TWO-DIMENSIONAL MEASUREMENT OF ULTRASOUND BEAM PATTERNS AS A FUNCTION OF FREQUENCY

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INTRODUCTION

In ultrasonic imaging and tissue characterization, it is desirable to know the pressure field of transducers. For a simple disc radiator operating in a piston mode, the field for continuous wave excitation may be calculated using diffraction theory. However, in practice, the field may be affected by transducer parameters such as backing and front surface matching. These effects are dependent on fabrication technique and sometimes difficult to control. Therefore, in order to ascertain imaging resolution or scattering volume dimensions which are determined by the beam profile, it is desirable to measure the actual pressure distribution.

It is common to obtain a beam profile by recording the signal response of a transducer as it is transversing a small target ball (1). The beam profile can also be measured by scanning a small piezoelectric hydrophone over the field (2). Transducer fields have been visualized in two dimensions using schlieren systems that employ an acousto-optical interaction (3). Two-dimensional measurement of transducer fields have been made by detecting the particle displacement at the field plane using laser scanning of a thin pellicle that moves in the sound field (4). This report describes the two-dimensional measurement of a beam pattern as a function of the excitation frequency.

In this study, an ultrasonic diffraction apparatus contained in a large water tank with precise spatial positioning has been used to measure the frequency-dependent continuous wave

two-dimensional beam patterns of ultrasound transducers. Both the mechanical movement and the sampling of the electrical signal representing pressure amplitude were under the control of a minicomputer-based system that was also used in processing and display of the data. Results are presented for a transducer used in tissue characterization studies. Comparisons with continuous wave calculations made using the Fresnel approximation show good agreement but asymmetries at certain frequencies are also demonstrated in the measured data.

METHODS

The two-dimensional spatial distribution of pressure emitted by the ultrasonic transducer under test was measured by scanning a commercially available microprobe in the plane of interest while exciting the transducer. The microprobe, a small piezoelectric hydrophone affixed to the tip of a hypodermic needle, was mounted on a fixture allowing angular adjustment in two planes. The fixture was attached to a gantry positioned to rotate the fixture in an arc around the center point of the transducer under test. The transducer under test was affixed to a holder on a platform which moved perpendicular to the plane of rotation (Figure 1). The motions are produced by stepping motors.

Tone burst signals long compared to periods (32 to 128 cycles) were gated from an oscillator to a power amplifier and applied to the transducer. The frequency of the oscillator was stepped between 2 and 8 Mhz in increments of 23.5 KHz to obtain measurement at 256 frequencies for each position of the microprobe in the scan plane. The signal received by the microprobe was amplified logarithmically with a dynamic range of 60 dB, gated, rectified and integrated over the duration of the time gate (Figure 2). The output signal proportional to log of the pressure field at the front surface of the microprobe was then digitized into 8 bit samples and stored in a disk file that also contained motor positional and other housekeeping information.

A commercially available piezoelectric transducer used in tissue characterization studies with ultrasound (5) was tested with this system. The transducer was made with an active circular disc having a radius of 0.238 cm and was specially encapsulated with a thin layer of silicon to prevent water from leaking in. The receiver microprobe was scanned in an arc with an increment of 0.25 degrees over 128 steps with a fixed radius of 13.5 cm around the center of the transducer. A total of 64 levels spaced 1.16 mm and centered on the transducer axis were