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## NEC visualization, optimization and sweeping tool

The 4nec2 tool is a windows- and Nec-2 or Nec-4 based tool for both the starting and experienced antenna modeler that can be used to create, view and check your antenna geometry structure and generate, display and compare near- and far-field radiation patterns. Also SWR, input impedance, F/B- and/or F/R-ratio for a range of frequency's on a linear or logarithmic graph (or Smith-Chart) can be displayed.

Furthermore an optimizer and sweeper is included. With this optimizer you are able to optimize antenna- and/or other environment-variables for Gain, resonance, SWR, efficiency and/or Front to Back ratio. With the sweeper you are able to graphically display the effect of changing one or more antenna- and/or environment-variables for a specified range of values/frequencies.

For the starting antenna-modeler a graphically based 3D geometry-editor is included which required no additional NEC knowledge while still enabling you to create and visualize current-distribution, far/near-field patterns and Gain/SWR charts.

To be able to use one of both optimizers or the sweeper, some basic knowledge about the NEC syntax is required. So one is able to (textually) create NEC based geometry structures and know something about the results when using GN, EX, LD, and FR cards.

Although this help-file might look comprehensive, this is not directly related to the complexity of the 4nec2 package but much more to the large amount of features available. Considerable effort was taken to get used to 4nec2 without the need to first read the complete help-file.

The 4nec2 tool consists of four general forms/windows: Main, Geometry, Pattern, Line-chart plus an Edit-, Matching-, Smith-chart and an Optimizer/Sweeper form. Each form contains a menu bar with menu-options. Most of these menu-options speak for themselves. Try out each of these menu-options and see what the results are. However there are some options who are more difficult to understand. These options are discussed in more detail further on in this help file. To get specific (context sensitive) help for a certain window/form just push the F1 when the form/window is on-top.

When the 4nec2X eXtended version is installed the real-time 3D-viewer is also available for use. However this version requires a more modern computer-system and graphics-card.

In all the forms you can process the general buttons F1 to F12, Ctrl+O and Ctrl+Z / Esc. These buttons, for which also a menu-option is included in the 'Main' form, have the following meaning



F1 Display this help file



F2 Select Main form



F3 Select Geometry form



F4 Select Pattern form



F5 Select Line-chart form



F6 View or Edit (4)nec2 input data



F7 Start NEC-engine and Generate new output data



F8 View NEC output-file



F9 Start/select 3D-viewer form



F10 Start Matching form



F11 Display Smith-chart form



F12 Optimize or Sweep variables



Ctrl+O Open (new) input file



Ctrl+S Save output file (as)

Ctrl+Z Exit program (also ESC may be used)

Some entry points to other Help information:

[Nec-2/4 reference](#)

[Validate structure](#)

[LC-Traps\(LD 6\)](#)

[Ground types](#)

[Propagation prediction](#)

[Wire table](#)

[Capture/Print](#)

[Variables and constants](#)

[Current-sources \(EX 6\)](#)

[Wire coating \(LD 7\)](#)

[MiniNec ground \(GN 3\)](#)

[gnuplot Plotting program](#)

[Genetic Algorithms](#)

[Troubleshooting](#)

[Modeling guide-lines](#)

[Wire loading \(LD 5\)](#)

[Auto-Segmentation](#)

[Using NGF files](#)

[Program Settings](#)

[DBW and dBuV conversion](#)

[About 4nec2](#)

The 4nec2 help file contains so-called context-sensitive Help, making it possible that when using the F1 key in a particular window or form, help-text describing that particular window/form is displayed.

For easy reading the content of the 4nec2 help-file is also available as a (rich)text file. To print this file, open and print the file "4nec2.rtf", located in the "..\4nec2\exe" folder, in your Word or Wordpad text editor.

Other recommended sources for NEC related informations are the Nec-2 and Nec-4 user-manuals and the excellent collection of antenna-modeling articles by L.B. Cebik (W4RNL), both available on the internet. You can further read the \_GetStarted.txt text-file included in the 4nec2 package.

The use of this 4nec2 software package is for own risk and the author of it cannot be held responsible for any faulty results or damage resulting from the use of this software.

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## Main form      F2      Show general data

In this form the general data, as listed in the 4nec2 input- or NEC output-file, is displayed. When the output-file is not yet generated, only few fields are filled.

After the 4nec2 program is started, by default, the last loaded Nec2/4 file input-file is re-opened. This file represents the data you are working with. This data is used to generate near- of far-field patterns and may also be used by the optimizer.

Using File -> [open](#) you are able to choose and open another \*.nec input-file. You are also allowed to select and open \*.ant (antenna optimizer) or \*.ez (Eznec) type input-files which are automatically converted to 4nec2 type input-files.

To support the starting antenna modeler, in version 5.3, a graphical based 3D 'Geometry editor' was included. The benefit of this editor is the fact that it is now much more easy to create/modify antenna structures. On the other side however, using this kind of editor, it is not possible to specify symbolic information as used by the optimizer/sweeper. For further information about using and selecting between the available types of editors, see [Edit](#).

It is furthermore possible to specify an output-file. If this is the case, the program displays the data present in the output-file, but it is not possible to generate new data or use the optimizer. This option is useful to compare intermediate output file data if [saved](#) with a different name.

Please note that all numbers used in 4nec2 use the **dot** as the **decimal separator**, independent of windows regional settings on the computer. So, especially for European users it is important to use the dot (.) instead of the comma (,) when entering decimal numbers.

Voltages and Currents specified and/or listed in the 4nec2 program use effective values. These are derived from the maximum values as listed in the NEC output-file by multiplication with 0.707.

Furthermore the voltage- and current-values displayed and the field-strength values shown for the Near- and Far-field-pattern are in accordance with the input-power specified in the 'Settings' menu-bar option. For further info about this, see the 'Input-Power' paragraph in [Settings](#).

With the menu-bar on this form you have access to the most important 4nec2 options and features.

With the Calculate -> [Generate NEC data](#) command it is possible to start the NEC-engine and generate new NEC output data. With the Calculate -> [Optimize design](#) command you can start the 4nec2 optimizer to optimize data made available through the 4nec2 input file

Use Calculate -> [Matching networks](#) to let 4nec2 automatically calculate L, Pi or T matching networks to create an 1:1 match and determine the losses for the selected network.

With the 'Show -> voltage sources' or 'show-> RLC loading data' option it is possible to view detailed voltage source or RLC loading data, including SWR, delivered or dissipated power.

Note however that if only two (connected) voltage sources are specified in the input file, it is assumed that a split voltage source is used. In the general data on the 'main (F2)' form and the impedance/SWR data on the 'line-chart (F5)' form the impedances and voltages are added. This is not the case if only one or more than two sources are specified.

Using 'File -> Import' one is able to import OpenPF or tab/white-space delimited far-field pattern data. This to let 4nec2 visualize the imported far-field pattern.

For a further description about the OpenPF format see [Pattern](#)

For an example of a tab/white space delimited far-field text file, open the file named

'FarFieldImportExample.txt' file in your '..\4nec2\plot folder'.

Such a text file contains one or more sets of full/3D far field data. Each set is preceded by a line prefixed with a # and containing the text 'Frequency' with a numeric frequency value.

After this a number of Theta sets are listed (from 0 to 180 degrees), each containing the gain values for a full 2D horizontal/Phi pattern (0 to 360 degrees).

If (during import) an optional frequency, theta or phi angle is specified, the set for this specific entry is filtered out. Else the first/only set is loaded.

### **Geometry builder**

Using the 'Run -> Geometry builder' menu-bar command one can start the 'Geometry builder'. This is a powerfull tool to automatically create complex geometry structures using 'auto-segmentation' and/or 'equal-area rules'.

To merge one or more structures to an existing model, open both the created \*.nec and your 4nec2 file using Notepad and cut/paste the required cards/lines into your model. To remove overlapping wires, use 'Geometry-edit', select and remove wires one by one or select more wires by dragging a rectangle around them and remove them as a whole.

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## Geometry form      F3      Show structure geometry

In this form, the structure geometry (including voltage sources, transmission lines, (wire)loading and patches) as defined in the input file or as generated in the output file is displayed. With the cursor movement key's or mouse you can rotate and shift the structure. With the page-up/down buttons you can zoom-in/out on the structure. When currents display or far-field pattern display is on these buttons zoom in/out on currents or far-field pattern. Other options are available as both keyboard-buttons and menu-bar options.

When no NEC output file is available the background is displayed in a none-white color, and some menu-bar options are disabled. When an output file is generated the data in this output-file is displayed. The background color is changed to white. The menu bar options are enabled according to the data in the output file.

After editing the input file (by pressing F6), initially the (modified) input file data is displayed (none-white background). This is done so you directly can see the modifications you made to the input file. To see the resulting output file data you first have to generate a new output file by pressing the Generate (F7) key.

You can switch between I(nput) and O(utput) file view by pressing the 'I' or 'O' button when the Geometry form is on top.

Wires/segments with a tag-number of 9800 or above are not displayed. This way it is possible to use far-away dummy wires while the main structure is still visible with normal scaling. Structure validation (see below) is also not performed on these dummy wires.

You may left-click on any wire or segment to select a wire/segment and view additional information. To 'reset' click anywhere else on the form. If a wire/segment is selected and the right mouse button is pressed, the 'wire/segment' pop-up menu is displayed. One useful option in this menu is the 'center' option. With this option you can set the rotation center for the structure on the middle of the selected wire/segment. With 'reset' you reset the center to the origin for the Y,Y,Z axis.

A selected wire is displayed in blue color with a filled and an open black circle. The closed circle is end-1, the open circle is end-2 for the selected wire.

A further special and important option, which requires more explanation, is the "Validate" menu-bar option. This option can be used to manually or automatic validate the most important NEC segment- and geometry-requirements. When the output-file view is active more segment checks are available than with input-file view. For a further description of what kind of checks are performed see Validate.

Automatic Geometry-checking is done before each Nec-run. Automatic Segment-checking is always done after the Nec-run. Because of the time-consuming nature of the Geometry-checks, one can enable or disable automatic geometry-checks, using the "auto geo-check" menu option on the "Geometry (F3)" form. Segment checking is always active.

Further geometry validation can be done using "Show -> Open ends". With this you you can check for open ends. Using "Show->Junctions" you can check for the number of connected wires at junctions. And last but not least you can use the "3D-viewer" to validate your structure. This viewer shows all wires with their real radius. This way it is very easy to see if certain wires intersect or not. At junctions with short fat segments you should check if a segments 'volume' does not lay more than about 1/3 in another segments 'volume'.

Under the 'Show' menu-bar option the following log-data is available:

- Last NEC input Pure Nec 2/4 input data which was send to the NEC engine for last run.

- Auto-segm log        Logging about geometry modifications made by the auto-segmentation process
- Step-rad log        Logging about geometry changes made by stepped radius correction process
- Symbol conversion    Intermediate values for converted and calculated symbols/variables

The near- and far-field menu-bar options are only available if an output file is loaded which contains near- or far-field data, generated with the RP- or NE/NH card or by using the Generate (F7) command. You can toggle the display for the near/far-field on or off with the menu-bar option or with the "R"(adiation) button.

When far-field display is enabled you can use the 'far-field' menu-bar option to let 4nec2 colorize the far-field pattern using gain/magnitude, tilt/phase, axial ratio or sense data from the output-file.

With the "<" and ">" key's it is possible to switch between the different hor/vert/total or X/Y/Z patterns. If there are multiple patterns selected on the "Pattern (F4)" form for comparison, these key's are used to switch directly between the far-field patterns for the different NEC output-files.

Under the 'wire/segment' menu bar option you can 'walk' through all the structure wires/segments, select a specific wire/segment and display the wire geometry (input file) data or the segment current in polar or cartesian notation (output file). It is also possible to select a wire/segment by clicking with the mouse on or near a wire/segment.

When the display of current-distribution is enabled, and also a freq-sweep calculation was performed, the function of the cursor/arrow key's is changed from structure movement/rotation to frequency 'movement'. Using the left- and right arrow key's one can 'walk' through the frequencies included in the sweep and inspect the change in current-distribution over the structure while changing the frequency.

*Tip: for optimal display of current-distribution with changing frequencies it's recommended to use current- instead of the default voltage-sources. See Edit for more info about specifying excitation sources.*

One can perform a frequency sweep by specifying a start-, stop- and step-frequency or by specifying a list of frequencies included in a text file. See 'Generate' for more info about this subject.

Use 'Currents->Multi color' and 'Currents->Incr./Dec. Log-factor' to visualize current distribution for small currents over gridded surfaces and/or large external structures.

You can use the 'Plot' menu-option to create and/or print linear 2D gnuplot graphs for one, more or all currents in the geometry structure.

Use the 'File->Print' to capture and print/save the geometry structure or other forms or windows.

The 4nec2 tool was initially developed to assist on wire-geometry structures and the display of (arbitrary shaped) surface patches is not that sophisticated. For instance the current on patches are not visualized (yet), also structure validation is only performed in a limited way for patches. Rectangular, triangular and quadrilateral patches are displayed according the specified XYZ-coordinates. For arbitrary shaped patches a square shape is assumed. However not always appropriate, this will give you well enough information about if center-, normal-vector and/or patch-area data are correctly specified.

Under 'Show -> Povray' you may select between the generation of a true 3D geometry or far field pattern povray file.

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## **Validate      Validate geometry structure**

The Validate menu option on the Geometry (F3) form is used to check a large number of NEC requirements concerning the geometry structure and segmentation. With this, there are two different tests to distinguish:

- \* Geometry checking/validation
- \* Segment checking/validation

Because the “Geometry check” (especially for models containing a large number of wires) can take some time, model validation is split into two different tests. Geometry validation is (optionally) performed before each Nec-run, Segment validation is automatically performed after each Nec-run. With ‘set auto Geo-check” on the Geometry form you can enable/disable automatic geometry checking.

After a geometry-check with errors and/or warnings a report-log is displayed. After a segment-check with errors a message is displayed. To get a report-log for the segment-check, manually run a segment-check. After each test all wires/segments subjected to warnings or errors are displayed in grey and red colors. Use the left mouse-button, to select a wire and get specific segment error/warning info for the selected wire/segment.

**Geometry-check** validates the below:

- 1) Crossing or unconnected segments.

This error condition occurs when the distance between two or more segments is below  $\text{seg-length}/1000$  and the connection point is not a wire-end or a segment junction.

- 2) Intersecting wires/segments.

This warning is generated when the volumes of two or more wires are intersecting at a point other than their wire ends

- 3) Sharp angles or too short/thick segments.

This warning is generated when the intersecting volume of two or more wires, connected at their end-points or segment-junction becomes too large.

- 4) Overlaid wires

This error condition occurs if two or more wires are overlaid (same end-points)

- 5) Unequal segmentation for parallel wires.

This warning is generated if parallel wires within  $1/20$  wavelength distance and having an ‘overlap’ length of more than  $1/10$  wavelength have unequal segmentation.

- 6) Vertical/horizontal wire height below xxx.

This condition occurs when the height of one or both of the end-points for a certain wire goes below the limit as specified by its direction and the use of reflection coefficient or sommerfeld/norton ground.

Note however that above warnings (or even errors) do not say that your model is not usable. They merely inform you about where extra attention might be needed to improve accuracy.

**Segment-check** validates the below:

(L = segment length, R = segment radius, wl = wavelength, A=area)

Run segment-checks '9' Generate error/warning report and view log-file

Show all seg-checks '0' Show results of all below checks.

			Warning(gray)	Error (red)
Segment Length	'1'	Check segment length	$L > wl / 10$	$L > wl / 5$ or $L < wl / 1000$
Segment Radius	'2'	Check segment radius	$R > wl / 100$	$R > wl / 30$
Segm. Len / Rad	'3'	Check length/radius (def.) (EK)	$L < 8 * R$ $L < 2 * R$	$L < 2 * R$ $L < 0.5 * R$
Junc. L big / L small	'4'	Check length at junction	-	$L1 < 5 * L2$
Junc. R big / R small	'5'	Check radius at junction	$R1 > 5 * R2$	$R1 > 10 * R2$
Junc. Len / Rad	'6'	Check len/rad at junction	$L < 6 * R$	$L < 2 * R$
Surf-patch area	'7'	Check max patch-area	Error when : $A > (wl*wl)/25$	
EX/LD requirem.	'8'	Check EX/LD requirements		

Furthermore the 3D-viewer is also extremely useful for further analyzing and detecting crossing, intersecting and/or overlaid (fat and short) wire-segments (at sharp junction angles).

Additional validation for the geometry structure is possible by performing an Average-Gain test or Convergence test



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## **Pattern form      F4      Show far- or near field pattern**

In this form the far- or near-field pattern data is displayed.

### **Far-field display**

If far-field data is requested, the far-field is displayed in a polar diagram. You can select between linear- or the ARRL-style (semi-logarithmic) scaling. When scaling is in dB's, by default the ARRL-style is set to let the minor lobes be more distinguishable. When scaling is in V/m linear-scaling is set and recommended for use.

With the arrow-key's you can 'walk' through the different Phi- or Theta-angles. When calculations for a range of frequencies are asked (frequency sweep), the left- and right-arrow keys are used to 'walk' through the frequency range.

If the 'display far-field option' is enabled on the 'Geometry (F3)' form, the selected pattern is highlighted in the complete 3D drawing. Selections made on the 'Pattern (F4)' form are reflected on the 'Geometry' form.

When clicking on or near the far-field pattern line, the far-field data (angle and gain/field) for this point is displayed. Click anywhere else on the form to clear this data.

With the 'Home' key you can select one of three normalization types (logged in the upper left) when viewing far-field Gain-data.

Using the 'compare' option ('Insert' and 'Remove' key's) you can compare far-field radiation patterns for two or more previously generated output-files. You may add a total of 5 different far-field patterns. You can also remove a pattern and add a different one. The only thing you must keep in mind is that the number of theta- and phi-steps for the patterns to compare must agree.

With the '>' or ',' and '<' or '.' keys you may cycle through the different far- or near-field columns/patterns as included in the output file data. The default pattern for the far-field is the 'Total gain' pattern. Using 'Far-field->Show Multi pattern' you can display all patterns together.

To show the circular polarized components RHCP- and, LHCP gain or E (left) and E (right) for the far-field pattern, check the 'show circular polarization' option on the 'Settings' menu and use the '<' or '>' keys to cycle between the circular polarized components, or use the 'M' key to show all components using a Multi-pattern view.

With the 'G'(eometry) key or 'Show -> structure' option you can include structure geometry in the near-of far-field pattern display. Try the other menu-bar options to see what action they perform.

For information about beam-width, nr of lobes, max-gain and/or front to back ration you may enter the 'I'(nfo) key or select 'show -< info'. Also the 'J' key or 'show->indicator' may be usefull to get additional information. This indicator is also displayed if you click on or near the pattern-line. When one or more patterns to compare are loaded and 'information' or 'indicator' is enabled, the '<' and '>' keys are used to select between the different loaded patterns.

Use the 'OpenPf' menu bar option to import or export far-field data using the OpenPF file format. This way one is able to exchange far-field data between 4nec2 and for instance Eznec or AO. This way could also store (export) generated far-field patterns for later usage, by importing it into another or similar model.

Using the 'FFtab' menu bar option one is able to generate an Eznec style FarField table. One (requested) usage for this could be to import the far field table into a program like Tant.exe for

calculating Antenna Temperature and G/T ratio data. For further info see <http://www.yu7ef.com/LowTemperatureAnt.htm>

You can use the 'Plot' menu-option to create and/or print none-polar 2D or 3D far-field graphs using the gnuplot program.

## **Near-field display**

If near-field data is requested, the near-field data is displayed in the XY, XZ or YZ plane. You can select a specific Z, Y or X position with the left or right arrow-keys. You can set the active display plane with the 'spacebar'. When pressing the Page-up and Page-down key's you can switch between this 2D view and a line-chart view in which the field-strength is displayed as function of the X, Y or Z position. In the 2D view you can select the vertical X, Y or Z position for the graph with the up- and down-arrow key's

When displaying near-field data points on or in close proximity of the geometry structure this may result in a large maximum field strength value for certain field-points. This will also result in a large difference between the minimum and maximum field-strengths values, resulting in a low 'color-resolution' for the near-field display. To avoid this, two options are available. First you can 'remove' field-points with field strength above a specified value. This is done with the 'Del' key in the pattern window. The second option is to set the linear field strength scale to a more (anti) logarithmic scale. This is done with the <Alt> and <page-up> or <page-down> keys. For both options also menu-items are included in the pattern form. These changes will also affect the display of the 3D pattern on the geometry form.

The default 'pattern' for the near field is the 'E/H Total' pattern. This 'E/H Total' pattern is not included in the output file data, but is computed as the 'sum' of the E/H(x), E/H(y) and E/H(z) fields. With the '>' or ',' and '<' or '.' keys you may cycle through the different near-field patterns for E/H(x), E/H(y), E/H(z) and E/H(total).

This 'total pattern' is calculated as below (as discussed by L.B.Cebik):

Ex, Ey, Ez = magnitude given in peak volts/m or peak amps/m  
Px,Py,Pz = phase angle of Ex, Ey, Ez

$Cp = Ex*Ex*cos(2*Px)+Ey*Ey*cos(2*Py)+Ez*Ez*cos(2*Pz)$   
 $Sp = Ex*Ex*sin(2*Px)+Ey*Ey*sin(2*Py)+Ez*Ez*sin(2*Pz)$   
 $Tp = Cp*Cp+Sp*Sp$

$Etot = Sqrt ( 0.5 * (Ex*Ex+Ey*Ey+Ez*Ez+Sqrt(Tp) ) )$

Furthermore keep in mind that the data as shown in 4nec2 is presented in RMS volt/m or RMS amp/m and based on the power level set in the 'Settings' menu.

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## Line-chart form      F5      Show impedance, SWR and gain graphs

This form is used to display the input impedance, the SWR and, if specified, the gain, front-to-back (F/B) and front-to-rear (F/R) ratio as function of frequency- or variable-change on a line-chart. The form contains valid information if a frequency-sweep is requested with the Generate (F7) command or when a Sweeping-action (F12) was performed.

When the charts are too rude, try a smaller frequency/sweep step-size. If this is not possible you can smoothen the curve, by letting 4nec2 do a cubic-spline interpolation on the graph. Note however that this option can introduce considerable errors when the curve goes steep up or down, so increasing the number of calculation steps is recommended. Use 'View->Smooth' or the "O" key to smooth the curve. The maximum usable number of steps is set in the 'Settings' menu on the 'Main' form.

Use 'Show -> Log X-scale' ("F" key), to switch between linear and logarithmic frequency/variable axis scaling. Use 'Show -> Log Y-scale' ("L" key) to switch between linear and logarithmic Y-axis scaling. Initially after a frequency- or variable-sweep the R-in, Z-in and SWR graphs are set to logarithmic scaling. The others default to linear scaling. If values pass the Y=0 line, like when X-in is changing from inductive to capacitive, the chart can not be set to logarithmic scaling.

You may click anywhere on a graph to let 4nec2 display additional X,Y value information. Use the left/right arrow key to move the selection.

The form can be resized by dragging the window-borders.

Try the menu-bar options to see what actions can be performed on the graphs.

With the 'Tab' key you can select one or both of the Graph windows for changing the scaling or switching between Linear or Logarithmic (if possible).

Impedance and SWR information is also available on the Smith-chart (F11) form.

**Note:** If two (connected) voltage sources are specified in the input file, it is assumed that a split voltage source is used. In the general data on the 'main (F2)' form and the impedance/SWR data on the 'line-chart (F5)' form the impedances and voltages are added. This is not the case of only one or more than two sources are specified.

If more than two voltage- or current sources are specified use 'V/I source -> previous/next' to switch the SWR- or Impedance-plot from one source to the other.

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## **Edit F6 Enter/modify or delete 4nec2 input data**

With this function you can view, enter or modify your 4nec2 antenna input-model. With version 5.3.0 and later can select between three different kind of entry systems, so called 'editors' to use: The Notepad-, NEC-based- or the graphically-based geometry editor. You select between one of these editors with the Settings menu-bar option. When pushing the F6 function key (or using Edit->Input file on the Main(F2) window) the selected editor is started and available for entering or changing your antenna-model/geometry-structure

With version 5.6.5 a fourth editor, based on the old NEC-editor was added. You can select between below four types of editor:

- Notepad edit
- Nec-edit (old)
- Geometry-edit
- Nec-edit (new)

The drag-and-draw style 'Geometry-editor' (or the new NEC-editor) is especially suited for the starting Antenna-Modeler, whereas the experienced NEC user may prefer 'Notepad-' or the old style NEC-editor.

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### **Notepad edit**

This is the 'traditional' (4)nec2 windows-editor, which lets you directly modify the (4)nec2 input-file. When using this editor it is presumed the user has good knowledge about the NEC-syntax, because no syntax checking is done. On the other side this delivers maximum flexibility to use any kind of Nec-card and/or symbolic- and equational data.

One important difference between this Notepad- and the other editors is the fact that the Notepad-editor requires closing (or saving) the new data, before the NEC-engine can be run. The other editors can stay active when performing a NEC calculation (F7 key).

To create new 4nec2 input-files using Notepad, Open an existing NEC-file, edit it and save it using a different name. If done, use again the 'open' command to load the newly created file.

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### **Geometry edit**

This drag-and-draw style geometry editor graphically supports the user in drawing/moving/rotating wires and placing sources, loads and transmission-lines. The user is guided in selecting between the available source-, load- and ground-types. Pre-defined wire-radius, wire-conductivity and ground-parameter settings are available and one can select between metric, feet, inch or wavelength based length and/or radius units.

With this editor however it is not possible to specify symbolic (and equational) data to be used within the optimizer/sweeper. This due to the drag-and-draw based nature of the editor.

See Geometry-edit below for further help-information.

See Menu-bar functions for a listing of available functions.

*n.b. If someone has suggestions for a general usable algorithm to convert 3D numerical wire end-coordinates to a SYmbol based lay-out, to be used by the optimizer/sweeper, please let me know.*

*Despite numerous thoughts about this I did not yet succeed in finding an acceptable solution.*

However; in version 5.4.0, a first try was done to write the output of the Geometry editor to the corresponding \*.nec file using symbols(variables) which then could be used by the optimizer to improve the model. Select 'Options -> Write symbols/variables' in the 'Geometry-edit' window to switch between default NEC syntax and 4nec2 symbolic syntax. Use 'distinguish XYZ coords' to avoid using the same symbol for both X,Y and/or Z coordinates when they are the same value.

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### **NEC editor (old)**

This text-based NEC-syntax aware editor guides the user when entering or changing 4nec2 input-data. In contrast to the above editor, no pre-defined radius, conductivity or ground specifications are available, but it is throughout possible to include symbolic- and equational-data to be used within the optimizer or sweeper.

With this editor the selected GW, LD or EX card in the Edit window is highlighted on the Geometry window. If a wire is selected on the Geometry window, the corresponding GW line is highlighted in the Edit window. Any (wire)changes made in the Edit-window are reflected on the Geometry window whenever the current row on the Edit-window is changed

You may select one or more lines to be used for cut, copy and/or paste. Pressing SHIFT and clicking the mouse or pressing SHIFT and one of the arrow keys (UP ARROW, DOWN ARROW, LEFT ARROW, and RIGHT ARROW) extends the selection from the previously selected row item to the current row. Pressing CTRL and clicking the mouse selects or deselects a row in the list. You can also use copy/paste to copy and/or paste (using the clipboard) between the NEC-editor and other text-based NEC-(input)files.

To add a new NEC card, use 'new line' and select the required card-type from the 'card' combo-box. When selected use the <TAB> key to fill the next fields for the selected card-type. When field-entry is done, use up/down-arrow to add the new card-data to the list of NEC cards. As long as the card-data is not added to the list it is possible to change the card-type. Once added to the list it is not directly possible to change the card-type. To do so, first delete the current card-line/row.

While editing you do not have to save your data first to see the Nec results. Just click the "Calculator" button or push <F7> to run the NEC-engine using the current data as displayed in the Edit window. Once you are satisfied (or not) you can save your data (or not) using 'File->Save(as)'

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### **NEC editor (new)**

Because I didn't like the old style Nec-editor, I decided to create a new spreadsheet style Nec-editor. For the moment the new Nec-editor is only Nec2 compatible, however in the near future Nec4 support will be added. For those using 4nec2 together with a Nec4 engine it's suggested to use the Notepad editor or the old style Nec-editor.

You can select the new style Nec-editor on the Main (F2) window by using 'settings->Nec edit (new)'

You can start the editor by using the F6 key (or select 'Edit -> Nec input-file'). After this a new window should show up containing multiple Tabs, some with an Excel style grid and some with ordinary text- and/or drop-down boxes. To navigate around between the individual cells in the Excel style grid, use the up/down/left/right arrow keys or directly select a cell using your mouse.

When navigating between cells, the help-text box (just below the menu commands) is updated for each new cell.

This new Nec-edit window will show you below Tab pages:

## **Symbols**

On this page you can specify and/or modify all Symbols (variables) used in your model. At the bottom of this page you can select between different scaling methods. Scaling does affect the data on the Geometry page and all symbols used on this page. When 'custom' scaling is selected one can enter a user specific scaling factor. Note that you may also specify symbols to be used on the 'Source/load', 'Frequency/Ground' and other Tab-pages.

**Note:** when using already existing Nec input (example) files it's possible that one or more SY variables have been re-used (defined more than once). These (position dependent) SY variables are mostly defined just before they are used in multiple GW, LD or EX lines. A warning message is generated when saving such a file.

To avoid unexpected results using the new Nec-editor, these files (which have been created with the Notepad- or old-style Nec-editor) need some slight modifications so that all used SY variables are unique throughout the Nec input-file.

## **Geometry**

The Geometry page does contain all data used to specify the model's geometry structure. On the first column (named 'type') you can select between the different geometry types:

- Wire, to specify a straight wire containing the specified number of segments
- Helix, to specify a helical or spiral structure built from straight line segments
- Arc, to specify a circular arc built from straight line wire segments
  
- copy/move, to move and/or copy one or more of the preceding geometry lines
- rotate, to rotate preceding geometry lines to create a cylindrical structure
- mirror, to mirror the structure in X, Y and/or Z-plane to benefit from symmetry
  
- arbitrary shaped surface-patch, to specify an arbitrary surface with known area
- triangular sp, ditto for a triangular shape
- rectangular sp, ditto for a rectangular shape
- quadrilateral sp, ditto for a quadrilateral shape
- patch continuation, to specify a string of rectangular/quadrilateral patches
- multiple (rectangular) sp, to cover a rectangular region with a number of rectangular patches

To specify tapered wires, both in segment-length and/or in wire-radius, check the 'use wire tapering' box. If checked, additional columns for straight wire rows will show up.

## **Source/Load**

Using the check-boxes at the top of this page, one can specify additional antenna structure data such as:

- Excitation sources; at least one source, mostly a voltage- or current-source, is needed to get useful output-data

- Wire/RLC loads; used to specify wire conductivity, trap/RLC loads or wire insulation. You may use a single or multiple antenna materials.
- Transmission lines; to model open-wire or coaxial feed/transmission lines. These are equational lines and do not contribute to the radiation pattern.

### **Frequency/Ground**

With this page you can specify the environment in which the antenna is placed. A (design) frequency specification is required. When no ground is specified, free space is used.

If the antenna is placed above none-perfect ground, one can use the drop-down boxes to select between different ground types. Select 'user-specified' to manually enter specific ground conditions.

Check 'use ground screen' to model an additional radial wire ground screen.

Check 'use second ground' to model a two-stage ground as on a hill-top or near a cliff or (salty) beach.

### **Others**

This page is used to enter more specific Nec2 data. You may (un)check 'Ground connection' if you would like to have your wires with an end at  $Z=0$  to be connected or isolated from ground.

The 'Read/Write geometry' box is used to read or write predefined geometry structures.

There's no harm in always using the 'extended kernel'

### **Comment**

To provide your model with additional comments, use this page.

### **Menu-bar commands**

On top of the Nec-edit window a number of menu-bar commands are available. Most of them will be familiar to the average computer user, however some require additional explanation. Under the 'Cell' menu-option, cut/copy/paste commands are available for editing a single cell. Under the 'Rows' menu-option, cut/copy/paste commands are available for editing multiple rows at once.

Under the 'Selection' menu-option commands are available to perform certain actions on a number of selected cells. To select one or more cells, hold down left mouse-button and drag around over the cells you would like to include in the selection. Or click on the upmost row or leftmost column to select a specific column or row. After a selection has been made you can use 'make same value', 'add same value' or 'multiply same value' to treat all selected cells the same way. Use 'make same value' to enter equal values in all selected cells. Use 'add/multiply same value' to add or multiply existing cell values with a second user supplied value.

Use 'Options->Auto update geometry window' to let 4nec2 automatically update the Geometry (F3) window after each change. However if a complex structure is specified using large number of geometry lines this updating could become irritatingly slow. If this is the fact, uncheck the menu-bar option.

To let 4nec2 automatically resize column-widths when window size is changed, check the 'autoresize columns' option.

You can individually change column widths by clicking and dragging the column separator bars on the upmost row (containing the header names). These settings will be saved, so next time when Nec-edit is started, your column widths will be restored.

## **Command buttons**




Two command buttons have been placed on the Edit window. From right to left, a Save button and a Calculate button. The Save button saves all changes to the current file (as does File->Save). The Calculate button does start a new Nec calculation using actual data, whether or not this data is saved before. If you don't like the outcome resulting from latest changes you can quit the edit window without saving.

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## **Geometry Edit**

This editor is used to specify the antenna structure like creating a (schematic) drawing. In the edit window a 2D or 3D-view of the antenna input-file geometry is displayed which can be modified using select-, draw- and drag/drop methods.

To switch between 2D and 3D view, select one of the four leftmost view-mode buttons labeled "3D", "XZ", "YZ" or "XY" on the upper left of the Edit-window. For 2D view you can switch between XZ, YZ or XY plane.

Next three buttons    are used to Add, Select or Delete (new)wires or source/load/Tr-line objects.

The rightmost seven object-buttons are used to select the kind of object on which you want to perform an edit, create or delete operation. These objects are divided into two groups. A first group with both drag/drop- and textual-edit capabilities and a second group with only textual-edit capabilities. Wires, Sources, Loads and Transmission-lines belong to the first group. Comment, Frequency and Ground-parameters belong to the second group.



Select, Add or Remove (new) wire(s).



Select, Add or Remove voltage/current sources.



Select, Add or Remove RLC/Wire-loading, LC-traps or Wire-coating.



Select, Add or Remove transmission-lines.



Add or modify comment or edit wire-data on spread-sheet form



Enter or modify design frequency or select 'thin-wire' kernel.



Add, modify or remove ground specifications.

When viewing a structure or modifying non-wire objects you may use either 3D or 2D view. When modifying Wire-geometry it is advised to use only the 2D-view to avoid unexpected results. This because when moving a wire in 3D-view it automatically connects to the nearest available wire. To undo a faulty movement, use the right mouse-button while the mouse-pointer is over the selected wire or use the 'edit' menu.

To select between metric, feet, inch or wavelength as the length/radius units use the 'Settings' menu-bar option in the "Main" window.

## **Modify existing objects**



To modify an existing object, select the type of object (wire, source, load, etc...) by clicking the corresponding top-row object-button. If a none drag/drop-type object is selected the corresponding data is directly available on the right part of the edit-window.

When a 'drag/drop' type object is selected you will also have to select the desired object from the range of similar objects by clicking on the appropriate item in the 2D or 3D picture or by using the scroll-bar on the mid-right part of the screen.

If an object is selected the wire or segment on which it is located is highlighted and the mouse-pointer changes from the default arrow to a two- or four-point arrow, indicating that the object is ready for moving. The corresponding object data is available for textual editing on the right of the screen. If a two-point arrow is visible, the whole wire is movable. When a four-point arrow is visible only one end is moved.

Note: When modifying a drop-down-list or a text-box-value, enter the <Tab> key, click another text-box or anywhere inside the picture-box to let 4nec2 know that the value has changed and the model can be repainted.

In 2D-view, wires can be moved to any other 2D position. According to the "Snap to grid" or "Snap to wire" check box setting, the moved wire-end(s) 'snap' to the nearest grid-position or to another near wire-end. When a wire is moved in 3D-view it always automatically connects to the nearest wire. The 'snap'-range for 'Snap-to-wire' corresponds to roughly half the grid-line spacing.

When a wire is selected the wire is displayed with a green and red open or filled box on either side of the wire. The bleu box represents end-1, the red box end-2. A filled (blue or red) box indicates that this wire-end is connected to one or more other wires. (positive NEC current flows from end-1 to end-2, so in the direction of end-2. Think about the 'red' end-1 as the back-light of a car).

To release connected wires or to keep them connected while moving, (un)check the "Keep connected" check box within the wire-data. This option is also in effect when modifying the XYZ end-position, length or theta/phi wire-data text boxes.

When a two- or four-point mouse-pointer is visible one can use the right mouse-button to perform additional edit operations. It is possible to connect or disconnect a certain wire-end by using the right-mouse button while the mouse-pointer is over a selected wire-end. "Disconnect end" or "Connect to near wire" are only available when the mouse-pointer is over a certain wire-end. Most other actions are available if a certain wire is selected.

When the mouse-pointer is not located over an object (default pointer visible) the right mouse-button is used to shift the whole picture up/down or left/right.

Sources, Loads and Tr-line(ends) can only be moved from one wire/segment to another wire/segment. They automatically snap to a near segment. The 'snap-range' for this equals half the grid-line spacing.

#### Add new objects

To add new objects, select the "Add" button. The mouse-pointer changes to a cross-hair indicating "Add" mode is active.

When object-type "Wire" is selected (2D view), click inside the picture-box to set end-1, hold down the button, draw the wire and release to set end-2. By default the third (depth)dimension in the 2D view is set to zero (highlighted text-box on right side of screen). You may modify this value to create objects for other 'depth'-coordinates.

Use "Options->Hide wires not in plane" to draw overlapping or almost overlapping 2D- structures for different 'depth'-coordinates (for instance cubical quads). This will avoid selecting the wrong wire and

new or moved wires do not accidentally connect to wires lying in another 'depth' plane.

When a wire is created or the length for a wire is changed the number of segments is automatically updated according the specified "Set segmentation" option. You can select between "low", "medium" and "high" segment-count in the "Options" menu-bar option, corresponding to 10, 25 or 100 segments per half/wave. When a whole wire is moved the number of segments is not changed.

To avoid updating the segmentation when wire length is changed, select/check "Stop segmentation" in the above menu. This could be (temporary) usefull when a precise segment-count was already specified due to short wires/sharp bents

If the (design)frequency for the model is changed the segment-counts are not automatically updated. Use the "Recalculate segm." option to let 4nec2 recalculate the segmentation for the selected wire(s) according the specified segmentation density and new frequency. (use Ctrl+A to select all wires).

When creating new wires, it is not strictly needed to position the mouse-pointer on the exact XYZ coordinates. After having drawn (part of) the required structure you may select a wire and use the end-1 or -2 edit-boxes on the right part of the window to specify more exact coordinates. Use the end-1 or -2 option-boxes to specify which wire-end should stay in position. Use the 'Keep connected' box to specify whether other connected wires should stay connected or not after modifying the wire-data.

The default radius used for new wires is made equal to the radius specified for the last added/create wire (available wire with the highest wire-number). When adding the first wire to a new model, the wire-radius is explicetely asked for. Use "Snap to grid" to place wire-end coordinates relative to the specified grid. Use 'Snap to wire' to automatically connect a moved wire-end to another nearby wire-end.

To add a source- or load-object, click the desired object-type button, click anywhere inside the picture-box to create a new source/load object and drag the source/load onto the desired wire/segment using the left mouse-button. When done, edit the source/load data on the right part of the screen to select between different source/load types and to specify additional source/load data.

To add a Transmission-line object, click the Tr-line button and click on the desired wire/segment to set end-1 of the new Transmission-line. Hold down the left mouse-button and move onto the second wire/segment to set the other end-2 of the new Transmission-line. Edit the data on the right part of the screen to set char-impedance, line length and/or crossed line.

To create/modify ground parameters use the right-most button and select between free-space or the other available ground-types. To specify a linear or radial cliff, select the "second/far ground" box to specify additional ground data.

Use the "Create" menu to create rectangular-, grid-style-, circular- or helix-type shapes. Using the 'circle' option you can also create triangles, squares and other n-sided structures by specifying a number of sections of 3 or 4 or more. You can create wire-arcs by deleting one or more wires from a previous created circle.

### Selecting multiple wires

To select multiple wires for moving, deleting, copying or pasting click anywhere near a wire, hold down the left mouse-button and move the 'selection-box' over the wires to select. When 3D view is active hold down the <Shift> key to avoid rotating the 3D structure. To add distinct wires to the current selection, use the <Ctrl> key while selecting other wire(s). When in 2D view it is sometimes possible not all selected wires are visualized (red color), because one or more wires may overlap each other.

A selection of multiple wire always contains a 'main' wire. This wire is displayed as a more thick line

with a green and red open/filled box on either side. To move a selection of multiple wires, locate the mousepointer over this 'main' wire till the mouse-pointer changes to a 2-point arrow. When no previous wire was selected the 'main' wire is the first of all selected wires. If a single wire was previously selected the selected wire becomes the 'main' wire.

When moving multiple wires the complete selection is snapped to a grid-point or nearest wire indicated by the end-1 or end-2 of this 'main' wire. To 'snap' for a certain end, click near the required end when moving is started.

When having selected one or more wires you can use the right mouse-button to perform additional actions.

One special operation is the "Rotate and Move" action. With this operation (similar to the original NEC based GM card) you can rotate and/or move selected wires or you can create one or more similar structures, for instance to create a stack of yagi's. When using the rotate and move operation, it is important to keep in mind the order of transformations. First, all selected wires are rotated around the X-axis for the specified amount of clockwise degrees followed by rotation around the Y-axis, followed by rotation around the X-axis. Finally the resulting structure is moved according the specified X,Y,Z distances.

When the 'Create N new structures' option is selected, each new structure is created with the selected or previous created structure as the reference for the next transformation.

Another operation is "Rescale wire(s)". This operation is used to scale all selected wires to a new frequency or by a specified scaling-factor. This scaling involves both wire length/coordinates and wire-radius.

Two **important** things to keep in mind using above operations is the fact that the "Keep connected" check-box is not in use (unselected but connected wires are not moved) and these operations can only be undone by performing 'reverse' operations.

To rotate a certain wire around one of his ends, first move the end to the center of the XYZ-axis, do the rotation and then move the wire back, or directly edit the the Phi/Azim or Theta/Elev text boxes on the right part of the screen. If the latter action is performed, bu sure you selected the correct "Fix end-1" or "end-2" check-box.

You can use the "Resequence tag-nr" operation to renumber the tag-nr's after creating, cutting, copying and/or pasting one or more wires.

*Tip:* Use the 3D-viewer together with the Geometry-edit function and meanwhile switch between both windows to see the immediate 3D results when changing wire lengths, positions and/or radius. This to avoid overlaid or intersecting wires.

### Spread-sheet wire-table edit

Another way to modify Wire-data is by selecting the "Wire data/Comment" object-button. All wire data is displayed in a spreadsheet like grid for textual editing. You can select, remove, delete cut and/or copy one or more wires to get the wire sequence that suits your needs. You can also cut and/or paste textual (wire) content to or from another document.

You can use the operations in the "Edit" menu to perform similar actions on one or more selected cells, rows or columns. For instance to change wire-diameter for the whole or part of the structure or set the segment-count to user required values.

### Other

Select the "Show Nec" menu-bar option to see the corresponding NEC cards and to become used to

the NEC syntax. Use "Options -> Write symbols/variables" to switch between default NEC and symbolic 4nec2 syntax.

To create a new design, use "New" from the "File" menu. This will clear the drawing and reset all data. Before starting the drawing it is required to enter the 'design frequency'. This will also initialize the grid/axis-size according to the specified wavelength.

While editing you do not have to save your data first to see the Nec results. Just click the "Calculator" button or push <F7> to run the NEC-engine using the current data. Once you are satisfied (or not) you can save your data (or not) using 'File->Save(as)'

Some shortcut-key's:

W	show/hide wire-nr	X	set YZ plane
T	show/hide tag-nr	Y	set XZ plane
E	show/hide ends	Z	set XY plane
S	show/hide segments	3	set 3D view

<Home>	Reset view
<Page-up>/<Page-down>	Structure zoom in/out
Shift + <Page-up>/<Page-down>	Grid zoom in/out
<up>/<down>/<left>/<right>	Rotate 3D view

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#### Menu-bar functions:

##### File

New	Clear screen and create new model
Open	Open other existing model/input-file
Save	Save current model
Save as	Save current model using another name
Exit	Exit editor without saving changes

##### Options

Set square picture	Resize window so circular structures are shown circular.
Show struc/wire loading	Toggle the visualization of wire- and structure loading.
Hide wires not in plane	Hide overlapping wires when in 'Add-mode'
Set segmentation	Set low, medium or high segmentation (for new/changed wires)
Stop auto-segmentat.	Do not recalculate when wire-length(s) is/are changed
Redo segmentation	Redo (exact) segmentation for selected wires in structure
TAB as fieldseparator	Use <Tab> as field separator when saving model to file
Write symbols/variables	Use symbols(variables) when saving model to file
Distinguish XYZ coord.	Use different symbols for X,Y or Z coordinates of same (abs)value

##### Edit (wire-model view)

Connect closest wire	Automatically connect selected wire-end to closest wire.
Disconnect end	Disconnect selected wire-end from attached wire(s).
Split wire	Split selected wire into 2 or more sub-wires.
Reverse wire	Reverse end-1 and end-2 of selected wire.
CeNter at wire	Center window at middle of selected wire.
Rescale wire(s)	Perform rescaling for one or more selected wires
Rotate/move wire(s)	Rotate and/or move one or more selected wires
Select All	Select all wires for the model
Copy wire(s)	Copy one or more selected wires
Paste wire(s)	Paste previously cut or copied wires

Cut/Delete wire(s)	Cur or delete one or more selected wires
Resequence Tag-nrs	Renumber all tag-numbers starting with 1.
Undo delete	Undo previous delete for one or more wires
Undo Move	Undo previous move for one or more wires
<b>Edit (spread-sheet view)</b>	
Rotate / Move Wire(s)	Rotate and/or move wires for one or more selected rows
Insert wire	Insert new row/wire
Delete wire	Delete current wire
Make &Same value	Make selected cells, row(s) or column(s) all same value
Add same value	Add specified value to selected cell(s), row(s) or column(s)
Multiply same value	Multiply selected cell(s), row(s) or column(s) with value.
Cut	Cut one or more selected rows/wires
Copy	Copy one or more selected rows/wires
Paste	Paste previously cut pr copied rows/wires
<b>Create</b>	
Rectangle	Let 4nec2 create a rectangular structure
Rect-grid	Let 4nec2 create a rectangular gridded structure
Circle	Let 4nec2 create a circular structure
Helix	Let 4nec2 create a helical structure
Radials	Let 4nec2 create some radials
Show Nec	View how the current model would be saved in textual format.
Segm-info	View wire- and segment info.

## **Notepad- and Nec-edit**

The default/minimal lay-out for a simple 4nec2 input file is the following:

Zero or more CM (comment) cards.  
 One CE (comment end) card  
 One or more GW (wire geometry) cards  
 One GE (geometry end) card  
 One FR (design frequency) card  
 One or more EX (excitation point) cards  
 Zero or one GN (Ground condition) card  
 Zero or more LD (loading) cards  
 One EN (end of file) card

You may include comment in the input file used by 4nec2 by using the ' character (single quotation mark) anywhere in the input file. See also the example files on your 4nec2 home-folder.

You may also hide specific (far away) wires in your geometry structure by using tag-numbers in the range 9800-9900. This way the model initially might be more correctly scaled. Don't specify tag-numbers above 9900, because these tags are internally used by 4nec2 to model Current-sources.

To use the built-in 4nec2 Current-source Excitation-type see [Current-sources \(EX 6\)](#)

To use the built-in 4nec2 LC-trap Loading-or Wire-coat loading type see [LC-Traps \(LD 6\)](#) and [Wire coat \(LD 7\)](#)

For additional ground- and/or wire-loading data see [Ground conditions](#) or [\(wire\) loading](#)

All text after the first EN card is ignored, so you may use this area for temporary cutting and pasting of NEC cards.

With version 5.7.0 and later it's also possible to enter the position of Voltage/Current sources (EX), Spot-loads (LD) and Transmission lines/Networks (TL/NT) on the wire in percents from the beginning (end-1).

You do this by entering a value from 0 to 100 followed by a percent (%) sign. 4nec2 will automatically convert this percentile distance to the required segment-number. Note however that the more segments a wire consists of the more precise the positioning will be related to the specified percentile value.

For those who are not yet familiar with the NEC syntax and/or antenna modeling, there are a lot of recommendable articles, written by L.B. Cebik (W4RNL), available on the internet.

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## **EX 6 Specifying Current Sources**

Besides the use of the standard NEC Voltage Sources (EX 1), 4nec2 also supports the use of Current Sources. To make this work, the standard NEC type for the EX card is extended with an additional type 6 specifying a current source. When using a text editor as the 4nec2 entry system the fields for this card are the same as those for the voltage source, however the real and imaginary parts are specified in Amperes

When using the 'geometry editor', current-sources are automatically created when 'Current' is selected as the excitation source type.

Internally in 4nec2 this EX type 6 is converted to a voltage-source on a dummy segment and connected to the initial segment through a network NT-card. To see the results of the internal current- to voltage source conversion, use 'Show -> Nec 2 input' on the 'Geometry (F3)' window after a (4)Nec2 calculation is done or select the 'show Nec' menubar option when using the 'geometry editor'.

Mostly the default Nec voltage-source (EX 0) is used. When modeling with multiple sources where the current for each source requires a specific phase relationship, the use of current-sources (EX 6) is needed.

### **Split sources**

When two sources are specified on two nearby and connected segments, a so called split-source is assumed. Such a split-source is useful to specify a source on a segment junction, such as could be used for an inverted-V antenna. Furthermore split-sources are very useful to preserve symmetry when a GX card is involved. This to minimize calculation time.

For a split-source impedances and voltages are added on the 'Main (F2)' and 'Line-chart (F5)' windows. This to represent a single source.

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## **LD 6 Specifying LC-Traps**

Together with the use of the standard NEC Loading types from LD1 to LD5, 4nec2 also supports the use of the LC-Trap loading type. To make this work, the standard NEC type for the LD card is extended with an additional type 6; specifying an LC-trap. The fields for this card are the same as for the parallel/Series RLC card, except for the R(esistance) field. For the LC-trap this field (F1) represents the unloaded-Q of the inductor. A zero in this field defaults to a unloaded-Q of 100.

When using the 'Geometry' editor you can select 'LC-trap' after adding a new or selecting an existing RLC-load object. The corresponding LD card is automatically created.

When using a text editor as the 4nec2 entry system the LD 6 card has the below syntax:

Cmd	Tag-nr	Start-seg	End-seg	coil-Q	L (in H)	C (in F)	[fr]
LD 6	2	1	16	16	5.5e-6	45e-12	

Internally in 4nec2 this LD-type 6 is converted to a parallel-RLC loading type. For calculating the coil loss-resistance (which depends both on coil-Q and the reactance X of the coil) the design frequency from the nec input-file (First FR card) is used to get to coil reactance.

Optionally you can specify different frequencies to use for reactance- and thus loss-calculation for each coil/trap.

Internally in 4nec2 this LD-type 6 is converted to parallel-RLC loading type using the frequency value as specified on the initial FR-card. To see the results of the internal LD conversion, use 'Show -> Nec 2 input' on the 'Geometry (F3)' window after a (4)Nec2 calculation is done or select the 'Show Nec' menubar option when using the 'geometry editor'.

You may also specify the start- en end-segments as a percentile distance (0 to 100) from the beginning of the wire.

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## LD 7 Specifying Insulated wires (Wire-coating)

Besides the default NEC Loading types from LD1 to LD5, 4nec2 also enables you to specify data for the insulation wrapped around conducting wires. This insulation produces shortening effects in the specified wires, thus lowering the velocity factor. To make this work, 4nec2 uses an extra LD7 type.

The method used in this was described by L.B. Cebik in '[www.cebik.com/amod/amod83.htm](http://www.cebik.com/amod/amod83.htm)'

When specifying insulated wires, there are two radii of interest. First the radius of the conducting wire (as specified in the GW card) and second the radius of the wire plus insulation. The difference between both values is the thickness of the insulation layer.

Furthermore the dielectric constant for the insulation material is of interest. In 4nec2 a high insulating effect (very low conductivity) for the material is presumed.

On the internet the below **dielectric constants** were found:

Aluminium-oxide	10
Bakelite	3.5 - 4.5
Copper-oxide	18.1
Glass	5.0 - 9.0
Glass (window)	7.6
Mica	4.0 - 8.0
Neoprene	4.0 - 6.7
Oil	1.5 - 4.7
Paper	1.6 - 2.6
Parrafin	2.0 - 3.0
Pertinax	4.3 - 5.5
Plexiglas	2.6 - 3.5
Polycarbonate	2.9 - 3.2
Polyethylene	2.4
Polyamide (nylon)	3.4 - 3.5
Polystyrene	2.4 - 3.0
Porcelain	5.0 - 6.5
PVC (hard)	3.0 - 4.0

PVC (soft)	4.0 - 5.0
Rubber	2.7 - 3.2
Shellac (Nat.)	2.9 - 3.9
Styrofoam	1.03
Teflon	2.1
Water (destil)	34 - 78
Wood (dry)	1.4 - 2.9

Most plastics appear to have a dielectric constant (permittivity) between 2.0 and 3.5. The dielectric constant of air is around 1.0, so if we would specify a value of 1.0, no matter what radius we would get the performance of bare wire.

When using the 'Geometry' editor you can select 'Coat' after adding a new or selecting an existing RLC-load object. The corresponding LD card is automatically created.

When using a text editor as the 4nec2 entry system the LD 7 card has the below syntax:

Cmd	Tag-nr	Start-seg	End-seg	Diel-const	Coat-radius (mtr)
LD 7	2	1	16	2.8	.003

The parameters 'Tag=nr', 'Start-seg' and 'End-seg' are the same as the corresponding parameters used by the LD 0 through LD 5 command's.

You may also specify these start- en end-segments as a percentile distance (0 to 100) from the beginning of the wire.

The first floating point parameter 'Diel-Const', specifies the dielectric constant for the insulation material used. The second floating-point parameter specifies the overall radius for the wire plus insulation.

Internally the LD7 command is converted to an LD2 command using the below equation:

$$L = 2e-7 * (\text{diel} * R/r) ^ (1/12) * (1 - 1/\text{diel}) * \text{Ln}(R/r)$$

L Value for distributed inductance in Henry/meter

diel Dielectric constant (as specified in the LD7 command)

Ln Natural Logarithm

R Radius of of wire plus insulation (as specified in the LD7 command)

r Radius of wire (as specified in the corresponding GW command)

This equation is especially suited for dielectric-constants between 2 and 3.5, the normal range of insulation materials used by radio amateurs.

To see the results of the internal LD conversion, use 'Show -> Nec 2 input' on the 'Geometry (F3)' window after a (4)Nec2 calculation is done or select the 'Show Nec' menubar option when using the 'Geometry editor'.

#SK

### GN 3 Specifying MiniNec type ground

When 'connecting' wires to a Real (SomNec)- or Finite (Fast)- ground (using a Z-value of zero) the reported antenna impedance is usually unpredictable. To avoid this, use Real/SomNec ground with an elevated radial system or, when using verticals, use the MiniNec ground type.

When computing far-field data the MiniNec ground takes into account the ground conductivity and dielectric constant at a distance. However, when computing currents and antenna input-



impedance it considers the ground to be perfect. (as could be the case using a nearly perfect buried radial system).

This ground system however is only valid when the antenna structure does not contain horizontal wires below 0.2 wavelength. This mostly restricts the use to vertical antennas. When modeling other antenna types, use an elevated radial system together with the Real/SomNec ground type. (see <http://www.cebik.com/> for more info about this subject).

The MiniNec ground type is available through the "GN 3" extension on top of the default "GN -1" to "GN 2" default NEC command set.

When using a text editor as the 4nec2 entry system the LD 6 card has the below syntax:

```
1
2 Cmd      I2      I3      I4      Diel-const Conductivity
3 GN 3      0       0       0       14       0.006
4
5 Internally in 4nec2 this GN-type 3 is converted to a combination of perfect ground (GN 1)
6 and a second circular cliff ground-medium (GD 0 0 0 0 diel cond). This second ground
7 medium starts at a distance zero from the antenne and also has a height of zero.
8
9 To see the results of this internal GN conversion, use 'Show -> Nec 2 input' on the
10 'Geometry (F3)' window after a (4)Nec2 calculation is done or select the 'Show Nec'
11 menubar option when using the 'geometry editor'.
12
13
14 #SK
```

## Using a Numerical Green's Function file (NGF)

10 Numerical Green Function files (NGF) are used to split a nec-based geometry structure in one or more a static reusable part(s) and a dynamic part. As the static part for instance one could specify a number of different refelctor screen's while the dynamic part describes the radiator. Both parts are created using standard nec input-files.

11

12 For the first file, the static part, the structure is pre-calculated, thus generating a so called NGF file. This NGF file is created by adding a '**WG**' card to the nec input-file.

13

14 In the second file, containing the more dynamic part (e.g. the radiator) a card is added which specifies to import/include the pre-generated NGF file. This file is 'imported' by using the '**GF**' card.

15

16 Mostly the (first) input-file creating the NGF file contains far more geometry cards than the file using the NGF file. Because the NGF file is pre-generated, (re)calculation the overall structure will much more time efficient.

17

18 The frequency and ground-settings to use must be specified in the first file, producing the NGF file. The second file which uses the pre-generated NGF file may not contain any FR or GN/GD cards.

19

20 When using Numerical Green's Function files (NGF) some considerations must be taken into account.

21

22 Using the Nec2dXS\*.exe engines it's possible to explicitly specify the name of the NGF file to use. The following syntax applies:

23

- 24 To create a NGF file : **WG file.ext**
- 25 To use a NGF file : **GF file.ext**
- 26
- 27 'file.ext' can be any file-name like 'ngf.nec' or 'screen.ngf' or 'refl.ngf'. When no NGF file-name is specified the name defaults to 'NGF2X.NEC'. These files are placed in your '..\4nec2\exe' folder.
- 28
- 29 When a NGF file-name is specified it's also possible to use the 'Print table of coordinates' flag. The following syntax applies:
- 30
- 31 To print a coord-table : **GF 1 file.ext**
- 32 Don't print coordinates : **GF 0 file.ext**
- 33
- 34 Furthermore note that when using/importing a NGF file, 4nec2 is not able anymore to automatically detect the specified number of segments from the \*.NEC input-file. To let 4nec2 select the appropriate nec2dXS\*.exe engine it is needed to manually set the total number of segments.
- 35
- 36 This is done with 'Setting -> Nec-engine -> Min-nr segments'. You can enter a value just above the total number of segments specified in both \*.nec files. (the one generating the NGF file and the one using the NGF file)
- 37
- 38 Also because ground parameters are specified in the binary \*.NGF file and thus are not directly available through the second \*.NEC file it is required to use an appropriate GE (-)1 or GE 0 specification in the second \*.NEC file so 4nec2 knows if it has to generate a half (180 degree) or a full (360 degree) far field pattern.
- 39
- 40 #\*K

## **Symbols Declaration of symbols/variables**

- 41 In version 4.0 and later versions, variables, also known as symbols (especially for those using Antenna Optimizer by Brian Beezley) were introduced.
- 42
- 43 With this feature you can assign a certain numeric value or numeric expression to a (character) variable. For instance you may set the variable 'len' to 20, and use this variable anywhere in your 4nec2 input-file where you want to specify a length of 20.
- 44
- 45 This is done by including a special card in your 4nec2 input file with the "SY" identifier. For instance, if you want to specify a length of 20, a height of 10 and a width =0.1, you specify the following:
- 46
- SY len=20, hgh=10, width=0.1
- 47 You have to include the SY card before using the variable in one of the succeeding NEC cards.
- 48
- 49 Furthermore you may include expressions/equations when declaring variables. For instance:
- 50
- SY len=10, height = 5+10\*len ' Height is 5; increased with 10 times length
- 51 Valid operators in these are + , - , \* , / and ^
- 52

53 You may also include functions like sin", "cos", "tan", "atn", "sqr", "exp", "log", "log10", "abs", "sgn", "fix", "int" and "mod". For instance:

54

SY ang=60, len=20, lenX = len\*cos(ang), lenY = len\*sin(ang)

55 Or even

56

57 SY dist=30mm, diam=1.3mm, Z0 = 276 \* log10 ( (2\*Dist) / Diam)

58

59

60 Standard scientific precedence rules apply. If they must be overruled you can use brackets.

61

62 Below operators are also included, however I did not yet find any real use for it:

63

"and", "or", "not", "xor", "eqv" and "<", ">", "<=", "<="

64 You may divide your variable declarations over one or more SY cards. The SY cards can be included anywhere in your input file as long as the variables are declared before they are used. You can then use these variables and/or equations in any NEC card you should like.

65

66 Variable declarations have to be separated by comma's (",").

67

68 A couple of fixed pre-defined identifiers are also included. They are:

69

cm (centimeter)

70 mm (millimeter)

71 in (inch)

72 ft (feet)

73 pF, nF, uF, nH (pico-, nano and micro Farad)

74 nH and uH (nano- and micro Henry).

75 Note that the variables and identifiers are not case sensitive.

76

77 When variables are used in two or more 4nec2 input-files it is possible to declare them only once in a separate definition-file. Use 'Settings -> predefined symbols' to view, add, delete or modify these predefined symbols. This file could be used to declare, for instance, AWG # wire gauges, your default ground parameters and/or wire conductivity values.

78

79 Prefdefined variables (constants) can be 'overwritten' in 'SY lines' in the 4nec2 input file.

80 **Remark:** Please do not use the above mentioned pre-defined identifiers or functions as SYmbol names because this will lead to unpredictable results.

#SK

## Modeling guide-lines

81

82 Although most of the below described guide-lines are (automatically) checked when loading or generating new output-data or by using the structure validation option it is suggested to keep the below modeling guide-lines in mind when creating new or modifying existing models.

### Wire modeling

83

84 Len = segment length

85 Rad = segment radius (diameter/2)

86 WL = Wave Length

87

88 1) Positive current flows from end-1 to end-2

2)  $len < WL/10$  for accuracy in most cases

$len < WL/20$  in critical regions

89  $len < WL/5$  on long straight segments

90 3) Avoid extremely short segments ( $len < .0001 WL$ )

4) 'rad' must be small relative to 'len' and 'WL'

91  $rad < len/2$  with default thin wire kernel

92  $rad < 2*len$  with extended thin wire kernel

93  $rad < len/10$  default usage

94 5) Avoid - Large changes in radius, especially on short segments

- Sharp bends in thick wires

6) Wires that are connected must contact at segment ends  
(connection separation  $< len/1000$ )

7) Use equal source segment length and lengths for segments next to source

8) No voltage sources (EX 0) or loads at wire open ends

9) Use same segmentation for close parallel wires.

9) GE (Geometry End) usage

GE 0 : No ground (free space)

GE 1 : Ground plane present, 'touch' wires ( $Z=0$ ) are connected to ground

GE -1 : Ground plane present, 'touch' wires ( $Z=0$ ) are insulated from ground

#### Wire grid modeling

1) Grid-size is not too critical (appr.  $WL/10$  at midband)

2)  $Len/rad$  not critical ( $10 < len/rad < 30$  good for wires attaching surface)

3) Minimize 'len' and 'rad' changes ( $<2:1$ ) at connection pts of wires and surfaces

4) Use denser gridding ( $2^*$ ) at connection points of wires and surfaces

5) Also acceptable for thin structures (plates, wings, etc)

6) Try two segments/side

7) Not usable for surface charges or currents

#### Surface patch modeling

1) Make sure surface is closed and not too thin (no plates, fins or wings)

- 2) Maximim patch size may not exceed  $0.2 * 0.2 WL$
- 3) Corners are defined using right hand rule.
- 4) Avoid long thin/narrow pathes
- 5) Large patches on smooth surfaces, smaller ones on curved areas
- 6) Currents are defined at centre only, so not good for edge currents
- 8) When wires are connected they must do so at patch centers
- 9) Use 'wire-grids' where edge connections are needed.
  - Wire grid equals surface if mesh is 'small enough'
  - Problem:
    - can't afford real fine meshes (\*)
    - Sparse meshes have too much L, not enough C
  - Possible solutions:
    - negative L distributed loading
    - fat, rod-like wires

#\$K

## **Calculate F7 Generate NEC output-data**

This general option is used for generating new NEC output-data.

If one of the below described options is selected, first of all, 4nec2 pre-processes the active \*.nec input file to remove all comment and to solve the variable- and constant definitions. The resulting intermediate file, containing pure NEC input-data is placed in the "\out" folder with the \*.inp extension. When this is done, the Nec-2 or Nec-4 engine is started and the \*.inp file is red by the engine to generate new NEC output-data. This output-data is placed as an \*.out output-file in the "\out" folder. When all calculations are done 4nec2 open this output-file and the results are displayed on the F2 to F5 forms.

When a Sommerfeld-Norton ground is specified, 4nec2 automatically generates or copies the appropriate ground file to be used by the Nec-2 engine. These ground files (with the \*.gnd extension) are stored in the "\out" folder. If the requested file already exists, it is copied; otherwise a new one is created with the somnec engine. When using the Nec2dXS engine the SomNec data is calculated by the engine itself and the additional somnec engine and ground files are not required.

When the 'Generate' command-button is selected, a pop-up window is displayed with different options to choose from.

### **The following generate options are available:**

- |                    |   |
|--------------------|---|
| Use original file  | Run NEC-engine and generate new output from active *.nec input file                 |
| Far field pattern  | Run NEC and generate specified 3D far field pattern for input file                  |
| Full               | Generate full 3D far-field pattern.   |
| Ver.               | Generate vertical far-field pattern for specified phi angle.                        |
| Hor.               | Generate horizontal far-field pattern for specified theta angle.                    |
| Frequency sweep    | Run NEC and request for calculations for a range of frequencies                     |
| Gain.              | Run NEC and generate SWR and Gain graphs for specified phi and theta.               |
| Ver.               | Generate vertical far-field pattern for each frequency and SWR and Gain graphs.     |
| Hor.               | Generate horizontal far-field pattern for each frequency and SWR and Gain graphs.   |
| Full               | Generate 3D far-field pattern to get full Gain, F/B- and F/R-ratio data for graphs. |
| Near field pattern | Run NEC and generate specified near field pattern                                   |

E-flid	Generate near-electric-field data and show in 2/3D pattern and graph style.
H-flid	Generate near-magnetic-field data and show in 2/3D pattern and graph style.
360 degree Gain table	Generate ItsHF 360 * 90 degree Gain-table for specified frequency
Gain @ 30 frequencies	Generate ItsHF 90 degree Gain-tables for 30 frequencies

Batch (button) To run multiple files as a single batch, see below.

More (button) To define more settings. Visible when one of both ItsHF options is selected.

### Use Original file

When this option is used, the 4nec2 input file is converted to default NEC format and send directly to the NEC-engine, without further modifications and/or additions. You can use this option for a quick first test after creating a new nec file or to specify calculation options not supported by 4nec2.

*When using one of the other (below) options it is recommended to remove all RP and NE/NH cards from the \*.nec input file.*

### Far-field pattern

The most used calculation probably will be the default far-field pattern calculation. This pattern determines in which direction you antenna system will radiate/receive best and in which direction signal is suppressed. It may also be used for signal-coverage studies and interference-level analysis.

When the default far-field (full, horizontal or vertical) pattern is requested one must specify the resolution to use. This resolution value defines the stepsize increments for the Phi/Azimuth and Theta/Elevation angles.

When a ground(plane) is involved, only the upper half of the 'radiation-sphere' is calculated. When low resolution (< 1 deg.) is specified it is possible that the max-nr of field-points is exceeded. If so, use the 'ver' or 'hor' option, or increase the max-nr of far-field points in the settings menu.

When running a Full/3D far field pattern, by default the radiation-efficiency and the Receiving Directivity Factor (RDF) are also calculated and displayed on the Main (F2) window. RDF is specified as the difference between (maximum) forward-gain of an antenna and the calculated average-gain of the antenna. For more info, see [Radiation-efficiency](#).

Note that when running a horizontal/vertical 2D pattern or when a surface-wave request is made, no radiation-efficiency is calculated.

On the middle-right of the window one can specify if an average-gain-test (AGT) should be performed. With this you can check if your antenna model is more or less a valid Nec2/4 model. See [Average Gain-Test](#) for additional info about the subject. Running an average-gain test is only possible if the full/3D far-field option (without surface wave) is selected.

Experienced NEC users can use the 'expert' button to set special far-field calculating options. For additional info about these 'XNDA' options, please consult the Nec-2 or Nec-4 user-guide. Default XNDA settings are:

- 1: Ver/Hor/total field,
- 0: No normalization
- 0: Power-gain
- 2: Compute average-gain

If required, '[Auto-segmentation](#)' or '[Step-radius correction](#)' can be enabled through the '[Settings](#)' menu.

When the far-field option is selected, besides the Gain values the default E-field is calculated. If required,

one can check the "E-flid" box. If done so, one may enter a certain distance (in Km) for which the E-field is calculated. (Use "<" and ">" on the Pattern [F4] window to switch between Gain and E-field values).

By default only the space-wave and the ground-reflected wave are used for far-field calculations. To include the surface-wave in the calculations, check the "Surf-wave" box. If this is used, additional parameters are required:

- Max-Z        Maximum height (meter) for which the far-field is calculated.
- Dist         Distance for which the far-field is calculated, mostly set to 1 Km

## Frequency sweep

When a frequency-sweep is requested (starting with version 5.8.0) one can choose between two further options:

- a) Sweep by specifying a start- and stop frequency together with a fixed step-size (delta frequency)
- b) Sweep using a predefined list of frequencies. If this is required, the 'from file' box should be checked.

Starting with version 5.8.0 one can let 4nec2 show you the change in current-distribution by 'walking' through the list of calculated frequencies. For further info see the Geometry window.

When an **a**) type frequency-sweep is requested, additional Start, Stop and Step-size data have to be specified. Do not specify a Start (and Stop) frequency very much apart from the design frequency, otherwise certain NEC requirements, such as segments per wavelength, might be violated.

To evaluate the performance over a wide range of frequencies you could consider using the Sweeper function with Auto-segmentation enabled.

With the first option, called 'Gain' you must supply the Phi/Theta or Azimuth/Elevation Forward-angle for which a Gain-graph should be plotted. Because only one far-field point is calculated (that for the specified direction) no F/B-ratio and F/R-ratio data is available or displayed.

To get F/B (front-to-back) or F/R (front-to-rear) plots; select one of the other options. Ver(tical)-, Hor(izontal)- or 3D-pattern. Using the 'Ver' and 'Hor' options, for each frequency step, a complete vertical- or horizontal-pattern is calculated for the specified Theta/Elev or Phi/Azim angle. Furthermore the F/B and F/R ratio is calculated and plotted on the 'Line-chart (F5)' form. These ratios are calculated for the selected plane. To get F/B and F/R-ratio calculated in 3D space (as generally used), select the 3D option.

Note that non-directional antenna systems don't produce meaningful F/B- and/or F/R-ratio data.

Note also that when using the 'Full' option only the whole 3D pattern for the last frequency-step is displayed on the 'Pattern (F4)' form. This to limit the overall memory usage for the 4nec2 package. To visualize multiple patterns, select the 'hor' or 'ver' option. Use the arrow-keys to visualize the changing of the pattern (play-back) for the specified frequency-range.

When specifying the main-beam direction the backward direction is automatically updated, according to the selected option (ver/hor or 3D) and the free-space/ground-plane settings. You may overwrite these defaults manually with your own settings.

When the **b**) type frequency-sweep is requested one can specify the list of frequencies to use by selecting 'Settings -> pre-defined frequencies' on the 'Main (F2)' window. Be sure to specify the list of frequencies with increasing frequency values, else you will get a somewhat corrupted 'line-chart' display.

## Gain calculation

By default forward-gain is calculated as the single gain-value for the specified direction. F/B ratio is calculated as the difference in gain between the forward- and backward-directions. The F/R-ratio is calculated as the difference between the forward-gain and the maximum gain-value for the backward half of the radiation pattern which is centered around the backward-direction.

To get more control over how forward-gain and F/B-ratio are calculated (especially usefull when optimizing) it is possible to specify delta-theta and -phi values for both the forward- and backward-direction. If a none zero value is specified the gain over the specified region as defined by the Theta/Phi value plus or minus the specified delta value is averaged. The number of averaging steps is determined by the specified resolution.

### Sommerfeld ground

When using the Real/SomNec ground in a frequency-sweep in conjunction with de default nec2d engine, the 'negative conductivity trick' is used, in which the Real/SomNec ground data is generated only once for all frequencies. However this Nec-2 behaviour will generate less precise data.

To overcome this 'problem' one could use the Sweeper function and specify the frequency as a variable or you could select the enhanced nec2dXS engine. This modified Nec-2 engine recalculates the Real/SomNec ground data for each frequency-step, so precision is not degraded.

### Troubleshooting

During generation of near/far-fields, frequency-sweep- or ItsHF-data, additional NEC card's are added to the original \*.nec input file. If error's are generated during calculation, you may inspect this temporary NEC input-file by selecting 'View -> Last NEC input' on the 'Geometry (F3)' form, just after performing the (failed) calculation. Use the F8 function-key to inspect NEC output-file data.

### **Near-field pattern**

The field close to the antenna is called the near-field. This field is quite different from the far-field that characterizes propagated electromagnetic waves. Near-field intensities are very usefull for EMI studies, RFI and TVI minimization or FR-hazard analysis.

In contrast with the far-field, the near-field is calculated over a 3D grid of points. Start, Stop and Step-size values for the three dimensions X, Y and/or Z have to be specified. Mostly a step-size of (Stop – Start) / 20 will be fine. You can select between the electric or magnetic component of the near field to be computed.

Use the 'test' button to let 4nec2 automatically create start-, stop- and stepsize-settings for a 3D volume which includes the whole geometry structure. This to quickly create initial near-field patterns which can then be used to further fine-tune the start-, stop- and stepsize settings.

### **ItsHF option**

With version 5.6.0 and later a more user-friendly interface with the ItsHF software has been created. The new interface enables you to create two different types of ItsHF compatible Antenne input-files:

- Full 360 degree Gain table for sepcified/design frequency for the antenne under test ([type 13](#))
- Set of 2D gain tables for a specified Phi/Azimuth angle for frequencies from 2 to 30 Mhz ([type 14](#))

Both types of antenna files (and other pre-defined ItsHF types) can then be used to create Area-coverage or Point-to-point plots. After the antenna files are created one can let 4nec2



automatically create 4 kinds of plots:

- Area-coverage map                      Plot showing propagation performance on a (partial) world-map.
- Point-to-point time plot              Chart showing propagation performance as function of time
- Point-to-point distance plot        Chart showing propagation performance as function of distance
- Point-to-point graph plot          Chart showing propagation performance as function of time and frequency

Above 'propagation performance' can be visualized using user selectable parameters like 'Signal strength at receiver', "Signal to Noise ratio", 'Maximum usable frequency' or 'Radiation angle'

Besides transmitter- and receiver-antennas and -locations, the ItsHF propagation prediction software requires additional settings to automatically create the requested plot. These parameters, settings and options are discussed under [ItsHF propagation prediction](#).

To use the ItsHF software package it must be installed on your computer system. Use '[Settings](#) -> Folders' to specify your ItsHF home folder.

#\$K

### **Batch mode**

With version 5.4.1 running 4nec2 in batch-mode was added. This way one is able to run 4nec2 for a complete set of 4nec2, Antenna-optimizer or EZnec input-files as a single batch of work.

To use this feature, Open the "Generate (F7)" form/window and select the required calculation option. After this, click the "Batch" button at the bottom of the window. If done so, a new "Batch processing" form/window is displayed. To add files to the list, select the required files using Windows-Explorer (with Ctrl- and Shift key's), drag them to the Batch-processing window (while holding down the left-mouse button) and drop them onto the window. All selected files are now automatically added to the list of files to process. You can add a single file using the "Add" button. To delete one or more files, select these files using the left mouse-button and click the "Del" button. To select (and delete) all files use Ctrl+A.

When all required files are added, click the "Start" button to let 4nec2 process all listed files. In the column labeled "Status" the outcome of the calculation and geometry/segment validation is logged.

To (temporarily) halt batch processing of input-files, click the "Halt" button and wait till the NEC calculations for the current file are done. If you think this will take too long, you can alternatively abort the NEC calculations by clicking/selecting the NEC-engine in the windows task-bar and clicking the close button of it. To resume batch processing use the "Start after last" menu-option.

When all files are calculated, depending on the "File -> Refresh 4Nec2 data" option you can move the focus or double-click on any of the listed files to let 4nec2 immediately load and display the data for the selected file.

Click on the 'File' column-header to sort all file-names in ascending or descending order.

Batch processing can also be used to convert multiple antenna-optimizer (\*.ant) or Eznec (\*.ez) input-files into Nec based files.

#\$K

### **Command-line mode**

With version 5.7.3, none-interactive command-line mode was added. This way one can start 4nec2 from a windows batch file (\*.bat) and let 4nec2 read the specified 4nec2 input-file, pre-process the data, run the Nec2/4 calculation engine and create a Nec output-file.

To create useful far- or near-field data one must add his/her own RP, NE or NH command in the \$nec2 input-file to be used. One can use the 'use original-file option' on the "Calculate (F7)" to check the results of the RP, NE or NH card specified.

To use 4nec2 in command-line mode, create (for instance) a test.bat file (in the same folder where the input-files are listed) and use below syntax:

```
"C:\4nec2\exe\4nec2.exe <file1.nec> -l"  
"C:\4nec2\exe\4nec2.exe <file2.nec> -l"  
"C:\4nec2\exe\4nec2.exe <file3.nec> -l"  
etc...
```

When the "-l" argument is not used, 4nec2 does start in 'normal' interactive mode with the specified input-file.

#\$K

## Auto-segmentation

When optimizing and/or sweeping antenna performance, it is likely that dimensions and/or frequencies are changing, so it is possible that certain NEC requirements, such as the minimum number of segments per half-wave are not met any more. To overcome this problem, Auto-Segmentation is used.

If this feature is enabled (See [Settings](#) on Main window), each calculation/optimization/sweeping step, the wire length for each wire is checked against the actual wave-length and the specified number of segments per wire, and the position for voltage/current sources, RLC-loading and transmission lines is updated.

If a certain number of segments is already specified in the input file, at least this number of segments is set with auto-segmentation. This to avoid auto-segmentation decrease the number of segments specified for critical regions. If you do not want to specify a minimum, set the number of segments to one.

If the number of segments is preceded by a "+" sign the number of segments is fixed, meaning, the segments for this wire are not affected by the auto-segmentation process.

When enabling the Auto-Segmentation feature, you are asked to specify the number of segments per half-wave. Although, mostly accuracy improves if more segments are specified, also the computation time is increased. For 'simple' structures, without sharp angles, a value from 10 to 20 will be sufficient. If precise impedance values are required or if wires joining at sharp angles are used more segments could be required. If you are not sure what amount to specify, please use increasing values and compare the results. (You could do this using the [Sweeper](#) function). Also abrupt current changes on the structure might indicate an insufficient number of segments. One place more segments aren't better is if wires of different diameters are connected.

If computer performance is an issue, you could consider not to use the auto-segmentation feature. If this feature is disabled, the processing especially for large input files with many wires is speed-up.

#\$K

## Step-radius correction

When modeling Yagis or other antennas with stepped diameter wires, 4nec2 can perform an automatic stepped radius (stepped diameter) correction.

If this feature is enabled (See [Settings](#) on Main window) a substitute element is created for each tapered one found (with certain restrictions, see "Tapering to perfection" by L.B. Cebik at [www.cebik.com](http://www.cebik.com)). The

substitute element has a uniform diameter and a length that yield essentially the same self-impedance as the tapered diameter element. Thus, the substitute can be expected to behave--either by itself or in an array of elements--in the same way as the tapered element. All this to minimize inaccuracy when using large radius differences on a single element.

It does no harm to request the use of a stepped radius correction even in cases where the correction can not be applied. However, this results in some unnecessary processing that will increase the total time needed for calculations so I suggest you not use StepRad except in cases where it is necessary.

The conversion program has a limitation in that it will not apply the correction to Yagi elements unless they are parallel to either the X or Y axis. Yagis that "point" in a direction other than a multiple of 90° azimuth, or Yagis that have been oriented for vertical polarization, will not be corrected

In case of problems using this option, please don't hesitate to ask me for support.

#\$K

### ***Average-Gain-Test***

To check the reliability of your model, you can run an 'average gain test' (AGT). To run such a test, use the 'Generate (F7)' command, select 'Far field pattern' and check 'Aver-Gain test'. Then click the 'Generate' button.

When the 'expert' button is selected and using the lowest option-box, one should select the '1 – average gain' option to perform this same test. (The other option-boxes could be left to 1:Ver/Hor/Tot field, 0: no norm, 0: power-gain).

To get usefull test results 4nec2 automatically (temporary) removes all wire- and other resistive loading and (if specified) changes the gound-conditions to perfect-ground when doing the required calculations.

The test-results are presented on the main (F2) form.

The following gradation can be made for the Average-Gain-Test results:

> 0.95	and <	1.05	Model is likely to be accurate
> 0.90	and <	1.10	Model is usable for most purposes.
> 0.80	and <	1.20	Model may be useful, but can be improved.
< 0.80	or >	1.20	Model is questionable and should be refined.

When the resulting value is below 0.8 or above 1.2 the value is displayed in red color.

The db value between brackets can be used to correct the far-field pattern gain.

#\$K

### ***Radiation efficiency***

If ground-, wire- or other R(LC)-losses are involved, the value for 'Radiation efficiency' might be usefull data.

Radiation efficiency is defined as the ratio of 'pure' radiated power to the antennne input-power.

This data is automatically generated and displayed on the 'Main' form when a full/3D far-field request is made. When using the 'expert' one can manually decide between letting Nec2/4 calculate average-gain and thus radiation-efficiency data. To do so, set the lower option box on the 'Generate (F7)' form to "2: Radiation efficiency" .

#\$K

## **Open file      Ctrl+O      Open NEC input file**

This general option is used to open another input (or output) file. You may specify an alternative folder or file-extension to search for. When opening the selected file, the program first try's to locate the corresponding output file with the extension \*.out. When such a file exists, this file is loaded and the data is displayed on the Main, Geometry, Pattern and Line-chart forms.

When the default output file is not available, the \*.nec input file is loaded, pre-processed and converted to a \*.inp file and the corresponding data is displayed in the Main and Geometry forms. The Pattern, Line-chart and Smith-chart forms are not available.

It is possible that the 4nec2 program generates an error when or after loading a default or temporary output file. This is mostly the case if the output file is incomplete, because incorrect input file data is used. If this is the case, remove the \*.out file from the "\out" folder, change the \*.nec input file and try again.

When specifying an input-file with the '.ant' extension it is assumed you selected a AO (antenna optimizer) or Nec-wires input file and you are asked if this file has to be converted to 4nec2 format. If confirmed, most of the input data is automatic translated from AO/Nec-wires format to 4nec2 format.

However the following items must be checked for:

- The need to include the optional GX card when X-axis symmetry was specified.
- Additional excitation and spot-loads when the GX card is included.
- Excitation and spot-load placement on wire ends.

When specifying an input-file with the '.ez' extension it is assumed you selected an EZnec type input file and you are asked if this file has to be converted to 4nec2 format. If confirmed a new file with the same name but with an ".nec" extension is created and opened.

For as far as I (the author) am aware all Eznec files should automatically be converted without needing further (manual) corrections.

On the internet, nec files with the slightly different Unix/Linux text-file format are available. If you would want to load such a file, this format is automatic detected by 4nec2. If so, you are asked if this file has to be converted to the default windows type text-file.

#\$K

## **Save file as      Ctrl+S      Save output file as**

This general option is used to save the active output file data to an output-file with a different name. This option is useful for comparing different far field radiation patterns or if you want to save calculation or optimizer results for later investigation. (Open file with \*.out or other extension)

When comparing different far field patterns be sure these files are generated with the same Theta en Phi settings. If not, you won't be able to open these files.

If you want to compare optimizer results with manual generated results note that the optimizer only calculates far-field points for theta angles between 0 and 90 (ground) or 180 (free-space) degrees and this is only done when a resolution unequal zero is set.

If you are not sure which RP card settings are used for a specific calculation or optimization cycle, open the \*.out output-file (F8 key) and look for the RP settings.

#\$K

## **Settings      Modify user-, program- or memory-usage settings**

The Settings option on the Main form is used to modify default-, user- or program- settings. The setting under 'memory settings' are program settings. The maximum values for these settings depend on you computer configuration.

The following settings are available:

Notepad edit	Use windows default Notepad editor to edit input-file
NEC editor (old)	Use old-style NEC-syntax aware editor to edit input-file
Geometry edit	Use drag-and-draw style geometry editor to edit input-file
NEC editor (new)	Use new-style NEC-syntax aware editor to edit input-file
Auto-Segmentation	To enable auto-segmentation feature and specify nr of segments
Step-radius corr.	To enable stepped-radius correction.
Show circular-polar.	Show circular polarization components E-left/right instead of E-theta/phi
Char-impedance	To set the characteristic line impedance for SWR plot and Smith chart
Input-power	Input power used for voltage, current and field strength calculations
Phi/Azim unit	To select between Phi/Theta and Elevation/azimuth usage.
Length unit	To select between meter, wavelength, feet or inch as length unit.
Radius unit	To select between millimeter or inch/Awg as radius unit.
Predefined Freq's	To edit the list of fixed frequencies for a 'from file' frequency-sweep.
Predefined symbols	To edit your predefined SYmbols list.
Nec-engine:	
Nec2d engine	Use Nec2d*.exe as NEC calculation engine (1)
Nec2dXS engine	Use Nec2dXS*.exe engine, especially for windows-XP systems (2)
Nec4D engine	Use Nec4D*.exe as NEC calculation engine (3)
special engine	Use special engine
Manual select	Use 'min-Nr segments' to select engine-'size' or specify Nec4
engine name	
Min-nr segments	To set the nec2d(XS).exe as selected by 4nec2 (see below)
Memory usage:	
max-nr fld-points	Maximum nr of near/far field calculation points
max freq/sweep	Maximum nr of steps for frequency/variable-sweep.
max-nr LD cards	Maximum nr of (wire) loading cards
max-nr TL cards	Maximum nr of transmission-lines
max-nr EX cards	Maximum nr of excitation sources
max-nr 3D-points	Maximum nr of points used in 3D-viewer (graphics memory)
max-nr of SYmbols	Maximum nr of SYmbols to use with optimizer/evoluter.
Optimizer settings:	
Absolute steps	If selected use absolute steps else use relative steps
Max-initial step size	Initial/maximum step size used for the optimization process in %
Step size if optimized	Step size for which the optimization is considered to be ready in %
ItsHF settings:	
--- area coverage----	By default only the type-13 area-coverage antenna file is generated
Create 'Area' input-file	If selected create *.ICE/REC/VOA area-plot input file
Calculate Area-plot data	If selected create *.IG1/RG1/VG1 plot/data-file
Show Area-plot on screen	If selected generate and show Area plot on the screen
--- Point-to-Point -----	By default, only the type-14 point-to-point antenna file is generated
Create 'Point' input-file	If selected create *.ICE/REC/VOA point-to-point input file

Calculate Point plot-data	If selected create time/distance/graph plot-data file
Show Point-plots on screen	If selected generate and show point-to-point plot on screen
--- engines-----	Select prediction model/engine to use
use ICEPAC	If selected, use ICEAREA/ICEPAC model for calculation
use REC533	If selected, use RECAREA/REC533 model for calculation
use VOAcap	If selected, use VOAREA/VOAPAC model for calculation

Other settings:

Rear segment size	To specify the size of the rearward segment for F/R calculation
Wait for DOS-box	If checked wait in calculation engine dos-box for Enter key
Fast/(auto)redraw	To select between maximum speed or automatic screen refresh
LIN min. value	Default minimum scale value for linear far field dB-scale
LOG min. value	Default minimum scale value for logarithmic far field dB-scale

Folder settings

Notepad editor	To set the path to Notepad.exe or other custom editor
Wordpad editor	To set the path to Wordpad.exe or other custom editor
ItsHF folder	To set the main/home-folder for the <u>ItsHF</u> propagation prediction program
gnuplot folder	To set the main/home-folder for the ' <u>gnuplot</u> ' plotting program
NecWin+ folder	To set the main/home-folder for NecWinPlus

Input power

The 'power' setting is used to compute the structure currents and the magnitude for the near electric and magnetic field. The effect is that the voltage for the voltage source on the EX card is modified in such a way as if it would be perfectly matched and delivers the specified input-power to the antenna structure. (Constant power mode, (multiplication with  $\text{SQRT}(\text{specified\_input\_power} / \text{input\_power\_from\_output\_file})$ ) If you would like to keep the original specified voltage in the EX card, please specify an input-power of 0 (zero) watts. (Constant voltage mode)

Please note also that the Voltages and Currents specified in the 4nec2 program are effective values, and not maximum values as used by the NEC-engine.

Number of segments

The maximum number of segments that can be modelled on your system depends on the of physical memory (RAM) available on your computer. For different number of segments separate engines (requiring different amounts of memory) are selected by 4nec2.

Select 'Help -> About 4nec2', to see the total amount of physical memory available on your system.

In version 5.0 or later, 4nec2 automatically calculates the engine-'size' that is required. Mostly this will be fine. The engine selected is the one specified by both the number of segments (and patches) in your model and the 'Min-nr of segments' setting (see below). If segment-count goes up, a 'larger' engine is automatically selected.

However in special cases when using the the NGF (numerical Green's fuction) or related to GX and GM cards, it is possible the wrong engine is selected. (an error like: "nr of segments and surface patches exceeds dimension limit" may be generated). If this is the case when using a Nec-2 based engine, you could switch to 'manual selection'. To do this, set the 'Manual select' option and then specify the 'Max-nr of segments' setting. The engine(size) used now is selected according the number of segments specified.

When using a licensed Nec-4 engine you can use this option to manually specify the executable

file-name to use as the NEC-engine

The following table gives you some indication about the available public-domain Nec2d engines, the maximum number of segments to calculate and the minimum required amount of RAM. Note however that these numbers are based on running the old DOS operating system. Because 4nec2 is based on the windows-XX system, less memory is available for the nec engine, especially when running windows-XP which uses a large amount of available memory by itself.....

	Name of executable	Max number of segm.	Approximate memory use (MB)
	/ NEC2D.EXE	256	1.5 (*)
These are	NEC2D512.EXE	512	5
found in	NEC2D960.EXE	960	16
nec-pc.zip	NEC2D1K4.EXE	1392	32
	\ NEC2D1K9.EXE	1950	60
	/ NEC2D2K8.EXE	2800	122
These files	NEC2D4K.EXE	4000	247
are in	NEC2D5K7.EXE	5700	500
nec-pc-x.zip	NEC2D8K1.EXE	8100	1006
	\ NEC2D11K.EXE	11000	1852

(\*) NEC2D.EXE should be in the directory from where you run the other executables, it is the only one that contains the DOS-extender. The others borrow it from NEC2D.EXE.

Nec2dXS engines are available for the following maximum number of segments:

Nec2dXS500	max 500 segments	(5 Mb)
Nec2dXS1k5	max 1500 segments	(40 Mb)
Nec2dXS3k0	max 3000 segments	(150 Mb)
Nec2dXS5k0	max 5000 segments	(512 Mb)
Nec2dXS8k0	max 8000 segments	(appr 1Gb)
Nec2dXS11k	max 11000 segments	(appr 2Gb)

By default 4nec2 uses the smallest executable available for the number of segments specified in the \*.nec inputfile. However when using the original nec2d engine this may cause problems on systems with 128 Mb of RAM or more.

When using a 'simple' nec input file with few segments in combination with a 'small' exe and with a 'large' amount of RAM, a message "Program requires MS-DOS mode,...." might be displayed. If this is the case, increase the number of segments in the 'nr of segments' setting, till the message no longer appears. On the other hand, don't set a far too big number of segments, because this will decrease calculating performance.

For troubleshooting and additional information about engine selection, see: [troubleshooting](#)

ZIP files for the nec2d and the nec2dXS executables can be found at the "Unofficial NEC archives": (See <http://www.si-list.org/swindex2.html>) or on the 4nec2 home-page at <http://www.qsl.net/4nec2/index.html>.

These \*.exe files should all be placed in your ..\4nec2\exe folder.

Additional notes:

- (1) The Nec2d engine used is the one created by Jos Bergervoet.
- (2) The Nec2dXS engine is based on the nec2dX engine made available by Raymond Anderson.
- (3) The Nec4D engines are available as a licensed product from Lawrence Livermore National Laboratory.

The Nec2dXS engine is an improved engine as it does not require the additional Somnec2d.exe program. Besides this, when running a Nec-2 frequency sweep the Real/SomNec ground data is recalculated for every frequency-Step. The original nec2d engine calculates this Real/SomNec ground data only once (using a negative conductivity setting. For more info, see nec-2 user-manual), so accuracy is improved.

#\$K

## **ItsHF Propagation prediction using the ItsHF package**

In this paragraph the Area- and Point-to-Point Coverage options available with the Generate command are described in more detail. These both options are used in conjunction with the HFwin32 high frequency propagation-modeling program developed by NTIA/ITS, which is freely available on the Internet. (See <http://elberts.its.blrdoc.gov/hf.html>) or do a Google search.

Within the combination of 4nec2 and the ItsHF package/program it is possible to create Area-Coverage maps or create Point-to-Point plots. By default the ItsHF package contains a number of pre-defined antenna types to be used for propagation prediction. 4nec2 however enables you to create your own ItsHF type antenna input files based on your (4)nec2 model.

On the Generate (F7) form you can choose between two 4nec2 specific types of ItsHF antenna files to create:

- 360 degree Gain-table (Type 13: 360 degree Gain-table (Gain table versus azimuth and & elevation angle)

- Gain @ 30 frequencies (Type 14: Gain-table at 30 frequencies (Gain versus elevation angle & frequency)

When running a propagation prediction both Transmitter (Xmtr) and Receiver (Rcvr) antenna must be specified. If <current> is set as the antenna (type) to use, the above selected antenna-type is automatically created from your Nec model (if not already available) and used for the prediction.

### **Running a prediction**

Before running a propagation prediction you must choose between four types of plots:

- Map Area-coverage plot showing propagation performance on a (partial) world-map.
- Time Point-to-point chart showing propagation performance as function of time-of-day
- Distance Point-to-point chart showing propagation performance as function of distance
- Graph plot Point-to-point chart showing propagation performance as function of time and frequency

After having selected the required plot-type additional settings can be specified and/or modified as listed below:

#### Phi-max

(or Azim-max) When generating an ItsHF antenna-file you will have to specify the NEC based phi/azimuth angle for the main beam for the antenna under test. Usually this will be 0 or 90 degrees. This value is used so the NEC main-beam angle corresponds to the ItsHF main-beam azimuth angle of 0 degrees.

#### Bearing

For a point-to-point type of plot (time, distance or graph) it is required to specify both the transmitter



and receiver location. Both these locations determine the antenna direction (bearing) from transmitter to receiver and from receiver to transmitter. When changing one or both locations the antenna direction for the transmitter is automatically updated. Manual modification however is still possible. For an area-coverage plot a receiver location is not strictly needed. This location however is used to determine the default antenna direction.

### Map

This box let's you select between the different map 'sizes' for an Area-Coverage plot. Selection is disabled when a time, distance or graph type plot is selected. When using <default> the setting as specified in the 4nec2.ice (.rec or .voa) template file is used

### Power

Using this text-box you can overrule the default transmitting power as specified under 'Settings' on the Main (F2) window.

### Param

This selection box let's you select between the different parameters to visualize on the plot. Selection is disabled for a 'Graph' type of plot. For the moment you can select the following:

- |                        |   |
|------------------------|---|
| - <use default file>   | Use parameter(s) as specified in 4nec2 template file (see below). |
| - Signal at receiver   | SDBW – Monthly median signal power at receiver (dBW).             |
| - Noise at receiver    | NDBW - Monthly median noise power at receiver (dBW)               |
| - Field strength       | DBU – Monthly median field strength at receive location (dBu)     |
| - Signal/Noise ratio   | SNR – Monthly median signal-to-noise ratio (dB)                   |
| - % above req. SNR     | REL - Time availability, % days/month SNR exceeds required SNR    |
| - Max usable frequency | MUF - Maximum Usable Frequency – monthly median (MHz)             |
| - Radiation angle      | ANGLE – Radiation angle at Xmtr (degrees)                         |

Note: Due to some strange inconsistency between the ItsHF Time/Distance and Graph type of plots, with the Graph type plot it is required to manually select the required plot once the prediction calculations are done and the ItsHF plot-window pops-up. This manual intervention is not required for the Area-Coverage, Time and Distance plots.

'Required SNR' is specified using the 'Mode of operations' available through the <More> button.

See [DBW and dBuV conversion](#) for conversion from DBW and dBuV to S-meter readings.

### Fixed

To set Fixed contour scaling for Area-coverage-maps and Graph-plots and fixed Y-axis scaling for time- and distance-plots. When not set scaling is done automatically by the ItsHF program. Fixed Contour/Y-axis scaling is usefull when using the picture-viewer to scroll through a set of plot-files. Sets of plot-files are created when a none-zero time-span is selected for area-coverage map's or when the 4nec2 [Variable-sweeper](#) is used.

You can use the ItsUtil.exe program ('Run -> ItsHF colors and scaling' on 'Main [F2]') to change Color-, Contour- and/or Y-axis-scaling for Area-coverage, Graph and Time/Distance plots to meet specific needs.

### Month

To select the (starting) month of interest. Furthermore this sets the so-called Smoothed Sunspot Number,

(SSN) which is an important propagation parameter. When selecting <def>, the value from the template file is used. If a certain month is selected, this value together with the specified year is used to let 4nec2 automatically get the proper SSN from the internal 'sunspot.txt' file.

### SSN

To select the year for setting the Smoothed Sunspot Number (see above) this selection box is used. To manually specify the SSN value (in the second text box), select the 'manual' setting.

### UTC

The UTC selection box is used to specify the (starting) time-of-day for which a (set of) prediction(s) should be done. Set <def> to use the value from the template file.

### Span

You can run multiple Area-Coverage or Point-to-Point Time, Distance or Graph plots for a selected time-span.

When running an Area-Coverage predictions for a certain time-span, multiple plots are created. All plots are automatically cut and pasted into the new 'picture-viewer' window with which you can manually scroll through or switch between the different plots.

When running a Point-to-Point Distance prediction for a certain time-span, you must use the 'New plot' menu-bar option on the plot-window to manually select between the different plots. This same option is used to select between the different frequencies as specified using the <More> button (see below). Time, Distance and Graph plots are not automatically copied to the 'picture-viewer' window.

When an Area-Coverage map is selected additional 'frequency' and 'month' span-selections are available. These are used to create a set of plots for each frequency as specified using the <More> button or a set of plots for 6 months with 1 or 2 month interval.

### Location

Both of these command buttons are used to specify the transmitter (Xmtr) or Receiver (Rcvr) location. A new window will pop-up, in which you first will have to select the file-name containing a list of locations to choose from. After this selection all locations in the file are listed on the second part of the window. You can click the top-row for a specific column of the list to sort the list. You can select a certain location by double clicking in the desired location.

### Antenna

Using these both command buttons you can specify the antenna used at the transmitter (Xmtr) or Receiver (Rcvr) location. A new window will pop-up, in which you first will have to select the folder containing the antenna files to choose from.

The 4nec2 folder contains the type-13 and -14 antenna-files created in previous 4nec2 sessions. Select <Current> to automatically create (or re-use) the type-13 or type-14 antenna-file for the current antenna under test.

After selection all antennas contained in the selected folder are listed on the second part of the window. You can click the top-row for a specific column of the list to sort the list. You can select a certain antenna by double clicking in the desired antenna.

The 'Transmit' and 'Receive' folders contain general HAM related transmit- and receiving antennas. All receiving antennas are omni-directional and the Dipole- and Yagi-types are artificial derivations of their directional counterparts.

These omni-directional receiving antennas are especially usefull for Area-coverage prediction, because

for each receiver in the 'grid of receivers' and as seen from the receiver another direction/bearing applies. If you would use a directional receiving-antenna with a direction/bearing of 0 degrees (aimed North) the receivers North of the transmitter would be pointing with their backs towards the transmitter whereas the receivers to the South would be properly aimed. If propagation would be the same in all directions and you would use an omnidirectional transmitting antenna this would result in unequal coverage.

These artificial receiving antennas are also perfectly usable as a receiving antenna in point-to-point predictions.

### More (button)

This button is used to specify additional circuit related parameters:

Mode of operation which determines the minimum required signal to noise ratio for the selected mode. (Used to calculate the '% above req. SNR' (REL) parameter)

'Noise level at receiver', which specifies the Man-made noise level at the receiver location(s).

Above settings are used when running a 'Signal/Noise ratio' (SNR) or '% above req. SNR' (REL) prediction

'Extra Frequencies', for the Point-to-Point Time- and Distance-plots, additional frequencies to calculate a plot for can be specified. After prediction calculations are done you can use the 'New plot' menu-bar option on the ItsHF time- or distance plot-windows to select a plot for a different frequency or even for all frequencies at once.

Using the 'HAM-bands' or 'Broadcast' buttons, initial/default frequencies for Ham- or Broadcast bands are set. One can manually change these values.

When using the ItsHF package its important to keep in mind that the ItsHF programs uses azimuth and elevation angles whereas 4nec2 and NEC by default use Phi and Theta angles. For later 4nec2 versions however it is possible to switch between Phi/Theta and Azimuth/Elevation presentation.

When elevation increases from 0 to 90 degrees, the theta angle changes from 90 or -90 degrees to 0 degrees. Azimuth increases in a clockwise direction from 0 to 360 degrees. Phi increases in an anti-clockwise direction from 0 to 360 degrees.

All automatically generated area-coverage or point-to-point input-files are derived from default 4nec2.ice, 4nec2.rec or 4nec2.voa template files as located in your '..\ItsHF\areadata\default' or '..\ItsHF\saved\default' folders. This is especially true if, for the selection boxes on the Generate form, the <default> selection is used. When other selections are used the settings as specified in the template files are overruled by the setting as selected.

You are free to modify these template files. For instance to set a larger area-coverage grid-density. You can do so by using 'Run -> ItsHF Area Coverage' in the 'Main (F2)' window, select the 'default folder and open the 4nec2.\* file. After modification, save this file under the same name. Next time you run a predication the new settings are used (if not overruled by the user-settings on the Generate form).

To use the ItsHF software package it must be installed on your computer system. Use 'Settings -> Folders' to specify your ItsHF home folder. In this same Settings-menu you can choose between the ICEPAC, VOACAP or REC533 model to use for the propagation-prediction. At the time of writing this the VOACAP and ICEPAC models are considered to be the most accurate. Note that folder-names containing more than eight characters are not allowed. If possible use the default C:\ITSHFBC folder.

## Propagation Prediction using the Variable-sweeper

You may use the Variable-sweeper to see the effect of changing certain antenna dimensions on propagation performance. To do so, first select 'Sweep' as the required function and then select 'type-13' or 'type-14' as the antenna-type of interest using the 'Option' selection-box on the optimizer/sweeper form. During sweep a number of ItsHF antenna-, input- and output/plot-files are created. For this, the 4nec2 (antenna) filename is truncated to six characters and a two character sequence-number is added to this left-over filename to distinguish between the different calculation steps. This may produce a lot of files in the ..\antenna\4nec2, ..\areadata\4nec2 or ..\saved\4nec2 folders. If disk-space is an issue you may delete these files without further problems.

During the sweep all created plot-files are cut and pasted into the 'picture-viewer' window with which you can manually scroll through the different images if calculations and plottings are finished. You can use the 'Save' or 'Print' buttons to save or print specific images. Use the 'Sel(ect)' button to select part of an image for save or print.

### Steps to distinguish when running a prediction:

For Area-coverage map generation 4nec2 processes the following steps:

- 1) Nec is run and depending on the antenna-type selected, output data for a 90 \* 360 sample far-field request or for a 90 sample far-field request at 30 frequencies is generated and translated into a type-13 or type-14 antenna input-file with name <name>.n13 or <name>.n14.
- 2) From the ItsHF parameters specified on the Generate form and (depending on the model selected in the settings menu) a <name>.ice, <name>.rec or <name>.voa Area-Coverage input-file is created.
- 3) Using both the Area-coverage and Antenna input-files the ItsHF engine for the specified model is run and an Area-coverage plot/output-file is created with name <name>.ig1, <name>.rg1 or <name>.vg1
- 4) If not specified otherwise in the settings menu the generated output/plot-file is displayed on the screen. You can move the mouse around the Map and click a location to read distance and parameter values or use the 'Parameter' menu-option to select another parameter to plot.

For Point-to-point plots, 4nec2 processes the following steps:

- 95 Nec is run and depending on the antenna-type selected, output data for a 90 \* 360 sample far-field request or for a 90 sample far-field request at 30 frequencies is generated and translated into a type-13 or type-14 antenna input-file with name <name>.n13 or <name>.n14.
- 96 From the ItsHF parameters specified on the Generate form and depending on the model selected in the Settings menu a <name>.ice, <name>.rec or <name>.voa Point-to-point input-file is created
- 3) Using both the Point-to-Point and Antenna input-files the ItsHF engine for the specified model is run and an Time-, Distance or Graph- output-file is created with name <model>T.dat, <model>D.dat or <model>G.dat
- 4) If not specified otherwise in the Settings menu the generated output-data is displayed as a Time, Distance or Graph plot on the screen. You can manually select between the different time- and/or frequency plots using the 'New plot' menu-option.

The following files/extensions are used in the process:

ICEPAC

VOACAP

REC533

- Type 13 ant-file:	<name>.n13	<name>.n13	<name>.n13
- Type 14 ant-file:	<name>.n14	<name>.n14	<name>.n14
- Template-file:	4nec2.ice	4nec2.voa	4nec2.rec
- Area Input-file:	<name>.ice	<name>.voa	<name>.rec
- P-to-P Input-file:	<name>.ice	<name>.voa	<name>.rec
- Area output-file:	<name>.ig1	<name>.vg1	<name>.rg1
- P-to-P output-file	icepacX.dat	voacapX.dat	rec533X.dat

For the P-to-P output file the 'X' character is replaced by T, D or G for Time, Distance and Graph plot requests.

Type-13 and -14 antenna input-files are created in folder '..\ItsHF\antennas\4nec2'.

Area-coverage input-files are created in folder '..\ItsHF\areadata\4nec2'.

Area-coverage plot-files are created in folder '..\ItsHF\areadata\4nec2'.

Point-to-point input-files are created in folder '..\ItsHF\saved\4nec2'.

Point-to-point output-files are created in folder '..\ItsHF\run'.

The filename <name> for your antenna under test is truncated to eight characters for use with the ItsHF software.

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## 360 degree Gain-table

(Type 13: 360 degree Gain-table [Gain table versus azimuth and & elevation angle])

When using the ItsHF software to run a propagation prediction, one needs to specify the antenna-types used at the transmitter (Xmtr) and receiver (Rcvr) locations. ItsHF by itself already contains a large number of more or less general antenna-types. Performance (radiation pattern) for these pre-defined antenna types is determined by equations, which are run by the ItsHF engine when a prediction is done.

You can view the far-field radiation pattern for these predefined antennas by using the ItsHF built-in antenna-viewer. This viewer is started using the 'Run -> ItsHF antenna-view' menu-command on the 'Main (F2)' window.

On the other side ItsHF enables us to use so called gain-tables, in which for each theta/phi value covering half the hemisphere a gain-value is listed. When propagation in a certain direction has to be calculated, ItsHF consults these tables and uses the listed gain for the required direction.

When using 4nec2 together with the ItsHF software we distinguish two different antenna-types using gain-

Tables: a) the type-13 antenna, containing a full 3D 90\*360 degree gain-table for a single frequency and b) the type-14 antenna, containing a set of 1\*90 degree gain-tables for specified phi/azimuth-angle, but for all integer frequencies from 1 to 30 Mhz.

Both of these antenna-types are created using 4nec2. This is automatically done by selecting the required antenna-type in the 'Generate (F7)' window. If an antenna-file for the selected type is already available it is re-used. You can overrule this behaviour by checking the 'run Nec' check-box.

The '360 degree Gain-table' option on the Generate window lets you generate 360 \* 90 degree Gain-table file for a single frequency (type-13). This type of file is the default antenna file to use for calculating and plotting Area-coverage Maps for your antenna structure under test.

When running a Time- or Distance plot for the working/design frequency for the antenna under test (as is the case running a plot through 4nec2) a type-13 antenna files is the one to use. However when Time/Distance plots for multiple frequencies are run, type-14 files are preferred.

When using a type-13 file to run a Area-coverage map for multiple frequencies or to create a Point-to-point Graph type of plot (propagation versus time and frequency) keep in mind that this single 360 degree radiation pattern is used for all frequencies steps ranging from 2 to 30 Mhz, so type-14 antenna-files (Gain @30 frequencies) are the better choice.

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## Gain @ 30 frequencies

(Type 14: Gain-table at 30 frequencies [Gain table versus elevation angle & frequency])

In the description about the [type-13](#) antenna-file it is explained how these antenna-files are created and how these are used by 4nec2/ItsHF.

The 'Gain @ 30 frequencies' option on the Generate window lets you create a set of 1 \* 90 degree gain tables for a single Phi/Azimuth angle. For each whole/integer frequency between 1 and 30 Mhz a set of 90 gain values (one for each theta/elevation angle) is generated.

The Phi/azimuth angle for which each vertical pattern is generated is defined by the difference between the real 'bearing' between the Transmitter- and Receiver location (listed behind the Xmtr/Rcvr antenna button) and the 'Bearing' (antenna direction) value as (manually) specified on the 'Generate' form.

This type of file (type-14) is the default antenna input-file for calculating and plotting the point-to-point Graph type of plots (frequency/time). These graphs for instance can show you the MUF, SNR or field strength as function of frequency and time of day.

Type-14 files can also be used for multi-frequency Area-coverage and point-to-point Time- and Distance-plots. When a none integer (design) frequency is specified used/selected the pattern to be used for the prediction is interpolated from the patterns for the two nearby integer frequencies.

When generating a type-14 antenna file through 4nec2 note however that segmentation can become an issue. because both at 2 and at 30 Mhz Nec-requirements must be met. Depending on the frequency range of interest and the accuracy needed, you can run a default 4nec2 far-fiels 3D pattern at both the upper- and lower frequencies to check if Nec-requirements are not violated or not, and if so, how much.

On the other hand however one will rarely use a single antenna for all frequencies between 2 and 30 Mhz. For those who would like to specify different antennas for specific frequency-bands or –ranges one could use the original ItsHF point-to-point user inteface. With this it is possible to specify up to 10 different antennas with corresponding frequency-ranges.

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## 3D viewer form      F9 Show geometry/pattern in real-time 3D.

The 3D-viewer form is available only for the extended freeware version 4nec2X, and requires a computer system on which the Microsoft DirectX 8.0 or later hardware-acceleration drivers are installed. For further information about how to check for DirectX or how to install, see the \_ReadMeFirst.txt file.

The 3D viewer is used to display structure geometry and/or 3D far- and near-field pattern in real-time 3D. Compared with the Geometry-view F3, this viewer shows the structure much more as it is in real-life. It also shows the real wire-radius.

However when the radius becomes too small to be visible, for instance for wire-antennas, a correction is applied on the wire-radius, to keep it visible. A check box is available on the right of the form, which is enabled if it's possible to re-enable the real-radius display.

This way it is very easy to see if wires are overlaid or intersect (at unexpected places) or not. Also at junctions with short fat segments the intersected area should not be more than about 1/3 of the segment length. With some experience it's also possible, for wire grids, to check the 'equal area' rule.

When patches are included in the structure geometry, the 'shiny' side of the patch is the one from where the normal-vector is pointing outwards. This side of the patch should be considered as being part of the NEC calculation process.

Use the structure drop-down box to select different structure-display options.  
Use the 'Res' button to reset all zoom-, shift- and/or rotate-actions.

The following key's and mouse-buttons are available to change the viewing-position.

	<u>Key-combination:</u>	<u>Mouse-action:</u>
- Rotate structure	Left/Right or Up/Down arrow	Move mouse with left button pressed
- Move structure	Ctrl+Left/Right-arrow	Move mouse with right button pressed
- Forward/backward	Ctrl+Page-up/down	Move mouse with both button pressed
- Zoom-in/out	Page-up/down	

When the display of currents is enabled, and also a freq-sweep calculation was performed, the function of the cursor/arrow key's is changed from structure movement/rotation to frequency 'movement'.

The upper drop-down box lets you select different types of structure (geometry) display. If 'wires' or 'segments' is selected, the red end is end-1 and the green end is end-2.

If 'currents' is enabled use the 'Log factor' scroll-bar to visualize small currents on gridded/external objects.

If NEC output-data is available the drop-down boxes on the right of the form are enabled. This lets you visualize the 3D far- or near field E/H pattern in 3D. You have the choice between single-color or multi-color mode. In multi-color mode a blue to red scale is applied to the pattern for which the color corresponds to the color-scale on the left of the form.

When, for the far-field, the 2D-slice display option is selected, a 2D-pattern slice is displayed for a certain theta/elevation or phi/azimuth value. You can change the Theta/Elevation or Phi/Azimuth angle for which the slice is displayed, on the 'Pattern (F4)' form while simultaneously watching the 3D form. In the 'Pattern (F4)' form, use the space-bar to switch between horizontal/vertical slice.

When on the Pattern-form multiple far-field patterns are selected to be compared against each other,



you can also switch between these patterns on the 3D-viewer form. Use the selection-box in which the file-name is displayed to select one of the patterns. You may also use the '<' and '>' keys (with or without <Shift>)

On certain computer monitors it showed up that color display sometimes is not optimal. To overcome this 'problem', use Ctrl+C to bring-up the color settings window. Select the appropriate structure part and use the sliders to change color or to alter background- or, directional-light intensity.

When no key's are pressed for a certain amount of time, the structure is rotated automatically. You may maximize the window and use this functionality as a kind of screen-saver. You may use the 'Z' key to start spinning directly without waiting for the time-out.

When structures are viewed with a large number of (bent)segments and/or junctions, a certain simplification is done when creating the 3D picture. For instance, by default, all wire ends are closed and wire-radius-changes and junctions for more than two segments are smoothed.

For very high-segment structures these actions are not performed. This is represented by the 'Quality' slide bar on the lower right corner. Eventually one can use this slide-bar to change the default 3D structure quality and increase speed, ranging in three steps from left to right.

- Left : Show 'simple' structure as a wire-grid.
- Middle : Show structure with open ends and none smoothed junctions
- Right : Show high-res structure with closed ends and smoothed junctions

FPS = number of frames (screen refreshes) per second.

Tri's = number of triangles used to construct the 3D objects

When a large number of far/near-field points is requested or when structures with a large number of segments and with 'high-quality' are viewed, it could be necessary to increase the 'Max-nr of 3D-points' in the setting-menu. If so, a message will inform you about this possibility. However, because this setting also affects the amount of video-card memory used, large values can sometimes result in strange video effects. If so, lower this setting.

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## **Matching F10 Impedance matching networks.**

For maximum power transfer from the source to your antenna/load and/or to reduce transmission-line losses it is needed to match your antenna to the characteristic impedance ( $Z_0$ ) of your feed/transmission-line. In many cases however it is not possible to choose all impedance such that overall matched conditions result. These situations require that matching networks be used.

In general, matching networks are constructed with reactive components only so that minimal loss is added to the overall network. For frequencies up to approximately 500 MHz matching networks containing lumped elements (L, Pi or T networks) may be used. The circuit elements (capacitors and inductors) must be small enough relative to wavelength.

Another way of antenna to feedline matching is called Stub-Matching and uses parallel or series stubs. These stubs are open or closed (at the end) pieces of transmission-line with different impedance placed somewhere along the feedline.

A third method is called Series-Matching. This method uses a series matching system consisting of three sections of transmission line. The middle section does have different characteristic impedance.

### **L, Pi or T-network matching**

Using L, Pi or T-networks it is theoretically possible to match any source/load impedance combination. However in practice certain reactance/resistance values could result in additional component losses and the use of lumped elements does reduce your overall system bandwidth.

4nec2 supports the automatic calculation of the required components for low- and high-pass L, Pi and T(ee) networks using the 'Matching (F10)' window/form.

When this form is first displayed 4nec2 checks if already a matching network is present. If not, the antenna/structure input-impedance value and the design-frequency is copied into the 'Matching (F10)' form and the  $Z_0$  as specified under the 'Settings' menu is set as the (source) impedance to match. With these impedance's then the required component-values to create low- and high-pass L, Pi and Tee networks are calculated and displayed on the screen.

For both inductors and capacitors their quality 'Q' may be specified using the Q-coil and Q-cap. Text-boxes. By default capacitors are considered lossless (indefinitely high Q, entered as zero), whereas inductors are given a default Q of 250. If sufficiently high (100-300) then the low series resistance will not influence the required network components for a 1:1 match much.

To let 4nec2 automatically add the matching network to your (4)nec2 antenna design, first select the required network and then click the "use network" button and let 4nec2 generate new NEC data. You can use the default option "use original file" to generate only the new input-impedance.

If done so, 4nec2 will create a (far-away) dummy wire, place the voltage-source on it and connect this dummy wire with the original excitation wire/segment through a network NT-card. The Y11, Y12 and Y22 values to be used with the NT card are calculated when the network is selected. After generation the new input impedance together with the resulting losses for the selected matching network will be displayed on the 'Main (F2)' window.

As long as the 'Matching (F10)' window is active you can re-generate using other selected networks. Once the 'Matching' window is closed you will first have to generate the 'raw'

input-impedance using the default 'Generate (F7)' function, before you are able to use the 'Matching (F10)' window again.

For Pi and Tee networks by default 4nec2 uses the lowest possible Q. This to minimize losses. If more manageable components or extra attenuation of undesired frequencies is desired (for Pi and Tee) a different/higher value may be specified in the min-network-Q textbox. A higher network-Q however will increase network-losses and reduce bandwidth.

Note:

- You may manually change Z-ant, Z-src and/or Frequency to let 4nec2 directly reflect these changes in the calculated L, Pi or Tee network-values. This way you can use this form as a general tool to match for other impedances and/or frequencies
- After a certain L, Pi or Tee network has been selected, you can also manually change component values (L, C, Ql or Qc) or the network-Q to see how these changes directly affect the NT network parameters Y11 to Y22.
- Click the 'use network' button to see the effect on overall input-impedance and power losses in the network due to your manual changes (tolerances) of Network component values.

You will see that using inferior components and thus lowering component-Q (and increasing network-Q for Pi/Tee) will increase losses and deviate the input-impedance more and more from the specified Z0. On the other hand an infinite high coil- and capacitor-Q (enter a value of zero) will deliver an exact 1:1 match.

Click the <Reset> button to restore all fields to their initial values.

### **Stub/series matching**

You can reach the stub/series matching form by clicking the 'stub' button on the upper-right on the Network matching form.

When the form is first displayed 4nec2 checks if a matching network is already included. If not, the antenna/structure input-impedance value is copied onto the Stub-matching form as 'Z-load (antenna)'. The design-frequency and the Z0 (as specified on the Main-form's settings-menu) are also copied onto this form.

With the 'select matching network' selection box you can choose between the matching network to use. For now, below types are available:

- Series section; this type of match uses three sections of transmission line in series, in which the middle transmission line does have different impedance. The impedance transformation is defined by the Z0 of the series section, the length of (default) feed/transmission-line from antenna to the middle series-section and the length of this series-section. An arbitrary third (lower) length of (default) feed-line connects the series section to your rig.

- Parallel stub, open or short; this type of matching-network also uses a second different type of transmission-line which is connected somewhere between the antenna and your rig on the feedline. The parallel stub is connected as the name already implies in parallel with your feedline. The impedance transformation is defined by the distance between antenna and the point on the feedline where the stub is connected and the characteristic impedance and length of the stub-line. The required lengths are influenced by the fact whether you choose to use a short or open end for you stub.

- Series stub, open or short; this matching-network uses the same principles as the parallel stub, but now the stub is connected in series with one of both feeder-lines. For the series stub one can also choose between an open or a short stub.

Also included on the form are two selection boxes to select both types of feed/transmission-line. The first sets your default type of feedline; the second sets the characteristics for the series-section or stub-line. When 'user-specified' is selected you can manually enter characteristic-impedance ( $Z_0$ ) and/or velocity-factor ( $V_f$ ) values.

For each selection the resulting line-length results are displayed in the lower 'edit/select results' portion of the window. If 'none' is displayed, there is no valid solution for the selected network and/or type of transmission-line(s). You will have to select another network or transmission-line. For each selection 2 possible solutions are available, labeled A and B. When stub-matching is used one can furthermore select between using a short or open stub. This selection is done by using the 'select solution' selection-box or by clicking on one of the length text-boxes. Values highlighted represent the actual selection.

To use the selected matching-network with specified lengths in your model, click the 'use selection' button. 4nec2 will now automatically add the required transmission lines to your model with the specified lengths and configuration and calculate the results, which are displayed on the Main(F2) and Geometry(F3) form.

You can also manually overwrite the lengths as initially calculated by 4nec2 on the stub-matching form. This way you are able to see what results you get if you do not exactly follow the calculated line-lengths.

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## **Smith Chart      F11      Show impedance and SWR on Smith-chart**

In this form the input impedance is plotted on a Smith-chart. When a Nec based frequency-sweep was done more than one impedance point is plotted. The active SWR is displayed as a circle. On the left of the Form additional information such as reflection loss, SWR in dB, refl-coeff (U/I), refl-coeff (P) and return loss is displayed.

With the Shift+left or Shift+Right buttons you can specify any length of transmission line connected between the load and the generator and read the resulting impedance. With Ctrl+P you can capture and save/print the Smith-chart form for further graphical analysis.

When you requested a frequency-sweep you can 'walk' through each frequency with the RIGHT and LEFT arrow-keys. The corresponding frequency and the real and imaginary values for the impedance are displayed in the lower right of the form. With the 'X' button you can switch between polar- or cartesian-notation. With the 'Home' button you can switch between a normalized chart or a chart based on the characteristic impedance.

With pressing the Right or Left button together with the SHIFT button a second phase line is displayed. With this line you may specify a length of feed-line. On the lower left of the form a second pair of values is displayed, showing the real and imaginary values for the impedance on the other side of this feed-line, corresponding with the given SWR and phase angle.

When selecting a phase difference of 180 degrees ( $\lambda/4$ ) this can also be used for reading the admittance values for the selected impedance. You can add and remove your own user impedance/admittance points by pressing the Insert and Delete keys.

The grid for the Smith chart can be changed between fine and course with the corresponding option under the Show menu-bar option. For those who want to further customize their grid layout; the layout is described in the Smith.dat files in the "\exe" folder, but before changing it, be sure you made a backup of this file.

Position your mouse and push <Insert> to add manual points, or use right mouse-button. Push <Delete> to remove last manual point.

Use the 'Export' menu-bar option to export your smith-chart data in Touchstone (Z or S params) or Microsmith (\*.gam) format.

Use the 'Import' menu-bar option to (re)import a Touchstone (Z or S prams) or Microsmith (\*.gam) data/export-file. When importing data you are asked if existing data-points should be cleared or not. If existing data is cleared, the new import data is also available through the line-chart form.

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## The Optimizer and sweeper F12

The optimizer/sweeper is started by pressing the F12 key or by selecting calculate -> optimize on the menu-bar in the Main window. The optimizer, as part of the 5.4 and later versions, contains four different options:

- Optimize Use the traditional hill-climbing method to optimize you design
- Evolve Use Genetic Algorithms to evolve (optimize) your antenna design
- Sweep Use the Sweeper to visualize the effect of user specified design/variable changes.
- Conv-test To validate your model by running an automatic Convergence-test

You may select between one of these options with the "Function" box on the upper-left of the optimizer window. With the "Option" box you can select between different sub-options. For most cases 'Default' will be the appropriate choice.

The traditional hill-climbing optimizer was based on principles as described by Brian Beezley and used by the AO (antenna-optimizer) program. A scaled down freeware version of this program is available at the ARRL web-site.

For a description of how to 'evolve' your desing using the genetic algorithm based optimizer see [Genetic Optimizer](#), but before doing so, please read the below section about how to specify the antenna properties and variables to optimize/evolve.

A description of the traditional hill-climbing optimizer is given below, a description of the [Sweeper](#) function is given in a separate section. How to run a convergence-test is described in [Conv-test](#).

When you want to use the optimizer the 4nec2 input file must include variables (constants). These variables serve as input for the optimizer. You may specify any combination of variables (and/or equations) anywhere in your 4nec2 input file (GW, LD, EX, FR card).

You can select only "simple" variables (constants) as the ones to optimize. These are variables not containing any expressions like +, -, \*, functions and/or other equations. These "simple" variables are the ones that are altered during the optimization process. (See the 3el-inverted-V.nec file for a more dedicated example).

The optimizer window is devided into four different sections, one input and three output sections.

### Antenna properties to optimize

The main input-section is named 'settings', and is used to specify the variable(s) to modify and the (antenna) properties to optimize. These properties are SWR (standing wave ratio) ,Gain (forward gain or Electric-fld), F/B (Front to back ration), F/R (Front to Rear ratio), R-a (Input resistance), X-a (input reactance) and/or Eff. (Efficiency). When the 'include surface wave' box is checked, the Gain property defaults to E-fld.

For each of these properties you must specify the importance of it by specifying a value between 0 and 100% (weighting factor). This factor determines the effect on the overall performance for the corresponding property. For instance when optimizing only on SWR, the SWR factor is 100% and the other factors are set to zero. You can toggle this weighting factor between 0 and 100 by right clicking on the "SWR", "Gain", "F/B", "F/R", "R-a", "X-a" or "Eff." text label or on the corresponding text box. Other values have to be entered by keyboard. (Negative values or values > 100% are allowed).

By default the SWR and X-in properties are minimized and the Gain, F/B, F/R, R-in and Eff. properties are maximized. In order to change these defaults or to specify your own targer value, click with the right mouse-button on the corresponding text-label (SWR to Eff). A pop-up menu is displayed in which you can specify if you want to maximize or minimize this property or if you want it to reach a

user-specified target value.

The following targets are set when optimization towards minimum or maximum (the default) is selected:

Property	Min	Max
SWR	1	100
Gain	-999	100
F/B	-999	+999
F/R	-999	+999
R-a	0	9999
X-a	0	+9999
Eff.	0	100

When no (wire)loading cards (LD) are included, optimizing on efficiency has no effect.

User specified targets are accepted for values anywhere between -9999 and +9999. Note however that if one specifies a target of +9999 for, for instance, forward Gain, this does not improve optimizer accuracy. A target in or near the range of theoretical (min/max) property values for the antenna type to optimize will yield better results.

The absolute difference between the actual value and the target value for each property is rescaled to a range from 0 to 10000 and summed according the specified weighting factors. The resulting value is used as input for the optimization process.

The optimizer calculates electric-field values in relation to the specified input power value, so optimization is done with a constant power setting and not as might be expected with a constant voltage (or current) setting. If the latter is required, select a power-level of zero watts and specify an appropriate voltage- or current-source.

When optimizing for (forward) Gain or F/B-ratio you will have to specify the Theta and Phi angle for which the Gain (and F/B, F/R ratio) should be calculated. If a resolution of 0 degrees is specified the Gain (and F/B ratio) is calculated for this one and only angle. To optimize on F/R-ratio it is required to use a none-zero resolution to enable gain calculation and maximization to be performed for the whole 180 degree backward-region.

It is possible to specify a certain forward- and/or backward-region for which the Gain or F/B ratio should be averaged. This is done by specifying a certain resolution in combination with a delta-Phi and/or delta-Theta (d-Phi, d-Theta) value. Averaging is performed for angles between  $\Phi - d_{\Phi}$  and  $\Phi + d_{\Phi}$ . The same holds for the Theta and  $d_{\Theta}$  angles. The resolution determines how many iteration-steps are made between  $+ d_{\Theta}/\Phi$  and  $- d_{\Theta}/\Phi$  angles. Using a none-zero resolution will show a considerable increase in required optimization time, because far more gain angles are calculated.

### Frequency-sweep

With version 5.1 the possibility to optimize over a certain frequency-band (for instance the 40-meter band) was added. To enable this option, check the 'freq-sweep' box. If done so additional input-boxes are displayed in which you can specify the start- and stop-frequencies and the step-size thus specifying the frequency-band of interest.

For each frequency step a complete set of results is calculated. All results for each property are then summed and divided by the freq-step count at the end of the sweep to get the average values to be used as input for the optimization process.

### Antenna dimensions/characteristics to change

To optimized one or more of the properties, antenna dimensions/characteristics have to be modified. These dimensions/characteristics are represented by (combinations of) "simple" variables. All available "simple" variables to optimize are displayed in the upper left box on the settings section. You select one or more variables by clicking on the variable name. Then this variable is added to the box on the right. This box lists all the variables, which are used to optimize the selected antenna properties. You can remove a variable by clicking again on the variable name in the left or right box.

When using the genetic optimizer (evolve) you will also have to specify the minimum and maximum allowable variable values. This determines the so called 'search-space', in which feasible solutions are searched. By default the minimum value equals the actual variable value divided by 2, the maximum value equals the actual value times two.

### **The traditional optimization process**

If the traditional optimizing function is selected, clicking the 'Start' button starts the optimizer. First of all some initial calculations are done to determine the sensitive and direction for the selected variables on the requested propertie(s) to optimize. The results of these calculations are shown in the upper right section. After that, the actual optimization is started and the variables are modified with a certain initial step-size to achieve better performance. The results of these optimization steps are displayed in the lower left and right section.

The first initial/max step size determines how quickly an optimization solution will be found. A small step size could lead to a long optimization run. With a too big step size it is possible that with sensitive variables it is possible that the first minimum/maximum is skipped. This value is available in the 'Settings -> optimizer' menu. Mostly a max/initial step size of 10% will be fine.

Optimization steps continue as long as there is still improvement. When there is no further improvement a new sensitive run is performed to determine how the selected variables have to be modified to achieve, if possible, a new better performance and new optimization steps, with smaller step sizes, are done. This continues till the step-size has reached a certain minimum step-size and the optimization process stops. This minimum step size determines how accurate the minimum/maximum will be. This value can be changed in the 'Settings -> Optimizer' menu. Mostly a value of 0.01% will be fine.

By default the delta step size is relative to the active value of the variable to optimize. However it is possible to use absolute (fixed) step sizes. If this option is selected in the Settings -> Optimizer menu, after a sensitivity run, an absolute delta step size is initially calculated and this step size value is not changed until the minimum/maximum is passed and a new sensitivity run is performed.

You can examine the optimization results on the two lower output sections on the window. (Intermediate) variable results are stored in the file \*.opt on the 4nec2 main home-folder.

To save the new optimized variable values to the original \*.nec input file, use the 'Update Nec-file' button on the optimizer window. The existing variable values are overwritten with the new values.

It is possible to halt the optimizer before the process automatically stops by pressing the 'Halt' button. After the optimizer is stopped or halted you may exit the optimizer or alter, add or remove variable or property settings and continue by pressing the "Resume" button. The optimization process continues with the latest calculated variable values. To (re)start with the initial variable values, you have to exit the optimizer and start it again without saving the results.

When only one variable is selected the optimizer can be initially forced in a certain direction to find the next maximum/minimum. This is done by selecting "increase" or "decrease" in the Upper left Function box on the 'Settings' section of the window. After the first maximum/minimum is passed, the normal optimization process is continued.



After optimization it is wise to validate the new geometry structure, and if you updated/saved your results, to perform an additional Average-Gain-Test.

#### Additional Gain and F/B settings

When selecting Forward gain (Gain), front-to-back (F/B) or front-to-rear ratio (F/R) also the angles which define the forward- or backward-direction and a certain pattern-resolution must be specified. Optionally delta-Theta and delta-Phi values can be specified. This is used to average the forward (and/or backward) gain over a certain region between Theta/Phi - delta\_theta/phi and Theta/Phi + delta\_theta/phi. The step-size determines the number of averaging steps. (see Generate for additional information. These delta-theta or -phi values can be used to minimize both maximum or average side-lobe level in a certain direction.

By default when ground is specified, the backward theta/elevation angle used for the F/B ratio calculations is set to the same value as the theta angle used for the forward-gain (Theta-back = Theta-forward and Phi back = Phi-forward+180). If free space is selected the backward-angle used is the angle on the opposite side of the XY plane (Theta-back = 180-Theta-forward and Phi-back = Phi-forward+180) It is possible to manually overrule the default backward Theta and/or Phi angles to be used for the F/B ratio calculations.

Furthermore one may include ground wave calculations or select between Horizontal-, Vertical- or total-gain, E-theta, E-Phi or E-radial when performing the Forward gain of front-to-back/rear optimizations.

#### Output log

During the optimization process, the optimizer variable- and property values (calculated results) are logged in a log file called "Optimizer.log". This log-file is located in the 4nec2 home-folder. This log-file is available for further examination of the results using the 'Show' command button. The next time the optimizer is started, the old log-file is replaced with the new version.

To visualize the results and/or behaviour of the optimization process one can use the 'Plot results' command-button. After this you will be asked for a property- and one or two variable-names for which a 2D or 3D plot is generated using the gnuplot program.

#### Tip(s):

- 1) During the optimization process you can resize or move the 'Optimizer' window to make more/other data visible. You can 'click' on one of the other windows or use the F2 to F5 key's to bring one or more of the windows in front of the other or you can 'drag' one or more of the windows aside.
- 2) You can only change a certain viewpoint on the 'geometry (F3) or 3D (F9) form or select a specific 2D pattern type on the F4 form, when the optimizer is halted. You can do this before the 'Start' button is used, or you can temporarily pause the optimization after it is started by pressing the 'Halt' button, change setting and press 'Restart'.
- 3) To sequentially switch from Genetic- to Hill-climbing-optimization or back, for the same input-file, use "Update Nec-file" to temporarily save the results of the previous run, exit the optimizer and open/load this temporary file as input for the next optimization run. Use 'seed with curr-data' to use existing optimization data in the Genetic optimization process.

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## The variable-sweeper

In the optimizer window it is possible to evaluate the effect of changing one or more antenna or environmental dimensions. This is done by selecting the 'Sweeper' option in the Function box on the upper left of the Optimizer window. The dimensions to sweep must be specified as variables in the 4nec2 input file.

After the Sweeper function is selected, one or more variables to sweep have to be selected in the 'Available variables' box. For each variable selected it is now possible to specify the min(start) and max(end) values for the sweep. It's not required for 'max' to be greater than 'min'. For instance to sweep from 20 to 10 specify 20 as the 'min'-value and 10 as the 'max'-value.

Furthermore the number of steps for the sweep must be specified. This is done in the 'Nr of steps' Box'.

By default the 'used fixed stepsize' box is checked, resulting in equal steps when the variable values are changed from min to max. If un-checked multiplicative steps are used. In this case it is not possible to sweep from <0 to >0 or reverse.

The Theta/Elev and Phi/Azim value boxes are used to specify the angles for which the forward gain, F/B-ratio and for none-zero resolutions, the F/R-ratio is calculated. It is furthermore possible to include ground wave data at a specified distance or to select between Horizontal, Vertical and total gain, E-theta, E-Phi or E-radial when sweeping on forward-gain.

If a none zero resolution is specified one can select between the horizontal or vertical (or 3D) pattern to be displayed for each step during the sweep. The angle for which the hor/ver pattern is calculated is determined by the specified leftmost Theta/Phi values. All generated patterns can be played-back (using the arrow-keys) after the sweep when the Pattern form (F4) is selected.

Because full F/R (and F/B) data is not available when only far-field values are calculated for a certain horizontal or vertical slice, the 3D-pattern option is available. Using this option full gain, F/B and F/R data is generated to be visualized through the 'Line-chart (F5)' window. When this 3D option is selected no horizontal or vertical far-field pattern play-back data is available, because only the last generated full 3D pattern is stored.

Sweep output data (to be imported in a spreadsheet or other programs) is also reported through the optimizer/sweeper log-file. To view this data, select 'View -> Optimizer log' on the Geometry window.

When a none zero resolution is specified, sweeping speed will decrease because of the additional gain calculations, especially when the 3D option is used.

### Note:

Sweeper results are stored in memory only and not on disk (as is the default 4nec2 behaviour), so if 4nec2 is shut-down or another (4)nec2 input-files is selected the sweeper results are lost. The log-file is kept till a new optimization or variable-sweep is done.

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## ***Convergence-Test***

During a convergence test the design/model is validated by running it over a number of steps, in which for each next step the number of segments for all wire is increased by a certain amount (20-50%) while Gain, Input-impedance, Efficiency and other values are observed. These values will have to converge towards a certain value.

To automatically run such a test select the Conv-Test function on the Optimizer window. If done so, the number of steps to run from default- to the highest allowable number of segments is calculated and displayed in the 'Nr of steps' text-box. When started, on each step the number of segment for wires (for which the highest allowable segmentation is not yet reached) is increased with 33%, till all wires have (almost) reached maximum segmentation.

When done, click the "Exit" button, and on the "Line-chart (F5)" window Gain- and Impedance-data is visualized for further evaluation. Abrupt changes or an increasing slope for one or more of the graphs on the chart could point to an unreliable model.

For a description about how to use the Theta/Elev and Phi/Azim input boxes (to specify the angles for which Gain and F/B ratio are calculated) see the Sweeper function.

## The Genetic Optimizer

The genetic algorithm (GA) used in 4nec2 is a real-value based algorithm. This GA includes a number of selection-, crossover- and mutation-techniques like Roulette-Wheel-, SUS-, or tournament selection, N-point-, Blend- or Simulated binary crossover and random-, gaussian- or none-uniform mutation.

### Why use GA's ?

GA's are fundamentally different from other optimization techniques. Analytical optimizers usually compute derivatives (hill-climbing/gradient methods) to locate maximum or minimum points for the function being optimized. GA's by contrast, create random populations of individuals/chromosomes which are then 'evolved' to converge to an optimum solution. Gradient methods produce one 'best' answer, but they are often trapped in local extremes, which prevent the global optimum from being found. GA's can produce groups of solutions, no one of which is necessarily the global optimum, but all of which are 'good' solutions.

Furthermore when a large number of variables is involved with mutual influences among each other, performance of the GA is expected to be better than that of the Hill-Climbing optimizer.

One drawback of GA's is that it mostly takes more time to optimize a design using a GA than it takes to optimize using traditional methods.

Before starting the algorithm, the variables to optimize must be selected, together with their minimum and maximum allowable values (limits). These user-selectable upper- and lower- limits define the boundaries for the 'search-space'. Mostly these limits are set according to physical limits, like available space, maximum height or width etc.

However, setting a too wide range may slow down the GA and might cause it to miss a good solution, because it searched not long enough. Setting a too narrow range might exclude useful and interesting solutions. Experience in this is the most important factor and insight in what may affect antenna performance is also very useful.

Each variable to optimize is called a gene. All the genes together form the chromosome. When the GA is started an initial random population is created by uniform random selection of the gene value on the interval between the lower and upper variable limits.

A population is a group of N chromosomes or individuals. Each individual representing a different 4nec2 antenna design. The GA 'evolves' the initial random population by creating successive generations of individuals. The population size N is constant from generation to generation, but the individuals comprising the population are genetically altered from one generation to the other.

One of the most important features of a GA is its ability to optimize a population using any desired measure of 'goodness'. Unlike gradient methods GA's easily handle discontinuous functions. The only requirement for a useful 'Figure Of Merit' (FOM) is that it is calculable. The data used for the FOM is usually generated by a separate computer program (calculation engine) that models the system being optimized and not by the GA itself. The GA inputs data from the engine and uses this to compute the FOM or fitness values. This procedure is also known as the 'objective' function.

The FOM calculation used with the GA is the same as the one used with the traditional hill-climbing 4nec2 optimizer.

For one or more antenna properties a weighting factor from 0 to 100 (or more) percent is specified by the user, together with an optional target value (click on property using right mouse-button). The absolute difference between the actual value and the target value for each property is then rescaled to a range from 0 to 10000 and summed according to the specified weighting factors. The resulting value is then used as input for the rank-based fitness calculations as described below.

Generation after generation is created this way with the expectation that each successive generation will contain better antenna designs. But because of its stochastic nature a GA may not create improved designs in every successive generation, and the FOM/fitness-value may actually go down. Experience has demonstrated that a well-designed GA will converge to an optimum solution if allowed to run for enough generations with a sufficient large population size.

## **GA parameters**

All parameters used by the 4nec2 GA are available on the 'Optimizer' form (F12). It may be required to click the 'GA' (option) button to make them visible.

### Max-generation.

This parameter sets the maximum number of generation after which the evolution of new populations will stop. You are now able to save any of the resultant antenna design files or exit the optimizer and/or consult the summary log-file for all population data (use 'Show Log' button). You can also resume the generation of new populations by pressing the 'Resume' button. A new set of 'max-generation' populations is now processed.

You may halt Evolution, before the max number of generations is reached. For instance because the solutions have converged, an adequate solution is available or if you want to change one or more of the Genetic Operators and resume.

### Halt if N % same fitness

During the GA evolution process, the overall fitness of all the individuals will increase and finally converge around a certain solution. At this point most of the chromosomes (with exception of the ones just mutated) will have a similar fitness. You can specify to halt the optimization if a certain percentage of individuals have reached the same maximum fitness value. Mostly this value will be somewhere around 50-90%. To be sure all generations as specified by the 'max-generation' setting are evolved, set this percentage to 100%.

### Population size

This parameter specifies the number of chromosomes (individual antenna designs) included in each population. As a general rule, values in the range 30-200 provide a good starting point, depending on the number of segments and how fast a CPU is available.

### Seed with current data

This option is used to seed the coming GA run, thereby initiating the GA search around a particular solution in its search space. The 'seed' individual (design) is inserted as individual #1 in generation #1. Its function is similar to the 'Elitism' function as described below.

### Save best file for last N generations

When a GA run is completed either because it was aborted or because the maximum number of generations was reached, all individual \*.nec antenna designs for the last population are available in the "\opt" sub-folder below your current \*.nec input-file folder. Furthermore for a specified number of last generations the \*.nec file for the best individual is saved. This number of last generation is specified in the field "save best file for last .N. generations".

### Update Nec-file button

This command button is used to let the user select the best file from last N generations. After this the original \*.nec input file is updated with the new variable-values from the selected file and the results are saved to a file with the same or a different name. This file could then be used as a temporary or final result or as a seed for subsequent GA runs.

### **GA specific parameters**

The other GA specific parameters are described in the more general [Genetic Algorithms](#) section. These parameters are supplied for those who want to further explore the (dis)advantages of Genetic Algorithms for optimization of antenna designs.

It is strongly recommended that every one using the GA optimizer reads this section.

As a good starting point one could use the below settings:

- Linear Ranking
- Roulette Wheel Selection, chromosomes to re-use=1
- Blend Crossover, alpha = 0.5, probability = 70%
- Uniform mutation, probability = 4%

With all possible ranking-, selection-, crossover- or mutation-operators you will be able to get good results. However specification of very different crossover- or mutation probabilities may result in unsuccessfull or unwanted evolution of your design.

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## Capture and Save or Print form/window (picture viewer)

With version 5.4.1 or later you can capture any form, window or other part of the screen for printing or saving as a bitmap file. You can also copy the captured part of the screen to the clipboard to paste it into your favorite text- or graphic processing tool. As an extra feature you can also paste any other image placed on the clipboard back into the 4nec2 capturing tool for printing or saving.

With version 5.6, additional functionality (picture viewer) was added to capture a range of pictures/images. Each additional picture pasted from the clipboard is added to the already existing range of pictures/images. If two or more pictures are pasted, a scroll-bar is visualized with which you can scroll through the range of pictures. You can also use the right- and left-arrow key for this. The '0' to '9' number-keys are available for direct switching between two separate pictures. This picture-viewer function is used in conjunction with the ItsHF propagation prediction software to 'animate' the propagation-changes during the day, the year, between different frequencies or as the result of an antenna-variable sweep.

To capture and print/save the current/active 4nec2 form, use the "Show -> Print" menu-bar option on each form or use the Ctrl+P key's. A new pop-up window is displayed in which, by default, as a small image the captured form is visible. Then, use the "Print" button to print the image on your default printer or use "Save" to save the image as a bitmap file.

The following function/buttons are available

- Form        To capture the last active 4nec2 form/window. (first select window, then use button)
- Window     To capture any other (none 4nec2) window. (click button first, then select window)
- Screen     To capture the whole screen.
  
- Clear      To clear the captured image
- Sel.        To switch to full-size image and select partial image to print/save
  
- Print      To print the captured image on your default printer
- Save       To save the captured image as a bitmap (\*.bmp) file
  
- Copy      Copy the image to the clipboard.
- Paste     Paste an image from the clipboard for printing or saving.

When "Window" is selected you will have to activate/select the window you would like to capture for printing or saving. After the message-box is closed you will have to seconds to do so.

When you captured a complete form/window or screen and would like to print/save only part of this image, use the 'Sel'(ect) button. The image will change to full-size and while pushing the left-mouse button you can select any part of the image for printing or saving. Use 'Res'(et) to reset the selection and/or try again.

When using Hewlett-Packard (HP) LaserJet Series II printers it is possible that a general protection fault is generated or that only a blank page is printed. To eliminate this problem, reset the color depth of the video driver on your System to 256 colors or less, or 8 bits per pixel or less. You can do this by changing the display properties (Click left mouse button on blank part of your desktop)

You can also use the [gnuplot](#) program to directly print 2D and/or 3D graphs/plots through the 'plot' menu-option/command.

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## **gnuplot      The gnuplot plotting program**

In version 5.4.0 and later the use of a separate freeware plotting program called 'gnuplot' was added to the 4nec2 package. The gnuplot program is used by 4nec2 to plot and print 2D and 3D charts/graphs for various data available through the "plot" menu-bar option on the "Geometry (F3)", "Pattern (F4)", "Line- chart (F5)" windows and through the "plot" button on the "Optimizer (F12)" window.

However, before 4nec2 is able to use the gnuplot program, it has to be downloaded from the Internet at <http://www.gnuplot.info/download.html> and installed on your system. After this the gnuplot main directory/folder path has to be specified in 4nec2 by selecting "Setting -> Folders -> gnuplot" on the "Main (F2)" window. See Settings for additional info.

When a plot request is made for a certain data-item two additional windows are displayed. The "plotting options" window in which a number of plot-options can be changed and the "gnuplot graph" window itself in which the resulting graph(s) is/are displayed.

In the "gnuplot graph" window (which belongs to the gnuplot program), when a 2D graph is displayed you can use the right mouse-button to zoom-in on the graph. Use the "u" key to unzoom and/or reset. When a 3D graph is displayed you can use the left mouse-button to rotate the graph.

To **print** the current plot/graph click on the graph icon located on the left at the title-bar for the "gnuplot graph" window and select 'Options->Print'

In the "plotting options" window you can set/switch the following plotting options:

### **General options:**

- Color            To switch plotting color(s)
- Line-width      To change the width of the plotted lines and/or points
- Style            To switch between different plotting styles
- Point-type      To switch point-types for 'points' and 'linespoints'; plotting-style
- Smooth          To 'smooth' the graph by selecting a smoothing algorithm.
- Grid-lines      To enable/disable the grid-lines display.
  
- Open plot        To open/load a previously saved plot/graph.
- Add plot         To add a previously saved plot/graph to the current plot.
- Save plot        To save the current plot/graph for future use.
- Rem plot         To remove/delete the last added plot/graph from the current plot.

### **2D options**

- Log X-axis      To switch between a linear or logarithmic X-axis
- Log Y-axis      To switch between a linear or logarithmic Y-axis
- Double Y-axis   single(left) or double(left+right) Y-axis when two or more plots loaded
- Y2 or Y1 grid   To switch between left(Y1)- or right(Y2) Y-axis grid-lines.

### **3D options**

- View as map     To switch between a 3D or a 2D map-view.
- Size             To change the size of the 3D or map-view.
- Show surface    To switch between grid- or a closed-surface 3D style.
- Log Z-axis      To switch between a linear or logarithmic vertical Z-axis
- Contour plot    To display contour lines on the 3D or map-view
- Nr cont          To change the number of contour lines to display.



- Surface colors To switch between color mapping styles.
- Color style To select between different color maps.
- Make surface To create full 3D surface when only limited (scattered) 3D data is available

All plotting commands generated by 4nec2 are send to gnuplot through a third (normally minimized) command window "gnuplot". You can open/restore this window in case of problems and/or if you are curious about the commands used. But before doing so, I would suggest to first consult the gnuplot help-files available in the '..\gnuplot\doc' folder.

For those interested in the effectiveness of the optimization algorithms used by 4nec2 it is possible to use the 'plot' button after an optimization run (hill-climb or genetic) is done and visualize the search results or 3D search-space....

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## **POVRAY Generate true 3D views**

With this feature you are able to generate true 3D views for your geometry structure or the far field radiation pattern.

This feature works in conjunction with the Povray ray-tracing software, freely available on the internet at <http://www.povray.com/>

The povray files are generated under the “..\4nec2\pov” folder. These files are based on the default povray file named default.pov under the “..\4nec2\exe” folder. In this default file the settings for the light source and the camera position are described. For the more experienced povray users it is possible to modify this default file to get other light or camera settings.

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## DBW and dBuV to S-meter conversion

The following table shows how S DBW (median signal power expected at the receiver input terminals) values can be mapped to S meter readings. There are a few assumptions: the receiver input impedance is 50 Ohms and the transmission line loss is minimal. Also we assume that the S meter is correctly calibrated. In practice, S meters are mostly imprecise and can only give relative readings. (dB values are rounded to integer numbers)

S DBW	dBuV	microvolts	S Meter
-64	74	4050	S9+40 dB
-73	65	1350	S9+30 dB
-83	55	450	S9+20 dB
-93	44	150	S9+10 dB
-103	34	50	S9
-109	28	25	S8
-115	22	12.5	S7
-121	16	6.25	S6
-127	10	3.13	S5
-133	4	1.56	S4
-139	-2	0.78	S3
-145	-8	0.39	S2
-150	-14	0.20	S1

For ease-of-use one could use the below approximation:

S9 equals 34 dBuV  
S9 equals -103 DBW  
each 6 dB less equals one S-point

## Equations to Calculate The Median Voltage at the Input of the Receiver

Ohm's Law:

$$E = I \cdot R \text{ or } I = E/R$$

Power formula:

$$P = EI$$

P is in Watts, E is in Volts and I is in Amps and R is in Ohms.  
Then:

$$P = E \cdot [E/R] = (E^2)/R$$

Solve for Voltage:

$$E^2 = [P \cdot R]$$

Convert to dB:

$$10 \text{ Log } E^2 = 20 \text{ Log } E = 10 \text{ Log } [P \cdot R]$$

Express E in terms of microVolts such that  $E(V) = E(uV) \times 10^6$ , then:

$$20 \text{ Log } E + 20 \text{ Log } [1V / 10^6] = 10 \text{ Log } [P \cdot R]$$

$$E(\text{dBuV}) - 120 = 10 \text{ Log } P + 10 \text{ Log } R$$

Assume  $R = 50 \text{ Ohms}$ :

$$E(\text{dBuV}) - 120 = 10 \text{ Log } P + 10 \text{ Log } (50 \text{ Ohms}) = P(\text{dBW}) + 17$$

$$E(\text{dBuV}) = P(\text{dBW}) + 17 + 120 = P(\text{dBW}) + 137$$

Finally, E in uV is  $10^{(E(\text{dBuV})/20)}$  or  $\text{antilog} [(E(\text{dBuV})/20)]$ . Example:  $35 \text{ dBuV} = 10^{(35/20)} = 56 \text{ uV}$ .

NOTE: VOACAP computes the signal power [S DBW] which is equivalent to the P(dBW) in the above equations. DO NOT confuse the predicted field strength in the VOACAP output, DBU (dB relative to 1 microVolt per meter), with the voltage at the receiver as given by dBuV (dB relative to 1 microVolt) in the above equations.

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## Ground types

Below some various ground types with their conductivity and dielectric constant are given. These values can be used when specifying the GN card for the types 0 (finite ground) and 2 (Sommerfeld-Norton)

Note: When using GN type 2, the required ground file is automatically generated

<u>GN card, soil Description:</u>	<u>Conductivity</u> In S/m	<u>Permittivity</u> (Diel-const.)	<u>Rel-Quality</u>
Salt water	5.0	81	
Fresh water	0.001	80	
Pastoral, low hills, rich soil, typical from Dallas, TX, to Lincoln, NE	0.0303	20	Very Good
Pastoral, low hills, rich soil, typical of OH and IL	0.01	14	Good
Flat country, marshy, densely wooded, typical of LA near the Mississippi River	0.0075	12	
Pastoral, medium hills, and forestation, typical of MD, PA, NY (exclusive of mountains and coastline)	0.006	13	
Pastoral, medium hills, and forestation, heavy clay soils, typical of central VA	0.005	13	Average
Rocky soil, steep hills, typically mountainous	0.002	12-14	Poor
Sandy, dry, flat, coastal	0.002	10	
Cities, industrial areas	0.001	5	Very Poor
Cities, heavy industrial areas, high buildings	0.001	3	Extremely Poor

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## Wire conductivity

Below a wire conductivity table to be used for LD card type 5, wire loading

Material	Conductivity	
	S/m	
Perfect	9.9e99	(lossless)
Silver	6.29e7	
Copper	5.80e7	
Pure Alumin.	3.77e7	
Al. 6063-T832	3.08e7	
Al. 6061-T6	2.49e7	
Brass	1.56e7	
Phospor bronze	9.09e6	
Stnlss Stl 302	1.39e6	

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## AWG Copper Wire Table

AWG Copper Wire Table, converted to metric units.

Note: To get wire radius, divide Diameter by 2.

	Diameter AWG (mm)	Area (mm <sup>2</sup> )	Ohms per 1000 m	Meters per kg	Meters per ohm	Max.I (A)
0000	11.6840	136.5159	0.1608	1.05	6217.9	0.0000
000	10.4038	108.2399	0.2028	1.32	4931.7	0.0000
00	9.2659	85.8573	0.2556	1.66	3910.6	0.0000
0	8.2525	68.1031	0.3225	2.10	3102.9	0.0000
1	7.3482	53.9963	0.4065	2.65	2459.7	0.0000
2	6.5430	42.8114	0.5128	3.34	1950.7	22.0000
3	5.8268	33.9511	0.6463	4.22	1546.9	17.5000
4	5.1892	26.9280	0.8153	5.31	1226.8	13.8000
5	4.6203	21.3468	1.0279	6.70	972.9	11.0000
6	4.1148	16.9316	1.2963	8.45	771.4	8.7100
7	3.6652	13.4338	1.6345	10.65	611.7	6.9100
8	3.2639	10.6530	2.0610	13.43	485.2	5.4800
9	2.9058	8.4434	2.5988	16.94	384.7	4.3500
10	2.5883	6.6991	3.2772	21.36	305.1	3.4400
11	2.3038	5.3074	4.1339	26.94	242.0	2.7400
12	2.0523	4.2120	5.2100	33.96	191.9	2.1700
13	1.8288	3.3445	6.5715	42.83	152.2	1.7200
14	1.6281	2.6508	8.2841	54.00	120.7	1.3700
15	1.4503	2.1035	10.4462	68.08	95.7	1.0830
16	1.2903	1.6649	13.1759	85.87	75.9	0.8530
17	1.1506	1.3239	16.6142	108.29	60.2	0.6810
18	1.0236	1.0478	20.9482	136.56	47.7	0.5390
19	0.9119	0.8315	26.4140	172.21	37.9	0.4270
20	0.8128	0.6606	33.3005	217.12	30.0	0.3370
21	0.7239	0.5240	41.9948	273.78	23.8	0.2690
22	0.6452	0.4162	52.9528	345.22	18.9	0.2120
23	0.5740	0.3295	66.7979	435.31	15.0	0.1700
24	0.5105	0.2607	84.2192	548.98	11.9	0.1330
25	0.4547	0.2067	106.2008	692.18	9.4	0.1056
26	0.4039	0.1631	133.8911	872.78	7.5	0.0853
27	0.3607	0.1301	168.8648	1100.37	5.9	0.0672
28	0.3200	0.1024	212.9265	1387.71	4.7	0.0530
29	0.2870	0.0824	268.4711	1750.25	3.7	0.0418
30	0.2540	0.0645	338.5827	2206.78	3.0	0.0333
31	0.2261	0.0511	426.8373	2782.81	2.3	0.0270
32	0.2032	0.0413	538.3858	3509.23	1.9	0.0213
33	0.1803	0.0325	678.8058	4424.97	1.5	0.0163
34	0.1600	0.0256	855.9711	5579.05	1.2	0.0128
35	0.1422	0.0202	1079.3963	7035.91	0.9	0.0000
36	0.1270	0.0161	1360.8924	8868.74	0.7	0.0000
37	0.1143	0.0131	1716.2073	11184.95	0.6	0.0000
38	0.1016	0.0103	2164.0420	14105.39	0.5	0.0000
39	0.0889	0.0079	2729.0026	17791.19	0.4	0.0000
40	0.0787	0.0062	3441.6010	22430.33	0.3	0.0000

## Genetic Algorithms

Genetic algorithms (GA's) are stochastic search methods that mimic the metaphor of natural biological evolution. These algorithms operate on a population of potential solutions applying the principle of survival of the fittest to produce better and better approximations to a solution. At each generation, a new set of approximations is created by the process of selecting individuals according to their level of fitness in the problem domain and breeding them together using operators borrowed from natural genetics. This process leads to the evolution of populations of individuals that are better suited to their environment than the individuals that they were created from, just as in natural adaptation. Genetic or evolutionary algorithms model natural processes, such as selection, recombination and mutation. They work on populations of individuals instead of single solutions.

An individual, also called chromosome, is a solution to a problem. A chromosome is made up of a collection of genes which are simply the parameters to be optimized. An objective function is used to determine the fitness (relative performance) of an individual.

At the beginning of the computation a number of individuals (the population or collection of chromosomes) are randomly initialized. The objective function is then evaluated for these individuals. The first/initial generation is produced. If the optimization criteria are not met the creation of a new generation starts. Individuals are selected according to their fitness-rank for the production of offspring. Parents are recombined to produce offspring and offspring is then mutated with a small probability. The fitness of the offspring is then computed. The offspring (together with an optional number of parents to survive into the next generation (elitism)) are inserted into the population replacing the original parents thus producing a new generation. This cycle is performed until the optimization criteria are reached.

### Selection and Ranking

Selection determines, which individuals are chosen for mating (recombination) and how many offspring each selected individual produces. The first step is ranking of individuals according their fitness. By default linear ranking is used.

#### Ranking

The population is sorted according to their FOM values. The ranking assigned to each individual depends only on its position in the individuals rank and not on the actual FOM value. Rank-based fitness assignment overcomes the scaling problems of the proportional fitness assignment. (Stagnation in the case where the selective pressure is too small or premature convergence where selection has caused the search to narrow down too quickly.) Rank-based fitness assignment behaves in a more robust manner than proportional fitness assignment and is the default method used.

If required 'exponential' ranking can be used. The use of non-linear ranking permits higher selective pressures than the default linear ranking method. Exponential ranking requires an additional 'base' value. With this value the selective pressure is controlled. This value is the base for the  $(\text{rank}-1)$  exponent. For  $\text{base} > 1$ , on average better individuals will be selected, for large 'base' values only the best ones.

Common 'base' values are between 1.1 and 1.5. Base values  $< 1$  would benefit below average individuals.

The following list shows the recalculated fitness values for exponential ranking for a given base



value:

rank	fitness for base:	2	3	.5
1		1	1	8
2		2	3	4
3		4	9	2
4		8	27	1

Probability as used with the roulette-wheel or SUS selection (see below) equals individual fitness divided by the sum of all fitness values.

The actual selection is performed in the next step. Parents are selected according to their fitness by means of one of the following algorithms:

- Roulette-wheel selection (SSR)
- Stochastic Universal Sampling (SUS)
- Select Top best percent (truncation)
- Tournament selection

#### Roulette-wheel selection (SSR)

The simplest selection scheme is roulette-wheel selection, also called stochastic sampling with replacement (SSR). This involves the following technique: The individuals are mapped to contiguous segments of a line, such that each individual's segment is equal in size to its fitness. A random number is generated and the individual whose segment spans the random number is selected. The process is repeated until the desired number of individuals is obtained. This technique is analogous to a roulette wheel with each slice proportional in size to the fitness. The below list gives an example.

Individual:	1	2	3	4	
Fitness	1	8	2	4	(exp-ranking with base 2)
Selection probability	1/16	1/2	1/8	1/4	

#### Stochastic Universal Sampling (SUS)

Stochastic universal sampling provides zero bias and minimum spread. The individuals are again mapped to contiguous segments of a line, such that each individual's segment is equal in size to its fitness exactly as in roulette-wheel selection. Here equally spaced pointers are placed over the line, as many as there are individuals to be selected. Consider  $N$  as the number of individuals to be selected, then the distance between the pointers is  $1/N$  and the position of the first pointer is given by a randomly generated number in the range 0 to  $1/N$ . For 4 individuals to be selected, the distance between the pointers is  $1/4=0.25$  All individuals are selected in a single 'turn of the wheel'.

It is claimed that stochastic universal sampling ensures a selection of offspring, which is closer to what is deserved, than roulette wheel selection.

#### Top N percent selection (truncation)

Compared to the previous methods 'Top N percent' selection is a more artificial selection method. It is used by breeders for large populations/mass selection. In Top N percent selection individuals are sorted according to their fitness. Only the best N percent of the individuals are selected for parents. These selected parents are randomly chosen to produce offspring. The parameter is the percentage of the population to be selected as parents and takes values ranging from 50%-10%.

#### Tournament selection

In tournament selection a number *Tour* of individuals is chosen randomly from the population and the best individual from this group is selected as parent. This process is repeated as often as individuals to choose. The selected parents are randomly chosen to produce offspring. An additional parameter for tournament selection is the tournament size. This takes values ranging from 1 - N (number of individuals in population)

If tournament size is 1 this defaults to random selection. A tournament size of N defaults to best selection. 2 (standard and not very selective ) and 7 (relatively highly selective) are popular values.

Using larger tournaments has the effect of increasing the selective pressure, since below average individuals are less likely to win a tournament, while above average individuals are more likely to win.

### **Elitism**

One way to ensure that the best individual(s) will increase from one generation to the next is to re-use the best chromosomes from each generation in next one, bypassing the selection, crossover and mutation operators for those chromosomes. This strategy is frequently referred as 'elitism'. Its benefit is obvious, but there may be a cost, namely loss of diversity in the population. If elitism is used the number of best chrom's re-used in the next population is specified in the 'Chro's to re-use' field.

### **Recombination**

Recombination is done through crossover and mutation. After selection has been carried out, the parents to create the new population are known.

The crossover operator is a method of sharing information between chromosomes; it combines the features of two parent chromosomes to form two new offspring., with the possibility that good chromosomes may produce better ones. The crossover operator is not usually applied to all parents. A random choice is made, where the like hood of crossover being applied depends on the so-called crossover probability. This probability plays a central role in Genetic Algorithms. Its value is mostly set somewhere between 60-90 percent.

The mutation operator arbitrarily alters one or more genes (variables) of a selected chromosome so as to increase structural variability of the population. The role of mutation in GA's is that of restoring lost or unexplored solutions into the population to prevent the premature convergence of GA to sub-optimal solutions. It ensures that the probability of reaching any point in search space is never zero. Each gene/variable in the chromosome undergoes a random change according the mutation probability, which mostly has a value between 1 and 4 percent. For large number of variables the lower values could be specified, for fewer variables a higher value could be appropriate.

The below real-value based crossover algorithms are available:

- Arithmetic crossover
- Heuristic crossover
- Blend crossover (BLX)
- Simulated binary crossover (SBX)
- 1-point crossover
- 2-point crossover

- Uniform crossover

#### Arithmetic crossover

With arithmetic crossover offspring variables are created at a certain point linear between both parent values. The position is determined by the 'alpha' parameter. The below equation is used:

$$\begin{aligned}\text{offspring1}(j) &= \alpha * \text{parent1}(j) + (1-\alpha) * \text{parent2}(j) \\ \text{offspring2}(j) &= (1-\alpha) * \text{parent1}(j) + \alpha * \text{parent2}(j)\end{aligned}$$

#### Heuristic crossover

This crossover operator uses the fitness values of the two parents to determine the direction for which to create new offspring. The offspring are created according to the following equations:

$$\begin{aligned}\text{offspring1}(j) &= \text{best-parent}(j) + \text{Rnd} * (\text{best-parent}(j) - \text{worst-parent}(j)) \\ \text{offspring2}(j) &= \text{best-parent}(j)\end{aligned}$$

Rnd = a random value between 0 (inclusive) and 1. The offspring variables are clipped between the variables upper- and lower limits.

#### Blend crossover (BLX)

With blend crossover a point is chosen randomly on the (extended) interval between both parent variables. The parameter alpha specifies the amount for which this interval is extended on either side of the interval. For example:

parent1 variable : 10, parent2 variable : 20 -> delta interval : 20-10=10

if alpha = 0.5 then the range for offspring random variable selection is between  
 $10-(0.5*\text{delta}) = 5$  and  $20+(0.5*\text{delta}) = 25$

The below equations are used to create offspring:

$$\begin{aligned}\gamma &= (1+2*\alpha) * \text{Rnd} - \alpha \\ \text{offspring1}(j) &= \gamma * \text{parent1}(j) + (1-\gamma) * \text{parent2}(j) \\ \text{offspring2}(j) &= (1-\gamma) * \text{parent1}(j) + \gamma * \text{parent2}(j)\end{aligned}$$

Rnd = a random value between 0 (inclusive) and 1. The offspring variables are clipped between the variables upper- and lower limits.

It is claimed that BLX with an alpha parameter of 0.5 performs better than other alpha values. BLX with an alpha value of zero is the equivalent to flat crossover that uniformly samples offspring between the two parents.

#### Simulated binary crossover (SBX)

Simulated binary crossover (SBX) was developed by incorporating the essence of the self-adaptation mechanism into the crossover operator. This approach is similar to BLX in the sense that the offspring is created in proportion to the difference between the parents but SBX has a unique property – that is, solution-points near the parents are more likely to be selected as their offspring than solution-points distant from the parents

An additional parameter, the distribution index is required. This is a nonnegative real number. A large value gives a higher probability for creating near parent solutions and a small value allows distant solutions to be selected as children solutions

As an example: 2.0 produces distant- and 5.0 near-parent offspring.

It was reported that a GA with SBX outperformed a GA with BLX – 0.5 on some test functions.

### 1-point crossover

In 1-point crossover one crossover position  $k$  between 1 and  $N$  (number of variables) is randomly selected and the variables exchanged between the individuals about this point, then two new offspring are produced. Consider the following two individuals with 5 variables each, which will also be used to illustrate the other types of recombination:

parent1	12.5	88.4	22.6	4.5	33.2
parent2	10.5	102.0	15.8	9.2	42.1

The chosen crossover position is: 2  
After crossover the new individuals are created:

offspring1	12.5	88.4	15.8	9.2	33.2
offspring2	10.5	102.0	22.6	4.5	42.1

### 2-point crossover

In 2-point crossover two random "switching" points are chosen between 1 and  $N$  and the variables exchanged between the individuals about both points and again two new offspring are produced.

### Uniform crossover

Uniform crossover performs an exchange of variable values between two individuals by looping through all variables from 1 to  $N$  and randomly deciding from which of both parents to get the variable value. The other offspring is created the 'inverse' way.

parent1	12.5	88.4	22.6	4.5	33.2
parent2	10.5	102.0	15.8	9.2	42.1

For each variable the parent who contributes its variable to the offspring is chosen randomly with equal probability. After crossover the new individuals are created:

offspring1	12.5	102.0	22.6	9.2	42.1
offspring2	10.5	88.4	15.8	4.5	33.2

## **Mutation**

After recombination through crossover, offspring undergo mutation. Offspring variables are mutated by the addition of small random values, with low probability. The below real-value based mutation operators are available:

- Boundary
- Uniform
- Gaussian
- None-uniform

### Boundary mutation

A mutation operator that replaces the value of the chosen variable with either the upper or lower bound for that gene (chosen randomly).

### Uniform mutation

With uniform mutation the value for the selected variable is replaced by a random value chosen uniformly from the interval between the user-specified lower- and upper variable bounds.

### Gaussian mutation

A gaussian distribution represents a bell-shaped curve around a certain mean value and with a certain width, called the deviation. If a random gaussian number is generated, there is a bigger possibility that it is generated near the mean value and a smaller possibility that it is generated further away. For a standard-deviation of one and a mean of zero, 68 % of all random values are between +1 and -1, between -2 and +2 are 95% of the values and between -3 and +3 are 99.7 percent of all values.

With the gaussian mutation operator, an additional 'sigma' value is used. The default for this value is 2, meaning that a deviation value is chosen equally to the difference between the user-specified upper- and lower gene-bounds divided by 2. Resulting in a possibility of 95 percent that the generated value is in range. You may manually change this 'sigma' parameter to use other deviations. The 'mean' value for the random number equals the current gene-value to mutate.

The new variable/gene value is clipped if it falls outside of the lower- or upper-bound for the gene.

If a 'sigma' of zero is specified, the actual sigma value is related to the number of generations, ranging from 2 at the start to almost zero at the end; according the below equation:

$$\text{sigma} = 0.5 * 1 / (1 + \sqrt{\text{generation number}})$$

This will enable a more broad search at the beginning and narrow it at the end of the process.

### None-uniform mutation

Another mutation operator that increases the probability that the amount of the mutation will be close to 0 as the generation number increases. This mutation operator keeps the population from stagnating in the early stages of the evolution then allows the genetic algorithm to fine tune the solution in the later stages of evolution. The chosen gene is mutated according to the following equations:

mutated gene    a) gene + delta(gener\_nr, MAX-var)    for Rnd() < 0.5  
                  or b) gene - delta(gener\_nr, var-MIN)    for Rnd() >= 0.5

$$\text{delta}(t, Y) = Y * (1 - \text{Rnd} ^ ((1 - t / \text{max\_generations}) ^ b)$$

t = gener\_nr

b = user parameter specifying degree of dependency on nr of iterations.

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## Nec-2/4 Short Reference guide

Fieldnr ->	1	2	3	4	5	6	7	8	9	10	11
Wire geom	GW	TagNr	NrSegs	X1	Y1	Z1	X2	Y2	Z2	rad	
No ground	GE	0	-	-	-	-	-	-	-		
Gnd plane		1	(Mirror struc, current expans, GN required: rad-W blank)								
Ground		-1	(Mirror struct, no current exp, GN required)								
Free space	GN	-1	-	-	-	-	-	-	-		
Finit. gnd		0	W-rad	0	0	diel.	cond.	radius	(changes RP)		
Perf. gnd		1	-	-	-	-	-	-			
Sommerfeld		2	0	0	0	diel.	cond.	0			
Voltage src	EX	0	Tagnr	Segnr	--XX	U-real	U-imag				
Current src		6	Tagnr	Segnr	--XX	I-real	I-imag				(*)
Nullify	LD	-1	-	-	-	-	-	-			
Serie RLC		0	Tagnr	beg-S	0/end	R(ohm)	L(H)	C(F)			
Paral. RLC		1	Tagnr	beg-S	0/end	R(ohm)	L(H)	C(F)			
Serie RLC		2	Tagnr	beg-S	0/end	R	Xl	Xc			
Paral. RLC		3	Tagnr	beg-S	0/end	R	Xl	Xc			
Impedance		4	Tagnr	beg-S	0/end	Z(ohm)	0	0			
Wire cond.		5	Tagnr	beg-S	0/end	Y(S/m)	0	0			
LC trap		6	Tagnr	beg-S	0/end	coil-Q	L(H)	C(F)			(*)
Insul-wire		7	Tagnr	beg-S	0/end	Diel-c	Radius				(*)
Trans-line	TL	Tag-1	Seg-1	Tag-2	Seg-2	Z0	Length	G1r	G1i	G2r	G2i
Network	NT	Tag-1	Seg-1	Tag-2	Seg-2	Y11r	Y11i	Y12r	Y12i	Y22r	Y22i
Freq.lin.	FR	0	steps	0	0	Start	St-siz	-			
Freq.log.		1	steps	0	0	Start	St-siz	-			
All curr.	PT	-2	-	-	-	-	-	-			
No curr.		-1	-	-	-	-	-	-			
Spec curr.		0	Tagnr	beg-S	0/end	-	-	-			
Receiv. pat		1	Tagnr	beg-S	0/end	-	-	-			
All charg.	PQ	-1	-	-	-	-	-	-			
Spec charg.		0	Tagnr	beg-S	0/end	-	-	-			
Far Field	RP	0	nr-Th	nr-Ph	XNDA	sta-Th	sta-Ph	siz-TH	siz-Ph	0/dist	0/gain
add surf-W		1	nr-Th	nr-Ph	XNDA	sta-Th	sta-Ph	siz-TH	siz-Ph	distan.	0/gain
Gnd cond.		2,3	nr-Th	nr-Ph	XNDA	sta-Th	sta-Ph	siz-TH	siz-Ph	0/dist.	0/gain
Gnd screen		4	nr-Th	nr-Ph	XNDA	sta-Th	sta-Ph	siz-TH	siz-Ph	0/dist.	0/gain
Condit+Scr.		5,6	nr-Th	nr-Ph	XNDA	sta-Th	sta-Ph	siz-TH	siz-Ph	0/dist.	0/gain
Elec. Field	NE	0	nr-X	nr-Y	nr-Z	sta-X	sta-Y	sta-Z			
Magn. Field	NH	0	nr-X	nr-Y	nr-Z	sta-X	sta-Y	sta-Z			
Geometry :	XX	I1	I2	F1	F2	F3	F4				
		12	3-5	6-10	11-20	21-30	31-40	41-50			
Prog ctrl :	XX	I1	I2	I3	I4	F1	F2	F3	F4	F5	F6
		12	3-5	6-10	11-25	16-20	21-30	31-40	41-50	51-60	61-70 71-80

--XX: 19: 0=No action, 1=print rel admit. matrix  
 20: 0=No action, 1 print imp's for freq sweep

XNDA: 17: 0=major/minor axis, 1=vert/hor gain  
 18: 0=no norm. gain, 1-5=norm gain  
 19: 0=power gain, 1=directivity gain  
 20: 0=no averaging, 1=average gain, 2=radiation-efficiency

TL: Multiple ports are connected in parallel

If connected to segment with LD, LD is in series with TL

NW: LC fields: positive -> L in Henry, negative -> C in Farad

Note: - This summary is far from complete. It only lists the most important cards used by the author for his initial steps on the antenna-modeling path.  
- Use the 'NEC editor' (See 'Settings' option on the 'Main' form) or consult the Nec-2 or Nec-4user-manual to assist with filling the appropriate positions for the different NEC cards.  
(\* ) 4nec2 extension to default 'NEC-language'

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## **Information and Troubleshooting**

For problems concerning memory-settings or those related to segment/dimension limits and the selected NEC-engine, see [Settings](#)

For additional information or troubleshooting, see the `_ReadMeFirst.txt` text file located in your 4nec2 home-folder. Or contact the author (See [About](#))



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## About 4nec2

The 4nec2 program initially was made as a home building project because there were no means for defining a user specified antenna structure with the I<sub>ts</sub>HF propagation software, but when more and more features were added it seemed to me that it would be nice if other people could also use the program. So the program reached the Internet where it is free for download.

The first version was developed in the year 1995 under the DOS operating System with the Q-basic language. In the following year it was ported to windows-95 and modified to run with the visual basic 3.0 version. Unfortunately this visual basic version was based on the older 16-bit operating system layout, so real "multi-tasking" was not supported. Version 4.0, was the first 32 bit version. With this version the NEC-editor, variables/symbols and the optimizer were included.

Later on, new versions with additional features and possibilities were created such as a real-time 3D viewer and a graphically based geometry-editor and provisions were added to also read/process Nec-4 based in- and output-files. The name 4nec2 however was not changed, but it should now be seen as "for NEC too", meaning another piece of software to use with NEC.

However, because it's a home building project and I don't have very much time testing all the program features, it is most likely that there are still errors in the program included. If you detect such an error, please contact me, and if possible describe the problem, include your NEC based input file and I will try to correct the problem and send you an updated version.

If you have any remarks, complaints, questions or suggestions for additional features or would like to add or alter functionality, please don't hesitate to contact me at [4nec2@gmx.net](mailto:4nec2@gmx.net)

**Unfortionally because of the rapidly increasing amount of Spam and Virusses and thus to avoid deleting your mail as Spam, please include "4nec2 modeller" as the subject !!**

Finally I want to thank Raymond Anderson for giving me the opportunity to publish this program on the internet, Livio Cicala for his help with my first steps on 3D-Drawing, Hardy Lau for his extensive support to get 4nec2 work together with Nec-4 based files and all others who contacted me to report bugs, information and/or suggestions.

Greetings from Holland,

Arie Voors.