Octiv™ 2.0 is here

Existing **Octiv™** models to be replaced with **Octiv™ 2.0** models to enhance performance in non-50 ohm environments.

Octiv™ 2.0 will officially launch in July 2017. **Octiv™ 2.0** is a significant upgrade to the **Octiv™** product range and will provide a major improvement in performance in non-50 ohm environments. To achieve this, the calibration method has been redesigned and improved. Therefore, it is classified as a new product and existing Octiv™models will be phased out.

Existing **Octiv™** *customers, with compatible models, will be automatically upgraded to* **Octiv™ 2.0** *during the next scheduled calibration.*

Why Launch Octiv™ 2.0?

To understand the need for **Octiv™ 2.0**, the limitations of the existing **Octiv™** platform will first be described. When **Octiv™** was developed, the focus of the calibration method was to ensure absolute accuracy of 1% into 50 ohms at a fixed frequency and temperature. Unit-to-unit repeatability was expected to follow, which it does at the calibration points but is not guaranteed away from those points.

The overwhelming feedback from our customers has been that unit-to-unit repeatability of 1%, in non-50 ohm environments, is essential for applications such as chamber-to-chamber matching in the semiconductor industry. Absolute accuracy into 50 ohm is still expected. It is acknowledged that absolute accuracy away from 50 ohms will vary with impedance phase.

Once these customer requirements were better understood, a research program was initiated to investigate the elements of the original calibration method that would allow unit-to-unit repeatability drift away from 1%.

The first item to be addressed was temperature variation of the **Octiv™** hardware. It was found that the values reported could drift significantly over the operating temperature range. A detailed calibration of the **Octiv™** hardware temperature was implemented.

The second item to be investigated was temperature variation of the calibration rig. A temperature drift was found in the reference load impedance. A temperature controlled environmental chamber was designed to regulate the temperature of the entire calibration rig. This proved to be very effective and eliminated temperature variation effects on the calibration accuracy.

The final item to be addressed was the need for a **Gold** and **Silver Octiv™** calibration standard to be implemented in order to ensure 1% repeatability across a wide range of impedances. A detailed calibration was carried out on a **Gold-standard Octiv™** against our NIST traceable Gold reference thermal power meter. The relative accuracy of the calibrated **Gold-Standard Octiv™** power measurements were verified to be within 0.3% of our Gold-Reference across the operating frequency range.

Silver-standard **Octiv™** units were calibrated against the **Gold-standard Octiv™**. The relative uncertainty of calibrated **Silver-standard Octivs™** was found to be better than 1%. Production **Octivs™** are calibrated against one set of the silver standard units, the other set of silver standard units being used to test for drift over time.

The advantage of calibrating against a **Silver-standard Octiv™** is that a wider range of power conditions can be incorporated into the calibration procedure, while keeping the calibration time reasonably short. It was found that units being calibrated in production, against the Silver standard, now show unit-to-unit repeatability of less than 1% for a very wide range of power and impedance values.

Octiv™ 2.0 Calibration Method

1. *Gold-Standard Calibration*

The **Gold-Standard Octiv™** calibration process incorporates two individual steps, one for frequency and one for temperature. The frequency calibration is the more difficult of the two. It uses multiple measurements against traceable standards to calibrate the output of the **Octiv™** sensor. The temperature calibration ensures that when no inputs change (except device temperature), the output remains constant.

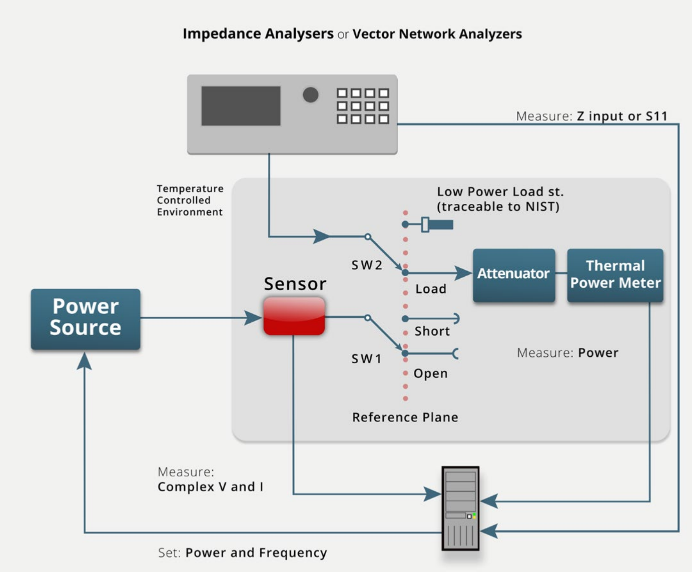

Figure 1: Gold-Standard Octiv™ calibration set-up.

An impedance network exists between the **Octiv™** calibration plane and the Gold-Reference power meter. This impedance network consists of a co-axial transmission line cable and/or a RF attenuator. Therefore, the **Gold-Standard Octiv™** is calibrated at the reference plane shown in figure 1. The calibration process requires several measurements to be performed at the reference measurement plane. Short, Open and 50 ohm impedance standards are used. These standards are traceable to the National Institute of Standards and Technology (NIST).

To perform the **Gold-Standard Octiv™** calibration, the output port is alternately connected to each impedance standard and raw voltage and current values from the uncalibrated sensor are measured. Open and Short measurements are straightforward to implement. For the 50 ohm calibration step the golden-reference power measurements need to be transformed to the **Gold-Standard Octiv™** calibration plane.

Gold-Reference Specification	
Reference Type	Thermal Power Meter
Absolute Uncertainty	±0.04dB (0.92%) 95% confidence (2σ)
Relative Uncertainty	±0.01dB (0.23%) 95% confidence (2σ)

Table 1: Gold-Reference specifications

1.1 *Gold-Reference to Gold-Standard calibration transfer*

An accurate impedance versus frequency measurement is taken for the attenuator and 50 ohm power meter combination using a network analyser as depicted in figure 1. During calibration, power measurements are taken from the Gold-Reference and are transformed to the **Gold-Standard Octiv™** reference plane using the impedance versus frequency characteristic.

Voltage and current levels at the reference plane are calculated from:

$$V_{rms} = \sqrt{\frac{P_{Load}}{\cos(\theta)} \times Z_{Load}} \quad (1)$$

$$I_{rms} = \frac{V_{rms}}{Z_{Load}} \quad (2)$$

V_{rms} and I_{rms} are rms values of voltage and current and P_{Load} and Z_{Load} are absorbed power and input Impedance of the load at the reference plane. Precise knowledge of P_{Load} and Z_{Load} is critical for accurate calibration. For calibration at low powers the dependence of Z_{Load} on absorbed power can be assumed negligible. For calibration at high powers (> 100 W) the load impedance and attenuation of the setup will vary due to heating effects. To counteract the heating effect, the **Gold-Standard Octiv™** is manufactured with a high sensitivity low power range to enable accurate calibration at low power levels. Before each calibration step, the load is brought to thermal equilibrium. Calibration of the **Gold-Standard Octiv™** at multiple frequencies and power levels can take several hours to complete. The errors for voltage and current associated with this calibration setup can be expressed as;

$$V_{error} = \Delta P_{Load} + \Delta Z_{Load} \quad (3)$$

$$I_{error} = \Delta P_{Load} + \Delta Z_{Load} \quad (4)$$

Where ΔP_{Load} is the power meter measurement error and ΔZ_{Load} is the input *impedance* error of the power meter.

The setup for calibration as a function of frequency is shown in figure 1. The **Gold-standard Octiv™** sensor collects uncalibrated voltage and current measurements at the measurement points for each frequency and each power level. To transform these measurements to actual voltage and current values the following equations are used;

$$V = AX + BY \quad (5)$$

$$I = CX + DY \quad (6)$$

where V and I are actual complex voltage and current at the reference plane. X and Y are complex values of digitised signals at the input of the analogue-to-digital converter. A, B, C and D are unknown complex parameters that are determined by calibrating the sensor at the reference plane using three standards i.e. open, short and 50 ohm. For each frequency and power level the 50 ohm load and short circuit are used to evaluate the A and B parameters. Similarly, the 50ohm Load and open circuit measurements are used to evaluate the C and D parameters.

The errors in the calibration transfer for voltage V and current I can be expressed as;

$$I_{error} = \frac{\Delta G_{Att} \pm \Delta P_{Meter} \mp \Delta Z_{Att}}{2} \quad (7)$$

$$V_{error} = \frac{\Delta G_{Att} \pm \Delta P_{Meter} \pm \Delta Z_{Att}}{2} \quad (8)$$

where ΔG_{Att} is the attenuator gain error, ΔP_{Meter} is the power meter error, and ΔZ_{Att} is the attenuator impedance error.

The relative uncertainty of the Gold-Reference thermal power meter used is 0.23%. The uncertainty of the attenuator impedance is shown in figure 2 to be 0.2% below 60 MHz. There is also a phase error that needs to the factored in which is due to the error in the measurement of the attenuator impedance:

$$Phase_{error} = \Delta Z_{Att} \quad (9)$$

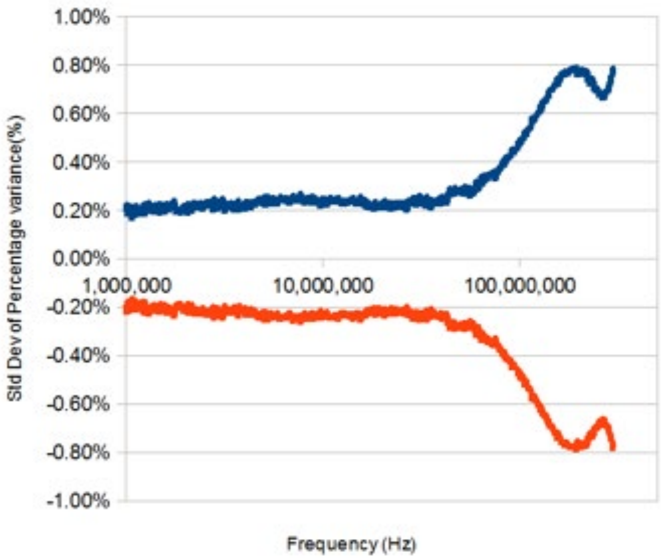

Figure 2: Attenuator Impedance Uncertainty v Frequency

For phase measurements, the **Octiv™**'s repeatability is 0.1^0. The phase uncertainty of the attenuator impedance as shown in figure 3 and is 0.25^0 below 100 MHz. This gives the **Octiv™** a phase uncertainty of 0.35^0.

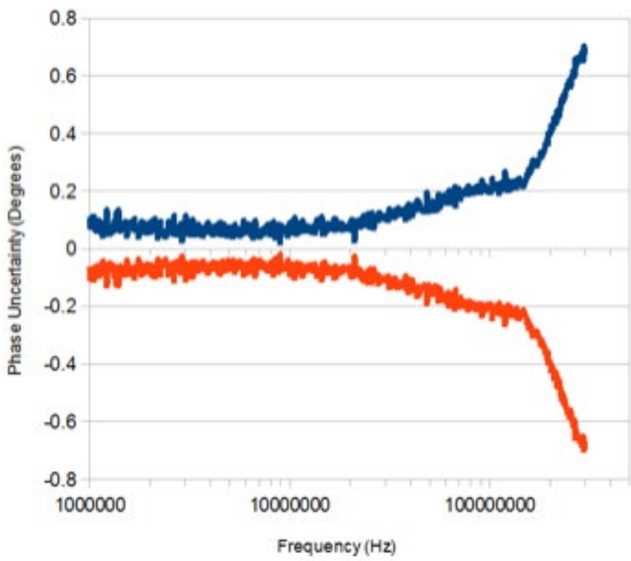

Figure 3: Attenuator Impedance Phase Uncertainty v Frequency

To confirm the calibration transfer accuracy, the method outlined is used to calibrate the **Gold-Standard Octiv™** against the Gold-Reference power meter. Then, a verification procedure is carried out where the calibrated Gold-Standard power, voltage and current readings are compared against the Gold-Reference for a range of power settings and repeated many times. The result is summarised in table 2.

Gold-Standard Specification relative to Gold-Reference 95% confidence (2σ)	
Uncertainty	±0.013dB (0.3%)
Repeatability	±0.013dB (0.3%)

Table 2: Gold-Standard Octiv™ specifications

1.2 *Temperature Calibration*

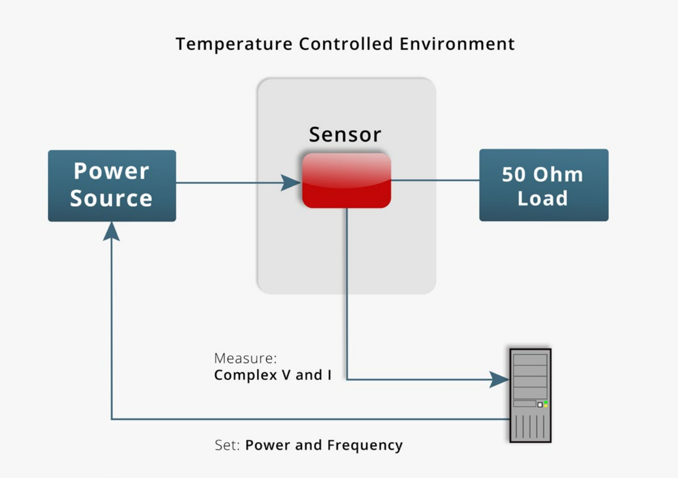

Figure 4: Octiv™ Temperature Calibration Setup

The setup for the temperature calibration is shown above in figure 4. A power source supplies a constant power through the sensor, which is in a temperature controlled environment, to a 50 ohm load. As explained earlier, when power is applied to the 50 ohm load we must wait until the load has reached thermal equilibrium and there is no longer any change in load *impedance* so that we know the power is constant. At this point the output from the **Octiv™** is monitored and the temperature in the temperature controlled environment is varied. The error in the output due to temperature can then be measured and the temperature calibration coefficients are stored in the **Octiv™** memory. This calibration reduces the **Octiv™** voltage and current measurement errors to ± 0.2% due to temperature.

2. *Silver-Standard*

Once the Gold-standard **Octiv™** is calibrated and verified against the Gold-reference, it is used to calibrate **Silver-Standard Octivs™**. The Silver-Standard units are used to calibrate **Octiv™** units in production. Multiple **Silver-Octivs™** are produced, one set is used for calibration in production while another is used to check for drift over time.

Figure 5 shows the setup used to calibrate **Silver-Standard Octivs™** against the Gold-Standard. At this stage of the calibration, the temperature controlled environment is no longer needed. The need for a highly calibrated 50 ohm reference is not necessary either. This means that a standard high power 50 ohm load can be used, which enables calibration levels, for the specified array of fundamental frequencies that need to be calibrated. Power, Voltage, Current and Phase are read from the **Gold-Standard Octiv™** (for 50 ohm, Open and Short terminations) and used to calibrate the silver units. Up to 15 harmonics of each fundamental frequency are also calibrated.

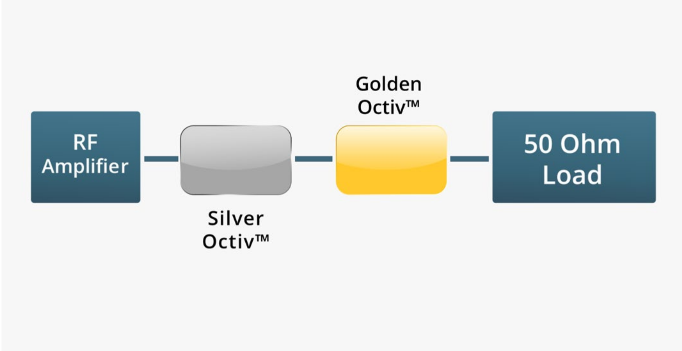

Figure 5: Silver-Standard Octiv™ calibration setup

After the Silver-Standard units are calibrated, they are repeatedly verified against the Gold-Standard. The resultant uncertainties are summarized in table 3.

Silver-Standard Octiv™ specification relative to the Gold-Standard - 95% confidence (2σ)	
Measurement	Uncertainty
Voltage	±0.04 dB (0.5%) 400kHz – 100MHz
Current	±0.04 dB (0.5%) 400kHz – 100MHz
Power (50 ohm)	±0.04 dB (1%) 400kHz – 100MHz
Phase	±0.1⁰ 400kHz – 100MHz

Table 3: Silver-Standard Octiv™ specifications

3. *Production Octiv™ Calibration*

In production, **Octiv™** units are calibrated against the silver-standard. The setup is shown in figure 6. The **Gold-Standard Octiv™** is replaced with the production **Octiv™** in the setup, the Silver-Standard remains in the same position. **Octiv™** units are calibrated using the exact same procedure as used for calibrating Silver-Standards against Gold-Standards.

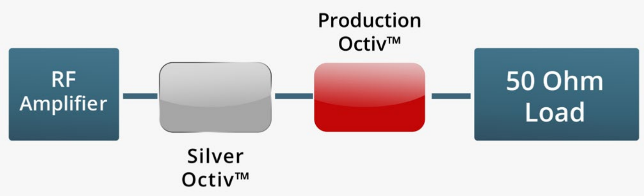

Figure 6: Silver-Standard Octiv™ calibration setup

The result of the production **Octiv™** calibration uncertainty evaluation is summarized in table 4.

Production Octiv™ 2.0 Specifications relative to the Silver-Standard Main Measurement Parameters

RF Voltage	Range	Uncertainty (95% confidence (2σ)
RF Current	0.1 Arms – 20 Arms	0.5% or 10 mA, whichever is greater
Phase Angle	± 180⁰	0.1⁰
Power (50 ohms)	12kW (standard)	1% or 1W, whichever is greater
Fundamental fre-quency range	400kHz – 80MHz	-
Harmonic frequency range	400kHz – 240MHz	-

Table 4: Production Standard Octiv™ specifications

If you would like any further information on the **Octiv Range**, or any of our products, please contact us at:

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