

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

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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 zenith to perform deep sky calibrations.

The objective of this note is to put forward some remarks, suggestions and question marks about such a possibility, which had not been fully considered so far.

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 well known. This raises several conditions :

- avoid **galactic sources**; this is probably possible a large fraction of the time. Then, the sky temperature is 2.71 K within 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 emissions 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%.
- verify, for such a cold source, the relevance of the usual Rayleigh-Jeans approximation (to relate brightness temperatures to the received power).

Total power radiometer(s) (TPR)

The available signal will be :

$V \approx k_0 (T_{geo} + T_{rec})$; where

- T_{geo} is the geophysical signal collected by the antenna; as seen above, T_{geo} will be of the order of 4 K, known within 0.1 K at best.
- T_{rec} 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)
- k_0 is the simplest way of characterizing the transfer function. Hopefully the receiver will be linear or maybe quadratic within an adequate 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 : k_0 and T_{rec} . The sky measurement alone is not sufficient to derive both. We have nevertheless a lot of a priori information on both k_0 and T_{rec} ; there is also the possibility of using a "hot" source on board, and the possibility of using one or several vicarious targets. 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 $200 / \sqrt{\text{bandwidth} * \tau} = 0.046 / \sqrt{\tau}$. Therefore an integration time of the order of a few tens of seconds at most ought to be adequate.

There is a possibility to obtain an independent information by assessing the standard deviation $\sigma(TB)$ of the measured brightness temperature, which ought to be proportional to the brightness temperature itself.

However, this can only be accurate if the number of measurements is very large, which implies that the elementary integrating time should be very small. Typically, for achieving a 0.1 K standard deviation with this kind of technique, about 10^6 values are needed ; this would require both the possibility to obtain the data (optional 0.1 ms integrating time, typically !) and to build the resulting histogram on board before downlinking. Unless other information can be retrieved from $\sigma(TB)$, this does not seem worth the effort.

Interferometric radiometer

Observing the sky will first provide a set of complex visibility functions V .

Perhaps an useful way to consider these deep sky data consist of noting that they have many similarities with what results from injection of **correlated noise**, which is considered for MIRAS on board calibration with respect to receiver amplitudes and phases.

The sky data correspond to an operating point very low on the receiver response curve; one has to know whether the calibration on such a cold source is representative of the way the receivers operate for the nominal range of target brightness temperatures.

On the other hand, sky data include the entire channels, beginning with each antenna, whereas with noise injection, the initial part of each channel has to be left out of the calibration loop. Conversely, the visibilities now become sensitive to each specific antenna characteristics. Of course, such characteristics will have been accurately measured before the launch.

Same as in the previous case, the spread of V measurements is expected to be related to the total equivalent noises at the input of each couple of receivers. This might in principle provide information on such receiver characteristics. However the total number of samples available when looking at the sky will set a very severe limitation.

Further remarks.

Assume the sky pointing is performed by rotating a full circle over an orbit duration: then we have 4 angular degrees per minutes. Perhaps this provides an order of magnitude of the total time available for deep sky observation.

(The case of scenes obtained throughout such a rotation, when the Earth limit crosses the field of view, deserves a discussion).

Another reference is provided by the PROTEUS manual, when stipulating that the unavailability covers about 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.

Conclusions.

The deep sky calibration of total power data has a clear interest, provided the matter of the rear lobe is cleared.

Concerning interferometric data, the central question is: could we use sky data instead of on board injection of correlated noise ? If it were possible, this would have serious advantages, since the distributed noise injection system being contemplated is fairly complicated. The issue, however, seems far from simple.

The Phase A study includes an analysis of possible uses of a partial view of the sky. Hopefully, it will be possible to extend this analysis in order to address the question above.

On the system side, the assumption made above (full circle with constant angular velocity over one orbit) may not be the proper one.

Finally, it is not known to which extent (and for how long) the thermal and mechanical characteristics of the radiometer can be expected to stay constant as the radiometer is steered away from its nominal attitude..