



Octiv VI Probe

RF Measurement and Plasma Control Sensors

<https://impedans.com/octiv-mono-rf-wattmeter>

<https://impedans.com/octiv-poly-vi-probe>

<https://impedans.com/octiv-suite-vi-probe>

The Octiv VI Probe

Precision RF Measurement

The Octiv VI Probes are a range of compact sensors for RF measurements. They are completely pulsed RF-compatible and have a wide variety of communication options for easy use in the field.

Parameters Measured:

- ✓ Voltage, Current, Phase
- ✓ FWD, REF (50 Ω region), Delivered Power
- ✓ Impedance, SWR
- ✓ Choose any 5 frequencies from 350 kHz to 240 MHz or 40 kHz to 4 MHz, all on the one sensor
- ✓ Frequency agility (will track frequency tuning)
- ✓ Harmonic Content (Poly/Suite)
- ✓ Monitor Multiple frequencies simultaneously (Poly/Suite)
- ✓ Voltage and Current waveform reconstruction (Suite Only)
- ✓ Realtime Ion flux measurements (Suite only)
- ✓ Harmonic Phase (Suite Only)

Lab RFX Calibration

- ✓ Calibration is done with the best reference standards available on the market
- ✓ RF Power is calibrated by a Calorimeter
- ✓ Impedance is calibrated with a Vector Network Analyzer (VNA)
- ✓ Sensors are calibrated for temperatures up to 80C
- ✓ If better calorimeter or VNA standards come on the market, the Octiv will improve with that standard



The Octiv VI Probe

Precision RF Measurement

Pulsed RF Monitoring

- ✓ Detects RF pulsing automatically and begin to report the pulse frequency and duty cycle in real time
- ✓ Integrates over the pulse shape to accurately measure average power, voltage, current, impedance while pulsing
- ✓ Example: 1kW CW, then turn on a 1kHz pulse at 50% duty cycle, the Octiv will still report 1 kW power, plus the pulse frequency and duty cycle.
- ✓ All automatic, so just one mode for technicians to use for all RF purposes

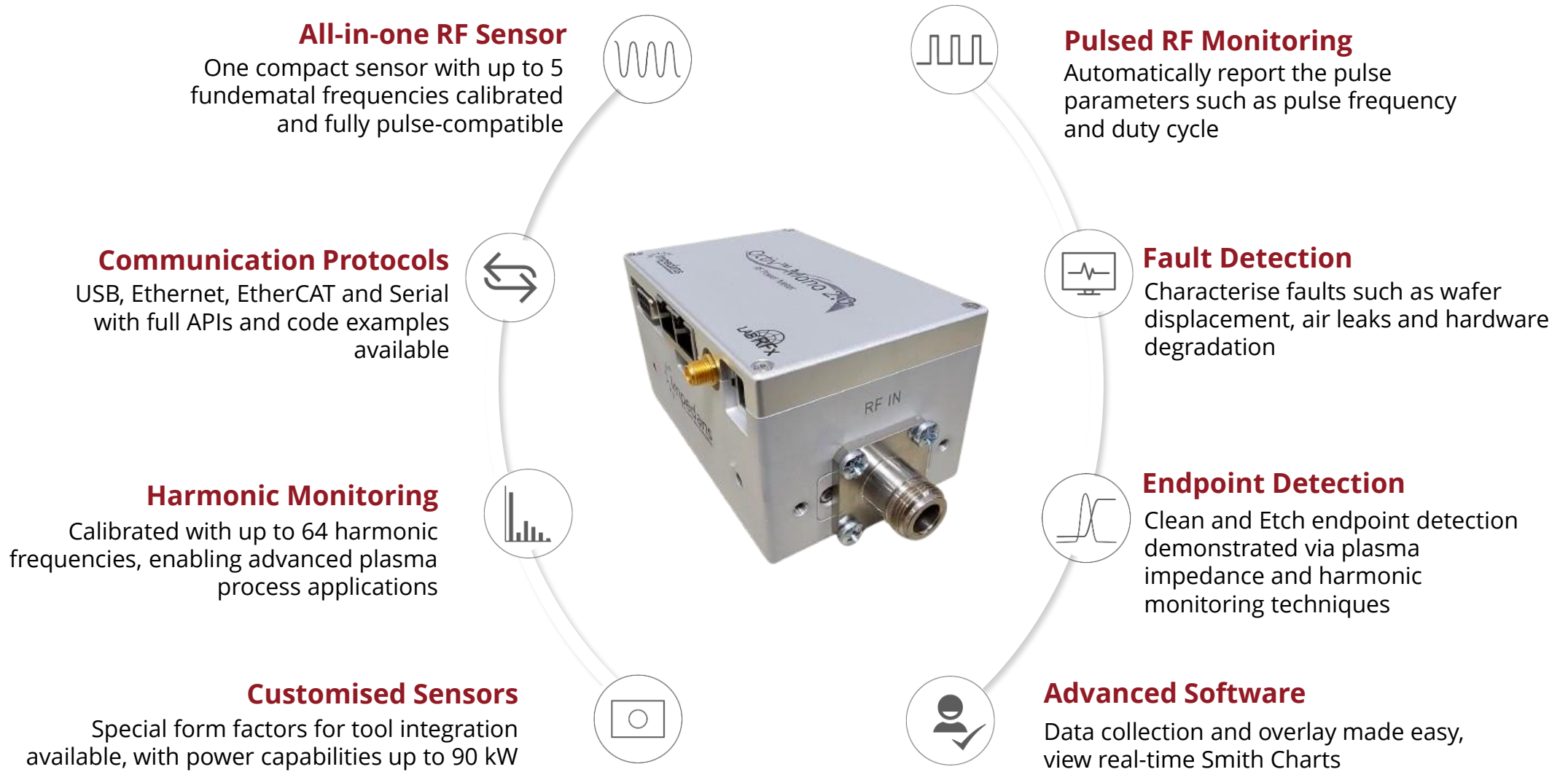
Communication Protocols

- ✓ USB
- ✓ Ethernet
- ✓ EtherCAT
- ✓ RS232
- ✓ Full APIs available for all
- ✓ LabView interface also available
- ✓ Smart Phone display available
- ✓ Fully field upgradable



Meter View			
● Voltage	● Power	● Current	● Forward Power
52.25 V	24.16 W	0.92 A	48.16 W
● Pulse Period	● Pulse On Time	● Pulse Frequency	● Pulse Duty Cycle
999.97 μ s	501.87 μ s	1000.03 Hz	50.19 %

Key Features



Technical Specifications

Parameters Measured	Range
Frequency Range (Fundamental)	40 kHz → 4 MHz 350 kHz → 240 MHz
Frequency tracking range	±10 %, or ± 2 MHz above 20 MHz
Power Resolution	0.25 W
Power Uncertainty	±1 % for f_0 : 2 → 60 MHz ±2 % otherwise
Voltage Range (typical)	0.3 V to 3000 V_{rms} custom available to 20 kV_{rms}
Voltage Resolution	0.1 V_{rms}
Voltage Uncertainty	±1 % or 1 V_{rms} whichever is larger for f_0 : 2 → 60 MHz ±2 % or 1 V_{rms} otherwise
Current Range (typical)	2.5 mA_{rms} to 25 A_{rms} custom available to 120 A_{rms}
Current Resolution	2.5 mA_{rms}
Current Uncertainty	±1 % or 0.1 A_{rms} whichever is larger for f_0 : 2 → 60 MHz ±2 % or 0.1 A_{rms} otherwise
Phase Range	±180°
Phase Resolution	0.02°
Phase Uncertainty	< ±1°



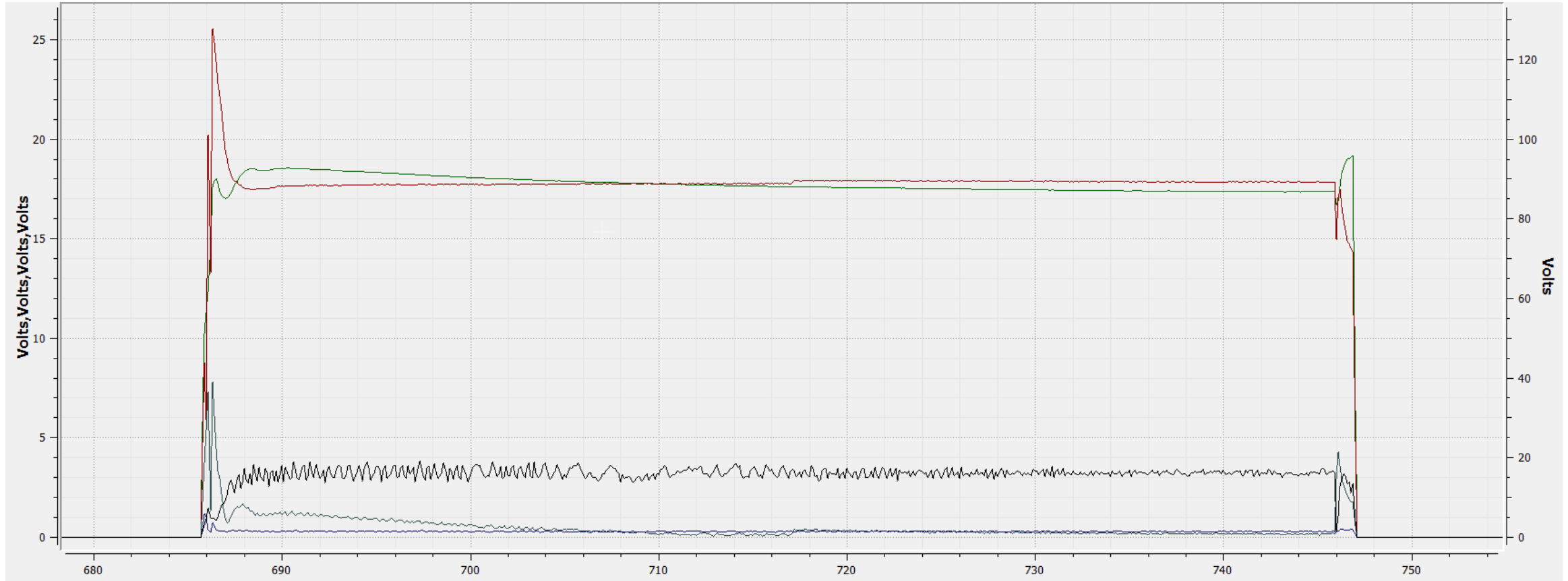
Technical Specifications

Parameters Measured	Range
Pulse Frequency Range	10 Hz to 100 kHz
Pulsed RF Time Resolution with TTL sync	1 μ s
VSWR Range for 1% Power Accuracy Verified	6:1
Uncertainty Confidence Interval	95% (2σ)
Absolute Unit to Unit Uncertainty	1.4% for current and voltage
Run to Run Repeatability - Frequency	0.3 Hz
Run to Run Repeatability - Power	0.1 % or 0.05 W, whichever is greater
Run to Run Repeatability - Voltage	0.05 % or 0.01 V, whichever is greater
Run to Run Repeatability - Current	0.05 % or 0.01 A, whichever is greater
Run to Run Repeatability - Phase	0.005 degrees

- ✓ Octiv data has been published in nearly 100 papers, see <https://impedans.com/octiv-publications>
- ✓ To arrange a technical discussion, contact support@impedans.com



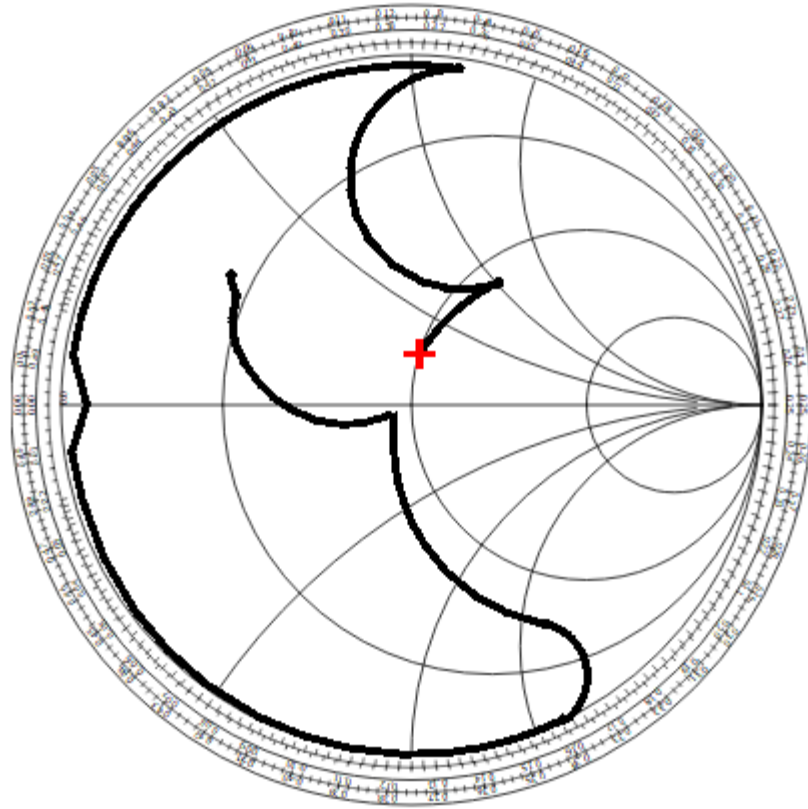
Example Data: Voltage Data



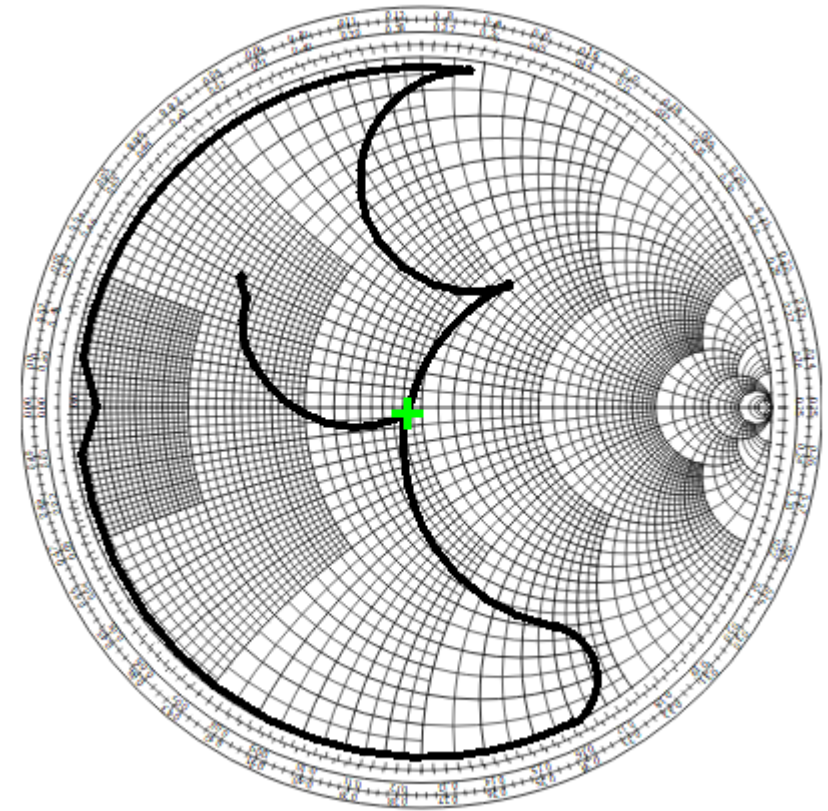
Example of Fundamental (right axis) and the Harmonics 2-5 (left axis) being plotted in the Octiv software

Example Data: Smith Chart

Simple Smith Chart View

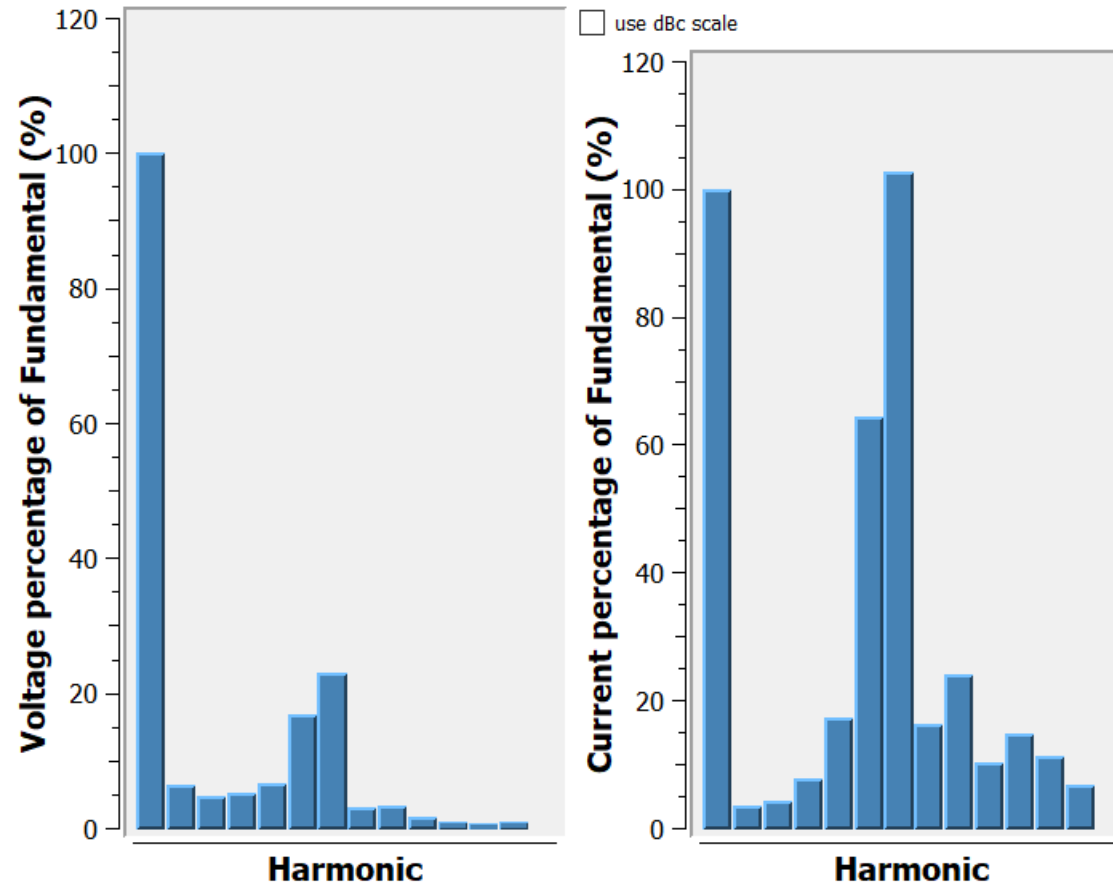


Advanced Smith Chart View



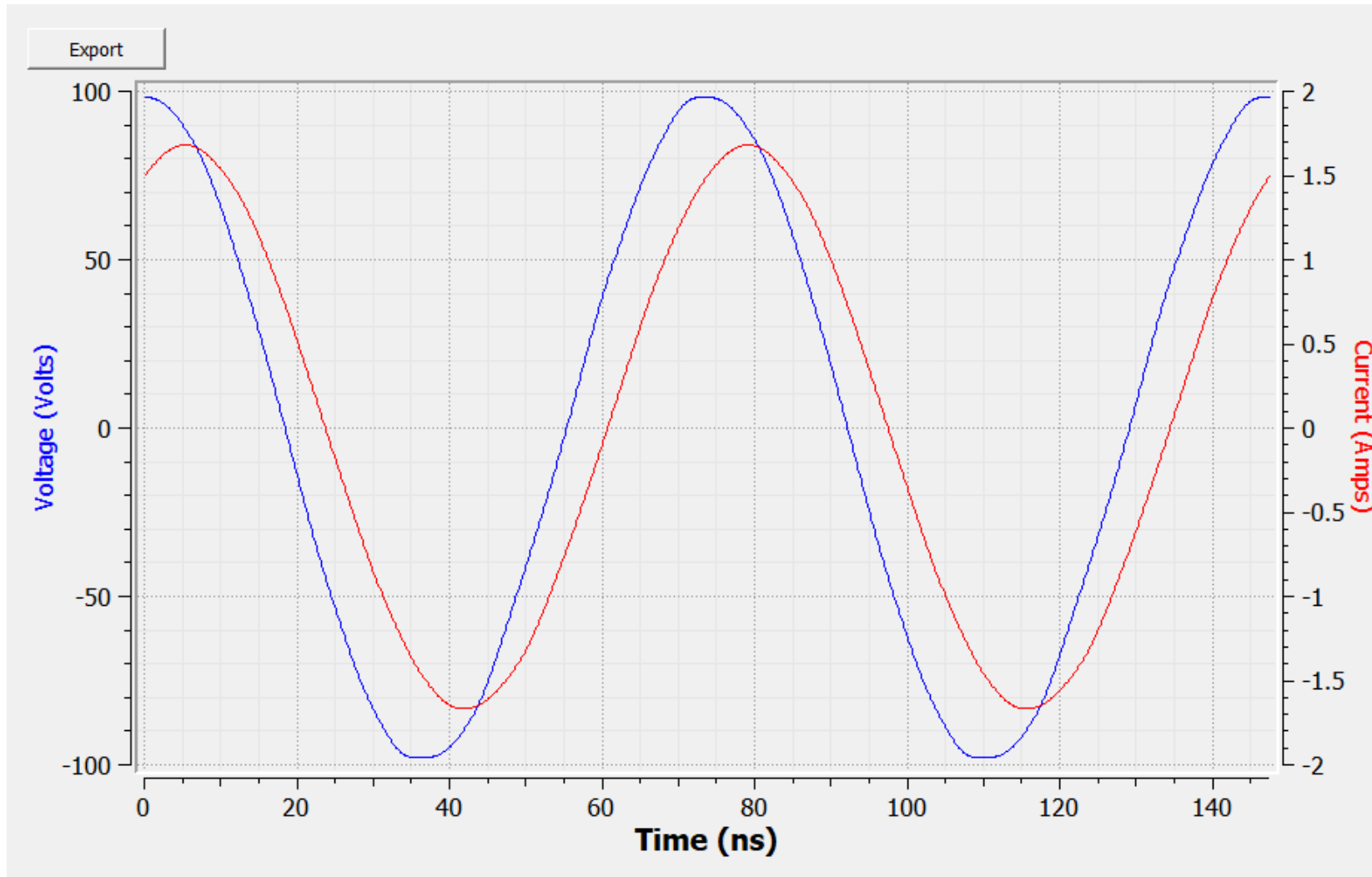
*Example of Smith Chart showing the characterisation of a match box.
Green plus displayed when matched to 50 Ohms*

Example Data: Harmonic Profiles



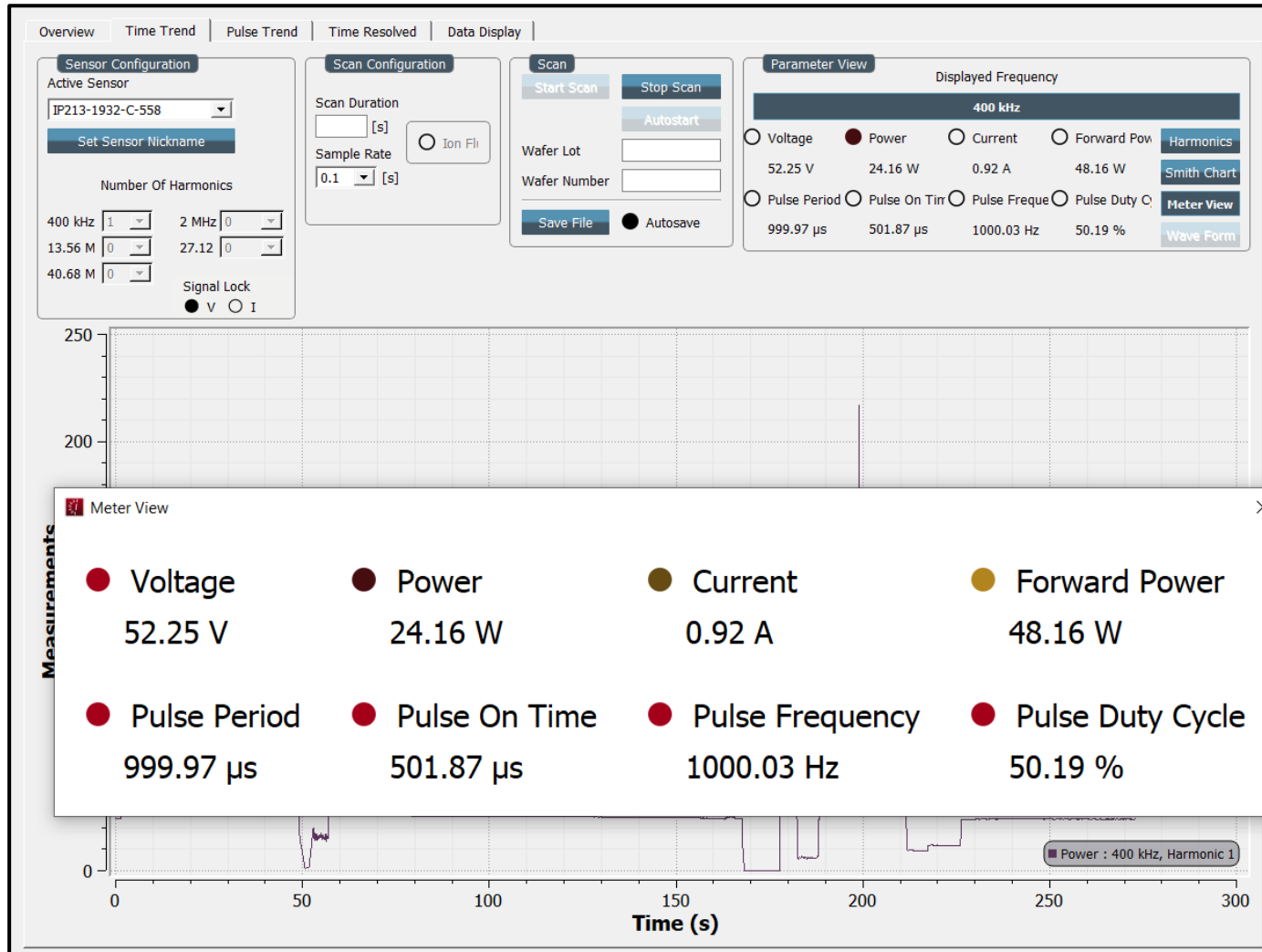
Example of the harmonic profile for voltage and current as shown in the Octiv software

Example Data: Waveform Reconstruction



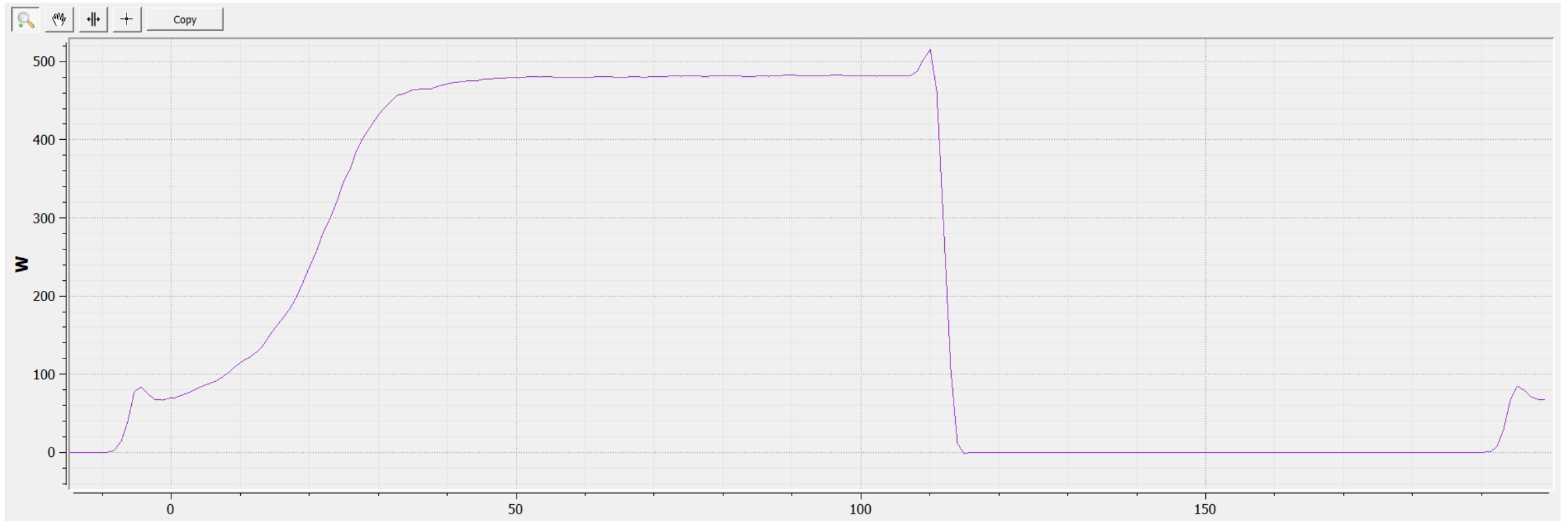
Example of the Waveform reconstruction of the Voltage and Current

Example Data: Pulsed RF Parameters



Example of live pulse frequency and duty cycle monitoring

Example Data: Time-Resolved Pulsed RF Data



Plot of power for a 5 kHz pulsed RF N₂ Plasma. X-axis in units of microseconds

Octiv Applications

Ion flux and DC Self-Bias measurement in an asymmetric CCP

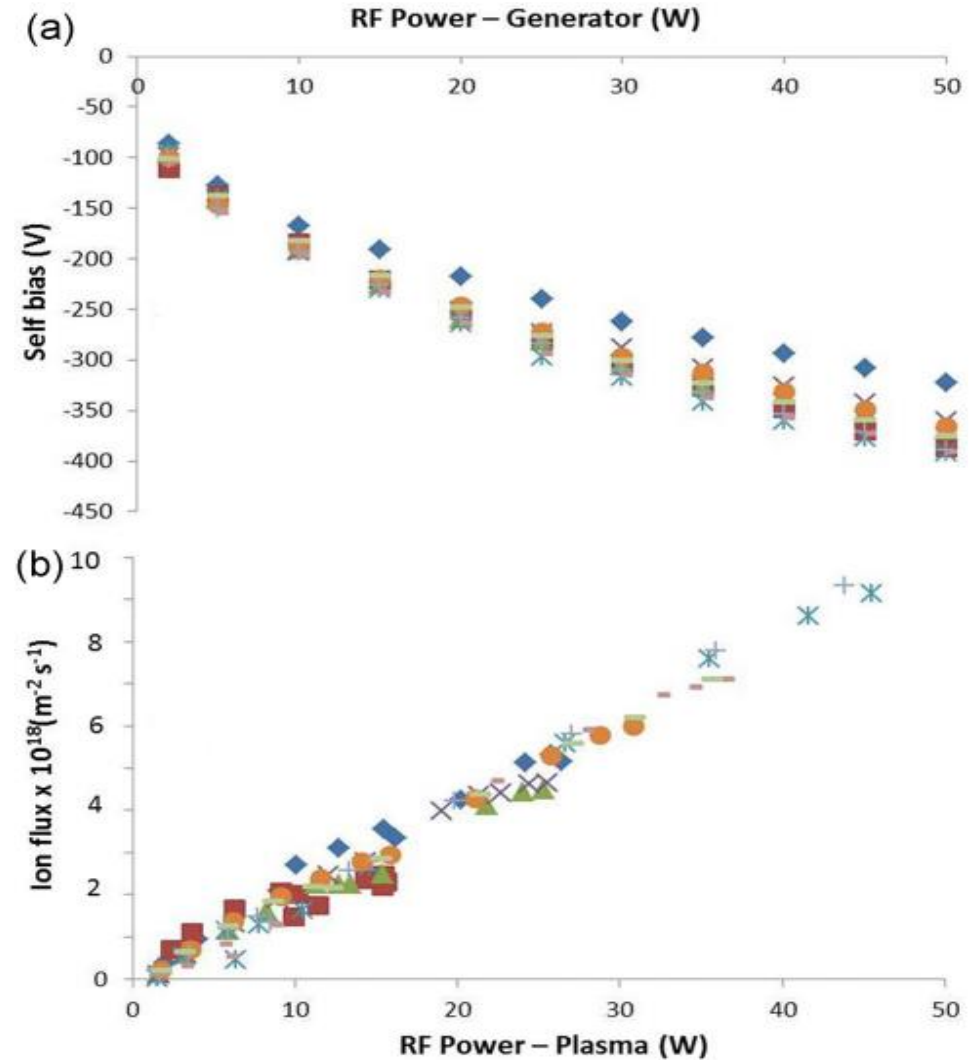
An experimental and Analytical Study of an Asymmetric Capacitively Coupled Plasma Used for Plasma Polymerisation

DOI: 10.1002/ppap.201400026im

The objective of this paper was investigate the effects that gas composition had on the DC self-bias and the Ion flux.

Some example data is shown to the right

<https://www.impedans.com/octiv-suite-20-application-note-oc12>



The self bias, ion flux and plasma power for a variety of gases. (\diamond) Argon, (\bullet) Oxygen, ($*$) Allylamine, (+) Heptylamine, (-) HMDSO, (\diamond) Diglyme, (Δ) Acrylic acid and (x) Propionic acid

Impedans Ltd | Octiv Technical | October 2024

Microsecond measurement of the evolution of pulsed RF plasmas

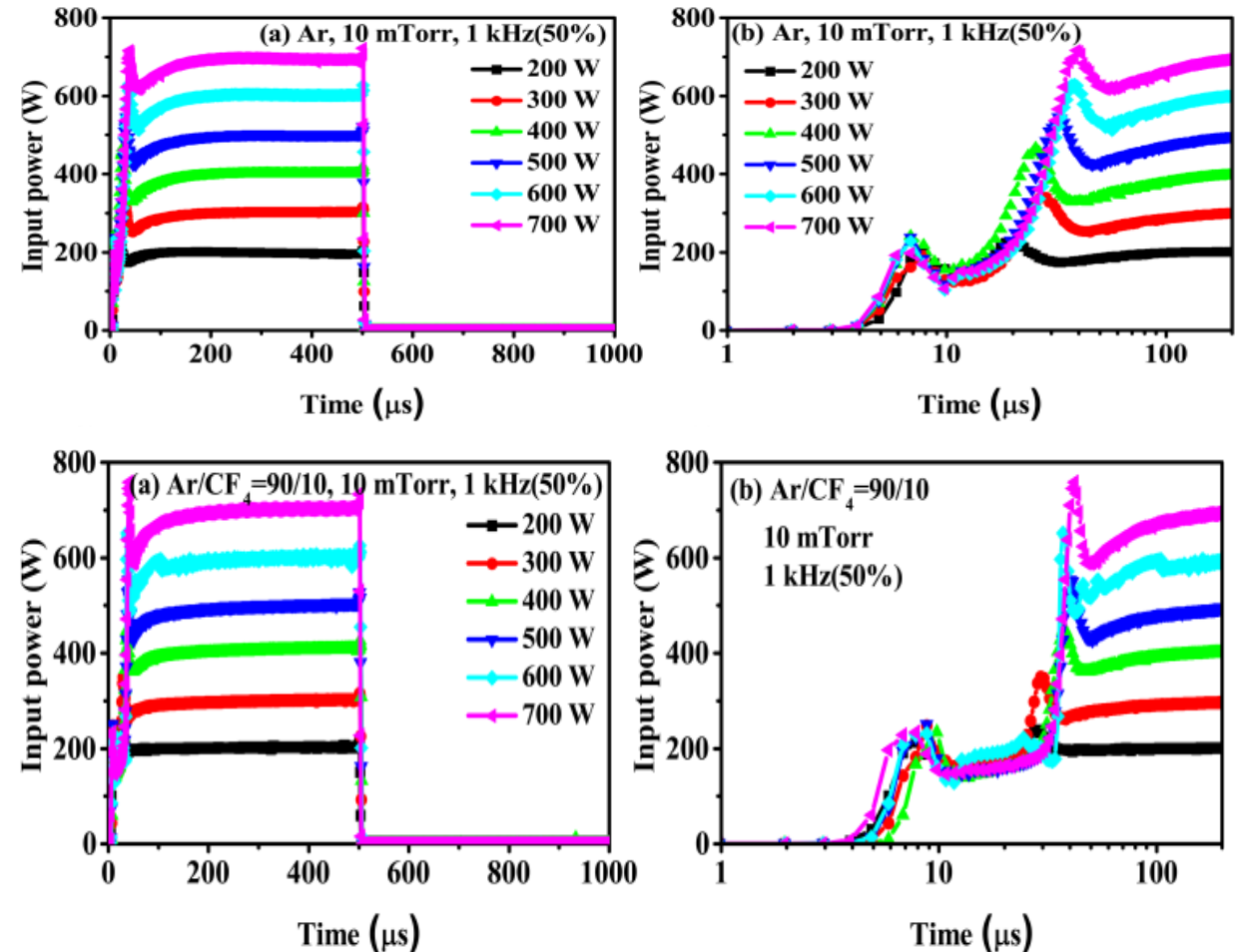
Complex transients of input power and electron density in pulsed inductively coupled discharges.

DOI: 10.1063/1.5114661

The objective is to investigate the effects of the Power and Pressure (not shown here) on the evolution of the input power on a microsecond timescale for Ar and Ar/CF_4 .

Some example data is shown to the right

<https://impedans.com/langmuir-and-octiv-application-note-lp15-oc08>



Examples of the effect of the power in pulsed Ar and Ar/CF_4 on a microsecond timescale

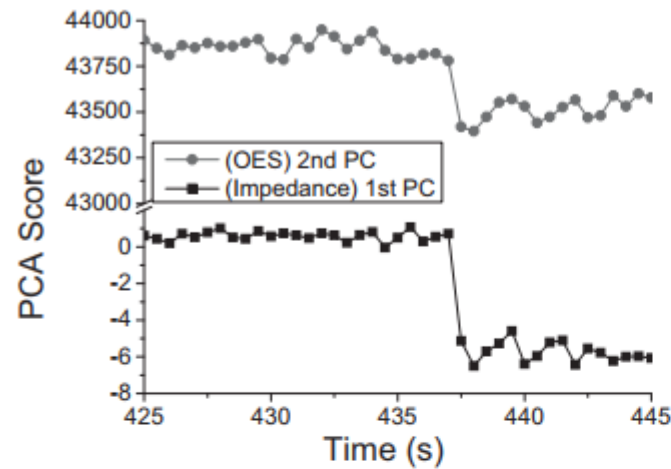
Application - Clean and Etch Endpoint Detection

Real-Time Endpoint Detection of Small Exposed Area SiO₂ Films in Plasma Etching Using Plasma Impedance Monitoring with Modified Principal Component Analysis

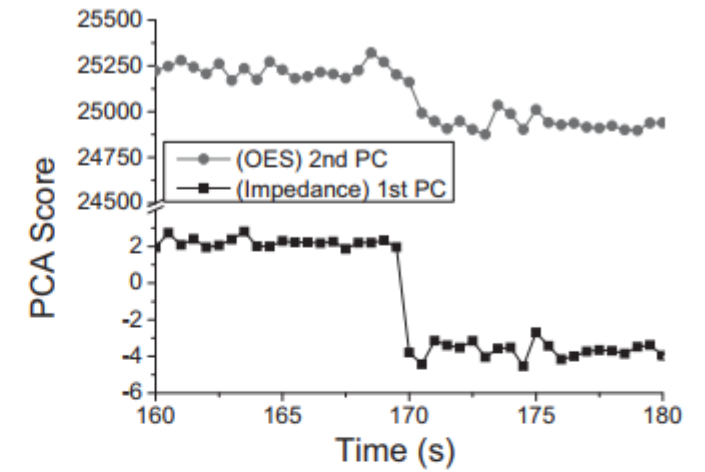
Principle component analysis (PCA) was used to combine all the data from an Octiv sensor vs all the optical channels from an OES.

Etch endpoint was measured for various open areas, from 2% down to 0.5%

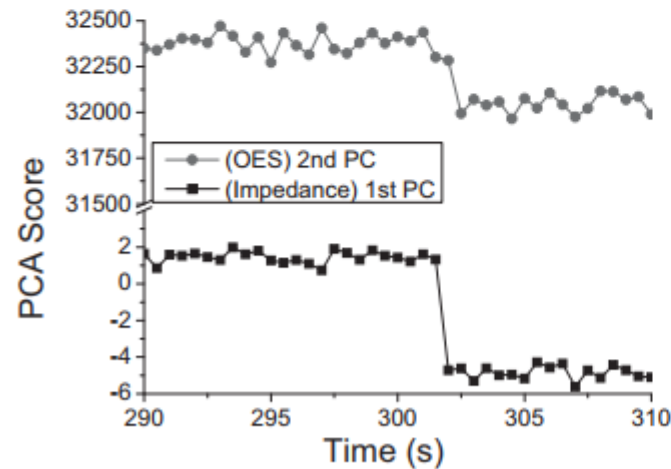
Monitoring RF had at least twice the sensitivity compared to multivariate OES techniques



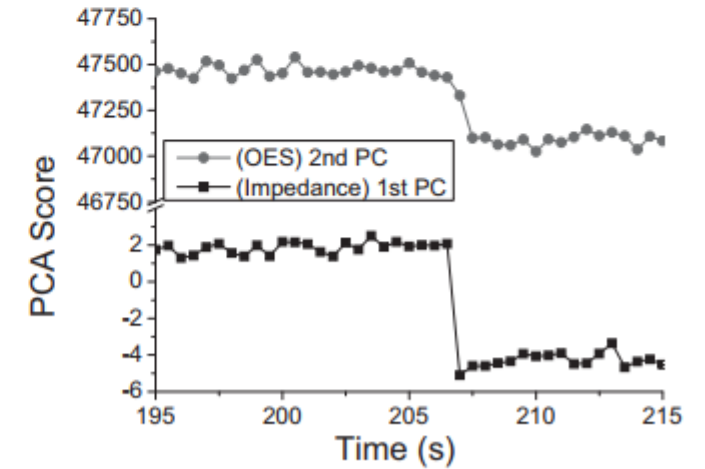
(a) 2.0% oxide area target wafer



(c) 1.0% oxide area target wafer



(b) 1.5% oxide area target wafer



(d) 0.5% oxide area target wafer

Application - Fault Detection – Air Leak Detection

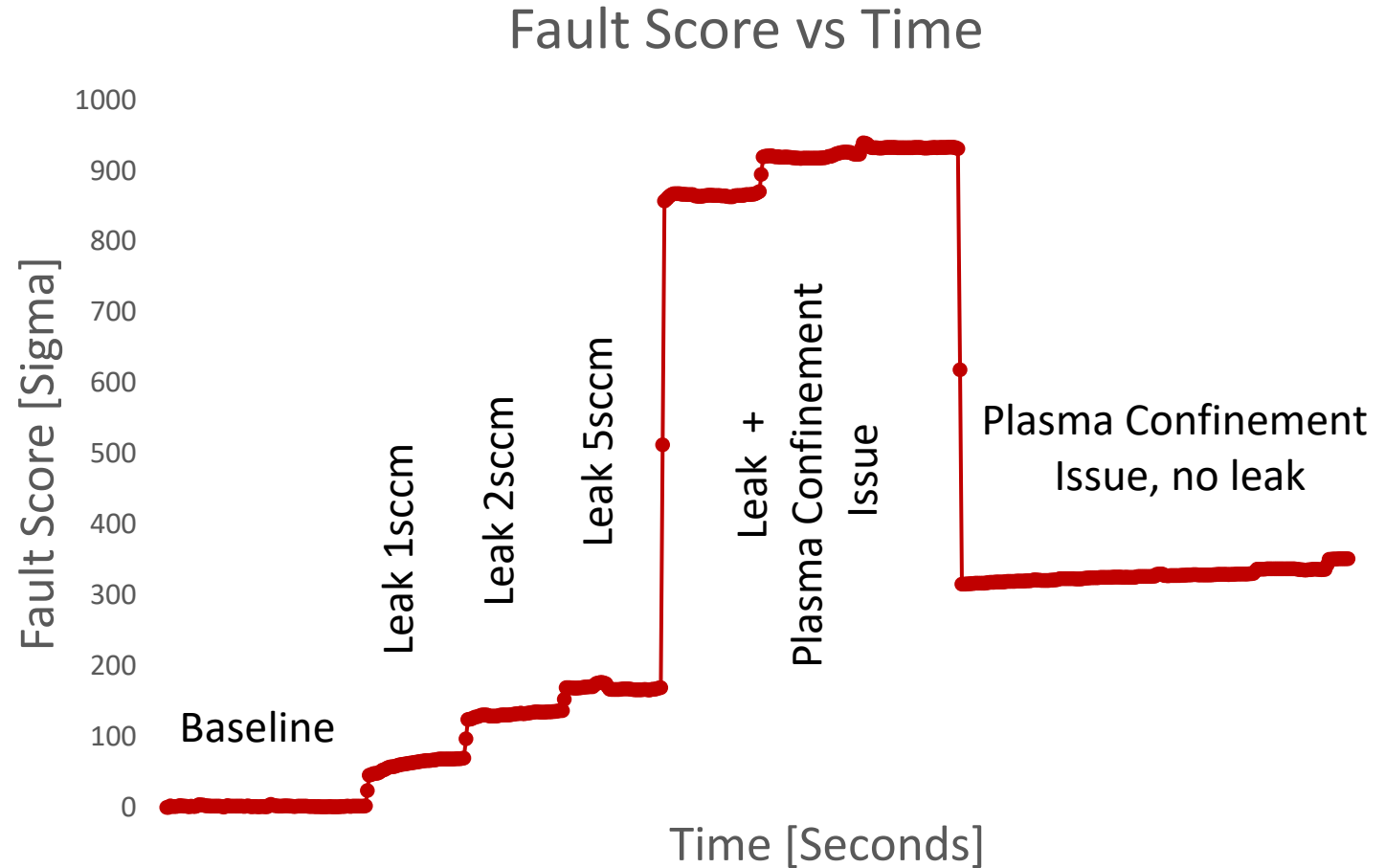
Detection of air leak

Real time detection of a change in gas, here due to an unwanted air leak into the chamber

Some example data is shown to the right

When a large amount of extra air was present, the plasma expanded out into the windows, hence the very large jump in the Fault Score. The extra plasma remained after the air leak was removed

This is detectable due to the change in the plasma impedance and in the plasma harmonic emissions



Examples of the effect of the introduction of an air leak on the statistical score

The Challenge

Needing to improve the performance, and extend the lifetime, of an aging fleet of plasma etching tools, this long-time Impedans client sought a solution with the following requirements:



- Monitor the vital-signs of each plasma etching tool
- Determine the health of the RF power delivery subsystem
- Identify if the substrate was properly positioned by the robotic arm
- Communicate data seamlessly to the factory host
- Prevent product scrappage and reduce maintenance costs

Our Solution

The **Octiv** RF sensor was integrated in the etching tool RF path, at the output of the matching network. The key RF parameters were measured and streamed over the network to the factory host. Data was recorded, time-stamped and



stored in the customer's data base along with the tool context data. The data captured during fault events were later analysed. Correlations between RF data and fault conditions were established. Control limits were then applied to relevant parameters, excursions from which are used to indicate faults and initiate corrective action.

The Process

Impedans' RF and mechanical design teams identified the optimum location for **Octiv** RF sensor installation. A custom sensor form factor was designed. A first unit was then manufactured and installed. Data was captured while the tool was in production over a predefined period. Product was inspected off line in the usual way. The time stamps for defective products were correlated with RF data from **Octiv**. Impedans experts analysed and modelled the

RF data and identified fault signatures. Corrective action procedures were implemented based on Impedans recommendations. Impedans software experts worked closely with the customer's software team to implement a simple, robust Ethernet protocol to communicate sensor data to the factory host. Once the first few product scrap events were prevented, roll out across the entire fleet was initiated.

Achievements



RF Power Subsystem Health

The first problem to be solved was product scrappage due to stress in the power delivery subsystem. Impedans experts discovered that certain plasma etch processes were operating at the edge of the matching unit's impedance range. This caused the matching unit to become unstable, occasionally. The RF data collected by the **Octiv** sensor was used to identify the onset of this unstable mode. The problem was solved by restarting the process.

Substrate Misplacement

Substrate misplacement on the electrostatic chuck, due to component wear and tear, was periodically leading to wafer scrappage. This fault was undetectable from the pre-existing tool feedback i.e. forward and reflected power showed no error. Thus, several hours of scrappage could go undetected. **Octiv** provided a clear signature of the substrate misplacement fault enabling corrective action to be taken.

Reduced Maintenance Time

Due to the reliability of the RF data provided by **Octiv**, test wafer qualifications were reduced by 70%, enabling higher throughput of production wafers.

Results at a glance



70% REDUCTION
in Tool
Maintenance time



SEVERAL HOURS
Scrap Prevention
Per Fault



10% INCREASE
in Product Throughput



>1000% RETURN
On Investment in 1 year



>\$1 Million

Projected saving in maintenance and Scrap Reduction per tool per annum directly attributed to the integration of **Impedans' Octiv Sensing Platform**

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