Radiometeor Forward-scattering Observations with a Portable System

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– Ljubljana, May 2008 –

Meteor Studies

- Each day, billions of meteoroids enter the Earth's atmosphere and form long **trails** of ionized particles ($80\,\mathrm{km} < h < 120\,\mathrm{km}$).
- The free electrons are capable of "reflecting" radiowaves coming from the Earth's surface ($< 1\,\mathrm{s}$).
- Origin: 41% meteor streams have been linked with comets or asteroids; 16.7% don't have confirmed links; the rest are of **unknown** origin.
- Meteor activity study offers:
  - Meteoroids stream structure determination.
  - A "diagnostic tool" for study of the atmosphere .

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Any meteor stream modelling will require accurate measurements of meteoroid flux.

Historical Review

- At the end of 1920s radio reflections on "E Region" was identified.
- After the World War II, with the information obtained by unused radars transformed into radiotelescopes, the principles of radio meteor scattering were established.
- In the 1950s simple radar systems were set up and today we have various radio meteor detection facilities.
- Substantial efforts have also been done by scores of radio amateurs. With the *boom* of high quality data it seems that the theoretical work is somehow lagging behind ...

Objectives

General Objective

Create a portable device for meteor activiy registration that allows observation from different geographical positions.

The system should have the following features:

- Receive VHF $(30\,\mathrm{MHz} < f < 100\,\mathrm{MHz})$ signals using the forward-scatter method.
- The equipment must be easy to uninstall, move and setup on different geographic locations.
- Show the registered meteor activity in specified periods of time.

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Meteor Observations Methods

- Optical:
  - Visual.
  - Photography.
  - Photoelectrical.
  - Video (CCD and Light Intesifiers).
- Radio:
  - Backscatter.
  - Forward–scatter.

Radio observation allows continuous registration without any interference of atmopheric variables, neither field restrictions which limit optical methods.

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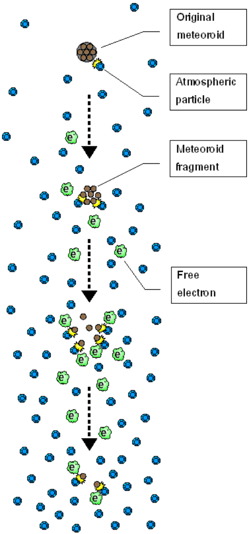
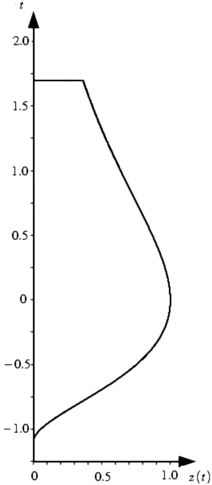
Meteor Origin
Meteoroid Ablation and Trail Ionization

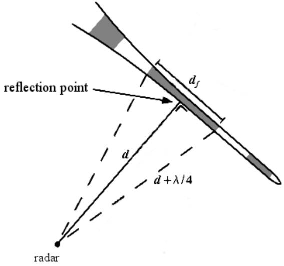


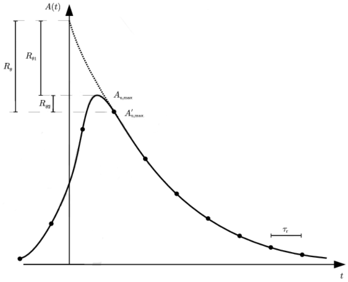
Classical Light Curve



Scattering off Meteor Trails
Backscatter off underdense trails

- The free electron density is assumed as "low".
- The radiowaves can completely penetrate the trail (without large attenuation).
- Each e^- receive the electric field individually and, collectively, they scatter the wave coherently.





The received signal amplitude will behave as...

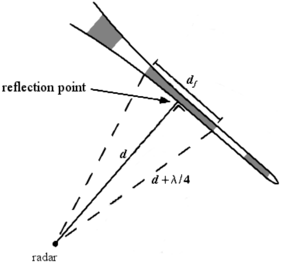
$$A_\mathrm{u}(t) = A_{\mathrm{u,max}}\, e^{-\frac{t}{\tau}}$$

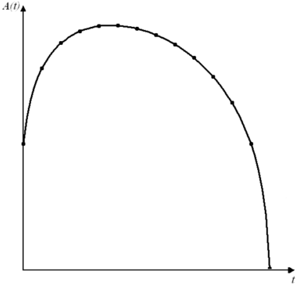
where

$$\tau = \frac{\lambda^2}{16\pi^2 D_\mathrm{a}}$$

Scattering off Meteor Trails
Backscatter off overdense trails

- The free electron density is assumed as "high".
- The radiowaves will not be able to penetrate the trail.
- The core of the trail will behave as plasma (similar to a metallic cylinder with radius r_c).





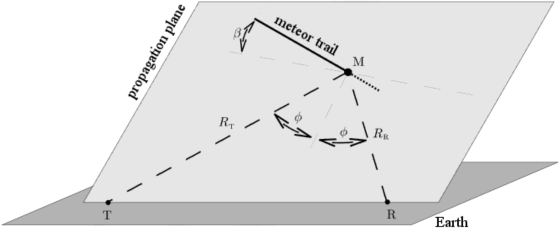
The received signal amplitude will behave as...

$$A_{\mathrm{o}}(t) = A_{\mathrm{o,max}} \sqrt{\frac{r_{\mathrm{c}}(t)}{r_{\mathrm{c,max}}}}$$

where

$$r_{\mathrm{c}}(t) = \sqrt{\left(r_0^2 + 4D_{\mathrm{a}}\,t\right) \ln \frac{\alpha \lambda^2 r_e}{\pi^2 (r_0^2 + 4D_{\mathrm{a}}\,t)}}$$

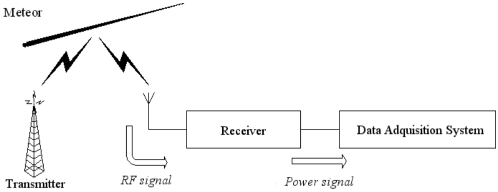
Scattering off Meteor Trails
Forward-Scatter



The geometry of this situation includes the influence of **half forward-scatter angle** (ϕ) on the received signal level...

- Underdense $\Rightarrow \tau = \frac{\lambda^2 \sec^2 \phi}{16\pi^2 D_a}$
- Overdense $\Rightarrow r_c(t) = \sqrt{(r_0^2 + 4D_a t) \cdot \ln \frac{\alpha(\lambda \sec \phi)^2 r_e}{\pi^2(r_0^2 + 4D_a t)}}$

System Description
Basics

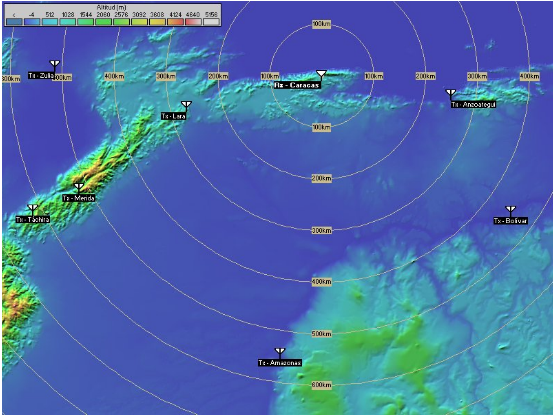


Basic System Diagram

Practical advantage

Using *forward-scatter* we can “hear” signals coming from broadcast transmitters and focus exclusively on receiver set-up.

System Description
Preliminar Survey



- Initial Rx Location: Caracas.
- Frequency: Luminance Carrier TV Ch 6 VHF (NTSC) – 83.25 MHz –

Tx Location	Amazonas	Anzoátegui	Bolívar	Lara	Mérida	Táchira	Zulia
$A_{\mathrm{u,max}}$ (μV)	0.48	3.10	0.89	6.39	0.93	1.44	2.18
$A_{\mathrm{o,max}}$ (μV)	0.80	5.89	1.50	12.04	1.56	2.38	3.65

System Description
Receiver Equipment

Features

- Model: IC-PCR1500 (*ICOM, Inc.*).
- Type: PC Radio (10 kHz – 3.3 GHz).
- Sensibility: 0.4 μV (SNR=10 dB @ "CW").
- Interface: USB.
- Software: Propietary (only under *MS Windows*).
- Antenna: Simple Dipole ($z = 50\,\Omega$).
- Dimensions: $146 \times 41 \times 206$ mm.
- Weight: 1.2 kg.

Minimum requirements for the control PC. . .

- *Processor Intel Pentium III - 450 MHz.*
- *Interface USB 1.1 ó 2.2*
- *Hard Drive with 50 MB free.*
- *RAM Memory of 128 MB.*
- *Display of 1024 $\times$768 px resolution.*

System Description
Adquisition and Storage

Hardware

- Type: Portable PC.
- Model: 8710p (*Hewlett-Packard*).
- Processor: 2.2 GHz.
- RAM Memory: 2 GB.
- Hard Drive: 160 GB.
- Dimensions: 394 × 33 × 275 mm.
- Weight: 3.375 kg.

Software

- Aplication: **Spectrum Lab** vers. 2.4 (Büscher, 2007).
- Type: *Freeware*.
- Audio signal FFT analysis.
- Pre–defined functions.
- *Script* management.

Total dimensions of the system

4808.66 cm^3 — 4.575 kg

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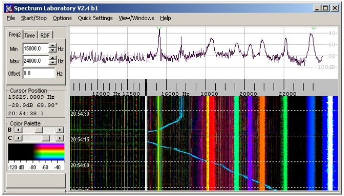

Main window of *Spectrum Lab*

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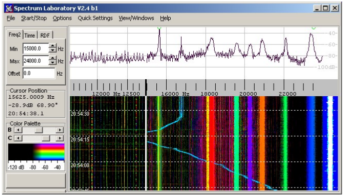
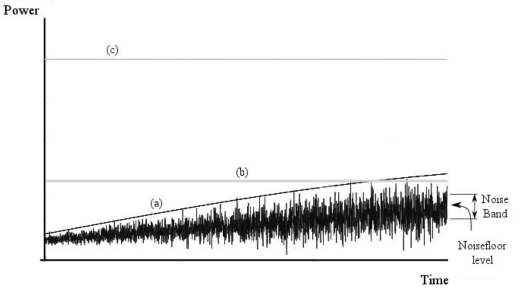


Main window of *Spectrum Lab*

Detection Strategy

- Flux density $Q(m_0)$ determination for a meteoroid stream is based on meteor reflection counts.



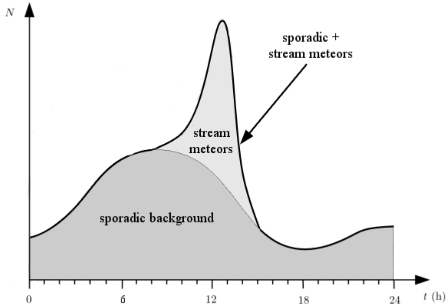
- Selection criterium: $P_{obs} > P_{th}$, where...

  (a) $P_{th} = P_r + n \times \sigma_{P_r}$

  (b) $P_{th} = \overline{P_r} + n \times \sigma_{\overline{P_r}}$

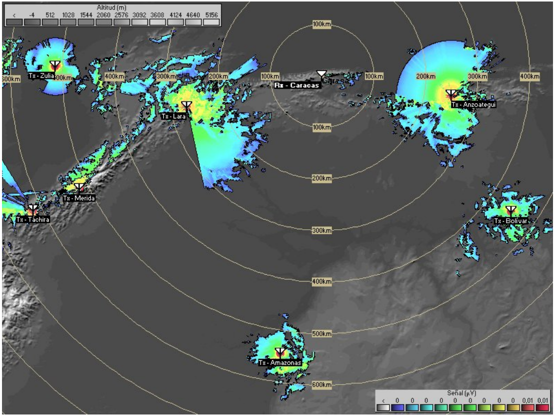
  (c) $P_{th} = n \times \overline{P_r}$

Sporadic Activity Determination



In order to obtain the meteor activity of a selected stream it is necessary to substract the **background sporadic activity**.

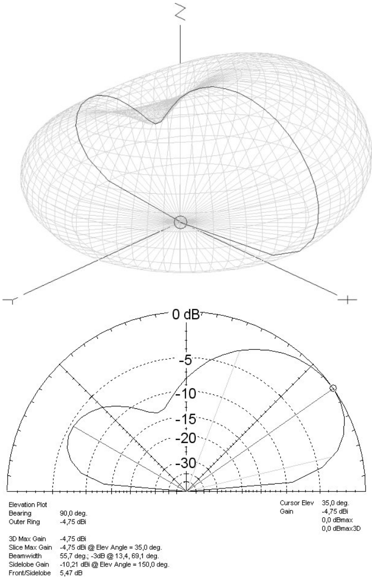
Observing Location: Caracas, Venezuela
Direct Signal Reception



- Latitude:
  $10^\circ\, 30'\, 33''$ N
- Longitude:
  $66^\circ\, 53'\, 40''$ W
- $f_L = 83.25$ MHz
- Estimation:
  Irregular Terrain Model.

Transmitter	Amazonas	Anzoátegui	Bolívar	Lara	Mérida	Táchira	Zulia
$A_{\mathrm{R}\ 50\%}$ (μV)	0.04	0.25	0.13	0.42	0.00	0.00	0.10
$A_{\mathrm{R}\ 90\%}$ (μV)	0.00	0.09	0.07	0.19	0.00	0.00	0.06
Azimuth ($^\circ$)	189	100	126	257	245	245	273

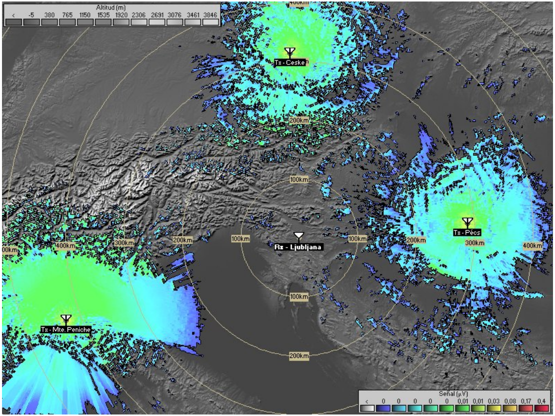
Observing Location: Caracas, Venezuela
Antenna and Storage



- Antenna set-up: *5 cm from the roof and at 30° angle from the vertical* ⇒ “real ground plane”.
- Main lobe aiming at ≈ 260°.
- Reception Mode: CW.
- Filter BW: 2.8 kHz.
- Register method:
  - Original audio (continuous).
  - Conditional (moving threshold).

Observing Location: Ljubljana, Eslovenia

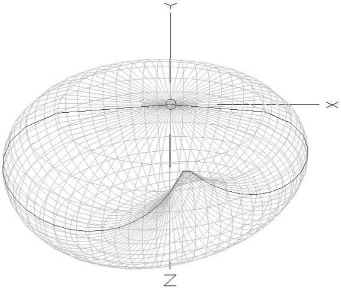
Direct Signal Reception

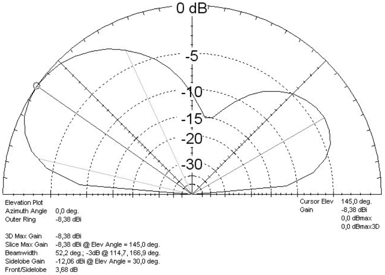


- Latitude: $46^\circ\,02'\,18''$ N
- Longitude: $14^\circ\,29'\,06''$ E
- $f_L = 62.25$ MHz
- Estimation: *Irregular Terrain Model.*

Transmitter	Ceske	Pécs	Mte. Penice
$A_{\mathrm{R}\ 50\%}$ (μV)	0.42	0.39	0.08
$A_{\mathrm{R}\ 90\%}$ (μV)	0.13	0.12	0.04
Azimuth ($^\circ$)	357	87	253

Observing Location: Ljubljana, Eslovenia
Antenna and Storage



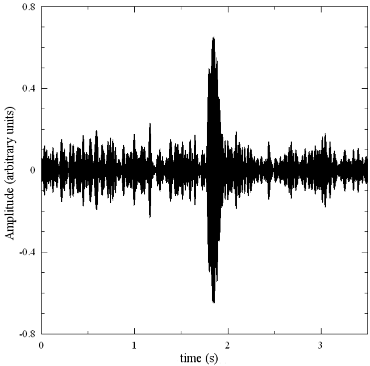


- Antenna Set-Up: *5 cm from the wall and at 22.5° angle from wall's normal* ⇒ "real ground plane".
- Main lobe aiming at ≈ 250°.
- Reception mode: CW.
- Filter BW: 2.8 kHz.
- Register Method:
  - Conditional (moving and fixed threshold).
  - Images (*plotter*).
  - Archives (rates).

Observations

Caracas

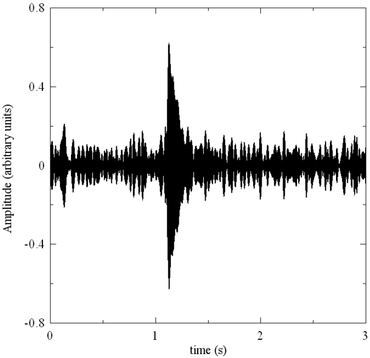
- Lapse: 16/10/07 to 08/11/07.
- Moving threshold detection.
- Audio (11000 sps @ 16 bit).



21/10/2007 06:15:06 UT

Ljubljana

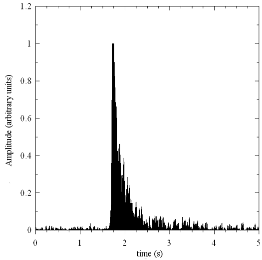
- Lapse: 20/12/07 to 10/01/08.
- Multiple criteria detection.
- Audio (5512 sps @ 16 bit).



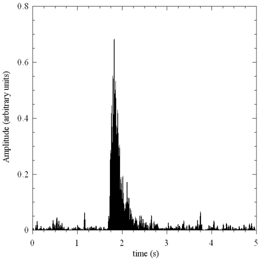
02/01/2008 13:32:30 UT

Observations from Caracas

Meteor Reflection Profiles

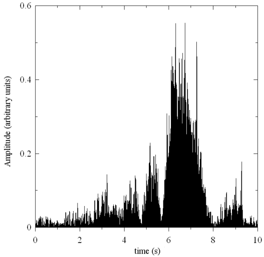


21/10/2007 06:15:06 UT

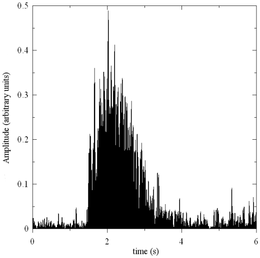


22/10/2007 01:27:12 UT

Underdense



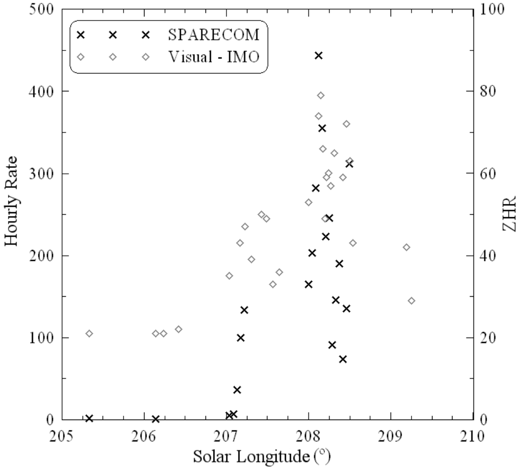
20/10/2007 23:05:05 UT



22/10/2007 04:41:11 UT

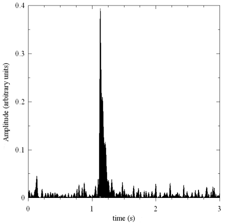
Overdense

Observations from Caracas
Orionids Activity in 2007



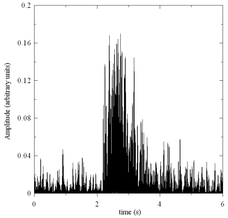
SPARECOM	$\Rightarrow$	Maximum: $\lambda_\odot = 208.125^\circ$	(Sub–maximum: $\lambda_\odot = 208.498^\circ$)
IMO	$\Rightarrow$	Maximum: $\lambda_\odot = 208.150^\circ$	(Sub–maximum: $\lambda_\odot = 208.464^\circ$)

Observations from Ljubljana
Meteor Reflection Profiles



02/01/2008 13:32:30 UT

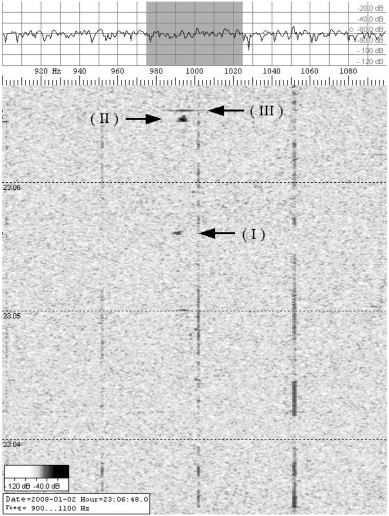
Underdense



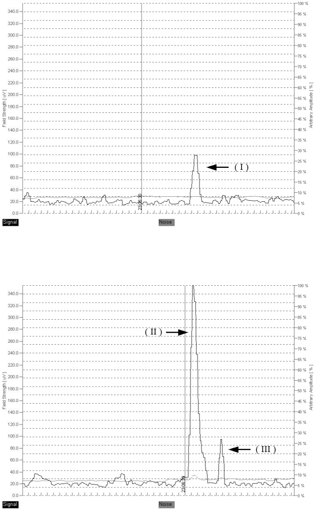
02/01/2008 01:29:15 UT

Overdense

Observations from Ljubljana
Spectrogram and Plotter Windows



Spectrogram (*Cascade Graphic*)



Plotter

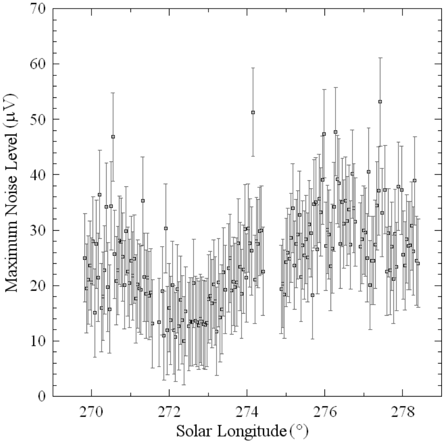
Observations from Ljubljana
Detection Criteria

Between December 22 and 30 2007 the system registered the **Maximum Noise Level** (RM) for each observation hour...

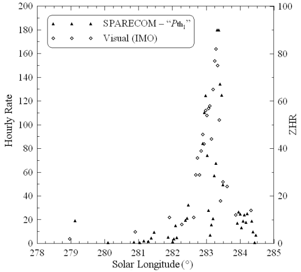
$$\overline{\mathrm{RM}} = 24.85\ \mu\mathrm{V}$$
$$\sigma(\overline{\mathrm{RM}}) = 8.27\ \mu\mathrm{V}$$

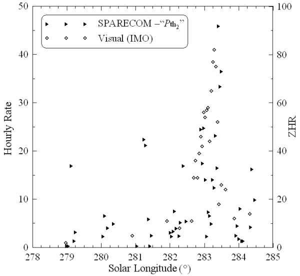
$$\Downarrow$$

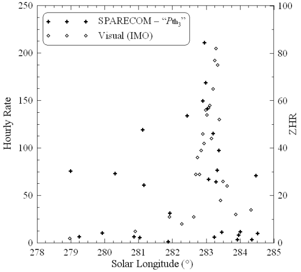
$$P\mathrm{th}_3 = -43.07\ \mathrm{dBm}$$
$$P\mathrm{th}_4 = -41.73\ \mathrm{dBm}$$
$$P\mathrm{th}_5 = -35.10\ \mathrm{dBm}$$

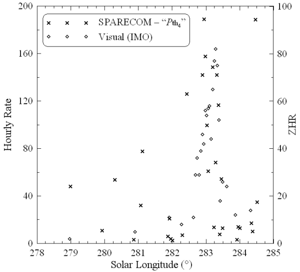


Observations from Ljubljana
Quadrantids Activity in 2008









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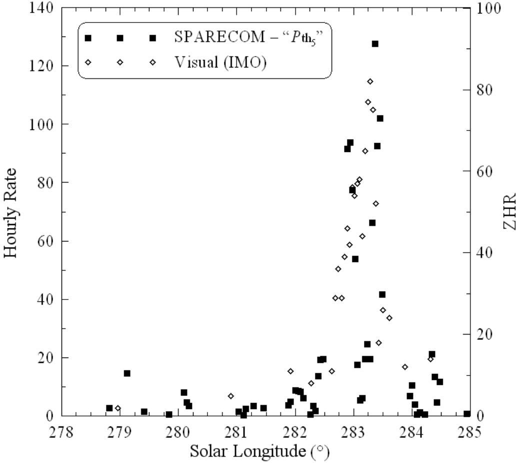

SPARECOM $\Rightarrow$ Maximum: $\lambda_{\odot} = 283.365^{\circ}$

IMO $\Rightarrow$ Maximum: $\lambda_{\odot} = 283.285^{\circ}$

Observations from Ljubljana
Storage Strategy

Storage Strategy	Format	Specifications	Information Rate (MB/h)
Continuous audio	WAVE	11000 sps	75.71
Conditional audio	WAVE	11000 sps	31.44
Conditional audio	WAVE	5512 sps	14.94
Plotter images	JPEG	800 × 600 px	47.55
Plotter images	JPEG	640 × 480 px	16.75

Information rates according to the storage strategy estimated on mean size of the files and mean activity rates.

Conclusions

- We established a system for meteor detection using the forward-scatter method in the VHF (30 to 100 MHz) frequency range.
- The system is **portable** as specified in the requirements.
- We recommend registration method that requires the minimum hard disk capacity.
- The activity curves of the meteor showers observed with the system show **substantial agreement** with the results of other reseach.

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Further Reading

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