ZONE Sonography™: What It Is and How It's Different

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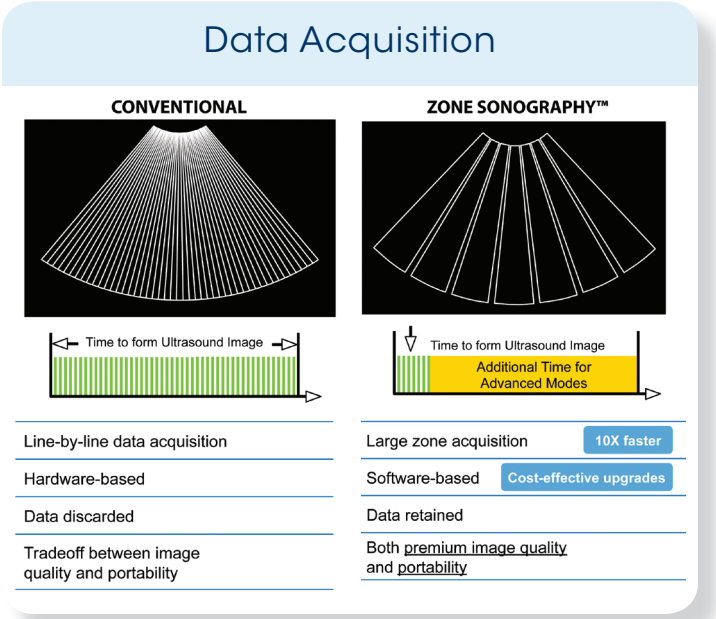
ZONE Sonography is an entirely new approach to ultrasound image acquisition and processing. Conventional systems acquire acoustic data line-by-line and focus it with a beamformer using only a small fraction of the actual information contained in the echo data set. ZONE Sonography has the ability to utilize all of the information contained in the returning echo data set and as such can cover the field of view in much fewer transmit / receive cycles. While it might be intuitive that simultaneously collecting data from these larger regions would be more efficient, it is understandably less intuitive that fewer acquisitions could result in improved image quality. ZONE Sonography enables this performance advantage by retrospectively analyzing these complete echo data sets to synthesize a continuous transmit focus at every image point.

Some of the image quality improvements include:

1. Focused image across the full field of view
   a. Dynamic transmit & receive focus (Every pixel in the frame is in focus)
      i. No need for transmit focal zone control (and resultant frame rate tradeoffs)
   b. Enhanced image resolution, uniformity, contrast, and penetration
2. Faster acoustic acquisition
   a. Temporal accuracy (reduced motion blur)
   b. Acoustic time available to interleave modes without compromise
3. Patient specific imaging
   a. Compensating for physiological sound speed variations in patients
4. Novel Techniques
   a. Compound Contrast imaging
   b. Flexible image formats (phased array imaging on curved transducers, linear on curved, etc)

ZONE Capture vs. Line-By-Line Acquisition: Acoustic Efficiency

The ZONE acquisition approach extracts more information on each transmit receive cycle and is thus more efficient.



Faster Data Acquisition Regardless of the specific equipment, all conventional ultrasound systems form only one or a few receive beams from each transmit excitation. ZONE Sonography, however, interrogates a relatively smaller number of large zones and extracts more information from each acquisition. Additionally, continuous transmit focusing eliminates the need for multiple transmit focal zone acquisitions. Since the speed of sound traveling through tissue is a physical constant, ZONE Sonography has a significantly faster acoustic acquisition time.

Constraint on Performance is Processing, Not Physical Properties ZONE Sonography transfers the acoustic acquisition bottleneck (tied to the laws of physics) to a processing constraint (tied to the current engineering technology node). A quick acoustic "snapshot" of the patient is stored in the Channel Domain Memory, which is later retrospectively processed to form the image. As processor technology continues to evolve, this performance will improve accordingly.

Channel Domain Processing™: Flexibility

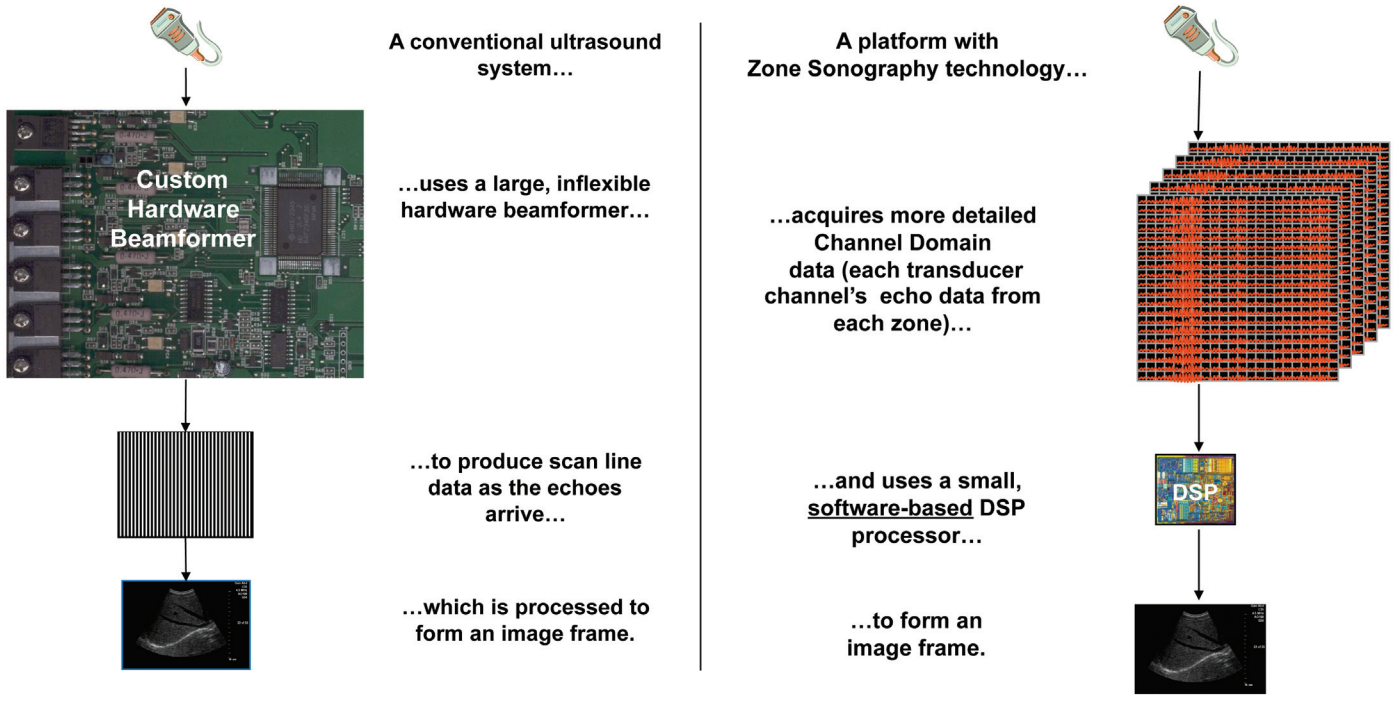
A flexible software-based Channel Domain Processor™ captures a complete echo dataset.

Channel Domain Data In conventional ultrasound systems, each line is formed by summing together the weighted contributions of all the channels in the transducer. As soon as each line is formed, the original channel data is discarded. In contrast, ZONE Sonography stores an entire frame of raw channel data in the Channel Domain Memory. The original raw echo information is reprocessed multiple times in the Channel Domain Processor to form the image.

The availability of the complete data set increases both flexibility and capability. For example, the system could reprocess the Channel Domain Data multiple times using different algorithms to develop an optimum solution.The result would be an optimum image from the available data. One example of this approach is ZONARE's unique ZONE Speed Correction Technology (ZST™).

Software architecture Conventional systems typically implement their digital beamformers in custom-designed hardware. Only the back-end processing is implemented in software, requiring field upgrades for front-end enhancements. ZONE Sonography, on the other hand, is extensively implemented in software on both the front and back ends, with the promise of substantial clinical benefits (size, power, and future upgradeability).

Signal Processing Block Diagram



The efficiency of ZONE Sonography makes this software-based processing possible. Compared to a traditional beamformer system, the acoustic efficiency of zone-based data acquisition drastically reduces the amount of raw channel data per frame. Additionally, the generalized focusing of ZONE sonography is more efficient since it can take advantage of spatially dependent sampling requirements.

Continuous Transmit Focus: Image Quality

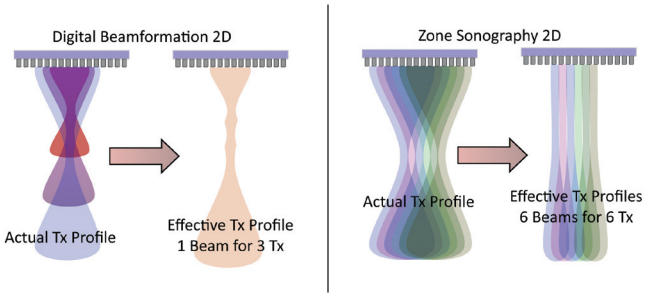
The image is two-way focused at every point. One of the key technical innovations of ZONE Sonography is the ability to provide a continuously focused transmit beam. Conventional systems dynamically focus on receive, but their transmit beams use a fixed focus. ZONE Sonography provides a two-way (transmit & receive) focus at every point in the image, resulting in a more uniform image with higher contrast, improved resolution, and better penetration. Additionally, this is accomplished with fewer acoustic transmit cycles than conventional systems.

For an ultrasound imaging system to produce high quality images, the region of interest must be sufficiently sampled acoustically, both in the range and azimuth (lateral) dimensions in order to prevent aliasing artifacts. In the range dimension, the Nyquist sampling rate is set by the combined two-way transmit/receive pulse bandwidth. In the lateral dimension, the Nyquist sampling theorem requires that an adequate number of combined two-way transmit/receive beams laterally sample the region of interest. The final image resolution and contrast image resolution and contrast are determined by the thickness of the round-trip acoustic beam profile.

Conventional systems link a fixed focus transmit with a dynamically focused receive. Due to depth of field constraints, the transmit focus is typically weaker than the receive focus, so the two-way profile is dominated by the finer receive profile. Once the transmit beam is launched, the transmit contribution to the two-way beam profile is fixed. The lateral number of transmits required is set by the finer lateral sampling requirements of the round-trip profile, instead of the reduced sampling requirements of the transmit beam alone. For typical conditions, this results in about a factor of three or more transmit firings than required. Additionally, the limited depth of field for each acquisition requires multiple transmit foci for a uniform image.

Through ZONE Sonography processing, transmit and receive sampling requirements are decoupled. ZONE Sonography utilizes the complete channel data set from multiple, overlapping zones to retrospectively improve the estimate of each echo location. Conventional systems discard this information. Transmit and receive path length differences are accounted for retrospectively in Channel Domain Processing in order to create a continuous transmit focus for all points. The penalty for this is increased processing requirements, but this is a good tradeoff since it will improve over time (unlike the laws of physics).

2D Digital Beamformation vs. 2D Zone Sonography



Therefore, transmit beam density is no longer determined by the round-trip beam as is generally the case with conventional imaging.

Instead, an optimal transmit beam sample rate can be utilized, typically resulting in a > 3x decrease in acquisition time. Synthesizing a continuous transmit focus along every receive beam effectively produces a round-trip beam focused at all depths, eliminating the need for multiple transmit foci. This results in another > 3x reduction in acquisition time, for a > 9x total echo acquisition time reduction compared to a conventional system.

Since the image is 2-way focused at every point, and a typical ultrasound image has over 500 range samples, the net effect is equivalent to a conventional beamformer-based system using 500-600 focal zones.

The end result is a uniform, spatially invariant image with improved resolution, contrast, and penetration. This includes higher detail and better contrast resolution. It also translates into improved signal-to-noise ratio which means better penetration on difficult patients and lower temporal distortion.

Glen Mclaughlin, Ph.D. is the Founder & Chief Technology Officer of ZONARE Medical Systems, Inc. Dr. Mclaughlin has over 20 issued patents in the field of ultrasound along with a number of publications. He is an international lecturer on future trends in ultrasound technology and has established numerous joint research projects with leading institutions around the world.

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