Evaluating The Suitability Of OSP Connectors For Calibration Kit Use

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Introduction

Resulting from a lack of strict adherence to IEEE 287 general precision connector/ laboratory precision connector specifications (GPC/LPC), the Omni-Spectra push-on (OSP) connector type is not generally considered to be suitable for calibration kit use. Although this is the dominant opinion among microwave connector and metrology experts, data that either disputes or confirms this assertion is not readily available. Therefore, the purpose of this study is to answer the following questions*:

1. Do corrected measurements of an OSP-terminated device under test (DUT), made with an OSP calibration kit, produce less repeatable results as compared to the measurements of the same DUT type using 3.5-mm-to-OSP adapters and a 3.5 mm calibration kit? How does measurement repeatability behave over multiple calibrations with respect to these two calibration scenarios?

2. When using an OSP calibration kit to effect corrected measurements of an OSP-terminated DUT, do the resulting measurements reveal a properly corrected DUT-to-test system interface (assuming DUT connectors are "standard" OSP connectors)? In short, how does the corrected reference plane area appear in the time domain?

*The study's premise is included at the end of this article. See *Appendix A*.

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This article investigates the differences in vector network analyzer (VNA) measurement precision when using a non-precision interface calibration kit (OSP-based), as opposed to a precision interface calibration kit (3.5-mm-based) in conjunction with the use of OSP-to-3.5-mm adapters.

Description Of Test Equipment

The following equipment was used in the study:

- ***Vector Network Analyzer (VNA):*** Hewlett Packard 8510C, frequency range 0.045 GHz to 50 GHz, GORE unit I.D.# EA1049.

- ***3.5-mm Calibration Kit:*** Hewlett Packard 85052B 3.5 mm calibration kit. Short-open-load-thru (SOLT)-type kit equipped with both sliding and broadband/low-band loads. Sliding loads are stipulated for use above 2 GHz.

- ***OSP Calibration Kit:*** SOLT-type kit equipped with both sliding and broadband/low-band loads. Kit on loan to GORE from the manufacturer

- ***Device Under Test (DUT):*** GORE G4 cable type (0.120 inch nominal jacket diameter, solid center conductor, general-purpose microwave cable type), OSP (pin) to OSP (socket) assembly. A quantity of three assemblies was produced for the purposes of this study.

- ***Test Port Extensions:*** For the OSP calibrations, GORE model FB0HD0HD038.0, a GPC 7 to GPC 7 terminated assembly, 38-inches in length. For the 3.5-mm calibrations, GORE model FB0HA0HB038.0, a 3.5 mm ruggedized port socket to 3.5 mm ruggedized DUT pin terminated assembly, 38 inches in length.

Test Procedure

Below is an outline of the test procedure that was followed. It is important to note that, for the purposes of this experiment, the term “mate/de-mate” describes completely disconnecting then reconnecting the DUT from both port 1 and port 2 vector network analyzer test interfaces.

- ***Test Point #1:*** All three DUT samples (see *Device Under Test* description above) were tested to ensure uniform and predictable performance in both loss and stability.

- ***Test Point #2:*** After verifying that DUT performance was uniform and repeatable across like assemblies (as was described in *Test Point #1*), one DUT from the three produced was selected at random for the experiment.

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- ***Test Point #3:*** A 20-measurement "trace noise" test of the DUT (i.e., 20 measurements without disturbing DUT or measurement system) was performed.

- ***Test Point #4:*** Twenty measurements were made utilizing a mate/de-mate process of the DUT at OSP interface. The mate/de-mate process was employed before each measurement.

- ***Test Point #5:*** *Test Point #4* was repeated over at least three consecutive calibrations; before each calibration, the measurement system connections were broken, cleaned, and re-established. Worst-case data was presented.

- ***Test Point #6:*** A second round of tests consisting of *Test Point #4* and *Test Point #5* was conducted using 3.5-mm-to-OSP adapters produced by Maury Microwave (Ontario, CA). Mate/de-mate operation took place at the OSP interface. For these tests, a 3.5 mm, full 2-port calibration (omitting isolation) was applied

Procedural Notes

- During testing, movement of the DUT and the associated test port extension was restricted in an effort to maintain a controlled test environment.

- It was acknowledged that connector repeatability could skew the results of the experiment; therefore, the DUT's performance was verified by performing upwards of 10 mate/de-mate operations before collecting data. This was done to ensure a proper and consistent mating technique was established, assuring the optimal DUT performance during each connection

- The VNA configuration was as follows: Full two-port calibration, omitting isolation, 0.045 GHz to 18.045 GHz, 401 points. Averaging set at 256 for calibration, reduced to 16 for DUT measurement. Smoothing not used. Preferably, only one test port extension is employed

Test Data: Trace Noise

In *Figure 1*, each data point represents the standard deviation of 20 S21 insertion loss measurements at each frequency point; 401 frequency points in total are represented in each graph. *Figure 1* illustrates the absolute measurement precision capability of the instrument under the given test conditions – this assumes no change in the DUT or measurement system during the 20 consecutive measurements. This comparison of trace noise demonstrates the analyzer's highly repeatable and precise measurement capabilities.

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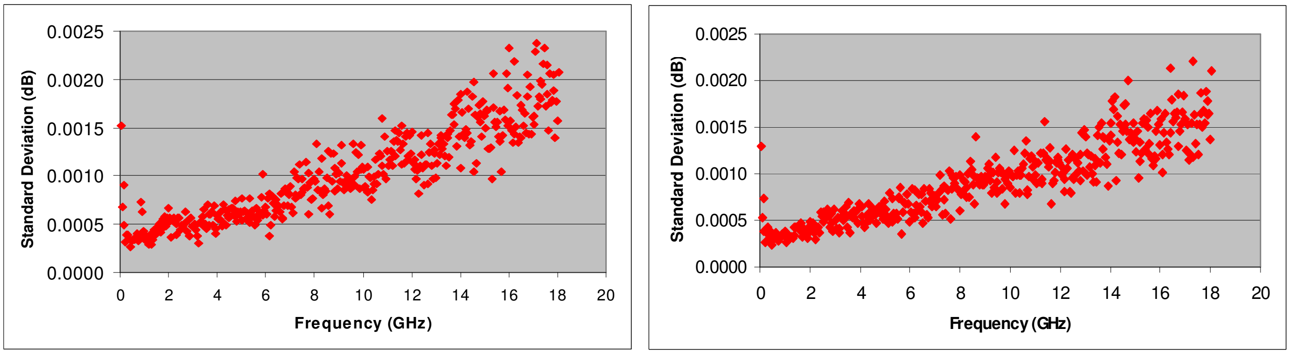

Figure 1: Trace noise – standard deviation of S21 insertion loss measurements for OSP calibration (left) and 3.5 mm calibration (right), S12 results similar.

Test Data: Repeatability Of OSP Calibration Vs. 3.5-mm Calibration

In *Figure 2*, each data point represents the standard deviation of 20 mate/de-mate S21 insertion loss measurements at a frequency point; 401 frequency points in total are represented in each graph.

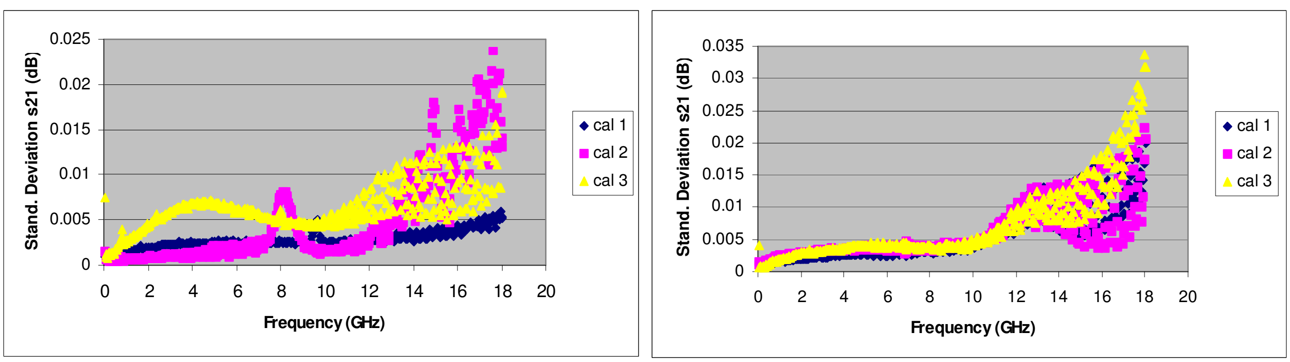

Figure 2: Standard deviation of S21 insertion loss for OSP calibrations (left) and 3.5 mm calibrations (right), S12 results similar.

It is important to note that the same DUT is represented in both graphs. The differences are that the left-hand graph reflects measurements based upon an OSP calibration, while the right-hand graph reflects measurements based upon a 3.5 mm calibration and the DUT fitted with 3.5-mm-to-OSP adapters. The results of this comparison indicate a high degree of repeatability through 14 GHz when employing a 3.5 mm calibration and adapters. The dispersion of data above 14 GHz is attributed to mismatch ripple, resulting from connector and adapter effects. Mismatch effects become more prominent at higher frequencies.

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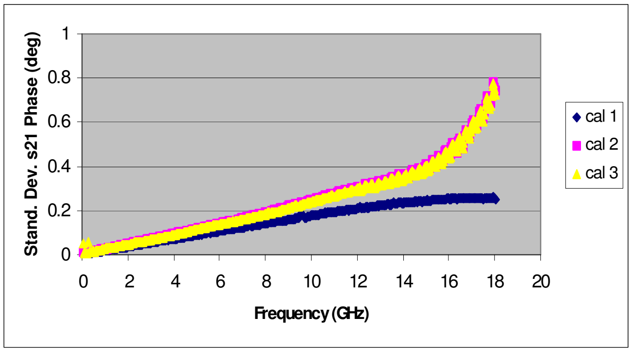
Figure 3 represents the standard deviation of 20 mate/de-mate S21 insertion phase measurements at a frequency point; 401 frequency points in total are represented in each graph.



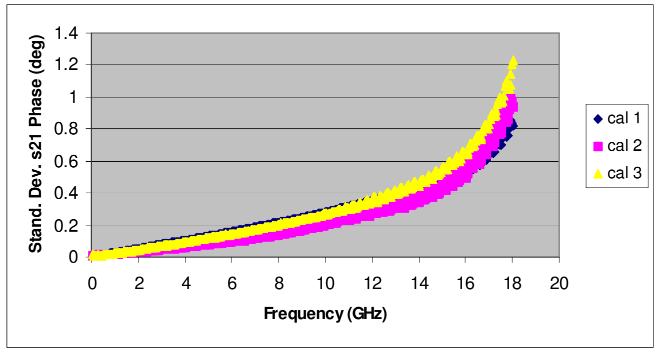


Figure 3: *Standard deviation of S21 insertion phase for OSP calibrations (left) and 3.5 mm calibrations (right), S12 results similar.*

Insertion phase becomes an important consideration when working with phase-matched assemblies. The ability to record consistent phase length (time delay) measurements time and time again is demonstrated in the graphs above. The OSP calibration trials indicate a difference in insertion phase standard deviation of 0.52 degrees at 18 GHz. This equates to 0.081 ps. The 3.5 mm calibration trials produced a difference in standard deviation of 0.3 degrees at 18 GHz, equating to 0.046 ps.

Test Data: Time Domain Comparison – Step Stimulus

Figure 4 illustrates S11 time domain behavior of the DUT across the two calibration techniques. Specifically, we are "looking into" the OSP pin connection of the DUT. The time domain data is presented with a -0.5 ns delay; therefore we are able to view time domain performance 500 ps before the calibrated reference plane. Each grouping of traces represents 20 mate/de-mate measurements overlaid.

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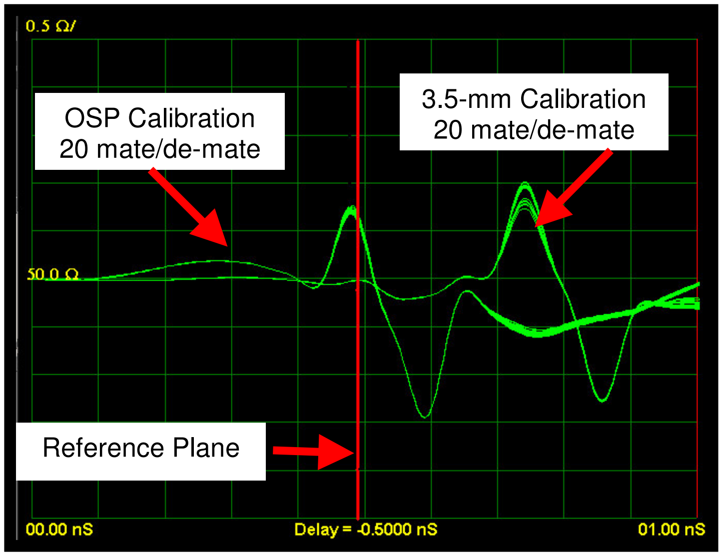

Figure 4: *S11 time domain data. 20 overlaying mate/de-mate measurements of DUT using 0SP and 3.5 mm calibrations. Signal flow is from left to right into cable assembly.*

Note the performance of the OSP calibration both before and at the reference plane. Compare this the performance to that of the 3.5 mm calibration – this behavior was predicted in the study's premise, found in *Appendix A*. Clearly, impedance at the reference plane is not held at 50 ohms when using the OSP calibration kit. At the 3.5 mm reference plane, impedance is held at 50 ohms, proceeding through the 3.5-mm-to-OSP adapter, into the OSP pin connector (represented by the inductive then capacitive humps), and, finally, entering the cable.

Conclusion/Findings

Data presented in this study is the result of over 300 individual S-parameter measurements. Efforts were made to ensure that both calibration platforms performed as intended by their manufacturers. The results of this study are summarized as follows:

- Calibrated insertion loss/insertion phase measurements of the OSP-equipped DUT, using an OSP calibration kit, provided *no distinct advantage* over the alternative, i.e., calibrated measurements using a 3.5 mm calibration kit and the DUT fitted with quality 3.5 mm to OSP adapters.

- Overall, measurements using the OSP calibration kit produced *slightly lower standard deviation at peak frequencies* as compared to the 3.5 mm calibration configuration, but not necessarily across the entire measured frequency band.

- In comparing the two calibration methods, the 3.5 mm/OSP-to-3.5-mm calibration configuration consistently produced *well-behaved results, free of anomalies.*

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- Addressing the use of calibration kits under "real world" conditions, calibrated measurements of the DUT exhibited *greater repeatability/reproducibility* over multiple calibrations when using a 3.5 mm/OSP-to-3.5-mm adapter configuration.

- The OSP calibration kit is capable of producing measurements having *a very low standard deviation*, but time and again it was found that such results could not be readily reproduced. This conclusion is based upon the outcome of multiple calibrations conducted over a period of three days.

- To rule out the possibility of random occurrence, *the study was repeated a second time.* The results were consistent with the initial outcome – the 3.5 mm /OSP-to-3.5-mm configuration was more repeatable than the OSP configuration. The performance of the OSP calibration configuration tended to be erratic across a series of calibrations.

- The data clearly indicates that measurements of the OSP-equipped DUT, made using the 3.5 mm calibration (DUT fitted with 3.5-mm-to-OSP adapters) will yield highly repeatable results. This means, assuming no significant changes in DUT or measurement system performance, *measurements made today will be consistent with measurements made next week, next month, next year, etc.*

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Appendix A:

Premise For OSP Connector Calibration Kit Study

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This document attempts to predict, and give explanation to, the time and frequency domain performance inherent to S-parameter measurements made with a non-GPC/LPC-type calibration kit.

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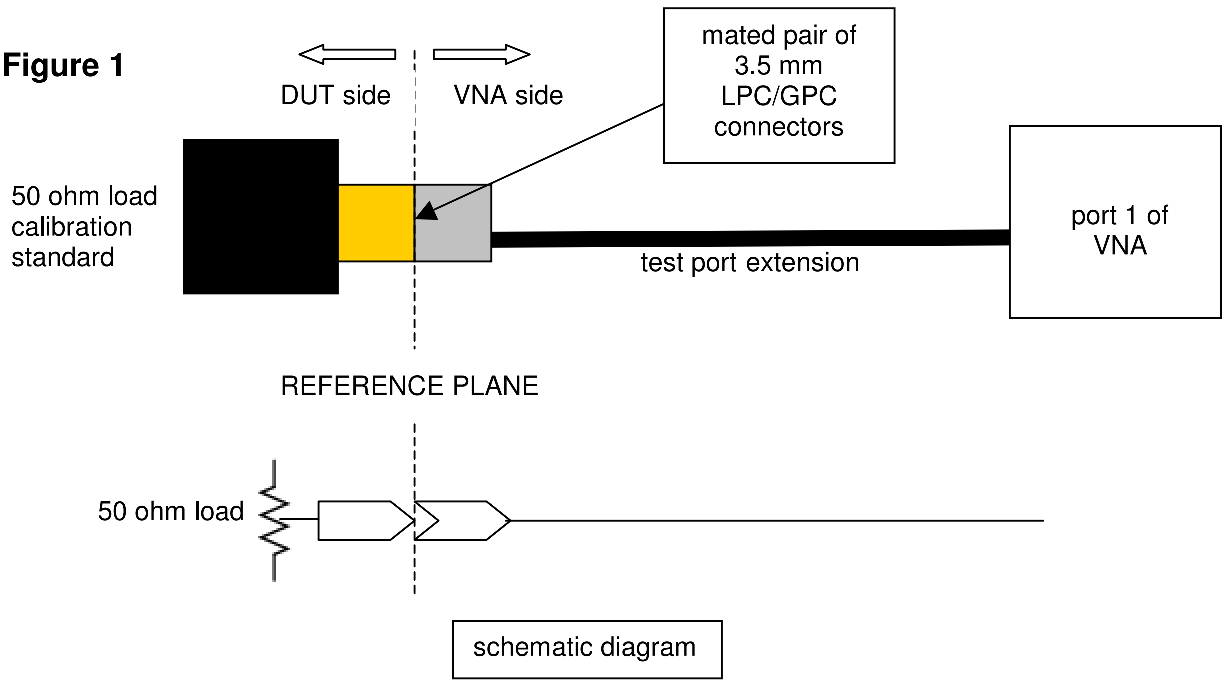
VNA Calibration Discussion

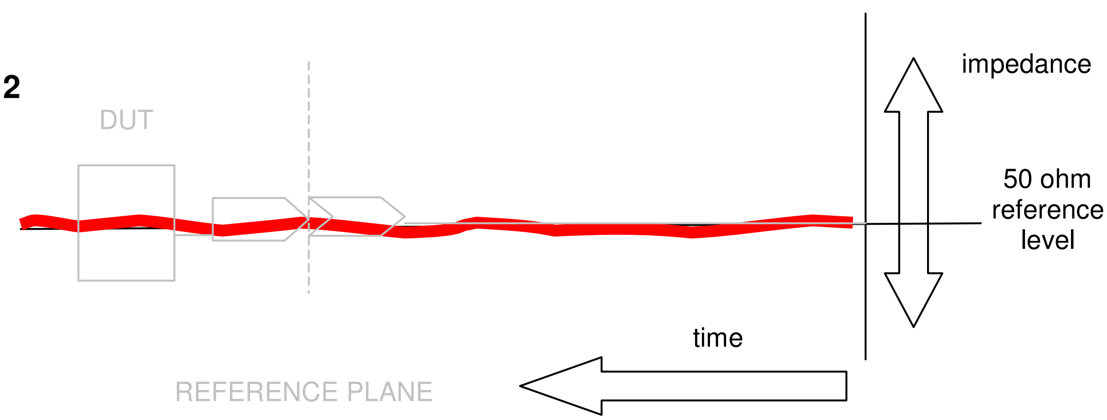
Consider a calibration kit using 3.5 mm, LPC-grade (Laboratory Precision Connector, IEEE 287 Standard) connectors – shown below in gold. The 50 ohm load standard is mated to a GPC-grade (General Precision Connector, IEEE 287 Standard) instrument connector – shown below in gray:

Figure 1



After calibration has been completed, a 50 ohm DUT having the appropriate 3.5 mm GPC-grade mating connector is connected to port 1. Looking through the connector interface into the DUT from port 1 of the VNA, an S11 return loss measurement in the time domain (step stimulus) will reveal the following:

Figure 2



The calibration standard and DUT interfaces are 3.5 mm LPC/GPC-grade, resulting in a well-matched interface with excellent repeatability over a large number of mate/de-mate

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cycles. To re-state: the above result can be reliably reproduced over a number of mate/de-mate cycles.

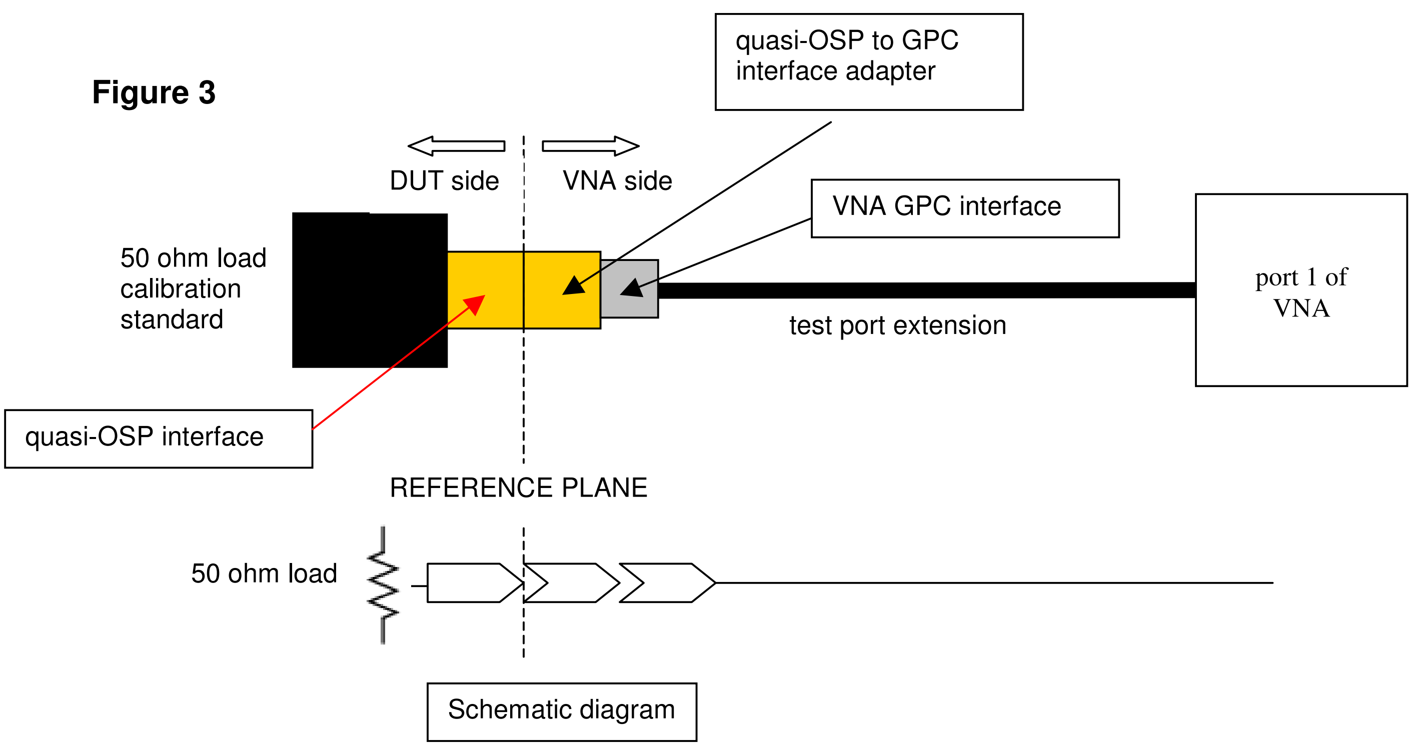
Important: VNA calibration removes systematic measurement errors (and can control random error to some degree). Measurement precision and accuracy is predicated upon the assumption that calibration standard interfaces and DUT interfaces are identical in their physical and electrical attributes.

Now consider a calibration kit using OSP-type connectors (shown below in gold). The OSP connector meets neither the GPC nor the more stringent LPC requirements, which are considered to be the industry standard for calibration kit use. GPC/LPC grades call for, citing only a short list:

- Air dielectric *only* at interface – GPC allows dielectric support bead, LPC does not.
- GPC/LPC impedance repeatability specifications cannot be met through the use of slotted contacts; dimensional control is far too difficult.
- Reference planes are to be coincident. This generally means using a threaded coupling mechanism or an elaborate fixture to maintain coincident geometry.

To somewhat remedy this situation, the calibration kit manufacturer creates a "quasi-OSP" connector, designing out as many of the LPC requirement violations as possible. The end result is a connector that is neither GPC nor LPC grade. This quasi-OSP is used in the form of an adapter – quasi-OSP to some common GPC-grade test interface (3.5 mm, 2.92 mm, N-type, etc.). In this form, it's employed when connecting the calibration standards, effecting a level of interface control for the purposes achieving calibration.

Figure 3



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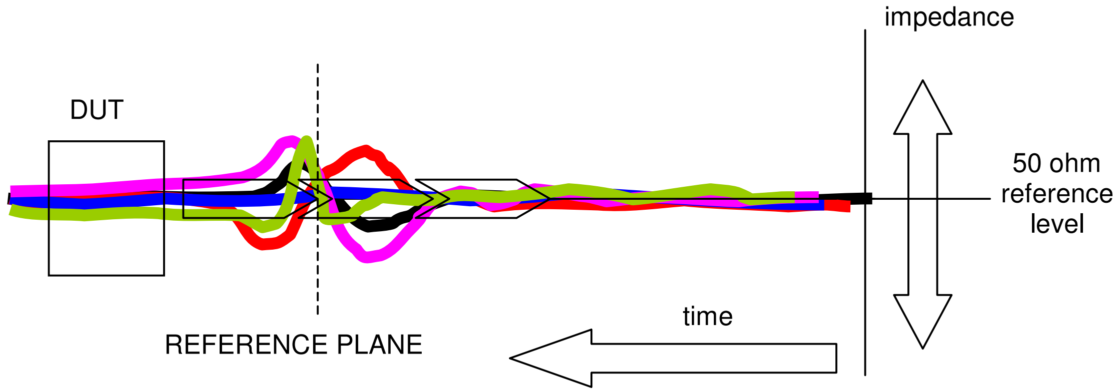
After calibration correction, viewing the above configuration in time domain will yield results similar to those in *Figure 2*. It is when an OSP-equipped DUT is tested that problems arise. In this case, the DUT, utilizing a "true" OSP interface, is connected to the quasi-OSP interface – a mating of two unlike connectors. As stated in earlier, to realize precision and accuracy in VNA measurements, the calibration standard interface and DUT interface must be identical – or very closely matched – in their physical and electrical attributes.

Again, looking through the connector interface into the DUT from port 1 of the VNA, an S11 return loss measurement in the time domain (step stimulus) reveals:

Figure 4



Each colored trace represents a measurement of the DUT after a mate/de-mate event. In some instances, the impedance discontinuities at the reference plane may be minimal. At other times, they may be significant. Since test error (both random and systematic) has not been minimized, it impinges upon DUT performance. By using a non-GPC/LPC-type connector, systematic connector errors can not be reliably corrected. *In fact, errors are now introduced that can easily be confused for actual DUT performance.*

A primary function of the calibration kit concept is to define a reference plane: a rigorously defined location that precisely divides measurement system from the DUT. The requirements for GPC/LPC connectors are formulated to ensure that the reference plane represents a very precise and stable entity, as close to the ideal as is possible. The underlying premise is that the connectors used on the DUT physically and electrically match the connectors used on the calibration standards (and the VNA port connections as well). In this way, calibration corrections applied to the DUT-to-VNA port interface will hold true, effectively correcting the systematic errors associated with the specific interface type being used.

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