MEASUREMENT FACILITY COMPARISONS WITHIN THE EUROPEAN ANTENNA CENTRE OF EXCELLENCE

#L. J. Foged[(1)], B. Bencivenga[(1)], O. Breinbjerg[(2)], S. Pivnenko[(2)], M. Sierra-Castañer[(3)]

[(1)] SATIMO Italy, Via Castelli Romani 59, 00040 Pomezia-Roma, Italy
Email: lfoged@satimo.com, bbencivenga@satimo.com

[(2)] Ørsted·DTU, Technical University of Denmark, Denmark
Email: ob@oersted.dtu.dk, sp@oersted.dtu.dk

[(3)] Technical University of Madrid (UPM), Spain
Email; m.sierra.castaner@gr.ssr.upm.es

1. INTRODUCTION

This paper gives an overview of the activities performed under the Antenna Measurement Techniques and Facility Sharing activity of the Antenna Centre of Excellence (ACE) within the EU 6th framework research program. In particular, the activities involving antenna measurement facility comparisons are discussed in detail. These activities are important instruments to verify the measurements accuracies for each range and investigate and evaluate possible improvements in measurement set-up and procedures.

Facility comparisons involving high accuracy reference antennas are key instruments for the evaluation, benchmarking and calibration of antenna measurements systems. Regular inter comparisons between accredited measurement facilities are also an important instrument for the measurement traceability and quality maintenance.

The purpose of the *Antenna Measurement Techniques and Facility Sharing* activity WP1.2 under ACE is to facilitate the consolidation and expansion of European expertise in research and development of antenna measurements. The present group include 15 European universities, research laboratories and companies. The activities are organized in different Work Packages (WP) each led by a different institutions as indicated below:

2. OVERVIEW OF THE ACTIVITIES

WP 1.2-2 *Standardization of Antenna Measurement Techniques.* The leader of this activity is SATIMO. The objective is to contribute to the standardization of primarily near – field antenna measurement techniques. Several advanced antenna measurement facilities employing these near-field techniques, have been in operation for a number of years but no international, and probably not even national, best practice recommendations or standardizations have yet been developed. Even for a specific near-field technique, e.g. the spherical near field technique, there are many possible practical implementations for the measurements procedure, and these can influence the measurement accuracy differently. There is thus a significant need to pursue very actively more cooperation, comparison and standardization of antenna measurement techniques.

WP 1.2-3 *Validation an benchmarking of antenna measurement facilities.* The leader of this activity is the Technical University of Denmark (DTU). The objective is to conduct comparisons of antenna measurement facilities among the participants of the ACE network, employing employing the DTU-ESA 12GHz Validation Standard Antenna, the SATIMO 0.8-12GHz Dual ridge horn and the SATIMO SH2000 horn (2-32GHz) as reference antennas. The purpose is to compare the capabilities of the participating facilities in selected areas of antenna measurements and provide input to the standardization of procedures for facility validation.

WP 1.2-4 *Development of measurement techniques for new antenna technologies.* The leader of this activity is UPM. The objective is to develop new measurement techniques and procedures for proper characterization of the new and emerging antenna technologies of the 5 vertical research activities of ACE. These are the 2.1 Millimetre and sub-millimetre wave integrated antennas, 2.2 Small antennas, 2.3 Wideband and multi-band antennas, 2.4 Planar and conformal arrays and 2.5 Smart antennas.

3. FACILITY COMPARISON CAMPAIGNS

Facility comparisons are important instruments to verify measurements accuracies and investigate and evaluate possible improvements in measurement procedures. Most international certifications require regularly scheduled comparisons with other ranges or reference laboratories as part of the certification maintenance.

Four antenna types have been employed in this activity. The DTU-ESA 12GHz Validation Standard Antenna (VAST), the SATIMO, SH800 0.8-12GHz Dual Ridge Horn (DRH) in the 1.5-6GHz band, the SATIMO SH2000 2-32 GHz Dual Ridge Horn and a set of calibrated Standard Gain Horns (SGH) covering the 1.5-40GHz range from the DTU-ESA Spherical Near-Field Antenna Test Facility have been employed. Similar comparison campaigns with other antennas have been carried out and reported previously in the literature an serve as reference for the comparison procedure [2]-[3].

3.1 SATIMO DUAL RIDGE 0.8-12GHZ HORN

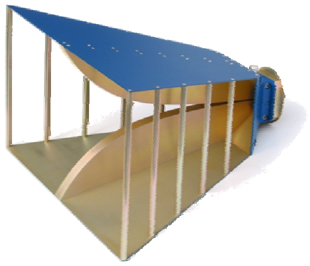
Due to the ridge, ridge horns are much smaller and less bulky that the corresponding standard gain horn at comparable frequencies. Carefully designed dual ridge horns have excellent return loss, cross polar and flat gain response (typically 7-15 dBi) in a 1:15 frequency range so very few horns are require to cover the operative range of an antenna testing facility. High quality designs are based on numerically controlled, precision fitted mechanical parts so very little performance difference can be observed between similar horns.

The Satimo Dual Ridge 0.8-12GHz Horn as shown in Figure 1 is widely used as a broadband reference antenna. The horn is connectorized and essentially an open, flared ridge waveguide with lateral bars designed to harmonize the gain with frequency curve. At low frequencies the bars appear as a closed surface and increase the boresight gain of the horn, whereas at high frequencies the bars are electrically transparent and the effective gain decreases.

In the frame of ACE an activity on comparative measurements have been performed involving different test facilities. The participating institutions where invited to participate at various levels. Measurements have been performed in the DTU-ESA Spherical Near-Field Antenna Test Facility at the technical university of Denmark (DTU), in both of the SATIMO multi probe spherical near field Systems (SG-64) in Atlanta (USA) and Paris (France), in the spherical near field system of technical university of Madrid (Spain) and the combined farfield/spherical nearfield test range of Saab Ericsson Space (Sweden and the farfield ranges of IMST (Germany) and National Centre for Scientific Research (Greece).

The data collection and processing is conducted by SATIMO in cooperation with the other participants and documented in an ACE report .

The traditional comparison of data involves the comparison of boresight gain and directivity values, however, the measurement differences and their sources are often better understood by direct inspection and comparison of the patterns. The direct comparison of large amount of measured pattern data is unfeasible by inspection of pattern differences alone. Therefore a statistical approach has been implemented that allow the comparison of data in a simple form.



$$\left(\frac{Dir_{Co,Cx} - Dir_{REFCo,Cx}}{Dir_{REFCo,Cx}}\right)\left(\frac{Dir_{Co,Cx}}{Dir_{CoBoresight}}\right)$$

Figure 1: Satimo Dual Ridge 0.8-12GHz Horn.

Figure 2: Weighted differences formula.

The statistical approach concerns the 60˚ forward cone of the radiated co and cross-polar patterns. This angle has been determined somewhat arbitrary but include field levels from 9 to 25 dB below the peak. The Ludwig III [7], co and cross polarised components are treated separately since the cross polar values include 2 cuts in 45˚ and 135˚ while the copolar values include 4 cuts.

Ideally comparison against a reference pattern should be based on a reference pattern which can be considered error free. However, as such a reference is not available for the present comparison it is of interest to define a reference pattern based on the measured radiation patterns to which a high degree of confidence can be attributed. For this purpose a reference pattern has been determined, for each measured frequency, as the geometric mean of the 4 measurements (SATIMO, DTU, SES, and UPM) excluding the most distant sample. From the reference pattern the standard deviation of the weighted differences for each measurement is calculated. This value expresses the effective variation over the 60˚ forward cone giving an indication of the measurement error level. The procedure is expressed in the formula shown in Figure 2, where directivity data are on linear scale:

The standard deviation σ is very useful to quantify the range in which measurements errors are distributed. It expresses the 68.3% confidence that the measurements error is within this level. The 99.7% confidence level is 3σ. The standard deviation expresses only the variation, but it does not consider a general shift. This also mean that this value "clean" the comparison from differences caused by pattern difference in the antenna back-lobe that are often due to differences in the measurement set-up. The impact of this is often very small in high gain measurements but can be a significant contribution when comparing medium and low gain antennas as in this case. A typical comparison is shown in Figure 3.Another statistical approach has been performed during this activity. Uncertainty analysis of measured data is not an exact science but nevertheless an important tool to determine error boundaries. Highly accurate reference data can be derived from the statistical treatment of measurements on the same reference antenna performed in the same condition in different ranges as explained in [9]. The reference data have been calculated as the weighted mean of each data entry where the weights are proportional to the estimated uncertainty [8]. The uncertainty associated with the improved reference data can be determined from the weighted mean of the uncertainties divided by the number of data entries. The formulas for the average data X_{typ} and associated uncertainty u_{typ} using a linear scale are illustrated below:

The formulas shown in Figure 4 give RSS values corresponding to the 1σ value with 69% confidence level assuming a normal distribution. The expanded uncertainty can be determined by applying a suitable coverage factor of 2 or 3 corresponding to 95% or 99% confidence level.

For each measured frequency a reference gain value has been determined as the weighted mean of all measurements. The comparison of the gain differences between individual measurements and the reference based on the weighted average approach show that each institution is performed well within the declared uncertainty budget. Most institutions are either always above or below the reference level throughout the frequency band. In the cases of the spherical near field facilities: DTU, UPM, SES and SATIMO this could indicate a general over- or under-estimation of the gain of the reference antenna when using the substitution technique.

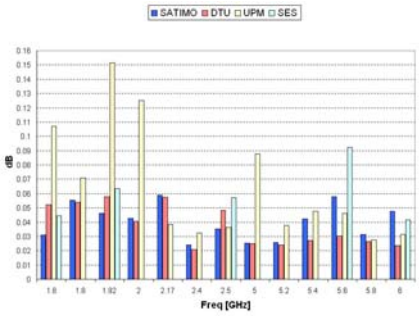


Figure 3: Copolar standard deviation from reference pattern in 4 cuts in forward 60° cone.

$$u_{typ} = 1 + \sqrt{\frac{1}{\sum_{i=1}^{N} \frac{1}{(1-u_i)^2}}}$$

$$X_{typ} = \frac{\sum_{i=1}^{N}\left(\frac{x_i}{u_i^2}\right)}{\sum_{i=1}^{N}\left(\frac{1}{u_i^2}\right)}$$

Figure 4: Formulas for calculating the weighted mean value and associated uncertainty.

3.2 SH2000 COMPARISON CAMPAIGN

A new activity particularly targeting the Ku and Ka frequency bands involving the SATIMO SH2000 dual ridge horn (2-32GHz) as shown in Figure 6 has been defined for ACE-2. This activity involves ACE and non ACE participants in Europe and US from the start.

The antenna to be measured is mounted on an absorber plate that will assure the independence of measurement setup as shown in Figure 6. Institutions involved in this activity are shown in Figure 8.

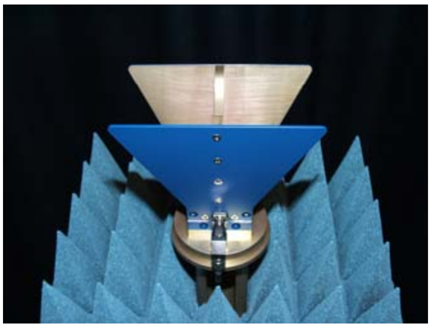


Figure 5: Satimo SH2000 Dual Ridge 2-32GHz Horn.

Figure 6 : Facilities and planning in ongoing facility comparison campaign on SH2000

REFERENCES

[1] Antenna Centre of Excellence, WWW.antennasvce.org

[2] J. Lemanczyk *et al.*, *IEEE Trans. Antennas Propag at.*, vol. 36, pp. 845-851, June 1988.

[3] C.F. Stubenrauch *et al.*, *IEEE Trans. Antennas Propagat.*, vol. 44, pp.1367-1374, Oct. 1996

[4] J. Lemanczyk, *IEEE Trans. Instrument. Measurement.*, vol. 44, pp. 347-350, April 1995. *rd*

[5] J.E. Hansen, "Definition, design, manufacture, test and use of a 12 GHz Validation Standard Antenna", *Technical Report R672,* EMI, Technical University of Denmark, October 1997.

[6] L. Foged *et al.*, "Facility comparison and evaluation using dual ridge horn", AMTA 2005.

[7] L. Foged *et al.*, "Comparative measurement of Standard Gain Horns", 28th ESA workshop, June 2005.

[8] L. Foged *et al.*, "Advanced modelling and measurements of wideband horn antennas", ANTEM Saint-Malo, June 2005.

[9] A.C. Newell, "Error Analysis Techniques for Planar Near Field Measurements", *IEEE Transactions on Antennas and Propagation*, Vol. 36, No. 6, pp. 754-768, June 1988.