GlobalStar II RX L-Band Antenna Spherical Near Field Measurement

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ABSTRACT

Abstract - Thales Alenia Space is in charge for the development, integration and production of the whole Global Star II satellite constellation. To support the production of the RX L-Band Active Antennas, a new Spherical Near test facility was developed and installed at Thales Alenia Space Italy premises. This paper gives an inter-comparison of the measurement results obtained among three facilities that are a Test Range installed at TAS-France, a Spherical Near-Field already available at TAS-Italy and the new SNF facility. The test comparison has been considered as a part the new SNF facility validation. In particular the comparisons of copolar and crosspolar patterns, peak directivity and general Antenna performances are shown.
The 18 terms technique, for the evaluation of the measurement error, was used to justify the differences between the measurement data obtained from the three facilities.
In Addition a general description of the test setup and the principle error sources found during the finalization of the test setup are given.

Keywords: Directivity, Error Analysis Pattern, Gain, SNF Measurements.

1. Introduction

Globalstar Inc. has commissioned to Thales Alenia Space, the design, development, integration and production of the new Globalstar II Satellite constellation, to replace the Globalstar I current one. To win the challenge in terms of time and cost, a strong collaboration between Thales Alenia Space and the various sub-contractors was needed.

Thales Alenia Space Italy – Rome is in charge of the RX L-Band Active Antenna production.

To satisfy the program needs, in particular to be able to guarantee a high rate production, consisting of 4 antennas per month, three different automatic test benches were developed to minimize time, cost and operator mistakes:

1. *HardLine Test Bench*: it's S-Parameter automatic test bench. This test allows to measure more than 3000 parameters and compare them with the predictions in 3 hours.
2. *Hat Coupler Test Bench*: it's an automatic test bench for the RF characterization of the antenna in temperature (gain, Linearity, Noise Figure and so on). A dedicated software for the hardware control and for the data post-processing was developed to have a real time information about the health and the performances of the antenna;
3. *Spherical Near Field Test Facility*: in collaboration with NSI inc. a new Spherical Near Field System was developed and installed at the new TAS-Italy antenna test center. Particular attention was dedicated to the acquisition speed and the S/N Sub-System performance, taking into account the very low signal level specified for the L-Band RX antenna under test.

In this paper the Spherical Near Field Test facility configuration and the activity performed for its validation are presented. The tight cooperation with TAS-F Toulouse, responsible for the design of the antenna and of the Engineering Bread-Board model realization and testing, allowed to better assess the performances of the new facility.

2. SNF Test Setup Description

With the Globalstar 2 program advent, Thales Alenia Space developed a new center for the antenna testing. A new building was organized to accommodate the following areas:

1. Antenna integration and alignment area;
2. Antenna Environmental Test area;
3. Antenna RF radiative test area;

The last section includes 4 Near Field Range, each one provided, installed and certificated by NSI:

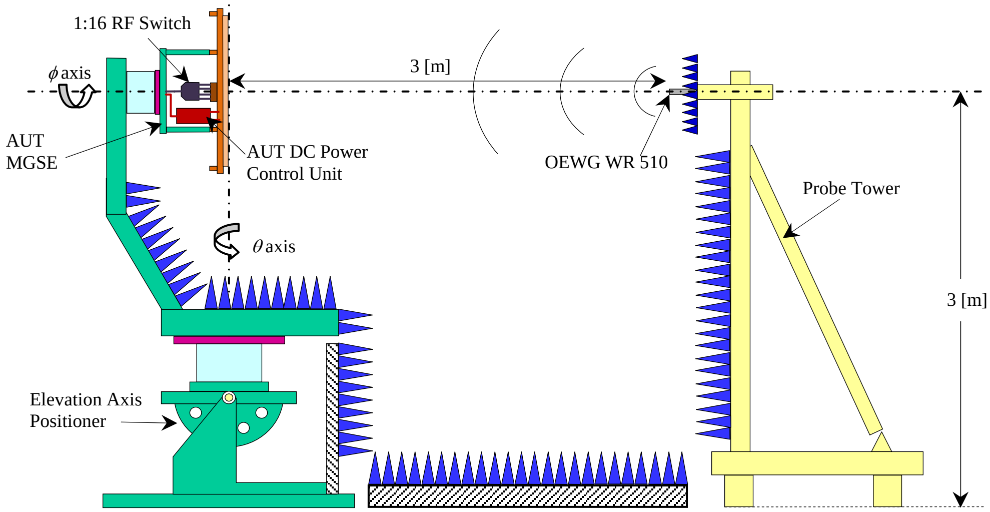

Figure 1 – SNFTR Test Setup Sketch

1. a 7m x 7m Horizontal planar Near Field operating from 1 up to 40 GHz;
2. a 3.5m x 3.5m vertical Planar Near Field operating from 1 up to 50 GHz
3. A Spherical Near Field with a Roll over Azimuth positioners operating from 1 up to 50 GHz
4. A new Spherical Near Field System with a Roll over Azimuth over Elevation operating from 1 up to 6 GHz (the new range being used for the Globalstar 2 L-Band antenna testing);

A scheme of the new Spherical near Field System is shown in figure 1. The anechoic chamber is a 9 x 7 x 7 m shielded one, totally covered with 18 inches broadband pyramidal absorbers, selected to reach the wanted level of reflectivity at L-Band

The antenna L-Bracket is a profiled aluminum structure to guarantee the proper stiffness during the measurement and the antenna handling operation, with appropriate SNF facility alignment capability and degree of freedom. Three different motors are installed: the *roll axis motor* is installed on top of the L-Bracket; the latter is accommodated over the *azimuth axis motor*. With this positioning Subsystem configuration the whole AUT SNF is acquired. The third motor, the *elevation axis motor*, is used to tilt the L-Bracket, in order to easily install/dismount the AUT from its mechanical interface (MGSE). The MGSE is a dedicated fixture designed to optimize the mechanical fixation and the RF and DC connection of the AUT. The presence of the alignment pins and of 6 calibrated I/F's on the MGSE, allows keeping the desired alignment of the various AUT's, once the MGSE has been aligned with respect to the SNF reference system. The conical shape and its overall dimensions lead to an increasing of the performances in terms of scattering and polarization purity. The surface of the violet face (see figure 2), where the 6 calibrated AUT I/F's are located (the points A-B-C-D-E-F), is completely covered by the AUT; an optimized height of the MGSE allows an easy mate and de-mate operation of the RF cables, and the decreasing of the struts scattering contributions, inside the angular region of interest.

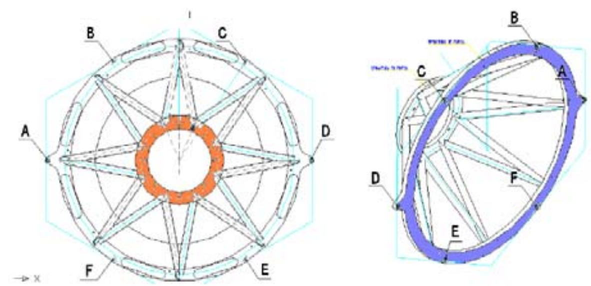

Figure 2: AUT MGSE configuration

A 16-port Beam Multiplexing Switch and an AUT DC power Unit find their location inside the AUT MGSE

This last units are fed by the DC power carried out through the 2 special slip rings assemblies, installed in the azimuth stage and in the roll stage. The proper DC power supply to the AUT is therefore guaranteed, in terms of ripples and signal variations and /or discontinuity due to the azimuth and the roll stage movements.

The RF subsystem is completely provided by NSI. The three main points are:

1. the Panther 9000 RF Subsystem
2. a 16 beam Multiplexing Switch;
3. LNA Amplifier;

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These items allow the Test Range to satisfy the demanding needs in terms of time and accuracy. The multi beam and multi frequency acquisition allow a drastic reduction of the test time for the complete characterization of the Antenna RF radiative performances; while the LNA improves the S/N ratio of the RF subsystem taking into account the very low RF signal level used during the test (Probe RF input Power lower than -49dBm – AUT input power flux density lower than -87 dBm/m2 – AUT output power lower than – 54dBm).

The probe used for the Near Field acquisition is an OEWG WR510.

In figure 3 a picture of the general test setup configuration is shown.

3. Test Range Validation and Comparisons

In order to have a good feeling about the measurement quality of the New Spherical Near Field Test Range, a full Range Validation Activity has been carried out. The principal steps are the following:

1. *Measurement of a SGH WR650*: a measurement of a SGH was done at the same GBL2 antenna test frequencies. The results were compared with respect to the predicted data obtained using CST microwave studio in terms of peak directivity, peak cross-polarization and patterns shape. These results allow to have a first feeling about the measurement goodness.
2. *Comparison between TAS-F and TAS-I Measurements* of the Bread-Board Model, representative of the GBL2 L-Band RX Antenna Flight model. The antenna was tested in Toulouse, in a quasi far-field test range, in TAS-I in a Spherical Near Field Test range (already available and validated) and the new one range. All the sixteen fixed beams, that the antenna can generate, have been tested and compared in terms of max Directivity, Crosspolar peak, Copolar and Crosspolar patterns. In the following figures are shown some of the radiative beams (number 2-5-10). Looking at the Copolar comparisons it can be seen a very good convergence for both main beam shape and side lobe shape. The good overlapping of each beam highlights the good reflectivity level in each direction for each anechoic chamber.

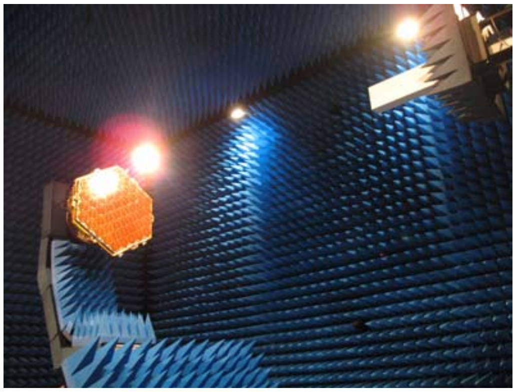

Figure 3: Set-up configuration

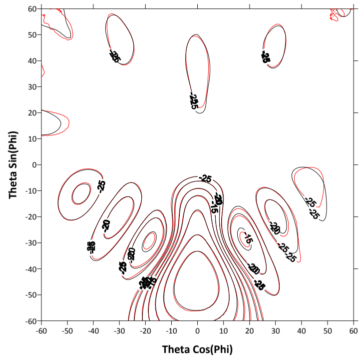

Figure 4: Beam 2 Copolar Comparison: TAS-F (red) vs. TAS-I (Black - Already Available)

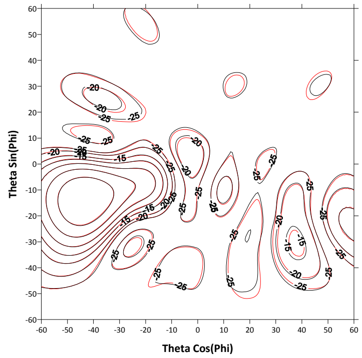

Figure 5: Beam 5 Copolar Comparison: TAS-F (red) vs. TAS-I (Black - Already Available)

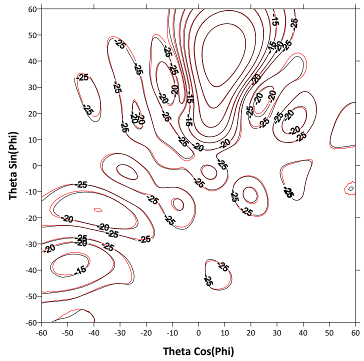

Figure 6: Beam 10 Copolar Comparison: TAS-F (red) vs. TAS-I (Black - Already Available)

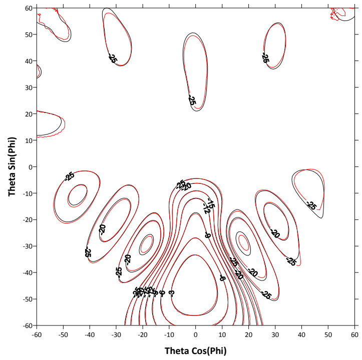

Figure 7: Beam 2 Copolar Comparison: TAS-F (red) vs. TAS-I (Black – the new facility)

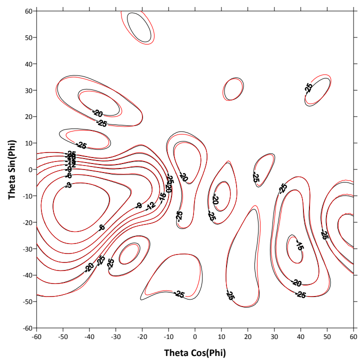

Figure 8: Beam 5 Copolar Comparison: TAS-F (red) vs. TAS-I (Black – the new facility)

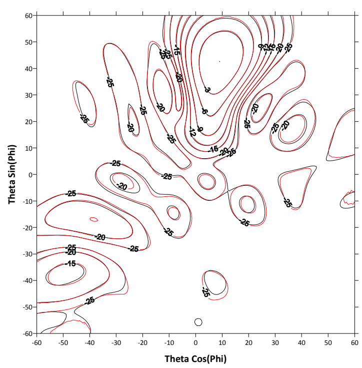

Figure 9: Beam 10 Copolar Comparison: TAS-F (red) vs. TAS-I (Black – the new facility)

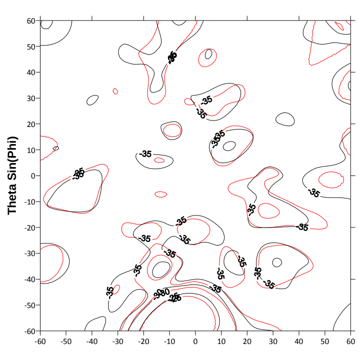

Figure 10: Beam 2 Cxpolar Comparison: TAS-F (red) vs. TAS-I (Black - Already Available)

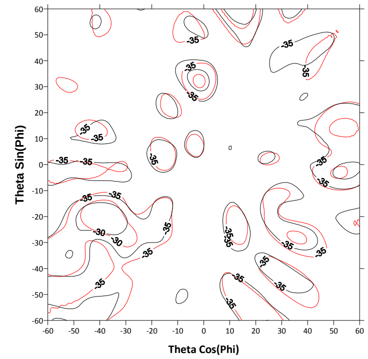

Figure 11: Beam 5 Cxpolar Comparison: TAS-F (red) vs. TAS-I (Black - Already Available)

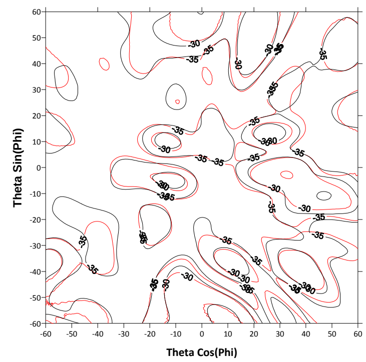

Figure 12: Beam 10 Cxpolar Comparison: TAS-F (red) vs. TAS-I (Black - Already Available)

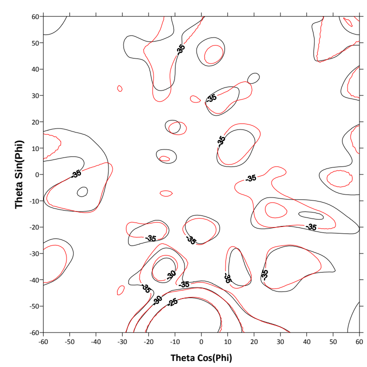

Figure 13: Beam 2 Cxpolar Comparison: TAS-F (red) vs. TAS-I (Black – the new facility)

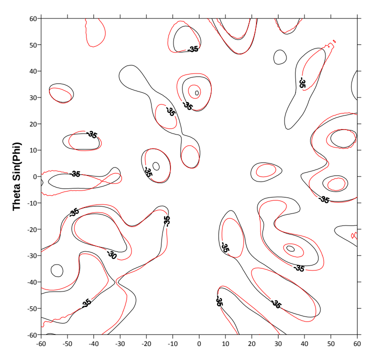

Figure 14: Beam 5 Cxpolar Comparison: TAS-F (red) vs. TAS-I (Black – the new facility)

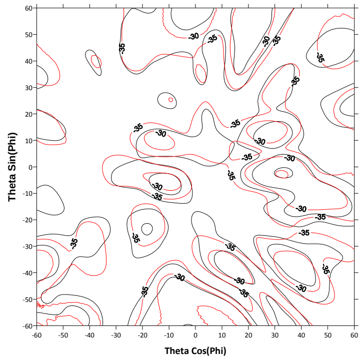

Figure 15: Beam 10 Cxpolar Comparison: TAS-F (red) vs. TAS-I (Black – the new facility)

The following tables report the comparisons in terms of copolar and crosspolar peak between the three facilities.

	Directivity Peak Comparisons		
	TAS-F	TAS-I	TAS-I (New)
Beam#01	14.95	14.99	14.99
Beam#02	19.62	19.67	19.62
Beam#03	19.58	19.62	19.60
Beam#04	19.29	19.27	19.35
Beam#05	19.51	19.47	19.55
Beam#06	19.53	19.57	19.61
Beam#07	19.53	19.49	19.59
Beam#08	19.52	19.44	19.54
Beam#09	19.67	19.60	19.65
Beam#10	19.54	19.58	19.64
Beam#11	19.50	19.44	19.54
Beam#12	19.52	19.56	19.54
Beam#13	19.61	19.68	19.67
Beam#14	19.46	19.53	19.56
Beam#15	19.31	19.36	19.43
Beam#16	19.61	19.65	19.65

Table 1: Directivity Comparison

	Crosspolar Peak Comparisons		
	TAS-F	TAS-I	TAS-I (New)
Beam#01	-24.02	-24.24	-23.75
Beam#02	-20.85	-20.40	-21.00
Beam#03	-19.69	-19.27	-19.38
Beam#04	-26.29	-26.37	-26.27
Beam#05	-22.86	-21.85	-22.48
Beam#06	-23.50	-23.58	-23.88
Beam#07	-24.60	-23.98	-24.13
Beam#08	-21.95	-22.62	-22.51
Beam#09	-22.64	-22.77	-23.98
Beam#10	-23.90	-23.85	-24.45
Beam#11	-24.71	-25.13	-25.22
Beam#12	-22.80	-22.60	-22.32
Beam#13	-22.02	-21.94	-21.84
Beam#14	-24.93	-25.06	-24.72
Beam#15	-23.03	-22.99	-23.94
Beam#16	-29.02	-28.00	-27.85

Table 2: Crosspolar Peak Comparison

3. *Error Budget Definition:* Using the 18 Terms Error budget Technique an analysis of the measurement uncertainties has been done. Following the philosophy of this method, each error source have been evaluated for each beam in the following two region:

   - *Main Beam Region (MBR)*: Spatial region of each beam where the level is higher than -10dB;

   - *Side Lobe Region(SLR) &Cross Region*: Circle with 54.3 deg radius;

   By different measurements the error pattern of each source is calculated; the worst case error level is evaluated, taking into account the 99% (3 sigma) of the total number of points inside each region. This value defines the SNF test Range uncertainty budget for the relevant beam. From the average of the error budget of each beam, the total SNF uncertainty budget is carry out.

Error Budget @ 99%				
	Level	***Error***	***Uncertainty***	
MBR	-3	-40	***0.09***	***-0.09***
	-6	-37	***0.12***	***-0.13***
	-10	-33	***0.19***	***-0.20***
SLR	-15	-28	***0.34***	***-0.36***
	-20	-23	***0.60***	***-0.65***
	-25	-18	***1.04***	***-1.19***
	-30	-13	***1.78***	***-2.24***
Cross Region	-3	-39	***0.10***	***-0.10***
	-6	-36	***0.14***	***-0.15***
	-10	-32	***0.23***	***-0.23***
	-15	-27	***0.40***	***-0.42***
	-20	-22	***0.70***	***-0.76***
	-25	-17	***1.21***	***-1.40***
	-30	-12	***2.04***	***-2.68***

Table 3: SNF Uncertainty Budget

An interesting effect found during the Test Range validation is the Beam depointing /distortion introduced by the misalignment of the facility. In particular the El0 and the Az0 error give an annoying rotation of the Main beam especially for the external beams. This effect, function of the phase and amplitude distribution error on the scanning area, seems independent by the kind of acquisition, (phi scan or theta scan).

Performing two different acquisitions by changing the Elevation stage (AUT in 0 and 180 deg), we obtained the results reported in the following figures for Beam9, and Beam13. As we can see from the following comparisons, the Elevation offset seems to have a larger effect for the beams on the Elevation plane, and a lower effect for the ones on the Azimuth plane.

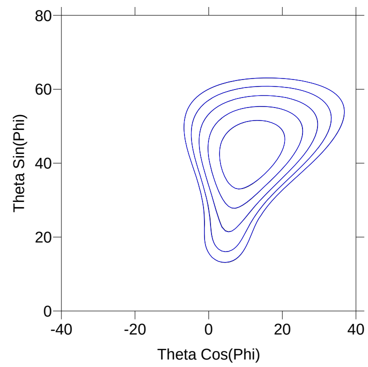

Figure 16: Beam9 – 0° vs 180° - EL 0.05deg

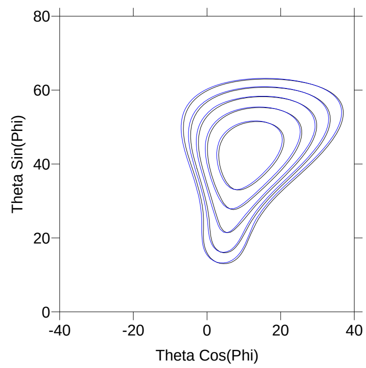

Figure 17: Beam9 – 0° vs 180° - EL 0.1deg

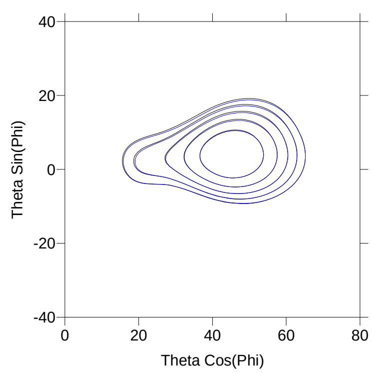

Figure 18: Beam13 – 0° vs 180° - EL 0.1deg

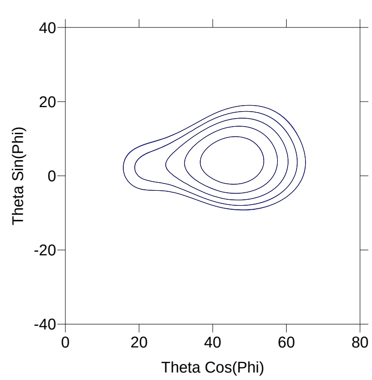

Figure 19: Beam13 – 0° vs 180° - EL 0.05deg

4. *Antenna Performances Comparisons*: the conclusion of the test range assessment was the comparison between the performances obtained by the post-processing of the data coming from the three different facilities and comparing them with the total uncertainties defined before. All the evaluated delta fall in the range of the total uncertainty of the relevant facilities (RSS of each facility uncertainty), showing that approach used to assess the SNF error budget, produced, likely, a "pessimistic" scenario of the facility performances.

7. SUMMARY

A general description of the New Spherical Near Field installed and validated in TAS-I Rome to support the GLB2 L-band RX Active antenna is shown. The comparisons of the Active Antenna Breadboard measurements, in terms of copolar and cross polar patterns and the post-processing data show a very good convergence. This ensured a successful test facility validation and the definition of performance uncertainty budgets for the GBL2 antenna production program.

8. REFERENCES

Hansen, J.E. Editor (1988), *Spherical Near Field Antenna Measurement*, Peter Peregrinus Ltd.

Allen C. Newell, Greg Hindman, *The Alignment of a Spherical Near Field Rotator using Electrical Measurements*, in the proceedings of the 19th annual AMTA Meeting and Symposium, 1997

Allen C. Newell, Greg Hindman, *The Effect of Measurement Geometry on Alignment Errors in Spherical Near Field Measurements* , In the proceedings of the 21th annual AMTA meeting and Symposium, 1999.

Allen C. Newell, Daniël Janse van Rensburg, *Estimating the Uncertainties due to Position Errors in Spherical Near-Field Measurements*, in the Proceedings of the 25th annual AMTA Meeting and Symposium, 2003

Allen C.Newell, Greg Hindman, *Quantifying the Effect of Position Errors in Spherical Near-Field Measurements*, in the proceeding of the 20th annual AMTA meeting and Symposium, 1998.