Antenna Modeling with NEC: Some Instructional Sources

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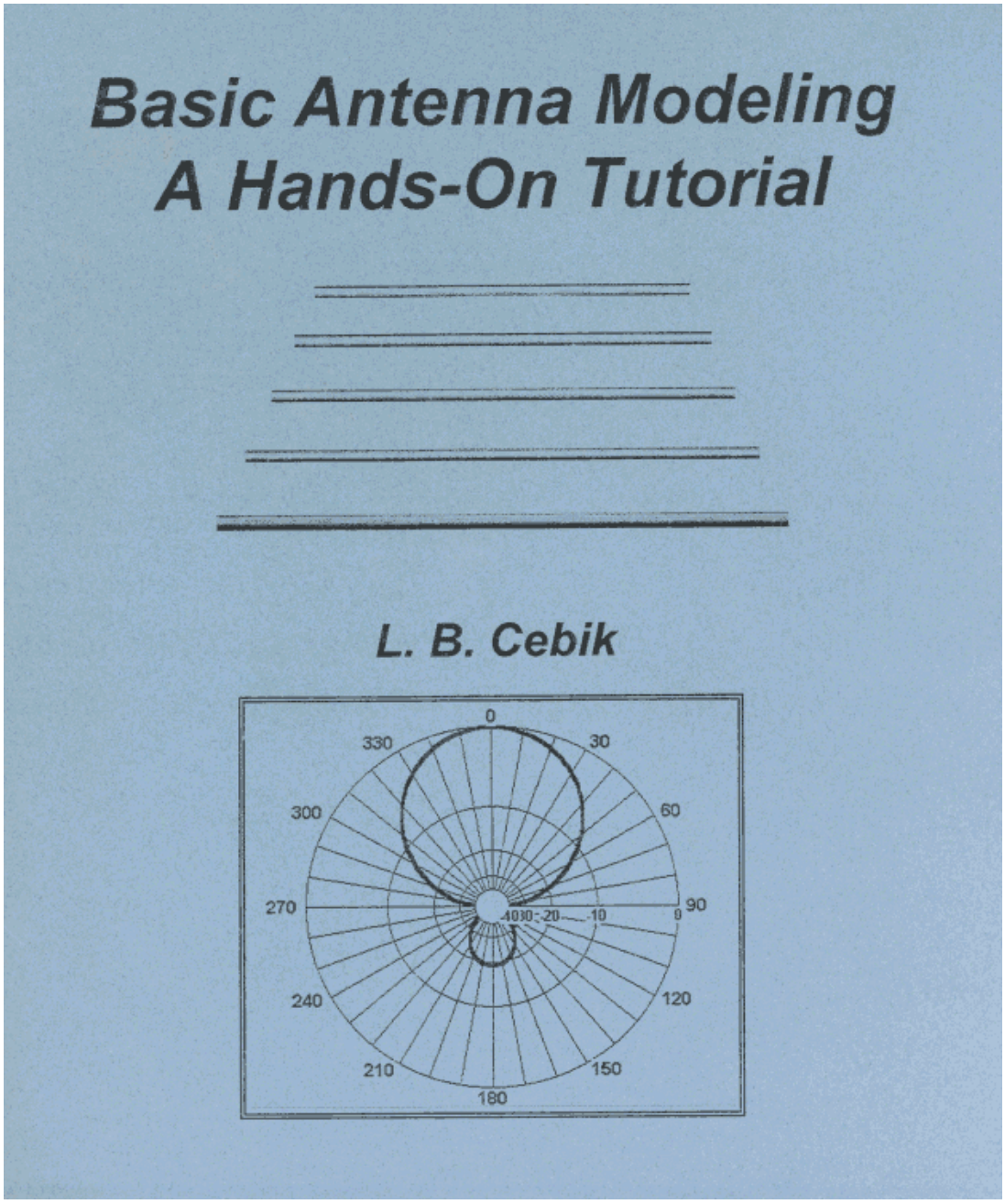
Over the multiple decades in which I have been involved in computer software antenna modeling, one of my aims has been to provide such guidance as I can, taken from both the basic program manuals for NEC-2 and NEC-4 and from my own experience, abetted by correspondence with other modelers. My goal has been to show not only the potentials of computer antenna modeling, but as well, to make other modelers with less experience keenly aware of the limitations within which models are reliable guides to real-world antenna performance and where they depart from reality. NEC (and MININEC) presume round wire antenna elements that are thin relative to the element length and therefore have built in limits in replicating some types of antenna structures commonly used, especially in the VHF range. As well, NEC models presume a single medium that surrounds the element and hence cannot replicate strip designs affixed to a substrate. One of the products of my educational goals has been the series of antenna modeling columns that accompanies each issue of *antenneX*.

Over the years, I have also developed three tutorial books, two dealing with basic antenna modeling in NEC and one with what I call the intermediate level of modeling. One of these books I wrote under contract with ARRL especially for their emerging series of continuing education course. In fact, the volume (*ARRL Antenna Modeling Course*) was the first of the technical courses offered by the League. (Their emergency operation series preceded this course.) To allow the user to track the hundreds of sample models with the text, the volume featured the two most-used programs of 2001, EZNEC v3.0 and NEC-Win Plus. For those with alternative programs, the sample model set includes .NEC format (ASCII) model files.

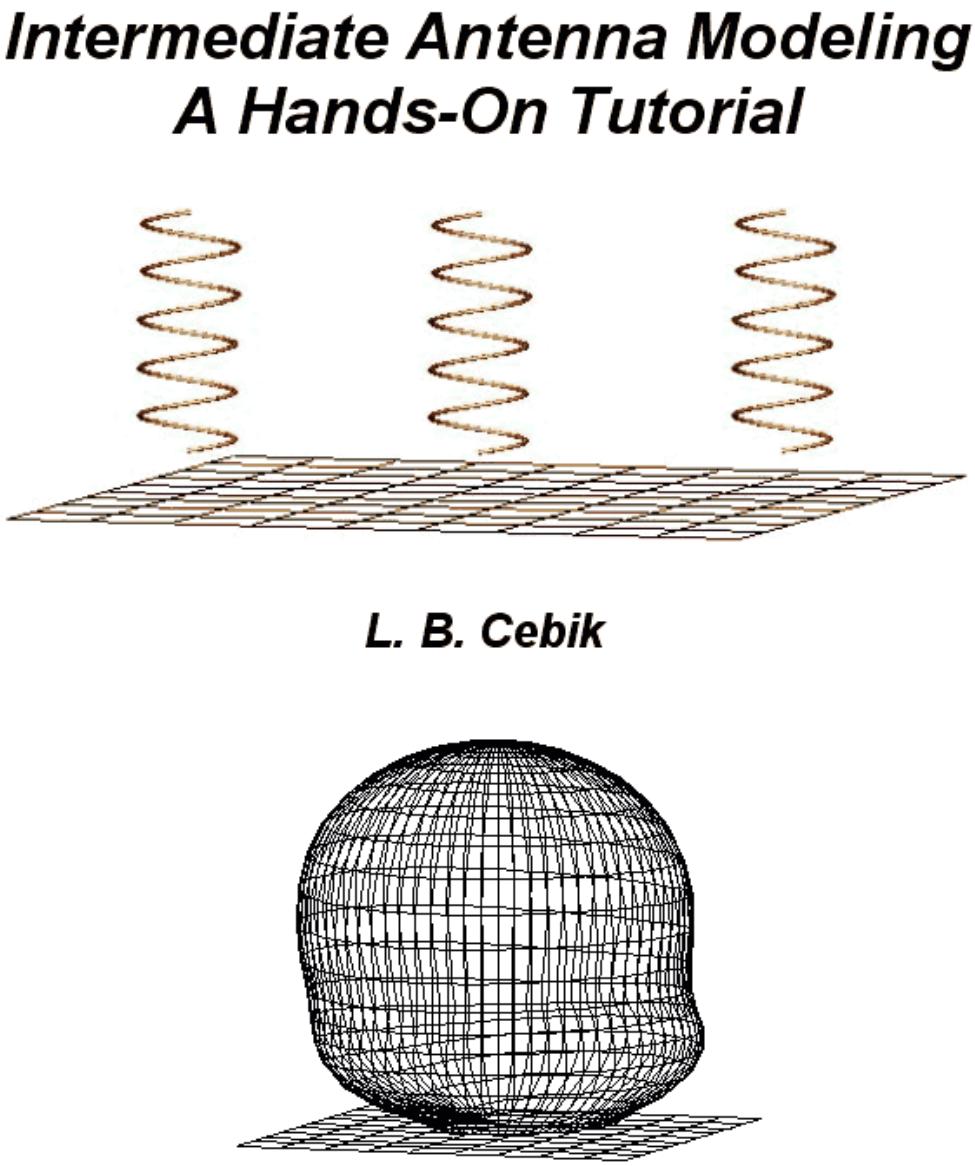
The general principle followed in the ARRL course applies to all of the tutorials that I have generated: a hand-on approach that connects the text to actual exercises employing antenna-modeling software. In this scheme, the reader/student can work with the text and see the points in action and even modify an exercise model to further reinforce his or her understanding of the material. Because the ARRL tutorial is part of a correspondence course, it used 30 lesson segments and provided sample multiple-choice questions for each lesson as a practice test in advance of the ones provided by the League. Although I have no connection to the execution of the correspondence course program at ARRL, I understand that the course is still popular.

For those who prefer a more solitary and wholly self-guided course of study, I wrote for NSI a volume called *Basic Antenna Modeling: A Hands-On Tutorial*. I created the self-study course in 1999, actually slightly in advance of the release of NEC-Win Plus. Therefore, all of the illustrations emerged from NEC-Win Pro, a fairly standard version of NEC-2 that makes available all of the program commands. NEC-Win Plus, like EZNEC, employs only a subset of the program's commands in order to ease the familiarization task facing every new modeler. The volume consisted of 21 chapters divided into three sections: Basic Modeling and Model Testing; Common Modeling Techniques, Limitations, and Work-Arounds; and Practical Antenna Modeling. An appendix provided a collection of useful data for modelers, including ground quality charts, material conductivity and resistivity values, wire-size tables, and frequency spectrum lists. The volume contains hundreds of illustrations, including NEC-type listings of most models. It also includes work sheets, both empty for the student to complete from his modeling work, and completed as an immediate check on the success of the exercise. A single example follows, referenced to an exercise model of a self-resonant dipole.

3-1	Test Data	Ex. 1		Reference	
Material	**Gain (dBi)**	**Source Z (R±jX Ω)**		**Gain (dBi)**	**Source Z (R±jX Ω)**
Lossless				2.14	72.1 + j 0.0
Copper				2.04	73.9 + j 1.6
6061 Al.				1.98	74.9 + j 2.4
Bronze				1.88	76.7 + j 4.0
St. Steel				1.47	84.8 + j10.0



In 2005, I had gathered enough material to develop a more advanced tutorial called *Intermediate Antenna Modeling: A Hands-On Tutorial*. I used the term "intermediate" on the basis of knowing that there is always something new and more to be learned about the software and its applications. But the new and larger volume allowed me to cover a larger territory that involved both NEC-2 and NEC-4.



Like the earlier volume, the new tutorial had 21 chapters, divided into 3 sections: The Geometry Commands; Far-Field and General Control Commands; and Special Outputs, Control Commands, and Techniques. Except for the surface-patch commands (which have no necessary relationship to surface patch antennas), the new tutorial covers the syntax, limitations, and application of every control command in NEC-2 and NEC-4. It also lays out in detail the differences between NEC-2 and NEC-4 versions of the same command. In some cases, the NEC-4 version translates into a usable NEC-2 command. In other cases, the

differences are radical, as in the GH command for creating helices. Compare the following two entries for the very same helical structure (where the parenthesized numbers refer to models).

NEC-2 GH Command (4-1)

Cmd	I1	I2	F1	F2	F3	F4	F5	F6	F7
	Tag No.	No. Segs	S	HL	A1	B1	A2	B2	RAD
GH	1	180	.3048	2.7432	.099	.099	.099	.099	.001

NEC-4 GH Command (4-6)

Cmd	I1	I2	F1	F2	F3	F4	F5	F6	F7
	Tag No.	No. Segs	TURNS	ZLEN	HR1	HR2	WR1	WR2	ISPX
GH	1	180	9	2.7432	.099	.099	.001	.001	0

In other cases, the differences are subtle, as in the reversal of entries in the near-field commands or the revisions to the relationship of ground specification to the Radiation Pattern (RP0) command. Of course, the volume covers the new commands added to the later program, which is still proprietary and requires a license to use. NEC-4 uses the expanded set of floating decimal places available in later versions of Fortran to increase the data in some of the commands, for example, in the CW (catenary wire) command. NEC-2 uses only the first seven of the floating decimal places.

Cmd	I1	I2	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
	Tag No.	No. Segs	X1	Y1	Z1	X2	Y2	Z2	Rad.	ICAT	RHM	ZM
CW	1	9	0	-.23	5	0	.23	5	.001	1	.25	4.9

The Intermediate volume is about 30-40% larger in number of pages than the basic tutorial. As well, it uses a slightly smaller print and omits the work sheets in the belief that users will be sufficiently advanced to create their own tally sheets for the 500 example models that accompany the intermediate tutorial.

Although both volumes were written with NSI software in mind, both are generally applicable to any version of NEC. In fact, both volumes include exercise models in .NEC format that can be read by any general version of NEC. (Of course, not all models are interchangeable between NEC-2 and NEC-4, so in several instances, the intermediate volume has a version designed for each program.)

Alas, NSI has become inactive as a developer and seller of NEC-2 and NEC-4 software. This presents two problems for the modeling student. First, as a minor point, the NEC-Win Pro and GNEC feature of providing screens for command entry without user concern for the required line syntax is no longer available to those just obtaining their own versions of NEC. Hence, some illustrations may no longer be relevant to the software in use. Second, and more significant, NSI printed and distributed the tutorials.

All is not lost. *antenneX* has the two volumes on individual CDROMs. Each disk contains both the text and the exercise models. If you are interested, you may visit the Shopping Shack and obtain one or both volumes. Although I have shown the cover pages of each volume, I have omitted illustrations from inside each. There are links from the **Shopping Shack** to

sample pages and chapters from the volumes to give you a clearer idea of the style and topical progression than I can give in this limited space.

The Basic volume is for the new antenna modeler who would like to become oriented to the conventions of modeling, such as using the Cartesian frame of reference for creating models and relating it to the resulting radiation patterns and data. The volume also records methods of evaluating model adequacy, work-arounds for working with some modeling limitations, and a large collection of practical antennas and their models to increase modeling proficiency. The following table of contents indicates the scope of coverage and the progression of modeling ideas and activities.

Chapter	*Title*
	Introduction
Part A	Basic Modeling and Model Testing
1	NEC-2 and NECWin Plus
2	Modeling Preparations
3	Basic Antenna Models
4	NEC Output Data
5	Careful Model Construction
6	Convergence Testing
7	Frequency Specification
Part B	Common Modeling Techniques, Limitations, and Work-Arounds
8	Source Types and Placement
9	Tapered-Diameter Elements
10	Geometry Limitations
11	Grounds and Applications
12	Resistive Loads
13	Reactive Loads
14	Transmission Lines
Part C	Practical Antenna Modeling
15	Monopoles and Ground Planes
16	Vertically Polarized Antennas and Arrays
17	Bi-directional Wire Arrays
18	Yagis
19	Horizontal Parasitic and Phased Arrays
20	VHF/UHF Antennas
21	Special Structures
Appendix	Some Useful Data for Antenna Modelers
Index	

The Intermediate tutorial is for modelers who have generally learned to model basic antennas well, but who wish to know how to get more out of NEC's command structure, both in terms of creating antenna geometries and in developing a wider array of output information. The table of contents for the intermediate volume shows the change of perspective that goes along with one's increased modeling skills.

Chapter *Title*

Introduction

Part A The Geometry Commands
1 A Review of NEC Fundamentals and Limitations
2 GW, GM, GS, and GE: Wire Entry Alternatives
3 GC, CW, and GA: Special Wire Shapes
4 GH in NEC-2 and NEC-4
5 GX and GR: Symmetry
6 WG and GF: Numerical Green's Functions and Wire Grids
7 Finding Geometry Limitations in a Model

Part B Far-Field and General Control Commands
8 Output Tables and Graphics
9 Far-Field Radiation Pattern Requests
10 Voltage and Current Sources and Frequency Specifications
11 Grounds: Types, Applications, and Specifications
12 Mathematical and Wire Transmission Lines
13 Impedance Loads and Their Limitations
14 Networks and Some of Their Applications

Part C Special Outputs, Control Commands, and Techniques
15 Power Information: Power Efficiency vs. Radiation Efficiency
16 Material Loads, Wire Insulation, and Work-Arounds
17 Special Radiation Pattern Data
18 Near-Field Analysis in NEC-2 and NEC-4
19 Receive and Scattering Data: Excitation and Data Requests
20 Miscellaneous Special Commands
21 Modeling by Equation

Appendix Some Useful Data for Antenna Modelers

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The appendix to the intermediate volume expands the collection of data useful to modelers embarking upon more ambitious tasks.

One question that occasionally comes my way is why I have not produced a similar volume for modeling with MININEC. The answer is simple because the MININEC situation is complex. MININEC 3.13 has been available to programmers for a very long time. It has some limitations that different programmers have approached in different ways. Antenna Model by Terisoft has addressed most of them in the most comprehensive fashion, but many old and new varieties of MININEC are available. Because there have been no rules governing file formats, virtually every version of MININEC that has been or is on the market uses its own file format system. There is for MININEC no root file format comparable to the ASCII files that comprise what we call the NEC format. Together, these two reasons make the creation of a generally applicable tutorial impossible. Exercise models would require innumerable replications in different file formats, and output results for the exercises might differ a bit or a lot, depending upon the version of MININEC in use.

I would not claim for a moment that either NEC tutorial volume is perfect—or even close. However, my feedback has been that each has been useful in its own right. I am pleased—of course—that neither personal tutorial will disappear, and that *antenneX* has chosen to offer them in a CDROM format. If you are interested, please visit the **Shopping Shack** for more extensive previews of the content and for information on how to obtain one or both.

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antenneX Online Issue No. 127 — November 2007
Send mail to webmaster@antennex.com with questions or comments.