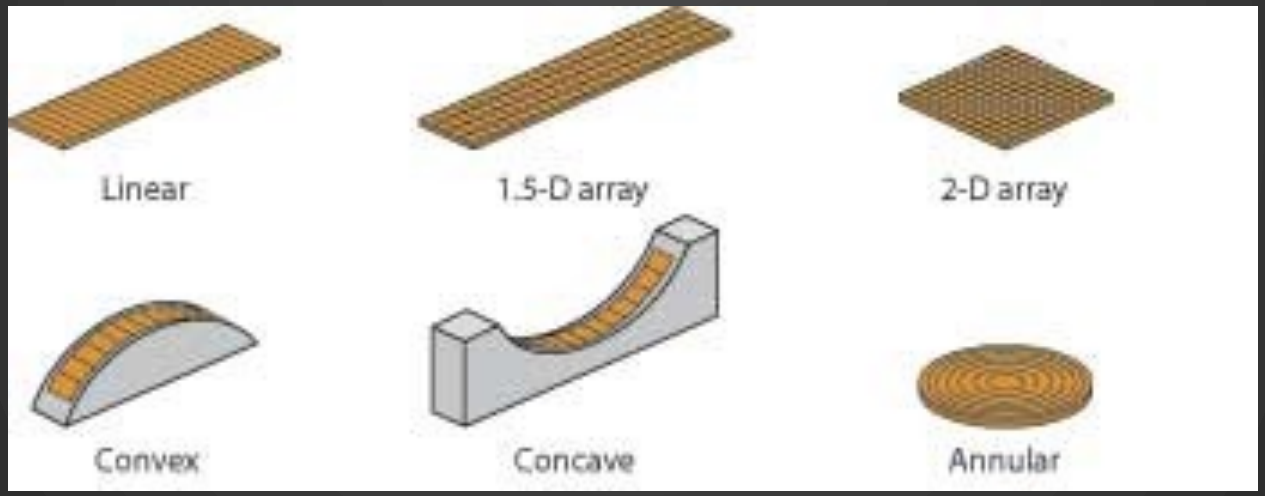


TWO-DIMENSIONAL IMAGING

TRANSDUCERS – CHAPTER 12

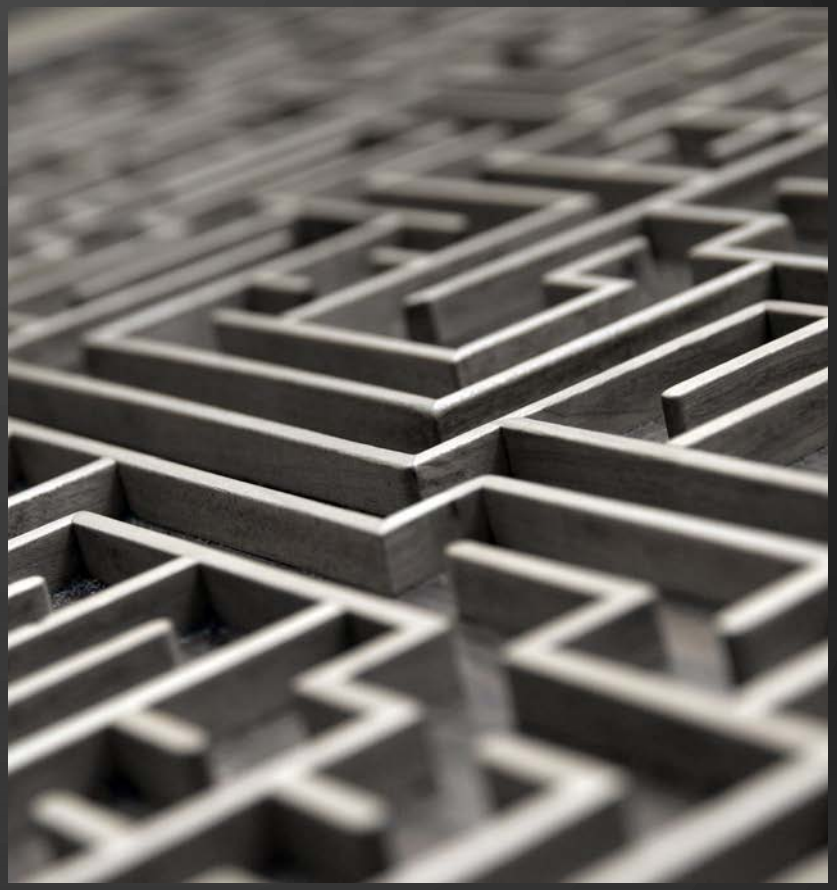
2D IMAGING DIFFICULTIES

Characteristics of sound causes problems for 2-D imaging:

1. Sound travels in a straight line

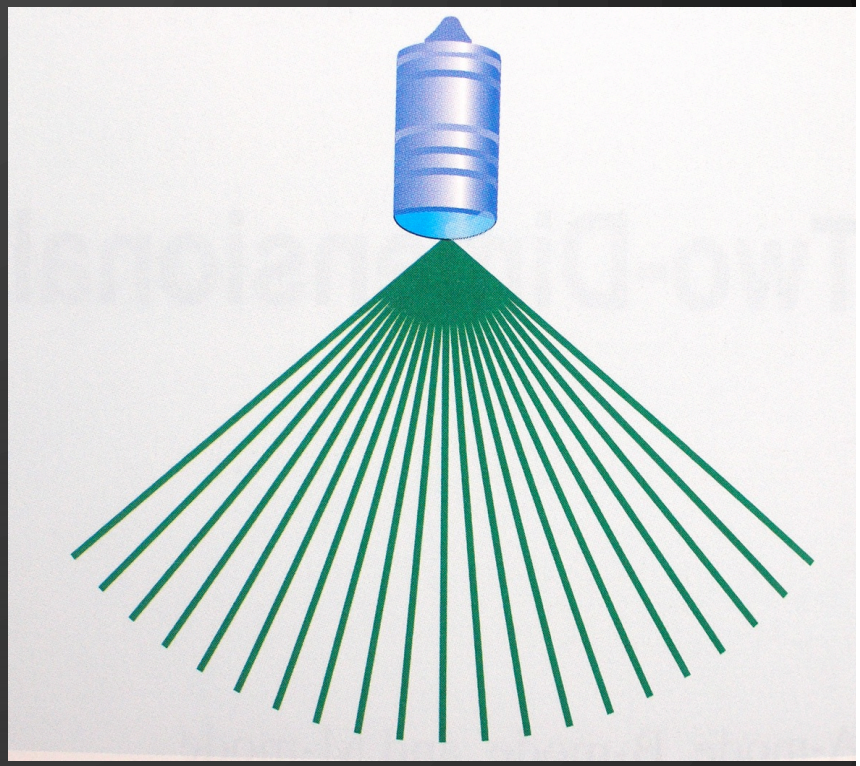
2. Narrow beam is needed for optimal resolution

Multiple pulses overcome these problems.

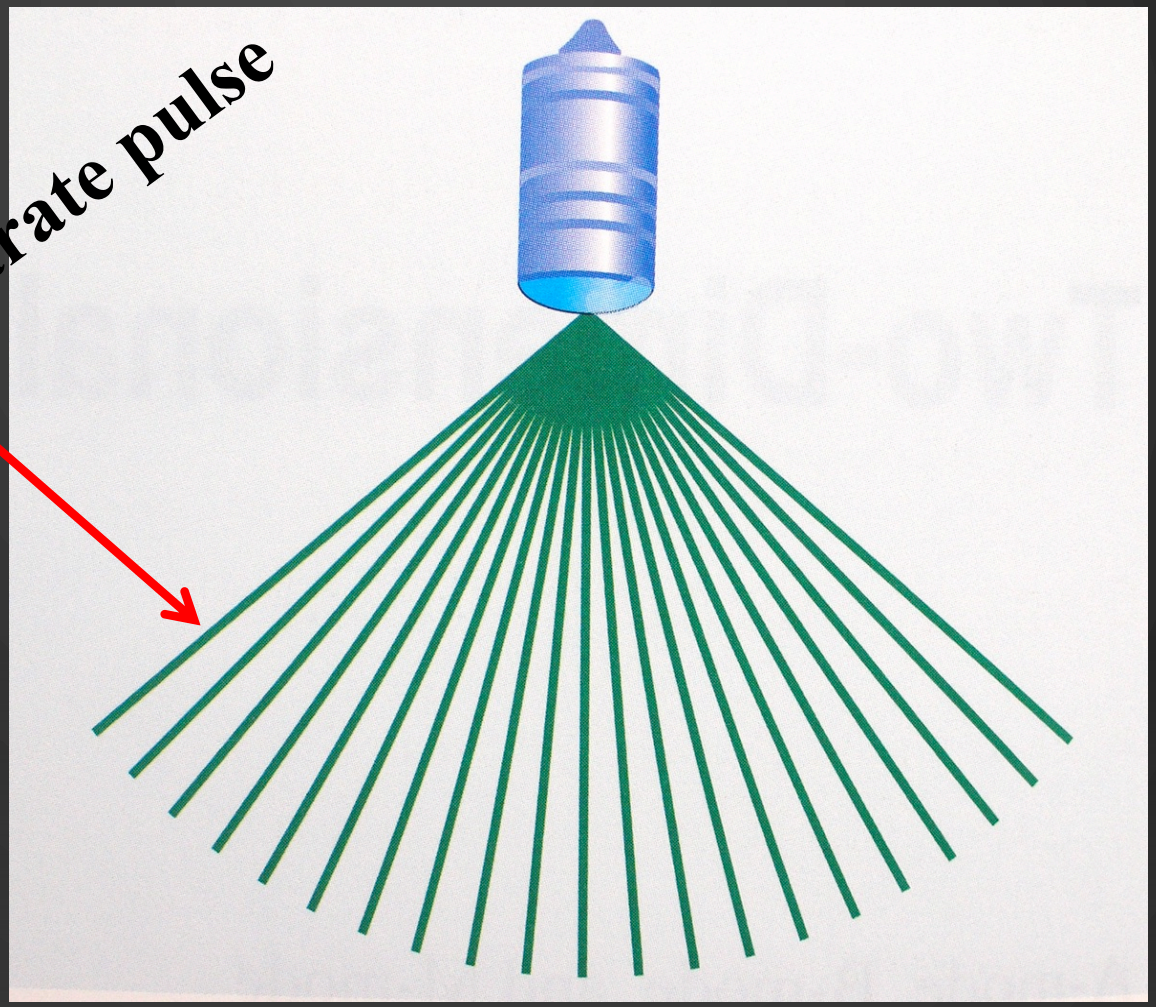


MODERN SYSTEMS

- transmits a pulse into the body
- listens
- reflections are received
- data is processed & stored
- another pulse is transmitted at a slightly different angle
- listens
- reflections are received
- data is processed & stored
- process repeats until the entire sector image is completed



Each line is a separate pulse



WHAT YOU WILL NEED TO KNOW ABOUT EACH TYPE OF TRANSDUCER:

- Shape and number of active elements
- Automatic redirection of the sound beams to create an image (beam steering)
- Methods of focusing for each beam
- Shape of the two-dimensional image
- Consequences of a damaged element or crystal

MECHANICAL TRANSDUCER (OLD SCHOOL!)

- Scan head contains one active element that is physically moved
- Crystals:
  - 1 crystal
  - Disc or coin shaped
- Steering:
  - Active element is moved by a motor, oscillating crystal or mirror through a pathway, automatically creating a scan plane.
- Focusing
  - Conventional/fixed: curvature of the PZT or an acoustic lens focuses the beam at a specific depth
    1. **internal focusing** (curved crystal)
    2. **external focusing** (acoustic lens)
  - Focusing occurs in vertical and horizontal planes

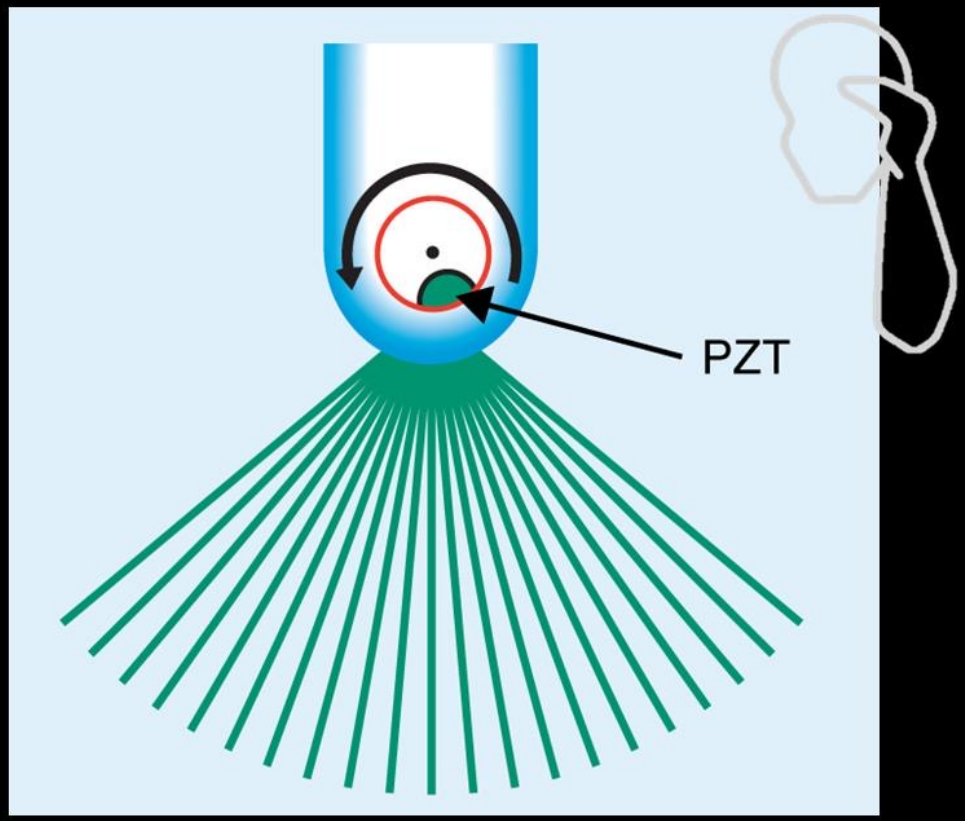
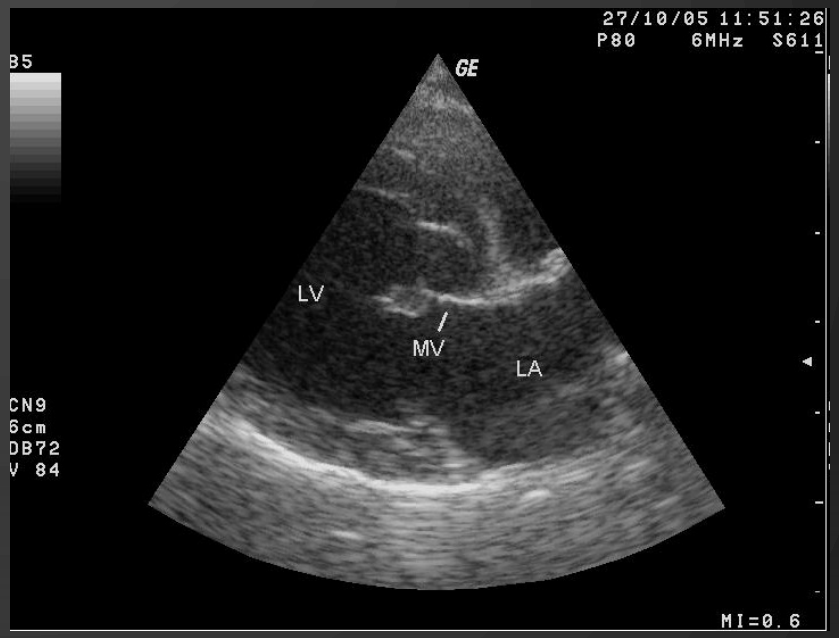


Fig. 12.3

With a mechanical transducer, the PZT crystal is **physically moved to create the** image.

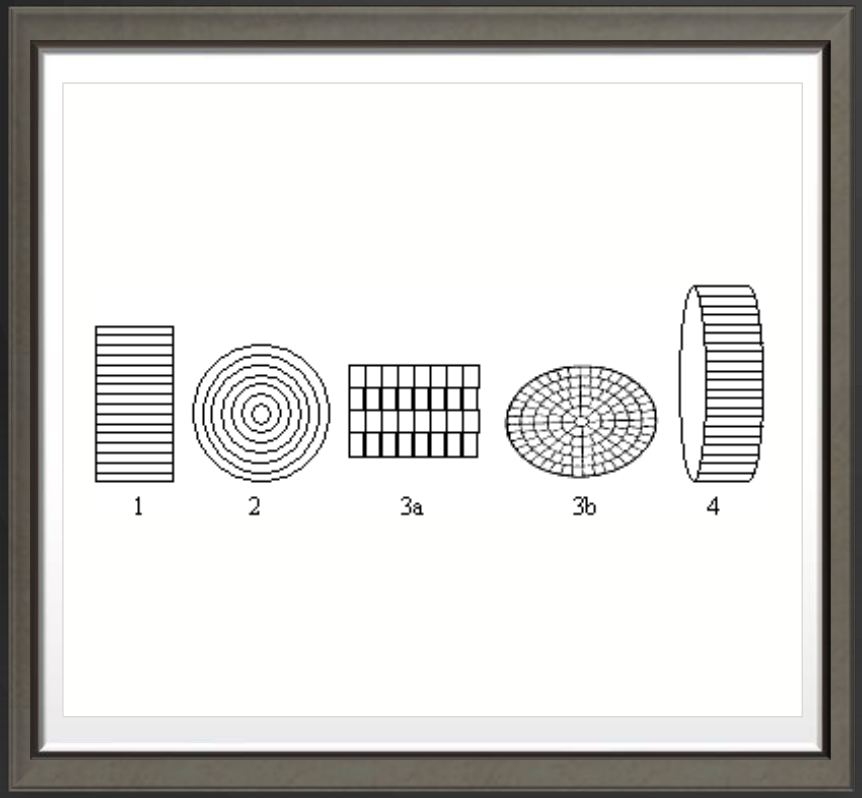
MECHANICAL SCANNING

- Image shape:
  - sector
- Defective crystal:
  - destroys entire image



MECHANICAL TRANSDUCERS

ARRAY TRANSDUCERS - MODERN



- **Multiple active elements from** a single PZT cut into separate pieces
- **Each element has a wire to its own electronic circuitry**
- **Channel is the combination of**
    1. **an active element**
    2. **wire**
    3. **system electronics**

TYPES OF ARRAY TRANSDUCERS

TYPE	ARRANGEMENT
Linear	Active elements are in a straight line
Annular	Elements are arranged as circular rings with a common center
Convex	Active elements are arranged in a bowed (arched) line; Also called a curved or curvilinear

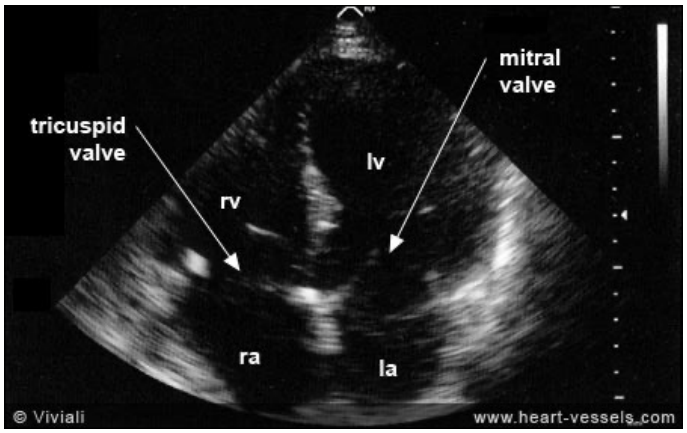
LINEAR PHASED ARRAY

- Compact with a small footprint. (footprint is the face of the transducer that comes into contact with the skin)
- Transducer is generally square shaped
- Crystals:
  - 100-300 elements arranged along the face of the probe.
  - Placed side by side
  - Each element is a narrow rectangle

Fig. 12.5

Elements of a linear phased array transducer are rectangular.

LINEAR PHASED ARRAY



- Image shape: fan or sector shaped image
- Beam Steering: image is built with an electronic steering process called **phasing**.
  - Sound beams are electronically transmitted in different directions without use of moving parts

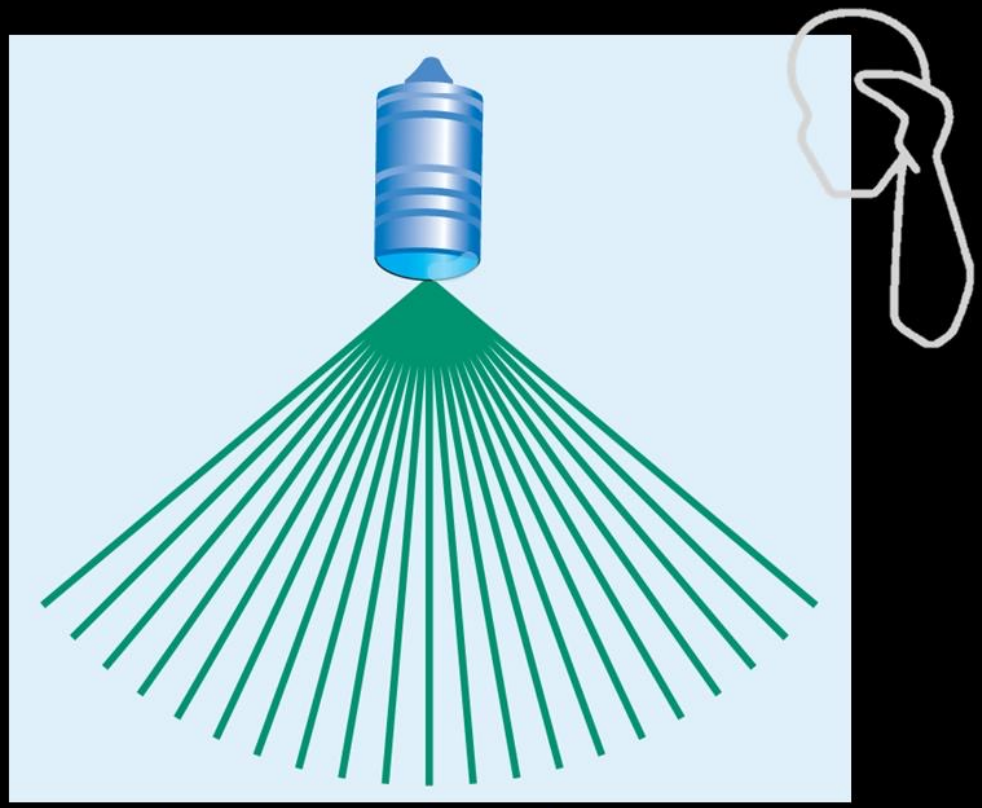


Fig. 12.6

With a phased array transducer, the sound beam is steered electronically without the use of moving parts.

LINEAR PHASED ARRAY

- Beam Focusing:
  - Focused electronically
  - Sonographer can modify the depth and amount of focusing of the sound beam
  - Multi-focusing capability
    - Can transmit multiple beams down the same scan line
- Damaged crystal:
  - Inconsistent or erratic beam steering and focusing.
  - Cannot effectively be determined by looking at an image.

LINEAR PHASED ARRAY

- **All elements must be fired to create each sound beam**
  - 64 channels all are excited and result in 64 small wavelets
  - They interfere constructively and destructively creating a single sound pulse with specific characteristics.
- The overall pattern of the electrical signals from the u/s system determines the sound beam's direction & focus.

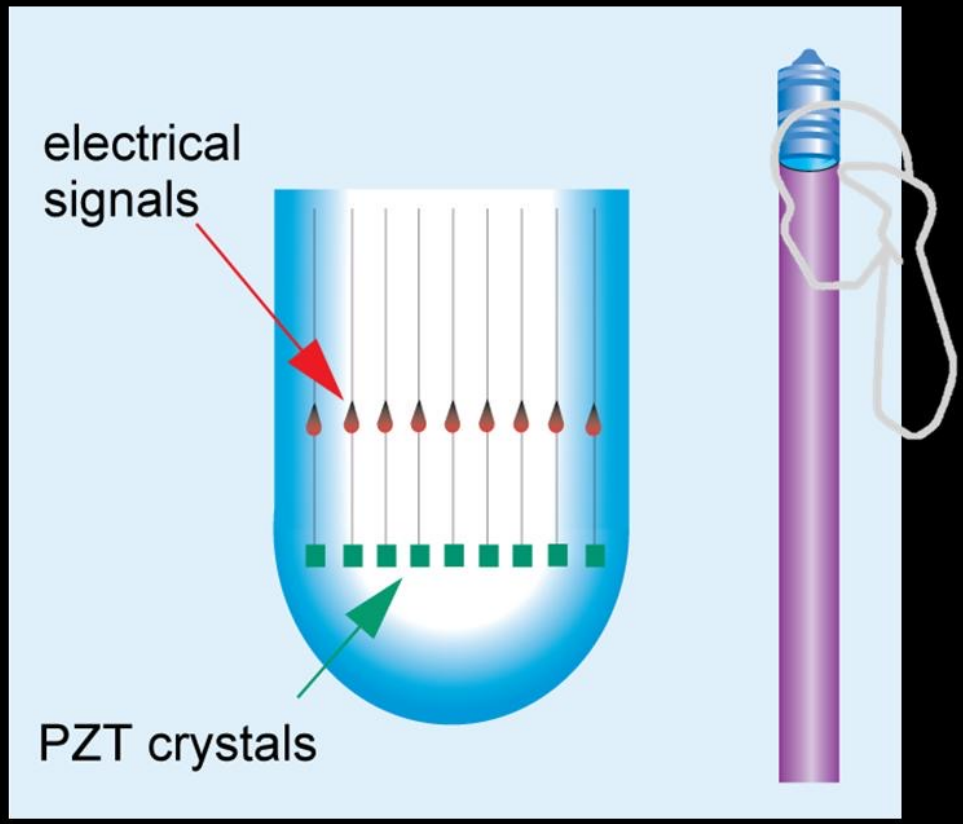


Fig. 12.7

Each active element creates a small sound wavelet. The wavelets interfere and form a single sound beam. The electrical signals will arrive at each of their respective active elements at exactly the same time. This specific electrical pattern creates a sound beam that is directed straight down.

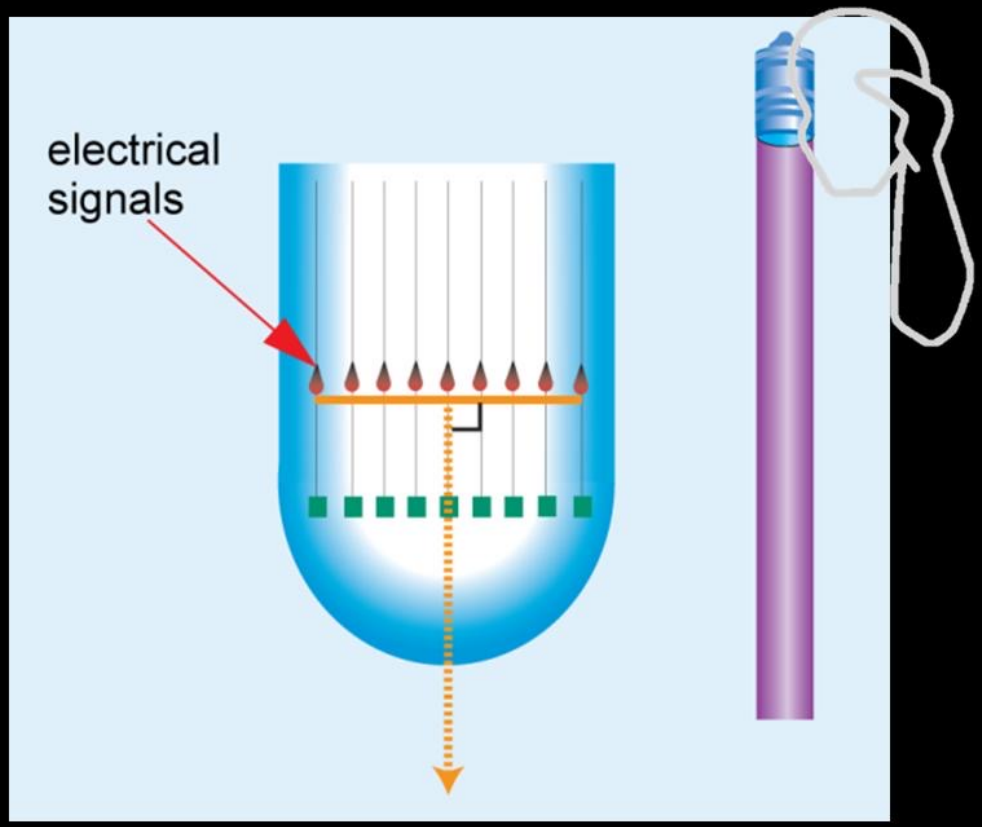


Fig. 12.8

The slope of the electrical spike line determines the direction that the sound beam is steered.

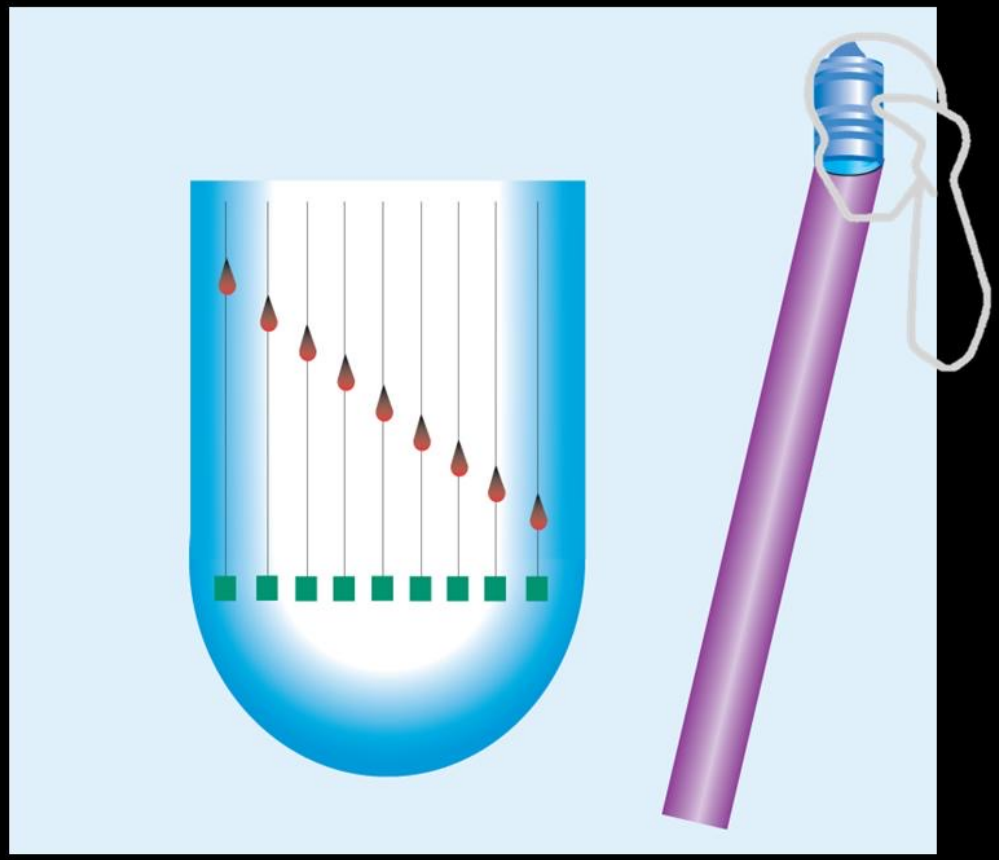


Fig. 12.9

Beam steering to the left is achieved with this electrical pattern in a phased array transducer.

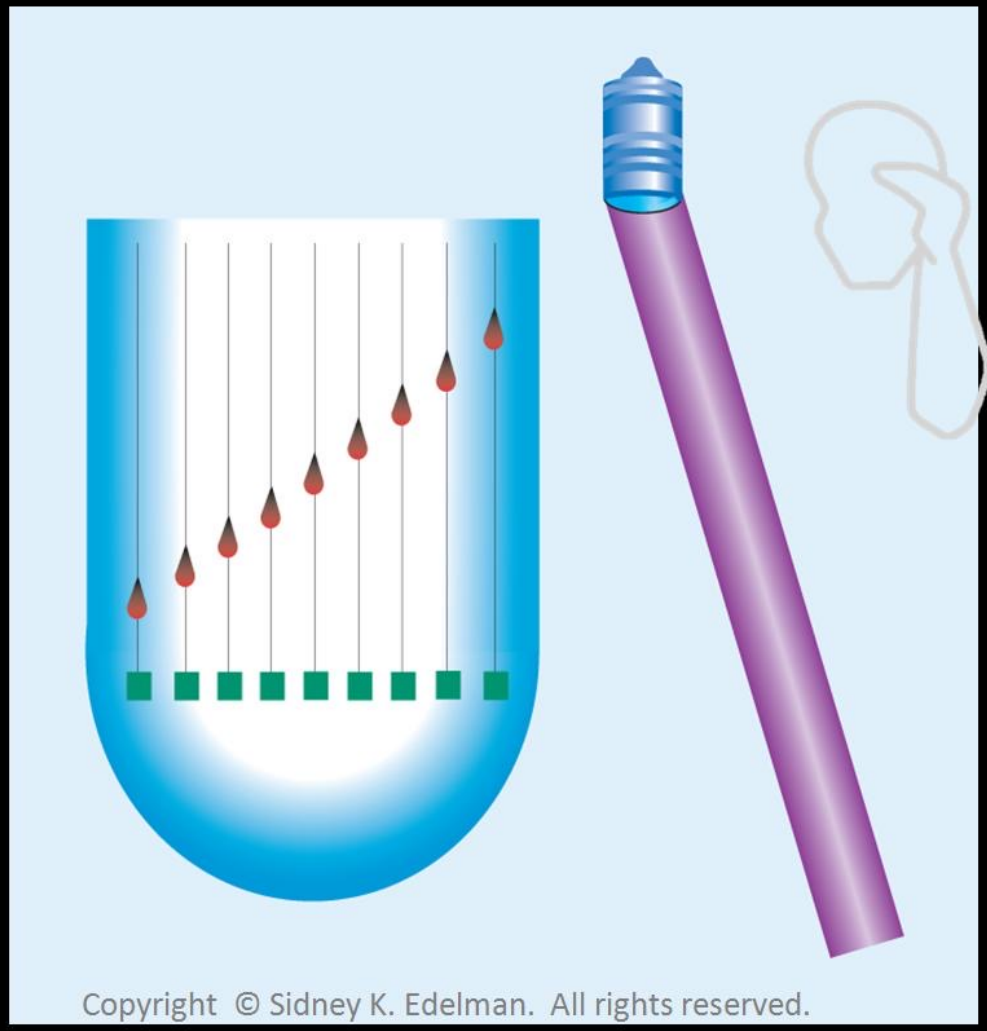


Fig. 12.10

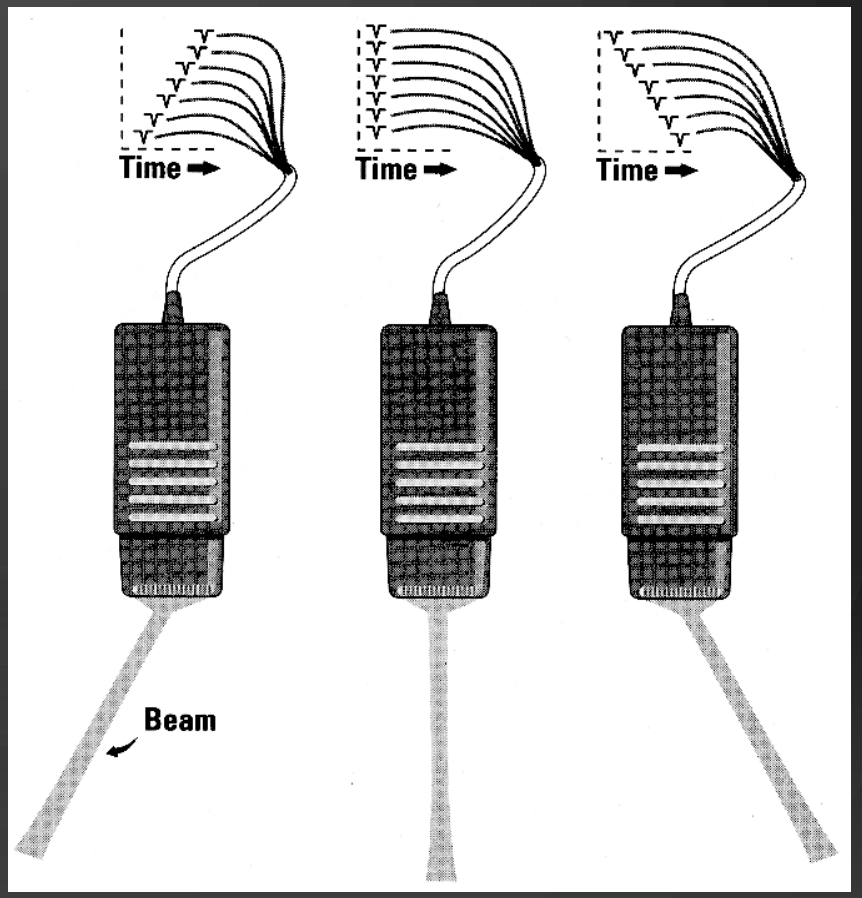
Beam steering to the right is achieved with this electrical pattern in a phased array transducer.

BEAM FORMER

- Creates the electronic firing patterns for a phased array

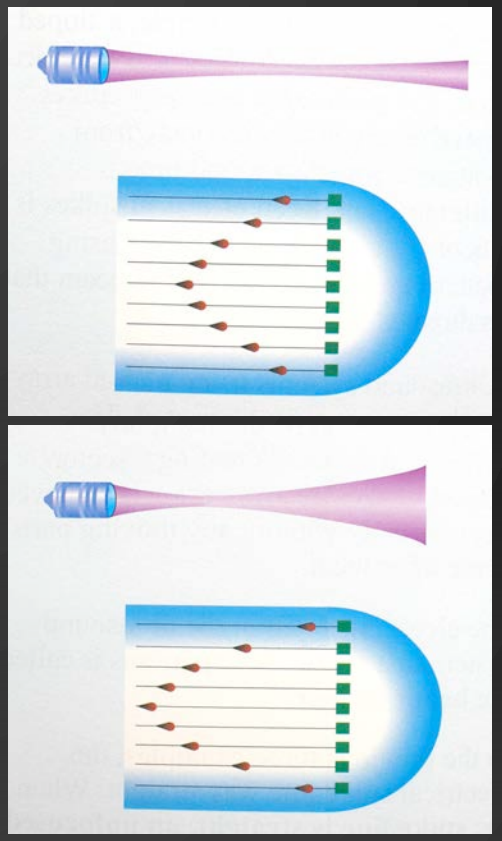
If the spiked line is straight , the sound beam created is an unfocused beam.

These beams have straight spiked lines and are all <u>unfocused.</u>



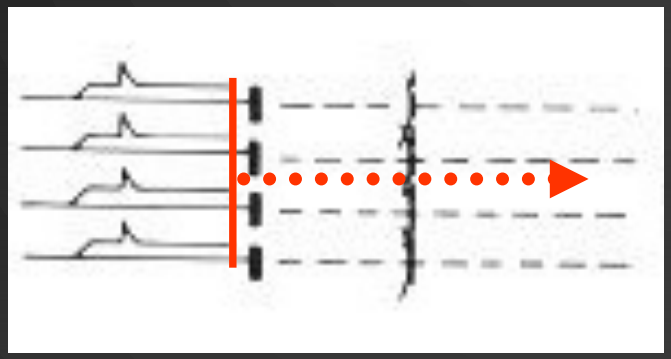
TRANSMIT FOCUSING WITH LINEAR PHASED ARRAY

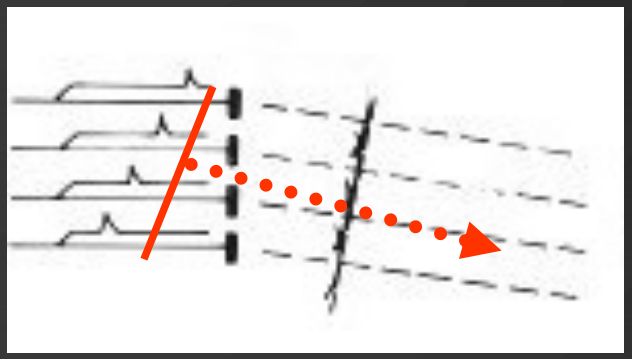
- A focused beam is created when the **electrical pattern is curved**
- A shallow or deep focus is created simply by altering the electricity (changing the curved pattern) emanating from the beam former



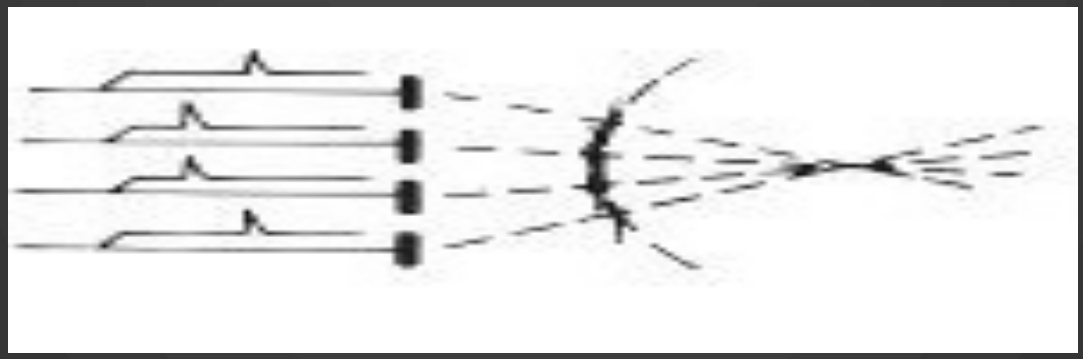
HOW DO I FIGURE IT OUT?

- If a firing pattern has a slope, then the beam is steered
  - Draw a line along the firing pattern of the beam.
  - Draw another horizontal line out from that pattern and that will display the direction of steering.

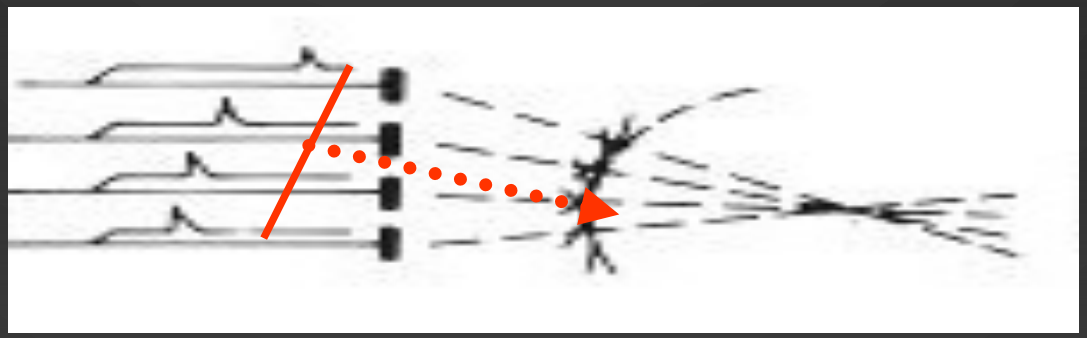




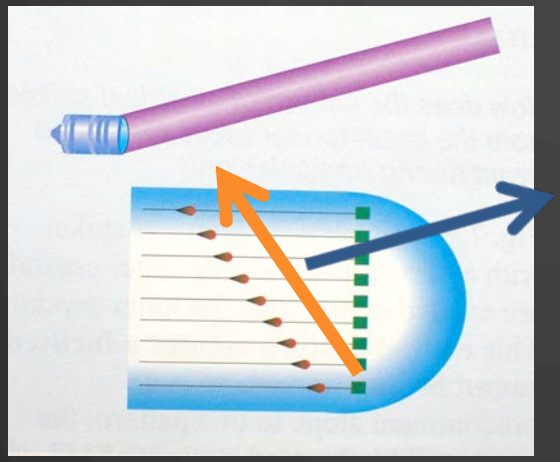
- If the firing pattern is curved, then the beam is focused.

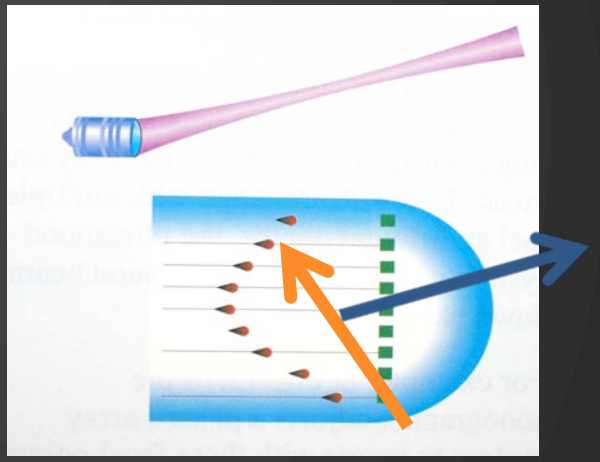


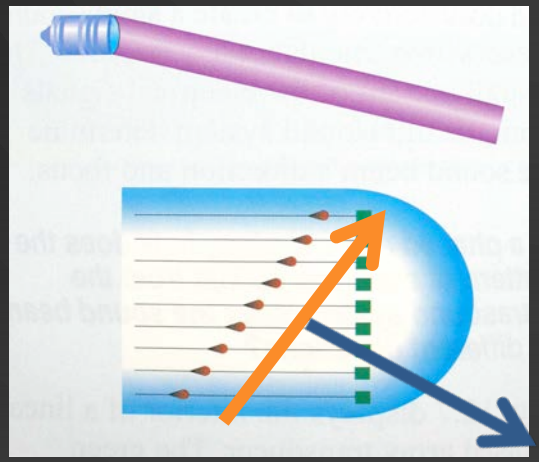
- If the firing pattern is curved and has a slope, then the beam is steered and focused.

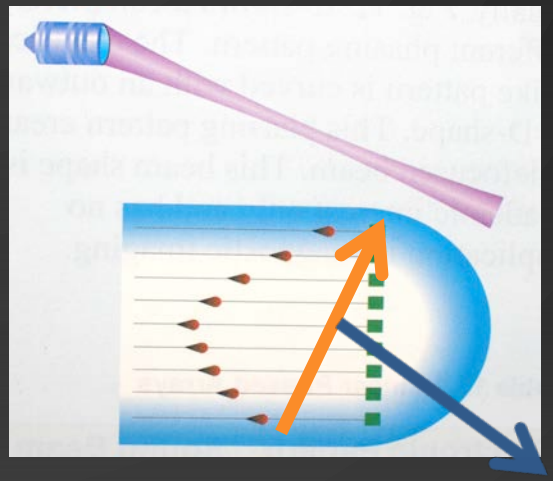


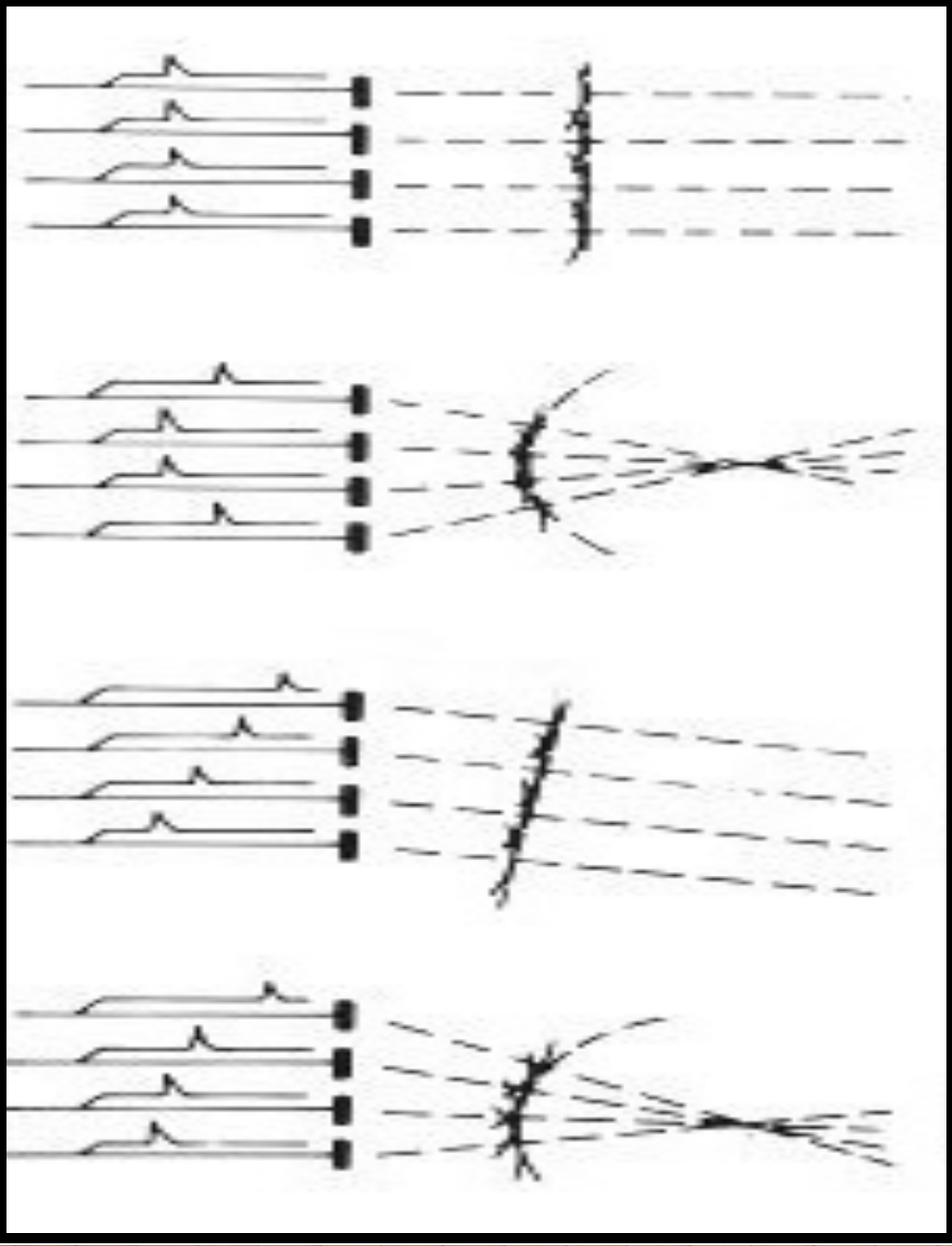
PHASING AND FOCUS











Sound beam directed straight line

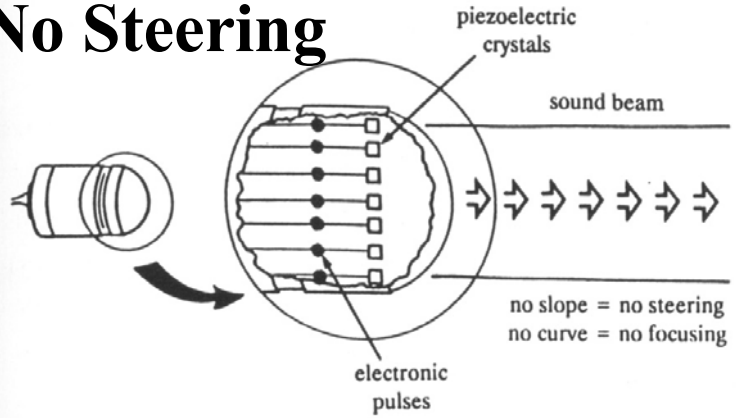
Focused Beam

Beam steered downward

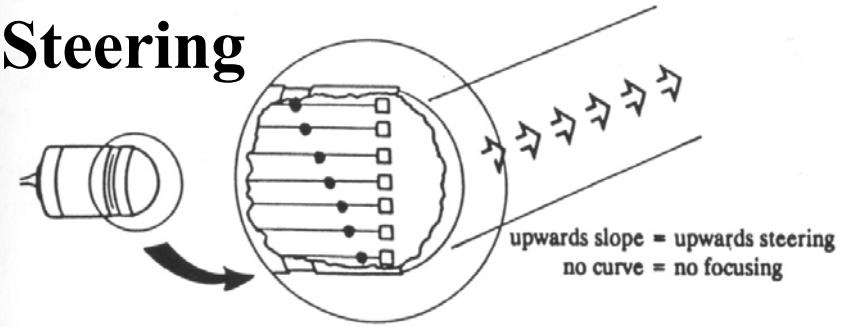
Beam focused and steered downward

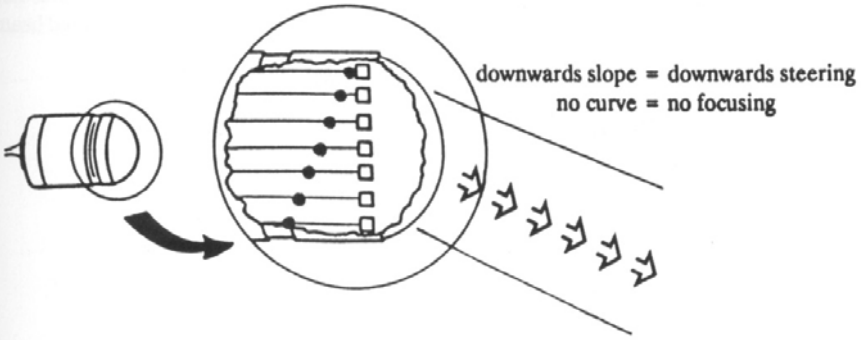
Note the differences:

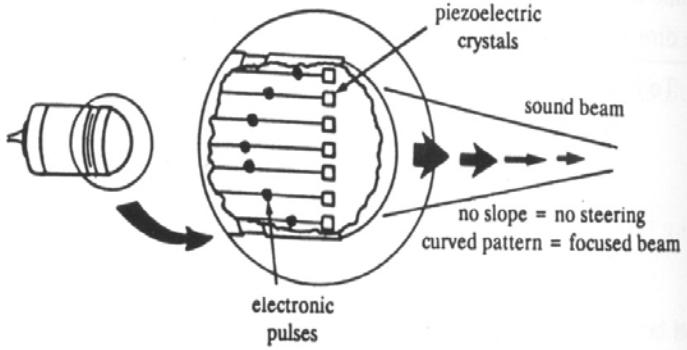
No Steering



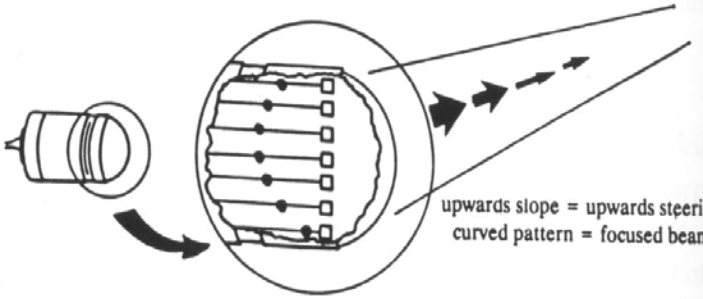
Steering

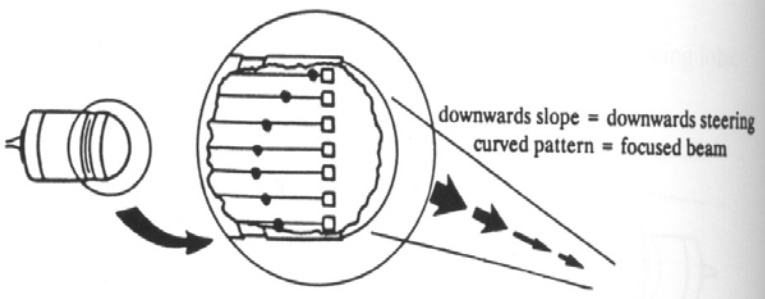






Steering & Focusing



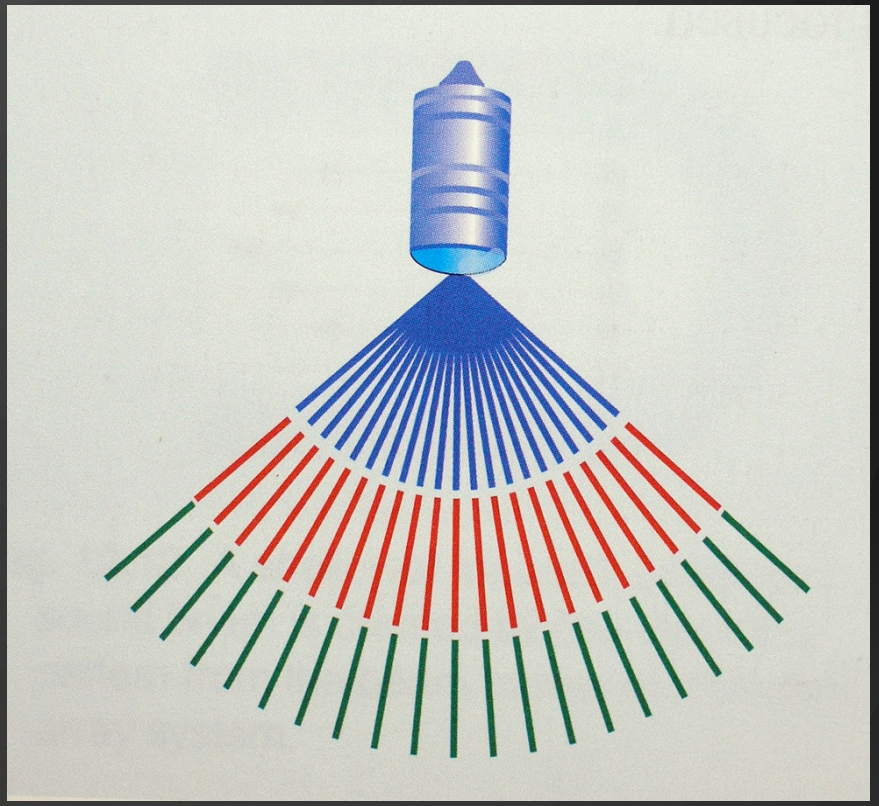


LINEAR PHASED ARRAY

Electronic Pattern	Sound Beam
Slope	Steering
Curvature	Focusing

MULTIPLE TRANSMIT LINEAR PHASED ARRAY

- A sound beam has a single focus
- To create an image with **multiple foci at different depths** the system must send multiple sound beams down each scan line.
- For 3 focal points each scan line must have 3 separate pulses, one for each focal zone



DYNAMIC RECEIVE FOCUSING

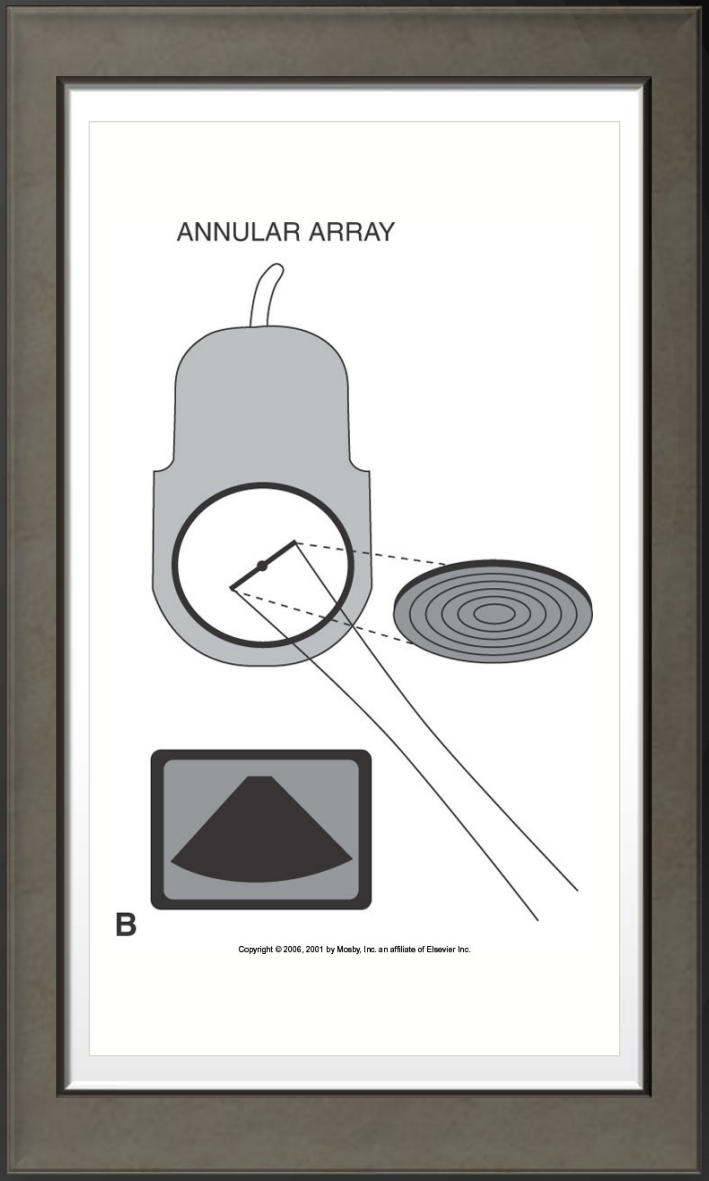
- AKA dynamic aperture
  - (performed by the machine)
- As the returning sound beam strikes the transducer, the size of the transducer surface listening for echoes is varied.
- This is accomplished by varying the number of elements used to receive the reflected signal

DYNAMIC RECEIVE FOCUSING

- Echoes arising early (from superficial structures) are received using only a few crystals from the array.
- As echoes return from deeper structures, the aperture is increased. More and more elements are used to listen.
- This optimizes our image quality

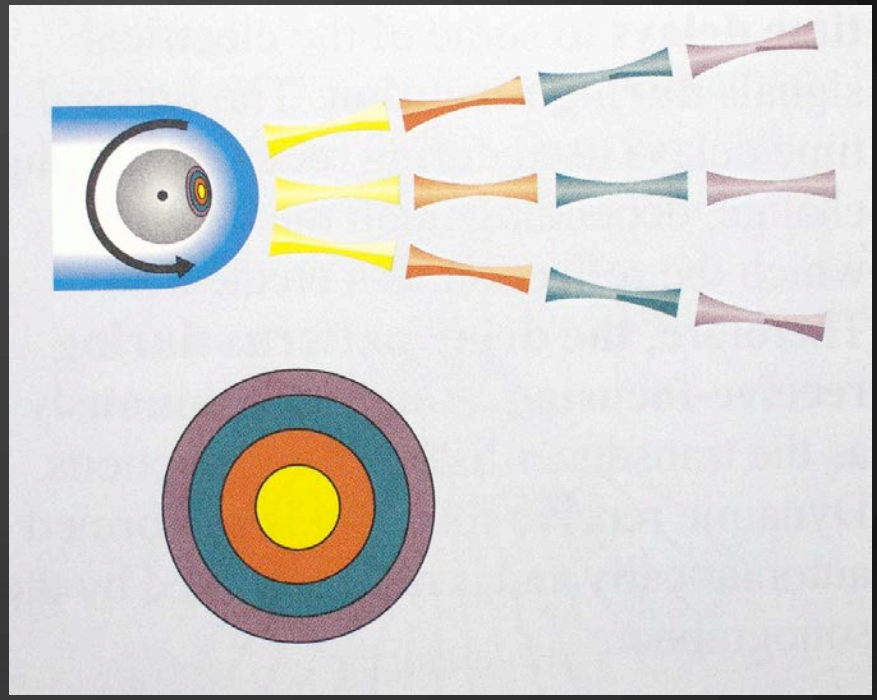
ANNULAR PHASED ARRAYS

- There are multiple ring-shaped elements with a common center.
- Beam Steering – is mechanical
- Beam Focusing – multiple transmit focal zones



ANNULAR PHASED ARRAYS

- Multiple transmit focus
- The inner, smaller elements create near field focus
- The larger elements create the far field focus
- By using all the elements multiple transmit focal zones are created



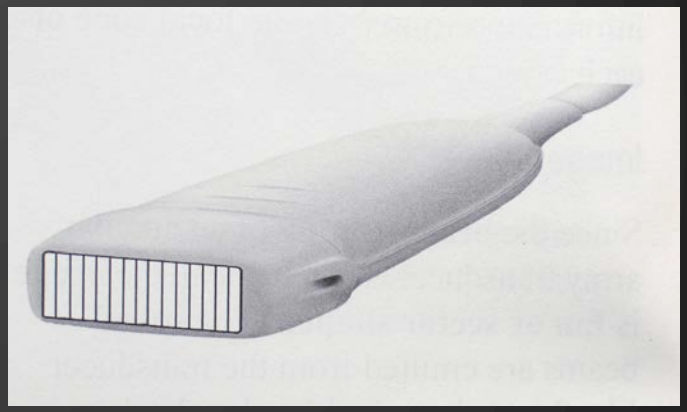
- ***REMEMBER- smaller diameter crystals create shallow focus beams , while larger diameter crystals create deeper focus beams.**

ANNULAR PHASED ARRAYS

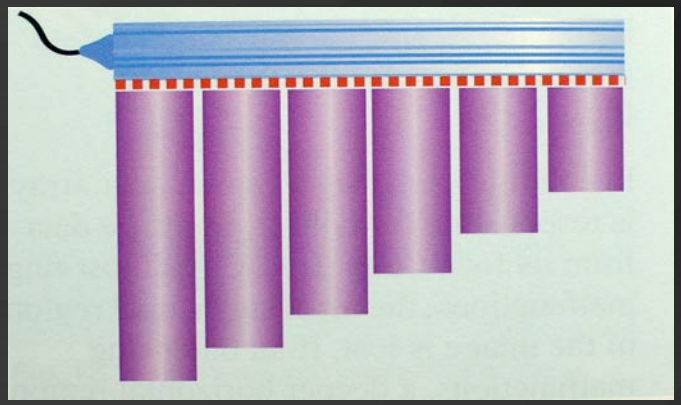
- Image Shape: Fan or sector shaped
- The final image is a composite **from only the focal zone of each crystal**
- Damaged PZT will create a **horizontal image loss** at a depth consistent with the damaged PZT, unlike a single element that might not show any image at all

LINEAR SEQUENTIAL ARRAYS

- Crystals:
  - 120 to 250 rectangular strips of PZT material located side by side
  - Each PZT is about l wavelength in width

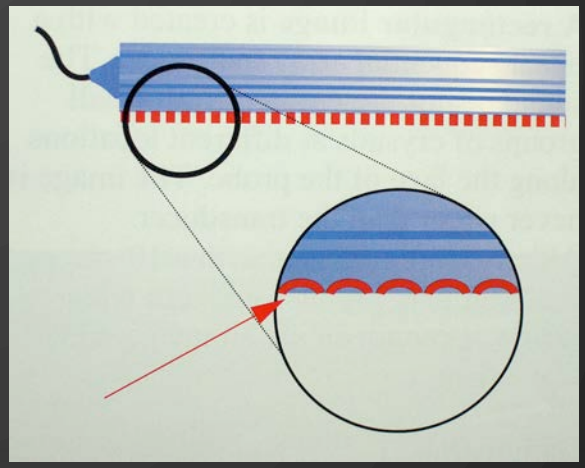


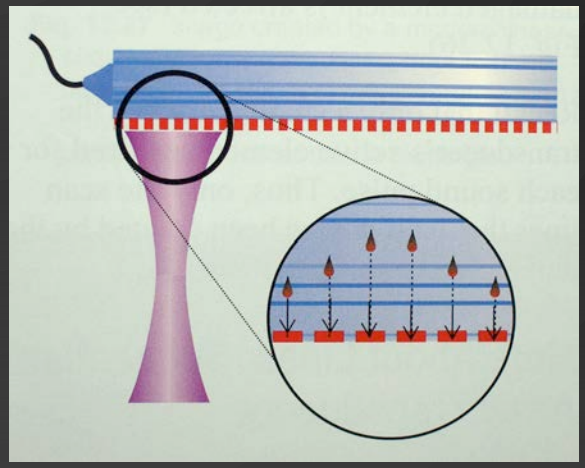
- Beam Steering:
  - The elements are fired in groups
    - The first 5 then 6-10 then 11-15 and so on



LINEAR SEQUENTIAL ARRAYS

- Beam Focusing:
  - Originally focused with a lens in front of the elements resulting in a fixed focus
  - Modern equipment are electronically focused





LINEAR SEQUENTIAL ARRAYS

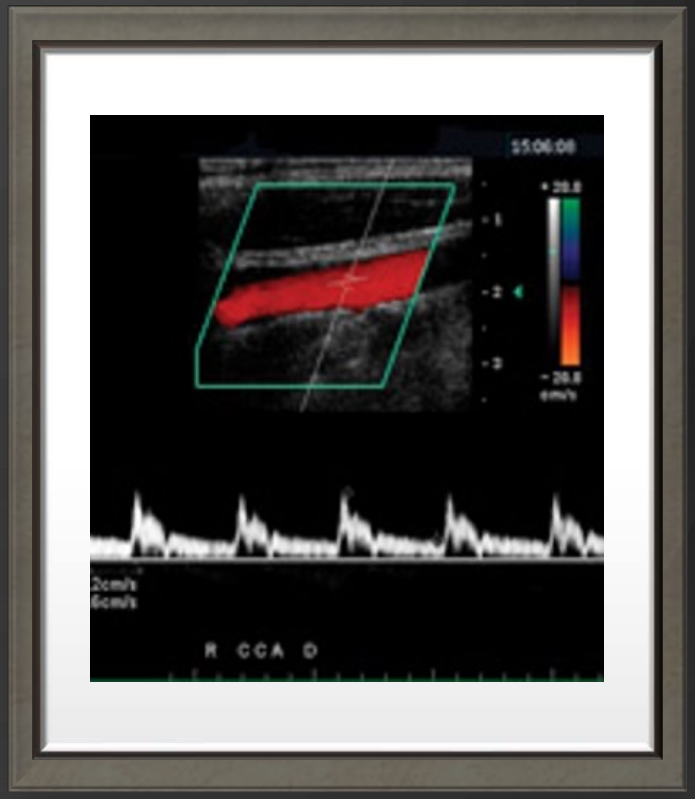
- The image shape is rectangular and never wider than the footprint of the transducer

LINEAR SEQUENTIAL ARRAYS

- Damaged crystals create a loss of image in the line that the elements are damaged

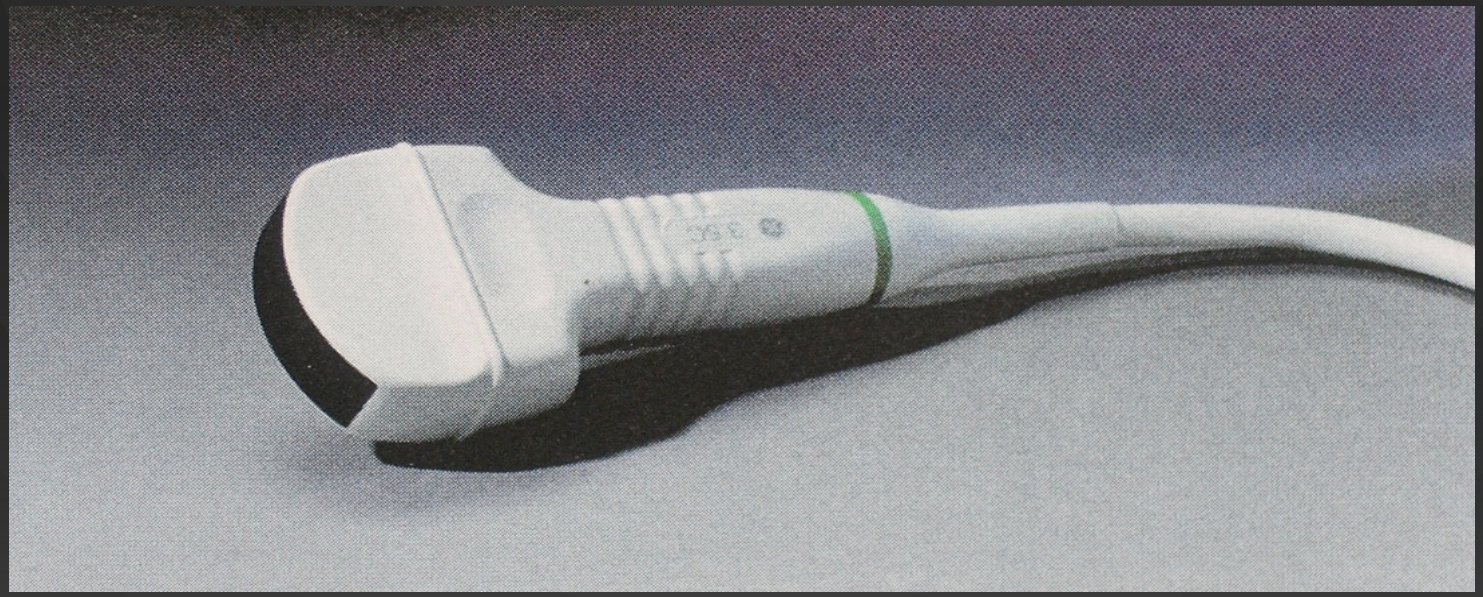
LINEAR SEQUENTIAL ARRAYS

- These images can be **steered electronically** creating a **parallelogram shaped** image
- Beam formers of phased array systems steer sound beams by introducing sloped –shaped delays in the electrical excitation spikes.
- Often used in vascular imaging to create a better reflector or to angle correct for spectral or color Doppler



CONVEX, CURVED OR CURVILINEAR ARRAY

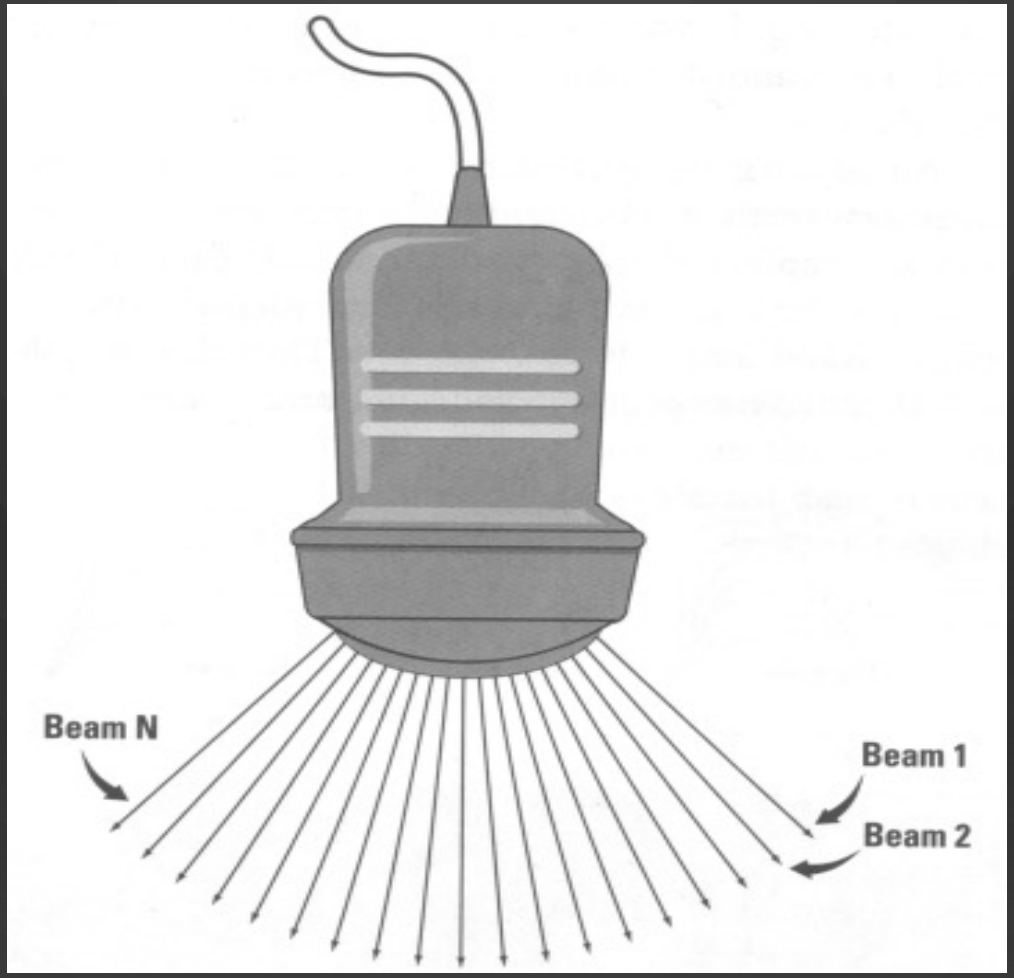
- These are basically linear transducers, but they have a curve



CONVEX, CURVED, CURVILINEAR ARRAY

- 120 to 250 rectangular strips of PZT material located **side by side**
- Each PZT is about l wavelength in width
- In convex sequential arrays some but not all crystals are fired simultaneously to create a single sound beam.
- The beams are directed straight out but are not parallel due to the arc.

The superficial region *does not* have a point. It is broad and curved.

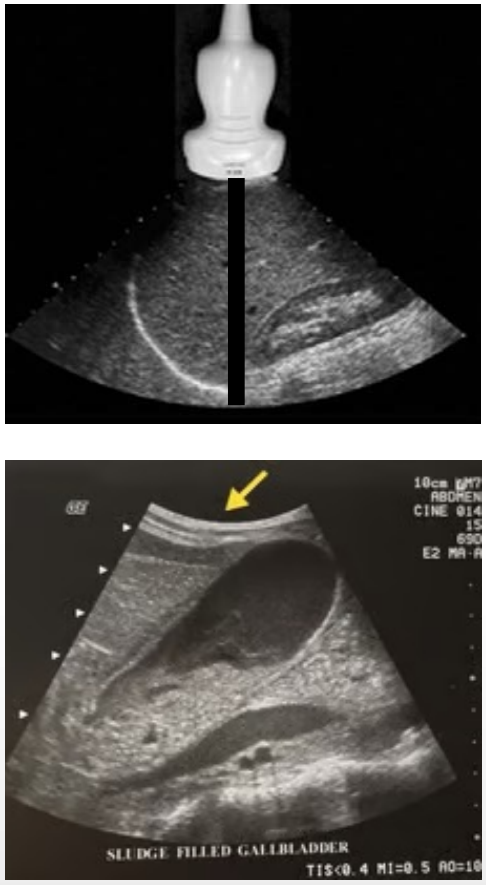


CONVEX, CURVED, CURVILINEAR ARRAY

- **Focusing** is done electronically.
- **Transmit focusing** is done by exciting the elements in the fired groups with an appropriate delay for the curved line pattern
- **Dynamic receive focus** uses electrical delays in the returning signals
- **Image shape**: blunted sector shape
- **Damaged crystals** create a loss of image in the line that the elements are damaged

CONVEX, CURVED, CURVILINEAR ARRAY

- Image shape: blunted sector shape
- Damaged crystals create a loss of image in the line that the elements are damaged

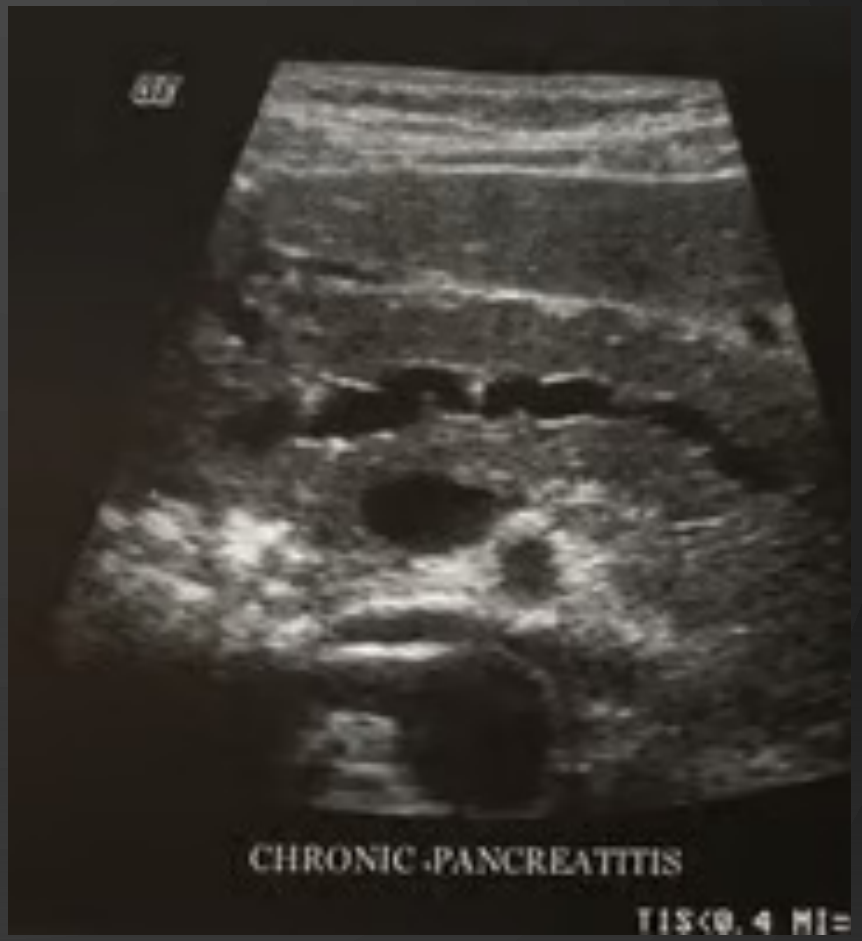


VECTOR ARRAYS

- Combines linear sequential and linear phased array technologies
- Sloped electrical delays create the virtual sector
- There are 120 to 250 rectangular strips of PZT material located side by side with the footprint often being rather small

VECTOR ARRAYS

- Beam focusing is similar to phased array transducers
- The electronic transmit focusing and dynamic range focusing improves the image quality
- The image shape is a **trapezoid** unlike curved array images the near field is flat

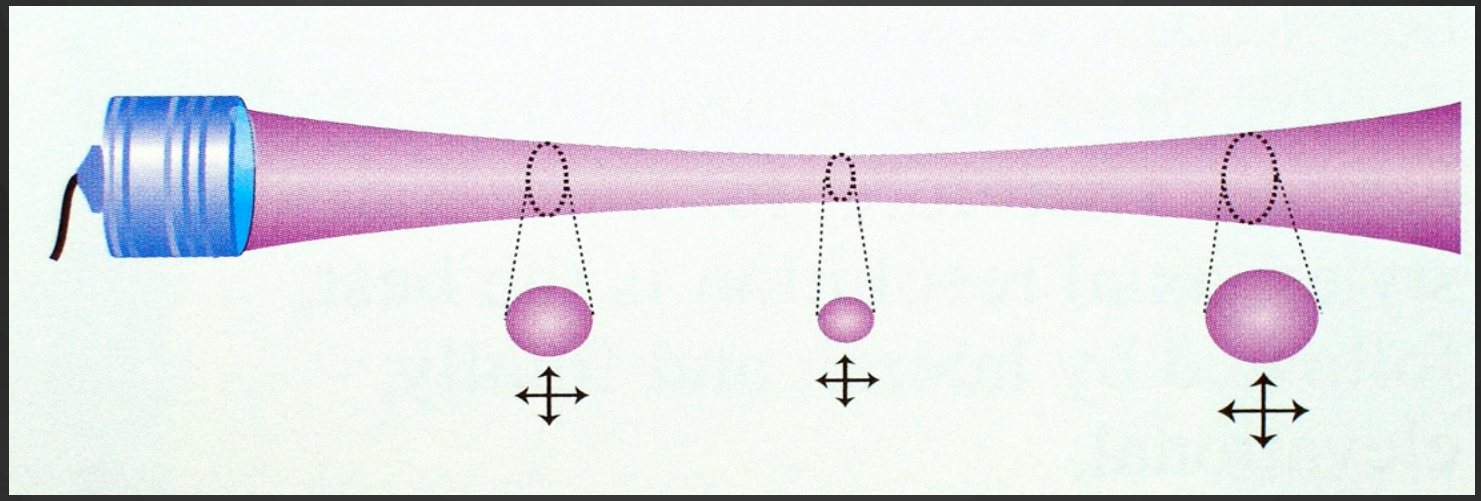


SLICE THICKNESS OR ELEVATIONAL RESOLUTION

- Axial and lateral resolution affects image quality
- Slice thickness also contributes to **image quality**
- Image resolution in reality deals with three-dimensional space
  - shallow to deep
  - side-to-side
  - above-to-below the imaging plane

SLICE THICKNESS OR ELEVATIONAL RESOLUTION

- Element shapes affect this resolution
- Disc shapes have the thinnest plane within the focal zone.



***Found in mechanical and annular phased array transducers**
***Have equal resolution in all planes**

SLICE THICKNESS OR ELEVATIONAL RESOLUTION

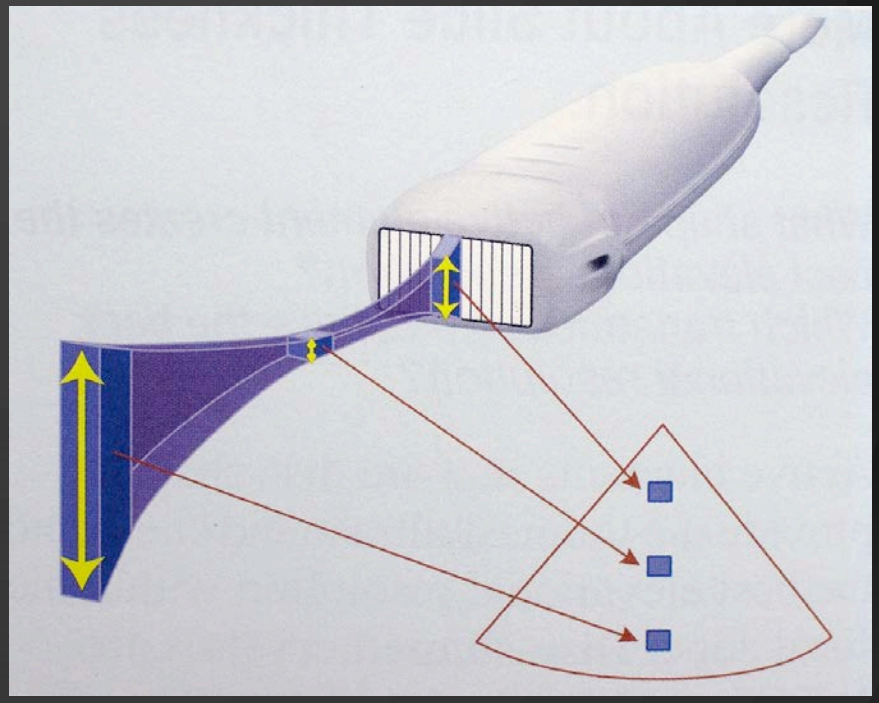
- Measured perpendicular to imaging plane
- The beam has a measurable thickness that varies with depth.
- Structures that are in the edges of the plane can create reflection that are demonstrated on the final image

SLICE THICKNESS OR ELEVATIONAL RESOLUTION

- For most linear, curved, and phased arrays the electronic focusing is for IN-PLANE width of the beam.
- An acoustic lens is used to create a thinner slice.

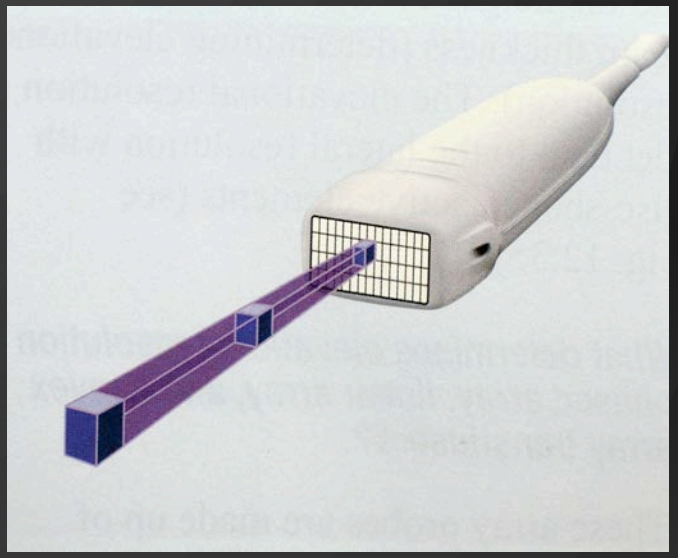
SLICE THICKNESS OR ELEVATIONAL RESOLUTION

- With rectangular elements phasing focuses the beam
- This narrowing improves lateral resolution but not slice thickness
- With regard to resolution, axial is best, then lateral, followed by elevational



1½ DIMENSIONAL ARRAYS

- Some modern transducers have improved slice thickness creating thinner beams by altering the single PZT to multiple crystals
- This changes the PZT number
- Might be 700: 7 rows high by 100 wide

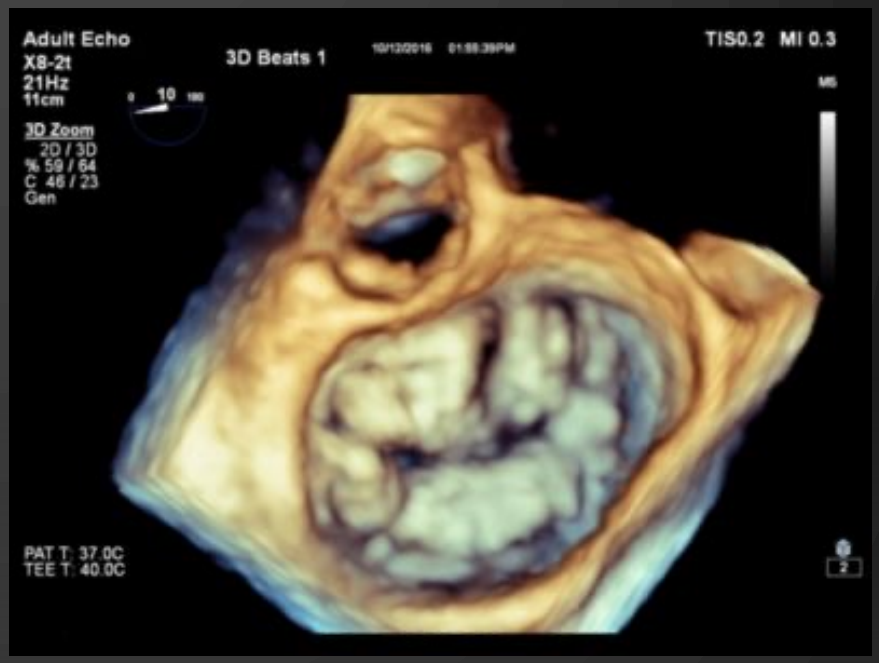


3-DIMENSIONAL IMAGING (3D)

- 2D array with thousands of elements arranged in checkerboard pattern
- Electronically focused in both lateral and thickness planes
- Electronically steered
- 4D= 3D in motion

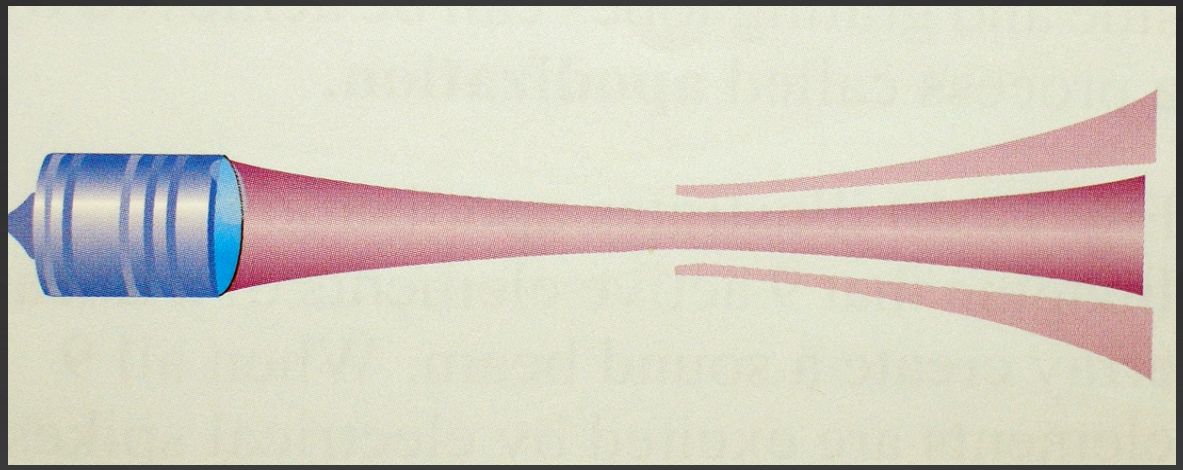
RENDERING

- Creates an image from 3D data and provides an element of realism to the image
- Constructs photo-like pictures with color, shadows, texture and optical effects.
- Images are computer generated



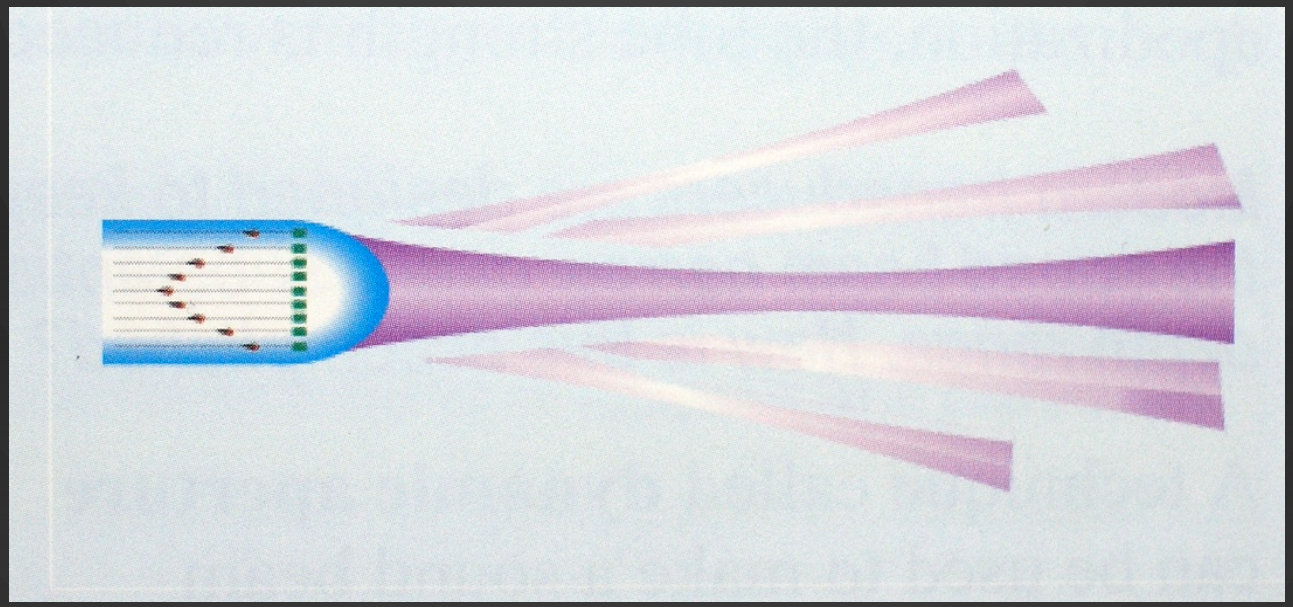
SIDE LOBES

- ***Side lobes*** are areas of sound at depths = or > the focal zone outside the main beam
- Created by single element, mechanical transducers
- The reflections can degrade the lateral resolution when they have enough energy



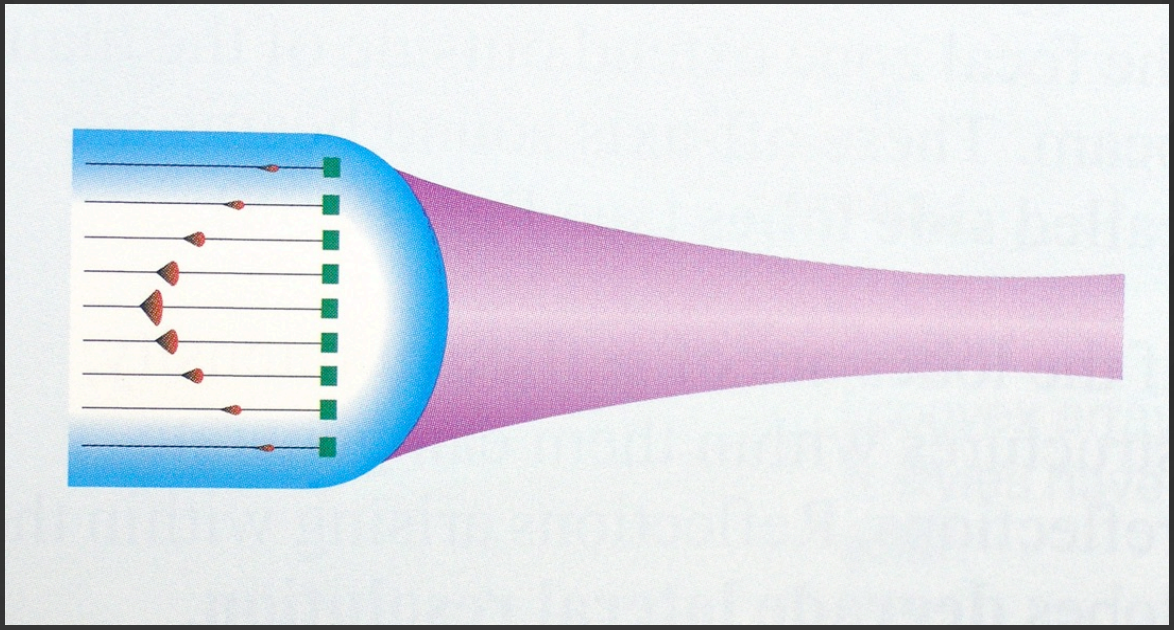
GRATING LOBES

- ***Grating lobes*** are created by array transducers
- Off axis beams degrade lateral resolution



APODIZATION

- The process that reduces the strength of grating lobes
- Accomplished by varying the intensity of the electrical signals sent to the crystals



SUBDICING

Crystal is divided into a group of smaller crystals- sub-elements

Electrically joined

Act as a single crystal reducing sidelines

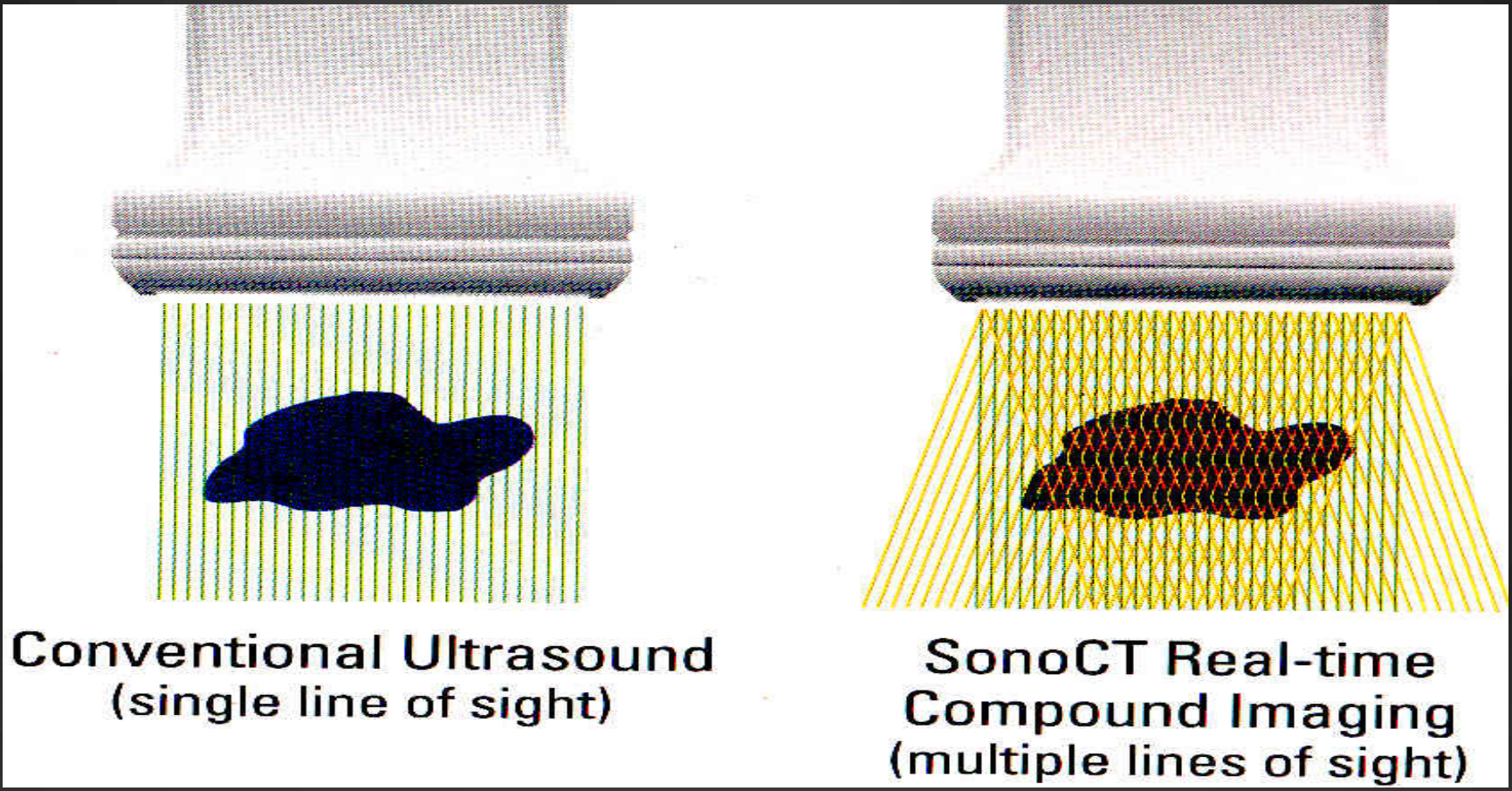
DYNAMIC APERTURE, VARIABLE APERTURE

- Technique that narrows the beam over a greater depth range and optimizes lateral resolution
- Accomplished by changing the number of crystals along the face of an array transducer probe used to transmit pulses or receive reflections.

TRANSDUCERS SUMMARY

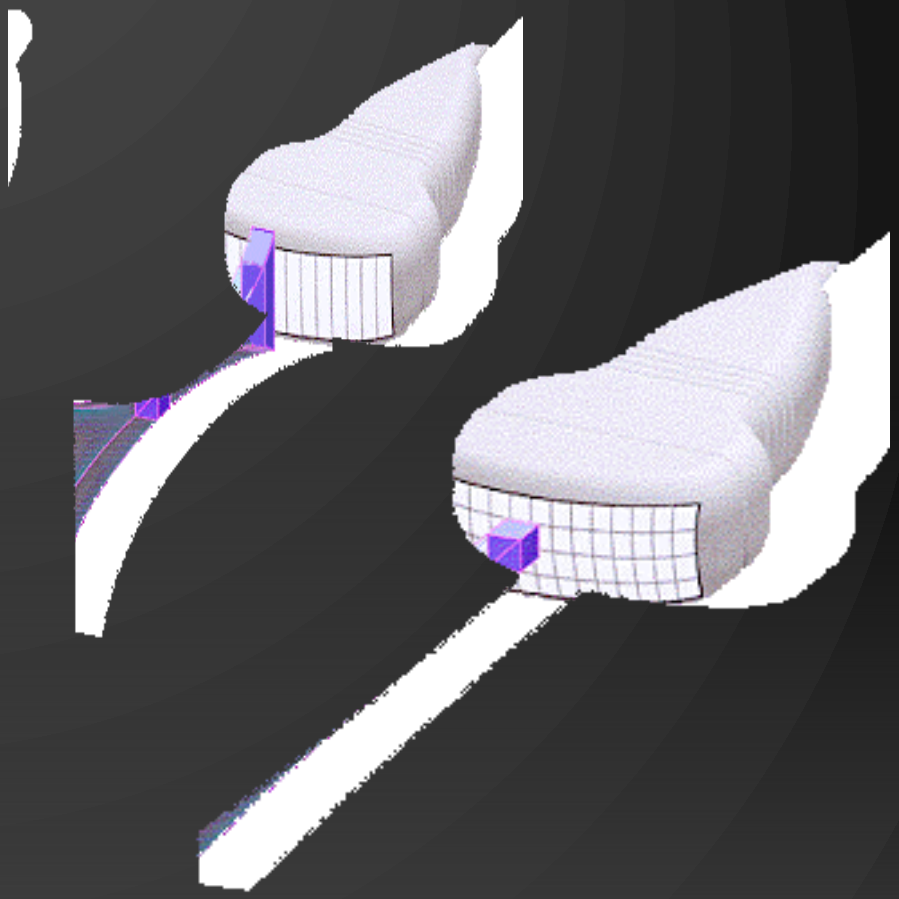
Transducer type	Image shape	Steering technique	Focusing technique	Crystal defect
Mechanical	Sector	Mechanical	Fixed	Image loss
Linear phased array	Fan or sector shaped	Electronic	Electronic	Inconsistent & erratic
Annular phased	Sector	Mechanical	Electronic	Horizontal line dropout
Convex sequential	Blunted sector	Electronic	Electronic	Vertical line dropout
Linear Sequential	Rectangular	Electronic	Electronic	Vertical line dropout
Vector	Trapezoid	Electronic	Electronic	Inconsistent & erratic

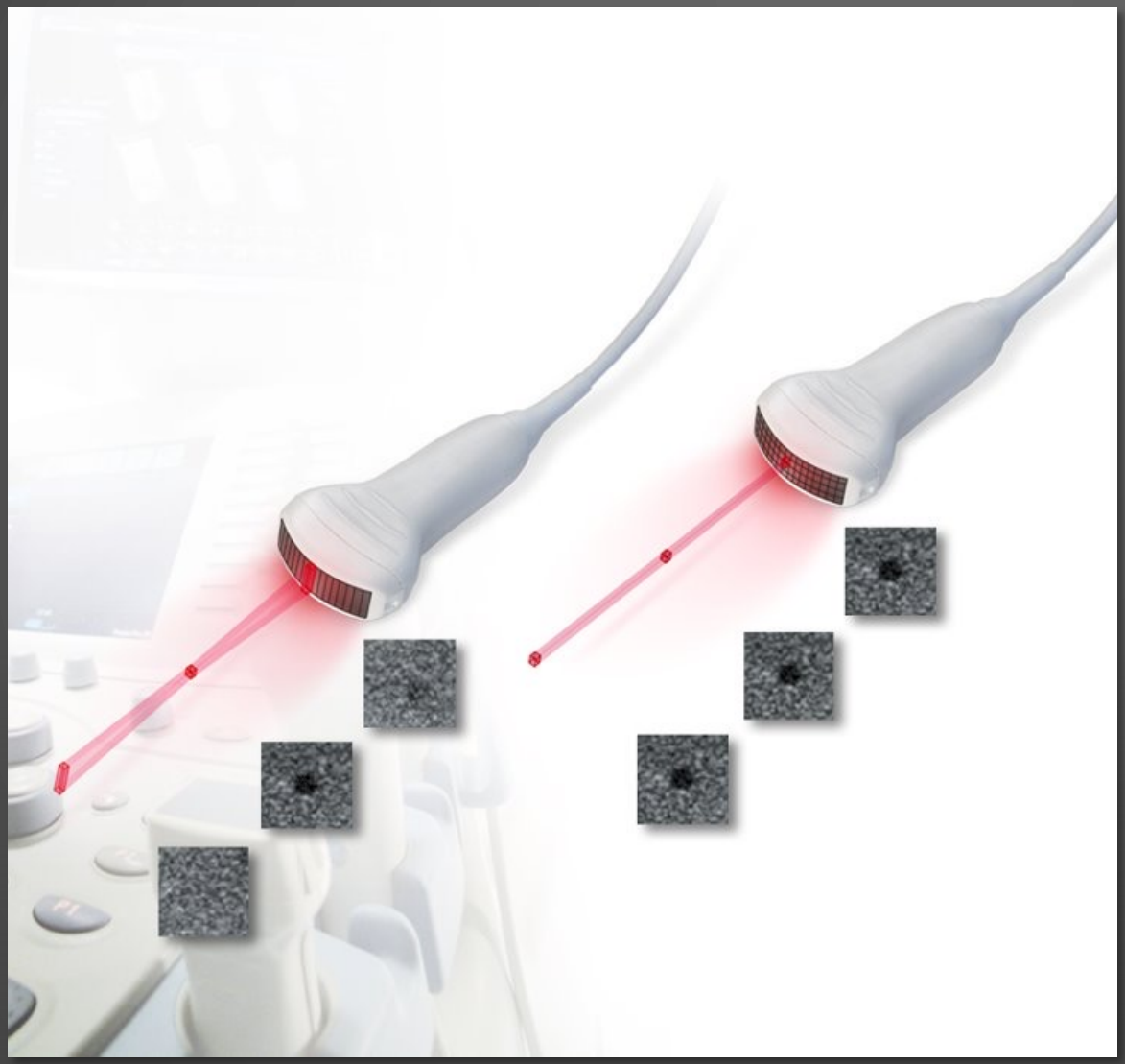
FYI

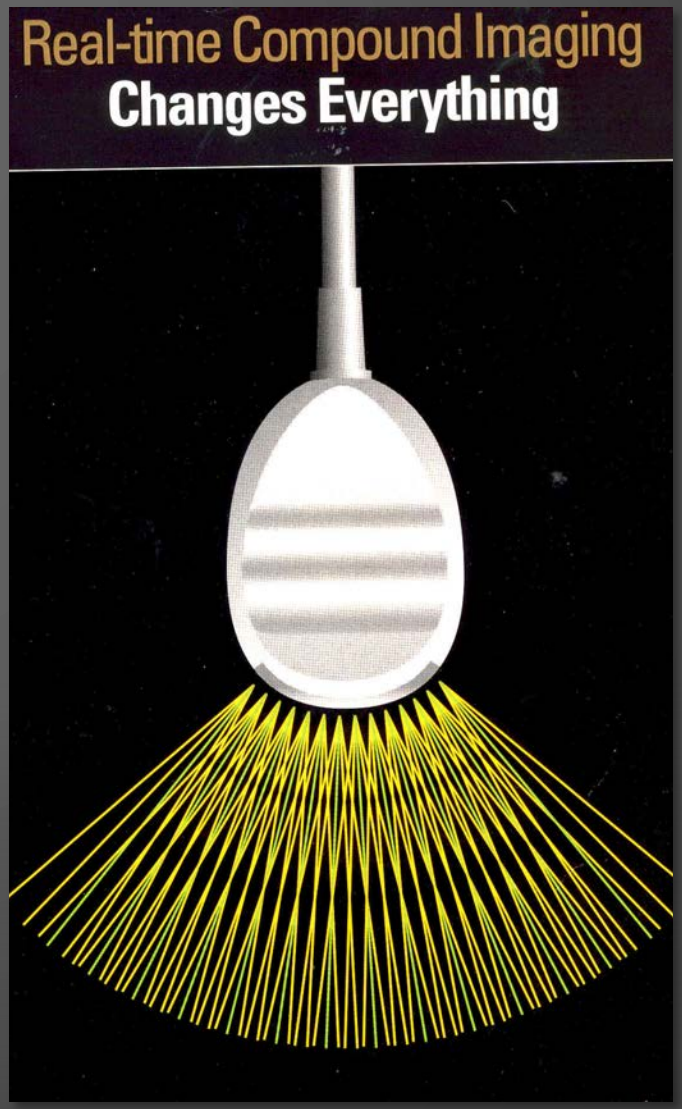

Conventional Ultrasound
(single line of sight)
SonoCT Real-time
Compound Imaging
(multiple lines of sight)

Matrix Array Transducers: Improve Spatial and Contrast Resolution

- **Breakthrough transducer technology**
- **Elements arranged in rows AND columns**
- **Enables beam forming in 3 dimensions**
- **MA's provide uniform beam thickness… uniform image consistency from near to far field**






Real-time Compound Imaging
Changes Everything