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Report

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Callisto spectrum measurements in Ootacamund

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Abstract. During a measurement campaign in winter 2006 spectrum measurements were done at different locations of Ooty radio telescope site. Measurements were done with a broadband scanner antenna connected to a Callisto spectrometer designed and built by ETH Zurich (Benz, 2004). This measurement campaign shall be the technical basis to decide how to continue concerning spectroscopic measurements below 1GHz with existing antennas and/or new ones. The results are presented and discussed in form of digitally zoomed spectrums in the most interesting radio astronomy frequency ranges.

Key words. Callisto, spectrum, cross modulation, interference.

1. Introduction

In view of IHY and also in view of an intention to upgrade Muthorai station, a measurement campaign was planned and organized between TIFR and ETH Zurich. The measurement took place after the IHY meeting in Bangalore between Dec. 3th and Dec. 4th 2006 at several location in the neighborhood of the observatory.

1.1. Station description

The large radio telescope near Ootacamund (Ooty) was set up by TIFR radio astronomers, in the picturesque Nilgiri Hills of South India in 1970. Designed and built in India, the Ooty Radio Telescope (ORT) is an off-axis parabolic cylinder 530 m long and 30 m wide operating at a nominal frequency of 326.5 MHz with a maximum bandwidth of 15 MHz at the front-end. The reflecting surface of the telescope is made of 1100 thin stainless-steel wires running parallel to each other for the entire length of the cylinder and supported on 24 steerable parabolic frames. An array of 1056 half-wave dipoles in front of a 90 degrees corner reflector forms the primary feed of the telescope. The unique feature of the design is that the telescope has been constructed on a hill which has a natural slope of about 11 degrees, the same as the geographical latitude of Ooty. This makes the long axis of the telescope parallel to the Earth's rotation axis, giving it an equatorial mount. A celestial source in the sky can be tracked for about ten hours at a stretch by mechanical rotation of the parabolic cylinder in the east-west direction. In the north-south direction, the telescope response is steered electronically by introducing a suitable phase and delay gradient. along the dipole array. The Ooty Radio Telescope came into operation in 1970 and has been in almost continuous use since then. Over the 25 years of its existence, it has produced many important astronomical results on radio galaxies, quasars, supernovae, pulsars, the interstellar and interplanetary media etc. One of the most successful observational programmes carried out for many years at Ooty was to determine the angular structures of hundreds of distant radio galaxies and quasars by the technique of lunar occultations. The application of this unique database to observational cosmology provided independent evidence against the Steady-State theory of Universe

Fig. 1. Dipole array Muthorai 500m x 30m at 327MHz dedicated to solar radio observations.

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Fig. 2. CALLISTO dual receiver, frequency agile spectrometer foreseen to upgrade Ooty for solar spectroscopy.

and supported the Big-Bang model of the Universe. The telescope is currently being used mainly for the study of pulsars, radio recombination lines and interplanetary scintillations. Geographic longitude: $E, 76^o40'02"$, geographic latitude: $N, 11^o22'56"$, altitude above sea level: 2250 meter.

1.2. Measurement instrumentation

We used a commercial scanner antenna 0.5...2060Mhz procured by CONRAD (Germany). The maximum SWR of the antenna was given to 1.6. The antenna has 2.7m coaxial cables of type RG-174 and BNC connector. The Callisto spectrometer e-C03 having a detector sensitivity of 25mV/dB including control cables and rf adapters was supplied by ETH Zurich. The channel resolution is 62.5KHz, while the radiometric bandwidth is about 300KHz. The sampling time is in the order of 1msec per frequency-pixel. The frequency is expressed in MHz and the detector output is expressed in milli volts. Both are stored in a simple ASCII file which can be analyzed with any spread sheet like EXCEL.

1.3. Acronyms

Different acronyms used in labels and text are described in table 1.

2. Results

2.1. Comparative overview Ooty/India versus Zurich/Switzerland

The measured spectrum was split into 7 sub spectra to better give comments on it. For plots, see figures 3, 4, 5, 6, 7, 8 and 9. The total spectrum is composed of 13120 channels 62.5KHz apart. In all plots shown below 0dB is referenced to the background noise level given by a 50Ω termination resistor at ambient temperature of about 20°C.

Abbreviation	description
Callisto	Radiospectrometer
CRAF	Committee on Radio Astronomy Freq.
DVB-T	Digital video broadcast terrestrial
ETH	Eidgenössisch Technische Hochschule
FM	Frequency modulation (Radio)
IHY	International Heliospheric Year
ORT	Ooty radio telescope
rf	radio-frequency
RISC	Reduced Instruction Set Computer
SWR	standing wave ratio
TIFR	Tata Institute of Fundamental Research
TV	Television
UHF	ultra high frequency

Table 1. Acronyms mentioned in labels and comments.

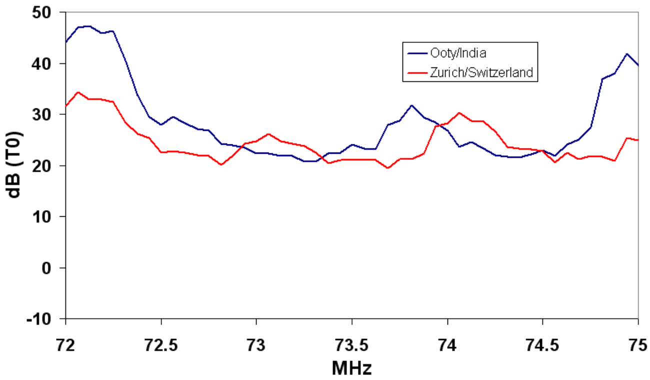

Fig. 3. Spectral overview measured in Ooty and Zurich observatory. Comparable, but high interference levels due to local electronic devices. Shared use of for the radio astronomy band 73MHz until 74.6MHz.

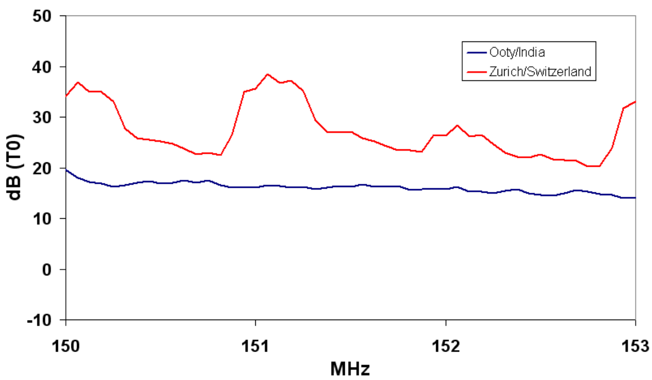

Fig. 4. Spectral overview measured in Ooty and Zurich observatory. Zurich interference level is much higher than in Ooty. The frequencies 150.05MHz until 153Mhz are reserved for radio astronomy. Primary use for radio astronomy.

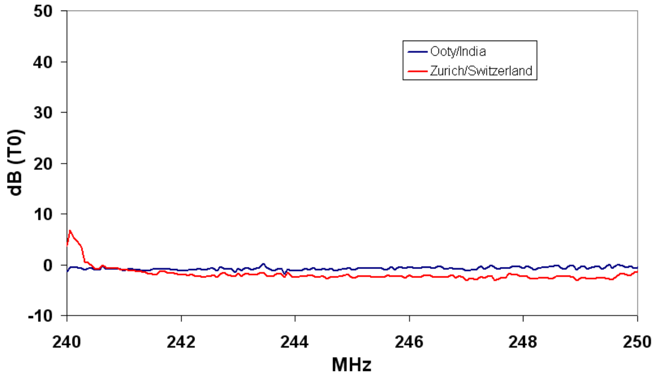

Fig. 5. Spectral overview measured in Ooty and Zurich observatory. Comparable low interference level in both countries. The frequency 245MHz is a fixed frequency for the measurement of quiet sun flux but shared with other services.

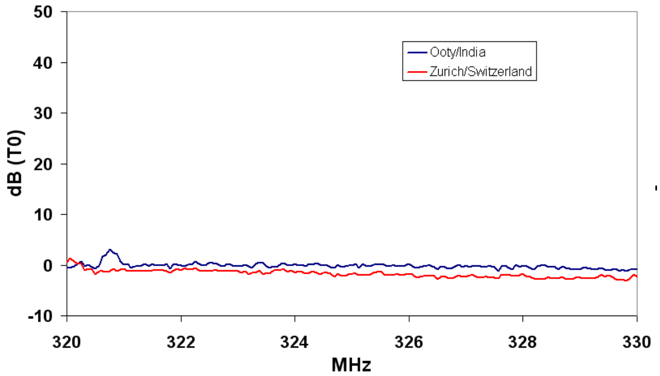

Fig. 6. Spectral overview measured in Ooty and Zurich observatory. Comparable low interference level in both countries. The range 322MHz until 328.6MHz is reserved for line observations. Primary use for radio astronomy.

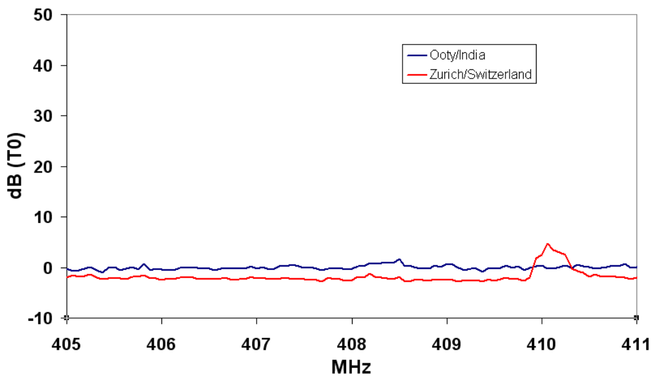

Fig. 7. Spectral overview measured in Ooty and Zurich observatory. Comparable low interference level in both countries. The range 406.1MHz until 410.0MHz is reserved for radio astronomy services. Primary use for radio astronomy.

2.2. Overview using 1 element of Muthorai telescope

Only one single element of Muthorai telescope was connected to CALLISTO including a preamplifier but with band pass filter taken out. Measurement of the quiet sun is called ON-source while the measurement away from the

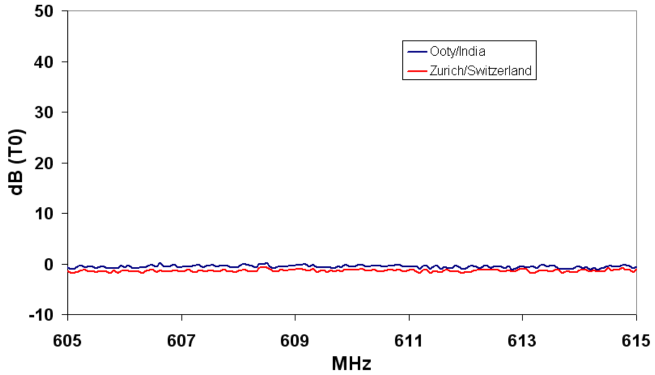

Fig. 8. Spectral overview measured in Ooty and Zurich observatory. Comparable low interference between these two countries. The range 608.0MHz until 614.0MHz is a non-exclusive band reserved radio astronomy services.

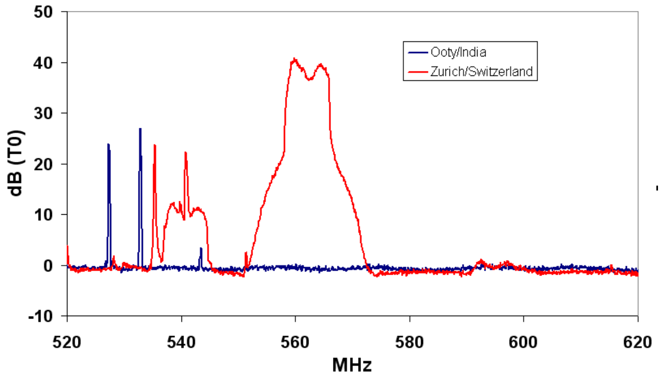

Fig. 9. Spectral overview measured in Ooty and Zurich observatory showing UHF TV band. In Switzerland (red plot) the range between 550MHz and 575MHz is used by DVB-T and thus no frequency can be use for observation. In Ooty (blue plot) there is only an analog TV channel Nr.28 where always a free channel in between can be found.

sun is called OFF-source. In figure 10 we see the difference expressed in dB. The local oscillator of the instrument at 296.6MHz is very strong and may even saturate CALLISTO. The frequency range between 310MHz and about 350MHz might be used for high temporal spectroscopic observation using CALLISTO with 80 channels 500KHz apart in 100msec per sweep. The Y-factor of more than 20dB is comparable with the Y-factor of 1 module of ORT telescope.

2.3. Overview using 1 element of ORT

Only one single element of ORT telescope was connected to CALLISTO without any preamplifier but with quite a long coaxial cable of about 50m length. Measurement of the quiet sun is called ON-source while the measurement away from the sun is called OFF-source. In figure 11 we see both plots while in figure 12 the difference is expressed in dB. In figure 11 we see the influence of the local oscillator at 296.7MHz. It shows up with more than 50dB and thus, saturates CALLISTO. We also see crossmodulation with

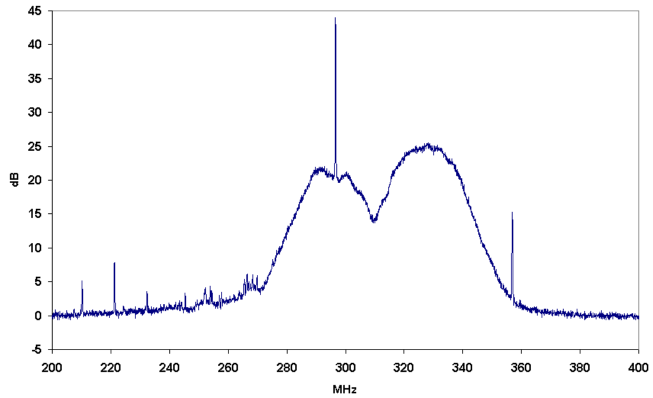

Fig. 10. Solar observation using one single module of Muthorai telescope. Plot of December 4th 2006 shows ON_{sun} - OFF_{sun} expressed in dB. Very strong LO level at 296.6MHz.

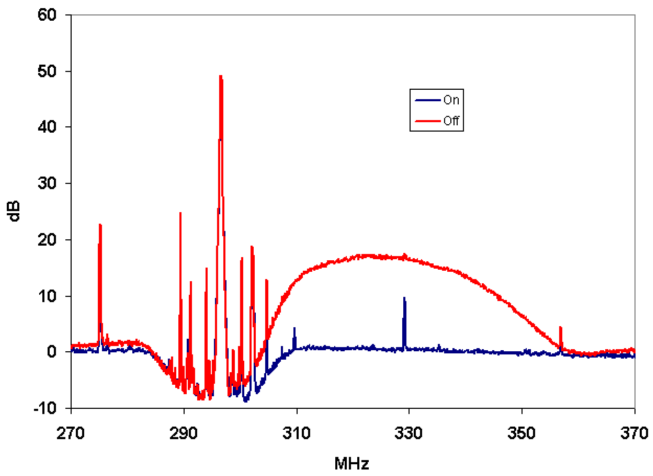

Fig. 11. Solar observation using one single module of ORT instrument. Plot of December 4th 2006 shows ON_{sun} and OFF_{sun} expressed in dB. Reference level is background noise level. High interference level due to local oscillator near 296MHz.

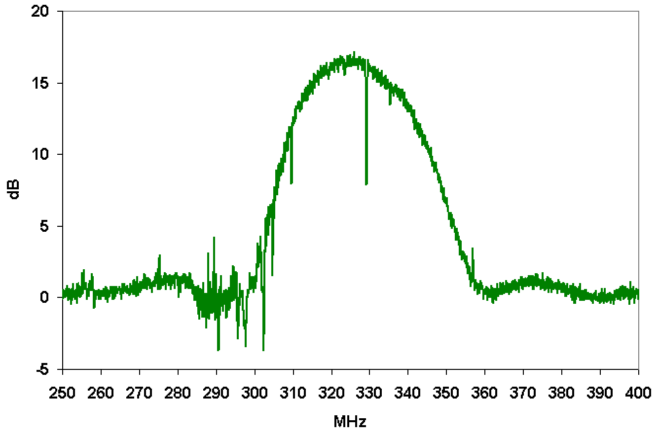

Fig. 12. Solar observation using one single module of ORT instrument. Plot of December 4th 2006 shows Y-factor=ON_{sun} - OFF_{sun} expressed in dB.

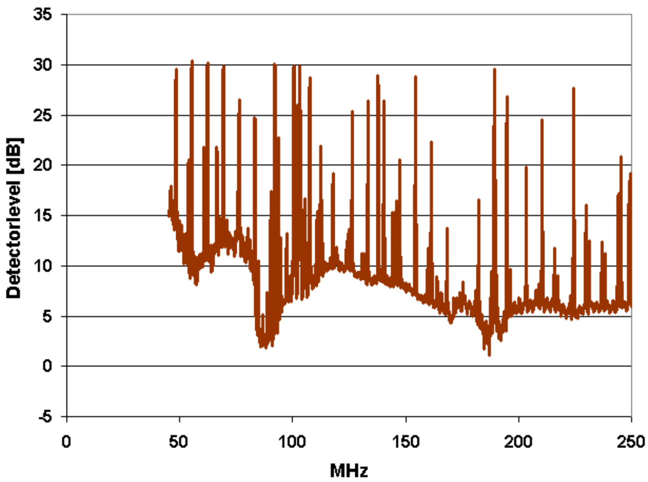

Fig. 13. Radio frequency monitoring using CALLISTO connected to a logarithmic periodic Yagi antenna. A lot of local interference due to nearby electronic devices.

other carrier signals between 285MHz and 310MHz. The leakage of the LO should be avoided because this level is really too high to be dealt with. In figure 12 the negative influence is almost compensated due to the difference of ON_{sun} - OFF_{sun} but there is still additional noise due to LO and also some military satellites in geostationary orbit between 280MHz and 310MHz. The negative peak at 329.25MHz is just 0.45MHz outside of the reserved radio astronomy band 322MHz ... 328.6MHz. One module of ORT might be used for high temporal spectroscopy between about 310MHz and about 350MHz even without preamplifier! The Y-factor of more than 15dB is comparable with 1 module of Muthorai telescope.

2.4. Overview using 1 logarithmic periodic antenna with CALLISTO

Observation was done near the institute with one single logarithmic periodic Yagi antenna pointing to the zenith. A preamplifier was mounted between the antenna the long cable going to CALLISTO in the library of the institute. The total plot composed of 13120 channels is split up into 4 sub band of 250MHz each, see figure 13 until 16. The reference level of 0dB is set to the background noise level at 608MHz.

2.5. Observation of X-flare with CALLISTO

Occasionally the sun was very active a few days after installation and configuration. Thus, during that time a couple of flares were recorded with Callisto. A very bright one was NOAA-event number 4600 on December 13th at 03:06, see figure 17.

3. Conclusions

Ooty is not yet suffering from DBV-T and other broad band applications and is thus, an ideal place for a fre-

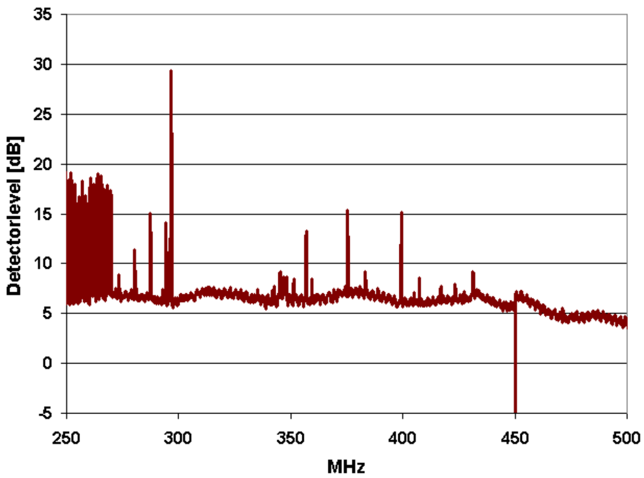

Fig. 14. Radio frequency monitoring using CALLISTO connected to a logarithmic periodic Yagi antenna. A lot of military satellites between 240MHz and 270MHz and a local oscillator at 296MHz. The negative peak at 450MHz denotes to the band gap in the receiver configuration.

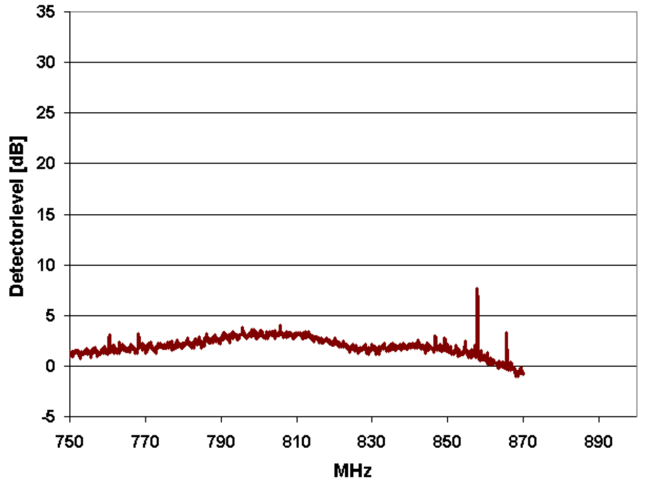

Fig. 16. Radio frequency monitoring using CALLISTO connected to a logarithmic periodic Yagi antenna. This part of the spectrum is very clean and undisturbed.

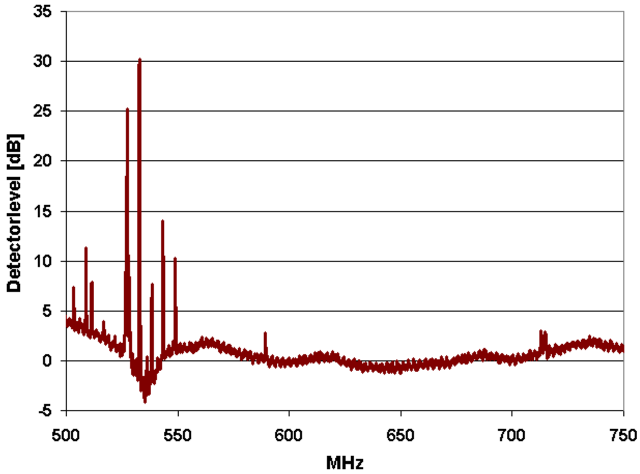

Fig. 15. Radio frequency monitoring using CALLISTO connected to a logarithmic periodic Yagi antenna. A local analog TV channel saturates CALLISTO between 527MHz and 532MHz.

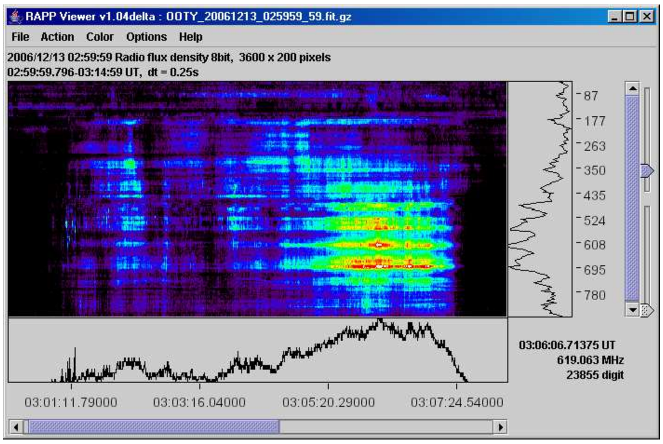

Fig. 17. Observation of X3.4 flare on December 13th at 03:06UT. It was recorded by NOAA as event number 4600.

quency agile spectrometer. All reserved frequencies are still free from interference. Most of the strong interferences are home made by local electronic devices and local oscillators. To mitigate self induced interferences we strongly recommend not to remote switch antennas electronically. But when needed then low pass filters and shielded cables should be used. Whenever possible, feed all coaxial cables down to the receivers. As soon as one wants to install a second system which is not frequency- and phase locked to the main receiving system it will suffer from electromagnetic interference from the neighboring system. One should try to shield all local oscillator components and also all IF components to prevent leakage of rf into the receiving antenna of CALLISTO. It is strongly recommended to move the logarithmic periodic antennas far away from the institute to reduce local interferences. An ideal antenna might be one element of the Muthorai telescope in combination with a logarithmic periodic antenna for the second channel. It should be possible to use 40MHz bandwidth for solar radio observation. If one decides for 80 channels per sweep and 10 sweeps per second (800 pixels per second in total) one could get a time resolution of 100msec and a frequency resolution of 500KHz. Since the Y-factor of one element is higher than 15dB a calibration using quiet sun and/or galactic plane is possible without special components in the focal plane (noise sources, switches etc.).

4. Relevant internet addresses

4.1. CRAF

`http://www.craf.eu`

4.2. Callisto

http://www.astro.phys.ethz.ch/instrument/callisto/callisto_nf.html

4.3. IHY

http://ihy2007.org/

4.4. X-flare

http://www.sec.noaa.gov/ftpdir/indices/events/20061213events.txt

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