Antenna Measurement Facility Comparison within the European Antenna Centre of Excellence

L. Foged[1], O. Breinbjerg[2], S. Pivnenko[2], G. Di Massa[3], C. Sabatier[4]

[1]Satimo Italian Office, Via Italo Torsiello 18, I-00128 Rome, Italy
[2] Ørsted·DTU, Technical University of Denmark, Denmark
[3] University of Calabria, Italy
[4] France Telecom R&D, France

***Abstract* — This paper gives an overview of the ongoing activities 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.**

I. Introduction

Antenna measurements constitute an indispensable part in the development of any wireless system. The increasing complexity and qualification requirement of modern antennas for civil, military and space applications implies that even the most advanced numerical models and computational tools cannot achieve a complete characterization. Fast and accurate antenna measurements are therefore an important tool for antenna analysis, validation, or calibration.

The purpose of the *Antenna Measurement Techniques and Facility Sharing* activity 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 4 Work Packages (WP) each led by a different institutions as indicated below:

II. Overview Of The activities

WP 1 *European Measurement Expertise Mapping*. The University of Calabria, Italy supported by other WP partners has developed a web-based database to map European expertise in antenna measurements [1]. The collection of information is a mean to identify parallel or complementary research activities in the antenna measurement field whose integration and coordination will be of benefit to advance the progress of ACE. The database provides the scientific and industrial community with a holistic outlook on antenna measurement services accessible in Europe facilitating the identification and the contact with the most suitable test facility for any application.

WP 2 *First Facility Comparison Campaign.* 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 the DTU-ESA 12GHz Validation Standard Antenna and the SATIMO 0.8-12GHz Dual ridge horn 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 3 *Facility Sharing, Feasibility Study and Initial Test Cases*. The leader of this activity is France Telecom, France with the objective to promote and increase the sharing of existing antenna measurement facilities and expertise among the ACE participants. The aim is to increase the effectiveness and expertise of the ACE facilities and prepare them to undertake measurements for external customers and partners as support to other antenna activities in ACE. There are three separate programmes within this WP: First, the external measurements projects where existing facilities carry out measurements for customers and partners not belonging to their own organization. Second, the sharing of standard gain horn antennas where ACE partners can request the loan of calibrated Standard Gain Horn from the DTU-ESA Spherical Near-Field Antenna Test Facility. Third, the personnel exchange programme where experts are exchanged between measurement facilities and/or research groups.

WP 4 *Recommendations for Measurement Procedures.* The leader of this activity is Satimo, France. This activity has two separate objectives. First, the development of "Recommended practices for near-field measurements" that has been initiated by the IEEE Antennas Standards Committee in 2003. Through this activity ACE members are actively contributing to the development of the IEEE standard. A separate document on recommended practices for spherical near field measurements including comments on probes and probe arrays have also been prepared and will be released by mid-2005. A second objective is the development of definitions for realistic performance evaluation of smart antennas.

III. 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.

Three antenna types have been employed in this activity. The DTU-ESA 12GHz Validation Standard Antenna (VAST), the SATIMO 0.8-12GHz Dual Ridge Horn (DRH) in the 1.5-6GHz band 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].

A. DTU-ESA 12GHz Validation Standard Antenna

The objective of this activity is to conduct a comparison of antenna measurement facilities employing the DTU-ESA VAST12 antenna as shown in Fig 1. This will serve to benchmark the participating facilities, to document the advantages and disadvantages of different measurement techniques as well as the practical implementations of these, and to provide inputs for the standardization of validation of antenna measurement facilities.

Fig. 1. The DTU-ESA VAST12 antenna.

The VAST12 antenna was developed by the Technical University of Denmark (DTU) for the European Space Agency (ESA) in the 1990s as a specially designed reference antenna [4]-[5]. The CFRP/foam structure ensures thermal and mechanical stability against differences in temperature and gravity orientation, respectively, between the participating facilities. The offset shaped-parabolic reflector, with different focal points in the two principal planes, and the corrugated circular feed horn provide a pattern with elliptical main beam and several challenging characteristics. The operating frequency is 12 GHz. For the present campaign, the polarization is linear and the gain about 30 dB, but with replaceable orthomode transducers and attenuators on the horn it is possible to change polarization and gain. The overall size of the antenna is 0.51x0.84x0.94 m3, and the weight is about 20 kg.

The first step of the campaign is to determine the Verification Test Plan that defines not only the radiation pattern parameters to be measured, but also the coordinate systems and the data formats to be used for the reporting of the measurement results. Thus, three different coordinate systems are defined: (1) the mechanical system using the flange of the antenna mechanical interface and a spirit level, (2) the electrical system using the peak directivity direction and the polarization of the radiated field, and (3) the optical system using a mirror cube mounted on the antenna. The Euler angles (φ, θ, χ) for the electrical and optical coordinate systems, as measured in the mechanical system, are (228.4, 0.6, 131.4) deg. and (228.3, 0.2, 132.0) deg., respectively. The second step of the campaign is then to make the first reference measurement at the DTU-ESA Spherical Near-Field Antenna Test Facility. Third, the VAST12 antenna is shipped to the 6 participating institutions and measured at 8 different facilities. Finally, the second reference measurement is conducted at the DTU-ESA Facility. The data collection and processing is conducted by DTU in cooperation with the other participants and documented in an ACE report to be released by mid-2005. An example of the comparison data is shown in Fig 2.

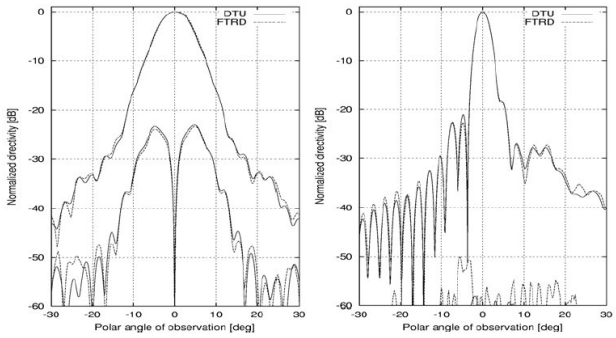

Fig. 2. Example of comparison data on the VAST antenna. Measurements performed in DTU and France Telecom.

B. 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 Fig 3 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.

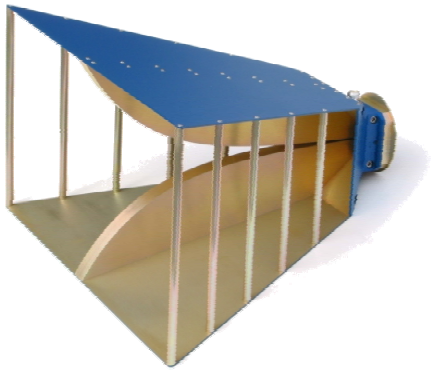

Fig. 3. Satimo Dual Ridge 0.8-12GHz Horn.

The Satimo horn is equipped with high reliability female 3.5mm or N-type connector for superior connector repeatability and durability. Connector savers can also be used to prolong the effective lifetime of the reference horn antenna since the change of the connector saver only requires a recalibration of the return loss performance of the antenna. This is particularly important due to the associated cost of accurate calibrations by reliable third parties.

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 already 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). Measurements are also planned in the facilities of IMST (Germany) and National Centre for Scientific Research (Greece).

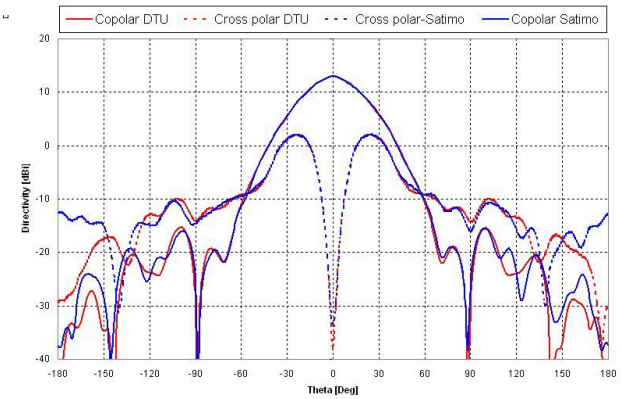

Fig. 4. Example of comparison data on the Satimo Dual ridge horn. Measurements performed in DTU and Satimo at 5.4GHz. The graph show the full sphere directivity in the diagonal plane.

The data collection and processing is conducted by SATIMO in cooperation with the other participants and documented in an ACE report to be released by the end-of 2005. Partial results will be published in mid-2005 [6] an example from this comparison is shown in Fig 4.

C. DTU-ESA Standard Gain Horns

ACE partners can request the loan of calibrated Standard Gain Horn from the DTU-ESA Spherical Near-Field Antenna Test Facility and compare the measured boresight gain and directivity values with reference data from DTU.

Fig. 5. Calibrated Standard Gain Horns from the DTU-ESA Spherical Near-Field Antenna Test Facility.

Measurements on three standard gain horns (SGH) covering the frequency range from 1.55 – 6 GHz as shown in Fig.5 have been performed in both of the SATIMO Multi Probe spherical near field Systems (MPS) in Atlanta, USA and Paris, France. Partial results from this activity have been published in mid-2005 [7] an example from this comparison is shown in Fig 6.

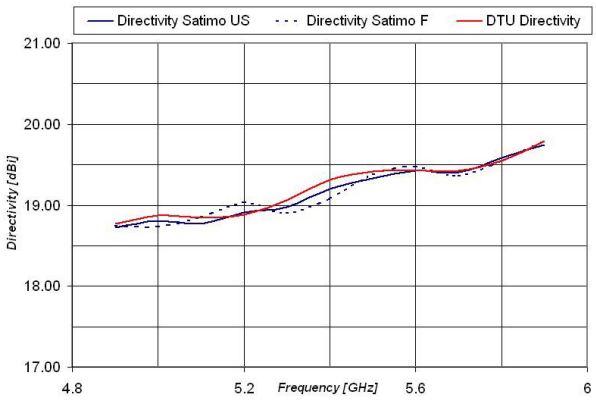

Fig 6: Comparison of measured boresight directivities in Satimo France, Satimo US and DTU at 4.90-5.90GHz.

IV. Transverse Activities within ACE

Transverse activities are actions involving other areas of the ACE network. The *Antenna Measurement Techniques and Facility Sharing* group is involved in three major such actions.

A. Measurements and numerical modelling

An activity involving the comparison of measurements and numerical modelling has been initiated with the *Wideband and Multiband antenna* activity. The antenna used for this activity is the Satimo Dual Ridge 0.8-12GHz Horn. The measurements where performed by Satimo involving 521 Frequency points, (each 10MHz) in the 0.8-6GHz bandwidth. The numerical modelling has been performed with a commercial FDTD program from a non ACE partner [8]. Both matching, peak directivity and pattern characteristics have been investigated [9]. A comparison of the measured and simulated boresight directivity are shown in Fig 7.

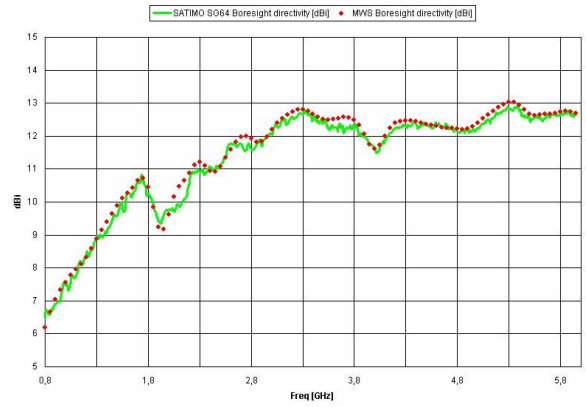

Fig 7: Comparison of measured and simulated boresight directivities at 521 frequency points. Satimo France and CST.

B. Recommendations for smart antenna measurements

An activity involving the definitions and recommendations for the realistic performance evaluation and measurements of smart antennas and Multiple Input Multiple Output (MIMO) systems has been initiated with the *Small Terminals and Smart Antenna Systems* activity. An ACE report on this action is expected by the end-of 2005. Further work in this area is expected to be conducted in future ACE activities and related programs as an independent activity.

C. Definition of Electromagnetic Data Interface

An activity involving the definition of an universal Electromagnetic Data Interface (EDI) has been initiated with the *Antenna software initiative (ASI)* and The European Space Agency (ESA). EDI is foreseen as a common European interface to electromagnetic data primarily stored in files. The EDI shall consist of a library with advanced file handling capabilities that can create, write and read files with electromagnetic data. Such data are far fields, near fields, s-matrices etc.

A preliminary and reduced form of the library is expected by the end-of 2005. Further work in this area is expected to be conducted in collaboration with ESA and in future ACE activities and related programs as an independent activity.

V. CONCLUSION

Facility comparisons are important instruments to verify measurements accuracies and investigate and evaluate possible improvements in measurement procedures. Regular inter comparisons between accredited measurement facilities are also an important instrument for the measurement traceability and quality maintenance. The activities in ACE provide a valuable possibility to pursue this activity on a large scale. Companies and institutions outside Europe and non members of ACE will subsequently be invited to participate in these activities.

The completion of the Electromagnetic Data Interface (EDI) is a very important component to facilitate future comparison campaigns and can therefore be seen as a critical component for the continuation of this activity in ACE.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance and support from all members of ACE. In particular: Peter Balling from the *Wideband and Multiband antenna* activity, Marta Martínez-Vázquez and Jan Carlson from the *Small Terminals and Smart Antenna Systems* activity, Guy Vandenbosch from the *Antenna software initiative* and Marco Sabbadini, ESA/ESTEC for their inputs and support.

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