Pulse radar transmitter for the Humain BRAMS array ?

Lucas Maurice, Adrien Manuel Mascarenhas, Antonio Martínez Picar, Christophe Marqué
Contact: `l.maurice@elisa-aerospace.fr`

Royal Observatory of Belgium
ELISA AEROSPACE ECOLE D'INGÉNIEURS
Solar-Terrestrial Center of Excellence

Backscatter

Radio Detection and Ranging (RADAR) is a system that uses radio waves to detect objects and measure their distance. It sends a radio signal toward an object, which is then *backscattered* to the radar. The range (distance) to the object can be estimated by measuring the time it takes for the signal to return.

The backscatter technique has been employed to detect radio meteor echoes and measure their height in the atmosphere.

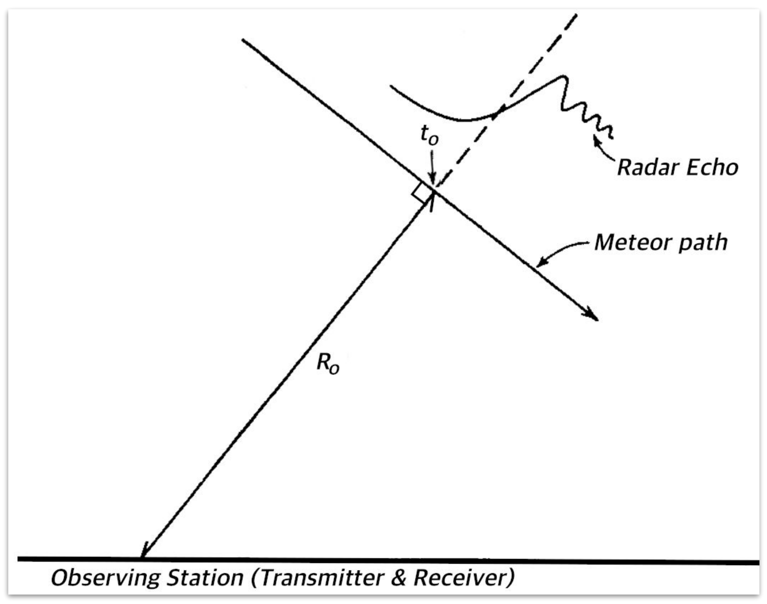

Figure 1 - Geometry of the meteor path relative to the observing station.

The Humain Radio-Astronomy Station

The Royal Observatory of Belgium manages a radio-astronomy site in southern Belgium, which houses a series of instruments, including the Small Phased Array DEmonstrator (SPADE) and the interferometer of the Belgian RAdio Meteor Stations (BRAMS).

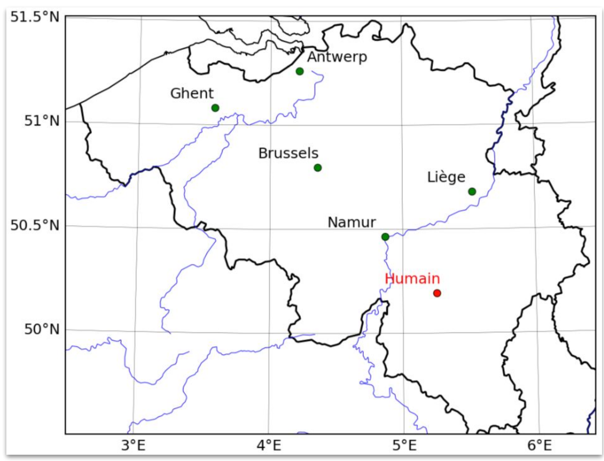

Figure 2 - Map of Belgium showing the location of the Humain Radio-Astronomy Station.

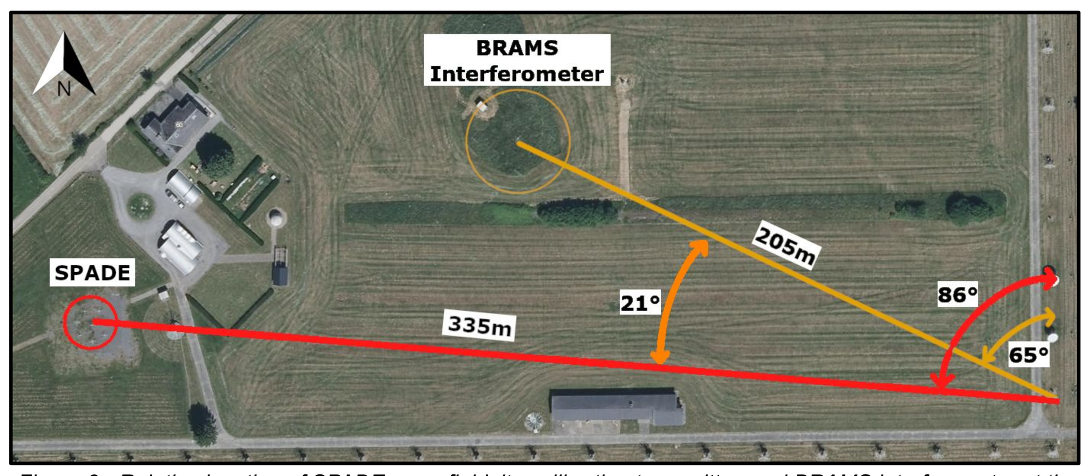

Figure 3 - Relative location of SPADE array field, its calibration transmitter, and BRAMS interferometer at the Humain Radio-Astronomy Station.

SPADE

- Radio-telescope built to monitor solar activity.
- Array of 8 elements & reflective ground plane.
- Frequency range: 20 – 80 MHz.
- Employing Software Defined Radio (SDR).

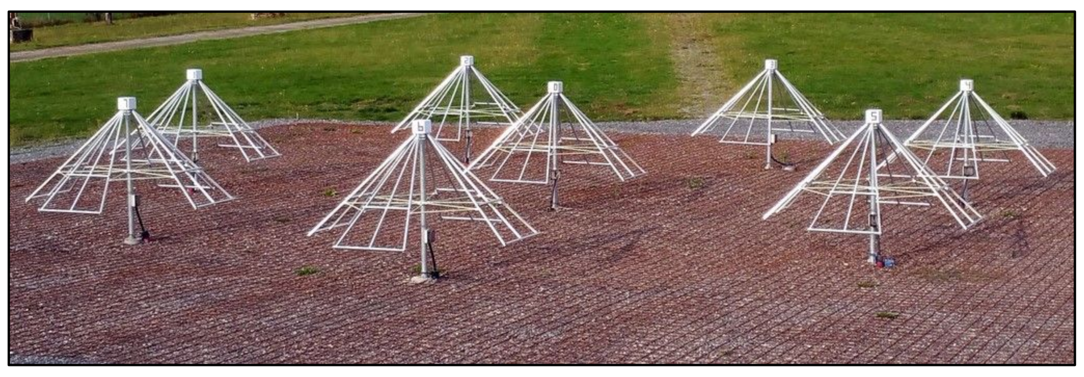

Figure 4 - View of the array field of SPADE.

BRAMS Interferometer

- BRAMS is a network of receiving stations to study meteors.
- Meteor echoes are observed by *forward-scattering* of a signal (f = 49.97 MHz) emitted by a dedicated beacon.
- BRAMS station in Humain is a 5-element interferometer.

A setup will provide periodically a well-known signal during short periods of time to perform SPADE calibration.

Is it possible to configure this transmitter to build a meteor pulse radar?

Humain Meteor Radar Design

Antenna Configuration

- The BRAMS interferometer is more sensitive towards the zenith.
- The transmitting antenna pattern should cover SPADE and the zenith.
- Several antenna pattern simulations shown that a *Log-Periodic Dipole Antenna* (LPDA) placed at 4.5 meters height and aligned along North-South axis can fulfill this requirement.

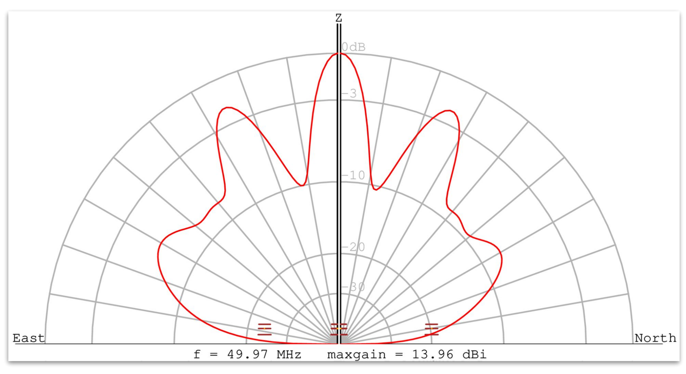

Figure 5 - Simulated vertical radiation patterns for the BRAMS interferometer.

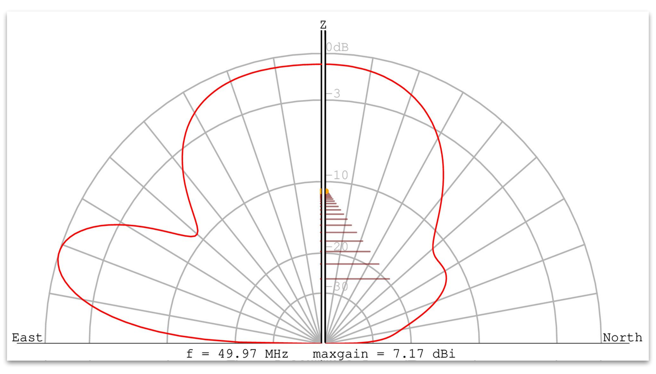

Figure 6 - Simulated vertical radiation patterns for the LPDA antenna at 4.5 m height.

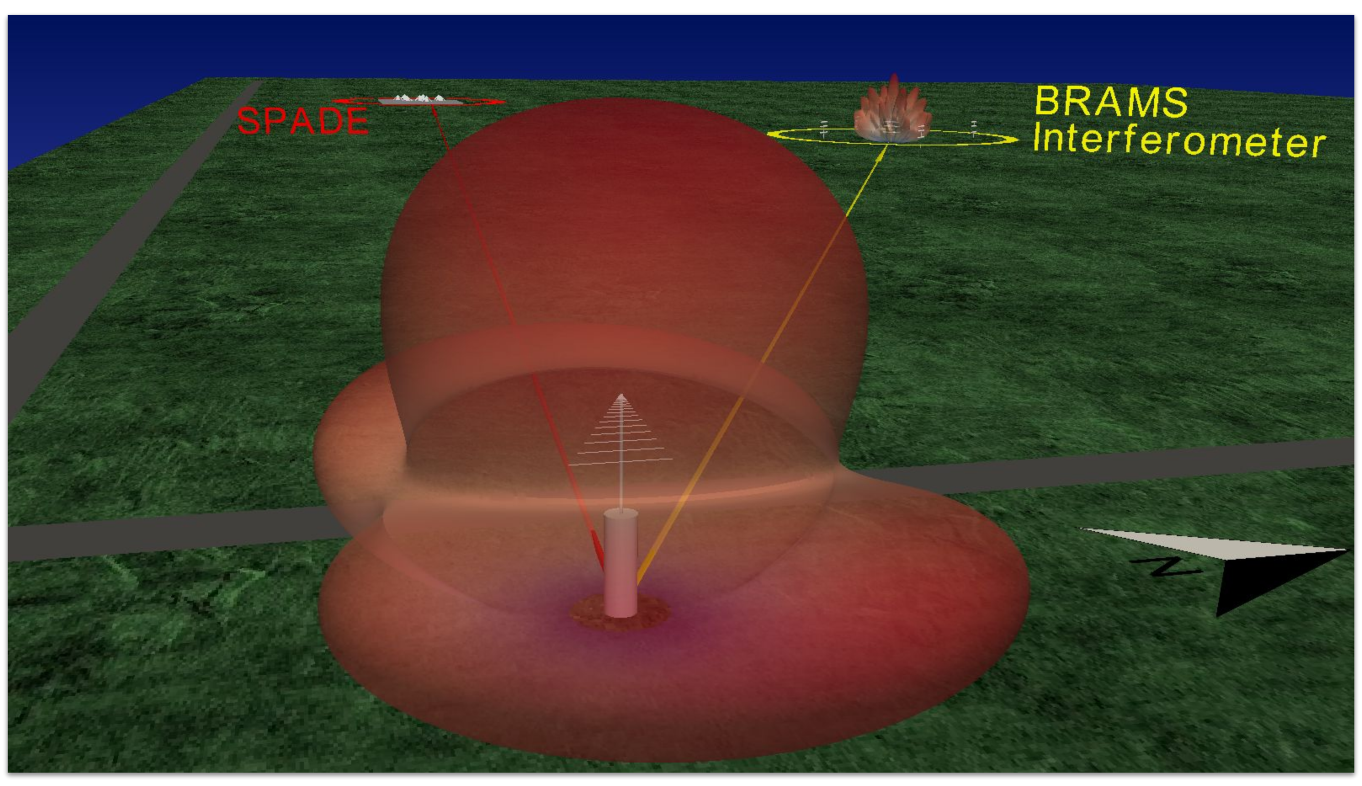

Figure 7 - 3D view of the radiation patterns for the radar transmitting antenna, the receiver (BRAMS interferometer) and SPADE.

Transmitter Configuration

- Software Defined Radio (SDR) technology will be used as a platform, most likely running on a Single Board Computer (SBC).
- The SBC will enable scheduling to operate as standard signal emitter for SPADE and as pulse generator for the BRAMS radar. GNU Radio will be used to generate the scripts required for both operational modes.
- The pulse will modulate a pure sine signal at a frequency slightly lower than the BRAMS beacon, ensuring that the regular forward-scatter observations remain unaffected.

Parameter	Value
Pulse Repetition Frequency	900 pps
Pulse Width	70 µs
Duty cycle	6.3 %

Table 1- Parameters for the proposed pulse radar.

Range determination

- Synchronization between transmitter and receiver is crucial.
- *White Rabbit Precise Time Protocol* offers sub-nanosecond accuracy while compensating for network-induced delays.

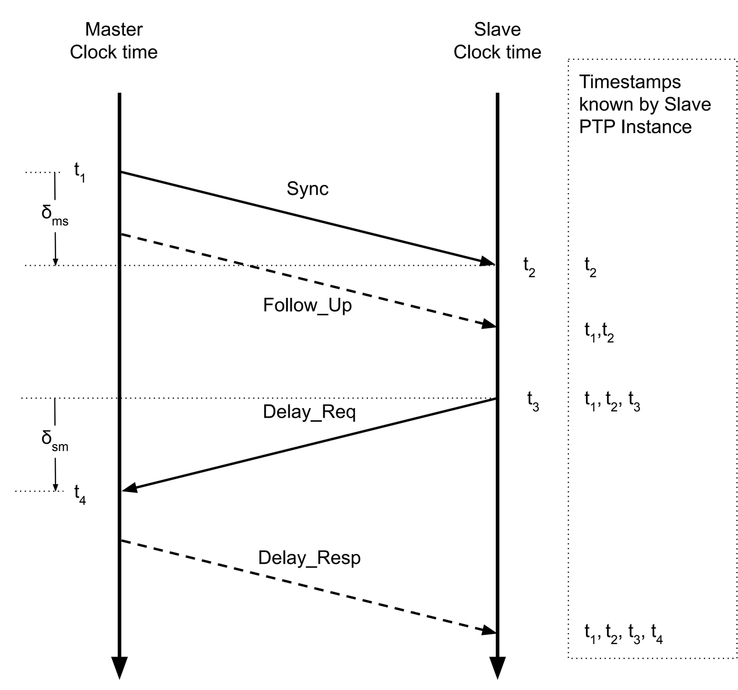

Figure 8 – White Rabbit PTP synchronization sequence diagram.

Transmitting Power

- For electron line densities slightly below $2{\times}10^{14}$, a height detection range of 70–120 km can be achieved with 12 kW output power.

Discussion

- Several SDR transmitters are available on the market. *HackRF One* stands out as a suitable choice due to its flexibility and low cost.
- The power budget impose the use of amplifier(s) to reach a total gain of approximately 60 dB. This will likely be the most expensive component of the design.
- A dual-mode transmitter can be set up at the Humain Radio-Astronomy Station using a strategically placed antenna, an SBC paired with an SDR receiver, and GNU Radio scripting. For the pulse radar transmitter operation, White Rabbit PTP synchronization and high-gain power amplifier(s) are required.