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A Substrate-Scalable SMA Connector Model

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Modelithics has introduced a substrate-scalable connector model format enabling accurate simulations and de-embedding of microwave connectors in design simulations.

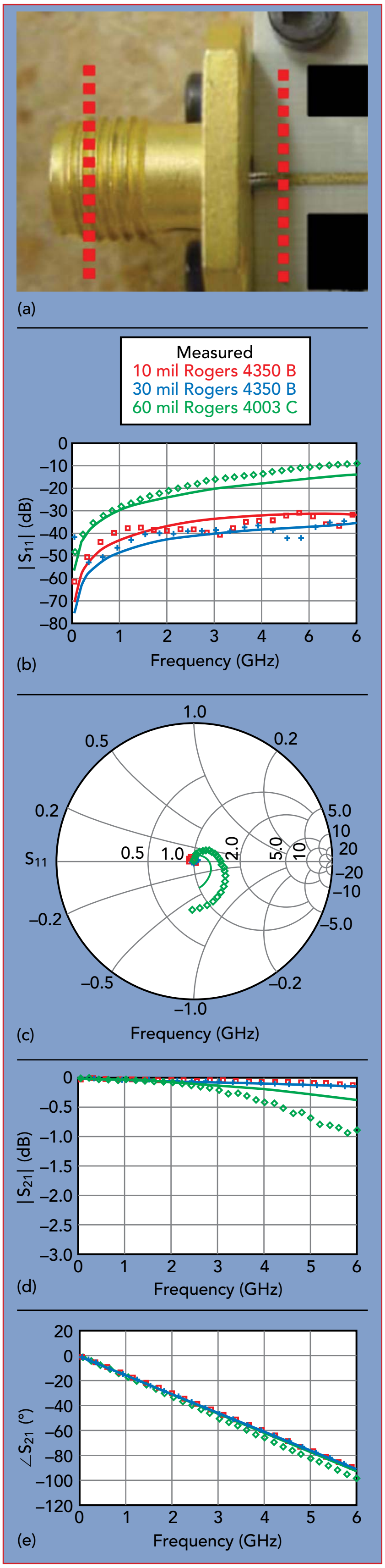
Coaxial connectorized measurements are a relatively easy and quick way to characterize circuits and components in the lab without getting into complicated fixture designs and on-board calibration standards. Coaxial connectors (e.g., SMA end-launch) provide a simple way to interface board-level designs to coaxial measurement systems; however, as with any measurement, not knowing where the measurement reference planes are and not being careful in calibration causes measurement and modeling inaccuracies. SMA connectors are designed to be low loss and minimize reflections, so the primary, but not only, effect is introducing a phase shift proportional to their electrical lengths. Their potential impact on performance is often overlooked during design, but like all other RF and microwave components, their actual performance will vary depending on the substrate they are mounted on. If the connector interface is not well matched, not only phase but the magnitude of transmission and reflection will be affected.

Connector effects can be accounted for and removed from the measurement in several ways. A calibration at the device under test reference planes can be performed, or the connectors and test fixture halves can be characterized separately and used to post-process the measured data in a simulator. Another approach is to use 3D electromagnetic (EM) analysis of the connectors and test fixture, to model their effects on performance. However, these techniques require custom calibration standards or appropriate software, know-how and, in the case of EM analysis, detailed knowledge of the connector's geometry and manufacturing material. Not everyone has the time and access to characterize test fixture effects in such detailed ways.

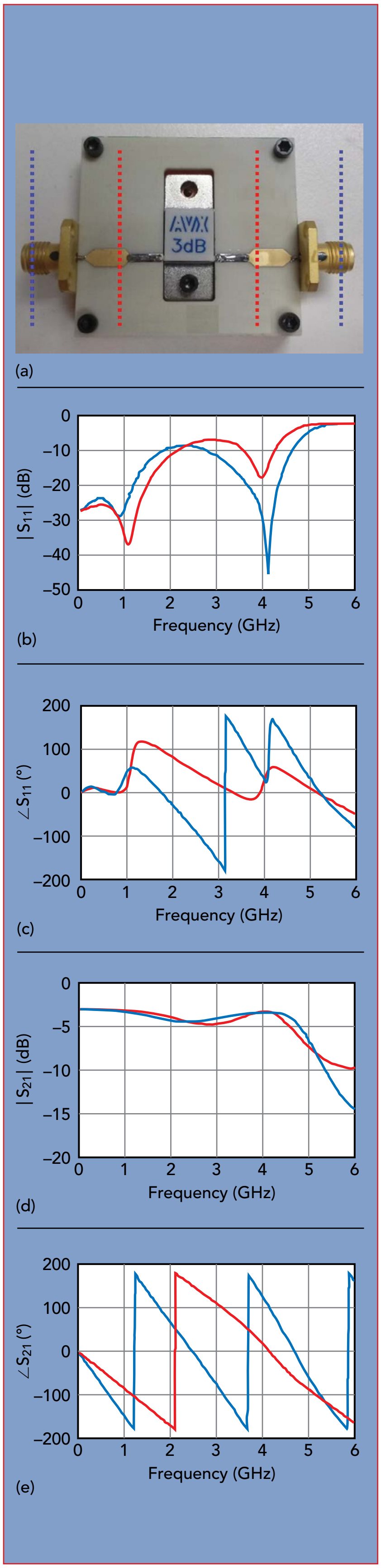
Alternatively, connectors can be accounted for within a simulator with a suitably accurate connector model. For use with ADS, Modelithics has created a substrate-scalable equivalent circuit model for the popular GigaLane PSF-S00-000 SMA jack connector that scales with the microstrip substrate height and dielectric constant. With the model, potential performance degradation related to the substrate or connector can be dealt with prior to circuit fabrication and testing. Or, a coaxial calibration can be performed, with de-embedding of the connectors done within a simulator. This connector model covers a substrate thickness to dielectric constant range of 2.2 $\leq h/\varepsilon_r \leq$ 17.1 mil and has been validated with measurements to 18 GHz. Using several Rogers' substrates, an equivalent circuit model was developed from data for a feed-thru configuration (i.e., only the connector) and validated with a back-to-back configuration (i.e., a microstrip thru line with connectors mounted on both sides). Examples of the model of the feed-thru configuration compared to measured performance are shown in ***Figure 1***.

If the connector is poorly matched on a substrate (i.e., a return loss less than 15 dB), the connector will also affect the magnitude of the measured data. If the connector is relatively well matched on a substrate (i.e., a return loss greater than 15 dB), the connector will have less of an effect on the magnitude, except for the insertion loss; the effect is mainly a shift in reference planes. To illustrate this, ***Figure 2*** shows the measured data at two different reference planes for a 3 dB attenuator mounted on 60 mil thick Rogers 4003C. The measurement reference planes of the blue trace are set by the coaxial calibration, while the measurement reference planes of the red trace are set by a thru-reflect-line (TRL) calibration within the fixture. Note that the measurement at the coaxial measurement reference planes has significantly more S_{21} phase; it also shows that the return loss is very different between the two reference planes across the band and the insertion loss differs significantly at high frequencies.

To confirm that the multiple methods for removing connector and test fixture effects yield the same answer, ***Figure 3*** compares different data sets for the same 3 dB attenuator on 60 mil thick Rogers 4003C, using the same reference plane. The red trace shows the measured data obtained from a TRL calibration with tapers de-embedded in post-processing. The blue trace shows de-embedded data from a coax calibration using characterized test fixture data and ADS microstrip line models. The green trace shows data from the coax calibration de-



▲ **Fig. 1** **Measured vs. modeled (solid lines) S-parameters for the feed-thru configuration (a) using several Rogers substrates. $|S_{11}|$ (b), S_{11} (c), $|S_{21}|$ (d) and $\angle S_{21}$ (e).**



▲ **Fig. 2** **Comparing reference plane measurements of a 3 dB attenuator on 60 mil Rogers 4003C (a). $|S_{11}|$ (b), $\angle S_{11}$ (c), $|S_{21}|$ (d) and $\angle S_{21}$ (e).**

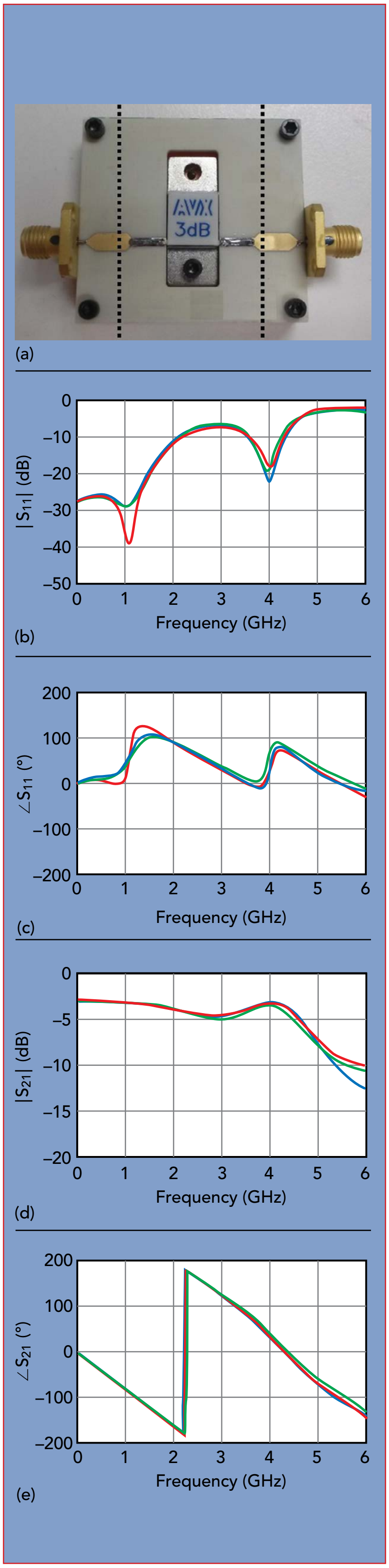


Fig. 3 Comparison of measured and modeled S-parameters of a 3 dB attenuator (a). $|S_{11}|$ (b), $\angle S_{11}$ (c), $|S_{21}|$ (d) and $\angle S_{21}$ (e).

embedded using Modelithcs' connector model with ADS microstrip line models. Excellent consistency is seen between the two connector removal methods though at least 5 GHz, with some difference in $|S_{21}|$ in the region above 5 GHz where the return loss is very poor.

When the physical construction and material properties are known, a full 3D simulation of the component on the test fixture is an alternative simulation option. The main challenge with a 3D simulation is that the geometry is often closely guarded by manufacturers. A recent solution from ANSYS is the ability to encrypt 3D models to protect the manufacturers' IP while allowing 3D component models to be shared and simulated within the 3D environment. Modelithics is now supporting encrypted 3D geometry model development for HFSS, in addition to the measurement-based equivalent circuit format. As an example, an encrypted 3D model for the GigaLane SMA jack connector is part of the Modelithics COMPLETE+3D Library for ANSYS HFSS.

Designers have several techniques to accurately account for connector and test fixture effects. A simulation-based approach often is the fastest path to design success. With accurate models, connectors and test fixtures can be accurately and quickly removed from the measurement, providing nearly equivilent results as using custom calibration standards and characterization software.

VENDORVIEW

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