

Embedding the Footprint into Very High Frequency Surface Mount Components through De-embedding Optimization

A. Rahman, M. Broman, and M. Howieson

Thin Film Technology Corporation

1980 Commerce Drive,

North Mankato, MN, 56003, USA

Phone: 507-625-8445, Fax: 507-625-9175, email: arahman@thin-film.com

Abstract

As Multiple decade GHz RF applications become more common place mass production approaches these applications in component forms that require low cost production processes. These standard mass production processes include both LGA and BGA component mounting processes. Advanced design techniques are required to create successful implementations of component performance criteria including the PCB footprint. Through accurate die simulation and characterized interconnecting structures extended into the uniform transmission line environment of the PCB. A sufficiently predistorted die function can be achieved through simulated optimization with de-embedding components in line with the simulated device under test. This has been empirically demonstrated through many 20GHz plus passive filter structures. Furthermore these BGA footprints have demonstrated very stable performance and nesting tolerances are held low through strict surface mount manufacturing process definitions and controls.

Keywords: Bandpass Filter, Simulation, Design flow, Pre-distortion, Optimization, Agilent ADS, Inverse-Scattering, BGA, Package Modeling, De-embedding

Introduction:

As gigahertz frequency applications enter the consumer market, mass production processes dominate the costing models of production. Inexpensive surface mount processes such as BGA and LGA become necessary to keep costs down.

process flows as in (Figure 1) are required. These advanced design process flows include pre-distortion in the initial design cycle. The pre-distortion process in this particular design process flow comes after sensitivity and yield analysis and before field solver verification steps. This pre-distortion process improves the die transfer functions ability to achieve predictable component performance as part of print circuit board assembly in the initial design cycle without additional design iterations.

Method:

Filters are a good example of these advanced design process requirements due to their precise transfer function definitions and frequent application utilization in current low cost systems. A common high frequency application demonstration available is a band pass filter for optical clock recovery. To design a filter component that will provide an expected performance characteristic after PCB mounting in a standard low cost fabrication process the ideal die component design needs to be optimized to a pre-distorted function to compensate for the packaging, mounting and circuit board footprint parasitic influences.

This pre-distortion design process step requires modern optimization capable simulation tools such as Agilent ADS that can run search algorithms for key design parameters that will tune the performance of the design simulation to meet pre-determined design goals that pass the component specifications while including simulated

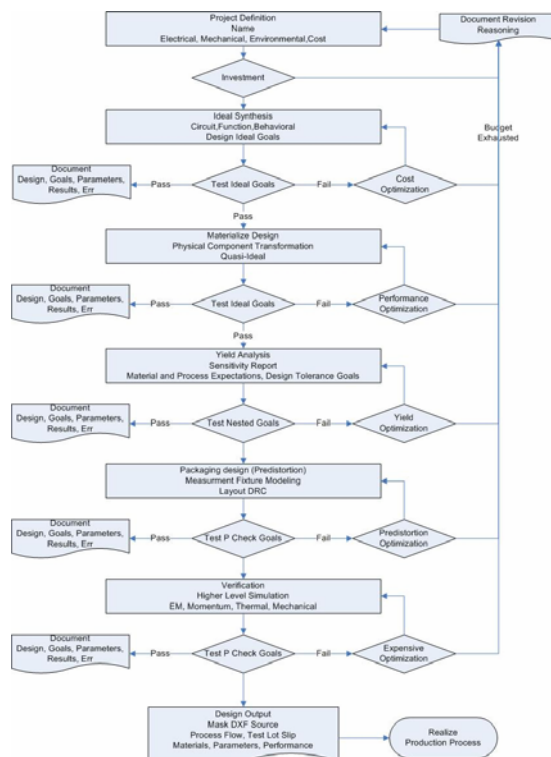


Figure 1 Design Process Flow

To achieve component performance fidelity with these packaging technologies, advanced design

models of the packaging and PCB footprint encapsulated in DUT measured device interface prototypes. In this project these component models are developed utilizing the process of inverse scattering. Inverse scattering is a process of iteratively developing a model that matches the measured device response. These footprint models are reusable and applicable to multiple component variations.

Design:

Filter die synthesis is a standard design process incorporated in most simulation tools for all typical material sets and topologies. In this case we are utilizing a standard alumina substrate material set and a coupled line structure to create a 22 GHz bandpass filter.

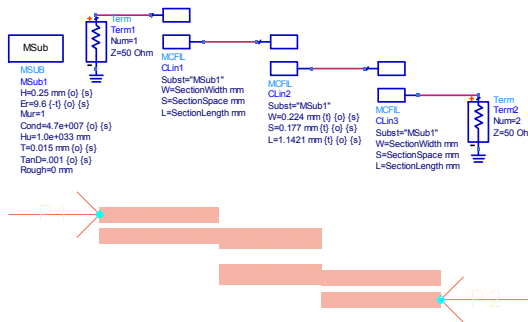
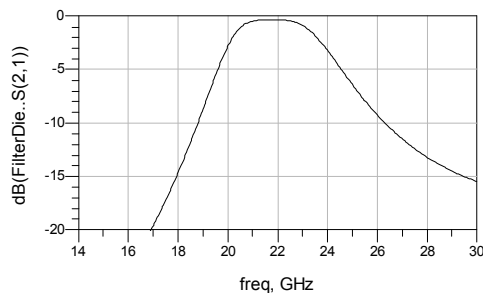


Figure 2 Ideal Filter Synthesis



Package De-embedding:

Putting this filter die design into a component package and maintaining the filter characteristics required by the application is achieved by having a very accurate packaging model. De-embedding the package model is derived by several methods including three dimensional finite element analysis (Fig 3), network analysis gating, inverse scattering, as well as others. The Process of inverse scattering consists of creating model of ideal simulation components and tuning the parameters to the response of a measured device in both time and

frequency domains until there respective responses converge.

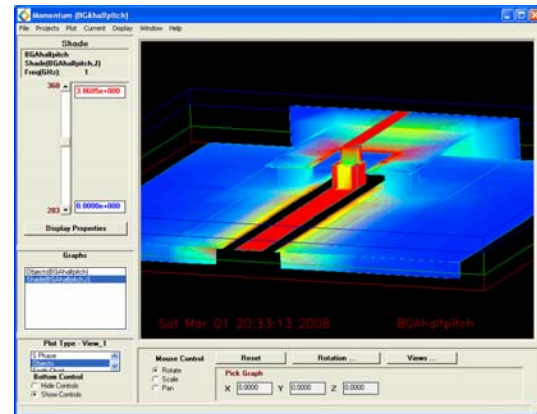


Figure 3 FEA Package Simulation

One of the most efficient models that take into account both frequency and time domain convergence is a string of transmission line discontinuities (Fig 4) that can be adjusted in impedance and length. This model is built mainly in the TDR domain (Fig 5) and then verified in the all other domains. When these domains are not in convergence the smith chart domain can help to analyze the differences in the comparison between measurement and model. The string of multiple parametric lossy components shown in the (Fig 4) shown match very well in all perspectives including insertion loss, return loss, Group delay, TDR, and the Smith chart (fig 6).

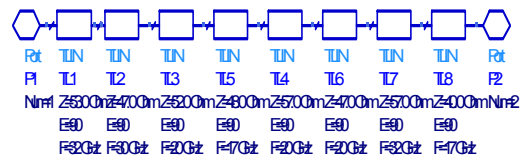


Figure 4 Package Model TLIN string

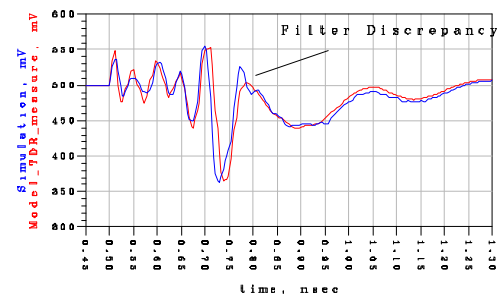


Figure 5 TLIN String vs PKG measurement

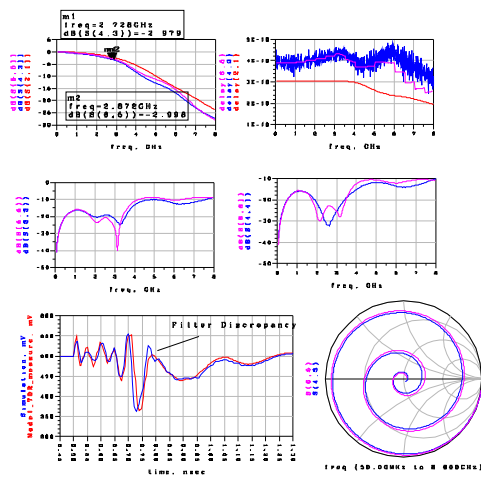


Figure 6 Model convergence in all domains

It is important to note that the package model needs to be carried out to the uniform transmission line environment at least a significant wavelength distance from the mounting discontinuities.

Pre-distortion Optimization:

With a filter die design and a good package model in hand the optimization process(Fig 7) is setup by including the model at each package I/O. In this case the filter package is symmetrical and the same model is used at both port 1 and port 2 remembering that the polarity of the model is important and inverted.

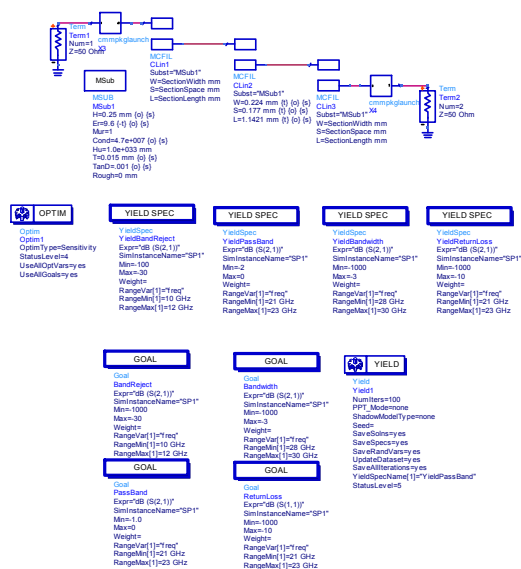


Figure 7 Package Model Optimization

Once these package models are inserted in the filter simulation the filter response changes to what we would expect to be more like the resulting packaged filter response. Re-optimizing the filter parameters such as coupling spaces and line widths will search(Fig 8) for a new filter die design that is

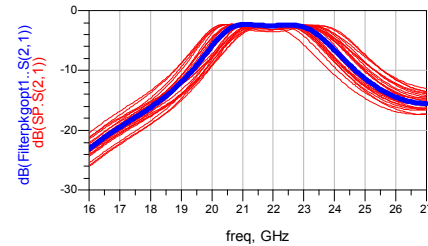


Figure 8 Optimization Search Results

effectively pre-distorted by de-embedding the footprint. The optimization process is based on filter function goal definitions defined by the application specifications in the original filter synthesis design process. This optimization searches within design constraints for an iterative solution that meets these goals with a simulation result that includes the package out to the calibration coaxial measurement planes in this case. Further Design process flow steps after this pre-distortion step includes yield sensitivity and Finite element verification.

Measured Results:

This project was fabricated and mounted in a coaxial measurement module that contains the footprint and BGA

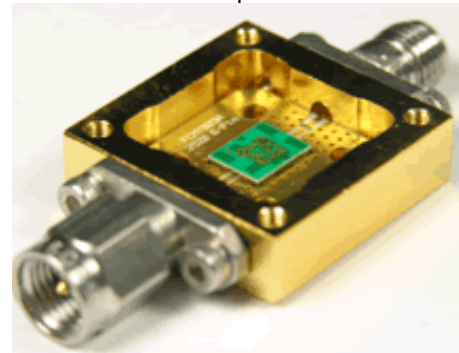


Figure 9 Measured Device Package

attachment method that was represented by the measured package model footprint used for the de-embedding process. The measured device results vs. the simulated expectations are represented in (Fig 10).

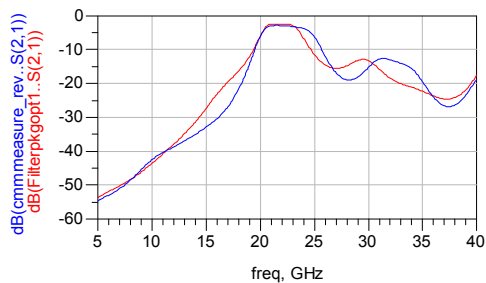


Figure 10 Simulation vs Measured Results

These surface mounted component measurements met the original optimization goals. As further acceptance testing the measurements were placed in the system simulation (Fig 11) and the end system specifications also passed acceptance testing shown the reduction of harmonic noise in the clock signal.

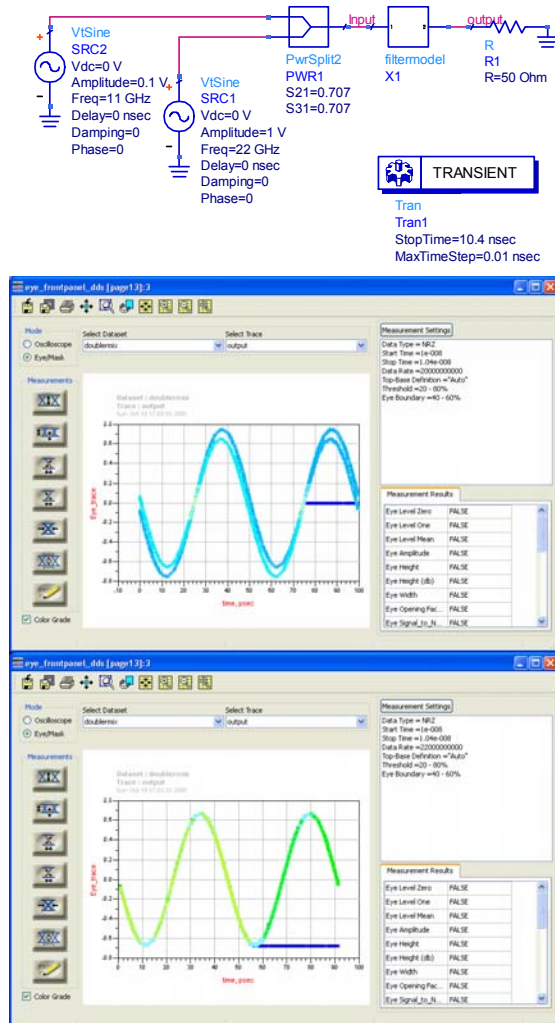


Figure 11 DUT measurement in System Simulation

Conclusions:

Acceptable measured results were achieved in one design cycle as represented by the surface mounted filter component and verified in system simulation.

Futher Actions:

Utilizing the error coefficients functions of the optimization search algorithms a method of quantifying the convergence of the models as well as the quality of the measured results to the design expectations can be implemented to create an cyclic model improvement method.

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