First considerations on the possibility to perform SMOS calibration on deep sky

Author Philippe Waldteufel

Date: 6/6/2000

Context

During the ESA CNES meeting held at CNES on May 29th 2000, it appeared that it was possible to consider the possibility to point the PROTEUS platform towards zenit to perform deep sky calibrations. The objective of this note is to evaluate the usefulness of such a possibility.

You will thus find below first considerations on this option for further discussions

General considerations

SMOS, as any spaceborne instrument will require a calibration procedure. However, the calibration of a 2D interferometer is somewhat challenging and will require a careful approach especially as the oceanographic applications are very demanding.

Currently the system is designed with an onboard, rather classical, calibration procedure for the different elements. A total power radiometer will be also available It is envisionned to use a sophisticated phase closure approach but obviously this will not be sufficient and we will need other means to achieve the required figures. The first options currently considered are:

- The area on Antarctica around Dome C
- A well monitored (SSS/SST) area in a stable ocean
- Well monitored "homogeneous" area over land (large test site)
- Possibly view "point targets" such as islands

But this will not enable to have a either a "cold point" or a very accurately known target. Hence, the idea to use the sky. The first idea was to slightly tilt the platform forward to view deep sky through the top tip of the FOV. This was not deemed very useful as it will be verydifficult to avoid contribution from the Earth etc..

The other solution is thus to tilt completely the satellite so that it looks at zenit for calibration purposes.

The goal of this note is hence to evaluate this possibility and to start identifying potential caveats so that the technical feasability can be assessed together with the scientific outcome (i.e., improvement of calibration) wrt induced "costs" to the mission. Obviously we do not want to jeopardise the mission.

First ideas on technical constraints as we can see them.

The technical team will eventually have to address this points but our first impressions are as follows:

1. The concept would be to stop the pointing control aroiund the equator (tbd as a function of tilt and cosmic environment) and let the platform remain fixed. Half an orbit later it should be pointing zenit. After a full orbit when pointing is back to normal attitude control would resume.
2. The advantages would be that with minimal (?) manouvering the instrument will be able to view a very large area of uniform and very well known temperature. The inconvenient is that we will loose on orbit or more (return to thermal equilibrium) of data.
3. The first question whether this is possible or would put to much of a constraint on the platform
4. Hwo would the platform and instrument behave as the "cold face" would be lokking towards the Earth and vice versa, also, would the thermal control be able to cope.
5. We can expect similarly that the instrument will have a very different thermal environment and the question are then: (i) how long to reach an equilibrium and (ii) how will this new temperature "map" will impact the measurements.
6. Finally, of course are the need to be sure that we will get good measurements, i.e. avoid the sun, point sources etc, but this does not seem to be an issue.

We will now deal with more pratical aspects of such manouvres.

Target knowledge power requirements

Looking at the sky has no meaning unless we can be sure that we are looking at a source which is perfectly known. This raises 3 conditions :

- avoid **galactic sources**; this is probably possible a large fraction of the time. Then, the sky temperature is 2.7 K within probably better than 0.1 K, and certainly quite stable.
- check that the sun contribution is negligible
- adress successfully the issue of the **rear lobe**. This is probably difficult. Nothing much is known about the rear lobe (since deep sky calibration was never considered). Typically this might be 20 dB below, and possibly very irregular. The rear lobe will collect emission from inhomogeneous sources (the visible part of the Earth is about 5000 km wide, so the chances of homogeneous ocean everywhere are scarce). Of course, there is also the variation with incidence angle. Assuming 20 dB below and an average 150 K upwelling TB, the resulting contribution is 1.5 K, probably impossible to know within better than 10%.

Consequently the geometry will have to be carefully studied.

The case of the total power radiometer(s) (TPR)

The available signal will be :

V = k0 (Tgeo + Trec) ; where

- Tgeo is the geophysical signal collected by the antenna; as seen above, Tgeo will be of the order of 4 K, known within 0.1 K at best.
- Trec is the equivalent noise temperature at the front of the receiver; of the order of 170 K (hopes are to bring this figure down to 150 K)

- k0 is the simplest way of characterizing the transfer function. Hopefully the receiver will be linear or maybe quadratic with reasonable accuracy over the range of interest. This formulation is anyway a simplified one, since the noise temperature may depend somewhat on the gain (as decreasing the gain increases the noise contribution from components down the receiving channel)

Then we have two unknowns : k0 and Trec. The sky measurement is not sufficient to derive both. We have a lot of a priori information on both k0 and Trec; there is also the possibility of using a "hot" source on board, and the possibility of using a vicarious target. The best way to use the sky measurement will depend on the quality of all these informations.

Provided the matter of the rear lobe is properly settled, the sky observation should provide a measurement with an accuracy better than most other calibration data, and would be therefore very useful.

The figure quoted above for accuracy on the source energy is about 0.1 K. The random uncertainty will be of the order of 200 / sqrt(bandwidth * tau) = 0.046 / sqrt(tau). Therefore an integration time of the order of a few seconds will be adequate.

There is a possibility to obtain an independent information by assessing the standard deviation of the measured brigthness temperature. Then the necessary time would probably be much longer (TBD)

The case of interferometric uncertainties

Observing the sky will provide a set of visibility functions.

(If one were to go into the reconstructing process, the alias free zone would be smaller than when looking at the Earth, since there would be no way to extend it to cases where ambigious zones origin from the sky, as the sky is the target itself).

Since the target is assumed completely homogeneous, and in addition to the full redundancies, visibilities ought to be the same whenever the **modulus** of the baseline is the same. But more than that the theoretical visibilities are in principle perfectly known. So there ought to be a wealth of informations (correlator offset and some combination of phase/modulus possible biases)

A major difficulty will be the required integration time (TBD). In principle, the noise in each receiving channel is uncorrelated, therefore its contribution to the visibilities is zero on the mean. On the other hand, the noise in each channel contributes to the scatter of each visibility, and it is the major contributor by far.

If it is possible to express things interms of temperatures, then the amplitude of the visibilities ought to be typically of 3 K, and their scatter typical of a noise driven by 180 K

In these conditions, perhaps the quickest way to consider the basic measurement is the spread of the visibilities, which would give indications about the total (Tge + Trec).

If the snapshot (0.3 s) std is 6 K, then to achieve 0.1 K one would need a time = 0.3 x 2 x 3600 = 2000 seconds. The 2 factor corresponds to commutation. This would mean that pointing zenit or a point would have to be maintained for about 33 minutes and might thus require controlling the platform for this period of with all that this would entail.

Remarks

Imagin the sky pointing is performed by rotating a full circle over an orbit duration : then we have 4 angular degrees per minutes. THis is confortably adequate for the total power. For the interterferometry, one would certainly require a larger dwell time.

Another reference: the PROTEUS manual stipulates that the unavailability covers avout 0.8% of the time. In order to stay in the same order of magnitude, the time devoted to calibration should not exceed 0.5%, that is about one orbit every 15 days, or 2 orbits every month.