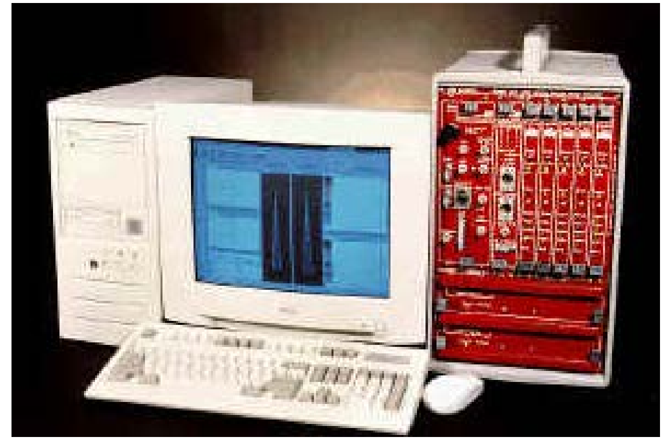
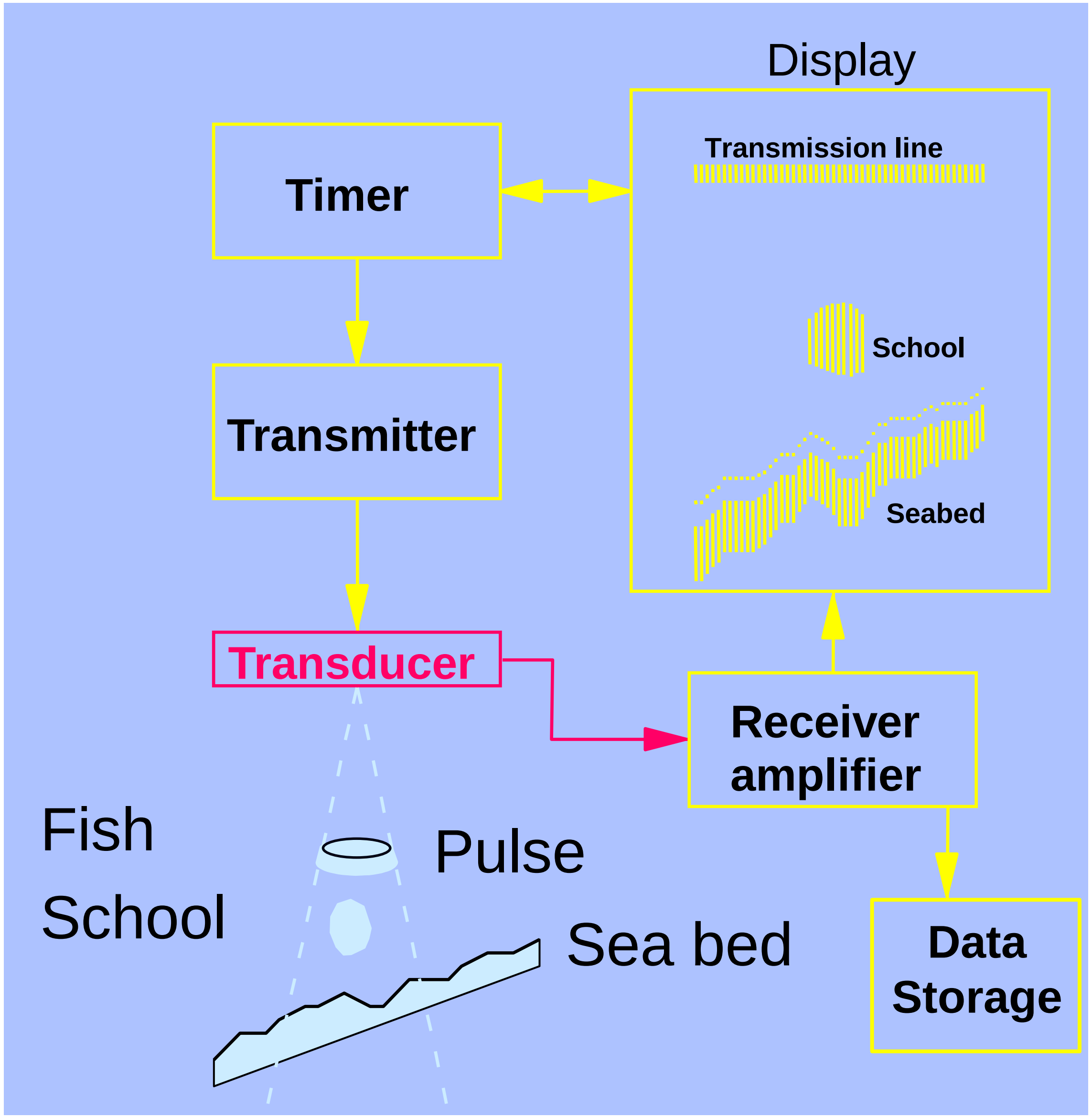
# Sonar Hardware





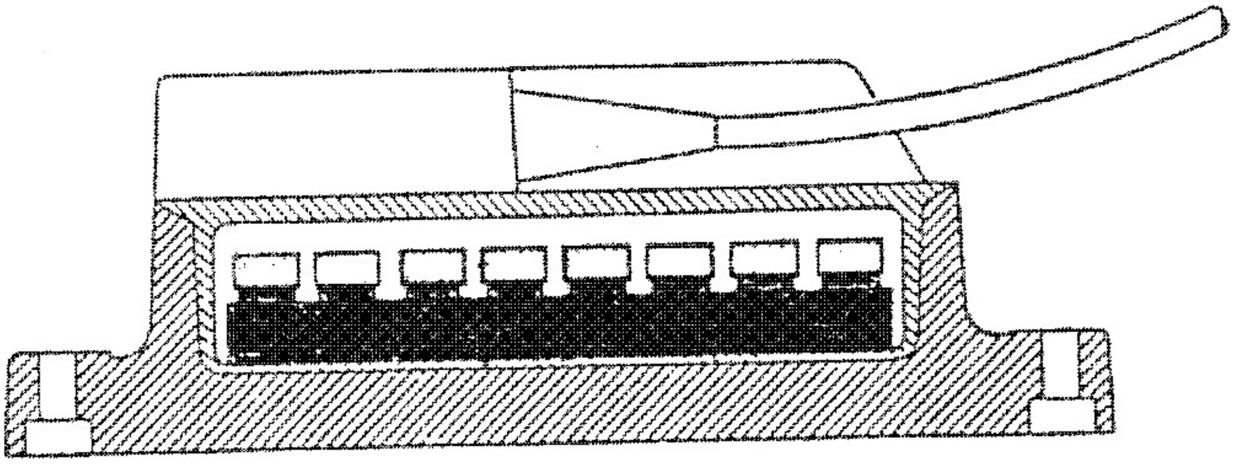

# Why Not Use Light?

# Sonar Components



# Transducers

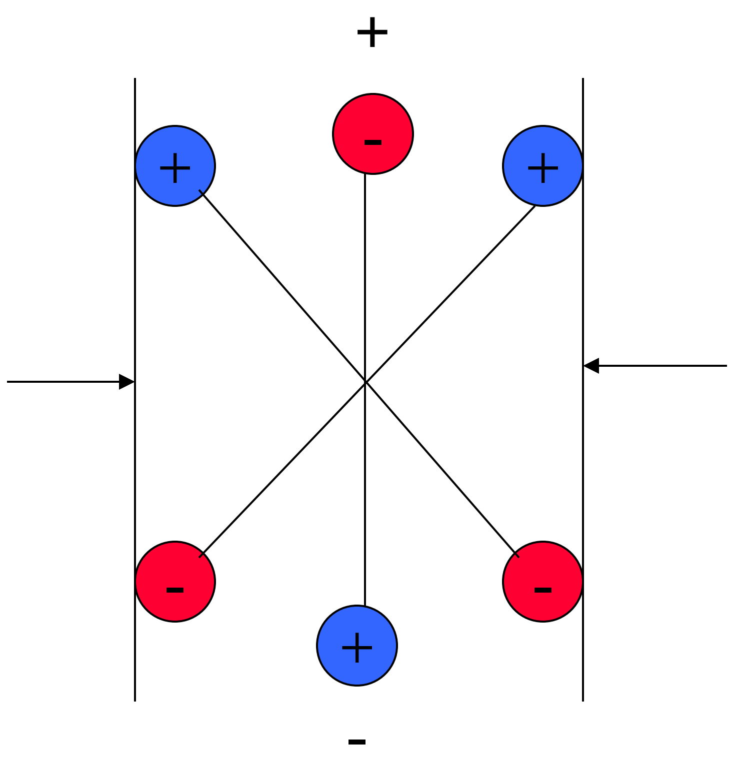
- piezo-electric: piezein (Greek) to squeeze or press
- apply voltage <--> generate pressure
- sandwiched material: steel, quartz crystal, steel
- efficiency: ceramic 50%, nickel 25%



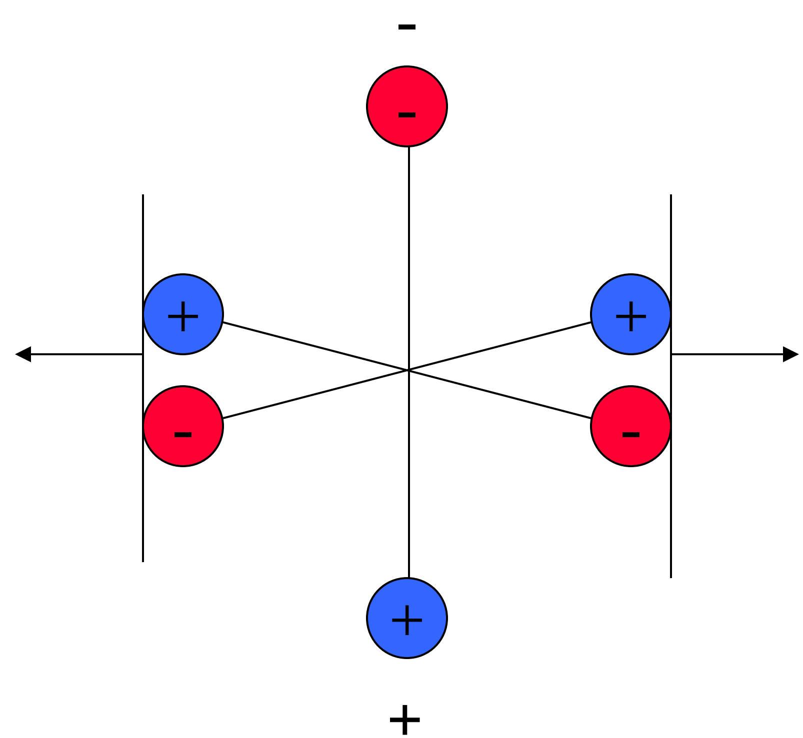
# Piezo-electric Effect

- crystals of silicon dioxide

Compression

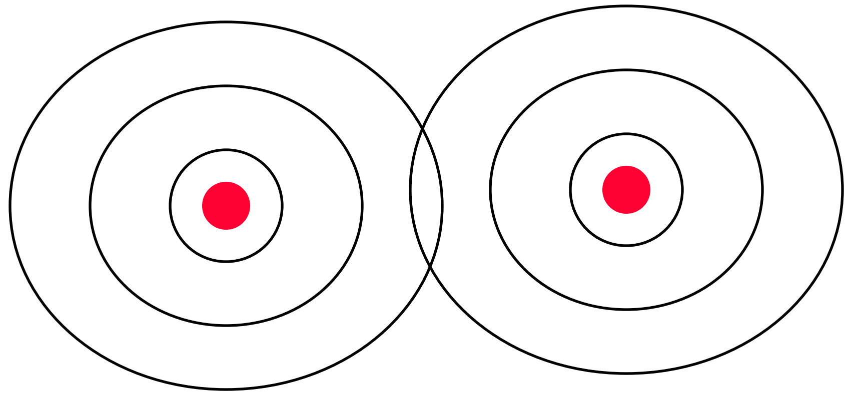



Tension/Rarefaction



# Hugen's Principle: Point Source Scattering

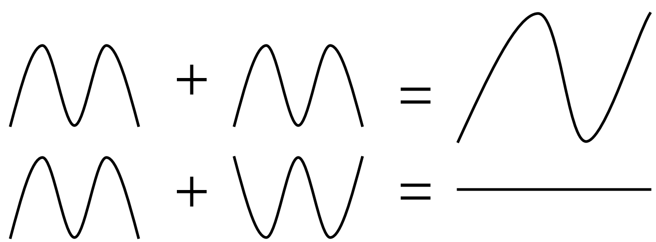
Every point in a wave field acts as a point source



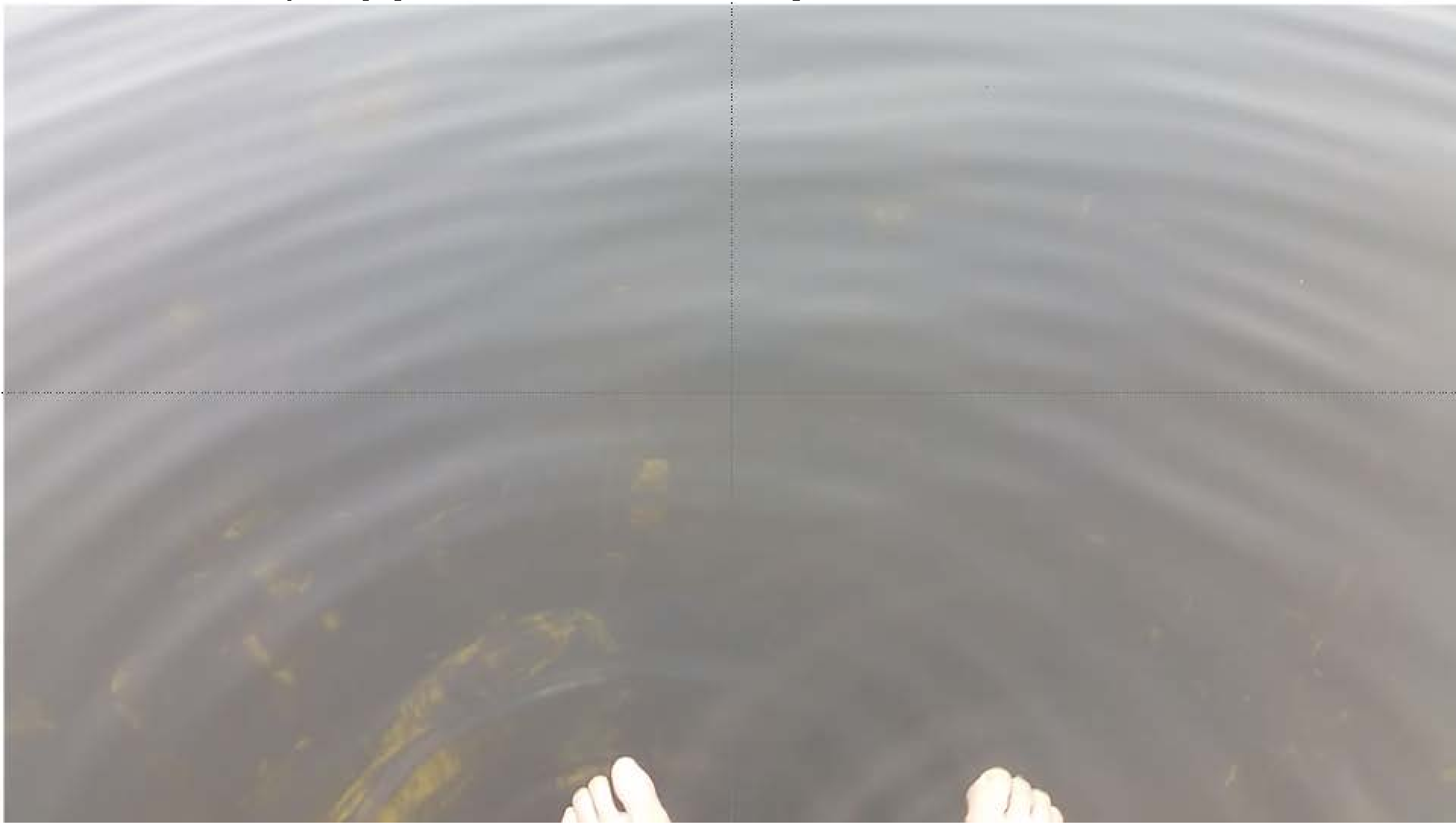
Interference among sources (e.g. ripples in a pond)

Constructive

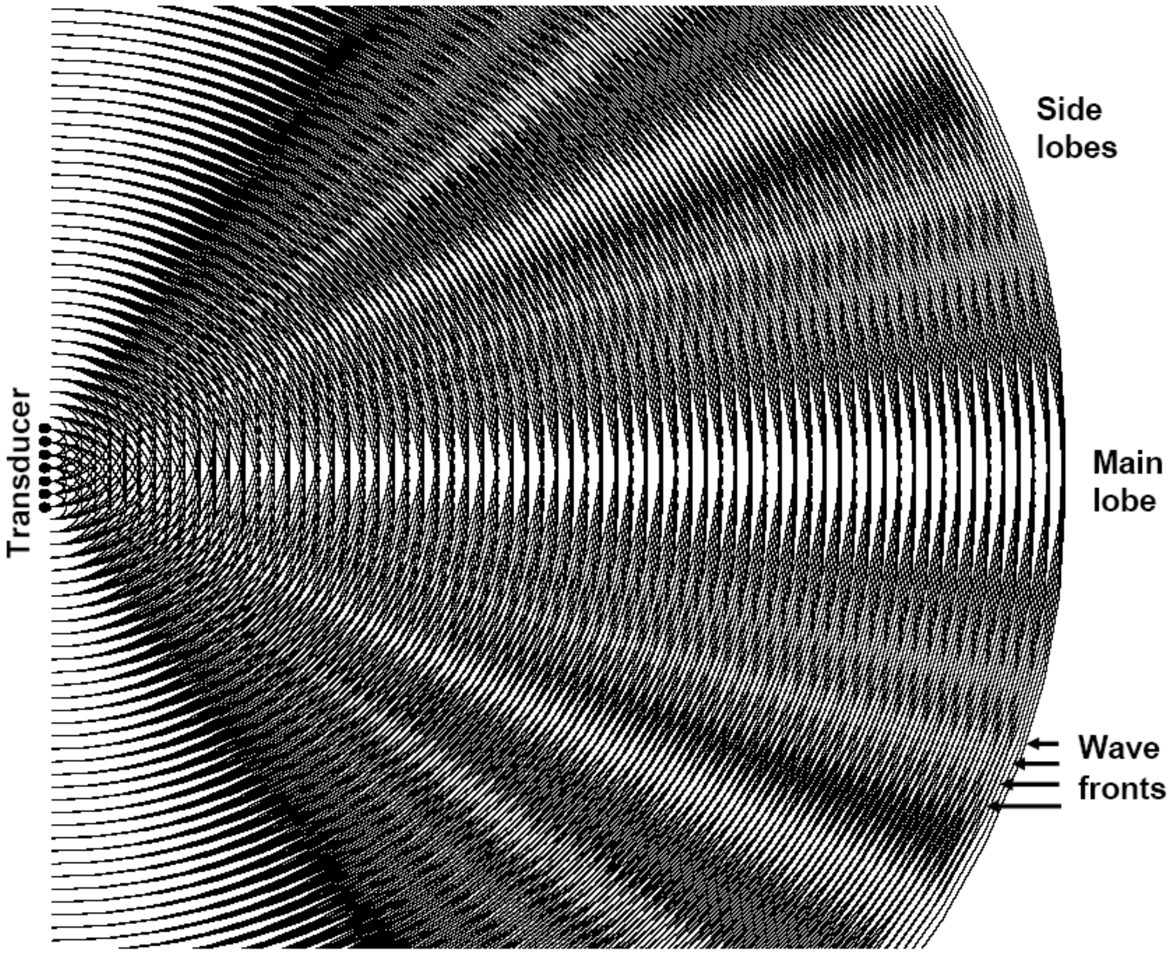
Destructive



# Hyugen’s Principle in Action



# Transducer Beam Pattern




Shading used to form main lobe through constructive and destructive interference

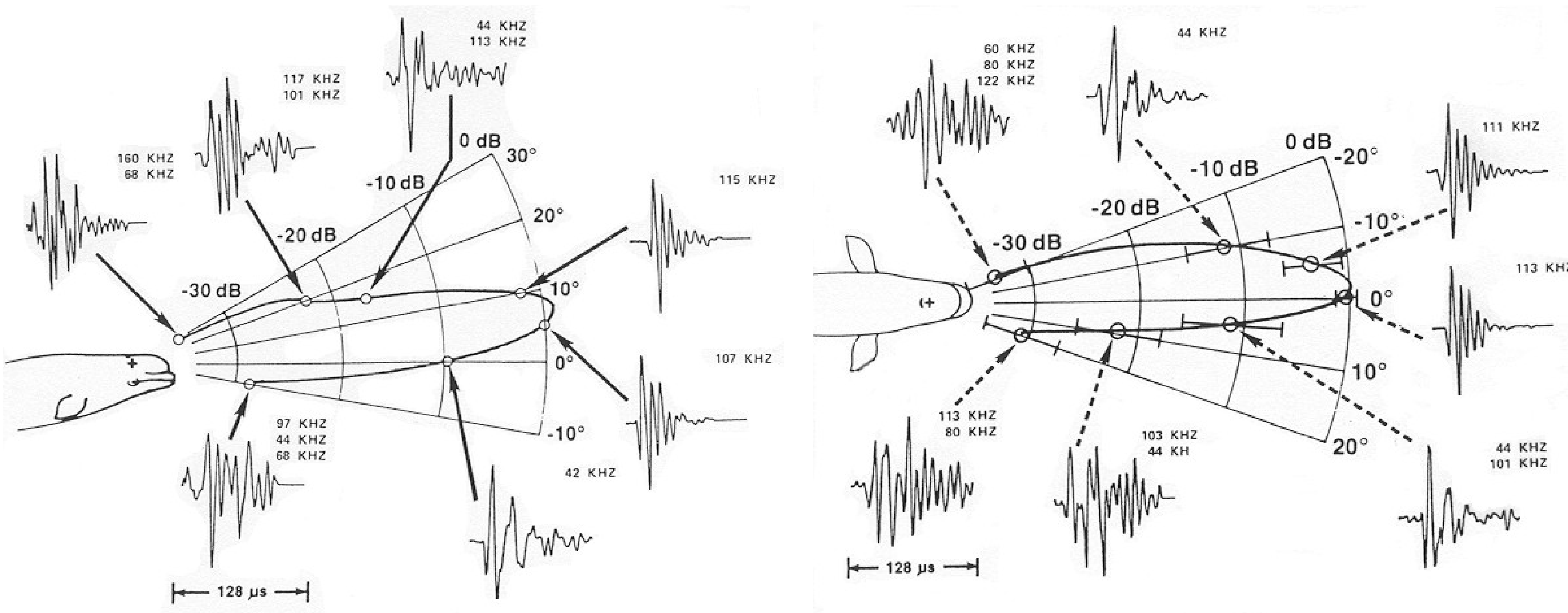
(pebbles thrown in a pond)

* sound pattern is independent of intensity

(flashlight with low batteries)

# Marine Mammal Beam Patterns

Beluga (*Delphinapterus leucas*)



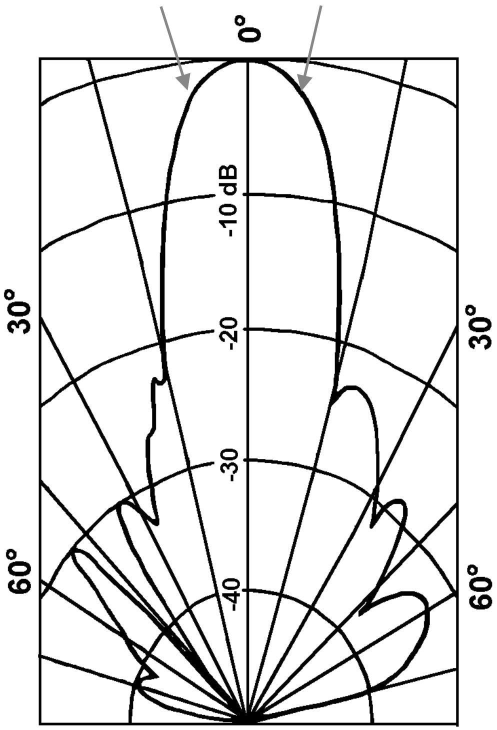

Au et al. 1987

# Forming an Acoustic Beam

- focusing energy in main lobe

tail mass

head mass




2 D Plot

small source: directional (e.g. tweeter)

large source: omnidirectional (e.g. subwoofer)

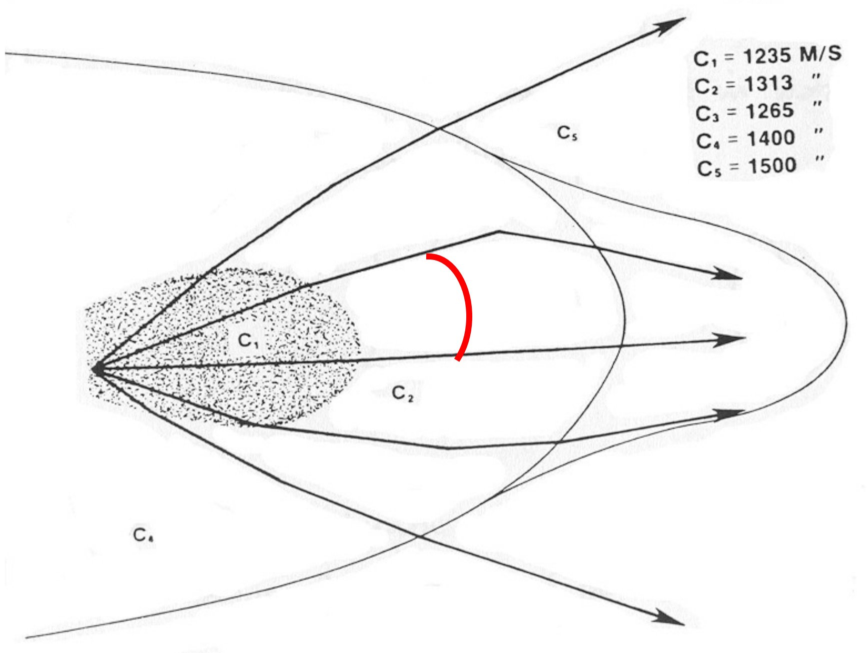
Beam angle = half power: $10*\log_{10}(0.5) = -3$ dB

# Focusing Sound in Cetaceans

- many cetaceans have 'lens-like' structures to focus sound

Bottlenose dolphin (*Tursiops sp.*)

Application of ray tracing and Snell's law (for sound): wave front is retarded in slower (i.e. less dense) medium




Result: wave fronts are refracted towards the normal

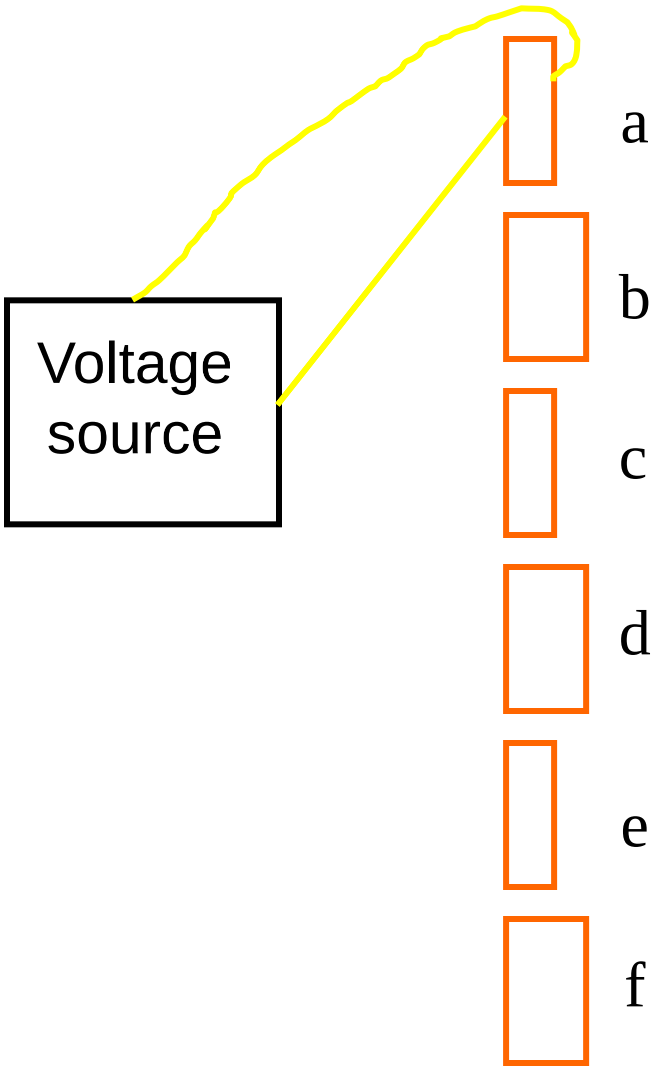
$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{c_2}{c_1}$$

If $c_2/c_1 = 0.5$, and $\theta_1 = 45^o$

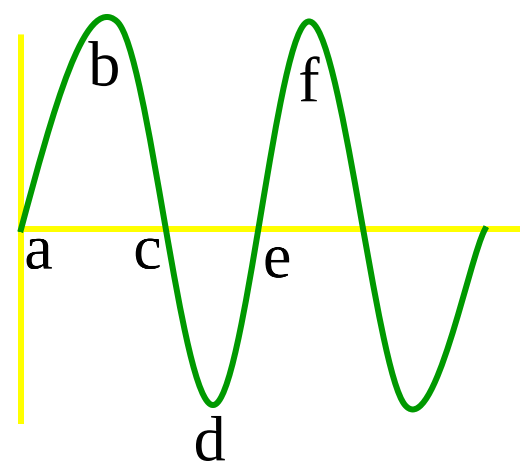
then: $$\sin\theta_2 = \frac{c_2}{c_1}\sin\theta_1 = 0.5\sin(45^o) \Rightarrow 21^o$$

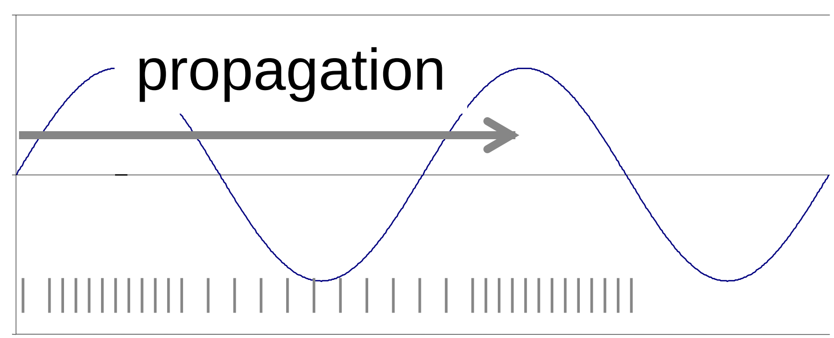
Check the sound speeds and ray paths

# Producing & Receiving Sound

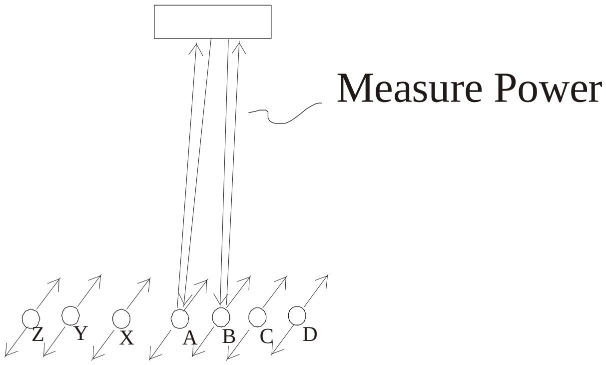



Oscillatory Signal



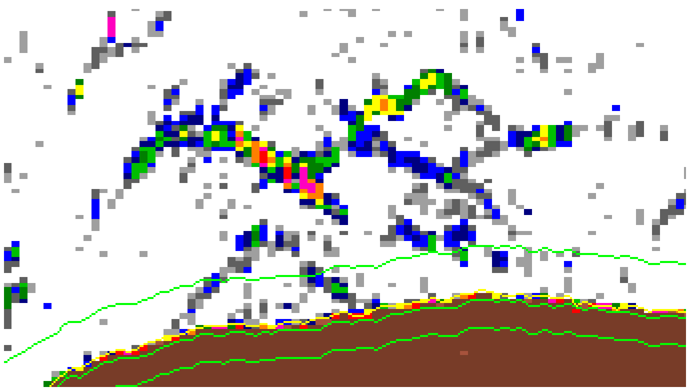



# Transducer Transmit & Receive

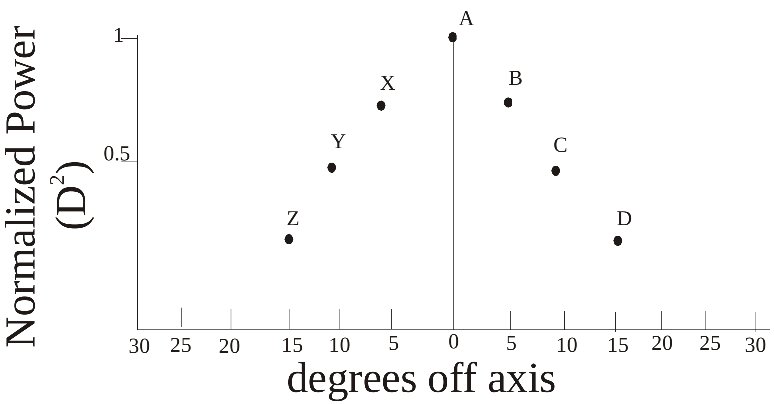



monostatic transducer (or transceiver): transmits and receives from same source

bistatic transceiver: transmits from one source and receives on a second

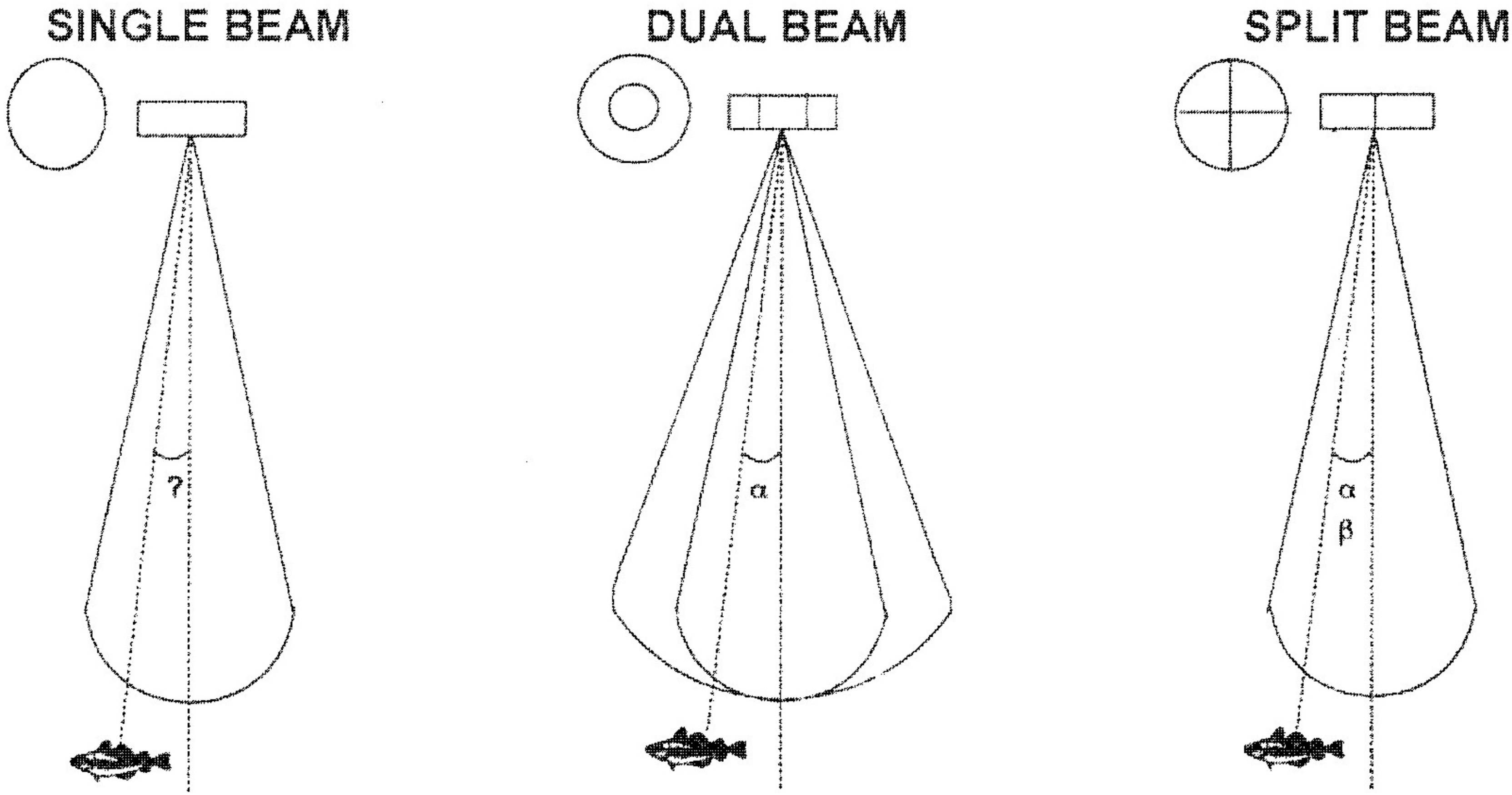


120 kHz, -65 dB threshold

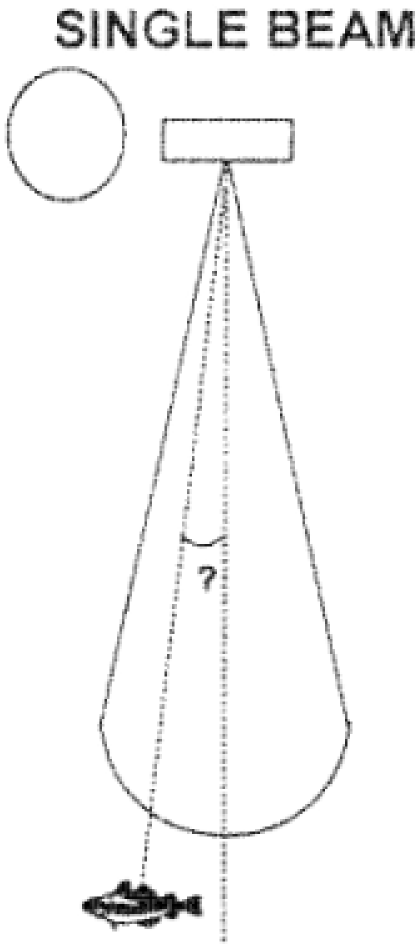



fingernail traces (i.e. boomerangs): due to differences in range and intensities

# Transducer Types

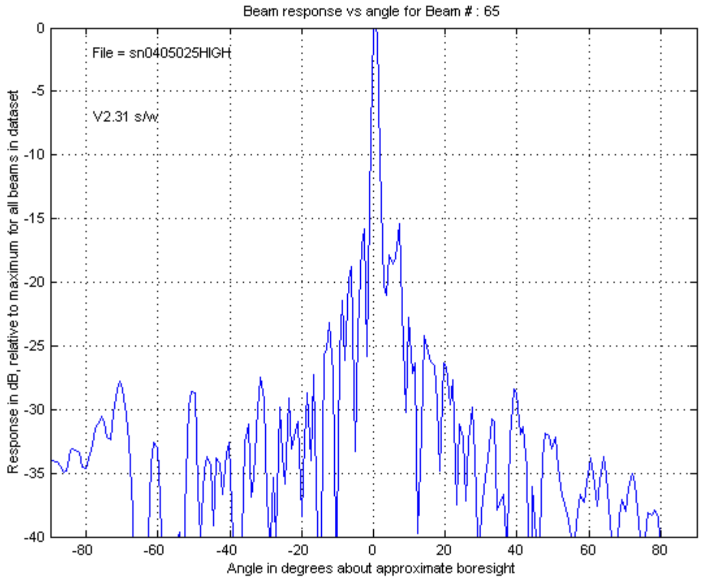


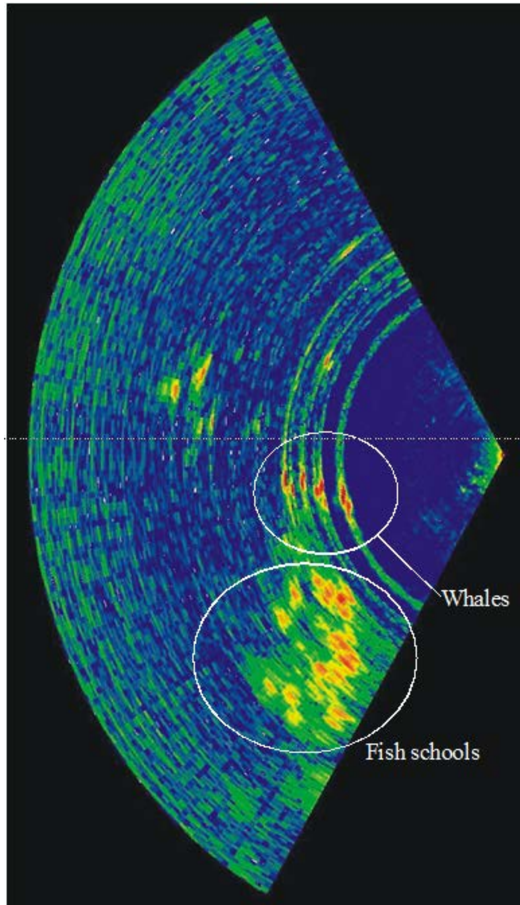
# Single Beam




- no way to locate target within beam
- assume statistical distribution within beam when estimating target strengths (e.g. Craig and Forbes algorithm)

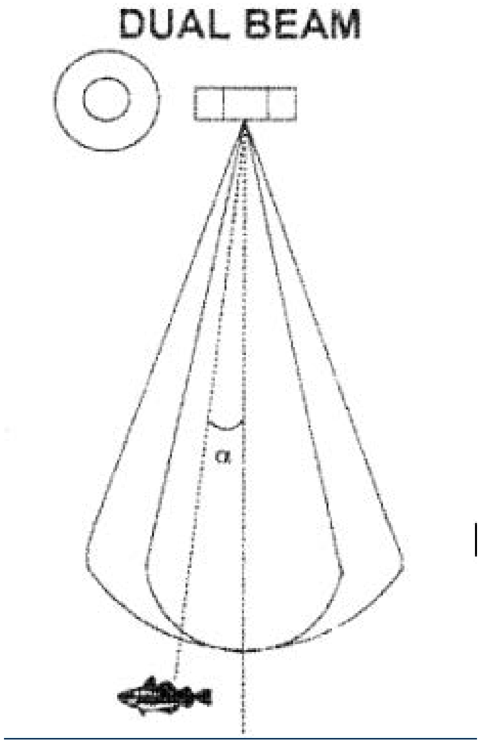
Single Beam in a Multibeam Sonar



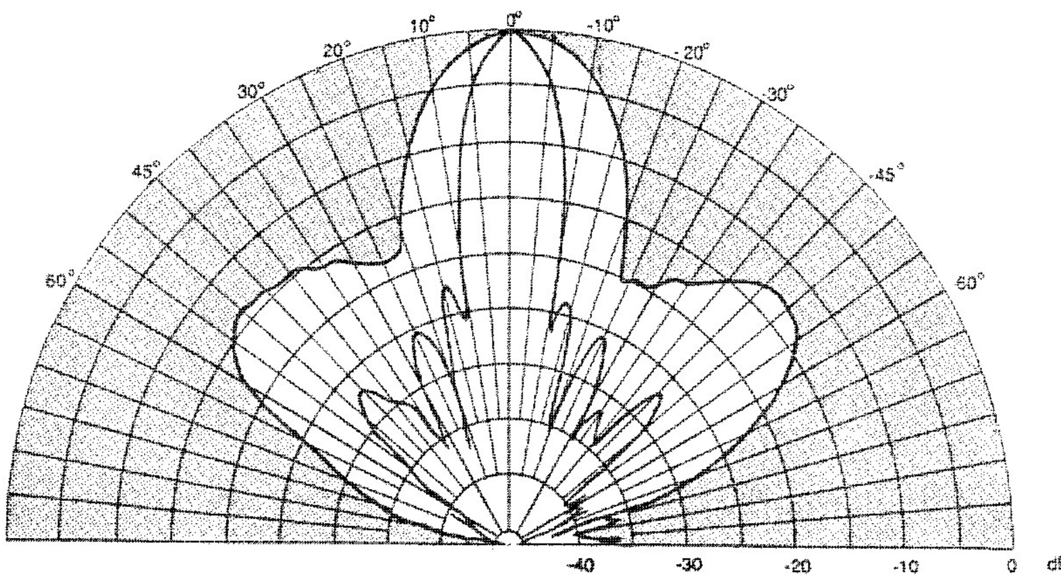

Halo effect from side lobes

# Dual Beam

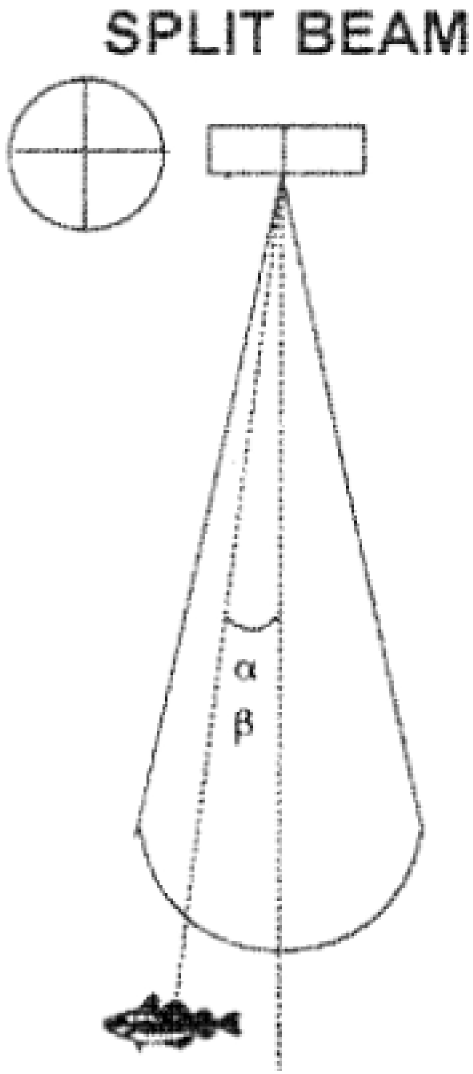



- two concentric beams
- transmit on narrow, receive on narrow and wide
- target angle a function of ratio of voltages received
- provides angle off axis (i.e. a ring)

Beam plot of a dual beam transducer

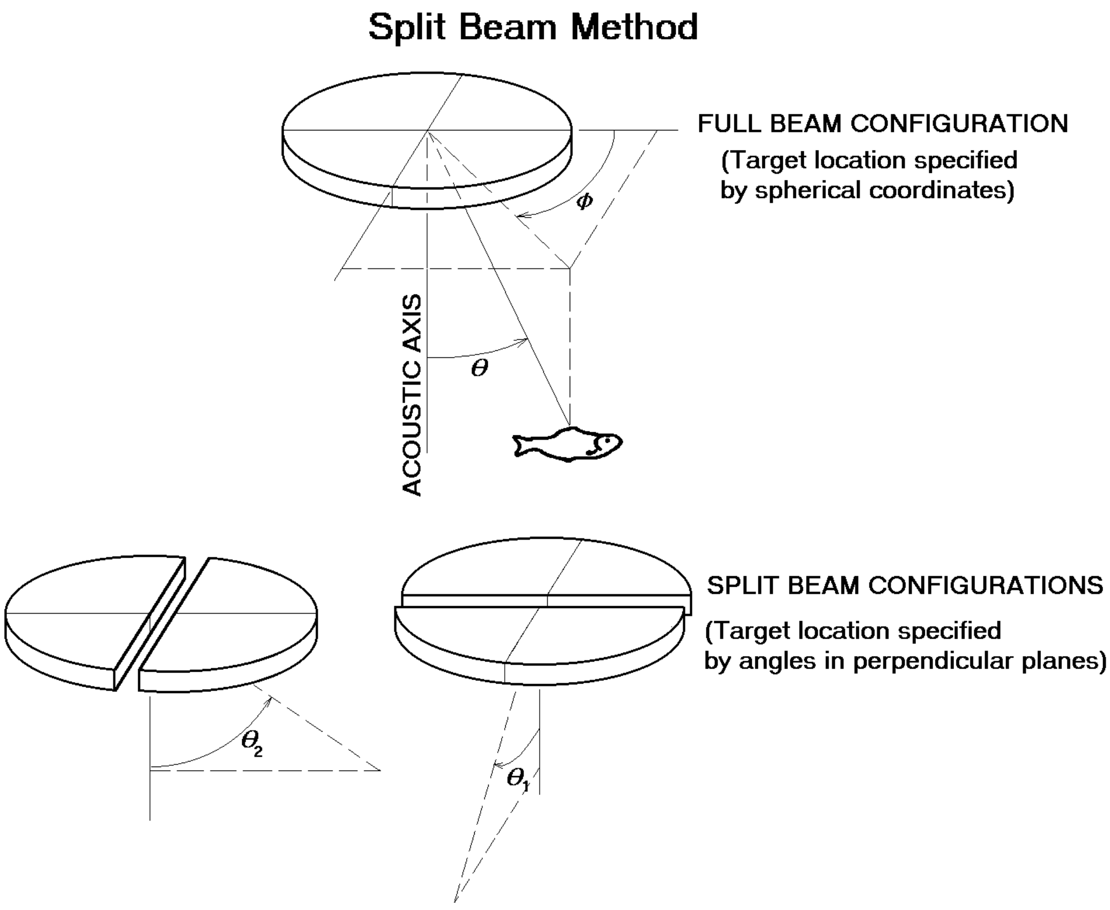


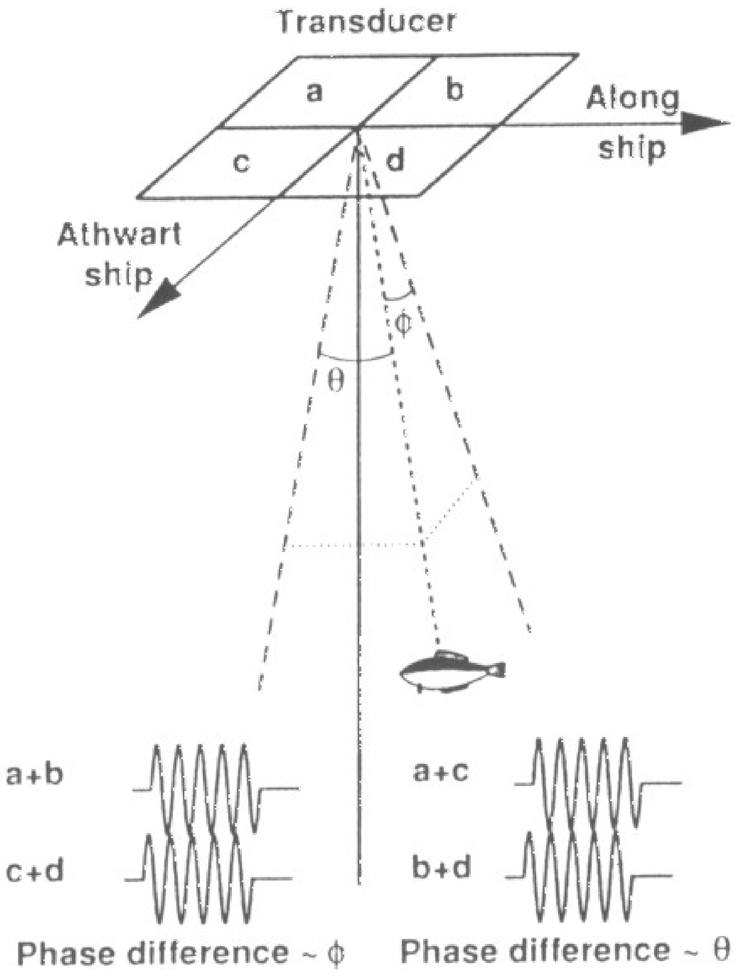
# Split Beam




- transducer receive elements divided into 4 quadrants
- angle along, angle athwart
- use time lag (i.e. phase differences) to derive 2 angles
- provides position in beam at intersection of 2 angles

# Split Beam Phase Differencing

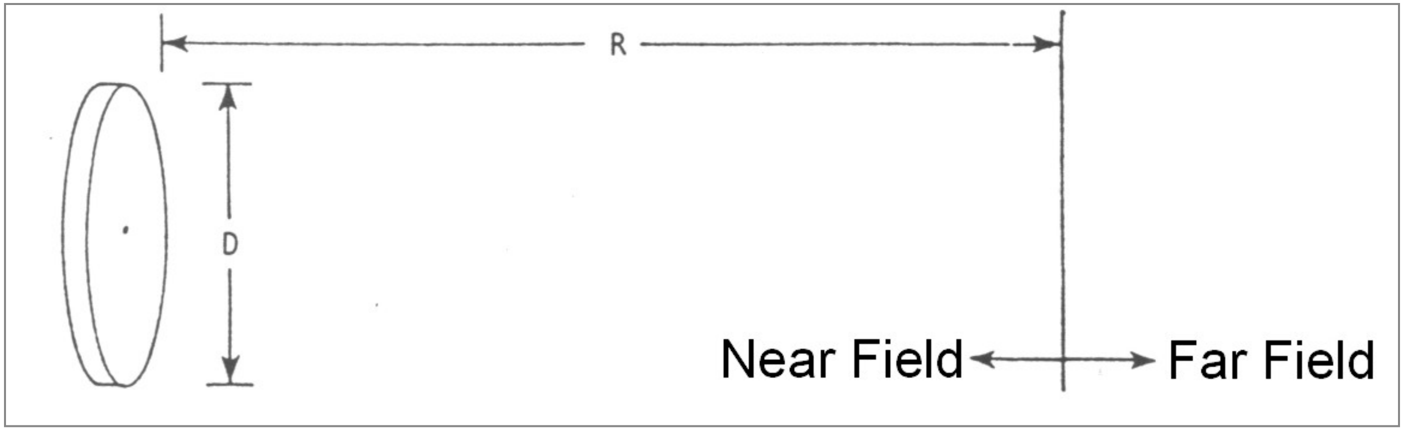



- compare athwart and along echo arrival times
- phase differences used to estimate angles θ and ϕ

# Near Field & Far Field

Far field: when incident wave front is normal to target



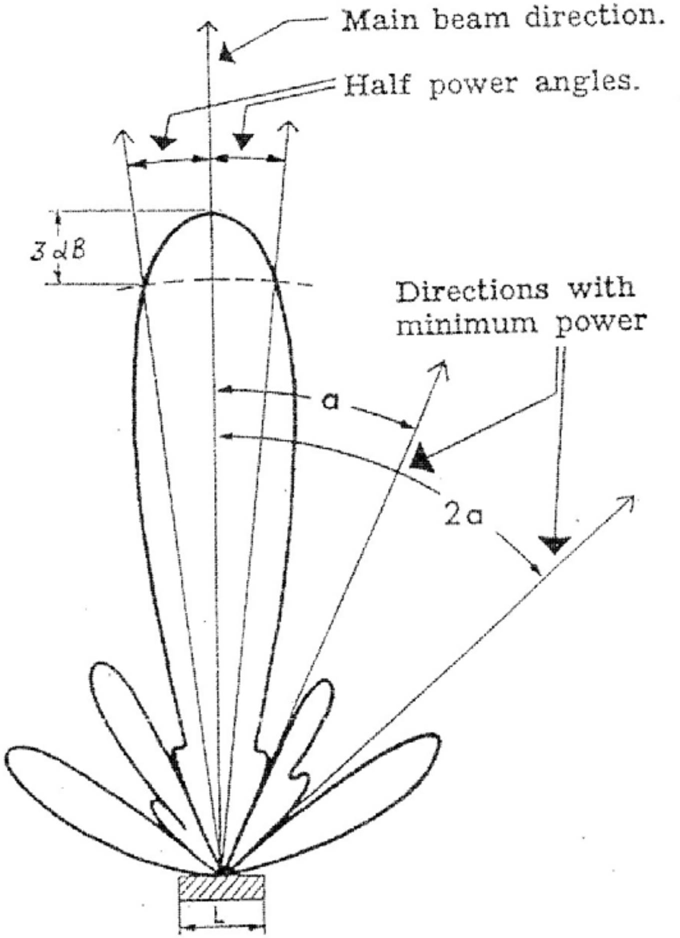

$$r = D^2/\lambda$$

where:

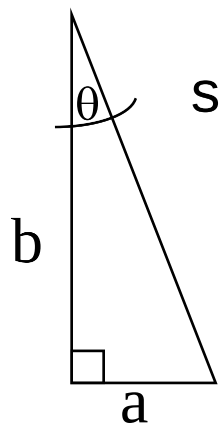
$r$ = far field range, $D$ = active transducer diameter, $\lambda$ = wavelength

ANSI-ASA S1.20.2013: $R_c = {\pi a^2}/{\lambda}$

# Swath at Depth




Half power points = -3dB power = $\theta$




since $\tan(\theta) = a/b$

(sohcahtoa)

$$swath(depth) = 2depth * \tan\left(\frac{beamwidth}{2}\right)$$

What is swath of a 7$^{o}$ transducer at 100 m? 12.23 m