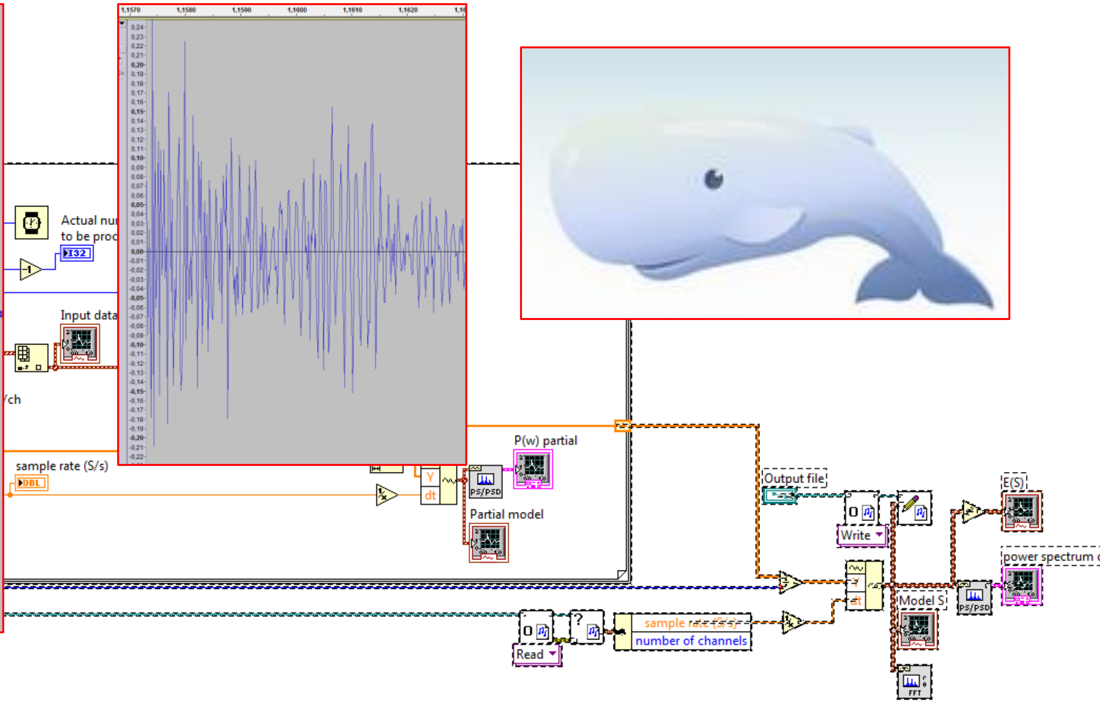
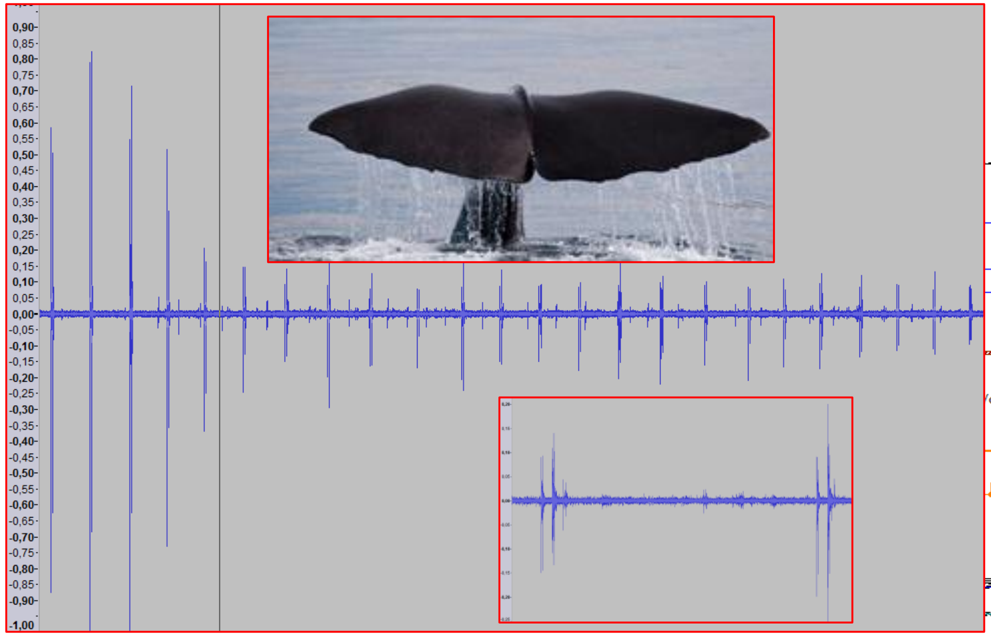


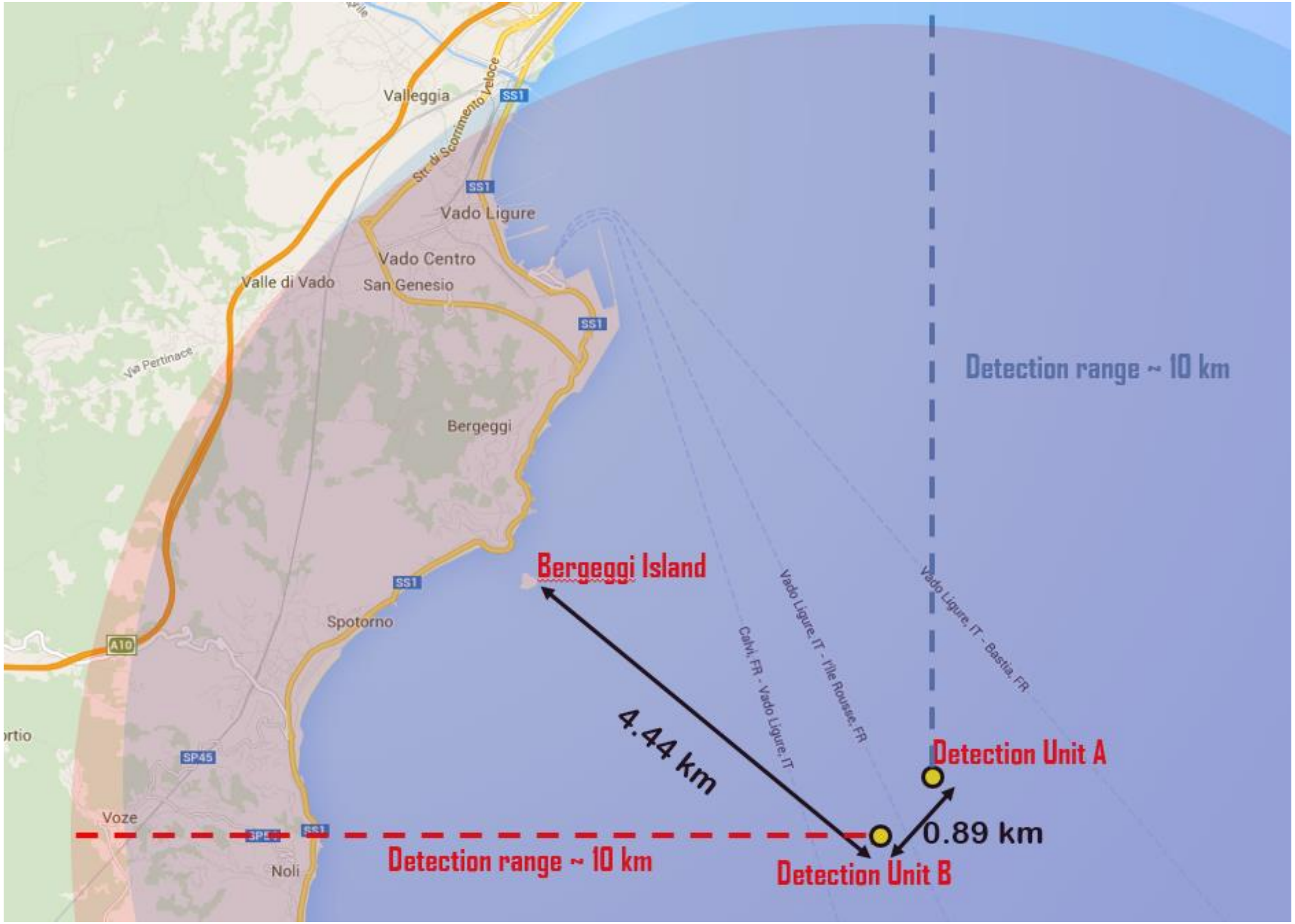


First steps into WhaleSafe project
Design of a detector for sperm whale clicks in acoustic signals

Alessi J [2], Bianchi C.N. [2], Bozzini G. [1], Brunoldi M. [1], Cappanera V. [3], Casale A. [1], Cavalleri O. [1], Corvisiero P. [1], Fanciulli G. [3], Falzoi N. [1], Grosso D. [1], Magnoli N. [1], Mandich H [2] ,Melchiorre C. [4] , Morri C. [2], Pesce A. [1], Povero P. [2], Stasi N. [5], Taiuti M. [1], Viano G. [4], Wurtz M. [2]

1. University of Genoa (Italy), DIFI
2. University of Genoa (Italy), DISTAV
3. Portofino MPA, Genoa (Italy)
4. Softeco Sismat, Genoa (Italy)
5. Capitaneria di porto Genova (Italy)

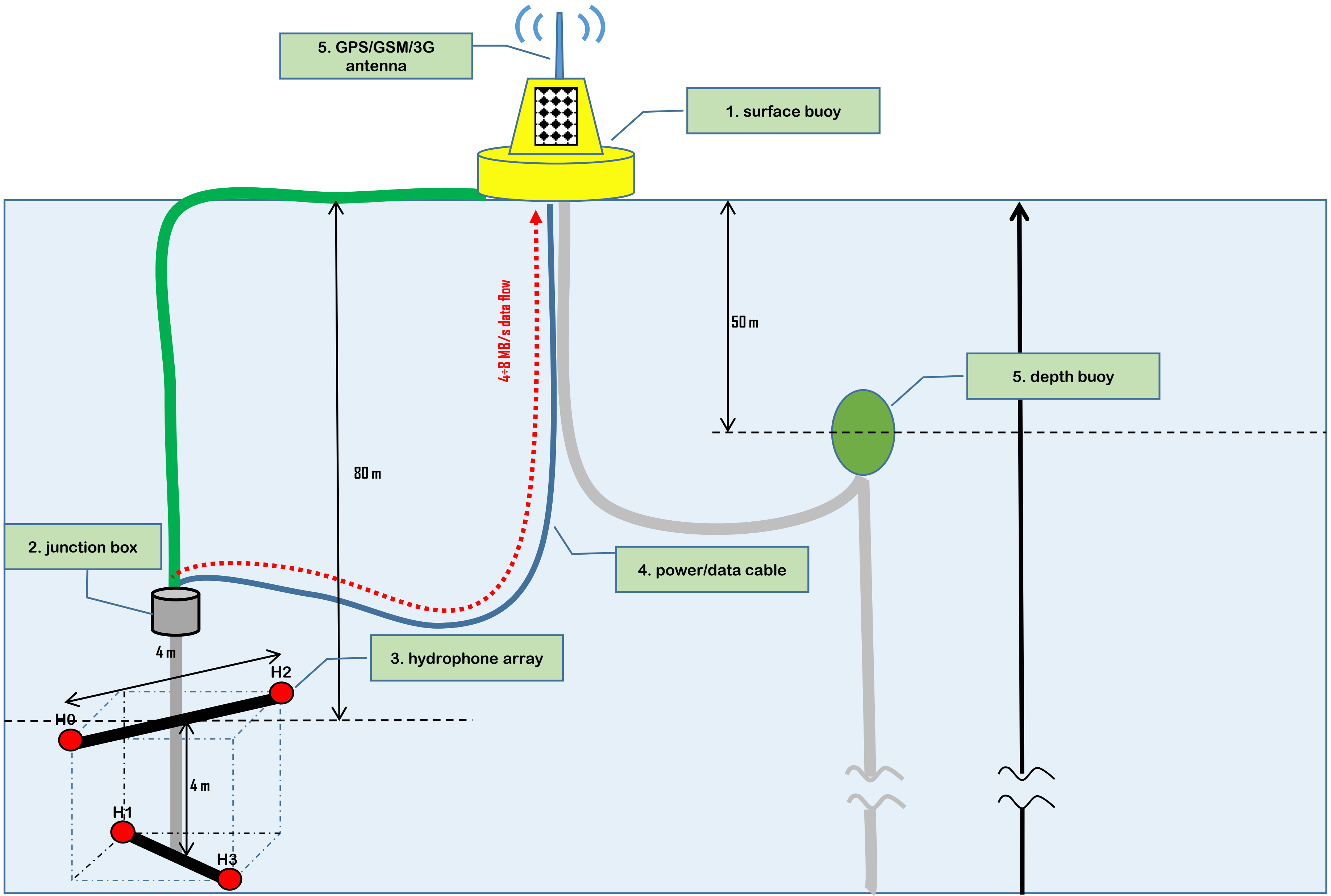
WhaleSafe project: aim, location, structure



- WhaleSafe project aim is to detect and track sperm whale to prevent collisions with boats and ships by issuing warning messages in real time to the involved actors
- Two buoys with four hydrophones onboard will be installed in Savona area and the collected data will be used to extrapolate the point where the whale should emerge
- It is required a detector with high sensitivity and specificity to obtain a high resolution of the track

This work will discuss a design of the detector based on what learnt from the analysis of available data

Structure of the surface buoy



Hardware on surface buoy and junction box

1. surface buoy (content)

- onboard PC (NI9081 cRIO)
  + I/O modules

- gps/gsm/3g device (SEA 9721)

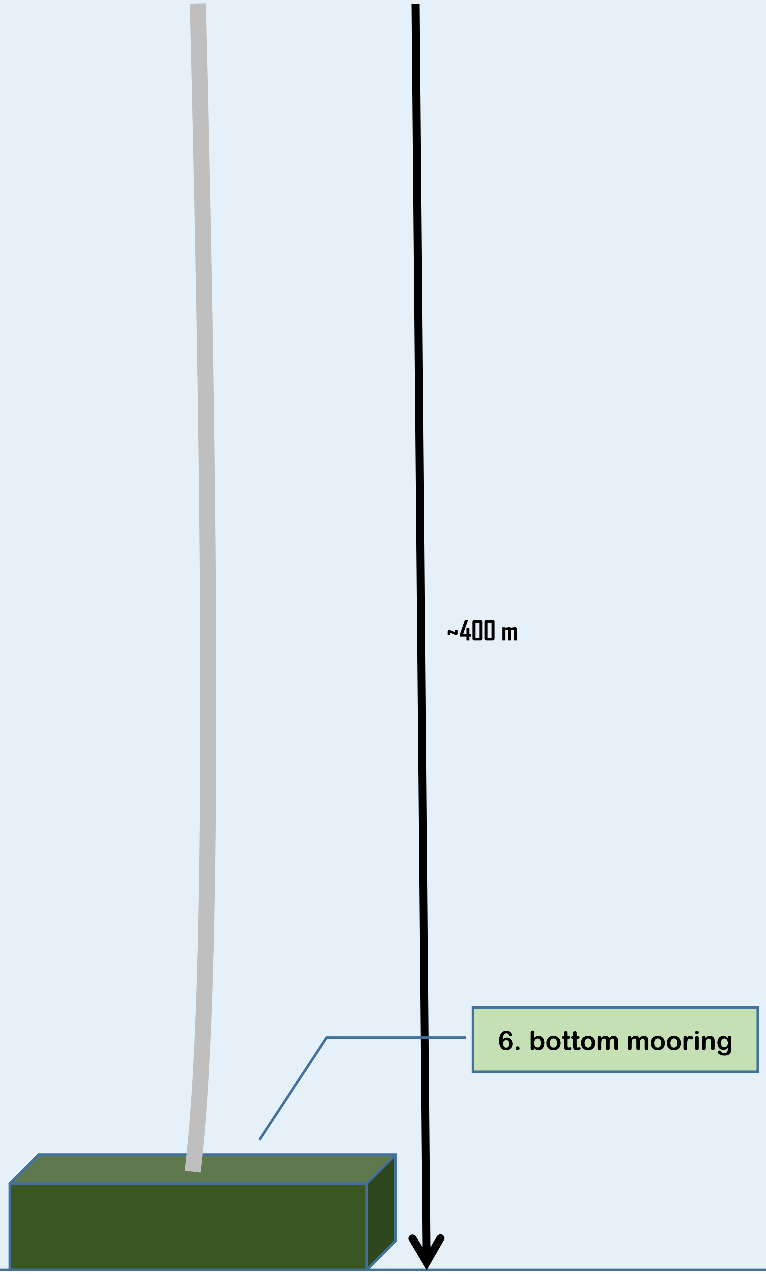
2. junction box (content)

- 4 ch 1MS/s 16bit A/D converter
  (NI9223 ADC)

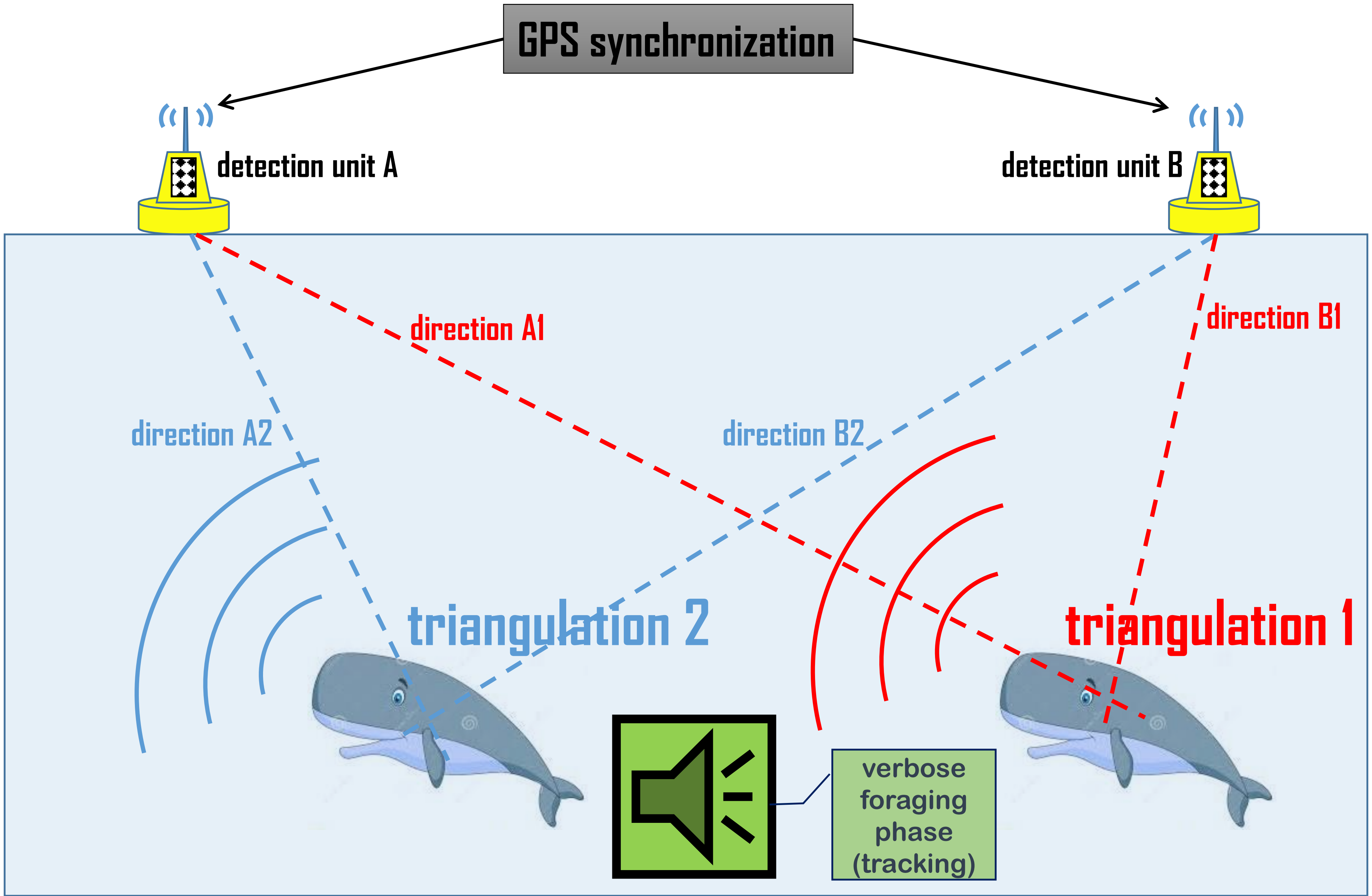
- 8 slot ethernetRIO expansion chassis
  (NI9149 ADC)

- 1° accuracy tilt/compass module

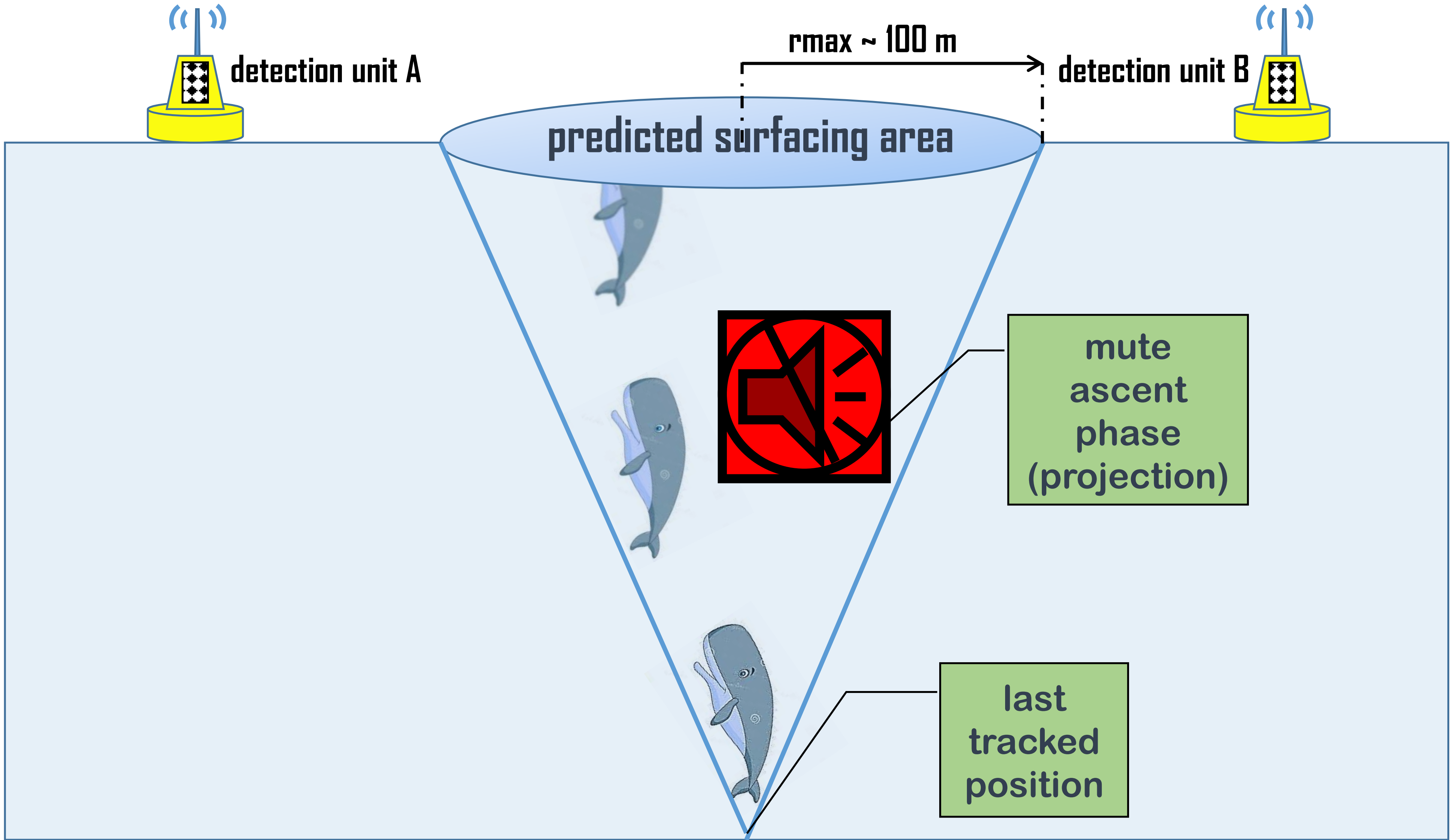
- RS232 input module (NI9870)



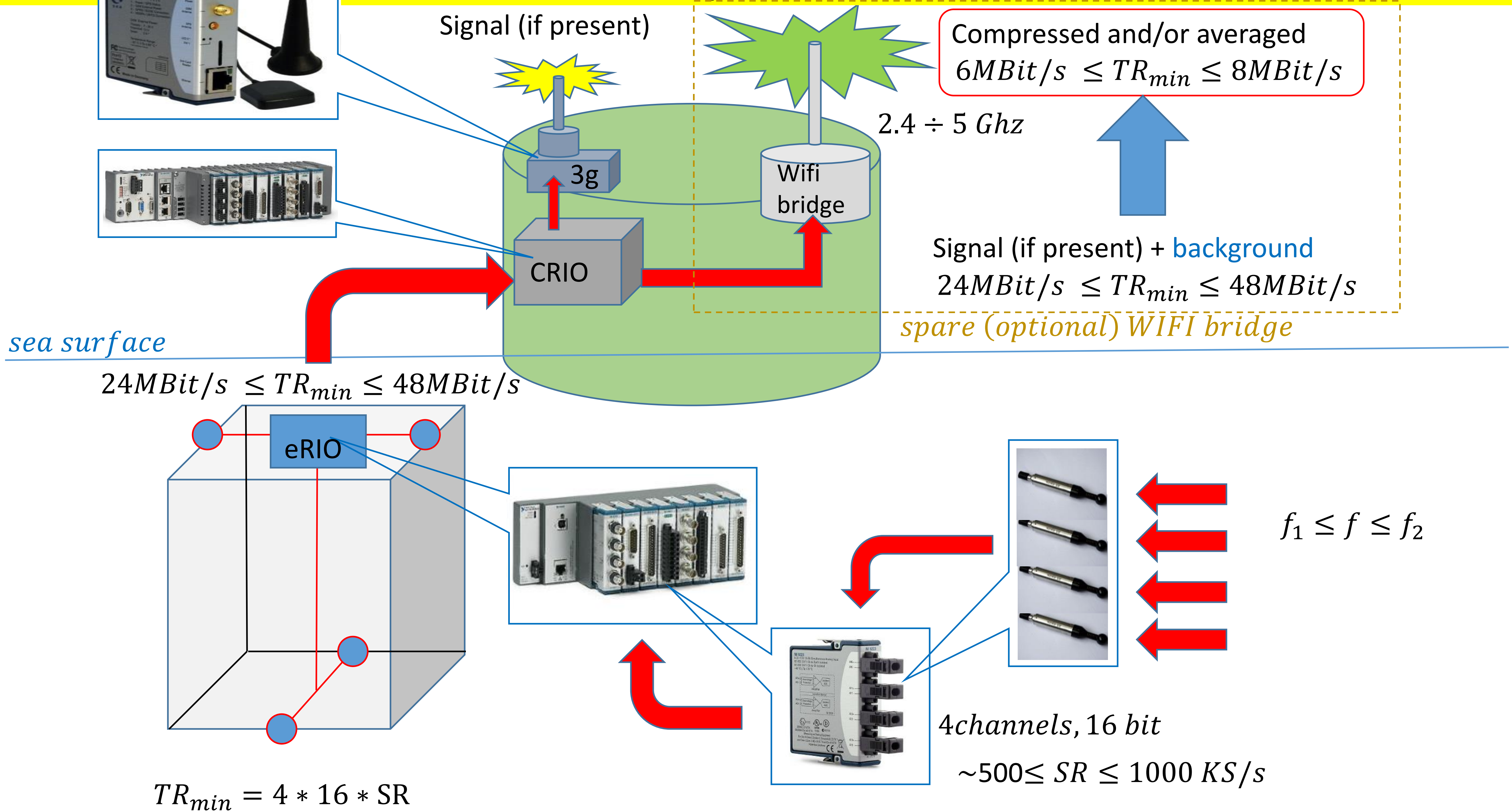
Whale tracking



Predicted surfacing area



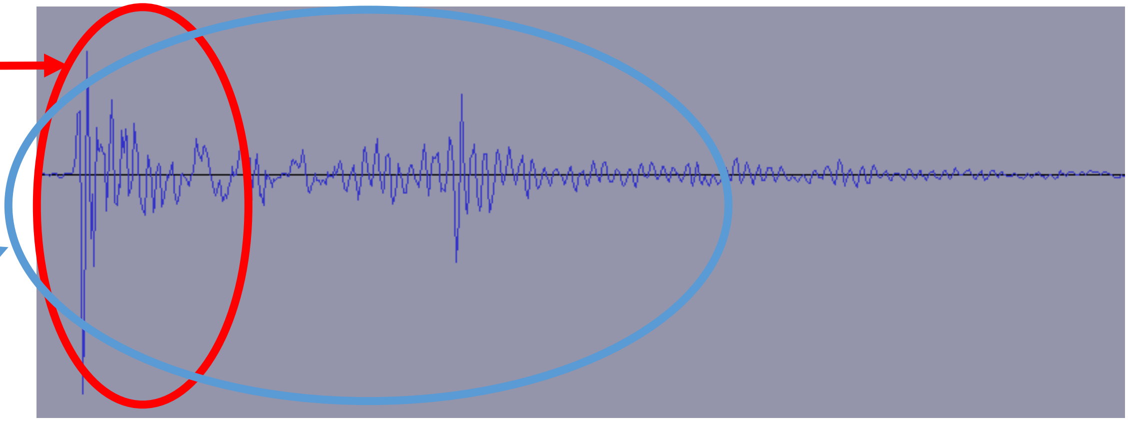
Acquisition



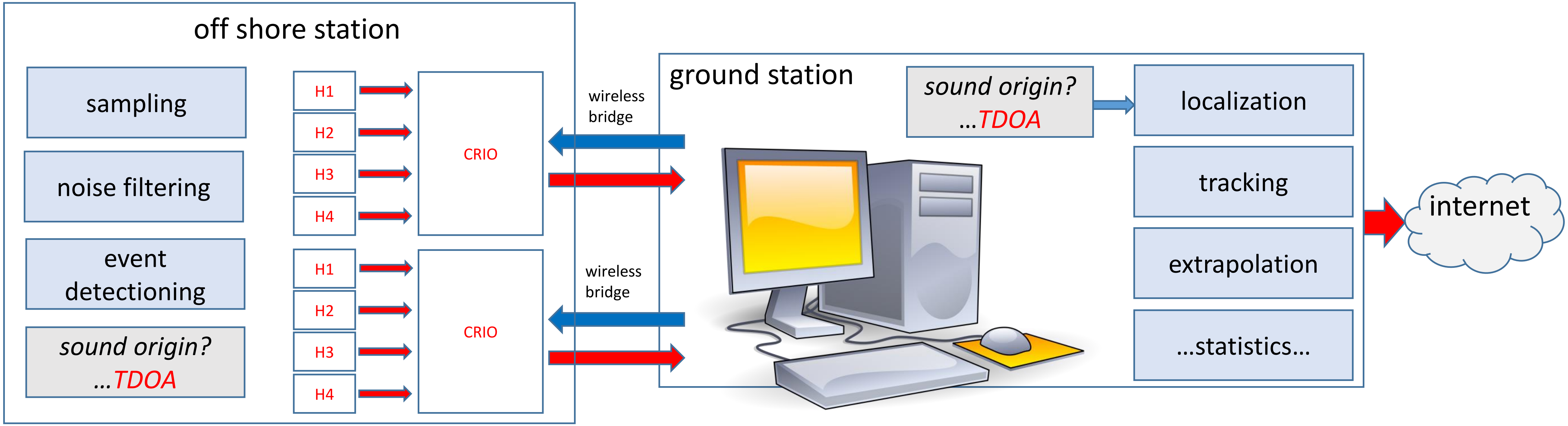
Transmission of events

- An *event* is a *click*
- A ***real event*** is a click detected by all 4 hydrophones connected to a buoy

NB clicks have "complex" structure
=> a more accurate analysis is required



The information we need is the time delay in peak from real events in 4 hydrophones



Detection of events

A good **detector** should:

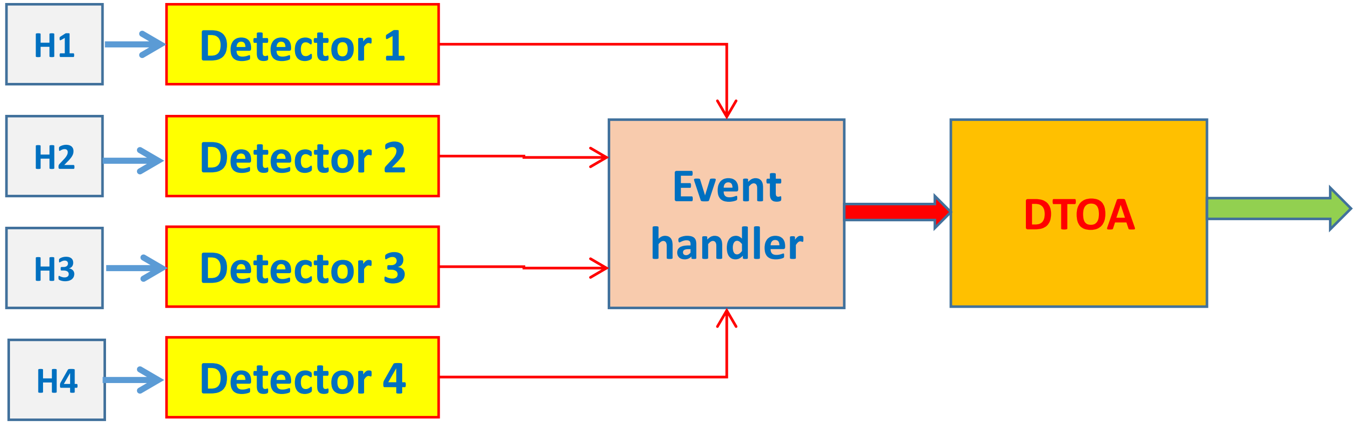
- Have **high sensitivity**
- Have **high specificity**
- Depend upon a **minimum number of external parameters**
- Work **RT** (real time) even on "limited" hardware

The detector should return:

› **a probability of event** and

› **a event position in time**

If 4 events are detected the **event handler** should send data to **DTOA** which compute **angles from peak delays**



What we learnt about «events»

- File sampled in the target area
- Whales relatively close to the detection unit (about 30|50m)
- Time resolution high enough to give information (up to 96KS/s, 48Kb/s)

We performed time domain analysis, spectral analysis and a first revision of literature we found:

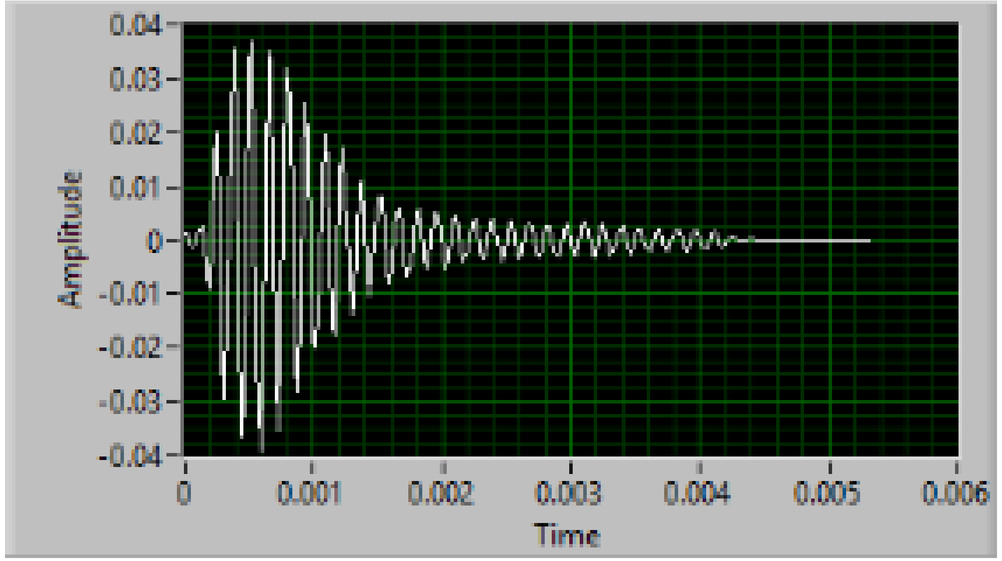
› clicks are centered at about 7Khz

› click shows at least 2 peaks
(known in literature as P0 and P1)

› P0 is shorter than P1

› Whole click is at maximum 0.01s

P0

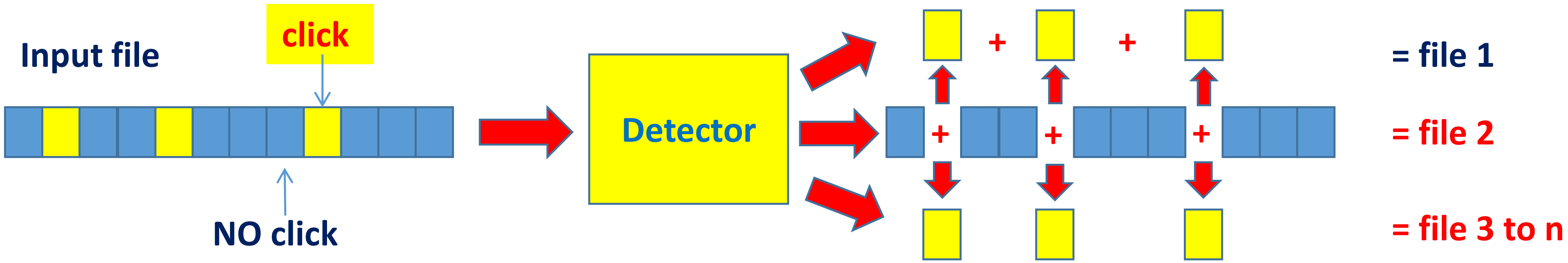


First step: to obtain a model from clicks we need automatic click extraction from data

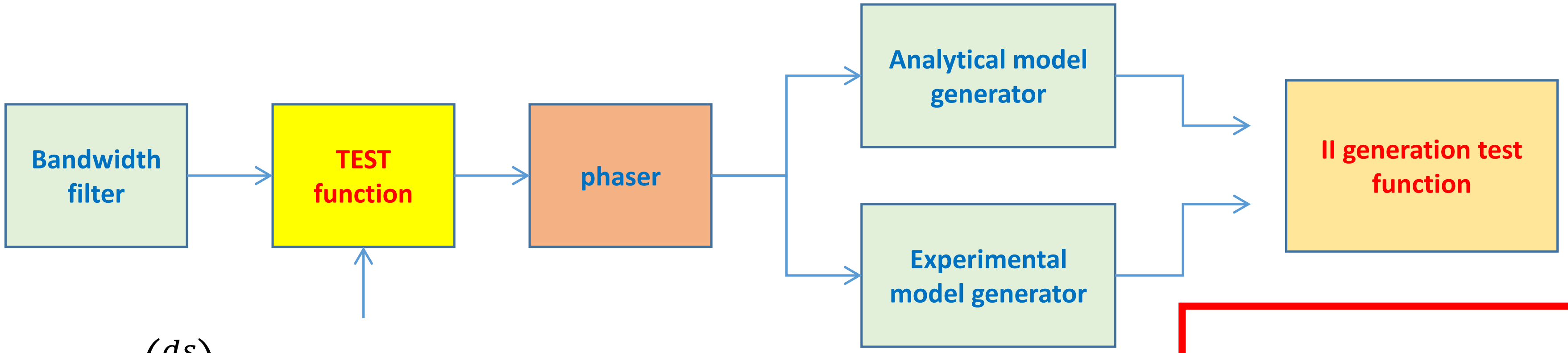
To test detector function candidates (we have a few, from literature too) we developed a procedure to allow us to compare candidates.

When a file with samples corresponding to a single channel is processed, the following files are generated from segments of 0.02s

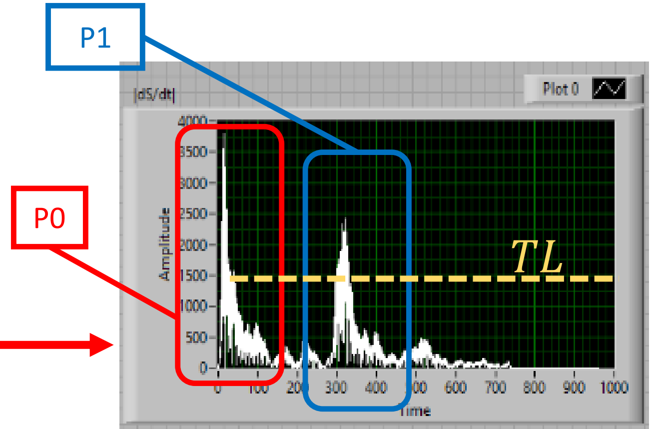
- file 1 has **only samples** (should contain **no background**)
- **file 2** has **no samples** (should contain **only background**)
- **file 3 to n** should contain **a single sample**

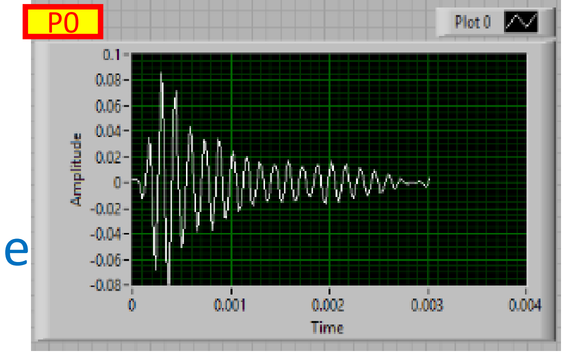


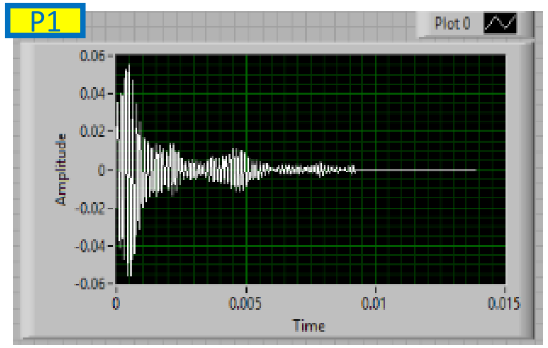
Obtaining a model from data
The elaboration chain and first detector function



$$\text{abs}\left(\frac{ds}{dt}\right) < TL(background)$$







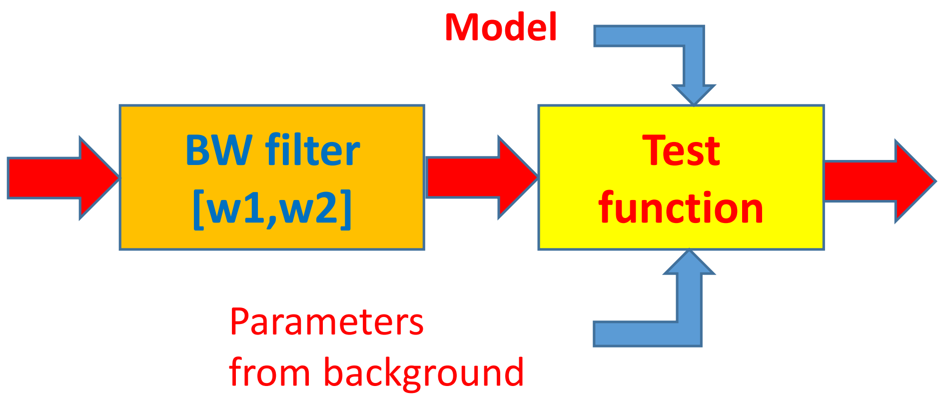
1. Raw data pass through a symmetric BW filter centered in f_0
2. The test function is applied to a vector of N samples (length $\Delta T = 0.02s$)
   (long enough to allow no more than one click)
   a file containing no clicks, one containing only clicks and one for ever click are gene
3. The window is clipped at click begin from the *phaser* (all signal must be aligned)
4. click t_0(P0) for P0 and t_0(P1) are evaluated. This is useful to measure
   - inter-click $t_0(P0_{i+1})$ - $t_0(P0_i)$ and
   - IP (which is related to the dimension of the whale): IP= t_0(P1) - t_0(P0)
5. An experimental model of P0 and P1 and an analytical model are generated
   they will be used to refine more advanced (specific) detectors
   (II generation test function) based on pattern matching technique

The «distance» between a sample and a model: second generation **real time detector** function

The central part of the detector is the test function

The test function should:

- be adaptative (change sensitivity accourding to the background)
- Match against a template (a model from statistics on samples or a theoretical model)
- depend upon the minimum number of parameters
- return true or false
  or a probability to compare against a given trigger value
  (which is essentially the same)
- be «fast» (must run RT off shore)
- be «simple» (must run RT off shore)
- possibly have **metric properties**



First candidate for the second generation test function for real time detection

We decided to give a try to this test function (normalized cross-correlation):

$$A = \frac{1}{n}\sum_i \left(\frac{x_i - \bar{x}}{\sigma_x}\right)\left(\frac{s_i - \bar{s}}{\sigma_s}\right)$$

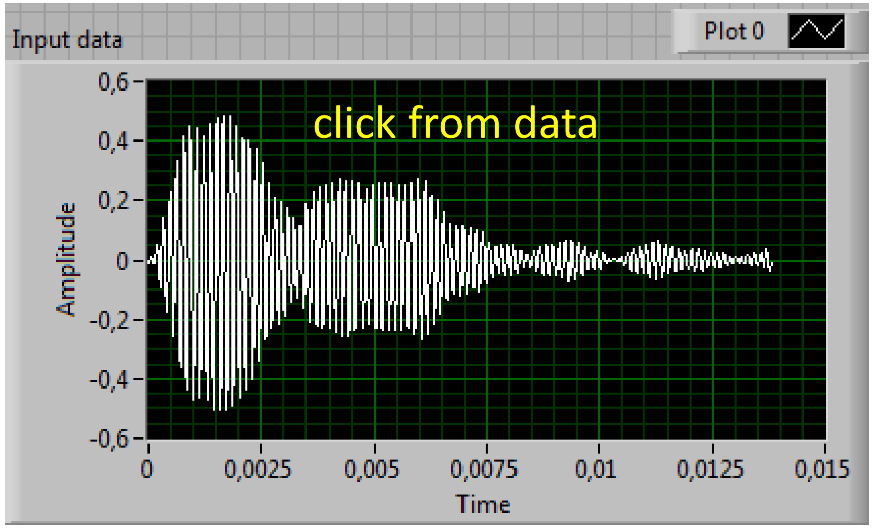
This is a pattern match function, it requires the pattern (a model of the click) we generated from samples

It has the following advantages:

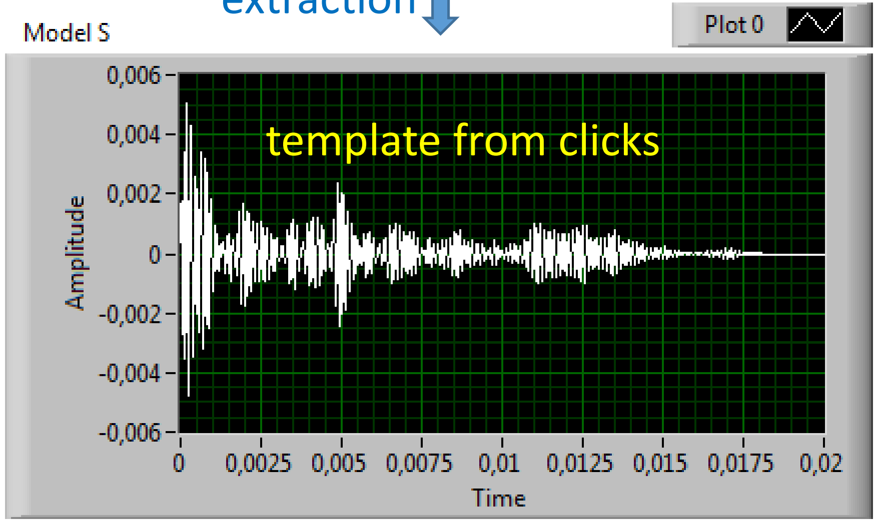
- $\tau_{delay} = arg_t \max((x * s)(t))$
- Compensate scales in both signal and sample
- Remove offset
- Return a number
- It is relatively simple/fast
  (we need RT and we have not too much computational power onboard)
- The 2° term may be precalculated

Conclusions, future work

- We have|may refine information about the click structure
- Simple model of the source is (dynamically) generated from raw data
- We have developed a prototype capable of extract clicks from an audio track in RT
- To select the best test function we built a tool to compare results from different test functions estimating sensitivity and specificity



extraction



test function

detection

theoretical model

Next steps:

- Calibrate hydrophones
- Collect data on site
- An accurate analysis of data from background and whales
- Refine the theoretical model we are working on
- Select the best test function (taking into account anything must work RT)