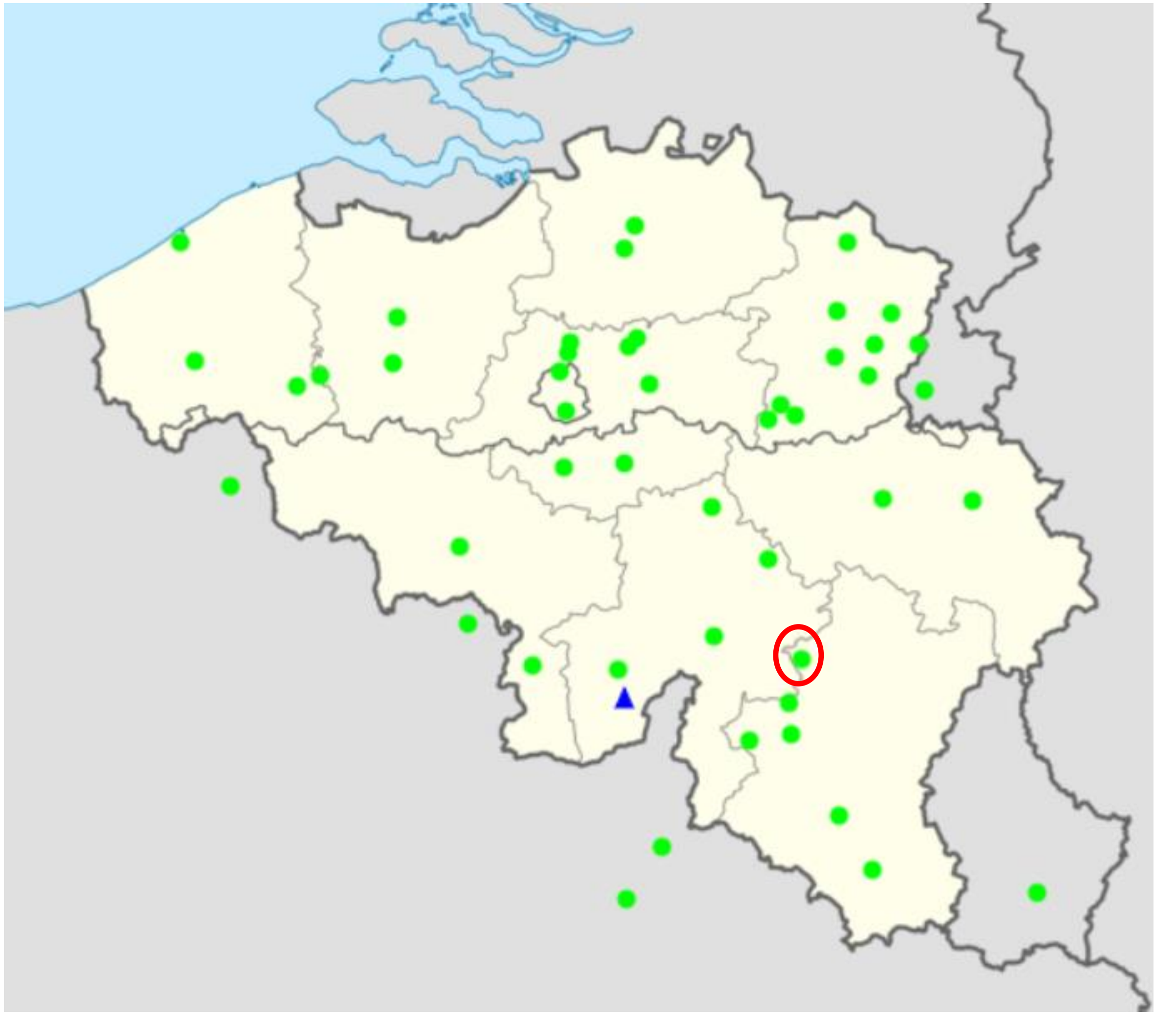
# Status of the BRAMS and MOMSTER projects

H. Lamy & BRAMS team

# BRAMS network : status in August 2023

- 46 active receiving stations.
- One interferometer located in Humain (red circle)



# Characteristics of the BRAMS transmitter

**General Characteristics**

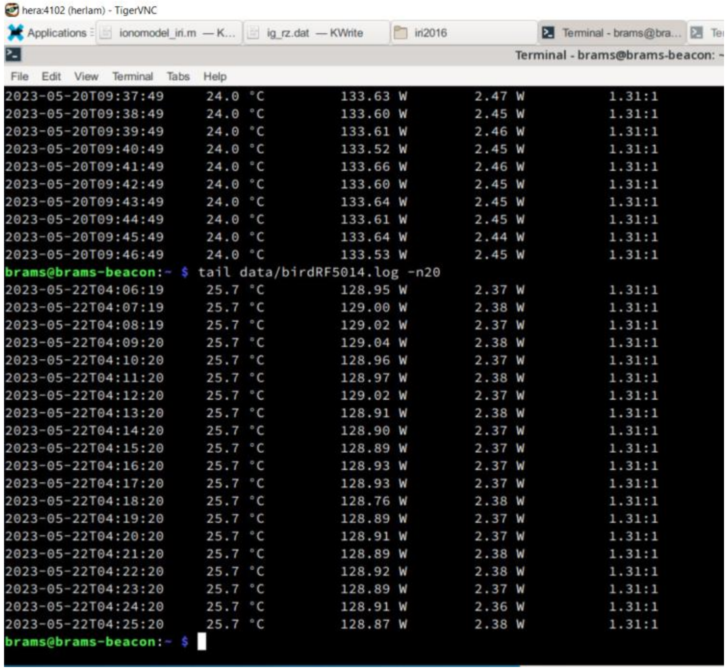
- ✓ *f*=49.97 MHz
- ✓ CW with no modulation
- ✓ Nominal radiated power: 130 Watts
- ✓ circular polarization towards zenith

**Mechanical Characteristics of the transmitter**

- two horizontal, mutually orthogonal, half-wave dipoles mounted on a mast
- 70 cm above an 8-m x 8-m metal grid acting as a ground plane
- grid at ~65 cm above actual ground
- 90° phase shift between dipoles (common feed via a Tee and 2 lengths of coax with difference in length of ¼ wavelength).

# Monitoring of the BRAMS transmitter

- Recent problems with our power amplifier from the Australian company TOMCO
- Need for a regular monitoring
- Currently done in 2 ways :
  - ✓ Measuring the voltages directly at the amplifier itself (for ~ 1 year)
  - ✓ Using a directional coupler to measure transmitted and reflected power (over a large frequency range, for ~ 6 months)
- The amplifier sometimes shows unexpected behavior + some dependance with temperature (no controlled environment)

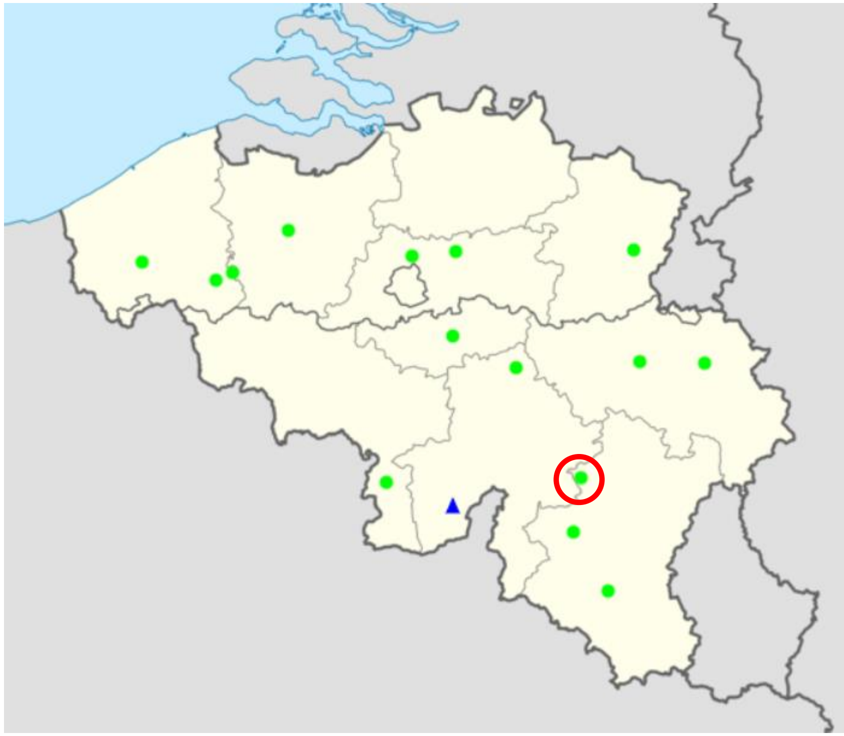



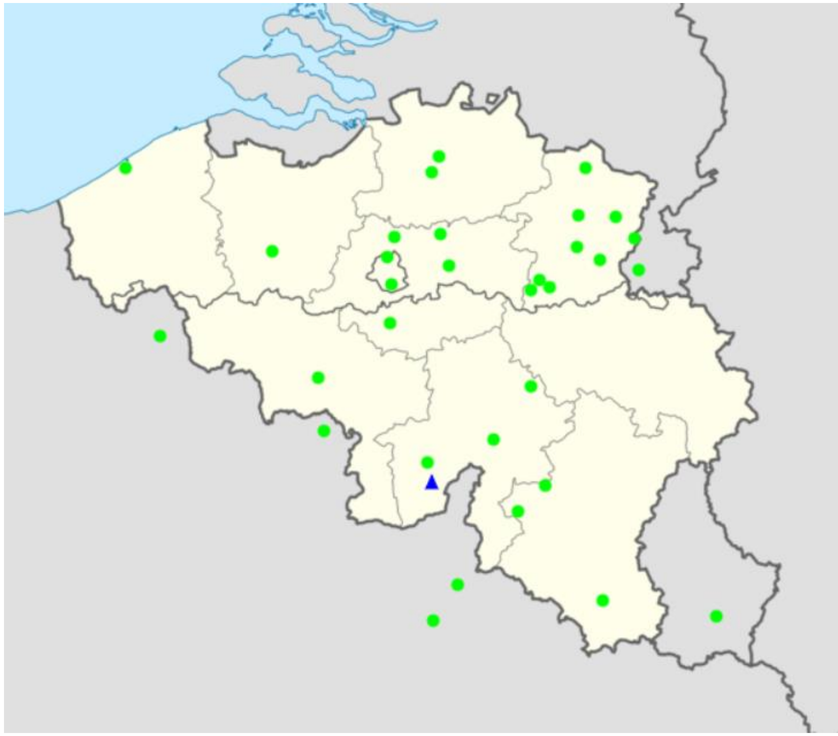
- In addition, we can control and reboot the signal generator remotely

- All these programs are installed on a Rpi accessible from a VLAN network in BIRA-IASB.

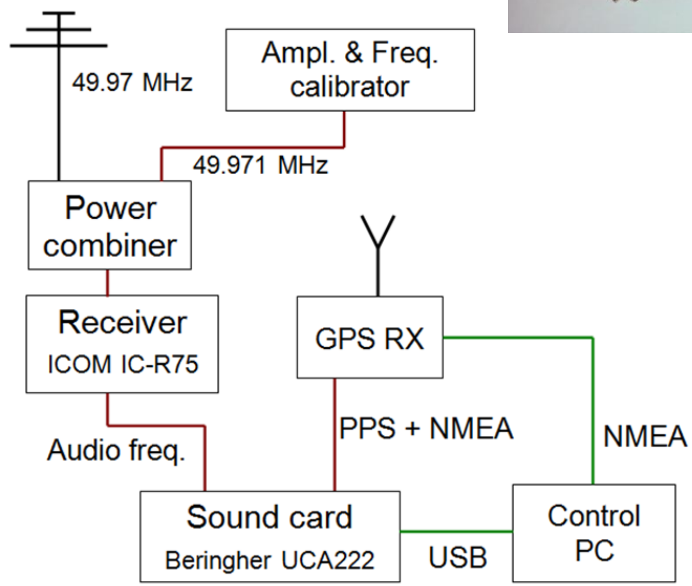
# BRAMS network : status in August 2023

- 14 stations with ICOM / PC (Stations 1.0)
- 32 stations with RSP2 / Rpi (Stations 2.0)
- The radio interferometer in Humain (AR5001)



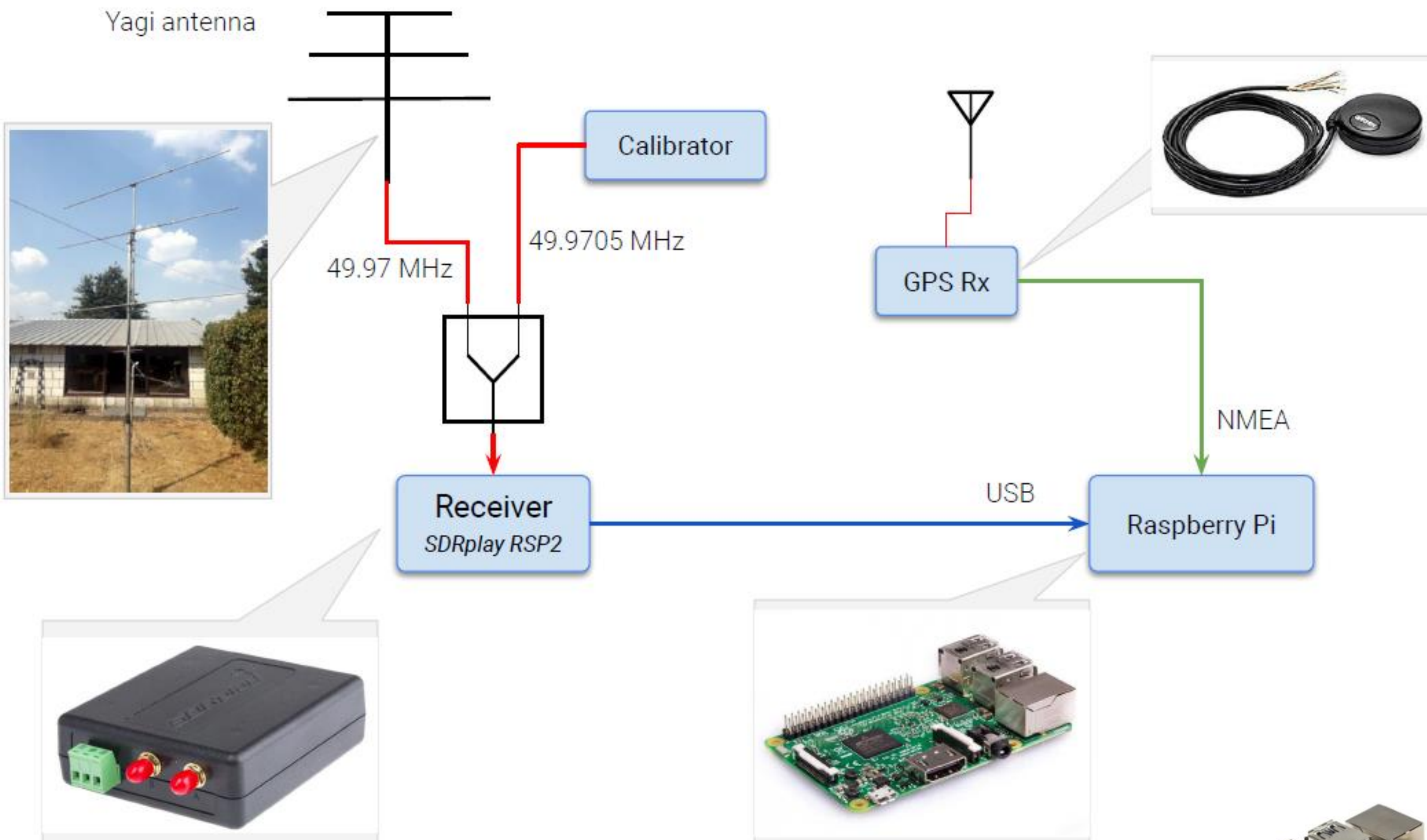


# BRAMS receiving stations 1.0



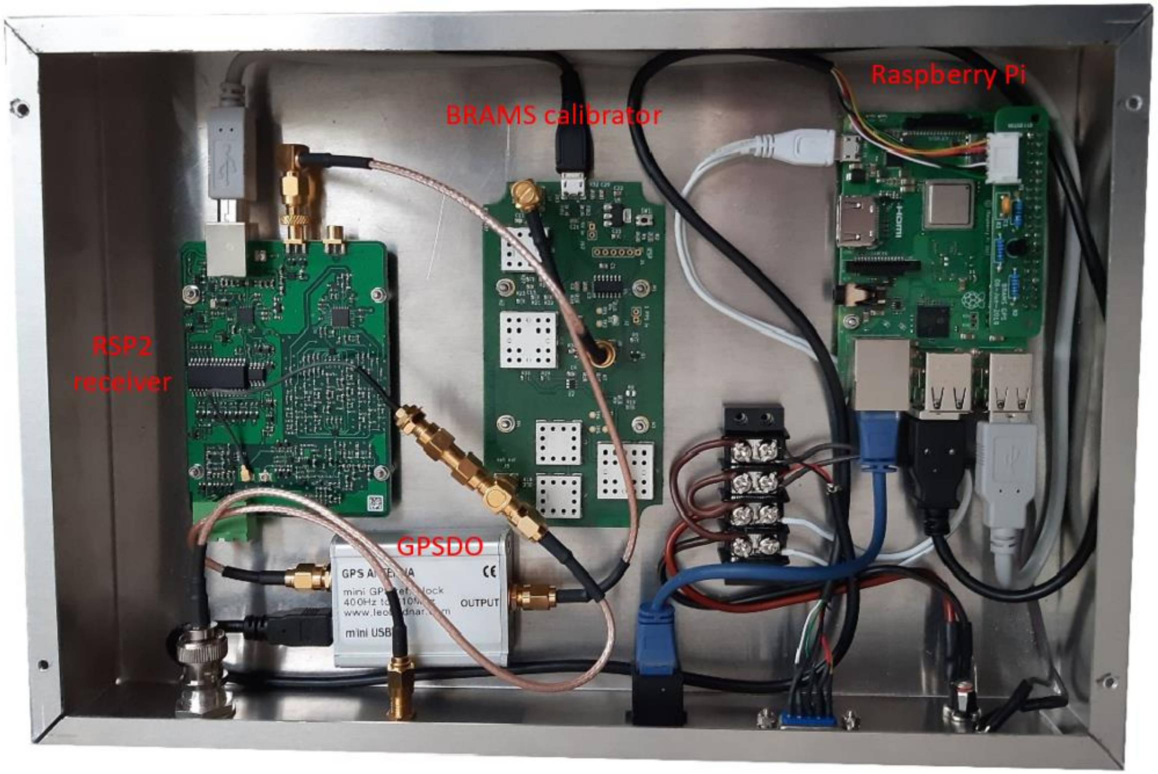


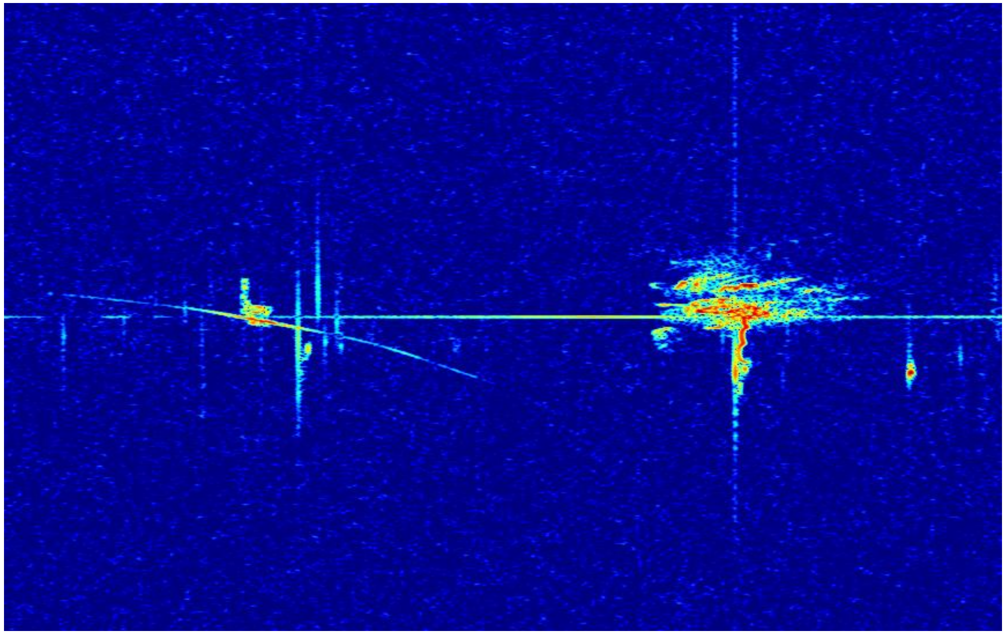
# BRAMS receiving stations 2.0




Currently RSP2 replaced by RSPDx and RPi replaced by ROCK 4 SE

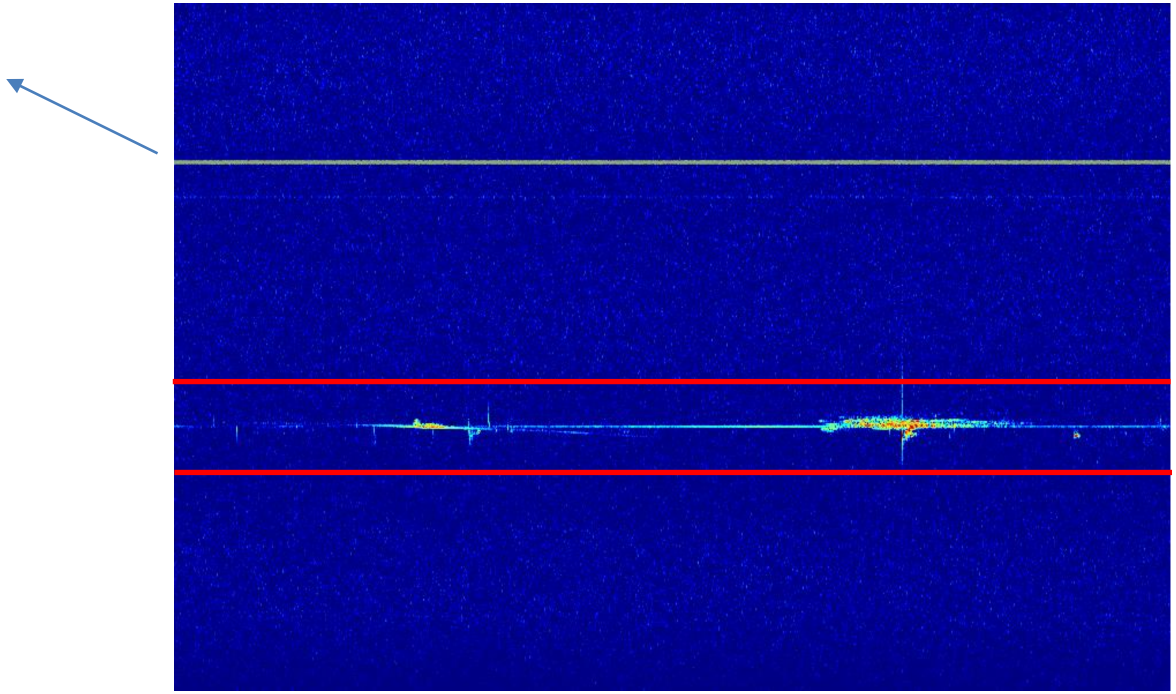
# Current material used for BRAMS 2.0





1000 Hz

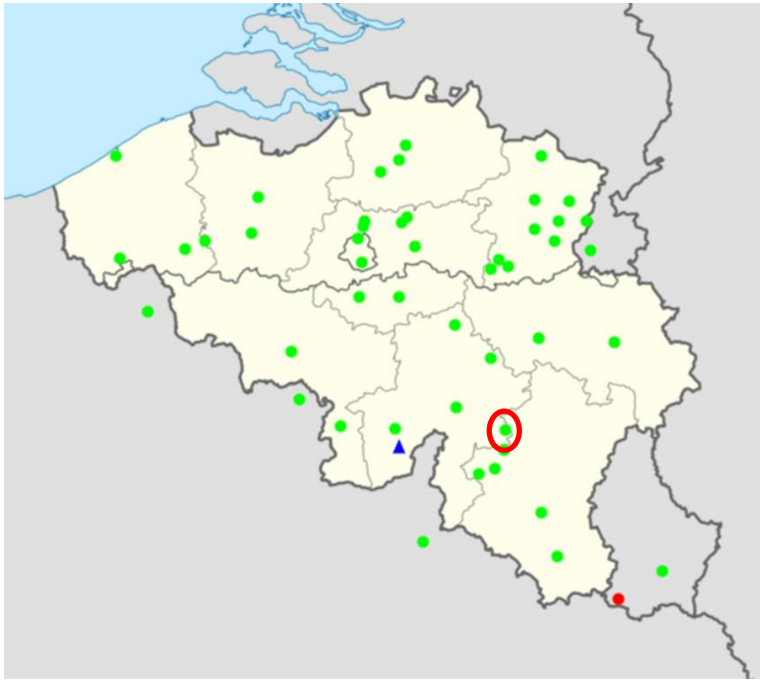
Calibrator

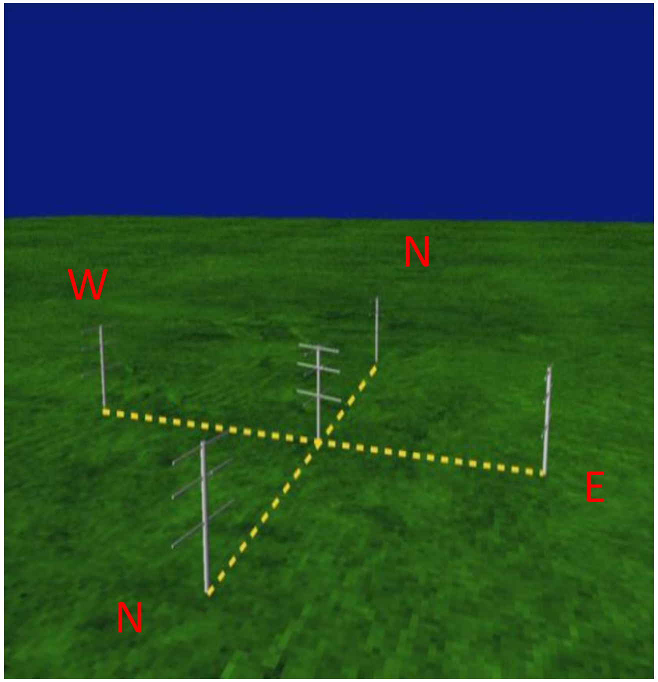


1500 Hz

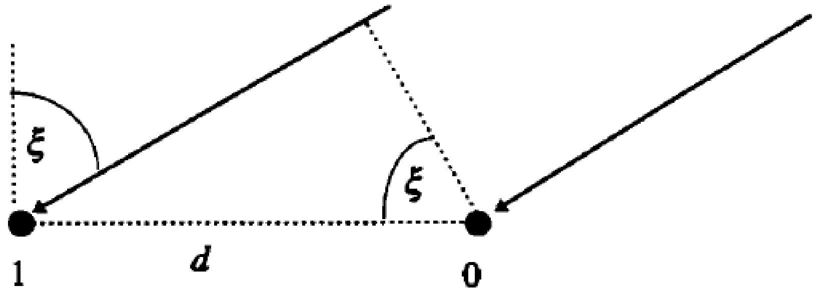
1000 Hz

# Radio interferometer in Humain



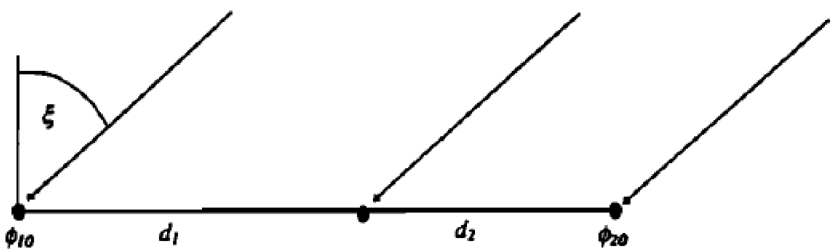



# Principle




$$\phi_{10} = -2\pi \frac{d}{\lambda} \sin \xi$$

Jones et al (1998)




$$\phi_{10} = -\frac{2\pi d_1}{\lambda} \sin \xi$$

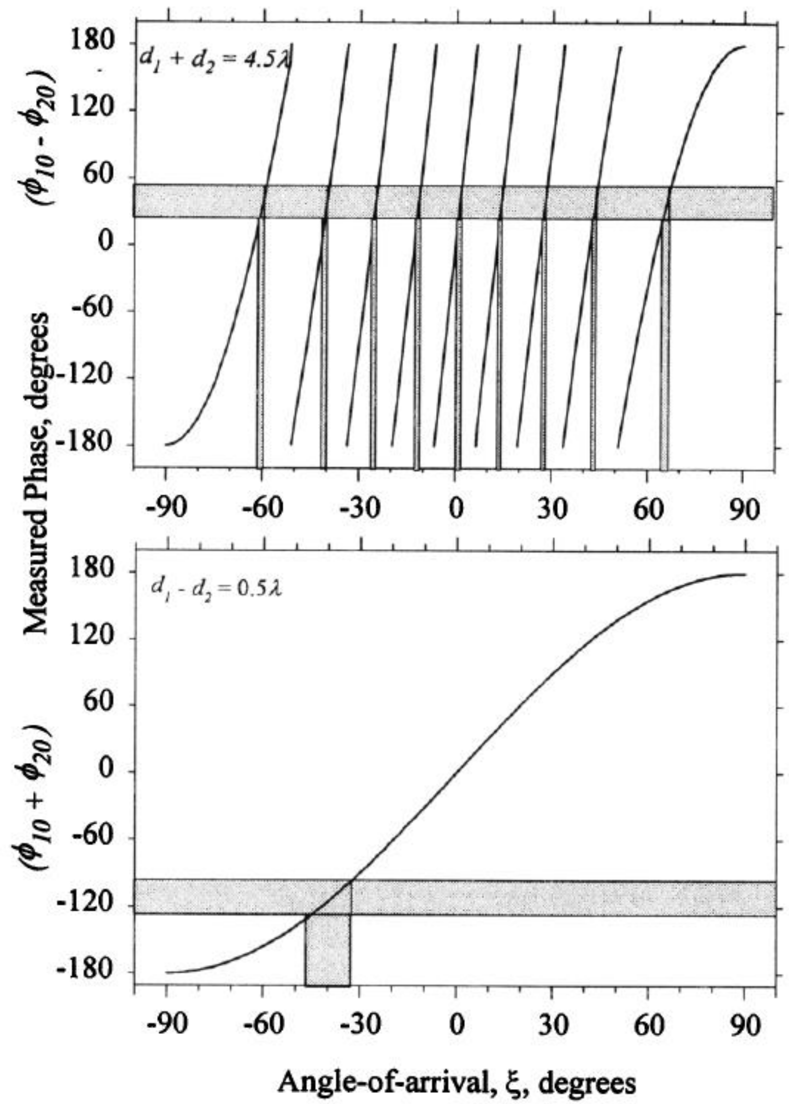
$$\phi_{20} = +\frac{2\pi d_2}{\lambda} \sin \xi$$

$$\sin \xi = -\frac{\lambda}{2\pi} \frac{(\phi_{10} - \phi_{20})}{(d_1 + d_2)}$$

$$\sin \xi = -\frac{\lambda}{2\pi} \frac{(\phi_{10} + \phi_{20})}{(d_1 - d_2)}$$

$d_1 = 2.5\ \lambda$
$d_2 = 2\ \lambda$

# Principle (2)




Jones et al (1998)

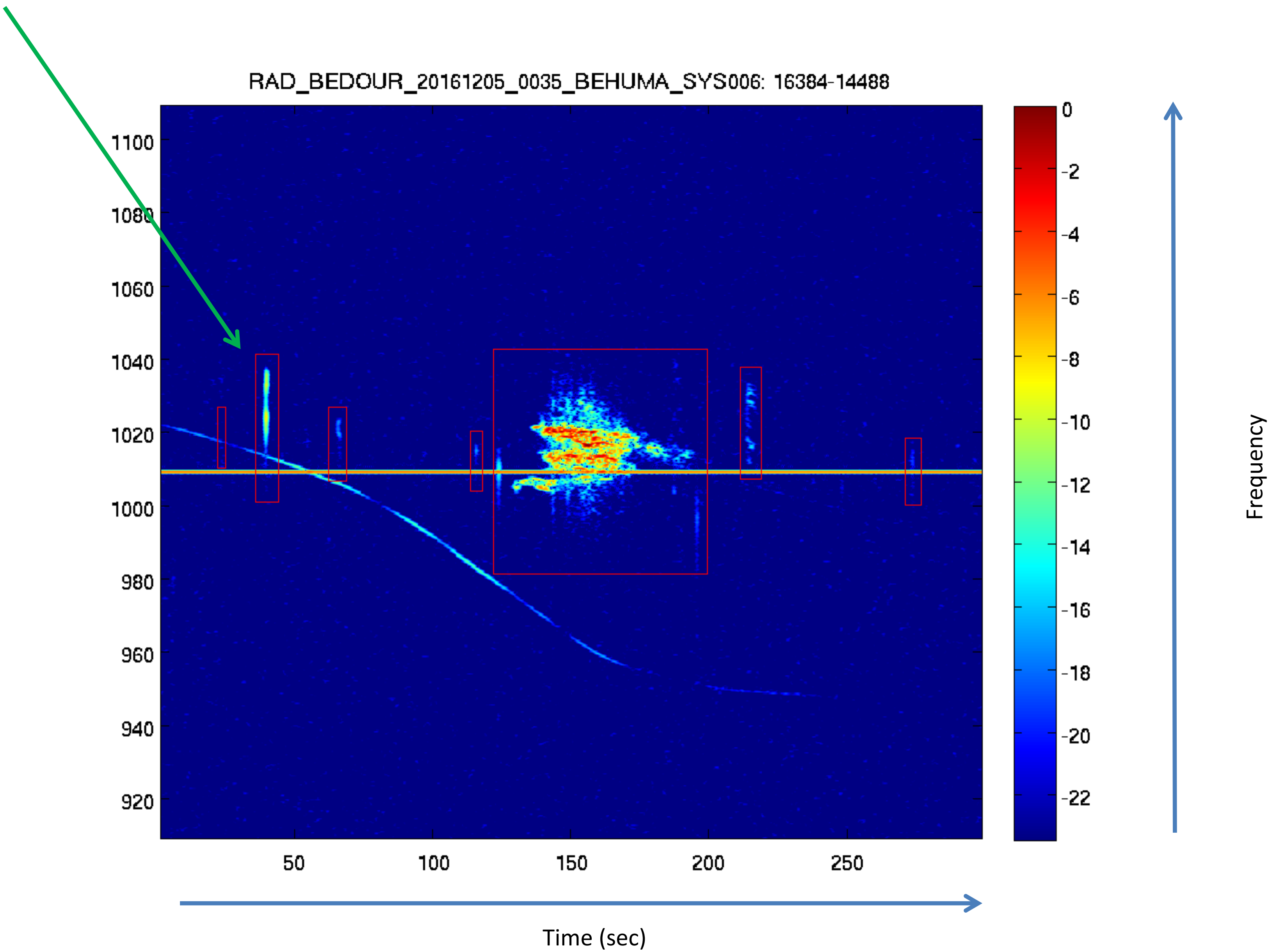
# Angles of arrival

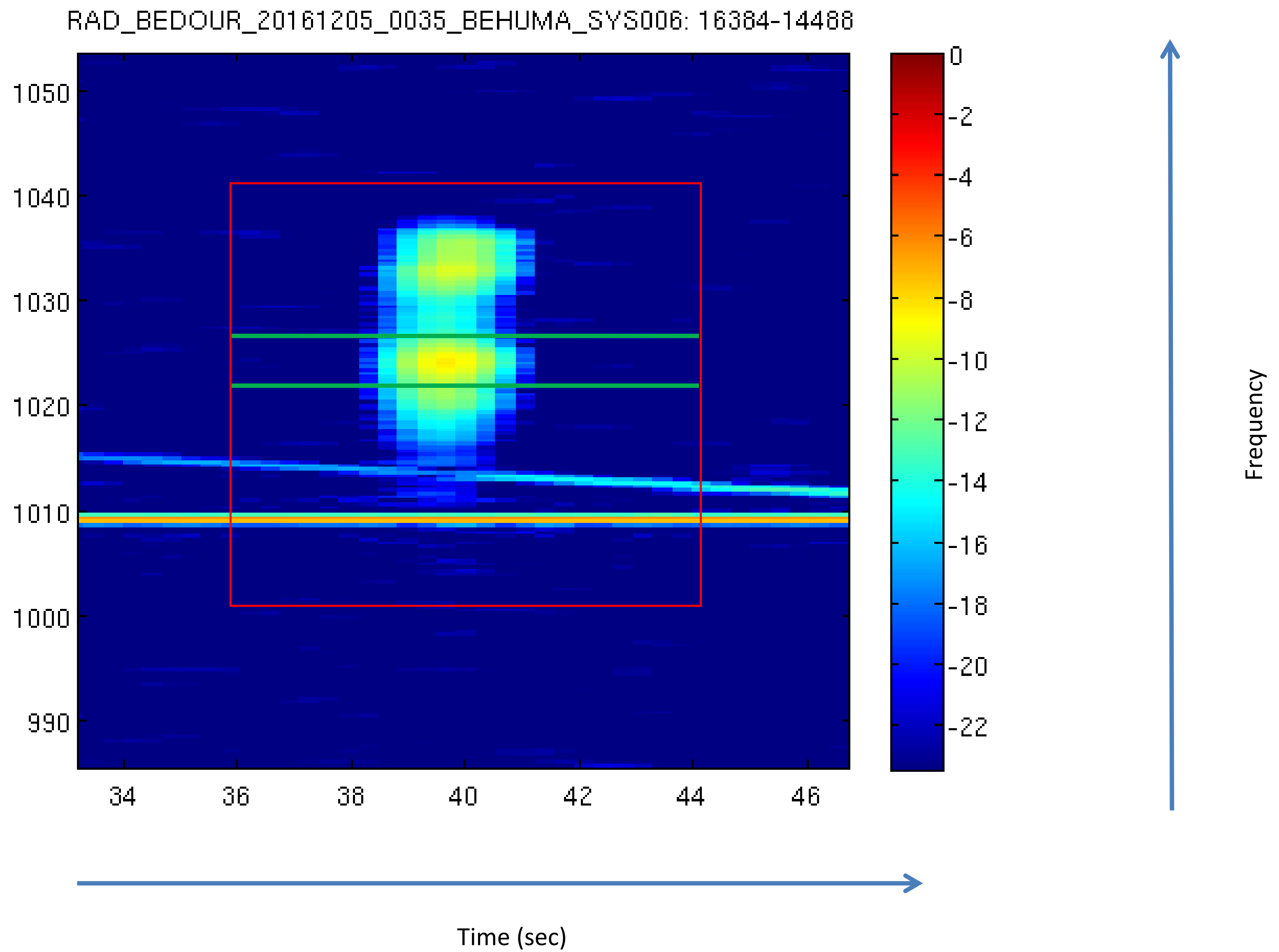
$$\beta = \tan^{-1}\left(\frac{\cos\xi_2}{\cos\xi_1}\right)$$

$$\alpha = \cos^{-1}\left(\frac{\cos\xi_2}{\cos\beta}\right) = \cos^{-1}\left(\frac{\cos\xi_1}{\cos\beta}\right)$$

$\alpha$ : elevation $\beta$ : azimuth (measured from North toward East)

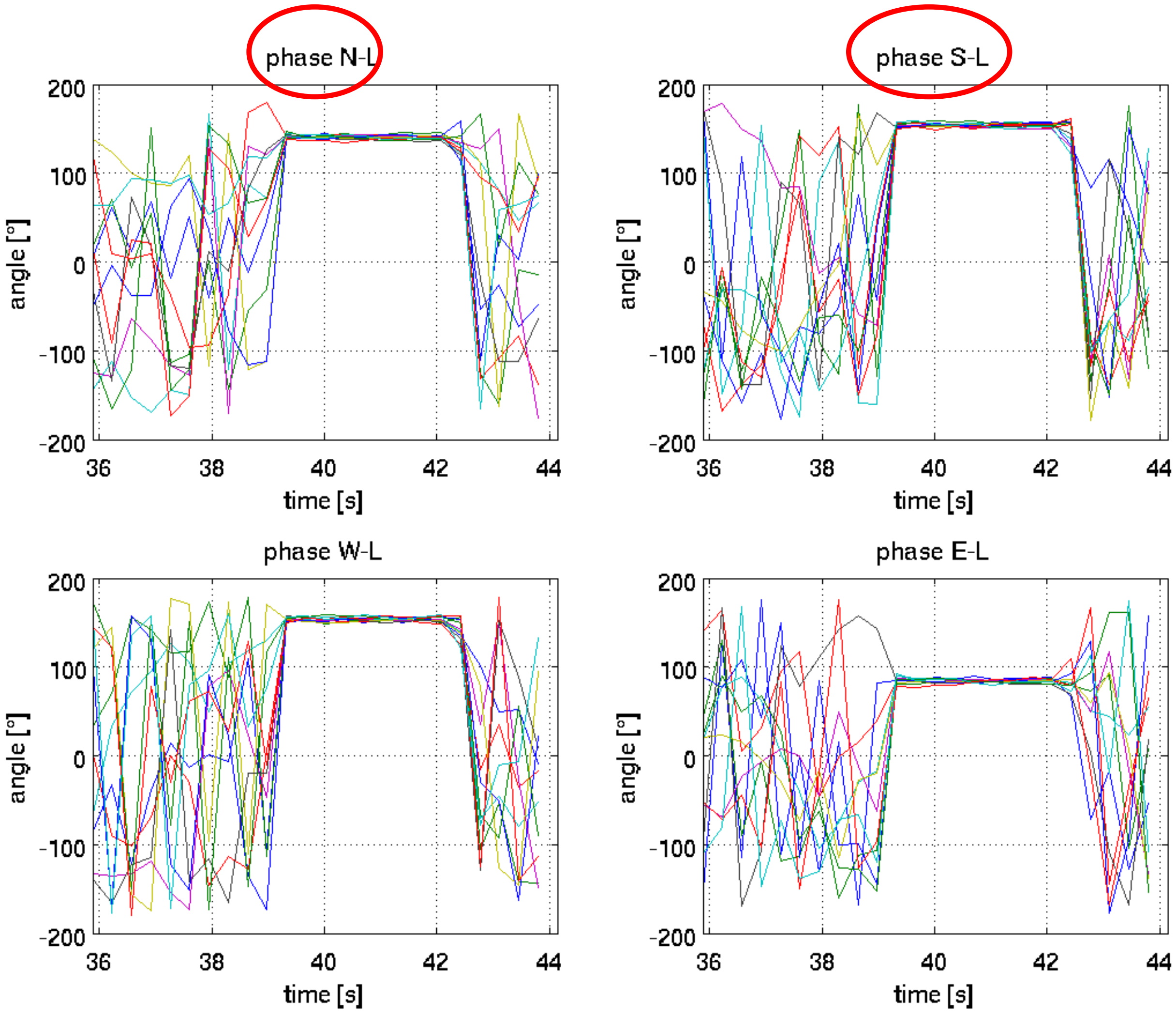
# An example


RAD_BEDOUR_20161205_0035_BEHUMA_SYS006: 16384-14488
1100
1080
1060
1040
1020
1000
980
960
940
920
50
100
150
200
250
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
Frequency
Time (sec)



RAD_BEDOUR_20161205_0035_BEHUMA_SYS006: 16384-14488
1050
1040
1030
1020
1010
1000
990
34
36
38
40
42
44
46
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
Frequency
Time (sec)

# Phase differences between antenna pairs

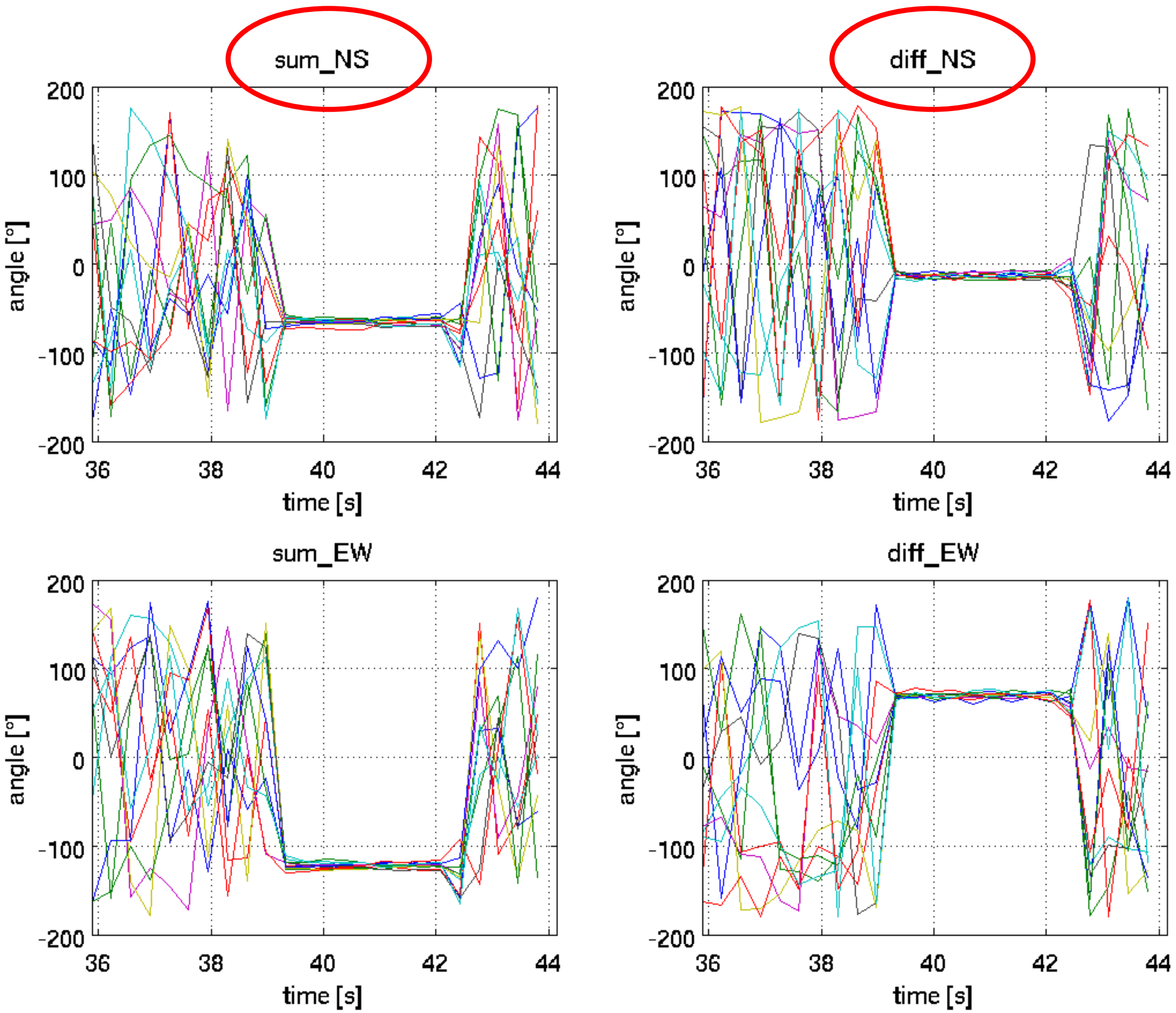



Each color =
1 frequency

$$\sin\xi = -\frac{\lambda}{2\pi}\frac{(\phi_{10} - \phi_{20})}{(d_1 + d_2)}$$

$$\sin\xi = -\frac{\lambda}{2\pi}\frac{(\phi_{10} + \phi_{20})}{(d_1 - d_2)}$$

# Sum & Diff of phase differences

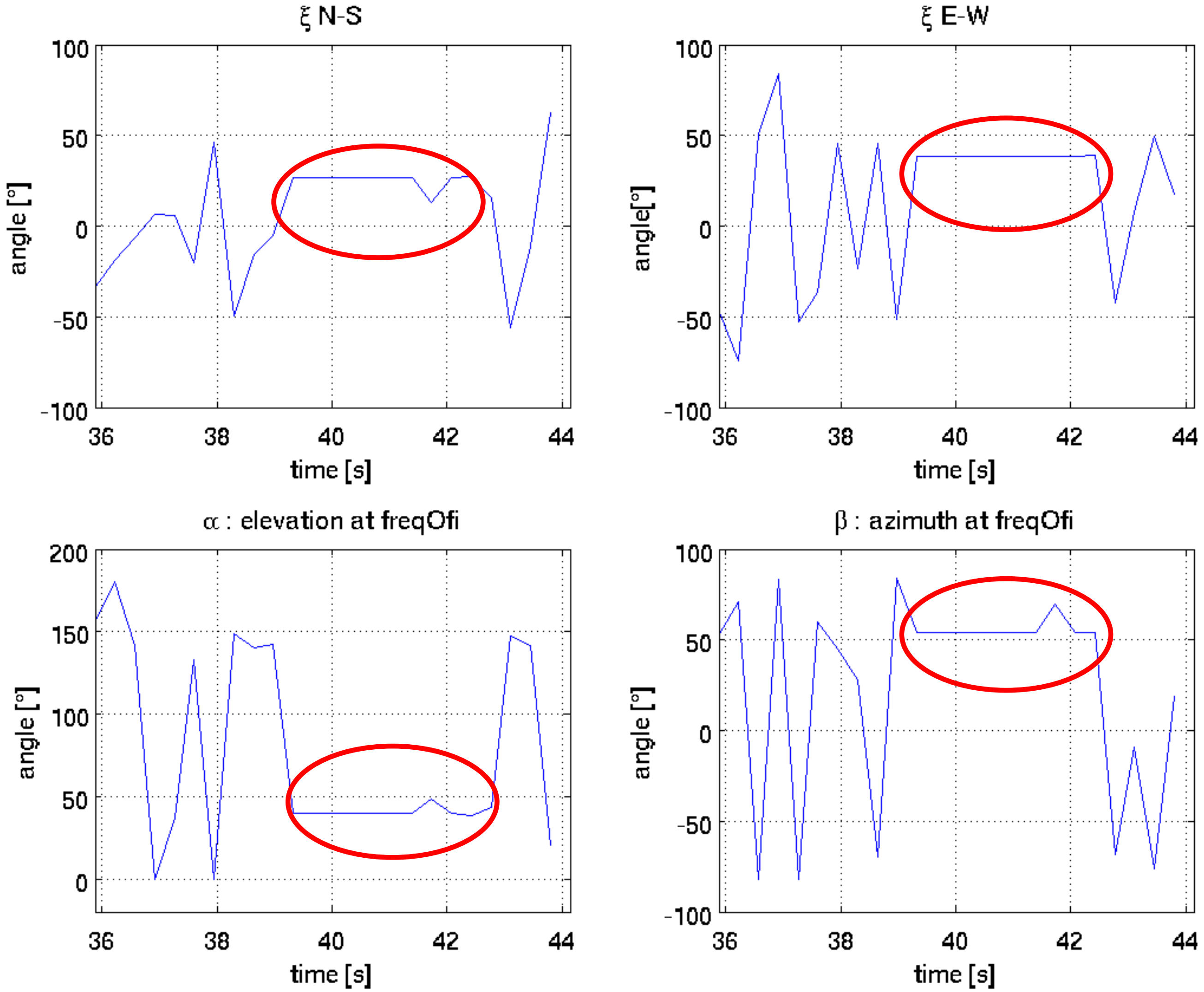



$$\sin\xi = -\frac{\lambda}{2\pi}\frac{(\phi_{10}-\phi_{20})}{(d_1+d_2)}$$

$$\sin\xi = -\frac{\lambda}{2\pi}\frac{(\phi_{10}+\phi_{20})}{(d_1-d_2)}$$

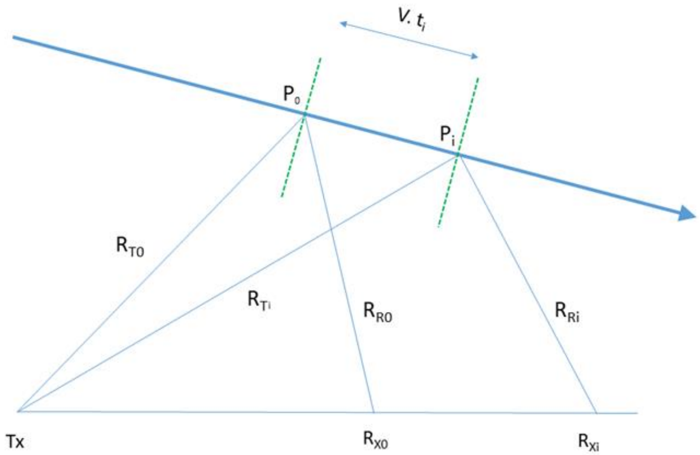
# Angles of arrival

Only one frequency



# Meteoroid trajectory and speed : method 1

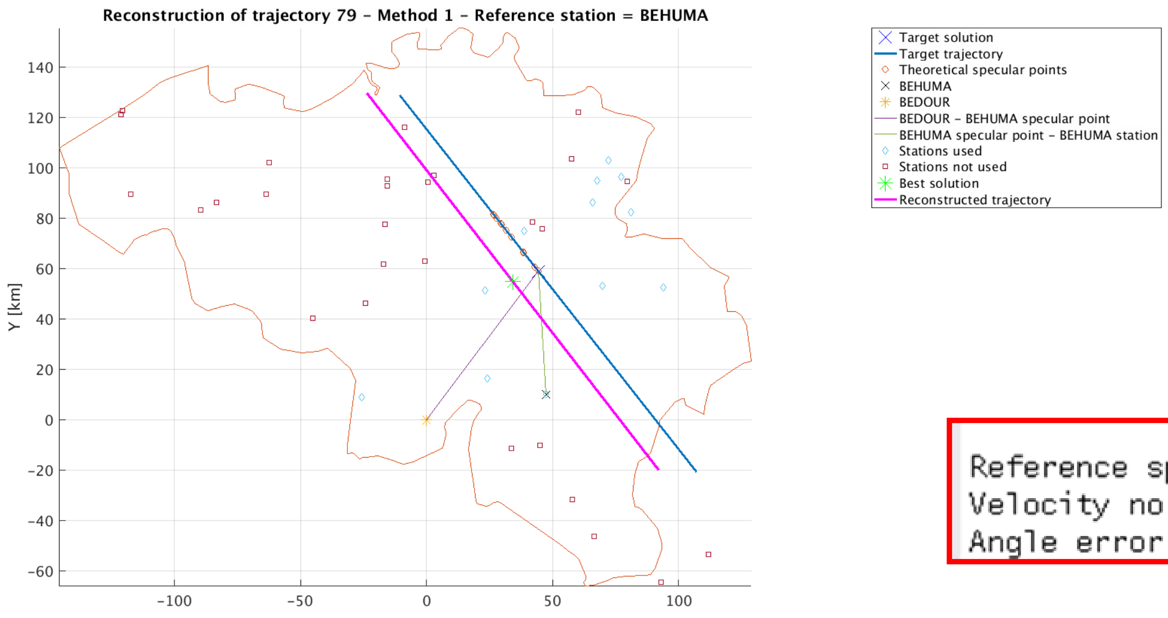
**Specular reflection** : $S_i = R_{Ti} + R_{Ri}$ must be minimum for each station *i*
**6 unknowns**: 3 coordinates of one specular point $P_0$ + 3 components of speed **v** (assumed to be constant)
**6 equations** : $dS_i / dt = 0$ i=1, …, 6

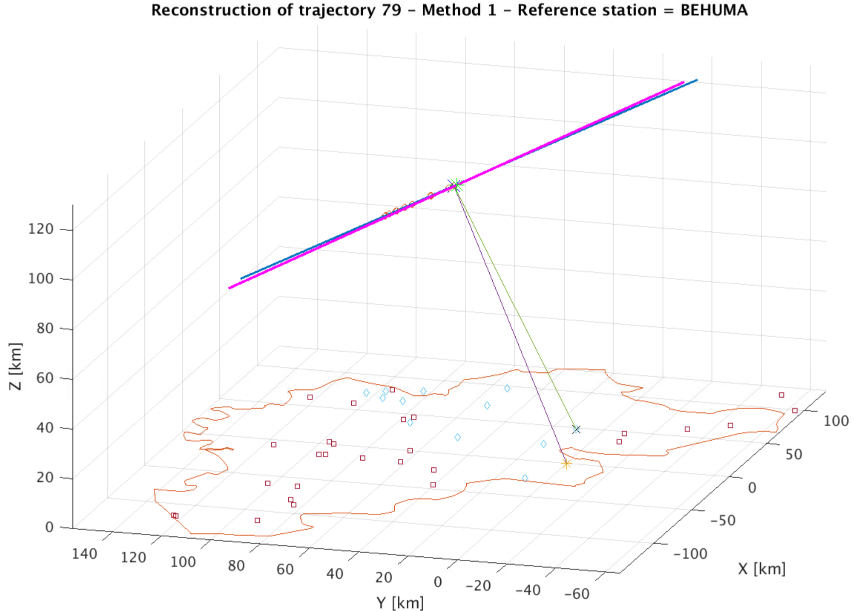



Set of ≥ 6 non-linear equations which contains the time delays $\Delta t_i$ between appearances of meteor echoes at station *i* and a reference station.

Non-linear solver + additional constraints on height of the specular reflection point (e.g., between 85 and 110 km) and speed values (≥ 11 km/s)

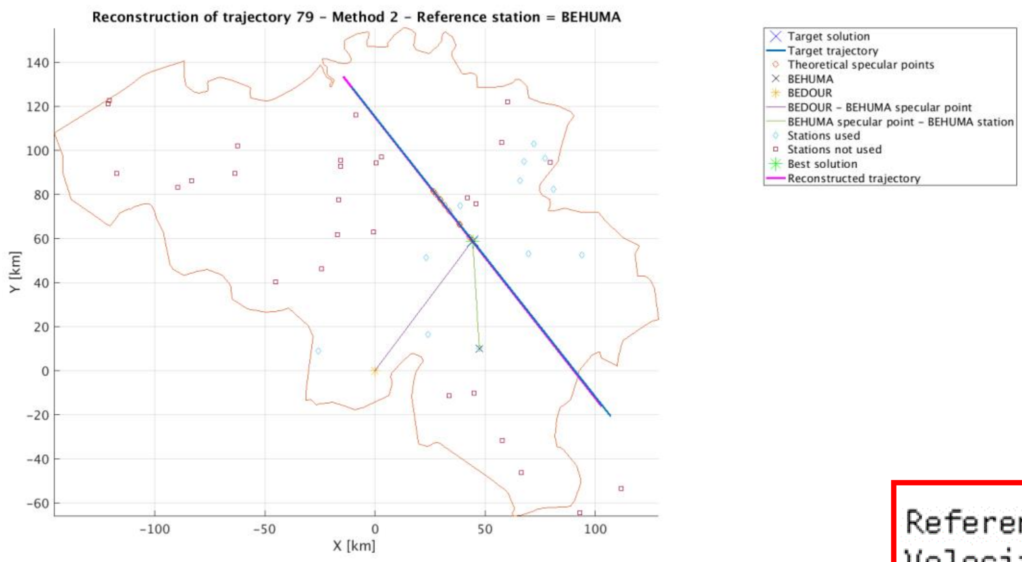
# Example of reconstruction : method 1



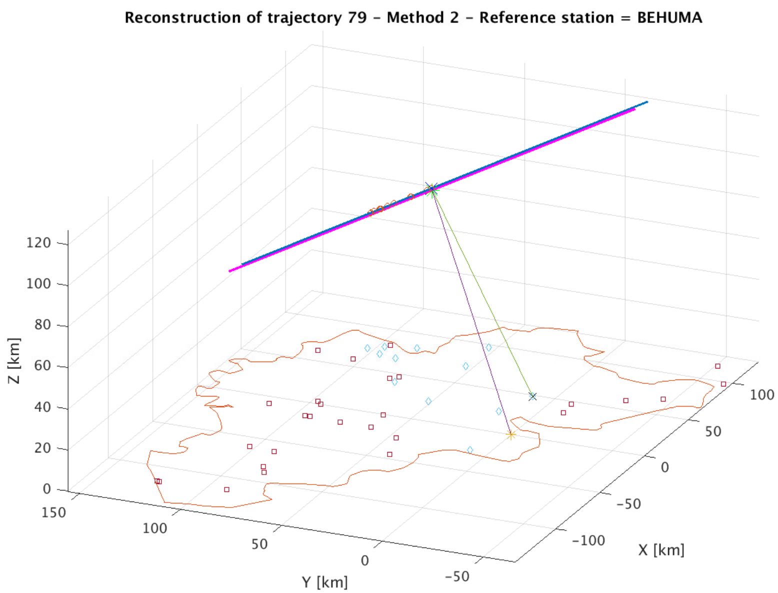




```
Reference specular point error [km] = 11.43
Velocity norm error [km/s] = 2.06
Angle error [°] = 1.14
```

# Example of reconstruction : method 2




```
Reference specular point error [km] = 0.83
Velocity norm error [km/s] = 0.89
Angle error [°] = 0.09
```



# Technical improvements for the BRAMS network in the frame of SORBET

# Increase of power

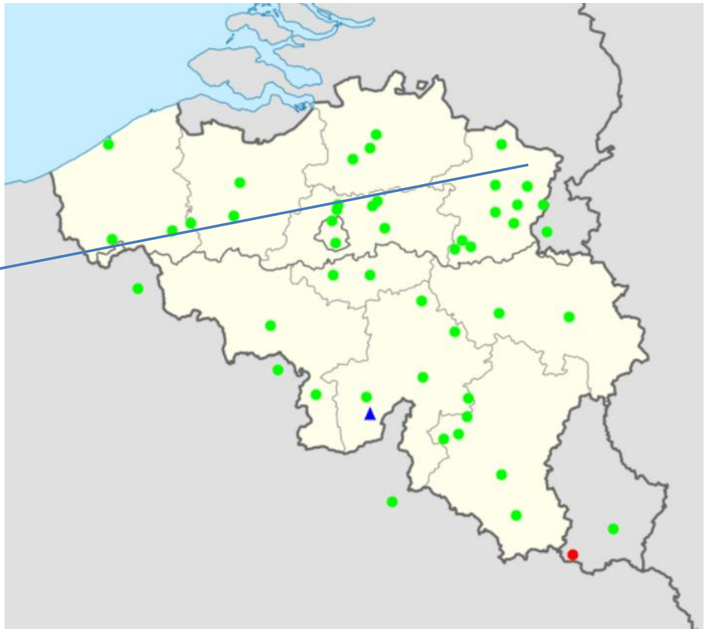
- Two main reasons :
  1. Some receiving stations are affected by local noise at our frequency that we cannot prevent. Usually, the background noise is ~ 5-6 dB too high and hides the fainter echoes for which SNR becomes too low
  2. Beyond 200-250 km from Tx, most Rx will only catch bright meteor echoes, which limits the sampled volume and prevents an international extension of the BRAMS network

- Recently we experienced issues with our power amplifiers, which revealed some unexpected and unwanted behavior. Need to replace them anyway!

- Goal : to transmit ~ 400 W CW + temperature-controlled environment (cabin)

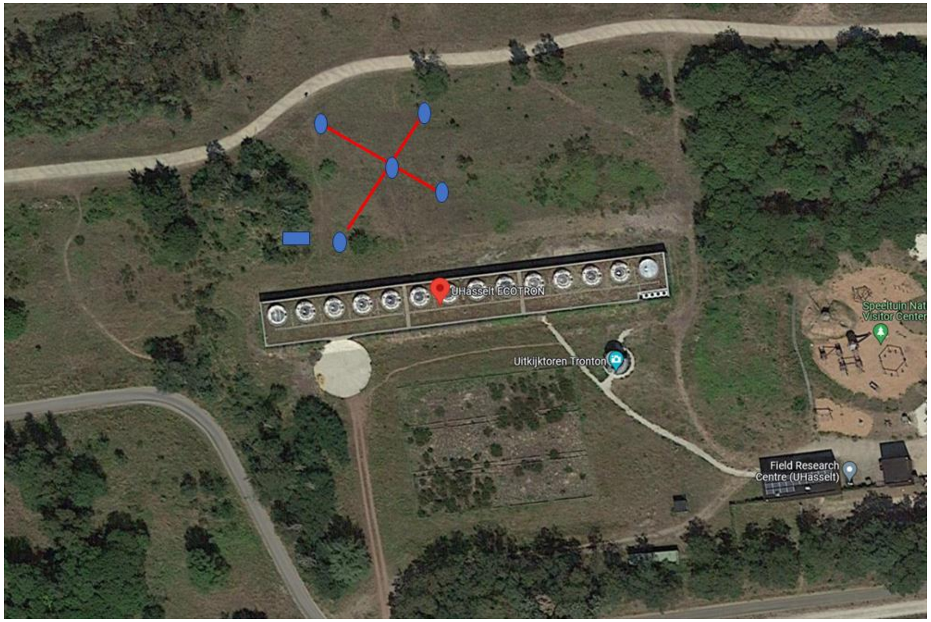
- Currently in the process of buying a new PA from a German company (MA). It would be custom-made for our frequency (MA)

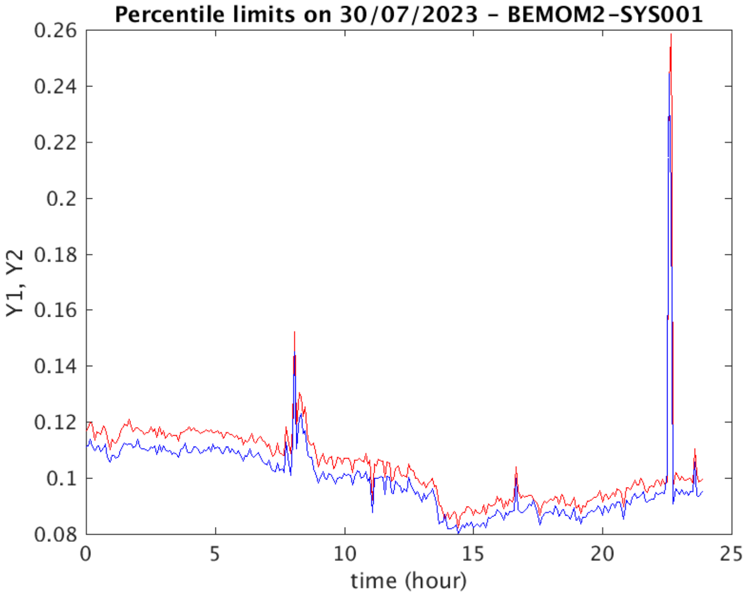
# Add of a second interferometer

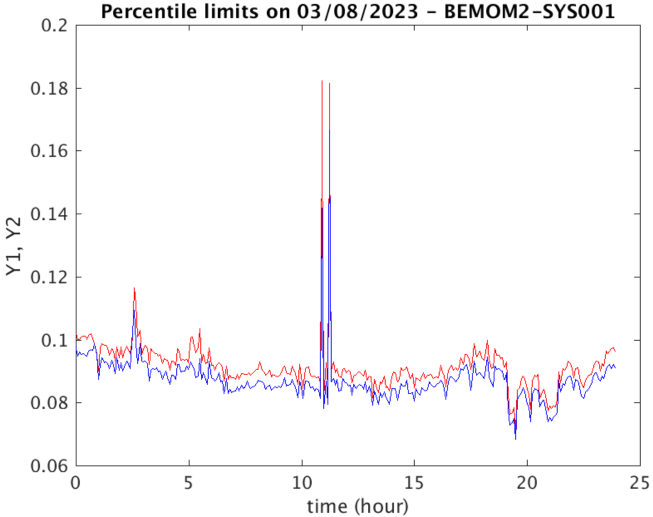



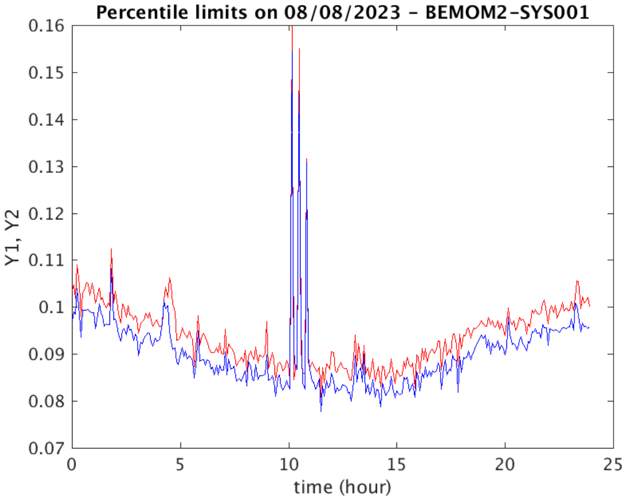
Large empty area near a National Park
Collaboration with Hasselt University

# Noise measurements



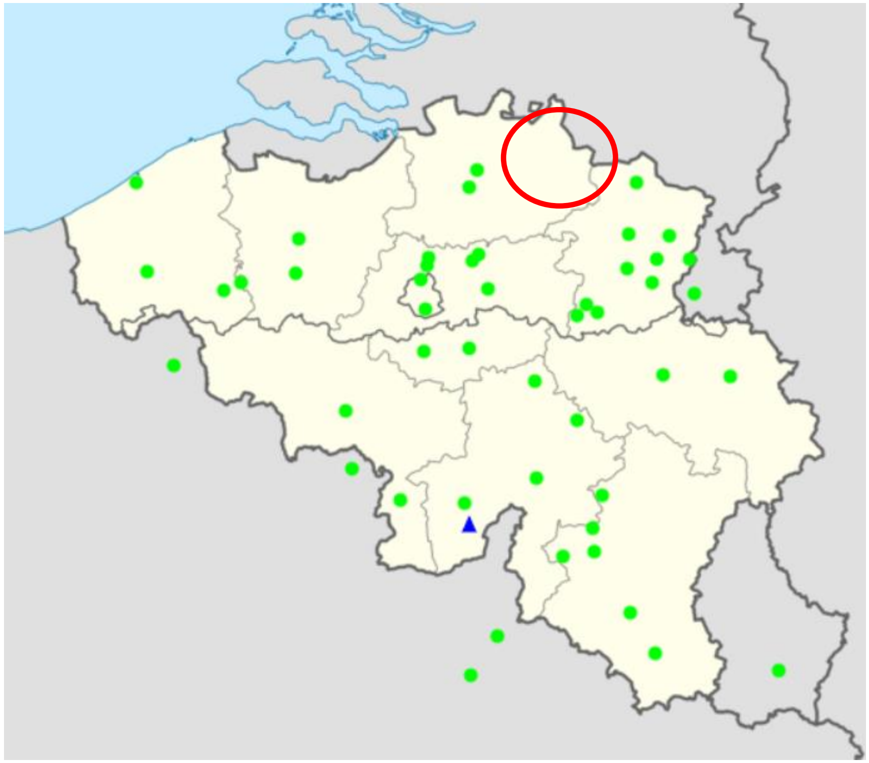



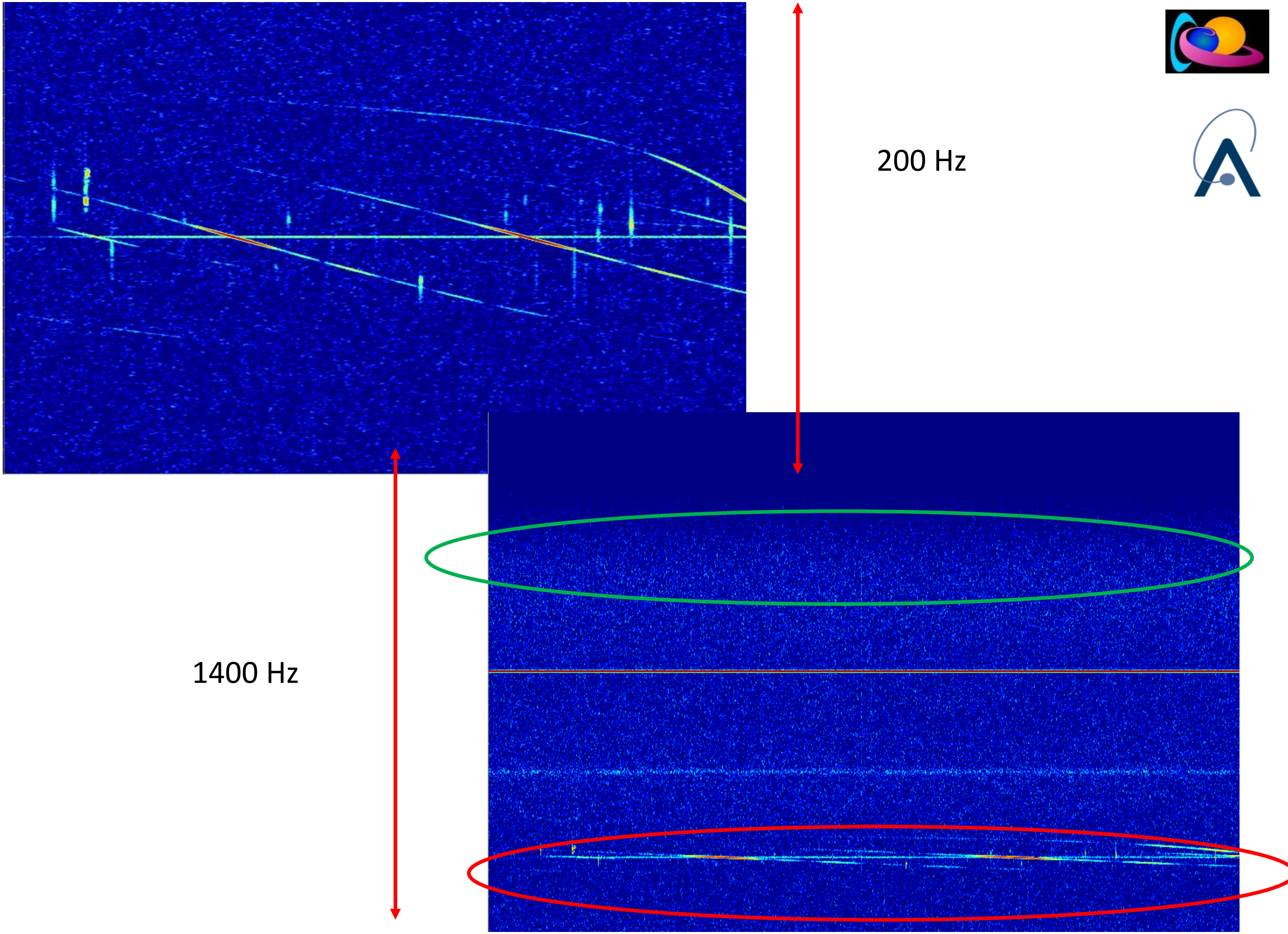



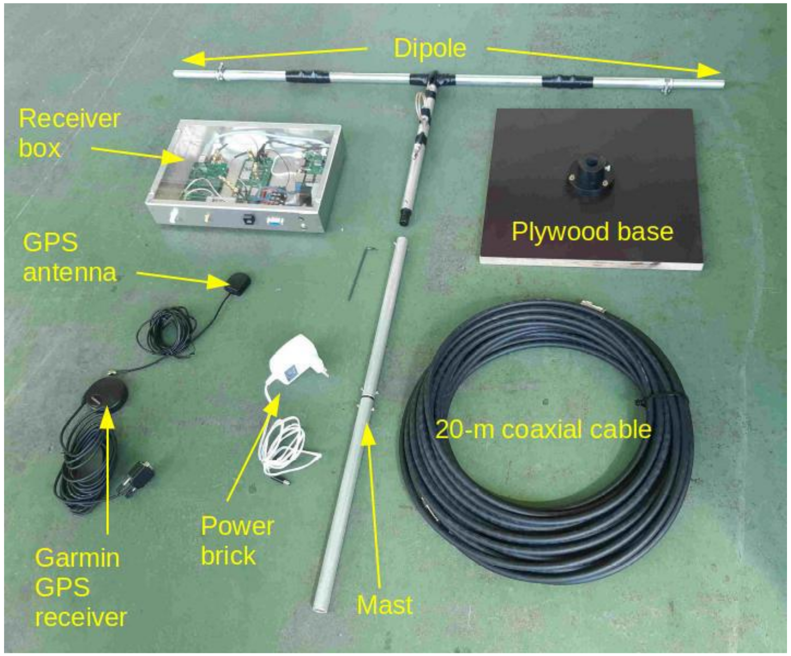
# Add of a second transmitter

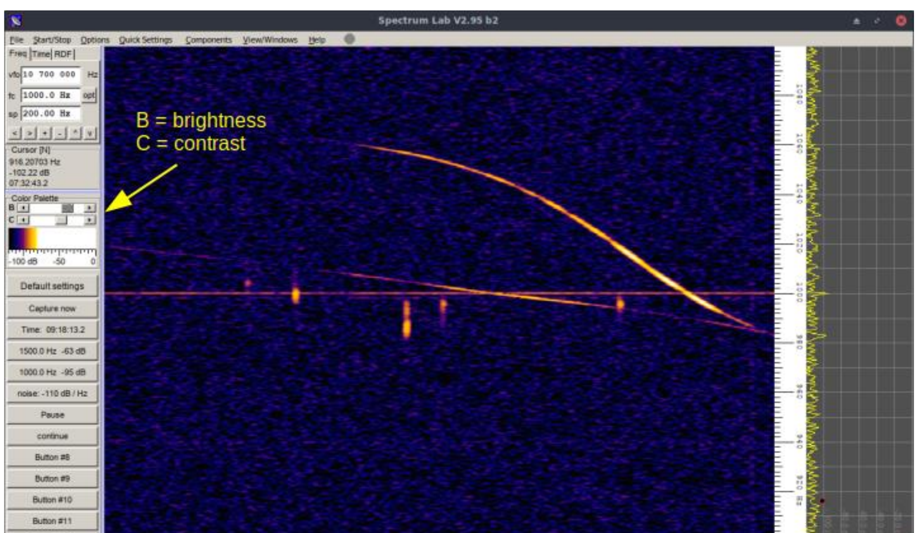
- Idea : use f = 49.9707 MHz → meteor echoes in the same audio bandwidth of current receivers
- Current Rx stations can be used as such. We double the number of pairs Rx-Tx
- RSP2 : still a lot of dynamics → no saturation
- Location : North of Belgium (red circle)




200 Hz
1400 Hz

# The MOMSTER project : BRAMS goes to schools



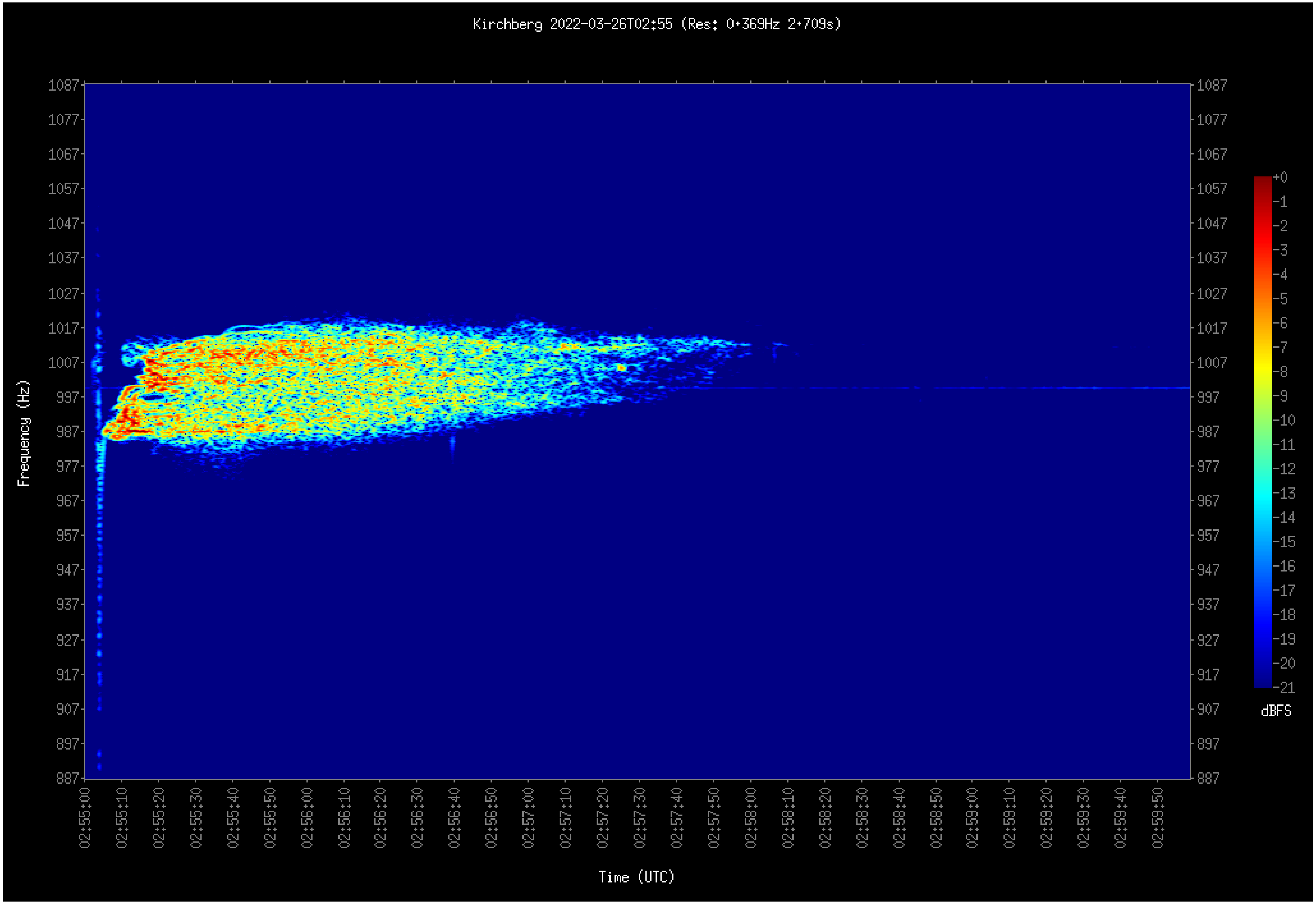




https:// momster.aeronomie.be

# Conclusions

- BRAMS network has reached technical maturity and is continuously expanding
- We are looking for stations in Germany near the Belgian border.
- MOMSTER project : looking for people interested in promoting this. We can share details.  Maybe looking at EU funding?

# Questions?


Kirchberg 2022-03-26T02:55 (Res: 0.369Hz 2.709s)
Frequency (Hz)
Time (UTC)
dBFS