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Peering into ultrasound machines

Ultrasound finds use in noninvasive imaging in cardiac, obstetric, gynecologic, and other diagnostic areas. What's inside this tool that is playing an expanding role in today's medical world?

The systems often operate in the 2- to 20-MHz frequency range. An ultrasound system transmits a phased array of sound waves through a linear transducer so that the waves constructively combine at a focal point. As the generated sound waves propagate toward the focal point, they undergo a slight change in direction and produce a reflected sound wave each time they cross through matter of different densities. A variable controlled amplifier scales the reflected sound waves before an ADC samples and passes the data to the front-end processing of the system.

The front-end processing controls and performs beam-forming, which involves steering and focusing the phased array of sound waves. Steering involves sweeping the angle and direction of the beam to focal points with a precomputed depth. Focusing involves exciting multiple piezoelectric elements in the transducer with precisely time-delayed pulses so that the sound waves converge at each focal point along a scan line. The receiver's beam-forming ability detects the time delay, phase, and amplitude of the reflected sound wave at each focal-point location to reconstruct the flight path of the waves using a delay and sum algorithm to support creating an ultrasound image.

The midprocessing end lacks a common definition, but it can include filter, detection, and compression processing on a scan line of beam-formed data. The filter processing is typically bandpass filtering to reduce noise. The detection processing extracts a signal from the envelope of the signal. A complex rotator demodulates the signal in baseband; lowpass filtering then eliminate side lobes. The system may perform additional lowpass filtering with decimation or interpolation before presenting this data for back-end processing.

The back-end processing focuses on forming quality images for display from the received data. A scan conversion interpolates raw-data coordinates to displayed-data coordinates. The raw data can be in Cartesian coordinates for linear probes or polar coordinates for curvilinear or phased-array probes. Frame-smoothing techniques reduce noise without blurring the image's edges. Edge-detection techniques can help remove this blurring. Doppler processing focuses on measuring and displaying shifts and motion of structures, such as blood flow, in the data. A CW (continuous-wave)-Doppler system is analog and is highly sensitive and selective so that it can estimate velocities.

Display-mode-dependent processing is vendor-specific and plays a critical role in producing images on the display. This type of processing can involve the combination of overlays, such as color Doppler and color-flow imaging. It can also include support for the user interface, including menus, help, and display options. Images courtesy Zonare Medical Systems (www.zonare.com); for more information about ultrasound, see "Diagnostic ultrasound gets smaller, faster, and more useful," *EDN*, this issue, pg 21.

