Antenna Measurement Intercomparison Campaigns in the framework of the European Association of Antennas and Propagation

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Abstract- **This paper gives an overview of the ongoing activities in the frame of the EurAPP [1] working group on antennas measurements and the first considerations on useful criteria for comparing and evaluating large amount of measured antenna data. This work comes from the experience acquired during the VI EU Framework network "Antenna Centre of Excellence (ACE) [2]" as reported in [3-9]. During that project, the activities spanned the frequency range from L-Ka band using different antennas (VAST12, SATIMO SH800 and SATIMO SH2000). The vast amount of data from different measurements institutions within Europe and US were used to establish a reference pattern for each of the high accuracy reference antennas. The reference patterns and the data from the facility comparison activities are considered important instruments to verify the measurements accuracies for antenna measurement ranges as well as to investigate and evaluate possible improvements in measurement set-ups and procedures.**

I. INTRODUCTION

Several facility comparison campaigns have been carried out during the last years in the framework of the different European Activities regarding to Antenna Measurements [3-10]. The Antenna Measurement Activity of the Antenna Centre of Excellence [2] of the VI Frame program of the UE, in the period of 2004 to 2007, began to define some reference antennas to be used for these purposes. A high directive reflector antenna, DTU-ESA 12 GHz VAST12 [11], and two dual ridge horns, SATIMO SH800 [12] in L, S and C band (SH800) and SATIMO SH2000 in Ku and Ka bands, were employed. After finishing the works of this network of excellence, the different tasks related to this topic have been continued in the frame of the COST ASSIST (IC0603) [13] and COST-VISTA (IC1102) [14] and now, included in the Antenna Measurement Working group of the EurAAP, where a specific task for Antenna Measurement Intercomparisons is ongoing.

The main lesson of these campaigns is that comparative measurements based on high accuracy reference antennas and involving different antenna measurement systems are important instruments in the evaluation, benchmarking and calibration of the measurement facilities. Regular inter comparisons are also an important instrument for traceability and quality maintenance. These activities promote and document the measurement confidence level among the participants and are an important prerequisite for official or unofficial certification of the facilities. In any case, both type of facilities, with or without ISO certification, need to conduct facility comparisons to properly validate their measurement procedures. In general, the goal of the facility comparison activities: to provide means to validate and document measurement accuracy from comparison with other facilities; and to allow the facilities to investigate and correct in case of "less compliance" or in some cases allow facilities to revise procedures and correct the measurements.

In this paper, we will review the work realized with the three first reference antennas, emphasizing in the achieved conclusions. Then, the ongoing intercomparison campaigns covering different kinds of reference antennas (SATIMO BTS 1940, SATIMO SH800, SATIMO SR-40 and SATIMO LTE MIMO antenna) are presented and the first results explained. Finally, some conclusions and future lines are extracted.

II. PREVIOUS ANTENNA MEASUREMENT CAMPAIGNS IN THE FRAME OF ANTENNA CENTRE OF EXCELLENCE

A. DTU-ESA 12 GHz VAST1 and SATIMO SH800 and SH2000 campaigns.

The VAST-12 comparison campaign took place during 2004 and 2005, with 8 facilities of 6 different institutions providing results (Saab Microwave Systems, France Telecom R&D, RUAG Aerospace Sweden, Technical University of Catalonia, Technical University of Denmark and Technical University of Madrid). The measurements were carried out in compact ranges (CR), far field (FF), spherical near field systems (SNF) and planar near field systems (PNF). DTU leaded this process and two measurements at the beginning and the end of the campaign were performed there. VAST12 is a very high quality antenna with a very directive radiation pattern (Fig.1).

Two wideband dual ridge horns were selected in these cases. In this case, the campaigns were headed by SATIMO. 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.

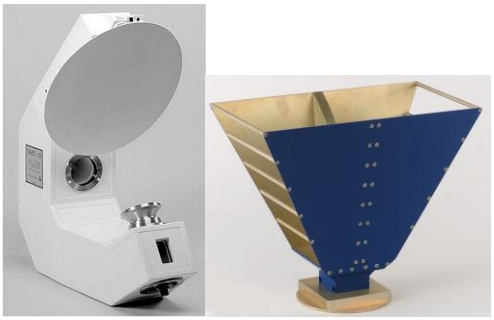

Figure 1. The ESA/DTU VAST12 and the SATIMO SH800 Dual Ridge Horn antennas

The first activity on comparative measurements for SH800 was performed involving different test facilities: 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 near field test range of Saab Ericsson Space (Sweden) and the far field ranges of IMST (Germany) and National Centre for Scientific Research (Greece). The data collection and processing was conducted by SATIMO in cooperation with the other participants and documented in an ACE report [2]. The traditional comparison of data involved the comparison of boresight gain and directivity values for different frequencies; however, the measurement differences and their sources are often better understood by direct inspection and comparison of the patterns. Since the direct comparison of large amount of measured pattern data is unfeasible by inspection of pattern differences alone, a statistical approach was implemented that allows the comparison of data in a simple form.

Figure 2. Participants for the SATIMO SH800 Intercomparison Campaign.

The next antenna, the SH2000 (2-32GHz) is dual ridge horn that combines a stable gain performance and low VSWR with wide band frequency operation. The horn is single linearly polarized with high cross-polar discrimination and is often used as a reference antenna for gain calibration of antenna measurement systems or as a wideband probe in classical far field test ranges. The horn is specifically designed to maintain a well-defined smooth radiation pattern in the direction of the boresight axis throughout the operational bandwidth. The horn is equipped with a high precision female 3.5 mm connector intermateable with SMA and K connectors. For the SH2000, 8 frequencies were selected in Ku and Ka bands and 11 different test facilities were involved.

B. *Reference values.*

This reference value and its uncertainty were obtained using the measured values and their uncertainties (1). In the case of single point values, the expressions are:

$$X_{typ} = \frac{\sum_{i=1}^{N}\left(\frac{x_i}{u_i^2}\right)}{\sum_{i=1}^{N}\left(\frac{1}{u_i^2}\right)} \qquad u_{typ} = 1 + \sqrt{\frac{1}{\sum_{i=1}^{N}\frac{1}{(1-u_i)^2}}} \tag{1}$$

The uncertainty associated with the weighted mean is "improved" if the measurements are truly independent. The previous formulas give RSS values corresponding to the 1σ value, with 69% confidence level assuming a normal distribution. From the reference pattern, the standard deviation of the differences for each measurement and in each direction was calculated. This value expresses the effective variation over the 45° forward cone giving an indication of the measurement error level in a single value. The procedure is expressed in (2), where directivity data for each angular position in linear scale is normalized respect the boresight value and the reference value:

$$f(\theta) = \left(\frac{Dir_{co,xp} - Dir_{ref\_co,xp}}{Dir_{ref\_co,xp}}\right) \cdot \left(\frac{Dir_{co,xp}}{Dir_{co,boresight}}\right) \tag{2}$$

The resulting number express the equivalent signal-to-noise level in which all deviations with respect to the reference pattern has been converted into an equivalent "noise". The calculated co-polar standard variation for each facility with respect to the weighted mean reference pattern is shown in Fig. 6. 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 errors are 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 means that this value "cleans" the comparison from differences caused by pattern difference in the antenna back-lobe (usually 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 for medium and low gain antennas, as in this case.

III. Ongoing Intercomparison Campaigns

Four antennas have been selected for the new campaigns in the frame of the European Association on Antennas and Propagation. These antennas cover a broad frequency band, different applications and different radiation patterns.

A. *Intercomparison campaign with SATIMO BTS1940 BTS antenna.*

In 2009, a new intercomparison campaign using the BTS1940 (Fig. 3) array began. This antenna is a linear array reference antenna with dual slant +45°/-45° or H/V polarized working in GSM1800 and UMTS bands (1710 to 2170 MHz). The array is specifically designed to achieve excellent crosspolar discrimination and to maintain a well defined radiation pattern in the direction of the boresight axis throughout the operational bandwidth. The BTS1940 antennas are equipped with high precision female N type

connectors for superior repeatability and durability. The nominal impedance is 50 ohm with return loss values better than -15 dB. The SATIMO linear array antenna BTS1940 has been measured in the reference coordinate system shown on the antenna in Fig. 7. The BTS1940 measurement stage is finished, and now SATIMO is processing the results. The first results (Fig. 3 and Table I) show good agreement in the comparison of radiation pattern comparisons at 1920 MHz and directivity for the first three facilities for five facilities.

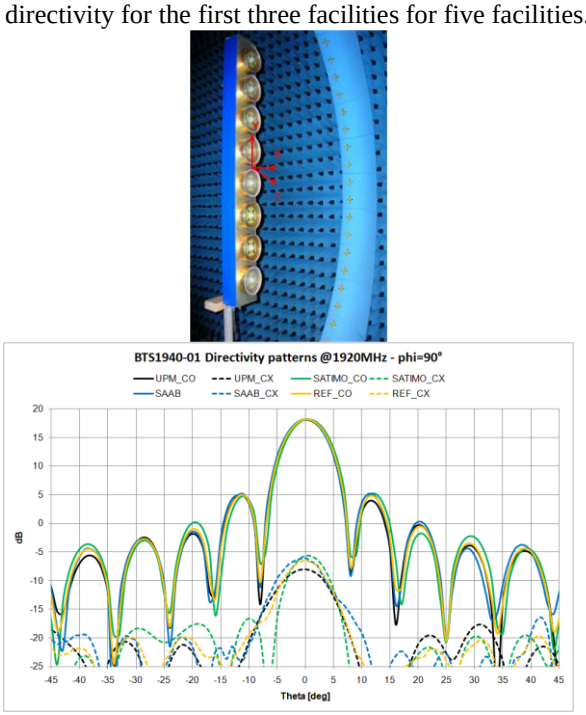

Figure 3: SATIMO BTS1940 in test configuration BTS 1940 and vertical pattern at SATIMO, UPM and SAAB compared with weighted reference value.

TABLE I

BORESIGHT DIRECTIVITY OF THE PARTICIPANT FACILITIES FOR BTS1940

	Boresight Directivity [dBi]				
	UPV	UPM	SAAB	Huawei	SATIMO
Freq [MHz]	***SNF***	***SNF2***	***CR***	***SNF3***	***SNF4***
1710	17,40	17,28	17,35	17,38	17,34
1795	17,77	17,62	17,73	17,68	17,63
1880	18,14	18,02	18,05	18,01	18,02
1920	18,33	18,17	18,22	18,17	18,15
2170	18,81	18,76	---	18,93	18,87
2200	18,79	18,77	---	---	18,85

B. Intercomparison campaign with SH800 dual ridge antenna.

The second antenna is again the SH800. In this case, the antenna has been modified in order to have a more stable setup. In particular, an absorber plate has been added behind the antenna to eliminate the sensibility to measurement setup and a cable has been added in order to have the same interface. The measured parameters are peak gain (IEEE definition) at discrete frequencies, directivity and gain patterns (Ludwig III co-polar and cross-polar) for 4 cuts (0º, 45º, 90º & 135º) and return losses. The participants must give the data in an appropriate format; give the description of measurement facility, the mechanical and electrical set-up description, the measurement procedure, the mechanical/electrical alignment, AUT alignment, and the uncertainty budget for the measurements. Fig. 4 shows the measurement results in the Stargate SG64 at SATIMO Paris facilities.

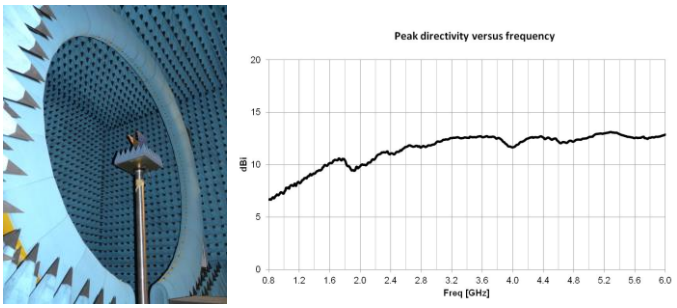

Figure 4. SATIMO SH800 antenna on SATIMO-Paris SG64 System and peak directivity measurement results.

C. Intercomparison campaign with SATIMO SR-40 antenna

In order to cover also higher frequencies and higher directivity antennas, the SATIMO SR-40 reference antenna has been selected. The frequencies to be measured in this case are 10.7-14.5GHz, 18-20GHz, and 28-31GHz, with a step of 100 MHz and 38GHz. The same antenna parameters and the same information than in the previous campaign is required for this measurement. Also in this case, the acquisitions are not completed, but preliminary results can be shown at this moment. Fig. 5 shows the pattern comparison (horizontal plane) at 10.7 GHz among 3 facilities and the reference value. Fig. 6 shows the averaged difference between each facility result and the reference value.

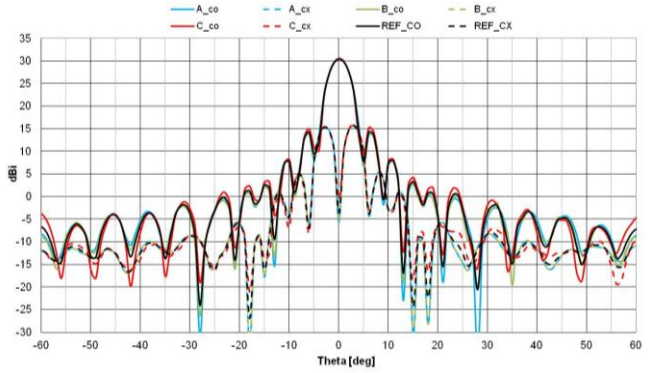

Figure 5. SATIMO SR40 first measurement results for pattern at 10.7 GHz.

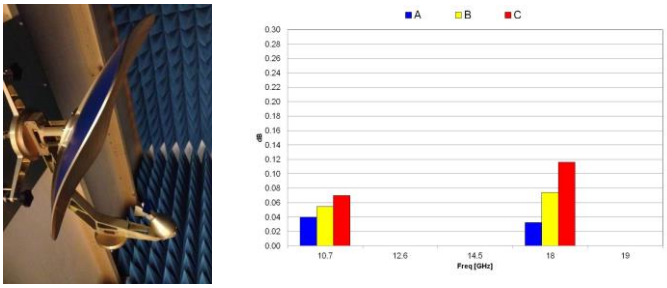

Figure 6. SATIMO SR40 antenna and statistical comparison of the co-polar radiation pattern at 10.7 and 18 GHz at 3 different facilities.

D. Intercomparison campaign for LTE MIMO Antenna.

Finally, in order to cover also small antenna measurements, a new campaign has been defined, and measurements will begin during this year 2013. In this case the CTIA 2x2 MIMO reference antennas (Fig. 7) have been proposed as reference antennas, during the WG5 progress meeting at

EuCAP2013 conference in Göteborg, Sweden, to be measured by the institutions of the Small Antenna Measurements Group. In particular, different designs (good performance, nominal and bad) have been done in order to investigate the effect of MIMO. The frequency bands are: LTE Band 2 (1930-1990MHz), LTE Band 7 (2620-2690 MHz) and LTE Band 13 (746-756MHz).

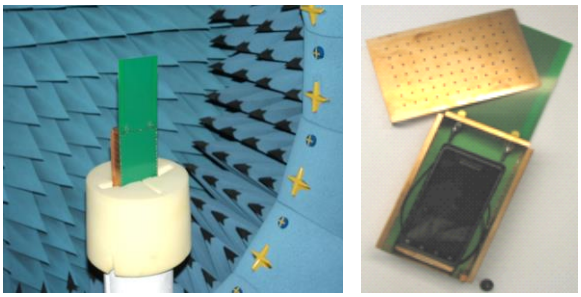

Figure 7. SATIMO CTIA 2x2 MIMO reference antenna in the Stargate SG64 System (SATIMO-Paris).

IV. Conclusions

The previous campaigns gave us a set of important conclusions to be considered during the antenna measurement intercomparison processes, summarized in:

- A very precise definition of the setup is necessary in order to assure that all participants are performing the measurements in the same way.
- The organization of the campaigns requires the exact definition of the objectives to be pursued, in order to prepare in advance the test plan, test procedure and the procedure for giving the results. Also, the deadlines for each laboratory must be assured in order not to extend the campaign for years.
- A unified procedure for getting the uncertainty for a specific measurement has to be agreed.
- In any case, this exercise is very useful for improving the quality of the facility (detecting errors) and the measurement capability of the participants.
- These campaigns have become very useful for the facilities that have the ISO17025 accreditation or are in the process. Also, regular inter comparisons are also an important instrument for traceability and quality maintenance.
- The reference value has to be obtained considering the uncertainty of each measurement and facility.

EurAAP Working Group about Antenna Measurements invites other laboratories to participate in the future campaigns.

Acknowledgment

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