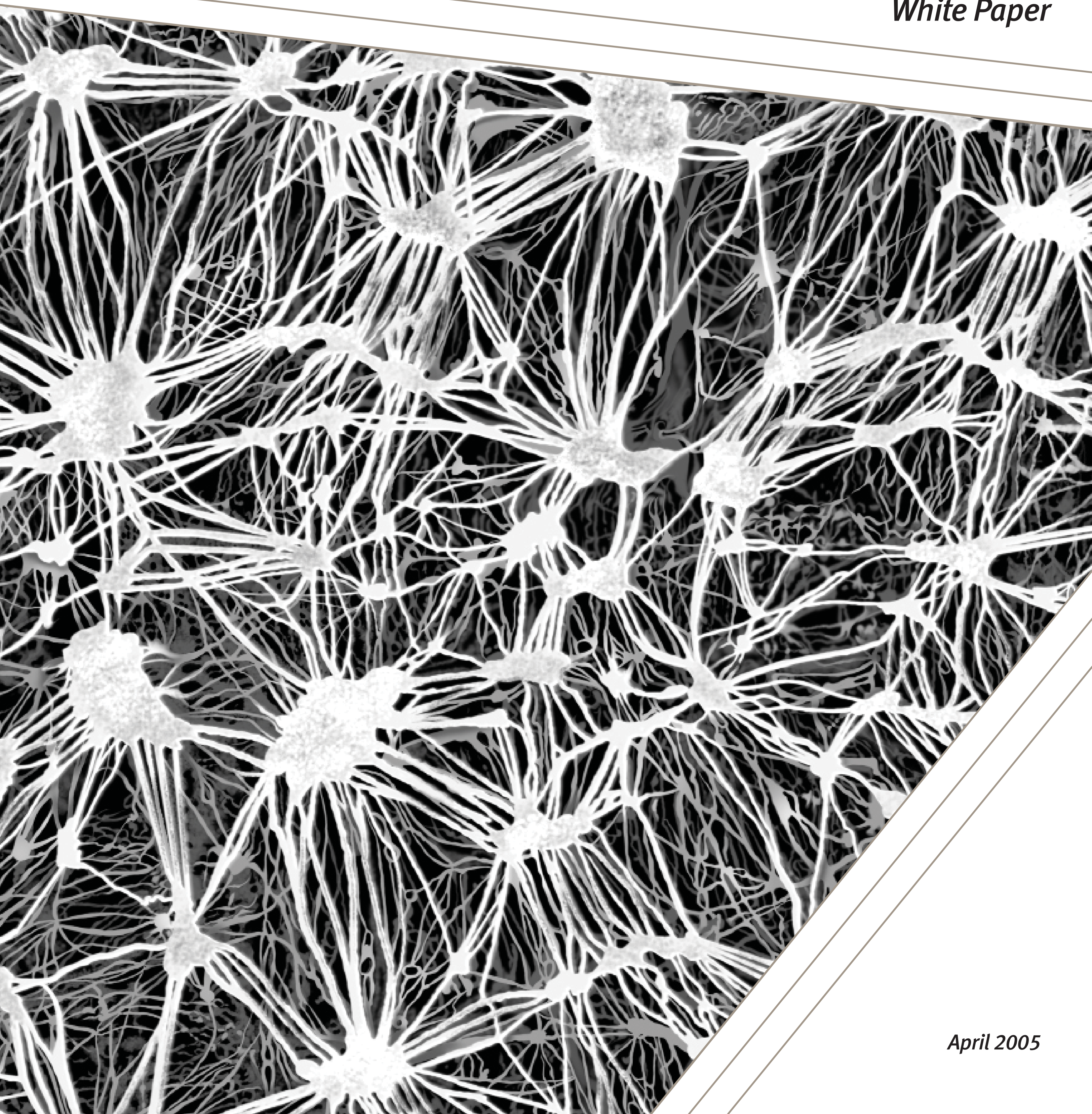
OSP Connector Calibration Kit Study

White Paper



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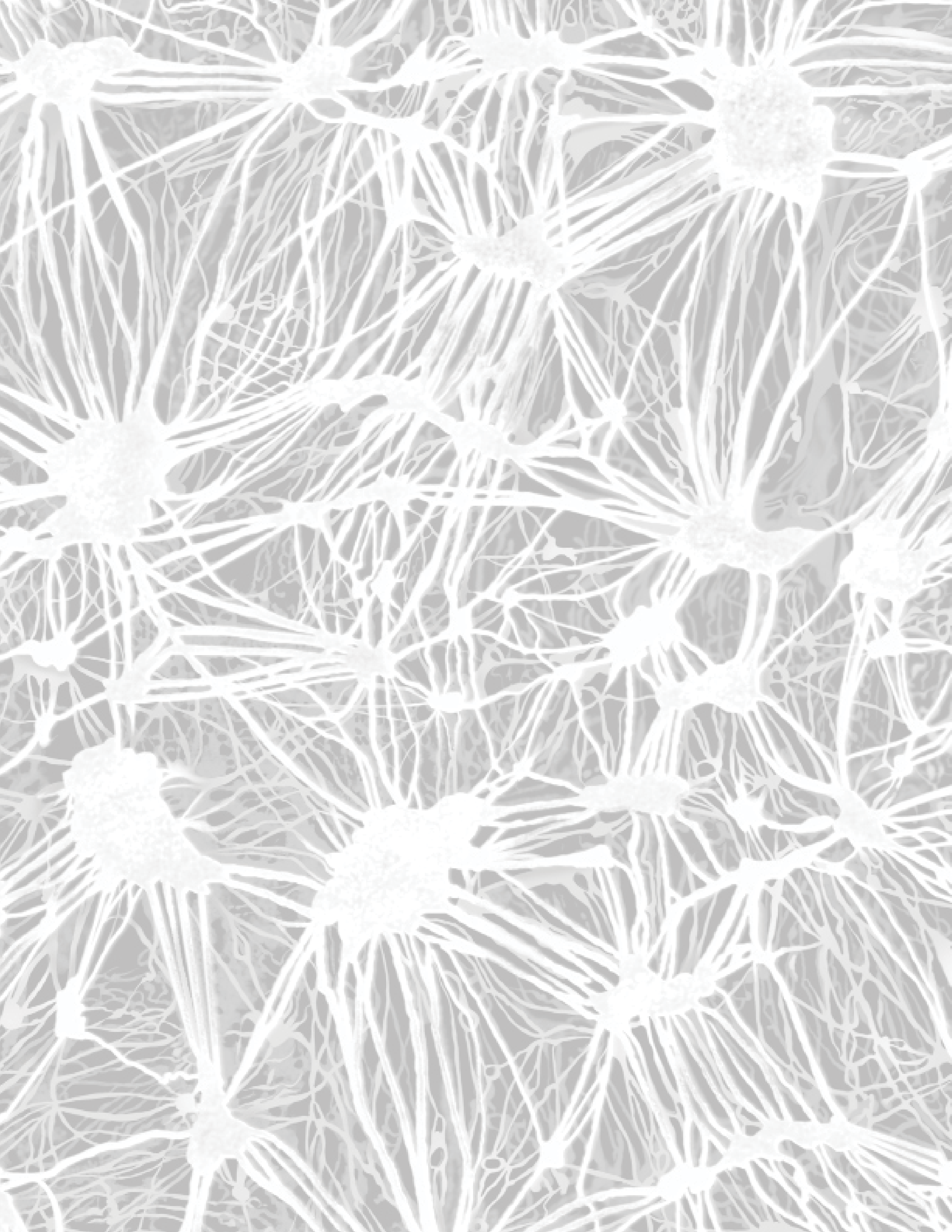

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Introduction

Resulting from a lack of strict adherence to IEEE287 General Precision/Laboratory Precision Connector specifications (GPC / LPC), the 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 neither disputes nor confirms this assertion is readily available; therefore, the purpose of this study is to answer the following questions*:

(1) Do corrected measurements of an OSP terminated 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, dated February 9, 2005. See Appendix A.

Description of Test Equipment

Vector Network Analyzer - Hewlett Packard 8510C, frequency range 0.045 GHz to 50GHz, GORE unit I.D.# EA1049. Unit calibrated on December 1, 2004 and is due for calibration on December 2, 2005

3.5-mm Calibration Kit - Hewlett Packard 85052B 3.5-mm calibration kit. SOLT-type kit equipped with both sliding and broadband/low-band loads. Sliding loads are stipulated for use above 2 GHz. Kit was calibrated on January 25, 2005 and is due for next calibration on January 25, 2006

OSP Calibration Kit - SOLT-type kit equipped with both sliding and broadband/low-band loads. Kit was calibrated on October 13, 2004 and is due for next calibration on October 13, 2005. Kit on loan to GORE from the manufacturer

Device-Under-Test (DUT) - Description: 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 (3) assemblies were 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 ruggedized DUT pin terminated assembly, 38-inches in length

Test Procedure

TEST POINT #1 - All three DUT samples (see Device-Under-Test descripti above) were tested to ensure uniform and predictable performance in both loss and stability

TEST POINT #2 - After verifying that DUT performance is 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

TEST POINT #3 - perform a 20-measurement “trace noise” test of the DUT i.e., 20 measurements without disturbing DUT or measurement system

TEST POINT #4 - 20 measurements utilizing a mate/de-mate process of the DUT at OSP

interface. Mate/de-mate process employed before each measurement

TEST POINT #5 - Repeat TEST POINT#4 over at least three consecutive calibrations, in where before each calibration, the measurement system connections are broken, cleaned and re-established. Worst-case data presented.

Important Note - 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 #6 - A second round of tests consisting of TEST POINT# 4 and TEST POINT# 5 will be conducted using 3.5-mm to OSP adapters - produced by Maury Microwave, Ontario California. Mate/de-mate operation will take place at the OSP interface. For these tests, a 3.5-mm, full 2-port calibration (omitting isolation) will be applied these tests, a 3.5-mm, full 2-port calibration (omitting isolation) will be applied

Procedural Notes

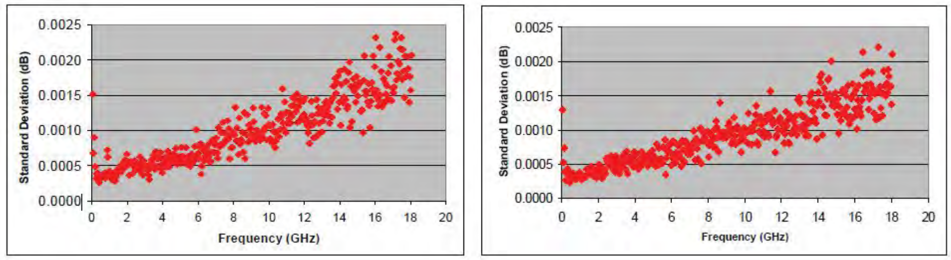
During testing, movement of the DUT and the associated test port extension will be restricted in an effort to maintain a controlled test environment.

It is 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

Vector Network Analyzer Configuration- Full two-port calibration, omitting isolation, 0.045GHz 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 will be employed

Test Data- “Trace Noise”

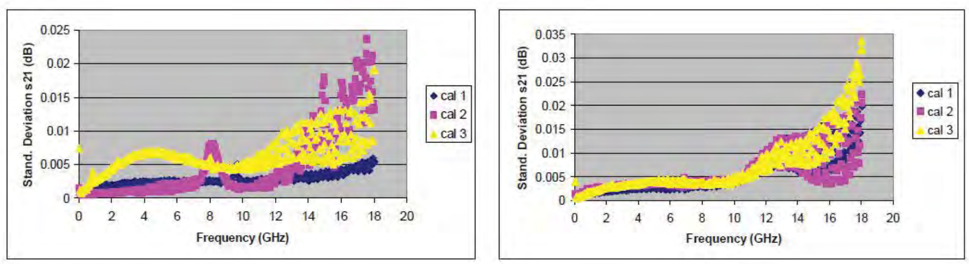
Figure 1: Trace noise - standard deviation of s21 insertion loss measurements for OSP calibration (left) and 3.5-mm calibration (right), s12 results similar



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 condition 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.

Test Data: Repeatability of OSP Calibration vs. 3.5-mm Calibration

Figure 2: Standard deviation of s21 insertion loss for OSP calibrations (left) and 3.5-mm calibrations (right), s12 results similar



In Figure 2, each data point represents the standard deviation of 20 mate/demate s21 insertion loss measurements at a frequency point; 401 frequency points in total are represented in each graph.

It is important to note that the same DUT is represented in both graphs. The differences being the left-hand graph reflects measurements based upon an OSP calibration, 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.

Figure 3:Standard deviation of s21 insertion phase for OSP calibrations (left) and 3.5-mm calibrations (right), s12 results similar

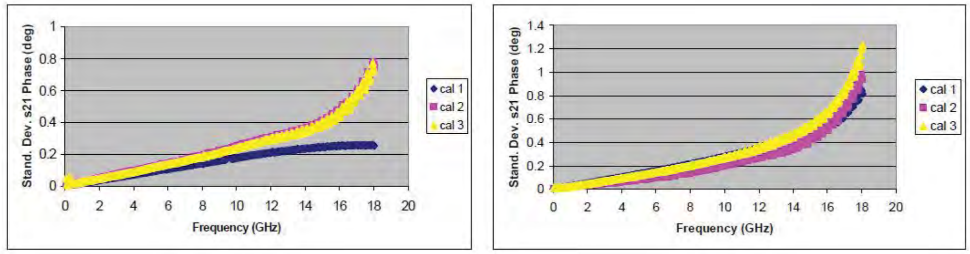


Figure 3 represents the standard deviation of 20 mate/de-mate s21 insertion phase measurements at a frequency point; 401 frequency points in total are represented in each graph.

Insertion phase becomes an important consideration when working with phasematched assemblies. The ability to record consistent phase length (time delay) measurements time and time again is demonstrated in the graphs at the bottom of page 4. The OSP calibration trials indicate a difference in insertion phase standard deviation of 0.52-degrees at 18 GHz. This equates to 0.081ps. The 3.5-mm calibration trials produced a difference in standard deviation of 0.3-degrees at 18 GHz, equating to 0.046ps.

Test Data: Time Domain Comparison- Step Stimulus

Figure 4: s11 time domain data. 20 overlaying mate/de-mate measurements of DUT using OSP and 3.5- mm calibrations. Signal flow is from left to right into cable assembly

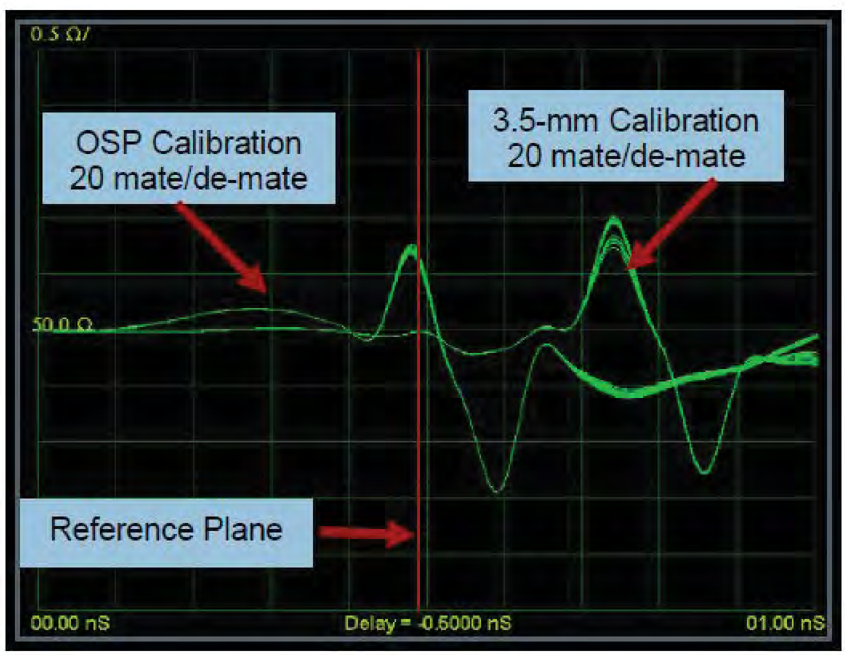


Figure 4 illustrates s11 time domain behavior of the DUT across the two calibration techniques. Specifically, we are “looking into” the OSP pin connection of the DUT. The time domain data is presented with a -0.5 ns delay; therefore we are able to view time domain performance 500 ps before the calibrated reference plane. Each grouping of traces represents 20 mate/de-mate measurements overlaid.

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, page 7. 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

• 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 3 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.

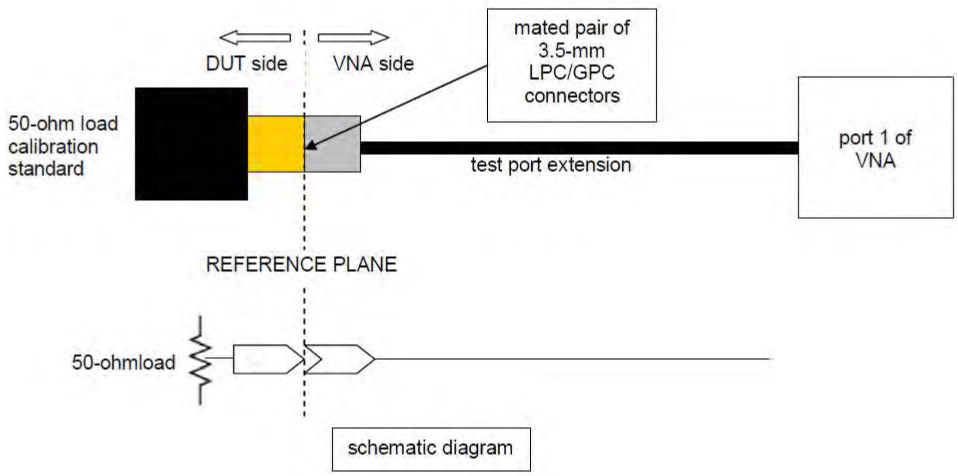
Appendix A:
Premise for OSP Connector Calibration Kit Study
February 9, 2005

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.

VNA Calibration Discussion

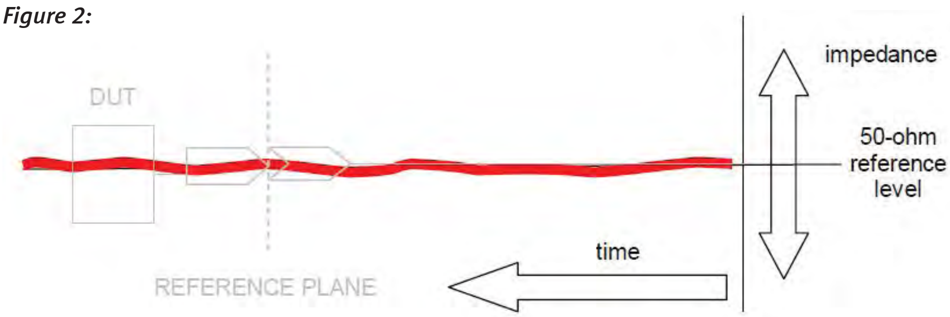
Consider a calibration kit using 3.5-mm, LPC-grade (Laboratory Precision Connector, IEEE 287 Standard) connectors - shown below in gold. The 50-ohm load standard is mated to a GPC-grade(General Precision Connector, IEEE 287 Standard) instrument connector - shown below in gray:

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 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:

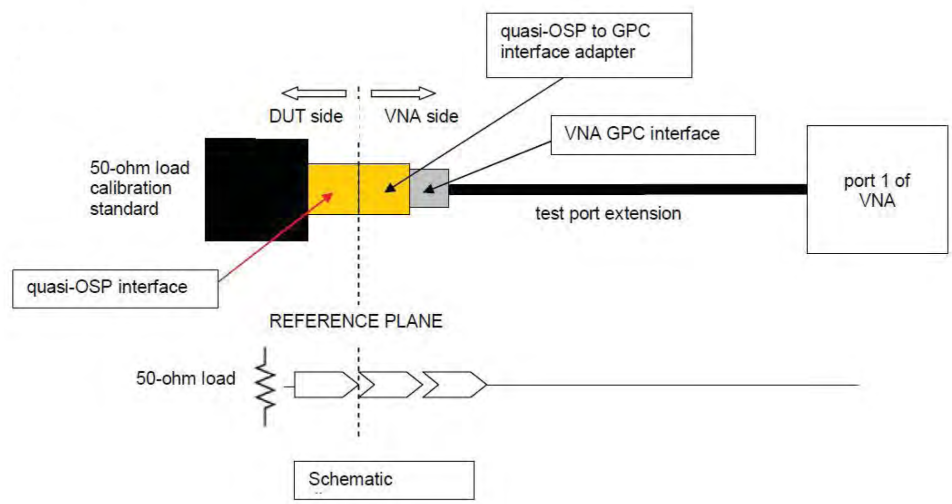
• air dielectric only at interface - GPC allows dielectric support bead, LPC does not

• 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

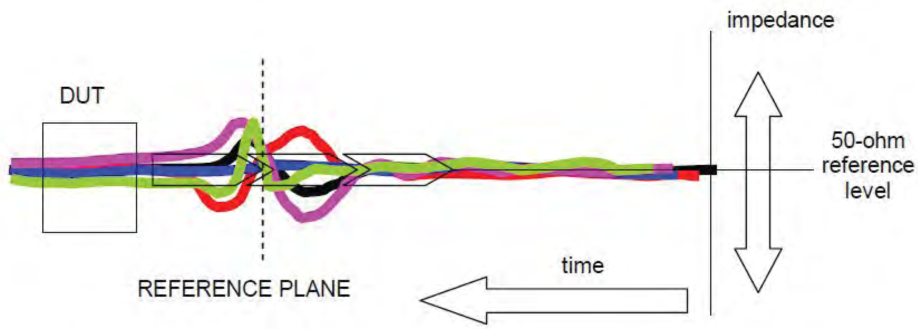
To somewhat remedy this situation, the calibration kit manufacturer creates a “quasi-OSP” connector, designing out as many of the LPC requirement violations as possible. The end result is a connector that is neither GPC, nor LPC grade. This quasi-OSP is used in the form of an adapter “quasi- OSP” to 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:



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:



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 Device-Under-Test. 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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