



Amirkabir University of Technology
(Tehran Polytechnic)

Application of Wavelet on Electromagnetic Integral Equation

Mohammad Mahdi Elyasi
Supervisor: Dr. Moradi

Faculty of Electrical Engineering

January 29, 2025

Outline

- 1 Brief Overview
 - Importance of Integral Equations
 - Motivation of Using Wavelet
- 2 Wavelet's Overview
 - Wavelet Basis
 - Types of Wavelets
 - Advantages of Wavelet
- 3 Relation between IE and Wavelet
 - Types of Integral Equations
 - Challenges with Traditional Methods
 - Why Wavelet Help
- 4 Applications
 - Mathematical Foundation
 - Solved Case
- 5 Results
- 6 Conclusion
- 7 References

- Basics of wavelets.
- Overview of electromagnetic integral equations.
- Applications and results.

Importance of Integral Equations

- Provide a mathematical framework for solving electromagnetic problems.
- Convert differential equations into a solvable integral form.
- Enable numerical solutions for complex geometries and boundary conditions.

$$f(x) = \lambda \int_a^b K(x, t) \phi(t) dt + g(x)$$

Motivation of Using Wavelet

- Efficient representation of functions and signals.
- Localized analysis in both time and frequency domains.
- Reduction in computational complexity for solving integral equations.

- Wavelet basis functions provide localized representations of signals.
- Constructed through dilation and translation of a mother wavelet.
- Enable sparse representation of complex signals.

$$\psi_{j,k}(x) = 2^{j/2} \psi(2^j x - k), \quad k \in \mathbb{Z}$$

Types of Wavelets

- Haar wavelets: Simplest wavelets with step-like functions.
- Daubechies wavelets: Compactly supported wavelets with various smoothness.
- Morlet wavelets: Used for time-frequency analysis.

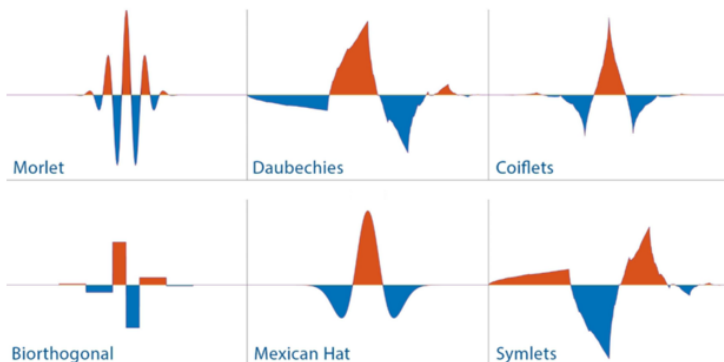


Figure 1: Different Wavelets.

Advantages of Wavelet

- Multi-resolution analysis for efficient signal representation.
- Localized analysis in time and frequency domains.
- Reduced computational complexity for large-scale problems.

Types of Integral Equations

- Fredholm integral equations: Defined over a fixed range.
- Volterra integral equations: Defined over a variable range.
- Boundary integral equations: Commonly used in electromagnetic problems.

$$f(x) = \int_a^x K(x, t)\phi(t) dt + g(x)$$

Volterra IE

$$f(x) = \lambda \int_a^b K(x, t)\phi(t) dt + g(x)$$

Fredholm IE

Challenges with Traditional Methods

- High computational cost for large-scale problems.
- Poor convergence for complex geometries.
- Difficulty in handling multi-scale behavior.

Why Wavelet Help

- Provide sparse representations of integral operators.
- Reduce computational complexity with efficient algorithms.
- Handle multi-scale behavior effectively.

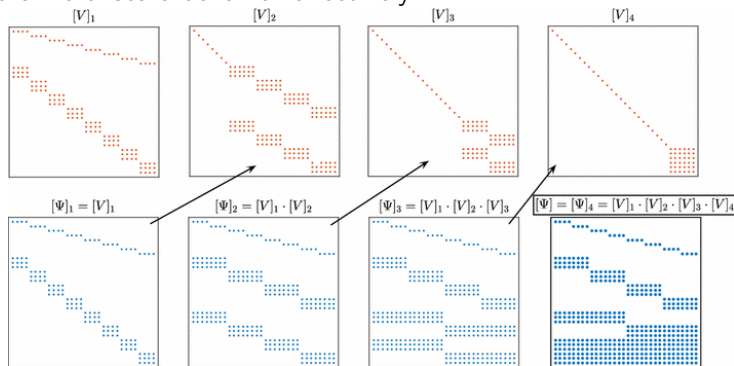


Figure 2:Example Sparse Matrix

- Underlying mathematical principles of wavelet theory.
- Connection between wavelet transforms and integral equations.
- Basis for developing efficient computational algorithms.

$$\sum_{j=0}^{n-1} k(\theta_i - \theta_j) \rho(\theta_j) w_j = f(\theta_i), \quad i = 0, 1, \dots, n-1.$$

$$\mathbf{K}\boldsymbol{\rho} = \mathbf{f},$$

Solved Case

- Case study of wavelet application in a real-world problem.
- Comparison with traditional methods.
- Demonstration of improved efficiency and accuracy.

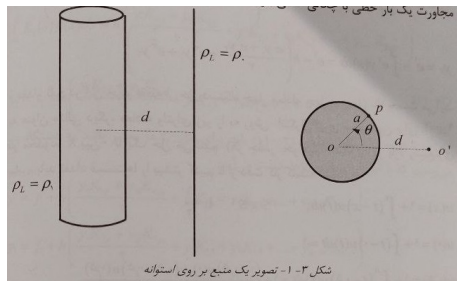


Figure 3:Case Study

Results

- Solved Case for two different compilers," Matlab and Python".

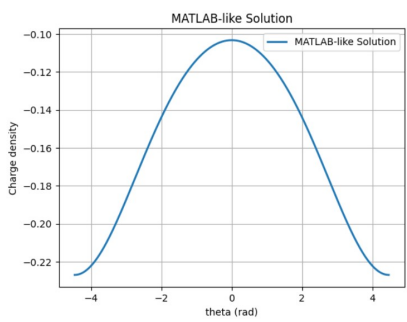


Figure 4:MATLAB-like Solution

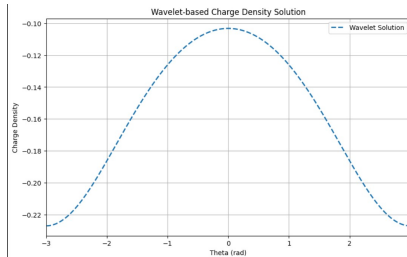


Figure 5:Wavelet-based Charge Density Solution

- Extraction of Coefficient with Multi-Resolution method.

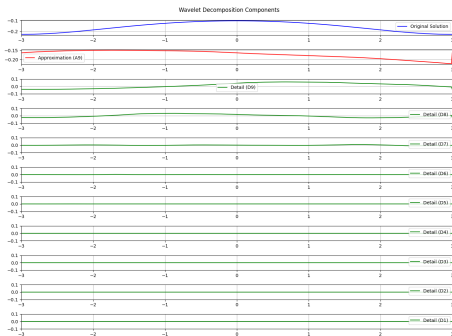


Figure 6: Detailed and Approximation

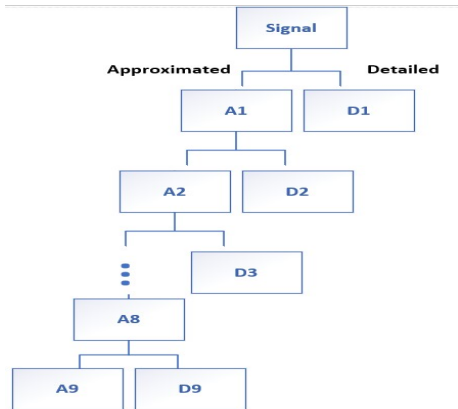


Figure 7: Tree Graph

Conclusion

- Benefits of wavelets for electromagnetic integral equations.
- Wavelet or other methods.

- 1 G.Moradi, Advanced Engineering Mathematics, AmirKabir University Of Technology, 2012 .
- 2 I. Daubechies, Ten Lectures on Wavelets, Society for Industrial and Applied Mathematics, 1992.
- 3 Github link, Application of Wavelet on EFIE at <https://github.com/MohammadMahdiElyasi/Application-of-Wavelet-in-Elctromagnetic-Integral-Equation>.

Thank you for your attention!



Amirkabir University of Technology
(Tehran Polytechnic)