A Study on Near-Field to Far-Field Transformation for Antenna Measurements in Non-Ideal Environments by using Spherical Harmonics

Leandre E. S. Silva, Guilherme S. Rosa, and José R. Bergmann

***Abstract*— In this paper, we present a study on near-field to far-field transformation algorithms via a spherical wave expansion method for antenna measurements. We describe a time domain filtering procedure that allows high accurate far-zone results in non-ideal environments. Preliminary results demonstrate that technique is a promising tool for computational-assisted antenna measurement facilities.**

***Keywords*— Near-field to far-field transformation, antenna measurements, spherical harmonics expansion.**

I. Introduction

The electromagnetic characterization of an antenna requires accurate measurements of it radiated fields under free-space conditions. Anechoic chambers can emulate such conditions, but direct far-zone field measurements should be addressed in the Fraunhofer region: the minimum acceptable far-zone distance increases linearly with the frequency, and with the square of the largest dimension of the antenna under test (AUT) [1]. Precise measurements require unfeasible huge facilities especially for large reflector antennas at high operating frequencies. On the other hand, a more practical measurement set-up characterizes the radiation of an AUT in the near-field (using compact chambers) and then it far-field radiation characteristics are numerically reconstructed via a near-field to far-field transformation (NF2FFT) [2], [3], [4], [5]. In this paper, we present a study on the spherical harmonics representation of the near-zone fields of an AUT through a semi-analytic algorithm in the frequency domain (FD). In addition, we evaluate the transient response of such AUT via an inverse Fourier transform. We investigate some echo suppression techniques by considering a representative scenario where an array of dipoles is placed in the neighboring of a large metallic plate. This plate is used here to emulate an (undesirable) object inside an anechoic chamber that will significantly disrupt the original environment. Preliminary results demonstrated that an early-time filter (a time-gating (TG) filter) enables the suppression of the undesirable scattering due to the plate in the time domain, and the subsequent Fourier transformation allows us to obtain very accurate far-field results in the frequency domain by using our spherical NF2FFT (SNF2FFT) algorithm. Further works are in progress in order to investigate other echo suppression techniques.

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II. Formulation Overview

To illustrate the properties of the echo suppression technique based on TG, let us consider a representative scenario where a planar array of four short dipole antennas is inside an anechoic environment. Suppose now this medium is disturbed by the presence of a scattering object such as those may be present in non-ideal or semi-anechoic chambers: a wall, the ground, metallic objects, an imperfect RF absorbing material, etc. Without loss of generality, we consider that a large metallic plate is placed at $d = 87.5$ cm away from the center of the array as depicted in Fig. 1. The spatial position and the relative dipole moment ($P = I\ell$, see [6, Sec. 3.7] for more details) of the antennas #1 to #4 are presented in Table I, where $\lambda_0 = 30$ cm. The electromagnetic fields at $r_0 = 2\lambda_0$ are presented in Fig. 2, and the perturbation due to the metallic plate clearly defaces this near-zone radiation pattern. If we transform these fields to the far-zone at $r = 100\lambda_0$ by using a conventional SNF2FFT algorithm [4], we can straightly obtain the magnetic field component H_ϕ shown in Fig. 3. It is apparent this FD far-field result is polluted by the scatterer.

When we Fourier-invert the near-zone fields by considering an exciton due to a band-limited transient pulse (centered at

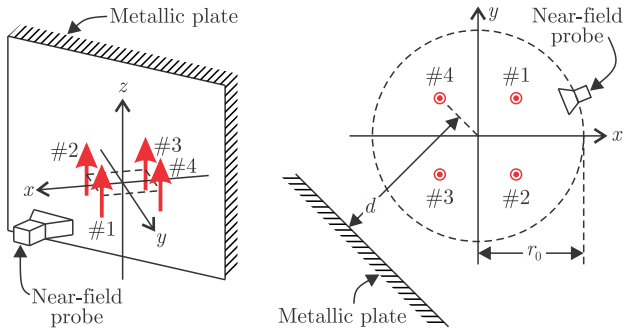

Fig. 1. Orthogonal and top views of the antenna array (dipoles #1, #2, #3, and #4) in the neighborhood of a large metallic plate.

TABLE I

Antenna	Position (r, θ, ϕ)	Moment P (A m)
#1	$\left(\lambda_0/(4\sqrt{2}), 90°, 45°\right)$	1
#2	$\left(\lambda_0/(4\sqrt{2}), 90°, 315°\right)$	1
#3	$\left(\lambda_0/(4\sqrt{2}), 90°, 225°\right)$	$\exp(j\pi/2)$
#4	$\left(\lambda_0/(4\sqrt{2}), 90°, 135°\right)$	$\exp(j\pi/2)$

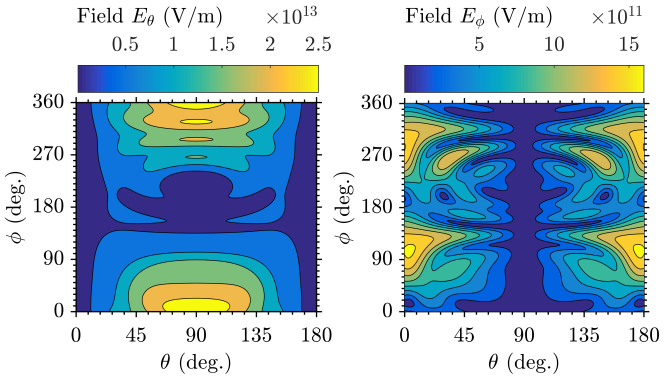

Fig. 2. Absolute value of the electric field components E_θ and E_ϕ observed at $r = r_0 = 2\lambda_0$, for 1 GHz.

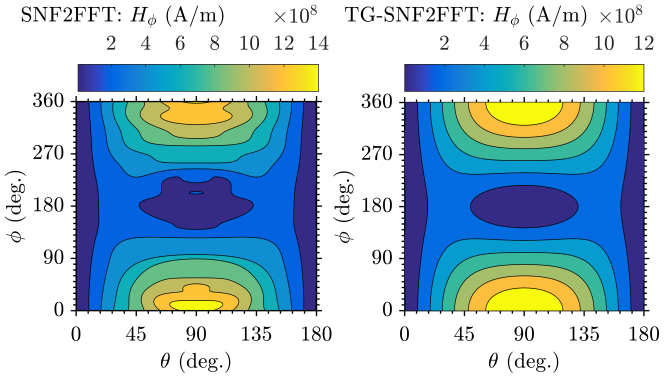

Fig. 3. Absolute value of the magnetic field component H_ϕ at $r = 100\lambda_0$ obtained via the conventional SNF2FFT (left) and by the TG-SNF2FFT (right) of the near-zone fields shown in Fig. 2. The two results are for 1 GHz.

1 GHz), we obtain transient field response as presented in Fig. 4. In the time domain, we can promptly recognize the *direct* contribution due to the antenna array being received before its reflections on the metallic scatterer. By estimating the free-space propagating time interval from the sources to the near-field probes, we can establish a time-gating filter at $t = 3$ ns for eliminating the late-time echo. Finally, we can Fourier-transform such filtered near-zone fields to the frequency domain and then employ our SNF2FFT algorithm [4]. Fig. 3 shows a comparison of the far-zone H_ϕ field component computed via the conventional SNF2FFT and the TG-SNF2FFT approach. In the latter, the symmetry of the fields was recovered properly. In addition, Fig. 5 compares the fields computed over the plane $\theta = 90°$ versus the exact closed-form solution [6, pp. 152–154] for the antenna array.

III. Summary and Work in Progress

The high accuracy of the TG-SNF2FFT demonstrates that this technique is a promising tool for antenna measurements in non-ideal environments. Further works are in progress in order to investigate other echo suppression techniques for reducing unavoidable perturbations by using a combined time-gating and spherical harmonics filtering.

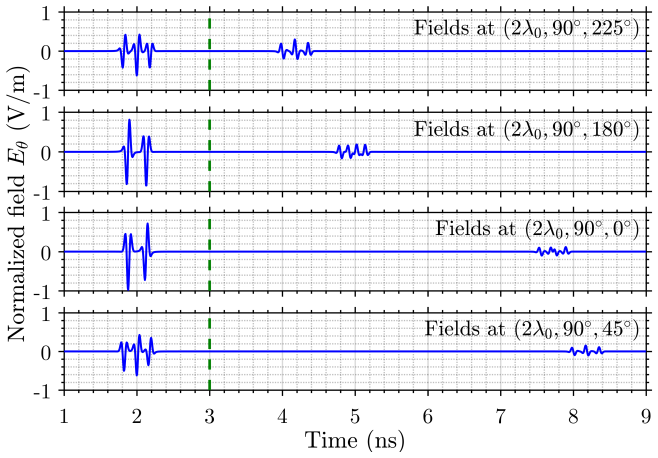

Fig. 4. Normalized transient response for the electric field component E_θ observed at four different points over the xy-plane (i.e., for $\theta + 90°$): $\phi = \{225°, 180°, 0°, 45°\}$. The vertical dashed-line indicates a time-gating frontier for filtering the long-time field scattered by the metallic plate.

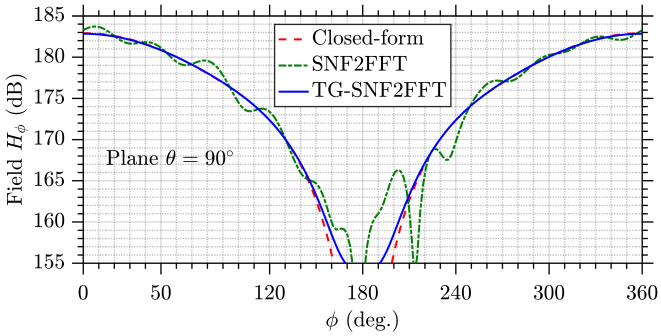

Fig. 5. A comparison of the magnetic field component H_ϕ (at $\theta = 90°$ and $r = 100\lambda_0$) in decibel obtained via the conventional and the time-gating SNF2FFT versus the exact closed-form solution from [6].

Acknowledgment

The authors would like to thank Intel Corporation for providing us the Intel Fortran compiler with the MKL numeric library. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code PROCAD 068419/2014-01.

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