Exact Evaluation of Sonnet's Thick Metal Model

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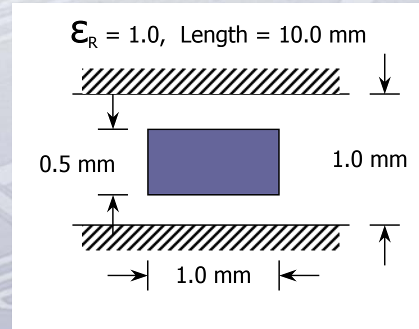
There is a wide spread misperception that Sonnet as a planar analysis either can not do thick metal, or that a volume meshing tool (e.g., finite elements) can do thick metal better. For this presentation, we use an exact (to within +/- 0.0006%) theoretical result for a very thick stripline. We compare results of a Sonnet convergence analysis and a volume meshing analysis.

Thick Metal Benchmark

- Theoretical Z_0 = 30.8887 Ω ± 0.0006%.
- Thickness fringing fields control 25% of Z_0.
- Correct answer known precisely.
- Thickness is significant.



Reference: S.B. Cohn, "Problems in strip transmission lines," IRE Trans. on MTT, vol. MTT-3, pp. 119-126, March 1955.

The reference cited here provides a nearly exact result for thick stripline. The result assumes that the fringing fields from one thick edge of the stripline do not couple to the fringing fields from the other thick edge. In this geometry, the thick edge is 0.5 mm thick. The gap between the top of the stripline and the upper ground plane is only 0.25 mm. The two thick edges are separated by the width of the line, 1.0 mm. Thus, the coupling between the thick edge fringing fields should be very small.

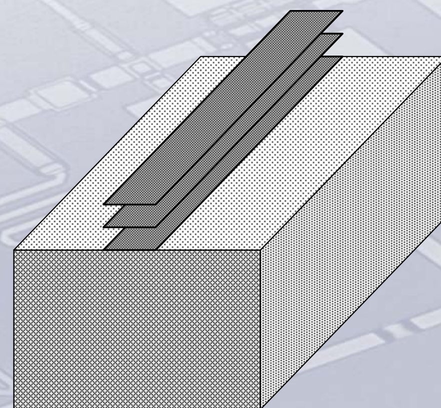
The magnitude of the error is estimated by using the thick stripline equations to evaluate a stripline with almost zero thickness. This result is compared to the exact solution for zero thickness stripline. The difference in characteristic impedance is 0.0006%. Thus, we estimate that the 30.8887 Ohm characteristic impedance for the thick line may be in error by as much as 0.0006%. In actuality, the error is most likely much less.

When we compare the characteristic impedance for the zero thickness result to the 0.5 mm thick result, we see a 25% difference (the 0.25 mm gap between each surface of the stripline and its nearby ground plane is the same in both cases). Thus we conclude that 25% of the characteristic impedance is due to thickness fringing fields.

Now we have two things which are critical for a good benchmark: 1) We have an essentially exact answer, and 2) The answer is very sensitive to the parameter of interest, namely, the effect of thickness. If there is something wrong with thickness analysis, we will see it with this benchmark. Most importantly, we obtain precise quantitative knowledge of the analysis error.

Sonnet Thick Metal Model

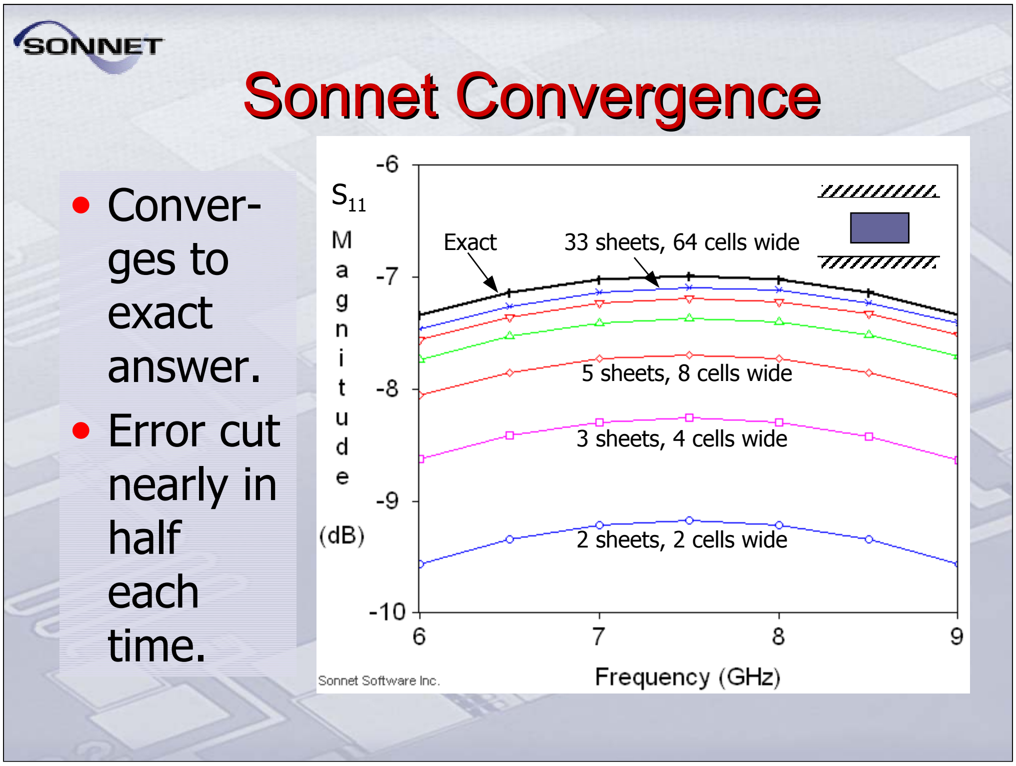
- Multiple sheets, three shown.
- Automated model (Ver. 9) includes vias connecting all edges.
- Check convergence as number of sheets increase.



The Sonnet N-sheet model is shown here. Three sheets are shown in the figure. As we increase the number of sheets, and as the cell size becomes smaller and smaller, the answer should converge to the correct answer. Prior to version 9, we had to enter each sheet manually. For the 3-sheet model shown here, we would have three port 1's on this end and three port 2's on the other end.

With Version 9, we use an automated thick metal. Just specify a thick metal type and type in the number of sheets. All the sheets are created automatically by Sonnet. To save analysis time, only the top and bottom sheets are complete. The other sheets are present only along the edges. In addition, vias are added along the entire length of each edge. In version 8, vias required a lot of memory. In version 9, a very efficient (merged cell) via is used, so analysis time is much faster. If an N-sheet model is used with conformal meshing, each sheet must still be manually entered as before.

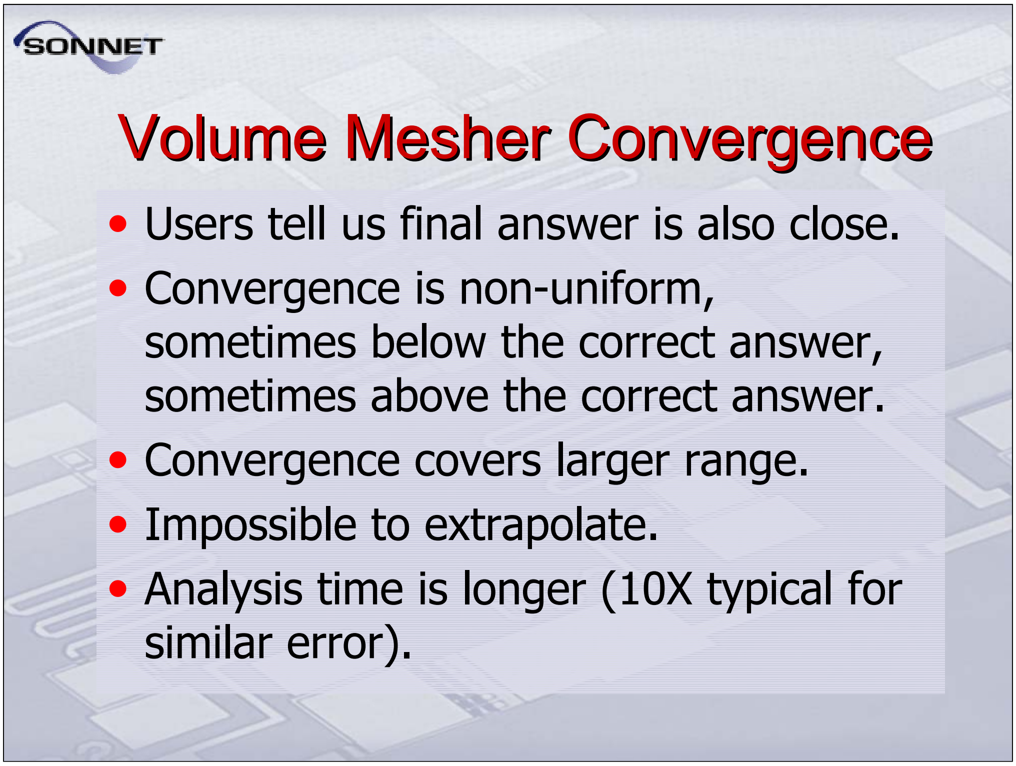
Now, we simply see how the result converges as we increase the number of sheets and make the cell size smaller.



Circuit theory, using a Z_0 of 30.8887 Ohms provides the curve labeled "Exact". Here we can see how the S_{11} for a 10 mm long line converges as we increase the number of sheets and decrease the cell width (increase the number of cells across the width of the line).

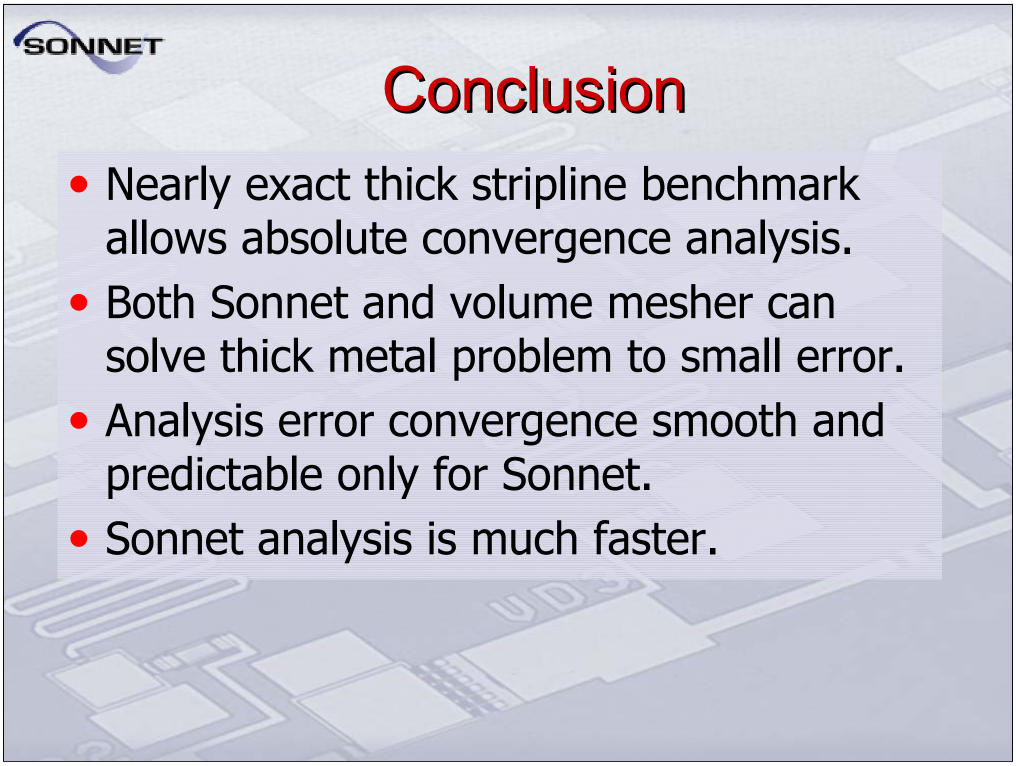
In each case, the number of cells across the line width is doubled. In addition, the number of layers into which the line is split is doubled each time. Note that the number of sheets is one more than the number of layers, thus the unusual sequence of 2, 3, 5, 9, etc. for the number of sheets. The number of layers is doubling each time.

In the plots of S11, above, notice two things. First, the Sonnet result is asymptotically converging to the exact answer. Second, the convergence is smooth, the error is reducing by about half each time the number of sheets is doubled and the cell width is cut in half. In fact, it is easy to extrapolate to nearly the exact answer. This is called a Richardson extrapolation. For example, the three sheet and the five sheet results can be extrapolated to within 1.1% of the exact result.



This benchmark is very easily analyzed on any EM analysis. For example, one user of a volume mesh analysis has described some results for the thick stripline.

On the positive side, we are told, the most refined volume mesh result is very close to the exact answer, just like Sonnet. However, the convergence is not smooth. Some of the results are above, while other results are below the correct answer. The volume mesher convergence covers a much larger range and there is no chance to do a Richardson extrapolation to estimate the correct result, or even to just estimate the error in a given result. Volume mesher analysis time is also much longer. This is typical for volume mesher analysis of planar circuits, because Sonnet is optimized for planar circuits. Volume meshers typically require at least 10 times longer to achieve a similar error level, as is the case here. In fact, for planar circuits where thickness is not critical, 100X to 1000X longer analysis times are common.



In conclusion, this thick standard stripline benchmark is both accurately known and strongly sensitive to the correct analysis of thickness. This makes it ideal for precisely quantifying analysis error in the analysis of metal thickness. We have shown how both Sonnet and a volume mesher can solve the problem, with sufficient effort, to high accuracy. However, the volume mesher convergence is not smooth and can not be extrapolated to the correct answer. The Sonnet convergence is smooth and is easily extrapolated to the correct result. This well behaved convergence also allows estimation of analysis error.

Finally, analysis time for the Sonnet result is much, much faster. This illustrates the high price paid when using volume meshers for planar circuit analysis.

This benchmark is very easy to perform and we strongly recommend that you perform this benchmark on each and every EM analysis that you use when metal thickness might become important In that way, you can make decisions based on knowledge, rather than having to guess.

Thank you for listening.