

# Index

<b>Resumen .....</b>	<b>7</b>
<b>Resum .....</b>	<b>11</b>
<b>Abstract .....</b>	<b>15</b>
<b>1. Introduction .....</b>	<b>19</b>
1.1. Motivation and objectives .....	19
<b>2. Ultrasound theory .....</b>	<b>25</b>
2.1. Acoustic waves.....	25
2.2. Linear acoustic wave equation in fluids .....	31
2.3. Non-linear regime: parametric sound generation .....	32
2.3.1. Historical Background.....	32
2.3.2. Parametric array: operating regimes.....	34
2.3.3. Nonlinear acoustic models .....	38
2.3.3.1. Westervelt equation.....	38
2.3.3.2. Burgers equation.....	39
2.3.3.3. KZK equation .....	39
2.4. Propagation medium.....	40
2.4.1. Acoustic medium properties.....	40

<b>3. Ultrasound generation: Ultrasonic Piezoelectric Transducer .....</b>	<b>47</b>
3.1. Historical background .....	47
3.2. Ultrasound generation: Piezoelectricity .....	49
3.2.1. Piezoelectric constitutive relations.....	52
<b>3.2.1.1. Piezoelectric ceramic case.....</b>	<b>54</b>
3.3. Ultrasonic transducer as a transmitter.....	56
3.3.1. characterization OF Electroacoustic parameters.....	64
3.4. Transducer elements .....	73
3.5. Scientific echosounder .....	79
3.6. Active Sonar equation.....	83
<b>4. Numerical Simulation Methods .....</b>	<b>85</b>
4.1. Transducer design and wave propagation .....	85
4.1.1. Brief historical background.....	86
4.1.2. Main concepts and Procedure .....	88
4.1.3. Mathematical description.....	89
4.1.4. Considerations.....	91
4.1.4.1. Limitations in the spatial discretization .....	92
4.1.4.2. Model convergence .....	92
4.1.4.3. Model simplification .....	93
4.1.4.4. Artificial boundary condition.....	94
4.1.5. Finite element software .....	94
4.2. K-SPACE PSEUDO SPECTRAL METHOD.....	96

<b>5. Ultrasonic Transducer Design.....</b>	<b>99</b>
5.1. Introduction .....	99
5.2. Active materials characterization .....	102
5.2.1. Parameters under test.....	103
5.2.2. Materials and methods.....	105
5.2.2.1. Acoustic impedance .....	108
5.2.2.2. Piezoelectric properties adjustment .....	112
5.2.2.3. Resonance frequency study as function of diameter/thickness ratio ..	123
5.2.3. Active materials characterization results.....	124
5.2.3.1. Acoustic impedance .....	124
5.2.3.2. Piezoelectric coefficients adjustment .....	126
5.2.3.3. Resonance frequency study as function of diameter/thickness ratio ..	130
5.3. Passive materials characterization .....	132
5.3.1. Parameters under test.....	132
5.3.2. Materials and Methods .....	134
5.3.2.1. Acoustic impedance .....	135
5.3.2.2. Transversal sound speed and attenuation coefficient experimental adjustment .....	138
5.3.3. Passive materials characterization results.....	140
5.3.3.1. Acoustic impedance .....	140
5.3.3.2. Transversal sound speed and attenuation coefficient adjustment.....	142
5.4. Prototype Modelling and Implementation.....	144

5.5. Transducer Characterization .....	150
5.5.1. Materials and methods .....	150
5.5.1.1. Electrical admittance measurement.....	150
5.5.1.2. Sensitivity and directivity measurements.....	151
5.5.2. Results.....	157
5.6. Fem modelling validation and design options.....	160
5.6.1. Fem modelling validation .....	160
5.6.1.1. Prototype 1: Pic255.....	161
5.6.1.2. Prototype 2: Pz37 .....	164
5.6.2. Design improvement.....	166
5.7. Conclusions.....	169
<b>6. Parametric echosounding in shallow water .....</b>	<b>171</b>
6.1. Parametric array: Preliminary study.....	172
6.2. Materials and methods .....	176
6.2.1. Transducer under study.....	176
6.2.2. Experimental set-up .....	179
6.2.3. Methodology .....	179
6.2.3.1. Amplitude in function of voltage measurement.....	179
6.2.3.2. Directivity measurement .....	181
6.2.3.3. Amplitude in function of distance measurement.....	182
6.2.4. Measurement parameters .....	183
6.2.4.1. Parametric frequencies selection.....	183

6.2.4.2. Amplitude signal .....	185
6.2.4.3. Signal length.....	185
6.3. Results .....	186
6.3.1. Parametric amplitude in function of voltage .....	187
6.3.2. Directivity measurements results .....	189
6.3.3. Amplitude as function of distance results.....	195
6.3.4. Experimental measurements Vs Numerical simulation.....	196
6.4. Transducer viability.....	201
6.5. Conclusions .....	210
<b>Conclusions .....</b>	<b>213</b>
<b>Acknowledgements.....</b>	<b>217</b>
<b>Referencias.....</b>	<b>221</b>
<b>Table Index .....</b>	<b>233</b>
<b>Figure index .....</b>	<b>237</b>