AIR-COUPLED AND WATER IMMERSION SECTORIZED ARRAY TRANSDUCERS FOR INDUSTRIAL AND MEDICAL ENDOSCOPY.

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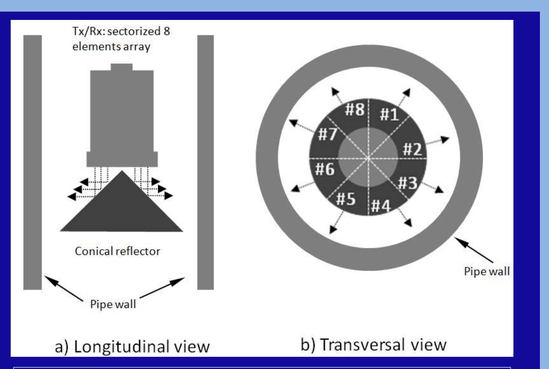
Abstract: This paper describes the design, fabrication, characterization and test of three sectorized array transducers: one for air-coupled operation (400 kHz, 25 mm diameter) and two for water-coupled operation (4 MHz, 10 mm diameter and 2 MHz, 5 mm diameter). The objective is to use these transducers in pulse-echo mode along with a conical reflector to generate a 2D cylindrical acoustic field with angular resolution that can be used for industrial and/or medical ultrasonic endoscopy. Some examples of use of these prototypes to inspect different pipes (size and materials) and to determine both inner diameter and wall thickness are also shown.

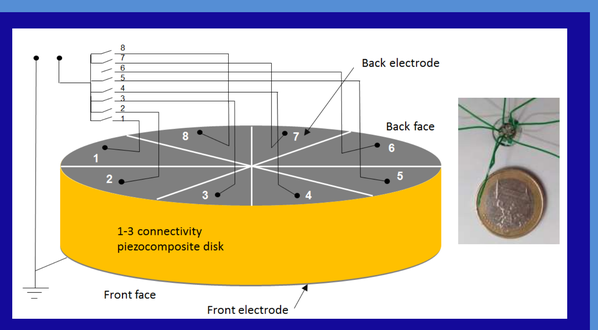
I. Sectorized array with conical reflector for endoscopy.



Schematic representation of the sectorized array transducer, the conical reflector and the pipe/ vessel

II. Transducers fabrication.

II.a Piezoelectric disk and array elements

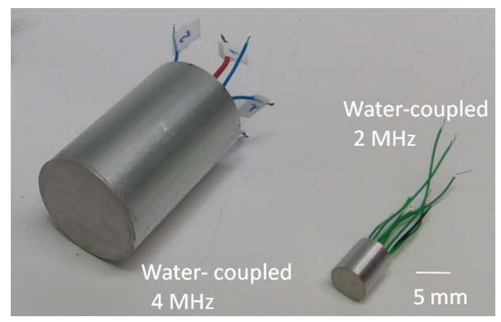


Left: Schematic view of the 8-elements kerfless sectorized array. Right: Picture of the 5 mm diameter water-coupled array (2 MHz) before encapsulation.

II.b Air-coupled array

Left: Picture of the prototype of the air-coupled 400 kHz sectorized array (housing outer diameter: 29 mm). Right: air-coupled array together with the conical reflector.

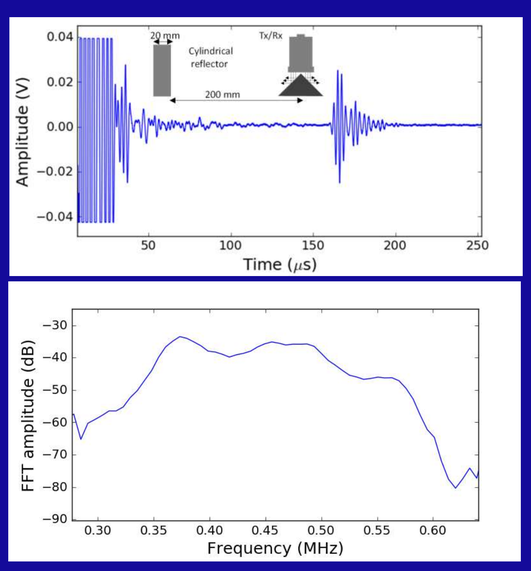
II.c Water-coupled arrays



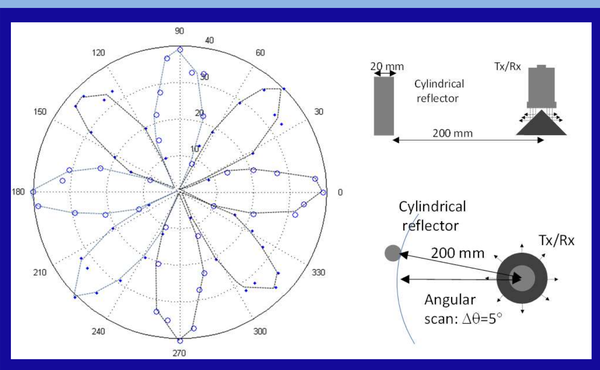
Picture of the prototypes of the 4 MHz array (left) and the 2 MHz array (right).

III. Arrays characterization

III.a. Air-coupled array

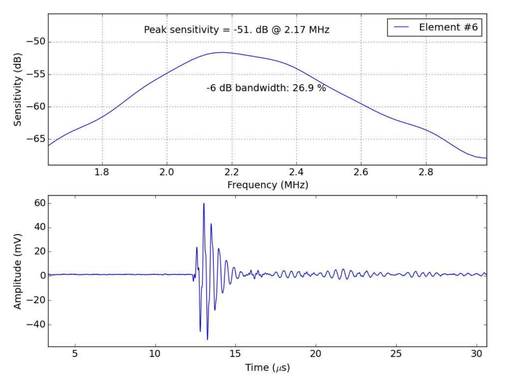


Received echo from a 20 mm cylindrical reflector located at 200 mm. Bottom: Magnitude of the FFT of the received echo.



Angular directivity of the elements of the air-coupled array

III.b. Water-coupled arrays

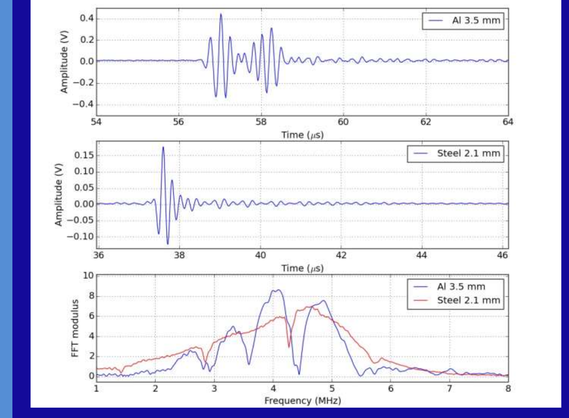


Sensitivity frequency band and received echo in time domain from a flat reflector by element #6 of the 2 MHz array.

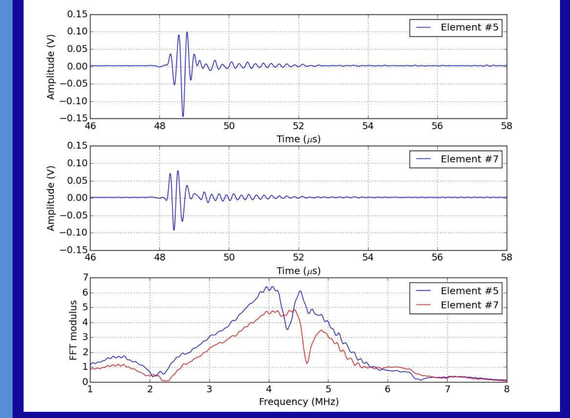
IV. Test of water coupled sectorized array for endoscopy

TABLE I. PIPES USED TO TEST THE WATER-COUPLED ARRAYS

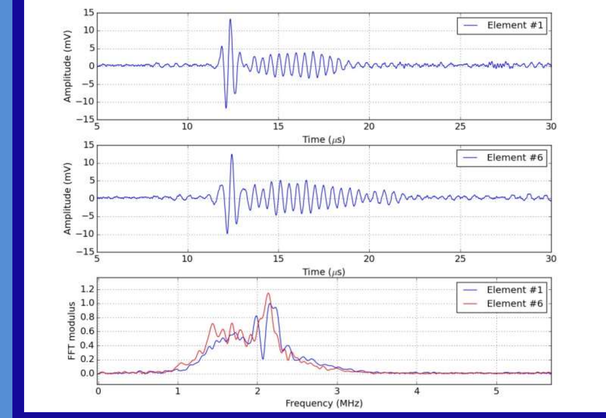
Pipe material	Wall thickness (mm)	Inner diameter (mm)	Wall first thickness resonance (MHz)
Al	1.5	15	2.1
Al	3.5	38	0.9
Steel	2.1	25	1.4



Echoes (and their FFT) received from two different pipes using the 4 MHz water coupled array and the conical reflector



Echoes and FFT received from one pipe (1.5 mm wall thickness) with two different elements of the 4 MHz water coupled array and the conical reflector.



Echoes received from one pipe (and their FFT) with two different elements of the 4 MHz water coupled array and the conical reflector. 1.5 mm thick Al pipe

VI. Conclusions.

Results confirm the viability of the proposed technique to fabricate air-coupled (400 kHz) and water- coupled (2 and 4 MHz) sectorized arrays with 8 elements using 1-3 connectivity composites. Arrays are used along with a conical reflector to generate a 2D cylindrical acoustic field with improved angular resolution that can be used for endoscopy. Angular resolution of this configuration has been shown for the 400 kHz air-coupled. Presence of this conical reflector does not alter frequency band or pulse shape. This solution has been tested for different pipes, showing that it is possible to obtain pipe inner diameter and wall thickness from time of flight measurements (when echoes do not overlap) or from the analysis of wall resonances (when the echoes appear overlapped).

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