Acoustic positioning system of closely-flying aircraft for SLR eye safety

This work is supported by JSPS KAKENHI Grant Number 20H01993.

As a spin-off part of:

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Project status (as of Oct 2023)

4-year KAKENHI project (FY2020-2023)

& additional collaboration projects

FY2020 Design

FY2021 Individual tests

FY2022 Assembly tests

FY2023 SLR test ← now

(budget hunting ongoing for the future development/deployment)

Tachikawa NIPR
2023-10-06

FY2023 status

Tests at Simosato in March, at Tachikawa in August+

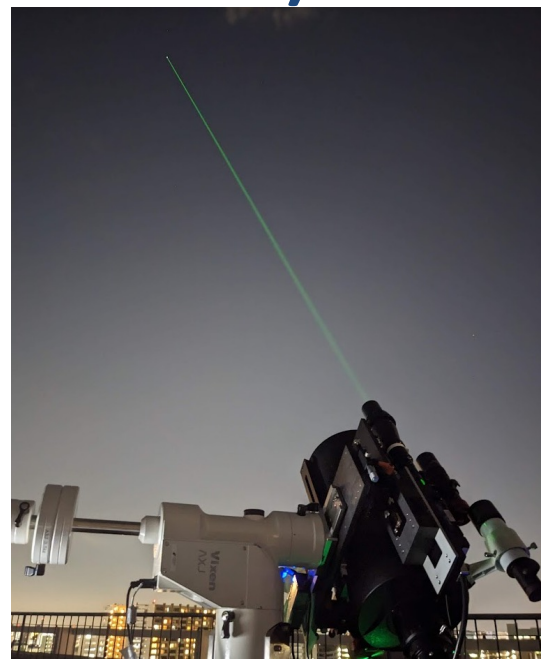
No returns from satellites yet

Improving the optical alignment scheme/equipment

Laser failure occurred on 6 Oct 😢

Eye-safety measures for SLR

One or multiple methods below (Re-arranging Wilkinson 2019):



Observer's eyes and ears

Microwave RADAR

Eye-safe LiDAR

ADS-B etc

Visual/Infrared camera image recognition

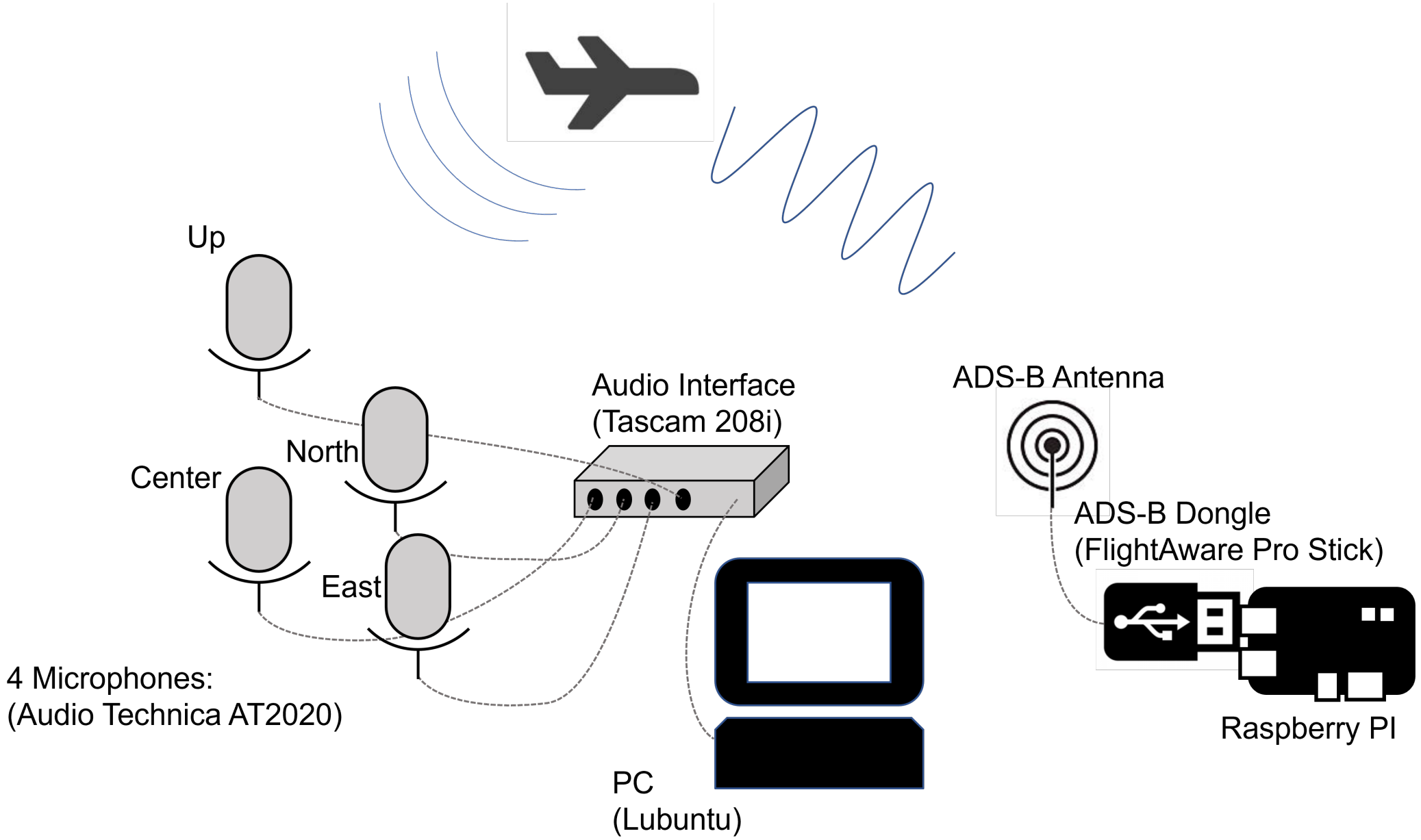
Local info (from airports etc)

Our idea

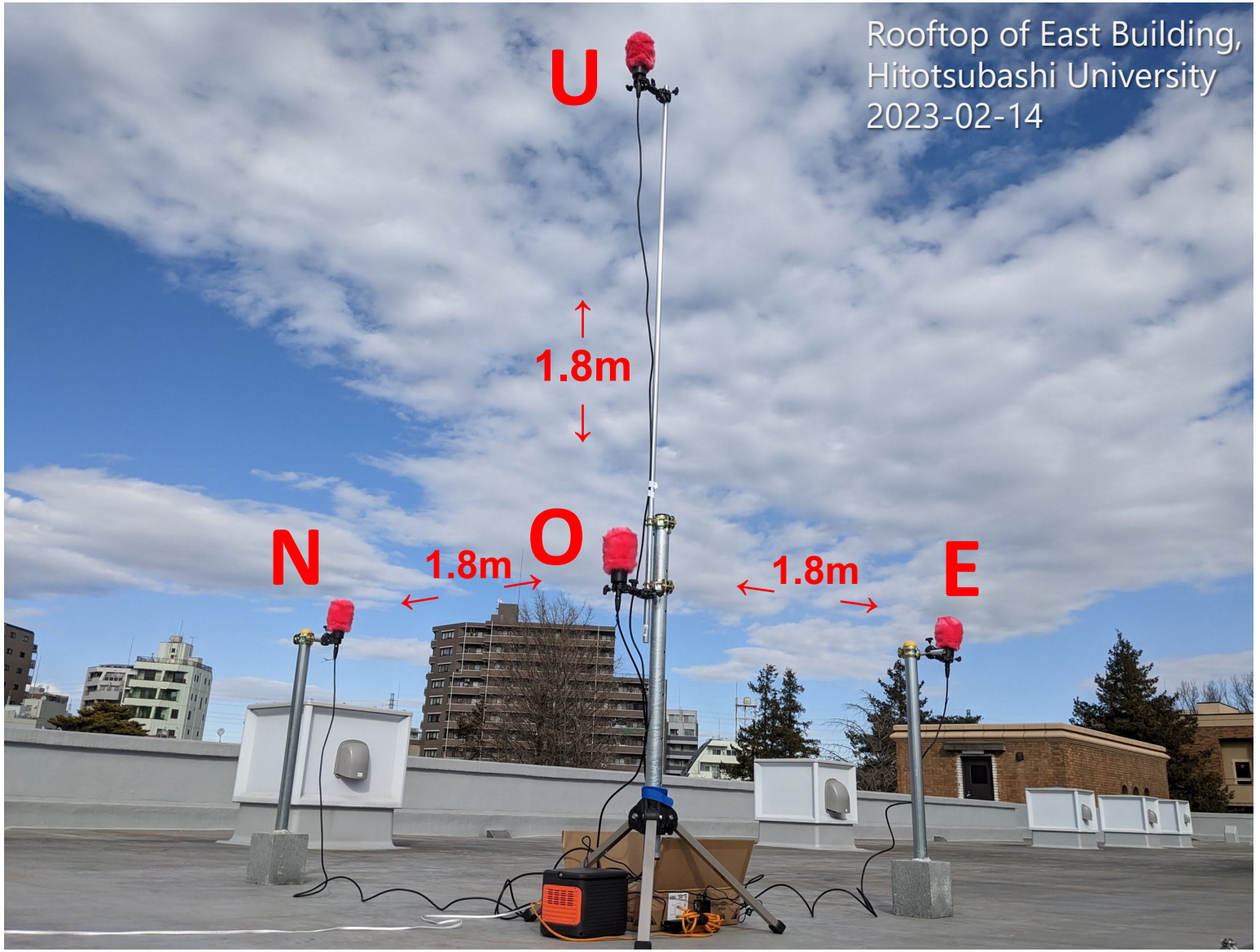
Small percentage of aircraft without ADS-B (not mandated in Japan), often flying closely.
Can we make use of acoustic info?
Affordable and compact system?

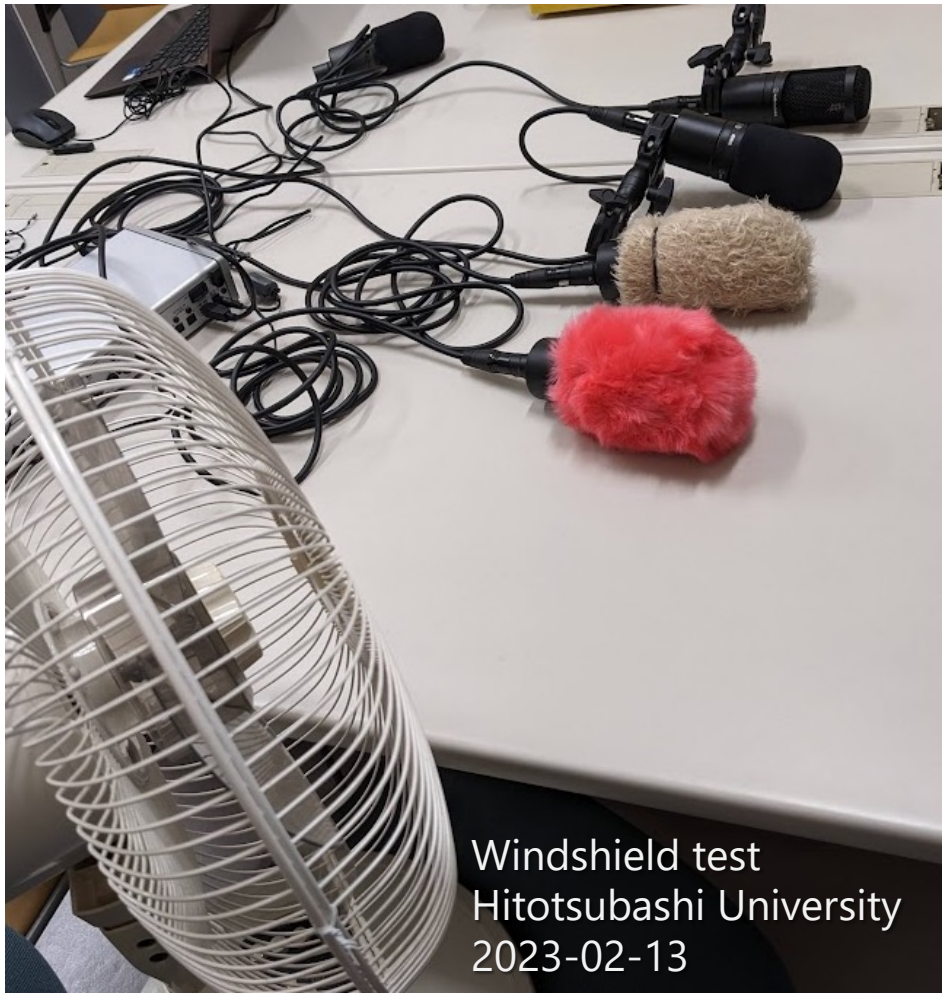
Probably new for SLR, but it had been a common technique until 1940's.

Acoustic aircraft positioning system: diagram

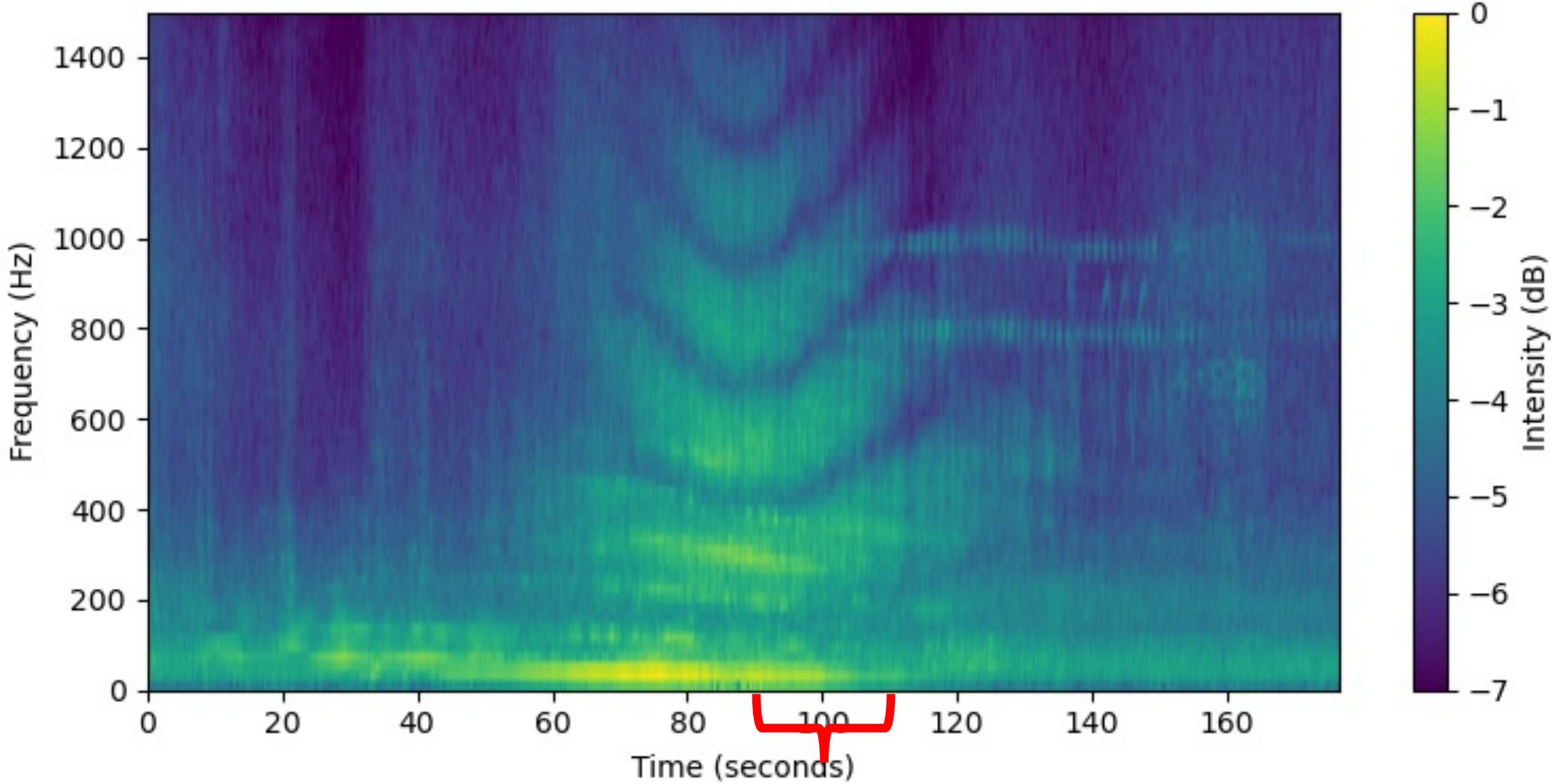


Acoustic aircraft positioning system: setup



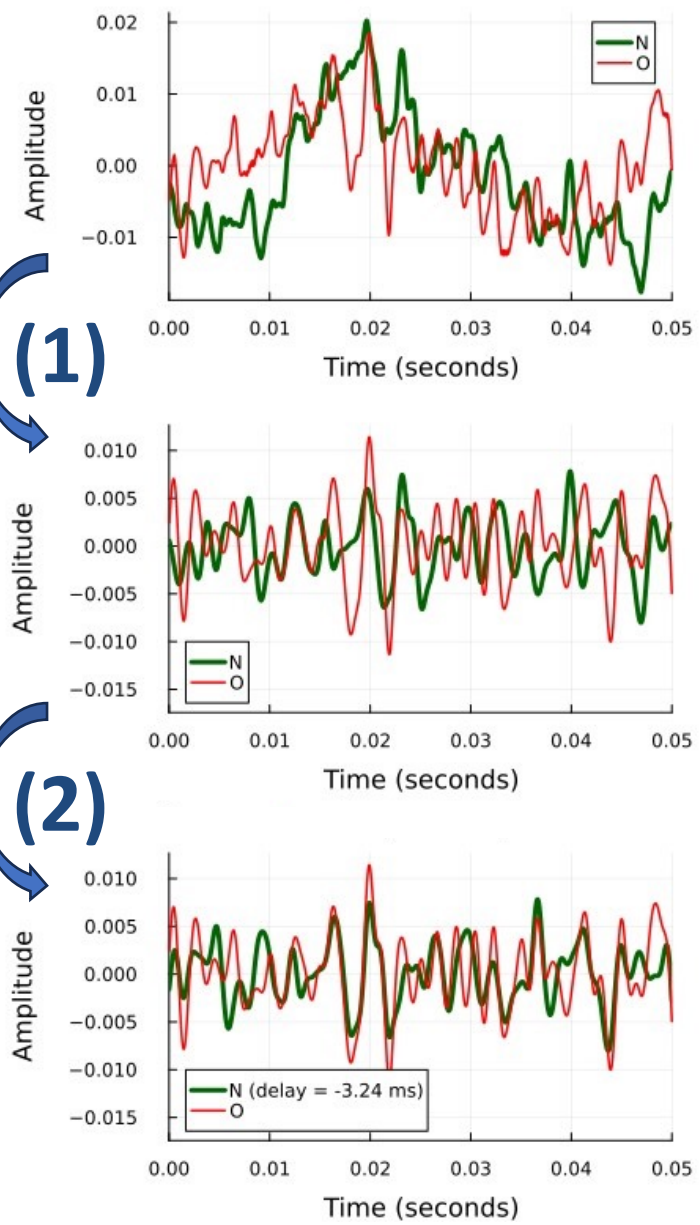


Recorded sound (amplified)



Data Processing Scheme

Implemented with Julia



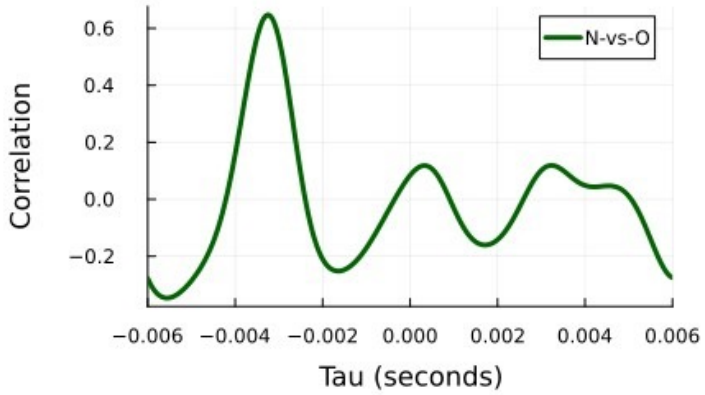
For each of O, N, E and U channels:

(1) Apply 80-800 Hz bandpass filter

For each of O-N, O-E and O-U baselines:

(2) Find the best "τ" that maximize the cross-correlation.

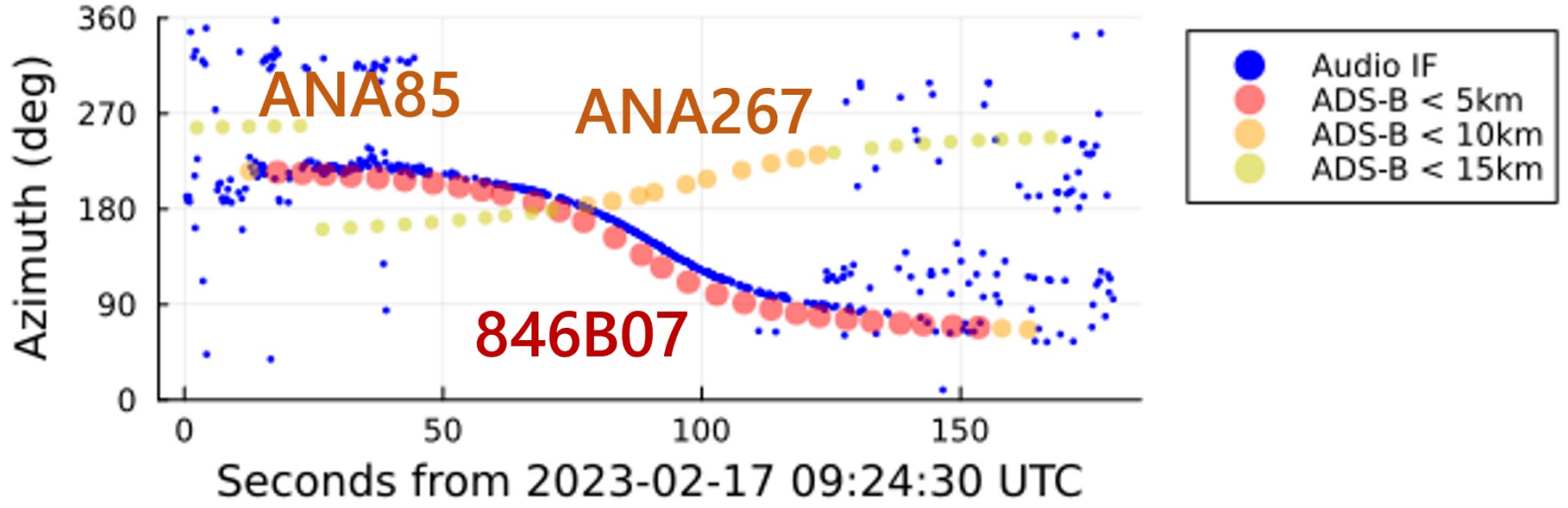
$$C_{Oi}(\tau) = \int_0^T x_O(t)x_i(t-\tau)dt$$

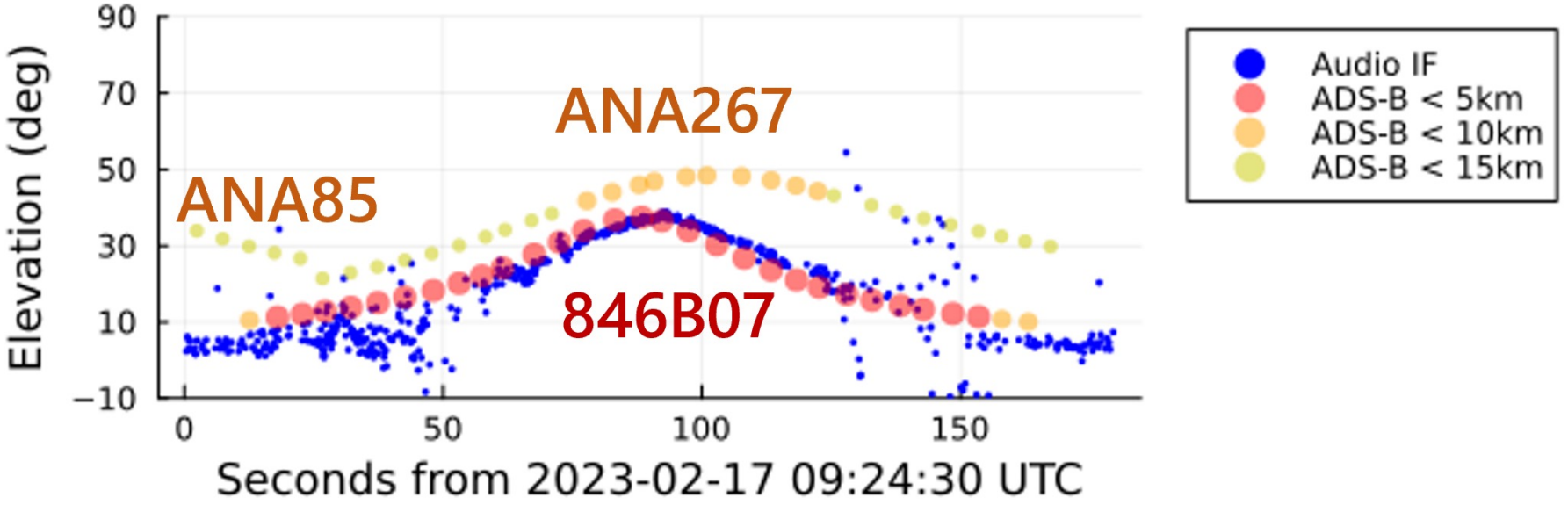


(3) With the best τ 's, calculate Az and El.

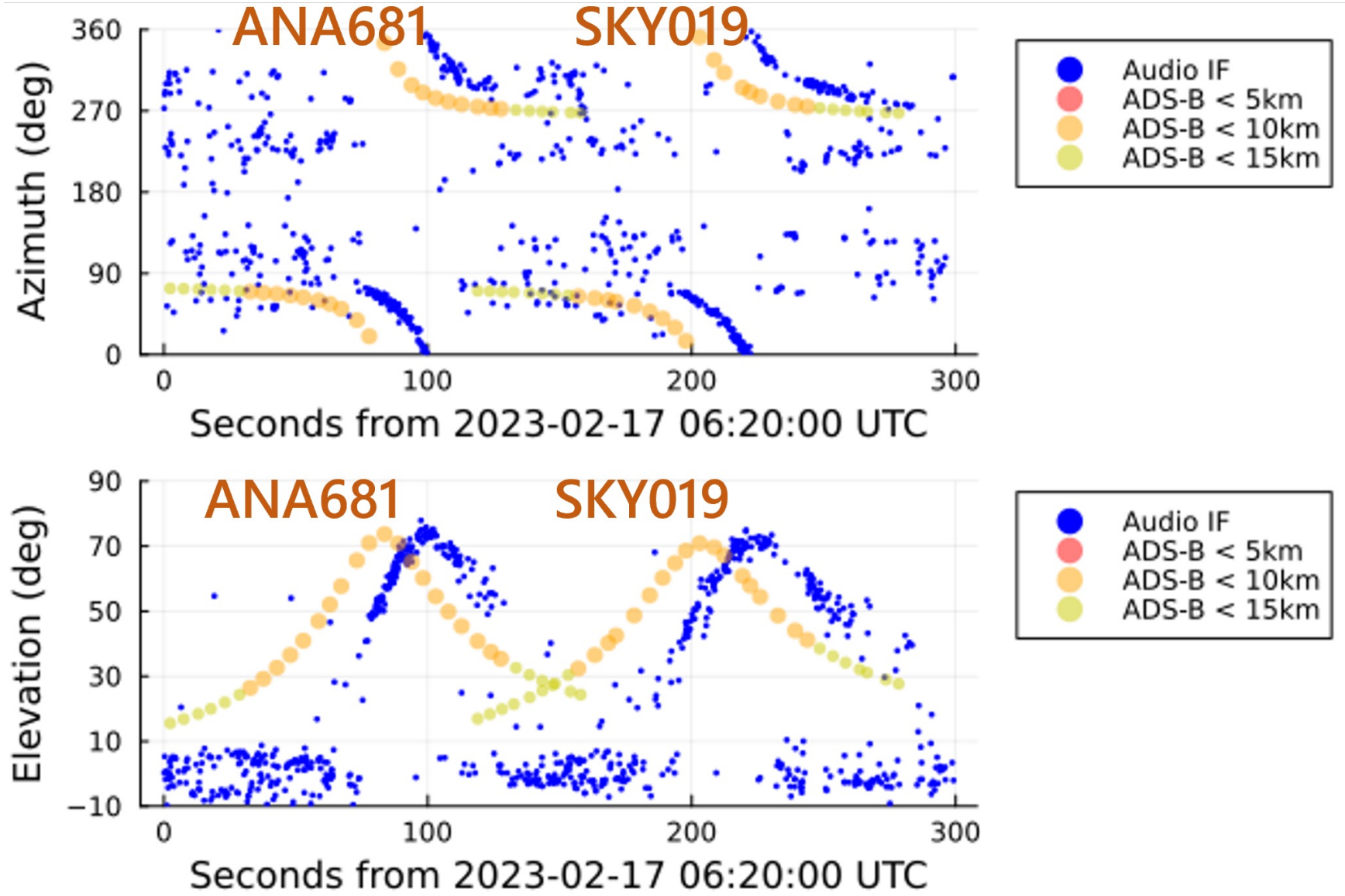
$$\tan Az = \left(\hat{\tau}_E{}^2/\hat{\tau}_N{}^2\right) \qquad \sin El = \left(\hat{\tau}_U{}^2/\left(\sqrt{\hat{\tau}_N{}^2+\hat{\tau}_E{}^2+\hat{\tau}_U{}^2}\right)\right)$$

[Az, El] Solutions compared with ADS-B





[Az, El] Solutions compared with ADS-B



Facts and Findings

Cost < 100,000 JPY (~ 700 EUR/USD)

Sensitivity

< 5 km: Almost certain → precision ~ 1 deg at the best cases

5-10 km: Sometimes

> 10 km: Hardly (possibly improvable)

Sound-Speed Delay (340 m/s → 10 km/30s) is inevitable

Baseline length: 1.8 m and 0.9 m works, but 0.45 m not.

Realtime capability

Data processing time: ~5% of sound duration.

Less useful when/where low-tone noise is dominant

But works ok with high-tone noise of huge buzz of cicadas.

Less useful at city centres surrounded by a lot of tall buildings

ELSEVIER

Advances in Space Research

Available online 5 October 2023

In Press, Journal Pre-proof ? What's this?

Acoustic positioning of closely-flying aircraft for eye safety of space laser applications

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https://doi.org/10.1016/j.asr.2023.09.067

Conclusions and Future works

Acoustic Aircraft Positioning

Possible, but limited to < 5-10 km distance.

Effective for closely-flying no-ADS-B aircraft.

Further tests

More microphones? More Sensitive ones? Sharper Directivity?

Automatic recognition and laser-stop signal generation.

Other applications?