PREVIEW OF THE ACOUSTIC LOCALISATION FEATURES IN THE UPCOMING NEW VERSION OF THE ELEKON BATLOGGER

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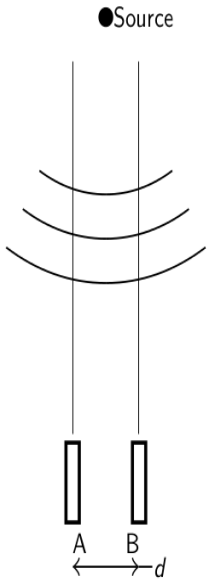
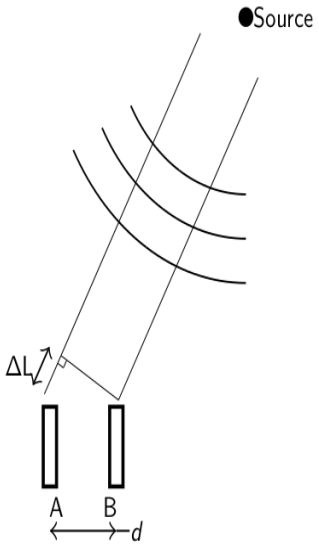
History of the technology

- CryoSat uses interferometric methods to localise radar returns to increase its spatial resolution.
- If you turn CryoSat upside down, put it on the ground instead of in space, and make it work with acoustic ultrasonic signals instead of microwaves, you have a **motion tracking bat detector**.

Geometry of the interferometer





- When the source of the call is directly between the microphones there is no phase shift.
- When The source of the call as off-centre, the change in path length ΔL causes a shift in phase.

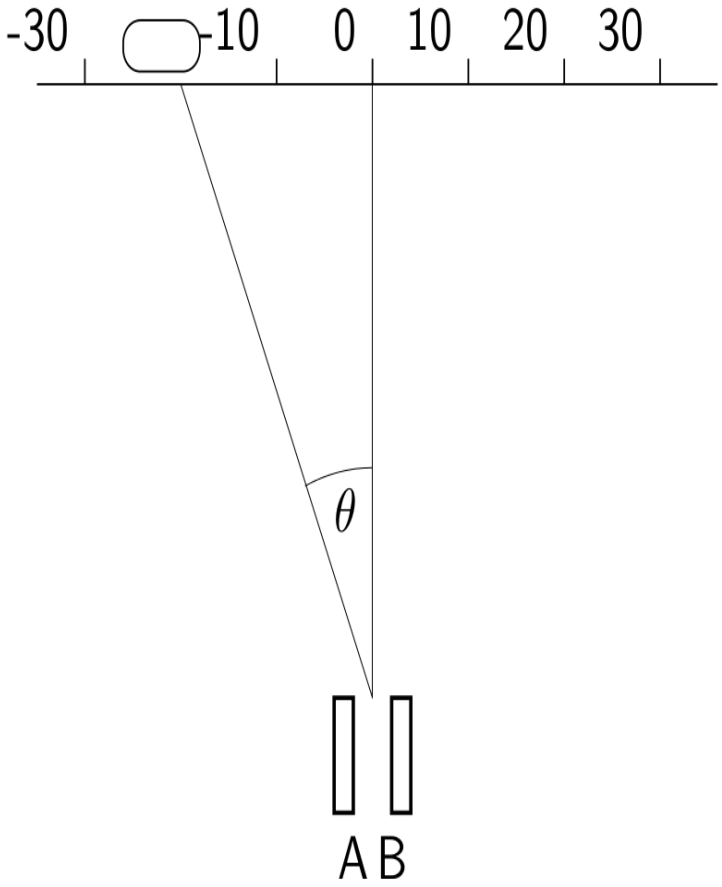
Call angle calculation

- Call angle is calculated from the phase difference ϕ, speed of sound *v*, frequency *f* and microphone separation *d*.

$$\theta = \sin^{-1}\left[\left(\frac{\phi - \phi_{cal}}{2\pi} + n\right)\frac{v}{fd}\right]$$

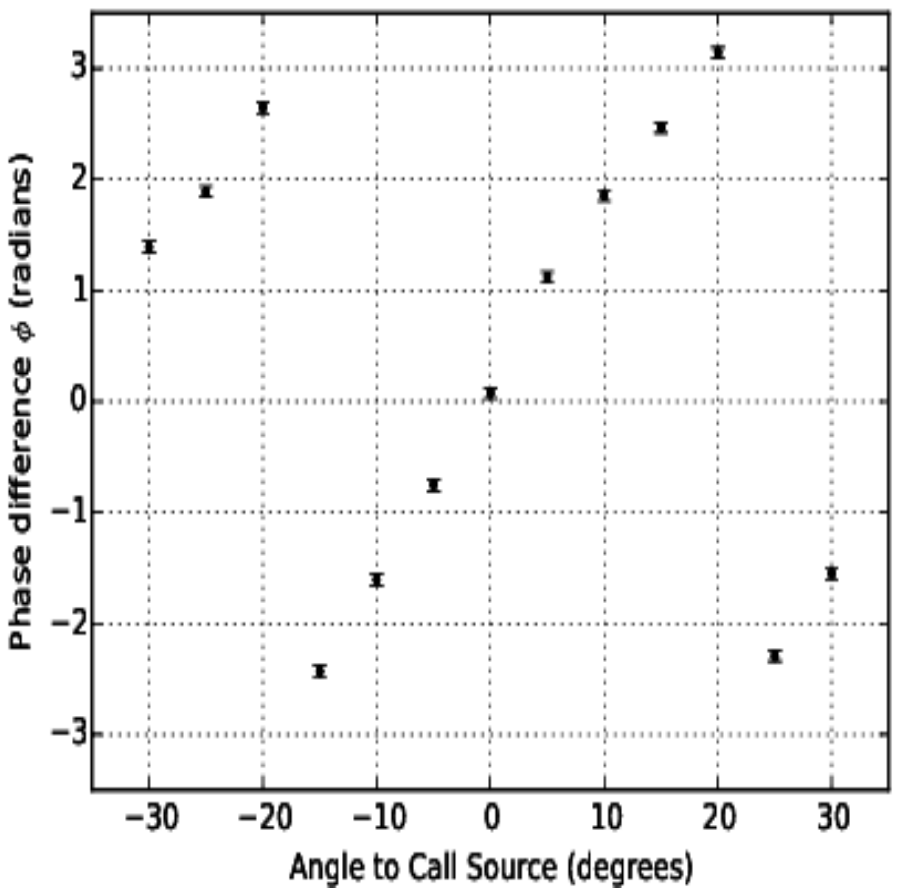
- ϕ_{cal} accounts for timing differences between the two microphones.

Laboratory experiment to test the method



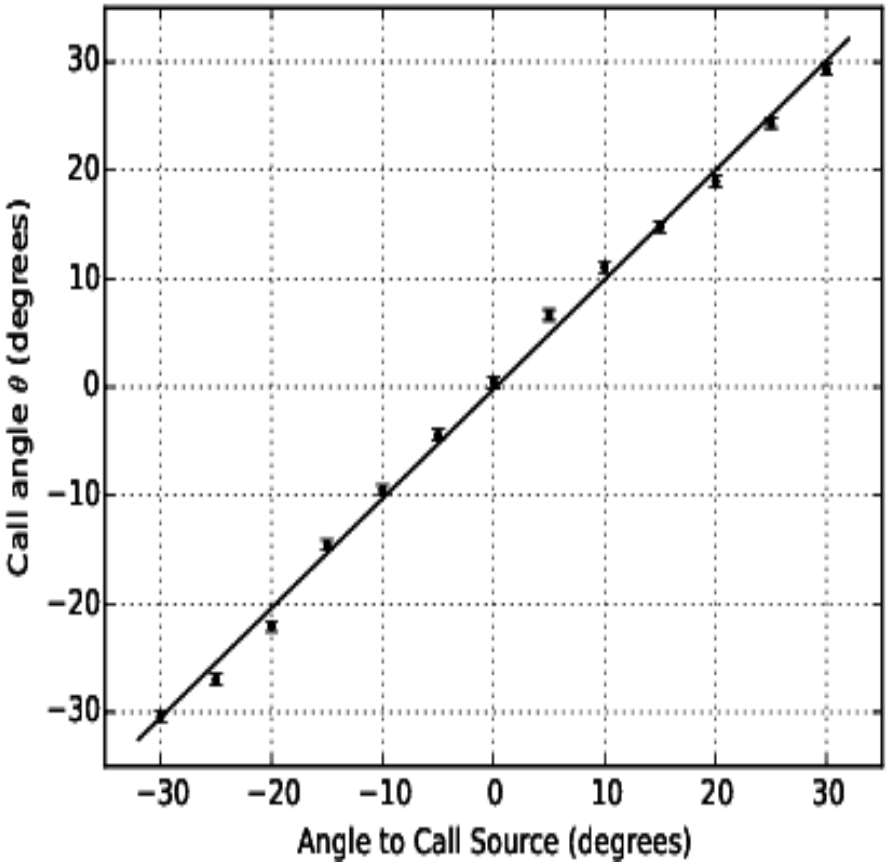
- We measured the phase angle at 13 different positions at equal angles.
- A 40 kHz sinewave source was used as a signal.

Phase difference as a function of call angle



- Phase difference varies with call angle.
- The error bars are small.
- Phase wraps at $\pm$ 25 degrees.

Measured call angle as a function of call angle

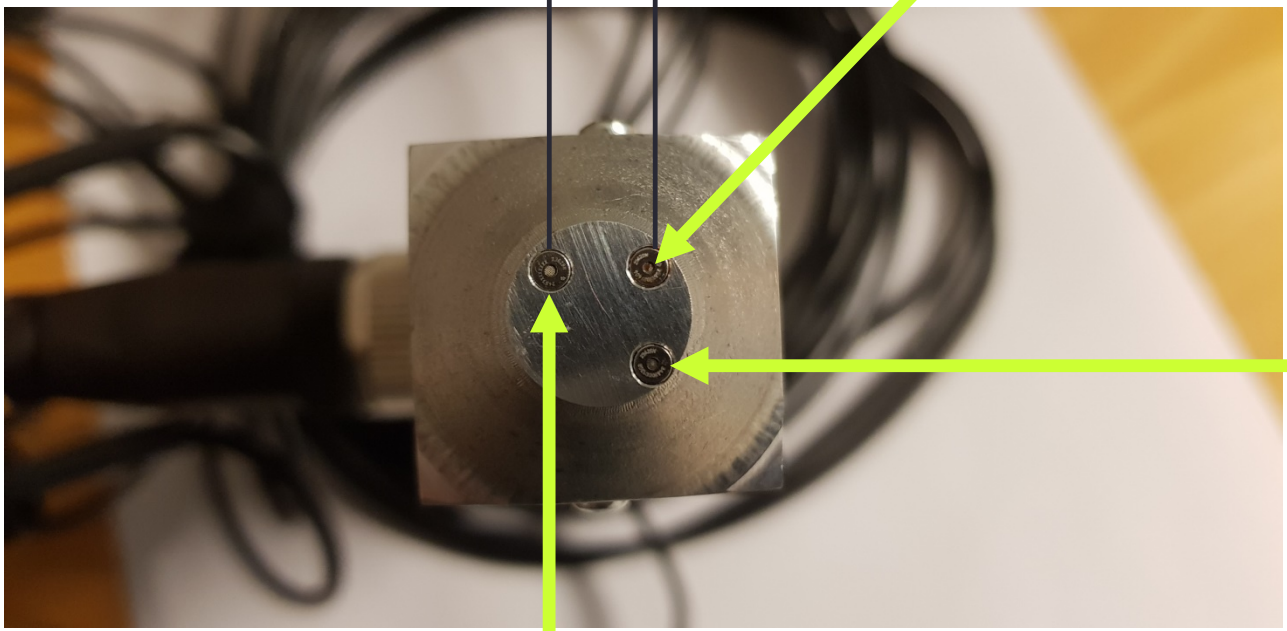


- Interferometry provides an accurate measure of call angle.

Why is this difficult?

Calculating the mean phase difference across the interferometer for complex animal calls is not trivial.

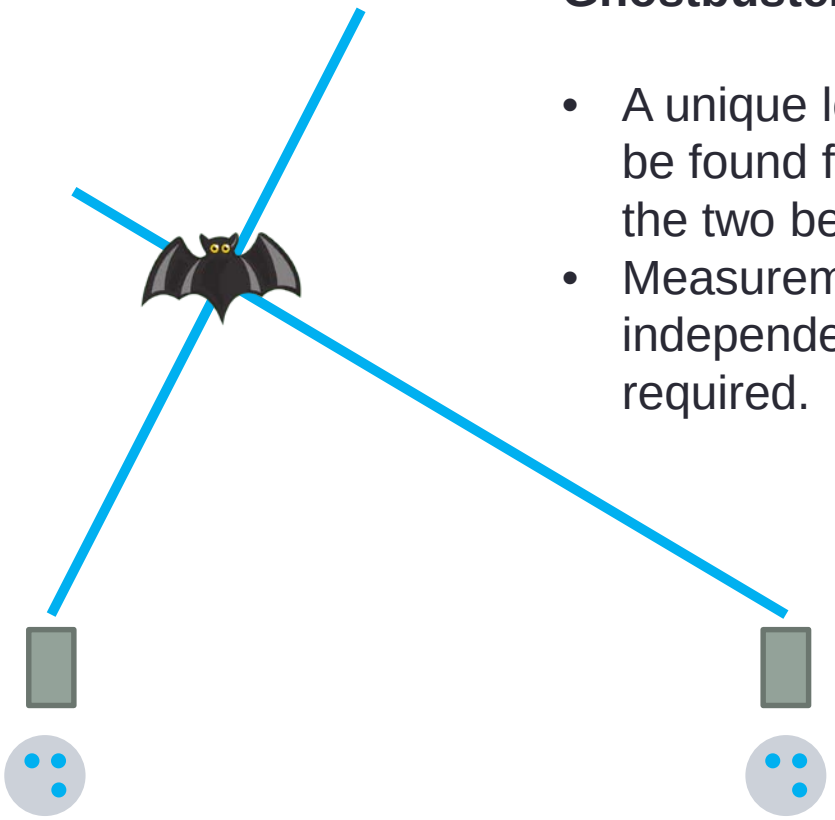
Two dimensions



Early 2D prototype.

Gives a unit vector (arrow) pointing towards the bat. (Azimuth and elevation).

Three dimensions



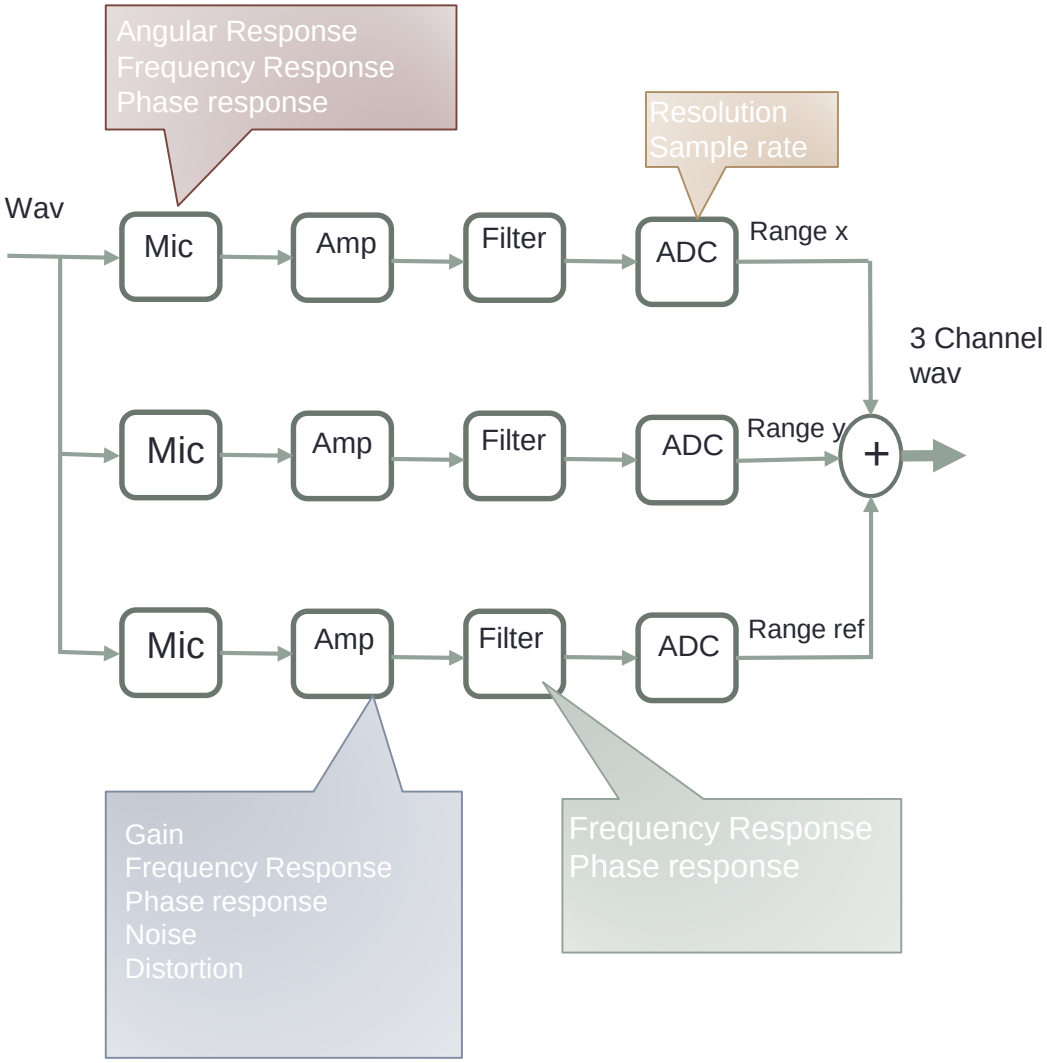
Ghostbusters method:

- A unique location in space can be found from the point where the two beams cross.
- Measurements are independent. No precise timing required.

Note: The measurements are from 2D interferometers.
The beams can project in and out of the page.

Robotic acoustic bench

Software Simulator



- Simulate real interferometers.
- Design new interferometers.
- Test species.
- Test source geometries.
- Test microphone layouts.
- Test effect of microphone directional response.
- Test the effects of different ADC widths and sample rates.
- Observe the effects of amplifier and filter frequency response – gain and phase.
- Observe the effect of noise.
- Generate datasets for phase algorithm design.

Elekon Batlogger EID

Old model Batlogger ‘C’.

- The new version of the elekon batlogger will this technology built in.
- The IP is held by the University of Exeter.
- Development is continuing at Aarhus University

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Some features

- The localisation algorithms will be built in. There is no requirement for offline processing. The device will provide angles and positions directly.
- It is designed to be easy to use by field ecologists.
- Data will be logged to cloud servers with access via a web application.
- Angular resolution about 2 degrees.
- Both Elekon and myself want to work with new users of the system, to help to improve the technology and to provide support to users.
- Aiming to have this released next year, ready for the 2019 field season.
- Price? Probably similar to the old batlogger ‘C’, around 2000 euros.

Advantages over traditional TDOA

- With TDOA you need to multiple microphones with precisely known positions.
- Fewer wires trailing over the survey site. Quick to install.
- With TDOA there is usually a requirement for offline processing, using, for example, Matlab software. This is specialist work and not something that bat workers can usually do.
- The sensors are small - about the size of a coin. A single sensor can show a lot about bat behaviour. Only two sensors are needed for a location.
- Precise timing between multiple devices isn’t required.
- Particularly suited to flying animals.

How can bat workers use the technology?

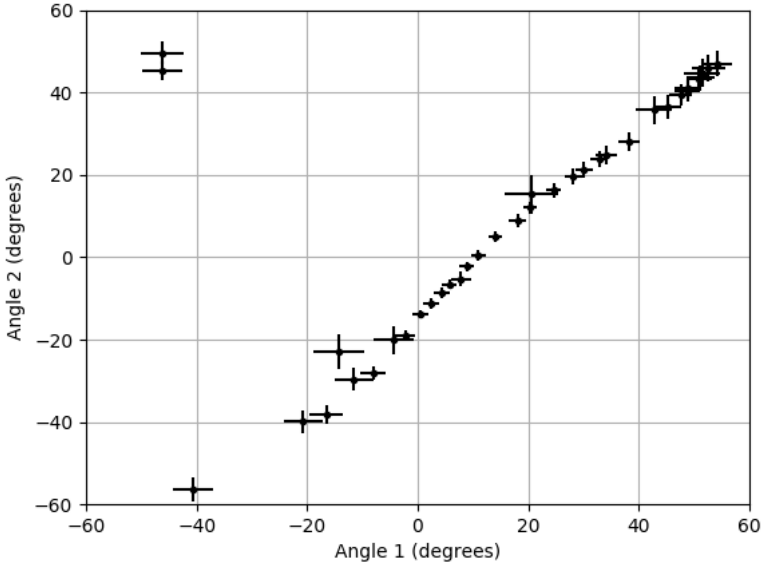
Interactions with infrastructure.

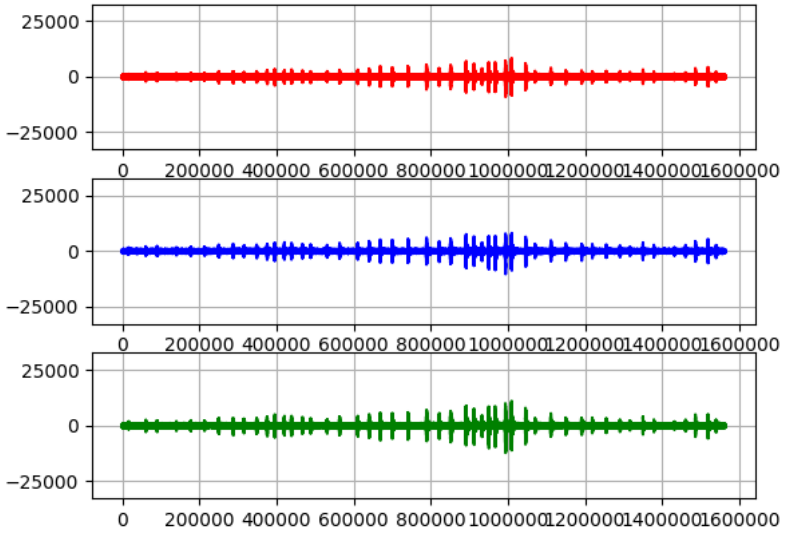
Activity surveys. Better data compared to traditional static recorders.

Emergence surveys

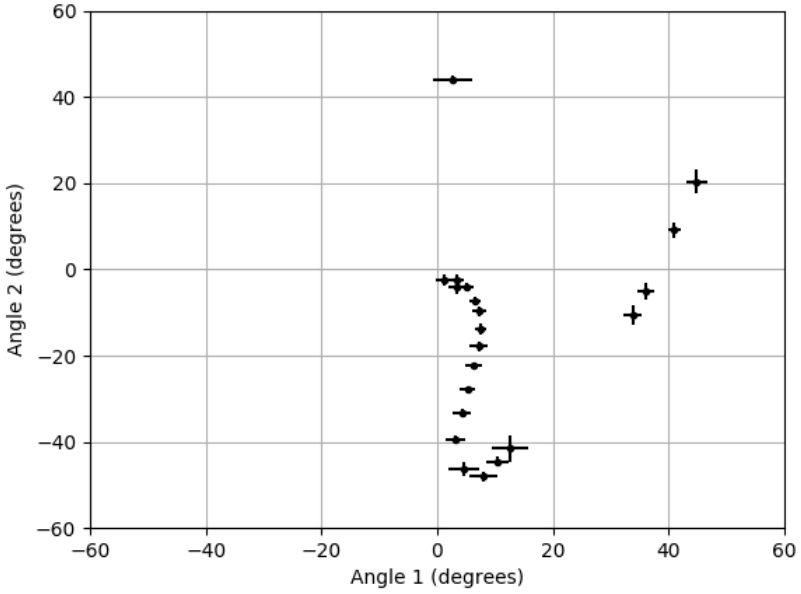
Linear features. Hedges. Routes to foraging sites. (Single interferometer)

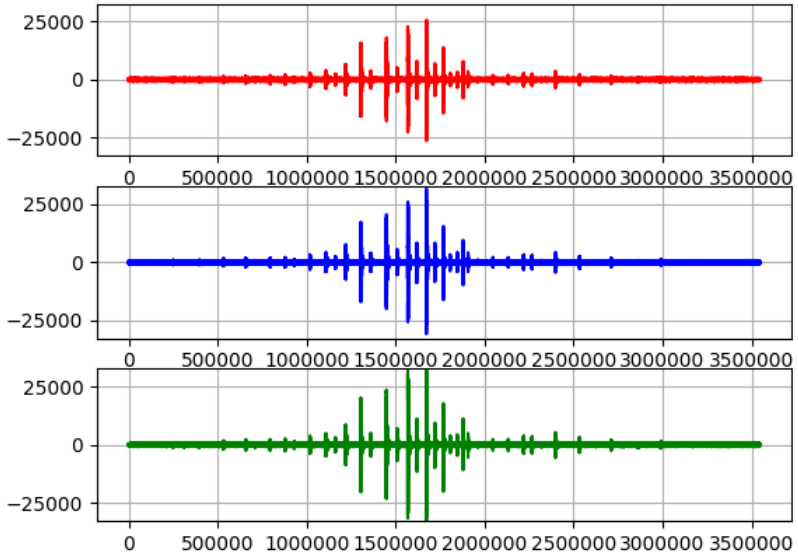
Some real measurements from an elekon prototype



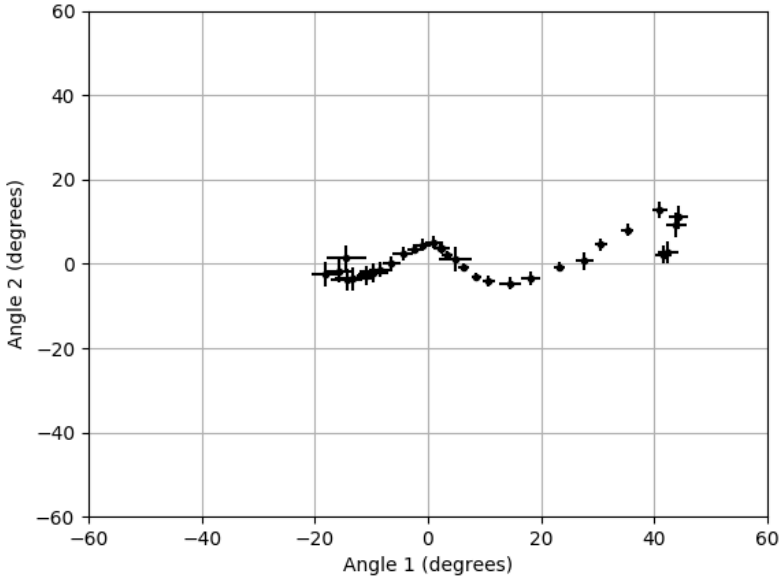


A more interesting trace





And another


Angle 2 (degrees)
Angle 1 (degrees)
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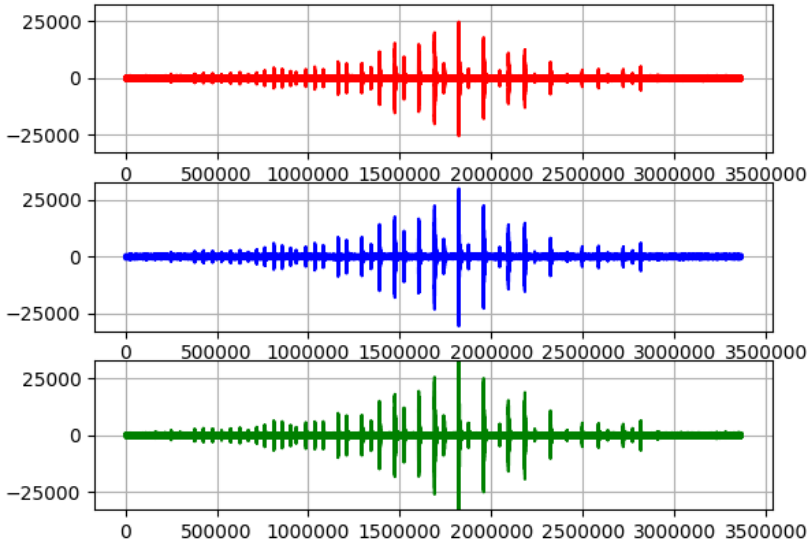
40
60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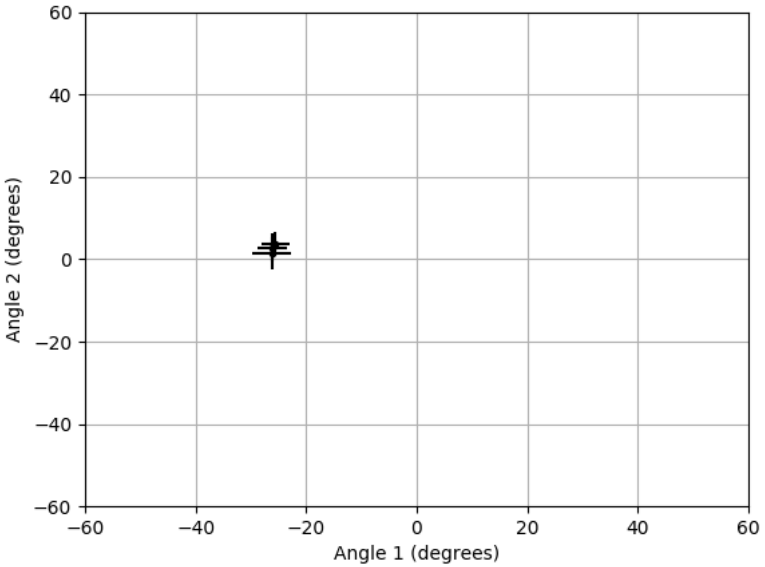
Low signal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Angle 2 (degrees)
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−40
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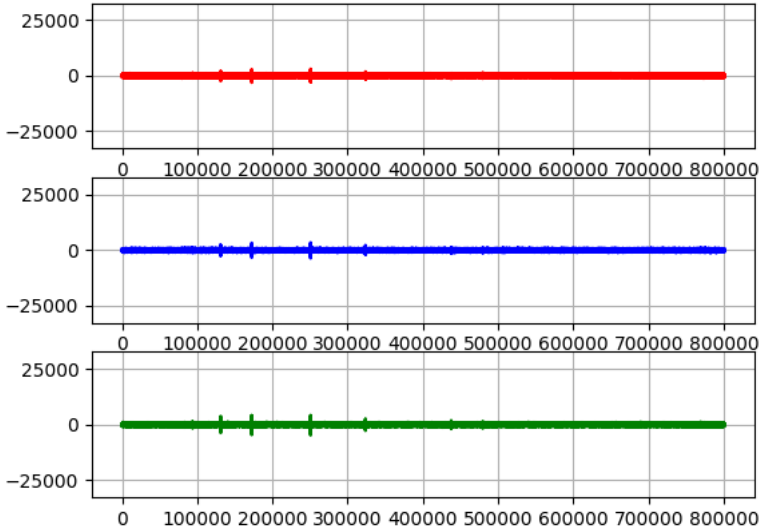
Angle 1 (degrees)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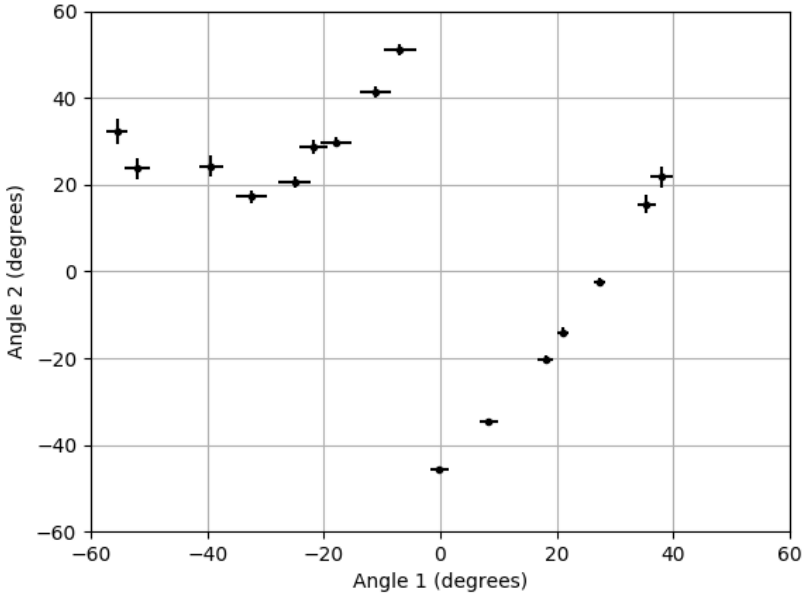
700000
800000

Two Bats!


Angle 2 (degrees)
Angle 1 (degrees)
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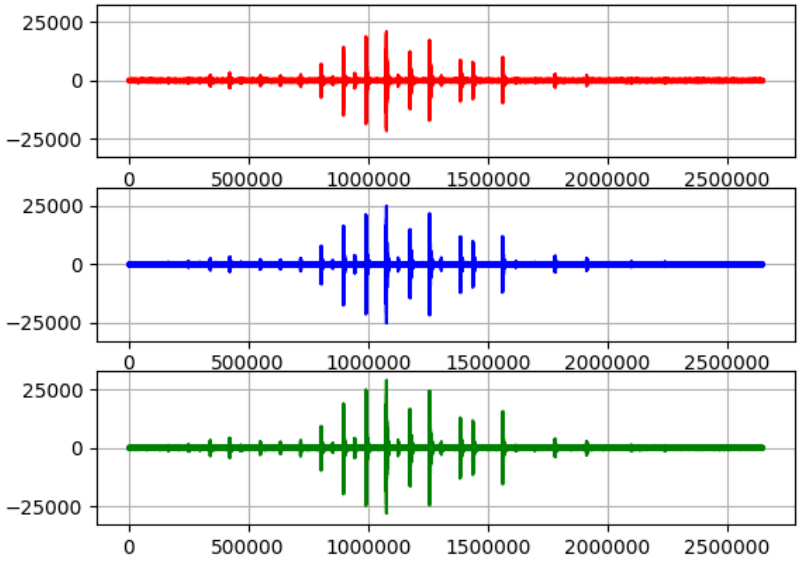
−20
0
20
40
60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2000000
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Next steps

- The next part of the process is to develop this as a survey method for ecologists.
  - What are best practices?
  - How do you interpret the data?
  - What are the errors?
  - When is it a suitable method?
  - Write the field manual (Not device operator manual).
- I would like to get a PhD student or postdoc to do this.
- Collaborations welcome!
- Ideas and feedback welcome.