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Third Stage

Radiological Equipment techniques

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Beam shape control in the scan plane

Scan plane focusing in transmission

Since the cylindrical lens does nothing to reduce the beam width in the scan plane, an electronic method of focusing must be provided if good lateral resolution is to be achieved. There are two factors that determine the focal depth of a transducer: the element diameter and frequency.

This is controlled by the operator, who sets the transmission focus at the depth for which optimum lateral resolution is desired. This ensures that the transmission beam is as narrow as possible there (the receive beam must also be narrow there, but this is considered next). Usually an arrowhead or other indicator alongside the image indicates the depth at which the transmission focus has been set. Pulses from all the elements in the active group must arrive at the transmission focus simultaneously in order to concentrate the power into a narrow 'focal zone'. However, the distance between an element and the focus, which lies on the beam axis passing through the centre of the group, is slightly, but crucially, greater for the outer elements of the group than for more central elements. Pulses from elements further from the centre of the active group must, therefore, be transmitted slightly earlier than those nearer the centre

Scan Plane Dynamic Focusing and Receive Aperture

1. Concept of Receive Focusing

Receive focusing means that, for each scan line, the ultrasound system becomes especially sensitive to echoes coming from a specific depth along that line—called the receive focus.

- This focusing narrows the receive beam near that depth.
- As a result, lateral resolution improves.

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2. How Receive Focusing Works

When an echo returns from the receive focus:

- All active transducer elements must contribute their signals at the same time.
- However, elements at the edges of the aperture are farther from the focus than those at the center.
- Therefore, the ultrasound machine must compensate for these differences in travel time.

3. Use of Electronic Delays

To align the signals:

- Echo signals from inner elements (which receive the echo sooner) are electronically delayed more.
- Echo signals from the outer elements (which have longer acoustic travel time) receive little or no delay.
- The delays are set so that:

(sound travel time from focus → element) + (electronic delay)
is the same for every element.

This ensures:

- All echo signals arrive in phase at the summing point.
- Echoes from the focal zone produce a strong combined signal.
- Echoes from other regions produce only weak, unfocused noise.

4. Automatic Control

In most ultrasound systems:

- Receive focusing is handled automatically.
- The operator cannot adjust the receive focus.
- The machine continually updates the focus depth to match the depth of the echoes currently being received.

This dynamic adjustment is known as dynamic receive focusing.

Increasing Receive Focus Depth

- Immediately after transmission, receive focus starts at zero depth.
- As echoes return from deeper tissues, the receive focus moves deeper.
- Sound takes 13 μs to travel to a depth 1 cm and return.
- Therefore, the machine advances the receive focus by 1 cm every 13 μs.

2. Continuous (Dynamic) Focusing

- Modern ultrasound systems shift the receive focus in hundreds of tiny steps during each echo-receiving period.
- Each step acts like a small focal zone.
- Together, these create an “effective reception beam” that stays narrow over a wide depth range, not only at one focus.

3. Dynamic Aperture

- As receive focus moves deeper, the system also increases the number of active receiving elements.
- A larger active aperture improves image quality because:
- Beam width at the focus is inversely related to aperture size.
- A larger aperture → narrower beam → better lateral resolution.

Slice Thickness

1. What Is Slice Thickness?

• Ultrasound beams have a finite width in the elevation (out-of-plane) direction.
• Because of this, echoes may come from structures near the scan plane but not actually inside it.
• These unwanted echoes appear as acoustic noise, reducing contrast resolution and penetration.

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2. Behavior of Slice Thickness

• The image represents a slice of tissue, not a perfect 2D plane.
• At any depth, slice thickness = beam width in the elevation direction.
• Slice thickness is smallest at the depth of the cylindrical lens focus (elevation focus).
• At this depth:
• Acoustic noise is lowest.
• Sensitivity is highest.

3. Relationship to Transmission Focus

• Sensitivity vs. depth depends on the scan-plane transmit focus chosen by the operator.
• When the scan-plane focus matches the elevation focus:
• The beam is narrow in both directions.
• Sensitivity is maximized at that depth.

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4. Improving Slice Thickness: Multi-Row Arrays

To improve slice thickness at depths other than the natural elevation focus, multi-row arrays are used:

a. 1.25D Arrays

- Each of the long strip elements is divided into 3 or 5 rows.
- Rows are activated progressively to expand aperture with depth.
- Provides some improvement in slice thickness, mainly by increasing aperture size.

b. 1.5D Arrays

- Multiple rows allow electronic delays to shape and focus the beam in the elevation direction.
- Electronic focusing (transmit and dynamic receive focusing) is applied in elevation.
- Elevation focal length can be adjusted automatically to match the scan-plane focus.
- Results in significantly narrower slice thickness over a wider depth range.

5. Why the Names 1.25D and 1.5D?

• These terms describe arrays that provide limited elevation control, but not full 2D control.

• They are used to distinguish them from true 2D arrays, which can focus and steer beams fully in both lateral and elevation planes.

Short Summary

• Slice thickness arises because the beam has width in the elevation direction, causing out-of-plane echoes.

• Noise is lowest and sensitivity highest at the elevation focus.

• Multi-row arrays (1.25D, 1.5D) improve slice thickness by expanding aperture and using electronic focusing in the elevation plane