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Satellite Accommodation of a Ku Multibeam Antenna with Polarisation Grid Sub-reflector

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1. Introduction

Today's satellite communication systems operate mainly in C and Ku frequency bands. They are characterized by broad regional coverage, relatively low satellite gain, EIRP and G/T, and modest data rates. Multibeam payloads and frequency re-use, associated to large bandwidth are the concepts that actual generation communication systems use to palliate these shortcomings. An antenna sub-system, able to provide both high gain & high level of Cross-polarisation discrimination over the service area while allowing frequency-reuse by means of spatial isolation, is presented. A representative breadboard, including a focal array of 21 horns and a polarisation grid has been manufactured and tested to prove the feasibility of the concept.

2. Mission description

The studied scenario is based on a European coverage shared in ten linguistic beams, using four different frequencies.

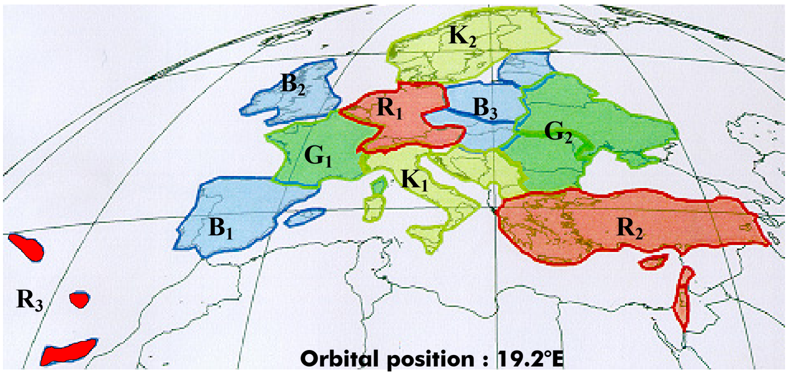

Figure 1: European coverage

Main specifications at antenna level are the following:

Frequency bandwidth:	Tx: 11.70-12.75 GHz & Rx: 13.75-14.50 GHz
Beam:	500 MHz (~8x36 MHz) / H or V linear polarisation
XPD:	> 27 dB over each service area
Side lobe isolation:	> 27 dB between beams of the same color
Power handling:	800 W at beam access (8 channels of 36 MHz)

3. Antenna Sub-System description

The global antenna system is composed of 3 antennas:

- Earth DGR antenna (∅1.8m) for Rx (all beams) and Tx (beam R3)
- East Antenna (main reflector 3.5x3.2m) for Tx (beams B1, B2, B3, K1, K2)
- West Antenna (main reflector ∅2.8) for Tx (beams G1, G2, R1, R2)

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Each East and West antenna is composed of:

- a main reflector
- a sub gridded reflector (SGR)
- a front-fed feed assembly (1.4 λ Potter horns + passive Waveguide BFN)
- a cassegrain feed assembly (1.4 λ Potter horns + passive Waveguide BFN)

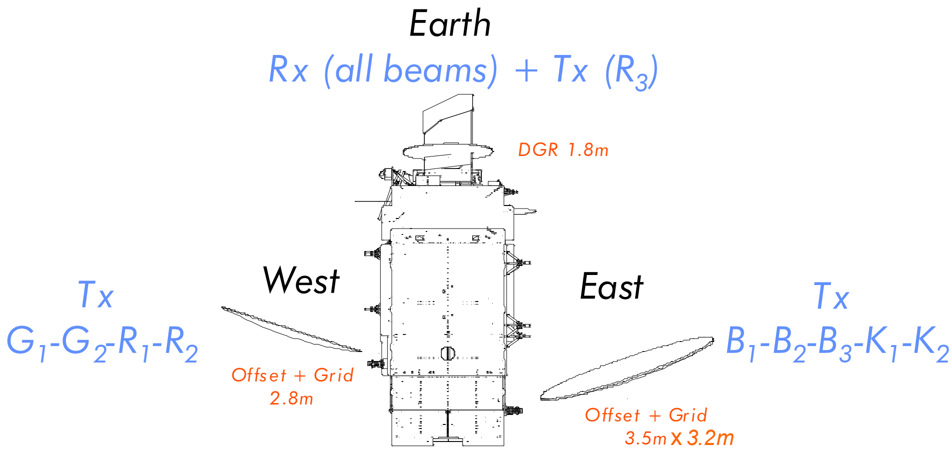

Figure 2: Antenna S/S accommodation

The large apertures allow the generation of both high gain and high gain slope needed to comply with isolation requirements. The insertion of a polarisation grid, based on Chu's patent [1], provides high XPD performances with moderate F/D ratio. The principle of the cross-polarisation compensation is to constrain, by using the SGR, the E-field vector distribution hitting the reflector such as the E-field on the antenna aperture has two symmetrical planes instead of only one (offset plane). The cross-polarisation pattern is spread on four lobes instead of two with drastically lowered level. By using such a concept, XPD performance can be approximately similar to the one obtained with Dual-Gridded Reflector. The main advantage of present solution is to comply with very large aperture (in the 3-4 m range) whereas DGR is limited in size around 2.2m due to actual technology.

Present work has been limited to the study of the focal array (feed + SGR assembly) of the East antenna.

4. Satellite accommodation and performed analyses

4.1 Launchers

The satellite is assumed to be a SPACEBUS 4C4. The stowed accommodation is compatible with the big launchers as ArianeV, AtlasV and Delta4M. The accommodation was driven by mechanical, thermal and thermo-elastic compromise, taking into account feeds and SGR behavior. Moreover, a specific care has been led to minimise all blockages and diffraction effects.

4.2 Mechanical behaviour

The feeds clusters have been designed to satisfy mechanical requirements for SPACEBUS 4C4 satellite from quasi-static and modal point of view: first frequency eigen mode is computed around 140 Hz in clamped configuration. The stiffness of the sub-reflector is computed around 40 Hz with air effect which is below standard specification. This is mainly due to both flat panel and large diameter of the grid (1.1 m). Discoupling with the satellite can be reached by a small curvature of the SGR.

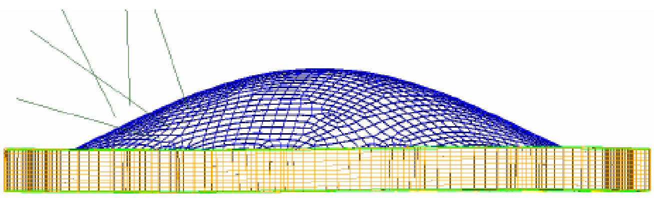

Figure 3: SGR 1rst mechanical eigen mode

4.2 Thermal control

The antenna thermal control shall maintain all constituting elements into their respective temperature range. The SGR and feeds are thermally discoupled to the platform. The thermal control consists in coating the whole sub-reflector and feeds with a sunshield tent, while keeping feeds thermal control outside this area. This solution prevents sun rays from entering and reflecting on the sub-reflector while allowing RF power to be normally transmitted. The most critical point is that high RF power is radiated towards the grid, which induces significant increase of temperature at sub-reflector level (qualification limit is reached with a transmitted power of 10 x 100W in Winter Solstice EOL).

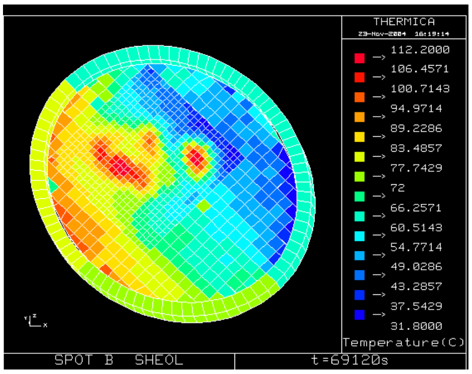

Figure 4: Thermal cartography of the sub-reflector (B side, WSEOL)

4.4 Thermo-elastic aspect

The Feeds and the SGR are fixed on the same shimplate attached directly to the central tube to maintain high thermo-elastic stability (i.e. fig 5). The SGR is also maintained with carbon bars. The SGR is constituted by a dual-gridded flat shell (symmetrical NIDA-Kevlar sandwich with // wires) and a carbon ring. The shell is attached to the ring thanks to bonded cleats.

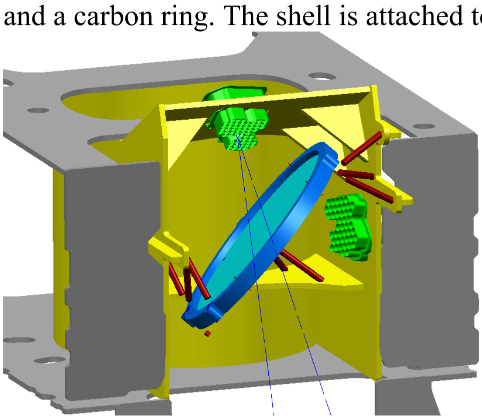

Figure 5: Feed + SGR accommodation

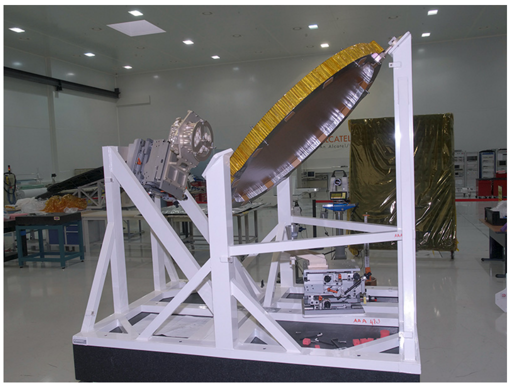

Figure 6: Manufactured BB
(Feed: AAS-F; Grid: ASTRIUM-ST)

4.5 RF aspect

A Breadboard fully representative of a Flight Model have been manufactured at EM (Electrical Model) level for the Feed cluster and EQM (Qualification Model) for the Grid (Fig 6), in order to validate the capacity to improve the XPD by using a polarisation grid. Beam B1 (Spain & Portugal) has been selected as the most representative one (1:21 passive BFN & severe antenna constraints).

The antenna simulations have been performed by using Physical Optics and Physical Theory of Diffraction on the radiating objects (sub and main reflector, structural panels and struts) [3]. Figure 7 shows the GRASP8 representation of all radiating objects. The RF analyses (CDR level) take into account manufacturing & thermo-elastic constraints at reflector level, scattering & coupling, amplitude & phase dispersions at feed array. The guaranteed performances are presented in table 1.

The manufactured feed cluster composed of 21 potter horns has been simulated taking into account all adjacent feeds with FEKO [4]. Very accurate correlation between measurement and simulations has been demonstrated in [2].

We have correlated the theoretical simulations to the reconstitution of co-pol & XPD patterns by using the measurement of the B1 feed cluster (fig. 8 and fig. 9). The antenna measurements of the manufactured Feed cluster in front of the SGR (i.e. Figure 6) are scheduled in Q2 2007.

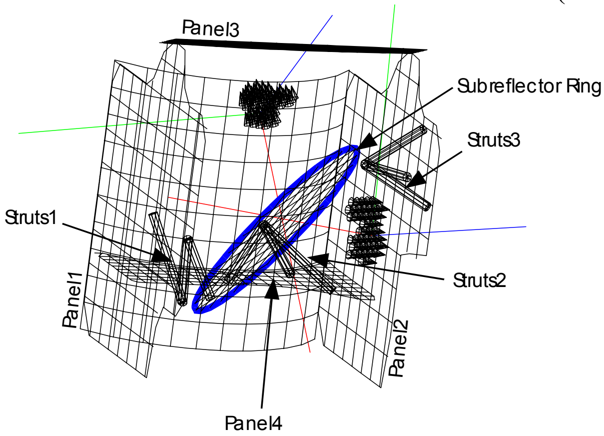

Figure 7: Scattering and diffraction model

	B1	B2	B3	K1	K2
Gain (dBi)	*37.7*	*39.5*	*38.6*	*36.3*	*37.2*
XPD (dB)	*33.3*	*34.4*	*38.4*	*36.1*	*34.5*
Side Lobe Isolation (dB)	*27.2*	*29.1*	*27.8*	*26.5*	*27.6*

Table 1: Antenna guaranteed performances

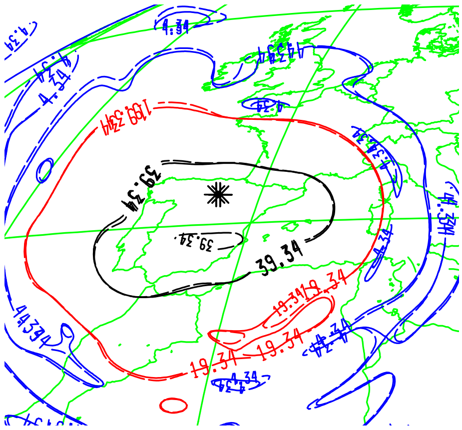

Figure 8: Co-polar patterns of Beam B_1 (theory) dotted line: Reconstitution with ideal reflector and feed cluster measurements

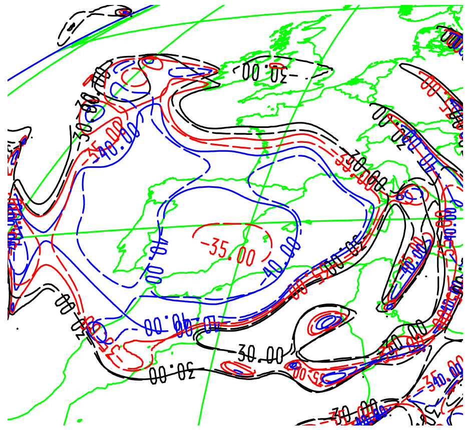

Figure 9: XPD patterns of Beam B_1 (theory) dotted line: Reconstitution with ideal reflector and feed cluster measurements

5. Conclusions

An antenna Sub-system able to provide similar XPD performances than Dual Gridded Reflectors with higher gain and isolation constraints has been accommodated on satellite and analysed from RF and thermo-mechanical point of view.

Further activities are needed to optimise the Flight Model design: stiffness improvement at SGR level by a slight shaping of the surface, increase of the transmitted power by using low loss or high temperature sandwich, optimisation of present accommodation to relax the severe constraints induces at feed and SGR level.

References

[1] T.S. CHU, “Method and apparatus for substantially reducing cross polarised radiation in offset reflector antennas”, US PATENT, 4,109,253, Aug. 22, 1978.

[2] E. VOURCH, "Ku-Multibeam Antenna with polarisation grids", to be published on AP-S 2007.

[3] GRASP8 software, TICRA

[4] FEKO software, EM Software & Systems-S.A.

Acknowledgments

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