International Facility Comparison Campaign at L/C Band Frequencies

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***Abstract*— Comparison activities in which a number of measurement facilities compare their measurements of the same antenna in a standard configuration have become important for documentation and validation of laboratory expertise and competence. It is also mandatory to have regular participation in such activities to obtain and maintain accreditations like ISO 17025. The main goal of the facility comparison activities is to provide a formal opportunity for the participants to validate and document their achieved measurement accuracy and procedures by comparison with other facilities.**

Since 2004, comparison campaigns with different scopes have been conducted on antenna measurements within various European activities. Results of these activities have led to improvement in antenna measurement procedures and protocols in facilities and contributions to standards.

In this paper we report on a recent EurAAP facility comparison campaign involving a medium gain ridge horn, MVI-SH800. The antenna is equipped with an absorber plate to reduce the sensibility to the measurement set-up in order to evaluate the improvement with respect to the previous ACE intercomparison activity, involving the same antenna lacking of absorber plate. The campaign covers measurement in the L and C band frequencies in different facilities in Europe and USA.

I. INTRODUCTION

Comparison activities in which a number of measurement facilities compare their measurements of the same antenna in a standard configuration have become important for documentation and validation of laboratory expertise and competence. It is also mandatory to have regular participation in such activities to obtain and maintain accreditations like ISO 17025 [1]. The main goal of the facility comparison activities is to provide a formal opportunity for the participants to validate and document their achieved measurement accuracy and procedures by comparison with other facilities. In fact, the measurement of any antenna performance parameter is considered to be incomplete without knowledge of the measurement accuracy [2], [3].

Since 2004, comparison campaigns with different scopes have been conducted on antenna measurements within various European activities: EurAAP (European Association on Antennas and Propagation) [4] supported by the European Cooperation in Science and Technology (COST) in the programs ASSIST IC0603 [5] and VISTA IC1102 [6] and the 6th EU framework network “Antenna Centre of Excellence” (ACE) [7]. Results of these activities have led to improvement in antenna measurement procedures and protocols in facilities and contributions to standards. Due to the direct benefits to the participants, the activities have been very successful and partial results have been published in IEEE referenced papers during the years ([8]-[24]). The large amount of measured data available have fostered fruitful discussion and research on the improvement of standard procedures, protocols and tools for performance verification like the facility comparison campaigns. As a further benefit, the campaigns have initiated a dialogue among different laboratories throughout Europe and USA and is spreading into Asia.

In this paper we report a recent EurAAP facility comparison campaign involving a medium gain ridge horn, MVI-SH800. The campaign covers measurement in the L and C band frequencies in different facilities in Europe and USA. The antenna is equipped with an absorber plate to enhance the correlation in different facilities by reducing the sensibility to the measurement set-up, in order to evaluate the improvement with respect to the previous ACE intercomparison activity ([8],[13]), involving the same antenna lacking of absorber plate. During that campaign, in fact, the measurement set-up was without absorbers and each facility provided the necessary absorbers to cover the antenna positioner. The results of 7 facilities will be shown in terms of gain/directivity patterns, equivalent noise level and the declared uncertainty will be checked against the whole set of measurements.

II. MEASUREMENTS INTERCOMPARISON

The intercomparison campaigns have fostered a fruitful discussion on the modernization and harmonization of the techniques to intercompare different measurements of the same antenna. The data elaborations strategies have recently been revised in [24] with the focus on the determination of the reference pattern, obtained from several independent measurements, and the equivalent noise level, intended as the correlation between the reference pattern and each measurement.

A. Reference Pattern

According to [24], a reference pattern can be computed using a weighted linear mean:

$$\mu_{Lin} = \frac{\sum_{i=1}^{n} w_i x_{i\,Lin}}{\sum_{i=1}^{n} w_{i\,Lin}} \qquad (1)$$

where:
n = total number of participants (and of measurements),
i = measurement of the *ith* participant to the campaign,
x_{iLin} = linear measurement.

The value for the weight wi associated to the ith measurement is given by:

$$w_{i\,Lin} = \frac{1}{\sigma_{i\,Lin}^{\;2}} \qquad (2)$$

where σ_{Lin} is the linear uncertainty computed starting from σ_{dB} that is the uncertainty, related to the measurement, declared by each facility.

B. Equivalent Noise Level

The correlation between each measurement and the reference pattern can be expressed though the equivalent “noise” level (EQN), evaluated, in dB, on a limited (±45° or ±60°) theta cone, with the following expression:

$$EqN_{dB} = \left[RMSE\left(\frac{Dir_{co,xp} - Dir_{ref\_co,xp}}{Dir_{co,ref\_boresight}} \right) \right] \qquad (3)$$

where:
RMSE is the Root Mean Square Error,
$Dir_{co,cx}$= Directivity (Co or Cx) of the measured pattern,
$Dir_{ref\_ co,cx}$ = Directivity of the reference pattern (Co or Cx),
$Dir_{co,ref,boresight}$ = Directivity of the co-polar component of the reference pattern in boresight.

During the previous ACE campaign involving the SH800 without absorber plate, the Standard Deviation has been used instead of RMSE. In case of good correlation, both give similar values of EQN. The Standard Deviation presented in [8][11] corresponds to (3) in a linear form.

When gain is available, one can compute the equivalent noise level with the following:

$$EqN = \left[RMSE\left(\frac{GainOffset_{co,xp} - Gain_{ref\_co,xp}}{Gain_{co,ref\_boresight}} \right) \right] \qquad (4)$$

where:

$$GainOffset_{dB} = Gain_{dB} - Offset_{dB} \qquad (5)$$

and the offset is given by:

$$Offset_{dB} = Gain_{dB,co\_boresight} - Gain_{dB,co,ref\_boresight} \qquad (6)$$

III. MVI SH800 WITH ABSORBERS PLATE

A. Test object

MVI SH800 is a Dual-Ridge Horn which combines stable gain performance and low VSWR with wideband frequency operation. The horn is single linearly polarized with excellent cross-polar discrimination. The unique horn design suppresses any possible excitation of higher order modes in the aperture and maintains a well-defined smooth radiation pattern in the direction of the boresight axis throughout the operational bandwidth. In this campaign, 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 enhance the correlation in different facilities by reducing the sensibility to the measurement set-up, as shown in Figure 1.

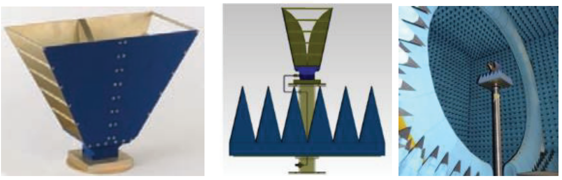

Figure 1. MVI SH800 with absorbers plate.

B. Measurement Campaign

The facilities that took part to the intercomparison and whose data are presented in this paper are:

- MVG Stargate64 in Atlanta-USA
- MVG Stargate64 in Paris, France
- Universidad de Oviedo, Spain
- Un. Politécnica de Madrid (UPM), Spain
- IMST, Germany
- NCSR Demokritos, Institute of Informatics & Telecommunications (NCSRD), Greece
- Inst.of High Frequency Technology, RWTH Aachen, Germany.

Figure 2 shows the location of the facilities with the indication of the type of measurement system.

Figure 2. Involved facilities in the SH800+absorbers plate campaign.

C. *Test plan*

The test plan and type of measurements are reported in Table I.

TABLE I. TEST PLAN FOR SH800 CAMPAIGN.

Full 3D Gain Measurement	Freq. Range	• [0.8-1]GHz, [1.5-2] GHz, [2.2-2.7] GHz step 10MHz for Freq ⩽ 1 GHz step 20MHz for Freq >1 GHz • 4, 4.5GHz • [4.9- 6]GHz, step 100MHz
	Phi	From 0° to 135°(45° step)
	Theta	From -180° to 180° (1° step)

IV. RESULTS

A. *Gain*

The results that will be shown hereafter are referred to the gain patterns measured by: MVG SG64 Paris, MVG SG64 Atlanta, UPM, IMST, NCSRD and Oviedo. The weighted gain reference pattern has been computed according to the 2σ uncertainties reported in Table II excluding University of Oviedo, whose uncertainty is under revision.

TABLE II. FACILITIES AND UNCERTAINTIES FOR THE REFERENCE GAIN PATTERN COMPUTATION

Facility	**Gain Uncertainty 2 σ @ freq [MHz]**			
	1800	**2500**	**4000**	**5000**
MVG SG64 Paris	0.6	0.6	0.6	0.6
MVG SG64 Atlanta	0.6	0.6	0.6	0.6
UPM	0.16	0.16	0.16	0.16
IMST	0.2	0.2	0.2	0.2
NCSRD	1.05	1.05	1.05	1.05
Oviedo	*	*	*	*

* under revision

1) *Gain Radiation patterns*

Measured co-polar and cross-polar gain patterns, at phi = 0° and 90°, at 1.8 GHz are compared with the weighted reference pattern, computed with (1), in Figure 3 and Figure 4.

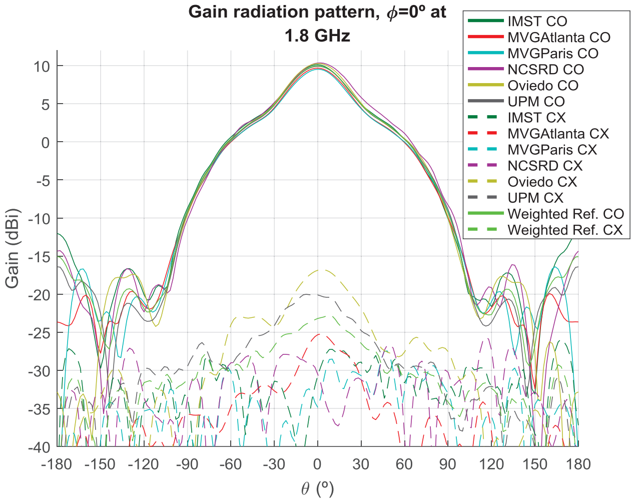

Figure 3. Gain radiation pattern at phi=0° @ 1.8 GHz. Weighted reference, MVG Paris, MVG Atlanta, UPM, IMST, NCSRD, Oviedo.

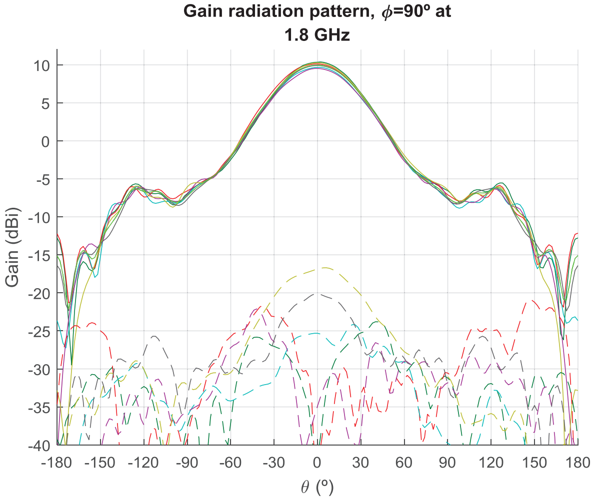

Figure 4. Gain radiation pattern at phi=90° @ 1.8GHz. Weighted reference, MVG Paris, MVG Atlanta, UPM, IMST, NCSRD, Oviedo (see legend of Figure 3).

2) *Equivalent Noise Level*

The EQN computed with offset gain patterns (4) in a ±45° theta cone is reported in Figure 5 and Figure 6 @1.8, 2.5, 4 and 5 GHz, computed at phi=0° and phi=90° planes for the co-polar component. The values of the peak IEEE gain are reported in Table III together with the difference (in red) with respect to the REF. The EQN as a function of theta at 1.8 GHz is shown for the co-polar components at phi=0° and phi=90° for all facilities in Figure 7 and Figure 8.

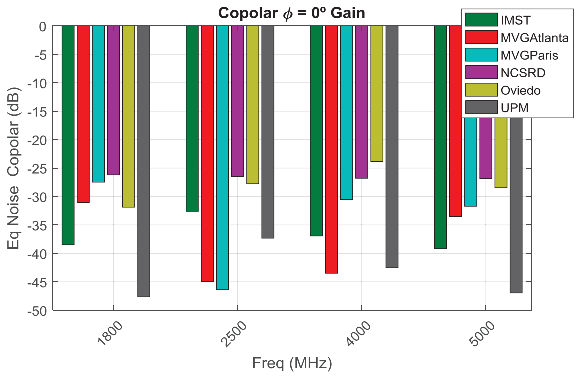

Figure 5. Equivalent noise level for the gain co-polar component at phi=0°.

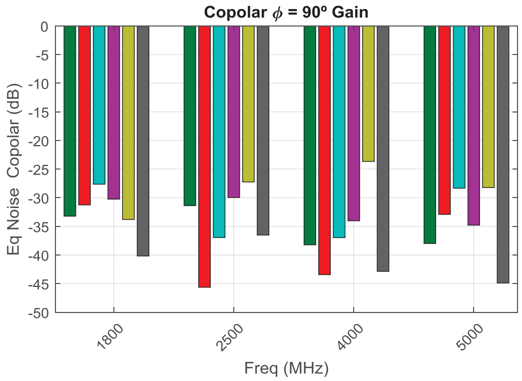

Figure 6. Equivalent noise level for the gain co-polar component at phi=90° (see legend of Figure 5).

TABLE III. PEAK IEEE GAIN

Freq [GHz]	Peak Gain						
	REF	***MVG P***	***MVG A***	***UPM***	***IMST***	***NCSRD***	***OVI***
1.8	9.96	9.52 -0.44	9.67 -0.29	9.91 -0.05	10.12 0.16	10.33 0.37	10.27 (0.31)*
2.5	10.38	10.35 -0.03	10.42 0.06	10.22 -0.16	10.63 0.25	10.74 0.36	10.89 (0.51)*
4	10.78	10.60 -0.18	10.81 0.03	10.73 -0.05	10.87 0.09	10.82 0.04	11.56 (0.78)*
5	11.6	11.26 -0.34	11.47 -0.13	11.56 -0.04	11.72 0.12	11.69 0.09	12.09 (0.49)*

*the REF has been computed excluding University of Oviedo

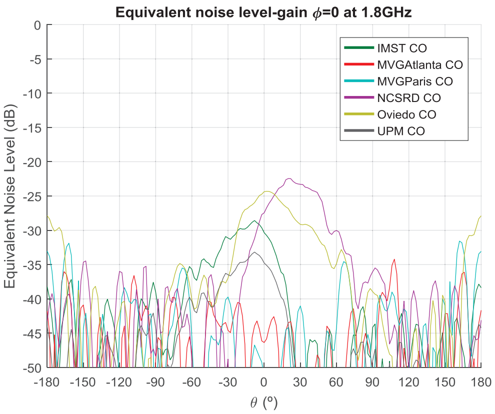

Figure 7. Equivalent noise level at 1.8GHz, phi=0° w.r.t. theta for the gain co-polar component.

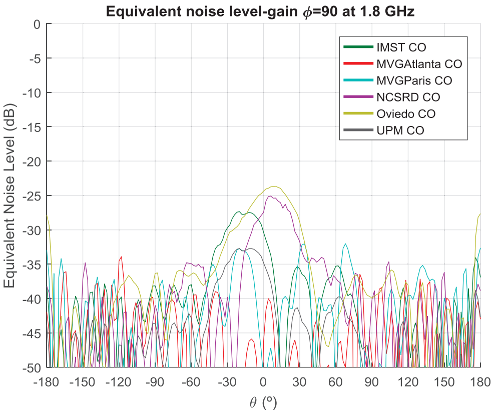

Figure 8. Equivalent noise level at 1.8GHz, phi=90° w.r.t. theta for the gain co-polar component.

B. Directivity

The results that will be shown hereafter are referred to the directivity patterns measured by: MVG SG64 Paris, MVG SG64 Atlanta, UPM, NCSRD, Oviedo, RWTH Aachen.

The weighted directivity reference pattern has been computed according to the 2σ uncertainties reported in Table IV excluding Oviedo, whose uncertainty is under revision.

TABLE IV. FACILITIES AND UNCERTAINTIES FOR THE REFERENCE DIRECTIVITY PATTERN COMPUTATION

Facility	**Directivity Uncertainty 2 σ @ freq [MHz]**			
	1800	**2500**	**4000**	**5000**
MVG SG64 Paris	0.3	0.3	0.3	0.3
MVG SG64 Atlanta	0.3	0.3	0.3	0.3
UPM	0.1	0.1	0.1	0.1
RWTH Aachen	-	0.20	0.20	0.16
NCSRD	1.06	1.06	1.06	1.06
Oviedo	*	*	*	*

* under revision

1) Directivity Radiation patterns

Measured co-polar and cross-polar directivity patterns, at phi = 0° and 90°, at 5 GHz are compared with the weighted reference pattern, computed with (1), in Figure 9 and Figure 10.

2) Equivalent Noise Level

The EQN computed in a ±45° theta cone, using (3) is reported in Figure 11 and Figure 12 at 1.8, 2.5, 4 and 5 GHz, computed at phi=0° and phi=90° planes for the co-polar component. The values of the peak directivity are reported in Table V together with the difference (in red) with respect to the REF. The EQN as a function of theta at 5 GHz is shown for the co-polar components at phi=0° and phi=90° for all facilities in Figure 13 and Figure 14.

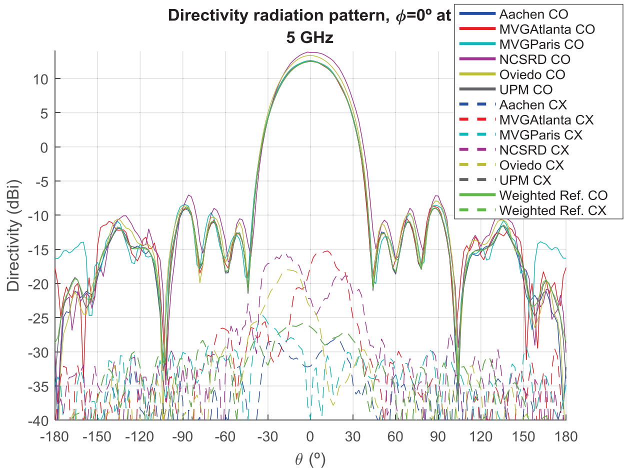

Figure 9. Directivity radiation pattern at phi=0° @ 5GHz. Weighted reference, MVG Paris, MVG Atlanta, UPM, NCSRD, Oviedo, RWTH Aachen.

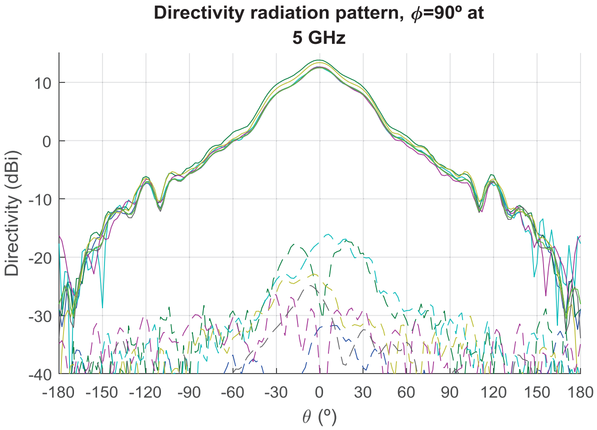

Figure 10. Directivity radiation pattern at phi=90° @ GHz. Weighted reference, MVG Paris, MVG Atlanta, UPM, NCSRD, Oviedo, RWTH Aachen (see legend of Figure 9).

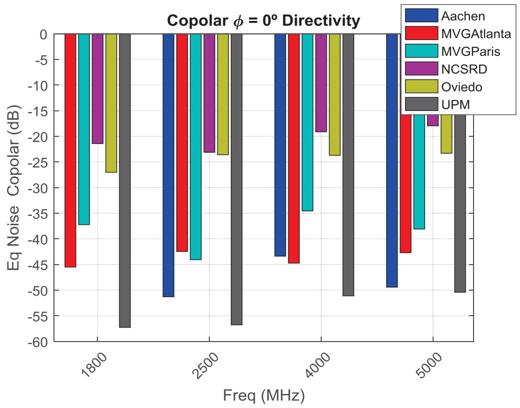

Figure 11. Equivalent noise level for the directivity co-polar component at phi=0°.

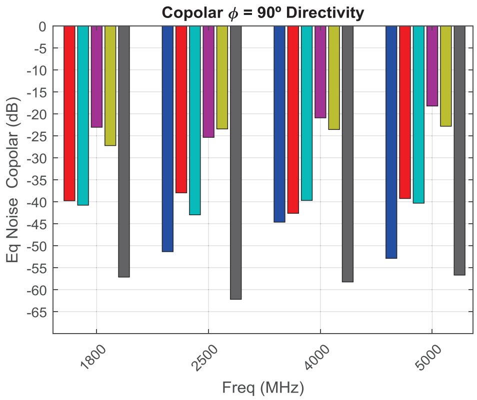

Figure 12. Equivalent noise level for the directivity co-polar component at phi=90° (sse legend of Figure 11).

TABLE V. PEAK DIRECTIVITY

Freq [GHz]	**Peak Directivity**						
	REF	***MVGP***	***MVGA***	***UPM***	***Aachen***	***NCSRD***	***OVI***
1.8	10.5	10.44 -0. 06	10.54 0.04	10.5 0	-	11.32 0.82	11.05 (0.55)*
2.5	11.24	11.22 -0.02	11.33 0.09	11.23 -0.01	11.29 0.05	11.90 -0.66	12.04 (0.8)*
4	11.62	11.65 0.03	11.61 -0.01	11.6 -0.02	11.68 0.06	12.46 0.84	12.38 (0.76)*
5	12.53	12.63 0.1	12.65 0.12	12.49 -0.04	12.56 0.03	13.80 1.27	13.38 (0.85)*

*the REF has been computed excluding University of Oviedo

V. CONCLUSIONS

The results of a facility comparison campaign involving a medium gain ridge horn, MVI-SH800, working at L and C band frequencies and equipped with an absorber plate to reduce the sensibility to the measurement set-up, have been presented. The antenna has been measured in 7 different facilities in Europe and USA, in the frame of the intercomparison activities based on high accuracy reference antennas supported by EurAAP, which have fostered fruitful discussion on the improvement of standard procedures for performance verification like facility comparison campaigns.

The measurements from the 7 different facilities are generally in very good agreement when compared to each other. The visible pattern agreement is confirmed by the equivalent noise level (pattern correlation) of less than ~ -30 dB. Very good agreement has been achieved also for performance parameters such as peak directivity and peak gain. Such results confirm the expected improvement with respect to the previous SH800 campaign (without absorber plate) where standard deviation errors were ~ 0.05 which corresponds to an EQN of - ~ 26 dB.

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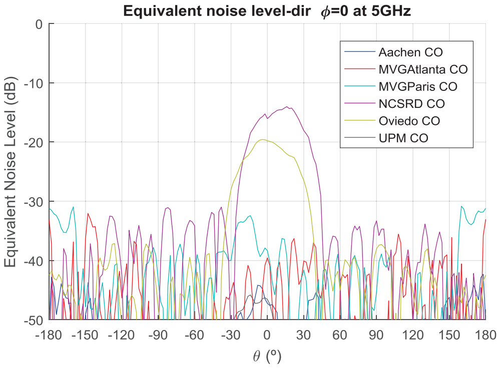

Figure 13. Equivalent noise level at 5 GHz, phi=0° w.r.t. theta for the directivity co-polar component.

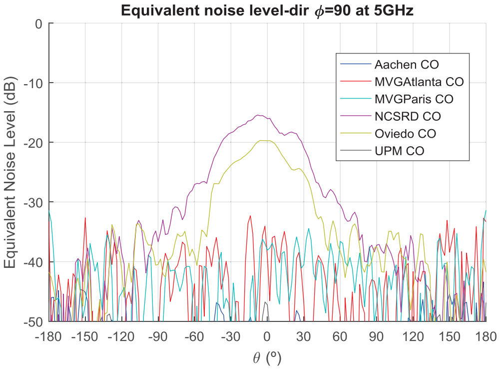

Figure 14. Equivalent noise level at 5 GHz, phi=90° w.r.t. theta for the directivity co-polar component.

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