THE MAPSAR MISSION: OBJECTIVES, DESIGN AND STATUS

Reinhard Schröder, Jürgen Puls, Irena Hajnsek, Friedrich Jochim, Jose-Luis Bueso-Bello, German Aerospace Centre – DLR, Microwaves and Radar Institute, P.O. Box 1116, D-82230 Wessling, Germany
Leri Datashvili, Horst Baier, Institute of Lightweight Structures – LLB, Technical University of Munich, Boltzmannstr. 15, D-85748 Garching, Germany
Mario Marcos Quintino da Silva, Waldir Renato Paradella, Instituto Nacional de Pesquisas Espaciais – INPE, Caixa Postal 515, 12201-970 São José dos Campos – SP, Brazil

Abstract

The Brazilian-German MAPSAR (Multi-Application Purpose SAR) mission is a proposal for a light and innovative L-band SAR sensor, based on INPE´s Multi-Mission Platform (500 kg class spacecraft). The main mission objectives are the assessment, management and monitoring of natural resources. The phase A study is planned to be finished by mid of 2006. The key component of the SAR instrument is the SAR antenna, which is designed as an elliptical parabolic reflector antenna. L-band (high spatial resolution, quad-pol) has been selected for the SAR sensor as optimum frequency accounting for the majority of Brazilian and German user requirements.

1 User Requirements

The MAPSAR mission [1] is tailored to optimally support the potential user groups in both countries taking into account distinct aspects of specific applications. A first workshop with potential end users of MAPSAR in Brazil was conducted to develop requirements and recommendations aiming at a joint DLR - INPE spaceborne SAR program. The consensus of the Brazilian working group was that a spaceborne SAR mission will provide a powerful new tool to acquire data and to derive important and unique information of vegetated terrain of the Amazon Region. Due to the enormous scarcity of up-to-date information, which is fundamental for planning and strategic decision-making about environmental assessment, management and monitoring of natural resources in the Brazilian Amazon, the proposed light spaceborne SAR initiative should be strongly oriented to a quasi-operational ("application-oriented") system. This is dedicated to thematic mapping purposes for topography, vegetation and deforestation, geology, hydrology, etc.

A second workshop of potential MAPSAR end users was conducted in Germany to join the final user requirements of both countries as the basis for the sensor and satellite design within the phase A study. The workshop revealed that the Brazilian applications are of high interest also for the German potential user community. Additional applications, which are of specific importance for the German user side, as biomass estimation, disaster monitoring and security complement the Brazilian disciplines. The common aim is a global biomass mapping mission covering major forest biomes of the globe (tropical and boreal regions). This requires the capability of polarimetry and interferometry SAR (Pol-InSAR) for forest height estimation which is directly related to forest biomass using allometry.

The Brazilian and the German requirements have been merged resulting in the final user requirements for MAPSAR. Due to the INPE´s multi-mission platform performance (mass, power generation, geometric envelope and data rate), main limitations were imposed upon the satellite configuration: use of a single frequency and a light weight antenna. The resulting reflector antenna concept limits the maximum instantaneous swath width to approximately 55 km. Table 1 summarizes the final specification.

Table 1: MAPSAR final specification taking into account user requirements and MMP constraints.

Frequency	L-band
Polarization	Single, dual and quad
Incidence Interval	20° - 45°
Spatial Resolution	3 – 20 meters
Swath	20 – 55 km
Orbit Inclination	Sun-synchronous
Coverage	Global
Look Direction	Ascending/descending
Revisit	Weekly
Data Access	Near real time
Additional Requirement	Stereoscopy and Interferometry

2 Mission Design

The wide spread applications require different radar polarizations and different spatial resolutions. Furthermore, stereoscopy and interferometry require different orbit repetitive cycles and coverage sequences. Nevertheless, the disciplines can be optimized by two different orbit heights in order to get appropriate coverage. In both cases sun-synchronous orbits are recommended by technical reasons. Considering the requirements of the Brazilian Multi Mission Platform and the SAR sensor it was concluded to concentrate the investigations on orbits with a height between 600 and 620 km.

3 MAPSAR Satellite

3.1 Platform

The MAPSAR satellite utilizes a modular concept, consisting of a payload module and a multi-mission platform (MMP). The MMP concept provides for a capability to support a variety of low Earth orbit missions using the same basic three-axis stabilized platform with different payload modules.

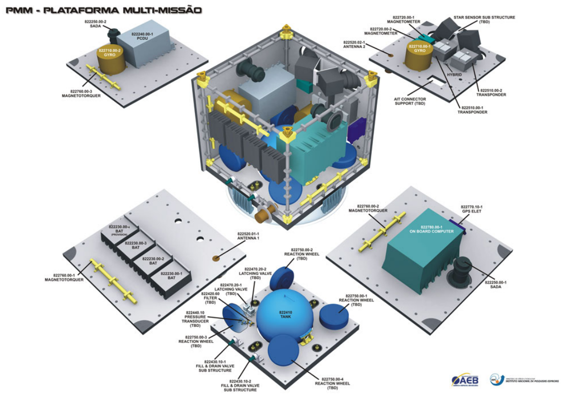

Figure 1: MMP pictorial view (blow up).

The MMP pictorial view is shown in figure 1. The MMP is already being developed by INPE and its first flight model shall be ready in 2007. Figure 2 shows an in-orbit view of the satellite configuration with the attached payload module.

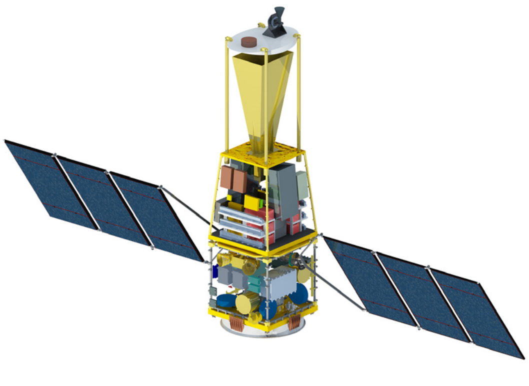

Figure 2: MAPSAR in-orbit satellite configuration**.**

3.2 SAR Antenna

A key problem for a L-band SAR is the large antenna size required compared to higher Earth observation frequencies. We considered a Cassegrain reflector configuration with an elliptical foldable parabolic main reflector with 7,5 m length in azimuth and 5 m width in elevation. The rigid sub-reflector is supported by four telescopic rods which are used for the deployment in orbit. The horn type prime radiator is firmly connected with the payload module. The resulting antenna gain in combination with a low orbit allows very good sensitivity with a reasonable power budget.

The mechanical concept for the antenna main reflector was identified as one of the critical technologies during a pre-phase A study. The SMART reflector concept [2][3], which is shown in figure 3, was adapted to the RF and system requirements of MAPSAR. Adaptation of the SMART concept to the MAPSAR requirements has been conducted mainly for the central unit of the reflector since the payload module of the system is placed into the central part of the reflector. By changing the angles in between of the main radial ribs a highly elliptical aperture is acquired (see figure 4).

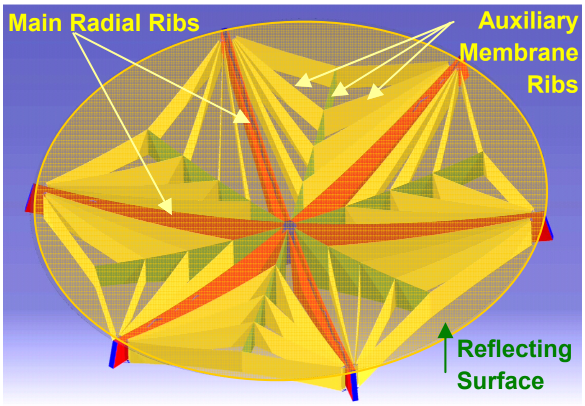

Figure 3: SMART reflector with membrane ribs.

The reflecting surface of SMART is a triaxially woven fabric of carbon fibre reinforced silicone (CFRS). The reflector structure includes the system of main and auxiliary membrane ribs, which are radially deployed and stiffened with a pantograph mechanisms placed in between of the main radial rib membranes. The pantographs are shown in figure 4 together with the triax CFRS reflecting surface and the satellite (the system of membrane ribs is omitted for better visibility).

According to the FEM analyses [2], the first eigen frequency of the reflector is above 2 Hz and corresponds to the rotation around the Z-axis. The first general buckling mode is related to the out-of-plane buckling of the pantographs and takes place at a load factor above 3. Thermal deformation analyses show that the surface RMS error is below 1 mm.

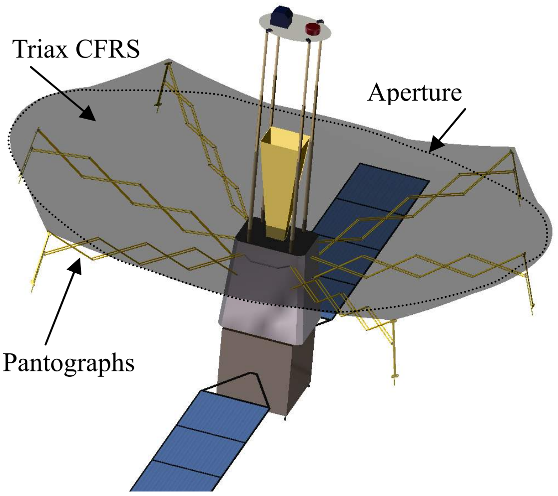

Figure 4: Pantograph supported deployment mechanism for the antenna main reflector.

The areal density of the triax CFRS material ranges from 120 to 140g/m² depending on the manufacturing process. A space qualification program of Triax CFRS is in progress. A standard thermal cycling test has been performed on CFRS specimens and no degradation of the material thermal and mechanical properties has been detected. Microscopic investigations after thermal cycling test have shown also no microscopic damage or micro cracking of the specimens. The low coefficient of thermal expansion (CTE) of CFRS (measured in the range of (-0.5 to -0.7)*10-6/°C) confirmed the high dimensional stability of the reflecting surface.

Radio-electrical qualification tests, performed for a frequency range from 5.5 to 8 GHz, have shown suitability of the triax CFRS as a reflecting material up to 10-12 GHz frequencies. Table 2 gives the summary of the test results.

Table 2: RF properties of Triax CFRS in the frequency range of 5.5 to 8 GHz.

Reflection loss	0.05…0.13 dB
Depolarization	< - 47…- 42 dB
Amplitude / Phase variations for two orthogonal polarizations	< 0.02 / <0.5 dB/°
Transmission coefficient	- 33…- 21 dB

Triax CFRS reflecting surface RF losses are insignificant and the other parameters are much better for L-band frequencies.

3.3 SAR High Power Amplifier

The high power amplifier for generation of the radar pulses was identified to be the second critical technology for the overall concept. A space qualified amplifier in the class of 1 kW is not yet available on the market. A new design was developed based on the power combining of four space qualified travelling wave tube (TWT) amplifiers with 250 W output power each (see figure 5). The power combining is done in wave guide technology where the second stage is directly performed in the orthomode transducer of the L-band horn. The power combining is controlled by low power phase shifters driving the TWTs. This concept also allows to avoid high power switching mechanisms by using polarization synthesis. The phase of one channel is switched between 0° and 180° for alternating radar pulses. This results in two independent polarizations which are tilted 45° against the horizontal plane. In the receive path of the instrument the phase switching is compensated and the final rotation of the polarization matrix can be done in the SAR processor.

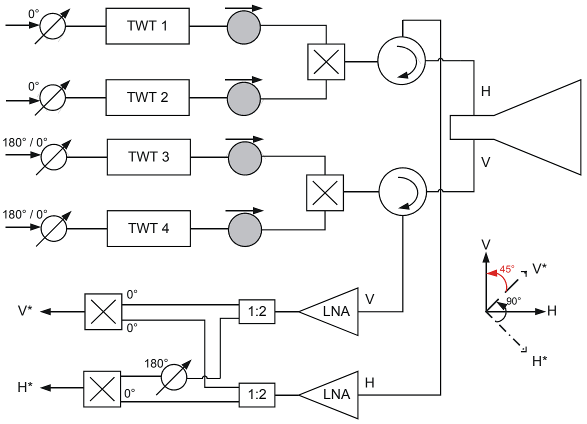

Figure 5: Power combining and polarization synthesis in the MAPSAR radar payload.

The preliminary integration of the radar hardware in the payload module is depicted in Figure 6.

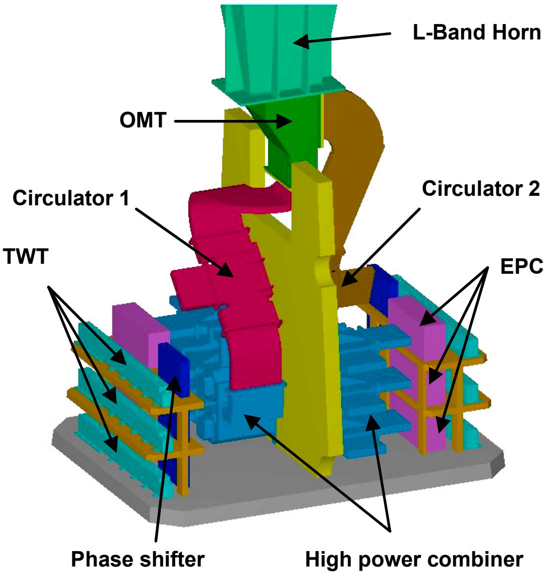

Figure 6: Preliminary integration of the key components of the radar instrument in the payload. module.

Table 3 presents a summary of the estimated mass budget for the MAPSAR payload. The total mass of the satellite is estimated to be 532 kg. In terms of dimensions the payload layout is compatible with the majority of MMP considered standard launcher family.

Table 3: MAPSAR payload estimated mass budget.

Sub-System	Mass [kg]
Mechanical Structure & Thermal Control	34
Antenna Main- and Sub-reflector	75
Radar instrument	125
Harness	6
Data Storage & Transmitter	42
Total Mass	282

3.4 SAR modes

Based on the user requirements, MAPSAR offers three different resolution modes (4 m, 10 m and 20 m) operated in the conventional stripmap mode. The chirp bandwidth is designed to operate up to the full 85 MHz allowed by the World Administrative Radio Conference (WARC). This enables a high resolution (HR) mode in the order of 4 m without increasing the complexity of the front-end and the antenna. For lower resolution modes the bandwidth is reduced accordingly. A single polarization mode (SPM), a dual polarization mode (DPM) and a quad polarization mode (QPM) are foreseen for all of these resolution modes. Table 4 lists the sensor and performance parameters for some of these modes.

Table 4: Selection of MAPSAR radar modes**.**

Parameter	HR Mode High Resolution SPM		MR Mode Medium Resolution DPM		LR Mode Low Resolution QPM	
Access region	near	far	near	far	near	far
Resolution Range / m	4,7	3,1	10	10	20	20
Resolution Azimuth / m	3,1	3,1	10	10	20	20
Incidence angle / °	20,3	47,6	20,0	48,1	20,0	36,8
Ground swath width/km	38,3	20,5	45,1	35	43,4	28
PRF / Hz	2650	2718	2660	2680	5320	5320
Pulse bandwidth / MHz	85	85	42,5	21,25	21,25	21,25
Sampling freq. / MHz	96	96	2x48	2x24	2x24	2x24
Pulse length / µs	25	25	10	10	10	10
Data rate / Mbit/s	262	300	267	300	247	249
RF peak power/W	1000	1000	1000	1000	1000	1000
Average DC power / W	~490	~500	~440	~440	~440	~440
NESZ / dB						
Image center	-23,6	-19	-28,9	-25,4	-34,6	-33,3
Image edge	-17,0	-18,3	-19,9	-23,3	-26,6	-30,9

In MAPSAR, the required range of incidence angles and the left/right looking are achieved by using the MMP agility capability. For an average orbit height of 620 km the corresponding field of view is between 20° and 48° incidence angle covering an area of 395 km on both sides of the satellite nadir track. Table 5 summarizes the radar beams, the corresponding incidence angle ranges and swath widths. These radar beams are available in the low resolution mode (20 m) and medium resolution mode (10 m) in SPM and DPM. The instantaneous swath width varies between 32 km and 55 km. In quad polarization mode the corresponding field of view is between 20° and 36° incidence angle, covering an area of approximately 245 km on both sides of the satellite nadir track. Typical swath widths in this mode range from 28 km and 43 km.

Table 5: Radar beam specification (SPM and DPM).

Beam number / km	Incidence angle range / °	Swath width / km	Eff. PRF / Hz
1	19,9 - 23,9	45	2660
2	23,7 - 27,3	42	3010
3	27,1 - 30,7	45	2660
4	29,6 - 33,3	47	2660
5	32,8 - 36,5	50	2910
6	36,1 - 39,8	55	2660
7	39,5 - 42,6	50	2900
8	42,2 - 45,2	51	2640
9	45,1 - 46,9	32	2870
10	46,2 - 48,1	34	2680

4 Summary

MAPSAR represents an innovative small satellite mission with an L-band SAR. The feasibility of the reflector antenna concept was demonstrated. The study was prepared by INPE, DLR and LLB, taking into account Brazilian and German user requirements. A high degree of innovation is presented in the design considering the small SAR payload, the reflector antenna and the remarkable sensor performance. The applications will take advantage of high spatial resolution L-band SAR with enhanced capabilities (polarimetry, stereoscopy, interferometry), particularly suitable for the Amazon region and Boreal forest operations.

The deployment of the reflector antenna and the high power amplifier are main technological challenges for this project, but nevertheless, after careful analysis, the SAR sensor is considered feasible.

The MAPSAR initiative aims at providing a "public good" service, not excluding commercial aspects. System deployment after phase A conclusion is estimated in five years, which leads to a possible system operation in 2011.

References

[1] Schröder, R.; Puls, J.; Hajnsek, I.; Jochim, F.; Neff, T.; Kono, J.; Paradella, W.R.; Quintino, M.M.; Valeriano, D.; Costa, M.P.F. *MAPSAR: A small L-band SAR mission for land observation.* In: Acta Astronautica, Volume 56/1-2, 2005, pp 35-43.

[2] Datashvili L.; Baier H. *Membranes and Thin Shells for Space Reflectors*, Proceedings of Earth & Space 2006, 10th ASCE Aerospace Division International Conference on Engineering, Construction and Operations in Challenging Environments, March 5-8, 2006 League City / Houston, Texas USA.

[3] Datashvili L.; Lang M.; Baier H. *Advanced reflector concepts*; Deutscher Luft- und Raumfahrtkongress 2004, 20.-25.09.2004, Dresden, Deutschland, Jahrbuch 2004, Band III.