DEVELOPMENT OF A FINE POINTING AND TRIM MECHANISM

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ABSTRACT

An overview is given of the antenna fine pointing and trim mechanism (FPTM) to be used for future geostationary telecom satellites operating with narrow beam coverage. The development goal is to reach TRL-5 (Technical Readiness Level according to [1]) by 2012.
The FPTM baseline is defined as a two axis mechanism based on flexible hinges and a linear piezo-electric actuator. The FPTM shall provide a pointing range of ±2 deg around two axes. A typical operational life of 15 years is targeted.
The FPTM development foresees improvements over current reflector pointing mechanisms as it shall provide higher pointing resolution (< 0.002 deg) and pointing accuracy eliminate backlash and reduce hysteresis, while meeting current levels for power consumption volume and stiffness.

1. INTRODUCTION

Multibeam satellites mainly using Ku or Ka-band systems require high pointing accuracy and resolution (0.005 deg). Conventional mechanisms use stepper motors which introduce backlash and hysteresis into the pointing budget. There is a need coming from future multimedia telecommunication platforms to increase resolution and depointing correction rates.
The FPTM development lead by RUAG Space Switzerland, takes into account future mission requirements by formally engaging Astrium SAS to participate in the definition of future antenna fine pointing requirements.
Applying piezo-electric actuator technology the FPTM development seeks to provide a technical solution for future reflector antenna pointing needs.

2. SCOPE of DEVELOPMENT

In order for the FPTM to achieve TRL5 status it is necessary to consolidate the future pointing needs with satellite platform primes. While Astrium SAS has been contractually engaged to provide support in the definition of the FPTM pointing requirements, TAS France has also been involved to comment before finalizing the FPTM design requirements.
After consolidation of requirements has been accomplished, a trade-off of designs is being conducted in May/June 2011 to select a baseline mechanical and actuator concept. During the following preliminary design phase, a bread board test will confirm piezo actuator life time and performance. In addition reflector and S/C integration aspects will be studied. In particular a HDRM concept will be suggested and a first estimate of launch loads will be made. It is expected that these results can already be presented at the ESMATS 2011.
The design will then be detailed by HTS GmbH, Dresden, incorporating test results and detailed analysis. As a result an EM of the FPTM will be manufactured and subject to a qualification test programme according to general ECSS [2] limits.

3. FPTM REQUIREMENTS

An effort was made to define an envelope of requirements which would be able to cover two major satellite platform configurations (Cassegrain Fig. 1 and Single-Offset Fig. 2).

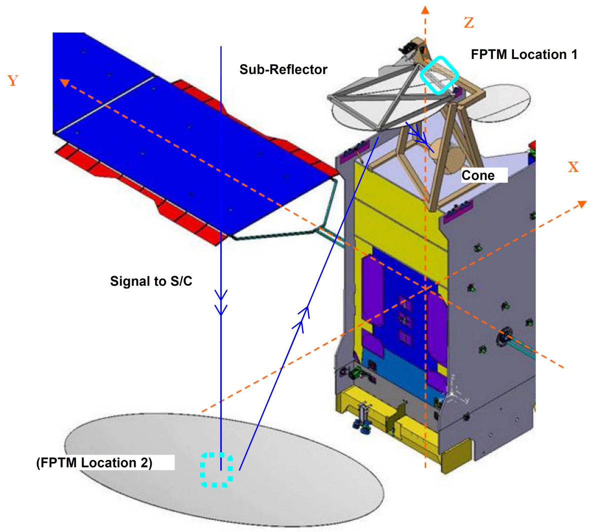

Figure 1. Cassegrain Configuration with Main (D=5m) and Sub Reflector (D=2m).

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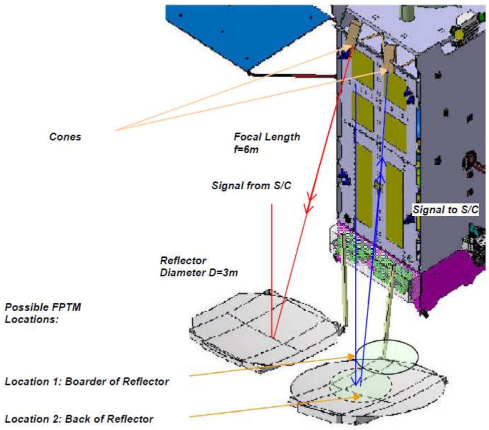

Figure 2. Single Offset Configuration with Main Reflector (D=5m).

As a baseline the FPTM shall be side mounted in order not to exceed current reflector stacking envelopes in launch configuration. This is applicable to both reflector configurations.
As a result of the collaboration with Astrium SAS and the comments supplied by TAS the key requirements for the FPTM are summarized in Tab. 1:

Table 1. FPTM Key Requirements.

Requirement Description	*Target Value*
Pointing range	± 2.0 deg
Pointing Accuracy	± 0.001 deg
Pointing Resolution	± 0.001
Pointing Speed	24 mdeg/s
Life Time (cycles)	2.5 mio
Life Time (travel deg)	870'000
Environmental Temperature	-185°C to +165°C
Translational Stiffness	1.5 10^5 N/m
Rotational Stiffness	2.0 10^4 Nm/rad

4. FPTM DESIGN CONCEPTS

Two design concepts based on flexible elements are currently being evaluated. One of which will be selected to be manufactured and tested as an Engineering Model (EM). Neither of the concepts require lubrication and can easily operate in ambient atmospheric conditions for ground testing as well as vacuum.
The FPTM is to be placed between reflector antenna and reflector deployment mechanism. As such the sole function of the FPTM is to fine point / trim the orientation of the reflector antenna. Both design concepts are capable of fulfilling the key requirements mentioned above (Tab. 1) hence catering for both S/C reflector configurations (Fig. 1 & Fig. 2).
Thermal decoupling from the reflector is foreseen with limited thermal flux allowed toward the S/C. The FPTM development will also provide a thermal control concept in order to deal with the general environmental conditions of a GEO orbit.
Both design concepts have integrated capacitive sensors in order to determine rotational position. These will be used for performance test purposes on ground but may also be integrated at S/C system level if needed for closed loop control.
Both concepts will be able to provide the necessary holding force in powered and unpowered status.

4.1. Monolithic Design Concept

The monolithic design concept has small flexible elements located at the diagonals of the cubus (Fig. 3). This configuration provides excellent stiffness and very little cross talk between the rotational axes in comparison to the trapezoidal design concept.
The design is compact and can be modularly fit between reflector antenna and reflector deployment mechanism.
The design may easily be adapted to accommodate an HDRM should the holding forces of the actuator show this to be necessary during launch.

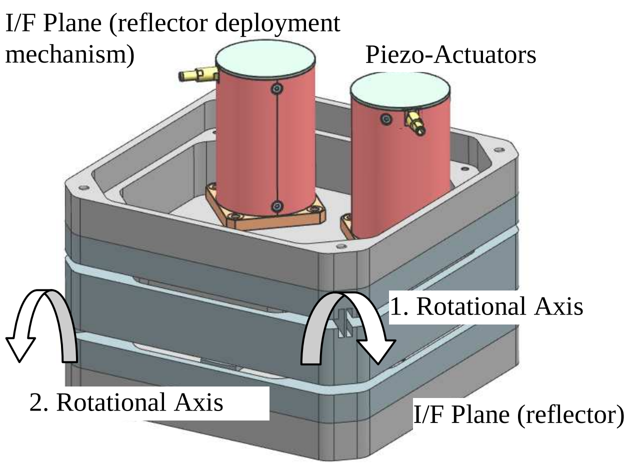

Figure 3. FPTM Monolithic Design Concept.

4.2. Trapezoidal Design Concept

The trapezoidal design concept extends the flexible blade concept and consists of two interconnected rotating planes (Fig. 3). The I/F plane movement is cinematically a combination of linear and angular displacements. While this may seem to be a disadvantage the linear displacements may be used in order to reduce focal depointing, a great advantage over the monolithic design.

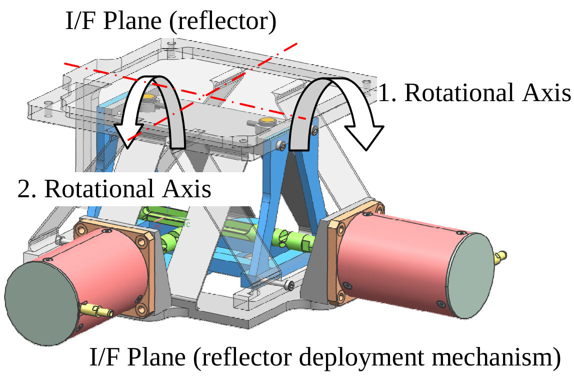

Figure 4. FPTM Trapezoidal Design Concept.

While the trapezoidal design concept is lighter weight then the monolithic design concept it may prove difficult to achieve stiffness requirement and implement an HDRM if deemed necessary.

4.3. Motorization Concept

While several piezo-actuator concepts are available walking-piezo type actuators provide the best performance in terms of holding force (unpowered), travel range and operating temperature. Using walking-piezo type actuators will also be able to profit from the experience RUAG Space has in designing piezo actuator drive electronics compatible to S/C platform needs, see [3], [4] and [5].

4.4. Drive Electronics

While the development of the drive electronics is not in the scope of the FPTM development project, a general concept has been derived based on the electronics developed by RUAG for LISA PAAM (Fig. 5).
Compatibility to S/C platform electronics is given in the example of the EUROSTAR 3000 platform.
The drive electronics are designed to communicate with S/C system electronics. At system level a number of steps is commanded defined by the pointing resolution. The FPTM drive electronics uses a closed loop control system, where the integrated angular sensor feed backs are used to accurately drive the FPTM to the required heading.

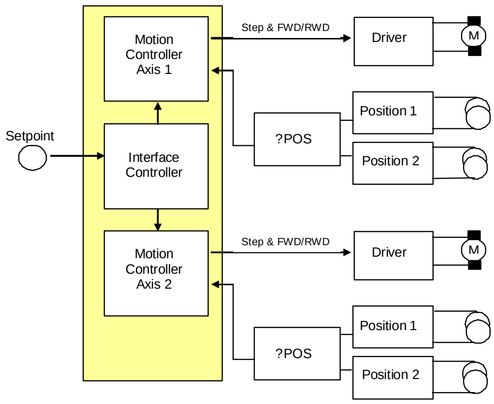

Figure 5. FPTM Drive Electronics Concept.

5. OUTLOOK

The requirement consolidation phase is currently coming to closure while first trade-off studies between the two mechanical design concepts and motorisation possibilities have begun.
Several technical issues still need to be addressed before the piezo-based technology may be considered a stepper motor replacement. Critical interest is given to:
- Costs to develop space qualified drive electronics
- Power Supply
- Mass
- Stiffness

5.1. Commercial Market

While current stepper motor solutions have drive electronics which are already integrated in many commercial telecom platforms, the specific power supply requirements of the piezo-actuators (high voltages) require new electrical interfaces to be developed and space proven.
The performance outcome of the piezo based solution shall provide sufficient improvements in terms of resolution, backlash, hysteresis and life-time in order to justify the development costs of the electronics.
RUAGs business case for the FPTM developed together with satellite primes is promising, especially with regard to the coming future commercial telecom platforms, which are currently being evaluated in the frame of early concept studies both at Astrium as well as Thales.

6. NOTES

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

7. REFERENCES

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