

User Manual:

PlasMaster PCU-L 250.1

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1. Introduction

The PlasMaster generators of Heuermann HF-Technik GmbH (HHF) are designed to enable an efficient operation of our diverse plasma jets and couplers, as well as other microwave applications, where an automated frequency adjustment is required to ensure an optimal energy transmission into the load. Details of the special patented technology to ensure an optimal energy transmission were published¹.

With a maximum output power of over 250 W in the ISM frequency band between 2.4 and 2.5 GHz, the PlasMaster generators are easy to use and offer all necessary process parameters required to monitor and optimize the application or small series production such as forward power, reflected power, or application frequency². For better integration in a production process, HHF offers the core capabilities of these generators as a module.

This document describes how to use the PlasMaster PCU-L 250.1 (250W, 2.45GHz-band) microwave generator. It will serve as a guide to all supported hard- and software features and covers the application of the corresponding plasma jets and couplers.

¹ Heuermann, H., Sadeghfam, A.: Analog Amplitude-Locked Loop Circuit to Support RF Energy Solutions, 64th International Microwave Symposium, San Francisco, May 2016

² The PlasMaster makes a so-called scalar hot S-parameter measurement at the output port.

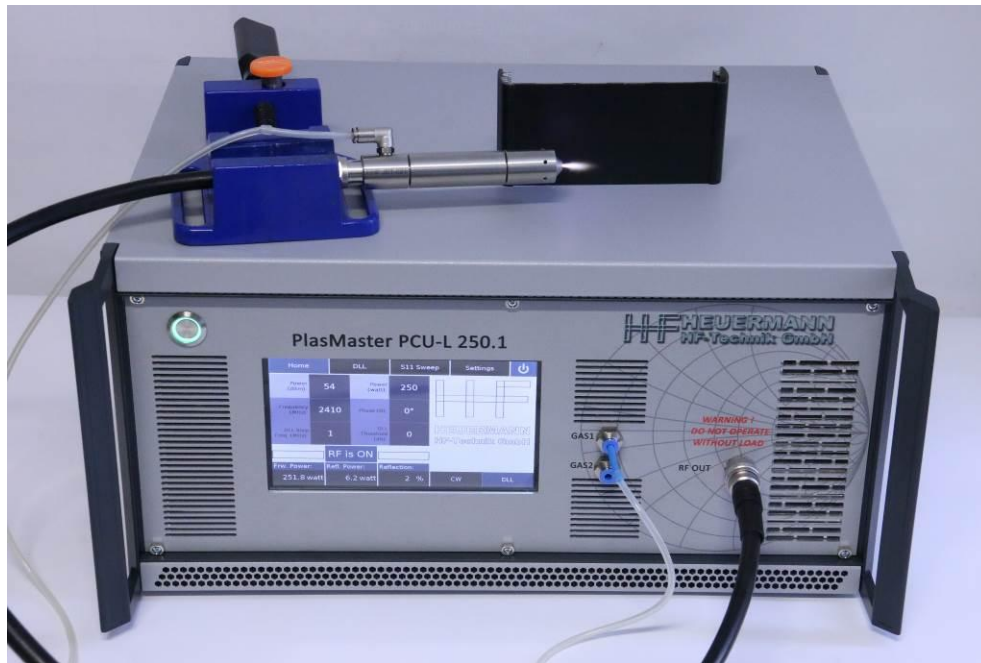


Fig. 1: The PlasMaster PCU-L 250.1 with a PS-Cle plasma jet.

Short overview of the features of microwave plasma jet, driven with the PlasMaster:

- Pure atmospheric 2.45 GHz plasma for continuous power levels of up to 250 W
- Applicable with nearly all gasses
- Available as stream line jet and plane jet
- Highly efficient, low loss plasma jets
- Relatively low plasma temperature since solely electrons are accelerated
- Relatively high plasma temperature at vicinity of nozzle due to high power density
- Usable by hand or robotized, genuine 100 % potential free
- Very low power consumption
- Maintenance free without wear off
- Compact, handy form and size
- Cost efficient technology, easily applicable to production facilities
- Further advantages for diverse applications presented below

Summary of Technical Applications: Industrial and medical applications using plasmas are increasing continuously. The following are some major applications using low power levels (below 100 W):

- Activating plastic surfaces for welding, melting, painting, varnishing, printing, coating, gluing, etc. as well as further processing steps
- Cleaning von different metallic surfaces for soldering, varnishing, coating, gluing, bonding, etc. as well as further processing steps
- Disinfection and sterilization of instruments in medical fields, even of wounds
- Aging treatment of components
- Further applications using higher power levels (above 100 W):
- Soft soldering and hard soldering of metals
- Amalgamation or fusing of surfaces and boring holes or vias
- Labeling or inscription of various materials
- Firing in of paint or varnish
- Cutting various materials
- Welding various materials
- Coating various materials

2. Features and Specifications

Below is an overview of the features of the PlasMaster generator:

Features

- Frequency range: 2400 MHz – 2500 MHz
- Maximum RF power output: ≥ 250 Watt
- Hard- and software based "Safe Operating Area" protection against thermal and RF overstress as well as lack of process gas (in the case of plasma jets)
- Operational modes:
 - Continuous Wave (CW)
 - Digital Locked Loop (DLL)
- Integrated digital frequency matching and energy delivery optimization (DLL)
- Very high-resolution RF parameter settings
- Very fast S11 sweep (reflection measurement) for process control
- 7" capacitive touchscreen
- Intuitive graphical user interface (GUI)

The mechanic specifications are as follows:

Specifications

- Size: 23 cm x 46.5 cm x 32 cm (h x w x l)
- Weight: 12 kg
- Gas flow rates
 - Gas 1: 5 – 20 sl / min (cooling gas e.g. air)
 - Gas 2: 2 – 10 sl / min (process gas e.g. argon)

The PlasMaster can support the following application with the additional jets:

Process gas	Application	Power level	Jet	Comments
Air	Activation	40 – 200 W	PS-Act	Broad plasma
	Cleaning / rapid heating	40 – 200 W	PS-Cle	Focused plasma
	Fluid	80 – 400 W	PP	Presently, only manual ignition
Argon/Varigon	Activation (low temperature)	2 – 10 W	MiniJet-S/R	Manual ignition
	Activation (low temperature)	5 – 100 W	PS-Ar	
	Coating, welding	40 – 200 W	PC-B	
	Coating, welding, activation, ...	60 – 400 W	PC-SF	Tested up to 200 W
No gas	Low pressure chamber	40 – 200 W	CC	Coupler

3. Operating the Generator

The PlasMaster generator is operated through the graphical user interface (GUI) visible on its touch display. The GUI starts automatically when the system is booted and provides easy access to the generator's extensive features.

Fig. 1 and 2 show the connections on the generator with the gas connections and the N-connector for the cable to the applicator.



Fig. 2: Front side of the PlasMaster PCU-L 250.1.

Use the main switch at the rear to power on the generator and then use the stand-by switch to start the graphical user interface (GUI). The operation of the generator is described in the following section.



Fig. 3: Rear view of the PlasMaster PCU-L 250.1.

4. The Graphical User Interface

The PlasMaster generator is operated through the graphical user interface (GUI) visible on its touch display. The GUI starts automatically when the system is booted and provides easy access to the generator's extensive features.

This chapter describes in detail how the GUI works and what you can do in each menu.

4.1 Basic Page Layout

Most pages of the GUI use the same basic layout.

① Menu Buttons

The menu buttons are used to navigate the various tabs of the GUI. These buttons are visible at all times and on any page. Currently, there are four menus in total:

- Home
- DLL
- S11 Sweep (reflection measurement)

For more information about each of these tabs, please see the respective sections below:

② Operation Mode Selection

These buttons determine the operational mode of the OEM kit. There are two operational modes available:

- CW Mode – Continuous Wave
The default mode. Generates a continuous wave signal with the possibility to change the frequency, power and phase³ of the wave.
- PWM Mode – Pulse Width Modulation
Pulsed operation mode. In this mode, the output power can be pulsed at a defined frequency with a defined duty cycle.
- DLL Mode – Digital Locked Loop
Digital frequency matching and energy delivery optimization.

³ For applications with multiple generators, where the respective phases needs to be determined, e.g. in heating applications. Not supported in the basic version.

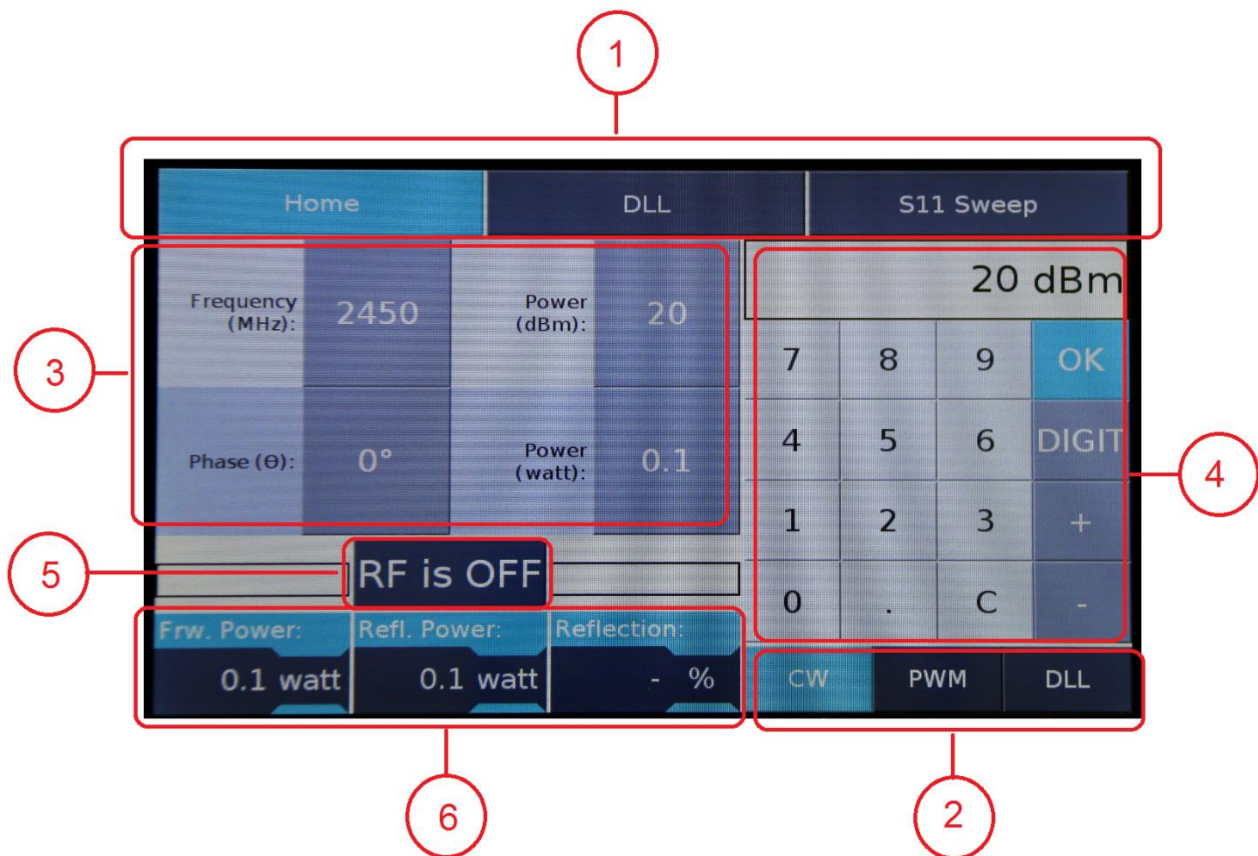


Fig. 4: The basic layout of the GUI.

③ Parameter Control Buttons

These buttons are used to configure the working parameters of the generator. The exact contents of these buttons will differ in each menu, but their purpose and functionality remains the same. In most cases, pressing one of these buttons will cause a numeric keypad to appear on the right side of the screen, through which parameter values can be put in.

④ Numeric keypad

The numeric pad only appears on screen when one of parameter configuration buttons has been pressed. It is used to input the value of the parameters. The inputs appear in the small entry field at the top of the numpad and are only applied only after pressing the OK button.

- 0-9 → Input the respective number.
- . → Add a decimal point.
- C → Clear the entry field.
- OK → Confirm and apply inputs.
- DIGIT → Move the digit indicator to the next position on the entry field.
- + → Increment highlighted digit by 1.
- - → Decrement highlighted digit by 1.

⑤ RF Power button

This button enables or disables the RF power output of the generator.

⑥ Power Readings

These three boxes indicate the Forward Power, Reflected Power and the reflected power in percentage of your system. The unit scale can be swapped between dBm and watt according to your preferences, by pressing on the dBm/watt indicators.

4.2 Home Menu

The first screen you will see after your generator has started up is the Home menu. This is where the most important controls are present. The controls on this page are used to change the basic properties your RF signal. By default, only the buttons for continuous wave (CW) mode are visible, but more controls become available as you enable other operational modes with the mode selection buttons in the bottom right.

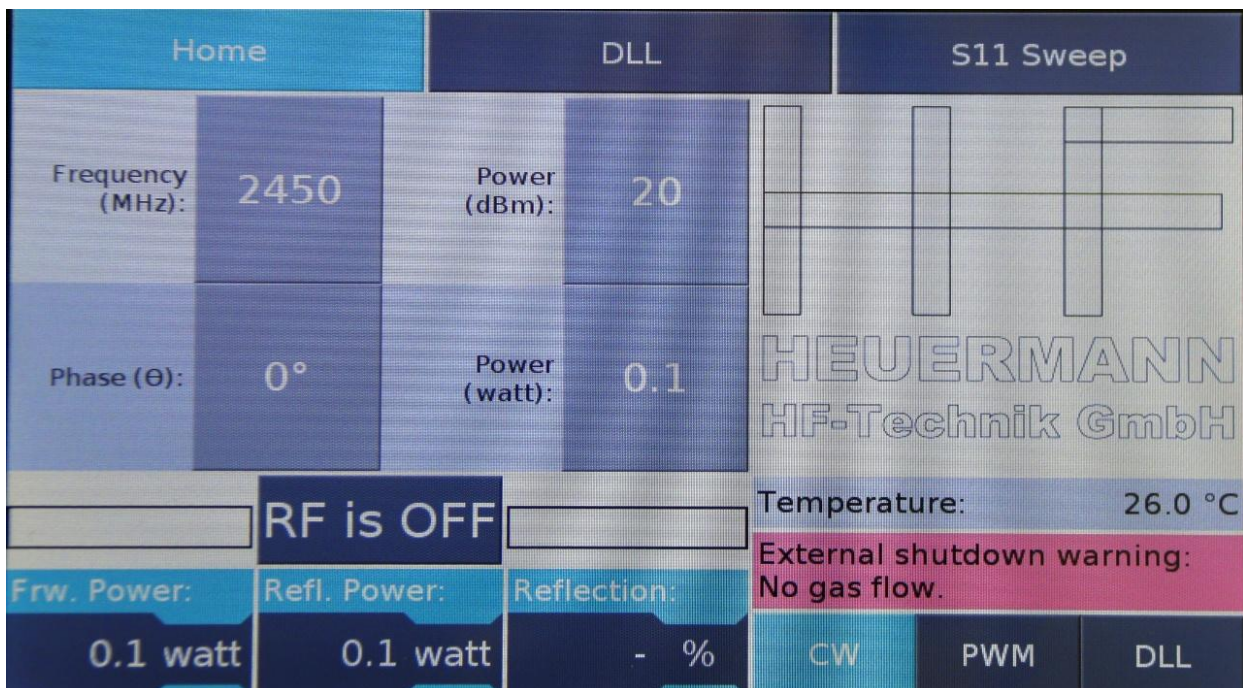


Fig. 5: The home menu of the GUI.

Below are the properties you can control in the home menu for each mode. The properties for CW mode are always relevant, so they remain permanently visible on the screen.

Continuous Wave (CW):

- RF power in dBm
- RF power in watt
- Frequency of the signal in MHz
- Phase of the signal

Pulsed Width Modulation (PWM):

Using this mode, two other parameters become visible:

- PWM Frequency in kHz
- PWM Duty Cycle in %

Note: When PWM mode is enabled, the frequency power level toggles between zero and the set power level, where the duty cycle denotes the power on phase.

Digital Locked Loop (DLL):

Using this mode, two other parameters become visible:

- DLL step in MHz
- DLL threshold in dB

Note: When DLL mode is enabled, the frequency button on the home page will function as an indicator for the currently locked onto frequency of the DLL.

There are two messages:

1. Temperature: This denotes the temperature of the power amplifier. The system will shut down if this reaches a critical value of over 80 °C. If this should happen, please make sure that the ventilation path is free before contacting us.
2. Gas flow monitoring: The system will not start if there is no or not sufficient gas flow, since this would lead to the plasma jets being damaged. In applications without airflow, please contact us to turn off this feature.

4.3 Energy Delivery Optimization - DLL Menu

The DLL menu serves as an advanced control panel for the DLL mode.

DLL mode attempts to find the best working frequency (i.e. minimum in reflected power = minimum in reflection value S11) in a bandwidth defined by the user. The optimization algorithm changes the frequency by “stepping” a certain amount of MHz to the right and left of the current “center” frequency, measures the S11 for each frequency and moves into either direction if the S11 is better by a certain “threshold” than that of the current center frequency. The algorithm loops in this way until stopped. This way it can dynamically follow changing impedance conditions of the applications and yet retain the best energy delivery efficiency for the process.

The technology is fast enough to drive most applications with changing impedances; plasma torches and plasma lamps included.

The DLL menu has the same layout at the Home menu but has a new set of control buttons to input parameters relating to the DLL mode.

The following parameters can be set for the DLL:

- Power dBm (same as value in home menu)
- Power in watt (same as value in home menu)
- Optimization interval upper frequency limit in MHz
- Optimization interval lower frequency limit in MHz
- Optimization search start frequency in MHz
- DLL step offset in MHz
- DLL threshold in dB (same as value in home menu)
- DLL algorithm loop delay in milliseconds

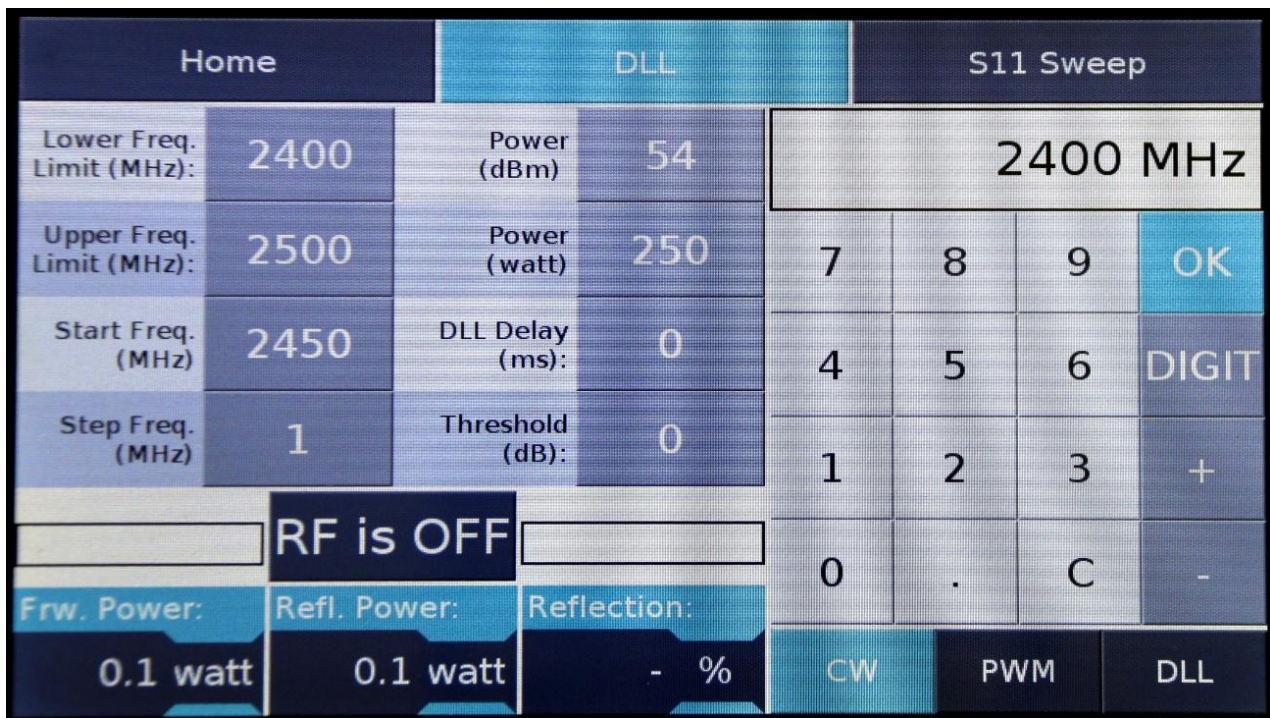


Fig. 6: The DLL menu of the GUI.

4.4 Reflection Measurement - S11 Sweep Menu

S11 is the ratio between reflected to incident wave. The S11 sweep menu allows the user to configure the parameters for an S11 sweep. An S11 sweep measures the S11 parameter across a frequency band specified by the user and generates a graph to visualize the results. This is the same functionality as for a scalar network analyzer.

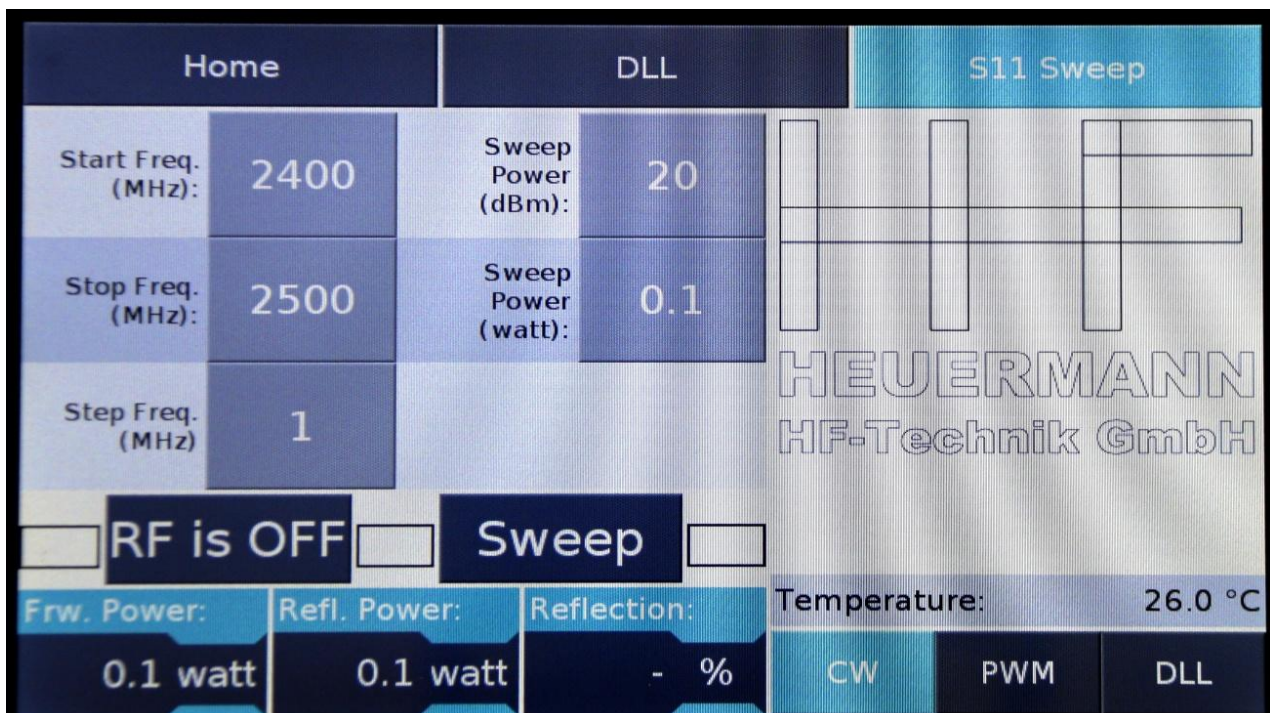


Fig. 7: The S11 sweep menu of the GUI.

The following parameters can be set for the S11 sweep:

- RF Power in dBm
- RF Power in Watt
- Measurement interval start frequency in MHz
- Measurement interval stop frequency in MHz
- Step offset in MHz

Note that 'Sweep Power' settings on this screen are disconnected from the RF Power settings in the other menus. Altering the power values for the S11 sweep will not cause your ongoing RF signal to change.

Additionally, this menu differs from the norm in that it adds a 'Sweep' button next to the existing RF enable button. Pressing this button will execute the S11 sweep with the provided parameters and lead you to the second page of the sweep menu, seen below.

The second page of the sweep menu shows a graph of the S11 ratio across the specified frequency band.

When you arrive at this page, it's important to note that the RF Power output of the OEM kit has been disabled (after the sweep). This is a safety precaution, because this screen has no power readings and ON/OFF controls.



Fig. 8: The settings of the S11 sweep menu.

There are four items of interest on this page:

① **Back button**

Returns the user to the first page of the S11 sweep menu.

② **Unit swap button**

Changes the unit / scaling of graph between logarithmic and linear.
By default, the notation of the graph is consistent with the notation of the power readings.

③ **Sweep button**

Run another sweep with the same sweep parameters.

④ S11 reflection graph

The S11 reflection graph visualizes the efficiency of the RF signal in the attached RF load within the selected frequency band. S11 is the ratio between reflected to incident wave.

- Displays an S11 ratio for linear scale
- Displays an S11 loss (dB) for logarithmic scale / dB notation

5. Operational Settings with Applicators

The preferred mode of operation for general applications is the DLL mode, where the ignition frequency and the operation frequency will be set automatically. When operating a plasma jet, set the lower frequency limit to a little below the operational frequency (e.g. 5 to 10 MHz), the upper frequency limit a little above the ignition frequency and the start frequency approximately at the ignition frequency. The THRESHOLD should be set to 0.5 dB. These frequencies are available in the datasheet of the applicator, be it a jet or a coupler.

Please ensure that the gas needed to cool the plasma jet flows through the generator at the rate stated in the datasheet. The generator monitors this and does not turn on to protect the jet.

6. Safety Instructions

- A. The plasma jets are hand-tuned. Do not disassemble! Assembling is only possible using hot S-parameter measurements.
- B. At higher power levels, the housing of the jet may turn very hot. Do not hold the jets in your bare hands. Since the radiated microwave power also increases, automated operation is recommended.
Keep a 50 cm distance from the jets. To monitor the radiated power, a simple hand held device (e.g. EME Guard 3140 from ANTENESSA) can be used.
- C. For longer usage, a good ventilation is essential.
- D. The plasma is very bright. Refrain from looking at it directly.
- E. Please ensure that the air flow is sufficiently high (PS-Act and PS-Cle). At too low flow levels, the plasma may turn yellowish or red, carrying with it traces of the inner electrode.

7. Contact

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