mm (lateral) strain measurement area and can be improved from now on. Strain images are superimposed on B-mode images with a translucent color scale. In the clinical measurement, elasticity images for breast and prostate cancer were obtained from more than 50 subjects, respectively. Some results showed the high availability of the elasticity image, that is, visualization of the expansion area of a tumor and detection of a small size (<5mm) of non-invasive ductal carcinoma. These results validate that the system can provide the high-quality and stable elasticity image in the clinical measurement.

This research is partly supported by grants of research promotion from the MEXT.

Session: 3G

TRANSUDCERS AND ARRAYS

Chair: K. Shung

University of Southern California

3G-1 4:30 p.m.

REAL TIME CYLINDRICAL CURVILINEAR 3-D ULTRASOUND

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In patients that are obese or that exhibit signs of pulmonary disease, standard transthoracic scanning may yield poor quality images. For these conditions, two-dimensional transesophageal echocardiography (TEE) is established as an essential diagnostic tool. Current techniques in transesophageal scanning, though, are limited by incomplete visualization of cardiac structures in close proximity to the transducer. Thus, we propose a 2D curvilinear array for 3D transesophageal echocardiography in order to widen the field of view and increase visualization close to the transducer face. As a precursor to this project, a 440 channel 5MHz two-dimensional array with a 12.6 mm aperture diameter on a flexible interconnect circuit has been molded to a 4mm radius of curvature. A 75 % element yield was achieved during fabrication, and an average -6dB bandwidth of 30 % was observed in pulse-echo tests. Using this transducer in conjunction with modifications to the beam former delay software and scan converter display software of the Volumetrics Medical Imaging 3D scanner, we obtained cylindrical real-time curvilinear volumetric scans of tissue phantoms including a field of view of greater than 120° in the curved, azimuth direction and 65° phased array sector scans in the elevation direction. Real-time volume rendered images of a tissue mimicking phantom with holes ranging from 1cm to less than 4mm have also been obtained. These images were achieved using a stepped subaperture across the cylindrical curvilinear direction of the transducer face and phased array sector scanning in the non-curved plane. This configuration can theoretically achieve volumes displaying 180° by 120°. The transducer is also capable of obtaining images through a curvilinear stepped subaperture in azimuth in conjunction with a rectilinear stepped subaperture in elevation,
Further increasing the field of view close to the transducer face. Current work includes development of an array for adapting these modifications to a 6mm diameter endoscope probe.

3G-2 4:45 p.m.

ADVANCES IN 2D ARRAY CATHETER TRANSDUCERS FOR REAL-TIME THREE-DIMENSIONAL INTRACARDIAC ECHOCARDIOGRAPHY

W. LEE*1, S. F. IDRIS2, P. D. WOLF1, and S. W. SMITH1, 1Duke University, Durham, NC, USA, 2Duke University Medical Center, Durham, NC, USA. Corresponding e-mail: warren.lee@duke.edu

Intracardiac echocardiography (ICE) is an imaging method that has been shown to be effective in guiding interventional cardiac procedures such as transseptal puncture and coronary sinus (CS) access for pacing lead implantation. In this paper, we describe advances in the design, fabrication and testing of two-dimensional catheter-mounted arrays for real-time three-dimensional (RT3D) ICE. Most recently, we have developed a 7 Fr (2.3 mm O.D.), 112 element 2D array utilizing a non-coaxial ribbon-based cabling technology. The transducer has a center frequency of 5 MHz, with a 6 dB fractional bandwidth of 30% and insertion loss of 73 dB (including 1 m of cable). The transducer was constructed on a six layer flex interconnect, with laser drilled vias and a 0.15 mm element spacing. The final element yield was 97%. The small size of the catheter enables RT3D ICE from within the coronary sinus not possible with previous ICE catheters. We present in vivo images of cardiac anatomy obtained from within the CS including the left and right atria, aorta, coronary arteries, and pulmonary veins. We also present simultaneous long and short axis views of the left ventricle, mitral valve, and left atrium with the 7 Fr catheter positioned in the right ventricle. We have also developed forward-viewing 2D array intracardiac probes that contain an integrated working lumen for interventional device delivery. The 14 Fr and 22 Fr probes have been used to obtain images of cardiac anatomy and simultaneous interventional device delivery in the in vivo sheep model including: manipulation of a 0.35 mm diameter guidewire into the CS, and guidance of a transseptal puncture using a 1.2 mm diameter Brockenbrough needle. The dual lumen probes may simplify cardiac interventional procedures by allowing clinicians to visualize cardiac structures and simultaneously direct interventional tools in a RT3D image.

3G-3 5:00 p.m.

A CANCELLATION BASED APPROACH FOR REDUCING ACOUSTIC CROSS-TALK IN ULTRASOUND ARRAYS

S. ZHOU* and J. HOSSACK, University of Virginia. Corresponding e-mail: hossack@ieee.org
Acoustic crosstalk is an undesirable characteristic that is always present to at least some extent in all ultrasound transducer arrays. Conventionally, it is controlled by physical separation and the use of lossy materials. We describe a new method for controlling crosstalk effects that makes use of cancellation techniques. The output from a selected element and the associated electrical excitation are measured and recorded. The output signal from an adjacent element is also recorded. These recorded values are used to populate a transmit transfer function matrix. The desired output function is then specified (i.e., finite output from selected element and zero from adjacent element). Upon solving the matrix expression, the required excitation function for both the selected element and adjacent elements are determined. The approach can be extrapolated to deal with the multi-element transmit focus case using linear superposition. While the approach requires the use of specially programmed waveform generators, it should be noted that these are finding more common use in commercial ultrasound scanners. Results obtained using Finite Element Analysis and from experiments are presented. In FEA simulations, reductions in crosstalk ranging up to 9 dB have been obtained. The results obtained during experimentation are significantly less (in the range 3 to 6 dB). It is believed that experimental crosstalk cancellation can be improved by better characterization of the experimental devices. One approach for improving the crosstalk characterization by using laser interferometry of element surface displacement is discussed. The approach has an analog in the receive processing path. The concepts and limitations of the approach when applied in the receive path are discussed.

The Whitaker Foundation

3G-4  5:15 p.m.

STRUCTURAL OPTIMIZATION OF ULTRASONIC TRANSDUCER STRUCTURES FOR IMPROVED SPECTRAL, TEMPORAL AND SPATIAL CHARACTERISTICS

D. J. POWELL*, J. MOULD1, L. CARCIONE1, P. REYNOLDS1, and C. S. DESILETS2, 1Weidlinger Associates Inc, 2Liposonix.

As the performance demands on the latest generation of ultrasonic transducers continue to grow, designers are continually seeking ways to push the operational envelope. For example, in the case of biomedical transducers, a prime objective would be to maximize acoustic performance whilst satisfying stringent FDA regulations.

We have previously discussed structural optimization methods to improve the spectral characteristics of multilayered transducers, however depending upon the particular application, a device’s temporal response and/or spatial response may provide more appropriate basis for developing figures of merit used for optimization purposes.
Effective optimization requires a fast forward solver coupled to a versatile optimization back-end. Numerically efficient time-domain finite element codes such as PZFlex may be used to facilitate the computation of a transducer’s transient response (both spectral and spatial) at any point with the confines of the finite element model. Furthermore, it is also possible to determine the transient response outside the confines if the finite element model via time-domain Kirchoff extrapolation. By computing the temporal response at all points along an arc, it is subsequently possible to extract the beam-pattern at arbitrary frequencies via the application of an FFT as a post processing step. This technique is both complete and comprehensive; however, for applications where the beam-pattern is required at only a handful of frequencies, it is not necessarily the most computationally efficient method.

Using our recently developed frequency domain Kirchhoff extrapolation technique, we can calculate frequency specific beam-patterns with only minimal computational effort. This new capability will be used to facilitate the structural optimization of a variety of transducer structures and subsequently provide not only improved temporal/spectral characteristics, but also, more desirable spatial characteristics such as reduced side-lobe and grating-lobe levels.

3G-5 5:30 p.m.

DUAL FREQUENCY ARRAY TRANSDUCER FOR ULTRASOUND-ENHANCED TRANSCRANIAL THROMBOLYSIS
T. AZUMA*1, S. UMEMURA1, T. KOBAYASHI2, M. IZUMI2, J. KUBOTA2, A. SASAKI2, and H. FURUHATA3. 1Hitachi Central Research Laboratory, Tokyo, Japan, 2Hitachi Medical Corporation, Chiba, Japan, 3ME Lab., Jikei University School of Medicine, Tokyo, Japan. Corresponding e-mail: t-azuma@crl.hitachi.co.jp

It is known that ultrasound can enhance thrombolysis with tissue plasminogen activator (tPA). A blood flow monitoring is essential to optimize the amount of tPA bolus and the duration and magnitude of therapeutic sonication. Ishibashi et al. found that an ultrasonic frequency of approximately 500 kHz was most effective for recanalization of a rabbit’s artery through a human temporal bone. However, this frequency is too low for ultrasonic blood flow imaging. Therefore, respective use of two frequencies for ultrasound-enhanced thrombolysis and ultrasonic imaging would be ideal. Since only a temple is the available acoustic window for transcranial ultrasound, the total aperture size for imaging and therapy is very limited. In order to expose ultrasonic waves at two frequencies for imaging and therapy from the same aperture, we propose a probe consisting of a therapeutic array with an imaging array overlaid on it. Between these two arrays, a frequency selective isolation layer was inserted to ensure independent oscillatory motions of the two arrays. The function of this layer is expected to reflect the waves from the imaging array and allow the waves from the therapeutic array to pass through. The thickness and acoustic impedance of the layer
was optimized for this function. Numerical simulation was performed using a finite element code, PZFlex. In this model, the imaging and therapeutic array used PZT ceramic with a center frequency of 2 MHz and 500 kHz, respectively. The imaging array had two acoustic matching layers. Several different thicknesses of the frequency selective isolation layer made of epoxy resin were tested. These results showed that the isolation layer with 50 micro-meters reduced the amplitude of the imaging pulse waves at 2 MHz reflected at the therapeutic array by 13 dB, while it reduced the amplitude of the therapeutic waves at 500 kHz only by 2 dB. A prototype array transducer is being constructed according to this analysis and its preliminary experimental results will be presented.

This Research is partly supported by Japanese Ministry of Health, Labour and Welfare.

3G-6 5:45 p.m.

MID- TO HIGH-POWER ULTRASOUND IMAGING ARRAYS - FROM ARFI TO HIFU
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Conventional ultrasound arrays are limited in their ability to transmit acoustic power into the human body. In some imaging modes, such as Doppler, heating of the array face beyond 41 degrees C, rather than FDA-mandated intensity thresholds in the body (e.g. ISPTA), is the limiting factor. The problem is considerably worse for imaging modes and therapy applications where the acoustic power requirements in the tissue are much higher, e.g. strain-based imaging such as ARFI and HIFU therapy. The present work looks to improve the power delivery capability of ultrasound arrays without sacrificing image quality by incorporating piezoceramic materials designed for high power drive into multilayer structures. The coupling of array element resonators for PZT8- and PZT4-type materials has been found to be between 0.60 and 0.64. This is slightly lower than the 0.70 for PZT5-H-type materials which are typically used in arrays designed for medical imaging. The clamped dielectric constant of these materials is between 500 and 700, considerably lower than that of the PZT5-H. A multilayer structure is capable of increasing the effective dielectric constant of the structure far above that of a single layer of PZT5-H. Thus it is possible to very closely match the electrical impedance of the array to the electronics. This is very important for HIFU designs where the impedance must often be matched by using transformers in the structure. This also has benefits in terms of raising the achievable bandwidth. Preliminary arrays have been fabricated using the PZT4 and PZT8 materials in single-layer form, and the bandwidth has been found to be 60%, compared to 70% for PZT5-H-based arrays. Sensitivity of the PZT4 and PZT8 arrays is about 6 dB lower, due to a lower coupling and dielectric constants. According to KLM model simulations, the use of PZT4 and PZT8 in multilayer ceramics and composites should make the bandwidth and sensitivity at least comparable to conventional arrays while improving the power delivery by a factor of two or more, without the need for electrical impedance matching transformers.

This work has been funded by NIH, ONR, and DARPA.