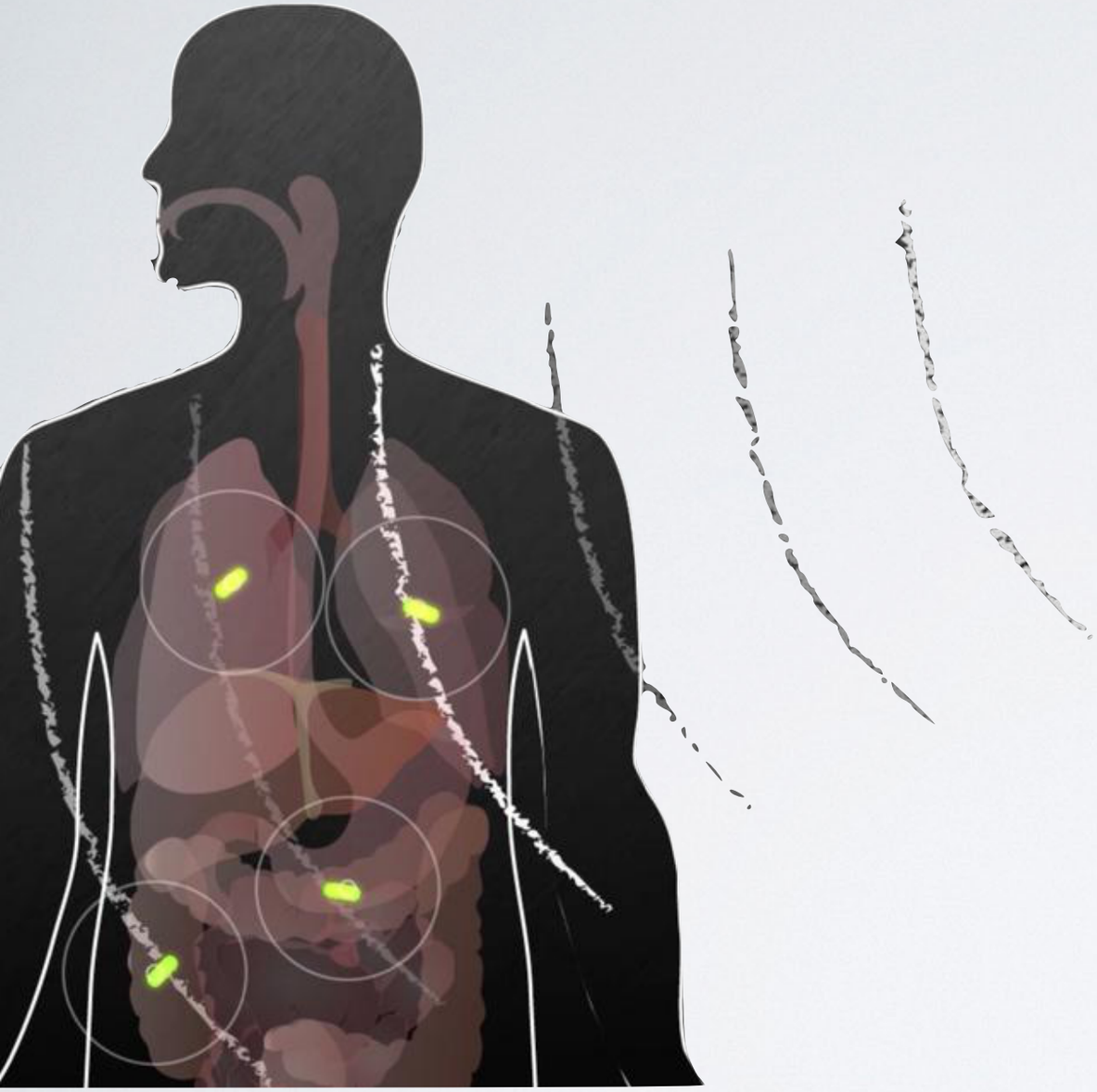
IN-VIVO NETWORKING

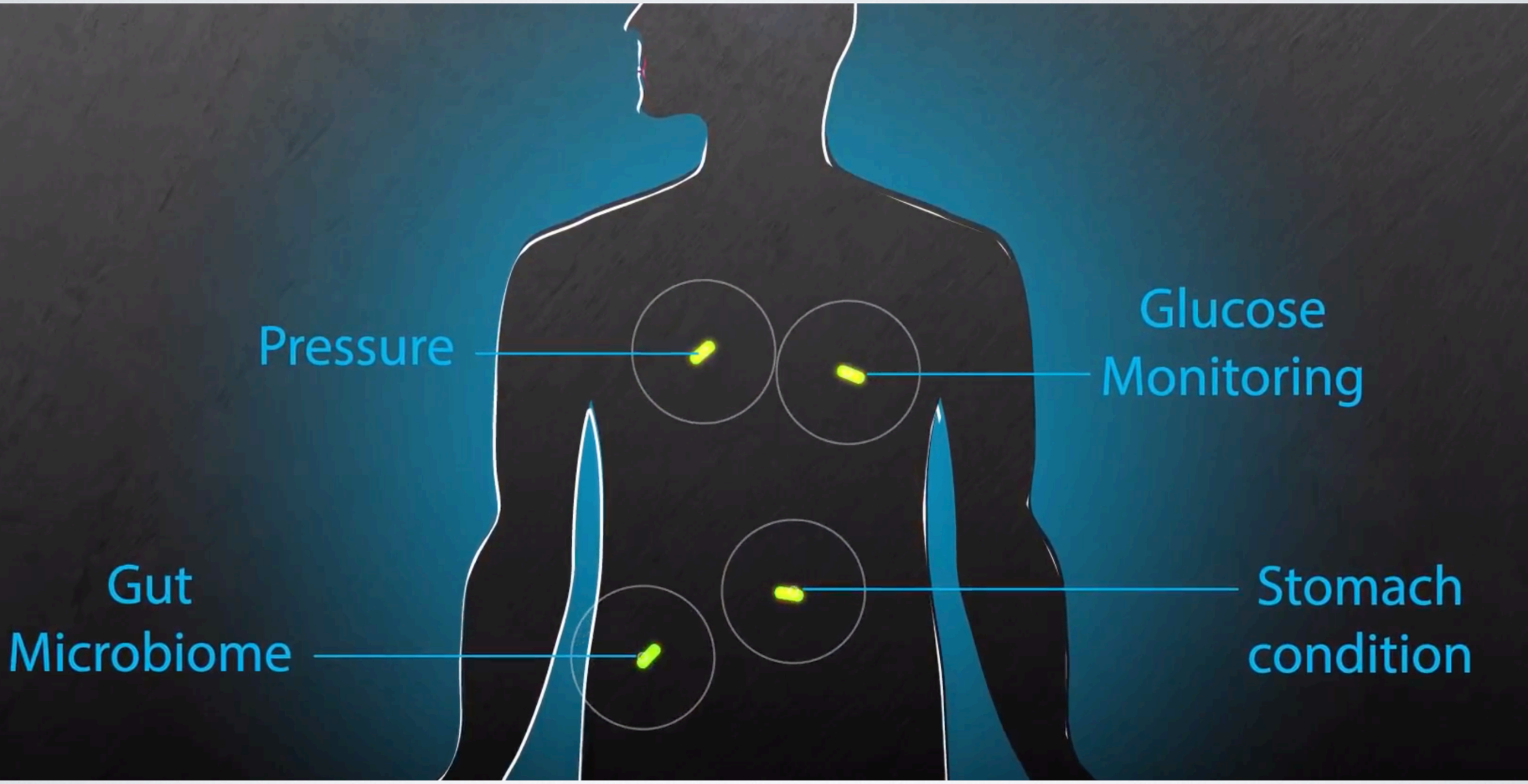
TARA BOROUSHAKI

Motivation and Challenges



IVN is a multi-antenna technique to remotely power up millimeter-sized in-vivo sensors and communicate with them.

Motivation and Challenges



Motivation and Challenges

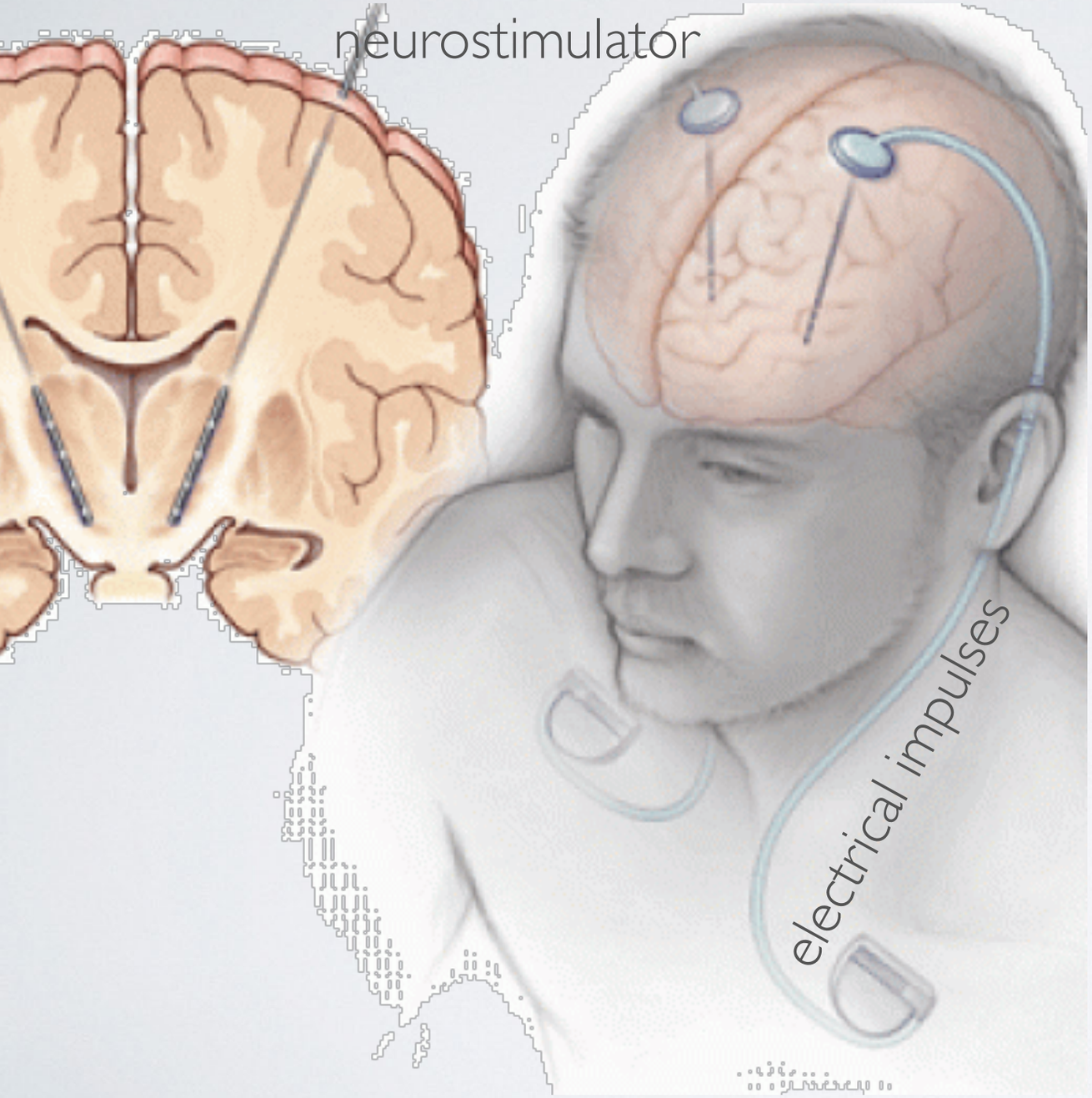
Deep brain stimulation

Parkinson's disease

Epilepsy

Severe depression

Motivation and Challenges



https://www.mdedge.com/ccjm/article/95707/neurology/deep-brain-stimulation-what-can-patients-expect-it

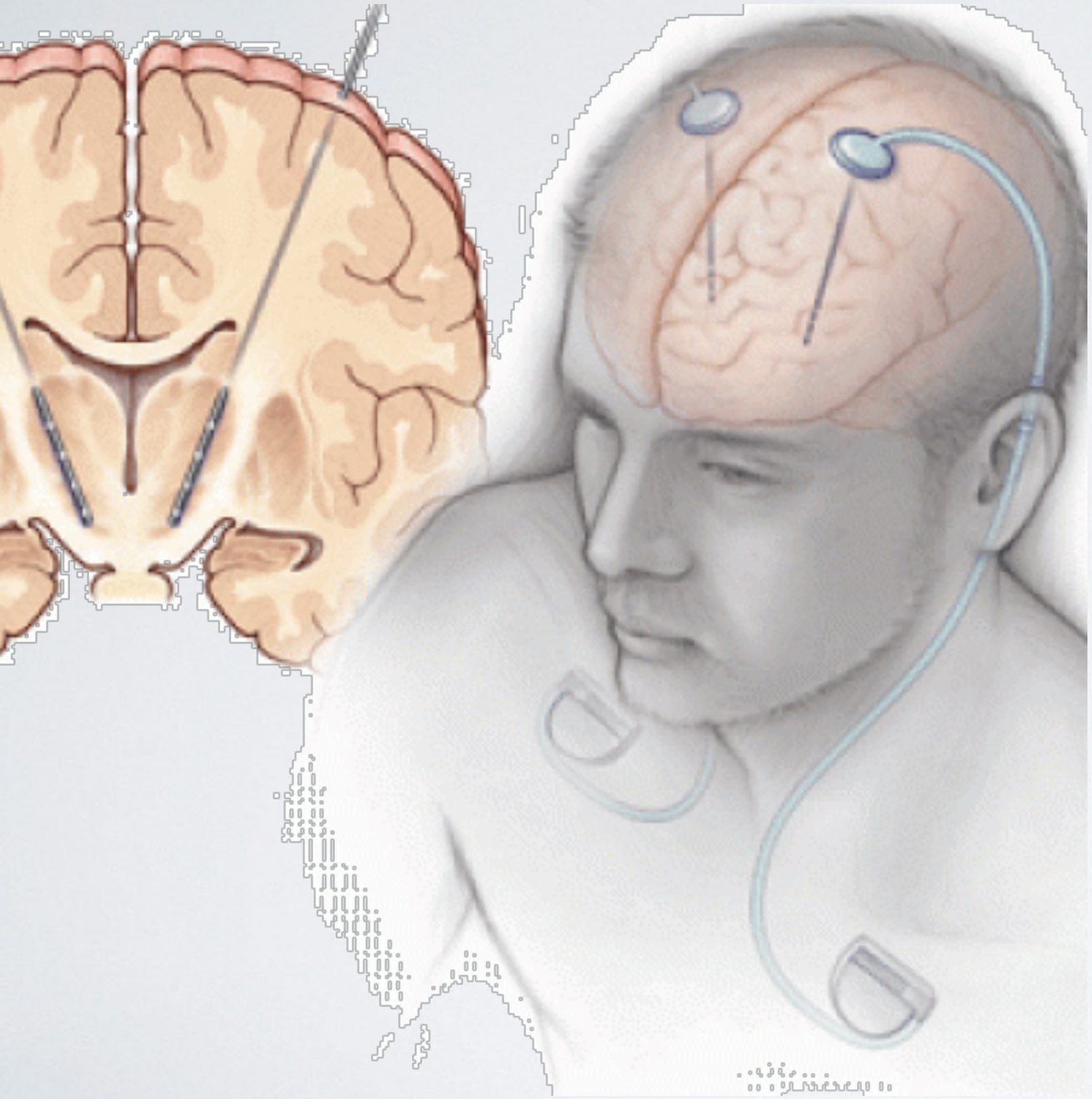
Deep brain stimulation

Parkinson's disease

Epilepsy

Severe depression

Motivation and Challenges



https://www.mdedge.com/ccjm/article/95707/neurology/deep-brain-stimulation-what-can-patients-expect-it

Deep brain stimulation

Parkinson's disease

Epilepsy

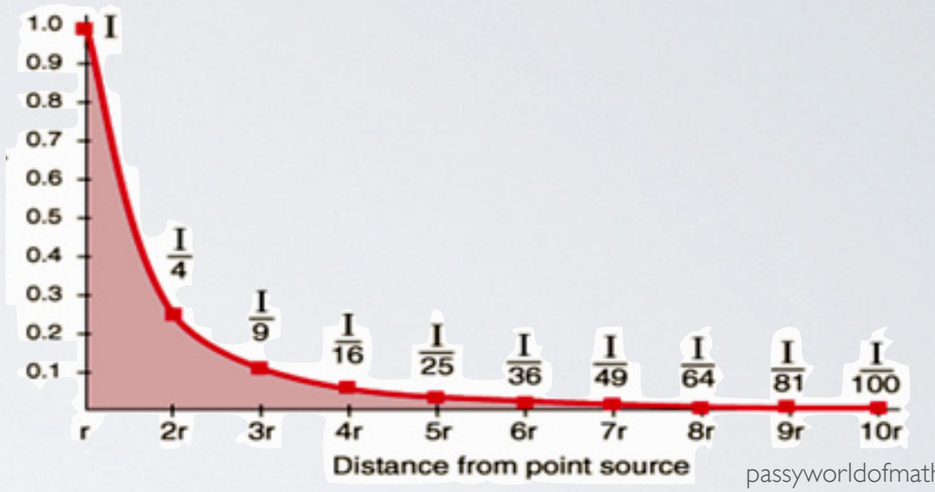
Severe depression

Costs between $30K and $50K

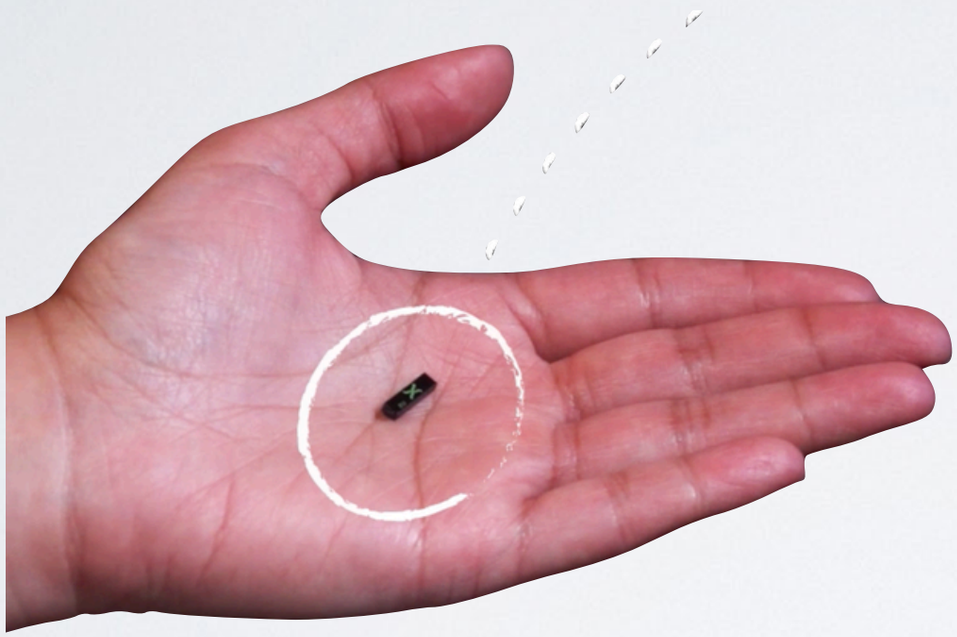
10-year survival rate of 51%

Motivation and Challenges

Exponential attenuation in body



passyworldofmathematics.com



Small size of device,
Small effective area for antenna

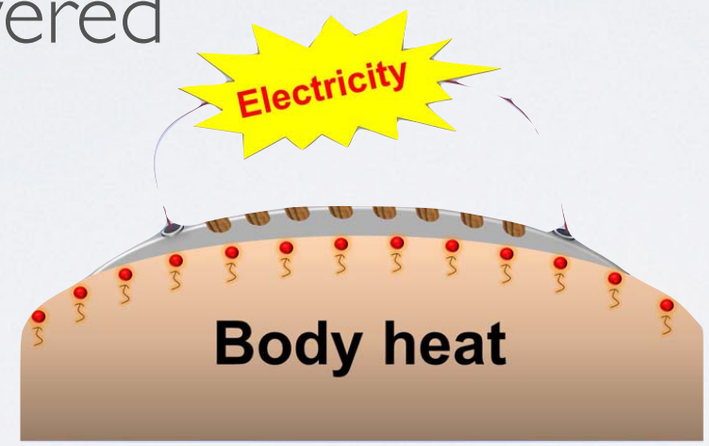
No channel feed back

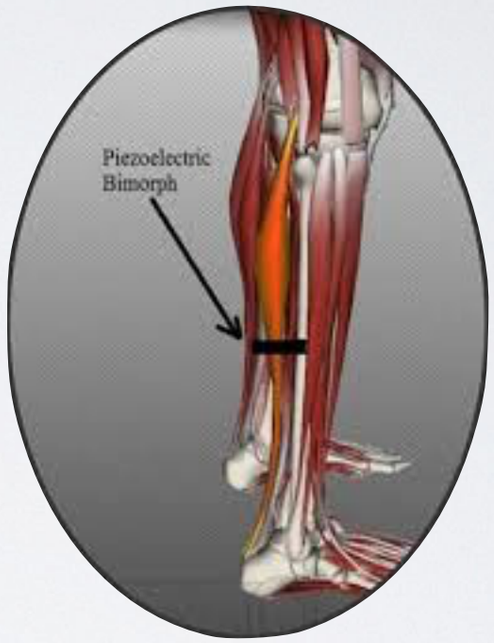
depositphotos.com

Previous Works

Energy-harvesting bioelectronics:

Self-Powered

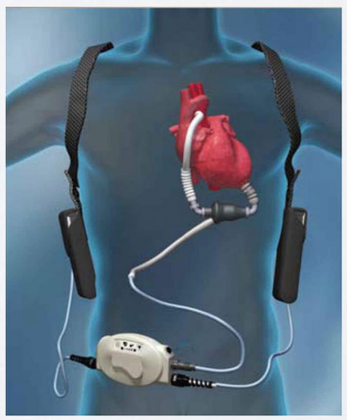


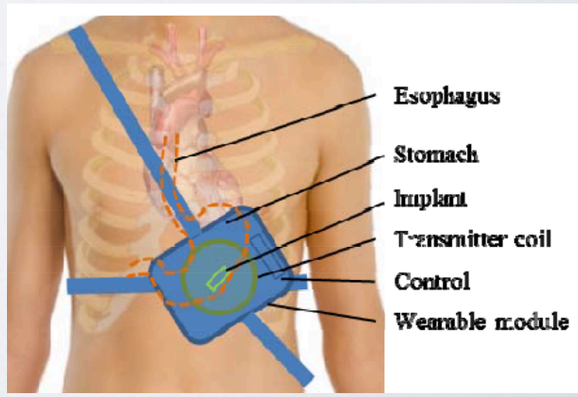


home.iitk.ac.in/~bishakh/

medlineplus.gov

Wirelessly Powered

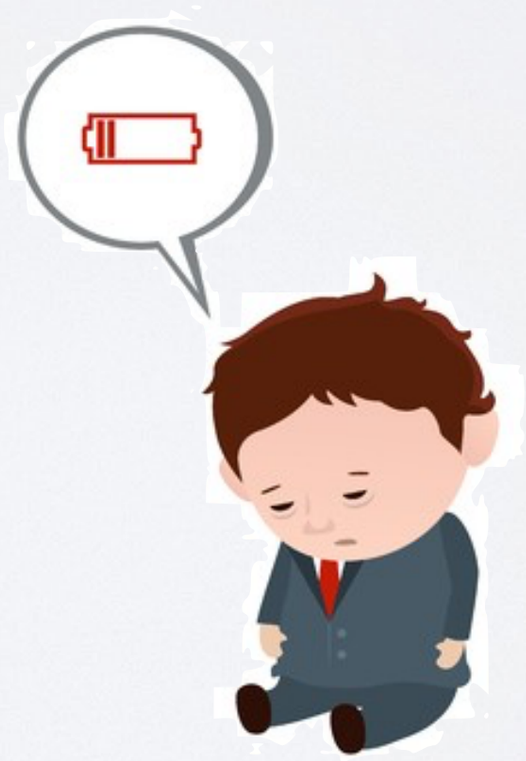




SEO, Y.-S., HUGHES, Z., ISOM, D., NGUYEN, M. Q., DEB, S., RAO, S., AND CHIAO, J.-C. Wireless power transfer for a miniature gas- trostimulator. In *Microwave Conference (EuMC),*

IVN

- Deeper in tissue (>10cm)
- Transmitter can be further from body (>1m)
- Battery-Free



en.clipdealer.com/vector/media/A:66544557?

Previous Works

Beamforming Algorithms:

MIMO:

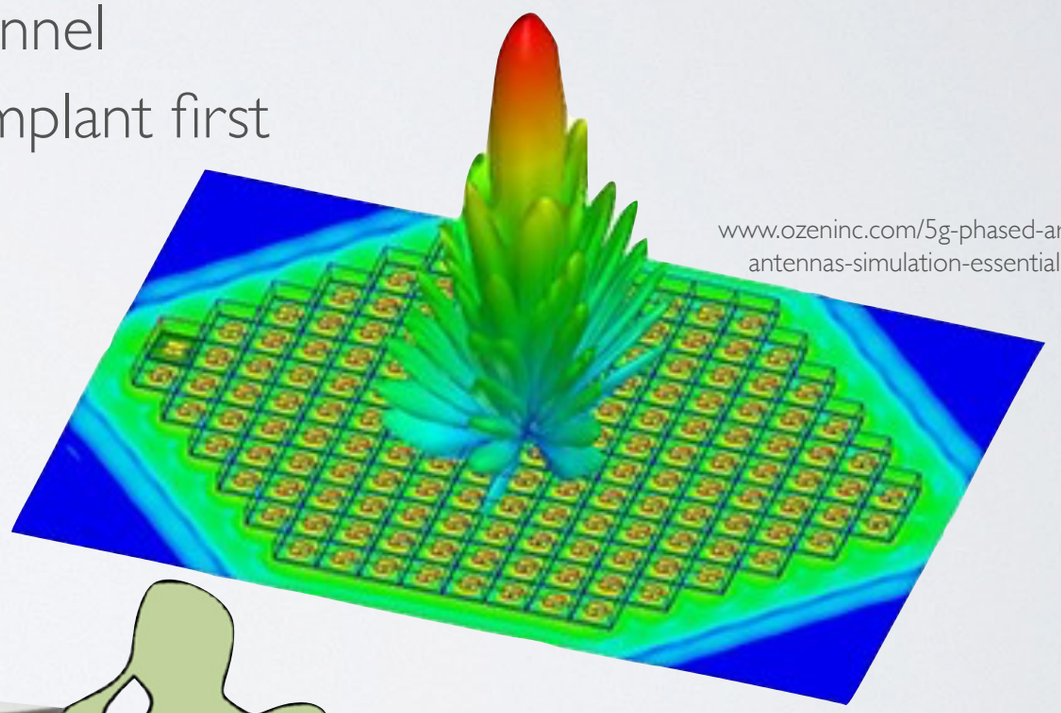
inverts the estimated channel

needs to power up the implant first

Antenna Arrays:

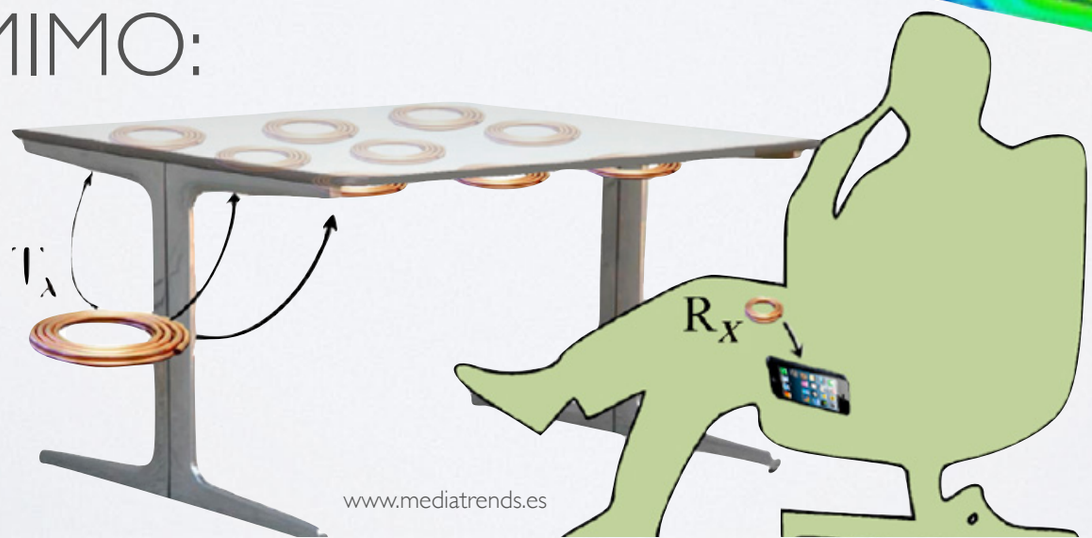
Not practical for

multi layer tissue



www.ozeninc.com/5g-phased-array-antennas-simulation-essentials/

MagMIMO:



www.mediatrends.es

IVN

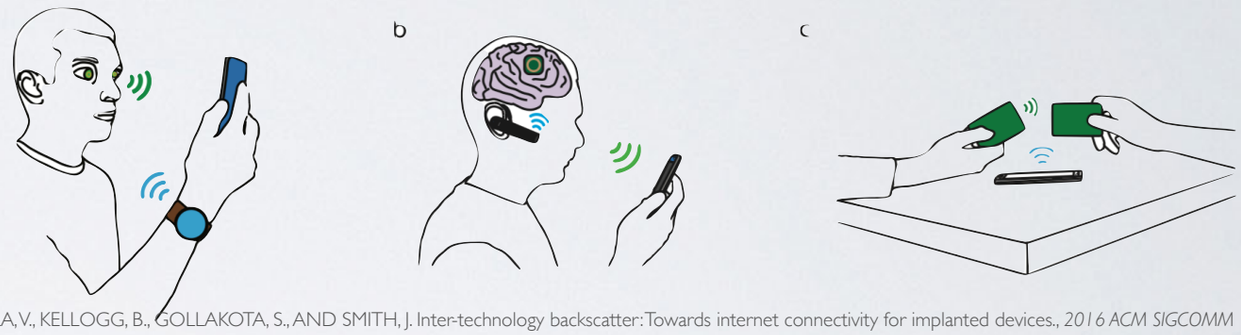
- Works under blind channel condition
- No need for receiver cooperation
- Maximizes peak power across space

Previous Works

Backscatter Networking:

HitchHike:

Similar range to RFIDs



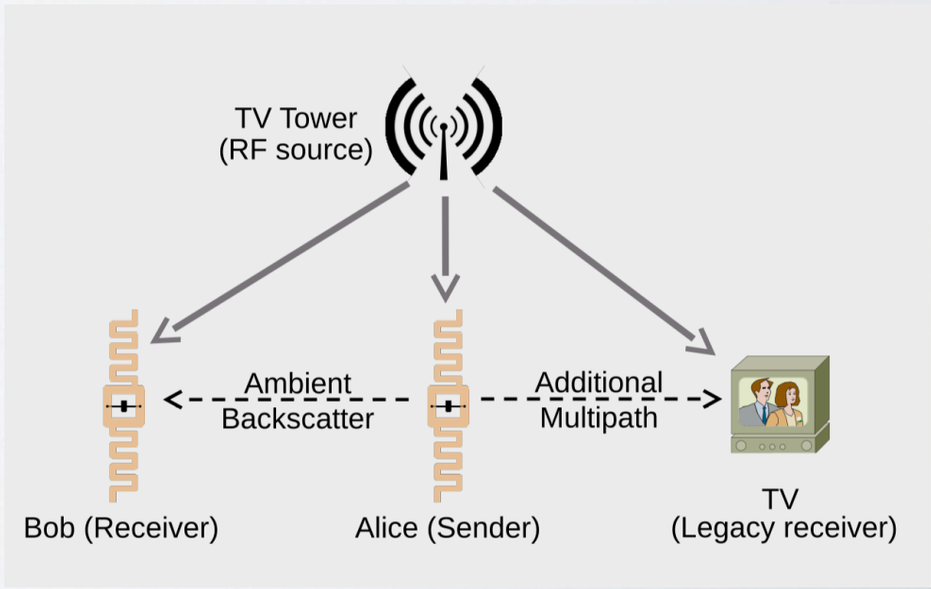
IYER, V., TALLA, V., KELLOGG, B., GOLLAKOTA, S., AND SMITH, J. Inter-technology backscatter: Towards internet connectivity for implanted devices., *2016 ACM SIGCOMM*

LoRa:

10 cm^2 battery is needed

Ambient backscatter:

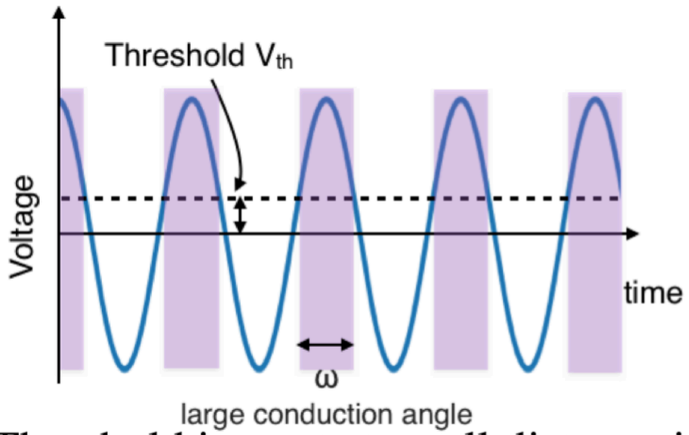
Not practical for in-door
Neither FCC compliant nor safe



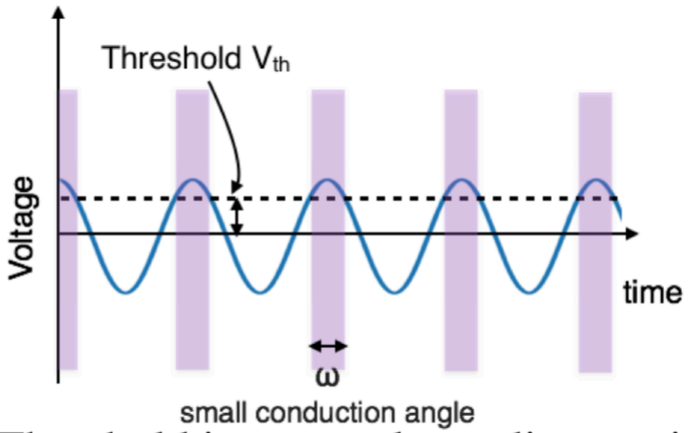
IVN

- FCC compliant and safe for humans
- Battery-Free
- Works in deep tissue

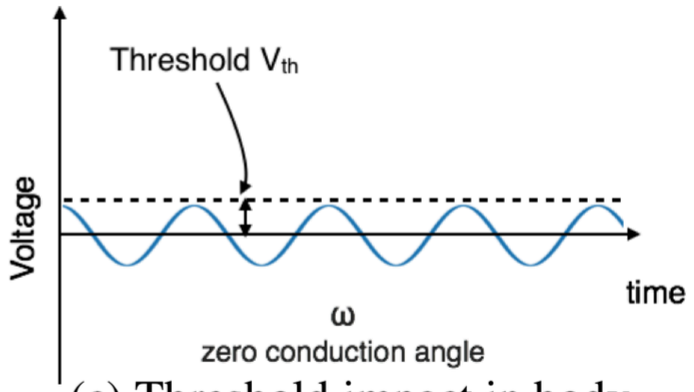
IVN strategy



(a) Threshold impact at small distance in air

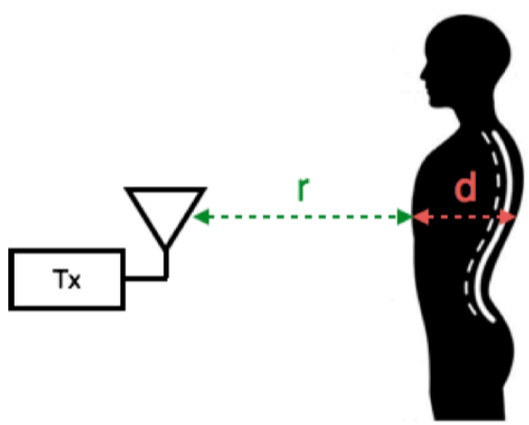


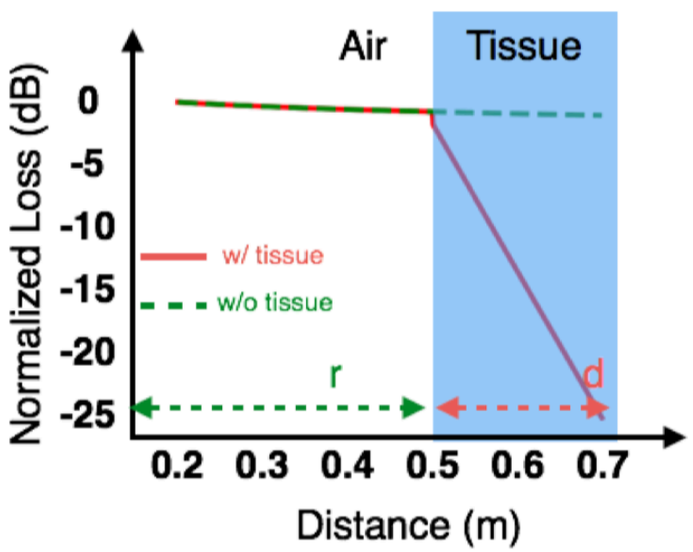
(b) Threshold impact at large distance in air



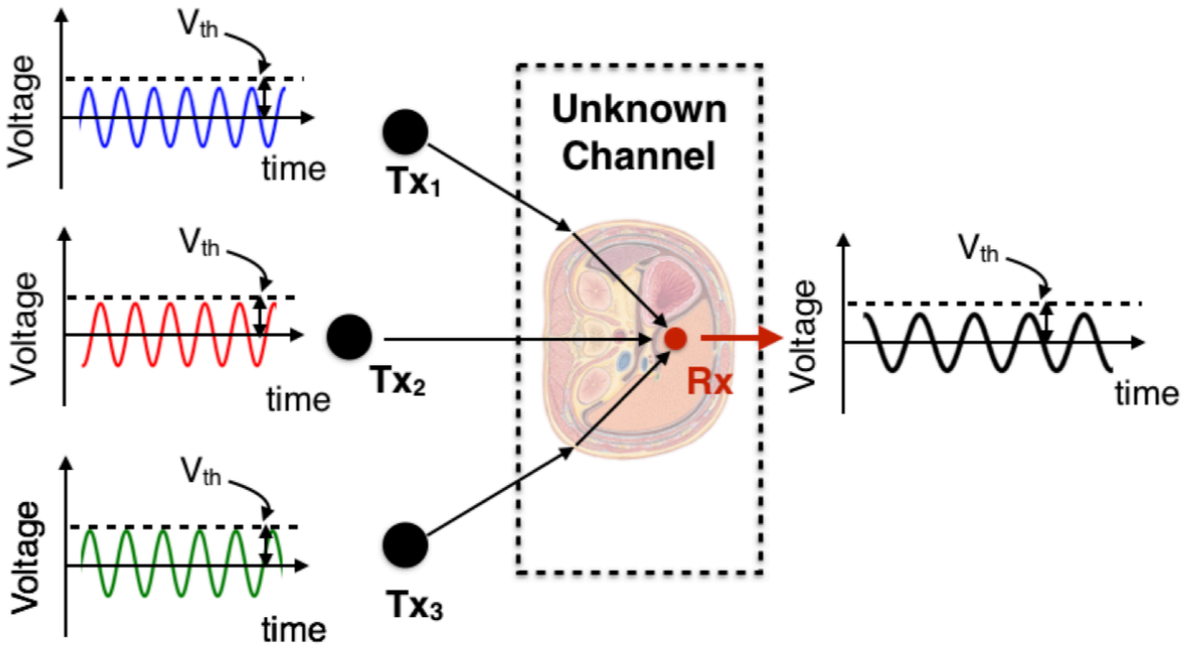
(c) Threshold impact in body

Power loss in tissue

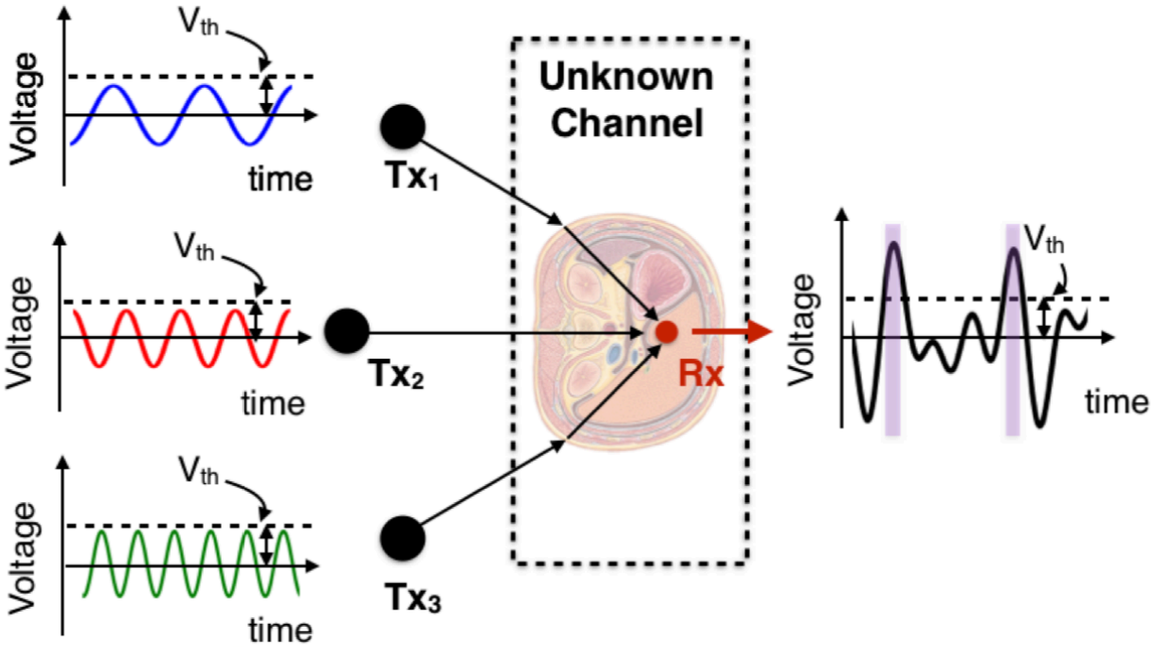




IVN strategy



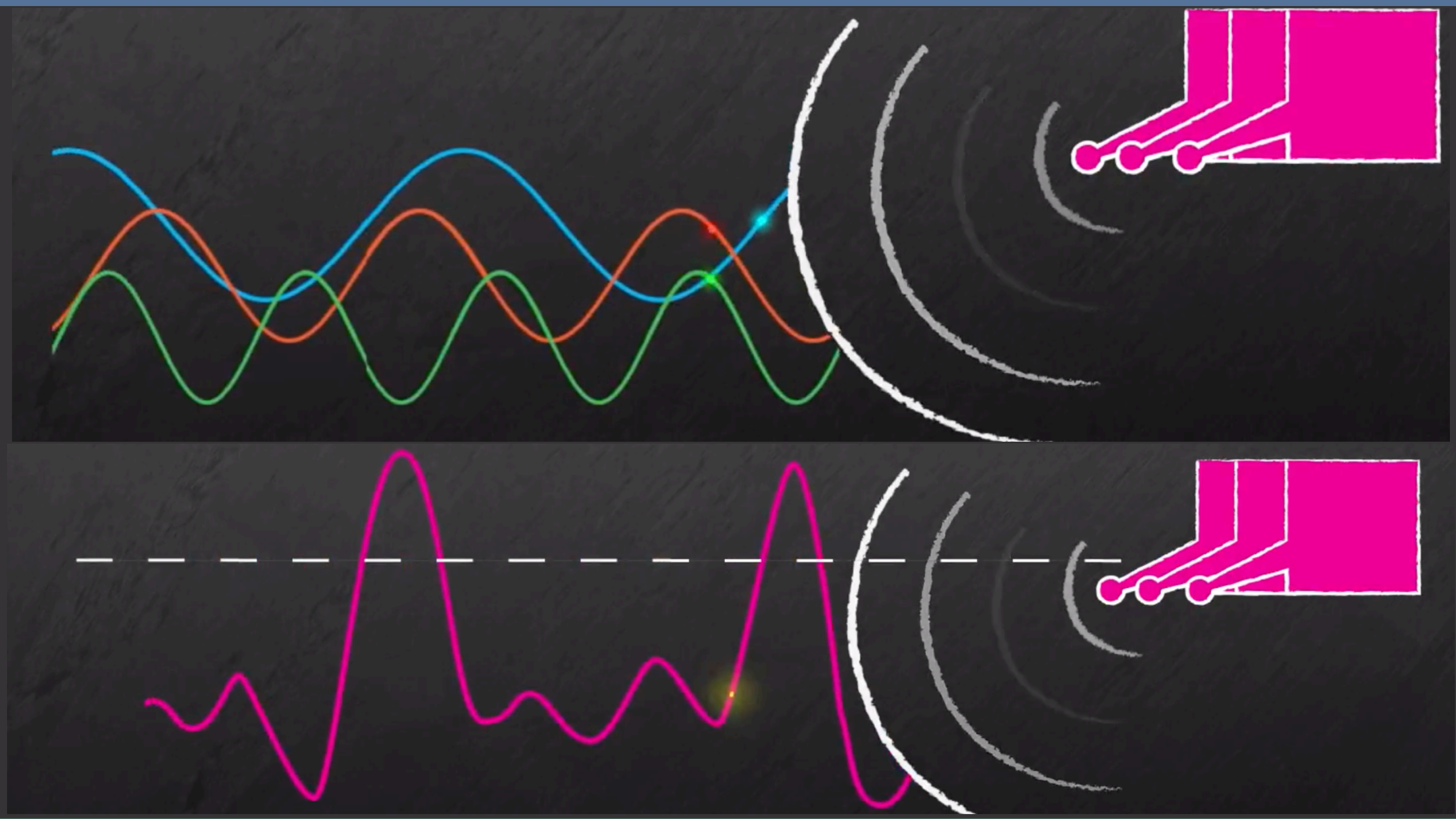
(a) Traditional beamforming under unknown channel conditions.



(b) IVN's CIB technique under unknown channel conditions.

Coherently-Incoherent Beamforming

IVN strategy



Frequencies Selection?

Frequency Selection

- Solve an Optimization problem:

$$\underset{f_1,\ldots,f_N}{\arg\max}\mathbf{E}_{\boldsymbol{\beta}}\left[\max_{t}\left|\sum_{i=1}^{N}e^{j(2\pi f_i t+\beta_i)}\right|\right]$$

maximizes the expected peak power
over all possible channel conditions

1- Ensure the sensor responses every T seconds.

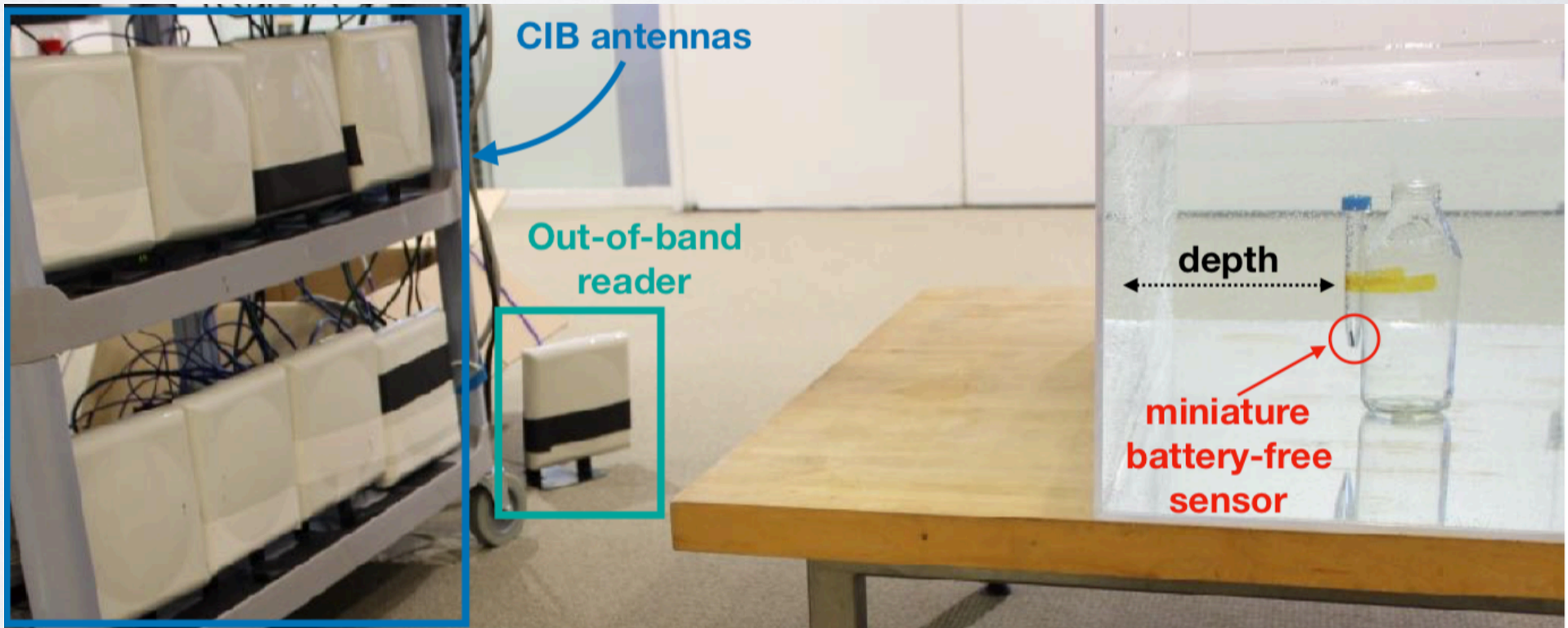
2- Sensor tolerates only a small fluctuation in the amplitude of its received signal

Jamming-Free Communication

Backscatter modulation is frequency-agnostic.

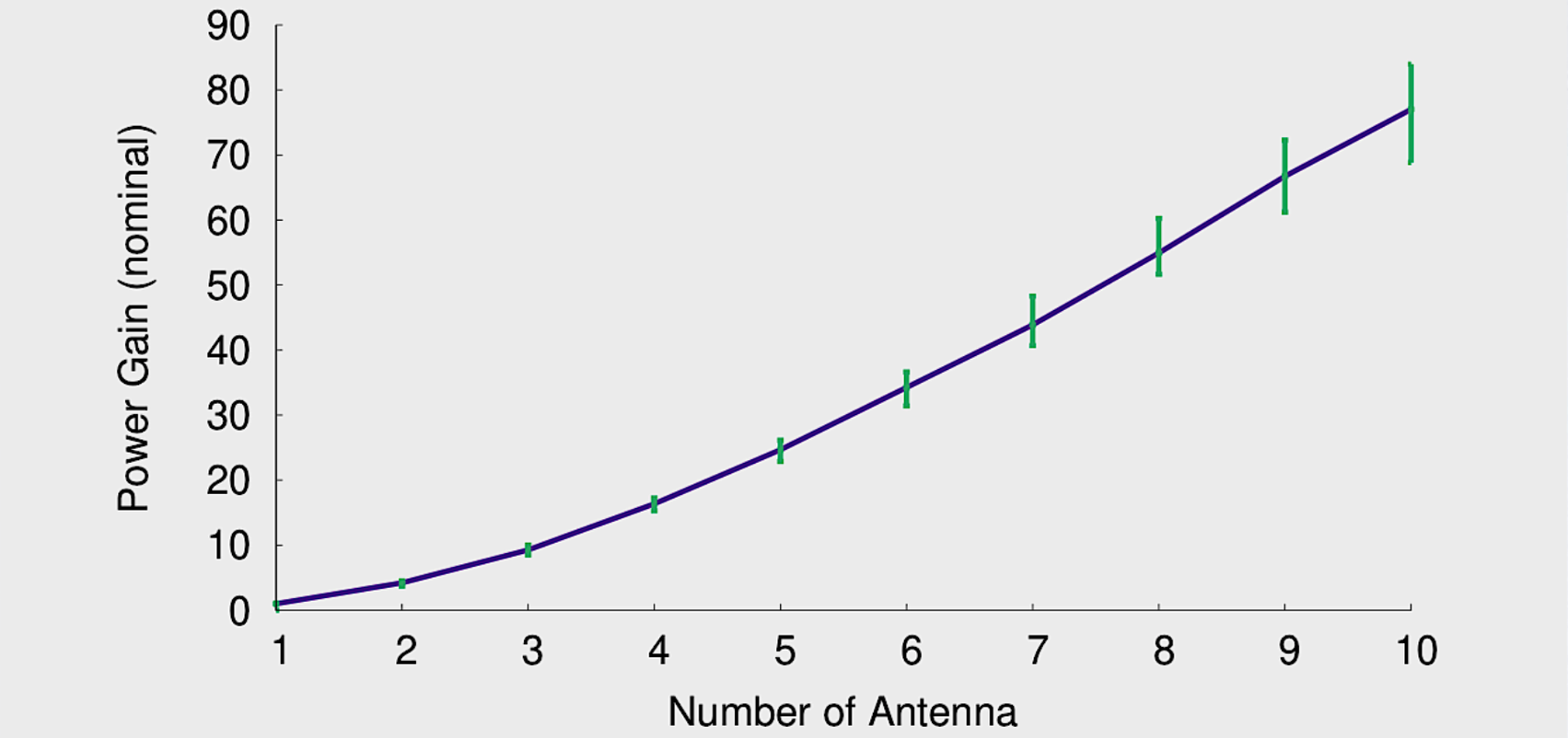
The reader sense and decode the response at a different carrier frequency than powering frequency.

Reducing self-interference



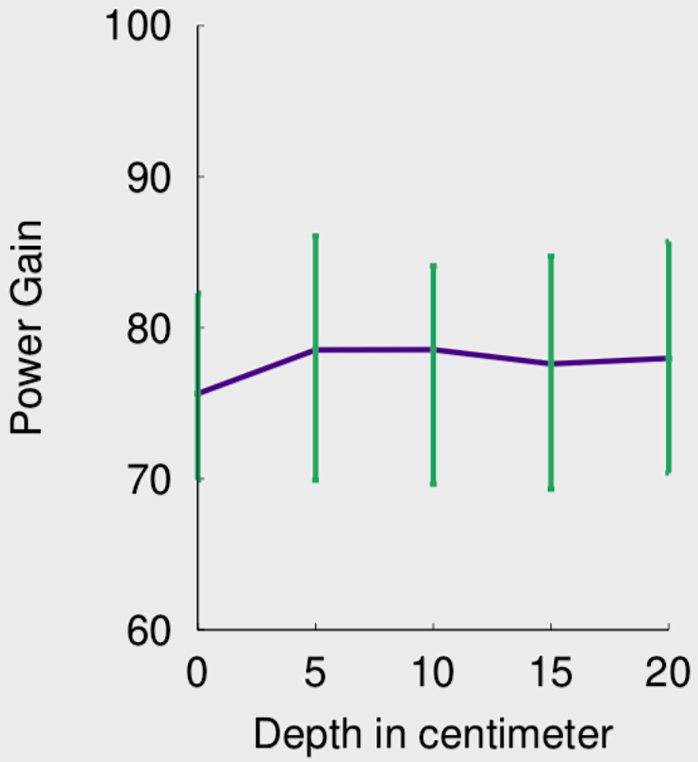
Evaluation and Results

Gain Vs # Antennas:

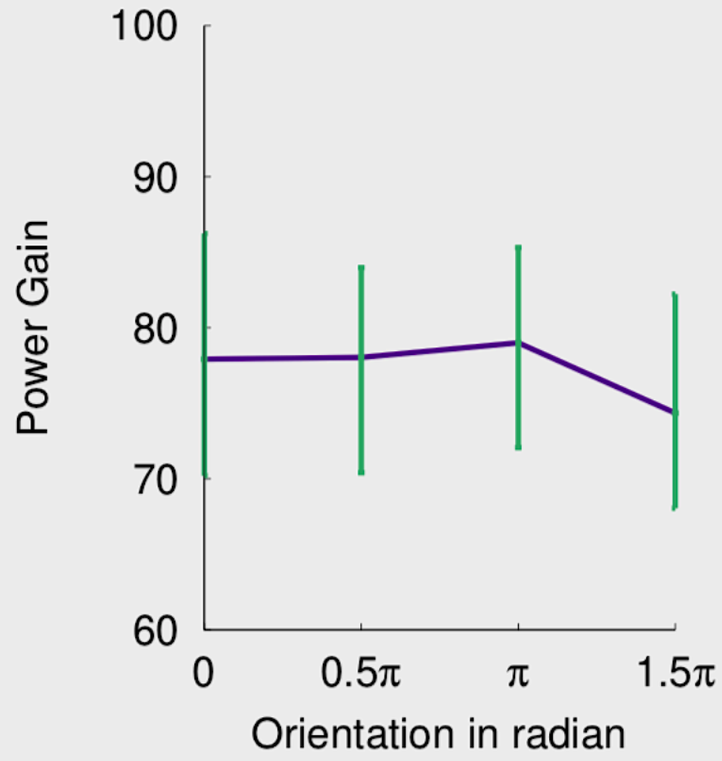


Evaluation and Results

Gain Vs Distance, Orientation:



(a) Power Gain vs Depth.



(b) Power Gain vs Orientation

Stable Gain

Blind to channel condition

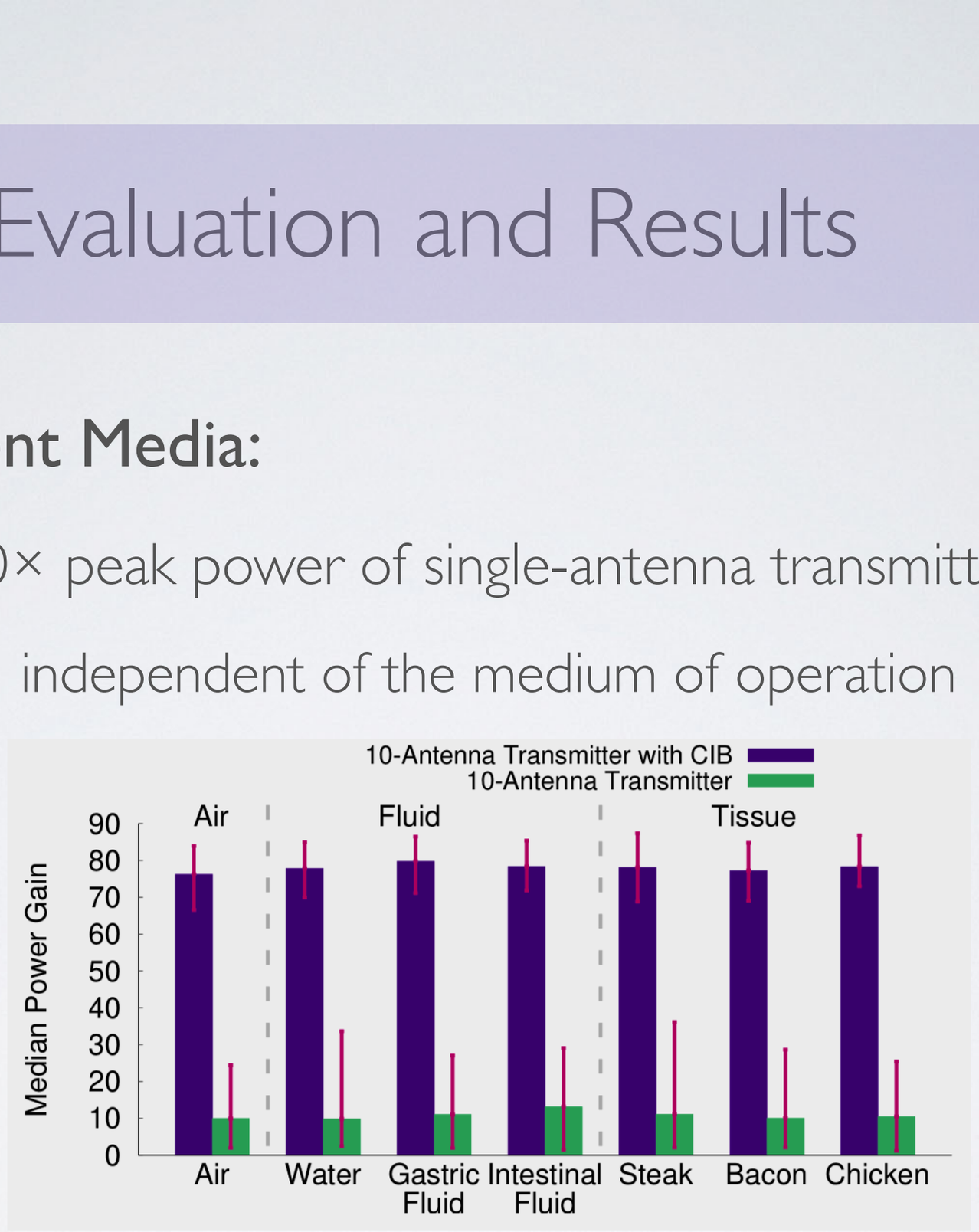
The received power decreases with depth due to path loss

Evaluation and Results

Gain Vs Different Media:

80× peak power of single-antenna transmitter

independent of the medium of operation

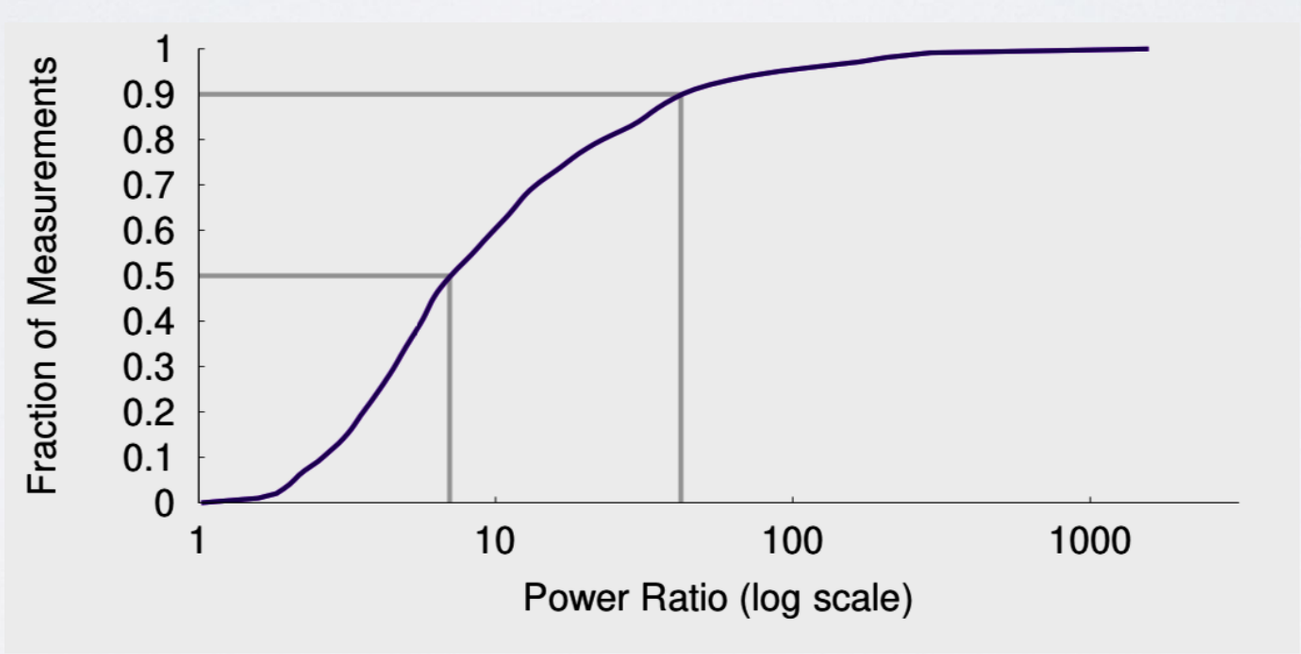


10-antenna traditional transmitter achieves a median gain of 10× from increasing the transmitted power.

Evaluation and Results

Gain Vs Traditional 10-antenna Transmitter:

the probability of the baseline having all its transmissions aligned at the receiver point is very low.



10-antenna transmitter may destructively interfere at various locations

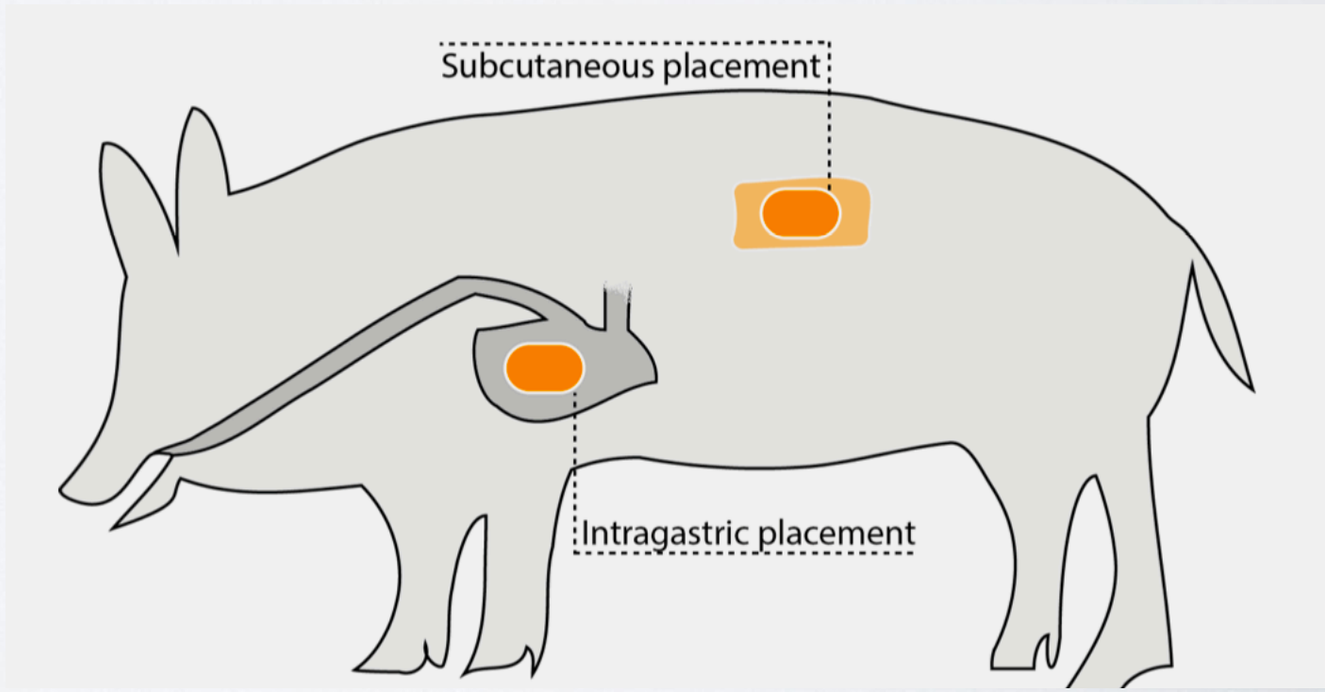
CIB achieves a median gain of 8× over the baseline

FLAWS?

Is it really channel blind?

- Not successful in communicating with the standard tag in 50% of the cases in the gastric.
- failed in all the experiments with miniature tag in the pig stomach.

Orientation blind?



Possible Future works

- Addressing Security and Privacy Issues

- Accuracy of localizing RFIDs which are 30 meters away

danielmiessler.com

https://www.youtube.com/watch?v=pwgwKlYkLP8