



Medical Image Reconstruction

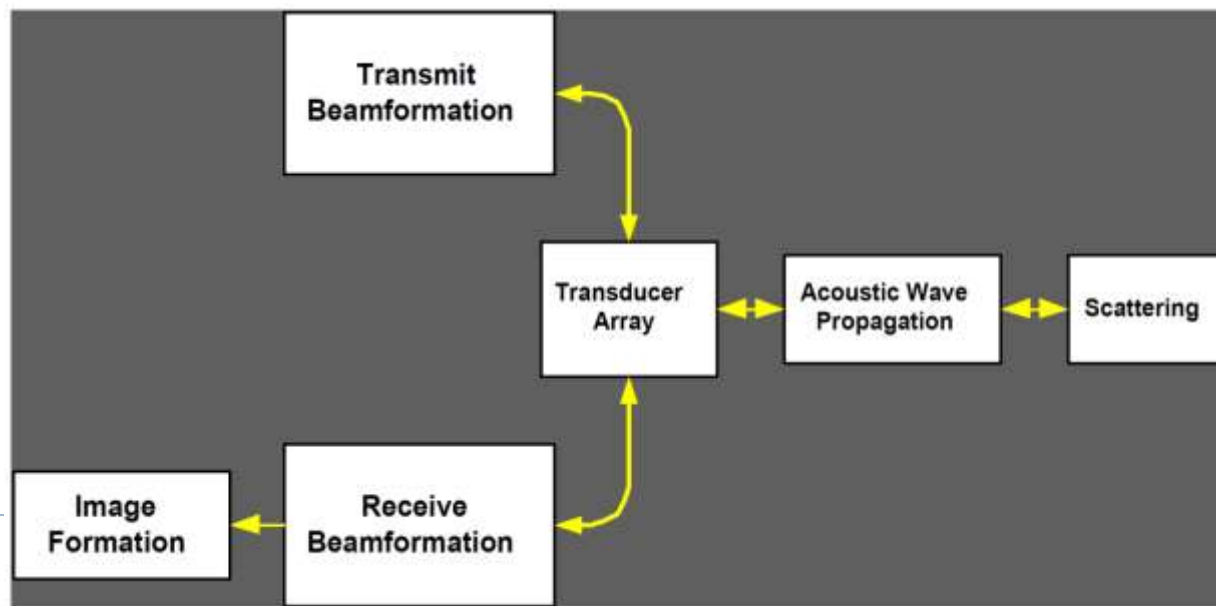
Term II – 2010

Topic 5: Synthetic Aperture Ultrasound Imaging

Professor Yasser Mostafa Kadah

Beamformer: Role in an Imager

- ▶ Perhaps the most important building block.
 - ▶ Soul of the machine?
- ▶ Probably the most expensive building block.
 - ▶ 30 -50% of parts & labor of a scanner

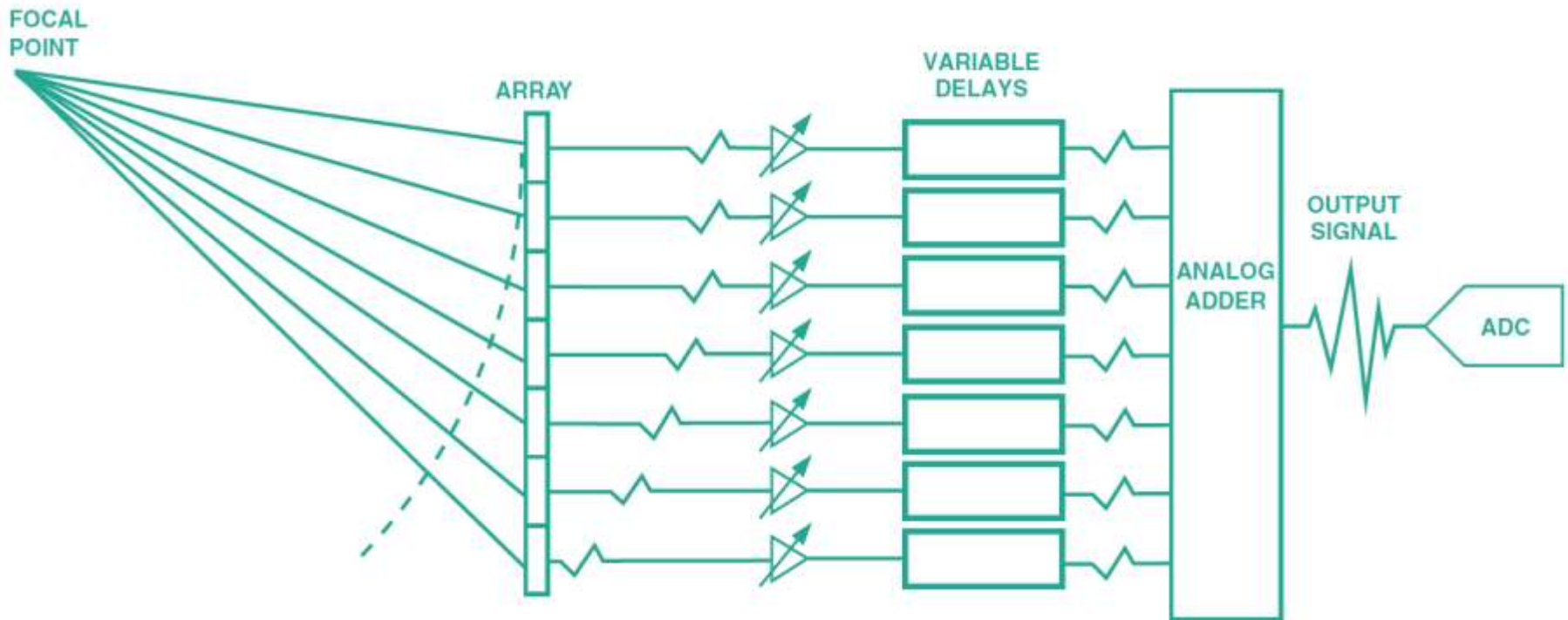


Beamformer History

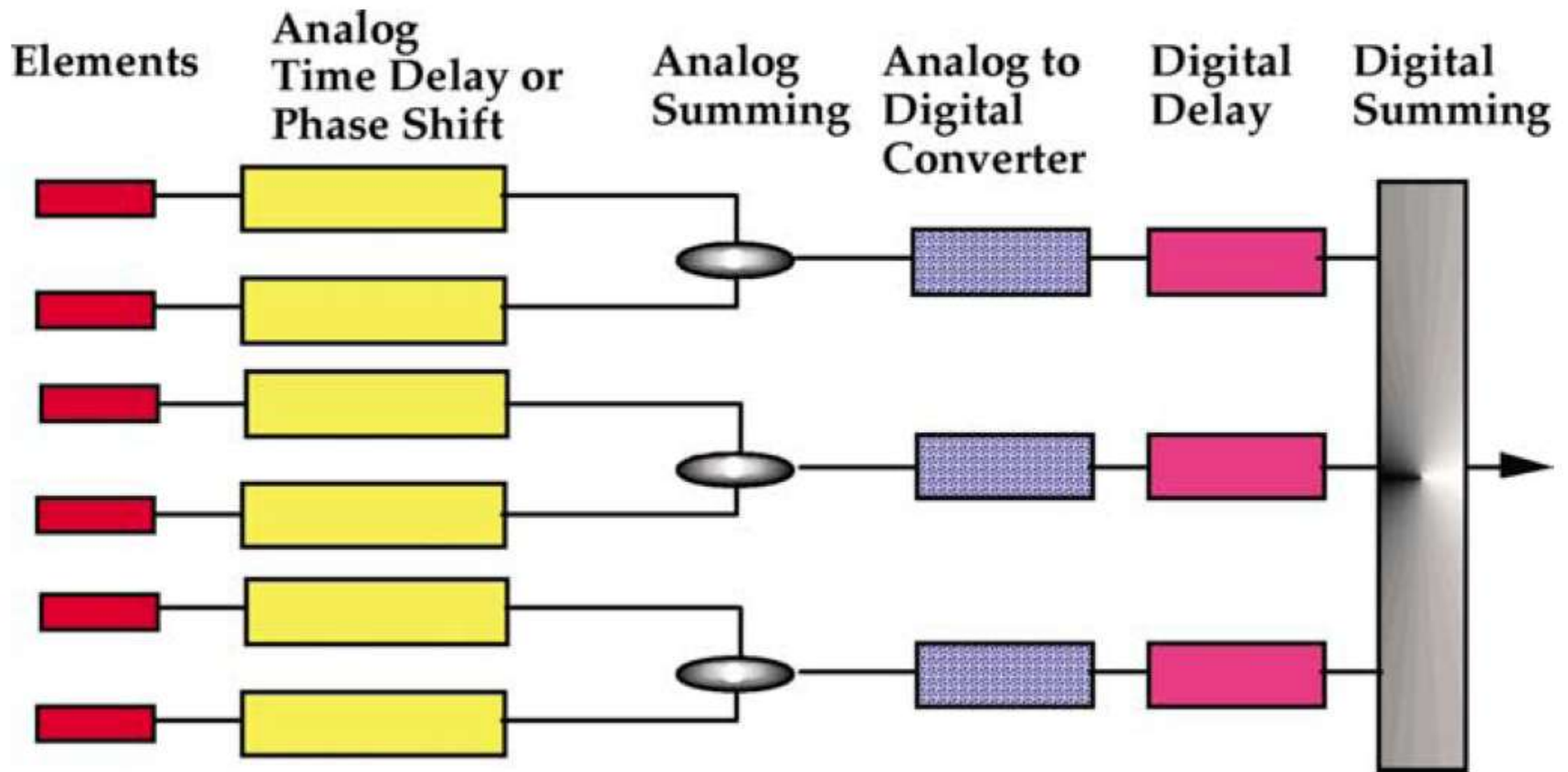
- ▶ Before the mid-70s
 - ▶ Single element scanners, no beamformer necessary
- ▶ 1975 -1980
 - ▶ Array based systems
 - ▶ Analog beamformation
 - ▶ Typically 32 channels
- ▶ Mid 1980s
 - ▶ High channel count systems (High = 128)
- ▶ Early 90s
 - ▶ Digital beamformation



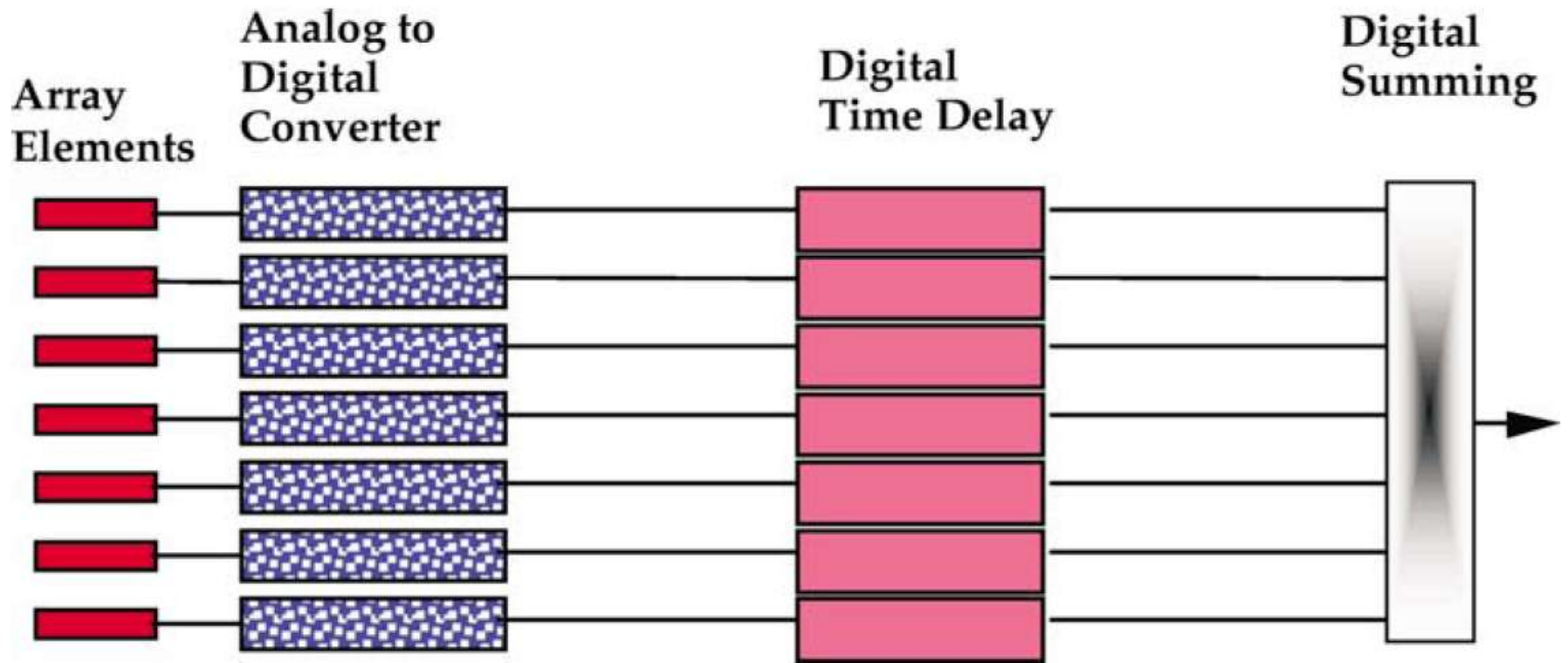
Analog Beamformer



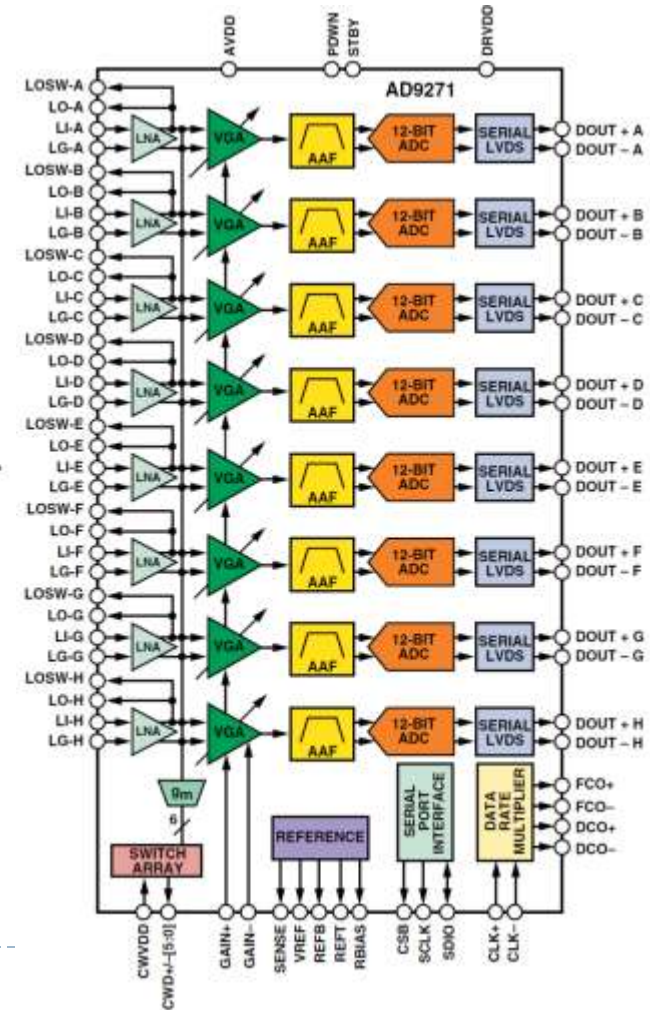
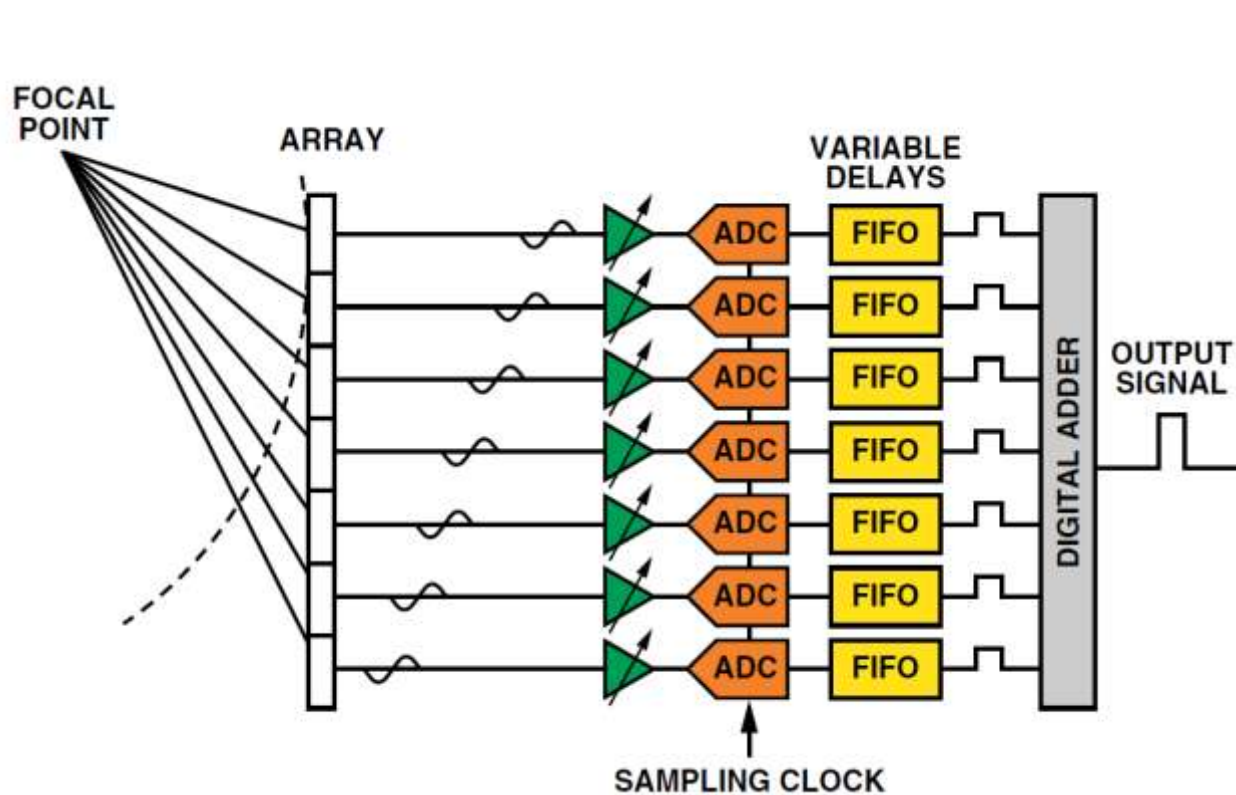
Hybrid Analog/Digital Beamformer



True Digital Beamformer

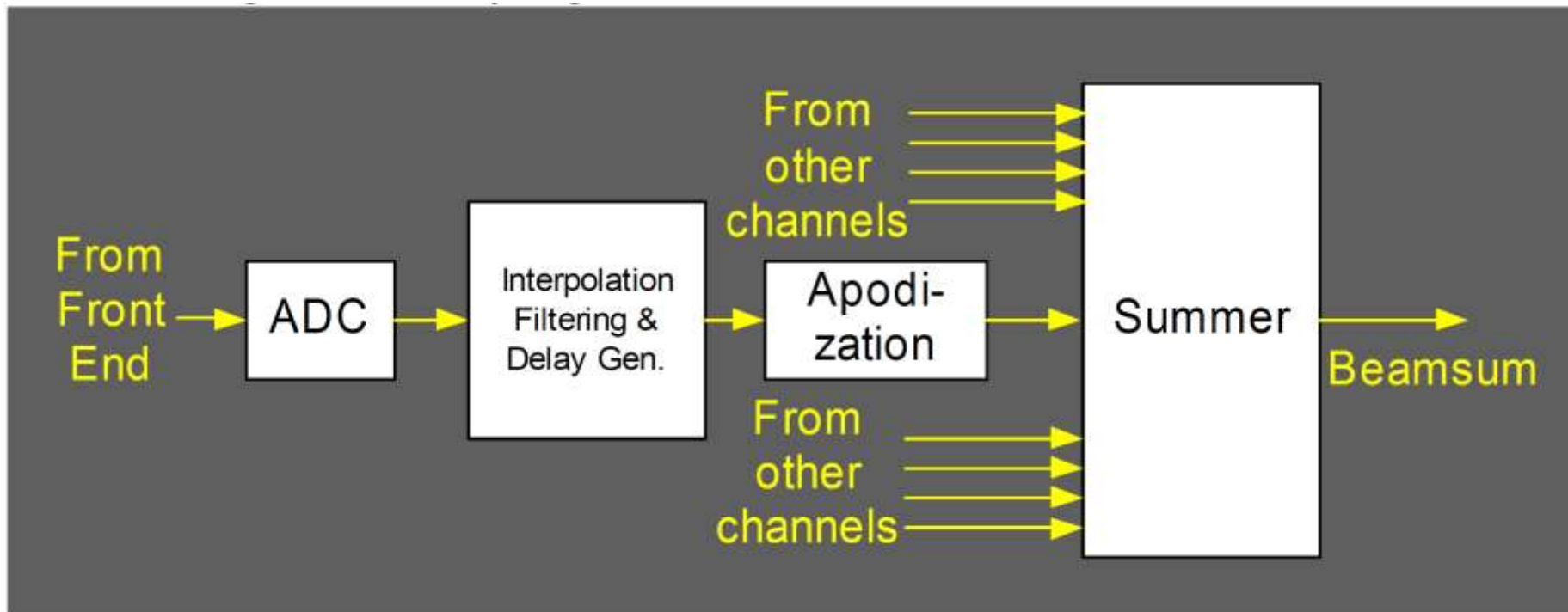


Digital Beamformer Hardware

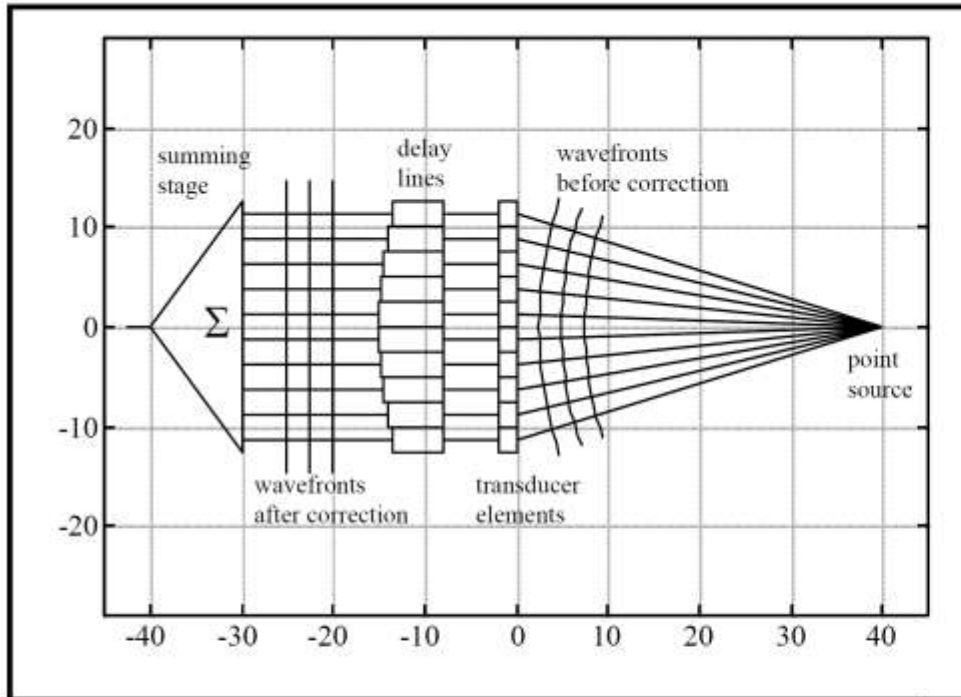


Receive Beamformer Functions

- ▶ Delay generation, dynamic and steering delays
- ▶ Apodization
- ▶ Summing of all delayed signals

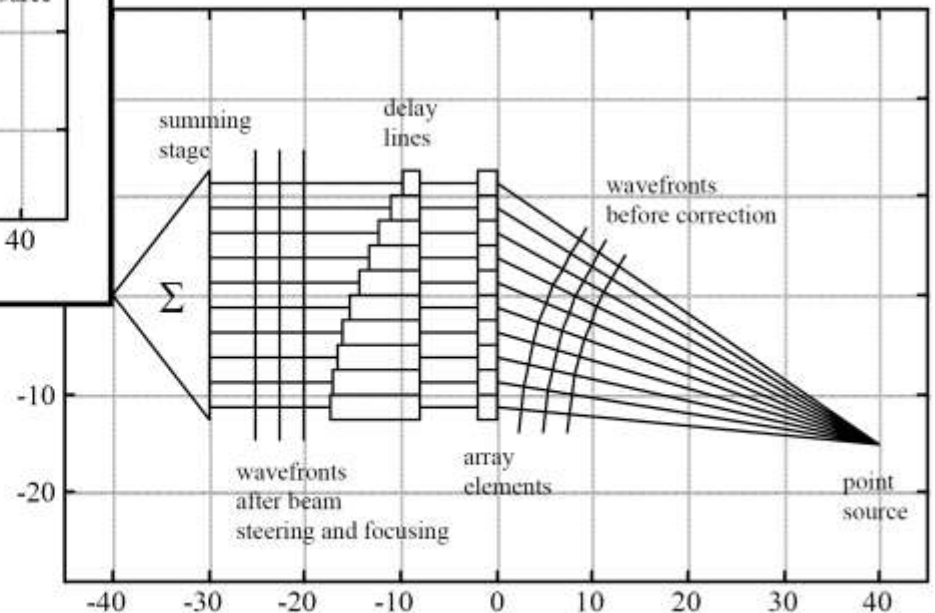


Focusing and Steering Delays



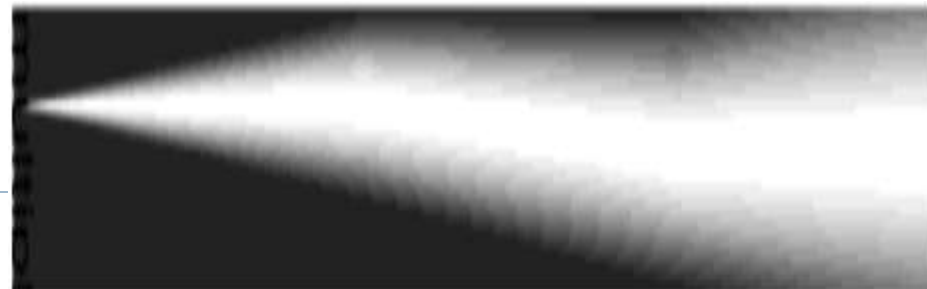
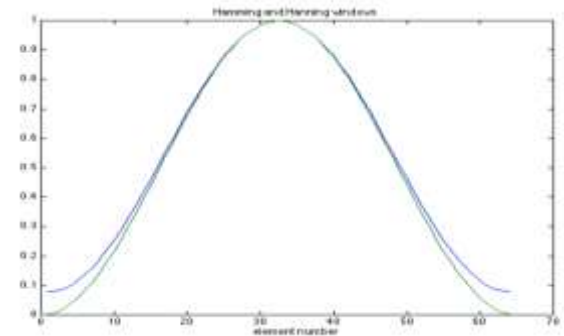
- Basic focusing type beamformation
- Symmetrical delays about phase center.

- Beam steering w. linear phased arrays.
- Asymmetrical delays, long delay lines



Apodization

- ▶ Main role
 - ▶ apply a weighting function to aperture
 - ▶ expand aperture w. receding wavefront
 - ▶ maintain image uniformity
 - ▶ supply walking aperture
- ▶ Implementation
 - ▶ multipliers
 - ▶ truly complex control
- ▶ Highly beneficial impact on beam.



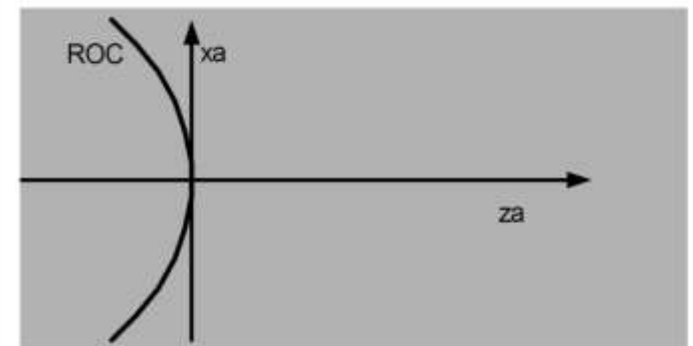
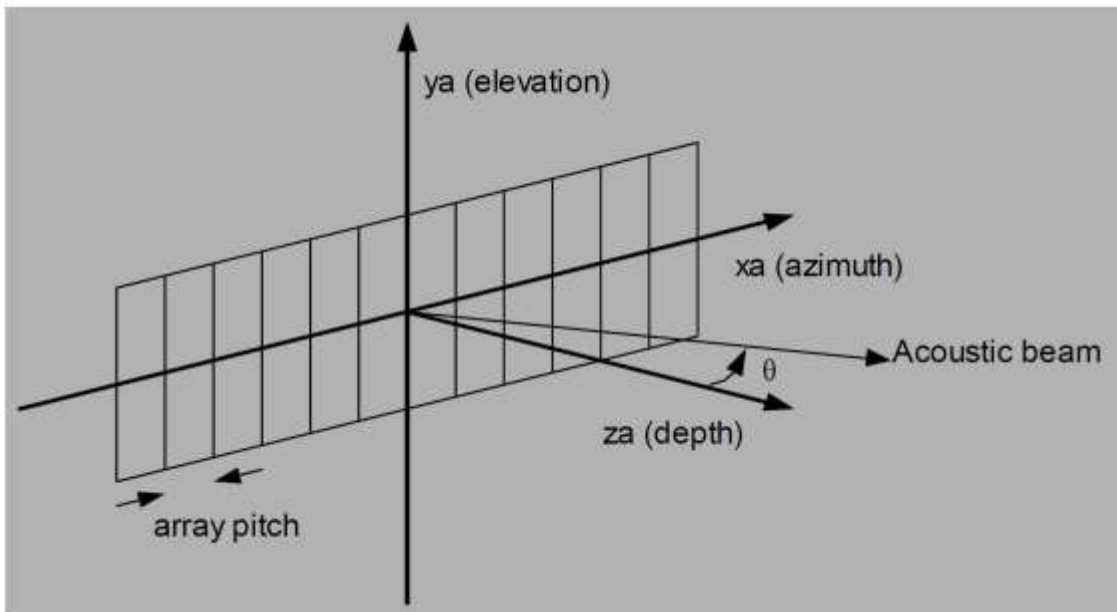
Types of Arrays and Beamformers

- ▶ Linear array beamformer
 - ▶ Generation of focusing delays
 - ▶ Beam steering by element selection
- ▶ Curvilinear array beamformer
 - ▶ Generation of focusing delays
 - ▶ Beam steering by element selection
- ▶ Phased array beamformer
 - ▶ Generation of focusing delays
 - ▶ Beam steering by phasing



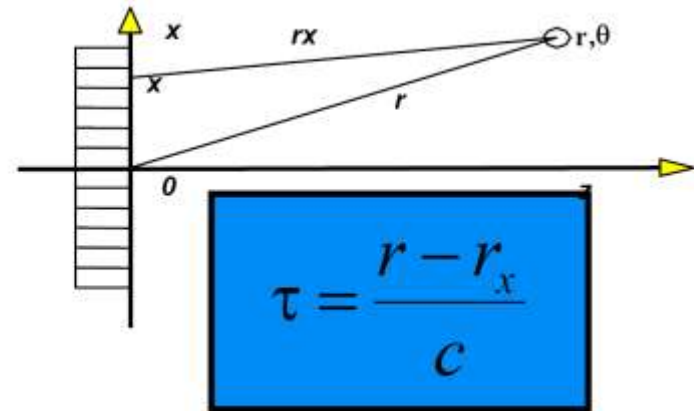
Array Geometries

- ▶ Definition of azimuth, elevation
- ▶ Scanning angle shown, θ , in negative scan direction.
- ▶ Similar definitions for a curved array



Delay Calculation from Geometry

- ▶ Delay determination:
 - ▶ simple path length difference
 - ▶ reference point: phase center
 - ▶ apply Law of Cosines
 - ▶ approximate for ASIC implementation
- ▶ In some cases, split delay into 2 parts:
 - ▶ beam steering
 - ▶ dynamic focusing

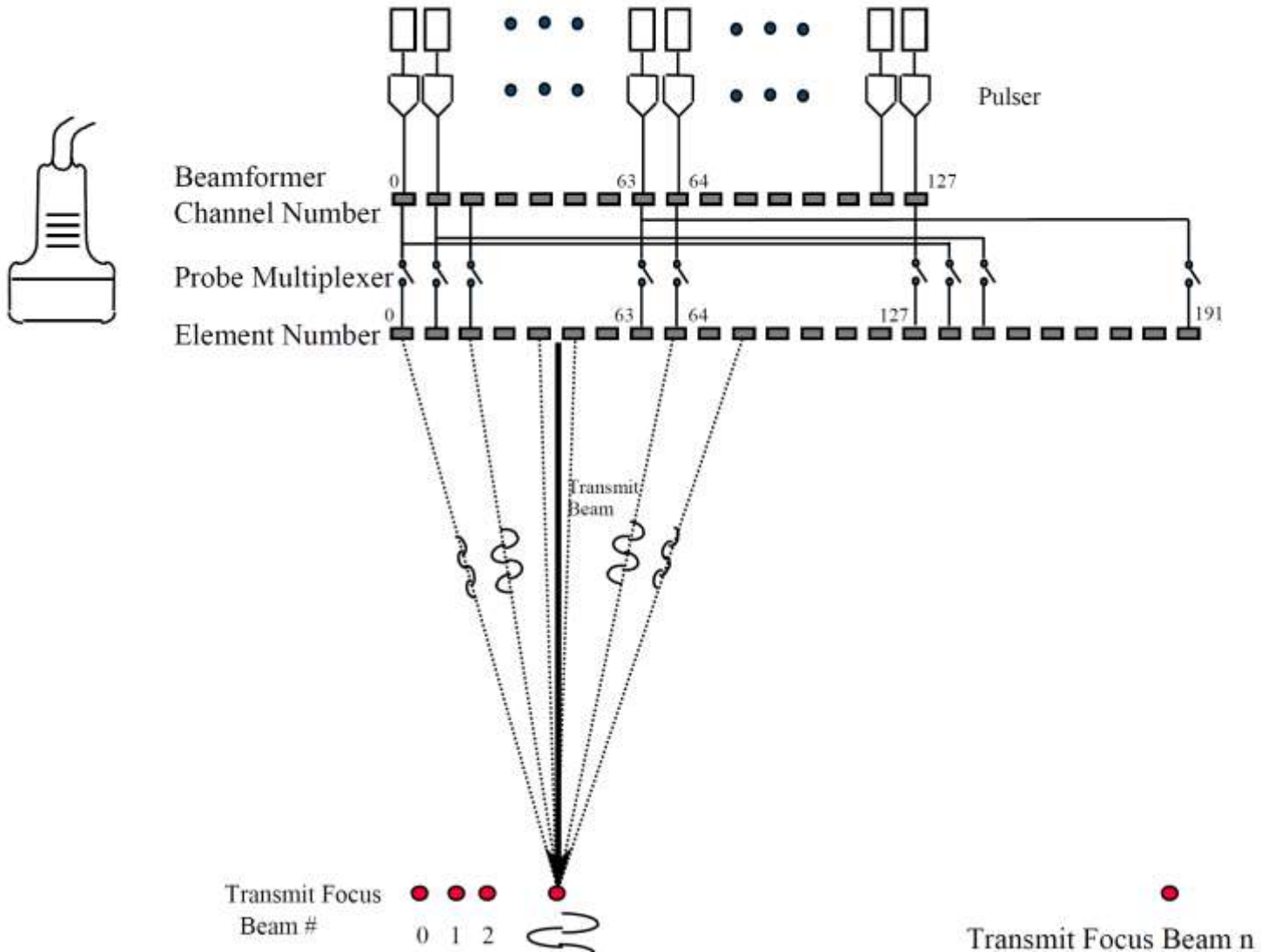


$$\tau = \frac{r - r_x}{c}$$

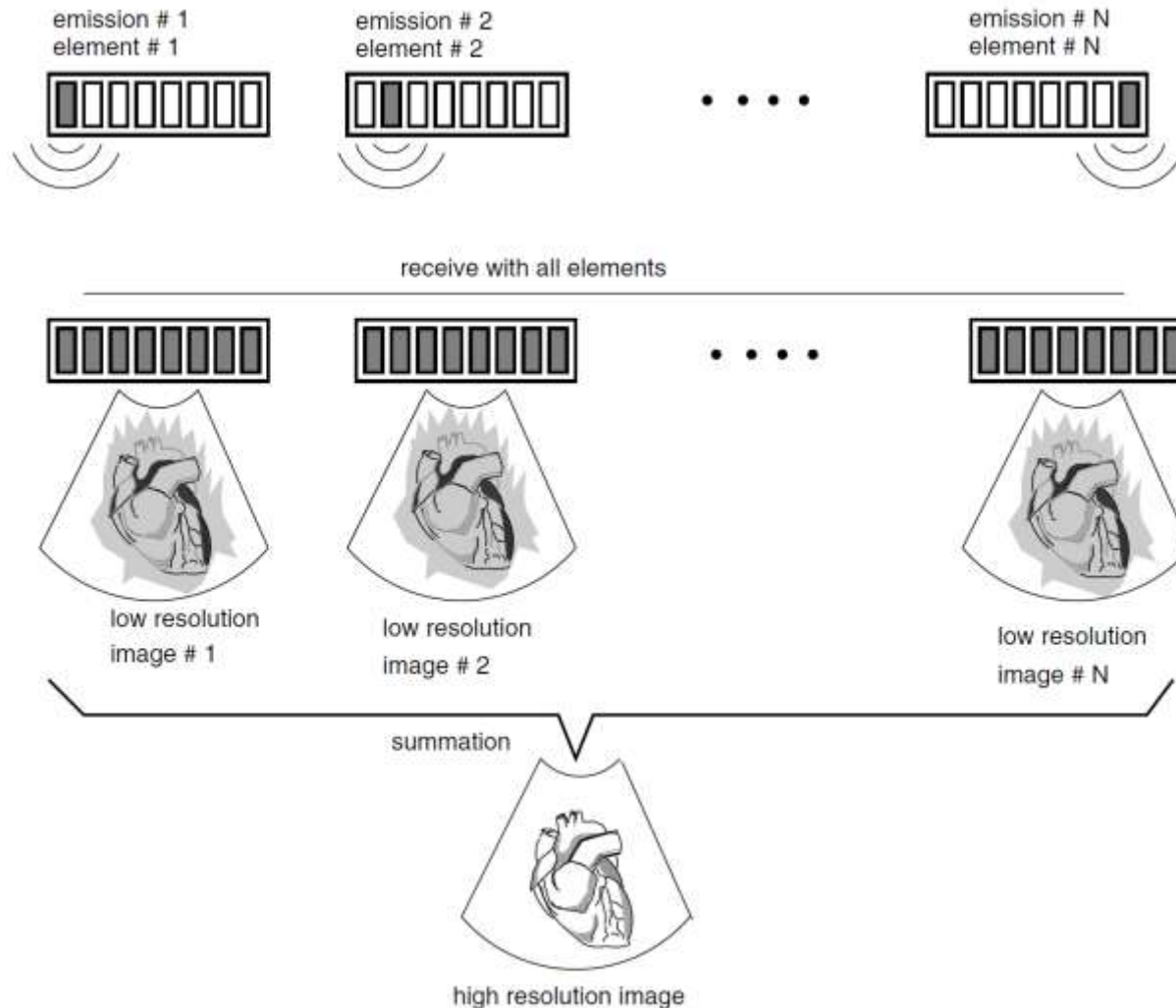
$$\tau = \frac{1}{c} \left[\sqrt{x^2 - 2rx \sin(\theta) + r^2} - r \right]$$

$$\tau = \tau_s + \tau_f$$

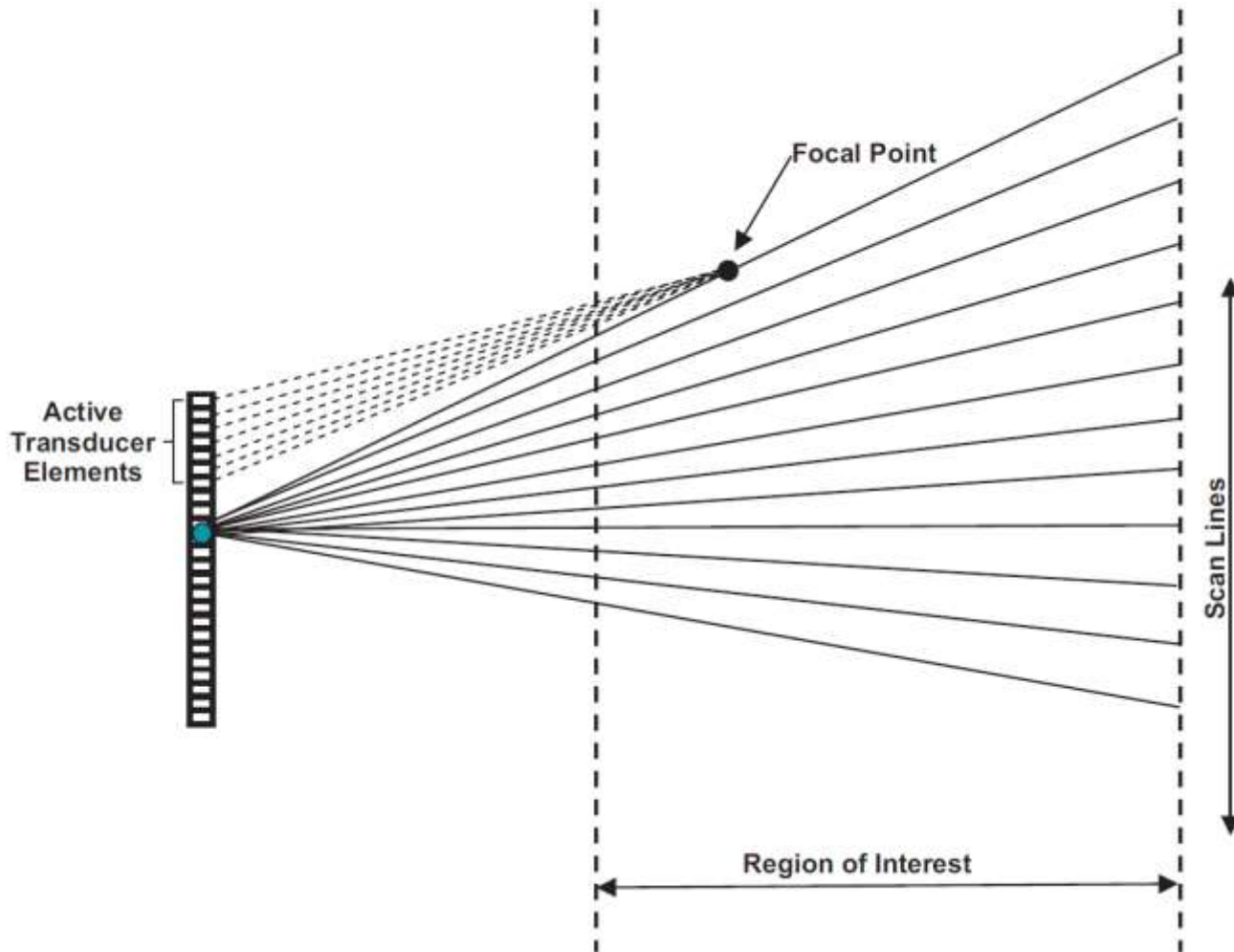
Transmit Beamforming



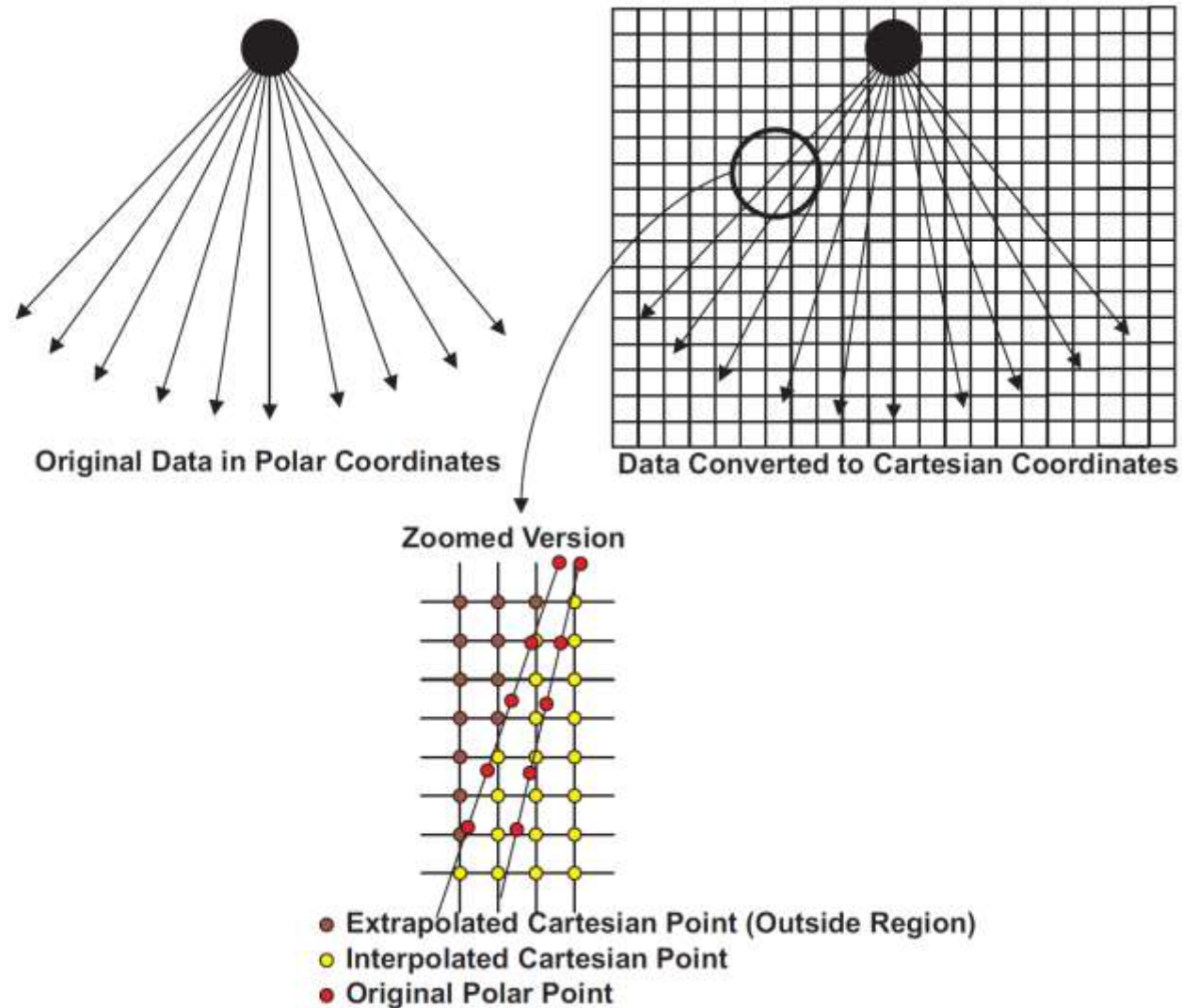
Synthetic Aperture Beamforming



Phased Array Scanning



Scan Conversion



Exercise

- ▶ Use one of data sets available on the class web site to reconstruct an ultrasound image. Assume any missing imaging parameters outside those given in the data set description. [5 Points]
- ▶ Do a literature search on the topic of ultrasound beamforming and scan conversion and come up with a list of all references related to the subject. [1 Point]

