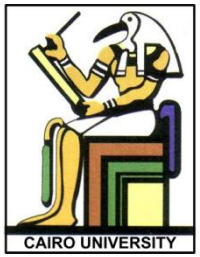


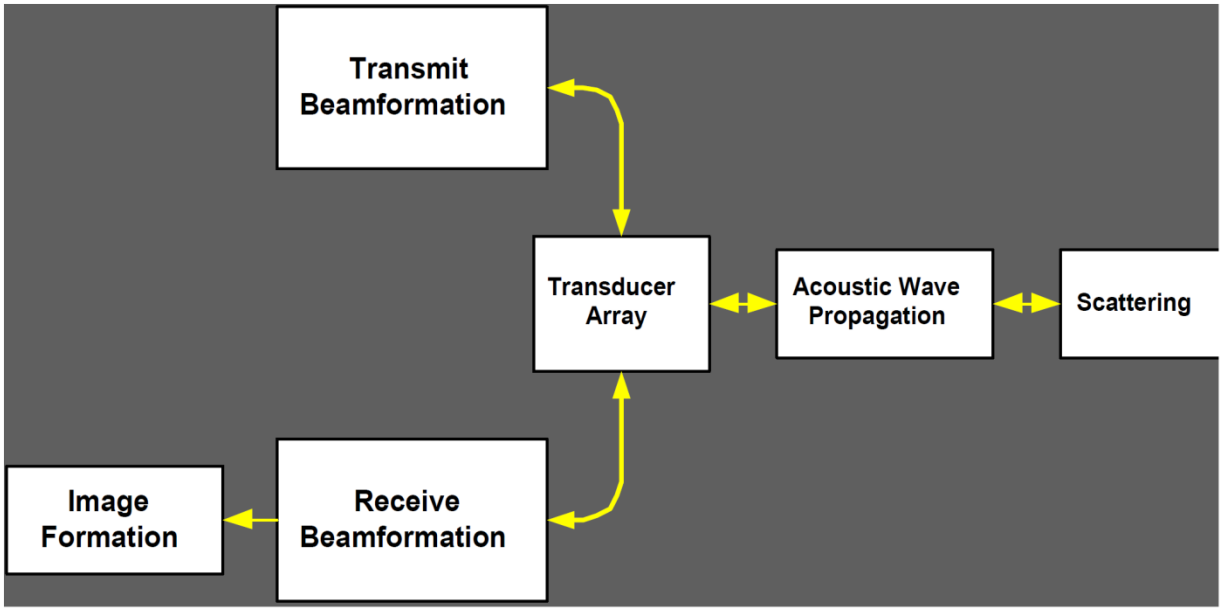
Medical Image Reconstruction
Term II – 2012

Topic 5: Synthetic Aperture Ultrasound Imaging

Professor Yasser Mostafa Kadah

Beamformer: Role in an Imager

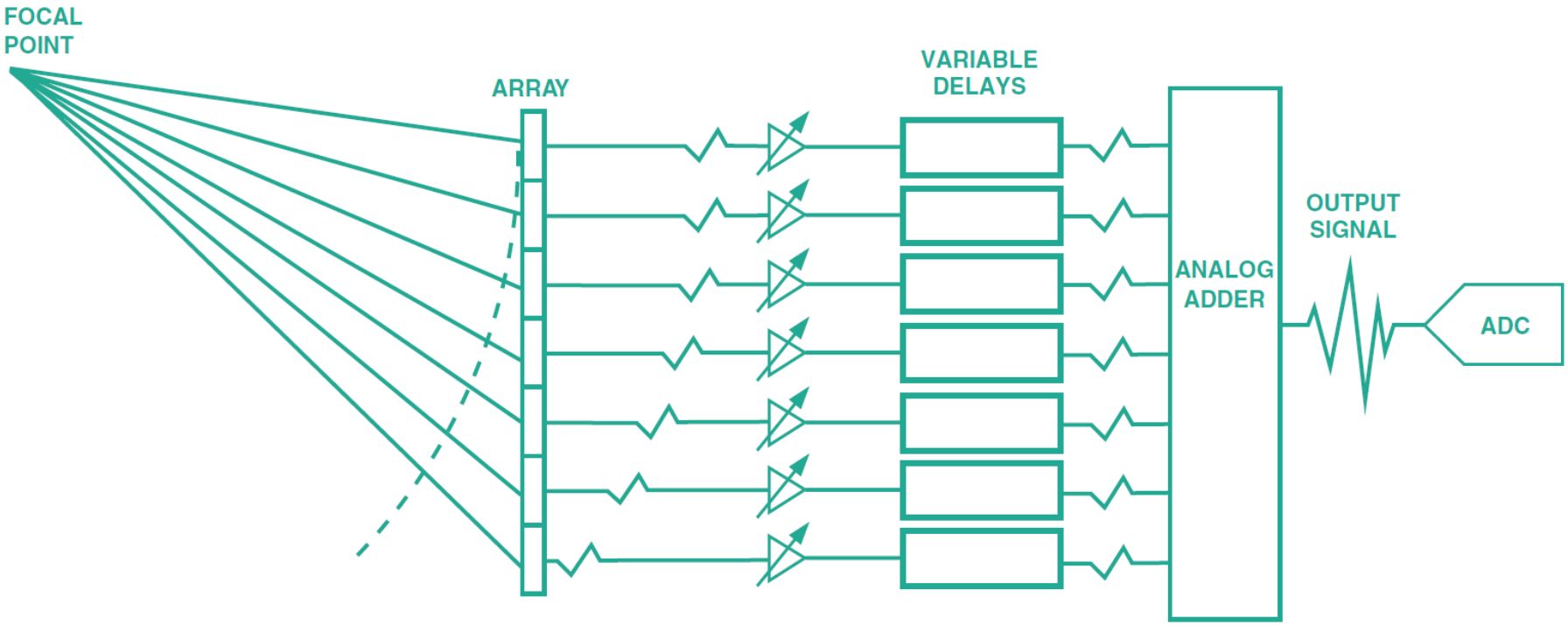
- Perhaps the most important building block.
  - Soul of the machine?
- Probably the most expensive building block.
  - 30 -50% of parts & labor of a scanner



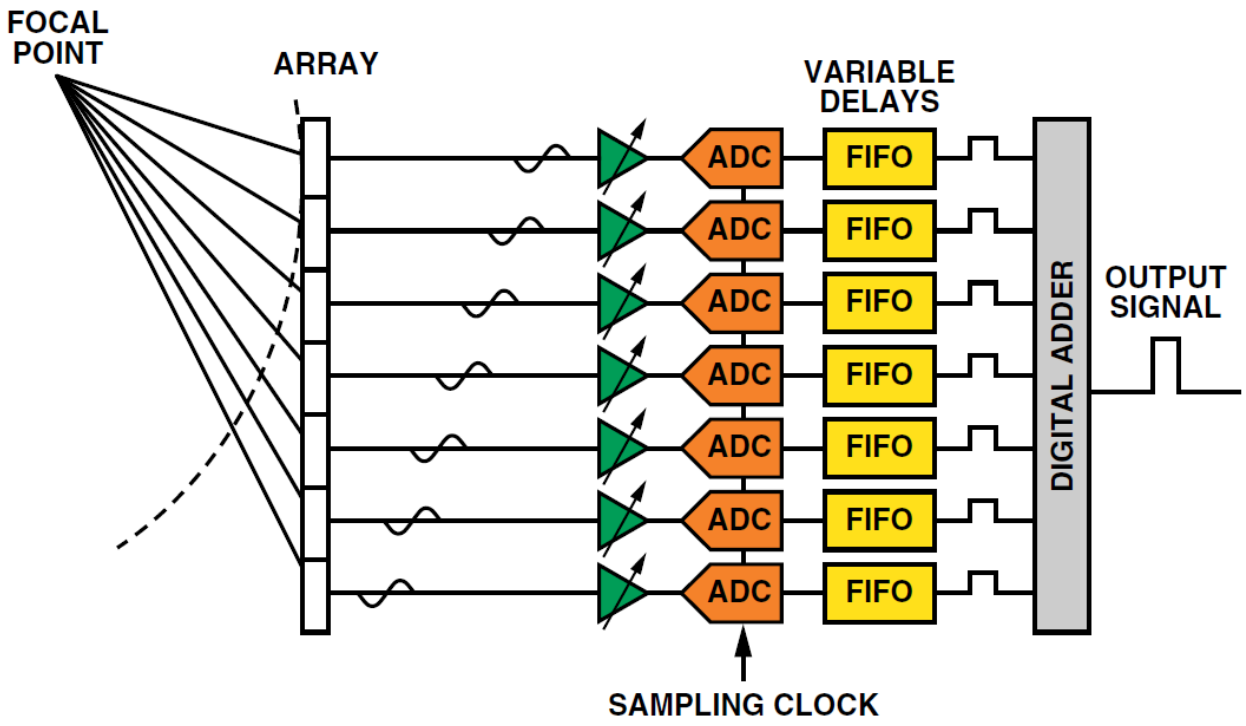
Beamformer History

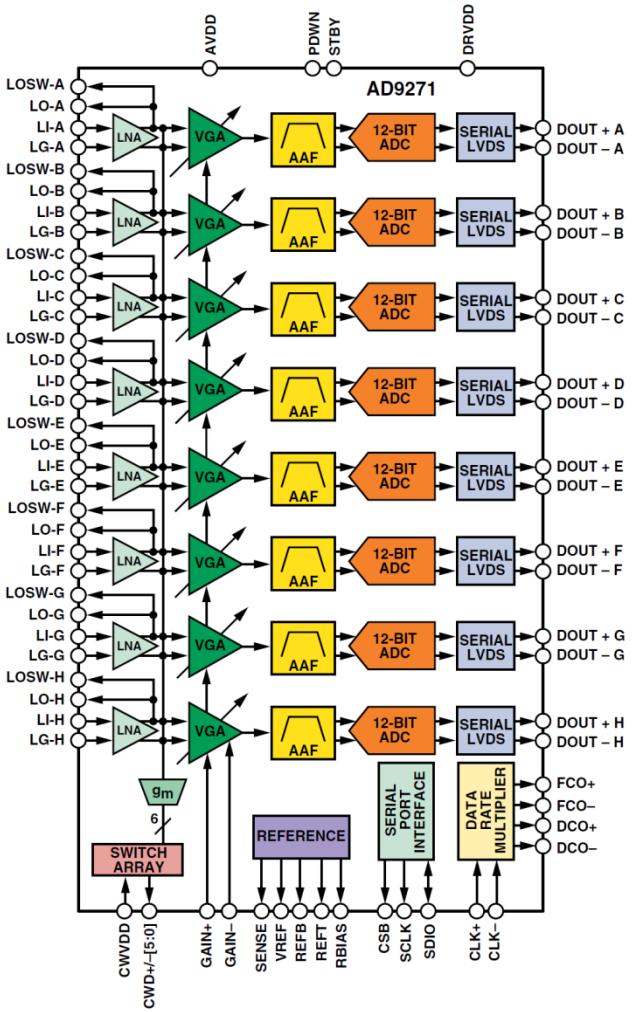
- Before the mid-70s
  - Single element scanners, no beamformer necessary
- 1975 -1980
  - Array based systems
  - Analog beamformation
  - Typically 32 channels
- Mid 1980s
  - High channel count systems (High = 128)
- Early 90s
  - Digital beamformation

Analog Beamformer



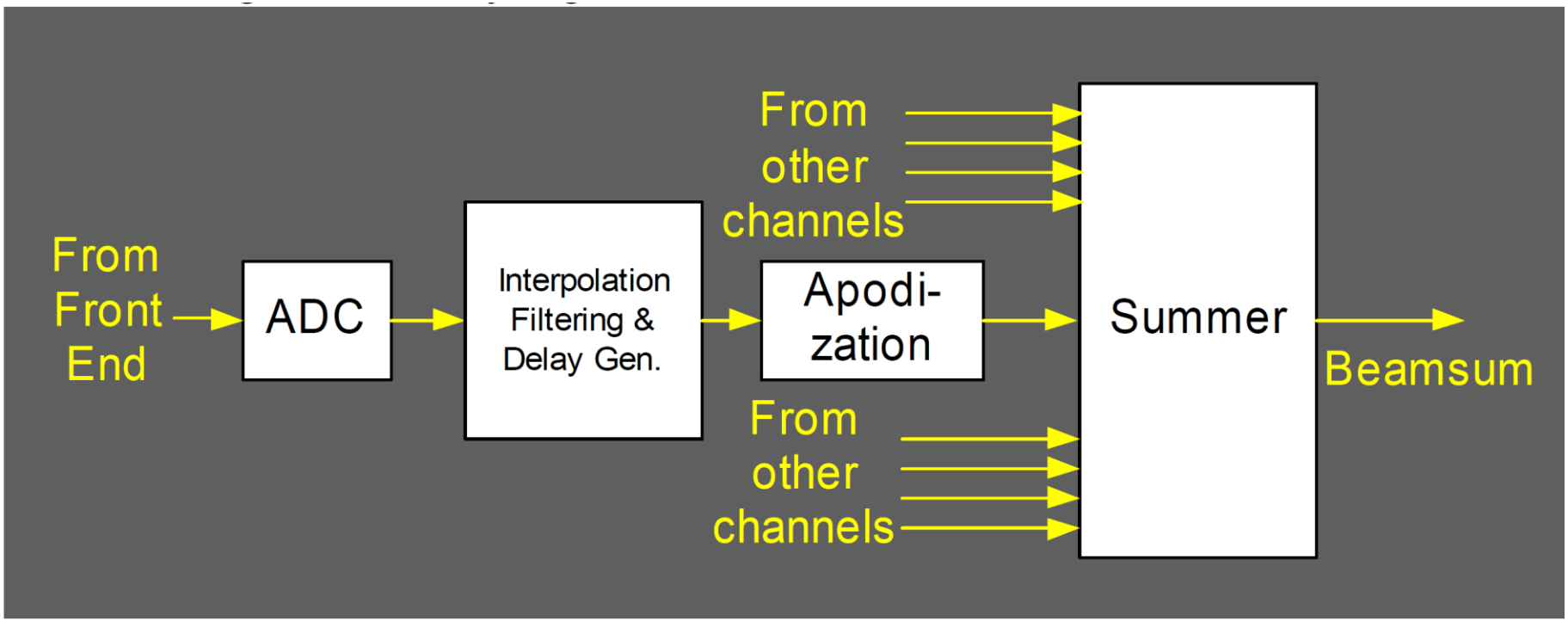
Digital Beamformer



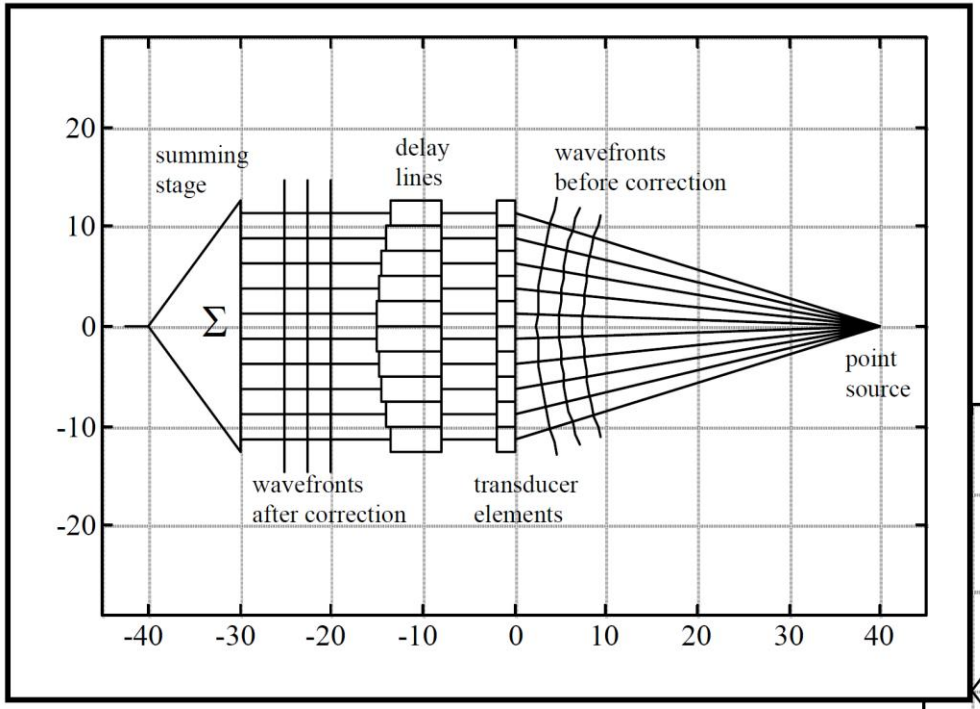


Receive Beamformer Functions

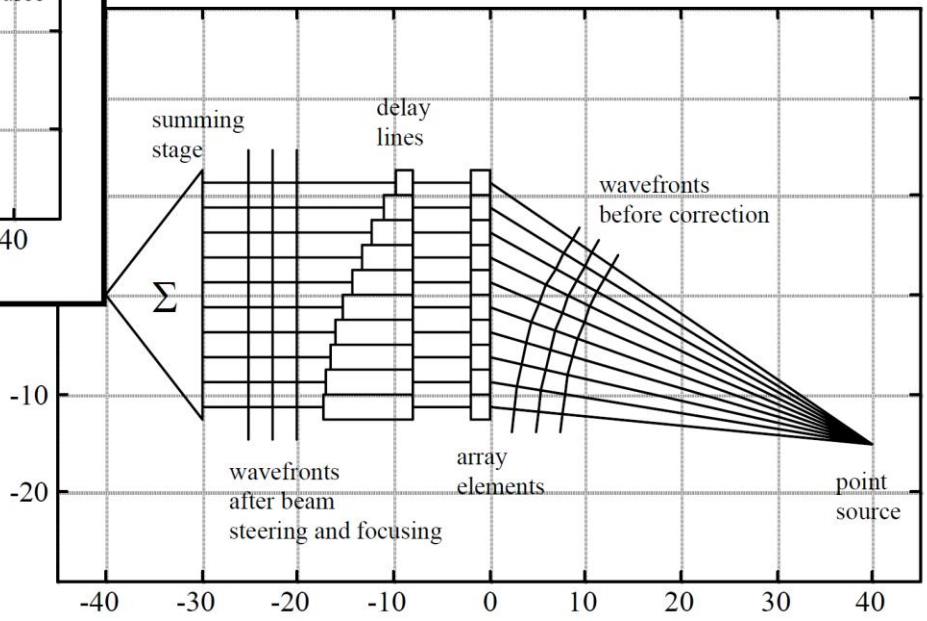
- Delay generation, dynamic and steering delays
- Apodization
- Summing of all delayed signals



Focusing and Steering Delays



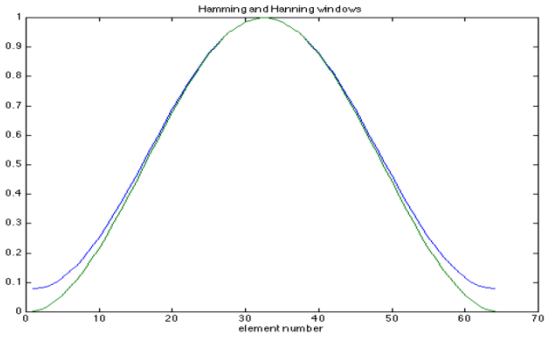
- Basic focusing type beamformation
- Symmetrical delays about phase center.

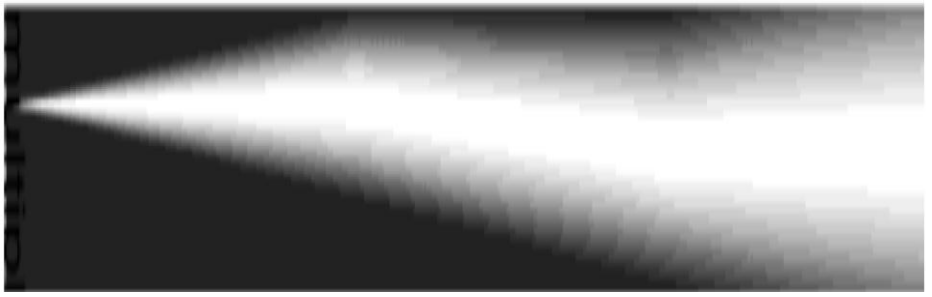


- Beam steering w. linear phased arrays.
- Asymmetrical delays, long delay lines

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.



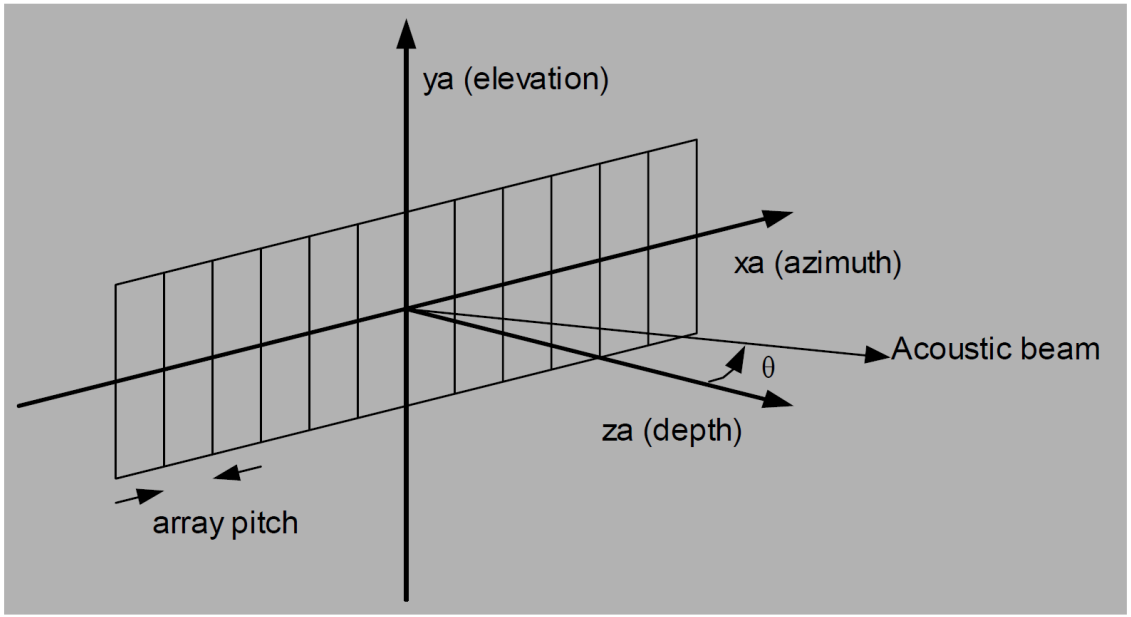


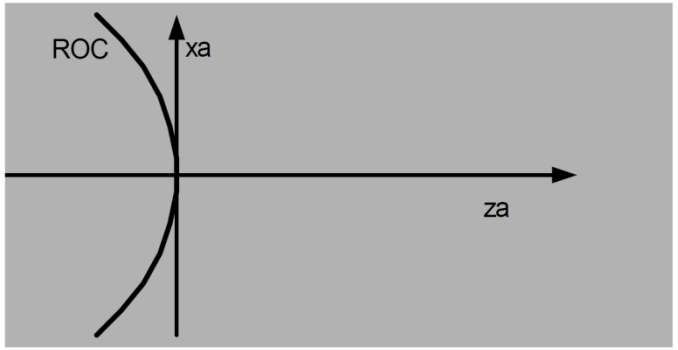
Types of Arrays and Beamformers

- 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

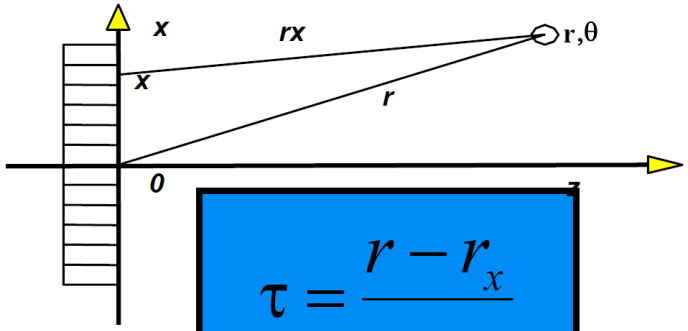
- Definition of azimuth, elevation
- Scanning angle shown, θ, in negative scan direction.
- Similar definitions for a curved array





Delay Calculation from Geometry

- Delay determination:
  - Simple path length difference
  - Reference point: phase center
  - Apply Law of Cosines
  - Approximate for practical implementation
- In some cases, split delay into 2 parts:
  - Beam steering
  - Dynamic focusing

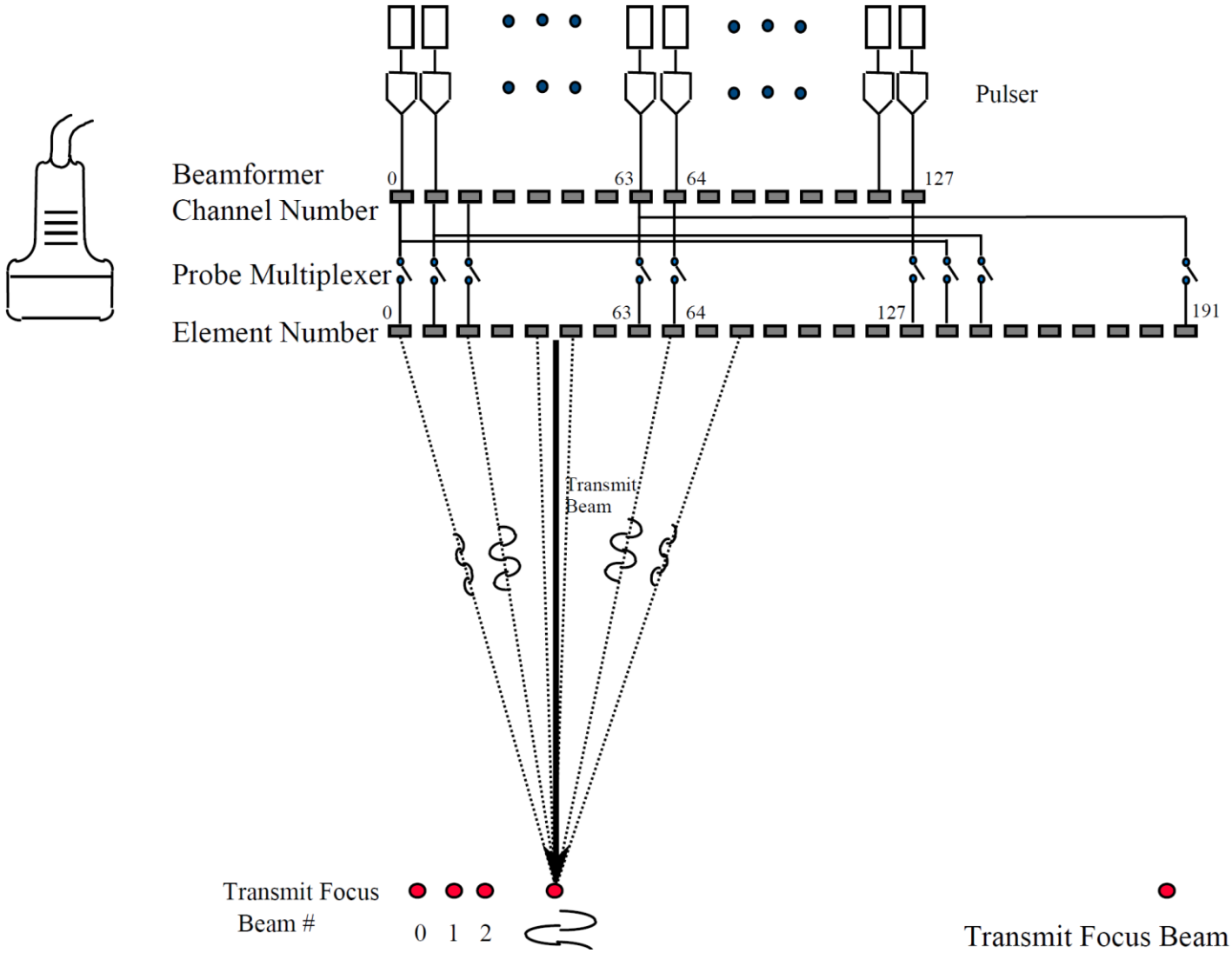


$$\tau = \frac{r - r_x}{c}$$

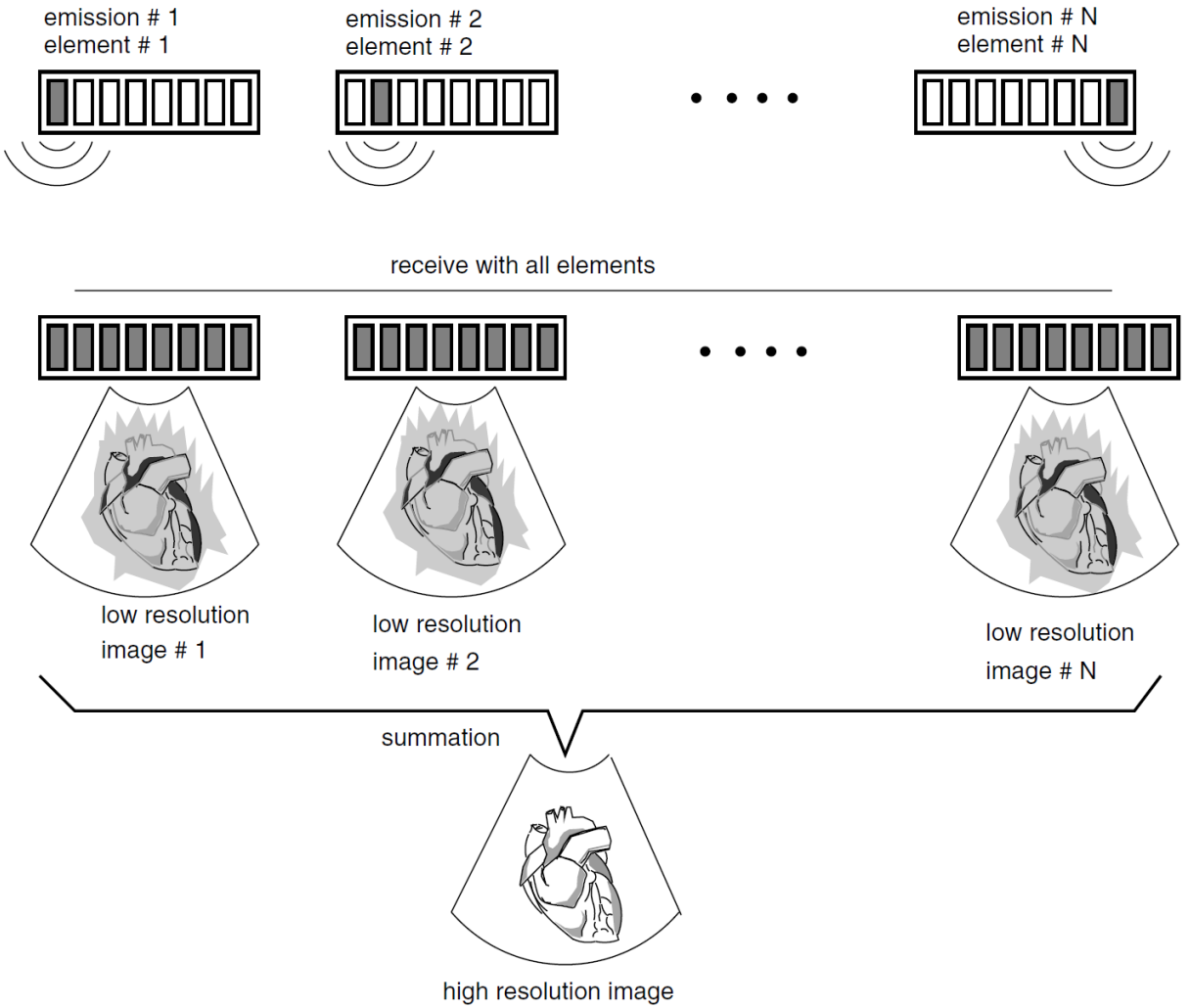
$$\tau = \frac{1}{c}\left[\sqrt{x^2 - 2rx\sin(\theta) + r^2} - r\right]$$

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

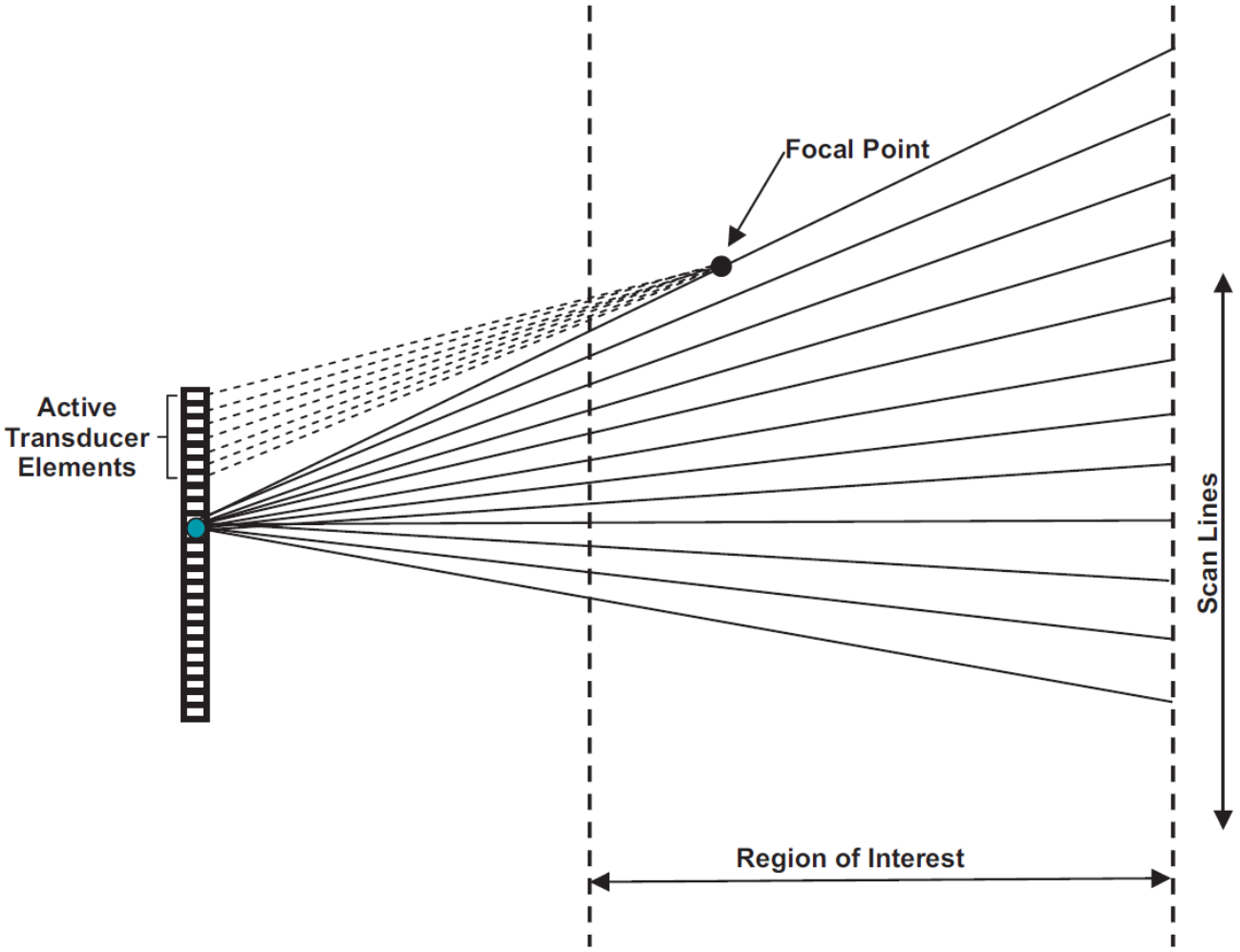
Transmit Beamforming



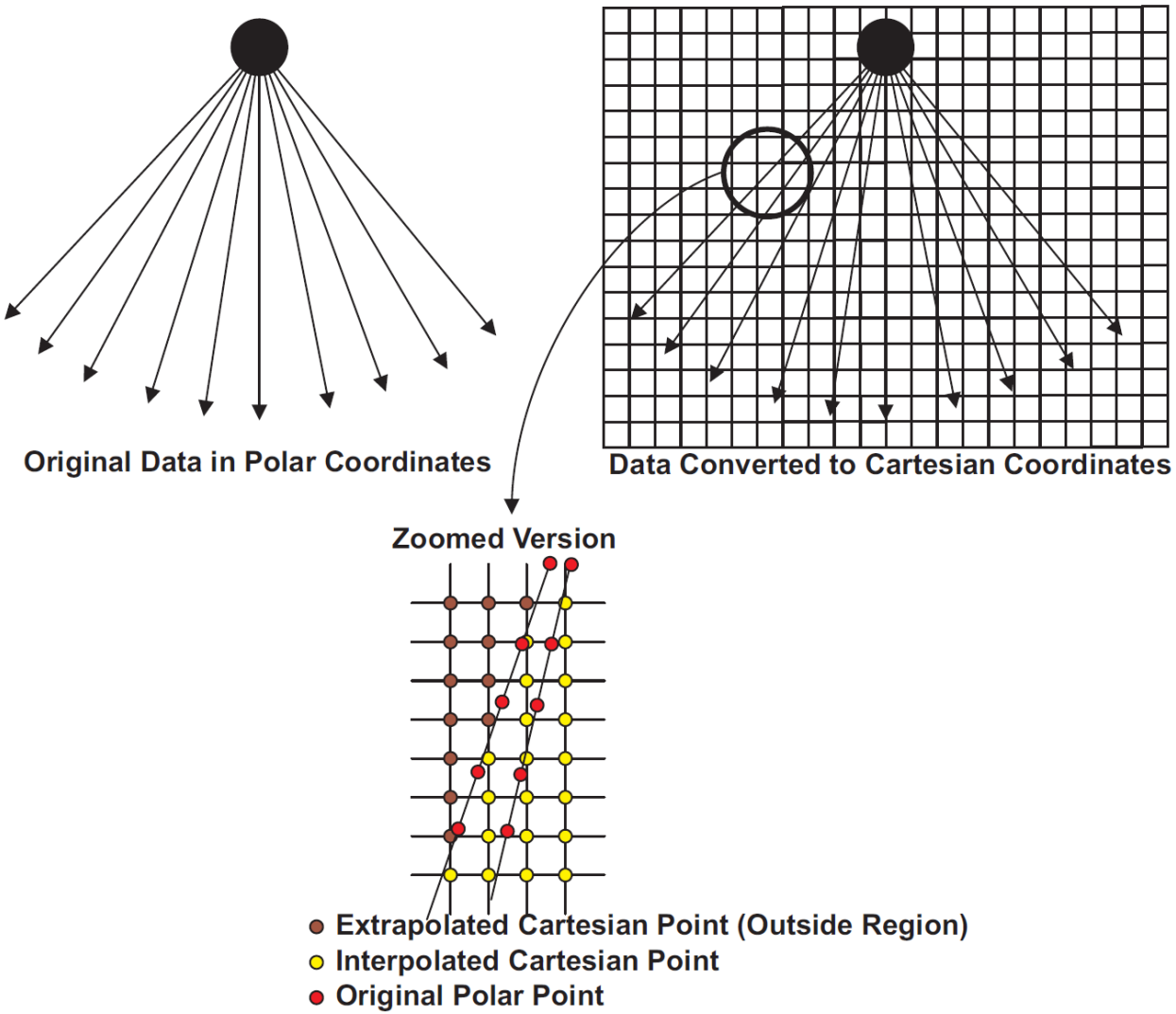
Synthetic Aperture Beamforming



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.
- Do a literature/patent search on the topic of ultrasound beamforming and scan conversion and come up with a list of all relevant references that should be the starting point for doing research on the subject.