# Radio set-up design for the FRIPON project

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The French FRIPON (Fireball Recovery and InterPlanetary Observation Network) project consists of about 100 allsky cameras which are currently being installed at various locations in France. The purpose of FRIPON is to detect large meteors thanks to optical systems, to compute the orbits of their parent bodies, and to predict as precisely as possible the impact locations of the related meteorites, if any. Video cameras deliver accurate target positions but lack the precision required for accurate meteor velocity measurements, a precision which is mandatory for good meteoroid orbits and meteorite location assessments. Therefore 25 radio systems, which are in charge to deliver accurate meteor velocities data, are being installed to complement the FRIPON video network.

## 1 Introduction

The French FRIPON project is using about 100 allsky video cameras (Colas, 2014) for observing large meteors. The video data are processed to obtain the orbit parameters of the related parent bodies, and also to determine the impact locations of the potential meteorites. Video systems are supposed to deliver good precision positional data, but due to the refreshment rate of the video frames, the computed meteor velocity would not be precise enough to obtain accurate parent body orbital parameters. Radio meteor observations should allow more accurate meteor velocity measurements, therefore about 25 radio systems are going to be added to the FRIPON video cameras network.

## 2 Radio observations principle

Due to its very high geocentric speed (~11 km/s up to ~72 km/s), a meteoroid creates a long column of free electrons when hitting the air molecules of the Earth atmosphere. During the first part of its travel in the upper atmosphere, the meteor body itself is surrounded by a plasma envelope. The ionized trail and the free electrons surrounding the moving body are able to reflect radio waves, as long as the frequency of these radio waves used to observe the meteors is lower than the critical frequency $f_c$.

$$f_c = \sqrt{\frac{e^2 \times N_e}{\Pi \times m}} = 9 \times \sqrt{N_e} \qquad [1]$$

with $m$ and $e$, representing the electrical charge and the mass of the electron, $N_e$ the number of free electrons per $cm^3$ and $f_c$ the critical frequency expressed in megahertz. The echoes of radio waves radiated by a distant transmitter which are scattered on the plasma surrounding a meteor are called head echoes. Head echoes are detectable as long as the frequency used to observe them is lower than $f_c$. (Close et al., 2002). It is desirable to use the shortest wavelength possible to observe the meteor head echoes, because the ERS (Equivalent Radar Surface) of the small sized plasma envelopes are not large. Knowing that the amplitudes of the meteor echoes decrease according to a $1/f^3$ law, powerful radio transmitters have to be used for detecting the head echoes.

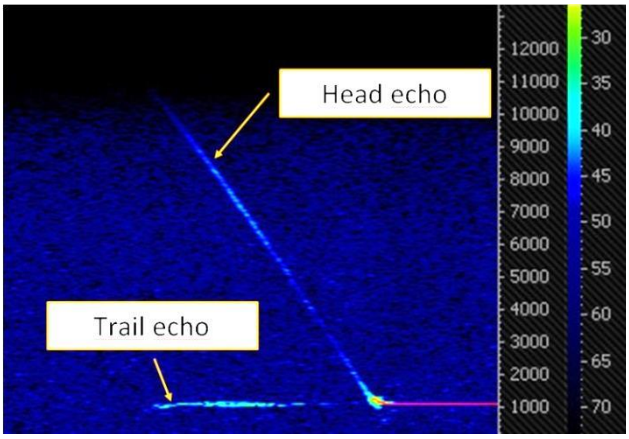


*Figure 1* – Example of spectral analysis of a meteor head echo received from GRAVES transmitter at Pic du Midi observatory.

If the observer and the transmitter are considered as not moving, a head echo at the observation location is affected by a variable frequency shift due to the Doppler-Fizeau effect. The moving target is illuminated by an incident radio wave which frequency is shifted according to the radial velocity between the meteor and the transmitter location. This radio wave is scattered by the meteor plasma. At the observation location, the frequency received from this scattered wave is shifted again in frequency according to the radial speed between the meteor and the observation location (Steyaert et al., 2010). So the resulting double Doppler frequency shift is directly linked to the 3D-geometry of the transmitter, receiver and moving target (see *Figure 1*). Therefore, using several time-synchronized radio receivers and a single transmitter, the reduction of the Doppler-Fizeau shifted head echoes recorded at separate locations should offer good precision velocity information.

## 3 Radio set-up

### *Radio system configuration*

At least two radio transmitters will be used for the FRIPON project: the military GRAVES radar located near Dijon (143.050 MHz) in the South part of France, and the BISA BRAMS transmitter located near Dourbes, Belgium (49,980 MHz) for the Northern part of the country.


*Figure 2* – Locations of BRAMS and GRAVES transmitters. The yellow pins show the various receiving places which have already successfully been tested with low gain receiving antennae.

*Figure 3* – FRIPON radio antennas installed on a roof at IMCCE, Observatoire de Paris.

### *Set-up design*

The highest geocentric velocity of a solar system meteoroid being around 72 km/s, the expected theoretical maximum Doppler-Fizeau frequency shift will be about 23 kHz for a 49 MHz transmitter such as the BRAMS set-up, and 67 kHz for the VHF GRAVES radar. Therefore, a large bandwidth receiver compatible with such values must be used. The cheap but efficient SDR (Software Defined radio) FUNcube Dongle Pro + developped by the AMSAT-UK association[1] has been selected or FRIPON. Technical details about this receiver are described in (Rault, 2013). 4 element 143 MHz and 5 element 49 MHz Yagi beam antennae are completing the radio set-up (see *Figure 3*).

[1] http://www.funcubedongle.com/

## 4 Conclusion

A small size, light-weight, low cost but efficient radio set-up has been designed for the FRIPON project. First operational results are expected at the end of 2015.

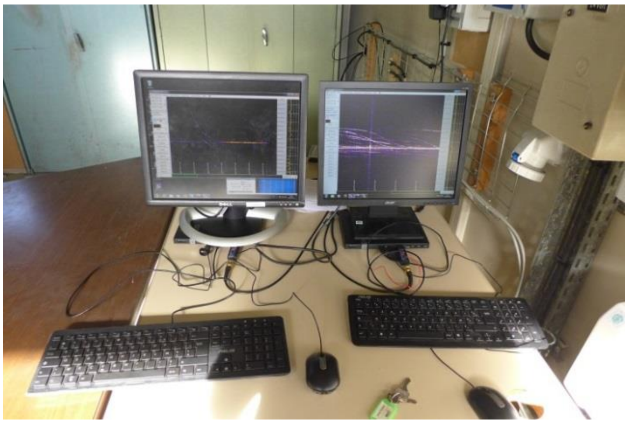

*Figure 4* – First lights of the 49 and 143 MHz FRIPON radio receivers running at IMCCE, Observatoire de Paris.

## References

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