CHAPTER 1. INTRODUCTION

Scientists and engineers frequently use computer simulations to gain insight into research and design problems. These computationally intense techniques often generate extremely large data sets that cannot be adequately analyzed and interpreted using traditional graphical approaches. As a result, visualization and its related techniques are becoming increasingly indispensable as a computational analysis tool.

Visualization techniques have been continually used to interpret large sets of empirical data in a variety of scientific fields, e.g. medicine (CAT and MRI scans), aerospace (wind tunnel analysis), weather forecasting, etc. Recent advancements in computing power have led to the implementation of more computationally intense methods and algorithms. These computational techniques have enabled scientists and engineers to simulate quantities that cannot be physically measured. Coupling computational methods with these visualization and analysis techniques produces an overall scientific tool that is unparalleled.

The objective of this research is to apply this visualization and analysis approach to computational electromagnetics in the area of antenna structures. By doing so we hope to provide insight into the behavior of the fields generated by antennas, as well as the currents induced on the structures. Armed with an understanding of these quantities, we might then be able to develop a better explanation of various electromagnetic radiating mechanisms.

1.1 Motivation

Antenna designers frequently attempt to understand the operation of an antenna using radiation patterns, impedance data and resonant frequencies. While these quantities give figures of merit of the antenna in a system, they do not provide essential insight into the governing radiating mechanisms. One way to gain such an insight is to view the fields and currents present on a radiating structure. However, it is quite difficult to experimentally measure electromagnetic field quantities near an antenna without altering its operation [1]. In the past, these experimental difficulties have limited the progress in understanding antenna structures.

Computational methods offer a solution to this problem. By simulating the operation of an antenna we can obtain electromagnetic field data near (or even internal to) a radiating structure. Now the primary concern becomes how to analyze the data. Since we are typically presented with multi-dimensional scalar or vector field data, visualization techniques are often necessary to perform the analysis. Visualization allows the data to be analyzed from a unique, global perspective. This format is well suited for analytical investigations and can also be used as a powerful debugging tool during modeling and simulation [2].

In addition to the visualization techniques described above, we may want to develop analysis tools to aid in the interpretation of the data. By employing image-processing concepts, electromagnetic waves that propagate with different velocities (both speed and direction) can be detected and filtered. This tool is necessary due to the wave nature of electromagnetic radiation. Image-processing techniques allow us to distinguish between standing and traveling waves. Additionally, if an antenna supports several different propagating waves (or modes), we can use this tool to analyze each mode independently. This is particularly useful when one wave is much larger in amplitude (dominant) than the other modes. If the modes are viewed concurrently, the effect of the non-dominant modes may be masked due to dynamic range problems. However, by filtering and analyzing one mode at a time we can fully understand the effect of each mode.

From the above discussion we can see why visualization and the related analysis techniques are important in antenna design. This thesis documents the development of these methods. Additionally, illustrative applications are shown in the context of outputs from a finite-difference time-domain (FDTD) computational code.

1.2 Organization

Chapter 2 discusses the development of a visualization capability. The operations needed to transport data from a computational code to a visualization package are explained. An overview of the visualization software is given. Methods of visualizing vector information are also discussed. An example of the visualization technique is then given in Chapter 3. FDTD data for a microstrip patch antenna is visualized. A comparison is performed between the visualized data and the theory of operation for the microstrip patch in order to show that radiation mechanisms can be obtained visually.

The image-processing techniques are developed in Chapter 4. Principles of the Fast-Fourier Transform (FFT) and Gabor filter are reviewed in order to provide a topological understanding of the process. Also, strategies for determining wave properties are given. An example of image-processing techniques is given in Chapter 5, where a rectangular waveguide is simulated in the FDTD code. Several modes are excited in the waveguide and the image-processing techniques are used to filter the various modes. For completeness, the results are compared to waveguide theory (field distributions, propagation constants, etc.)

Chapter 6 reviews what was accomplished and discusses limitations of the techniques presented in the thesis. Also, an explanation of how this work can be applied to the analysis of radiating structures is given along with a discussion of directions for future research.