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Investigations on Probe Phase Center Impact in Antenna Measurement Results Uncertainty for Spherical Near-Field Systems

G. Le Fur¹, F. Cano-Facila¹, L. Duchesne¹, D. Belot², K. Elis², L. Feat², A. Bellion², R. Contreres²

¹ R&D Department, MVG - SATIMO Industries, Villebon-sur-Yvette, France, Gwenn.le-fur@satimo.fr

² DCT/RF/AN, CNES (French National Space Center), Toulouse, France, Daniel.belot@cnes.fr

Abstract— This paper aims to provide an estimation of the probe phase center location impact in spherical Near-Field measurement systems. By using pattern results comparison the measurement uncertainty coming from the good knowledge of the probe phase center location will be quantified as function of the wavelengths and the measurement distances.

Index Terms—antenna measurement, measurement results uncertainties, Near Field system, probe phase center.

I. INTRODUCTION

Near Field techniques show good benefits for antenna measurement for many years. Uncertainties analysis for Near-Field antenna measurement system is well established by the well-known NIST 18 terms [1]. In this paper we focus investigations on the “probe z-position error”. This error appears when the distance from the center of rotation of the Antenna Under Test (AUT) to the phase center of the probe is different to that one considered in the Near-Field to Far-Field transformation process. If the phase center of the probe is well-known and consequently the measurement radius, this error is negligible. However, the phase center could change in a great way in frequency, especially by using wide band probes. Therefore, when measuring one a very large frequency range because the measurement distance is often considered constant for all the frequency points, there will not be a negligible z-position error. In fact, this is the situation in many measurement systems. Then it is interesting to investigate the error made as a function of the ratio between the maximum displacement of the probe phase center in the z direction (Δz) and the measurement distance considered. This error was estimated for a specific measurement system in [2]. This impact must also be shown by considering the wavelength of the measurement and the potential mutual coupling between the measurement probe and the AUT. The paper is organized as follow. First is briefly described the considered measurement system. Then is detailed the approach for the error estimation with the antenna pattern comparison chosen and the different cases studied. Finally are given the results uncertainties and some prospects.

II. CNES VHF NEAR-FIELD FACILITY

The measurement system considered is the single probe spherical near field measurement system located in the

chamber of the CNES in Toulouse France. This facility is dedicated to perform antenna measurement from 50 MHz to 200 GHz [3]. The chamber is shared by a compact range measurement system and a single probe Near-Field system. Above 400 MHz the compact range configuration is used. Below 400 MHz the Near-Field configuration is used. Nevertheless classical foam pyramidal absorbers are poorly efficient below 200 MHz. Therefore ripples due to reflections coming from the compact range reflector and from the chamber walls are present. In order to extend the operational measurement bandwidth down to 50 MHz a new wide band and dual polarized VHF probe has been designed and manufactured [2] (*cf.* Fig.1).

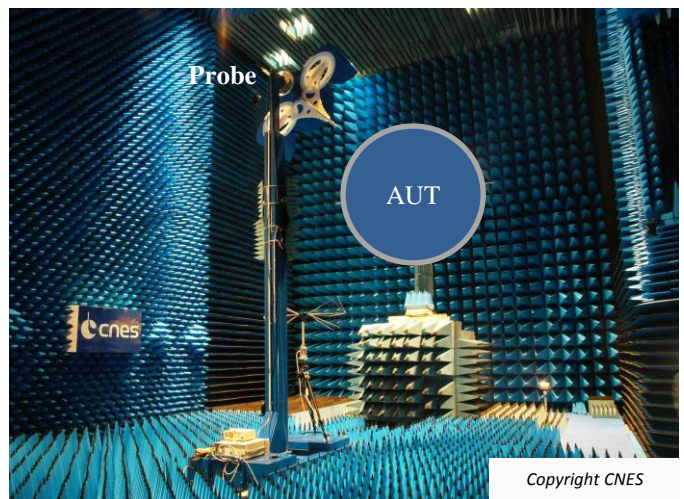


Fig. 1. Photograph of the dual polarized probe in the CNES VHF Near-Field system

III. INVESTIGATION DETAILS

A. Proposed approach for error estimation

In order to appreciate the error due to the probe phase center displacement, two main cases are considered. The first one consists in using the Mean Radius of Measurement (MRM) obtained by considering the mean location of the probe phase center on the measured frequency band. The second one consists in using the corrected Radius of Measurement (RM) obtained by considering the probe phase

center location for each frequency point. These two distances – MRM and RM – are involved in the Near-Field to Far-Field transform. Far-Field patterns are then compared to the reference pattern obtained by simulation. The approach used to compare the patterns is briefly described here after.

B. Antenna pattern comparison approach

The strategy to compare measured patterns in the Far-Field region is the one used in [4] within the EU Antenna Centre of Excellence where four different comparison approaches were presented in order to determine the accuracy of different measurement facilities. In our particular case, it was seen that the most appropriate comparison was the weighted logarithmic difference which is able to de-emphasize the noise and the large spikes. Two Far-Field antenna patterns are then compared using the weighted logarithmic difference. The weighted function W_{log} is composed by the $W_{n,3}$ noise function and the pattern weighting function W_p ($\beta = 0.3$) [4]. Thus the weighted logarithmic difference between two patterns $f_1(\theta, \varphi)$ and $f_2(\theta, \varphi)$ can be expressed by:

$$\Delta_{w,log}(\theta, \varphi) = W_{log}\Delta_{log}(\theta, \varphi) \quad (1)$$

With

$$\Delta_{log}(\theta, \varphi) = 20 \log_{10}f_1(\theta, \varphi) - 20 \log_{10}f_2(\theta, \varphi) \quad (2)$$

Each measurement result are compared to the simulated pattern (obtained by using FEKO EM simulation software) taken as reference. Once the difference has been computed, the mean (μ) and standard deviation (STD) values can be calculated in a usual way. These two factors are used as figures of merit to quantify the difference between the two patterns. Results are reported in section IV.

C. Using simulations of the measurement setup

First investigations are performed by using simulation of the CNES spherical Near-Field system including the model of the VHF wide band probe and an antenna under test. None other component of the system is present. AUT and probe are perfectly aligned and the AUT is rotated around ϕ and θ axis to obtain a full sphere Near-Field dataset. In such a way the two main errors considered are the probe z-position error and the mutual coupling between probe and AUT.

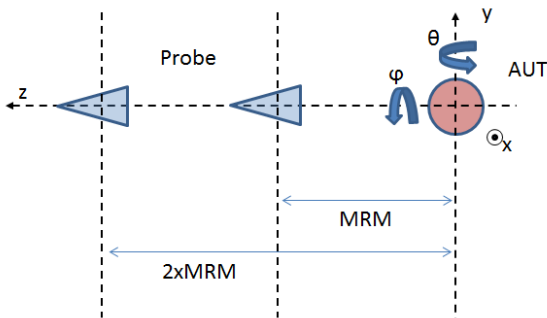


Fig. 2. Coordinate system and measurement radii

Two physical distances are considered. The second one (10 m) is twice than the first one (5 m) (see Fig.2). From those, MRM and RM electrical length are used to compute Far-Field pattern. The frequency range considered is from 50 to 200 MHz and the minimum sphere diameter including the AUT is 2.60 m. As an example, for this given AUT size and considering a measurement radius of 5 m, Far-Field region is reached for frequencies below 125 MHz. Above this frequency the effect of the probe phase center is thus expected bigger than the mutual coupling one. On the other hand below this frequency the mutual coupling effect is expected to be predominant. By increasing the measurement distance both effects should be mitigated. Results of the pattern comparisons in terms of μ and STD values are presented in section IV.

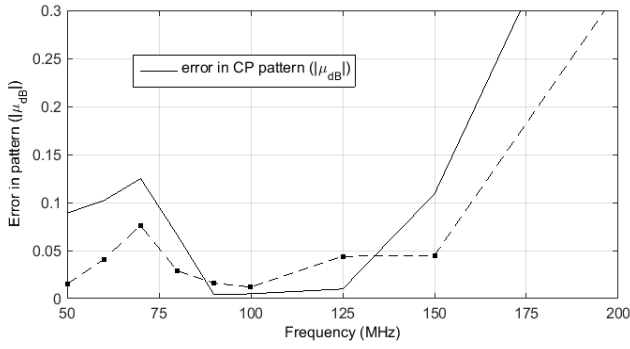
D. Using Measurements

Measurement campaign is just finishing in the CNES-VHF facility. Different AUTs with different sizes have been measured. Frequency ranges used are down to 50 MHz and up to 400 MHz. In contrast with the simulation of the measurement setup described above several error terms are involved in the measurement results uncertainties especially the one coming from the chamber reflectivity. Measurement results are currently processing in the same manner in order to appreciate the probe phase center contribution. Then only some preliminary patterns are provided as examples in the next section.

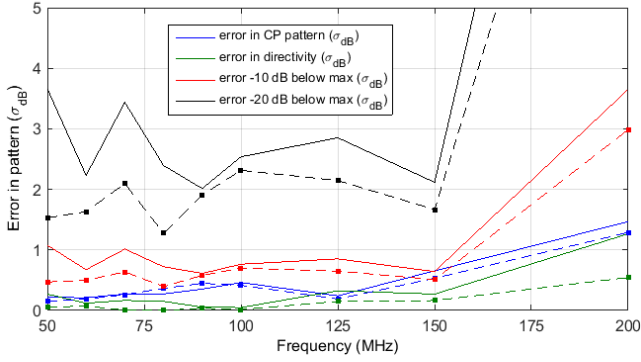
IV. RESULTS

A. Using simulations of the measurement setup

Results presented below are obtained by comparing four main cuts of the Far-Field patterns. Worst errors values are then retained. Plots report errors in terms of mean and standard deviations values of the weighted logarithmic differences on the whole frequency band. Obtained errors for the co-polarization, the directivity and the -10 dB and -20 dB below peak are reported. Solid lines refer to the results using the MRM and dashed lines to the ones using the good RM. A large benefit is observed by correcting the probe phase center location for the first measurement distance (see Fig.3.a and Fig.3.b). The z-probe phase center location was obtained through simulation. Its location relatively to the mean value over the frequency band is plotted in Fig.5. We observe bigger relative displacement for the low and the high frequency points. This behavior can be observed in the results obtained by using the small MRM where the Near-Field to Far-Field transform process is strongly involved.



(a)



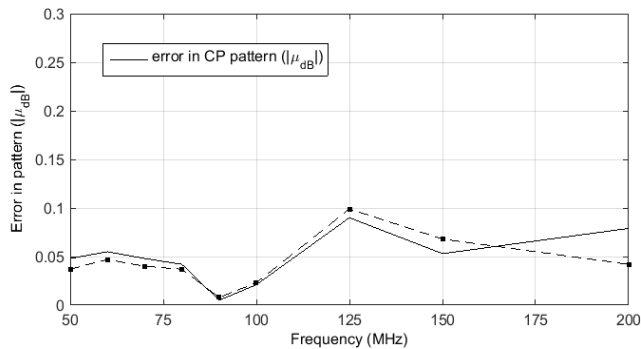
(b)

Fig. 3. Using MRM

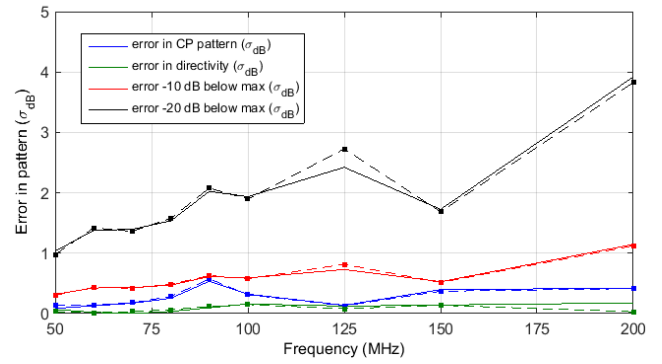
(a) Mean values of the weighed logarithmic differences

(b) STD values of the weighed logarithmic differences - Peak to peak errors

Concerning the twice measurement radius the benefit in correcting appears smaller (Fig.4.a and Fig.4.b). This can be first explained by Far-Field distance already reached for most part of the frequency band. A second explanation is the decreased ratio $\Delta z/\text{MRM}$ and then the reduced impact of the probe phase center displacement. However error levels are drastically reduced especially at low frequencies for the present case. By increasing the measurement distance is also reduced the mutual coupling between the AUT and the probe which involves in measurement uncertainties.



(a)



(b)

Fig. 4. Using 2xMRM

(a) Mean values of the weighed logarithmic differences

(b) STD values of the weighed logarithmic differences - Peak to peak errors

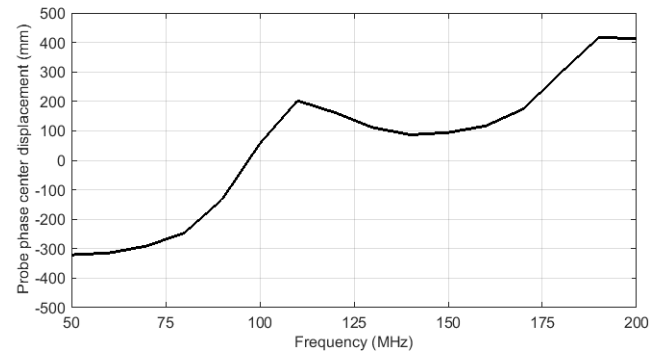


Fig. 5. Probe phase center location relative to its mean location.

B. Using measurements

As mentioned before measurement results processing are still under progress. Global results will be given for the conference. As examples are plotted two results of Far-Field patterns at 50 MHz. The minimum sphere size including the AUT is 1.4 m diameter and the measurement distance is 5.8 m. Fig.6.a presents the patterns obtained by using the MRM and Fig.6.b the ones by using the corrected RM. Co-polarization and cross-polarization for the two main cuts are reported to be compared with the simulation results. Very small differences can be observed between the two cases. Slight improvements are present on low levels e.g. on the cross-polarization patterns. Considering the AUT size, the frequency and the measurement distance these first results seem to show agreements with results for the larger distance taken in the simulation of the measurement setup.

V. CONCLUSION AND PROSPECTS

This paper proposes partial investigation on the probe phase center impact in antenna measurement results for a spherical Near-Field system. Pattern comparison approach is used to evaluate the probe z-position error. By using simulation of the actual considered system setup in VHF band reduced measurement results uncertainties are shown by correcting properly the measurement radius. The large frequency band and the different considered cases give insights on behaviors of the perturbations involved. For low frequency, increasing the measurement distance shows benefit on results uncertainties. This could be explained by the decrease of the mutual coupling and lower relative displacement of the probe phase center. Measurement data have to be provided to ensure these first observations. Different frequency ranges, measurement radiuses and AUT sizes must be considered in order to obtain a global observation of the probe phase center impact in spherical Near-Field measurement.

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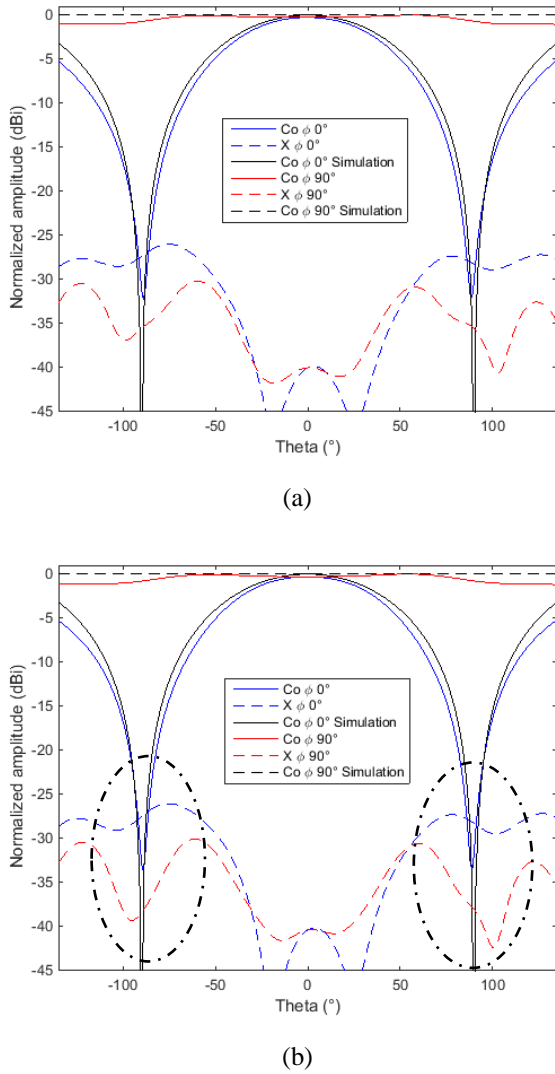


Fig. 6. Measured patterns results at 50 MHz
(a) using MRM - (b) using RM