# LORA / LORAWAN TUTORIAL 38 NEC Antenna Modelling Software, 4NEC2















## INTRO

In this tutorial I will explain what a NEC at the 4NEC2 antenna modelling software.

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#### In this tutorial I will explain what a NEC antenna modelling software is and how to use



- On Internet and YouTube you can find tutorials how to build certain antennas.
- But often I wonder what is the performance of these antennas? What if I use a slightly different wire diameter or slightly change the length of a at all?
- having to build the actual antenna right away.
- and metal structures.

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particular wire? Will these changes impact the antenna performance significantly of not

Using an antenna modelling software can help you to answer these questions without

• NEC (Numerical Electromagnetics Code) is a popular antenna modelling system for wire and surface antennas and simulates the electromagnetic response of antennas



- information you provide with regard to the ground and wire conductivity.
- But be aware, in the real world using the actual antenna, the result will be slightly where the antenna is mounted etc.

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• The accuracy of the calculation depends on how well you model the antenna and the

different compared to the simulation. This is caused by reflections, weather conditions,



- For example I used a steel coat hanger with a 3 mm wire diameter to build an antenna. I spend 2 hours to remove the plastic coating and cutting the antenna elements to their correct lengths.
- the VSWR.

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• For the LoRa/LoRaWAN tutorials I have build several simple antennas, which I will demonstrate in upcoming tutorials, and I have model these antennas. To my surprise most of these antennas behaves as predicted by the antenna modelling software.

• If you are planning to build your own antenna I highly recommend that you first model your antenna before actually building it. It will safe you time, money and frustration.

• When I finished building the antenna I used the NI20ISA antenna analyser to check



- The result was not great, my antenna has a VSWR of 3.
- to get a VSWR less than 2.
- radiation patterns. These radiation patterns are just as important as the VSWR.
- gateways are located on a flat area than this antenna will not perform great.

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• I decided to use an antenna modelling software to check what I have done wrong.

• By changing certain antenna parameters in the model I concluded that I used the wrong wire diameter. Instead of 3 mm I should have used a wire diameter of 1.8 mm

• The antenna modelling software also provides the horizontal and vertical antenna

• What if the main lobe is pointing upwards instead of sideways. If your sensors and



## NEC ANTENNA MODELLING SOFTWARE

- Here are a few NEC antenna modelling software:
  - has a 20 segments limit. http://www.eznec.com
  - 4NEC2 Available for Windows and its free. This tool has many options. https://www.qsl.net/4nec2/
  - http://www.w7ay.net/site/Applications/cocoaNEC/

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• EZNEC - Available for Windows. It has a free and a paid version. The free version

cocoaNEC - Available for MAC OSX and its free. This tool has limited options.



## NEC ANTENNA MODELLING SOFTWARE

mode helical antenna.



### Normal mode helical antenna modelled with the 4NEC2 program.

 So I ended up using 4NEC2 which I highly recommend. Unfortunately it is only available for Windows.

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I have used cocoaNEC but I encountered problems when trying to model a normal



## NEC

- Electromagnetics Code) engine which does all the calculations.
- and is an antenna modelling system for wire and surface antennas.
- More information about NEC-2: <u>https://www.nec2.org</u>
- The NEC2 documentation is composed of three sections: **Part II**: NEC Program Description - Code, http://www.radio-bip.qc.ca/NEC2/nec2prt2.pdf Part III: NEC User's Guide, <u>https://www.nec2.org/other/nec2prt3.pdf</u> Part III is the documentation you need.

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• The previous mentioned 3 antenna modelling software uses the NEC-2 (Numerical

NEC was developed by the Lawrence Livermore National Laboratory in the 1970s

Part I: NEC Program Description - Theory, <u>https://www.nec2.org/other/nec2prt1.pdf</u>



## NEC

### NEC2 quick reference: <u>https://www.mobilefish.com/download/lora/nec2\_quick\_reference.pdf</u>



## HOW IT WORKS

- In general, most antenna modelling software provides 2 input methods: - using a spreadsheet style editor
  - using a simple text editor



#### **Spreadsheet style editor**

•	•				dipo	le_vertical_86	38mhz					
	Edit:											
#	x	У	z	x	У	z	radius	segments	transform	•	name	co
1	0.0	0.0	0.9190	0.0	0.0	1.0810	0.9000 mm	21				
+	-							Display:	Metric		Show	w Card
	-					-						
	Environment	Variables	Transforms	Network	s Output	Control						Run

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#### **Text editor with card deck**

	•				📄 di	pole_vertic	al_868mhz.o	deck		
СМ СЕ	C0C	OANEC	2.0	2019	-7-9 12:01	2019-7-9	12:01			
GW	1	21	0.00	00000	0.000000	0.919000	0.000000	0.00000	1.081000	9.00E-04
GE FR	0 0	1	0	0	868.0000	0.00000				
EX	0	1	11	1	1.000000	0.00000				
RP	0	1	360	1000	80.00000	0.000	0.000	1.000	5.000E+03	
RP	0	360	1	1000	-90.000	0.000000	1.000	0.000	5.000E+03	
RP	0	91	120	1001	0.000	0.000	2.000	3.000	5.000E+03	
XQ										
FN										



## HOW IT WORKS

• There are antenna modelling software available (e.g. 4NEC2) where you can model the antenna by drawing it, using a Graphical User Interface (GUI).





# 4NEC2 ANTENNA MODELLING DEMONSTRATION



## INSTALL 4NEC2

- Goto <u>https://www.qsl.net/4nec2/</u> and download 4nec2 (setup.exe) The downloaded 4nec2.zip file contains file Setup\_4nec2.exe (v 5.8.16) Unzip this file.
- Install 4NEC2 by double clicking file Setup\_4nec2.exe. 4NEC2 can be installed on any directory. For example: c:\tools\4nec2
- The folder c:\tools\4nec2 contains: - The getting started guide: \_GetStarted.txt - The complete NEC-2 Manual, Part III: User's guide: Nec2.doc - The NEC2 Short reference card: Cards.rtf



## INSTALL 4NEC2

- The complete 4NEC2 help in document format 4nec2/exe/4nec2.rtf
- Many antenna model examples: 4nec2/models



## 1/2 WAVELENGTH DIPOLE ANTENNA





## 1/2 WAVELENGTH DIPOLE ANTENNA

- $\frac{1}{2}\lambda$  dipole antenna (vertical polarised).
- Antenna parameters: f = 868 MHz $\lambda = 0.34538 \text{ m}, \frac{1}{2}\lambda = 0.17269 \text{ m}$ wire material = stainless steel length = 0.173mwire diameter = 1.8 mmwire radius = 0.9 mm = 0.0009 mheight = 0.010 m (1 cm above ground)

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#### **Coordinates in meters**



- Start the 4NEC2 program.
- Close all windows except the Main window.
- Main menu select: Settings | Length unit | select your unit, for example: Meters Settings | Radius unit | select your unit, for example: Millimeters
- Enable Geometry edit
- Enable Auto segmentation

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🍟 Main [¥5.8.16] (F2) Settings Calculate Window Show Run Help File Edit Notepad Edit Ctrl+F1 🔤 🖸 📕 🤹 🕸 Q 🖓 Ctrl+F2 NEC editor Filename 868 Mhz Juency Geometry edit Ctrl+f3 0.345 velength. mtr NEC editor (new) Ctrl+F4 Voltage lent, Auto segmentation Stepped radius corr. Impedance jes comp. Parallel forn allel comp. Input Power S.W.R.50 w t power Char-impedance Efficiency cture loss m₩ pre-defined Frequencies Radiat-eff. work loss u₩ pre-defined Symbols RDF [dB] liat-power w. Show Circular-Polar. 🗖 Polar Environmer Loads Real/Som nd) Phi/Azim unit Length unit Radius unit NEC-Engine Comment Memory usage This is a d Optimizer/Eval ItsHF settings Other settings Folders Seg's/patches start stop count step 13 Pattern lines Freq/Eival steps Calculation time



- Open Geometry Editor (CTRL + F3) CTRL + F1: Notepad CTRL + F2: NEC editor
   CTRL + F3: Geometry edit (GUI editor) CTRL + F4: NEC editor (new)
- Geometry Editor:
   Options | Set Segmentation | Medium (25)





• An antenna consists of wires and each wire is subdivided into segments.



 $\frac{1}{2}\lambda$  dipole antenna

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- Draw a wire between 2 points:  $pI = (x_1, y_1, z_1)$  and  $p2 = (x_2, y_2, z_2)$ . - Divide the wire into segments. No of segments = 7 - In this example the feedpoint is located at segment #4.



 If the feedpoint is located in the middle odd number.



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• If the feedpoint is located in the middle of a wire the number of segments must be an

### $\frac{1}{2}\lambda$ dipole antenna

#segments = 6
This is not good. Feedpoint is off center.



• If the feedpoint is located at the end of a wire the number of segments can be an odd or an even number, it does not matter.



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### $\frac{1}{4}\lambda$ ground plane antenna



- But you can do it yourself, but it is not recommended. There are certain rules you must follow.
- If the number of segments is too low the calculations are not accurate. If it is too high the calculations takes a lot of time.

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• You can let the 4NEC2 program to automatically calculate the number of segments.



- The length of each segment must be between 5% and 10% of the wavelength.
- If the ratio of segment length to wire radius is greater than 8 the NEC engine simulates the current flow in the wire as a very thin current thread. The NEC engine uses the default "Thin Wire Kernel" (Do not use EK card)
- evenly distributed on the circumference of the wire for a more accurate result. In this situation you should use the EK card (Extended Thin Wire Kernel).
- Never make the ratio go below 2.

• If the ratio is between 2 and 8 the NEC engine should simulate the current to be



• Rules:

### Rule I: Segment length must lie between 5% $\lambda$ and 10% $\lambda$ Rule 2: Ratio = Segment length / wire radius If the Ratio is between 2-8 use the EK card If the Ratio > 8 do not use the EK card



#### • Example:

frequency = 868 MHz, thus  $\lambda$  = 345.38 mm Wire length = 175 mmWire diameter = 1.8 mm

#### • Answer:

 $5\%\lambda = 0.05 \times 345.38 = 17.269 \text{ mm}$  $10\%\lambda = 0.10 \times 345.38 = 34.538$  mm Segment length = Wire length / number of segments = 175 / 8 = 21.87 mm

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#### Question: Can the wire be divided in 8 segments and should EK card be used or not?



- The segment length=21.87 mm and lies between 17.269 mm and 34.538 mm The number of segments=8 is correctly chosen.
- Ratio = Segment length / wire radius Wire diameter = 1.8 mmRatio = 21.87 / 0.9 = 24.3The ratio is greater than 8, which means do not use the EK card.



## EKCARD

• Use the EK card to specify the use of the extended thin-wire kernel. EK stands for Extended Kernel. For example:



0 or blank = Use the extended thin-wire kernel (Ratio 2-8). -I or no EK card = Use the standard thin-wire kernel (Ratio > 8).



- Geometry Editor select: Options | No-auto-segmentation DO NOT SELECT Options | Set Field separator | TAB Options | Write Symbols / variables DO NOT SELECT File | New File | Save As | dipole\_demo.nec
- Set display frequency: 868 MHz (Press Enter) Save file and open dipole\_demo.nec



## CECARD

• Use the CE card to specify the end of the comment section. CE stands for Comment End. For example:

### CE



## GE CARD

• Use the GE card to specify the end of the geometry input. GE stands for Geometry End. For example:



- 0 = No ground.
- I = Ground plane present, wire-ends for Z=0 are 'connected' to ground. In LoRa systems this is not used.
- -I = Ground present, wire-ends are not 'connected' to ground (GN card required)



## FR CARD

• Use the NEC FR card to specify the design frequency. FR stands for Frequency. For example:



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Freq. stepping increment





3D view XZ plane YZ plane XY plane

Add new object Select object Delete object

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Wire geometry V/I sources RLC loading Transmission lines Comment/Wire data Frequency Ground parameters



• Model the antenna, first select XZ plane.

Ħ Add 🕅 m ₩.

• Draw a vertical line on the zaxis. Radius = 0.9 mmEnd-1 = 0, 0, 0.010 mEnd-2 = 0, 0, 0.183 mThe wire is automatically divided into 21 segments.





• Open Geometry window (F3). Show segments: Show | Segments Visually check the model. Validate | Run geometry check. Validate | Run segment checks. Save file and open dipole\_demo.nec

Keys	Description			
↑↓	Rotate up/down			
$\leftarrow \rightarrow$	Rotate left/right			
Page Down	Zoom out			
Page Up	Zoom in			
CTRL + ← →	Move left/right			
CTRL + ↑↓	Move up/down			
Home	Reset			



## GW CARD

• Use the NEC GW card to specify the wire dimensions. GW stands for Geometry Wire. For example:



The wire element is subdivided into a number of segments.


Add feed / transmission line (optional).
 Save file and open dipole\_demo.nec



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- P2 (0.05, 0, 0.1065), +0.01 m from segment 11 center
- Wire, with tag 2, divided into 3 segments
  - PI (0.05, 0, 0.0865), -0.01 m from segment II center

All units in meters Wire (Tag I) segment length = 8.8238 mm



## TL CARD

• Use the NECTL card to specify the transmission line. TL stands for Transmission Line. For example:



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The length of the transmission line in meters



• In all my antenna models, I never model the transmission line. For demonstration purpose I have shown how this is done in case you need it. Delete the transmission line and wire tag 2.



Add Voltage / Current source



 Select: Voltage Select Tag: I, Segment: II
 Voltage value: I + J 0V
 Enable: Fixed power-level
 Save file and open dipole\_demo.nec





## EX CARD

 Use the NEC EX card to specify the Voltage or Current source. EX stands for Excitation. For example:



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### I am always using: Voltage source = I+j0 volt (IV @ 0 deg)

Volts or Amps



Add wire conductivity.



• Drag mouse over the wire. Select: Wire-Ld Select G (S/m): St. Steel Select: Whole struct. Save file and open dipole\_demo.nec



## LD CARD

LD

• By default a perfect wire is used with zero loss. Use the NEC LD card to specify the wire conductivity. LD stands for Loading. For example:

0

Use loading type 5 to specify the wire conductivity

Electrical conductance in mho/meter

When both numbers are zero all segments of the wire element will have the wire conductivity

1390000

Tag number, referring to a specific element. If Tag number = 0 all elements have the same material conductivity.





## ELECTRICAL CONDUCTANCE

- The SI unit for electrical conductance is Siemens per meter (S/m). The archaic term for this unit is the mho (ohm spelled backwards).
- One mho is equal to one Siemens.



## ELECTRICAL CONDUCTANCE

Material	Electrical Conductance (mho/m or S/m)
Perfect	9.9 × 1099
Silver	$6.29 \times 10^{7}$
Copper	5.8 × 10 <sup>7</sup>
Aluminium	3.77 × 107
Alu-T832	3.08 × 10 <sup>7</sup>
Alu-T6	$2.49 \times 10^{7}$
Brass	$1.56 \times 10^{7}$
P-bronze	9090000
Stainless steel	$1.39 \times 10^{6}$
Insulator	0.00001

Source: 4NEC2 program



Specify ground parameters



 Select Type: Real ground Select: City industrial area Save file and open dipole\_demo.nec



- You can choose between 5 ground types. All ground types extends indefinitely to the horizon.
- Free space (GN I) There is an absence of any surface beneath the antenna. There is no ground influence. The antenna radiates in all directions without reflections. Use this option to compare antennas of similar types.
- Fast ground (GN 0 0 0 0 3 0.0001) Can model a ground screen (number of radials etc) at Z=0. Vertical and horizontal wires should not touch ground. Horizontal wires should be at least  $\lambda/10$  above ground.



• Perf ground (GN I) The ground has perfect conductivity. No losses!

Horizontal wires should not touch ground and should be above ground by a certain factor:  $(h^2 + r^2)^{1/2} > 10^{-6} \lambda$ h = wire heightr = wire radius $\lambda$  = wavelength

Vertical wires may touch the ground.

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The ground acts like a mirror and creates an image antenna identical to the original.



 Real ground (GN 2 0 0 0 3 0.0001) aka Sommerfeld-Norton ground.

Vertical and horizontal wires should not touch ground. Horizontal wires should be at least  $\lambda/200$  above ground.

Specify the ground conductivity near the antenna. You can also specify a second ground type that extends a specified radius.

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## Use this ground type for the highest accuracy of results for antenna models above



 MiniNec ground (GN 3 0 0 0 3 0.0001) elevated radial system or, when using verticals, use the MiniNec ground type.

Vertical wires may touch ground. Horizontal wires should be at least  $\lambda/5$  above ground.

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## When wires are connected to a real ground or fast ground (Z=0) the reported antenna impedance is usually unpredictable. To avoid this, use a real ground with an



### Ground type overview:



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#### Free space (GN - I)

No ground



## GN CARD

• Use the NEC GN card to specify the ground parameters. GN stands for Ground. For example:



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Conductivity in mhos/meter of the ground. Leave blank in the case of a perfect ground.

Dielectric constant of the ground. Leave blank in case of a perfect ground.



## GN CARD

## Free space: GN - I Perfect ground: GN I



## GROUND DIEL-CONST & CONDUCTIVITY

Ground	Diel-const	Conduct. mhos/meter
Poor	5	0.001
Moderate	4	0.003
Average	13	0.005
Good	17	0.015
Dry, sandy, costal	10	0.001
Pastoral hills, rich soil	17	0.007
Medium hills and forest	13	0.004
Mountainous hills < 1000 m	5	0.002
Rocky, steep hills	13	0.002
Fertile land	0	0.002

Source: 4NEC2 program (For ground type = 0, 2 and 3)



## GROUNDTYPE

### Ground

Rich agriculture land, low hills Marshy land, densily wooded Marshy, forested, flat Highly moist ground City industrial area City industrial average att. City industrial maximum att. Fresh water Fresh water 10° / 100 MHz Fresh water 20° / 100 MHz

Source: 4NEC2 program (For ground type = 0, 2 and 3)

Diel-const	Conduct. mhos/meter
15	0.001
12	0.0075
12	0.008
30	0.005
3	0.0001
5	0.001
3	0.0004
80	0.001
84	0.001
80	0.005



## GROUNDTYPE

#### Ground

Sea water Sea water 10°, up to 1 GHz Sea water 20°, up to 1 GHz Sea ice Polar ice Polar ice cap Artic land

### Source: 4NEC2 program (For ground type = 0, 2 and 3)

Diel-const	Conduct. mhos/meter
81	5
80	4
73	4
4	0.001
3	0.0003
	0.0001
3	0.0005



 Press the Calculate button to run the NEC engine.



 Select: Far-Field pattern Select: Full Resolution: 5 deg Press: Generate

Generate (F7) [Nec2	2dXS1k5] X						
O Use original file	Auto-Segm.						
Far Field pattern	Freq : 868 💌						
O Near Field pattern	🔲 from file						
<ul> <li>ItsHF 360 degree Gain table</li> <li>ItsHF Gain @ 30 frequencies</li> </ul>							
● Full ● Ver. ●	) Hor.						
Resol. 5 deg.							
Surface-wave	Run Average     Gain Test						
E-fld distance	Gamrest						
Expert settings							
<u>G</u> enerate Ba	tch E <u>x</u> it						



• In the Main window, you can see the calculated SWR.

	📸 Main [¥5.8.	.16] (F2)		
	File Edit Set	tings Calculate V	Vindow Show Run	Help
H.		9 3D 🛃 🛞 🖄	🥮 🙀 🔳 🕫	1 🛄 😲
	Filename 🛛	dipole_demo2.out	Frequency Wavelength	868 Mhz 0.345 mtr
	Voltage	113+j0V	Current	889 - j 428 mA
	Impedance Parallel form	103 + j 49.5 127 // j 263	Series comp. Parallel comp.	3.705 pF 0.698 pF
	S.W.R.50 Efficiency Radiat-eff. RDF [dB]	2.64 99.11 % 28.31 % 5.88	Input power Structure loss Network loss Radiat-power	100 W 888.3 mW 0 uW 99.11 W
	Environment		- Loads [	Polar
	FINITE GROUP RELATIVE DIE CONDUCTIVIT COMPLEX DIE	ND. SOMMERFELD LECTRIC CONST.= Y= 1.000E-04 MHO: LECTRIC CONSTAN	SOLUTION 3.000 S/METER NT= 3.00000E+00-2.07	'097E-03
	, Comment			
	Seg's/patches Pattern lines Freq/Eval steps Calculation time	21 2701 1 0.203 \$	start sto Theta -90 90 Phi 0 36	p count step 0 37 5 0 73 5



- In the Pattern window (F4) you can see the the vertical and horizontal radiation pattern. Use Spacebar to switch from Vertical plane to Horizontal plane.
- Click on blue line to show the gain at certain angles.
- Drag mouse to show the gain at certain angles.





## AZIMUTH & ELEVATION

- The azimuth angle symbol is  $\Phi$  (phi). Theta runs [0, 360) degrees.
- Elevation (or vertical plane) is the angle measured of the z-axis. The elevation angle symbol is  $\Theta$  (theta). Phi runs [0, 180) degrees.
- other software systems.

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#### • Azimuth (or horizontal plane) is the angle measured counterclockwise of the x-axis.

### • The above is based on the 4NEC2 antenna modelling software and can differ with





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### Coordinate system used by 4NEC2



## AZIMUTH & ELEVATION

• 4NEC2 example







## AZIMUTH & ELEVATION

• 4NEC2 example



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# The maximum gain is 6.18 dBi at azimuth $\Phi$ (phi) = 0° elevation $\Theta$ (theta) = 25°



• On main menu Press 3D button

😵 Main [¥5.8.16] (F2)										
File	Edit	Settings	Calculate	Window	Show	Run	Help			
6		P 🕫 🅄	) 🖄 🛞	in 19 🛞 🕅	2	- <b>:</b>	1			

?

• Select: Structure Select: Pattern Select: Tot-Gain



• Open Geometry window (F3) and select Show | Near / Far field Open Pattern window (F4) and display Vertical plane.





• On main menu Press Smith Chart button





- The VSWR = 2.64. This is too high! I will now optimise the antenna.
- Modify file dipole\_demo.nec and open the file in the Geometry Edit window.

```
CM This is a demonstration
SY length=0.173
SY height=0.01
CE
GW» 1»21» 0»0»height» 0»0»height+length»9.e-4
GE \gg 0
LD» 5»0»0»0»1390000»0
    0 > 1 > 11 > 0 > 1 > 0
     2 > 0 > 0 > 0 > 3 > 0.0001
GN
FR» 0»1»0»0»868»0
```



- Press the Calculate button.
- Close all windows except Main window.
   Select menu: Calculate | Start optimiser Note: To use the optimiser, the model requires at least one variable (aka symbol SY) to optimise.
- Select Function: Optimize Select: length Select: SWR = 100% Select Gain = 100% Press Start button

•‡•Optimizer a	nd Evaluat	or (F12)
Settings Function Optimize	Option Defaul 🔻	<b>Weighting factors (FOM) in %:</b> SWR Gain F/B F/R R-in X-in Ra
Variables	Selected	
length=0.173 height=0.01	length	Surf-wave at distance =1KmTheta7070Tot-gainPhi0180Tot-gainResolution5deg.Freq-sweepd-Thet00Frequencyd-Phi00868
		Start Update NEC-file Exit



• If length = 0.1625 m, the VSWR = 1.7093.

🗧 Optimizer: Ready												
- Settings-	Settings									Varia	ble Ser	nsivity:
Functio	n Opti	ion V	√eighti	ng fact	ors (FO	M) in %	:			Run:	length	
Optimize	🔻 Defau	1 - 1	SWR	Gain Fa	/B F/F	R-i	n X-in	Rad.				
Variable	s Sele	cted [	100   1	00 0	0	0	0	0		1.1	-1	
length=0	1625 Jeno	ith [	Surf-v	l vave at o	listance	= 1	Km			2.1	1	
height=0	01	, , T	These D		<u> </u>			_		3.1	-1	
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	Hesume Update NEU-file Exit								- 1			
-												
Calculate	d results:	]	Show Lo	g	Plot	result				Varia	ble Val	ues:
Calculate Run: SW	<b>d results:</b> R Gain	F/B	Show Lo F/R	9 R-in	Plot X-in	result Rad.	Res. %	Step %		Varia Run:	<b>ble Val</b> length	ues:
Calculate Run: SW 2-4 1.6	d results: R Gain i12 0.12	[ F/B 0	Show Lo F/R -0.04	9 R-in 78.653	Plot X-in -13.75	result Rad. 27.46	Res. % 0.031	Step % 0.5		Varia Run: 2-4	<b>ble Val</b> length 0.158	ues:
Calculate Run: SW 2-4 1.6 2-5 1.6	d results: 3 Gain 312 0.12 396 0.13	F/B 0	Show Lo F/R -0.04 -0.04	g R-in 78.653 79.754	Plot X-in -13.75 -10.47	result Rad. 27.46 27.5	Res. % 0.031 0.016	Step % 0.5 0.5		Varia Run: 2-4 2-5	ble Val length 0.158 0.1588	ues:
Calculate Run: SW 2-4 1.6 2-5 1.6 2-6 1.6	d results: Gain 12 0.12 96 0.13 79 0.15	F/B 0 0	Show Lo F/R -0.04 -0.04 -0.03	9 R-in 78.653 79.754 80.878	Plot X-in -13.75 -10.47 -7.155	result Rad. 27.46 27.55	Res. % 0.031 0.016 0.021	Step % 0.5 0.5 0.5		Varia Run: 2-4 2-5 2-6	ble Val length 0.158 0.1588 0.1596	ues:
Calculate Run: SW 2-4 1.6 2-5 1.6 2-6 1.6 2-7 1.6	d results: Gain 12 0.12 96 0.13 79 0.15 61 0.17	F/B 0 0 0	Show Lo F/R -0.04 -0.03 -0.02	9 R-in 78.653 79.754 80.878 82.022	Plot ×-in -13.75 -10.47 -7.155 -3.827 -0.477	result Rad. 27.46 27.5 27.55 27.59	Res. % 0.031 0.016 0.021 0.016	Step % 0.5 0.5 0.5 0.5		Varia Run: 2-4 2-5 2-6 2-7	ble Val length 0.158 0.1588 0.1596 0.1604	ues:
Calculate Run: SW 2-4 1.6 2-5 1.6 2-6 1.6 2-7 1.6 2-8 1.6 2-8 1.6	d results: Gain 12 0.12 96 0.13 79 0.15 61 0.17 38 0.18 06 0.2	F/B 0 0 0 0	Show Lo F/R -0.04 -0.03 -0.02 -0.02	9 R-in 78.653 79.754 80.878 82.022 83.188 84.277	Plot X-in -13.75 -10.47 -7.155 -3.827 -0.477 2.9952	result Rad. 27.46 27.55 27.55 27.59 27.64	Res. % 0.031 0.016 0.021 0.016 1.e-3	Step % 0.5 0.5 0.5 0.5 0.5		Varia Run: 2-4 2-5 2-6 2-7 2-8	ble Val length 0.158 0.1588 0.1596 0.1604 0.1612 0.162	ues:
Run:         SW           2-4         1.63           2-5         1.63           2-6         1.63           2-7         1.63           2-8         1.63           2-9         1.63           2-9         1.63	d results: Gain 12 0.12 96 0.13 97 0.15 61 0.17 38 0.18 96 0.2	F/B 0 0 0 0 0	Show Lo F/R -0.04 -0.03 -0.02 -0.02 -0.01 -0.01	9 R-in 78.653 79.754 80.878 82.022 83.188 84.377 85.589	Plot X-in -13.75 -10.47 -7.155 -3.827 -0.477 2.8952 6.2904	result Rad. 27.46 27.55 27.55 27.59 27.64 27.69 27.73	Res. % 0.031 0.016 0.021 0.016 1.e-3 7.e-3	Step % 0.5 0.5 0.5 0.5 0.5 0.5		Varia Run: 2-4 2-5 2-6 2-7 2-8 2-9 2-10	ble Val length 0.158 0.1588 0.1596 0.1604 0.1612 0.1628	ues:
Run:         SW           2-4         1.63           2-5         1.63           2-6         1.63           2-7         1.63           2-8         1.63           2-9         1.63           2-9         1.63           2-10         1.77           3-1         1.7	d results: 3 Gain 12 0.12 96 0.13 979 0.15 61 0.17 38 0.18 96 0.2 58 0.21 38 0.21	F/B 0 0 0 0 0 0 0	Show Lo F/R -0.04 -0.03 -0.02 -0.02 -0.01 -0.01 -0.01	9 R-in 78.653 79.754 80.878 82.022 83.188 84.377 85.589 85.835	Plot X-in -13.75 -10.47 -7.155 -3.827 -0.477 2.8952 6.2904 6.9744	result Rad. 27.46 27.55 27.59 27.64 27.69 27.73 27.74	Res. % 0.031 0.016 0.021 0.016 1.e-3 7.e-3 -8e-3 -8e-3	Step % 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5		Varia Run: 2-4 2-5 2-6 2-7 2-8 2-9 2-10 3-1	ble Val length 0.1588 0.1588 0.1596 0.1604 0.1612 0.1628 0.163	ues:
Run:         SW           2-4         1.63           2-5         1.63           2-6         1.63           2-7         1.63           2-8         1.63           2-9         1.63           2-9         1.63           2-10         1.77           3-1         1.77	d results: Gain 12 0.12 96 0.13 96 0.13 97 0.15 61 0.17 38 0.18 96 0.2 58 0.21 38 0.21 58 0.21	F/B 0 0 0 0 0 0 0 0	Show Lo F/R -0.04 -0.03 -0.02 -0.02 -0.01 -0.01 -0.01 -0.01	9 R-in 78.653 79.754 80.878 82.022 83.188 84.377 85.589 85.835 85.283	Plot X-in -13.75 -10.47 -7.155 -3.827 -0.477 2.8952 6.2904 6.9744 5.439	result Rad. 27.46 27.55 27.59 27.64 27.69 27.73 27.74 27.72	Res. % 0.031 0.016 0.021 0.016 1.e-3 7.e-3 -8e-3 -8e-3 5.e-3	Step % 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.1 0.125		Varia Run: 2-4 2-5 2-6 2-7 2-8 2-9 2-10 3-1 3-2	ble Val length 0.1588 0.1588 0.1596 0.1604 0.1612 0.1628 0.163 0.1626	ues:
Run:         SW           2-4         1.63           2-5         1.63           2-6         1.63           2-7         1.63           2-8         1.63           2-9         1.63           2-9         1.63           2-10         1.77           3-1         1.77           3-3         1.71	d results: 3 Gain 12 0.12 96 0.13 96 0.13 97 0.15 61 0.17 38 0.18 96 0.2 58 0.21 38 0.21 98 0.21 97 0.2	F/B 0 0 0 0 0 0 0 0 0 0	Show Lo F/R -0.04 -0.03 -0.02 -0.02 -0.01 -0.01 -0.01 -0.01 -0.02	9 R-in 78.653 79.754 80.878 82.022 83.188 84.377 85.589 85.835 85.283 84.978	Plot X-in -13.75 -10.47 -7.155 -3.827 -0.477 2.8952 6.2904 6.9744 5.439 4.5837	result Rad. 27.46 27.55 27.59 27.64 27.69 27.73 27.74 27.72 27.71	Res. % 0.031 0.016 0.021 0.016 1.e-3 7.e-3 -8e-3 -4e-3 5.e-3 -5e-3	Step % 0.5 0.5 0.5 0.5 0.5 0.5 0.1 0.125 0.125		Varia Run: 2-4 2-5 2-6 2-7 2-8 2-9 2-10 3-1 3-2 3-3	ble Val length 0.158 0.1588 0.1596 0.1604 0.1612 0.1628 0.1628 0.1626 0.1624	ues:
Run:         SW           2-4         1.63           2-5         1.63           2-6         1.63           2-7         1.63           2-8         1.63           2-9         1.63           2-9         1.63           2-10         1.77           3-1         1.77           3-3         1.77           4-1         1.7	d results: 3 Gain 12 0.12 96 0.13 96 0.13 97 0.15 61 0.17 38 0.18 96 0.2 58 0.21 38 0.21 98 0.21 98 0.21 98 0.21 98 0.21 99 0.21 99 0.21 90	F/B 0 0 0 0 0 0 0 0 0 0 0 0 0	Show Lo F/R -0.04 -0.03 -0.02 -0.02 -0.01 -0.01 -0.01 -0.01 -0.02 -0.01	9 R-in 78.653 79.754 80.878 82.022 83.188 84.377 85.589 85.835 85.283 84.978 85.222	Plot X-in -13.75 -10.47 -7.155 -3.827 -0.477 2.8952 6.2904 6.9744 5.439 4.5837 5.267	result Rad. 27.46 27.55 27.59 27.64 27.69 27.73 27.74 27.72 27.71 27.72	Res. % 0.031 0.016 0.021 0.016 1.e-3 7.e-3 -8e-3 -4e-3 5.e-3 -5e-3 6.e-3	Step % 0.5 0.5 0.5 0.5 0.5 0.5 0.1 0.125 0.125		Varia Run: 2-4 2-5 2-6 2-7 2-8 2-9 2-10 3-1 3-2 3-3 4-1	ble Val length 0.158 0.1588 0.1596 0.1604 0.1612 0.1628 0.1628 0.1626 0.1624 0.1626	ues:
Run:         SW           2-4         1.63           2-5         1.63           2-6         1.63           2-7         1.63           2-8         1.63           2-9         1.63           2-9         1.63           2-10         1.77           3-1         1.77           3-3         1.77           4-1         1.77           4-2         1.77	d results: 3 Gain 12 0.12 96 0.13 96 0.13 97 0.15 61 0.17 38 0.18 96 0.2 58 0.21 38 0.21 93 0.2 93 0.2	F/B 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Show Lo F/R -0.04 -0.04 -0.03 -0.02 -0.02 -0.01 -0.01 -0.01 -0.01 -0.02 -0.01 -0.02 -0.01 -0.02	g         R-in         78.653         79.754         80.878         82.022         83.188         84.377         85.589         85.283         84.978         85.222         85.054	Plot X-in -13.75 -10.47 -7.155 -3.827 -0.477 2.8952 6.2904 6.9744 5.439 4.5837 5.267 4.7974	result Rad. 27.46 27.55 27.59 27.64 27.69 27.73 27.74 27.72 27.71 27.72 27.71	Res. % 0.031 0.016 0.021 0.016 1.e-3 7.e-3 -8e-3 -4e-3 5.e-3 -5e-3 6.e-3 -1e-3	Step % 0.5 0.5 0.5 0.5 0.5 0.5 0.1 0.125 0.125 0.1		Varia Run: 2·4 2·5 2·5 2·6 2·7 2·8 2·9 2·10 3·1 3·2 3·3 4·1 4·2	ble Val length 0.1588 0.1588 0.1596 0.1604 0.1612 0.1628 0.1628 0.1626 0.1626 0.1625	ues:

• Press buttons: Update NEC-file and Exit



- Press the Calculate button.
- Select: Frequency sweep Select: Gain
  Select Resolution: 5 deg.
  Frequency start: 850 Mhz
  Frequency stop: 880 MHz
  Step: I
  Press Generate button

ſ	👖 Generate (I
	O Use origi
	<ul> <li>Far Field</li> <li>Frequence</li> <li>Near Field</li> </ul>
	○ ItsHF 360 ○ ItsHF Ga
	🖲 Gain 🛛 🤇
	Resol. 5
	🔲 Surface-w
	E-fld distar
	Expert settin
	FR : Start
	<u>Graphs:</u> T
	Forward
	<u>G</u> enerate





### • The generated plots.





• Another way to model an antenna is to use the NEC editor (new) (CTRL+F4).

ſ	🛉 dipole_demo.nec - 4nec2 Edit												
F	File Cell Rows Selection Options												
Default straight line wire-element													
Symbols <b>Geometry</b> Source/Load Freq./Ground Others Comment													
	Geo	ometry (S	caling=Mete	ers)							🔲 Use v	vire tapering	9
	Nr	Туре	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius		
	1	Wire	1	21	0	0	height	0	0	ght+length	9.e-4		
													_1

• I will not demonstrate how to use this editor. Try it yourself.

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## Press the tabs: Symbols, Geometry, Source/Load, Freq./Ground/Others and Comment




# PROCEDURE TO USE 4NEC2

the installed Geometry Builder tool.



• I will not demonstrate how to use this tool. Try it yourself.

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## • For complex geometries (Patch, Plane, Box, Cylinder, Parabola, Helix and Sphere) try





- such as cocoaNEC will not run when they encounter SY cards.
- This card deck can not be run in cocoaNEC because it uses SY cards and inline commands: https://www.mobilefish.com/download/lora/collinear\_868mhz\_4nec2.nec.txt
- predefined identifiers in the Symbol cards.

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• 4NEC2 software allows inline comments (single quotes) and SYmbol (SY) cards but these are 4NEC2 specific and is NOT part of the NEC2 specification. Other software

• You can use arithmetic operators, trigonometric functions, mathematical functions and



## Arithmetic operators:

- + plus. Example: SY a=2+3, result is 5
- minus. Example: SY a=2-3, result is I
- I division. Example: SY a=6/3, result is 2
- \* multiplication. Example: SY a=2\*3, result is 6
- ▲ power of . Example: SY  $a=2^3$ , result is 8

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- I s 2 esult is 6 ılt is 8



Trigonometric functions:
sin(Θ) - sine of an angle in degrees. Example: SY a=sin(30°), result is 0.5
cos(Θ) - cosine of an angle in degrees. Example: SY a=cos(60°), result is 0.5
tan(Θ) - tangent of an angle in radians. Example: SY a=tan(45°), result is 1
atn(y/x) - arc tangent of a value, result in degrees. Example: SY a=atn(1), result is 45°



 Mathematical functions: sqr(x) - square root of x. Example: SY a=sqr(4), result is 2 exp(x) - exponent of x (e<sup>x</sup>). Example: SY a=e(2), result is 7.38906  $\log IO(x) - \log \text{ base } IO \text{ of } x$ . Example: SY a=log IO(2), result is 0.30103 log(x) - natural log of x (ln x). Example: SY a=log(2), result is 0.69315 **abs(x)** - the absolute value of an int. Example: SY a=abs(-2), result is 2 sgn(x) - sign value of x. Example: SY a=sgn(-2), result is - I If x < 0, result = -1 If x = 0, result = 0 $|f \times >0$ , result = |



int(x) - remove the fractional part of x and return the resulting integer value. If x is negative, it returns the first negative integer less than or equal to x. Example: SY a=int(-2.4), result is -3
fix(x) - remove the fractional part of x and return the resulting integer value. If x is negative, it returns the first negative integer greater than or equal to x. Example: SY a=fix(-2.4), result is -2



 Predefined identifiers: **cm** - centimeter. Example: SY a=100cm, same as 1 m. **mm** - millimeter. Example: SY a=1000mm, same as 1 m. in - inch. Example: SY a = 100in, same as 2.54 m. **ft** - feet. Example: SY a = 10ft, same as 3.048 m. **pF** - pico Farad. Example: SY a=1pF, same as 1.0E-12 F **nF** - nano Farad. Example: SY a=InF, same as I.0E-9 F **uF** - micro Farad. Example: SY a=1uF, same as 1.0E-6 F **nH** - nano Henry. Example: SY a=InH, same as I.0E-9 H uH - micro Henry. Example: SY a=IuH, same as I.0E-6 H pi - Pl constant 3.14159. Example: SY a=pi



## AWG wire radius identifiers #0 - #20 - American Wire Gauges. Example: SY a=#20, same as 0.000406 m <u>https://www.mobilefish.com/download/lora/awg2metric.pdf</u> You can only use #0 - #20



- Do not cross wires.
- Do not model elements below the ground (z=0).

Ζ

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## $\frac{1}{4}\lambda$ ground plane antenna

The antenna model consists of 5 wires and not 3 wires.





# SOME INFORMATION ABOUT COCOANEC

- displayed in the 3D model.
- It is important to see all your antenna elements in 3D to verify if your antenna is correctly modelled.
- In cocoaNEC and 4NEC2 wire radius can be entered in American Wire Gauge format. For example: **#12**

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 cocoaNEC has several limitations which other antenna modelling software does not have. For example: You can not model helixes in the spreadsheet, and helixes are not



## COCOANEC

#### cocoaNEC











# MORE INFORMATION

 More information about 4NEC2: <u>https://www.qsl.net/4nec2/</u>

