Two-Dimensional Imaging

Chapter 12

Two-Dimensional Imaging

- A-mode and B-mode are nearly obsolete
- M-mode is still being used but mostly in cardiac imaging
- today almost all imaging uses 2D to display detailed anatomy

2D Imaging difficulties

- Sound travels in a straight line
- a narrow beam is is needed for optimal resolution
- using multiple pulses transmitted at different angles overcomes this problem

2D Imaging

- Modern systems transmit a pulse into the body then listens once received another pulse is transmitted at a slightly different angle then listens
- this process repeats until the entire sector image is completed

Mechanical Transducers

- Element is physically moved creating the scan plane
- Has 1 to 5 elements and coin or target shaped
- the image shape is like a fan the element moves like a cars windshield

Mechanical Transducers

- The beam is steered mechanically not electronically
- it has a fixed focus for each crystal and can have internal or external focusing
- if the PZT is damaged the entire image is trashed
Transducer Arrays

- Most modern transducers have an array of active elements
- This is made up of a single PZT cut into separate pieces called elements
- Each element has a is connected to wire and system electronics and are referred to as a channel

<table>
<thead>
<tr>
<th>Type</th>
<th>Arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Active elements are arranged in a single line</td>
</tr>
<tr>
<td>Annular</td>
<td>Elements are arranged in a circular ring with a common center</td>
</tr>
<tr>
<td>Convex</td>
<td>Active elements are arranged in a bowed line. Also called curved or curved linear</td>
</tr>
</tbody>
</table>

Linear phase array

- Small footprint transducer in which the beam is steered and focused electronically
- While small it has 100-300 elements
- Elements are 1/4 to 1/2 the sound's wavelength

- The image is fan shaped but without the moving parts like a sector
- This is done by electronically steering the sound called phasing

Linear phase array

- The beam can also be focused electronically allowing the sonographer to modify the depth of focus
- New systems also have multi level focusing
- A damaged PZT can be difficult to discover but results in a inconsistent beam steering and focus

- All elements must be fired to create the proper beam
- In the transducer has 64 channels all are excited and result in 64 wavelets
- The overall shape and pattern of the beam depends on the pattern of the arriving electronic signal
Linear phase array

- Look at the picture to the right, note the electrical signals are set to arrive at the same time.
- This pattern results in a sound beam going in one direction.

Linear phase array beam steering

- The beam's direction depends on the incident angle of the electrical signal on the PZT.
- If you draw a line in front of the electrical signal a line perpendicular to this line is the direction of the beam.

Linear phase array beam steering

- By altering the timing of the incident electrical signals the beam will alter its direction.
- The electronics that creates the phased patterns is the beam former.

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 emanating from the beam former.

Phasing and Focus

<table>
<thead>
<tr>
<th>Electronic pattern</th>
<th>Sound beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>slope</td>
<td>steering</td>
</tr>
<tr>
<td>curvature</td>
<td>focusing</td>
</tr>
</tbody>
</table>
Multifocus Linear phase array

- To create an image with multiple foci the system must send additional pulses for each scan line.
- For 3 focal points each scan line must have 3 separate pulses, one for each focal zone.

Dynamic range focus

- Focusing can also occur during reception.
- When an ultrasound receiver introduces time delays during reception more accurate images are created.
- This delay changes depending on the depth of the reflection therefore the delay patterns change continuously during receive focusing.
- The sonographer has no control over this.

Annular phased array

- The PZT gives the appearance of a bull's-eye; it has one center disc with multiple rings surrounding it.
- Beam steering is done mechanically; the transducer actually rotates around a center point.
- Beam focusing is done by the use of the various PZT.
- The smaller elements create near-field focus.
- The larger elements create far-field focus.
- By using all the elements multiple transmit focal zones are created.

Annular phased array

- The electrical impulse must be fired separately one for each ring; the information for each scan line is stored processed before the next one fires.
- The process repeat for each focal zone.
- A 5 ring element transmits 5 pulses one for each focal depth.
Annular phased array

• The image shape is like a fan or sector
• 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

• There are 120 to 250 rectangular strips of PZT material located side by side
• The elements are fired in groups
  – The first 5 then 6-10 then 11-15 and so on
• Each PZT is about 1 wavelength in width

Beam focusing

• Originally focused with a lens in front of the elements resulting in a fixed focus
• New equipment are electronically focused

Linear sequential arrays

• The image shape is rectangular and never wider than the footprint of the transducer
• Damaged crystals create a lost of image in the line that the elements are damaged
Linear sequential arrays

- These images can be steered electronically creating a parallelogram shaped image
- The steering occurs the same as previously described
- Often used in vascular imaging to create a better reflector or to angle correct for spectral or color Doppler

Convex Array

- These are basically linear transducers but they have a curve
- Also known as curved or curvilinear

Convex Array

- There are 120 to 250 rectangular strips of PZT material located side by side
- The elements are fired in groups
  - The first 5 then 6-10 then 11-15 and so on
- Each PZT is about 1 wavelength in width

Convex Array

- Linear transducer beams are parallel to each other
- In contrast since the PZT is curved the individual beams are no longer parallel

Convex Array

- Focusing is again done electronically
- Transmit focusing is done by exciting the elements in the fired groups with an appropriate delay for the curved line pattern
- The image shape is described as a blunted sector in the footprint of the PZT.
- 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 trapezoid unlike curved array images the near field is flat

Slice thickness and resolution

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

Slice thickness

- Measured perpendicular to imaging plane
- the beam is not thin but in fact is variable with depth.
- Structures that are in the edges of the plane can create reflection that are demonstrated on the final image

Slice thickness

- Slice thickness is synonymous with elevation resolution
- Elements shapes affect this resolution with disc shapes having the thinnest plane within the focal zone.

Slice thickness

- Some modern transducer have improved the resolution creating thinner beams by altering the single PZT to multiple crystals
- This changes the PZT number form 250 to 700
Special topics

- **Side lobes** are areas of sound at depths beyond the focal zone outside the main beam.
- The reflections can degrade the lateral resolution when they have enough energy.

Multi-D™ Array Transducer Technology

- Beamformation Along Elevation Plane
  - Precise Slice Thickness Control
  - Exceptional Near-, Mid- and Far-Field Detail and Contrast Resolution.
**Special topics**

- Similar to side lobes
  Grating Lobes are created by array transducers
- they have similar effect on resolution

**Apodization**

- Is the process that reduce the strength of grating
- accomplished by varying the intensity of the electrical signals sent to the crystals

**Dynamic aperture**

- Narrows the beam over a greater depth range
- accomplished by the systems changing the number of crystals on the transducer face when transmitting or receiving signals

**Spatial Compounding Plus**

Line Steering
Transmit/Receive Aperture-Based Compounding
Simulated images with five apertures NOT optimally arranged for speckle independence

Simulated images with five apertures arranged for speckle independence, but loss in lateral resolution due to aperture size

Independent components
Optimal aperture overlap