Sonnet 16 New Feature:
Enhanced Resonance Detection

Greg Kinnetz
Application Engineer
support@sonnetsoftware.com

May 2016

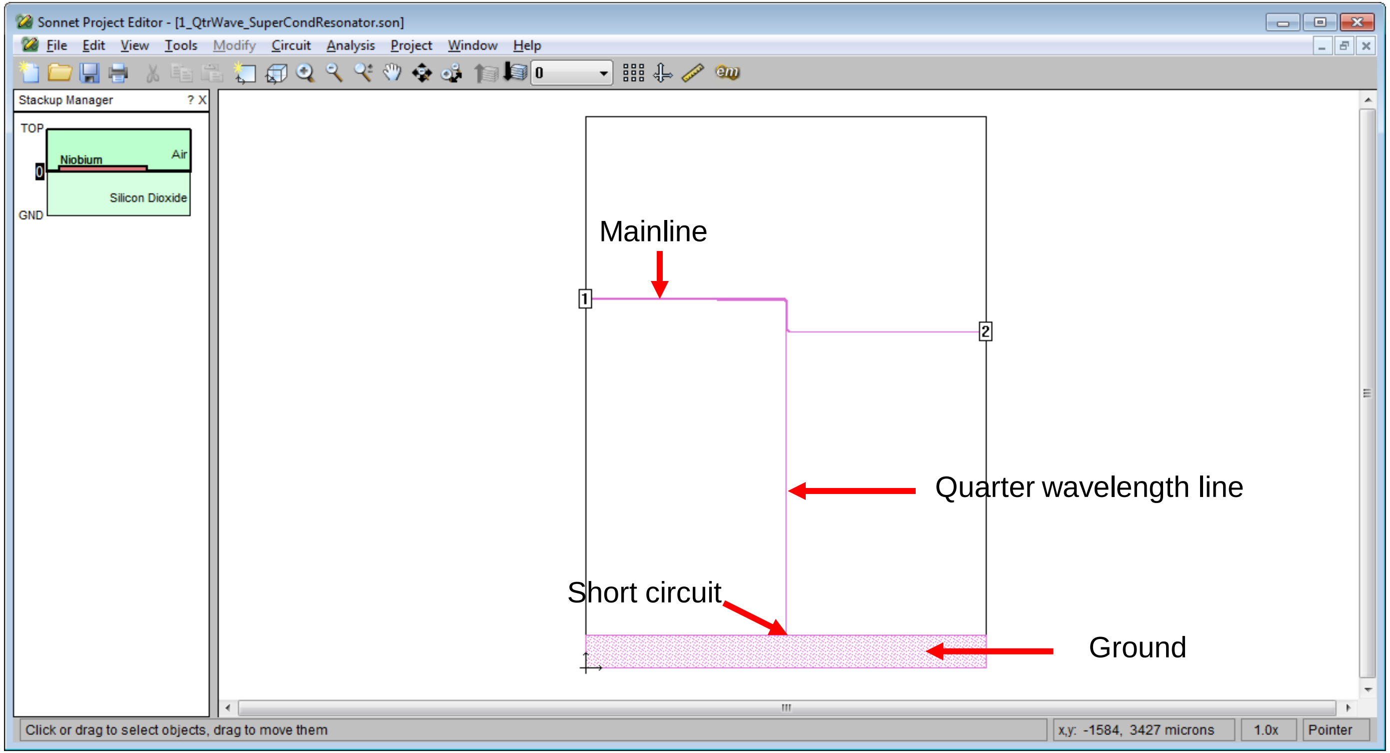
PRECISION ELECTROMAGNETICS

Introduction

- Adaptive Band Synthesis was added in Sonnet version 8. At the time, it was widely welcomed as an efficient way to sweep an EM model, replacing a time consuming Linear Sweep.
- The ABS algorithm generally has worked well with traditional RF circuits, especially filters. It has been refined with each passing Sonnet release.
- In recent years, we've seen increased interest in using Sonnet to model superconductor circuits. One of the more common circuits is a resonator, consisting of transmission lines or possibly inductors and capacitors.
- Due to the extremely high Loaded Q-Factor of these resonators, the bandwidth of the minimum or maximum present in the data is very small. ABS can partially resolve the resonance or miss it entirely.
- In Sonnet 16, a new feature was added called Enhanced Resonance Detection. It modifies the ABS algorithm behavior and does a better job detecting and resolving resonances.
- We will discuss the current state of ABS and how Enhanced Resonance Detection provides a solid improvement in ABS behavior with superconductor resonator models.

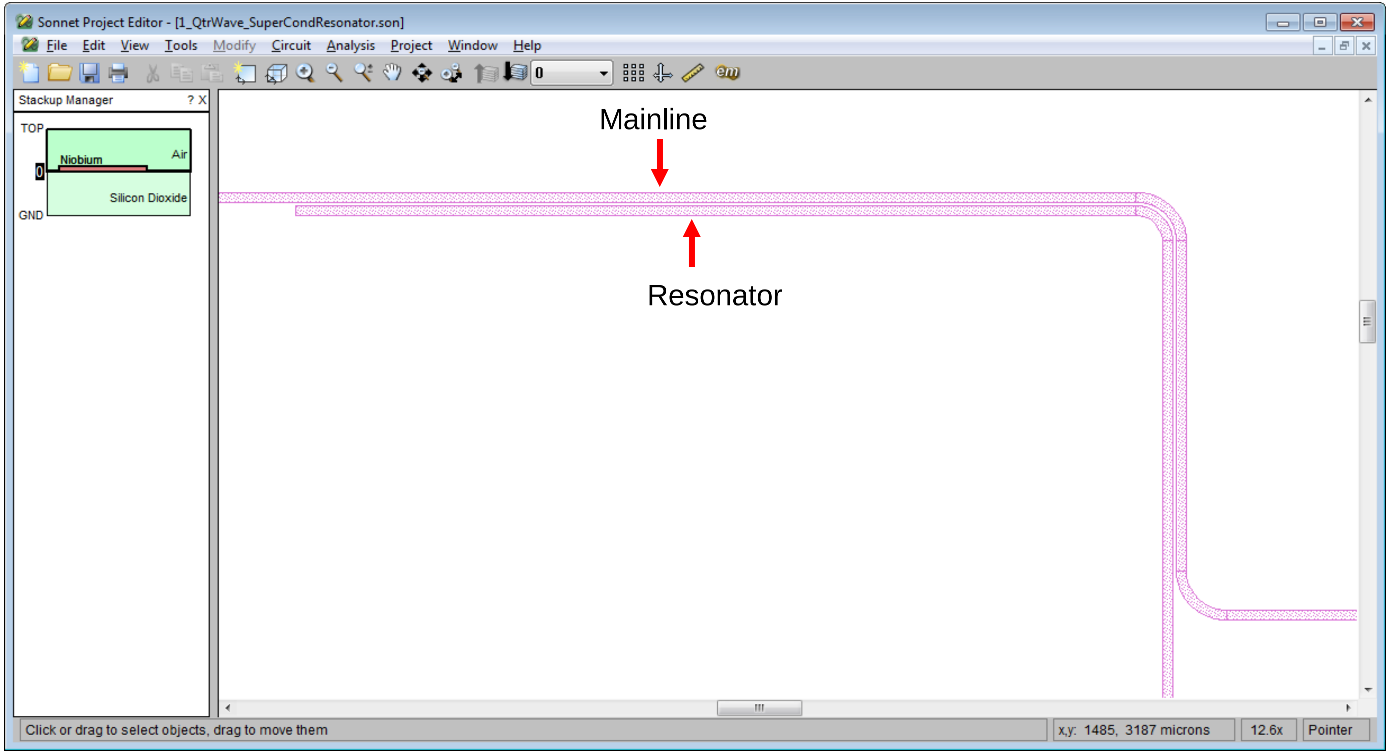
Single Resonator Model

Superconductor resonators use many of the traditional RF resonator structures such as half wavelength, open circuit transmission line. In this model, we are using a quarter wavelength, shorted microstrip line.

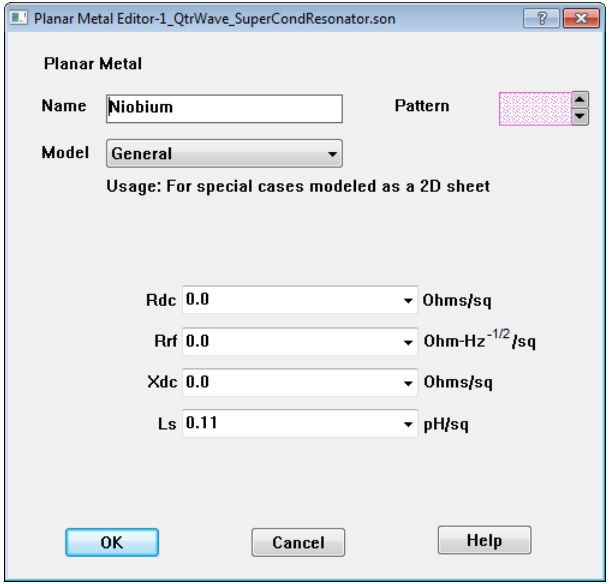


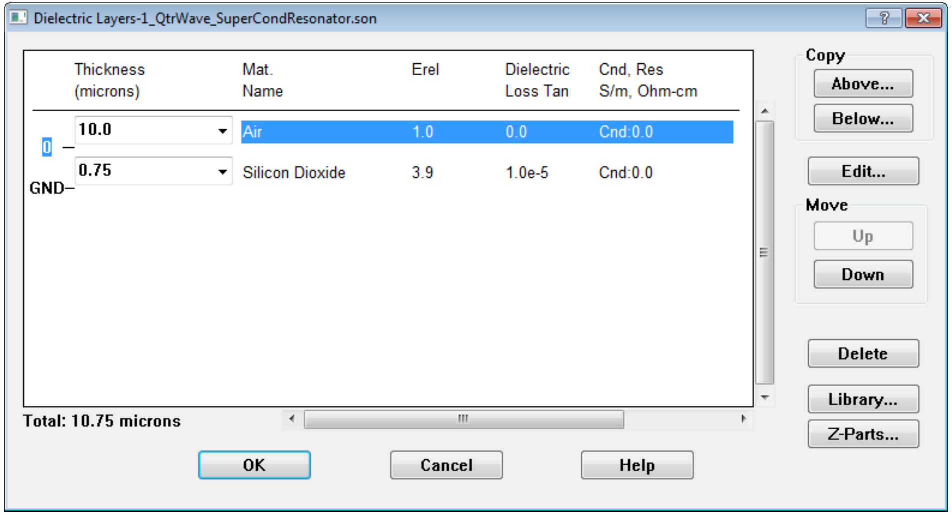
Single Resonator Model

This is a close up of the region where the resonator couples to the mainline. A substantial length of tight coupling is required to produce a significant resonance in the S-parameter curves.



Key Model Characteristics



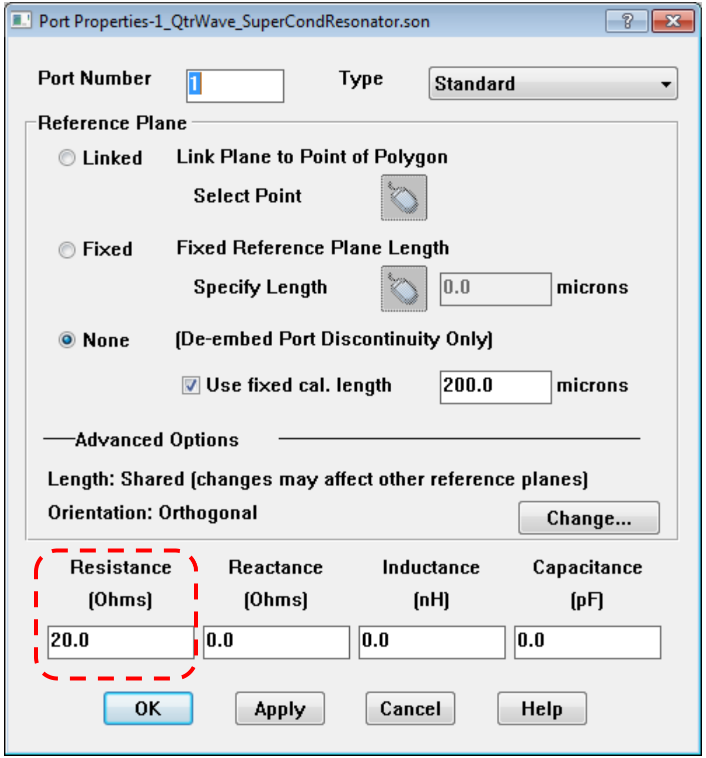


The Niobium metal is defined using a General Metal type. This allows us to enter a Kinetic Inductance value.

Since the metal is lossless, the Loss Tangent of the SiO2 dielectric layer controls the overall loss of the circuit. A small value of 1e-5 was entered to approximate the dielectric loss when cooled.

Key Model Characteristics

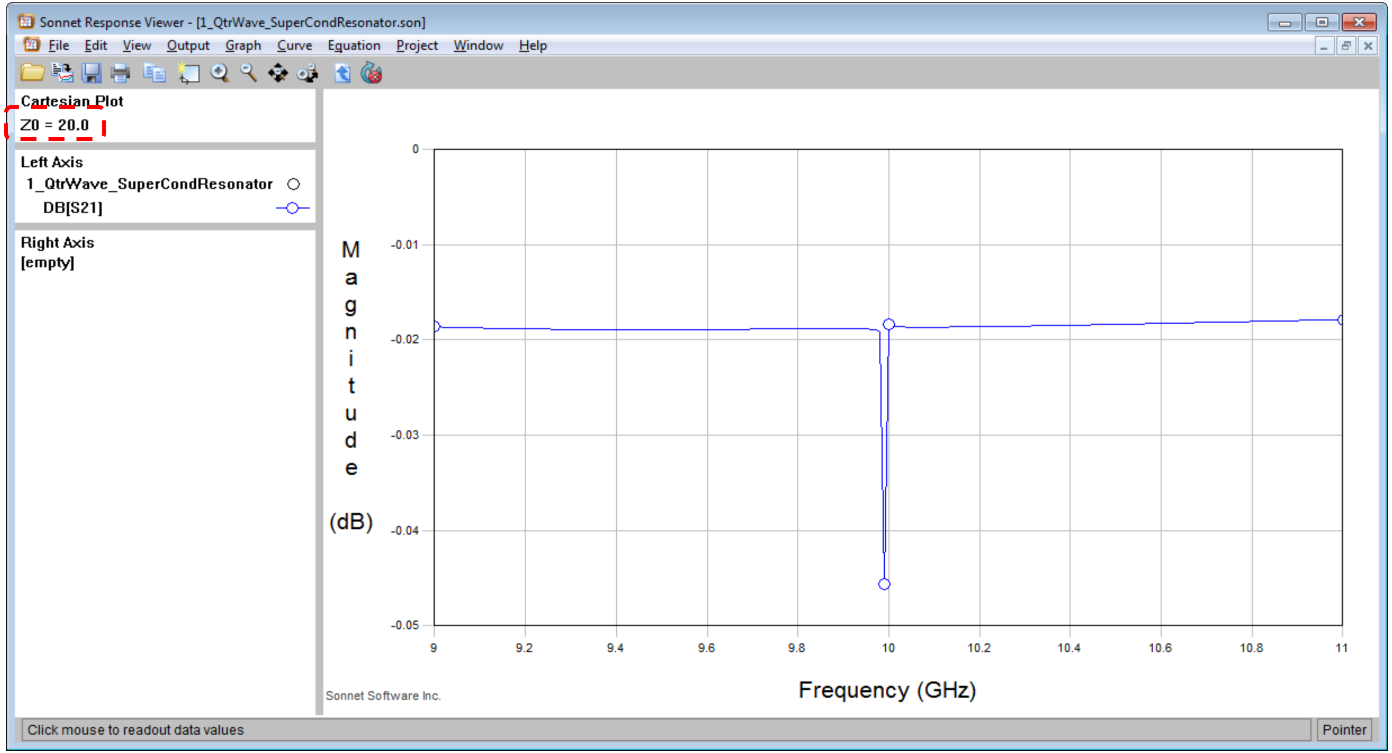
The Port Terminations were set to 20 Ohms in this model. With a SiO2 dielectric layer thickness less than 1 um, only low (<50 Ohms) Characteristic Impedance (Z0) values are practical.



dB[S21] Response - Initial Model

With this initial model, a default ABS Sweep was performed. We see that ABS detected a resonance near 10 GHz and partially resolved it.

Note that the Normalization Impedance for the graph matches the Port Termination setting in the project



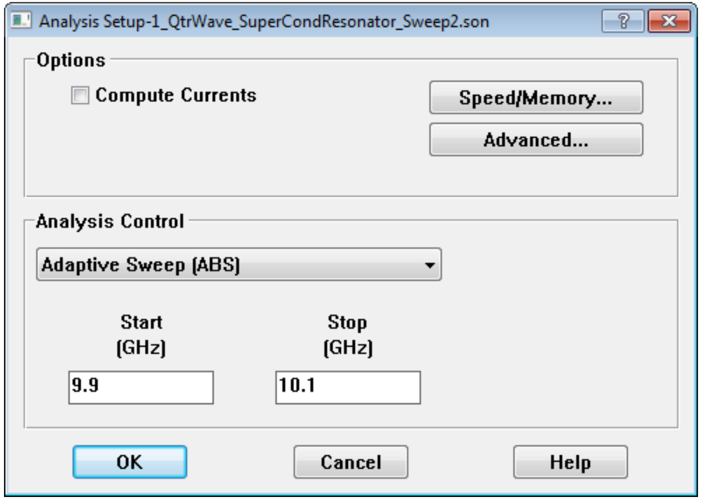
PRECISION ELECTROMAGNETICS

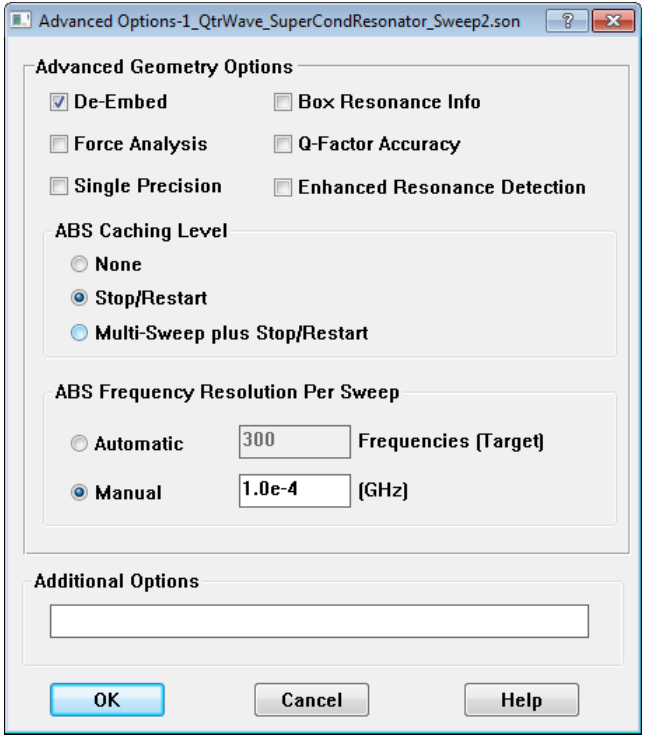
Analysis Setup – Second Sweep

We can resolve the resonance better by analyzing a second, narrower sweep with finer ABS Frequency Resolution. This can be performed in the same or a new project file. We will use a new project file for clarity.

We will use a 9.9 to 10.1 GHz sweep and a 0.0001 GHz ABS Frequency Resolution. This results in a total of 1001 data points. (Several will be full analysis points, while most will be interpolated)

The ABS algorithm can handle many interpolated points, but the ABS time grows with the quantity. A practical, soft limit is approximately 10000 points. This discourages us from running the original 9 to 11 GHz sweep with a 0.0001 GHz resolution.

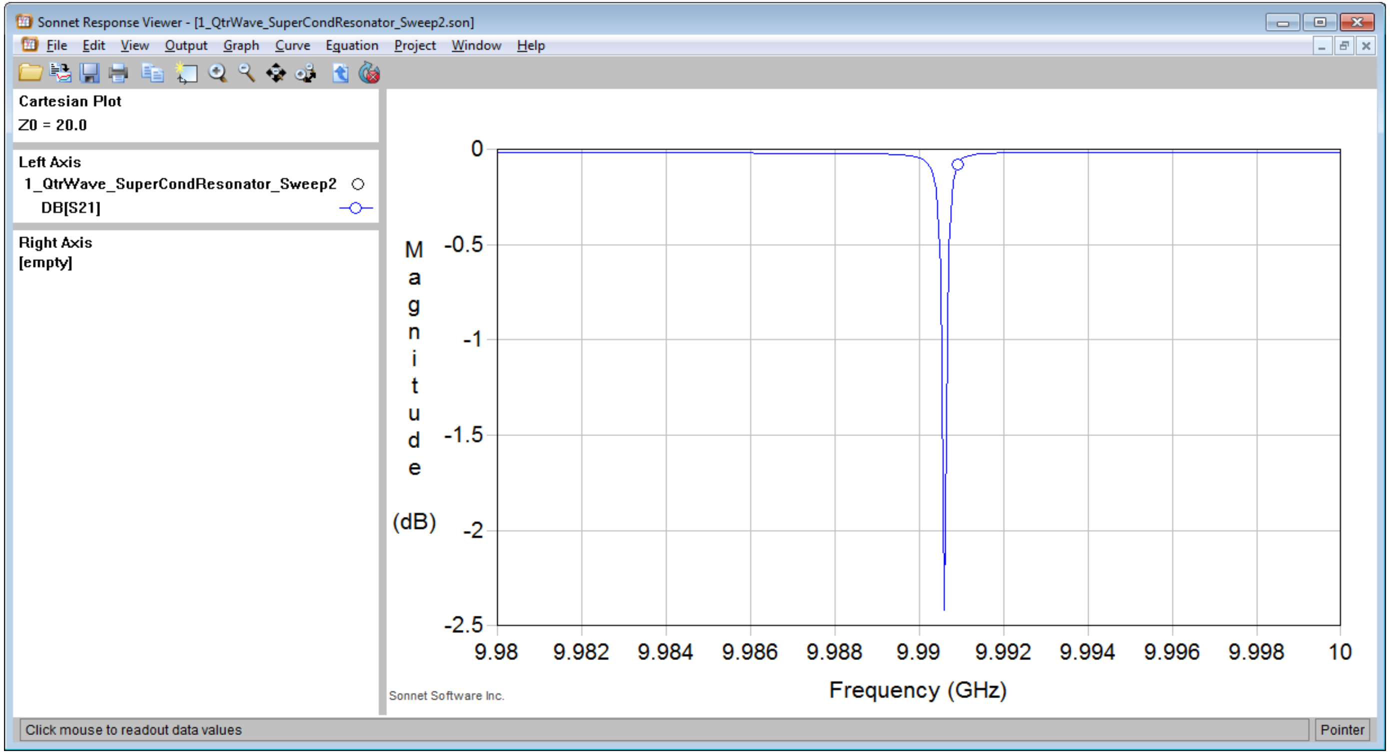




dB[S21] Response – Second Sweep

We see the resonance much more clearly in this second ABS Sweep.

The fine ABS Frequency Resolution allows us to magnify the graph frequency axis.



PRECISION ELECTROMAGNETICS

Superconductor Resonator Procedure

As we have seen, in Sonnet 15 and earlier versions, a multistep procedure is required to locate and resolve superconductor resonances. The general procedure is as follows:

1. Estimate resonant frequency of resonator
2. Analyze an initial model in Sonnet around the estimated resonant frequency.
3. Repeat Step #2 until resonance is detected. This will involve adjusting the ABS Start and Stop frequencies.
4. Adjust the ABS Start and Stop frequencies along with the ABS Frequency Resolution and reanalyze.
5. Repeat Step #4 until the resonance shape is sufficiently resolved in the curves. With some resonators, we may need to run a third or possibly a fourth sweep with even narrower bandwidth and finer ABS Frequency Resolution.
6. If there is more than one resonator in the circuit, several of these steps might need to be repeated for each one.

Sonnet 16

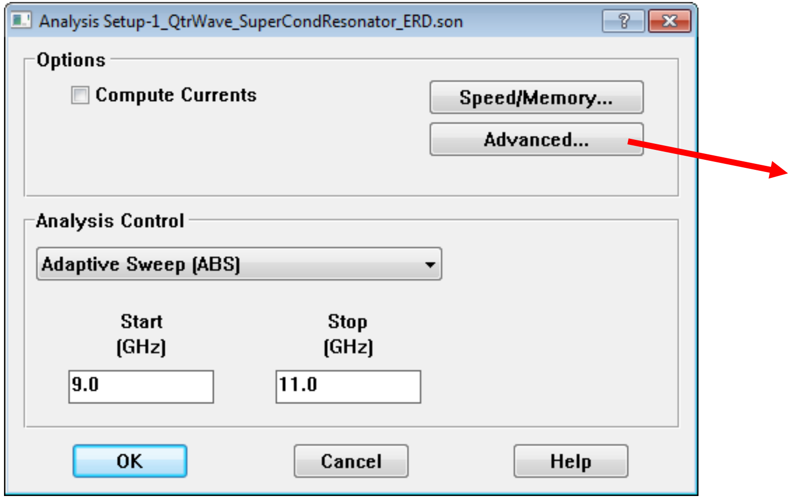
- Sonnet 16 includes a new feature called Enhanced Resonance Detection (ERD).
- It adds an intelligent, multi-pass routine to the default ABS Algorithm and eliminates the need to run multiple sweeps to locate and resolve high Q-Factor resonances.
- We will describe how ERD functions and apply it to this same quarter wavelength resonator model.

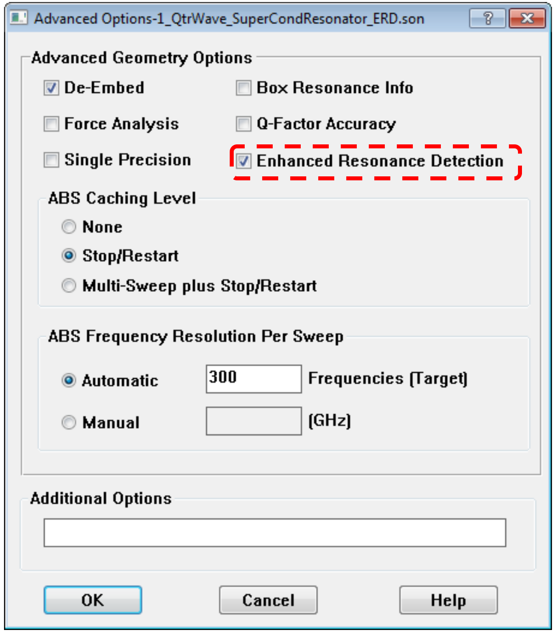
Enhanced Resonance Detection Algorithm

The Enhanced Resonance Detection Algorithm works as follows:

1. A regular, baseline ABS sweep is performed.
2. The ABS algorithm searches for resonances in the baseline interpolated dataset. An additional criterion is used, that is extremely sensitive to resonance effects in the data.
3. The ABS algorithm resolves all of the detected resonances by iteratively adding interpolated points near each resonance. This is done for all resonances simultaneously.
4. The ABS algorithm directs the EM solver to perform a new full analysis at the resolved resonant frequencies.
5. The ABS algorithm iteratively resolves all of the resonances once again, this time making use of the new full analysis frequency points. In the end, approximately 300 interpolated points are selectively added to the dataset around each resonance.

Enabling Enhanced Resonance Detection





To enable this feature, simply check the box in the Advanced Options dialog box.

Note that the full, 9 – 11 GHz wideband sweep can be used, along with the default ABS Frequency Resolution.

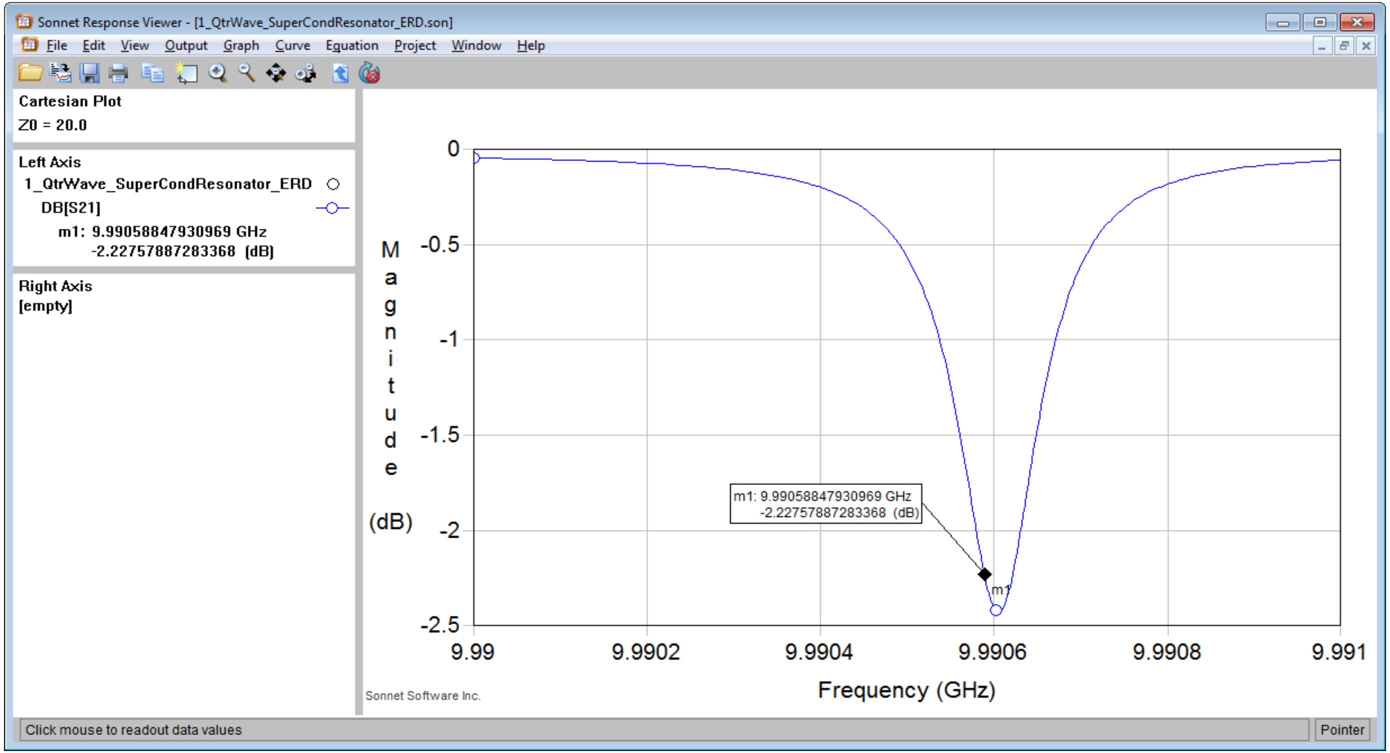
dB[S21] Response – Model with ERD

The ABS Sweep with ERD did a nice job with the curve. We can decrease the span of the X axis and clearly see the resonance.

Note that there is an additional full analysis point very close to the resonant frequency. (denoted by the circle symbol)

A Data Marker was also added to demonstrate the fine frequency resolution around the resonance.

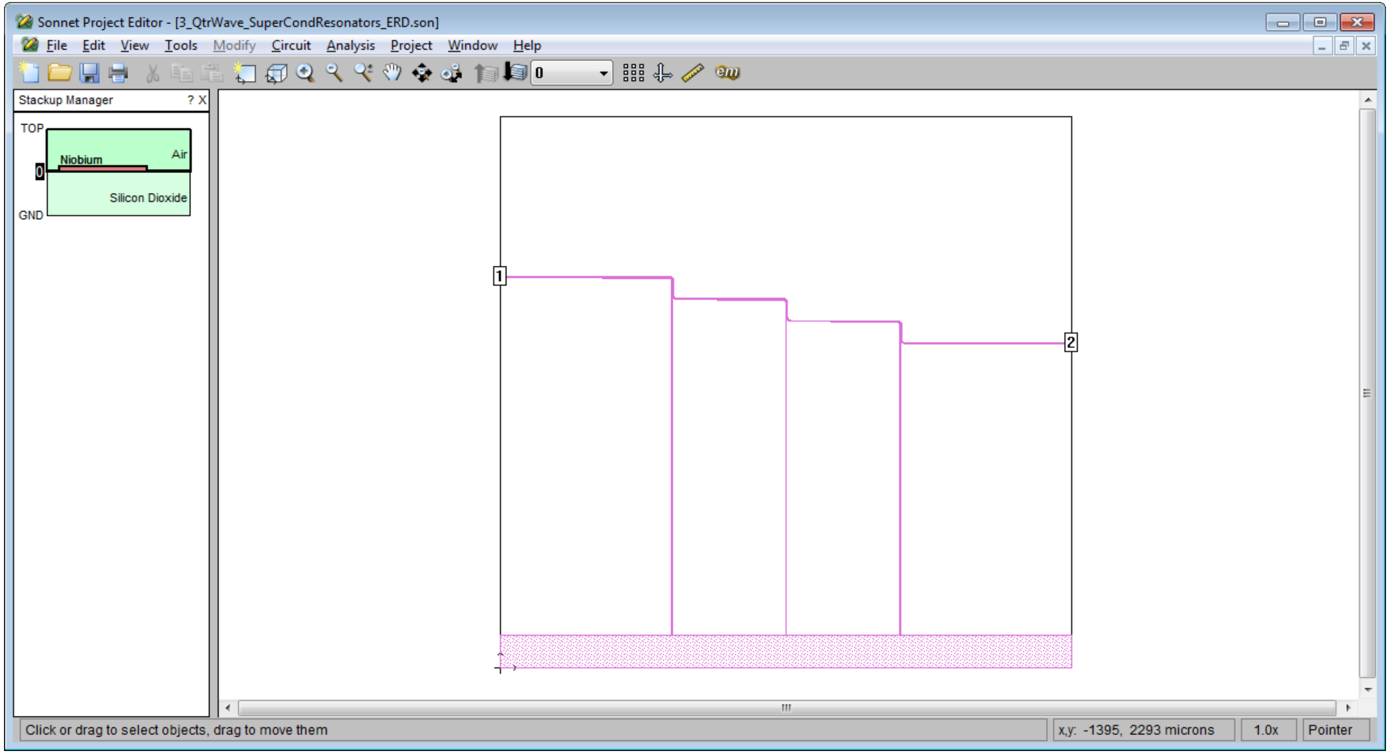
The frequency resolution capabilities have been improved in the Sonnet 16 Response Viewer. Note that we can clearly display to 15 significant digits.



PRECISION ELECTROMAGNETICS

Triple Resonator Model with ERD

The ERD feature can detect multiple resonances in a single sweep. We will try it next on this triple resonator model. In it, two more quarter wavelength resonators were added 200 um longer and 200 um shorter than the single resonator analyzed earlier.

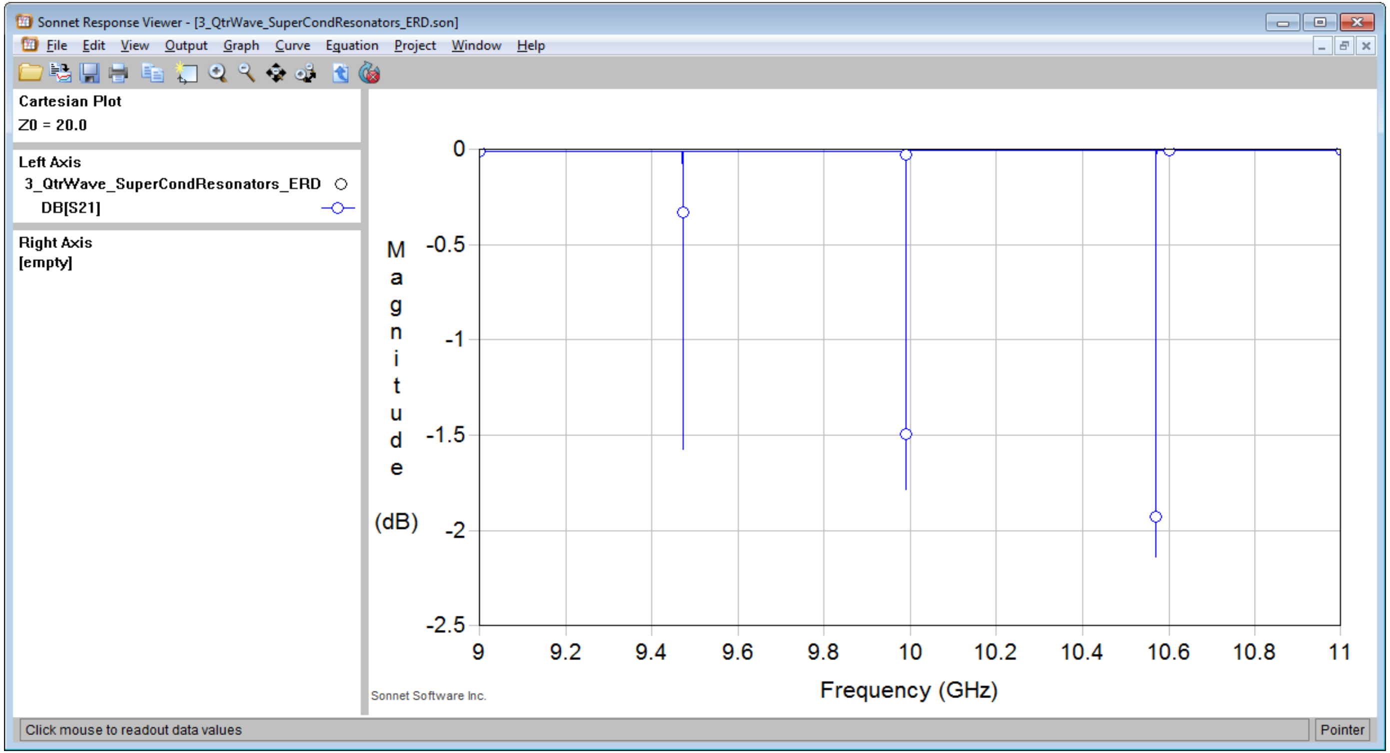


PRECISION ELECTROMAGNETICS

dB[S21] Response – Model with ERD

All three resonances are clearly detected in dB[S21].

Internal testing has shown even 10 resonances or more can be handled within a single analysis.



PRECISION ELECTROMAGNETICS

Solver Log File

For specific information on Enhanced Resonance Detection with a particular model, check the solver log file. Below is an excerpt from the "3_QtrWave_SuperCondResonator_ERD" model:

ABS: Detected 3 resonance(s) on iteration 5:

Resonance 1: FreqMin = 9.45 FreqCenter = 9.47095841551997 FreqMax = 9.49431233432808 GHz
Resonance 2: FreqMin = 9.96 FreqCenter = 9.99055611630658 FreqMax = 10.02 GHz
Resonance 3: FreqMin = 10.53 FreqCenter = 10.5704759895539 FreqMax = 10.61 GHz

ABS: Detected 3 resonance(s) on iteration 6:

Resonance 1: FreqMin = 9.45 FreqCenter = 9.47095793481362 FreqMax = 9.5 GHz
Resonance 2: FreqMin = 9.96 FreqCenter = 9.9905546981889 FreqMax = 10.02 GHz
Resonance 3: FreqMin = 10.53 FreqCenter = 10.570477823874 FreqMax = 10.61 GHz

If ERD was used during the analysis, sections like the ones shown above will appear in the log file. With each iteration, the solver is attempting to more precisely locate the resonant frequencies.

Final Comments

- The Enhanced Resonance Detection feature provides a large improvement in the ABS behavior for superconductor resonator models.
- ERD takes much of the guesswork out of configuring the analysis setup and eliminates multiple manual sweeps, thereby saving a large amount of user and EM analysis time.
- Generally speaking, ERD should be limited to superconductor resonator models. With RF models that utilize conventional processes (PCB, ceramic, semiconductor, etc), ERD will not likely have any effect. The reason is because the metal loss is significant and the standard ABS algorithm is sufficient to resolve the "moderate" Q-Factor resonance.

Contact Sonnet Technical Support at:

Phone: 315-453-3096
Toll Free (North America): 1-877-776-6638
support@sonnetsoftware.com

For additional technical resources please visit:

http://www.sonnetsoftware.com/support/
http://www.sonnetsoftware.com/resources/index.asp