



Amirkabir University of Technology  
(Tehran Polytechnic)

# Application of Wavelet on Electromagnetic Integral Equation

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# Brief Overview

- 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

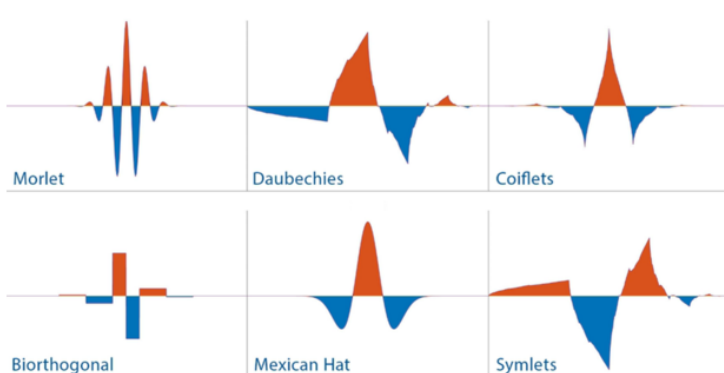
- Efficient representation of functions and signals.
- Localized analysis in both time and frequency domains.
- Reduction in computational complexity for solving integral equations.

- 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.



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**

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

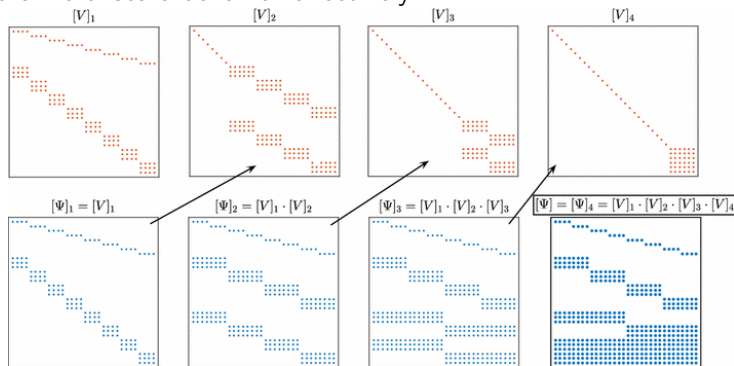
**Fredholm IE**

# 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.



Example Sparse Matrix

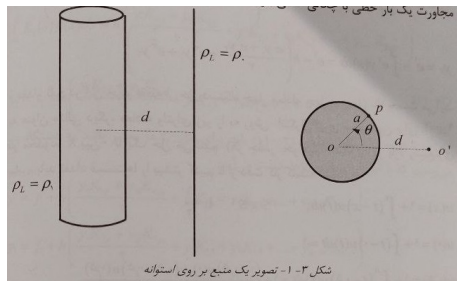
- Underlying mathematical principles of wavelet theory.
- Connection between wavelet transforms and integral equations.
- Basis for developing efficient computational algorithms.

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

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

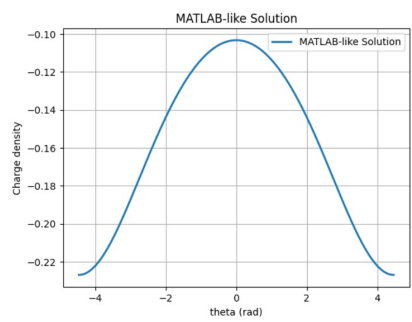
# Solved Case

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

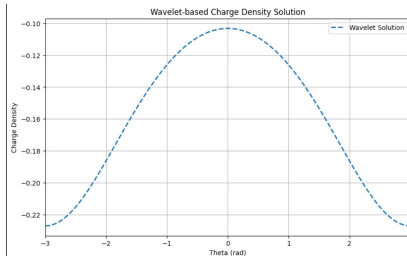


## Case Study

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

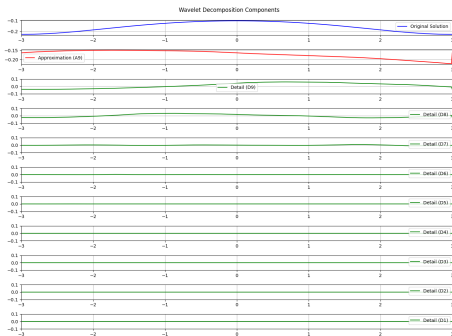


MATLAB-like Solution

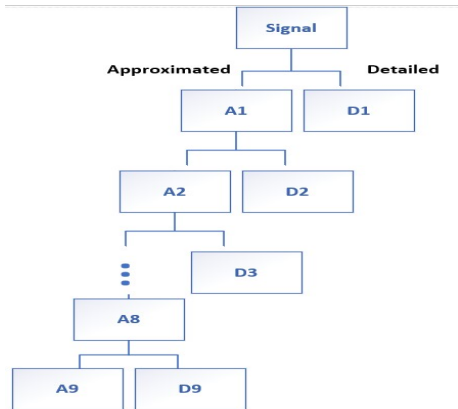


Wavelet-based Charge Density Solution

- Extraction of Coefficient with Multi-Resolution method.



Detailed and Approximation



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!**



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