User's Guide Rev 1.0

Plug and Play Kit for De-Embedding Software Algorithms Verification

Evaluate the Accuracy of De-Embedding Algorithms

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Table of Contents

Introduction

The purpose of the Signal Microwave Plug and Play Kit is to evaluate the accuracy of de-embedding algorithms following the procedures described in the associated documents described in References [1] and [2] on page 11. Figure 1 below shows the kit with optional attached edge mounted connectors, adapters and flush short.

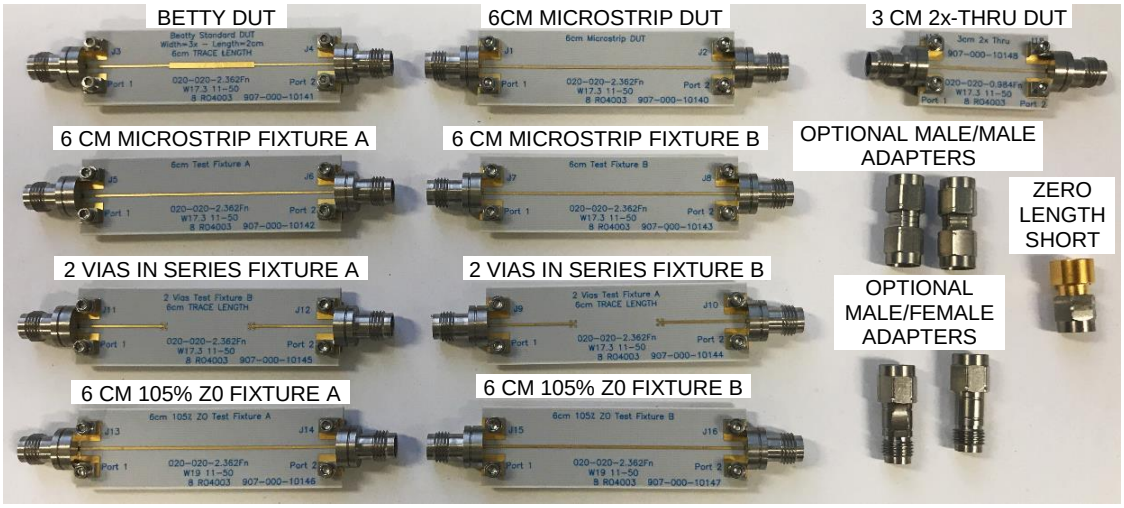


Figure 1. Kit with optional 1.85 mm edge connectors, adapters and flush short.

The kit is implemented on a Rogers 4003 dielectric with a NiAu plating (minimum of 75 µm Au thickness). The design trace width is 17.3 mil. The stack up is shown below.

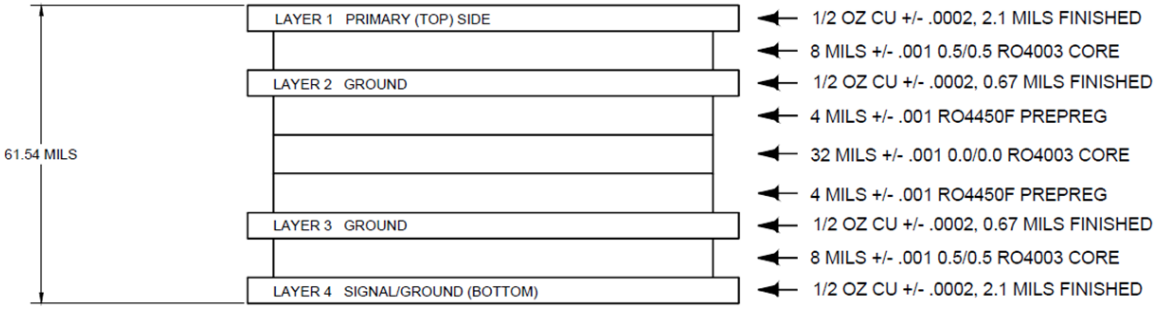


Figure 2: Test Coupons PCB stack up.

Kit Contents

The Plug and Play Kit is composed of 9 PCB test coupons.

Devices Under Test

1. 6 cm microstrip DUT
2. 6 cm Beatty standard DUT

Text Fixtures (side A and side B)

- 6 cm microstrip
- 6 cm microstrip with 2 vias in series
- 6 cm microstrip with 105% impedance

Connector De-Embedding 2x-Thru

- 3 cm microstrip

DXF files for each of the test coupons, for importing into simulation tools, are available on the Signal Microwave website at http://www.signalmicrowave.com.

The via design used on the two vias in series test coupon is shown below. Note that the intention was not to design the best possible via for the used stack up. The via is purposefully *not* optimal in order to stress the capabilities of the de-embedding algorithms.

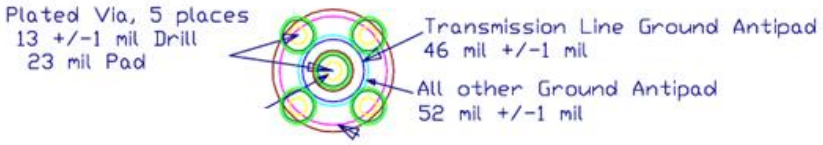


Figure 3: Via Design

Optional connectors and adapters

The connectors/adapters contents are optional and can be the following:

3. 18x edge coaxial connectors (2.92 mm, 2.40 mm or 1.85 mm)
4. 2x M/F Adapters and 2xM/M adapters all phase matched(2.92 mm, 2.40 mm or 1.85 mm)
5. 1x male flush short (2.92 mm, 2.40 mm or 1.85 mm)

The adapters need to be calibration grade and identical to those discussed in the associated documents described in Reference [2] on page 11

The following table lists part numbers of adapters from selected vendors.

Part #	**Description**	**# Required**	**Vendor**
8714C2	2.92 mm Adapter Male/Female	2	Maury Microwave
8714B2	2.92 mm Adapter Male/Male	2	Maury Microwave
7921C	2.4 mm Adapter Male/Female	2	Maury Microwave
7921B	2.4 mm Adapter Male/Male	2	Maury Microwave
7821C	1.85 mm Adapter Male/Female	2	Anritsu
7821A	1.85 mm Adapter Male/Male	2	Anritsu

The figure below shows the impedance profiles for the different test coupons in the kit (excluding the 3 cm microstrip 2x-thru coupon).

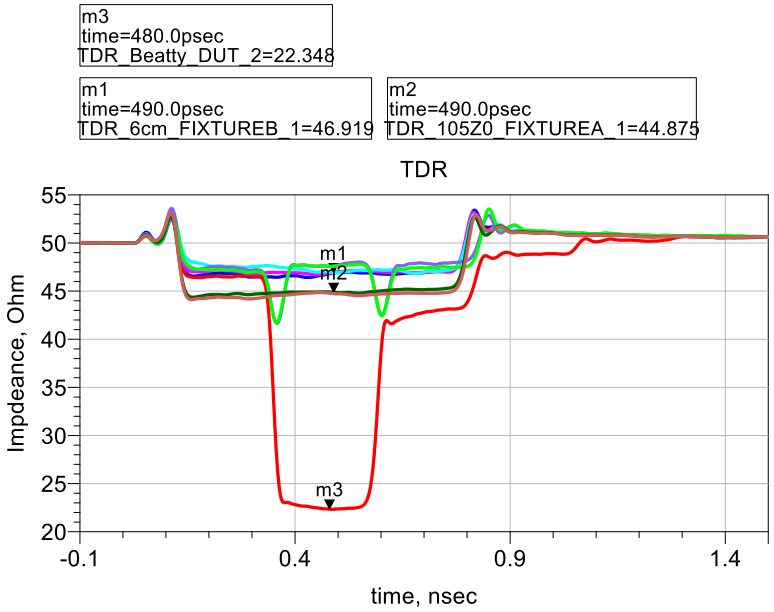


Figure 4. Impedance profiles for test coupons

Example Set of Measurements

The kit allows for a large number of experiments to be performed. The following set of measurements were used by the IEEE P370 standard technical committee as a vehicle to evaluate different de-embedding algorithms and provides an example on how the kit can be used.

M/F or F/M denotes a male to female adapter and M/M denotes a male to male adapter.

Each of the S-parameters files from the measurements below are usually named as M1 to M19 (Example sets are available on the Signal Microwave website at http://www.signalmicrowave.com.

DUT Measurements

1. F/M + 6 cm Microstrip DUT+ M/F
2. F/M + Beatty Standard DUT + M/F

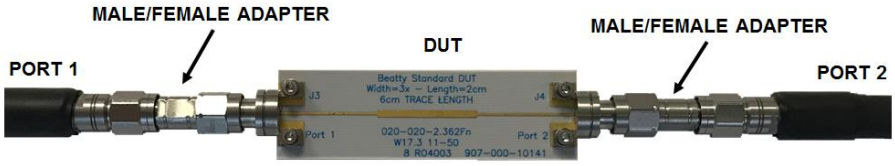


Figure 4: Setup example picture for measuring the DUT.

Test Fixture Measurement

3. 6 cm Test Fixture A + M/F
4. F/M + 6 cm Test Fixture B
5. 2 vias Test Fixture A + M/F
6. F/M + 2 vias Test Fixture B
7. 6 cm 105Zo% Test Fixture A + M/F
8. F/M + 6 cm 105Zo% Test Fixture B

2xThru Measurements

9. 6 cm Test Fixture A + M/F + M/M + 6 cm Test Fixture B (50 Ohm)
10. 2 vias Test Fixture A + M/F + M/M + 2 vias Test Fixture B (2 vias in series)
11. 6 cm 105Zo% Test Fixture A + M/F + M/M + 6 cm 105Zo% Test Fixture B (105%Zo 2xthru)

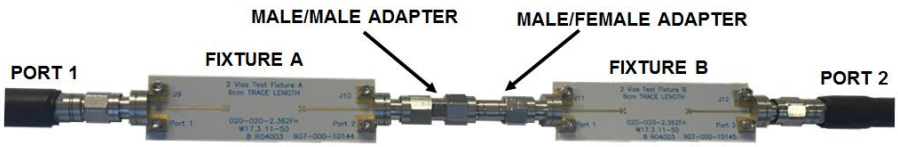


Figure 5: Setup example picture for measuring the 2x-thru of the test fixture.

Open/Short Measurements

Open/short measurement are only done for the 50 Ohm test fixture for comparison between and open/short with a 2xthru de-embedding. Only S11 is measured with nothing connected on the other port for an open measurement and the zero-length short for the short measurement.

12. 6 cm Test Fixture A + M/F + (open, nothing connected)
13. 6 cm Test Fixture A + M/F + (zero-length short)
14. 6 cm Test Fixture B + M/F + (open, nothing connected)
15. 6 cm Test Fixture B + M/F + (zero-length short)

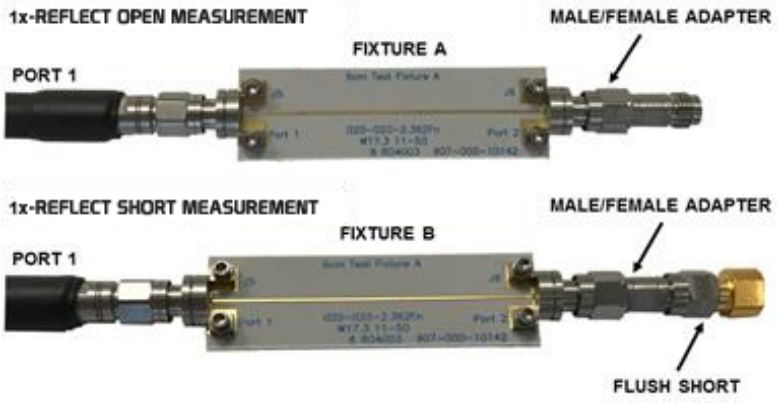


Figure 6: Setup example picture for measuring open and short for the 1x-reflect methodology.

DUT + Test Fixture Measurements

16. 6 cm Test Fixture A + M/M+ F/M + 6 cm Microstrip DUT + M/F + M/M + 6 cm Test Fixture B
17. 2 vias Test Fixture A + M/M + F/M + 6 cm Microstrip DUT + M/F + M/M + 2 vias Test Fixture B
18. 6 cm Test Fixture A + M/M + F/M + Beatty Standard DUT + M/F + M/M + 6 cm Test Fixture B
19. 2 vias Test Fixture A + M/M + F/M + Beatty Standard DUT + M/F + M/M + 2 vias Test Fixture B

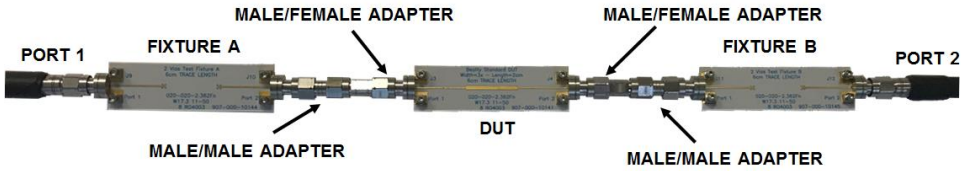


Figure 7: Setup example picture for measuring the DUT plus the test fixture.

The figure below is an example of the measured data with the Kit for the measurements M1, M9 and M16.

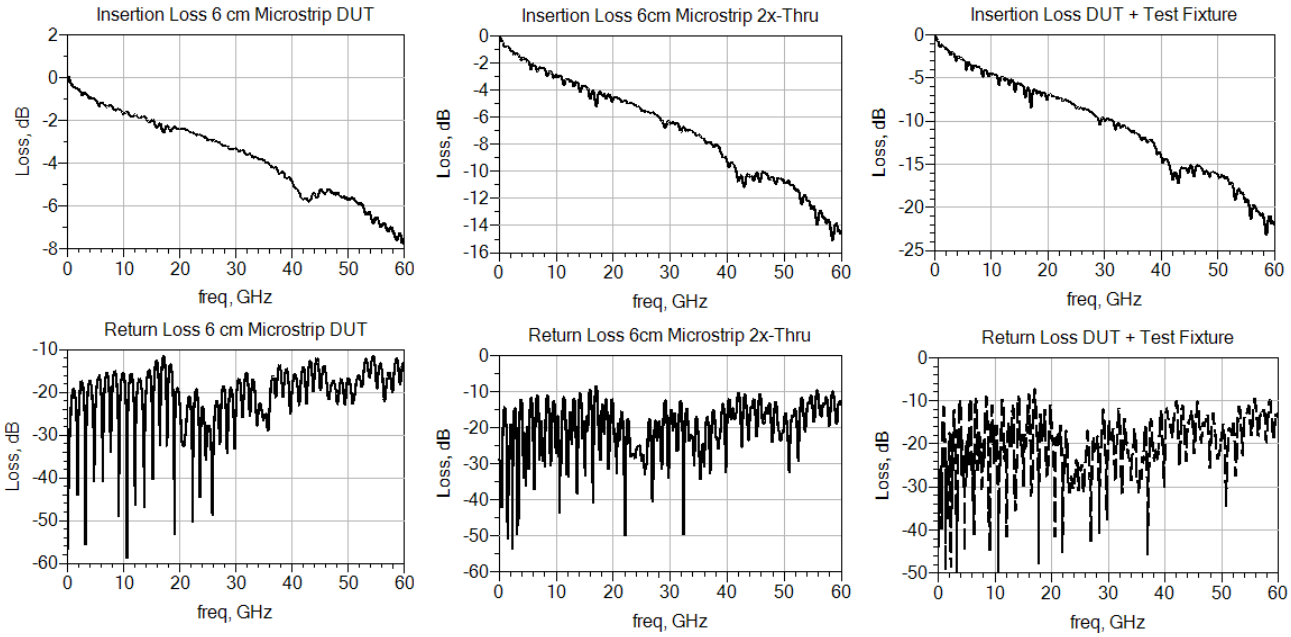


Figure 8: Example of measured data

De-Embedding Computations

The following set of de-embedding computations was used by the IEEE P370 standard technical committee as a vehicle to evaluate different de-embedding algorithms using the data provided in the previous section.

1. 6 cm microstrip using 50 Ohm test fixture and 50 Ohm 2xthru (M16 using M9 as 2x-thru)
2. Beatty Standard using 50 Ohm test fixture and 50 Ohm 2xthru (M18 using M9 as 2x-Thru)
3. 6 cm microstrip using 2 vias in series test fixture and 2 vias in series 2xthru (M17 using M10 as 2x-Thru)
4. Beatty Standard using 2 vias in series test fixture and 2 vias in series 2xthru (M19 using M10 as 2x-Thru)
5. 6 cm microstrip using 50 Ohm test fixture and 45 Ohm 2xthru (M16 using M11 as 2x-Thru)

6. Beatty Standard using 50 Ohm test fixture and 45 Ohm 2xthru (M18 using M11 as 2x-Thru)
7. 6 cm microstrip using 50 Ohm test fixture and open/short 50 Ohm test fixture measurement (M16 using M12/M14 as Open and M13/M15 as Short)
8. Beatty Standard using 50 Ohm test fixture and open/short 50 Ohm test fixture measurement (M18 using M12/M14 as Open and M13/M15 as Short)

Computations 7 and 8 are only possible if the de-embedding algorithm used supports them.

The reference de-embedding algorithm from the IEEE P370 standard is freely available at:

https://gitlab.com/IEEE-SA/ElecChar/P370

Each of the S-parameters files from the de-embedding algorithms above are usually named as E1 to E8 Example sets are available on the Signal Microwave website at http://www.signalmicrowave.com.

Note that the kit can also be used to evaluate the de-embedding algorithm accuracy for un-symmetrical test fixtures as indicated in the associated document described in Reference [3] on page 11.

The figure below shows one example of a de-embedding algorithm results and error evaluation (For details see Reference [2]).

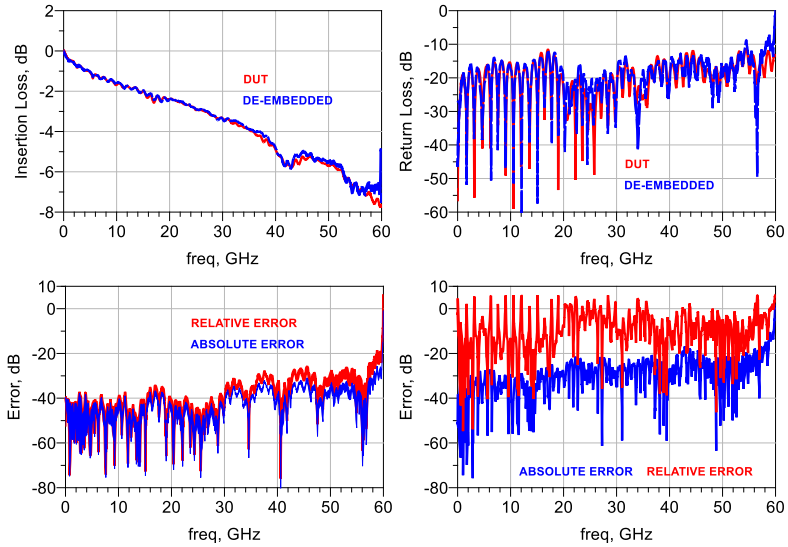


Figure 9: De-embedding results for the 6 cm microstrip DUT with the 6 cm microstrip test fixture using 2x-thru based de-embedding.

Using the kit for PCB Model Tuning Techniques Evaluation

The kit can also be used for the evaluation of using the Beatty standard for PCB model tuning as indicated in the associated document described in Reference [4] on page 11.

In this case the 3 cm 2x-thru coupon is used to de-embed the connectors from the Beatty standard DUT and 6 cm microstrip DUT test coupons so that the reference point is located on the microstrip trace 1.5 cm from the connector as shown in the figure below.

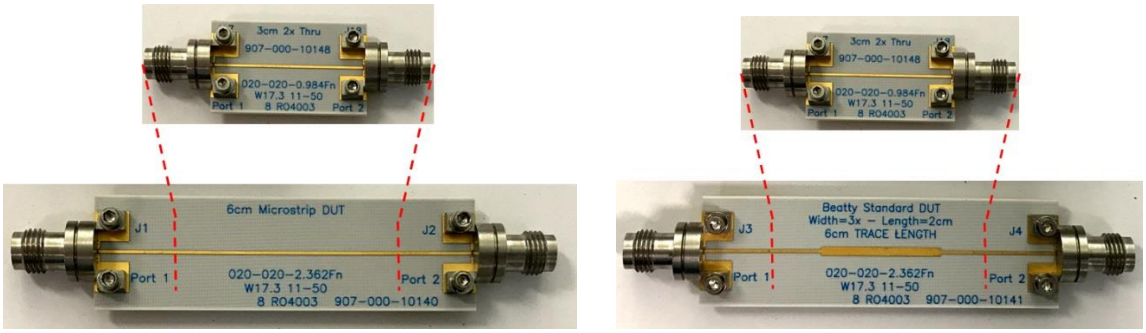
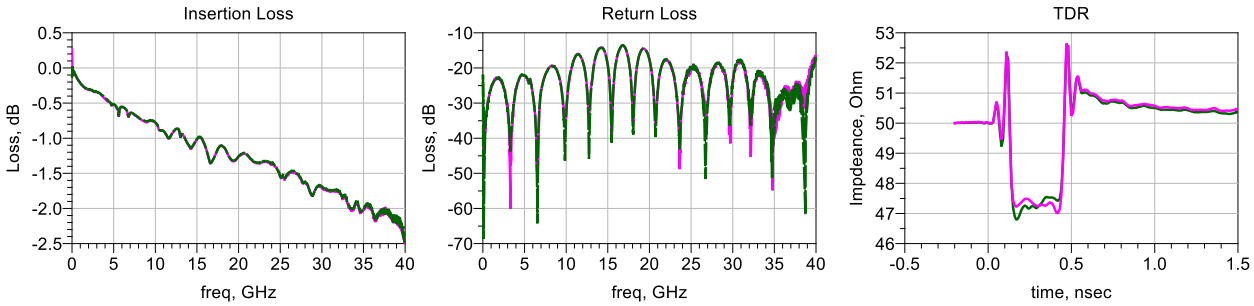


Figure 10:.De-embedding the connectors from the 6 cm microstrip DUT and the Beatty standard DUT.

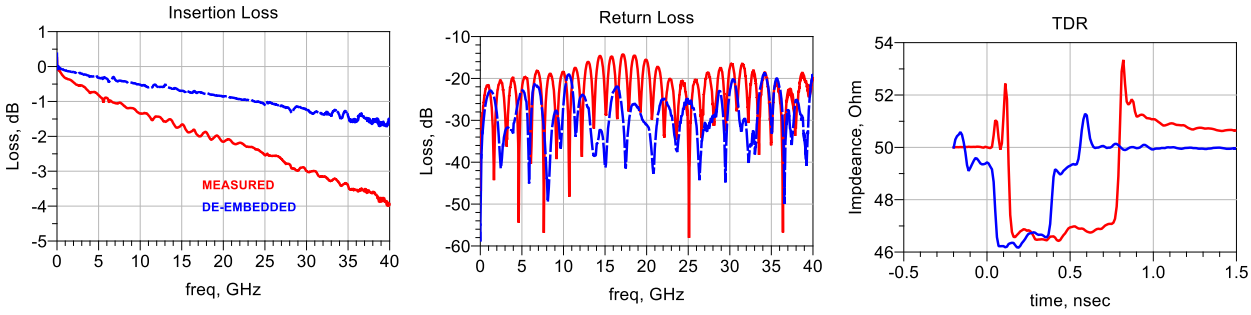
This means that after de-embedding we will have a 3 cm microstrip or a Beatty standard with a 0.5 cm 1x trace width on each side and in the middle a 2 cm 3x trace width microstrip. Note that the transition to the 3x trace width is made as sharp as possible as required to create a good series resonant standard as shown below:

Figure 11: Beatty standard transition

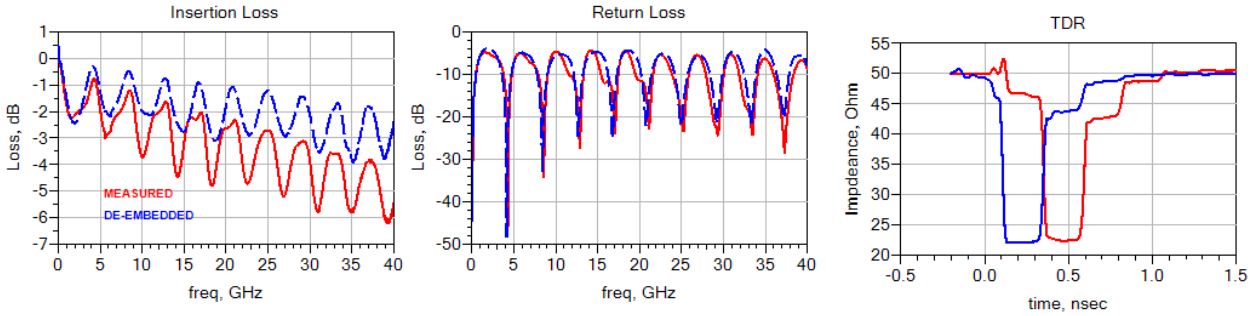
The figure below shows the measured 3cm microstrip 2x-Thru using a 2.92 mm edge connector.



The figure below the results of the measured and de-embedded results for the 6 cm microstrip with 2.92 mm connectors.



The figure below shows the results of the measured and de-embedded results for the Beatty standard using the kit with 2.92 mm connectors. One can see that after the de-embedding of the connectors the resulting insertion and return loss look much closer to what is expected from a perfect series resonator.



The de-embedded S-parameters from both of these structures allow for investigation and comparison of model tuning approaches using either a simple microstrip line or a series resonant standard as indicated in the associated document described in Reference [4] below. An example of using the technique presented in Reference [4] using this kit in ADS is on the Signal Microwave website at http://www.signalmicrowave.com.

References

[1] Heidi Barnes, Eric Bogatin and Jose Moreira "Development of a PCB Kit for S-Parameters De-Embedding Algorithms Verification," IEEE International Conference on Signal and Power Integrity, 2017.

[2] Heidi Barnes et al., "A NIST Traceable PCB Kit for Evaluating the Accuracy of De-Embedding Algorithms and Corresponding Metrics", DesignCon 2018

[3] Heidi Barnes and Jose Moreira, "Verifying the Accuracy of 2x-Thru De-Embedding for Unsymmetrical Test Fixtures", IEEE Conference on Electrical Performance of Electronic Packaging and Systems 2017.

[4] Heidi Barnes, Jose Moreira and Manuel Walz, "Non-Destructive Analysis and EM Model Tuning of PCB Signal Traces using the Beatty Standard," DesignCon, 2017.