KM3NeT
Opens a new window on our universe

Development of an acoustic transceiver for the KM3NeT positioning system

G. Larosa, M. Ardid, C.D. Llorens, M. Bou-Cabo,
J.A. Martínez-Mora, S. Adrián (for the KM3NeT Consortium)

VLVnT11 - Very Large Volume Neutrino Telescope Workshop
Erlangen, October 12-14

Introduction

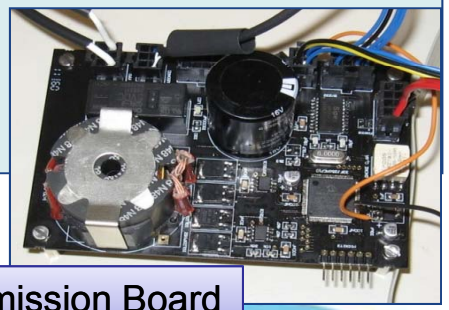
- In undersea neutrino telescopes, sea currents result in drifts of the top of the detection units and Optical Modules (OMs) up to several tens of metres.
- However, muon track reconstruction is based on:
  - precise arrival time of Cherenkov photons at the OMs(< 2 ns)
  - Monitoring the OM position with the corresponding resolution (< 40 cm)
- An acoustic triangulation system is needed to monitor the OM positions, so as to provide the tracking precision and angular resolution required for astronomical neutrino source searches.
- We present our effort in Development for this system for KM3NeT
  - In this talk, we focus on the prototypes and tests of the transceiver system (see S. Viola's talk for the description and details of the general Acoustic Positioning System)

Acoustic Transceiver proposed

- **Acoustic transducer:**
  - We have selected the commercially-available SX30 Free Flooded Ring from Sensortech, Canada, since it fulfils all the requirements:
    - It can operate as emitter and receiver with good efficiencies (20-40 kHz)
    - It can stand high power signals and high pressures
    - It can be affordable in the large number of units required by KM3NeT
- **Electronics**
  - Especially developed electronics to:
    - Fulfill the special requirements of the system: low-power consumption, configurable from shore, high intensity for emission, arbitrary signals for emission and low intrinsic noise.
    - Optimize to the transducer chosen
    - Reduced costs

Hydrophone

+

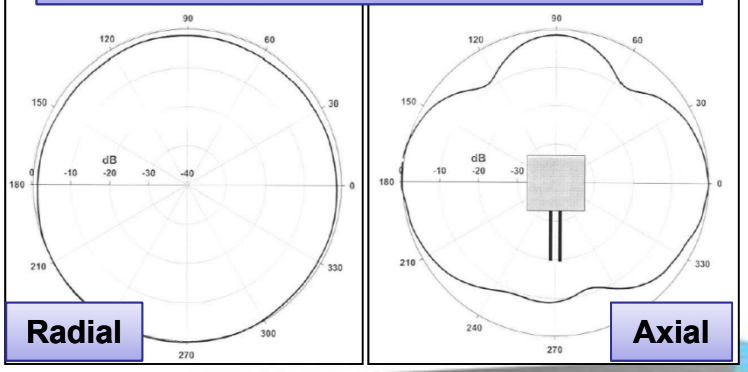


Sound Emission Board

Transducers: *Free Flooded Ring (FFR)* – Sensor SX-30

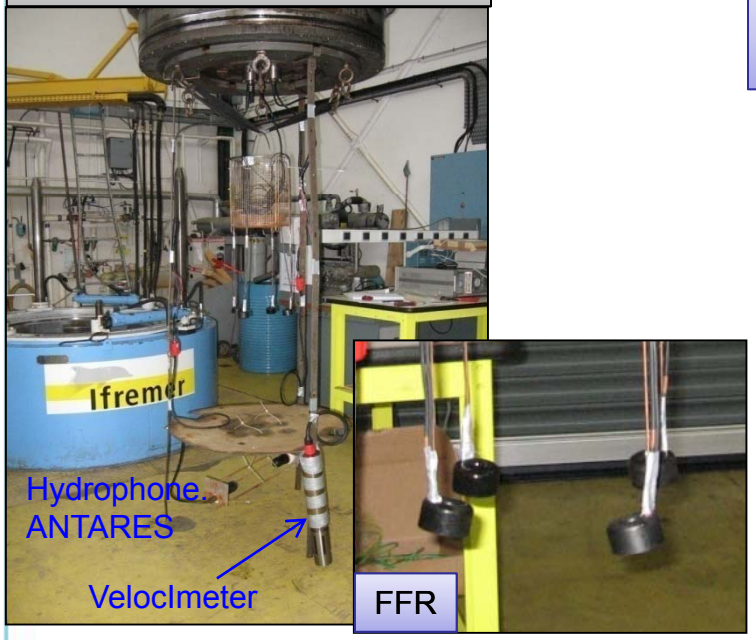
Resonance Frequency	30 kHz
Transmit Voltage Response, TVR	133 dB re µPa/V @ 1m
Receive Voltage Response, RVR	-193 dB re V/µPa @1 m
Useable Frequency range	20 kHz – 40 kHz
Beam pattern	Radial: Omni Axial: Toroidal (60°)
Efficiency	50%
Input Power	300 W (2% duty cycle)
Operating Depth (Metres)	Unlimited

Transmitting Directivity Response

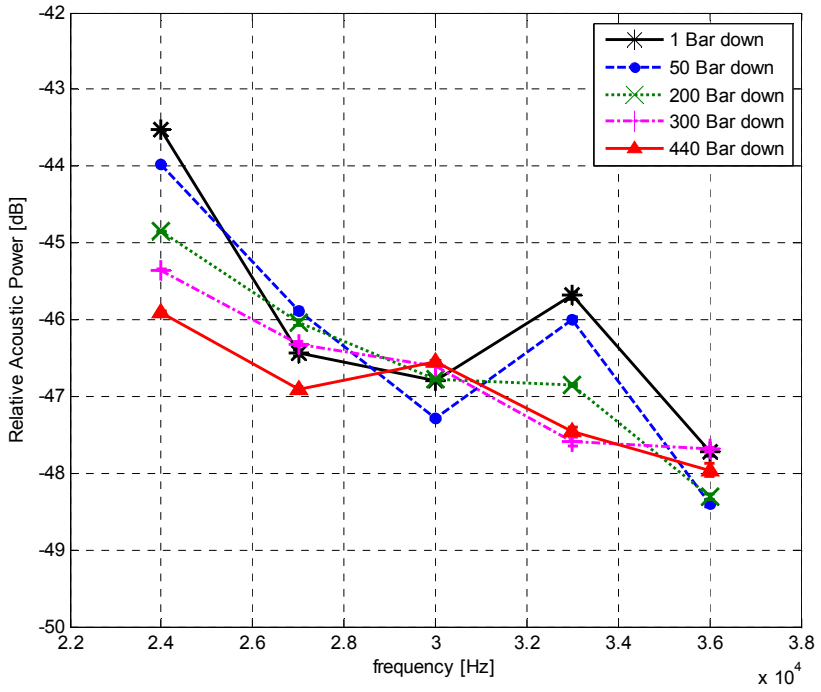


Pressure Tests of Acoustic Transducers

IFREMER (France)



Tests performed at the large hyperbaric tank at IFREMER-Brest



Pressure dependence study : tested up to 440 bar

Sound Emission Board (SEB) specifications

- Designed and adapted to the FFR transducers and to the neutrino infrastructure using power supplies of 12V and 5 V, respectively provided by the telescope. Power consumption <1W.
- Configurable and controlled from shore using low speed port (RS232,RS485…) and able to emit arbitrary intense short signals.
- Emission triggered by a LVDS signal with an accuracy better than 1μs.
- Relay for using the transducer as receiver.
- System life expectancy must exceed twenty years.

Blue: Communication and control
- Microcontroller DSPic

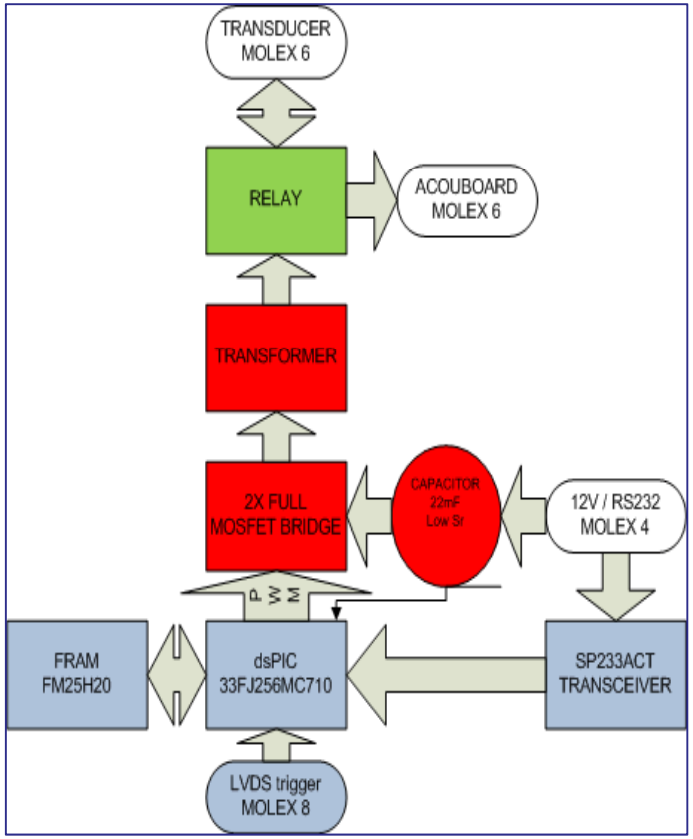
Red: Emission part
- digital amplification + transducer impedance matching
- V_{out} range: 35 V_{pp} ÷ 400 V_{pp}

Green: Reception part
- relay

Sound Emission Board

7.3x10.5 cm

Diagram of the SEB



Power consumption: 100 mA @+5 VDC
1 mA @+12 VDC

Tests of the Transducer in the tank

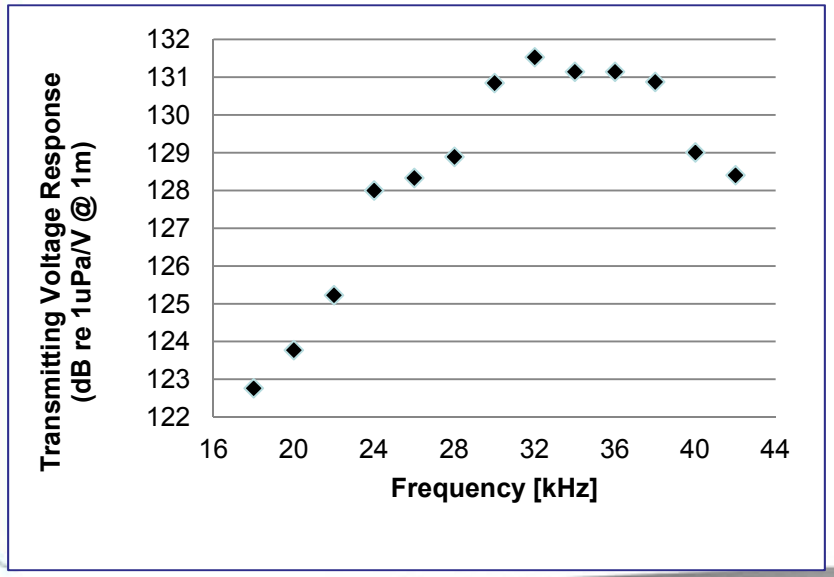
Nude FFR

To water block and facilitate its fixing in the mechanical structures of the telescope

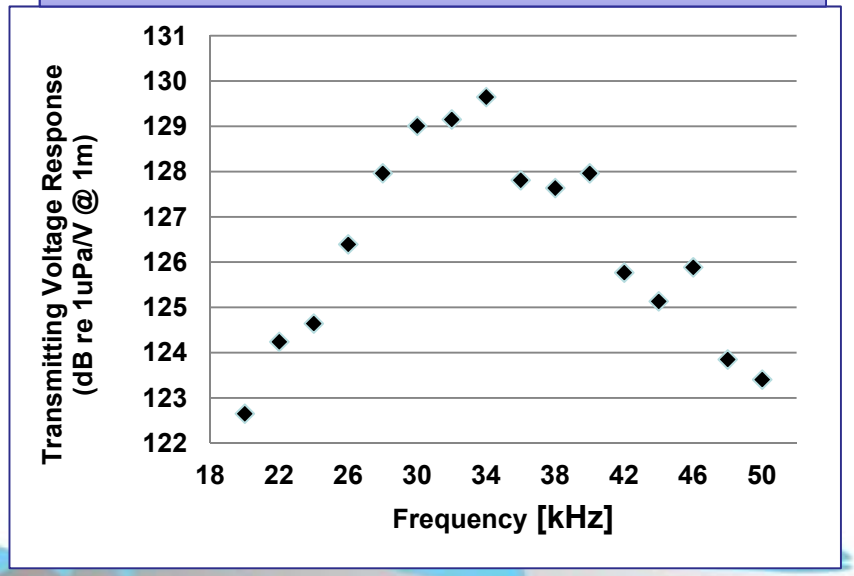
FFR over moulded

Polyurethane material

Transmitting Voltage Response of the nude FFR



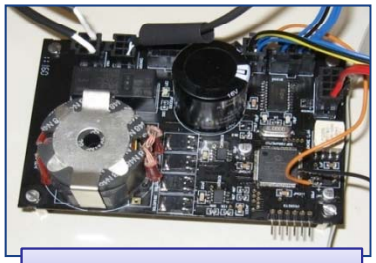
Transmitting Voltage Response of the FFR over molded



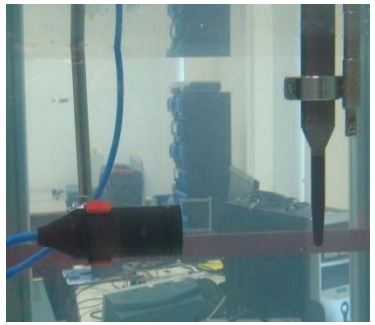
Tests of the Transceiver in the tank

FFR over moulded

+

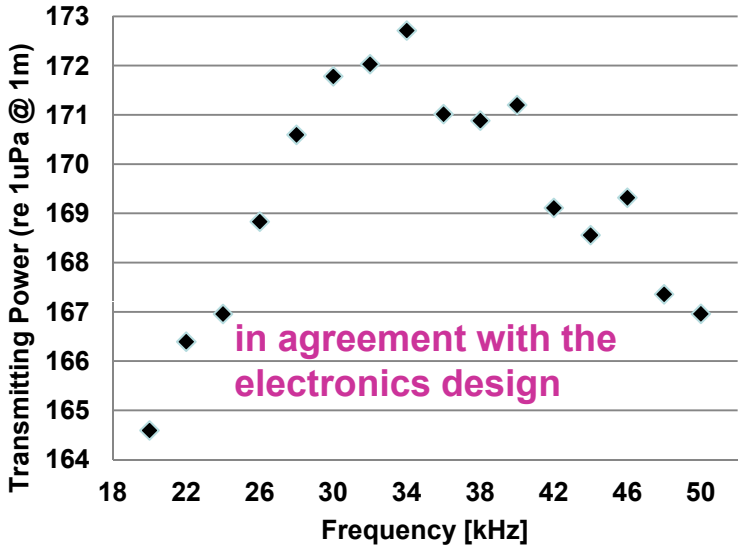


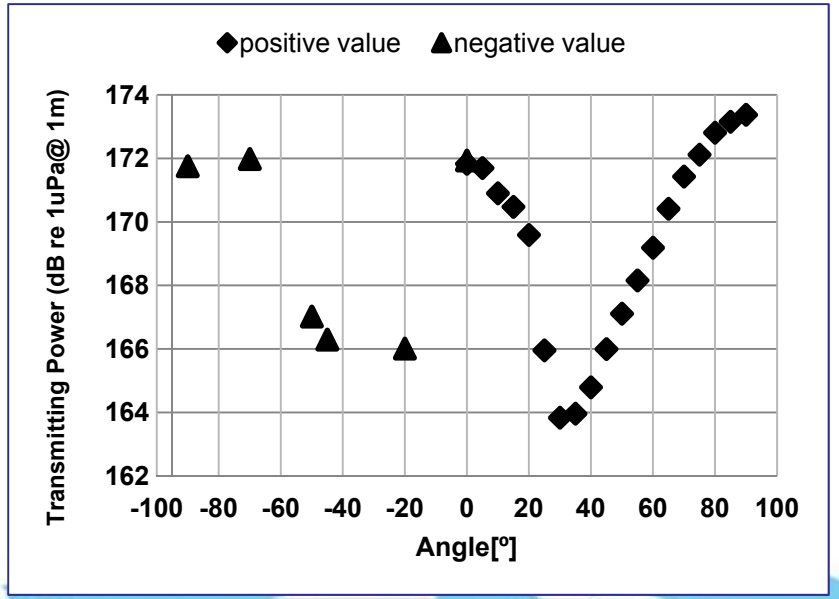
Sound Emission Board



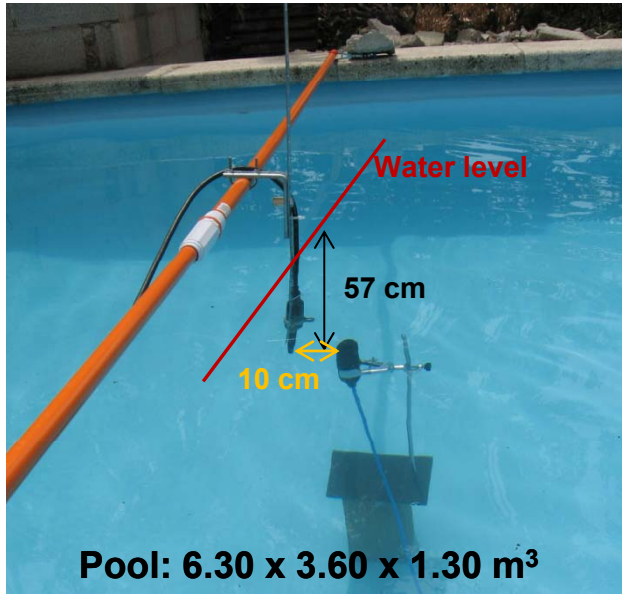
Tank: 87.5 x 113 x 56.5 cm^3

Transmitting Power of the System

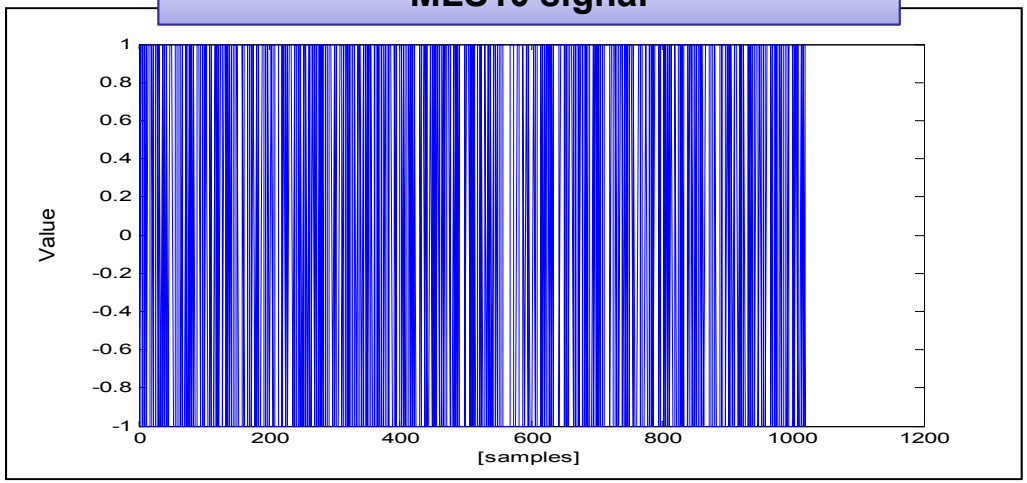




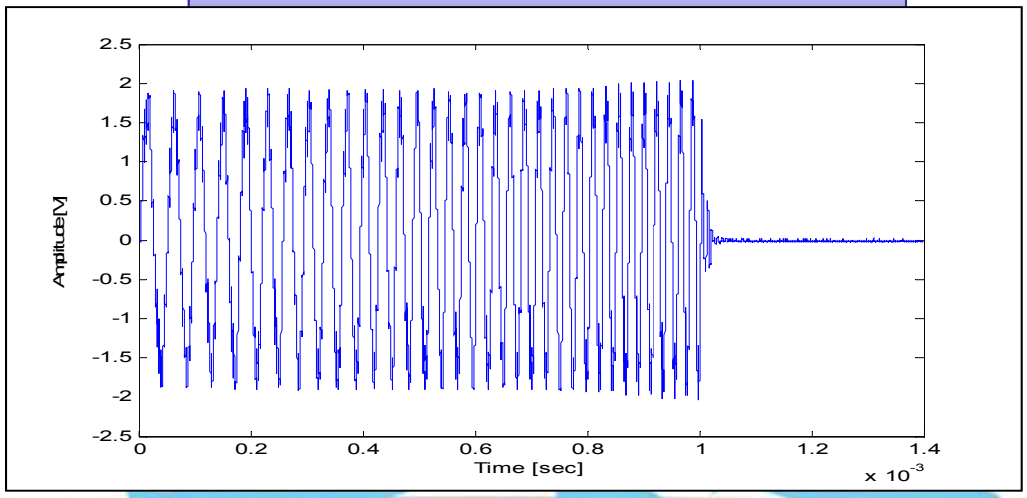
Tests of the Transceiver in the pool



MLS10 signal



Sine Sweep Signal: 20-48 kHz

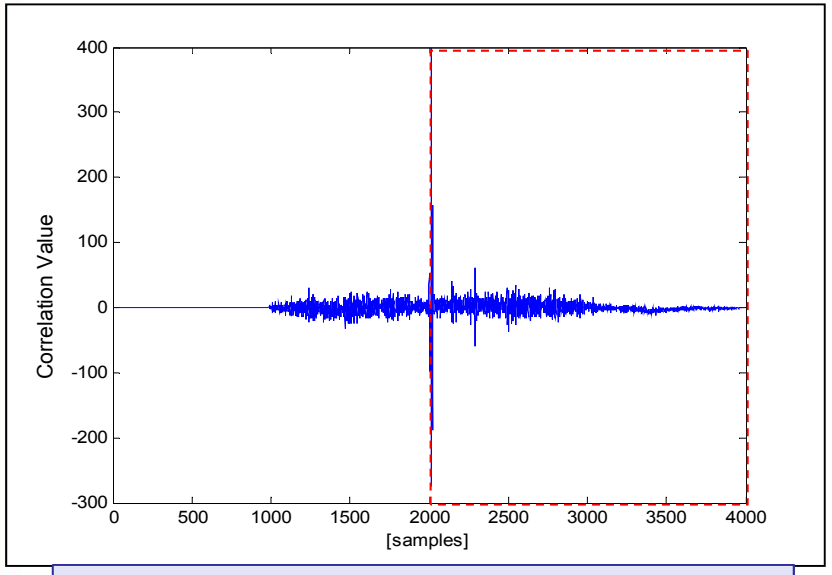


- **Test** the system **in water pool** to prove the system in different conditions from that of the laboratory (reflections coming later)
- **Study of different signals** to calculate the sound travel time (i.e. the distance between emitter and receiver hydrophone)

Tests of the Transceiver in the pool: MLS signal

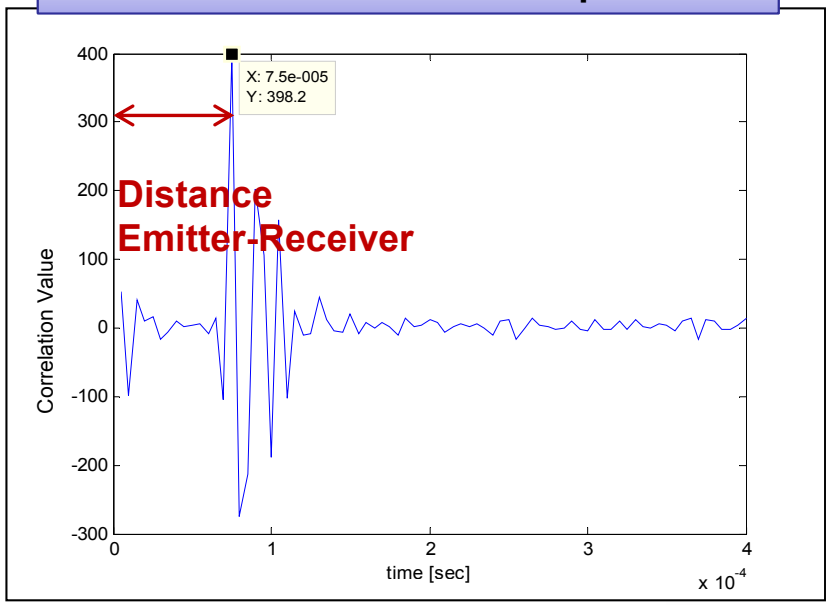
- Delay due at the electronics components of the board is ~5μs.
- Considering this delay the time travel sound calculated for MLS10 signals is the distance between the 0 and the maximum value in the right figure.

$$Distance_{E\text{-}R} = (75e\text{-}006 - 5e\text{-}006) * 1500 m/s = 0{,}10 \text{ m}$$



Correlation between MLS10 signal and received MLS signal

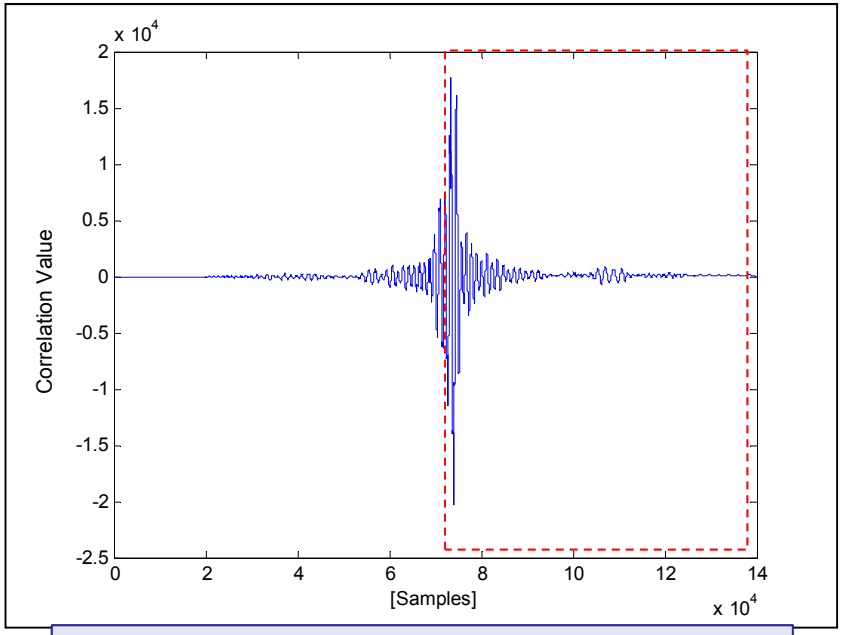
Detail of the correlation peak



Tests of the Transceiver in the pool: Sine Sweep signal

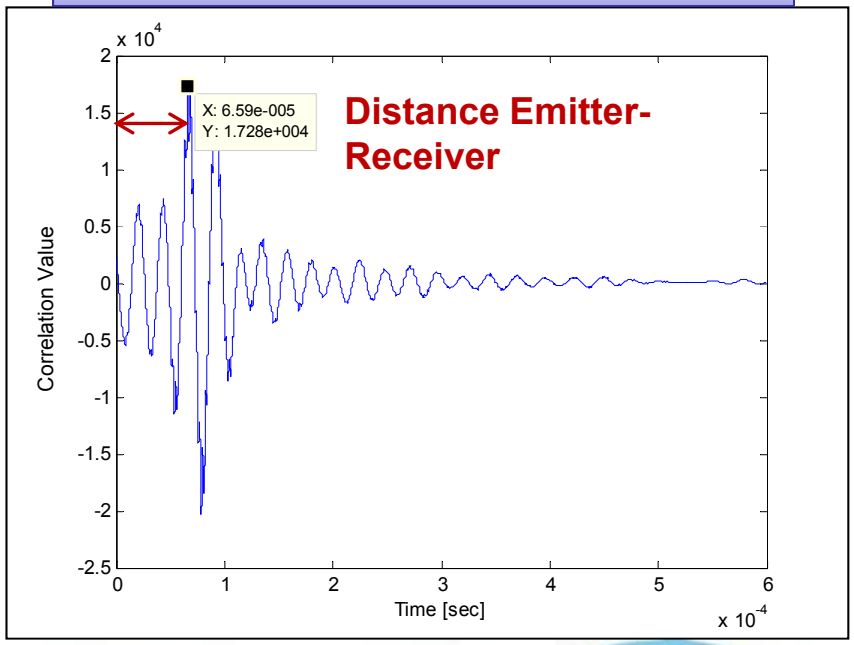
- Delay due at the electronics components of the board is ~5μs.
- Considering this delay the time travel sound calculated for MLS10 signals is the distance between the 0 at the maximum value of the right figure.

$$Distance_{E\text{-}R} = (659e\text{-}006 - 5e\text{-}006) * 1500 m/s = 0{,}10\ m$$

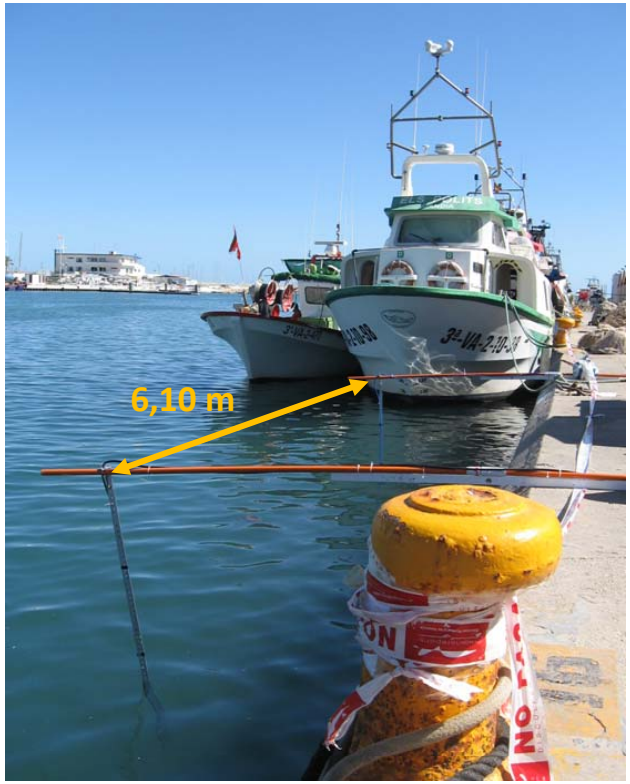


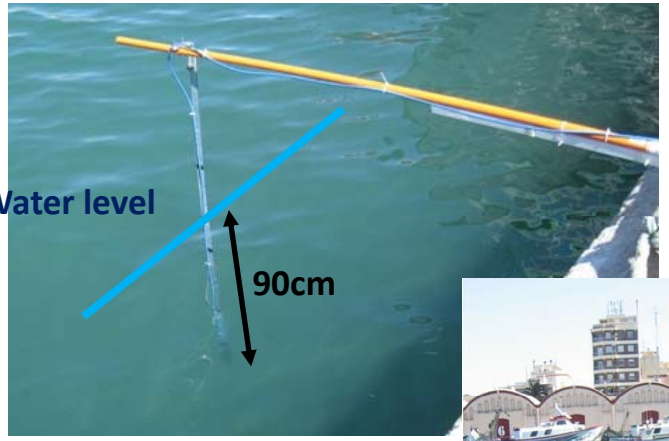
Correlation between sine sweep signal emitter and received

Detail of the correlation peak

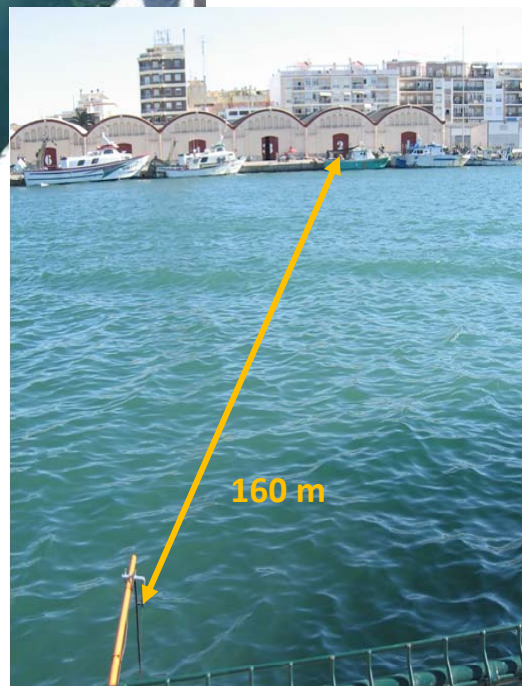


Tests of the Transceiver in Gandia harbour





In study



➢ Very recently, the system has been tested in Gandia harbour, at different distances to prove the system in sea ('noisy') conditions.

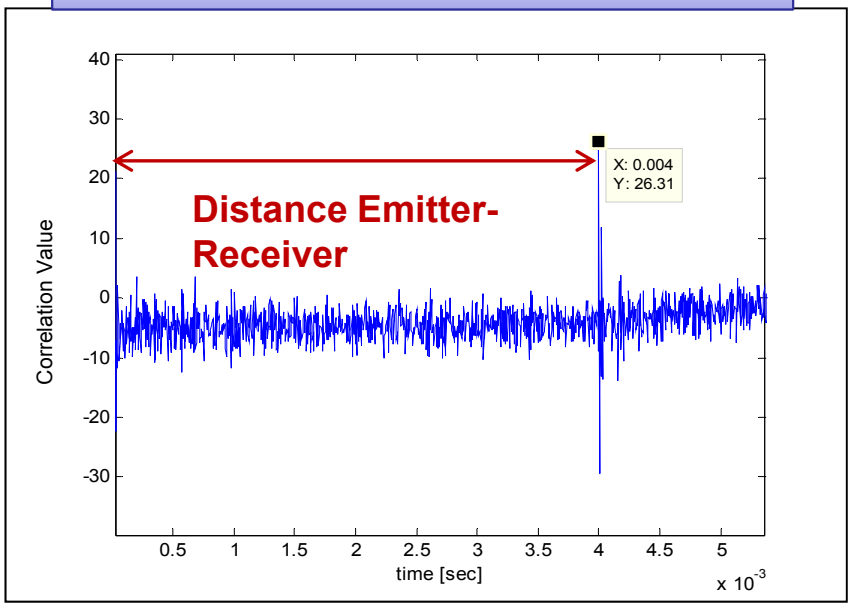
Tests of the Transceiver in Gandia harbour : MLS signal

- Delay due at the electronics components of the board is ~5μs.
- Considering this delay the time travel sound calculated for MLS11 signals is the distance between the 0 at the maximum value of the right figure.

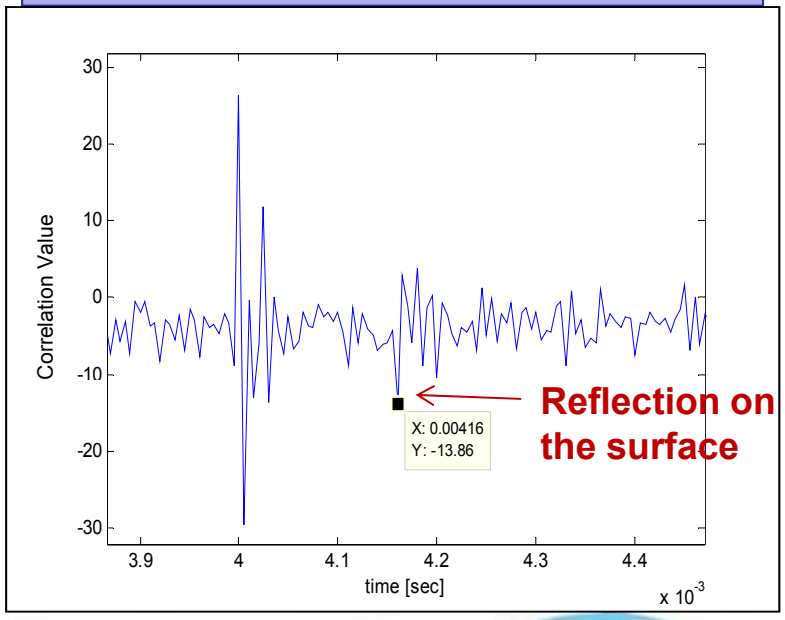
Preliminary

$$Distance_{E\text{-}R} = (4005e\text{-}006 - 5e\text{-}006) * 1500 m/s = 5{,}99 \text{ m}$$

Detail of the correlation peak



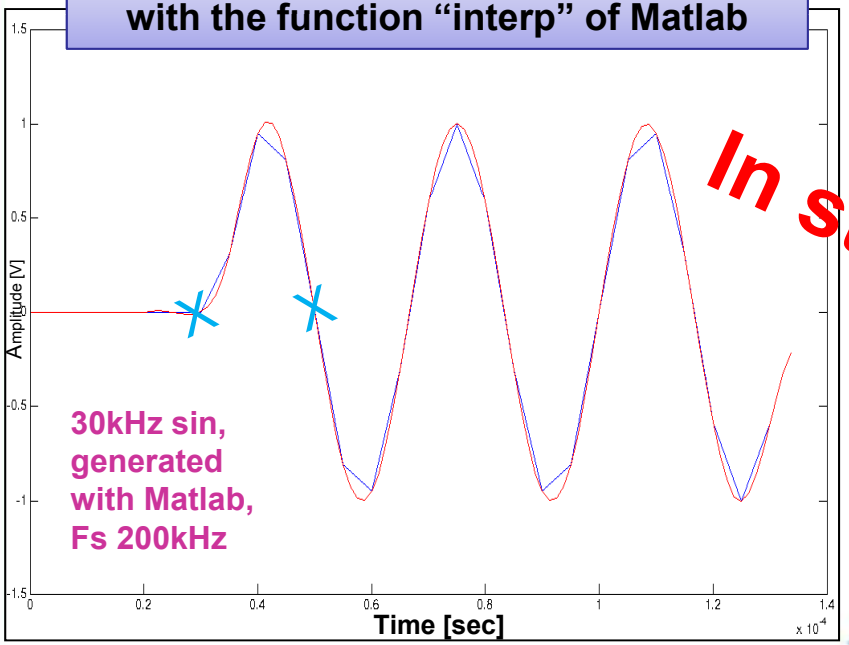
Zoom of the correlation peak



Study of the behavior of different signals and detection methods: detection time and signal-to-noise ratio

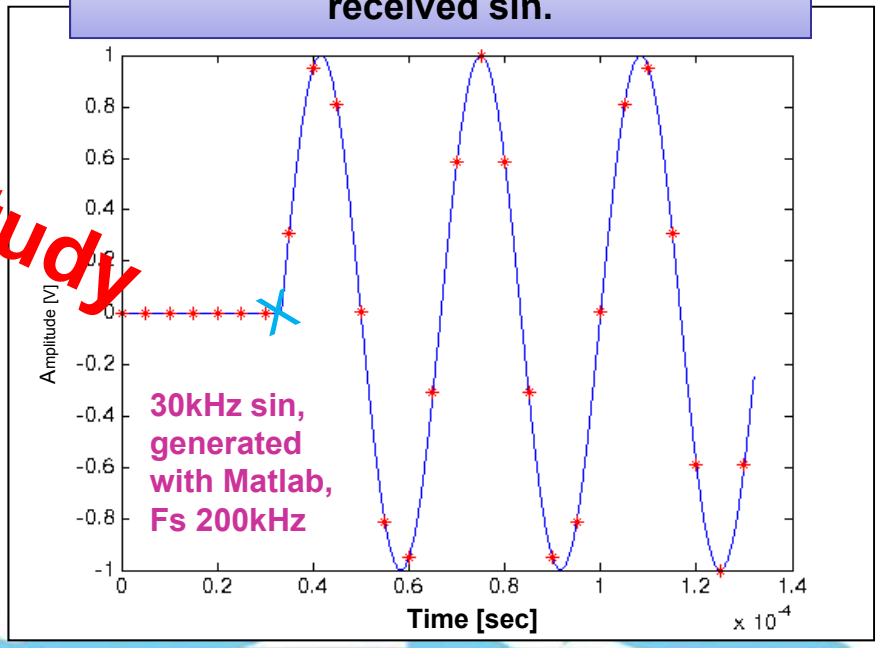
For example, with a sinusoidal signal we are studying two methods:
-Interpolate the received sinusoidal signal → difficulties in determining the exact point of intersection with the zero due to the reconstruction filter of the interpolation method.
- Create an adaptative algorithm to permit changing the value of ***A*** and ***Φ*** in the equation: ***Asin(ωt+Φ)***. To reconstruct the theoretical sin and to overlap it with the received signal to calculate the point of intersection with the zero.

Interpolation of the sinusoidal signal with the function "interp" of Matlab



In study

Overlap of the theoretical sin and the received sin.

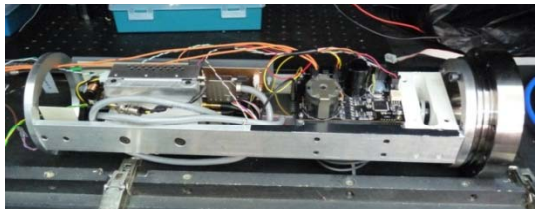


Implementation in the IL11 of ANTARES

➢On June 7th, 2011 the transceiver has been deployed at 2475 m depth. The connection of the Line to the Junction Box will be made when the ROV will be available and afterwards the transceiver will be tested in real conditions.

Anchor of the IL11 of ANTARES

FFR hydrophone with the support and the titanium laser container.



SEB integrated inside of the titanium vessel of the Laser calibrator.

Conclusions

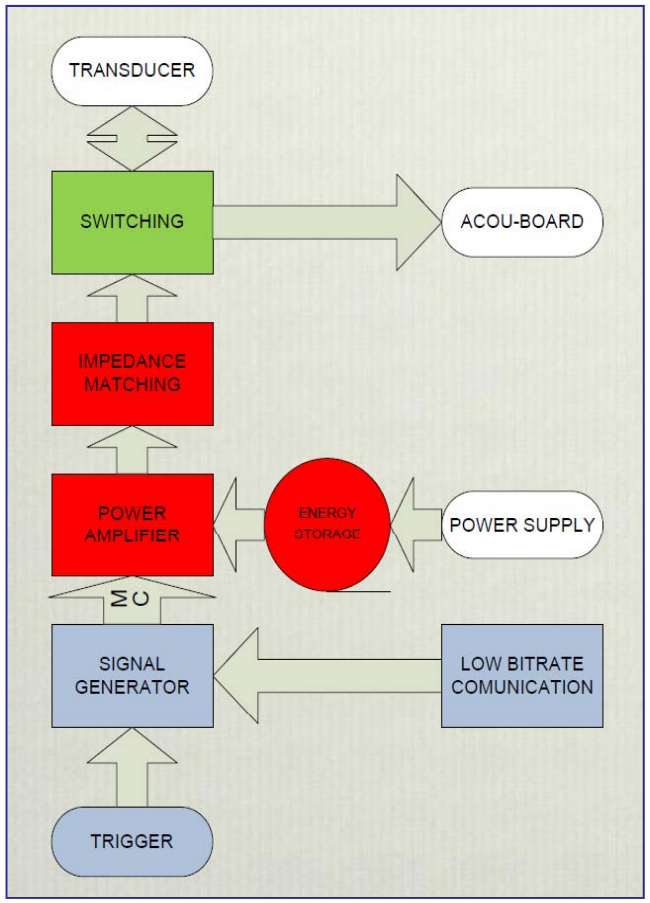
- The system developed at IGIC-UPV has been tested in the laboratory and in the pool accomplishing the requirements imposed by the KM3NeT collaboration.
  - reduced cost, low power consumption , high intensity for emission, low intrinsic noise and arbitrary signals for emission.
  - able to obtain a transmitting power of ~170 dB ref. 1 µPa @ 1m that combined with signal processing techniques will allow it to deal with the large distances involved in a neutrino telescope.
  - The system is very stable and precise in time.
- Our system is considered for implementation in the final configuration of the KM3NeT detector.
- At the present, our system is integrated in Antares IL11 (deployed and waiting for connection) and under integration process in NEMO phase II framework in order to be tested under real conditions.
- At this moment, a new prototype of the SEB improving the output impedance of the power part is being designed and developed in order to be able to feed the transducer more efficiently and reach transmitting power of ~180 dB ref. 1 µPa @ 1m.

KM3NeT
Opens a new window on our universe

Thanks for your attention

The Sound Emission Board: Basic block diagram

- ***According to the specifications required :***
- The switching connects the transducer to the "acou-board" when it is not in use for emission (reception mode).
- The impedance matching reduces the imaginary part of the FFR SX30 impedance and adapts the real part to get enough power with 12V.
- FFR with the maximum power available.
- The signal generator is configured via the low bitrate port. When ready to transmit , the FFR is connected to the power block by a relay. Then, when the generator acquires a trigger, the signal is emitted.



The Sound Emission Board: Impedance matching

- In order to emit with enough power for our requirements with a 12VDC power rail. The main part of the impedance matching is a transformer.
- We requested the design of two transformers for the prototype, the first one with 1:20 turns ratio (480Vpp, open output), and the second one with 1:30 turns ratio (720Vpp, open output).
- The transformers use the P36x22/N48 core from EPCOS.
- The frequency range goes from 5kHz to 60kHz.

The Sound Emission Board: Energy storage

We are using:

SEB with the aluminum electrolytic capacitor:
(Panasonic ECOS1CP223CA)
C=22mF, ESR=35mΩ,V=16V and 20 years of life expectancy with the 105º model.
According Panasonic datasheet.
ESR=Equivalent Serial Resistance

Improvement for new prototype:

New design with 100 tantalum capacitors:
(Vishay TR3E227K016C0100)
C=22mF, ESR=1mΩ, V=16V and 2200 years between fails “MTBF”.
According Vishay FIT CALCULATOR that use calculations defined in MIL-HDBK-217 (revision F)
FIT =52 parts /10^9 hours