A 2.6GHz Microstrip Hairpin Filter Design Using CAD and EDA Tools

This paper by Luigi Greco and Stephan Schmidt demonstrates the design of a four-section 2.6GHz microstrip hairpin filter using the Serenade Design Environment from Ansoft. The design was validated both by the use of Ansoft Ensemble 2.5D planar electromagnetic simulator and by the measurement of a prototype created with LPKF ProtoMat 95s and prepared with LPKF CircuitCAM and BoardMaster applications. The results from the two methods are compared and found to be in good agreement.

To compete in today's wireless communications industry CAD/EDA tools must be an integral part of the wireless product design cycle. Foremost on the minds of many design engineers is reduced design cycles and time-to-market. CAD/EDA tools are essential in addressing these issues. Simulation accuracy and ease-of-use are two important characteristics for CAD/EDA tools to possess if the design engineer is to achieve maximum productivity. In this paper the design of a 2.6GHz microstrip hairpin bandpass filter using the Harmonica circuit-level simulator in Ansoft Corporation's Serenade Design Environment is described. The design was exported to Ansoft's Ensemble (2.5D planar electromagnetic simulator) and to LPKF's prototyping applications via Serenade's layout tool, S2A. The main purpose of this exercise is to validate the results from Serenade to those from Ensemble and measured data. Table 1 summarises the CAD/EDA tools used in this exercise. Note that all the tools used are for the PC.

Filter design

A four-section microstrip hairpin filter topology was chosen to provide a bandpass response centred at 2.6GHz with a 3dB bandwidth of approximately 280MHz. The initial design was entered by schematic capture in the Serenade desktop, shown in Figure 1, using Harmonica's microstrip distributed elements library.

One of the distinguishing features of Harmonica's distributed library models is the Multiple Coupled Line element (MCPL), used in the coupling sections of the hairpin filter. The

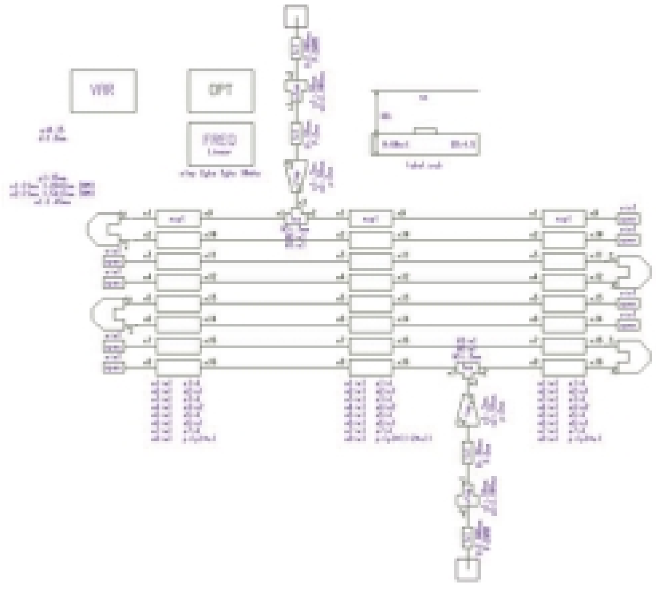

Figure 1: Schematic capture of the microstrip hairpin filter in Serenade.

PRODUCT	FUNCTION
Ansoft Serenade Design Environment	Schematic capture of the structure and simulate with the Harmonica circuit level simulator
Ansoft S2A	Serenade's layout tool
Ansoft Ensemble	2.5D planar electromagnetic simulator
LPKF ProtoMat 95s	PCB prototyping machine
LPKF CiruitCAM	CAD/CAM software to prepare the PCB
LPKF BoardMaster	Software used to control the ProtoMat 95s

TABLE 1: CAD/EDA tools used and discussed in this paper:

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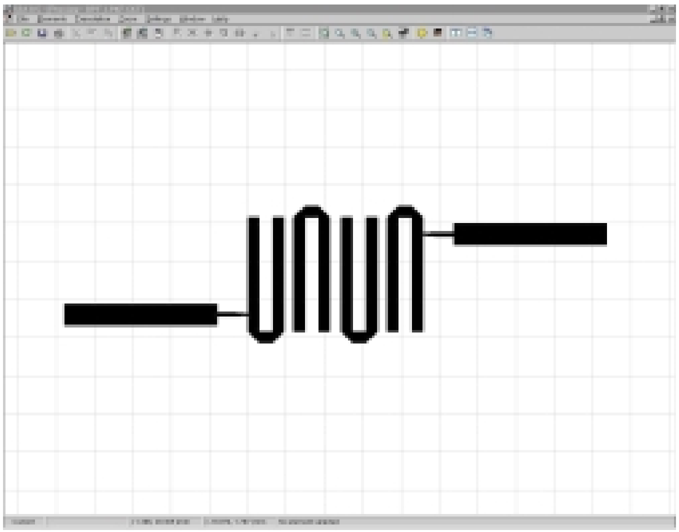

Figure 2: Layout file for the filter generated in Serenade's S2A layout utility.

MCPL element uses a full-wave spectral domain algorithm where the electrical characteristics of up to 20 coupled lines of any combination of widths and spacings can be accurately simulated over a given frequency range. As shown in Figure 1, the MCPL elements are the three sections of eight coupled lines each making up the straight segments in the hairpin filter.

The folds in the hairpin are represented as sub-circuits ("U-turn" symbols) consisting of a transmission line and a mitered bend on both sides. Because no enclosure cover was specified for the filter, radiation effects will be taken into account in the simulation in both Harmonica and Ensemble. The substrate defined in the schematic is that of Rogers TMM-4 whose specifications are listed in Table 2.

The filter design dimensions were optimized to meet the specifications in the passband. Because the MCPL elements can have any combination of widths and spacings, the symmetry of the filter was preserved by optimizing variables that represent the symmetrically opposed widths and spacings.

Filter construction

After the filter has been optimized in Harmonica, the topology is ready for layout. The S2A layout tool is launched from the Serenade Desktop menu to create an auto-generated layout. This is shown in Figure 2.

Next, a DXF file of the layout is created in S2A so that it can be imported to the LPKF CircuitCAM application and subsequently prepared for PCB machining controlled via the LPKF BoardMaster application. The CircuitCAM application is used to check and edit a layout as well as create isolation channels between conductor traces. This is shown in Figure 3. The final layout is sent to the LPKF ProtoMat 95s system for machining.

In addition to exporting a DXF file, S2A was used to export the Ansoft Neutral File Set (ANFS) used to create the filter design project for Ensemble. Figure 4 shows a false-color image "snap-shot" of the magni-

Substrate Thickness	60mils (1.524mm)
ϵ_r	4.5±0.045 @10GHz
Metallization	1oz Cu (1.4mil/0.036mm)
Tan δ	0.002

Table 2. Rogers TMM-4 Substrate Specifications

tude of the RF currents at 2.6GHz in the filter obtained after simulation in Ensemble.

Filter measurement

After the filter has been fabricated, SMA connectors were soldered to the filter. Figure 5 shows the final prototype used in the measurement. The insertion and return losses were measured using the HP 8510B network analyser. Serenade has the capability to read in and save S-parameters directly from a wide range of network analysers via a GPIB/HPIB interface.

Data comparison

Figure 6 show the comparisons between Harmonica, Ensemble and measured data for insertion and return losses. For a first-pass prototype, the data are in good agreement. Table 3 summarises the 3dB points, bandwidth and centre frequency for the three data sets.

Conclusions

The design and validation of a 2.6GHz microstrip hairpin filter has been described. Simulated data from Harmonica in Ansoft's Serenade Design Environment is compared

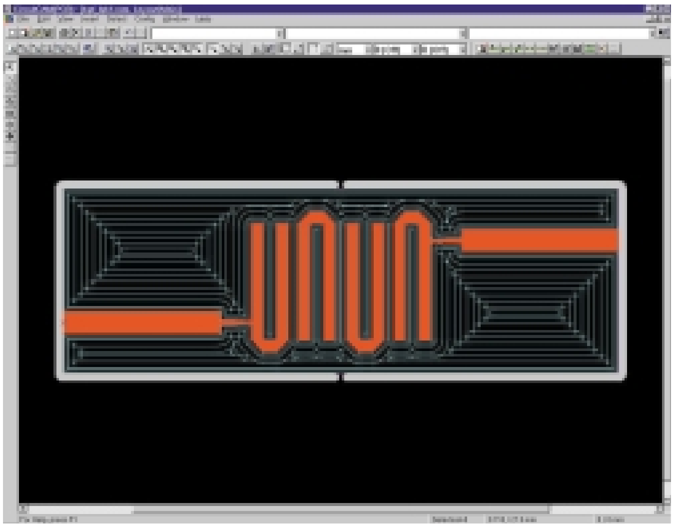

Figure 3: Cutting tool paths created in LPKF's CircuitCAM program for the filter.

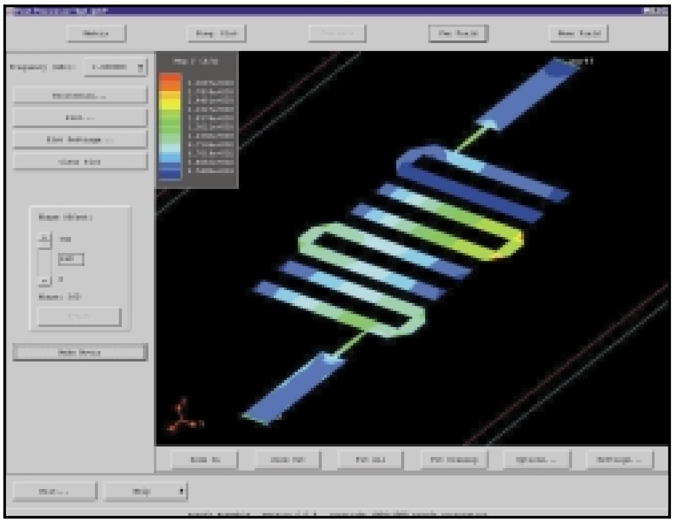

Figure 4: Ensemble model of the filter created exported via S2A.

with Ansoft's Ensemble 2.5D planar electromagnetic simulator and prototype measurement. The filter layout created by the S2A Layout tool was used to export a DXF file to LPKF's CircuitCAM and BoardMaster applications for fabrication on the ProtoMat 95s. The return and insertion losses from the Harmonica circuit simulator are compared against Ensemble and measured results, and were all found to be in good agreement.

Acknowledgments

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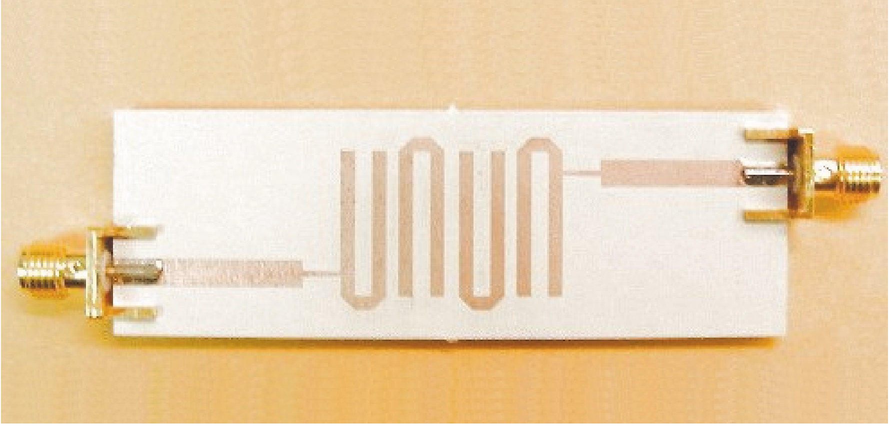

Figure 5: Photo of the completed filter.

	Lower 3dB Cutoff (GHz)	Upper 3dB Cutoff (GHz)	3dB Bandwidth (MHz)	Centre Frequency (GHz)
Harmonica	2.450	2.730	280	2.590
Ensemble	2.450	2.700	250	2.575
Measured	2.480	2.760	280	2.620

Table 3: Summary of the filter frequency characteristics between the 3 data sets. The centre frequency data are all within ±1% of 2.600GHz.

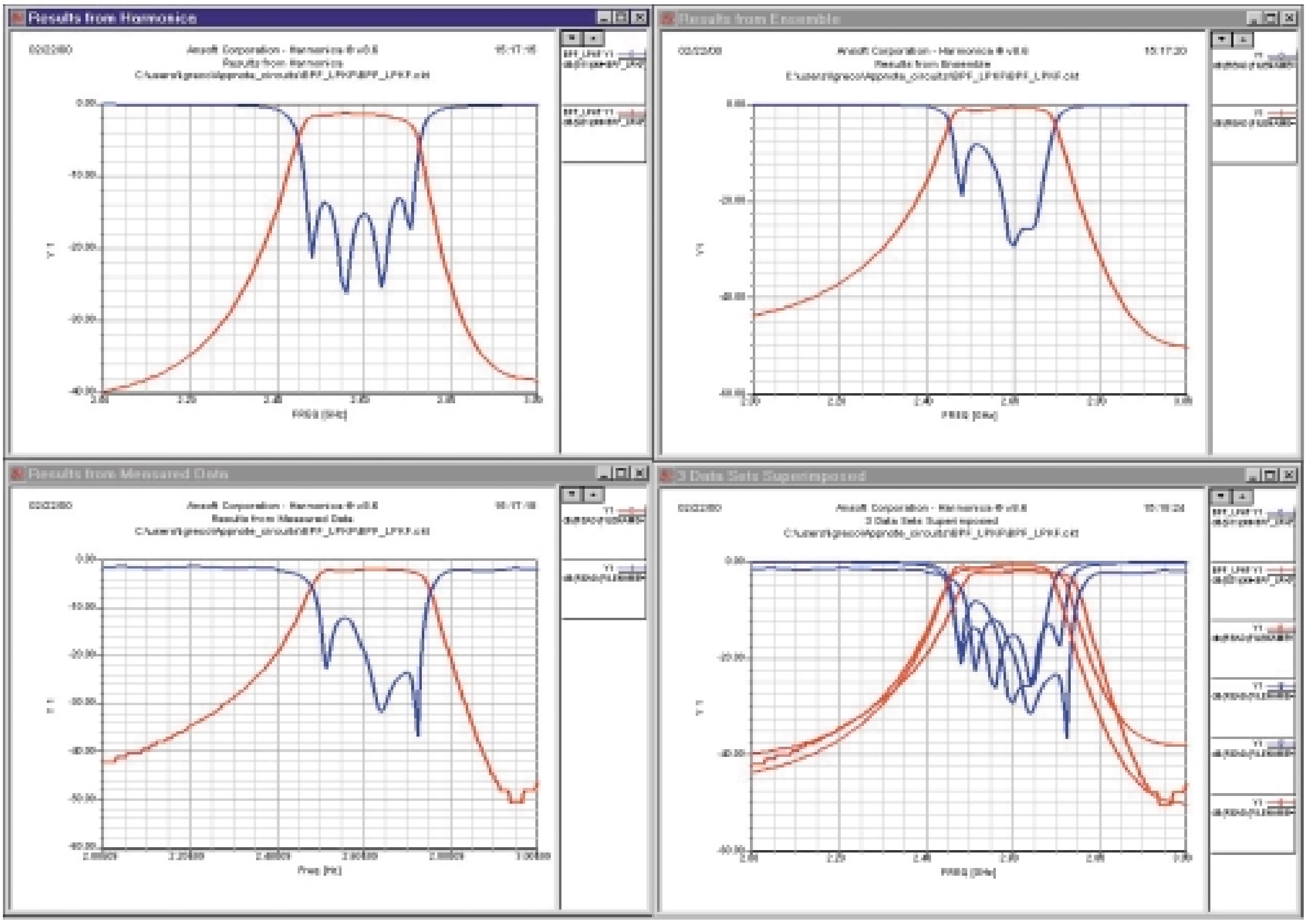

Figure 6. Comparison of the insertion and return losses for the hairpin filter. Clockwise from the upper left trace the results are from: Harmonica, Ensemble, measured data, and a superposition of all 3 data sets.