ATX LABS TECH BRIEF

Microwave Gage Field Calibration at the Test Bench and in Production

Calibrating the Microwave Gage for Hand Held Use is a Distinctly Different Animal from an ISO17025 Certified Calibration in a Lab under Controlled Conditions

A typical microwave gage, designed for the purpose of measuring the recession of a connector interface, requires a different calibration from the calibration of the underlying platform that hosts the ancillary attachments - like bushings and contact points; the underlying platform being a convention dial or digital indicator found in most machine shops.

In practice, a re-purposed dial indicator for measuring recession is no different in execution from a depth gage designed for the measurement of tire tread depth. To the degree that there's a difference between depth gages – those for tires vs. those for microwave connectors – the difference lies not in the concept but in the accuracy of the machining and expected measurement: the former being designed to measure in hundredths of an inch, the latter designed to measure in thousandths (mils for short), even tenths of thousandths (tenths for short).

The instrument comes with the expectation that the dial face, reading in increments of mils, meets that expectation in hand held use. However, the microwave gage has been re-purposed for hand held use – a use for which the underlying instrument was never designed. And therein lies the rub.

What is being calibrated in a lab is not the dial indicator with its ancillary parts for making a depth measurement, it is the underlying measuring device itself. One could calibrate the full rig – consisting of the indicator host + ancillary parts – but that would add cost and no additional value since the problem remains, namely, that actual handheld use is different from the lab calibration. Moreover, the lab cal is certifying the accuracy of the instrument as a measuring device under ideal conditions – and when the indicator is fitted with ancillary parts designed for hand held use – it is less than ideal by definition. The only way to have a lab cal reflect the conditions associated with a hand held use would be too scrap the normal protocols and attempt to duplicate field conditions. Simply not practical since to do so a lab would have to hire a considerable number of testers to generate some statistics associated with re-purposed, hand held use. Those generated statistics would be used to enrich the lab cal and new uncertainty guidance to reflect the hand held variance associated with field use.

The problem is explicitly this: in the lab, a gage is being calibrated in ideal vibration free conditions on a stand using gage block or some kind of automated highly precise micrometer, and what is being recorded is the deviation from the NIST traceable master that has a well bounded tolerance. So you have apples in the field and oranges in the lab.

To suggest how to get a handle on added uncertainty associated with

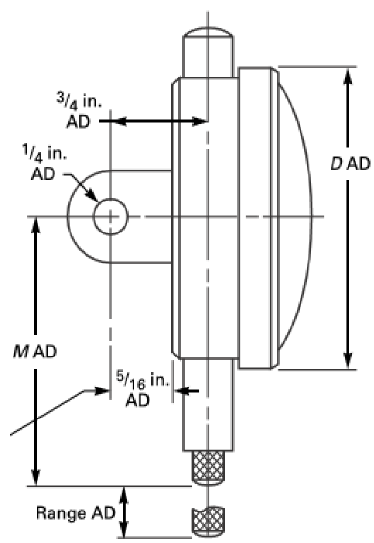

Figure 1

field use, let's first discuss lab cal conditions. The lab goes though all of the conventional steps consistent with any traceable calibration and provides an uncertainty budget consistent with guidance provided by ANSI B89.10.1M-2001. In doing this, a lab will typically grab an indicator by a fitted lug back or the stem (8mm or .375 inches) below the face. A typical indicator that hosts the ancillary parts to make a depth gage is pictured in **figure 1**. The lab then measures the changes in grade associated with gage blocks or micrometer steps and generates an uncertainty budget not unlike that of **Table C1** from the ANSI B89 Standard, as illustrated below.

There is a temptation to simply take this value, say a tenth (meaning one tenth of one mil, as it would commonly be expressed on a machine shop floor) and use it as the underlying uncertainty of a recession measurement. That would be a mistake. The only time it would be valid is when lab techs and engineers are built like vibration free stands operating under ideal conditions measuring traceable ASME BS:4311-1-1993 AAA gage blocks in a near perfect world at 20C. On planet earth, not likely.

Given that reality, the question then becomes the following: how does one understand the "lab certified calibration" that comes with an instrument, assuming one comes with the instrument? For years, in all of its literature, Keysight – one of the premier companies in the microwave space – has added the cautionary guidance that gages *"are only capable of providing coarse measurements . . . due to repeatability concerns", recommending an average of three measurements.*[1] Keysight goes on to remark that in the factory it uses special tools for measuring pin depth, one of which, under case 8282229173, Xiaoye Chen reveals is a Zygo white light interferometer microscope which measures pin depth without making physical contact.[2]

The repeatability concerns expressed in the above Keysight remarks reflect a natural and not unexpected variability in hand use, as well as the variation in surface contour that the gage sits on. Clearly in the field,

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both due to expense and the inability to remove the observer effect that is possible with noninvasive instruments like the light interferometer microscope used by Keysight, the level of uncertainty will be greater than in the lab. But that suggests that bounding uncertainty associated with hand held gaging is all the more pressing.

Standards like IEEE287LPC/GPC commonly call out GD&T specifications for the gaged surfaces, for example, 0.0005 inches (0.0127mm) – or 5/10ths - for both a flat datumless constraint and for perpendicularity relative to the datum of the connector's longitudinal axis. If the user's instrument is capable of discriminating tenths, and the surface variation is specified in tenths per standards like IEEE287, then the tester is measuring within the tolerance boundaries of the specified machine article. Hence repeatability is a function of at least hand use positioning and tolerance properties.

The upshot of the above is that there is a field calibration protocol, different from a lab one, that seeks to capture the above. Given the acknowledgment that gaging is inherently "coarse", to use the Keysight term, it becomes especially compelling to bound that coarseness so as to increase confidence in the gage measurement. This becomes especially critical in regions near "0" recession where the addition of uncertainty can suggest the possibility of procession and its untoward consequences – like female socket impairment due to compression forces.

ATX supplies an uncertainty application with its gages that is designed to add to the lab cal cert an additional measure of uncertainty that reflects specific hand held conditions and surface tolerances. The application captures data over a series of trials for both zero setting and a specific measurement, then generates a standard deviation of the mean, which is

NONMANDATORY APPENDIX C | ASME B89.1.10M-2001

TABLE C1 UNCERTAINTY BUDGET FOR A MECHANICAL INDICATOR CALIBRATION

Source of Uncertainty	Value, µin.	Distribution	Divisor	Standard Uncertainty	Standard Uncertainty^2
Calibration device MPE	30	Uniform (type B)	$\sqrt{3}$	17	289
Calibration device uncertainty	20	Normal (type B)	2	10	100
Repeatability	300	Normal (type A)	1	300	90,000
Resolution	200	Uniform (type B)	$\sqrt{3}$	Not used	Not used
Thermal effects	11.5	Uniform (type B)	$\sqrt{3}$	7	49
				Combined Standard Uncertainty^2:	90,438
				Combined Standard Uncertainty:	≈ 300 µin.
				Expanded Uncertainty Expressed Using $k = 2$:	≈ 600 µin.

then added on a root sum square basis to the lab cal uncertainty before expansion by 2 assigned by the lab for a 95% confidence level. After the addition of statistics associated with hand held use, the final result is again expanded by 2 in order to reflect a second order confidence level. This brings the user closer to an understanding of how hand held use, as opposed to use under ideal lab conditions, adds additional uncertainty. The measurement may still be judged as "coarse" - but at least some good faith effort was made to bound the measurement with a reasonable degree of uncertainty.

Another way to express the above is that the repeatability metric of the lab only reflects specific lab conditions: hence, it needs to be repeated in the field to capture still another set of conditions that depart – sometimes significantly depending on the user – from the lab. Assuming use in a typcial lab, temperature is probably a third order effect at best, so any application that pretends to add understanding to the uncertainties of field use is likely capturing the bulk of the effect by concentrating on repeatability as a function of variations related to user and surface. So the tester in the field or at the bench has two dominate variables to carry forward into a new understanding of uncertainty: the measurement uncertainty stated by the cal lab, and the repeatability associated with hand held use. And the latter is relatively easy to capture.

In a nutshell, calibrating a microwave gage for hand held use is a distinctly different animal from an ISO17025 lab certified calibration in a controlled environment. The lab cal is merely a baseline number to which the uncertainty of field conditions has to be added. Another ATX Tech Brief, *The Art of Microwave Connector Gaging for Optimal Field Calibration,* explores this subject a bit more thoroughtly.

This work was done by Victor R. Spelman, MSEE and Emily Milstein, of ATX Labs.

1. OSM, 85133-90017: Keysight 85133E/F/H NMD-2.4 mm -f- to 2.4 mm and Flexible Test Port Return Cables, p.3-5ff.

2. November 12, 2016: Case ID 8282229173: Gaging Accuracy, Keysight IAE.

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