The MAPSAR Mission: Objectives, Design and Status

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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 mission is currently investigated by INPE and DLR in a phase A study as a follow up of a preceding successful pre-phase A study. The phase A study is planned to be finished by end of 2005. 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. The MAPSAR mission is tailored to optimally support the potential user groups in both countries taking into account the present status of current and planned SAR spaceborne programs, which should be complemented by the special mission characteristics of MAPSAR.

Keywords: MAPSAR, Spaceborne L-band SAR, High resolution polarimetric radar, DLR/INPE joint mission, phase-A study, Amazon and Boreal forest.

1. Introduction

The ability of a SAR to provide high-resolution imagery independent of weather or sun light is particularly important for regions of the planet that present restrictions to the use of optical sensors due to the presence of rain, perennial clouds, haze and smoke (e.g., the Amazon region) or where solar illumination is insufficient (Polar regions). Beside this, imaging radars also have the ability to penetrate a vegetation canopy, which is not possible using optical sensors.

In general, the acquisition of information in tropical regions, particularly in rain forests is complicated due to the large continental extension, poor accessibility, and complex nature of the environment. SAR systems have not only the capability to image but also to measure bio-/geophysical environmental parameters of such a “complex environment” in a systematic and repetitive manner in support of natural resource assessment and the monitoring processes that are essential parts of procedures for sustainable environmental management.

The sensitivity of SAR to the macro-topography (slopes, tilts, broad undulations in the terrain), the surface roughness (roughness on the scale of the SAR wavelength) and to the presence of moisture or liquid water content of a medium affecting the complex dielectric constant, makes it an ideal instrument for thematic mapping and resource management purposes in the tropical region, and when stereoscopic capabilities are available, for topographic mapping. In addition, the large ratio of SAR return from land versus water is primarily a function of contrast of dielectric properties and surface roughness, providing a striking interface which also facilitates coastal delineation and related mapping application (flooding, wetland and hydrological studies in the Brazilian Amazon).

On the other hand, forest biomass is today one of the most unknown parameters in dynamic ecosystem change especially with respect to a reliable global Carbon-flux modelling. In many regions of our planet even a mere forest classification is missed. Parallel to the ecological dimension, and under the light of the Kyoto protocol, this problem has also a political dimension that increases the responsibility of the scientific community to provide exact answers. The fact that biomass information is especially missed in remote areas (i.e. tropical and boreal forest ecosystems) combined with the fact that these ecosystems contain the biggest amount of forest biomass make remote sensing techniques a challenge. However, optical remote sensing sensors are in general not capable of measuring forest biomass or monitoring the dynamics of deforestation and biomass regeneration. An alternative methodology is the estimation of forest biomass based on the estimation of forest height from radar remote sensing data. One of the key challenges facing imaging radars is to force evolution from high-resolution qualitative imaging to accurate high-resolution quantitative measurement. One very promising way to extend the observation space is the combination of interferometric and polarimetric observations. SAR interferometry is today an established technique for the estimation of the height location of scatterers through the phase difference in images acquired from spatially separated locations at either end of a baseline.

The initiative of the joint study of a light spaceborne SAR is a consequence of a long term Brazilian-German scientific and technical cooperation that was initiated between INPE and DLR in the seventies. The decision to continue the studies on the MAPSAR mission between both partners was established by the end of 2003 based on the promising results of the preceding pre-phase A study. Taking into account the specific and complementary experience of both partners, the sharing of the thematic responsibilities within the study was agreed. Brazil is responsible for the platform and integrated satellite analysis and Germany for the payload and orbit analysis.

2. Context and User Requirements

The MAPSAR mission is tailored to optimally support the potential user groups in both countries taking into account distinct aspects of specific applications. Thus, in April 2002, a working group of Brazilian SAR scientists and technical experts (potential SAR end-users) met at INPE (São José dos Campos, Brazil) to perform a review of the use of imaging radar to derive surface characteristics important for tropical applications. The first workshop of potential end-users of MAPSAR was structured for the purpose of (1) performing an assessment of the current understanding of the applications of SAR in Brazil and (2) developing end-user 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. Furthermore, it was strongly recommended to have a series of satellites aiming at the operational aspects and the program continuity.

In addition, when starting the phase A study in December 2003, it was agreed between both partners that the MAPSAR concept should include an airborne SAR campaign to develop user-oriented (value added) products including commercial applications through these data results. This airborne SAR campaign is planned to be conducted in May 2005 in Brazil with the German E-SAR and the Brazilian SIVAM/SIPAM systems to provide fully polarimetric L-band data of dedicated test sites for different fields of application. With adapted processing and simulation techniques it will be possible to simulate the expected MAPSAR image products.

In April 2004, 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 presented in **Table 1**.

Table 1: User Requirements for MAPSAR (normal = Brazil, italic = Germany)

Application /MAPSAR parameters	Agriculture	Cartography	Disaster (Oil slick/Ship Monitoring)	Forestry	Geology/ Geo-morphology	Hydrology	Oceano-graphy	Urban Mapping
Frequency	L *L/C*	L *C*	C *L*	L *, C *L*	L *L*	L, C *L*	C *L*	L *C/L*
Polarization / Polarimetry	quad. pol *quad. pol*	N. E. *N. E.*	VV, HH *quad. pol*	quad-pol. *quad. pol*	HH, HV *quad. pol*	quad. pol. *quad. pol*	quad-pol *quad. pol*	quad-pol *quad. pol*
Incidence Interval	variable *25°-45°*	variable (45 °) *(45 °)*	20°-30°/ 45°-60° *variable*	20°-45° *25°-35°*	large interval *large interval*	20°-45° *20°-45°*	High (45-60°) *(45-60°)*	40°-45° *variable*
Spatial Resolution	30 m *1-70 m*	5 m *3-5 m*	30-50/15 m *3-5 m*	10 m *10-70 m*	5 – 10 m *3-5 m*	10 m *10-100 m*	variable(High/ Moderate) *(High/Moderate)* *5-20 m*	5 m *Regional:3-5 m* *Global:10 m*
Swath	30 km *10-30 km*	N. A. *variable*	150-350 km *variable*	100 km *variable*	40-100 Km *40-100 Km*	100 km *50-400 km*	350 km(ScanSAR&bFineModes) *10-100 km*	40-100 km *50 km*
Orbit Inclination	N. A. *sun-syn*	sun-syn *sun-syn*	sun-syn *sun-syn*	sun-syn *sun-syn*	sun-syn *sun-syn*	sun-syn *sun-syn*	sun-syn *sun-syn*	sun-syn *sun-syn*
Look Direction	N. A. *asc/desc*	asc/desc *asc/desc*	asc/desc *asc/desc*	N . A. *asc/desc*	asc/desc *asc/desc*	asc/desc *asc/desc*	N. A. *asc/desc*	asc/desc *asc/desc*
Revisit	15 days *< 15 days* *daily-yearly*	N. A. *seasonal*	< 1 day *< 1 day*	monthly *seasonal/ yearly/10 y*	seasonal *seasonal*	10 – 15days *< 15 days* *48h-96h*	daily *daily-monthly*	N.A. *weekly-monthly*
Access to data	real-time *real-time*	N. A. *regularly*	real-time *real-time*	N. A. *Regularly*	N. A. *regularly*	N. A. *Near real time*	real-time *real-time*	N. E. *Regularly*
Additional Require-ment	*InSAR*	stereoscopy *InSAR (opt.)*	*InSAR*	*InSAR*	stereoscopy *InSAR*	*InSAR(opt.)* *SWE/ Multi-mission (sensors)*	raw data *InSAR Multi-mission (sensors)/ wave mode*	*InSAR (opt.) Multi-mission (sensors)*

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 antenna concept imposes the maximum instantaneous swath width to approximately 55 km. **Table 2** summarizes the final specification.

Table 2: MAPSAR final specification taking into account user requirements and MMP constraints

Frequency	**L**
Polarization	**single,dual and quad. pol.**
Incidence Interval	**20°- 45°**
Spatial Resolution	**3-20 meters**
Swath	**20 km - 55 km**
Orbit Inclination	**sun-synchronous**
Coverage	**global**
Look Direction	**ascending/descending and left/right looking**
Revisit	**weekly**
Access to data	**near real time**
Additional Requirement	**Stereoscopy and InSAR**

The requirements summarized in **Table 2** confirmed the requirements of the pre-phase A study [Kono et al. (2003)].

3. Mission Design

These 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 coverages. In both cases sun-synchronous orbits are recommended by technical reasons.

Considering the performance of the Brazilian Multi Mission platform and the SAR sensor design, it was concluded to investigate orbit heights between 600 and 650 km in more detail. As a preliminary choice for the interferometric applications an orbit with a 7 days repetition cycle and daily overlapping of the consecutive passes was selected. It guarantees a global coverage (besides of the poles) and therefore near global monitoring. The second orbit is optimized for stereoscopic applications (see **Figure 1**). It can be selected either as a sub-cycle orbit to the primary orbit (39 days orbit) or as an orbit with a small daily drift (41 days orbit) in order to observe slow daily developments in a selected area. The satellite bus is able to perform the required orbit maneuvers and to guarantee the envisaged 4 year mission lifetime. Different mission scenarios will be proposed in order to fulfill user requirements to the maximum possible extent. The capability of dual pass SAR interferometry in the case of the slowly varying orbit will be one of the great advantages of this mission.

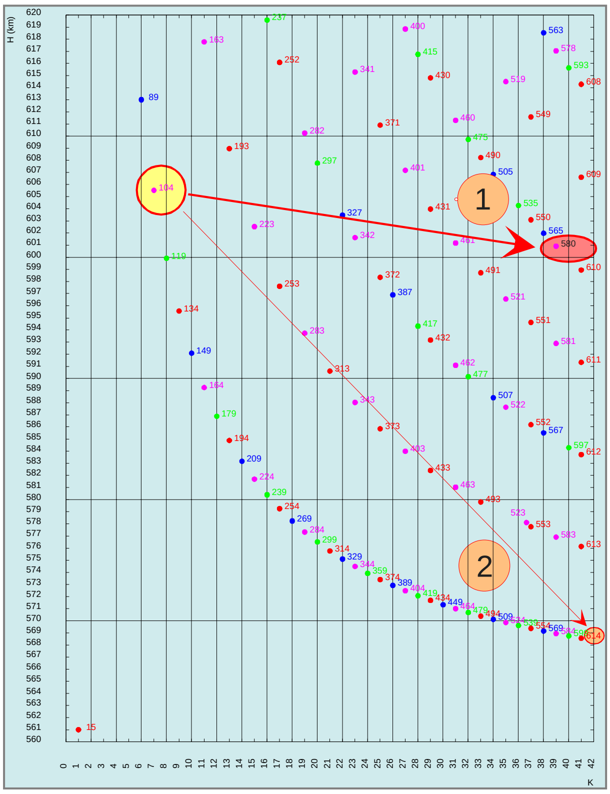

Figure 1: Options for MAPSAR orbit sub-cycles
(1= 39 days repeat cycle , 2= 41 days repeat cycle).

4. MAPSAR Satellite

The MAPSAR satellite utilizes a modular concept, consisting of a payload module and a multi-mission platform (the MMP). The payload module (including antenna and SAR electronics) is shown on top of **Figure 2**. On the bottom it is possible to see the pictorial view of the MMP, with the two wing solar array.

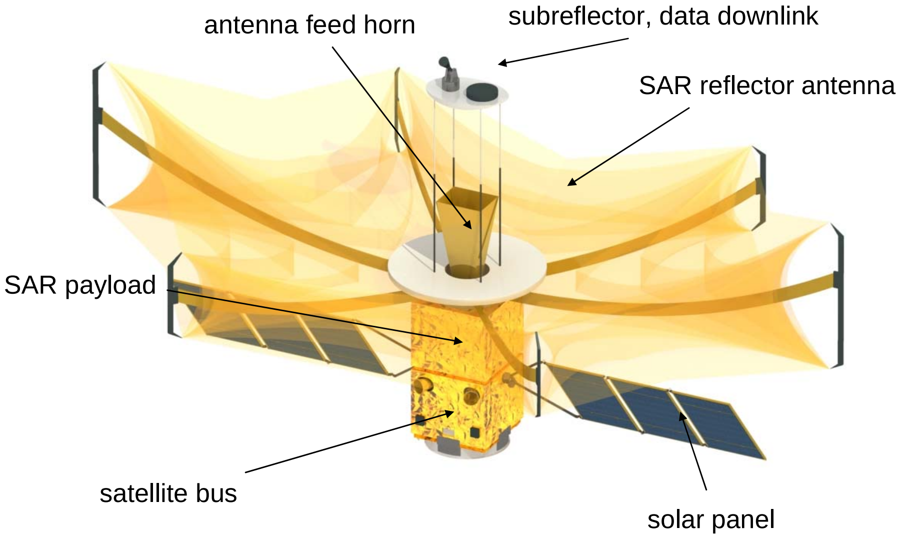

Figure 2: The MAPSAR satellite.

The Multi-Mission Platform 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. The MMP block diagram and pictorial view are shown in **Figure 3**. The MMP is already being developed by INPE and its first flight model shall be ready by middle 2006.

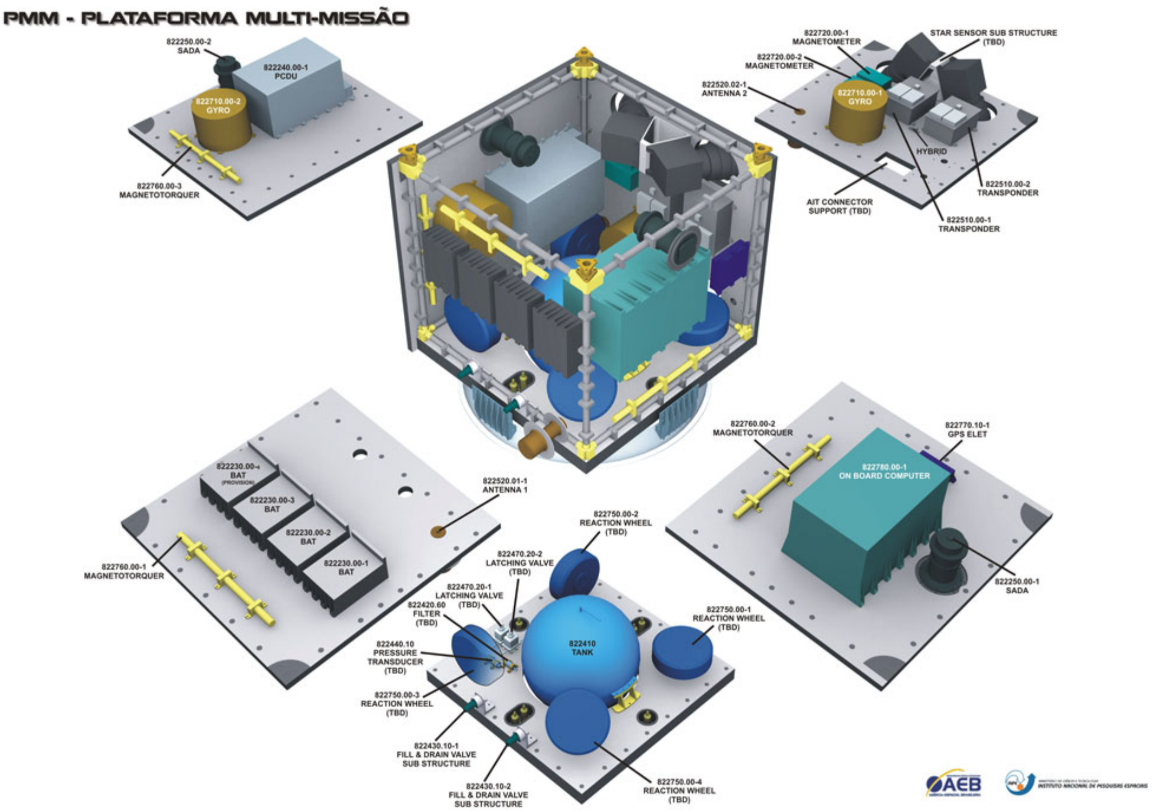

Figure 3: MMP Pictorial View (blow-up).

5. SAR instrument

In MAPSAR, the required range of incidence angles and the left/right looking are achieved by using the MMP agility capability (**Figure 4**).

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. In full polarization mode there is a reduction of the access region. 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.

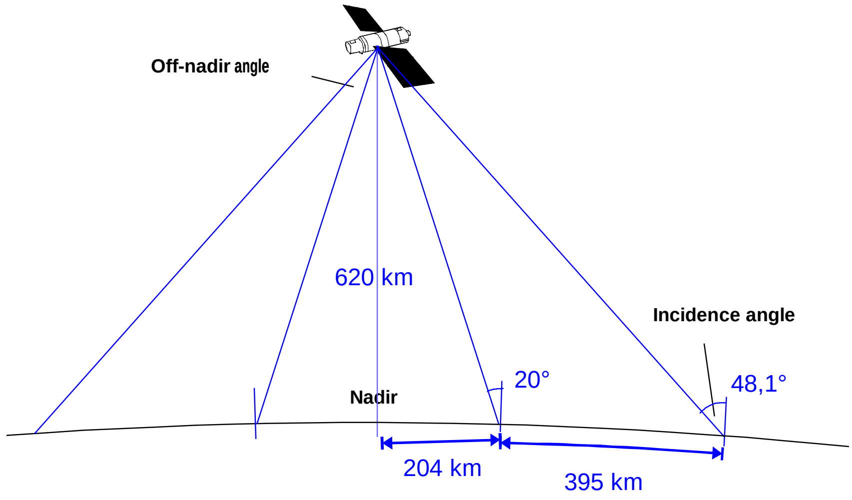

Figure 4: Access region of the SAR sensor.

Figure 5 shows a possible pattern for the radar beam specification over the whole access region (SPM and DPM). Due to the variation of height over ground even for a fixed orbit these beam patterns change depending on the current imaging geometry.

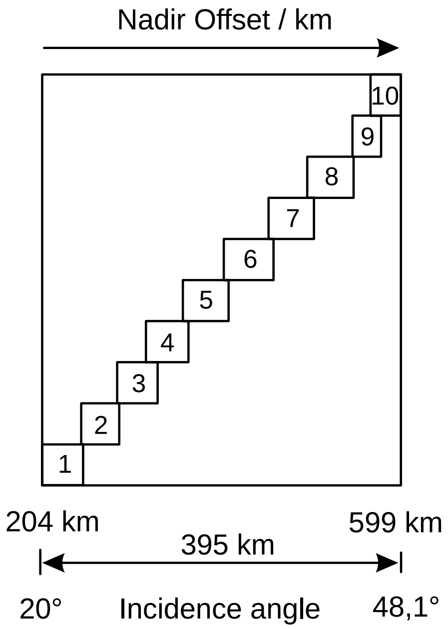

Figure 5: Radar beam specification

Table 3: Radar beam specification (medium/low resolution)

Beam number / km	Incidence angle range / °	Swath width / km	Eff. PRF / Hz
1	19,93 - 23,95	45,1	2660
2	23,76 - 27,32	41,9	3010
3	27,12 - 30,71	44,5	2660
4	29,69 - 33,31	46,9	2660
5	32,86 - 36,52	50,4	2910
6	36,15 - 39,86	54,8	2660
7	39,50 - 42,69	50,0	2900
8	42,22 - 45,24	51,0	2640
9	45,16 - 46,92	31,6	2870
10	46,28 - 48,08	33,5	2680

The radar beams in **Figure 5** are available in the low resolution mode (20 m) and medium resolution mode (10 m) in single and dual polarization (SPM, DPM). The instantaneous swath width varies between 31 km and 55 km. In medium resolution quad polarization mode (QPM) the instantaneous swath width varies between 22 km and 23 km. In low resolution QPM mode the instantaneous swath width varies between 28 km and 44 km. MAPSAR offers also a high resolution mode (3m) with instantaneous swath widths ranging from 5 km to 38 km.

A Cassegrain type antenna with a parabolic reflector was chosen for the SAR, mainly due to MMP performance. The size of the reflector is approximately 7.5 meters in length and 5 meters in elevation. Compared to active phased-array antennas, the reflector type is much lighter and allows use of higher bandwidths and full polarimetric measurement with less additional complexity. As a disadvantage, the reflector antenna doesn't allow electronic beam steering and ScanSAR mode.

The investigations on the reflector are performed in cooperation with the Institute of Lightweight Structures of the Technical University of Munich. A new concept has been proposed which consists of radial foldable rods and a rigid central part. The investigations showed no principal difficulties to fulfill the geometry requirements, stowed volume, surface accuracy, stiffness, mass and other mechanical requirements. A demonstrator is under development to validate the antenna concept during phase A.

6. Conclusions

An innovative high resolution satellite mission with an L-band SAR is under investigation. The study is being prepared by DLR and INPE, taking into account Brazilian and German user requirements. By the end of 2004 half of an ESA standard phase A feasibility analysis will be accomplished. Final conclusion will happen at the end of 2005. 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.

Feasibility and compatibility will be demonstrated at platform, payload and applications level. For user requirements demonstration together with value added products generation, simulated images will be produced using data acquired through airborne campaigns.

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, what leads to system operation in 2010.

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