Ka-band Antenna for High Speed Data Return for earth observation and space science missions

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Abstract

This paper presents an alternative design for a payload telemetry data subsystem (PTDS) antenna working in ka-band. Our main driver for this antenna design, was to propose a compact concept with no move of the feed during the connection with the ground station. All the steps of the design are described, and the main results are presented (including the first performances measured on a mock-up).

Keywords : Antennas payload telemetry data subsystem, beam waveguide, septum polarizer, scrimp horn, multimodal horn, Particle Swarm Optimization, multimodal analysis, physical optics, compact test range

1. Introduction

Many solutions are well known and used for transmitting to a ground station data coming from earth observation or science satellite missions, starting from isoflux antennas, up to mechanical pointing mechanism or to electronic steering array antennas.
According to the mission, and to the needed data rate to be transmitted, a specific design can be preferred to another one. The notion of cost and reliability is also an essential point that it is advisable to consider.
With the increase of the resolution embellish with images and especially of the satellite reduction size three new needs appeared: 1-The absence of micro-vibrations. 2-The need of fast mechanism and of a compact solution. 3-The absence of jump of phase during the data transmission.
Taking into account all this new needs, and as CNES have also developed an other new concept called "tripod mechanism", we have decided to investigate an alternative design, presented hereafter.

2. General Design Description

Various solutions were envisaged and our choice quickly turned to a 90° offset reflector architecture, as shown in Fig 1.

We describe below the diverse stages of our initiative with the main results obtained for the optimization of the parts constituting our antenna.
Before going to this technical part, let's review the main specifications which are aimed:

- Bandwidth : from 25500 to 27000 MHz.
- Minimum gain : 26 dBi
- VSWR better than 1.2
- Dual Circular Polarization with an XPD better than 30 dB in a +- 10° angle
- Compact and light weight solution
- Low vibration concept with no phase shifts during motion

The geometry is quite simple to analyse and the preliminary characteristics (dimensions) are also presented in Fig 1.
During the transmission to earth, only the reflector is moving (scan of -+ 70° or more if necessary).

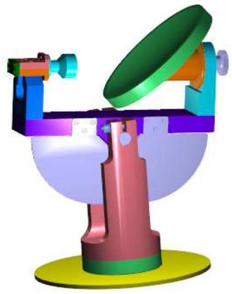
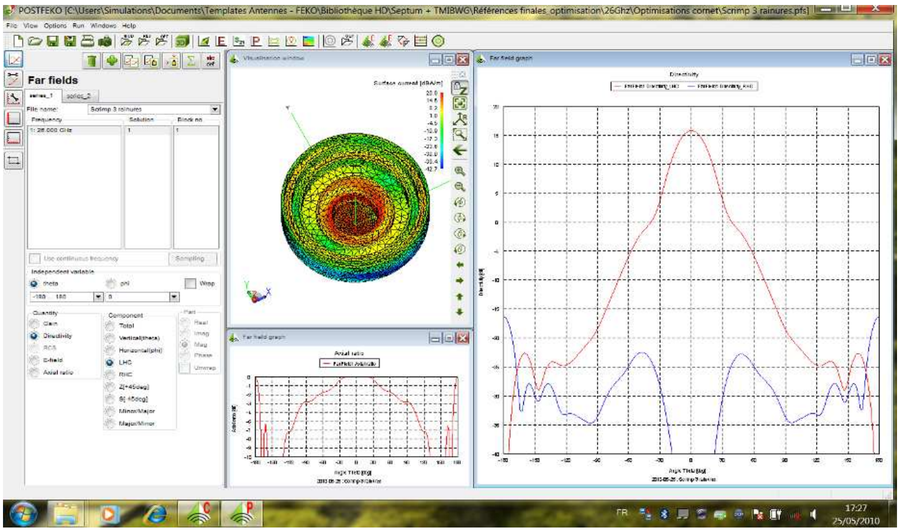
	<u>Geometry main characteristics</u> : Parabolic reflector : diameter 47 mm Offset angle : 90° Focal length : 24 mm Yc (reflector central point coordinate): 46 mm Y1 (down reflector coordinate) : 22.5 mm Y2 (up reflector coordinate) : 69.5 mm

Figure 1: Preliminary design of the antenna

2.1 Scrimp Horn design and optimization

In order to obtain a compact geometry, we have decided to choice a scrimp horn fed with a septum polariser to obtain the circular polarisation.
The scrimp horn (**S**hort **C**ircular **R**ing **l**oaded horn with **M**inimized cross-**P**olarization) is a very interesting device**.** By using a multimodal way, this device allows high aperture efficiency, low cross-polarisation and low VSWR over a broad frequency band. This antenna was specifically developed for applications with stringent requirements on electrical properties and light weight, low volume restrictions. To optimize our scrimp antenna, we have used our own software that mix mode matching analysis and PSO optimizer. All results are then verified with a commercial software that use "exact methods" like SRSR, CST of FEKO (as shown just below).



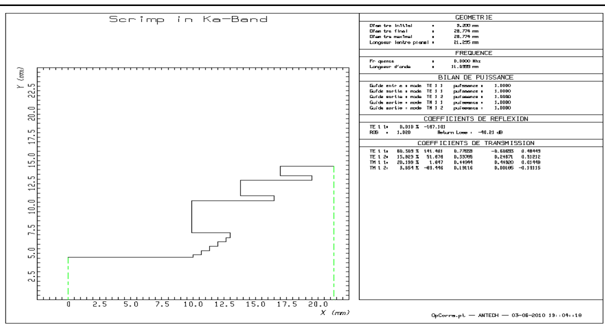
	<u>Main characteristics</u>: waveguide diameter : 9.2mm aperture diameter : 28.96 mm length : 12.7 mm 3 axial corrugations Directivity > 15.5 dB ROS < 1.05

Figure 2: Final Scrimp antenna profile

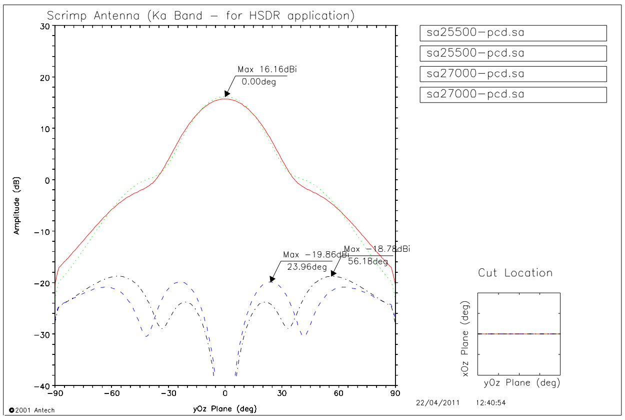


Figure 3: Final Scrimp antenna radiating performances

2.2 Septum polarizer design and optimisation.

Initially designed with square guides, the original septum polarizer, was first described by Chen & Tsandoulas [1]. Some improvements have then been realized in particular by modifying the concept into circular guide [2].

A septum polarizer allows to convert linear polarized signal into circularly polarized signal and also acts as an orthogonal mode transducer (OMT). It is compact easy to manufacture an allow good performances (fig 7 & 8) with a typical bandwidth that could be greater than 10 %. It is obvious that a numerical optimizer is needed to reliably estimate the component's performance with respect to axial ratio, isolation or return loss. We have made the a choice to use CST, for this kind of application and the flexibility of the goal function. The counterpart to pay, will be the time to obtain a solution.

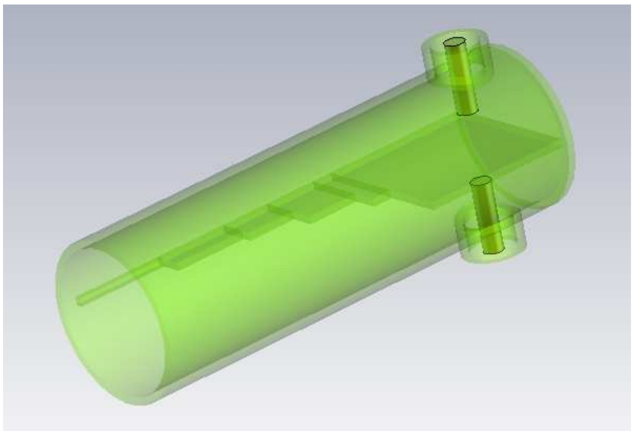
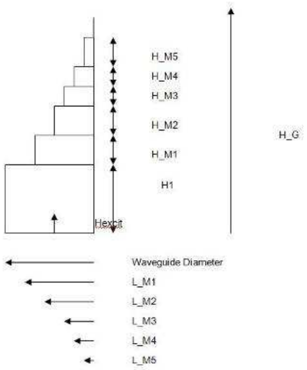


Figure 5: Septum OMT (with 5 steps)



Waveguide diameter : 9.2 mm
Hexcit : 2.85 mm
H1 : 8.15 mm
L_M1 : 5.71 mm
L_M2 : 4.16 mm
L_M3 : 2.75 mm
L_M4 : 1.55 mm
L_M5 : 0.69 mm
H_M1 : 1.57 mm
H_M2 :3.28 mm
H_M3 :3.66 mm
H_M4 :4.77 mm
H_M5 : 5.96 mm
Coaxial pin diameter : 1.27 mm
Coaxial diameter : 2.93 mm
Septum loaded on 545 Ohms (waveguide impedance)

Figure 6: Example of a candidate geometry

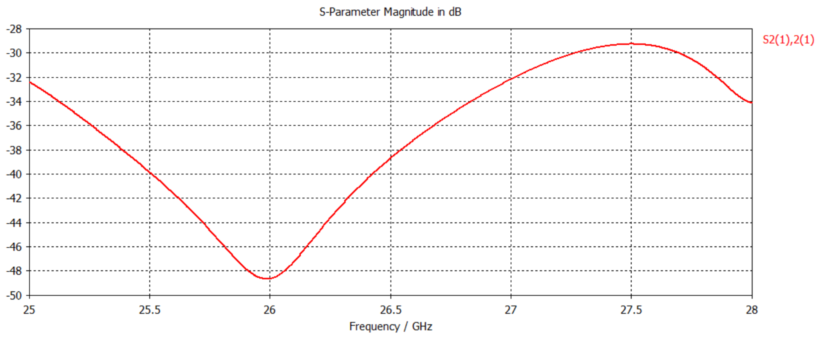


Figure 7: Standing Wave Ratio (Feed port)

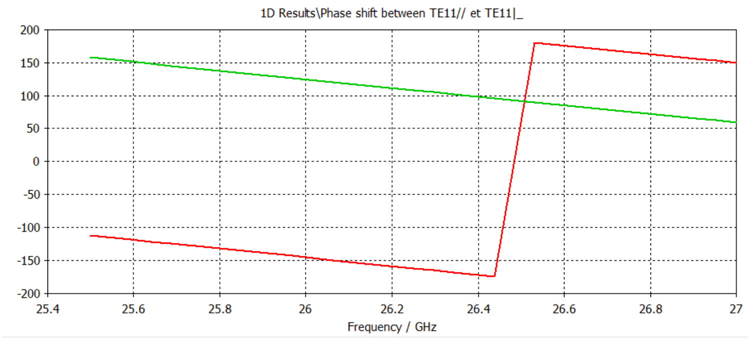


Figure 8: Phase performances (Modes TE11)

We can notice that this device could be considered in two parts: the first one to obtain a 90° between the TE11(parallel an perpendicular) and the other one more dedicated to the matching.

We have also tried to put a "mushroom" at the end of the excitation probe, but at the have preferred to take it over to allow a bigger ease of mechanical realisation.

4. Final computed performances

So far, we have computed the feed performance (scrimp + polarizer), by using different techniques (chaining scattering matrix and global simulation by using CST - figure 9 and 10) and we have then simulated this assembly in front of the reflector (by using OP techniques).

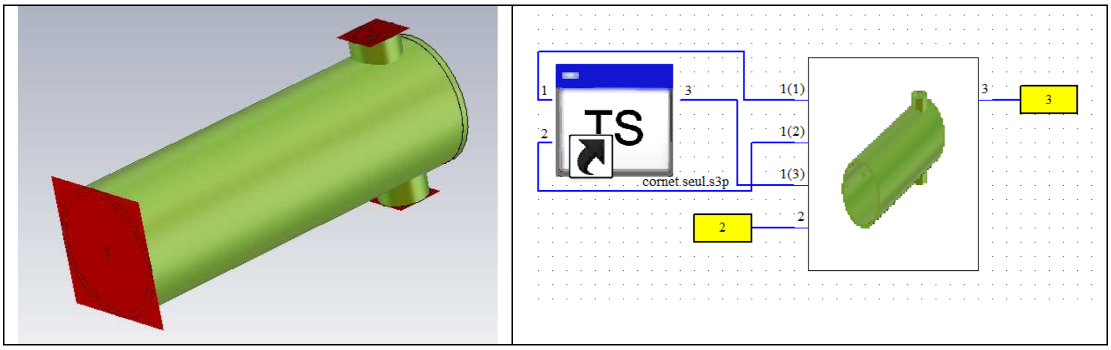


Figure 9: Chaining scattering procedure

Figure 10: Complete Feed

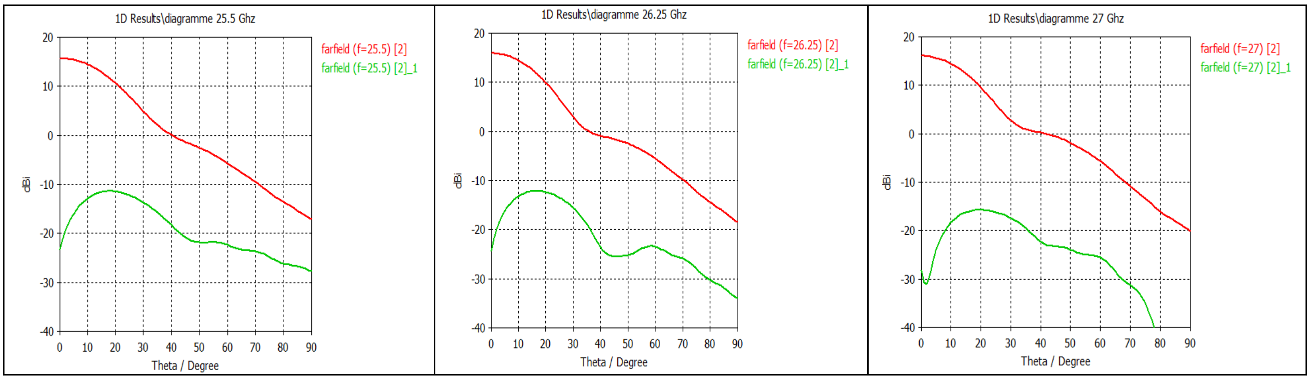


Figure 11: Complete Feed patterns

Associated with the reflector, all the expected performances are obtained.
The minimum expected gain is higher than 26.4 dBi.
The results, shows also a good XPD performances (greater than 30 dB) over all the bandwidth (25500 to 27000 MHz) over 20° angle.
We can notice the typical offset geometry sidelobe levels with no big impact on the performances.
The global efficiency of the antenna is around 70 %.
The patterns are presented in Fig 12, at different frequency (co and cross polarization)

Note: Before sending our equipment to realization, we have made a parametric analysis taking into account all the technological constraints to verify that these performances will not be altered.
A tolerance of 20µm has been specified to the company (SAP), in charge of the mechanical realisation.

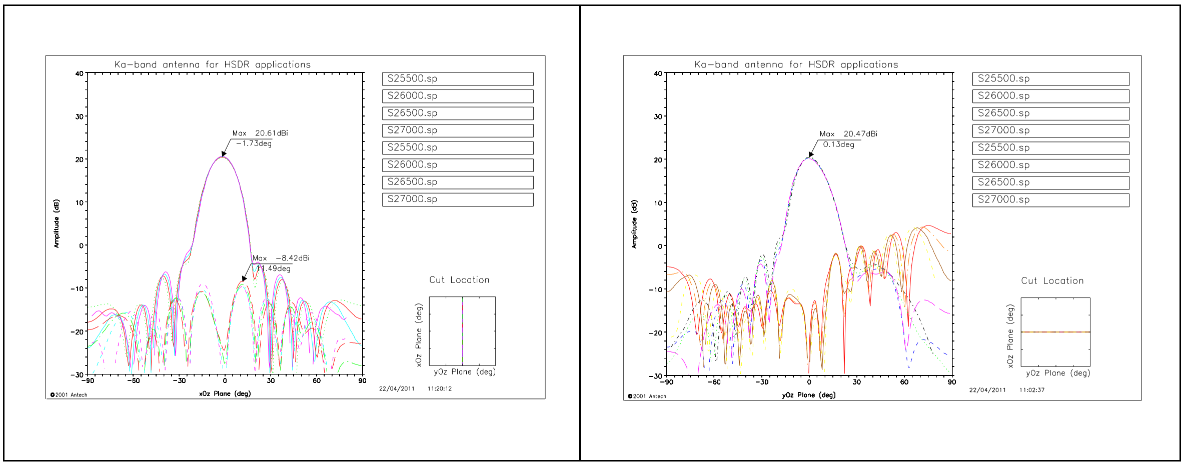


Figure 12: Pattern of the complete antenna

5. Mock-up results presentation

The mock-up is presented, just below.

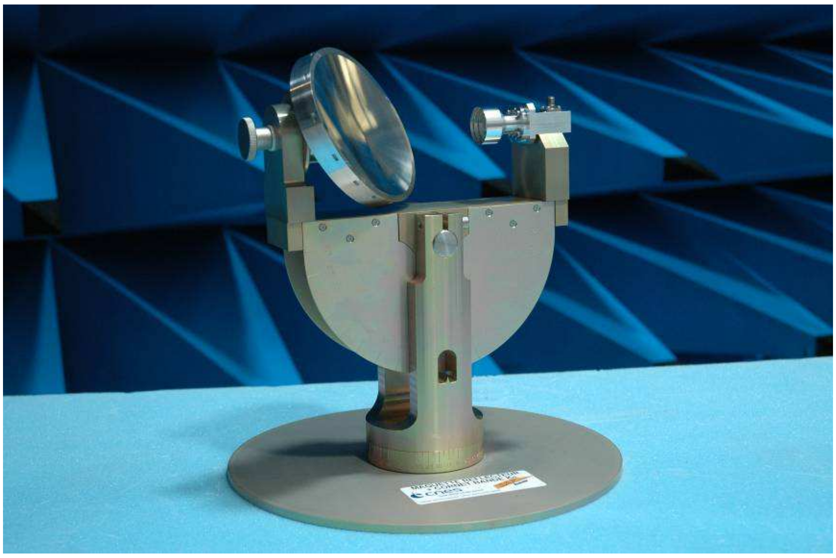


Figure 13: Complete Mock-up

The first results are good but present light distances on which we already work (back simulation and mechanical control).
The XPD of the feed is not as good as expected (25dB / 30dB expected), probably due to a VSWR that is lower than our expectations (fig.14).
We think that the addition of an adjusting screw would allow to obtain the expected performances.
Due to the geometrical reflector mechanical difference shown in figure 15, a small rise of the first lateral side lobe is noticed, influencing only little the expected gain performance. A resumption of the model's geometry was nevertheless launched, to verify our hypothesis.

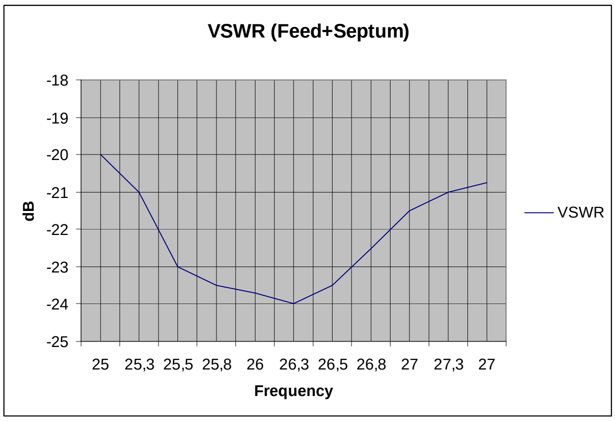
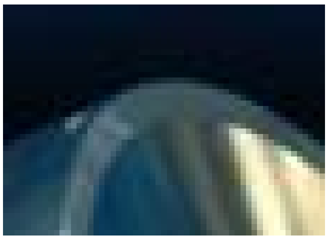


Figure 14: VSWR of the feed (septum + feed)



Reflector's edges
(Zoom)

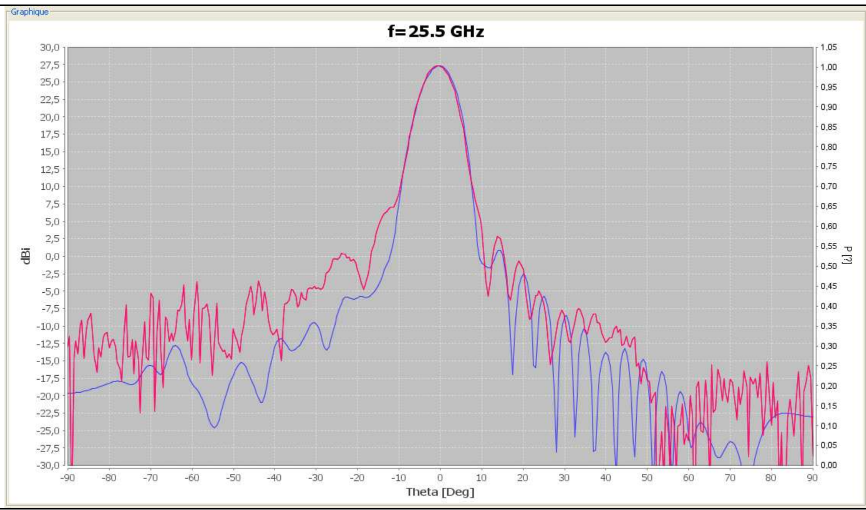


Figure 15: Pattern of the antenna (Blue=calculed, Red=mesured)

6. Conclusion

The goal of this work was to analyse an alternative to classical concept like gimballed or tripod mechanisms. We have demonstrated that it is possible to consider a new concept that also provide great radiofrequency performances.
This new concept can be considered for the choice of solutions answering the requirements of the considered projects.

These procedure and results obtained in this study will be strengthened thanks to another model (realized in X band) which will be the purpose of next publications.

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Acknowledgments

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