Small Antenna Design
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by Douglas B. Miron, Ph.D.
I dedicate this work to my mother,
Florence Ethel Coolidge.
She gave me love, liberty, and a backbone.
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Miniaturization of electronic systems has accelerated over the last few decades and this process feeds expectations for even smaller components and systems in each new generation of equipment. Antennas have not been exempt from this pressure to be made smaller. Often, the result has been the use of antennas that are reduced in size without regard to their performance. This has led to needlessly poor system efficiency and reduced range. In this text we discuss the limitations on small antenna performance, possible trade-offs, recent developments, detailed design and optimization.

Antenna performance is fundamentally a function of size measured in wavelengths at the operating frequency. “Electrically small” antennas are those that are small compared to the wavelength, not necessarily small compared to the people who use them. The wavelength at the middle of the AM broadcast band is 300 m, so a tower 30 m tall is called electrically small even though it’s 15 times the height of a tall man. Small in the antenna business can mean “electrically small,” “low profile,” or “physically small.” Historical applications have included mine communications, broadcast transmission and reception, and mobile radio communication for both military and civilian uses. Present and future applications include the historical ones plus mobile telephones and handheld combinations of telephones and wireless data links for video and computer mobile networks, and wireless data networks that include both stationary and mobile elements. Versions of these networks are being designed and deployed in the obvious area of personal communications, and areas as diverse as medical monitoring and industrial production. The performance and efficiency (battery life, for example) of any of these systems depend in a very basic way on each device’s ability to get its signal out and capture the signals from the other elements in the network. The antenna is the component that does it.

The intended reader for this book is the design engineer with a B.S.E.E. degree. Chapter-end problems have been written so that the book can also be used in a senior-level elective course. Most people graduating from such a program have an exposure to electromagnetic theory but no experience in RF circuits or actual antennas. Some mathematics is necessary to understand the concepts
presented, but few derivations are given. Each topic will begin with a discussion of the physical principles involved. The simplest possible illustration will be used first, one with analytic results available if possible. Then more complex and more practical versions of the topic will be presented. The emphasis is on the intelligent use of formulas where available and applicable, and numerical modeling. The analytic results for simple structures not only provide useful guidance in themselves, but they also serve as checks or standards for the numerical modeling process. The ideal situation is achieved when analysis, numerical simulation, and experimental results all agree, and published results are used whenever possible.

A major concern of this work is to bring small antenna design into the current computational environment. Familiarity with the Windows operating systems, C++, and MATLAB® is assumed, but not entirely essential. A reader familiar with C will not find it difficult to read the program listings in the book. Some historically important data has been converted from graphical form to curve-fit equations so that the entire design process can be done on the computer. Many original modeling programs have been written for both traditional and novel antennas and supporting structures.

Teaching is the third way of learning. First, one learns as a student, then as a practitioner. To teach, one has to understand even better to pass the art and science on to another. Unlike this Preface, the book is written mostly in the style of informal lecture and conversation. It is as much a story as a textbook.
Doug Miron earned his degrees from Yale and the University of Connecticut. He was educated as a general-purpose EE, later specializing in control systems. He has worked, taught, and published in nearly every area of electrical engineering. He began his professional interest in radio frequency systems, circuits, and antennas at Hermes Electronics Ltd, Dartmouth, Nova Scotia, in 1974. He continued research on RF circuits and small antennas while teaching at South Dakota State University from 1979–1996. Among other activities, he has published several articles and papers on numerical impedance matching, LC and microstrip circuits, numerical antenna simulation, and also discovered the volume-loaded small dipole.
What’s on the CD-ROM?

Numerical methods are the main tool used in this book. The main numerical tool is NEC2, the U.S. Government-developed code for modeling wire antennas. The folder NEC has source code and executables for the current user-modified version of this code. The root folder also has a public-domain GUI in a .zip file. In addition, the NEC folder has many C++ programs to generate NEC input files for various antennas and structures. These programs read text files with numbers describing the geometry and operating conditions for each antenna and structure. Examples of such text files and other utility programs are also in the NEC folder.

MATLAB was used for data analysis in many of the examples in the book. Utility programs to find the equivalent circuit Q, bandwidth, resistance components, and antenna voltage for a given power input are in the MATRF folder. This folder also contains programs for impedance-matching design, both narrow-band and wide-band. Also, there are programs for generating data used in some of the book’s examples, including the NEC basis functions and curve-fitting with these functions.