

Callisto spectrum measurement at Humain station ROB

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Abstract. During a measurement campaign in May 2006 spectrum measurements were done at Humain station in Belgium. Humain is part of the ROB (Royal Observatory of Belgium) located south of Brussels, capital of Belgium. Measurements were done with a broadband logarithmic periodic antenna connected to a Callisto spectrometer designed and built by ETH Zurich, see (Benz, Monstein and Meyer, 2005). This measurement campaign shall be the technical basis to decide how to continue concerning fixed frequency measurements and also spectroscopic measurements below 1GHz. The results are presented in total overviews as well as in form of a digital zoom on the most interesting frequencies ranges. An extreme difference in polarization was detected. While horizontal polarization leads to acceptable results, vertical polarization can not be used by Callisto spectrometer because the power level is too high and therefore produces cross modulation.

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

1. Introduction

In view of IHY and also in view of an intention to upgrade Humain station, a measurement campaign was planned and organized between ROB and ETH Zurich. The measurement took place on May 24th 2006 from 09:00 to 11:00 in the laboratory at Humain station.

1.1. Station description

All details (taken from the CRAF-website) of the Humain radio observatory are as follows. Geographic longitude: $05^{\circ}15'19''$, geographic latitude: $50^{\circ}11'31''$, altitude above sea level: 293 meter, diameter telescope 1: 7.5 meter (Würzburg Riese), diameter telescope 2: interferometer with 48 elements of 4 meter diameter (asymmetric T shape). Available observing mode: single dish. Frequencies used currently: 406.1–410.0 MHz, single dish 608.0–614.0 MHz interferometer. Research programs: solar research.

1.2. Measurement instrumentation

We used a commercial logarithmic periodic antenna HL023 A1 manufactured by Rohde&Schwarz (Germany). The maximum SWR of the antenna was given to 1.6. The antenna (figure 1) including stative, tripod and 9m coaxial cables of type RG-213 was supplied by "Institut Belge

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Fig. 1. Logarithmic periodic antenna at Humain station connected to Callisto spectrometer. Top right in the background an old "Würzburg Riese", remains from World War II. In the background left the East-West arm of the old solar interferometer.

des Services Postaux et des Télécommunication". The Callisto spectrometer FM3 having a detector sensitivity of 48mV/dB including control cables and rf adapters was supplied by ETH Zurich. Between antenna and Callisto a 1GHz low pass filter manufactured by "Mini Circuits" was inserted to keep the spectrometer free from mobile communication interferences. All local mobile phones had to be switched off during the measurements. In addition, all nearby computers and other electronic devices were switched off.

| Abbreviation | description |
|--------------|------------------------------------------|
| ACF | Auto correlation function |
| BII | TV band III 174MHz-230MHz |
| Callisto | Radiospectrometer |
| CRAF | Committee on Radio Astronomy Freq. |
| DVB-T | Digital video broadcasting terrestrial |
| ETH | Eidgenössisch Technische Hochschule |
| FM | Frequency modulation (Radio) |
| HP | Horizontal polarization |
| IHY | International Heliospheric Year |
| NE | North East |
| NW | North West |
| rf | radio-frequency |
| ROB | Royal Observatory of Belgium |
| SE | South East |
| SS | South |
| SWR | standing wave ratio |
| SW | South West |
| Tetrapol | cellular trunked radio system (Schengen) |
| TV | Television |
| UHF | ultra high frequency |
| VHF | very high frequency |
| VP | Vertical polarization |

Table 1. Acronyms mentioned in labels and comments.

1.3. Acronyms

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

2. Results

2.1. Comparative overview Humain versus Bleien

A comparison between Humain station (ROB) and Bleien observatory (ETH Zurich) is given in figure 2. Both spectra were taken in elevated south direction in horizontal polarization. While Bleien is extremely suffering from strong interferences due to pager systems (negative background between 140MHz and 170MHz), Humain is able to cope with the present situation. Quite a lot of noise is also induced by electromagnetic coupling due to transient control signals sent out by Phoenix-2 switched spectrometer below 300MHz. Cross modulation at Bleien observatory leads also to a rather fidgety background. The background is much 'cleaner' at Humain than at Bleien and is thus almost ideal for spectral observations. Noise level below 100MHz is much higher at Bleien compared to Humain. On the other hand BIII-TV12 at Humain is much stronger than at Bleien observatory. If filtering by selecting the best polarization should not be sufficient then traps might be inserted into the antenna system. For a quarter of an hour spectral overview, see figure 28.

2.2. Spectral overview SW HP

A complete spectral overview 45MHz until 870MHz in SW direction using horizontal polarization is shown in figure

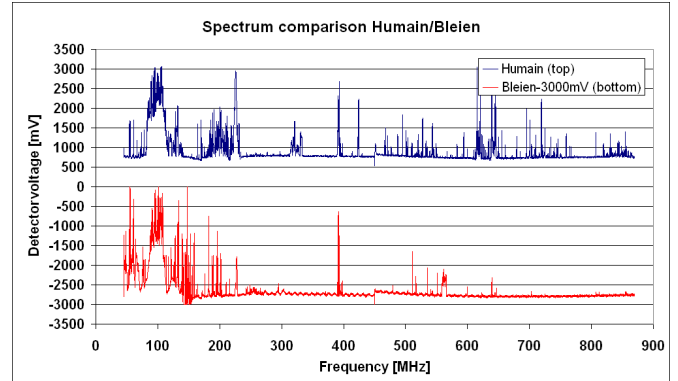


Fig. 2. Spectral overview measured at Humain station (blue) and Bleien observatory (red) in elevated South direction. To better visualize it, Bleien spectrum is shifted down by a dc voltage of -3000mV.

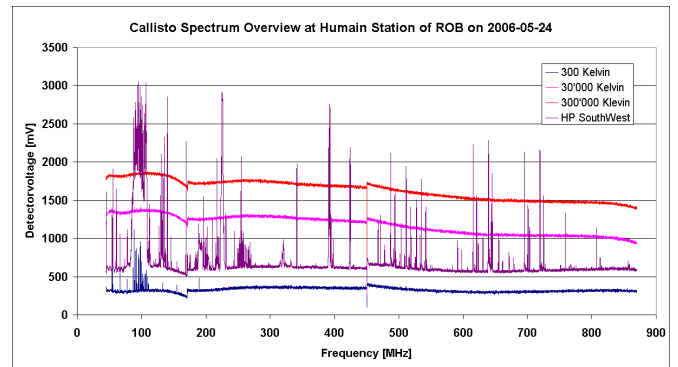


Fig. 3. Spectral overview of horizontal spectrum measured at Humain station in SW direction. An external semiconductor noise source was used to generate calibration signals with very different temperature levels. In every overview plot there is inserted a cold load (300K) in blue, a warm load (30'000K) in purple and a hot load (300'000K) in red.

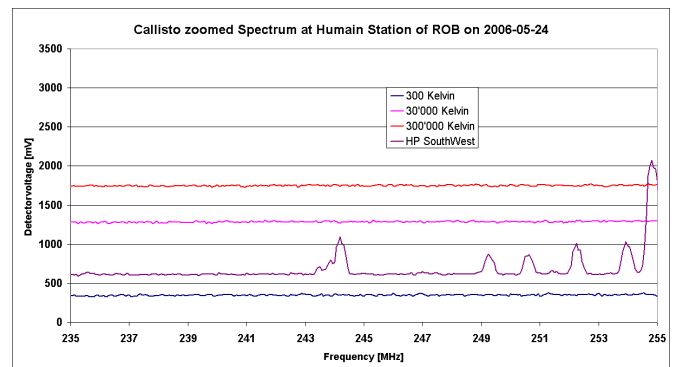


Fig. 4. Spectral zoom near 244MHz of horizontal spectrum measured at Humain station in SW direction.

3. A digital zoom near 244MHz is presented in figure 4, another at 410MHz in figure 5 and a third one at 607MHz in figure 6.

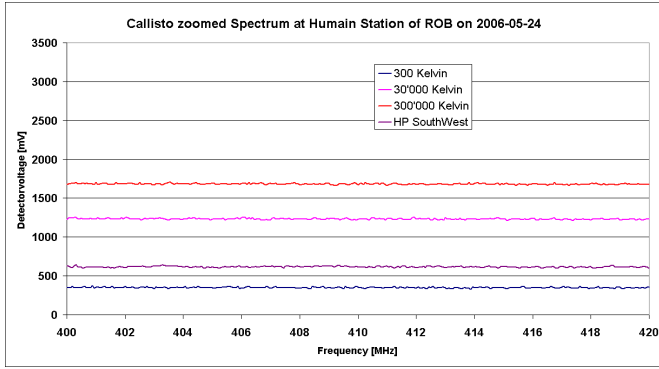


Fig. 5. Spectral zoom near 410MHz of horizontal spectrum measured at Humain station in SW direction.

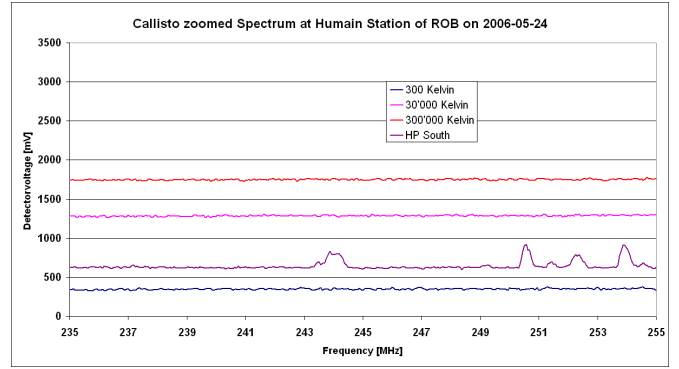


Fig. 8. Spectral zoom near 244MHz of horizontal spectrum measured at Humain station in SS direction.

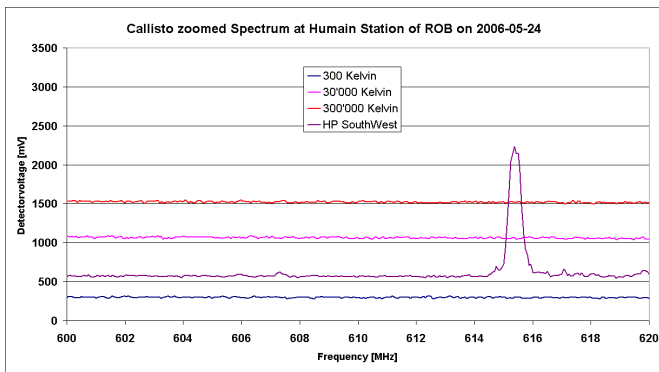


Fig. 6. Spectral zoom near 607MHz of horizontal spectrum measured at Humain station in SW direction.

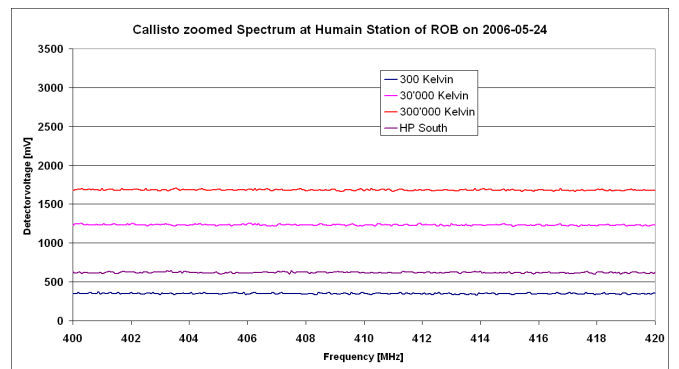


Fig. 9. Spectral zoom near 410MHz of horizontal spectrum measured at Humain station in SS direction.

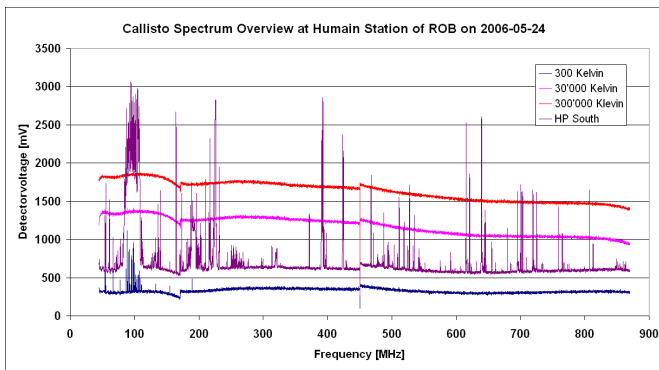


Fig. 7. Spectral overview of horizontal spectrum measured at Humain station in SS direction.

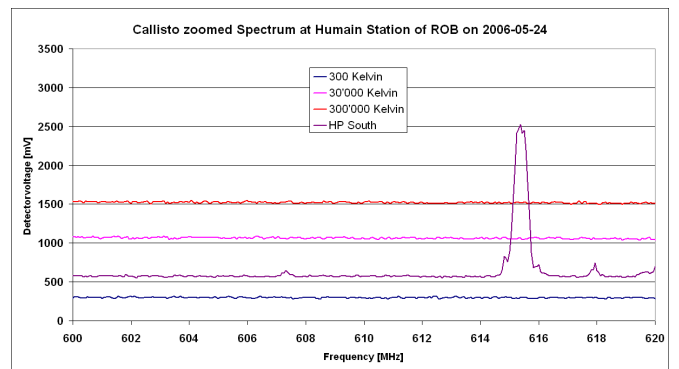


Fig. 10. Spectral zoom near 607MHz of horizontal spectrum measured at Humain station in SS direction.

2.3. Spectral overview SS HP

A complete spectral overview 45MHz until 870MHz in S direction using horizontal polarization is shown in figure 7. A digital zoom near 244MHz is presented in figure 8, another at 410MHz in figure 9 and a third one at 607MHz in figure 10.

2.4. Spectral overview SE HP

A complete spectral overview 45MHz until 870MHz in SE direction using horizontal polarization is shown in figure 11. A digital zoom near 244MHz is presented in figure 12,

another at 410MHz in figure 13 and a third one at 607MHz in figure 14.

2.5. Spectral overview NE HP

A complete spectral overview 45MHz until 870MHz in NE direction using horizontal polarization is shown in figure 15. A digital zoom near 244MHz is presented in figure 16, another at 410MHz in figure 17 and a third one at 607MHz in figure 18.

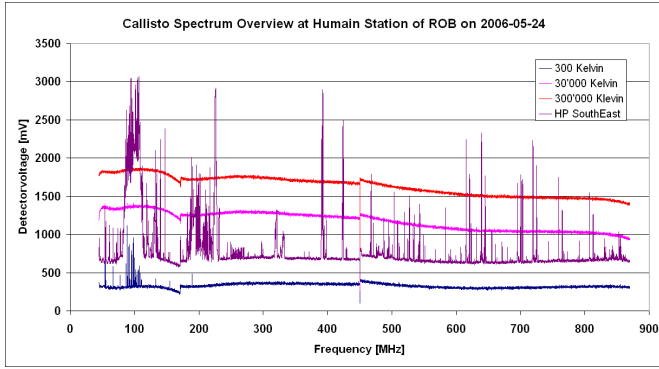


Fig. 11. Spectral overview of horizontal spectrum measured at Humain station in SE direction.

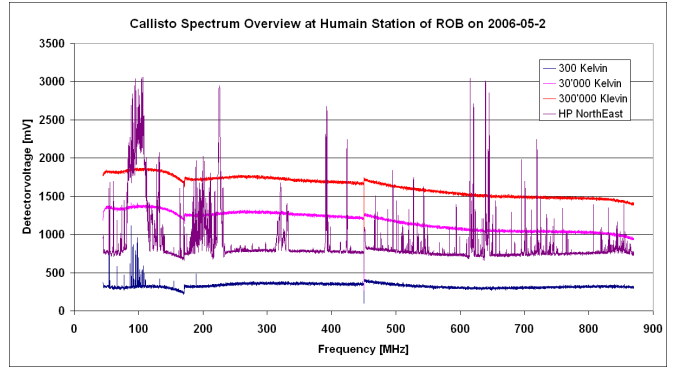


Fig. 15. Spectral overview of horizontal spectrum measured at Humain station in NE direction.

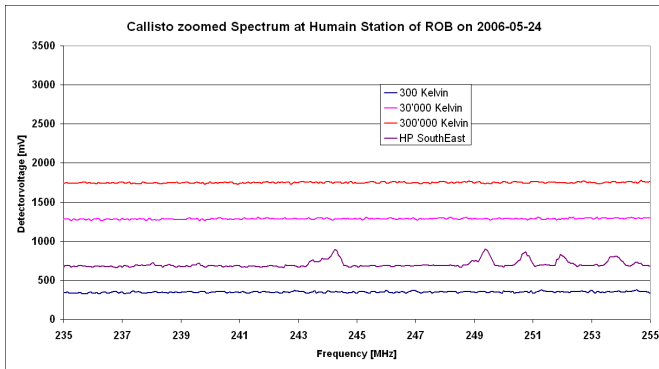


Fig. 12. Spectral zoom near 244MHz of horizontal spectrum measured at Humain station in SE direction.

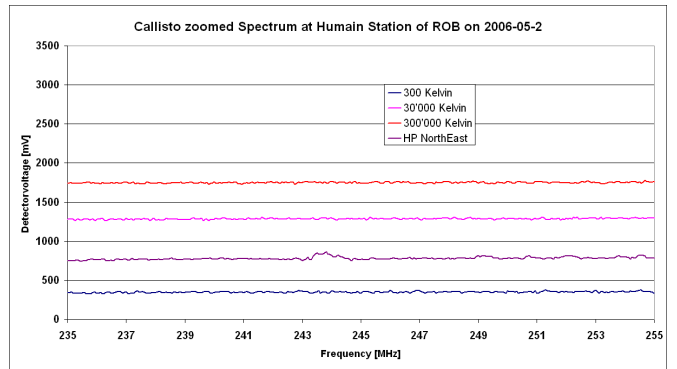


Fig. 16. Spectral zoom near 244MHz of horizontal spectrum measured at Humain station in NE direction.

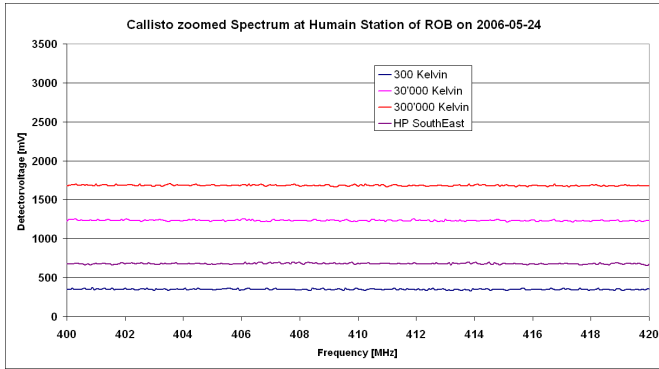


Fig. 13. Spectral zoom near 410MHz of horizontal spectrum measured at Humain station in SE direction.

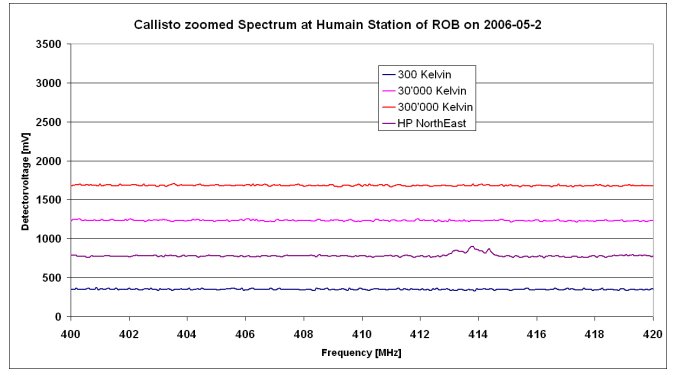


Fig. 17. Spectral zoom near 410MHz of horizontal spectrum measured at Humain station in NE direction.

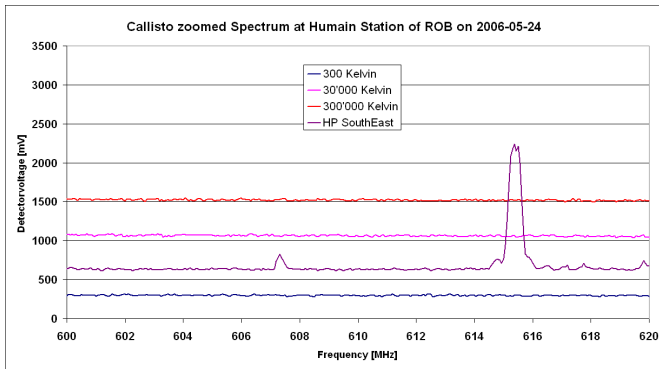


Fig. 14. Spectral zoom near 607MHz of horizontal spectrum measured at Humain station in SE direction.

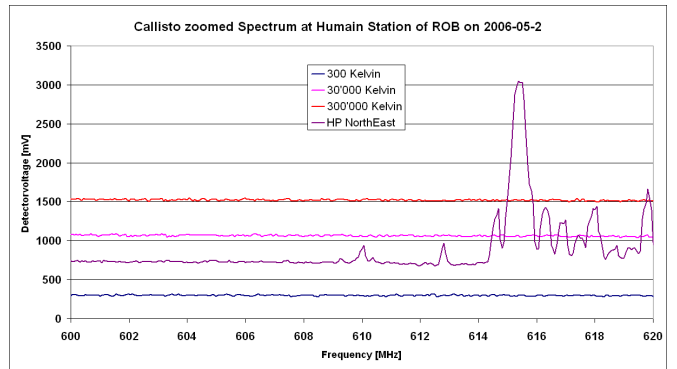


Fig. 18. Spectral zoom near 607MHz of horizontal spectrum measured at Humain station in NE direction.

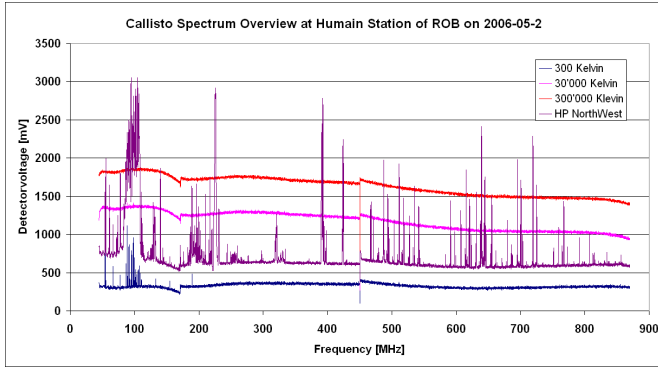


Fig. 19. Spectral overview of horizontal spectrum measured at Humain station in NW direction.

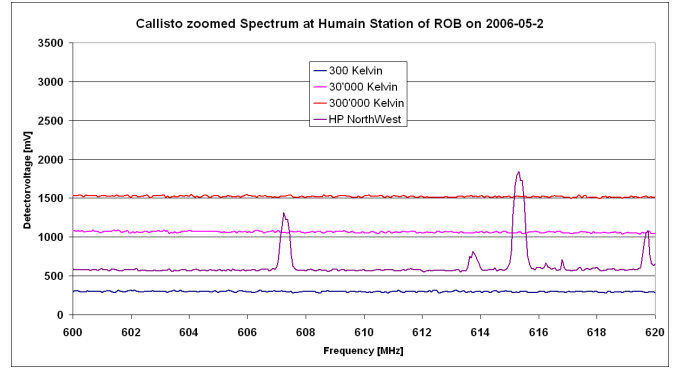


Fig. 22. Spectral zoom near 607MHz of horizontal spectrum measured at Humain station in NW direction.

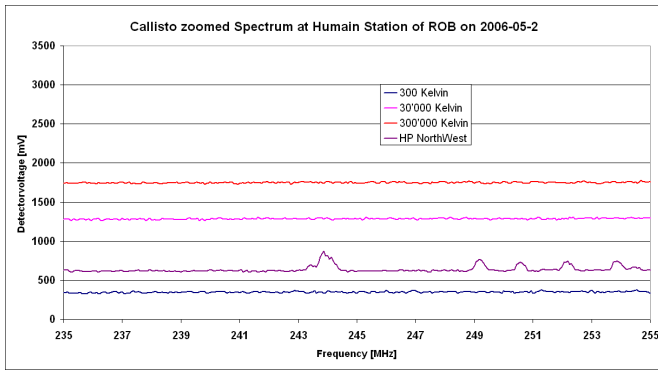


Fig. 20. Spectral zoom near 244MHz of horizontal spectrum measured at Humain station in NW direction.

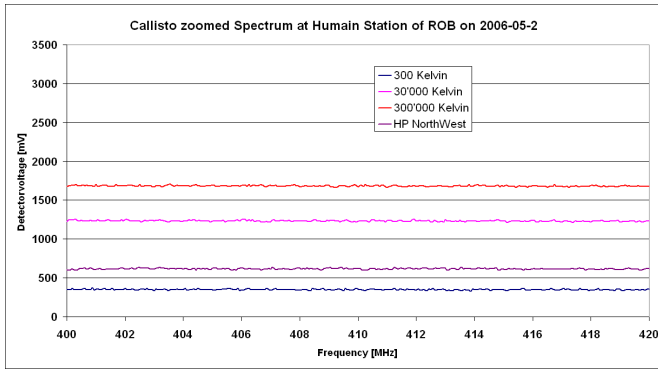


Fig. 21. Spectral zoom near 410MHz of horizontal spectrum measured at Humain station in NW direction.

| Abbreviation | description |
|--------------|------------------------------------|
| 91.563MHz | FM Radio |
| 93.500MHz | FM Radio |
| 95.375MHz | FM Radio |
| 104.75MHz | FM Radio |
| 106.81MHz | FM Radio |
| 164.94MHz | Services for inland ships/postcars |
| 225.44MHz | TV-BII channel 12 |
| 392.34MHz | Tetrapol (Schengen communication) |
| 424.81MHz | Tetrapol (Schengen communication) |

Table 2. Strongest carriers detected in vertical polarization.

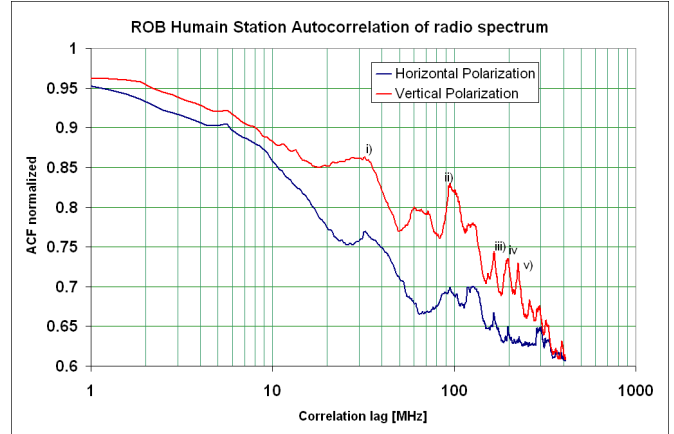


Fig. 23. Autocorrelation function of vertical and horizontal spectrum measured at Humain station.

2.6. Spectral overview NW HP

A complete spectral overview 45MHz until 870MHz in NW direction using horizontal polarization is shown in figure 19. A digital zoom near 244MHz is presented in figure 20, another at 410MHz in figure 21 and a third one at 607MHz in figure 22.

2.7. Spectral overview SW, SS, SE, NE VP

With the current setup it was not possible to measure vertical polarized radio spectrum due to the fact that several nearby vertically polarized transmission sta-

tions completely saturated the internal receiver within Callisto. Nine very strong transmission carriers were detected through the serious analysis of the spectrum, details see table 2. An autocorrelation shown in figure 23 was applied to the data of vertical and horizontal polarized spectrum captured in southern direction SS. Bump i) denotes to cross modulation between Tetrapol and TV-BII, peak ii) represents 1st harmonic of FM radio, iii) again denotes to cross modulation between Tetrapol and TV-BII, iv) also denotes to cross modulation between Tetrapol and TV-BII and v) denotes to interference between Tetrapol and inland ship/postcar communication services.

Allan Time 244MHz Humain Station ROB

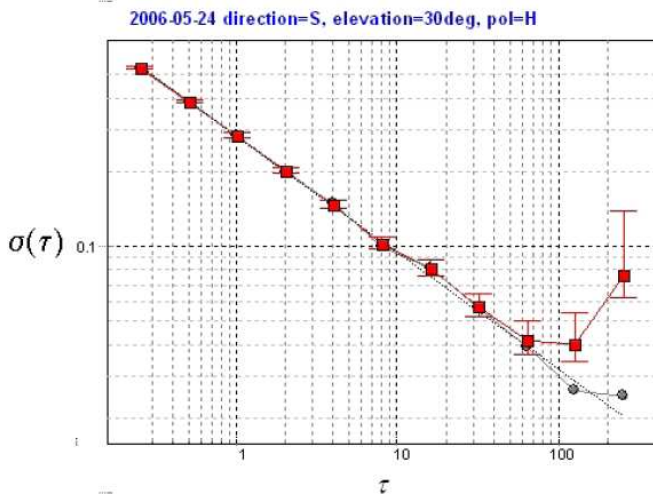


Fig. 24. Allan-time and Allan-variance of horizontal polarized spectral line at 244.19MHz measured at Humain station.

Allan Time 607MHz Humain Station ROB

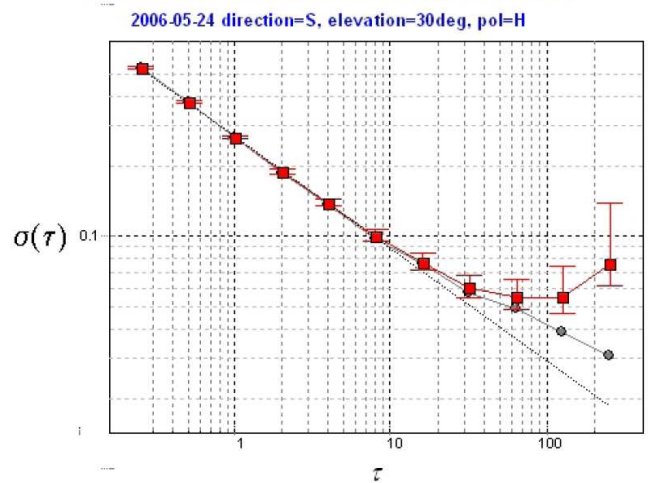


Fig. 26. Allan-time and Allan-variance of horizontal polarized spectral line at 607.19MHz and measured at Humain station.

Allan Time 410MHz Humain Station ROB

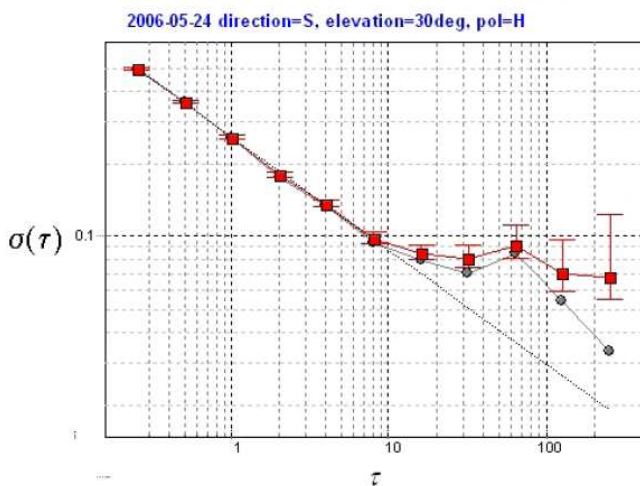


Fig. 25. Allan-time and Allan-variance of horizontal polarized spectral line at 410.22MHz measured at Humain station.

2.8. Allan time 244.19MHz

Although just between DVB-T and Tetrapol carriers, the radio astronomy frequency 244.19MHz seems to be ideal for absolute measurements. The measured Allan-time shown in figure 24 of 100sec 'on the air' is very good and the Allan-variance follows nicely the radiometric equation.

2.9. Allan time 410.22MHz

Although just between one Tetrapol and another Tetrapol carrier, the radio astronomy frequency 410.22MHz seems quite good for absolute measurements. The measured Allan-time shown in figure 25 of 30sec 'on the air' is sufficient and the Allan-variance follows nicely the radiometric equation.

2.10. Allan time 607.19MHz

Far away from Tetrapol, TV BII and FM-Radio, the radio astronomy frequency 607.19MHz seems to be ideal for absolute measurements. The measured Allan-time shown in figure 26 of 100sec 'on the air' is very good and the Allan-variance follows nicely the radiometric equation.

2.11. 15 Minute of spectrum at 30degree elevation SS

Figure 27 shows a quarter of an hour continuous measurement using a standard Callisto frequency program with 200 pixels per sweep and 4 sweeps per second. The antenna was pointed to South having 30degrees of elevation in horizontal polarization. The most bright bands represent FM-Radio, TV-BIII channel 12 and DVB-T (channel 12+). The rest of the spectrum is surprisingly quiet. The radio frequencies of the different transmitters in horizontal polarization don't interfere with each other due to their moderate power level at the antenna terminal. Integration time equals 1msec per pixel, while the radiometric bandwidth is about 300KHz. Just for comparison, see reference spectrum 28 using identical configuration. Bleien spectrum looks quit similar to Humain station, for details see overview in figure 2.

3. Conclusions

From the present data one may derive several predictions. Reserved frequencies for Radio Astronomy are still available (245MHz, 410MHz and 608MHz at Humain station. Even spectral measurements should be possible by avoiding vertical polarization. Several bands of spectral ranges are almost free from interferences (cross-modulation and direct radiation) and thus available for radio astronomy. Using the present setup with Callisto, it is not possible to observe in vertical polarization due to high interference levels. This might be optimized using traps (band stop

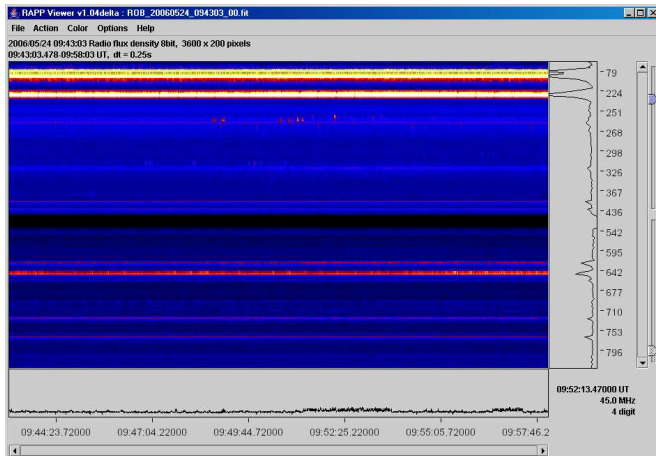


Fig. 27. Continuous measurement 800pixels/second in full frequency range of Callisto measured at Humain station. The frequency program used was originally optimized for Bleien.

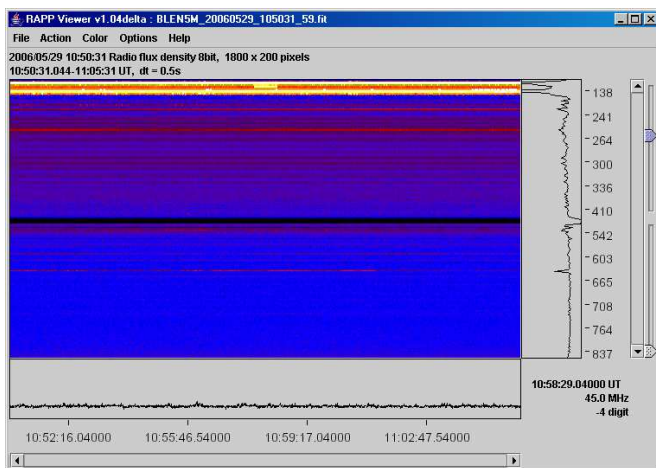


Fig. 28. Continuous measurement 800pixels/second in full frequency range of Callisto measured at Bleien station. The frequency program *frq00201.cfg* was optimized for Bleien to avoid strong known carriers.

filters) against Tetrapol, TV-BII and FM-Radio and/or by inserting high pass filters above Tetrapol frequency thus, observations below 425MHz are probably difficult to make. Instead of measuring broad band spectra from 45MHz to 870MHz it might be useful to split the spectrum in different sub bands with appropriate antennas to avoid direct radiation or spillage from commercial, private and federal transmissions. Observations in direction NE should be avoided due to high rf power levels probably originating from nearby town Liège. To mitigate self induced interferences we strongly recommend not to switch antennas electronically. Whenever possible feed all coaxial cables down to the receivers. As soon as one want to install a second system which is not frequency- and phase locked it will suffer from electromagnetic interference from the neighboring system.

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ment ready. I thank Jean-Luc Dufond and Aydin Ergen for preparing, installing and holding the antenna in strong and cold wind. Thank also to "Institut Belge des Services Postaux et des Télécommunication" for ceding antenna, mechanical parts and cables.

References

Arnold O. Benz, Christian Monstein and Hansueli Meyer, *CALLISTO A new concept for solar radio spectrometers*, Solar Physics 226, 143 - 151 (2005).