Numerically Enhanced Antenna Measurement Technique

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***Abstract*—We address the measurement of antennas placed on a complex structure; the aim is to employ information on the platform geometry to significantly reduce the necessary number of samples for a given accuracy. We propose a measurement technique based on expressing the field via a set of numerically-generated basis functions; these basis functions are related to the radiation of specific sources placed on the platform. Results in a controlled synthetic environment are presented, with emphasis on the effect of noise and on the achievable sampling rate compared to the classical one prescribed by Nyquist criterion.**

I. Introduction

Nyquist criterion gives a lower bound to the number of sampling points where the field of a radiating structure must be measured in spherical coordinates to be able to express the field on any direction with arbitrary accuracy using spherical harmonics [1]. However, when one can exploit additional information, a smaller number of samples can be used [2]. In this contribution, we consider the case of an antenna placed on a electrically larger structure, called a *platform*.

The additional information we can leverage on is given by the spatial occupation of the antenna in isolation, its position on the platform, and the geometry of the platform itself.

II. Method overview

We denote with $\boldsymbol{E}(\theta,\phi)$, the field radiated by the antenna placed on the platform in the angular direction (θ,ϕ). We call it *target field*. We want to express it as a linear combination of N basis function $\boldsymbol{f}_n(\theta,\phi)$. With

$$\tilde{\boldsymbol{E}}(\theta,\phi) = \sum_n \alpha_n \boldsymbol{f}_n(\theta,\phi) \tag{1}$$

we want

$$\boldsymbol{E}(\theta,\phi) = \tilde{\boldsymbol{E}}(\theta,\phi) \tag{2}$$

Given L samples of the field $\boldsymbol{E}_\ell = \boldsymbol{E}(\theta_\ell,\phi_\ell)$, we enforce (2) on these points

$$\boldsymbol{E}_\ell = \sum_n \alpha_n \boldsymbol{f}_n(\theta_\ell,\phi_\ell) \tag{3}$$

and solve the linear system of equations resulting from (3) to determine to coefficients α_n. The basis functions are easy to evaluate on any angular direction, so, once the coefficient have been established, the linear combination (1) can be easily evaluated on any spherical point of interest. We call *reconstructed field* the field obtained evaluating (1) with the coefficients determined solving (3). If the basis functions are vector spherical harmonics, classical results apply to set the minimum angular step where samples $\boldsymbol{E}(\theta_\ell,\phi_\ell)$ have to be collected [1].

In this work, we consider numerically build basis functions, which exploits additional information on the platform and the antenna position to reduce the number of needed samples.

We build the basis functions considering a surface enclosing the main radiating part (i.e. the antenna placed on the platform) and evaluating numerically the field radiated by each elementary source in the presence of the platform. We use the Method of Moments (MoM) [3]. We generate triangular meshes on the surface surrounding the structure and on the one representing the platform, to use classical Rao-Wilton-Glisson (RWG) functions [4]. We compute the current induced on the platform by each elementary source and use that to evaluate the radiated field. Both electric and magnetic elementary sources are placed around the antenna, and the MoM problems are solved with an iterative method (GMRES) coupled with a fast algorithm to evaluate matrix-vector products [5]. As the independent elementary sources are placed only on a surface enclosing the antenna (not on the surface enclosing the whole structure), some residual discrepancy between the target and the reconstructed field is unavoidable. We analyze if the reduced number of sample points justifies the small difference.

A. Results

We test the method with synthetic data, to assess its performance in a controlled environment. Given the target field, we corrupt it with synthetic noise to represent actual thermal noise and imperfections in measurements. We consider signal-to-noise ratio (SNR) level of 40 dB and 30 dB. We consider a dipole antenna on a small ground plane placed on a plane mock-up (see inset in Figure 1). The working frequency is 3 GHz. The mock-up has wingspan and tip-to-tail dimensions around 1.2 m and 0.5 m, respectively, namely around 12 and 5 wavelenght. We should sample the field radiated by the antenna on the platform with a $3.5°$ step and the field radiated by the antenna in isolation with a $14°$ step [1]. We

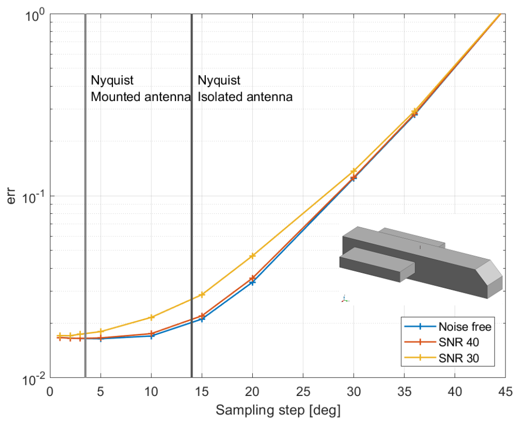

Fig. 1. Relative error (see (4)) for different SNR cases (average over 10 realizations). The inset shows the geometry used in the test.

have 617 RWGs on the mesh surrounding the antenna and around 50000 RWGs on the platform. We change the number of matching points L varying the angular sampling step from $1°$ to $45°$. Form each value, we compute the coefficients α_n solving (3) in the least squares sense and use them to evaluate the reconstructed field $\tilde{\boldsymbol{E}}$. We compare the target field $\boldsymbol{E}$ and the reconstructed field $\tilde{\boldsymbol{E}}$ on a 1 degree grid of the whole sphere. As a global figure of merit, we use the relative error

$$err = \|\boldsymbol{E} - \tilde{\boldsymbol{E}}\|_{S^2} / \|\boldsymbol{E}\|_{S^2}$$
$$\|\boldsymbol{f}(\theta,\phi)\|^2_{S^2} = \int_0^{2\pi}\int_0^{\pi} |\boldsymbol{f}(\theta,\phi)|^2 \sin(\theta)\,\mathrm{d}\,\theta\,\mathrm{d}\,\phi \qquad (4)$$

In Figure 1 we show a plot of the relative error (4) with respect to the sampling step. Results with SNR of 30 dB and of 40 dB are averaged over 10 realization. The sampling step prescribed by the Nyquist criterion for the antenna in isolation and the mounted antenna are highlighted with thick grey lines.

In Figure 2 and in Figure 3, we show two cuts of the target field, the reconstructed field, and their pointwise difference, for two level of SNR, for sampling step of $15°$ and $20°$, respectively. The agreement between the target and the reconstructed field is very good in both the cases.

B. Conclusion

We presented some results on the use of numerically built basis functions to expand measured field of an antenna positioned on a complex platform. The basis functions are generated computing the field radiated by elementary sources placed on a surface enclosing the antenna. These functions account for the geometry of the platform and the spatial occupancy of the antenna, and allow a good reconstruction of the radiated field from few measured samples. Tests with synthetic data show a good performance against noise and down-sample with respect to the classical Nyquist criterion.

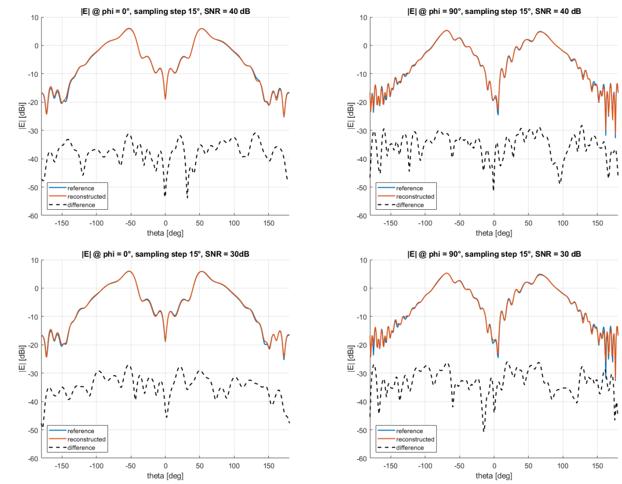

Fig. 2. Reference FF and reconstructed FF patterns. To build the reconstructed pattern, samples are acquired with a $15°$ step and SNR values are 40 dB (top row) and 30 dB (bottom row).

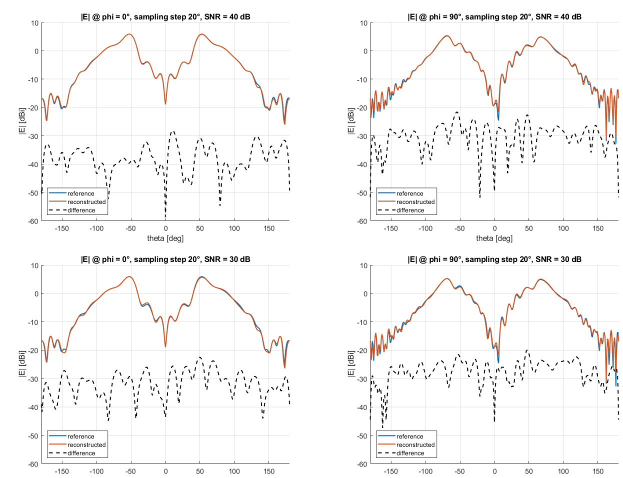

Fig. 3. Reference FF and reconstructed FF patterns. To build the reconstructed pattern, samples are acquired with a $20°$ step and SNR values are 40 dB (top row) and 30 dB (bottom row).

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