EZNEC User Manual

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Welcome

Welcome to **EZNEC® Pro+ version 7.0**!

This manual has been written to cover both **EZNEC Pro/2+** and **EZNEC Pro/4+** with their various calculating engine variations. "**EZNEC**" or "**EZNEC Pro+**" refers to both types.

It's assumed that you know basic Windows operation, such as clicking, dragging, and selecting, and references will occasionally be made to common Windows tools such as Notepad or the Windows Explorer. Please consult your Windows documentation if you're not familiar with basic Windows techniques.

There will be no support available for the program or manual. I regret that I won't respond to any enquiries by any means including email. No updates for either are anticipated.

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Introduction

Acknowledgements

Dan Maguire, AC6LA, the author of AutoEZ, has spent countless hours testing, finding bugs, suggesting improvements, proofreading and suggesting improvements to the manual, to not only **EZNEC Pro+ v. 7.0** but also its predecessors going back to **EZNEC v. 4.0**. A program of this quality simply wouldn't have been possible at all without his extensive and expert help. His feedback, bug finding and chasing, insightful suggestions, and careful proofreading over a very long time were immeasurably helpful. **EZNEC v. 7.0** is a much better product and would not have even been possible without his help. Dan was also instrumental in finding several serious bugs in NEC-5 after its release shortly after the death of its principal author G.J. "Jerry" Burke. Dan spent countless hours documenting the bugs, and testing and documenting numerous intermediate and final fixes for them. And Dan was also responsible for making it possible for **EZNEC v. 7.0** to model wire insulation when using an NEC-5 calculating engine. This was not built into NEC-5 but Dan found a method developed by Steve Stearns, K6OIK, to implement it by modifying the descriptions sent to NEC-5 by **EZNEC** and not requiring any modifications to NEC-5 itself. Again, Dan did extensive testing and documentation of the result, and was essential to its implementation in **EZNEC Pro+ v. 7.0.3**. Thank you, Dan and Steve!

Many other people tested **EZNEC** during its developmental stages and provided invaluable suggestions for new features and improvement of existing ones, ways to make the user interface easier to use, and reviewed the manual. And, of course, they've found and reported many bugs and actively helped in tracking them down. This has occurred for every version of **EZNEC** and its predecessor ELNEC. Since each version has built upon the previous ones, the people who have helped with any version have made a very substantial contribution to the present one. I am grateful and indebted to all. I hasten to add, however, that shortcomings of the program and remaining bugs are entirely my responsibility and not at all theirs.

EZNEC Pro+ v. 7.0 is built upon v. 6.0, and it upon 5.0, and so forth. So the help provided by beta testers for all previous versions was also essential to the development of this program.

The following people have been involved in testing of the current program or previous versions over a period of more than 30 years:

Dick Adler, K3CXZ (sk)
Vil Arafiles
Bert Barry, VE3QAA
Jack Belrose, VE2CV
Steve Best, VE9SRB
Jim Breakall, WA3FET
Gary Breed, K9AY
Jim Bromley, W5GYJ
John Brosnahan, W0UN (sk)
Paul Carr., N4PC
L.B. Cebik, W4RNL (sk)
Al Christman, K3LC

Paul Ciaciolo, W1VLF
Bill Clarke, WA4BLC
Tony DeBiasi, K2SG
John Devoldere, ON4UN (sk)
Tim DuBose
Ed Farmer, AA6ZM
Dick Gardner, N1AYW
Dick Green, WC1M
Ernie Guerri, W6MGI (sk)
Linley Gumm, K7HFD
Jerry Hall, K1TD
Ed Hanlon
Ed Hare, W1RFI
Bob Haviland, W4MB (sk)
Wes Hayward, W7ZOI
Rus Healy, K2UA
Tim Holzheimer, N6DIY
Gerd Janzen, DF6SJ
Dan Kaeo, KF6A (sk)
Dick Kiefer, K0DK
Dan Maguire, AC6LA
Joshua Mardling, VE1CEN
Doug McGarrett, WA2SAY
Geoff Mendenhall, W8GNM
Mike Mladejovsky, WA7ARK
Guy Olinger, K2AV
Greg Ordy, W8WWV
Neill Prohaska, AE7AE
John Reilly, N0TA
Danny Richardson, K6MHE (sk)
Dave Rodman, KN2M
Bob Rullman, K7MSH (sk)
Jim Sanford, WB4GCS
Rudy Severns, N6LF
Steve Stearns, K6OIK
Roger Steyaert, K7RXV
Dean Straw, N6BV
Jim Streible, K4DLI (sk)
C.H. "Buck" Walter
Perry Wheless, K4CWW
Harald Wickenhäuser, DK1OP

Although I've listed a call sign beside most of the testers' names, many of them are also professionals, some actively involved in antenna design and using **EZNEC** professionally. Many are Professional Engineers, quite a few have Ph.D. degrees, and several are college professors. I've left off the titles mainly because I don't want to inadvertently slight someone whose title I don't know. But these are all people who selflessly donated their time and expertise to improving the program you're using today. We owe all of them a great deal of thanks.

Speaking of which. . .

This manual will be read by both professional and amateur users, so I'll like to emphasize one point. Although amateur radio callsigns are listed for most of the fine people acknowledged above, many – in fact most – of them are highly experienced and regarded professionals in addition to being licensed amateurs, and many use **EZNEC** professionally.

NEC

EZNEC is fundamentally an interface for the powerful Numerical Electromagnetic Codes (NEC) developed by several people over a period of many years, funded by the U.S. Government. **EZNEC**'s actual antenna calculations are done with NEC-2, -4.2, and now -5. The principal authors of these remarkable programs are G.J. Burke and A.J. Poggio, although a number of others made significant contributions and are acknowledged in the respective NEC manuals. **EZNEC** simply couldn't exist if not for the inspired work by these people.

Several serious bugs were found in NEC-5 after its release shortly before the death of its principal author, G.J. "Jerry" Burke. These were found mostly by Dan Maguire, AC6LA, who also did very extensive testing and documentation of proposed solutions. Correcting the bugs would not have been possible without his major contributions. Steve Stearns, K6OIK developed a method to implement wire insulation modeling with NEC-5 which could be implemented by **EZNEC**. Thanks to Steve for developing and sharing this method and to Dan for his extensive testing and documenting -- and talking a "retired" developer into implementing it.

Acknowledgement and Special Thanks: Jordan Russell and Inno Setup

All variations of **EZNEC** version 4.0.31 and later use the open source **Inno Setup** installer, created by Jordan Russell. This is a tremendously rich and powerful but easy to use installer. I'm very grateful to the author and any other contributors who have obviously put in a tremendous amount of effort in developing this fine application and have made it available to be freely used at no charge. It wasn't chosen for **EZNEC** because it's free – it was chosen because it's simply the best installer available, at any cost, for the job.

Acknowledgement: vbAcellerator Software

This product includes software developed by vbAccelerator. (http://vbaccelerator.com) I thank vbAccelerator for generously making this high quality software available at no charge. The full license statement and disclaimer is in the Legal Notices section of this manual, Third Party Software Legal Notices.

Acknowledgement: Info-Zip Software

All **EZNEC** program types make use of file compression and decompression software which is generously provided free of charge by Info-ZIP. A list of contributors to this project can be found in the Third Party Software Legal Notices section of this manual.

Acknowledgement: Scintilla Software

All **EZNEC** program types make use of Scintilla editor software which is generously provided free of charge by Neil Hodgson (scintilla.org). The full

license statement and disclaimer is in the Legal Notices section of this manual, Third Party Software Legal Notices section of this manual.

Guarantee

There is no guarantee offered for **EZNEC Pro/2+ v. 7.0** or **EZNEC Pro/4+ v. 7.0**. Use them at your own risk.
Please refer to the Legal Disclaimer for additional information..

Notes For International Users

Although **EZNEC** is offered only in an English language version, a very sizeable fraction of its users are outside the U.S. or even English-speaking countries. A great deal of effort has been made to make **EZNEC** work correctly on computers set for the standards of other countries. This means that if a comma (,) is set as the decimal separator by the Windows Control Panel Regional Settings, all numbers should be displayed with that convention, and all numerical inputs are designed to accept that convention. (The decimal separator is automatically chosen according to your language preference. However, it can be changed to another character via the Regional Settings if desired.) You must use the separator chosen for the computer when entering numbers into **EZNEC**. (There are a few exceptions to this, detailed below.) Dates should be displayed according to your standard. All outputs should print correctly on A4 as well as U.S. sized paper, and the program should otherwise operate normally in all respects. If you encounter any operation, at any time, which requires you to enter or view data in a format other than the standard convention for your country, please let me know. Of course, all details you provide will be helpful.

Exceptions

EZNEC might be unable to correctly format numbers when run on some operating systems if both the decimal and thousands separators are set to characters which aren't standard for the region of operation. If the setting causes a problem, **EZNEC** will detect it and show an error message when the program starts.
EZNEC cannot interpret Unicode characters outside the normal ASCII set. All file and path names used by **EZNEC** must not contain these characters.
A period (.) is used as the decimal separator in all comma-delimited output files such as Lastz.txt. Comma-delimited output files are intended to be used for importing data into spreadsheets and other such programs. In this format, fields are separated with commas, so the period must be used for decimals. It is also used for IONCAP/VOACAP program files which expect this convention.
NEC-format files read and written by **EZNEC** use the U.S. standard, because most compiled versions of NEC-2 and NEC-4.2 expect and produce files using this convention. Please let me know if you have any information to the contrary, or if you see any indication that **EZNEC** is *not* producing or interpreting these files with U.S. conventions.
Thousands separators are not used in **EZNEC**. However, certain settings of this option might cause a problem. See the first paragraph in the **Exceptions** section.

Getting Started

Using Help

The manual is accessed by opening the Help menu and selecting Contents. The three tabs are

- Contents: Shows the table of contents.
- Index: Opens a comprehensive index.
- Search: Allows you to search for any word or (surrounded by quotation marks) phrase in the manual.

The manual contains numerous hyperlinks which when clicked open the referenced topic. You can navigate forward and backward through the viewed topics with the Forward and Back arrows above the tabs.
EZNEC includes a context-sensitive help system. At any point in the program, pressing the F1 key or a Help button if available, will open the Help system to the topic dealing with the currently active form, control, or dialog box. If no topic is found, the Help system will open showing the table of contents.

A Few Essentials

First, especially if you have **EZNEC Pro/4+**, ***please make one or more backup copies of your program!*** Read the Reinstalling or Copying EZNEC section for important information.
In this manual, **EZNEC** and **EZNEC Pro+** mean both **EZNEC Pro/2+ v. 7.0** and **EZNEC Pro/4+ v. 7.0**. Any references to NEC-4 mean NEC-4.2 only; NEC-4.1 (and 4.0 if it existed) are not supported by **EZNEC** but owners of NEC-4.1 can obtain an upgrade to NEC-4.2 by contacting LLNL.
EZNEC Pro/2+ and **EZNEC Pro/4+** are able to use external NEC-4.2 and NEC-5 calculating engines. NEC-5 is the latest NEC program, is very reasonably priced, and has advantages over even the current industry standard NEC-4.2. I highly recommend purchasing and using it. It's available from LLNL. Installation instructions are here. Be sure to read the following topic: NEC-5 Status.
You can greatly increase **EZNEC Pro+**'s capabilities with AutoEZ. See the AutoEZ topic for more information.
There will be no support for the program or manual. Although I and a number of volunteer testers have worked very hard and done our best to make both the manual and program as bug-free as possible, bugs surely remain in both, and both could be improved. But I regret that I won't respond to any comments or questions about either. After 31 years of developing, selling, and supporting **EZNEC** and its predecessor ELNEC, I'm retired.
Although a number of people have provided extensive help with testing and suggesting improvements to the program, I have written every one of the tens of thousands of lines of code (except for the integral NEC calculating engines, which I've modified) and am solely responsible for any bugs and deficiencies and for which I sincerely apologize.
Finally, enjoy using **EZNEC Pro+**! I promise you'll learn from it, as I continue to do.

Roy Lewallen

NEC-5 Status

NEC-5 was first released in early 2020. Its principal author, Gerald "Jerry" Burke regrettably passed away just one year later. NEC-5 is a remarkable work and a worthy legacy but the inevitable few bugs, some unfortunately serious, have been discovered in the program. As of this writing in early 2024, LLNL hasn't found anyone to support NEC-5 and be committed to correcting these or make future changes as necessary.

So that **EZNEC Pro+** users can have a more bug-free NEC-5 to use, and with the very extensive help of Dan Maguire AC6LA (author of AutoEZ) in finding, testing, and verifying, I fixed the bugs we've found and recompiled the NEC-5 console program which **EZNEC Pro+** can use for calculations. LLNL has agreed to distribute this with new NEC-5 purchases and provide no cost updates to users who purchased the original program. See the LLNL web site for purchasing and update information. Note that only the "command line" or "console" program originally named NEC5CL.exe has been modified; the bugs remain in the other program types currently being distributed by LLNL. As of this writing in April 2024, the current debugged program is called NEC5 x13. See https://eznec.com/NEC-5.htm for additional information.

In the **EZNEC Pro+** Utilities menu is a selection that lets you easily tell if the NEC-5 program you're using is a modified one. The original, unmodified program can give incorrect results when using current sources or MININEC type ground, and crash under some circumstances. The causes of those are fixed in the modified program. The current modified program is identified as "X13" on the second line of its output file.

I highly recommend purchasing NEC-5 and using it with **EZNEC Pro+**, even if you have **EZNEC Pro/4+**. Some of its many advantages are described in the Calculating Engines topic. And the current price for individual use is less than even **EZNEC+** was -- $110. See the LLNL web site for details and the current pricing.

What's New in v. 7.0

All features which were available in **EZNEC Pro/2** v. 6.0 are incorporated into **EZNEC Pro/2+** v. 7.0 with a few exceptions described below. **EZNEC Pro/4** v. 6.0 was identical to **EZNEC Pro/2** except for the inclusion of an internal NEC-4.2 calculating engine. That also holds true for **EZNEC Pro/4+ and /2+**.

NEW FEATURES

External calculating engines - Both **EZNEC Pro/2+** and **EZNEC Pro/4+** can use external NEC-4.2 and NEC-5 programs for calculations. See Calculating Engines for details.

Individual wire loss - Each wire can have different loss if desired. See Using The Wires Window.

Improved NEC format file reading - A number of deficiencies were addressed and corrected. See Working With NEC Format Files.

Plot display enhancements - Line widths and object sizes can be changed in the 2D, 3D, SWR, and View Antenna displays. See Graphics Windows Menus.

Charge density table - New Options menu selection to optionally add charge density data to the Currents table. See Options.

Example files and Test Drive updates - Example files have been updated to replace MININEC type ground with Real, High Accuracy ground where MININEC ground isn't needed. The Test Drive tutorial has been updated to use the new files and to show values consistent with them and the use of the internal NEC-2D calculating engine. Original versions of example files which were changed are in a Legacy subdirectory. See Test Drive Introduction and the remainder of the Test Drive.

Undo Calculating Engine Change - Certain features are automatically enabled or disabled, and items such as a second ground medium can be deleted when changing calculating engines. (See Calculating Engines for more information about features.) So calculation engine changes can now be undone or redone.

Wire Segment Intersection Conversion - Descriptions containing wires intersecting at segment junctions can automatically be converted to the now-required wire end connections. See Segment Junction Intersections.

DELETED FEATURES

Operation with Windows XP or Vista - **EZNEC** v. 6.0 program types other than **EZNEC Pro/4** were able to run on those operating systems provided that the machine had an Intel CPU. Neither **EZNEC Pro/2+** nor **EZNEC Pro/4+** will operate on any system earlier than Windows 7. **EZNEC Pro/2** v. 6.0 will be made available at no charge for a limited time for use on systems using XP or Vista and having an Intel processor.

Legacy 2D plot grid

NEC-4 SEGCHK - Checking geometry with the NEC-4 SEGCHK function instead of or in addition to the **EZNEC** geometry checking function is no longer an option.

NEC-4.1 support - **EZNEC Pro+** does not support NEC-4.1 and will not read or write files in that format. See LLNL for information about upgrading NEC-4.1 to NEC-4.2.

Segment junction intersections - Wires are no longer allowed to intersect at segment junctions, but only contact at wire ends. A new feature allows automatic conversion to wire end connections. See Segment Junction Intersections.

OTHER CHANGES

NEC file format - NEC format assumed for reading and used for writing NEC format files is now determined by the current calculating engine selection.

Directory locations - In response to the continued increase in file locations which Windows prohibits writing to, the main **EZNEC Pro+** working directory has been moved to the C: drive root directory and all files are written to it and its subdirectories by default. Most of these locations can be moved (see Options) but doing so is discouraged. A subdirectory of C:\Program Files [(x86)]\ is still used for the program files but **EZNEC** writes no files to it.

Calculating Engine Type Memory - Unlike previous versions of **EZNEC**, the calculating engine type selection isn't shared with other **EZNEC** versions on the same machine. The **EZNEC Pro+ v. 7.0** calculating engine choice is saved at a different Registry location than previous versions.

Single precision calculating engines -- Single precision internal NEC-2 and NEC-4.2 calculating engines are now recommended only for some very large models where insufficient RAM is available to allow double precision

operation. So these engines are now available only by setting a Special Option.
NEC Radials -- NEC radials, previously available in **EZNEC Pro** without setting a Special Option, now require one.
Transformers -- The default winding impedances when creating a new transformer have been changed from 1 to 50 ohms to be closer to typically encountered impedances.
No Hardware key -- Not really a change, since no hardware key has been required for **EZNEC Pro** beginning with v. 6.0.34. No hardware key is or ever will be required for **EZNEC Pro/2+** or **EZNEC Pro/4+**.

What Was New in v. 6.0

This topic describes the differences between v. 6.0 and the previous version, 5.0. If you're upgrading directly from an earlier version, please also see the appropriate "What Was New" topics.
New tutorial topic Taking Car 6 For A Spin will get you acquainted with the major new features of **EZNEC** v. 6.0. It's intended for users who are already familiar with basic **EZNEC** operation.
File Locations - Previous versions of **EZNEC** conformed to an earlier Windows standard of installing programs under the Program Files directory and having them write primarily to their own directory. Many later operating systems, however, have restricted permissions for Program Files and its subdirectories, making **EZNEC** unable to write into its own directory. On those systems where it's permitted, written files are diverted to a "virtual store" which is buried deep within the file structure and difficult to locate. To solve these problems, **EZNEC** v. 6.0 conforms to the most current Windows standards for file locations. See File Locations for details.
If you have an earlier version of **EZNEC** installed on your system, **EZNEC** v. 6.0 will copy your description (.EZ) and IONCAP files to the new locations the first time it runs. The original files are left intact but are not used by **EZNEC** v. 6.0. If they are currently in a directory under C:\Program Files [(x86)] this will be done without prompting and you will be notified of the change. If those files are currently in some other location, you'll have the opportunity to accept or reject the move.
The Control Center Utilities menu has a new selection that shows all folder locations.
Previous **EZNEC** versions permitted changing the locations of temporary and ground files; v. 6.0 does not.
Operating System Requirements -- All **EZNEC** v. **6.0** program types require Windows XP Service Pack 3 (SP3) or later, 32 or 64 bit. Earlier operating systems are no longer supported.
Faster Calculations -- **EZNEC** v. 6.0 calculating engines are more highly optimized and make greater use of multiple processors, so speed improvements of two or more times over v. 5.0 are typical. Much greater speed improvement is possible with very large models using **EZNEC Pro** on 64 bit systems, described below.
Better Loaded/Trapped Yagi Accuracy -- (Note: this doesn't apply to **EZNEC Pro/4** when using an NEC-4.2 calculating engine, which doesn't require the described correction). Because of errors inherent in the NEC-2

code used for most **EZNEC** calculations, it isn't able to accurately model sensitive antennas such as Yagis made with telescoping tubing or otherwise varying diameter. **EZNEC** has been able to correct this very well but only when a Yagi isn't trapped or loaded. NEC-2 based **EZNEC** has not been able to accurately model trapped or loaded Yagis or certain other antennas of varying diameter. **EZNEC** v. 6.0 applies advanced correction methods that make reasonably accurate modeling of loaded and trapped Yagis possible for the first time without needing NEC-4. Because of the many variables involved, no specific guarantee of accuracy can be made, but tests have shown significantly improved accuracy compared to earlier **EZNEC** versions which couldn't correct these antennas at all. See Stepped Diameter Correction Overview for more information..

Graphical Wire Modification -- Some modifications to the model can be done graphically in the View Antenna display. Selected wires can be deleted, wire ends can be moved to other existing wire ends, and new wires can be created which connect other existing wire ends. See Graphical Wire Operations.

View Antenna Display Enhancements -- In the View Antenna display, pressing the X, Y, or Z keyboard keys positions the display to be viewed from the X, Y, or Z axis. Pressing <Shift> at the same time positions the view from the negative axis. The Wire Information pop-up window now shows the magnitude of current at the closest wire end if it has been calculated.

Segment Limits - **EZNEC+** now has 2000 segment capability, increased from the previous 1500. The **EZNEC Pro** limit has been increased from 20,000 to 45,000. Standard and Demo programs remain unchanged at 500 and 20 respectively.

Split Wires Feature -- New feature splits a wire into multiple wires. See Using The Wires Window.

Wire Scaling Enhancements -- You can now restrict scaling to one or two axes, and choose the point about which the scaling takes place. Described in Using The Wires Window.

Insertion Object Placement Check -- Inaccurate, sometimes highly inaccurate, results can sometimes occur if insertion objects are incorrectly placed. The segmentation check now gives warnings if the recommended placement guidelines are violated. See Placing Insertion Objects on Segments.

Segmentation Check Option -- You can now suppress warnings of Conservative level segmentation guideline warnings via the Control Center Options menu Segmentation Check selection.

Discontinued Features -- External Smith chart programs, View Antenna display data window. ***[EZNEC Pro/4 only:]*** External NEC-4.2 calculating engine.

EZNEC Demo Only:

EZNEC-ARRL Capability -- 500 segment capability with specially "signed" files from the *ARRL Antenna Book* CD. See **EZNEC-ARRL**.

EZNEC+ Only:

More Segments -- **EZNEC+** now allows a maximum of 2000 segments.

EZNEC+ and EZNEC Pro Only:

Catenary Creation -- Automatically creates a catenary wire. Optionally replaces an existing straight wire with a catenary. This realistically represents the sag in a real wire, which can have a significant effect on impedance.

Touchstone (.s1p) Format Files -- In addition to LastZ.txt, **EZNEC+ and EZNEC Pro** now generate a Touchstone (.s1p) format file of reflection coefficient or impedance for input to RF design programs. The files are created each time an SWR or frequency sweep is run

EZNEC Pro Only:

Major Speed Improvement for Very Large Models -- Previous versions of **EZNEC Pro** could only access about 2 GB of RAM. This made it necessary for **EZNEC Pro** to use the disk for virtual memory with models of roughly 10,000 - 15,000 or more segments, which dramatically slowed calculations. **EZNEC Pro** v. 6.0 installs 64 bit calculating engines on 64 bit operating systems (later than Windows XP) which have access to a major fraction of installed RAM. If sufficient RAM is installed, virtual memory use is avoided and calculations are much faster. Tests have shown speed improvements of ***ten times*** with some models needing virtual memory use with v. 5.0 but not with v. 6.0. Note that this level of improvement requires a 64 bit operating system later than XP and sufficient installed RAM to avoid virtual memory use. See Very Large Models for more information.

More Segments -- The maximum number of segments permitted by **EZNEC Pro** v. 6.0 is 45,000, increased from the previous limit of 20,000.

Wire Grid Creation Enhancements -- The wire grid creation feature has been expanded to allow creating a box. End wires on any side of a wire grid can be omitted to facilitate connection to other structures.

Meander Line Creation -- **EZNEC Pro** automates the process of creating a meander line for planar loading or other purposes.

Spiral Creation -- The helix creation feature now includes the option of making a linearly varying spiral, including flat spirals.

Additional NEC Format "Cards" Read -- See Working With NEC Format Files for a complete list.

EZNEC Pro/4 Only:

NEC-4.2 Implementation -- NEC-4.2 introduces three major advancements from NEC-4.1: Allocatable arrays, current sources, and an advanced Sommerfeld ground model. The first two have been features of all **EZNEC** program types from its inception, and of its predecessor ELNEC since its introduction in 1990. The new Sommerfeld ground (GN3) model is incorporated in **EZNEC Pro** v. 6.0 as "Extended Accuracy" ground. All other changes and improvements made in NEC-4.2 have been incorporated into **EZNEC Pro** v. 6.0.

What Was New in v. 5.0

This topic describes the differences between v. 5.0 and the previous version, 4.0. If you're upgrading from v. 5.0 and are already familiar with it, go directly

to What's New in v. 7.0. If you're upgrading directly from an earlier version, please also see What Was New in v. 4.0.
EZNEC v. 5.0 marks the transition of **EZNEC** from an antenna analysis tool to an antenna *system* analysis tool. The new Transformer and L Network objects, in addition to the ability to include transmission line loss, extend the modeling capability for the first time from the antenna all the way back to the transmitter. Array phasing networks, tuners, impedance matching networks, along with realistic effects from transmission line loss, can now be part of the model. For the first time, the performance of the entire system can be seen.
New tutorial topic A Lap Around Track 5 covers use of virtual segments, L networks, and transformers. It's intended for users who are already familiar with basic **EZNEC** operation.

Insertion Objects

Not a new feature, but a new designation for the objects which can be inserted into a wire. These include the sources, loads, and transmission lines of previous versions, plus the new transformers, L networks, and Y parameter networks described below. They share a number of properties besides being inserted in wires, hence the new collective name of Insertion Objects.

Program Names

EZNEC Pro programs **EZNEC-M** and **EZNEC/4** have been renamed **EZNEC Pro/2** and **EZNEC Pro/4** respectively. As before, the sole difference is the availability in **EZNEC Pro/4** of NEC-4.2 calculating engines.

Transformers

Ideal transformers can now be connected between wires, between a transmission line and a source or wire, or in other places in a model.

L Networks

L Networks are powerful new objects which can be used to simulate a wide variety of networks, including phase shift and impedance matching networks. They can be cascaded to form pi, tee, and other more complex networks.

Parallel Connected Loads

A common problem in modeling with **EZNEC** has been the connection of a load in parallel with a source or transmission line, because a load, unlike other insertion objects, is connected in series with any other insertion object in the same segment. **EZNEC** v. 5.0 introduces the parallel connected load which as the name implies is connected in parallel rather than series with other insertion objects.

Transmission Line Loss

Loss can now be included in transmission line objects. If desired, the amount of loss can be made to automatically vary with frequency at approximately the same rate as a real transmission line in the HF-UHF range.

Wire Scaling

You can now easily scale wires or a group of wires and, optionally, their diameters by a constant. See Scale Wires in Using The Wires Window.

New 2D Plot Grid Style

A new grid style is offered for the 2D pattern plot. An advantage of the new style is a half-circle display when ground is specified, allowing larger plots. The traditional style is still available if preferred. The choice appears in the Control Center Options menu, 2D Plot Grid Style selection. When using the new style grid with a linear plot scale, you can also select the value represented by the center of the plot.

Additional Impedance Displays (EZNEC+, EZNEC Pro only)

There are several new ways to display the impedances from an SWR sweep, besides the traditional SWR plot: reflection coefficient magnitude, return loss, and Smith chart. Note that the Smith chart is an impedance display only, and not a substitute for a Smith chart program that interactively aids in designing matching networks.

Additional Advanced Wire Features (EZNEC+, EZNEC Pro only)

New, powerful features have been added to make multiple copies of wires (with each copy rotated and/or translated from the previous one if desired), generate a cylindrical structure, and reflect wires in one of the principal planes. See Making Multiple Offset and/or Rotated Copies of Wires, Making a Cylindrical Structure, and Reflecting Wires in a Plane in Using The Wires Window. These are replacements of the former **EZNEC Pro**-only feature of direct NEC 'card' entry, but are more versatile and easy to use.

IONCAP/VOACAP file writing (EZNEC+, EZNEC Pro only)

EZNEC can write type 13 IONCAP/VOACAP files after running a 3D plot. These files contain gain data at every degree of azimuth and elevation in a defined format.

Increased frequency sweep steps (EZNEC+, EZNEC Pro only)

Standard **EZNEC** allows up to 1,000 frequency steps for SWR and frequency sweeps. 10,000 are now permitted for **EZNEC+** and 100,000 for **EZNEC Pro**.

Y Parameter Networks (EZNEC Pro only)

Y Parameter Networks can be used to simulate nearly any kind of two port network at a single frequency by defining the port characteristics with y parameters. Familiarity with y parameters is required for use, however. This is a direct implementation of the NEC network.

Plane Wave Excitation (EZNEC Pro only)

The model can be excited by a plane wave from a distant source, instead of being excited by conventional sources. This allows finding the scattering cross section and directly finding the output of a receiving antenna.

What Was New in v. 4.0

This topic describes the differences between v. 4.0 and the previous Windows version, 3.0. If you're upgrading from v. 4.0 and are familiar with it, you can skip this section and go next to What Was New in v. 5.0.

Undo/Redo

EZNEC v. 4.0 has unlimited undo/redo capability.

Control Center Menus

The Plot menu no longer exists. Its functions have been moved to the Desc Options line in the Control Center Information Window. The Information

Window now contains all the choices which are saved with the description file, except for the near field and frequency sweep setups, which remain in the Control Center Setups menu.

Segments

The new **EZNEC+** program type permits 1500 segments. The **EZNEC Pro** program types (**EZNEC Pro/2** and **EZNEC Pro/4**) now allow 20,000. Note, however, that files as large as 6 GB can be written for the largest possible pro models at double precision, and calculation times can run to more than a day with 2 GHz machines.

Segmentation Check (formerly Guideline Check)

The **EZNEC 3.0** "Guideline Check" has been renamed "Segmentation Check" to reduce confusion with the new Geometry Check (below). As before, the Segmentation Check is only run when opening a file and under a few other conditions, and its results won't inhibit calculations. It now takes into account the velocity factor when evaluating buried wires (**EZNEC Pro/4** only), which can result in warnings in descriptions which didn't formerly generate any.

Geometry Check

EZNEC v. 3.0 has a Guideline Check feature to check the model against modeling guidelines for segment length. In **EZNEC v. 4.0**, this has been renamed Segmentation Check and a new Geometry Check feature has been added. This powerful feature, run automatically before each calculation, checks the model for errors such as wires crossing at other than a wire end or segment junction, wires occupying the same space or overlapping, or wires coming too close to each other.

Wires Window Features

There are a number of new, powerful features in the Wires Window Wire menu: Rotate Wires, Move Wires XYZ, Stack, Copy Wires (which allows making offset copies), and Change Loop Size. These can be used with a group of selected wires, or with a sequential group of wires selected after choosing the action to perform. There's a new Create menu, with the familiar Create Radials and, for **EZNEC Pro** users, Create Wire Grid. Check out the two new additions, Create Helix and Create Loop. Create Loop and Change Loop Size should be of particular interest to quad designers, although they're useful for many other applications.

The new "Rotate Wires" feature shouldn't be confused with the Elevation Rotate End and Azimuth Rotate End features accessed by right-clicking a wire end cell – present in both v. 3.0 and 4.0. The new feature allows rotating any group of wires around any axis, around the end or center of any wire, or around any point in space, while the right-click feature rotates a single wire around one of its ends.

View Antenna Display

The display can now be moved by dragging while holding down the right mouse button, and zoomed by dragging while holding down both buttons. See Using The View Antenna Display. Because of the new use of the right mouse button, the Wire Information popup window appears when you pause the

cursor over a wire. This behavior can be changed via the WireInfoDist Special Option.

Circular Polarization (EZNEC+ and EZNEC Pro only)

There are several new 2D and 3D plot, and Far Field Table display options: right and left circular polarization, and linear component along the major and minor axis of an elliptically polarized field. These are selected via the new Desc Options line in the main Control Center window. Click Desc Options, then select the Plot tab, then the Fields tab. Note that the selection affects the 2D and 3D plots and the FF Table.

Plot Displays

Major enhancements have been made to the 2D plot display. When displaying multiple fields (e.g., Total, Vertical, and Horizontal), you can click on the field name in the list at the left of the display, and the cursor will move to that field. The data in the data window will reflect the values for that field. When you add saved traces to the display, you can view only one field at a time, selected via the Mult Trc Fld choice in the 2D plot window View menu. There, you can choose among the fields selected in the main window Desc Options dialog box for the normal 2D display. If you add traces to the display, clicking on the name of any added trace file at the left of the display will move the cursor to that trace, and the data in the data window will reflect the value for that trace. Also, an extra line will appear in the right column of the data window, giving the field strength of the selected trace relative to the primary trace at the cursor angle.
The minimum step size for the 3D plot is now 1 degree instead of 2.

Calculating Engines

There's now a fully double-precision NEC-2 engine choice (plus and pro only), selected via the Control Center Options menu. All calculating engines are faster than before, most notably in the calculation of currents. The amount of speed improvement depends on which engine you've selected, what portion of the total calculation time is needed for the calculation of currents, and the type of CPU you have. But it can be quite spectacular with the NEC-2 engines, in particular. In program types allowing a choice of more than one calculating engine, the choice is shown just above the FF Plot button in the Control Center.

Wire Insulation

EZNEC v. 4.0 has the capability of including the effect of wire insulation. See the new Wire Insulation topic for more information.

Improved Printing

If you chose other than the default printer in **EZNEC** v. 3.0, your choice would become the system default printer. Also, many printer property choices were ignored by **EZNEC** v, 3.0. These deficiencies have been corrected.

Easy Import of Wire Coordinates from NEC Files (EZNEC+, EZNEC Pro only)

An additional format is allowed for importing wire coordinates from an ASCII file: the NEC GW "card" format. See the Wire Coordinate File topic for more information. This is the "second format" discussed in that topic.

Multiple Instances (EZNEC Pro only)

Multiple instances are permitted in the pro programs, including doing simultaneous calculations. The instance number is identified by a number in parentheses in the title bar of each window.

Other

Multiple Instances -- **EZNEC** v. 3.0 permitted multiple instances to be operating at the same time, provided that calculations weren't run. Because of the way certain new features were implemented, the v. 4.0 standard and plus program types don't allow more than one copy to run at once.

Ground -- The Real, Fast (reflection coefficient) ground type is no longer available. With today's machines, the saving in calculation time over the High Accuracy (Sommerfeld) ground isn't significant, and the Fast option is limited in accuracy with low antennas. Description files with Fast ground specified are converted to High Accuracy when opening, and will be saved with High Accuracy ground.

Loads -- When you convert from R + jX to RLC type loads (either directly or due to combining descriptions with different load types), you now have the option of conversion to a parallel RL or RC equivalent.

Wire Connections -- Wire end coordinates will always be modified to be identical if the wire ends are deemed connected (same coordinates within about 1/1000 segment length), because NEC always does this. It was formerly an option (Options menu Auto Coord Match), but no longer is.

LastZ.txt – (**EZNEC Pro** only): LastZ.txt files for instances beyond the first will persist in the **EZNEC** output directory as LastZ_N.txt, where N is the instance number. The file for the first instance will still be simply LastZ.txt.

Messages -- The tooltips can now be turned off, as well as the new message warning you if the description has changed before opening a new description, via Messages On/Off in the Options menu.

Crash Recovery -- A feature that I hope won't see much use. . . if you should ever encounter a program crash, the next time you start the program you'll get a prompt giving you the opportunity to recover to the model as it was just before the crash.

Ground Wave Analysis -- (**EZNEC Pro** only): Ground wave analysis can produce somewhat different phase angles for the polarization components than earlier versions, particularly when the observation point is many wavelengths from the origin. The cause is some slight changes in internal constants. The calculation of the phase at many wavelengths is sensitive to very small changes in these values. However, the important thing is the relative phases of the components, which remain very close to the same as in previous versions.

NEC Format Files -- (**EZNEC Pro** only): **EZNEC Pro** v. 4.0 can read GH (helix) and IS (wire insulation) "cards". **EZNEC Pro** will accept a file if it contains at least one GW, GH, or GA "card" in addition to a source. New

Special Option choice LD5Translation = First will cause **EZNEC Pro** to apply the wire loss parameters of the first LD5 "card" read as global Wire Loss, and ignore additional LD5 "cards".

Getting Acquainted with EZNEC

The fastest way to get acquainted with **EZNEC** is to take the Test Drive. This leads you through some of the basic operations. After the Test Drive, you'll be ready to model simple antennas. Then as you progress and want to learn more, begin reading the Building The Model chapter. For detailed information about a window or menu, look in the Reference chapter. And, as you use **EZNEC**, press the F1 key when you have a question about a particular menu, control, or display. It's not possible to cover all menus, controls, and displays, but many of the important ones or ones particularly needing explanation do have links. If a link isn't present, the manual will open to an introductory section.

The **EZNEC** manual might seem long and complex. This isn't because **EZNEC** is hard to use or learn, but because it has a rich set of features, and every effort has been made to explain them as thoroughly as possible. The combination of hyperlinks, detailed index, and comprehensive search capability make it easy to find information about any topic of interest.

I'm sure you'll find **EZNEC** to be a valuable and educational tool.

Printing The Manual

Nearly all Windows software currently being sold uses a help system for a manual, as **EZNEC** does. I personally disliked help systems for some time, but after getting used to using them, have come to greatly prefer them to printed manuals. Among the advantages are the hyperlinks, or jumps, allowing instant movement between topics, and extensive indexing.

However, many requests have been received from **EZNEC** users for a printed or printable manual. So a printable manual has been made available for those who want one. At the time of this writing you can download the printable manual from http://eznec.com/ez70manual.html but this site will be active only for an indeterminate time. The manual can be freely copied, printed, and distributed.

The printed manual is generated from the help file by the software used to develop the help file. The conversion process may have some imperfections, so the resulting format isn't flawless. However, because the on-line help system is intended to be the primary manual for **EZNEC**, and any formatting changes would have to be repeated each time the manual is updated, comprehensive editing and correction of minor formatting flaws in the printable manual wasn't undertaken.

The manual is available in both Microsoft Word (.doc) or Adobe Acrobat (.pdf) formats. The free Adobe Acrobat Reader is readily available via the web. An increasing number of other applications can also directly display and print these files. The printable manual comes in two versions, formatted for U.S. (8.5 X 11 inches) and A4 (210 X 297 mm) letter size paper.

Program Version Compatibility

A great deal of effort has been made to keep programs and description files compatible in both forward and reverse directions. This has been largely successful; ELNEC (**EZNEC**'s predecessor) dating back to 1990 can read and use **EZNEC Pro+ v. 7.0** files, although source and load placement will require adjustment and most insertion objects, which didn't exist in ELNEC, will be ignored. Similarly, the earliest ELNEC files can be opened and read by the current version of **EZNEC**. All versions between are similarly compatible. However, because earlier versions can't be aware of the features which follow, a file created with a later version of **EZNEC** won't necessarily be complete when opened with an earlier version. In some cases it's been possible to adapt new features to retain full compatibility with older versions. For example, virtual segments didn't exist prior to **EZNEC** v. 5.0. But when a description file is saved, the virtual segments are converted to real segments on a distant wire so that earlier **EZNEC** versions can properly process the model. But there's simply no equivalent to most new features. Transformers and L networks, for example, were introduced in **EZNEC** v. 5.0. There is no equivalent in earlier versions, so if a file containing these objects is opened with an earlier version, those objects will simply be missing. And there is likely no way any substitute can be devised, so it won't be possible to analyze the model with the earlier version.

Test Drive

Test Drive Introduction

The best way to get familiar with **EZNEC** is to take it for a spin. Let's analyze a 20-meter dipole hung 30 feet up in the back yard. If you've started **EZNEC**, you should see the Control Center. The file Dipole1.ez is included with the program and should be installed at the proper location, so we'll start with that antenna and modify it as necessary.

EZNEC has an unlimited number of Undo and Redo steps. So if you make a mistake at any time, simply press <Ctrl>-Z to undo changes in the reverse order in which they were made. Or open the Edit menu in the Control Center (main window) or any of several other windows and select Undo. Changes can be re-done after undoing by selecting Redo from the Edit menu.

Notes: <Enter> means the Enter key, <ESC> is the Escape key. You can type any entry in uppercase, lowercase, or any combination. When text to be typed is surrounded by single or double quotation marks, don't type the quotation marks themselves Numerical results you see might differ very slightly from the ones shown in the tutorial because of different calculating engines being use, or differences in the order of internal calculations in various program versions and revisions..

EZNEC includes a context-sensitive help system. At any point in the program, pressing the F1 key, or a Help button if available, will open the Help system to the topic dealing with the currently active form, control, or dialog box. If no topic is found, the Help system will open showing the contents.

Values shown for gain, impedances, and other results might differ slightly from what's shown here. These examples were done using the integral EZCalcD (NEC-2D) calculating engine in all **EZNEC Pro+** programs. NEC-5 might show results that are significantly different because of its different placement of insertion objects.

The Test Drive begins with Along The Straightaway.

Along The Straightaway

This exercise leads you through the creation of a simple dipole, and illustrates some of the basic steps in creating an **EZNEC** model. Most of the steps could be done in any order. The order of steps in this exercise is pretty much arbitrary. If you'd like to take a break before finishing the tutorial, you can simply end **EZNEC** by selecting Exit from the Control Center File menu, and the next time you start **EZNEC**, it will resume where you left off. Or you can save the description by selecting Save Description As from the File menu, or by clicking the Save As action button, and giving the file a name. Then you can open the description by selecting Open from the File menu, or clicking the Open action button, and specifying the name you used for saving.

In the Control Center, locate the Open action button and click it. This will open a file selection dialog box. Select Dipole1.ez, or enter ‘dipole1' in the "File name" text box and click Open. Click here if you have trouble.

The bar at the top of the Control Center information window should now read "Dipole in free space" -- this is the title of the antenna description stored in file Dipole1. Let's enter a title for our back yard dipole.

Click anywhere on the information window title bar (where the text "Dipole in free space" is), and a dialog box will open for you to enter the new name. Enter ‘Back yard dipole', then click Ok or press the <Enter> key. Notice that the information window title bar now shows the new description name.

Now let's change the frequency to 14 MHz --

Click anywhere on the Frequency information window line, or on the selection button to its left. Enter ‘14' in the dialog text box, and click Ok or press <Enter>.

Let's choose feet for a convenient unit of measure. (This isn't the most convenient for international users, but please select feet for this example.)

Click on the Units line or the selection button to its left, then select Feet, and Ok.

The ground type for model Dipole1 is Free Space, and we'll want to model this antenna over ground. This will be taken care of after we define the wires and sources.

Next we'll describe the antenna itself. **EZNEC** gives you the ability to see the modifications you're making as you make them. To take advantage of this powerful feature,

open the View Antenna window by clicking the View Ant action button in the Control Center.

In the View Antenna Window,

click to open the View menu. If a checkmark appears next to Show Controls, click Show Controls to turn the control box off.

This turns off the control and data boxes, which aren't needed now. Next,

open the Wires Window by clicking on the Control Center "Wires" line, or the selection button to its left. Position the Wires and View Antenna Windows for convenient viewing. You can resize the View Antenna Window if desired by dragging a side or corner. It's ok to cover all or part of the Control Center for the time being.

The Wires Window is where the wires of the antenna are actually defined. The position of each wire in space is specified by giving its x, y, and z coordinates. These coordinates represent distances from the origin. For example, look at the numbers in the Wires Window for Dipole1. It consists of one wire which extends along the y axis. The y coordinate of End 1 is about –0.82 feet, and the y coordinate of End 2 is about +0.82 feet, so the wire is about 1.64 feet long. You can confirm this by moving the mouse cursor to the y-axis line in the View Antenna display (where the wire is – it might be a little hard to see at the moment) and leaving it still for a moment to open the Wire Information window. Alternatively, you can move put the mouse cursor over the selection button at the very left of Wire 1 in the Wires Window and right-click it.

Dipole1 is a half wavelength long at about 300 MHz, so it's much too short for our 20 meter dipole. Let's make the wire the length we want.

Assuming our back yard dipole was designed using 468/f(MHz) to determine the length, the length is 33.43 feet. **EZNEC** doesn't require any symmetry, and we're free to choose where in space we put the origin (except that it has to be at z = 0 if a ground is used) so for convenience we'll put one end of the wire at x,y = 0, 0 and the other at x,y = 0, 33.43. Placing it along the y axis makes the maximum lobes in the direction of the x axis. Ground is always defined as

being at z = 0 (for the innermost medium). Since the antenna is horizontal and up 30 feet, the z coordinate of both ends is 30. To enter the coordinates,

Click on the Wires Window cell for Wire No. 1, End 1, Y (where the current value is –0.82…), and change the value to 0.

Notice that the mark on the button at the left has changed to a pencil. This indicates that the row (wire) has been edited. Note also that the number you've entered is shown in red. This indicates an edited value. The edited value won't be accepted by **EZNEC** until you click on another row of the grid, move the insertion point off the row with the <Tab> or arrow keys, or press <Enter>. You can undo an edited value, but only before it has been accepted, by pressing <Esc>. Pressing <Esc> again will undo all edited values in the row. And you can undo any already accepted change with the Undo feature, available in the Edit menu or by pressing <Ctrl>-z on your keyboard.

Move to the next cell (End 1 Z) with the mouse or <Tab> key and enter 30.

The coordinates of End 1 are now 0, 0, 30.

Similarly, modify the End 2 coordinates to be 0, 33.43, 30.

Finally, define the wire diameter. We'll assume the antenna will be made from 12 gauge (AWG) wire.

In the "Diameter" column, enter '#12'. (**EZNEC** will also accept the diameter in inches or other appropriate units depending on the Control Center Units selection.)

The last column is to define the number of segments for the wire. 11 is a reasonable number for pattern analysis of a half-wave antenna, so we don't need to change it. (We do need an odd number of segments so we can put our source in the middle of the wire.)

Then

press <Enter> so **EZNEC** will accept the values.

Notice that the View Antenna display has changed to show what the new antenna looks like. You should see a horizontal wire parallel to, but above, the y axis. If you don't, go back to the Wires Window and correct the coordinates. End 1 coordinates should be x, y, z = 0, 0, 30, and End 2 coordinates should be 0, 33.43, 30.

Move the mouse cursor to the wire in the View Antenna display, and leave it still for a moment to open the Wire Information window. The length of the wire should be 33.43 feet. If it isn't, correct the coordinates in the Wires Window.

The next step is to define the source. This is connected at the point where the power is applied to the real antenna, in this case the center of the wire.

Close the Wires Window by clicking the close button in the upper right corner (the small box with the "X" mark).

Open the Sources Window by clicking on the Sources line in the Control Center information window, or on the selection button to its left.

In the Sources Window grid, you can see that there's one source (source no. 1), which is placed on wire #1, 50% from end 1. This is where we want the source to be. However, this is a good time to practice a little with the Sources Window.

In the Sources Window, locate the cell in the % From E1 column in the Specified Pos. group. Change the value from 50 to 25 and press <Enter>.

This change had several effects. First, the value shown in the % From E1 column in the Actual Pos. group changed from 50 to 22.7273. When you specify a source (or load or transmission line) position, **EZNEC** attempts to place it as close as it can to the specified position. But it's restricted to placing the source in the center of a segment. (In reality, the source excitation is spread over the whole segment, but it's easier to visualize as being at a single point.) So **EZNEC** tells you, in the Actual Pos. group, where the source is actually placed. So the Actual Pos. group columns show that the source is 22.7+ percent from end 1 of the wire, and it's on the third segment from end 1. You can see this placement in the View Antenna display. (You can maximize the display by clicking the maximize button -- the one with a square -- near the upper right corner, for better viewing, then return it to normal size by clicking the same button again. Segment junctions are shown as dots on the wire.)
The benefit of specifying source, load, and transmission line positions in terms of percent from the wire end is that the wire length or number of segments can be changed without affecting the relative position of the source (except as necessary to place it at a segment center or, with NEC-5, a segment junction).
The source type, shown in the Type column, is a current source. The Sources Window also show the source amplitude and phase, in this case one ampere at zero degrees. When a model contains only a single source, the magnitude, phase, or type have no effect on the pattern, dBi gain, or source impedance. So we'll leave these as they are for now.
Now restore the source to the correct position in the middle of the wire.

Press <Ctrl>-z on your keyboard to undo the change you just made.

The source should now appear in the middle of the wire in the View Antenna display, and the Actual Pos. should now show as 50 percent, on segment 6.
The source could have been connected through a transmission line. However, a lossless line will affect only the impedance seen by the source. It will have no effect on the antenna gain, pattern, or other characteristics. No transmission line will be used in this example.

Close the Sources Window by clicking the close button in the upper right corner.

Now it's time to deal with the ground. Presuming you don't have a perfect ground plane in your back yard (and for many wavelengths in all directions), you'll want to do the analysis over "real" ground.

Click on the Ground Type line, and select Real.

MININEC type ground allows direct connection to the ground and considers it perfect when calculating currents and impedances. But perfect ground will give unrealistic results if horizontal or sloping wires are below about 0.2 wavelength high. That's not a problem here, but it's recommended that MININEC ground be used only when a zero loss ground connection is needed, and High Accuracy ground should be used in all other cases. (Extended Accuracy ground can also be used when available but usually with very similar results and at the expense of longer calculation time.)

Choose High Accuracy, then Ok.

Finally, we need to specify the ground characteristics.

Click on the main window Ground Descrip line. This opens the Media Window.

Note that the Ground Descrip selection isn't visible unless Ground Type is Real. The Media Window is where specification of Real ground is done. One or two ground media can be specified, but we'll only need one for this model.
When we changed the ground type to Real, one ground medium was created. The conductivity and dielectric constant of newly-created grounds can be set for your local ground conditions by means of the Control Center Options menu Default Ground Const selection. The values initially used by **EZNEC** are those of "average" or "good" ground (conductivity of 0.005 S/m, dielectric constant of 13). These are the values you should see in the Media Window at this point, unless you've changed the default ground constants.
For this exercise, let's suppose your back yard has the characteristics of "very good" ground.

Move the mouse cursor to either the Cond. or Diel. Const. cell in the Medium No. 1 row, and click the right mouse button. Note: Make sure the mouse cursor, not just the text insertion point, is in the designated cell when you right-click.

This will open the Ground Characteristics dialog box.

Select the Very Good option, then click Ok.

The Media Window should show 0.0303 for the conductivity, and 20 for the dielectric constant.

Close the Media Window by clicking the close box in the upper right hand corner.

This completes creation of the model itself. We can now choose what to calculate and display. Note that all the information in the Control Center information window is saved with the description when the description is saved to a file. In addition, frequency sweep and near field analysis setups, and the selections in the Control Center Description Options Window, are saved in this file.
We know that the dipole's maximum lobe will be broadside to the wire, but at what angle above the horizon will it be maximum? We'll run an elevation plot to find out. (3D plotting is covered in "On The Race Course", in the last section of the Test Drive.)

Click on the Plot Type row in the Control Center.

This opens the Plot Type dialog box.

Select Elevation, then Ok.

The azimuth angle for the plot is zero degrees (broadside to the antenna) which is where we'd like to look, and all the other parameters look fine. To plot the pattern,

Click the FF Plot action button.

This tells **EZNEC** to compute and display the 2D far field pattern. You might briefly see the Calculation Progress Window while the calculation is running. When it's finished, you should see the plot and some text below it with information about the pattern.

If you don't see the text below the plot, open the 2D Plot Window View menu, and select Show Data.

The plot represents an elevation "slice" of the antenna pattern. From the text in the data box, you can see that the pattern is maximum at 34 degrees above the horizon, and other information about the pattern. You can see the antenna gain (second row in the data box, on the right) at any elevation angle by moving the cursor. This can be done by simply clicking on the 2D plot. The

cursor will move to a point on the plot which is on an imaginary line from the plot center to the mouse cursor location. Note that the mouse cursor must be in the plot window when the button is initially pressed, although it can be moved outside the window while being held down. You can also press and hold the left mouse button and drag the cursor to the desired angle. The cursor can also be moved with the arrow keys (for fine steps) or the <Page Up> and <Page Down> keys (for coarser steps). Before using the arrow keys, you should click on the 2D plot window. Otherwise, they might adjust some other program parameter or control.

Click the Src Dat action button in the Control Center.

This gives you information about the source. The fact that the impedance of about 74 - j 43 ohms has a negative reactive part indicates that the antenna is operating below resonance and needs to be lengthened if resonance is important. The formula of 468/f (MHz) feet is an approximation, and the exact resonant length depends on the wire diameter and height above ground. The Source Data display also shows that if a 50 ohm transmission line were connected to this antenna, the SWR on the line would be about 2.2:1. If a 75 ohm line is used, the SWR on the feedline would be about 1.8:1.

Close the Source Data display by clicking the close box.

In the View Antenna display, an additional line has appeared above the antenna wire. This indicates, by the distance of the line from the wire, the magnitude of the current along the wire. You can see that the current is maximum at the antenna center and tapers to zero at the ends. The current indication appears only after calculations have been done, and it can be removed from the display if desired. (To find out how, click anywhere in the View Antenna Window to make it the active window, then press F1 on your keyboard to open context sensitive help.)

In the 2D Plot Window, open the File menu and select Save Trace As. Enter the name "Back Yard Dipole", and click Save.

This saves the 2D plot (trace) in a file named Back Yard Dipole.pf. We'll use it in the next exercise.

Save the antenna description by clicking the Save As action button, entering the name ‘Back Yard Dipole', then clicking Save.

This concludes the drive down the straightaway. If you'd like to try your hand at a little more complex maneuvering, try taking **EZNEC** Through The Curves. You can continue directly from here, or you can exit **EZNEC** and do the next exercise later.

Through The Curves

If you haven't yet done so, take **EZNEC** "along the straightaway". In this section you'll begin with the plot generated by the "straightaway" drive and get introduced to a few of **EZNEC**'s more advanced features. Ready to go? Let's see how an inverted vee compares with our back yard dipole.

If you've shut down **EZNEC** since doing the "along the straightaway" exercise, you'll have to open the back yard dipole description after starting **EZNEC**. This is done by clicking the Control Center Open action button, entering the name ‘Back Yard Dipole', and clicking Open. You should also open the View Antenna window by clicking the View Ant action button.

Open the Wires Window by clicking on the Wires line of the Control Center information window.

We'll make the inverted vee by beginning with a dipole, then use one of **EZNEC**'s powerful editing features to convert it into an inverted vee without having to calculate any additional wire end coordinates.
An inverted vee can't be made from just one wire since it's bent in the middle and all wires must be straight. So we'll have to add another wire and use each of the two wires for half of the inverted vee. Let's put the center of the antenna at x, y, z = 0, 0, 30 (30 feet straight up from the origin). Note that end 1 of wire 1 is already at this point, but we'll need to modify its length to be suitable for the new antenna. To make the new inverted vee the same length as the original dipole, each of the two wires should be 16.715 feet long. So first we'll modify the existing wire to be this length. Watch the View Antenna display when you press <Enter> in the following step.

Change the End 2 Y coordinate to 16.715 and press <Enter> to make **EZNEC** accept the new value.

If you watched the View Antenna display when you pressed <Enter>, you saw that the wire appeared to change both its length and height above ground. The height, however, didn't really change. The reason for the apparent change is that **EZNEC** rescales the View Antenna display each time you change a wire, making it as large as possible without going beyond the window boundaries. Although the relative dimensions of everything on the display are correct, you can't determine absolute values from this display. Notice that in the display, the height of the wire is a little less than twice its length, which is the correct proportion.
The coordinates of Wire 1 should now be 0, 0, 30 (end 1) and 0, 16.715, 30 (end 2). If not, manually correct them and press <Enter>.
Now we'll add the second wire. A wire can be added at least two ways. The simplest way to add a single wire is to simply type its coordinates and other parameters on the add row, identified by the asterisk (*) on the button to its left. In this step, you'll also learn how to use one of **EZNEC**'s powerful editing shortcuts.

Position the mouse cursor over any of the cells of **End 1** of the add row and click the right mouse button.

This opens the list of shortcuts. When no coordinates have been entered yet, the only option is Connect End To.

Click it. In the dialog box, enter the value 1 in each of the two boxes.

This tells **EZNEC** that you want to connect this end (end 1) of the current wire (the new wire) to end 1 of wire 1.

Click Ok or press <Enter>.

There should now be two wires shown in the grid, numbered 1 and 2. The coordinates of end 1 of wire 2 are the same as the coordinates of end 1 of wire 1, as a result of the last step. Take a look at the column labeled Conn. (Connections) in the End 1 group. This shows which wire and end is connected to an end. In the wire 1, end 1 Connections column, you should see "W2E1". This tells you that wire 1, end 1 is connected to wire 2, end 1. Likewise, the entry in the wire 2, end 1 column shows the connection to wire 1, end 1 as "W1E1". In this example, the connection is pretty obvious, since the coordinates of the two ends are right above and below each other. But you'll find this feature handy with more complex antennas. If more than one wire is connected to an end, only one connection will be shown in the

Connections column, but by following the connections you can identify all the wires connected together.
There are a couple of other things to point out about the new wire (wire 2). Notice that it's the same diameter as wire 1, and has the same number of segments. By default, **EZNEC** gives a new wire the same diameter and number of segments as the preceding wire. It will, of course, use other values you specify if you do specify them.
In the View Antenna display, you can see the new wire you've created, although it might not be too obvious. It extends from one end of the horizontal wire (wire 1) to the origin, right along the z axis. If you don't see the numbers beside the wires, select Objects from the View Antenna display View menu, and check the Wire Numbers box, then Ok.
End 2 of the new wire is at the default coordinates of 0, 0, 0. When a ground is specified (as it is here), a z coordinate of zero automatically means a connection to ground. This shows in the Wires Window Wire 2 End 2 Connection column as "Ground". Now it's time to fix end 2 of wire 2.

Change the wire 2, end 2 coordinates to 0, -16.715, 30, and press <Enter>.

Notice in the View Antenna display the effect this change has on the antenna. Wire 2 now looks like an extension to wire 1.
We could have reversed the ends of wire 2 with no effect on the overall result. The choice of which end to call end 1 and which to call end 2 is pretty much arbitrary. One thing to keep in mind, however, is that reversing the ends causes a reversal in the direction of current which **EZNEC** reports. So when multiple sources are used, or where the currents are of interest, it's wise to be systematic in assigning the end numbers. For example, in an array of phased vertical antennas, you should face all end 1s the same way, so all element currents will be defined as flowing in the same direction. For this antenna, though, the choice of end 1 makes no practical difference.
Our new antenna has twice as many segments as the back yard dipole. That's no problem and doesn't need changing.

Close the Wires Window.

You can see in the View Antenna display that the source (represented by the circle) is still on wire 1. To make a dipole or inverted vee from the two wires, the source has to be at the junction of the two wires. However, the NEC calculating engines used by **EZNEC** spread the source excitation over a whole segment (or, conceptually, places it at a segment center), except for NEC-5 where the excitation is next to a segment junction. We don't have a segment center at the center of the antenna, so what should we do?
One solution to this problem is to insert a third wire between the two and put the source on it. However, this can be trickier than it seems, because of NEC's general fussiness about source placement. The best solution is to make use of **EZNEC**'s split sources, which can be placed at a wire junction. Please click the link for more information about them.

Open the Sources Window by clicking the Sources line in the Control Center information window. Click the cell in the Source 1 Type column.

As soon as you click the cell, a small button with an arrow appears in the cell. This indicates that several distinct choices are available. Clicking on the button opens a pull-down list of choices.

Select ‘SI' (for 'Split Current'). Then move to the % From E1 column in the Specified Pos. group and change the value from 50 to 0.

This will put a split current source at end 1 of wire 1.

Press the <Enter> key.

On the View Antenna display, you should now see two source circles, one on each side of the wire 1 – wire 2 junction. You can rotate the display for better viewing by pressing the left mouse button while the cursor is in the display window, then moving the mouse while holding the button down. You can also resize the display by dragging any of the sides of the window.

At this point, we have a dipole again, but made from two wires instead of one.

Click the FF Plot action button to generate a 2D plot. In the 2D Plot window, open the File menu and select Add Trace. If you saved the trace from the "Along the Straightaway" exercise, you should see a file named "Back Yard Dipole". Click it, then click Open.

This overlays the back yard dipole plot with the plot from the new dipole. It should overlay exactly, showing that the new dipole, made with two wires and a split source, and centered with respect to the x axis, has the same pattern as the single wire, offset dipole with a standard source. This illustrates that you have a great deal of flexibility in modeling your antenna.

Click the Src Dat Control Center action button.

The indicated impedance is slightly different than it was for the original dipole. Most of the difference is due to the fact that the new dipole has twice the number of segments. But small differences in reported impedance are to be expected whenever a model is changed, however slightly. The differences are insignificant for any practical purpose. If you'd like to experiment a little, open the Wires Window and change the number of segments on the wires, keeping the number the same for both. Then click Src Dat again to see the effect of this change on the source impedance. Repeat for several different numbers of segments. Close the Wires Window when you're finished to get it out of the way.

Close the Source Data display.

Now we'll make the dipole into an inverted vee. At this point, most other modeling programs would require you to do some trigonometry or carefully draw the inverted vee on graph paper to determine the coordinates of the wire ends. But not with **EZNEC**. We'll use **EZNEC**'s Rotate feature to make it into an inverted vee with an included angle of 90 degrees.

Before proceeding, it's a good idea to save the description. This way, an easy recovery can be made if too many errors are made -- although you can undo any changes you've made since opening a new description or starting the program.

Click the Control Center Save As action button. Furnish a name, such as "Temp" (don't use "Last" – it's used by **EZNEC** for the description present when the program ends), then click Save.

Open the Wires Window by clicking on the Wires line in the Control Center information window.

With the mouse cursor over the X, Y, or Z coordinate cell of **Wire 1, End 2**, click the right mouse button. (Remember, the mouse cursor has to be over the right cell, regardless of where the text insertion point is.)

This opens the shortcut list.

Select Elevation Rotate End. Enter the value -45, and click Ok.

This rotates end 2 of wire 1 downward 45 degrees, without changing end 1. In the View Antenna display, you should now see wire 1 drooping downward 45 degrees. Rotate the View Antenna display if desired by clicking in the display window and dragging with the mouse. If you don't see this, you should return to the dipole by either re-entering the wire end coordinates or by reopening the file you saved a moment ago by clicking the Open action button and selecting the file. Then try the rotation feature again.
The 2D plot disappeared as soon as you modified the antenna wire. This is intended operation. **EZNEC** removes any displays that are no longer valid. As soon as you modified the wire, the display no longer represented the pattern of the current antenna, so it was closed.
Now repeat the rotation for the second wire.

With the mouse cursor over the X, Y, or Z coordinate cell of **Wire 2, End 2**, click the right mouse button. Select Elevation Rotate End. Enter the value –45, and click Ok.

You should see the completed inverted vee in the View Antenna display.
If the inverted vee looks ok, close the Wires Window.

Click the FF Plot action button to generate a 2D plot.

The plot should resemble the dipole plot. To see how the pattern compares to the dipole's,

Open the 2D Plot display File menu and select Add Trace. Locate the Back Yard Dipole file you saved at the end of the "Along The Straightaway" exercise and click Open.

Note that when automatic outer ring scaling is selected, it's scaled for the largest of all the plots being displayed. It can be shown that the center of current for a sinusoidal distribution is 1/3 of the way from the current loop. This means that the effective radiation strength from the inner 1/3 of the inverted vee equals that from the outer 2/3 (since the current is heavier toward the center). If we raise the inverted vee by 3.94 feet, it will place this current center at 30 feet, which was the height of the dipole's center of current. Let's try it and see what happens:

Open the Wires Window if you've closed it. Open the Wire menu and select Change Height by. Enter 3.94 in the bottom text box and click Ok or press <Enter>.

Again the 2D plot is closed as soon as the model is changed.

Close the Wires Window if desired, then click the FF Plot action button. Add the Back Yard Dipole trace to the 2D display as you did before.

The higher inverted vee is closer to the dipole pattern but still has slightly lower maximum gain. This shouldn't be surprising if you investigate the patterns in more detail. The inverted vee has more radiation off the end, reducing the gain from the side. But as you can see, the gain difference between the dipole and inverted vee is less than one dB (providing the centers of current are at the same height).
This concludes the "Through The Curves" exercise. If you'd like to learn some additional techniques, try taking **EZNEC** On The Race Course. You can continue directly from here, or you can exit **EZNEC** and do it later.

On The Race Course

This section takes you through some of **EZNEC**'s more advanced features.
Open the back yard dipole model included with **EZNEC**:

Click the Control Center Open action button, and select and open the example file BYDipole1.ez.

Let's look at the full 3D pattern.

Click the Plot Type line in the Control Center information window. Select 3 Dimensional, then Ok.

Click the FF Plot action button to start the calculation.

When the calculation finishes, you'll see a full three-dimensional (3D) display of the dipole pattern. You'll note that it doesn't look much like the textbook pictures you may have seen. This is because the textbook pictures usually show a dipole in free space or, at most, over a perfect ground. This, on the other hand, is the model of a dipole over real ground.

You can move the 3D display around to view it from different angles. Position the mouse cursor anywhere on the 3D plot window. Press and hold the left mouse button down as you move the mouse. The mouse cursor has to be in the 3D plot window when the button is initially pressed. However, once the button is down the mouse cursor can be moved anywhere on screen. You can also do fine positioning with the arrow keys, as long as you first click anywhere in the 3D plot window.

One of **EZNEC**'s powerful features is the ability to view individual 2D "slices" of the 3D display. To use this feature, the 3D display control box must be activated. If you see some controls to the left of the plot, the control box is on. If not, you need to turn it on at this point by opening the 3D display View menu and selecting Show Controls.

In the control box Highlight section, choose Elevation Slice.

The 3D plot will dim, and an elevation "slice" will appear in a distinctive color. (You can modify these colors via the 3D display Options menu Colors selection.) The two control box scroll bars are now active, and can be used to change the slice and to move the cursor.

Most of the scroll bars in **EZNEC** can be adjusted in several different ways. You can click on the arrow boxes at the ends to move the control a single step. Holding the left mouse button down when on an end box moves the control rapidly. If you click in the area between the adjustment bar and the end box, the control will move in larger steps. Or you can simply drag the adjustment bar to the desired position. Finally, the keyboard arrow keys will move the control if it has focus (that is, if it's the currently active control).

Now click the Show 2D Plot box at the bottom of the 3D display control box.

This turns on the 2D display, where the currently highlighted "slice" of the 3D plot is shown. Notice that as you change the 3D "slice" and the cursor position, the 2D plot changes accordingly. Turn on the 2D display control and data boxes as follows.

On the 2D plot, open the View menu. If Show Controls isn't checked, select it. Repeat for Show Data if it isn't checked.

The 2D display controls track the corresponding controls on the 3D display. So once a 3D plot has been calculated, various "slices" can be selected directly from the 2D display if desired.

When the Plot Type is 3D, the only way to open the 2D display is from the 3D display (either by checking the Show 2D Plot box in the control box, or by selecting Show 2D Plot in the 3D display View menu). If you close the 3D

display and want to reopen it, click the FF Plot action button in the Control Center.

Experiment with the 2D and 3D controls, selecting different "slices" and "slice" types, and moving the cursor.

You can move the cursor in the 2D display by clicking in the 2D plot window. After clicking in the 2D plot window, the cursor can also be moved with the arrow keys and <Page Up> and <Page Down> keys. And, when the 2D control box is being shown, you can move the cursor with the appropriate scroll bar.

Various information about the 2D pattern is shown in the 2D display data box (under the plot). One entry, on the right side, is the gain given as "dBmax". This is the gain relative to the maximum value anywhere in the 3D pattern.

Open the View Antenna display by clicking the Control Center View Ant action button. In the View Antenna display, open the View menu and select Objects. Check the 2D Pattern box and click Ok.

The 2D "slice" now appears on the View Antenna display. This shows how the "slice" is oriented relative to the antenna. Notice that as you change the selected "slice" with either the 2D or 3D controls, the View Antenna display changes accordingly. Also notice that as you rotate either the 3D or View Antenna display, the other changes position to match. (They don't track moment to moment, but synchronize when the mouse or keyboard key is released.)

One last point to mention before leaving the 3D display. You can save a 3D plot from this display (File/Save 3D Plot), but you can't open one from the 3D display or superimpose 3D plots. You can specify any azimuth or elevation "slice" of a saved 3D plot to add to the 2D display. Or, you can recall and view the entire 3D plot with TraceView.

Close all the windows except the Control Center.

Now let's run an SWR plot of the antenna.

Click the SWR action button. Enter 14, 14.4, and .1 (0.1) in the Start Frequency, Stop Frequency, and Frequency Step boxes respectively. Then click Run.

This will run an SWR sweep, with the results being shown when the sweep is finished.

Turn on the control and data boxes via the SWR display View menu, if they're not already on.

You can move the cursor on the SWR graph to any position by clicking on the graph near the point where you want the cursor to go, or by dragging the cursor. You can also move the cursor with the arrow keys after first clicking anywhere on the SWR graph. As the cursor moves, you can see the SWR for that frequency in the data box below the graph.

The graph clearly shows that the antenna is too short, if lowest SWR on 20 meters is a goal. This is indicated by the fact that the SWR decreases clear across the band.

Let's make the antenna resonant at 14.1 MHz. One way would be to adjust the lengths of the wires and find resonance by trial and error. But we'll use another method. First we find out just where the antenna is currently resonant. We know it's at or above 14.4 MHz, so

Click the SWR action button. Enter 14.3 and 14.8 in the Start and Stop frequency boxes, and click Run.

From the graph, the SWR is lowest at about 14.4 MHz. What we'll do is change the frequency to 14.4 MHz so we'll have a resonant antenna but at the wrong frequency. Then we'll rescale that resonant antenna to the right frequency.

In the Control Center information window, click the Frequency line. Enter the value 14.4, then Ok. Click the Frequency line again. Enter the value 14.1. But this time, check the Rescale box before clicking Ok.

Open the View Antenna display by clicking the View Ant action button. Hover the mouse cursor over the wire in the View Antenna display to show the wire information popup. You can see that **EZNEC** has lengthened the wire to about 34.14 feet. (It was originally 33.43 feet.)

Close the View Antenna display. Click the Control Center Src Data action button.

The source impedance still has a slight negative reactance (about –2.8 ohms), indicating that the antenna is still a very small but insignificant amount short of resonant.

Close the Source Data display. Click the SWR action button. Enter 14, 14.35, and .01 for the Start, Stop, and Step Frequencies, then click Run.

This shows the SWR across the 20 meter band, with the minimum very near 14.1 MHz.

You won't always get such a precise result when using this method, for a couple of reasons. One is that we sometimes guess at the initial resonant frequency, although this can be made more precise by running additional SWR sweeps with finer steps. The second reason is that when an antenna is scaled, the wire diameter isn't changed if it's specified as an AWG gauge. The diameter of our antenna wire is specified as #12, so it wasn't changed with the scaling. Exact scaling requires changing the wire diameter in the same proportion as the antenna length. **EZNEC** doesn't do this when wire diameter is specified as a gauge, because it would usually result in a diameter which doesn't correspond to any standard wire size. Ground conductivity also doesn't scale linearly with frequency. This will generally make a noticeable difference only with the patterns of vertically polarized antennas, however. Both factors are generally negligible, though, when the frequency difference is small.

You might want to feed the antenna with 75 ohm line instead of 50 ohm line. An alternate Z0 is available for analysis. It's set in the Control Center information window, as Alt SWR Z0. Since we didn't change it, its value is 75 ohms, which was the value in the BYDipole1 description we started with. To see what the SWR would be on a 75 ohm feedline,

Select the Alt option in the SWR display control box Z0 section.

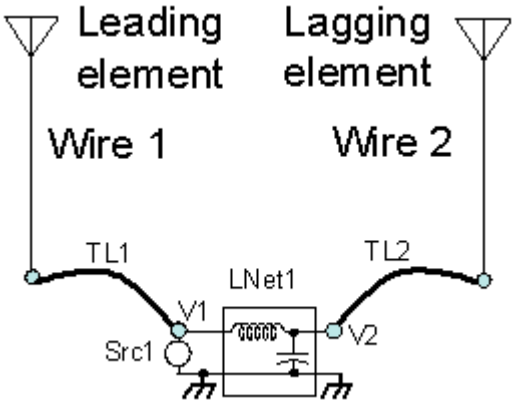
75 ohm feedline feeding this antenna would have a lower SWR than 50 ohm line. (However, the SWR is low enough that it's unlikely to make any difference in performance unless the feedline loss is exceptionally high.) If analyzing an antenna with more than one source (such as the example antenna 4Square), you can select which source to view using the up-down control in the SWR display control box.

This concludes On The Race Course, and the Test Drive.

Now you've taken **EZNEC** for a good run. The Building The Model chapter gives tips for creating models and interpreting results. The Reference chapter contains complete information about each menu and its features.
The Stacked Yagis section contains an additional step-by-step tutorial that illustrates additional **EZNEC** features. You might want to go through it now or at a later time.
A Lap Around Track 5 is an additional tutorial, covering the use of transformers, L networks, and virtual segments. However, it's recommended that you get more familiar with basic **EZNEC** operation before going through it.

A Lap Around Track 5

This section of the Test Drive tutorial will acquaint you with using the transformer and L network insertion objects, and virtual segments. These features were introduced in **EZNEC v. 5.0**. It's assumed that you're already familiar with basic **EZNEC** operation.
The examples involve modeling L network type feed systems for phased arrays. The design of the feed systems of the two examples used here are described in Chapter 8 of the 21st Edition of the *ARRL Antenna Book*, which became available at just about the same time as **EZNEC v. 5.0**.
The first example is a two element cardioid array fed with an L network feed system:



Of course, transmission lines TL1 and TL2 each have two conductors, and the models have two sets of two terminals just like the L network object LNet1. The second conductor is omitted from the diagram for simplicity.
The ARRL Antenna Book example design shows that the value of the series inductor in the L network needs to be 1.815 uH and the shunt capacitor 199.7 pF to achieve the correct element current ratios, with transmission lines TL1 and TL2 being quarter wavelength 75 ohm lines. With an EZNEC model, you'll be able to not only verify that the design is correct, but also to check the pattern and impedance over a range of frequencies.
We'll begin with a model of a two element array using the "simplest" feed system -- a feed system using only two transmission lines whose lengths are calculated with a special program for the purpose. It looks just like the diagram above, except that there's no L network, and TL1 and TL2 have particular unequal lengths. The chief advantage of the L network feed over the "simplest" system is its adjustability.

In the Control Center, locate the **Open** action button and click it. This will open a file selection dialog box. Select **Cardioid TL ARRL Example.ez**.

The bar at the top of the Control Center information window should now read "Cardioid with feed system".

Open the View Antenna display, where you can see that the two transmission lines are connected from the two elements to a short connection wire, Wire 3. The source is also connected at that wire.

Click the **FF Plot** Action Button to generate a 2D plot. Then save it by opening the **File** menu 2D Plot Window, then selecting **Save Trace As**. Enter the name **Cardioid TL ARRL Example** and click **Save**.

You now have a pattern which can be used to verify that the following steps produce an equally good result. The first thing we'll do is replace Wire 3 with a virtual segment. Prior to **EZNEC v. 5.0**, it was necessary to create a short wire any time you wanted to connect sources or transmission lines in parallel. Virtual segments are now available to make this unnecessary.

The source and both transmission lines connect to Wire 3, so we need to change all three connections.

Close the 2D Plot Window to reduce clutter. Open the Sources Window by clicking on the Sources line in the Control Center. In the **Specified Pos. Wire #** column, replace **3** with **V3** and press <Enter>.

The source is now connected to Virtual Segment 3. (The number 3 was chosen simply because it's the number of the wire it replaces. Any number from 1-999 could have been chosen.)

Close the Sources Window and open the Transmission Lines Window. In the End 1 Specified Pos. Wire # column, replace **3** with **V3** in both rows, then press <Enter>. Close the Transmission Lines Window.

The source and transmission lines are now still connected together as before, but on Virtual Segment 3 rather than Wire 3. Wire 3 is no longer needed so it can be deleted:

Open the Wires Window. Select Wire 3 by clicking on the box at the left of the line, which will highlight the line. Then press the <Del> key on your keyboard. Click **Ok** in the dialog box which appears. Close the Wires Window.

The source and transmission lines are now gone from the View Antenna display, since they connect to virtual segments whose location isn't specified. To see all virtual segment connections,

Open the **View** menu in the View Antenna display and select **Show Virt Seg Conn**.

This shows what is connected to each of the virtual segments. From it you can see that Source 1 (Src1), End 1 of Transmission Line 1 (TL1-1), and End 1 of Transmission Line 2 (TL2-1) are connected to Virtual Segment 3.

Close the Virtual Segment Connections display.

The model should work exactly as before. To check the pattern,

Click the **FF Plot** Action Button. In the 2D Plot Window, open the **File** menu and select **Add Trace**. Locate and double-click **Cardioid TL ARRL Example.pf**.

This superimposes the previously saved pattern over the current one. As you can see, the two plots overlay exactly, as they should.

Close the 2D Plot Window.

Now we'll change the transmission lines to a quarter electrical wavelength each and add the L network. Please refer to the diagram above as you do the next steps. First let's change the transmission line lengths and connections.

Open the Transmission Lines window.

It shows that the velocity factor of the two transmission lines is 0.66, and we'll continue using the same type lines. In the Control Center, the wavelength is shown as 137.562 ft at this frequency, so a quarter electrical wavelength transmission line is 137.562 * 0.66 * 0.25 = 22.698 ft.

Enter this value into both rows of the **length** column and press <Enter>.

From the diagram above, we see that Transmission Line 1 will be connected to Virtual Segment 1, and Transmission Line 2 to Virtual Segment 2.

Change the Transmission Line 1 **End 1 Specified Pos. Wire #** value from **V3** to **V1**. Change Transmission Line 2 End 1 from **V3** to **V2**. Press <Enter>. Close the Transmission Lines Window.

In the diagram, the source is connected to Virtual Segment 1.

Open the Sources Window. Change the wire connection from **V3** to **V1** and press <Enter>. Close the Sources Window.

Now it's time to create the L Network.

Open the L Networks Window.

We want to specify the L network branch impedances as an L and C rather than fixed R and X. So

In the L Networks Window, open the **Other** menu and click **Change L Network Type**. In the dialog box which opens, select the **RLC** button and click **Ok**.

The L Networks Window now has columns for R, L, and C. We'll do the connections first, then enter the L and C values. In an L network model, the shunt component is always at Port 2. (Or, to put it another way, Port 2 is the port having the shunt component across it.) So from the diagram it's apparent that Port 1 is connected to Virtual Segment 1 (V1) and Port 2 to Virtual Segment 2 (V2). Each L network consists of two rows in the L Networks Window grid. The upper row of the Specified Pos. and Actual Pos. columns are the connection to Port 1, and the lower row for Port 2. For the remaining columns, the upper row is for the series branch and the lower row for the shunt branch. The meaning of each cell is indicated by the column heading.

Connect Port 1 to Virtual Segment 1 by entering **V1** in the **Port 1 Wire #** cell. The is the upper cell of the leftmost two-row column. Immediately under that entry, in the lower column (**Port 2 Wire #**), enter **V2**. In the upper (Series Branch) row of the **L** column, enter the value in uH of the series inductor, **1.815**. In the lower (Shunt Branch) cell of the **C** column, enter the value in pF of the shunt capacitor, **199.7**. Press <Enter>.

The configuration defaults to series connection, and empty cells are set to zero which for a series connection means a short circuit. So the series branch has only the inductor and the shunt branch has only a capacitor. The first two rows of your L Networks Window grid should look like this:

L Networks

	No.	Specified Pos.		Actual Pos.		R (ohms)	L (uH)	C (pF)	R Freq (MHz)	Config
		Port 1 Wire #	Port 1 % From E1	% From E1	Seg	Series Branch	Series Branch	Series Branch	Series Branch	Ser Br
		Port 2 Wire #	Port 2 % From E1	% From E1	Seg	Shunt Branch	Shunt Branch	Shunt Branch	Shunt Branch	Sh Br
▶	1	V1				Short	1.815	Short	0	Ser
		V2				Short	Short	199.7	0	Ser

You might have to use the horizontal scroll bar to see some parts of it.

We haven't specified an R Freq because we're using an ideal inductor for this example.

If the L Networks Window display looks ok, close the L Networks Window.

The L network feed system is complete.

Press the **FF Plot** Action Button to see the resulting pattern. In the 2D Plot Window, open the File menu, select Add Trace, and locate and double-click **Cardioid TL ARRL Example.pf**.

Notice that the added trace overlays the plot perfectly. If it doesn't, you might want to try going through the steps again. The finished project is furnished as example file **Cardioid L Network Feed ARRL Example.ez**.

This model can be used to investigate how the pattern and feedpoint impedance vary with frequency and with such things as ground resistance. If desired, realistic transmission line loss and L network component loss can also be included.

In the second example, you'll use a transformer and series capacitor to improve the impedance match of an array.

Open example file **4 Square L Network Feed ARRL Example.ez**. This is the 4 square L network feed system example from Chapter 8 of the 21st Edition *ARRL Antenna Book*. It can be (and in fact was) developed from **4 Square TL ARRL Example.ez** using exactly the same process as used in the first example. But the purpose here is to illustrate how a transformer and series capacitor can be added to the model to improve the impedance match.

The changes we'll make will be made between the array common feedpoint and the source, so it will have no impact at all on the array pattern or gain. Only the impedance will be affected.

In the Control Center, click the **Open** Action Button, then locate and double-click **4 Square L Network Feed ARRL Example.ez**. Click the **Src Dat** Action Button and look at the reported impedance and SWR.

As you can see, the impedance of about 10.6 + j3.8 ohms is too low for a good match to a 50 ohm feedline. As is, the SWR on a 50 ohm feedline (which is what we'll use for this exercise) connected to the common feedpoint would have an SWR of about 4.8:1. It appears that a 4:1 impedance ratio transformer would improve the impedance match considerably. We'll insert this transformer between the source and its connection to the array feed system. Before we begin, we need to know two things: the wire or virtual segment the source is connected to, since that tells us where the common feedpoint is; and what virtual segment numbers have been used so we can choose a new one for the source-transformer connection. We can get both bits of information from the Virtual Segment Connection display, since interconnections in this model which don't need a wire connection use virtual segments.

Close the Source Data Window. (You don't have to close each window before opening another -- it just reduces clutter to close windows which

aren't being used.) Open the View Antenna display. In the View Antenna display, open the **View** menu and click **Show Virtual Seg Conn**.

This display shows that the source (Src1) is connected to Virtual Segment 5, and virtual segment numbers 5 and 6 have been used. So we want the low-impedance side of the transformer to go to the array common feedpoint Virtual Segment 5 and the high-impedance side to connect to the source. We'll create Virtual Segment 4 for that purpose.

The transformer requires specifying an impedance for the two ports, or windings. Their ratio will be the impedance transfer ratio. As explained in the Transformers topic, the values of impedances chosen should be in the general ballpark of the impedances connected to the windings. So we'll use 50 and 12.5 ohms for the two windings, which will give us the desired 4:1 impedance ratio.

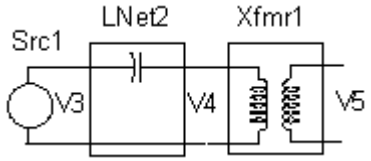
Open the Transformers Window. In the **Port 1 Specified Wire #** column, enter **V4** to connect Port 1 of the transformer to Virtual Segment 4. Enter **V5** in the **Port 2 Specified Wire #** column to connect Port 2 to Virtual Segment 5 (the array common feedpoint). In the **Port 1 Rel Z** column, enter **50**, and enter **12.5** in the **Port 2 Rel Z** column. The **Rev/Norm** connection column will default to Normal, but in this application it doesn't make any difference. After entering the impedances, press <Enter>.

That completes the transformer entry. You can close the Transformers window. All that's left is to move the source to new Virtual Segment 4 where the transformer primary is connected.

Open the Sources Window. Change the **V5** position entry to **V4**. Press <Enter>. Click the **Src Dat** Action Button.

The impedance seen by the source is now very close to four times what it was before. It won't be exact because of program accuracy limitations and the small unavoidable model transformer resistance. The SWR for a 50 ohm transmission line is now 1.45:1, much improved from the previous value.

Although this SWR is acceptable for nearly all purposes, let's see how much we can improve it by cancelling out the 15.33 ohms of inductive reactance with a series capacitor. A quick calculation shows that 15.33 ohms of capacitive reactance requires a 1452 pF capacitor. We want it to be between the source and transformer, in series. The final impedance matching system will look like this:



We'll need to create additional Virtual Segment 3 as a place to connect the source and input to the new L Network.

How do we make an L network with a missing shunt branch? An easy way is to use a parallel RLC configuration and set all three component values to zero. In a parallel configuration, a specified value of zero means an open circuit, so setting all three to zero results in a completely open circuit.

Close the Source Data Window and open the L Networks Window. In the add row below the currently defined L Network 1, specify a

connection to **V3** for Port 1 and **V4** for Port 2. In the top row of the new network, enter **1452** in the **C** column. This is the series branch. In the bottom row of the Config column, enter **P** or select **Par** from the drop-down box. Press <Enter>.

Notice that the R, L, and C values for the shunt branch (bottom row) all show **Open** as they should. The final step is to move the source onto new Virtual Segment 3.

Close the L Networks Window and open the Sources Window. Change the position of the source from V4 to V3 and press <Enter>.

The impedance transforming system now looks like the figure above.

Click the Src Dat button to see the impedance.

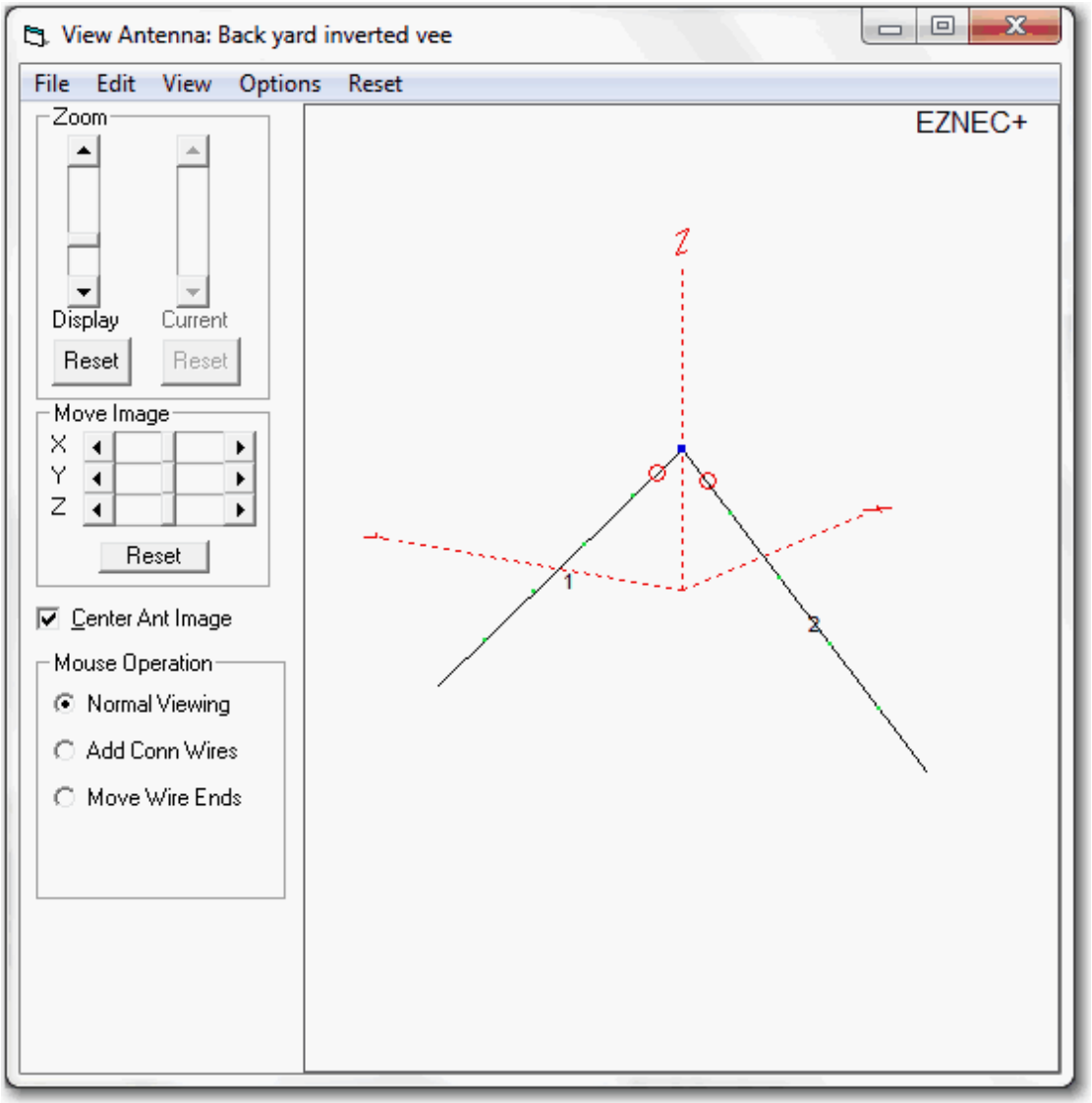
It's now about 42.2 + j0.003 -- the reactance is virtually gone as we planned, and the SWR is down to less than 1.2:1.

The finished project is available as example file **4Square L Network Feed With Z Matching.ez**. This completes the lap around Track 5.

Taking Car 6 For A Spin

EZNEC v. 6.0 allows you for the first time to make antenna modifications graphically rather than with the Wires Window. Here are some examples showing how to take advantage of this capability. We'll also see how the new Split Wires feature can be used to advantage.

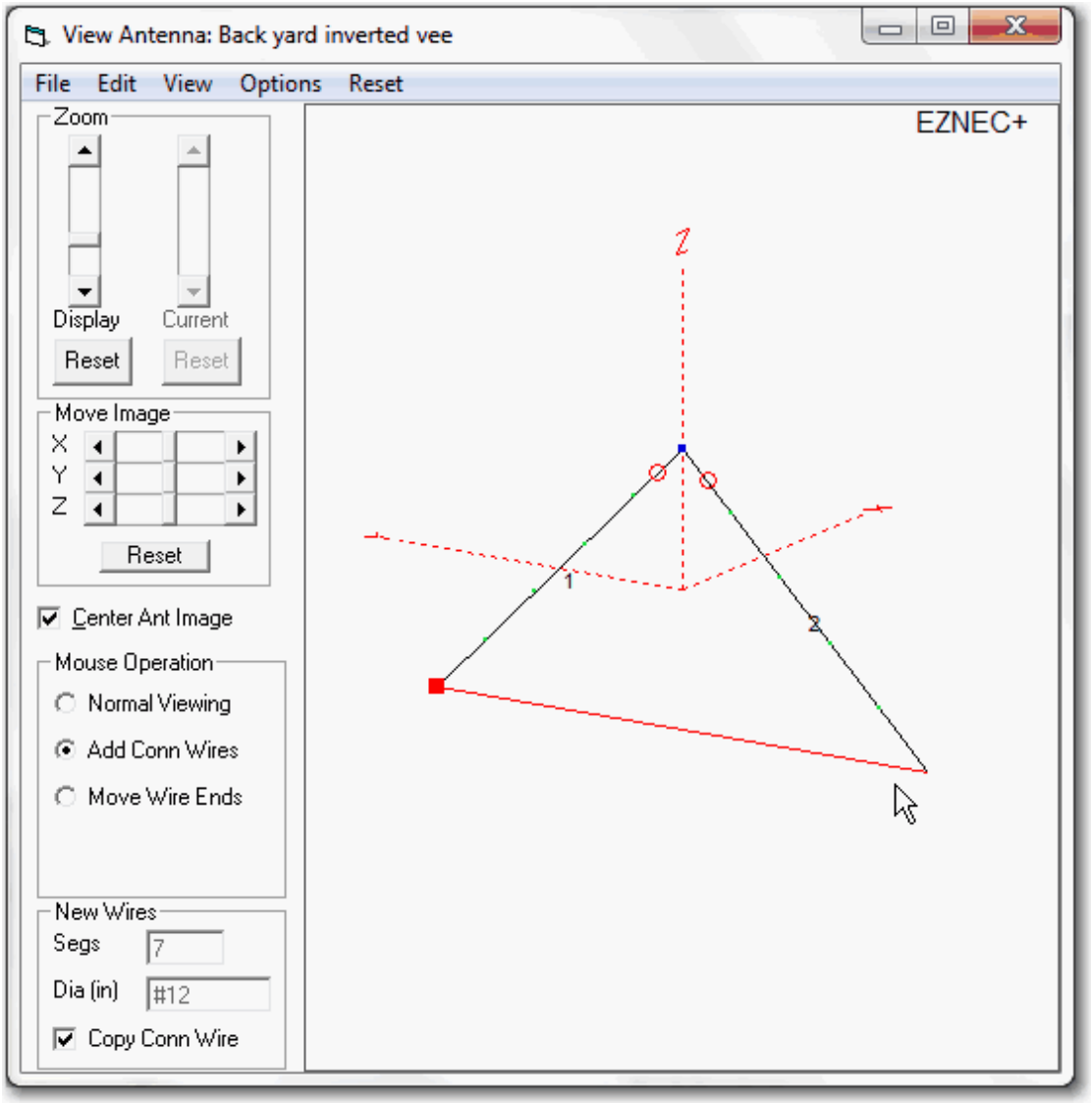
Open the BYVee.EZ example file and open the View Antenna display. In View Antenna, check the Center Ant Image box for better viewing. It should look something like this:



Let's suppose we have this antenna in the back yard and want to see the effect on pattern and impedance if we add a wire across the bottom to make a triangle. Previously, we would have had to enter the coordinates of the new wire into the Wires Window add row. The coordinates could have been entered as W1E2 and W2E2. But with very large models where the wire numbers might have been turned off, it's necessary to pause the mouse cursor over one end to identify it with the pop-up wire information display to determine the wire number and end.

Here's how we can do it now:

In the Mouse Operation frame, choose Add Conn Wires. Move the mouse cursor to the lower end of wire 1, left-click the mouse but don't hold the button down. You'll see a large red square appear at the lower end of wire 1. In a more complex model, you might sometimes accidentally select the wrong wire. If you do, just press <Esc> to cancel the selection. Next, move the cursor to the existing wire end where you want to connect the second end of the new wire. A red line will follow the cursor, jumping to the nearest acceptable point, like this:



In this case there's only one acceptable connection point -- the wire 1 - wire 2 junction is excluded because a new wire to there would overlay wire 1. When the red line is in the desired position, right-click the mouse to complete the operation, and the new wire is in place. You can use the undo feature to start over if the wire isn't where you intended.

The new wire has the same diameter, number of segments, and insulation as the wire connected to its first end -- wire 1 in this case. If the Copy Conn Wire box was unchecked, we could have specified the diameter and number of segments. Any desired insulation would have to be added manually in the Wires Window after the new wire is created.

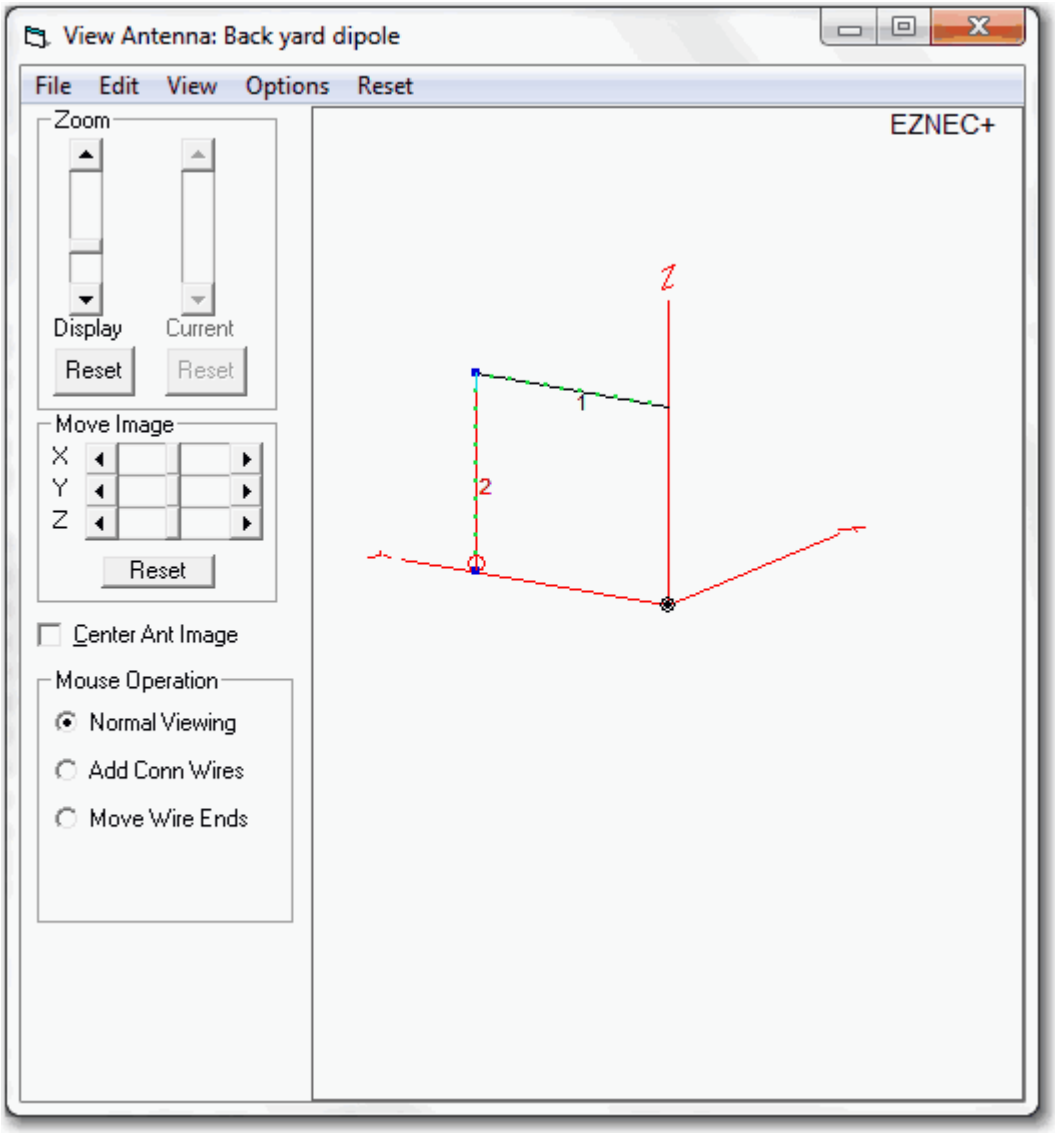
Now let's investigate a Windom type antenna - a horizontal antenna fed with a single wire, usually off center. Our model will connect the single wire directly to ground. To model a real installation, the entire path to ground, over the outside of the rig and maybe following the mains power system to the Earth, would have to be included for good accuracy. Nonetheless, the simplified model can be instructive and might be a good representation of a portable setup.

For this example we'll build models to investigate the effect of moving the single wire feeder to various points along the horizontal wire.

Start with the BYDipole1.EZ example file. Open it and open the View Antenna Display. We'll create another wire from end 2 of the existing wire to ground. Because one end of the new wire isn't connected to any existing wire end, we can't use the Create Wire feature of the previous example. Instead, open the Wires Window by clicking the Wires line in the Control Center. In the add row at the bottom, in End 1 column X, Y, or Z, enter "W1E2" (without the quotes), then <Enter>. Then enter the same thing in End 2 column X, Y, or Z and <Enter>. The Wire 2 line should show Zero Len in the Conn columns. Now change only End 2 Z to zero and <Enter>. This puts the bottom of the new wire directly under wire 1 end 2.

Because the Z coordinate of wire 2 is zero, it's connected to ground which should only be done with Perfect or MININEC type ground. So in the Control Center, click the Ground Type Line then the MININEC selection, and click Ok. This produces a zero resistance connection as though a perfect ground plane were underneath, and the horizontal wire is high enough to permit good results with that ground type. Another possibility would be a slightly elevated radial system over High Accuracy (or with **EZNEC Pro/4**, Extended Accuracy) ground -- see Connecting Wires to Ground for more about this topic.

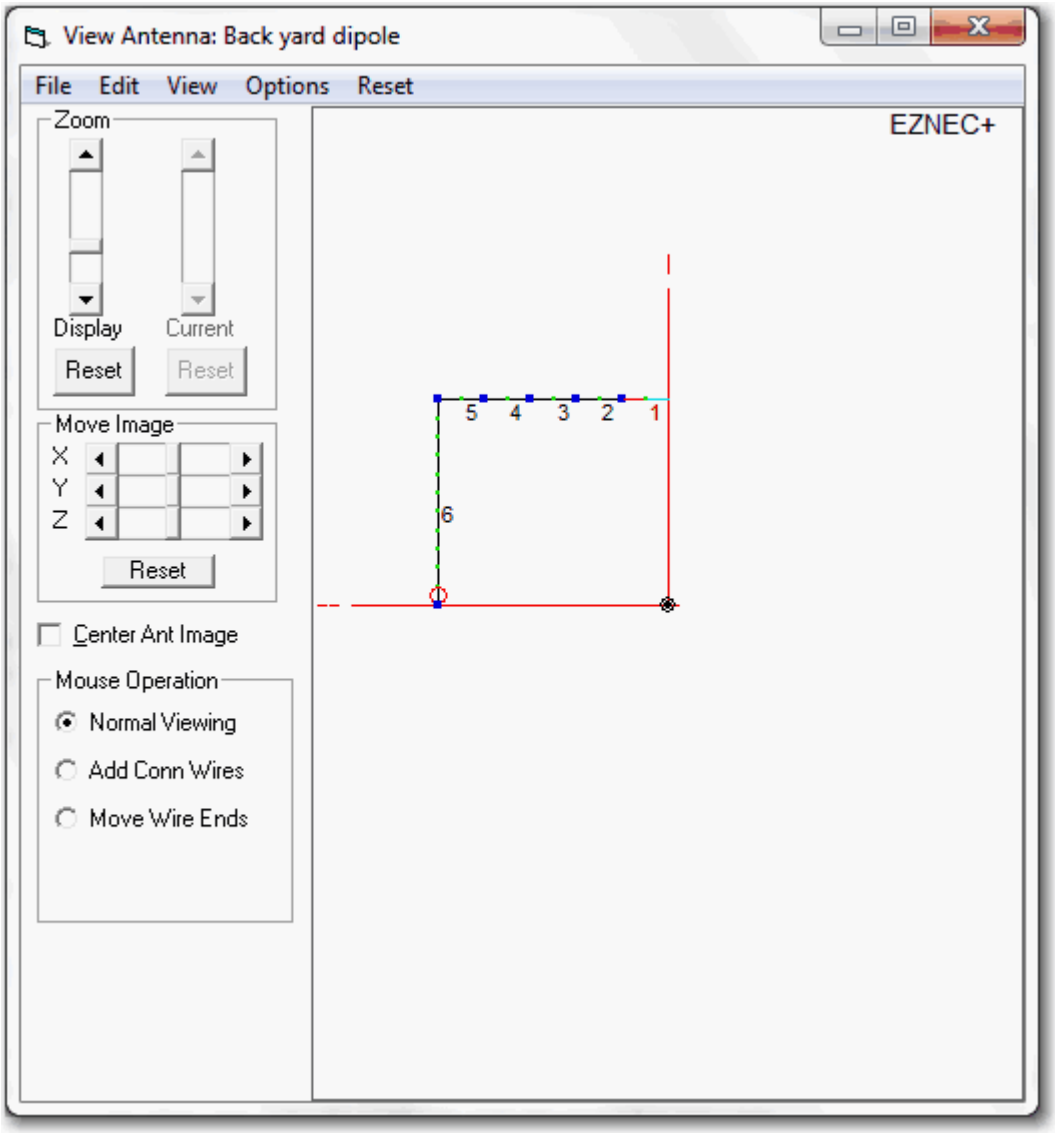
To finish the initial single-wire fed antenna, move the source to the bottom of wire 2 by clicking the Sources line in the Control center display. In the Sources Window that opens, change the Specified Pos Wire # to 2 and the % From E1 to 100 and press <Enter>. Your model should look like this:



You can close the Sources Window if you'd like.

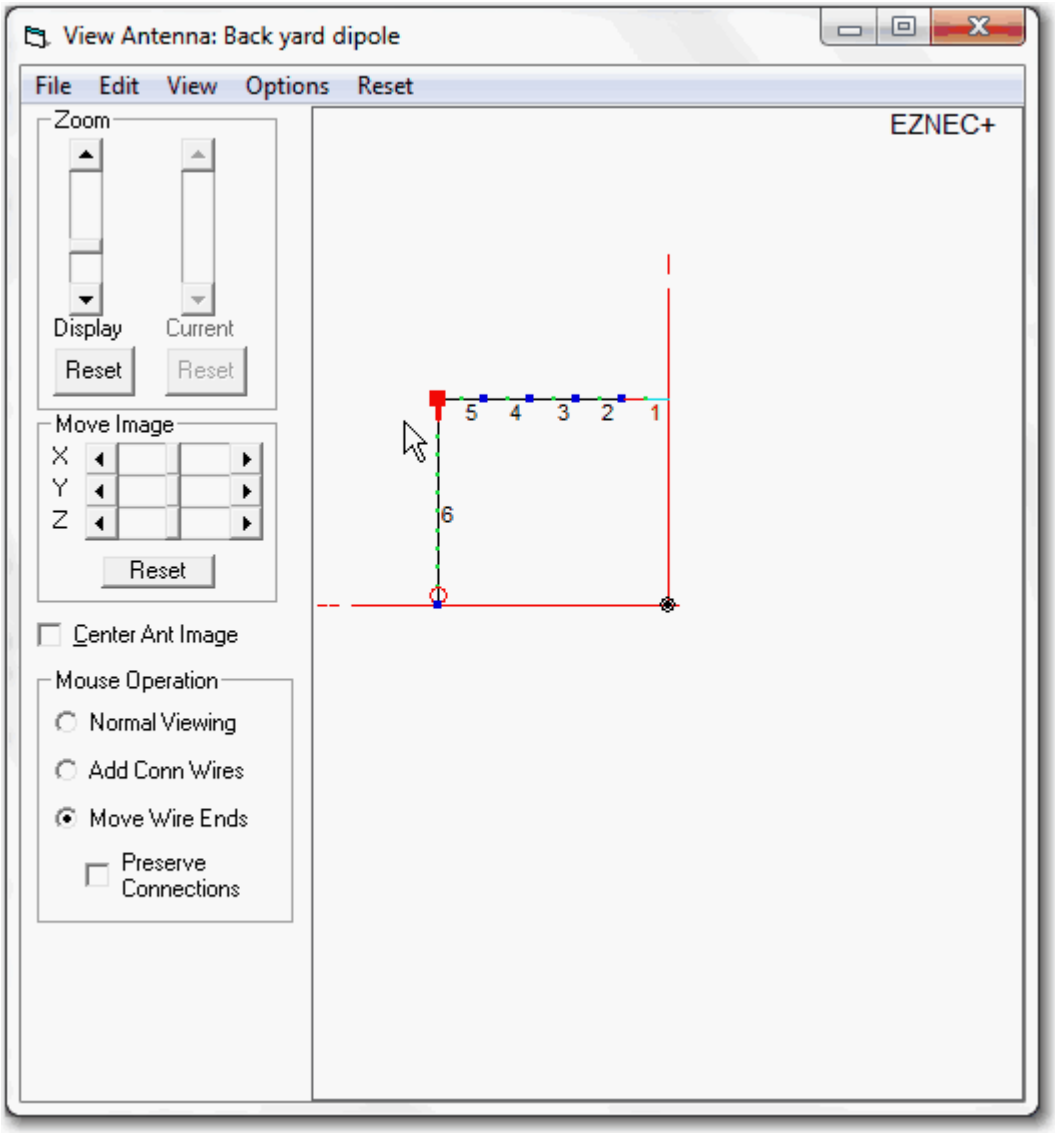
We can't connect the top end of wire 2 just anywhere along wire 1 because wires can connect only at ends. What we need are wire ends that we can connect to. That's easily done with the new Split Wires feature. In the Wires Window, open the Wire menu and select Split Wires. In the dialog that opens, enter 1 in the Last wire to split box so that both first and last are 1. Let's split the wire into 5, so enter 5 in Number to split each into, then click Ok. Wire 1 is now replaced by wires 1 to 5, and former wire 2 is now wire 6.

Let's look at the model straight on to make the next steps a little easier. It's not necessary, but a good place to point out another new feature. Note that the X axis goes off to the right behind the antenna. To maintain the same relationship between front and back, we'll look at the antenna from the direction of the -X axis, that is, from the "front" as we're currently viewing it. Click anywhere on the View Antenna display window to give it the focus. Then hold down <Shift> and press the X on your keyboard to rotate the view. Try just X to see what happens -- now you see it from the direction of the +X axis. The Y and Z keys work the same for their respective axes. When you're finished experimenting, return to the -X axis view with <Shift>-X, to look like this:



Now let's tap wire 6 along the horizontal wire (represented in the model by 5 wires). In the Mouse Operation frame, choose Move Wire Ends. The next step is to select the top end of wire 6 and not the left end of connected wire 5. It's pretty easy here but can be a little trickier for more complex models. The main requirement is to move the cursor to a point closer to wire 6 than wire 5, and closer to the desired wire end than any other wire end. In this case this is satisfied by any point along or near the top half of wire 6. You can also pause the cursor over the wire near the end and look at the pop-up window. The wire and end numbers it shows are the ones which will be selected. Selection can be made, however, at greater distances from the junction than required for the pop-up window to appear.

With the cursor in the correct position, momentarily left-click the mouse. If you successfully selected the top end of wire 6 you'll see this briefly before you move the mouse:



If you see a different segment highlighted, press <Esc> and try again.

In addition to the red square of the Add Conn Wires operation, the segment of wire 6 nearest the junction is highlighted to show which wire was chosen for moving. As before, you'll see a red line to the proposed new connection point, and the process is finished by right-clicking.

If the Preserve Connections box is checked, all wire ends connected to the selected end are moved. In this example, moving the left end of wire 5 would result in overlapping wires, so Preserve Connections should be unchecked. Remember, though, that you can easily undo any change.

Select Normal Viewing in the Mouse Operation frame to restore mouse operation to normal.

Now for a brief look at the new wire scaling enhancements.

Open example file 20m5elya.EZ and open the View Antenna display. Suppose we want to try increasing the lengths of the three directors (elements with positive X coordinates) without changing the element spacing. But we want to change all the various diameter sections in the same proportion, not just the end sections.

The first thing we have to do is select the wires for scaling. In the View Antenna display, zoom the display by moving the mouse with both keys held

down, and move the display by moving the mouse with the right key down, until you can easily see the wires of the three directors. You should see that the directors consist of wires 23 through 55. When fewer wires need to be modified, it's convenient to select them directly in the View Antenna display -- see Using The View Antenna Display for details. For this project it's easier to use the Wires Window, and we'll have to use it for the scaling operation anyway. Open the Wires Window by clicking on the Wires line in the Control Center. In the Wires Window, click the box to the left of wire 23 to highlight that line. Scroll down to wire 55 with the scroll bar at right. Then hold down the <Shift> key and click the box to the left of wire 55. Wires 23 through 55 should now be highlighted. Confirm that you've selected the right wires by looking at the View Antenna display and seeing that the directors have been highlighted. Disregard cyan colored segments -- that's how **EZNEC** shows which is end 1. All or half of a wire can be this color if it has only one or two segments.

With the wires selected, open the Wire menu in the Wires Window and select Scale Wires. No wire range selection is shown because the wires have been selected before opening Scale Wires. Let's increase the lengths of the elements by 10%, so enter 1.10 for the Scale Factor. We don't want to change the element spacing which is the separation in the X direction, so uncheck the X box in the Axes frame. This model is all at Z = 0 so checking or unchecking the Z axis box will have no effect. For an antenna above ground, we'd check it if we wanted to scale the antenna height, and uncheck it if not. Scale Center allows you to set the point from which scaling takes place. That would be important if we needed a particular part of the model to stay put and the rest to expand or contract relative to that point. We're scaling only in the Y direction and the elements are centered along Y = 0, so the origin is a suitable choice for symmetrical scaling relative to the element centers.

You probably wouldn't want to scale wire diameters on an antenna like this, since it would result in non-standard diameters for tubing. Leave that box unchecked. Now click Ok. You can see the rescaling take place in the View Antenna display, but it can be deceiving -- the display automatically rescales to insure that the whole model will be on screen when unzoomed and at any position. So the director and driven element will seem to shrink as the others extend. It should be apparent, though, that the directors have gotten longer relative to the other two elements.

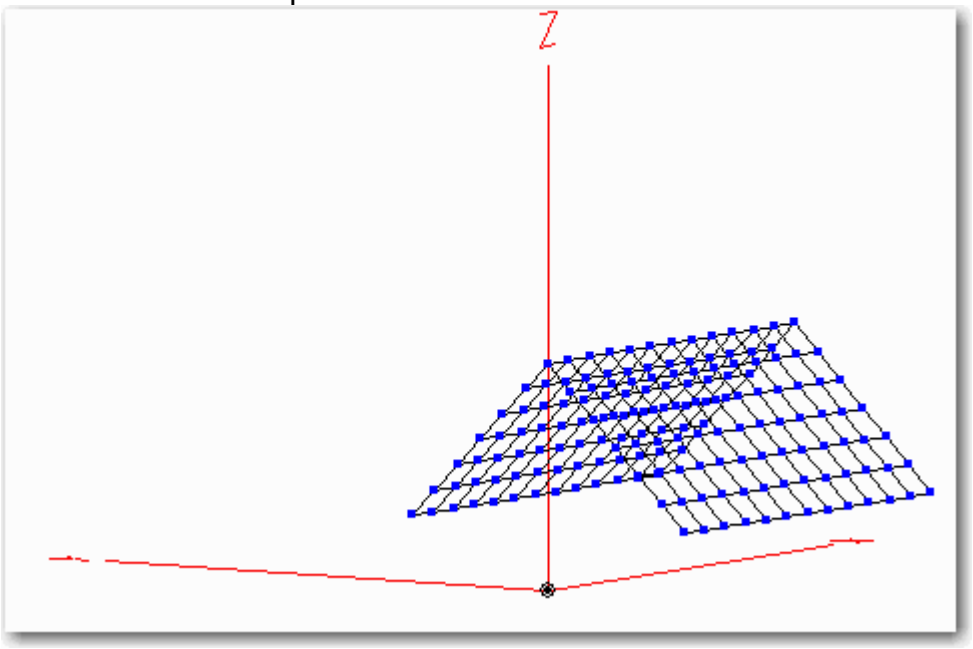
The remaining new features are largely self explanatory. Be sure to read What's New in v. 6.0 and try them out. Feel free to experiment -- remember, you can always undo any number of changes you've made.

Plus Octane Fill Up

This topic demonstrates some of the advanced features available in ***EZNEC Pro+***. Although you can create a wire grid model of a flat surface with a few keystrokes using the Wire Grid Creation feature, this exercise illustrates the use of several other very powerful features in the process of creating a model of a metal roof. The techniques shown here can be used to create other complex models. It's assumed that you've gone through at least some of the preceding Test Drive topics and know how to do the basic operations. Remember that if you make a mistake you can easily undo as many steps as necessary and try again.

Among the features used in this exercise are Split Wires, Make Multiple Copies, Rotate Wires, Reflect Wires, Scale Wires, Change Height By, Copy Wires, and Group Modify. All these are found in the Wire menu of the Wires Window.

We're going to create a model of a metal house roof consisting of two flat sections sloping down at 45 degrees from the ridge line which is 20 feet above the ground. Each of the flat sections is 20 by 40 feet, and we want the model to be useful up to 30 MHz. The finished model will look like this:



And we're going to do this by entering the coordinates of only two wires, each one along an axis!

We'll model each of the flat sections as a wire grid. At this point you should read the manual section on Wire Grid Modeling. In that section, you found that a wire grid model is like a screen with holes about 0.1 wavelength on a side, and that the model requires approximately 220 * A segments, where A is the area in square wavelengths. So the first step is to determine about how many segments we'll need in order to make sure the model size will be reasonable.

Start by opening the simplest of the provided ***EZNEC*** example files, Dipole1.EZ. We'll be working in U.S. units so the first thing to do is to change the Units to Feet. (If you don't know how to do both of those steps, please go through the first few Test Drive sections, then return here.) Next, change the frequency to 30 MHz. You don't need to rescale -- we'll be modifying the single wire of this model before long, anyway.

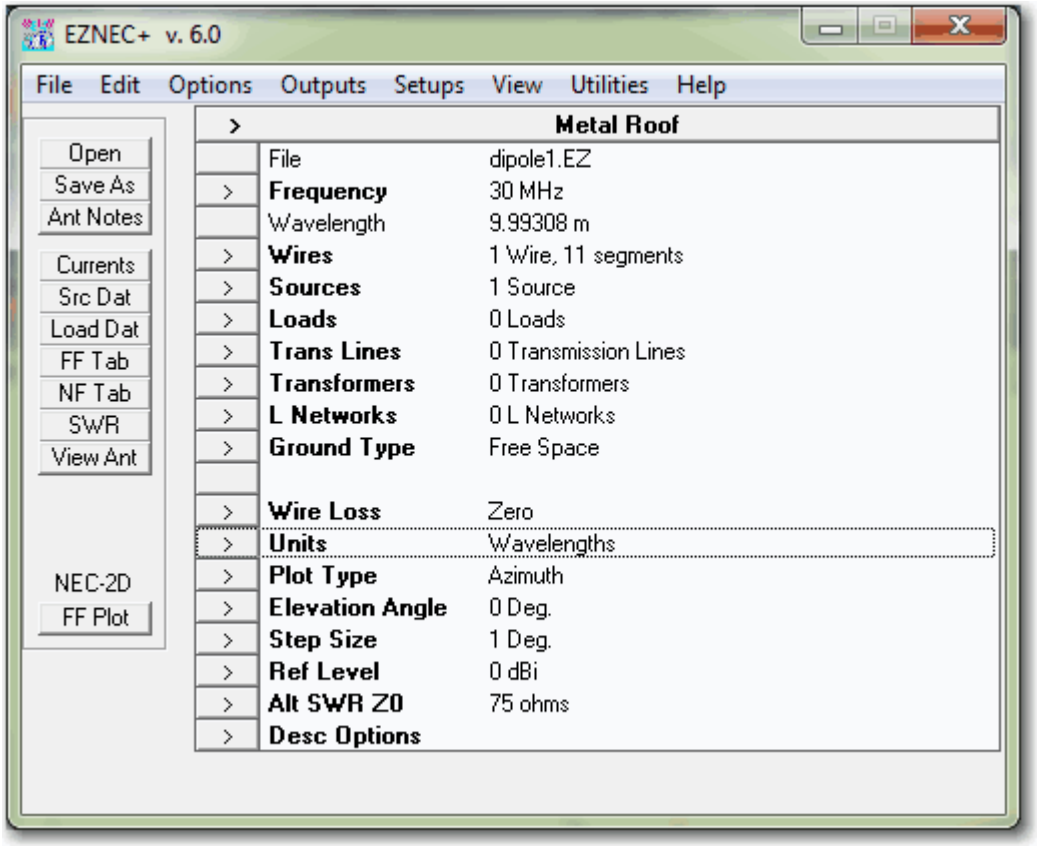
In the main window you can see that the wavelength at 30 MHz is about 32.8 ft, so a square wavelength is 32.8 x 32.8 ~1076 square feet. Each of the flat roof surfaces is 20 x 40 = 800 square feet so the total area for the two is 1600 square feet which is 1600 / 1076 ~1.5 square wavelengths at 30 MHz. So we'll need about 220 * 1.5 = 330 segments for the two roof surfaces.

First we'll create a model of one of the flat surfaces as single wire grid at a convenient coordinate system location for modeling. The 20 x 40 foot surface is about 0.61 x 1.22 wavelengths. Since we want the wire spacing to be about 0.1 wavelength, we'll make the grid 6 x 12 squares in size. So what would be the wire spacing with that number of squares? It would of course be 0.61 / 6 x

1.22 / 12 wavelengths or 0.61 / 6 * 32.8 x 1.22 / 12 * 32.8 feet which are all uneven numbers. So here's the first trick: We'll make the grid exactly 0.6 x 1.2 wavelengths and scale it to exactly the right dimensions later.

In the main window, change the Units to Wavelengths with Wire Diameter (in the Wavelengths dialog box) also in Wavelengths. If you'd like, change the title of the model by clicking on the title line and entering the new one.

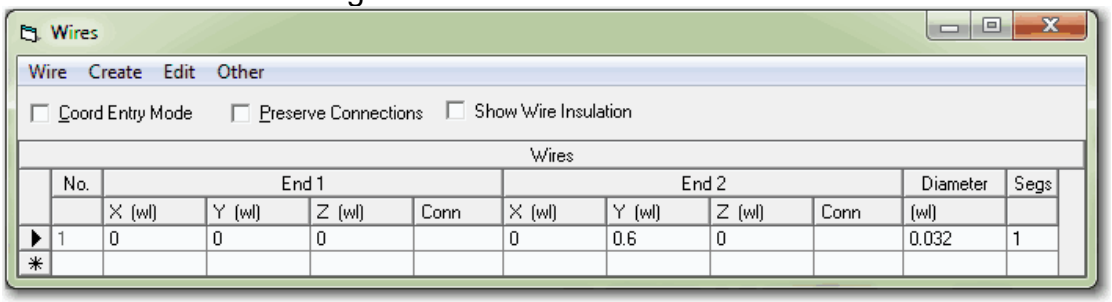
Your main window should look like this:



Open the View Antenna display in order to visualize the effect of each step.

First make a wire along the short side of the surface by modifying the existing dipole wire:

Open the Wires Window. Replace the Wire 1 coordinates, diameter, and number of segments as shown below.



EZNEC requires that wires intersect only at their ends, so we can't just use a single wire with multiple segments. To get wire ends where we need them for the cross connecting wires, we'll be splitting this wire into six wires, each having one segment. When splitting, ***EZNEC*** will give the new wires a number of segments that most closely retains the original segment length. So giving

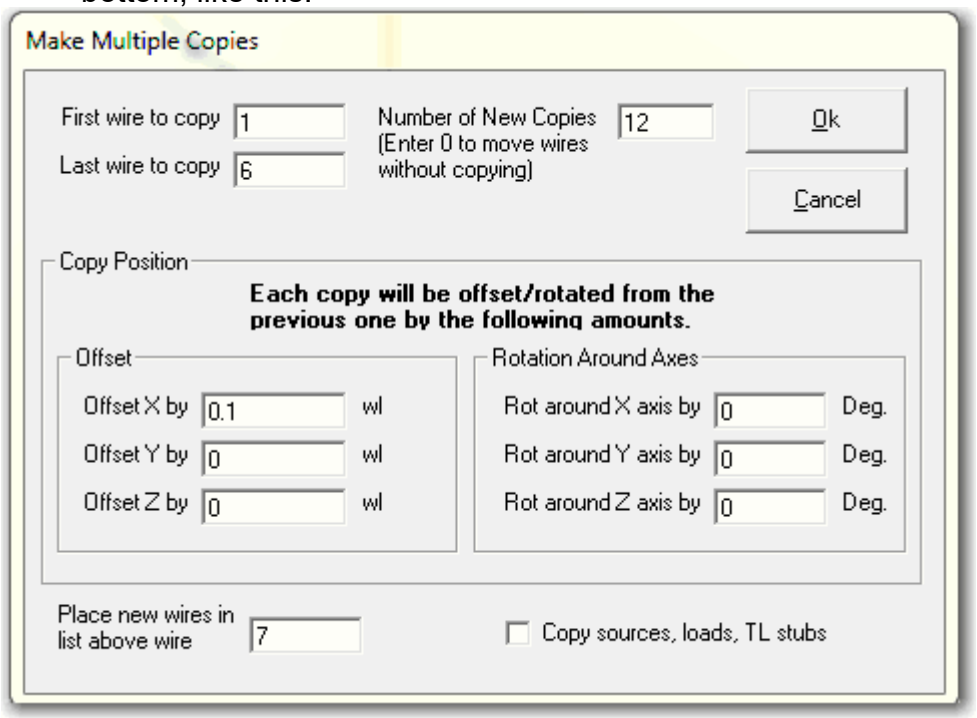
this one wire any number of segments between 1 and 6 will result in the new wires having one segment. If they ended up with more it would be easy to correct, but we'll save a step by forcing it to create one segment wires in the first place. The wire diameter is approximately the wire spacing of 0.1 wavelength divided by pi as explained in the Wire Grid Modeling topic. Note the subheading of the Diameter column in the figure above. If yours does not say (wl), go back a couple of steps, click Units in the main window, and select Wavelengths for Wire Diameter. Then re-enter the wire diameter in the Wires Window. The new wire is along the Y axis in the View Antenna display. It might be hard to distinguish since it will probably be highlighted and the same color as the axis line. You should see the source on the wire.

Now we're ready to split the new wire into six wires to provide connection points for the cross wires. In the Wires Window, open the Wire menu at the top and select Split Wires. The first and last wire will both be 1 since there's only one wire in the model. In the "Number to split each into" box enter 6, then click Ok.

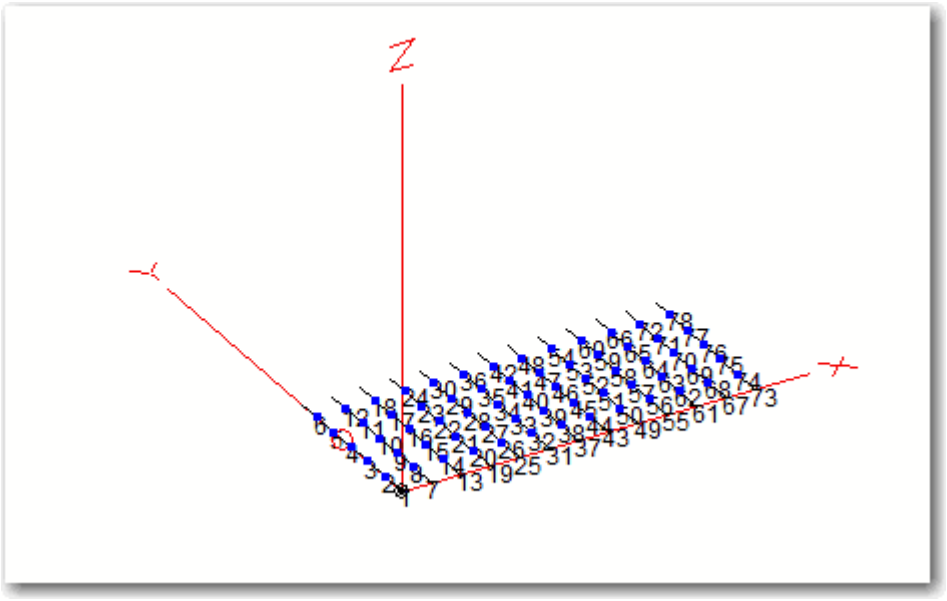
You should now see six, one segment wires in the Wires Window and the View Antenna display.

The next step is to create the remainder of the wires parallel to the short side. We need to make 12 copies of our current six wires, spaced 0.1 wavelength apart.

In the Wires Window, open the Wire menu and select Make Multiple Copies. The only values we have to change from those already entered are the Number of New Copies (enter 12) and Offset X by (enter 0.1 or just .1), and uncheck the "Copy sources, load, TL stubs" box near the bottom, like this:



Then click Ok and you should see this in the View Antenna display:



Use the Zoom control on the left (or press both mouse buttons and move the mouse upwards) to enlarge the display of wires so you can more easily see the results of the next steps.

Next, we'll repeat the same process as before to create the cross wires.

In the add line below Wire 78 in the Wires Window, make a 1.2 wavelength wire extending from the origin along the X axis side of the grid:

Wires

Wire Create Edit Other

Coord Entry Mode | Preserve Connections | Show Wire Insulation

Wires

No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(wl)	
65	1	0.4	0	W64E2	1	0.5	0	W66E1	0.032	1
66	1	0.5	0	W65E2	1	0.6	0		0.032	1
67	1.1	0	0		1.1	0.1	0	W68E1	0.032	1
68	1.1	0.1	0	W67E2	1.1	0.2	0	W69E1	0.032	1
69	1.1	0.2	0	W68E2	1.1	0.3	0	W70E1	0.032	1
70	1.1	0.3	0	W69E2	1.1	0.4	0	W71E1	0.032	1
71	1.1	0.4	0	W70E2	1.1	0.5	0	W72E1	0.032	1
72	1.1	0.5	0	W71E2	1.1	0.6	0		0.032	1
73	1.2	0	0		1.2	0.1	0	W74E1	0.032	1
74	1.2	0.1	0	W73E2	1.2	0.2	0	W75E1	0.032	1
75	1.2	0.2	0	W74E2	1.2	0.3	0	W76E1	0.032	1
76	1.2	0.3	0	W75E2	1.2	0.4	0	W77E1	0.032	1
77	1.2	0.4	0	W76E2	1.2	0.5	0	W78E1	0.032	1
78	1.2	0.5	0	W77E2	1.2	0.6	0		0.032	1
	0	0	0		1.2	0	0		.032	1

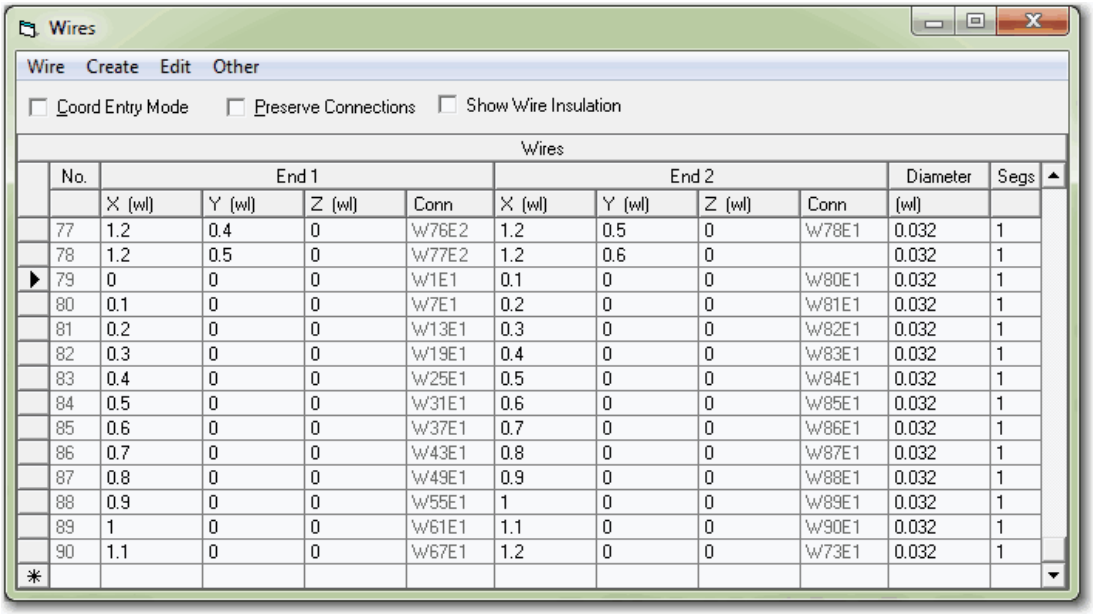
and press the <Enter> key. This is the second and last wire we'll actually enter coordinates for, in making the roof!

You should now see a new wire 79 extending on the X axis along the long side of the grid.

Split the new wire into 12: Open the Wires Window Wire menu and select Split Wires. Enter 79 in the "First wire to split" box. The "Last wire to split" box should already contain 79. Enter 12 for "Number to split each into" then click Ok.

You should now see new wire numbers 79-90 along the X axis.

In the Wires Window, look at the Conn column. There should be entries in those columns for wires 79 through 90 as shown below. If not, there was something wrong about the number of wires created or the spacing of the first set of wires which is causing the wires to not connect.



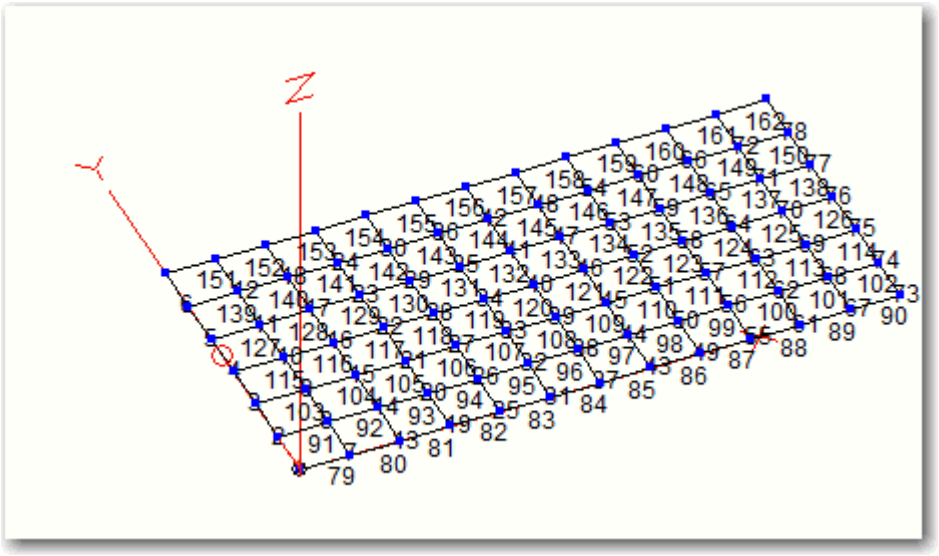
Wires

No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(wl)	
77	1.2	0.4	0	W76E2	1.2	0.5	0	W78E1	0.032	1
78	1.2	0.5	0	W77E2	1.2	0.6	0		0.032	1
79	0	0	0	W1E1	0.1	0	0	W80E1	0.032	1
80	0.1	0	0	W7E1	0.2	0	0	W81E1	0.032	1
81	0.2	0	0	W13E1	0.3	0	0	W82E1	0.032	1
82	0.3	0	0	W19E1	0.4	0	0	W83E1	0.032	1
83	0.4	0	0	W25E1	0.5	0	0	W84E1	0.032	1
84	0.5	0	0	W31E1	0.6	0	0	W85E1	0.032	1
85	0.6	0	0	W37E1	0.7	0	0	W86E1	0.032	1
86	0.7	0	0	W43E1	0.8	0	0	W87E1	0.032	1
87	0.8	0	0	W49E1	0.9	0	0	W88E1	0.032	1
88	0.9	0	0	W55E1	1	0	0	W89E1	0.032	1
89	1	0	0	W61E1	1.1	0	0	W90E1	0.032	1
90	1.1	0	0	W67E1	1.2	0	0	W73E1	0.032	1

As the final step of creating the first flat surface, we'll make another six copies of the X axis wires. This time we'll preselect the wires to copy rather than entering them in the Make Multiple Copies dialog box. This technique can be used for any of the Wires Window features, and doesn't require that all selected wires be sequential. (To select non-sequential wires -- not done here -- hold down the <Ctrl> key while selecting the desired wires.)

In the Wires Window, click on the box at the very left of Wire 79 to select (highlight) it. Then hold down the <Shift> key and click the box to the left of Wire 90. Wires 79 through 90 should now be selected. Open the Wire menu and select Make Multiple Copies. Notice that no range of wires is shown as before. That's because we've preselected the ones to be copied. Enter 6 for Number of New Copies, 0.1 or .1 for Offset Y by. The Copy Sources. . . box doesn't matter since there aren't any objects on the selected wires. Click Ok.

You should see this in the View Antenna display:



In the Wires Window, verify that both ends of all wires have an entry in the Conn column, indicating that connections have been made at all wire ends.

Congratulations! You've just created your first wire grid. You might want to save this for future use. As you'll see, we can easily modify it to suit various purposes, and it can be added to other models. Note that all ***EZNEC*** description files must contain a source, so you can leave it where it is and move or delete it later as necessary. Beginning at this step you'll probably see a warning in the Segmentation Check about the source segment being connected to multiple wires. You can ignore this warning.

Now let's make this into our roof but it's time to think about scaling to make the model exactly the right size. Our specified dimensions of the flat surfaces were 20 x 40 feet and the dimensions we've used are 0.6 x 1.2 wavelengths or about 39.34 by 19.67 feet. The ratio of side lengths of the current model is the same as the original specification, so scaling can easily be done at any time by simply changing the size of the whole model. If we had needed to scale the sides by different factors, it would be easiest to scale it now before creating oddly placed copies. ***EZNEC***'s Scale Wires feature can scale in one direction at a time at different scale factors, but this is most easily done when the object is flat. But since we don't need to separately scale the two dimensions we'll leave scaling to the last.

To begin completing the roof we'll tilt the current surface 45 degrees by rotating it around the X axis.

> In the Wires Window open the Wire menu and choose Rotate Wires. Again, most of the values are already set to what we want -- all wires are selected and we'll use the origin as the rotation center. In Rotation Amount, enter 45 into the box and select CW. Select X for the Rotation Axis and click Ok. Note that if you do multiple rotations (or have to go back and modify an incorrect rotation), the values from the last rotation will be pre-entered so might require changing.

One long side of the grid should still be along the X axis and the other should be below the XY plane, that is, the grid should be tilted downward. ***EZNEC*** defines rotation direction as looking down the axis toward the origin which is why CW was chosen for the direction. If you can't remember, just try either CW or CCW and undo and rotate the other way if it isn't what you wanted.

Now we'll make the other half of the roof by reflecting the existing half in the XZ plane. But we have to do something first. As it is, ***EZNEC*** will refuse to make a reflection if any wires are either crossing the reflection plane boundary or lying on it. Our wires 79 - 90 are along the X axis which is in the reflection plane. So we'll have to delete those wires and recreate them after doing the reflection.

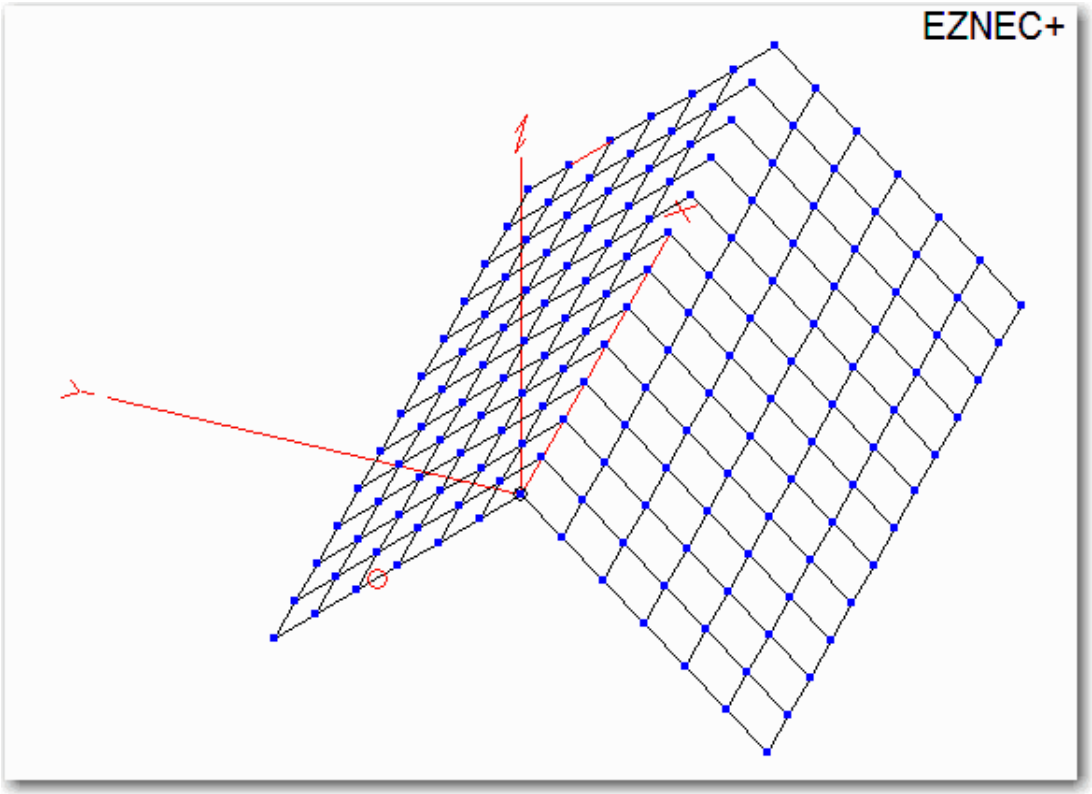
In the Wires Window select wires 79 through 90 by highlighting them as in a previous step, press the <Delete> key, then click Ok. (You could also have opened the Wire menu, selected Delete Wires, entered the wire range, and clicked Ok.)

The wires along the X axis should now be missing.

Open the Wires Window Wire menu and select Reflect Wires. This feature allows simultaneous reflections in multiple planes, but we're going to reflect the tilted grid only in the XZ plane.

All wires are already selected. Check the XZ Reflection Plane box and verify that the others are unchecked. Uncheck the "Copy sources, loads, and trans lines" box and click Ok.

In the View Antenna display, you can hold down the left mouse button an move the mouse to rotate, hold down both mouse buttons an move the mouse to zoom, and press the N key on your keyboard to turn off the wire numbers. You should be able to see something like this:



There are many ways we can recreate the missing wires along the ridge line without doing any calculations. One way, for example, would be to rotate one grid back up to horizontal, make an offset copy of one of the sets of wires parallel to the X axis, and rotate the grid back down. Another would be to use the View Antenna graphical modification feature to quickly create the wires. Let's employ a third method instead using the Group Modify feature, since this will also illustrate some other features.

In the View Antenna display, turn the wire numbers back on by pressing the keyboard N key. Open the View menu and select Objects. Under Wire Numbers select Centered then click Ok. This moves the numbers to the centers of the corresponding wires. You can also determine wire numbers when the wire numbers are off by hovering the mouse cursor over a wire and looking at the popup which appears. Note that one set of wires closest to the X axis consists of numbers 229-240. Select these in the Wires Window by clicking the very left of the Wire 229 line, then holding <Shift> and clicking the left of the Wire 240 line.

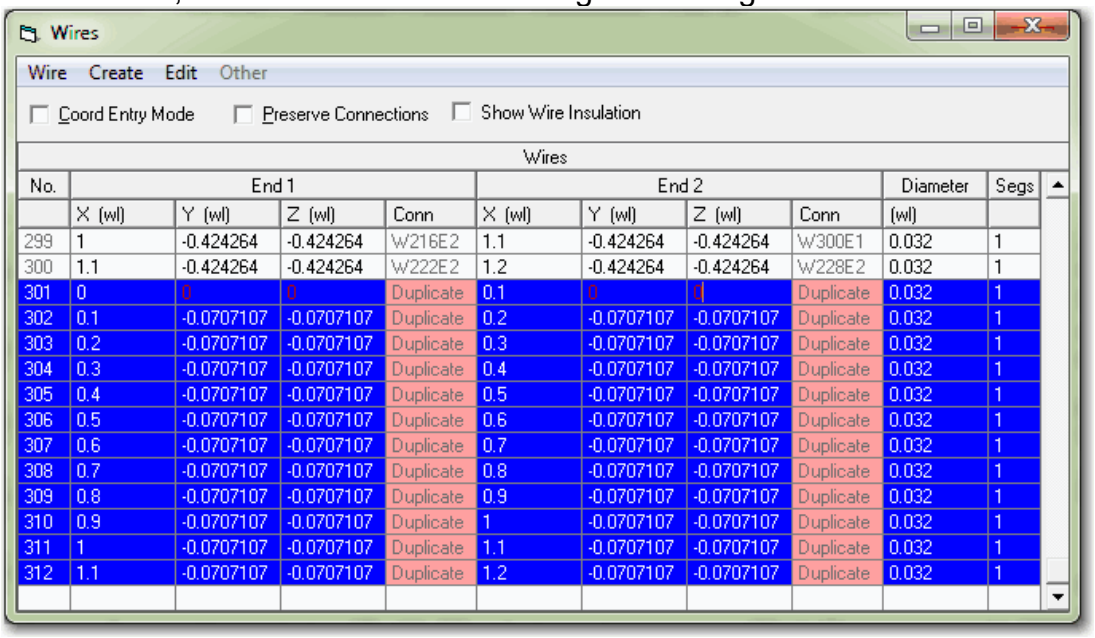
We'll make an exact copy of these wires, then move the copy into place.

Open the Wire menu and select Copy Wires. No changes to the default values are necessary since we're making exact copies. Click Ok, then Yes when warned that exact copies are being made. Scroll down in the Wires Window and you can easily spot the new wires by the red "Duplicate" entries in the Conn column.

We want to move these wires to the X axis. We'll do it by changing all their Y and Z coordinates to zero.

Select all the new wires (301 - 312) by clicking at the left end of the Wire 301 line to highlight it, then holding the <Shift> key down and clicking the left end if the Wire 312 line.

Open the Wire menu and select Group Modify. The selected wires will turn a darker blue color. In Group Modify mode, all changes made to any of the selected wires will be applied to all of them. Change the Y and Z coordinates of both ends of wire 301 (or any other wire) to 0 as shown, to move the wires to the ridge line along the X axis:



No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(wl)	
299	1	-0.424264	-0.424264	W216E2	1.1	-0.424264	-0.424264	W300E1	0.032	1
300	1.1	-0.424264	-0.424264	W222E2	1.2	-0.424264	-0.424264	W228E2	0.032	1
301	0	0	0	Duplicate	0.1	0	0	Duplicate	0.032	1
302	0.1	-0.0707107	-0.0707107	Duplicate	0.2	-0.0707107	-0.0707107	Duplicate	0.032	1
303	0.2	-0.0707107	-0.0707107	Duplicate	0.3	-0.0707107	-0.0707107	Duplicate	0.032	1
304	0.3	-0.0707107	-0.0707107	Duplicate	0.4	-0.0707107	-0.0707107	Duplicate	0.032	1
305	0.4	-0.0707107	-0.0707107	Duplicate	0.5	-0.0707107	-0.0707107	Duplicate	0.032	1
306	0.5	-0.0707107	-0.0707107	Duplicate	0.6	-0.0707107	-0.0707107	Duplicate	0.032	1
307	0.6	-0.0707107	-0.0707107	Duplicate	0.7	-0.0707107	-0.0707107	Duplicate	0.032	1
308	0.7	-0.0707107	-0.0707107	Duplicate	0.8	-0.0707107	-0.0707107	Duplicate	0.032	1
309	0.8	-0.0707107	-0.0707107	Duplicate	0.9	-0.0707107	-0.0707107	Duplicate	0.032	1
310	0.9	-0.0707107	-0.0707107	Duplicate	1	-0.0707107	-0.0707107	Duplicate	0.032	1
311	1	-0.0707107	-0.0707107	Duplicate	1.1	-0.0707107	-0.0707107	Duplicate	0.032	1
312	1.1	-0.0707107	-0.0707107	Duplicate	1.2	-0.0707107	-0.0707107	Duplicate	0.032	1

Then press <Enter>. The Y and Z coordinates of both ends of all the selected wires will change to zero and you should see the wires along the ridge line (X axis) in the View Antenna display. Open the Wire menu and click Group Modify again to turn it off.

The basic roof is now constructed. Next we'll scale it to the correct size of 20 by 40 feet for each grid. The size of 0.6 by 1.2 wavelengths is 19.7 by 39.3 feet, less than 2% from the specified 20 by 40 feet, so in nearly all

circumstances it wouldn't need adjustment for any practical use. But we'll scale it to illustrate the process.

In the Wires Window open the Wire menu and select Scale Wires. Scaling the wires on all axes from the origin will simply multiply all wire coordinates by the scale factor, resulting in exactly proportional scaling. All that's needed is to enter the scale factor of 1.017 and click Ok. If the scale factor were large, we would have checked the box to rescale wire diameters but it's not necessary with this small a change.

The final step is to raise the roof to the specified height of 20 feet at the ridge line.

In the main window, change Units to Feet. Then open the Wire menu in the Wires Window and select Change Height by. Enter 20 in the Height change box and click Ok.

The roof model is now complete. It can of course be moved and rotated as desired.

For fun let's put a 15 meter vertical on the roof and see what the pattern is over average ground. With grid spacing of 0.1 wavelength at 30 MHz, the model will be a good representation of a solid surface at any frequency 30 MHz or below.

In the main window click Ground Type and choose Real, High Accuracy ground then click Ok. Look at the Ground Descrip line in the main window. If it doesn't show (.005, 13), click the Ground Descrip line. Right-click on either the Cond. or Diel. Const. column to open a selection dialog with various ground characteristics. Choose Average: pastoral, heavy clay and click Ok.

To find the center of the roof, press the Z key to view the antenna from the direction of the +Z axis. Count six wires from two adjacent sides to locate the center and note that it's at the junction of wires 37, 187, 306, and 307. Hover the mouse cursor over any of the four wires, close to their junction at the center and notice the end number shown in the popup display. For example, holding the cursor over wire 307 near its junction with the other three wires you'll see Wire 307 End 1, telling us that End 1 is the end of Wire 307 at the center of the roof. In the main window, change the frequency to 21 MHz. Don't check the rescale box! Change Units back to Wavelengths with Wire Diameter Units of Inches.

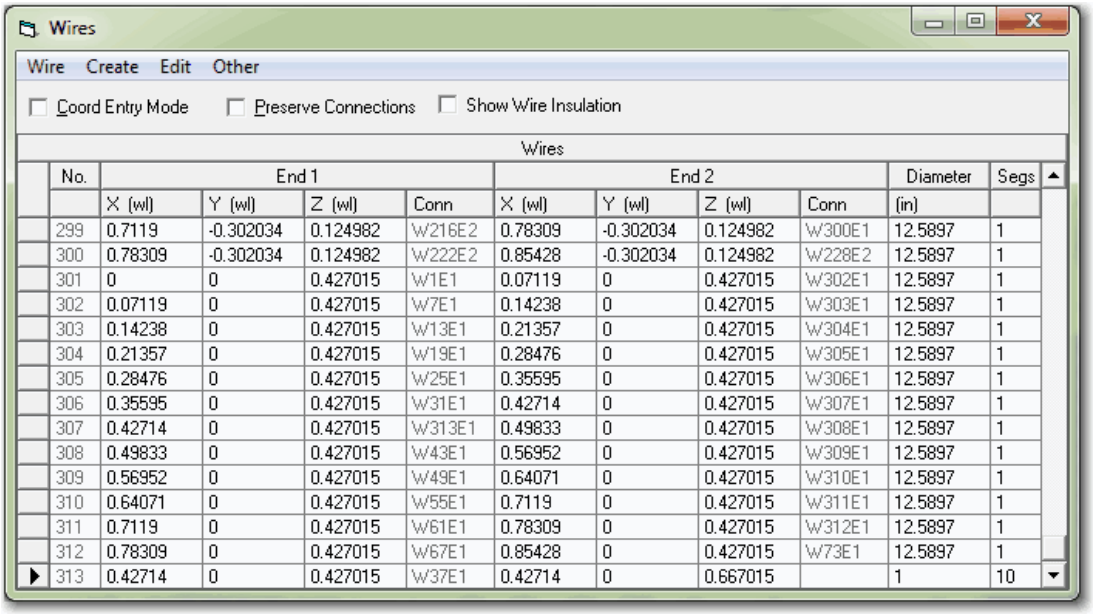
We'll make an approximately resonant vertical 0.24 wavelength high and one inch in diameter.

In the add line at the bottom of the Wires Window (below Wire 312) enter w307e1 in the End 1 X, Y, or Z cell and press the <Enter> key. This creates a wire with its end 1 connected to End 1 of Wire 307, at the center of the roof.

We want the other end to be straight above this, so an easy way to avoid typing in duplicate X and Y coordinates is to initially specify the same location for End 2 as for End 1.

Enter w307e1 in the End 2 X, Y, or Z cell and press <Enter>. Then add 0.24 to the End 2 Z coordinate of .427015 and enter the result (0.667015) in the End 2 Z cell to place End 2 of the new wire 0.24 wavelength directly above End 1. Enter 1 in the new wire Diameter cell and 10 in the Segs cell then press <Enter>.

Your Wires Window should now look like this:

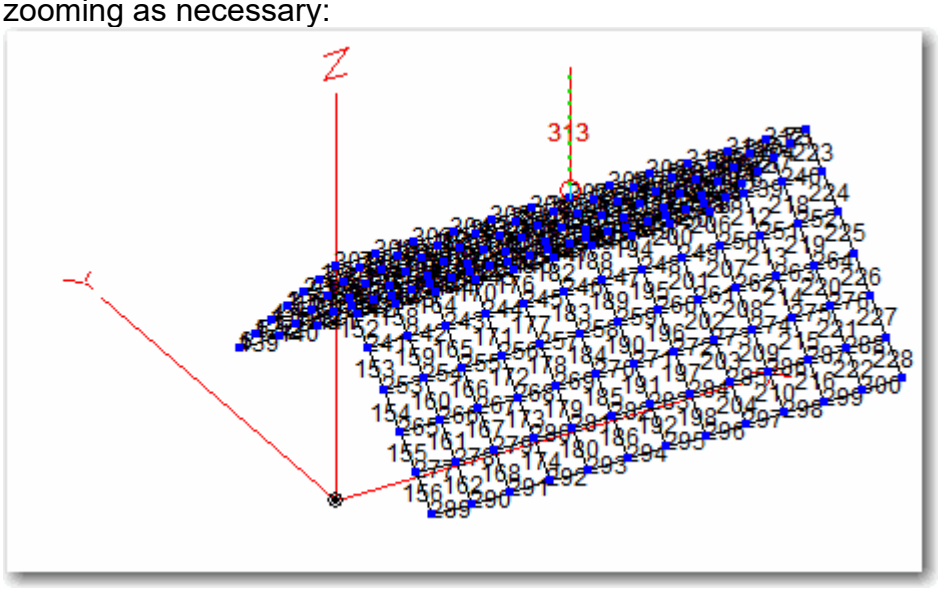


No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(in)	
299	0.7119	-0.302034	0.124982	W216E2	0.78309	-0.302034	0.124982	W300E1	12.5897	1
300	0.78309	-0.302034	0.124982	W222E2	0.85428	-0.302034	0.124982	W228E2	12.5897	1
301	0	0	0.427015	W1E1	0.07119	0	0.427015	W302E1	12.5897	1
302	0.07119	0	0.427015	W7E1	0.14238	0	0.427015	W303E1	12.5897	1
303	0.14238	0	0.427015	W13E1	0.21357	0	0.427015	W304E1	12.5897	1
304	0.21357	0	0.427015	W19E1	0.28476	0	0.427015	W305E1	12.5897	1
305	0.28476	0	0.427015	W25E1	0.35595	0	0.427015	W306E1	12.5897	1
306	0.35595	0	0.427015	W31E1	0.42714	0	0.427015	W307E1	12.5897	1
307	0.42714	0	0.427015	W313E1	0.49833	0	0.427015	W308E1	12.5897	1
308	0.49833	0	0.427015	W43E1	0.56952	0	0.427015	W309E1	12.5897	1
309	0.56952	0	0.427015	W49E1	0.64071	0	0.427015	W310E1	12.5897	1
310	0.64071	0	0.427015	W55E1	0.7119	0	0.427015	W311E1	12.5897	1
311	0.7119	0	0.427015	W61E1	0.78309	0	0.427015	W312E1	12.5897	1
312	0.78309	0	0.427015	W67E1	0.85428	0	0.427015	W73E1	12.5897	1
313	0.42714	0	0.427015	W37E1	0.42714	0	0.667015		1	10

Finally, move the source onto the bottom of the new wire.

In the main window click the Sources line and in the Sources Window Specified Pos. Wire # column for Source 1 enter 313, replacing the value of 4 which was there.

Your View Antenna display should look like this after repositioning and zooming as necessary:



In the main window, change the Plot Type to 3D then click FF Plot.

By choosing Azimuth Slice and checking the Show 2D Plot box in the 3D Display window you can change the elevation angle and see that the pattern isn't circular as with a vertical over a symmetrical radial ground screen, with the distortion varying with elevation angle. This is caused primarily by radiation from the non-symmetrical roof rather than by reflection from it -- pattern-generating reflection takes place far beyond the roof.

Building The Model

Introduction to Modeling

Modeling is the technique of evaluating the performance of one object or system by evaluating the performance of a substitute called a model. Models can be physical objects, like a reduced size scale model antenna sometimes used for evaluating HF antennas. Models can also be purely mathematical, like the equations you use in circuit analysis. The accuracy of the results are never better than the accuracy with which the model matches the real object. For example, a model of a circuit consisting of a battery and resistor will do a poor job of predicting the current if the battery is old and the model doesn't include internal resistance. Likewise, a model for analyzing UHF circuits which doesn't include accurate inductive and capacitive effects won't produce accurate results. So it's imperative that you learn the limitations of your modeling tools. This manual will help you in that endeavor.

Skillfully used within its limitations, **EZNEC** can do a remarkably accurate job of predicting antenna performance. But remember, it's analyzing a **model** of an antenna, not an actual antenna. So its accuracy is always limited by the accuracy of the representation of the real antenna and its environment by the model. In some cases, the tools simply are not available to make an accurate representation, so approximate results are the best that can be obtained. For example, a parabolic reflector can be approximately modeled as a wire grid, but the representation will not accurately predict low-level lobes or characteristics sensitive to dish smoothness. But for many antennas under a wide range of circumstances, **EZNEC** will give you startlingly accurate results. And for most antennas, the results will be close enough for nearly any practical use.

Building a good model and interpreting the results requires considerable skill. This manual is intended to help you acquire the skills necessary to get consistently good results.

You may want to take the Test Drive before or during the reading of this chapter.

Modeling With EZNEC

All antenna models are made from **EZNEC** components – wires, insertion objects, and ground media. The accuracy of the model depends on how accurately the actual antenna and its environment can be represented by the model made from these components. Some physical objects, like a physical wire or metallic tube, are easily modeled with high accuracy. Some, like a round loop or small flat metal plate, must be approximated. And some, like a close helically wound dipole antenna, might not be able to be modeled accurately at all with the available components. But a very wide variety of objects can be successfully modeled with **EZNEC**.

All **EZNEC** operations are accessed via the Control Center. This is the form which opens when you start **EZNEC**, and stays open while **EZNEC** is running.

The following sections will lead you through the steps of building a model. You can get additional information by clicking on the links.

Choosing a calculating engine

EZNEC Pro/2+ and **EZNEC Pro/4+** are able to do calculations with several different types of calculating engine. A new user can start with the integral NEC-2 calculating engine and may never need either of the others. Users needing to model antennas such as loaded or trapped Yagis or wanting to include buried conductors in a model will need to add either NEC-4.2 or NEC-5. **EZNEC Pro/4+** includes an NEC-4.2 calculating engine, but NEC-5 is highly recommended for use with both **EZNEC Pro/2+** and **EZNEC Pro/4+**. See Calculating Engines and Installing & Using External NEC-4.2 and -5 for additional information.

To select among installed calculating engines, open the Options menu and select Calculating Engines. To make the choice persist after you end the program, open the Options menu again and click Save As Default at the bottom of the list.

NEC-5 places insertion objects at different locations than the other calculating engines, and it's not nearly as sensitive to segmentation and object placement. Every effort has been made to point this out in the following sections where appropriate.

Installing & Using External NEC-4.2 and -5

Both **EZNEC Pro/2+** and **EZNEC Pro/4+** can use external NEC-4.2 and NEC-5 calculating engines which are purchased from LLNL. Among the various programs you'll receive, you'll need to use the "command line" or "console" application. A modified version of the NEC-5 console application, NEC5CL_x11.exe, is now available from LLNL. It has a number of bugs fixed which were in the original NEC-5 distribution. You should use this for your **EZNEC Pro+** NEC-5 calculating engine unless a later modified version is available when you read this. See LLNL for details on how to get it, and NEC-5 Status for additional information. I highly recommend NEC-5.

The NEC5_x11 LLNL distribution includes a 32 bit version (NEC5CL_x11_32bit.exe) which should be used only on 32 bit systems because of its memory access limitations, and it hasn't been as extensively tested as the 64 bit version.

At this writing, the NEC-4.2 application is NEC42W64CL.exe (64 bit) or NEC42W32CL.exe (32 bit). Use the one appropriate for your operating system. The 64 bit version will allow access to much more memory and therefore handle many more segments.

A way to determine if an application is 32 or 64 bit is described in the Calculation Time section of Very Large Models.

Installation: The NEC applications can be located anywhere on the system as long as **EZNEC** and the applications can read from and write to the location. C:\Program Files [(x86)]\ and subdirectories aren't a good choice since applications aren't permitted to read from or write to them on many systems. It's recommended that you install them in the **EZNEC Pro+** documents folder which by default is C:\EZNEC 7.0\Docs.

After copying the NEC application(s) to the system, start **EZNEC Pro+**. Open the Options menu and select External Calculating Engine File, then the file type (NEC-4.2 or NEC-5). Navigate to the NEC application location, select the

application, and click Open. You should see a message asking if you want to make it your default file for that external calculating engine type -- click Yes. If you don't see the message, open the Options menu again and click Save As Default at the bottom. Repeat for the other calculating engine type if you have both. In the future you can change the file which will be used, either temporarily or as a new default, by the same method. ***NOTE:*** The format of information sent between **EZNEC** and the external engine is different for NEC-4.2 and NEC-5. **EZNEC** assumes when told to run an external calculating engine that it's the correct type. Attempting to run an NEC-4.2 external calculating engine when NEC-5 is the selected type in **EZNEC**, or vice-versa, will result in errors and possibly a crash. So be sure that the NEC application specified as the NEC-4.2 External Calculating Engine File really is an NEC-4.2 console application, and likewise for NEC-5.

Using the External Engine: Choose the calculating engine you want to use by opening the Options menu and selecting Calculating Engine. The choice you make will remain active only until you end the program, unless you re-open the Options menu and click Save As Default at the bottom of the list.

The **EZNEC** interface is the same when using external and internal calculating engines, with a couple of exceptions:

- Some features aren't available with various calculating engines. See the Calculating Engines topic for details.
- Insertion object placement is different with NEC-5 than with internal or external NEC-2 or NEC-4.2 engines. See NEC-5 Object Placement for details.

Internal calculating engines communicate with the main **EZNEC** program as they run, to provide calculation progress information. There is no such communication when an external calculating engine is running, so what you see will be different. This is described in The Calculation Progress Window topic.

Before doing any calculation with an internal calculating engine, **EZNEC** checks available RAM and sends information to the internal calculating engine telling it how much memory is needed for the immediate calculating run. This communication doesn't take place with external engines which manage their own memory requirements independently of **EZNEC**. Any difficulties with external engine memory access or allotment that might occur are due solely to the internal design of those applications.

Opening The Description File

EZNEC doesn't have a provision for starting with a blank description; it always begins with the last antenna you've analyzed. So it's helpful to accumulate a collection of template antennas which are similar to the types you commonly model. These make fast and easy starting points for developing your new model.

A description file is opened by clicking the Control Center Open action button or clicking the Open selection in the Control Center File menu. If **EZNEC** isn't already running, it can be started with the desired description file open by dragging the description (.EZ) file to the **EZNEC** shortcut icon on your Windows desktop, or, if you chose to associate **EZNEC** with .EZ files at installation time, simply double-clicking on the .EZ file in Windows Explorer.

To open an NEC-format file, follow the above procedure, but include the extension .NEC when you enter the file name. Likewise, to save a file in NEC format, include the .NEC extension. **Use of NEC format files is strongly discouraged** except when necessary to transfer models to or from another analysis program, since some features aren't available or are lost in the translation, and **EZNEC**'s ability to read and write files in this format is limited.

Modeling The Antenna Structure: Wires

About Wires

When modeling an antenna, you'll generally spend most of your time working on the physical structure made up of the antenna's conductors. That's the subject of this chapter.

It's important to realize that **EZNEC** doesn't know, or care, what you consider to be the "antenna" and what other conductors in the model might represent. If you've included conductors to represent towers, rain gutters, fences, or other antennas, they're just as much a part of the model and the calculation as the part of the model you consider to be the "antenna". The whole model is a single coupled system to **EZNEC** just as it is in the real world. (I've often commented to amateurs seeing strange results from multiple antennas in a small area that they don't have several antennas – they have one antenna with several feedpoints. And this is just how **EZNEC** looks at it.)

All antennas in an **EZNEC** model are made from "wires". In this manual the term "wires" refers to the **EZNEC** component of that name. Real, physical wires are called "physical wires". The distinction is important because **EZNEC** wires are idealized models of the real thing, much like a resistance is an idealized model of a resistor. **EZNEC** wires are also used to model other physical objects such as cars or other structures. Connected as a grid, or screen, they can be used to model flat conductive surfaces.

EZNEC models every antenna as a collection of straight wires. **Straight** should be emphasized; a round loop, for example, must be modeled as a polygon of straight wires. The diameter of each wire can be freely chosen, and the program will give accurate results with diameters from arbitrarily small up to at least 0.02 wavelength. With some imagination, nearly any type of conducting structure can be modeled as wires (although not always practically or with great accuracy). For example, a metal wall can be modeled as a grid of wires with a mesh on the order of 0.1 wavelength or less.

You tell **EZNEC** where the wires are placed in space by giving their x, y, and z coordinates relative to a universal origin, or 0,0,0 point. You're free to decide where the origin is, except that ground is always assumed to be at the height of the origin (z = 0). (There are also some additional considerations involving the origin choice when two ground media are included in the model.)

EZNEC has several features to make entry within the coordinate system as easy as possible; they're described in the Wire Coordinate Shortcuts section.

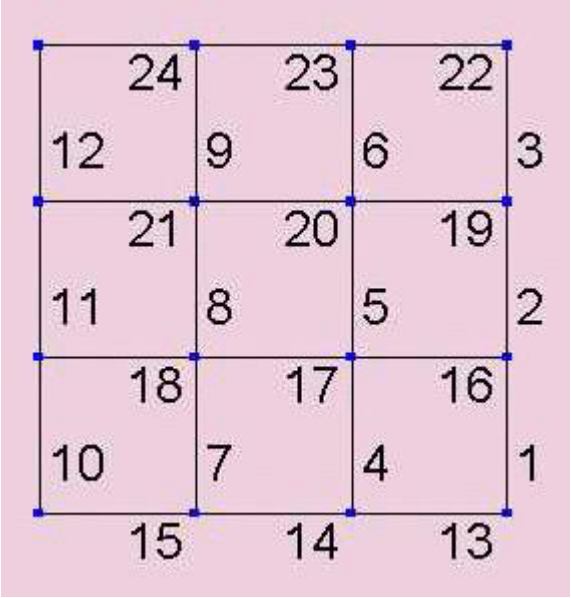
Wires are connected whenever an end of both have the same coordinates (actually, if the ends are within about 0.001 segment length of each other).

Wires can be connected only at their ends. **EZNEC** automatically connects wire ends which have very nearly identical coordinates. The actual criterion used by **EZNEC** is that wire ends have to be within about 1/1000 of a segment length to be connected. The coordinates of any wire ends which are

close enough to be considered connected will be modified as necessary by **EZNEC** to make them identical. If a ground is used, any wire end with z coordinate within about 1/1000 segment length of zero is considered connected to ground and its z coordinate is set to exactly zero. **NOTE:** For High Accuracy or Extended Accuracy ground, the connection will be unpredictably lossy (resistive). See Real Ground Types.

Serious errors will occur if wires cross or occupy the same space. Because wires can be connected only at their ends, simply crossing wires won't connect them, and would cause severe calculation errors if not for **EZNEC**'s Geometry Check feature which prevents calculation when this error is present. As an example, modeling an "X" - shaped structure with the recommended restrictions requires four wires if the cross members are connected at the center of the "X".

Modeling the following wire grid



requires 24 wires. Each side of each square is a separate wire. See Segment Junction Intersections for additional information.

A common problem involves wire spacing. When wires are to be close but not connected, users frequently space them very close, sometimes a fraction of an inch or centimeter when the wavelength is tens of meters. This isn't good practice, and can lead to numerical problems. (It's difficult for any program to deal with wires which are 40 meters long but spaced .0001 meter apart.) Always use realistic spacing. If you're analyzing a 3 MHz antenna, you probably can space wires six inches (15 cm) without materially affecting the antenna operation. If you can, do so. If you can't, make sure the results aren't unduly sensitive to the spacing or number of segments. If they are, numerical problems might be occurring. More information about closely spaced wires and wires intersecting at an acute angle is given in the sections below.

Wires are divided into segments for computational purposes, and good segmentation is essential to accurate results. See the Segmentation section for more information about this important topic.

Several NEC guidelines are checked by the automatic Segmentation Check. It runs automatically when you open a file or change the wire description, or you can run it manually at any time. There are two sets of guidelines: conservative and minimum recommended. In general, the conservative guidelines will

result in more segments and better accuracy than the minimum recommended. It's impossible to place an accuracy figure on either set of guidelines, because the effect of small errors in current amplitude or distribution can vary greatly, depending on the type of antenna and the role the wire plays. As a general rule, you should use more conservative guidelines when modeling antennas which have a narrow bandwidth or use parasitic elements, such as a Yagi. See Segmentation for more information. More serious errors, such as crossing or overlapping wires are detected by the Geometry Check, which can be run manually at any time but always runs at the beginning of a calculation. Unlike the segmentation check, you can't choose to ignore these errors; **EZNEC** will refuse to do the calculations if geometry errors exist. Bear in mind that neither check can find all possible errors, so care and knowledge on the part of the user are still required. ***NEC-5 is much less sensitive to segmentation than the other calculating engines, so most of the segmentation checks are unnecessary and not done.***
The Some Special Cases section describes special considerations which need to be taken when modeling several common configurations. Additional and more detailed information about the Wires Window and View Antenna display can be found in the Reference section.

Segmentation

Each wire is divided into segments for analysis purposes. The NEC calculating engine assumes that the current has an particular shape over the length of a segment, and that the currents of adjacent segments match at their junctions and some distance beyond. This makes the problem one of finding a finite number of impedances, currents, and field strength contributions. Some of the skill in modeling is in choosing the number of segments. **EZNEC** will choose for you (with its automatic segmentation feature) if you wish, but its choice will often not be best. Although accuracy generally improves when more segments are specified, computation time increases approximately as the square of the number of segments, increasing to the cube of the number for very large models. A useful rule of thumb is 10 segments per half wavelength for pattern/gain analysis, and perhaps twice that number if really accurate impedance values are required. Wires joining at very acute angles may require more segments (see Acute Angles). If in doubt, a straightforward way of telling whether you've specified enough is to increase the number and see how much the results change. You should also develop the habit of looking at the currents on the wires. Abrupt current changes might indicate an insufficient number of segments (but note that apparently abrupt phase reversals at wire end connections may be due to internal conventions of assigning current direction – see Interpreting The Results). One place more segments aren't better is if wires of different diameters are connected in a configuration which **EZNEC** can't correct with its stepped diameter correction. (This is a problem only for the internal NEC-2 calculating engines.) See Stepped Diameter. Determining a reasonable number of segments isn't as hard as it sounds. You'll soon get a good feel for about how many you need to get the shape of a pattern or a feedpoint impedance with the accuracy you need.

Altering the number of segments is often part or all of a solution to a problem of poor average gain. Refer to that topic for more information.
In looking at models created by **EZNEC** users, it's apparent that many people use more segments than necessary. This is usually no disadvantage in small models, but it unnecessarily increases calculation time, and often is the source of a perception that not enough segments are available. One important thing to keep in mind is that if a wire carries little current, it contributes little to the overall field, since the field is proportional to the current. Consequently, wires that carry little current can often be given fewer segments than the "minimum recommended" number, or even removed from the model altogether. The exception to this is situations where deep nulls or high front-back ratios have to be determined. In those cases, even the small fields from wires with little current can modify the results and should be undersegmented or removed with care. When studying the effect of an undriven nearby antenna, the model of the nearby antenna can frequently be undersegmented or simplified a great deal. For example, the elements of a 20 meter beam are far from being resonant on 15 meters, so constant diameter, somewhat undersegmented elements could be used for the 20 meter beam when analyzing its effect at 21 MHz. The tip in the Log Periodic Antennas section for segmenting that type of antenna might give you some ideas for others.
See Some Special Cases in "Modeling The Antenna Structure" for some examples where the number of segments or segment length requires special consideration. Also see the index under "Segments" or "Segmentation" for additional references.
EZNEC Pro/2+ and EZNEC Pro/4+ permit a maximum of 45,000 segments.

Using The Wires Window

Other than the Control Center, the Wires Window is probably the part of the program you'll interact with most. This is the place where the basic structure of the antenna is defined. The antenna is made from straight wires. The location, diameter, and interconnection of these wires are all defined in the Wires Window. The Wires Window has many powerful features that allow you to quickly create and modify even very complex models without having to enter hardly any wire end coordinates.
Open the Wires Window by clicking on the Control Center Wires line or the button to its left.
Wires are defined by specifying their end coordinates in the appropriate grid cells. However, several structures such as loops and helices can be created without specifying any end coordinates. Also, wires and groups of wires can be easily modified and copied, so you can almost always begin with very simple geometries and then modify the wires to reflect the actual design.
Several wire modifications can be made graphically in the View Antenna Display. See Graphical Wire Operations for information.
Menus and selections in the following paragraphs refer to the Wires Window. Unless otherwise noted, a sequence like Wire/Add refers to first the menu, then the selection(s). For example, Wire/Add means the Add selection in the Wires menu (in the Wires Window).

Adding Wires

To add any number of wires, select Wire/Add. Enter the number of wires in the upper box. If the lower box is left unchanged, the new wire(s) will be

added below the existing wires. If desired, you can specify other locations for the new wire(s) by entering the position in the lower box.
To add a single wire, you can also simply type the coordinates, diameter, and number of segments in the add row, then press <Enter> or click on another row of the grid. Any cells left blank will be filled with duplicates of the values for the last wire.

Entering End Coordinates

Coordinates are entered in the appropriate columns of the grid. Coordinates can also be modified by means of editing shortcuts. International users: Numbers must use the decimal separator defined by your Windows regional setting.

Entering Wire Diameter

Diameter can be entered as a number or as American wire gauge (AWG). The units used for numerical diameter are shown near the top of the grid column. To enter diameter as a wire gauge, prefix it with '#'. For example, AWG 12 wire is specified as #12. Note that wires specified as gauge aren't scaled if frequency scaling is done, but can be scaled with the Scale Wires feature. See About Wires for diameter limitations.

Entering The Number of Segments

The number of segments is entered in the Segs column. Choosing the correct number of segments is something of an art and skill. See Overview for more information.

Defining Wire Insulation

Please refer to Wire Insulation for a full description of this feature.

Defining Wire Loss

Skin-effect loss will be calculated and used for each wire based on the frequency, wire diameter, and the bulk resistivity and relative permeability of the wire material entered in the grid. (Important note: The bulk resistivity is a frequency-independent characteristic only of the material, not to be confused with RF resistivity which is derived from the bulk resistivity, diameter, and frequency.) You can directly enter values in the appropriate grid cells, or right-click any of the wire loss cells to open a convenient dialog box where you can choose some common materials. To give all wires the same loss, click the Wire Loss line in the Control Center and enter the desired values. Individual wires can be changed afterward if desired. See Wire Loss for more information.

Selecting Wires

Deleting, copying, and moving wires require first selecting which ones are to be operated on. In addition, wires can be selected before starting Group Modify. To select a wire, click on the button on the left side of the appropriate row. The selected wire will be highlighted. To select additional wires, hold <Ctrl> down when clicking the button. To select a group of wires, select the first wire, then hold <Shift> while clicking the last wire in the group[1].

Deleting Wires

The current wire, or selected wires, can be deleted by pressing the <Delete> key. Alternatively, a sequential group of wires can be deleted by selecting Wire/Delete and specifying which to delete.

Changing the Position of Wires in the List

To move wires in the list, first select the wires as described above. Then Move Wire(s) in List from the Wire menu. You'll be asked for the location in the list

for them to be put. You can also select Wire/Copy or Wire/Move Wire(s) in List before selecting wires, in which case you'll be asked for a range of wire numbers to copy or move.

Copying, Moving, and Rotating Wires[1]

To copy, move, or rotate wires in the model, first select the wires as described above. Then open the Wire menu and select Copy Wires, Move Wires XYZ, Rotate Wires, or Stack. The individual dialog boxes offer additional choices for the action you've chosen. You can also choose the action from the Wire menu before selecting wires, in which case you'll be asked for a range of wire numbers to copy or move. The Rotate Wires feature can be useful in changing the orientation of wire structures which are otherwise fixed. For example, the Create Radials feature creates a horizontal radial structure which can be reoriented using Rotate Wires.

Scaling Wires[1]

Lengths and optionally diameters of any selection of wires can be multiplied by a constant factor by selecting Scale Wires in the Wire menu. The form which opens lets you choose the center of the scaling and in what directions (along which axes) scaling takes place. Distances of all wire ends from the chosen center point in the chosen directions are scaled by the specified factor. To change the lengths of wires while keeping one end fixed, use the Change Length By or Change Length To shortcut instead.

Splitting Wires[1]

Any wire can be split into multiple equal length wires by selecting Split Wires in the Wire menu.

Making Multiple Offset and/or Rotated Copies of Wires[1]

Multiple offset and/or rotated copies of a wire or group of wires can be made with the Make Multiple Copies feature in the Wire menu. Each copy is offset and/or rotated from the previous one by the specified amount. This feature can also be used to move a wire or group of wires without copying, although this can be done more easily using other features.

Making a Cylindrical Structure

The feature makes copies of the selected wires and places them in an evenly spaced circle around the Z axis. Choose Make Cylindrical Struct in the Wire menu.

Reflecting Wires in a Plane[1]

A copy of selected wires can be made which are positioned as though reflected in any of the three principal planes by choosing Reflect Wires in the Wire menu. Note that the direction of reflected wires might appear reversed from the originals depending on their orientation and the reflection plane. Therefore, the phase angle of copied sources might have to be changed by 180 degrees to achieve the expected result.

Modifying Wires[1]

Wires can be modified individually, or if desired, a group of wires can be modified at the same time using the Group Modify feature. The procedure is the same for both cases, except that to modify a group of wires, Group Modify must first be activated.

Basic modification of one parameter is done simply by entering the new value in the cell, then pressing <Enter> or clicking on a cell in another grid row. But **EZNEC** also has a number of shortcut features that make it easy to modify wires. These shortcuts are described in a separate section.

A wire end, optionally including connecting wires, can be moved to another existing wire end directly in the View Antenna display. See Graphical Wire Operations for details.

Modifying A Group of Wires – Group Modify[1]

See Group Modify for information about this feature.

Changing the Antenna Height[1]

To change the height of the entire antenna or any group of wires, select Wire/Change Height By, and enter the amount by which you want to change the height. This simply modifies the z coordinate of both ends of all wires by the specified amount.

Changing Loop Size

This feature is described in the Advanced Wire Features section.

Printing or Saving the Wire Coordinates

To print the wire coordinates or save them to a file, select Other/Print/Save Wire List. This opens the **EZNEC** Editor with a formatted list of the wire coordinates. You can save or print the data from this window. For a similar display which includes other features of the model such as sources and loads, see the Control Center Outputs menu.

Other Features

In addition to the features in the Wires Window Wire menu, **EZNEC** has a number of powerful features in the Create menu, described in the Advanced Wire Features section.

- **Wire Information (wire, segment length)** – You can see the wire and segment length for any wire by right-clicking the box at the left of the row.
- **Importing Wires** – Wire end coordinates can be imported from a simple ASCII file. This isn't intended to substitute for **EZNEC**'s file format, but primarily as a way to import wire end coordinates generated by another program. Wires are imported by selecting Import Wires From ASCII File in the Other menu. The file format is detailed in the Wire Coordinate File section. You can add the imported wires to your existing description or you can replace the existing wires with the imported ones. See Importing Wire Coordinates for additional information.
- **Change Units, Retain Numbers** – This option allows you to recover from an easy trap to fall into. It's easy to begin entering data only to find that you're not using the units you intended. For example, you might be entering data intended to be in meters into a grid where the units are feet. This option, in the Other menu, lets you recover without having to re-enter the coordinates. It will change the units but leave the numbers you entered (and all others in the grid) intact.
- **Coord Entry Mode** – This check box is just above the data entry grid. When checked, all columns except the wire coordinate columns are skipped. This allows faster entry of a large number of wire coordinates. If you find yourself using this feature frequently, it might mean you haven't learned how to use some of the time and effort saving features described above.
- **Preserve Connections** – This can be very useful but must be used with caution. It's a good idea to use the View Antenna display while this feature is enabled. When Preserve Connections is on and you modify a

wire end, all wires connected to that end are also modified so their connections to it are preserved. This can be used with Group Modify to preserve the connections of all modified wires. If selected wires are both modified and connected to each other, unpredictable results can occur. So be sure to verify that each operation did what you intended before doing the next modification, and use the undo feature when necessary. Preserve Connections is turned off each time you close the Wires Window. The Preserve Connections box in the View Antenna display which appears when moving wires is not linked to the Wires Window Preserve Connections box; each affects only operations in its own window.

A number of other features are described in the Features chapter of the Reference section.

Tip: *Turn on the* ***View Antenna display*** *when entering or modifying values in the Wires Window. This allows you to immediately see the changes you've made.*

[1]Examples using these features appear in the Test Drive tutorial section Plus Octane Fill Up.

Graphical Wire Operations

Several modifications can be made to a model directly in the View Antenna Display. All changes made in the View Antenna Display can be undone like all other model modifications.

Selecting Wires

To select a single wire, double-click it. To select additional wires, hold down the <Ctrl> key and click. This will also deselect a previously selected wire. Wires selected in the View Antenna Display are also selected in the Wires Window, where various operations can be performed on them. The selected wires can also be deleted in the View Antenna Display as described below.

Delete Wires

To delete wires, select as described above, then press the <Delete> key on your keyboard.

Add Connecting Wires

This feature allows you to add a wire between any two existing wire ends. In the Mouse Operation frame at the left of the View Antenna Display, select Add Conn Wires. The New Wires frame opens below to allow you to choose the diameter and number of segments of the new wire. If Copy Conn Wire is checked, the new wire will have the diameter and number of segments of the highest numbered wire connected to the beginning end point of the new wire.

To begin, left-click the point where you want the new wire to start. A large square will appear at that point. Press the <Esc> key to cancel the selection if you need to choose a different location. After choosing the start point, move the mouse cursor to the desired end point of the new wire and right-click to finish the operation. Any needed modification to the wire can be done in the Wires Window as it is for any wire.

Move Wire Ends

With this feature you can move a wire end (and optionally all connecting wires) from its current location to the end of any other wire. Select Move Wire Ends in the Mouse Operation frame at the left of the View Antenna Display. If you want to move all the wires at a multiple wire junction, Check the Preserve

Connections box; if you want to move only one wire end, leave it unchecked. Left-click near the wire end you want to move. A large square will appear at the selected junction, and the closest segment of the wire to be moved will be highlighted. Only one wire will be highlighted even if Preserve Connections is checked although all wires connecting to the same junction will move. Press <Esc> to cancel the operation at any time before movement is finalized. Right-click at the desired new location to finalize the movement.
Note that the Preserve Connections box is independent of the Preserve Connections box in the Wires Window. Each affects operations only in its own window.

Wire Coordinate Shortcuts

EZNEC includes many features to help you modify wires without having to determine coordinates. For example, you can easily change the length of a wire or rotate it about one end. Shortcuts can be applied to either individual wires or, in Group Edit mode, to groups of wires.
Wire coordinate shortcuts can be applied in two ways, both in the Wires Window. One is to right-click any coordinate cell in the Wires Window grid. The other is to enter a special shortcut abbreviation for the desired action into a coordinate cell. (Shortcut text abbreviations aren't case-sensitive.) Each of the selections below appears in the popup menu you get if you right-click one of the coordinate cells. For example, to use the first method to change the coordinates of wire 4 end 1 so that it connects to wire 3 end 2, you right-click the X, Y, or Z column in the End 1 group of the Wire 4 row. This opens the shortcut popup menu. Select Connect End To. In the dialog box, enter 3 in the Wire to connect to box, and 2 in the End to connect to box, then click Ok or press <Enter>. To use the second method, enter **W3E2** in the X, Y, or Z column in the End 1 group of the Wire 4 row, then press <Enter> or move the mouse cursor to another cell.
Unless otherwise noted, the shortcut is applied only to the end of the wire where the mouse cursor is located when the right mouse button is pressed. This will be called the "current end". A change will be applied only to the current wire (that is, the wire number of the row where the mouse cursor is located when the mouse is right-clicked) unless in Group Edit mode. If in Group Edit mode, the change will be applied to all selected wires. See Using The Wires Window for more information about Group Edit.
All shortcuts except Change Coordinate By will or can change all three of the end coordinates (x, y, and z) regardless of which of the three cells the mouse cursor is placed on or where the shortcut text abbreviation is entered.
International users please note: Floating point numbers (numbers with a fractional part) must have the proper decimal separator.
NOTE: Only the Connect End To shortcut is available in the Add Row (the blank line at the bottom of the grid).

Connect End To

This is a convenient way to connect a wire end to an end of another wire. Simply specify the wire number and end to which you want the current end connected. The text abbreviation for this shortcut is **W#E#** where # are the number of the wire and end you want to connect to. See the example above.

Change Coordinate By

This shortcut adds or subtracts the specified amount to or from the current end coordinate. Unlike all other shortcuts, this affects only the particular coordinate where the entry is made. The text abbreviation for this shortcut is **++#** to increase, or - -# to decrease, the coordinate by #. For example, to decrease the Wire 4, End 2 y coordinate by 3, you can enter **- -3** in the appropriate cell.

Change Length By

This shortcut changes the length of a wire by the specified amount. The current end is modified while the other end is fixed. Wire direction is unchanged. The text abbreviation for this shortcut is **L+#** to increase the length by #, or **L-#** to decrease it by #. The length of a zero-length wire can't be changed because the direction isn't defined.

Change Length To

Use this shortcut to make the wire a particular length without changing the wire direction. The current end is modified and the other end is fixed. The text abbreviation for this shortcut is **L#** to change the length to #. The length of a zero-length wire can't be changed because the wire direction isn't defined.

Multiply Length By, Divide Length By

These function like Change Length By, above, except they multiply or divide the length by the specified amount rather than adding or subtracting a fixed amount. The text abbreviation for this shortcut is **L*#** to multiply and **L/#** to divide.

Elevation Rotate End, Azimuth Rotate End

This shortcut rotates the current end of the wire, leaving the length and other end fixed. The rotation amount is specified in degrees. For elevation rotation, a positive angle causes rotation upward, negative downward. For azimuth rotation, a positive angle results in counterclockwise rotation, negative in clockwise rotation. When elevation rotation is done, the azimuth angle of the wire is unchanged. A vertical or near-vertical wire can't be rotated in elevation because the azimuth angle is undefined. When azimuth rotation is done, the elevation angle of the wire is unchanged. The text abbreviation for these shortcuts are **RE#** and **RA#** for elevation and azimuth rotation respectively, where # is the angle to rotate in degrees.

Additional operations and more detailed information can be found in The Wires Window chapter in the Reference section.

Wire Loss

Realistic wire loss can be included in the model. In the vast majority of typical antennas, wire loss doesn't cause enough difference to be of concern, but it can be important particularly with electrically small antennas. If the metal is plated, the plating material should be specified unless the plating is exceptionally thin or the frequency low. Copper-clad steel wire consisting of a thick layer of copper over steel will have the loss characteristics of copper, so copper should be specified. If you're not sure whether a plating is several skin depths thick, run a calculation with the resistivity of the plating metal, then with the underlying metal. The actual antenna performance will be somewhere between these limits. (In some special circumstances, it can theoretically be a bit outside the limits, but not enough to be likely to alter any conclusions about antenna performance.)

Wire loss can be specified for each wire in the Wires Window or for all wires in the model by clicking the Wire Loss line in the Control Center Information Window. This opens a dialog box which allows you to choose from a number of common metals or enter the resistivity and permeability. In the Wires Window, right-click any of the wire loss characteristics cells to open the dialog box.

Please note: The value used by **EZNEC** is the *bulk resistivity* of the metal, not the DC or RF resistance per unit length of the wire. The bulk resistivity doesn't change with wire diameter, frequency, or length; it's a function only of the metal of the wire or the outer layer of the wire if plated and the plating is at least several skin depths thick. **EZNEC** calculates the actual loss including skin effect from the bulk resistivity, permeability, frequency, and wire diameter to determine how much resistance each wire has. If you know the DC resistance per unit length of a solid, non-plated or –layered wire, you can calculate the bulk resistivity of the metal from $R_b = R' A$ where R_b is the bulk resistivity in ohm-meters, R' is the wire's resistivity in ohms per meter length, and A is the cross-sectional diameter of the wire in square meters.

Wire loss is especially important to include in a model showing low source resistance. In these antennas, wire loss can sometimes be substantial. You can determine the amount of loss caused by the wire by calculating the pattern with zero wire loss and realistic wire loss and comparing the gain.

If feedpoint resistance is very low and your model has a single source, you should temporarily remove the wire loss to insure that the source resistance without loss isn't negative. A negative source resistance with a single source model is an indication of numerical problems, and it can sometimes be concealed by wire loss. See Source Placement Precautions for more information.

Wire Insulation

As of EZNEC Pro+ v 7.0.3, this feature is also available with an NEC-5 calculating engine, and beginning with v. 7.0.4, NEC-5 can also join the other calculating engines in including insulation loss. No change in NEC-5 is required. The effect of normal insulation loss is usually insignificant.

Important note: **The Wire Insulation feature is accurate only for a thin insulation layer, and dielectric constants in the range of those of typical wire insulating materials. Thickness on the order of the wire diameter or greater may give inaccurate results. Attempts to extend its use to purposes other than simulating the effect of wire insulation will produce inaccurate results. This includes attempting to use it to simulate the dielectric material in patch (microstrip) antennas.**

EZNEC has the capability of including the effect of wire insulation. The parameter choices appear as new columns in the Wires Window grid. These columns can be hidden for convenience if desired, via the checkbox above the grid. If you right-click any of the insulation columns, you'll get a dialog box for convenient entry. Here's how the dialog box works:

The first three fixed choices, PVC (polyvinyl chloride), PTFE (Teflon), and PE (polyethylene or polythene), will enter values for dielectric constant (k, or relative permittivity) and loss tangent into the grid but won't alter the thickness value already in the grid. The None choice and the three custom choices will

replace the thickness value. Choices, including custom values, are saved permanently unless you close the dialog box with <Esc> or Cancel. The intent of the custom values is to let you enter parameters appropriate for some specific wire you might be using for antenna construction.
To set insulation to zero, enter a thickness of zero. For convenience, there's a None choice in the dialog box which will do this. A dielectric constant of 1 and loss of zero also will result in no insulation.
Insulation thickness is scaled when the antenna is scaled. Insulation properties of added wires are copied from the wire just preceding, as are the diameter and number of segments.
The Segmentation and Geometry checks and the stepped diameter correction don't take any notice of the insulation, since its effect as a percentage of wire length is generally small (typically on the order of 2 - 3 percent). Segment length rules won't change significantly when using wire insulation unless the insulation is on buried wires and is relatively thick. When the insulation's dielectric constant is considerably lower than that of the medium (possible only with buried conductors, available only with NEC-4.2 and NEC-5), the velocity factor increases significantly, so segments can be longer. But this isn't accounted for by the Geometry Check.
The characteristics of PVC vary widely, so the values are a rough average for the HF range. The Custom windows can be used for any values you think are better.
While **EZNEC** permits you to specify insulation loss, you'll find that even a fairly gross loss tangent usually doesn't make a huge difference. PTFE and PE are pretty constant over a wide range of frequencies, so the fixed values should be adequate for nearly any use. Loss tangent stays relatively constant with frequency while conductivity doesn't, so loss tangent was chosen for loss specification. For any reasonable loss tangent, the loss tangent is for practical purposes equal to the dissipation or power factor. So table values of DF or PF can be used directly. The level of loss associated with normal wire insulation generally has only a small effect on overall performance, so it will probably be most useful for unusual coatings.

Importing Wire Coordinates

Wire coordinates can be imported from an ASCII file in a simple format, either replacing or adding to the existing model. This can be used to import coordinates from another program. To import wire coordinates, select Import Wires From ASCII file in the Wires Window Other menu, or the Control Center File menu. The file format is described in the Wire Coordinate File section.
Combining and importing are sometimes confused. If you want to add an existing description to your present model, see Combining Antenna Descriptions.

Other Wire Considerations

Some NEC-2 and -4.2 literature cautions against permitting the center of a segment to lie within the volume of another wire. See the Geometry Check topic for an illustration of this condition. It can occur when segments are short, wires have large diameters, and intersection angles are acute. I haven't been able to devise a test which shows any adverse effects from permitting this to happen, so it should be allowed to happen only if erroneous results are likely

to be recognized if they should occur. The Geometry Check tests for this condition, but the test can be disabled for the current description via the Control Center Desc Options selection. This choice is saved with the description. NEC-5 seems much more tolerant of this condition.
A case was found where **EZNEC** produced results with NEC-2 which were very inaccurate, and showed great sensitivity to the number of segments. This case was where a wire approached the middle of another at an angle, but wasn't connected, like an insulated guy wire at the midpoint of a tower. Reliable results were obtained only by spacing the end of the "guy wire" from the "tower" by about a segment length. With slightly closer spacings, reasonable results were obtained by making sure the segment lengths of both wires were the same, and the junctions were directly across from each other, as viewed through the bisector of the angle they formed. NEC-4.2 and NEC-5 calculating engines may not be as sensitive, but use care with this wire arrangement, and make sure it isn't highly sensitive to the number of segments.
See Segment Junction Intersections if you have a model containing wires intersecting at segment junctions.

Advanced Wire Features

Advanced Wire Features Introduction

Advanced wire features are available for easily creating and modifying antenna structures. Some features are available only for some program types; refer to the following topics to see which program types have which features.
Structure creation features are accessed via the Wires Window Create menu. Others are accessed via the Wire menu. See Using The Wires Window for discussion of additional features.

Catenary Creation

This feature is located in the Create menu of the Wires Window.
A wire suspended between two supports doesn't form a straight line, but if uniform in material and diameter forms a type of sagging curve called a catenary. **EZNEC** can create an approximation to a catenary curve with a series of short straight one-segment wires. Even a moderate amount of sag can alter antenna characteristics very significantly. For example, example model BYDipole1.EZ shows an impedance of about 74.4 - j42.5 ohms (NEC-2D calculating engine). Replacing the wire with a catenary extending between the same end points but with a five foot sag results in an impedance of 91.7 + j45.6.
The amount of sag of a physical wire depends on a number of factors including the weight and flexibility of the wire ,the tension, and the height difference between ends. **EZNEC** requires you to specify the amount of sag in any one of five ways. Use whichever is most convenient.
In the Create Catenary dialog there are two basic ways to define the wire to be represented by the catenary. One way is to uncheck the "Replace wire with catenary" box and enter the catenary end coordinates, diameter, and number of segments (one wire per segment) in the boxes below. Specify the amount of sag and click Ok. The catenary will be created at the specified location and the added wires placed at the end of the wire list.

An easier way is to create a conventional straight wire before opening the Create Catenary dialog, and give it the characteristics of the desired catenary (diameter, number of segments, and if desired, insulation). Place a source or other insertion objects on it as needed. Open the Create Catenary dialog, check the "Replace wire with catenary" box, and enter the number of the wire to be converted to a catenary. When you click "Ok", the specified wire will be replaced by a catenary and insertion objects on the original wire will be placed in the same relative positions on the catenary.
When the "Replace wire with catenary" box is checked, data cannot be entered in the direct entry boxes below, but when a valid wire number is specified, the characteristics of that wire are loaded into the direct entry boxes. The data in the direct entry boxes can be modified only by unchecking the "Replace wire with catenary" box, which disables the replacement feature. If you want to replace a wire but with different diameter, number of segments, or end coordinates, you must close the Create Catenary dialog and modify the wire, then reopen Create Catenary and select the wire.
Tip: Tto place a source at the center of a catenary when directly defining it and not replacing a wire, specify an odd number of segments (wires). Then place the source on the middle wire. For example, if the catenary has 51 segments and comprises wire numbers 35 to 85, place the source on wire number (35 + 85) / 2 = 60.

Helix Creation

The helix creation dialog box opens when you select Helix from the Wires Window Create menu. A helix should be used whenever possible to model a loading coil or any other coil where the current at one end can be different from the other due to radiation and/or significant electrical length. The assumption of equal currents at the ends of lumped loads make them unsuitable in those situations.
Most entries in the helix creation form are self-explanatory. In the Turns/Spacing/Length frame, you must choose any two measures for the length; the third will be calculated and entered automatically. If you check the "Extend ends to helix axis", an extra wire will be created on each end of the helix, extending to the helix axis. Turn spacing should be at least two wire diameters, and ideally several wire diameters. A few experiments, making use of the Undo feature, will quickly get you acquainted with the various features.
If the Make Spiral box is checked, diameters of the two ends can be separately specified and a linearly varying spiral will be created. A flat spiral will result if length is zero and one end diameter is zero.

Loop Creation

To create a loop, open the Create menu in the Wires Window and select Loop. Although the dialog box might appear complex, it's actually quite simple to use. Most items are self-explanatory. The wire diameter can be entered either as a value, or as a wire gauge, just like wires in the main wire entry grid. In the Loop Size frame, you can define the loop size in any one of three ways, by circumference, side length, or the approximate diameter (the diameter of the circumscribed circle). As you enter a value, the remaining two are calculated for you. You can position the loop anywhere, and can orient it with its axis in any of the three principal directions.

Loop Resizing

You can use the loop resizing feature (Wires Window, Wires menu, Change Loop Size) to change the size of any polygonal loop. The first step is to specify the loop, by selecting the wires in the Wires Window or View Antenna display. Or you can click the selection before you select wires, in which case you'll have to choose a set of wires in numerical sequence. The selected wires have to be connected in a loop, of course, and no wires can be connected to the loop other than the wires comprising the loop. If you've recently created a loop, its wires will be entered as an initial choice. The buttons and text box at the bottom of the dialog box allow you to modify the size with any of three different operations, on any of three loop size measurements.

Radial Creation

EZNEC's automated radial creation feature is a convenient way to make a group of radial wires, for ground systems, vertical antenna top hats, or any other radial structure. This feature is accessed from the Wires Window, Create menu, Create Radials selection. When this selection is made, a dialog box appears which prompts for a range of "prototype" wires. To make a simple set of radials, you should first create a single radial wire. End 1 of the radial wire should be where you want the center of the radials to be. Enter its number as both the first and last wires in the prototype group. In the bottom box, enter the total number of radials you want the finished structure to have, then click Ok. The radials will be created, fanning out horizontally and evenly around end 1 of the prototype wire. A vertical wire can't be used as the prototype.

More complex radial structures can be made by specifying a group of wires as the prototype radial to be copied. A prototype group of wires has to be sequentially numbered (that is, you can't use wires 1, 2, and 4 as the prototype group, for example) and must be connected end 1 to end 2. This group of wires will then be duplicated, centered around end 1 of the first wire in the prototype group. The first wire in the group can't be vertical, since this would result in the first wire of the copies all occupying the same space.

Radial wire structures in orientations other than the horizontal plane can be made by first creating the radials, then using the Rotate Wire feature to rotate the structure to the desired orientation.

Wire Grid Creation

This feature also allows creating a closed wire grid box.

A wire grid is a good way to simulate a flat, solid, conductive surface such as a metal roof or car top, or an enclosed box. A wire grid looks like a screen, with each side of each screen hole made from a wire. (See the diagram in the About Wires section.) In general, the best implementation is for each side of each hole to be a single one-segment wire. Although wire grid modeling is an art in itself, a few general rules have evolved which give good results for most situations. One is that the size of the holes (that is, the wire spacing) shouldn't exceed about 0.1 wavelength. Some studies have indicated that a coarser structure is adequate far from the source, where current is lower. The same general rule should be followed here as for elsewhere in any model, that segmentation needs to be finer when the current changes rapidly from one

segment to another. Another general practice is to make the surface area of the wires equal to the area of the surface being modeled. This requires larger diameter wires than normally used (diameter equal to the spacing divided by pi), but usually produces the best results.

EZNEC provides an automated method which greatly simplifies the creation of wire grids. Wire grid definition is done with a dialog box opened by selecting Create Wire Grid from the Wires Window Other menu. It requires you to specify the coordinates of three corners of the grid, then **EZNEC** will do the rest. You can adjust the wire spacing and diameter if you wish. But the default values, which follow the rules described above, are generally adequate.

The Wire Grid Creation dialog box is opened by choosing Other/Create Wire Grid in the Wires Window.

In the dialog box, note the rectangular area with "GRID" shown in the center, and with "Side A" and "Side B" labeled. This represents the physical grid. Sets of text boxes labeled "X", "Y", and "Z" are placed close to the corners of the grid which their coordinates represent. That is, the coordinates on the upper left are for the upper left corner of the grid (the junction of Side A and Side B), and so forth. Other options are "IEW" for Include End Wires, and Create Box. Unchecking IEW for any side will inhibit creation of the outside wires of the grid on that side. This allows more convenient connection to other structures in some cases. If Create Box is checked, additional parameters appear at the bottom of the window to allow defining an enclosed box.

The approximate number of wires to be created is shown near the lower left. If insufficient information has been entered to calculate the number of wires, "Data incomplete" appears.

Note: After creating a wire grid using the default wire spacing, Segmentation Check will show that the segment length exceeds the conservative maximum. This is normal and no reason for concern.

X, Y, Z (three sets) – In these boxes, enter the coordinates of three corners of the grid. Note that it's possible to create a parallelogram as well as a rectangle by the appropriate choice of coordinates. The units of the coordinates are the current units chosen for **EZNEC**, which is shown below the lower left set of coordinates.

IEW (Include End Wires) – If one of these boxes is unchecked, the wires along that side will be left off. This option is used when connecting two wire grids, to avoid creating duplicate wires at their junction.

Grid Spacing – Allows you to specify the spacing between wires (the width of the holes). The default value of 0.1 wavelength can be easily selected by checking the box.

Wire Diameter – Allows you to specify the wire diameter. The default value of spacing/pi, which results in wire area equal to modeled surface area, can be selected by checking the box.

Create Box – If checked, an enclosed box will be created.

Box Parameters - Define additional characteristics of the enclosed box. Visible only when Create Box is checked.

Meander Line Creation

This feature creates a flat meander (zig-zag) line useful for planar loading. It's located in the Wires Window Create menu.

"Side wires" refers to wires in the long direction of the meander; "width wires" are wires crosswise to the meander, i.e., the width of the meander is the length of a "width wire". Only full cycles of meander are created. Wires can be deleted after creation if partial cycles are needed. Parameters are self-explanatory. Some experimentation should quickly clear up any questions.

Stepped Diameter Correction

Stepped Diameter Correction Overview

The following information applies only to the NEC-2 calculating engine(s). The problem described here doesn't occur when using NEC-4.2 unless there are extreme differences in the diameters of connected wires. NEC-5 seems to be nearly completely immune to this problem.

NEC-2 is known to be inaccurate in modeling connected wires having different diameters, such as Yagi antennas made with telescoping tubing. (Note: This is sometimes called being "tapered". It shouldn't be confused with **EZNEC**'s segment length tapering.) The problem gets worse as the segments near the junctions get shorter and as the diameter difference gets larger. The error is small enough that it's not important for many applications, such as evaluating a tower top-loaded with a beam. However, if the stepped diameters are on a parasitic element or exceptionally high-Q antenna, the inaccuracy can cause significantly bad results. **EZNEC** incorporates methods based on the one developed by Dave Leeson and described in his book *Physical Design of Yagi Antennas* (ARRL, 1992) for calculating an equivalent wire of constant diameter to replace a group of wires of different diameters.

The original Leeson method provides excellent results but only under a narrow range of conditions, and **EZNEC** will apply it only under those circumstances. The requirements are that:

- There must be at least two wires in the group.
- At least two of the wires must have different diameters.
- All wires in the group must be collinear (in a straight line). A consequence of this is that no more than two wires can be connected at any junction.
- All wires must be connected to each other.
- Both ends of the group must be open, or one end open and one connected to ground.
- The group must be nearly resonant (within about 15% of half-wave resonance if both ends are open, or within about 15% of quarter-wave resonance if one end is grounded).
- Only one source is permitted in the group, and it must be at the center if the ends are open, or at the bottom segment if the group is grounded. If the ends are open and the center of the group is a wire or segment junction, the source must be a split source. If the group is grounded, the source must not be a split source.
- The rules for loads are the same as for sources, except that two equal loads must be used wherever a split source would be used.
- A single transmission line can be connected to the group. If the ends of the group are open, the center of the group must be a segment center -- not segment or wire junction -- and the transmission line can be

connected only to this segment. If the group is grounded, the transmission line can be connected only to the bottom segment.

These criteria apply to typical full size Yagi elements made from telescoping tubing, one of the most demanding cases where the correction is needed, but any loading other than at the center or the presence of any traps violate the conditions so the Leeson correction won't be applied..

Beginning with **EZNEC** v. 6.0, additional correction methods are applied when some of the above conditions aren't met. Tests with several loaded Yagis have shown much better correction than the basic Leeson substitution, and very much better than no correction at all. However, testing has been limited and there are undoubtedly configurations which won't be corrected well. So be cautious in accepting the accuracy of any model having stepped diameters and which don't meet the criteria above. A poorly corrected Yagi model will generally exhibit inaccurate front-back ratio and to a lesser degree a shift in resonant frequency.

A bright notice will appear on the **EZNEC** screen during calculation when the stepped-diameter correction is being used for one or more groups of wires. You can see exactly what the substitutions are from the Wires Window by selecting Other/Show Stepped Dia Correction. (See Using The Stepped Diameter Correction Display.)

The correction can be disabled from the Options Menu if desired, but this isn't recommended.

In situations where wires of different diameters are connected but **EZNEC**'s stepped-diameter correction doesn't apply, a technique can be used to minimize the error. This is to use the minimum number of segments possible -- that is, make the segments as long as possible -- and do not use segment length tapering. (Exception: wires very near ground. See Elevated Radial Systems. The accuracy of NEC-2 is worst in the presence of stepped diameters when the segment length/diameter ratio is small. Especially when confronted with a large difference in diameters, the best accuracy will be obtained if you use the automatic segmentation feature in the Wires Window, and select (M)in. recommended. The accuracy is still not likely to be good enough for accurate modeling of parasitic elements if the built-in correction can't be applied.

The inaccuracy of NEC-2 in the presence of large steps in diameter typically shows up as an incorrect reactance. If you design an antenna with parasitic elements having connected wires with largely differing diameters, **EZNEC** will give an accurate idea of the antenna performance. However, it will show the performance occurring at not quite the correct frequency. When you actually build the antenna, you can expect the predicted performance, but may need to adjust parasitic element lengths slightly to achieve that performance at the desired frequency. For example, if **EZNEC** shows your "X-beam" to have a gain of 6 dBi, front/back ratio of 20 dB, and feedpoint SWR of 1.5:1 at 14 MHz, you might find when you build it that the front/back ratio is much worse than predicted at 14 MHz but is very good at 14.5. In this case, you would need to lengthen the parasitic element until you get the best front/back ratio at 14 MHz. The beam will then have very nearly 6 dBi of gain and 1.5:1 SWR at 14 MHz.

Using the Stepped Diameter Correction Display

This is generally used only with the NEC-2 calculating engines. See Stepped Diameter Correction Overview for detailed information.
The stepped diameter correction display shows you exactly what substitutions **EZNEC** has made to correct for connected wires of different diameter. One of its most important uses is to make sure that all the elements of a Yagi or similar antenna are being corrected.
The stepped diameter correction display is shown by first opening the Wires Window, then choosing Show Stepped Dia Correction from the Other menu. One of two indications will be shown for each wire. If coordinates and diameter are shown for the wire, that wire is being corrected, and the coordinates and diameter are those of the wire being substituted by **EZNEC**. Notice that the diameter of all substituted wires in an element are the same, and that the element length has been modified slightly. These are the consequence of the substitution process, and will give accurate results. The other possible indication is a message, spread out over several columns, briefly telling why the "group" (of connected wires) hasn't been corrected. All the elements in a Yagi, for example, should be corrected. So if any elements show as not being corrected, you should return to the ordinary Wires Window display by selecting Show Stepped Dia Correction from the Other menu (to turn it off), fixing the problem, and checking again until all wires are being corrected.

Some Special Cases

Acute Angles

NEC has some difficulty in accurately modeling multiple wires joining at a very acute angle, such as with a "fan" antenna, the difficulty being greater with NEC-2 than with NEC-4.2. NEC-5 seems to be much more tolerant but you should use some caution before accepting that. The problem has a different cause than the MININEC problem of "cutting corners", and quads are modeled very well by **EZNEC** without special attention. However, when modeling very acutely-intersecting wires, evaluate the results carefully, particularly if a source or load is at or near the junction. It has been reported that **EZNEC**'s segment length tapering feature (originally developed for MININEC-based ELNEC) improves the accuracy in this situation, provided that the wires all have similar diameters. Segment length tapering is likely to degrade the accuracy with wires of greatly different diameter. (Exception: wires very near ground. See Elevated Radial Systems. Another method which has been reported to work is to put a separate source on each wire, rather than a single one near their junction.
One problem with wires intersecting at an acute angle is that it's often difficult to avoid the problem of the center of one segment lying within another wire. This problem is most likely when segment length is short near the junction. See the Other Wire Considerations and Geometry Check topics for additional information.

Buried Wires

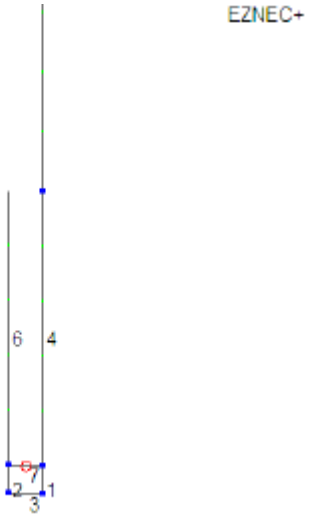
NEC-2 is not able to model buried wires or conductors, so all conductors must be above ground unless using the **EZNEC Pro/4+** internal NEC-4.2

calculating engine or an external NEC-4.2 or -5 engine with either **EZNEC Pro+** program type.
The remainder of this section applies only when NEC-2 is not being used. For information about simulating buried wires with NEC-2, see Vertical Antennas And Buried Radials and Connecting to High Accuracy Ground.
There are only a few restrictions on modeling buried wires with NEC-4.2 and -5, as follow:

1. The Real, High or Extended Accuracy (NEC Sommerfeld) ground model must be used.
2. Horizontal wires should be at least several wire diameters below the surface.
3. Wires can penetrate the ground (z = 0) only at a segment junction. It's recommended that penetration be done at a wire end. That is, have the above-ground wire end at z = 0, and make the portion below ground be a separate wire, connecting to the above-ground wire at z = 0. This way, the connection won't move, and the requirement will be satisfied, if you change the wire lengths or number of segments.
4. The velocity factor under ground is often a fraction of the velocity factor in free space. Consequently, many more segments are required for the most accurate results. **EZNEC Pro/4**'s Segmentation Check takes this into account and shows warnings or cautions if segments are too long. On the other hand, the loss associated with ground often permits coarser segmentation than general guidelines indicate. This is one of those cases where some experimentation, trying different numbers of segments to see where accuracy begins suffering, is required if the segment count needs to be minimized.

Closely Spaced Wires

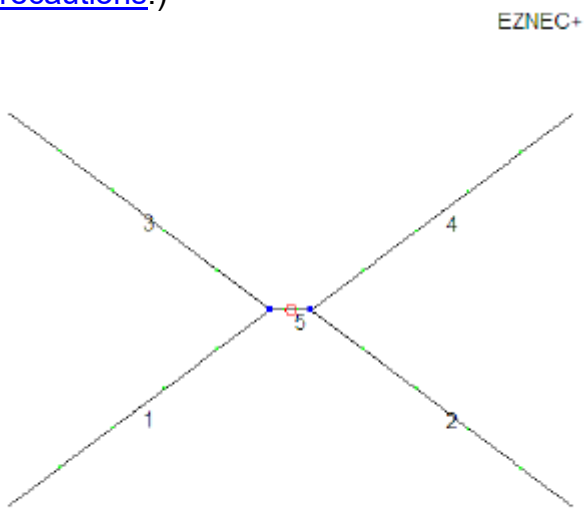
This applies only when using NEC-2 or -4.2 calculating engines. NEC-5 doesn't seem to have this requirement.
When modeling parallel or nearly parallel wires which are closely spaced with NEC-2 or -4.2 calculating engines, it can be very important to align the segment junctions. That is, they should be directly across from each other. This is particularly true if the segment length is greater than the wire spacing. As the segment length gets shorter compared to the wire spacing, this requirement becomes less important. When segment junctions are misaligned but need to be aligned, results can change dramatically as segmentation is changed.
The easiest way to assure that aligned parallel wires have aligned segment junctions is to give the wires identical lengths and numbers of segments. If the wires are staggered or different lengths, break them into more wires. Make the portions of the wires which are directly across from each other into separate wires of equal length and number of segments. An example of this technique is shown below, where the long wire of a J-pole antenna was broken into two wires. Wire 4 is made the same length and given the same number of segments as parallel wire 6. The upper wire is segmented to make its segment length approximately equal to the segment length on wire 4. (This is a close up view – some of the long wire, and its number, aren't shown.)



If it's necessary to test whether alignment is necessary in a particular situation, change the segmentation of one of the wires so that the segment junction alignment changes, and note the change in results. If the change is significant, segment alignment is important.
In all cases, wire spacing should be at least several wire diameters.

Crossed Dipoles

To model two dipoles fed at a common point (sometimes called "crossed dipoles" -- see figure below), feed by inserting a wire between the pairs of dipole halves and place the source on the wire. The wire length should be a minimum of 0.02 wavelength, and have three segments when using NEC-2 or -4.2 calculating engines or two segments for NEC-5. (See Source Placement Precautions.)



Elevated Radial Systems

A number of people have showed an interest in modeling systems of radial wires placed at very low heights above ground. A system of very low wires can be used to simulate the performance of buried radials. Experiments were done comparing various modeling codes, resulting in the following guidelines:

1. The minimum recommended height for modeling ground radial systems is 0.0001 wavelength, or the diameter of the vertical wire, whichever is greater.
2. No special techniques are required if the radials are at a height of at least 0.001 wavelength and at least the diameter of the vertical wire. Ordinary segmentation can be used. Even stepped diameters don't require special attention with the NEC-2 engine in this situation. This height is recommended for simulating buried radials with NEC 2, or radials placed on the surface of the ground.
3. If the radials are between 0.001 and 0.0001 wavelength high, segment length tapering should be used. The minimum segment length should be made equal to the height of the radial system. The default maximum is adequate. In the Minimum Segment Length box, enter the height of the radial system above ground. When placed on such a short wire, the source must be surrounded by equal-length segments. After tapering, combine the source wire and the one above into a single wire with 3 segments, then move the source to the center of this wire. If, for example, the original vertical wire was wire 1, with end 1 at the bottom (as in example file ElevRad1.ez), first taper all wires. Then select any coordinate of end 2 of wire 1 and enter 'W2E2' to make its coordinates the same as end 2 of wire 2. Change the number of segments of wire 1 to 3. Then delete wire 2. Finally, move the source to the center of wire 1. The result should look like ElevRad2.ez.

I don't know of any good experimental measurements of the sky-wave field strength from verticals with elevated radial systems. There are a few ground-wave measurements. NEC-2 and NEC-4.2 both show ground-wave field strengths for elevated systems which are stronger than some measurements seem to indicate, particularly at frequencies of 3 MHz and below, so there may be some doubt about the accuracy of the signal strengths reported by **EZNEC** for elevated radial systems.

End Fed Antennas

A frequently asked question is how to model an end fed antenna. This often comes after putting a source at the end of a wire representing the antenna and seeing results which don't seem right. Results from this model *aren't* right, and the following will explain why.

An **EZNEC** source, like a real transmitter, signal generator, or for that matter a battery, has two terminals. The current flowing out of one terminal must equal, in both magnitude and phase and at every instant, the current flowing into the other. When a load is connected between the terminals, an electrical circuit is formed, and the amount of current flow conforms to Ohm's law. If a load is connected to only one terminal, the source sees an open circuit and no current flows to or from either terminal. One terminal of real sources is often connected to a metallic board or chassis and called "ground". This nomenclature doesn't impart any special properties, however -- it's still just a collection of conductors to which one of the two terminals is connected, and which must obey the current equality rule.

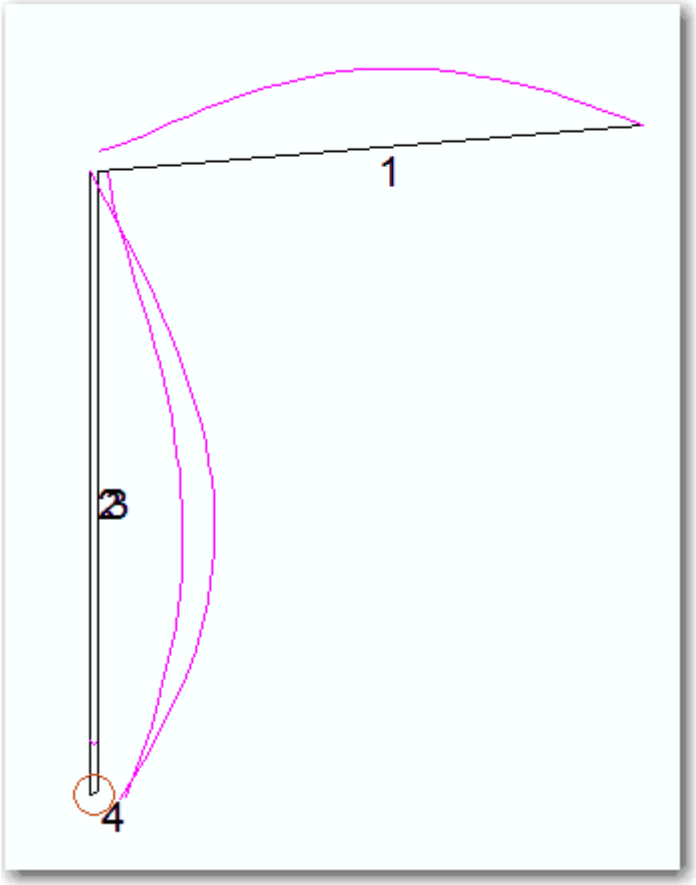
When a source is connected to a dipole, there is of course an open circuit at DC. However, mutual coupling between the dipole halves creates a displacement current through the intervening space, providing a path for current between the source terminals. Likewise, a grounded vertical induces current in the ground which, at the bottom of a source at its base, exactly

equals the current the source is putting into the antenna. That is, the current up into the antenna from the source exactly equals the current flowing into the other terminal of the source from the ground.

Now suppose you have a very, very small battery powered transmitter. Connect one of the transmitter terminals (it doesn't matter which one) to the end of a very high, horizontal wire, and leave the other end open circuited. What happens? You've connected a load (the antenna wire) to one terminal, but there's nothing connected to the other. The source sees an open circuit and no current flows into the antenna wire or anywhere else. An EZNEC source is distributed over the segment on which it's placed -- this is approximately equivalent to placing it at a point in the center of the segment. Consequently, it's not possible to put a source completely at the end of a wire -- the closest it can come is a half segment from the end. But unless the segment length is very long, what you'll see if you place a source on the open circuited end of a wire is a very high impedance (typically consisting of a large capacitive reactance) and very low current. This is because one terminal of the source is very nearly open circuited since it's effectively connected only to a very short piece of wire. The small amount of current which does flow is due to the mutual coupling between the antenna wire connected to one source terminal and the half segment length wire connected to the other terminal.

So why does a real end fed antenna work? The answer is that there's a path for current from the source terminal not connected to the "antenna". (I'm going to put "antenna" in quotes from here on to emphasize that the end fed wire isn't the whole antenna.) Let's look first at a single wire connected directly to the "hot" terminal of a transmitter coaxial antenna connector. The other, "ground", terminal of the connector is its inside surface -- the current flowing on that inner surface has to equal the current on the center, "hot" conductor. Current from the "hot" terminal can only flow to the single wire "antenna". But the current from the "ground" terminal can flow from the inside of the connector over the edge to the outside, and from there over the chassis. If the chassis is completely isolated from the Earth and any large or long conductors, the other "half" of the antenna will be the chassis itself. Like the **EZNEC** model with a source a half segment from the end of a wire, the transmitter will see a high impedance and there will be very little current flowing to the "antenna". In practice, there will also be some capacitive coupling to the Earth and probably other nearby wiring, which will increase the current somewhat. If the chassis is coupling to other wiring, that wiring is carrying antenna current and is a part of the actual antenna or radiating system. If you connect a "ground wire"-- a wire to the Earth, the mains ground system, or just a long wire to nowhere -- to the transmitter chassis, you've provided another path for current from the transmitter "ground" terminal. It now flows from the inside of the connector to the outside, over the chassis, and down the wire. The wire current consists of current induced by mutual coupling with the "antenna" and, if there's a path to the Earth, current conducted from the Earth which was induced into it by the "antenna". The real antenna is now the "antenna" wire and the "ground" wire. Both are carrying current -- equal amounts at the transmitter -- and both are radiating. Calling one "ground" doesn't change its properties -- it's just as much a part of the antenna as the intended "antenna". This is why adding a "ground" wire to a receiver often makes a marked improvement in reception when its "antenna"

consists of a single wire. **If you want a model to tell you what the real antenna system will do, you have to include the whole antenna system -- which includes the outside of the coaxial feed line and any other conductors connected to the transmitter chassis -- in the model.**
What would happen if you connected the single wire "antenna" to the transmitter connector shell -- that is, to the transmitter case -- rather than the "hot" terminal? You'd end up with an open circuited transmitter, a very high load impedance, and very small current. This isn't because one terminal is "hotter" than the other; it's simply because there's no alternate path from the center conductor terminal to the outside as there was for the "ground" terminal. The center conductor is truly open circuited. But if you connected your "ground" wire to the "hot" terminal with the "antenna" on the "ground" terminal, you'd get essentially the same results as with the two reversed, assuming no other current paths from the chassis.
Finally, let's consider the common end fed or Zepp antenna. One conductor of a feed line is connected to the antenna and the other is left unconnected.



Wire 1 is the "antenna" and wires 2 and 3 are the "feed line". The source is at the bottom of the "feed line", connected between wires 2 and 3. Although there is no current at the top of wire 2 (the left "feed line" wire), there is current at the bottom. And, in fact, it's equal in magnitude and opposite in phase to the current at the bottom of wire 3. This will always be the case for wires connected to the two terminals of a source. The source isn't connected to an open circuit as it would be if placed at the end of the "antenna" wire.

The current at the end of the "antenna" is not zero, and it's equal and opposite to the common-mode current flowing on wires 2 and 3. Common-mode current is the difference between the two individual conductor currents, and it results in radiation just as though there were a single current of that value flowing on a single conductor. That is, the "feed line" radiates just as the "antenna" does. That's why the two terms have been placed in quotation marks. In this case, the length of the "feed line" is about the same as the length of the "antenna", and the "feed line" common mode current is about the same as the "antenna" current, so the "feed line" radiates about as much as the "antenna". So both the "feed line" and "antenna" have to be included in the model in order for either the impedance or the pattern to be correct.
In a real installation, there will also be some path from the source -- the transmitter -- to the Earth, or at least some additional connected conductors. If so, the common-mode current from the "feed line" will travel along these conductors, and they will radiate also and must be included in the model.

Feedlines and Baluns

The radiation properties of a coaxial feedline can be modeled by connecting a wire of the coax shield's diameter to the point on the antenna where the shield connects. The wire is then routed (using additional wires to simulate bends) to ground along the path taken by the actual feedline. The ground path from the transmitter/receiver should be included, with wires of appropriate size. This can be done whether or not an **EZNEC** transmission line model is used to model the inside of the feedline. (See the Using Transmission Lines chapter for more information about using transmission line models. The Modeling Coaxial Cable topic also has additional information.) The job of a "current balun" or "choke balun" is to insert an impedance in the path formed by the outside of the shield. To model a balun, insert a load in series with the "coax" wire (the wire simulating the outside of the coax) at the point where a balun would be placed. A good balun will have an impedance of the order of 500-1000 ohms, and may be resistive, reactive, or a combination depending on construction. Accurate modeling requires knowledge of the balun impedance at the frequency of interest. The balun reduces the current in the "coax" wire, which means that the current on the outside of the actual coax feedline is reduced. It sometimes is necessary to insert more than one balun (quarter-wavelength spacing is typical) to reduce feedline outside current to a low level. Coaxial feedlines connected to "unbalanced" antennas like ground plane antennas aren't immune to induction of current, either, as you can confirm with **EZNEC**.

Folded Dipoles

When the two parallel wires of a folded dipole are equal diameter, the feed point impedance is four times that of a standard dipole. Multiplying factors other than four can be obtained by choosing different diameter ratios. However, changing the ratio of wire diameters of an **EZNEC** folded dipole model won't change the impedance transformation ratio. It will remain at four for any diameter ratio. This is a consequence of an approximation of the underlying NEC code used by the calculating engines. The only way to accurately accommodate unequal wire diameters in a folded dipole or similar

structure (such as a typical gamma match) is to model each wire as a cylindrical collection of smaller diameter wires.
A folded dipole model will usually generate Segmentation Check errors due to the end connecting wires being shorter than recommended. This usually will not cause any significant calculation errors and can be ignored. See Segmentation Check for more information.

Gamma Match

A gamma match consists of a rod parallel to a driven element and a series capacitor, with the rod commonly being smaller diameter than the element. When the gamma rod and element are different diameters, **EZNEC** can produce results that aren't very accurate for reasons described in the Folded Dipoles topic. So plan on some adjustment being necessary on a gamma matched system designed with **EZNEC**. Also be sure to read and apply the information in Closely Spaced Wires.

Linear Loaded Antennas

"Linear loaded" antennas (generally Yagis) are physically shortened by attaching to the elements wires which are parallel to, and spaced close to, the elements. **EZNEC** will not give accurate results for this type of antenna when using an NEC-2 calculating engine unless all the wires of a given element are the same diameter. This is due to NEC-2's inaccuracies when dealing with connected wires of different diameters and the fact that even small parasitic element errors have a major effect on the performance of a beam antenna. The stepped diameter correction used by **EZNEC** with its NEC-2 engine is not accurate for typical linear loaded elements and will not be applied to them .This limitation doesn't apply when using NEC-4.2 or NEC-5 calculating engines.

Log Periodic Antennas

An integral part of log periodic antennas is the transmission line connecting the elements. This must be included in the model, since no valid assumptions can be made about the relative voltages and currents at the element centers. Transmission line segments between elements can be included as either wire models or as transmission line models.
The following applies only when using NEC-2 or NEC-4.2 calculating engines, and not when using NEC-5: If wire models are used, it can be difficult or impossible to place the source in a way that fulfills all the requirements for source placement (on a wire of at least 0.02 wavelength and three or more segments) as described in Source Placement Precautions. Results should be tested by changing the number of source wire segments, source wire diameter, and other parameters near the source to see if the answer remains relatively stable. The Average Gain feature should also be checked, and it can be used to correct the indicated gain to some extent. See the LogPer.ez example file and associated Antenna Notes file for more information.
Here's a tip for reducing the number of segments required to model a log periodic antenna. Set the frequency to the lowest frequency of interest, then use automatic segmentation to segment the model. Note the number of segments in the longest element. Then re-segment the other elements to each have the same *number* of segments as the longest element.

Alternatively, you can use the highest frequency and the shortest element to determine the number of segments – the result should be about the same in either case. The principle being used here is that at a given frequency, only a few elements have significant current. The segmentation of the other elements is less important, since they contribute little to the overall field. Using the method of using the same number of segments on each element assures proper segmentation of the active elements without using an unnecessarily overlarge number of segments on the other elements.

Multiband Antennas

EZNEC is well suited for modeling multiband antennas. Keep in mind the segment length, however. Remember that as you increase the frequency the segment length increases in terms of wavelength. In general, you should double the number of segments each time you double the frequency. A bare minimum number of segments for a square loop is about four per quarter wavelength. This means four segments per side at the frequency at which the loop is a full wavelength in circumference, eight per side at twice the frequency, etc. Run Segmentation Check from time to time if you have doubts about the segment length.
Some commercial multiband antennas have a transformer at the feedpoint. This will typically be so far from ideal in its operation over multiple bands that **EZNEC**'s ideal transformer object won't adequately imitate its characteristics. Refer to the transformer chapter for additional information.

Patch (Microstrip) Antennas

Patch or microstrip antennas usually consist of two parallel conductive plates separated by a dielectric material. Because **EZNEC**'s NEC calculating engine has no ability to model dielectric materials, these antennas cannot be modeled with **EZNEC**. Some users attempt to use the wire insulation feature to simulate a dielectric material. ***This does not work!*** Including wire insulation in the model only changes the effective self impedance of the wire and does not model the effect of the dielectric on fields coupled to other conductors. This coupling is an essential part of the operation of patch (microstrip) antennas so results will not be accurate.

Small Loops

NEC-2 is unable to accurately model small loop antennas. If this is attempted, a zero or negative feedpoint impedance and accompanying error message may result. NEC-4.2 is more tolerant, but problems might still be encountered with very small loops. Double precision versions of both engines permit smaller loops than the standard or single precision versions. Tests with a square loop in free space, one segment per wire, showed reasonably accurate results with loops down to the following minimum circumferences:

Double precision calculating engines:
NEC-2: 0.0005 wavelength
NEC-4.2: 10^{-7} wavelength
NEC-5: 0.0001 wavelength

Single precision calculating engines:
NEC-2: 0.05 wavelength
NEC-4.2: 0.001 wavelength

These should be used as guidelines only, as accuracy can depend on a number of factors.

Segment Junction Intersections

NEC allows wires to intersect at segment junctions. **EZNEC Pro+** does not -- it permits wires to connect only at their ends. Earlier **EZNEC** versions permitted this although it was strongly discouraged. But it resulted in some incorrect connection indications, and inclusion of NEC-5 as a calculating engine option has created additional problems.
Because NEC allows them, segment junction intersections occur fairly commonly in NEC format files and in **EZNEC** descriptions derived from them. To allow these descriptions to be used by **EZNEC Pro+**, an automated conversion process has been added.
Segment junction intersections are detected by the Geometry Check which normally runs just before a calculation is requested or the description is to be saved. If any are detected, a message appears with an option to automatically convert the model. Choosing Yes will split all wires having junction intersecting wires into a series of single segment wires, resulting in the intersections being at wire ends as required.
If a description also has insertion object placement errors, these must be corrected first before the Geometry Check will be allowed to run.
Unlike all other errors which prevent calculations, segment junction intersections won't prevent a description from being saved.

Stacked Yagis

Stacked Yagis or other antennas can be modeled easily with **EZNEC** by using the Stack feature. A step-by-step example follows. In this example, we'll stack two of the Yagis of the example file 20m5elya.ez.
In the Control Center, locate the Open action button and click it. This will open a file selection dialog box. Select 20m5elya.ez and click Open. Click here if you have trouble.
The bar at the top of the Control Center information window should now read "Five-element Yagi" -- this is the title of the antenna description stored in file 20m5elya.ez.

In the Control Center information window, click Units and change the units to Feet for convenience.

Click the View Ant action button to open the View Antenna Window, and the Wires line in the Control Center information window to open the Wires Window.

In the Wires Window, open the Wire menu and select Stack.

This opens the Stack dialog box. Note that all wires, number 1 to 55, have been entered into the first two boxes. Those are the desired wires for this example. If you had wanted to stack only some of the wires in the description, you can enter the range of wires here. You can also select the wires in the Wires Window before opening the Stack dialog box, in which case the top two boxes won't appear.

The third box indicates where the new wires will appear in the Wires Window wire list. 56 indicates that the new wires will be placed at the end of the list.
Let's put the second Yagi 40 feet above the original.

Enter 40 in the Stacking distance box, and click Ok.

That's all there is to it!
This completes the stacking process. If desired, you can change the height of both Yagis by choosing Change Height By in the Wires Window Other menu, making sure that the range of wires to change is 1 – 110. In the Control Center you can add a ground, choose a new title, and save the description.

Vertical Antennas And Buried Radials

The effect of radials and other buried ground systems is widely misunderstood. In a typical quarter wavelength high vertical antenna, the ground has two distinct and somewhat independent effects. One is that the current flowing into the base of the antenna is matched by an equal current flowing from the ground to the other feedline conductor. This current flows through the ground and incurs loss in the process. The primary purpose of a buried ground system is to reduce this loss by increasing the conductivity of the ground near the antenna. The effect of a poor ground system is to reduce the antenna efficiency. This reduces the strength of the radiated field, but doesn't change the antenna pattern.
The second effect is less widely appreciated but is often of much greater importance. The elevation pattern of any antenna is created by a combination of a field travelling directly from the antenna to a point in space above the horizon, and the field reaching the same point after being reflected from the ground. The relative strength and phase of these two fields are what make the lobes and nulls of the vertical pattern. As it turns out, vertically polarized waves are affected differently by the ground reflection than horizontally polarized waves. While horizontally polarized waves reflect nearly perfectly from even relatively poor ground (except at high angles), vertically polarized waves do not, and are affected most when reflecting at a low angle. The net effect is that the pattern of a vertically polarized antenna is profoundly modified by the ground reflection. With real ground, there is very significant loss of the low angle field. This can be illustrated by running the Vert1.ez example model, saving the 2D trace of the elevation pattern, changing the ground type to Perfect, and running again. Adding the previously saved trace to the one created with Perfect ground shows this effect graphically. Note that Vert1 uses the MININEC-type ground model which includes no conductive loss (the first effect described above), only the ground reflection effects. The ground reflections which cause the low-angle pattern reflections take place farther from the antenna than most common radial ground systems extend, so *ground radial systems have little or no effect on the ground reflection phenomenon*.
Please keep these two effects in mind while reading the following discussion.
Buried radials can be directly modeled only with **EZNEC Pro/4+** using its internal NEC-4.2 calculating engine or by either **EZNEC Pro/2+** or **EZNEC Pro/4+** using an external NEC-4.2 or NEC-5 calculating engine (see Buried Wires and Calculating Engines). With the internal NEC-2 calculating engine they have to be simulated. There are three ways to simulate buried radials. One is to use the NEC radial model. This isn't generally a good approach,

because it only modifies the effect of the ground conductivity on the pattern due to ground reflection (the second effect described above), and not the conduction loss. The NEC radial model can't be used to assess antenna efficiency, and as mentioned above, radials of reasonable length have little effect on the ground reflection. And the NEC radial model tends to give an erroneous estimation of the effect of the radial field on ground reflection due to the simplistic way it evaluates reflections.
The second approach is to model buried radials by substituting radials just above the ground surface. This does a moderately good job of predicting the ground system efficiency as well as whatever pattern modification (typically minor) results from the radial system. With this approach, the High Accuracy Real ground type must be used. See Connecting to High Accuracy Ground for more information.
The third approach is to use MININEC-type ground, which models the ground reflection but not the conductive loss, and simply add a resistive load at the feedpoint to simulate the radial system loss resistance. The NEC radial model can be used in addition if desired. Approximations for the amount of resistance for a given number of radials can be found in Chapter 8 of *The ARRL Antenna Book*. (This reference gives total resistance for a quarter wave vertical, so subtract 36 from the values shown to use as the ground system resistance.) These are of course approximate. Direct measurement is better yet. If you have an antenna analyzer or similar way to measure your antenna's feedpoint resistance, follow this procedure:

1. Measure the antenna's feedpoint resistance. If you can only measure impedance, the resistance will be the impedance at resonance.
2. Add a load to the model at the feedpoint and adjust its value until the feedpoint resistance matches the value you measured.

Wire Grid Modeling

EZNEC Pro+ programs include a feature to automate the process of creating flat, rectangular wire grids. Even if you're creating wire grids manually, you should read the information in the Wire Grid Creation section which also describes use of the automated feature. This section gives general guidelines for wire spacing and diameter.

Before beginning a wire grid model, you should estimate the number of segments which will be required. The approximate number required, based on 0.1 wavelength spacing, is 220 * A, where A is the area in square wavelengths. Some compromises might have to be made to avoid exceeding the standard program's segment limit. You can see that the number of segments required for a given physical size of object depends on the wavelength at which the analysis will be done. A car, for example, can be modeled as a pretty simple wire frame at HF. But even just a roof will require a very large number of segments at UHF. You can often increase the wire spacing as you get farther from the source(s). A grid can conveniently be thinned by selecting and deleting wires in the View Antenna display and modified with the Graphical Wire Operations.

The Test Drive tutorial topic Plus Octane Fill Up describes the manual creation of wire grids and methods to quickly manipulate them. The

techniques described there can also be used for some non-rectangular geometries and other special cases.

Always remember that wires must contact and connect only at their ends, so you shouldn't cross wires in the grid or elsewhere.

Yagi Antennas

A conductive boom, whether electrically connected to the elements or not, can modify Yagi antenna operation in some cases. However, if an antenna is perfectly symmetrical and the boom is exactly along the center line of the elements, **EZNEC** will not show any effect from it regardless of its diameter. This is because a simplification made by NEC is to assume that all the current on a wire is concentrated along a line at the wire's center. A model can be modified to account for a boom by modifying the diameters of the of the elements close to the boom. Methods for determining the amount of correction can be found in Leeson, *Physical Design of Yagi Antennas* (ARRL, 1992). The book also covers corrections for various types of clamps.
Information about modeling stacked Yagis can be found in the Stacked Yagis section.
The following remarks apply only when using the NEC-2 calculating engine:
Yagi antennas with full size (near half wavelength) unloaded and untrapped elements can be accurately modeled with the internal NEC-2 calculating engine. When made from telescoping tubing, or other materials where the element doesn't have a constant diameter over its whole length, **EZNEC** corrects for NEC-2's stepped wire diameter problem. However, correction is less certain for elements which aren't nearly a half wavelength long (i.e. elements which contain loading coils or traps, or which are "linearly loaded"). As detailed in the Stepped Diameter Correction Overview topic, advanced correction methods are applied to these cases but the accuracy depends on many factors which haven't been fully determined. **EZNEC** with NEC-2 can model shortened Yagis with known good accuracy only if their element diameters are constant. The overall performance of shortened antennas with tapered diameter elements can still be determined, but there may be a frequency shift in the results from the actual frequency where that performance will occur. **EZNEC** v. 6.0 and 7.0 use advanced techniques to more accurately correct a wider range of Yagi variations but can't be fully tested for every possible situation.
When modeling a Yagi with near half wavelength elements, it's important to follow the rules outlined in Stepped Diameter Correction Overview to allow **EZNEC** to apply the best correction. **EZNEC** provides a method to show when a correction is being applied as it should. This is the stepped diameter correction display, and its use is described in Using The Stepped Diameter Correction Display. You should consult this display each time you design or modify a Yagi model to make sure all elements are being corrected.

Insertion Objects

About Insertion Objects

Insertion objects are sources, loads, transmission lines, transformers, L networks, and Y parameter networks. These are objects which are inserted into wires or virtual segments.

All insertion objects have some important common properties, which are:

1. Insertion objects have one or two **ports** (often referred to as the **ends** of transmission line objects). Sources, loads, and transmission line stubs have a single port which is inserted into a wire or (except for series connected loads) a virtual segment. The others have two ports, which must be connected to two separate real or virtual segments. The two ports of the transformer object correspond to the two windings, of an L network the "input" and "output", and the ends of a transmission line object. Each port has two **terminals**.
2. An insertion object effectively cuts the wire into which it's inserted, placing itself (or its port) in the wire. The current into one terminal of a port always exactly equals the current out of the other terminal of the same port; therefore, ***insertion objects do not radiate or electromagnetically couple to wires or other objects***.
3. When multiple insertion objects are placed on the same segment, all are connected in parallel, **except** conventional (series connected) loads, which are placed in series with other objects on the same segment.
4. The polarity of a port -- that is, in which direction the "+" and "-" terminals are connected -- is determined by which terminal is closest to end 1 of the wire. This varies some depending on the object, and you'll find more information in some of the individual object topics. However, the two ports of all two port insertion objects are always phased the same relative to the end 1 - end 2 directions of the wires into which they're inserted.

Insertion object windows (e.g., Sources Window, L Networks Window, etc.) also have a number of common features. See Placing Insertion Objects on Segments and Using Insertion Object Windows for more information.

If at least one port of an insertion object is placed on a wire, the object is shown in the View Antenna Display. See Using The View Antenna Display for a description of the symbols used.

Placing Insertion Objects On Segments

All insertion objects have to be placed on real or virtual segments. (All insertion objects with the single exception of the series connected (conventional) load can be placed on a virtual segment.) For insertion objects with two ports, the two ports must be connected to different real or virtual segments. There will be two sets of input specifications for two port insertion objects, so the following steps apply for each of the two ports.

You can visualize the placement as cutting the wire at the center of a segment (or, when using NEC-5, right next to a segment junction -- see NEC-5 Object Placement) and connecting the two terminals of the insertion object (or the two terminals of one of the ports of a two port insertion object) to the broken ends. That is, it goes in series with the wire. When multiple insertion objects

are placed on the same segment, all are connected in parallel, except conventional (series connected) loads, which are placed in series with other objects on the same segment.

To place an insertion object port on a wire

The insertion object port location is specified by wire number and location on the wire. In the appropriate object input window (e.g., Sources Window, Transformers Window), enter the wire number and the percentage of the way from end 1. For example, to place a source on end 2, enter 100 for the percentage from end 1. A shortcut is available for end or center placement. In either of the columns in the Specified Pos. group, you can enter **W#E#** where the two #s represent the wire and end numbers, for example **W3E2** to place it at end 2 of wire 3. To place a source at the center of the wire, you can enter **W#C**. **EZNEC** places the insertion object as close as it can to the specified position, and tells you the placement location in the Actual Pos. columns. To enable placing an insertion object at exactly the center of a wire, give the wire an odd number of segments when using NEC-2 or NEC-4.2 or an even number when using NEC-5.

To place an insertion object on a virtual segment

In the wire number column of the object input window grid, enter the letter V followed by a number of your choice between 1 and 999, for example **V23**. Other insertion objects connected to this virtual segment will be placed in parallel with it. The percent from end 1 column isn't used for virtual segment connections.

Insertion object placement for best accuracy

The following applies to NEC-2 and NEC-4.2 calculating engines. NEC-5 is largely insensitive to these issues.

EZNEC's NEC-2 and -4.2 calculating engines can produce inaccurate results under some conditions of insertion object placement. In some cases the error is minor, in others major. The following rules should be followed whenever possible:

Segments immediately adjacent to the insertion object should have the same length and diameter as the segment containing the insertion object and should be in a straight line. If the insertion object is on the end segment of a wire, only a single wire should connect to it. An often convenient way to insure these conditions are met is to place the insertion object on a wire having at least three segments, and not on one of the end segments. The condition of segments being in a straight line is often violated when using a split source, such as at the center of an inverted vee or the corner of a square element. This, however, is usually a case where any error is minor and can be detected with an Average Gain test.

Violation of these guidelines are shown as warnings in **EZNEC**'s Segmentation Check.

Important: Sometimes it's impossible or impractical to conform to all the guidelines. See Segmentation Check for more information.

NEC-5 Object Placement

The different structure of NEC-5 compared to other NEC versions requires different placement of insertion objects. This results in both some obvious and some subtle differences in model creation and result interpretation.

When using NEC-2 and -4.2, objects are placed at segment centers. In NEC-5, they're placed instead at segment junctions. This can simplify certain models such as an inverted vee, where a source can be placed directly at the apex rather than using a "split source" to simulate this placement. It's also possible with NEC-5 to place a source, load, or other object at the very bottom of a vertical antenna.

For most situations, you can visualize the placement as being exactly at the segment junction. ***But this isn't exactly correct, and it can lead to some unexpected and strange seeming results.***

Before proceeding, please open the example file Network connection test.EZ then click the Ant Notes button at the left of the Control Center. Follow the steps described there to learn about a very important concept: that ***objects are placed on wires just adjacent to segment junctions, not exactly at segment junctions. Consequently, objects on different wires at a wire junction aren't in the same location even though they seem to be "at" the same segment junction.***

In **EZNEC** models, this distinction is necessary only when an insertion object is placed at the end of a wire. **EZNEC** won't let you do calculations if an object is placed at an open end, so it applies only to an object placed at the junction of two or more wires. NEC allows wires to connect not only at wire ends but also at all segment junctions, and **EZNEC** will allow it for compatibility with some existing NEC models only if specifically permitted with a Special Option. But ***it's very strongly discouraged*** and **EZNEC** won't permit locating insertion objects at some of the locations allowed by NEC-5 adjacent to these intersections.

NEC-5 allows the user to specify at which side of any segment junction an insertion object is placed, but **EZNEC** does not. **EZNEC** always places an object at end 2 of a segment (the end closest to end 2 of the wire) with the single exception of placement at end 1 of a wire that's connected to another wire or ground. In that case -- only -- the object will be placed at end 1 of the first segment if the specified position is within a half segment of end 1 of the wire. And if that's done, the Actual Pos. (relative) Seg. number shown in the insertion object placement window (e.g., Sources Window) will be zero. In other words, relative segment 0 in the **EZNEC** insertion object window means end 1 of the first segment. Otherwise the location is end 2 of the segment number shown.

All insertion objects except series connected loads are connected in parallel with other insertion objects. But occasionally it's necessary to connect, say, two transformers in series. The best this could be done with NEC-2 or NEC-4.2 would be to place them on adjacent short segments. With NEC-5 you can put them effectively at the same place yet in series using the technique illustrated above by the example file -- connect two wires end to end and place one transformer at the end of each wire. They're at different locations (on different wires but against the same junction), yet as close together as they could be and connected in series.

When reading an NEC-5 format file, **EZNEC** will refuse to place an object if its position is specified to be at end 1 of a segment unless that position is at end 1 of a connected wire.

Using Insertion Objects Windows

The following operations are common to all insertion object windows (e.g. Sources Window, Transmission Lines Window, etc.):

Placing Objects on Segments

See Placing Insertion Objects On Segments.

Selecting Objects

Deleting, copying, and moving objects require first selecting which ones are to be operated on. In addition, objects can be selected before starting Group Modify. To select an object, click on the button on the left side of the appropriate row. The selected object will be highlighted. To select additional objects, hold <Ctrl> down when clicking the button. To select a group of objects, select the first object, then hold <Shift> while clicking the last object in the group.

Deleting Objects

The current object, or selected objects, can be deleted by pressing the <Delete> key. Alternatively, a sequential group of objects can be deleted by selecting object/Delete and specifying which to delete.

Copying and Moving Objects

To copy or move objects in the list, first select the objects as described above. Then select <object>/Copy or <object>/Move <object>(s) in List where <object> is the name of the object (e.g., Source, L Network, etc.). You'll be asked for the location in the list for them to be put. You can also select <object>/Copy or <object>/Move< object>(s) in List before selecting objects, in which case you'll be asked for a range of object numbers to copy or move.

Modifying Objects

Objects can be modified individually, or if desired, a group of objects can be modified at the same time using the Group Modify feature. The procedure is the same for both cases, except that to modify a group of objects, Group Modify must first be activated. Basic modification of one parameter is done simply by entering the new value in the cell, then pressing <Enter> or clicking on a cell in another grid row.

Using Sources

About Sources

Sources are insertion objects which represent places where power is applied to an antenna. Every **EZNEC** model must contain at least one source unless plane wave excitation is being used. Source voltages and currents are, like all other **EZNEC** voltages and currents, RMS.

NEC-2 and -4.2 are notoriously sensitive to source placement, and careless placement can lead to subtle errors in calculation results. NEC-5 isn't nearly as sensitive.

Like other insertion objects, sources are connected in an imaginary break in a wire. They are connected in parallel with all other insertion objects at the same location except for series connected (conventional) loads. The positive terminal of the source always points to end 2 of the wire, so a source with zero phase angle will produce current which flows from end 1 to end 2 of the wire. These connections are dictated by the structure of NEC.

With NEC-2 or -4.2, the restriction of source placement to segment centers prevents placing a source at a wire junction. Junction placement is sometimes desirable, for example in a vee type antenna. **EZNEC** includes special split source types to allow you effectively place sources at wire junctions when required. Insertion objects are placed at segment junctions when using NEC-5, so split sources aren't necessary or available.

If you want to keep the total power into the antenna constant, you can select Power Level from the Control Center Options menu and specify the desired power. When this option is used, the specified source voltages and/or currents of multiple sources will be maintained in the specified ratio, but their absolute values will be adjusted by **EZNEC** to furnish the specified total power to the antenna. If a single source is used, its value will be adjusted as necessary to provide the specified power. This feature is useful when absolute values of field strength (near or far field), voltages, currents, or power loss need to be known for a given power input. There is no way to control the power sent to an individual source if the model contains more than one source, other than manually adjusting the source voltage or current until the desired power is obtained. I'm not aware of any application for which this would be necessary or desirable.

A source is shown in the View Antenna display as an empty hollow circle.

Detailed information about specifying sources is in the Using The Sources Window topic.

Using sources as ammeters or voltmeters

All insertion objects, including sources, are placed in parallel except series connected loads. For brevity, all objects except series connected loads will be referred to below as *parallel connected objects*.

A zero volt voltage source can be used as an ideal current meter to measure the current at the center of any segment *not* containing other parallel connected objects, and a zero ampere current source can be used to measure the voltage across other parallel connected objects, or across a small gap. A zero volt voltage source is effectively a short circuit so can be placed in a wire without disturbing normal operation if the segment is otherwise empty except for series connected loads. If, however, other parallel connected objects are on the same segment, the source will be placed in parallel with them, effectively short circuiting them. A zero ampere current source is effectively an open circuit, so if it's placed at the same location as other parallel connected objects, it won't disturb the circuit and will report the voltage across the other objects. If placed on a wire without other parallel connected insertion objects, it will effectively create a small gap and report the voltage across the gap. For example, the voltage across an insulator can be measured by making the model wire continuous and placing a zero ampere current source in the wire at the insulator location. The current or voltage being measured appears in the Source Data display.

Source Types

Four conventional source types are available with **EZNEC**: voltage, current, and with NEC-2 and NEC-4.2, split voltage and split current. (NEC has additional types which aren't implemented.) In addition, plane wave excitation is available. When you specify a "split" source, **EZNEC** actually creates two sources, and places them on adjacent segments closest to the position you

specified. Split sources are shown in the View Antenna display as two sources, but appear everywhere else as a single source. Split sources are included so you can place sources at wire junctions with NEC-2 and -4.2, such as on an inverted vee antenna. They are not available or needed when using NEC-5 which places sources and other insertion objects at segment junctions. See Placing Sources At Wire Junctions with NEC-2 and NEC-4.2 for more information about using split sources, and Placing Sources On Segments for more information about using conventional sources.
If the antenna contains only one source (a split source is counted as one source), it makes no difference whether a current source or voltage source is used, unless you have a need to know the field strength when a specific voltage or current is applied to the antenna. However, the choice can make a profound difference if multiple sources are used. Voltage sources will always maintain the specified voltages, and therefore the specified ratio of voltages, regardless of the impedances they encounter. Similarly, current sources maintain the specified currents and current ratio. One of the most common applications for multiple sources is in modeling phased arrays. Most arrays are designed to work with a specified current ratio (because the fields produced by the elements are proportional to their currents), so current sources are generally used in this application. See Using Multiple Sources and Phased Arrays for more information about using multiple sources, and the Plane Wave Excitation chapter for information about using plane wave excitation.

Using The Sources Window

Open the Sources Window by clicking on the Control Center Sources line or the button to its left. **Note:** Both conventional source and plane wave excitation are specified using this window. To change from plane wave excitation to conventional sources, open the Other menu in the Sources Window. The following applies to conventional sources only -- the Plane Wave Excitation chapter covers use of that feature.

Specifying the Source Position

Like other insertion objects, all loads have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details. Special considerations for sources are described in Placing Sources on Segments and Placing Sources At Wire Junctions.

Specifying the Amplitude and Phase

When a single source is used, the amplitude and phase will make no difference to the pattern, gain, or impedance. Only the source and load voltage, current, and power, and absolute field strength (in V/m or A/m) will change. If a power level has been specified, even these won't change as you change the source amplitude and phase. Amplitude and phase are most important when multiple sources are used, in which case their relative values are what count. See example files Cardioid.ez and 4Square.ez which illustrate the use of multiple sources.

Using sources as voltmeters or ammeters

A zero volt voltage source can be used as an ideal current meter to measure the current at any point in a wire. A zero ampere current source can be used to measure the voltage across a small gap. For example, the voltage across an insulator can be measured by making the wire continuous and placing the

zero ampere current source at the insulator location. It will effectively create a gap at that point. The current or voltage being measured can be seen in the Source Data display.

Specifying the Source Type

Move the cursor to the right-most column. Click on the arrow at the right of the cell to open the pull-down list. Choose the desired source type from the list, or enter the appropriate letter or letters in the cell. See Source Types for more information.

Selecting, Adding, Deleting, Copying, Modifying, and Moving Sources

See Using Insertion Objects Windows.

Plane Wave Excitation

Plane Wave Overview

EZNEC allows excitation of the model with a single fixed plane wave source as well as with conventional voltage and/or current sources. The plane wave source cannot be used in combination with conventional sources. The plane wave source generates a plane wave from a specified direction at an apparently infinite distance. The user specifies the direction of the source and the polarization and magnitude of the wave. The wave induces currents in the model's wires. The program reports the fields which result from those currents, with results being exactly the same as if those currents had been created by conventional voltage and/or current sources. However, note that in general the current distribution on the wires is different when the antenna is excited by an impinging plane wave than when excited by voltage and/or current sources.

This feature is useful in determining the scattering cross section of a model structure, or in direct determination of feed point voltage or current of a receiving antenna for a given field strength. For example, open circuit antenna voltage resulting from an incident plane wave is easily determined by placing a high resistance load at the point of interest and clicking Load Dat to see the resulting voltage. A zero ohm load can be placed to conveniently monitor short circuit current at a specific segment, or the Currents button can be used to see the currents at all segments. To find the maximum available power which an antenna can extract from a wave, first excite the antenna with a conventional voltage or current source and find the source impedance by clicking Src Dat. Then place a load having the complex conjugate of that impedance in place of the source, and change to plane wave excitation. Load Dat will report the resulting maximum power. To find the "effective length" of a receiving antenna in meters, divide the open circuit voltage as described above by the incident plane wave amplitude in V/m. **Note:** Be sure to read Using Plane Wave With a Ground Plane if using plane wave excitation with a ground plane .

Specifying Plane Wave Excitation

To specify plane wave excitation, open the Sources Window by clicking on the Sources line in the Control Center. If conventional sources are shown (the default), open the Other menu in the Sources Window and choose Change Source Type. The Sources Window grid then changes to allow specification of

the plane wave source. Most of the parameters are self-explanatory. Pol Ang is the orientation of the electric field when the source is linearly polarized, and the orientation of the major axis when circularly polarized. The angle represents the rotation counterclockwise of the E field from downward-oriented, in the plane normal to the direction to the source, with rotation direction defined by looking from the distant source toward the origin. The axial ratio choice is available and used only when circular polarization is specified. Note that the amplitude is in volts RMS per meter, rather than peak volts per meter as used in NEC. The polarization type dictates only the polarization of the source. The choice of polarization types to display in outputs is made the same as for conventional sources, via the Desc Options choice in the Control Center.
It's important to realize that when a ground plane is present, the amplitude and polarization of the plane wave striking the antenna model might be different from the specified plane wave, that is, the one emanating from a distant source. Be sure to read Plane Wave Excitation With a Ground Plane if a ground plane is present.

Plane Wave Excitation With a Ground Plane

Because the plane wave apparently emanates from a source which is an infinite distance from the origin, the plane wave interacts with the ground between its point of origin and the antenna. Consequently, the magnitude and polarization of the plane wave striking the antenna are generally different than the specified plane wave magnitude and polarization. That is, the specified values define the plane wave before striking the ground en route to the antenna, which is likely to be different from the wave at the antenna.
As one simple example, a vertically polarized plane wave arriving horizontally over a perfect ground will have an amplitude of exactly twice the specified value at ground level. The same wave arriving over a ground of finite conductivity will have zero amplitude at ground level.
An intuitive feel for the effect can be gained by looking at the far field radiation pattern of a conventionally excited antenna placed over ground, in the direction of the plane wave source. If the field is, for example, zero in that direction, the field from a plane wave coming from that direction will also be zero. Unfortunately, there is no direct way for **EZNEC** -- or NEC -- to directly report the field strength of the wave after ground reflection. It can, however, be deduced by means of an electrically short model test antenna. This difficulty doesn't occur in free space analysis, where the field at the antenna is always as specified for the plane wave source.
Special note when using MININEC type ground with plane wave excitation - MININEC type ground is recommended with plane wave excitation only with NEC-5 for the following reason.
When using conventional sources with MININEC type ground, the ground is set to perfect conductivity when calculating the model's impedances and currents. Then it's set to the specified real ground characteristics to calculate the fields resulting from those currents. NEC-5 uses the same process with a plane wave, that is, it sets the ground to perfect while calculating the currents induced by the plane wave. Then it uses the real ground characteristics to find the fields.

But unlike NEC-5, MININEC type ground isn't an integral feature of NEC-2 and -4.2. **EZNEC**'s internal calculating engines have been modified to approximate this ground type, and unconventional specifications are used in the input file of an external NEC-4.2 calculating engine to do the same. While this works as intended with conventional sources, it works differently with plane wave excitation. Unlike NEC-5, NEC-2 and -4.2 apply the real ground characteristics while the induced current is being determined, typically resulting in much less induced current than with NEC-5.
There's still a difference between MININEC type and High or Extended Accuracy ground with plane wave excitation and NEC-2 or -4.2, however. With MININEC type ground, any conductor connected to the ground, such as a ground mounted vertical, will have a zero ohm connection to the ground, while it will have an unknown series impedance to ground when using High or Extended Accuracy ground.
In Interpreting the Results, it's explained that the field strength can be presented as dB relative to the field produced by a free space object of one square wavelength cross section, or dBsw. When over a ground plane, the field produced by an object with one square wavelength free space scattering cross section will generally be quite different from 0 dBsw. This is because of the effect of the ground on the field scattered from the object. It's exactly the same problem as determining the gain of an antenna relative to a dipole when the antenna is over ground -- in free space, you can simply subtract 2.15 dB from the reported gain in dBi to find the gain relative to a dipole. However, over ground, the only way the comparison can be made is to model a dipole at the same height as the antenna and compare its gain to that of the antenna. Likewise, to find the scattering cross section of an object over ground, it's necessary to compare the field strength (in dBsw or V/m) to that of a similarly placed object of known scattering cross section.

Interpreting Plane Wave Results

The same tabular and graphical outputs are available with plane wave excitation as with standard voltage/current voltage source excitation, with a few differences. First, note that the Options menu Power Level specification has no effect when using plane wave excitation, since there can be no specific total power associated with the plane wave. For the same reason, Average Power isn't shown when plane wave excitation is chosen. In the Control Center Options men, Far Field Table Units selection, you can see that the non-ground wave far field values will be reported in either "mV/m X dist" or "dBsw". The first of these is the product of the field strength and distance from the origin. The field strength at any distance is simply the reported value divided by the distance from the origin in meters **provided that** the observation location is in the far field **and** that the distance is large compared to any antenna dimension. The field is of course caused by scattering, or radiation from the current induced on the antenna conductors by the incident field. Reported values don't include the incident field from the plane wave source. The "dBsw" notation you'll see in the 2D Plot Window data box and in the Far Field Table means dB relative to one square wavelength scattering cross section for an object in free space. An object in free space having a scattering cross section of one square wavelength in a given direction will produce a field of 0 dBsw, and objects with greater and lesser cross sections

will produce correspondingly greater or lesser fields. (***Caution!*** This isn't true when over a ground plane. See Plane Wave Excitation With a Ground Plane regarding use of plane wave excitation and a ground plane.) Because the scattering cross section is an area, the dB is calculated using the same rule as for power, e.g., approximately 3 dBsw will result from a scattering cross section of two square wavelengths in free space. If you're familiar with NEC-2 or -4.2, the values reported as dBsw by **EZNEC** are the same as those shown as dB or dBi by NEC when plane wave excitation is used. (Be sure to remember, though, that the plane wave amplitude is peak value in NEC and RMS in **EZNEC**.) Note that the polarization of the scattered field is often different from that of the incident wave. The polarization of the incident wave is that of the plane wave source when in free space, but not necessarily so over a ground plane.

The choice of polarization types to display in outputs is made the same as for conventional sources, via the Desc Options choice in the Control Center.

Source Placement

Source Placement Precautions with NEC-2 and NEC-4.2

If modeling an end fed antenna, please see End Fed Antennas.

This topic applies only to NEC-2 and NEC-4.2 calculating engines. NEC-5 is much less sensitive to source placement.

NEC is very sensitive to source placement, and subtle errors can result if sources are placed incorrectly. Whenever possible, you should try to follow these rules:

1. The source shouldn't be placed on a wire which is shorter than about 0.02 wavelength, particularly if adjacent wires connect at an angle.
2. The segments adjacent to the source segment should be the same length and diameter as the source segment. If placing it on a short wire, it's good practice to give the wire three segments to insure this condition.
3. Segments beyond the adjacent segments shouldn't be drastically different in length and diameter from the source segment and segments adjacent to the source segment.
4. Sources shouldn't be put on a wire which is part of a small loop.
5. It's usually better to use a split source at wire junctions than to insert a short wire containing the source.

It's often not possible to follow all these rules and still accurately model the antenna, so compromises sometimes have to be made. One of the most powerful tools for evaluating source placement is **EZNEC**'s Average Gain feature. Whenever a 3D plot is calculated, **EZNEC** calculates the "average gain" by integrating the total radiation pattern power and dividing it by the power furnished by the sources. This is reported at the bottom of the Control Center form. Source placement problems are often indicated when the average gain value of a lossless model is significantly different from one. (See the numbered list below for how to set loss to zero.) Source placement can then be modified to bring the average gain as close as possible to one in the lossless model, after which the lossy objects can be restored to normal. *Note* (**EZNEC Pro/4** only): Average Gain can't be used to evaluate source placement if the model includes buried wires.

EZNEC's Segmentation Check detects and notifies you of some common placement errors.

To use Average Gain to test source placement:

1. Save the current description (optional - you can use the undo feature to restore the original model if you prefer)
2. In the Control Center, choose Plot Type/3 Dimensional.
3. If any Real ground type is specified, change the Ground Type to Perfect.
4. If any loads, L networks, or Y parameter networks are specified, set their resistances to zero, or delete them.
5. Set all transmission line loss to zero.
6. In the Control Center, set the Wire Loss to Zero.
7. In the Wires Window, check the Show Wire Insulation box and set Insulation Loss Tan to zero for all wires.
8. Do a far field plot. Note the average gain reported at the bottom of the Control Center form. If you see ***Model contains loss*** to the right of the average gain, it means that all losses have not been removed, so you should review the steps above and remove the remaining loss. The average gain won't be meaningful for this purpose if there is any loss in the model, indicated by the ***Model contains loss***. If the 3D pattern has very narrow lobes, it might be necessary to reduce the step size for greater accuracy. However, 5 degrees is generally adequate. The field strength (and gain) error is approximately equal to the deviation of the average gain from one (zero dB). That is, if the reported average gain is +2 dB, the gain and field strength reported by **EZNEC** is about 2 dB greater than reality. Source placement should be modified to make the average gain as close to one (zero dB) as possible. If full correction can't be made, the average gain in dB should be subtracted from the field strength results. This correction method might be considerably in error if the model contains multiple sources, but should be reasonably accurate for a single source.
9. Note the modifications you made to improve the source placement. If modifications were extensive, it's probably easiest to restore the loads, wire loss, and ground type to the lossless model. If minor, it might be easier to open the saved original file and apply the source placement modifications to it.

Even though sources appear in the View Antenna display to be placed in the center of a segment, the source is actually distributed over the entire segment. If source placement is critical (for example, in a base-fed half-wave vertical or center-fed full-wavelength dipole if impedance is important), the length of the segment containing the source can become important. The shorter the source segment is made, the more closely it imitates one connected at a single point. A simple test can show if this is important. Divide the wire containing the source into a reasonable number of segments, remembering to follow the rules at the top of this section. Run the program and note the results which are important to you (such as gain, or impedance). Move the source over one segment and repeat. If the results change more than you're willing to accept, you'll need to minimize the length of the source segment. One way to do this is to use segment length tapering.

Placing Sources On Segments

Like other insertion objects, all sources have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details.
EZNEC's split sources mimic single sources placed at a wire or segment junction with NEC-2 and -4.2, but they're really made from two conventional sources placed on the segments adjacent to the chosen junction, as shown in the View Antenna display. Connecting a source to a transmission line requires that a wire be created for both the source and transmission line to connect to. No more than one source can be placed on a given segment. Split sources are not available or needed with NEC-5 which places objects at segment junctions.
Use standard (non-split) sources whenever possible, and use split sources only when it's necessary to put a source at a wire junction with NEC-2 or NEC-4.2.

Placing Sources At Wire Junctions with NEC-2 and NEC-4.2

This does not apply when using an NEC-5 calculating engine, which places loads and other insertion objects at segment junctions.
Conventional **EZNEC** sources have to be placed on a segment with NEC-2 and -4.2, so simulating a source at a wire junction requires special techniques.
The preferred method is to use **EZNEC**'s split sources, which are intended for just this purpose. When you specify a split source, **EZNEC** actually creates two sources, and places them on adjacent segments closest to the position you specified. Split sources are shown in the View Antenna display as two sources, but appear everywhere else as a single source. Split sources are positioned just like conventional sources, except that the position chosen by **EZNEC** will be the closest segment junction or wire end rather than the closest segment center to the position you specify. When using split sources, make sure that any load placed on the segment containing one source has a corresponding load on the segment containing the other, and avoid putting transmission lines on segments with split sources. Split sources can't be placed at a multiple-wire junction, and shouldn't be placed where the segment length or wire diameter is different for one source than the other. Split sources also can't be placed on an open wire end, because one of the actual sources making up the split source would be off the wire altogether.
The N4PCLoop1.ez and BYVee.ez example files illustrate the use of split sources.
Another way to put a source at a wire junction is to insert an additional short wire at the junction, and place the source on it. This technique would be used for multiple dipoles with a common feedpoint, for example. But care has to be taken if this method is used. Be sure to review Source Placement Precautions before doing this. Sometimes it's helpful to taper the segment lengths away from the junction, using **EZNEC**'s Segment Length Tapering feature.

Connecting Sources to Ground

A common question is how to connect one end of a source to ground. The answer is to connect a wire to ground (by giving one end a zero z coordinate) and specify a position of either 0% or 100% from end 1 of the wire, depending on which end is grounded. This will place the source right at the bottom if

you're using an NEC-5 calculating engine, or in the center of the bottom segment if not. Example description file Vert1.ez illustrates this method. Wires should only be connected to Perfect or Real, MININEC-type grounds. See example file Vert1.ez for an example and Connecting Wires to Ground for more information.

Multiple Sources

Using Multiple Sources

You have to take some precautions when using multiple sources in an antenna to avoid currents which are 180 degrees from what you intended. In phased arrays of parallel wires, make sure that end 1 of the wires are all facing the same direction (for example, all wire end 1's of a vertical array connected to ground). Reversing a wire will reverse the effective polarity of all sources in that wire because positive current from a source is always directed toward end 2, and positive current is defined a current flowing toward end 2.

An ambiguity can arise when placing a split source at a wire junction with NEC-2 or -4.2 because the polarity can depend on which wire the source "belongs" to and which way this wire is facing. A split source placed on a junction of two wires "belongs" to the wire specified as its desired position. Therefore, it will be placed with the positive terminal facing end 2 of the specified wire. Ambiguity can be avoided by making the wires face the same direction by connecting them end 1 to end 2.

Other factors have to be considered when using NEC-5. See NEC-5 Object Placement for more information.

Whenever you use multiple sources in any antenna other than simple, parallel wires, it's highly recommended that you look at the currents in the wires and make sure they're really flowing in the direction you thought. See Interpreting The Results.

Phased Arrays

EZNEC allows you to model phased array feed systems provided that they're made exclusively of transmission lines and networks, and provided that the transmission lines don't interact with the antenna as wires. (**EZNEC** doesn't model coupling to transmission line objects.) Example description files CardTL.ez and 4SqTL.ez are examples of this. To investigate various possible patterns, instead of modeling transmission lines, place a current source at each element's feedpoint and vary the element currents by changing the source magnitudes and phases. A very valuable capability of **EZNEC** is to tell you what the element feedpoint impedances are when an array is correctly fed. This information is required to design a feed system to produce the desired current ratio. To determine the impedances, insert current sources at the feedpoints, with the currents being in correct ratio. Clicking the Control Center Src Dat (Source Data) action button will tell you the feedpoint impedances. 4Square.ez and Cardioid.ez are examples of phased arrays fed with multiple current sources.

Using Loads

About Loads

Loads are insertion objects which represent a lumped impedance that can be inserted into a wire. Like sources, these are easy to place with **EZNEC**, and appear connected across an imaginary gap in the wire. Like sources, loads are actually distributed along the entire segment, but conceptually can be regarded as being at the segment center.
Loads are characterized by **type**, **configuration**, and external **connection**.
Load impedances can be specified as one of three **types**: as an impedance consisting of fixed resistance and reactance (R + jX type), as an RLC combination (RLC type), or as a quotient of Laplace transform polynomials (Laplace type). These are explained in more detail in the following section.
The RLC type gives you three different choices or **configurations** for interconnection of the resistance, capacitance, and inductance.
There are two ways of connecting loads when sharing a segment with other insertion objects, series and parallel **connection**. This is explained in detail in the Load Connections topic.
Loads are entered and modified via the Loads Window. Operation varies some with the load type chosen, and detailed information about specifying each type of load is given in Using the Loads Window chapter. Load placement is identical to placement of sources, as explained in Placing Sources On Segments.
In critical applications, the same restrictions should be applied to loads as to sources regarding placement. See Source Placement Precautions. I don't know of any way to assess load placement problems with the Average Gain feature as is done with sources, so the only way to spot problems is to modify placement and observe how much the result changes.
Like all other insertion objects, **EZNEC** loads do not radiate, except that the segment the load is placed on does radiate like any other segment.
Series connected loads are shown in the View Antenna display as empty hollow squares. Parallel connected loads are shown as empty hollow diamonds.

Load Types

Three different load **types** are available, R + jX (resistance and reactance), RLC, and Laplace. Each has its advantages, as outlined below. Note that all loads in a model must be the same type, so a compromise sometimes has to be made in choosing which type to use.
R + jX – This load type is the fastest and simplest to use. You just specify the resistance and reactance. Because the impedance of an R + jX load doesn't change with frequency while a real load (if it contains reactive components) does, the R + jX load type is most useful for frequency independent loads (i.e., pure resistances) or for analysis at a single frequency or a narrow range of frequencies.
RLC – This load type is most convenient if you know the values of equivalent R, L, and C of the load you're trying to model. Not all components have to be present, so this type can also be used for modeling any combination of the three, including a single R, L, or C. A powerful feature of this model type is that the resistance can be made to vary with frequency to simulate skin effect

loss (such as an inductor exhibits) or insulation loss. Each load's resistance can be set independently, so you can make some vary and some not if you wish. You enter RLC loads directly as values of R, L, and C for this load type, rather than as resistance and reactance. The impedance of the combination varies realistically with frequency.
Three configurations of RLC type loads are available: series, parallel, and "trap" (series RL with parallel C). The "trap" model is useful for modeling inductors as well as traps or other parallel resonant circuits.
Laplace – This load type can be used only by people who understand how to calculate the Laplace polynomial quotient which represents a circuit. Explanation of this is beyond the scope of this manual, and interested readers should consult a text on circuit analysis for more information. The advantage of this load type, for those who are able to use it, is that relatively complex combinations of components (that is, R, L, and C) can be modeled. The impedance of a Laplace load varies with frequency, although the resistance can't be made to vary with frequency as in the RLC load type.
More detailed information about specifying the various load types can be found in Using The Loads Window chapter.

Load Connections

There are two ways of connecting loads when sharing a segment with other insertion objects, series and parallel external **connection**. As the names imply, series connected loads are placed in series with other insertion objects sharing the same segment. This connection might be used for such things as a series loading coil or a resistance representing ground loss at the base of a vertical antenna. Parallel connected loads are used when a lumped impedance has to be connected in parallel with another insertion object. A typical use for these would be to represent a hairpin matching wire connected in parallel with a source or transmission line at an antenna feedpoint, or to represent a shunt capacitor used for impedance matching. The choice of connection type is made with the other load characteristics.
Choice of connection for each load is made in the right-most column of the Loads Window, labeled **Ext Conn**. Enter **S** or select **Ser** in the drop-down list for series connection, or enter **P** or select **Par** in the drop-down list for parallel connection.
Series connected loads are shown in the View Antenna display as empty hollow squares. Parallel connected loads are shown as empty hollow diamonds.
The internal model of the parallel connected load is more complex than a conventional load, so conventional loads are recommended except where the parallel connection is needed. Parallel connected loads can be placed on virtual segments; series connected loads cannot.
There should be no significant difference in results when using one connection type or another unless some other object is connected to the same segment. The phase angles of load voltages and currents reported in the Load Data display might be 180 degrees different, however, due to different definitions of polarity for the two object types. For a detailed explanation of the reason for this, see Parallel Connected Loads Polarity in the Reference section.

Special attention has to be given to placement of parallel connected loads when using NEC-5. See NEC-5 Object Placement for more information.

Placing Loads At Wire Junctions with NEC-2 and NEC-4.2

This does not apply when using an NEC-5 calculating engine, which places loads and other insertion objects at segment junctions.
Like a source, a load is distributed over a segment with NEC-2 and -4.2, so conceptually can be regarded as being placed at a segment center. Direct placement on a segment or wire junction isn't possible, but it can be simulated with two loads.
To simulate a load at a wire junction, split it into two equal loads of half the value and place each one on the adjacent segment. When **EZNEC** spots identical loads on segments adjacent to a wire junction, it shows voltages, currents, impedances, and losses of the combination as well as the individual loads, in the Load Data output.

Loading Coils

The currents at the ends of real loading coils are often substantially different because of radiation and/or physical length. When this occurs, the **EZNEC** load model, which has equal currents at the two terminals, does a poor job of representing the coil, and considerable inaccuracy can result. Whenever possible, a helix rather than a load should be used to model a loading coil.
Coils frequently have a significant amount of loss which should be included in the model. Measurement is the best way of determining the loss, but even a guess may be adequate. Air-wound inductors typically have Q's in the range of 200-400 or so. This means that you can estimate the equivalent series R as about 1/200 to 1/400 the reactance. If using this range of values impacts your result, you might want to make a measurement or better estimate of the Q.

Traps

A trap has a primary resonance at only one frequency, but still represents a significant impedance at other frequencies and on other bands. So a trap model has to be reasonably accurate over the entire range of antenna operating frequencies (or at least over the range being modeled). The only way to accurately model a trap is either by measuring its impedance at each frequency of interest, or by knowing the equivalent L, C, and R components, and how R varies with frequency. These in turn must be measured unless you can talk the manufacturer out of this information (or have constructed the trap yourself from known components). Traps frequently will cause a couple of dB loss at one frequency or another, so failure to include loss resistance will lead to overly optimistic results. The trap RLC load model, as its name implies, is particularly useful for modeling traps. If the trap is physically large or long enough that unequal currents can occur at the ends, an **EZNEC** load can result in considerable error. When possible, a helix should be used to represent the coil. A wire can be added along the center of the helix and a suitable capacitive load inserted in the wire to represent lumped trap capacitance.

Using The Loads Windows

Load Types And The Loads Window

The Loads Window is where impedances are placed on the wires in the model. Open the Loads Window by clicking on the Control Center Loads line or the button to its left. Like other insertion objects, all loads have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details. Loads can be specified in three different ways, as R + j X, RLC, and Laplace types. The types can't be mixed, so all loads have to be of the same type. The appearance and operation of the Loads Window depends on which load type you've selected.

The load type is saved with the description file, so when you first open the Loads Window (from the Control Center), it will reflect the type of load specified for the current description. You can change the load type at any time from the Loads Window by selecting Change Load Type from the Other menu. ***NOTE:*** When you change the load type, all existing loads are converted to the new type if possible. Most conversions are not reversible, so if you change back to the original load type, loads are likely to be different than the originals. For example, if you specify a parallel RLC type load and change to the R + j X load type, the impedance of the load will be calculated and entered as the R + j X impedance. If you change back to the RLC load type, the R + j X impedance will be converted to a series RL or RC circuit. Changes can, of course, be completely reversed with the undo feature.

The R + j X Loads Window

R + j X type loads are expressed as a series combination of resistance (R) and reactance (X). The impedance of R + j X loads does not change with frequency.

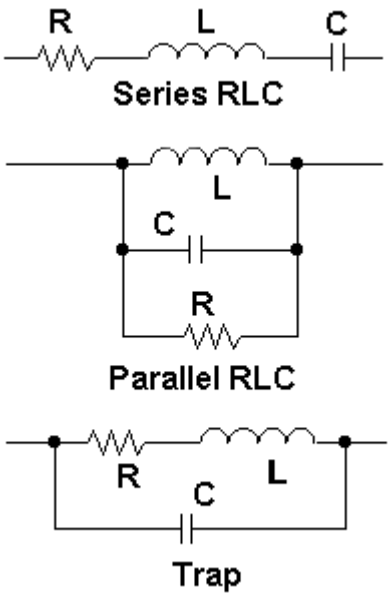
The load number column and specified and actual position columns function the same as for the Sources Window.

The impedance of each load is entered as resistance (R) and reactance (X) in the appropriate columns. The value of R cannot be negative.

See Load Types for information about other types of loads, and changing the load type, and Load Connections for information about specifying the connection type.

The RLC Loads Window

RLC loads are defined as a combination of R, L, and C components. They can be connected in any of three different **configurations**: series, parallel, or as a "trap" configuration, as shown below. R can optionally be made frequency dependent.



Values of R, L, and C are entered in the appropriate columns. **EZNEC** will calculate and use the impedance of the RLC combination as required.
See Load Types for information about other types of loads, and changing the load type.

Config Column

The rightmost column is used to select the type of RLC circuit, Series, Parallel, or Trap. This selection can be made by entering "S" or "Ser" for Series type, "P" or "Par" for Parallel type, or "T" or "Trap" for Trap type. Or you can click the cell to activate the drop-down list arrow, click the arrow to open the list, then make the selection.

R, L, C Columns

Series Configuration RLC Loads

The R, L, and C are connected in series. Any of the three components can be replaced by a short circuit by entering "0" (the number zero), "S", or "Short" as the value, or by leaving the grid cell empty. Note that there is no way to specify a zero capacitance (open circuit) in a Series type RLC load; an entry of zero will be interpreted as a short circuit.
The resistance of typical wire and tubing increases as the square root of frequency, so the resistance can be made to vary in this way for the Series RLC type. See "R Freq Column", below.

Parallel Configuration RLC Loads

The R, L, and C are connected in parallel. Any of the three components can be replaced by an open circuit by entering "0" (the number zero), "O" (the letter O), or "Open" as the value, or by leaving the grid cell empty. Note that there is no way to specify a zero resistance or inductance (short circuit) in a Parallel type RLC load; an entry of zero will be interpreted as an open circuit.
The parallel model is frequently used for relatively high impedance loads, where dielectric loss often dominates. Consequently, the frequency dependence of R is that of typical dielectrics; that is, it decreases in inverse proportion to frequency. See "R Freq Column", below.

Trap Configuration RLC Loads

This load type can be used to represent objects other than traps. For example, it can be used to model an inductor, accounting for the frequency-

dependent conductor resistance and shunt capacitance. It was called a Trap type simply because this is one of the common applications. The Trap type RLC load consists of a resistance R and inductance L in series. The series combination is in parallel with a capacitance. The series RL circuit is a reasonable model of a real inductor, and the shunt capacitance can represent stray inductor capacitance, a physical capacitor, or a combination of the two. The frequency dependence of R is the same as for the Series type RLC load.
In this load type, entry of zero for R or L results in that element being replaced with a short circuit. Entry of zero for C results in replacement with an open circuit. As for the other RLC load types, the short circuit can also be created by entering "S" or "Short", and the open with "O" or "Open".

R Freq Column (all configurations)

The "R Freq" column is the frequency at which the resistance has the value specified in the R column. If any value other than zero is specified as the R Frequency, the resistance will vary with frequency as described above. (Series resistance – Series and Trap types -- changes in proportion to the square root of frequency. Parallel resistance – Parallel type – changes in inverse proportion to the frequency.) Enter zero in this column to keep the resistance fixed with frequency. The current frequency can be conveniently entered by clicking the cell to activate the drop-down list arrow, clicking the arrow, then clicking the highlighted frequency value which appears.

Ext Conn Column (all configurations)

See Load Connections for information about choosing the load connection.

The Laplace Loads Window

Laplace type loads are impedances which are defined as Laplace coefficients. This load type is most useful for representing complex combinations which can't be represented by other load types. Any combination of R, L, and C up to fifth order can be represented with Laplace type loads. Because Laplace type loads represent R, L, and C components rather than fixed impedances, the impedance varies with frequency as appropriate for the components comprising the load. However, R cannot be made to vary with frequency as with RLC type loads. *Do not use this load type unless you are familiar with the use of Laplace transforms, the explanation of which is beyond the scope of this manual.*
Impedances are entered as Laplace coefficients, with zero to fifth order from left to right and numerator on the top and denominator beneath. At least one denominator coefficient must be non-zero.
See Load Types for information about other types of loads, and changing the load type. See Load Connections for information on choosing the external connection type in the Ext Conn column.

Using Transmission Lines

About Transmission Lines

There are important differences between the NEC transmission line objects used by **EZNEC** and real-life transmission lines, so there are several things you have to be aware of in order to use them effectively.
The first characteristic is shared by all other two port insertion objects. The only parts of the transmission line object which exist as far as the program is

concerned are the ends. Imagine the model as being two sets of portable terminals which can be placed in any two segments. The current and voltage at one set of terminals relative to the other is just the same as though there were a transmission line connected between them. But the transmission line can be any length you specify, including longer or shorter than the physical distance between the "terminals". Although the terminals are accessible to connect to the antenna wires, the transmission line itself is "somewhere else". So, unlike real transmission lines, **EZNEC** transmission line objects don't interact with the antenna fields. That is, the currents in the model's two conductors are always equal and opposite, so the line doesn't radiate or have current induced by coupling. In many real-life cases, a transmission line does interact with the antenna fields, and becomes a radiating part of the antenna. This can be caused by coupling to the antenna due to non-symmetrical placement of the feedline, or by presenting the feedline with an unbalanced source or load. **EZNEC** transmission line objects are suitable for modeling symmetrically-placed balanced lines such as a log-periodic feed distribution line or W8JK phasing line. They aren't suitable for modeling, for example, a quarter-wavelength phasing stub extending outward from a collinear antenna, since the stub wires in a real collinear antenna have unbalanced currents and will radiate. Coaxial lines laid on the ground, such as in a vertical phased array feed system, may carry current on the outside just like a ground radial wire. In many cases this can be ignored and the EZNEC Pro model used. A coaxial cable with field interaction (that is, with current flowing on the outside of the shield) can be modeled with a combination of a wire and transmission line object as described in Modeling Coaxial Cable. A two-wire line which interacts with the antenna's fields has to be modeled as wires.

The second thing to realize about **EZNEC**'s transmission line objects is that all ends which aren't specified as a shorted or open stub must be connected to wires or virtual segments. If you want to connect a source directly to a transmission line (that is, connect the two terminals of a source in parallel with the two terminals of one end of a transmission line), the easiest way is to specify the same virtual segment for both as the "wire number". The disadvantage to this method is that you don't have any visual representation of the transmission line in the View Antenna display. An alternate method is to create a short, one segment wire (short so it doesn't interact appreciably with the antenna field) not too far from the antenna and connect both source and transmission line to it. Then you'll see the transmission line in the View Antenna display. Remember, the physical distance between the ends of the transmission line in your model don't have to be the same as the line length -- it can be either greater or less -- unless you specify Actual Distance for the transmission line length.

Third, when a transmission line is connected to the same segment as another insertion object, it's important to be aware of the way they're connected together. A transmission line is connected in parallel with any other insertion object except a series connected load, in the same segment.

Finally, you should be aware of the limitations of the transmission line loss model, detailed in the Transmission Line Loss topic.

Connection is sensitive to wire direction. If two vertical elements are defined with one having end 1 grounded and the other end 2 grounded, transmission lines connected to their grounded ends from the same point would result in

reversed signals to the two antennas. Imagine each end of a transmission line having two terminals, "1" and "2". A normally connected line will always be connected so that terminal "1" is closest to end 1 and "2" closest to end 2 of each wire, regardless of the physical orientation of the wires. Each transmission line can be reverse connected if desired, which reverses this connection, just like giving a physical line a half twist.
Two examples of phased array antennas using transmission line feed are included as example description files CardTL.ez and 4SqTL.ez.
Transmission lines are defined in the Transmission Lines Window. Except for stub ends, all transmission line ends (ports) have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details. With NEC-2 or -4.2 calculating engines there's no way to connect a transmission line end at a wire junction; the best you can do is to insert a short wire between the wires and place the transmission line end on it. Follow the same procedure and cautions as described at the end of the Placing Sources At Wire Junctions section. With NEC-5, all insertion objects including transmission lines are placed at segment junctions.
A transmission line stub can be created by declaring one end to be open or short circuited. Remember, though, that it's not capable of radiating, so this stub model can be used only in those situations where a real stub wouldn't radiate.
More detail about use of the Transmission Lines Window and its features can be found in the Using The Transmission Lines Window topic.

Using The Transmission Lines Window

EZNEC uses NEC transmission line models. There are several very important differences between these and real-life transmission lines, which are discussed in About Transmission Lines. If you aren't familiar with the use and limitations of NEC transmission line models, please acquaint yourself with these differences before using them.
Transmission lines have two ends unless they're specified to be an open or short circuited stub. Stubs have only one end.
Transmission end positions are specified in the same way as for other insertion objects. Like all others, both ends (ports) of all transmission lines have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details.

Specifying Connections

Like other insertion objects, all transmission line ends (ports) except stub ends have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details

Specifying a stub

A stub is specified by declaring one end to be either open or short circuited. You can simply enter ‘O' or ‘S' in the Wire # column, or you can click the arrow on the right side of the cell and select open or short circuit from the pull-down list.

Specifying Length

Transmission line length can be specified in three different ways: physical length, electrical length, and physical distance between ends. If you specify physical length in current length units, the model acts like a line with that physical length. If specified in degrees (electrical length), the line acts like a

line of that electrical length. ***Note:*** The electrical length of a line specified in degrees doesn't change with frequency like a real line would. This type of length specification is recommended only for single-frequency analysis.
Any of these three specifications can easily be made by right-clicking the cell in the Length column, choosing the specification type, and entering a value if required. Described below are shortcuts for the three methods.
Physical Length – To specify physical length, simply enter the length in current units, or right-click the Length column. The physical length of the model doesn't have to bear any relationship to the distance between its ends. See About Transmission Lines for further explanation.
Electrical Length – Enter the length followed by '**d**' for 'degrees' in the Length column.
Actual Distance – Enter '**a**' in the Length column. This will make the line length the straight-line distance between the ends. This choice isn't available if one end is shorted or open, that is, the transmission line is a stub. If Actual Distance is specified and one or both ends are connected to virtual segments, an error message will appear when you attempt to do calculations.

Specifying Characteristic Impedance (Z0)

In the Z0 column, you can either enter the characteristic impedance in ohms, or you can right-click the cell to open a dialog box with more options. The dialog box lets you choose from a list of common cable types, or enter the wire diameter and spacing of parallel wires. If you use the parallel wire entry, **EZNEC** will assume air insulation unless you give a velocity factor. If you enter a velocity factor, **EZNEC** will infer an effective dielectric constant and calculate the impedance based on this dielectric constant. So the parallel wire entry can be used for ladder line, twinlead, or other dielectric-insulated lines as long as you know the velocity factor. The results of its calculations are shown at the lower left of the dialog box.

Specifying Velocity Factor

To specify velocity factor, enter a positive number no greater than one in the VF column. Alternatively, you can right-click the cell to open the same dialog box as described above.

Specifying Reverse or Normal Connection

Connection orientation is selected in the Rev/Norm column. Normal connection means that the same conductor of both ends will face the same wire end number. That is, if one line conductor is labeled 1 and the other 2, conductor 1 will connect on both wires toward the wires' end 1 and conductor 2 toward the wires' end 2. Specifying a reverse connection reverses the connection to one of the wires, reversing the phase of the voltage and current from the transmission line.

Specifying Loss

Transmission line loss is entered as loss in dB per 100 ft or 100 m depending on the description Units setting. If you want to enter the loss in dB/100 m when the choice is dB/100 ft, simply change the Units to Feet or Inches, enter the loss, then change back. Similarly, change to a metric Units value to allow loss entry in dB/100 m. The Loss Freq is the frequency at which the specified loss will be applied to the transmission line. At frequencies above or below this, the loss will be adjusted to mimic the approximate change in attenuation with frequency of a real transmission line over the HF - UHF frequency range. If the Loss Freq is set to zero, the specified loss will be applied at all

frequencies. Be sure to read Transmission Line Loss to learn about some of the limitations of this model.

Selecting, Adding, Deleting, Copying, Modifying, and Moving Transmission Lines

See Using Insertion Objects Windows.

Transmission Line Loss

Loss can be added to the transmission line models if desired, in the Transmission Lines Window. Loss is specified in dB/100 ft if model Units are Feet or Inches, or in dB/100 m if Units are Meters or Millimeters. If Units are Wavelengths, dB/100 ft will be used only if Inches is chosen for diameter units. The 100 ft or 100 m figure refers to the physical length of the transmission line. If the alternate specification is desired, the Units can be temporarily changed, the loss entry made, then the Units changed back. A second option is the "loss frequency", entered in the "Loss Freq" column. This value is used as follows:

-- If the Loss Freq = 0, the specified loss in dB/100 ft or dB/100 m will be applied at all frequencies.

-- If the Loss Freq is any other value, the specified loss will be applied to the transmission line at the specified frequency. At other frequencies, dB loss proportional to the square root of the frequency will by applied. For example, if the loss is specified as 1.0 dB/100 m and the loss frequency is specified as 10 MHz, the line loss used by **EZNEC** will be 1.0 dB/100 m at 10 MHz, 1.414 dB/100 m at 20 MHz, 2.0 dB at 40 MHz, 0.707 dB/100 m at 5 MHz, and so forth. This is evaluated each time a calculation is made, including at each frequency of a frequency sweep calculation.

Important Notes

The loss of real cables, particularly coaxial cables, is determined by many factors. Besides the obvious conductor and dielectric losses, conductor plating, braided shield roughness, roughness of a stranded center conductor, and other effects can contribute noticeably to the total loss. These vary in complex ways with frequency. So a single loss specification is less than adequate for a completely accurate calculation of cable characteristics. However, these multiple factors are often unknown, so **EZNEC** uses an approximation which is reasonably good over a wide frequency range.

The single transmission line loss specification in dB/100 ft or m is used to calculate a complex characteristic impedance and complex propagation constant for the line. **EZNEC** bases these calculations on an idealized transmission line model which has only resistive conductor (skin effect) loss and no dielectric loss. This approximation is reasonably good throughout the HF and UHF range for most common transmission line types, but not at the lower end of MF and below, or at microwave frequencies and above. Outside the MF through UHF range, the assumption that loss is proportional to the square root of frequency becomes invalid, and at microwave frequencies and above, the calculation of characteristic impedance also becomes inaccurate. The inaccuracy of the square root of frequency assumption can be minimized by only specifying a loss frequency which is close to the analysis frequency. The error of the characteristic impedance calculation can be minimized only

by having relatively low loss cables in the model, and ones which are reasonably well matched to their loads. Users of the professional programs (**EZNEC Pro/2** and **EZNEC Pro/4**) can use a Y parameter network to accurately represent any transmission line at a single frequency, providing that the cable characteristics (complex characteristic impedance and complex propagation constant) are known. Before becoming too concerned about the accuracy of the loss model, try changing the specified loss and see how much this changes the overall result. If the overall result doesn't change much with specified loss, then the accuracy of the loss model isn't critical.

Modeling Coaxial Cable

A non-radiating coaxial cable is electrically identical to a non-radiating two-wire line, so an ordinary transmission line model can be used for modeling a non-radiating coaxial line. A radiating coaxial cable can be modeled quite well with a combination of transmission line model and a wire. The transmission line model represents the inside of the coax, and the wire represents the outside of the shield. The wire is the diameter of the shield, and connected where the shield of the actual cable is. It should follow the same physical path as the real coaxial cable. One of the example files, DipTL1.ez, shows how this is done. (See its Antenna Notes file for more information.) If the coax cable doesn't radiate, the current on the additional wire will be zero, and the additional wire contributes nothing to the analysis so can be removed.
There's no way to use the transmission line model to accurately model a radiating two-wire transmission line (one with common mode current present). If it's necessary to do this, the line will have to be modeled as two parallel wires. See Closely Spaced Wires for precautions.

Using Transformers

Transformers

Transformers are insertion objects which are specified via the Transformers Window, opened by clicking the **Transformers** line in the Control Center.
The ideal transformer model object is intended to simulate real transformers or impedance transforming networks. Like any other model, however, they have a number of limitations and peculiarities, and come with some cautions. The chief limitation is probably the fact that real transformers often don't behave like ideal ones, so be sure to carefully read note 1 below.
As a two-port network, a transformer shares much in common with the transmission line model. Each port (or "winding") must be connected to a wire or virtual segment, which it effectively cuts at the insertion point. Wires to which it connects can be any physical distance apart. Like transmission lines, transformers are connected in parallel with a source, transmission line, Y parameter or L network, parallel connected load, or other transformer connected to the same segment. They're in series with series connected (conventional) loads connected to the same segment. At each port, the current into one terminal exactly equals the current coming out of the other, so there is no common mode current or radiation. The "turns ratio" is the square root of the ratio of specified port impedances, which should be chosen to be in the ballpark of the impedances to which they're connected. For example, in an

application transforming about 50 to 200 ohms, don't specify 0.5 and 2, or 5000 and 20000 ohms for the transformer impedances. See item 2 below for the reason. Here are some further notes and cautions:

1. ***Remember that real transformers are far from ideal.*** Real transformers seldom maintain the specified transformation ratio over a very wide frequency or impedance range. In addition, they commonly add a substantial amount of series and shunt impedance except within a fairly narrow frequency and impedance range. In particular, transformers or baluns used for multi-band antennas typically depart dramatically from ideal behavior. So don't expect the model transformers to act anything like a real transformer over a wide frequency range.
2. The models are not quite ideal. Because of the way they're implemented, the transformer models actually have a small but usually insignificant resistance in series with each winding. The value of this resistance is based on the specified port impedances, such that if the specified impedances are in the ballpark of the impedances to which the ports are connected, the resistance will be insignificant. There's quite a bit of leeway here, however, so you don't have to be precise about it. *Please note:* The specified impedances aren't winding impedances, and they aren't the values of the series resistances. They should be chosen as explained above.
3. The method used to create these models doesn't lend itself to making a model of a "current balun" (common mode choke). A conventionally connected transformer model will, however, act as an ideal current balun, with a transformation ratio of your choice.

An example of the use of a transformer model is in the A Lap Around Track 5 topic in the Test Drive tutorial.

Using The Transformers Window

Open the Transformers Window by clicking on the Control Center Transformers line or the button to its left.

Like other insertion objects, both ports of all transformers have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details.

In addition to connection location, you have to specify port impedances and a choice of normal and reverse connection.

Specifying Impedances

The ratio of the two specified impedances will be the square of the "turns ratio". For example, a transformer specified as having a port 1 impedance of 50 ohms and port 2 impedance of 200 ohms will provide an impedance transformation of 1:4, or a voltage step up of 1:2, from port 1 to port 2. Although specified impedances of 1 and 4 ohms will provide the same transformation as 50 and 200, you should specify impedances which are in the general ballpark of the impedances actually seen by the transformer. The reason for this is explained in the Transformers topic. This isn't highly critical.

Specifying Normal/Reverse Connection

The Normal/Reverse connection column allows you to invert the transformer connection, effectively reversing the two terminals of one port. This is useful not only for effecting an intentional phase reversal, but also to force the

polarity to be the same when the ends of connected wires are physically reversed. For example, suppose you wanted to connect a transformer between the base of two grounded vertical wires such that the voltage and current were the same at both ends with respect to ground. If end 1 of one wire was the ground end and end 2 of the other wire its ground end, you'd have to choose the reverse transformer connection to get the desired result. This is because like any other insertion object, the polarity of the connection is determined by the end 1 - end 2 direction of the wire rather than some physical direction.

Selecting, Adding, Deleting, Copying, Modifying, and Moving Transformers

See Using Insertion Objects Windows.

Using L Networks

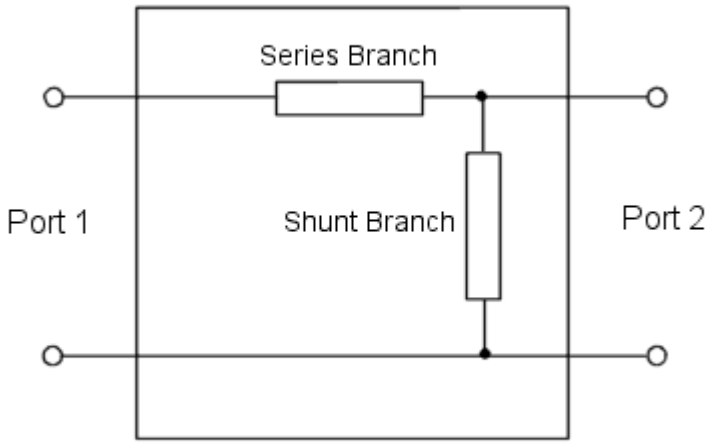
L Networks

L networks are a powerful type of insertion object which can be used to model impedance matching networks, phase shift networks, attenuation pads, and many other network functions. They can be cascaded to create tee, pi, and more complex types of ladder networks. Unique features of the **EZNEC** L Network are:

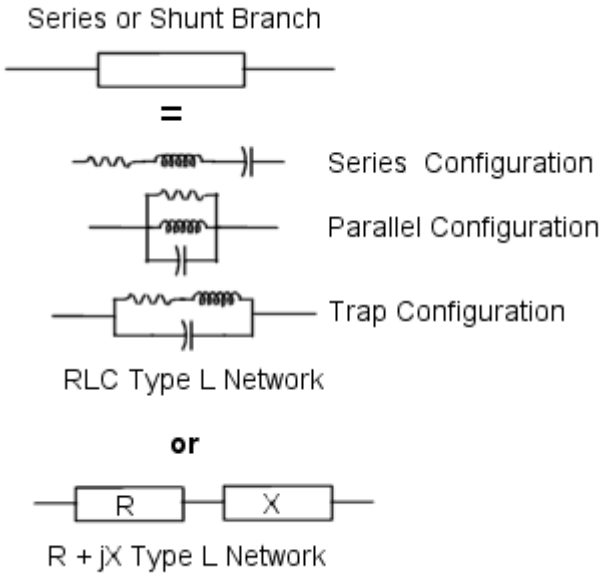
- The two internal branches of the network can consist of more complex combinations of series, parallel, or "trap" connected components.
- Components making up the branches can be specified as inductances, capacitances, and resistances so that their impedances change with frequency like real components.
- Resistances can be made frequency dependent to mimic conductor or insulation loss.

Please refer to the Insertion Objects topic for some important characteristics of L networks.

L networks have two **ports** and contain two **branches**, a **series** branch and a **shunt** branch. The shunt branch is always connected across port 2:



Each branch contains the equivalent of an **EZNEC** load of either the RLC or R + jX type. (The Laplace load type isn't available for L networks.) Like loads, all branches of all L networks have to be the same type, although they don't have to be the same as the type chosen for **EZNEC** loads. Like loads, the components of an RLC branch can be connected in a series, parallel, or "trap" configuration which simulates a capacitor in parallel with a lossy inductor. The following diagram summarizes the combinations:



Like **EZNEC** loads, specifying a value of zero for a parallel connected RLC component means "component missing" rather than a literal value of zero For example a zero value in a series configuration means a short circuit in place of that component; a zero value in a parallel configuration means an open circuit.
L networks can be connected in tandem to make pi, tee, or ladder networks. This is made easier with the virtual segment feature.

Extreme differences between the impedances of the two branches should be avoided when using a single or mixed precision calculating engine. See L Network Limitations for more information.
Example files using an L network are 4Square L Network Feed ARRL Example.ez, Cardioid L Network Feed ARRL Example.ez, and 4Square L Network Feed With Z Matching.ez. Step-by-step development of the latter two is given in the A Lap Around Track 5 topic of the Test Drive tutorial.

Using the L Networks Window

Open the L Networks Window by clicking on the Control Center L Networks line or the button to its left. Each L network occupies two lines in the input grid. The upper line contains port 1 wire connections and series branch components; the lower line is port 2 wire connections and shunt branch components. A step-by-step tutorial on using L networks is featured in the Test Drive tutorial chapter A Lap Around Track 5.

Specifying Connections

Like other insertion objects, both ports of all L networks have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details.

Specifying Type, Configuration, and Values

Each L network branch contains the equivalent of an **EZNEC** load, so specification of the components in the branch is done in the same way as for loads. The R + jX Loads Window and The RLC Loads Window topics describe the process for the chosen branch type. See L Networks Overview for a detailed description of the L network object.
Extreme differences between the impedances of the two branches should be avoided when using a single or mixed precision calculating engine. See L Network Limitations for more information.

Selecting, Adding, Deleting, Copying, Modifying, and Moving L Networks

See Using Insertion Objects Windows.

L Network Limitations

L networks are more affected by the limitations of single-precision arithmetic than most other objects. When the series and shunt branches have very different impedances, for example if one is shorted or open and the other contains a component or components, numerical truncation could cause large errors if the values were passed directly to a single precision calculating engine or the **EZNEC** mixed precision NEC-2 engine. This problem is avoided in **EZNEC** by limiting the impedance ranges of the branches when using single or mixed precision calculations. When necessary, **EZNEC** modifies the values used for calculation by applying these limits. Application of limits depends on the absolute and relative impedances specified for the branches, and won't usually be apparent in the results. The limitation is most likely to be noticed when **EZNEC** raises the impedance of a shorted branch. In some cases, the resulting impedance used for calculation can be as high as one ohm. This won't usually cause any significant change in results, but might be noticeable in some extreme cases.
These limitations can be avoided by always using a double-precision calculating engine as recommended. (In **EZNEC Pro+ v. 7.0**, double precision

calculating engines are standard and single precision engines can be used only via a Special Option.) The increased resolution of the double precision engines increases the allowable impedance ranges to the point where no applied limitation will cause a noticeable change in results. Commonly available external NEC-4.2 and NEC-5 calculating engine programs are double precision.

Using Y Parameter Networks

Y Parameter Networks

Y Parameter Networks are insertion objects which can be used to simulate most two port networks. The network's admittance characteristics are defined as y parameters. These admittances don't change with frequency, so the model must be changed for each frequency if the network is intended to represent one which includes real reactive components.
This feature, intended for engineering-level users, is the direct equivalent of the NEC network (NT) model. Connection rules are the same as for other insertion objects. Full discussion of y parameter network techniques is beyond the scope of this manual; it's assumed that the user is familiar with the use of these networks.
Very briefly, the Y Parameter Network object is a two port network defined by y parameters y11, y12, and y22. The y parameter networks are reciprocal, so y21 = y12. Standard rules and definitions for two port networks and y parameters apply. Currents are defined as positive flowing into the positive port terminals, and
i1 = v1 * y11 + v2 * y12
i2 = v1 * y12 + v2 * y22
from which it can be seen that y11 is the admittance looking into port 1 with port 2 short circuited (v2 = 0), and y22 the admittance looking into port 2 with port 1 short circuited (v1 = 0). Y12 is the short-circuit current at port 2 divided by the voltage at port 1, or the short-circuit current at port 1 divided by the voltage at port 2.
Transmission lines, transformers, and L networks cover most of the common uses for networks and are simpler to use. In addition, L networks allow use of realistic components with frequency-varying impedances. But more complex networks can be devised if desired by using this feature. Remember that the y network impedances don't change with frequency, so in networks which aren't purely resistive, the y parameters will usually have to be redefined for each analysis frequency.

Using the Y Parameter Networks Window

Open the Y Parameter Networks Window by clicking on the Control Center Y Parameter Networks line or the button to its left.

Specifying Connections

Like other insertion objects, both ports of all Y parameter networks have to be placed on real or virtual segments. See Placing Insertion Objects on Segments for details.

Specifying Y11, Y12, and Y22

The real and imaginary parts of each admittance are entered in the appropriate cells in the grid. Y11 is the admittance looking into port 1 with port 2 short circuited, Y22 the admittance looking into port 2 with port 1 short circuited, and Y12 is the short-circuit current at port 2 divided by the voltage at port 1, or the short-circuit current at port 1 divided by the voltage at port 2. See Y Parameter Networks for additional information.

Selecting, Adding, Deleting, Copying, Modifying, and Moving Y Parameter Networks

See Using Insertion Objects Windows.

Modeling Ground

About Ground Models

Ground has a profound effect on the antenna pattern, and sometimes on its efficiency and feedpoint impedance. **EZNEC** provides several choices for modeling these effects. The three basic ground types, selected via the Control Center Information Window Ground Type line, are Free Space, Perfect, and Real. Free Space is no ground at all. Perfect is a perfectly conducting ground plane which is completely flat and infinite in extent. The Real ground type is further subdivided into several models, discussed in Real Ground Types. Real ground is also flat and infinite in extent and depth, although one downward step from the flat surface is permitted (see Using Two Ground Media).

When anything but Free Space is specified, ground always begins at Z = 0 and occupies everything below that. Except for Free Space or when using an NEC-4.2 or -5 calculating engine, no wires can have a Z coordinate less than zero. Whenever any ground type other than Free Space is specified, no wire can have both ends at Z = 0, that is at the ground surface, with any program type. Horizontal wires should be at least 1/1000 wavelength above (and when using NEC-4.2 or -5, also below) the ground. See Elevated Radial Systems for more information about low horizontal wires.

EZNEC Pro+, when using an NEC-4.2 or -5 calculating engine, is able to model buried wires. When using NEC-2, it's not.. However, buried radial systems or other buried conductors can be simulated with the NEC-2 engine -- see Buried Wires for information.

Free Space – Free space analysis is computationally the fastest. It's useful for comparing antennas when the end operating environment isn't known, or for comparing the pattern of a model antenna with published free-space patterns of other antennas. When antennas have similar vertical patterns in the main direction of interest, the gain of the antennas when mounted over ground at the same height will differ by about the same amount as the free-space gain. A dipole and a Yagi of a few elements are in this category, so the free-space gain of a Yagi compared to that of a dipole is very nearly the same as the gain difference when both antennas are mounted at the same height. This isn't true, however, for antennas with different polarizations, such as a ground plane and dipole, or for antennas with quite different vertical patterns, such as a dipole and W8JK antenna.

Free space analysis is also useful when working with a line-of-sight antenna having a downward-tilting pattern. When any ground is specified, **EZNEC** will always report zero signal level at any elevation angle below the horizon. So

either free space or near field analysis has to be used to determine how much signal is being directed downward.
Perfect – Perfect ground is useful to simulate the highly conductive ground seen in some antenna test chambers and ranges. It's can also be used for comparing results with textbook patterns that make the assumption of perfect ground. I've often used it to educate people about the effect of finite ground conductivity on antenna patterns by comparing perfect ground results with real ground results. Yet another use is when evaluating source placement with the Average Gain feature. To use Average Gain for evaluating source placement errors, loss must be reduced to zero. Ground loss can be reduced to zero by temporarily changing the ground type to Perfect.
Wires can be connected directly to perfect ground, and the connections have zero resistance.
The one thing you shouldn't use the perfect ground type for is simulating real Earth ground.
Real – The Real ground types are used for simulating actual Earth ground. Unfortunately, none of the models are faultless -- otherwise there would be only one Real ground model type instead of two (or for NEC-4.2 calculating engines, three). It's important to know which to use in a given circumstance, so please carefully study the sections about Real ground types and Limitations of Real Ground Models.

Real Ground Types

EZNEC provides two or three different models for simulating "real" – as opposed to perfect -- ground. None do the job perfectly, and one is generally the best for a given situation. It's important to know which ground model to use and what the limitations of each are.
The Real ground models are MININEC-type, High Accuracy, and Extended Accuracy. Not all are available with all calculating engines -- see the graphic in Calculating Engines for specifics. The choice is made via the Control Center Information Window Ground Type line. Ground characteristics are defined in the Media Window, which is opened by clicking the Ground Descrip line or button in the Control Center. The Real ground models share these common characteristics:

- All are perfectly flat and infinite in extent.
- All are homogeneous to an infinite depth.
- All have user-defined conductivity and relative permittivity (dielectric constant).
- All allow a maximum of two media, each with its own characteristics. The second medium can be at a lower level than the first if desired.

The ground model consists of one or two media, (NEC-5 permits only one) which are separated by a radial or linear boundary. If the radial boundary is chosen, the first medium is a disk, with the second medium occupying the remainder of the (infinite) ground plane. If the boundary is linear, the first medium occupies the ground to the -x side of a line parallel with the y axis, the remainder of the ground being the second medium. The "boundary" is the radius of the disk (radial type) or the x value of the dividing line (linear type).
When a new Real ground is created, the initial values for its conductivity and dielectric constant are determined by the values entered in the Control Center Options menu Default Ground Const selection.

NEC-2 is not able to model buried wires, so **EZNEC Pro/2+** isn't able unless an external NEC-4.2 or -5 calculating engine is used. NEC-4.2 and -5 calculating engines are able to model buried wires only when using the High Accuracy or Extended Accuracy ground types.
The unique characteristics and uses of each Real ground type are outlined below.

MININEC-TYPE

MININEC-type ground is not recommended unless direct connection must be made to the ground, for example in modeling a ground mounted vertical. High or Extended Accuracy ground should be used in other cases.

Like the High and Extended Accuracy real ground models, the MININEC-type model takes ground conductivity and dielectric constant (relative permittivity) into consideration when it calculates the pattern and gain. However, it considers the ground to be perfect when calculating the impedances and currents. The net effect is that a connection to MININEC-type ground has zero resistance (unlike the High and Extended Accuracy ground models) so there's no ground conduction loss, but the effect of ground on the pattern is included. When using current or voltage sources, impedances and currents calculated with MININEC-type ground are the same as for Perfect ground. However, this is not the case when using plane wave excitation since the impinging plane wave reflects off the non-ideal ground before reaching the antenna.
MININEC-type ground results in faster calculation than High and Extended Accuracy ground, and is satisfactory if the antenna doesn't contain any horizontal wires which are lower than about 0.2 wavelength, or higher if the wire is much longer than a half wavelength or so. However, the speed difference is minor for models of moderate size, so High or Extended Accuracy ground should be used unless direct connection to ground is needed. MININEC-type ground is needed when modeling grounded wires, such as verticals. When using MININEC-type ground, a load must be added to grounded wires at the grounded segment if ground system loss is to be simulated.

Do not use this ground type if the model contains horizontal wires lower than about 0.2 wavelength. The minimum height increases for horizontal wires longer than about a half wavelength.

This ground type can't be used with buried wires (available with NEC-4.2 and -5).

Some features aren't available with some calculating engines when using MININEC-type ground. See the graphic in Calculating Engines for specifics.

MININEC-type ground isn't recommended for use with plane wave excitation and NEC-2 or -4.2 calculating engines. See Plane Wave Excitation With a Ground Plane for details.

HIGH AND EXTENDED ACCURACY

Of these two ground types, NEC-2 offers only High Accuracy ground, NEC-5 only Extended Accuracy, and NEC-4.2 both.
High or Extended Accuracy (NEC Sommerfeld or GN2/GN3) ground is required for antennas with low horizontal wires, and is highly recommended for use unless a direct, zero-ohm connection to ground is required. When

High or Extended Accuracy ground is used, a Sommerfeld-Norton interpolation table is calculated. Although this calculation is quite fast with modern computers, the resulting table is saved on the disk when using an internal calculating engine. If future runs require a table with similar values, an already-calculated table is read and used instead of repeating the calculations. The key parameter which determines whether an existing table is close enough is the ground's complex permittivity (which is a function of the frequency and the ground conductivity and permittivity). If a table is found for a magnitude within a user-specified tolerance of the required magnitude, it will be used. You can change this tolerance, if desired, from the Control Center Options menu. A tolerance value of a percent or so is adequate where horizontal wires aren't extremely close to the ground. In situations requiring high accuracy, or where there are low horizontal wires, a much smaller tolerance, perhaps 0.05% or even 0%, is recommended. This applies only when using internal NEC-2 or -4.2 calculating engines.
Direct connection of wires to High or Extended Accuracy type ground shouldn't be made. See Connecting Wires To Ground.
High or Extended Accuracy ground is required for modeling buried wires with NEC-4.2 or -5 calculating engines.

Extended Accuracy

This ground model is available only NEC-4.2 or -5 calculating engine. It's the GN3 ground type introduced in NEC-4.2, and gives significantly improved accuracy in some situations, including ones where the ground conductivity and/or dielectric constant are outside the range normally encountered for Earth ground or water. There can be, however, a high price to be paid for this improvement: Extended Accuracy ground slows impedance calculation by approximately a factor of four. This is the dominant time consuming part of the overall calculation with large models, so Extended Accuracy ground should be used only when needed, especially when the model is large. Extended Accuracy ground shares the limitation of High Accuracy ground in that the ground is assumed to be homogeneous to an infinite depth. High Accuracy
Descriptions saved with High Accuracy ground can have their ground type automatically changed to Extended Accuracy when opened and using an NEC-4.2 calculating engine via the Default NEC-4 Ground Type selection in the Options menu. This should be done only with awareness of the speed penalty incurred with Extended Accuracy ground. High Accuracy ground isn't available with NEC-5, so models with High Accuracy ground will be converted to Extended Accuracy when opened with NEC-5.

Limitations of Real Ground Models

EZNEC's Real ground model might not be representative of some real ground situations. At lower frequencies, current penetration becomes deep, with skin depth being on the order of several meters at the lower end of the HF range. Real ground is likely to be stratified with widely varying conductivity and dielectric constant within this depth range. Because NEC, therefore **EZNEC**, assumes a perfectly homogeneous ground of infinite depth, the model may not accurately reflect the antenna's actual environment. While NEC is believed to be accurate in its evaluation of the model, it cannot accurately predict antenna performance if the model does not adequately represent the

real situation. Consequently, **EZNEC** results for antennas with very low horizontal wires or [NEC-4.2 and -5 calculating engines only] with buried wires, particularly at lower frequencies, may be of limited usefulness in predicting actual antenna system performance. **EZNEC** is not able to model ground as being composed of other than a single homogeneous material of infinite depth. **EZNEC Pro/2+** is not able to model buried wires except with an external NEC-4.2 or -5 calculating engine..
Another factor limiting the ability to predict antenna performance when ground is a major factor is that actual ground conductivity appears to vary with frequency, an effect not accommodated by **EZNEC**. Consequently, conductivity values for frequencies other than the frequency of use might not be accurate.
It's also important to be aware of your limited ability to make realistic connections to ground, as outlined in Real Ground Types.
See Vertical Antennas and Buried Radials for more about the limitations of Real ground models.
The Real, High Accuracy (Sommerfeld) ground model will produce erroneous results if the ground conductivity is specified to be much greater than that of salt water (about 5 S/m) and an NEC-4.2 calculating engine is being used. Extended Accuracy ground should be used if ground parameters are outside this range.. NEC-2 is more tolerant than NEC-4.2 of high conductivities when using High Accuracy ground, and NEC-5 has only Extended Accuracy and not High Accuracy ground. Overall, NEC-5 appears to produce slightly more accurate results than NEC-4.2 and might have a wider range of acceptable ground characteristics.

Using The Media Window

Note: A second ground medium isn't available when using an NEC-5 calculating engine.
This window is available when Real ground type is selected, and is opened by clicking on the Ground Descrip line or selection button in the Control Center. The ground constants entered in this menu are used somewhat differently for two purposes. When Real/High or Extended Accuracy ground is chosen, the constants of the first medium are used during determination of antenna impedance and currents. When a second medium has been defined, the constants of both media are used during pattern calculation, by modifying the strength and phase of the field reflected from the ground. (Exception: Only the first medium is used when ground wave or near field analysis is being done.) Ground constants are not used if Free Space or Perfect ground is specified, and are used only for pattern calculation if Real/MININEC-type ground is being used. Real/MININEC-type analysis assumes a perfect ground during impedance and current calculations. See Real Ground Types and Ground Media for more information.

Selecting the Conductivity and Dielectric Constant

The conductivity in Siemens/meter and the dielectric constant (relative permittivity) can be entered directly in the corresponding columns if desired. Right-clicking either of these columns opens a dialog box giving you a choice of a wide variety of typical ground types. The selection of ground conductivity makes little difference for horizontal wires of moderate height, but it can be very important for vertically polarized antennas. When a medium is first

created, its initial conductivity and dielectric constant values are determined by the Control Center Options menu selection Default Ground Const.

Adding A Second Medium

To add a second medium, click Add in the Medium menu, or simply enter the values in the add row at the bottom of the grid. Empty cells or newly created media will use the conductivity and dielectric constant values specified by the Control Center Options menu selection Default Ground Const. Please review Using Two Ground Media before using a second medium.

Completing the Specification

Enter the second medium height and boundary in the remaining two columns. These values are fixed and can't be altered for the first medium. To change the boundary type between the media, select Boundary Type in the Medium menu.

Adding an NEC Radial Model

See The NEC Radial Model.

Using Two Ground Media

This applies only to NEC-2 and NEC-4.2 calculating engines. NEC-5 permits only one ground medium.

The ground may be broken into two "media", each having its own conductivity and dielectric constant (relative permittivity). The second medium can be at a different height, but must be at the same level or below the first medium. The media can be arranged in parallel slices or concentric rings. One use of two media would be to model an antenna on a lake surrounded by land. A very important thing to understand is that the second medium is used only for far field pattern calculations, and is ignored for all other purposes. Be careful when using two media, and keep the following in mind:

1. Even if you place the antenna over the second medium, **EZNEC** will always use the ground constants and height (z = 0) of the first medium for calculation of the impedances and currents.
2. The second medium is used only for far field calculations. Near Field and Ground Wave calculations assume that the first medium is of infinite extent, and ignores the second medium.
3. The effect of the second medium is taken into account only in a very simplified way. The vertical pattern is generated by tracing "rays" direct from the antenna and reflected from the ground. When a second medium is used, the ground reflection "ray" is determined by whichever medium it strikes the top of. The "ray" does not penetrate either medium, and diffraction or similar effects aren't considered. *Because of this, a highly conductive inner medium and normally conductive outer medium is **not** a good model of a ground radial system, and shouldn't be used for this purpose.*
4. Buried wires available with NEC-4.2 will always be treated as though they're immersed wholly in the first medium.

When a second ground medium is first created, its conductivity and dielectric constant are set to the default values determined by the Control Center Options menu Default Ground Const selection.

Connecting Wires to Ground

A Wire end is connected to ground by specifying a zero z-coordinate. **EZNEC** actually considers a wire end to be connected to ground if it is within about 1/1000 of a segment length of ground. A good general practice is to space unconnected vertical or sloping wires at least several wire diameters above ground. A wire with both ends within 1/1000 segment length of ground is not permitted and will produce an error message.
If you connect a wire to ground when using the High or Extended Accuracy real ground type, the program makes the connection with an unpredictable series resistance. **EZNEC** will warn you when this situation occurs. Use the MININEC-type ground when modeling antennas with vertical, grounded wires if the ground system itself isn't part of the model.
Sometimes it's necessary with NEC-2 to both make a ground connection and use High Accuracy ground. A technique for simulating this is described in Connecting to High Accuracy Ground.

Connecting to High Accuracy Ground

This applies also to Extended Accuracy ground, available only with NEC-4.2 and -5.
Sometimes it's necessary to make a ground connection and use High Accuracy ground. An example of this situation is in modeling a Beverage antenna, where a connection is needed for the termination resistor. Another example is an inverted L antenna where the horizontal portion is lower than about 0.2 wavelength. The NEC-4.2 and -5 calculating engines are able to model buried conductors, so you can directly model the buried ground system to be used with the antenna. See Buried Wires for more information.
With the NEC-2 calculating engines the best way to approximate a buried radial system is by creating horizontal radials just above the ground, and make the "ground" connection to the radials. A height of between about 1/100 and 1/1000 of a wavelength is suitable, but in any case no less than several wire diameters. If a low impedance connection is required, make the radials about a quarter wavelength or odd multiples long, and avoid lengths approaching a half wavelength or multiples. These aren't free space wavelengths, however, but wavelengths for a wire at the radial height. A half wavelength for a wire very close to the ground will be less than in free space, though. You can determine the wavelength by modeling a dipole at the height of the radials and adjusting its length until it's resonant. Be sure you're seeing the lowest (series) resonance, which for very low wires will occur with a dipole length somewhat less than a free space half wavelength. The best radial length will be about half the resonant dipole length.
Radials can easily be constructed using **EZNEC**'s automated radial creation feature. Above ground radials will show resonant effects more sharply than buried radials, but will provide a reasonable approximation of a buried radial system.

The NEC Radial Model

If you would like to use the NEC buried ground radial model, please first read this section very carefully. It deals only with the NEC ground radial model available in the Media Window (Other menu), not the "Create Radials" feature

in the Wires Window, or radials modeled as wires. **This option is not available when using NEC-5 for calculations**.
The NEC buried ground radial model is not actually a model of buried wires, and ***it does* not *model the effect of ground radials on antenna impedance, current, loss, or efficiency***. It does approximately model the effect of ground radials on the pattern, an effect which is generally slight, unless ground radials are extraordinarily long. (See Vertical Antennas And Buried Radials for more information.)
The effect of the NEC buried ground radial model on feedpoint impedance is different than the effect of a real radial system on a real antenna. The presence of any NEC radials at all, even one very short radial, will change the NEC-calculated ground connection resistance to zero, but only at the point (x, y, z) = (0, 0, 0). Experiments have shown this to not always be true when using the NEC-2 engine and wires connecting to ground at a sloping angle. The resistance of connections to ground at other points will have an unpredictable resistance, as they do without the radials. This means that the ***model radials won't accurately predict the input impedance of a grounded wire such as a vertical antenna***. The NEC buried ground radial model is used only for calculation of ground reflection coefficients for the far field patterns. Even for this limited use, the buried radial model isn't accurate unless there are many radials and the radial field. Accuracy is also poor when the radial field diameter is only a fraction of a wavelength and/or the antenna is relatively close to the radial field. For typical vertical antenna radial fields, a model with radial wires suspended just above the ground (or below the ground with **EZNEC Pro/4)** results in much greater accuracy than using the NEC radial model. The conductivity of the radials is "peanut-buttered" over the entire ground area that the radials cover (varying with distance from the origin), and the result is simply paralleled with the ground conductivity in the region where the radials are placed. Four radials simply look like thinner "peanut butter" than 120 do.
Once again, ***the NEC model radials do* not *represent a true picture of the effect of real ground radials***. Other methods are generally preferred, as outlined in Vertical Antennas And Buried Radials. Ground radials can be modeled with reasonable accuracy using **EZNEC Pro/2+** with an external NEC-4.2 or -5 calculating engine or with **EZNEC Pro/4+** with either of those or its internal NEC-4.2 engine, so the use of the radial model isn't generally recommended if any of these is available.
Before it can be used, the NEC buried radial model feature must be enabled by means of Special Option NECRadials.
Once this feature is enabled, radials can be entered and modified via the Other menu in the Media Window. This selection will be unavailable (grayed out) unless all the following conditions are met:

1. The feature must be enabled with the Special Option referenced above.
2. Ground type must be Real, MININEC-type.
3. There must be two media (not available with NEC-5)
4. The media boundary type must be radial, not linear. (When the boundary is radial, the upper heading of the rightmost Media Window column is "R Coordinate", not "X Coordinate". You can change it via the Media menu.

5. Ground Wave analysis must be turned off.

When all these conditions are met, the choice will be available, and you can select the number and diameter of the radials. The radial length is always the diameter of the first medium, so to change the length you change the boundary of the second medium.

If desired, you can enter the wire diameter as wire gauge (AWG) by typing '#--' where "--" represents the wire gauge. Gauges of wires larger than #0 (i.e., #00) are not permitted.

After the entry is complete and the dialog box closed, the number of radials will appear in the Control Center Information Window as part of the Ground Descrip entry.

Interpreting The Results

Currents

The currents at the center of each segment can be displayed with the View Antenna feature or seen in tabular form by clicking the Control Center Currents action button. The currents give important information about antenna operation. In addition, they're invaluable in assessing whether the antenna is working as intended and in spotting conditions where **EZNEC** is being used beyond its capabilities. Note that the View Antenna display is intended as a visual aid. Although the overall display is correct, it has been smoothed so that details about the current along a single segment or at the junction of two segments may not be precise. If you need this level of detail, refer to the tabular data.

The currents and optional charge densities shown in the Currents display and the currents shown in the View Antenna display are those at the segment centers. The Source Data and Load Data displays show currents at the positions of the sources and loads. When using an NEC-2 or -4.2 calculating engine, sources, loads, and other insertion objects are placed at segment centers so Source or Load Data currents will be the same as those on the respective segments in the Currents display. However, insertion objects are placed at segment junctions in NEC-5, so you won't see any currents in the Currents display which are exactly the same as those in Source or Load Data.

One thing to look for is symmetry. If the antenna is symmetrical, the currents should be also. If not, some error has been made in wire definition, source placement, or some other area. For example, the current from the vertical part of a ground plane antenna should split evenly among the radials if the radials are the same length and evenly spaced. Make it a habit to look for these symmetries and you'll spot problems before bad results lead you astray.

Another thing to look for is abrupt and unexplained current changes (instead of a smooth change from one segment to the next). This usually is due to not having enough segments but might be due to some other factor causing **EZNEC** to be operating beyond its limits. Sudden current reversals may be no cause for concern as they might be due to the way the wires have been defined. Positive current flow always is defined as being from end 1 to end 2, so if two end 1's or two end 2's are connected together, a 180-degree shift in current direction will be indicated at the junction of the wires (provided View Antenna phase information is on or you're looking at the currents in tabular form). The current actually is continuous as it should be, but the definition of direction changes from one wire to the other. There's nothing wrong with connecting wires in this fashion but don't be confused by the currents **EZNEC** shows as a result. Watch for this also when using multiple sources -- see Using Multiple Sources.

Current phase information can be included on the View Antenna display, but it frequently conceals important information about what's happening to the magnitude of the currents. See The View Antenna Display for more information about this feature.

The importance of currents is underscored by the fact that the field generated by a wire is proportional to the current flowing on it. If one element of a multi-element antenna shows a small current relative to the others, it's not

contributing much to the overall field. It might, however, be generating just enough to deepen a null in the pattern. If your model contains several nearby wires, towers, and other objects, a look at the currents on them will quickly tell you whether they're having a significant effect on your antenna's performance. If the current on an object is small relative to the current on your antenna, you generally can remove it from the model without much impact on the result (unless deep nulls are important; even small fields can have a significant effect on nulls). Shorter conductors require more current than long ones to have the same effect.
Charge density can optionally be included in the Currents display via a choice in the Control Center Options menu. This can be useful in determining the E field strength near the wire.
If using plane wave excitation, see Interpreting Plane Wave Results for additional information.

Load Data

Load data are shown by clicking the Load Dat action button in the Control Center. The RMS voltage across, RMS current through, impedance of, and power loss of each load is shown. In addition, the total load loss is shown in watts and dB. The loss figures are invaluable in determining the loss caused by traps, loading coils, and the like. You can also determine the voltage across the load or current through it under actual operating conditions by entering, via the Power Level selection in the Control Center Options menu, the total power supplied from the source(s).
If two identical loads appear on identical adjacent segments with NEC-2 or NEC-4.2 calculating engines, **EZNEC** will also show you the data for the two loads together. This is so you can simulate a load placed at a wire junction by splitting it in half and putting it on adjacent segments as described in Placing Loads At Wire Junctions. This does not apply to NEC -5 where loads and other insertion objects are placed at segment junctions.
Series and parallel connected loads might show a 180 degree phase difference in voltage and current. See Parallel Connected Loads Polarity for an explanation.
The currents and optional charge densities shown in the Currents display and the currents shown in the View Antenna display are those at the segment centers. The Source Data and Load Data displays show currents at the positions of the sources and loads. When using an NEC-2 or -4.2 calculating engine, sources, loads, and other insertion objects are placed at segment centers so Source or Load Data currents will be the same as those on the respective segments in the Currents display. However, insertion objects are placed at segment junctions in NEC-5, so you won't see any currents in the Currents display which are exactly the same as those in Source or Load Data.

Source Data

The impedance, SWR, RMS voltage, and RMS current at each source can be viewed or printed by clicking the Src Dat action button in the Control Center. In addition, a graph of the SWR vs. frequency can be displayed by clicking the SWR action button. If **EZNEC** reports a very low value of resistance at any source, be careful -- this might indicate operation beyond **EZNEC**'s limits. If two elements are closely spaced and fed out of phase (W8JK-type antennas),

the low resistance is real but the real antenna might not work like **EZNEC** predicts unless you've included wire loss (a Control Center choice). Losses become important when the resistance is low, so be sure wire loss is included if a low resistance is indicated. Negative resistances sometimes are reported for multi-element arrays. These actually can occur but are subject to the same cautions as low positive resistances. (The SWR for these sources will be reported as "undefined", and shown on the graph as infinite.) A negative source resistance where only one source is used is positive indication of operation of **EZNEC** beyond its capabilities. Very small loops, particularly ones containing a source, are often the cause of this condition.
The SWR shown is the SWR which would be present on a transmission line connected in place of the source. Values are given for 50 ohm and user-specified feedline impedances. (The user-specified impedance is selected with choice Alt SWR Z0 the Control Center Information Window.) The SWR is directly calculated from the source impedance. If a source is connected to a transmission line model and you want to know the SWR on the transmission line, the SWR reference impedance must match the characteristic impedance of the transmission line.

Negative Input Resistance

Occasionally a negative resistance might be shown at one or more sources. If a single source is being used, this is a positive indication of a numerical error, since it represents an antenna which is producing, rather than accepting power. The most common cause is a source placed in a very small loop. (See Small Loops.) When multiple sources are used, a negative input resistance can be a valid result. This actually occurs in some arrays, and represents an element which is delivering power back to the feed system. It gets this power from the other elements via mutual coupling. The 4Square example description illustrates this characteristic. There's more information in the Antenna Notes file for this example.
The currents and optional charge densities shown in the Currents display and the currents shown in the View Antenna display are those at the segment centers. The Source Data and Load Data displays show currents at the positions of the sources and loads. When using an NEC-2 or -4.2 calculating engine, sources, loads, and other insertion objects are placed at segment centers so Source or Load Data currents will be the same as those on the respective segments in the Currents display. However, insertion objects are placed at segment junctions in NEC-5, so you won't see any currents in the Currents display which are exactly the same as those in Source or Load Data. The Source Data display isn't available when plane wave excitation is being used.

Far Field Table

The Far Field Table is accessed by clicking the FF Tab action button in the Control Center. It shows the field strength at each azimuth and/or elevation angle. If you've selected a 3D plot type, you'll be asked which data to display and how it's to be organized.
The Far Field Table data can be shown in several different formats, as selected via the Control Center Options menu Far Field Table Units selection. They are:

dBi or dBref – Shows the same data as the 2D plot. Values are relative to the reference value set by the Control Center Ref Level choice, or in dBi if the reference level is zero.
mV/m for 1 kW at 1 mile – Gives the field strength in mV/m at one mile, assuming a supplied power of 1 kW. Any setting of the Control Center Options/Power Level is ignored.
mV/m for 1 kW at 1 km – Same as above, but at a distance of 1 km.
Ground wave analysis choices
dBi or dBref – Same as for ordinary far field.
mV/m – Absolute value of the field at the distance and height specified in the Control Center Information Window. You'll generally want to set the power level, via the Control Center Options menu Power Level selection, before using this option.
Additional choices when a plane wave source is used:
dBsw or dBref - dB relative to one square wavelength scattering cross section.
mV/m X dist - Divide the reported value by the distance in meters to get field stregth in mV/m at that distance.
See the Options section of the Control Center Menus chapter in the Reference section for more details.
You can also choose whether to show linear or circular components. This is done with the Control Center Desc Options selection, Plot/Fields tabs.
Display of the phase angles of the field components can be removed via the Special Option FFPhase.
If using plane wave excitation, see Interpreting Plane Wave Results for additional information.

Near Field Table

Unlike far fields, the near fields can be oriented in any direction. They are broken into three components, in the X, Y, and Z directions. A total is also shown. The total is generally all that will be used unless you have an interest in the orientation of the E or H field. **EZNEC** also reports, near the top of the list, the largest field that was found. Be careful that none of the steps falls inside a wire; if it does, the results for that step won't be meaningful, and it could be reported as the maximum value. Near field analysis uses only the first ground medium. If two ground media are defined, the second will be ignored.
Because the ratio of E (electric) to H (magnetic) near field depends on the antenna type and the distance from it, the two fields must be analyzed separately.
Note that "Near Field" analysis actually reports the total field, so it's valid at any distance, including far from the antenna and including the ground wave field. Field strengths are RMS values. For more information, see Near Field Analysis in the Reference section.
Remember that many factors affect the results from a modeling program. ***EZNEC should not, under any circumstances, be used to determine whether the energy or field strength from an antenna presents a hazard or unsafe condition.*** This applies to all results, including both Far Field and Near Field.

If using plane wave excitation, see Interpreting Plane Wave Results for additional information.

Far Field Patterns

Three choices of far field plot are available, (2D) Azimuth, (2D) Elevation, and Three Dimensional (3D), although only azimuth is available if the ground wave component is included. Any elevation angle can be chosen for azimuth plots, and any azimuth angle for elevation plots. 2D plot range can be restricted if desired. The step size can be chosen; a too-coarse step size results in a jagged pattern, and a very fine step size may produce more data than needed or desired. Both the observation distance and height above ground can be freely chosen when the ground wave component is included. **EZNEC** includes a visualization aid for orienting the pattern relative to the antenna, in the View Antenna display, where the 2D pattern plot or a "slice" of the 3D plot can be superimposed on the representation of the antenna. More information about these features can be found in The 2D Display and The 3D Display sections of the Reference chapter.

Because the far field sky wave from a horizontally polarized source is zero at a zero elevation angle for any ground type, and a vertically polarized source produces zero sky wave for any finite-conductivity ground, attempts to calculate a 2D pattern without the ground wave component under these conditions will result in an error message.

The 2D Data box (activated via the 2D Display View/Show Data selection) shows a summary of key pattern characteristics, such as beamwidth and front/back ratio.

EZNEC offers an alternate azimuth coordinate choice, "compass bearing". This presents azimuth angles in degrees clockwise from the +y axis (straight up on the 2D plot), to correspond to compass bearing. The choice is made in the Control Center Options Menu as Angle Convention. No change to any plot orientation occurs when changing between standard and bearing representations; only reported angles change.

Various options for far field display can be selected in the Control Center window and the Control Center Desc Options selection.

If using plane wave excitation, see Interpreting Plane Wave Results for additional information.

Antenna Efficiency

Antenna efficiency is defined as the fraction of the applied power which is radiated. The remainder of the applied power is lost as heat in lossy parts of the antenna structure. System efficiency can also include the effect of ground, feedline, and matching network loss.

EZNEC allows you to set all losses to zero, resulting in a 100% efficient antenna or antenna system. You can determine efficiency by comparing the gain from this perfect system with one having realistic losses.

To set losses to zero and create a 100% efficient (lossless) antenna:

1. In the Control Center, set the Wire Loss to Zero.
2. In the Wires Window, set any insulation loss to zero.

3. If the antenna contains any loads, L networks, or Y parameter networks, set their resistances to zero, or delete them. Transformers can also introduce loss, so delete those if possible.
4. If there are any transmission lines in the antenna, set the line loss to zero.

If any kind of Real ground is specified and you want to include the ground loss in the efficiency calculation, change the Ground Type to Perfect.
If you want to include feedline and matching network losses in the efficiency calculation, do steps 3 and 4 above for feedlines and matching network components as well as for antenna components..
If there are only a few items to change, it's easiest to switch between the lossy and lossless models by using the Undo/Redo feature. Otherwise, it might be easier to save the different configurations with different file names.
If the pattern of the antenna with loss is nearly the same as the pattern of the lossless antenna, you can simply compare the gains of the two at the pattern maximum. If they differ by, for example, 6 dB, the efficiency is 25% = 1/4. If the patterns are different, it will be necessary to use the Average Gain feature to find the efficiency. (It can also be used if the patterns are the same, to simplify numerical calculations.) You simply divide the numerical Average Gain of the antenna with loss by the Average Gain of the lossless antenna. For example, if the Average Gain with loss is 0.25 (-6 dB) and with no loss 1 (0 dB), the efficiency is 0.25/1 = 25%.

Reference

Features

Antenna Notes

Antenna Notes are a way to include notes with your antenna description. An Antenna Notes file is an ordinary ASCII text file which has the same name as the associated antenna description file, but with a .txt extension in place of the description file .ez extension. The Antenna Notes file is kept in the same directory as the description files. Antenna Notes files can be edited with any text editor, or from within **EZNEC**.

To create, view, or edit an Antenna Notes file for the current description, click the Control Center Ant Notes button which opens the file in the **EZNEC** Editor. When you're finished, select File/Save within the Editor, then close it. To edit the Antenna Notes file for another description, open the File menu and select Edit Antenna Notes.

When you save an antenna description, you might see a dialog box asking you what to do with the corresponding Antenna Notes file. Both the Antenna Notes file associated with the current description, and the one associated with the saved file name are shown, to help you decide. This dialog box won't appear if the text in the two files is identical or if you're saving the file with the same name as when it was opened.

You can also use Antenna Notes with NEC format files. Operation is similar to operation with .ez files, except that you'll see a temporary file name when you open the **EZNEC** Editor. With NEC format files, Antenna Notes are saved as a series of CM (comment) "cards". When you open the Antenna Notes for editing, **EZNEC** copies the CM card comments to a text file and opens that instead. Because there is no separate permanent Antenna Notes file, *changes you make aren't permanent until they're written into the NEC format file*. This isn't done until you save the description. So be sure to save the description file after you edit the Antenna Notes.

Automatic Segmentation

Automatic wire segmentation is available in the Wires Window (Wire/Auto Seg) and in the Segmentation Check display (Segmentation menu, enabled only if one or more wires produces a warning). Two choices are offered, Conservative and Minimum Recommended. The Conservative choice is best for general use. If computation time becomes too long or the total number of segments becomes excessive, the Minimum Recommended choice can be used. In any case, don't blindly depend on the automatic segmentation to always choose the optimum number of segments. There are many occasions, such as several described in the chapter "Some Special Cases" in "Modeling The Antenna Structure" which require more segments. In some other cases, such as placement of a source or load on a short wire or when dealing with closely spaced parallel wires, the segment length or alignment is important. Automatic segmentation won't recognize these special circumstances, so it will be up to you to determine how many segments are required.

Probably the best use of automatic segmentation is as a first segmentation of a new antenna description, as an initial setting.

Segmentation Check has a related feature called Fix Segs which is described in the Segmentation Check topic.

Average Gain

Average Gain is a valuable tool in detecting situations where **EZNEC**'s calculating engine is having difficulty, particularly in situations involving source placement. A second use for Average Gain is to evaluate the amount of loss incurred by the reaction of the field with a finitely-conducting ("Real") ground, wire or wire insulation, or other components such as transmission lines or L networks whose losses aren't separately reported.

The Average gain is the total power in the far field (determined by integrating the far field in all directions) divided by the power delivered to the antenna by the sources. It's shown at the bottom of the Control Center after a 3D far field plot has been run. It is not computed for Azimuth or Elevation plot types.

EZNEC's NEC-2 and -4.2 calculating engines are very particular about the length of segments containing sources, and nearby segments. When placement isn't to its liking, an error in the form of inaccurate gain and impedance will frequently occur. Without an independent means of evaluating gain, this error can go undetected. A solution to the problem is to calculate the Average Gain. Average Gain is meaningful for assessing the validity of results only when no loss mechanisms (wire loss, resistive loads, "real" ground, etc.) are present in the model. When the Average Gain is one (with no loss present), the program is producing correct results. If it deviates significantly from this value, results are in error, and source placement should be altered if possible. Every effort should be made to correct the problem. But if this isn't possible, the pattern and gain figures can be corrected by dividing them by the Average Gain (or by subtracting the Average Gain in dB from them). The procedure for using Average Gain to evaluate source placement is detailed in the Source Placement Precautions section.

To use Average Gain to assess wire or ground loss, you should first confirm that the Average Gain is near unity when all loss has been removed from the model. When lossy factors have been restored, the Average Gain indicates the loss incurred by these factors, so comparison of the loss and no-loss Average Gains can be used to evaluate efficiency. The Source Placement Precautions section details how to set losses to zero. The message ***Model contains loss*** appears at the bottom of the Control Center adjacent to the Average Gain if loss is present in the model, to alert you to the fact that the Average Gain should not be expected to be equal or nearly equal to one (zero dB).

If it's not possible to reduce the Average Gain to nearly unity (zero dB), the gain can be corrected with fair accuracy by subtracting the Average Gain in dB from the reported field strength in dBi. For example, if the reported gain is 2 dBi and the Average Gain is 3 dB, the actual gain is 2 - 3 = -1 dBi. If there is only one source, the feedpoint resistance can also be corrected by multiplying the reported feedpoint resistance by the plain numerical (not dB) Average Gain. Unfortunately, the reactance error isn't predictable so can't be corrected by this method, and the feedpoint resistance correction won't work if there are multiple sources.

NEC-5 isn't nearly as sensitive to the placement of sources and other insertion objects, but Average Gain can still be very useful to verify that calculation errors from other causes aren't occurring.

Combining Antenna Descriptions

Antenna descriptions can be combined into a single model. One typical use would be to separately analyze Yagi antennas for different bands, then combine them to study interactions. Or parasitic structures might be modeled separately then combined in various combinations in a single model. To add an existing antenna description to the current model, choose Add Description from the Control Center File menu. Note: Saved descriptions must always contain at least one source. So if you want to save a model of a parasitic structure (that is, one which doesn't have a source), you have to add a source to it. This source can be deleted after combining it with an existing description which does have a source.

Combining and importing are sometimes confused. If you want to add wires whose coordinates are in an ASCII file, or want to replace your current model with wires from an ASCII file, see Importing Wire Coordinates.

EZNEC Editor

The **EZNEC** Editor is basically a copy of the Windows Notepad functionality. It's used as a convenient way to edit text files from within **EZNEC**. Controls, menus, and operation are very similar to Notepad, although occasionally you'll see a difference. The **EZNEC** editor is automatically opened to display a number of **EZNEC** files and outputs.

A few words about fonts -- When used for displaying tabular outputs like Currents, Source Data, Far Field Table, and so forth, the **EZNEC** Editor restricts your choices to fixed-width fonts such as FixedSys and Courier New. This permits the columnar data in these files to be properly aligned. Some fonts, such as FixedSys, are screen fonts only and can't be printed. If this happens, either Windows or **EZNEC** will substitute another font during printing. If Windows substitutes a variable-width printer font for a fixed-width screen font, the columns in certain outputs won't line up properly. If this happens, select a printable fixed-width font. The Editor will remember the last fixed width font you chose, and will continue to use it in the future until you change it again.

You can use the **EZNEC** Editor to view or edit any file, not just **EZNEC** files, by selecting View File or Edit File from the Control Center File menu. The only difference between these two is that if you open a file with the View File selection, you won't be allowed to save it under the same name. That is, it protects the original file from being changed by the editing process.

Frequency Sweep

EZNEC's frequency sweep capability can be a very valuable tool in evaluating antenna performance over a range of frequencies. However, operation is somewhat different in the frequency sweep mode, so it's important to understand the operation in order to get the most from this feature. Note that the frequency "sweep" is actually discrete steps. These can be evenly spaced or, if read from a file, any frequencies in any order.

In non-frequency sweep operation, **EZNEC** calculates antenna impedances, currents, and pattern, and keeps the current and pattern information. When changes are made to the antenna, only necessary recalculations are done. For example, when the plot elevation angle is changed, only the pattern is recalculated. This is not the case with frequency sweep. It's not practical to keep all the information for all frequencies, so final calculation results are written into an ASCII file after each frequency step. Data present in arrays are erased and **EZNEC** is reset before beginning calculations at the next frequency. Therefore, calculation results from a frequency sweep are available only in the form of the file containing the data and, optionally, a trace for each frequency. The exception to this is that data from the last frequency in the sequence can be viewed.

The frequency sweep can be run only when the Control Center Plot Type selection is Azimuth or Elevation. It can't be run when 3D plot type is selected.

One or two outputs are available from the frequency sweep: data output is always available for selection; 2D far-field plots (traces) are available only when far-field analysis (with or without ground wave) is chosen for frequency sweep. You can choose to have **EZNEC** save any combination of these. Additional impedance and SWR data are always saved, in a separate file, regardless of the outputs you choose to keep. These data are used for the SWR Graph, and reside in a comma-delimited ASCII file named LastZ.txt in the **EZNEC** output directory. This file remains after the program ends and may be used for other purposes as desired.

Following is a detailed description of the features in the Frequency Sweep Setup dialog, which is opened via the Control Center Setups menu, Frequency Sweep selection.

Frequency Sweep Off/On

Turns frequency sweep off and on.

Frequency Selection

Selects frequencies to be used for the sweep. Frequencies can be specified in one of two ways. If specified as start, stop, and step frequencies, the frequency steps will be evenly spaced, extending from the start frequency to the stop frequency. If a frequency sweep input file is specified, frequencies are read in order from the file, and there are no restrictions on spacing or order.

Start, Stop, and Step Frequency (MHz) – Specifies the range of frequencies to sweep, and the step size.

Read Frequencies From File – If this is checked, Start, Stop, and Step Frequency entries will be disabled, and a file name is required. The file must contain a list of frequencies to be used in the sweep. See "Frequency Sweep Input File" for details about the file format. If unchecked, File Name, Select, and Edit File are disabled.

File Name – Shows the name of the input file you've chosen, if Read Frequencies From File is checked. You can not enter a file name in the text box; the file must be chosen by using the dialog box opened with Select.

Select – Opens a dialog box to allow you to choose an input file.

Edit File – Opens the file shown in the File Name box for editing in the **EZNEC** Editor. If no file name has been selected, opens a dialog box allowing you to choose one.

Field

Field To Calculate – Selects whether **EZNEC** will run a far field or near field analysis for the frequency sweep. If Near Field is chosen, pattern plot output and pattern analysis data are not available, and field strength table data will be near field.

Output

Selects what data will be calculated and saved during the frequency sweep. There are three general categories of output, listed below. For each category, the output file name is specified by clicking the Select button, and the choice is shown in the corresponding text window.

Pattern Plots – If this is checked, 2D pattern plots will be saved, and shown when the frequency sweep is completed. This selection is disabled if Near Field is chosen as the Field To Calculate. Select this option when you want to see or save 2D plots for all the sweep frequencies. These plot (trace) files aren't automatically erased when the sweep ends, so they can be treated later like any other trace files. It's recommended that you use a name like "temp" for files you won't want to view at a later date, and use this same name each time you want to see frequency sweep plots but don't need to keep them. The extension .P# is added to the file name you specify, with # being 1 for the first frequency, 2 for the second, etc. These are **EZNEC** OpenPF binary plot files, and are not readable without specialized software. To save far-field plot data in readable, ASCII form, check Data File and Field Strength Table.

Data File – Saves selected data in ASCII format in a text file. The choices of data which can be saved, in the dialog Data File Contents section, are listed below.

Field Strength Table – Saves a table of field strength values for each frequency, either far field or near field, as determined by the Field To Calculate choice. The format of the data is the same as for the single frequency tabular far field (FF Tab) or near field (NF Tab) display. The locations in space where near field strength is calculated are defined in the Near Field Setup dialog.

Source Data (Incl. SWR) – Saves source data (impedance, voltage, current, power, and SWR), in the same format as for the single frequency Source Data (Src Dat) display.

Load Data – Saves load data (impedance, voltage, current, and power) in the same format as for the single frequency Load Data (Load Dat) display.

Currents – Saves wire currents in the same format as for the single frequency Currents display.

Pattern Analysis – Saves information about the plot such as maximum value, angle at which the maximum occurs, front/back or front/side ratio, etc., essentially the same information that is presented in the 2D Display Data Window. This choice is disabled when Near Field is selected as the Field To Calculate.

Although any extension can be specified for the file name by first choosing "All files" in the "Files of type" window of the file name selection dialog box, it's recommended that you let **EZNEC** add a ".txt"

extension by leaving "Text files" as the "Files of type" choice. This cues Windows to the fact that the result is a plain ASCII text file.

Geometry Check

This powerful feature, which runs automatically before each calculation or saving a file, checks the model for errors such as wires crossing at other than a wire end, wires occupying the same space or overlapping, or wires coming too close to each other.

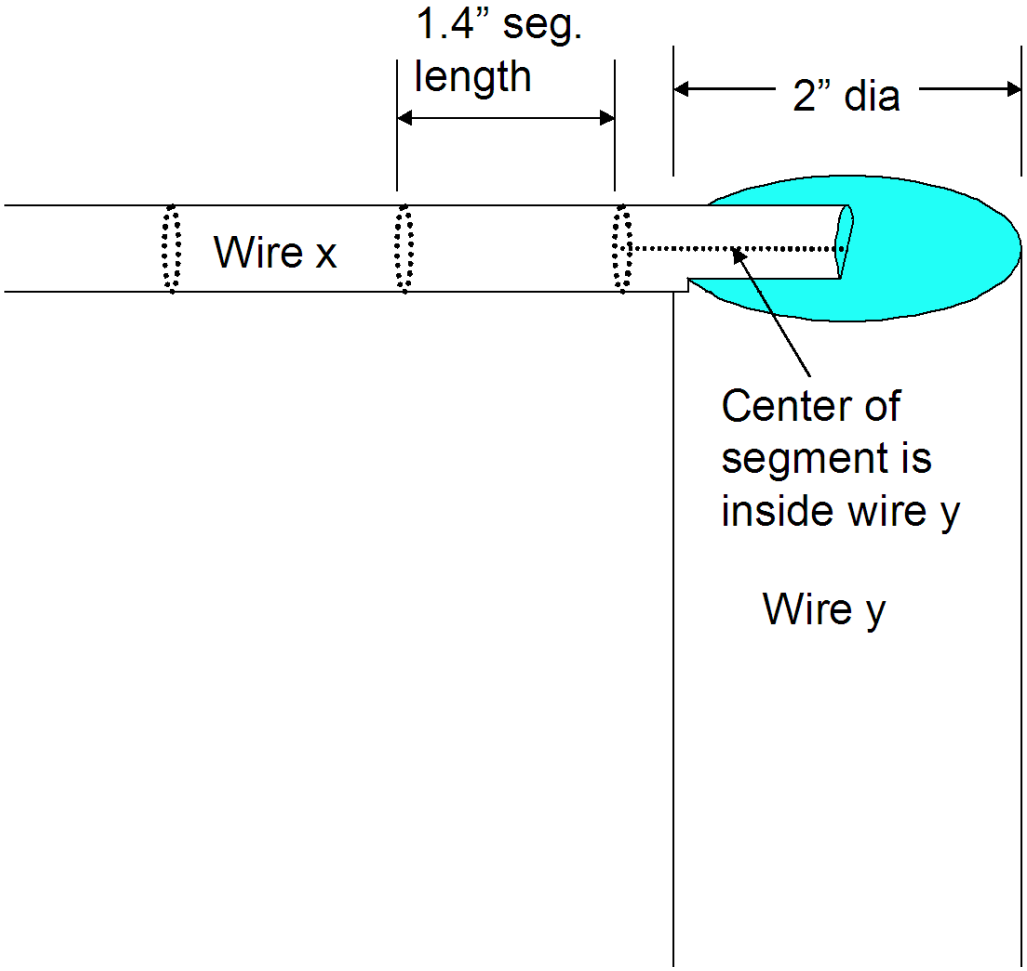
One type of geometry now considered an error is wires intersecting at segment junctions rather than at their ends. These are permitted by NEC and earlier **EZNEC** versions but not permitted with **EZNEC Pro+**. However, NEC files created by external programs and imported into **EZNEC** can contain segment junction intersections and these can be automatically converted to be acceptable -- see Segment Junction Intersections for details.

There's also an option in the Desc Options dialog (opened by clicking Desc Options in the white pane of the **Control Center**), General tab, to allow calculations to proceed if the only errors found are that a segment center is within another wire (see below). This choice is saved with the description, since the condition sometimes causes serious calculation errors and sometimes not, but it's sometimes hard to avoid. It doesn't appear to be a problem with NEC-5 so isn't checked for when using that calculating engine.

For users familiar with NEC-4.2, the Geometry Check tests for the same kinds of errors as NEC-4 and -5's SEGCHK. However, it's faster and a bit more conservative than SEGCHK, and it catches some geometry errors which SEGCHK doesn't. And it's present in **EZNEC** regardless of the calculating engine choice, even NEC-2.

"Center of wire x end segment within wire y" is a message seen when using NEC-2 and -4.2 and which brings frequent requests for explanation, so a detailed description of its cause has been included here. It occurs when two wires are connected at an angle. Suppose, for example, that one wire (let's call it wire y) has a diameter of two inches, and another wire (wire x) is connected to it at a right angle, as shown in the diagram below. If the segments of wire x are shorter than two inches, the center of the end segment of wire x will be inside wire y. The message will appear with longer wire x segments and/or smaller wire y diameter if the angle between the wires is acute. Sometimes this condition causes serious computation errors, and sometimes not. If possible, it should be avoided by decreasing the diameter of wire y, lengthening the segments of wire x, or both. The Geometry Check report of this condition can be overridden for the current model, allowing calculation to proceed, via the Desc Options selection, General tab, in the Control Center (main window). Use caution if choosing to override. An Average Gain check should be run, although a good value isn't a guarantee that results will be valid.

This doesn't seem to be a problem with NEC-5, so the error doesn't appear when that calculation engine type is in use.



Ground Wave Analysis

Ground wave analysis is similar to far field analysis in that it uses approximations valid only in the far field, but differs in that it includes the ground wave, and reports the absolute field at a specified distance rather than a relative one at an arbitrary distance.

Ground wave analysis is enabled via the Gnd Wave Dist (ground wave distance) Control Center selection. When Ground Wave analysis is enabled, the Elevation Angle or Azimuth Angle selection changes to Observation Height, which you can also specify. Note that if an observation height greater than zero is chosen, the ground wave distance is the horizontal distance from the origin to the observation point, i.e., the projection of the actual distance on the XY plane. The actual distance from the origin to the observation point is the square root of the sum of the squares of the ground wave distance and the observation height. If ground wave analysis is enabled, Plot Type is restricted to Azimuth. Results can be presented as a dBi plot, or in a table of dBi or absolute electric field values, the choice being selected with the Control Center Options menu Far Field Table Units selection. Ground wave analysis may be done with any ground type except free space. Note: If more than one medium is defined with Real ground, the analysis will be done using only the constants of the first medium as though it extends to infinity; the second medium, if present, will be ignored.

Ground wave analysis isn't available when using an external NEC-4.2 program and MININEC type ground.

Group Modify

Modifying A Group of Wires, Sources, Loads, or Transmission Lines

The Group Modify feature is common to all the Input Grid Windows except the Media Window. It's a powerful feature for modifying a number of items at once. Many of the normal editing features and shortcuts apply when Group Modify is activated.

Group Modify is activated by selecting Group Modify from the Wire, Source, Load, or Transmission Line menu and specifying the range of item numbers to be modified. Alternatively, the items can be selected before making the menu selection. While Group Modify is active, the selection is frozen, and items can't be added to or removed from the selected group. Any changes made to any of the items is applied to all items in the selected group. Most changes which can be done on individual items, including shortcuts, can be done on a group of items using Group Modify.

To turn Group Modify off, select Wire, Source, Load, or Transmission Line/Group Modify again.

An example using this feature appears in the Test Drive tutorial section Plus Octane Fill Up.

Multiple Instances

Multiple instance operation is available with **EZNEC Pro+** programs. An additional *instance* of the program is initiated by starting **EZNEC Pro+** again when the program is already running. Windows associated with instances after the first are identified on the main window title bar with a parenthetical number, e.g., (2) for the second instance. This allows working on or running calculations for more than one problem at a time. Some caution must be used when running multiple instances, however, because certain data are shared among all instances. These include options selected in the Options Menu and saved as defaults; Special Options in the EZNEC.INI file; and positions and sizes of windows when closed and re-opened. For example, if the Wires Window of one instance is closed, the next Wires Window of any instance which is opened will open with the size and position of the recently closed window. If any Options are saved as default, they will be read and used by any newly starting instance. And when any instance is closed, its description is saved as Last.ez which will be loaded by the next instance that's started.

Open instances can be closed in any order and new ones opened at any time.

Near Field Analysis

As of this writing, **EZNEC** and similar programs are accepted by the FCC and some counterpart bodies in other countries as permissible for calculating compliance with RF exposure requirements. However***, EZNEC results should never be used in any judgements regarding human safety***. Please carefully read the Legal Disclaimer for further information.

Near field analysis, as it applies to **EZNEC**, is something of a misnomer, because the complete field is actually calculated and reported. So near field analysis results apply equally well in the far field.

EZNEC presents near field data only in tabular, not graphical, form. Reported field strengths are RMS.
Near field analysis is run by clicking the NF Tab button in the Control Center. (***Note:*** This feature is disabled when MININEC-type ground is selected with an external NEC-4.2 calculating engine. For more information, see "MININEC-type" in the Real Ground Types topic.) The points in space where **EZNEC** will calculate the field strength are specified in the Near Field Setup dialog, chosen in the Control Center Setups menu, Near Field selection. The entries in the dialog are described below.
Start, Stop, Step Columns – These are the locations in space, relative to the origin, where **EZNEC** will calculate the field strength values. **EZNEC** begins at the **Start** location, and steps by increments in the **Step** column until the **Stop** location is reached.
X, Y, and Z or Dist, Zen Ang, and Az Ang rows – The titles of the rows depend on the **Coordinate System** selection. For Cartesian coordinates, the rows represent the x, y, and z distances from the origin in current units. For spherical coordinates, they represent the radial distance from the origin in current units, the zenith angle (angle downward from the z axis, equal to 90 degrees minus the elevation angle) in degrees, and the azimuth angle (angle counterclockwise from the x axis) in degrees.
Field – Either the E (electric) or H (magnetic) field can be calculated. As distance from the antenna increases, the ratio E/H approaches 120 pi, so at sufficient distances, calculation of only one field is adequate because the other is then known. This isn't true, however, when close to the antenna.
Coordinate System -- Stepping can be done either in Cartesian (x, y, z) or spherical coordinates, but results are always shown in Cartesian coordinates. See X, Y, and Z or Dist, Zen Ang, and Az Ang rows, above, for explanations of the spherical coordinates.
Total Steps – This shows the total number of locations at which the field will be calculated. You can update this window by pressing <Enter> when the cursor is in any of the position entry boxes.

Writing IONCAP/VOACAP Files

EZNEC can write type 13 input files for IONCAP, VOACAP, and related programs. This file contains field strength data for each degree of azimuth and elevation in a defined format. The files generated by **EZNEC** are directly readable by IONCAP type programs.
To generate an IONCAP/VOACAP file, first you must have a model with some type of ground specified; this feature isn't available with free space models. In the Control Center, set the **Plot Type** to **3 Dimensional** and the **Step Size** to 1 degree. Then calculate a 3D far field pattern by clicking **FF Plot** or **FF Tab**.
After the calculation is finished, there are three places where you can initiate the file writing action. If you chose the plot option, open the **File** menu in the 3D Plot Window, and select **Write IONCAP/VOACAP File**. If you chose the table option, you can click the **Write IONCAP/VOACAP File** button at the lower left of the formatting dialog box which opens when the calculation is complete, or you can choose a format and use the option to write the IONCAP/VOACAP file in the **File** menu of the tabular data display. After clicking any of these, you'll be prompted for a file name. If you don't specify an extension for your file name, **EZNEC** will use .13. However, you can specify

any extension you'd like. You can, of course, navigate to another directory before saving. See **Options**, below, for how to change the default directory for saving IONCAP/VOACAP files. Depending on the options you've set (see below), you might have a choice for the orientation of the data in the file. After making your selection, click **Ok** to write the file.
Consistent with IONCAP/VOACAP standards, the azimuth angles in the files represent a clockwise progression from the zero degree entry, regardless of whether you've chosen a conventional CCW angle or compass bearing display for your other **EZNEC** outputs. There are two choices for the zero reference, explained below.

OPTIONS

Default directory (folder)
You can change the directory which appears in the file saving dialog box, either for just the current **EZNEC** session or permanently, via the Control Center **Options** menu **Folders** selection. You should set this to the location where your IONCAP type program expects antenna files to be.
Zero degree reference
Basic IONCAP/VOACAP programs expect the data for zero degrees azimuth to correspond to the antenna pattern maximum. However, some variations prefer or accept an absolute azimuth angle. So **EZNEC** allows you three choices:
1. Zero degree data in the plot always represent the gain in the direction of "North", or zero compass bearing -- up on the 2D display; in the direction of the +Y axis.
2. Zero degree data in the plot always represent the gain in the direction of the pattern maximum (defined by **EZNEC** as the azimuth direction at which the pattern gain is at its highest for all azimuth and elevation angles).
3. **EZNEC** will prompt you for a choice between the above two whenever the pattern maximum is not at zero degrees azimuth.
Increasing angles in the file represent field strength at increasing compass bearings, i.e., in a clockwise direction, regardless of the zero angle choice.
You make your choice in the Control Center **Options** menu, **IONCAP/VOACAP Zero Angle** choice. Be sure to open the Options menu again and choose **Save As Default** if you want the choice to persist after the current **EZNEC** session.

Rescaling

An antenna can easily be rescaled for a new frequency by clicking the Frequency line or button in the Control Center Information Window, then checking the Rescale box. The items which will be rescaled are wire end coordinates, wire diameter if not specified as wire gauge, wire insulation diameter, second medium height, second medium boundary, ground wave distance and observation height, and transmission line lengths if not specified

in degrees. (Transmission line Z0 isn't modified even if it was initially entered as wire diameter and spacing.)
The above items will be modified even if Wavelengths is the chosen unit of measure.
Note that results might not be exactly the same after rescaling, for several reasons. One is that not all items are rescaled. For example, if you defined some wire diameters as wire gauge, they won't be scaled, so the final antenna won't have exactly the same proportionality as the original. Another factor is ground and wire conductivity. Neither of these is scaled, yet the resistance of both changes with frequency as a consequence of the difference in skin depth. So a scaled antenna will generally perform very closely to, but not exactly like, the same antenna before scaling.
Rescaling of any wire or group of wires, optionally including wire diameter and insulation thickness, can be done via the Scale Wires feature in the Wires Window. This feature allows much more flexibility including the ability to restrict scaling to certain axes and to specify the scaling center.

Segment Length Tapering

Note: The process of making an element from telescoping tubing is called *tapering* by some authors, and corrections for NEC-2's inaccuracy in modeling these is sometimes called *taper correction*. **EZNEC** uses the term *segment length tapering* or *segment tapering* to refer to the process of stepping, or tapering, segment lengths, rather than diameters. (The process of correcting NEC-2 for steps in wire diameter is called *stepped diameter correction*.)
Multiple wires joining at an acute angle sometimes require shorter segments than single straight wires or wires joining in a line, particularly when a source or load is near the junction. This is seen with antennas such as multiple dipoles connected to a common feedpoint. Another case is with very low elevated radial systems. The straightforward solution in this situation is to increase the number of segments. However, doing so increases computation time. The technique described here provides high accuracy with a smaller total number of segments.
Instead of making the entire wires out of short segments, the segments can be made short near the junction, gradually increasing, or *tapering*, to a greater length away from the junction. **EZNEC** automates this process but it's useful to know how the procedure works so you can optimize it for your particular purpose. The basic procedure is to replace the original wire with several wires of different lengths. The new wire closest to the junction is made very short and with one segment. The second wire is made twice the length of the first, also with one segment. This process is continued until the segment length becomes long enough (say, 1/20 wavelength), and the remainder of the original wire is made up of a multiple-segment wire of approximately this segment length. In the automated process, you can choose the minimum and maximum segment lengths or use the default values of 1/400 and 1/25 wavelength.
This technique shouldn't generally be used if connecting wires have different diameters, unless perhaps when using an NEC-4.2 or NEC-5 calculating engine, and it might not be necessary with NEC-5. See Stepped Diameter Correction Overview.

Segment length tapering isn't available (the menu choice will be grayed out) if more than one wire is selected or if you're in Group Modify mode.
To length taper segments:

1. Save your antenna description. Segment length tapering is permanent and can't be undone.
2. In the Wires Window, select Taper Segs in the Wire menu. This opens a dialog box.
3. Select the wire you want to taper, and which end of the wire is to be the end with the shortest segment length. The default maximum and minimum segment lengths are suitable for most purposes, but you can modify these values if desired.
4. The number of segments and wires which will be created by the process are shown in the dialog box. If this is ok, click Ok and the specified wire will be tapered.

The new collection of wires will be shown in the Wires Window with a distinctive color, so you can easily keep track of which wires you've tapered.
*Tip: To create a group of tapered radial wires, create a single segment tapered wire, then use **EZNEC**'s radial creation feature to make the remaining radials with it as a prototype.*

Segmentation Check

The NEC-5 calculating engine is much more tolerant of the issues discussed below than NEC-2 and NEC-4.2. Consequently, only the maximum segment length is checked when using it. The last two paragraphs also apply to NEC-5, however.
Segmentation Check detects some common violations of NEC modeling guidelines, namely segments which are too long or short, segment length/diameter ratio out of bounds, and insertion object placement warnings. Unless automatic operation is disabled via the Control Center Options menu, Segmentation Check is run whenever the program is started, a new description is opened, the frequency is changed, or wires are imported from an ASCII file. It can be run at any time from the Control Center Outputs menu. There are two sets of guidelines, conservative and minimum recommended. In general, you should keep your antenna within the minimum recommended guidelines, and observe the conservative guidelines if the antenna is narrow band or critical. Always be aware, however, that even this doesn't guarantee a sufficient number of segments. See Segmentation for more information. Segmentation Check output is shown with the **EZNEC** Editor, so you can save or print the data if desired.
Display of conservative guideline warnings when run automatically can be suppressed with the Segmentation Check selection in the program Options menu.
If any errors are found, an additional menu **Segmentation** is shown in the Editor. This allows you to have **EZNEC** automatically adjust the number of wire segments to conform to the NEC guidelines. The choices in this menu are as follows:

Fix Segs – Adjusts the number of segments only on wires which violate guidelines.

Auto Seg – Adjusts the number of segments on all wires to the minimum number required to meet guidelines.

Each of these selections has two additional choices, allowing you to adjust to conservative or minimum recommended guidelines (explained above). Neither, however, automatically corrects insertion object placement errors.
Caution: Segmentation Check does not find all possible description errors, only the ones listed above.
Important: There are occasions where the segmentation and/or insertion object placement recommendations can't be followed, such as with the wires at the ends of a folded dipole (unless Segment Length Tapering is used) or a source at the bottom of a ground plane antenna, and cases where automatic segmentation can't clear the warnings or errors. In many cases, this won't cause serious calculation errors, but an Average Gain check should be run in those cases. A satisfactory result with this check usually indicates that no serious errors will result from the segmentation or insertion object placement guideline violations.
Wire grids created using the **EZNEC Pro** wire grid creation feature (Wires Window) with default spacing will show violation of conservative guidelines. This is normal and not of concern.
Velocity factor is taken into account when evaluating the segmentation of buried wires. This often generates warnings when segments are physically quite short. (To see the velocity factor being used, click Ground Info in the Control Center Utilities menu.) Ground loss is usually so high that coarse segmentation is adequate, so you shouldn't be overly concerned about messages warning of too-short segments on buried wires.

Stepped Diameter Correction

A method used by **EZNEC** to correct for an NEC-2 inaccuracy when modeling connected wires of different diameters. It's most accurate only under a limited number of conditions, most notably full-sized Yagis made from telescoping tubing, but will correct some other models reasonably well. Stepped diameter correction isn't necessary when using an NEC-4.2 or NEC-5 calculating engine. See Stepped Diameter Correction Overview for more detailed information.

SWR Graph

The SWR sweep is run by first clicking the SWR action button in the Control Center. If a sweep has recently been run and the model not changed since, you'll be asked whether to view the existing data. If you choose No, or if there's no existing valid data, you'll see a dialog box which allows you to enter the start, stop, and step (increment) frequencies for the sweep. These values are shared by the Frequency Sweep function. Alternatively, you can have **EZNEC** read a list of frequencies from an ASCII text file. The requirements for this file are detailed in the Frequency Sweep Input File section. After entering your selections, click Run to begin the sweep. At the conclusion of the sweep, the SWR Display will open, showing the results. Use of this display is covered in the Using The SWR Display section of the Reference chapter.
After the sweep is finished, a file named LastZ.txt is present in the **EZNEC** output directory. This file contains impedance results from the sweep, and persists after the program ends. The data in this file can be used for analysis by other applications if desired.

TraceView

TraceView mode is a way to look at, compare, or print previously saved traces (far field pattern plots) without having to run far-field calculations. TraceView mode is also capable of displaying some plot files in the OpenPF standard format generated by programs other than the **EZNEC** family, but this operation isn't guaranteed. TraceView can also be used to translate plot files to .PF format from the .ENT format of ELNEC and **EZNEC** v. 1.0.

STARTING TRACEVIEW

EZNEC can be put into the TraceView mode at any time by selecting TraceView from the Control Center View menu. Alternatively, **EZNEC** can be started in the TraceView mode by entering **<path>\EZW /TV** in the Windows Start/Run text box, where <path> is the **EZNEC** program path. If you use TraceView frequently, you might want to set up a desktop shortcut to start **EZNEC** in TraceView mode.

RUNNING TRACEVIEW

When TraceView first starts, you'll be prompted for a *primary* trace file. This can be any current-version 2D or 3D **EZNEC** plot (trace) file having the extension .PF or .P#, or files from ELNEC and **EZNEC** v. 1 having extensions .ENT or .F#, which you've previously saved. If you haven't saved any plots from previous **EZNEC** calculations, there won't be any to view with TraceView, and TraceView can't be used. The chosen plot can be viewed in the same manner as a regular **EZNEC** plot. Additional traces can be added to the 2D plot or "slice", but only the primary trace field strength values can be shown in tabular form. The primary trace also determines the initial value of the plot outer ring if automatic scaling is chosen, and characteristics shown in the Control Center are those of the primary trace.
Menu selections and operation are the same in TraceView as for the standard mode, except that many menu items are missing (because TraceView is for viewing only), and the Open selection prompts you for a primary trace file rather than a description file. You can select a new primary trace at any time with the Open button or File menu item.
If the primary trace file is in ELNEC or **EZNEC** v. 1.0 format (.ENT or .F# extension), it can be saved as a .PF file by selecting Save Trace As in the 2D display File menu. This choice won't be available if the primary trace file is already in .PF format.

ENDING TRACEVIEW

You can end TraceView by ending **EZNEC**, or you can change to the normal mode by clicking TraceView in the Control Center View menu.

Undo/Redo

EZNEC has unlimited undo/redo capability. This applies to all choices saved with the antenna description, but not to program-level changes like the selections in the main window Options menu. Undo/redo is done via the Edit menu in the Control Center (main window) and several other windows, which can be used interchangeably. Undo is reset when a new description is opened. If the previous description has been changed, you'll see a prompt

asking you if you want to save it before proceeding. This prompt can be turned off via Control Center Options menu selection Messages On/Off.
Undo/redo can be used for other purposes than just correcting errors. For example, suppose you make a model of a two element array fed with two sources. To see how its performance compares to a single element, first run and save a 2D plot of the array pattern. Then delete one element (which will also delete its source) and run a 2D plot. Add to the plot the saved trace from the array calculation to see the differences, and restore the array by undoing the element deletion. Any change you make can quickly be evaluated by this method.

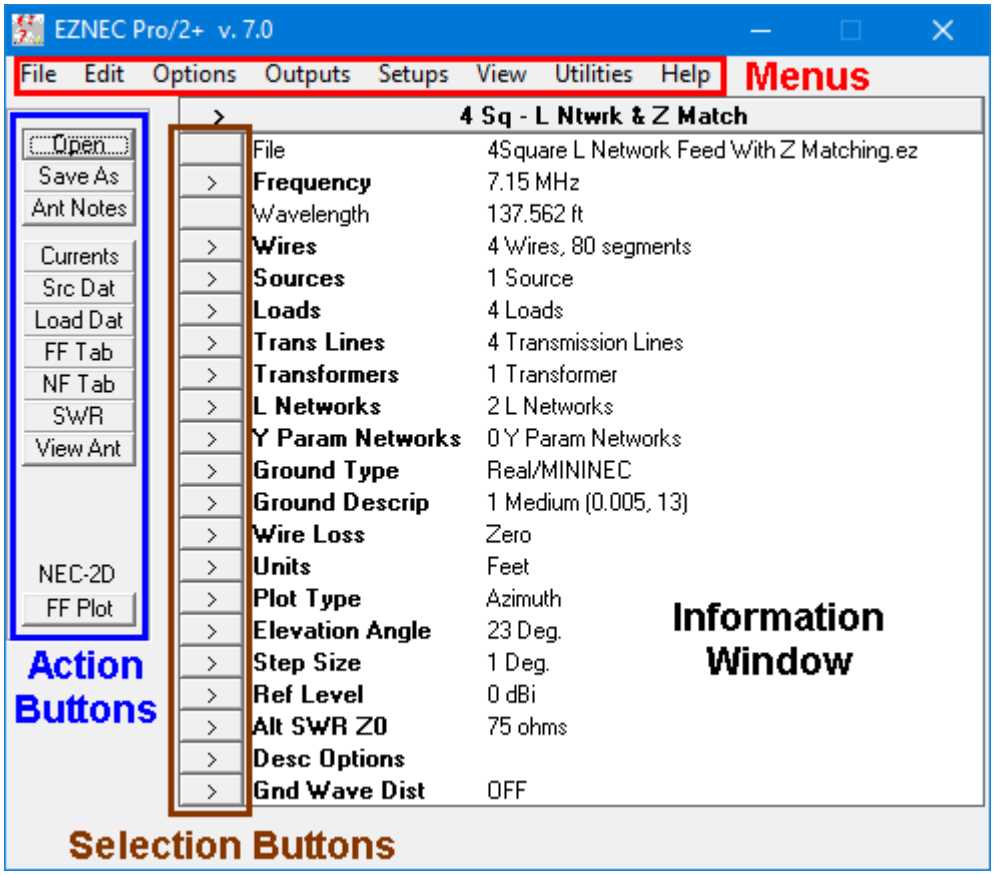
Virtual Segments

A Lap Around Track 5 in the Test Drive tutorial will help you learn how to use virtual segments.
NEC requires that all insertion objects be connected to (inserted in) a wire segment or, when using NEC-5, at a segment junction. There are many occasions where you want to connect two insertion objects, for example a source and one end of a transmission line, in parallel but not to any wire in the model. For this purpose, **EZNEC** provides ***virtual segments***. In the normal insertion object specification for wire number, simply enter the letter "V" followed by a number you wish to assign to the virtual segment, for example, "V10". Specify the same virtual segment number for any other insertion objects you want to connect in parallel with it. This will result in the objects being connected in parallel. Any type of insertion object can be connected to a virtual segment *except split sources or series-connected (conventional) loads*. Unlike all other insertion objects, series-connected loads are connected in series, rather than parallel, with other objects on the same segment. The parallel-connected load is provided for use whenever a load is to be connected in parallel with other objects on a real or virtual segment.
Virtual segment numbers can be any integer from 1 to 999 and don't have to be used in order or follow any other sequence or pattern.
A list of the virtual segments and the insertion objects connected to them can be seen by opening the View Antenna Display, then selecting **Show Virtual Seg Conn** in the **View** menu. See Virtual Segment Connection Display for more information.
When a model containing virtual segments is saved and opened with **EZNEC** v. 3.0 or older, the virtual segments are converted to real segments on a distant wire. Likewise, they appear as real segments on a distant wire when the model is saved or opened in NEC format.

The Control Center

Control Center Introduction

The Control Center is as its name implies – the center and beginning point for all **EZNEC** operations. It appears when **EZNEC** first starts, and remains present until the program ends. It contains several distinct areas, shown below:



Information Window – This window shows information about a number of important parameters of the antenna being modeled. Any of the information in this window which can be changed is saved with the antenna description in the antenna description file.

Selection Buttons – These buttons allow you to change the item shown on the corresponding line. Buttons which don't have a '**>**' mark, or which have a dim mark, can't be changed. Selections can also be chosen by clicking anywhere on the corresponding line in the Information Window. Most selections will open a dialog box or input grid. These functions are detailed in the Selections section. Note that the Title line above the Information Window is also one of the available selections.

Action Buttons – These buttons start various common actions, such as opening the View Antenna display or starting a pattern calculation. The function of each button is detailed in the Control Center Action Buttons section.

Menus – The menus contain a wide variety of items, most of which are program related. An exception is the selections in the Plot menu, which are saved with the antenna description. Each selection in each menu is described in the Control Center Menus section.

The Control Center Menus

Control Center Menus Introduction

It's important to note the unique function of the Setups and Options menus. The Setups menu is unlike the other Control Center menus in that choices made in this menu are saved with the antenna description file, just like the

Information Window items. They will be restored each time you open that description file.
The Options menu contains items which apply to all antenna descriptions until **EZNEC** is ended, at which time your choices are discarded unless you've selected Save As Default. Whenever you choose Save As Default -- the last selection in the Options menu -- all Options menu selections are permanently saved and will be restored each time you start **EZNEC**.
Each selection of each of the menus is detailed in the sections which follow.

File

Open Description – Allows you to select an existing antenna description (model). To open an NEC format file, include the extension .NEC with the file name.
Save Description As – Allows you to save the current antenna description (model) as a file. To save a file in NEC format, include the extension .NEC with the file name.
Add Description – Allows you to select an antenna description (model) to add to the current model. See Combining Antenna Descriptions for more information.
Restore Default Folder – **EZNEC** remembers the last folder you used for opening or saving a description, so the next time you open or save a description, the last folder you used is listed as the initial choice. This selection resets the initial choice to the description file folder specified in the Folders section of the Options menu.
Import Wires From ASCII File – This choice allows you to select an ASCII file containing wire coordinates, which will be imported into **EZNEC**. See Importing Wire Coordinates for more information, and Wire Coordinate File for the file format.

Add to Existing Wires – The wires in the ASCII file will be added to the current model.

Replace Existing Wires – The wires in the ASCII file will replace the wires in the current model.

Edit Current Antenna Notes – Opens the antenna notes file for the current model in the **EZNEC** Editor.
Edit Antenna Notes – Allows you to select an antenna notes file to edit.
View File – Prompts you for the name of a (text) file to view with the **EZNEC** Editor. Although you can modify the text in the editor, you won't be allowed to save the file under the same name, so the original file content is protected from modification. The default folder which appears when you first choose this option is the **EZNEC** output folder for convenient viewing of **EZNEC** output files. However, it can be used for viewing any text file.
Edit File – Same as View File, above, except that the original file content isn't protected, and you're allowed to save a modified text under the same file name.
Exit Without Saving – **EZNEC** normally saves the current description in a file named Last.EZ, which it loads the next time it starts. However, if you select this choice, the current description won't be saved. This is useful if the current description is defective, thereby preventing **EZNEC** from saving it, or if you've done a quick experiment but want **EZNEC** to start up the next time with the

same description it started up with for the current session. Clicking Yes to exit without saving ends the **EZNEC** session.
Exit – Normal way to end **EZNEC**. Saves the current description in Last.EZ and ends the program. Does the same thing as clicking the close box in the upper right corner of the Control Center.

Edit

Undo, Redo – Allows you to undo changes made to the description or calculating engine type since the description file was opened, and to redo any changes that were undone.

Options

All selections in this section remain effective until the program ends. They can be made permanent (that is, they become the new default values) by clicking Save As Default at the bottom of the list. All those which are applicable except for Calculating Engine are shared with older versions of **EZNEC** on the same machine.
Angle Convention – **EZNEC** allows you to represent azimuth angles in either of two ways. Changing from one way to the other has no effect on the model, antenna view, or the graphics plots. The only effect is in the angles reported in various tables and data outputs.

> Compass Bearing – Zero is in the direction of the +y axis (at the top of the 2D azimuth plot display). Angles increase as you go clockwise from zero.
> CCW From X Axis – Zero is in the direction of the +x axis (to the right of the 2D azimuth plot display). Angles increase as you go counterclockwise from zero. This is the convention commonly used in mathematics and physics.

AutoComplete/AutoSuggest – In the file selection dialog boxes, two automatic features can come into play on some Windows operating systems when certain Internet Explorer options have been chosen. One of these, AutoSuggest, appears as a drop-down list of files beginning with the same letters as any you have entered in the file name text box. The other, AutoComplete, automatically enters in the text box one of the selections from the list. Unfortunately, there's no way to limit the suggestions or autocompletion to files with extensions appropriate for the purpose at hand. So there's no way to guarantee that either the suggested or autocompleted file names are acceptable. AutoComplete, in particular, can be a nuisance if it selects a file name having an unacceptable extension. These features can be turned off (and on) in the Windows Internet Explorer Tools menu, and the settings there apply to all Windows applications. (Please refer to your Windows or Internet Explorer documentation for details.) The AutoComplete/AutoSuggest option in the **EZNEC** Options menu allows you to choose separate settings for AutoComplete and AutoSuggest to be used by **EZNEC**. As with all other Options menu items, these settings apply only until you end **EZNEC** unless you select Save As Default in the Options Menu after making your other selections.
Calculating Engine – Allows you to choose the engine used for calculations. The calculating engine being used is shown just above the FF Plot button in the Control Center. See Calculating Engines for more details about the

various choices. ***Note:*** This selection is independent of and not shared with older **EZNEC** versions.

EZCalcD (NEC-2D) - Internal double-precision NEC-2 calculating engine.

EZCalc4D (NEC-4D) *(**EZNEC Pro/4+** only)* - Internal double-precision NEC-4.2 calculating engine, recommended for general use with **EZNEC Pro/4+**. It's up to ten times faster than the standard external NEC-4.2 engine, and has greater accuracy for a number of situations.

External NEC-4.2 - External NEC-4.2 calculating engine furnished by the user. Some features available with the internal EZCalc4(D) engines such as ground wave and near field analysis with MININEC type ground aren't available.

External NEC-5 - External NEC-5 calculating engine furnished by the user.

EZCalc (NEC-2) - Internal mixed-precision NEC-2 calculating engine which does some calculations in single precision and some in double. This engine uses about half the memory required by EZCalcD so can be used for very large models where model size and RAM limitations make use of virtual RAM necessary with the double precision engine and not with the single precision engine, or when insufficient RAM is otherwise available for the double precision engine. It's not recommended for use otherwise, and is made available via a Special Option. Accuracy is adequate for most purposes but will be less for some cases such as transformers, L and Y parameter networks, and very small loops.

EZCalc4 (NEC-4) *(**EZNEC Pro/4+** only)* - Internal single-precision NEC-4.2 calculating engine. See the description of EZCalc above.

External Calculating Engine File -- Allows you to choose the location and name of external NEC-4.2 and NEC-5 calculating engine executable (.exe) files.

Show Ext Calc Eng Console -- The "command line" or "console" type programs used as external calculating engines by EZNEC display a black window when running. The most commonly available NEC-4.2 program shows a few intermediate steps during the calculation process, and the NEC-5 program shows only one. But this might be of interest in some cases. This option allows you to have the window appear never, only when not running an SWR or frequency sweep, or always. The default is never, which is recommended for most operation.

Default Ground Const – Allows you to enter values of ground medium conductivity and dielectric constant which will be used when you create a new ground medium. You might want to set these to reflect the properties of your local ground.

Folders – Allows you to specify the default locations of various files used by **EZNEC**. To select a folder, double-click your choice. The folder name and path will appear under the white window, and the folder icon will show that the folder is open. *Remember that your choice will be effective only until the program ends unless you re-open the Options menu and select Save As Default at the bottom of the Options menu selection list.*

Each of the following dialog boxes includes a Default Folder button. This will return the selection back to the folder which has been saved as the default

value. It's useful when you've selected a folder for temporary use and want to return to the normal default location.

Description (.EZ) and Plot Files - Location of the description files and 2D and 3D plot files.

Docs and Output Files - Location of most files generated by EZNEC, except ones having their own folder options. Suggested location for external NEC-4.2 and NEC-5 calculating engines and their input and output files. Several other folders are subfolders of this by default.

IONCAP/VOACAP Files - Default location of the IONCAP/VOACAP files. You should set this to the directory expected by your IONCAP type program.

Misc App Data Files - Location of binary files used by EZNEC for communication with the internal calculating engines, and not generally needing to be accessed by the user.

Ground Data Files - These files are generated by the internal calculating engines and consist of Real, High or Extended ground calculations. Their contents are re-used to save time when values for similar ground conditions are required.

Ground File Tolerance – When **EZNEC** does an analysis with Real, High or Extended Accuracy ground, it checks to see if the necessary ground data have already been calculated and saved as a ground data file. Each file corresponds to a particular combination of frequency and ground conductivity and dielectric constant, so a file might already exist for a combination which is just slightly different than the current conditions. If the difference is small, the file data can be used with a negligible degradation of accuracy, and the time required to recalculate the data is saved. The initial default value of one percent is adequate for most use. If you encounter periodic "jumps" in a frequency or SWR sweep, the tolerance might be too high. Also, if you're trying to resolve very small differences in patterns, particularly involving vertically polarized antennas where the ground characteristics are more important, you might want to set the tolerance to a smaller value, perhaps 0.1%. For extremely sensitive calculations, a setting of zero will force **EZNEC** to recalculate the data unless conditions match to within about five decimal places.

Show Charge Density -- Toggles the inclusion of charge density in the Currents display.

Messages On/Off – Allows you to suppress the "Description has changed" message when you open a new description, and the tooltips that appear when you pause the cursor over some controls.

Default NEC-4 Ground Type -- This option sets the program behavior when using an NEC-4.2 calculating engine and opening files saved by program versions or types where Extended Accuracy ground isn't available. If set to Extended Accuracy, the ground type in those files will automatically be set to Extended; if set to High Accuracy, no change will be made when a file is opened.

This option defaults to High Accuracy because of the substantial calculation speed penalty exacted by use of Extended Accuracy ground. This should be considered before changing the setting to Extended Accuracy. See Real Ground Types for more information.

Segmentation Check – This determines when the Segmentation Check utility will be run.

Auto - Show All - Automatically runs when a new description is opened, the calculation engine is changed, wires are imported from an ASCII file, or the frequency is changed.

Auto - Minimum Warnings Only - Automatically runs as above but doesn't warn of violations of Conservative guidelines unless run manually.

Manual – Runs only when selected from the Control Center Outputs menu.

Plot Printing

Printed Plot Line Width - Allows you to adjust the width of the lines in the printed plots. This affects only the Plot section of the Graphics Windows, and only when printed. It has no effect on the screen display. When the width is set to a value greater than one, lines normally shown broken (separate 2D polarizations; and View Antenna axes when offset from the origin, and current polarization markers) will be printed as solid.

Printed Plot Data Font - Selects the font to be used for printing the Data section of the Graphics Windows. It has no effect on the screen display or on the Plot section of the printed output.

Power Level – If the Absolute V, I sources box is checked, voltage and current sources will have the values declared in the Sources Window. The total power applied to the antenna will then be determined by a combination of these values and the feedpoint impedances. If you uncheck the box and enter a non-zero value for the power level, all sources will be adjusted *in proportion* to result in the specified power being applied to the antenna. The specified power will be the total power from all sources, and it won't vary with antenna impedance. The values shown in the Sources Window will represent relative, not absolute voltage and current values. The actual voltages and currents can be seen in the Source Data display. This is a powerful and useful feature for a number of applications.

Stepped Diameter Correction – Determines when Stepped Diameter Correction will be used.

EZNEC Pro/2+ *only:*

On (recommended) – **EZNEC** will use Stepped Diameter Correction when possible.

Off – **EZNEC** will not use Stepped Diameter Correction. This setting may lead to inaccurate results for some types of antennas, most notably Yagis having elements made from telescoping tubing.

EZNEC Pro/4+ *only:*

NEC-2: On, NEC-4, -5: Off (recommended) – Enables Stepped Diameter Correction when using the NEC-2 calculating engine only. Because the NEC-4.2 and -5 engines are relatively free from the stepped diameter problem, Stepped Diameter Correction is disabled when one of these engines is selected.

Always off – Stepped Diameter Correction is always disabled. This setting may lead to inaccurate results for some types of antennas, most notably Yagis having elements made from telescoping tubing.

Always on – Stepped Diameter Correction is always on. This would not generally be chosen unless it was desired to see its effect in NEC-4.2 or -5.

IONCAP/VOACAP File Zero Angle - Sets the reference for zero degrees when generating IONCAP/VOACAP files. See Writing IONCAP/VOACAP Files for details.

Far Field Table Units – Selects the units used in the Far Field Table. These have no effect on any other outputs or displays.

dBi or dBref – Shows field strength in dBi or, if a non-zero dB reference is chosen (see below), in dB relative to that reference.

mV/m for 1 kW at 1 mile – Shows the field strength in mV/m at a distance of one mile, for an applied power of 1 kW. Note: When this option is selected, the Power Level selection (above) is not used for the Far Field Table.

mV/m for 1 kW at 1 km – Shows the field strength in mV/m at a distance of one km, for an applied power of 1 kW. Note: When this option is selected, the Power Level selection (above) is not used for the Far Field Table.

The units below which are displayed depend on whether ground wave analysis is being done. With ground wave analysis off, the choices have the same effect as those above. The choices for units with ground wave analysis and conventional sources are:

mV/m – Output in mV/m at the distance specified as the Control Center Gnd Wave Dist. If the power level has been specified using the Power Level selection (above), this power is used; if not, the power resulting from the absolute source voltages and currents is used.

dBi or dBref – Same as the corresponding non-ground wave choice.

Additional units available with a plane wave source are:

dBsw or dBref - dB relative to one square wavelength scattering cross section.

mV/m X dist - Divide the reported value by the distance in meters to get field stregth in mV/m at that distance.

Near Field Table Format – Selects whether near field phase information is to be shown. The narrow format output doesn't include phase information, and may produce a more easily readable output when viewed or when printed to a portrait-oriented page. This setting affects the output saved in the frequency sweep output file as well as the single frequency near field output display.

2D, 3D Plot Scale – This allows you to choose between two types of scale for the 2D and 3D plots.

ARRL Type – This scale is the standard scale used by the ARRL and in many amateur publications. It's a logarithmic-dB scale which shows the pattern maxima with greater detail at the expense of compressing minor lobes. This scale is generally recommended for amateur use because the plots will be more easily compared to published ones.

Linear dB – As the name implies, this is a plain dB scale, linear with respect to dB. It extends 40 dB from the outer ring to the center of the scale. Although the outer ring value in dBi is adjustable, the range from the center to outside is not.

Show Freq on 2D & 3D Plots – When this option is on (checked), the frequency is shown at the lower right side of the 2D and 3D plot displays. Note that the frequency won't appear at the lower right of the 2D display when the results of a frequency sweep are being shown.
Default 3D Step Size – **EZNEC**'s minimum step size of one degree is too fine to show detail when doing general purpose 3D plotting. This menu selection allows you to set the default step size when a 3D plot type is initially chosen.
View Antenna Wire Numbers – Selects whether the wire numbers are shown when you first start the View Antenna display, and whether they appear centered on the wires or offset. You can change these choices in the View Antenna Display, but that setting cannot be made permanent, while this setting can.

Initially On – Wire numbers are on when you first start View Antenna.
Initially Off – Wire numbers are off when you first start View Antenna. Use this setting if you frequently work with complex models, where the wire numbers overlap and become unreadable.
Initial Position – Selects whether the wire numbers are initially centered over the wires or are offset.

Save As Default – Clicking this choice makes all the values selected in the Options menu permanent. Unless it is clicked, any changes made will be discarded when **EZNEC** ends. Any changes made after it is clicked will likewise be discarded at the end of the session unless it is clicked again to save the changes.

Outputs

Analyze - Visible only by setting the Analyze Special Option. Shows in a separate window an analysis of the selected 2D plot 'slice'.
Geom and Seg Check – Runs both the Geometry and Segmentation checks (see below).
Segmentation Check – Runs the Segmentation Check, which checks the model for violation of several NEC guidelines.
Geometry Check – Runs the Geometry Check, which detects a number of conditions that aren't allowed, such as wires overlapping, or intersecting or crossing at other than a wire end or segment junction.
Show Description – Shows a summary of the antenna description as plain ASCII text in the **EZNEC** Editor. This includes wire coordinates, source and load locations, etc. The displayed description can be printed or saved to a file. A similar display, with only the wires coordinates, is available in the Wires Window Other menu.

Setups

Frequency Sweep – Opens the frequency sweep setup dialog, to set up parameters for the frequency sweep.
Near Field – Opens the near field setup dialog, to set up parameters for near field analysis.

View

TraceView – Puts **EZNEC** into TraceView mode, for viewing, printing, or comparing saved far-field pattern plots (traces) without having to do any calculations.

Utilities

Various selections are available depending on the Util Special Option. Utilities requiring higher numbers are primarily of use only to advanced users or ones wanting to experiment with **EZNEC**. At the top of each group is the Util Special Option value needed to make that group visible. The first group is always visible by default.

GROUP 0 - always shown

Edit .INI File – A number of special options can be enabled by entering statements in the EZNEC.INI file in the **EZNEC** output directory. These are generally options which are seldom used, or are used only for special purposes. This selection opens the EZNEC.INI file in the **EZNEC** Editor for easy modification. Most changes made to the EZNEC.INI file aren't effective until **EZNEC** is exited and re-started. If you edit the EZNEC.INI file and want to apply the changes, save the file, exit **EZNEC**, allow a few seconds for the disk cache to write saved information on the disk, and re-start **EZNEC**.

Calculation Time – Shows the times which were taken for various calculations. No numbers will be shown until **EZNEC** completes a calculation. Note: When a frequency or SWR sweep is run, only the time for the last frequency calculation is shown, not the time for the entire sweep.

Ground Info – Gives detailed information about ground characteristics when Real ground type is selected.

Memory Info – Gives information about available computer memory. This report is directly from the Windows system, and might not agree with some other analysis tools. Note that it's not uncommon for the available memory (RAM) to be at or near zero; Windows routinely uses the disk as virtual memory, and frees up RAM as needed.

Component Version Numbers – Shows the complete version numbers of each of the major components of **EZNEC**.

Show Folders -- Shows the folders being used by **EZNEC** for input and output files.

Show Running Instances -- Shows instances that are running simultaneously. The instance making the query is identified with an asterisk.

Identify NEC-5 Version - Tells whether or not you are using a modified NEC-5 calculating engine identified as "X##". See NEC-5 Status for more information.

GROUP 1

Last RW File Pgm Ver -- If the most recent description file operation was reading, shows what version of the program wrote the file. If the most recent description file operation was writing, shows the current program version.

Show EZFile Info -- Shows additional information about the description file at the time it was last written.

GROUP 2

Stop at EZCalc Call -- Ends program after calculating engine input files (including integral engine binary file) have been written but before the calculating engine has been started. Used for calculating engine troubleshooting.

Help

Contents – Opens this help file and shows the contents.
About EZNEC – Shows the program version number and copyright and trademark notice. Also shows if internal 64 bit calculating engines have been installed and are being used.

Information Window and Action Buttons

Control Center Selections

All selections in the Control Center Information Window are part of the antenna description and are saved with the antenna description (.EZ) file. Selections made in the Setups menu are also saved with this file.
Title – This selection isn't marked except with a **>** symbol. It's the gray bar just above the white Information Window, and contains the title of the description. Clicking anywhere on this line opens a dialog box for you to enter a title for your antenna model.
File – Shows the name of the last file saved or opened. This is for information only and can't be changed.
Frequency – Shows the current frequency, or if Frequency Sweep is enabled. Click this to change the frequency or rescale your model to another frequency.
Wavelength – Shows the wavelength in current units. This is for information only and can't be changed.
Wires – Shows the number of wires and segments in the model. Clicking opens the Wires Window, for adding, deleting, or modifying the antenna structure.
Sources – Shows the number of sources in the model. Clicking opens the Sources Window, for adding, deleting, or modifying sources.
Loads – Shows the number of loads in the model. Clicking opens the Loads Window, for adding, deleting, or modifying loads.
Trans Lines – Shows the number of transmission lines in the model. Clicking opens the Transmission Lines Window, for adding, deleting, or modifying transmission lines.
Transformers – Shows the number of transformers in the model. Clicking opens the Transformers Window, for adding, deleting, or modifying transmission lines.
L Networks – Shows the number of L networks in the model. Clicking opens the L Networks Window, for adding, deleting, or modifying transmission lines.
Y Param Networks – Shows the number of Y parameter networks in the model. Clicking opens the Y Parameter Networks Window, for adding, deleting, or modifying transmission lines.
Ground Type – Shows the type of ground model chosen. Clicking it allows you to choose the ground type.
Ground Descrip – This entry appears only when one of the Real ground type models is chosen. It shows how many ground media (1 or 2) have been defined, and their conductivities and dielectric constants. Shows NEC radials

if specified. Clicking opens the Media Window, for modifying ground characteristics and NEC radials.
Wire Loss – Shows which wire loss characteristic has been chosen. Clicking opens a dialog box allowing you to specify a wire loss characteristic.
Units – Shows which primary unit of length you've chosen. Clicking opens a dialog box allowing you to choose the primary units of measure.
Plot Type – Shows which plot type – azimuth, elevation, or 3 dimensional, you've chosen. Clicking opens a dialog box allowing you to choose the plot type. When Ground Wave Analysis is active, this option is fixed at Azimuth, the only type allowed with ground wave analysis.
Elevation Angle, Azimuth Angle or Bearing, or Observation Height – This selection isn't available when 3D Plot Type is specified. When doing an azimuth plot, it shows and allows you to choose the elevation angle for the 2D azimuth plot. When doing elevation plot, it allows you to choose the azimuth angle or compass bearing. When Ground Wave Analysis is active, shows and allows you to choose the height of the observation point.
Step Size – Shows and allows you to choose the angular increment for the 2D or 3D plot. Minimum step size is 0.1 degree for 2D plots, 1 degree for 3D plots. Maximum for both is 90 degrees, although such a large value would result in an unusable coarse display. 2D step size must evenly divide into 180 degrees, and 3D step size into 90 degrees; error messages will appear if any of these conditions isn't met.
Ref Level – All outputs showing field strength will be relative to the value shown here. If you want, for example, to show gain relative to the gain of a dipole in free space, set this value to 2.15 dBi. (This choice is meaningful only when doing free-space analysis. As shown in the Test Drive, a dipole mounted over ground exhibits gain several dB greater than this amount.
Alt SWR Z0 – Various displays show or output SWR assuming a 50 ohm system and a second impedance of your choice. This is where you choose the second impedance. A typical use would be an antenna fed with 50 ohm line through a 4:1 impedance step down transformer. If you set the Alt SWR Z0 to 12.5 ohms, the indicated SWR is what you would see on that 50 ohm line.
Desc Options – This selection allows selection of several properties which are saved with the description file. Under the General tab, you can choose to have the Geometry Check ignore the situation where the center of a segment is within another wire. This sometimes can't easily be avoided and, while it sometimes causes erroneous results, it often doesn't. See the Geometry Check topic for additional information. Under the Plot tab are a number of 2D plot choices, including linear and circular polarizations to show on the 2D plot.
Gnd Wave Dist – Shows the horizontal distance to the ground wave analysis observation point. Clicking it allows you to select the distance and to turn ground wave analysis on and off.

Action Buttons

Several of these actions are explained in more detail in the Interpreting The Results chapter.
Open – Click this to open a different antenna description file. ***Note:*** *All unsaved information in the existing file will be lost. Save your existing*

description if you want to preserve it. ***[EZNEC Pro only]:*** To open an NEC format file, include the extension .NEC with the file name.
Save As – Click to save your current antenna description. ***[EZNEC Pro only]:*** To save a file in NEC format, include the extension .NEC with the file name.
Ant Notes - Opens the current Antenna Notes file for viewing or editing if one exists for the current description, or optionally creates one if not.
Currents – This opens the Currents output, which shows the currents on the wires in tabular form, running a calculation if necessary.
Src Dat – Opens the Source Data output, which shows the voltage, current, power, impedance, and SWR at each source, running a calculation if necessary.
Load Dat – Opens the Load Data output, which shows the voltage, current, power, and impedance of each load, running a calculation if necessary.
FF Tab – Opens the Far Field Table output, which shows the far field strength in tabular form, running a calculation if necessary.
NF Tab – Opens the Near Field Table output, which shows the near field strength in tabular form, running a calculation if necessary.
SWR – Opens a dialog box so you can define the sweep parameters for the SWR Graph.
View Ant – Opens the View Antenna display, which gives you a 3 dimensional view of the antenna.
FF Plot or **Freq Swp** – Begins a far field pattern calculation or frequency sweep.

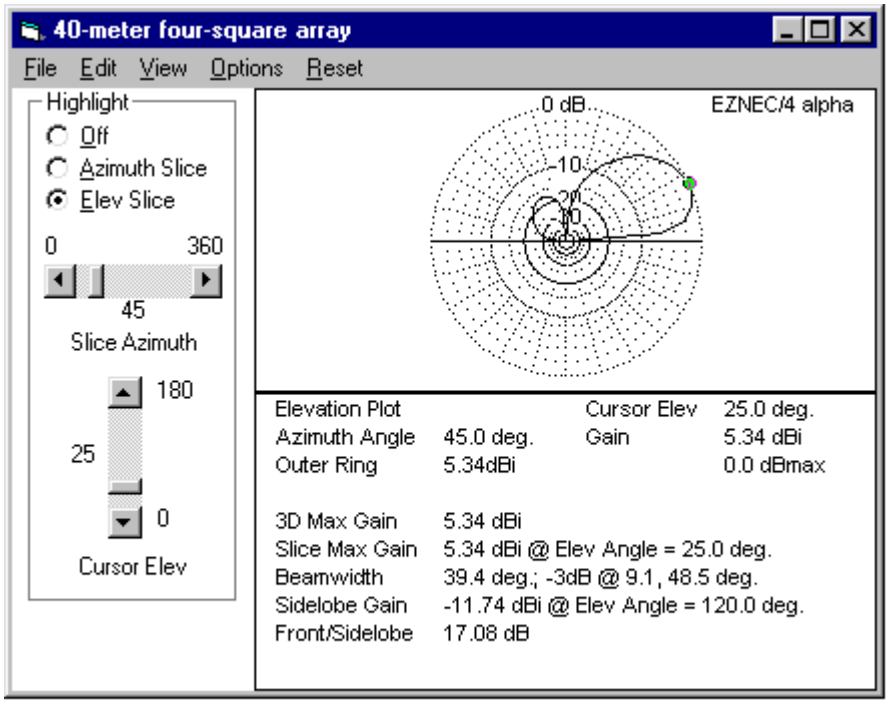
The Graphics Windows

Graphics Windows Overview

The 2D Plot, 3D Plot, View Antenna, and SWR displays have a number of common features, so all are grouped together here. They are collectively called the Graphics Windows.
All Graphics Windows can be sized by dragging an edge or corner, or can be maximized or minimized by use of the controls in the upper right corner of the form. Minimum sizes apply to some forms, limiting the size adjustment range.

Graphics Windows Sections

The Graphics Windows are divided into sections, as shown below. Not all Graphics Windows contain all three sections. The Control Box section of the 2D Plot Display, which is shown below, is available only when the 3D Plot Display is also on. The Data and Control sections can be turned on or off via the menu File selection.



Plot or Display
The Plot or Display section contains the actual graphical information being displayed.

Data
The Data section contains additional information about the plotted data.

Control
The Control section contains controls to alter the Plot display.

Graphics Windows Menus

Menus
All Graphics Windows have all or most of the following Menu selections. The selections function the same for all displays, except for exceptions noted below.

FILE

Print Plot – Prints the Plot section of the window on the printer. The plot is sized to print the page; its size isn't adjustable. The line width of the Plot section can be adjusted from the Control Center Options menu.
Print Plot and Data (2D, SWR only) – Prints the Plot and Data sections of the window on the printer. The Data text is printed below the plot. The line width of the Plot section and the font used for the Data section can be adjusted from the Control Center Options menu.
Printer Setup – Opens a dialog box allowing you to choose the printer and paper type and characteristics.
Add Trace (2D only) – Opens a dialog box allowing you to choose a trace to add to the existing display. Information about added traces, and gain comparison to the primary trace, can be displayed in the Data Box if desired. See Using the 2D Display for more information. The colors of added traces

can be selected via the 2D display Options/Colors/Recalled Traces selection, described below. Trace types which can be added are:

.ENT – 2D Trace files created by ELNEC and **EZNEC** family products prior to v. 2.0.

.F# -- 2D Trace files created by ELNEC and v. 1 **EZNEC** family products frequency sweeps.

.P# -- 2D Trace files (OpenPF format) created by v. 2 and later **EZNEC** family products frequency sweeps.

.PF – 2D trace files (OpenPF format) created by v. 2 and later **EZNEC** family products.

.PF3 – 3D trace files (OpenPF format) created by v. 2 and later **EZNEC** family products.

Remove Trace (2D only) – Removes traces added via the selection above. Clicking this option opens a list of added traces. Clicking on an item in the list will remove that trace. This selection isn't available if no traces have been added.

Save Trace As (2D), Save 3D Plot (3D) – Use this selection to save the 2D or 3D trace. A 2D trace can be added to a later display for comparison. Either a 2D or 3D trace file can be opened in TraceView mode as a primary trace. The plot will be saved in OpenPF format with a .PF (2D) or .PF3 (3D) extension.

Show Added Trace Info (2D only) – Shows additional information about added traces. This selection is disabled if no traces have been added.

Restore Default Folder (2D, 3D only) – When you save a 2D or 3D trace or add a 2D trace, **EZNEC** remembers the last directory you chose and takes you there when you open the file choice dialog box. If you've navigated your way to some obscure directory and want to return to the directory where you normally store trace files, click this selection before choosing Add Trace or Save Trace As. This selection returns the initially displayed directory to the one chosen in the Control Center Options menu Folders/Description (.EZ) and Plot Files selection.

EDIT

Undo – Allows you to undo any change you've made to the description since opening it, in reverse sequence to the order in which the change was made. A change made anywhere in the program can be undone from any window having an undo selection.

Redo – Allows you to redo changes which have been undone.

Copy Plot – Copies the Plot section of the display to the Windows Clipboard as a bitmap. This allows it to be pasted into any Windows application which can accept graphical objects. Unlike the Print Plot selection above, the plot is not redrawn to a larger scale; the plot is copied exactly as it is. If the copy is later enlarged, quality will be poor because of the limited number of pixels in the original. It's best to adjust the **EZNEC** plot size to the actual size desired for the copy before creating the copy. Alternatively, you can first maximize the plot by clicking the maximize button near the upper right corner of the window. For best resolution, turn off Controls and Data sections (via the View menu) if on. Then do the copy. The resulting copy will have the highest possible resolution, and many applications will be able to reduce it to the desired size while retaining high quality.

Copy Plot and Data (2D, SWR only) – Copies the Plot and Data sections of the display to the Windows Clipboard as a bitmap. See the above comments regarding quality. This selection isn't available if the Data section is turned off. (The Data section can be turned on via the View menu.)

VIEW

Mult Trc Field (2D only) – This choice is enabled only when one or more traces have been added to the basic display, and a Desc Options choice has been made to plot multiple polarizations, for example Vert, Horiz, Total. Only one polarization can be shown when the display has multiple traces. This menu selection allows choosing which of the polarizations to show.
Show 2D Plot (3D only) – Turns the 2D Plot Display on and off. This allows viewing and detailed analysis of any 2D "slice" of the 3D plot.
Show Controls – Turns the Control section of the display on and off. NOTE: This isn't available for the 2D display unless a 3D display is on, with a "slice" of the 3D plot being shown on the 2D display.
Show Data (2D, SWR only) – Turns the Data section of the display on and off.
Show Data Lines (2D only) – When on (checked), lines are added to the 2D display, showing the directions of the pattern maximum, -3 dB points, and sidelobe, as reported in the data box. This option is available only if the Show Data option is checked. Colors for these lines can be chosen in the Options menu.
Show Objects (View Antenna only) – Allows you to select which of various objects is displayed in the plot section of the display, such as currents, segment dots, etc. These are detailed in the View Antenna Display Objects section.

OPTIONS

Colors – Allows you to choose the colors for objects displayed in the plot section of the display. **NOTE:** Choices will persist only until the program ends, unless the Colors menu is re-opened and Save As Default is clicked. Also allows resetting choices to the saved default colors. **NOTE:** Background color choice is ignored when printing.
Sizes and Widths -- Allows you to select line widths and object sizes in most graphics windows. One of the selections is Restore Default Sizes and Widths which will restore to the last saved default values.
Save As Default -- Saves colors, sizes, and widths as the default values. Unless this is clicked after changing colors, sizes, or widths, the changes will persist only until the program ends.

RESET (2D, 3D, VIEW ANTENNA ONLY)

Reset Cursor to Max (2D, 3D only) – Resets the cursor to the point of maximum field strength. In the 3D display, this option isn't available unless highlighting is on, and the highlighted slice is also returned to the one containing the maximum field strength.
Reset Position (View Antenna, 3D only) – Rotates display to the default position.
Reset All (View Antenna, 3D only) – Resets position, and all other choices such as zoom (but except colors) to initial values.

Creating Graphics Files

EZNEC does not directly create graphics files in common formats like .bmp, .gif, or .jpeg. However, it's still easy to do. In any of the Graphics Windows, open the Edit menu, then select one of the Copy options. This will copy the current display to the Windows Clipboard. Open a graphics application such as Paint which is furnished with Windows, and paste the Clipboard contents into it. The graphic display can then be saved to a file in any of the formats available in the graphics program. Of course, it's not necessary to save or convert the graphic display in order to insert it into a word processor or other application. It can simply be pasted there directly from the Windows Clipboard. For tips to get the best quality of saved or pasted graphic display, see the Edit section of the Graphics Windows Menus topic.
Note that .pf format files saved as "trace files" are not graphics files. They are binary files which contain only numerical field strength data, and no information about how to plot or display it.

Using The View Antenna Display

The View Antenna display is one of **EZNEC**'s most useful displays. With it you can see what the antenna looks like and see changes as they're made, look at the currents on each wire, see how the pattern is oriented relative to the antenna, and much more. You'll find it useful to leave this display open most of the time. Several model modifications can be done graphically in this display, described separately in Graphical Wire Operations.
The display window shows, to scale, what the antenna looks like. Various objects can optionally be shown on this view in addition to the antenna, as described below.

The Menus

The menus are detailed in Graphics Windows Menus.

The Controls

The Control Window, to the left of the display, can be turned on and off via the Show Controls selection in the View menu. It has controls enabling you to zoom, center, and move the image, and zoom the displayed currents after running a calculation. *Moving or zooming the display have no effect on the antenna model. They only change the way you're looking at it.* Note that you can also move and zoom the display (but not the currents) with the mouse. See Mouse Operations, below.

The Axes – When an antenna is first viewed, the intersection of the axes represents the coordinate system origin. If you move the antenna with the controls or by clicking the Center Ant Image box in the Control Window, the axes no longer represent the absolute coordinate system. When this is true, they become broken rather than solid. The origin marker (a dot surrounded by a circle) continues to show the true position of the origin even when the display is moved or zoomed.

Special Key Functions

N - Turns wire numbers on or off

X, Y, Z - Positions display to view from the X, Y, or Z axis. Hold down <Shift> with the key to view from the negative axis.

<Delete> - Deletes selected wires. See Selecting Wires below.

Mouse Operations

Rotating - To rotate the display, position the mouse cursor anywhere on the display window. Press and hold down the left mouse button. You can then rotate the display in two directions by moving the mouse while the left button is held down. Although the mouse cursor must be on the display window when the button is first pressed, it can be moved outside the window if necessary while the button is down. You can use the keyboard arrow keys for fine rotational positioning, but only after clicking in the display window to give it the focus.

Moving – To move the display, position the mouse cursor anywhere on the display window. Press and hold down the right mouse button. You can then move the display. It will move in the direction of one of the axes, the one most closely parallel to the mouse movement, so you might have to rotate the display in order to achieve movement in the direction of a particular axis.

Zooming – To zoom the display, position the mouse cursor anywhere on the display window. Press and hold down the both mouse buttons. This does not zoom the currents; that can be done only with the scroll bar.

Selecting Wires

The wire closest to the mouse cursor will be selected when the left mouse button is double-clicked. Additional wires can be selected by pressing and holding the <Ctrl> key while clicking with the left mouse button. <Ctrl>-clicking a selected wire will deselect it. Double-clicking a wire will always deselect all other wires.

The View Antenna display and Wires Window are coordinated. Whenever the Wires Window is on, wires selected in the Wires Window will be automatically selected in the View Antenna display, and vice-versa.

Wire Information

You can see information about any wire including length and end coordinates by pausing the mouse cursor over the wire. One important use of this feature is identifying which end of the wire is which – among the information shown are the coordinates of the wire end closest to the cursor, and that end is identified in the display. The behavior of the popup can be altered with Special Option WireInfoDist.

Displayable Objects

A number of objects can be added to the basic View Antenna display. These objects can be turned on or off via the Objects selection in the View menu. Following is a description of each choice you see when you make this selection. All items are on (shown) when its corresponding box is checked.

Axes – Selects the axes.

Currents – Adds currents to the display. Current magnitude is indicated by distance of the current indicator from the corresponding wire. This is a very useful feature in determining which parts of the model are contributing to the pattern. Currents aren't shown until a calculation has been done.

Current Phase – Modifies the current display to show phase by rotating the current lines around the wires. This is sometimes useful in conjunction with the Current Phase Markers (particularly when looking at phased arrays), but it often only obscures the current magnitude information.

Current Phase Markers – Added markers which can be selected if Current Phase is on. These markers show a solid line in the direction of zero phase and a dashed line in the direction of +90 degrees. These help show the current phase when Current Phase is being shown.

Segment Dots – Turns segment and wire junction dots on or off.
Wire Numbers – These are very useful when building, modifying, and troubleshooting a model. However, with a complex unzoomed model, they become an indistinguishable mass. The setting of the wire numbers is remembered until you quit **EZNEC**. The state of the wire numbers when you first start **EZNEC** can be set with the Control Center Options menu View Antenna Wire Numbers selection. You might want to make the initial state be off if you commonly model complex antennas. The wire numbers can be centered on the wires or offset. Wire numbers can also be toggled on and off by pressing the **N** key when the View Antenna window is active The wire number size can be changed if desired via Special Option VAObjTextSizePct..
2D Pattern – once calculated, a 2D pattern can be added to the display. This is particularly useful in showing the orientation of the plot to the antenna. If "Semi-Solid" is chosen, lines are added to give you a better idea of the real pattern shape and what it represents. The 2D plot won't appear if a 3D plot has been run and no slice is highlighted. See Using The 2D Display for more information about 2D plot orientation.
2 Port Objects – Shows two port insertion objects.

Object Symbols

Symbols shown in the display are:

Hollow circle	Source
Hollow square	Series-connected load
Hollow diamond	Parallel-connected load
Square with letter	Two port insertion object

The letter in a two port insertion object box identifies the type of object:

T	Transmission line
X	Transformer
L	L network
Y	Y parameter network [**EZNEC Pro** only]

A two port insertion object which is connected to two wire segments is drawn as a square box between the two segments. Dashed connecting lines are drawn from the two segments to the box. Different colored lines are used to identify the ports. The colors of the connecting lines can be chosen via the **Colors** selection in the **View** menu.

A two port insertion object which is connected between a wire segment and a virtual segment is shown as a square box at the wire segment. a short dashed line of the color of the port connected to the virtual segment extends to one side of the box, left for port 1 and right for port 2. At the end of the line is the virtual segment number to which the port is connected. For example, a transformer having port 1 connected to wire 1 and port 2 connected to virtual segment 4 would be shown as a box at the appropriate segment on wire 1 with a short line of the port 2 color extending to the right. "V4" would appear at the end of the line. An open or short circuited transmission line stub is identified in the same way, except with "S" for short and "O" for open in place of the virtual segment number.

Insertion objects which are connected only to virtual segments do not appear in the View Antenna display, but can be found in the Virtual Segment List. Open the **View** menu and select **Show Virtual Seg Conn**. See Virtual Segment Connection Display for more information.

Using The 2D Display

The 2D Display shows the result of a far field azimuth or elevation pattern calculation, which is a "slice" of the actual full three dimensional antenna pattern. It can also be used in conjunction with the 3D Display to show an elevation or azimuth "slice" of the 3D plot. This display automatically opens when a 2D (azimuth or elevation) pattern calculation is requested with the Control Center FF Plot action button. To use the 2D plot to show a "slice" of the 3D pattern, open the 2D Display from the 3D Display View menu, or check the Show 2D Plot box in the 3D Control Window.

Many of the menu items are the same as for the other graphics displays, so they're covered in a separate section Graphics Windows Menus. Be sure to look this section over, because it explains how to do such things as add traces to the display. This makes it easy to compare antennas and plots and see the results of changes.

The 2D plot can include Data Lines and a Cursor. Neither of these is shown if the Data Window is turned off via the View menu.

Orientation

An azimuth plot is always oriented as though looking down on the antenna. The top of the display is in the direction of the +Y axis, so the +X axis is to the right. When using conventional mathematical angles (Angle Convention selection "CCW From X Axis" in the Options Menu), angles increase as you go counterclockwise, zero degrees being to the right. If you've chose the "Compass Bearing" selection, zero degrees is at the top, and angles increase as you go clockwise. It's often helpful to add the 2D plot to the View Antenna display for a visual indication of the relative orientation of the antenna and plot. See Displayable Objects/2D Pattern in Using The View Antenna Display for details.

An elevation plot is always viewed from ground level, looking from the direction of the chosen azimuth angle. The same plot will be shown but reversed in direction if viewed from the opposite direction (that is, an azimuth angle 180 degrees from the original). When initially viewing a 2D "slice" of a 3D pattern, **EZNEC** will choose the initial orientation based on the pattern maximum, so the viewing angle might not be immediately obvious. Likewise, when switching between azimuth and elevation "slices", an apparent reversal of viewing angle may occur. If you have trouble visualizing the pattern orientation, adding the 2D plot to the View Antenna display as described above is helpful.

Navigation and Advanced Features

EZNEC has a number of features to help you analyze 2D antenna patterns. If you've chosen to display multiple polarizations, for example Horiz, Vert, Total, via the Desc Options choice in the Control Center, you can move the cursor from one polarization trace to another simply by clicking its name in the key list at the left of the 2D plot window. The Data Window (see below) reports the

field strength (as gain relative to isotropic) of that polarization component. If you add traces, you can switch the cursor to any trace by clicking the corresponding file name in the key list at the left of the 2D plot window. When this is done, and additional line of data appears in the right column of the Data Window, showing the gain of that trace relative to the primary (calculated) trace at the cursor's angle. This makes quantitative pattern comparisons simple.

Data Window

The Data Window shows useful information about the 2D plot: maximum gain, front/back or front/side ratio, 3 dB beamwidth, and other parameters. The items on the right side of the window show the values at the cursor, so change as the cursor is moved. The cursor is moved by clicking anywhere on the Plot Window, and the plot cursor will move to a point on the direct line between the placed clicked and the center of the plot graph. You can drag the cursor around the plot by holding the mouse button down as you move the mouse. The mouse has to be on the Plot Window when initially clicked, but can leave the window afterward if the button is held down. The cursor is always present when the Data Window is open, and never present when it's closed.

The up and down keyboard arrow keys can be used to move the cursor in small steps, and the <PageUp> and <PageDown> keys to move it in larger steps. It's first necessary for the Plot Window to have the focus. It can be given focus by clicking anywhere on it with the mouse.

The Data Lines show the angles at which EZNEC has determined the maximum forward gain, -3dB points, and sidelobe occur. The "sidelobe" is the lobe with second highest gain. Data Lines can be turned on and off from the View menu, and won't appear if the Data Window isn't being shown.

Control Window

The Control Window is opened from the View menu. However, it's not accessible unless the 3D plot is also open, since the controls are used primarily to select slices for display. When open, the controls in the Control Window are the same as those in the 3D Control window, and the two sets of controls track.

Whether to show the frequency on the plot can be chosen in the Control Center Options menu.

Using The 3D Display

The 3D Display opens automatically after running a far field pattern calculation when the Plot Type is 3 Dimensional. It shows a full pattern plot. To make the plot easier to visualize, you can highlight any azimuth or elevation "slice", and easily see its shape and where it fits into the overall pattern. The highlighted slice can optionally be shown in the 2D Display or superimposed on the View Antenna display.

Many menu operations are common among all the graphics displays, so they're covered in the common section Graphics Windows Menus.

Orientation

The 3D plot is always oriented in the same direction as the antenna in the View Antenna display, after releasing the mouse button following a 3D Plot or View Antenna rotation. This helps in visualizing the orientation of the pattern relative to the antenna.

Rotating the 3D pattern

The 3D pattern is rotated in the same way as the View Antenna display, by holding down the left mouse button while you move the mouse.

Highlighting a slice

To take full advantage of the 3D display, turn on the Control Window from the View menu and select either Azimuth Slice or Elev Slice. The 3D plot will dim, and the highlighted slice will be shown in a distinctive color. You can select the slice and move the cursor with the scroll bars. Note that you can also drag the scroll bar slider bar.

Displaying a 2D slice

If you check the Control Window Show 2D Plot box or select Show 2D Plot in the View menu, the 2D Display opens and shows the highlighted slice. If the 2D Control Window is shown, the 2D controls will track the 3D controls. This combination of 2D and 3D plot combines detailed analysis with easy visualization.

If you open the View Antenna Display, you can add the 2D slice to the display via the View Antenna View menu Objects selection. It will move as you change the 3D slice.

Using The SWR Display

The SWR Display is shown after running an SWR sweep. This in turn is started by clicking the SWR action button in the Control Center, then entering frequencies or an input file name and starting the sweep as described in the SWR Graph section. This section describes use of the resulting display.

Many menu operations are common among all the graphics displays, so they're covered in the common section Graphics Windows Menus.

The SWR Display shows the impedance seen by each source. The most basic is a graph of SWR vs. frequency. The SWR is not necessarily the actual SWR on a transmission line, but is the SWR which would be on a line if the line were connected between the source and antenna. Several other displays are described below.

If you turn on the Control Window via the View menu, you'll have a choice of the SWR for two values of line characteristic impedance (SWR). One impedance is 50 ohms. The other can be changed to a value of your choice by clicking on the Alt SWR Z0 line in the Control Center Information Window. Also in the Control Window is a selector allowing you to choose the source for which to display the SWR, in the event your model has more than one source.

Additional information appears in the Data Window below the plot. The Data Window is turned on or off from the View menu. In this window, you can see the impedance and reflection coefficient as well as the SWR.

The cursor can be moved by clicking on the display window or by dragging with the mouse. You can also use the arrow keys, after clicking once on the display window with the mouse to make sure the display window has the focus.

There is an additional Display Type selection in the View menu. This allows selection of the data display as either SWR, reflection coefficient magnitude, return loss, or Smith Chart. When Smith chart is chosen, additional selection Data Markers is enabled. As with the SWR plot, a cursor is present when the Show Data selection is checked in the View menu, and the cursor position can be changed by clicking near the point of interest or by using the keyboard

arrow keys after first clicking on the plot to make it the active window. And, like the standard SWR plot, information about the selected frequency point is shown in the data window below the plot. The vertical scale factor of the rectangular plot types is fixed, as is the Smith chart scale. The program remembers the last plot type choice, and uses that plot type the next time an SWR sweep is run. Note that the Smith chart display is a display only, and not a substitute for a Smith chart program with interactively aids in the design of matching networks.

Additional Information

Calculating Engines

EZNEC Pro+ is basically a user interface for the complex and powerful NEC (Numerical Electromagnetics Code) series of "codes" developed by the U.S. government. Because they do the actual calculations of antenna impedances, currents, and fields, they're referred to here as *Calculating Engines*.

EZNEC Pro+ can use three different versions of NEC -- 2, 4.2, and 5 -- as calculating engines while maintaining the same basic user interface. Each NEC version has its own advantages, disadvantages, and limitations which are discussed below. The newest NEC version, NEC-5, also requires changes to how some models are designed, described in the NEC-5 Object Placement topic. NEC-4.1 is not supported by **EZNEC Pro+** but anyone having this program can contact LLNL for an upgrade to NEC-4.2.

The NEC versions which both **EZNEC Pro/2+** and **EZNEC Pro/4+** can use are NEC-2, NEC-4.2, and NEC-5. Both **EZNEC Pro+** programs include an integral or "internal" NEC-2 calculating engine. (The "internal" engines are actually separately compiled executable files, EZCalc(4)(D).exe, but are specifically designed to work with **EZNEC** and can't function independently.) Both **EZNEC Pro+** programs are also able to do calculations with an external user-supplied NEC-4.2 or NEC-5 program. **EZNEC Pro/4+**, only, includes an internal NEC-4.2 calculating engine that's much faster than the external NEC-4.2 engine which is commercially available. See Installing & Using External NEC-4.2 and -5 for more information about the external calculating engines.

MAJOR DIFFERENCES

NEC-2

- Does not allow buried conductors
- Subject to stepped diameter errors
- Sensitive to insertion object placement, especially sources
- Enhanced version included in **EZNEC Pro/2+** and **EZNEC Pro/4+**

NEC-4.2

- Allows buried conductors
- Not subject to stepped diameter errors
- Sensitive to insertion object placement, especially sources
- Enhanced version included in **EZNEC Pro/4+**
- External NEC-4.2 program (purchased from LLNL) can be used with **EZNEC Pro/2+** and **EZNEC Pro/4+**
- External NEC-4.2 program relatively slow

NEC-5

- Allows buried conductors
- Not subject to stepped diameter errors
- Insensitive to insertion object placement
- Not subject to several other NEC-2 and NEC-4.2 sensitivities and restrictions
- Requires different insertion object placement than NEC-2 and -4.2
- Not included in **EZNEC Pro/2+** or **EZNEC Pro/4+**
- External NEC-5 program (purchased from LLNL) can be used with **EZNEC Pro/2+** and **EZNEC Pro/4+**
- External NEC-5 program relatively fast

FEATURE DIFFERENCES

This graphic, prepared and kindly furnished by Dan Maguire, AC6LA, shows some additional differences:

Feature Availability vs Engine Choice
for EZNEC Pro/2+ and EZNEC Pro/4+

Feature	Calculating Engine			
	EZCalcD (NEC-2D)	EZCalc4D (NEC-4D)	External NEC-4.2	External NEC-5
Insulated wires	✓	✓	✓	✓
Buried wires		✓	✓	✓
Unconnected 1-seg wires with insertion objects	✓	✓	✓	
Split sources	✓	✓	✓	
Two ground media	✓	✓	✓	
Two ground media with MININEC ground	✓	✓		
Ground Wave calculation with MININEC ground	✓	✓		✓
Near Field calculation with MININEC ground	✓	✓		✓
Real/High Accuracy (GN2) ground	✓	✓	✓	
Real/Extended Accuracy (GN3) ground		✓	✓	✓

Notes:

1) Features not listed such as lossy transmission lines, L networks, and transformers are available with all engines.
2) The EZCalc4D engine is available only to existing EZNEC Pro/4 users.
3) External NEC-4.2 and/or NEC-5 engines must be purchased from LLNL.

AC6LA

ADDITIONAL DETAILS

NEC-2

NEC-2 is in the public domain and readily available as both source code and a compiled program. It has been the primary engine used by **EZNEC** since its introduction in 1995. Because NEC-2 is the only public domain version of NEC, it is the only one freely and publicly available for **EZNEC** use. The internal **EZNEC** NEC-2 calculating engine is highly modified and much faster than the original NEC-2 programs, and it has many added features and capabilities not present in the original program.

In very many cases, NEC-2 will give results which are virtually identical to those of NEC-4.2 and NEC-5. However, there are some notable cases where it won't.

NEC-2 can't model buried conductors - A system of buried ground radials can only be simulated by radial wires placed just above the ground. Ground

system ohmic losses can also be included in a model by using MININEC-type ground which uses perfect ground for impedance and current calculations and adding a lumped resistive load at the ground connection point.
NEC-2 is quite sensitive to placement of insertion objects such as sources and loads, and failure to follow guidelines sometimes can result in significant errors. Problems can also occur when segments are too short, too long, or too short compared to the wire diameter. **EZNEC** contains guideline check routines to alert you to situations where this might be a problem, and is able to detect many cases where a problem is occurring. These are discussed in detail in Placing Insertion Objects On Segments, Placing Sources On Segments, and Segmentation Check.
Potentially the most significant limitation of NEC-2 is that it produces an error when wires of different diameters are connected together. The error is usually quite small, but it can be very significant when it occurs in a high Q antenna such as a Yagi. Yagis made from telescoping tubing of different diameters are subject to this problem. Available in **EZNEC** is Stepped Diameter Correction which does a very good job of correcting this, but only for Yagis and other antennas with full-size (that is, near half-wavelength) elements and no traps or loading. Alternative methods of correcting for the stepped diameter error were added at **EZNEC** v. 6.0 which do a reasonably good job of correcting some antennas with loading coils and/or traps. But the exact conditions under which the method works well are unknown, and it's not possible to predict how accurate the result will be for a given antenna. If you don't have **EZNEC Pro/4+** and the stepped diameter error is a problem for your modeling, **it's highly recommended that you purchase NEC-5 to use with EZNEC Pro/2+**. It's available from LLNL for a very reasonable price, and will allow buried conductors as well.

NEC-4.2

Until recently, NEC-4.2 was considered to be the most advanced modeling program of its type, and it's in very wide use in many organizations and industries world wide. Its results have been time tested and found to be extremely accurate except for a few well-known situations.
NEC-4.2 is subject to the same insertion object placement and some of the segment length requirements described above for NEC-2, but is almost completely free of the stepped diameter problem of NEC-2. It can still appear, but only with huge diameter steps and not with anything resembling telescoping tubing steps. So it's an excellent calculating engine to use for all types of Yagis and other high-Q antennas as well as all the others which NEC-2 can handle. Models can include buried wires.
EZNEC Pro/4+ includes an integral enhanced NEC-4.2 program which is much faster and has a few more capabilities than the NEC-4.2 program available from LLNL. NEC-4.2 is not public domain, and licenses are administered by LLNL. All purchasers of earlier versions of **EZNEC Pro/4** provided a copy of their LLNL NEC-4.2 license prior to the purchase which was the condition under which **EZNEC Pro/4** was allowed to incorporate it. I will attempt to make **EZNEC Pro/4+** available to those users free of charge. But since I will no longer be available to verify that any other potential users have purchased an NEC-4.2 license from LLNL, **EZNEC Pro/4** will regretfully no longer be available, and **EZNEC Pro/4+** will not be available except to

existing **EZNEC Pro/4** users. There are, however, two ways that similar capabilities can be had with **EZNEC Pro/2+**:

1. Purchase an NEC-4.2 license from LLNL. You'll receive an NEC-4.2 program which you can use as an external calculating engine with **EZNEC Pro/2+**. It will run much more slowly than the internal **EZNEC Pro/4+** calculating engine and have a few limitations (see the graphic above), but results will be virtually identical. Formerly quite expensive, LLNL has dropped the price to the same very reasonable price as NEC-5.
2. **Recommended.** Purchase an NEC-5 license from LLNL and use the provided program with EZNEC Pro/2+ (or EZNEC Pro/4+). The price is very reasonable, the speed is much faster than an external NEC-4.2 program, and NEC-5 has a number of advantages over NEC-4.2 as described in the NEC-5 description below.

NEC-5

NEC-5 is the newest of the NEC programs and is structured somewhat differently in order to eliminate many of the limitations, restrictions, and peculiarities of NEC-4.2. From all evidence, it succeeded very well. Like NEC-4.2, its licensing is administered by LLNL, and the price is easily within the reach of the average amateur. The "console" or "command line" program that comes with the purchase of a license can be directly used as a calculating engine by **EZNEC Pro/2+** or **EZNEC Pro/4+**. The calculating speed isn't as great as EZNEC Pro+ integral NEC-2 or NEC-4.2 calculating engines, but it's much faster than an external NEC-4.2 program. **I highly recommend it for all but the most casual EZNEC Pro+ users.**

Like NEC-4.2, NEC-5 models can include buried conductors, but it's almost completely insensitive to insertion object placement or segment length (except that segments shouldn't be too long), and such things as the need to align segment junctions on closely spaced wires as in NEC-2 and -4.2. Both NEC-2 and NEC-4.2 have limits on the minimum sized loop that can accurately be modeled. NEC-5's minimum size is between those of NEC-2 and NEC-4.2. Other, usually minor disadvantages are:

- It requires more segments than NEC-2 or -4.2 to fully converge on a fully accurate result.
- It is not able to model more than one ground medium.
- It isn't able to use Real, High-Accuracy ground but only the potentially much slower (but more accurate) Extended-Accuracy ground.
- Insertion objects are placed at segment junctions rather than segment centers, which requires modification of some existing **EZNEC** models, and a learning curve for people familiar with **EZNEC** or other NEC-2 or -4 based programs. The NEC-5 Object Placement topic describes this in more detail.

The originally issued NEC-5 contained a number of bugs, some of which would affect results when used with **EZNEC Pro+**. LLNL is now making available a version which has had those fixed, and allowing no-cost updates to that version from the original. At the time of this writing, the modified version is called NEC5 x13. You should obtain and use the updated version with **EZNEC Pro+**. See https://eznec.com/NEC-5.htm and the LLNL topic for more information.

LLNL

Lawrence Livermore National Laboratory, which administers licensing for the copyrighted software NEC-4.2 and NEC-5.
To obtain an NEC-5 license or to update an originally issued (unmodified) NEC-5 program to a modified (debugged) one, or
To obtain an NEC-4.2 license or upgrade NEC-4.1 to NEC-4.2 ,
go to https://eznec.com/xLLNL_info.htm for current links.

See NEC-5 Status for more information.

File Locations

Following are the default locations of files read from and written to by **EZNEC**. Ones marked with an asterisk (*) can be changed via the Folders selection in the Control Center Options menu. Substitute "Program Files (x86)" for "Program FIles" below if the operating system is 64 bit.
Caution - File locations used by earlier versions of **EZNEC** are not changed by installing v. 7.0, and v. 7.0 locations -- except those modified via the Options menu -- are different. So if for any reason you run an earlier version of **EZNEC** after installing v. 7.0, files you've saved with one version may not be visible to the other unless file locations used by both old and new versions are set to the same folder.
Program Files - **Program Files Folder\EZNEC 7.0** (C:\Program Files [(x86)]\EZNEC 7.0) - Main executable file, calculating engines, and other files used for **EZNEC** functionality. These files are essential to **EZNEC** operation. **EZNEC** does not write or modify any files in this directory or subdirectories. The directory where program files are placed can be chosen during the installation process, but it is recommended that the default location be used. External NEC-4.2 and NEC-5 calculating engines should *not* be put in this directory. See Installing & Using External NEC-4.2 and -5.
Working Files - Files written by **EZNEC** during operation are kept in C:\EZNEC 7.0 and subdirectories. See Options for details.
NOTE: The Temp subdirectory of the Docs folder is used by **EZNEC** and deleted when the program normally ends. So don't use it for any other purpose!

AutoEZ

AutoEZ (Automated use of **EZNEC**) is a separate application that can enhance the power of **EZNEC** by allowing variables to be used in place of or in addition to any numeric value found in any part of an **EZNEC** model, such as wire End 1/End 2 XYZ coordinates, the number of segments in a wire, the magnitude and/or phase of a voltage or current source, the R+jX or RLC values in a load or L network, or any other place where a number might be used. Such variables can then be automatically set to a range of values by doing a "variable" sweep in place of or in addition to a traditional "frequency" sweep. Among the many AutoEZ features are:

- For existing **EZNEC** models, semi-automatic replacement of wire XYZ coordinate numeric values with variable names if desired.

- An **optimizer** with the ability to optimize on any combination of SWR, feedpoint R/X, 2D pattern gain, pattern front/back, or pattern front/rear, all at one frequency or over a range of frequencies.
- A **Resonate** button to automatically find the resonant frequency or adjust the dimensions of a model (such as dipole length or loop circumference) to achieve feedpoint resonance.
- **File translation**: In addition to reading AutoEZ (.weq) and **EZNEC** (.ez) format model files, AutoEZ can read NEC (.nec or .inp), K6STI AO and NEC/Wires (.ant), MMANA-GAL (.maa), DXE Yagi Mechanical (.stm), K7NV Yagi Stress (.ys2), K6STI YO (.yag), and N6BV Yagi for Windows (.yw) format models. Some restrictions apply for other than AutoEZ and **EZNEC** formats. Any of these formats can be saved in either AutoEZ or **EZNEC** format, hence AutoEZ can be used to do "format translations" for many models.
- Functions to create stepped diameter Yagi elements, loops (such as for quad antennas), radials, and wire grids. Variables may be used if desired.
- Functions to move, copy, rotate, or scale wires with the ability to use a variable to control the operation.
- Automatic temporary removal of all loss from the model (ground loss, wire loss, transmission line loss, etc.) followed by automatic calculation of 3D average gain as one way to judge the accuracy of the calculated results.
- Automatic way to vary the segmentation of the model and then plot the change in feedpoint impedance and 2D pattern metrics as a way to judge if the calculated results have converged.
- Dozens of illustrated examples from simple (show how a dipole feedpoint impedance varies as height above ground changes) to extremely complex (model a 4-square array with hybrid coupler feed system as part of the model; model a SteppIR® Yagi with the wire ends "going around the trombone loops" as the frequency is changed). Model files are available for all examples to allow expanding on the scope of the example topic.
- One-screen at-a-glance collection of the most frequently used charts (feedpoint R and X; feedpoint SWR; 2D pattern gain, front/back, front/rear) where the X axis of the charts can be frequency or a sweep of a variable value.
- Automatic creation of High Pass Tee, Low Pass Pi, High Pass L, or Low Pass L impedance matching networks to be included with the model. Matching can be done for a single frequency or at multiple frequencies across a band or bands to see the range of component values required or to simulate an auto-tuner.
- Automatic creation of series section (Regier) or shunt (parallel) stub transmission line matching solutions.
- Built-in list of 100 different transmission lines to allow easy setting of frequency-agile Zo, VF, and loss field values for transmission lines.
- 2D radiation pattern chart in either polar or rectangular format. 2D plots can be for Total/Vert/Horz dBi or Far Field electric field strength or Near Field electric field strength.
- Near Field electric or magnetic field strength 3D chart.

- Custom chart to plot just about anything on the X axis vs just about anything on the Y axis. An Excel trendline can be added to do regression analysis on the charted data.
- Free Demo version available with all the features of the standard program except limited to calculating models with no more than 30 segments.

The AutoEZ user interface is very similar to that of **EZNEC** and the communication and data sharing between the AutoEZ and **EZNEC** programs is automatic and completely transparent to the user. For more information see the **Quick Start Guide**, various **Detailed Information** sections, and the **Collected Short Examples** all starting at the AutoEZ home page.

Single Precision Operation

Single or mixed precision calculating engines are not recommended unless required by memory limitations. See Very Large Models for more information.

A mixed precision NEC-2 calculating engine is incorporated into **EZNEC Pro/2+** and **EZNEC Pro/4+**, and **EZNEC Pro/4+** also includes a single-precision NEC-4.2 calculating engine (EZCalc4). However, double-precision engines are standard and recommended for use. The choice of calculating engine precision affects the size of model at which virtual memory operation will take place; it will happen with a smaller number of segments (approximately 0.7 times as many) when running double-precision calculations than when running single precision. In addition to the inherent slowing during virtual memory operation, operation may also be slowed somewhat because of the increased sizes of arrays which must be written to and read from the disk during calculation. Approximately twice as much memory and temporary disk space will be used for double precision operation. The maximum number of segments and wires which **EZNEC** will accommodate is the same for both single and double precision. See Very Large Models for more information about virtual memory use and techniques to minimize calculation time.

The interface portion of the program is mostly single precision, with the exception of L network, transformer, and Y parameter network parameters. Consequently, wire coordinates, for example, are passed along to the calculating engine as single-precision numbers, and single-precision arithmetic is used to determine wire connections within the interface. Also, some functions done by the interface such as wire height modification are done in single precision. Marginal conditions of wire connection (where wire ends are not the same but are very close to 0.001 segment apart) should be avoided. Both **EZNEC** and the calculating engine modify coordinates slightly to force a match when wire ends are extremely close, but it could be possible for one to force or assume a connection and the other not, under marginal conditions. So while unlikely, this situation should be avoided. When using an internal or external NEC-4.2 engine or external NEC-5 engine, the output of the interface portion of the program is an NEC input file which is passed to the calculating engine. The precision of all calculations is determined by the calculating engine choice.

Commonly available external NEC-4.2 and NEC-5 calculating engines are double precision.

See Options for information on selecting the appropriate calculating engine. L Network Limitations has information about the impact of precision choice when the model contains L networks.

SimSmith

EZNEC programs through v. 5.0 created input files for one or two external Smith chart programs for aiding in designing impedance matching networks. Those programs are now obsolete so support has been discontinued. A very capable program is currently available that can directly use **EZNEC**'s LastZ.txt or Last.s1p file for input. This program is SimSmith by Ward Harriman, AE6TY. See http://ae6ty.com/Smith_Charts.html for information.

Software Incompatibilities

Antivirus and Anti-malware (-adware or -spyware) Programs – When set to constantly check for "virus-like" activity, some programs cause a very significant slowing of the calculations when using an internal calculating engine. It appears to be due to interception and analysis of the messages sent from the calculating engine to the main program in order to show calculation progress. Slowing in terms of a fraction of total calculation time will be greatest for simple models, since this is when the time spent sending calculation progress messages is the greatest fraction of total calculation time. Total slowing will be most noticeable when doing a frequency or SWR sweep of a relatively simple model. If the slowing is objectionable, it can be alleviated either by turning off the feature in the antivirus or anti-malware program, or by directing **EZNEC** to update the calculation progress display less frequently. The latter is done by setting Special Option CalcProgReduction.
Anti-malware or "security" programs occasionally block **EZNEC**'s access to files or quarantines or deletes files needed by **EZNEC**. This can sometimes be prevented by appropriately setting the interfering program's security level or instructing it to allow **EZNEC** to operate.

The Calculation Progress Window

The Calculation Progress Window appears whenever **EZNEC** is doing a calculation. It functions somewhat differently when using internal or external calculating engines to do calculations but always remains on the screen until calculations are finished. No **EZNEC** operations except canceling the current calculation can occur while it's being displayed. It shows several important pieces of information in addition to allowing you to terminate calculations before they finish.
Calculating Engine Type -- The title bar shows which calculating engine is being used. "NEC-2(D)" and "NEC-4(D)" refer to the internal NEC-2 and NEC-4.2 calculating engines respectively.
Frequency – The frequency is shown just below the title bar. This is particularly useful when doing a frequency sweep.
Stepped Diameter Correction – This message appears under the frequency if one or more groups of wires is being corrected with the stepped diameter correction feature (normally used only with the internal NEC-2 calculating engines). Its appearance doesn't guarantee, however, that all elements of a

Yagi, for example, are being corrected. To determine this, you have to use the Stepped Diameter Correction Display. Stepped Diameter Correction will normally be disabled when using an NEC-4.2 or -5 calculating engine, so this message won't appear in those cases.

Disk Use As Virtual RAM -- If the internal NEC-2 or -4.2 calculating engine can't find enough available RAM, it uses the disk as virtual RAM. Although Windows will do this on its own, the routines built into NEC are much more efficient for the purposes of doing the necessary calculations. You won't see this message except with very large models, and then most likely on 32 bit operating systems which allow access to much less memory.

Calculation Progress – This part of the display is different depending on whether using an internal or external calculating engine.

Internal calculation engines (EZCalc(4)(D) NEC-2 or -4.2 -: Several progress bars appear in the window as the calculation runs. Which bars appear is determined by the calculations being done. A ground file calculation bar appears only when using Real, High or Extended Accuracy ground, and then only if **EZNEC** failed to find a file containing suitable data from a previous calculation. Progress as shown on the bars doesn't necessarily proceed at a constant rate, so you shouldn't be concerned if it seems to speed up, slow down, or occasionally pause as calculations proceed. Sometimes the current calculation is split into two parts, "Factor" and "Solve", if certain insertion objects are present in the model. The "solve" portion tracks the progress of combining the main matrix with networks, which can take considerable time with very large models. (See Very Large Models.) You'll also see a "Geometry Check" bar showing the progress of **EZNEC**'s Geometry Check.

External calculating engines (NEC-4.2 or -5): There is no communication between **EZNEC** and the external calculating engines as there is with the internal engines, so the progress of a single calculation can't be known or shown and no progress bars appear. However, **EZNEC** starts the calculating engine at each step of an SWR or frequency sweep so a progress bar shows the fraction of the total number of steps which have been done.

Cancel – Clicking this button will stop calculations and return you to the main interface part of the program. There might be a delay before the program responds to your cancellation request, particularly when using an internal calculating engine with models having a very large number of segments.

Reinstalling or Copying EZNEC

To reinstall or copy **EZNEC**, simply copy the installer file you downloaded to the target machine and run it. **EZNEC Pro/2+** will be available at https://eznec.com but only for a length of time that's not known at this point. Replacement copies of **EZNEC Pro/4+** won't be readily available, so be sure to make backups of the copy you've obtained.

When **EZNEC** is installed, entries are made in the system Registry and files are placed in locations other than the program directory. These entries and files are essential to **EZNEC** operation. Consequently, a copy of the files in the **EZNEC** program and/or working directories after installation isn't sufficient

to reinstall the program or to copy it to another machine. It can be done only as described above.
There is no restriction to copying or sharing **EZNEC Pro/2+**. **EZNEC Pro/4+** contains software copyrighted and administered by Lawrence Livermore National Laboratory, so its use is limited to people or organizations which have purchased an NEC-4.2 license from them. I will no longer be confirming that a license has been issued, so **EZNEC Pro/4+** will not be distributed except to people who previously purchased some version of **EZNEC Pro/4** at which time their possession of an NEC-4.2 license was confirmed.

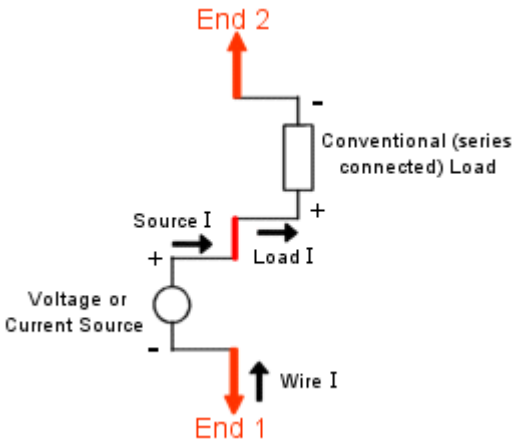
LastZ.txt and LastZ.s1p files

The LastZ.txt file is created when a Frequency Sweep or SWR sweep is run. It contains, in comma-delimited ASCII format, the impedance and SWR at each source and frequency. It remains in the **EZNEC** output directory after the program ends and can be used for other purposes if desired. Text headers in the first line identify the field contents.
LastZ_sorted.txt is a differently ordered variation of LastZ.txt. When the description has multiple sources, LastZ.txt lists data for each of the sources at the first frequency, then at the second frequency, etc. LastZ_sorted.txt lists all the frequencies for source 1, then all the frequencies for source 2, and so forth. The two files contain the same data.
The LastZ_src#.s1p files contain impedance (Z11) or reflection coefficient (S11) information for each source in Touchstone format. The default parameter and format are reflection coefficient magnitude and angle (S MA) but others can be selected with Special Options. The impedance reference is 50 ohms but a Special Option allows the Alt SWR Z0 value to be used instead. These files are written during each SWR and frequency sweep.

Parallel Connected Loads Polarity

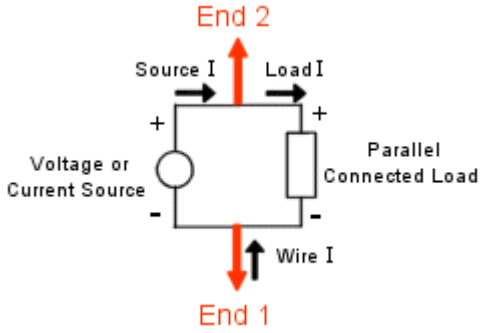
Polarity Differences Between Series and Parallel Connected Loads

The polarity of voltage and current reported in the **Load Data** display will usually be opposite for series and parallel connected loads. The polarity reversal will be evident as a 180 degree difference in phase of current and voltage. This is caused by a difference in definition between the two load connections in the definitions of which terminal is considered to have positive voltage relative to the other and which direction is defined for positive current flow. The conventions, and the reason for the difference, are explained below.
First consider a source and conventional (series connected) load connected to the same segment of a wire (red). The load, as the connection type implies, is connected in series with the source. The wire is shown in red. Defined voltage polarity is shown for the source and load, and the positive direction of current flow for each object is shown with an arrow.



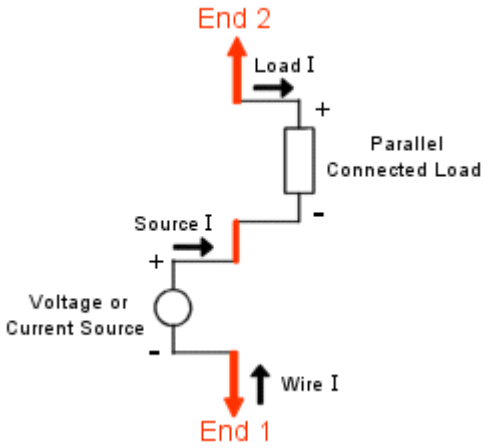
If the source is producing, say, 1 ampere at a phase angle of zero degrees, the Load Data display will report 1 ampere at zero degrees, because the directions of the source and load currents are defined the same -- that is, the positive current arrows are pointing in the same direction, away from end 1 of the wire and toward end 2. This is also the direction of the wire current. One would expect the current through the load to be the same as the current from the source, since both are in series, and the chosen definitions of current direction cause them to be the same. The voltage drop across the load has to be defined as shown, so that the impedance will be equal to V/I.

Next consider a parallel connected load in parallel with a source:



Here, the voltage across the load is the same as the voltage across the source, so we would expect the load voltage to be reported as being the same as the source voltage. And the convention for defining the voltage polarity of the load has been chosen to make this so. But notice that *the convention for voltage polarity is opposite that for the series connected load* -- the + terminal of the parallel connected source is toward end 2 of the wire, while the + terminal of the series connected load was toward end 1 of the wire. Without this different definition, the load voltage would be reported as being the negative of the source voltage when the two are connected directly in parallel, a situation sure to be confusing. Once the voltage convention is determined, the convention for positive current is also fixed in order to make the load impedance equal V/I. Like the series connected load, the direction of positive current is into the load from the positive terminal. But because of the voltage definition reversal, the direction of positive load current is away from end 2 of the wire toward end 1. Relative to the wire, this is the reverse of the direction of positive current for the series connected load.

The difficulty arises when a parallel connected load is placed in series with the source. This can't be done on the same segment as done with the series connected load, but it could be, say, on the adjacent segment. That situation looks like this:



Compare this to the first diagram, with the series connected load, and it's apparent that the definitions of polarity of both the load voltage and current are opposite for the two types of loads. This has no impact on any results except for the phase angle of voltage and current shown in the Load Data display. Whenever you directly replace one load type with the other, you'll see a 180 degree change in both voltage and current.
The only way to avoid the reversal between types is to reverse the convention of one type of load or the other. If the series connected load were reversed, the load current would be shown as reversed in phase from the source current when the two are directly in series. If the parallel connected load were reversed, its voltage would be opposite in polarity from that of a parallel connected source. So the conventions shown above were chosen. These are also the conventions used by NEC, so using them in ***EZNEC*** helps when making comparisons to NEC results.

Very Large Models

Several factors should be considered when working with models of several thousand segments. The following information is provided to help you optimize the analysis of these very large models.
Calculation Time – There are two major time-consuming portions of the calculation, impedance calculation (matrix fill), and current calculation (matrix factor). The first increases as about the square of the number of segments, while the second increases approximately as the cube. So for very large models, the second process usually dominates. Another part of the current calculation, "solve", can become extremely long if the model contains a large number of transmission lines. Adding ground to a free-space model will also slow calculations substantially, and use of Extended Accuracy (NEC-4.2 GN3) ground instead of High Accuracy ground with an NEC-4.2 calculating engine can cause dramatic slowing. (NEC-5 doesn't have a High Accuracy ground option and NEC-2 doesn't have Extended Accuracy ground.) Specially compiled fast calculating code is used in the internal calculating engines for the current calculation portion, but only if the program isn't forced to use the

disk for virtual memory. Consequently, a major speed reduction will occur if this mode becomes necessary.
Internal 64 bit calculating engines are installed with **EZNEC Pro** on a 64 bit operating systems. These have access to a very much larger amount of RAM than 32 bit engines, so virtual memory operation isn't necessary if sufficient RAM is available on the system. But a maximum size 45,000 segment model would require about 16 GB of available RAM if run in single precision and 32 GB for double precision. No program can use all the system RAM, so amounts greater than this would have to be installed to avoid virtual memory operation. External NEC-4.2 and NEC-5 calculating engines have their own memory management and are readily available in 64 bit versions. To easily tell if an application (including calculating engines) is 64 bit, right-click it in Windows Explorer, choose Properties and the Compatibility tab, then check the "Run this program in compatibility mode for" box. Windows Vista will be the earliest choice in the drop-down list if the program is 64 bit. Be sure to click Cancel when finished!
To avoid extremely slow calculations with very large models, install EZNEC Pro on a 64 bit system with as much RAM as possible, and reduce the number of segments as necessary to avoid virtual memory operation. And don't use Extended Accuracy ground unless absolutely necessary. (Note that NEC-5 doesn't have a High Accuracy ground option or virtual memory mode.)
Segments – In my experience of viewing models created by **EZNEC pro** users, many models use more segments than necessary. Calculating time is approximately proportional to the square of the number of segments for small models and to the cube of the number of segments for large models, so reducing the number of segments is always desirable. The Segmentation section contains tips for reducing segment use.
Virtual RAM Use – NEC-2 and -4.2 will use the disk for virtual memory if necessary. See Calculation Time above for more information. When virtual memory is in use, more than 40 GB is required for temporary storage for the largest models, and files of about 25 GB are written. NEC-2 engines require several times the temporary storage space as NEC-4.2 engines, due to a different calculation method. When using an internal calculating engine, **EZNEC** will check your available disk space before beginning calculations, and will refuse to run if not enough is available. I don't know how external calculating engines, which do their own memory management, would react to this condition.
Networks – The presence of networks can slow the solution a great deal, particularly in very large models. In one model with 9000 segments, 100 networks nearly doubled the calculation time, so reduction of the number of networks can make a striking difference. One network is created for each transmission line, Y parameter or L network, or transformer. NEC-2 also creates one for each current source and two for each "split" current source. Combining of the networks with the main large matrix shows in the calculation progress window as "Calculating currents: Solve". During the time this progress bar is filling, you might also see constant disk activity, particularly if the disk is being used for virtual RAM. Reducing the number of networks or the number of segments will shorten this portion of the calculation.

Bailing Out – You can terminate running calculations by clicking the **Cancel** button in the Calculation Progress Window. It might take some time to respond, so please be patient; the calculation will stop. You'll also find that if you cover any of the **EZNEC** windows during a lengthy calculation, there might be a delay before they redraw. Both these delays are due to the fact that the calculating engine communicates with the main program only at discrete times, and updates and button responses can only be serviced at these times. External calculating engines can sometimes be stopped by closing the console (command) window when it's visible -- see Options.

EZNEC Pro+ And NEC

There currently are two programs in the **EZNEC Pro+** family: **EZNEC Pro/2+** and **EZNEC Pro/4+**.

EZNEC Pro/4+ can use an included enhanced NEC-2 calculating engine or an enhanced NEC-4.2 engine integrated with **EZNEC Pro/4+**. **EZNEC Pro/2+** is supplied with only the included enhanced NEC-2 calculating engine. This is the only difference between the two programs. Both programs can also run user-supplied external NEC-4.2 or NEC-5 programs as their calculating engines. However, there are several significant differences between **EZNEC Pro+** and NEC. The following is important chiefly to users who are familiar with NEC.

Voltages and currents: NEC uses peak values for voltages and currents. **EZNEC Pro+** interprets and reports values in RMS. An NEC input file having a 1.0 volt source, when read by **EZNEC Pro+**, will result in an **EZNEC Pro+** source of 0.707 volts. Similarly, the currents reported by **EZNEC Pro+** will reflect RMS values. The power reported by **EZNEC Pro+** is the same as that reported by NEC. (**EZNEC Pro/4+** communicates to the integral NEC-4.2 calculating engine via standard NEC input and output files. If you view the NEC input file created by **EZNEC Pro/4+** and the output file created by the NEC-4.2 calculating engine, you'll see the translation in value that takes place. This is also true of external NEC-4.2 or -5 calculating engines run with either **EZNEC Pro+** program.)

Data input: Instead of editing an ASCII file, descriptions are entered via a spreadsheet-like entry system. This allows very easy modification, and the ability to immediately see the result on the antenna structure. (Note, however, that **EZNEC Pro+** can read and write NEC-format files, to a limited extent and can import wire descriptions from a simple-format ASCII file.)

NEC features: Not all NEC features are implemented in **EZNEC Pro+**. Those not implemented include symmetry, patches and non-air primary medium. **EZNEC Pro+** is chiefly oriented toward the analysis of wire antennas.

Files: Although **EZNEC Pro+** can read and write NEC format description files, some functionality may be lost if this format is used exclusively. Full features are available only by using **EZNEC** format (.EZ) files.

Angles: **EZNEC Pro+** uses elevation angle in place of zenith angle. Elevation angle is measured upward from the horizon (XY plane). **EZNEC Pro+** also permits an alternate method of displaying azimuth angle. This corresponds to compass bearing, and is measured clockwise from the +y axis. The choice is made in the Control Center Options menu.

Power: In NEC, all voltage sources are absolute. **EZNEC Pro+** permits you to specify a particular power level. If this is done, all voltage and current sources

will be adjusted in proportion to obtain the specified total power. This is useful for determining, for example, voltage stress on or power dissipation of loading components under actual operating conditions, or of near field strength resulting from a specific power input. The power level is specified in the Control Center Options menu.

Average Gain: **EZNEC Pro+** reports an average gain of 1.0 (0 dB) whenever the integrated total radiated power equals the power supplied from the sources, whether or not ground is specified. The NEC value of average gain varies with the region specified for the radiation pattern, and equals 2 when radiated and input powers are equal and ground is specified.

Networks: When a double precision calculating engine is used, **EZNEC Pro+** sends network parameters to the NEC calculating engine as double precision data. NEC, even when compiled for double precision, has no equivalent way to input double precision data. This can cause differences between double precision **EZNEC Pro+** and NEC results when networks have been specified, particularly when NEC networks are derived from **EZNEC Pro+** L networks.

Plane wave excitation: NEC-4.2 and -5 allow excitation with a plane wave source at the same time as conventional voltage sources. **EZNEC Pro+** does not; only one type of excitation can be used at a time. **EZNEC Pro+** also doesn't have provision for sweeping the plane wave source location.

Bugs: **EZNEC Pro+** has corrected several bugs found in NEC-2 and earlier revisions of NEC-4.2. The latest revision of NEC-4.2 has corrected the bugs in that program, but a number of versions of NEC-2 are available which might give different results from the integral NEC-2 calculating engine.

Working With NEC Format Files

Writing files in NEC format is relatively straightforward. To save a description in an NEC format file, simply include the extension .NEC when you specify the file name. The remainder of this section deals with reading NEC format files. NEC-2, -4.2, and -5 files have some differences, described below. When reading or writing NEC format files, **EZNEC** will use the format appropriate for the currently selected calculating engine.

Because **EZNEC** is not intended to use NEC format files for routine input and output, there are some deficiencies other than ones detailed below in both reading and writing.***EZNEC (.EZ) format files should always be used instead unless it's necessary to import or export a description in NEC format.*** NEC-4.1 has some additional differences and is not supported by **EZNEC**.

To import an NEC format file into **EZNEC**, include .NEC as the extension when you specify the file name.

A number of NEC features aren't implemented in **EZNEC**, so exact translation of all files can't be done. However, many files can be directly translated, and most geometry cards, which usually constitute the majority of complex files, will be translated.

Time didn't permit complete testing with NEC format files having Tag numbers that aren't sequential. EZNEC assigns wire numbers in the order that "cards" are read, and might encounter difficulties if Tag numbers are in a different order. If you encounter interpretation difficulties with a file having non-sequential Tag numbers, try reassigning them to be sequential.

There are a few differences between NEC-2, and NEC-4.2, and NEC-5 format files, as follows:

RP requires ground medium information in NEC-2 and not in NEC-4.2 or -5

Phi and theta are reversed on NE and NH between NEC-2 and NEC-4.2 or -5.

GN2 ground isn't available with NEC-5

GN3 ground is available only with NEC-4.2 and -5; NEC-2 does not recognize this ground type.

NEC-5 interprets GN, GD and some other "cards" differently than the other NEC types.

Files will be read and written according to the format of the calculating engine type in use at the time.

The following "cards" are read but some with altered interpretation as detailed below: CE, CM, CW, EK, EN, EX, FR, GA, GC, GD, GE, GH, GM, GN, GR, GS, GW, GX, IS, LD, NE, NH, NT, NX, RP, TL, WG, XQ.

CE, CM - The first 30 letters of the first CE or CM card becomes the title. Additional lines not beginning with "!" are interpreted as Antenna Notes.

EK - When using the NEC-2 calculating engine, **EZNEC** normally sets the extended thin wire kernel automatically depending on wire diameter; this card will override the internal setting. It has no effect except when using an NEC-2 engine.

EN - Terminates **EZNEC** translation.

EX - **EZNEC** is able to read and write EX “cards” defining voltage, current, and plane wave sources (different numbers for the various calculating engines) when opening and saving descriptions in NEC format. If both conventional and plane wave sources appear in an NEC format file, **EZNEC** will read both types. However, unlike NEC, **EZNEC** won’t use both types simultaneously; you must choose which to use when running **EZNEC**. When saving a description in NEC format, only the source type (conventional or plane wave) currently selected in **EZNEC** will be saved to the NEC format file. This is to prevent an NEC program reading the file from using both source types and producing a different result than **EZNEC**. NEC-2 and -4.2 type 4 and 5 sources will be converted to type 0. The magnitudes of all sources are divided by the square root of two to convert from NEC's peak convention to **EZNEC**'s RMS convention. This is done so that powers reported by the programs will agree. As of v. 7.0.4, EX4 and EX6 "cards" will be interpreted as current sources regardless of the calculating engine in use.

FR - Frequency step data will be ignored. Frequency stepping must be manually set in **EZNEC**'s Frequency Sweep Menu.

GA - If more than one GA card have the same tag number, sources, loads, etc. applied to that tag number will only be placed on the arc defined by the first GA card with that tag number. **EZNEC** will assign individual wire numbers to each one-segment wire making up each arc.

GD, GN - All parameters are translated. If a second medium is defined on both cards, the last card read will dominate. Note that NEC-5 uses these differently than NEC-2 and -4.2. With the latter two calculating engines, a radial ground screen will be ignored if only one medium is defined; if two are defined and the boundary is radial, the ground screen perimeter will be set

equal to the boundary between the media. Please see additional GD, GN, RP comments below.
GE - The I1 specification will be ignored. **EZNEC** automatically sets the equivalent value to 0 when no ground plane is present, 1 if a ground plane is present and no wires extend below the ground, and -1 if any wires do extend below a ground plane. (Calculation for the latter case will be permitted only if an NEC-4.2 or -5 calculating engine is used and Real, High Accuracy or Extended Accuracy ground has been selected.)
GH - Although not documented in the NEC-2 manual, some versions of NEC-2 include GH, but with a different parameter format than NEC-4.2 and -5. **EZNEC** automatically determines which format is being used and places a message in the translation information window. Parameters causing tapered turn spacing or wire diameter are ignored (except the sign -- see the following information); only constant-spacing, constant wire diameter helices are created. In some NEC-2 implementations, the length parameter is positive for a right-hand helix, negative for a left-hand helix. In others, the sign of the turn spacing parameter determines the handedness. So if either parameter is negative, a left-hand helix is constructed; otherwise, the helix is right-handed.
GM - Only entire wires will be operated on. If a specified segment does not fall on a wire end, the whole wire containing that segment will be included in the operation. The tag increment number ITG1 is ignored, and new wires assigned numbers in accordance with **EZNEC**'s method.
GN - NEC-2 and -4.2 GN 0 (reflection coefficient type ground) will be converted to High Accuracy (Sommerfeld) ground type. **EZNEC** doesn't support reflection coefficient type ground.
GR - Tag increment number ITG1 is ignored, and new wires assigned numbers in accordance with **EZNEC**'s method.
GS - The coordinates and diameters of all wires which have been read prior to encountering the GS card will be multiplied by the third parameter on the line (FSCALE).
GW - Tag numbers are ignored. Wires are sequentially numbered in the order they appear in the file. Insertion objects will, however, be placed on the proper wires.
GX - Tag increment number ITG1 will be ignored, and new wires assigned numbers in accordance with **EZNEC**'s method.
IS - This is written only when using an NEC-4.2 calculation engine, since non-**EZNEC** versions of NEC-2 and -5 don't support this feature and might crash if an IS "card" is in the input file. However, IS "cards" in any .NEC format file opened by **EZNEC** will be read and translated (using NEC-4.2 parameter definitions) regardless of the calculating engine in use. Only entire wires will be operated on. If a specified segment does not fall on a wire end, the whole wire containing that segment will be included in the operation.
LD - Types are translated as follows:

- -1 (short all previously defined loads) -- Not translated.
- 0, 1 (series, parallel RLC) -- Translated directly as loads.
- 2, 3 (series, parallel RLC per unit length) -- Translated as loads with impedances calculated from the lengths of segments they are on. Note that these will be **EZNEC** lumped loads which will not change impedance if the segment length changes after the initial translation.

- 4 (R+jX) -- All **EZNEC** loads must be RLC or all must be R+jX. So if any other load type besides type 4 is present except a type 5 load translated as wire loss or type 5 loads which aren't translated, type 4 loads will be converted to series RLC and the **EZNEC** load type will be set to RLC. Otherwise, they'll be translated directly as R+jX and the **EZNEC** load type will be set to R+jX.
- 5 (wire loss) -- An LD type 5 card which covers all the segments in the model (i.e, LDTAG, LDTAGF, and LDTAGT are 0, 1, and the number of model segments respectively) or all segments in a wire or wires is directly translated and sets the wire loss for the wire, wires, or whole model. All other type 5 cards are converted to series RLC loads based on the segment length and wire diameter where they are placed, and with R that changes with frequency in the same manner as line loss. The L won't change with frequency, although this is generally a minor effect with wires. Note that these will be **EZNEC** lumped loads which will not change impedance if the segment length or wire diameter changes after the initial translation
- Others are not translated.

NE, NH - Only the first NE or NH card will be read. The information contained on the card will be entered in the **EZNEC** Near Field Setup Menu. ***Note:*** The convention for phi and theta is reversed between NEC-2 and the other calculating engines. A caution is shown in the translation window when these cards are encountered.
NT - All parameters are translated.
NX - Terminates **EZNEC** translation.
RP - **EZNEC** will ignore requests to print major, minor axis gains or do field normalization, directive gain, or gain averaging. Please see additional GD, GN, RP comments below. If no RP card is present, default values will be entered.
TL - Shunt loads will be ignored.
XQ - Any value other than 2 is interpreted as being 1, since **EZNEC** can't do simultaneous plots.
All other cards are ignored.
Translation of the input file will terminate after the first EN or NX card is read.
Additional GD, GN, RP comments: Due to the complex interaction of ground specifications among GD, GN, and RP cards, **EZNEC** may not interpret the ground specification in the same way as NEC does. Be sure and check the ground type and specification after reading an NEC file. This is especially true when using the NEC buried radial (radial ground screen) model with NEC-2 or -4.2.
When **EZNEC** is forced to interpret a card in a different way than NEC, it will add a notice to the display shown at the end of the translation.
EZNEC disregards the positions of data on the line. Fields are delimited by spaces, tabs, or commas. Any number of spaces or tabs may be used. A field is considered blank or zero if it is surrounded by commas. For example, '3 , ,51,4' is interpreted as four fields of value 3, 0, 51, and 4. Spaces and tabs adjacent to commas are ignored; spaces and tabs elsewhere are interpreted as delimiters. For example, '3 15,, 7 42 ,' will be interpreted as having fields of value 3, 15, 0, 7, 42, 0.

Comments can be added to individual lines if desired by delimiting with an exclamation point (!). Anything following an exclamation point on any line will be ignored.
Please note: Partial translation of NEC files, or defective NEC files, might cause a program crash because many of **EZNEC**'s cross checks aren't done when reading NEC files.

Special Options

A few choices are likely to be so seldom used that they don't justify being put into a menu. However, **EZNEC** still provides a way to enable or change these choices. In the **EZNEC** output directory is a file named EZNEC.INI. **EZNEC** reads this file each time it starts, so it can be used to communicate the values of special options.
The EZNEC.INI file can be edited with any text editor or you can conveniently open it for editing with the **EZNEC** Editor by choosing Edit .INI File in the Control Center Utilities menu. The file must be saved with the new value(s) for them to take effect.
Options marked with an asterisk (*) are checked each time the affected operation is done. For example, a change in S1PZ0 becomes effective the next time the LastZ_src#.s1p output file is created. ***Do not include the asterisk in the EZNEC.INI file entry.*** Options not marked with an asterisk will not take effect until the next time the program is restarted.
All entries are case insensitive. Spaces around the **=** sign are optional. All entries are put into the file in the [Special Options] section; that is, they go below that heading.
Diagnostic files are written either in the **EZNEC Pro+** AppData folder or the Docs folder. The Options menu Folder selection can be used to locate these.

2D Plot Appearance or Printing

2DDataBoxDispFontSize = # (4 - 30, default =depends on window size) Set size in points of text shown in the data box below the 2D plot. Has no effect on printed output.
2DPolLines = Solid Causes V and H or RHC and LHC polarization component traces to be solid instead of broken in the 2D display.

Diagnostic Information Printing

WriteCMADiag = True Caused the internal calculating engines to write EZCalcCMDiag.txt containing information about the memory allocation process.
WriteEZCalcDiagI = True Causes internal calculating engines to write diagnostic file EZCalcDiagI.txt to help diagnose certain numerical problems.
WriteMonInfo = True Causes information about monitors and monitor configuration into LastRun.log.

File Reading and Writing

RWEZ1 = Enable Enables reading and writing .EZ1 format files (used for undo).
ReadTmp = Enable Enables reading .EZ1 format files with .Tmp extension (used for undo) if RWEZ1 is enabled.

ReadEN = Enable Enables reading of .EN (ELNEC) format files. Note: This is added to the Open File type drop-down list.
The following Special Options affect the content of the LastZ_src#.s1p files:
* **S1PZ0 = ALT** Sets reference impedance of Last.s1p output file to Alt Z0 set in Control Center.
* **S1ParamType = <letter>** (S or Z, default = S) Sets parameter type of Last.s1p output file.
* **S1PFormat = <text>** (MA or RI; also DB if parameter type = S, default = MA) Sets format type of LAst.s1p output file.
EZNIF = <name> (Default = EZ.NEC) Name of NEC-4.2 input files
EZNOF = <name> (Default = NEC.OUT) Name of NEC-4.2 output files
EZNIF5 = <name> (Default = EZN5.NEC) Name of NEC-5 input files
EZNOF5 = <name> (Default = NEC5.OUT) Name of NEC-5 output files
* **GNFile = <name>** (Must contain a period or be upper case NOFILE) Adds a file name to the GN "card" of both saved and calculation engine input NEC-5 format files.
MaxCMWidth = # (33 or greater, default = 75) Sets the maximum width in characters of CM "card" lines used for Antenna Notes in NEC format files.

Memory Use
WSPad = # (>0, default = 0) Adds the specified amount in MB to the RAM reserved by the calculating engine.
MaxRamMB = # Limits the amount of RAM in MB which will be made available to the internal calculating engines. Any value less than 2048 will be ignored.
* **x64MinUnusedRAMMB = #** (Default = 1024) Sets minimum amount of system RAM in MB which won't be used by the internal calculating engines on 64 bit systems.
* **x64MaxUsedAvailRAMPct = #** (Default = 100) Sets percentage of allocated RAM which can be used by the internal calculating engines on 64 bit systems.
* **x64MaxUsedRAMPct = #** (Default = 75) Sets percentage of total system RAM which can be used by the internal calculating engines on 64 bit systems.

Stepped Diameter Correction
* **EZSDCC = Off** Disables Stepped Diameter Correction requirement for insertion object positions along wires.
* **SDC0LenTolPct = #** (Default = 15) Group length must be within this percentage of resonant length for Stepped Diameter Correction to occur.
SDCLog = On Causes writing of file SDC.log containing detailed information about the Stepped Diameter Correction process from the most recent calculations using Stepped Diameter Correction.
SDCOptRunTimeQuery = True Causes Stepped Diameter Correction options to be set each time SDC runs, rather than once at startup.
* **SDCSLPosCk = Off** Disables Stepped Diameter Correction collinearity requirement.

Other
AltFont = <font> (Default = Arial) Sets font type used by program. Must be the name of a valid font.

Analyze = On Adds "Plot Analysis" selection to the Control Center Outputs menu which shows in a separate window essentially the same information that appears in the 2D Data Window. Like many other data displays, it can show the information in comma delimited format for convenient export.
ButtonFontName = <fontname> (Default = MS Sans Serif) Sets the font type for the Control Center Action Buttons. Must be the name of a valid font, such as Arial. See ButtonFontSize below.
ButtonFontSize = # (Default = 8) Sets the font size in points for the Control Center Action Buttons. Can be fractional for Ariel and some other fonts.
CalcProgReduction = # where # is a number from 0 to 3; other values ignored. Use when the program is slowed by an anti-virus or anti-malware program. (See Software Incompatibilities.) Limits how often the calculation progress indicator is updated during calculation. A value of zero results in normal operation. Higher values (up to 3) reduce the update frequency, speeding operation but making the calculation progress indication less smooth.
CursorBorder = None Turns off the outline around the outer border of the cursor in the 2D, 3D, and SWR plots.
dBuVperM = True Causes near field and ground wave display to be in dBuV/m. This will be peak rather than RMS if PkNFVals is also True
EnableNegRLC = On Enables entry of negative R, L, or C values for loads and L network components. This is allows including certain active networks in the model.
EZETWK (ON or OFF, default automatic) Forces the extended wire kernel to be used with the internal NEC-2 calculating engine and in saved NEC-2 format files.
FFPhase = Off Removes phase information from the Far Field Table.
ForceGndCalc = Yes Forces a ground calculation to be done every time when Real, High or Extended Accuracy ground is specified. This prevents EZNEC from using data from any saved ground data file and ensures absolute repeatability of results.
MaxGLCLines = # (10 minimum, default = 50) Sets the maximum number of lines shown in the Guideline Check display.
MaxNFSteps = # (100000 minimum, default = 100000) Sets the maximum number of allowed near field analysis steps.
MaxSLTRows = # (2 minimum, default = 15) Sets the number of visible rows in input grid displays (e.g., Sources, Loads, etc.)
NECRadials = On Enables use of NEC radials See The NEC Radial Model before using.
* **NoUnixCk = TRUE** Disables check for Unix-style line terminations when reading NEC format files.
PeakNFVals = True Causes near field values to be peak rather than RMS.
* **PrDataLineSp = #** (1 to 2, default = 1.1) Sets the line spacing for data from a Data Window printed under a 2D plot. It affects only printed output.
PrinterMargin = # (Number representing inches, or cm if followed by a "c" or "C", maximum 3 inches or ~7.6cm, default 0.75 inches) Sets the width of the margins around printed graphics plots (2D, 3D, SWR, and View Antenna displays).

SaveEZCalcIO = True Prevents the normal deletion of the EZCalcIN.dat and EZCalcOT.dat or EZCalcIO.dat binary files sent to and from the integral calculating engines.
SinglePrecision = Enable Enables single and mixed precision calculating engines.
SrcZSigDig = # (3 - 7, default = 4) Sets number of significant digits in Source Data impedance display. Useful when trying to detect very small impedance changes. *Note*: This affects only resolution and has no impact on accuracy.
Util = # (0 - 2, default = 0) Sets which items are displayed in the Utilities menu.
WireInfoDist = # (0 to 20, default = 3) Sets the distance in pixels within which the cursor has to be before the Wire Information popup window appears. If the value is <1, the popup window will appear only when the right mouse button is clicked while holding down the <Ctrl> key.

OpenPF Plot File Format

EZNEC saves 2D and 3D plot (trace) files using the OpenPF standard. Files using this standard are commonly given the extension .PF, and **EZNEC** uses this for ordinary 2D plot files. However, plots generated by the frequency sweep are given extension .P #, where # represents the frequency step. 3D plot files are given the extension .PF3. All these conform to the following standard. The standard is included here for those who want to develop compatible software or who have a need to directly read the data in these files.
Important Note: Although the plot files written by **EZNEC** conform to the OpenPF standard, and **EZNEC** is able to read some 2D plot files produced by users or other programs, **EZNEC** isn't generally able to import or correctly read OpenPF files created by users or other programs.

OpenPF Plot File Standard Version 1.0 June 1, 1995

The following standard was developed by Brian Beezley and Roy Lewallen as a common format for sharing data files between programs. Although we both contributed to the content, the original proposal was Brian's, and he is the author of the following standard and did the majority of the work. We encourage others to adopt this standard.

OpenPF is an open, nonproprietary standard for computer files that contain electromagnetic field data. OpenPF is intended for files created by antenna analysis programs and for files containing measurements. OpenPF files can be used to archive or transport data. Programs can use the files to plot fields and radiation patterns on a screen, printer, or plotter.

The OpenPF file format is extensible. Data is organized into blocks that begin with a block type identifier followed by block length. This structure allows a file parser to skip and ignore blocks it's not designed to handle, including block types defined in future revisions of OpenPF.

The blocks defined below provide for 2D relative far field data (azimuth and elevation radiation patterns) and 3D absolute near and far field data. 3D radiation patterns can be represented by a set of 2D data blocks.

The file format enables a single file to contain near and far field data, absolute and relative data, azimuth and elevation data, low and high resolution data, partial and full data cuts, data for multiple frequencies, and unidentified data.

The file format provides for new fields in future OpenPF revisions without the overhead of reserved bytes. New fields can be appended to any file block. File parsers that use block length to advance to the next block will skip over new fields.

OpenPF uses standard coordinate systems. For rectangular coordinates, X and Y are in the horizontal plane and Z is height. For spherical coordinates, R is radial distance, phi is azimuth angle, and theta is zenith angle. For cylindrical coordinates, rho is horizontal distance, phi is azimuth angle, and z is height. Azimuth angle is 0 along the X axis and increases in the XY plane toward the Y axis (counterclockwise). Zenith angle is 0 along the Z axis and increases in the Z-phi plane toward the phi ray. Units are meters and degrees.

OpenPF files use the Intel processor "little endian" data convention (least significant byte first for multibyte data). Bit number 0 is the least significant bit. Bits marked as reserved are undefined and should not be assumed to be 0. OpenPF files use the file extension ".PF".

In the descriptions that follow, word means a 16 bit unsigned integer and FP means a 32 bit, single precision, floating point number that conforms to the IEEE-754-1985 standard. ASCII means a character string that uses the extended ASCII PC-8 symbol set.

HEADER

OpenPF files begin with a block of the following format:

Version byte
Header length word
Source length byte
Title length byte
Environment length byte
Notes length word
Source ASCII
Title ASCII
Environment ASCII
Notes ASCII

Version

This byte identifies the OpenPF version used to generate the file. The version number consists of a major revision (an integer) and a minor revision (an integer between 0 and 9) separated by a decimal point. The upper nibble (4 bits) contains the major revision and the lower nibble the minor.

Header Length

This field is the total length of the header in bytes. File parsers should use this length to advance past the header instead of assuming that data blocks begin immediately after the notes string. Future OpenPF revisions may define additional fields after the notes string. Header lengths less than 3 are invalid.

Source, Title, Environment, and Notes Lengths

These fields specify the lengths in bytes of the ASCII strings. Zero is valid.

Source String

This string identifies the data source. This may be an antenna analysis program, an antenna test range, a laboratory, etc. No bytes are allocated for a zero length string.

Title, Environment, and Notes Strings

The title string describes the antenna. The environment string describes the antenna environment (free space, antenna height, ground constants, etc.). The notes string contains auxiliary information that might be displayed only upon request. Data blocks that follow may contain strings that override these global strings. No bytes are allocated for zero length strings.

DATA BLOCKS

Data following the header is organized into blocks. Each data block begins with block type (a byte) followed by block length (a word). Block types 0 through 127 are standard and reserved. Programs may use types 128 through 255 for special purposes, but block length must always follow block type so that file parsers can skip over the block. Blocks may appear in any order. The following standard blocks are defined:

NOP BLOCK

Block type byte (0)
Block length word

REST OF BLOCK

Block type 0 is a no-operation block. Its purpose is to provide a standard ignore-me block. Normally this block isn't used, but it may be convenient when patching a file. Block length is the total length of the block in bytes. Block lengths less than 3 are invalid.

RELATIVE FAR FIELD BLOCKS

Block type byte (1-16)
Block length word
Title length byte
Environment length byte
Notes length word
Frequency FP
Plane byte
Plane angle FP
Symmetry byte
Number of points word
First angle FP
Angular increment FP
Data points each FP
Title ASCII
Environment ASCII
Notes ASCII

Block types 1-16 contain planar cuts of relative far field data as follows:

Block Data Units

1 Total magnitude dBi
2 Horizontal magnitude dBi
3 Vertical magnitude dBi
4 Right circular magnitude dBic
5 Left circular magnitude dBic
6 Major axis magnitude dBi
7 Minor axis magnitude dBi
8 Ellipticity dB
9 Total phase degrees
10 Horizontal phase degrees
11 Vertical phase degrees
12 Right circular phase degrees
13 Left circular phase degrees
14 Major axis phase degrees
15 Minor axis phase degrees
16 Polarization tilt degrees

Ellipticity is the length of the minor axis of the polarization ellipse divided by the length of the major axis expressed in dB (the IEEE-754-1985 floating point code for -infinity is valid). Polarization tilt is the counterclockwise angle between the major axis and the E(theta) direction.

Block Length

This field is the total length of the block in bytes. Block lengths less than 3 are invalid.

Title, Environment, and Notes Lengths

These fields specify the lengths of the ASCII strings in bytes. Zero is valid.

Frequency

Frequency is in MHz.

Plane

This byte is 0 for azimuth data (constant zenith angle) and 1 for elevation data (constant azimuth angle). Other values are reserved.

Plane Angle

This field is the zenith angle for azimuth data and the azimuth angle for elevation data.

Symmetry

The bits of this byte have the following meaning when set:

Bit	Azimuth Data	Elevation Data
0	X symmetry	XY symmetry
1	Y symmetry	Z symmetry

Symmetry means that the data has the same value when reflected about the line or plane indicated. For azimuth data, bits 0 and 1 refer to the X and Y axes. For elevation data, they refer to the XY plane and the Z axis. Both bits may be set simultaneously. Bits 2-7 are reserved.

Number of Points

This field is the number of data points that follow. 0 is valid.

First Angle

This field is the angle of the first data point.

Angular Increment

This field defines the sign and magnitude of the angular difference between successive data points.

Data Points

The data set begins at the first angle. The angles of successive data samples differ by the angular increment.

Title, Environment, and Notes Strings

When string length is nonzero, the string overrides the corresponding header string for this block. When zero, the header string applies for this block and no string space is allocated.

ABSOLUTE NEAR AND FAR FIELD BLOCKS

Block type byte (64-81 & 96-101)
Block length word
Title length byte
Environment length byte
Notes length word
Frequency FP
Power FP
Coordinate system byte
Symmetry byte
Number of A points word
First A FP
A increment FP
Number of B points word
First B FP
B increment FP
Number of C points word
First C FP
C increment FP
Data points each FP
Title ASCII
Environment ASCII
Notes ASCII

Block types 64-81 contain absolute fields. Block types 67-81 are field components resolved in rectangular coordinates. These blocks are defined as follows:

Block	Data	Units
64	Power density	watts/square meter
65	Peak E magnitude	volts/meter
66	Peak H magnitude	amps/meter
67	Px Poynting vector	watts/square meter
68	Py Poynting vector	watts/square meter
69	Pz Poynting vector	watts/square meter

70 Ex magnitude volts/meter
71 Ey magnitude volts/meter
72 Ez magnitude volts/meter
73 Hx magnitude amps/meter
74 Hy magnitude amps/meter
75 Hz magnitude amps/meter
76 Ex phase degrees
77 Ey phase degrees
78 Ez phase degrees
79 Hx phase degrees
80 Hy phase degrees
81 Hz phase degrees

Block types 96-101 contain absolute electric field components resolved in spherical coordinates as follows:

Block	Data	Units
96	E(R)	magnitude volts/meter
97	E(phi)	magnitude volts/meter
98	E(theta)	magnitude volts/meter
99	E(R)	phase degrees
100	E(phi)	phase degrees
101	E(theta)	phase degrees

Use block type 65 for peak E magnitude.

Block Length, String Lengths, and Frequency

These fields are the same as for relative far field blocks.

Power

This field is antenna input power in watts.

Coordinate System

This byte specifies the coordinate system used to locate data points (it does not specify the coordinate system used to resolve field components). The byte is 0 for rectangular coordinates, 1 for spherical coordinates, and 2 for cylindrical coordinates. Other values are reserved. Coordinates are defined as follows:

Coordinate System	A	B	C
0	Rectangular	X	Y Z
1	Spherical	R	phi theta
2	Cylindrical	rho	phi z

Symmetry

The low order bits of this byte have the following meaning when set:

Bit	Meaning
0	A-coordinate symmetry
1	B-coordinate symmetry
2	C-coordinate symmetry

Here, symmetry means that the data has the same value when the coordinate is negated (this definition is not the same as that for relative fields). Any of the bits may be set simultaneously. Bits 3-7 are reserved.

Number of A, B, or C points

These fields specify the number of points for each coordinate. 0 is invalid. The total number of data points is the product of A, B, and C. For rectangular coordinates, the field is computed over a point, line, rectangular surface, or rectangular volume. For spherical coordinates, the field is computed over a point, line, circle, disc, spherical surface, spheroid, or portion thereof. For cylindrical coordinates, the field is computed over a point, line, circle, disc, cylindrical surface, cylindrical volume, or portion thereof.

First A, B, and C

These fields specify the starting values of each coordinate.

A, B, and C Increments

These fields define the sign and magnitude of the difference between successive coordinate values.

Data Points

Points are ordered as follows: A cycles from first to last, then B, and finally C. The coordinate values of successive data samples differ by the A, B, or C increments.

Title, Environment, and Notes Strings

These fields are the same as for relative far field blocks.

Input File Formats

Frequency Sweep Input File

The frequency sweep input file contains a list of frequencies to be used for the frequency sweep. Its name is specified in the Control Center Setups menu, Frequency Sweep selection.

Frequencies are in megahertz (MHz), and consist only of numbers. They may be in any order and do not have to be equally spaced. (They will be sorted in increasing order for display.)

Frequencies must be separated by spaces, carriage returns, or a combination of these. If your regional decimal separator is a period (.) and not a comma (,), a comma may also be used as a separator, alone or in combination with spaces or carriage returns.

Any line not beginning with a number is considered to be a comment, and ignored. They may be entered anywhere in the list.

Entries of zero, or empty fields, are ignored.

A negative entry will terminate reading of the file, so that only values preceding the negative entry will be used. This is a convenient way to limit processing to only the first part of a lengthy list.

Wire Coordinate File

The wire coordinate file is used for importing wire coordinates via the Wires Window or the Control Center, by choosing Import Wire Coordinates from ASCII File in the File menu. Two different file formats can be used. Note that NEC file format can also be used.

First Format Type

The ASCII import file consists of an optional line defining the units to be used for coordinates and diameter, followed by one line per wire giving the end coordinates, diameter, and, optionally, number of segments. Comments may appear anywhere in the file. Tabs, spaces, commas, or any combination may be used as delimiters.

The optional units specification is done on one line and must precede all wire definitions. If absent, wire coordinates and diameters are assumed to be in meters.

Wire definitions consist of end 1 coordinates, end 2 coordinates, and diameter. If desired, the number of segments can be added as an eighth field. If the segment field isn't included, the wire will be automatically segmented using the "conservative" criterion.

The file is case-insensitive. Blank lines, and any text on a line following a semicolon will be ignored. Blanks, tabs, or any combination can be used as delimiters (separators between fields or individual specifications). **Commas can be used as delimiters only if your decimal separator is not a comma. Number format must correspond to your Windows regional setting. That is, if you normally write one-and-one-half '1,5', then it must be written that way in this file.**

Imported wires can be used to add to or replace an existing definition.

Example 1 (for the U.S. and other regions having a period as the decimal separator):

This is the wire configuration for the 4-square array of example description file 4SQUARE.EZ. Note that a complete antenna description must also include sources, which must be added from within **EZNEC**.

```
; Example file for EZNEC wire importing: four square array.
; ONLY FOR REGIONS WITH PERIOD DECIMAL SEPARATOR.
; NOTE that wire import files don't contain sources or information other than wires.
; To actually make a 4-square array with the information from this file
; requires specification of sources, frequency, ground type, etc.
; The first non-comment line is the units specifier. This will cause:
; -- Program UNITS to be changed to FEET
; -- Wire coordinates to be interpreted as being in feet
; -- Wire diameter to be interpreted as being in inches
ft in
; Next are the wire specifiers. Spaces, commas, and tabs are used in this example
; as delimiters to illustrate the flexibility available. As this file is written, these
; wires will be automatically segmented using "conservative"
; density. If desired, an additional field could be added to any line to cause
; "minimum" recommended density, or a specific number of segments.
; The first three numbers are the end 1 coordinates (in feet because of
; the first unit specifier above). The next three are the end 2 coordinates
; (ft). The seventh number is the diameter (in inches because of the
; second unit specifier).
0,0,0 0 0 32.75 1.5
0 34.42 0 0 34.42 32.75 1.5
```

34.42, 0 0 34.42 0 32.75, 1.5
34.42 34.42 0 34.42,34.42 32.75 1.5
; Normally the wire specifications would be written to be easier to read.
; The above format was chosen to illustrate the flexibility available in
; choosing field delimiters.

Example 2 (for regions having a comma as the decimal separator):
This is the wire configuration for the 4-square array of example description file 4SQUARE.EZ. Note that a complete antenna description must also include sources, which must be added from within **EZNEC**.
; Example file for EZNEC wire importing: four square array.
; ONLY FOR REGIONS WITH COMMA DECIMAL SEPARATOR.
; NOTE that wire import files don't contain sources or information other than wires.
; To actually make a 4-square array with the information from this file
; requires specification of sources, frequency, ground type, etc.
; The first non-comment line is the units specifier. This will cause:
; -- Program UNITS to be changed to METERS
; -- Wire coordinates to be interpreted as being in meters
; -- Wire diameter to be interpreted as being in millimeters
m mm
; Next are the wire specifiers. Only spaces or tabs are used in this example
; as delimiters to separate fields. Commas are not allowed as field delimiters
; in regions where a comma is used as the decimal separator. As this
; file is written, these wires will be automatically segmented using "conservative"
; density. If desired, an additional field could be added to any line to cause
; "minimum" recommended density, or a specific number of segments.
; The first three numbers are the end 1 coordinates (in meters because of
; the first unit specifier above). The next three are the end 2 coordinates
; (meters). The seventh number is the diameter (in mm because of the
; second unit specifier).
0 0 0 0 0 9,9822 38,1
0 10,4912 0 0 10,4912 9,9822 38,1
10,4912 0 0 10,4912 0 9,9822 38,1
10,4912 10,4912 0 10,4912 10,4912 9,9822 38,1
; Normally the wire specifications would be written to be easier to read.
; The above format was chosen to illustrate the flexibility available in
; choosing field delimiters.

Complete Rules for Wire Files Used for Importing with the first format type
General:
No distinction is made between upper and lower case letters.
A semicolon (;) and anything to its right on a line will be ignored.
Blank lines will be ignored.
Spaces, tabs, or combination may be used as delimiters. Commas may be used in regions (such as the U.S.) where a comma is not the decimal separator.
There are two types of specifications: wires and (optional) units.

Units specification line (optional) must precede all wire specifications.
Text fields (only) can be surrounded by quotation marks (" "). These are coordinate units, diameter units, wire diameter specified as wire gauge, and "M" specifying minimum segmentation. Quotation marks are not required for any field.
The user will be given the choice of adding the wires to the existing description or replacing the existing description with the wires.

Units Specifications:

Zero, one or two unit specifiers may be included.
Unit specifiers must precede all wire specifications.
If two specifiers are given, they must appear on the same line and be separated by a valid delimiter.
The first unit specifier is the coordinate unit specification. It will modify the **EZNEC** UNITS selection, and wire coordinates in the import file will be interpreted as being in the specified units. If the units specifier line is absent, all coordinates and diameters will be interpreted as being in meters.
The second unit specifier (optional) is the diameter specification. Wire diameters will be interpreted as being in these units. The units used by the program for wire diameter may be different than, and will not be determined or changed by, this specification. (For example, if both the coordinate and diameter units specifications are feet, **EZNEC** will change its UNITS to feet. If a diameter is given in the import file as 0.5, it will be interpreted by **EZNEC** as having a diameter of 0.5 feet. However, **EZNEC** shows diameters in inches when UNITS are feet, so after importing, the wire will show up in **EZNEC** as having a diameter of 6 inches.) If no diameter unit specifier is given, wire diameters will be interpreted as being in the same units as the end coordinates.
Only the first two letters of each specifier is read. They are interpreted as follows:

M or ME - meters (If M is used alone, it must not be followed by any other character, including a period.)
MI or MM - millimeters
FT or FE - feet
IN - inches
WA or WL- wavelengths

Wire Specifications:

Wire specifications must have at least 7 fields.
Fields are end 1 x, y, z coordinates; end 2 x, y, z coordinates; diameter; and, optionally in an eighth field, number of segments. See below for more information about the segment field. Wires having zero length or diameter will be rejected. Coordinates are interpreted as being in the units specified by the first unit specifier. If no unit specifiers are given, they will be interpreted as being in meters, not in the units currently being used by the program.
Diameters are interpreted as being in the units specified by the second unit specifier. If no second unit specifier is present, they will be interpreted as being in the same units as the end coordinates. The diameter of any wire may be given as AWG wire size, using #n where n is an integer > 0. (n can have more than one digit.) The optional segmentation field can contain the number of segments for the wire or the letter "M". "M" will result in minimum-recommended count automatic segmentation for the wire. If the segmentation

field is blank, or contains any other non-numeric value, zero, or a negative number, the wire will be automatically segmented using "conservative" criteria.
Fields beyond the eighth will be ignored.

Second Format Type

This format is provided to allow easy importing of wire coordinates from an NEC input file.
Only GW lines are read. **EZNEC** will assume this format if it finds any line in the file beginning with GW.
The standard NEC format is required: GW followed by the tag (ignored), number of segments, end coordinates, and radius (not diameter). No fields are optional, and U.S. format is required. If any line is found beginning with "GW", the file is assumed as being GW format, and all other lines in the file, including dimension specifications, are ignored, and all values are assumed to be meters. Comments can follow the data on the line by preceding the comment with an exclamation point. This format enables importing wires (only) directly from an NEC file, or from GW lines cut and pasted from one. Note that the **EZNEC Pro+** programs allow direct reading of NEC format files, including most of the other "card" types, so this method of input isn't usually necessary.

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Updates (Maintenance Releases)

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Reporting bugs

Sorry, no support is available for **EZNEC Pro+ v. 7.0**. All efforts have been made to make the programs as bug-free as possible, but some will always remain.

Program Crash

A program is said to crash when it abruptly ends due to an internal error. The most severe crashes can cause a computer to stop responding to any input (hang), requiring a reset or shutdown and restart. More common and less severe crashes affect only the program causing it, and typically display some sort of error message before ending the program. When a program crashes, all information which has not been saved is usually lost. However, **EZNEC** saves your description each time you make a change, and can usually restore it -- and the undo history of all changes that were made since opening the original description -- the next time you start **EZNEC** following the crash.
Every effort has been made to prevent **EZNEC** from crashing. However, I regret that no support is available if you encounter one.

How to Contact Me

I'm sorry, I will not respond to queries or suggestions regarding **EZNEC** or its manual. I'm retired.

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