The Role of Additive Manufacturing Technology in the Design of Sparse Transducer Arrays

Sparse Array Prototyping

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Abstract

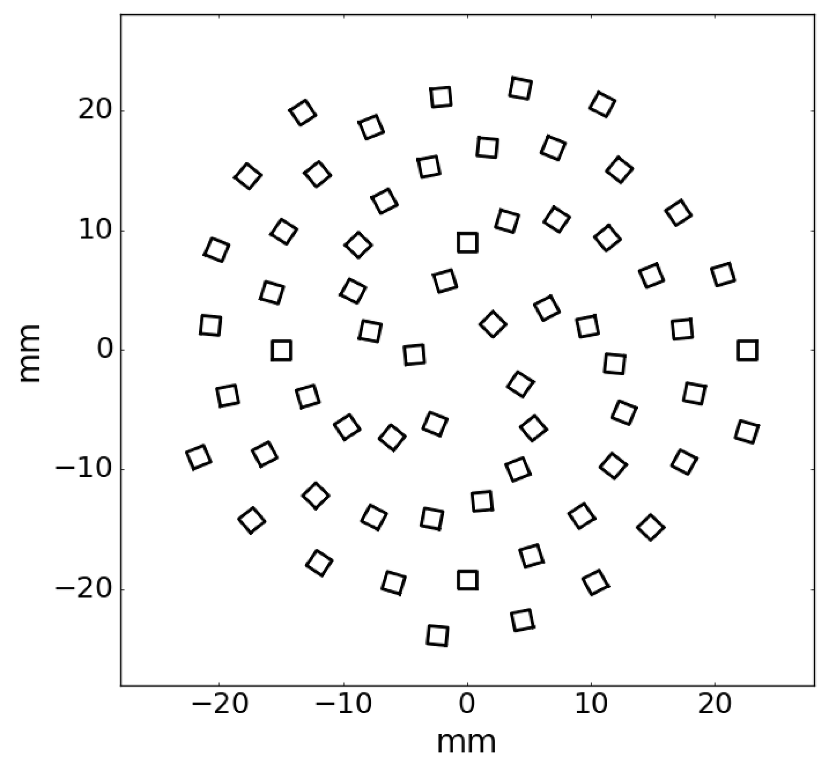
The main challenge for 2D array manufacturing comes from the large number of elements required to achieve an acceptable image quality. Sparse arrays have been proposed as a compromise solution. Although we can find in the literature a lot of examples about sparse arrays models, there is a significant lack of experimental prototypes.

Introduction

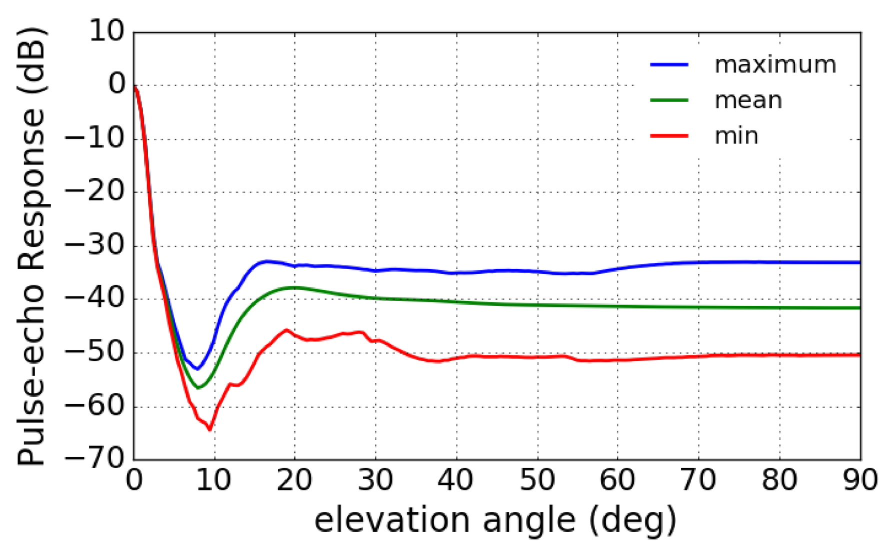
Large two-dimensional (2D) arrays offer very promising prospects due to their capability to obtain information of a volumetric space. However, large 2D matrix apertures involve a high number of elements. This leads to some challenges at several levels: (i) at manufacturing level, due to the large number of elements involved (ii) at signal conditioning level, because the elements offer low radiation area and low sensitivity; (iii) at system control level, owing to the complexity of acquiring, processing and managing a large volume of data; and finally, (iv) at the economic level, because of the high cost associated with the transducer and the systems.
In order to address these problems, the capabilities to manufacture structural parts of sparse arrays based on Additive Manufacturing technology have been analysed in this paper.

Sparse Array

Specifications for the proof of concept: lateral resolution less than 1.5°, no more than 64 elements, operation frequency of 1.5 MHz and a dynamic range higher than 30 dB.



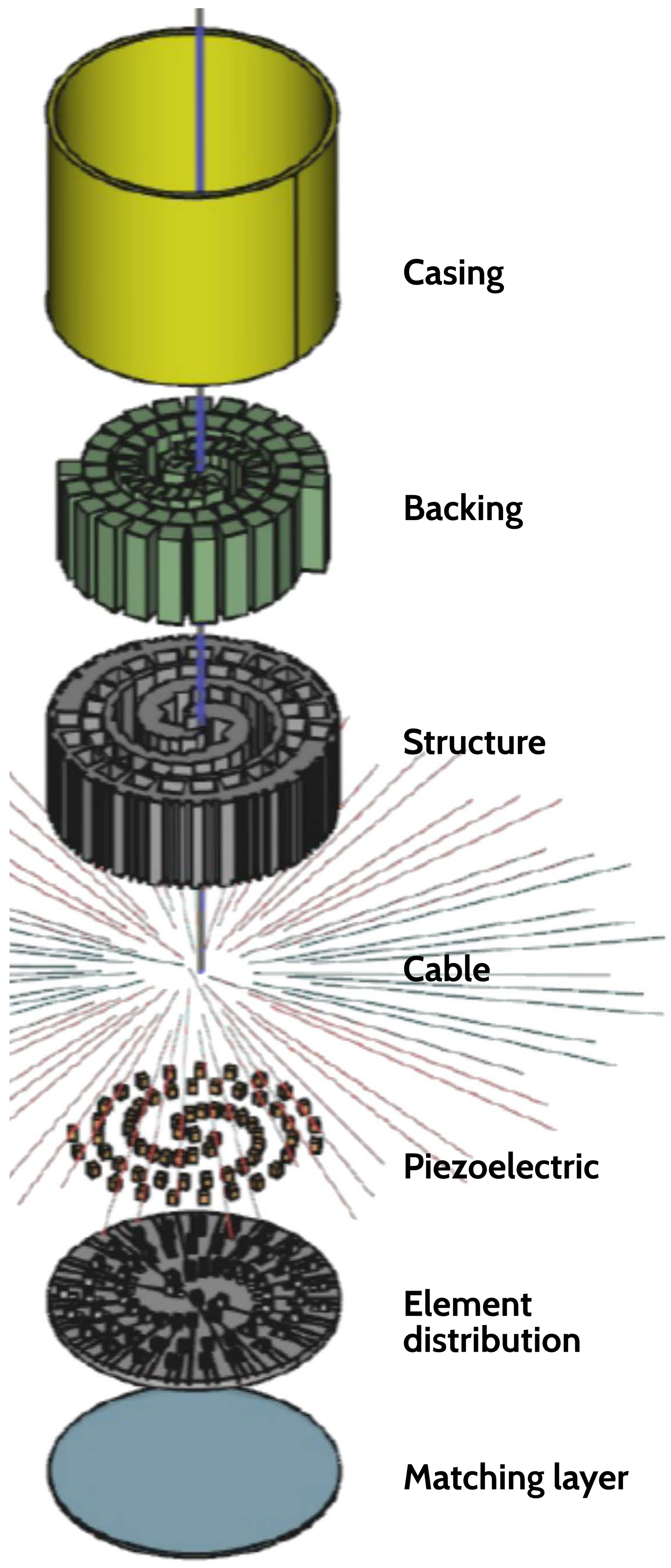
Sparse array based on a Fermat spiral with a divergence angle equal to 140°.



Lateral profile of the Point Spread Function computed in the semisphere. At each elevation angle: blue line, maximum values; green line, mean values; red line, min value.

Prototype

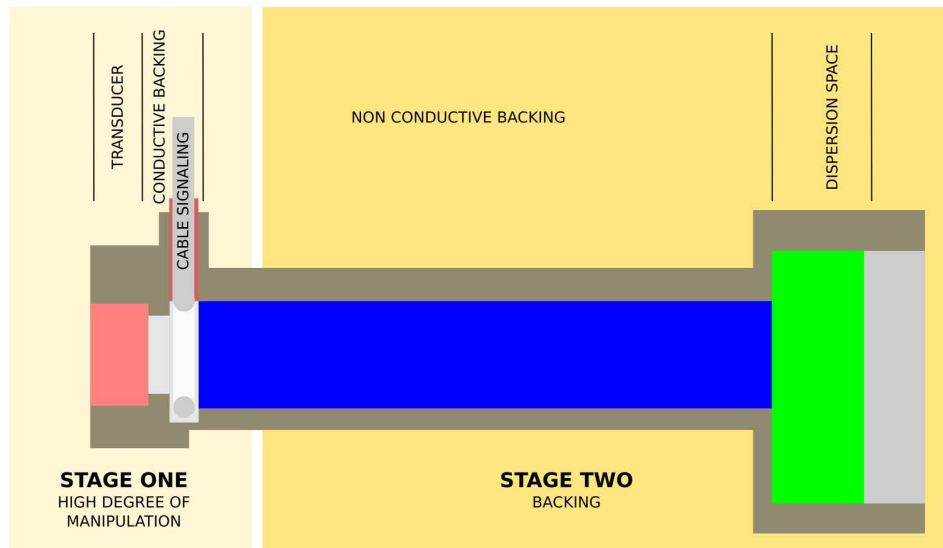
Exploded View:

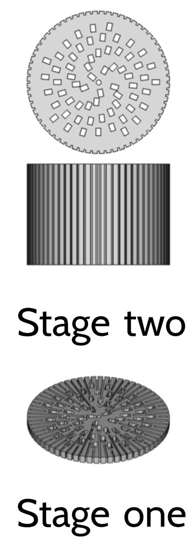


Array Element Structure

The manufacturing process is divided in two stages produced as separated parts.

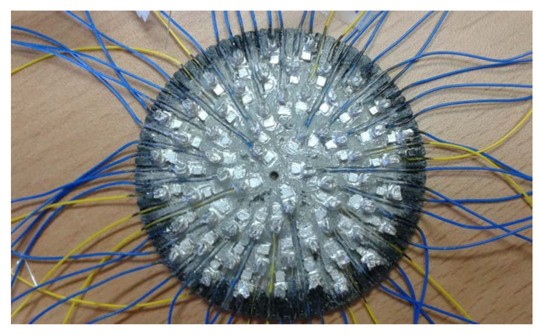
- The **first stage**, where the piezoelectric elements, the cables and the electric contacts are placed. The elements are piezocomposite transducers.
- The **second stage**, where the main part of the backing is placed.





Manufacturing Process

Stage One. Elements inserted at their locations. The slots for the cables placement and attaching are included.

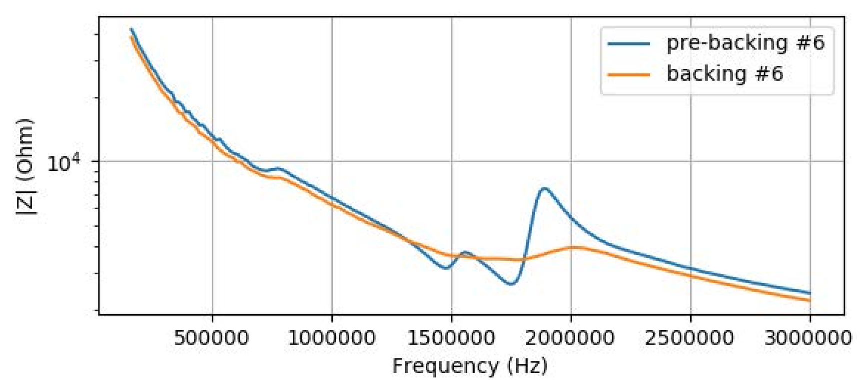


Stage One. Each cable has been attached in a column near its corresponding element. Conductivity is achieved through silver paint.

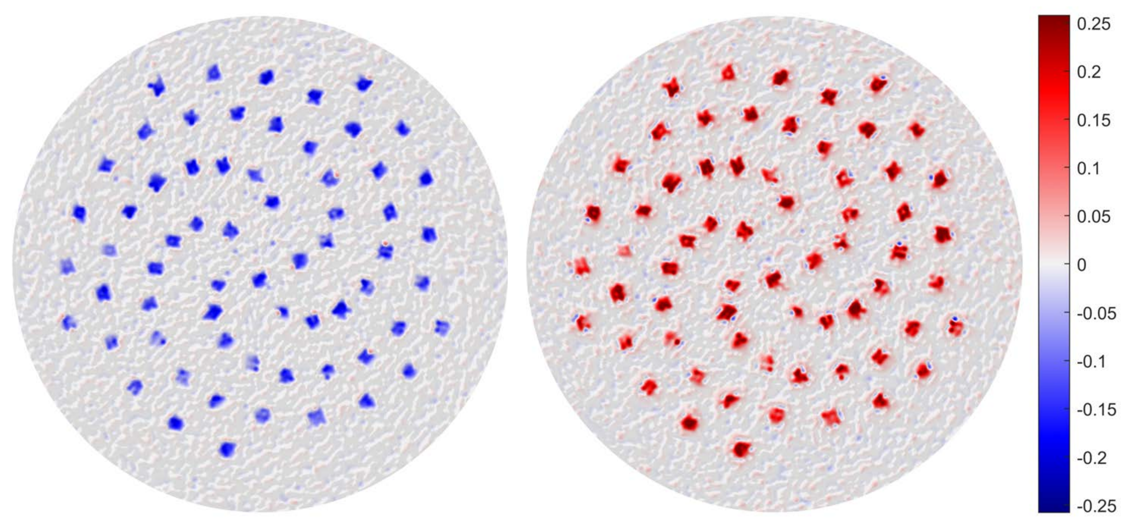
Stage Two. Backing structure is distributed in independent columns for each transducer.

Stage One and Stage Two assembled. Silver paint was used for the ground plane. In the outer side, vertical slots for the wires have been included.

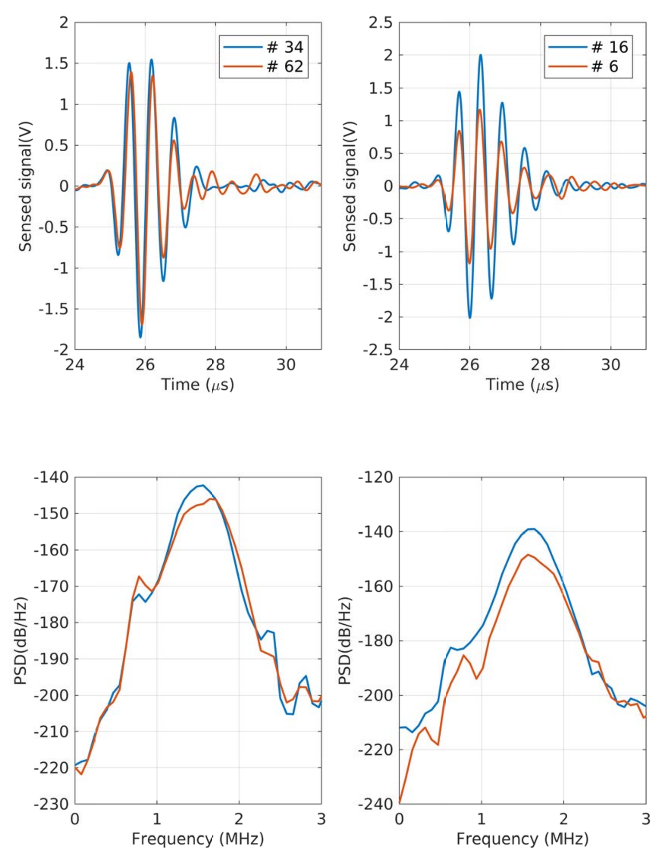
Experimental Results



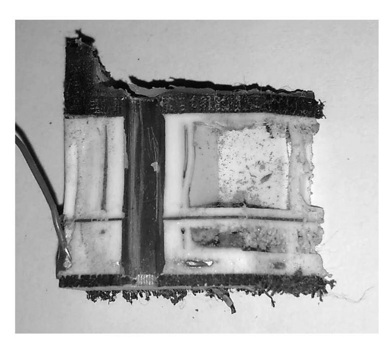
Electrical impedance of the element number 6. In blue, previous to the insertion of the backing. In orange, after the insertion of the backing.



Displacement of the ceramic piezocomposites when an excitation of 400 V is applied in one spike of $0.5\frac{\lambda}{c}$ wide. On left is presented the first semicycle. On right, the second. (Polytec PSV-400 Scanning Vibrometer)



Temporal response and Power Spectral Density of four elements of the aperture.
L: elements 34 and 62.
R: elements 6 and 16.



Section of the element structure in a test prototype.

Conclusions

In this work a sparse array of 48λ diameter and 64 elements based on a Fermat spiral distribution has been designed and manufactured. The ultrasonic aperture has been manufactured employing Additive Manufacture Technology. This technique has shown to be very versatile, cost-effective and it seems to be adequate for the development of risky proof-of-concept.

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