Impedans
PLASMA MEASUREMENT

OCTIV RF VOLTAGE/CURRENT SENSORS

FOR YOUR RF PLASMA MEASURMENT AND CONTROL APPLICATIONS

Octiv^{TM} Poly 2.0

Radio-frequency VI Probe for Accurate In-line Power and Impedance Measurement

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 Poly 2.0

The Octiv Poly 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 measure RF process conditions 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 suite or integrated directly with any software platform using one of our advanced communication protocols. There is a solution for every application.

The Octiv Poly 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 generator control, fault detection, chamber finger printing, chamber-to-chamber matching and process end-pointing. Advanced, NIST traceable, calibration methodology ensures that accuracy is maintained across the range of process impedances encountered in the industry.

Key Features

- Choice of 5 frequencies on a single sensor, measures multiple frequencies simultaneously.
- Unrivalled accuracy into 50 Ω and non-50 Ω 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.
- Frequency tracking to ± 10% of the fundamental frequency.
- Pulsed RF monitoring for multi-level pulsing and multiple frequencies simultaneously.
- Multiple communication protocols and customizable form factor.

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.
- Achieve on-line impedance measurements with similar accuracy to expensive, off-line, vector impedance analyzers for chamber matching applications.
- 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.

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. There are four analog output channels available to output one parameter per channel. Analog levels are 0 – 5V. Two digital output channels are also provided (0 – 3.3V) which can be used for alarming for example.

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

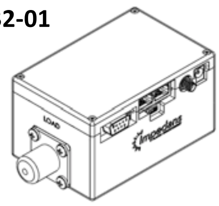
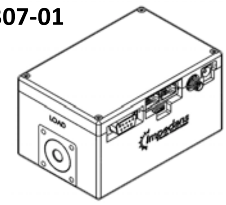
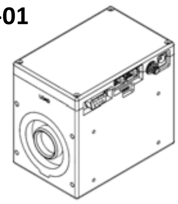
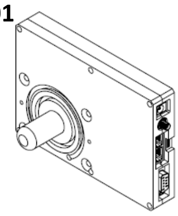
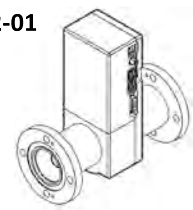
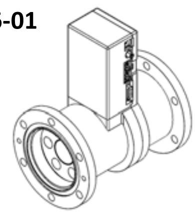
Advanced, NIST traceable calibration techniques, developed through a decade of research, have been implemented to extend the accuracy from 50 Ω out to the edge of the Smith chart, where a lot of real-world plasma processes operate. Impedance measurements have been verified against an industry standard vector impedance analyzer. Power accuracy is maintained across the verifiable range to VSWR 6:0:1.

Model Options

Table 1: Octiv Poly 2.0 – Model Specifications

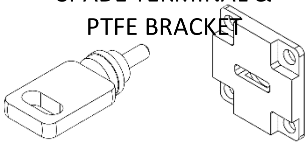
Model #	Fwd Power Range[1]	Frequency Ranges[2,3]	Connector
02-0232-01	1.5 W – 12 kW	350 kHz – 100 MHz	QC Type
02-0324-01	0.5 W – 5 kW	40 kHz – 400 kHz	QC Type
02-0307-01	1.5 W – 12 kW	350 kHz – 100 MHz	B6N Multicontact Socket[4]
02-0314-01	1.5 W – 12 kW	350 kHz – 100 MHz	B20N Multicontact Socket[5]
02-0308-01	1.5 W – 12 kW	350 kHz – 100 MHz	B20N Multicontacts
02-0252-01	3 W – 30 kW	350 kHz – 100 MHz	EIA 1-5/8"
02-0306-01	9 W – 90 kW	350 kHz – 100 MHz	EIA 3-1/8"

Table 2: Octiv Poly 2.0 – Model Form Factors

02-0232-01 	**02-0307-01** 	**02-0314-01** 
02-0308-01 	**02-0252-01** 	**02-0306-01** 

[1] Connector and VSWR dependent.
[2] Five fundamental frequencies can be selected within this range, each with a sub-range of +/- 10%.
[3] Custom options also available
[4] Spade terminal and custom LC connector options available.
[5] Adapters for B20N-to-QC and other connectors available

Table 3: Model 02-0232-01 Connector Options

MODEL DETAILS	STANDARD CONNECTORS[6]	
02-0232-01 QUICK CHANGE (QC) INTERFACE 	HN FEMALE 	HN MALE 
	N FEMALE 	N MALE 
	7/16" FEMALE 	7/16" MALE 
	LC FEMALE 	LC MALE 
	C FEMALE 	C MALE 
	EIA 7/8" 	EIA 1-5/8" 
	SPADE TERMINAL & PTFE BRACKET 	

[6] Others available on request.

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

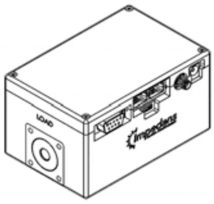
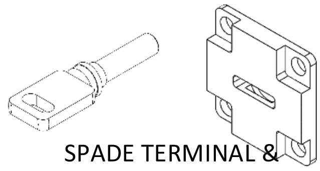
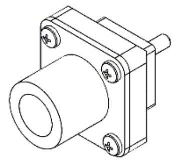
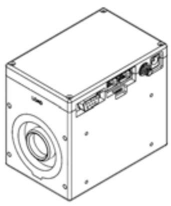
MODEL DETAILS	RF INTERFACE	CONNECTOR OPTIONS[7]
02-0307-01 6 mm MULTICONTACT (B6N) INTERFACE 	RF INPUT (GENERATOR) & RF OUTPUT (LOAD) 6 mm SOCKET 	 SPADE TERMINAL & PFTE BRACKET
		 LC FEMALE CONNECTOR

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

MODEL DETAILS	RF INTERFACE	CONNECTOR OPTIONS[8]
02-0314-01 20 mm MULTICONTACT (B20N) INTERFACE 	RF INPUT (GENERATOR) & RF OUTPUT (LOAD) 20 mm SOCKET 	 M10 SCREW
		 20 mm PLUG

[7] Custom options available on request.
[8] Adapters available on request e.g. B20N-to-HN

Table 6: Model 02-0308-01[9] Interface

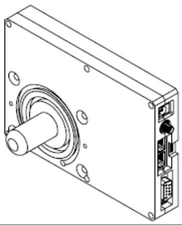
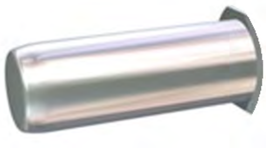
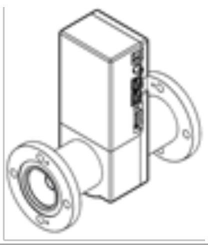
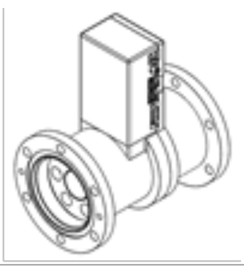
MODEL DETAILS	INPUT INTERFACE	OUTPUT INTERFACE
02-0308-01 20 mm MULTICONTACT INTERFACE 	RF INPUT (GENERATOR) 20 mm PLUG 	RF OUTPUT (LOAD) 20 mm SOCKET 

Table 7: Model 02-0252-01 & 02-0306-01 Interface[10]

MODEL DETAILS	INPUT INTERFACE	OUTPUT INTERFACE
02-0252-01 EIA 1-5/8" INTERFACE 	RF INPUT (GENERATOR) INTERFACE EIA 1-5/8" 	RF OUTPUT (LOAD) INTERFACE EIA 1-5/8" 
02-0306-01 EIA 3-1/8" INTERFACE 	RF INPUT (GENERATOR) INTERFACE EIA 3-1/8" 	RF OUTPUT (LOAD) INTERFACE EIA 3-1/8" 

[9] Ideally suited for OEM integration as generator output sensor or match unit input sensor.
[10] Adapters to other RF connector types available on request.

Connectivity Options

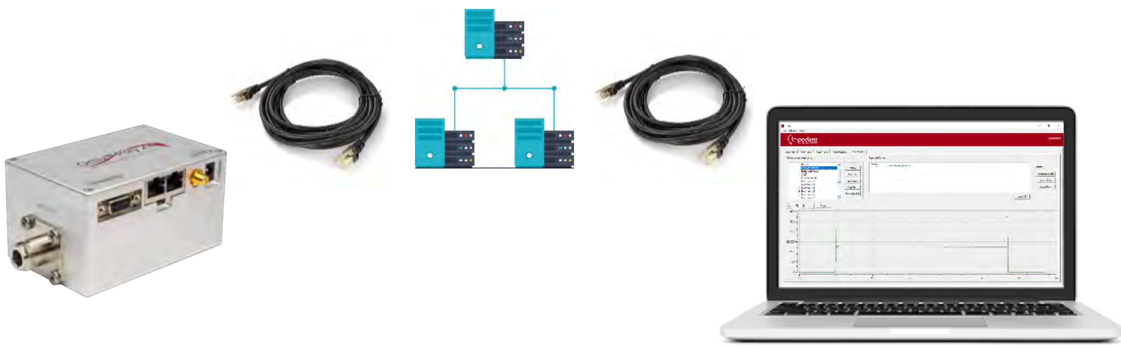
Connect directly to a PC through the micro USB port

- 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)	
F_0	Fundamental frequency
F_N	Harmonic frequency number
V	RMS Voltage (magnitude)
I	RMS Current (magnitude)
Phase (θ)	Phase of the current relative to the voltage
P	Delivered power (V*I*cos**θ)**
P fwd	Forward power
P ref	Reflected power
Z complex	Complex impedance in the form R+jX
Z polar	Impedance in polar form with magnitude and phase angle
Gamma	Reflection coefficient
SWR	Standing wave ratio
J_i	Ion flux, calculated for rf biased electrodes
Harmonic phase	Phase between fundamental voltage or current and its harmonics
Additional outputs	
Smith Chart	Smith chart tracking of impedance variation
Harmonic spectrum	Harmonic amplitude frequency spectrum
Waveform view	Time dependent waveform display of voltage and current

Specifications

Table 9: General Specifications

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

Table 10: Frequency Specifications

VI Probe Specifications – Frequency	
# Fundamental Frequencies (F_0)	Choose 5 from the fundamental frequency range. Measures 5 simultaneously.
F_0 Range	$350\ kHz - 100\ MHz$
F_0 Specials	$40\ kHz$ & $162\ MHz$ models available on request
Harmonic Frequency (F_N) Range	$350\ kHz - 240\ MHz$
Frequency Resolution	$1\ kHz$
Frequency Accuracy	$\pm 1\ kHz$
# F_N	≤ 15 per fundamental (64 max.), ≤ 32 simultaneously
F_0 Modes	CW, CW with Tuning, Multi-level Pulsing with Tuning
F_0 Tracking Rate	10 $kHz/\mu s$
F_0 Tracking Range	$\pm$ 10% or $\pm$ 2 MHz, whichever is less

Table 11: Voltage & Current Specifications

VI Probe Specifications – Voltage & Current	
Voltage Dynamic Range	80 dB
Voltage Range (Typical)	$0.3\ V\ to\ 3000\ V_{\text{RMS}}$, custom available
Voltage Resolution	$0.1\ V_{\text{RMS}}$
F_0 Voltage Uncertainty (95% Confidence)	$\pm 1\%$ or $1\ V_{\text{RMS}}$ (whichever is larger) for F_0 in the range 2 – 60 MHz. $\pm 2\%$ or $1\ V_{\text{RMS}}$, where $F_0 < 2$ MHz & $F_0 > 60$ MHz
F_N Voltage Uncertainty (95% Confidence)	$\pm 5\%$ or $1\ V_{\text{RMS}}$, for F_N in the range 350 kHz – 240 MHz
Current Dynamic Range	80 dB
Current Range (Typical)	$2.5 mA_{\text{RMS}}\ to\ 25\ A_{\text{RMS}}$, custom available
Current Resolution	$2.5\ mA_{\text{RMS}}$
F_0 Current Uncertainty (95% Confidence)	$\pm 1\%$ or $0.1\ A_{\text{RMS}}$ (whichever is larger) for F_0 in the range 2 MHz – 60 MHz $\pm 2\%$ or $0.1\ A_{\text{RMS}}$ for $F_0 < 2$ MHz & $F_0 > 60$ MHz
F_N Current Uncertainty (95% Confidence)	$\pm 5\%$ or $0.1\ A_{\text{RMS}}$ for F_N in the range 350 kHz – 240 MHz

Table 12: Impedance & Phase Specifications

VI Probe Specifications – Impedance & Phase	
Impedance Range	0.01 Ω - 10 kΩ (Voltage and current level dependent)
Impedance Uncertainty	See Smith Charts
Phase Range	$\pm 180^0$
Phase Resolution	0.02^0
F_0 Phase Uncertainty (95% Confidence)	$\pm 1^0$
F_N Phase Uncertainty (95% Confidence)	$\pm 1^0$, where $F_N < 100$ MHz

Table 13: Pulse Monitoring Specifications

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

Table 14: Absolute Uncertainty Specifications

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

Table 15: Run-to-Run Repeatability Specifications

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

Dimensional Drawings

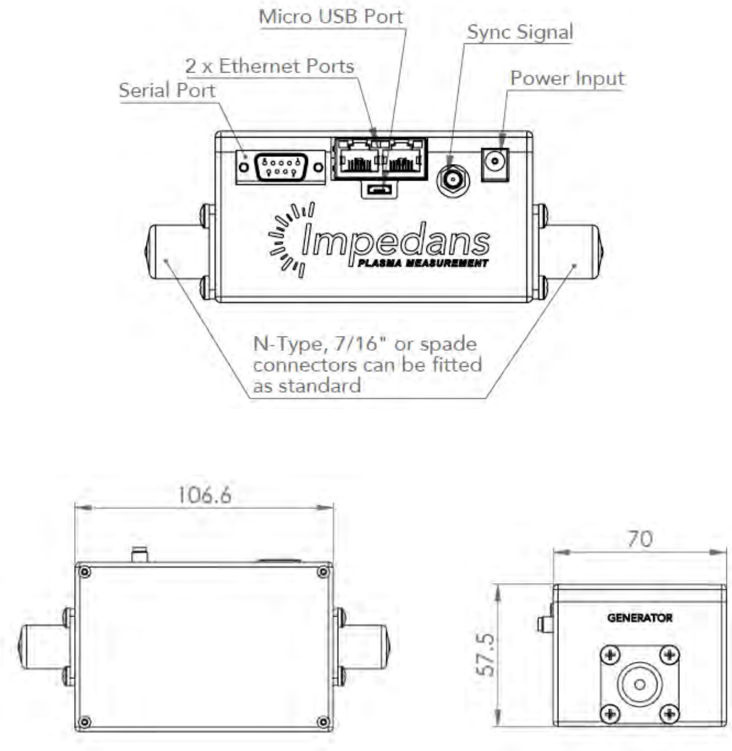


Figure 1: Dimensional drawings of the standard Octiv Poly model 02-232-01 with Quick Change RF connector interface. All dimensions are in mm. Contact Impedans for dimensional drawings of other models.

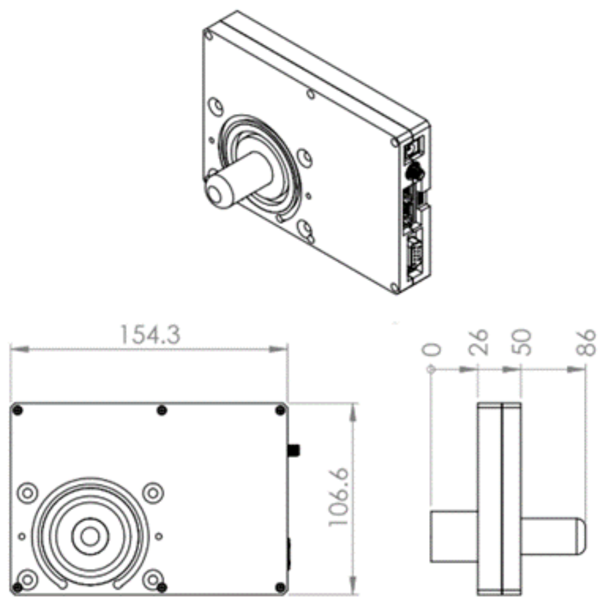


Figure 2: Dimensional drawings of model 02-0308-01.

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.

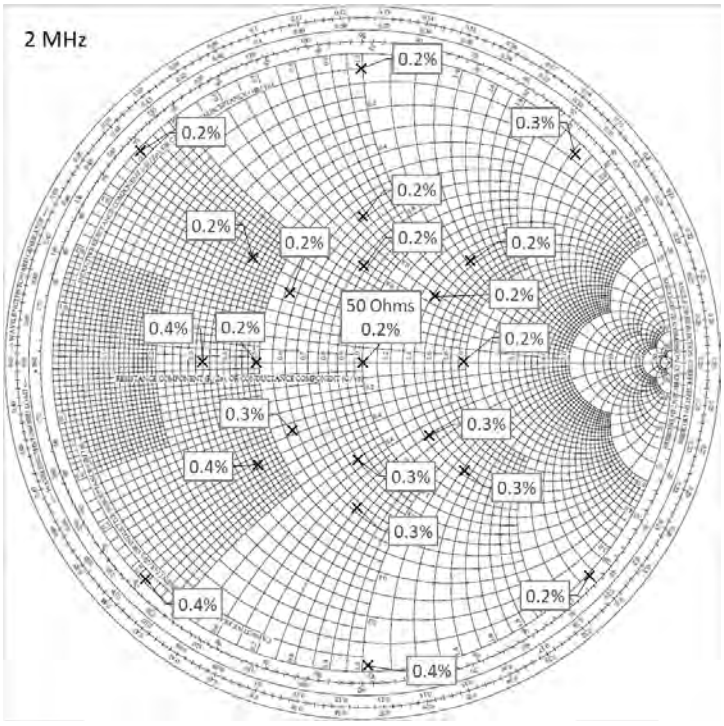


Figure 3: Typical 2 MHz impedance verification of an Octiv unit against VNA.

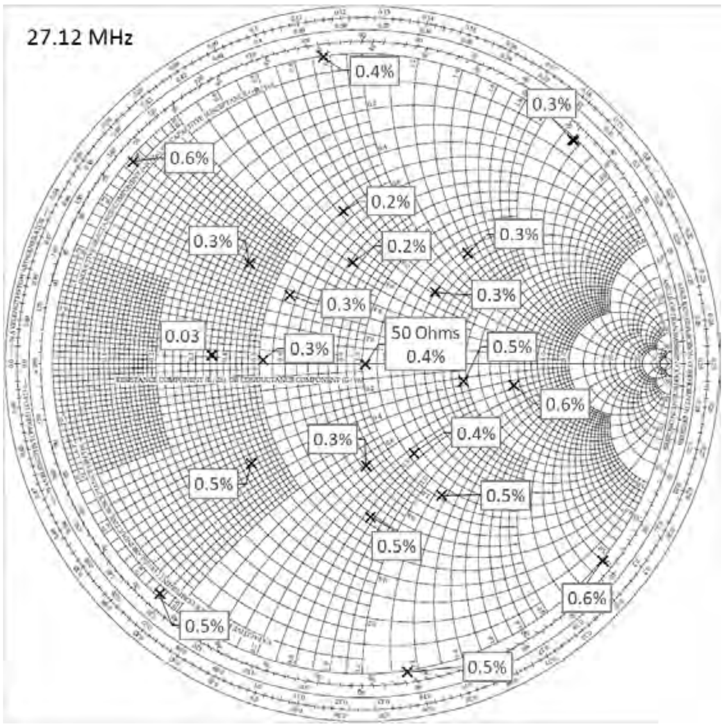


Figure 4: Typical 27.12 MHz impedance verification against VNA.

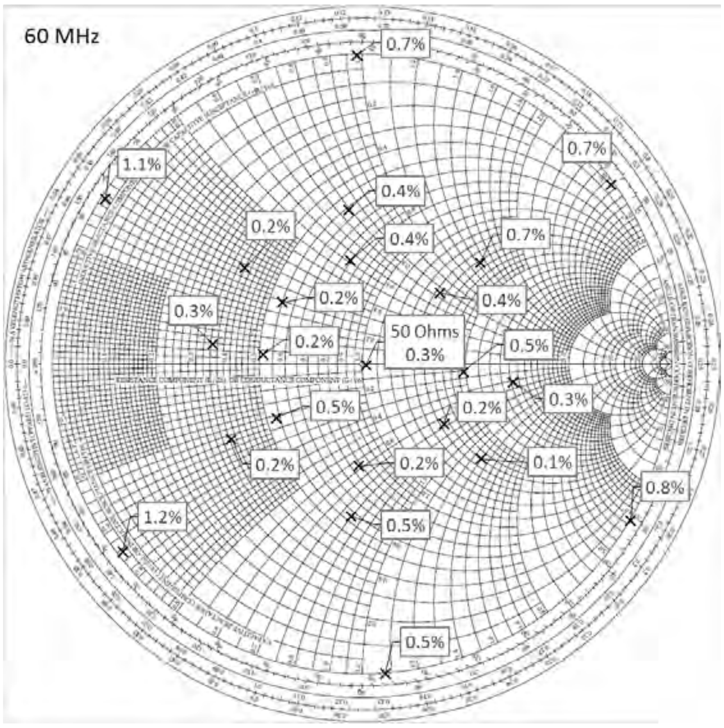


Figure 5: Typical 60 MHz impedance verification against VNA.

Power Measurement

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

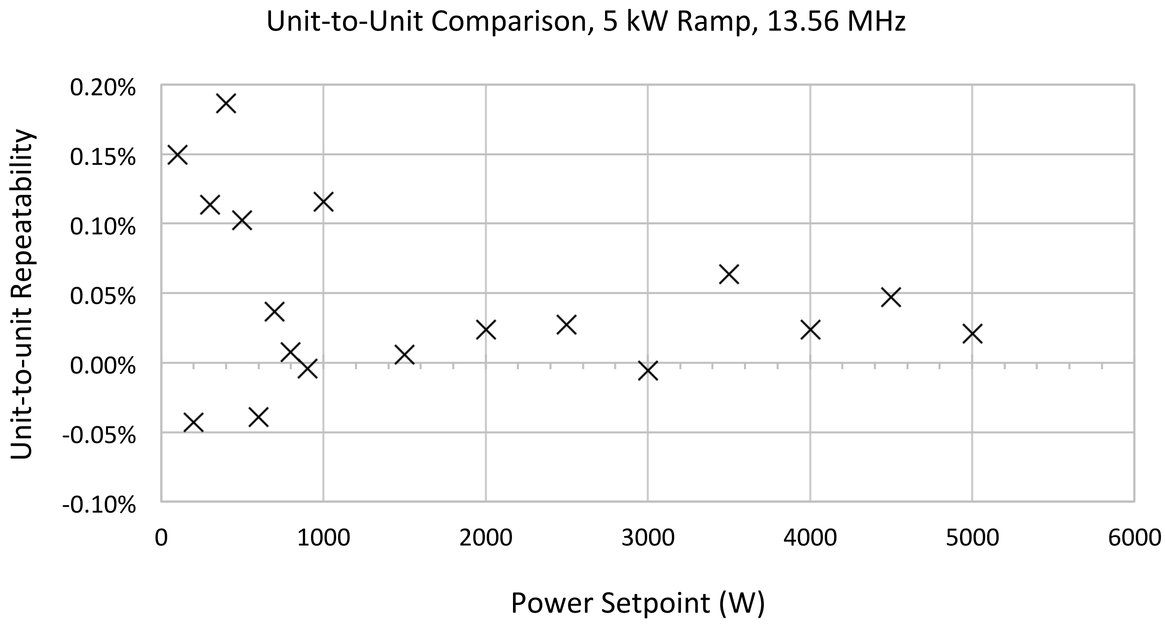


Figure 6: Unit to unit repeatability versus power. The Y axis shows the percentage difference between the two units at each setpoint power.

Software Display

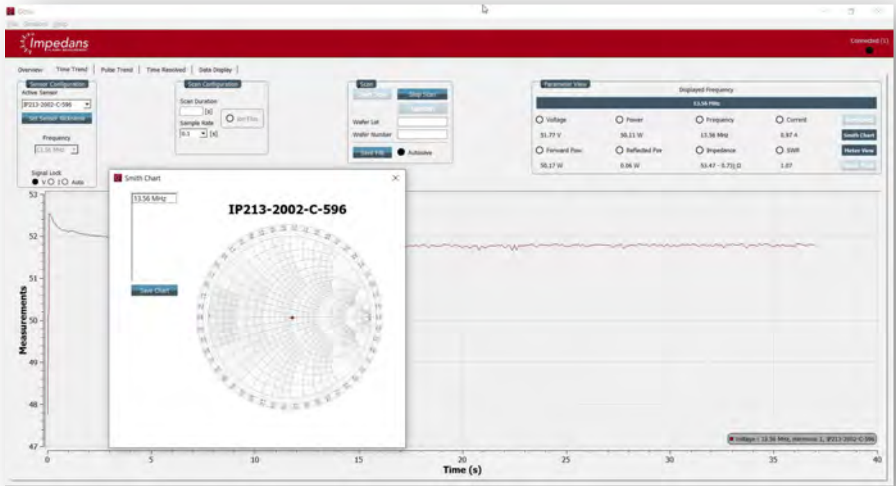


Figure 7: Example of the smith chart.

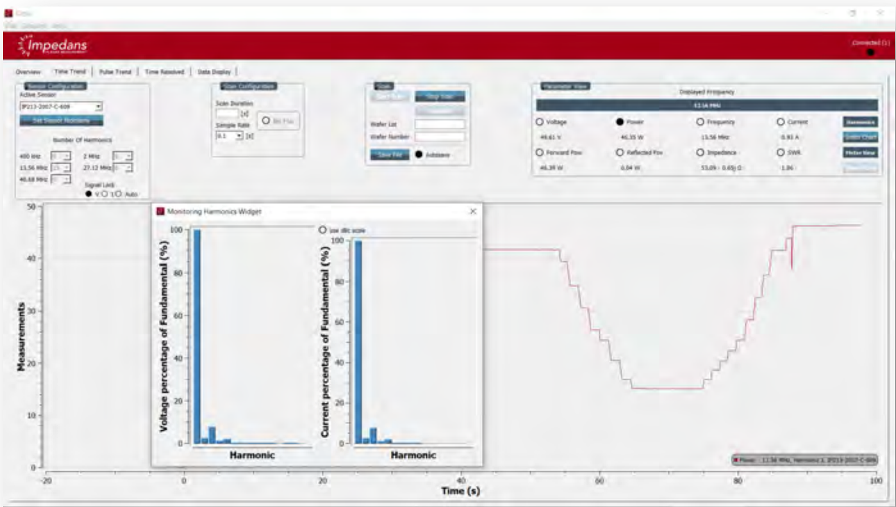


Figure 8: Example of the harmonic spectrum.

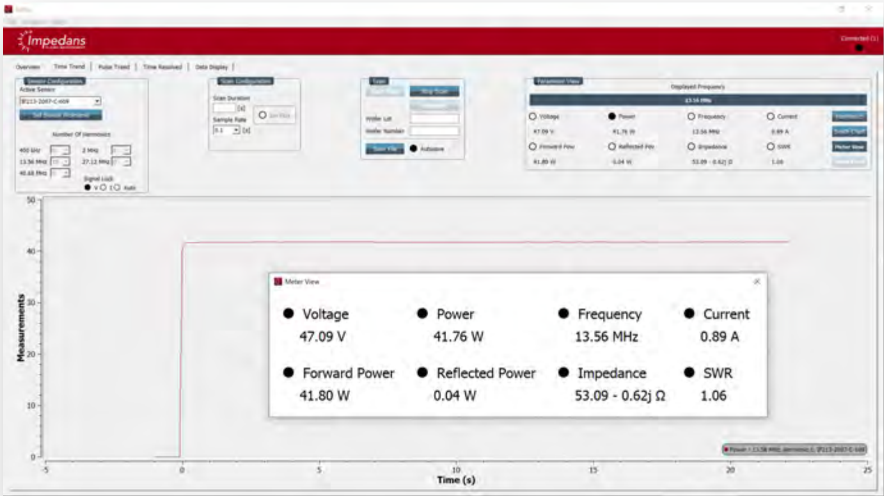


Figure 9: Example of the meter view.