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# Radio observations and evaluation of the meteor showers between May 4 and August 25, 2012

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Radio meteor observing for astronomy purposes is still alive, despite the fact that traditional TV transmitters used for decades tend to disappear. Encouraging results are obtained in the aeronomy/geophysics domain when searching for evidence of modifications of the Earth/ionosphere waveguide by discrete ionized meteor trails.

## 1 Introduction

This short survey aims to show that, despite the fact that TV transmitters traditionnally used for meteor forward scatter observations tend to disappear, radio observers are now starting to develop their own dedicated transmitters, and are using new kinds of transmitters, such as military and radio-navigation systems to continue their studies. Radio observation of meteors does not only concern astronomy: another growing part of radio meteor studies is dedicated to the interactions between meteors and the D and E layers of the Earth's ionosphere.

## 2 Forward scatter detection of meteors

Band I analog TV transmitters have been used for many years for detecting meteors and for analyzing their signatures. Their strong video and sound carriers radiated in the low VHF part of the radio spectrum (around 60 MHz) were offering optimal echoes for several decades. Unfortunately, analogue TV is presently replaced almost everywhere by digital TV transmissions, which is bad news for radio observers, mainly for two reasons:

1. the previous analogue sound and video strong carriers are now replaced by a comb of low-power multiple discrete frequencies; and
2. the DTTV (digital terrestrial TV) transmissions do not use the low VHF Band I anymore, but most of them are located now in the UHF part of the radio spectrum (Bands IV and V, from 470 to 862 MHz)

The higher frequencies and the reduced power of each discrete carrier no longer yield strong echoes, so the UHF DTTV is not suitable at all for observing meteors.

So what kind of transmitters can be used nowadays?

Dedicated transmitters have been developed in Belgium, such as the VVS[1] beacon, located near Ypres running on 49,990 MHz and the BRAMS (Belgian Radio Meteor Stations) beacon, located near Dourbes and working on 49,970 MHz.

The powerful military radar GRAVES[2] is also useful for tracking meteors. The transmitter of this bistatic radar is located near Dijon, France, and its transmission frequency is 143.050 MHz. A team of French amateurs belonging to the AAV[3] is also experimenting presently with several low power radionavigation VOR (VHF Omni-directional Range) beacons transmitting around 115 MHz (Figure 1). New radar systems are under study, such as a radar of the European Space Agency ESA, as part of the Agency's *Space Situational Awareness Programme*. First studies are assessing several frequencies such as 435, 1200, and 3200 MHz. The North American Aerospace Defense Command NORAD is planning to replace their present 216 MHz transmitters by S band equipement.

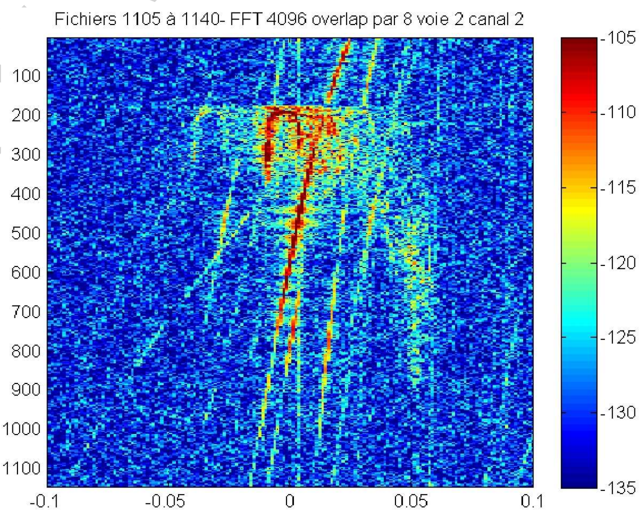


*Figure 1* – Example of a VOR forward meteor scatter received near Paris, France, by AAV members using a vertical 3-element Yagi beam antenna.

[1] *Vereniging voor Sterrenkunde*, the Flemish astronomical association.

[2] *Grand Réseau Adapté à la Veille Spatiale*, or "Large Network Adapted to Monitoring Space".

[3] *Association Astronomique de la Vallée*, or the astronomical association of the Orsay region south of Paris.

## 3 Meteors and correlated VLF events studies

### 3.1 Observations at Armagh

An observation program dedicated to the correlation between meteors and VLF events has been initiated by Apostolos Christou in 2011 at Armagh Observatory, thanks to Europlanet funds (Figure 2).

The Armagh set-up consists of a ELF/VLF reception chain buit by James Finnegan according to the author's design (Rault, 2010), and by several TV cameras already in use at the observatory.

The program is based on a correlation analysis between meteor video observations and simultaneous ELF/VLF radio events.

The first observational results should be published soon by Jonathan Quinn from Armagh Observatory.

### 3.2 Observations at Pic du Midi

A combined radio/video observation campaign was performed during the Geminids 2011 shower at the Pic du Midi Observatory (Figure 3), using the following equipment:

1. 3 and 11 $\mu$m infrared ONERA cameras;
2. WATEC and Lheritier high sensitivity IMCCE cameras; and
3. VHF and VLF radio equipment (Figure 4).

Preliminary results of VLF/video correlation campaigns for the 2010 and 2011 Geminids give similar results as the first campaign for the 2009 Geminids, i.e., 30 to 40% of meteor-and-ELF/VLF-events give positive correlations.

*Figure 2* – ELF/VLF antennas used at Armagh Observatory.

*Figure 3* – ONERA 3 and 11 $\mu$m cameras under test at Pic du Midi Observatory during the Geminids 2011 campain.

*Figure 4* – VLF magnetic loop and VHF vertical whip antenna installed at Pic du Midi Observatory for the Geminids 2011 campaign.

## 4 Searching for VLF propagation disturbances induced by meteors

The D ionospheric layer density and altitude variations induced by solar wind particules and solar X-rays radiation produce well-known SIDs (Sudden Ionospheric Disturbances) on the propagation of VLF radio signals.

At a reception location, a VLF signal radiated by a man-made transmitter consists of the vectorial sum of a ground wave (following the surface of the Earth) and of a sky wave reflected by the D layer of the ionosphere. Depending on the respective amplitudes and phase of the sky and ground waves, the result at the receiving location can be a constructive or a destructive interference (Figures 5 and 6).

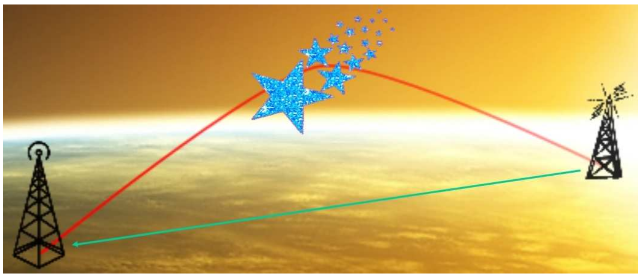

*Figure 5* – One-hop sky wave and direct ground wave of a VLF transmission interference at the receiving location.

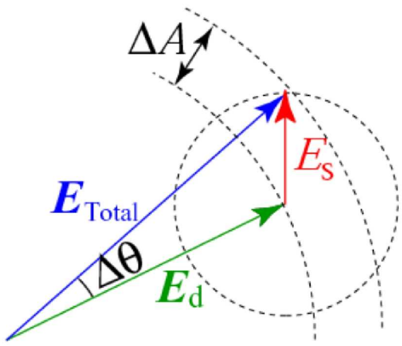


*Figure 6* – $E_{\mathrm{total}}$ is the vectorial sum of the direct ground wave $E_{\mathrm{d}}$ and of the reflected sky wave $E_{\mathrm{s}}$.

Most meteors interfere with the D and E layers of the ionosphere, at altitudes between 80 and 120 km, so one can wonder if an ionized meteor trail could be sufficiently effective to modify the propagation of VLF radio waves. Therefore, the following experiment was implemented:

1. signals from a distant VLF transmitter (DHO38 located in Germany) were recorded 24 hours a day before, during, and after the Geminids 2011 at the Pic du Midi Observatory (OPM on the map in Figure 7);

2. the French radar GRAVES (GRV) located near Dijon was used to detect meteors, and its meteor pings were simultaneously recorded with the VLF signals amplitude;

3. correlations between meteor occurences and VLF amplitude records were searched for.

During the 2011 Geminids shower, at least one positive correlation was clearly identified, showing a constructive interference on the amplitude of the French VLF transmitter FTA (middle curve on Figure 8) signals and a destructive interference on the amplitude of the German VLF transmitter DHO38 (bottom curve) signals.

Former studies aimed to show that large meteors were capable of disturbing the propagation of VLF radio signals. The observations discussed here seem to be the first evidence of perturbation of a VLF radio signal by a discrete meteor, however.

The shapes of both disturbances are similar to the ones induced by solar X rays and solar particules bursts, i.e., starting with a sharp edge, and then recovering slowly when free electrons recombine progressively with ionized molecules.

To observe further evidence of "M-SIDs" (Meteor Sudden Ionosphere Disturbances), a network of 10 amateur observers was set up during the 2012 Lyrid shower. Figure 9 shows the observing (triangles), the VHF transmitters used for detecting meteors (circles), and the VLF transmitters (squares). The data of the 2012 Lyrid campaign are being processed and the detailed results will be published in a forthcoming issue of *WGN, the Journal of the IMO*.

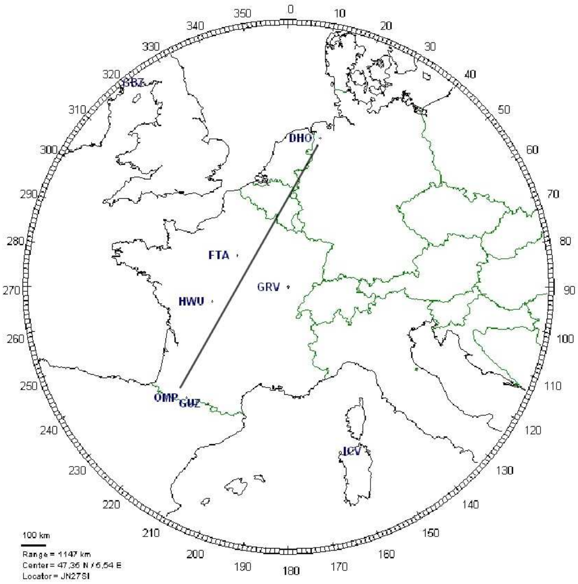


*Figure 7* – DHO38 VLF transmitter (DHO) signals recorded at Pic du Midi Observatory (OPM) and correlated with meteor pings detected thanks to the GRAVES radar (GRV).

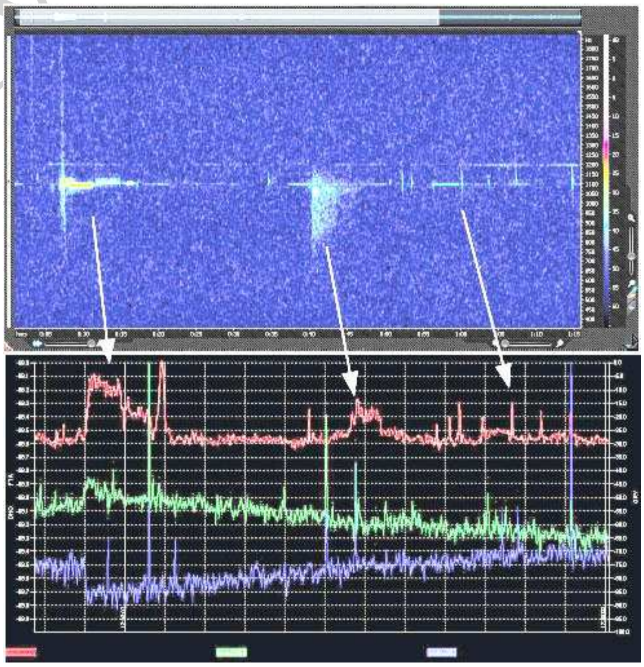

*Figure 8* – The first of three consecutive meteor pings (top curve) triggers a VLF amplitude disturbance on DHO38 (bottom curve) and FTA (middle curve).

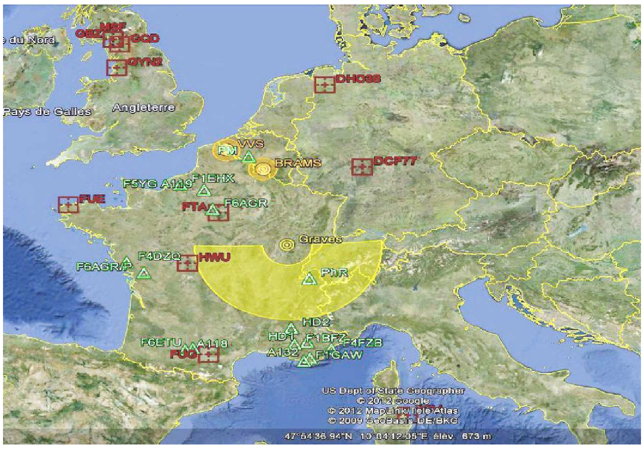


*Figure 9* – Lyrids 2012 observation geometry set-up.

## 5 Conclusions and future work

In spite of the progressive disappearing of the VHF TV transmitters which were in use for a long time, meteor radio observers are still able to work thanks to dedicated transmitters such as the BRAMS beacon, and military or aeronautical radio-navigation systems.

On the meteor astronomy side, the next effort should be for radio observers to use such VHF transmitters for accurately measuring speed vectors of incoming meteors, which is a major request on the side of professional astronomers. On the aeronomy/geophysics side, studying interactions of meteors with the upper layers of the atmosphere is of growing interest.

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