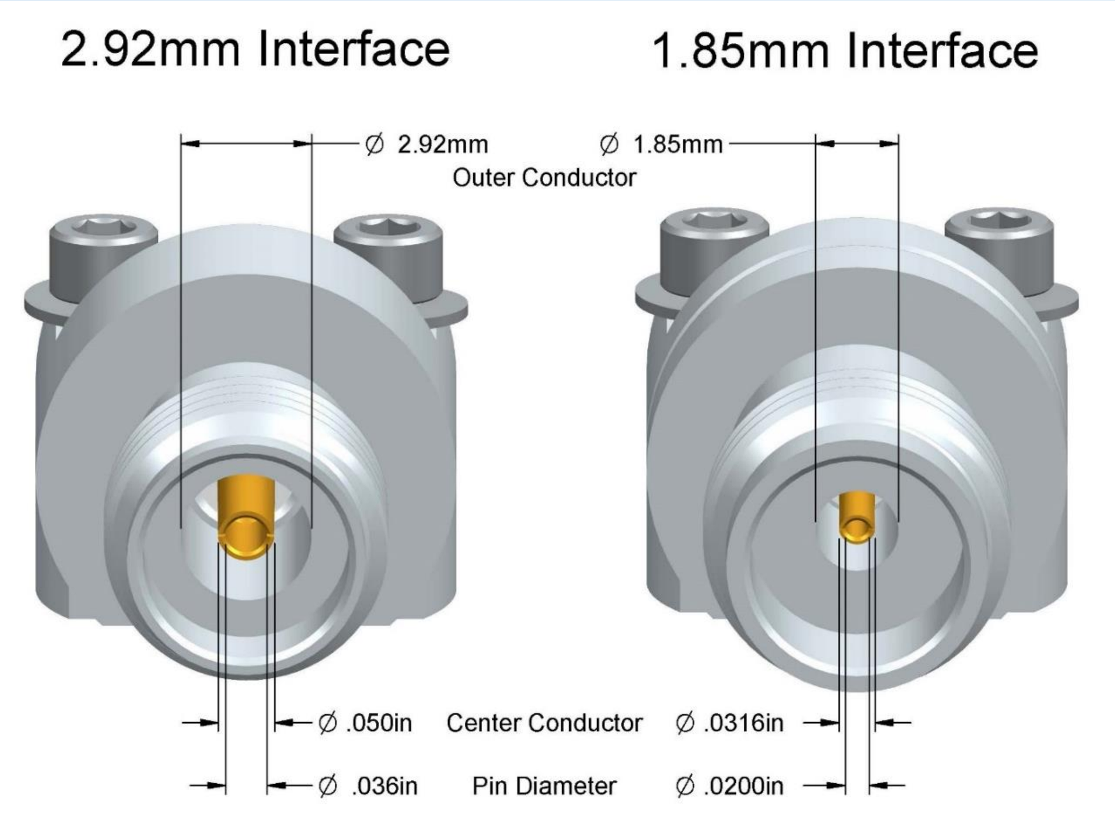
Microwave Connectors Basics

- Topics of Presentation
    - Microwave Test Connector Definitions and Details
    - Signal Microwave Testing Methodology and Data Analysis
    - Board Mount Connectors
    - Field Replaceable Connectors
    - 1.85mm Push-On Adapters
    - Measurement Verification Boards

Explanation of Connector Nomenclature

- 2.92mm interface and 1.85 mm interface refers to the inner diameter of the outer conductor of the interface
- There are 2 families of connectors that these fall into and are commonly used for test.
  - SMA, 3.5mm, 2.92mm
  - 2.4 mm, 1.85mm



2.92mm Interface 1.85mm Interface

Photo of Signal Microwave connectors

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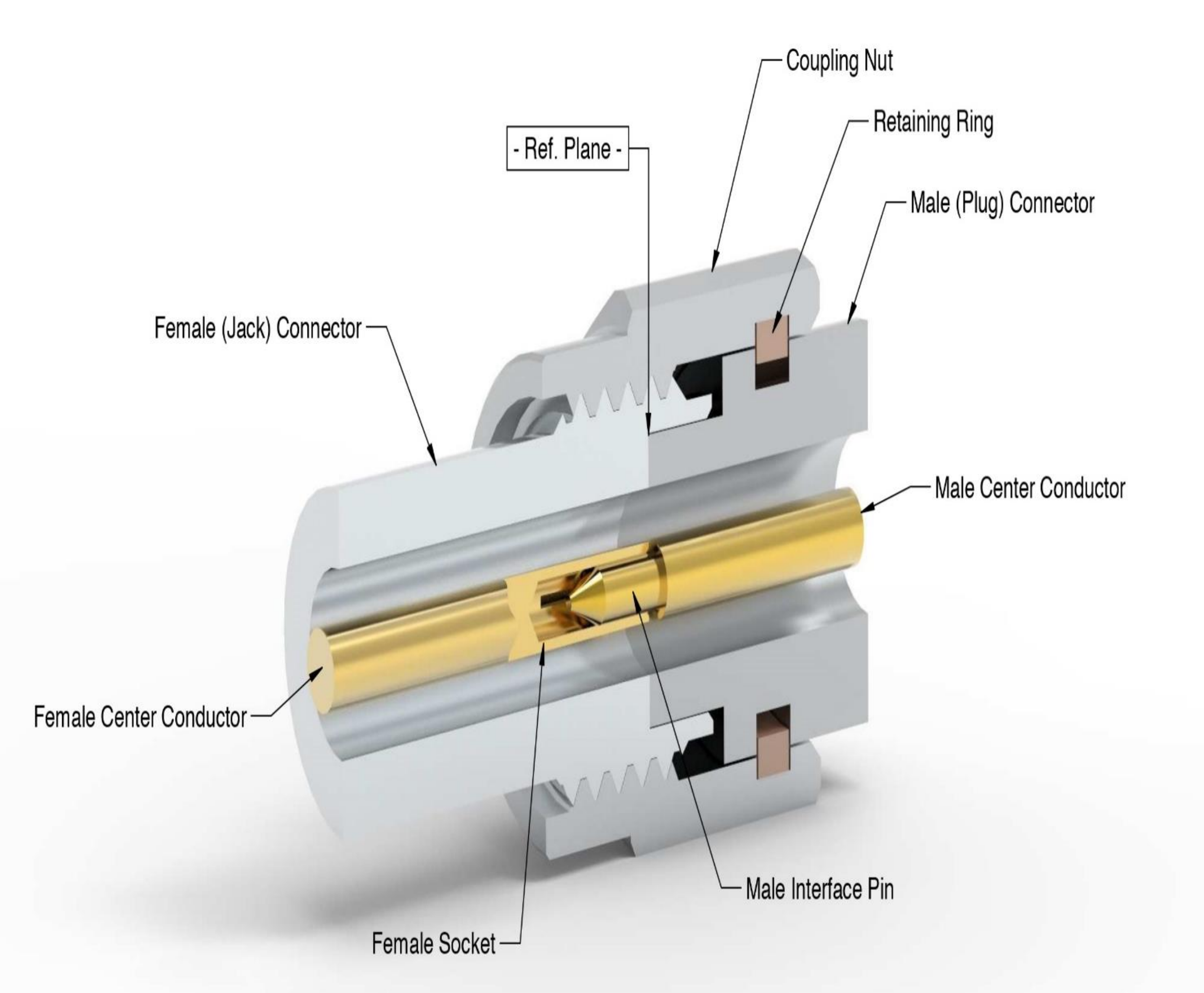
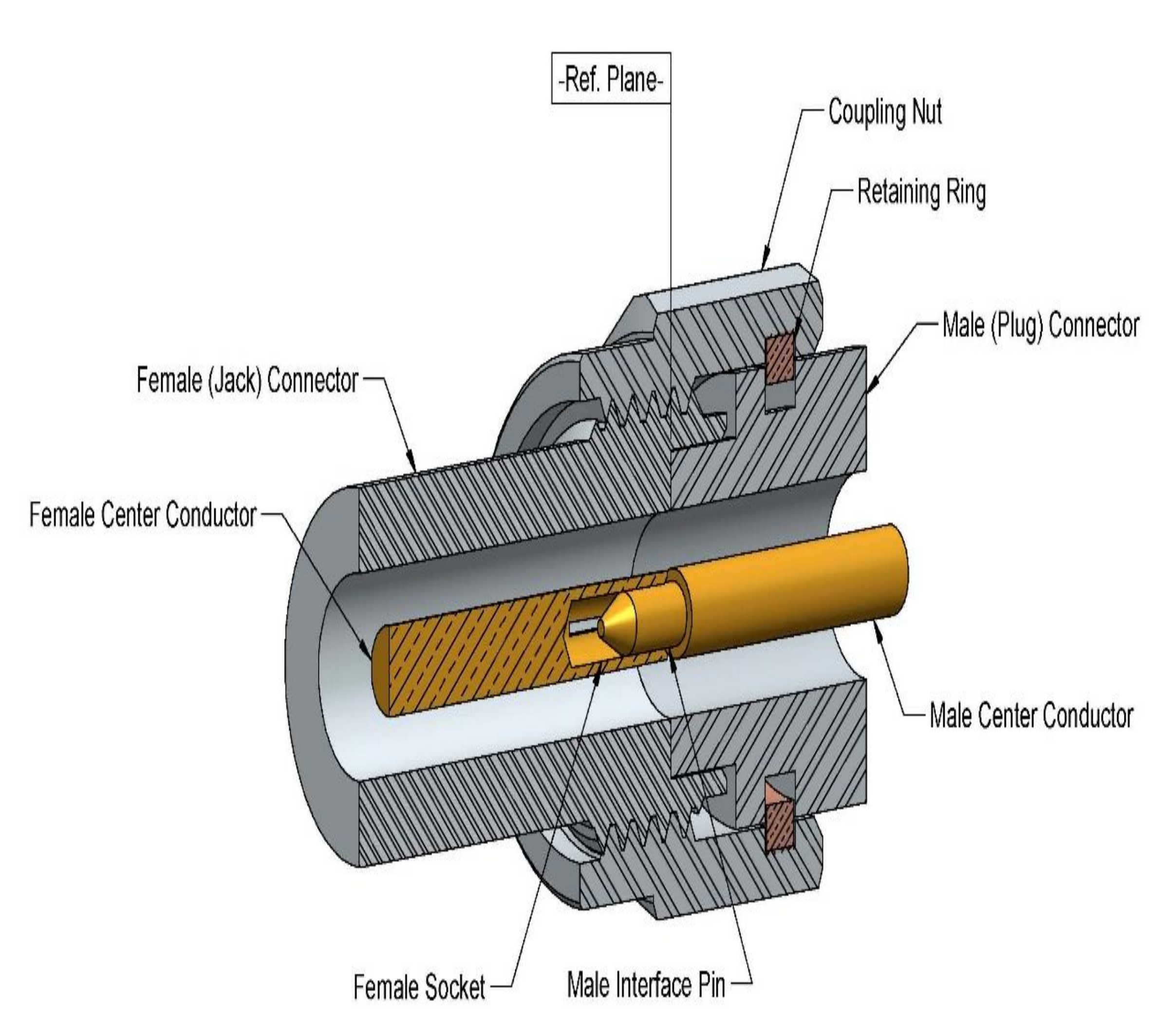
Cutaway Side View of a Mated Connector Pair

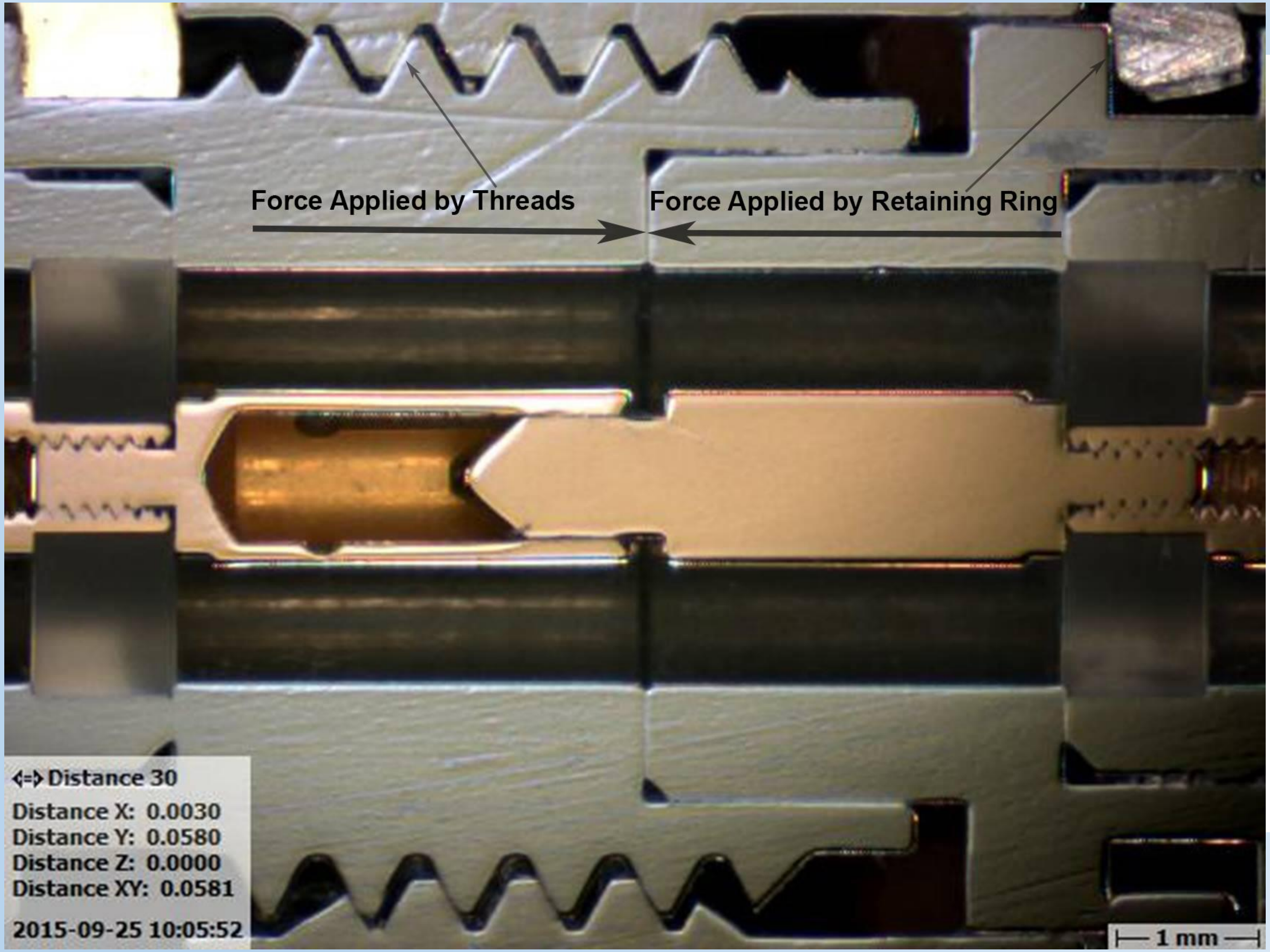


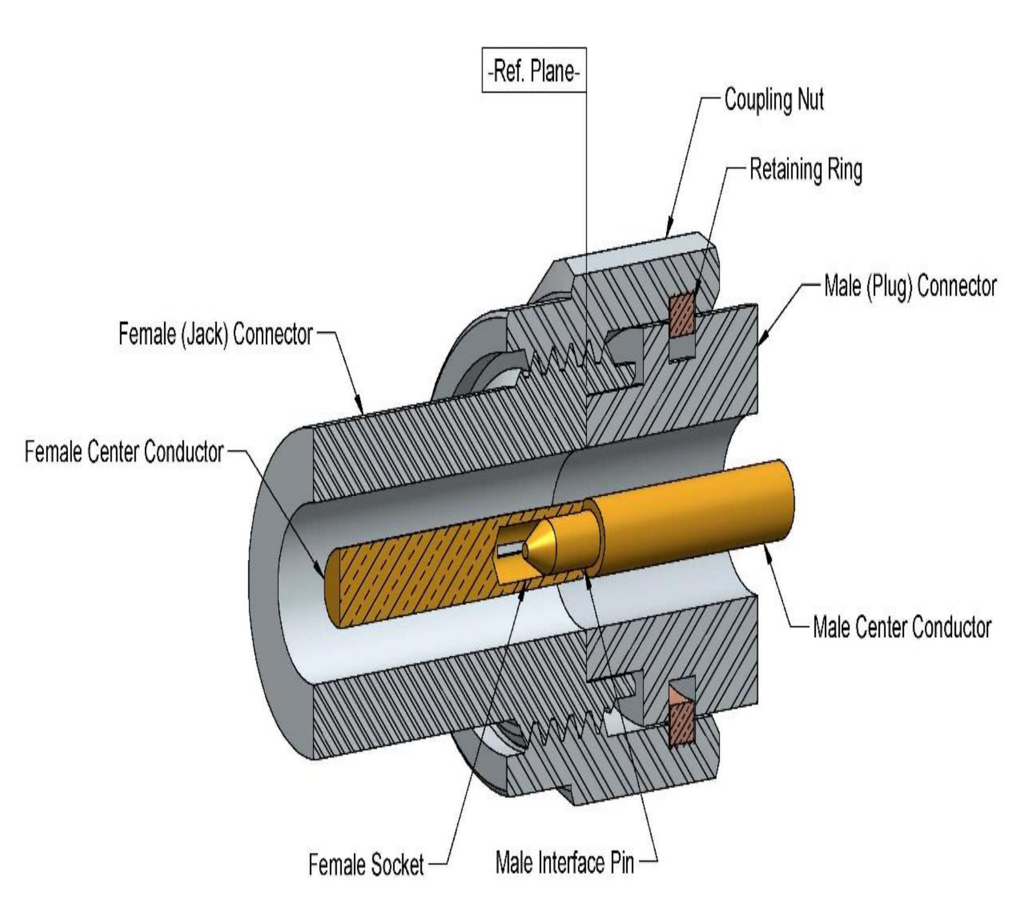
Shaded View



Cross-Hatched View

Sectioned connector pair under compression





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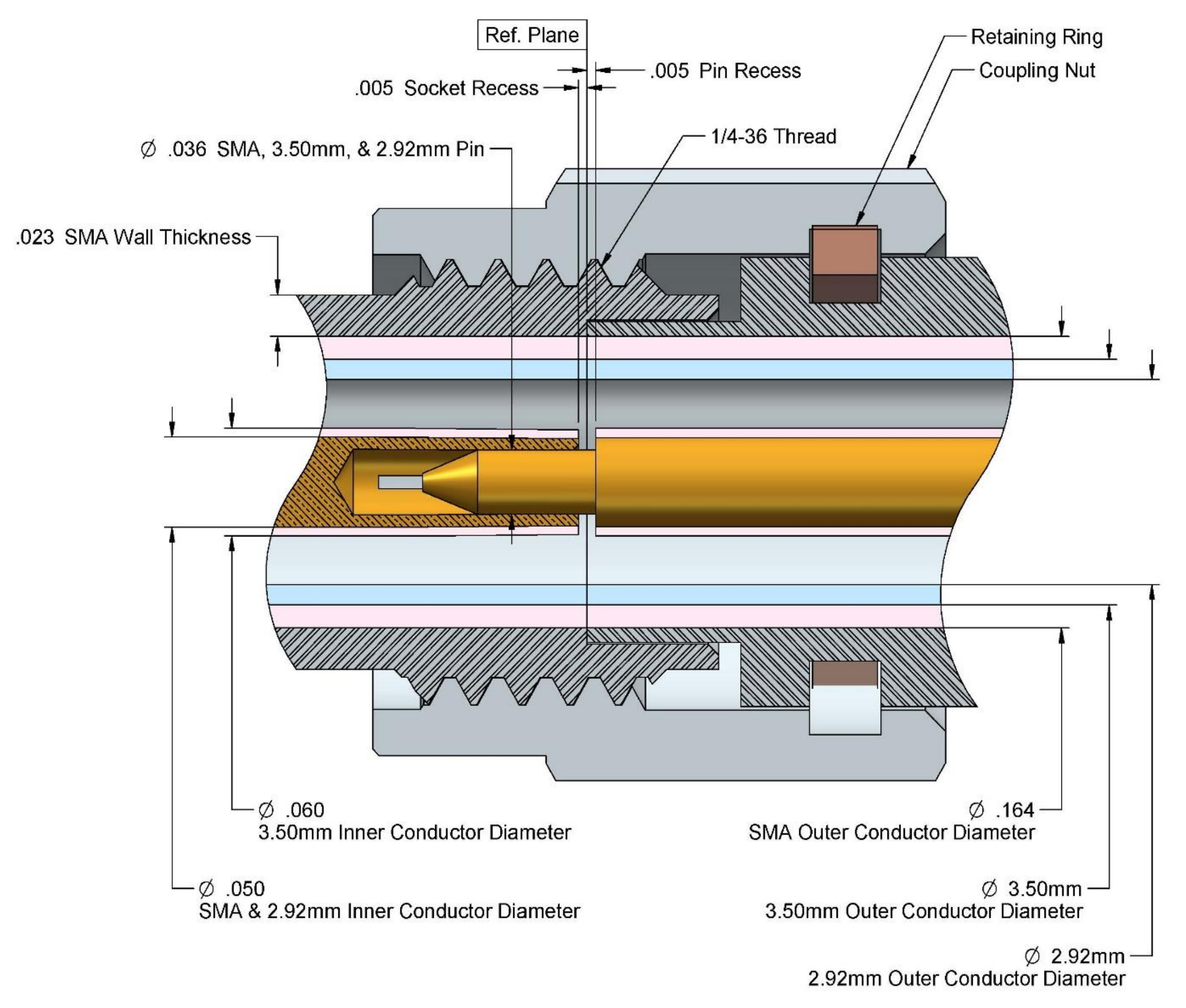
SMA/3.5mm/2.92mm

- SMA interface connectors (27 GHz bandwidth)
  - These were first made commercially available by Omni-Spectra as the OSM
  - Early versions were typically rated to 18 GHz or lower (shown in illustration)
  - Southwest Microwave created a 27 GHz “Super SMA” that is now the standard
- 3.5mm interface connectors (33 GHz bandwidth)
  - Developed by Amphenol and HP (now Keysight) as precision connectors to test SMA
- 2.92mm interface connectors (40 GHz bandwidth)
  - Developed by Wiltron (now Anritsu) as a higher frequency test connector to test SMA connectors
- All of these connectors are compatible with each other



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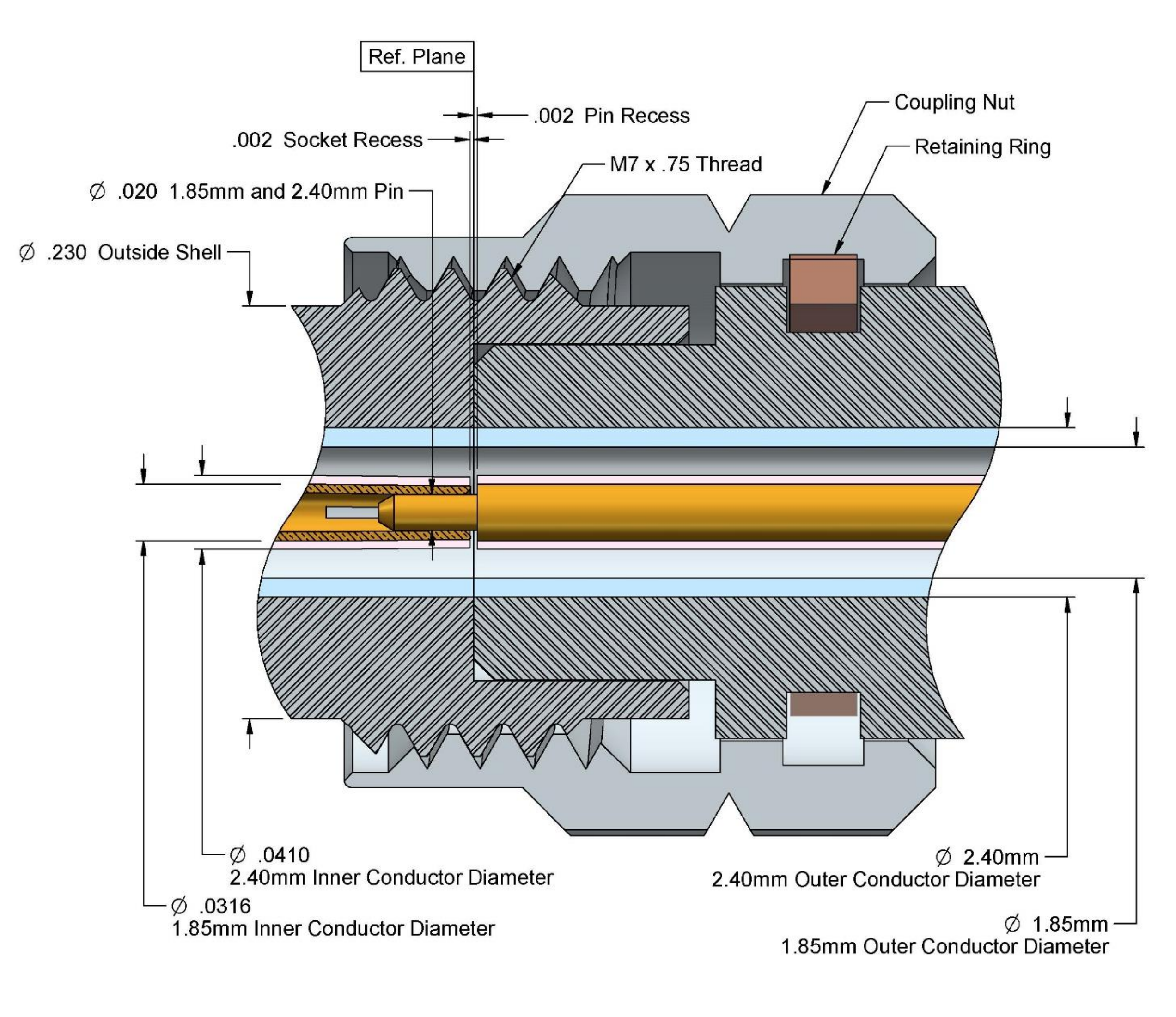
2.4mm/1.85mm

- 2.4mm interface connectors (50 GHz bandwidth)
  - Developed by Amphenol and HP (now Keysight) as precision connectors to test to higher frequencies than the SMA class of connectors can test to
- 1.85mm interface connectors (67 GHz bandwidth)
  - Commercial version developed by Wiltron, Now Anritsu
- These connectors are compatible with each other



MIL-STD-348B, released in 2014

- http://www.landandmaritime.dla.mil/Downloads/MilSpec/Docs/MIL-STD-348/std348.pdf

- Signal Microwave uses this standard to specify the interface dimensions
- MIL-STD-348A was released in 1988
- The current standard covers 40 different RF connector interfaces
- A section for test connectors is included in the current release

IEEE-287 - 2007

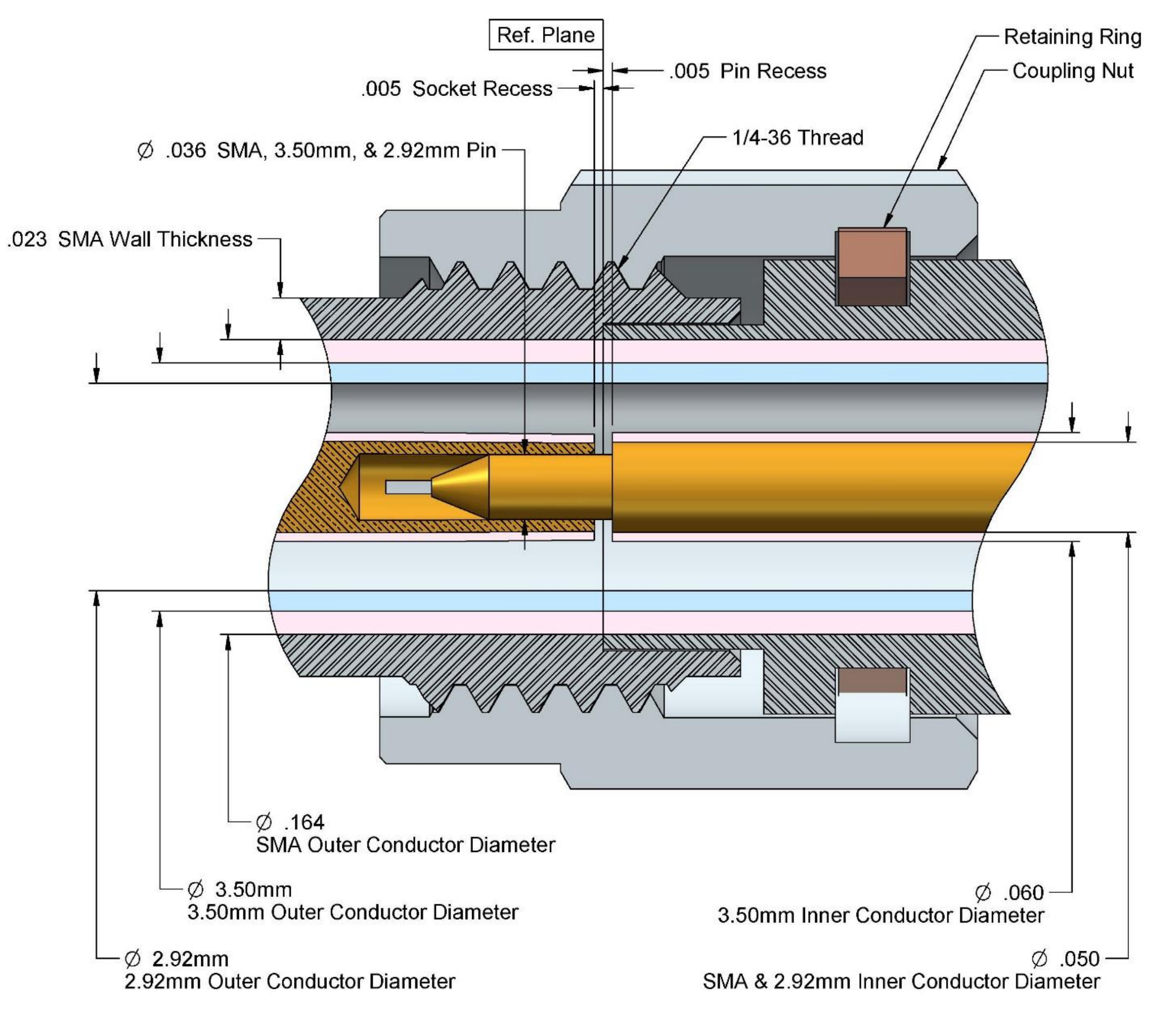
- This is the standard that defines the 2.92mm and 1.85mm connectors for test and measurement use
- Signal Microwave uses this standard for specifications
- Commercial grade 2.92mm and 1.85mm connectors may not conform to every specification defined
  - There are critical dimensions that users expect even commercial grade connectors to conform to even if they do not know about IEEE-287
- MIL-STD-348 and MIL-PRF-39012 are often referenced but did not include a 2.92mm interface until 2014 which is listed as an SMK. They cover SMA connectors that are compatible with 3.5mm and 2.92mm connectors

Materials Used by Signal Microwave

- Outer conductor (housing) is 303 stainless steel per ASTM A582 and passivated per AMS 2700 Method 1 type 2
  - The material used meets the requirements of DFARS (Defense Federal Acquisition Regulation Supplement)
  - DFARS requires that the steel must be smelted in the US or EU
- Center conductor is BeCu Alloy UNS C17300 per ASTM B196, heat treated to condition TH04
  - The heat treating is for hardening the metal to create force in the socket
- Center conductor plating is gold per MIL-DTL-45204, Type II, Grade C, .000100”-.000150” thick over electro-plated Nickel per QQ-N-290A, .000150” - .000300” thick
- Plastic Bead is Neoflon per ASTM D1430 or AMS 3650
  - This material was formerly known as Kel-F

Common Failure Modes

- Solder joints breaking
  - Caused by movement of the center conductor
  - Improper connector mating (turning the connector and not the coupling nut only)
  - Cable movement
- Connector barrels snapping off
  - Weak material (Brass)
  - Thin walls (18 GHz SMA)
- Resonances (suck-outs)
  - Often due to poor concentricity



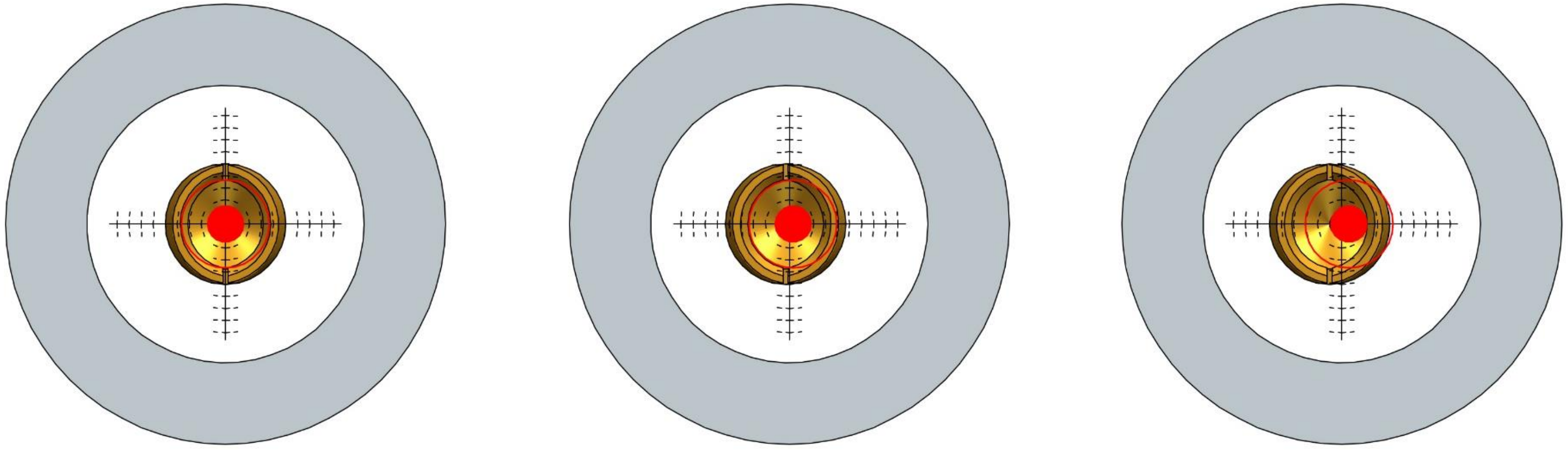
Concentricity

Connectors are designed to accommodate a certain amount of mis-alignment. The pin has a smaller center point and a lead in angle. The socket has a chamfer to act as a “catcher’s mitt” to allow the pin to be caught in the socket.

Poor concentricity can lead to resonances (suckouts) or, worst case, damaged connectors.

Signal Microwave measures concentricity in TIR which is the Total Indicated Runout when the feature being measured is rotated around the datum axis.

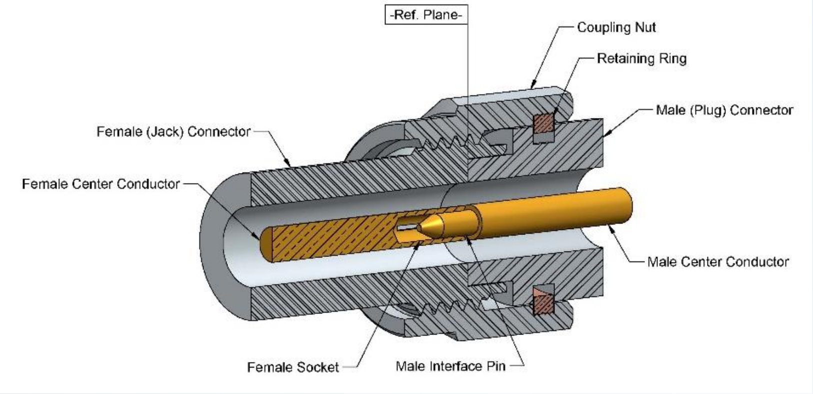
In higher frequency connectors, and precision connectors, the dielectric at the interface is typically air. When the dielectric at the interface is air, there is no force holding the center conductor in place like there is in an SMA connector.



Contact and Pin are Centered

Contact and Pin are Offset .003" TIR

Contact and Pin Offset .006" TIR



Frequency Domain Testing

- S-Parameters are measured in the frequency domain
- Typical instrument for measuring S-Parameters is a VNA
  - A VNA sweeps through a frequency range and stops (locks and levels) at each frequency to make the measurement
  - The typical frequency ranges used by Signal Microwave are 40 MHz to 40 GHz and 70 MHz to 70 GHz, both of which are 1,000 points
  - When the frequency steps are the same as the start frequency this is called a harmonic sweep and the VNA can convert the frequency domain information to time domain

Analysis of 2 Port Frequency domain measurements

- Frequency Domain measurements are defined as “scattering Parameter” or S-Parameters
- The 2 most common S-Parameters are S11 and S21
  - S11 is the measurement of reflected energy at port one and usually stated as return loss or VSWR
  - S21 is insertion loss and is the measurement of the total energy that arrives at port 2 compared to the energy that is injected into port 1

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Return Loss, VSWR, and Reflection Coefficient

- Return Loss, VSWR, and Reflection Coefficient are all measurements of S11
- What does a VNA actually measure for S11?
  - Energy is sent through the test port and reflected energy, energy coming back to the test port, is measured. The ratio of the reflected energy to the sent energy is the actual measurement made by a VNA. This is called the reflection coefficient.
  - The typical specifications used in the industry are Return Loss or VSWR. For connectors VSWR has better resolution so is commonly used.
  - The “ups and downs” of the Return Loss or VSWR graphs are due to phasing of the reflections. What should be looked at is the envelope of the peaks. (This will be discussed with an example in a couple of slides)

What is a VNA calibration

- There are 2 levels of calibration
  - Once a year calibration of the instrument
    - This makes sure the internal components of the VNA are within specification
  - Calibration specific to the Test set-up using known standards
    - The VNA needs to be set up for the devices that are going to be tested
    - This sets a start point for the measurements referred to as the “reference plane”
    - To “tell” the VNA where this starting point is, there is a system of equations with the uncertainties that needs to be solved
    - One portion is to remove the noise of the system
    - The other portion is to tell the VNA where the measurement is starting and resolve uncertainties
  - Types of Calibration
    - SOLT, TRM/LRM, TRL/LRL, SSST (triple offset shorts),
    - Autocal is SOLT with extra terms

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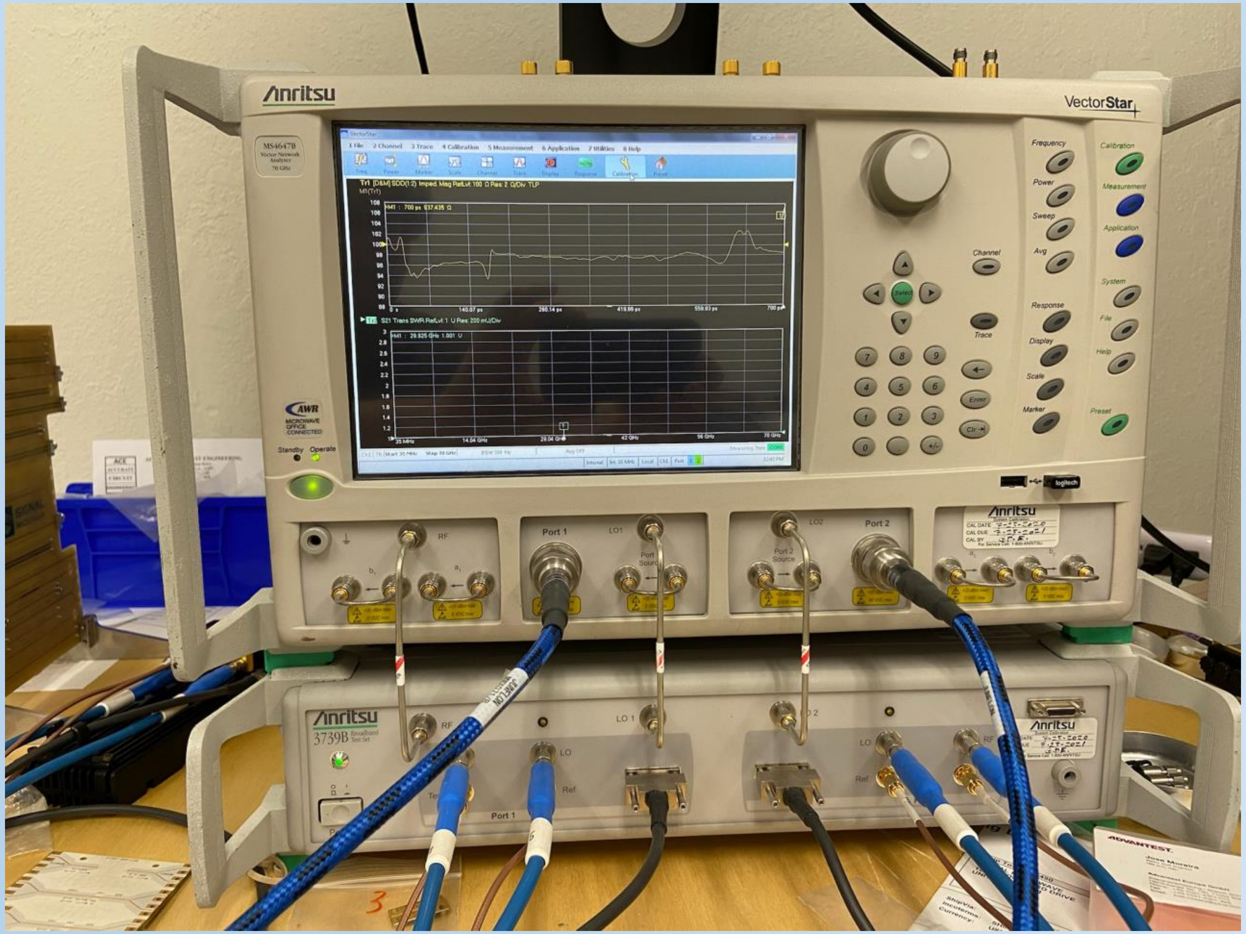
VNA System and Cal Kits



Anritsu 125 GHz Vector Network Analyzer MS4647B

Anritsu 40 GHz model 3652A and 70 GHz model 3654D calibration kits

Anritsu 110 GHz model 3656B calibration kit

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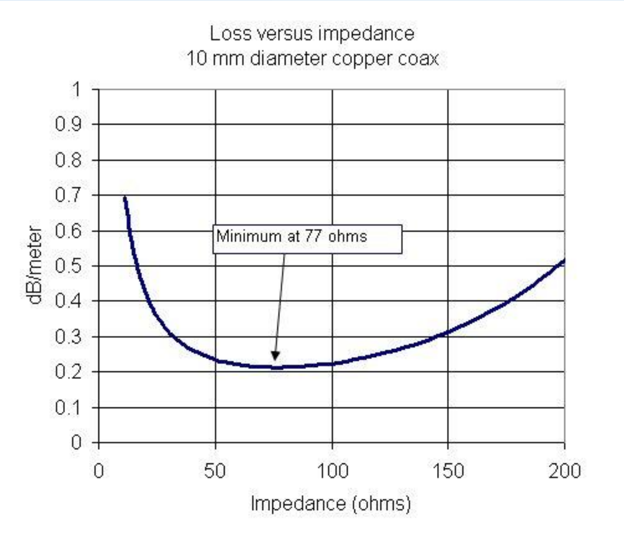
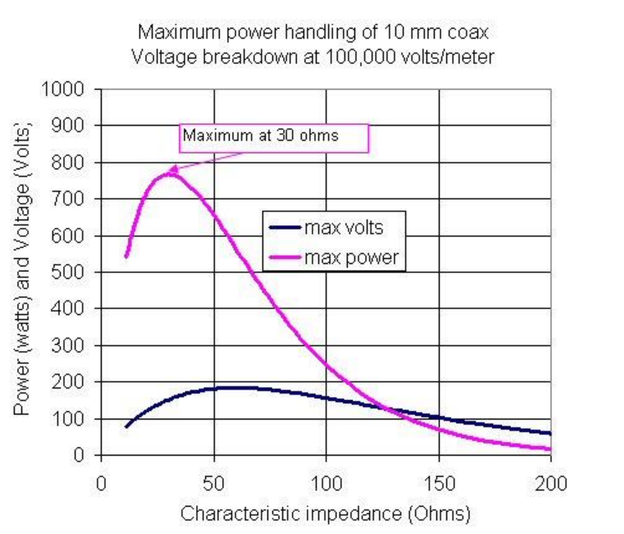
How to verify the Calibration

- Level 1 verification: noise
- The common way is to measure the through, often the same through used during calibration
  - This will show that the noise has been “calibrated out”
  - This does not verify that a measurement will be accurate
- Level 2 verification: accuracy
- The official way is to use a NIST traceable verification device and compare the results to the supplied results of the device
- In the RF industry users create their own verification standards
- For the digital industry we have created a verification standard

Why 50 ohms?

- 50 ohms is not magical. Microwave energy can propagate through a large range of impedances.
- For minimum loss the ideal impedance is 77 ohms.
- For maximum power handling the ideal impedance is 30 ohms.
- 50 ohms was chosen as a standard back in the 1930s based on a compromise of power and loss
- Graphs are from the Microwaves 101 website
- http://www.microwaves101.com/encyclopedias/why-fifty-ohms





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The result of impedance changes on reflections

- Formula for VSWR based on impedance
  - $VSWR = (1 + \frac{(Z-50)}{(Z+50)})/(1 - \frac{(Z-50)}{(Z+50)})$
- Here is an example using 52 ohms
  - $VSWR = (1 + \frac{(52-50)}{(52+50)})/(1 - \frac{(52-50)}{(52+50)}) = \frac{1.02}{.98} = 1.04$
- For a long transmission line without major mechanical transitions, such as PCBs or cables, it is valid to relate most reflections to impedance changes
- The connector to board transition (launch) cannot be simplified to looking at reflections as only impedance changes.
  - The reflections are due to the changes in structure and the energy transitioning from a coaxial line in the connector to a planar line in the board.
  - Reflections can actually be minimized by using sections that are not 50 ohms.

Z	VSWR	Return Loss
50	1	
52	1.04	34.15
54	1.08	28.30
56	1.12	24.94
58	1.16	22.61
60	1.2	20.83
62	1.24	19.40
64	1.28	18.22
66	1.32	17.21
68	1.36	16.33
70	1.4	15.56

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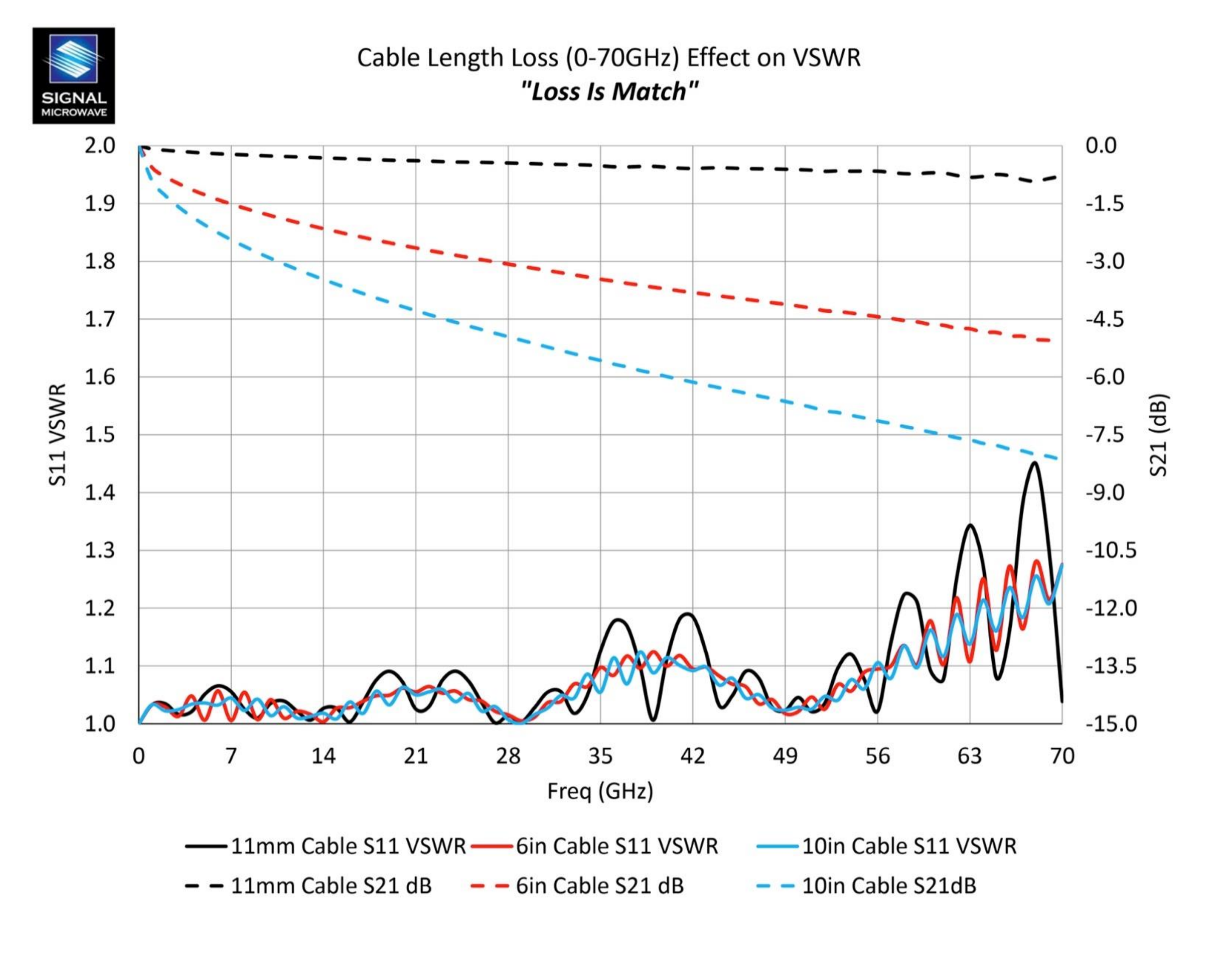
S11: VSWR or return loss; when to use which

- Rho: Reflection Coefficient is the actual measurement made by a VNA
    - This is the ratio of reflected power to transmitted power
    - Return Loss and VSWR are calculated based on Rho
- VSWR: When reflections are small, such as in a connector, VSWR gives better resolution
- Return Loss: When reflections are higher, such as in a board, Return Loss is a better indicator of what the system is doing

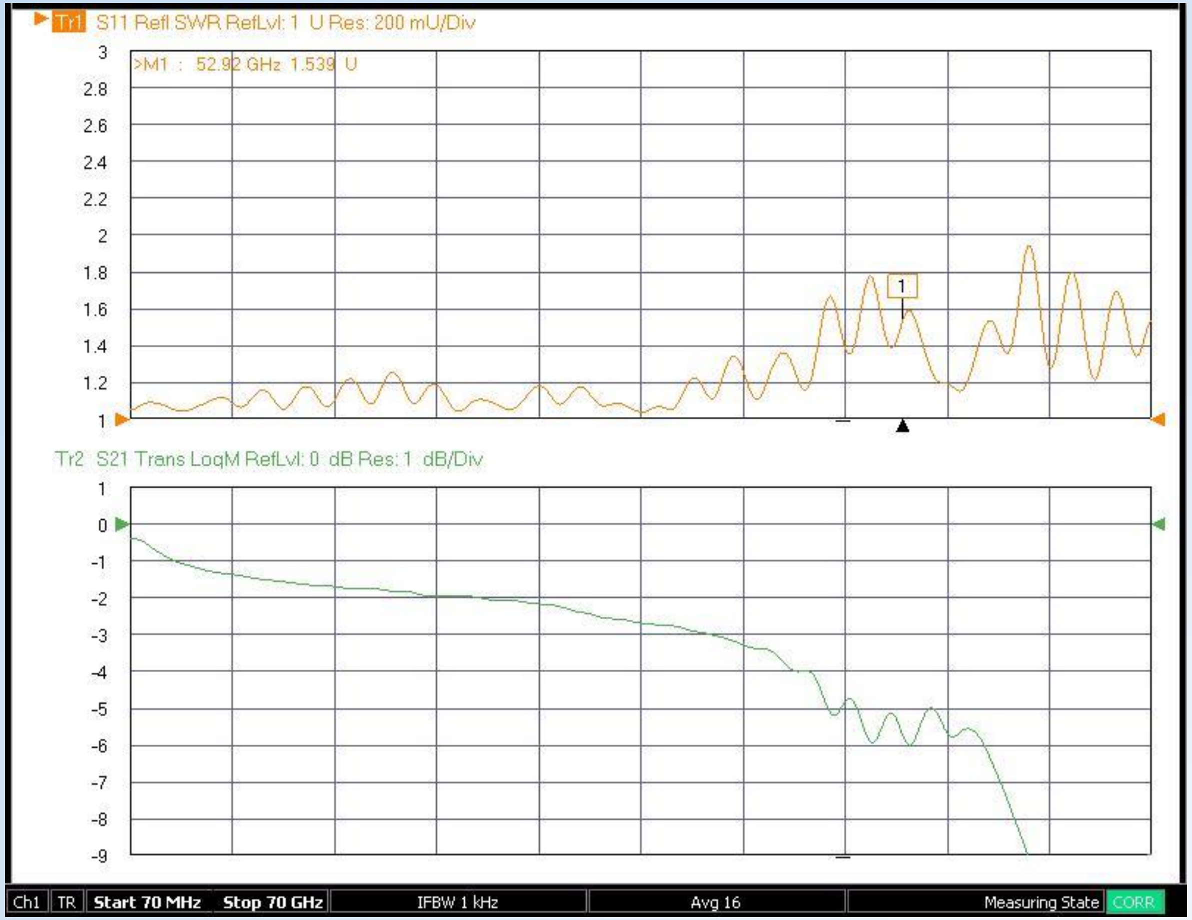
"Loss is match"

- In a typical 2 port passive transmission line system where the reflections mostly come from the connector transitions, adding loss between the transitions reduce the reflections seen at one port.
- This can be a cable or a PCB.
- The example shown is for a cable where the length is extended thereby adding loss between the 2 connectors.
- The reflected energy at port one is a combination of the reflected energy from port one and port two
- By adding loss between the two connectors, the reflected energy from port two is reduced and results in a lower VSWR (greater return loss).



Bandwidth

- This is my demo board 007-007-1Fn with 70 GHz connectors
- The total frequency range of the sweep is 70 GHz.
- The linear portion of the loss easily goes through 42 GHz. This board is then good through 40 GHz which is what I needed for the ELF40 connectors.
- Then there is a portion of the sweep with ripple through 56 GHz.
- It completely cuts off by 59.5GHz.
- I call this a 40 GHz board useable to about 58 GHz. Beyond 58 GHz hardly any energy is going through it.
- Notice that the VSWR jumps from 1.4 (15.563 dB return loss) to 2.0 (9.542 dB return loss) through the 70 GHz sweep.
- Some people would only look at S11 and say this board is a 9.5 dB return loss board through 70 GHz even though hardly any energy is going through the board past 59 GHz.



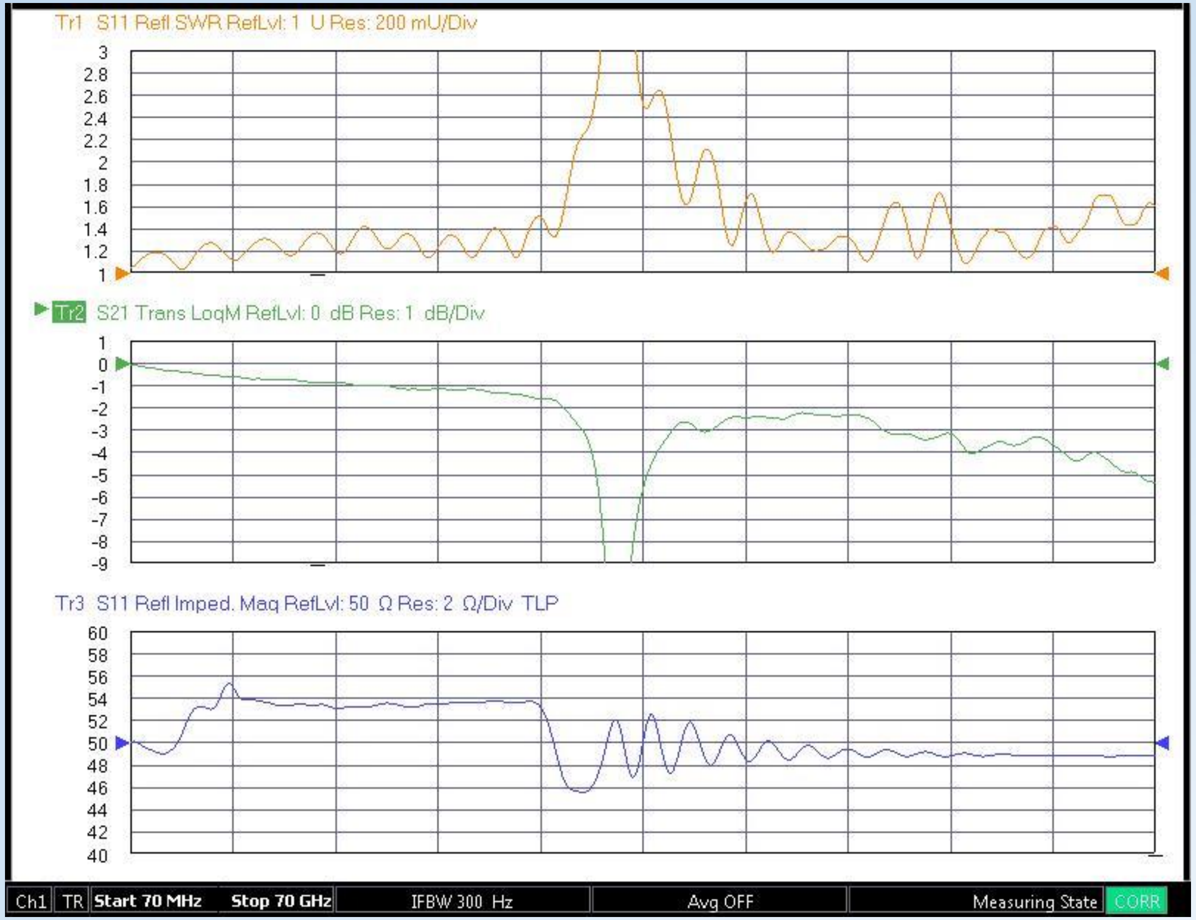
“Suckouts”

A “Suckout” refers to when the energy is lost unexpectedly

In this case there is a drastic suckout that occurs between 30 – 35 GHz.

These are typically due to resonances which can occur in the physical structure at specific frequencies and the energy cannot pass through the transmission line

This particular one is due to a resonant cavity created in the connector due to manufacturing issues



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VLF40-002 Vertical Launch Connector

- 2.92mm Interface
- Board Mounted
- 40 GHz Bandwidth
- Vertical Launch
- Screw-on Mounting
- Compression Fit
- No Soldering Required

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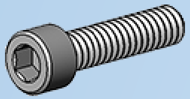
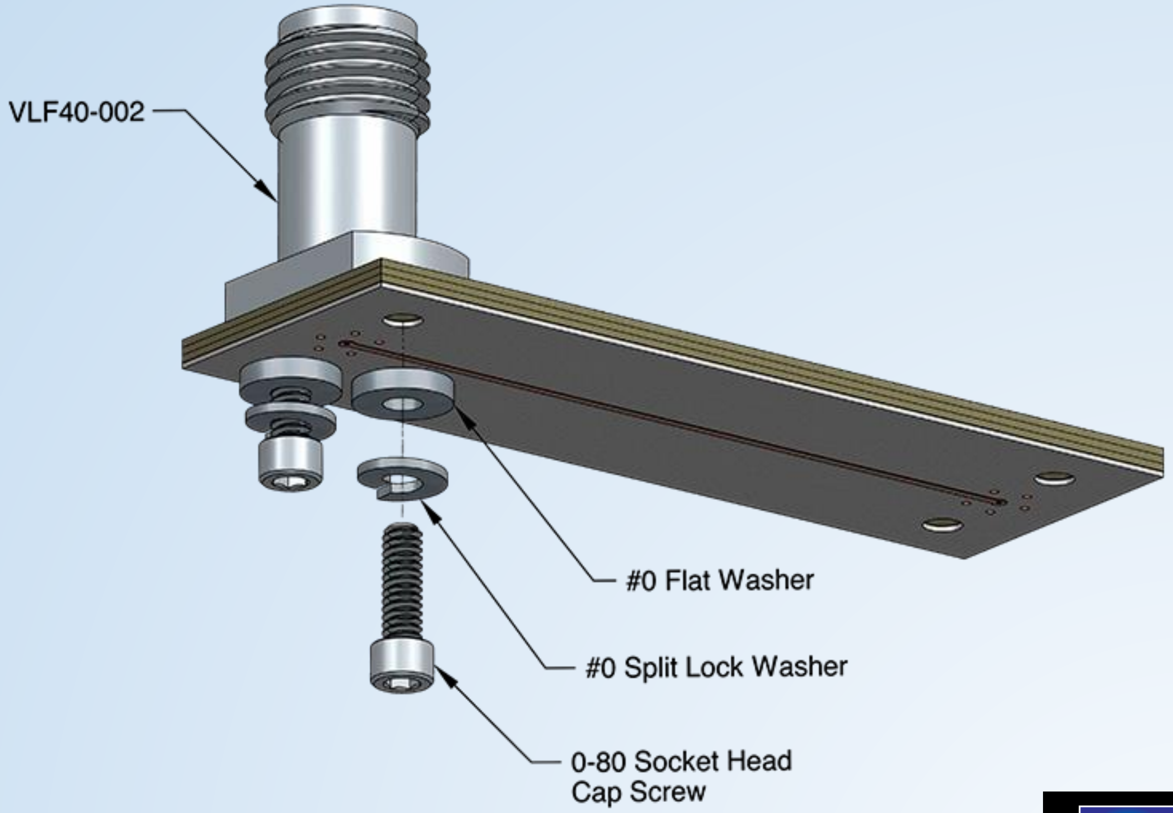
Vertical Launch Connector Board Installation Resources

- This is a list of 0-80 screws from McMaster Carr. These are made of 18-8 stainless steel.
- They are socket head cap screws and requires a .050" hex wrench for installation.
- A complete list including washers and wrenches are on the website



Length	Thread length	Qty per box	Part number	Price per box as of January 2014	Board thickness (including any washers)
3/32"	Full	100	92196A051	$6.91	Max .030"
1/8"	Full	100	92196A052	$6.18	Max .065"
5/32"	Full	100	92196A053	$7.15	Max .095"
3/16"	Full	100	92196A054	$6.28	Max .125"
1/4"	Full	100	92196A055	$7.22	.040" – .200"
5/16"	Full	100	92196A056	$7.48	.110" – .250"
3/8"	Full	100	92196A057	$7.73	.165" – .315"
7/16"	Full	100	92196A048	$8.11	.230" – .375"
1/2"	Full	50	92196A070	$10.01	.290" – .440"
9/16"	Full	100	92196A049	$10.42	.350" – .500"



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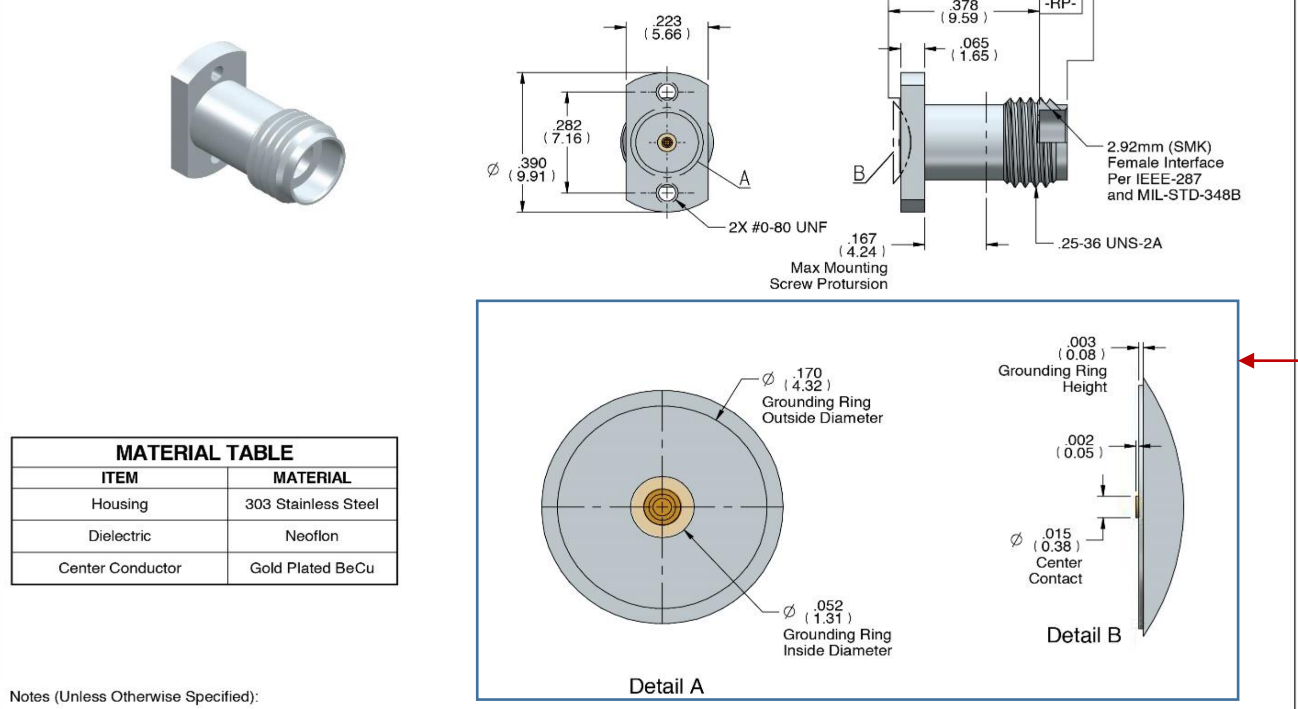
VLF40-002 outline drawing

- Shown is the VLF40-002 outline drawing and a picture of the connector
- This shows the section where the connector geometry is defined for the part of the connector that interfaces with the board. The box in the drawing is added here to isolate that section.



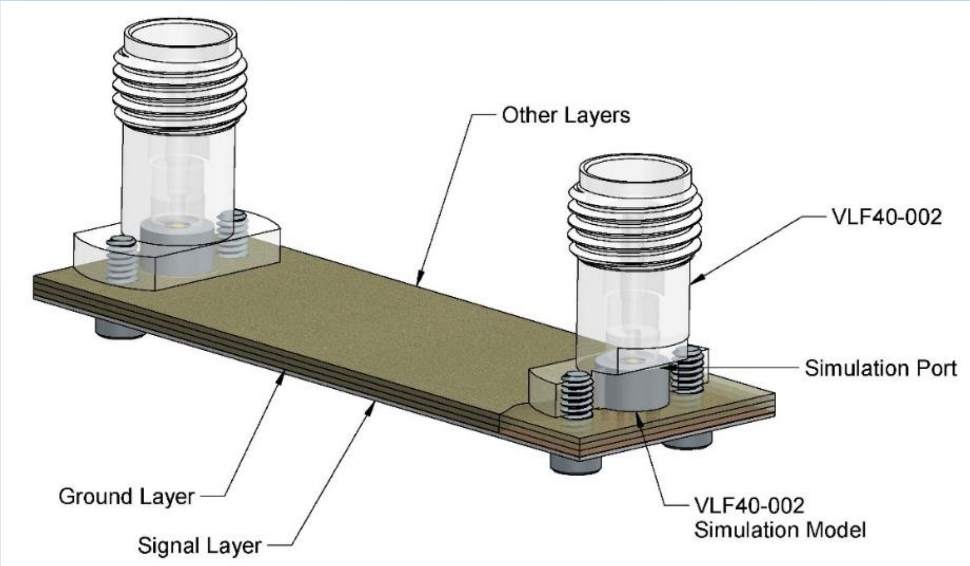
MATERIAL TABLE	
ITEM	MATERIAL
Housing	303 Stainless Steel
Dielectric	Neoflon
Center Conductor	Gold Plated BeCu

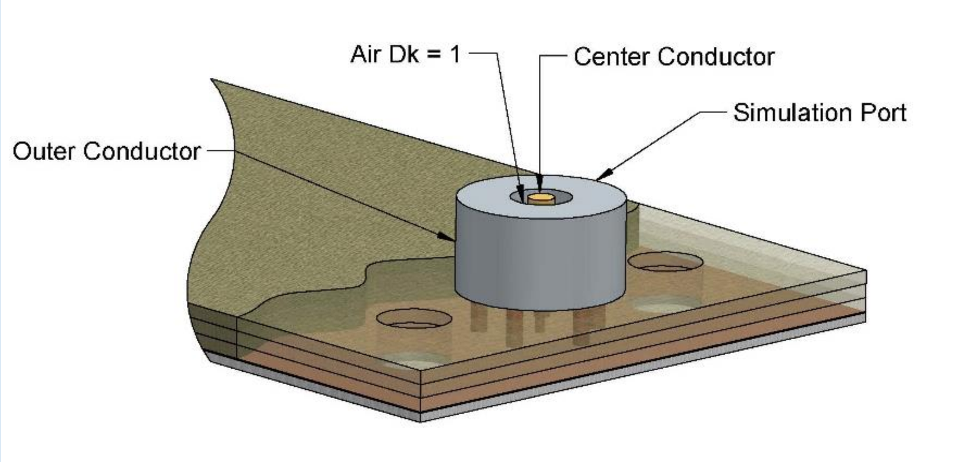
Notes (Unless Otherwise Specified):
1. All Dimensions are in Inches.
2. All Angles are in Degrees.
3. All Dimensions in (XXX) are in Millimeters.

APPROVAL	DATE	DWG NO VLF40-002	REV B
BR	03/25/15	FILE NAME: VLF40-002 Outline.dft	SHEET 1 OF 1

VLF40-002 rear (board) end of the connector

Board Launch Design Resources





VLF40-002 3D Simulation Model

- A 3-D model of the launch portion of the connector is available for import into common 3D electro-magnetic solvers.
- These file formats include .igs, .stp, .X_T, .SAT, and other formats compatible with HFSS, CST and other 3D EM solvers.
- This is the launch portion of the connector and is used to develop optimized board layouts.
- For port 1 Create a 50 ohm port on the end of the launch portion, we take care of the rest of the matching in the connector
- For port 2 create a 50 ohm port in the transmission line of the board.

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Back to back testing of connectors

- A connector by itself cannot be tested.
- 2 connectors are required for testing so there will always be an interface between them which will be included in the measurement
- Assuming fairly well behaved connectors which have only a few major points of reflection the following occurs:
  - The reflected energy of the second connector, with little attenuation, will combine with the reflected energy of the first connector as it is measured at the VNA
  - The phasing of this combined energy is dependent on the electrical distance between the reflections
  - Over a frequency range these combinations will be constructive and destructive.
- The insertion loss for each connector is the half of the total insertion loss

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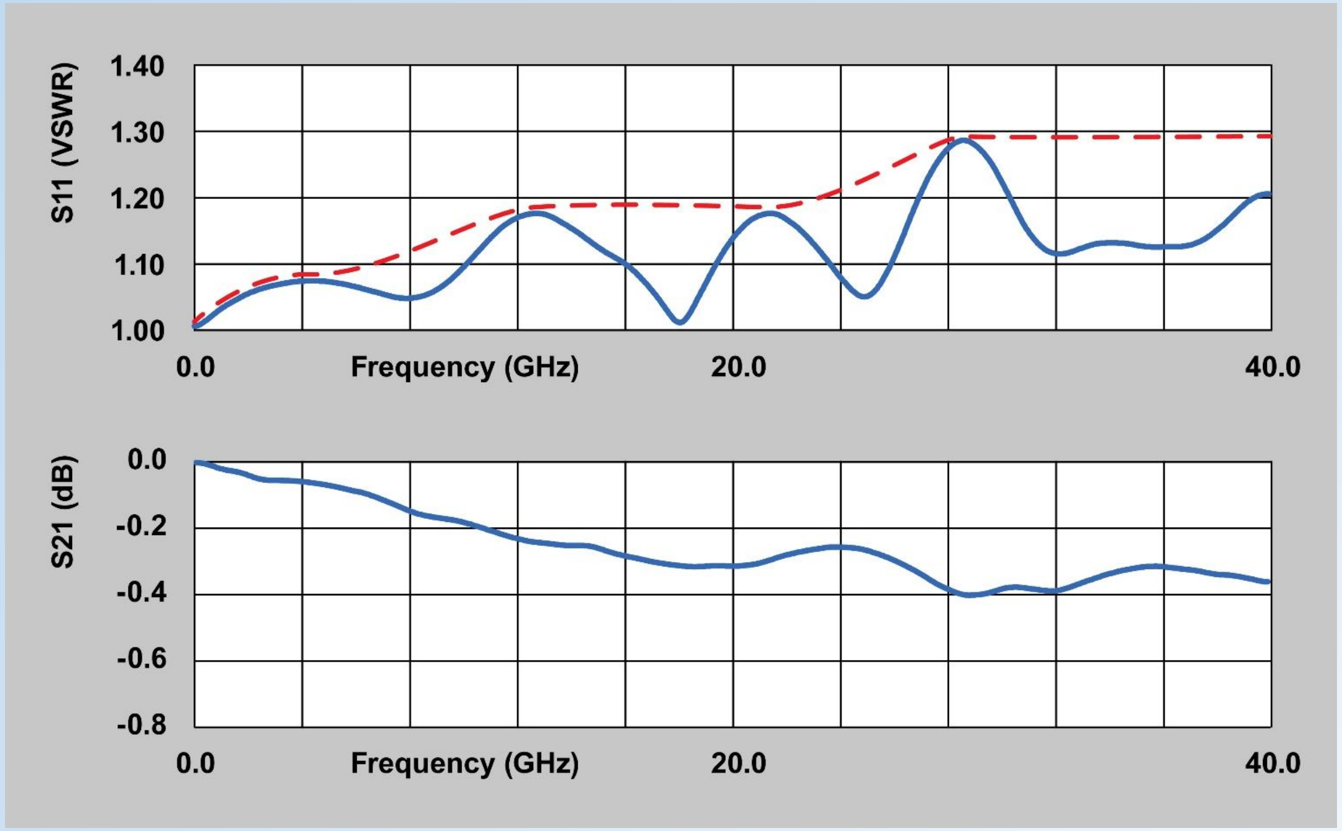
Analysis of Reflections and Loss

- Assuming that the test fixture has very little loss:
    - The maximum reflections are an accurate measurement of the reflected energy of each connector combining in a constructive manner.
    - In VSWR the measurement of the individual connector is the square root of the VSWR of both connectors.
    - An idea of the number of reflections and distance between them can be analyzed by the frequencies at which the maximums and minimums occur.
- Insertion Loss for each connector is half of the total Loss



Max VSWR 1.3:1 for the pair (18 dB RL)
$\sqrt{1.3}$ = 1.14:1 for each connector (24 dB RL)
Total Insertion Loss for the pair is .4 dB
Insertion loss for each connector is .2 dB

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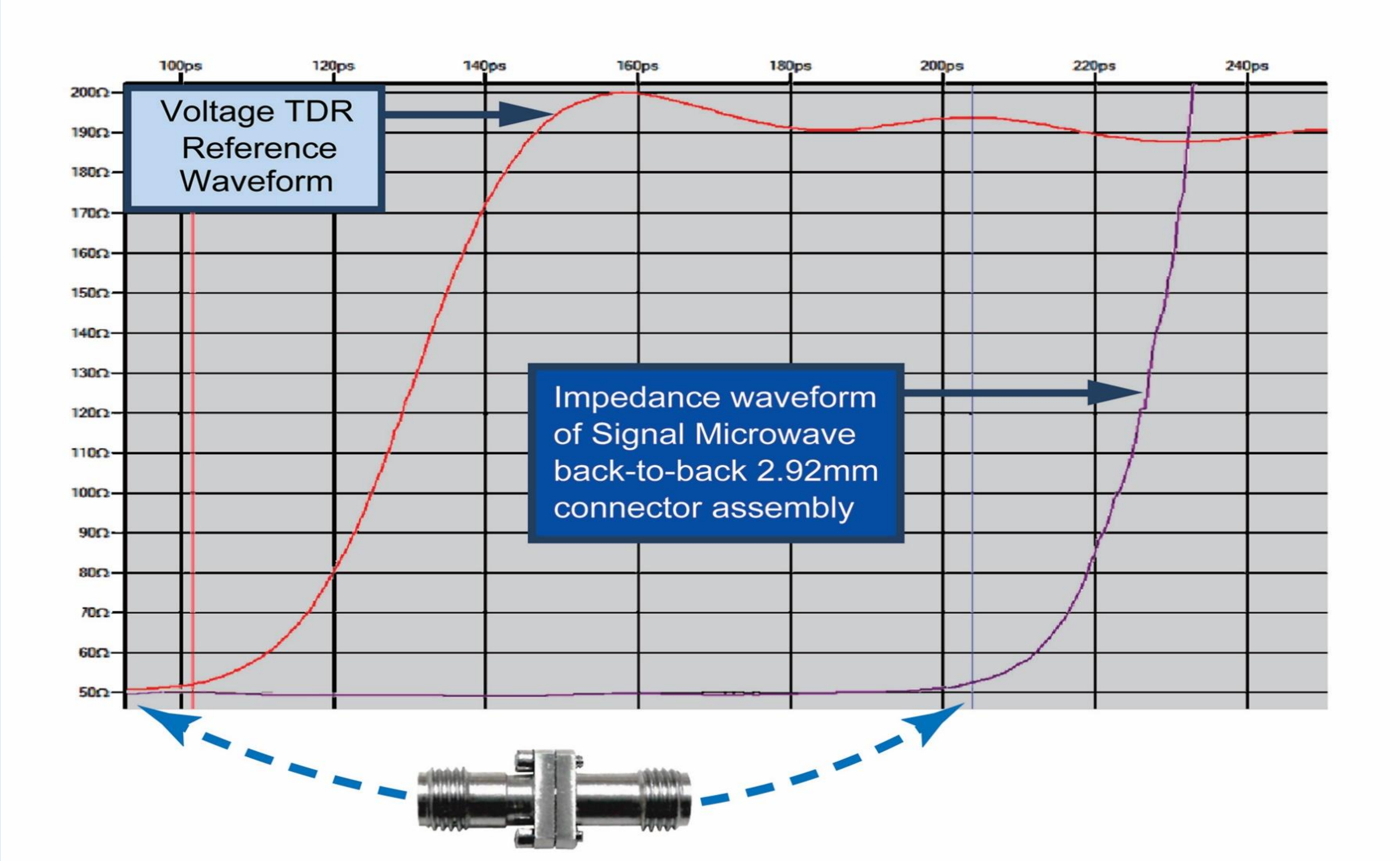
VLF40 TDR Test Data measuring Impedance



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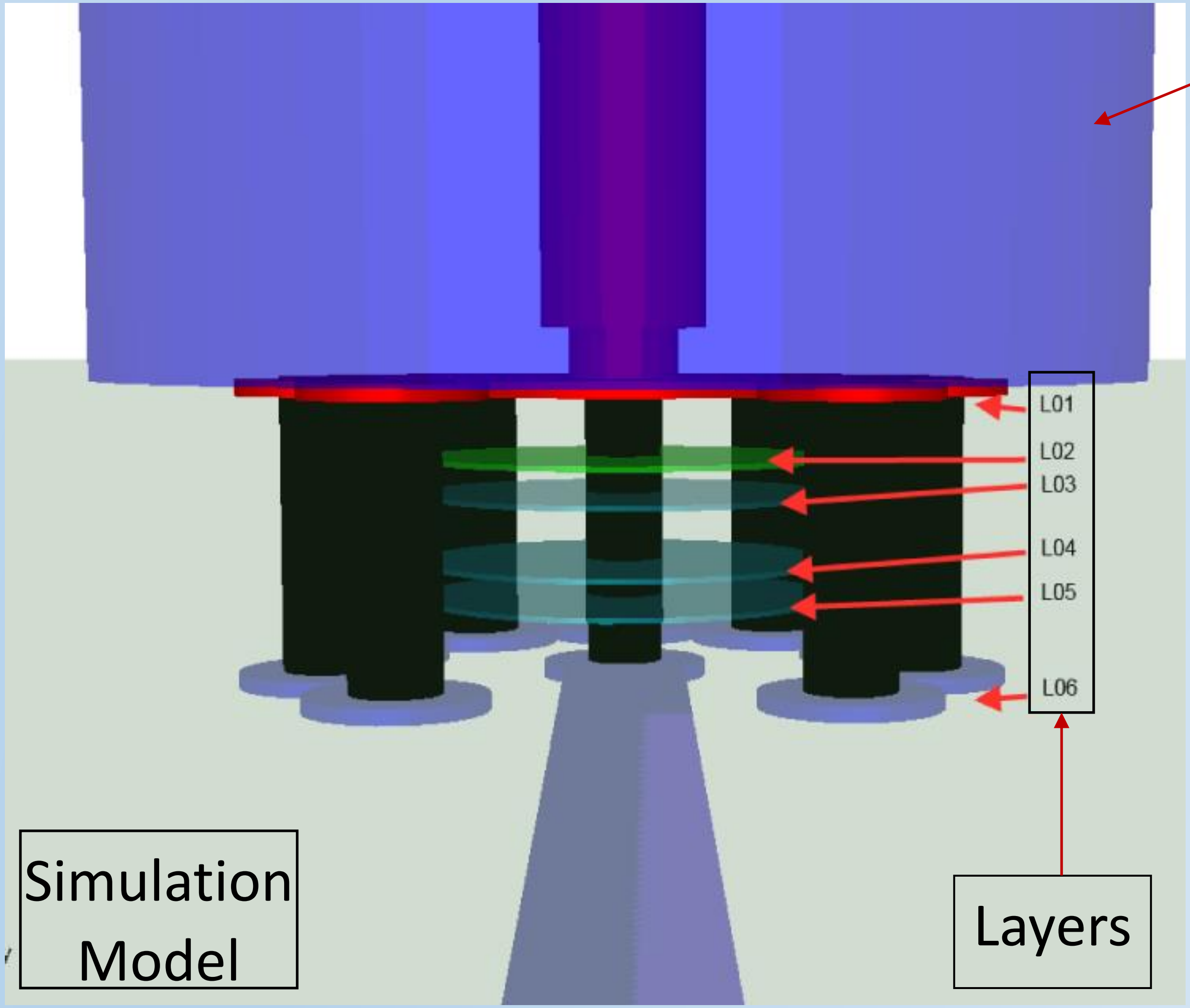
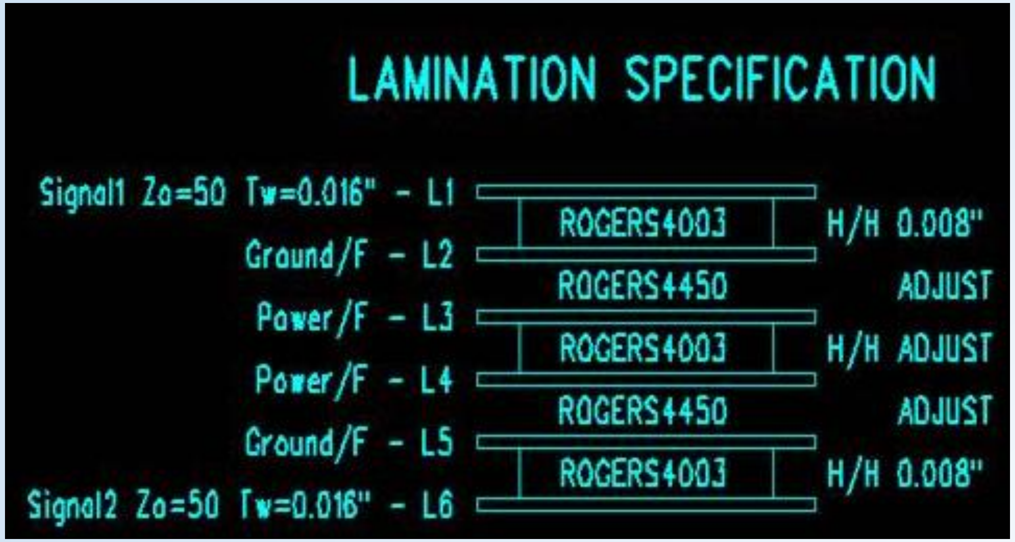
Example of a board stack-up and a model

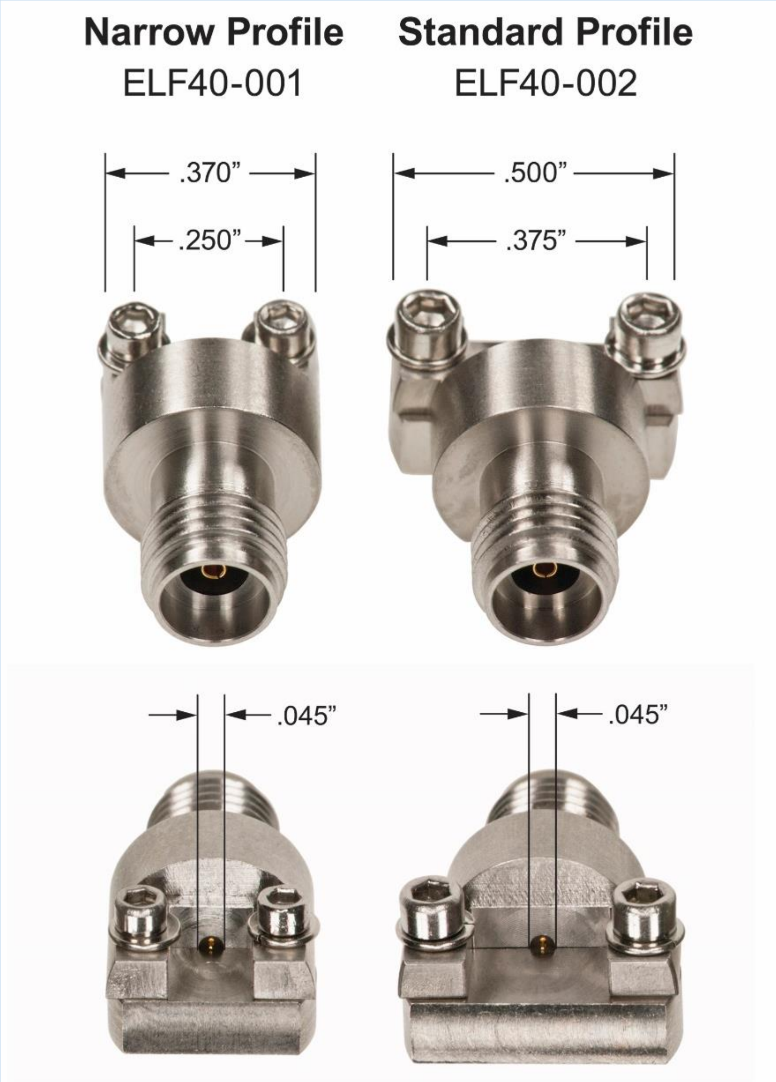


Connector Simulation Model

- L01 and L06 modeled with 2 mil thickness
- L02 to L05 modeled with 0.7 mil thickness
- 4450F modeled with 4 mil thickness
- All 4003 substrate layers modeled with 8 mil thickness

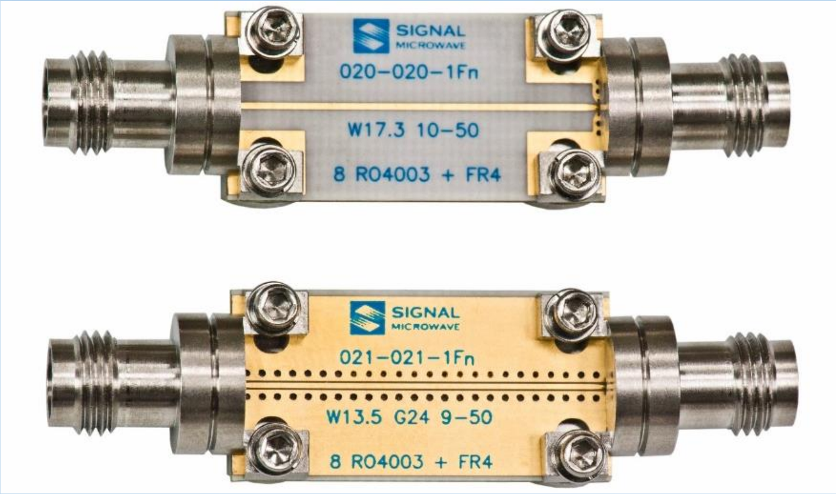


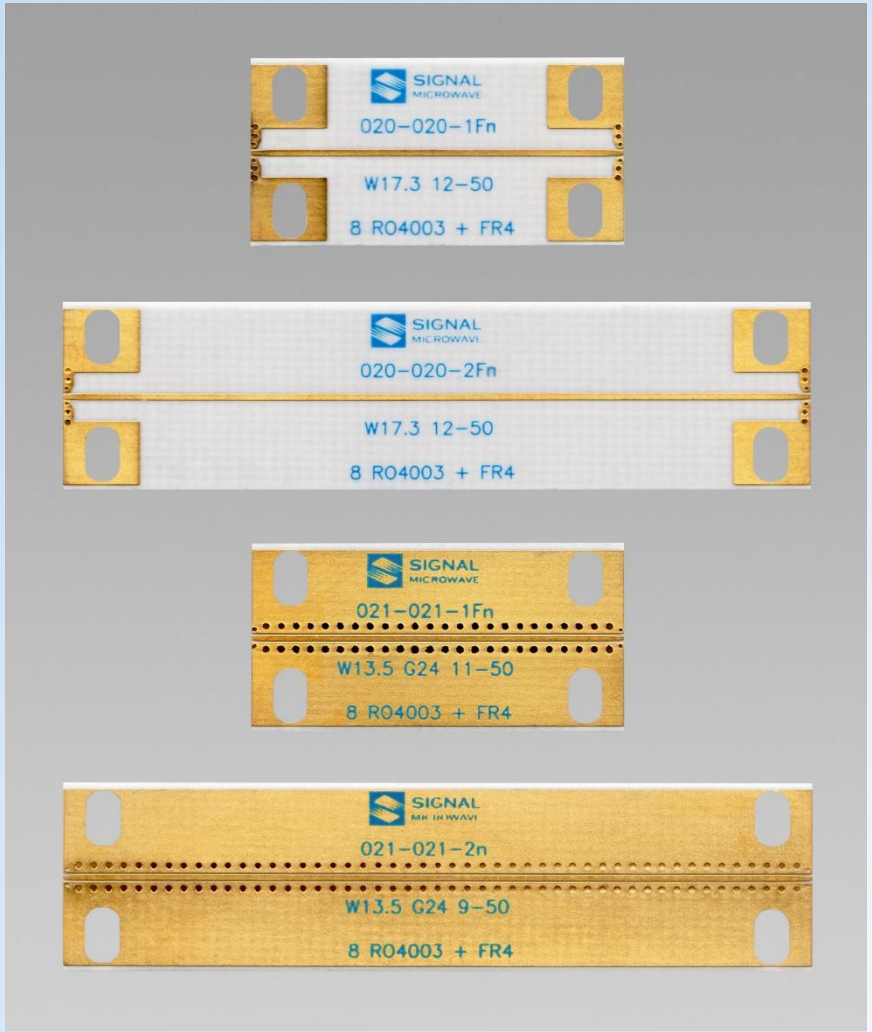
ELF40, ELF50, and ELF67 Edge Launch Connectors



- 2.92 mm, 2.4mm, and 1.85mm Interfaces
- 40, 50, and 70 GHz Bandwidth
- No Soldering Required
- Only the Top Ground is connected to the board
- Board Design Support Available
- Test Boards Available

How to test Edge Launch Connectors



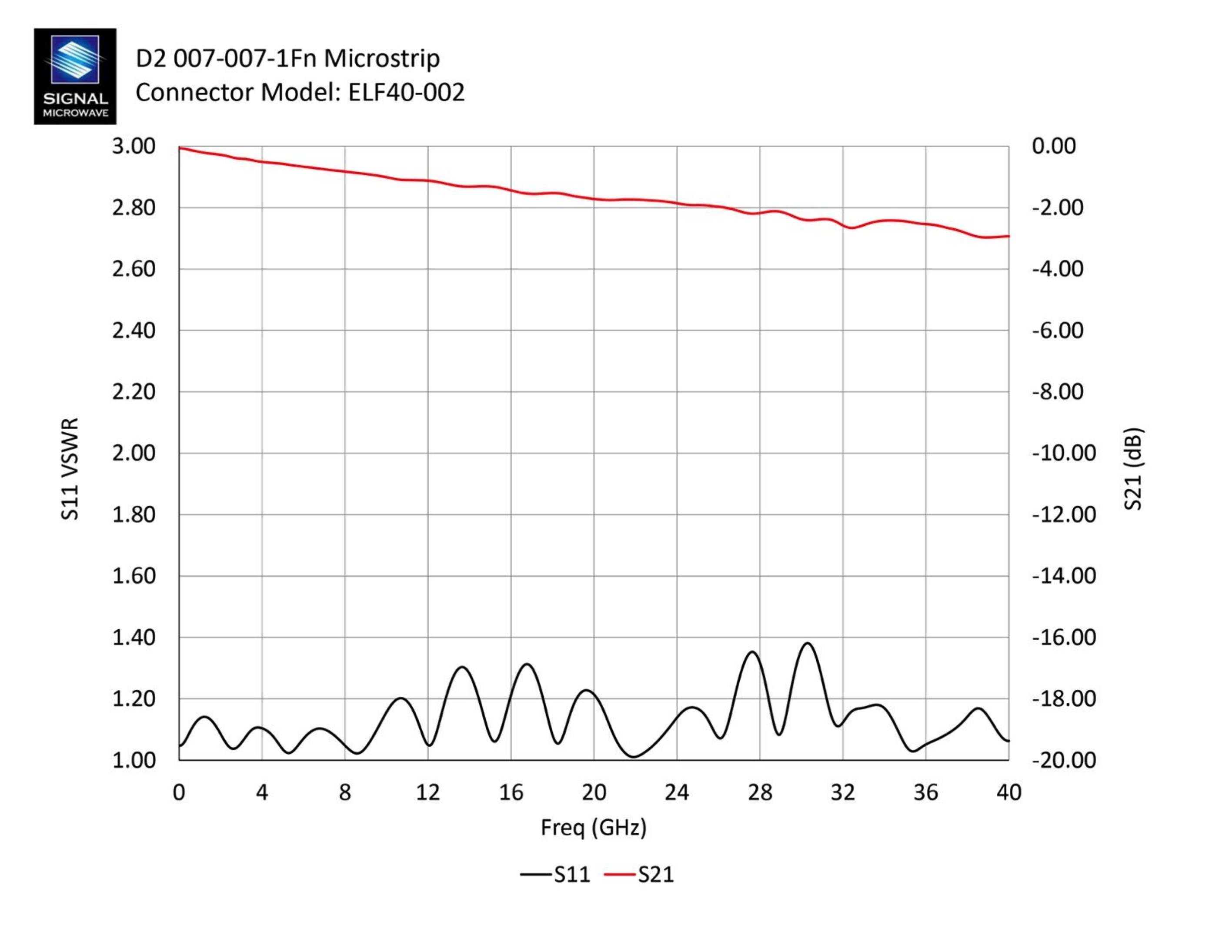


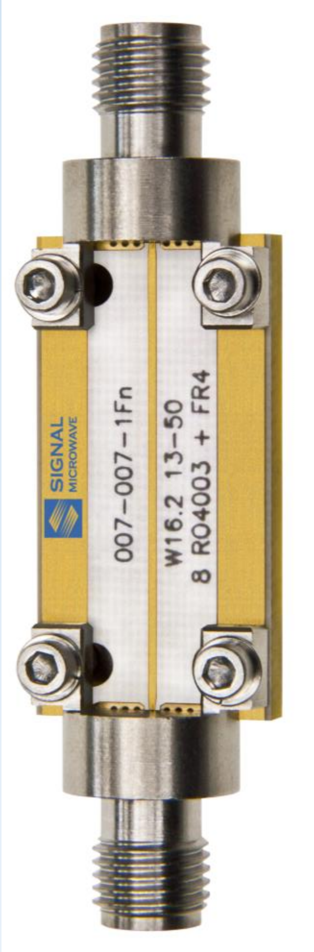
- The connectors cannot be tested alone so test boards are required
- The purpose is to test the connectors, not the boards so the board performance needs to be better that the connector
- Refer to the paper in this link for more information:

http://mpd.southwestmicrowave.com/showImage.php?image=439&name=Optimizing%20Test%20Boards%20for%2050%20GHz%20End%20Launch%20Connectors

Typical Test Data of a Test Board with Connectors

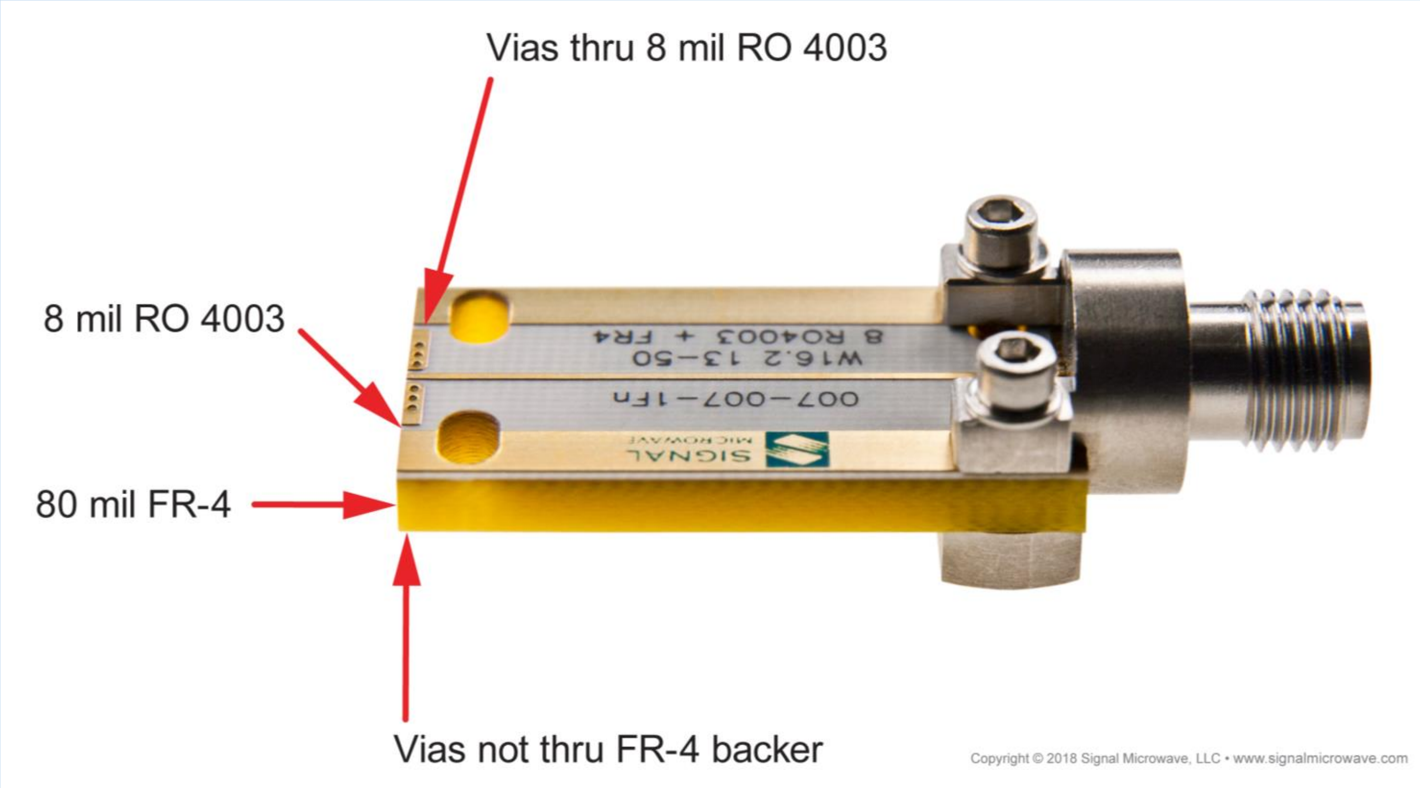
- Swept through 40 GHz
- Max VSWR less than 1.4:1 (Signal Microwave spec is 1.6:1 max)
- Smooth insertion loss curve with slight ripple at the higher frequencies



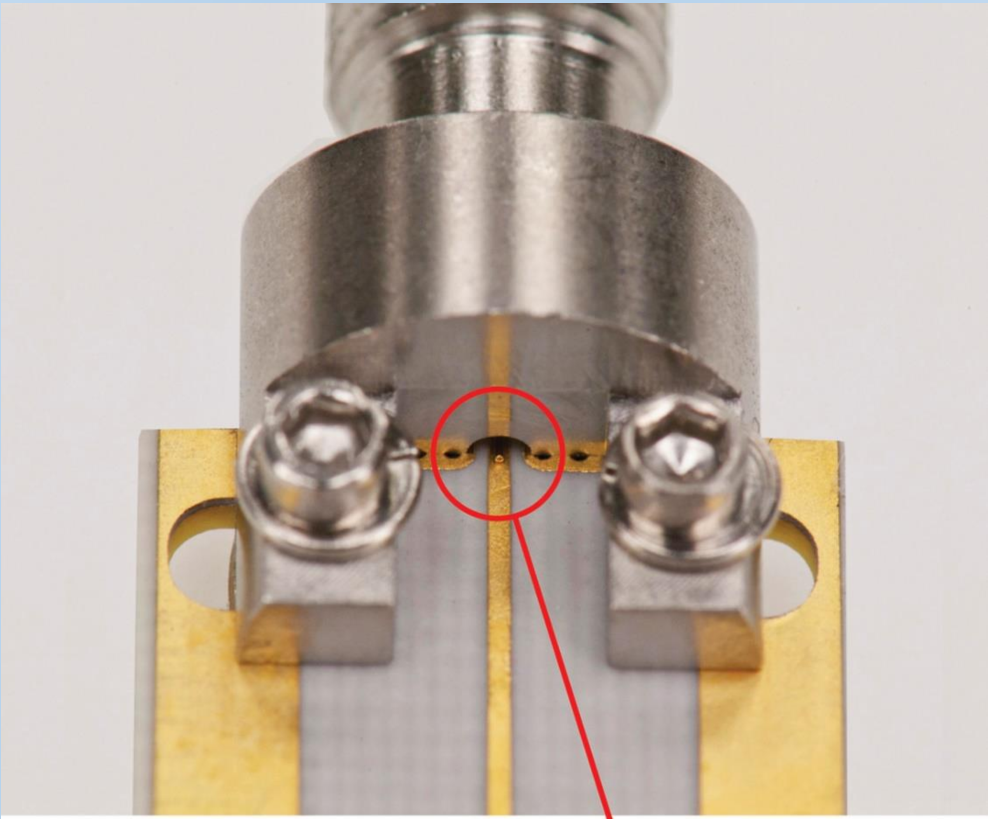


Signal Microwave Test Board Configuration

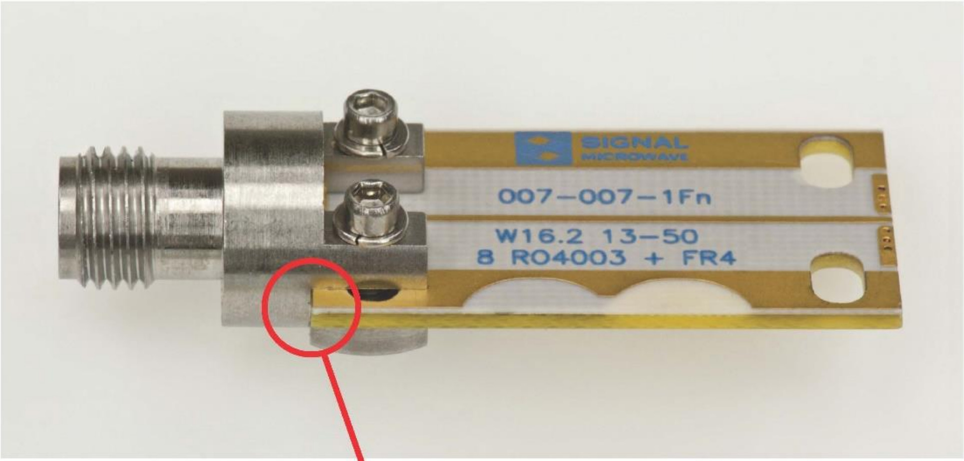
- Launch Design Optimized to not Require a Bottom Ground
- 8 mil RO4003 processed separately, including plating through the vias
- FR-4 laminated to the board as a stiffener
- No need to back drill vias



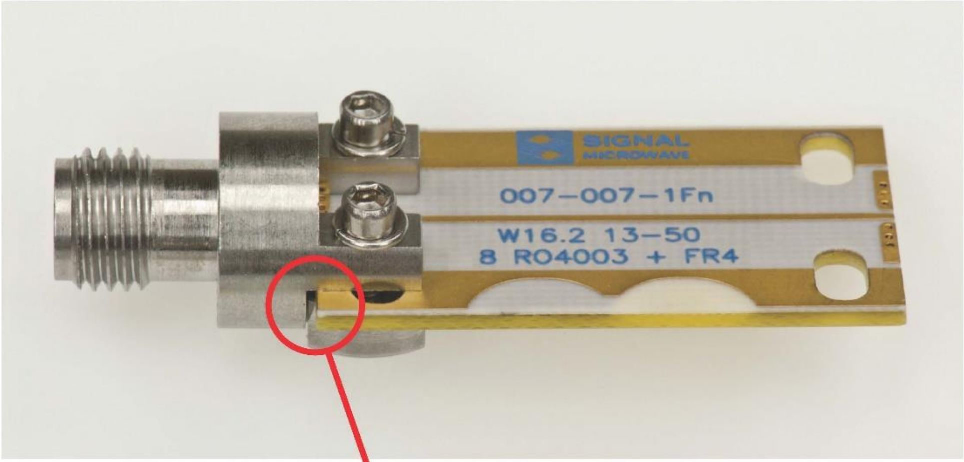
Proper installation



Pin Centered



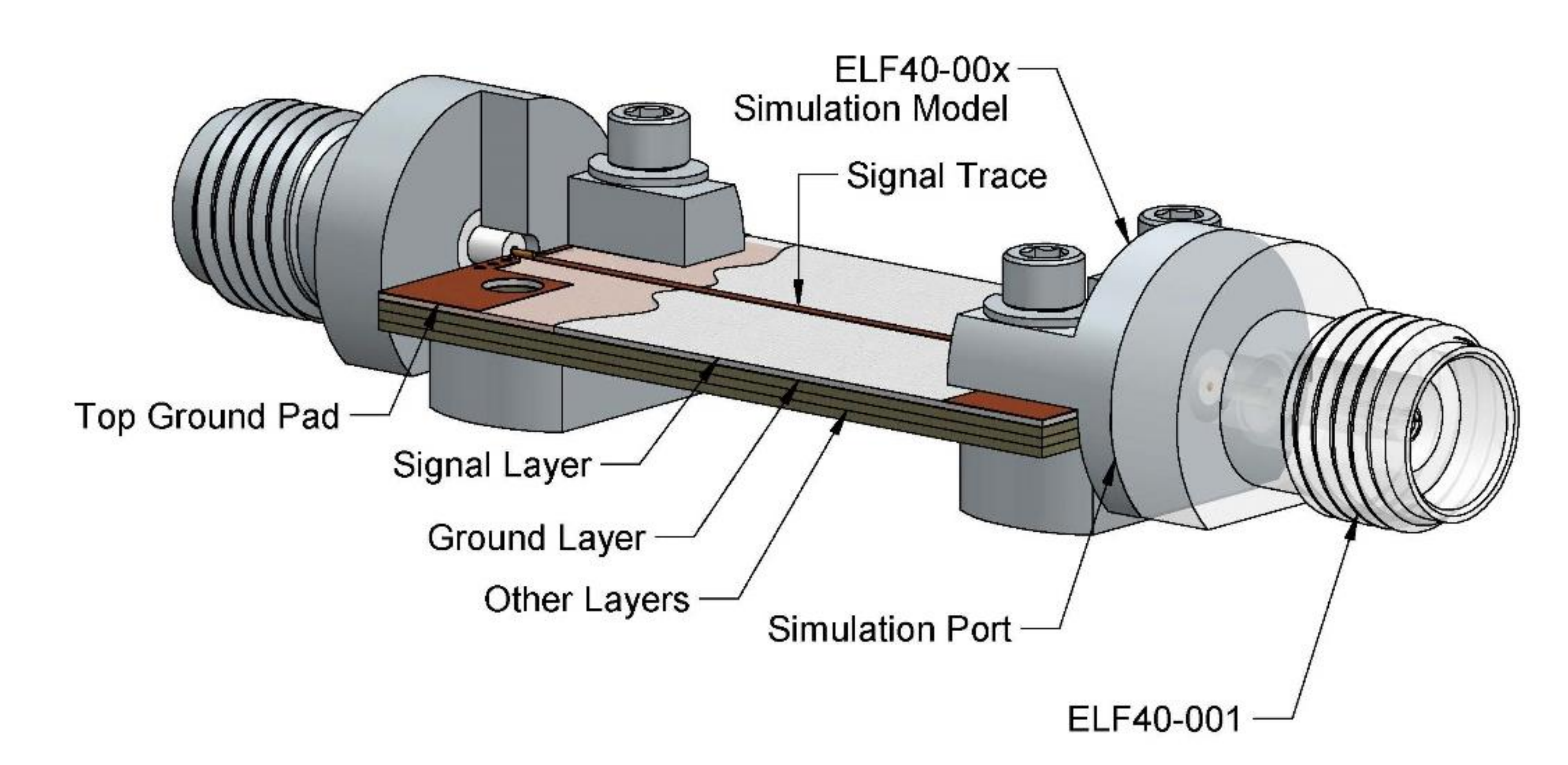
Board Mounted Flush to Connector
(zero gap for smooth signal transition)



Gap causes poor connection
at higher frequency

Typical board stack-up example for Edge Launch

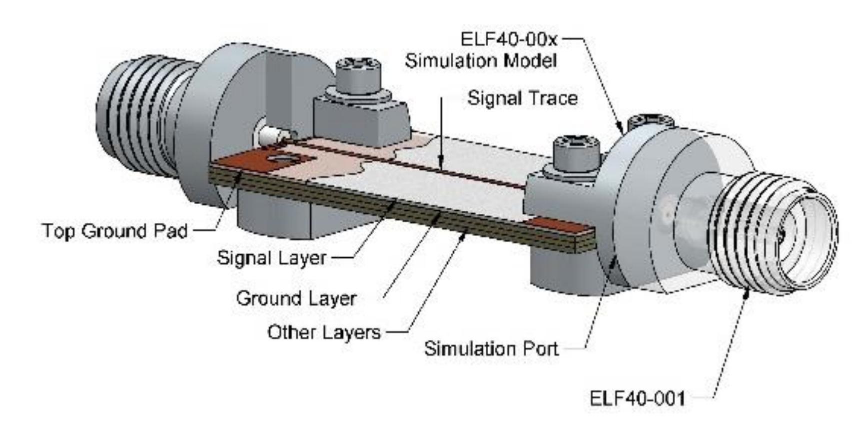
- The top layer is the microwave signal layer
- There is a ground layer directly under the signal layer.
- The launch from the connector only uses the top ground transition to the internal ground layer.

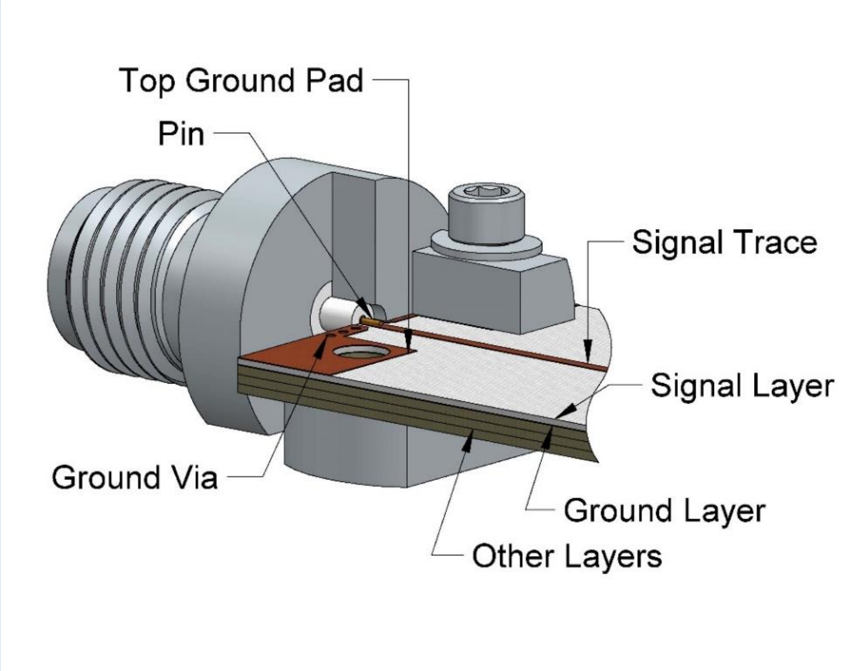


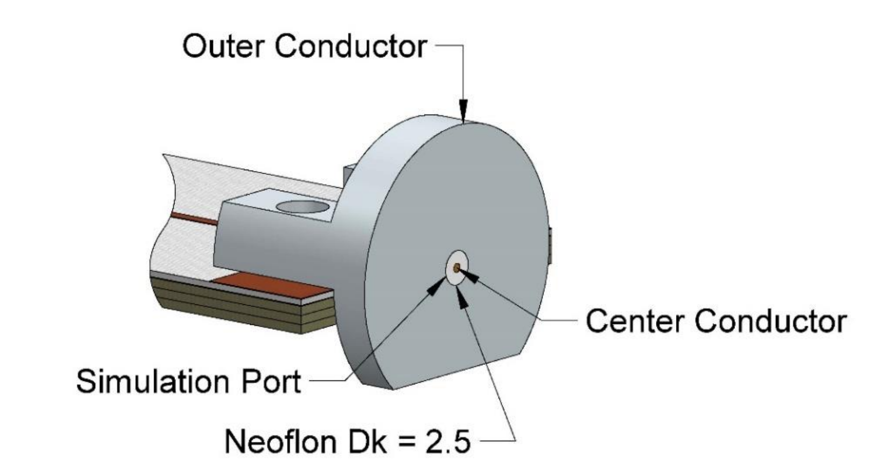
SIGNAL MICROWAVE

ELF40 Simulation Model

- The simulation model includes the launch portion of the connector along with the mounting legs of the .370” body part which is worst case for performance.
- Models available in common 3D graphic formats
- .igs, .stp, .X_T, .SAT, and other formats are available

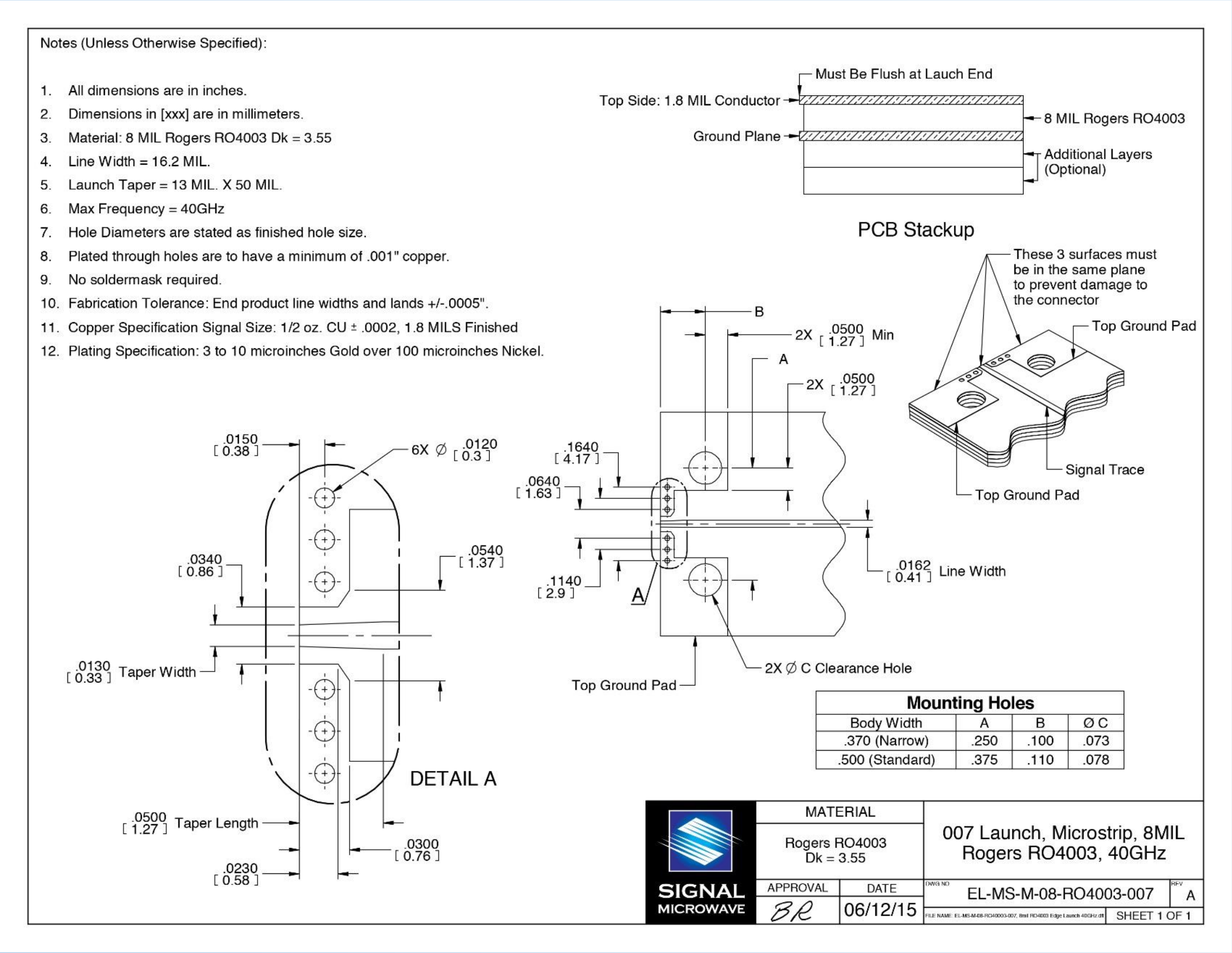






ELFxx-00x 3D Simulation Model

Microstrip Design Example for 8 mil RO4003



List of current board layouts for Edge Launch

1. 8 mil RO4003 Microstrip 40 GHz – Layout 007
2. 8 mil RO4003 GCPWG 40 GHz – Layout 008
3. 8 mil RO4003 Microstrip 70 GHz – Layout 020
4. 8 mil RO4003 GCPWG 70 GHz – Layout 021
5. 5 mil RO5880 Microstrip – Layout 031
6. 10 mil RO4835 Microstrip – Layout 032
7. 10 mil RO4350 Microstrip – Layout 033
8. 8 mil Megtron 6 Microstrip – Layout 034
9. 10 mil RO4350 GCPWG – Layout 035
10. 10 mil isola Astra Microstrip – Layout 036
11. 10 mil isola Tachyon Microstrip – Layout 037

ELF110 Edge Launch Connectors

ELF110-001

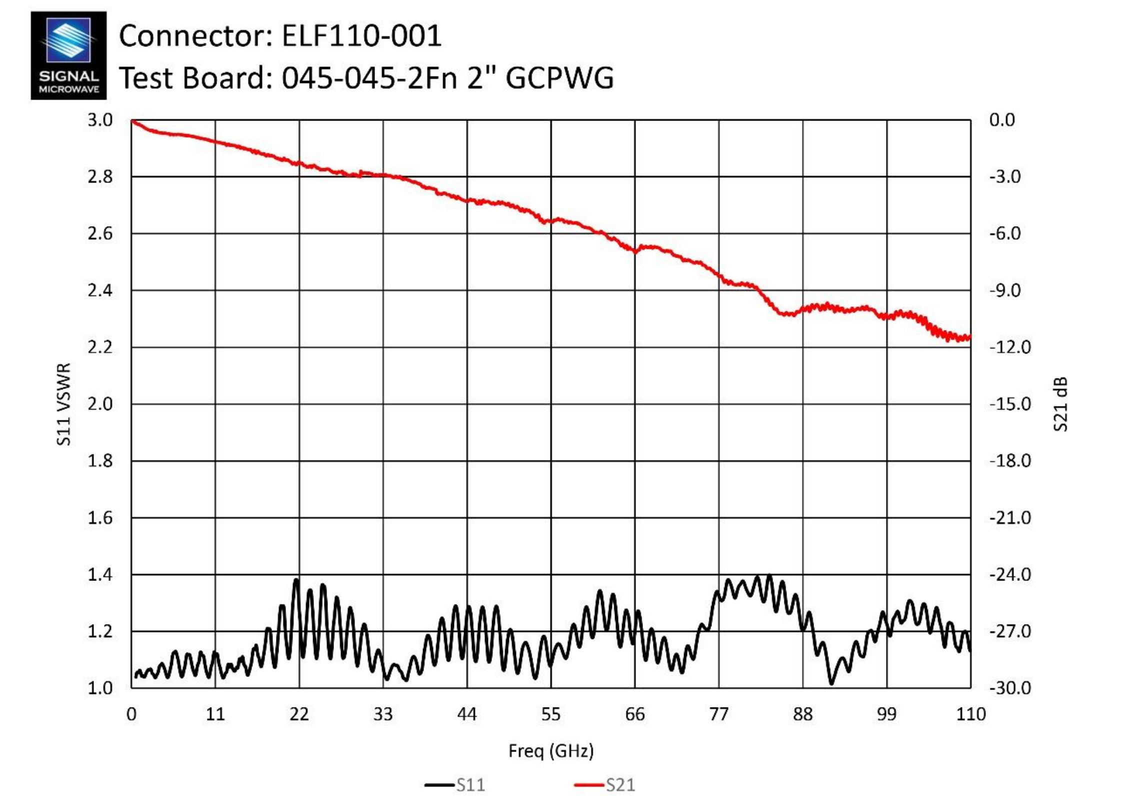
ELF110-002

- 1.0mm Interface with a bandwidth of 110 GHz
- Lowest priced on the market at around $400 each
- No Soldering Required
- Smaller pin size for higher frequency
- Body sizes are the same as our other edge launch connectors
- Only the Top Ground is connected to the board
- Board Design Support Available
- Test Boards Available
- The only 1.0mm edge launch connector with published test data

SIGNAL MICROWAVE

Test Boards and Data

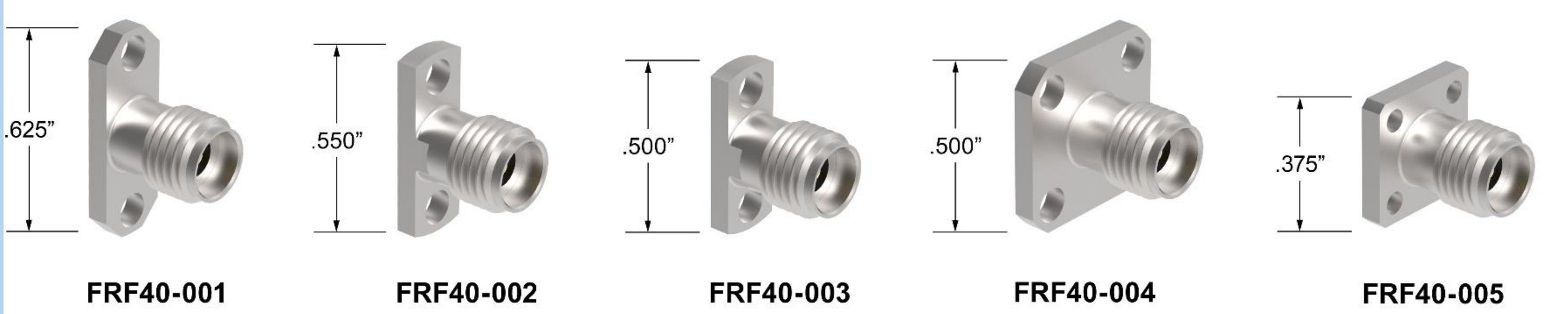
- Boards were developed with Isola
  - Isola wanted to show their material will work to 110 GHz
  - Signal Microwave needed test boards
- Special configuration of Isola Astra material was used
  - Isola Astra MT 77
  - 4.9 Mil thick
  - Dk = 2.9
  - Dk of material was measured using a free space method
- Signal Microwave designed the layout to work to 110 GHz
- Boards and connectors were tested at Isola
- Plots for all of the boards are available
- Test boards are available as loaners only
- Board layout information is available for free to the customer



VSWR 1.4:1 typical (15 dB return loss)

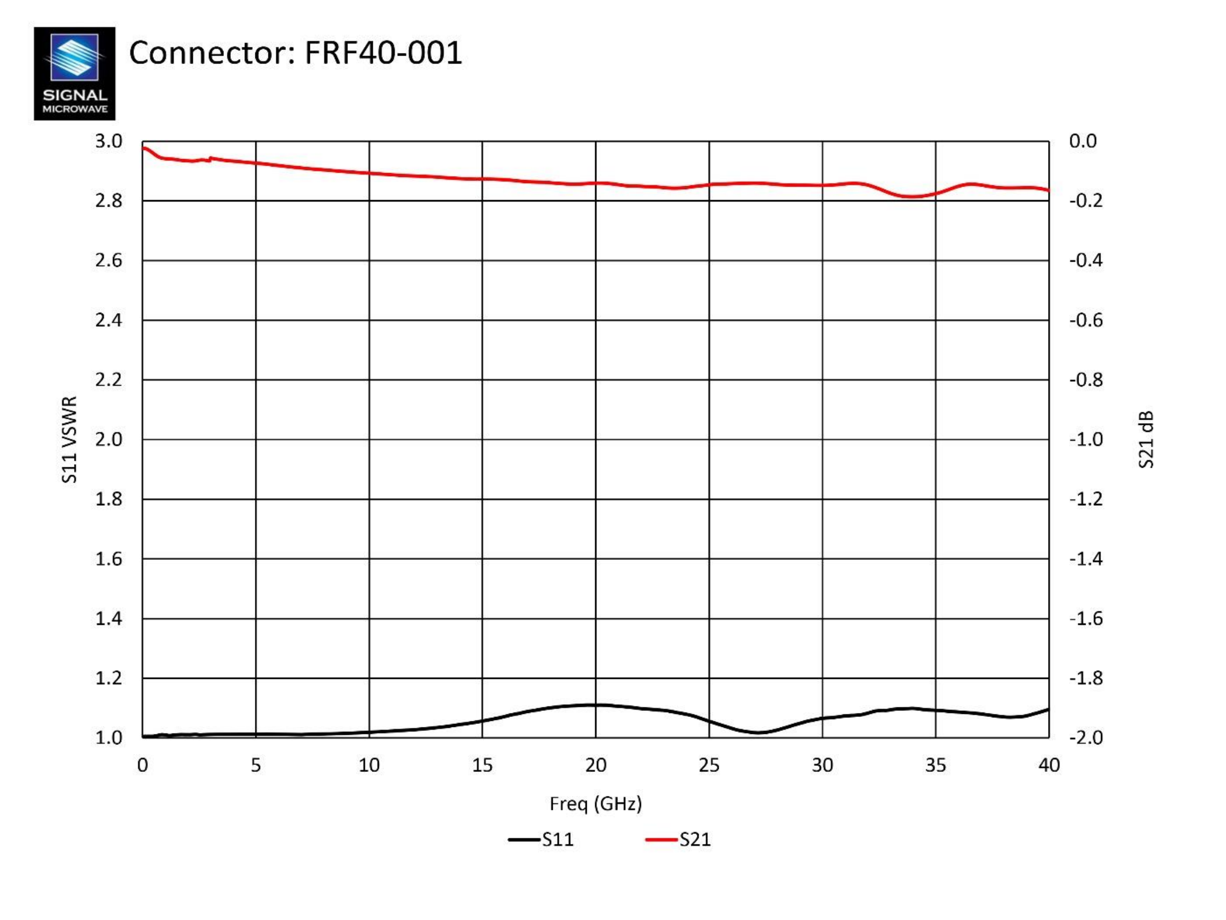
FRF40 Field Replaceable connectors

- 2.92mm Interface - mode free through 40 GHz
- Low VSWR:
  - DC – 27.0 GHz......1.10:1
  - 27.0 – 40.0 GHz....1.15:1
- Rear socket for a 12 mil launch pin or glass to metal (hermetic) feedthrough
- Direct replacement for the Anritsu K and Southwest Microwave 12 mil pin versions
- Commercial grade version with temperature range from -55C to +105C
- Launch accessories in development
- Standard 2 hole and 4 hole versions available

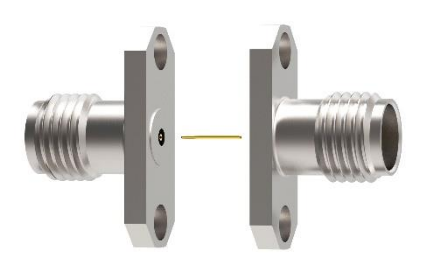


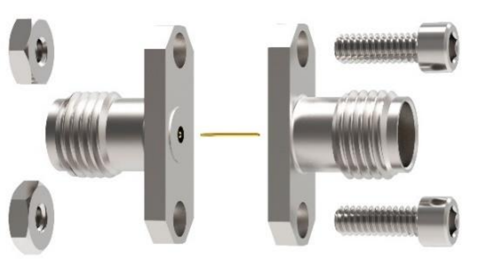
SIGNAL MICROWAVE

FRF40 Testing as a Back-to-Back Pair



- Back-to-back pair data includes both connectors.
- Individual connector data can be extracted if the pair is symmetrical and low loss
- S21: For insertion loss each connector is ½ total loss of the pair
- S21 = .1 dB per connector
- S11: For VSWR the square root of a pair is the VSWR of each individual connector
- VSWR $\sqrt{1.12}:1 = 1.06:1$





Threaded Connectors or Blind Mate (Push-On)

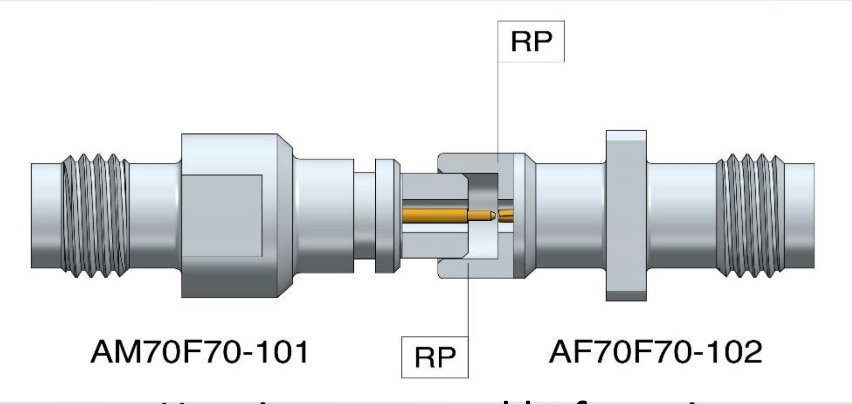
- Traditional RF connectors are threaded
- Advantages:
  - These allows the connector mate to establish a determined reference plane
  - Supported by NIST traceable calibration standards
  - They are tried and true for RF performance
- Dis-Advantages
  - they are cumbersome to make connection
  - Space is required for the coupling nuts reduces connector density

- Blind mate (non threaded) connectors were introduced later
- Advantages:
  - They are mechanically easier to use
  - No coupling nuts - more density can be achieved
- Dis-Advantages
  - There is not an established electrical reference plane
  - Not supported by calibration standards
  - Have only recently been added to Mil-STD-348

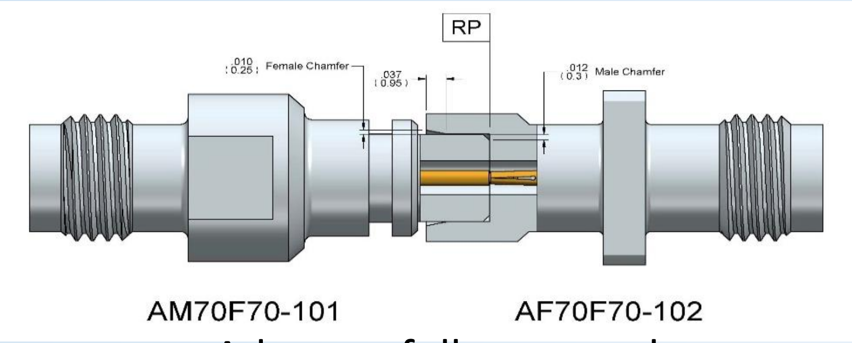
SIGNAL MICROWAVE

1.85m push-on connectors

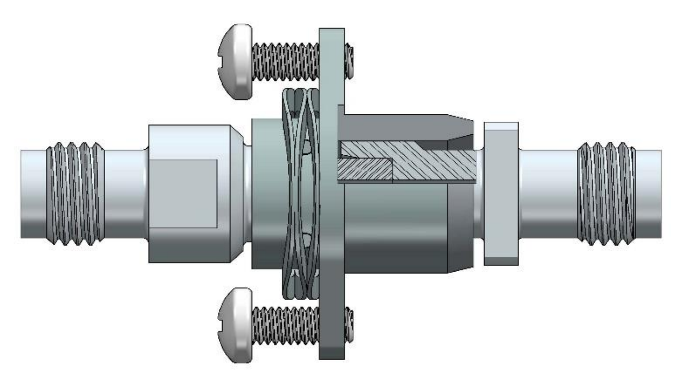
- Developed for Advantest for a 60 GHz WiGig application
- Requirement was for a NIST traceable interface that could be a push-on
- Goes in an ATE system
- Requires a 3D float mount
- The ATE system creates the mating force normally applied by the coupling nut



Housings engaged before pins



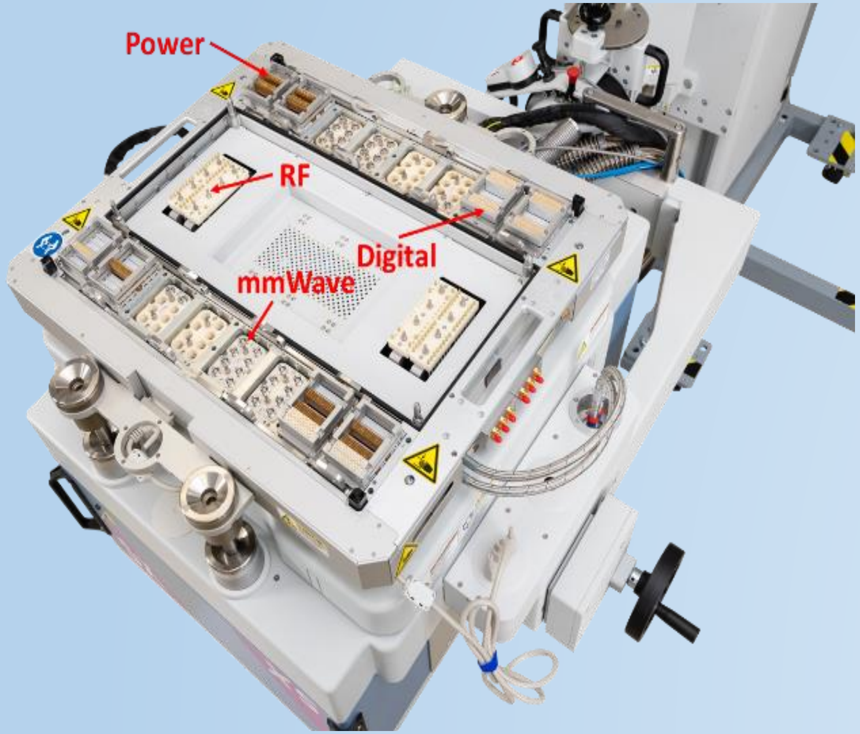
Adapters fully engaged

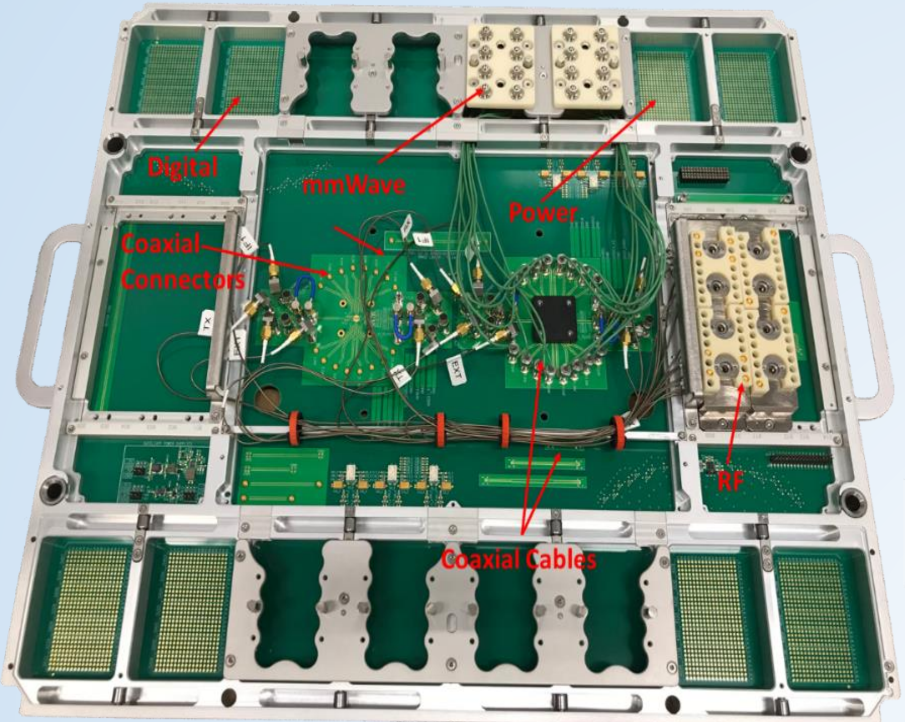

Adapter pair in a float mount

SIGNAL MICROWAVE

Test System Application

- Pictured is the current Advantest ATE system where the adapters are being used
- Picture on the left is the Advantest V93000 ATE system top side showing the different interconnects for digital, power, RF and mmWave
- Picture on the right is the bottom side of an Advantest V93000 ATE test fixture showing the mating connectors and signal routing.

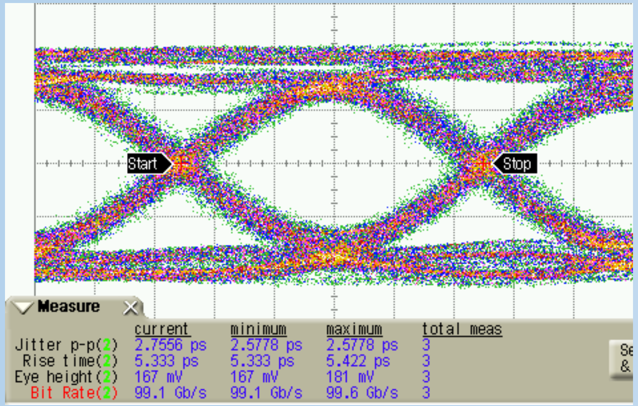


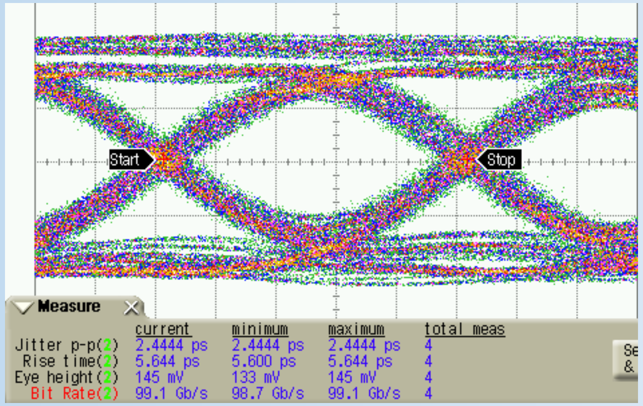


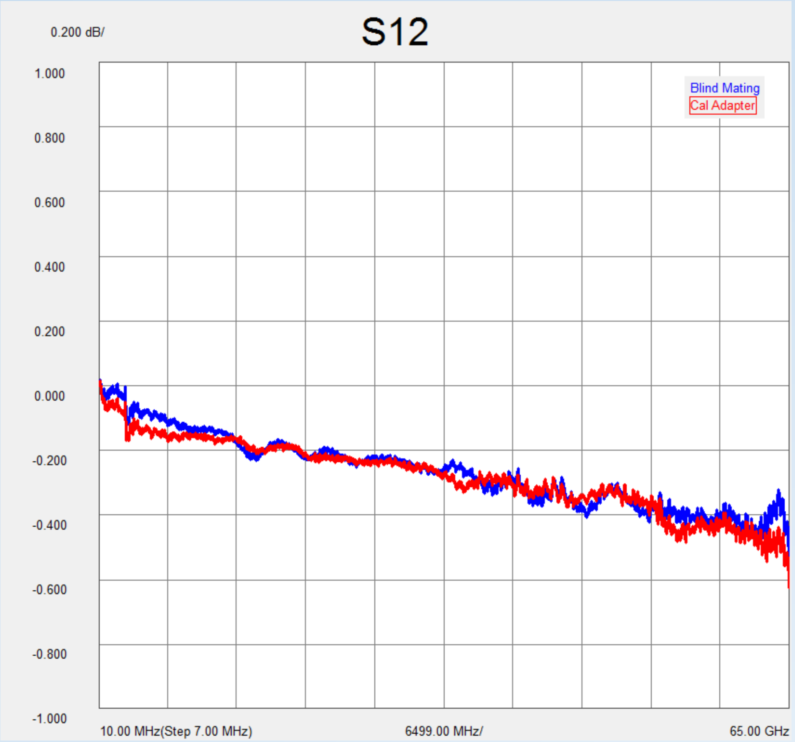
SIGNAL MICROWAVE

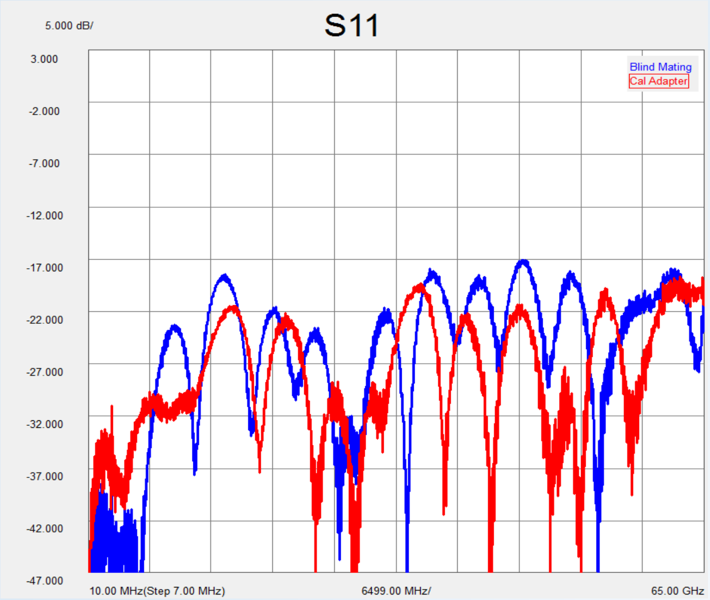
1.85mm Push-On Adapter Data

- The top right chart is insertion loss (S21) comparing a metrology grade adapter with a pair of blind mating adapters
- The bottom right plot is return loss (S11) of 17 dB comparing a metrology grade adapter to a pair of blind mating adapters
- The bottom left plot is an eye diagram of the metrology grade adapter
- The center left plot is an eye diagram of a pair of blind mating connectors
- Initial testing of the Signal Microwave adapter pair was to 110 GHz and they worked mode free to 100 GHz







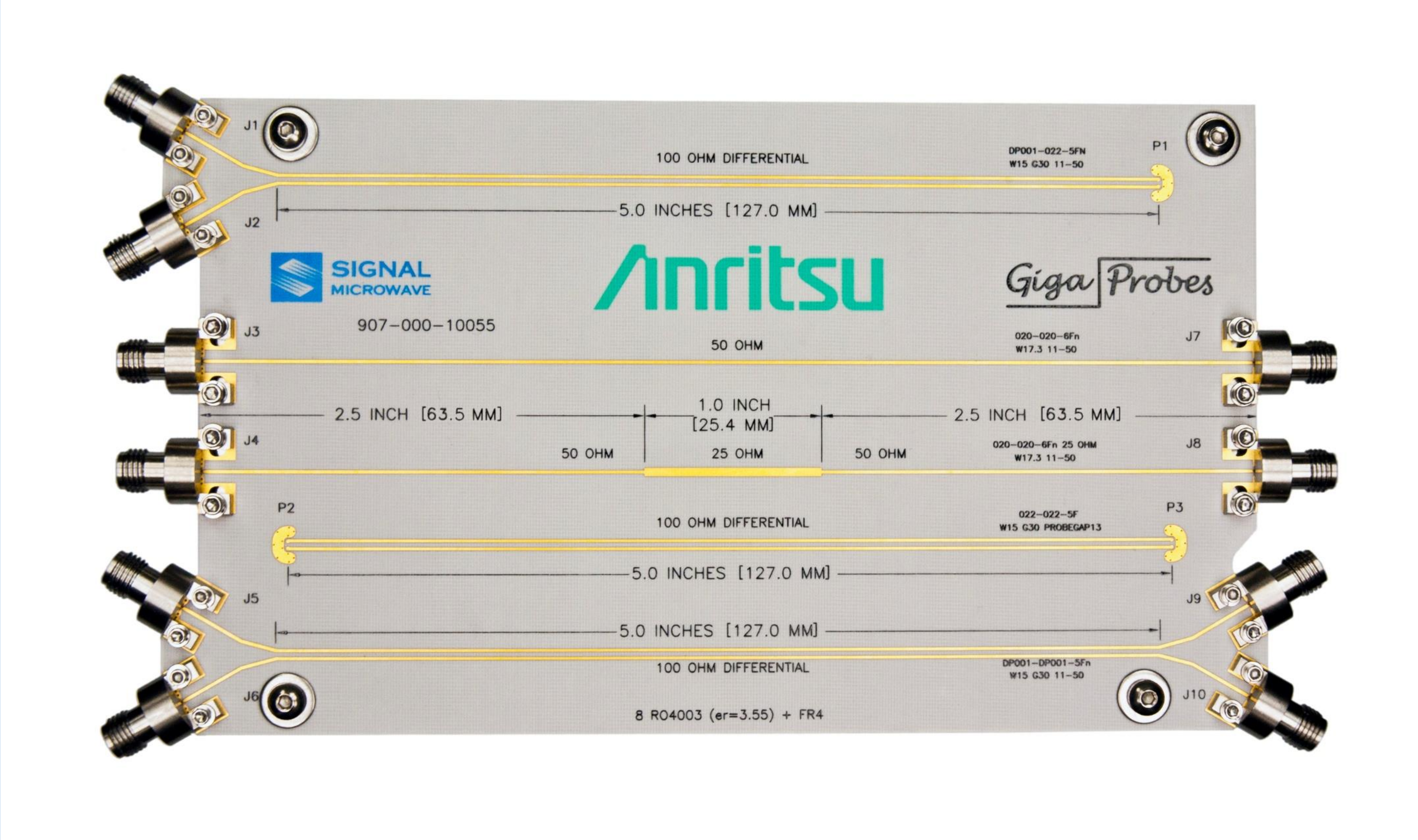


SIGNAL MICROWAVE

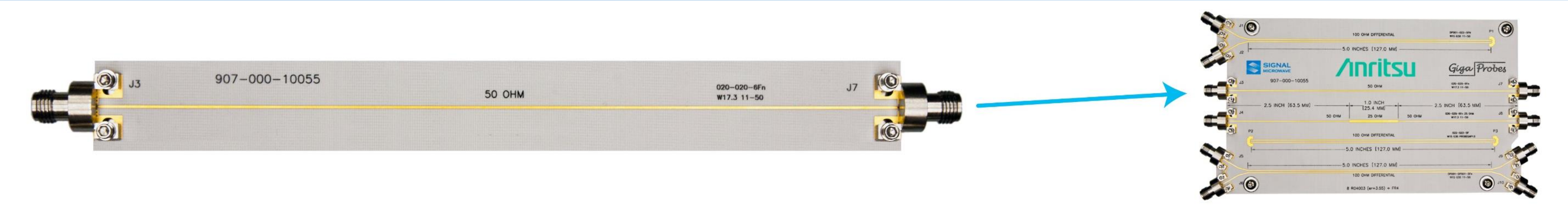
Measurement Verification Boards

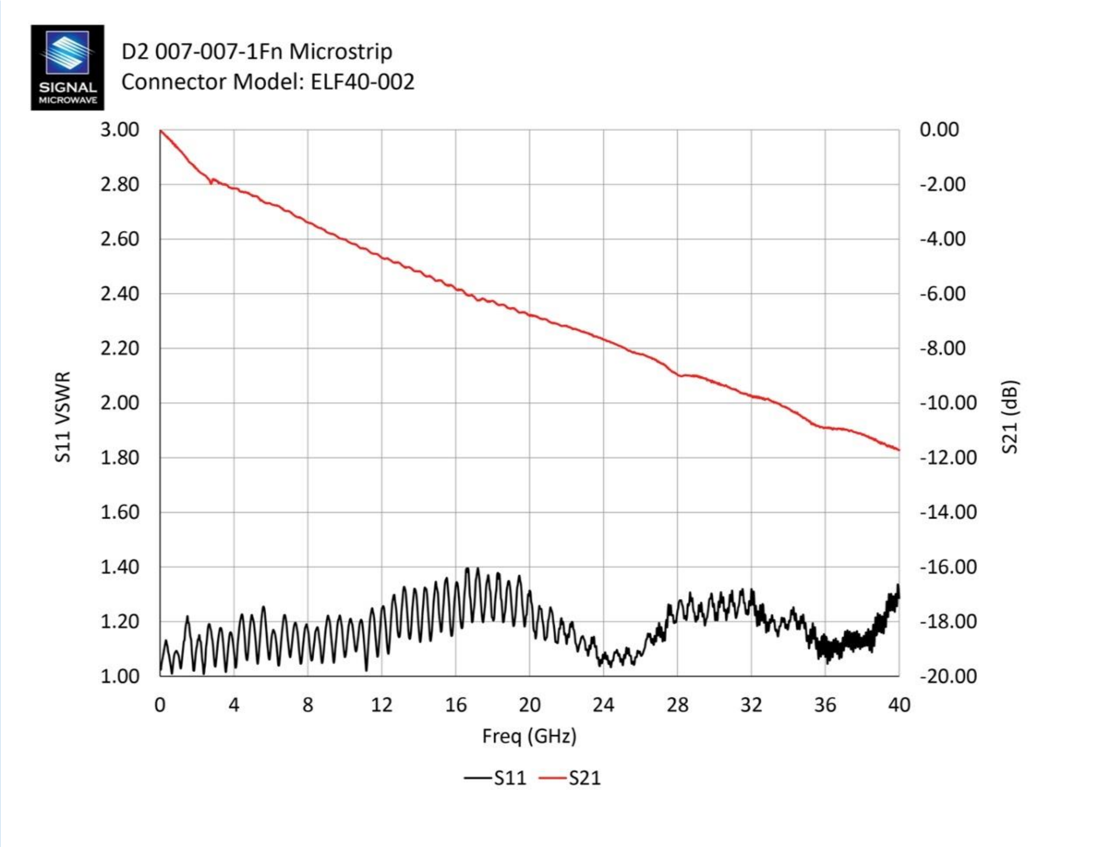
- This work started so we could show the excellent performance of our connectors to customers. We needed the best possible test platforms to do that.
- There are two major purposes for these boards:
  - Measurement verification
  - Improvement in transmission line performance
- Measurement verification
  - "Golden Standard" boards with data which can be used to verify a test set-up including calibration verification
- Improvement in transmission line performance
  - Helps us provide designs that have the best possible performance
  - Gives us the ability to make recommendations to customers based on data
  - Shows the excellent performance of the connectors

Probe and Connector Demo Board



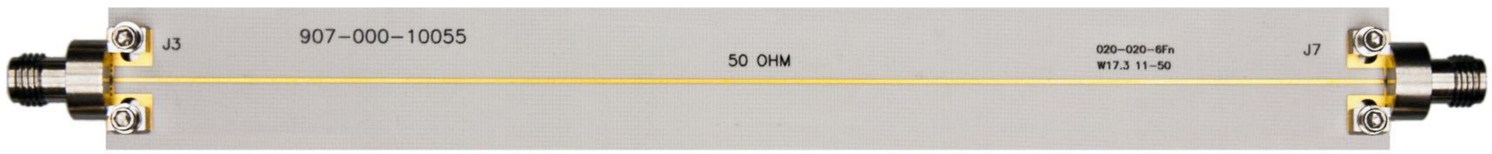
Through Line S-Parameters

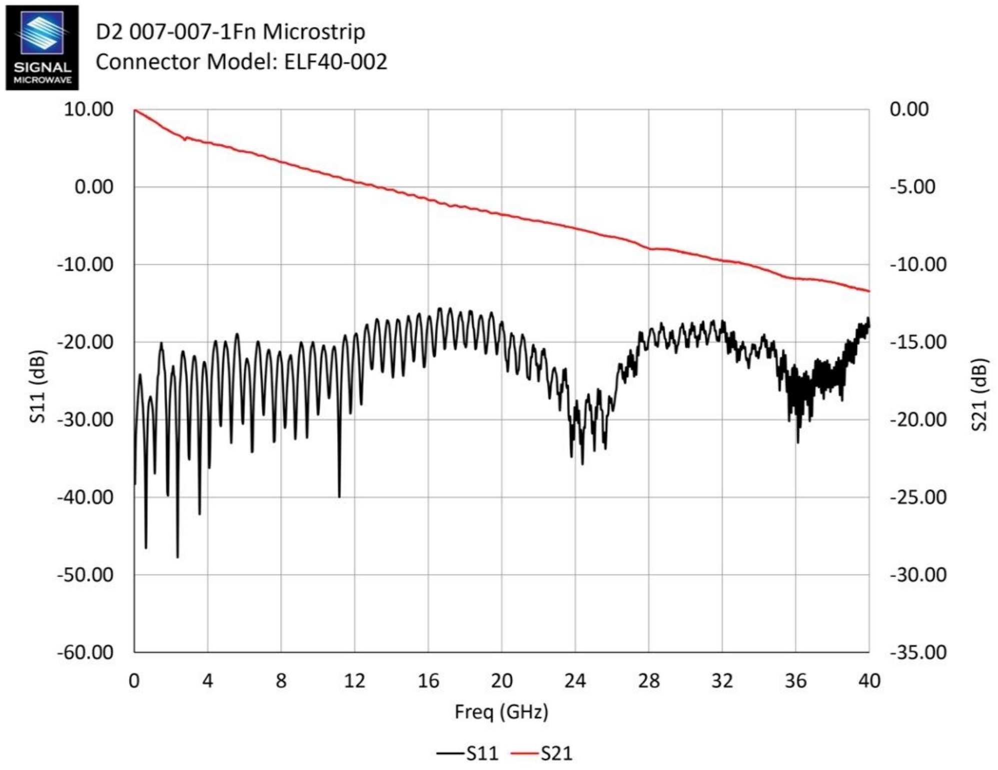




- Here is a plot showing the measured S11 and S21 results for the 50 ohm through line on the demo board
  - S21 shows 40 GHz of bandwidth
  - S11 shows a max VSWR of 1.4

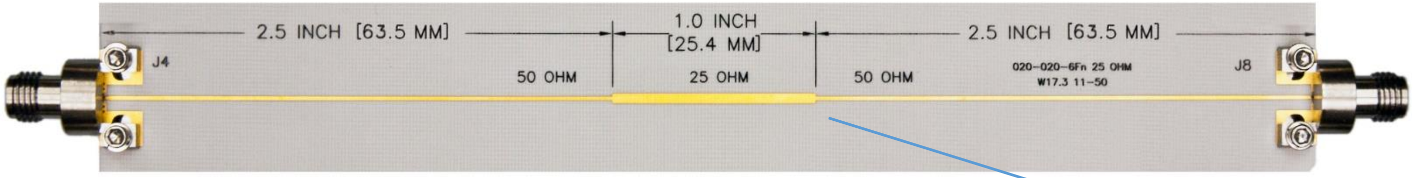
Through Line S-Parameters return loss

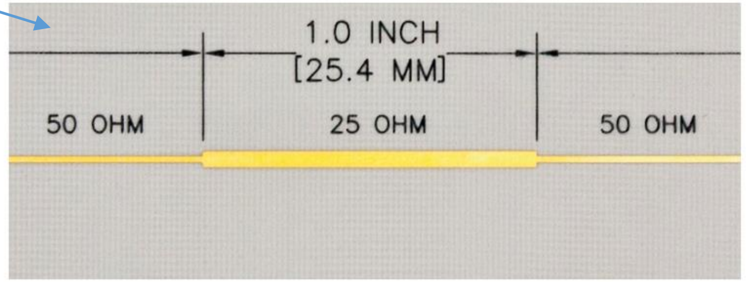


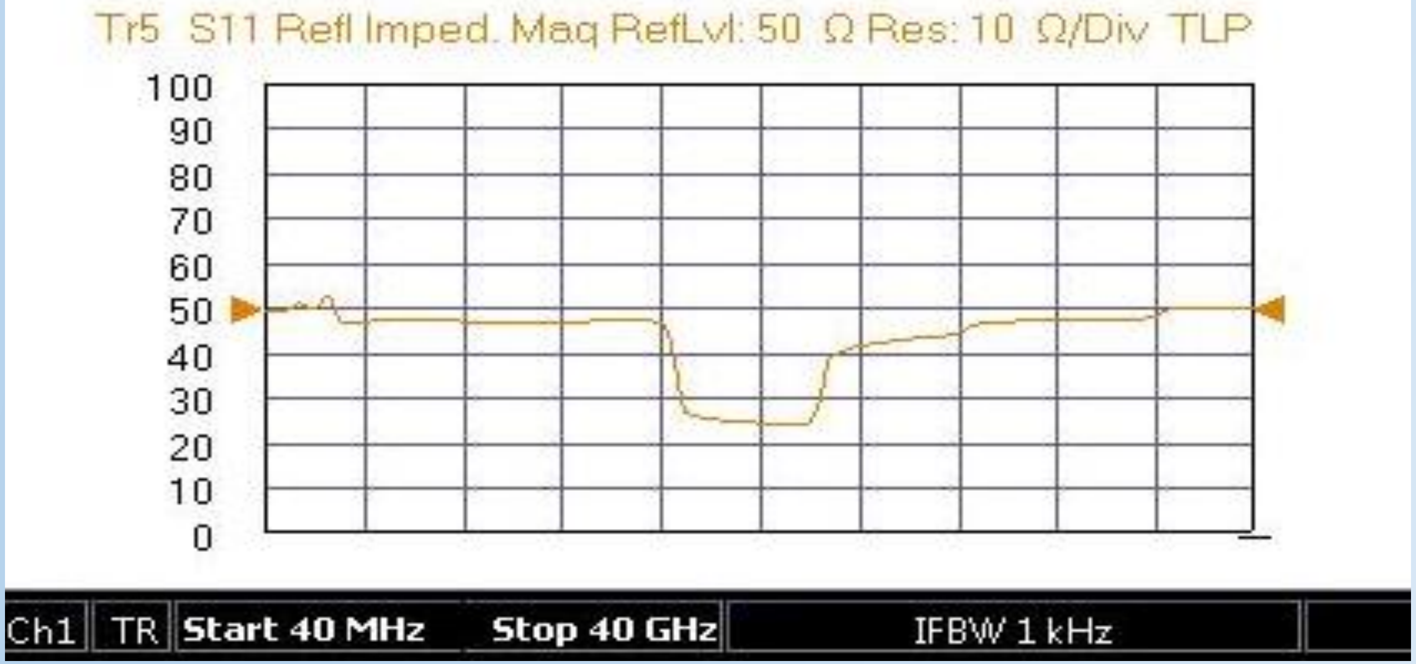


- Here is a plot showing the measured S11 and S21 results for the 50 ohm through line on the demo board
  - S21 shows 40 GHz of bandwidth
  - S11 shows a return loss of 15 dB

Beatty Standard TDR from a VNA



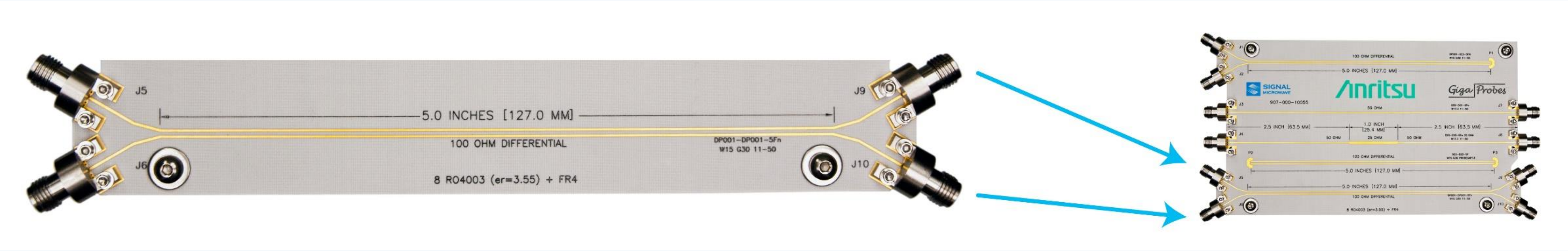


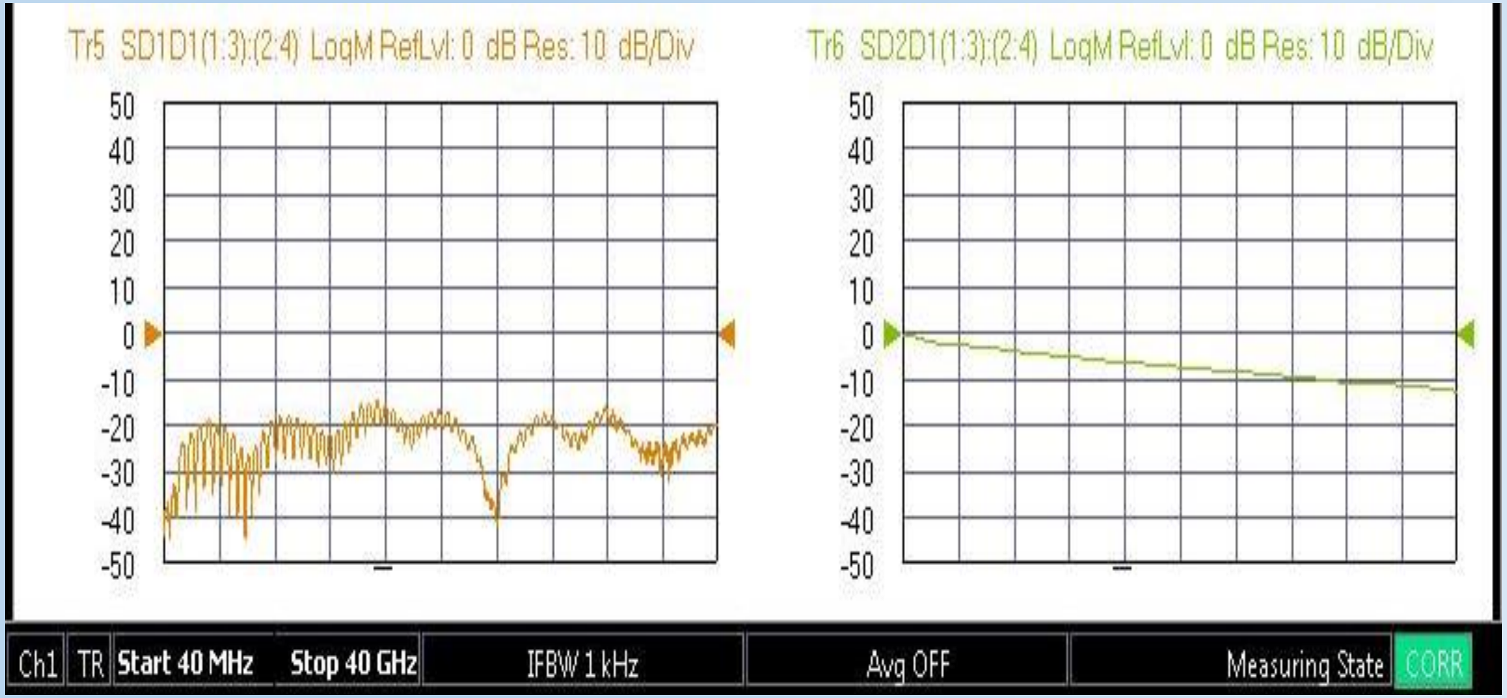


- TDR plot of the 25 ohm Beatty standard line clearly showing the 25 ohm section

SIGNAL MICROWAVE

Probe and Connector Demo Board

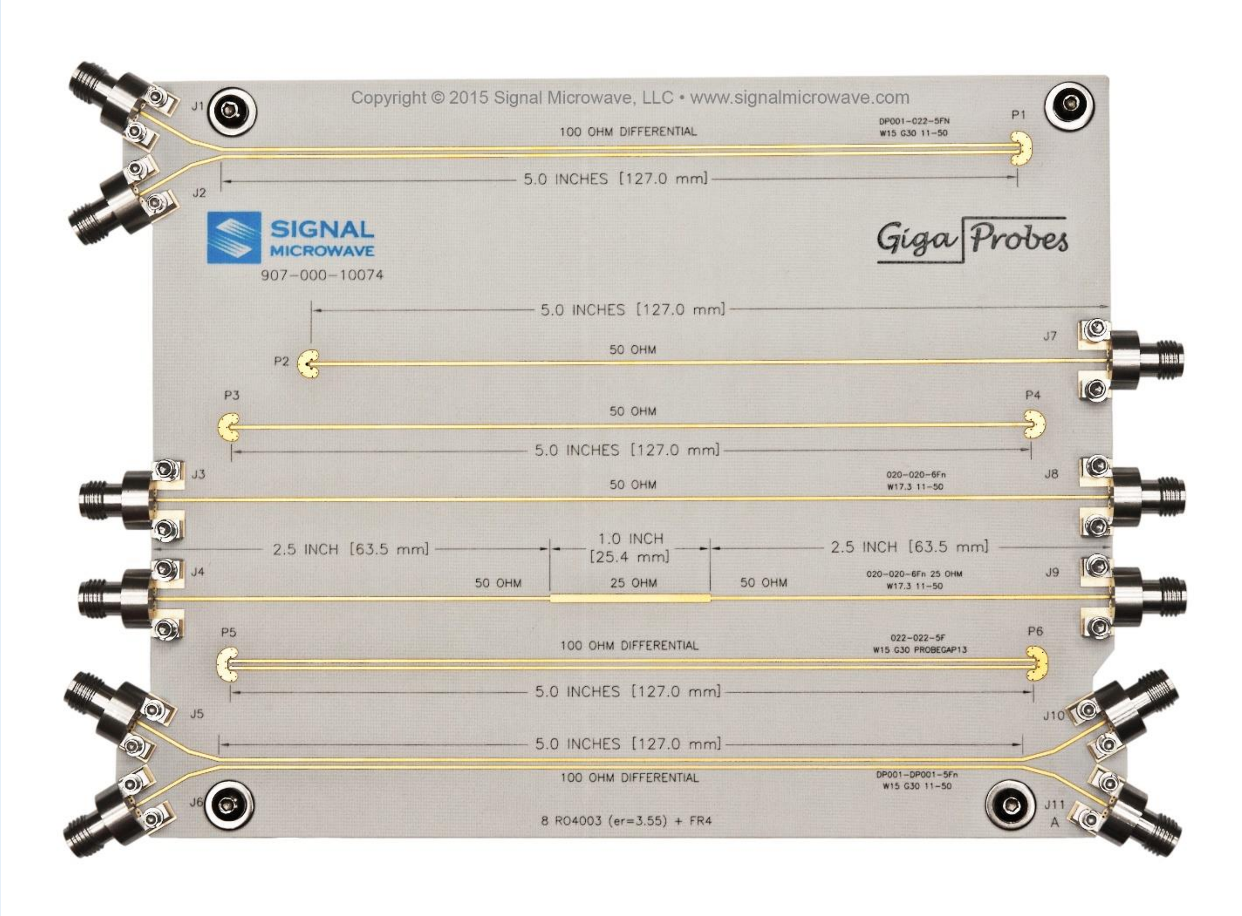




- Here is a plot showing the differential return loss and insertion loss for the 100 ohm through line on the demo board
  - SD2D1 shows 40 GHz of bandwidth
  - SD1D1 shows a return loss of 15 dB

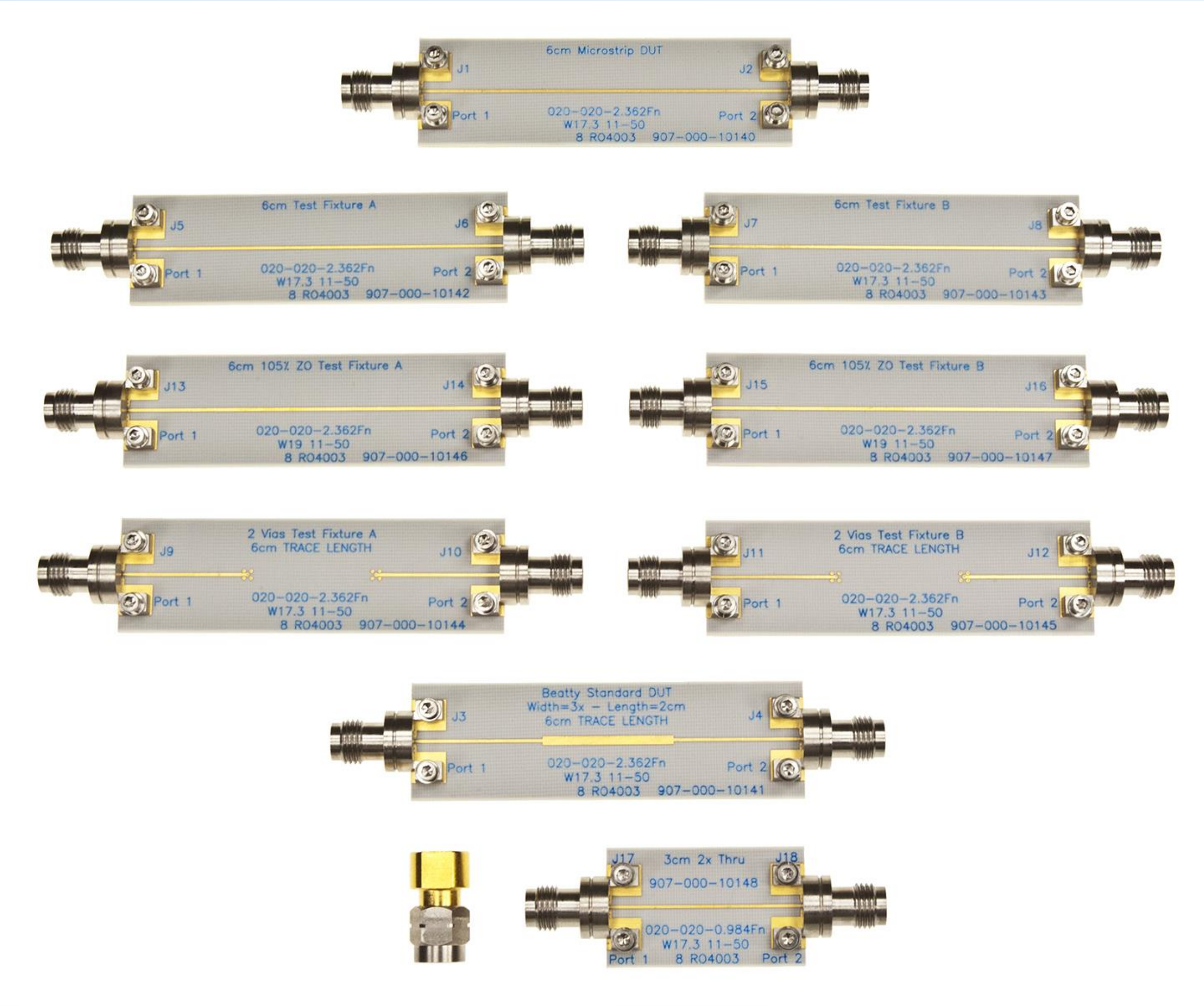
Measurement, Calibration, and Experimental Boards

- This a series of miscellaneous boards to better understand different transmission line structures such as 100 ohm differential pairs.
- It started with our affiliation with GigaProbes
- We see this part of the market expanding and we want to be prepared to support them as well
- Shown is one of the boards done for GigaProbes to verify probe measurements



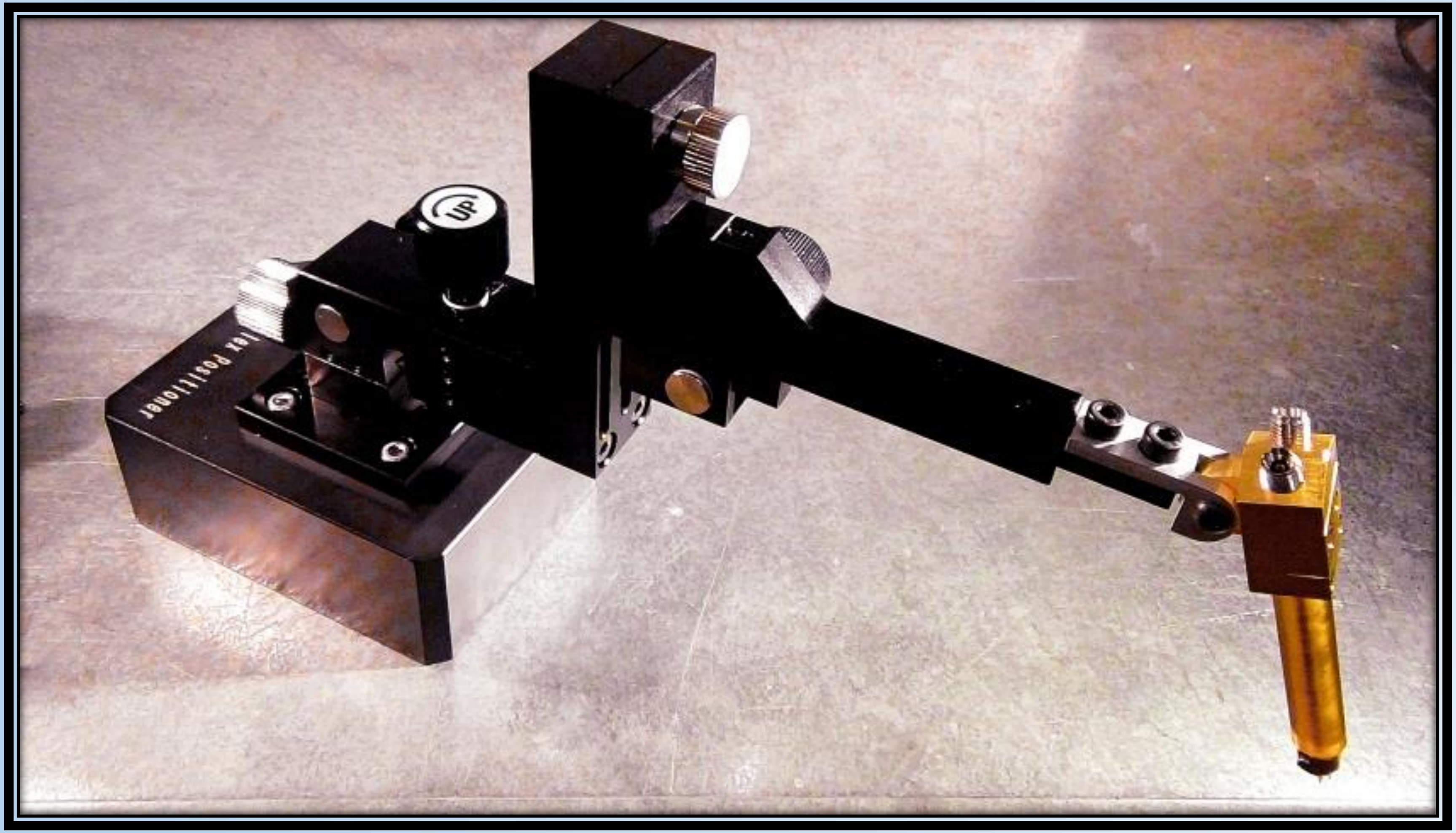
Plug and Play De-Embedding Kit in Support of IEEE P370

- IEEE P370 Committee Title
  - Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz.
- The committee is part of the EMC track of IEEE which is where Signal Integrity is placed
- Boards are part of the track that is evaluating de-embedding techniques
- Each board is measureable to a NIST traceable reference plane
- Verify consistency of measurements after software upgrades
- Training tool for learning how to use different de-embedding techniques

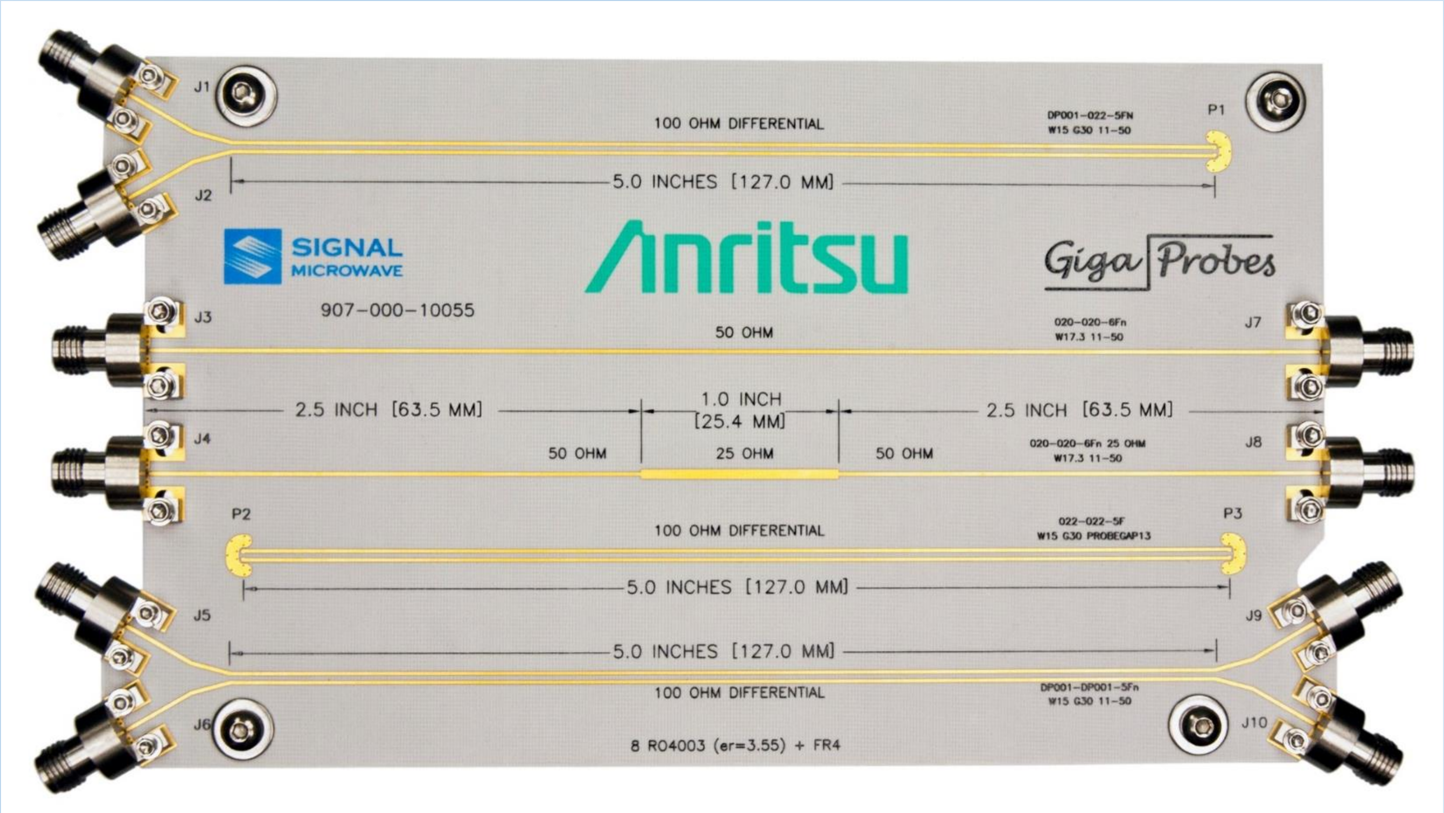


SIGNAL MICROWAVE

GigaProbes DVT40 Desktop Probing System

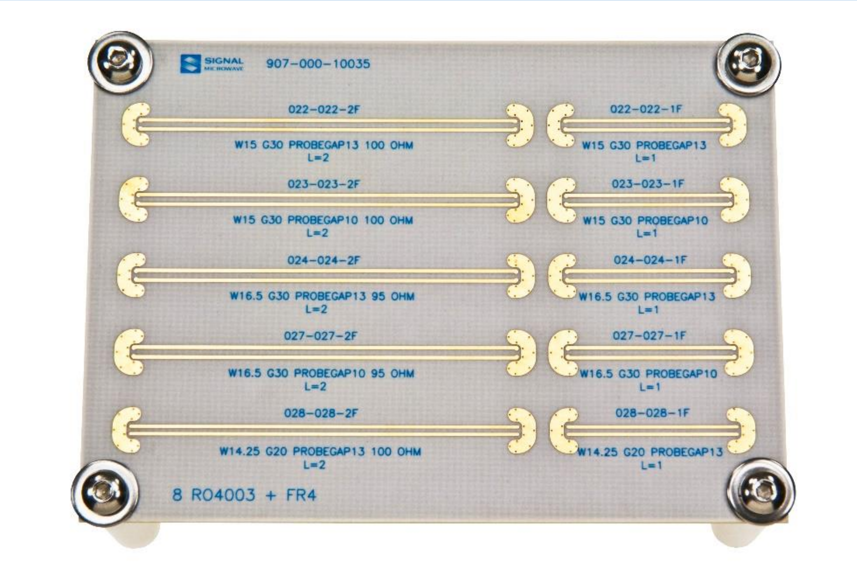


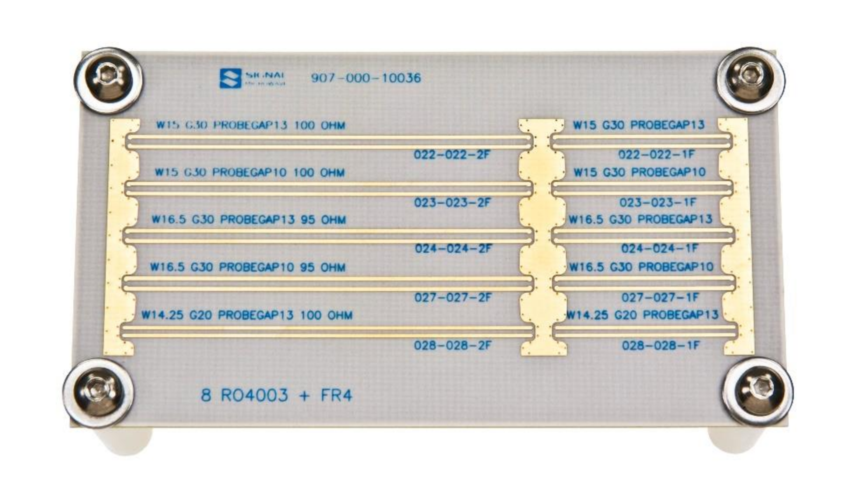
GigaProbes® DVT40 Differential Probe and Anritsu Demo Board



SIGNAL MICROWAVE

Probe Launch Test Boards





- These boards are experimental to test probe launch geometries and line impedances

- It includes a series of similar lines with incremental changes in line spacing and probe landing pad patterns

- Line spacing changes are to work on correlation between predicted impedance and measured impedance

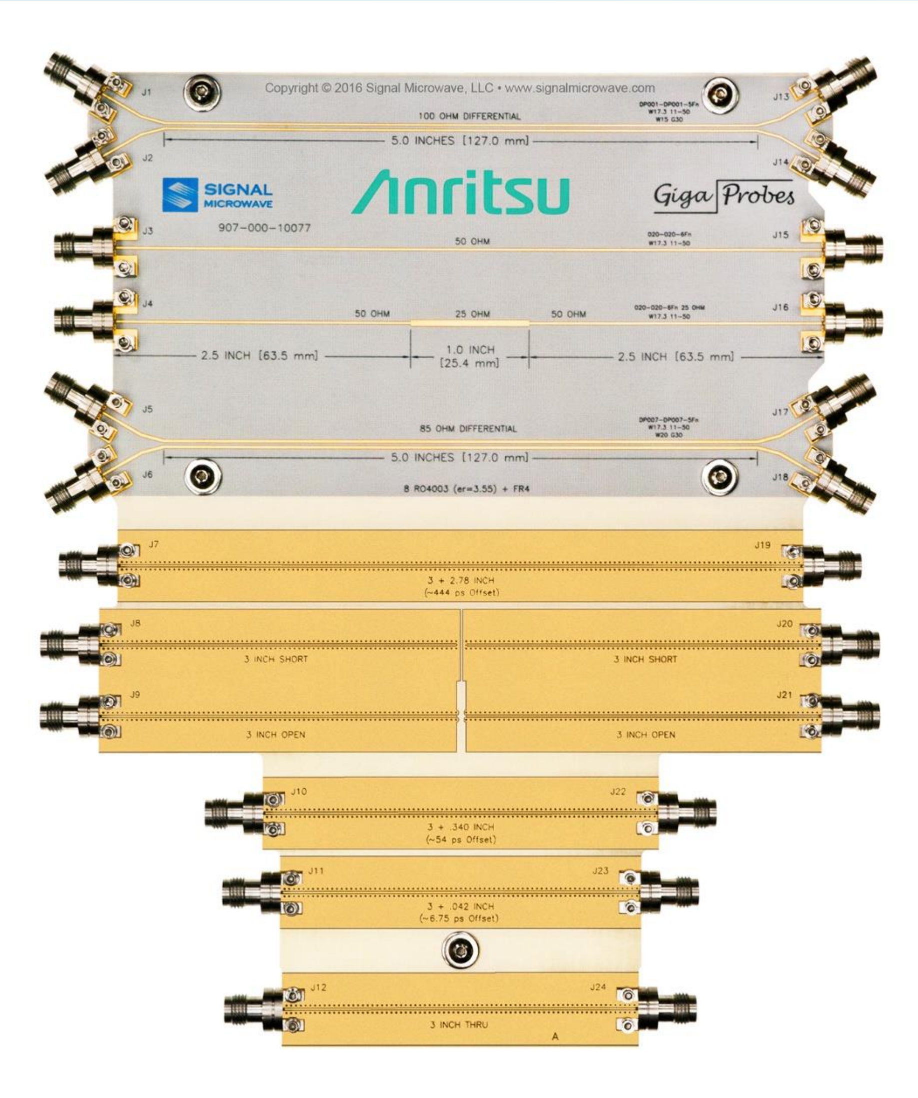
LRL Calibration Board for Anritsu

- LRL is a calibration technique to move the measurement reference plane past the connectors and into the board

- Developed for Anritsu as a training tool for their applications engineers

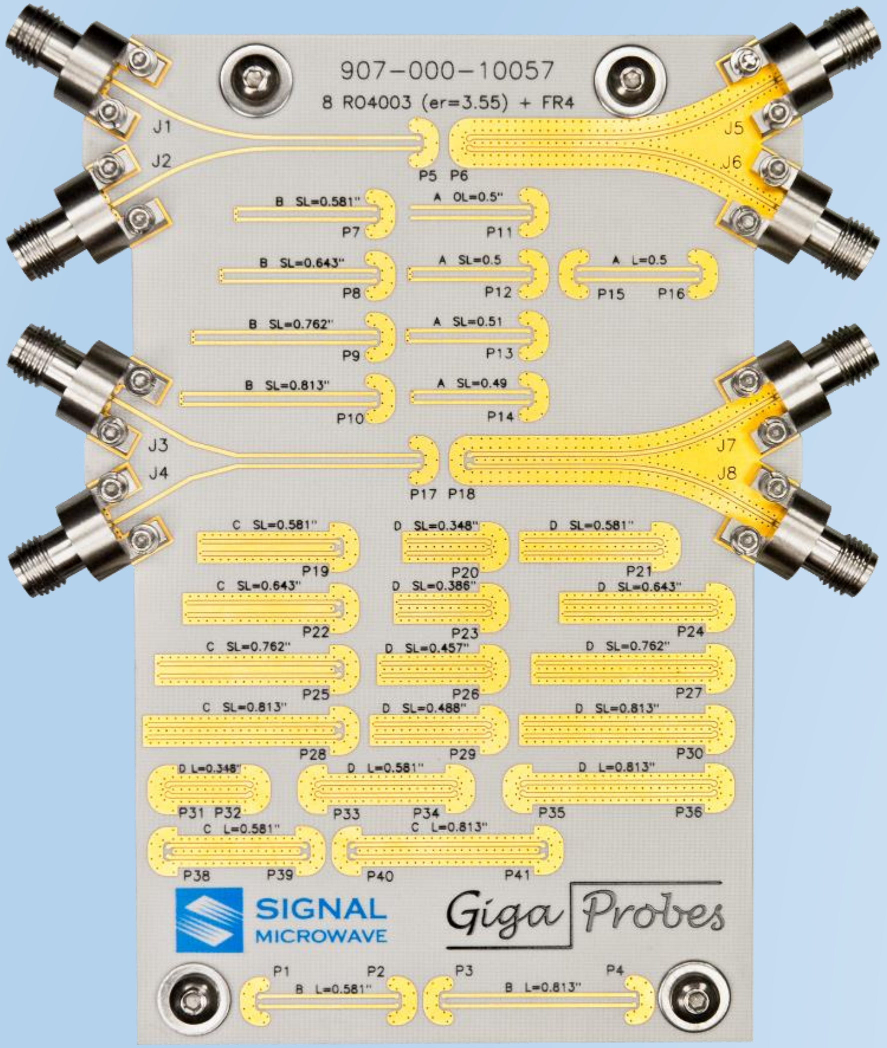
- Has been sold to other customers to help them experiment with LRL calibration techniques

- Referred to a TRL by Keysight



SIGNAL MICROWAVE

Gigaprobe Calibration Development Board



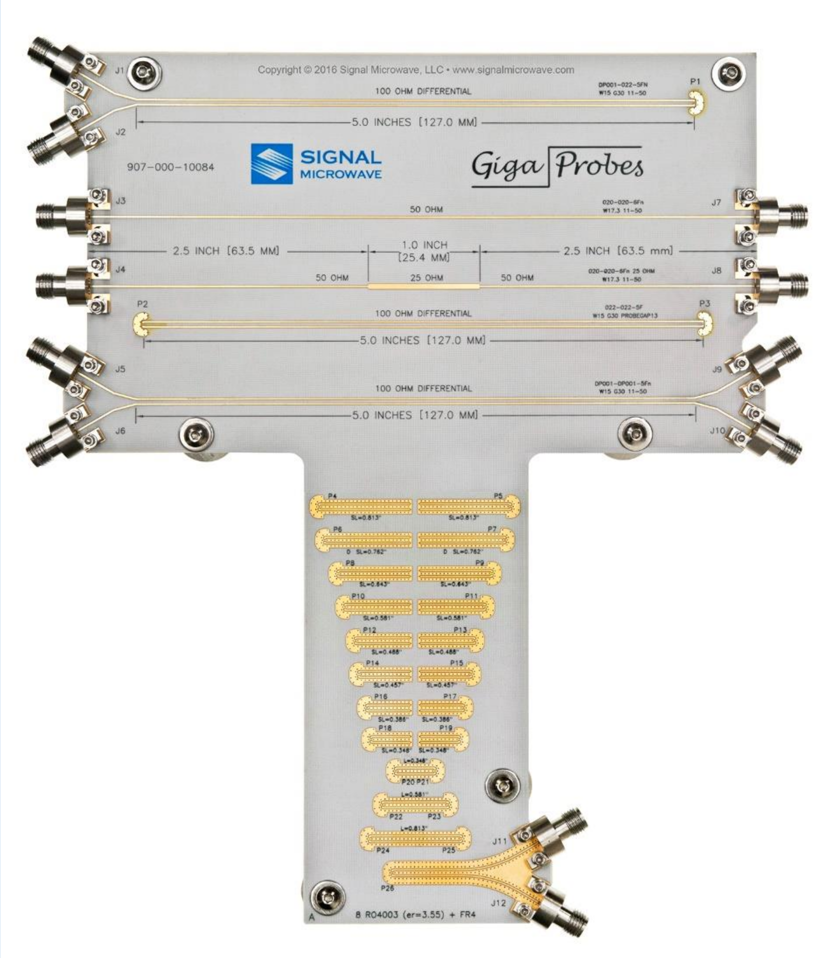
- Experimental board to test various calibration methods for use with the GigaProbe DVT 40 differential probe
- The lines are both 100 ohm differential and 50 ohm single ended separated by vias
- The calibration methods it was designed to try are:
  - LRM
  - SOLT
  - Triple Offset Short

Finalized LRM Calibration Board for GigaProbes

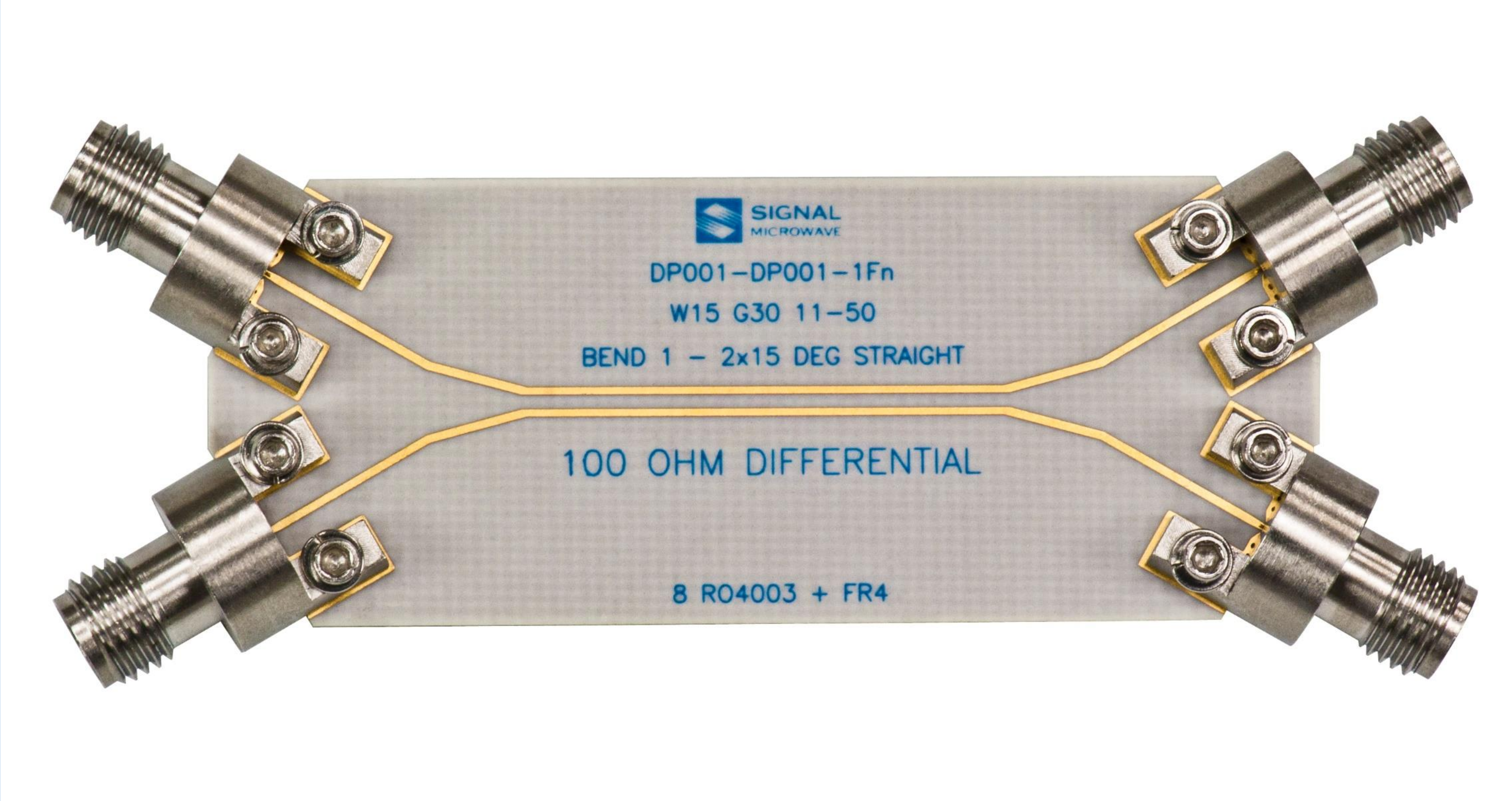
- LRM is another calibration technique

- It moves the measurement reference plane through the probe and onto the board

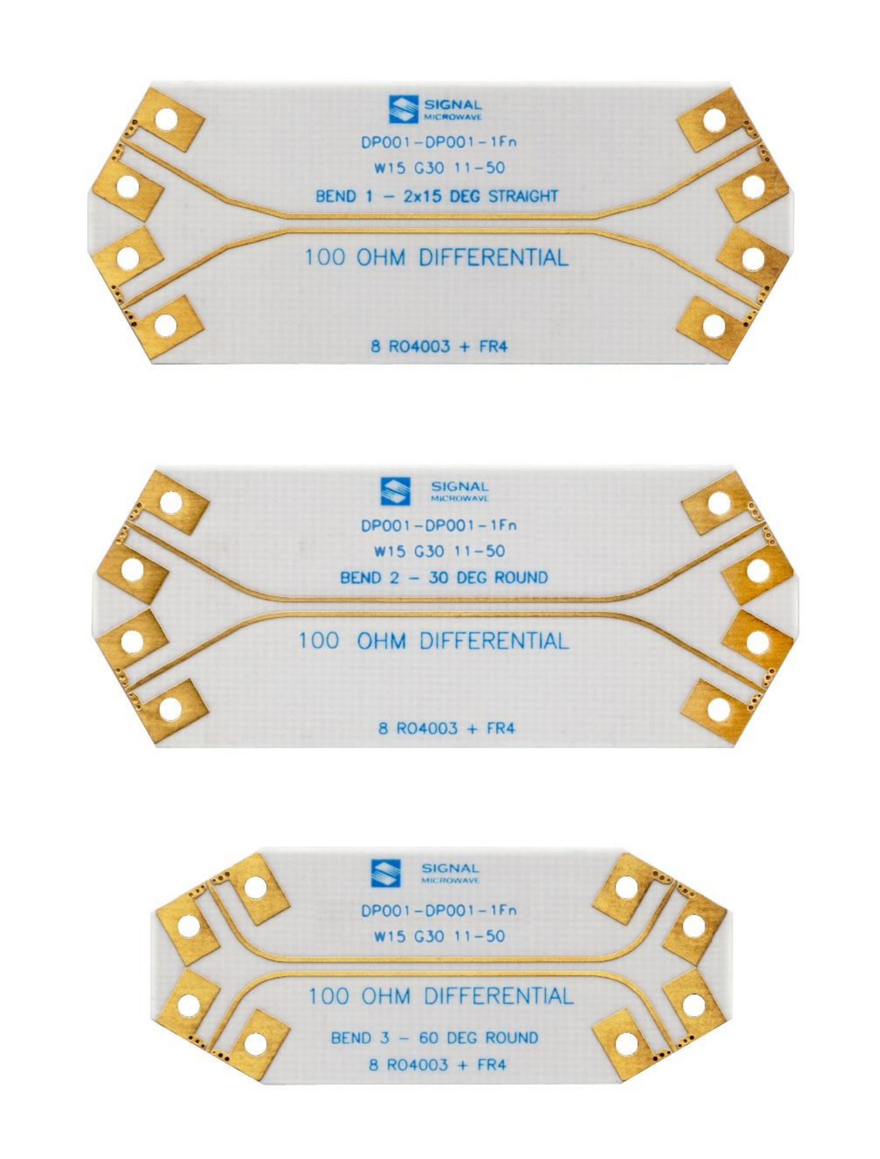
- Referred to as TRL by Keysight

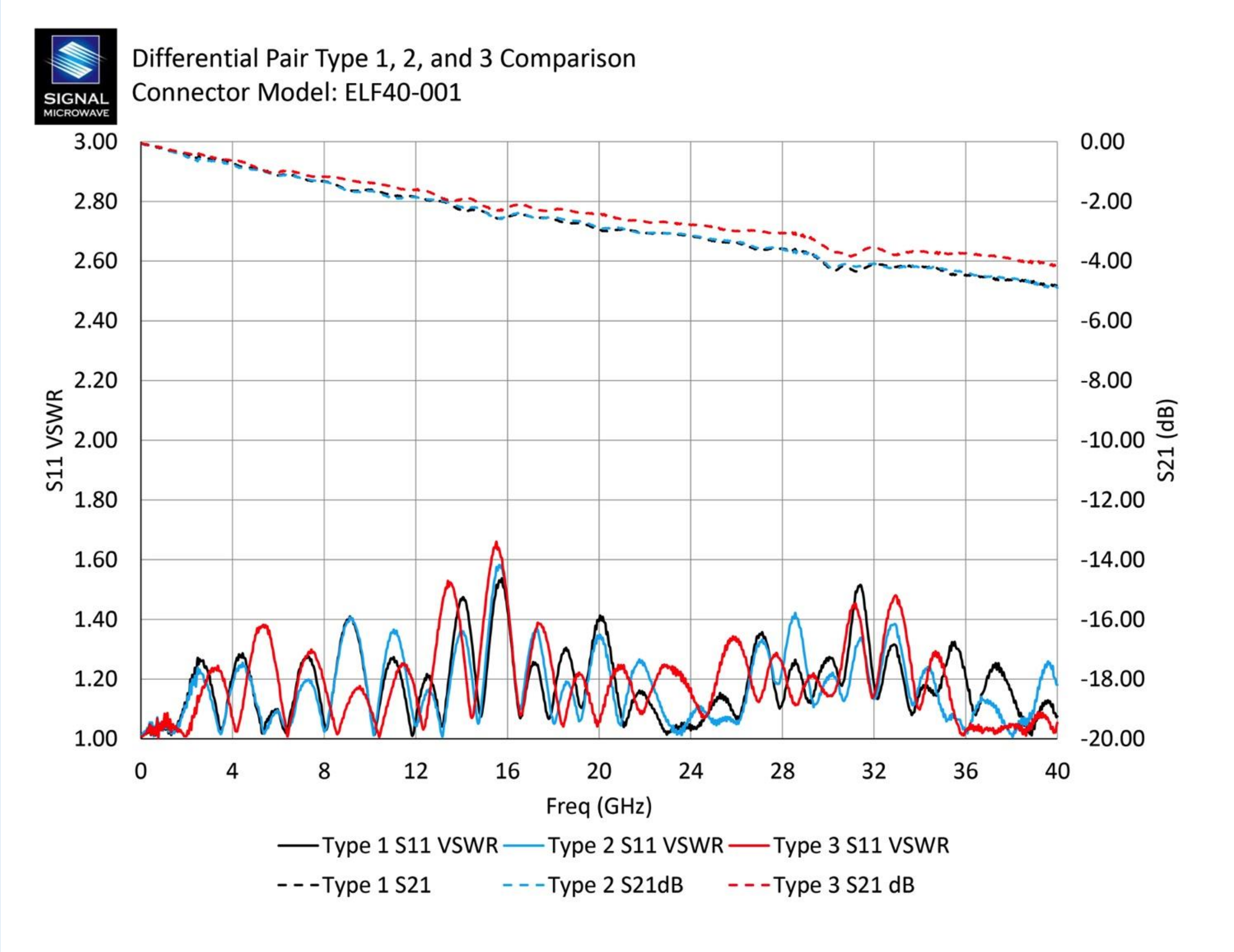


Single Ended to Differential Transitions

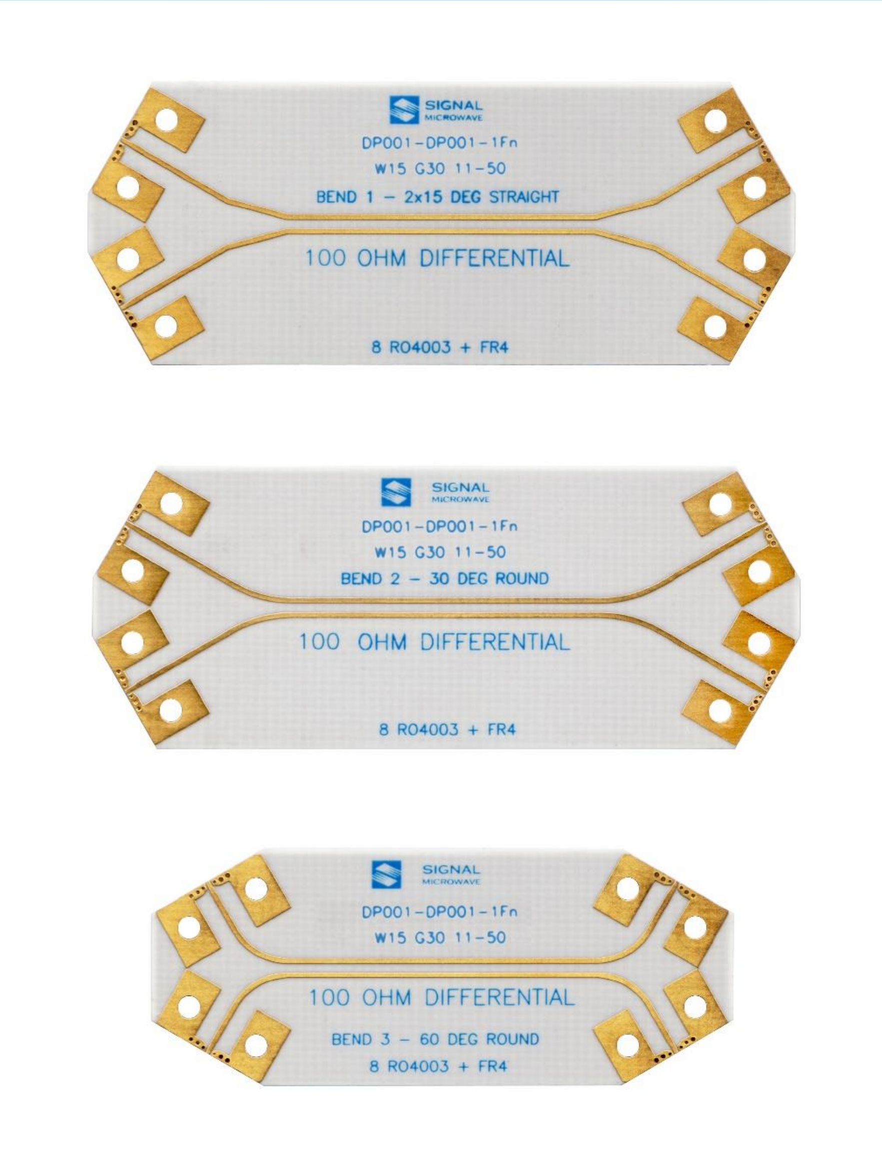


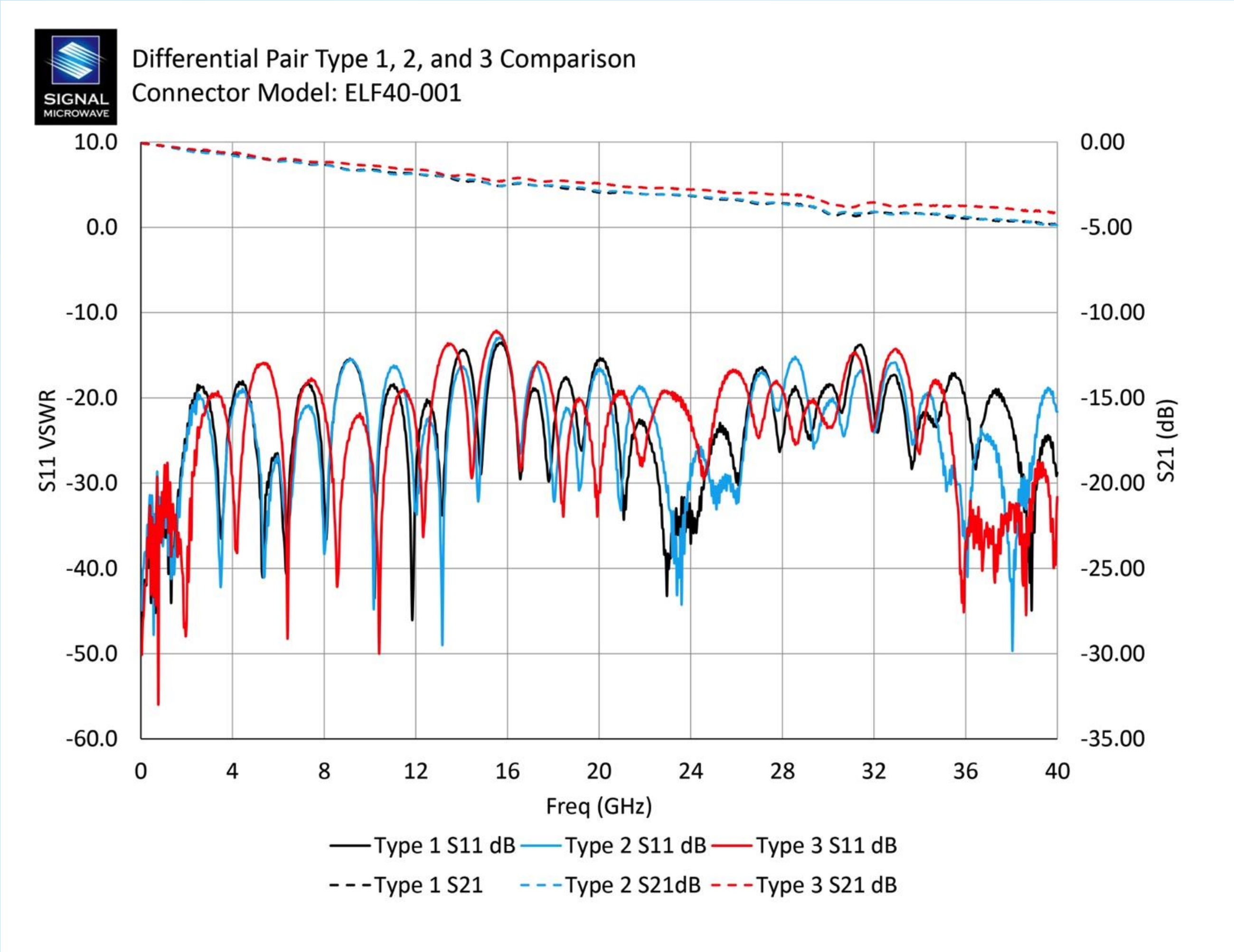
Comparison of Bend Geometries



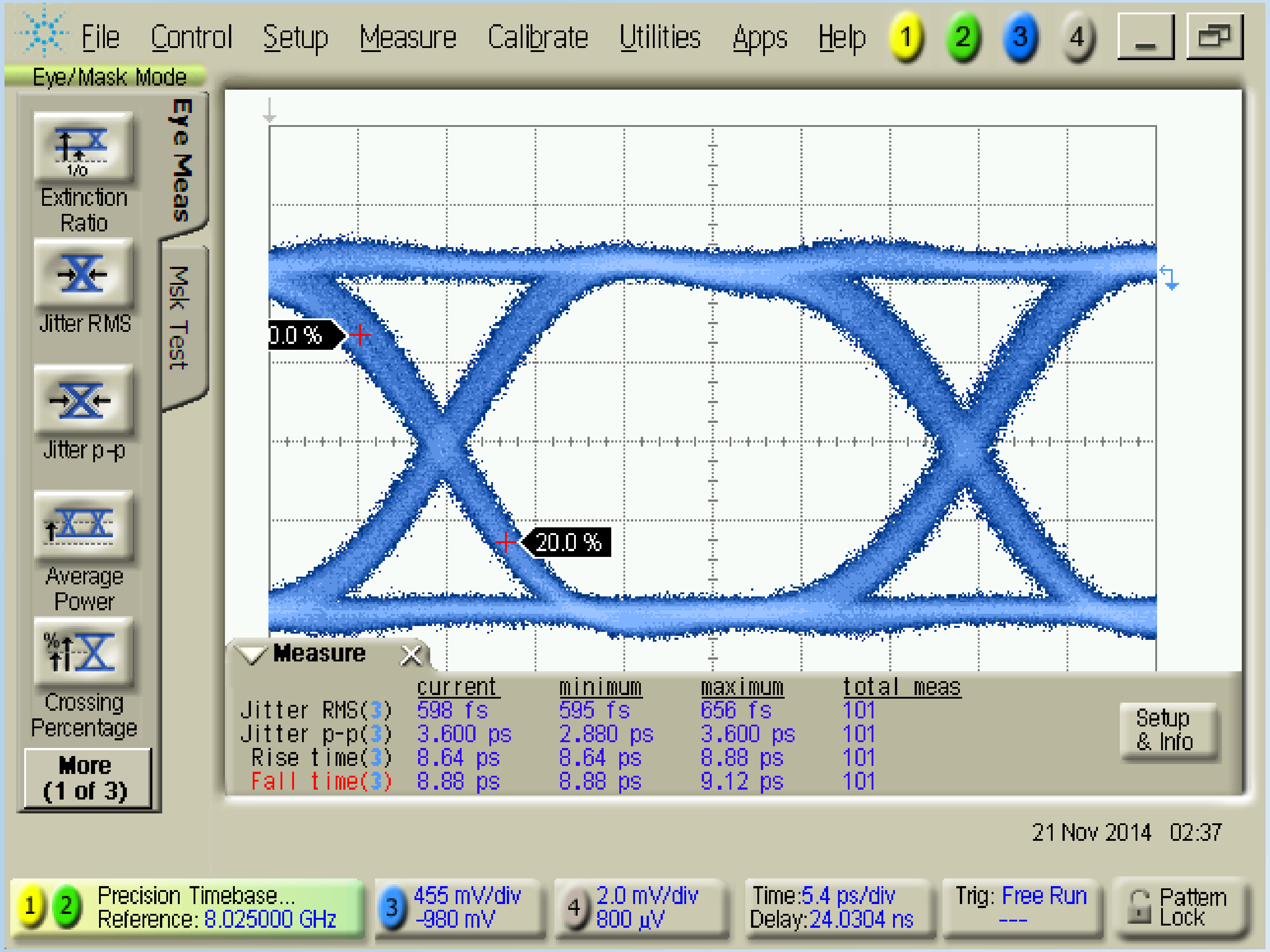


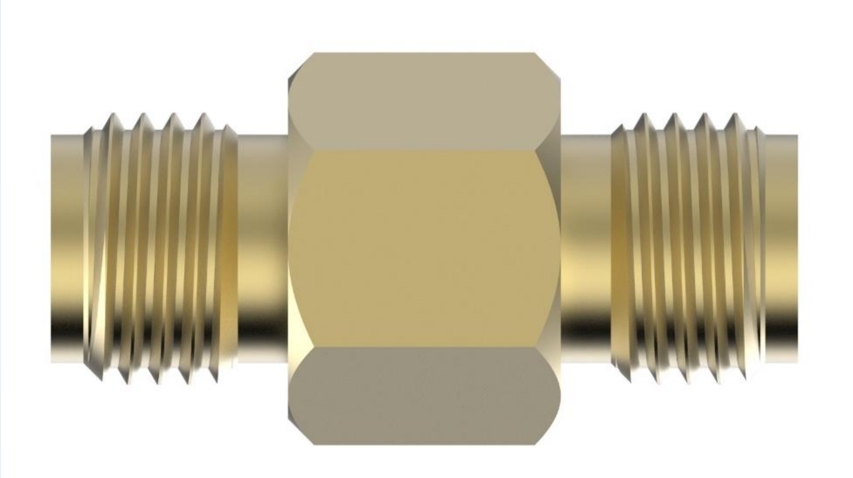
Comparison of Bend Geometries Return Loss





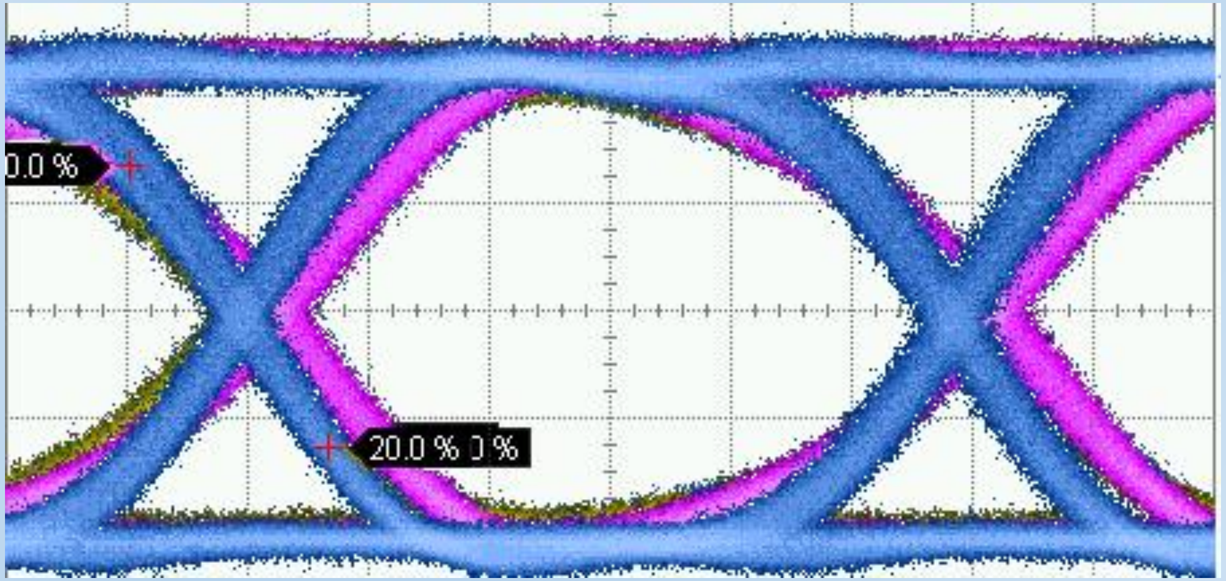
Eye Diagram Testing Baseline Measurement



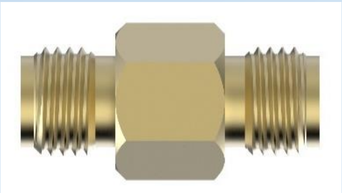


SIGNAL MICROWAVE

D2 1-1 007-007-1Fm with TDR



Blue



Purple

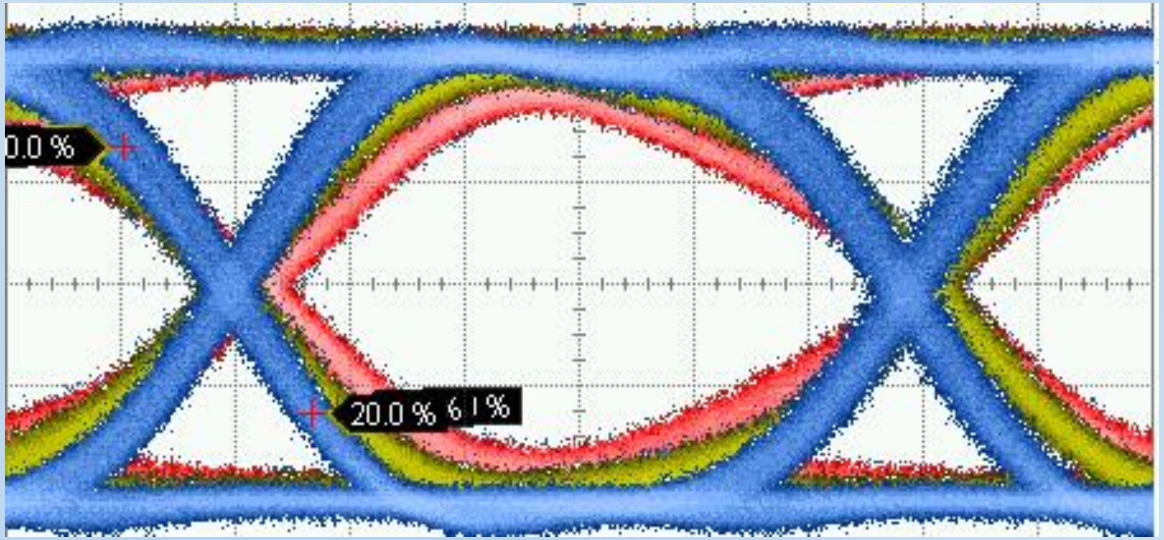
Green

- Different lengths of microstrip line with connectors were measure for jitter and rise time to see the changes due to length.
- Length does not appear to make much difference on the eye diagram.
- Jitter is reduced in the longer line
- Rise is slowed by the longer line

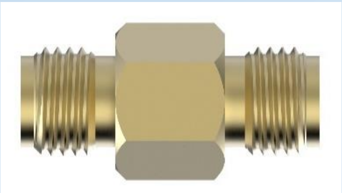
	Jitter RMS (fs) min	Jitter RMS (fs) max	Jitter p-p (ps) min	Jitter p-p (ps) max	Rise Time (ps) min	Rise Time (ps) max	Fall time (ps) min	Fall time (ps) max
adapter	595	656	2.880	3.600	8.64	8.88	8.88	9.12
1 in MS	602	638	2.778	4.111	10.78	11.11	11.78	11.89
2 in MS	531	556	2.778	3.333	12.56	12.78	13.22	13.33

SIGNAL MICROWAVE

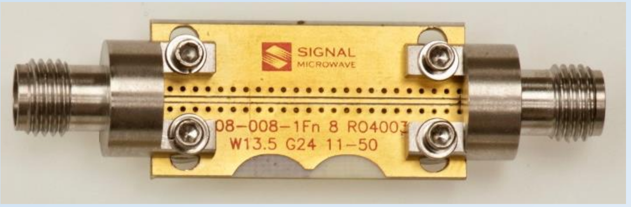
D2 1-1 007-007-1Fm with TDR



Blue



Green

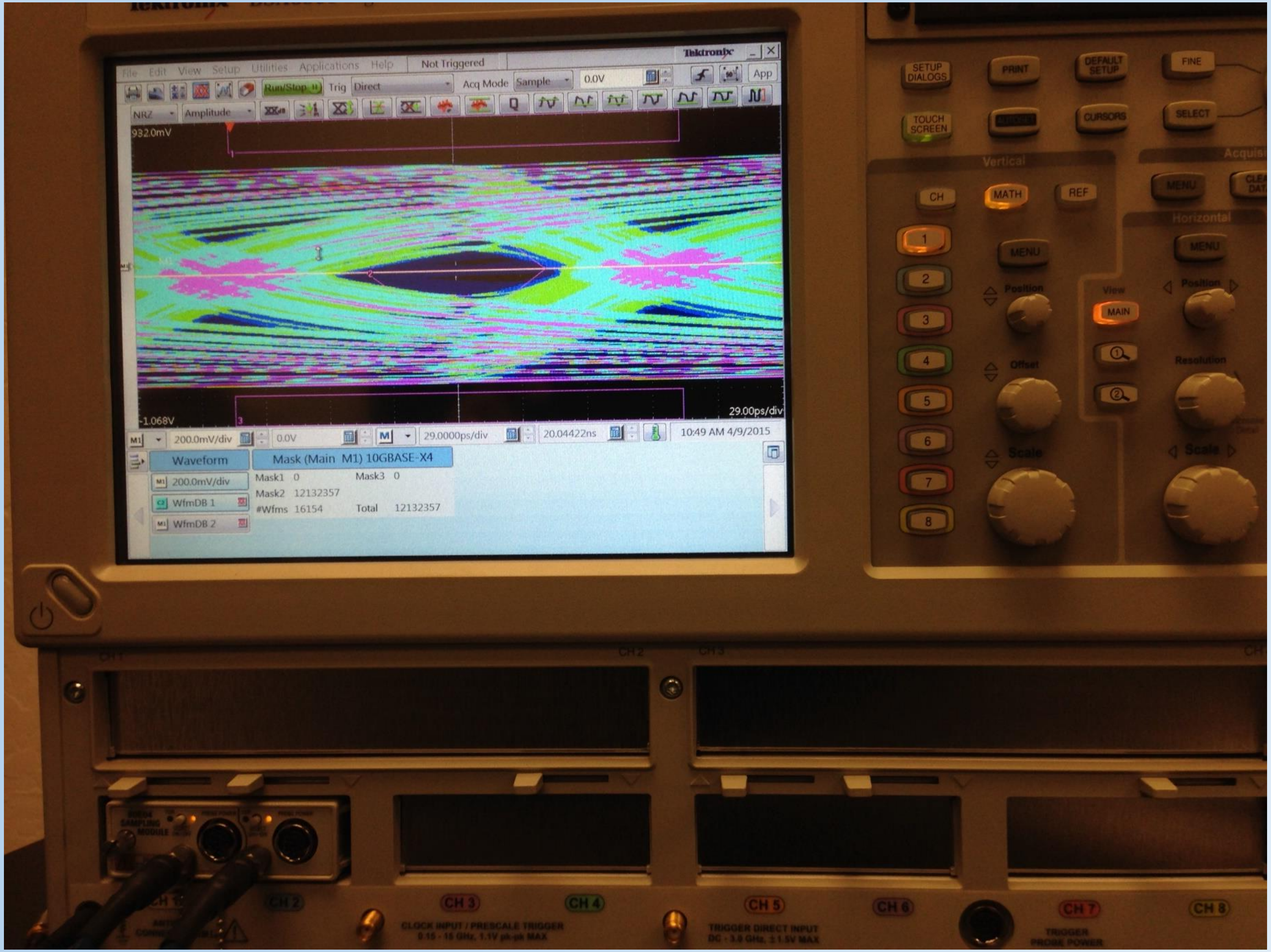


Red

- Different lengths of GCPWG line with connectors were measure for jitter and rise time to see the changes due to length.
- Length does make a difference on the eye diagram.
- Jitter is reduced in the longer line
- Rise is slowed by the longer line

	Jitter RMS (fs) min	Jitter RMS (fs) max	Jitter p-p (ps) min	Jitter p-p (ps) max	Rise Time (ps) min	Rise Time (ps) max	Fall time (ps) min	Fall time (ps) max
adapter	595	656	2.880	3.600	8.64	8.88	8.88	9.12
1 in GCPWG	573	606	3.467	3.929	11.09	11.32	11.67	11.9
2 in GCPWG	553	592	2.947	3.853	13.37	13.71	14.05	14.62

Picture of Eye Diagram seen at a Customer



SIGNAL MICROWAVE

Conclusion/Additional Resources

- We believe we are the best in the industry in creating solutions for challenging high frequency interconnect applications.
- Product Catalog:
  - https://signalmicrowave.com/pdf/Signal_Microwave_Product_Brochure.pdf
- Connector 3D models for simulation are available for most products, see the products page on our website
  - https://signalmicrowave.com/products
- A microwave connector presentation is available on our website
  - http://signalmicrowave.com/microwave-connectors-basics-presentation.pdf
- A technical paper on how to use 3D EM simulation for board launch designs:
  - https://signalmicrowave.com/pdf/Transparent_Connections_Paper_Web-Email_200_083018.pdf
- Comsol Keynote speech on the design process of a 70 GHz adapter system and 110 GHz board launch connector
  - https://www.comsol.com/blogs/keynote-video-optimizing-test-connector-designs-with-rf-simulation/
- Microwave Journal article on a durability test of our 1.85mm (70 GHz) blind mate float mount adapter system
  - Development and Verification of a 1.85 mm Coaxial Interconnect for mmWave ATE | 2021-03-06 | Microwave Journal