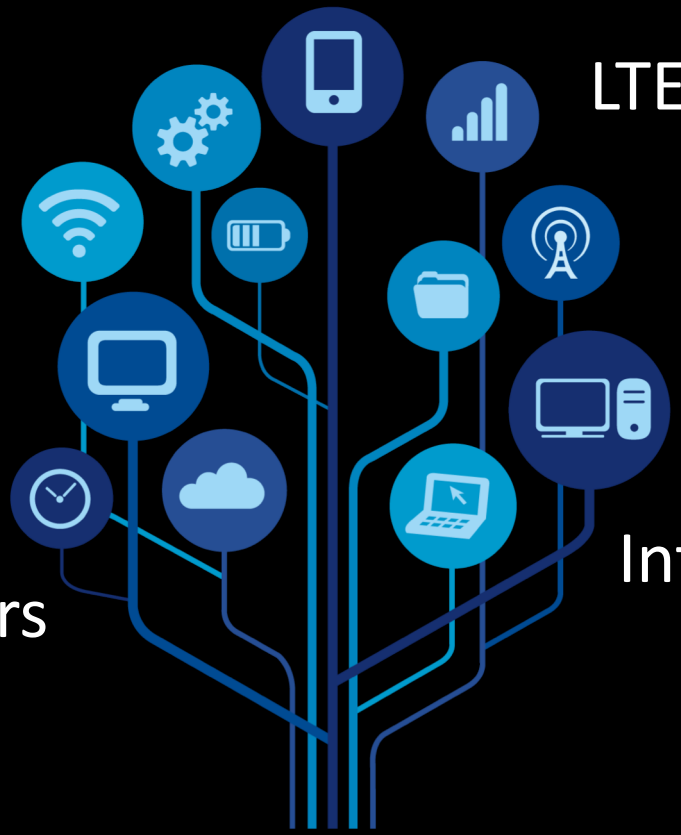
In-Body Backscatter

Deepak Vasisht
Guo Zhang
Omid Abari
Dina Katabi

Hsiao-Ming Lu
Jacob Flanz

Wi-Fi

LTE

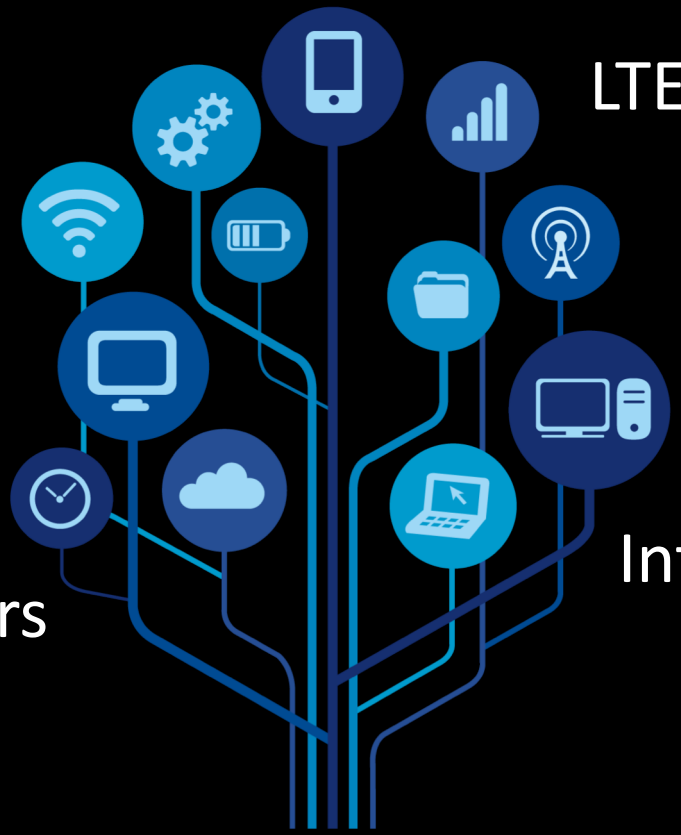


Internet

Datacenters

Wi-Fi

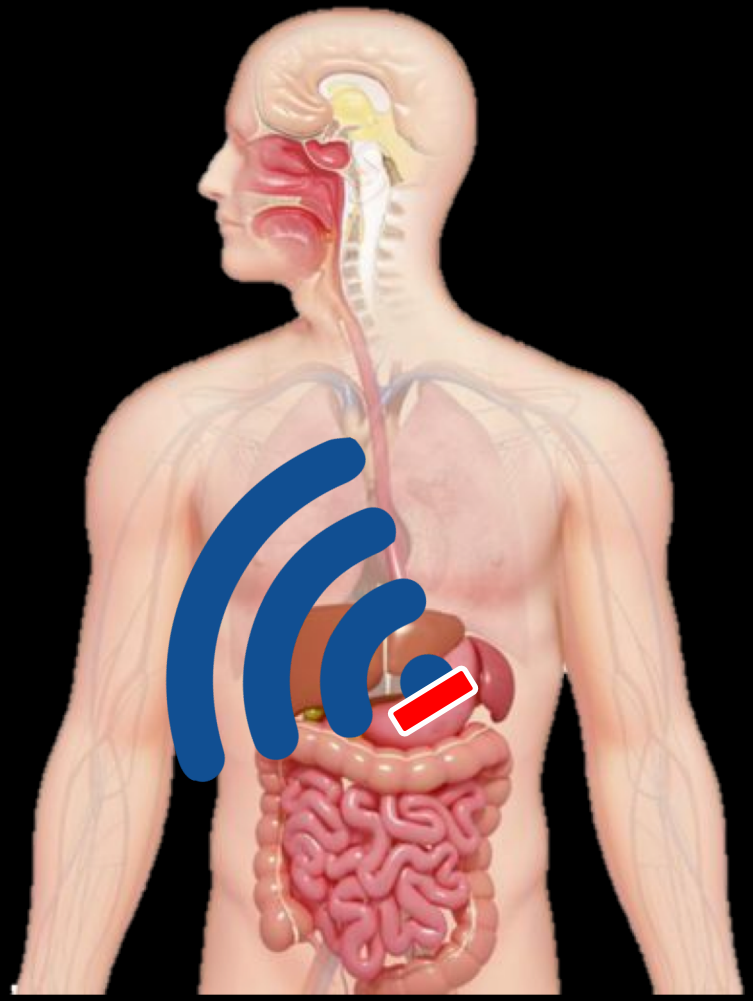
LTE



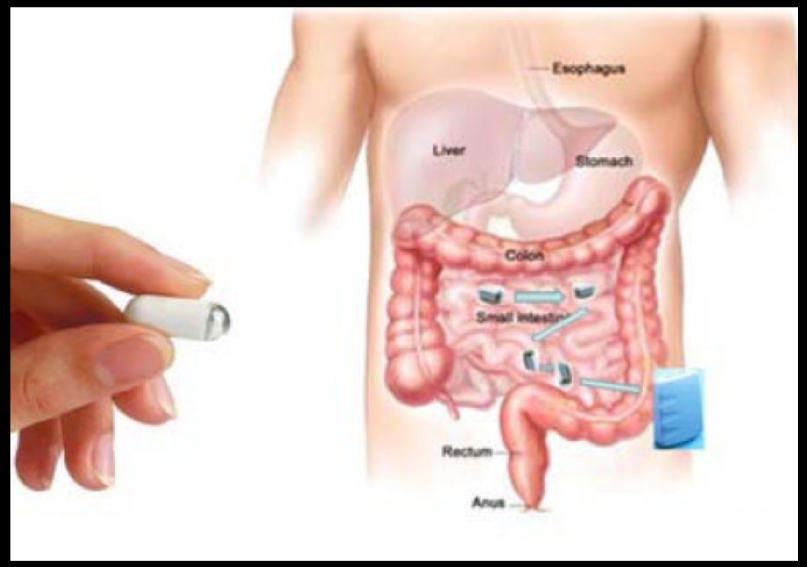
Datacenters

Internet

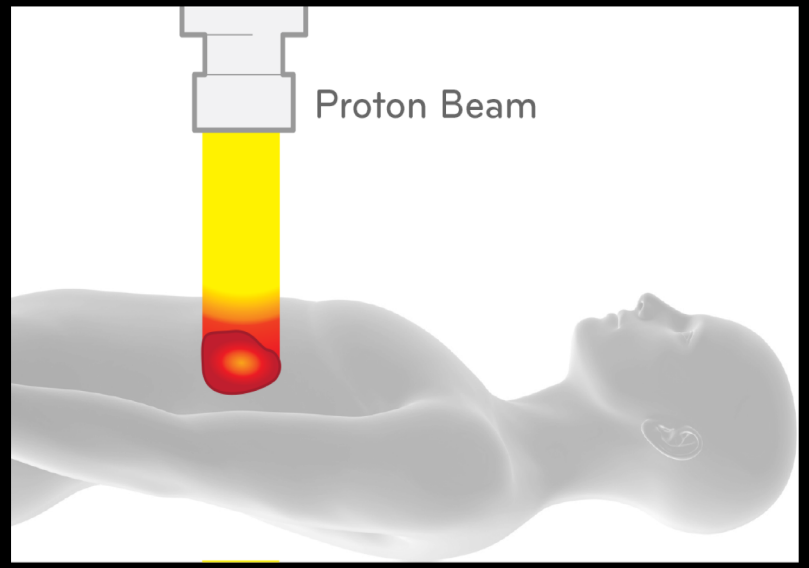
In-body Networks



Medicine is Changing…

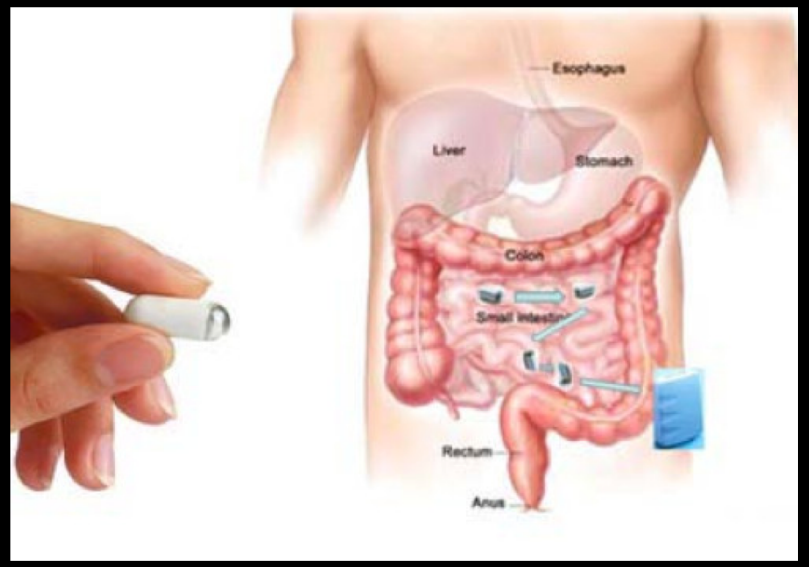


Capsule Endoscopy



Cancer Radiation Therapy

Medicine is Changing…



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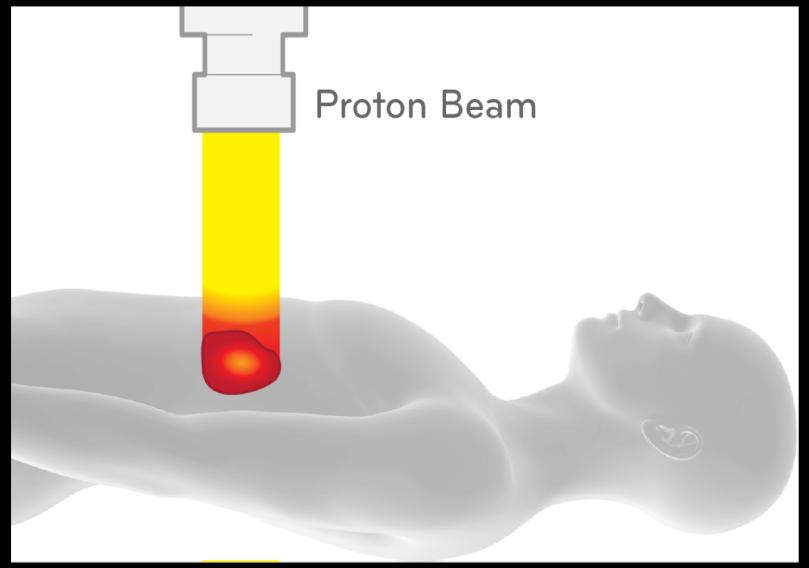


Cancer Radiation Therapy

In-body devices need **communication** and **localization**

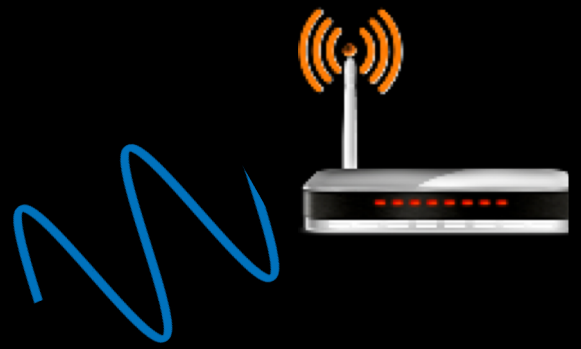
How can we do in-body communication and localization?

Can we simply use a Wi-Fi/LTE?

Problem: Huge power demands

Use backscatter – zero transmission power requirement

Backscatter

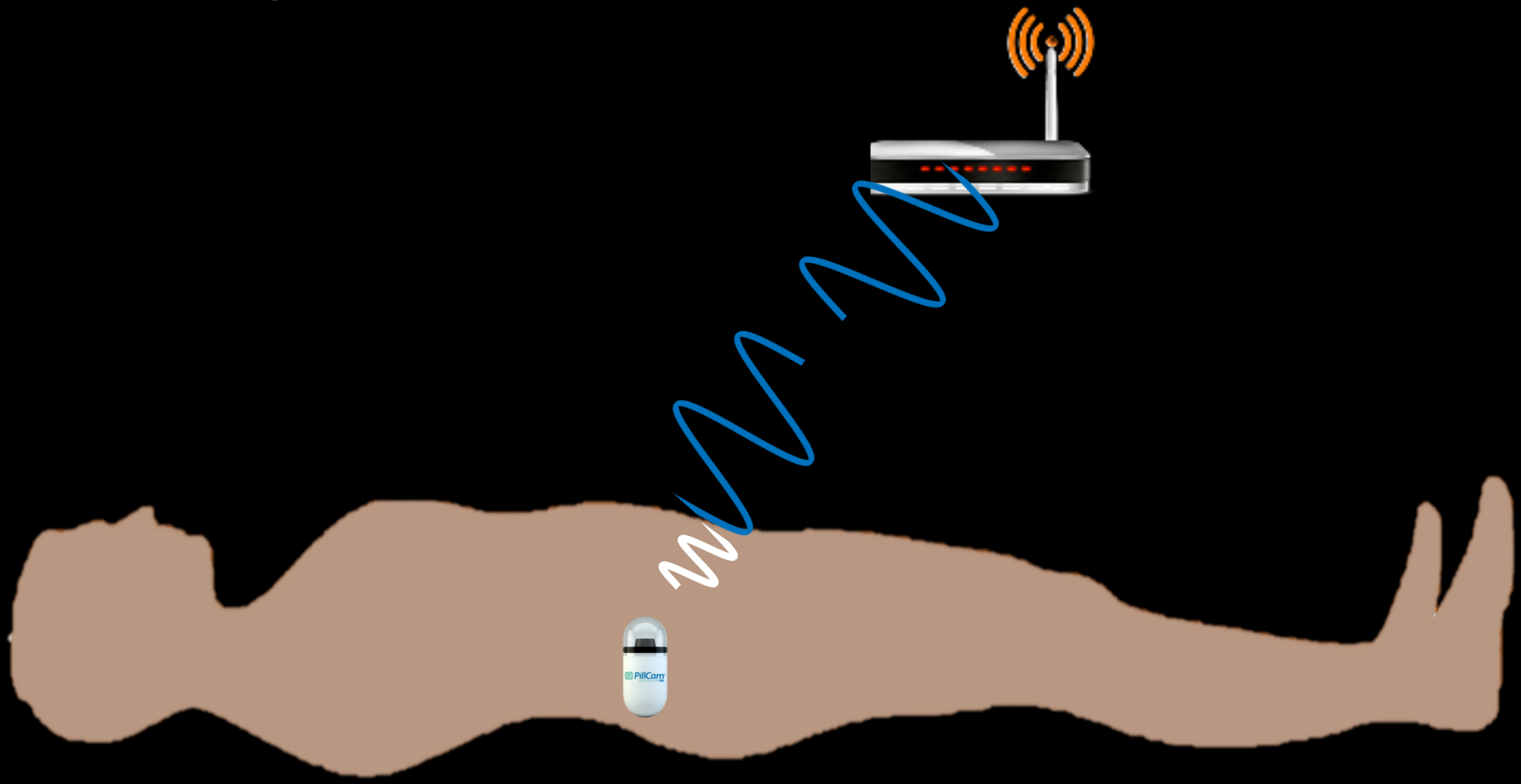


Can we use backscatter in-body?
Not as is!

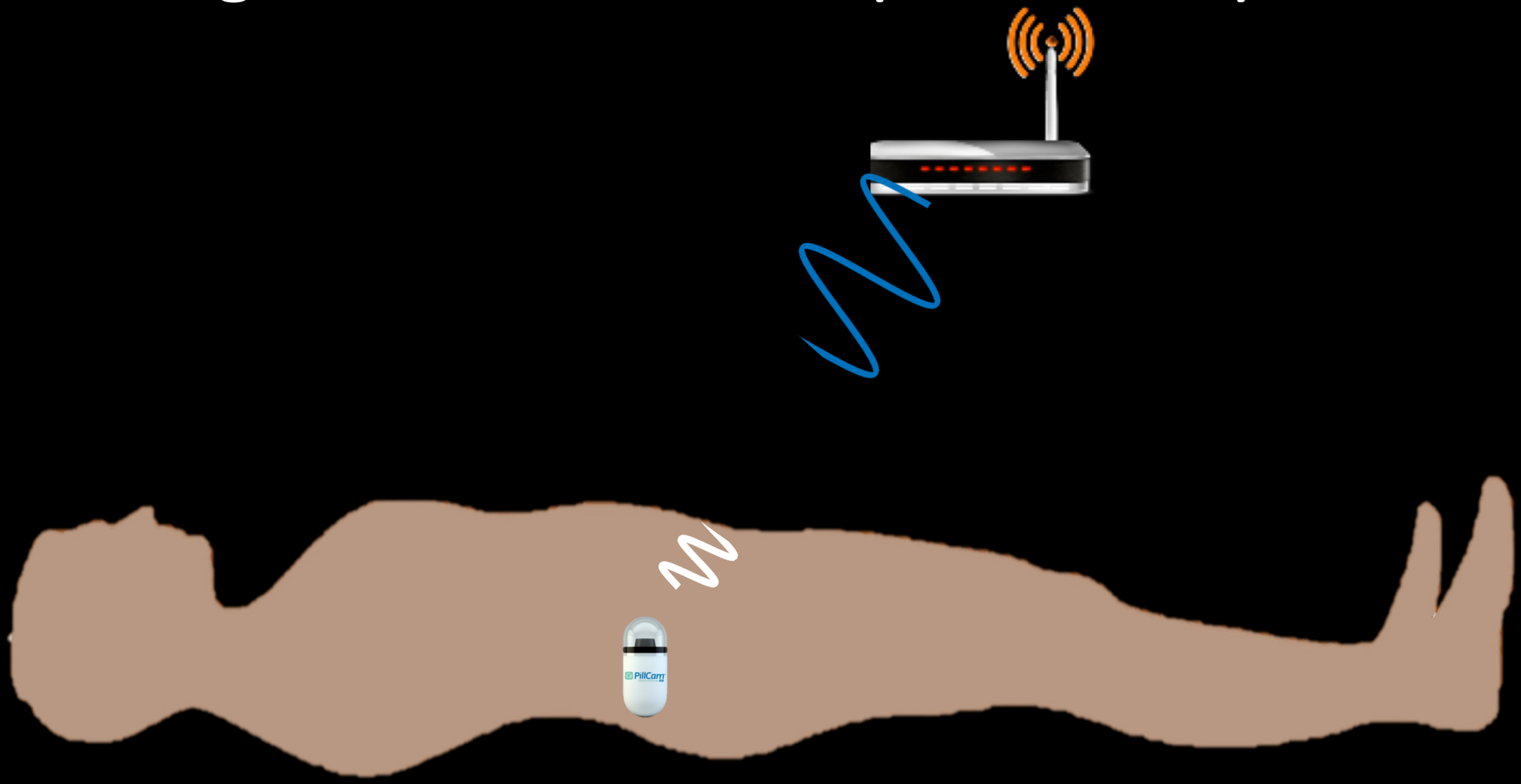
ReMix

In-Body Backscatter Communication and Localization

Problem: Signal is Reflected off the Skin



Problem: Signal Attenuates **Exponentially** In-Body



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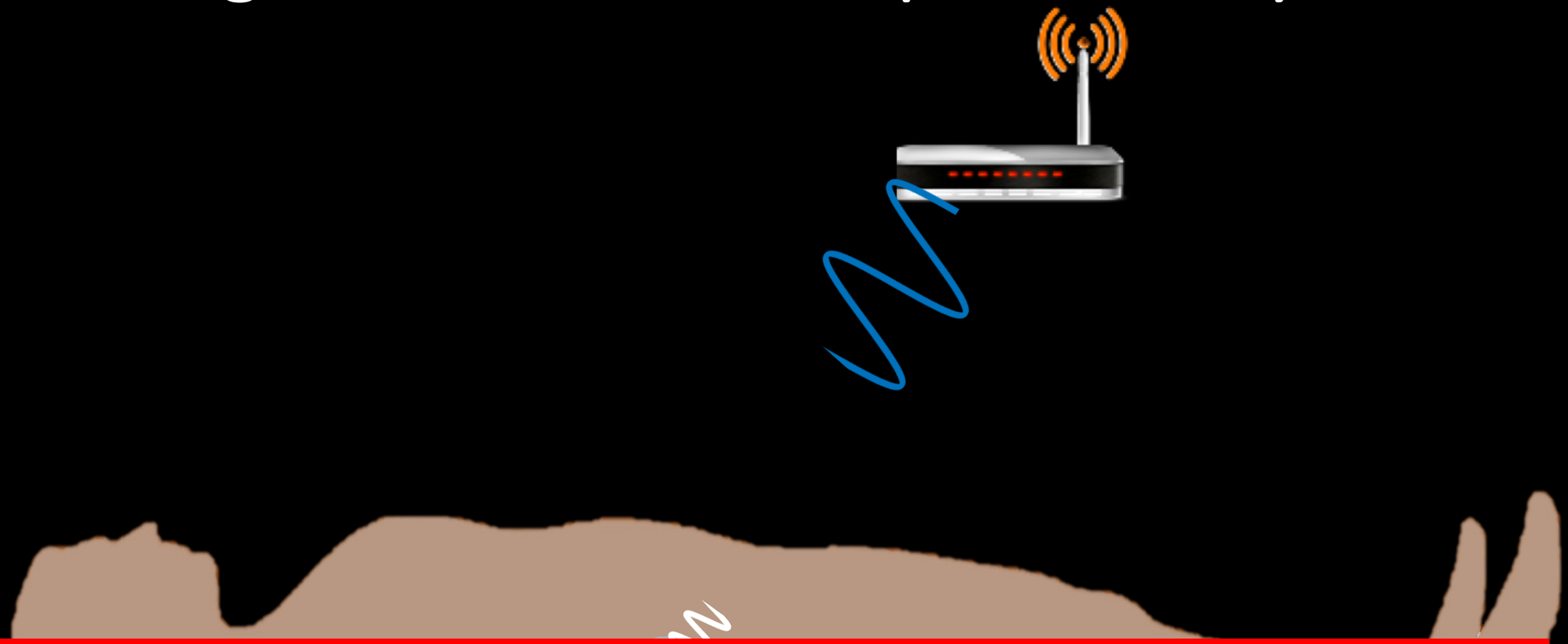
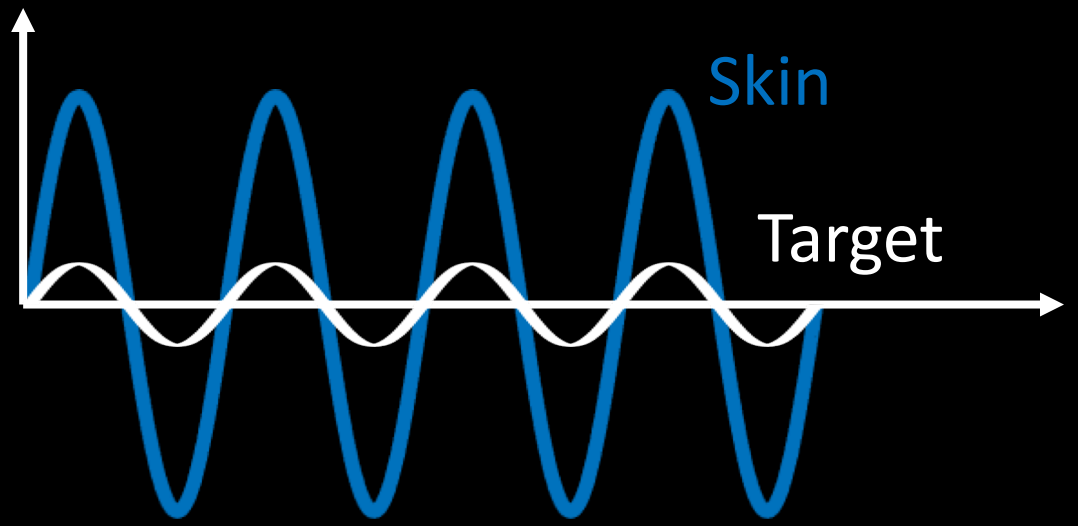


Challenge: Reflection from the skin is 100 million to 1 billion times stronger than the target signal

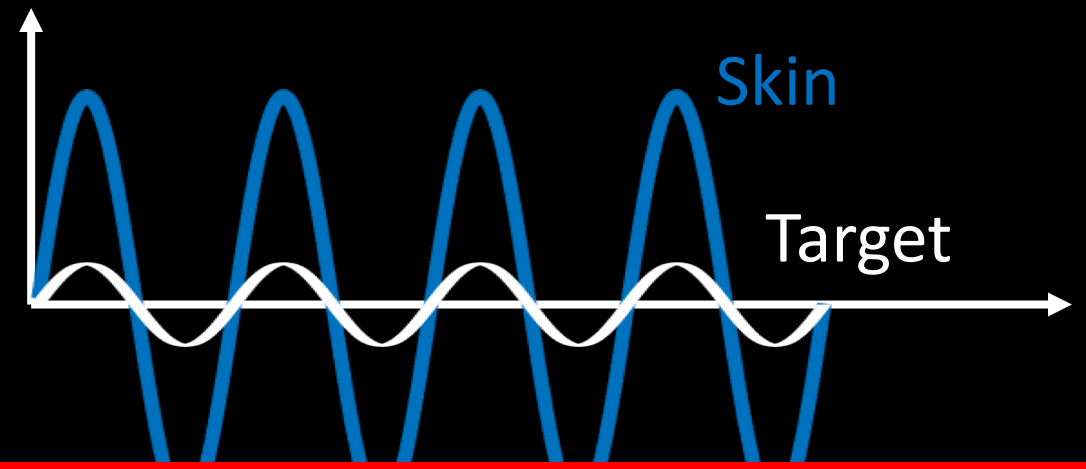
How can we separate the minute target reflections from the HUGE skin reflections?

Can we transmit more power from the AP?



How can we separate the minute target reflections from the HUGE skin reflections?

Can we add an amplifier to the target?



Need a simple, passive solution

Our Solution: Use Schottky Diode

- Simple and small
- Passive – requires no power source
- Non-linear behavior (non-ideal)

Our Solution: Use Schottky Diode

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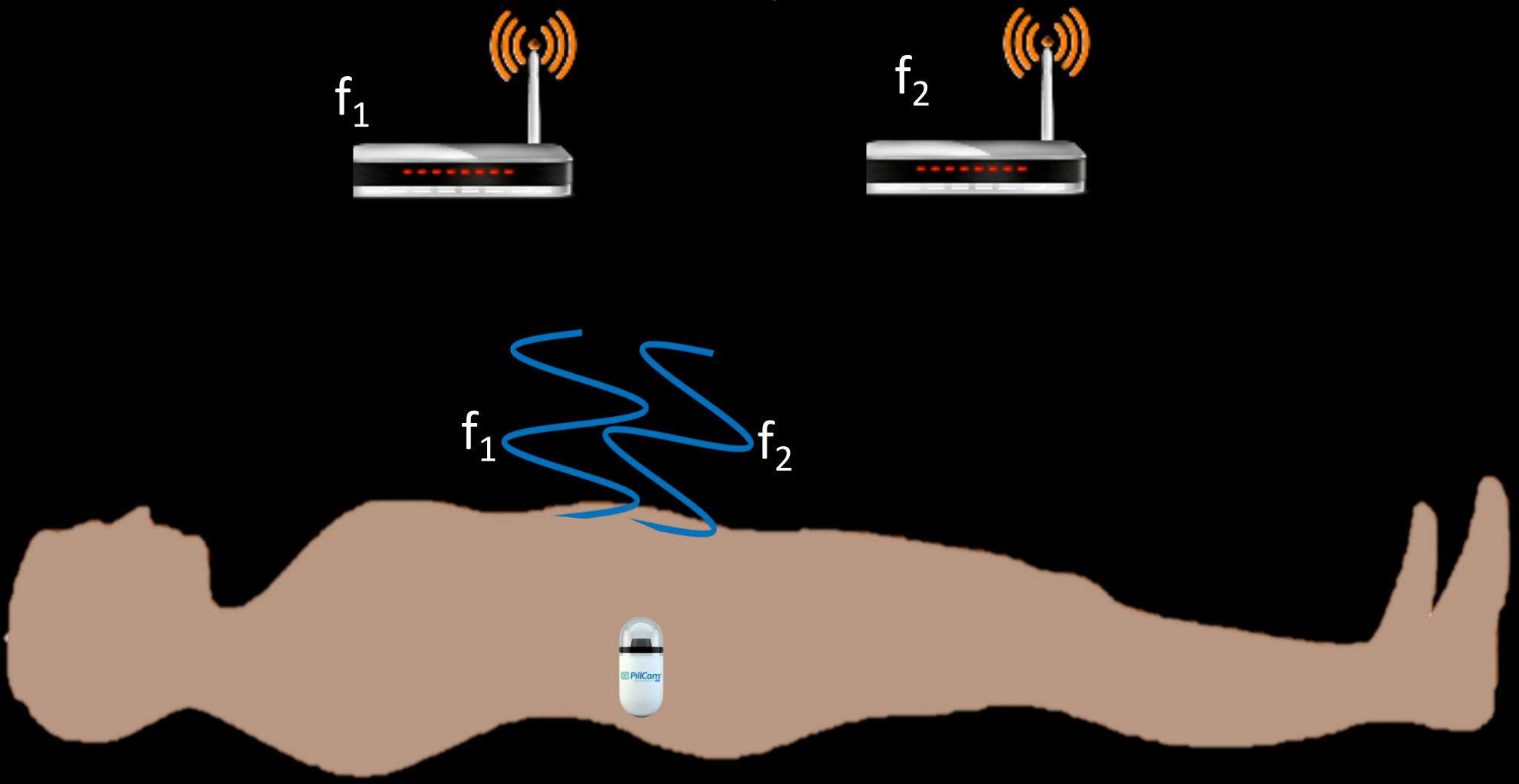

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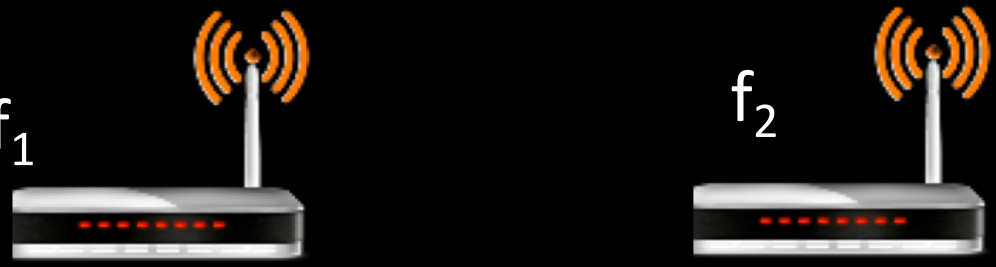

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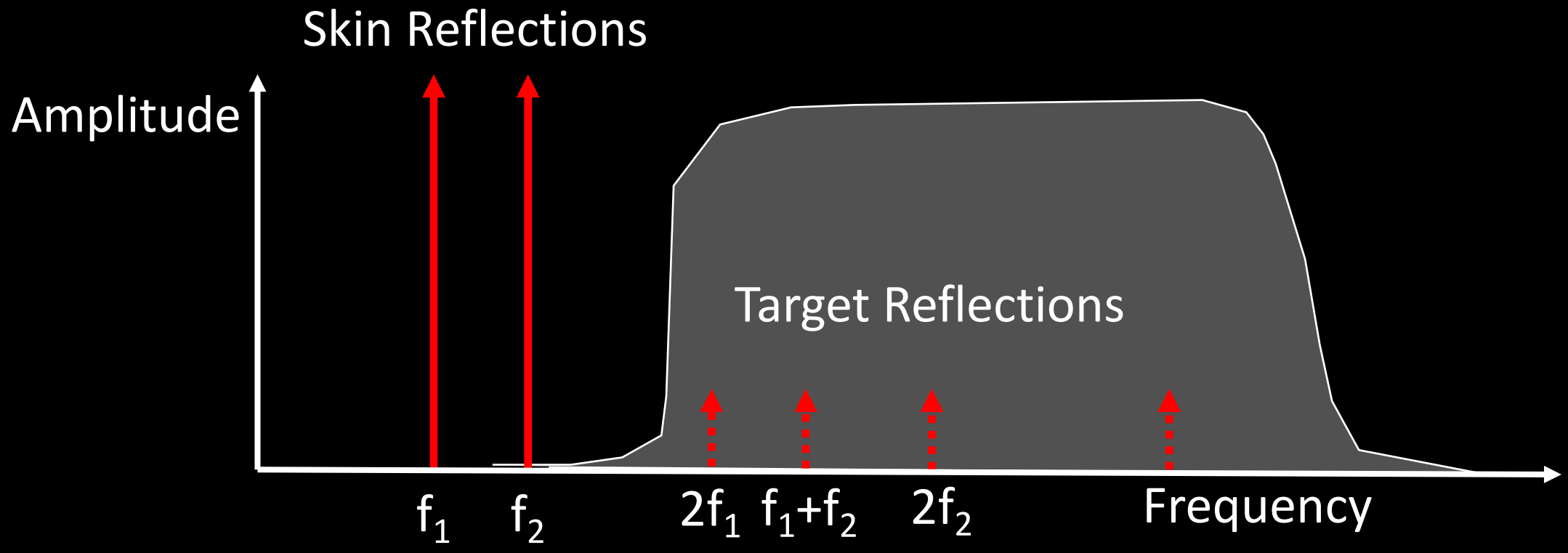
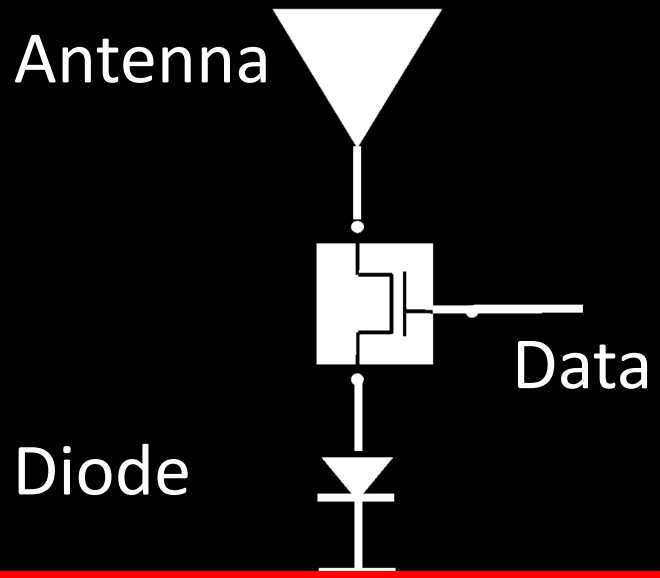


ReMix Backscatter: Schematic

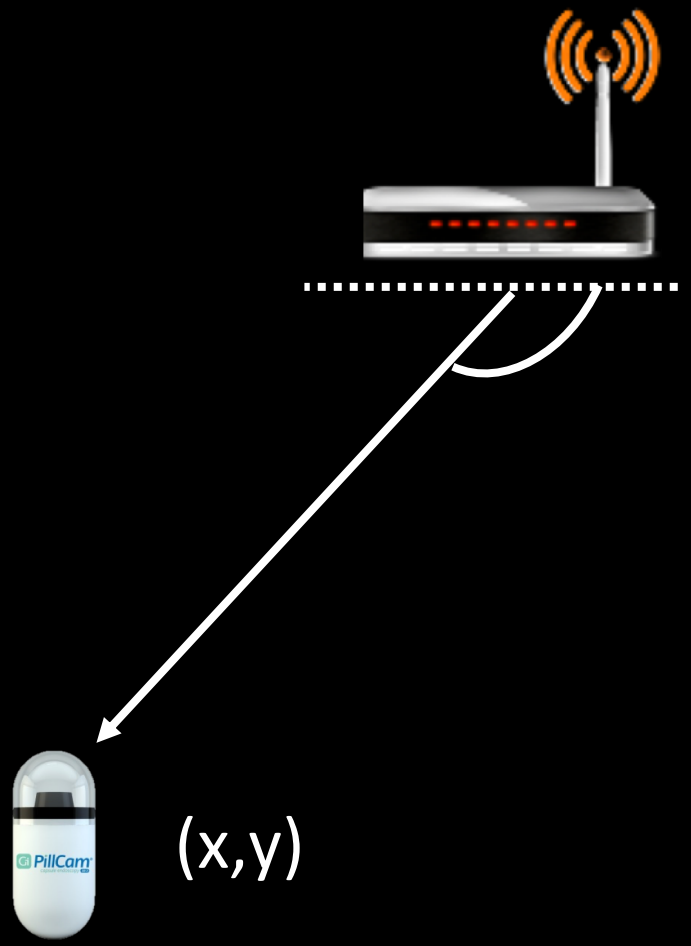


Can cause large frequency shifts

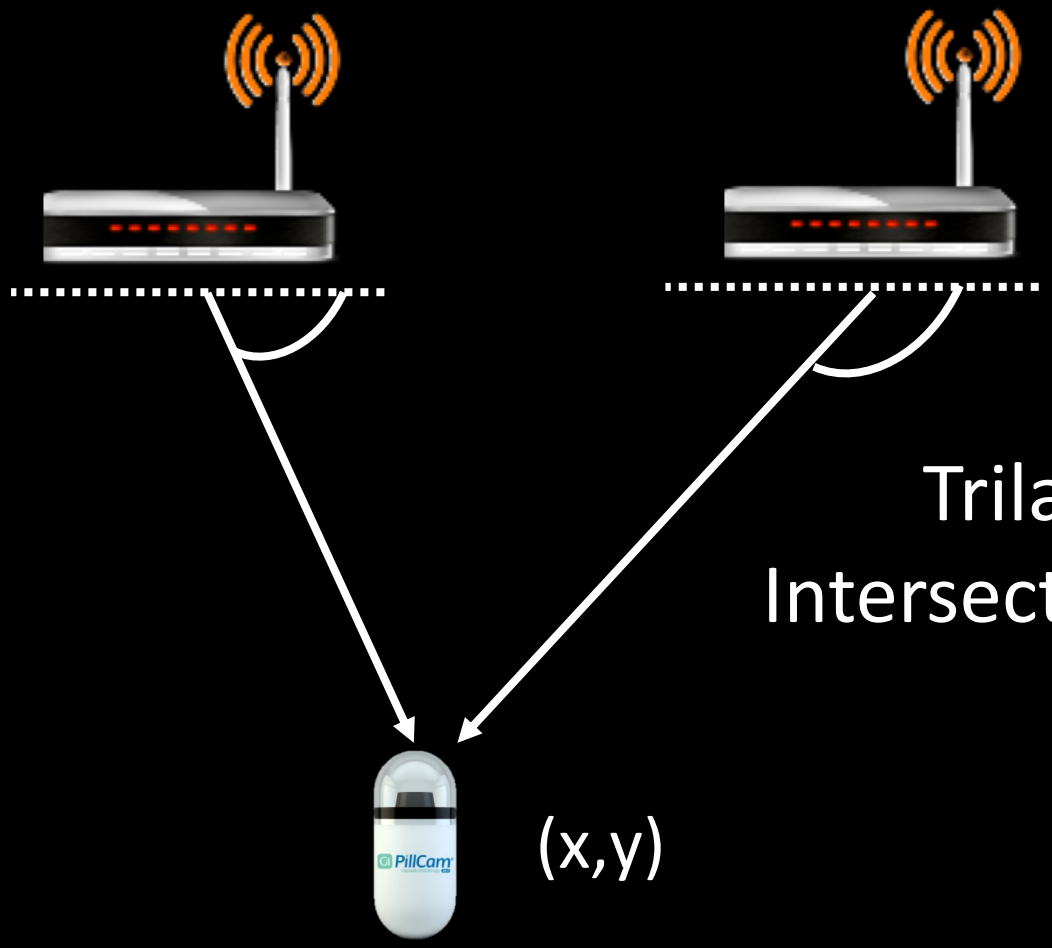
ReMix Uses a Schottky diode to cause frequency shifts and filter out skin reflection

ReMix
In-Body Backscatter Communication and Localization

RF-based Localization



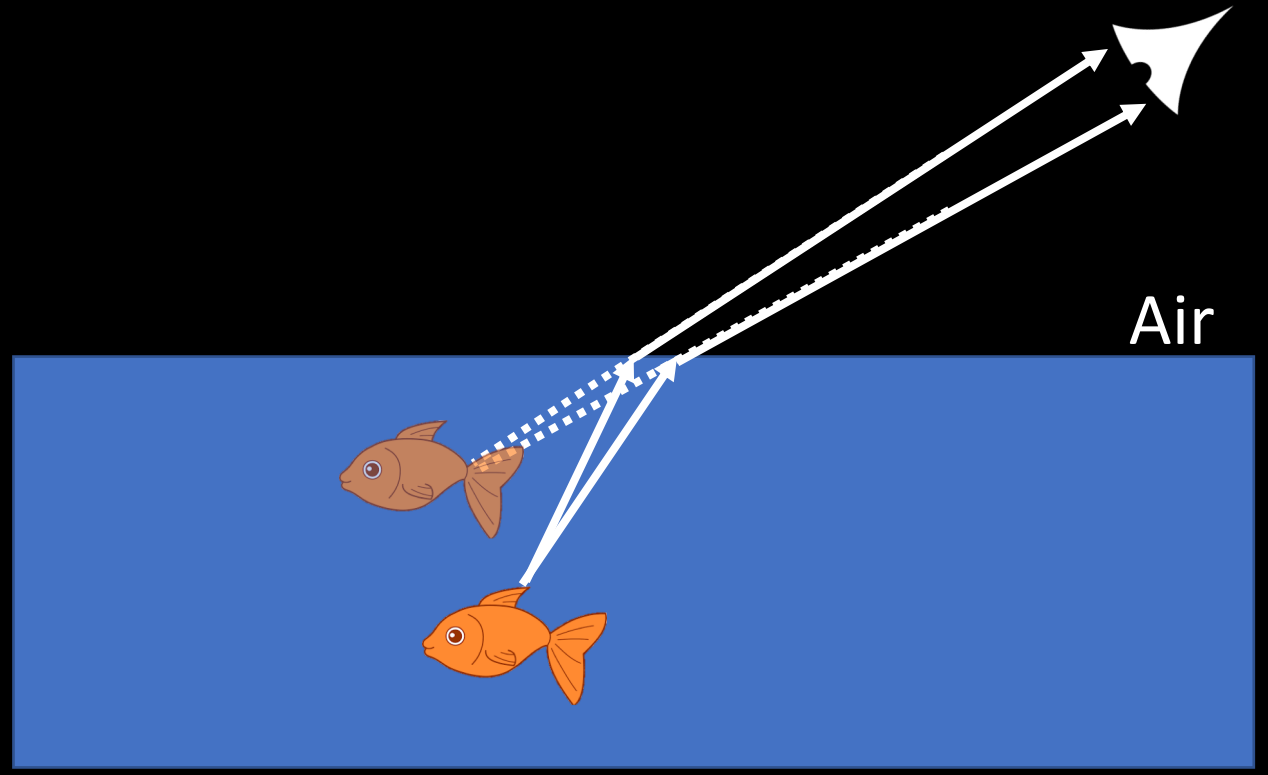
RF-based Localization



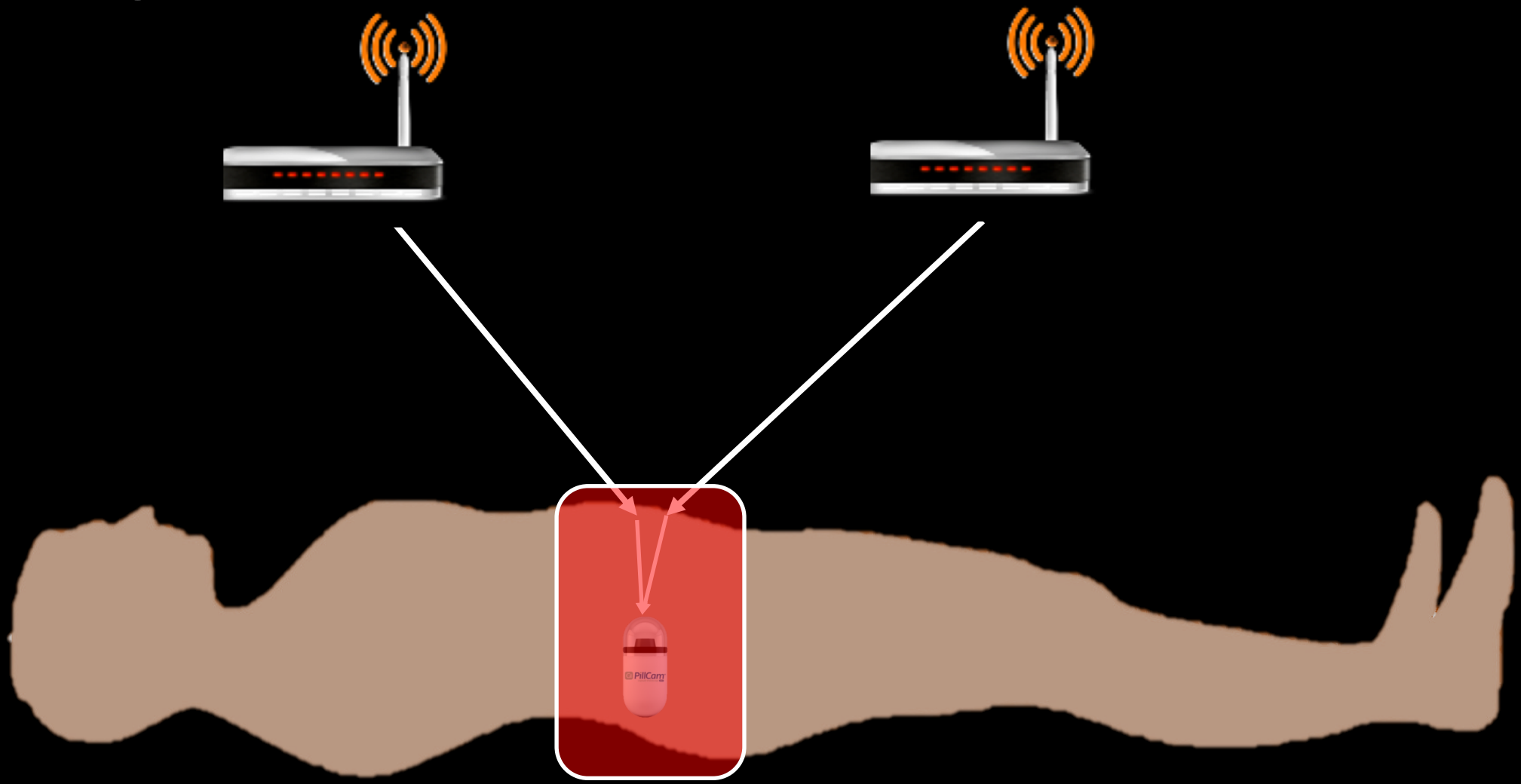
(x,y)

Trilateration:
Intersect straight lines

What changes in-body?



Challenge: Refraction



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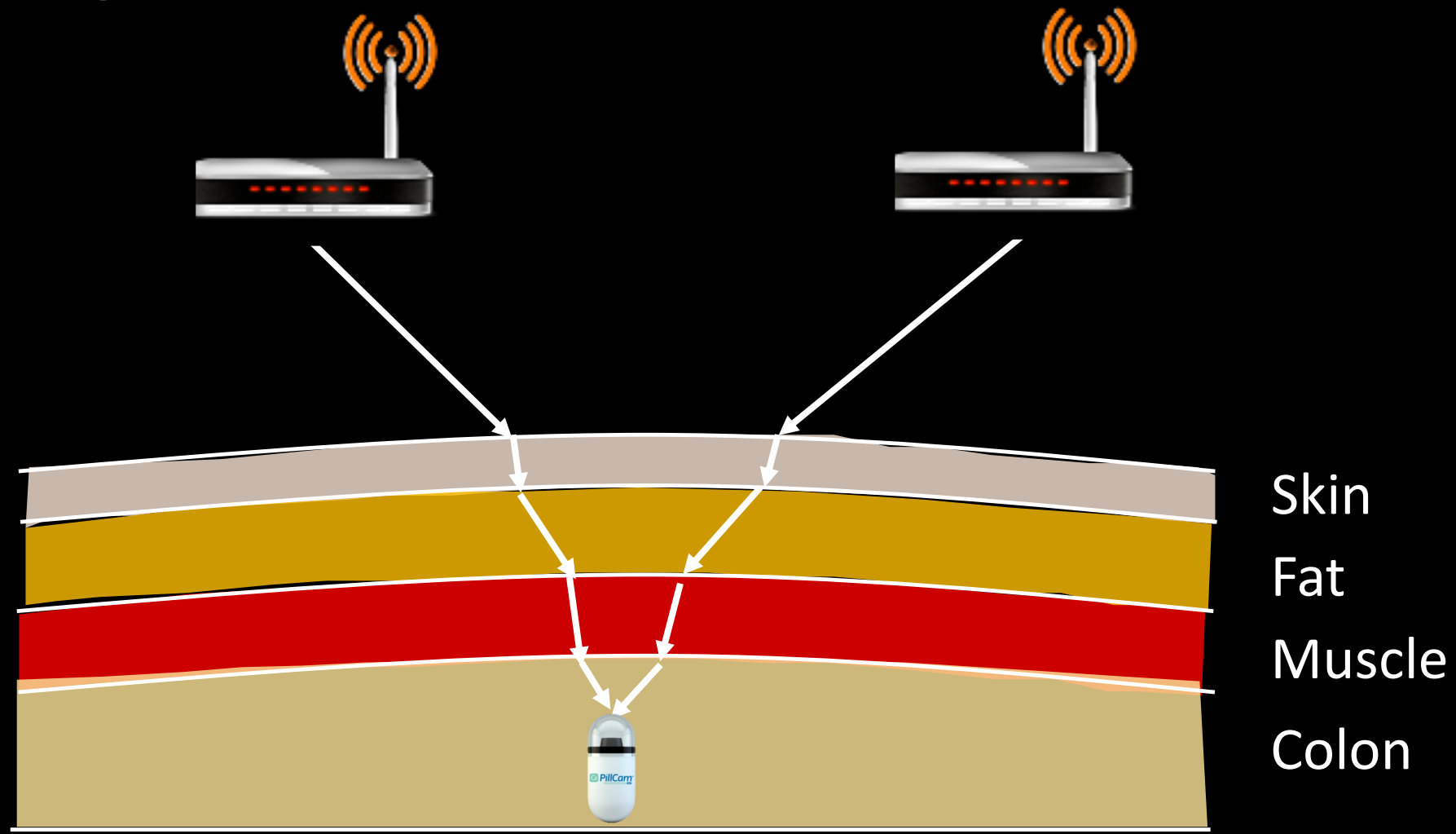
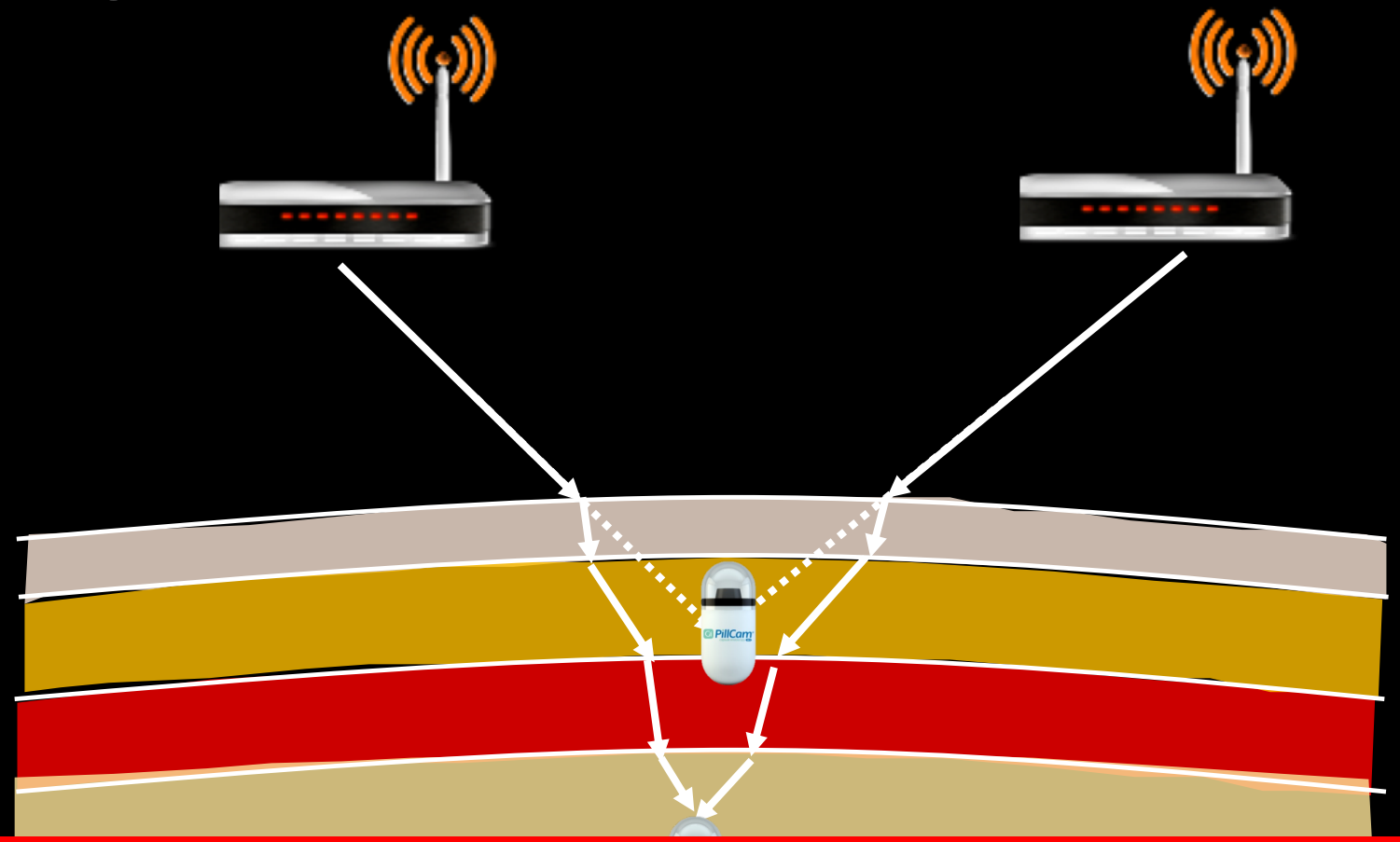


Challenge: Refraction



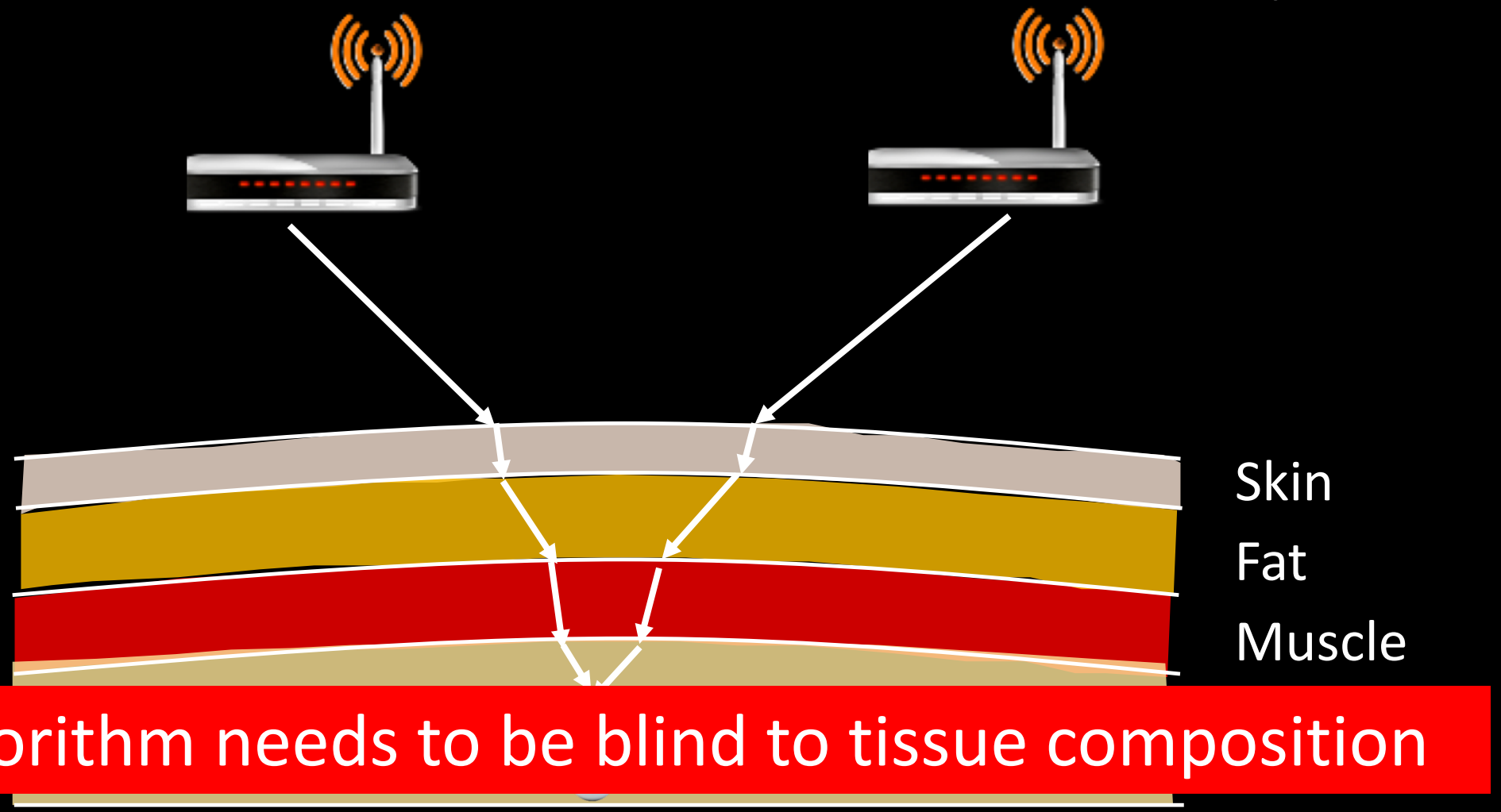
Cannot use existing localization models

Our Solution: Localization Model with Splines

Straight Line model

Spline-based model

Our Solution: Localization Model with Splines



Algorithm needs to be blind to tissue composition

Observation: Two Tissue Classes

Oil-based Tissues

Fat

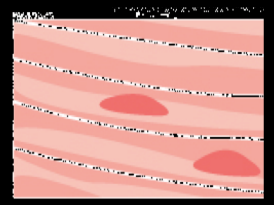
Colon

Breasts

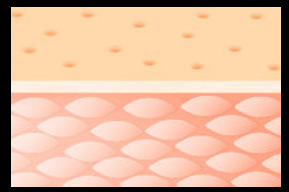
Bone marrow,
Bone cortical

Water-based Tissues

Blood



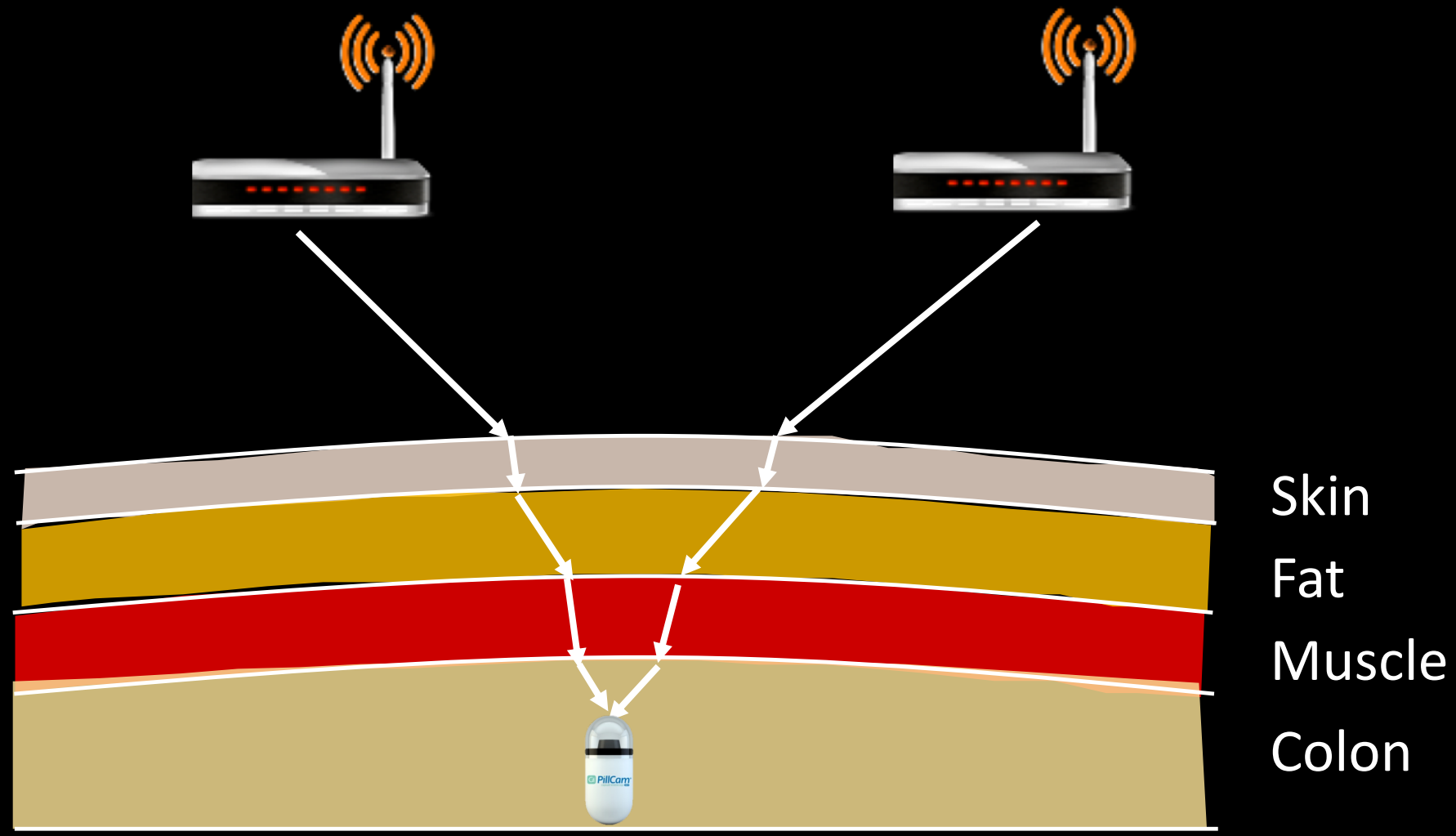
Muscle



Skin

Cornea

Group Similar Tissues



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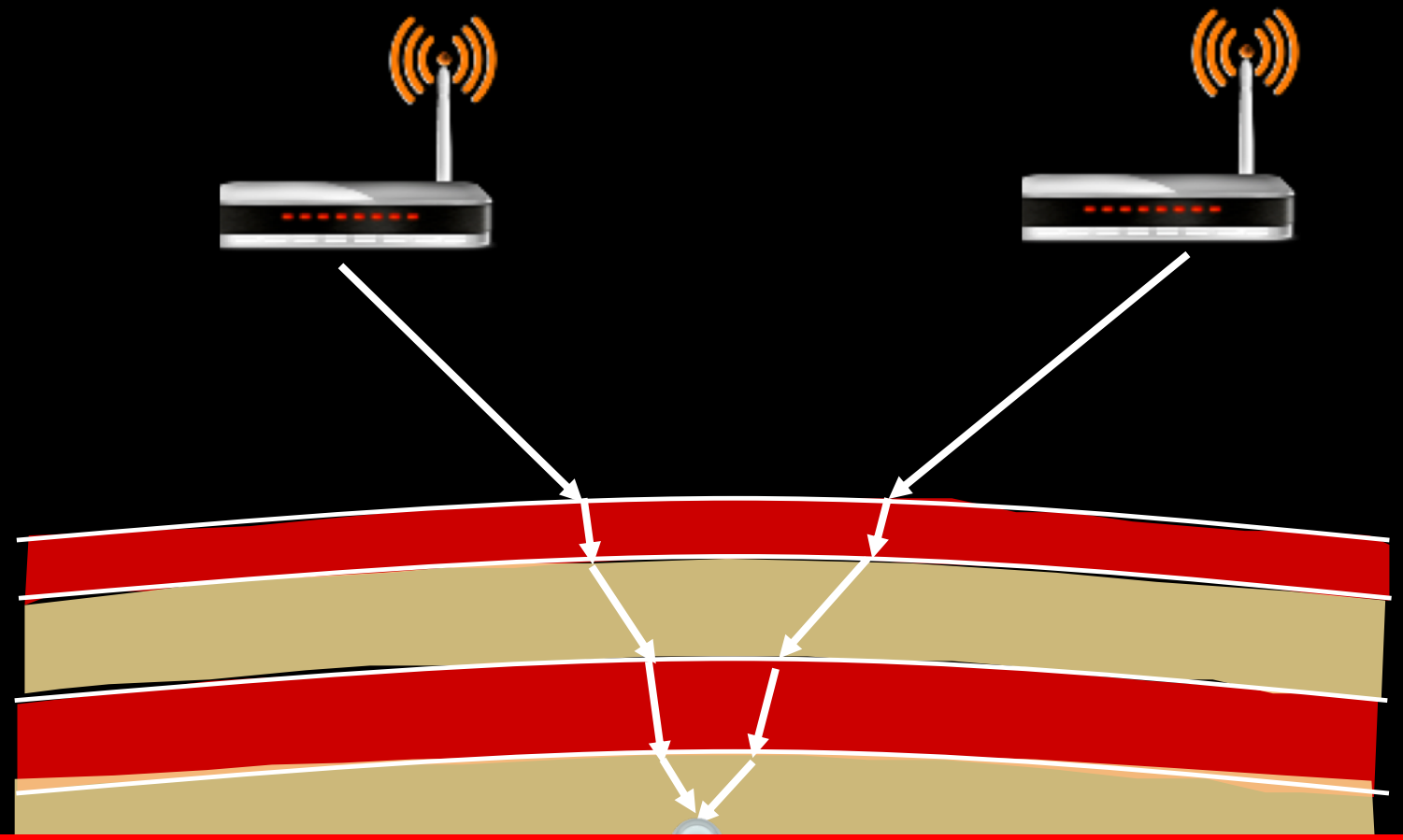

Water-based

Oil-based

Water-based

The order and the number of the layers is unknown

Insight: Tissue-Order can be Changed

Lemma [Informal]: the order of the tissue layers can be changed without impacting the phase of the signal

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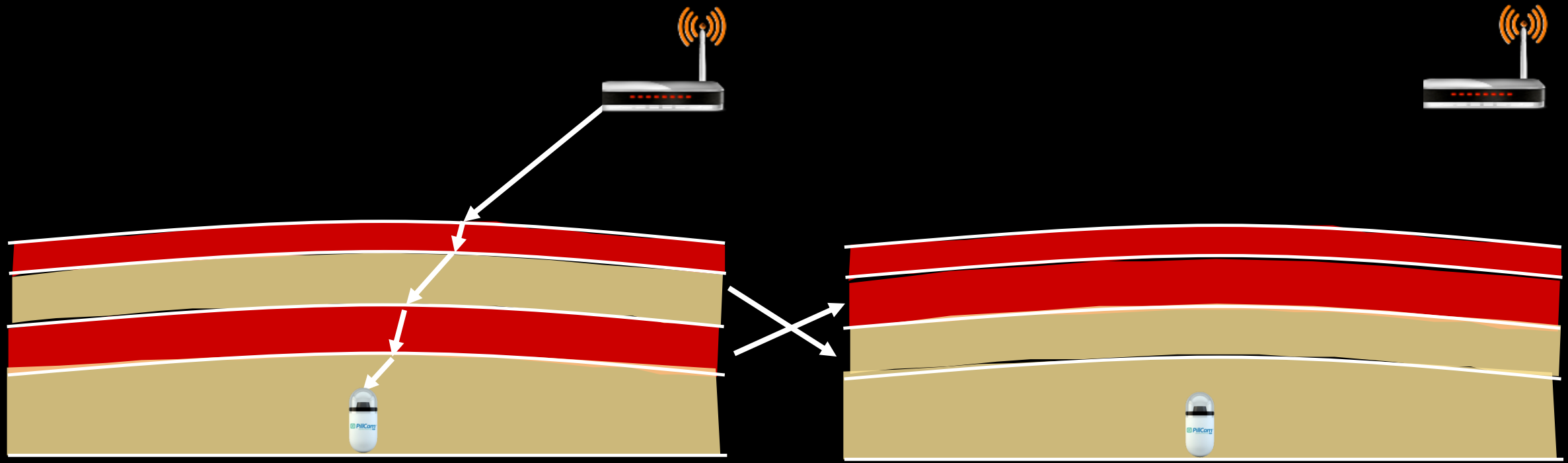
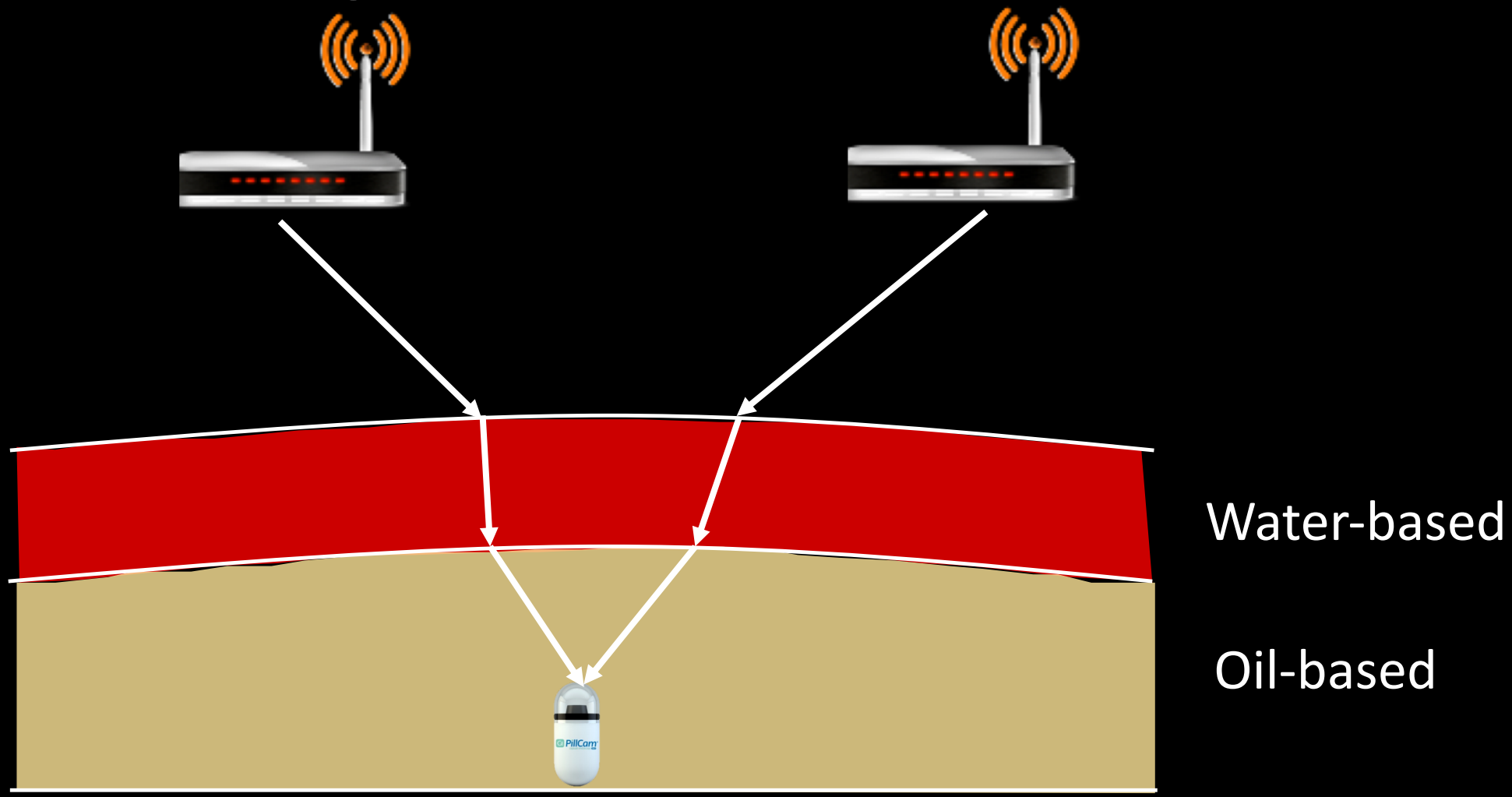


Tissue Rearrangement



Localization Constraints

Refraction Constraints (Snell's Law)

$$Re(\sqrt{\epsilon_i}) \sin\theta_i = Re(\sqrt{\epsilon_r}) \sin\theta_r$$

Geometric Constraints

$$d_i = \frac{l_i}{\cos\theta_i}$$

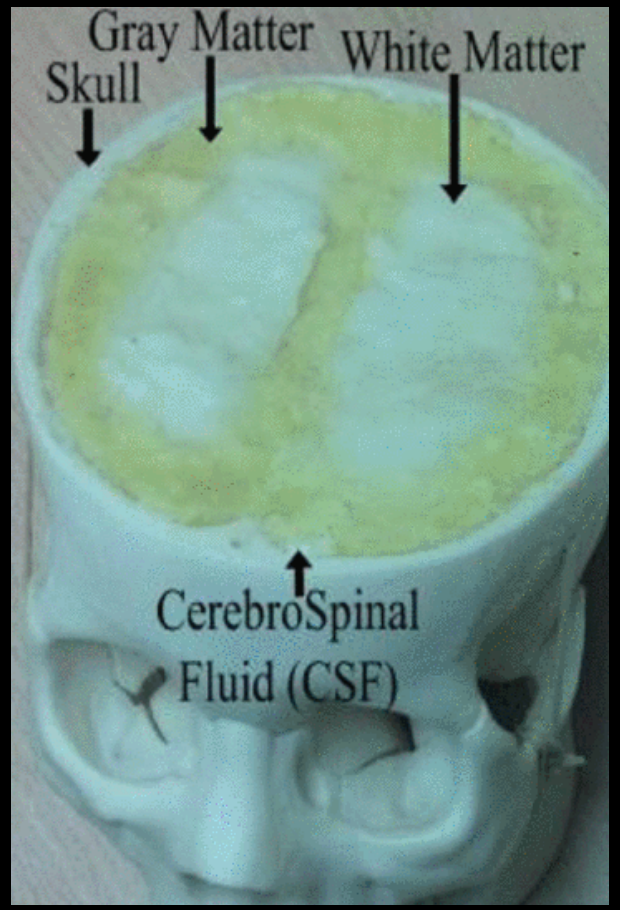
ReMix models signal propagation as a spline to perform in-body localization

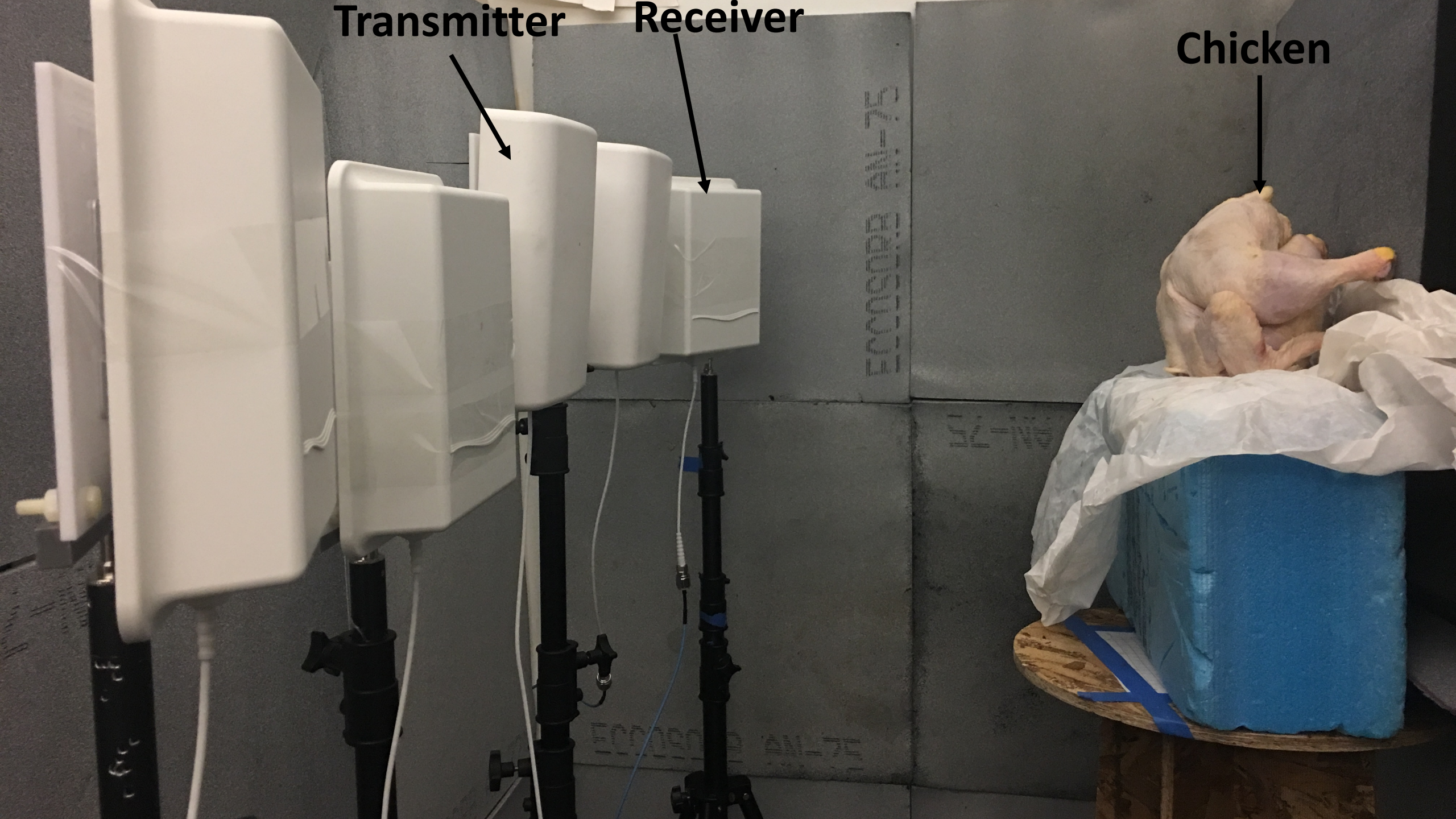
ReMix Evaluation

Evaluation: Emulating Human Tissues

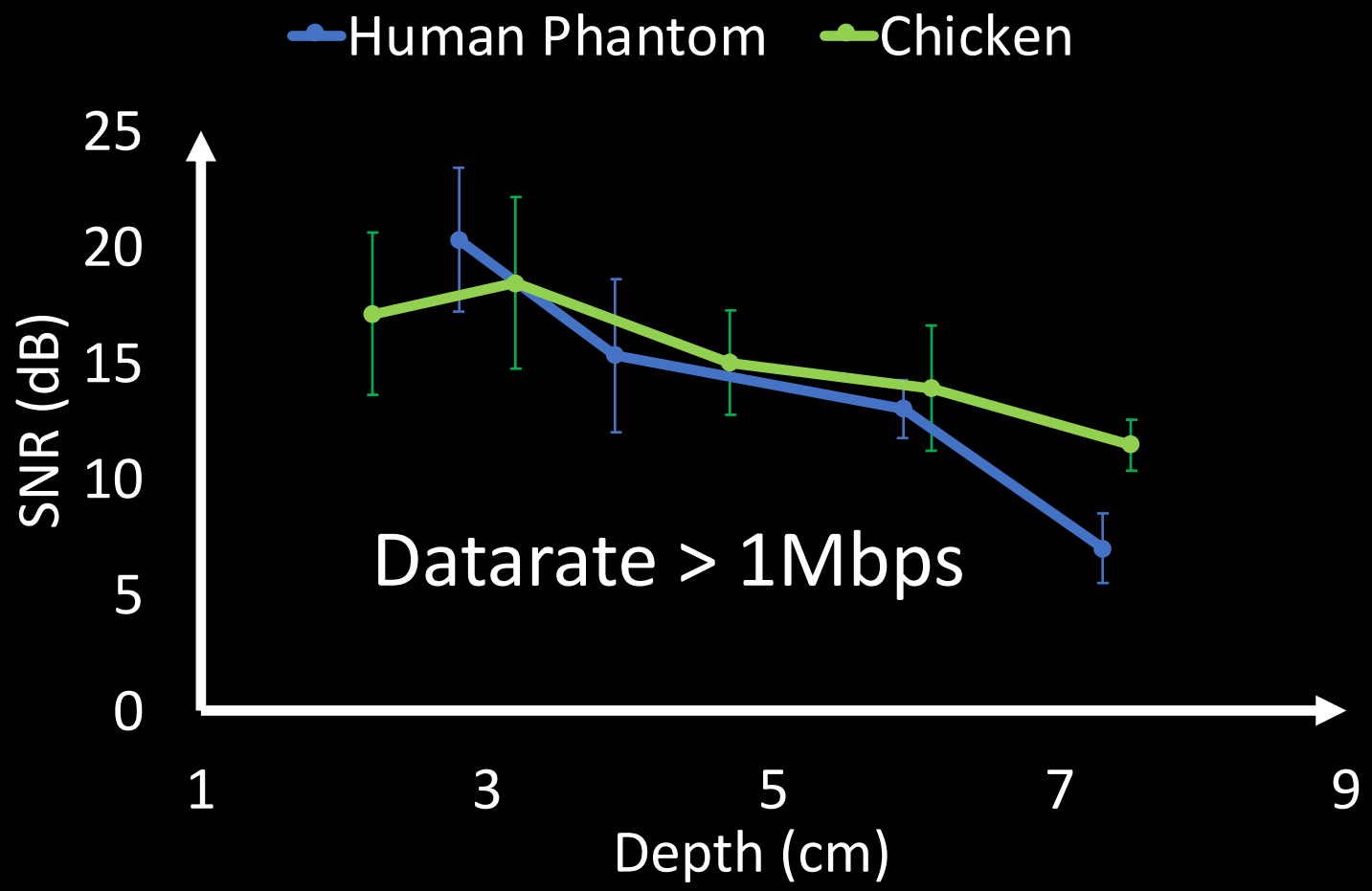
Animal Tissues

Human Tissue Phantoms

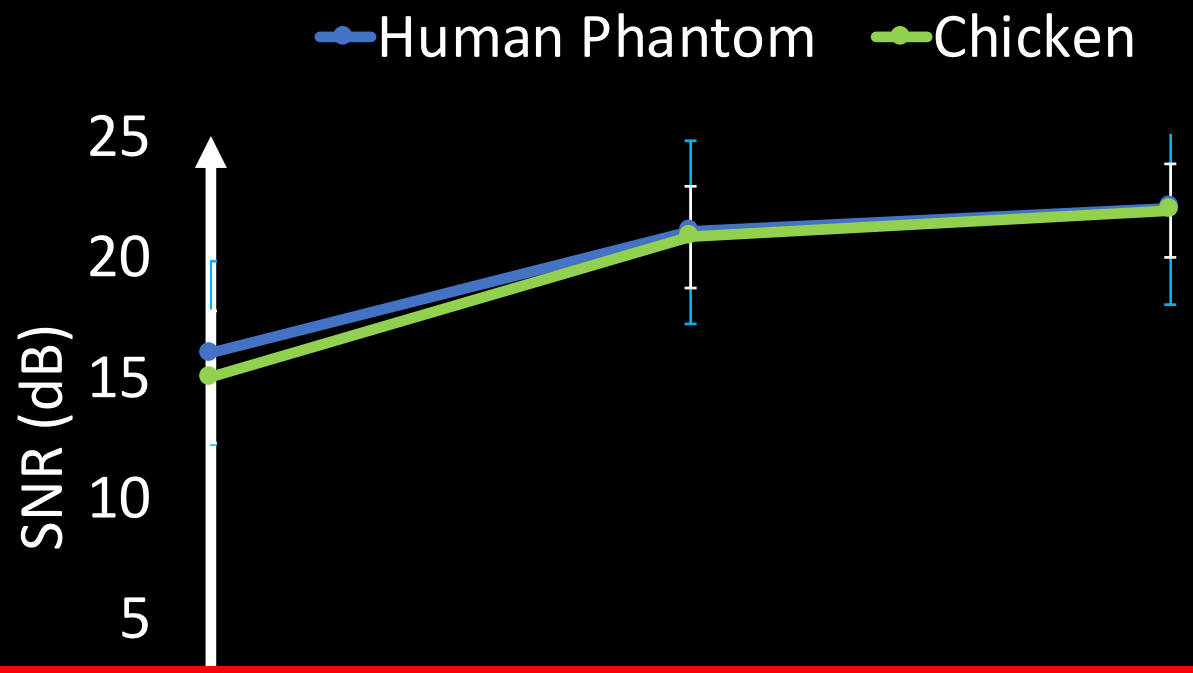



Transmitter
Receiver
Chicken

Evaluation: Backscatter Communication

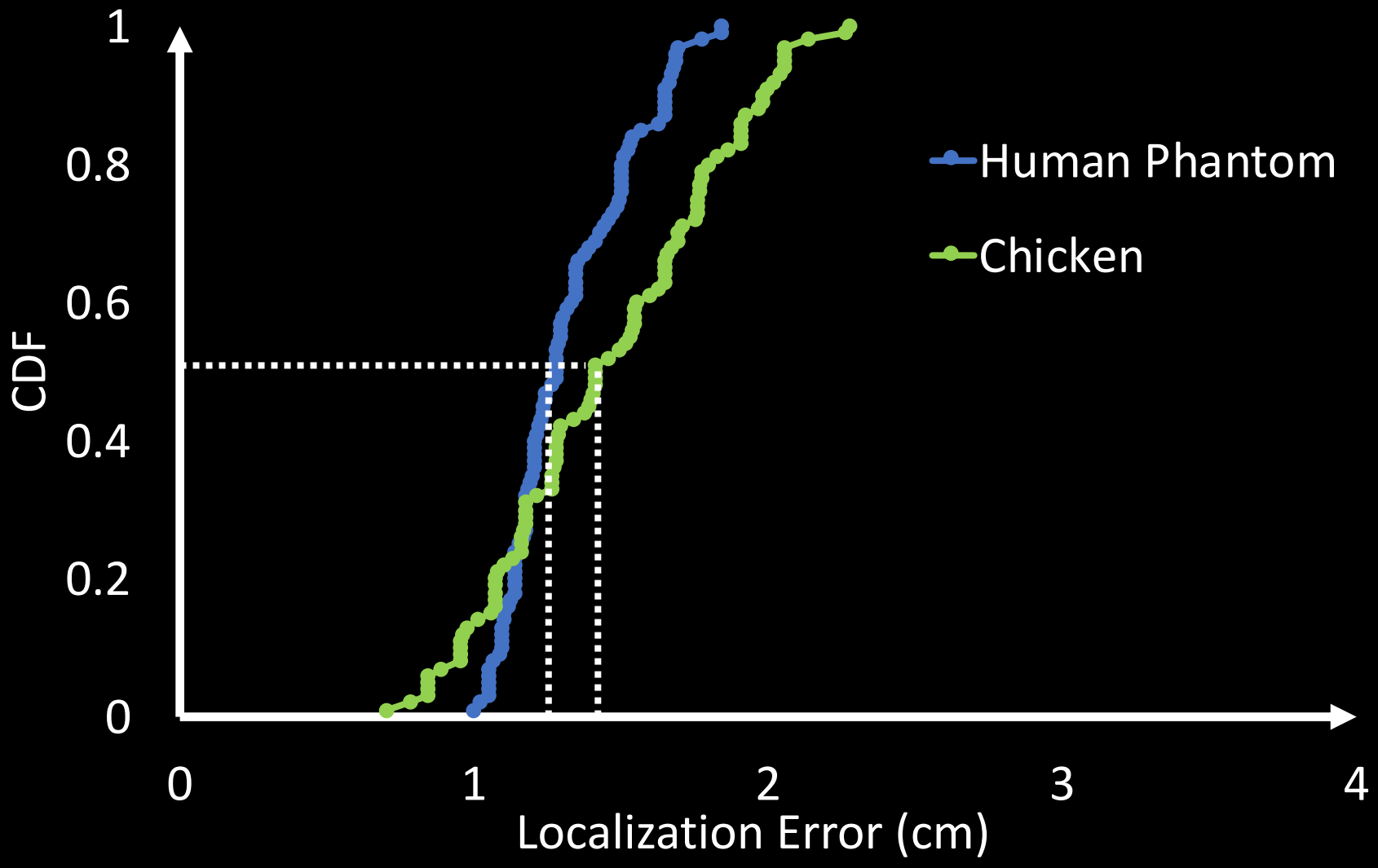


Evaluation: Backscatter Communication



ReMix can enable backscatter communication for in-body implants

Evaluation: Localization

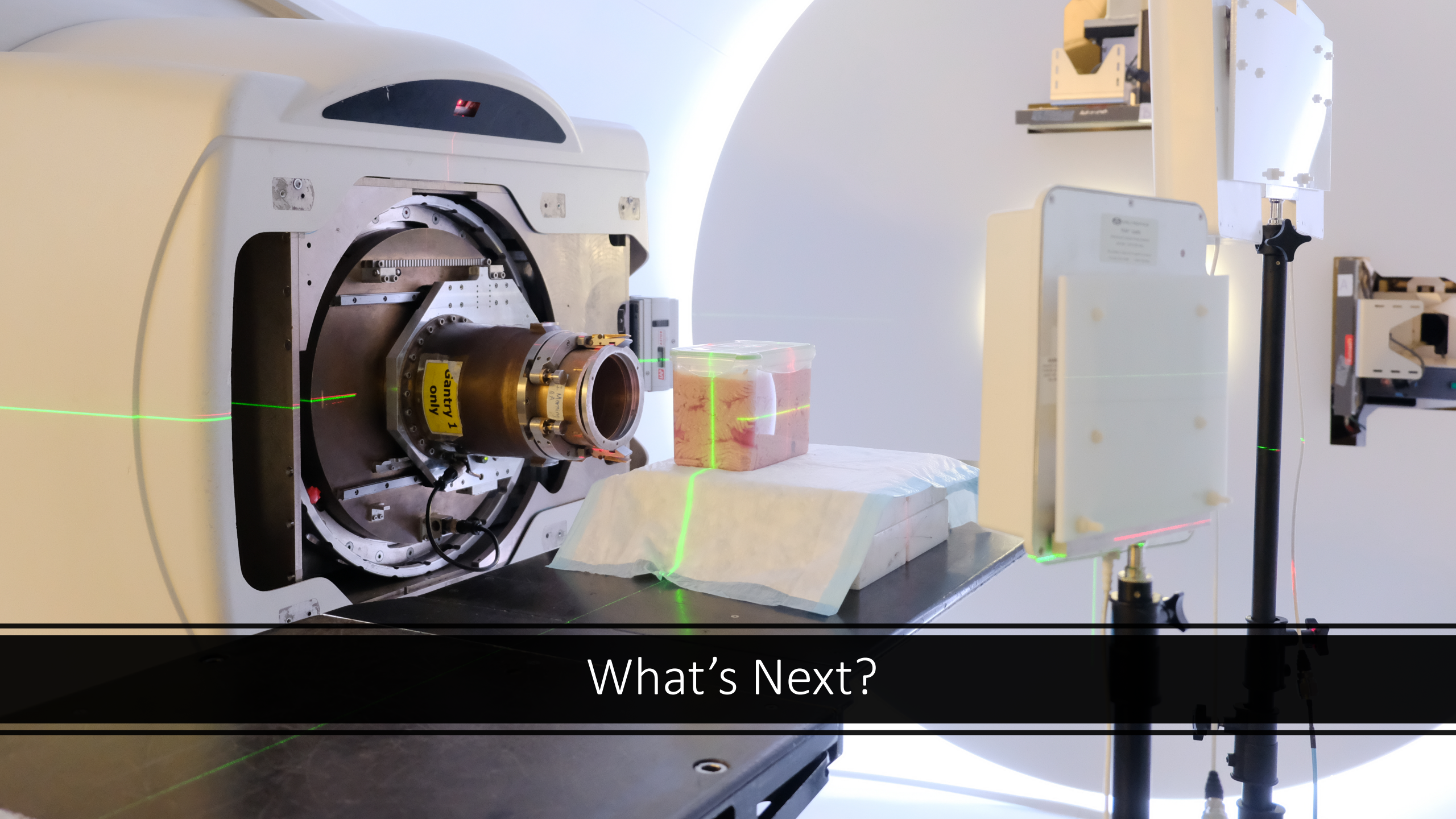


Evaluation: Localization

ReMix can accurately locate in-body devices by modelling human body refraction properties

Related Work

- Backscatter Networks: Bharadia et al [SIGCOMM 2015], Zhang et al [SIGCOMM 2016], Zhang et al [SenSys 2016], …
- In-air Localization: Kotaru et al [SIGCOMM 2015], Vasisht et al [NSDI 2016], Kumar et al [MobiCom 2014], ..
- In-body Capsules: PillCam, MicroCam, ..
- Medical Imaging: X-rays, MRI, Ultrasound …



What's Next?