HF OPERATORS

Introduction to Antenna Modeling
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EZNEC

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- EZNEC Antenna Modeling software

- EZ = Easy

- NEC = “Numerical Electromagnetics Code”

- This product offered by Roy Lewallen  W7EL

http://www.eznec.com/
What is NEC?

The Numerical Electromagnetics Code (NEC), credited to Gerald Burke, is an algorithm and generic computer application, originally written in FORTRAN. Developed in the 1970s, it is a popular antenna modeling method for wire and surface antennas. The code was made publicly available for general use and has subsequently been distributed for many computer platforms from mainframes to PCs. 

Wikipedia
The Computation

NEC “looks” at

- the current flowing in the antenna
- divides the antenna into a number of discrete segments
- assigns an average value of current for that segment
- calculates the field strength from each of the segments at a particular point in space
- repeats the calculation for a vast number of points in space all around the antenna
- renders the calculation into parameters of interest
Parameters of Interest

- Element Dimensions
- Resonant Frequency
- Feed Point Impedance
- SWR
- Radiation Patterns – Azimuth and Elevation
- Gain
- Effect of Ground
- Effect of Height above Ground
But First, a Review

- Characterizing Antenna Radiation
- Azimuth
- Elevation
- Gain
- Effect of Ground
Azimuth Pattern

- Horizontal degrees
  - think compass

- 0° to 360°

- Describes the radiation strength “around” the antenna in the horizontal plane
**Vertical Pattern**

- Degrees above horizontal
- 0° to 90°
- Describes the radiation strength upwards, in the vertical plane
- EZNEC refers to Vertical as Elevation

ARRL
Antenna Gain

- Ability of an antenna to focus energy in a particular direction, at the expense of other directions

- Gain is measured in deci-Bels (1/10 of a Bel) “dB”

- dB is always a relative measurement, so what is antenna gain measured relative to?
Isotropic Antenna

- EZNEC Gains are referred to the ISOTROPIC antenna.

- An Isotropic radiator
  - radiates equally in all directions
  - cannot be realized (built)
  - used as an absolute reference

- Gain of a real antenna is given as dBi where “i” means with respect to isotropic
Real Antennas

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- Half wave dipole has a gain of 2.15 dB (factor of 1.6x) over an Isotropic radiator *in free space*

- Antenna Gain, is often measured with respect to the half wave dipole.

- Gain referred to as dBd where “d” means dipole

- If an antenna spec provides a gain figure of X dB, you do not know if the gain is referenced to a dipole or isotropic.

- Which antenna has most gain? 9dBi or 9 dBd or 9 dB ?
Antennas in free space have radiation patterns that differ from those near to ground (earth)

The earth (being somewhat conductive) acts like a mirror reflecting downward radiation back up

Reflected radiation combines with direct radiation to at various vertical angles which results in cancellations (nulls) and re-enforcements (gain)
EZNEC Control Center

- The opening window
Set FREQUENCY to 14.2 MHz, design center for our dipole
- Wavelength auto calculated
- Wires to follow
- Sources to follow
- Loads = 0 (none used)
- Transmission line = 0 (none used)
- Ground type = Real / Mininec
- Ground Description = Medium 1
- Wire Loss = 0 (assume lossless)
- Units = feet
- Plot Type = 3D (3 dimensional)
- Step Size = 5 degrees (good enough)
- Ref Level = 0 dBi (dB intrinsic)
- Alt SWR Z0 = 50 ohms (coax feed line)
- On to the antenna .....
Calculations

Once parameters are entered,

1. View Ant does antenna look OK?
2. Run SWR does ant appear resonant at expected design frequency?
3. Run FF Plot compute the field patterns.
   » Click on 2D plot
   » Click Elevation slice
   » Click on Azimuth slice

Do patterns meet your expectations?

Play with various parameters to optimize
How to Build an Antenna

- Model is constructed of “wires”
  - can be wire of all gauges or Tubing of various diameters

- Built in 3 dimensional space

- Use a Coordinate System called “Rectangular” to define the antenna in space
  - X = Side to Side dimension
  - Y = Front to Back dimension
  - Z = Height above ground
Coordinate System

- Origin is our reference point
- Coordinates specified as (X, Y, Z)
- Origin is (0, 0, 0)
- Units along an axis can be feet, meters etc
- Out 2 units on X; out 2 units on Y, up 3 units on Z
- Our point in space is labeled as (2, 2, 3)
Antenna Example

- Build a 20 M dipole (half wave)
- Horizontally oriented
- 40 feet high, since the tree height = 40 feet
- Center fed
- Estimate each leg about 16 feet long
- Have to choose a ground type ..... 
- And not going to model the transmission line
Coordinate Determination

- Feed point will be at the origin
- X = 0 feet. Will construct the antenna along the X axis
- Y = 0 feet as antenna does not extend into Y dimension
- Z = 40 feet (the tree .. right ?)
- Leg 1 will extend from the origin to X = +16 feet
- Leg 2 will extend from the origin to X = -16 feet
Draw Wire Coordinates

- Wires must be straight line segments.
- Determine wire END coordinates in the reference frame

![Diagram showing wire coordinates]

Origin: (0, 0, 40)
Feed Point: (X, Y, Z)
End: (-16, 0, 40)
End: (+16, 0, 40)
Wire Designations

- Assign a wire number to each straight segment
**Wire Table**

- Enter each wire in table.
- Connect ends
- Open WIRES from Control Center
- Enter Coordinates, each wire, each end

Choose a wire size i.e. #12
- Divide wire into (current) segments. Total all wires max 500
Wire Table Check

- Wire end connectivity, check feature
- Wire 1 end 1 (W1E1) connects to wire 2 end 1 (W2E1)
- Must be so because both “origin” coordinates are the same
- Check wire ends per table to be certain they are as expected
- Then view the antenna …
View Antenna

- Close Wires table
- Click on View Ant
- Does it look Correct?
- Rotate view by holding down left button and drag view
Ground Characteristics

- Click Ground Description

- Default describes AVERAGE ground

- Clay, Hills, Forestation

- If yours is different,

  - C.C. > Options > Default Ground Const...

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Ground Type

- Free Space
  - not applicable

- Perfect
  - not applicable

- Real – recommended

- MININEC
  - best all around model of real ground conductivities for a wide variety of antennas
Feed Point

- Insert a SOURCE at the feed point
- Click Sources

- EZNEC may suggest a location
- Wire 1, End 1, 1.5% from W1E1
- Very close to center of antenna. This will be OK
- For greater accuracy, insert a very short third wire at feed point and put Source in middle. Requires redefining coordinates at origin / feed point to connect Wire 1 and 2 to new wire 3 in the Wires table.
Run SWR

- Click SWR
- Enter start & stop frequencies
  - Band is 14.0 to 14.35
  - Design may have SWR out side of band so choose wider
  - 13 to 15 MHz and 0.1 MHz steps

- Click RUN
Result

- On the right track
- Shows resonance
- Click on graph at minimum
- Read Resonance = 14.9 MHz
- Read SWR = 1.14:1
- Read Feed Point Z ~ 57 ohm R + 0.5 ohm C reactive
Re-Work Resonance

- Resonance too high
- Antenna too short
- Go to Wires
- Add some length X
- Run SWR 14.0 to 14.350
- Iterate to 14.2MHz
- Read SWR – added ~ 11” (0.9 ft)
3D Plot

- Click FF (far field) Plot
- Yikes!
- Shows 3 dimensional radiation plot. Can rotate view by left click and drag
- Best to look at the 2D Plot
- Click “Show 2D Plot” and Elevation slice
Elevation Plot

- Shows max gain lobe as **Green** line
- Half power – 3dB points as **Violet** lines
- 180 degree point as **Blue** line
- Table at bottom shows,
  - Max gain 8.22 dBi
  - At vertical angle of 25°
  - With a beam width of 27°
- Moving cursor provides info for other points on pattern, i.e. null of -13.6 dB at 60°
Azimuth Plot

- Click Azimuth Slice
- Read data at bottom
  - Max gain at 90°
  - Beam Width ~47°
  - Null along Ant -10.6 dB
- Move cursor to investigate directional performance
Current Distribution

- Produced when running SWR
- Violet line shows current in antenna
- Slider controls allow for more detailed examination in complex antennas
- Useful to see where currents are actually flowing, particularly if there are other conductors in the model
Increase Height to 1λ

- Change HEIGHT to achieve a lower angle on radiation
- On Control Center, click Wires > Other > Change Height By ...
- Add another 26 ft for total of 66 ft = one wavelength

- Run SWR 14.0 to 14.35
- Run FF
- Click 2D Plot

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**Full Wave Height = 1\lambda**

- Note difference in vertical radiation pattern

- **Primary lobe at 15°**
  - Gain 7.33 dBi
  - Much lower than 25°
  - Good for long DX skip

- **Secondary lobe at 50°**
  - Gain ~ 5 dBi
  - Good for North America skip

- **Beam Width** 14°
- **Null at 90°**
  - No energy lost to “space”
Decrease Height

- Decrease height from 66 ft by -33 feet for a total of 33 ft = ½ wave

- Run SWR
- Run FFT
- Click 2D Plot
Half Wave Height $= \frac{1}{2}\lambda$

- Single vertical lobe at $50^\circ$
- Gain of 7.02 dBi
- Beam Width $35^\circ$
- -12 dB null at $90^\circ$
- Not a bad compromise for a low antenna. May be better than at 40 feet!
Inverted VEE at $1/2\lambda$

- Common design, hang center of dipole from tower
- OK fro ends to droop down
- Important to keep feed point high
- Control Center > Wires
- RIGHT click on wire end > Elevation Rotate End …
- Do both ends !

- Check Antenna View
Inverted VEE View

- Looks OK
- Run SWR
- Run FF Plot
**VEE Performance at 1/2λ**

- Still at ½ wave above ground
- Vertical lobe at 30°
- Gain 6.24 dBi
- Azimuth beam width 45°
- 8.9 dB null at 90°
- Not much change from horizontal results and easier to install
Comparisons

- Example: Overlay VEE with Dipole elevation pattern

- Save Dipole 2D elevation pattern
  - in the 2D plot window, File > Save trace as .. *.PF file

- When VEE 2D elevation plot is displayed
  - Click File > Add Trace .. > select file
Comparisons

- Blue trace is dipole, not much difference....
Summary

- Build the desired antenna
- Run the application
- Look at the results
- Redesign as needed
- Try different designs
- Experiment with other features

- The Results are the Reality
Other NEC Programs

- EZNEC currently at V5.0  (this demo V3.0)
  - currently $89 US for basic version
  - download or CD available

- ARRL ANTENNA HANDBOOK
  - EZNEC Ver. 3 is provided FREE!
  - ARRL Book is not ~ $45US

- QST Nov 2000, 4 Part series
  - Beginners Guide to Modeling with NEC
  - antenna “Guru“  Cebik W4RNL (SK)

- Check out other modeling software
  - http://www.dxzone.com/catalog/Software/Antenna_analysis/