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Solar radio observations and radio interference monitoring in Roztoky

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Abstract. This paper is part of a planned measurement campaign in which spectrum measurements were carried out at different locations worldwide within potential locations of the e-Callisto network. The results of measurements at the Callisto observing station in Roztoky, which took place at the beginning of May 2013, are presented. Measurements were made out with a special low cost broadband logarithmic periodic antenna connected to a Callisto spectrometer designed and built at ETH Zurich (Benz, 2004). This study provides the technical basis to decide whether it is possible to make solar spectroscopic measurements below 1 GHz ($\lambda > 30$ cm) at the observing station. In terms of electromagnetic interference, Roztoky is not perfect for broadband spectroscopic solar radio astronomy observations due to non negligible radio interference level from the nearby FM-transmitters. Nevertheless, low frequency observations below 80 MHz, as well as observations in some small bands above 116 MHz can be done.

Key words: Callisto – spectrum – interference

1. Introduction

The influence of coronal mass ejections (CMEs)on the Earth, a major cause of space weather disturbances, represents one of the basic unsolved problems in solar-terrestrial physics research and space weather forecasting. Modern ground-based and space-borne high-technology systems are strongly dependent on complex electronics, which is vulnerable to damaging effects of space weather. Consequently, continuous observations and forecasting of space weather effects is of crucial importance. Type II solar radio bursts are currently one of the main observable precursors of CMEs that reach the Earth within a few hours, or days after bursts. These bursts are associated with coronal shock waves propagating from the low to high corona and have dynamic spectra with a downward drifting frequency. They are usually observed below 400 MHz. Therefore, techniques for solar burst recording should be useful for solar radio observatories engaged in space weather forecasting and the routine detection and documentation of solar radio events. In view of the International Space Weather Initiative (ISWI) and the future upgrading of radio astronomical instruments at the Roztoky observatory, a measurement campaign was planned and organized between the Roztoky observatory and ETH Zurich, with a financial support from the latter institution. The measurements presented here took place on 30 April 2013 in Roztoky, the north-east Slovakia, after an installation and configuration of an antenna, a Callisto radio spectrometer (instrument serial number eC66) and a low noise preamplifier (LNA09). The Callisto (Compound Astronomical Low frequency Low cost Instrument for Spectroscopy and Transportable Observatory) is a frequency agile radio spectrometer dedicated to solar radio astronomy and a radio frequency interference monitoring; see section entitled 'Relevant internet addresses'. More than 58 Callisto instruments are installed worldwide at different longitudes and latitudes with the intention to observe the Sun for 24 hours per day throughout the year. All these instruments are connected via the internet and comprise the e-Callisto network with an archive which is open for data access to everybody.

2. Observations at the Roztoky station

2.1. Roztoky station description

The village of Roztoky is located in the northeastern Slovakia, about 17 km west of the town of Svidník. The astronomical observatory is in a natural setting that has low technical infrastructure associated with electricity transmission, radio, and telephone and that might produce radio interference. The Callisto was installed at an observing station a few hundred meters east of the optical observatory on a small hill above Roztoky. The front part (the antenna and the preamplifier) is mounted outside and the back part (spectrometer, power supplies and the control PC) is inside of a wooden shelter. Underground cables provide the internet connection and electrical power. This station was established and is maintained by Dukla Organisation for Education and Research and the Roztoky local section of the Slovak Union of Astronomers (MO SZA Roztoky).

Table 1. Geographical coordinates of the log-per antenna at the Roztoky observing station.

Coordinate	value
Latitude	49.4° North
Longitude	21.5° East
Height	410 m above sea level
Local Time	GMT + 01h

2.2. Measurement instrumentation

We used a commercial log-periodic antenna, model CLP-5130, made of aluminum and mounted on a wooden tripod. The frequency range of the antenna is from 50 MHz to 1300 MHz. The antenna was connected to a low noise preamplifier, Mini Circuits $ZX60 - 33LN+$ (gain = 20 dB, NF = 1.0 dB). A 10 m long low loss coaxial cable connected the preamplifier to the Callisto system inside of the temporary building. The application software was the latest version available, V1.17. The Callisto spectrometer, including control cables and RF adapters, was supplied by ETH Zurich. The Callisto frequency range from 45 MHz to 870 MHz in three sub-bands. The channel resolution is 62.5 KHz, while the radiometric bandwidth is about 300 KHz. The sampling time is exactly 1.25 ms per a frequency-pixel and the integration time is about 1 ms. The frequency in the output data (a spectral overview only) is expressed in MHz and the detector output for a special function 'save spectral overview' is expressed in millivolts. The detector sensitivity is 25.4 mV/dB. For long term burst observations the Callisto provides FIT-files which contain the frequency axis and the time axis as binary tables, while the intensity is expressed in digits taken from the analog-digital converter, ADC. The spectral overview is stored in a simple ASCII file which can be analyzed on any spread sheet such as IDL, Mathcad and Excel. An additional measurement was taken at this location by connecting a 50 Ω resistor to the Callisto. The resistor provides broadband reference noise of an order of 300 Kelvin. The external radio frequency interference is then expressed in dB with respect to the noise reference and denoted by 'external noise'.

Table 2. Acronyms mentioned in labels and comments.

Abbreviation	description
ADC	Analog to Digital Converter
Callisto	Radiospectrometer of ETH
CRAF	Committee on Radio Astronomy Frequencies
DAB-T	Digital Audio Broadcast Terrestrial
DVB-T	Digital Video Broadcast Terrestrial
ETH	Eidgenössisch Technische Hochschule
FM	Frequency modulation (Radio)
HRN	Roztoky observing station
IDL	Interactive Data Language
IHY	International Heliospheric Year
RFI	Radio Frequency Interference
TETRA	International police communication
TV	TeleVision

Figure 1. The logarithmic-periodic antenna CLP-5130-1 from CREATE at the Callisto observing station in Roztoky during its installation and configuration. The antenna, dedicated to observations of solar dynamic flares is mounted on a temporary wooden tripod positioned to the current position of the Sun.

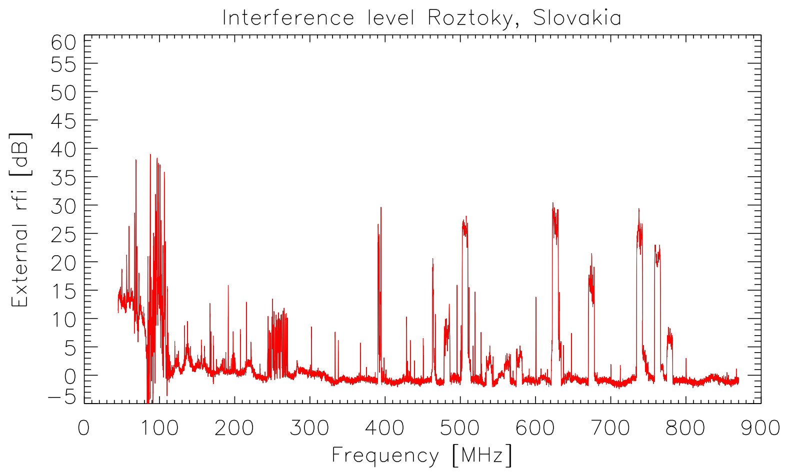

Figure 2. A spectral overview with 13'200 channels from a log-periodic broadband antenna measured at the Roztoky observing station. The spectra show some strong FM-transmitters around 100 MHz, TETRA at 400 MHz and DVB-T above 500 MHz. The negative dB in the FM range around 85 MHz indicates that the system is saturated. The plot also shows downlink transponder signals from military satellites near 250 MHz, indicating good sensitivity of the whole system.

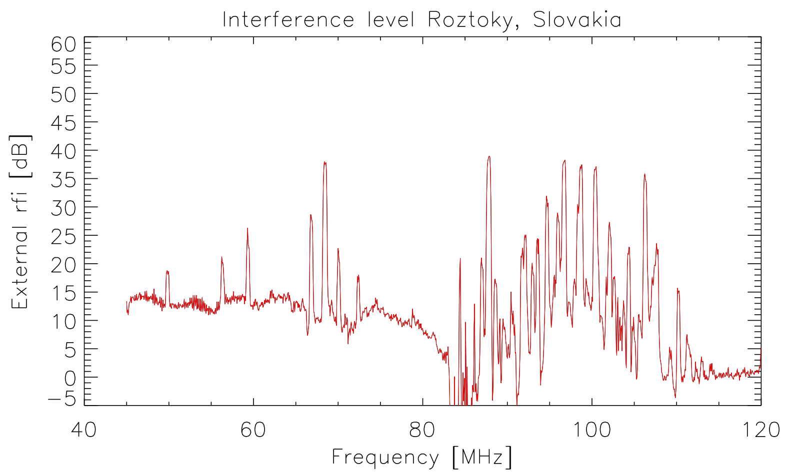

Figure 3. A spectral overview with 1280 channels from a log-periodic broadband antenna measured at the Roztoky observing station. A relatively low interference level below the FM-band indicates, that the system is suitable for solar burst observations at those lower frequencies. The frequencies 70.45 - 74.8 MHz are reserved for radio astronomy but shared with other mobile services.

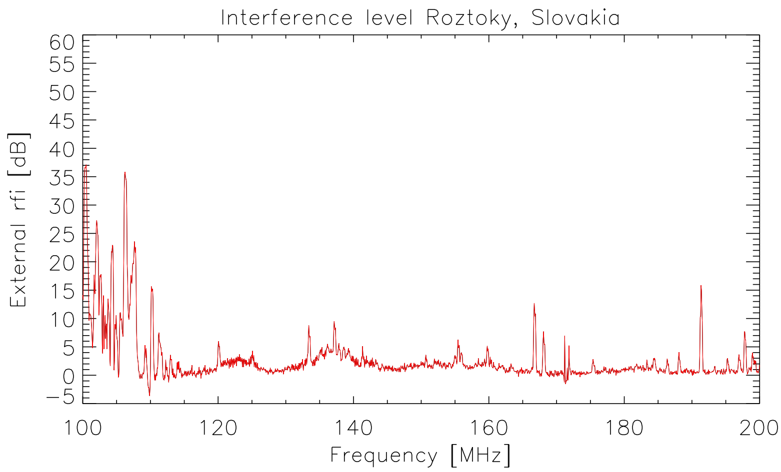

Figure 4. A spectral overview with 1600 channels measured at the Roztoky observing station. Relatively low interference levels between the FM-band and VHF indicate,that the system is suitable for solar observations in that range. The frequencies 150.4 - 151.4 MHz are reserved for radio astronomy, but shared with other services.

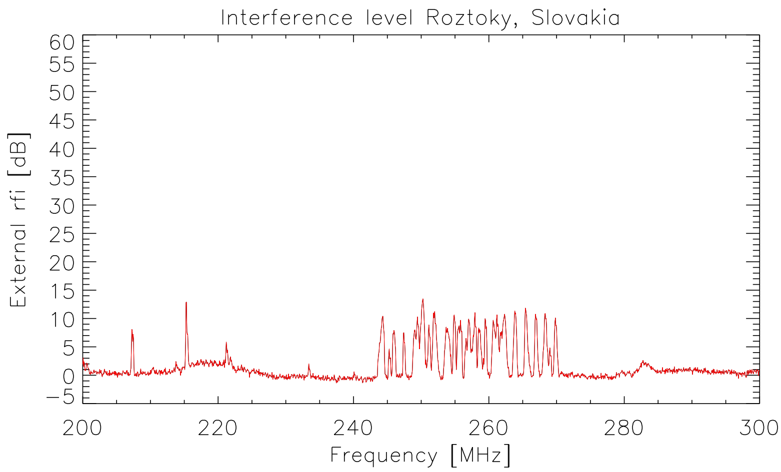

Figure 5. A spectral overview with 1600 channels measured at the Roztoky observing station. The rather low interference levels in this sub-band indicate, that it is perfect for solar observations. The frequencies around 245 MHz are not reserved for radio astronomy, but internationally used for solar flux measurements. This range is ideal for observations of solar type I flares. One can clearly see downlink transponder signals from US military satellites between 245 MHz and 270 MHz. A relative signal level around 10 dB proves that the system works properly.

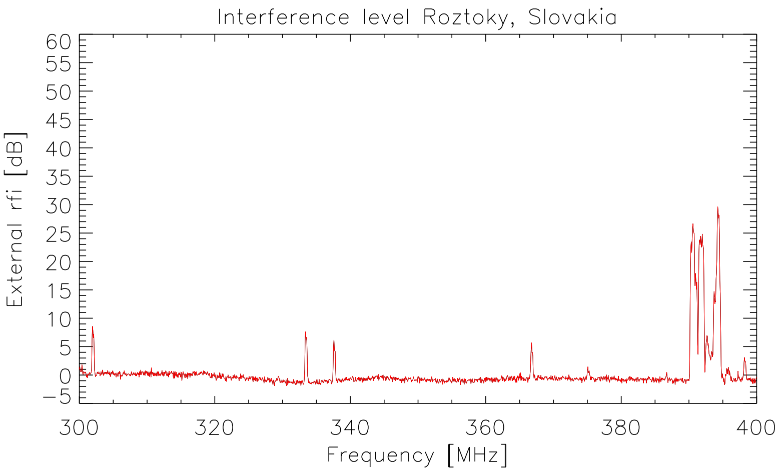

Figure 6. A spectral overview with 1600 channels measured at the Roztoky observing station. Although the spectra indicate some small standing waves (probably due to an improperly matched antenna), the rather low interference level makes this band perfect for solar observations. The frequencies 322 - 328.6 MHz are reserved for radio astronomy (deuterium line), but shared with other mobile services. This range would also be ideal for observations of solar type I, type II and type III flares. Frequencies above 380 MHz are occupied by TETRA, the international police information system. These are quite strong and carry the risk that the receiver could become saturated if, by chance, the antenna is directly pointing to the interfering transmitter.

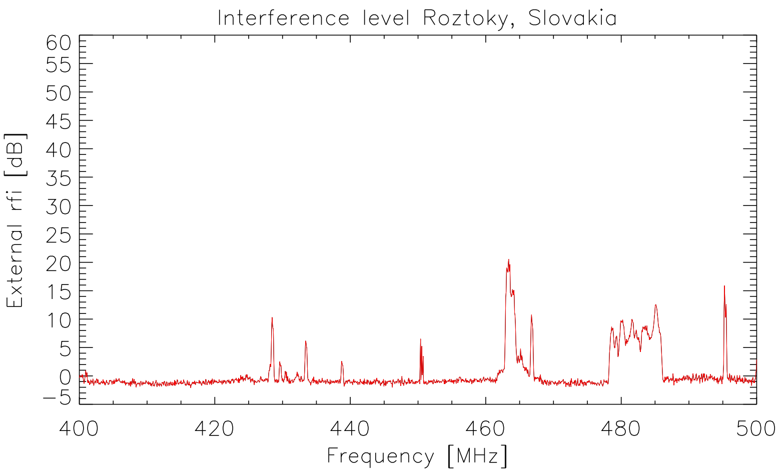

Figure 7. A spectral overview with 1600 channels measured at the Roztoky observing station. The rather low interference level is perfect for solar observations below 460 MHz. The frequencies 406.1 - 410 MHz are reserved for radio astronomy (solar flux monitoring), but shared with other services.

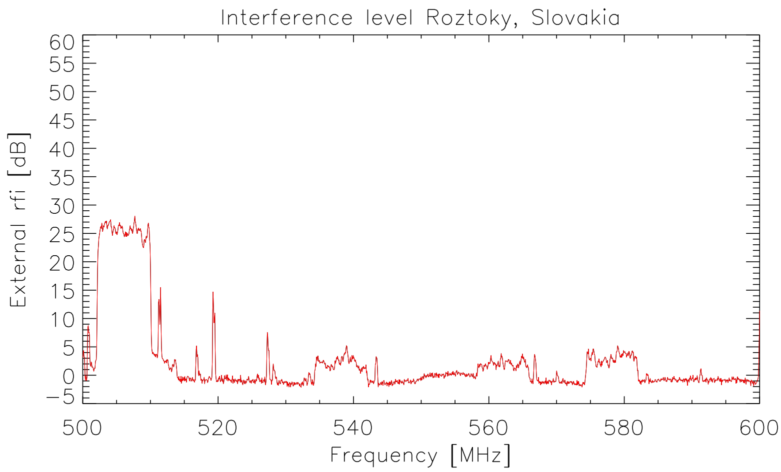

Figure 8. A spectral overview with 1600 channels measured at the Roztoky observing station. A high interference level can be seen in this range. The channels are used for DVB-T.

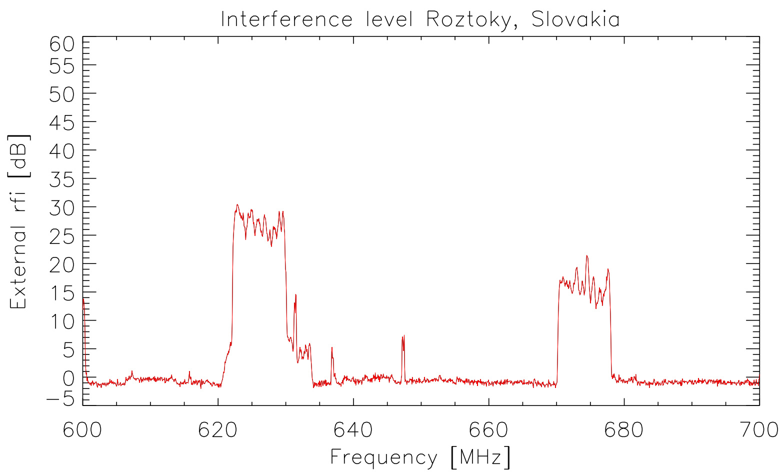

Figure 9. A spectral overview with 1600 channels measured at the Roztoky observing station. A rather high interference level can be seen in this band. The frequencies 608 - 614 MHz are reserved for radio astronomy (solar flux monitoring and pulsar observations), but shared with other services. Above 620 MHz there is a strong DVB-T interference, but some individual channels may be used for solar observations.

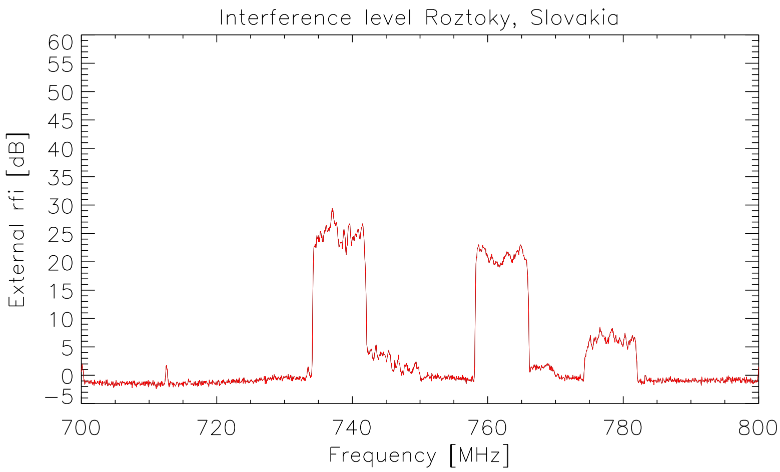

Figure 10. A spectral overview with 1600 channels measured at the Roztoky observing station. A very low interference level can be seen in this band. This range would be ideal for solar observations of decimetric pulsations. However, there are two strong DVB-T channels which reduce the number of RFI-free channels.

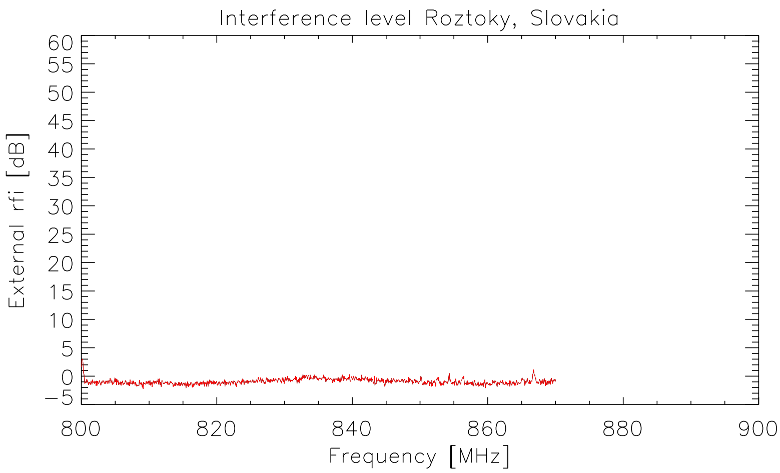

Figure 11. A spectral overview with 1120 channels measured at the Roztoky observing station. A very low interference level in this whole sub-band makes the latter suitable for solar observations.

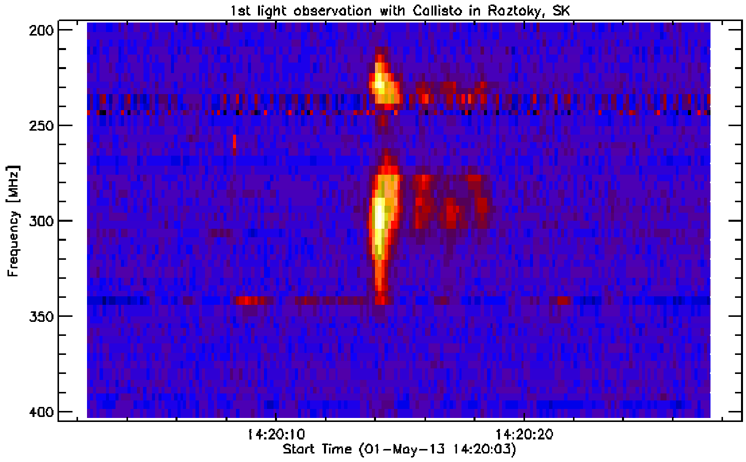

Figure 12. 1st light at Roztoky observed with the Callisto radio spectrometer showing a small type III burst (1st of May burst). Horizontal stripes are produced from local interference. A time resolution is of 250 ms and the spectrum is composed of 200 frequency channels. Each channel can be freely preprogrammed in the Callisto between 45 MHz and 870 MHz.

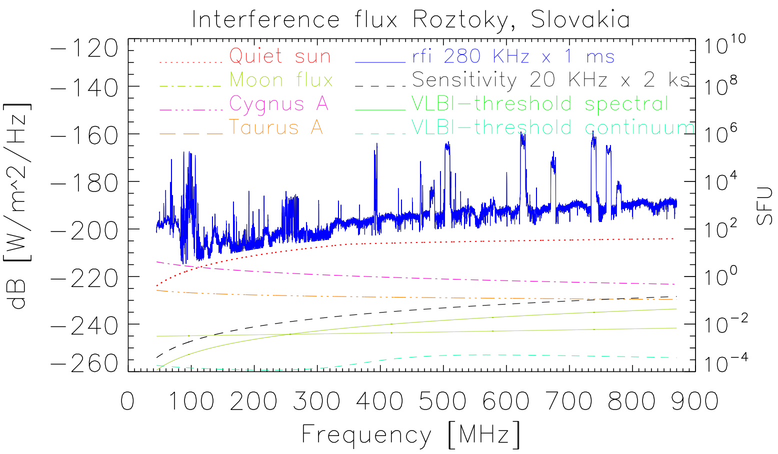

Figure 13. A spectral overview expressed in flux units for comparison with quiet Sun, Moon and other celestial radio sources. Also shown are current sensitivity and potential sensitivity with a long integration time of 2000 seconds. In addition, the plot shows the VLBI threshold level for spectral and continuum observations according to ITU-R RA.769. (ITU, 2002)

2.3. Spectral overview and details

The overall measured spectrum is shown in Figure 2. The spectral overview for Roztoky is composed of 13'200 channels with a 62.5 KHz spacing. In all plots shown below, 0 dB is referred to the system noise level given by the 50 Ω resistor (termination attached to the receiver) at $\sim 300\ Kelvin$ ambient temperature. The spectrum was taken with the antenna erected and pointed to the Sun during its transit obove Roztoky. For better visualization, the overall spectrum was split into ten detailed (zoomed) spectra relevant to solar radio astronomy. These are shown in Figures 3-11. A calculation of the external noise was done according to the following.

$$Y_{dB} = \frac{ysky_{mV} - yref_{mV}}{25.4\ mV/dB}. \tag{1}$$

For the online light curve, as well as FIT files, dB can be calculated from:

$$Y_{dB} = \frac{ysky_{digit} - min(ysky_{digit})}{255\ digit} \frac{2500\ mV}{25.4\ mV/dB}. \tag{2}$$

In addition, the Roztoky spectral overview was transformed into flux units (Jansky) for easier comparison with the known flux levels of several celestial sources, see Figure 13. The plot also demonstrates that with additional 10 dB of antenna gain one could observe the quiet Sun.

2.4. Long time observation with CALLISTO

Although the Sun was not active at the time of the installation and configuration, we observed it during lunch time for a couple of hours. The amount of cross modulations during the time of observation due to nearby transmitters is acceptable under the present conditions (nearby towns of Bardejov and Svidník). By a careful selection of quiet frequencies (statistics over many spectral overviews taken at different times of the day), it might be possible to improve the situation. During the preliminary tests we received a 1st light solar radio type III burst in the VHF range, see Figure 12. In Roztoky, solar radio observations can be performed independently of weather conditions from 07:00 UT until 15:00 in winter season and from 03:00 UT until 19:00 UT during summer. Every day, a PC program automatically adjusts the observation time based on longitude, latitude, altitude and elevation of the horizon.

3. Results and conclusions

The radio spectrum acquired at the Roztoky site is not as good as previously expected in terms of RFI and, hence, Roztoky is not ideal as a host site for a solar frequency agile or even an FFT spectrometer below 1 GHz. Nevertheless, observations of dynamic solar bursts are possible and again the Callisto instrument proved to be a cheap, but powerful tool for spectroscopy, as well as for monitoring and analyzing of the RFI in the 45-870 MHz band. With a currently available tooling and instrumentation, it was not possible to study the interference situation below 45 MHz and above 870 MHz. This task would require appropriate test antennas and spectrum analyzers or converters in front of the Callisto. Given a high level of interference, the following actions will be taken into account,

- Installation of a 'chicken-wire' fence to protect and shield the antenna from remote FM and TV transmitters. A reduction of RFI by an order of at least 10 dB is expected.
- Putting the antenna below the horizon into a hole, such that it cannot see the interfering transmitters but still can point to the Sun. We expect an additional attenuation of at least 3 dB.
- Adjust the antenna polarization in a way that it is perpendicular to the polarization of the strongest interfering transmitter.

All RFI mitigation actions will be monitored, analyzed and reported in a separate paper.

The main advantage of the e-Callisto network is observing the same solar bursts at several locations, allowing the scientist interested to select the best data for analysis. Or, he/she can correlate between different stations with identical observations. It has already been demonstrated that observations from several stations can simply be added to improve the signal-to-noise ratio because the bursts are correlated (increasing signal) while RFI is not correlated, therefore decreasing the RFI and noise. All observatories are constantly encouraged to cooperate among themselves and to motivate young students to make use of the e-Callisto network. During international meetings the network is promoted and it still keeps growing with a rate of about 3 instruments per year.

4. Relevant internet addresses

- CALLISTO ⇒ http://www.e-callisto.org

  This website contains full access to all data (FIT-files) of the network. It also contains all software to operate the instruments and do a data analysis. It also contains a full description of the hardware, software, maintenance and operating.

- IHY ⇒ http://ihy2007.org/

  IHY2007 was the starting point of the Callisto project. The Callisto was designed to support developing countries to take part in modern solar radio science. Now IHY2007 has officially been closed. But all activity is continuing within ISWI.

- ISWI ⇒ http://www.iswi-secretariat.org/

  ISWI website presents all other instruments which were installed and put into operation. The Callisto is only one of many instruments.

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References

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