

Simulation of $5/8 \lambda$ vertical dipole antenna

Example:

Frequency $f=27.174$ MHz

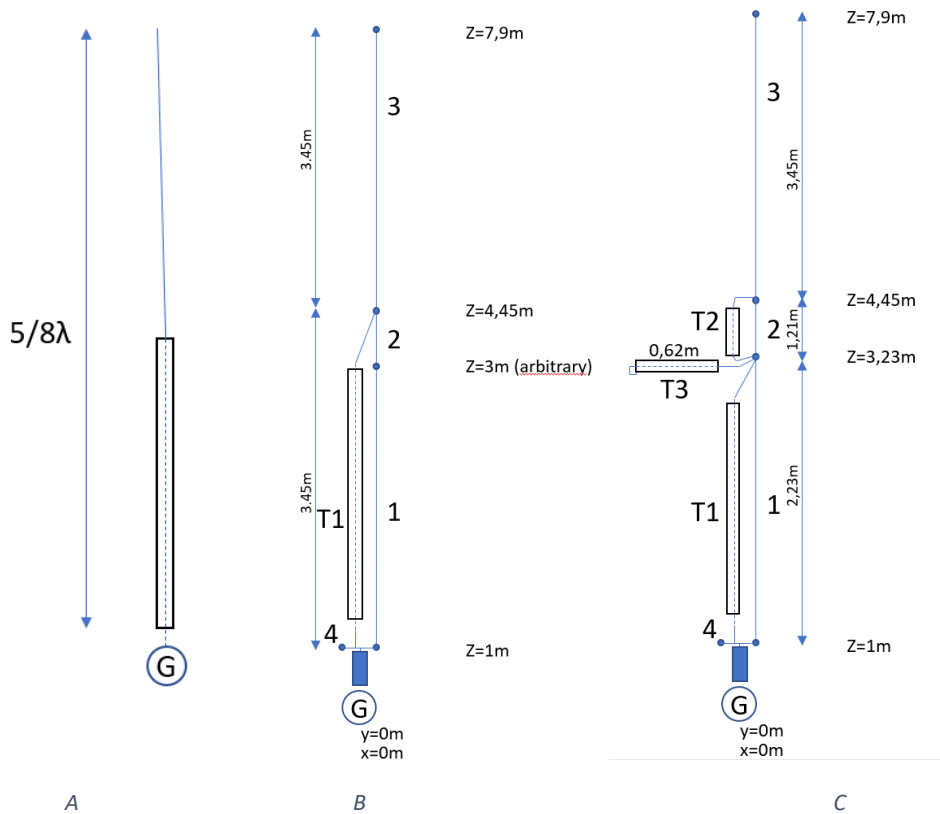
c = speed of light in vacuum

$$\text{Wavelength: } \lambda = \frac{c}{f} = \frac{3 \cdot 10^8 \text{ m/s}}{27.174 \cdot 10^6 \text{ 1/s}} = 11,04 \text{ m}; \frac{5}{8} \lambda = \frac{5}{8} * 11,04 \text{ m} = 6,9 \text{ m}$$

Simulation tools (Free of charge to download)

EZNEC Pro/2+. EZNEC is a registered trademark of Roy W Lewallen.

SimSmith: Copyright Edward Harriman, AE6TY



Kuva 1: Antenna model elements

A: Basic model of $5/8 \lambda$ vertical antenna. Bottom half acts as a transmission line. Its shield is the other half of the dipole and radiates. A common mode choke to isolate other part of the feedline is necessary.

B: Antenna described as wire elements (1-4) and a transmission line (T1) for EZNEC initial simulation. Z represents distance from ground plane in meters. X and y are the other coordinates.

C: Antenna described as wire elements and transmission line sections for matching. The lengths of the elements are initially unknown (except the total length of $5/8 \lambda$) and need to be designed separately e.g. using Smith Chart.

Step 1: Find out load impedance at the dipole at the physical feed point

Configure EZNEC according to antenna model B to run simulation in EZNEC to find out what the feed point impedance at the lower end of T1 is without impedance matching.

```

Source Data
File Edit Search Format Help
EZNEC Pro/2+ ver. 7.0
5/8 Gain Gipole 08/09/2022 17.26.36
----- SOURCE DATA -----
Frequency = 27,174 MHz
Source 1 Voltage = 210,6 V at 80,17 deg.
Current = 1 A at 0,0 deg.
Impedance = 35,96 + J 207,5 ohms
Power = 35,96 watts
SWR (50 ohm system) = 26,021 (75 ohm system) = 18,477

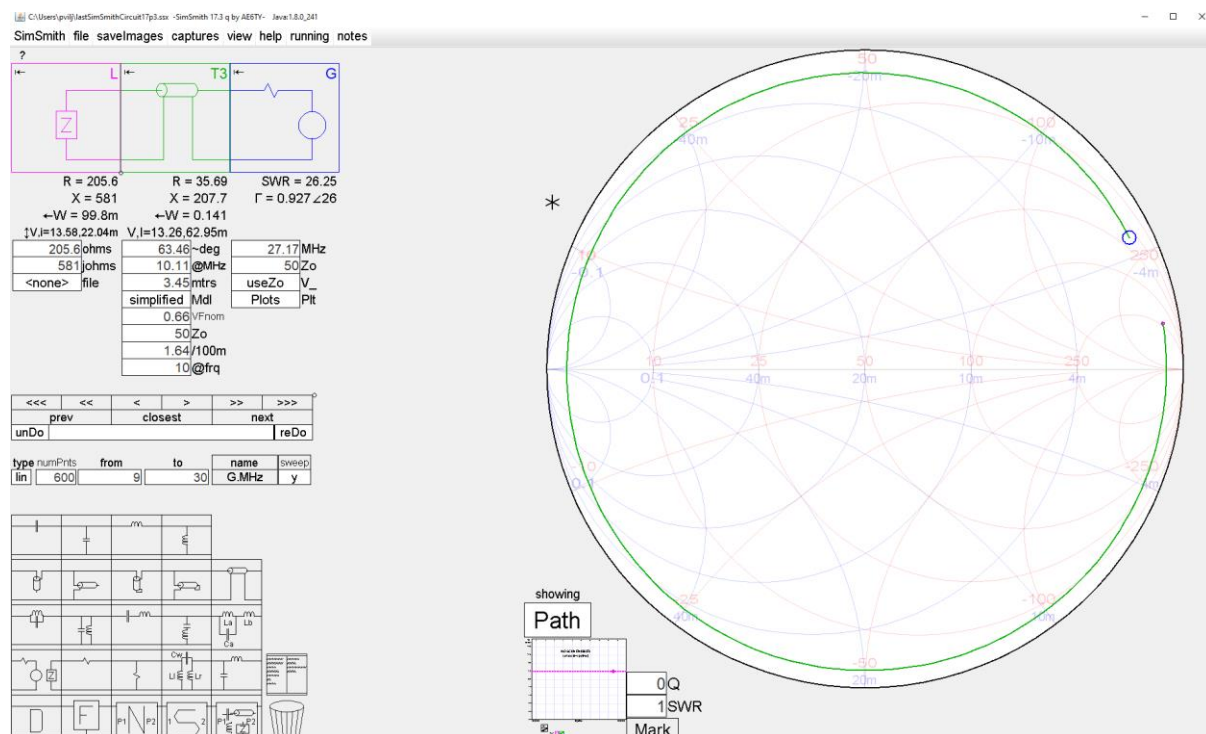
```

Kuva 2: Result of simulation of feedpoint impedance

Impedance according to simulation is about $36 + j208 \Omega$.

Step 2: Find out antenna impedance at the center of the dipole

Put previous impedance and transmission line T1 (velocity factor 0.66 in this example) in a Smith Chart e.g. SimSmith. Resistance and reactance at "load" i.e. at the upper end of transmission line T1 can now be varied so that previous step's impedance $36 + j208 \Omega$ realizes at the lower end of T1. It turns out that at load the impedance must be about $206 + j581 \Omega$. In the below picture it can be seen that adding a transmission line rotates the impedance clockwise (green trace) on a constant SWR circle (a circle which center point is in the middle of the chart)



Kuva 3: Simulation of dipole and transmission line as part of the antenna

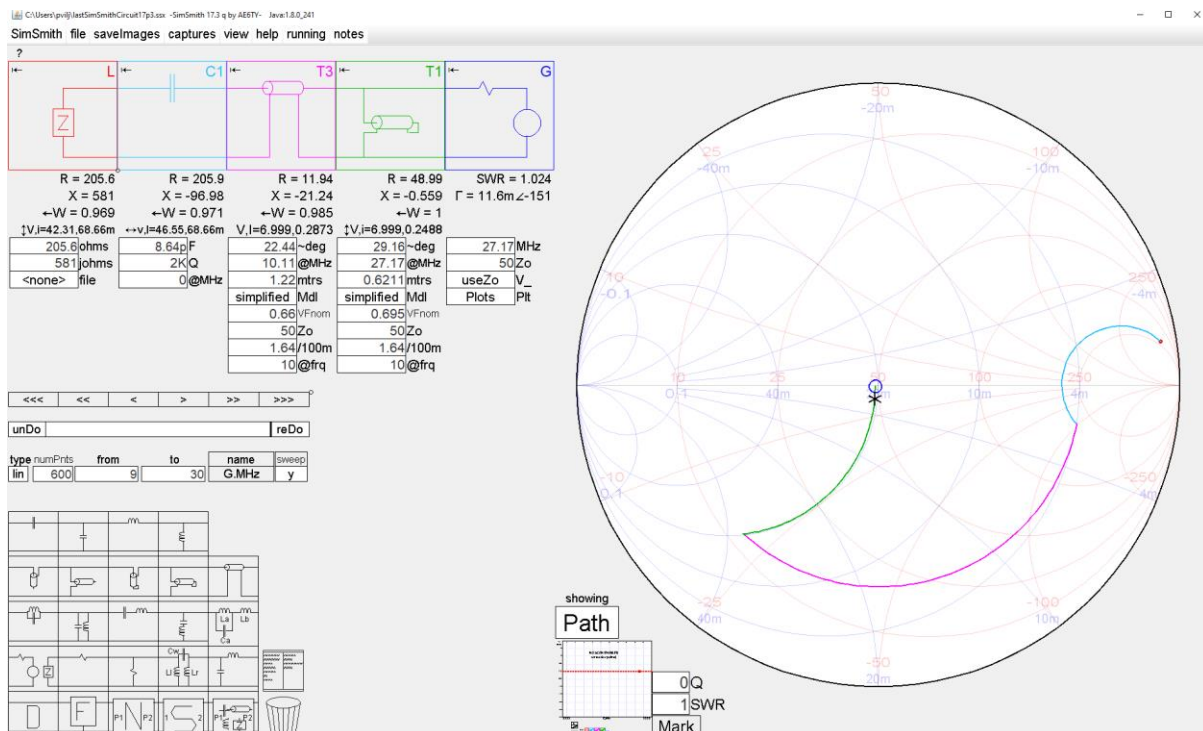
Step 3: Design the matching network

The idea is to bring the impedance in the middle of the chart, at $50 + j0\Omega$. We start with the impedance at the middle point of the dipole determined in step 2 (red dot in the graph below at about 3 o'clock). First add a series capacitor C1. It rotates impedance at a constant resistance circle counter-clockwise, blue trace. Value of C1 determines how far to go, having impact on the next element. There are many combinations of C1 and transmission line T3 lengths in the below graph which all fulfill target to reach circle on which the green trace is on. In this example $C1 = 8.64\text{pF}$ and its reactance $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi * 27,174 * 10^6 * 1/8,64 * 10^{-12} \text{As/V}} = 678\Omega$.

Next add a length of transmission line to further rotate clockwise, pink trace, length of transmission line and its velocity factor determines how far to go. The target is to go until a constant conductance circle which goes through the midpoint of the chart is crossed, in this case 1,22m.

Then a reactive component, a transmission line with a shorted end can be added (green trace) to bring the impedance at the center. Again, length of the stub transmission line and its velocity factor determines how far "up" impedance transfers. Length of stub needs to be 0,62m.

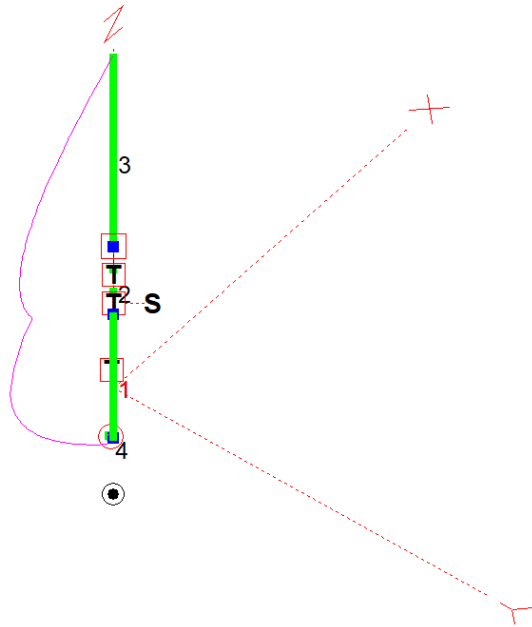
At this point basically any length of feedline of 50Ω can be added as "rotating the impedance" does not change its value anymore, other than by additional resistive losses. This means that the necessary length of radiating coax can be added without having major influence on the matching.



Kuva 4: Simulation of matching network

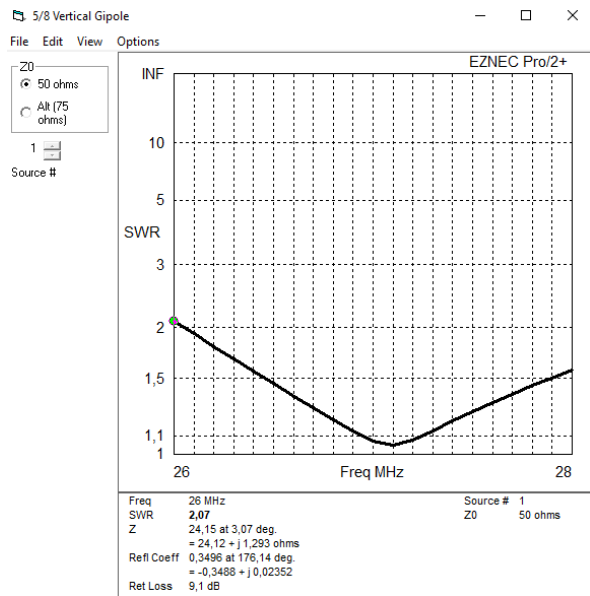
Step 4: Check the result in EZNEC

Configure EZNEC according to antenna model C (see EZNEC elements in the end)



A

Kuva 5: Current distribution in the radiating elements

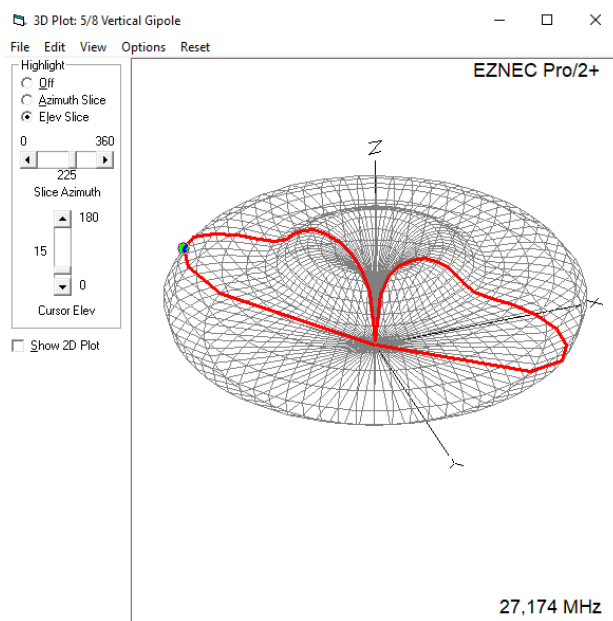


B

Kuva 6: SWR after matching

A: Current in the radiating elements with matching (pink trace)

B: Resulting SWR



Kuva 7: Far field plot with elevation slice

EZNEC Pro/2+ v. 7.0

File Edit Options Outputs Setups View Utilities Help

5/8 Vertical Gipole

- File 5_8SirioGainmaster_match.EZ
- > **Frequency** 27,174 MHz
- Wavelength 11,0323 m
- > **Wires** 4 Wires, 170 segments
- > **Sources** 1 Source
- > **Loads** 1 Load
- > **Trans Lines** 3 Transmission Lines
- > **Transformers** 0 Transformers
- > **L Networks** 0 L Networks
- > **Y Param Networks** 0 Y Param Networks
- > **Ground Type** Real/MININEC
- > **Ground Descrip** 1 Medium (0,005, 13)
- > **Wire Loss** Copper
- > **Units** Meters
- > **Plot Type** 3D
- > **Step Size** 5 Deg.
- > **Ref Level** 0 dBi
- > **Alt SWR Z0** 75 ohms
- > **Desc Options**
- > **Gnd Wave Dist** OFF

Average Gain = 0,295 = -5,30 dB *Model contains loss*

Wires

Wire Create Edit Other

Coord Entry Mode Preserve Connections Show Wire Insulation Show Loss

| No. | End 1 | | | | End 2 | | | | Diameter (mm) | Segs | Wire Loss | | |
|-----|-------|-------|-------|------|-------|-------|-------|------|---------------|------|-----------|------|--------|
| | X (m) | Y (m) | Z (m) | Conn | X (m) | Y (m) | Z (m) | Conn | | | R (ohm-m) | Perm | Type |
| 1 | 0 | 0 | 1 | W4E2 | 0 | 0 | 3,23 | W2E1 | 1 | 80 | 1,74E-08 | 1 | Copper |
| 2 | 0 | 0 | 3,23 | W1E2 | 0 | 0 | 4,45 | W3E1 | 1 | 3 | 1,74E-08 | 1 | Copper |
| 3 | 0 | 0 | 4,45 | W2E2 | 0 | 0 | 7,9 | | 1 | 80 | 1,74E-08 | 1 | Copper |
| 4 | 0 | -0,1 | 1 | | 0 | 0 | 1 | W1E1 | 1 | 7 | 1,74E-08 | 1 | Copper |

Kuva 8: EZNEC wire elements

Transmission Lines

Trans Line Edit

| No. | End 1 Specified Pos. | | End 1 Act | End 2 Specified Pos. | | End 2 Act | Length (m) | Z0 (ohms) | VF | Rev/Norm | Loss (dB/100 m) | Loss Freq (MHz) |
|-----|----------------------|-----------|-----------|----------------------|-----------|-----------|-------------|-----------|------|----------|-----------------|-----------------|
| | Wire # | % From E1 | | Wire # | % From E1 | | | | | | | |
| 1 | 4 | 50 | 50 | 2 | 0 | 16,6667 | Actual dist | 50 | 0,66 | N | 0 | 0 |
| 2 | 2 | 0 | 16,6667 | 3 | 0 | 0,625 | Actual dist | 50 | 0,66 | N | 0 | 0 |
| 3 | 2 | 0 | 16,6667 | Short ckt | | | 0,5 | 50 | 0,66 | N | 0 | 0 |

Kuva 9: EZNEC transmission lines

| Loads | | | | | | | | |
|-------|-----|----------------|-----------|-------------|-----|--------|--------|----------|
| | No. | Specified Pos. | | Actual Pos. | | R | X | Ext Conn |
| | | Wire # | % From E1 | % From E1 | Seg | (ohms) | (ohms) | |
| ▶ | 1 | 3 | 0 | 0,625 | 1 | 0 | -678 | Ser |
| * | | | | | | | | |

Kuva 10: EZNEC loads

EZNEC simulation elements.