ALIGNMENT SENSITIVITY AND CORRECTION METHODS FOR MILLIMETER-WAVE SPHERICAL NEAR-FIELD MEASUREMENTS

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ABSTRACT

Millimeter-wave measurements on spherical near-field scanning systems present a number of technical challenges to be overcome to guarantee accurate measurements are achieved. This paper will focus on the affect of mechanical alignment errors of the spherical rotator system on the antenna's measured performance. Methods of precision alignment will be reviewed. Sensitivity to induced mechanical alignment errors and their affect on various antenna parameters will be shown and discussed. Correction methods for residual alignment errors will also be described. The study includes 38 and 48 GHz data on the Alphasat EM model offset reflector antenna measured by TeS in Tito, Italy on a NSI-700S-60 Spherical Nearfield system, as well as a 40 GHz waveguide array antenna measured by NSI on a similar NSI-700S-60 Spherical Nearfield System at its factory in Torrance, CA, USA.

Keywords: near-field, spherical, alignment

1.0 Introduction

The described alignment sensitivity and correction method have been carried out in the NSI Spherical Near Field in the TeS - Teleinformatica e Sistemi plant located in Tito (Pz), South Italy. The TeS is a company belonging to Space Engineering Group.

The AUT is the ALPHASAT EM antenna operating in the Q and V bands. In this frame, we have carried out the RF tests to tune the alignment of the NSI-700S-60 Spherical Near-Field system. The EM antenna is a single parabolic off-set reflector shown in Figure 1, during the integration,

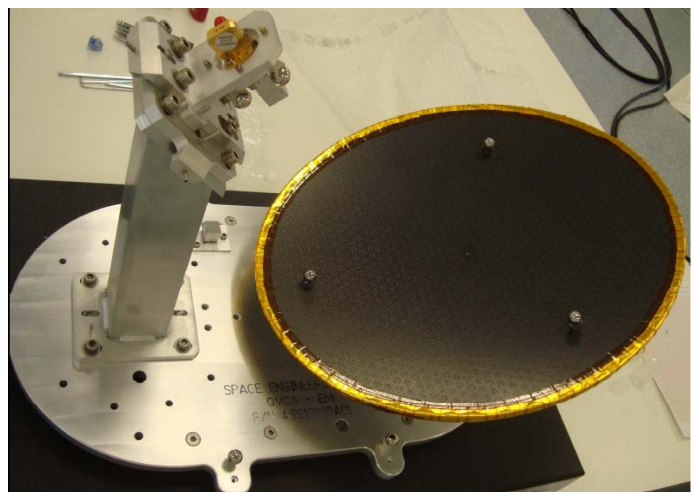

Figure 1– QVCA EM integration

and in Figure 4 installed in the SNF. This antenna is representative of the complete PFM antenna farm shown in Figure 2. The antenna system has been designed in the frame of the ESA/ASI ALPHASAT/INMARSAT I-XL program. The TDP#5 (Technology Demonstration Payload 5) part of this program, includes the Q/V -band Communications Antenna (QVCA) and the Q and Ka propagation experiment. The project finality is to assess the feasibility of these bands for future commercial applications. Space Engineering S.p.A is responsible for the TDP#5 of the complete activities flow from the design to the delivery of the qualified space hardware.

The detailed description of the design and test activities on this antenna farm is reported in [1]

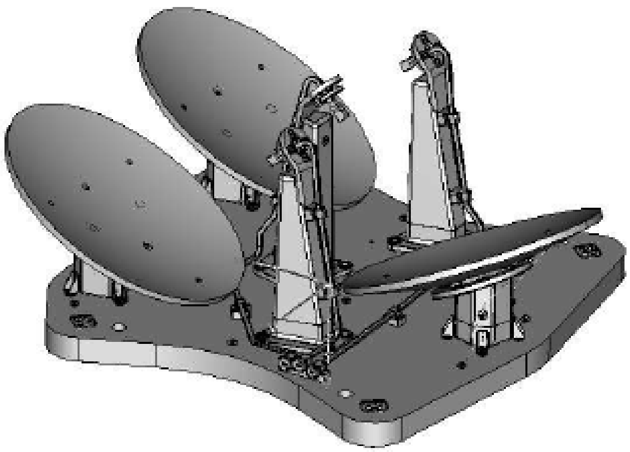

Figure 2- QVCA PFM sketch

The QVCA PFM make use of three off-set reflector antennas installed on the same base-plate to illuminate three earth stations in Europe (Figure 3)

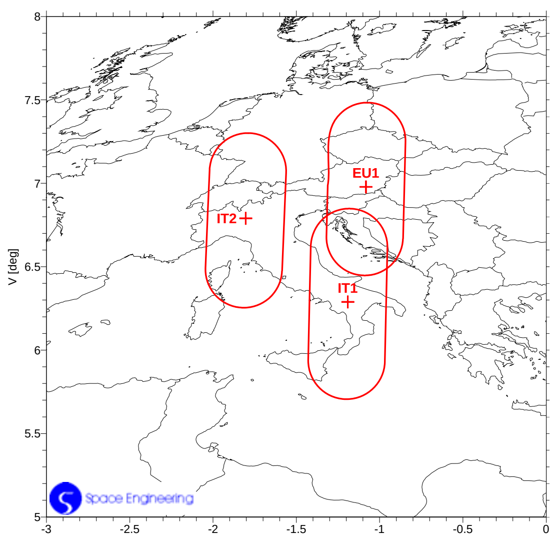

Figure 3– QVCA PFM coverage

The high alignment accuracy requirement comes from the required RF antenna link performances.

2.0 Near-field Test Range

The test range is a combination near-field / far-field system with a NSI-700S-60 spherical near-field scanning system installed in a 12 m x 7 m x 6.5 m rectangular anechoic chamber provided by Siepel.

Figure 4 shows the Alphasat QVCA EM antenna installed on the NSI-700S-60 positioner in the chamber. The system includes a probe tower in close proximity that is used for near-field measurements, and a far-field probe tower at a distance of about 7 m away used for far-field measurements as shown in Figure 5

The system uses an Agilent PNA, combined with NSI's 50 GHz Distributed Frequency Converter and 50 GHz mixers to provide excellent signal sensitivity at the required frequencies. Figure 6 shows the scanner and RF subsystem configuration.

Figure 4– QVCA EM in the Tito plant NSI SNF

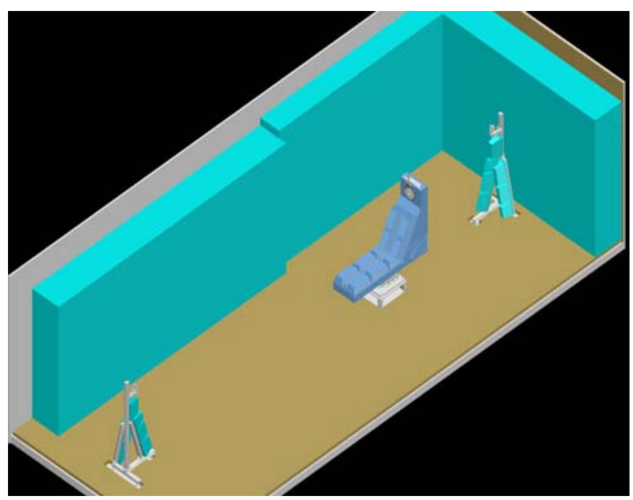

Figure 5– NSI-700S-60 Spherical Near-field / Far-field

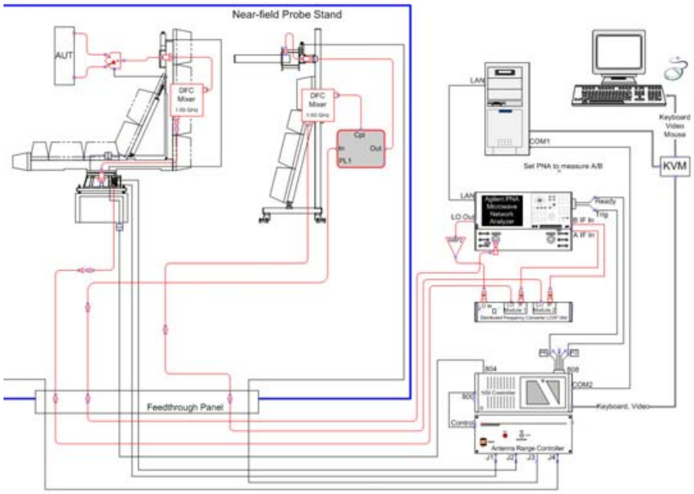

Figure 6– System Block Diagram

3.0 Alignment Issues

The system was aligned by NSI during installation, using the 5-axis laser alignment system described in [2]. This alignment is done prior to the antenna and probe being installed. NSI has also developed an RF alignment technique that can be done <u>with</u> the antennas installed and is useful to check and optimize the alignment with the weight of those devices included. Some studies of alignment sensitivity are shown in [3] and [4]. The 5-axis laser alignment technique can achieve system alignment to better than about 0.05° and 1 mm for all key alignment parameters, and the RF alignment technique is used to refine the pointing and intersection errors further.

For the Alphasat requirement, at such a high frequency, we have recently performed additional studies of sensitivity of the alignment on the boresight measurements of high frequency antennas. The prior sensitivity studies in [3] primarily focused on sidelobe and directivity errors. In the NSI-700S-60 SNF system with 40 GHz waveguide array antenna, we conducted an alignment perturbation study, where we misaligned the theta-zero error (angle from the phi rotation axis to the probe) in 0.02° increments up to 0.12° and observed the resulting far-field alignment error.

The NSI software allows measuring antenna performance on spherical near-field systems with two different geometries, that we typically designate ‘180phi’ and ‘360phi’ (Figure 7). In one case the Antenna Under Test (AUT) is rotated thru 360° about its axis and the theta stage is only rotated on one side 0-180°,and in the other case, 180phi case, the AUT is only rotated 180° in phi, and the theta stage is rotated over ±180°. Comparison between these two geometries are instructive in evaluating the range alignment and reflection performance, and combining the results from both datasets in what we call a ‘redundant’ dataset can be used to improve range performance. Further information on this technique is described in [6]

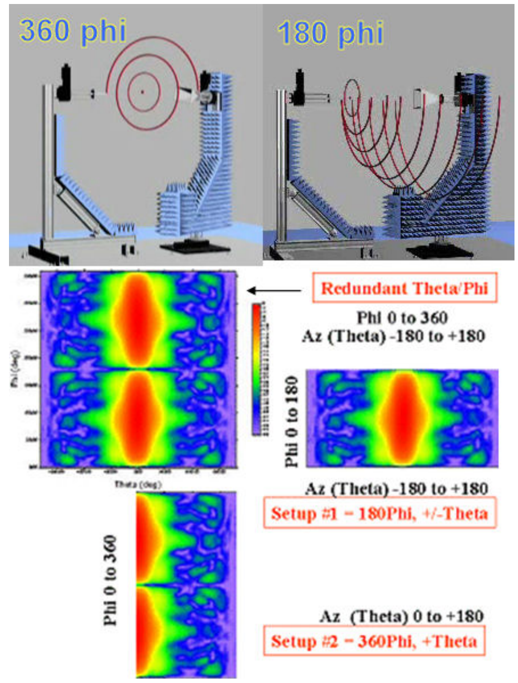

Figure 7– Redundant data set through full rotation of theta and phi rotators, versus the two full spheres that can be derived for the “360 phi” or “180 phi” configurations

In the following figures, we show the alignment sensitivity of the 40 GHz WG array to the theta-zero misalignment induced as described above.

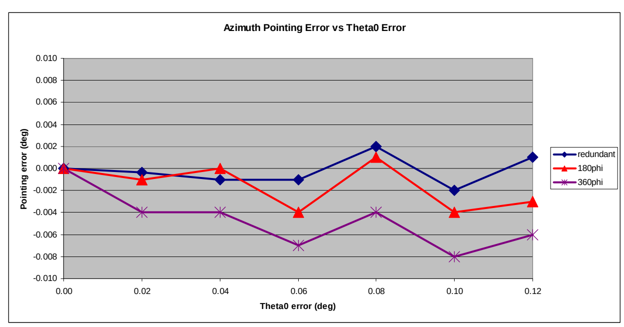

Figure 8– WR28 WG Array Azimuth beam pointing error vs Theta-zero error for different SNF measurement geometries

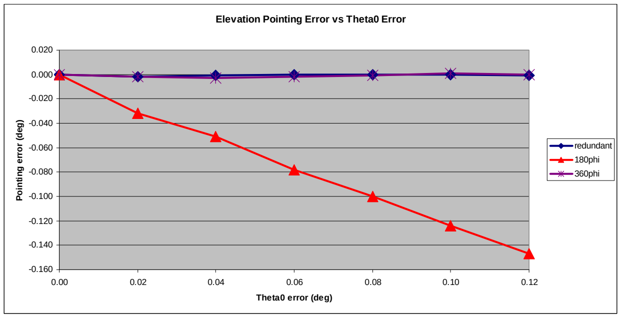

Figure 9– WR28 WG Array Elevation beam pointing error vs Theta-zero error for different SNF measurement geometries

Note that two different vertical scales are used in the figures. The azimuth beam pointing sensitivity to the theta-zero errors are small – about 0.008° worst case for the 360phi geometry, 0.004° for the 180phi geometry, and only 0.002° for the redundant test. The elevation beam pointing is seen to be much more sensitive to the 180phi geometry. This is because the AUT is only rotated 180° in phi in this measurement geometry, which can magnify this particular error, whereas the 360phi and redundant measurements rotate the AUT the full 360° in phi. The elevation error with the 180phi geometry is almost directly proportional to the theta-zero error induced, however the 360phi and redundant tests show only a negligible beam pointing error of less than 0.002°. So the conclusion from these measurements is to use the redundant measurement technique for best performance or the 360phi geometry if the double test time of the redundant technique is undesirable.

Similar tests were conducted on the Alphasat QVCA EM and we saw very similar results for 38 GHz and 48 GHz frequencies (see Figure 10). Again, the use of the redundant data measurement scheme is seen to help to minimize sensitivity to alignment errors.

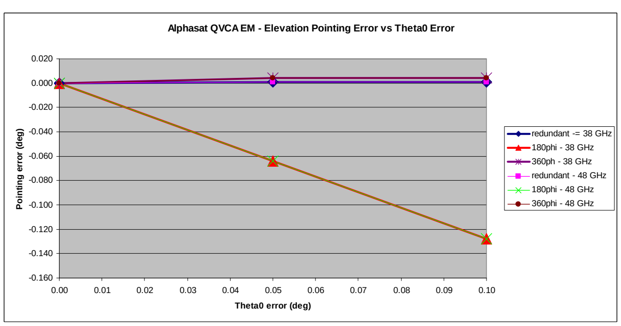

Figure 10– Alphasat QVCA EM Elevation beam pointing error vs Theta-zero error for different SNF measurement geometries

4.0 Alphasat Near-field Measurements

Before starting the test activity all the required SNF measurement parameters have been defined. The Maximum Radial Extent (MRE) is 0.36 m as shown in Figure 11. The angular acquisition step size for this MRE at the test frequency of 48.4 GHz for the Alphasat QVCA EM reflector is 0.49°. The near-field acquisition angular sector is shown in Figure 12, with the truncation of data beyond ±25° having been determined to have a negligible affect on system parameters of interest.

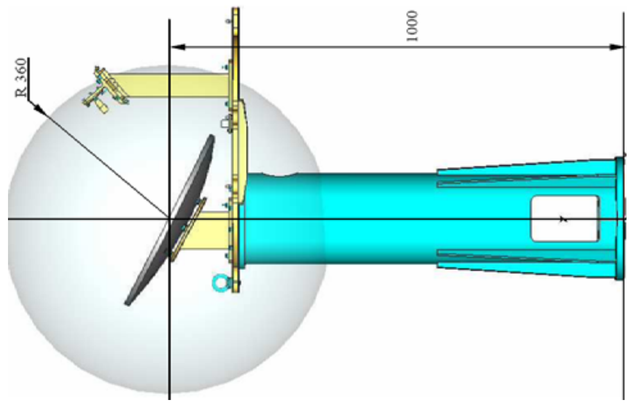

Figure 11- QVCA EM MRE

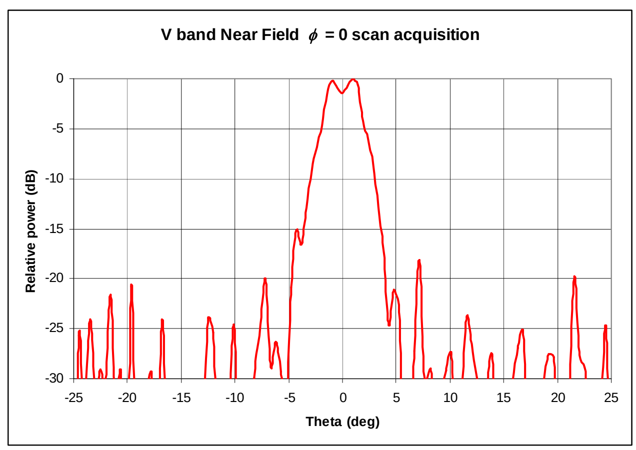

Figure 12- QVCA EM scan window (including practically all the antenna energy)

To check the positioner alignment, the RF alignment test (classic "flip" test) has been performed making use of a dedicated NSI script showing the azimuth misalignment and the intersection error. Result is shown in Figure 13.

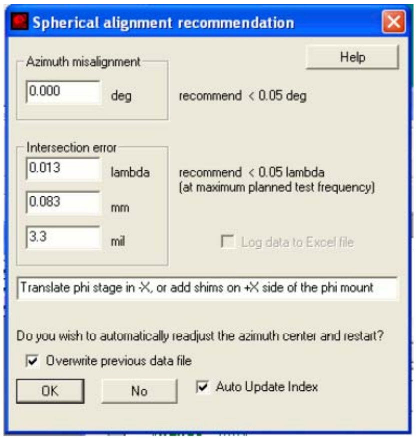

Figure 13–QVCA flip test

In Figure 14 and in Figure 15 are shown the measured radiation patterns (after the alignment activity) superimposed to the computed radiation patterns

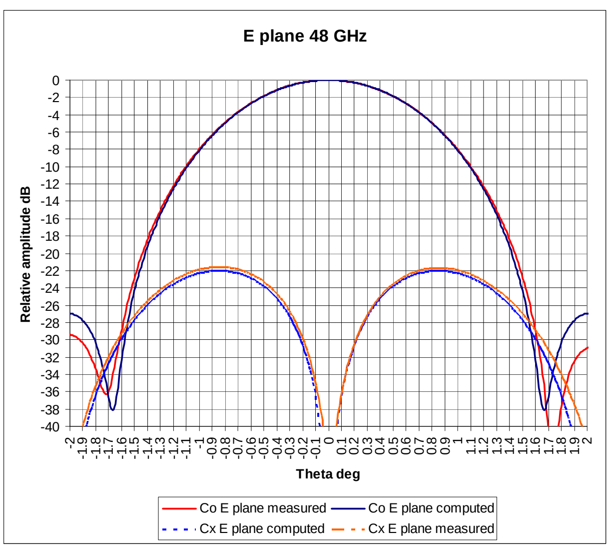

Figure 14- QVCA E plane measured and computed patterns

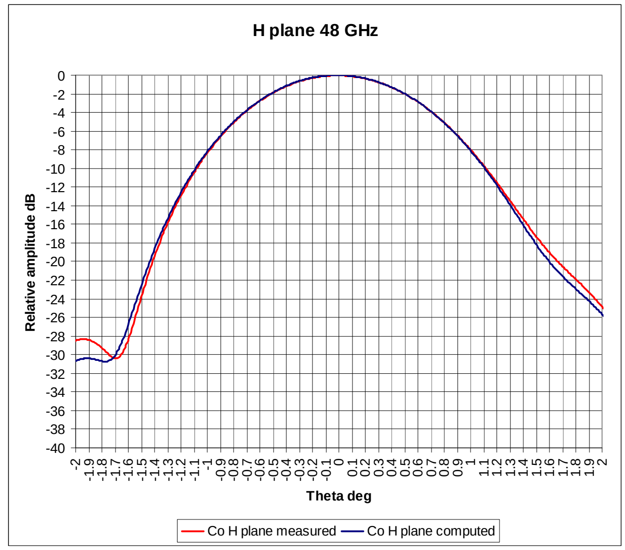

Figure 15- QVCA H plane measured and computed patterns

From these last 2 figures appear clearly that excellent alignment and measurement accuracy have been achieved. The E field cut is almost perfect while in the H plane appears more a pattern distortion starting 10 dB down than a beam misalignment. The beam alignment requirement was 0.03° corresponding to the allowable losses of 0.3 dB as shown in Figure 16.

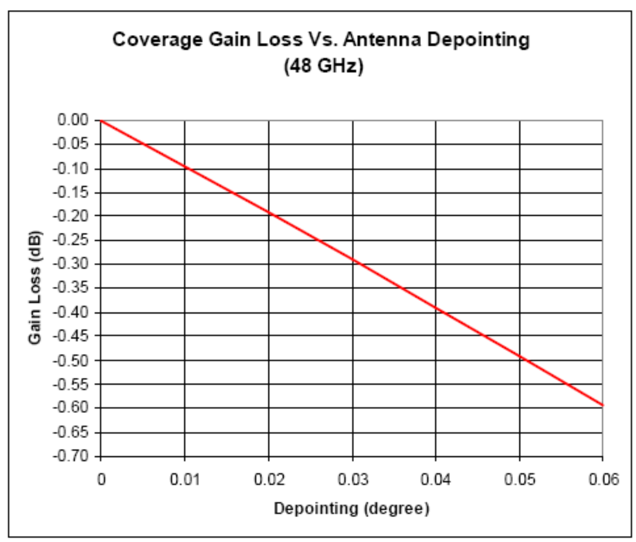

Figure 16– QVCA link losses Vs. beam misalignment

5.0 . Summary

This paper has briefly described some of the challenges to achieving high accuracy spherical near-field measurements on millimeter wave antennas. Results of some alignment perturbation studies on millimeter wave antennas at two different spherical near-field ranges have been shown. The use of the redundant spherical measurement geometry technique has been shown to reduce sensitivity to alignment errors. The alignment methods have proved useful to the success of the ALPHASAT EM antenna measurement campaign conducted by TeS in Q and V bands.

6.0 REFERENCES

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7.0 ACKNOWLEDGMENTS

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