Relation of the geometry of the piezoelectric element with the effect of crosstalk in the response of an ultrasonic transducer

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Abstract
The response of an ultrasonic transducer either for medical or industrial applications is based on the components of the transducer, mainly in its active element, i.e. the piezoelectric ceramic, this work based its hypothesis in that the degree and intensity of the phenomenon of the crosstalk is related to geometry and distribution of these elements. Currently all the design and construction processes of a transducer have the problem that the crosstalk affects the performance and the response of the transducer. It is worth mentioning that ceramics being the active element of the transducer are one of the generators of the crosstalk phenomenon, not all transducers have the same configuration or geometry of their elements, which drift in different degrees and intensities of crosstalk, here it is presented how the square geometry in conjunction with the distribution of the array may cause a high degree of crosstalk. However round geometry wich in theory presents less degree of crosstalk, it is more difficult to use due to the effective area that possesses a transducer.
Simulations where the geometry of the piezoelectric element changed were made, it was seen that the degree of crosstalk depends on the geometry and the distribution of elements in the array.

Introduction
The development of tools that enable to obtain a better diagnosis or measurement has grown rapidly and one of these tools for the diagnosis through detection and measurement are the ultrasonic transducers. This area presents a considerable technological advance during the last years [T. To Whittingham, 1997]. A notorious example of these developments is that these transducers have evolved from simple transducers to matrix transducers, the performance of the ultrasonic transducer is directly related to the electrical, mechanical, and piezoelectric properties of piezoelectric materials [Kino and De Silets, 1979].
The development of the technology has allowed that each day there are transducers with a better resolution, smaller due to microelectronics and the materials, allowing that the transducers have a greater number of elements and more elaborated configurations, however there are some problems, as the phenomenon known as "Cross-talk" (CT), "Cross-coupling" or crosstalk, which has direct effects on the response of the transducers.
Many factors contibute to the presence of CT, one of these factors are the changes of dimensions of the piezoelectric elements forming the transducer array, these changes of dimensions are caused mainly in the construction phase and they are usually occur during

the welding process of the electrodes, where there may be a loss up to 50% or more of the effective area of the element.

Methodology
Figure 1, shows the geometry used in the simulation using the Finite Element Method (FEM) of a piezoelectric ceramic, this simulation consisted in decreasing the width of the Piezoelectric ceramic, proposed by Sanchez [Sanchez, et al, 2011], in where the size of ceramics as a medium generator of the phenomenon of the CT is also studied.
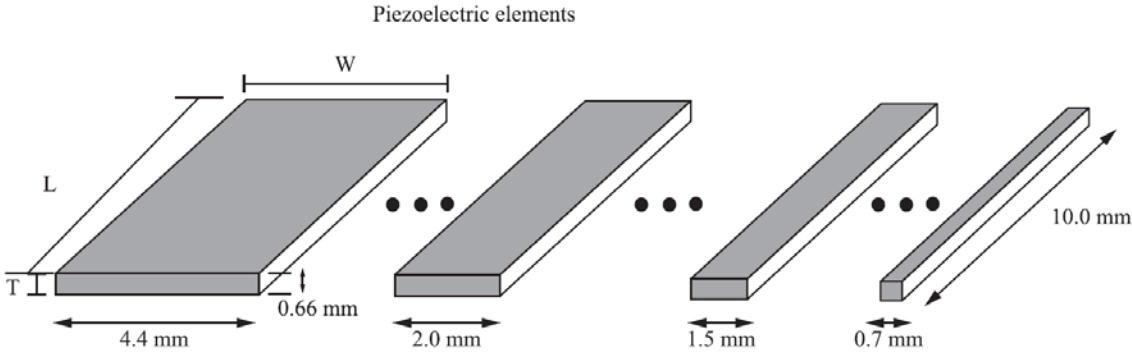
Piezoelectric elements

Figure 1 geometry in the simulation of a Piezoelectric ceramic

The number of elements in an array, also can be an important factor in the generation of the phenomenon of CT since the more elements you have, the closest these elements must be from each other, because the array cannot grow infinitely, since it loses functionality. Based on this principle the elements that are added to the configuration of the array should occupy the area assigned to the transducer, which implies greater proximity of elements, as shown in Figure 2, regardless the number of elements in the array.
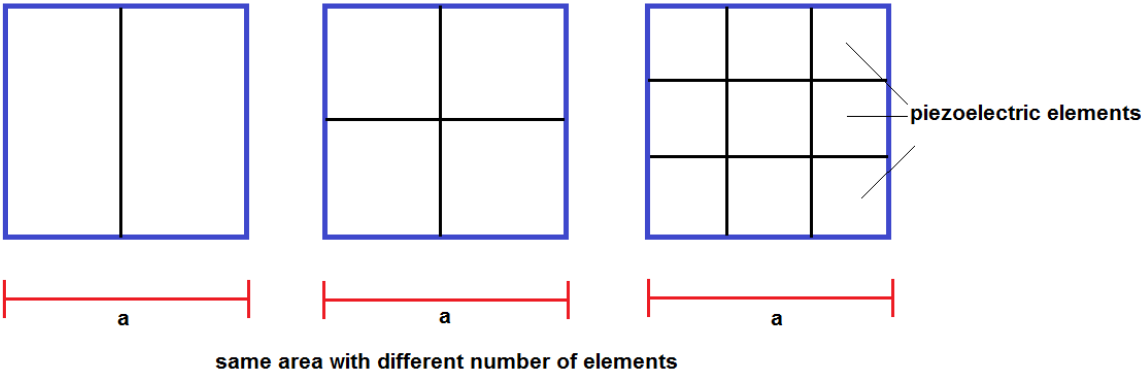
same area with different number of elements

Figure 2 geometry used in the simulation of a four piezoelectric ceramics array for the evaluation of "Cross-talk"

Results

After the simulations when the dimensions of a Piezoelectric ceramic are reduced, i.e. starting from a ceramic with dimensions of 10.0 x 4.2 x 0.66 mm, until you reach a ceramic with (a bar) dimensions 10.0 x 0.7 x 0.66 mm, were performed experimental measurements were carried out as shown in Figure 3, in order to verify if the dimensions of piezoelectric ceramics that are part of a transducer may be a factor in the generation of the phenomenon of CT, no matter if this reduction in the dimensions was performed using the same ceramic.
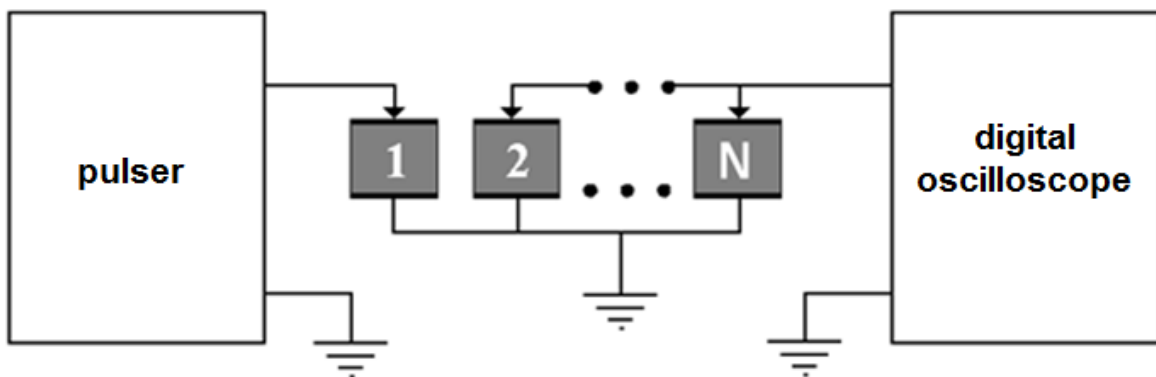

Figure 3 experimental diagram of a piezoelectric ceramics array for the measurement of "Cross-talk"

Figure 4 shows the response of the ceramics as it is reduced in dimensions, this was done using Matlab (version R2010a), with data from previous simulations as shown in Figure 1. There is a displacement of the resonance frequency as a function of the dimensions, as well as the CT effect, with greater influence on the elements of similar dimensions (as in the case when the width and the thickness is almost identical). This is due to the mode of vibration of the elements, and it is estimated that this fact leads to an increase of the CT after the lateral vibration is directed to the adjacent elements through the material between elements (Gori et al, 2001;) Turnbull and Foster, 1992).

The arrows in Figure 4 point the positions of the lateral mode (LM) and the thickness mode (TM), which are clearly separated, but when the dimensions are beginning to be closer (lateral dimension value), there is a tendency to converge between two modes.This is due to the phenomenon of physical coincidence between the modes arising as a result of the approximation of dimensions of the element. This is a counterproductive effect that involves, among other things, the reduction of the working frequency, resulting in a poor performance of the transducer.
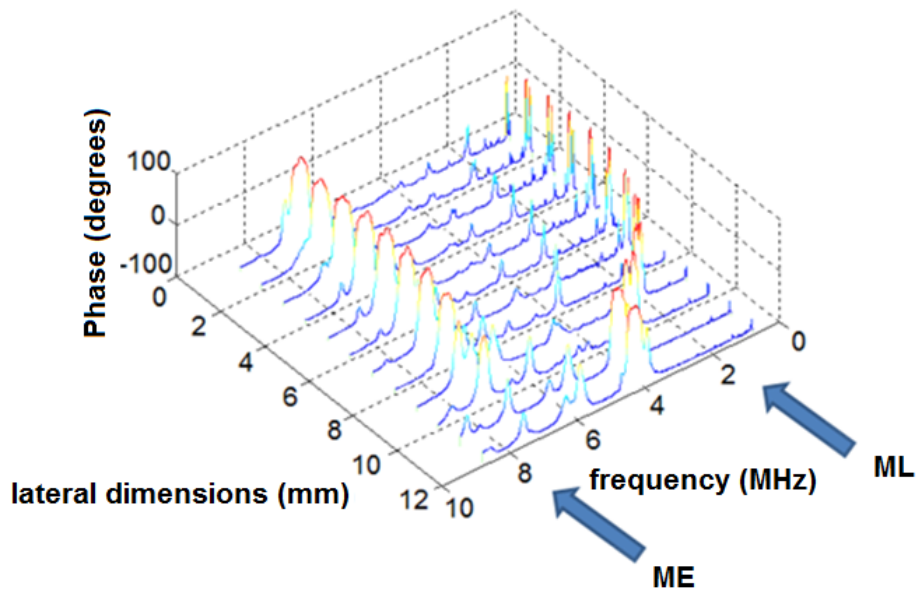
Figure 4 Frequency plot when reducing the dimensions of the Piezoelectric ceramic, a convergence between the center oscillation frequency and the one generated by the "Cross-talk"effect is observed.

The hypothesis that the geometry and the proximity between the piezoelectric ceramics in an array are factors in the generation of CT was corroborated carrying out simulations using square ceramic (PIceramics), with the same frequency of oscillation (8 MHz). Figure 5 shows the zone where the ceramics are closer here the interaction due to the lateral vibration mode is more intense and it is located where the ceramics match in geometry.
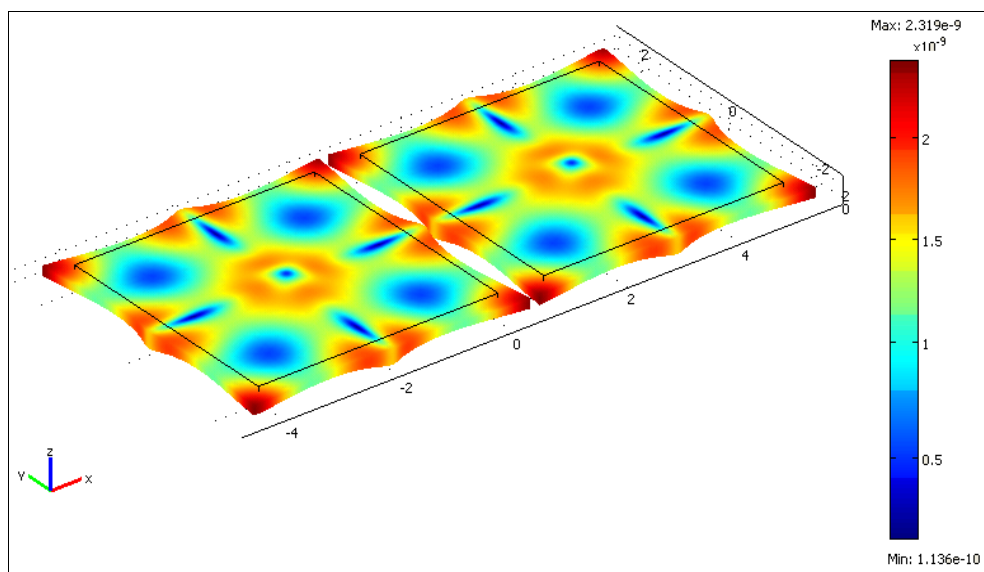

Figure 5 simulation of an array with two square ceramics (4.2 x 4.2 x 0.66 mm), the interaction increases where ceramics are closer ($\lambda/4$), due to the geometry.

Conclusions

The simulation presented in figure 5 shows the presence of the CT phenomenon that we want to study, we focus to observe different variants of the response obtained, in the case of Figure 5, shows a view where you can see the emitted wave in its lateral mode by the ceramics of the arrangement, presents areas where this energy is magnified. Several works express [Kino and Désilets(, 1979, Smith et ael, 1979, Turnbull and Foster, 1982, Guess and Campbell, 1985, Frederick et ael, 1990, Wojcik et ael, 1996)], that the CT phenomenon is enhanced by the interaction produced by lateral vibration of an element, and due to the proximity between the elements this phenomenon acquires higher energy which eventually leads to a poor performance of the transducer, with problems such as decrease in the intensity of the radiation beam, or attenuation in the intensity of the ultrasonic beam.

Based on the results, it is necessary to focus during the design and construction process in a good selection of materials with properties of acoustic attenuation to reduce as much as possible the presence of the CT phenomenon, this phenomenon is inherent in the construction of arrays using piezoelectric elements, but it can be attenuated so that their contribution to the performance of the transducer is less harmful. It is also necessary to have and find new piezoelectric materials that present acoustic features that allow to have a low CT figure.

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