A, M- & B-mode imaging

⇒ Structure (static)

⇒ Dynamic behavior (structure)

Opportunity to observe/quantity
movement of fluid ⇒ blood flow
Doppler Effect → Doppler Imaging

Initially assume source $\vec{v} = 0$:

- Observer (transducer)
- Source

$\lambda = \frac{c}{f_0} \quad \Rightarrow \quad \lambda_{obs} = \lambda_{actual}$

$f_{obs} = f_{actual} = f_0$

Source moves with $\vec{v} > 0$ along line to observer

Observer (transducer)

$c - \vec{v} \cdot \vec{n} = \lambda_{obs} \neq \frac{c}{f_0}$

$f_{obs} \neq f_{actual}$

$f_{obs} \neq f_{actual}$

$\Rightarrow \quad \lambda_{shorter} \quad w_i = f_{incident} \Rightarrow \quad f_{obs} = \frac{c}{c - \vec{v} \cdot \vec{n}} f_0$
Generalize to any $\theta$:

Reflected plane waves

$\frac{\lambda \cos \theta}{f_0} = \text{"wavelength"}$

If reflective surface

$\Rightarrow$ effective wavelength $\lambda_{\text{obs}} = \frac{c}{f_0}$

$\Rightarrow$ effective frequency $f_{\text{obs}} = \frac{c}{\lambda_{\text{obs}} f_0}$

Doppler freq $f_D = f_{\text{obs}} - f_0$

Assume $c \gg \lambda \cos \theta$

$\Rightarrow f_D = \frac{\lambda \cos \theta}{c} f_0$

$f_D = (\frac{c}{c - \lambda \cos \theta} - 1)f_0 = \frac{\lambda \cos \theta}{c - \lambda \cos \theta} f_0$
In US the transducer is both source and observer and the reflection boundary is moving, we get doubling of observed shift.

\[ f_{o,s} = \frac{2v \cos \theta}{C} f_0 \]
Ultrasound physics/Signal formation

Treat as plane wave close to z-axis

Face of transducer fluctuates at ~MHz to establish waves in the adjoining medium.

→ induced $E$ on the crystal to produce strain ... mechanical displacement of the face

⇒ produce waves

⇒ incident waves will produce $E$ reciprocal relation

⇒ signal reception

0 (mm)

1 cm

$\sim 50-60$ over $\sim 2-3$ cm
What is the “field” produced by the transducer?

3 regions

1. (Very) Near the face of the transducer
   ⇒ "Geometric" region/approximation
   Very close to the face, the wave hasn’t spread... very true “plane” wave (cylinder) extended from the face

2. Plane-wave-only... out to some given distance

3. Fresnel approximation ("near-field")

4. Fraunhofer approximation ("far-field")
For circular transducer: \( a = \frac{D^2}{4\lambda} \)

For square transducer: \( A = \frac{D^2}{2\lambda} \) (side length = D)

(\( \frac{D}{12} \) "kind B" radius for a square)
Look at distance from center of transducer

Beam intensity is "planar" if we look at B0

$F_{wh}$

$\frac{-d}{2} \quad 0 \quad \frac{d}{2}$

sin structure to the beam

$\Rightarrow$ side lobes can produce reflections which we will interpret as artifacts.