Review of Positioning in ANTARES

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Calibration Issues for km3

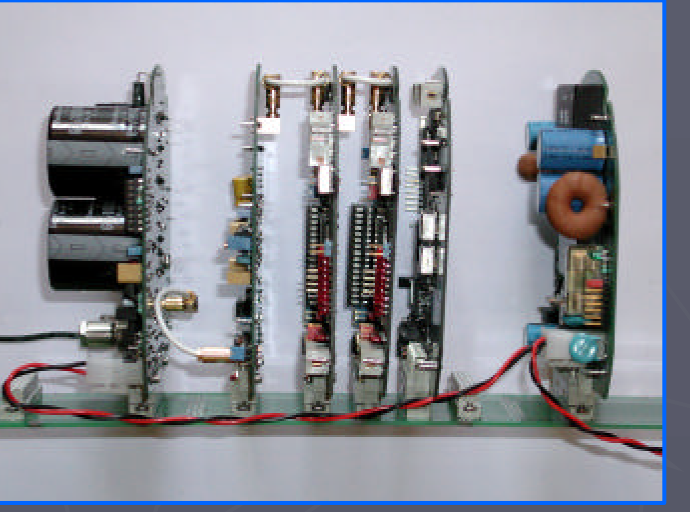
- We need to ask ourselves what needs to be continuously monitored to ensure the scientific performance of the telescope is not compromised
- Already discussed the need for accurate timing information which governs the telescope’s pointing accuracy
- However, for a device comprising photon detectors deployed in a medium where they are not in a fixed position any uncertainty in position is ultimately the same as an uncertainty in timing (1ns = 22cm in water).
- Therefore we need to closely monitor the positions of the photon detectors.

ANTARES Instrumentation

- ANTARES has a range of equipment deployed to enable the exact position of the optical modules to be determined and continuously monitored
  - High frequency long baseline (LBL) acoustic transponders
  - Hydrophones on detector strings
  - Tiltmeters
  - Compasses
- … plus subsidiary Instrumentation necessary to understand the water properties (which themselves can affect the acoustic measurements
  - CTD (current, temperature, depth)
  - Velocity of sound profiler

High frequency LBL system

- Positioning is determined using acoustic triangulation between transducers and hydrophones on the lines
- Works in 40kHz to 60kHz frequency interval
- 5 hydrophones per line, greater density towards top of line (where greater deflections expected) 1 transmitter/receiver per line at the BSS (line bottom)
- Use time of travel for triangulation to give a 3D position
- NB, hydrophones can be considered as fixed points on timescales of 1 minute or so



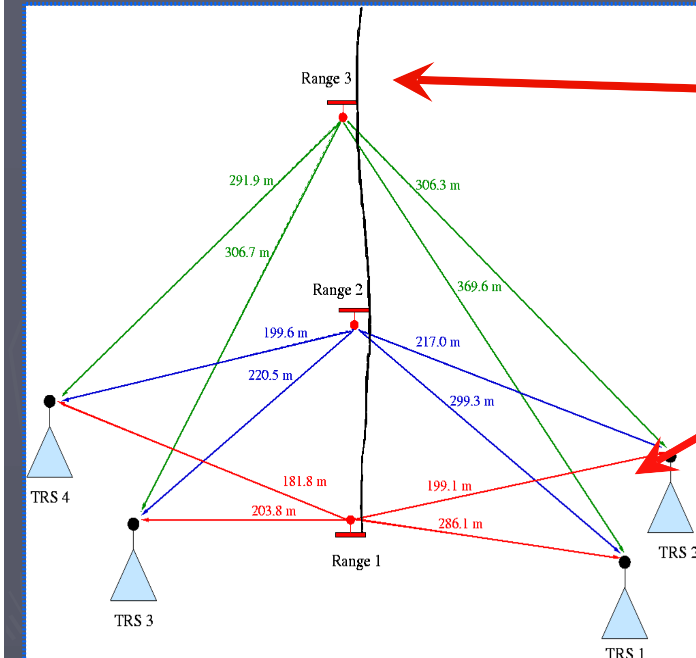
HF LBL system

- RxTx module
  - a transducer (emitting and receiving hydrophone) placed at the top of a pole on the BSS, 6 electronic boards included in the SCM and an electrical link cable.
    - configuration of the emitted acoustic signal (frequency, amplitude, duration)
    - generation of the acoustic pulse
    - configuration of the acoustic detection parameters (frequency, analogue and digital gains, detection threshold, active time window)
    - detection of the acoustic pulse
    - recording of the time-stamp at emission and reception
    - transmission of the time-stamp and the detected acoustic signal amplitude to the shore station.

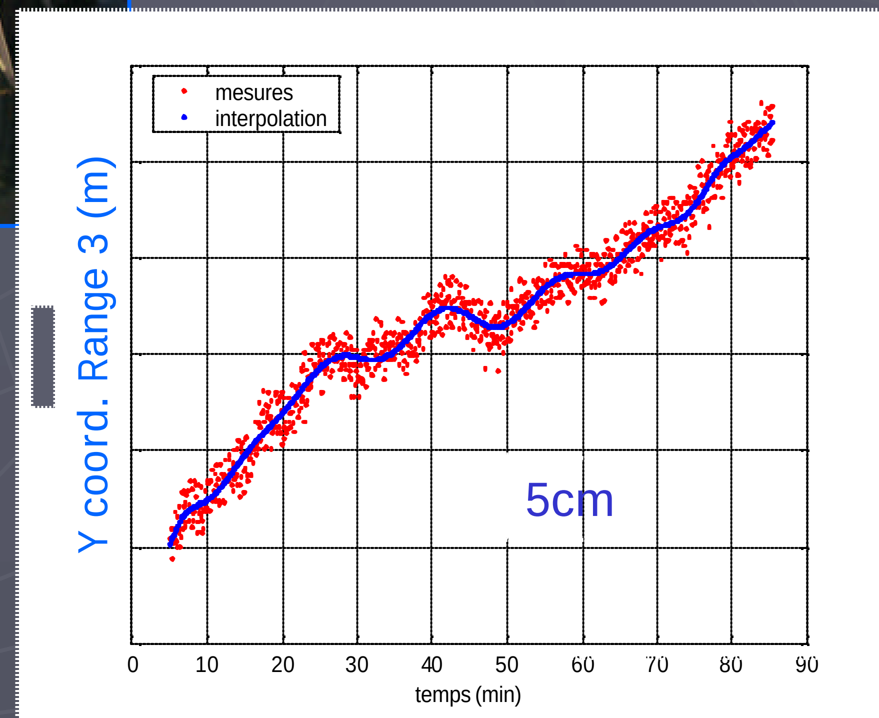
HF LBL system

- Rx module
  - receiving hydrophone placed on the OMF, 3 electronic boards included in the LCM and an electrical link cable.
    - configuration of the acoustic detection parameters (frequency, analogue and digital gains, detection threshold, active time window)
    - detection of the acoustic pulse
    - recording of the time-stamp at reception
    - transmission of the time-stamp and the detected acoustic signal amplitude to the shore station.

HF LBL prototype



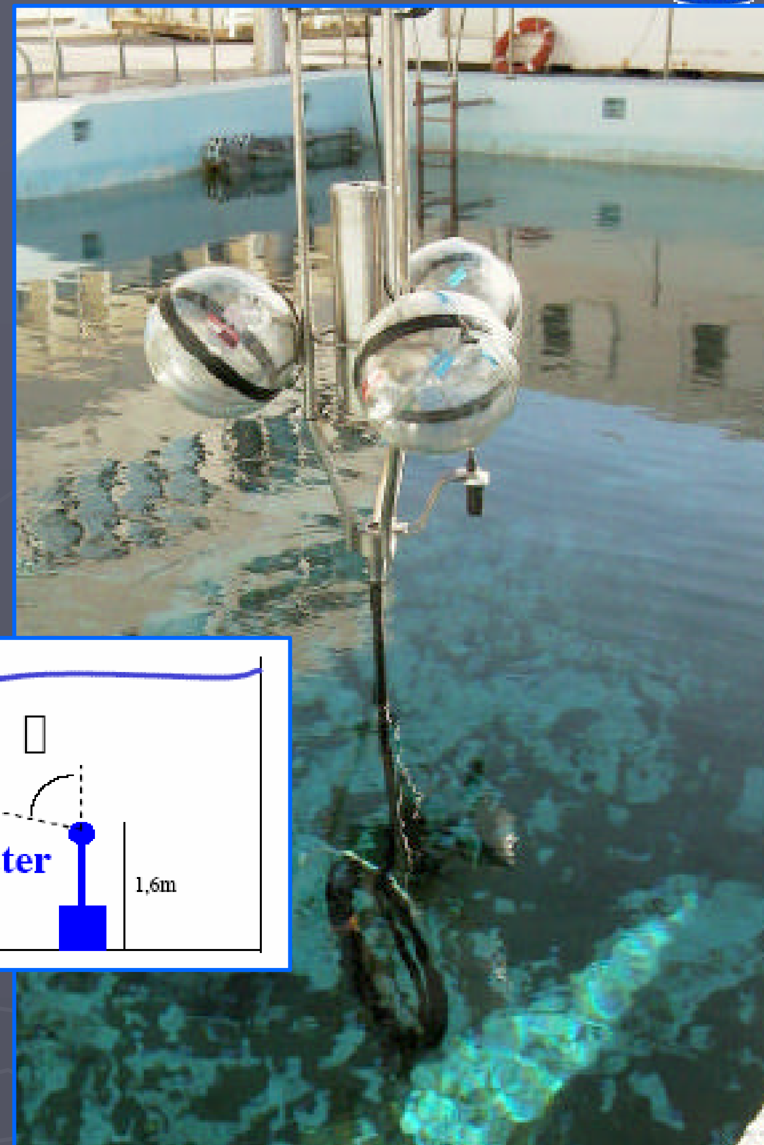
distance	Precision (σ)
Inter-rangemeter	~ 1 cm
Inter-transponder	~ 1 cm
Range-Transponder	≤ 3 cm

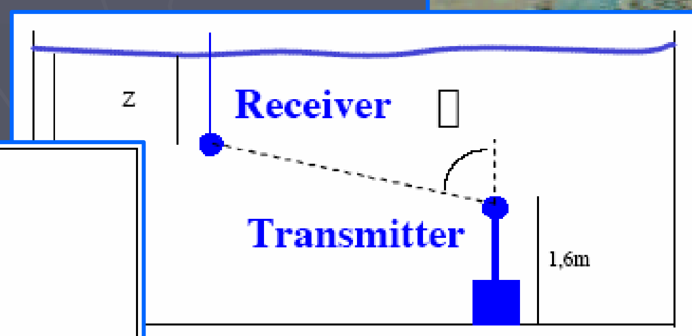


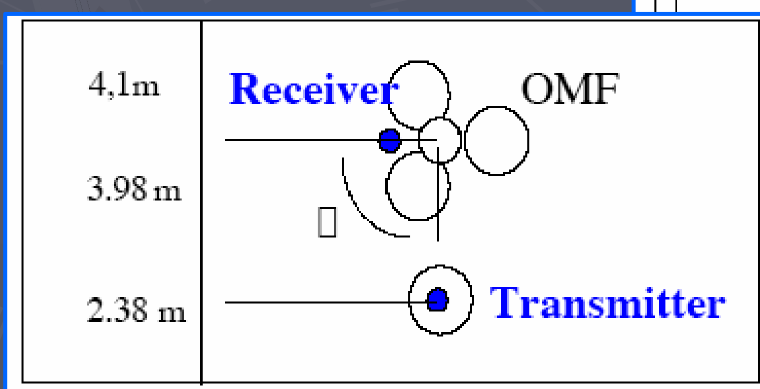
Triangulation ~5 cm final precision

Recent HF LBL work

- Tests in IFREMER pool
  - Studies of timing delays, etc. as a function of transmission frequency, threshold
  - Acoustic jitter as a function of OMF orientation
  - Comparison of acoustic and physical distances

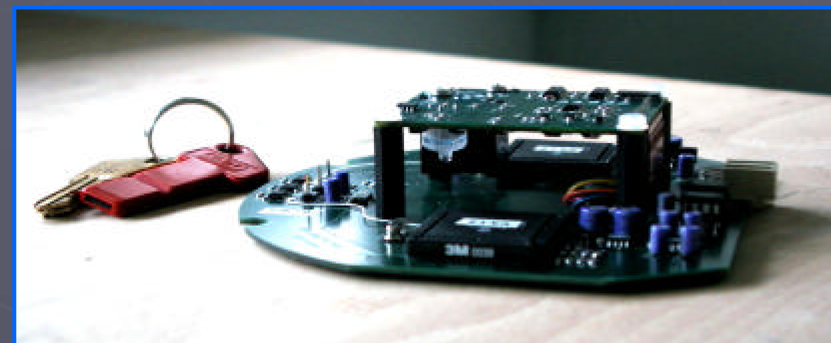




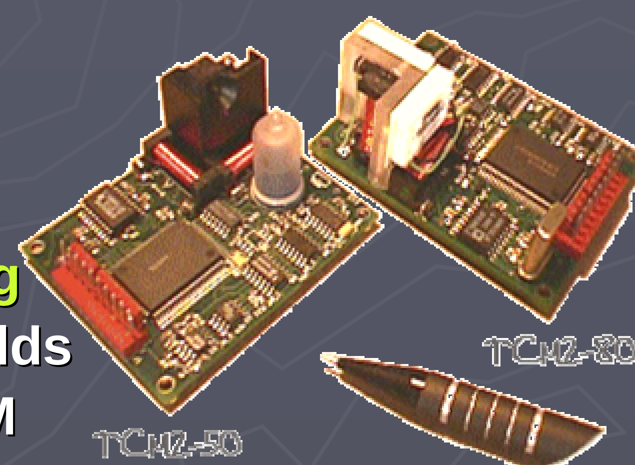


Tiltmeters and Compass

- Integration of Tiltmeter-Compass sensor board in ANTARES electronic containers
  - Local measurement of tilts (roll, pitch) and heading of storeys

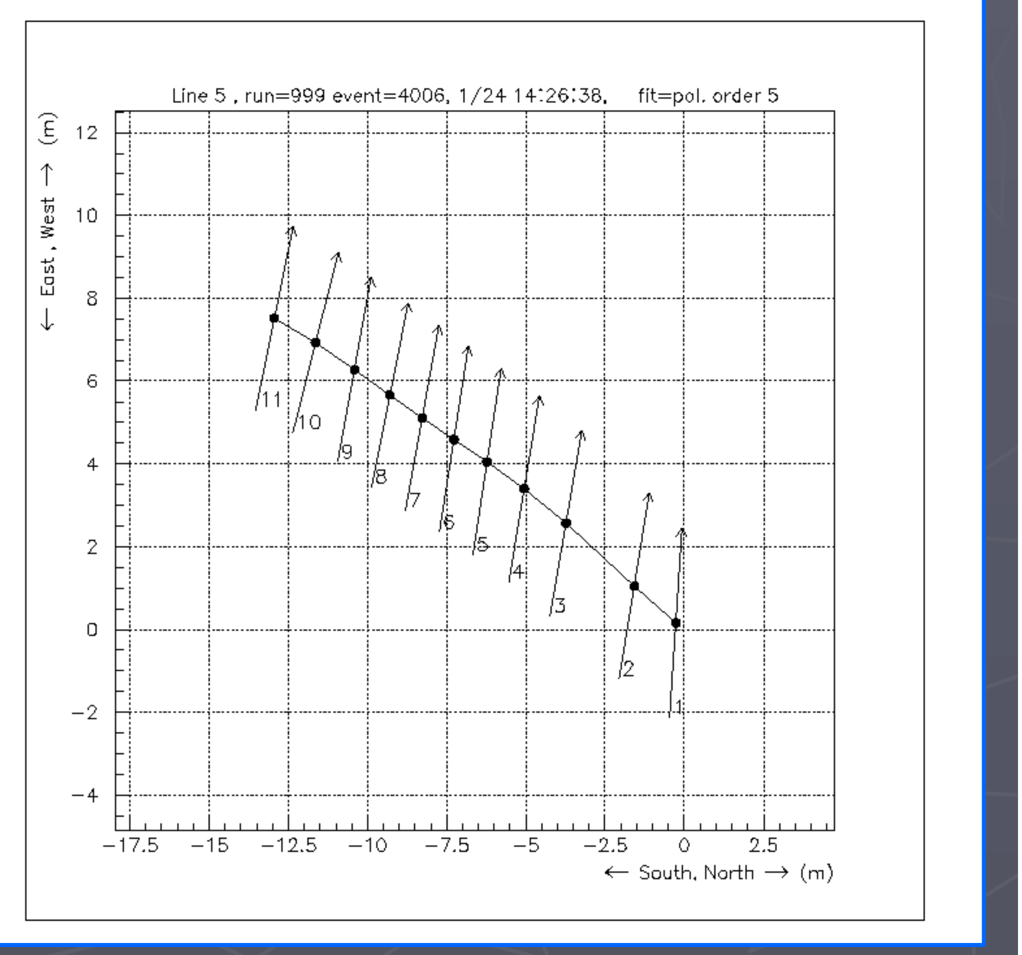


- Selected sensor :
  TCM2 by Navigation Precision Ltd
  - RS232 serial link interface, low power consumption (20 mA)
  - Tilt measurement range : ±20° on 2 axes
  - **Accuracy : 0.2° in tilt, 0.5-1.0° in heading**
  - **Compensation of parasitic magnetic fields**
  - **Performance, linearity checked at CPPM (good agreement with manufacturers spec.)**



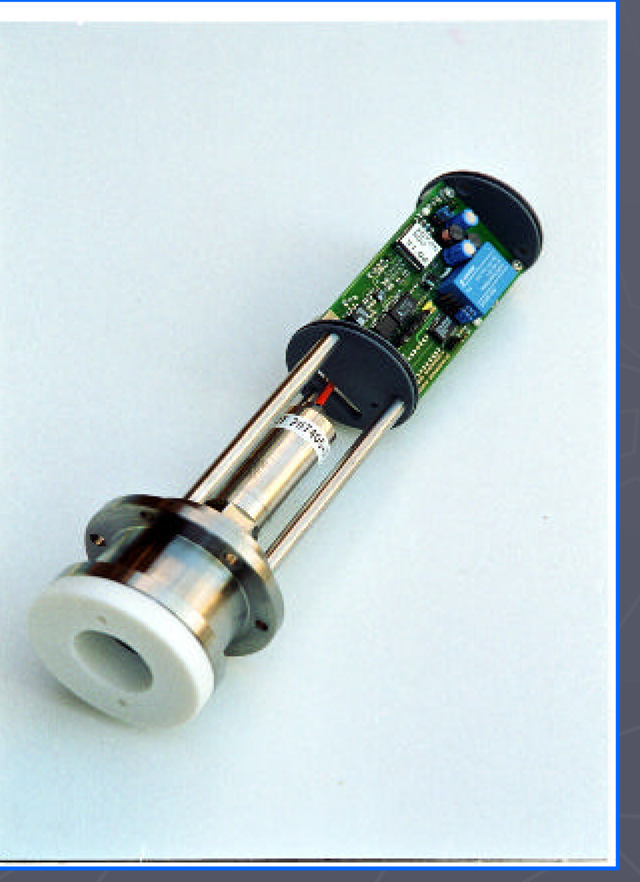
Performance

- Position stability from compass data indicates no twist along the string - headings stable to within 2^0 over one week of operation
- Tilt stability monitored via top and bottom tiltmeters - stable to 0.2^0 over a one week period
- Reconstructed line shape from combined tiltmeter and compass data show a straight string inclined at 2.5^0 to the vertical



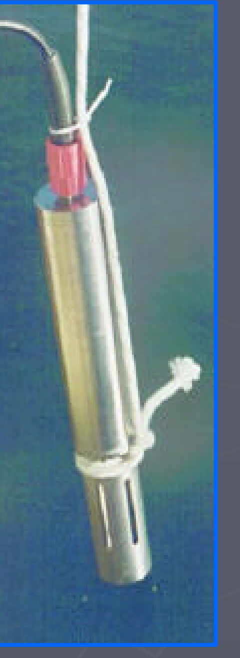
Pressure sensor

- Installed on each ANTARES Line anchor to determine its depth (relative altitudes)
- Device developed and made by GENISEA :
  - Titanium container
  - 48 VDC external power, RS232 serial link
  - **Pressure sensor DRUCK piezo-electric range 0-300 bars**
  - **Precise calibration at IFREMER-Brest between 190 and 260 bars Precision obtained : < 0.01 bars**



Determination of sound velocity

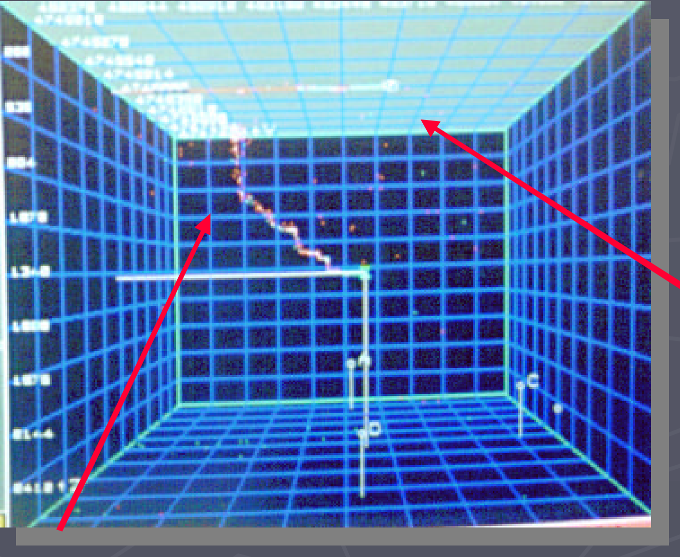
- Essential measurement for conversion Propagation times ↔ Distances
  - **Obtained by GENISEA sound velocimeters distributed about the detector**
    - **Give reference local measurements**
    - Titanium container, 48 VDC external power, RS232 serial link
    - **Calibration at IFREMER-Brest in regulated thermal bath : precision ~ 5 cm/s**



- Sound velocity in water is function of Temperature, Salinity, Pressure
  - Sound velocity profile taking into account of pressure variations
    with hydrophones altitudes
  - Possible variations of Temperature + Salinity controlled with CTD made by GENISEA :
    - Titanium container, 48 VDC external power, RS232 serial link
    - Conductivity-Temperature probe by FSI :
      precision T ~ 0.01°, S ~ 0.01 mS/cm

Acoustic navigation system

- Acoustic Long BaseLine Low Frequency (8-16 kHz) system allowing a dialogue between the surface ship and beacons fixed on each line anchor (releases)
- System mandatory for :
  - Follow up and control of descent and final positioning of the lines
  - Follow up and navigation of submarine vehicle during connection operations
  - Measurement of detector geodetic position by acoustic + GPS
- Required precision on beacon position by acoustic triangulation :
  - **Few metres in real time**
  - **1 metre after statistical calibration**



Conclusion

- Acoustic positioning to a few cms is possible using
  - Relatively cheap (typically a few k€) off-the shelf products such as hydrophones, tiltmeters, etc.
  - In order to fully exploit the system some additional instrumentation is needed (CTD, pressure, velocimeter, etc.)
  - Such a system could scale well to km3
    - Acoustic signal would not degrade over the greater distances between strings
    - A simple, cost-effective solution