Application Note

Miniaturized Hairpin Filter Design with FilterSolutions® and Sonnet Software's *em*® Analysis Program, in Microwave Office®

Nuhertz Technologies

This application note illustrates the technique for creating a design for a miniaturized microwave hairpin filter design. The paper follows the synthesized design created by FilterSolutions as it is optimized by using the Sonnet electromagnetic analysis program. . Further processing for simulation and optimization of the circuit is made possible in NI-AWR Corporation's Microwave Office® program, an important tool used in this study. http://www.awrcorp.com/

FilterSolutions creates filter circuits based on user-entered response and design requirements. The program is used for the design of both Distributed and Lumped elements. (In addition, the program can also be used to create Digital and Active filters).

Sonnet Software provides a full line of Electromagnetic software products ideal for high frequency analysis. View the entire suite of programs at: http://www.sonnetsoftware.com/.

While FilterSolutions' versatility makes it useful in many applications, the design of a miniaturized hairpin best demonstrates the seamless tool flow of the FilterSolutions design into Sonnet's electromagnetic optimization.

Tuning and Optimizing

Synthesized planar filters generally require multiple tuning attempts and/or optimizations to achieve maximum performance. This tuning technique normally requires multiple manual edits to the synthesized circuit values and repeated electromagnetic optimizations. The optimization can take the form of using Sonnet's em port tuning technique. Another alternative is the use of a circuit simulator compatible with Sonnet's *em*®, such as Microwave Office from National Instruments' AWR Corporation.

Minimizing Board Space

Traditional Hairpin designs will generally be inefficient in space utilization. There would be a large amount of wasted space as illustrated in Figure 1.

In addition, Hairpin designs are all-pole designs. This design permits wide bandwidth.

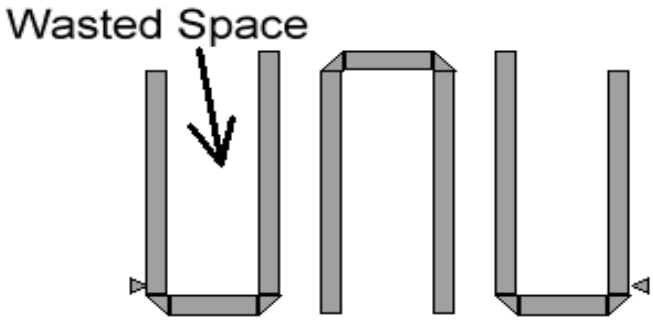

Figure 1

When synthesized using FilterSolutions, the result is a more efficient used of board space achieved by folding the hairpin ends as shown in Figure 2.

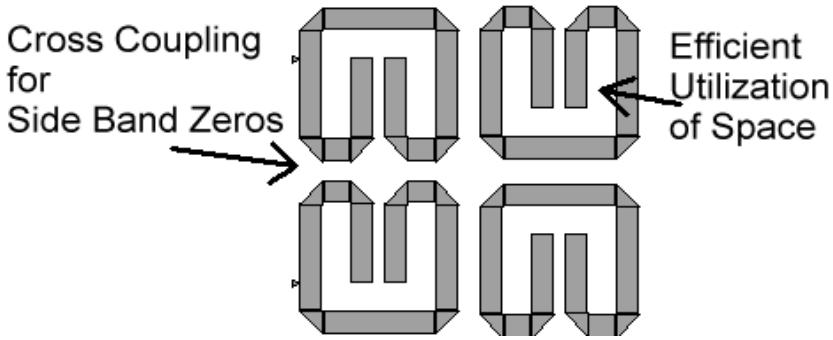

Figure 2

The cross coupling products produce sideband zeroes that result in a narrower passband.

Issues in Analysis

Closed-form circuit level analyses of folded Hairpin filters generally produce poor results without accounting for the considerable cross-coupling of the folded elements. (Figure 3).

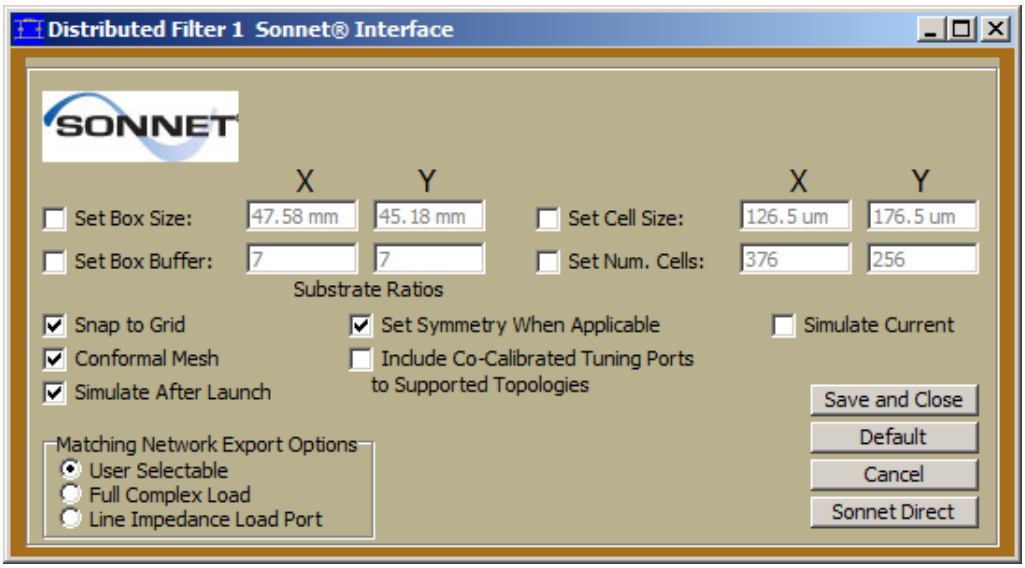

Figure 3

Manual Tuning in FilterSolutions using the Sonnet Export Control Panel

An illustration of the use of the export control panel is shown in Figure 4. Nuhertz recommends that the 'Snap-to-Grid' and 'Conformal Mesh' options are utilized. Before the em analysis is performed, select "Simulate after Launch" then "Save and Close." (See Figure 4).

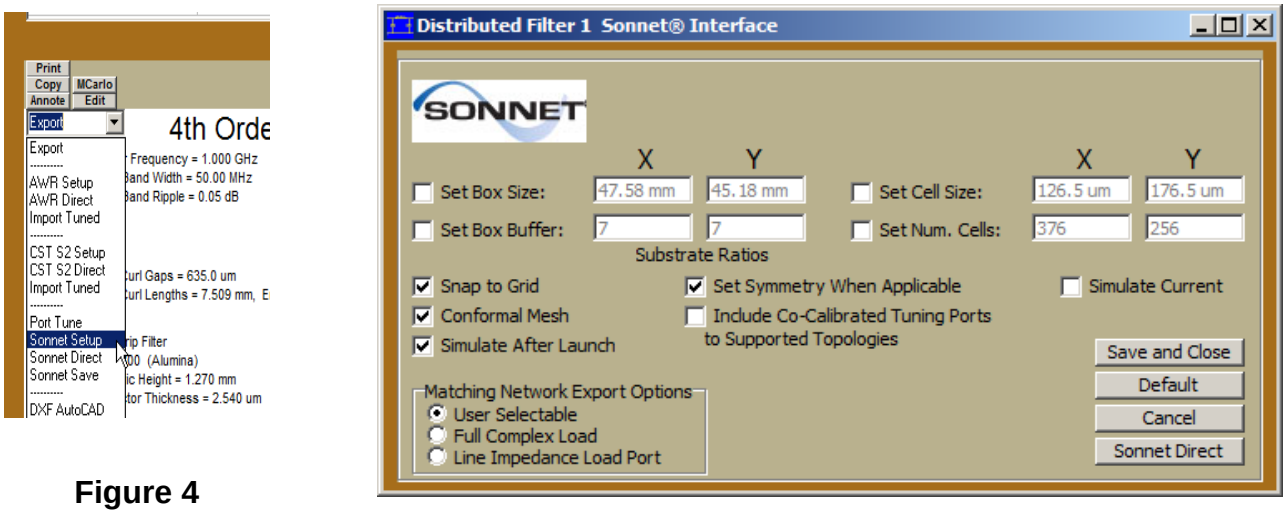

Figure 4

The next step is moving the synthesized circuit into Sonnet by clicking on "Sonnet Direct." The resulting Sonnet rendition is as shown in Figure 5.

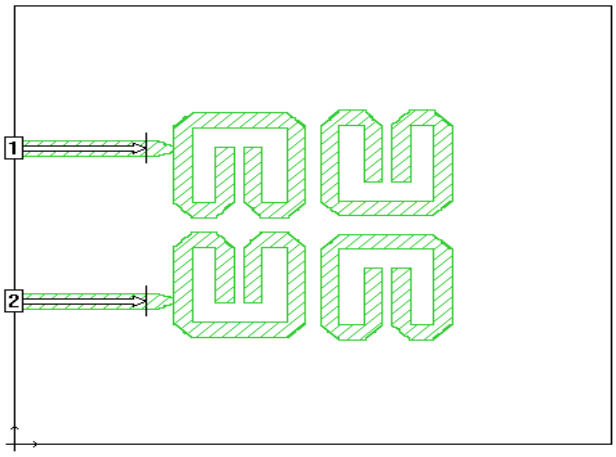

Figure 5

The circuit response can then be viewed and measured in Sonnet's *em* (Figure 6),

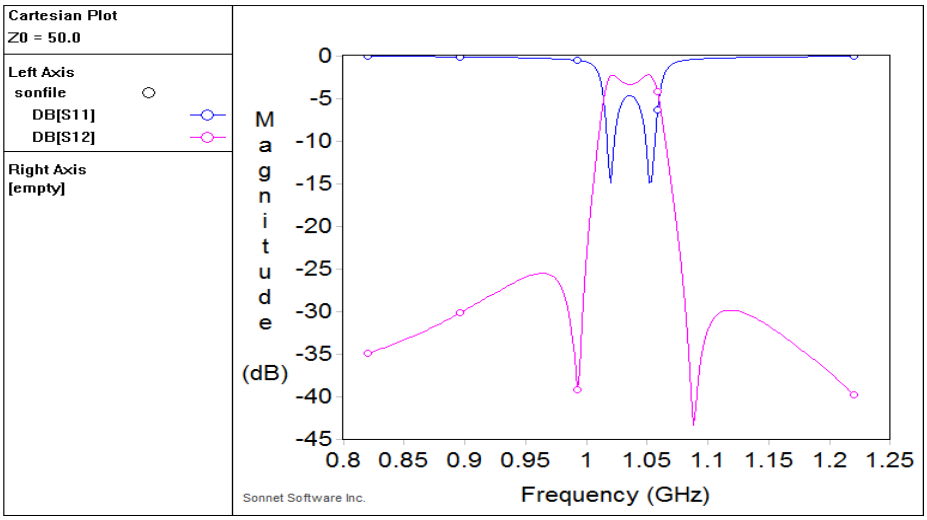

Figure 6

and re-imported into FilterSolutions with the substitution of the Sonnet generated geometry as shown in Figure 7.

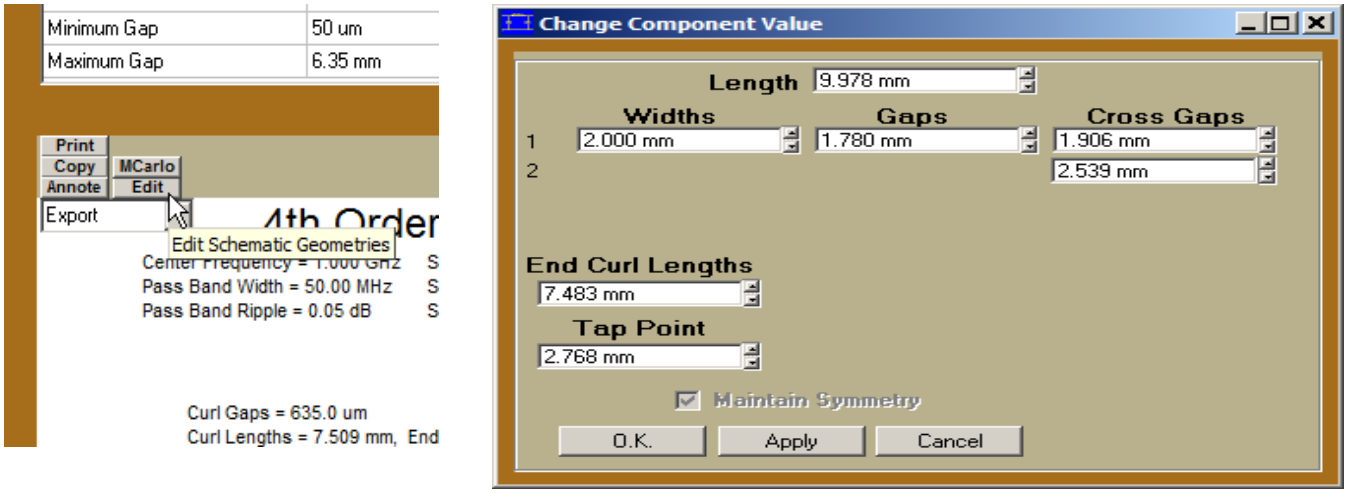

Figure 7

The process may be iterated until the desired Sonnet electromagnetic response is achieved, as shown in Figure 8.

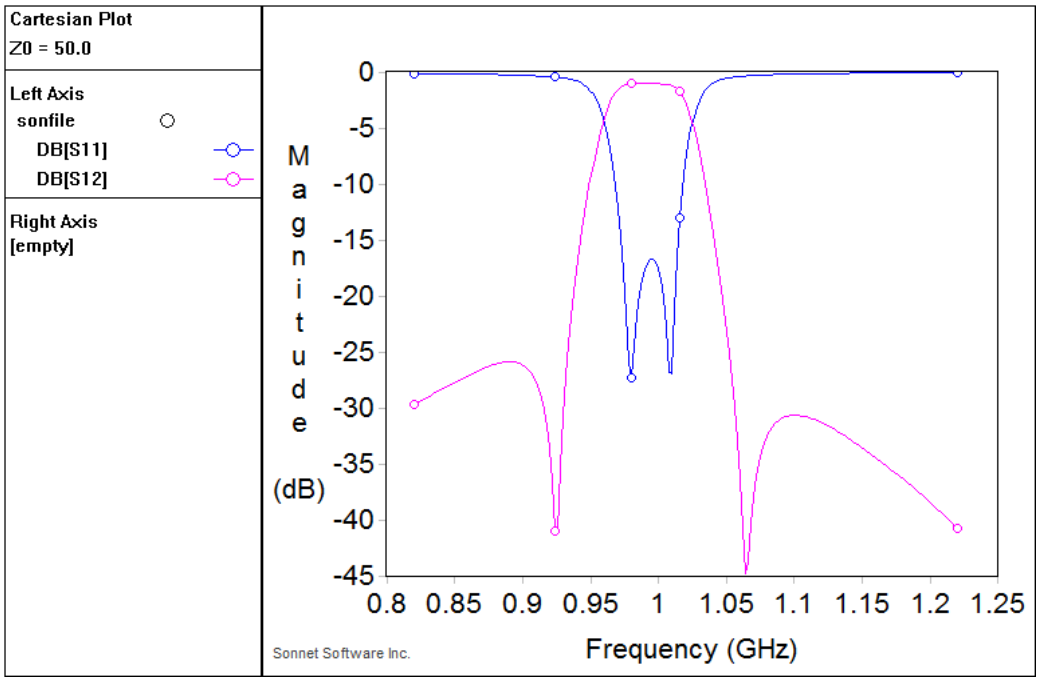

Figure 8

Co-Calibration

Sonnet has incorporated a technique called co-calibrated internal ports in their *em* program. These internal ports can be inserted into the resutant Sonnet filter before re-importing the design into FilterSolutions. The resultant circuit can then be used as the target for simulation and optimization using tools such as AWR's Microwave Office. See figures 9 and 10, below:

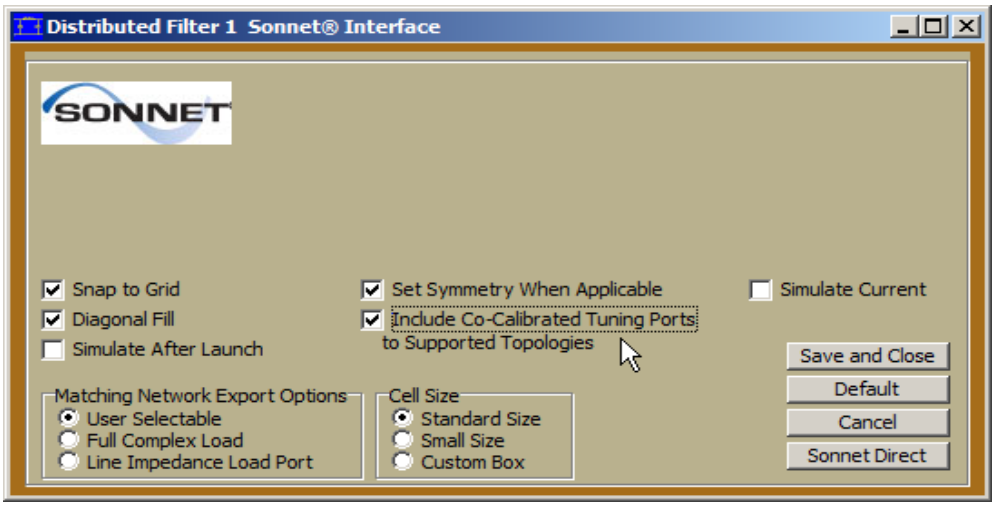

Figure 9: Selecting Co-Calibrated Ports

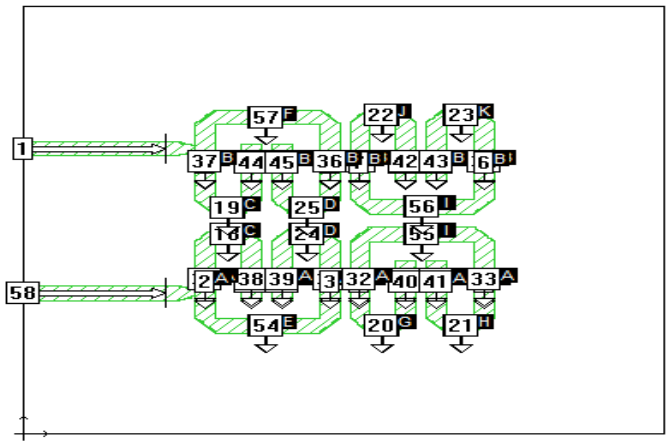

Figure 10: Representation in Sonnet *em*

Port Tuning in Microwave Office

Importing the circuit into AWR's Microwave Office is simple, with well-defined and explicit directions. The schematic is automatically set up in Microwave Office, looking like the screen shown as figure 11.

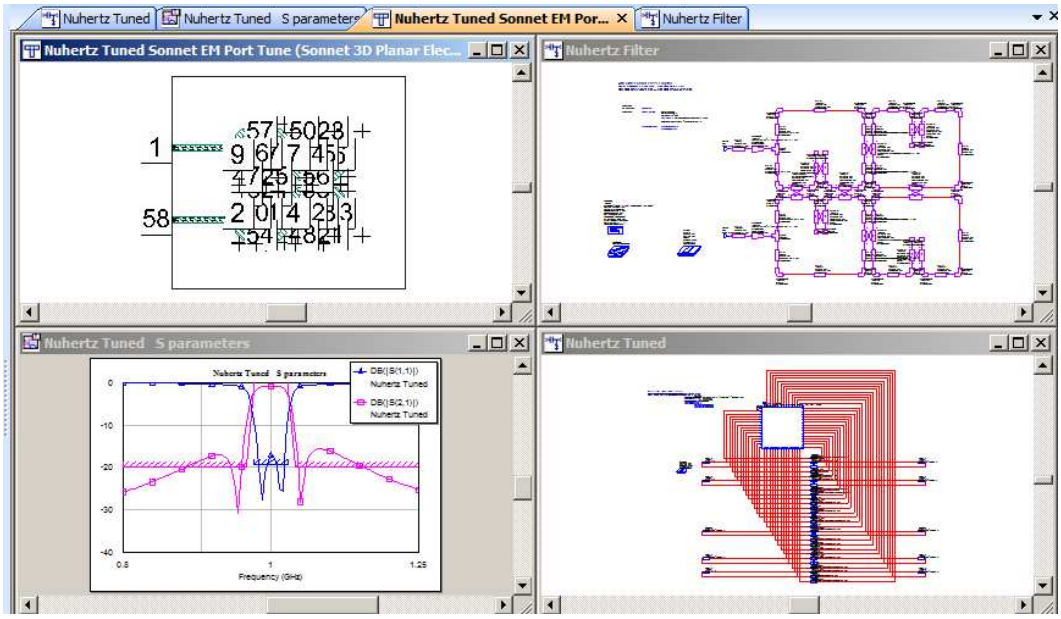

Figure 11
Filter with co-calibrated ports, imported into Microwave Office

The additional small transmission line components are connected into the filter so as to complete the filter. These "tuning" transmission line components can then be optimized in Microwave Office so as to realize the desired filter response. The small changes indicated by the new tuning element values are used to modify the filter layout so as to realize the tuned response. All of this optimization is done at full circuit theory speed. Since almost the entire circuit response is due to the Sonnet electromagnetic simulation, the Microwave Office calculated response has nearly full Sonnet accuracy.

Finally, figure 12 shows the resulting port tuned filter's electromagnetic response:

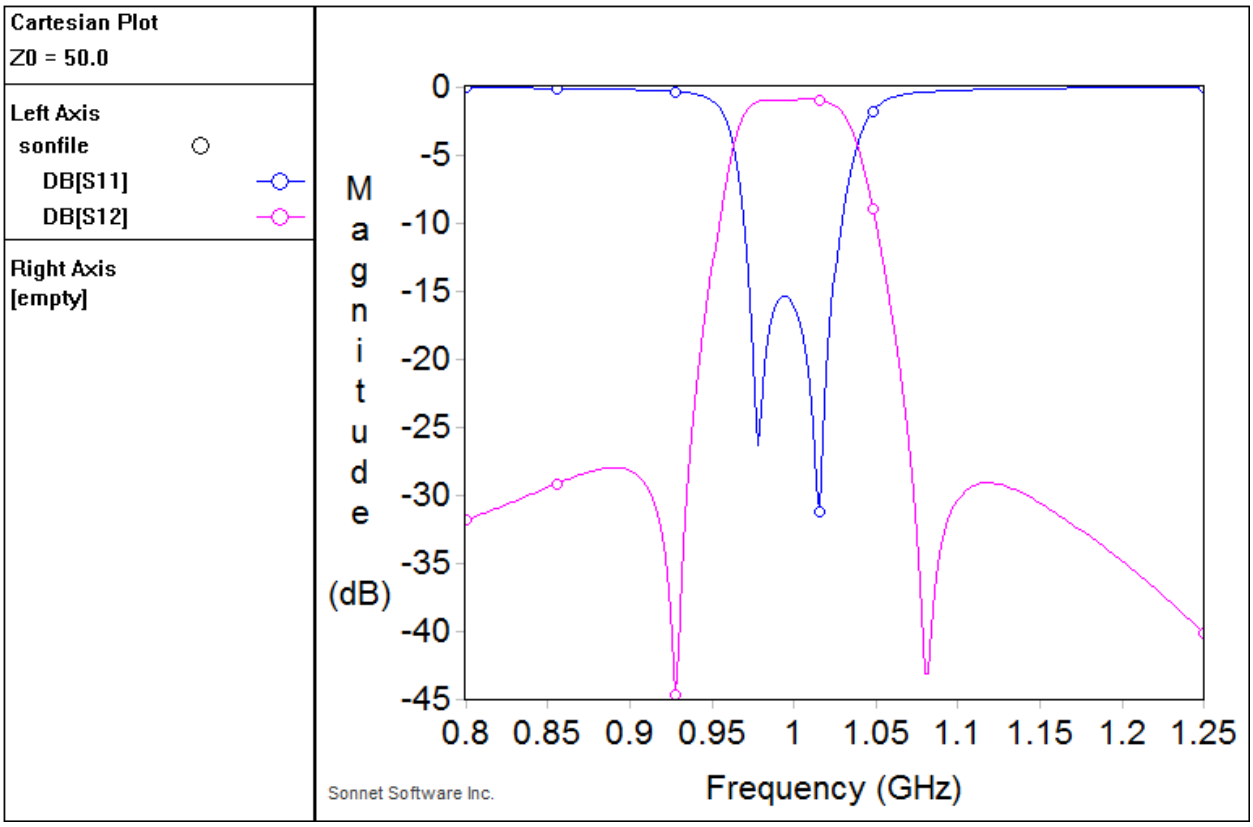

Figure 12

Conclusion

A 1 GHz Hairpin resonator filter, with a desired response shape, has been synthesized in FilterSolutions. The filter was then resynthesized with the substitution of folded hairpin resonators in lieu of the unfolded topology.

The electromagnetic response, taking all cross-coupling products into account, was determined using the Sonnet Software program 'em" After several iterative tuning steps the internal co-calibrated ports were introduced into the filter architecture.

The filter, now with internal tuning ports was optimized in AWR's Microwave Office to achieve best response results.