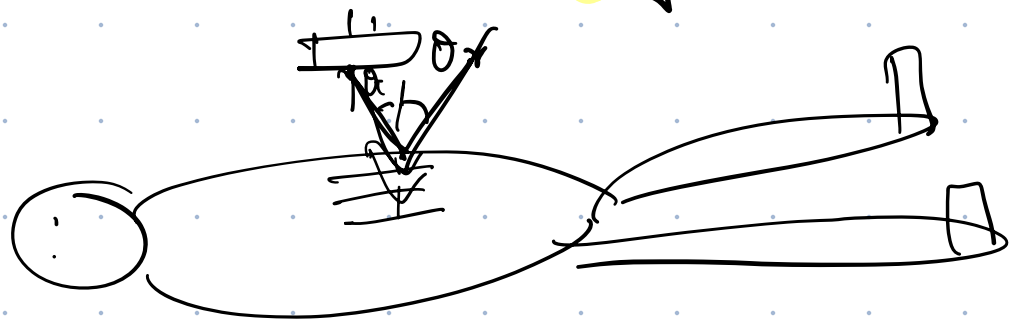
Today

- In-body Networks
  - Applications
  - RF - Across Media
  - Communication
  - Localization
  - Results.

Applications

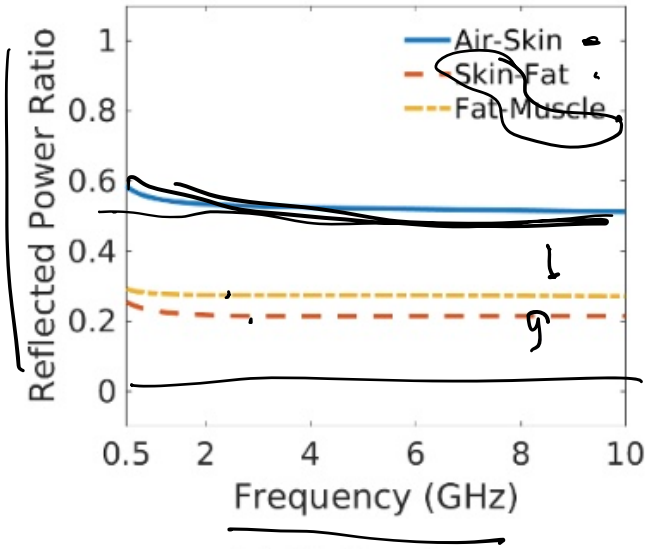
- Radiation Therapy.
- Continuous Glucose Delivery.
- Capsule Endoscopy.
  - battery
  - camera
- Micro-robots.

Reflections



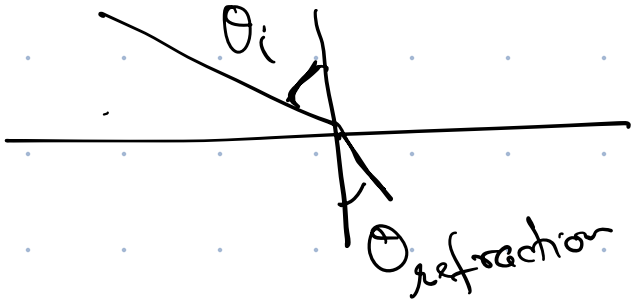
$\varepsilon_r \Leftarrow$ electrical permittivity of the medium

$$\frac{P_r}{P_t} = \frac{|\sqrt{\varepsilon_{r_1}} - \sqrt{\varepsilon_{r_2}}|}{|\sqrt{\varepsilon_{r_1}} + \sqrt{\varepsilon_{r_2}}|}$$



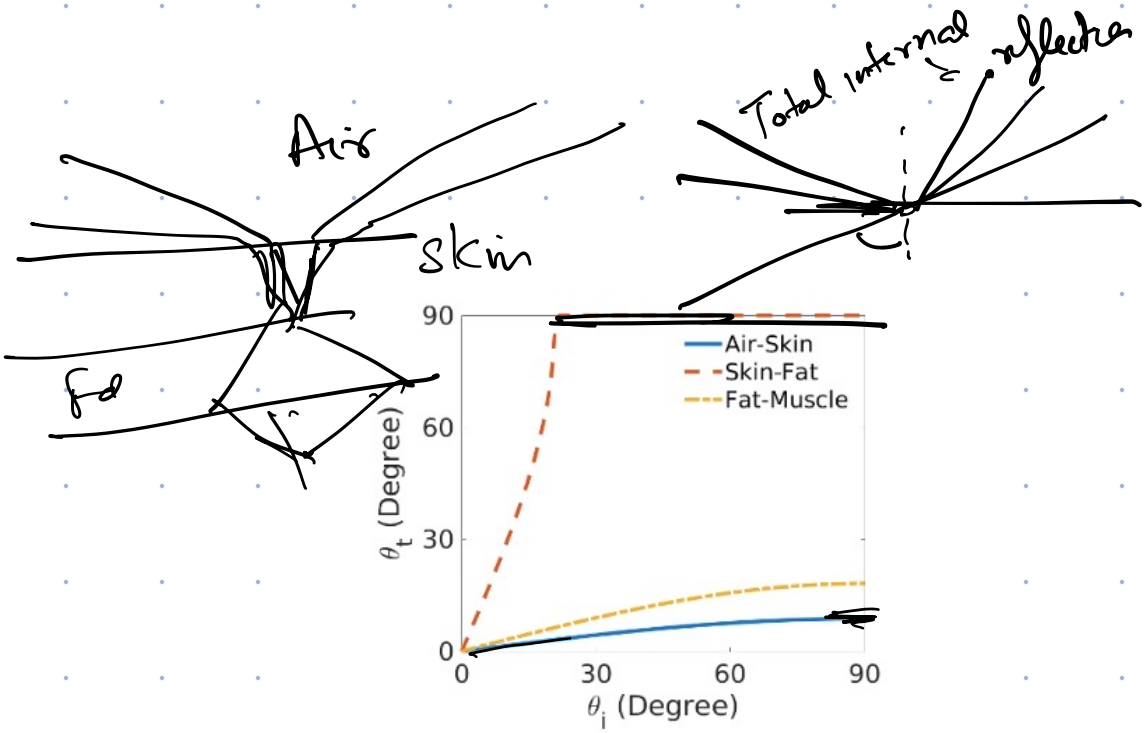
(c) Reflection

Refraction



$$Re(\sqrt{\varepsilon_{r_1}})\ \sin\theta_1 = \text{constant}$$

$$Re(\sqrt{\varepsilon_{r_2}})\ \sin\theta_2$$

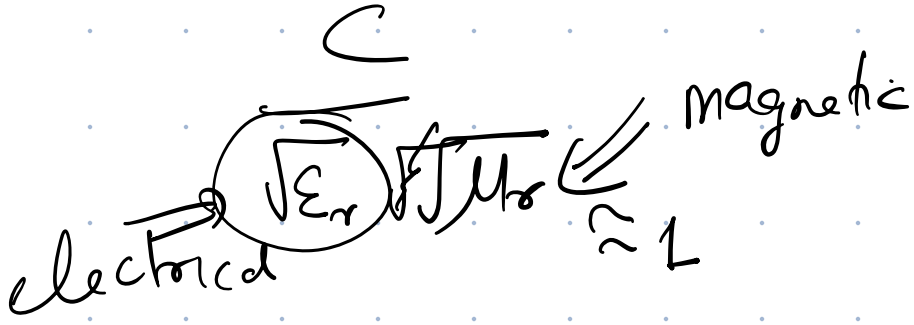


(d) Refraction

Attenuation & Phase

speed of light = c

$= 3 \times 10^8$



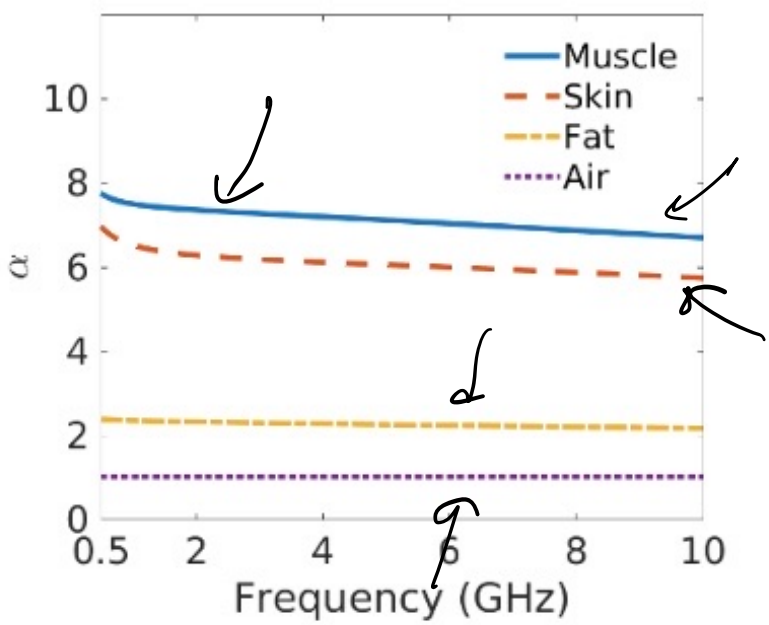
$$\sqrt{\varepsilon_r} = \alpha + \beta j$$

$$h = a e^{-j \frac{2\pi}{\lambda} d}$$

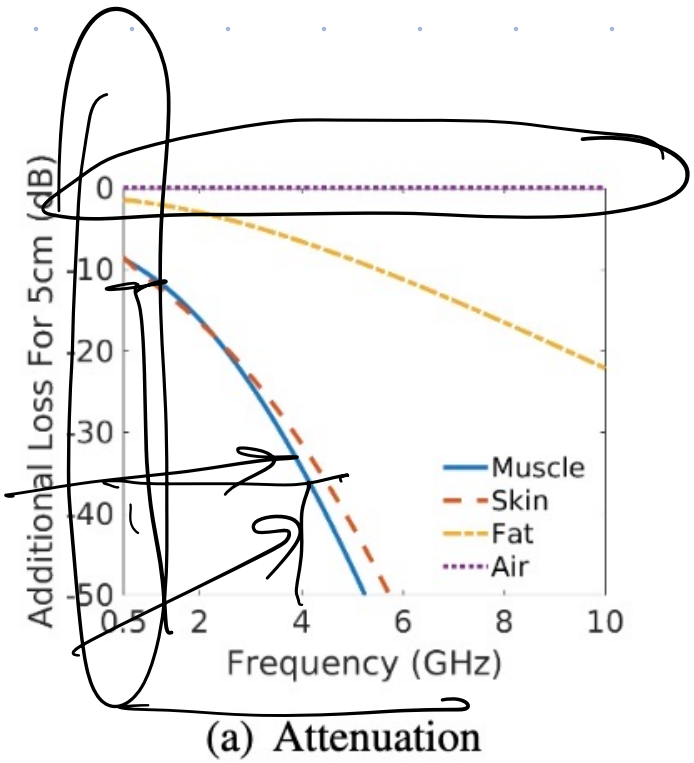
$$= a e^{+j \frac{2\pi}{c} df}$$

$$= a e^{+j \frac{2\pi}{c} (\alpha + \beta j) fd}$$

$$= a e^{+j \frac{2\pi}{c} \alpha f d} \; e^{-\frac{2\pi}{c} \beta f d}$$

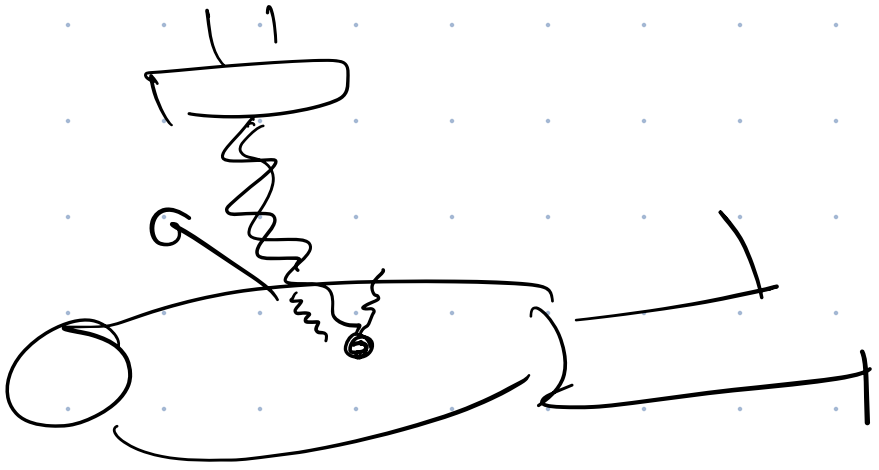


(b) Phase Change

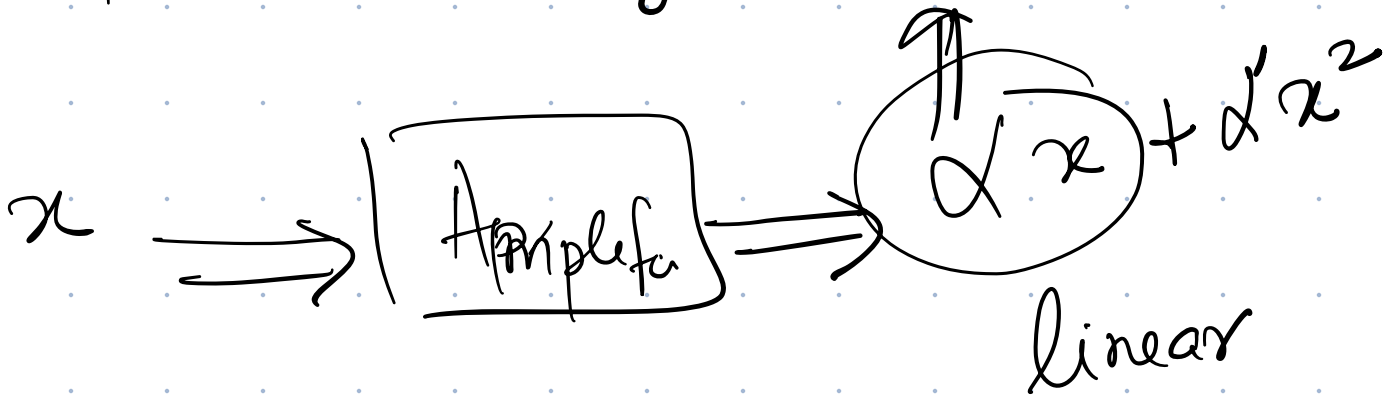


(a) Attenuation

Communication



Non-linearity.



$$\sin(2\pi f_1 t)^2 \Longrightarrow \alpha \sin(2\pi f_1 t)$$

$$\alpha_1 \sin(2\pi f_1 t)$$

$$+\alpha_2 \sin(2\pi\, 2 f_1 t)$$

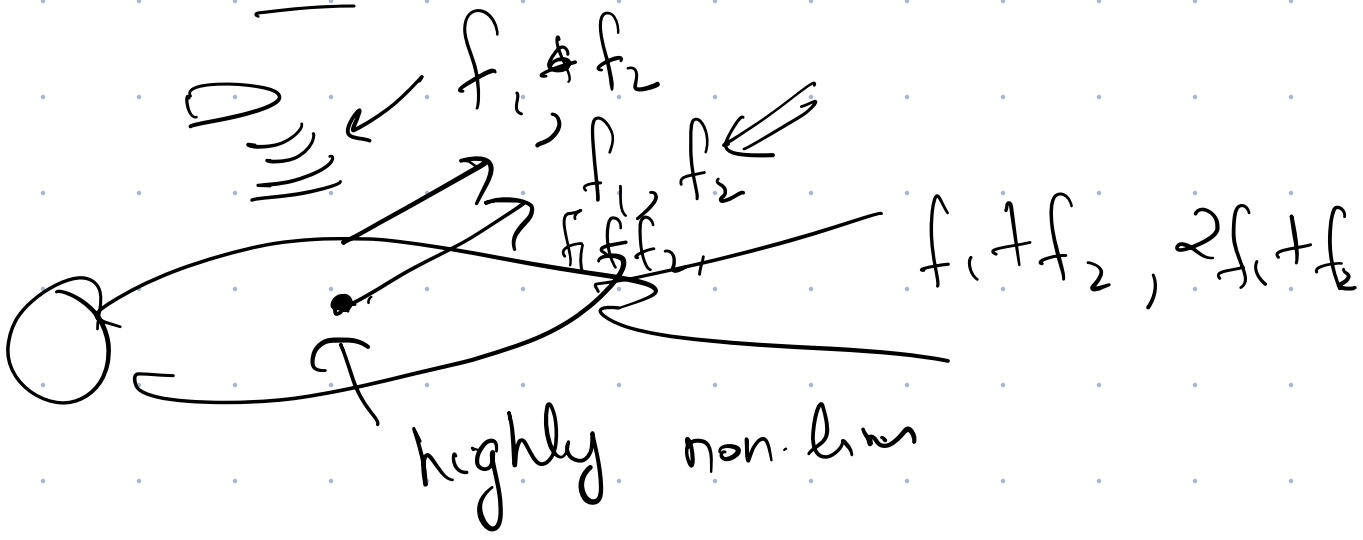
$$+\alpha_3 \sin(2\pi 3 f_1 t)$$

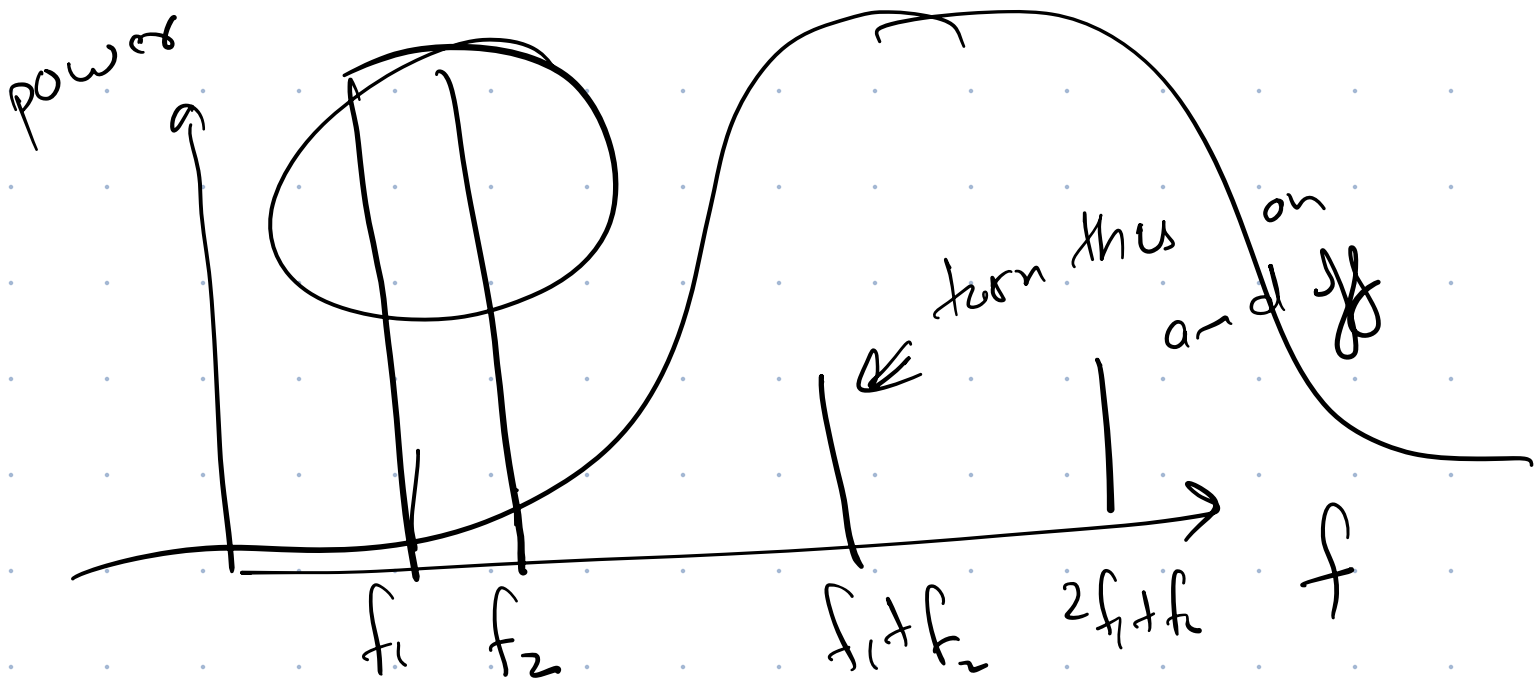
$(\sin(2\pi f_1 t) + \sin(2\pi f_2 t))^2$

$\Rightarrow \sin 2f_1, 2f_2,$

$f_1 + f_2$

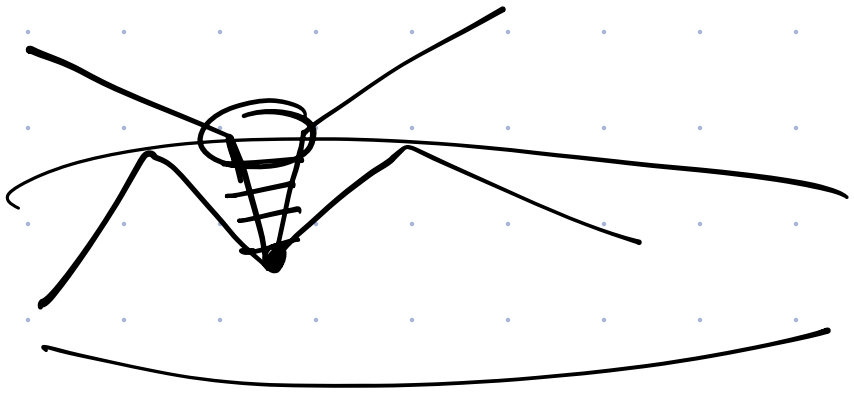
$2f_1 + f_2, \quad 2f_2 + f_1$



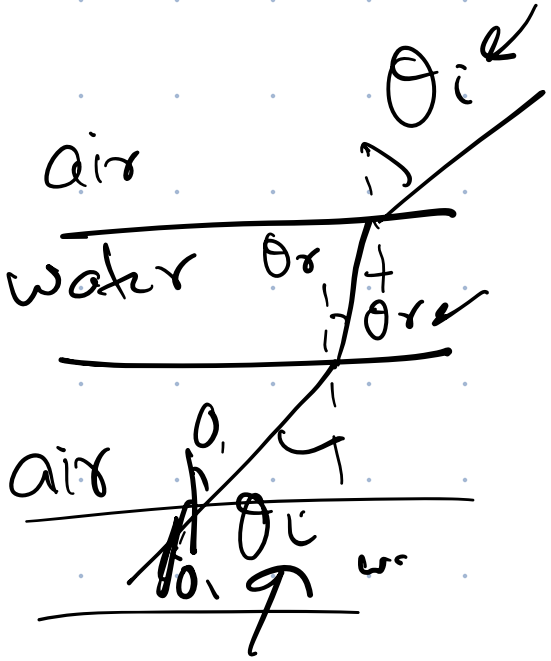


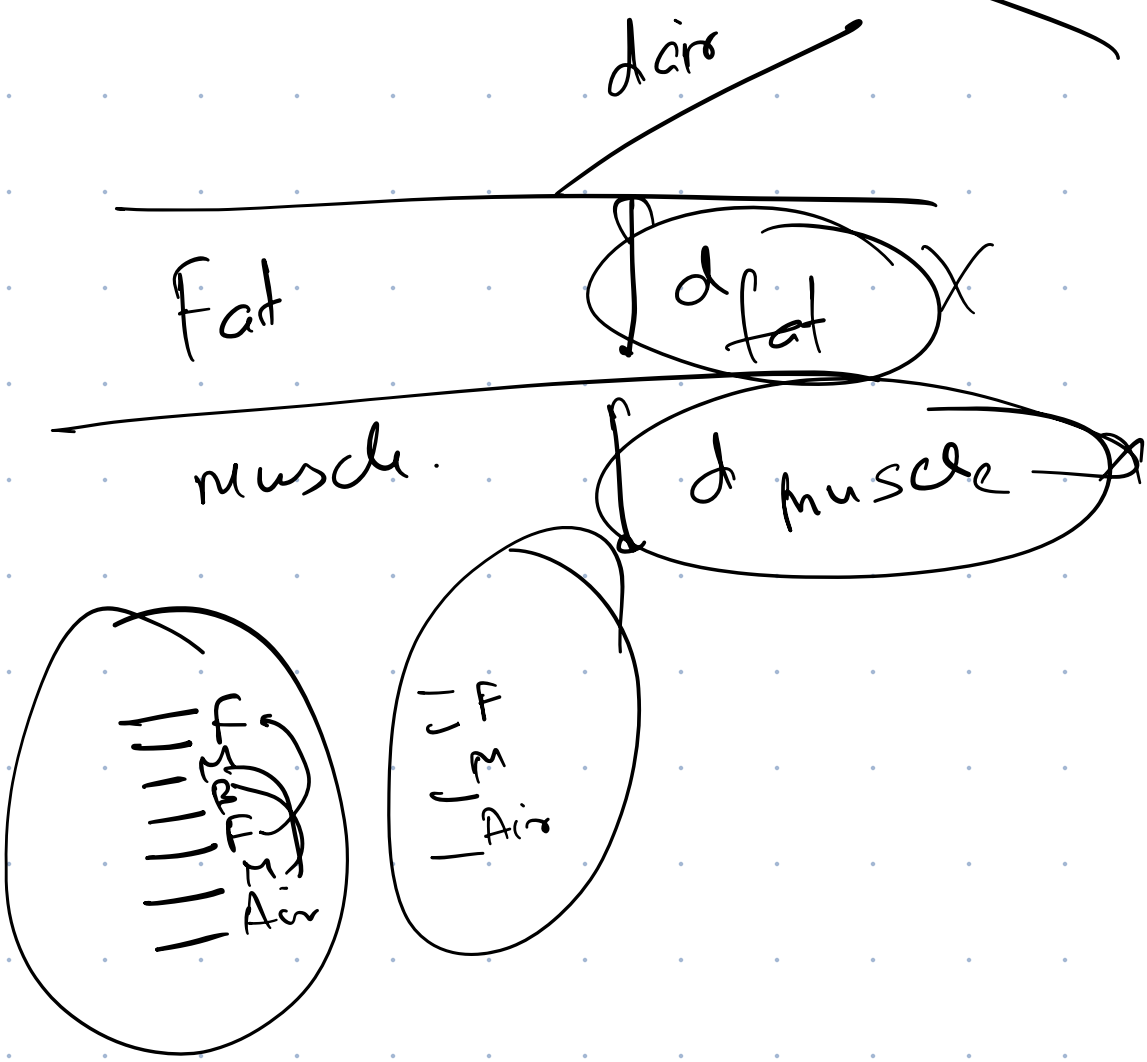
Localization

① Signal comes out at a small range



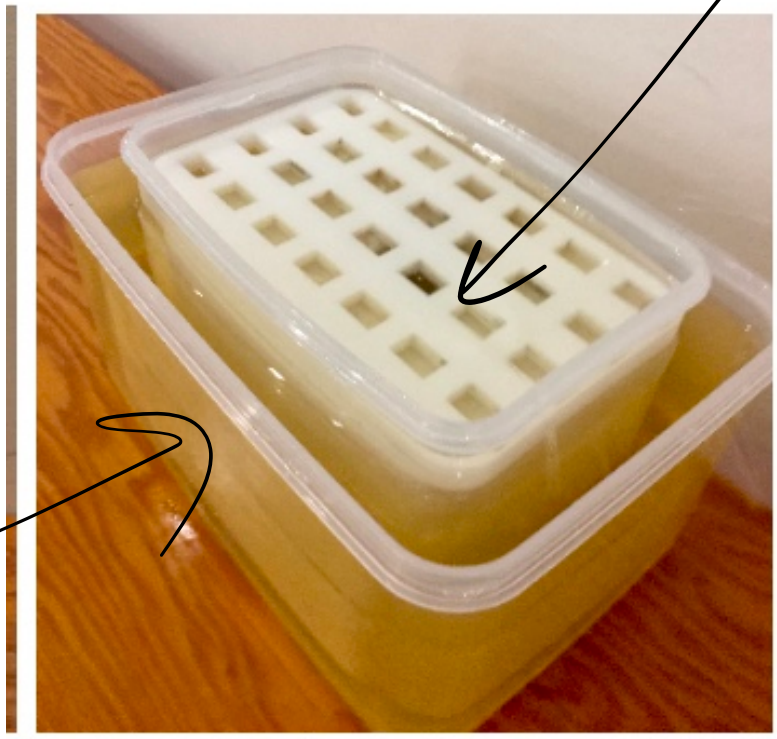
② Order of layers does not matter for phase.

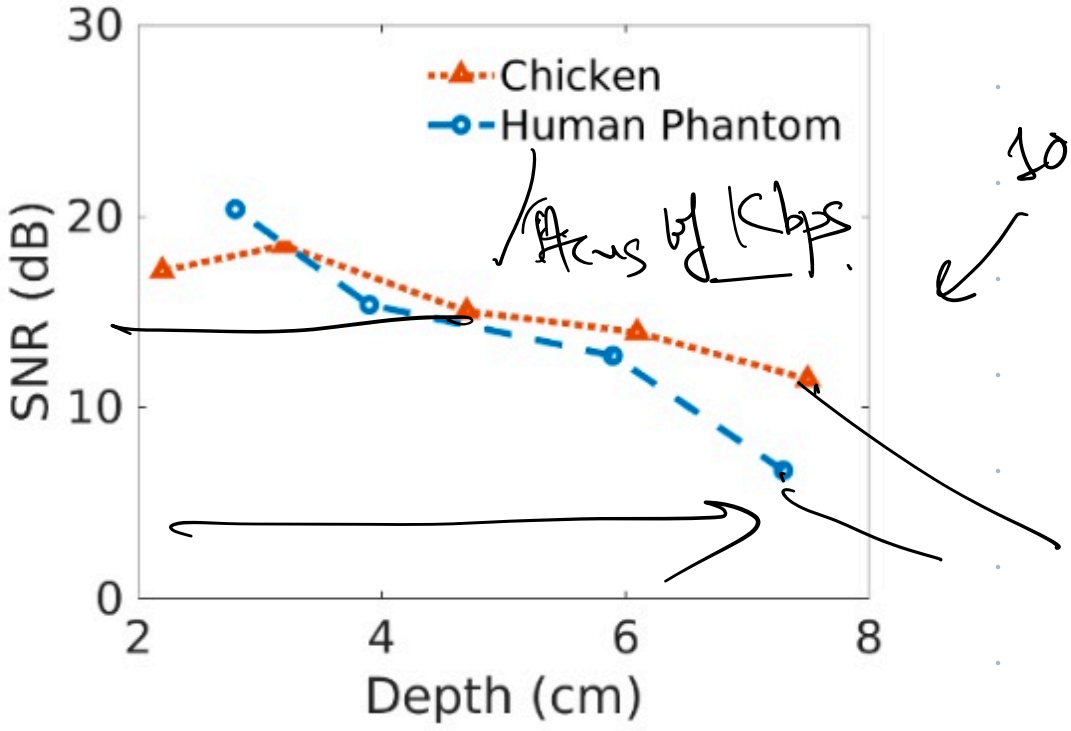


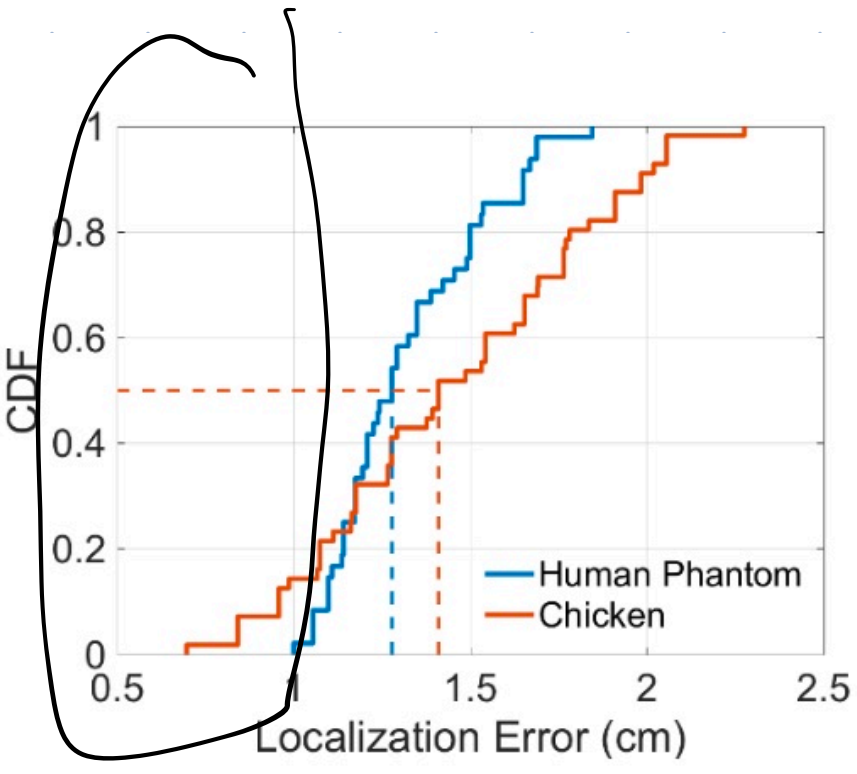

dair
Fat
dfat
muscle
dmuscle
F
M
B
F
M
Air
F
M
Air

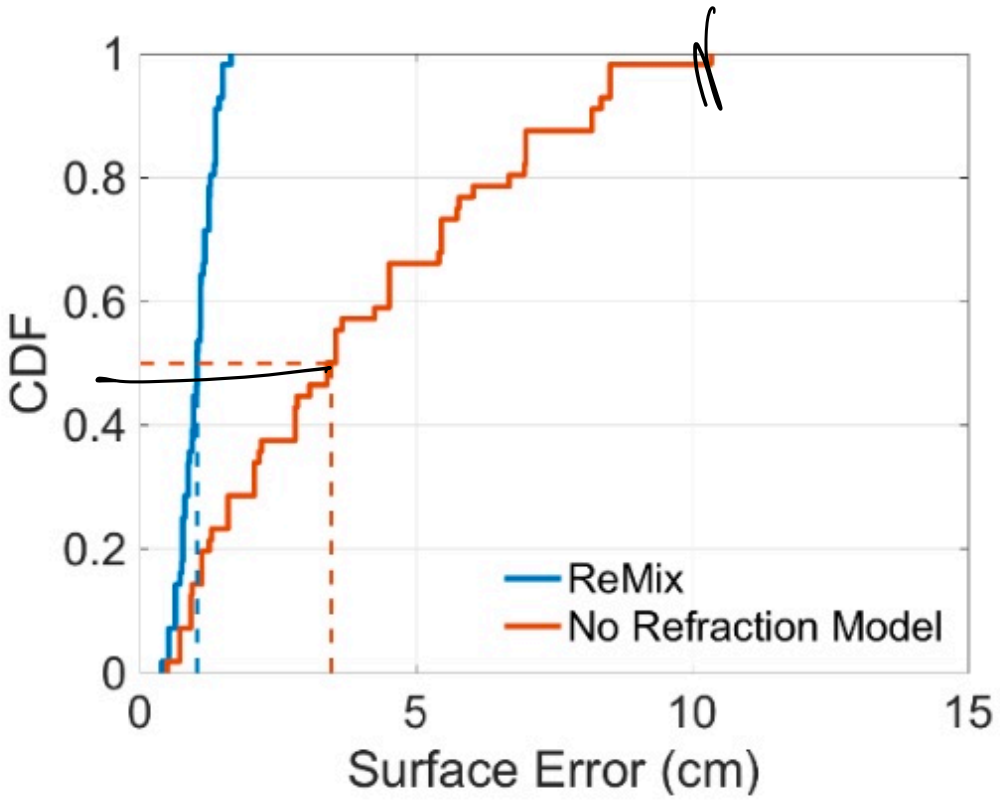
Evaluation

phantom




30
20
10
0
SNR (dB)
2
4
6
8
Depth (cm)
Chicken
Human Phantom


1
0.8
0.6
0.4
0.2
0
CDF
0.5
1
1.5
2
2.5
Localization Error (cm)
Human Phantom
Chicken


1
0.8
0.6
0.4
0.2
0
CDF
0
5
10
15
Surface Error (cm)
ReMix
No Refraction Model

Limitations

- Assumption
- Magnetic vs. RF vs. Acoustics.
- Power transfer