Categorical Course: New Developments in Transducer Technology
Wednesday, March 17, 1993 7:30 am–9:30 am

New Developments in Transducer Array Technology

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Linear one-dimensional (1-D) phased arrays are now firmly established as the principle transducer technology for diagnostic ultrasound imaging. In this course, the basic physics of phase array transducers will be reviewed giving particular attention to the issues of sensitivity, sidelobe levels, and grating lobe levels. The effects of these factors on image quality will be discussed and comparative evaluation of array structures such as phased linear and phased annular arrays will be presented. The ongoing development of two-dimensional (2-D) arrays represents the next step in the evolution of transducers. The addition of the second dimension allows focusing in both the azimuthal (image plane) and the elevation (out of plane) directions. In addition, 2-D arrays have the potential for volumetric imaging and phase aberration correction which are not possible with linear 1-D arrays. The current state of 2-D arrays will be reviewed and the prospects for future developments will be discussed. The recent emergence of imaging at very high frequencies (20–80 MHz) in applications such as intravascular imaging poses some very demanding problems with respect to transducer array development. Most of the difficulties encountered in this application are related to the size and high impedance of the individual elements. The advantages and disadvantages of approaches to overcome these difficulties will be discussed and compared.

New Developments in Transducer Materials

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Ultrasonic transducers for medical imaging have been built largely using piezoelectric materials developed during World War II, the lead zirconate/lead titanates (PZT). Advances in transducer performance have been achieved through quarter-wave matching, improved materials processing and assembly, and more complete understanding of piezoelectric resonant structures. Several potential competitor piezoelectric materials have been developed, including lead metaniobates, PVDF, and modified lead titanates. However, these materials have found only limited applications in medical transducers. In the last 10 years, several new piezoelectrically active materials have evolved which are being used now in many products, and are expected to find even more applications. These materials, which include ceramic/polymer composites, new piezoelectric polymers, high dielectric constant ferroelectrics, relaxor ferroelectrics, and multilayer piezoelectric structures, will be discussed. In particular, the properties of these materials which will impact transducer performance will be compared to standard materials, and new devices that could be based on these materials will be described. These devices will include elevational focus arrays, 2-D arrays, higher bandwidth arrays, array elements switchable with DC bias voltages, and arrays with complex geometries.

New Developments in Beam Propagation

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Since the first limited diffraction beam was discovered by J. Durnin in 1987, both theoretical and experimental studies of these beams have been carried out in optics. The theoretical limited diffraction beams keep a small main beam width and can propagate to infinite distance without spreading, however, they may not be realized because of the requirement of an infinite aperture and energy. In practice, the limited diffraction beams are truncated in aperture but continue to have a small main beamwidth and large depth of field (pencil-like) as compared to conventional focused beams at their focuses. Recently, these beams were developed further and studied in acoustics. Their applications to acoustic imaging, biological tissue characterization, and nondestructive evaluation of materials have been explored. In this course, the fundamental characteristics and new development of the limited diffraction beams will be presented. Their formation by a 50 mm diameter, 2.5 MHz, and 10 element broadband annular array transducer and propagation in water will be displayed in a movie. The resulting beams have small main beam-widths (2.53 mm and 4.7 mm for Bessel beam and X wave, respectively) propagating and nonspreading over large depths of field (216 mm and 358 mm for the Bessel beam and the X wave, respectively). Preliminary study of the applications of the limited diffraction beams to medical ultrasonic imaging, biological tissue characterization, and nondestructive evaluation of materials will be presented. The results show potential usefulness of the limited diffraction beams in these areas. Post processing of images obtained with the limited diffraction beams could be simplified because of the depth-invariant property of the beams. Advantages and disadvantages of these novel beams will be addressed.

Journal of
Ultrasound
in Medicine

VOLUME 12, NUMBER 3 (SUPPLEMENT) MARCH 1993

OFFICIAL PROCEEDINGS 37TH ANNUAL CONVENTION

March 15–18, 1993
Honolulu, HI

Official Journal of the American Institute of Ultrasound in Medicine

Jian-yu Lu Mar. 15, 1993