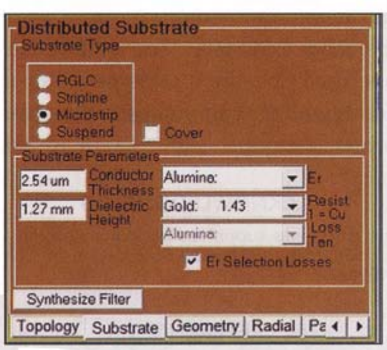
Synthesize Distributed Element Filter Designs

A filter design program adds power, speed, and accuracy through its addition of co-simulation capabilities, thanks to some well-known electromagnetic simulation software tools.

SYNTHESIS OF filter circuits utilizing transfer-function characterization has traditionally been a strong design tool for engineers needing to create lumped, active, and digital filters. Over the last decade, the use of transfer-function-based filter synthesis has also been extended to distributed-element circuits. Software programs such as FilterSolutions® from Nuhertz Technologies (www.nuhertz.com) have been quite accurate and robust for lower-frequency designs, but relatively unproven at microwave frequencies. At microwave frequencies, for example, the effects of electromagnetic (EM) interactions introduces first-order inaccuracies to predictions provided by the transfer-function method.

At increasing frequencies (diminishing wavelengths), filter segments and interconnections start to act like distributed components. Sometimes these effects are evidenced as parasitic circuit elements which must be factored into a filter design, so as to account for these extra circuit elements. Often, these distributed component effects are used intentionally as part of the filter's resonators or other components. In addition to parasitic circuit elements and distributed component effects, the effects of the filter housing often influences the response of a filter—especially when the enclosure walls or covers are close to the filter substrate—in an attempt to reduce the overall size of the packaged filter.

1. This screen shows the various types of filter responses available for modeling in the Filter Solutions software.



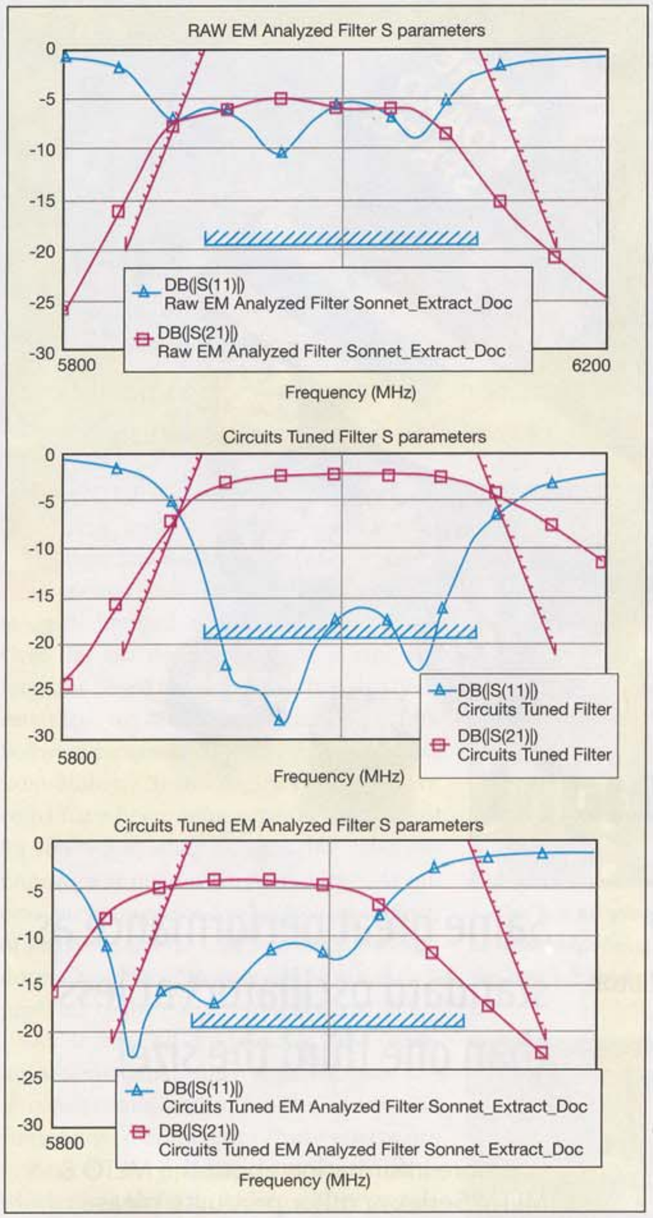
2. This screen shows an example of a distributed filter design panel in the Filter-Solutions software.

In the effort to validate the FilterSolutions filter design software for use at higher frequencies, Nuhertz perfected its interface with AutoCAD®, the well-known artwork layout tool from Autodesk (usa.autodesk.com), for seamless exchange of data. More significantly, Nuhertz also created data output options to allow direct access to the circuit simulation products of AWR Corp. (www.awrcorp.com), such as Microwave Office™, as well as to the electromagnetic (EM) analysis tools from both AWR and Sonnet Software (www.sonnet-software.com).

Using FilterSolutions, a circuit designer can synthesize a filter from among a dozen different filter types available in the software's design library, using either passive lumped elements or one of the user-controlled, distributed-element design topologies (**Figs. 1 and 2**). The software supports the realization of distributed filter designs in microstrip, stripline, and suspended-substrate configurations. The synthesized design can then be passed into one of AWR's circuit simulators for circuit tuning or optimization, and then returned to Filter Solutions. When further process or tuning by means of EM analysis is required, the design can be passed to the powerful tools available from AWR Corp. or to the EM planar three-dimensional (3D) analysis software em from Sonnet Software.

Figure 3(top) shows the S-parameters for forward transmission (S_{21}) and return loss (S_{11}) for a "raw" synthesized filter created in FilterSolutions, ready for further circuit simulation and analysis in Microwave Office. The responses are plotted from 5.8 to 6.2 GHz. When the filter was evaluated in the Sonnet EM simulation environment, in order to check layout and enclosure effects, the design clearly showed deficiencies in meeting the S_{21} and S_{11} performance requirements.

While the use of FilterSolutions (as of Version 13.0) for



3. These responses for a fifth-order Chebyshev bandpass filter show the "raw" filter performance (top), the circuit tuned filter (middle), and the filter with EM analysis applied (bottom). (Plots courtesy of AWR Corp.)

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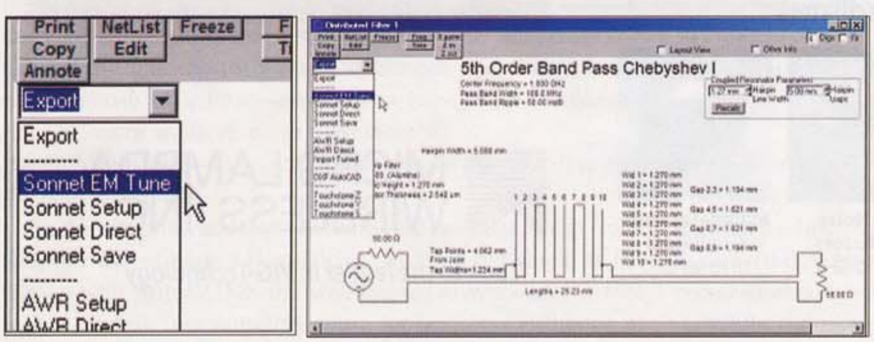
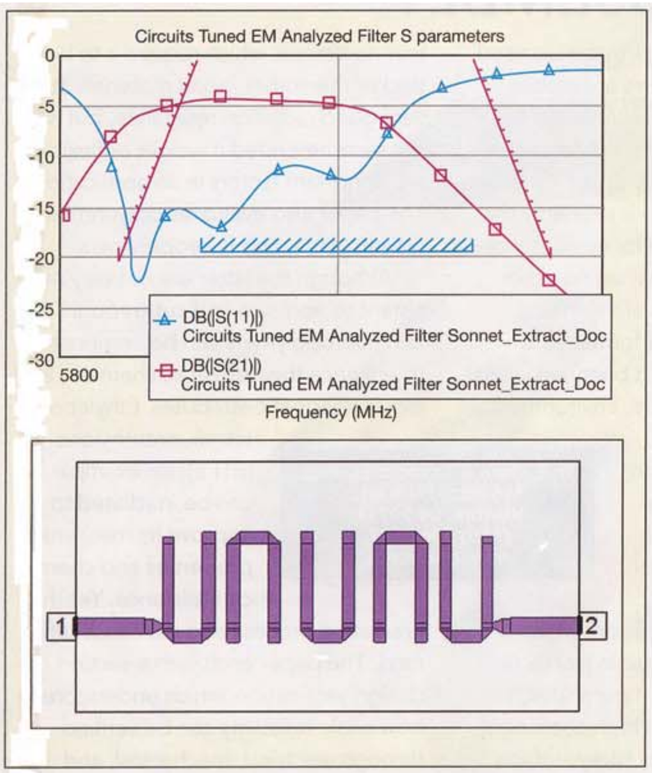
microwave filter designs has been validated for use in both lumped-reelement and distributed-element circuits, the additional use of EM modeling is critical for unveiling the "hidden" effects of circuit layouts, board materials, packaging, etc. Traditional circuit tuning techniques are often adequate, but frequently produce nonoptimal (and sometimes unacceptable) results. As shown in **Fig. 3(middle)**, the use of traditional circuit tuning shows an improvement in the circuit analysis filter performance, while **Fig. 3(bottom)** shows that the use of traditional circuit tuning techniques may significantly degrade the EM performance of the filter, when all EM interactions between both adjacent and nonadjacent circuit elements and interaction with the housing are considered.

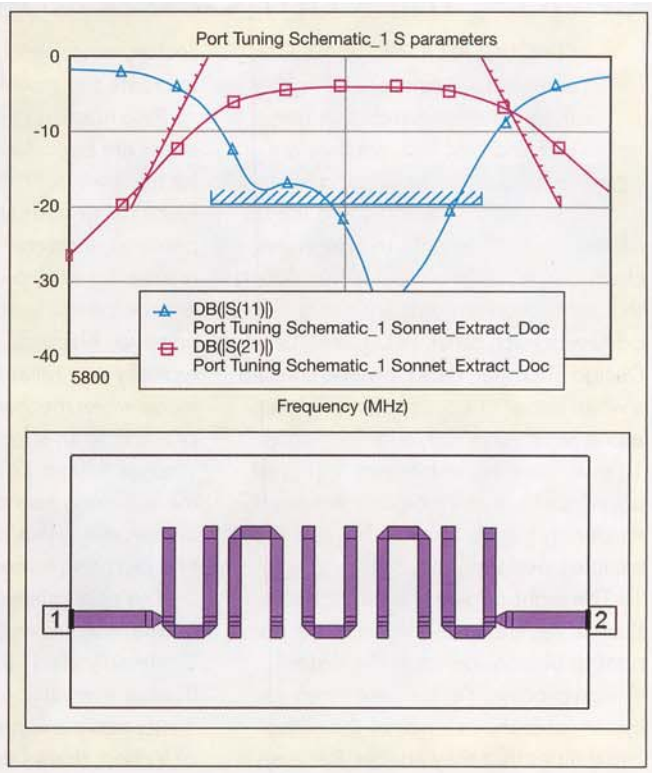
Beginning with release 13.1, FilterSolutions has taken the circuit solution technique an important step further: performing EM co-simulation of a design using Sonnet Software's new Co-calibrated™ internal ports feature—a technique referred to as EM port tuning. Co-calibrated ports are associated with a calibration group, with all ports in that group sharing a common ground. They are de-embedded simultaneously during an analysis to remove all cross-coupling, even when they are closely spaced, with no limit on the number of ports in a calibration group. The calibrated ports provide the capability for internal tuning of the circuit. These internal ports can be used in a circuit simulator to independently connect ideal tuning elements into the circuit geometry. For instance, the Co-calibrated ports feature mightbeusedforcalibratedinternalconnections for later attachment of a sophisticated nonlinear transistor model in an electrical circuit simulation.



4. This is an example of how the Co-calibrated internal port feature from Sonnet Software can be applied. (Courtesy of Sonnet Software.)



5. The S-parameters (top) show the forward and reflected transmission responses prior to circuit-tuned EM analysis, with the filter layout shown before EM port tuning (bottom).



6. The S-parameters (top) show the forward and reflected transmission responses of the experimental filter following EM port tuning, along with the layout (bottom) after tuning.

The latest version of Filter-Solutions can take advantage of this heightened modeling accuracy developed by Sonnet Software to perform optimization at the speed of circuit network analysis. Optimization can help correct for a wide range of error sources in a filter design, including cross coupling, parasitic circuit elements, transmission line and discontinuity model inaccuracies, and packag e interactions. The use of EM simulation, for example, can predict the effects of a housing's metal cover on a filter passband center frequency, and provide insight into the steps needed for proper and accurate tuning of the filter. Version 13.2 of FilterSolutions, when used with the EM tools from AWR and Sonnet Software, is the industry's first filter synthesis tools to automate the EM tuning process for filters. This combination of software tools makes it possible for a filter designer to specify, synthesize, and optimize a filter design to EM accuracy in minutes without the need for extensive familiarity with the EM tool itself.

For example, using Sonnet Software's EM port tuning methodology, Version 13.2 of FilterSolutions has been validated for the design of hairpin resonator and interdigital filter structures, fabricated in stripline, microstrip, and suspended-substrate media. The program optimizes S_{11} performance to levels of 15 to 20 dB on a consistent basis. Designs have also optimized S_{21} forward-transmission performance to fit within a required passband specification, for example, for filter insertion loss at the center frequency or for a given passband around the center frequency. **Figures 4(left) and 4(right)** show the technique for passing a schematic diagram from FilterSolutions to Sonnet Software's EM tools for EM port tuning, with a partial view of Sonnet's export menu screen shown on the left and the schematic view shown on the right. The end result is electromagnetically corrected geometry, in which S_{11} and S_{21} responses have been optimized, as shown in **Figs. 5 and 6**. The design optimization is accomplished in a matter of several minutes.

Co-simulation of proven filter design tools like FilterSolutions with industry-standard EM simulation packages, such as the powerful software tools available from AWR Corp. and Sonnet Software, can dramatically improve the accuracy of high-frequency filter designs in a variety of media, including microstrip, stripline, and suspended-substrate architectures. Version 13.2 of FilterSolutions incorporates EM port tuning capabilities for hairpin and interdigital filters. The next release of the software is anticipated to extend the EM port tuning capabilities to combline and other filter topologies. MWRF

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“The BEST in Filter Design”

Nuhertz Distributed Element Filter Design Synthesis

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