Webb 3.1 $\quad T_I = \dfrac{4Z_1Z_2}{(Z_1+Z_2)^2}$ (Eqn 3.14)

Muscle $Z = 1.7$

Kidney $Z = 1.62$

$T_I = 0.9994$

Air $Z = 0.0004$

muscle $Z = 1.7$

$T_I = 0.0009$

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bone $Z = 7.8$

muscle $Z = 1.7$

$T_I = 0.5877$

Big T_I means not much reflection (little echo!), small T_I means not much transmission — so other objects can't be imaged beyond that interface (shadowing).

Webb 3.6

Transmission from crystal to skin is governed by product of T_I (crystal → Layer) and T_I (Layer → skin)

$$T_{I,\text{tot}} = \frac{4 Z_c Z_L}{(Z_c + Z_L)^2} \cdot \frac{4 Z_L Z_s}{(Z_L + Z_s)^2} = \frac{16 Z_c Z_s Z_L^2}{(Z_c + Z_L)^2 (Z_L + Z_s)^2}$$

To maximize this, maximize

$$T = \frac{Z_L}{(Z_c + Z_L)(Z_L + Z_s)}$$

(Note, Z are always positive)

$$\frac{dT}{dZ_L} = \frac{(Z_c Z_L + Z_c Z_s + Z_L Z_s + Z_L^2)(1) - Z_L (Z_c + 2Z_L + Z_s)}{(\quad \text{something} \quad)^2}$$

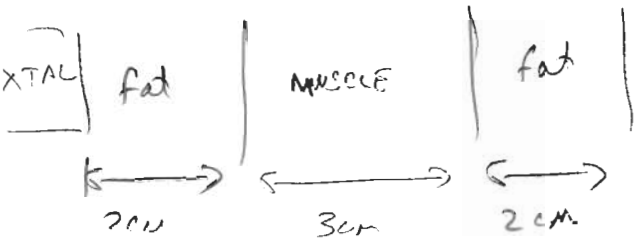
Focus on numerator:

$$Z_c Z_L + Z_c Z_s + Z_L Z_s + Z_L^2 - Z_L Z_c - 2 Z_L^2 - Z_s Z_L = 0$$

Gives $Z_c Z_s = Z_L^2$

So $Z_L = \sqrt{Z_c Z_s}$

Webb 3.10



$\alpha_{Fat} = 7$ dB/cm

$\alpha_{MUSCLE} = 5$ dB/cm

$\alpha_{LIVER} = 5$ dB/cm

$Z_{Fat} = 1.38$, $Z_{MUSCLE} = 1.7$, $Z_{LIVER} = 1.65$

Fat - Muscle 27.6 μsec

4 cm path length = 4×7 dB/cm = 28 dB loss

$$R_I = \frac{(Z_{fat} - Z_{muscle})^2}{(Z_{fat} + Z_{muscle})^2} = 0.01 \approx -20 \text{ dB}$$

echo from interface is $-28 - 20 = -48$ dB.

Muscle - fat 65.6 μsec

4 cm in fat = 28 dB loss

6 cm in muscle = 30 dB loss

R_I at muscle - fat = -20 dB

(Almost no loss at muscle - fat interface on return path)

echo is $-28 - 30 - 20 = -78$ dB

fat – Liver 93 μsec

4 cm in fat = 28 dB loss

6 cm in muscle = 30 dB loss

4 cm in fat = 28 dB loss

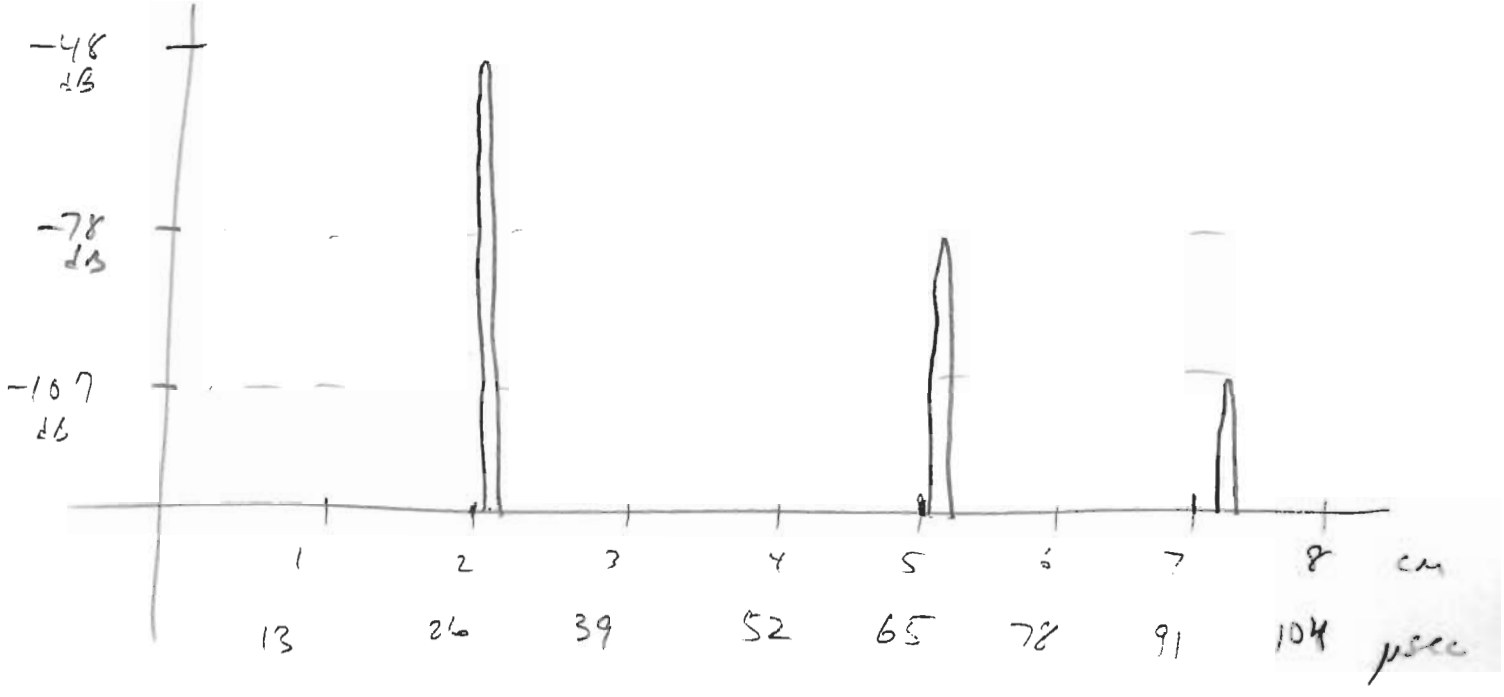
86 dB path loss

Transmission from fat → muscle ≈ no loss

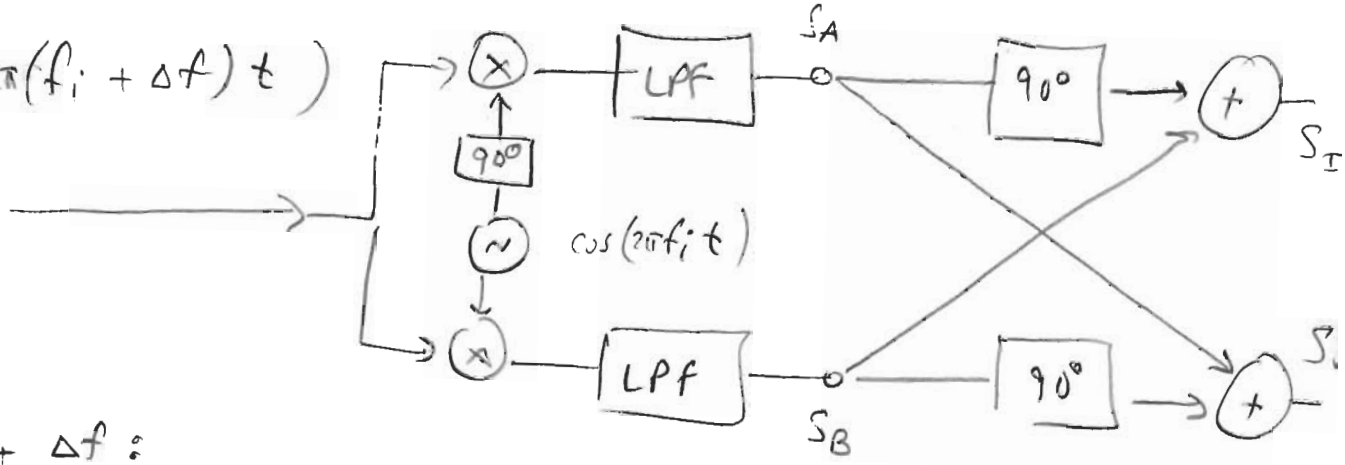
Transmission from muscle → fat ≈ no loss

R_I at fat – liver interface is 0.008 or about −21 dB

Total loss = −86 − 21 = −107 dB



Webb 3.16



For $+\Delta f$:

$$S_a(t) = \frac{A}{2}\cos\left(2\pi\,\Delta f\,t - \frac{\pi}{2}\right)$$

$$S_b(t) = \frac{A}{2}\cos\left(2\pi\,\Delta f\,t\right)$$

$$S_I(t) = \frac{A}{2}\cos\left(2\pi\,\Delta f\,t - \frac{\pi}{2} + \frac{\pi}{2}\right) + \frac{A}{2}\cos\left(2\pi\,\Delta f\,t\right)$$

$$= A\cos\left(2\pi\,\Delta f\,t\right)$$

$$S_Q(t) = \frac{A}{2}\cos\left(2\pi\,\Delta f\,t - \frac{\pi}{2}\right) + \frac{A}{2}\cos\left(2\pi\,\Delta f\,t + \frac{\pi}{2}\right)$$

$$= 0.$$

If we have $-\Delta f$:

$$S_I(t) = 0$$

$$S_Q(t) = \frac{A}{2}\cos\left(2\pi\,\Delta f\,t + \frac{\pi}{2}\right) + \frac{A}{2}\cos\left(2\pi\,\Delta f\,t + \frac{\pi}{2}\right)$$

$$= A\left(\cos\,2\pi\,\Delta f\,t + \frac{\pi}{2}\right)$$

$$= -A\sin\left(2\pi\,\Delta f\,t\right)$$