Tips and Tricks for Using Sonnet® Lite

— Free EM software will radically change the way you do high frequency design —

by

James C. Rautio
Sonnet Software, Inc.
1020 Seventh North Street, Suite 210
Liverpool, NY 13088
(315)453-3096
info@sonnetusa.com
http://www.sonnetusa.com

First published in Microwave Product Digest, October 1999.
Reprinted with permission.

Introduction

Until now, serious high frequency electromagnetic (EM) software cost tens of thousands of dollars. This means only so-called "high-end" users benefit from the power of EM analysis. What happens to all the potential "low-end" and "medium-end" users? They are locked out of the most important high-frequency software development of the decade! To solve this problem, in June of 1999 Sonnet Software introduced a new product, Sonnet® Lite, and established a new price point in the EM software industry: zero. Sonnet Lite is totally, completely, absolutely, and forever free!

Sonnet Lite is based on the full Sonnet Suite of 3-D planar EM software. Introduced in 1989, Sonnet is the first commercially successful high-frequency EM analysis tool. With over 10 years of intense commercial application, Sonnet is firmly established as the most accurate and stable tool available anywhere at any cost for the high frequency analysis of 3-D planar circuits.

We made the Sonnet Lite feature list as large as we possibly could consistent with the simple fact of life that we still need the high-end customer to remain commercially viable. However, since the only customer we need to remain commercially viable is the high-end customer, we simply limited the ability of Sonnet Lite to do the very largest high-end problems. Everyone else, who could previously not even touch serious EM software, can now solve all their medium and small size planar EM problems for free. In fact, with care and some ingenuity, a number of large high-end problems can even be solved with Sonnet Lite.

How Does It Work?

The Sonnet EM analysis is based on a method-of-moments technique. The circuit metal is first meshed into small subsections. The EM coupling between each possible pair of subsections is calculated and this fills a big matrix. The matrix is inverted, yielding all currents everywhere in the circuit metal. This, in turn, determines things like S-parameters, which can be used in other analysis programs.

The Sonnet analysis has very high accuracy because it calculates all couplings between subsections using a 2-D Fast Fourier Transform (FFT). In signal processing, application of the FFT requires uniform time sampling of a signal. In EM analysis, the FFT requires uniform space sampling across the two dimensions of the substrate surface. Thus the analyzed circuit metal falls on a uniform underlying FFT mesh. The FFT approach also requires the circuit to exist inside a conducting, shielding box. Approximations are available to include radiation.

A common alternative technique requires a four dimensional numerical integration to calculate each pair-wise coupling. This approach has the advantage of eliminating the underlying uniform mesh, however, it comes at the cost of sometimes extensive numerical integration time and the additional error involved in the numerical integration process. The FFT used by Sonnet quickly calculates all couplings to full numerical precision. In contrast to the FFT approach, numerical integration requires an open environment allowing radiation while a shielded environment must be approximated.

When and if a serious planar numerical integration based EM tool becomes freely available, the user will find the relative advantages and disadvantages tend to compliment Sonnet's FFT based tool.

Capabilities

Most planar high-frequency circuits require either one or two levels of metal for EM analysis. Sonnet Lite can handle both cases (high-end users sometimes need more and must use the full Sonnet Suite). The circuit described in this article (a filter on Alumina) uses only one level of metal. A spiral inductor, which needs an air-bridge to make an output connection, uses the second level of metal for the air-bridge. Sonnet Lite can handle both types of problems.

Table 1. Summary of Sonnet Lite Features
Up to 2 metal levels.
Up to 3 dielectric layers (any thickness, dielectric constant, and loss).
Up to 4 ports.
Up to 16 Mbytes memory (full matrix).
Vias to ground and between levels.
Free nodal circuit analysis included.
Free color current distribution plotting and animation.
Free S-parameter data plotting utility included.
Free SPICE lumped model synthesis included.
Full Sonnet Suite documentation (Adobe Acrobat reader included).

Vertical current (perpendicular to the substrate surface) is allowed by the inclusion of vias. Vias to ground and air-bridges (which require vias from one metal level to another) can be included in Sonnet Lite circuits. Because Sonnet allows all three dimensions of current (in a planar circuit), and evaluates full 3-D electric and magnetic fields, we call Sonnet a "3-D planar" tool. Analyses that allow only two dimensions of current are called 2½-D (provided 3-D electric and magnetic fields are still allowed).

Sonnet Lite circuits use either two or three dielectric layers. For example, the bottom dielectric layer might be Alumina, and the top dielectric layer could be air. Each layer can be of any dielectric constant, any thickness, and any loss.

Robustness is an important aspect of the Sonnet FFT approach. For example: an ultra-thin dielectric layer (say, 0.1 micron silicon nitride), an ultra-thick layer (say, 100 meters of air), a very high dielectric constant (say, 1,000), or high loss (even a highly conducting substrate like silicon); are all included exactly in Sonnet. Non-FFT techniques lose robustness when approaching these kinds of extremes, especially with conducting substrates.

With the exact inclusion of conducting substrates, Sonnet Lite is seeing strong usage for high-frequency circuits on silicon. Spiral inductors on silicon, normally a very difficult problem, are easily and quickly solved. Measured and calculated results are typically essentially identical.

The majority of high-frequency circuits have between one and four ports, all of which Sonnet Lite can analyze. Sonnet Lite produces S-parameter data for these circuits and saves the results in a text file. The results for all of these component circuits are usually then connected together into the complete circuit using nodal circuit theory software.

But what if the user does not have a nodal analysis program? Sonnet includes one for free! It is simple, but it does connect measured or calculated N-port data, ideal resistors, capacitors, inductors, and transmission lines together into large circuits (Table 2). In addition, it has a special capability that no other nodal analysis program has: it can include references to Sonnet circuit geometry files and launch Sonnet Lite EM analyses automatically. After the Sonnet Lite analysis is complete, it automatically incorporates the resulting S-parameters into your nodal circuit analysis. This capability has some intelligence too, if valid S-parameters are already done, it does not re-analyze the circuit, the valid results are used directly. This is critical for large circuits. There is no limit on the number of nodes used in a Sonnet Lite nodal analysis. This free nodal analysis uses a text file for input of the nodal circuit description and is based directly on a format well known in the industry.

Table 2. Summary of Nodal Analysis Features
Include N-port S-parameters from any source (measured or calculated).
Ideal lumped resistors, capacitors, and inductors.
Ideal transmission lines.
Sonnet Lite analyses can be included as circuit components.
Included Sonnet Lite analyses are automatically launched, but only if needed.

As described above, Sonnet fills and then inverts a matrix. If there are 100 subsections in a circuit, the matrix is 100x100. Sonnet Lite handles problems requiring up to 16 Mbytes of memory. This means up to about 1400 subsections can be analyzed. If loss is included, memory requirements double, resulting in a limit of about 1000 subsections. (Users of the full version of Sonnet have no limit and also take advantage of a slightly faster matrix solver that physically stores only half of the full symmetric matrix, cutting memory requirements by half.)

Sonnet Lite also includes the regular Sonnet Suite tools for displaying current distributions in full color including animation (emvu^{TM}), and for charting S-parameters in rectangular, Smith, and polar plots with printing (emgraph^{TM}). S-parameters from any common source can be plotted with emgraph. These tools, especially emvu, are excellent for drawing the attention of college students (see sidebar at the end of this article) and for making presentations. When unexpected results are seen (e.g., "We have a funny glitch in S_{21}!"), viewing the current distribution usually reveals the cause (e.g., "Hey, part of the circuit is resonating!").

The basic objective when using Sonnet Lite is to cast the problem into a form which allows analysis with one or two metal layers, one to four ports, and up to 16 Mbytes of memory. The ingenious and persistent user will find very few problems that can not be solved using Sonnet Lite.

Getting Started

To get your free copy of Sonnet Lite, visit http://www.sonnetusa.com. The download is 14 Mbytes. If that's too much to take at one time, the big download is also split into 5 small files that you can download one at a time. At times, site loading is heavy, early morning hours (East Coast time) are best if problems are encountered.

Alternatively, you can order a CD-ROM from Sonnet Software (315-453-3096) for the cost of shipping and handling ($10 domestic). The CD-ROM also includes an 1882 biography of James Clerk Maxwell. If you want to wait for a trade-show, we frequently give out the CD-ROM as a freebie to attendees.

The software is copyrighted, but you are free to distribute copies to anyone you like as long you make no changes and charge no more than the cost of distribution.

Installing the software is very fast, however, it will not install on computers which also have the full Sonnet Suite installed. (Full Sonnet Suite users frequently use the full Sonnet at work and Sonnet Lite at home).

Once installed, be sure to go through the tutorial. This takes an hour or so and you will then be familiar with about 80% of Sonnet Lite's features and you can immediately start serious work. If you are going to be using Sonnet Lite a lot, we highly recommend reading the entire documentation package as you go along. With over 16 years of intense development, we have packed a lot of capability into Sonnet and we have also learned a lot about how to efficiently and accurately analyze planar EM problems. All that information is in there and we are particularly proud of the ease with which it can be read and understood. This is "must" reading for power users.

As installed, Sonnet Lite runs circuits requiring up to 1 Mbyte of memory. To enable Sonnet Lite for 16 Mbytes, an email registration is required. Sonnet Lite prompts you for the needed information and either sends the email for you, or you can make a text file and send it to us manually. A software key, which enables the software for full 16 Mbyte use, is emailed back to you. Occasional re-registration is required. Registration reply is fully automated and all requests at all hours of the day are immediately fulfilled.

An Accuracy Example

As mentioned above, Sonnet's principle advantage is accuracy. To illustrate, we take a simple gap discontinuity. This is a 2-port, one metal level circuit that can be analyzed with very little memory. It qualifies as a simple low-end problem.

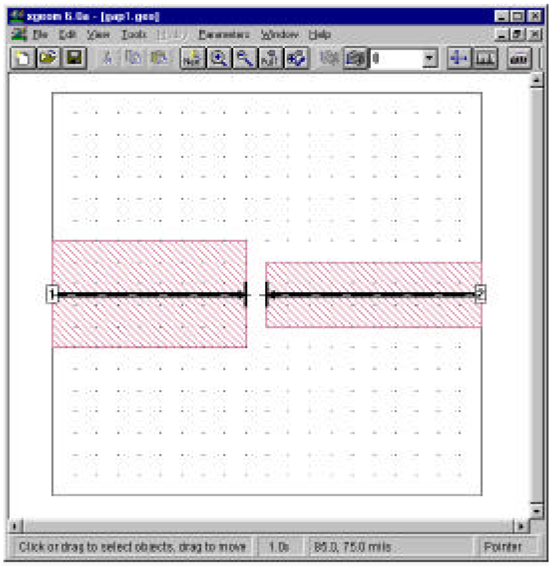

Figure 1. This asymmetric gap is used to demonstrate the power of the Richardson extrapolation in achieving ultra-accurate EM results with minimal numerical effort**.**

The gap, shown in Figure 1, is on 25 mil Alumina. Port 1 is a 25 mil wide line and port 2 is a 15 mil wide line. The gap is 5 mils. The initial 5 mil cell size is shown by the mesh of dots in the figure. This view is looking down on the substrate surface. The conducting sidewalls of the box are at the edge of the substrate. Note the dashed line through the center of the box. This indicates that the circuit is symmetric. Only the top half of the circuit needs to be analyzed and memory requirements are cut to one quarter of a full analysis.

The S-parameters are de-embedded to the reference planes indicated by the arrows. This de-embedding is just like the de-embedding used by modern Automated Network Analyzers (ANA's). The Sonnet de-embedding is especially precise because the circuit is contained in a box with perfectly conducting sidewalls. These sidewalls are used during de-embedding to establish a perfect short circuit de-embedding standard. This is not possible in open environment, numerical integration based analyses.

Using Sonnet Lite, we can get 1) Quantitative error estimates, and 2) Very high precision results, as desired. This is based on the fact that Sonnet analysis error nearly always decreases in direct proportion to cell size. If we analyze our gap discontinuity with a 5 mil cell size, and then with a 2.5 mil cell size, the difference between the two results is just about half the error. If we know half the error, we can simply subtract the entire error from the result! There are a few exceptions to this rule, so one should always proceed carefully. For most cases it works well. This technique is known as "Richardson extrapolation".

The Richardson extrapolation depends having only one dominant error source. If there are multiple error sources (possible in Sonnet, common in many other techniques), then the error convergence is non-monotonic, with the result oscillating about the final value. If this is the case, the Richardson extrapolation fails. If you keep cutting cell size in half and the answer converges smoothly, everything is fine.

Richardson extrapolation can be used with numerical integration based tools, however due to additional error sources (e.g., numerical integration error and lack of a perfect short circuit for de-embedding), extra care must be used.

The error characteristics of Sonnet have been explored in detail and have been published in the archival literature. Numerous references are included in our on-line bibliography (http://www.sonnetusa.com). Also included in the bibliography are papers published by Sonnet users demonstrating the kinds of problems being worked today with Sonnet. Everyone who publishes a paper for which Sonnet or Sonnet Lite is used is encouraged to send the reference to us so it can be included in the Sonnet bibliography.

Table 3 shows the Richardson extrapolation for the 10 GHz S_{21} magnitude of the gap discontinuity of Figure 1. Based on the rate of change of the "Converged Answer" column, I estimate the exact answer to be 0.1728 +/- 0.0003. This error is less than 0.02%! Note that the error of the first (5 mil cell size) analysis is about 14%. With some ingenuity and only a little additional numerical effort, we have achieved some serious improvement. Electromagnetics is important to use when you need accuracy, and when you need accuracy, don't be satisfied with a single number, demand error bounds too!

Table 3. Richardson Extrapolation for Gap Discontinuity

Cell Size (mils)	S21 mag.	Difference	Converged Answer	Analysis time (Sec)
5.000	0.148365			2
2.500	0.159334	0.010969	0.170303	2
1.250	0.165647	0.006313	0.171960	3
0.625	0.169029	0.003382	0.172411	12

Analysis times in Table 3 are for a 450 MHz Pentium II.

Figures 2-5 show the current distribution on the gap for each cell size. Note how current concentrates (red) at all metal edges. This is called the edge singularity. It must be well represented for an accurate analysis. Some techniques tend to represent the edge singularity poorly. In any EM analysis, if accuracy is important and the edge singularity is ragged or not present at all, view the results with extreme skepticism! Current distribution visualization is good for more than making pretty pictures. The smoothness, or the raggedness, of a current distribution gives a good, fast, and reliable indication of the relative quality of an electromagnetic result. The Richardson extrapolation provides an absolute quantitative measure of quality.

With this sort of precision, this gap discontinuity result can now be used with confidence in a narrow band filter design, as we will demonstrate next. A spreadsheet is most convenient for doing a Richardson extrapolation. Alternatively, one can use the results obtained using the smallest cell size, if the error is low enough (often the case for non-critical applications).

In the next example, the gap discontinuity is part of a larger circuit. The S-parameters of the gap are used without extrapolation. If the accuracy of a Richardson extrapolation is desired, it can be performed as a final step in the overall analysis procedure described below.

By the way, all the analyses in this section required under 2 Mbytes of memory.

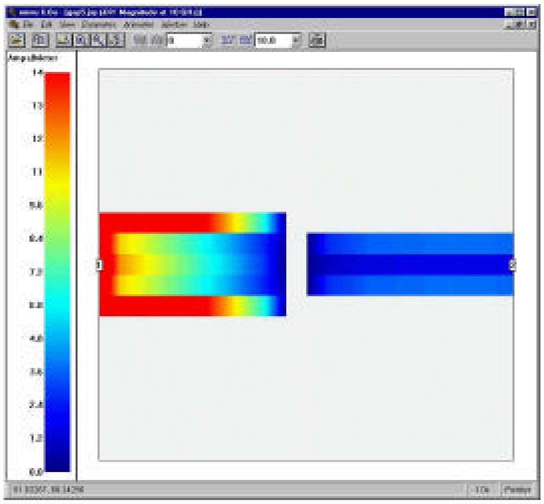

Figure 2. Even with a 5 mil cell size, the current distribution on the gap shows a clearly defined edge singularity. Red is high current, blue is low current.

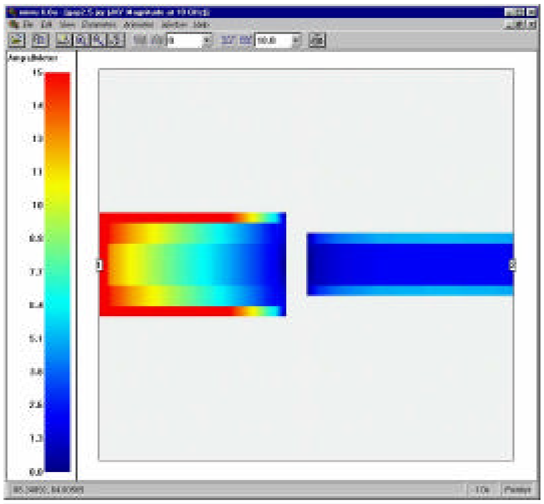

Figure 3. Cutting the cell size in half also cuts the error in half. This is the current distribution on the same gap with a 2.5 mil cell size.

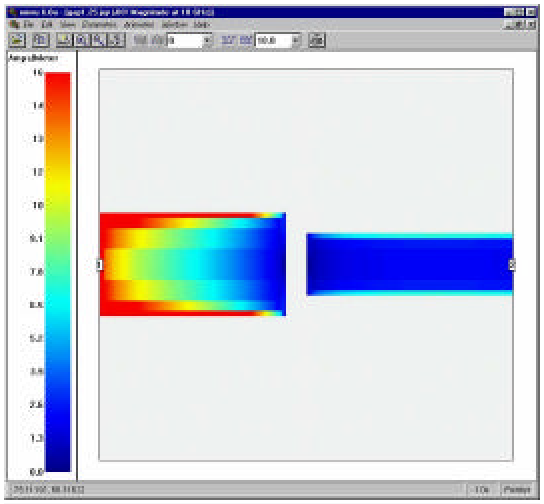

Figure 4. Cutting the cell size in half once more. We now have a 1.25 mil cell size. Notice how the edge singularity is becoming sharper.

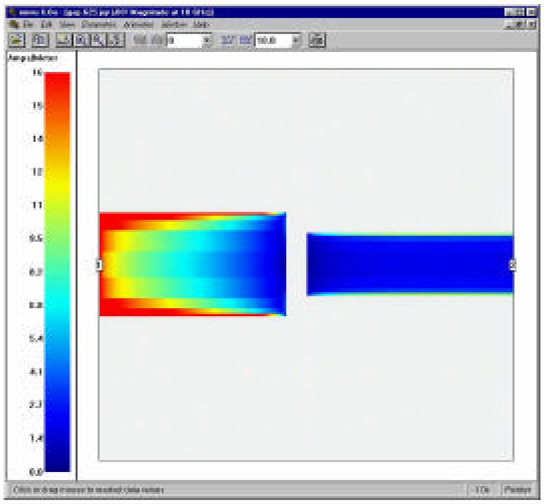

Figure 5. With a cell size of 0.625 mils, we see a very narrow edge singularity with current changing smoothly on the interior of each line. The steps in the current distribution are due to Sonnet automatically using a larger cell size where the current changes slowly.

Analyzing a Big Circuit

The best way to get around the limits of Sonnet Lite and analyze a high-end problem is to break the large problem into small pieces, analyze each small piece, and then put everything back together using nodal analysis. Since Sonnet Lite has its own built in nodal analysis, this can be done entirely within Sonnet.

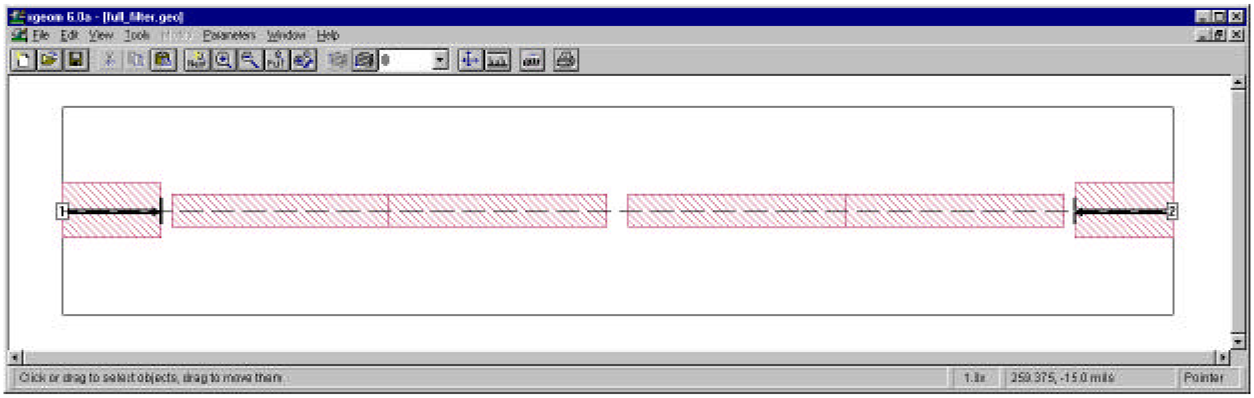

Figure 6. This filter is analyzed in two different ways. First, the complete filter as shown is analyzed in a single Sonnet run. Then, the filter is broken into small pieces and placed in a Sonnet net-list. The net-list launches all needed EM analysis and automatically connects the results together for the final result.

The filter we analyze here is shown in Figure 6. The resonators are both 200 mils long. The central gap is 10 mils and the end gaps are 5 mils. Actually, this entire filter requires fewer than 700 subsections, even with the very small 0.625 mil cell size. Thus, the entire filter can still be done using Sonnet Lite. However, as we will show, there is still a big advantage in breaking the filter into small pieces, analyzing each piece, and then connecting all the pieces back together into a complete filter.

The first component is the gap discontinuity of Figure 1. We stored the layout in a file named "gap1.geo". The second component is a gap between two identical 15 mil wide lines. The layout file is "gap2.geo". The third and final component is a 100 mil length of 15 mil wide transmission line. Its layout is stored in a file called "tline1.geo".

Then we created a net-list, Figure 7, describing how to analyze and connect all the components together. This

```
! Analyze components of a filter and combine together.
DIM
     FREQ      GHZ

CKT
     GEO       1 2      gap1.geo      OPT=vd     CTL=ctl.an
     GEO       2 3      tline1.geo    OPT=vd     CTL=ctl.an
     GEO       3 4      tline1.geo    OPT=vd     CTL=ctl.an
     GEO       4 5      gap2.geo      OPT=vd     CTL=ctl.an
     GEO       5 6      tline1.geo    OPT=vd     CTL=ctl.an
     GEO       6 7      tline1.geo    OPT=vd     CTL=ctl.an
     GEO       8 7      gap1.geo      OPT=vd     CTL=ctl.an
     DEF2P     1 8      FILTER

FILEOUT
     FILTER     Touch   full_filter.rsp   S MA R 50

FREQ
     SWEEP     8.0 14.0 0.025
```

Figure 7. The net-list used to analyze the filter in small pieces. EM analyses specified by each GEO line are automatically launched by Sonnet and the results are then connected together for the final result.

format has been widely used over the years. Today, most high-end tools use schematic capture, however, experienced users still prefer net-list input. Once familiar with it, a net-list is actually easier and faster to use. Schematic capture, on the other hand, makes a better presentation and has a shorter learning curve. If you have access to a schematic capture circuit analysis and prefer it, by all means use it. If not, Sonnet Lite gives you a nice little net-list based circuit analysis tool with a price that can't be beaten!

The first two lines in the net-list of Figure 7 set the frequency units to GHz. The next block defines the circuit. In this case all the circuit components are "GEO" components. When Sonnet Lite sees a GEO component, it launches an electromagnetic analysis according to the parameters on the line. The first line starts an analysis of gap1.geo, the layout for the input gap discontinuity. Analysis options ("OPT=vd") are "v" for verbose, and "d" to invoke de-embedding. The analysis frequencies are set in the file "ctl.an".

The structure of this circuit follows the net-list. First is the gap1 discontinuity connected from node 1 to node 2. Next are two lengths of tline1, each 100 mils long, to make a 200 mil long resonator. Between nodes 4 and 5 is a 10 mil wide gap between 15 mil wide lines. Then, two more 100 mil long tline1 components and the final gap1 discontinuity. This final component is connected backward (port 1 to node 8 and port 2 to node 7) because port 1 is the 25 mil wide port line (see Figure 1). The last line of the circuit block defines a two port named "FILTER" with node 1 connected to port 1 and node 8 connected to port 2.

The "FILEOUT" section defines a standard file format ("Touch"), file name, and S-parameters, Magnitude/Angle format, with normalizing Z_0 = 50 Ohms.

The frequency section specifies analysis at 8 GHz to 14 GHz with a step of 0.025 GHz. This is a total of 241 frequencies. With EM analysis involved, this could take a very long time! Fortunately, as described next, we actually do EM analyses at only seven frequencies.

This is how it works: Sonnet sees the first GEO line and launches an EM analysis at frequencies specified in the control file "ctl.an". This file (two lines: “GHZ”, then "FRE 8 14 1") was created in a text editor and tells Sonnet to analyze the gap from 8 to 14 GHz with a step of 1 GHz.

Sonnet then launches all other needed EM analyses at the frequencies specified in the file "ctl.an". When a result for a component is needed a second time, the previously calculated results are used and the analysis is not needlessly repeated.

When all the EM analyses are complete, the results are connected together using a nodal analysis. For this step, the frequencies in the FREQ block are used. Since we have EM results available at only seven frequencies and we are asking for the complete circuit at 241 frequencies, the EM results are automatically interpolated to the required frequencies.

How can this interpolation possibly succeed? It succeeds because the individual EM analyzed components change slowly with frequency. This technique is very powerful if you can break a large circuit into small pieces that are not resonant. Do not use this interpolation, for example, with an entire resonator (as a single component) near its resonant frequency. Small pieces of a resonator are no problem.

Let's summarize what we have done:

1) We analyzed three components (two gaps and one transmission line) electromagnetically.
2) Each component varies slowly with frequency and was analyzed at only seven frequencies.
3) The S-parameters of each component were then interpolated to 241 frequencies.
4) The interpolated S-parameters were connected together to form the complete filter (which, by the way, varies rapidly with frequency).

Figure 8 shows the resulting S-parameters. Note the very high frequency resolution.

New users often express skepticism that this approach can possibly work. Such skepticism is to be encouraged, especially since we can easily and quantitatively evaluate most objections. In this case, we simply analyze the full filter and compare the results to the net-list based EM analysis. In fact Figure 8 includes data from both cases, one from the net-list EM analysis and the other from an EM analysis of the complete circuit. The two curves are nearly indistinguishable.

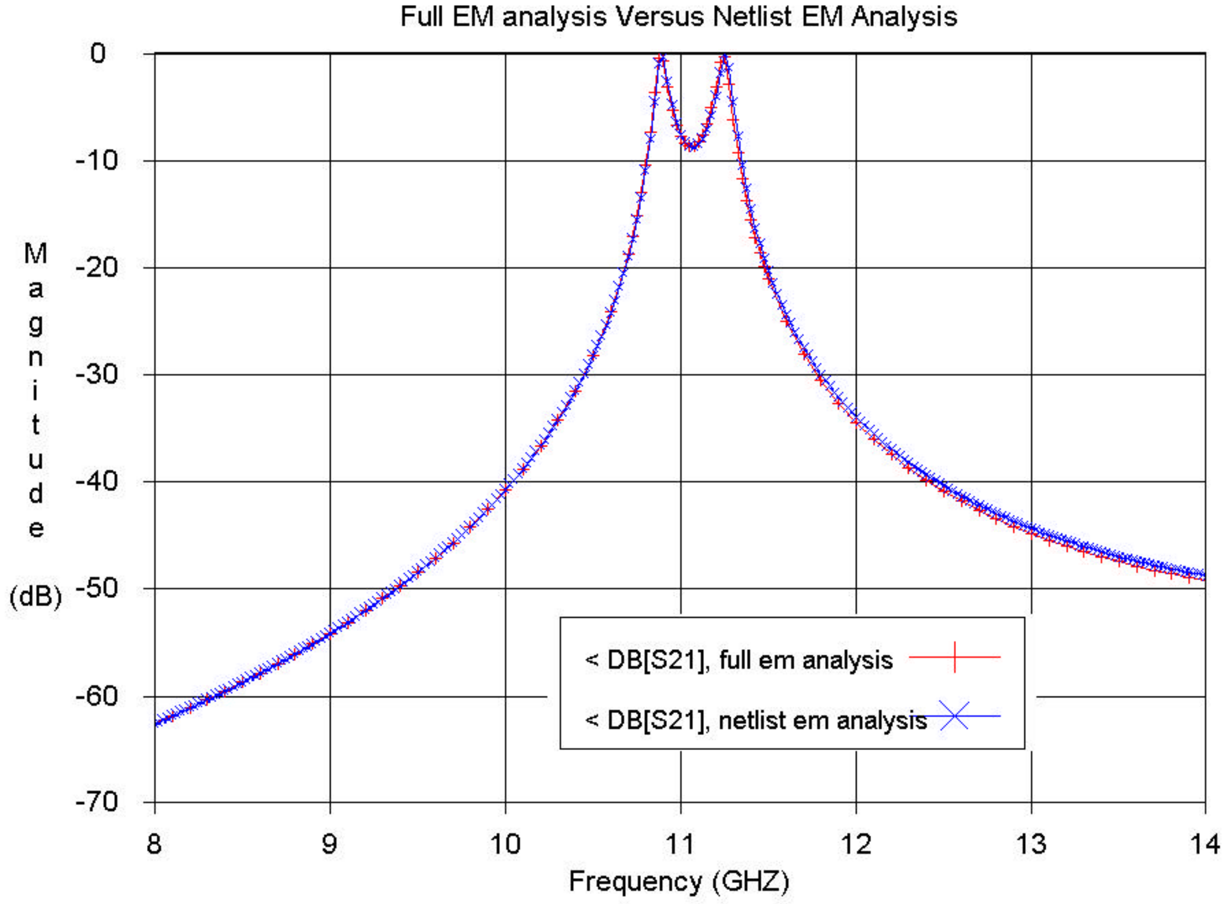

Figure 8. The result of the full filter analysis. The full EM analysis and the net-list based EM analysis give nearly identical results.

The total time required for the complete analysis at 241 frequencies was just over one hour. Total time required for the net-list EM analysis at the same frequencies was about five minutes.

This same technique is easily applied to the more common parallel-coupled line filter. The transmission lines of the above filter now become 4-port coupled transmission lines while the gap discontinuities from above become 4-port junctions between the coupled lines. When working with such filters, keep in mind that small changes in coupled line spacing are likely to result in no significant changes in the S-parameters of the junction between the coupled lines. In addition, circuit theory coupled transmission lines might even be usable, depending on their accuracy. The coupled line junctions, however, must be EM based. An example is described in detail in the documentation supplied with Sonnet Lite (em User's Manual, pg. 111-124).

Making Changes

The dimensions of this filter were arbitrarily selected. This explains why, as a filter, this circuit does not work well. We have two distinct resonances separated by some distance, rather than the desired single band-pass.

There are several alternatives here. For complex filters, the best approach is to fit a circuit theory analysis model to the calculated data using a circuit theory optimizer (not available in Sonnet Lite). In addition, again using a circuit theory optimizer, optimize that same circuit theory model to meet your filter requirements. Now you know the percentage changes required in gap width and resonator lengths. Simply make the changes in the layout files and repeat the EM analysis.

For serious work, this approach[1] is extremely powerful and, presently, underutilized. This technique invokes the accuracy of an EM analysis combined with the speed of a circuit theory analysis. While direct EM optimization is starting to become popular (at least among EM software marketers), direct EM optimization should be avoided if at all possible. A lot of time can be wasted while trying to avoid understanding how a circuit really works.

How does this circuit work? The resonator lengths determine the average of the two resonant frequencies seen, and the coupling determines the separation between the observed resonant frequencies. More coupling means more separation between the resonant frequencies.

With this knowledge, can we find an inexpensive (i.e., no optimizer of any kind) way to design our filter? Certainly. We want the two resonant frequencies closer together, so let's make the central gap (gap2.geo) bigger.

Here is where the true value of a net-list EM analysis is seen. A change in only the central gap means that only gap2.geo is re-analyzed. Previously calculated data for gap1.geo and tline1.geo

---

[1] This approach was recently developed by both John Bandler from a theoretical point of view and by Tony Pavio from an applied point of view, I first saw this technique as developed by Herb Thal in 1979 and applied to waveguide filter design.

are still valid. The new analysis requires just over 30 seconds for all 241 frequencies! This is so fast that we just tried a few values for the gap until we found one that was desired. The result is shown in Figure 9 (central gap = 27.5 mils). Note that this new data is calculated every 5 MHz (previously, it was every 25 MHz). Since no new EM analyses were required for this new frequency step size, this final result was calculated nearly instantaneously.

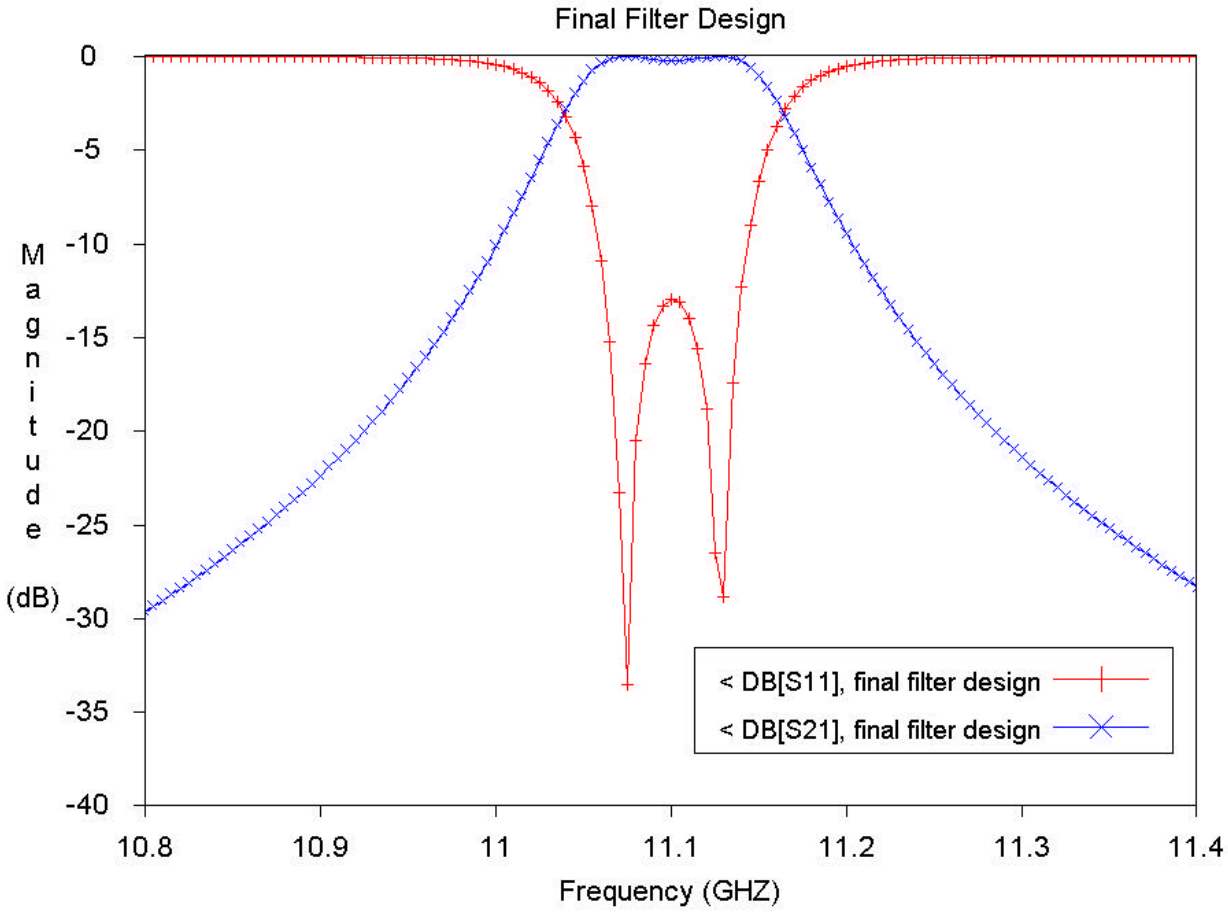

Figure 9. When the central gap is tuned to 27.5 mils, the above results are obtained. After changing only the central gap, the full 241-frequency analysis is obtained in about 30 seconds, thanks to the net-list based EM analysis.

If we had gone with the analysis of the complete filter, at one hour for 241 frequencies, it would be impractical to make quick changes and see what happens. In contrast, while making small changes to the net-list EM analysis, the designer does not even have time for a cup of coffee!

To proceed with this design, one would next tune the resonator length to the desired center frequency by adjusting the length of tline1.geo. The length and resonant frequency are directly proportional, so this means only one more analysis (all of 30 seconds long!). Then one would add metal and dielectric loss. Finally, if very high accuracy is required, cell size should be cut in half (or doubled) with a Richardson extrapolation applied to the entire filter result providing a nearly exact answer.

It should be noted that there is no other tool in the world, at any price, that can duplicate the above analysis with the same cell size (i.e. accuracy) and with the same or better speed. Sonnet Lite does it fast and free.

Conclusion

We have shown how to use the free Sonnet Lite EM simulation suite to analyze circuits of various complexities. While Sonnet Lite can not handle arbitrarily large circuits, with ingenuity and persistence, a designer can actually analyze very large circuits. The particular approach described here involves breaking a circuit into small components. The small components are quickly analyzed. Since the small components vary slowly with frequency, they need be analyzed at only a few frequencies. These results are then interpolated and connected together by means of a net-list based nodal analysis to form the complete, highly frequency sensitive circuit, in this case, a band-pass filter. All the software needed to perform this entire procedure is contained in the free Sonnet Lite package.

The validity of the technique is demonstrated by comparison with a complete analysis of the entire filter. The usefulness of this technique is further demonstrated by making changes in part of the circuit and quickly analyzing the effect on the entire circuit response. This allows a very effective and time efficient coupling between circuit theory optimization and EM analysis validation or, as is the case here, it allows a simple trial-and-error design procedure.

Prior to the introduction of Sonnet Lite, EM analysis was available only to advanced, high-end users. Now, with Sonnet Lite available for free, serious EM analysis can be used by anyone and everyone. This is electromagnetics for the masses. Welcome to a new decade.

Acknowledgement

This Sonnet Lite and the net-list based EM analysis capability were made possible by funding from DARPA under the MAFET program.

The Origin of Sonnet Lite - A Personal Perspective

Back in 1983, after having spent a few years as a microwave designer, I decided to pursue a degree in electromagnetics (EM) at Syracuse University. Having had a little exposure to the potential for EM in high frequency design, I was excited and very strongly committed to learning EM theory, especially numerical techniques. Unfortunately, even then, I was the oddball. During my entire time as a graduate student, I was the only full time US citizen pursuing any high frequency related topic in the entire department. Every other US citizen I knew in graduate school was doing software or digital design. EM and high frequency was universally considered drab, difficult, and old fashioned. This perception was common even among many faculty!

These perceptions are more severe today. Nearly all EE students dream of things like CPU design. RF amplifiers or narrow band filters? Dulls-ville!

This situation would be no problem if there were no need for high-frequency designers. However, high-frequency designers are now needed desperately, and the need is growing. We need to attract at least a few students from the digital track, and we need to do it now. How?

One way is to make advanced state-of-the-art tools freely available to students at all levels (more is needed than just a few copies in select laboratories). There will be at least a few of these students who have a natural inclination towards high-frequency research. Our objective is to get these students "hooked" on high frequency design. What better way than to freely put serious EM software right on their personal computers. Let them amaze their peers with their complete mastery of the black magic of high-frequency design. What student, with high-frequency inclinations, would not be absolutely enthralled watching, on her own computer, a current distribution animation for a circuit she just designed!

Our industry needs even more high-frequency software freely available for student use. I personally encourage all vendors to follow Sonnet’s lead in this matter. The future of our entire industry may well be at stake.

James C. Rautio, President
Sonnet Software, Inc.