# ATX LABS TECH BRIEF

## ATX has Developed High Speed Macro Profiling for Constraining Uncertainty in Recession Measurements of Microwave Connectors

By using a macro profiling sampling technique it is possible to bound the uncertainty in a gage measurement when using coarse instrumentation

In essence, the gaging of a microwave connector interface for the purpose of determining pin depth is a profiling technique in which the gage's features match the scale of the features being probed and measured.

Given the nature of the instrument – typically a dial or digital indicator - that has been re-purposed for hand held use, and given the geometric properties and machine tolerances of the form being measured, gaging tends to be rich in uncertainty. The final object of gaging is to determine the degree of compliance with Standards like IEEE287 that provide recession criteria for precision connectors from 3.5mm to 1.85mm, as well as Type N.

This Brief explains a technique for advancing the art of gaging to capture the uncertainty of a gage measurement in real time as part of a data acquisition exercise.

### Introduction

As outlined in a previous Tech Brief, *The Art of Microwave Gaging for Optimal Field Calibration*, there are three forms of gaging: optical, threaded and free style. The former relies on the use of a white light interferometer to provide a non-intrusive measurement of pin depth by removing the so called observer of Heisenberg effect. The latter two are mechanical in nature, the former relying on a threaded attachment to the connector under test, the latter relying on manual, free style attachment.

The argument was advanced in the above cited Tech Brief that both techniques should yield the same results. In both cases, a surface is being engaged that has non-deformable physical properties. The only condition affecting the result is the contour of the surfaces as determined by GD&T tolerance call outs in Standards like IEEE287LPC/GPC. Hence if the Standard requires a flatness – as well a datum specific perpendicularity – of 0.0005 inches or 5/10ths, and if the Standard also calls for a pin depth no greater than 0.0005 inches (LPC) – then a gage measurement is taking place within the boundaries of the tolerance of the surface to be engaged.

The only difference between threaded gaging and free style gaging is the manner of alignment of surface being probed, and probing means itself, namely, the gage. In the threaded case, the gage puts a load on the surface that is proportional to the torque and inversely proportional to the product of the coefficient of friction of the thread and thread major diameter. At about 160 lbs of force, the probing end of the gage aligns to the surface as the threaded bodies move with the loose cavity of the thread. In the free style case, the user manually tilts the gage to align with the surface. With care and skill, the result should be equivalent. Nothing moves axially in gaging except the gage itself. This is inherently a macro gaging exercise, given the nature of the surface tolerance and the scale of the probing gage's means. Micro profiling would be more an exercise to determine the Ra of a surface, typically 16 millionths of an inch, the specification called out by IEEE287.

In threaded and free style gaging, the user must extract from the measurement an estimate of pin depth based on several samples of the connector's interface. In doing so, the tester must be mindful of the following: [i] **Ua** – the ISO17025 cal tolerance assigned to the gage after calibration and before expansion by a factor of two to capture a 95% confidence level; [ii] **Ub** - the type A component of uncertainty due to what can broadly be characterized as repeatability. Ideally, assuming best practice techniques in the hand of a skilled tester, this will be based on the standard deviation of the mean, also called standard error, which most engineers are familiar with. [iii] **Uc** - the Type B component of uncertainty related to the resolution of the instrument. For a digital gage, that is commonly proportional to the least significant digit and inversely proportional to one twice the square of three. [iv] **M** - the mean of several sample measurements where care is taken to sample the full 360 degree plane that is normal to the connector's main axis.

More components can be added, including but not limited to temperature effects, zero setting instability, and reproducibility associated with gaging under a variety of conditions, but the values Ua, Ub and Uc should capture the bulk of the uncertainty. The final uncertainty, U, will be given as:

$$U = M \text{ +/-} [2(Ua^2 + Ub^2 + Uc^2)^{(1/2)}]$$

expressed at a confidence level of 2 or 95%, consistent with common practice.

Gaging is inherently an approximate art and subject to a strong repeatability component even before you get to concerns regarding reproducibility. Keysight, a leader for decades in advancing the concern that all measurements be bounded by uncertainty, makes the following comment in its literature on gaging:

"Do not use the gages for precise pin depth measurements. . . . **[i]**The connector gages are only capable of performing coarse measurements. They do not provide the degree of accuracy necessary to precisely measure the pin depth of the cable connectors. . . . **[ii]** Only the factory — through special gaging processes and electrical testing— can accurately verify the mechanical characteristics of the cable connectors." [1]

That is a sober reminder that gaging is a sensitive art. Given the

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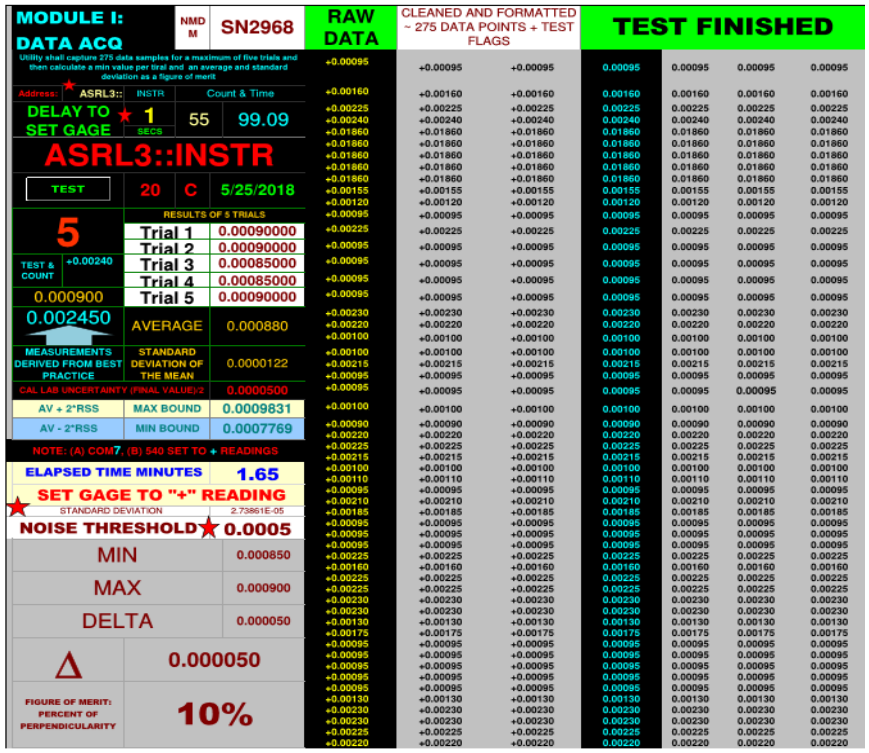


inherent uncertainty of gage measurements, no matter the technique – free style or threaded – ATX recommends the capture of as many data points as possible to calculate the recession as a function of surface tolerance, especially within the pin depth constraints advanced by Standards like IEEE287GPC/LPC that call for general precision pin depth of no greater than 2 mils (0.002 inches, 0.05mm), and for lab precision pin depths of no greater than 5/10ths (0.0005 inches, 0.0127mm).

### Macro-Profiling

Pursuant to the above objective, ATX has developed a high speed capture algorithm built around the acquisition of serial data in real time that links to an uncertainty module for the calculation of uncertainty as a function of repeatability as well as the elements of uncertainty referenced above. The full system has the following components.

### I – Digital Indicator Platform

. A digital indicator having a calibrated accuracy of no greater than +/- 0.0001 (0.0025mm) forms the host platform for a bushing and contact probe tailored for the proposed connector species under test. The indicator has an SPC port that provides the primary data link. The indicator is advantaged by a data hub that transfers measurements to a high speed computer.

The indicator is further advantaged by having an open host platform that is easily shed in a matter of seconds by a simple tool provided. An open platform implies lower carrying cost since any ISO17025 cal lab can perform a traceable calibration with uncertainties at a fraction of what it may otherwise cost – that being the case since mechanical cal labs are extremely plentiful, generally carrying A2LA or equivalent accreditation. And accredited labs are automated for dial and digital indicator calibration, yielding extremely short turn over times.

### II – ATX Dedicated Excel Application: Vertex

A custom Excel application with compiled VBA is devoted to both data retrieval and number crunching for the purpose of evaluating uncertainty. The Excel app embeds extremely efficient, low level serial code that manifests as a direct link to the instrument without the cumbersome idiosyncrasies of so called “Wedge” applications that are useful for streaming data to the location of a cursor but less useful for evaluation data, or for repetitive column structured sampling with dedicated or programmable hard limits. The application is broken up into three

| MODULE II ~ CERTIFICATION WITH TRIAL DATA & UNCERTAINTIES | | | |
|---|---|---|---|
| Address: ASRL7:: | INSTR | Count & Time | |
| RELAXATION PEERIOD | 5 SECS | 55 | 70.20 |
| ASRL7::INSTR | | | |
| 5 | RESULTS OF 5 TRIALS | | |
| | Trial 1 | 0.0009000 | |
| | Trial 2 | 0.0009000 | |
| TEST & COUNT 75 | Trial 3 | 0.0008500 | |
| | Trial 4 | 0.0008500 | |
| 0.000000 | Trial 5 | 0.0009000 | |
| 0.001000 | AVERAGE | 0.0008800 | |
| MEASUREMENTS DERIVED FROM BEST PRACTICE | STANDARD DEVIATION OF THE MEAN | 0.0000122 | |
| CAL LAB UNCERTAINTY /2 | | 0.0000500 | |
| AV + STDEV + CL | MAX BOUND | 0.0009831 | |
| AV - STDEV - CL | MIN BOUND | 0.0007769 | |
| NOTE: (A) COM7, (B) 540 SET TO + READINGS | | | |
| As found after five trials with a Mit 543-792B Digital Gage having a maximum uncertainty of +/- 0.00012, as certified by an ISO 17025 accredited and traceable calibration in an A2LA accredited lab. | | | |
| PRODUCT | | CONNECTOR | SERIAL |
| TPX-35NMDF-35NMDM-39 | | NMDM | SN2968 |
| DATE | 5/25/2018 | TEMP | 20.0 |
| LAB MANAGER | VRS/MSEE | | |

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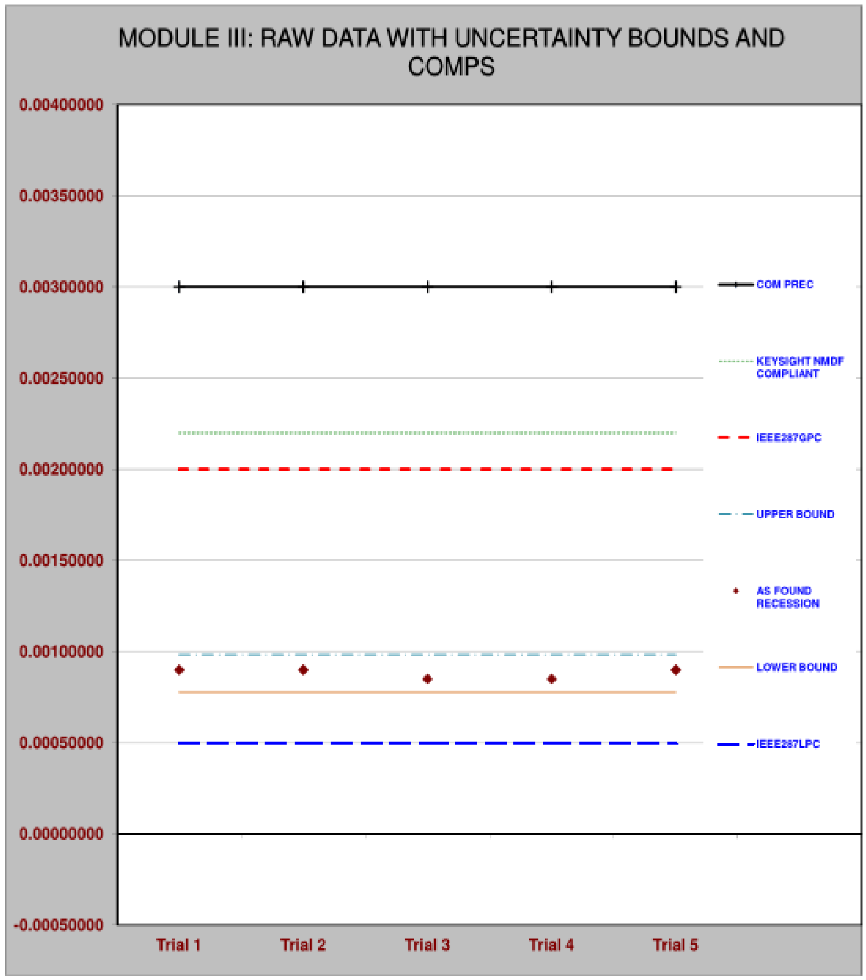
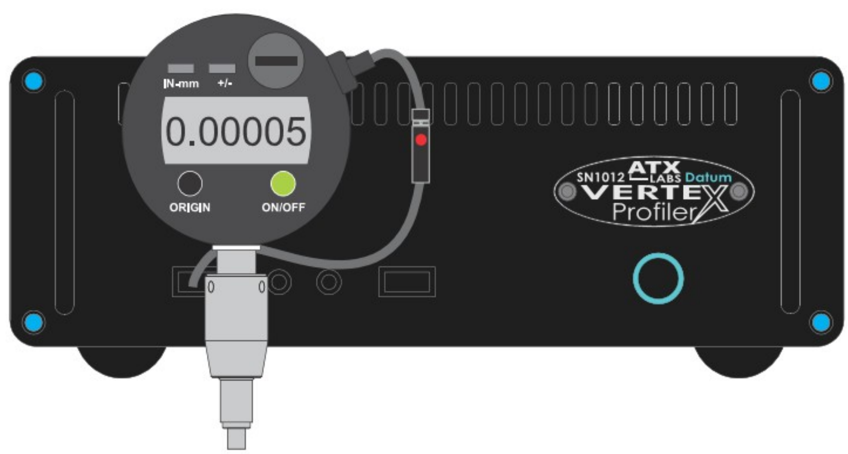
modules.

In **module I**, pictured above, raw data is captured as 275 data points in real time in five separate trials while prompting the user to engage and release the gage. For example, the user is prompted to place the gage on the reference plane for repeated readings normal to the connector's main axis at different points, thereby capturing best case pin depth in each of the five trials. After capture, the data is cleaned of serial port overhead and ready for numerical analysis. The full test takes about 90 seconds. During the process, the module monitors and flags noisy data, which is a rare occurrence.

In **module II**, pictured at the right on page 2, the embedded uncertainty algorithm evaluates the UA, Ub and Uc components cited above and provides a final uncertainty expressed at a confidence level of k=2 - as well as providing uncertainty bounds.

In **module III**, pictured at right, the raw data is plotted along with the upper and lower uncertainty bounds, and with – for guidance – the pin depth thresholds for a variety of standards and practices, including IEEE287LPC and GPC, common practice precision.




The application is premised on the idea that repeated sampling of the connector interface around the perimeter of the seating plane, along with uncertainty analysis that captures at minimum the components of repeatability, resolution and initial ISO17025 cal tolerance – will provide added value to a measurement which is inherently approximate.

### III – Dedicated Computer

A dedicated, high speed instrumentation computer with boundary layer advantaged airflow is the final component running Win10 and Excel

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2016 on top of the Keysight IO Libraries Suite and vi code dedicated to efficient serial capture.

The use of a dedicated instrument creates an extremely efficient platform for the robust delivery of code bypassing the maintenance issues often associated with code only offerings, while guaranteeing speed of execution. The system's hardware is illustrated in the figure above.

The computer has an ultra small form factor with a weight of 2 kg and measures 8.27 (210mm) x 2.83 (72mm) x 9.25 (235mm).

*This work was done by Victor R. Spelman and Emily Milstein of ATX Labs, Vineyard Haven Massachusetts.*