Chapter 3
Wavelets in Boundary Integral Equation:
Applications in Radiation Problems

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ABSTRACT

Wavelet transforms and wavelet bases are widely used for analyzing and solving problems related to science and engineering techniques. This growth is mainly due to specific properties that result from decompositions on wavelet bases. In this chapter, the authors propose the electromagnetic modeling of wire antennas by two different methods: the method of moment's procedure matching point and the moments-wavelets method for solving the integral equation and modeling the characteristics of each structure. A detailed reminder on wavelet theory: definition, multi-resolution analysis, different families, wavelet properties, and use of wavelet bases in the method of moments. In the second part, the dipole antenna, loop antenna, and helix antenna are examined in order to demonstrate the advantages of MoM-wavelets compared to the method of moments with the traditional bases.

INTRODUCTION

The numerical approximation of Maxwell's equations, computational electromagnetics (CEM), has emerged as a crucial enabling technology for radio-frequency, microwave, and wireless engineering. The art of computation of electromagnetic (EM) problems has grown exponentially for three decades

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due to the availability of powerful computer resources. Solving electromagnetic problems requires the application of Maxwell's Equations with the appropriate formulation and boundary conditions. Many powerful numerical analysis techniques have been developed in this area in the last 50 years (Constantine, 2005), (J. Orfanidis, 2010), (F. Harrington, 1992).

The aim of this chapter is to provide an introduction to computational electromagnetics (CEM) with a focus on the most popular technique used in contemporary research and development projects. The focus is on the solution of Maxwell's equations by means of the method of moments (MoM) and wavelets. Wavelets found their application in solving integral equations, resulting in sparse impedance matrices. This is due to features of vanishing moments, orthogonality and multiresolution analysis in wavelets (Jaideva et al., 2009; Mallat, 2009; Rickard, 2007).

This chapter is designed to serve as an introduction to computational electromagnetics for radio-frequency applications. It assumes the reader has completed typical undergraduate courses in electro-magnetic field theory, and has some basic knowledge of antenna design and microwave systems.

Solving electromagnetic problems requires the application of Maxwell's Equations with the appropriate formulation and boundary conditions. The chapter starts with a review of the electromagnetic theory pertinent to moment method problems. We will summarize Maxwell's Equations and formulations for radiation, and derive Green's functions introduced in those relationships (Wang, 1993).

Section 1 is devoted for formulation theories of the integral equation, using Green's function. In this section we introduce the method of moments (MOM), a numerical technique used to convert these integral equations into a linear system that can be solved numerically using a computer.

In Section 2 a detailed reminder on wavelet theory: definition, multiresolution analysis, different families, wavelet properties and use of wavelet bases in the method of moments. Section 3 presents applications of wavelets in solving integral equations. Several examples have been study to illustrate the method of moments-wavelets; it is applied to analysis and modeling of Dipole, circular and helix antenna.

Review of the Electromagnetic Theory

Electromagnetics, the study of electrical and magnetic fields and their interaction, has been one of the core technologies of the twentieth century, and shows every sign of continuing this into the twenty-first. Whilst there are many useful ways of subdividing the field, power frequency versus radio frequency, or alternatively quasi-static versus full-wave, is one of the most insightful here. This section focusses exclusively on radio-frequency, full-wave electromagnetic modeling, as typically encountered in communication systems (Balanis, 2005; Harrington, 1992).

Maxwell's Differential Equations

The core of modern electromagnetic engineering is of course Maxwell's equations. In the present thesis we will limit the analysis to the time-harmonic electromagnetic fields, described by the complex-valued vector fields $\vec{E} = \vec{E}\left(\vec{r}\right)$ and $\vec{H} = \vec{H}\left(\vec{r}\right)$ called the electric field strength vector and magnetic field strength vector, respectively.

$$\vec{E}\left(\vec{r},t\right) = Re[\vec{E}\left(\vec{r}\right)e^{i\omega t},\ \vec{H}\left(\vec{r},t\right) = Re[\vec{H}\left(\vec{r}\right)e^{i\omega t} \tag{1}$$