Thin Film Technology Corp.

30 GHz Attenuator Performance and De-Embedment

November 2014

Theory of De-Embedment.

Due to the need for smaller packages and higher signal integrity a vast majority of todays RF and Microwave components are utilizing surface mount technology (SMT). The quandary lies in how to evaluate these components since no direct connection is available to the component and purchasing all of the different test probes would be expensive. This is where the evaluation board has its benefits.

The evaluation board allows the user to evaluate the component using a vector network analyzer (VNA) and common coaxial cables. This solution also comes with its draw backs. Any loss contributed by the PCB will be embedded into the measurement of the system and the only way to accurately measure the component itself is to de-embed this loss. Hence the development of de-embedment techniques.

The process of de-embedding a Device Under Test (DUT) can be preformed by analyzing the sum of the scattering transfer parameters (T-Parameter) which make up the measurement. By using simulation to model the T-Parameters of the fixture, they may removed from the system or de-embedded if you will, to result in only the T-Parameters attributed to the DUT. While Scattering Parameters (S-Parameters) are measured from the VNA it is mathematically more convenient to use the T-Parameters and the relationship of S to T Parameters is shown in **Figure 0.2**.

Figure 0.3 shows the signal flow from port A through the DUT to port B, also the internal S-Parameter flow that is the contribution from the diagramed part of the system. Since S-Parameters and T-Parameters are directly related. We may generate the equation shown in **Figure 0.1** which the left side shows through the use of the T-Parameters that the multiple of each respective portion is equal to the measured data and on the right, the de-embedment of the portions attributed to the fixture leaves only the DUT or portion of interest.

$$[T_{MEASURED}]=[T_A][T_{DUT}][T_B] \longrightarrow [T_A]^{-1}[T_A][T_{DUT}][T_B][T_B]^{-1} = \mathbf{[T_{DUT}]}$$

Cascaded network of T-Parameter comprising the measurement.

De-embedment of T-Parameters attributed to the fixture leaving only the DUT.

WHERE $[T] = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix}$

AND $[T][T]^{-1} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$

Figure 0.1: T-Parameter Theory

$$\begin{pmatrix} b_1 \\ a_1 \end{pmatrix} = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix} \begin{pmatrix} a_2 \\ b_2 \end{pmatrix}$$

$$\begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix} = \begin{pmatrix} -\dfrac{S_{11}S_{22}-S_{12}S_{21}}{S_{21}} & \dfrac{S_{11}}{S_{21}} \\ -\dfrac{S_{22}}{S_{21}} & \dfrac{1}{S_{21}} \end{pmatrix}$$

Figure 0.2: S to T Parameter Relationship

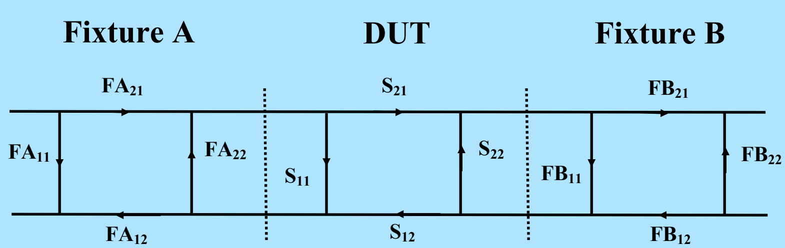

Figure 0.3: Signal Flow Through The System

What we intend to show is that the general method used at Thin Film Technology Corp. to accurately model the scattering parameters of the fixture using simulation software and de-embed this from the results will yield an accurate model of the DUT. We will also show that this result can be confirmed using test probes to directly measure the component without the fixture and thus confirm the method. In this application note we have used Thin Film Technology Corp's ATT0805, 30 GHz Attenuator.

Reference for de-embedment simulation and theory:

Agilent De-Embedding and Embedding S-Parameter Networks Using a Vector Network Analyzer. Agilent, 2014, www.anlage.umd.edu, 11/21/14

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Product Description and Applications:

The Thin Film Technology Corp's ATT0805 Attenuator is designed for use in frequencies from Dc to 30GHz with attenuation values from 0dB to 10dB in 1dB steps. This surface mount, 0805 chip size, provides excellent performance with flat insertion loss, and return loss of less than -15dB or better up to 30GHz. This is an ideal low cost solution for high frequency and high performance applications. With the reliability of Thin Film materials and processes, the ATT0805 is product built for the most sensitive applications.

This application note will detail the procedure Thin Film Technology Corp. has used to de-embed the component from the loss of the evaluation board and thus give a true measurement result of the components performance.

Mounting Conditions:

Evaluation Board: Rogers 4350B PCB evaluated using Southwest Microwave end launch clamps as shown in Figure 1.1. Connector Model 292-07A-5

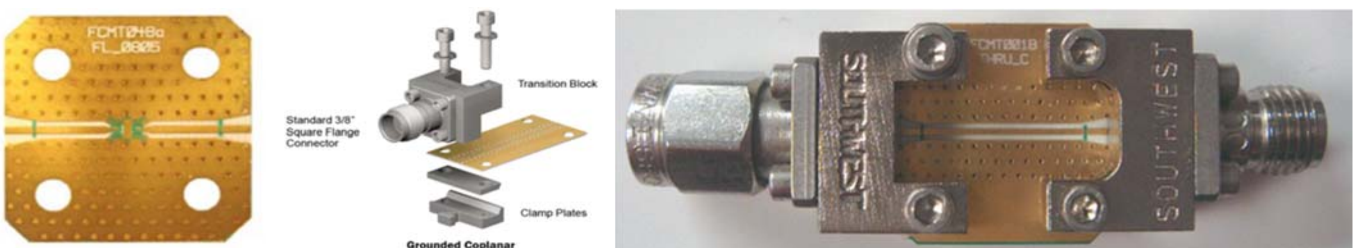

Figure 1.1: ATT0805 Rogers Evaluation PCB and Illustration and Example of Southwest Microwave Super SMA End Launch Clamp Connectors

Solder Paste: Sample parts mounted to Rogers PCB using Indium Corporation solder paste(95.5Sn, 3.8%Ag, 0.7%Cu) PASTEOT-800201P. Using a hand mounting method and TFT Lead-Free reflow profile:
http://www.thin-film.com/uploadedcontent/documents/Soldering_Profile.pdf

Measurement Conditions:

Measurement Equipment: HP8722D 40GHz Vector Network Analyzer (VNA) Calibrated. See Figure 1.2.

Figure 1.2: HP Model 8722D 40GHz Vector Network Analyzer.

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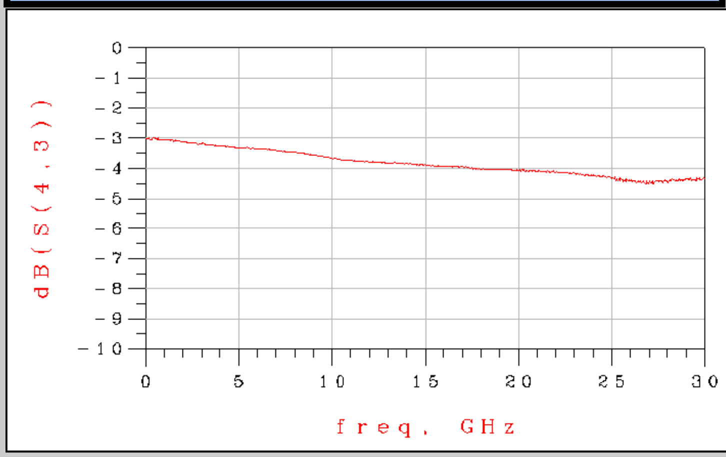
Measured Data:

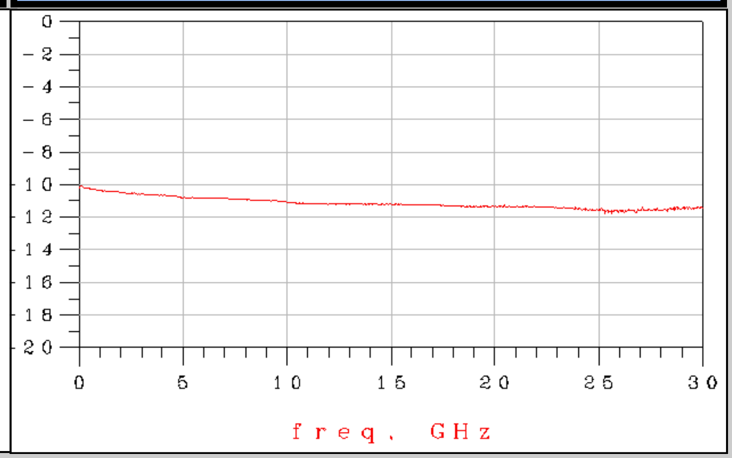
Measurements were taken of a PCB mounted ATT0805 with specified attenuation values of -3dB and -10dB using the method described here. A thru traced PCB from the same panel as the evaluation board was also measured as a trace loss indictor. The measurement of the thru coupon is imperative to modeling any loss in the evaluation board trace as theory suggests.
See product data sheet: http://www.thin-film.com/uploadedcontent/documents/AT02M750-04.pdf

Evaluation Board Measured Data

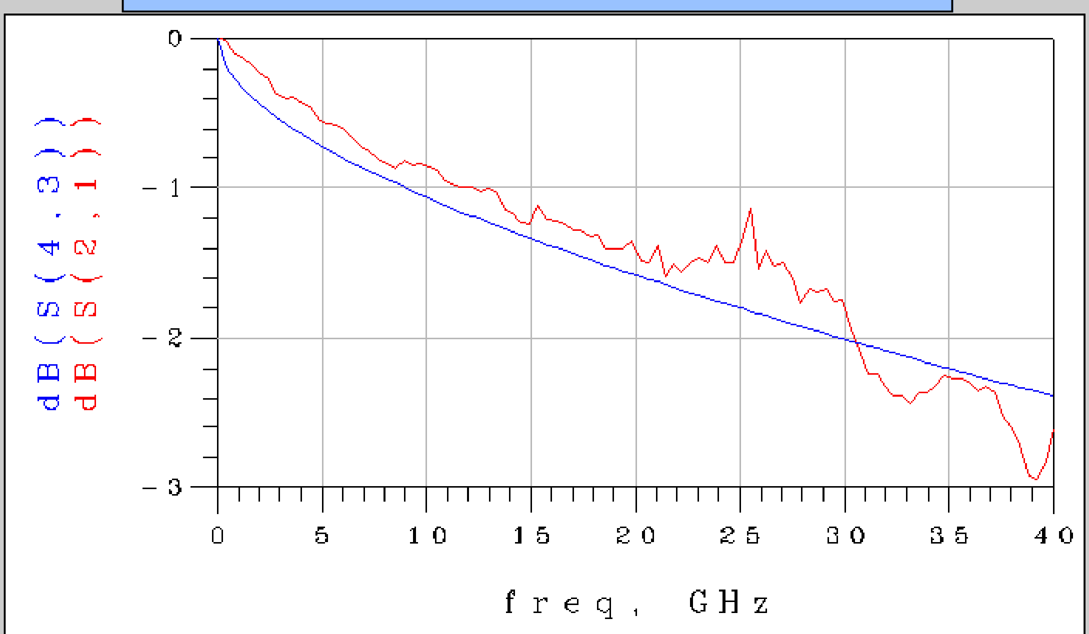
ATT0805-03R0-M Measured data from the evaluation board –3dB specified value.



ATT0805-10R0-M Measured data from the evaluation board –10dB specified value.



Thru Trace Board Measured Data vs Model



—— Simulated 14.7mm Thru Trace PCB Loss

—— Measured Data of The Thru Trace PCB Loss

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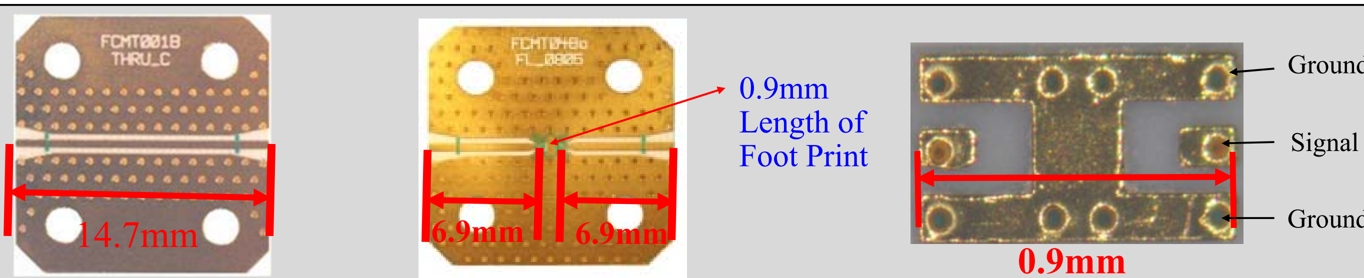
Coupon Analysis:

Since the thru traced board is not exactly the same as the evaluation board, the difference must be accounted for to accurately model the loss from the PCB and connectors. Since the model of the thru traced board is an close representation of the measured data, taking into account the difference in trace length between the thru coupon and the evaluation board will yield a usable model of the system loss without the loss thru the component. See **Figure 3.1** below.



Length of Signal Trace of Thru Coupon

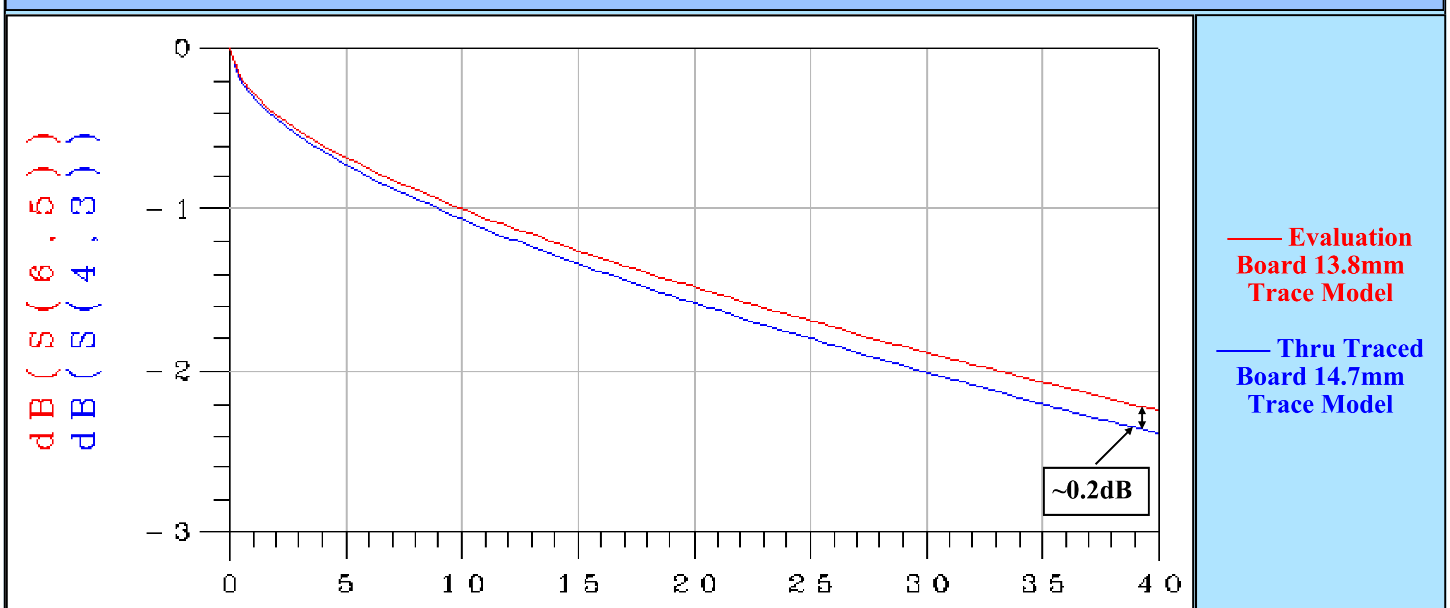
Length of Signal Trace of Evaluation Coupon

Figure 3.1:Thru vs Evaluation Board Signal Trace Length

Evaluation PCB Trace Loss Analysis Conclusion:

As can be seen after subtracting the distance from signal in to signal out of the component from the length of the thru board signal trace we are left with the length of lossy trace in the evaluation PCB. The model of the trace loss may now be re-evaluated using this length. In the case of the ATT0805 evaluation rogers PCB this length is equal to 14.7mm - 0.9mm = 13.8mm. **Figure 3.2** shows the model of the evaluation board trace loss relative to the thru traced board loss, showing a difference around 0.2dB. This is significant consider the component has attenuation tolerances of ± 0.75dB. Now with a close approximation of the evaluation PCB loss model, the loss of the PCB may be de-embedded from the system performance yielding the a true representation of the component performance.

Figure 3.2: Thru Traced Board Model Vs Evaluation Board Model:



As can be seen above, the loss of the coupon has a significant effect on the measurement of the system contributing 2dB of loss thus showing the importance of de-embedment.

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Simulation of The Component:

Now that a model of the evaluation board has been established, the system may be simulated. Thin Film Technology Corp utilizes Agilent's ADS simulation software for component design and improvement. ADS is also an excellent software for modeling electrical systems. Figure 4.1 details a de-embedment technique schematic used to simulate the component by subtracting the trace loss model from the evaluation board measured data as well as taking into account the 50 ohm system impedance. Yielding the results in Figure 4.2

Figure 4.1: Schematic Simulator Technique

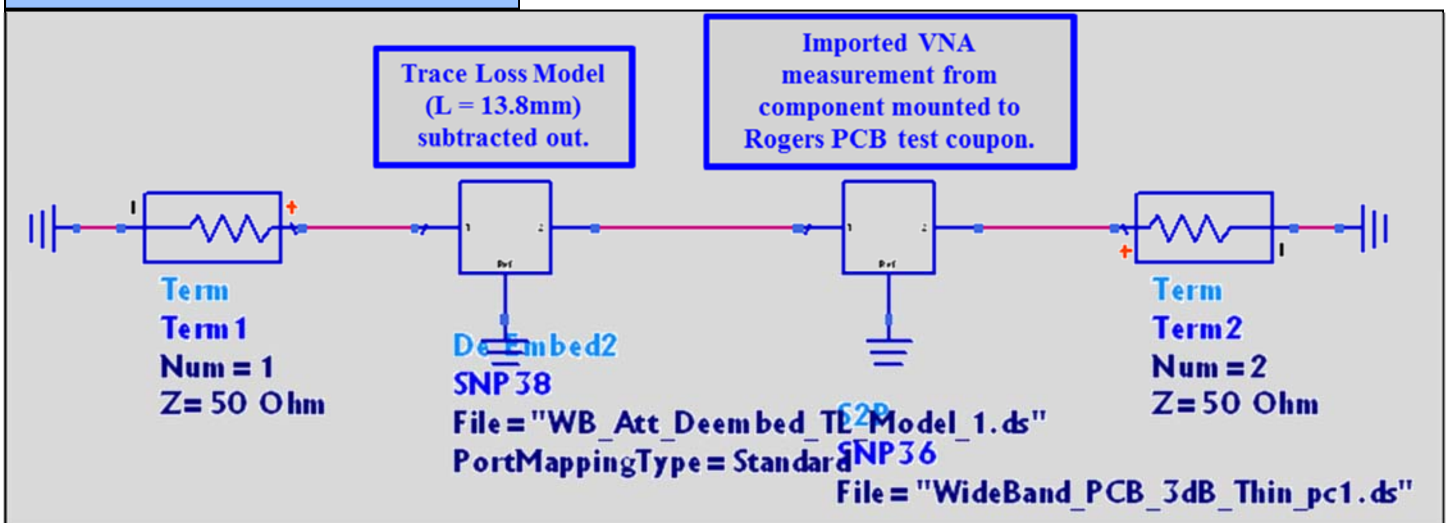
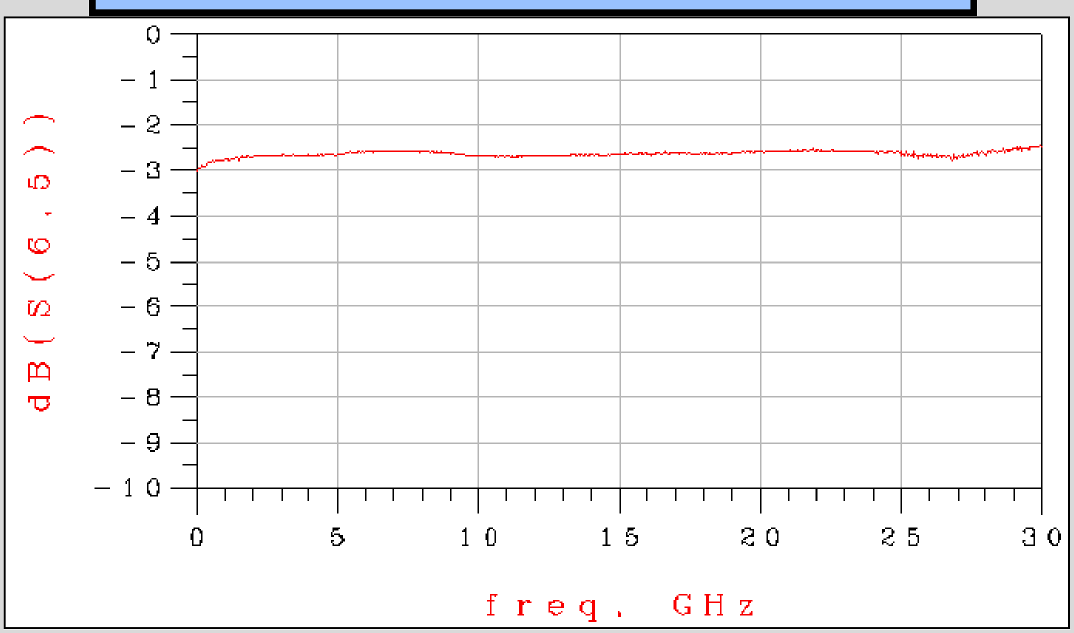


Figure 4.2: De-Embedment Results

ATT0805-03R0-M De-Embedded results from the simulator technique shown in Figure 4.1 –3dB specified value.



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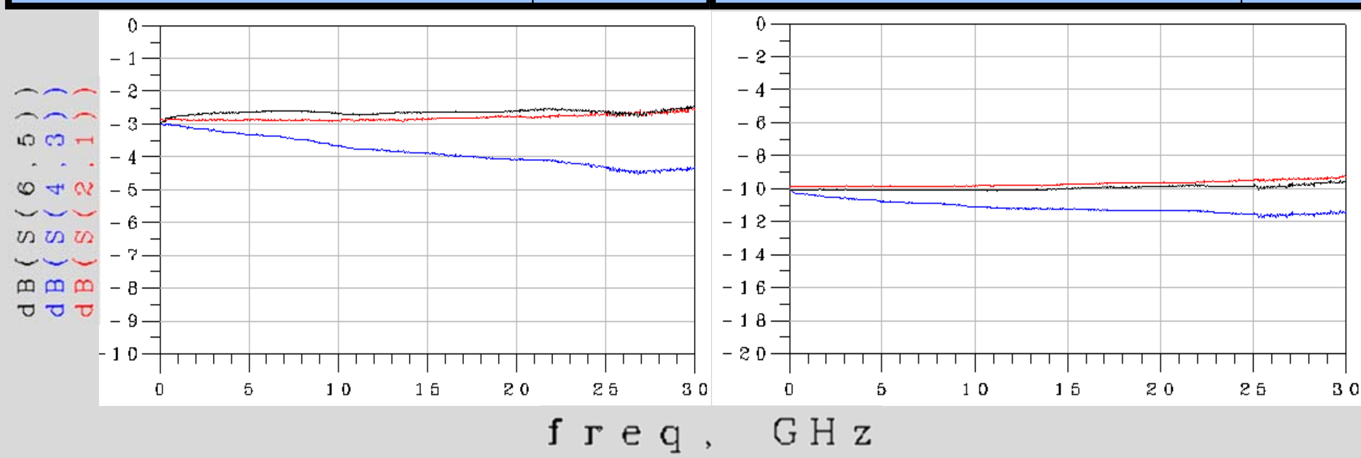
De-Embedment Result Verification:

For the average end user an evaluation board is critical for evaluating the performance of high speed components. The evaluation board also allows for examination without the need for expensive evaluation probes but this also makes de-embedding critical for a proper evaluation. Nevertheless probes allow for measurement of a component accurately without the need for the product to be mounted on a PCB as the probe directly contacts the components terminations and is almost the same results as a de-embedded evaluation board measurement. Hence properly calibrated probe measurements can be utilized to verify the results of de-embedment.

Figure 5.1 shows the evaluation board measurement, the results of the de-embedment procedure detailed here and the Ground-Signal-Ground (GSG) probe measurement of the component.

ATT0805-03R0-M De-Embedment Verification Data–3dB specified value. | ATT0805-10R0-M De-Embedment Verification Data–10dB specified value.



—— Evaluation Board Measured Data —— De-Embedded Evaluation Data Results —— Probe Measured Data

Figure 5.1: De-Embedment Results vs Probe Measured Data

Conclusions:

By evaluating the loss per unit length in our thru PCB trace and correlating this to the length of the evaluation board a closely related model of the loss contribution by the board trace can be produced. Subtracting this loss from systems measurement in theory should yield a true measurement of the component to be evaluated. As shown in Figure 5.1 above, the yielded result has little relative difference from the probe measurement. Thus proving this method to be sufficient to evaluate the mounted part.

In the case of TFT's ATT0805 30GHz Attenuator, the yielded model shows extremely favorable performance and flat insertion loss well out to the specified frequency. With flat insertion loss and return loss less than –15dB at 30GHz, the ATT0805 is an ideal part for frequencies ranging from DC-30GHz. Please contact the factory today for an evaluation board and view the data sheet on the web at: http://www.thin-film.com/uploadedcontent/documents/AT02M750-04.pdf.

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