Calibrator for UHE Neutrino Acoustic Detection in Underwater Telescopes

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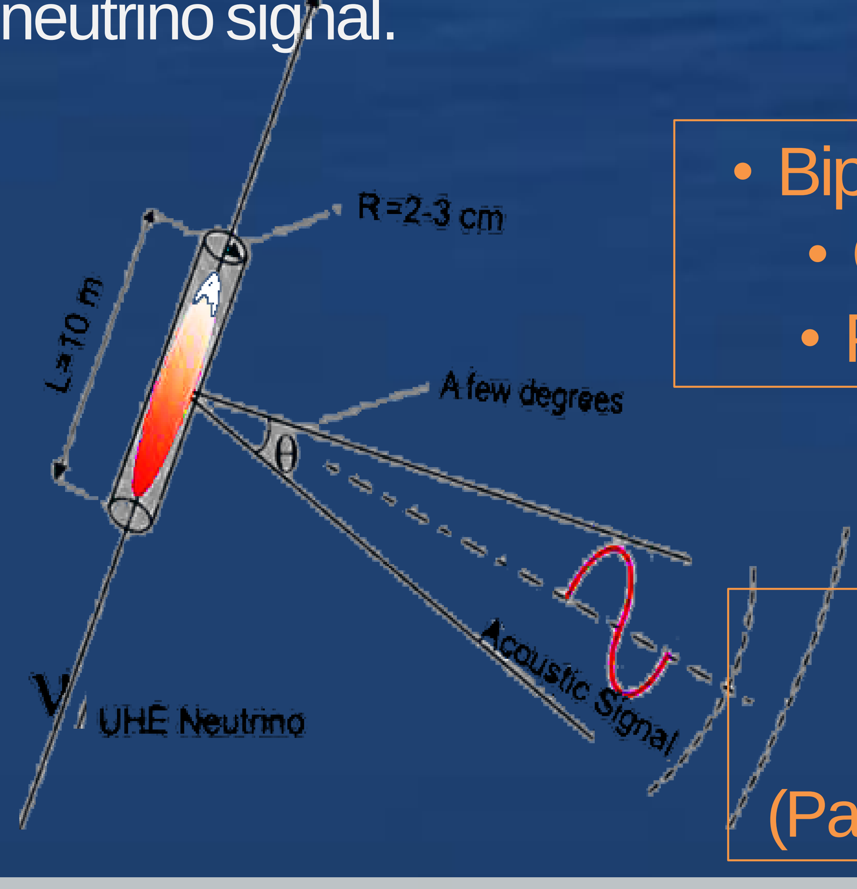
Abstract

Underwater neutrino telescopes require in situ acoustic calibration in order to assure the optimal performance of sensors dedicated to the acoustic detection of ultra-high energy neutrinos. Moreover, sensor calibration is necessary to evaluate the acoustic detection and the efficiency of the entire detector. A first prototype of a compact acoustic array able to mimic the acoustic neutrino signal is presented. Parametric acoustic source technique has been used to reproduce the neutrino signal.

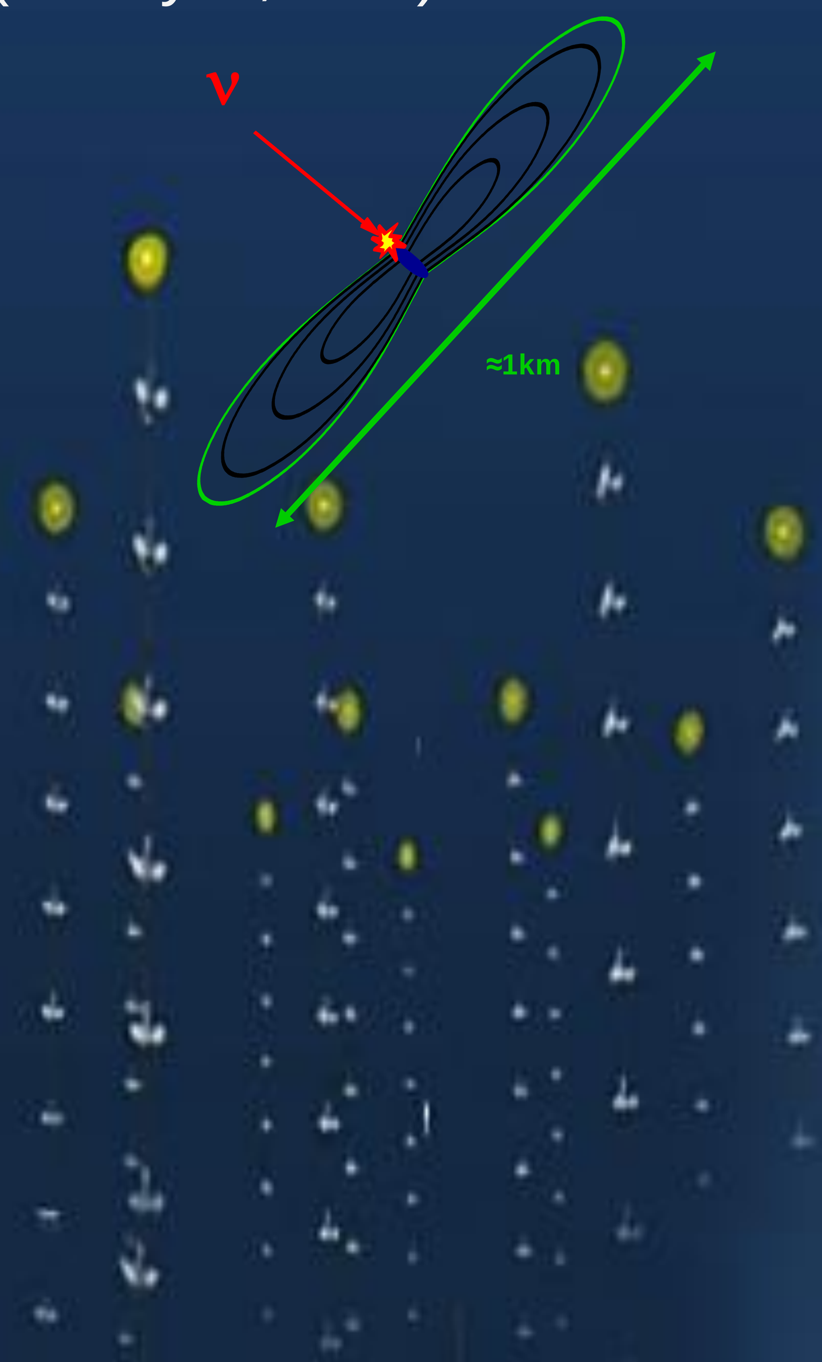


- Bipolar Pulse in time domine
- Cylindrical Propagation
- Pancake Directivity ≈ 1º

Compact Array Calibrator
(Parametric Acoustic Source)

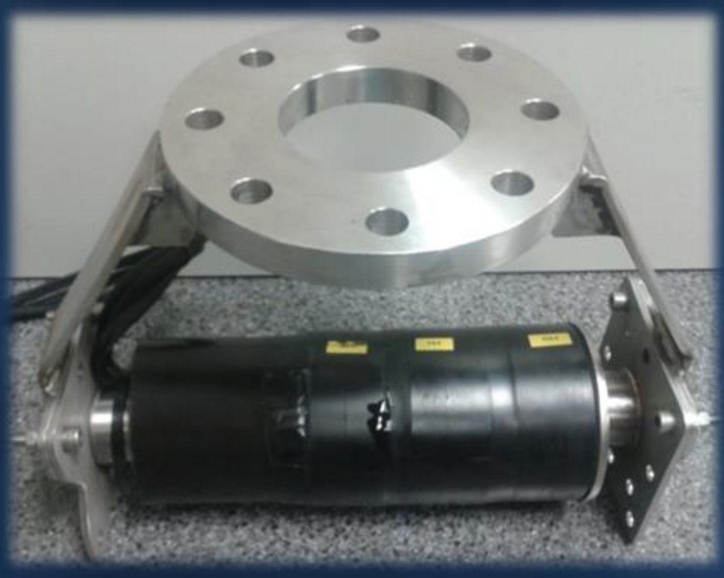
Acoustic Neutrino's Signal

When a UHE neutrino interacts with a nuclei in water, the energy is deposed in the medium fast and locally. A pressure pulse is generated and propagated perpendicularly to the direction of the hadronic shower produced. The amplitude of this signal is related with the energy deposed and its duration is related with the increase of temperature in the medium (Askaryan, 1957).

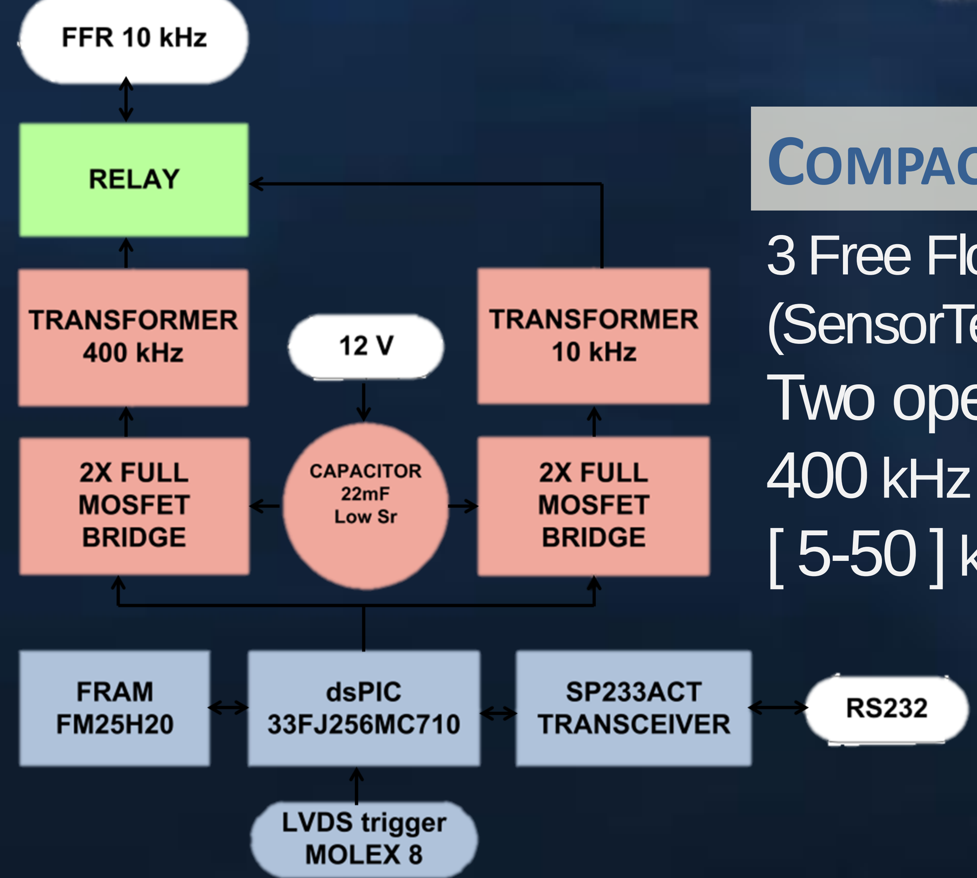


Parametric Acoustic Generation

Westervelt (1963).
When two intense monochromatic beams (two close frequencies) travel together through a medium, in the region of nonlinear interaction, secondary harmonics of these frequencies are produced. The secondary parametric beam has the same directivity pattern as the primary beam, enabling low frequency beams (difference frequency) with high directivity



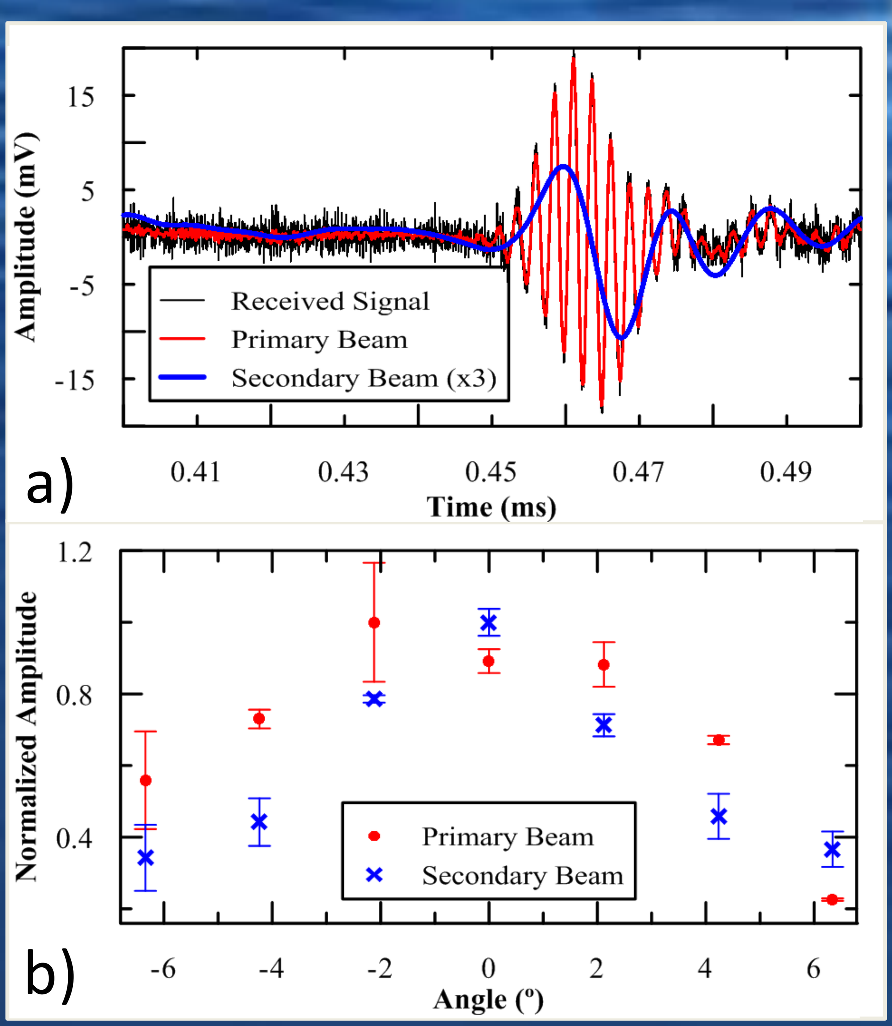
Associated Electronics



Compact Array Design

3 Free Flooded Ring FFR-SX83 (SensorTech) (36 x 27 x 12) cm^3
Two operation modes:
400 kHz → parametric generation
[5-50] kHz → calibration, positioning

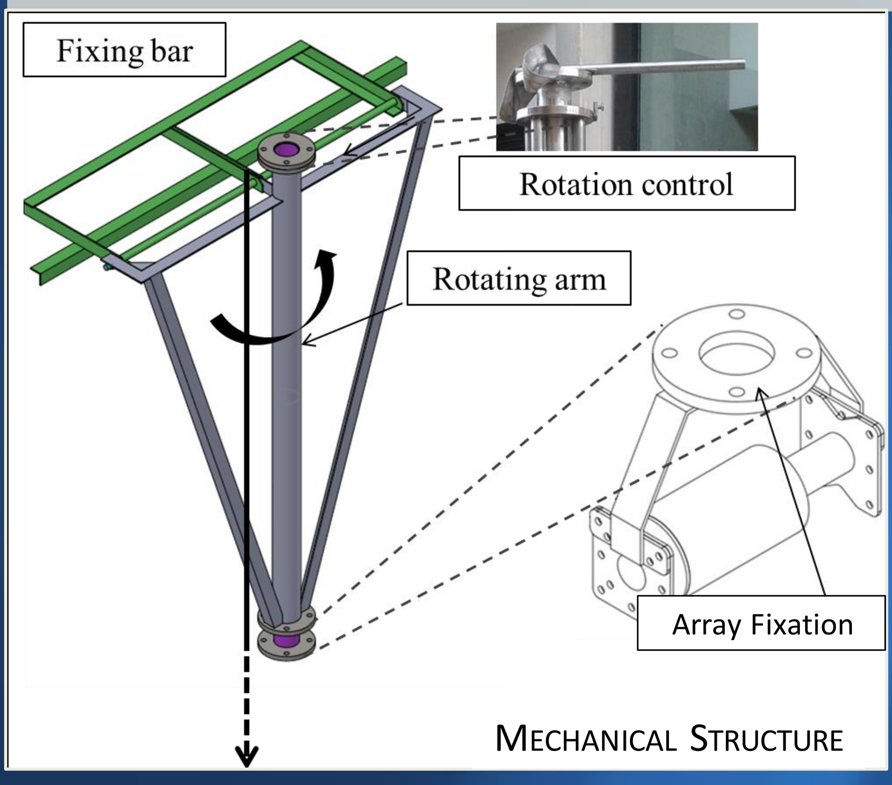
$$p(x,t) = \left(1 + \frac{B}{2A}\right) \frac{P^2 S}{16\pi\rho c^4 \alpha x} \frac{\partial^2}{\partial t^2} \left[f\left(t - \frac{x}{c}\right) \right]^2$$



Waveform and Directivity

Parametric generation studies show that the time shape of the secondary signal is related with the second time derivative in time of envelope of the primary signal, following the upper equation. **(a)** Received signal and the primary and secondary beams obtained after band-pass filtered **(b)** Directivity patterns of primary and secondary beam measured with the array

Sea Campaign Plan & Equipment



Mechanical Structure

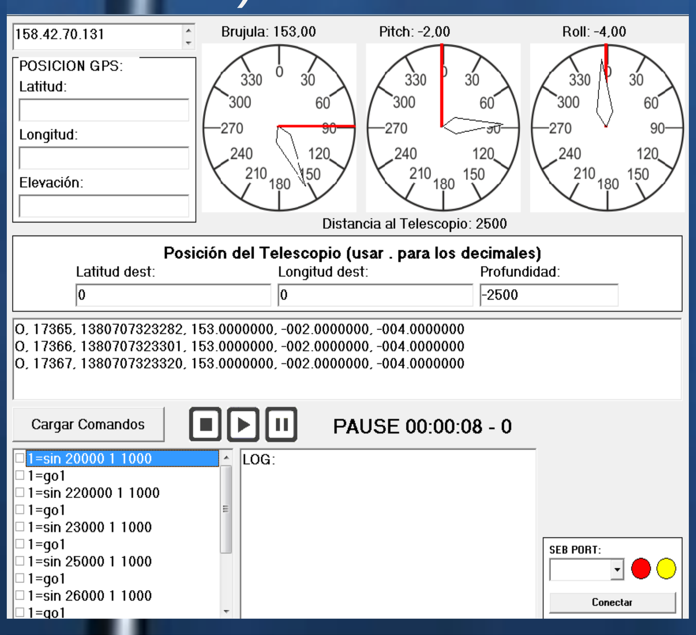
In order to test it in a future sea campaign a mechanical structure has been built in order to:

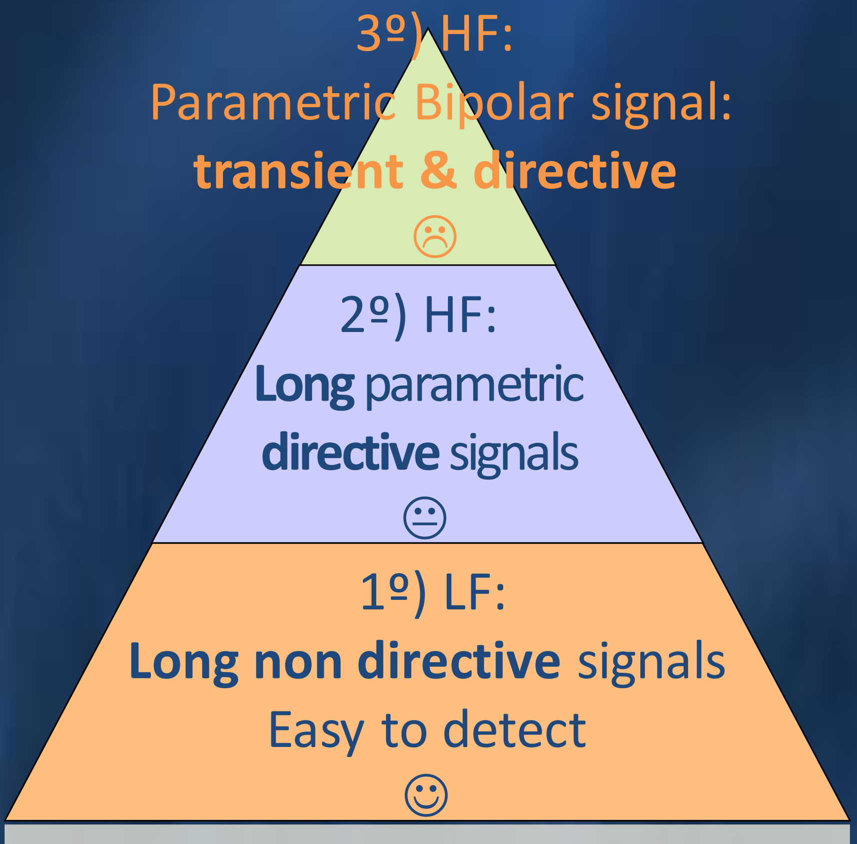
- Fix the device to the boat.
- Dip it.
- Control the rotation angle (very important point due to the high directivity of the bipolar pulse, in order to be able to point the emitter to the receivers).

Monitoring System

Emitted signal monitoring and its associated location information:

- GPS position of the array
- Time of emission
- Orientation information: tiltmeter and compass.





3 Steps Calibration Plan

1 st Calibration Step

3 step calibration, increasing progressively the difficulty.
1º) Emitting long broadband low frequency non directive signal (sweep signal). It is directly emitted, so it could be of high amplitude. Since this is low frequency signal attenuation is small, moreover it is not directive so orientation is not difficult.

2 nd Calibration Step

Emitting long parametric signal. Incorporating the directivity challenge, so high frequency and lower amplitude, but it could be still taken advantage of signal processing techniques.

3 rd Calibration Step

The parametric bipolar signal, that is transient and directive. The emission might be tagged, that is, preceded and followed by signals of the previous modes. In this way it will be easier to look for the bipolar signal during the post processing, looking at the correlation peaks of the received signal and the known expected tag signals.

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MultiDark Multimessenger Approach for Dark Matter Detection