A NEW DEPLOYMENT CONCEPT FOR A SPACE BASED SAR ANTENNA

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ABSTRACT

SAOCOM is an argentine satellite which main instrument is a Synthetic Aperture Radar (SAR). The 25 m^2 SAR antenna is divided in seven panels, the middle one attached by a specific support structure to the satellite bus and two lateral wings with three deployable panels each. The deployment concept for the antenna wings is presented in this paper, being its main advantages: a very simple design with no need of additional support structures like deployable frames on the back of the antenna; minimizes the antenna mass complying with strength and stiffness requirements and the radiant surfaces of the different panels do not face each other in the stowed configuration, facilitating the use and location of snubbers to achieve the required dynamical characteristics.

INTRODUCTION

The **SAOCOM** Mission is an Earth Observation System dedicated to the remote sensing data exploitation. This is a scientific program that will carry a total of 5 instrument/experiments, being the main one a SAR antenna. The spacecraft will move in a LEO polar orbit, pointing to the earth, because the earth observation instruments.

The main goals of the Mission are related to the monitoring of regions of interest in Argentina and the capability to monitor other regions on request of other countries, with the following capabilities and purposes:

- gathering of, in real time, high resolution (10 meters) information from large areas of interest, independently of meteorological and illumination conditions (day and night) by means of active microwave sensors.
- monitoring of natural hazards and potentially dangerous environmental human activities (oil patches, fires, coastal pollution, etc.)
- fast collection, processing and transmission of the information to users.
- provision with quality and cost effective services for environmental resources management.

The SAOCOM Mission is funded and supported by the Argentina Government as a Public Service Investment, and the management is under Argentinean Space Agency (CONAE) responsibility. In the frame of a Cooperation Agreement between CONAE and the Nuclear Energy Agency (CNEA), a R&D institution, the latter assumed the responsibility for the mechanical and structural design and subsequent manufacturing of the SAR antenna.

The satellite will operate in a polar, sun-synchronous orbit at 659 km altitude with a 98º inclination. The repeat cycle of the orbit will be a maximum of 17 days. The SAR antenna is designed to operate in L-band with a central frequency of 1275 MHz.

The irradiating area of the SAR antenna will be 25.6 m^2, with a height of 2.56 meters and a length of 10.0 meters and a distributed architecture, i.e., the RF transmission and reception modules will be mounted on the antenna itself and connected to each irradiating assembly.

The SAR antenna irradiating area in deployed configuration shall maintain a flatness better than 23 mm ($\lambda/10$), taken this value as a peak to peak value between any two points.

The SAR antenna shall be designed to obtain a first natural frequency of vibration in deployed configuration equal or higher than 2.5 Hz.

Taken the SAR antenna fixed to the satellite at 4 points, their natural frequencies of vibration in launch or stowed configuration shall be higher than 44 Hz in the axial axis or principal axis of the satellite and higher than 22 Hz in lateral axis or the horizontal plane axis.

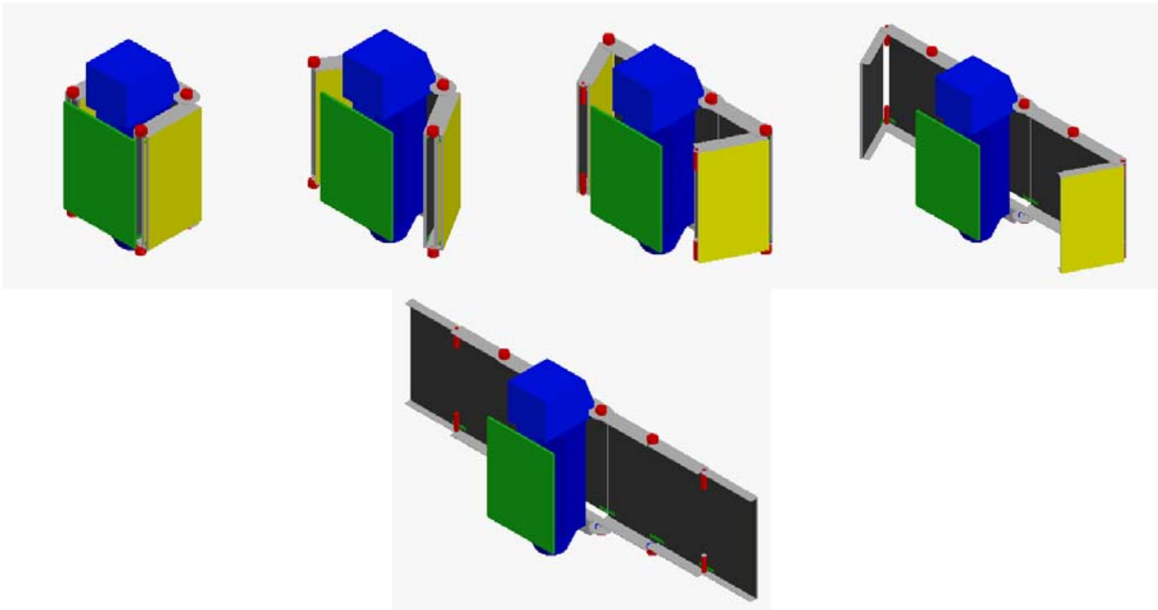

Figure 1: Antenna deployment sequence

MECHANICAL CONFIGURATION

The antenna is divided in 7 panels; a central one that is fixed to the satellite bus by means of an interface structure and two lateral wings composed by three panels each which are folded in a spiral manner. The deployment sequence is presented in Figure 1.

One of the main features of the design is the use of two lateral beams located at the sides of the panels that provide the necessary structural stiffness, avoiding the use of other supporting structures, giving a very "clean" configuration and allowing the spiral stowing of the wing panels.

The SAR antenna is designed as a modular system to facilitate the system integration divided in 3 modules, one of them composed by the central panel and the interface structure and the other two by the wings.

The antenna design presents many advantages:

❖ it is very simple, with no need of additional support structures like deployable frames on the back of the antenna;
❖ the adopted design minimizes the antenna mass complying with strength and stiffness requirements;
❖ the radiant surfaces of the different panels do not face each other in the stowed configuration;
❖ the lateral beams have different heights so they can also act as supports points (snubbers) between panels when the wing is folded and they form a continuous beam when the deployed configuration has been reached.

The antenna can be thought as "divided" in two main structures: the radiating panels and the structural panels.

The radiating panels are composed by 15 arrays of 8 circular slots. The radiating array is a multilayer arrangement composed by sets of copper clad thin laminates and a dielectric foam as indicated in Figure 2. The copper clad laminates layers are used for the circular slots plane, the conductive paths plane and the ground plane respectively.

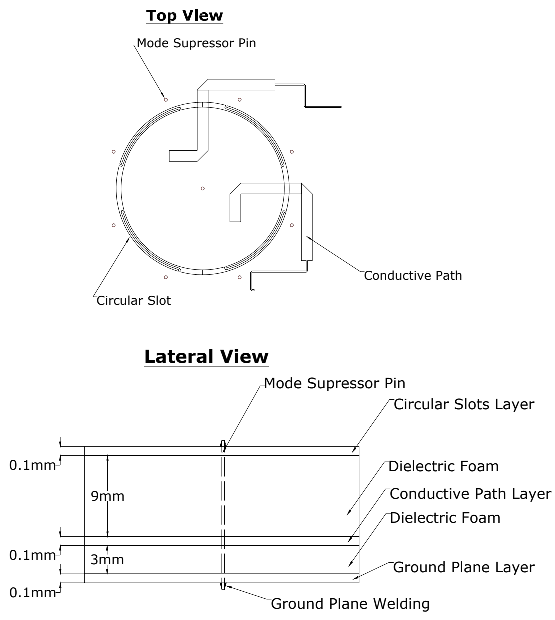

Figure2: radiating structure scheme

Two lateral fiber glass U beams, with a thermal expansion coefficient similar to that of the copper clad laminates, will be located at the sides of radiating structure in order to increase the multilayer structure stiffness. This assembly will then be attached to the structural panels by means of six carbon fiber composites lateral supports. The inner part of the lateral supports will have a solid lubricant to allow the longitudinal thermal expansion of the array. Also, a central support will be used to avoid the in-plane movements of the radiating array. A schematic view of the radiating arrays with the supports is shown in Figure 3. A detailed view of the central support and one of the lateral supports can be seen in Figure 4.

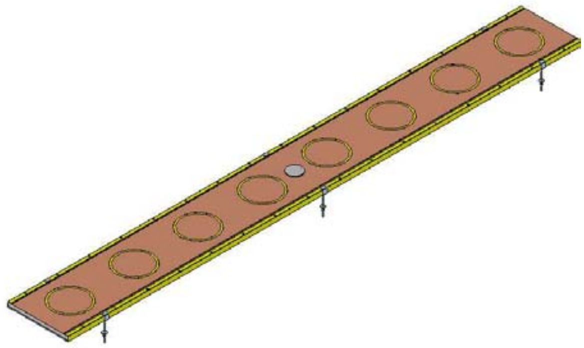

Figure 3: schematic view of a radiating array with its supports

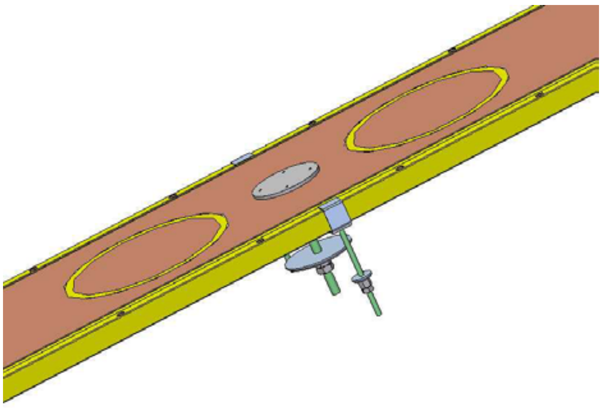

Figure 4: detailed view of the central support and one of the lateral supports

The structural panels will be made with an Aluminum honeycomb core and facings of multilayer shell $[0/60/{-60}]_S$ UHM CFRP. Till the present, the study of the structural behavior (static and dynamic) of the antenna in the folded and deployed configurations has been done by FEM analysis. Based on the mechanical environmental specifications, the fundamental frequencies of vibration of the antenna in both configurations have been verified to be higher than the minimum requirements. The first natural frequency of vibration obtained for the deployed antenna is 3.9 Hz. A schematic view of the corresponding first vibration mode can be seen in Figure 5.

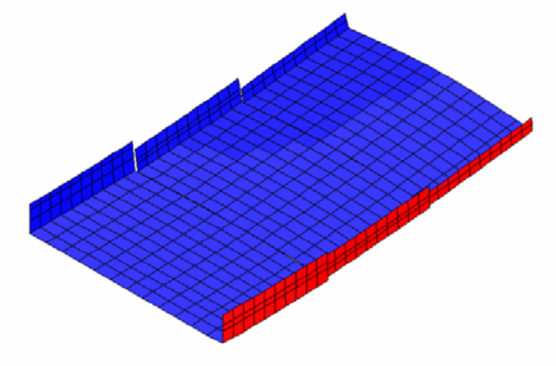

Figure 5: first vibration mode of the deployed antenna

An analysis of the dynamic behavior of the full satellite using a simplified model of the bus coupled to the antenna have been performed to verify that the fundamental frequencies are higher than the minimum requirements and also a quasi-static model analysis for the launch loads of different support configurations between the 3 panels when the antenna is folded has been performed.

Thermo elastic effects have been analyzed to evaluate the influence of temperature changes on the irradiating assemblies structure and the deployment system performance. The temperature changes also have an important influence in the design of the supports between the SAR antenna and the satellite bus.

DEPLOYMENT SYSTEM

The deployment system includes the following mechanisms: kick-off springs, hinges, guides, restraint-release mechanisms, actuators and latches. A brief description of their function is presented in the next paragraphs with an emphasis on the actuators requirements and selection.

- *Kick-off springs*: their function is to generate the needed initial force for the deployment.
- *Hinges*: the hinges are the rotation points of each deployment stage. There are two hinges between successive panels.
- *Latches*: the latches must assure the final deployed position of the panels accomplishing the flatness design requirements along the antenna operational life. There are two latches between successive panels. A schematic view of a latch in its closed position can be seen in Figure 6.

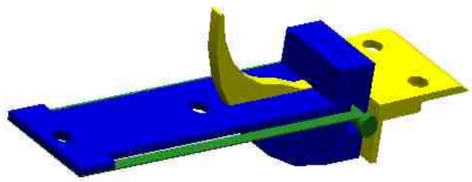

Figure 6: Schematic view of the latch

- *Guides*: the guides have as main function the control of the deployment sequence avoiding the aperture of a panel until the previous one has totally deployed and are formed by a rail and a pin that remains together until the deployment stage is completed. There are two guides for the first and second deployment stages of each wing. The location of the guides and latches in the deployed configuration of a wing is shown in Figure 7.

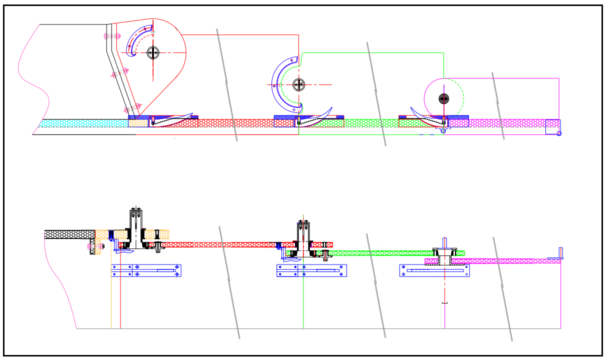

Figure 7: guides and latches in the deployed configuration

- *Restrain-Release Mechanisms:* The restrain–release mechanisms have as primary objectives to secure the antenna in its stowed configuration during launch. Two restrain- release mechanisms based on a Kevlar cable and two redundant thermal knives for each wing are foreseen to be used. This type of mechanisms has been developed by Dutch Space and had been successfully used in many satellites.

The use of pyrotechnics has also been considered but the possibility to avoid shocks and to allow a smoother release process drove the final selection. The need of two restrain-release mechanisms on each deployable wing is based on structural analysis considerations.

- *Actuators*: they have to provide the necessary torque for the complete deployment of the panels, taking into account the resistive torque generated by cables, friction, latches, inertia, etc., assuring also a smooth deployment of the panels and avoiding excessive impact forces between panels when the lock is produced.

A very careful establishment of the actuator requirements is essential to the success of the antenna deployment. Different actuator alternatives can be chosen for a certain application and then a comprehensive and structured selection method is advisable for a good selection [1].

Two actuators “concepts” were considered and analyzed for the deployment system: a passive one, using different kind of springs, and an active one using electrical rotational actuators. When a passive actuator is used, dampers are also necessary in order to control the deployment velocity. If electrical rotary actuators are used the guides are not necessary.

For the passive system the use of spiral or compression springs were analyzed. A third alternative using a carbon fiber composite leaf that act as a spring was also considered.

The spiral springs alternative was first considered due to its high torque and large displacement capabilities, although exhibit a nonlinear torque throughout deployment, but after calculating the resultant dimensions, their weight proved to be an important concern.

Compression springs have been used extensively for simple applications but also for deploying satellite antennas [1]. In this case the resultant volume of the springs presented some problems due to the available space to accommodate them, as in the case of the fiber carbon composite leaf alternative.

Three dc motor types are suitable for in-space applications. The principal uses of each one of them is presented in Table I [2]

Table I: Uses of DC Motors for Space Applications

Brush motor	Brushless motor	Stepper Motor
1) Limited life applications. 2) Low RPM applications 3) High torque applications	1) Fuel valve control actuators 2) Solar array deployment 3) Control moment gyroscopes 4) High RPM applications 5) Light weight applications 6) Low thermal emission applications	1) Optic drives 2) Solar array deployment 3) Gimbals positioning 4) Low torque applications 5) Open loop micropositioning 6) Timer switching

The main advantages of brush motors are their low cost, simplicity and availability, while the main disadvantages are brush dust, low efficiency, short motor life, limited speed and poor thermal characteristics in vacuum. Life in a vacuum of brush motors can be very short due to accelerated brush wear, typically from 10 to 400 hours. Although, advances over the years make them viable choices as long as the potential problems are understood [3].

Brushless motors presents as advantages a higher efficiency, no brushes debris and approximately double output torque over brush motors of the same size. The main disadvantages are higher electronic cost and a greater motor drive complexity.

Stepper motors have the advantage, over brushless motors, that even drive electronics is required there is no need of commutation feedback. But, also, stepper motors may present unexpected problems when the motor drive is loaded with a high inertia, and then there is the possibility of instability causing erratic operation [3].

Actuators, passive or active, shall be sized to provide over the full range of travel an actuation torque that exceeds the resistive torque multiplied by an uncertainty factor. Expressions for the calculation of the minimum required actuation torque can be found in ESA Standards [4]. Also, the Goddard Space Flight Center dictates a relationship for the minimum active torque required for mechanisms of spacecrafts managed by this Center [5].

Different resistive torque components, e.g. inertia, friction, cables, latches, etc., were analytically estimated and a ratio of four between the torque provided by the actuator to the resistive torque [3] was imposed for a first sizing of the actuators. Some tests are at present being developed to support the analytical resistive torque estimations.

Of course, not only the required active torque has to be taken into account when the selection of the actuator is made. A trade-off analysis was performed weighting:

- Cost
- Mass
- Reliability
- Complexity
- Qualification
- Integration
- Heritage
- Time
- Manufacturing
- Impact on Zero-g device

As a result of the trade-off analysis the use of active actuators has been chosen for the deployment system. A pre-selection of the different rotational actuator alternatives is being performed at present.

The position of the rotary actuators for the first and third panels deployment, considering the volumes of two of the actuators alternatives under consideration, are presented in Figure 8.

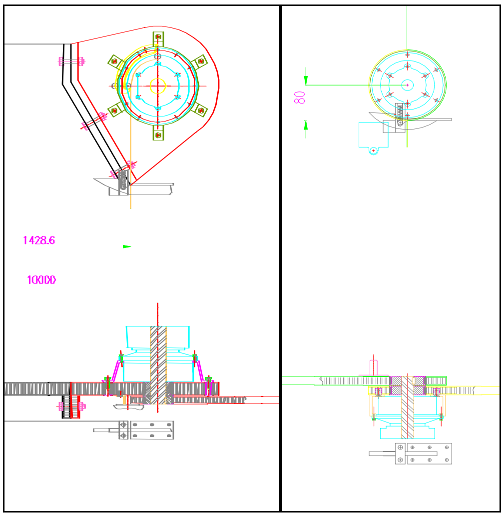

Figure 8: Rotary actuator positions for the first and third panel

An important issue to consider is the lubrication of in-contact surfaces. The selection of appropriate coatings for the different deployment system mechanisms is central to the correct operation of the deployable structure. In addition to the requirement to allow low resistance motion there may be a requirement to transmit a significant amount of interface pressure under static conditions and under transient conditions, as in the hinges case. Hence, the selected coating must possess the capability to retain good friction characteristics and whilst resisting fracture under applied loading.

Solid lubricants for in contact metallic surfaces are going to be used in order to prevent high friction forces or microweldings formation.

An important consideration for the employment of a solid lubricant film is that the film must be well bonded to the substrate material, but there are many parameters which can affect the performance of a solid lubricant. Some of these factors are:

- Type of materials in sliding contact;
- Geometry of sliding materials;
- Contact stress or pressure;
- Surface to which solid lubricant is applied;
- Substrate hardness,
- Substrate surface topography;
- Temperature;
- Speed;
- Storage time and conditions;

For the deployment system mechanisms sputtered Molybdenum disulfide (MoS_2) or lead (Pb) based lubricants are being considered. In some cases an interlayer of TiN will be added to the bulk materials.

CONCLUDING REMARKS

A brief description of the SAOCOM SAR antenna, with an emphasis on the deployment system, has been presented. The SAOCOM Mission is an Earth Observation System dedicated to the remote sensing data exploitation.

The antenna is divided in 7 panels; a central one that is fixed to the satellite bus by means of an interface structure and two lateral wings composed by three panels each folded in a spiral manner.

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ACKNOWLEDGMENTS

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