The interferometer in Humain

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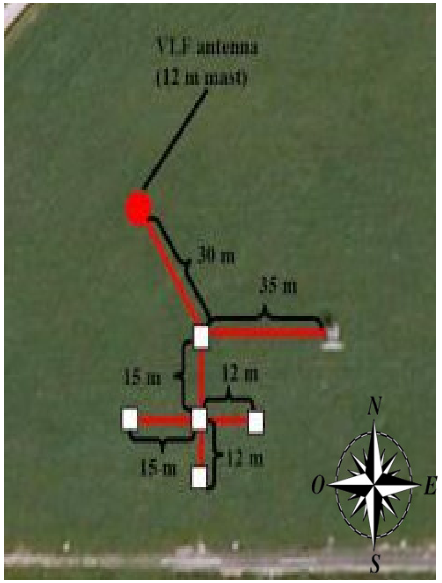
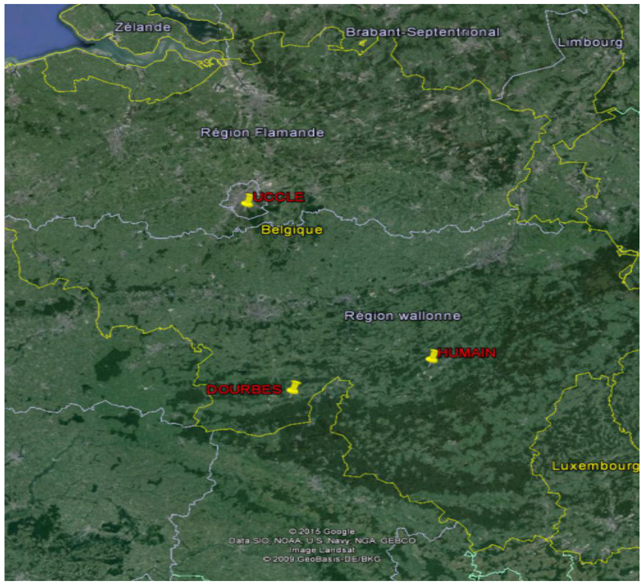
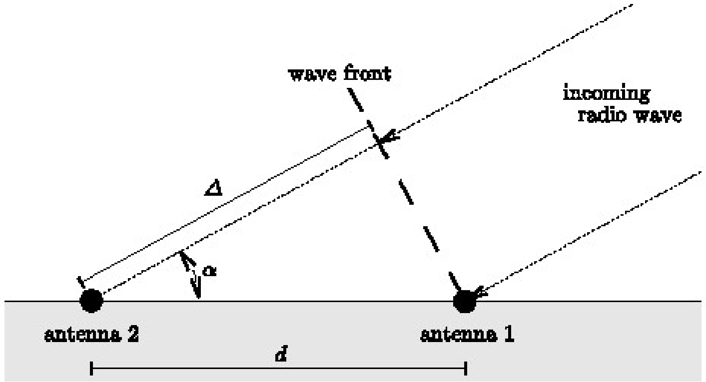
BRAMS interferometer

- Located in Humain (50.16°N, 5.22°E)
- 5 antenna configuration: 2 orthogonal sets of 3 aligned Yagi antenna with the central one common to the two sets.
- All antennas are mounted vertically to decrease the influence of the ground
- In principle it allows to determine the angle of arrival of the signal without ambiguity with an accuracy ~1° using the **Jones method (1998)**. It will help the retrieval of individual trajectories from multi stations observations.





Jones method



In principle, direction (α) of the signal can be deduced from the phase of the signal on antenna 2 relative to antenna 1 given by:

$$\phi_{21} = \phi_2 - \phi_1 = -2\pi \frac{d}{\lambda} sin(\alpha)$$

But : since $\phi_{21} \epsilon [-\pi; \pi] \rightarrow \xi$ determined unambiguously in $\left[-\frac{\pi}{2}; \frac{\pi}{2}\right]$ only if $d < 0.5\,\lambda$

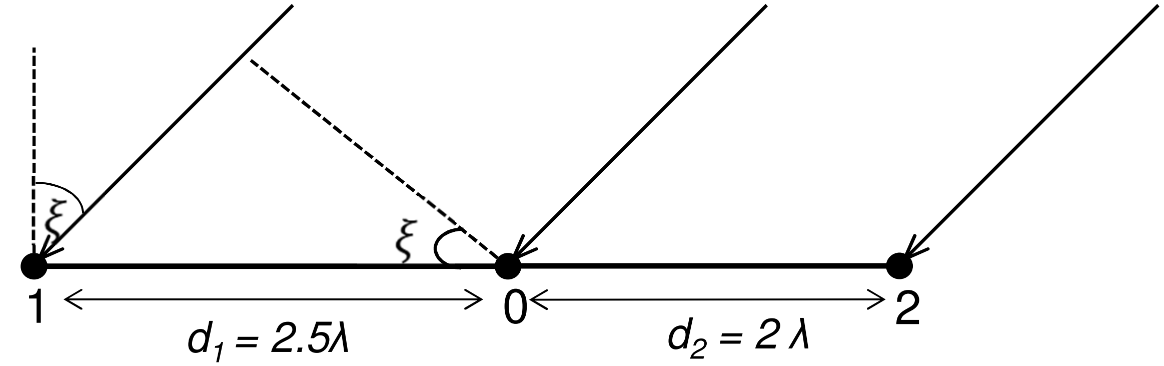
But : if $d < 0.5\,\lambda$:

- the error $\Delta\xi = \frac{\lambda \Delta\phi_{21}}{2\pi d cos(\alpha)}$ is important
- The mutual coupling between both antenna becomes so important that the measured values of ϕ can be in error.

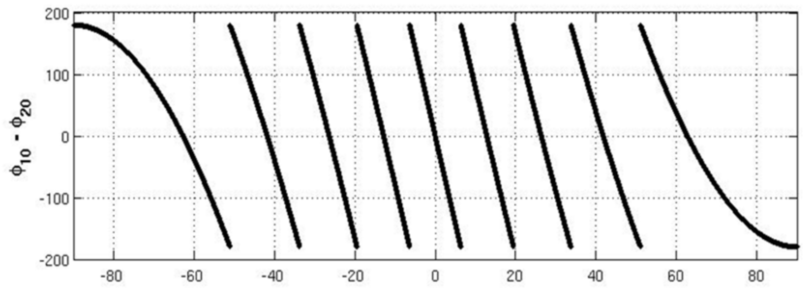
According to Jones, the best compromise between weak mutual coupling effect and weak error in AoA is to set the separation between antenna to a multiple of 0.5λ greater than 1.5λ

But

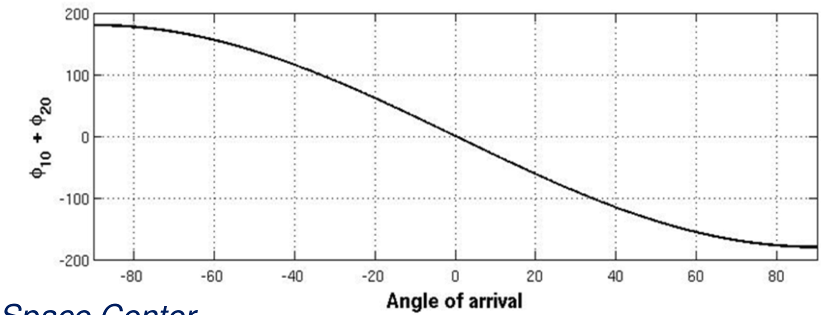
Solution to avoid ambiguity: add a 3rd antenna



$$\begin{cases} \phi_{10} = \phi_1 - \phi_0 = -2\pi \dfrac{d_1}{\lambda} sin(\xi) \\ \phi_{20} = \phi_2 - \phi_0 = +2\pi \dfrac{d_2}{\lambda} sin(\xi) \end{cases}$$



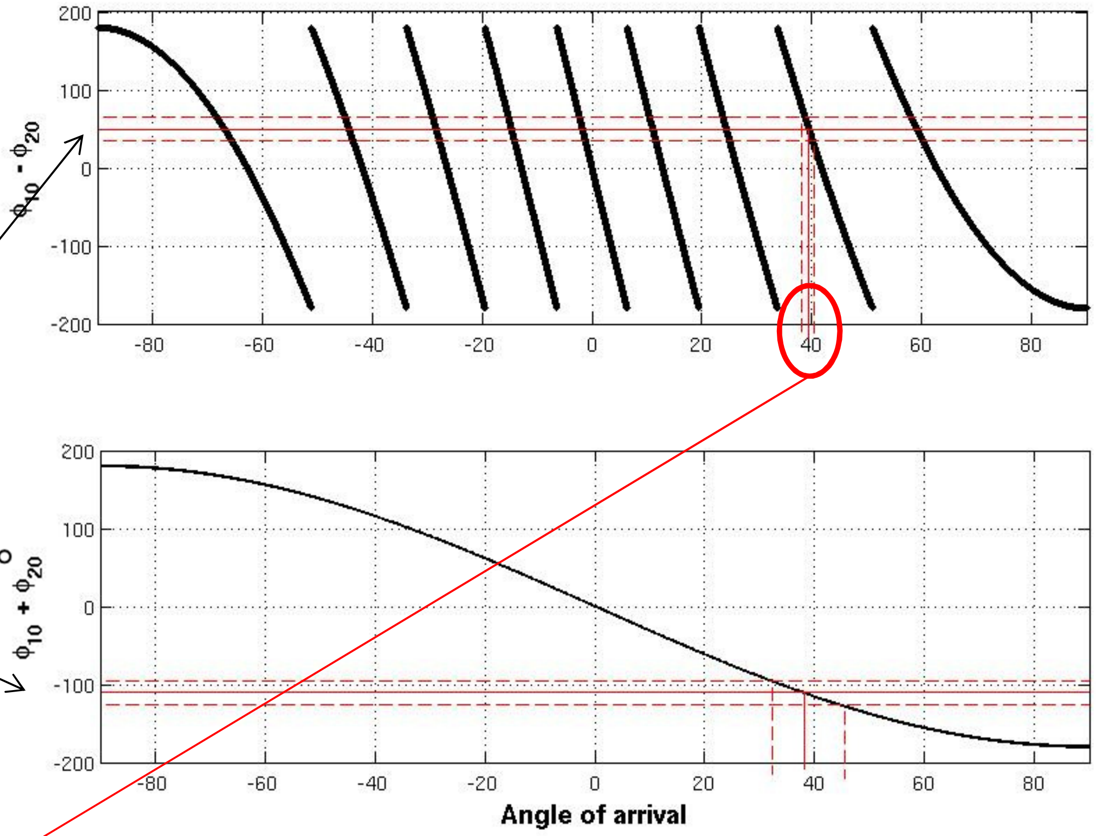
Several solutions,
Accurate



One solution,
Inaccurate

Example

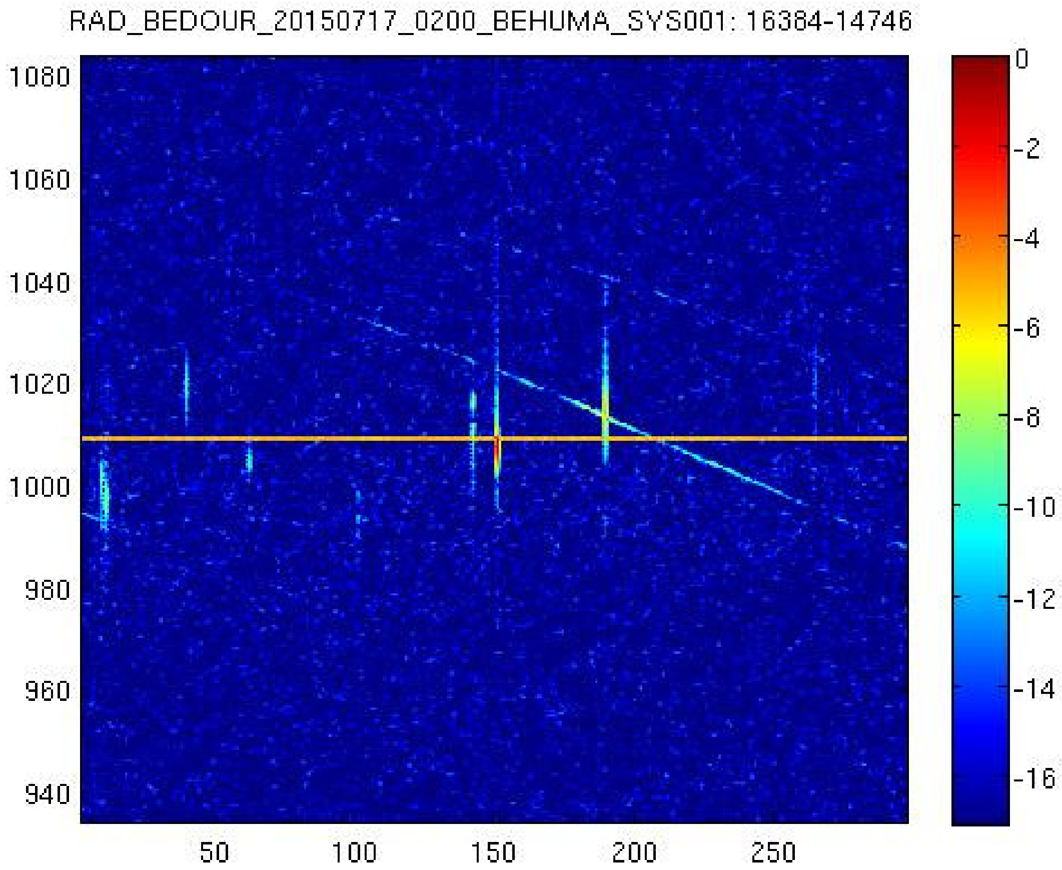
- Theoretical plots in black
- With $d_1 = 2.5\lambda$ and $d_2 = 2.0\lambda$,
- we have measured
  - $\phi_{10} - \phi_{20} = 50° \pm 15°$
  - $\phi_{10} + \phi_{20} = -110° \pm 15°$



$$\xi = 39° \pm 0.7°$$

Some results

We use a spectrogram deduced from measurements performed in Humain the 17th july, 2015 (02h00)

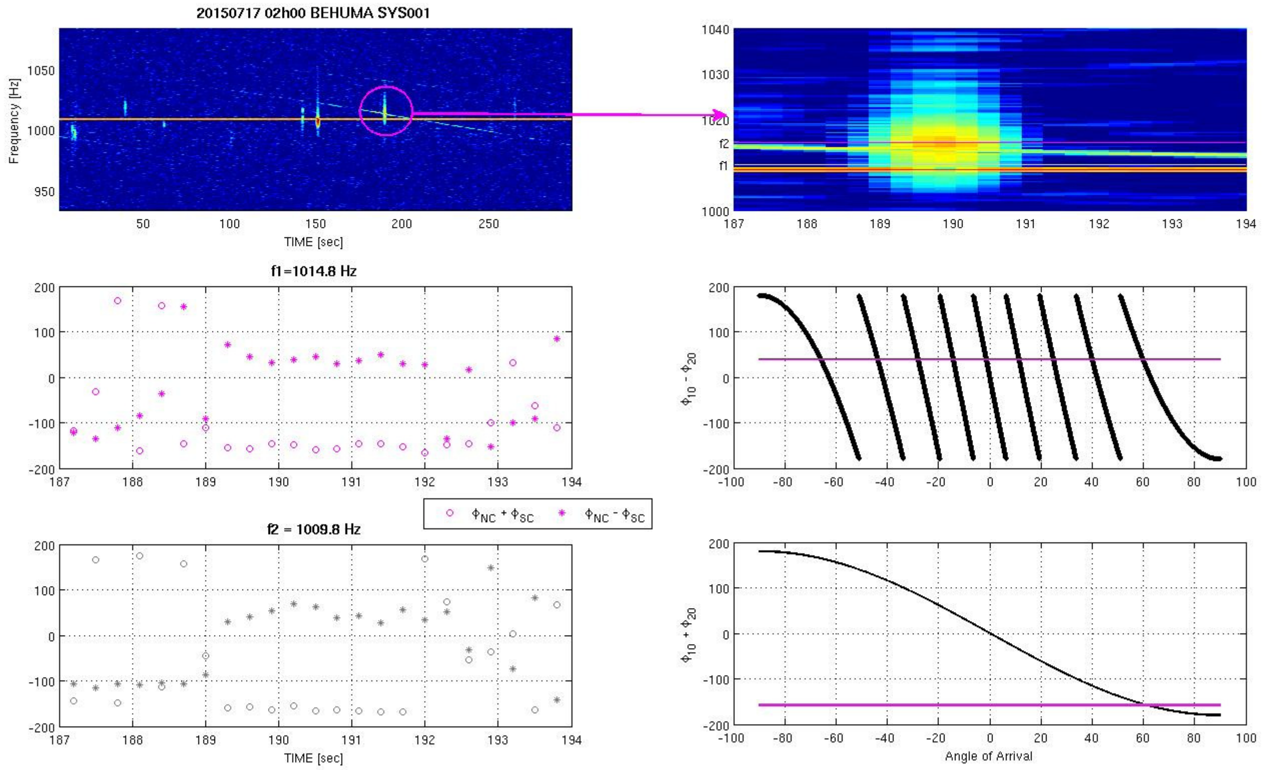


- We use a moving temporal window of 3 seconds to calculate the phase of this signal as a function of time for the frequencies of interest.
- We present in the following slides $\phi_{NC} - \phi_{SC}$ and $\phi_{NC} + \phi_{SC}$ as a function of time where

$$\phi_{NC} = \phi_{North} - \phi_{Center}$$
$$\phi_{SC} = \phi_{South} - \phi_{Center}$$

Similar results are obtained using east and west antennas.

Underdense meteor (two differents frequencies)



Before and after the meteor, sums and differences (of phase differences) are somewhat noisy.

During meteor, sums and differences are constant.

We can use these values to compute the angle of arrival

As expected, we found the same values whatever the frequency used

Calibration of the interferometer

RAMON:

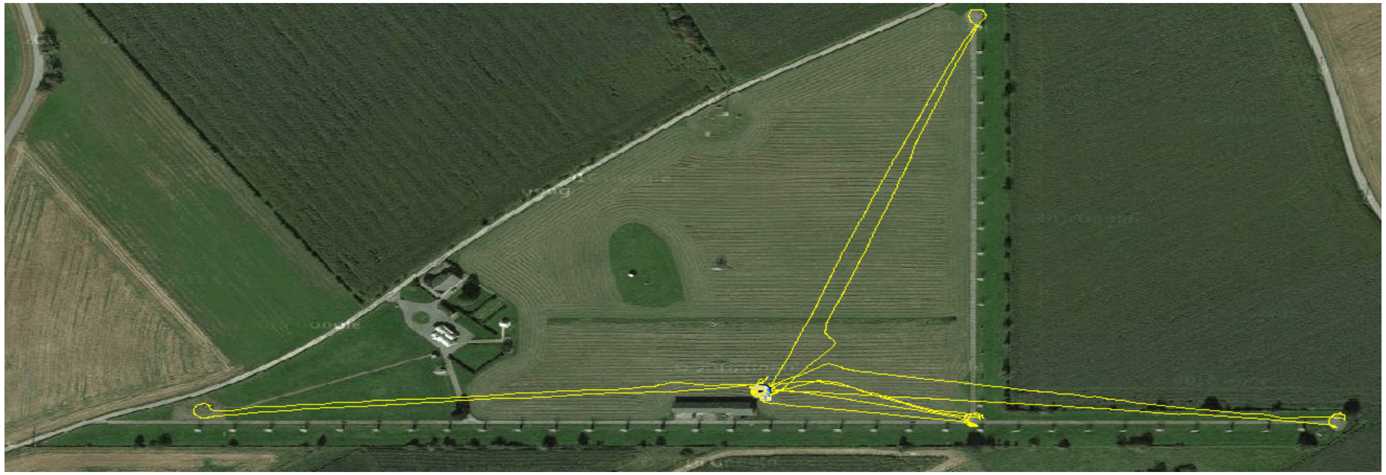
Equipped with a simple antenna
+ a transmitter at a given frequency
Attenuation of 20 dB

Difficulty : the drone must fly in the far-field domain of the interferometer

$$\sim \frac{2D^2}{\lambda} \sim 250 \text{ m}$$

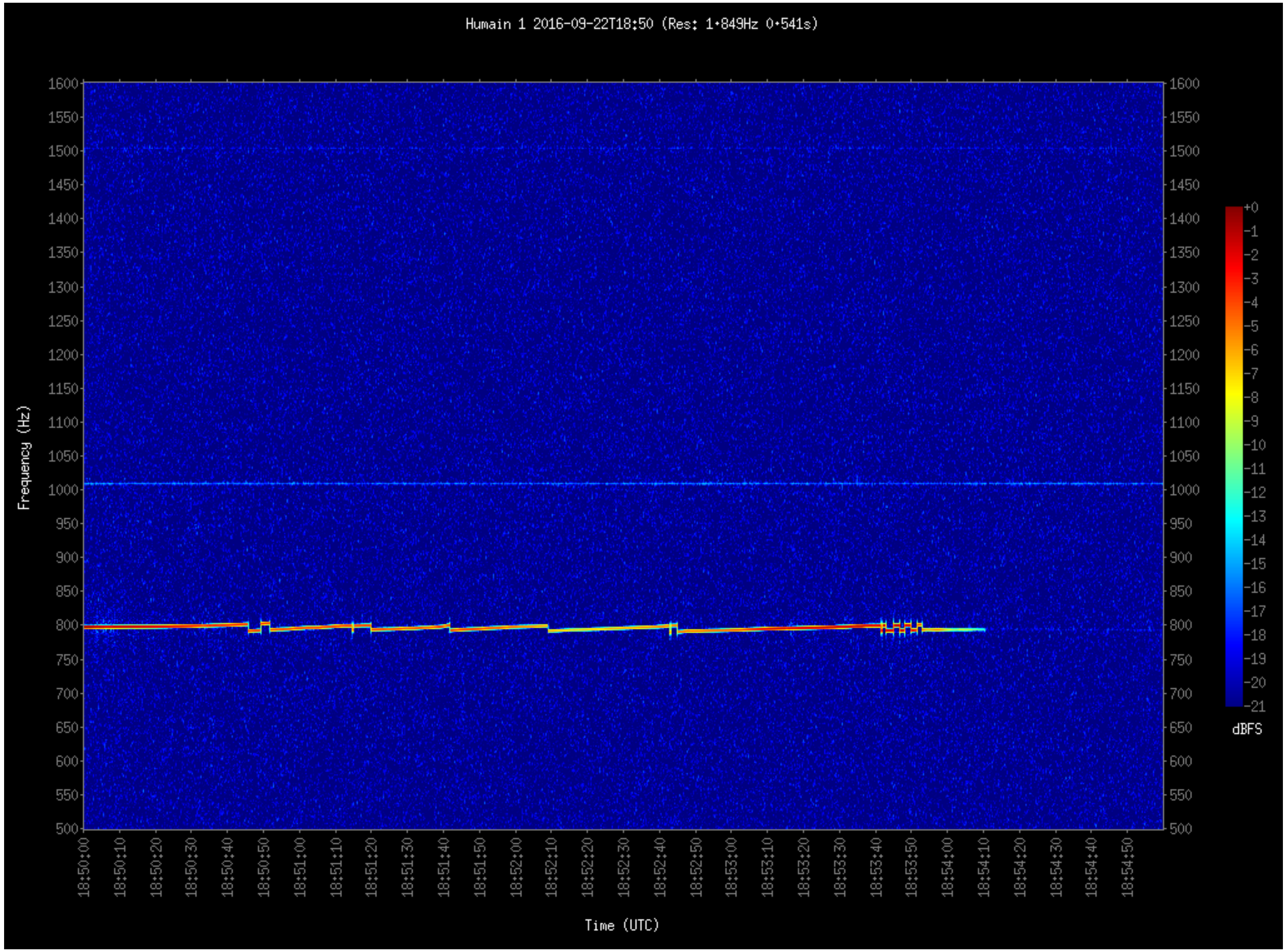
Calibration of the interferometer

Flight ID (n)	Point ID	Point Latitude (°)	Point Longitude (°)	Point Altitude (m)	Initial Time - UT (yyyymmddhhmmss)	Final Time - UT (yyyymmddhhmmss)	Azimuth (°)	Colatitude (°)	Distance (m)
92	NE	50.1943804	5.2573896	140	20160922104001	20160922104046	40.06	63.27	307.9086969
93	SE	50.1914857	5.2602146	140	20160922105006	20160922105052	105.95	70.80	418.0539225
94	SW	50.1915694	5.2512872	140	20160922110326	20160922110410	248.66	63.64	309.7145401
95	S	50.1915050	5.2573695	140	20160922111620	20160922111705	120.80	56.69	252.2122615
96	S	50.1915050	5.2573695	140	20160922112916	20160922113001	121.17	56.32	249.7619588



Attempt to apply the Jones method to retrieve the correct angle of arrival using the second flight.

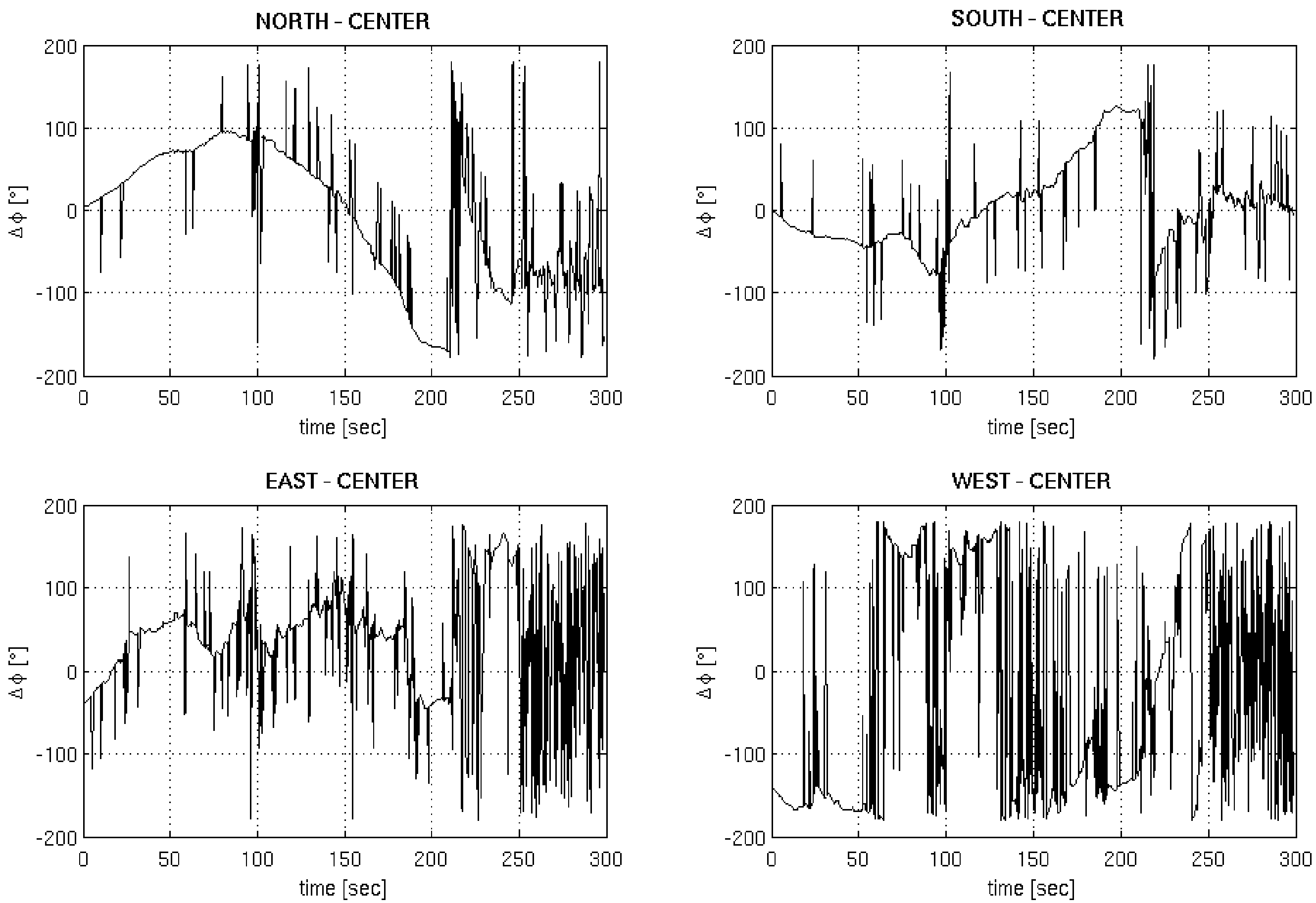
Calibration of the interferometer



Calibration of the interferometer

Application of the Jones method: very first results

At the frequency of the drone signal, we compute the phase difference as a function of time.
A structure seems to emerge but it remains some unexplained outliers.
The angle of arrival is not succesfully retrieved
After 250 s, the drone stopped emission



Work in progress to find the correct values