A-posteriori Correction Methods for Antenna Measurement by Wavelets

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Context

- In the domain of antennas, design and prototyping phases are always followed by a measurement phase, which goal is to reliably assess the reached performances with respect to the expected specifications.
- The accuracy is limited by perturbations : spurious reflections, coupling, noise,...
- Many post-processing methods already exist to extend the capabilities of measurement devices

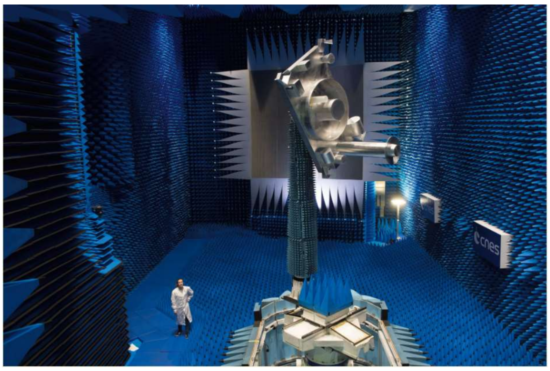


Figure: CNES anechoic chamber

Objectives

Improve antenna measurement post-processing and correction with wavelets

- Introduce spherical wavevelet expansion as tools instead of traditional plane-waves or spherical harmonics
- Improve deconvolution method in term of localization, computational time and compression
- Test of the developped methods on simulations and real measurement data

1D wavelets

Wavelet family

- Constructed so as to capture the various scales of variations of the signal
- Composed of [1] :
  - Mother wavelet ψ_1
  - Daughter wavelets : dilated versions of the mother wavelet ψ_n
  - Scaling function ϕ
  - Translated versions of these functions
- Properties:
  - Orthonormal basis localized in both space and spectrum.
  - Very well-known analysis and data compression tool

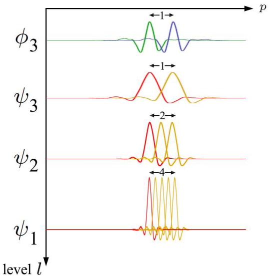


Figure: 1D wavelet basis [1]

Spin Spherical Wavelets

Properties [2]

- Spherical wavelet theory developped with sampling theorems [3]
- Scaling function Φ and wavelet functions at various scales Ψ_j for $j \in [J_0, J_{max}]$
- Good localisation properties both spatially on the sphere and in harmonic space
- The spin : parameter $s = 0$ (scalar data) $s \pm 1$ (vectorial data), also linked with the polarisation

$\Rightarrow$ Extraction of spatially localised, scale-dependent features in vectorial signals of interest, in spherical geometry

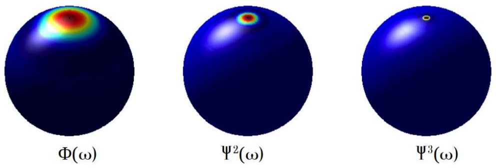


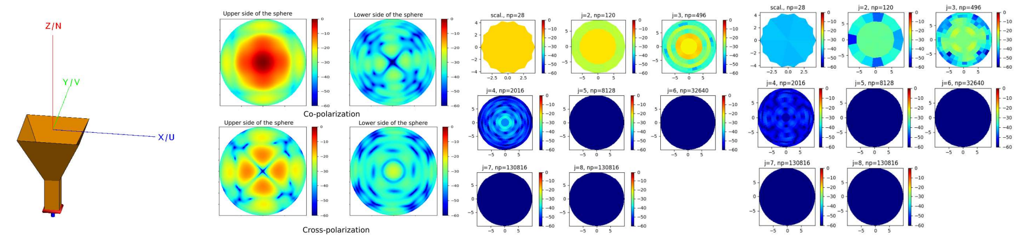
Figure: Axisymmetric scale discretised spherical scaling and wavelet functions for scales $j \in \{2, 3\}$.

Multiresolution Analysis of Usual Antenna Radiation Pattern With Spin Spherical Wavelets

Pyramidal horn antenna

$\Rightarrow$ use of the package s2let [2]

- Properties:
  - TE10, TE01 (with a 90° phase shift) modes square guide
  - 6.5 GHz
  - Circularly polarized
  - Aperture of 0.14 m × 0.14 m
  - Simulated with Altair Feko
  - Method of moments
  - 3^{rd} Ludwig definition for co and cross-polarisations
- Observations:
  - The higher the order of the wavelet, the smaller the variations
  - The co and cross-polarizations decomposition differentiable by mean of the spin parameter
  - More interesting for antennas with fastest variations like large antennas



(a) Horn antenna (b) Radiation pattern (c) Co-polarisation, spin=+1 (d) Cross-polarisation, spin=-1

Figure: Configuration of the horn, radiation pattern (dB) and multiresolution wavelet coefficients associated with the scaling function and the different spin spherical wavelet levels for $j \in \{1, \cdots, 8\}$ the horn antenna (dB)

The antenna measurement as a convolution

Current work

- Equivalence principle
- Reciprocity theorem

$\Rightarrow$b=h$\circledast g$ with b the signal measured on the port of the antenna, h a field corresponding to the radiation of the probe in the environment nearby the antenna ang g the radiation pattern of the antenna.

Deconvolution methods for antenna measurement correction

Test zone field compensation [4]

- Correction of localized defaults
- Usualy implemented with spherical harmonics
- Objective is to implement it with spin spherical wavelets

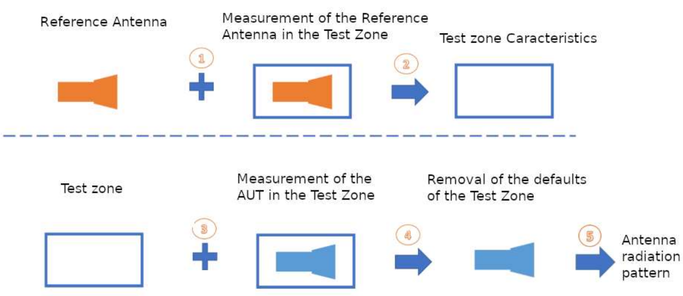


Figure: Test zone field compensation method

Published papers

[1] Quennelle, A., Chabory, A., Pouliguen, P., Contreres, R., Le Fur, G. (2022, March). Analysis of Antenna Radiation Patterns by Means of Spherical Wavelets. In 2022 16th European Conference on Antennas and Propagation (EuCAP) (pp. 1-5). IEEE.

[2] Quennelle, A., Chabory, A., Pouliguen, P., Contreres, R., Le Fur, G. (2022, Juin).Analyse de diagrammes de rayonnements d'antennes au moyen d'ondelettes sphériques. 22ièmes Journées Nationales Microondes.

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[1] S. G. Mallat, "A theory for multiresolution signal decomposition: the wavelet representation," IEEE transactions on Pattern Analysis and Machine Intelligence, vol. 11, no. 7, pp. 674–693, 1989.

[2] B. Leistedt, J. D. McEwen, P. Vandergheynst, and Y. Wiaux, "S2let: A code to perform fast wavelet analysis on the sphere," Astronomy Astrophysics, vol. 558, p. A128, 2013.

[3] J. D. McEwen and Y. Wiaux, "A novel sampling theorem on the sphere," IEEE Transactions on Signal Processing, vol. 59, no. 12, pp. 5876–5887, 2011.

[4] J. T. Toivanen, T. A. Laitinen and P. Vainikainen, "Modified Test Zone Field Compensation for Small-Antenna Measurements," in IEEE Transactions on Antennas and Propagation, vol. 58, no. 11, pp. 3471-3479, Nov. 2010, doi: 10.1109/TAP.2010.2071335.

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