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Analysis of an 868 MHz Loop Antenna

Purpose of this document:

Introduction: In this application note we demonstrate the electromagnetic analysis of a planar antenna for the ISM frequency band 868 MHz - 870 MHz with Sonnet Professional.

Table of contents:

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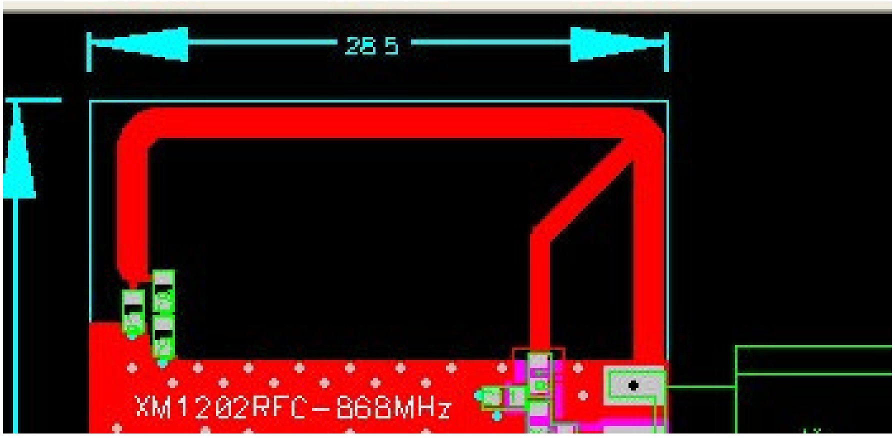
Introduction

In this application note we demonstrate the electromagnetic analysis of a planar antenna for the ISM frequency band 868 MHz - 870 MHz with Sonnet Professional.

The antenna layout used for this demonstration was developed by Dr. Lutz Konstroffer, RF Consult, www.rfconsult.com and is shown in the picture below.



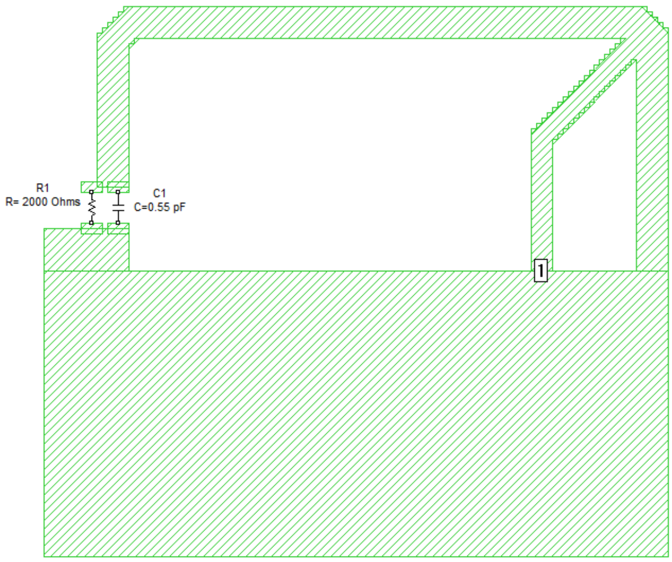
The planar antenna consists of an "n"-shaped PCB trace that is tapped by a feed line at a well defined position. One end of the trace is directly connected to the reference metallization (lower right hand side in the picture), and the other end is connected via a set of SMD elements to the reference metallization (lower left hand side).

The set of SMD elements includes a 2 kΩ resistor and a shunt capacitance. The capacitance is built with two SMD capacitors connected in series. Although the 2 kΩ resistor introduces losses, its usage is necessary to make the antenna robust and insensitive against it's environment.

The current through the PCB trace flows from one end over the SMD elements into the reference metallization, and then back into the other end of the trace. As the current flow forms a loop, the antenna type is magnetic.

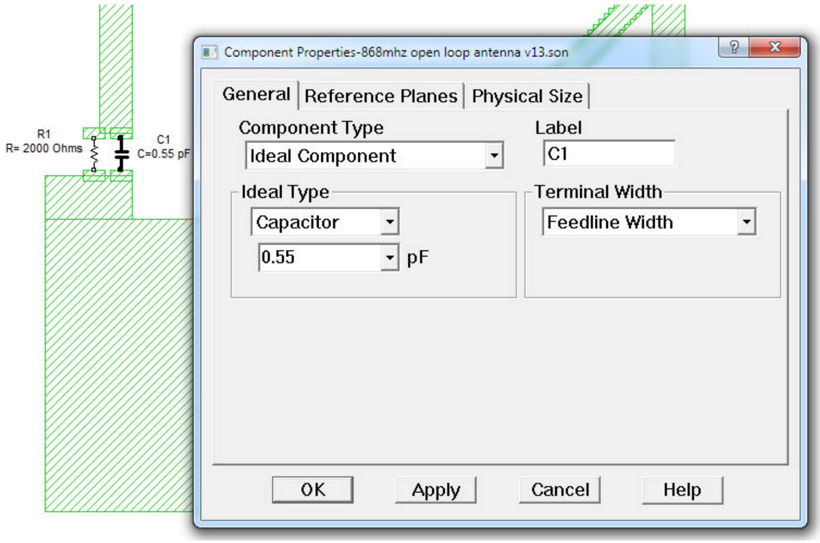
Antenna model in Sonnet

The picture below shows the Sonnet model of the antenna.
The area with the green hatching is the metallization in the Sonnet editor.



Ports and components

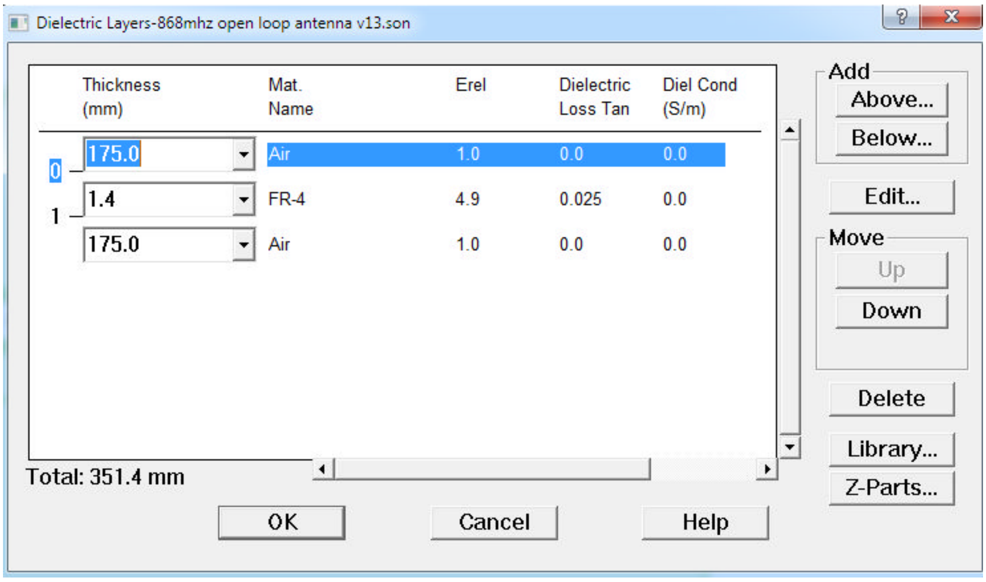
The feed (excitation) of the antenna is modeled with the ungrounded internal port 1 between the antenna feed line and the reference metallization. The SMD elements are modeled with Sonnet components



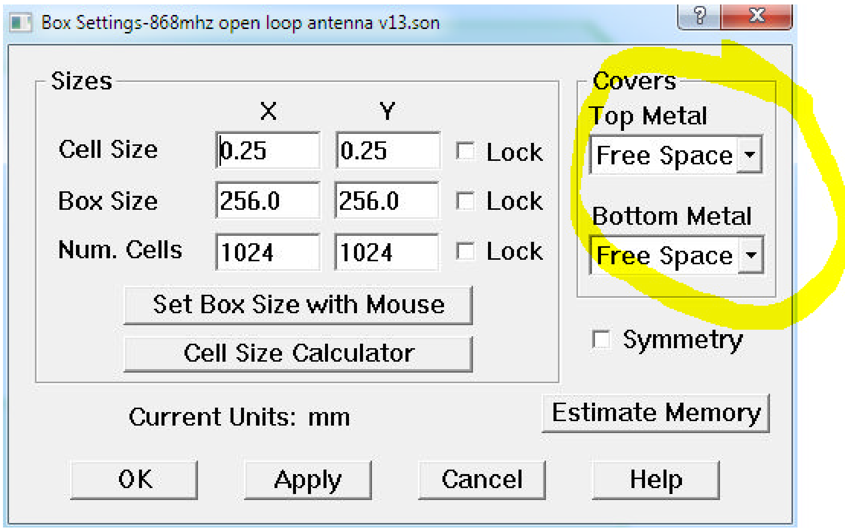
Important Note:
The electromagnetic analysis itself is independent of the port impedances. Using a different component value only requires a re-normalization, without repeating the field analysis. This means you can modify the values of the modeled SMD elements after the EM analysis. There is no need to re-analyze when the component value changes.

Dielectric layers

The PCB used in this example is a 1.4 mm thick FR4 substrate (Circuit > Dielectric Layers...). As shown in the screen shot below, you can also model the dielectric losses of the PCB. Two 175 mm thick air layers are added above and below the FR4 substrate in the Sonnet model. The thickness of each air layer is about $\lambda/2$ at 868 MHz.



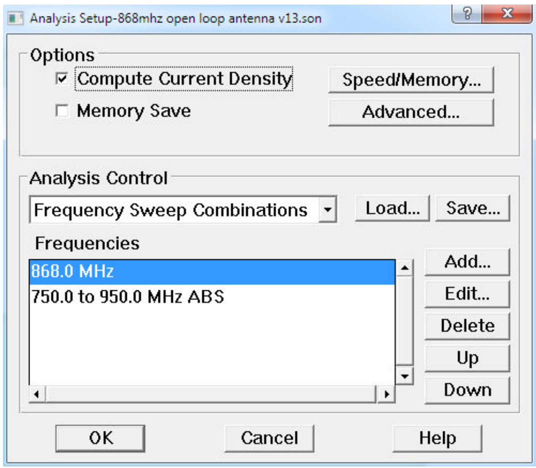
To allow radiation, the top and the bottom metal is set to "Free Space" (Circuit > Box...).



Technically, this setting places absorbing boundaries at the top and the bottom of the simulation box.

Analysis Setup

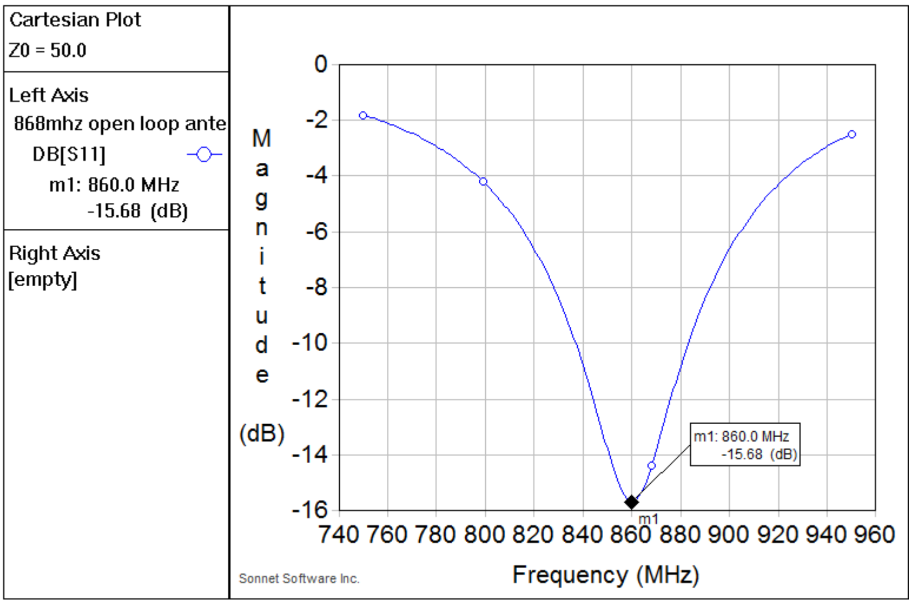
We select "Analysis > Setup..." in the Sonnet project editor to enter the analysis frequencies. In the Analysis setup dialog box we choose an ABS sweep and enter a frequency range from 750 MHz to 950 MHz.
We also mark the checkbox "Compute Current Density". This is necessary to determine the antenna pattern later, which is based on the current density data. To ensure that the current density is calculated for the center frequency (e.g. 868 MHz) of the ISM frequency band of interest, we add this single frequency value to the analysis control section before the ABS sweep is added.

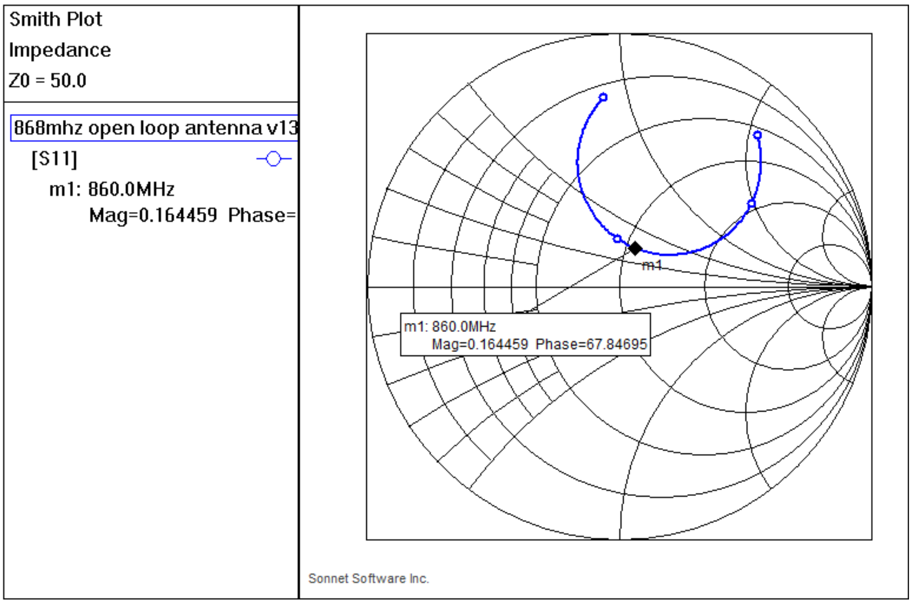


Analysis Results

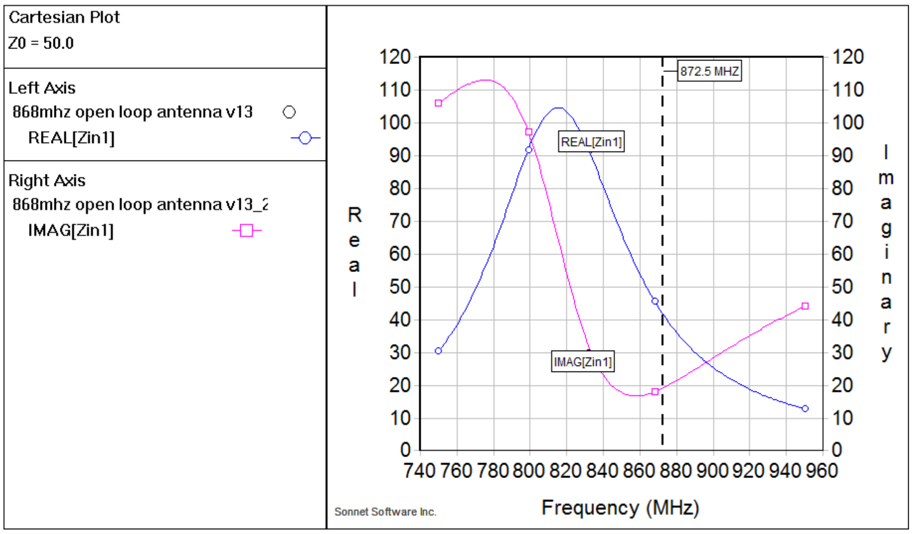
The simulation results can be displayed in many formats, e.g. S-parameters in Cartesian format or Smith Chart. You can also view the frequency dependent input impedance Z_{in} (magnitude as well as real and imaginary part).

In the following two screen shots the analysis result (matching, S11) is displayed in 50 Ω S-Parameter format. The curves are valid for a shunt capacitor value of 0.55 pF.





A plot for the input impedance Zin is shown in the next screen shot (real part left axis, imaginary part right axis). In this example, the condition imag(Zin) = 0 for an optimum matching at 50 Ω is almost met at the frequency of 869 MHz.

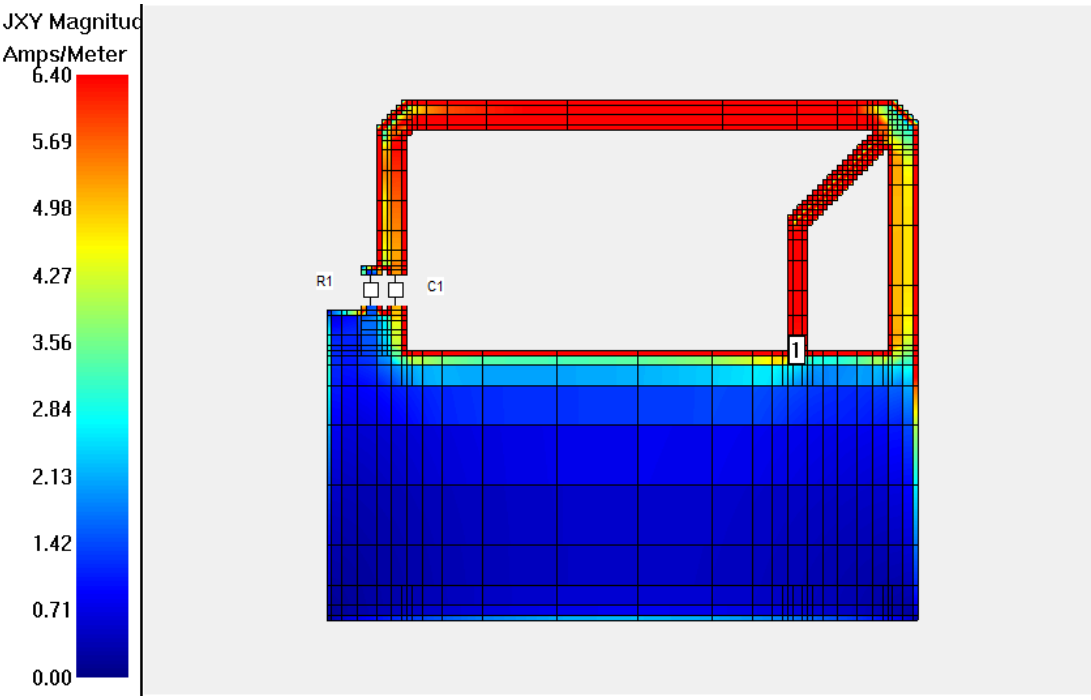


If needed, the component values can now be re-tuned to meet the specifications.

Current visualization

Beside S-Parameters and impedance values you can also analyze and view the current density distribution on the antenna metallization.

As example, the screen shot below shows the current density distribution for the resonant frequency 868 MHz (red = high current density, blue = low current density). In the beginning of this document we said the antenna current flows in a loop through the antenna trace and the reference metallization. We can now clearly verify this statement by examine the current density view.



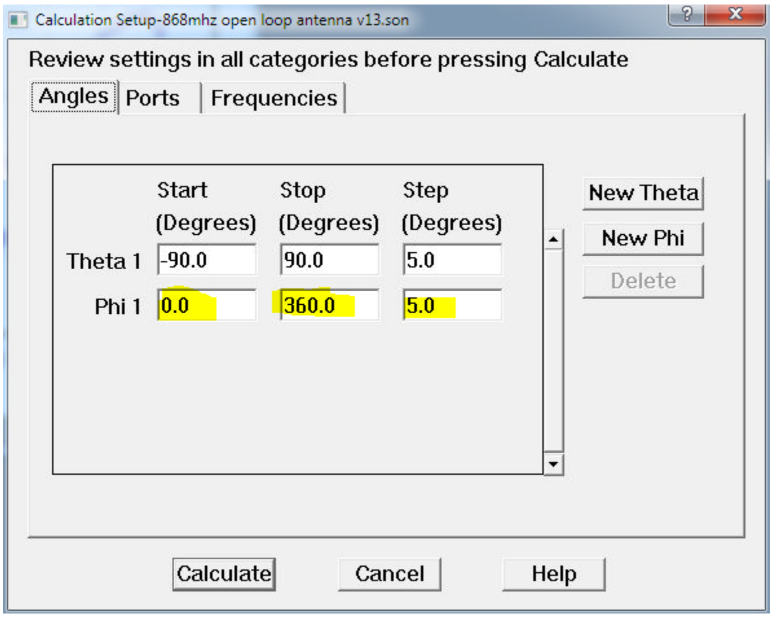
Antenna far field pattern

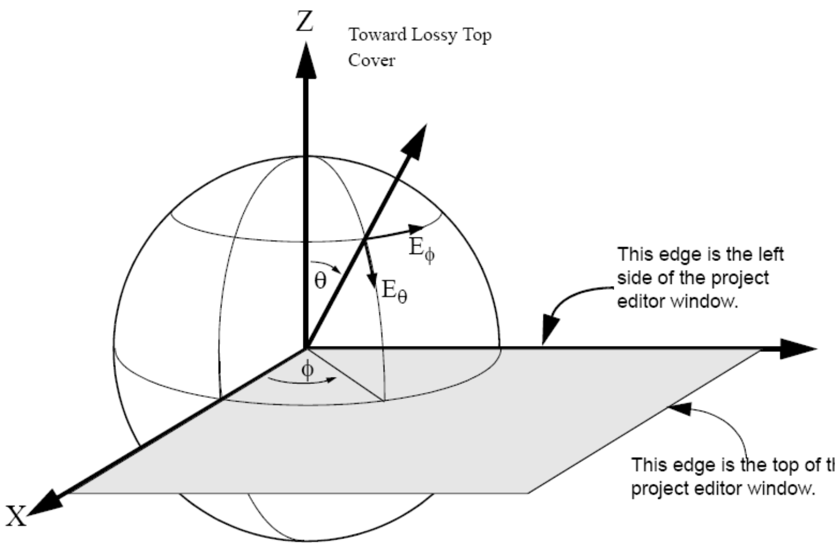
Calculation of the far field antenna pattern: The Sonnet far field pattern viewer calculates the far field pattern of the antenna from the analyzed current density and displays the antenna gain in 2D Cartesian or polar format. You can normalize the pattern to show the directive gain or the antenna gain.

Directive gain

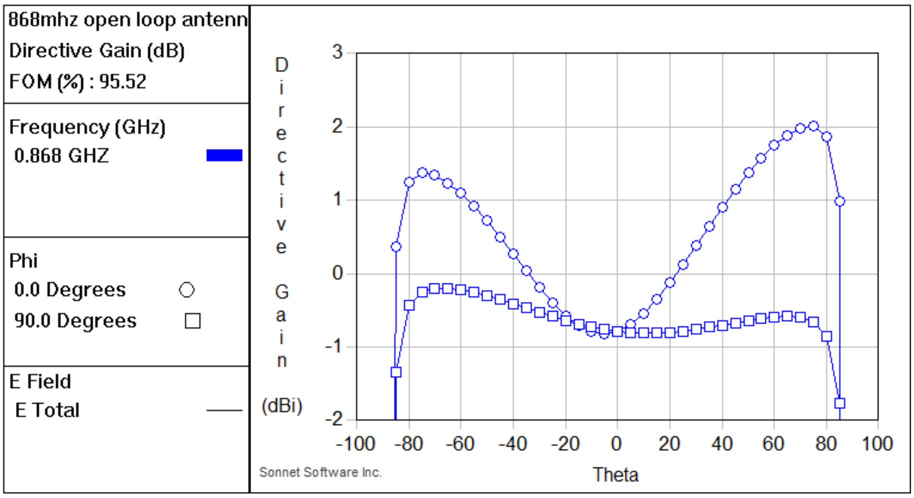
If you choose to display the directive gain (also known as directivity), the radiated power is normalized to an ideal, isotropic radiator that radiates the same total power. The output is the far field pattern of the antenna. Please note that any antenna losses will not be taken into account.

For directive gain, the antenna calculation must be set so that it samples the radiation for the complete sphere around the antenna.





The following screen shots shows the directive gain of the loop antenna for two theta-cuts at phi = 0° (XZ-plane) and phi = 90° (YZ-plane).

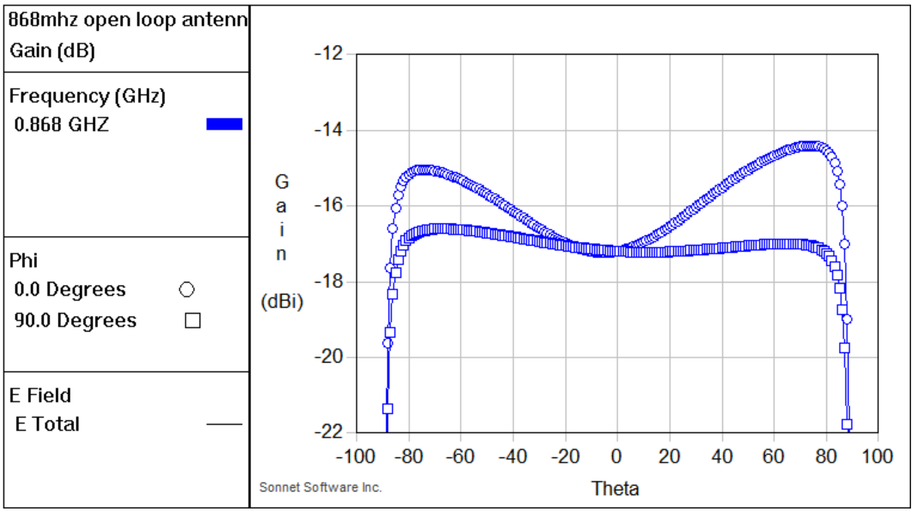


Due to the simulation method with a substrate that extends to infinity, the value at the horizon (Theta=+/-90°) is not exact. The drop seen in the simulation is a simulation artefact and does not exist in reality.

Gain

If you choose to display the gain (also known as power gain), the radiated power is normalized to the input power. All dielectric and metallic losses are taken into account. The gain is therefore always smaller than the directive gain.

In the menu, choose choose "gain" as normalization (Graph > Normalization... > Gain). An additional option is to take mismatch losses into account as well. This means that any mismatch (input reflection) will reduce the antenna gain. The following two screenshots below show the same theta-cut plots as above, but now for the normalization "gain". It can clearly be seen that the antenna gain is much smaller than the directive gain, due to the losses in conductors, dielectrics and in the resistor component.



Important note for Sonnet versions earlier than 13.52

When using components with Sonnet version 11 or 12, the antenna "Gain" is only accurate if you enable the "Include reflection" checkbox. This problem is solved in Sonnet 13.52 and later, so that gain is accurate with or without "Include reflection".