Scattering

⇒ production of spherical waves

⇒ Produced by the presence of "targets" within the medium that are physically smaller than $\lambda$.

⇒ Classical optics-based equations for reflection/transmission breakdown

⇒ Model becomes one of vibration induced by the wave target behaves as a spherical source.
spherical waves propagate out from the source

Some portion of the input wave is reflected from the source at \((0,0,d)\) and returns to the transducer ... covers 2d distance (again)

\[ \Rightarrow \text{Characterize reflection by a coefficient } R_{\text{in}} \text{ material medium} \]
Scattering Signal:

Outward wave taken as a plane wave:

\[ p(\text{out}) = A_0 e^{-\mu z} f(t - \frac{z}{c}) \]

Return due to the scattering source:

\[ p_s(r,t) = \frac{R}{r} e^{-\mu r} A_0 e^{-\mu d} f(t - \frac{d}{c} - \frac{r}{c}) \]

Signal is spherical, radiating from source.

- Reflected pressure.
- Attenuation on return.
- Time of arrival @ spherical source.
- Decay of signal since arriving at spherical source.
- Incident on the spherical source.

When \( r = d \), we are at the transducer.
Return signal:

\[ P_s(0,t) = \left( \frac{R}{d} \right) A_0 e^{-2\alpha d} f(t - \frac{2d}{c}) \]

Generally not a high proportion of incident energy ... and scaled by \( \frac{1}{d} \)
For visualization, scatter is useful.

Scatter produces low-level speckles/blur within tissue.

Tissue boundary, [bright line]

With scatter, tissue is "black" (no signal), so sequencing tissue necessitates a priori for evaluation.

Density of scatter varies by tissue.
Ultrasound Imaging in Practice

Signal is a “return” signal, with peaks (corresponding to tissue boundaries) at times of amplitudes that are

functions of

- distance
- speed of propagation
- tissue attenuation

Ignore variation

⇒ How do we use this??
Uses of US imaging modes

A-mode imaging

- Useful for dynamic imaging
- Return signal varies with tissue position

- Fixed source/observer (transducer is in a single fixed position)

- Generate a pulse every $T_R$ seconds
  ($T_R$ = repetition time)

- Plot the return signal on a scope with
  closed sweep at $T_R$ (D plot)

- e.g., heart valve
M-mode imaging (magnitude)

→ "Stack" A-mode images next to one another to graphically depict the temporal change in reflection boundary [2D spacetime image]

distance from transducer

boundaries shifted

See/visualize shift in reflection boundary & capture the nature & timing of the change (e.g., fetal heart monitoring)
B-mode imaging

⇒ Multidimensional imaging (space x space)

⇒ "Stack" A-mode images from multiple locations/angles next to one another

Option A

Option B

Single transducer option...

Each pulse is kept to a given line in space... stack to create a 2D A-mode image.

Track 1 occurs every T2