

## OCTIV RF VOLTAGE/CURRENT SENSORS

FOR YOUR RF PLASMA MEASUREMENT AND CONTROL APPLICATIONS



### Octiv™ Suite 2.0

Radio-frequency VI Probe for  
harmonic frequency spectrum and  
waveform analysis

#### Typical Frequencies

400 kHz, 2 MHz, 13.56 MHz, 27.12 MHz,  
40.68 MHz, 60 MHz

#### RF Voltage/Current Range

Up to 7 kV peak, up to 100 A rms

## Octiv Suite 2.0

The Octiv Suite 2.0 VI probe is the most advanced RF sensor on the market for in-line power and impedance measurement, with unrivaled accuracy and functionality. It is a non-intrusive, in-line sensor used to monitor the RF harmonic spectrum and waveform at the RF process input in real time to enable process and/or equipment control. It can be used as a stand-alone instrument with our state-of-the-art software or integrated directly with any software platform using one of our advanced communication protocols.

The Octiv Suite 2.0 VI probe helps you understand your RF process in more detail, troubleshoot process performance and identify process equipment faults. The sensor output can be used to set alarms or to control process equipment directly. The Octiv system is suitable for retrofit applications in the factory or for OEM integration in plasma tools, matching networks and RF generators. Typical applications include match unit and RF

and process end-pointing. Advanced, NIST traceable, calibration methodology ensures that accuracy is maintained across the range of process impedances encountered in the industry. The advanced waveform display functionality enables direct measurement of process parameters such as the ion flux to a substrate under processing.

### Key Features

- Choice of 5 frequencies on a single sensor, measures multiple frequencies simultaneously.
- Unrivalled accuracy into 50  $\Omega$  and non-50  $\Omega$  load impedances through our advanced calibration methodology.
- NIST traceable Voltage and Current accuracy of 1 % and phase accuracy of 1°.
- Accurate in-line impedance measurements around the Smith chart.
- Waveform display and harmonic phase reporting.
- Pulsed RF monitoring for multi-level pulsing and multiple frequencies simultaneously.
- Monitor plasma parameters directly, such as ion flux to the substrate during processing.

### Key Benefits

- Only one sensor required for multiple frequency applications, saving significant cost.
- Accurate voltage, current and impedance measurements at typical RF process impedances.
- Measurement accuracy traceable to NIST, ensuring reproducible and repeatable data from sensor to sensor.
- Virtual metrology of some of the key plasma parameters available, unique in the market
- Customizable for seamless integration into your process equipment and control loop.
- Significant cost benefits through the enablement of fault detection and early intervention.

### Low Cost of Ownership

Each sensor can cover five fundamental frequencies. The Octiv sensor has the widest measurement range for voltage and current on the market. The accuracy is maintained over the entire range.

### Cost Benefits

Enormous cost benefits can be achieved through integration of the Octiv with OEM equipment. Whether integrated in the matching network, the RF generator or the plasma tool cost benefits can be realized. Cost savings are achieved through general RF health diagnosis, fault detection and chamber impedance deviation reporting – all of which, if not detected early, can result in scrap events of very valuable wafers or substrates.

### Get Ahead of the Competition

For applications such as fast match tuning and pulse monitoring, the Octiv platform has the edge over its competition. With data report rates approaching 10 us, the Octiv technology is way ahead of the field in terms of performance, speed, accuracy and reliability. You can improve your product specification, relative to your competition, with the Octiv sensor integrated in your equipment. The Octiv Suite product has a time domain waveform display as well as the harmonic spectrum display. With this advanced functionality, reporting of plasma parameters such as ion flux is now available.

### Advanced Communication features

The Octiv platform comes equipped with a wide variety of communication options. USB or Ethernet connectivity is used to interface with the Octiv software suite. USB, TCP/IP, EtherCat, EtherNet/IP and serial protocols are available to communicate directly with the sensor.

### Simple Design for Ease of Integration

The Octiv product has a streamlined design consisting of a single, self-contained enclosure in which the analog detection modules, the digitization modules and the physical communication interfaces are all contained. The advantage is that the signals are digitized very close to where they are detected, dramatically improving noise performance and calibration accuracy. Other products on the market consist of up to three separate components; analog sensing head, analog transmission cable and digitization/control box. The three components must be calibrated as a set, the system must be calibrated more often and the integration with OEM equipment is more complicated.

### Improved Accuracy

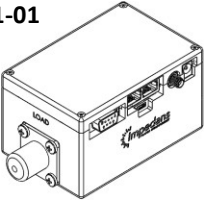
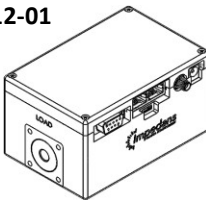
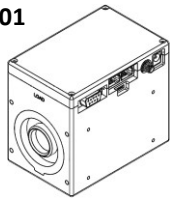
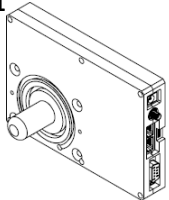
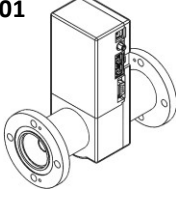
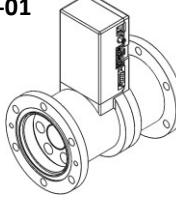
Advanced, NIST traceable calibration techniques, developed through a decade of research, have been implemented to extend the accuracy from 50  $\Omega$  out to the edge of the Smith chart, where a lot of real-world plasma processes operate. Impedance measurements have been verified against an industry standard vector impedance analyzer. Power accuracy is maintained across the verifiable range to VSWR 6.0:1.

## Model Options

Table 1: Octiv Suite 2.0 - Model Specifications

Model #	Fwd Power Range <sup>1</sup>	Frequency Ranges <sup>2,3</sup>	Connector
<b>02-0322-01</b>	1.5 W – 12 kW	350 kHz – 100 MHz	QC Type
<b>02-0325-01</b>	0.5 W – 5 kW	40 kHz – 400 kHz	QC Type
<b>02-0312-01</b>	1.5 W – 12 kW	350 kHz – 100 MHz	B6N Multicontact Socket <sup>4</sup>
<b>02-0315-01</b>	1.5 W – 12 kW	350 kHz – 100 MHz	B20N Multicontact Socket <sup>5</sup>
<b>02-0317-01</b>	1.5 W – 12 kW	350 kHz – 100 MHz	B20N Multicontacts
<b>02-0319-01</b>	3 W – 30 kW	350 kHz – 100 MHz	EIA 1-5/8"
<b>02-0321-01</b>	9 W – 90 kW	350 kHz – 100 MHz	EIA 3-1/8"

Table 2: Octiv Suite 2.0 - Model Form Factors

<p><b>02-0311-01</b></p> 	<p><b>02-0312-01</b></p> 	<p><b>02-0315-01</b></p> 
<p><b>02-0317-01</b></p> 	<p><b>02-0319-01</b></p> 	<p><b>02-0321-01</b></p> 

<sup>1</sup> Connector and VSWR dependent.

<sup>2</sup> Five fundamental frequencies can be selected within this range, each with a sub-range of +/- 10%.

<sup>3</sup> Custom options also available

<sup>4</sup> Spade terminal and custom LC connector options available.

<sup>5</sup> Adapters for B20N-to-QC and other connectors available

Table 3: Model 02-0232-01 Connector Options

MODEL DETAILS	STANDARD CONNECTORS <sup>6</sup>	
<p data-bbox="343 884 470 907"><b>02-0311-01</b></p> <p data-bbox="295 952 518 1008">QUICK CHANGE (QC) INTERFACE</p> 	<p data-bbox="766 470 885 492">HN FEMALE</p> 	<p data-bbox="1157 470 1268 492">HN MALE</p> 
	<p data-bbox="774 683 877 705">N FEMALE</p> 	<p data-bbox="1165 683 1260 705">N MALE</p> 
	<p data-bbox="750 896 901 918">7/16" FEMALE</p> 	<p data-bbox="1141 896 1276 918">7/16" MALE</p> 
	<p data-bbox="774 1108 885 1131">LC FEMALE</p> 	<p data-bbox="1157 1108 1260 1131">LC MALE</p> 
	<p data-bbox="774 1321 885 1344">C FEMALE</p> 	<p data-bbox="1165 1321 1252 1344">C MALE</p> 
	<p data-bbox="813 1556 901 1579">EIA 7/8"</p> 	<p data-bbox="1157 1545 1268 1568">EIA 1-5/8"</p> 
	<p data-bbox="734 1758 949 1814">SPADE TERMINAL &amp; PTFE BRACKET</p> 	

<sup>6</sup> Others available on request.

Table 4: Model 02-0307-01 Interface & Connector Options

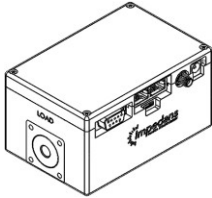
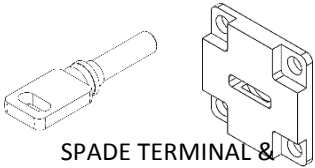
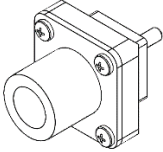
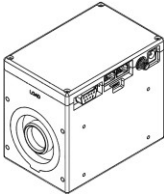



MODEL DETAILS	RF INTERFACE	CONNECTOR OPTIONS <sup>7</sup>
<p><b>02-0312-01</b></p> <p>6 mm MULTICONTACT (B6N) INTERFACE</p> 	<p>RF INPUT (GENERATOR) &amp; RF OUTPUT (LOAD)</p> <p>6 mm SOCKET</p>	 <p>SPADE TERMINAL &amp; PTFE BRACKET</p>  <p>LC FEMALE CONNECTOR</p>

Table 5: Model 02-0314-01 Interface & Connector Options

MODEL DETAILS	RF INTERFACE	CONNECTOR OPTIONS <sup>8</sup>
<p><b>02-0315-01</b></p> <p>20 mm MULTICONTACT (B20N) INTERFACE</p> 	<p>RF INPUT (GENERATOR) &amp; RF OUTPUT (LOAD)</p> <p>20 mm SOCKET</p> 	 <p>M10 SCREW</p>  <p>20 mm PLUG</p>

<sup>7</sup> Custom options available on request.

<sup>8</sup> Adapters available on request e.g. B20N-to-HN

Table 6: Model 02-0308-01<sup>9</sup> Interface

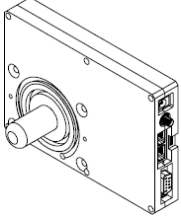
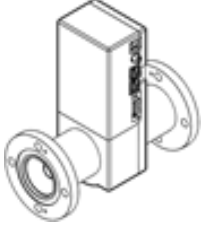

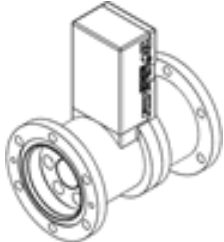

MODEL DETAILS	INPUT INTERFACE	OUTPUT INTERFACE
<p><b>02-0317-01</b></p> <p>20 mm MULTICONTACT INTERFACE</p> 	<p>RF INPUT (GENERATOR)</p> <p>20 mm PLUG</p>	<p>RF OUTPUT (LOAD)</p> <p>20 mm SOCKET</p>

Table 7: Model 02-0319-01 & 02-0321-01 Interface<sup>10</sup>

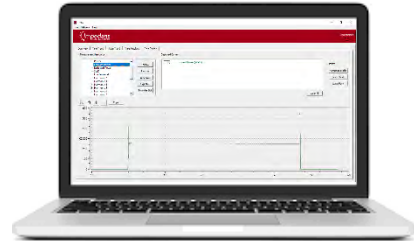
MODEL DETAILS	INPUT INTERFACE	OUTPUT INTERFACE
<p><b>02-0319-01</b></p> <p>EIA 1-5/8" INTERFACE</p> 	<p>RF INPUT (GENERATOR) INTERFACE</p> <p>EIA 1-5/8"</p> 	<p>RF OUTPUT (LOAD) INTERFACE</p> <p>EIA 1-5/8"</p> 
<p><b>02-0321-01</b></p> <p>EIA 3-1/8" INTERFACE</p> 	<p>RF INPUT (GENERATOR) INTERFACE</p> <p>EIA 3-1/8"</p> 	<p>RF OUTPUT (LOAD) INTERFACE</p> <p>EIA 3-1/8"</p> 

<sup>9</sup> Ideally suited for OEM integration as generator output sensor or match unit input sensor.

<sup>10</sup> Adapters to other RF connector types available on request.

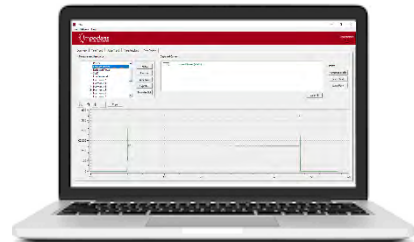
## Connectivity Options

Connect directly to a PC through the micro USB port



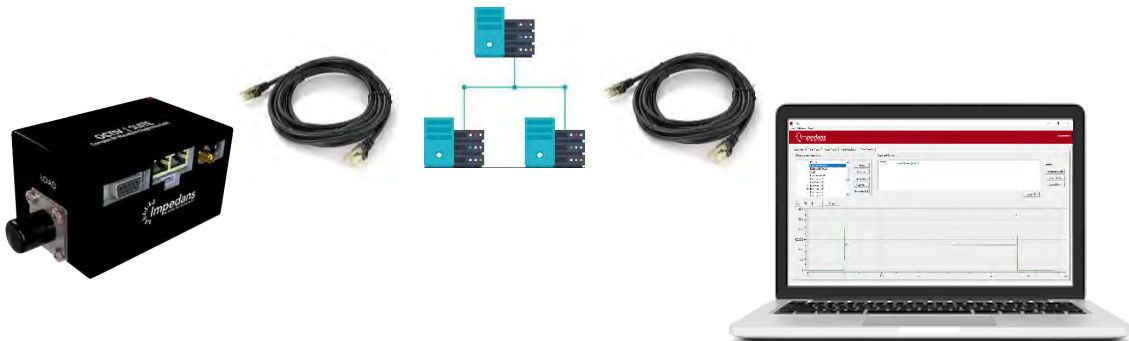
- or -

Connect directly to a PC through the RJ45 port. This requires a static IP address to be configured on both the sensor and the PC as described in the user guide.



- or -

Connect the sensor and PC to your building network. Use the 'Scan Network' function in the Octiv software to locate and connect to the sensor.





## Parameters Reported

Table 8: RF parameters measured by Octiv sensors.

Parameters measured by the Octiv sensors (many other RF parameters can be calculated and output on request)	
<b>F<sub>0</sub></b>	Fundamental frequency
<b>F<sub>N</sub></b>	Harmonic frequency number
<b>V</b>	RMS Voltage (magnitude)
<b>I</b>	RMS Current (magnitude)
<b>Phase (θ)</b>	Phase of the current relative to the voltage
<b>P</b>	Delivered power ( $V \cdot I \cdot \cos\theta$ )
<b>P fwd</b>	Forward power
<b>P ref</b>	Reflected power
<b>Z complex</b>	Complex impedance in the form R+jX
<b>Z polar</b>	Impedance in polar form with magnitude and phase angle
<b>Gamma</b>	Reflection coefficient
<b>SWR</b>	Standing wave ratio
<b>J<sub>i</sub></b>	Ion flux, calculated for rf biased electrodes
<b>Harmonic phase</b>	Phase between fundamental voltage or current and its harmonics
Additional outputs	
<b>Smith Chart</b>	Smith chart tracking of impedance variation
<b>Harmonic spectrum</b>	Harmonic amplitude frequency spectrum
<b>Waveform view</b>	Time dependent waveform display of voltage and current

## Specifications

Table 9: General Specifications

VI Probe Specifications – General	
<b>Calibration Standard</b>	NIST traceable [Power, Impedance]
<b>Calibration Cycle</b>	1 Year to maintain quoted accuracy
<b>Sensor Characteristic Impedance</b>	50 Ohms as standard
<b>RF Connectors</b>	QC range and various custom options
<b>RF Power Range</b>	Standard: 12 kW typical (connector dependent) High Power: 30 kW & 60 kW models available on request
<b>Operating Temperature Range</b>	10 <sup>0</sup> C – 80 <sup>0</sup> C, calibrated as a function of temperature
<b>Sensor Power Requirements</b>	15 - 24 V DC, 0.5 A
<b>Communication Interfaces (Standard)</b>	Micro USB, RJ45x2
<b>Communication Interfaces (OEM Options)</b>	Analog output x4 pin, Digital I/O x2 pin
<b>Connectivity (Impedans Software)</b>	USB 2.0, Ethernet
<b>Communication Protocols (Standard)</b>	USB 2.0, HTTP Web Service
<b>Communication Protocols (OEM Options)</b>	EtherCAT, EtherNet/IP, Serial
<b>Form Factor</b>	Self-contained single unit 58x70x107mm standard. Custom options also available.
<b>Parameter Report Rate (Standard)</b>	USB, Ethernet: 100 S/s
<b>Parameter Report Rate (OEM with Future Firmware Upgrades)</b>	USB, Serial: 100 kS/s max
<b>Sensor Pulse Synchronization</b>	External sync: TTL input Internal sync: Software level trigger

Table 10: Frequency Specifications

VI Probe Specifications – Frequency	
<b># Fundamental Frequencies (F<sub>0</sub>)</b>	Choose 5 from the fundamental frequency range. Measures 5 simultaneously.
<b>F<sub>0</sub> Range</b>	350 kHz – 100 MHz
<b>F<sub>0</sub> Specials</b>	40 kHz & 162 MHz models available on request
<b>Harmonic Frequency (F<sub>N</sub>) Range</b>	350 kHz – 240 MHz
<b>Frequency Resolution</b>	1 kHz
<b>Frequency Accuracy</b>	± 1 kHz
<b># F<sub>N</sub></b>	≤ 15 per fundamental (64 max.), ≤ 32 simultaneously
<b>F<sub>0</sub> Modes</b>	CW, CW with Tuning, Multi-level Pulsing with Tuning
<b>F<sub>0</sub> Tracking Rate</b>	10 kHz/μs
<b>F<sub>0</sub> Tracking Range</b>	± 10% or ± 2 MHz, whichever is less

Table 11: Voltage &amp; Current Specifications

VI Probe Specifications – Voltage & Current	
<b>Voltage Dynamic Range</b>	80 dB
<b>Voltage Range (Typical)</b>	0.3 V to 3000 V <sub>RMS</sub> , custom available
<b>Voltage Resolution</b>	0.1 V <sub>RMS</sub>
<b>F<sub>0</sub> Voltage Uncertainty (95% Confidence)</b>	±1% or 1 V <sub>RMS</sub> (whichever is larger) for F <sub>0</sub> in the range 2 – 60 MHz. ±2% or 1 V <sub>RMS</sub> , where F <sub>0</sub> < 2 MHz & F <sub>0</sub> > 60 MHz
<b>F<sub>N</sub> Voltage Uncertainty (95% Confidence)</b>	±5% or 1 V <sub>RMS</sub> , for F <sub>N</sub> in the range 350 kHz – 240 MHz
<b>Current Dynamic Range</b>	80 dB
<b>Current Range (Typical)</b>	2.5 mA <sub>RMS</sub> to 25 A <sub>RMS</sub> , custom available
<b>Current Resolution</b>	2.5 mA <sub>RMS</sub>
<b>F<sub>0</sub> Current Uncertainty (95% Confidence)</b>	±1% or 0.1 A <sub>RMS</sub> (whichever is larger) for F <sub>0</sub> in the range 2 MHz – 60 MHz ±2% or 0.1 A <sub>RMS</sub> for F <sub>0</sub> < 2 MHz & F <sub>0</sub> > 60 MHz
<b>F<sub>N</sub> Current Uncertainty (95% Confidence)</b>	±5% or 0.1 A <sub>RMS</sub> for F <sub>N</sub> in the range 350 kHz – 240 MHz

Table 12: Impedance &amp; phase Specifications

VI Probe Specifications – Impedance & Phase	
<b>Impedance Range</b>	0.01 Ω - 10 kΩ (Voltage and current load dependent)
<b>Impedance Uncertainty</b>	See Smith Charts
<b>Phase Range</b>	±180°
<b>Phase Resolution</b>	0.02°
<b>F<sub>0</sub> Phase Uncertainty (95% Confidence)</b>	±1°
<b>F<sub>N</sub> Phase Uncertainty (95% Confidence)</b>	±1°, where F <sub>N</sub> < 100 MHz

Table 13: Pulse Monitoring Specifications

VI Probe Specifications – Pulse Profiling & Monitoring	
<b>Pulse Profile – Standard Mode</b>	
<b>Acquisition Method</b>	Boxcar average
<b>Pulse Frequency Range</b>	10 Hz to 100 kHz
<b>Time Resolution</b>	1 $\mu$ s
<b>Acquisition Time</b>	> 1 second (pulse frequency dependent), average over many pulses
<b>Pulse Level Monitor [# Time Frames]</b>	2 per pulse period (more on request)
<b>Pulse Level Monitor [Report Rate]</b>	< 10 S/s (pulse frequency dependent)
<b>Advanced Pulse Mode for OEM Integration</b>	
<b>Acquisition Method</b>	Instantaneous sampling within pulse period
<b>Time Resolution for Data Sampling</b>	3.5 $\mu$ s
<b>Minimum Pulse Width</b>	3.5 $\mu$ s
<b>Data Sampling</b>	Data samples can be averaged or taken individually at different pulse times
<b>Data Report Rate</b>	Every 200 $\mu$ s moving to 10 $\mu$ s with future firmware upgrades
<b>Data Transfer Latency</b>	200 $\mu$ s min. @ 200 $\mu$ s report rate 30 $\mu$ s min. @ 10 $\mu$ s report rate

Table 14: Uncertainty Specifications

VI Probe Specifications – Uncertainty & Unit-to-Unit Repeatability	
<b>Absolute Uncertainty</b>	1% for Voltage and Current over verifiable range
<b>VSWR Range for Verifiable Uncertainties</b>	6.0:1
<b>Absolute Uncertainty Beyond Verifiable Range</b>	Inferred by verification against NIST traceable impedance analyzer. See Smith charts.
<b>Uncertainty Confidence Interval</b>	95% (2- $\sigma$ )
<b>Absolute Unit-to-Unit Uncertainty</b>	1.4% for Voltage and Current
<b>Unit-to-Unit Uncertainty in Calibration Batch</b>	< 0.5%

Table 15: Run-to-Run Repeatability Specifications

VI Probe Specifications – Run-to-Run Repeatability	
<b>Frequency (<math>F_0</math> &amp; <math>F_N</math>)</b>	0.3 Hz
<b>Power (<math>F_0</math> &amp; <math>F_N</math>)</b>	0.1% or 0.05W, whichever is greater
<b>Voltage (<math>F_0</math> &amp; <math>F_N</math>)</b>	0.05% or 0.01 V, whichever is greater
<b>Current (<math>F_0</math> &amp; <math>F_N</math>)</b>	0.05% or 0.01 A, whichever is greater
<b>Phase (<math>F_0</math> &amp; <math>F_N</math>)</b>	0.005 degrees

## Dimensional Drawings

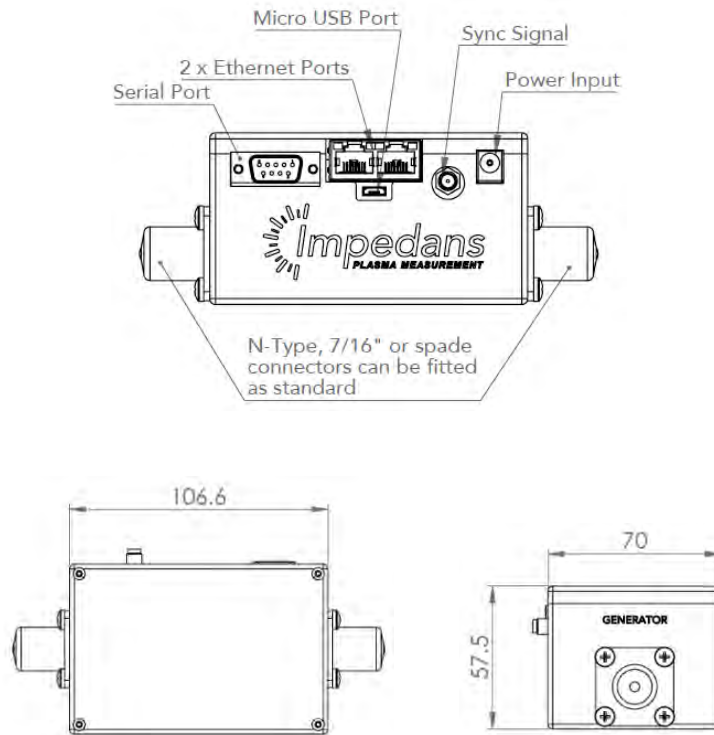


Figure 1: Dimensional drawings of the standard Octiv Suite model 02-311-01 with quick change RF connector interface. All dimensions are in mm. Contact Impedans for dimensional drawings of other models.

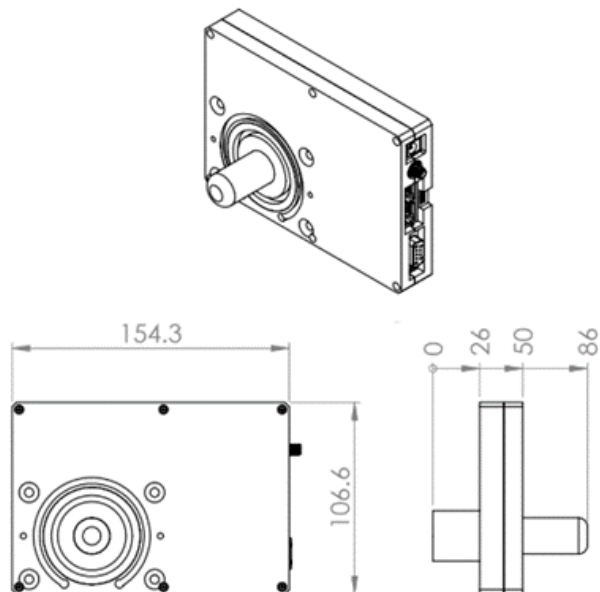


Figure 2: Dimensional drawings of model 02-0317-01.

## System Verification

### Impedans Measurement

The accuracy of calibration is verified by comparing the measurements of a range of fixed impedance loads from the Octiv sensor and from an industry standard vector impedance analyzer for a range of frequencies. Excellent agreement is found, out to the edge of the Smith Chart. Since there is no high accuracy NIST traceable standard for RF voltage and current, we infer the accuracy from the impedance accuracy across the Smith Chart and from power accuracy close to 50 Ohms verified through RF calorimetry.

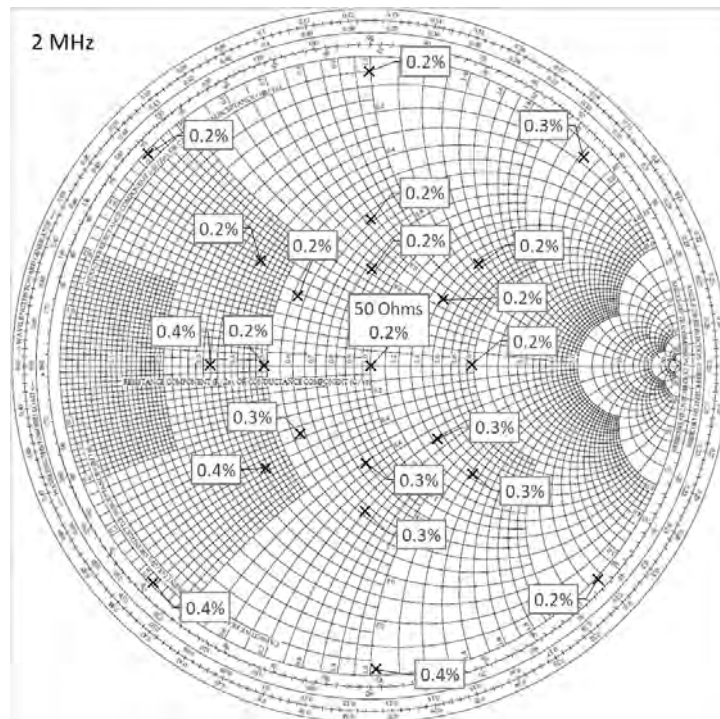


Figure 3: Typical 2 MHz impedance verification of an Octiv unit against VNA.

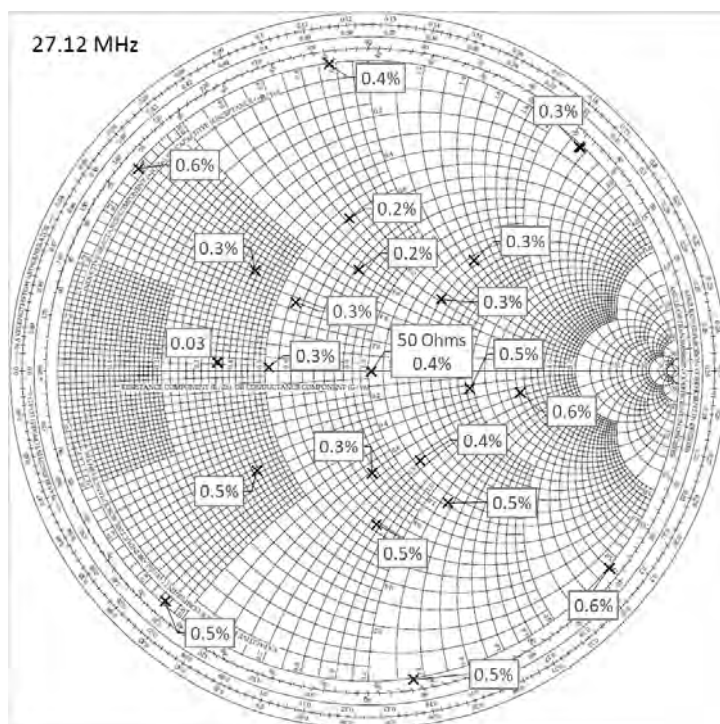


Figure 4: Typical 27.12 MHz impedance verification against VNA.

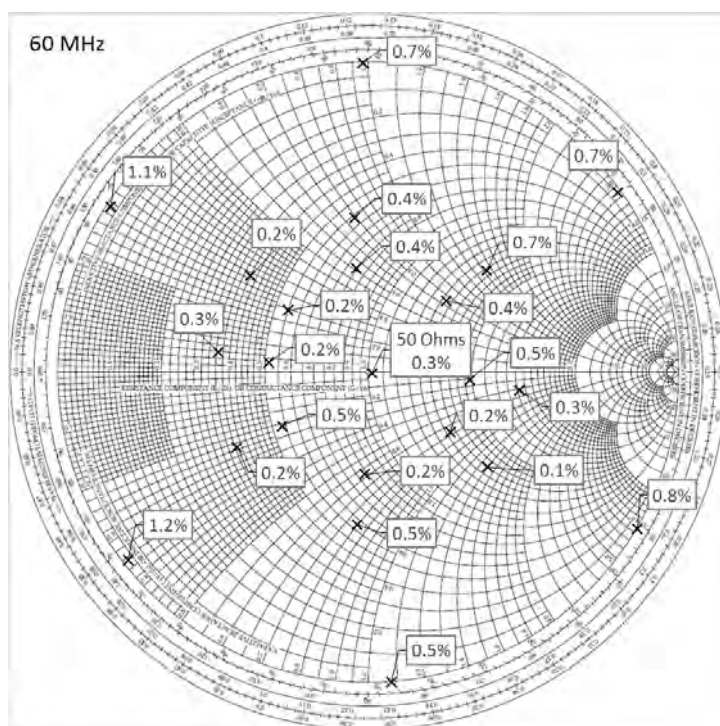


Figure 5: Typical 60 MHz impedance verification against VNA.

## Power Measurement

Unit-to-unit accuracy is verified by comparing power measurements, from pairs of calibrated Octvix, for a power ramp of 100 W to 5000 W into a 50 Ohm dummy load. A typical result is shown in figure 5.

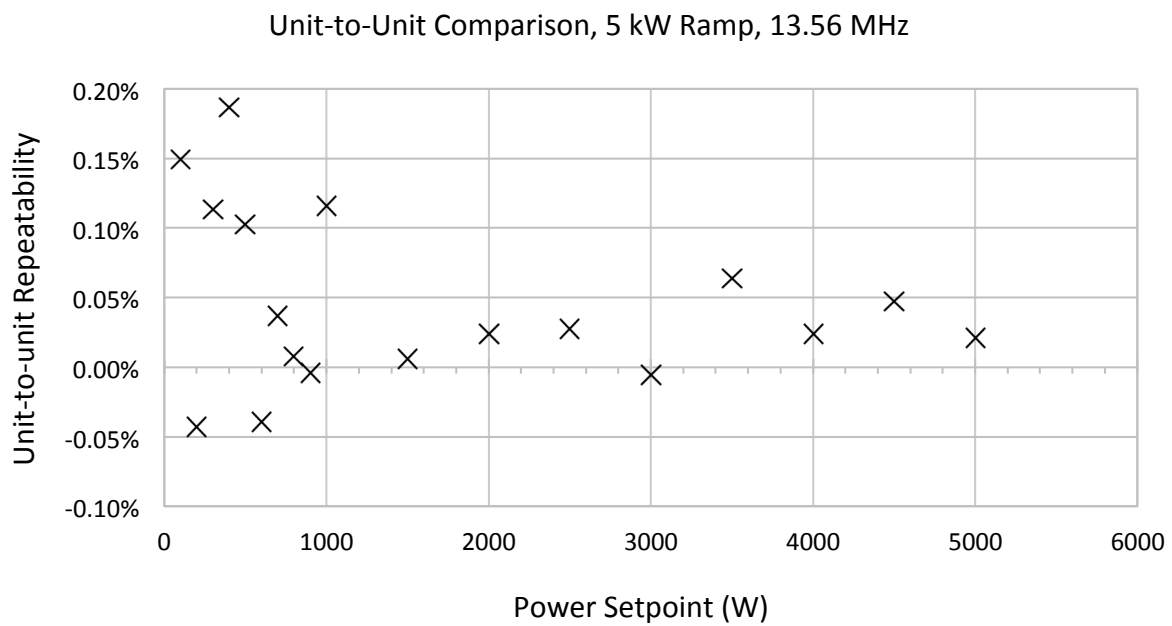


Figure 6: Unit to unit repeatability versus power. The Y axis shows the percentage difference between the two units at each setpoint power.



## Software Display

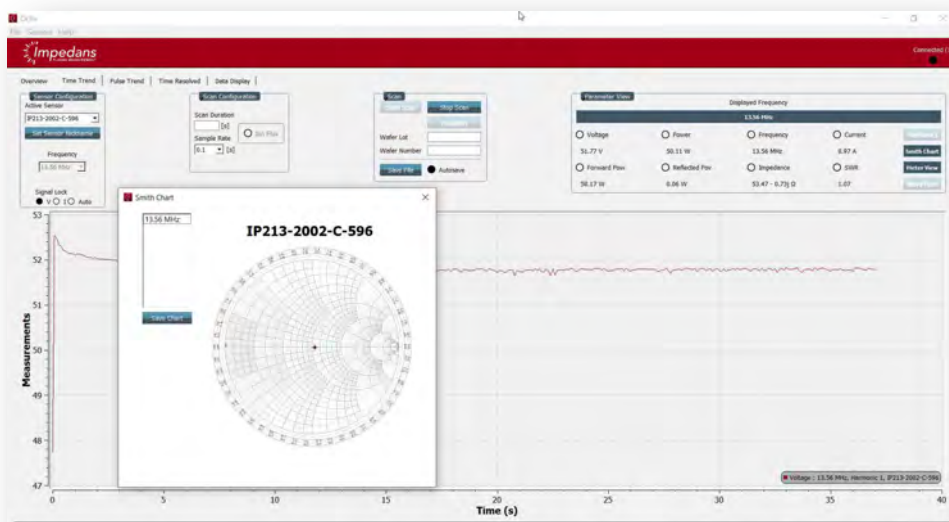


Figure 7: Example of the smith chart.

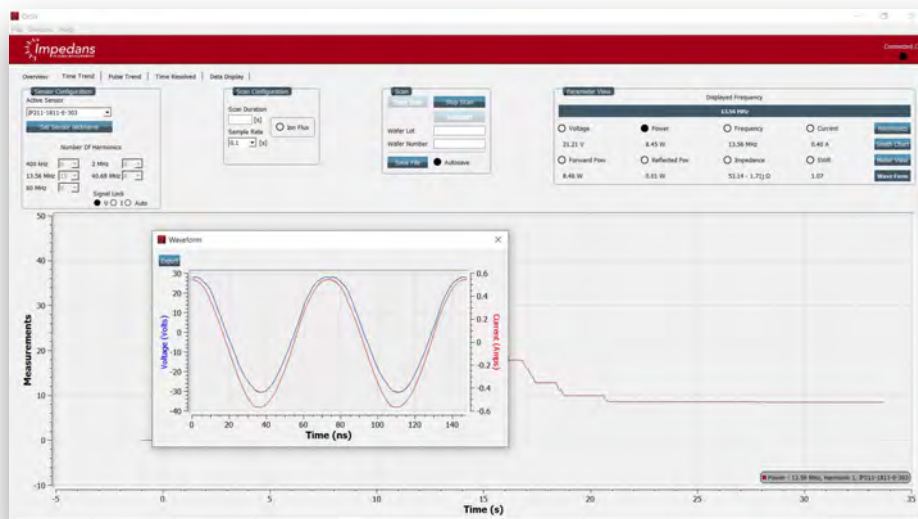


Figure 8: Example of the waveform.



Figure 9: Example of the meter view.