ULTRA-LIGHT DEPLOYMENT MECHANISM (UDM) FOR SECTIONED LARGE DEPLOYABLE ANTENNA REFLECTORS

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ABSTRACT

The Ultra-Light Deployment Mechanism (UDM) is a CFRP curved tape spring based mechanism suitable for the deployment of solid reflector antenna sections with a projected diameter of the full reflector of 4m to 7m and specific mass lower than 2.0 kg/m2.

High Tension Carbon Fibre / Cyanate Ester Resin prepregs are used to form curved tape springs which provide the necessary deployment motorization and reflector pointing stiffness while demonstrating excellent temperature stability.

This paper presents the design and test results of the UDM as well as its other possible areas of application.

1. INTRODUCTION

Available launcher fairing dimensions have always been a limiting factor to the maximum size of a solid antenna reflector (typically below 4.0 m aperture diameter).
Recently [4] the concept of a foldable segmented solid reflector has been revisited in order to meet short and medium term reflector needs. Studies (TRL 3/4) are demonstrating high credibility to the feasibility of future missions with large built in space reflectors (diameters from 4.0 up to approximately 7.0 m diameter).

The possibility to cut solid antenna reflectors into smaller sections in order to reduce the stowed envelope and increase the usable reflector diameter, has been considered in the past already, but very few attempts have been made to develop and fly this concept.

The CFRP based deployment mechanism presented herein demonstrates advantages in terms of mass, stiffness and complexity over other elastic collapsible hinges (ECH) based on metallic springs and over conventional deployment mechanisms.

Excellent thermo-elastic stability is ensured by the intrinsically very low coefficient of thermal expansion (CTE) of the basic materials.

In the scope of an ESA ARTES 5.1 research project the results presented in this paper represent the next stage efforts following ULMAAS [1] with the goal to reach TRL 5 of the UDM design.

In a joint effort RUAG Space and HTS GmbH have reached preliminary design status of the UDM presented herein with functional and integration requirements being supported by Astrium SAS.

2. DESIGN DESCRIPTION

The UDM is proposed to be integrated on a reflector antenna backing structure as seen in Fig. 1. The reflector mechanical reference configuration selected for this development is the typical “ultra-light reflector” technology as developed by EADS Astrium. In launch configuration the UDM’s are folded and the reflector tips held in place by 3 HDRM’s (Hold-Down Release Mechanism). One HDRM’s is foreseen at each of the UDM’s and a third holding the tip of the reflector to the main reflector section.

In order to achieve the required pointing accuracy and deployment motorization requirements a unique spring blade layout has been selected (Fig. 2). The blades are arranged in a so called X-Configuration. For launch configuration they are folded to 200° rotational angle.
The UDM is made of High Tension Carbon Fibre / Cyanate Ester resin prepregs. This combination provides low moisture absorption important to reduce low temperature degradation effects (micro cracking) and high temperature stability needed to limit relaxation effects to a minimum (loss of deployment motorization) and thermo-elastic induced distortions.

Preliminary analysis shows that the deployment shocks are below the specified 3000g limits. For the estimated shock loads structural integrity of the UDM has been demonstrated, hence no deployment shock damping elements are necessary. A deployment shock test in representative configuration will be anyhow performed during the test campaign.

‘14th European Space Mechanisms & Tribology Symposium – ESMATS 2011’
Constance, Germany, 28–30 September 2011

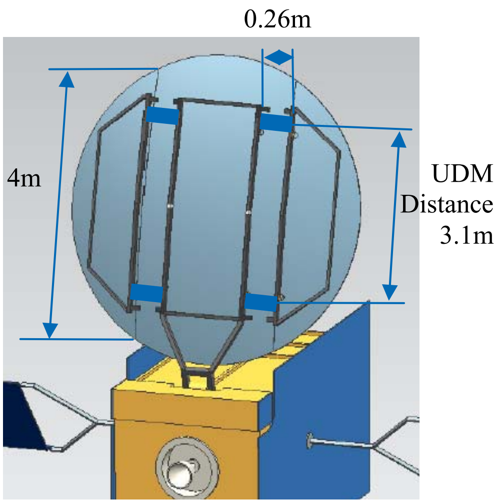

Figure 1. Proposed UDM Integration on Backing Structure of Reflector Antenna.

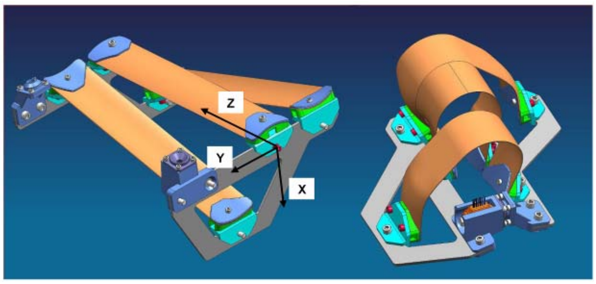

Figure 2. Unique Spring Blade Layout.

3. TEST RESULTS

The main concern addressed by the testing program was the degree of motorization loss due to relaxation effects at elevated temperatures. As described in [2] the off-axis stress relaxation behavior is driven by temperature and initial strain levels.

A bread board test set up (Fig. 2.) was chosen in order to determine the relaxation effects due to thermal and mechanical cycling. The UDM was prestrained to 200° rotational angle and submitted to thermal and mechanical cycling. The UDM was subject to a total of 8 thermal cycles from -150°C to +110°C and a total of 62 mechanical open/close cycles. Torque measurements were made at room temperature before and after the thermal cycling.

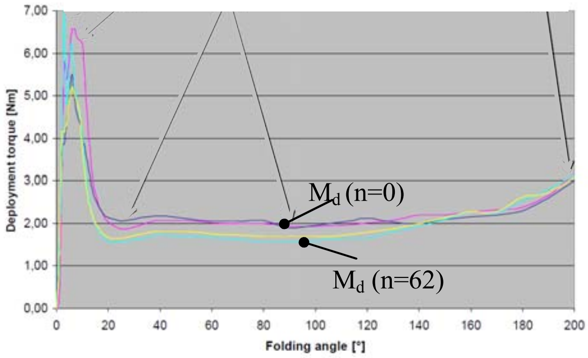

Figure 3. Deployment Torque Test Results.

The test results show (Fig. 3) that the minimum torque drops from 2.0 Nm to 1.6 Nm due to thermal effects and 7 deployments. Thereafter the UDM is stabilized; and only an additional motorization reduction of 0.1 Nm to 1.5 Nm due to the following 55 mechanical deployment sequences is observed.

In addition to the torque measurements, the stiffness of the UDM (Cx) was monitored during the thermal and mechanical cycling events. A simple test set up was used measuring displacement with optical sensors due to an applied load (Fig. 4).

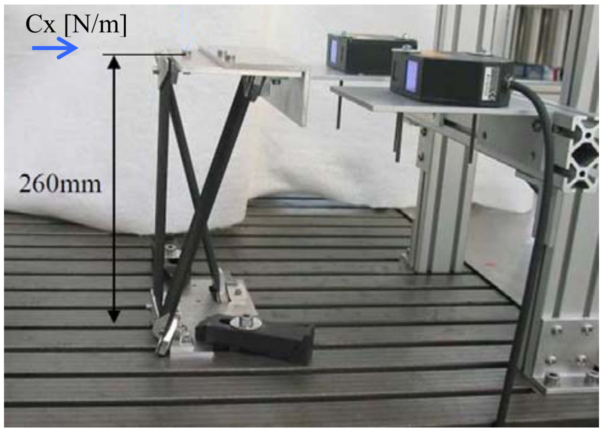

Figure 4. Stiffness Measuremnent Set-Up.

A slight increase in stiffness is measured which is assumed to be allocated to the resin hardening during thermal cycling (Fig. 5).

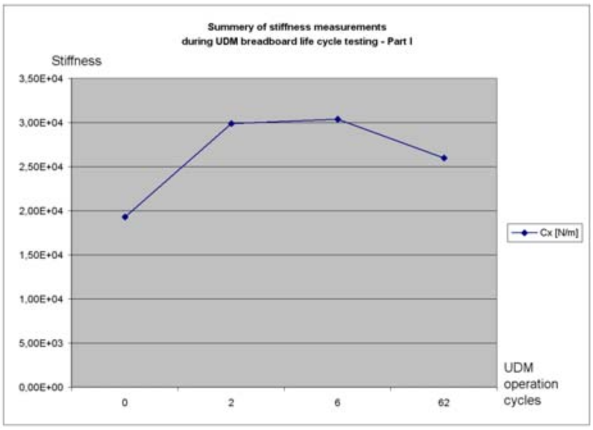

Figure 5. Stiffness Test Results (Cx [N/m]).

4. PERFORMANCE

The main performance parameters of the UDM are *stiffness* in order to achieve the required pointing accuracy and *motorization* in order to assure deployment of the reflector section. Structural integrity is easily demonstrated for launch and deployment shock loads.

Parameter	Requirement	Achieved	Verification
Motorization	> 0.1 Nm	1.5 Nm	Test
Linear Stiffness	> 1.0E+04 [N/m]	1.9E+04 [N/m]	Test
Rotational Stiffness	> 4.0E+03 [Nm/rad]	6.82E+03 [Nm/rad]	Analysis

5. OTHER APPLICATIONS

The stiffness and motorization properties of the UDM may be tailored to cater a number of applications.

- VHF Patch A rray Antenna Deployment Mechanism (Fig. 6) or Solar Array
- Solar Sail deployment mechanism (Fig. 7)

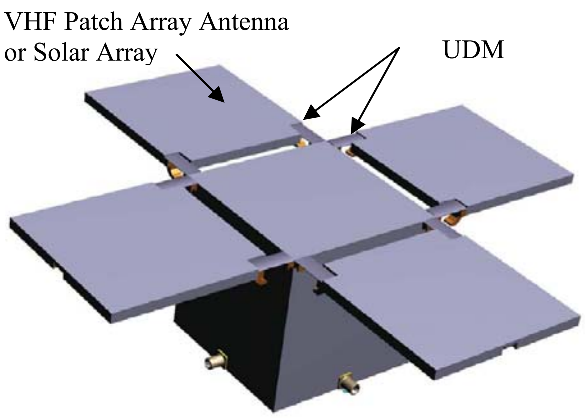

Figure 6. UDM used to deploy VHF Antennas (Could also be used to deploy Solar Arrays).

Figure 7. Possible Application for UDM - Solar Sail Deployment Module (Example taken from [3]).

6. NOTES

This paper will be presented at the poster session of ESMATS 2011 in Constance.

7. REFERENCES

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2. Kawai, M, Kazama, T., Masuko, Y. et al. (2002). Stress Relaxation Behaviour of Unidirectional Carbon/Epoxy Composites at Elevated Temperature and Analysis Using Viscoplasticity Model, Jpn. Soc. Mech. Eng., Vol.68 No. 673 A, pp 1320-1327.
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