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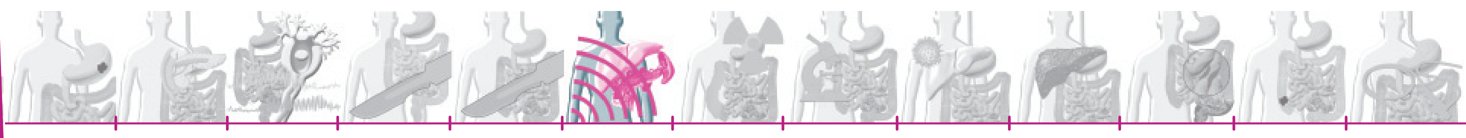

New Ultrasound Technique: Zone Sonography

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The new ultrasound technique “Zone Sonography” (McLaughlin 2004) represents a radical departure from the scanning and signal processing techniques that are typically relied on by all other ultrasound systems. In current, commonly used ultrasound systems, a “beamformer” (or specially programmed processor) emits a focused pulse from the sending crystals of the transducer onto the tissue. This pulse penetrates through body tissue and is reflected or sent back by the boundary layers. It arrives back at the transducer’s crystals, whereby the time it requires depends on the distance from the transducer. Next, the signals are pre-processed. The signals received by the neighboring transducer crystals are added up. Differences in time are corrected based on the distance to the transducer (dynamic focus) and loaded into the frame buffer by continuing to process signals before they are read out and displayed on the monitor. This process is repeated for each of the groups of crystals along the transducer. There are profound disadvantages to this method that interfere with further advancements, such as high frame rates and modern signal processing techniques.

Fig. 1

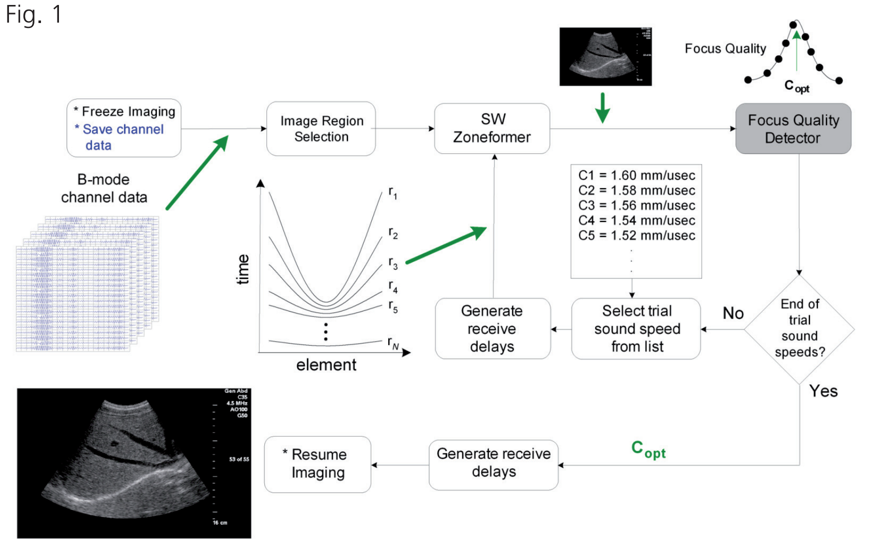

Figure 1: Block diagram of the sound speed correction algorithm (Glen W. McLaughlin, David Napolitano, Ching-Hua Chou, ZONARE Medical Systems, Inc. – Mountain View, USA)

Sequential scanning takes considerable time, because following each individual pulse that returns back to the transducer through tissue at the velocity of sound (1540 m/s), no new pulse can be transmitted until the first pulse has arrived back. Beamformers are rather expensive; require considerable hardware, as well as relatively high energy (heat development). Furthermore, they are difficult to program. The raw signal data that is reflected is not buffered. Therefore, it is impossible to put this information to further use in reprocessing the data. Every complicated attempt to process the signal is only possible at the expense of the refresh rate.

The new ultrasound technique referred to as “Zone Sonography” (ZONARE) has nothing more to do with conventional techniques. Broad surface (5-35 “zones” that lie next to each other), wide-banded ultrasound pulses are emitted without using a beamformer. All of the channels are capable of receiving. The raw signal data for each of the crystals is stored inside a “Channel Domain” memory based on how long it needed to travel. A digital signal processor (DSP) utilizes this data for pixel by pixel calculation of a dynamic synthetic transmission and receiving focus, as well as for other complex signal processing (see below) that can then be passed on to the frame buffer and monitor. Thanks to continuous focusing, the images are extremely homogeneous. There is no longer a switch for adjusting the focus.

Comment:

The revolutionary differences between Zone Sonography and conventional ultrasound techniques include the fact that the image is created roughly ten times faster (time saved for complex signal processing), raw data is buffered for every channel. Furthermore, while signal processing is complex, it is only dependent on the speed of the processor and not the velocity of sound. Last, but not least, hardware costs are lower and the dimensions of the system smaller. This technique opens up entirely new prospects, because it leads to modern and sophisticated analysis of signals and image analysis techniques that are capable of lifting sonography up to a new level of quality. The critical aspect that pertains to this technique is the question of whether the lack of the increase in the signal-to-noise ratio that conventional beamformers deliver can be compensated for by “virtual focusing”.

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Fig. 2

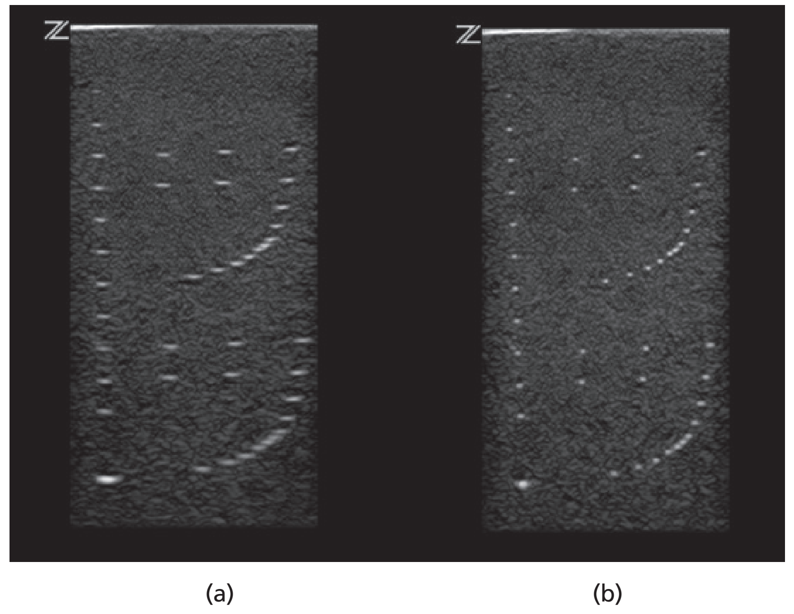


Figure 2: Ultrasonic phantom images: (a) Imaged at a sound speed of 1540 m/s. (b) Imaged at a sound speed of 1460 m/s. Note the difference in the lateral resolution of the point targets and how the lateral resolution degrades with depth when the sound speed estimate is incorrect. These images were obtained with a linear transducer (L10-5) at a centre frequency of 8.5 MHz and depth of 8 cm.

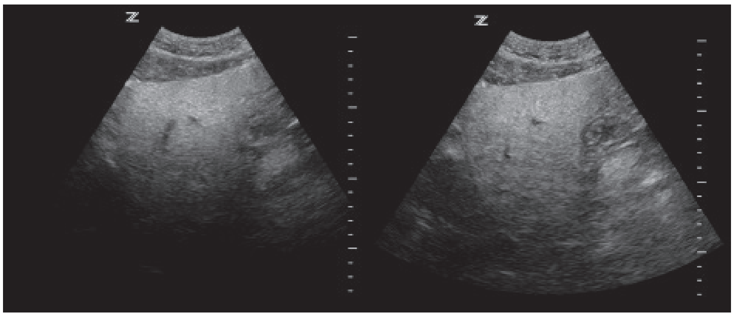
New Image Improvement Modalities through Zone Sonography

With all ultrasound systems, a uniform velocity of sound of 1540 m/s is assumed during focusing and measurement of transit times for human tissue. However, the homogeneity of tissue (the abdominal wall, for instance) with its respective inhomogeneity, when it comes to the velocity of sound, can result in tangible defocusing and undesirable signal disruptions.

In the paper of Napolitano 2006, an automated algorithm that determines the best possible velocity of sound for the individual channels, through an iterative process, using the data stored from the various channels (see figure 1), results in the highest contrast (signal-to-noise ratio) for the pixels of an image line (fast Fourier transformation of the signal frequency of neighboring channels, re-scaling of the distance to 1540 m/s) and, thus, produces the best possible image. For example, during experimental testing of this metric data, using a phantom and while examining the liver and kidneys, it was learned that a better image can be produced using a 4MHz transducer with a velocity of sound of 1480 m/s (sharper edges of the organs and S/N).

Comment:
This publication clearly expresses the possibilities for processing signals that the new ultrasound technique (ZONARE) has to offer. Much like the idea of an automatic focus setting that many cameras feature, the optimum signal to noise ratio for the velocity of sound is determined through an iterative process and the actual velocity of sound is measured rather easily. Whereas in this paper, correction of an entire image line is the overriding objective, correction of every centimeter of an image is now possible and this will result in yet another improvement to image quality. This means that automatically optimized system (signal) settings will be possible for individual patients.

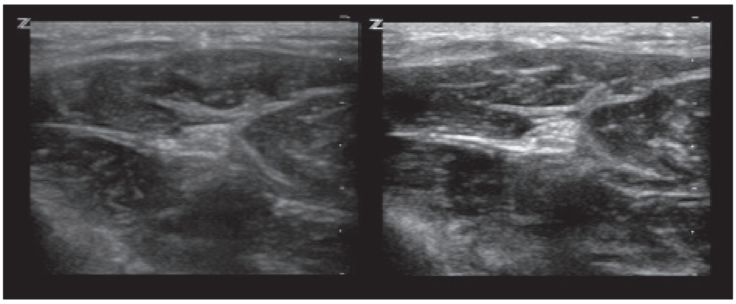
Fig. 3



a) b)

Figure 3. Ultrasonic images of a difficult to image liver: (a) Imaged at a sound speed of 1540 m/s. (b) Imaged at a sound speed of 1490 m/s and +2 dB digital gain to improve the signal-to-noise ratio. Note the differences in penetration, contrast resolution, boundary clarity, and detail resolution seen in image (b) compared with image (a). These images were obtained with a curved transducer (C5-2) at a centre frequency of 3.0 MHz and depth of 18 cm.

Fig. 4



(a) (b)

Figure 4. Ultrasonic images of a radial nerve: (a) Imaged at a sound speed of 1540 m/s. (b) Imaged at a sound speed of 1650 m/s. Note the differences in contrast resolution, boundary clarity, and detail resolution seen in image (b) compared with image (a). These images were obtained with a linear transducer (L10-5) operated under a frequency compounding modality at a depth of 3 cm.

Literature

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