with current medical imaging quality standards. It will be shown that a gain of 16 in the acquisition time can be achieved without any loss in lateral resolution.

[1] von Ramm, O.T., Smith, S.W. and Pavy, Jr., H.G., *IEEE Trans. Ultrason. Ferroelec. Freq. Contr. 38*, 100-8 (1991).

10.3 COMPENSATION FOR INOPERABLE ELEMENTS IN PHASED ARRAY IMAGING: CONTRAST RESOLUTION, Pai-Chi Li and M. O'Donnell, Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI 48109-2122.

To enhance the detection of low contrast lesions deep in the body, very large arrays (VLA) are of particular interest to improve spatial and contrast resolution of ultrasound imaging systems. Due to acoustically opaque structures in the body, however, a large number of array elements might not function properly in routine clinical application of a VLA. Generally, missing elements produce high sidelobes and possibly even a wider mainlobe if the total aperture size is reduced. An object dependent approach has been proposed to compensate for undesired beamforming artifacts due to inoperable array elements [1]. This algorithm utilizes multiple receive beams to both measure the scattering source distribution and to classify tissue structures. Given the number and position of inactive array elements, the lateral point response can be approximated and used in a total-least-squares (TLS) method to estimate sidelobe contributions from scatterers at undesired directions. Results on real measurements showed that this method can effectively reduce undesired beamforming artifacts, where compensated image quality is comparable to full array image quality even with 37.5% of the array elements missing (24 out of 64).

To further investigate the method's capabilities, extensive simulations have been done to quantify improvements in low contrast detectability in the presence of inactive array elements. Using image signal-to-noise ratio (SNR) as a quantitative performance measure, results indicate that contrast detectability is influenced by both the number of independent speckles and the sidelobe energy in the point spread function. If the number of missing elements is not significant, then the number of independent speckles does not change and sidelobe energy dominates detectability. After applying the compensation algorithm, contrast resolution can be restored, even surpassing that of the full array image. Both pictorial examples and numerical results will be presented and discussed.

[1] Li, P.-C., Flax, S.W., Ebbini, E.S. and O'Donnell, M., in *Proc 1992 IEEE Ultrasonics Symposium* (in press).

10.4 REAL-TIME IMAGING WITH LIMITED DIFFRACTION BEAMS, J-y. Lu, T-K Song, R.R. Kinnick and J.F. Greenleaf, Biodynamics Research Unit, Department of Physiology and Biophysics, Mayo Clinic and Foundation, Rochester, MN 55905.

Limited diffraction beams are a class of solutions to the isotropic-homogeneous scalar wave equation. Theoretically, these beams are nonspreading as they propagate to infinite distance provided that they are produced with infinite aperture and energy. In practice, they are nearly nonspreading over a large depth of field when produced with a finite aperture and energy. Because of the large depth of field, the limited diffraction beams could be applied to medical imaging, tissue characterization, and nondestructive evaluation of the materials.

In this report, we describe a real-time system that can produce either limited diffraction beams or conventional beams for *in vitro* or *in vivo* imaging. A 14-element, 3.5 MHz central frequency, and 25 mm diameter broadband 1-3 ceramic/polymer composite annular transducer was designed and mounted in a wobbler. A 14-channel transmitter that includes a digital waveform synthesizer for each channel, was designed and constructed. The waveform synthesizer can produce limited diffraction beams such as the Bessel beam and X wave, and conventional beams such as focused beams or weighted Axicon beams. A commercial APOGEE CX scanner was modified to interface with the transmitter and to receive the echo signals and produce real-time images. The dynamic focusing receiver of the APOGEE CX scanner was used in receive. Images of *in vitro* phantoms and tissue samples and *in vivo* human organs were obtained with various beams. A video tape of a beating human heart was recorded. The images obtained with limited diffraction beams have larger depth of field, good contrast, and better resolution than conventional beams. The resolution of the limited diffraction beams prompted some physicians to state they must be 5 MHz images.

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PROGRAM AND ABSTRACTS

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