Numerical simulation of BRAMS interferometer in Humain

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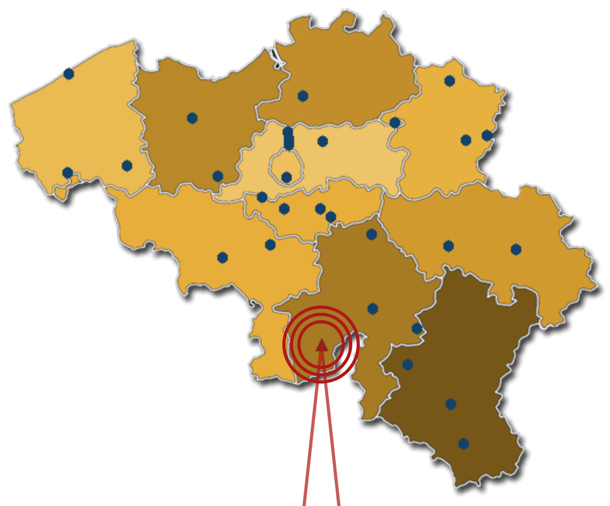
BRAMS

Belgian RAdio Meteor Stations



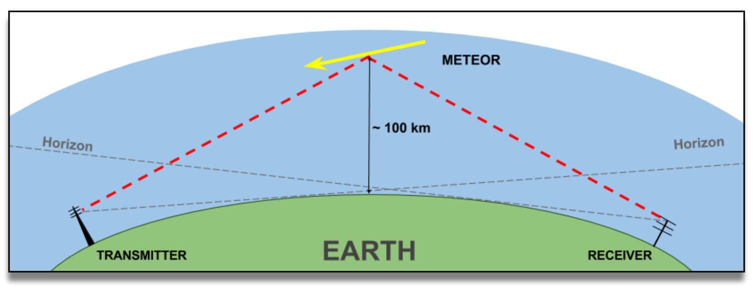
- **Main goal**: Study the meteoroid population
- Point-multipoint network with one dedicated **transmitter** and dozens of radio **receivers**
- Many receiving stations are hosted by ***amateurs*** or public observatories
- It is based on ***forward-scatter*** techniques

Most of the stations are ***basic receiving systems***

BRAMS Beacon

- Location: Dourbes
- Power: 150 W
- Signal: Continuous Wave (Sine)
- Frequency: 49.97 MHz
- Antenna System: Turnstile & Reflector

Forward scattering of radio waves



- The ionization trail produced by a meteoroid entering the Earth's atmosphere (***meteor***) can reflect a radio wave
- Receivers tuned to the transmitter's frequency can detect the signal (***meteor echo***)
- Note that the transmitter and receiver are not located in the same place

In order to obtain reliable information of meteoroids and meteoroid streams, among other parameters, it is important to know the performance of the antenna system regarding the many possible incoming directions of the meteor echo.

However, this value depends on many factors and usually getting reliable figures represents a challenge.

Performing **numerical simulations** are increasingly being applied successfully, using different methods.

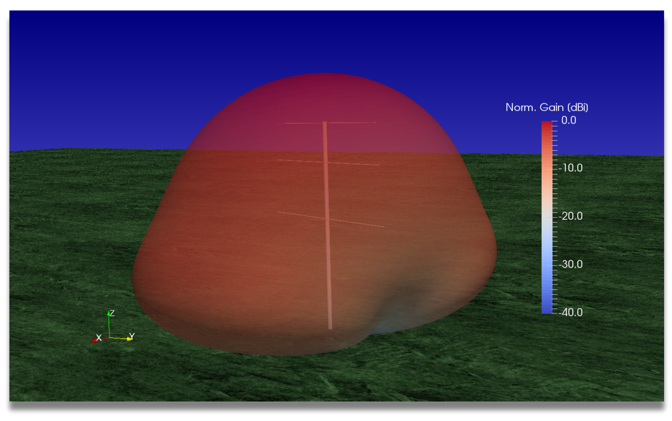
Typical Basic Receiving System

- Single antenna: 3-element Yagi
- Single receiver: ICOM IC-R75
- Amplitude & Frequency Calibrator
- GPS
- Sound Card + PC

Picture of the antenna located of the Uccle BRAMS station at the Royal Belgian Institute of Space Aeronomy (BISA) in Brussels

Antenna Directional Patterns

- Is a ***3D map*** of the antenna performance
- Depends on:
  - Antenna geometry
  - Relative position of the antenna and nearby objects/facilities
  - Terrain characteristics



Numerical simulation of the directional pattern of a typical BRAMS station antenna (Yagi 3-el) with a 90° elevation tilt

BRAMS Interferometer

Humain Radio Astronomy Station

The Solar Physics department of the Royal Observatory of Belgium (ROB) maintains and operates a solar radio-astronomy station in Humain (south of Belgium), which also hosts the BRAMS interferometer system.

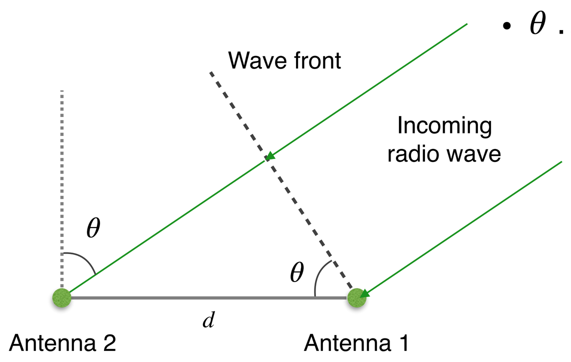
The array comprises five antennas and is intended to measure the direction of meteor echoes based on ***interferometry principles***.

Direction-Finding System

- The plane wave arriving at an angle is received by one antenna earlier than the other due to difference in path length
- The time delay τ of the incoming wave is given by

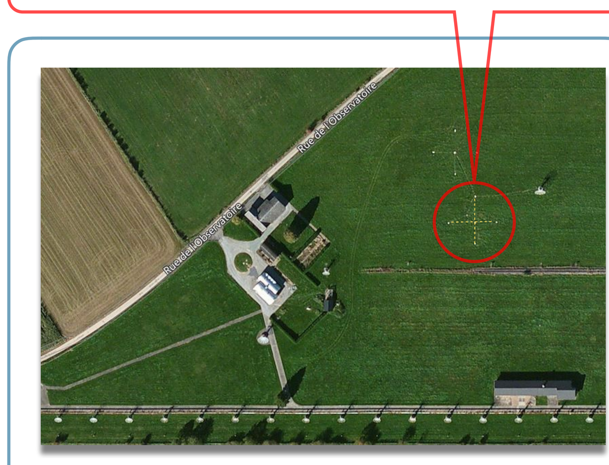
$$\tau = \frac{d \cdot \sin\theta}{c}$$

where:
- d … distance between antennas
- c … speed of light
- θ … Angle of Arrival (AoA)

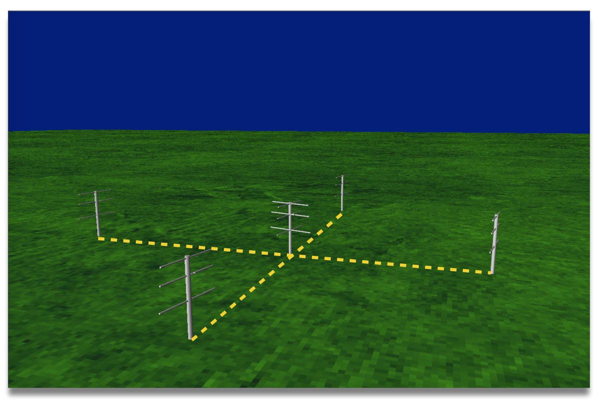


- Angular measurements in 3D can be obtained from two of such arrays arranged orthogonally

General view of the BRAMS interferometer in Humain.



Satellite view of the Humain radio-astronomy station facility. The array of antennas form a cross (dotted lines in yellow).



Visualisation of a computer-based modelling of the array.

Under the *direction-finding* operation, the interferometer works as a unit, so the antenna pattern of the whole array is needed in order to understand appropriately the level of the received signal.

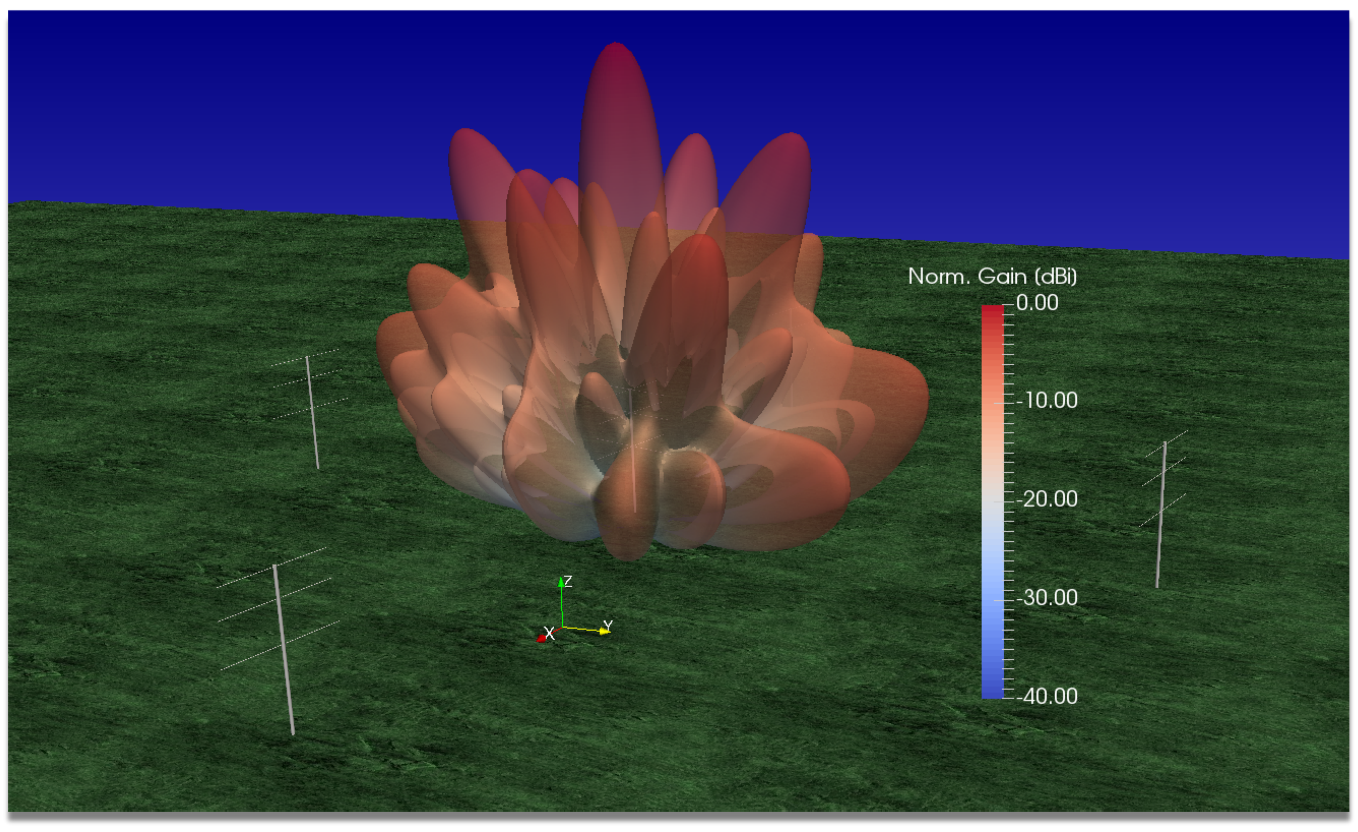
The mutual coupling between adjacent closely spaced antennas is an important consideration which can lead to errors in the measurements. These mutual coupling effects diminish as the spacing is increased, i.e., as the mutual impedance decreases. It is necessary taking this effect into account in order to obtain a reliable (antenna) array pattern.

Array Modelling

In order to obtain the directional pattern of the BRAMS interferometer, the initial approach of modelling the full array was adopted using *Numerical Electromagnetic Code* (NEC), which is a software package based on the *Method of Moments* (MoM) technique for analysing the electromagnetic response of an arbitrary structure. It is capable of dealing with ground effects and intrinsically takes into account any possible mutual coupling between the antennas.

Results

Numerical Simulation



Visualization of the (antenna) array pattern obtained by numerical simulation of the BRAMS interferometer in Humain. Gain is normalized regarding the maximum value (G_{max} = 14 dBi)

Detailed models of the antennas were prepared, including the conductivity of their elements as well as physical devices available in the antenna used for matching its impedance to Z_{in} = 50 Ω. Terrain characteristics (relative permittivity ε, and conductivity σ) were also taken into account in the model.

The receivers of the interferometer are *synchronized* which means that —initially— the feeders (excitation point of each antenna) must be kept aligned aligned for simulation purposes.

The result is shown in the gain-normalized visualization of the Figure on the left of this text. A total radiation pattern with very complex features is observed.

Summarizing the main characteristics:

- Main lobe pointing to the zenith with a **maximum gain of G_{max} = 14 dBi**
- Presence of **many secondary lobes** in ~65° elevation with only 1 to 2 dB difference below the maximum
- Existence of **several nulls** of 10 to 15 dB below the maximum in many directions (~80°, ~60°, ~45°, ~35°, …)

All these findings point to the fact that, if no phase manipulation is applied to the signals registered by the different receivers, the array will have *preferred observing directions* in the sky.