Wire Modeling Limitations of NEC *and* MININEC for Windows

Come listen to the authors of MININEC *as they describe its workings and compare it with* NEC-4.

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The History of *MININEC*

The original *MININEC* was written by John Rockway with a little prodding and support from Jim Logan. Over the years, the Rockway-Logan team has been responsible for the development of this code into one of the best known and most useful method-of-moments antenna modeling codes available. A number of other individuals have contributed small, but not necessarily insignificant, pieces to *MININEC*'s capability, but it has been the dual efforts of the Rockway-Logan team that has made *MININEC* into the powerful antenna-design and analysis tool it is today.

Because of the similarity in names, it is often stated that *MININEC* is but a personal computer (PC) version of its big brother, *NEC*.[2] This could not be farther from the truth, however. There are significant differences between these two codes. Both codes use the method of moments to solve for currents on electrically thin wires. However, each code starts with a different version of the integral formulation for the currents and fields for wires. Then, each follows significantly different algorithms to implement the method of moments.

In 1980, when the first version of *MININEC* was written, PCs had not been on the market for very long. They were relatively expensive and very limited in capability. PCs were generally regarded as mere novelties or toys. PCs were typically limited to 16 kB of memory with an eight-bit word length. There was no *FORTRAN* for the PC, so *MININEC* was written in *BASIC*. *NEC* was (and still is) a very powerful computer code, with tens of thousands of *FORTRAN* statements, originally written for use on large mainframe computers. In those days, PCs could not support such a large program. The formulation had to be changed to allow a simpler implementation of the method-of-moments in order to produce a more compact code. It would not be possible to include many of the powerful modeling options provided by *NEC*. Following the

[1]Notes appear on page 21.

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advice of Professor Don Wilton, at the University of Mississippi (now with the University of Houston), the first version of *MININEC* was written in 500 lines of *BASIC* that required 32 kB of memory. Nonetheless, this version proved surprisingly accurate for dipoles and monopoles.

The first public release of *MININEC* occurred in 1982.[3] The code was 550 lines of *BASIC* that would run on an APPLE II computer with 64 kB of memory. It could compute the current distribution, impedance and far-field pattern of an arbitrarily oriented set of wires in free space or over a perfectly conducting ground plane. Lumped-impedance loads were allowed at segment junctions except for segments intersecting with the ground plane. In addition, wires intersecting the ground plane were restricted to right angles. In interpreter *BASIC* (there were no *BASIC* compilers then) the problem size was limited to 10 wires and 50 currents (or 70 segments with junctions).

MININEC was an instant success. Almost immediately, a small user group developed and began to grow. In 1984, partly to meet the demand for *MININEC*, but also to share other computer algorithms, the authors teamed up with two colleagues: Peter Li and Dan Tam. They published a book that contained an improved version of *MININEC* along with some other useful algorithms.[6] *MININEC2*, as it became known, was not significantly different from its predecessor, but the limitation for wires intersecting the ground plane was removed. Wires could intersect the ground at any angle.

The power of PCs began to grow. Computers were getting faster, had more memory, and used math coprocessors. *BASIC* compilers also became available. These factors opened new vistas for *MININEC*. In 1986, the authors released *MININEC3*.[7] This code featured a new user interface that automatically determined wire connections from the user inputs for wire end coordinates. It could also read and interpret a limited *NEC* input data set. There was no way to save and edit geometry data, however. *MININEC3* included near-fields, a Fresnel reflection-coefficient correction to the real-ground patterns and an expanded lumped-parameter loading option. *MININEC* had grown to just over 1600 lines of *BASIC*. With a math coprocessor and a *BASIC* compiler, *MININEC3* could solve antenna problems with up to 50 wires and 50 current unknowns.

The next *MININEC* effort by the authors produced the *MININEC* system in 1988.[9] This was a valiant effort by the authors to provide improved problem definition, the ability to save features and improve on-line graphics. The release of the *MININEC* system happened to coincide with the introduction of Microsoft *Windows*, which took the PC world by storm. The authors were too close to publication to backtrack and implement a *Windows* system. Nonetheless, there were many worthwhile innovations in this code. This was the first version of *MININEC* that *required* a compiler, a *BASIC* compiler. All previous versions could run in interpreter *BASIC*. The solution time and storage requirements for rota-

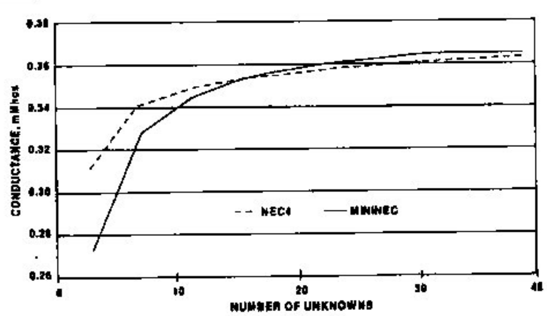

Fig 1—Conductance versus unknowns for a short dipole.

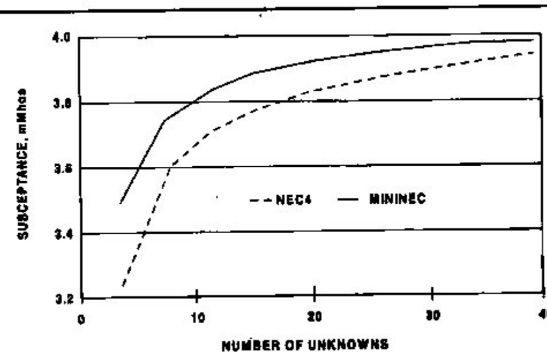

Fig 2—Susceptance versus unknowns for a short dipole.

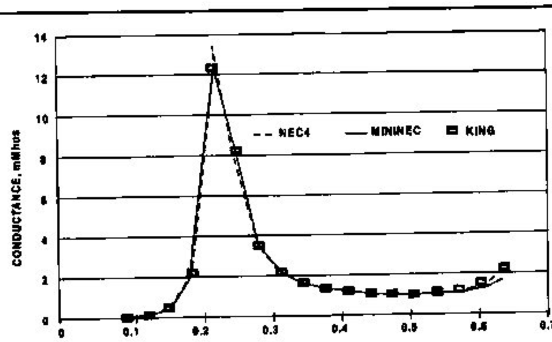

Fig 3—Dipole conductance vs. frequency (29 unknowns).

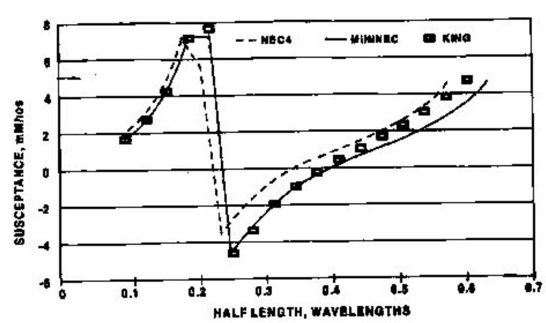

Fig 4—Dipole susceptance vs. frequency (29 unknowns).

tionally symmetric antennas were greatly reduced. The transpose elimination algorithm was available as a user-selectable option to allow computation of larger problems—up to 50 wires and 90 current samples or 190 segments were permitted—without recompiling.

Many others have also attempted to improve on *MININEC*. Most notable are the innovative user interfaces and graphics displays offered by Roy Lewallen[5] in 1991 and Brian Beezley[1] in 1992.

In 1995, the authors published the first of a series of *MININEC* for *Windows* codes. These codes represented the development of a *new version* of *MININEC*. An improved solution of the potential-integral formulation for the currents resulted in a more-accurate solution for currents on wires. In addition, *FORTRAN* was used for the computationally intensive portions of *MININEC*. This led to an increase in speed over previous versions.

The first code was *MININEC Professional for Windows.*[10] Because it is a *Windows* application, text and graphical outputs are easily transferred to other *Windows* applications such as spreadsheets and word processors. Mouse support and printer drivers are also supplied by the *Windows* environment. The input is a node-based geometry. That is, nodes define points in space (in Cartesian, cylindrical or geographic coordinates), and wires are defined between nodes. Entries are made in tables through individualized window screens. On line, context-sensitive help is provided along with preprocessing diagnostics. *MININEC Professional* is dimensioned for 1000 wires and 2000 unknowns.

In 1996, the authors published *MININEC Broadcast Professional* for *Windows,*[11] which is similar to its predecessor, but more powerful. Additional features include an improved voltage-source model, a plane-wave-source model, automated convergence testing, design analysis post processing, array synthesis and ground-wave calculations. *MININEC Broadcast Professional* is dimensioned for 2000 wires and 4000 unknowns.

Also in 1996, the authors published *MININEC* for *Windows,*[12] a simplified version of *MININEC Professional* that is more suitable for first-time users and their pocketbooks. This code is dimensioned for 400 wires and 800 unknowns.

The Modeling Process

We do not attempt to present the *new MININEC* for *Windows* formulation and method-of-moments procedure in this paper. Interested readers should refer to the *MININEC* documentation or other suitable texts. For the uninitiated, however, we will describe a few realities of modeling.

The *MININEC* formulation defines the relationship between the currents and charges on wires and the associated electric and magnetic fields. A number of simplifying assumptions make the results more tractable for computer programming. For example, all conductors are straight cylinders with lengths much greater than their diameters (ie, the thin wire approxi-

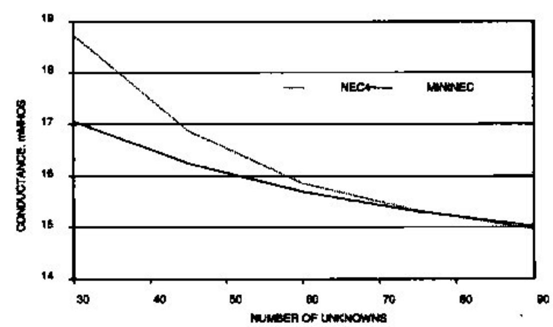

Fig 5—KH = 0.2 TEE antenna conductance vs. unknowns.

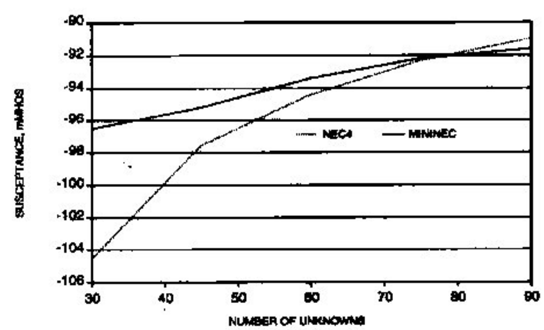

Fig 6—KH = 0.2 TEE antenna susceptance vs. unknowns.

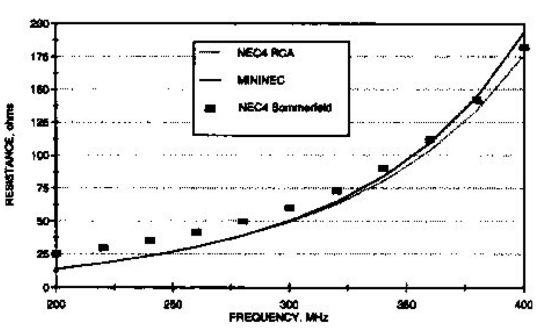

Fig 7—Dipole resistance of a dipole over average ground.

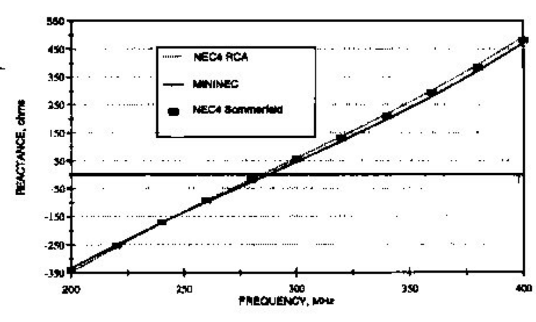

Fig 8—Dipole reactance of a dipole over average ground.

mation). The method of moments is used to translate the formulation into a system of equations that can be readily solved on a computer. The method of moments introduces further constraints on the model and the solution. For example, the solution requires that each wire is divided into a number of short segments and that any sources and loads are collocated with the segment connections. The simplifying assumptions and method-of-moments constraints combined with user experience defines the validity range for the antenna model and solution.

The modeling process, highly automated by the *MININEC* user interface, is reduced to six principle steps: (1) Geometry Definition, (2) Electrical Definition, (3) Model Validation, (4) Solution Definition, (5) Model Execution, (6) Output Display and Solution Analysis. Each of these steps is discussed in the following paragraphs.

Step 1, Geometry Definition: The antenna geometry is defined by specifying a set of nodes in a three-dimensional imaginary grid or coordinate system in space. These nodes become the wire ends. The grid may be in free space or include a ground plane. Coordinate dimensions are selected (feet, inches, centimeters, meters, etc). Wires are defined by connecting nodes. A radius and number of segments are assigned to each wire. The number of segments required depends on the wire length in wavelengths. A current node will be associated with each segment on every wire. These nodes are discrete points on the wires where currents will be computed. In the new *MININEC* series of computer codes, a three-dimensional display of the geometry as well as a tabular listing is available.

Step 2, Electrical Definition: The electrical circuit parameters for the antenna model are defined. The frequency (or set of frequencies) for the solution is specified. The number, location and strength of sources (eg, feed points) and loads are defined. Sources and loads must coincide with the location of current nodes defined in Step 1. The new *MININEC* codes provide a three-dimensional geometry display that indicates the location of sources and loads.

Step 3, Model Validation: The model is checked against the modeling constraints to determine that the geometry and electrical specifications are within the validity range. In the new *MININEC* codes, a three-dimensional geometry display is color coded to indicate warnings and errors. A diagnostic window provides a tabular display or warnings and errors.

Step 4, Solution Definition: The type of fields desired in the solution is specified. Types may be near-electric, near-magnetic or (far-field) radiation fields. The exact number and location for each to be computed must be defined.

Step 5, Model Execution: The currents are computed for the model defined by Steps 1 through 4.

Step 6, Output Display and Solution Analysis: The computed output is examined in tabular and graphical form to determine the validity of the results and eventual interpretation to the real world.

Modeling Accuracy

The accuracy of the results from using any numerical modeling code depends both on the user as well as on the code. The old adage "garbage in, garbage out" applies all too well. Given that a knowledgeable user has defined the antenna model within the modeling constraints, what kind of accuracy can be expected? How do the latest versions in the *MININEC* for *Windows* series of codes compare to the latest version of *NEC*? The following examples give an indication of what to expect. The results of the *MININEC* for *Windows* series of codes are compared with version 4 of *NEC*.

Dipoles

Any evaluation of a wire-antenna modeling code begins with the evaluation of a dipole antenna. Figures 1 and 2 show a comparison of the new *MININEC* to *NEC* in a typical convergence test for a short dipole in free space. In a convergence test the accuracy is determined as a function of the number of unknowns. A convergence test provides the rationale for selection of segment density for a desired accuracy. It also demonstrates the stability of the analysis. The dipole half-length is 0.159155 meters and radius is 0.001588 meters. Figure 1 shows the conductance versus the number of unknowns and Figure 2 shows the susceptance versus the number of unknowns. R. W. P. King[4] reports an admittance (conductance + j susceptance) of $0.25 + j3.87$ mS. These figures show that as the number of segments (unknowns) increases, the admittance of both codes converges toward approximately the same asymptotic values.

Figures 3 and 4 show the admittance results of *MININEC* compared to *NEC* for a short dipole over a range of frequencies. Figures 3 and 4 compare conductance and susceptance to frequency. Also shown are values from R. W. P. King.[4] The dipole has a half length of 0.25 meters and a radius of 0.00351 meters. The length-to-radius ratio is 142. The segmentation scheme provides 29 unknowns over the frequency band. Both codes perform very well.

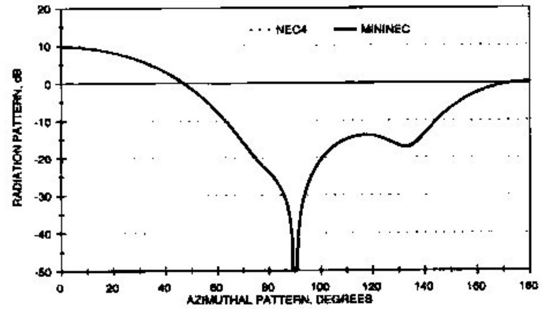

Fig 9—Radiation pattern of a three element Yagi.

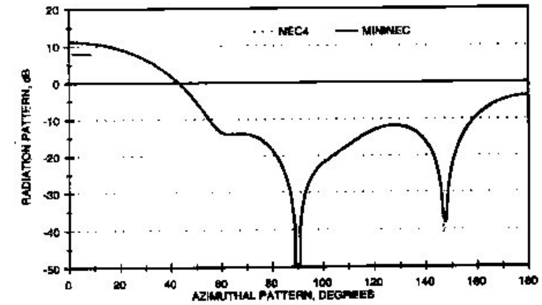

Fig 10—Radiation pattern of a five element Yagi.

Multiple Wire Antennas

A second step in an evaluation is calculation of a multiple-wire antenna. Figures 5 and 6 display *MININEC* and *NEC* conductance and admittance calculations for a T antenna described by King.[8] The specific antenna has KH = 0.2, where $K = 2\pi/\lambda$, λ is the wavelength and H is the height, in wavelengths. King reports an admittance for this antenna of $29.6 - j102.6$ mS.

Real Ground

Figures 7 and 8 show the impedance computed by *MININEC* compared to the impedance computed by *NEC* for a dipole over real ground. The antenna is a 0.5 meter center-fed dipole with 0.0005 meter radius at 0.1 meters above an average ground. The dielectric constant of the ground is 15, and the conductivity is 27.8 mS. Figure 7 shows the dipole resistance versus frequency and Figure 8 the dipole reactance versus frequency. Two sets of calculations are shown for *NEC*. One set of calculations is for the solution using the Fresnel reflection-coefficient method, and the other is for the Sommerfeld solution. These results have been obtained after checking the solutions of both codes for convergence. The Fresnel reflection-coefficient method is shown a good approximation to the more general, exact Sommerfeld solution.

Radiation Pattern

Figures 9 and 10 show the Yagi radiation patterns computed by *MININEC* compared to the radiation patterns of *NEC*. Figure 9 is the pattern for a three-element Yagi, and Figure 10 is the pattern for a five-element Yagi. The Yagi dimensions in meters are shown in Table 1.

Table 1—Dimensions of three and five-element Yagi antennas

Yagi	*3 element*	*5 element*
Reflector length	0.482	0.482
Driven element length	0.25	0.25
1st director length	0.442	0.428
2nd director length		0.424
3rd director length		0.428
Director spacing	0.2	0.2

The selected examples show that *MININEC* gives comparable results to *NEC*. This is not a complete picture of the comparison of these codes, but it gives the reader a glimpse of the results to be expected. A more thorough analysis of *MININEC* is presented in References 10 and 11. (Also see L. B. Cebik's article in this issue.—*Ed.*) This analysis shows that for a wide variety of problems *MININEC* and *NEC* provide comparable results.

References

[1]Beezley, B., *The MN4 Manual*, Vista, California, 1992.

[2]Burke, G. J. and A. J. Poggio, *Numerical Electromagnetics Code (NEC) —Method of Moments*, Naval Ocean Systems Center Technical Document 116, January 1981.

[3]Julian, A. J., J. C. Logan, J. W. Rockway, MININEC*: A Mini-Numerical Electromagnetics Code*, NOSC Technical Document 516, September 1982.

[4]King, R. W. P., *Tables of Antenna Characteristics*, IFI/Plenum Data Corporation, New York, 1971.

[5]Lewallen, R., "*MININEC*: The Other Edge of the Sword," *QST*, Feb 1991.

[6]Li, S. T., J. C. Logan, J. W. Rockway, D. W. Tam, *Microcomputer Tools for Communications Engineering*, Artech House, Inc, Dedham, Massachusetts, 1984.

[7]Logan, J. C. and J. W. Rockway, *The New* MININEC *(Version 3): A Mini-Numerical Electromagnetic Code*, NOSC Technical Document 938, September 1986.

[8]Prasad, S. and R. W. P. King, "Experimental Study of L-, T- and Related Transmission Line Antennas," *Journal of Research of the National Bureau of Standards—D Radio Propagation*, Vol 65D, No. 5, Sept-Oct 1961.

[9]Rockway, J. W., J. C. Logan, D. W. Tam, and S. T. Li, *The* MININEC *System: Microcomputer Analysis of Wire Antennas*, Artech House, Inc. Dedham, Massachusetts, 1988.

[10]Rockway, J. W. and J. C. Logan, MININEC *Professional for Windows*, EM Scientific Inc, Carson City, Nevada, 1995.

[11]Rockway, J. W. and J. C. Logan, MININEC *Broadcast Professional for Windows*, EM Scientific, Carson City, Nevada, 1996.

[12]Rockway, J. W. and J. C. Logan, MININEC *for Windows*, EM Scientific, Carson City, Nevada, 1996.