# Minutes of Meeting Kick-off Calibration Device Feasibility Study

Participants: See attached list
Dates: 2004-06-10
Venue: IRAM, Grenoble / France

**Decisions and action items are in bold.**

Agenda items 2004-06-10:
Start of meeting: 08:30
End of meeting: 14:00

-Welcome (Guelin):

-Introduction (Tan):
A short history of the plans for an amplitude calibration device on ALMA was presented. Originally two different schemes were foreseen. One system proposed consisted of dual loads at different physical temperatures mounted behind the sub-reflector. BIMA did experimental tests, funded by NRAO, with such a device and came to the conclusion that there is too much variation with frequency. For this reason this device has been abandoned for ALMA.
The second device was the so called semi-transparent vane. Experimental tests have been done at the IRAM 30 m telescope and this work led to the conclusion that the system would not be capable of providing the required accuracy. For this reason the ALMA Science IPT proposed to replace it with a multi-load calibration device as described in ALMA Memo 461 by Guilloteau and Bacmann. A formal CRE was submitted by the Science IPT earlier this year and in April the CCB made a decision on this CRE, thereby approving the feasibility study.
Given the ALMA timescales, including the schedule for the FE IPT, there is little time left to develop and produce the multi-load calibration device. In principle by autumn 2005 a first unit shall be available to be integrated with the first FE assembly.
Given this very limited time also the scope of this feasibility study shall be focussed and concrete. It should aim at those technical uncertainties in achieving an accuracy of less than 1 % in practice. For this a paper study and experimental validation based on available hardware is foreseen.
More details on calibration requirements can be found in the Calibration Specifications and Requirements document prepared by the Science IPT.
If this feasibility study comes to a positive conclusion the follow up will be the detailed design of a multi-load calibration device.

-Review of calibration system work (Martin-Pintado):
A brief overview of the theoretical and especially experimental work at the IRAM 30 m telescope for a semi-transparent vane calibration device is presented. From the experimental work it is clear that a 1 % amplitude accuracy is hard to achieve. This due to rx saturation and lack of stability.
For ALMA Band 3, where 4 junctions are used, and Band 7, where 2 junctions are used, the saturation problem is expected to be most severe. Actual saturation performance shall be

confirmed by experimental measurements. For Band 7 less than 1 % saturation at a 300 K load was measured for the prototype cartridge
When a wire grid is used as a semi-transparent device an accuracy of 1 % - 2 % seems ultimately feasible.

-Calibration system (Guilloteau):
An overview of the need for a multi-load calibration device to do amplitude calibration for ALMA was presented. Atmospheric transparency correction and saturation of receivers were addressed.
The relationship with band-pass calibration, basically amplitude vs. frequency, was highlighted.
A fringe benefit of using a, rotating, grid in the multi-load calibration device is that it might also be used for polarization calibration.
For Rx bands where there is practically no saturation, for ALMA this is true for bands 1 and 2, one can go back to a “traditional” calibration scheme using either hot or cold loads.

-Possible implementation (Carter):
A design concept fro the multi-load calibration device based on a rotary table is presented.
The concept is compatible with space restrictions as set by the antenna and FE assembly.
ALMA bands 1 and 2 will not use the multi load calibration device primarily because their beams are too large. Another reason is that amplitude calibration at these bands doesn’t suffer from non-linearity problems due to absence of SIS junctions in the RF down-converter.
The design concept illustrates the issue of providing sufficient thermal decoupling between individual loads at different temperatures.
The design concept leaves sufficient place for a Band 7 ¼ lambda polarization plate.

-Loads and grids at RAL (Matheson):
RAL has an interest and experience in high precision calibration loads for remote sensing applications.
They have evaluated a broadband, precision conical load from Thomas Keating / EAE Technology. Length of this load is about 300 mm for frequencies above 100 GHz. Effective temperature is accurate to about 0,5 K. The device is likely to be expensive, development costs were approximately k€ 300. EAE Technology owns the IP rights and charges for licensing.
RAL has developed in house calibration loads. Examples operating at 100 GHz and 300 GHz were shown.
RAL has also extensive experience in the design and production of wire grids.

-Discussion:

- It is clear that Rx saturation has a direct impact on amplitude calibration performance. Theoretical predictions have to be confirmed by actual measurements. For the Band 7 cartridge the theoretical prediction turned out to be too conservative. Characterization of Rx non-linearity, basically the SIS mixers, and subsequent correction is not regarded as a suitable option. Mainly because of uncertainty of long term stability and the large amount of parameters affecting SIS junction behaviour. **Cunningham and Tan will contact the cartridge groups and ask for measured saturation performance**. **Lazareff will do additional verification on the B7 mixers.**
- The grid coupling factor can be measured in situ on the sky. Grid coupling stability is the issue to be investigated. Frequency performance, 1 grid for the whole frequency range (84 – 400 GHz). This frequency limit is dictated by the saturation behaviour of the Rx and reduced accuracy spec for ALMA Bands 8 - 10. **Matheson to provide information of actual grid coupling stability. Guilloteau to confirm the grid stability requirement based on theoretical study.**

- Calibration load, issues to be addressed:
    - Effective temperature (validation by actual measurements with Band 7 Rx). RAL to provide a calibration load to IRAM. IRAM to make measurement with, high linearity, UvA SIS junction mixer (**MC to make measurement plan and do measurements**).
    - Performance with frequency, also measure at lowest Band 3 frequency of 86 GHz. This might be done at the ATF, needs confirmation. Are their other practical options to verify performance at 86 GHz?
    - Different load materials (Eccosorb, etc.) shall be investigated by RAL. Relevant properties of interest are e.g. RF absorption, thermal properties (incl. thermal conductivity), safety, lifetime, etc.
- Switching speed:
    - It shall be confirmed that less than 1 sec.switching time between different load configurations can be achieved with presented concept design (**IRAM**).
- A sensitivity analysis, e.g. influence of load temperature inaccuracies, shall be done (**Guilloteau**).
- Type of coupling for calibration loads: wire grid is the best solution, broadband device, lots of experience.
- Angle of grid: angle offset introduces uneven coupling to orthogonal Rx channels. Coupling can be calibrated, stability is then the issue.
- Polarization calibration might be feasible with the proposed multi-load calibrator: requirement 0,1 % amplitude, 6 degrees. This topic has low priority in this feasibility study given the limited time and resources. Might be addressed in the next phase. As a whole polarization measurements and calibration needs first attention by the Science and SE&I IPTs.
- The multi-load calibration device shall be compatible with a Band 7 ¼ lambda plate.
- For ALMA Bands 1 and 2 is Rx saturation not a problem. No grid will be needed for these bands, only hot and cold loads.
- Calibration software requirements need to be defined and communicated to computing IPT.

-Planning:

- Due to summer vacation and absence of Matt Carter the proposed end date of the feasibility study, end of Sep. ’04, is not feasible. End date shall be moved by a month to October 30, ’04.
- While Matt Carter is out of the office, tentatively July - Aug. ’04, Bernard Lazareff will replace him.
- Calibration load measurements: load suitable for operation at ALMA Band 7 (275 – 370 GHz), with temperature sensor + heater delivered to IRAM by **RAL, Dave Matheson**. Load enclosure to be decided between IRAM and RAL. Production takes about 6 weeks, can start immediately. Heater controller for calibration load to be provided by **IRAM**.
- Theoretical study of calibration load by **RAL**, Dave Matheson: size (frequency compatible with volume available), thermal. Grid coupling factor accuracy, sensitivity analysis eg. bending etc. (**RAL**). Absorber material analysis (**RAL**).
- Band 7 cartridge saturation performance will be investigated on prototype hardware by **IRAM**. Calibration load measurements with will be made using mixer with UvA SIS junctions by **IRAM**. Coordination of feasibility study project will be in the hands of Matt Carter (**IRAM**).
- Re-evaluate concept design (C**arter**) with regard to compatibility to FE assembly.
- Further sensitivity analysis of multi-load concept, feed-back of experimental results in performance prediction (**Bacmann, Guilloteau, Martin - Pintado**).

- Can 3 mm measurement be done at IRAM? **Carter to check this**. Alternatively Band 3 testing of calibration load might be done at the ATF. Cunningham to check this option **if IRAM can't do this**. Is Angel Otorola available for this task, **Tan to check if IRAM can't do this**.
- Provide information about Rx stability for cartridge bands (**Cunningham, Tan**).
- Preparation of final feasibility study report will be led by **Carter**.

-All aboard:

- Martin – Pintado asks how the Spanish activities for this feasibility study will be reimbursed. This will be done through IRAM using funds provided by ESO under the feasibility study agreement. This solution is accepted by Martin – Pintado.
- Reporting by SG, AB. Need atmosphere stability data from Spain.
- **Laing will inform the Computing IPT about the amplitude calibration software requirements.**

**List of attendees**

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