SMOS L1 Prototype

Impact of Solar Flare Occurrence in the SMOS L1 Data Processing

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1. INTRODUCTION

1.1. Purpose and Scope

The purpose of this technical note is to describe the impact of solar flares occurrence in satellite missions such as SMOS and to describe the approach taken to deal with this phenomenon in the SMOS L1PP Data Processing.

This document was produced in the scope of the "SMOS Level 1 Processor Prototype Development – Phase 3" project.

1.2. Acronyms and Abbreviations

FOV	Field of View
L1PP	Level 1 Processor Prototype
MIRAS	Microwave Imaging Radiometer with Aperture Synthesis
SMOS	Soil Moisture and Ocean Salinity
UPC	Universitat Politècnica de Catalunya

1.3. Applicable and Reference Documents

1.3.1. Applicable Documents

Table 1: Applicable Documents.

Ref.	Code	Title	Issue
[AD.1]	SO-SOW-CASA-PLM-0855	Level 1 Processor Prototype Development Phase 3 and Support Activities. Statement of Work	01
[AD.2]	SO-DS-DME-L1PP-0008	SMOS L1 Processor L1a to L1b Data Processing Model	2.3

1.3.2. Reference Documents

Table 2: Reference Documents.

Ref.	Code	Title	Issue
[RD.1]	A. Camps et al.	*Impact and Compensation of Diffuse Sun Scattering in 2D Aperture Synthesis Radiometers Imagery*, IGARSS	2005
[RD.2]	A. Camps et al.	*Sun Effects in 2D Aperture Synthesis Radiometry Imaging and Their Cancellation*	
[RD.3]	SMOSP3-UPC-TN-0002 v1.0	*Sun Self-estimation Algorithm*	2007
[RD.4]	Pasachoff	"Astronomy – From the Earth to the Universe"	
[RD.5]	D. M. Le Vine et al.	"Impact of the Sun on Remote Sensing of Sea Surface Salinity from Space"	2005
[RD.6]	N/A	National Geophysical Data Center http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarradio.html	

2. THE RADIO EMISSION FROM THE SUN IN THE L-BAND

The Sun is a strong source of radiation at L-band, being an important source of interference for radiometers on future satellite missions such as SMOS. The radiation from the Sun can affect passive remote sensing systems such as MIRAS in several ways, including line-of-sight radiation that comes directly from the Sun and radiation that is reflected by the surface to the radiometer.

Solar activity varies with a 11-year cycle [RD.4], and near solar minimum, solar contamination is not a problem unless the Sun enters near the main beam, which is never the case for the SMOS satellite [RD.2]. But near solar maximum, a significant contamination from the Sun can occur even when the signal enters via side lobes far from the main beam.

The solar flux at a given wavelength, F_{λ}, can be expressed in **solar flux units**, *sfu*, (1 sfu = 1×10^{-22} W m^{-2} Hz^{-1}). Values at different wavelengths are available daily from different ground stations around the world that monitor the Sun [RD.6].

The solar flux can be used to express the Sun intensity into an equivalent blackbody temperature by assuming that the Sun is a uniform thermal source (blackbody) and using the Rayleigh-Jeans approximation. At L band (1.4 GHz), the relationship between the equivalent temperature, T_{Sun}, expressed in kelvin, and the solar flux F_L , can be written as described in [RD.5]:

$$T_{Sun} \sim 2000\, F_L \qquad (1)$$

where F_L is the solar flux at L-band in solar flux units (sfu).

The radio emission from the Sun can be divided into two categories according to their characteristic scale of temporal variation [RD.5]:

$$T_{Sun}(t) = T_S(t) + T_R(t) \qquad (2)$$

T_S represents a slowly varying component (timescale of hours to days). At L-band, this is largely due to thermal emission from the hot plasma in the atmosphere of the Sun. This radiation varies randomly from day to day with a mean value and a standard deviation that follow the 11 year solar cycle, correlating with the number of sunspots.

Figure 1 shows the T_S component of the solar flux at 1.4 GHz between 1980 and 2005 [RD.6]. The correlation with the 11 year solar cycle can be clearly noticed. It is also noted that the flux does not exceed 250 sfu, even at the periods of high activity.

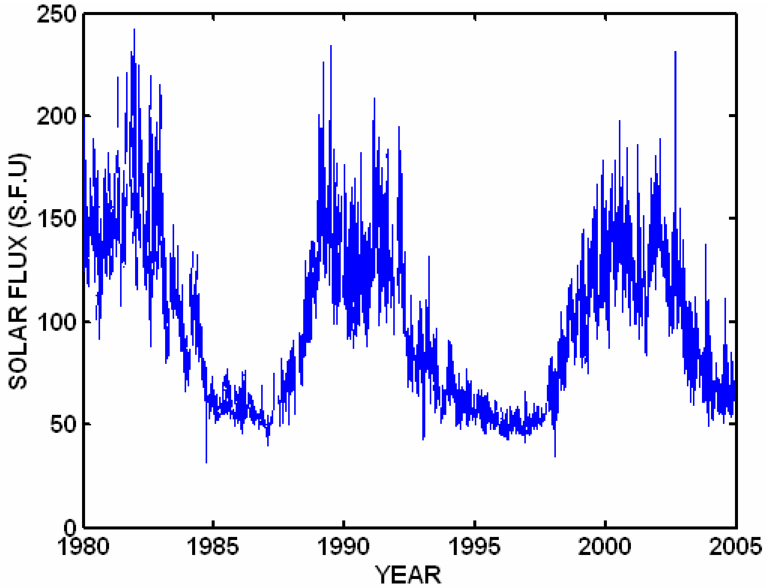

Figure 1 - Solar flux at 1.4 GHz at noon from Sagamore Hill [RD.6].

Figure 2 shows similar data for a period of one year with higher temporal resolution (blue curve for 1986, a minimum in the solar cycle; red curve for 1989, a maximum in the same cycle).

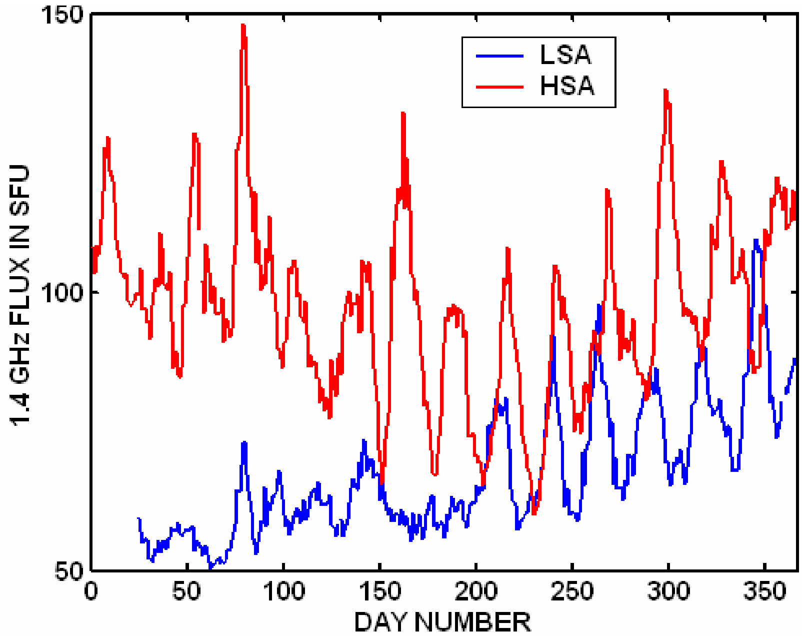

Figure 2 - Solar flux at 1.4 GHz at noon. High solar activity (1989, red) and low solar activity (1986, blue) [RD.6].

T_R represents a rapidly varying component (timescale of seconds to minutes) associated with solar flares.

3. SOLAR FLARES

A solar flare is a violent explosion occurring on the atmosphere of the Sun that can eject particles and emit radiation from all parts of the spectrum into space. Solar flares occur due to a sudden release of magnetic energy in the solar atmosphere and their frequency varies with the 11 year solar cycle. Very few solar flares are detected during periods of low solar activity. On the contrary, there can be thousands of flares during the periods of high solar activity.

These solar storms begin in a few seconds and can last up to a few hours. A typical flare lifetime is 20 minutes. Physical temperatures in the flare can reach 5 million kelvins [RD.4].

Thought the very brightest flares can occur at any time, flares are generally correlated with the solar activity cycle. The frequency of occurrence of solar flares can vary from several per day when the Sun is particularly "active" to less than one each week when the Sun is "quiet".

Energetic flare particles that are ejected from the Sun reach the Earth in a few hours or days and can cause a disruption in radio transmission. Flares have been known to affect satellites and the electromagnetic transmissions of many earthbound communication devices including computers, cell phones, pagers and automobiles.

Not all solar flares are associated with an increase of microwave radiation. When these increases occur, they are designated Solar Microwave Bursts (SMB).

Figure 3 shows the distribution of peak amplitude in solar flux units of radiation at L-band during SMB for a period of high solar activity [RD.6]. The last bar represents the remainder occurrences above the highest value represented in the figure. The figure shows that the maximum number of occurrences happen for peaks of solar flux with less than 100 sfu.

As seen in Figure 1, solar flux of 250 sfu is a rather large value for the T_S component and is likely to be encountered occasionally only during solar maximum. However, the contribution from solar flares can largely exceed this value. One can expect a significant number of flares with a flux exceeding 500 sfu during the course of a year at solar maximum as shown in Figure 3. However, the duration of all of these intense emissions is relatively brief as seen in Figure 4. Therefore, a reasonable approach proposed by Le Vine et al. [RD.5] is simply to flag the occurrence of flares and then evaluate the impact based on the reported magnitude. Data from a global monitoring network can be used a posteriori to determine if the flare was large enough to exceed a pre-defined threshold of tolerance.

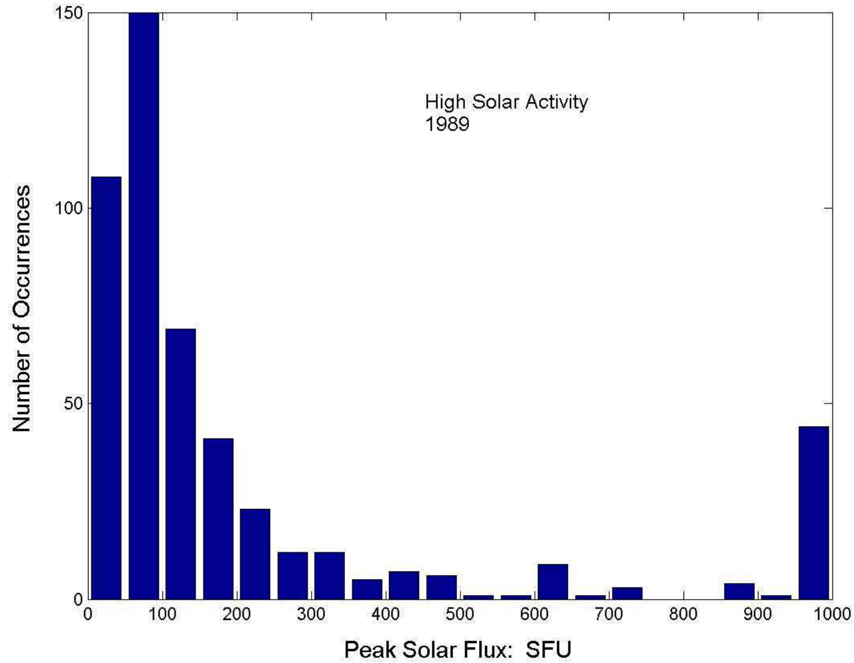

Figure 3 – Distribution of peak amplitude for SMB at 1.4 GHz during high solar activity [RD.6].

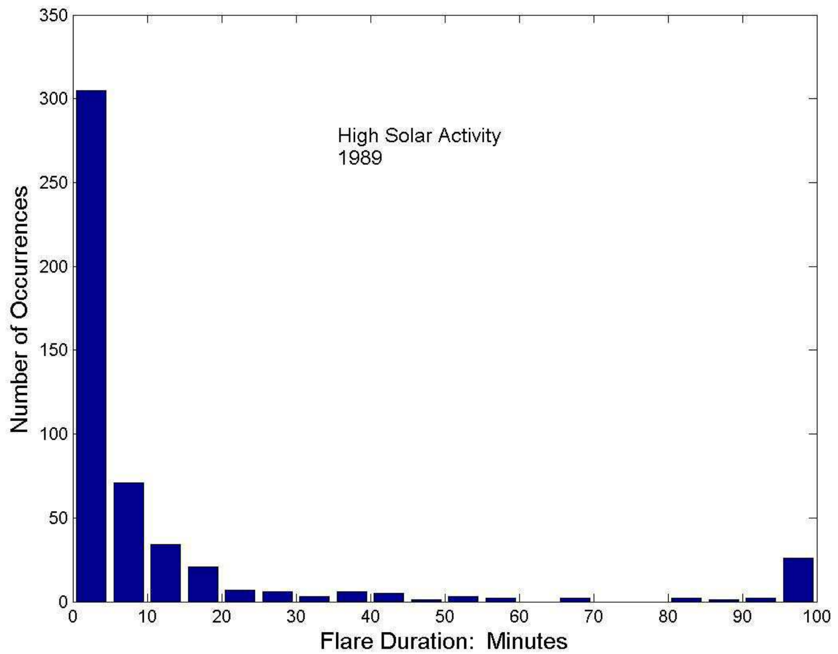

Figure 4 – Distribution of duration of SMB at 1.4 GHz during high solar activity [RD.6].

4. DISCUSSION

Although one should expect a significant number of flares with F_L greater than 500 sfu during the course of a year at the solar maximum (see Figure 3), most of the flares have much lower peak solar fluxes. Despite the fact that we do not have information regarding the specific duration of the stronger flares, the analysis of Figure 4 allow us to say that most of the flares have a very short duration (less than 20 minutes). The combined analysis of Figures 3 and 4 lead us to say that the occurrence of strong flares lasting long periods should be very low. In fact, the total duration of flares is less than 4% of the total time [RD.5]. In occasions other than the solar maximum, this duration will be even less.

5. RECOMMENDATION

Based on the previous considerations, we propose a **limiting solar flare threshold of tolerance** set to **250 sfu** for the purpose of the L1PP Data Processing.

According to (1), the **limiting solar flare threshold temperature** should be:

$$T_{Sun} = 500\,000 \text{ K} \quad (3)$$

Any Sun brightness temperatures above this limit should be indicative of a possible solar flare occurrence. In this case, the L1PP data processing might be performed normally (including the correction of the Sun effects according to the estimated brightness temperature), but the corresponding snapshots should be flagged as being affected by a solar brightness peak, and the user should proceed with caution.

Eventually the data might have to be totally discarded.