A CONSTANT BEAMWIDTH TRANSDUCER FOR ULTRASONIC APPLICATIONS

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Abstract - A new class of transducers which produce uniform wide beams (~ 20 degrees) at ultrasonic frequencies (~ 1-2 MHz) are being developed by the US Navy for ultrasonic applications. These transducers will provide a wide illuminated field of view for 2-dimensional ultrasonic imaging arrays. The design features a larger volume of active material, relative to conventional planar designs, which allows the application of higher drive fields. The prototype described in this article was driven to 200 VRMS and produced a sound pressure of 203 (dB re 1μPa at 1m) at a frequency of 2.0 MHz. The details of the ultrasonic Constant Beamwidth Transducer (CBT) design, its fabrication, and measured performance are presented. The ultrasonic CBT described in this paper will soon be incorporated into the Navy's Underwater Sound Reference Division (USRD)'s Transducer Standards Loan Program.

I. INTRODUCTION

Recent Navy interest in 1-3 piezoelectric composite has spurred the development of several unique wide band transducer element and array designs [1,2,3].

The use of a rigid, thermoplastic back- fill material between the ceramic rods of the piezocomposite allows the material to be thermoformed to any reasonable singly or doubly curved geometry. This, in conjunction with conventional printed circuit board plating techniques, enables the realization of a wide variety of single element and array configurations that were impossible, or too expensive to fabricate, with conventional block ceramic.

The application of 1-3 piezocomposite to the construction of a wide beamwidth ultrasonic projector was stimulated by the need for a rugged, high power, wideband projector element suited for deep submergence 2-dimensional sparse imaging arrays. Typically these arrays rely on multiple transmit elements to cover a relatively wide ensonification region.

As a result of the successful demonstration of this ultrasonic transducer, which provides a 20 degree beamwidth, future work will address devices having wider beamwidths (up to 60 degrees). Also the concept will be extended to smaller elements which could be placed onto sparse array apertures rather than being diced from monolithic layers of ceramic.

II. DESIGN

The design of the ultrasonic Constant Beamwidth Transducer (CBT), is based on the theoretical work of Rogers and Van Buren [4]. According to their analysis, the transducer maintains uniform acoustic loading and a constant directivity pattern with low sidelobe levels above a certain cutoff frequency. It also contains no near field. This is accomplished by controlling the surface velocity of a radiating spherical cap with Legendre function shading. This shading is axis-symmetric, being a maximum at the center of the transducer face and tapering to zero at the edge. Early CBT's were constructed using an array of circular disks arranged in individually shaded bands. In current practice this velocity shading is implemented using an area shading approach whereby the active material's electrode surface is reduced as a function of radius. Figure 1 shows the Legendre function area shading for the case of interest along with some other future designs. The largest two patterns in the figure are for the case of interest and measure 25.4 mm (1.0 in) in diameter. The figure also shows the relative size of the ceramic rods (light dots) with respect to the copper plated shading patterns. The rod lateral

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dimensions are 200 μm (7.8 mils) and are centered on a 320 μm (12.5 mils) pitch.

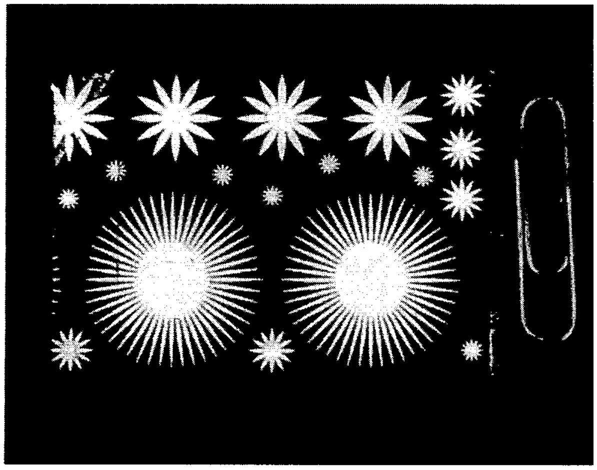

Figure 1: Electroplated fine scale 1-3 piezocomposite showing various area shading patterns

III. FABRICATION

Figure 2 shows the critical fabrication components of the ultrasonic CBT. The plated 1-3 piezocomposite disk is thermoformed using the three-piece aluminum molding tool (bottom center). At a temperature of ~ 65 °C (150°F) the plated composite may be carefully shaped to the required spherical cap geometry. The curved cap is shown at top center of figure 2 with a wire attached to its positive (shaded) electrode surface. Using the female portion of the molding tool, the wired cap is bonded to a USRD E8 standard transducer head assembly (upper left) using a polyurethane-based absorptive backing material. The mold allows the exit of the positive lead through a small groove machined on each of the female mold halves. A practice potting (without active layer) to a transducer head is shown in the upper right of the figure. Close inspection of the casting reveals the exit of a white wire.

After the active shaded cap has been mounted to the transducer head, the outer ground wire is attached and the unit is encapsulated with a 'Rho-C' polyurethane. The transducer head is attached to the tuning housing and is ready for test. The head and tuning housing of the E8 transducer standard were used in the fabrication for convenience. The measured results presented in the next section were obtained without tuning. Furthermore, ultrasonic CBT housings could be designed for other applications involving smaller, and/or conformal requirements.

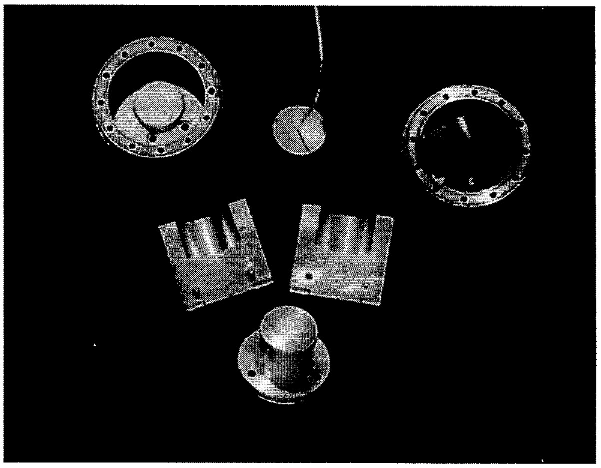

Figure 2: Transducer fabrication assembly tooling, active cap, and E8 transducer heads

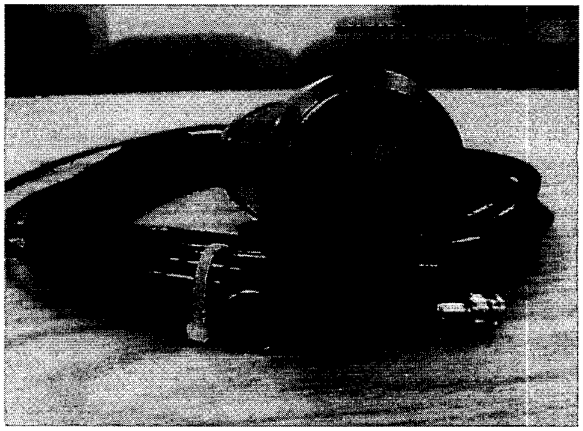

Figure 3: Ultrasonic CBT prototype ready for acoustic calibration

IV. MEASURED RESULTS

The ultrasonic CBT prototype shown above was acoustically calibrated under ambient water temperature, and hydrostatic pressure conditions. Future work will examine the transducer's performance as a function of temperature and pressure. Figure 4 shows a plot of the Transmitting Voltage Response from 0.1 to 3.0 MHz. The resonance which occurs at 1.02 MHz has a quality factor of approximately 6. This unit's on axis sound pressure level remained linear with drive up to 200 VRMS and produced a level of 203 (dB re 1μPa at 1m) at 2.0 MHz.

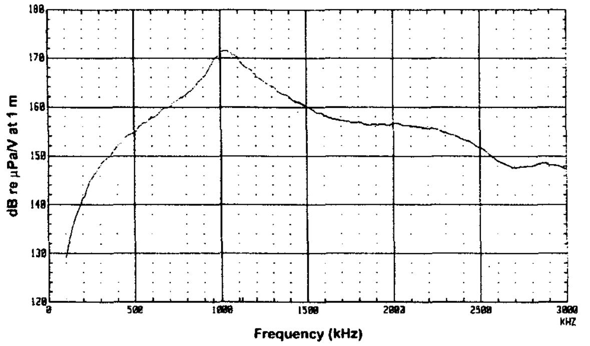

Figure 4 : Measured TVR for ultrasonic CBT prototype

The other acoustic parameter of interest was the prototype's spatial directivity as a function of frequency. Figures 5 through 7 show measured *transmit* beam patterns corresponding to drive frequencies 1.0, 1.5, and 2.0 MHz respectively. One notes that the design goal of a constant, 20-degree 3-dB beamwidth was achieved over this frequency range.

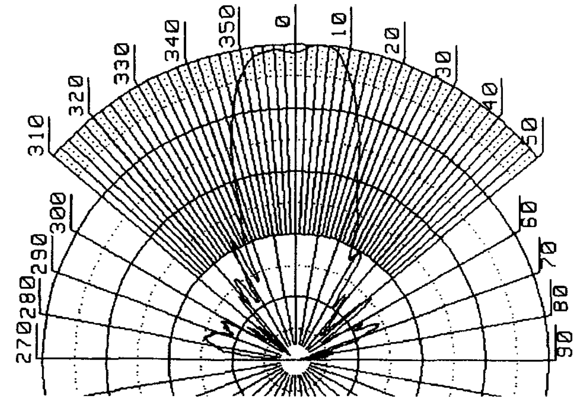

Figure 5: Measured ultrasonic CBT transmit beam pattern at 1.0 MHz

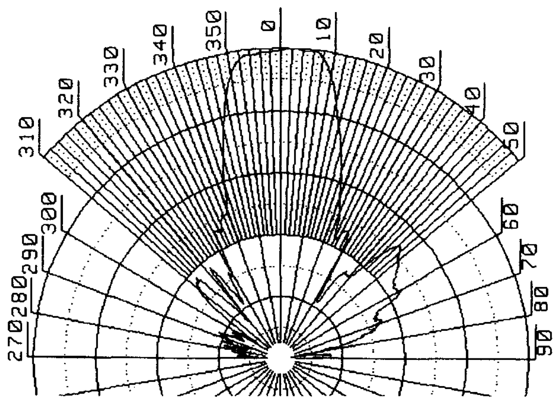

Figure 6: Measured ultrasonic CBT transmit beam pattern at 1.5 MHz

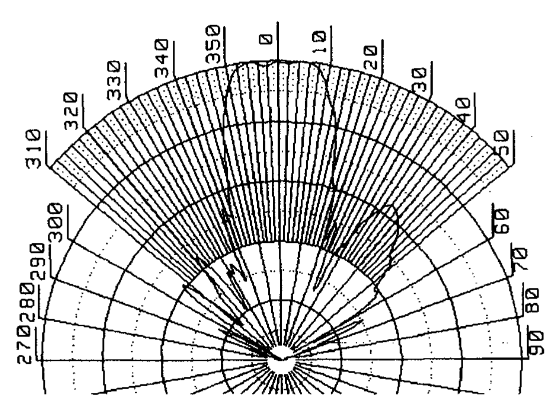

Figure 7: Measured ultrasonic CBT transmit beam pattern at 2.0 MHz

V. CONCLUSIONS AND FUTURE WORK

The design, fabrication, and measured performance of an ultrasonic version of the constant beamwidth transducer have been presented. The design allows wide beam ultrasound ensonification at considerable sound pressure levels. The measured results match well with theoretical predictions [5]. Future work will focus on further testing of the current prototype configuration and extending the concept to smaller sizes, wider beams, and higher ultrasonic frequencies.

VI. REFERENCES

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