2nd International Electronic Conference on Sensors and Applications 15-30 November 2015

2nd International Electronic Conference on Sensors and Applications 15–30 November 2015

New design of an acoustic array calibrator for underwater neutrino telescopes

M. Saldaña, C.D. Llorens, I.Felis, J. A. Martínez-Mora and M. Ardid

UPV – IGIC – Campus de Gandia (València)

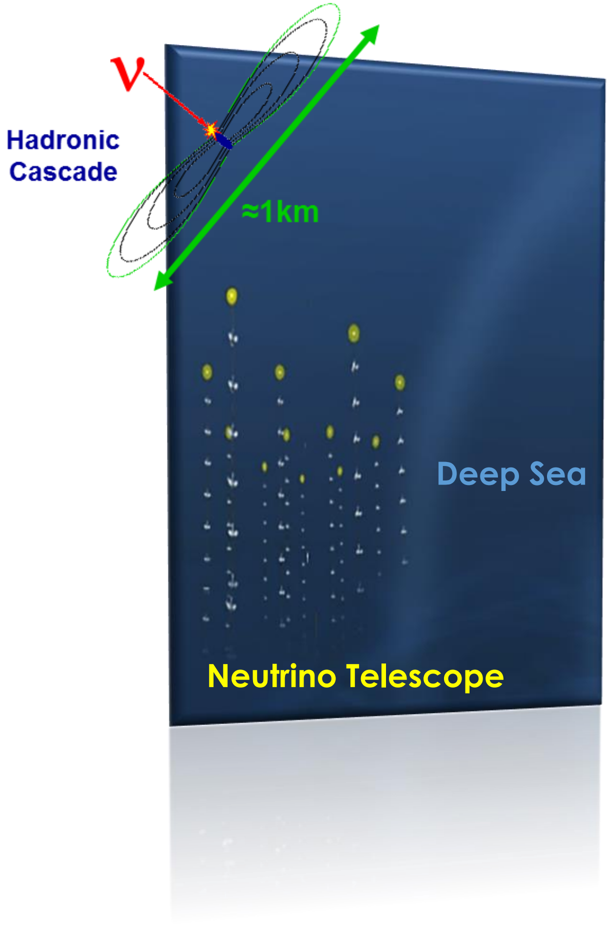
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

IGIC Instituto de investigación para la gestión integrada de zonas costeras

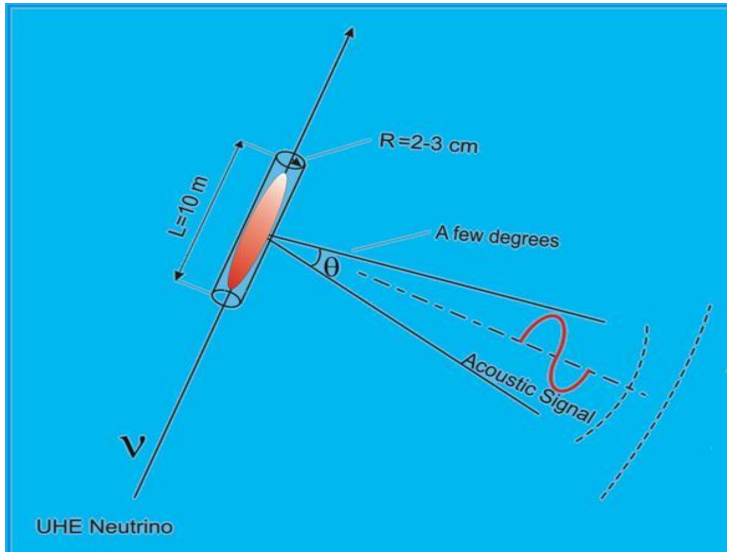
Contents

2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

Acoustic Neutrino's Signal



Energy deposition when a neutrino interacts with nuclei in water

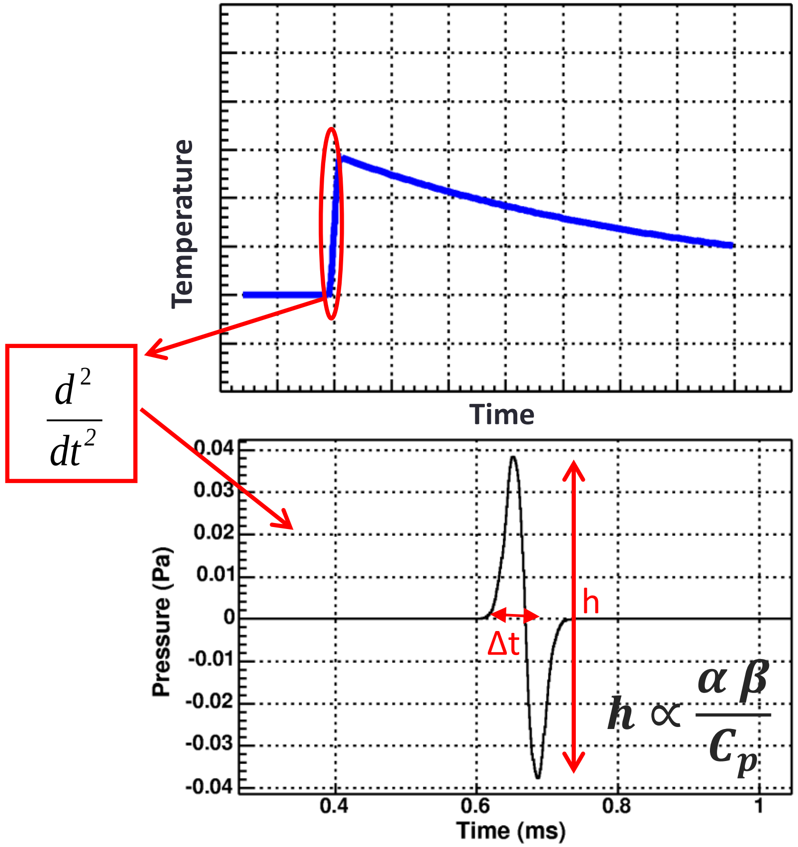


G.A.Askaryan. *Hydrodynamical emission of tracks of ionising particles in stable liquids*. J. At. Energy 3 (1957) 921.

- Bipolar Pulse
- Cylindrical Propagation
- Pancake Directivity ≈ 1º

The Thermo-Acoustic Model

Induces a local heating in a very short period of time leading to a short pressure pulse signal



2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

Need for a calibrator. Design Philosophy

A good acoustic calibrator can be very important to study the feasibility of the UHE neutrino acoustic detection technique and help to discriminate the signal from noise and background of transient signals.

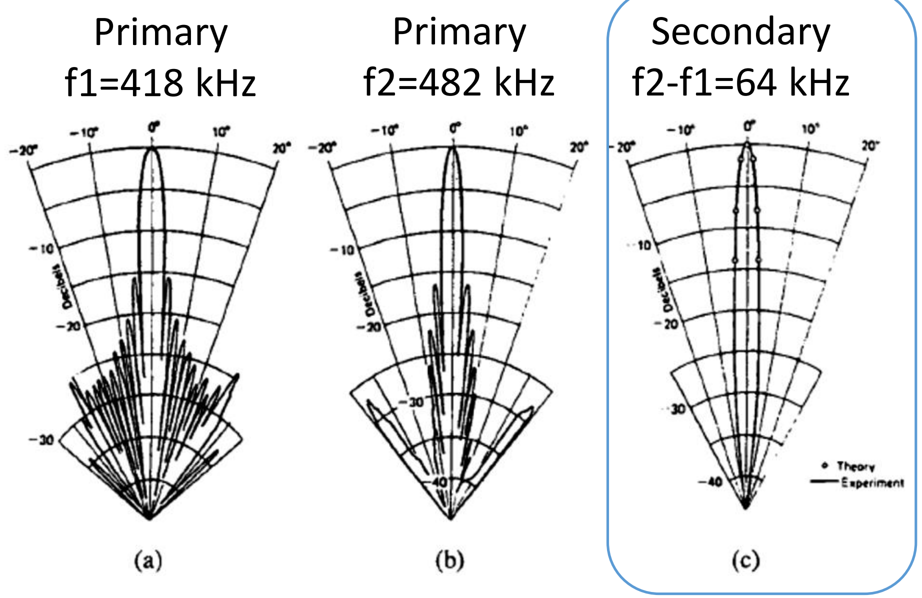
Useful tool to:

- Train and tune the acoustic detector
- Help to classify signals: background of transient signals
  - Marine life and natural phenomena
  - Anthropogenic/technical origin
- Perform *in situ* measurements of neutrino-like signals from a known source (Sea Campaigns or integrated in the infrastructure).
  - To verify the simulation results
  - To improve the signal classification algorithms
- Monitor the individual sensors and assess the full detection system

Compact Calibrator. Parametric Acoustic Source

Neutrino-like signals generation is achieved by using parametric acoustic sources

- **Parametric acoustic generation** (Westervelt, 1963) is a non linear effect used in different underwater **applications**.
- **Compact**: possible to obtain **directive low -frequency beams** from 2 directive high-frequency beams
- **Bipolar transient pulse** can be obtained from signal modulation
- Since the signal has to travel long distances, primary **high-frequency signal will be absorbed**.
- Main drawback: **low-power conversion efficiency**, usually less than 1%



2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

Compact Array Calibrator. Conceptual Design

New proposed design composed of an array of piezo ceramic tube transducers array emitting in axial direction

Array composed of new piezo tube ceramics emitting in axial direction

+

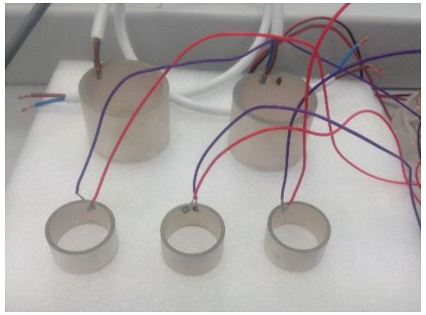
Operation at high-frequency by the parametric technique

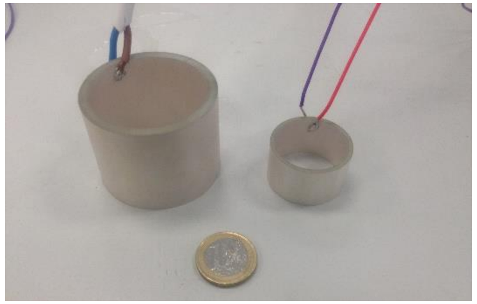
+

New specific electronics adapted to the transducers

Processes involved in the design

- Characterization of piezo-ceramics
- Ceramic Moulding (Heading/Backing)
- Array design
- Signal processing techniques
- Simulations
- Tests of the prototype

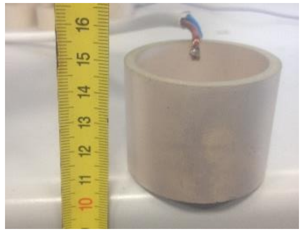




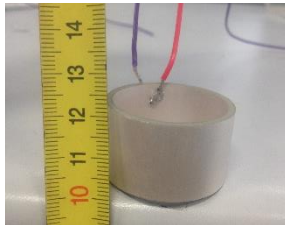
Compact Array Calibrator. Characterization.

System Characterization at the Laboratory water tank

Two Piezo-Tube Ceramics under study



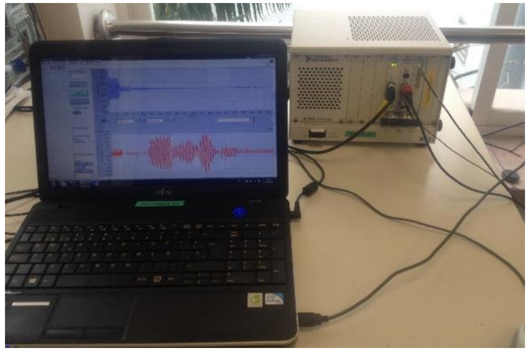
UCE-534541
OD=5.3 ID=4.5 H=4.1 [cm]



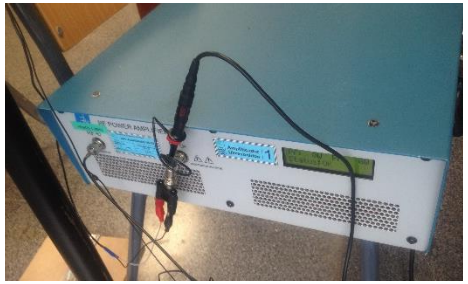
UCE-343020
OD=3.4 ID=3 H=2 [cm]

Equipment for characterization

Generator/Acquisitor
NI PXI 1031 DC - LAbView

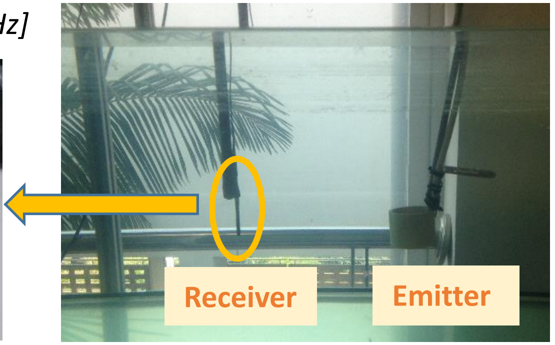


Amplifier



Receiver RESON TC4038
[Freq Range 10kHz–1MHz]

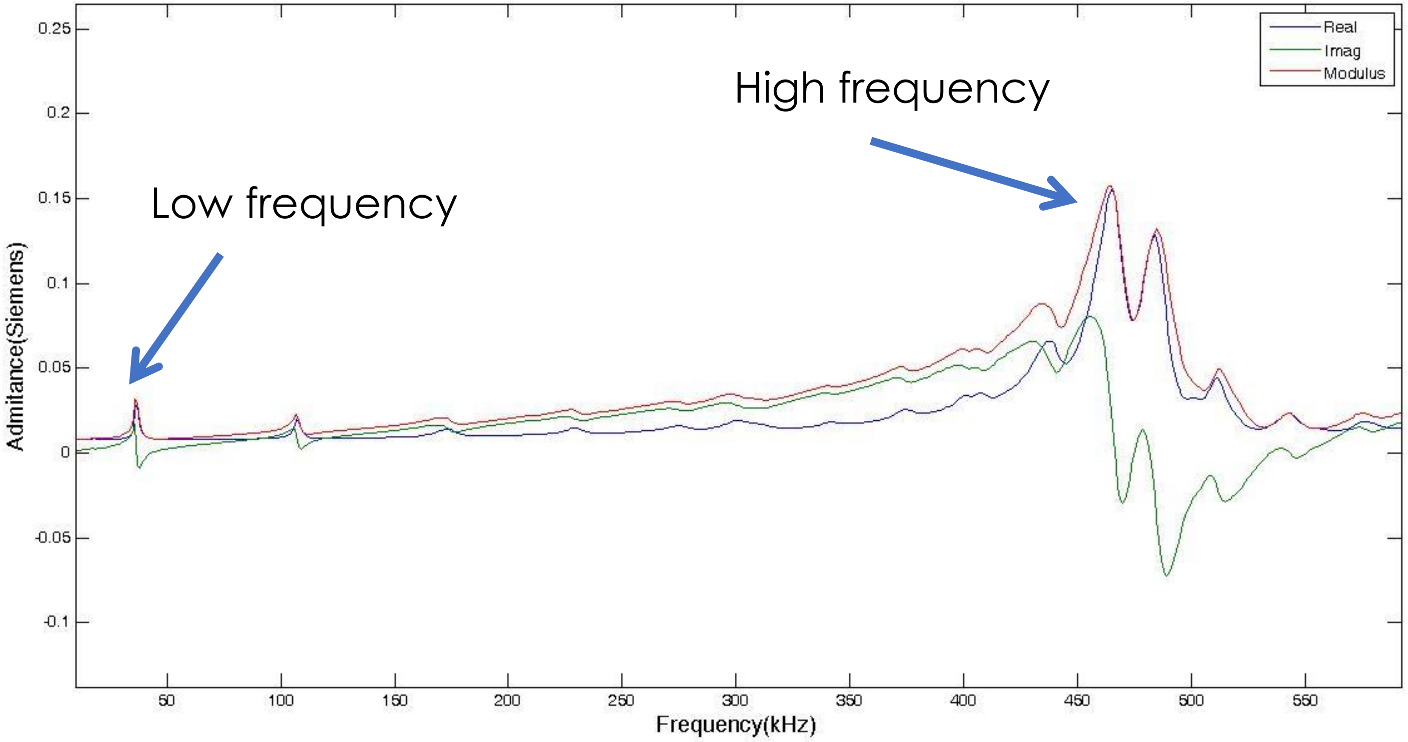
Water Tank



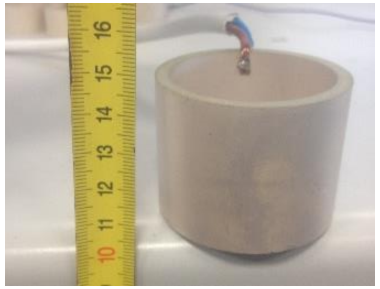
Compact Array Calibrator. Characterization.

Characterization of piezo-ceramics

Primary frequency of resonance is around 490 kHz and secondary resonance frequency at low frequency around 35 kHz.



UCE-534541
OD=5.3 ID=4.5 H=4.1 [cm]

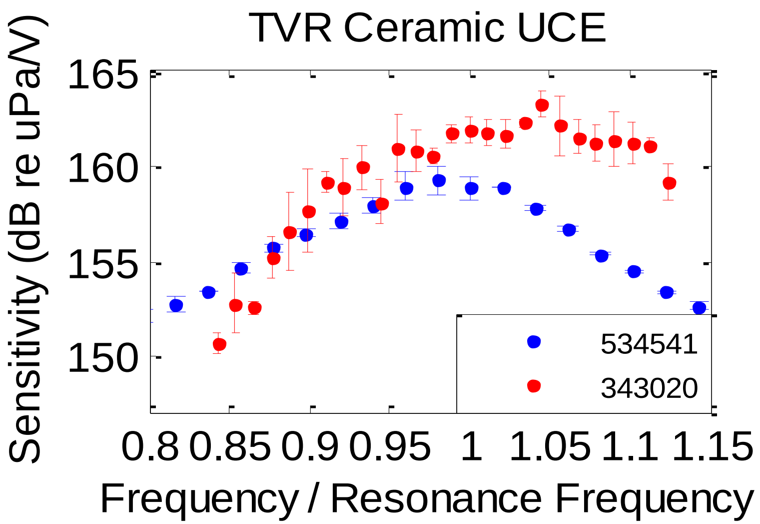


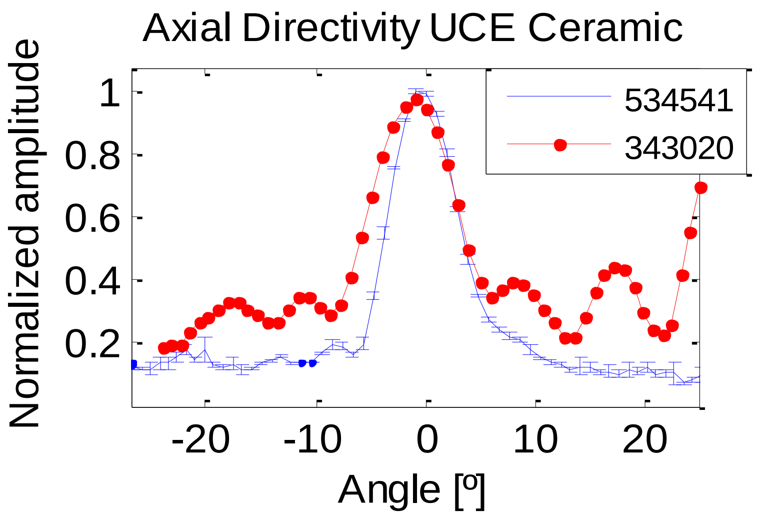
2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

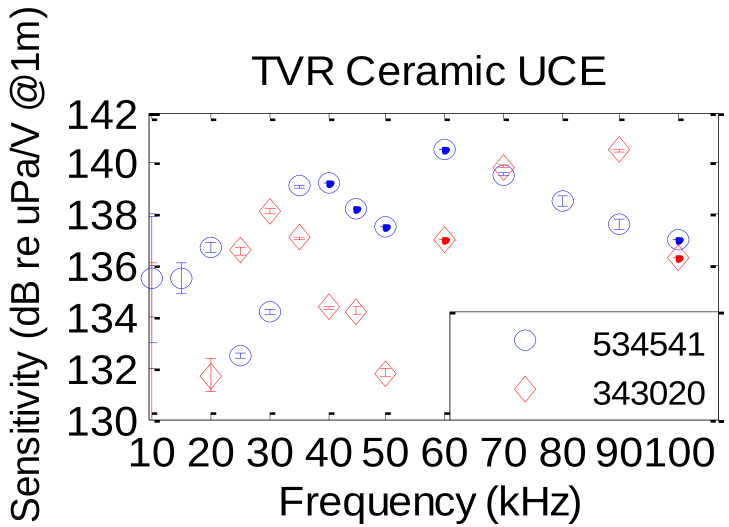
Compact Array Calibrator. Characterization

Characterization of piezo-ceramics

- Sensitivity of UCE-534541 -> 159 dB (re μPa/V at 1m) at F_R =490 kHz with a directivity of ±5º
- Sensitivity of UCE-343020 -> 162 dB (re μPa/V at 1m) at F_R =890 kHz with a directivity of ±7º
- The TVR at low frequency oscillates between 132 dB – 143 dB (re μPa/V at 1m).







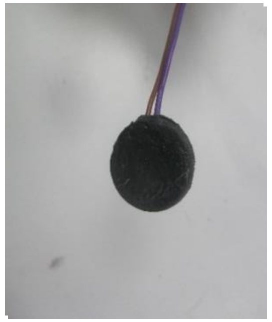
2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

Compact Array Calibrator. Moulding

First Tests for Ceramic Moulding (Heading/Backing)

Moulding RoyaPox511 Resin → No Loses

Moulding Poliutherane EL241F → 4-5 dB Loses



Goal

- Ensuring protection
- Holding
- Isolating
- Matching Impedance

Thickness matching accomplish λ/4 of the wave length emitted at the ceramic resonance frequency

Next → To Study the Effect on Parametric Emission

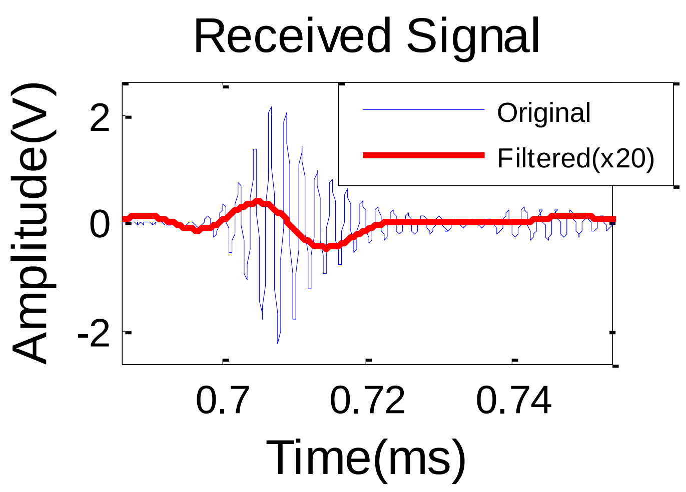
2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

Compact Array Calibrator. Parametric emission.

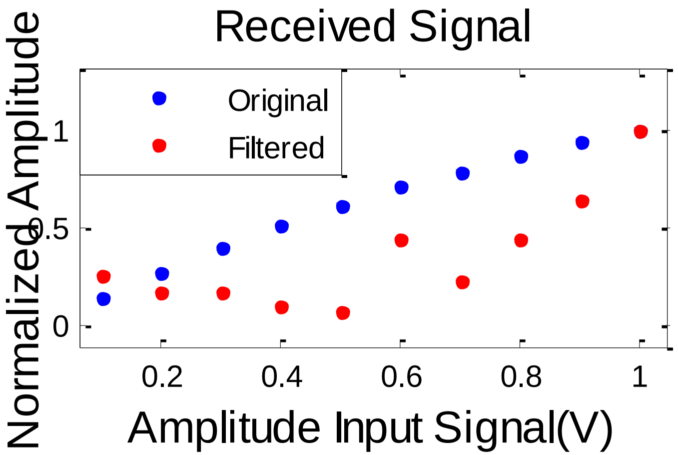
First Studies of the Parametric Bipolar Pulse Emission

Bipolar Shape

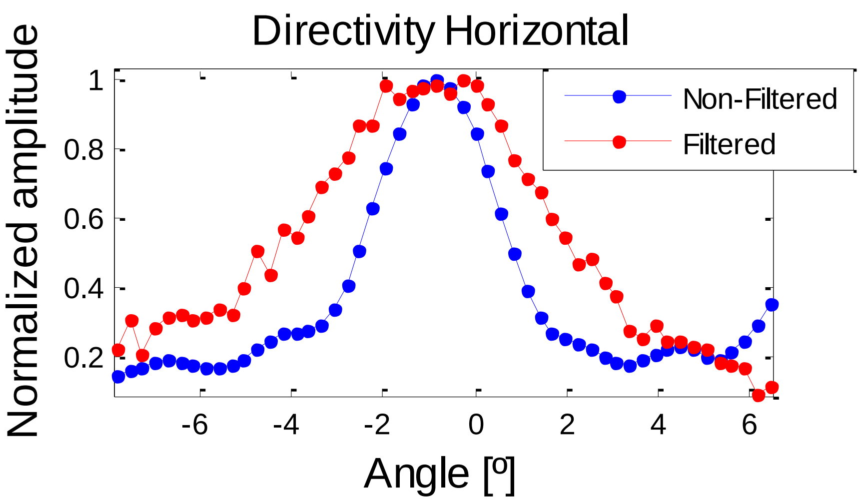
Original Received Signal (blue) and Filtered Received Signal (red) at low-frequency [5 kHz - 80 kHz]



Non-Linearity



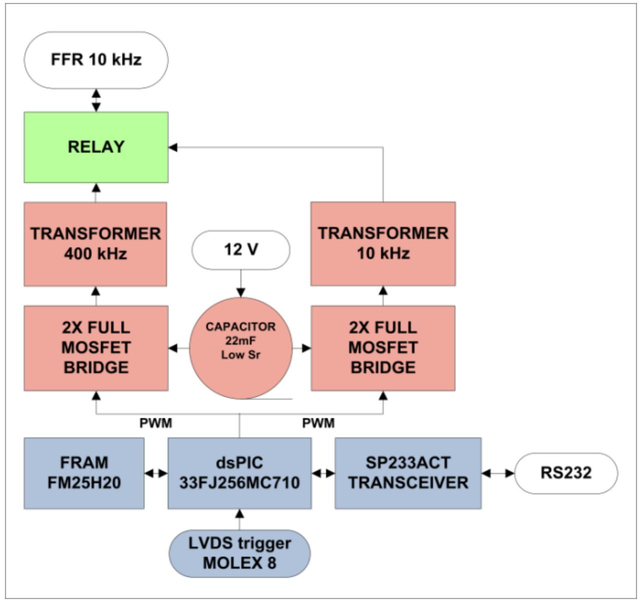
Similar Directivity



- ✓ The viability of the technique has been checked

- ➢ Low frequency beams with small transducer (High Frequency)
- ➢ Able to reproduce acoustic neutrino's directivity with few sources

Electronics and Functionality



- **Transducer Matching**
- **Signal Control and Generation**
- **Amplification**

Three Operation Modes

Functionalities: Training and tuning the acoustic detector, cross-checking the detector hydrophones

Challenge: Detecting the High directivity Bipolar pulse emitted from several km away

TAGGING the BIPOLAR pulse emissions Calibration in 3 Steps, increasing difficulty

1st Stage

Low Frequency:
Emitting **long non directive** signals
Easy to detect

2nd Stage

High Frequency:
Emitting **long** parametric **directive** signals

3rd Stage

HF:
Parametric Bipolar signal:
transient & directive

Summary

- Both ceramics are optimal candidates for the neutrino´s calibrator. They have a good sensitivity in both high and low frequency and narrow beam directivity at the high frequency which will lead to a tight low-frequency (parametric) directivity.
- Matching layer studies validate the materials for the ceramics covering.
- Generation of acoustic neutrino's-like signal has been achieved and validated. By using parametric technique.
- New electronics are under development for achieving larger efficiency in the high frequency emission.
- Future sea campaign foreseen for testing and using it.

Future steps

- Array structure design and moulding
- Final design of the electronics
- Signal processing techniques
- Simulations
- Long distance tests of the prototype
- In situ test at the telescopes AMADEUS/KM3NeT

2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

Thank you for the attention

Acknowledgements:

FPA2012-37528-C02-02, CSD2009-00064, PrometeoII/2014/079, ACOMP/2015/175