Qualification of the prototype spectrometer e-Callisto

Author(s):
Monstein, Christian

Publication Date:
2006

Permanent Link:
https://doi.org/10.3929/ethz-a-005306645

Qualification of the prototype spectrometer e-Callisto

Christian A. Monstein

ETH Zurich, Institute of Astronomy, CH-8092 Zurich, Switzerland

Draft 29.10.2006 / Updated 01.11.2006

Abstract. Expecting an increasing demand for low cost radio spectrometers in view of IHY, the existing design of Callisto was re-engineered. The re-engineering tasks took place in terms of manufacturing-time, weight, volume, power consumption and material-costs. Since almost everything changed in the former design the prototype needed to be re-qualified completely.

Key words. Allan time, SFDR, Bandwidth.

1. Introduction

The original Callisto (twin receiver) was composed of three separate printed circuit boards which pushed the price in the order of 1000$. The new concept of e-Callisto (single receiver) led to a dramatic cost decrease to about less than 200$, because only one single printed circuit board was used. All passive components are now in SMD technology and a software controlled gain control was introduced to cover all possible levels of rf signals at the antenna input terminal. All these changes made it necessary to repeat certain measurements to completely check the specification sheet. The following listed measurements were done in our lab using existing measurement instruments which were computer-controlled via a $IEEE488$ interface bus.

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

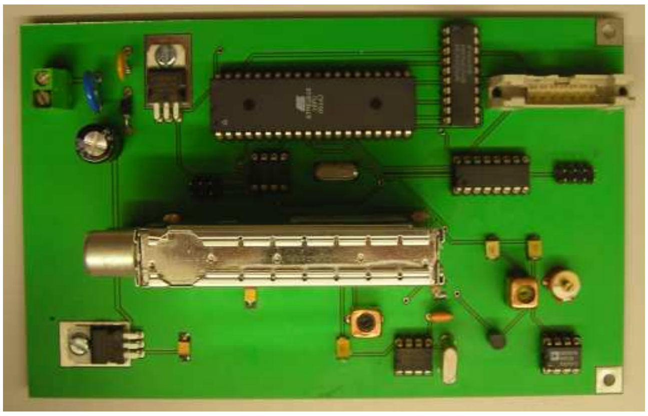

Fig. 1. Electronic board of double super-heterodyne spectrometer e-Callisto including tuner and RISC processor.

2. Measurements and Results

If possible, measurements were done using the automated test system, see figure 2 to guarantee reproducibility. All measurements were done in the electronic lab at IFA c-floor at ambient temperatures between 22°C and 23°C. All test programs were running as C++ code under Windows XP on a standard notebook connected to an USB-IEEE488 interface, purchased from National Instruments.

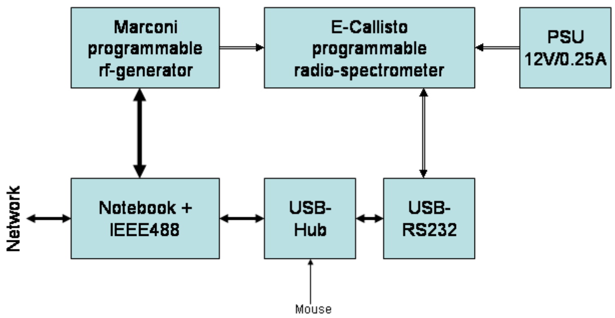

Fig. 2. Schematic of the automated test system using IEEE488 bus concept.

2.1. Power requirements

The spectrometer is designed such that one can use a standard power supply unit or an accumulator with nominally 12 volts. The lower the voltage, the lower the power consumption. But the voltage may not be lower than 8V otherwise one may expect undefined behaviors. For power plot, see figure 3

$$P = u\ i = 12V\ 0.25A = 3\ Watt(nominal) \quad (1)$$

Send offprint requests to: Christian Monstein, e-mail: monstein@astro.phys.ethz.ch

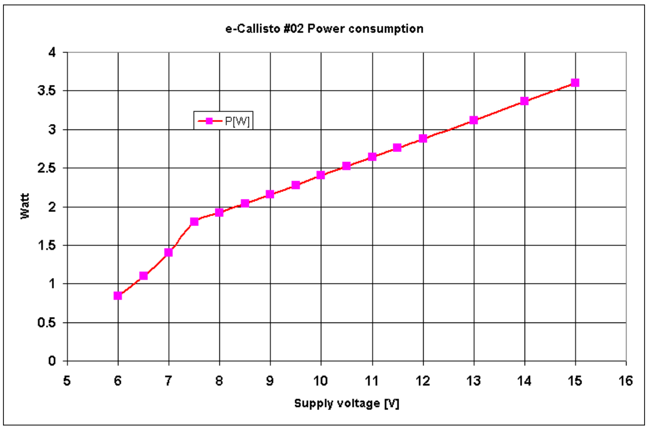

Fig. 3. Power consumption as a function of applied input voltage. E-Callisto supply range is limited between 8V and 15V dc. Nominal supply is defined to 12Vdc.

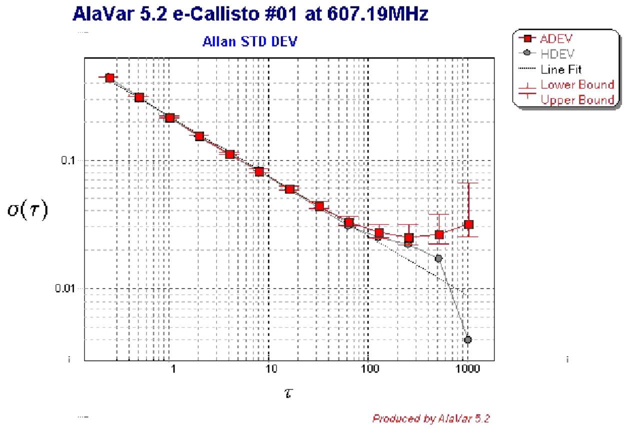

Fig. 4. Allan variance $\sigma(\tau)$ as a function of integration time τ. Allan time here is in the order of 300 sec.

Remark: We strongly recommend to use linear regulated power supplies instead of switched power supplies to keep electromagnetic interference as low as possible.

2.2. Warm up time

The measurement data to define warm up time were taken from the beginning of the Allan time measurements. The criteria was such that the detector value should show no change as a function of time. This was the case after about 20 minutes. It depends of course on power supply, environmental temperature and fixation of the spectrometer (cooling area). Remark: We recommend to not switch off e-Callisto between two successive measurements.

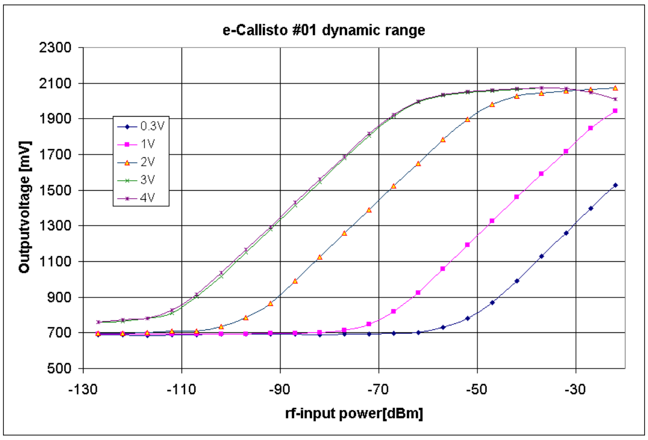

Fig. 5. Dynamic ranges as a function of gain voltage.

2.3. Allan time

The Allan time was measured in a special configuration. The antenna input was terminated by a 50Ω SMA-resistor with well defined rf power, where $P = kTB = 1.2\ 10^{-15}W$. After the measurements were done a quiet channel was selected and stored as a lightcurve in ASCII format appropriate for the software tool AlaVar. In most cases a channel next to the reserved radio astronomy frequency of 608MHz was selected. For each e-Callisto there is a AlaVar report on the web, an example is given in figure 4. For URL, see table at the bottom of this document.

2.4. Dynamic ranges

The measurement of the dynamic range was done at 4 different tuner-gain voltages (0.3V, 1V, 2V, 3V and 4V). An appropriate gain voltage has then to be selected for the individual application to prevent cross modulation in the tuner. This, due to strong interference levels of commercial radio-/tv-transmitters. These plots, see figure 5 were also used to determine the detector gradient g which was used later on to produce overall bandwidth plot. The gradient, according to the data sheet AD8307, should be in the order of $g = 25mV/db$.

2.5. Spurious free dynamic range SFDR

This measurement was done by applying a rf signal with increasing power level into the lower sub band at 173MHz. The first harmonic then felt into the frequency range of the mid band tuner and 2nd harmonic felt into the 3rd sub band tuner. All three frequency channels were measured and stored as a function of power. As soon as the mid band or the high band tuner showed a higher response than noise floor (as a consequence to the signal applied in the lower sub band tuner) then the SFDR can be determined in dB. For plot, see figure 5.

2.6. Sensitivity limit control

By applying a dc voltage to the gain control input of the tuner it is possible to change the sensitivity limit in a huge range covering more than 50dB. For plot, see figure 7.

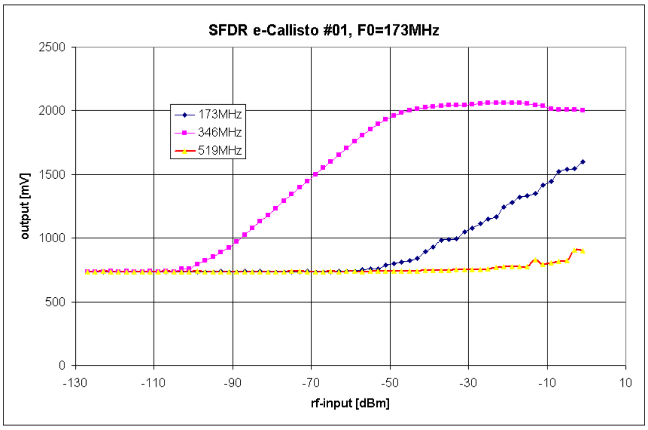

Fig. 6. Spurious free dynamic range at a standard gain voltage of 2.0Volts. SFDR is clearly above 40dB.

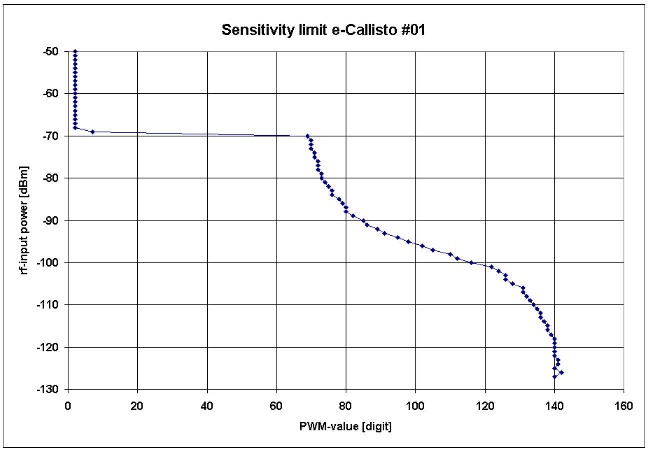

Fig. 7. Sensitivity limit as a function of applied pwm -value to the PWM-port of the RISC system.

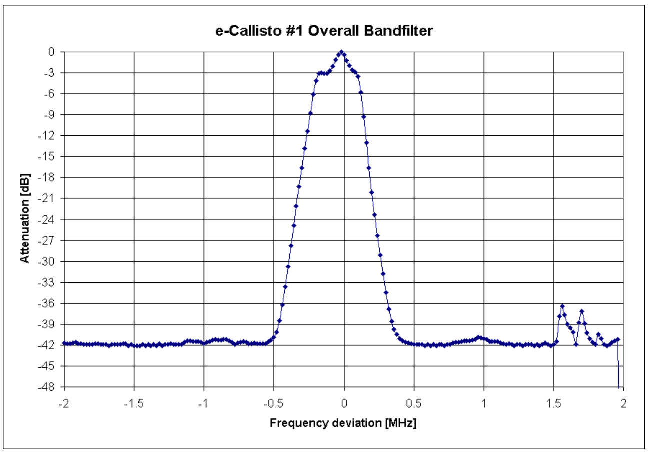

Fig. 8. Overall band filter response at 150MHz.

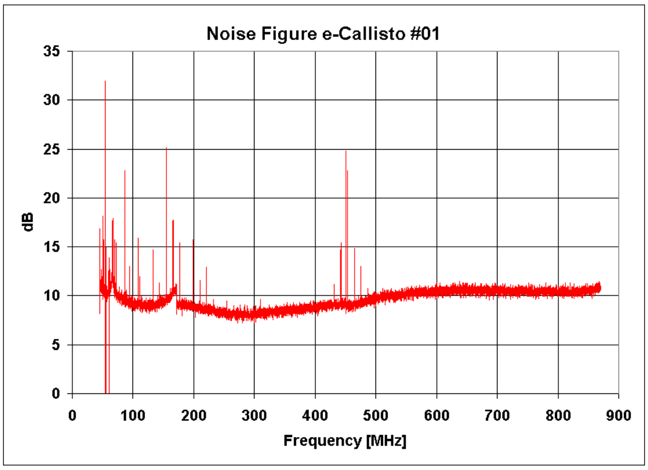

Fig. 9. Noise figure of e-Callisto (without preamplifier) using hot-cold-method. NF in average is below 10dB.

2.7. Overall bandwidth

At a fixed frequency of 150MHz a signal generator was slowly varied from 148MHy up to 152MHz in steps of 20KHz. The filter response was stored and plotted as a function of the applied frequency, see figure 8. The power level must be chosen such, that never a saturation can take place. We have chosen for -70dBm at a medium gain voltage of about 2V.

2.8. Noise figure NF

Noise figure measurement is rather difficult due to the nonlinear detector, the not very well known noise source and some impedance mismatch (50Ω/75Ω) at the antenna input connection. This measurement is just an approximation and should only verify the original data sheet of Philips. NF was evaluated by the hot-/cold measurement method using a semiconductor noise source together with the gradient measured in 'dynamic range'. The NF was calculated by the following approximation.

$$NF_{dB} = T_{excess} - 10\ log(Y - 1) \quad (2)$$

where $T_{excess} = +34.5dB - 10dB = +24.5dB$ and

$$Y_{dB} = \frac{V_{hot} - V_{cold}}{g} \quad (3)$$

where $g = 25mV/dB$ and $Y = 10^{Y_{dB}/10}$. For noise figure plot, see figure 9.

3. Conclusions

All the above mentioned measurements shall be part of the checklist within the MAIT. This, to show that every e-Callisto is produced in the same way and all parameters are within given specifications. Since we now have several automated test programs, all measurements can be repeated every time on request.

Acknowledgements. I thank Frieder Aebersold for perfectly milling the front plate and backplane for all e-Callistos.

4. Relevant internet addresses

4.1. Callisto

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

Abbreviation	description
AlaVar	Tool to evaluate Allan time/variance
Callisto	Low cost spectrometer
e-Callisto	Updated version of Callisto
ETH	Eidgenössisch Technische Hochschule
IEEE488	General purpose interface bus (hp-bus)
IHY	International Heliospheric Year (2007)
MAIT	Manufacturing, Assembly, Integration, Test
Philips	Manufacturer of tuner
PWM	Pulse Width Modulation
rf	Radio frequency
RISC	Processor with reduced instruction set
SFDR	Spurious free dynamic range
SMA	Small microwave adapter
SMD	Surface mount technology

Table 1. Acronyms mentioned in labels and comments.

Parameter	value and unit
Frequency range	45MHz ... 870MHz
Frequency resolution	62.5KHz
Bandwidth	300KHz (-3dB)
Dynamic range	-100dBm ... -10dBm
Gain control range	50dB min
SFDR	40dB min
Noise figure	15dB max
Allan time	100 sec
Sampling frequency int. clock	800s/sec max.
Sampling frequency ext. clock	1000s/sec max.
Channels	1...500, nominal 200
Supply	8V...15V/0.25A, nominal 12V
Warm up time	20 minutes
COM-parameter	115200N81
Weight	800 grams
Dimensions	w=110, h=80, d=205 mm^3

Table 2. Data sheet e-Callisto with most important parameters.

4.2. e-Callisto

`http://www.astro.phys.ethz.ch/instrument/callisto/ecallisto/applidocs.htm`