Deployment mechanism for an L-Band Helix antenna on-board the 3Cat-4 1U CubeSat

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Abstract

Earth Observation (EO) is key for climate and environmental monitoring at global level, and in specific regions where the effects of global warming are more noticeable, such as in polar regions, where ice melt is also opening new commercial maritime routes. Soil moisture is also useful for agriculture and monitoring the advance of desertification, as well as biomass and carbon storage.

Global Navigation Satellite System - Reflectometry (GNSS-R) and L-band microwave Radiometry are passive microwave remote sensing techniques that can be used to perform these types of measurements regardless of the illumination and cloud conditions, and -since they are passive- they are well suited for small satellites, where power availability is a limiting factor.

GNSS-R was tested from space onboard the UK-DMC and the UK TechDemoSat-1, and several missions have been launched using GNSS-R as main instrument, as CyGNSS, BuFeng-1, or the FSSCAT [1] mission. These missions aim at providing soil moisture [2], ocean wind speed [3], and flooding mapping of the Earth. L-band microwave radiometry data has also been retrieved from space with SMOS and SMAP missions, obtaining sea ice thickness, soil moisture, and ocean salinity data [4].

The 3Cat-4 mission was selected by the ESA Academy "Fly your Satellite" program in 2017. It aims at combining both GNSS-R and L-band Microwave Radiometry at in a low-power and cost-effective 1-Unit (1U) satellite. Moreover, the 3Cat-4 can also detect Automatic Identification System (AIS) signals from vessels.

The single payload is the Flexible Microwave Payload 1 (FMPL-1) [5] that performs the signal conditioning and signal processing for GNSS-R, L-Band microwave radiometry and AIS experiments. The spacecraft has three payload antennas: (1) a VHF monopole for AIS signals; (2) an uplooking antenna for the direct GPS signals; (3) a downlooking antenna that captures reflected GPS signals, and for the Microwave Radiometer. The downlooking antenna is a deployable helix antenna called the Nadir Antenna and Deployment Subsystem (NADS) which has a volume of less than 0,3U when stowed, achieving an axial length of more than 500 mm when deployed.

As part of this mission, the design of the NADS antenna, its RF performance, as well as the environmental tests performed in terms of structural and thermal space conditions will be presented.

Keywords

CubeSat, GNSS-R, microwave radiometry, earth observation, nanosatellite

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1. Introduction

Recent studies have shown the possibility to obtain soil moisture [2], ocean wind speed [3] and flooding with GNSS-Reflectometry. Moreover, the capabilities of GNSS-Reflectometry and Microwave L-Band Radiometry to improve soil moisture and ocean salinity measures [3].

The [3]Cat-4 mission [6] aims at demonstrating the technologies to perform with a 1 Unit (1U) CubeSat dual-band (L1 and L2) GNSS-Reflectometry, and Microwave Radiometry. The payload is implemented by the Flexible Microwave Payload 1 (FMPL-1) [5], the LHCP Nadir Antenna and Deployment Subsystem (NADS) and RHCP uplooking active antenna.

The NADS includes an L-Band helix antenna. This solution was implemented to have a directive LHCP antenna in a reduced space. Previous studies have been done with these types of deployable antennas [7,8,9], but most of them are focused on the radiofrequency design, and performance of the antenna rather than in the deployment mechanism itself, which is a critical part.

This article presents the design, functional and environmental results of a deployment mechanism for such a helical antenna. Section 2 describes the different mechanical parts of the NADS, and their functionalities. Section 3 presents the ambient tests, vibration tests and thermal vacuum tests results. Finally, section 4 presents the conclusions.

2. Antenna Deployment Mechanism

The NADS has two different configurations stowed, Figure 1, and deployed, Figure 2. The antenna is stowed during launch, and deployed once in orbit.

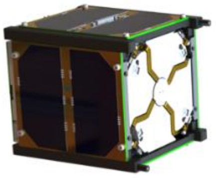

Figure 1 - NADS in stowed configuration

Figure 2 - NADS in deployed configuration

The deployment mechanism has been designed to ensure safety and functionality during launch, i.e., no unexpected deployments and resonances below 100 Hz. Moreover, the design also ensures the correct deployment of the antenna, and the expected RF performance once it is deployed. The different parts that conform the subsystem can be seen in Figure 3.

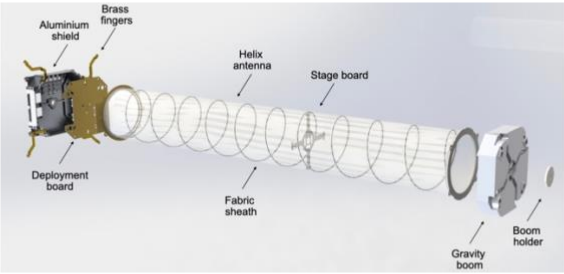

Figure 3 - NADS exploded view

In stowed configuration the NADS is held by five melting lines. One melting line holds half of the antenna, this line is secured in the Stage Board. Two more melting lines hold the gravity boom keeping the whole antenna stowed. Finally, four brass fingers prevent the antenna and gravity boom from moving, these fingers are secured by the boom holder. The boom holder is also held by two melting lines. Both the gravity boom and boom holder have redundant melting lines to prevent an unexpected deployment in case of failure on one of the lines.

The melting lines are arranged in the Aluminium shield so that there is contact between the lines and the burning resistors placed in the deployment board. There are primary resistors and redundant resistors.

The deployment is performed in three stages. The first stage releases the boom holder and the fingers, the second releases the gravity boom deploying half of the antenna, and the finals step deploys the complete antenna by releasing the stage PCB.

The deployment board includes feedback switches. The switches indicate if the melting lines are burnt, i.e., stage deployed, or not.

The deployment is executed through telecommand (TC). There is one TC for each melting line and the deployment sequence only proceeds to the next stage if the previous one has positive feedback from the switches.

Once the antenna is deployed the fabric sheath maintains the shape of the helix.

3. Verification Campaigns

In order to verify the design of the deployment mechanism a qualification model of the subsystem has been tested in ambient conditions by performing antenna deployments. Moreover, it has also been tested in the environmental conditions that will be experienced during launch including vibration tests, and in orbit with thermal vacuum tests.

3.1. Ambient Tests

The verification of the antenna design has been conducted by performing multiple deployments in ambient conditions.

To perform these tests the antenna is placed on a test bench, which holds the aluminium shield of the antenna as well as the gravity boom. This configuration allows to deploy the antenna in a horizontal position, minimizing the effect of gravity.

Figure 4 shows the deployment performed in one of the ambient tests.

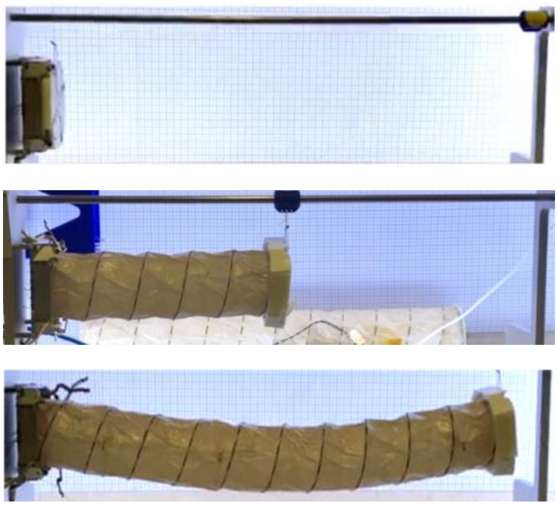

Figure 4 - NADS ambient deployment test sequence

3.2. Vibration Tests

The goal of vibration testing is to ensure that the first resonance of the subsystem is above 100 Hz and that the subsystem is able to withstand the structural stress suffered during launch by being functional after.

The NADS has been vibrated in all three axes and the metrics have been obtained using monoaxial accelerometers. The setup for the tests is shown in Figure 5.

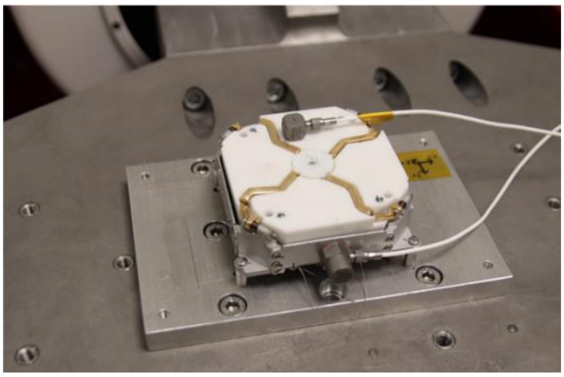

Figure 5 - NADS assembled in the Shaker slip table

The subsystem has also undergone a sine sweep test, which emulates the acceleration of the launcher. As well as, a random vibration test, emulating the structural stress induced by the rocket.

Out of the three accelerometers, one is the control, which adjusts the stress put to the subsystem. The other two are measurements of the subsystem. The resonant frequencies can be found in Table 1.

Table 1. First resonant frequencies

	X	Y	Z
Resonant Frequency (Hz)	600	700	500

The success criteria for the test campaign are based on a visual inspection and an ambient deployment test.

The NADS showed no movement in parts or fasteners after the vibration tests and the antenna was able to fully deploy, considering the test campaign successful.

3.3. Thermal Vacuum Tests

The goal of the Thermal Vacuum Tests is to verify that the NADS is capable of deploying in vacuum and with extreme temperatures. This emulates the environment that the subsystem will face when it is in orbit.

The Thermal Vacuum test performed consists of deploying the antenna at -35 ºC. The test was setup so it would recreate the ambient tests by placing the antenna assembled in the test bench inside a Thermal Vacuum Chamber (TVAC).

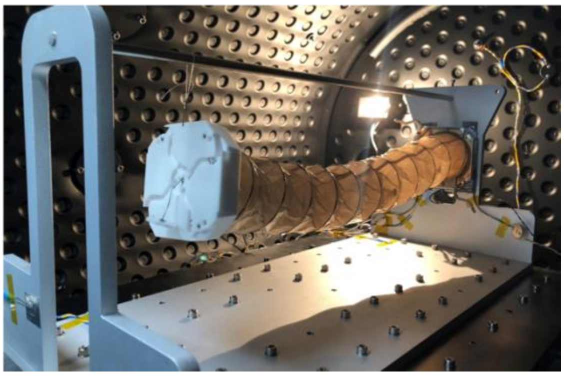

Figure 6 - NADS deployed inside ESEC-Galaxia TVAC

The test was considered successful since the antenna was deployed in vacuum conditions and at -35 ºC.

4. Conclusions

This article summarizes the design and characterization tests of a deployment mechanism for a helical antenna, following the CubeSat standard. This mechanism will fly on the ^{3}Cat-4 satellite, it conforms the NADS.

The NADS has two different configurations, it is stowed during launch and deployed when the satellite is in orbit. The design has considered safety, functional and performance requirements to ensure success on both configurations and also on the deployment of the antenna.

The subsystem has been verified through ambient testing, performing deployments of the antenna in order to verify the design. It has also been vibrated, to ensure the correct functionality during launch and the capability to deploy once it is orbiting. Finally, the correct deployment of the antenna in space conditions has been verified through a thermal vacuum test at -35 ºC.

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