# The VVS meteor beacon

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This presentation describes the construction of a dedicated meteor radio beacon, the first results achieved with it, and the future plans.

## 1 Forward scatter principle

The principle of forward meteor scatter is well known to the IMC participants. A radio transmitter which is "behind" the horizon for a receiver is received for a short while when an ionized meteor trail is formed with the correct geometrical orientation to reflect the transmitter broadcast. The signal from the receiver is fed into a computer, or in the old days — recorded by a pen recorder (Figure 1).

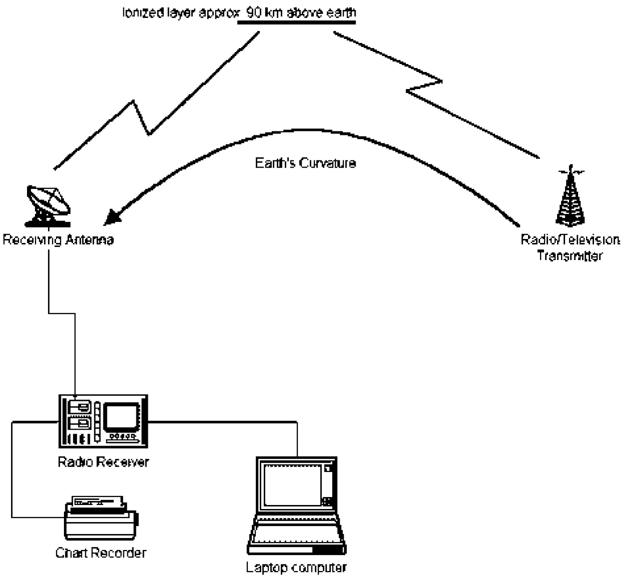

*Figure 1* – Forward scatter principle.

## 2 Frequencies used for forward scatter

The longer the wavelength, the stronger and the longer the reflections are. There is a practical low frequency limit, due to the bending of long wavelength signals along the Earth's surface. In practice, the frequency range 50 MHz to 144 MHz (a radio amateur band) is used.

Unfortunately — especially in densely populated areas such as Western Europe — there are almost no "empty" frequencies in the regular FM band (88–108 MHz). Almost every frequency is used (several times) by "local" stations which are received directly.

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Until a few years ago, advantage was taken from the fact that the frequency band for FM radio used in Eastern Europe was different from the one in Western Europe. Several receiving configurations used “East block” receivers or modified “regular” FM receivers to receive the 66–73 MHz band. In the meantime, most of these transmitters have been phased out, work at reduced power, or do not broadcast during night hours.

Most commonly used today are TV carriers in the VHF band, which are very strong, tens or hundreds of kW.

## 3 A beacon

Another possibility is to build your own dedicated transmitter for meteor scatter. Power output is of course much lower, but there are several advantages. The characteristics of the transmitter are well known, and there is only one transmitter at that frequency. Such a “beacon” constructed by Kimio Maegawa (Ogawa, 2005) in Japan is successfully in operation since several years. Although its power is “only” 50 W, it can be received several hundreds of kilometers away.

## 4 The VVS beacon

The VVS, Vereniging voor Sterrenkunde, is the largest amateur astronomy organization in Belgium, with 1900 members. The VVS grants funds to original projects proposed by their members, which might otherwise not be realized. Gaspard De Wilde, a retired electronics engineer and radio amateur (ON4ZK) for decades, together with the author filed a project for setting up a beacon similar to the Japanese one (Figure 2).

*Figure 2* – Gaspard De Wilde in his radio shack.

It got approved in November 2004. The transmitter was practically built at that moment, and tested on a “dummy load”, dissipating the RF (radio frequency) energy in a resistor rather than radiating by means of an antenna (Figure 3).

*Figure 3* – The transmitter on the test bench. At the top the dummy load (black), middle filter, bottom transmitter.

Next we looked for a home of the beacon by means of an announcement on the VVS mailing list and in the monthly magazine “Heelal”. As the beacon will be received directly (not through meteor reflections) in its immediate neighborhood, it is ideally not located in the center of the country. There should also be sufficient open space in order to minimize interference from buildings etc. Out of four offers, the one of Astrolab IRIS (a project and public observatory) at Zillebeke (2°55′ E, 50°49′ N), close to Ypres and the French border, was the winner. Moreover there is a hill range to the east, helping in minimizing direct reception in this direction, where most potential observers are located.

With the location known, the application file for the BIPT (Belgian Institute for Post and Telecommunications, formerly the PTT) could be completed. The power (50 W), antenna pattern (Figure 4), modulation (none, pure carrier), circular polarization are amongst the data to be provided. BIPT assigned 49.990 kHz to the beacon, just outside the 50 MHz radio amateur band. The beacon went “in the air” on April 16, 2005 (Figure 5).

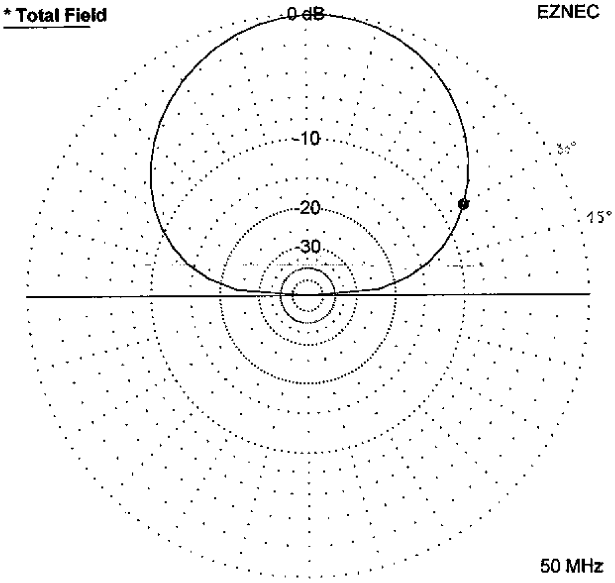


*Figure 4* – Theoretical vertical radiation diagram.

*Figure 5* – Celebrating the successful installation.

Back home the same day in Dessel (130 km east of the beacon), Gaspard was the first one to receive it, or — fortunately — not to receive the direct signal. Few meteor reflections were recorded, but the number increased in using an antenna with circular polarization similar to the transmitting antenna.

## 5 Spectral observations

A state of the art receiving installation consists of a (short wave) receiver with beat detector output, which is fed into the sound card of a PC. A spectrum program such as Argo, Spectrumlab, MAnalyzer, or HROFFT (from our Japanese colleagues) allows analyzing the received signal.

Underdense reflections show up as short pulses with a spread of up to 20 Hz (Figure 6). This spread is caused by (the Doppler shift of) the thermal velocity of the diffusion of the trail, amounting to a couple of 100 m/s. The central frequency of the various reflections shifts also by some tens of Hz with respect to the central reference frequency (800 Hz in the figure). This is due to the wind speed, which affects the complete reflecting part of the trail.

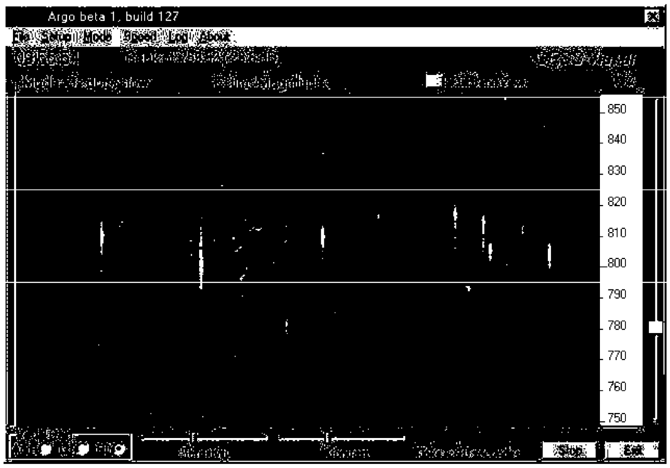


*Figure 6* – Numerous underdense reflections can be seen on this 6 minute recording.

Overdense reflections last much longer (tens of seconds), and exhibit coherent reflections on the expanding "metallic cylinder" (Figure 7). The directly received carrier can also be seen faintly in Figure 7. This is of help in tuning to the correct frequency.

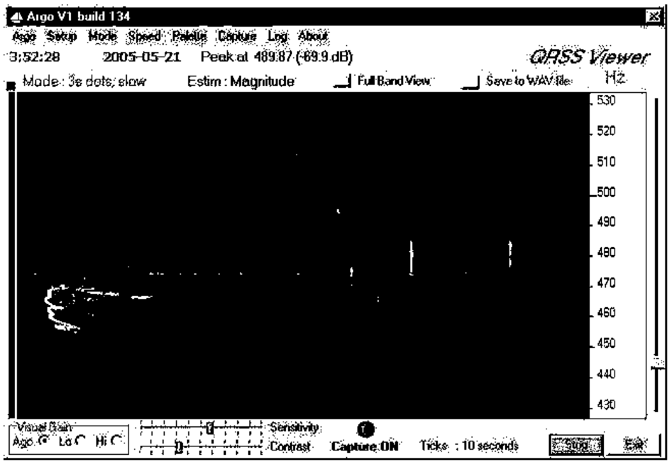


*Figure 7* – A typical overdense reflection at the left.

Visual fireballs up to a couple of hundred kilometers from the beacon cause big bursts lasting tens of seconds (Figure 8). The start of the signal is more accurate than timings made by casual observers.

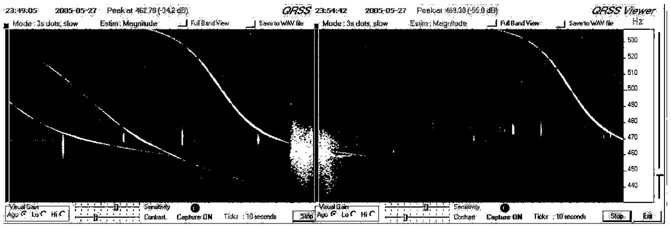


*Figure 8* – Burst caused by a fireball.

Meteor scatter can also be adversely affected by interference. Planes on a descent course to the national airport of Zaventem are very common (Figure 9). Although they do not harm the meteor observations too much, their number can be reduced in adjusting the direction of the receiving antenna.

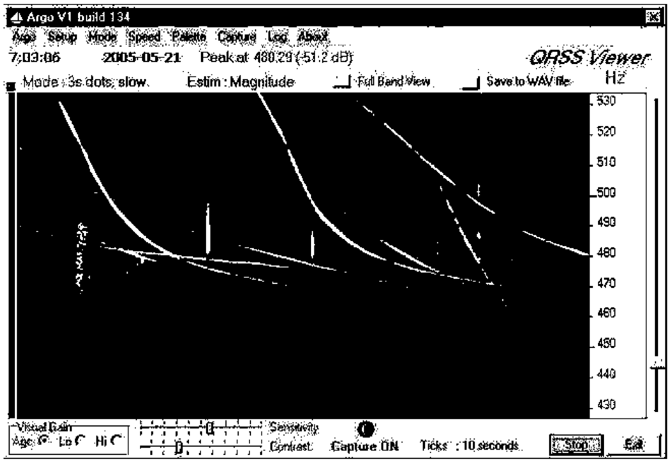
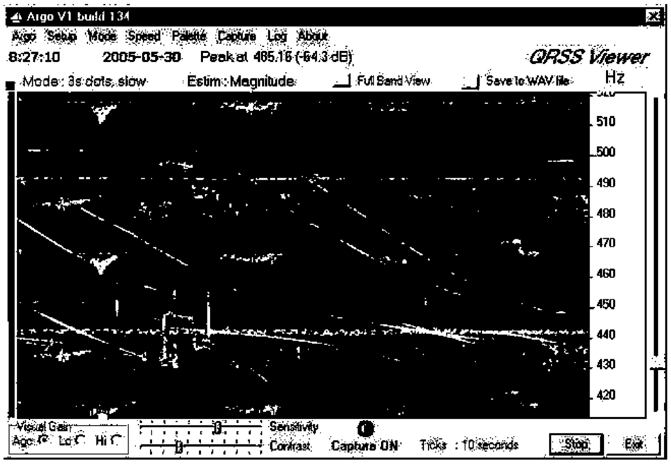


*Figure 9* – Plane spotting.

Far worse is “sporadic E”, which occurs mainly during daytime in summer. Non-linear propagation effects cause the same pattern to be repeated (Figure 10). Meteors are still visible, but the results become doubtful to say the least.



8:27:10 2005-05-30 Peak at 465.16 (-64.3 dB)

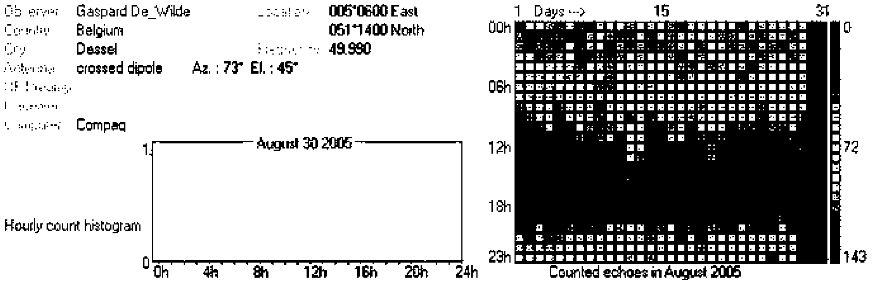
Mode: 3s dots, slow Estim.: Magnitude

Capture ON Ticks : 10 seconds

*Figure 10* – The signature of sporadic E.

## 6 Analyzing the Perseid observations made with the beacon

Gaspard’s hourly counts can be found on the Radio Meteor Observatory Online page of Pierre Terrier: `http://radio.data.free.fr`. The color coded graphical representation clearly shows the diurnal variation of the sporadics with a maximum during the local morning hours and a minimum in the afternoon (Figure 11). On top of the sporadic background comes of course stream activity. Apparently the Perseid activity is not “overwhelming”. The most significant Perseid activity took place on August 12 between $6^{\mathrm{h}}$ and $12^{\mathrm{h}}$ UT.


Observer Gaspard De_Wilde
Country Belgium
City Dessel
Antenna crossed dipole Az. : 73° El. : 45°
Compaq

005°0600 East
051°1400 North
49.990

*Figure 11* – Graphical presentation of Gaspard De Wilde’s hourly counts during August 2005.

The task of finding the “true” stream activity from the observed activity (be it as counts, or reflection duration) is far from easy.

We postulate the following model:

$$O_i(t) = S_i(t) + Z(t) \cdot \mathrm{OF}_i(T), \qquad (1)$$

where

$O$ : observed number,
$S$ : number of sporadics,
$Z$ : number of stream meteors,
OF : observability function for the stream,
with $T = (t - t_0)/D$ and $D$ the length of the day.

Given is:

$$O_i(t_j) \qquad \text{for observers } i = 1, 2, \ldots, n \qquad \text{at times } t_j,\ j = 1, 2, \ldots, w.$$

Wanted are:

$$S_i(t_j) \qquad Z(t_j) \qquad \mathrm{OF}_i(T_j).$$

This is a set of non-linear equations, which needs to be "solved" numerically in minimizing the quadratic error. In addition, only solutions $S_i(t_j)$, $Z(t_j)$, $\mathrm{OF}_i(T_j) \geq 0$ are meaningful.

As a special case we take:

one observer ($i = 1$);
model for stream activity $Z$ with few parameters;
three days of hourly count $w = 3 \times 24$;
find $S$ (24 values) and $OF$ (24 values).

and try it out on Gaspard's observations of August 11–13, 2005.

Although the fit of the calculated activity does not look too bad (Figure 12), the calculated sporadic activity and OF is not realistic (Figure 13). The sporadics for $0^h$–$2^h$ UT are overestimated, and those for $5^h$–$6^h$ UT are underestimated. On the other hand, the OF should be very low around $6^h$–$7^h$ UT, when the radiant elevation is high.

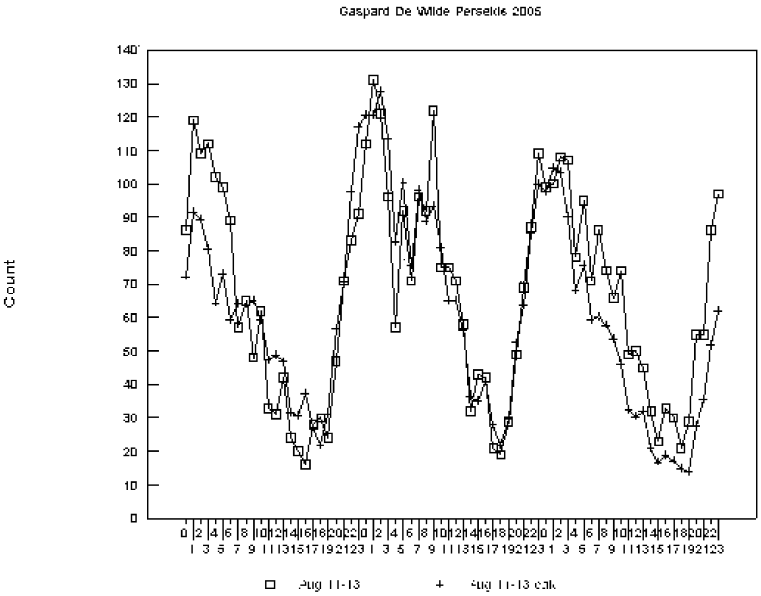


*Figure 12* – Observed and calculated Perseid counts.

Reason for this failure is the model of the stream that was chosen (Figure 14). A Gaussian curve with maximum on August 13, $6^h$ UT and standard deviation of 27 hours gave the "best" fit.

Our results do not coincide well with the visual ZHRs published by IMO (Arlt, 2005). Although the model for the forward scatter activity does not have to be identical to the visual one (the forward scatter activity covers fainter meteors than visually observed), a better fit is possible with a rather more "peaked" and asymmetrical curve. But that will be the subject of future publications, based on multi-station observations.

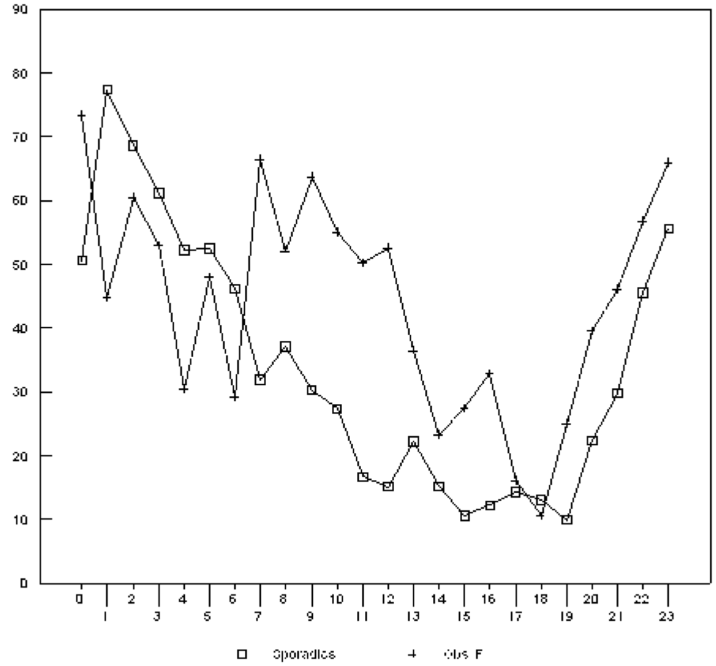


*Figure 13* – Calculated sporadic activity and OF.

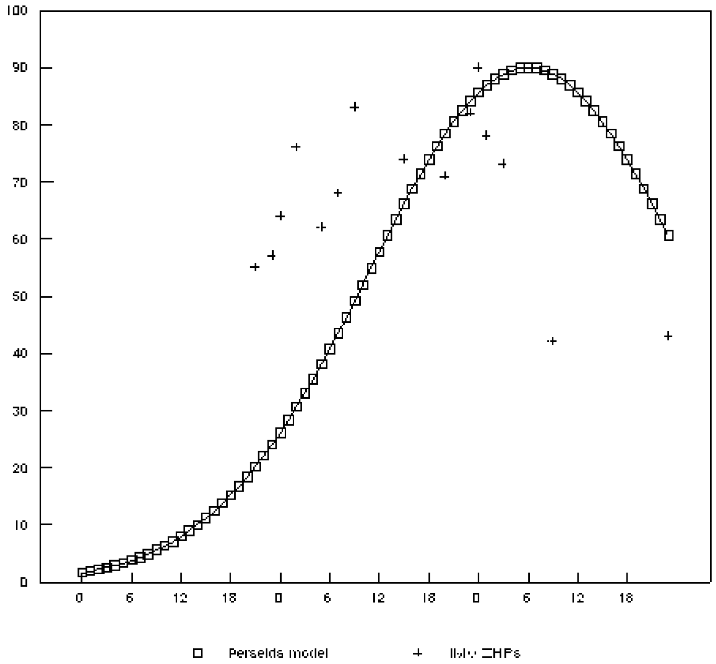


*Figure 14* – Assumed Perseid activity profile.

## 7 Conclusions and future plans

We are pleased with the overall quality of the beacon. The signal is stable, and can be observed at a not too great distance. Of course the beacon has relatively low power, and no useful observations can be performed at a distance of more than 400 km.

Most forward scatter set-ups receiving FM or TV carriers are "far" scatter, with the distance between transmitter and receivers being several hundreds to a thousand kilometers. We observe the beacon relatively nearby, which makes the geometrical conditions more interesting.

Tuning to the beacon frequency is less obvious than we thought. In order to achieve the scientific goals, we will need several permanent receiving stations. One is planned at public observatory Mira, Grimbergen (close to Brussels). With multiple receiving stations it is possible to eliminate local interference, obtain some information about the location of the reflecting trails, and establish various correlations.

## 8 Acknowledgments

Gaspard De Wilde and the author wish to thank the VVS, ir. David Erzeel of BIPT, Astrolab IRIS, Felix Verbelen, Patrick Vanouplines, and the VVS working groups Radio Astronomy, Meteors and Sun.

Figures 7 to 10 courtesy Felix Verbelen.

## References

Arlt R. (2005). "Perseids 2005, visual". `http://www.imo.net/news/perseids2005`.

McKinley D. W. R. (1961). *Meteor science and engineering.* New York, McGraw-Hill, 1961.

Ogawa H. (2005). "What is radio meteor observation?". `http://www.amro-net.jp/hro.htm`.

## Discussion

**Geoffrey Grayer:** *Why don't you see "flutter" on the traces identified as aeroplane reflections an your spectrogram plots, as you hear this on the audio?*

**Chris Steyaert:** Flutter is an interference phenomenon between the direct wave and the reflected Doppler shifted wave. A spectrogram shows the individual frequencies, not the result of the interfering waves (the phase information is lost).

**Frans Lowiessen:** *We have been using GB3LER, a radio beacon and are able to count up to 150–200 meteors per hour at times when no showers are active. By not using this beacon instead, but forward scatter seems to be working better at distances of 500–2000 km.*