Lecture 26: In-body devices

Applications

- Radiation therapy: How do you track where the tumor is for radiation therapy?
  - X-Ray: People move, and exposure to x-ray is harmful
  - RF!
- Continuous glucose delivery
- Capsule endoscopy: Can we develop a capsule (camera + battery) to make endoscopies more comfortable?
- Micro-robots

For these applications, we need a way to communicate the data from devices inside the body to computers outside the body

Reflections

- As the signal travels through different mediums (air, skin, fat, muscle), the signal will be reflected with different power
- Electrical permittivity of the medium ($\in_r$)
- $\frac{P_r}{P_t} = \frac{|\sqrt{\in_{r1}} - \sqrt{\in_{r2}}|}{\sqrt{\in_{r1}} + \sqrt{\in_{r2}}}$

Refraction

- As the signal travels through different mediums (skin, fat, muscle, etc.), the signal will be refracted (different angle)
  - Air-skin: steep angle
  - Skin-fat: angle widens
  - Fat-muscle: steep angle
- Total internal reflection: The refraction angle cannot be any greater, so we get reflection
- Although we know how these different mediums refract, we don't know the body composition of each individual

Attenuation & Phase

- Speed of light changes when going through the human body
  - The attenuation is exponential and the phase change is much faster
- Low frequency signals should be used because the signal attenuates too quickly for higher frequencies

Communication

Let's do communication at zero-power so that no batteries need to be in the body: Backscatter using non-linearity to our advantage!

- Have a device outside the body transmitting a signal with frequency $f_1 + f_2$
- Design an in-body device that is highly non-linear
- Then, the backscattered signals will contain $f_1 + f_2$, $2f_1 + f_2$, $3f_1 + f_2$ …

Localization

- Insights:
    - Signal comes out of a small region of the human, everything else gets reflected
    - The order of layers does not matter for phase if the layers are parallel
        - All “muscle” layers can be combined to model the signal
        - All “fat” layers can be combined to model the signal

Evaluation

- Experiment set-up:
    - Animal (tub of meat)
    - Phantom tissue (lab-grown “tissue”)
- Localization error:
    - Average: 1-1.5 cm
    - Maximum: ~2 cm

Limitations

- There are assumptions made to simplify the problem
- Different waves:
    - Magnetic
    - RF (suffers from attenuation, but no contact necessary)
    - Acoustic (cheap, but requires contact)
- Power transfer