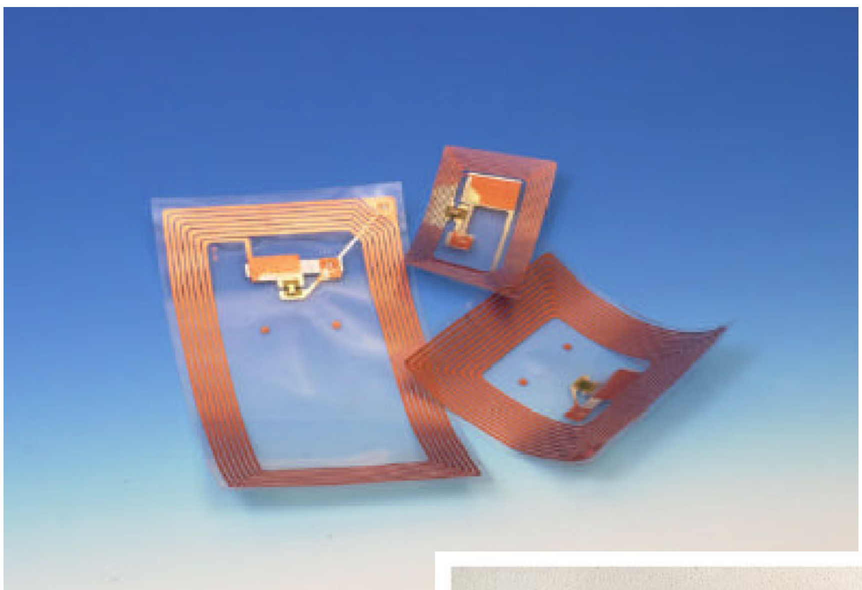
Using Electromagnetic Analysis for RFID Antenna Design

Sonnet Application Note: SAN-206A FEB 2006

Design Examples for 13.56MHz and 900 MHz RFID Antenna



Pictures Courtesy of Texas Instruments and Matrics

SONNET®

ELECTROMAGNETICS SPECIALISTS

Description of Sonnet Suites Professional

Sonnet Suites Professional is an industry leading full-wave 3D Planar Electromagnetic (EM) field simulation software based on the Method of Moment (MoM) technique which accounts for all coupling and radiation effects from DC to THz. It also takes full advantage of mathematically robust and reliable FFT formulation which avoids time consuming, error prone numerical integration. Both MoM and FFT combined gives Sonnet an added assurance that it will give outstanding accuracy every time on problems that have traditionally been difficult to solve. Problems with high dielectric constant, thin dielectric layers and/or small dimensions with respect to the wavelength are handled especially well with Sonnet. Sonnet continues to be an indispensable tool for designers involved in RF/Microwave circuits such as distributed filters, transitions, Low Temperature Co-fired Ceramics, multi-layer RF packages, coplanar waveguides, and antennas. In addition, Sonnet has proven successful in mm-wave designs as well as in EMC and EMI analysis.

Sonnet Professional Key Benefits

- Accurately model passive components (inductors, capacitors, resistors) to determine values like RLC and Q factor
- Accurately model multi layer interconnects and via structures
- Generate a technology accurate electrical model for arbitrary layout shapes
- Quantify parasitic coupling between components, interconnects and vias
- Include substrate induced effects like substrate loss and eddy currents
- Visualize the current flow in components, interconnects and vias

Sonnet Professional Key Features

- FFT based Method of Moments analysis for ultimate reliability and accuracy
- Easy to learn, easy and efficient to use
- Only one high precision analysis engine – no need to switch between solvers
- Patented Conformal Meshing strategy for very efficient high accuracy meshing of curved structures
- Finite thickness modelling (including advanced N-sheet model)
- Dielectric bricks for truncated dielectric materials (e.g. MIM capacitor)
- Adaptive Band Synthesis for fast and reliable frequency sweeps with a minimum number of EM samples - more efficient than traditional approaches
- Easy to use data display for analysis results, including R, L, C, Q evaluation
- Equation capability for pre-defined or customized calculation on simulated data
- All configuration and technology setup is menu / dialog based– no need to edit configuration text files
- Remote simulation capability
- Compatible with the LSF cluster and load balancing system
- Seamless integration with Cadence® Virtuoso® , Agilent EEsof EDA's ADS, AWR® Microwave Office® and Analog Office™ and Eagleware-Elanix GENESYS™ design environments
- Sonnet Software Inc. is a Cadence Connections partner

When to Use Sonnet Professional Analysis

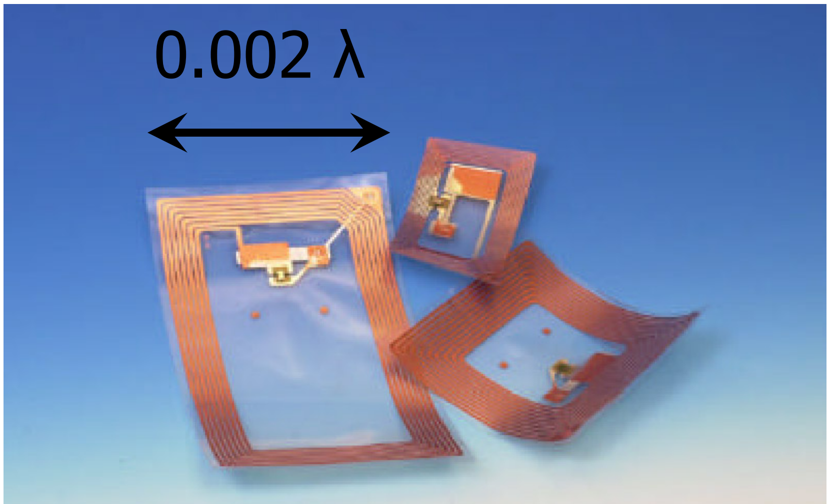
- When parasitic coupling is present.
  - Parasitic coupling is not always easy to predict without using electromagnetic analysis. Even elements which are "sufficiently" far apart can suffer from parasitic coupling: inductive or capacitive coupling, resonance effects due to grounding and surface waves that might propagate at the substrate boundary under certain conditions. Sonnet Professional analysis is based on the physical properties of your technology and will account for such physical effects.
- When accurate circuit models are not available or circuit model parameters are out of range.
  - Model based circuit simulators are based on models for a specific application, with limited parameter range. For example, only selected geometries, substrate types and substrate parameters are available. It is difficult to estimate the error induced by parameter extrapolation, so using models outside their designed parameter range is not suitable for critical applications.
  - Whenever a layout feature cannot be described by a circuit model, due to its geometry or technology, the physics based analysis with Sonnet Professional will provide the answer. An example for this could be a special inductor, capacitor or transformer which is not included in the design kit. Sonnet can be used to analyze those components "on the fly", or generate a full library of components models with trustworthy electrical results.

Introduction

Over the last several years, Radio Frequency Identification (RFID) has become a major market. With a large number of vendors, success will be determined by achieving a short time-to-market for the most creative ideas. In order to realize a fast time-to-market, fast and accurate electromagnetic (EM) analysis is an absolute requirement. This application note demonstrates using Sonnet to design a 13.56 MHz RFID inductor and a 900 MHz RFID antenna accurately and rapidly. Sonnet's extreme accuracy is a result of being based on the FFT (**Fast Fourier Transform**), and Sonnet's speed is the result of a revolutionary new interpolation (**Adaptive Band Synthesis**), both to be demonstrated. In addition, Sonnet's automated features, including parameterization and optimization, allow the designer to evaluate a large number of alternatives in an incredibly short period of time. As the wireless markets consolidate, making the most efficient use of the best CAD tools, including Sonnet for electromagnetic analysis, is key to survival.

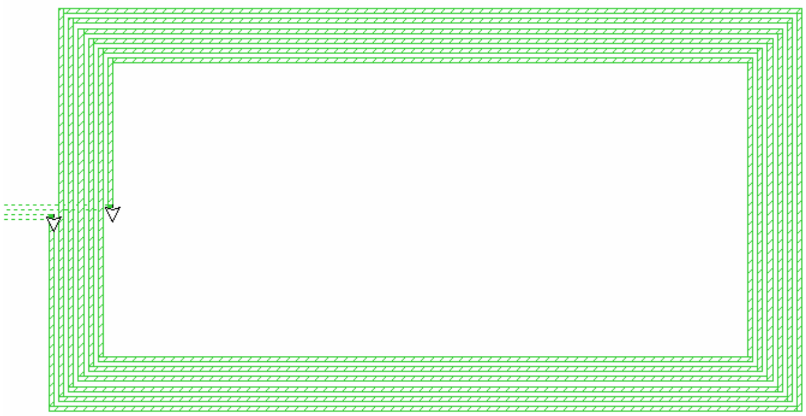
13.56 MHz Tag Design

There has already been a lot of work on RFID at 13.56 MHz. This is a world wide allocated frequency. However, the largest possible tag size is only a few centimeters. This size is a very tiny fraction of a wavelength. Thus a 13.56 MHz tag cannot possibly radiate very well. It is not an antenna. Rather, it works by inductive coupling, like a transformer. Its range is typically less than one meter. In order to read all the contents on an entire pallet, a longer range is needed.



Courtesy of Texas Instruments

This is a typical RFID inductor. It is a planar inductor with six turns, each 0.5 mm wide and separated by 0.5 mm. The coil is 78mm x 41 mm. The input port is on the left hand side. Metal loss is included. EM analysis time for this inductor is about 13 seconds per frequency on a Pentium M. Because this analysis uses the Sonnet ABS interpolation, accurate data at 300 frequencies is calculated from electromagnetic analysis at only four frequencies. This entire EM analysis took less than 1 minute.



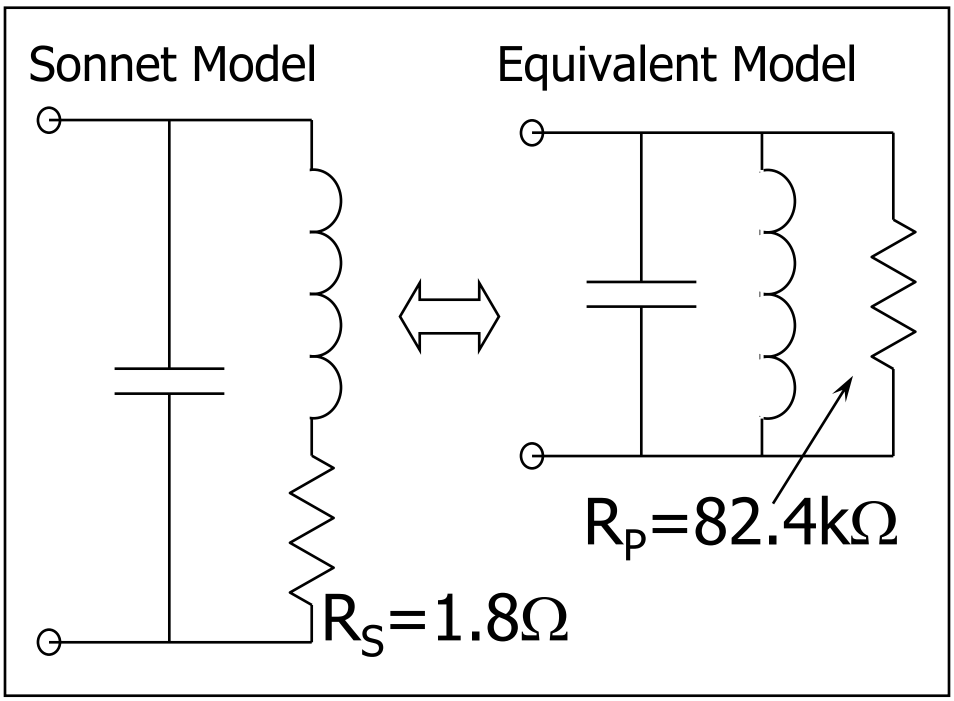
By using the Sonnet Option **Analysis->Output Files->PI Model**, a lumped equivalent PI-model sub-circuit is generated. The output, shown here, is in the PSPICE format. Models are generated between two frequencies. To check the PSPICE results, it is always good to compare the lumped element values between two netlists near the frequency band of interest. In this case, the first SPICE netlist is generated from data at 12.1 and 13.3 MHz. The second SPICE netlist is generated from data at 13.3 and 14.65 MHz.

As you can see, they both give almost exactly the same answer. This means that the PSPICE model generated by Sonnet is working well for this circuit. We shall use this PSPICE model to design the rest of the RFID circuit.

```
* Analysis frequencies: 12.1, 13.3 MHz
.subckt SON9_2 1 GND
C_C1 1 GND      1.185049pf
L_L1 1 2        4495.387nh
R_RL1 2 GND     1.770104
.ends SON9_2

* Analysis frequencies: 13.3, 14.65 MHz
.subckt SON9_3 1 GND
C_C1 1 GND      1.198058pf
L_L1 1 2        4493.561nh
R_RL1 2 GND     1.859145
.ends SON9_3
```

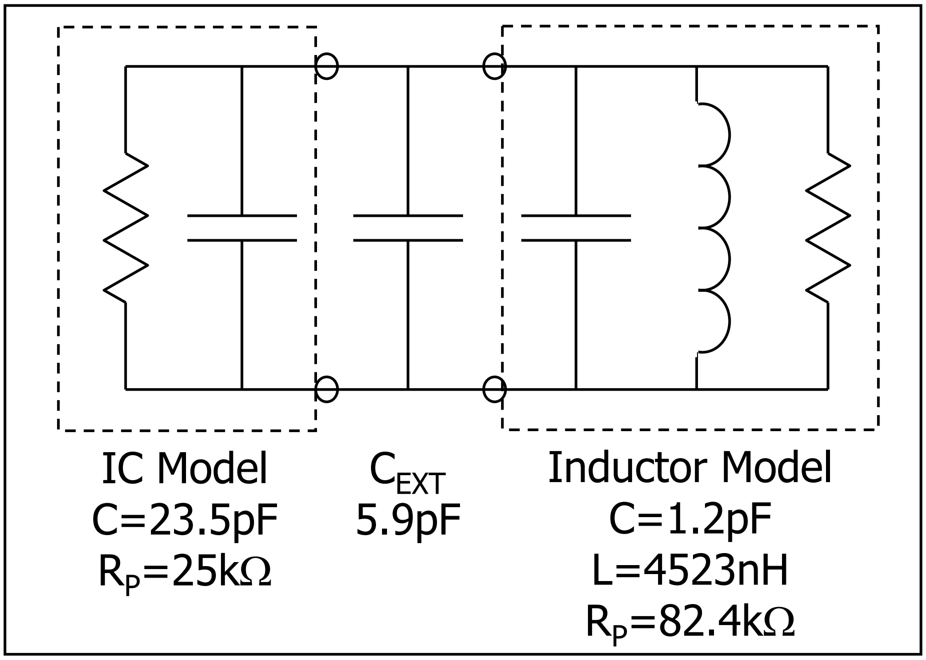
The Sonnet SPICE model is on the left. The Sonnet model includes a resistor in series with the inductor. This is most realistic. However, for some calculations, we would also like to know what the equivalent parallel resistance is. This is easily calculated using the equation at the bottom. For a series resistance of 1.8 Ohms, the equivalent parallel resistance is 82.4 kOhms. From the Sonnet generated SPICE model, the capacitance is 1.2 pF and the inductance is 4495 nH.



$$R_P = R_S(1 + X_S^2 / R_S^2)$$

The RFID IC we wish to use has a total of 23.5 pF of internal capacitance. The inductor, as calculated by the Sonnet SPICE model, already has 1.2 pF of capacitance. In order to make a 4495 nH coil resonant at 13.56 MHz, we need a total of 30.6 pF. Thus in order to achieve the best match between the tag coil and the RFIC, we must add an external capacitor of 5.9 pF to tune the inductor to 13.56 MHz when it is connected to the RFID IC.

This is a schematic of the entire tag coil circuit. The RFID IC is on the left. It has both an internal capacitance and resistance. The external 5.9 pF capacitor is in the center. The inductor model generated by Sonnet is on the right.



It is interesting to calculate the total impedance of the resonant circuit at resonance. This is simply the parallel combination of the RFID IC internal resistance of 25 kOhms with the 82.4 kOhms equivalent parallel resistance of the coil. The total resistance is about 19 kOhms. This is the impedance that the RFID IC will see at resonance.

We can now use any nodal circuit analysis to complete the RFID design. The Sonnet nodal analysis is shown here. It is also available in the free SONNET Lite™ and can be used to analyze this circuit.

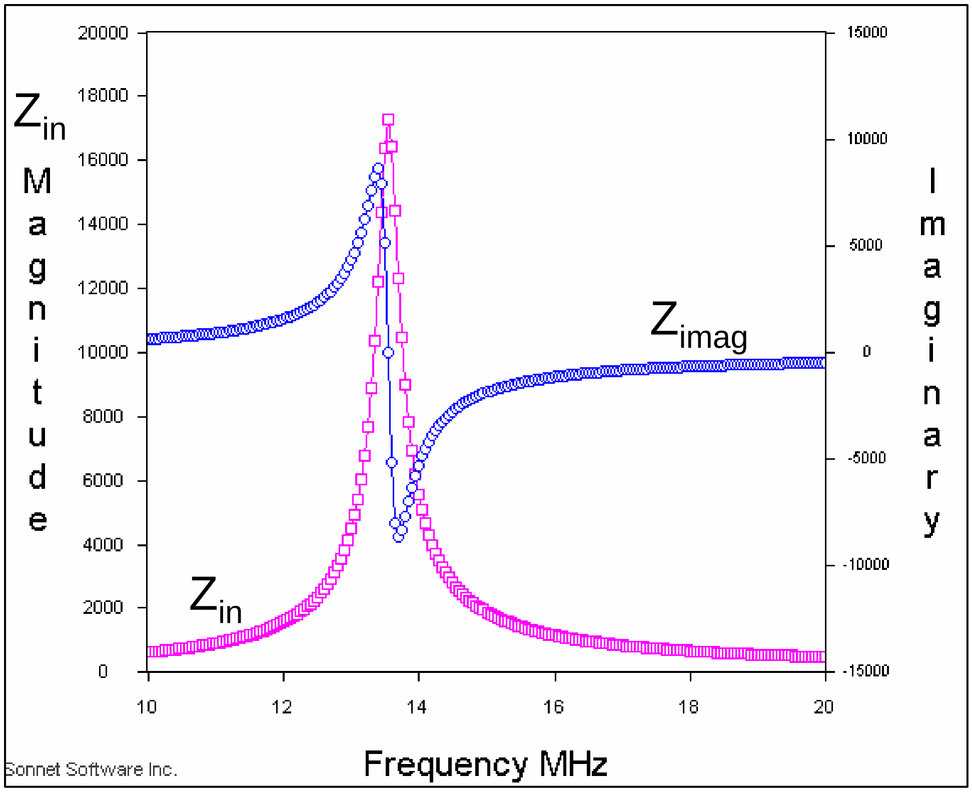
The RFID IC capacitance and resistance are included in the first two lines. The external capacitance is included in the third line. The fourth line begins with "PRJ". This includes the Sonnet project file for this inductor. If the data in the Sonnet project file is ready, it just reads the data and proceeds with the nodal analysis. If the layout has been changed and the old data is no longer valid, then this line causes Sonnet to calculate new electromagnetic data automatically.

```
    CAP 1 C=23.5        ; RFID IC Model
    RES 1 R=25000.0     ; RFID IC Model
    CAP 1 C=5.9         ; External Capacitor
    PRJ 1 RFID_1.son Hierarchy Sweep
DEF1P 1 Net Main Network
```

This line includes the Sonnet EM inductor data, automatically re-analyzed only if needed.

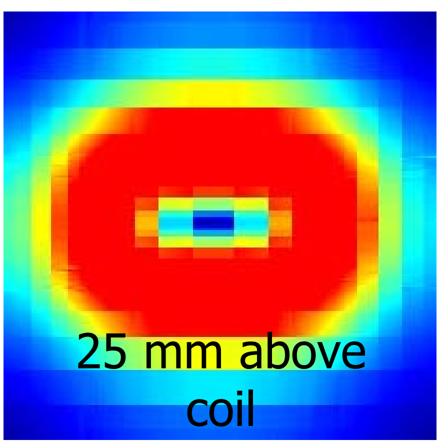
This is the result of the Sonnet nodal analysis. Notice the plot of Z-parameter magnitude shows a maximum input impedance at resonance. Also notice that the imaginary part of the input impedance is zero at resonance.

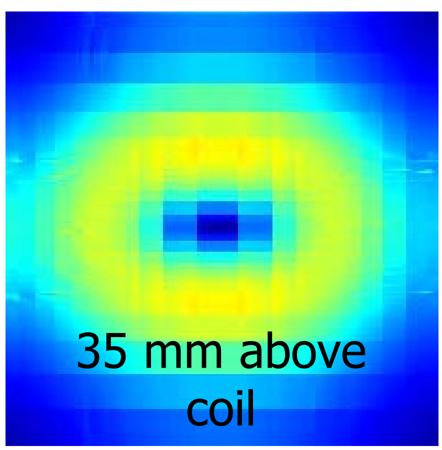
At resonance, the input impedance is almost 19 kOhms, as predicted. Thus, at resonance, with no other coil nearby, the RFID IC will see a pure resistance of almost 19 kOhms.

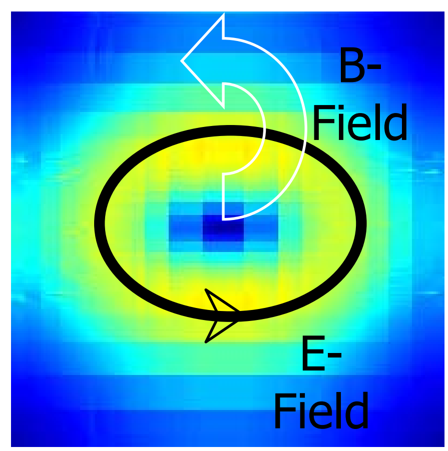


To see the inductor fields, we can use a "sense layer". Sonnet only allows viewing of electric fields that are parallel, or tangential, to the surface of the substrate. In these views, red is strong E-field. Blue is almost no E-field.

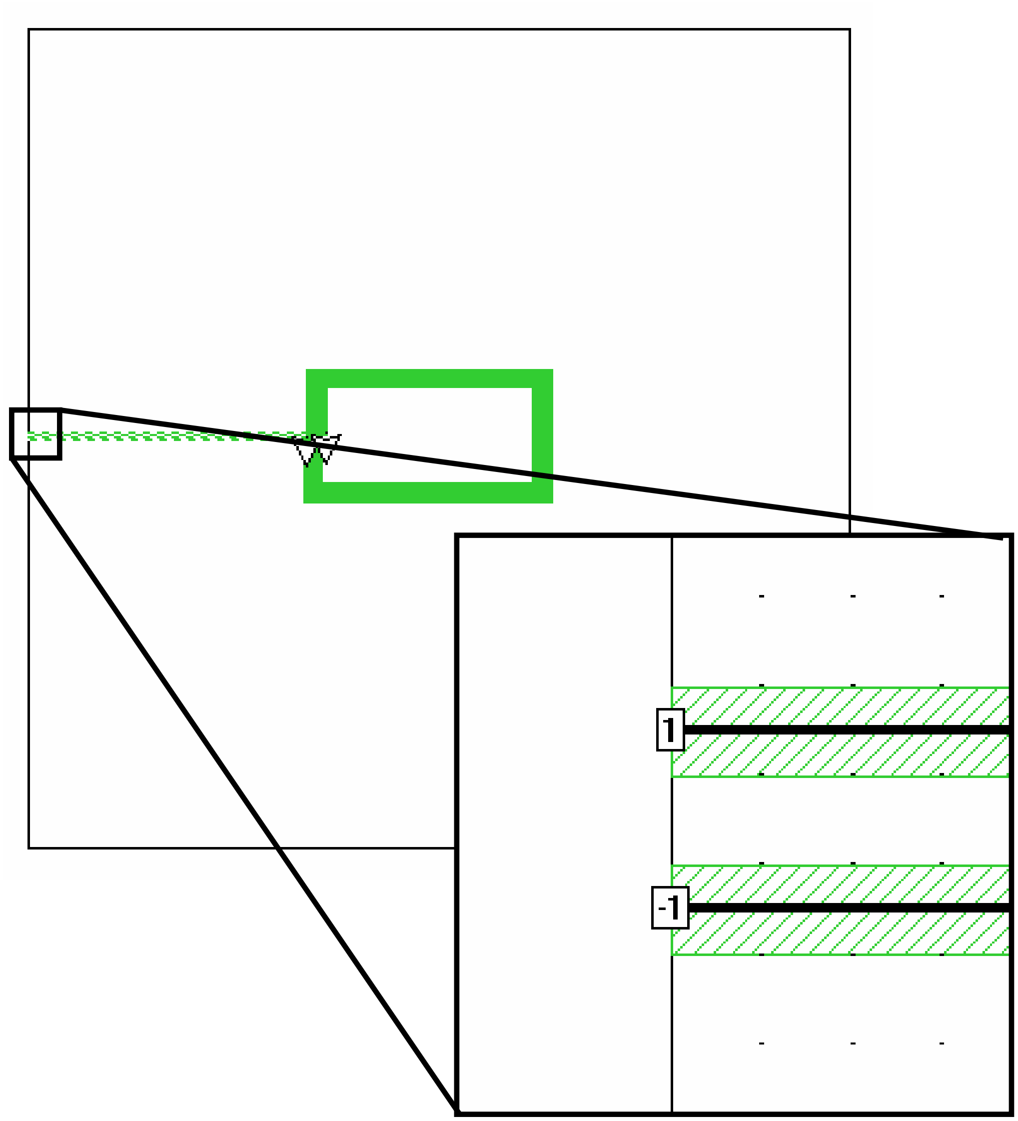
The first plot shows tangential E-field 25 mm above the inductor. The tangential E-field is strongest near the windings of the coil. The same is true at 35 mm above the inductor, only now the fields are less strong. Sonnet does not plot B-field directly, but it is easy to see what the B-field does. From Maxwell's equations, we know that the B-field "curls" around the E-field. This is just like B-field curling around a current carrying wire. This is shown in the last figure on the right. Thus, by looking at the 2-D tangential E-field, we can very easily see the full 3-D B-field curling around the inductor.





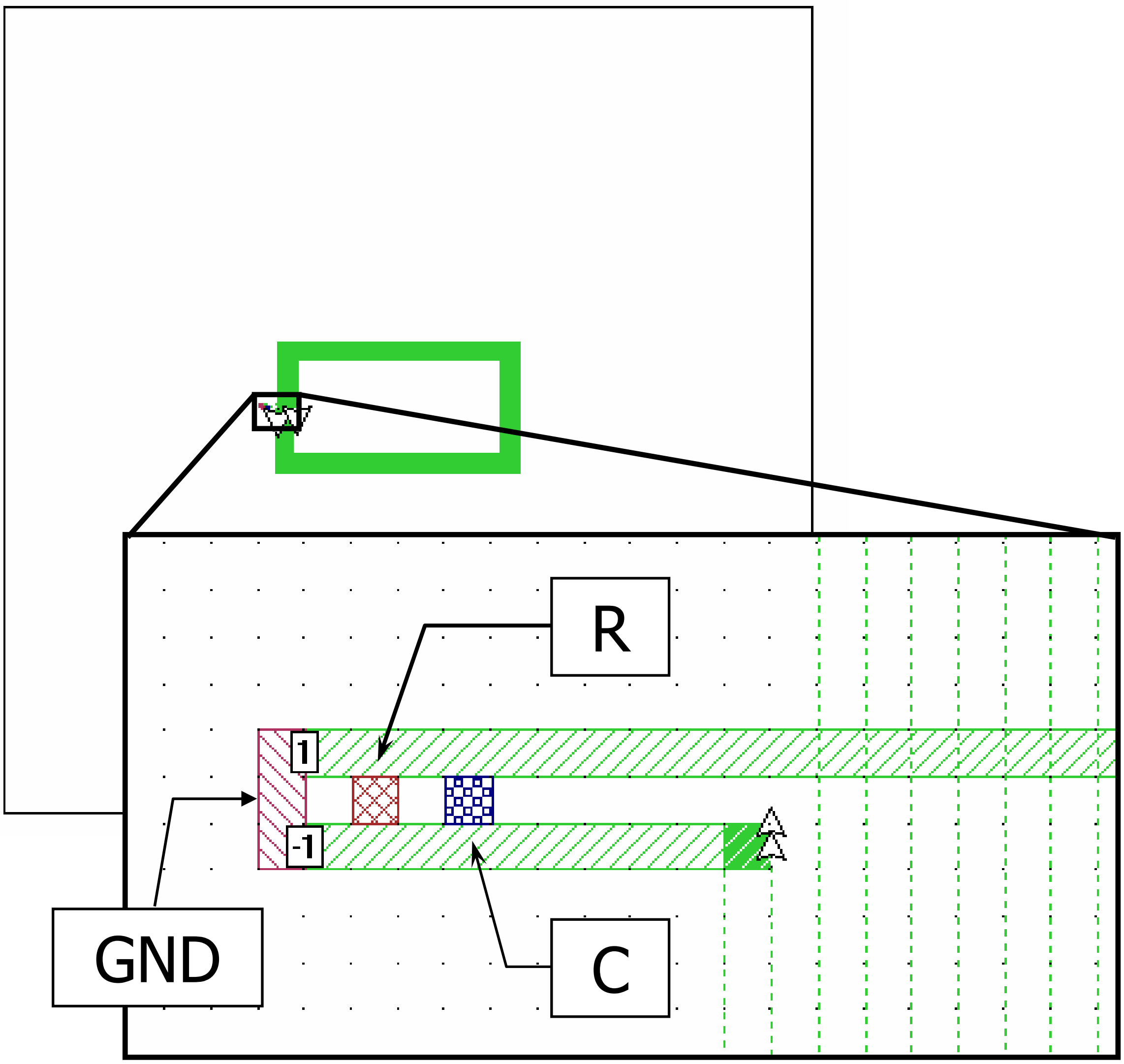


The port we have used for all the analyses so far has been at the far left edge of the substrate. At the box edge, we have a side of the perfectly conducting box which contains the entire circuit. This box side-wall gives a perfect ground reference and results in the highest possible accuracy. As described in the Sonnet documentation, the Sonnet de-embedding can shift the reference plane from the actual port location at the box side-wall to the inductor. Thus, the long transmission line connecting the port to the inductor is removed from all calculations.

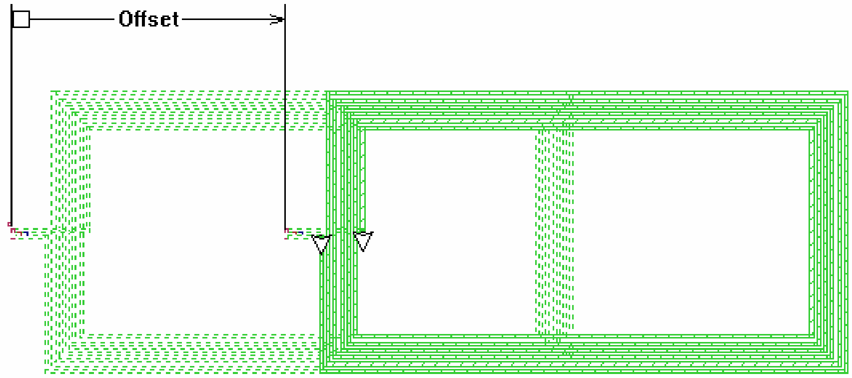


We can also use a slightly less accurate port. In this case the port is close to the inductor. In addition, we have added a small resistor, “R”. This is a patch of metal whose resistance is set to 25 kOhm/square. One square of this resistance exactly models the internal resistance of the RFID IC. The square marked “C” has a metal with surface reactance set to –399.5 Ohms/square. One square of this special reactive metal exactly models the 23.5 pF RFID IC internal capacitance and the 5.9 pF external capacitance at 13.56 MHz. Note that this reactance stays constant at all frequencies. Thus, it is exactly accurate only near the resonant frequency, but, for this case, that is no problem. The result using this port is almost the same as before.

Special metal types are added by using **Circuit->Metal Types->Add**. The capacitor is a “General” metal type with all values equal to zero except for XDC. Since there is no longer any transmission line to remove, and the port discontinuity is very small, we can turn de-embedding off (**Analysis->Setup->Advanced->uncheck De-Embed**).

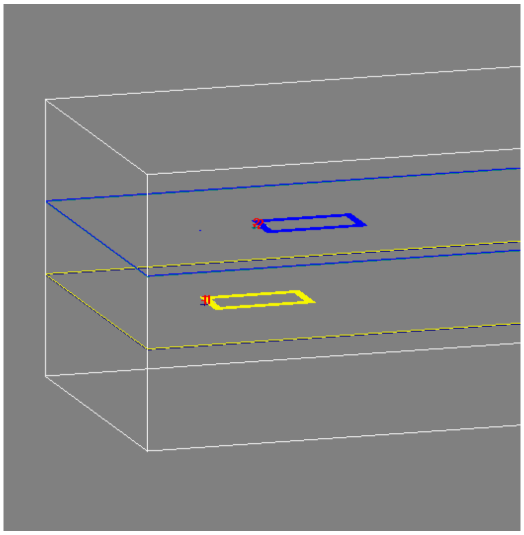


How does coupling vary with the offset between the reader coil and the tag coil? To check this, we added a second inductor 50 mm above the first one. We also made the box containing the circuit bigger. This is important because we do not want the inductor to get too close to the sidewalls.



For the analysis, we vary the offset from 0 mm to 160 mm in steps of 40 mm. The reader inductor is shown with an offset of 40 mm.

Sonnet is set up to automatically calculate a full frequency sweep for each of the five reader coil positions. Each frequency sweep generates about 300 data points. Because the Sonnet ABS interpolation is used, analysis at only four frequencies is needed to generate data at all 300 frequencies.



Before we look at the results, we shall discuss what the results mean. For our circuit, we will assume that the tag coil is connected to port 1 and the reader coil is connected to port 2.

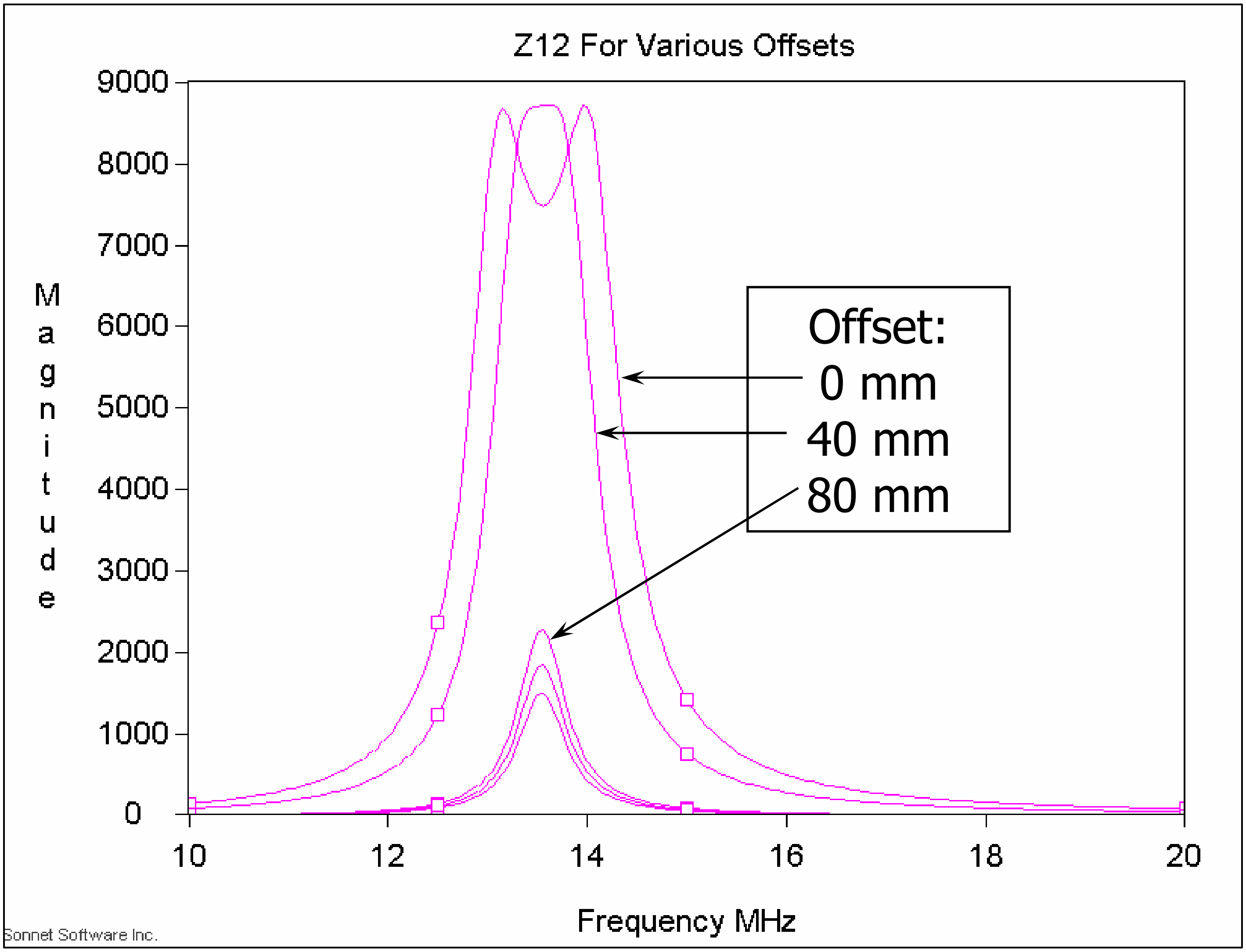
$$V_{TAG} = I_{READER} Z_{12}$$

One important question to ask is how much voltage is generated at the tag coil port when we put current into the reader coil port. This is just the value of Z12. For example, if Z12 is 9000 Ohms, then 1 mA into the reader coil (port 2) will generate 9 volts on the tag coil port.

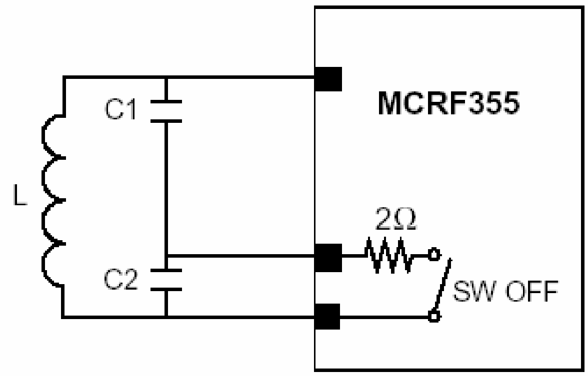
Since the Sonnet layout includes the internal resistance of the RFID IC, a full 9 volts will appear at the RFID IC to be used for operation.

We see that for both 0 mm offset and for 40 mm offset, the value of Z12 is just under 9000 Ohms. Thus, the RFID IC will have just under 9 Volts to operate for every 1 mA of current going into the reader coil.

The value of Z12 drops off quickly at 80 mm. At this location, the reader coil has just passed beyond the edge of the tag coil. Coupling drops off rapidly. The tag coil now gets only about 2 Volts for every 1 mA flowing into the reader coil.

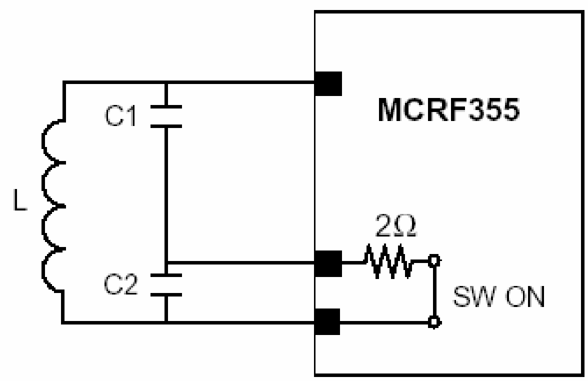


Once the tag coil gets enough power, it operates by repeatedly de-tuning the capacitor in the tuned circuit. When the tag resonant circuit is de-tuned, the tag coil has no effect on the impedance of the reader coil. When the tag coil is resonant, it couples strongly to the reader coil and changes the reader coil impedance. It is this change in impedance which is read by the reader.



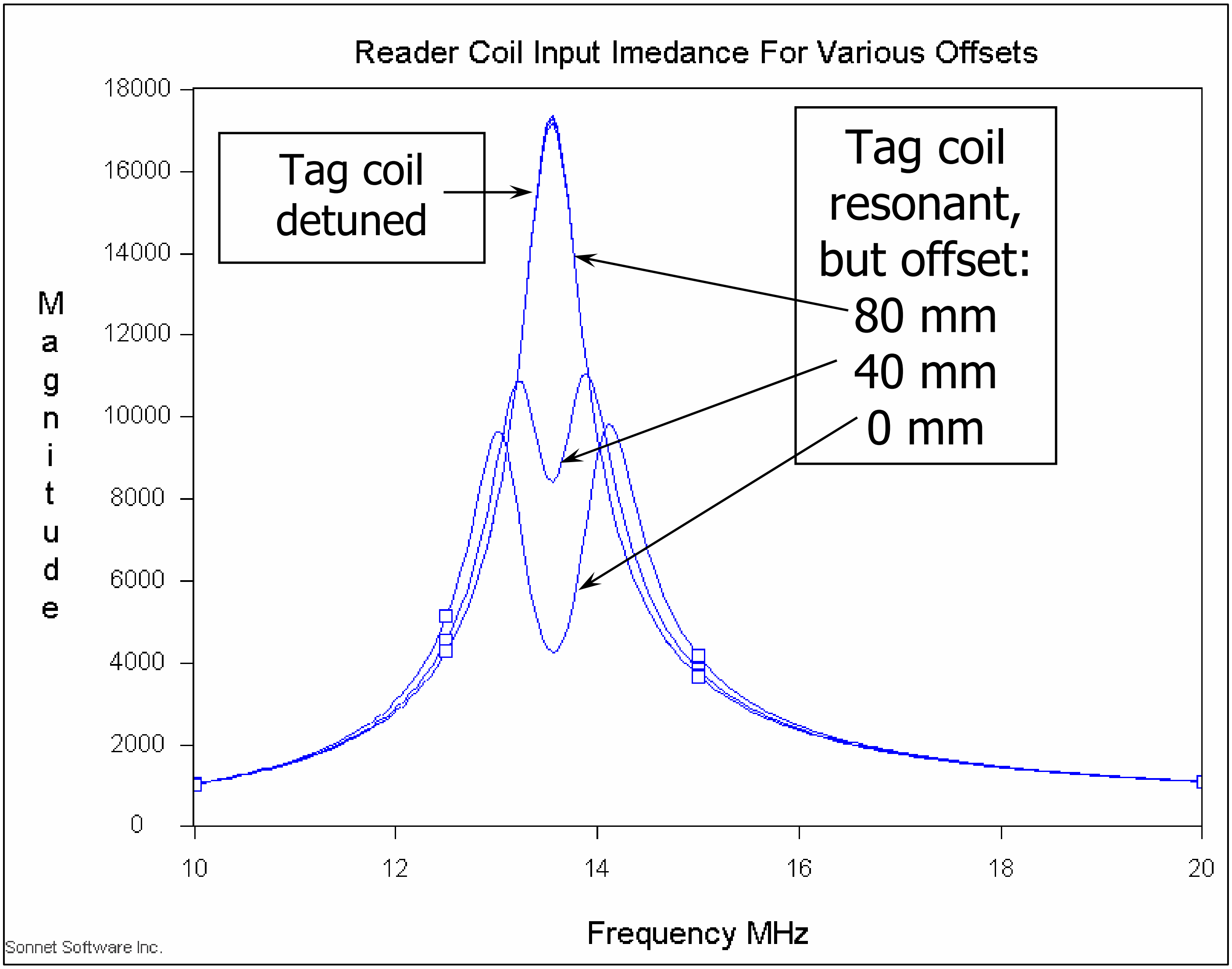
When the tag coil is resonant, the input impedance of the reader coil is Z22. When the tag coil is de-tuned, the tag coil has no effect. In this case, the reader coil impedance is the same as if there is no tag coil there at all. In the next plot, we can see this difference directly.

By sensing this change in coil impedance, the reader can read the information sent by the tag coil.

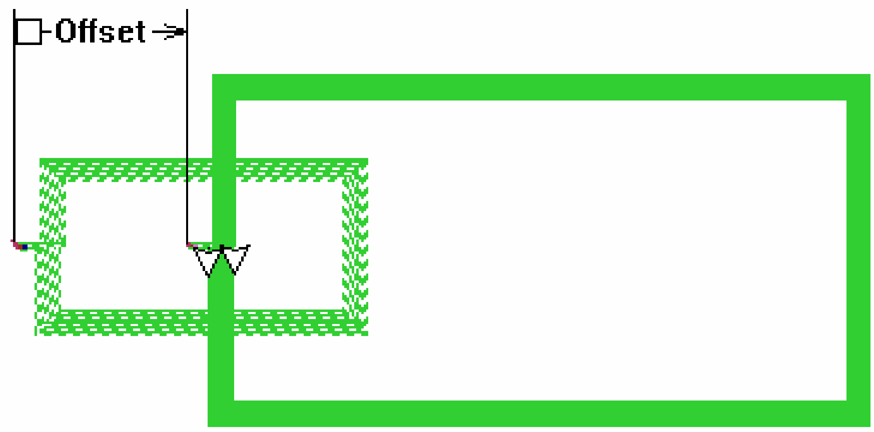


When there is a large offset between the reader coil and tag coil, the tag coil has no effect on the reader coil. The reader coil has an input impedance of about 18000 Ohms. When the tag coil is de-tuned by the RFID IC, the tag coil will also have no effect on the reader coil. In this case, the reader coil input impedance will also be 18000 Ohms, regardless of where the tag coil is located.

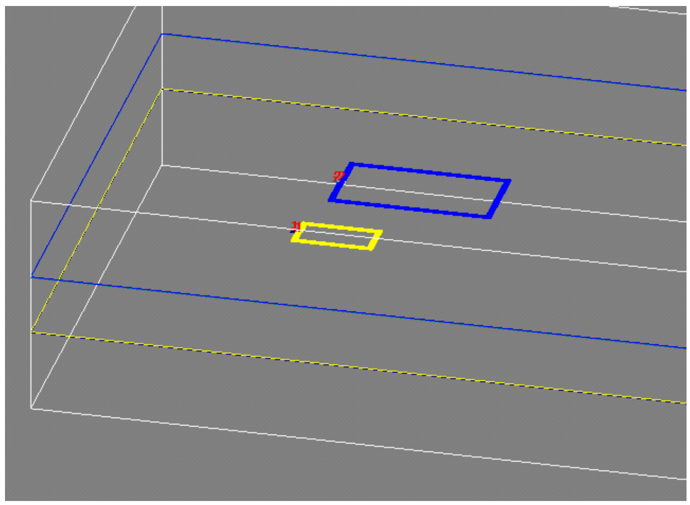
When there is 0 mm offset between the tag coil and the reader coil, the resonant tag coil couples strongly to the reader coil. The reader coil input impedance then becomes only about 4000 Ohms. If the offset is 40 mm, the resonant tag coil changes the reader coil input impedance to about 8000 Ohms. At 80 mm offset and above, there is little change. At 80 mm offset, the reader coil has moved so there is no overlap with the tag coil. There is also almost no coupling.



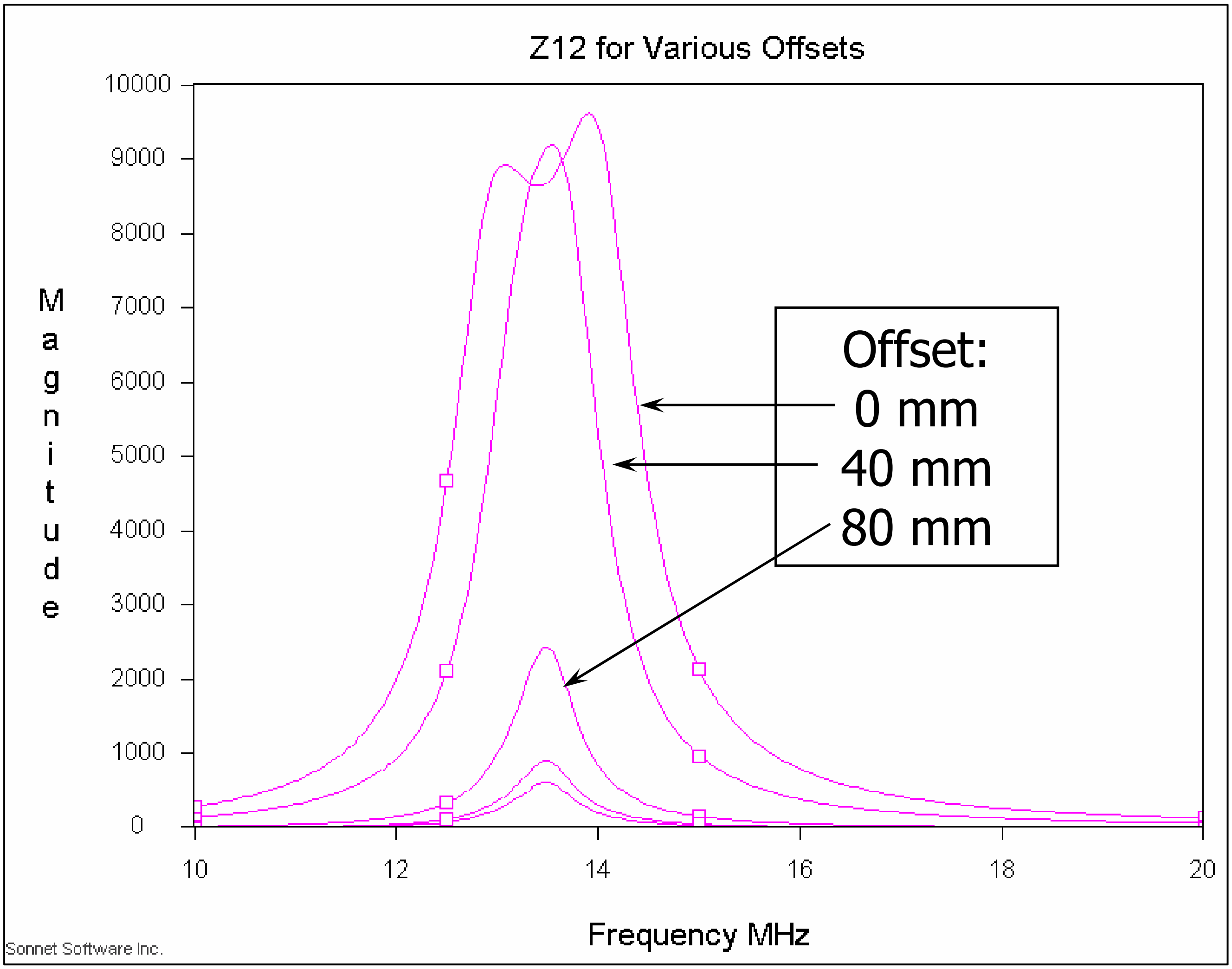
What happens when the reader coil is doubled in size? This is shown here. As mentioned before, in order to keep high accuracy, we must keep the sides of the box away from the inductor. Thus, we doubled the size of the box for this analysis. Also, because the inductor is larger, a smaller capacitance is needed for resonance. Now a total of only 8 pF is needed.



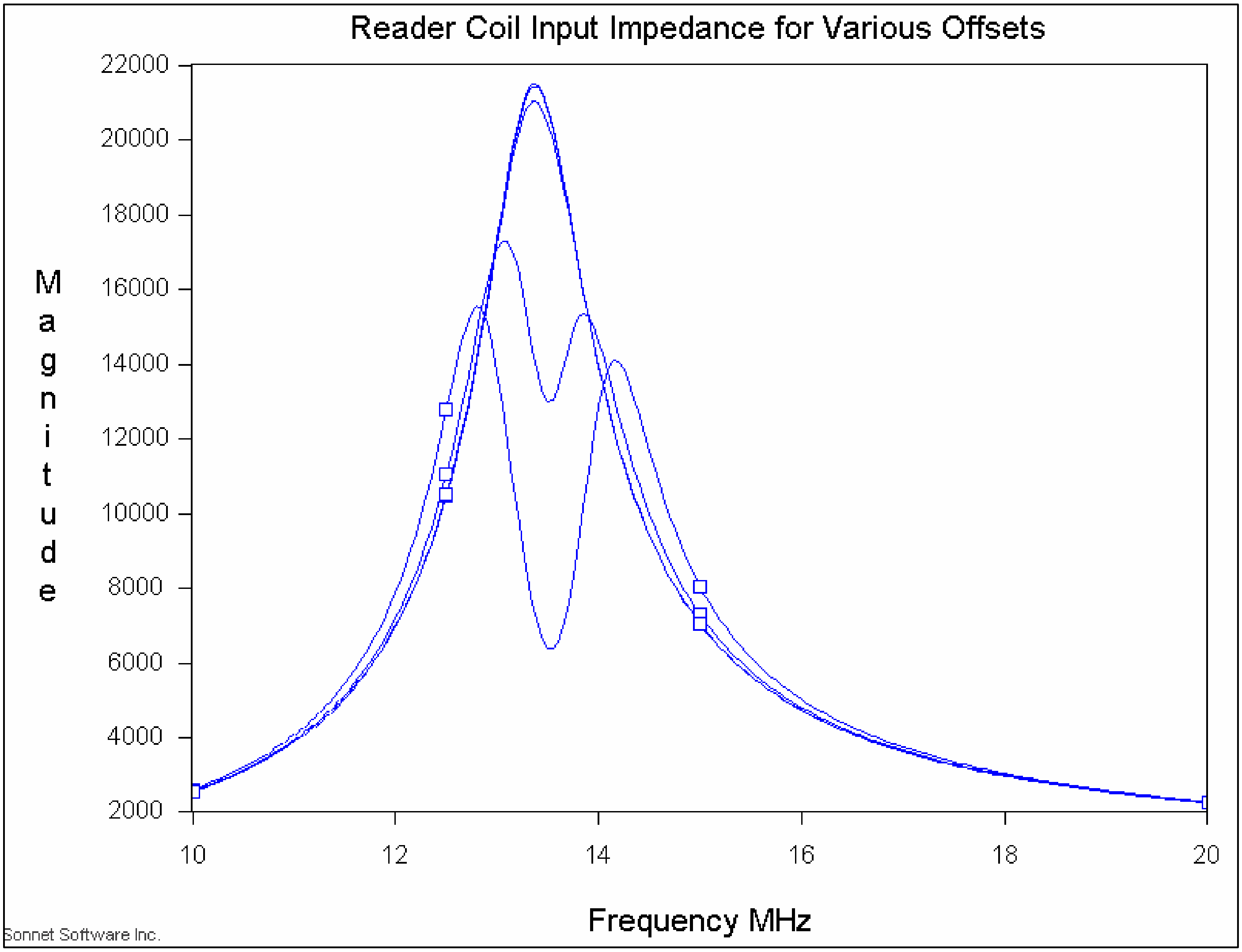
Here, the reader coil is shown offset 40 mm to the right of the small tag coil. Note that at 80 mm offset, the reader coil will no longer overlap any part of the tag coil, and we would expect almost no coupling, just like in the previous case.



Here is the coupling for different offsets. With the larger coil, the RFID IC receives a little more voltage. Now, for each 1 mA flowing into the reader coil, slightly more than 9 Volts is generated at the tag coil. As before, at 80 mm offset, when the reader coil no longer overlaps the tag coil, coupling suddenly becomes small. This tells us that the reader coil can read any tag which is inside the area of the reader coil. Thus, because this coil has a larger area, it can read tags over a wider area.



As before, we can see how much the input impedance of the reader coil changes from when the tag is resonant to when the tag is de-tuned. The peak of the curve is the reader coil input impedance when the tag coil has no effect. This is the same thing as the tag coil being de-tuned. Thus, when the tag coil is de-tuned, it will have an input impedance of about 21000 Ohms. At 0 mm offset, the resonant tag coil will cause the reader coil input impedance to drop to about 6000 Ohms.



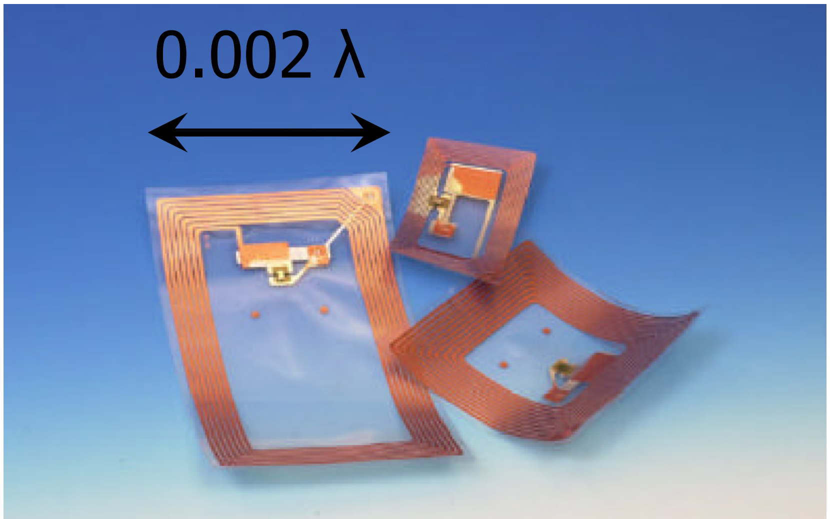
We have just shown how Sonnet's EM and nodal analyses can be used to easily analyze RFID tag coils. We precisely calculated the additional capacitance required. We also included metal loss effects on the coil performance and evaluated how the coupling between the RFID reader and tag change as the reader coil is moved.

In the following section, the paper continues with a design methodology for a 900 MHz RFID antenna.

900 MHz Tag Design

As stated earlier, the largest possible tag size is only a few centimeters. At 13.56 MHz, this size is a very tiny fraction of a wavelength. Thus a 13.56 MHz tag really works by inductive coupling, like a transformer. Its range is typically less than one meter. In order to read all the contents on an entire pallet, a longer range is needed.

In contrast, a 900 MHz RFID antenna is about one half wavelength long, or about 14 cm. A half wavelength antenna is known as a dipole. A dipole is a very good radiator. RFID tags using dipoles at 900 MHz have a range of up to 10 meters. This works well for large pallets of product.

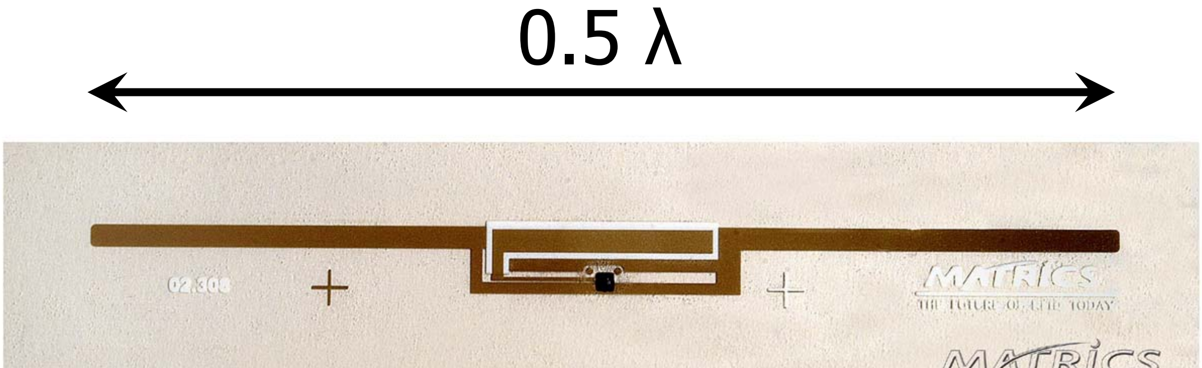


Courtesy of Texas Instruments

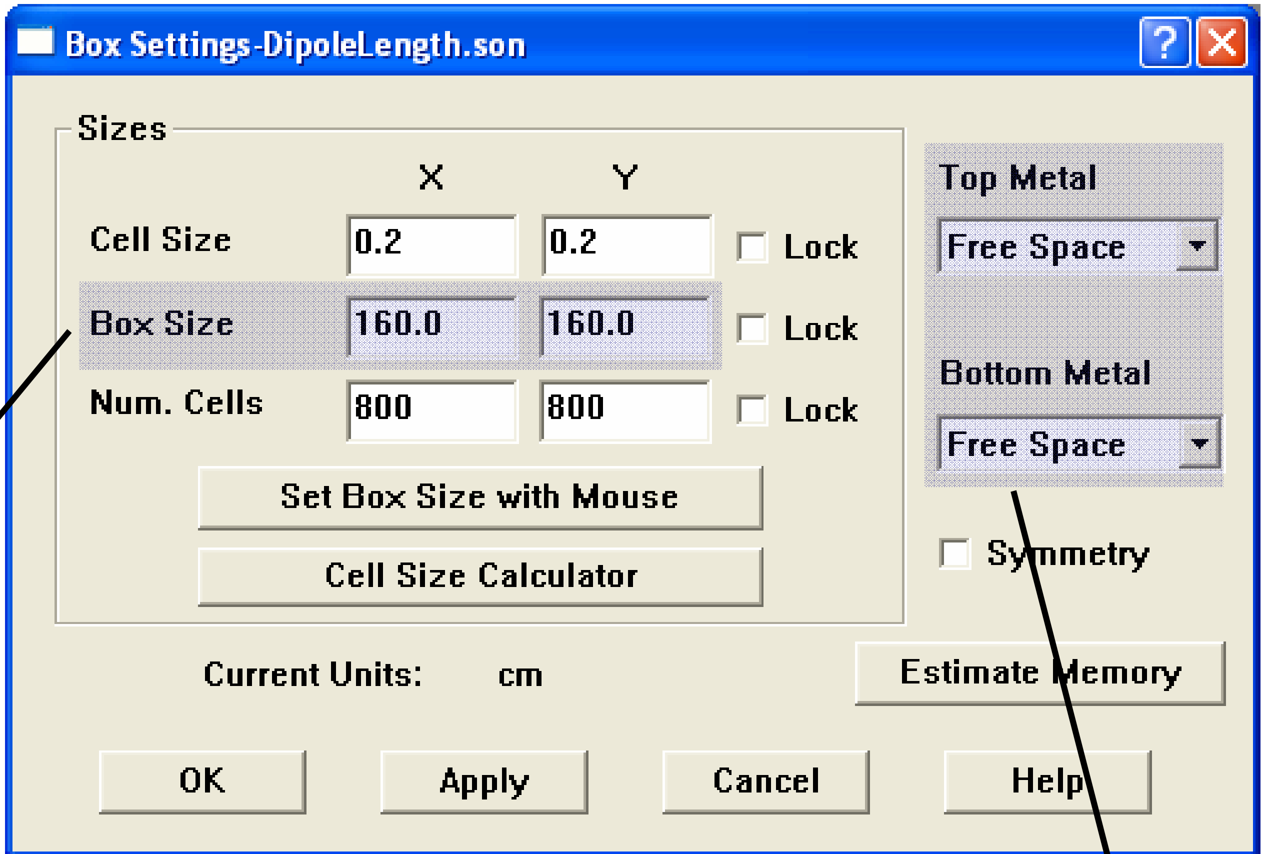
The example tag shown below is from Matrics. The complex connections in the center are probably to provide a good impedance match to the small silicon RFIC chip in the very center.

Unfortunately, there is not yet a world wide frequency allocation for RFID at 900 MHz. Europe and US have different allocations fairly close to 900 MHz. Japan is considering an allocation near 960 MHz. The design example for this presentation assumes 960 MHz.

A common RFID antenna at 900 MHz is a simple dipole. We describe how to analyze a dipole in Sonnet. Unfortunately, the simple dipole bandwidth is too narrow to handle uncertainties in the environment around the RFID tag. We show one alternative to increase the dipole bandwidth. Then, we explore how various changes in the dipole environment affect the RFID tag. Finally, we describe how to make the dipole smaller.



Courtesy of Matrics

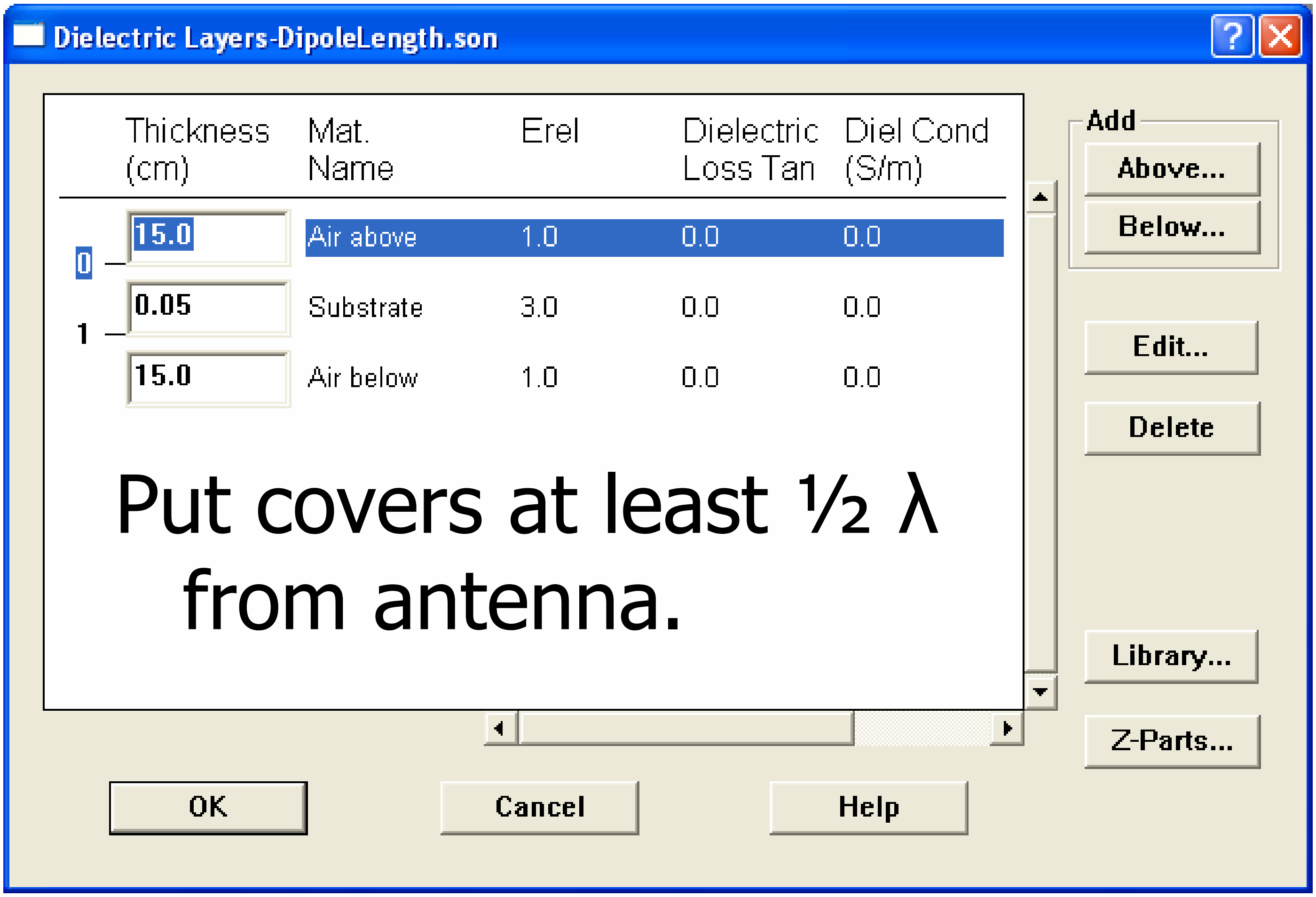


The Sonnet analysis assumes the circuit is contained in a lossless, shielding box. So how can we analyze a dipole?

First, we remove the top cover and ground plane of the box, this is easy to do in Sonnet. We simply set the top cover and bottom cover to **Free Space**. Free space is represented by 377 Ohms per square, this is the impedance of free space. This works well provided the top and bottom covers are not too close to the antenna.

The perfectly conducting sidewalls must be present in order for Sonnet to use a 2-dimensional FFT (Fast Fourier Transform). The FFT is required for high accuracy and speed. While the sidewalls must be present, we can move them a long distance from the dipole. In this case, it should be at least 40 cm. We have doubled that to 80 cm just to be safe. This gives us a box size of 160 x 160 cm. The cell size is 0.2 x 0.2 cm. Therefore the FFT size is 800 x 800. Sonnet now uses an extremely efficient "mixed radix" FFT algorithm, so this size is computed quickly even though it is not a power of 2.

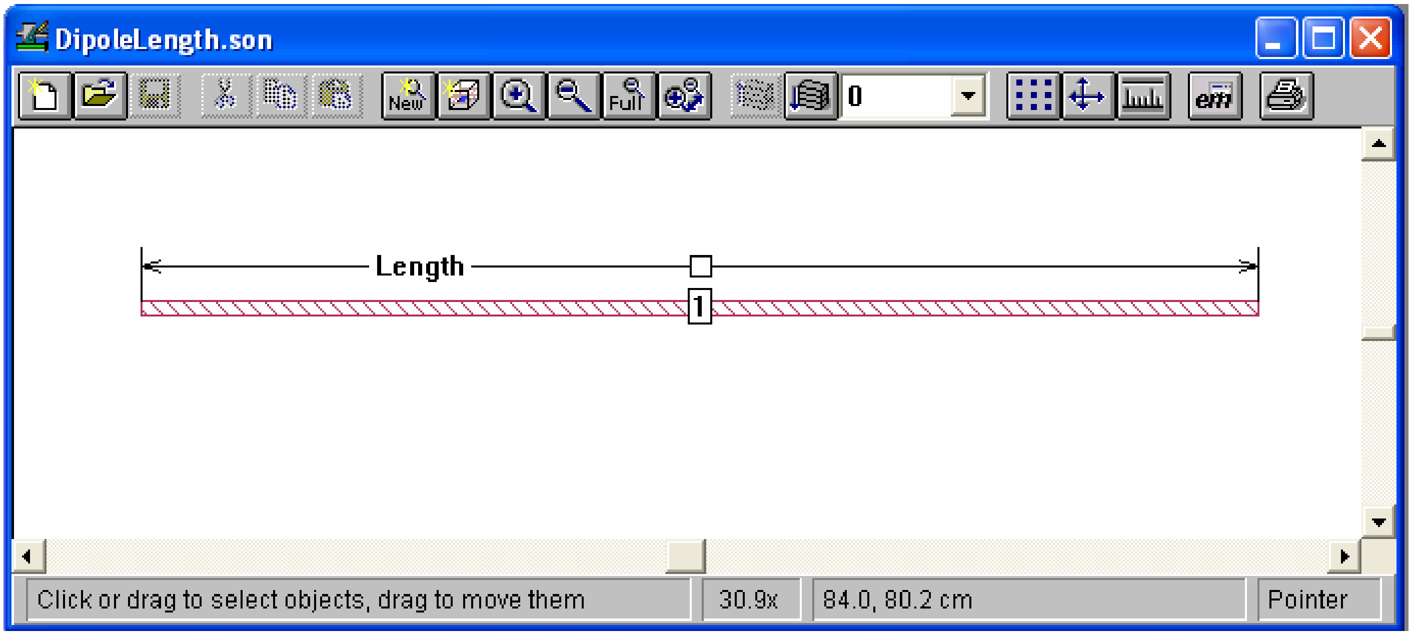
For antennas that are perfectly symmetric about a center line, we can turn on **Symmetry**. This option is in the middle of the right hand side. This results in an analysis up to 8 times faster. While our first antenna, a simple dipole, is symmetric, the other antennas are not, so we did not use the option here. The analysis of this first antenna is already so fast, it would make very little difference here.



As mentioned above, removing the top and bottom covers is done by assuming a surface resistivity of 377 Ohms per square. This simulates free space as long as the top and bottom covers are not too close to the antenna. Placing the covers about ½ wavelength from the antenna is usually sufficient. This is about 15 cm as shown here.

To be sure that 15 cm is far enough away, first perform an analysis with both covers 15 cm from the antenna, as shown here. Then increase the distance to 30 cm. However, this also increases the size of the sidewalls. The larger sidewalls can cause a problem. Thus, if you increase the cover distance to 30 cm, you should also double the box size to 320 x 320 cm. When this is done for the antennas in this presentation, almost exactly the same answer is calculated. Thus 15 cm cover distance and a box 160 x 160 cm is OK.

For this example, we use a substrate 0.5 mm thick with a dielectric constant of 3.



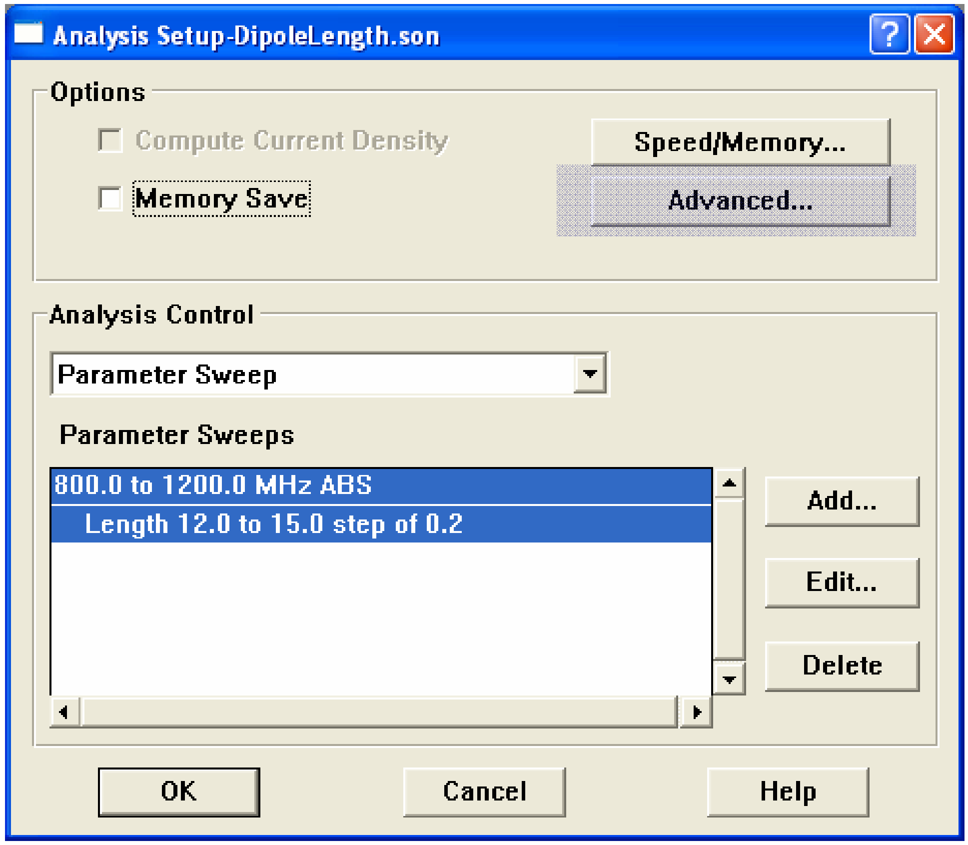
Here is a simple dipole captured in Sonnet. The dipole is very very small compared to the box size, so we show a highly zoomed view.

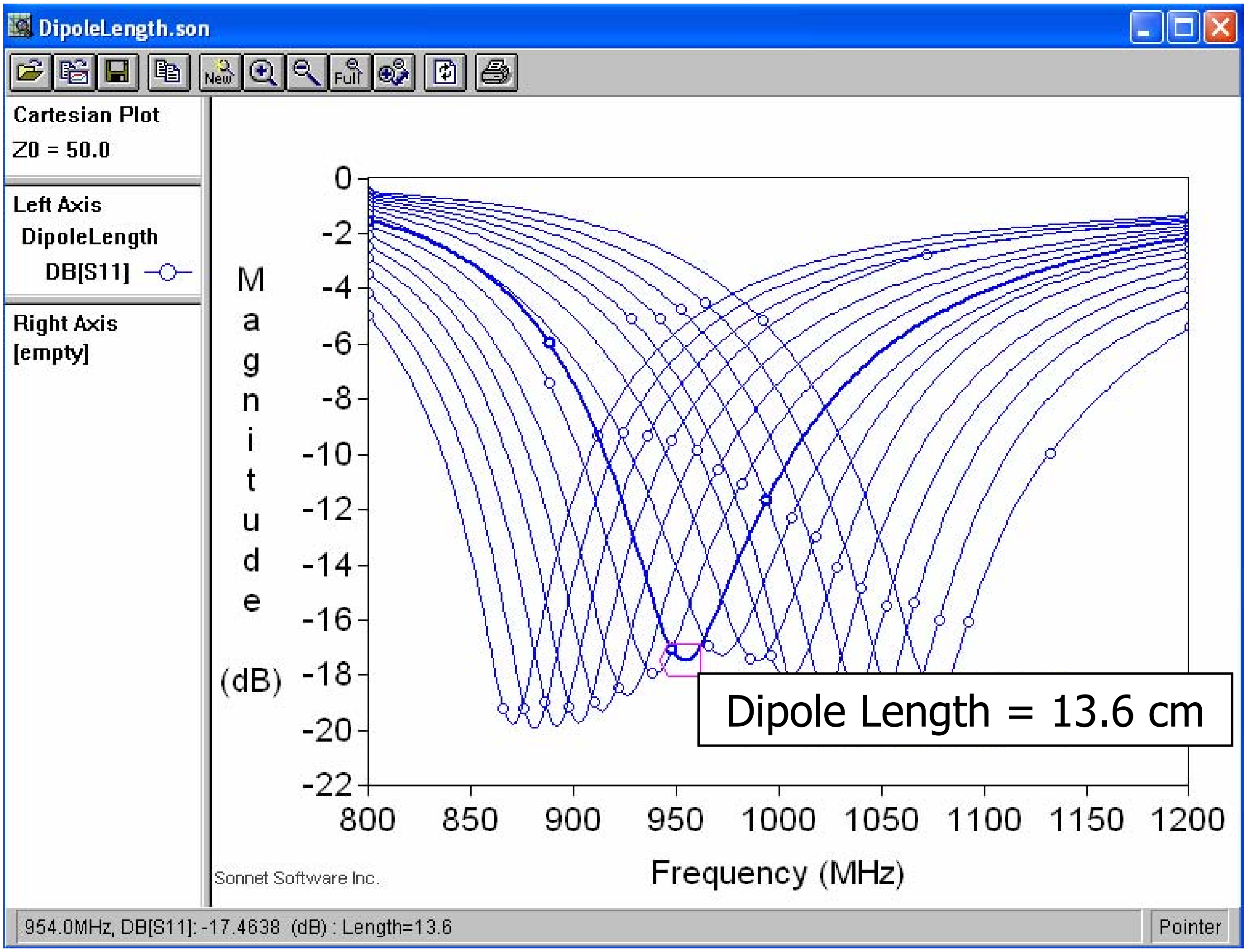
The length of the dipole is set as a **Symmetric Parameter**. For a symmetric parameter, the square point in the center, near the port, remains stationary. When "Length" is changed, both end points move outward. Thus the dipole remains in the center of the box as the parameter Length changes.

The width of the dipole is 2 mm. We will sweep the length of the dipole and see how the resonant frequency changes.

All ports in EM analysis have some kind of port discontinuity. Usually this port discontinuity must be removed. Typical port discontinuities are about 0.1 pF of capacitance. In this case, we expect such a port discontinuity will not make a big difference. To be sure, analyze with and without de-embedding and see what the difference is. For this case, with and without de-embedding gives almost exactly the same answer, so we analyze the antennas without de-embedding. To turn de-embedding on and off, use the check off box in the Advanced Setup options.

We want to see what length to make the dipole so it is resonant on our design frequency. Thus, we have specified a **parameter sweep**. In one session, Sonnet will analyze the entire dipole for Length from 12 to 15 cm, every 0.2 cm. For each length, Sonnet analyzes from 800 to 1200 MHz. Sonnet's ABS, or **Adaptive Band Synthesis**, is used.

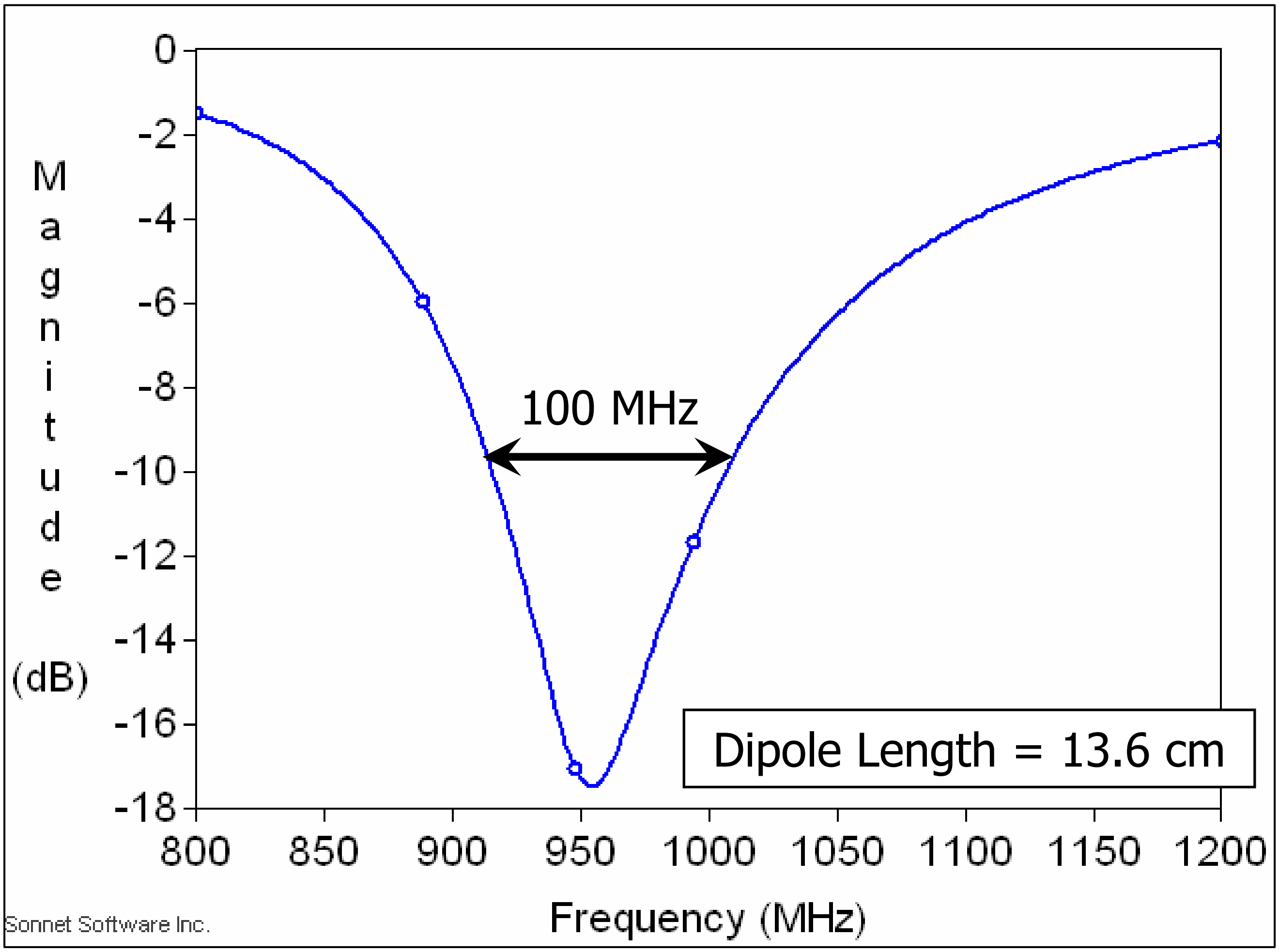




We analyzed the dipole for lengths from 13 to 15 cm. S11 (reflection) magnitude is plotted. We can now simply pick the length of dipole that gives us the desired resonant frequency. In US and Europe, allocated frequencies are around 900 MHz. For Japan, expected allocation is around 960 MHz. For this example, we pick a dipole length of 13.6 cm giving a resonant frequency very close to 960 MHz. The darker S11 curve is for the 13.6 cm long dipole.

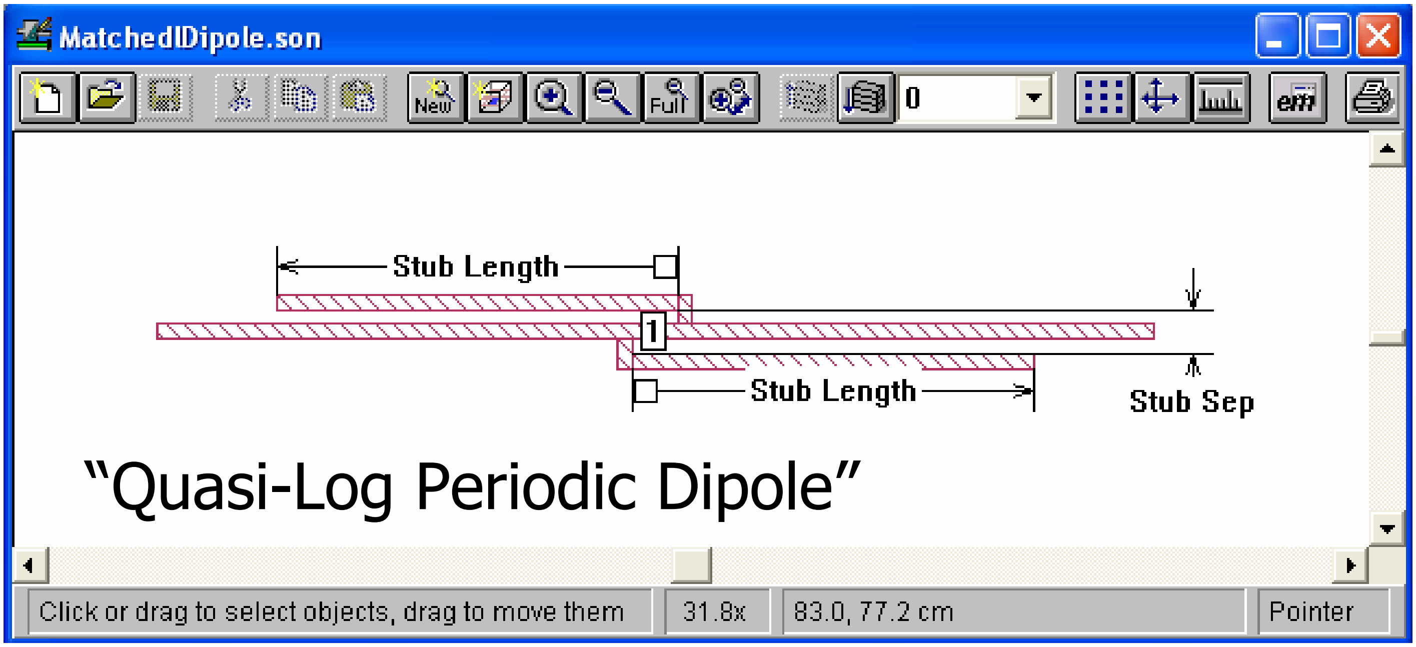
Performing and plotting a parameter sweep like this is very easy. By looking at a family of curves, we can understand a circuit much better than if we use automatic optimization. It is also easy to show how the antenna VSWR changes with respect to the length of the antenna.

Analysis time for each frequency point is 2 seconds on a 1.6 GHz notebook computer. Each curve required analysis at 5 frequencies. This is 10 seconds per curve and 2.5 minutes for the entire parameter sweep. With fast analysis like this, many different ideas can be quickly considered.



A dipole is a very good antenna. But for this application a dipole has one big problem. Specifically, the dipole has a narrow bandwidth. RFID normally operates on a single frequency, so we would think that this is not a problem. However, we do not have complete control over the environment of the dipole. If an RFID tag is designed to be resonant at the right frequency when it is placed on an empty box, it might move to the wrong frequency when the box is filled with metal cans, or even just placed near another box filled with metal cans. Or, if the RFID tag is designed to operate on a box filled with metal cans, it might move to a wrong frequency when the box is filled with glass bottles.

Thus, we must design the RFID tag to have a bandwidth wide enough to take into account all possible changes in its environment. 100 MHz is not likely to be enough.

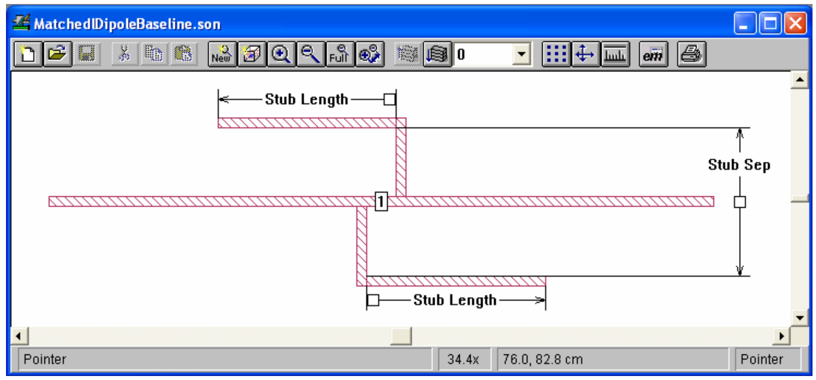


We spent a few hours looking at many different possibilities. Most of the ideas to increase dipole bandwidth did not work. Fortunately, the analysis of each design was very fast. Thus, we were able to try many different ideas until we found one that worked. This is the idea that worked.

This is similar to the broad band log periodic antenna. A log periodic is many closely spaced dipoles with the phase of each dipole reversed along the array. Can we get a broad band dipole by creating a log periodic antenna with only 2 dipoles? Here we see a 2 dipole log periodic array with the shorter dipole viewed as a tuning stub. So now, we perform a 2-parameter sweep. We sweep both the stub length and the stub separation over a large range and plot all the data. Then we simply pick the dipole we want.

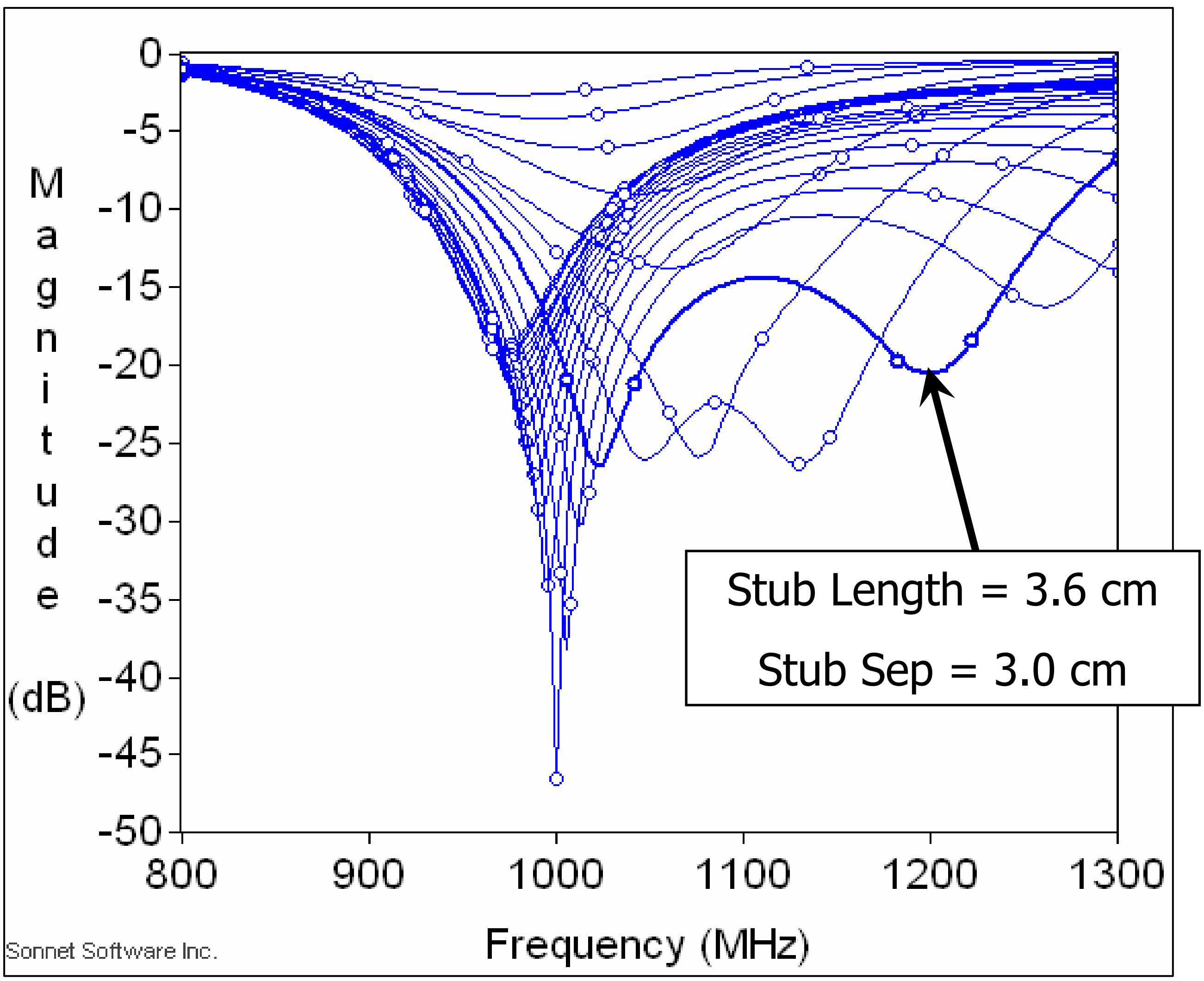
When we have the stub separation set to 3 cm and the stub length to 3.6 cm, we have a very broad band dipole well matched into 50 Ohms. Notice that if we can accept a match that is not as good, we can have a broader bandwidth. If we need a better match, then we can use a dipole with less bandwidth.

We only plot data for a stub separation of 3 cm. For much smaller separations we get similar plots except that the dipole is well matched into a lower impedance, for example, 25 Ohms.

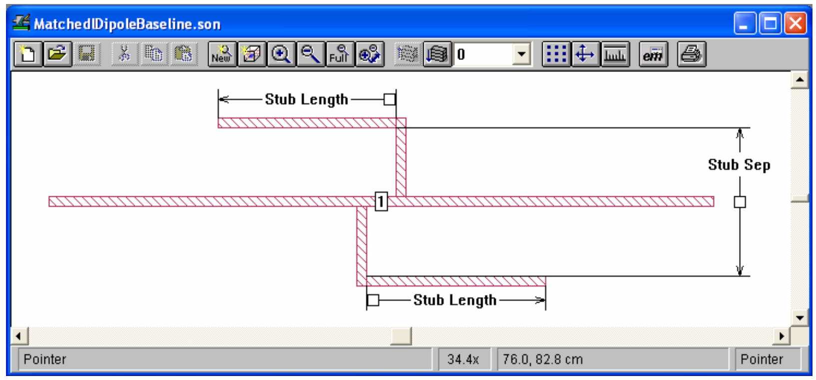


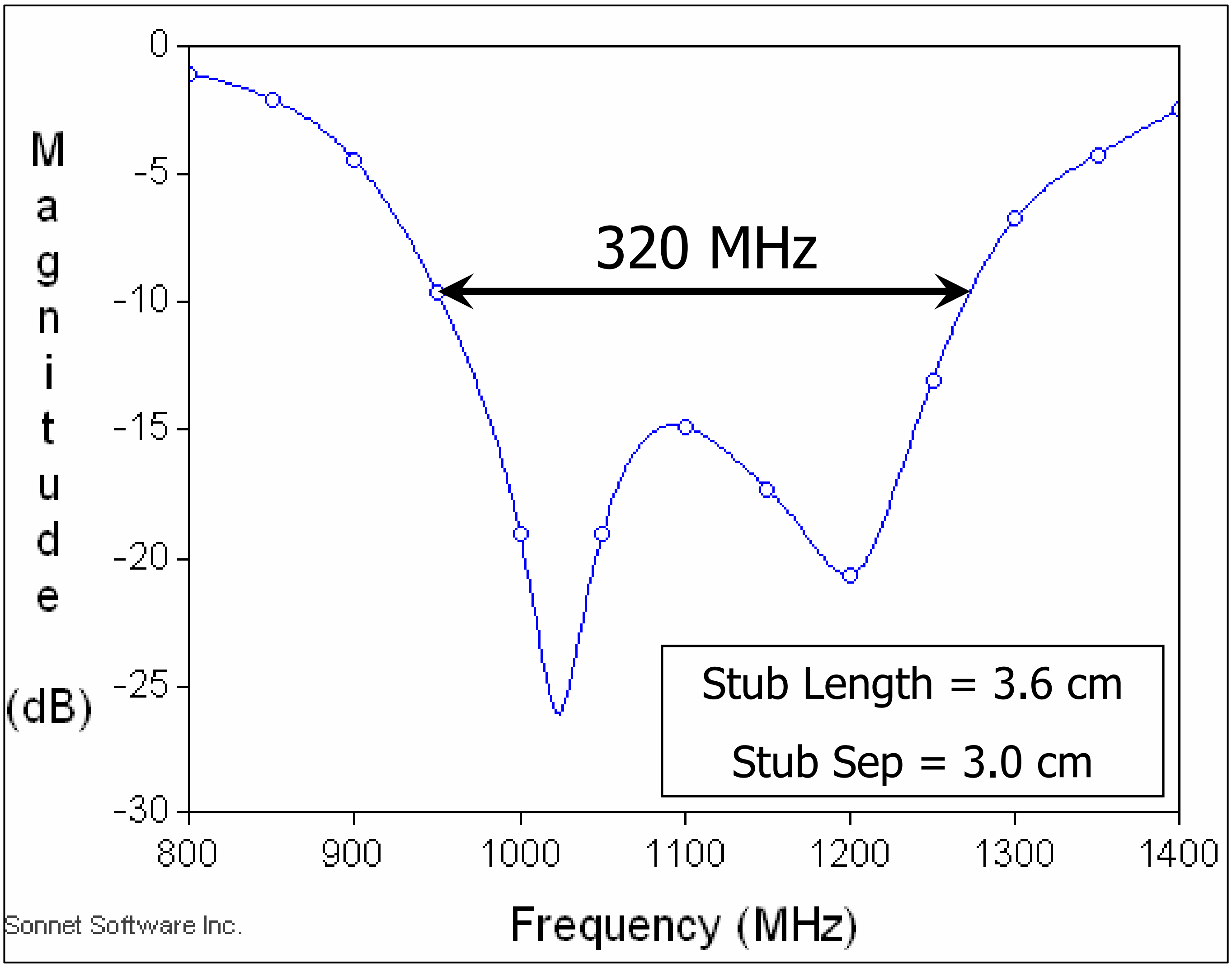
If higher impedances are required, we can use folded dipoles. For example, this dipole could be printed on both sides of the RFID tag and the ends of each dipole connected together through the tag material. This yields about 4 times higher input impedance. To work properly, the dipoles on each side of the RFID tag can not be directly on top of each other.

The key to success here is in having a very fast analysis and plotting many different cases. Then, by viewing a large family of curves, we have a good understanding of what is happening.



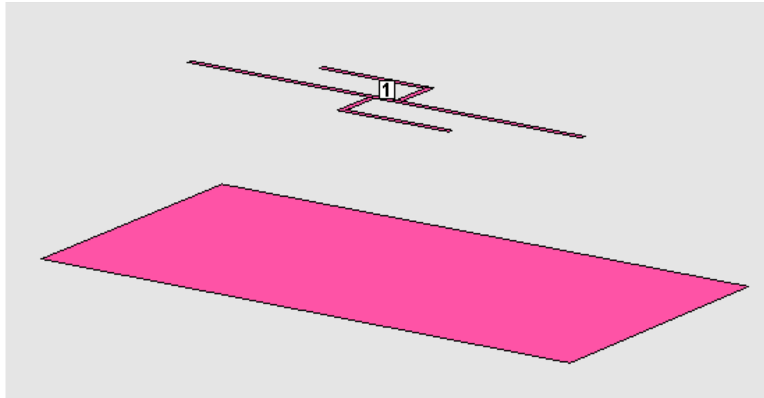
Here is the broad band dipole design. The bandwidth is over three times larger than with the simple dipole. If the dipole environment is well controlled, we could have designed the dipole to cover 880 – 1200 MHz. Such an RFID tag will cover American, European, and Japanese RFID frequencies all in one tag. With the design shown here, we allow maximum variation in the dipole environment. Any material coming near the antenna will most likely lower the resonant frequency. For this antenna, the resonant frequency must be lowered by 320 MHz before it will fail.

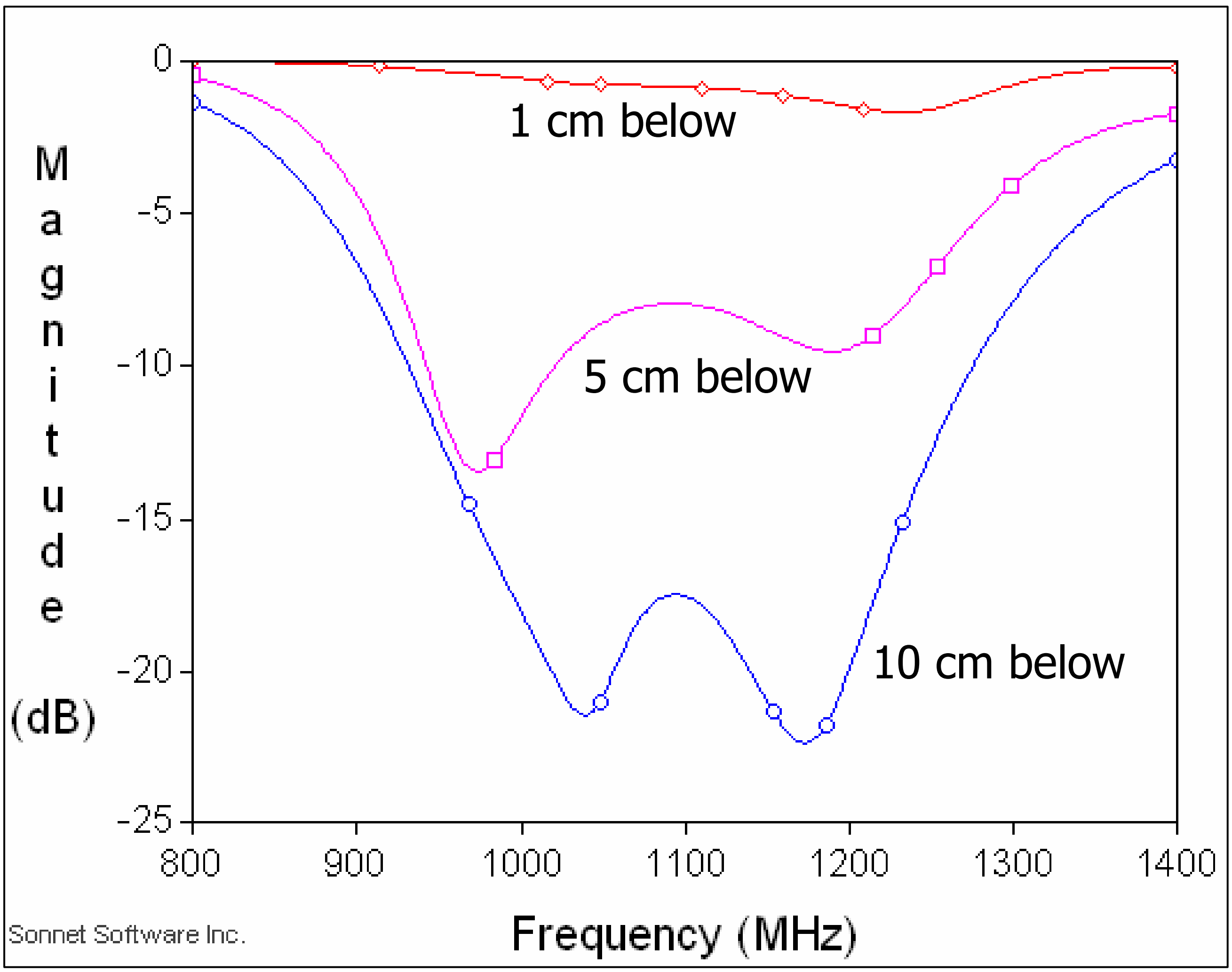




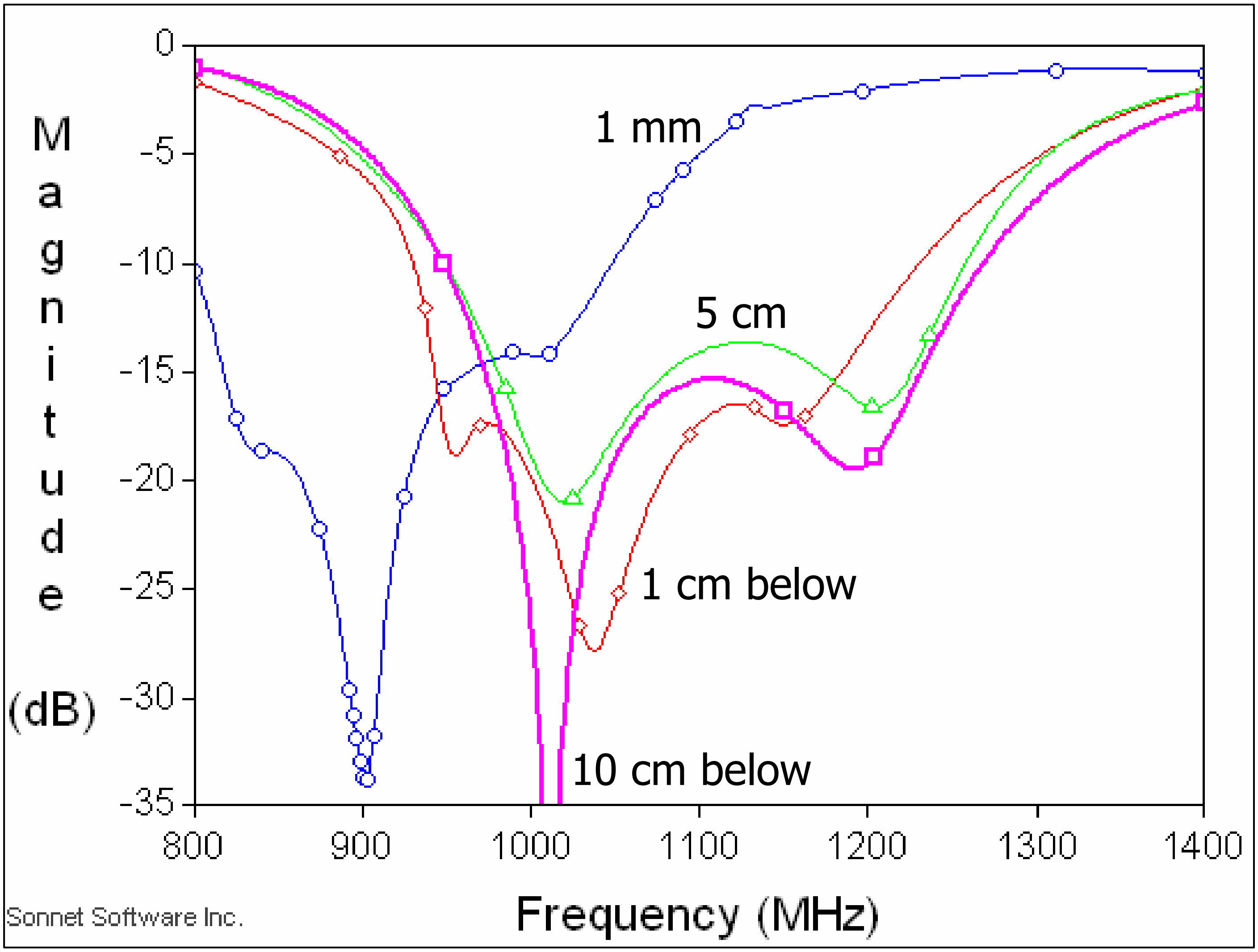
What happens when we bring large metal plate near the RFID tag? Here we see the result as we bring an 9 x 18 cm sheet of metal close to the tag, as shown in the figure. The tag will probably still work with the metal 5 cm away, but the tag range will be significantly reduced with the metal plate 1 cm away. Large nearby pieces of metal can have a strong effect on a dipole. Remember that a dipole is a good antenna and has a large range. This is also why it can be sensitive to nearby metal.

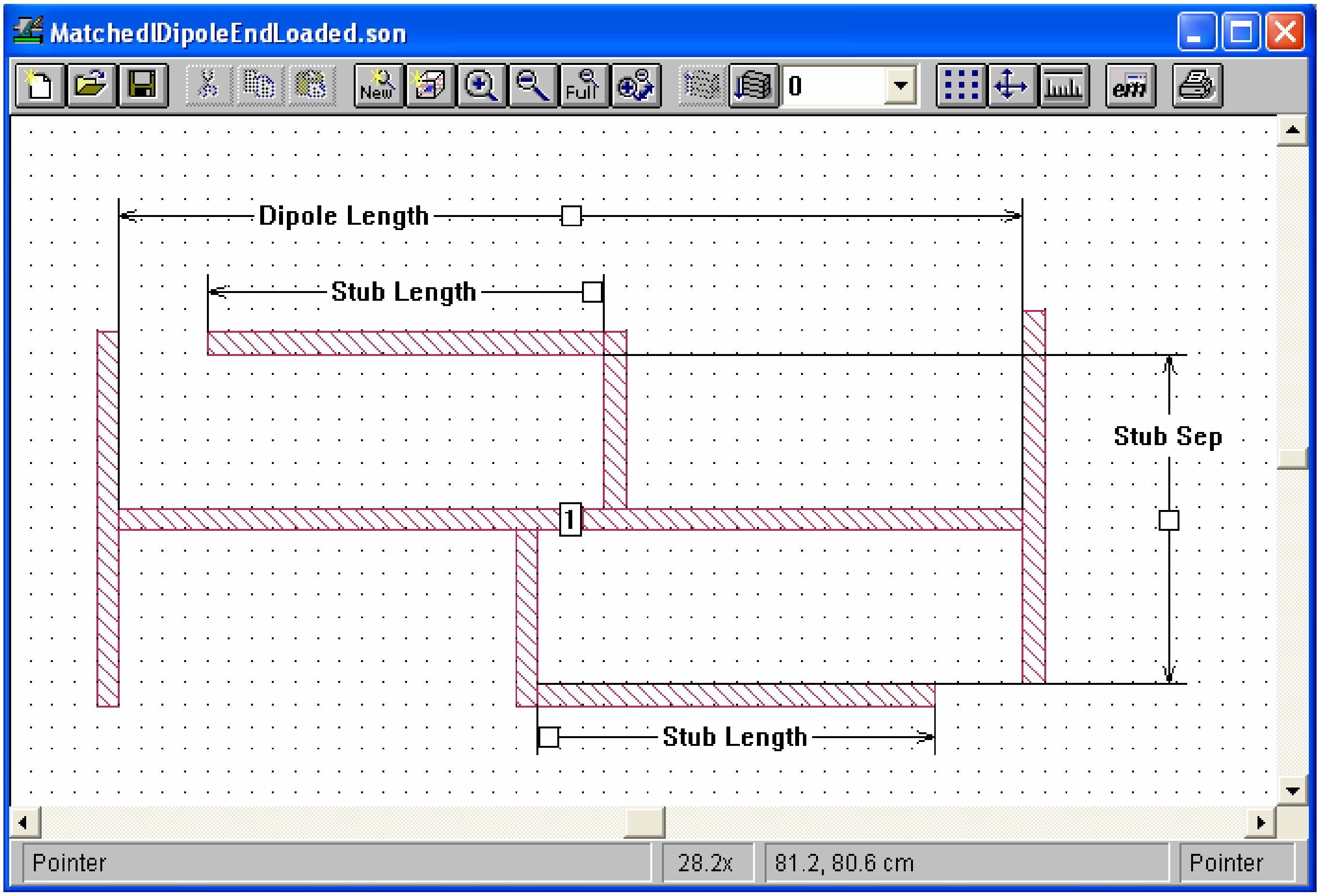
If an RFID tag must work efficiently with nearby metal, the design should include the nearby metal. But then, the tag might fail if the nearby metal is removed. One way to solve this problem is to print nearby metal on one side of the tag so that the nearby metal is always there. Such an RFID tag ground plane need not be solid. It could be a mesh or grid to significantly reduce the amount of metal required.



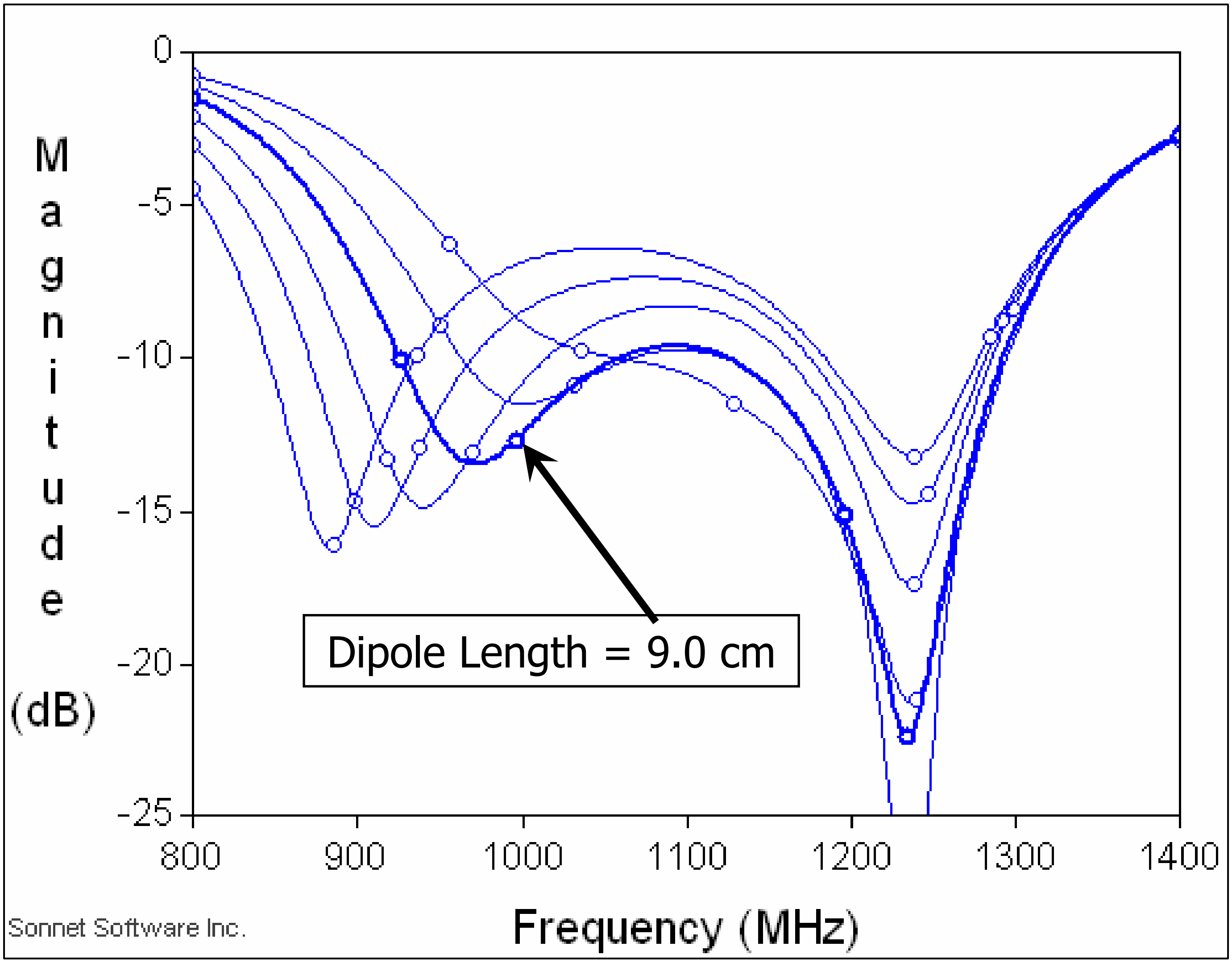


What happens when we bring a large 1cm thick layer of glass close to the RFID tag? Here we see very little effect until the glass is only 1 mm away from the RFID tag. Even at 1 mm away, the RFID tag should still work with full range. Thus, we see that the broad band dipole provides a big advantage over the simple narrow band dipole.



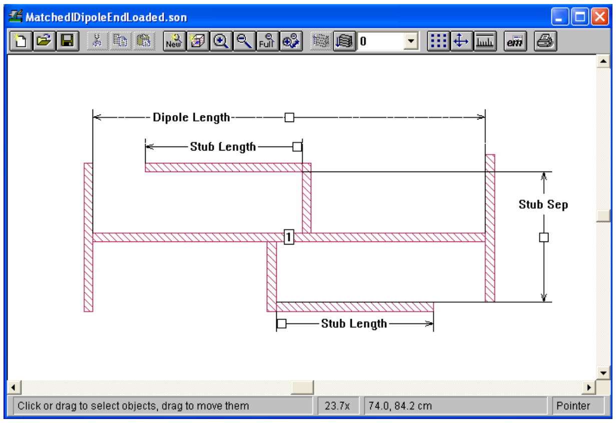


This dipole is 13.6 cm long. It would be nice to have the dipole a little shorter. This can reduce the cost of the RFID tag. Here we try capacitive end loading. For this parametric sweep, we sweep only the Dipole Length. Then we select the dipole that has the desired response.

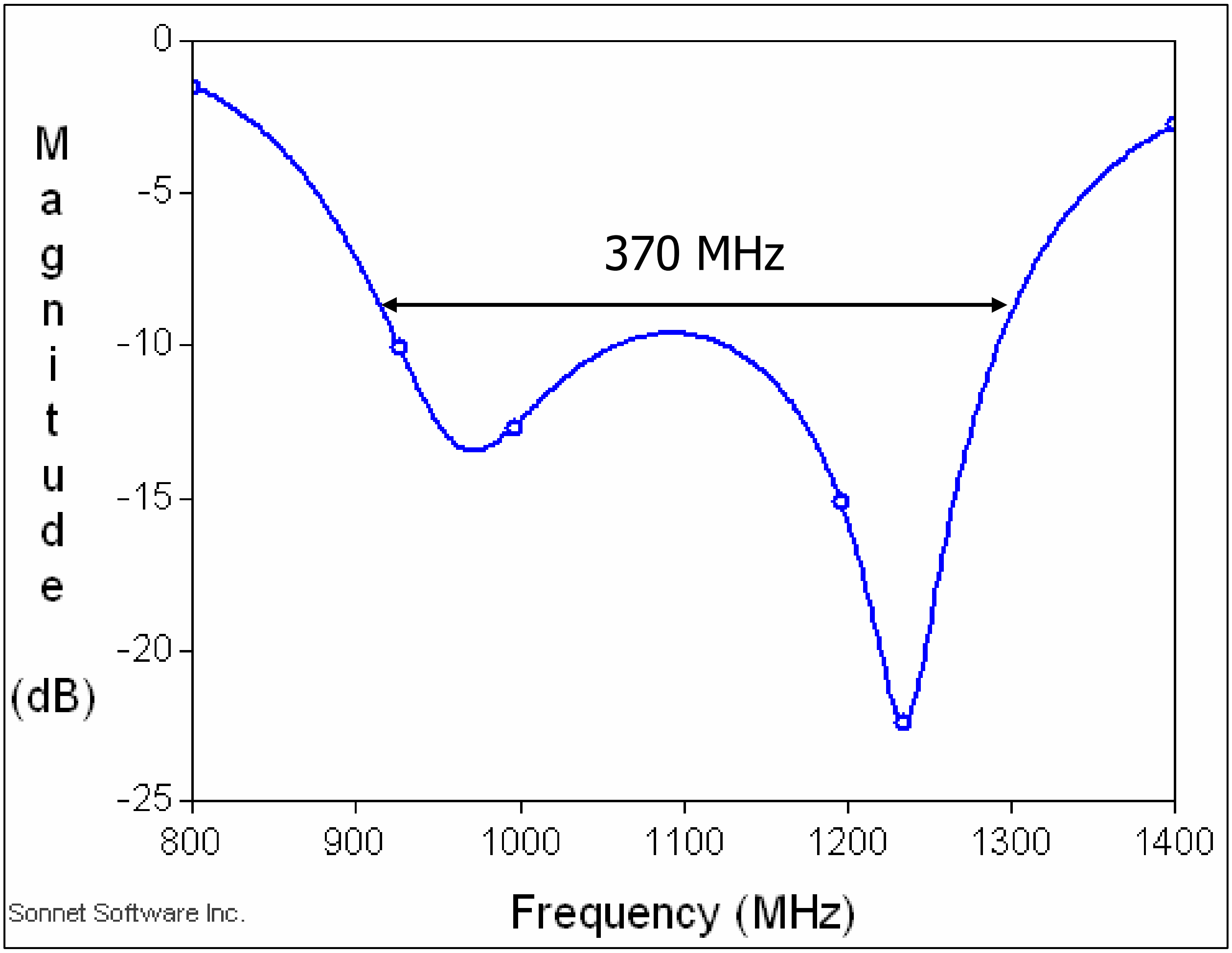


A dipole length of 9 cm provides a good response.

The in-band reflection has increased to -10 dB. It would be nice to have a smaller reflection coefficient. By selecting other parameters, like the size of the capacitive end loading stubs, or the stub separation, it is very likely that this reflection coefficient can be improved. However, notice that the bandwidth has increased to 370 MHz.



In conclusion, the 900 MHz RFID has a very large upside potential for supply chain impact. There is a clear possibility that billions, and even trillions of tags could be in use within the next few years. However, in order to see wide use, the tags must be made inexpensive, compact, and insensitive to the surrounding environment. In order to ensure fast time-to-market with the most creative RFID products, designers must have the right tools to accurately analyze many different tag designs quickly. This allows a designer to try numerous ideas in a very short time. This is called *Rapid Virtual Prototyping*. This application note has demonstrated that Rapid Virtual Prototyping can be achieved by making use of fast and accurate electromagnetic analysis. By applying this design method, the designer can discard the ideas that don't perform and quickly find one or two creative ideas that work very well.



For questions about this paper or would like to obtain Sonnet examples used in this article, please, contact Sonnet Software, Inc.

Sonnet Software, Inc.
Phone: 315-453-3096
Toll Free in North America: 877-7SONNET
Email: info@sonnetsoftware.com
Web: www.sonnetsoftware.com

Sonnet Software, Inc.
Phone: 315-453-3096
Toll Free in North America: 877-7SONNET
Email: info@sonnetsoftware.com
Web: www.sonnetsoftware.com

United States Regional Sales:
Eastern US Sales Office: 203.439.0815
Western US Sales Office: 303.443.2646

Japan:
Sonnet Giken Co., Ltd.
Phone: 43-463-6663
Email: info@mail.sonnetsoftware.co.jp
Web: www.sonnetsoftware.co.jp

Germany, Austria, Netherlands:
Muehlhaus Consulting & Software GmbH
Phone: +49 (2302) 91438-0
Email: info@muehlhaus.com
Web: www.muehlhaus.com

UK, Ireland:
SJ Technologie
Phone: +44 (0)1536 524255
Email: John @ SJTechnologie.co.uk
Web: www.sjtechnologie.co.uk

Sweden:
Gritek Konsult AB
Phone: +46 8-24 2312
Email: amos.griner@gritek.se

Italy:
Medeos
Phone: +39 02 4586 2160
Email: info@medeos.it
Web: www.medeos.it

Taiwan:
Nearson Marketing Group
Phone: +88-6-3-5332541
Email: csw7786@ms8.hinet.net

China:
United Right Technology
Phone: +86-10-67082450
Email: urt@urtgroup.com
Web: www.urtgroup.com

India:
ICON Design Automation
Phone: +91-80-5272030
Email: idapl@vsnl.com
Web: www.icon-dapl.com

Russia:
ElecTrade, Ltd.
Phone: +7-095-974-14-80
Email: potapoff@eltm.ru
Web: www.eltm.ru