# MODELING THE STRUCTURAL AND ACOUSTIC BEHAVIOR OF SONAR TRANSDUCER WITH ATILA CODE AND GiD

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**Key words:** Transducer Arrays, Finite Element Method, ATILA FEM Code, GiD Graphical Interface, Crosstalk, Fluid Pressure.

**Abstract.** *Many important issues in transducer arrays design, such as crosstalk, cannot be accurately studied using analytic method due to the complexity of the partial differential equations involved. Finite element method (FEM) is the only appropriate way to gain more detailed information. In this paper, a 2D finite element model is constructed to modeling the structural and acoustic behaviour of transducer arrays, using ATILA code and GiD graphical interface. Several different analyses were designed to examine a different aspect of acoustic behaviour of sonar transducer. It was found that crosstalk affect pressure fields in fluid (water).*

## 1 INTRODUCTION

The active sonar is a system that allow transmitted and received acoustic signals, it is consisting of both a projector and hydrophone. Figure 1 shows the geometry of transducer arrays considered in this paper [1], it is a low frequency transducer arrays developed for shallow water with 300 kHz resonance. It is composed of six piezoelectric elements, and mounted in a housing whose main function is to provide mechanical support for array, separated by an acoustically and electrically inactive material (Filler) which prevents acoustic wave propagation between elements. A waterproof material is used to protect the piezoelectric transducer elements; this material is usually selected to possess approximately the same acoustic properties than water to reduce energy loss at the water interface. The matching layers at the front face are used to adapt the different acoustic impedances of piezoelectric and water respectively, there are one or more (usually two) matching layer to increase the bandwidth [2]. The typical center-to-center spacing between transducer elements is $d=\lambda/2$. Usually, these transducers operate at their resonant frequency. If the resonant frequency is $f_r$=300 kHz, c=*1500 m/s* speed of sound in water, then the wavelength, is $\lambda$=0.5 cm.

Due to crosstalk through transducer arrays structure, sonar beam patterns are distorted and a low level sensitivity can also be obtained. Much study of this problem can be found in literature [2]. Several approaches based on numerical methods and experimental methods have been proposed [3]. In this work, we built several array with and without structure, with and without matching layers, and using classical housing (Aluminum). A 2D finite element model is constructed to modeling the structural and acoustic behaviour of sonar transducer using ATILA code and GiD graphical interface.

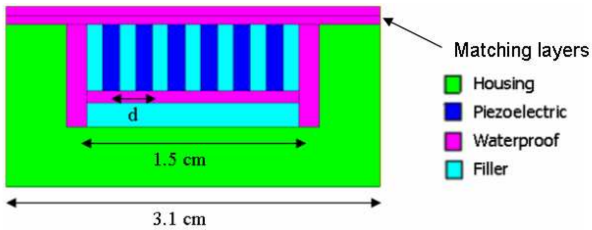


Figure 1: Geometry of the transducer arrays

## 2 MODELING TOOLS

Finite element method is widely used for the modeling of piezoelectric transducers. It is a method of transforming a continuum system to its equivalent discretized system in which the system is divided into elements [4]. ATILA (Analysis of Transducers by Integrating LAplace equations) is a user interactive finite element code originally developed by many French scientists and engineers during 1980s, and is specifically developed for modeling of two or three dimensional elastic, piezoelectric, magnetostrictive and fluid structures [4]. With ATILA, you can perform static, modal, harmonic and transient analyses of your active structures. Because the formulation is organized around a strong electrical/mechanical coupling and a strong fluid/structure coupling, ATILA is a very efficient design tool for all types of active materials applications: actuators, transducers, sensors, and so on. The program modules are independent, which means that we can customize the software configurations to meet your specific needs. Different types of materials can be used for the design of heterogeneous 2D and 3D structures, and multiple excitation sources (electrical potentials, currents into inductors, displacements, forces and pressures) can be used at the same time. Applications include sonar and acoustic transducers (piezoelectric and magnetostrictive), piezoelectric transformers, piezoelectric and magnetostrictive motors and most piezoelectric and magnetostrictive actuators and sensors (piezoelectric valves, magnetostrictive pumps, piezoelectric accelerometers, magnetostrictive torque sensor).

Due to complexity of creating data files of ATILA code, we used GiD graphical interface to creating data files by defining geometry we want to study, the materials it is composed, and constraints. He allows generates a mesh (for finite elements, finite differences or other methods) and transfers geometric data [5].

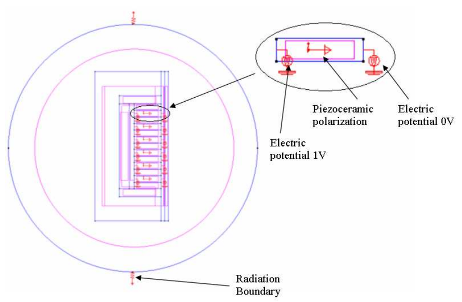


Figure 2: Boundary condition and piezoelectric polarization

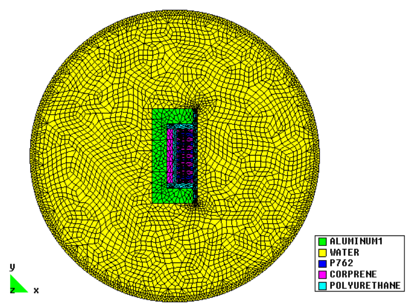


Figure 3: Automatic meshing of transducer arrays

## 3 SIMULATION RESULTS

The proposed procedure to modeling sonar transducer is to use GiD for creating data file; we choose the geometry described in Figure 1. A 2D plane strain condition is considered, that imply the absence of strain in the third geometrical dimension, which physically means a structure with either a very thin (plane stress) or an infinitely long (plane strain) third dimension [6]. For this simulation we use harmonic analysis with loss. A non reflecting boundary condition to the fluid domain (water) is applied; it creates a limit (not infinite) on the finite element mesh of the fluid. This condition and piezoelectric polarisation are shown in Figure 2. After choosing quadrilateral finite element type to describe the region under study, and size of mesh spacing that is related to the smallest acoustic wavelength used, GiD allows the use of an automatic mesh generator which creates node coordinates and element topologies Figure 3. Finally, when the data file is created, ATILA can run, provides a results file and some file containing arrays for post processing. A graphic display of the directivity patterns and sensitivity can be easily obtained graphically. Animated views of the vibrating structure or of the pressure in the fluid are also available on graphic terminals.

Due to symmetry of the problem it is sufficient to simulate only the half of the device when we excite all element with the same excitation at the same time. In this work, we are interested in modeling complete transducer arrays, in order to use beamformer which is to send sounds in one direction $\theta$. The beamformer is due to applying of a time delay between adjacent elements $\tau_n$ (1) [7], where $n=[0,\dots,N-1]$, $N$ denotes total number of element, and $\theta$ is the angle between transmitting direction and the direction of the array. We excite each elements by an electric potentiel of magnitude 1V, and phase $\varphi_n$ (2).

$$\tau_n = \frac{nd}{c}\cos\theta \tag{1}$$

$$\varphi_n = 2\pi f_r \tau_n \tag{2}$$

Figure 4 shows the modeling of six piezoelectric elements in water without other materials. We found the exact direction that we have imposed. In the purpose, to display the effect of matching layers, Figure 5 shows the modeling of transducer arrays without matching layers, and Figure 6 shows the results of complete transducer arrays at the direction $\theta$=30°. Comparing these results, we can see that matching layers increase the bandwith, but the crosstalk is important. On the other hand, Figure 7 shows the results of complete transducer arrays at the direction $\theta$=60°. In this time, we observe that crosstalk increase respectively with transmitting direction, and we find important side lobes.

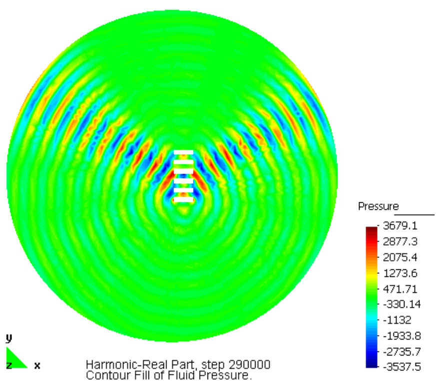


Figure 4: Fluid pressure of six elements without structure $\theta$=30°

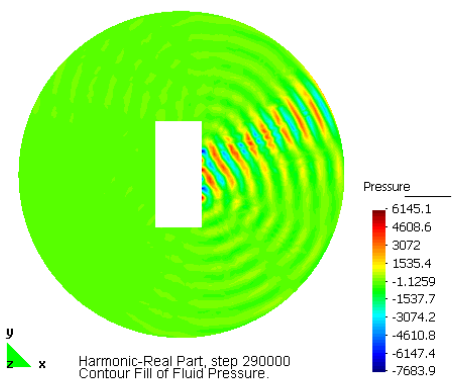


Figure 5: Fluid pressure of transducer arrays without matching layers $\theta$=30°

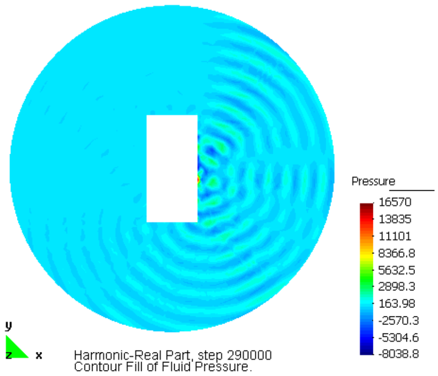


Figure 6: Fluid pressure of six elements with structure $\theta$=30°

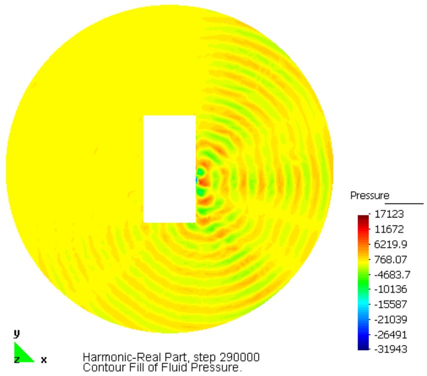


Figure 7: Fluid pressure of six elements with structure $\theta$=60°

## 4 CONCLUSIONS

In this paper the effet of crosstalk due to sonar structure was investigated. A 2D finite element model to analyze crosstalk, using ATILA code and GiD graphical interface has been shown. Future applications will also handle complete transducer arrays including environmental noise and the role of sonar dome.

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