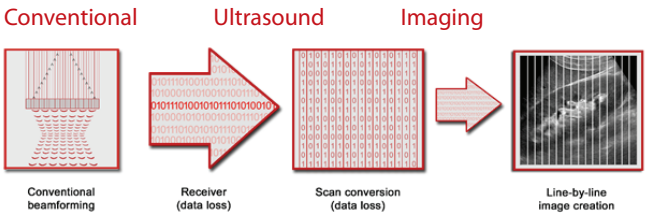
ZONE Sonography® Technology (ZST+)

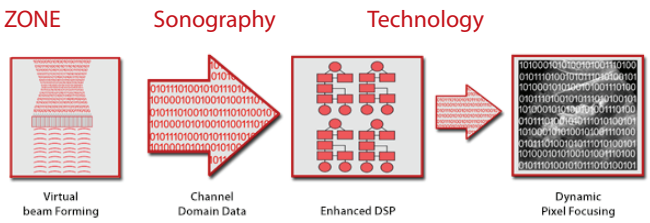
Introduction

ZONE Sonography® Technology+ (ZST+) is a revolutionary, software-driven approach to acoustic data acquisition and image formation that breaks the barriers of conventional ultrasound imaging based on innovative channel data processing methods. Introduced in 1999, ZST was the first virtual beamforming method approved for use in clinical practice. Thanks to continuous advances and improvement in this core technology, ZST+ has matured into the premier advanced ultrasound imaging architecture that makes novel and innovative diagnostic applications possible. Traditionally, ultrasound acoustic data was acquired line-by-line and focused with a digital beamformer using only a small fraction of the actual information contained in the data set.



By using larger acoustic zones, instead of line by line formation, ZST+ has the potential to capture and utilize virtually all of the information contained in the larger returning acoustic data set. In so doing, it creates high quality, maximally focused images using far fewer transmit/receive cycles. While it might be intuitive that simultaneously collecting data from these larger zones would be more efficient, it is understandably less intuitive that fewer acquisitions could result in improved image quality. However, ZST+ achieves this performance advantage with its unique Technology Triad. This proprietary approach to advanced ultrasound imaging architecture consists of:

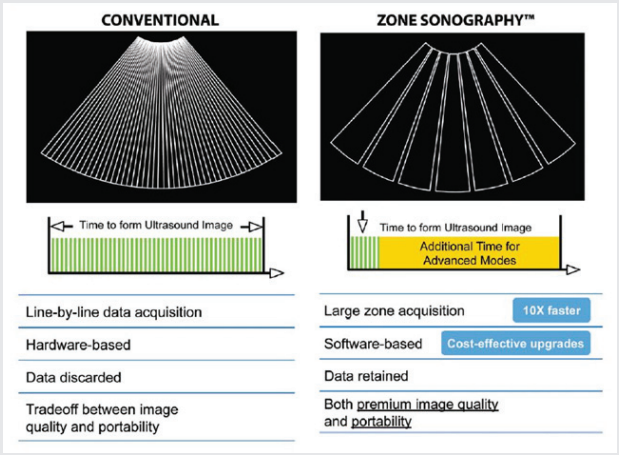
- Advanced Acoustic Acquisition (AAA)
- Dynamic Pixel Focusing (DPF)
- Enhanced Digital Signal Processing (eDSP)



Advanced Acoustic Acquisition

Advanced Acoustic Acquisition (AAA) is a software-based data acquisition method that captures up to 90% of the returning acoustic data and then processes it up to 10x faster by interrogating a relatively smaller number of large zones and extracting more information from each acquisition. Conventional ultrasound systems can capture only a few receive data sets from each transmit event due to processing time requirements for each data set which creates an acoustic acquisition backlog that results in processing constraints. This inherent limitation is overcome by using a flexible, software-based channel domain processor.

Advanced Acoustic Acquisition



Channel Domain Data

In conventional systems, imaging lines are formed by summing together the contributions of all the channels in the transducer. As soon as each line is formed, the original channel data is discarded. In contrast, ZST+ stores an entire frame of raw channel data in the Channel Domain Memory and this information is reprocessed retrospectively multiple times to form the image. As this image formation method is software-based, it provides several clinical imaging advantages:

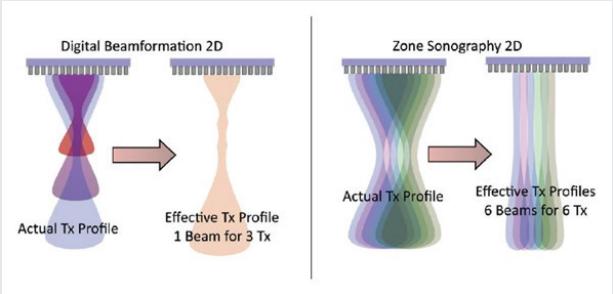
- Extremely fast and accurate display of anatomical motion and hemodynamic states (temporal resolution)
- Reduced tissue motion artifact
- Exceptional frame rates
- Every frame is crystal clear with seamless cine playback

Dynamic Pixel Focusing

Diagnostic ultrasound has achieved its accepted role and proven efficacy in clinical diagnostics by consistently producing high-resolution images of the human body. 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 resulting in poor depth penetration and the need for multiple focal zones. For an ultrasound imaging system to produce high quality images, the region of interest must be suffi-

ciently sampled in both the axial and lateral dimensions to prevent several types of imaging artifacts. Dynamic Pixel Focusing permits utilization of the complete channel data set received from multiple, overlapping zones to retrospectively improve the position and focus of each individual data point. Using software algorithms to synthetically focus along every point in the receive beam effectively produces a round-trip beam focused at all depths, eliminating the need for multiple transmit foci. The image is 2-way focused at every point. A typical ZST+ ultrasound image has over 500 range samples, so the net effect is equivalent to a conventional beamformer-based system using 500-600 focal zones.

Conventional Beam Forming vs. ZONE Sonography



This proprietary method translates into a 2D image that is fully focused from skin line to deepest depth without the need for manual focal zone adjustment. Dynamic Pixel Focusing improves efficiency and the user-experience by reducing need for manual focal zone adjustments and providing a uniform image with improved spatial and contrast resolution throughout the entire field of view. Clinical benefits of Dynamic Pixel Focusing include:

- Full field-of-view focus on transmit and receive
- Use of higher frequency probes for improved image quality at depth
- Improved clinical confidence in imaging neonates to bariatric patients

Virtual Beam Formation

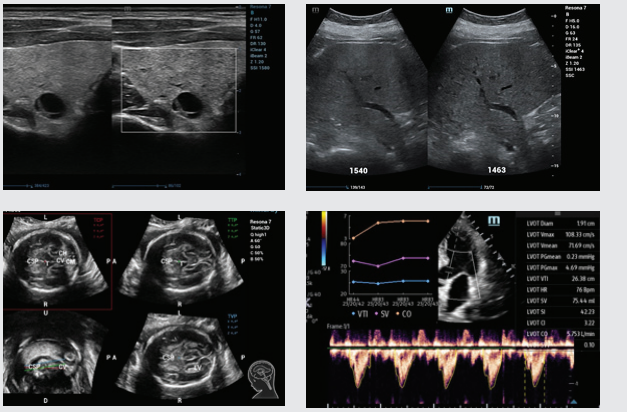
Acquisition of data using fewer transmit/receive pulses (Advanced Acoustic Acquisition) with a fully focused image (Dynamic Pixel Focusing) are the foundational principles of virtual beam formation. Image processing from conventional systems is replaced with retrospective reprocessing using Channel Domain Data stored in a Channel Domain Memory. Virtual beamforming is achieved by the extensive, concurrent, high speed postprocessing of stored raw data using graphics processing units (GPU). The result of this method is improved detail and contrast resolution, improved temporal resolution, and enhanced penetration. Additionally, there is a reduction of imaging artifacts associated with conventional acquisition methods.

Enhanced Digital Signal Processing

Enhanced Digital Signal Processing (eDSP), the third foundational principle of Mindray's Technology Triad, is a proprietary and innovative method of analyzing the larger and more robust acoustic data set and converting it to a raw storage format, enabling manipulation at any time. In conventional ultrasound systems, each line in an image frame 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. Conversely, ZST+ stores an entire frame of raw acoustic data in Channel Domain Memory. The stored acoustic data is then reprocessed multiple times to form a single image frame. The availability of the more complete data set increases both flexibility and capability and permits multiple, retrospective processing passes on stored data. This enables extremely fast creation of multiple frames (up to 1,200 fps) on the back-end. Additional processing, analysis, and display of data contained within these frames make new applications and technologies possible. Innovative applications enabled by eDSP include:

Advanced imaging applications

- Automated Sound Speed Compensation (SSC) – *The ability to automatically detect and analyze different tissue characteristics to determine the optimal signal speed needed for improved image quality. This unique, one-touch, intelligent algorithm improves lateral, spatial, and contrast resolution and imaging at depth.*
- HD Scope - *a proprietary method of enhanced tissue characterization that applies various filtering and processing algorithms to a specific region of interest. This processing method results in improved spatial and contrast resolution making it a great tool for assessing indeterminate lesions and discrete pathology to improve diagnostic confidence.*
- Smart Tools Technology Suite – *automated AI algorithms based on big data that intelligently analyzes anatomy to calculate frequently used measurements and quickly display critical information. Smart Tools Technology is available to examine fetal brain, fetal heart, cardiac fluid management, lung fluid and more.*

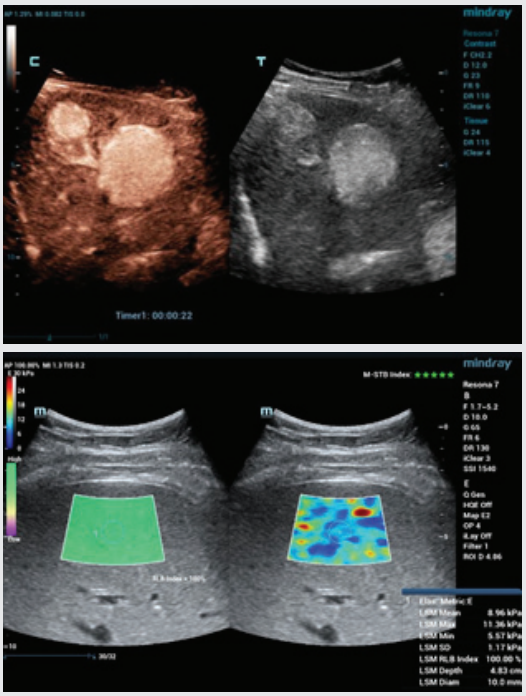


Technologies enhanced by ZST+:

Advanced tissue property assessment

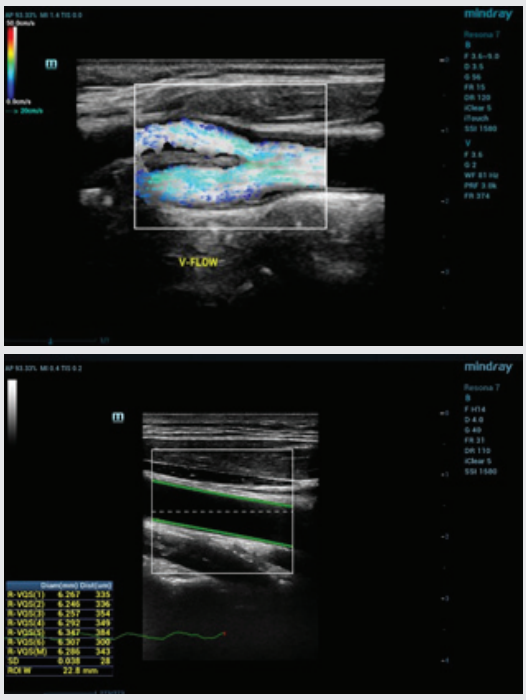
- CEUS (UWN+) – *the ZST+ acquisition method uses less energy at a lower mechanical index resulting in decreased bubble destruction, longer contrast agent duration, and less contrast dosage used. Pixel by pixel frame creation provides consistent image quality and uniformity throughout the entire field of view. UWN+ technology uses the non-linear fundamental signal combined with the 2nd harmonic signal to increase sensitivity, improve contrast-tissue ratio, and improve penetration.*

- Suite of Elastography Methods: Natural Touch Elastography (NTE), Sound Touch Elastography (STE), Sound Touch Elastography Quantitative Analysis (STQ) – *ZST⁺ increases the amount of data acquired and improves signal to noise ratio compared to conventional beamforming. Ultra-wide beam tracking technology allows for rapid acquisition rates (up to 10KHz) for general imaging depths while using less acoustic power.*



Advanced hemodynamic methods

- V Flow – *Vector Flow is an innovative method, based on plane wave acquisition, that analyses the speed and the direction of blood cells flowing through an ROI during an entire cardiac cycle. This Doppler angle independent method of analysis allows for the simultaneous observation of red blood cells moving at low and high velocity in any direction, including reverse.*
- Radio-frequency Vessel Quantitative Stiffness (RVQS) - *proprietary technology that automatically identifies the intimal surface of the artery and tracks changes in vessel diameter over several cardiac cycles. On-board software then calculates the stiffness of the interrogated vessel, a metric useful in cardiovascular risk assessment schema.*



ZST⁺ Advantages

The powerful capabilities of ZST⁺ provide significant benefits to ultrasound imaging. The acquisition of larger and more robust acoustic data sets coupled with proprietary, industry-first virtual beamforming methods and innovative signal processing techniques translates into a number of unique imaging advantages. These include extremely fast image processing and display for noticeably improved temporal resolution; exceptional image uniformity throughout the field of view with improved spatial and contrast resolution. ZST⁺ also has the ability to generate novel and exclusive advanced diagnostic applications while improving the performance of established imaging technologies. Virtual beam formation will continue to shape the future of ultrasound imaging in impactful ways, allowing for more powerful technology, improved workflow tools, and the inclusion of more AI-based advancements. ZST⁺ has paved the way for the future of ultrasound.

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