Department of Systems and Biomedical Engineering

Medical Equipment: Ultrasound Imaging (4)

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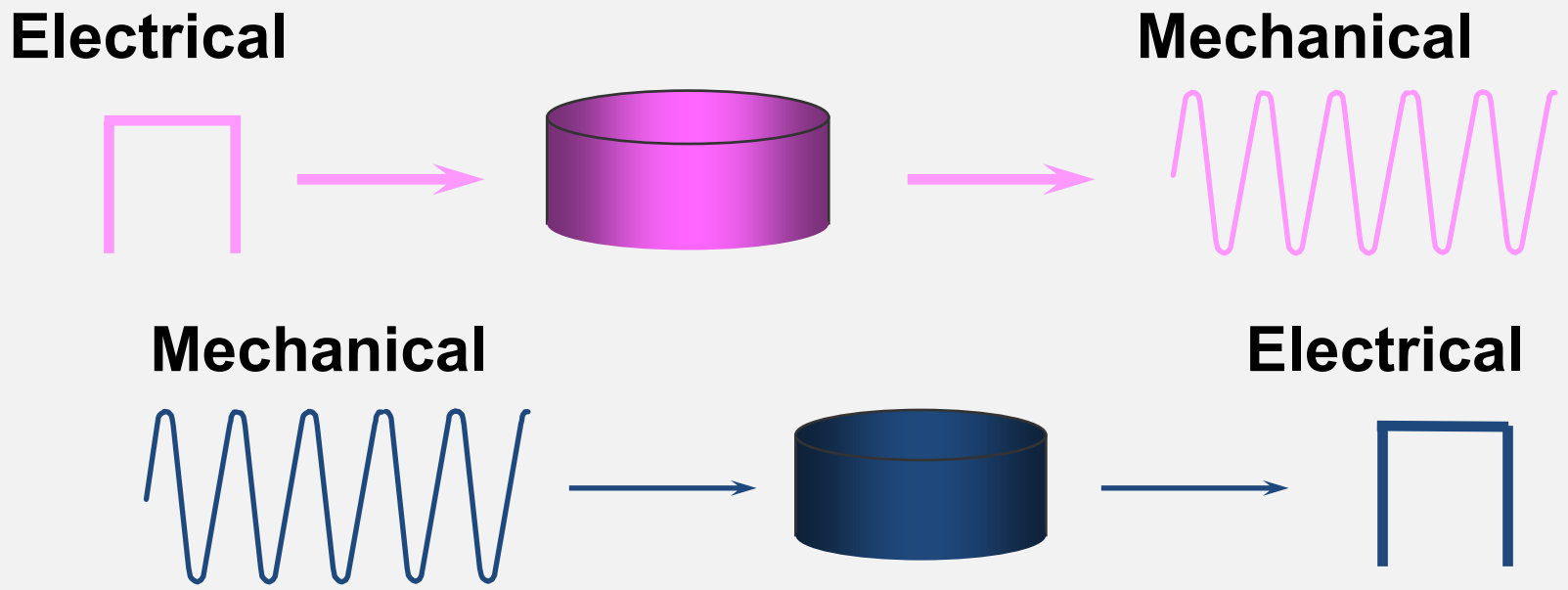
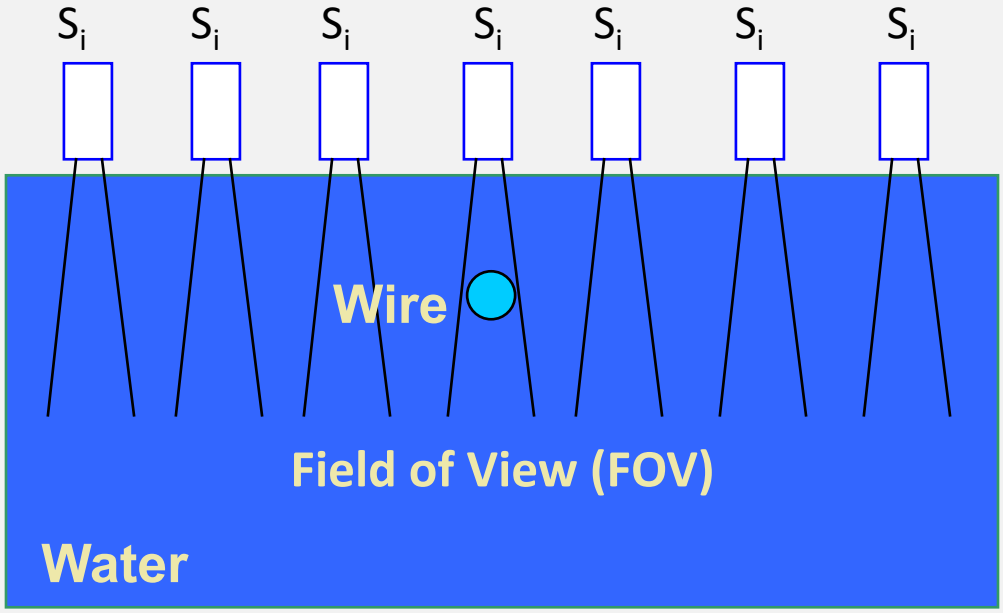
Ultrasound Transducer

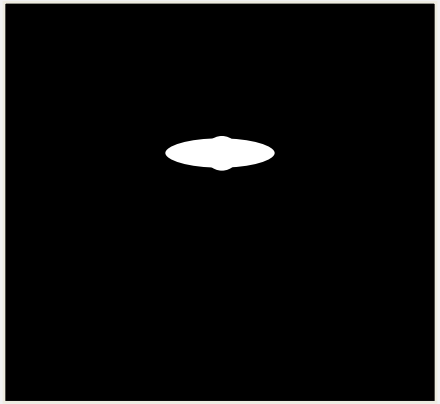
Transducer contains piezoelectric elements/crystals which produce the ultrasound pulses. These elements convert electrical energy into a mechanical ultrasound wave, and vice versa.



Ultrasound Transducer

In order to reconstruct a B-mode image for the FOV, a single element transducer is moved so that the beam is swept through the tissues as the pulse-echo cycle is repeated.

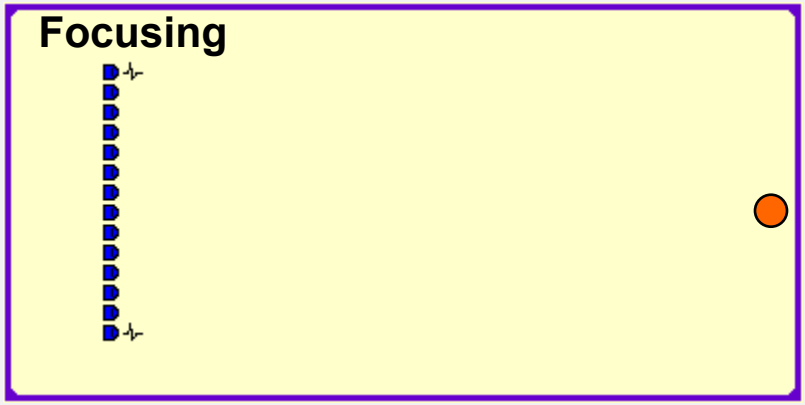




B-mode Image

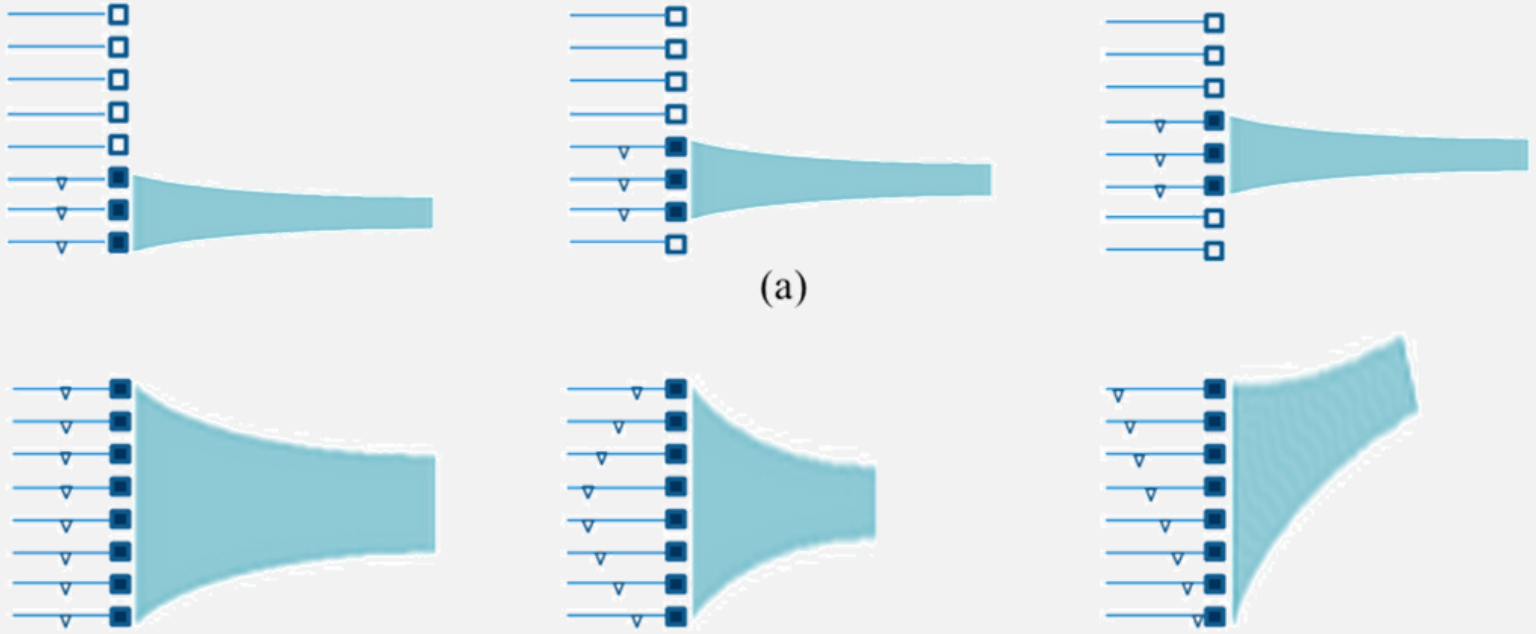
Ultrasound Transducer

- The beamformer is the part of the scanner that determines the shape, size and position of the interrogating beams by controlling electrical signals to and from the transducer array elements.



Ultrasound Transducer

- Using electronic scanning, array transducers move the beam between positions, and allow changing the shape and size of the beam to suit the needs of each examination.



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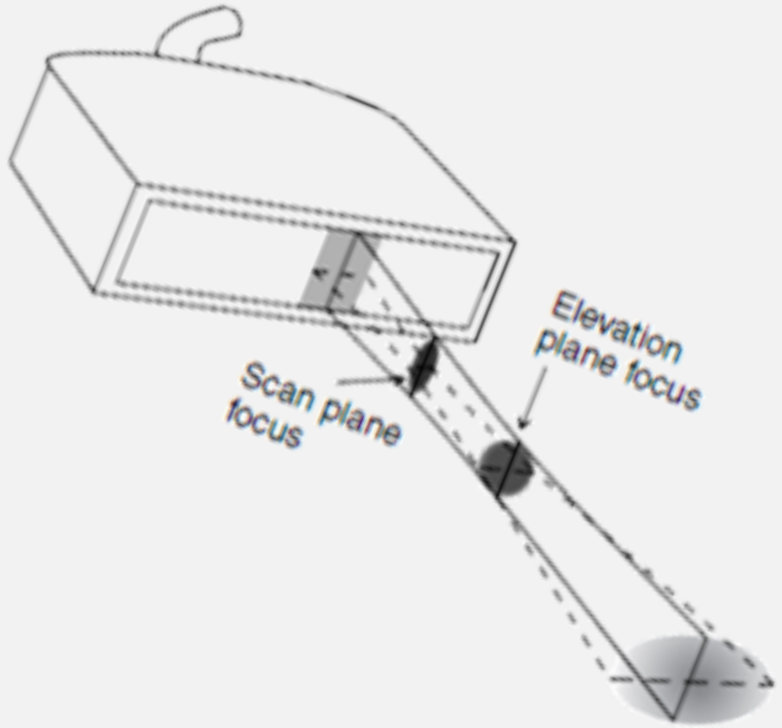
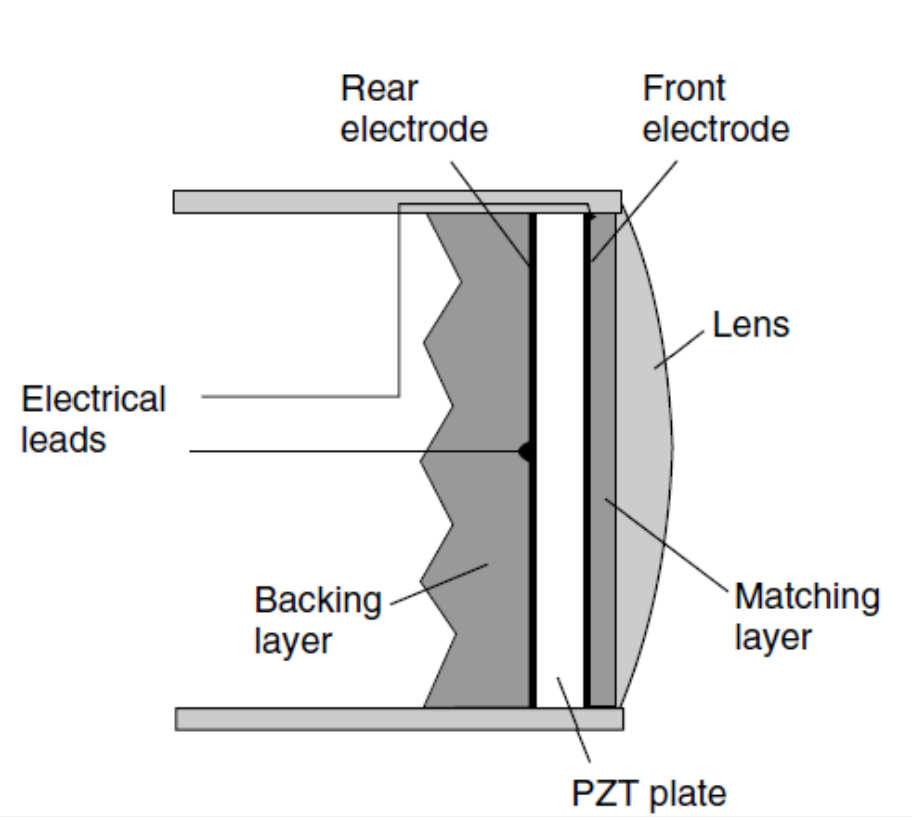
Ultrasound Transducer

- The beam is moved electronically along the length of the transducer face.
- The plane passes through the beam at right angles to the scan plane, is the elevation plane.
- The beam width in the scan plane determines what is referred to as the lateral resolution of the scanner.
- The elevation plane defines the ‘slice thickness’, and hence the acoustic noise of the image and, to some extent, the sensitivity of the scanner.



Ultrasound Transducer

- Some piezoelectric materials occur naturally (quartz) but the piezoelectric material normally used in medical imaging is a synthetic ceramic material: lead zirconate titanate (PZT).
- The PZT slab vibrates most strongly at the frequency for which its thickness is half a wavelength, giving rise to the term ‘half-wave resonance’ .



Ultrasound Transducer

- The matching layer should have a thickness equal to a quarter of a wavelength. Second, it should have an impedance equal to $\sqrt{(z_{PZT} \bullet z_T)}$, z_{PZT} is the impedance of PZT and z_T is the impedance of tissue.

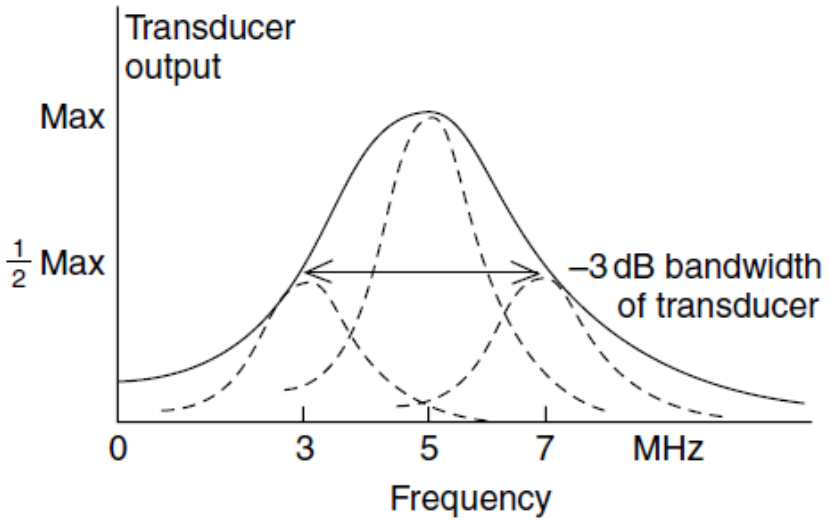


Fig. 3.5 The –3 dB bandwidth of a transducer is the range of frequencies over which the output power for a given applied peak-to-peak voltage is within a factor of 2 of the maximum. A multi-frequency probe must have a large bandwidth, so that it can transmit and receive pulses with several different centre frequencies (pulse spectra shown dashed).

Ultrasound Transducer

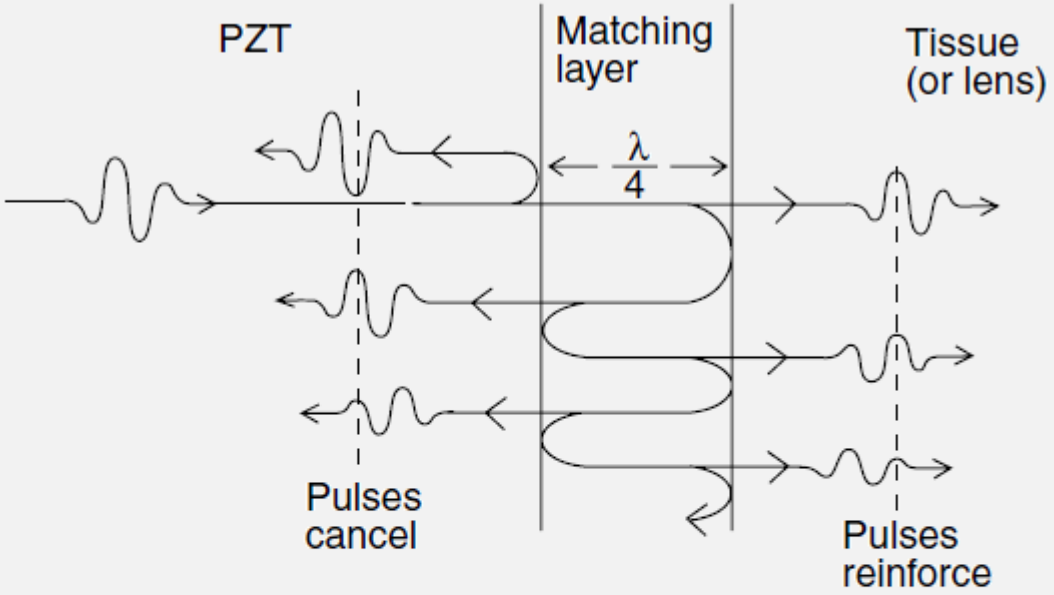
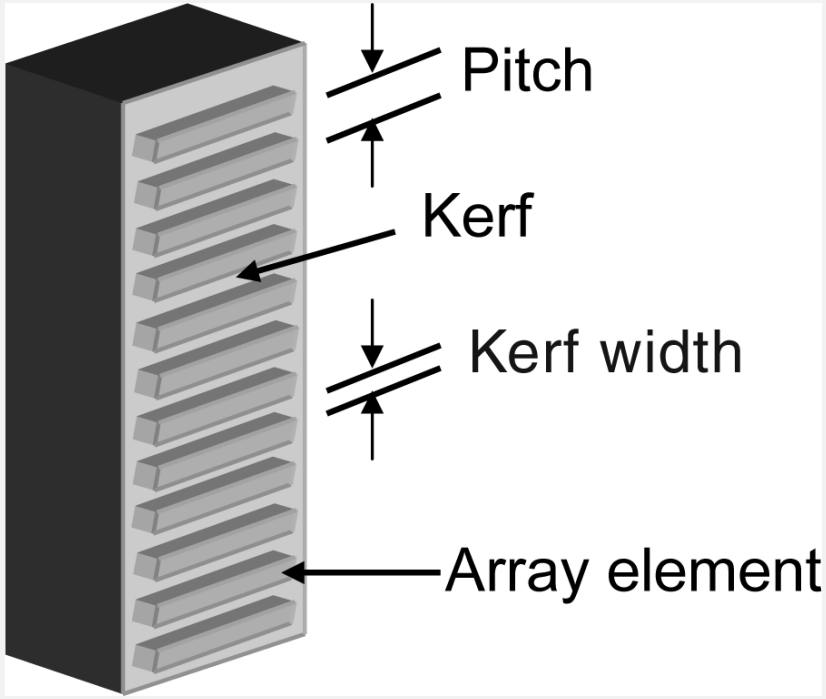


Fig. 3.4 Quarter-wave matching layer. Reverberations within the plate produce multiple transmissions into the patient that reinforce each other to give a large-amplitude resultant pulse. The resultant of the multiple reflections back into the PZT cancel out the original (top) reflection back into the backing layer.

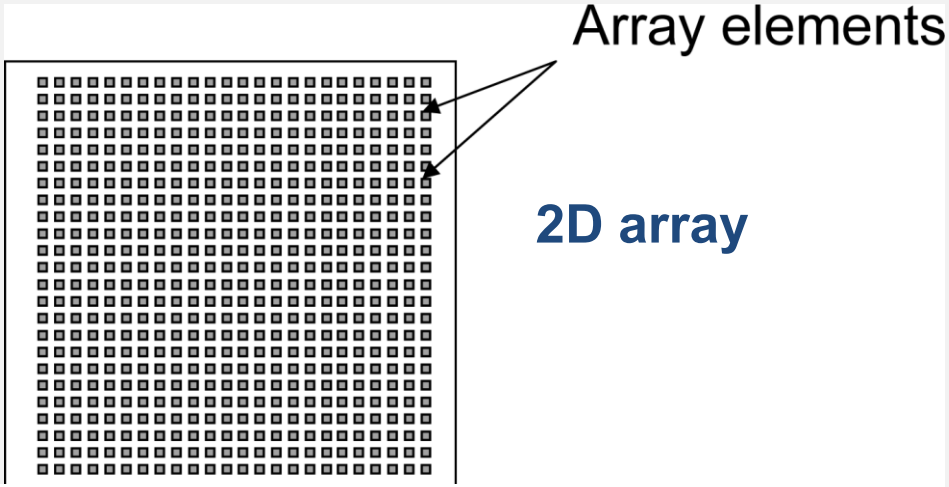
Ultrasound Transducer

- Near the focus of the lens, the width of the beam is least and the transmitted amplitude, or receive sensitivity, is greatest.
- In linear-array transducers, focusing in the scan plane is achieved entirely by electronic means, and so a cylindrical lens, producing focusing only in the plane perpendicular to the scan plane (elevation plane), is used.
- Elements of ultrasound array may be rectangular in shape and arranged in a line (called linear or one-dimensional array; square in shape and arranged in rows and columns (called two-dimensional array); or ring shaped and arranged concentrically (called annular array).

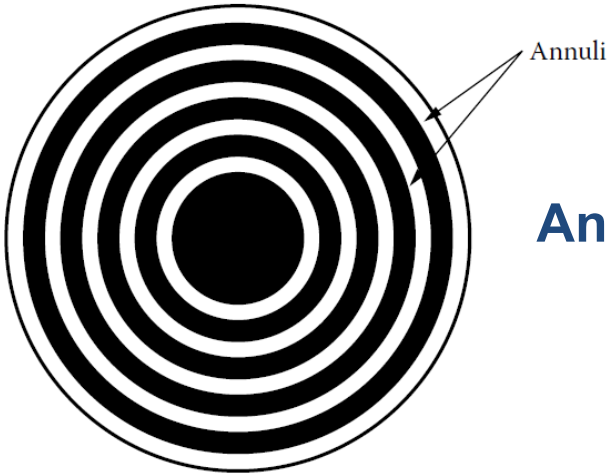
Shapes of Arrays



Linear/curvilinear array



2D array



Annular Array

Linear and Curvilinear Arrays

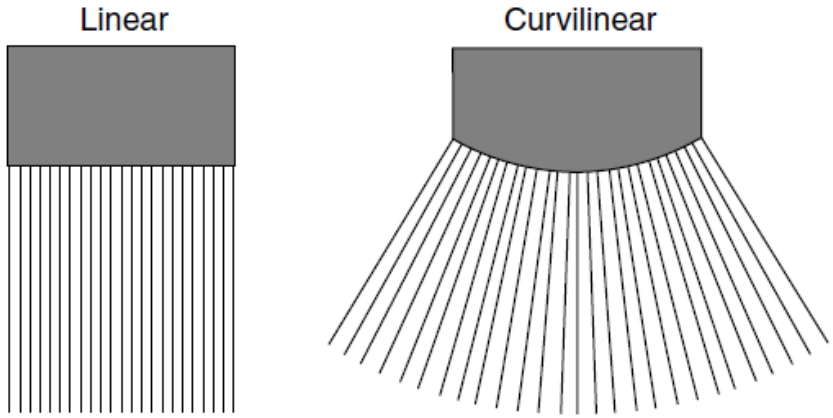
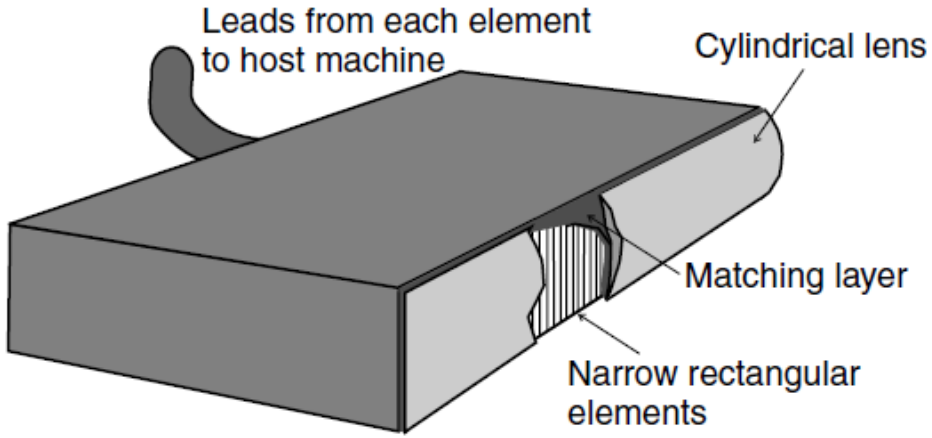
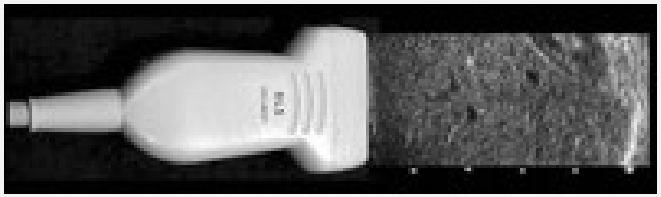
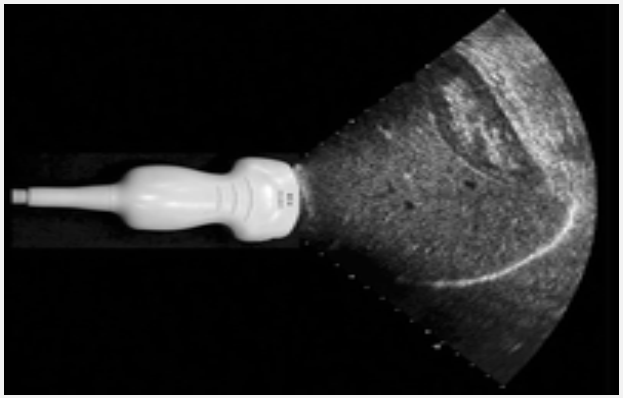


Fig. 3.6 Linear and curvilinear scan formats.







Ultrasound Transducer

- The number of elements of linear array range from 128-256.
- The width of each array element is typically about 1.3 wavelengths (λ), being a compromise that gives a reasonably wide array

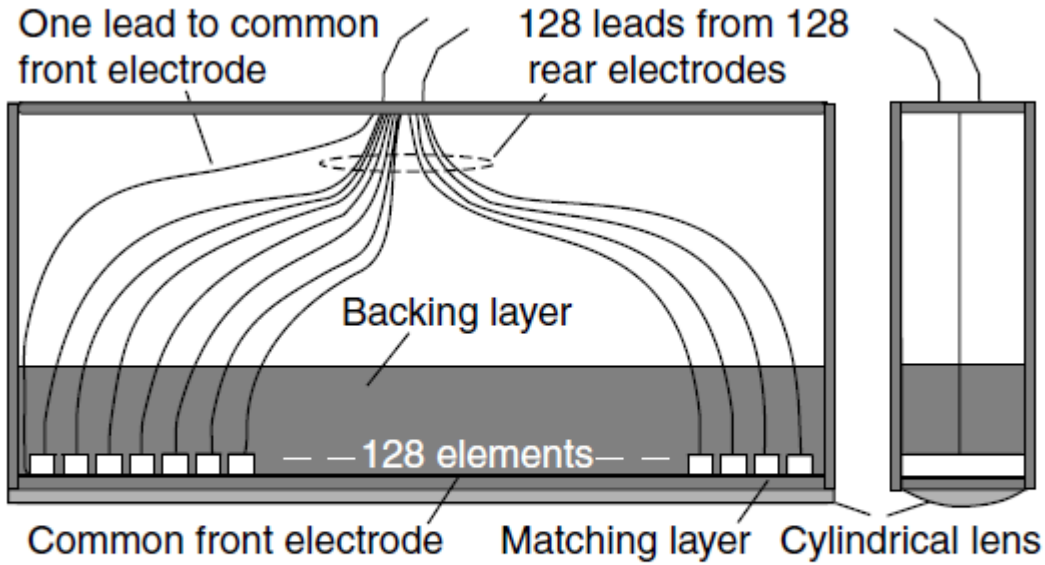


Fig. 3.8 Section through a linear-array transducer. For clarity, the sub-dicing of each element is not shown.

Active Groups & Electronic Focusing

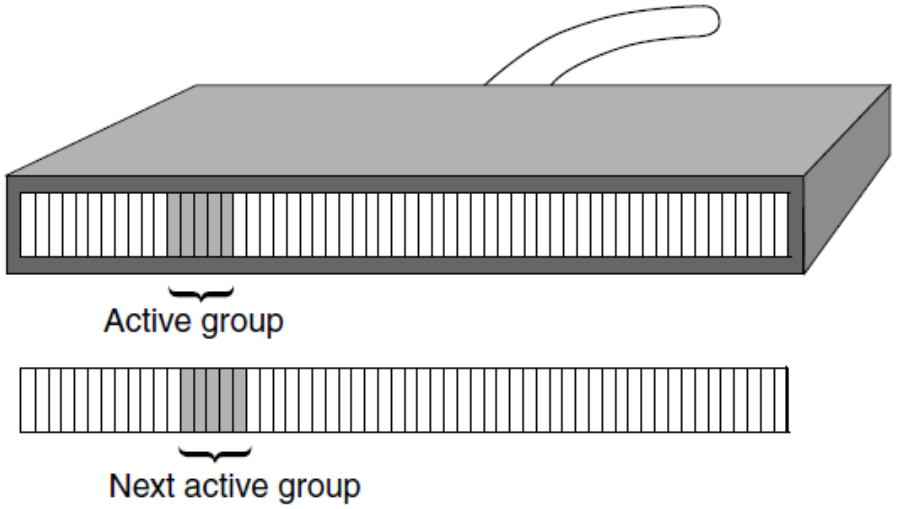


Fig. 3.9 The active group is stepped along the array by dropping an element from one end and adding a new on to the other. In reality, the active group would contain at least 20 elements rather than the five shown here.

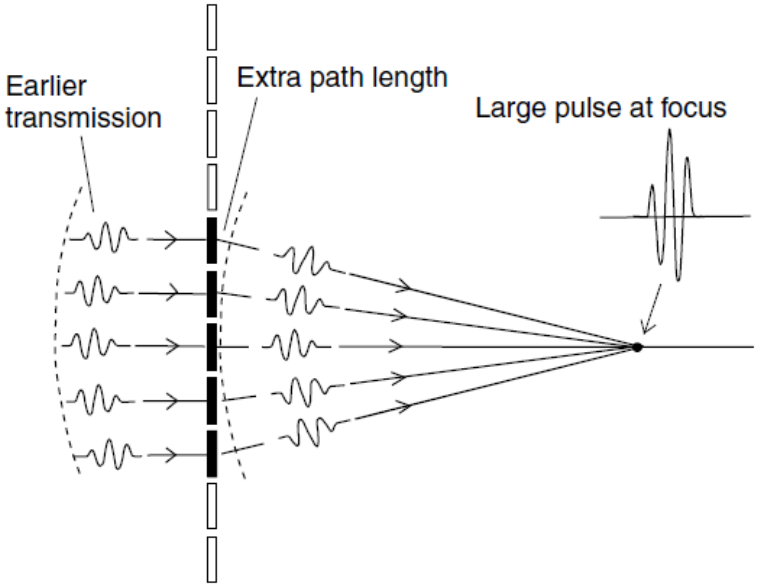
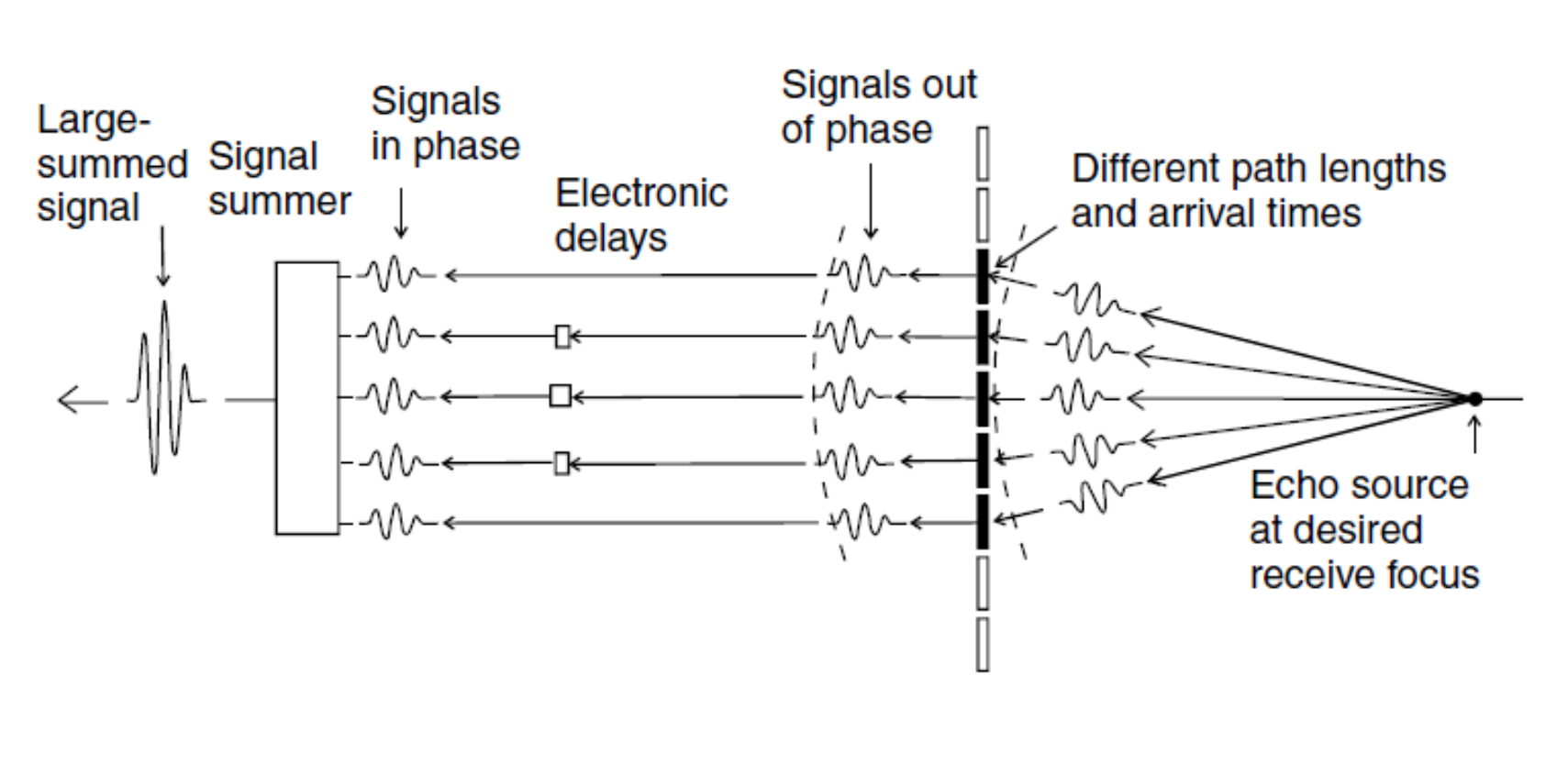
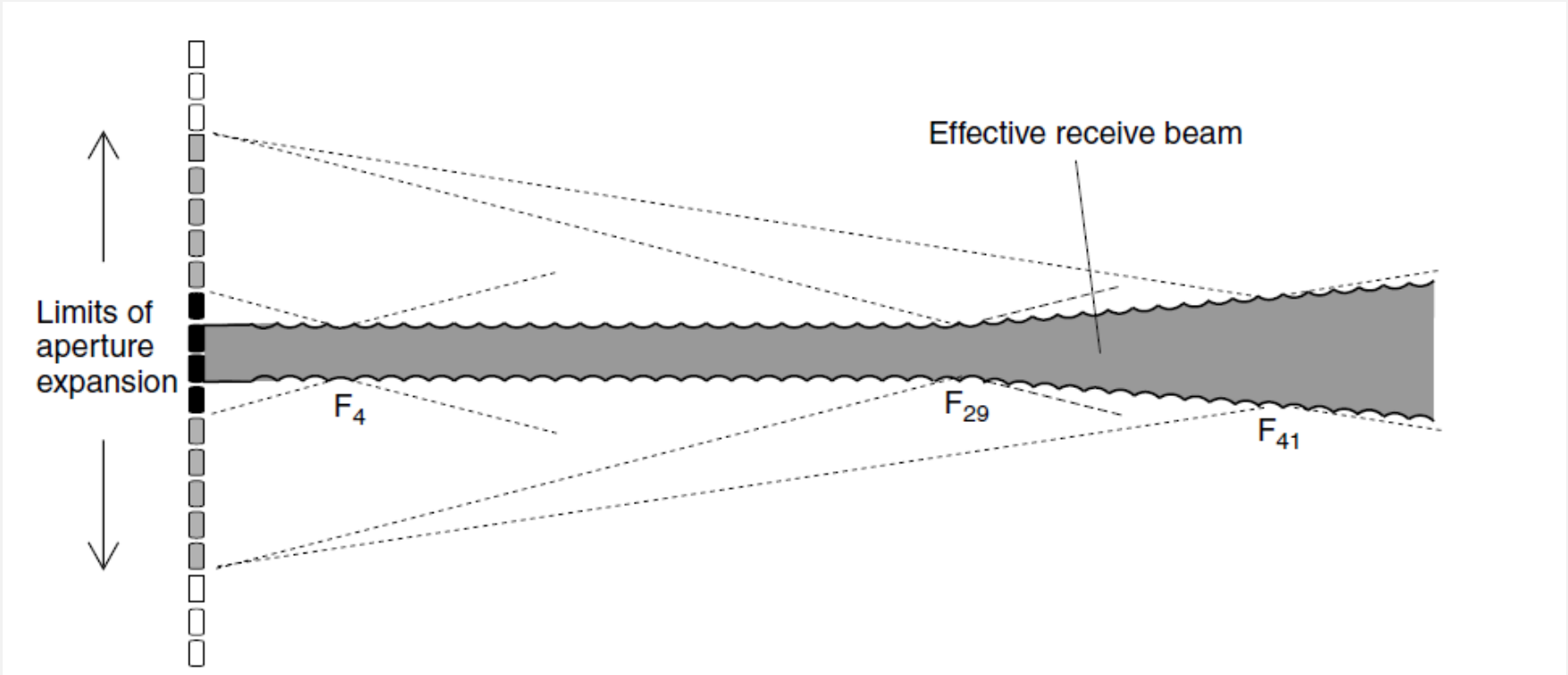


Fig. 3.10 Creating a transmission focus for a linear-array transducer. In order to form a large-amplitude pulse at the focus, pulses from all elements must arrive there at the same time. This is achieved by transmitting slightly earlier from elements that are further from the centre of the group.

Receiving Delay

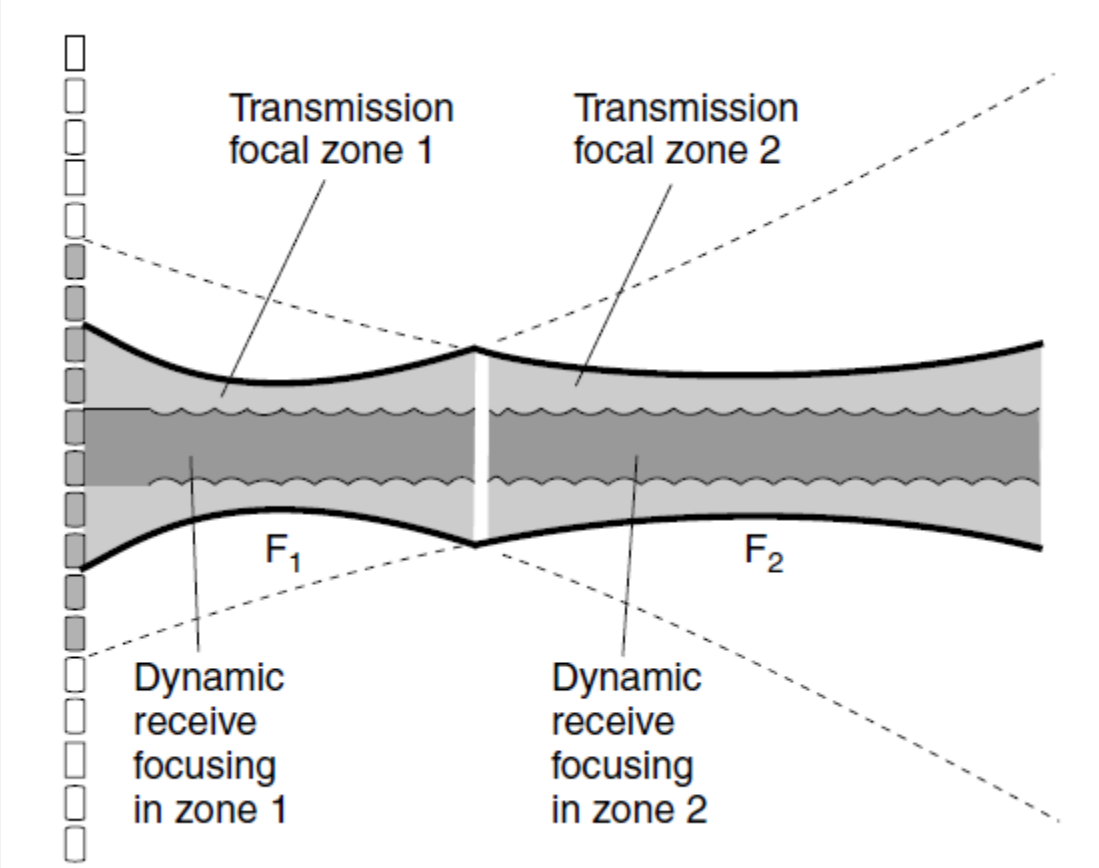


Dynamic Focusing



Multiple-zone Focusing

Targets lying between the transducer and a point about half-way between the two foci are interrogated with a transmission pulse focused at F_1 . Targets beyond the halfway point are interrogated by transmitting another pulse along the same scan line, but focused at F_2 .



Apodization