

ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO

Laboratory Wave Probes Dynamic Performance Evaluation

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Naval and Ocean Laboratory Tank

- Experimental facilities
 - Testing tank
 - Wave response
 - Movements and Forces
- Equipments and Sensors
 - Instrumentation
 - Accelerometer, Displacement Gauge(optical, acoustic, magnetic...), Load Cell, Wave Probe
 - Data Acquisition
 - Computer based, data logger
- Signal Analysis
 - software, “by hand”



Wave Elevation Instruments Most Used among ITTC Members

Measuring Technique	Resistance	Servo	Capacitance	Acoustic
Responses	19	15	11	6

Resistive and Capacitive: water level changes cause electrical circuit parameters changes

Acoustic: time travel between water surface and fixed probe
(acoustic wave speed known)

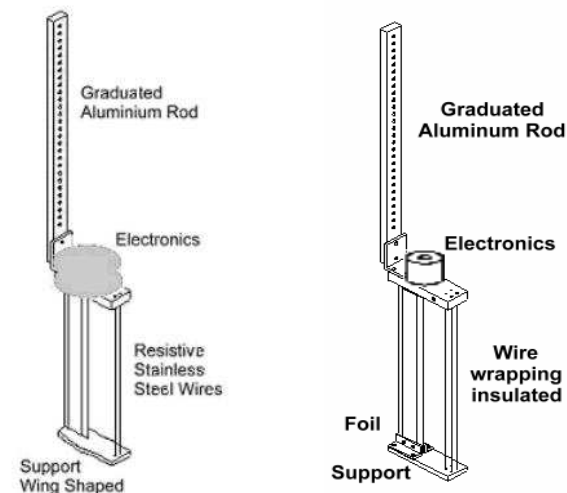
Servo: water level changes cause electrical circuit unbalances



Sensors Main Characteristics

Resistive and Capacitive:

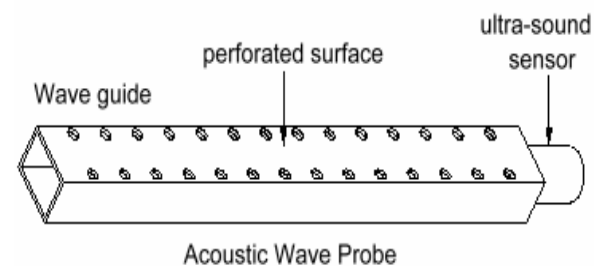
- Simple and Cheap Electronic and Mechanical parts
- Stable and Reliable
- Surface Piercing
- Sensitive to Water and Water Surface Conditions



Acoustic:

- Sophisticated Electronics
- High Accuracy
- Non Contact
- Sensitive to Media Properties
- Wave Steepness Sensitive

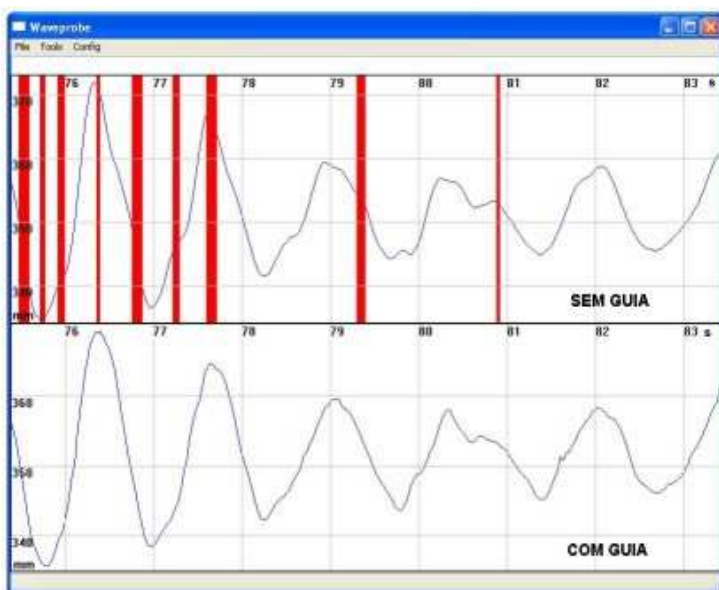
no scale



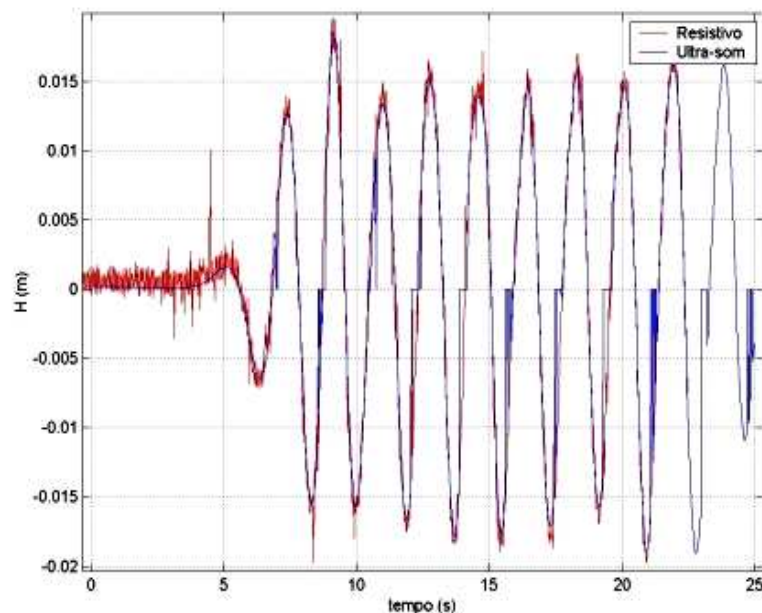


Acoustic Wave Probe Output

Experimental Tests



Acoustic Sensor Signal Loss
And New Design with Guide

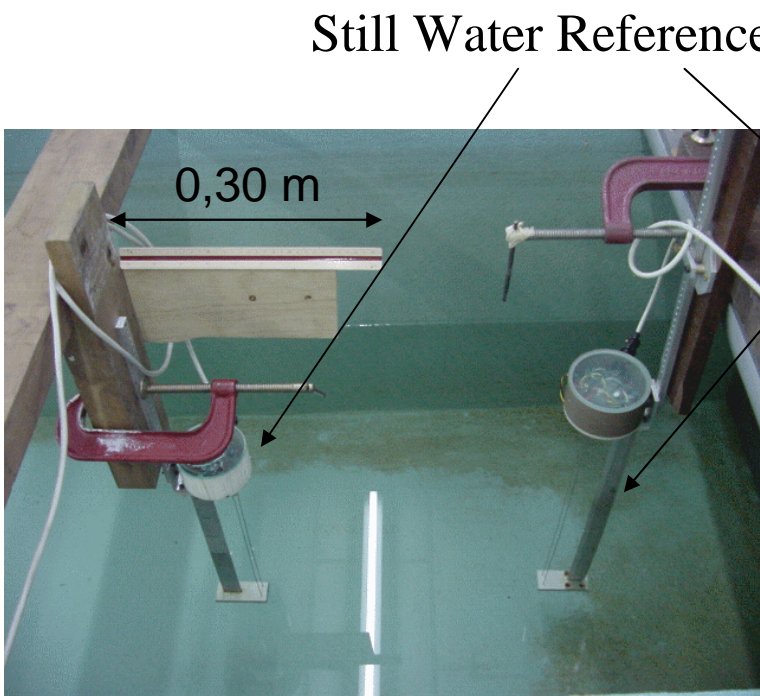


Signal Output Comparison between
Resistive and Acoustic Wave Probes

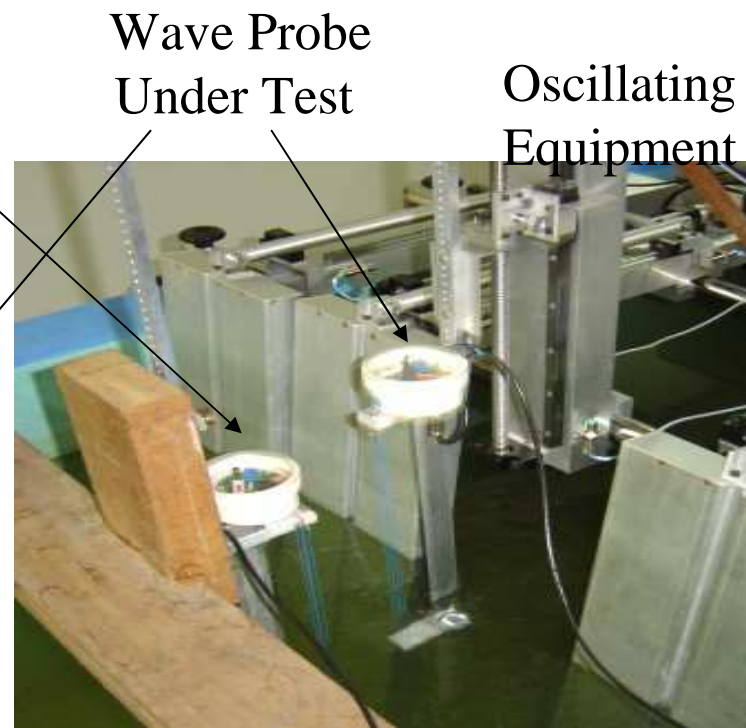


Dynamic Calibration Setup

Experimental Tests



Resistive Wave Probe

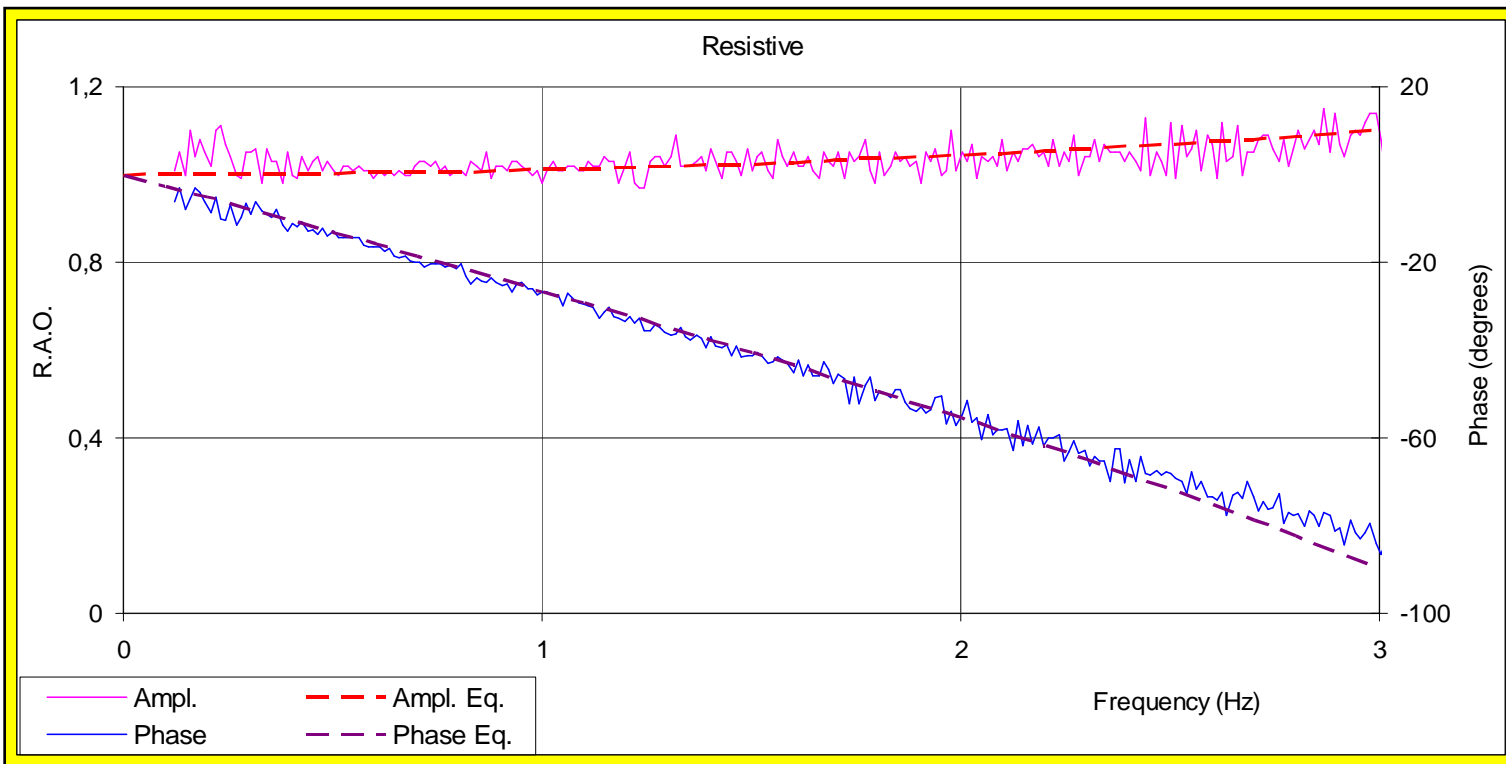


Capacitive Wave Probe



Resistive Wave Probe

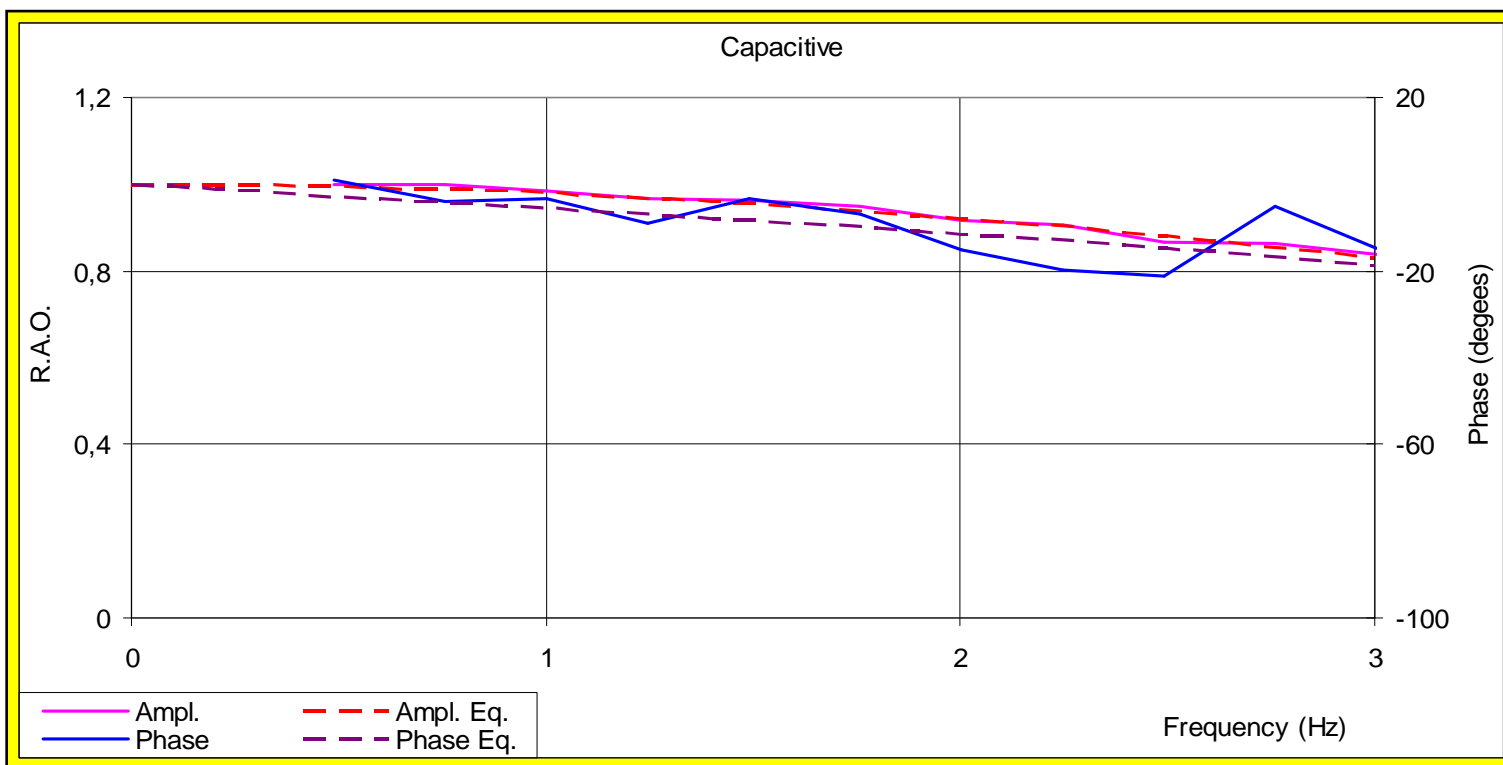
Dynamic Response





Capacitive Wave Probe

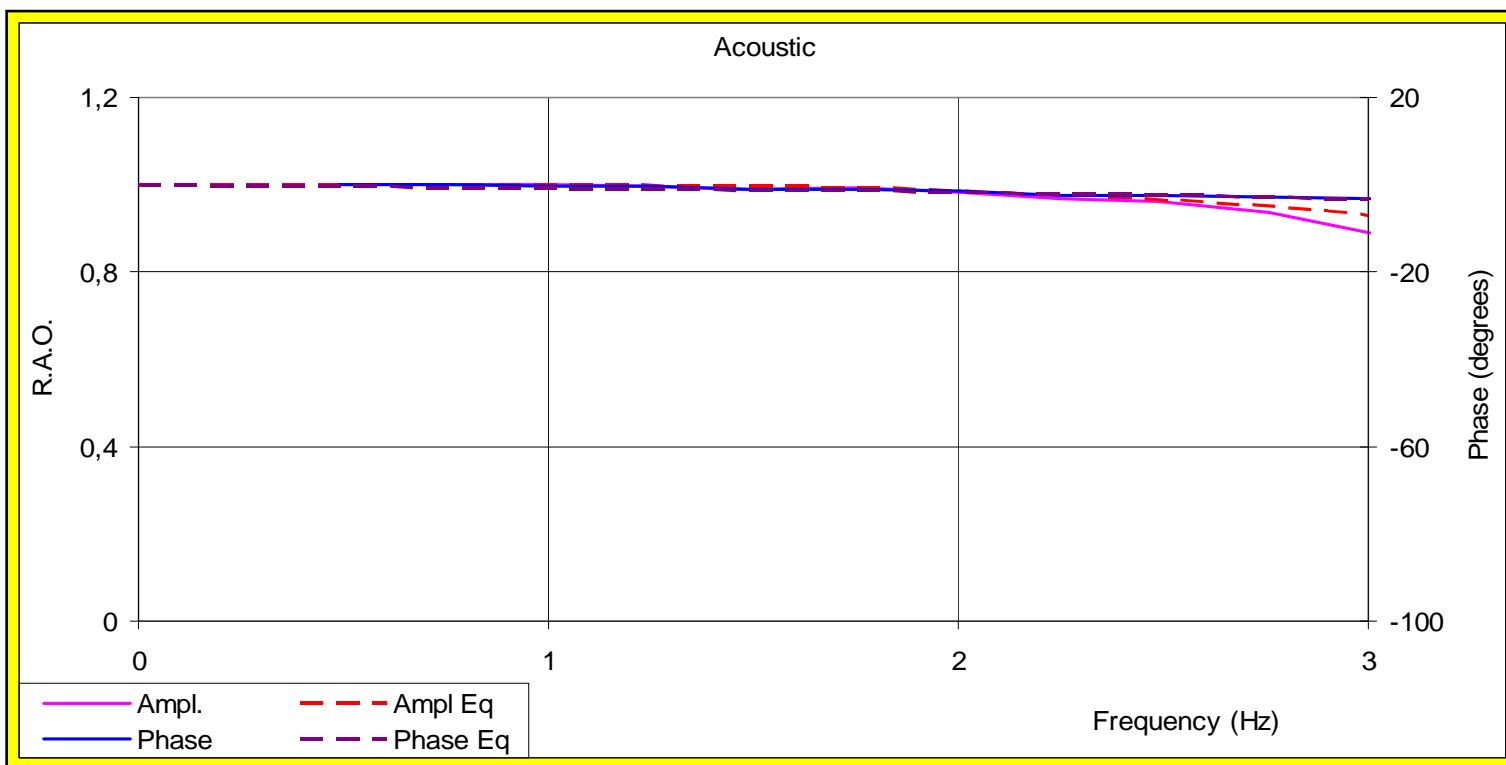
Dynamic Response





Acoustic Wave Probe

Dynamic Response





Wave Probes Calibration Results

Frequency response mathematical model

$$R.A.O. = \frac{1}{\sqrt{\{(1-\beta^2)^2 + (2\zeta\beta)^2\}}} \quad \text{and} \quad \tan(\phi) = \frac{2\zeta\beta}{1-\beta^2}$$

Frequency response cutoff for all wave probes tested.

Wave Probe Sensor Type	Cutoff Frequency Criteria (Hz)		
	Amplitude ($\pm 5\%$)	Phase (-5°)	Phase (-18°)
Resistive	> 3	< 0,5 *	0,65 *
Capacitive	1,59	0,9	2,92
Acoustic	2,74	> 3	> 3

* Linear variation [ϕ (degrees) = -27,61 {Frequency (Hz)}]



Conclusions

- The wave probes developed “in house” are precise and low cost, and wave-guided acoustic sensor were successfully tested to wave steepness up to 14%;
- To wave frequencies above 0.5 Hz the resistive sensor showed phase response variations and above 1.5 Hz the capacitive sensor showed amplitude response variations; and
- Problems like electrical noise, cross talk, signal loss, low sensitivity, water properties and temperature variations were solved by special design techniques;
- The variations of water, or transmitting media, properties and temperature must be taken into account before measurements or by static calibration each time the wave probe will be in use;
- All wave probes must be calibrated statically and dynamically, with appropriated equipments to reach the desired accuracy.



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