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Accurate High Frequency Lumped Filter Design with Discrete Optimization

Overview

FilterSolutions®, the world leading filter design software created by Nuhertz Technologies®, works in conjunction with Modelithics® to synthesize and optimize lumped LC filter designs at frequencies up to at least 5GHz. The filter circuit synthesis is initially created in FilterSolutions. Modelithics models provide high frequency accuracy, and the discrete optimization is provided in National Instruments' Microwave Office®.

A filter designer enters lumped element filter design requirements and vendor part families directly into the FilterSolutions interface. The synthesized results are then exported into Microwave Office using selected Modelithics part families. The user then selects "Discrete Local Search" as the desired optimizer. Once in Microwave Office, the designer re-simulates the exported design, and uses the Microwave Office discrete optimizers as necessary to meet user design requirements. Further design accuracy may be achieved by then optimizing interconnect geometry.

Design Example

In the example shown below, the following set of design goals is used:

Passband Attenuation (S11):	20dB
Passband Center Frequency:	1GHz
Passband Width:	500MHz
Stopband Attenuation (S12):	60dB
Stopband Width:	800MHz

FilterSolutions determines that a seven pole Elliptic filter will achieve the design goals.The inductor count is minimized by selecting a zigzag topology, requiring only six inductors.

The "ideal" design of this filter is shown in Figure 1.

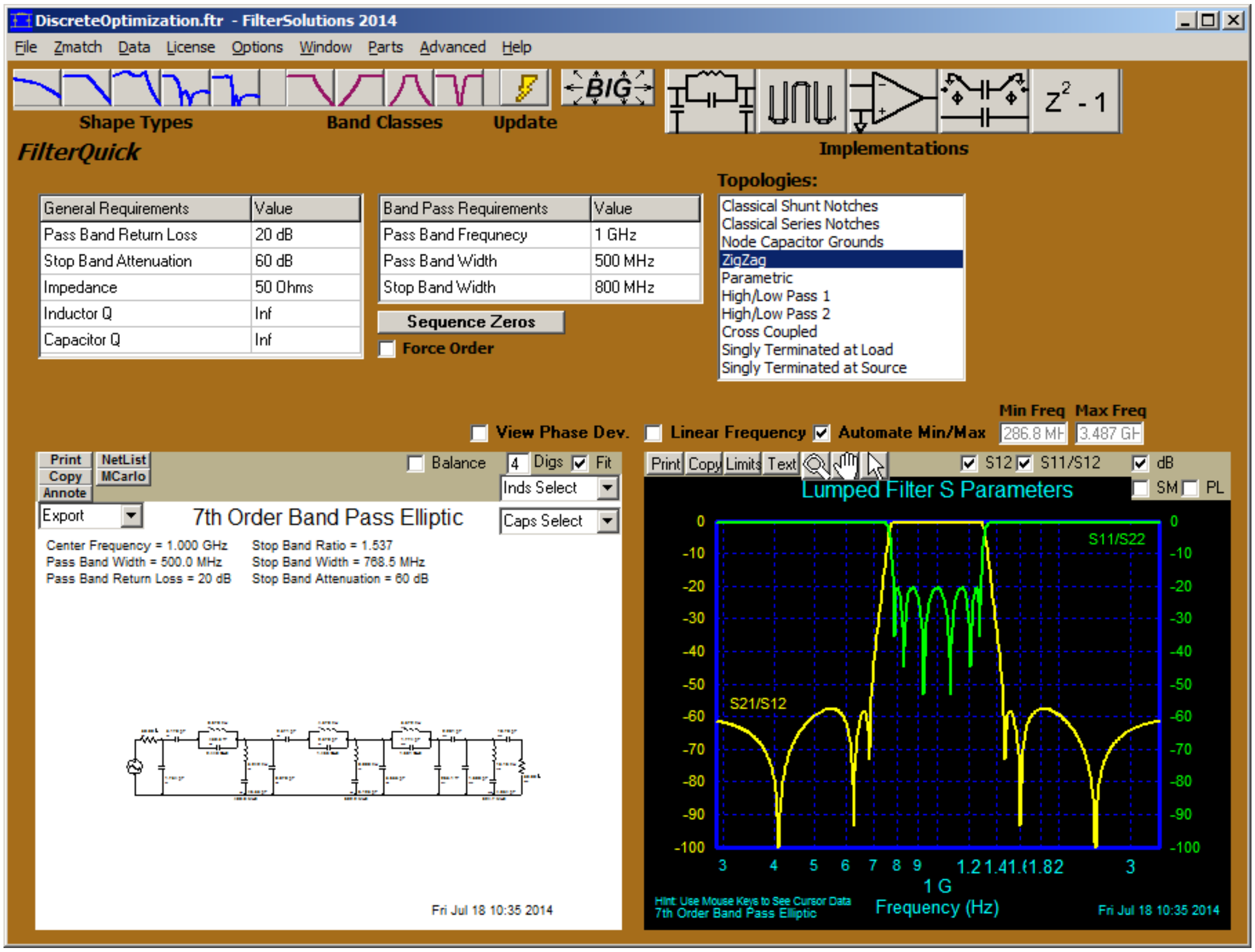


Figure 1: Ideal Design in FilterSolutions, Using the program's FilterQuick® Interface

Design Optimization

"Modelithics CLR" is selected in the AWR export panel to replace ideal elements with high-accuracy equivalent circuit models. Rogers Corporation 20 mil substrate, Murata LQ Inductors and ATC 600L Capacitors are selcted as being a good balance between size and performace at the design frequencies. Different families can be selected and added as desired. Baseline interconnect geometries and interconnect optimization limits are set. The entries are shown in Figure 2.

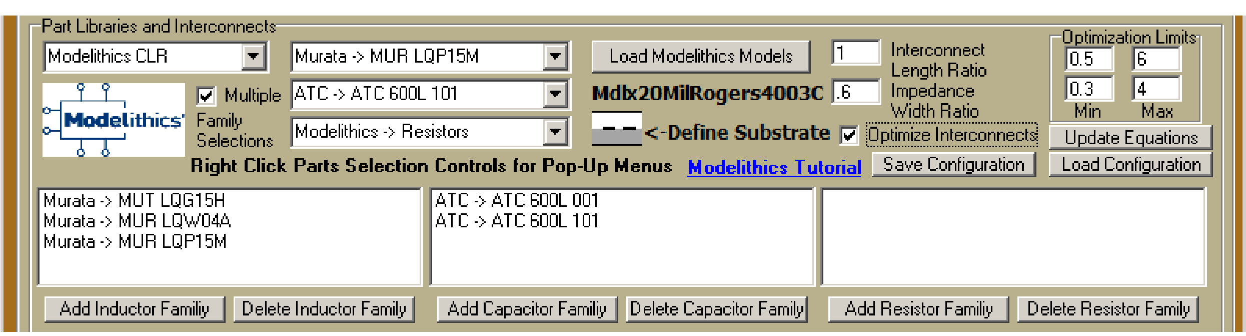


Figure 2: Modelithics Setup Panel Entries

The synthesized filter is exported into Microwave Office initially without selecting "Optimize Interconnects". Inductor and capacitor values are set in Microwave Office using discrete equations enabled for optimization. The raw, non-optimized Microwave Office simulation is shown in Figure 3. Note the significant error between the optimization goals and actual simulated S12 and S11. These discrepancies are due to a combination of element value errors, element parasitics, and interconnect parasitics.

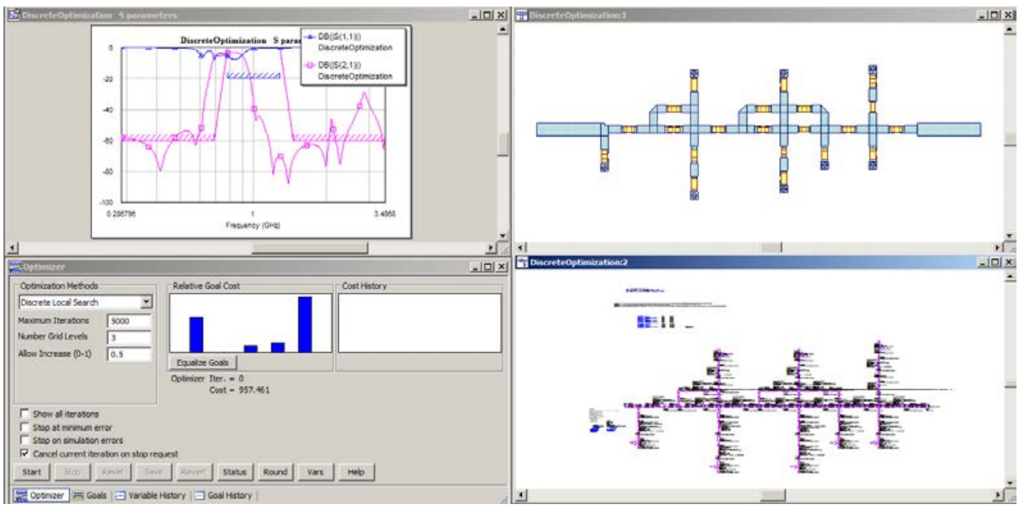


Figure 3: Non-optimized simulation with Modelithics parts and interconnects.

By launching Microwave Office optimization process at this point, the optimizer will select existing "discrete" values for elements that are available from the vendor for the part series selected, or for other optionally discrete values, such as specific microstrip line widths available to the designer. When optimization is completed, the S11 and S12 curves are shown to be much closer to the optimization goals. (See Figure 4).

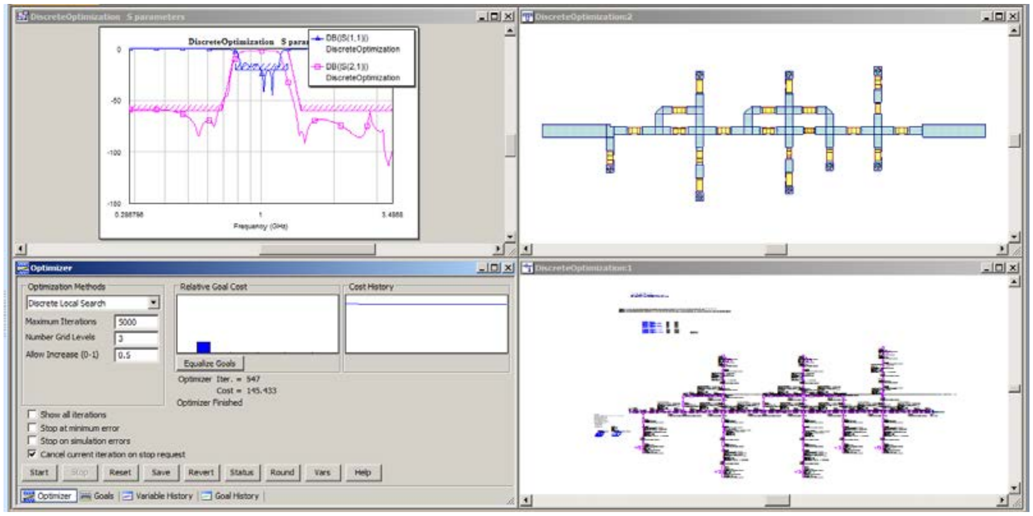


Figure 4: Results of Discrete Optimization using Modelithics Element Values

Once discrete optimization is completed, interconnect geometry may be optimized, if desired, by selecting, “Optimize Interconnects”; and then selecting, “Enable Equations”. This process is shown in Figure 5.

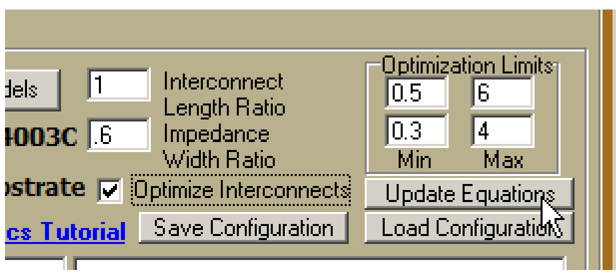


Figure 5: Making Interconnect Geometry Equations Tunable and Optimizable

Launching the Microwave Office optimizer again at this point allows fine tuning of the frequency response, bringing it much closer to the response requirement, as shown in Figure 6, below.

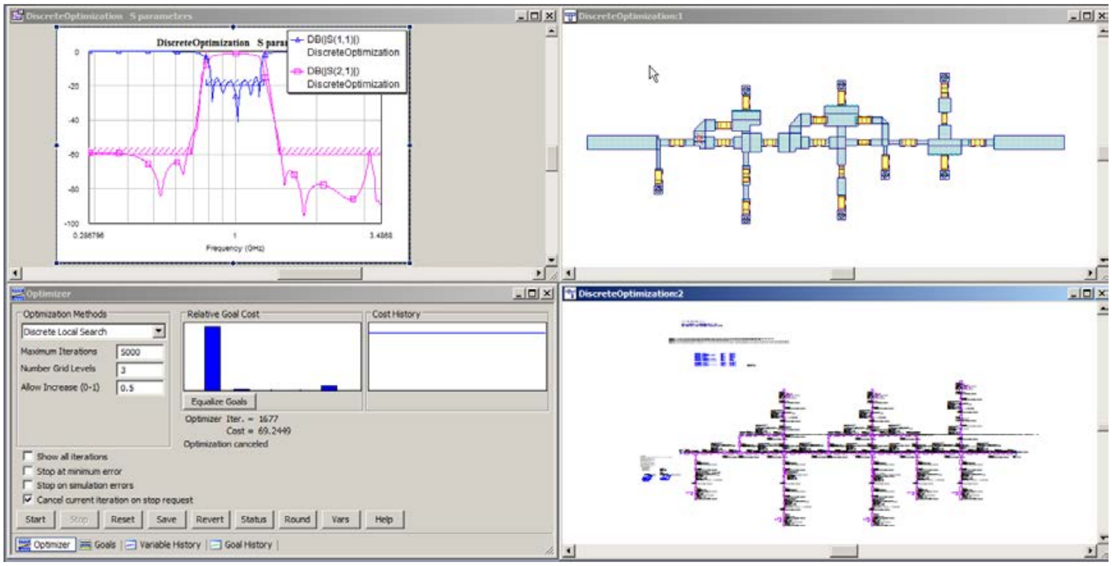


Figure 6: Optimized Frequency Response

At the 1 GHz design frequency, errors may still exist due to interconnect parasitics and interaction between interconnects that cannot be accounted for by circuit analysis. An electro-magnetic (EM) analysis using a Microwave Office supported tool, such as Axiem, will often reveal errors, as shown in Figure 7. Such errors are expected to increase with frequency. A 5 GHz design for example, would be expected to have significantly more error. (Note the slight degradation of S11).

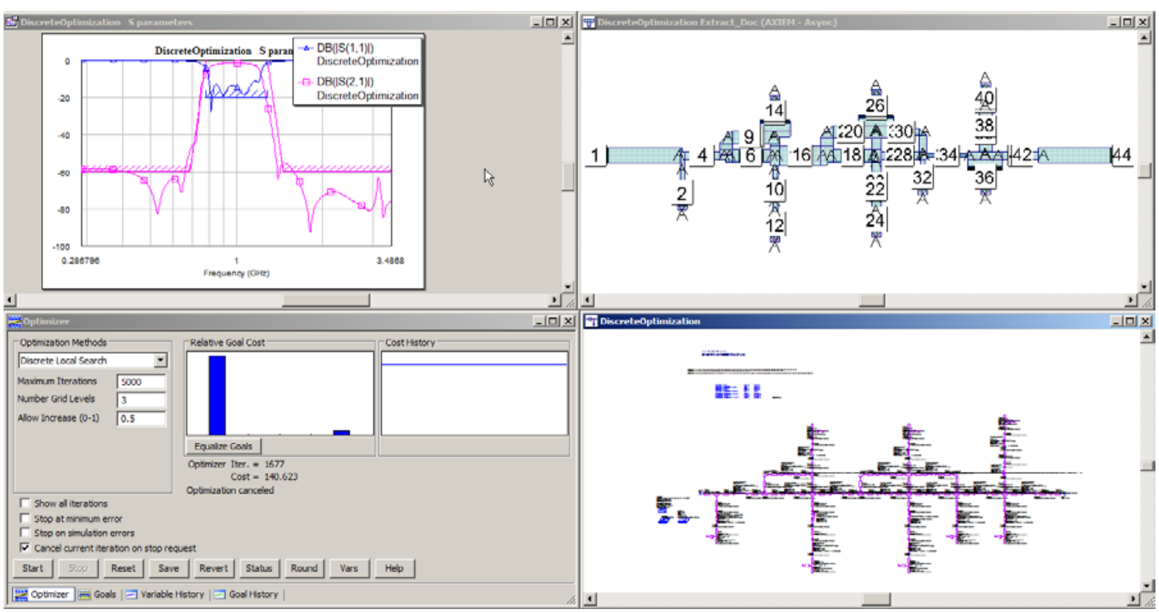


Figure 7: Electro-magnetic Analysis of Optimized Filter

It is possible to then electromagnetically optimize the filter design. Right-clicking on the Microwave Office schematic extraction block to enable EM extraction and then right-clicking again allows one to extract to the electromagnetic tool of one's choosing. Axiem is the tool used in Figure 8 below. (Note that electromagnetic optimizations are considerably slower than optimizing in circuit simulations, but the electromagnetically corrected values for S12 and S11 are eventually made to be acceptably close to the design requirements targets).

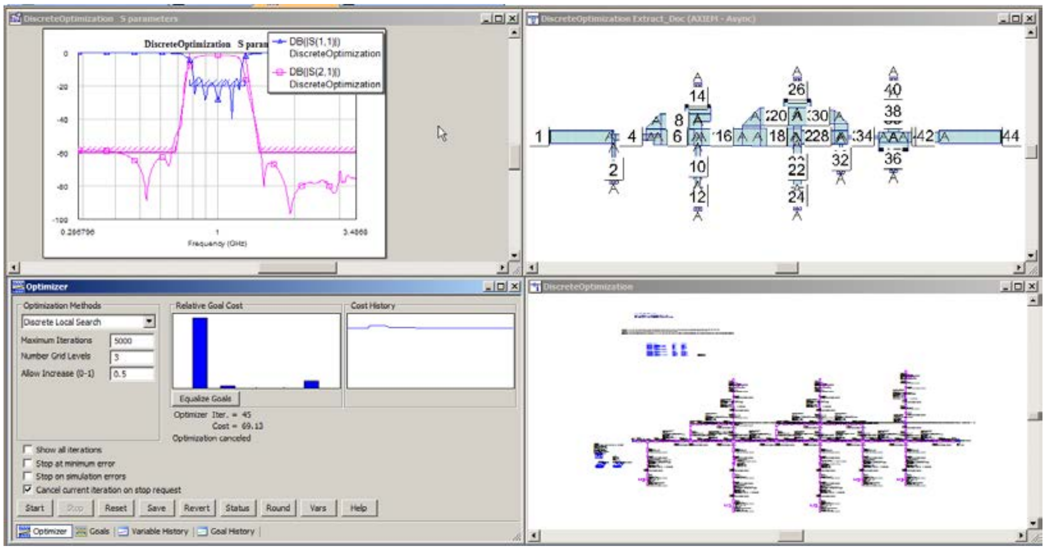
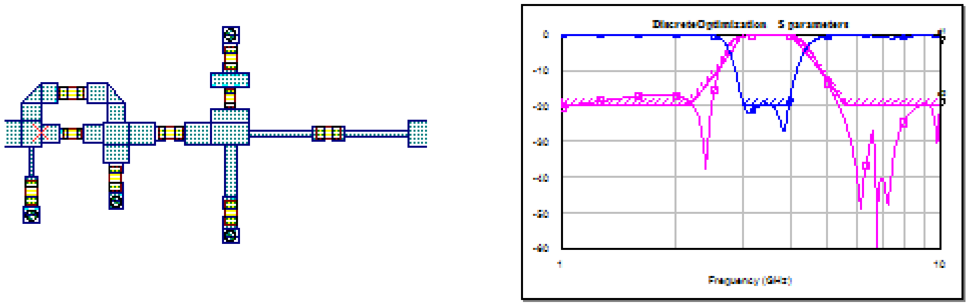


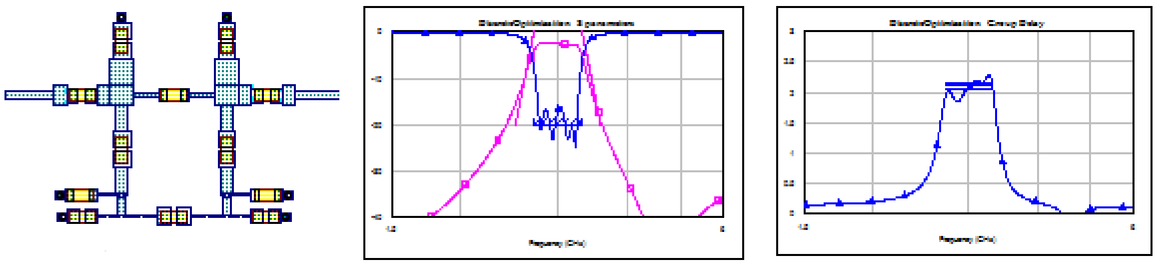
Figure 8: Electromagnetically optimized for S11 and S12 using Axiem

Other Design Examples

Figure 9 illustrates examples of simpler designs accurately hitting higher frequency design requirements based on simulated EM analysis in Axiem.



- 3 to 4 GHz, 3 Pole, Minimum Inductor ZigZag Filter, and EM response



- 3 GHz, 20% BW, 4 Pole, Bridge Element Delay Equalized Filter, and EM Response

Figure 9: Other Higher Frequency Filter Design Examples with Discrete Optimization

Conclusion

Expert synthesis in FilterSolutions, along with Modelithics' model accuracies, efficient National Instruments discrete optimization, and use of EM analysis tools such as Axiem, is a technique using multiple tools that accurately meet high frequency design requirements. The seven-pole Elliptic filter used as the example is of medium complexity. The design is shown to be accurately achievable for frequencies up to at least 1 GHz. Simpler filter designs, such as the other examples shown in Figure 9, are achievable at higher design frequencies.