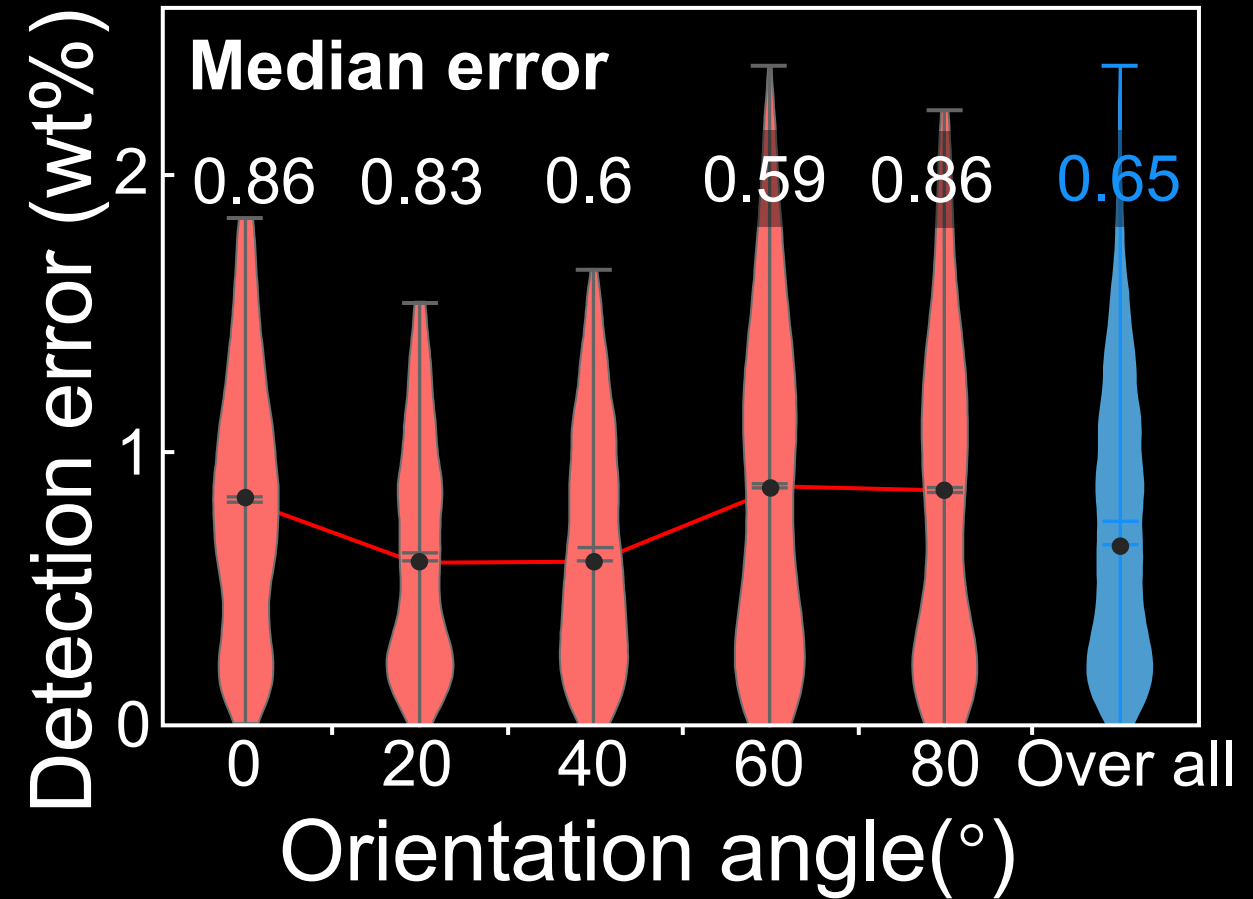
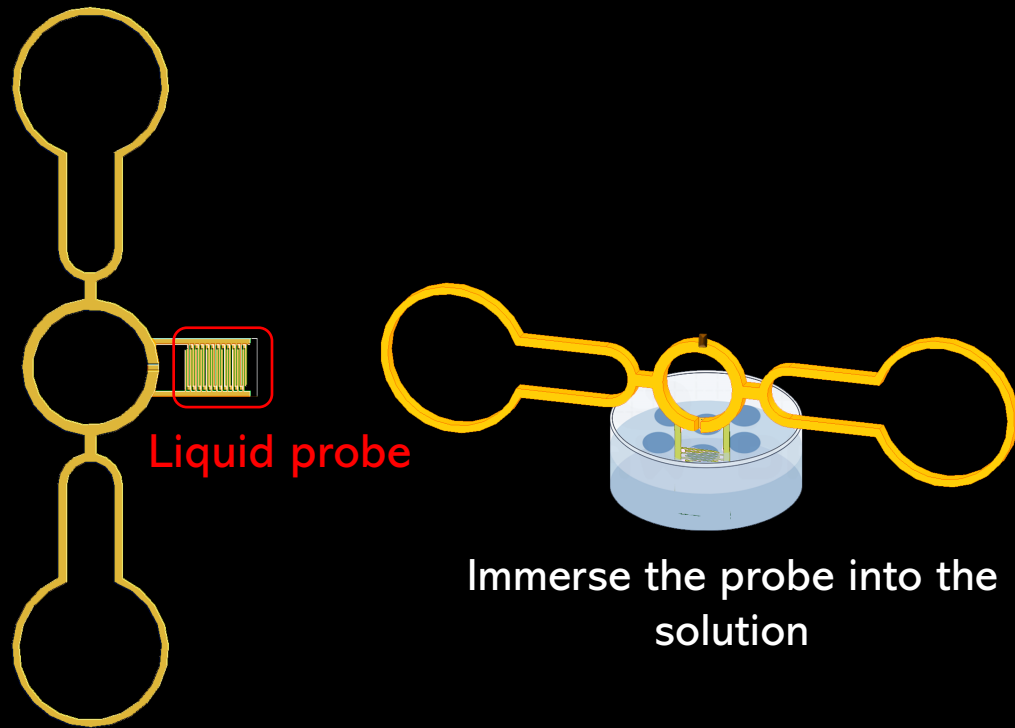
Interdigitated Structure



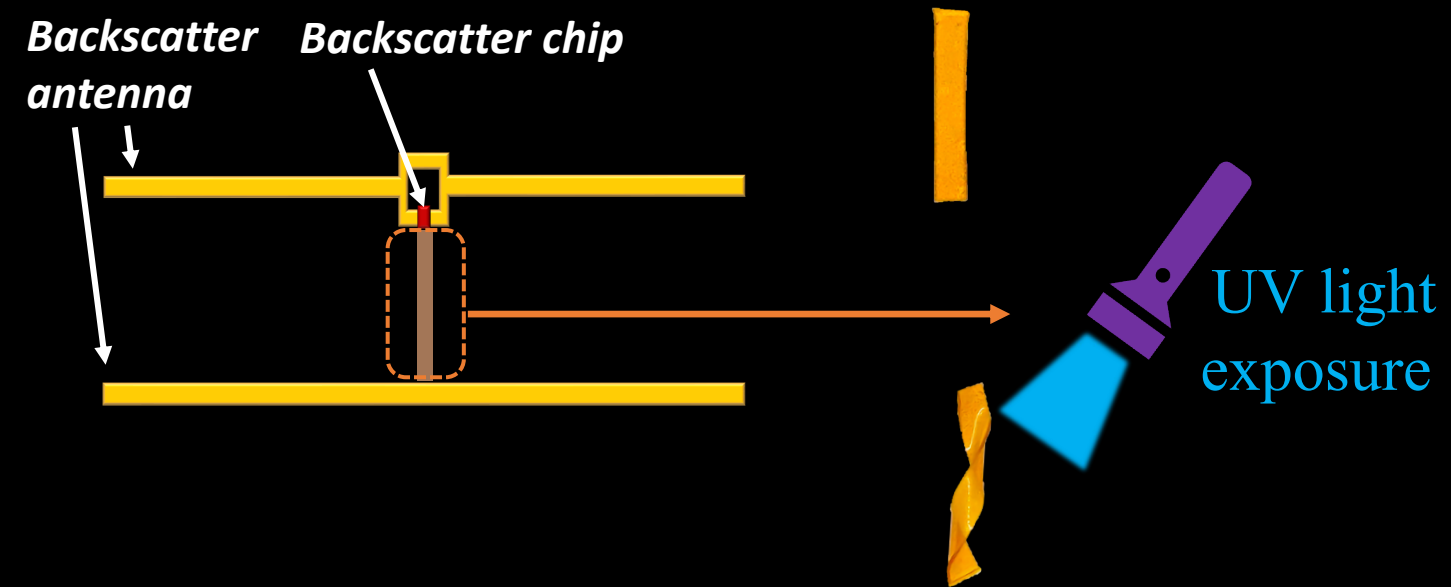
Bovine bone protein solution



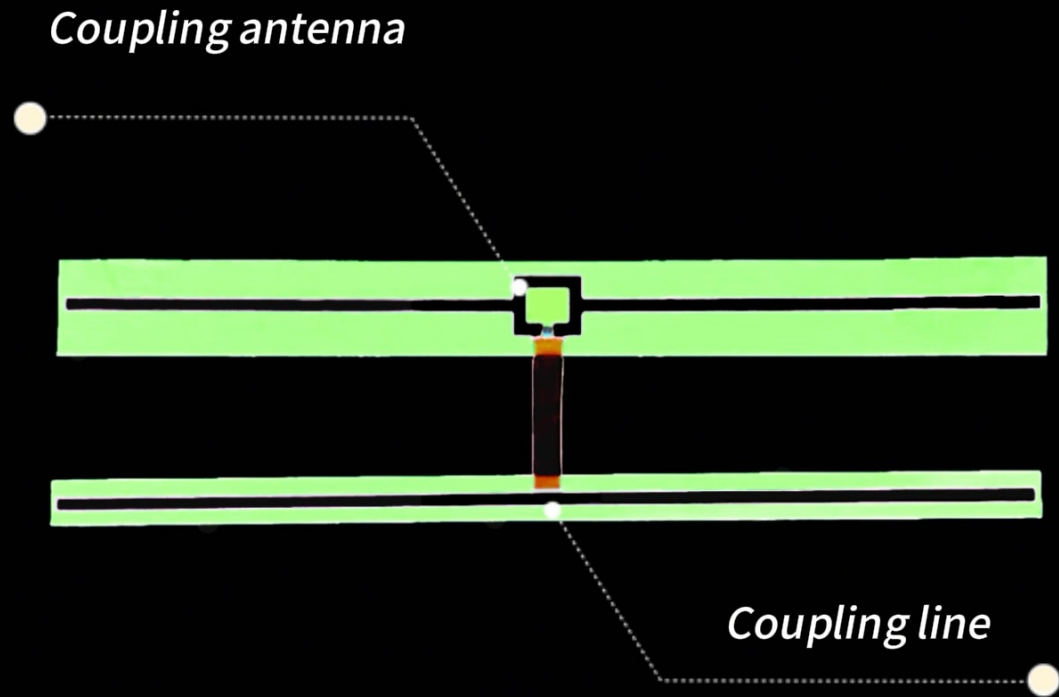
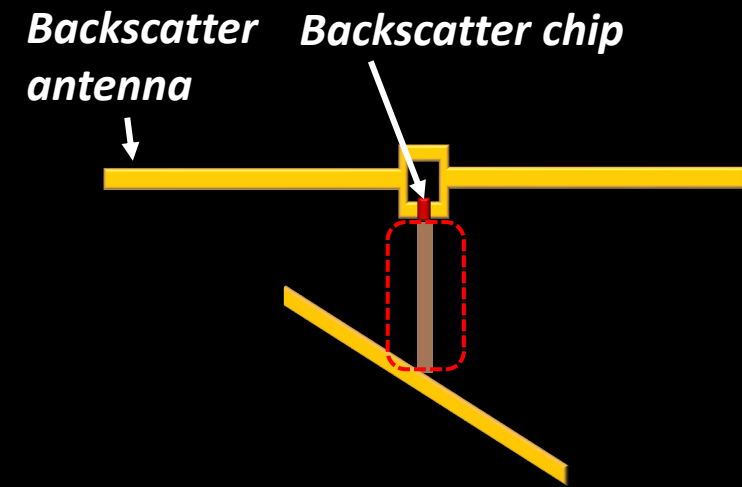
New APP: Liquid Concentration Sensing



New APP: UV-Light Sensing

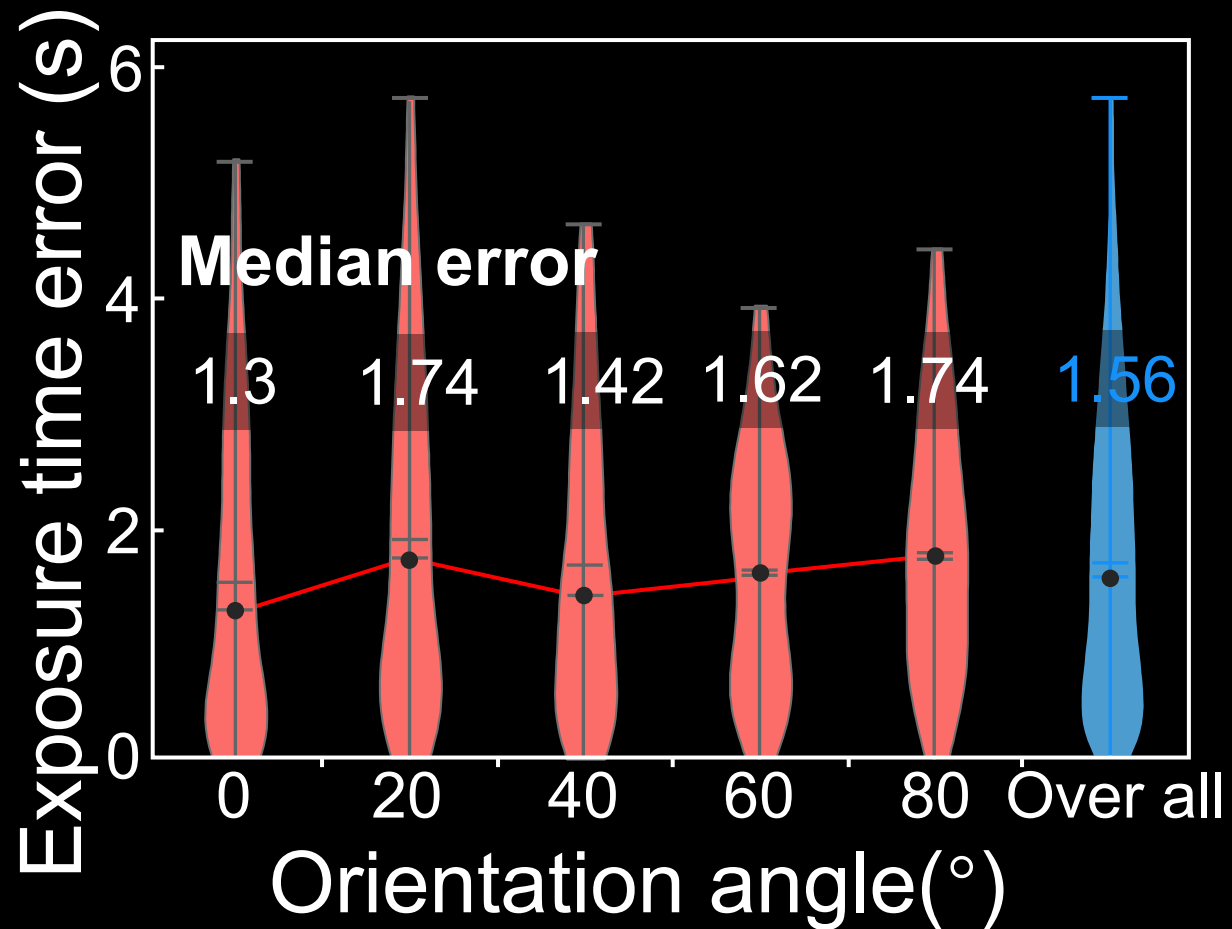
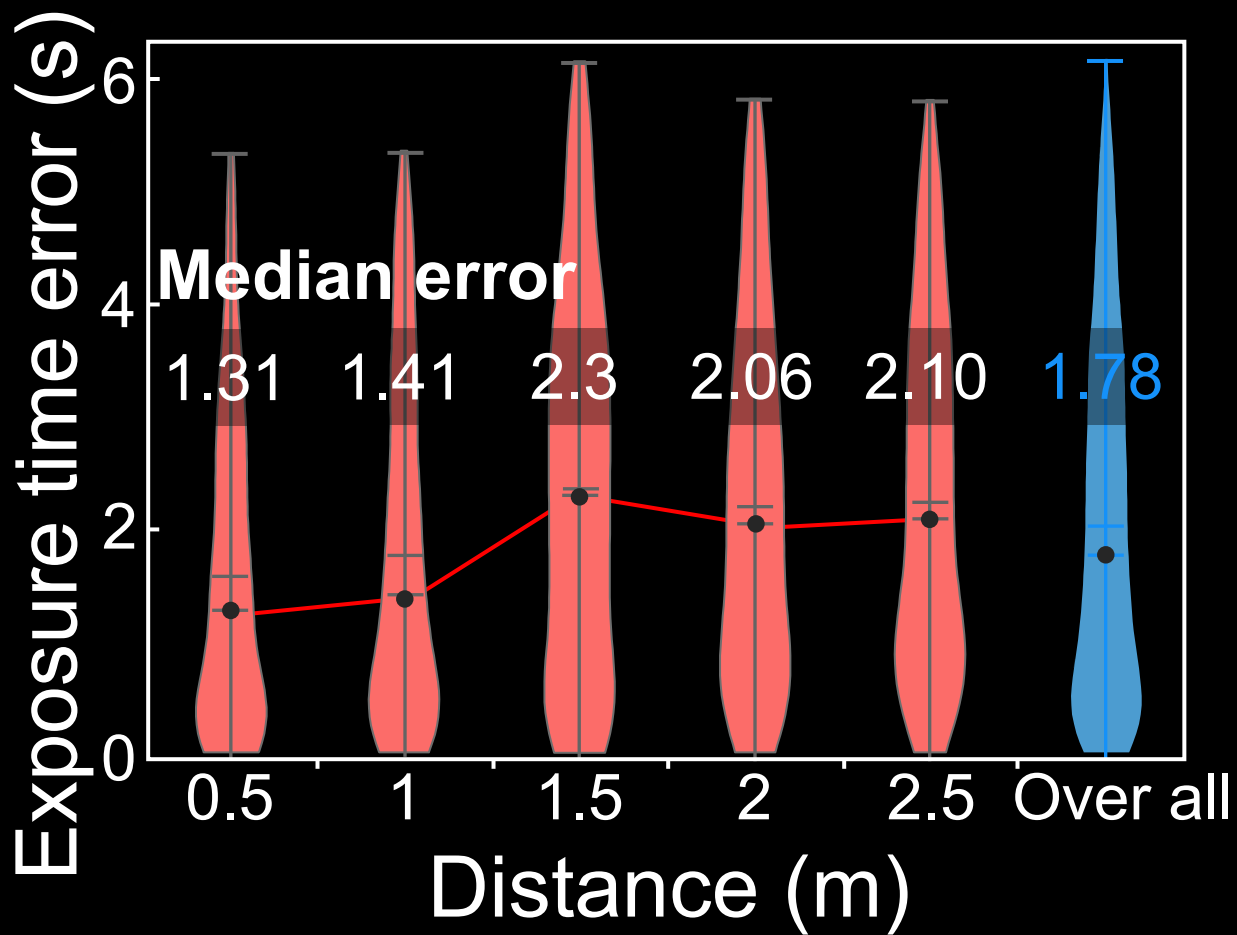


New APP: UV-Light Sensing

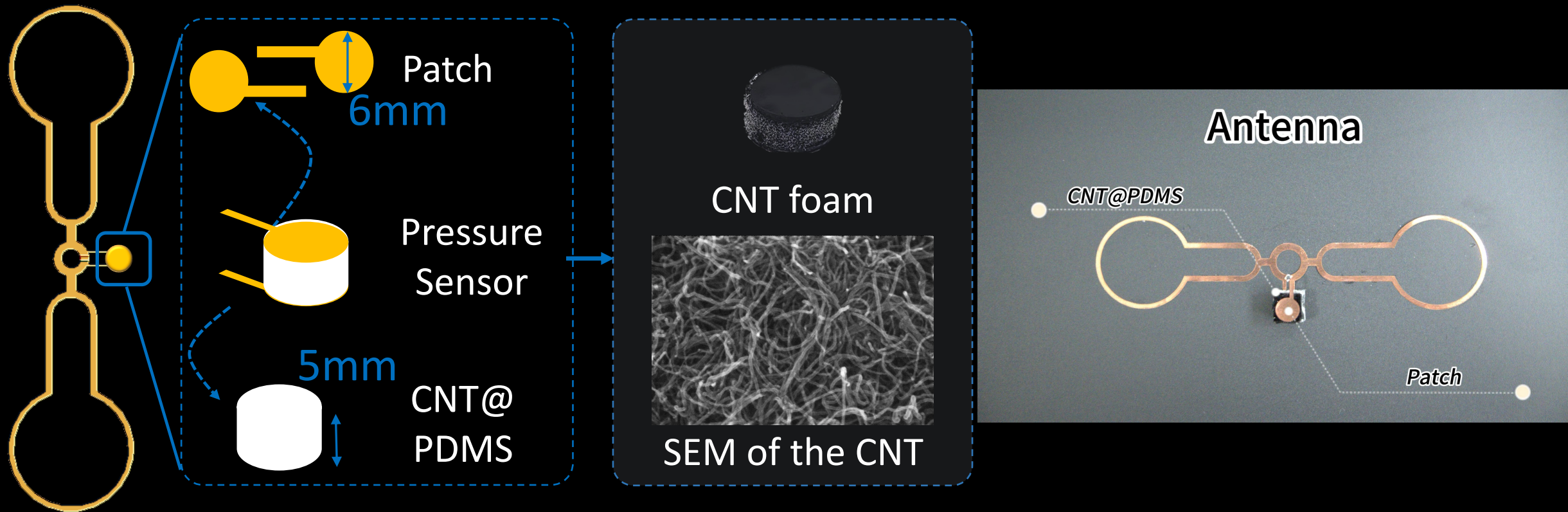


OhmScan tag

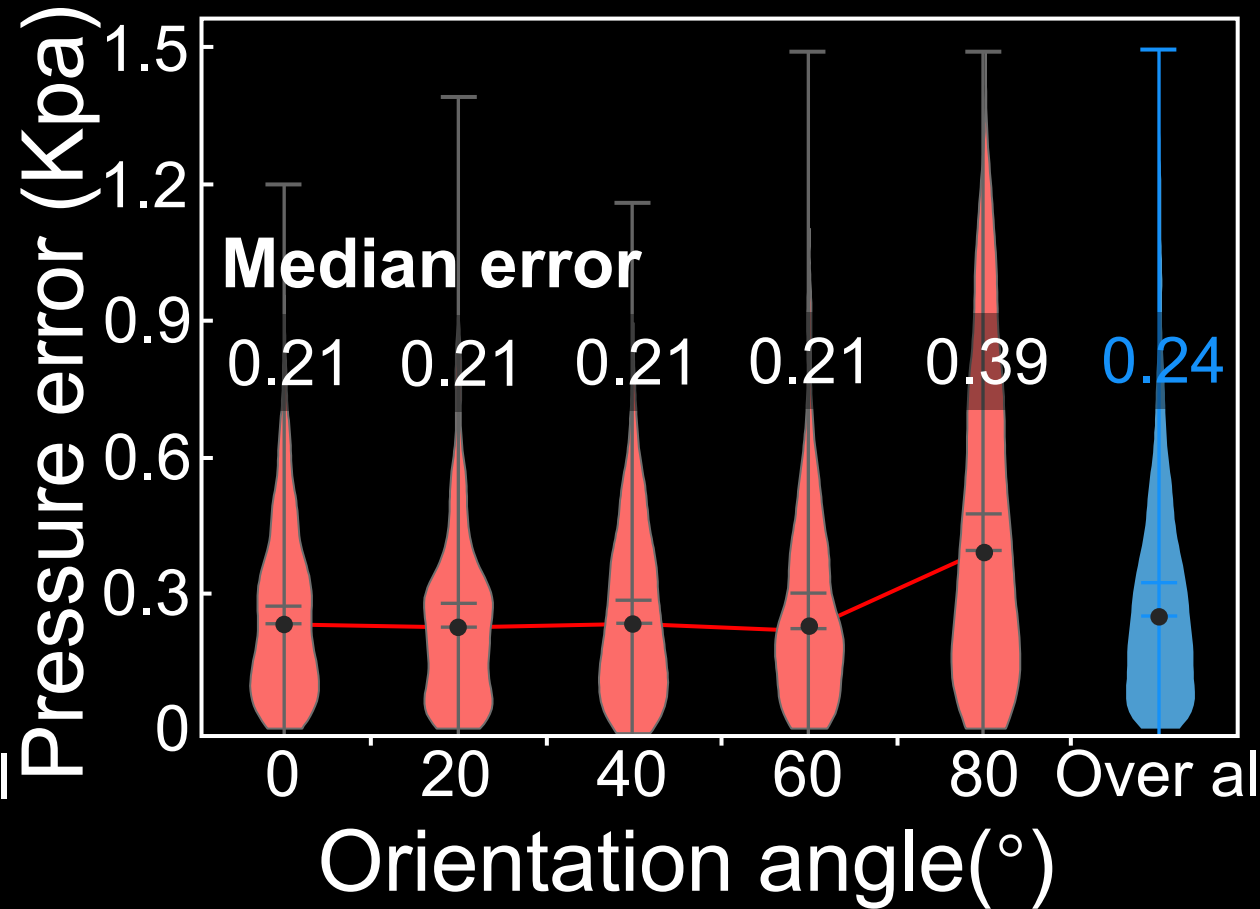
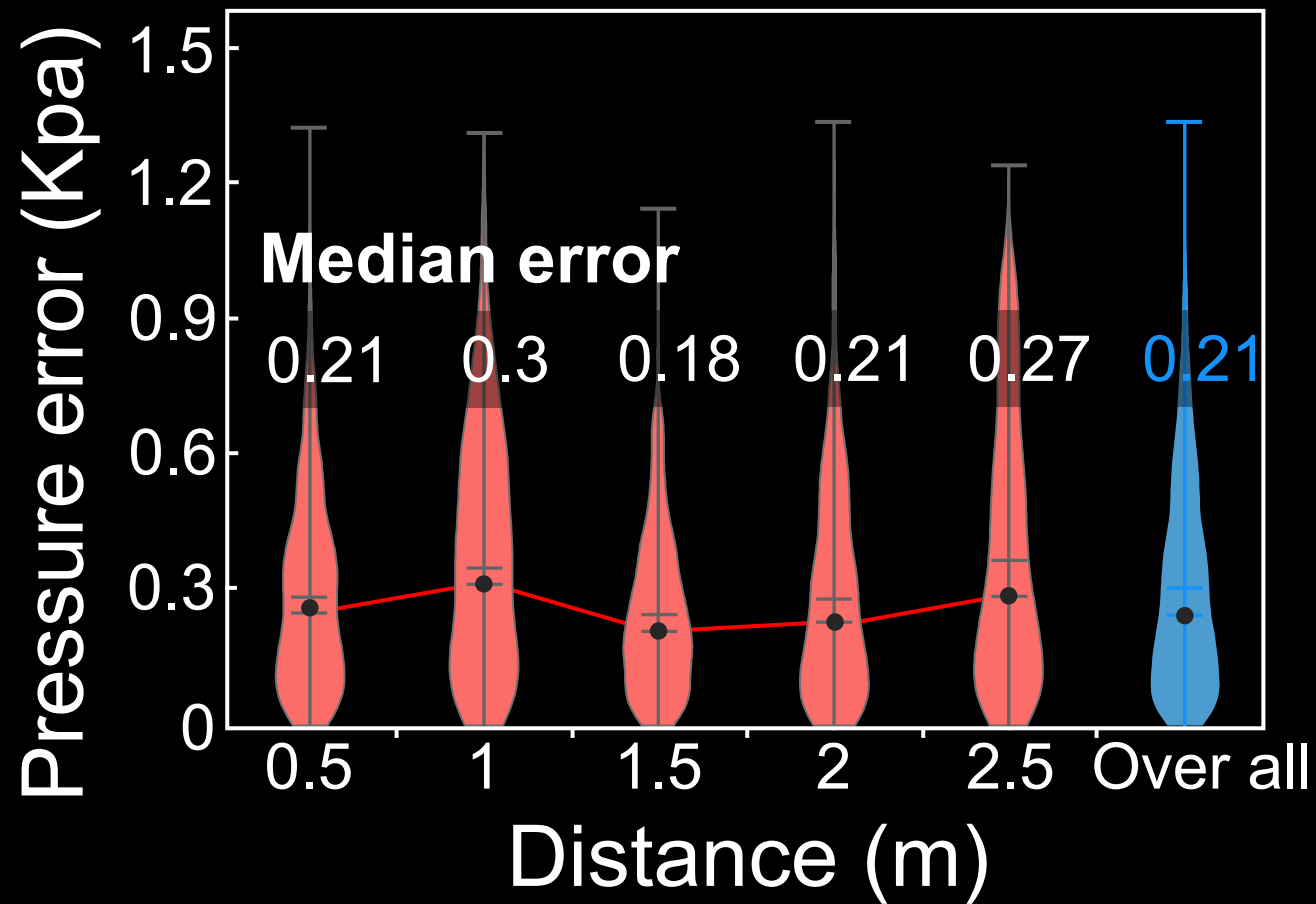
New APP: UV-Light Sensing



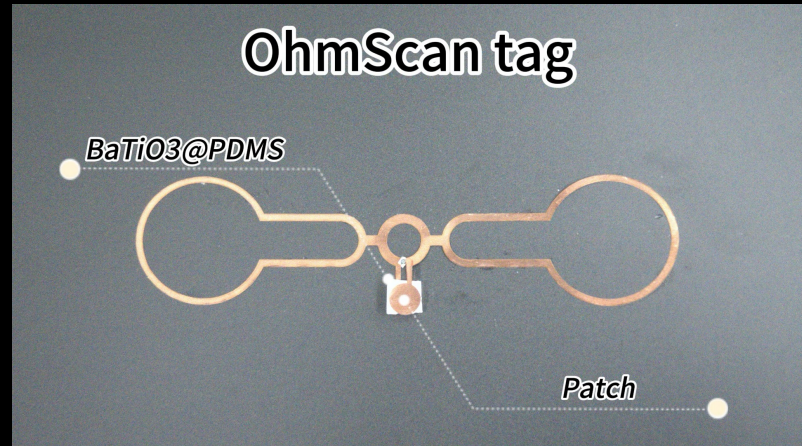
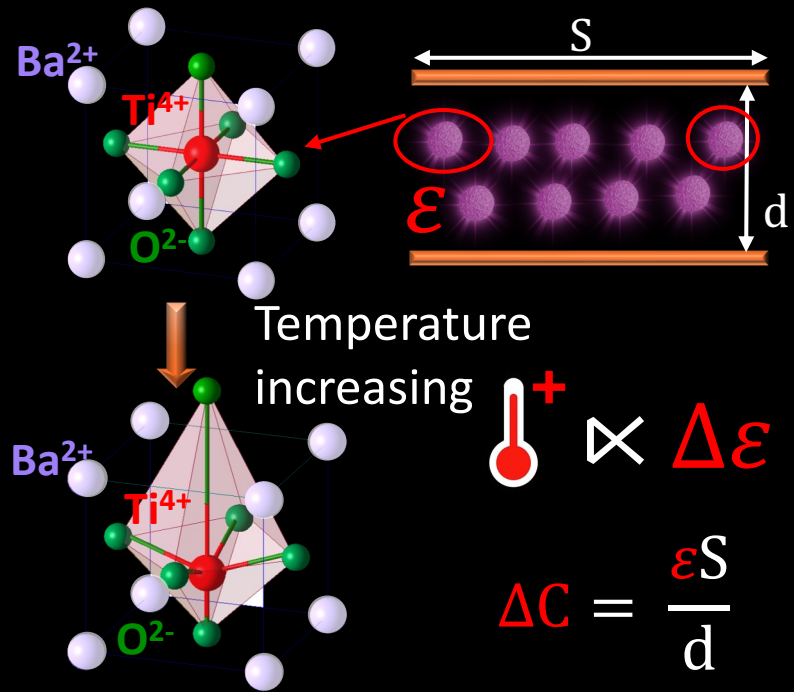
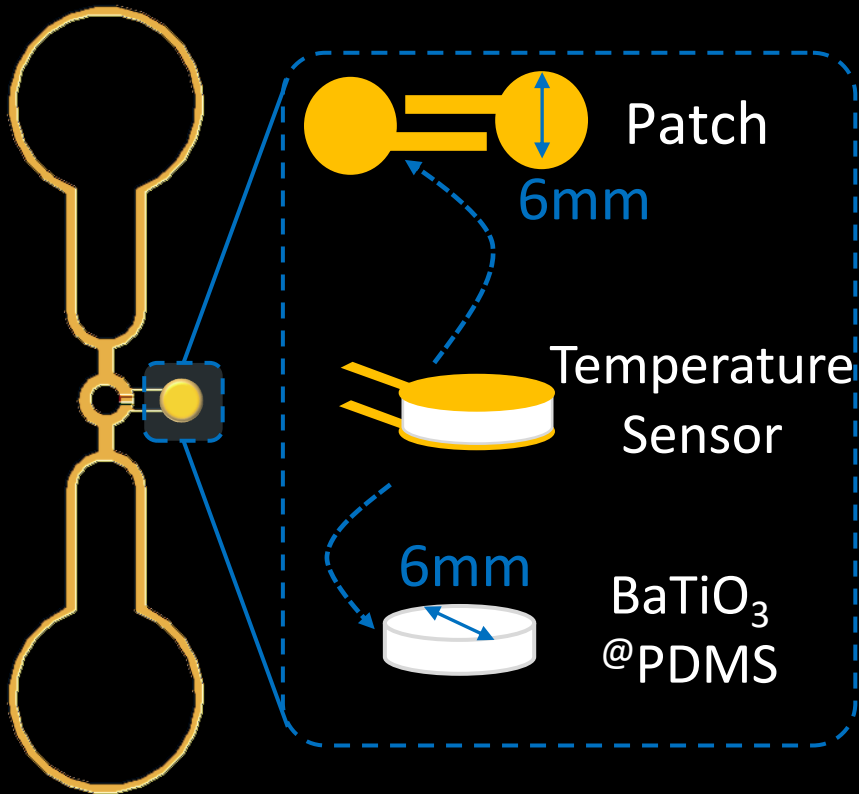
New APP: Pressure Sensing



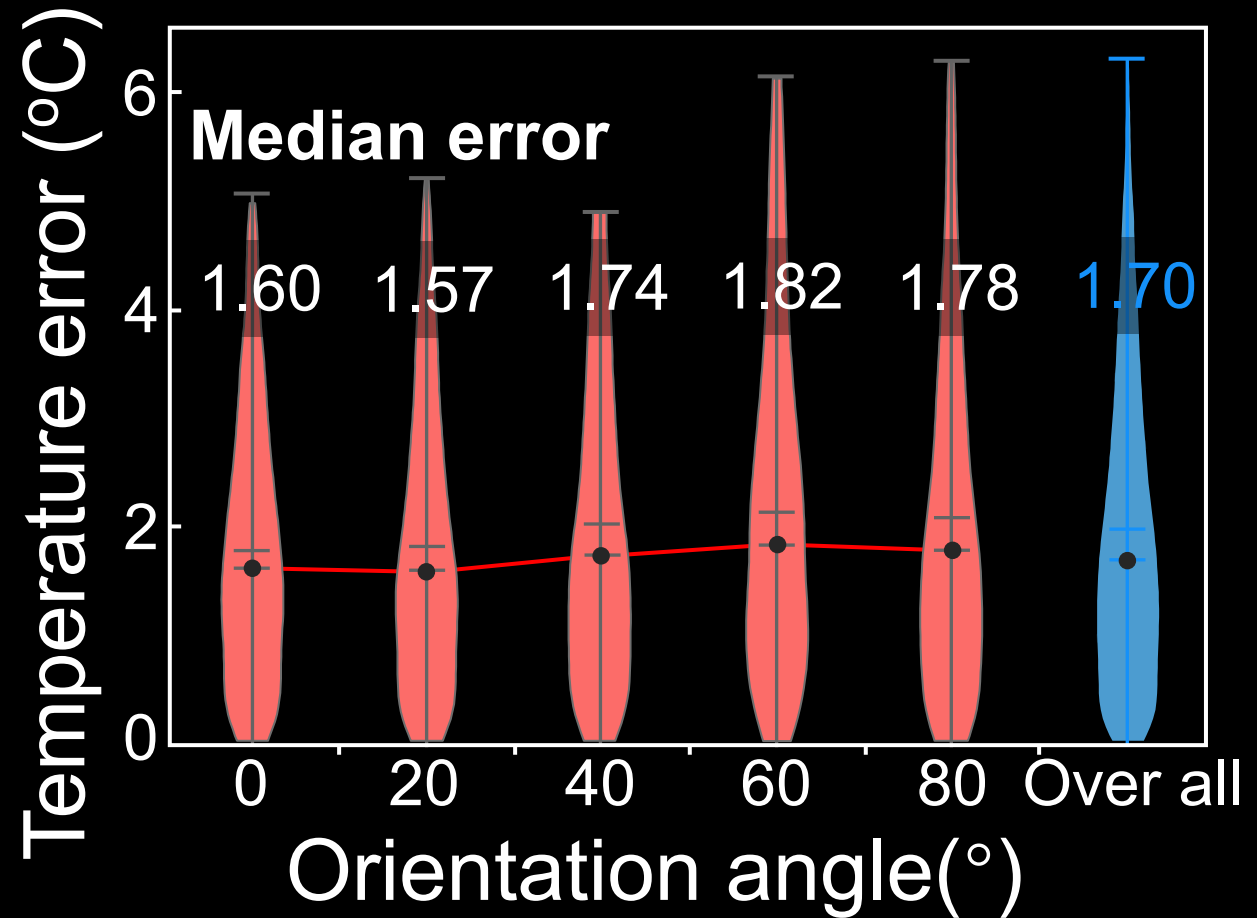
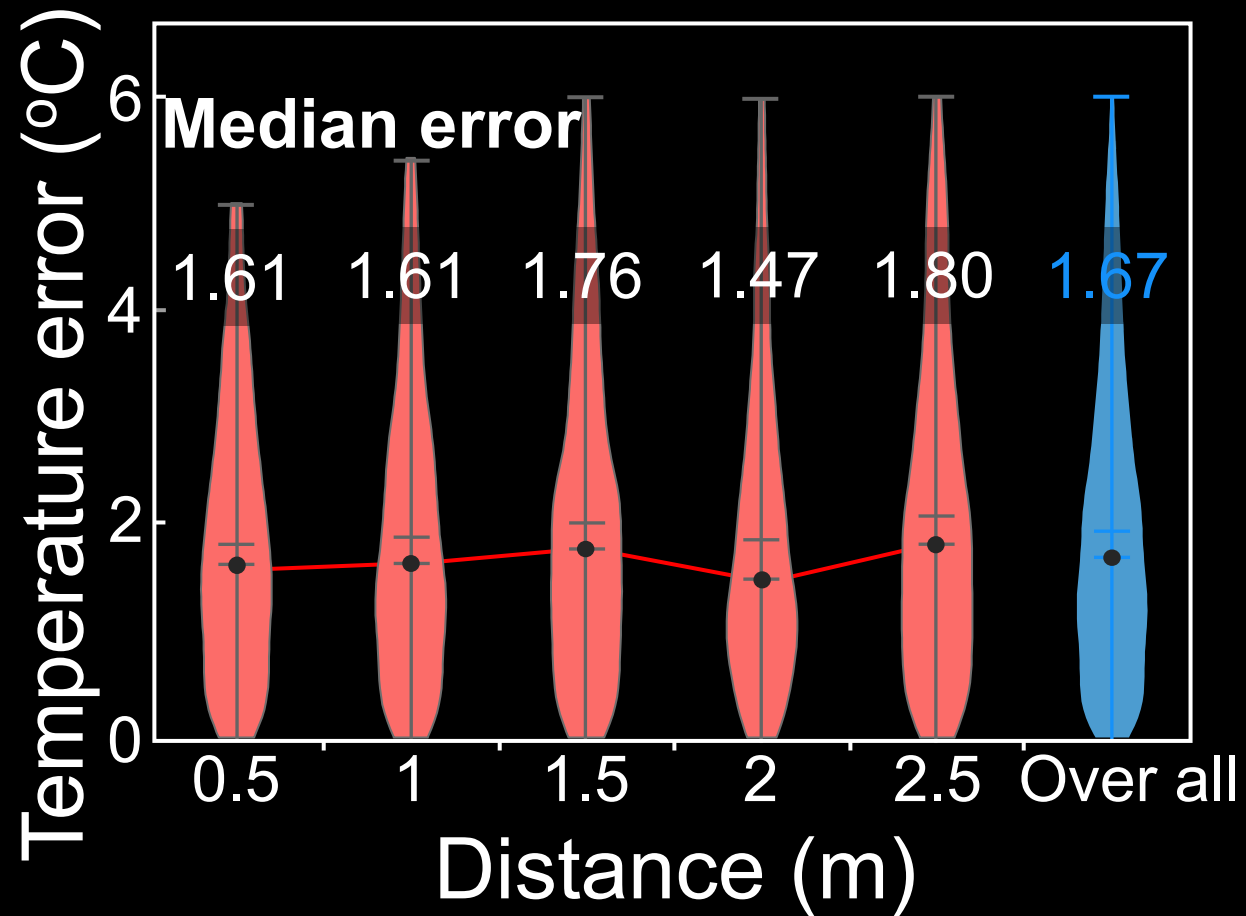
New APP: Pressure Sensing



New APP: Temperature Sensing



New APP: Temperature Sensing



Q & A

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