Ultrasound Innovations: Modern focusing methods

Have you noticed that the latest generation of ultrasound systems is able to produce a well-focused image over the whole field of view without troubling the user to set a transmit focal depth? In previous generations of technology, a transmit focal depth was chosen and the beam was destined to converge to this depth once the pulse was transmitted. In reception, swept focusing was used to track the depth of origin of the echoes to produce a narrow, almost continuously focused receive beam. Each pulse-echo cycle gave rise to a single, or at most four, B-mode lines (using parallel beam-forming), building up the image line by line.

The latest ultrasound systems use a synthetic aperture technique that removes the need to set a transmit focus. A similar technique was introduced in shear wave elastography systems to achieve the high frame rate required for shear wave imaging. In the shear wave system, a plane wave (i.e. one that stretches across the whole field of view) was generated by firing all the transducer array elements at once. The echoes received by the array elements were stored and then processed to form the image lines, using receive focusing and parallel beam forming techniques, so that a complete image was formed from a single transmission. Although this gave a high frame rate, the image quality was restricted in terms of beam width and penetration due to the lack of a transmit focus. Better image quality could be achieved by combining the stored echo information from a small number of consecutive plane waves transmitted at slightly different angles. At points in the image where the angled plane waves intersected, the echo signal was reinforced (Figure 1). This technique could be applied to each point in the image, producing improved resolution and contrast, although with some reduction in frame rate.

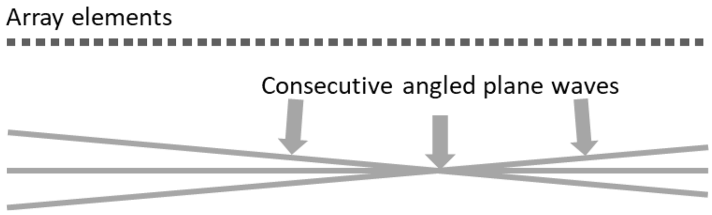

Figure 1

The resulting echo signal for the enhanced image point is equivalent to that produced at the transmit focus of a conventional system. In a conventional system with a fixed transmit focus, a curved wave front is formed which converges on the focal point. Using angled plane waves, the curved wavefront is effectively synthesised from several (e.g. three, as in Figure 2) separate transmissions. Using the stored echo information from all three transmissions, a focus can be synthesised at every point in the image, resulting in an image that is focused everywhere in transmission and reception.

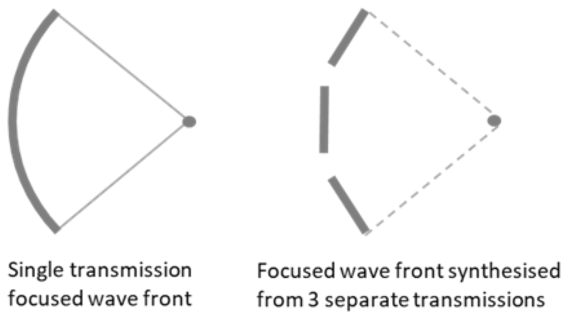

Figure 2

Storing and processing echo information from the whole image from a number of separate transmit waves requires a huge amount of processing power. In addition, the lack of any transmit focus can lead to restricted penetration. The latest generation of imaging systems uses an adaptation of the angled plane wave technique. Rather than plane waves, they transmit a series of broad, weakly focused, overlapping transmit beams, which are stepped across the field of view (Figure 3). Each point in the image is hence interrogated by multiple transmit beams, and the echoes received from each are stored before being combined to form a composite image.[1,2] In a single focused transmit beam, the concave wave front converges towards the focus, and beyond that diverges as a convex wave. For a single location, say in the pre-focal region (Figure 3), the overlapping wave-fronts from successive transmit waves intersect at different angles. Where they intersect, the stored echoes are reinforced when combined. The timings of echoes from other transmissions for this location are adjusted so that all coincide at this point.[3]

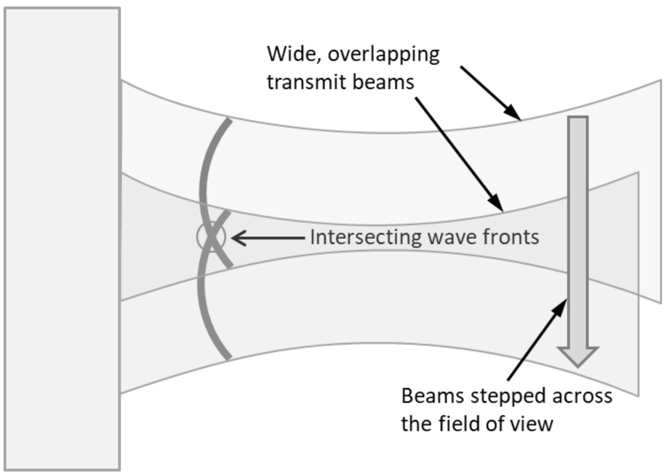

Figure 3

Using the stored echo information from one sweep of the overlapping transmit beams, this process can be applied to every location in the field of view, resulting in an image that is focused everywhere in transmission and reception, a process often referred to as retrospective transmit focusing. This approach requires echo information to be stored and processed only for the region where the beams overlap. The weak transmit focusing improves penetration and as the total number of transmissions per frame is reduced, higher frame rates are generated.

Such techniques have only become commercially viable since the arrival of very powerful image processing chips designed mainly for the computer games market.

References

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3. Bradley C. 2008. Retrospective transmit beam formation. Siemens white paper. Available at: https://cdn0.scrvt.com/39b415fb07de4d9656c7b516d8e2d907/1800000000064734/cc581ee74214/Whitepaper_Bradley_1800000000064734.pdf