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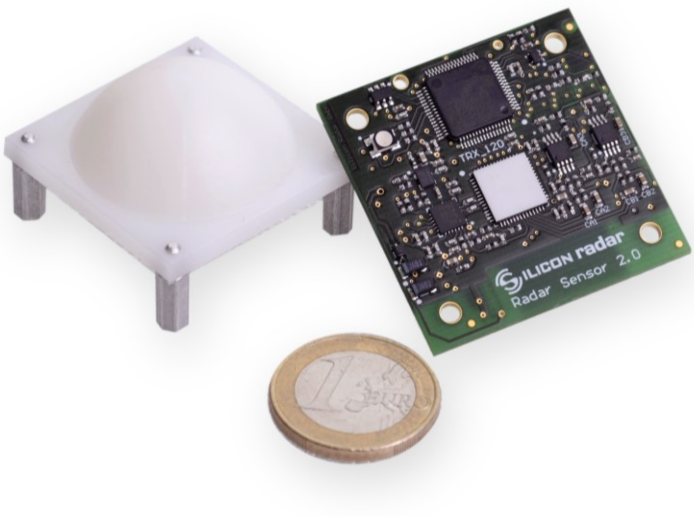
User Guide SiRad Simple® Evaluation Kit



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Version Control

Version	Changed section	Description of change	Reason of change
1.0	all		Initial document
2.0	all	Content and appearance	Hardware & firmware update
2.1	5.1	Firmware info for flashing	Added info for older Easy Kits
2.2	6	Added section	Added mechanical drawing
2.3	all	Software updates	Updates

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1 Overview and Package Contents

Thank you for purchasing Silicon Radar's SiRad Simple® Evaluation Kit. SiRad Simple® is an easy to use, state-of-the-art 122 GHz radar sensor including a high performance target recognition algorithm and WiFi connectivity.

What's in the box?

The SiRad Simple® Evaluation Kit consists of one 122 GHz sensor board and one lens assembly as shown in Figure 1 (left). The SiRad Simple® Evaluation Kit comes with a free graphical user interface for user-friendly parametrization of the sensor and multiple visualization modes for radar data, shown in Figure 1 (right).

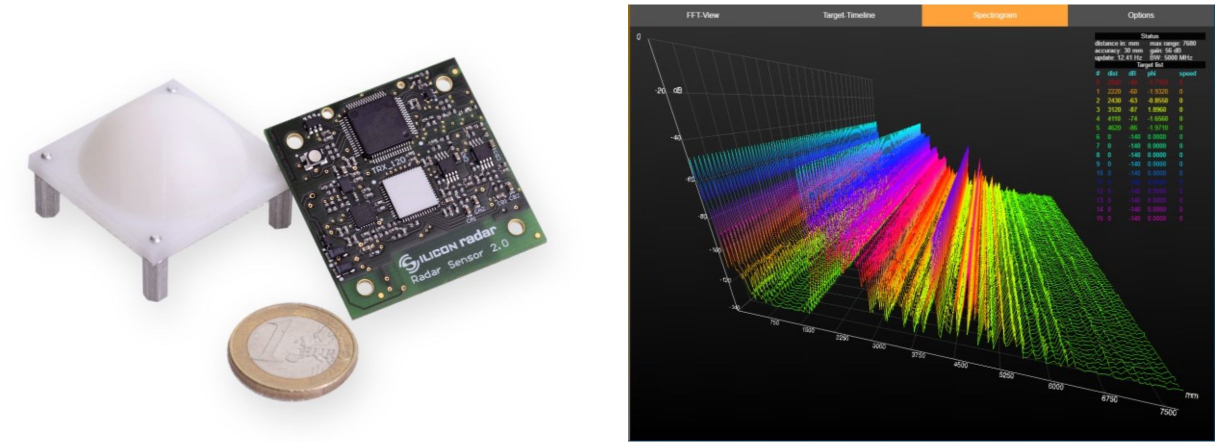


Figure 1: SiRad Simple® Evaluation Kit (left) and graphical user interface (right)

The SiRad Simple® Evaluation Kit demonstrates the performance and parameters of the 122 GHz radar transceiver chip of Silicon Radar. The aim of the evaluation kit is to showcase the FMCW / CW radar mode using a beginner-friendly system. Due to the flexibility of the system, it can be used to change important radar parameters on-the-fly to learn the basics of radar signal processing or to find specific parameter settings for a certain radar sensor application.

Silicon Radar puts the focus of the SiRad Simple® Evaluation Kit on an easy-to-use approach and supports the customer with a set of default key parameters guaranteeing a proper operation of the sensor (including automatically set parameters of optimized operation mode).

1.1 Overview

The SiRad Simple® Evaluation Kit is an experimental showcase system for Silicon Radar's highly integrated 122 GHz IQ transceiver with antennas in package. For more information about the features of Silicon Radar's transceiver chips, all data sheets are available on the Silicon Radar webpage[1].

We developed the evaluation kit to demonstrate our millimeter-wave sensors to measure the distance and velocity using RADAR principles. Both, frequency modulated continuous wave (FMCW) or continuous wave (CW), principles are applied.

1.2 Features

The SiRad Simple® Evaluation Kit feature set includes:

- phase locked loop (PLL) running the integrated low phase noise Push-Push VCO in the transceiver chip,
- frequency lock control to automatically adjust the start and stop frequencies of the generated FMCW radar frequency ramp,
- programmable FMCW parameters,
- 122 GHz ISM band or ~7 GHz high bandwidth FMCW operations,
- analog signal conditioning to amplify and filter the I and Q output signals of the transceiver,
- Analog-to-Digital-converter to digitize the I and Q receiver signals,
- microcontroller to do
  - PLL setup, ramp configuration, A-D conversion,
  - signal processing and target recognition for up to 16 targets simultaneously,
  - transfer to the host system, trigger configurable GP output pins,
- web-based graphical user interface to change relevant parameters, plot the FFT of the baseband channels, display the distance and velocity measurements and the target list,
- standard USB or WiFi communication to PC,
- DC-DC conversion to provide single supply from USB or an external DC supply.

1.3 Application

The SiRad Simple® Evaluation Kit is supposed to be used for short-term evaluation purposes in laboratory environments only. All regulations of the according Silicon Radar Evaluation Agreement may apply.

IMPORTANT:

The radar front ends are able to use a larger bandwidth than what is allowed in the ISM bands. In most countries, the bandwidth is limited to 1 GHz between 122 GHz and 123 GHz for production purposes by law. Please check your local regulations. It remains the customer's responsibility to assure the operation of the front end according to local regulations, especially applying to frequency band allocations outside of the laboratory environment. Silicon Radar and its distributors will not accept any responsibility for consequences resulting from the disregard of these instructions and warnings. Please also refer to Section 7 of this document.

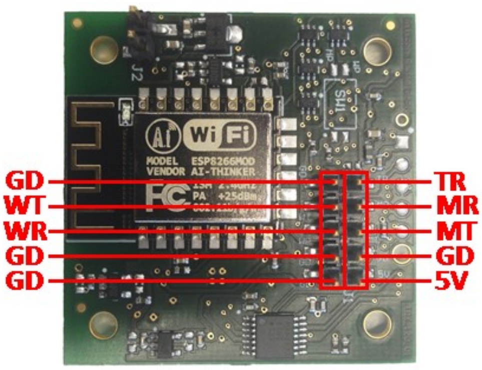
[1] https://siliconradar.com/products/

2 Installation

2.1 Hardware Setup

2.1.1 Understanding the External Header (J1)

The external header in Figure 2 is used to connect to the sensor board in different operating modes. In UART mode, the external header is used to connect a UART cable with RX/TX lines and power supply to the sensor board. The data connection setup via UART is explained in Section 2.1.2. In WiFi mode, the external header is used to connect the WiFi module to the microcontroller on the board. The wireless data connection setup via WiFi is explained in Section 2.1.3. In programming mode, the external header is used to program either the WiFi module or the microcontroller, please see Section 5. The external header can also be used to trigger measurements manually via the external trigger line (TR), also see Section 3.2.3.1.

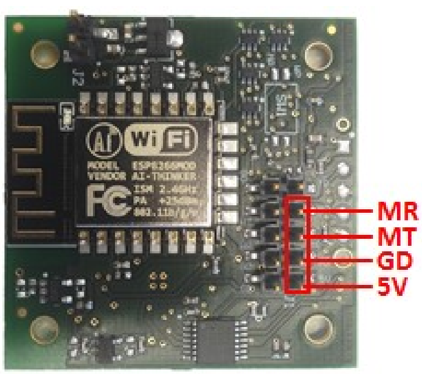


Pin	Description
5V	+5V
GD	GND
MT	microcontroller TX*
MR	microcontroller RX*
TR	external trigger line*
WT	WiFi TX*
WR	WiFi RX*
	*** 3.3V tolerant only!**

Figure 2: External header (J1) pinout

2.1.2 Data Connection via UART Cable (UART Mode)

The UART interface pins of the sensor board are shown in Figure 3 (left). You can use the UART interface to connect the sensor board to a PC or in a target application with a serial interface. Figure 3 (right) shows the sensor board with an FTDI cable attached to the external header (J1), which provides a virtual serial port via USB to a PC. **Make sure to use a cable with 3.3V TTL (TX/RX) levels!**



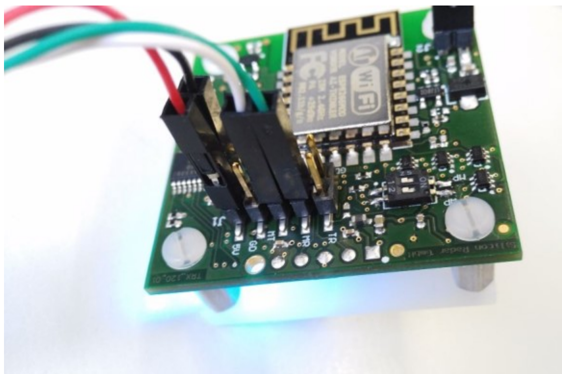


Figure 3: UART pinout on J1 (left) and UART to USB connection via FTDI cable at J1 (right)

The FTDI cable's VCC is connected to +5V, the cable's GND to any GD pin (there are four), the cable's RX to the TX line of the microcontroller (MT) and the cable's TX to the RX line of the microcontroller (MR).

Make sure that both DIP switches are in their OFF positions and the power jumper (J2) for the WiFi module is open (switched off). Please proceed to Section 2.1.4 to install the lens (optional) or to Section 2.2 for running the Evaluation Kit software.

2.1.3 Wireless Data Connection via WiFi (WiFi Mode)

The WiFi interface pins of the sensor board are shown in Figure 4 (left). To run the sensor in WiFi mode, use the three jumpers delivered with the sensor and close the power jumper (J2) for the WiFi module (switched on) and connect two jumpers between MT/WR and MR/WT. Apply +5V to the 5V pin and GND to the any GD pin (there are four) of the external header (J1).

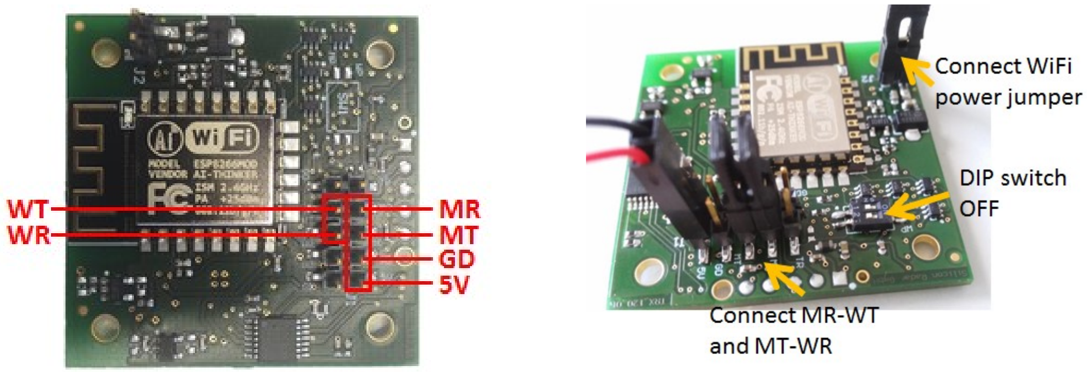


Figure 4: WiFi pinout on J1 (left) and WiFi mode configuration (right)

Please proceed to Section 2.1.4 to install the lens (optional) or to Section 2.2 for running the Evaluation Kit software.

2.1.4 Mounting the Lens (Optional)

The maximum range of the 122 GHz front end is approximately 40 meters with an opening angle of around +/- 30 degrees (-6dB) for strong targets like a building or car. With the lens mounted, the opening angle decreases to around +/- 4 degrees. Figure 5 shows a schematic diagram of the two configurations modes - with and without the lens. The range will only increase slightly when mounting the lens.

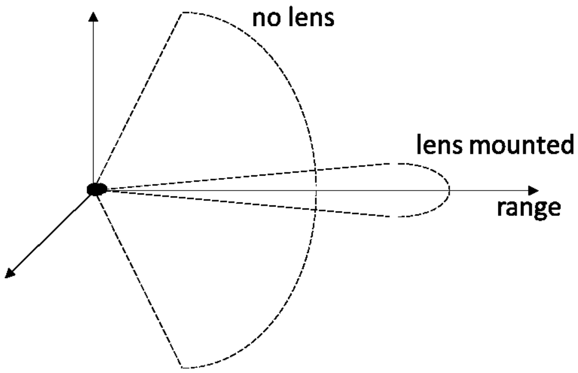


Figure 5: Schematic comparison of range with and without the lens

Please install the lens at a distance about 10 to 15 mm away from the radar front end's surface, see Figure 6. You can use the provided 10 mm spacers to mount the lens.

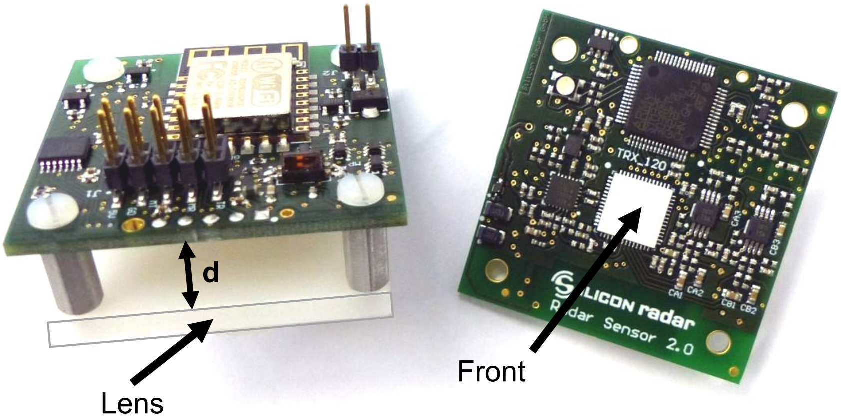


Figure 6: Mounting the lens

The lens has a focal length of 15 mm with an opening angle of +/- 4 degrees. If it is installed closer to the radar front end, the beam will be wider.

2.2 Software Installation

2.2.1 Software Requirements

The SiRad Simple® Evaluation Kit software for PC is available at the Silicon Radar webpage[2] upon request. There are two options to connect the sensor to the Evaluation Kit software, either using a UART-USB connection provided by a virtual COM port – explained in Section 2.2.2 – or via WiFi – explained in Section 2.2.3. The hardware setup for the UART and WiFi connection modes have been explained in Section 2.1.2 (UART) and 2.1.3 (WiFi).

Please configure the sensor board for either the UART mode (for the USB connection) or the WiFi mode before proceeding to one of the next sections.

The Evaluation Kit software requires a web browser (not included in the software package) that supports WebGL, for example, Google Chrome Browser or Mozilla Firefox. WebGL requires a graphics card that supports OpenGL. Further, the software requires a 32 bit Java JRE or JDK version 8 update 111 or later to be installed on the system running the software. Please also see Table 1 for the software requirements.

Please note that 64 bit Java is not supported by the software package.

Table 1: Software requirements

Requirement	Software / Version
Operating system	Microsoft Windows 7/10
Java	32 bit Java JRE / JDK 8u111[3] or higher
Browser	Chrome Browser or Mozilla Firefox

[2] https://siliconradar.com/evalkits/

[3] https://www.java.com/en/download/ or https://adoptopenjdk.net/

2.2.2 Connecting to the Board via USB

The sensor board can be connected to a PC via USB through an FTDI cable (delivered with the evaluation kit), which provides a virtual COM port. We recommend using a cable with FTDI chipset instead of cheaper alternatives since a lot of our customers found the cheaper alternatives to be very unstable. If you want to use a cheaper alternative, skip the next point and see the vendor's website of your cable.

Installing the FTDI driver

Usually the driver is automatically installed by Microsoft Windows once the FTDI cable is connected to the PC. Therefore, the PC has to be connected to the internet and the automatic driver installation feature has to be enabled (default behavior). If you need to install the driver manually, go to the FTDI Chip website[4] and download the latest VCP driver. Once the FTDI driver is installed, the FTDI cable connected to the sensor and to the PC should provide a virtual COM port.

Installing the Evaluation Kit's COM2WebSocket tool

The Evaluation Kit software contains a COM2WebSocket tool that creates a WebSocket from the virtual COM port to provide it to the graphical user interface. You can find the tool in the Install Package in the 'Software' folder. The COM2WebSocket tool is portable and can be copied to a path of your choice on your PC. Make sure that the java.exe of your Java JRE or SDK installation is available in the PATH variable of Windows, then start it by double clicking the Com2Websocket.jar file. Alternatively, you can also change the path to the 'java.exe' file of your Java installation in the file 'runme.bat' of the COM2WebSocket tool and then run it by a double click on the 'runme.bat' file. In the COM2WebSocket application window, select the virtual COM port number that belongs to your sensor board and select 230400 baud as the baudrate like shown in Figure 7. A click on the 'connect' button opens a WebSocket server, which is fed with the data coming from the sensor board. Proceed to Section 2.2.4 for running the graphical user interface.

Connecting to the Evaluation Kit via terminal program instead of WebGUI (optionally)

Optionally, you can connect to this serial port using a terminal program such as PuTTY[5] or Realterm[6] instead of the Com2WebSocket Tool and WebGUI. Use the following UART settings: 230400 baud, 8 bits, 1 stop bit, no flow control. You should see plenty of protocol output from the sensor like in Figure 7 (left).

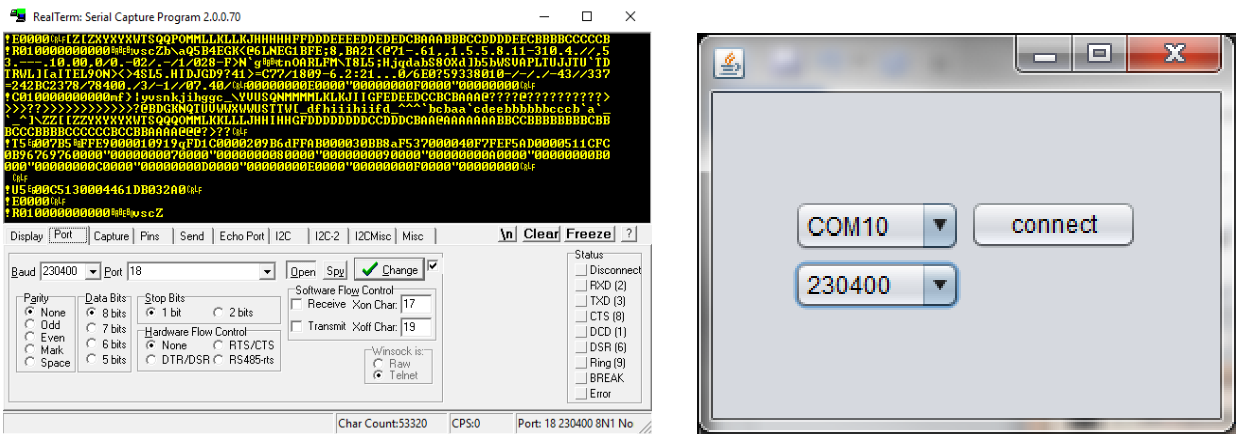


Figure 7: Terminal output of the sensor (left) and COM2WebSocket tool (right)

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[4] https://www.ftdichip.com/Drivers/VCP.htm

[5] https://www.putty.org/

[6] https://realterm.sourceforge.io

2.2.3 Connecting to the Board via WiFi

Please be aware that the WiFi module has a limited transfer rate. The maximum possible frame update rate is about 10 Hz when using the WiFi connection. Once you power-up the sensor module in WiFi configuration, the WiFi module's LED is flashing in blue. The WiFi module opens an own access point. This may last approximately 40 seconds. Please set the WiFi module of your PC to use automatic IP address selection via DHCP to get an IP address from the sensor. If your PC's WiFi module uses a static IP, it might not be possible to connect to the WiFi module of the sensor. Connect to the sensor's WiFi access point using the following login credentials:

SSID: **SimpleRadar-<uuid>** Password: **SimpleRadar**

or

SSID: **EasyRadar** Password: **Greetings**

Once the sensor's WiFi module has opened an access point, it waits for approximately 40 seconds until it starts the sensor operation and the blue LED is switched off. On Windows, the IP address that was assigned by the sensor's WiFi module to your PC can be checked in the network manager. Proceed to Section 2.2.4 for running the graphical user interface.

2.2.4 Starting the Graphical User Interface (Silicon Radar WebGUI)

You can find the Silicon Radar WebGUI in the Install Package in the 'Software' folder. It is portable and can be copied to a path of your choice on your PC. The user interface is started by opening the 'startSimple.html' file in a Chrome or Firefox Webbrowser. Once the WebGUI is launched, the main window is displayed, also see Figure 8 (left).

WiFi only: If you are using a WiFi connection to connect to the sensor board, unfold the 'COM' section in the control panel on the left side of the WebGUI. Provide the IP address and the port of the WiFi module of the sensor you want to connect to before you proceed, like so: '192.168.4.1:9090'. The standard port is 9090.

Click the 'Connect' button on the top left to connect to the WebSocket provided by the COM2WebSocket tool or to the WiFi module of the sensor board. The WebGUI should display the sensor data as shown in Figure 8 (right).

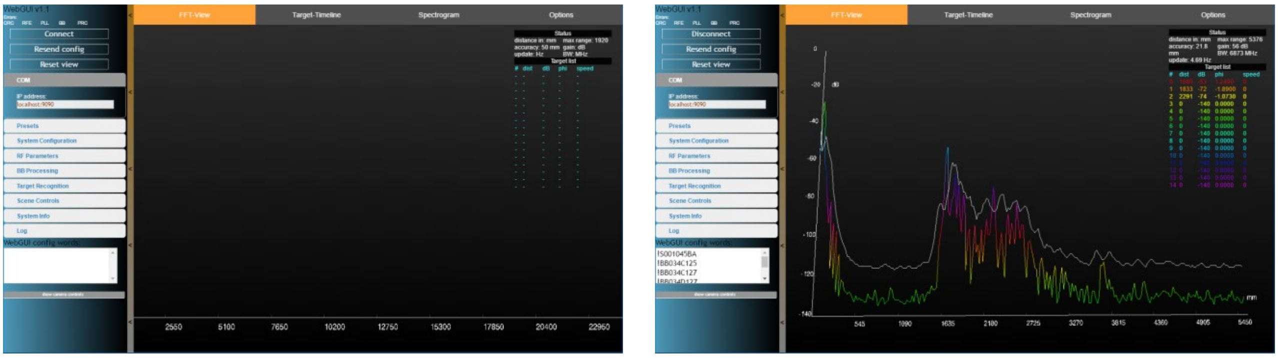


Figure 8: Silicon Radar WebGUI after start (left) and connected to a sensor (right)

The WebGUI can now be used as described in Section 3.

3 Getting Started with the Silicon Radar WebGUI

3.1 Understanding the User Interface

The SiRad Simple® Evaluation Kit is developed to demonstrate the functionality of Silicon Radar's transceiver chips as millimeter-wave distance and velocity sensor front ends. Once the WebGUI is launched, the main window is displayed like shown in Figure 9.

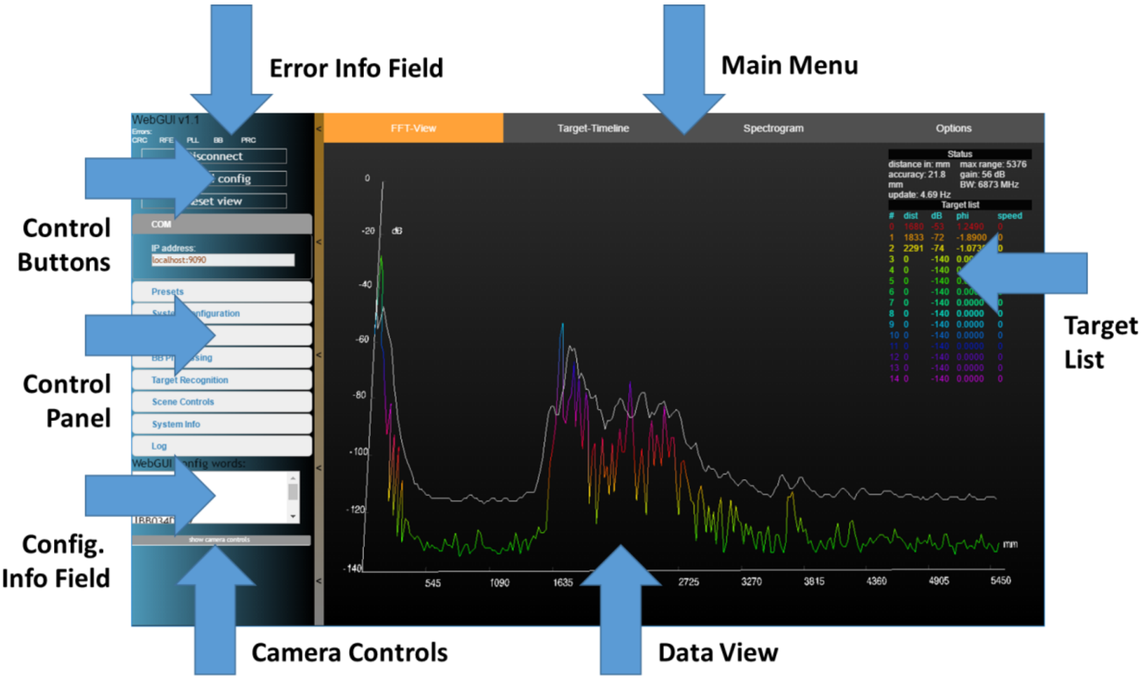


Figure 9: Main panels of the Silicon Radar WebGUI

The Silicon Radar WebGUI consists of four main panels:

- control panel on the left side,
- main menu on the top of the screen - with the active view in orange,
- scene/canvas itself - where the sensor data is displayed,
- target list with the status fields on the right side of the screen (draggable).

The control buttons on the top left corner are used to connect the WebGUI to the sensor:

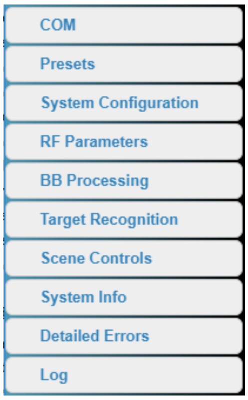
Connect: used to connect the WebGUI to the WebSocket provided by the Com2WebSocket tool, which should be started before connecting the WebGUI.

Resend config: used to send the current settings to the sensor. Usually, the settings made in the WebGUI will immediately take effect on the sensor, however, this feature is useful when a sensor was reset or reconnected.

Reset view: resets the view area to use the maximal available window space for displaying the data and centers the view in the view area.

3.2 Using the Control Panel (Sensor Settings)

The control panel on the left side of the WebGUI provides the controls for the user interface. It is used to connect to the sensor, to send commands and to change the data view. The control panel contains the sections shown in Figure 10.



Tab	Description
COM	communication options
Presets	load and save settings
System Configuration	system settings
RF Parameters	radio and frequency settings
BB Processing	baseband processing settings
Target Recognition	target recognition settings
Scene Controls	scene control options
System Info	hardware information
Detailed Errors	retrieve detailed error info
Log	recently sent control frames

Figure 10: Control panel with its different tabs

3.2.1 Communication Options (COM Tab)

The standard setting 'localhost:9090' is for communication via the USB port, see Figure 11 (left). If you are using WiFi, type in the IP address and the port 9090 of the sensor's WiFi module like in Figure 11 (right), for example, '192.168.4.1:9090'.

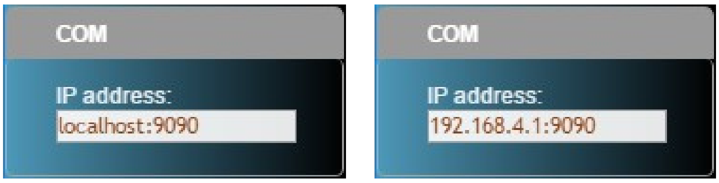
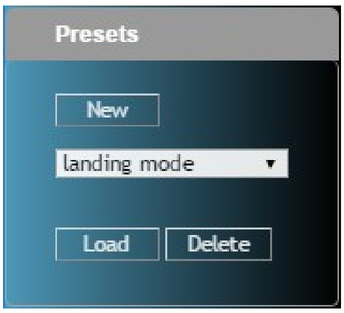


Figure 11: COM tab of the Control Panel for USB (left) and WiFi (right) communication

3.2.2 Load and Save Settings (Presets Tab)

Load predefined settings: You can load predefined settings via the dropdown box in the 'Presets' tab, see Figure 12 (left). Choose a setting and press 'Load'. The factory presets are explained Figure 12 (right).



Setting	Description
landing mode	high accuracy: 25 mm, distance: 6.4 m, update rate: 17.67 Hz
max accuracy	***very high accuracy: 6.2 mm***, short distance: 3 m, update rate: 11.29 Hz
max distance	low accuracy: 75.1 mm, ***long distance 38.4 m,*** update rate 7.96 Hz
max update rate	high accuracy: 30 mm, distance: 7.6 m, ***high update rate: 31.65 Hz,*** no spectrum output
standard	high accuracy: 30 mm, distance: 7.6 m, max update rate: 12.56 Hz

Figure 12: Presets tab (left) and predefined settings (right)

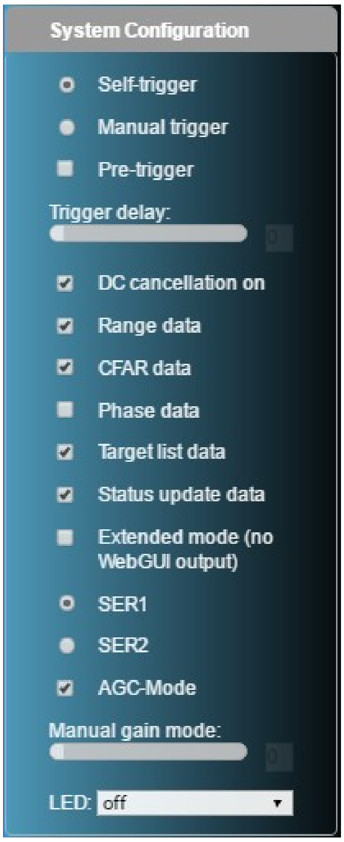
<u>Save own settings:</u> To save your settings, click the 'New' button. The dialog in Figure 13 appears. Enter a preset name and description for your settings and click 'Save'. All settings are stored as cookies in your browser so that they are available next time when you open the browser. **Please make sure that your browser saves and keeps cookies (Mozilla Firefox) or local storage is enabled (Chrome Browser) to enable this feature. Do not use a 'private' mode and do not set up your browser to delete all saved content each time you close the window.**

Figure 13: Save settings in the Presets tab of the Control Panel

<u>Delete settings:</u> To delete settings, choose a preset name and click 'Delete'. In case you accidentally deleted one of the factory presets that are explained in Figure 12 (right), those will be automatically restored next time you open the browser.

3.2.3 System Settings (System Configuration Tab)

The 'System Configuration' tab shown in Figure 14 is used to control the kind and amount of transmissions from the sensor.



Setting	Description
Self-trigger	sensor triggers itself continuously
Manual trigger	manual or external triggering mode
Pre-trigger	used to synchronize measurements
Trigger delay	set a delay between trigger and measurement
DC cancellation	switch DC offset compensation on
Range data	transmit distance data frames
CFAR data	transmit CFAR data frames
Phase data	transmit phase data frames
Target list data	transmit target list data frames
Status update data	transmit status data update frames
Extended mode	switch to raw data output
SER1	connect to the sensor via WiFi or UART
SER2	**<reserved>**
AGC-Mode	switch automatic gain control on
Manual gain	set a gain (when AGC-Mode is switched off)
LED	choose an LED operating mode

Figure 14: System Configuration tab of the Control Panel

3.2.3.1 Triggering measurements

You can choose between the two triggering modes 'Self-triggering' and 'Manual triggering'. You can find the steps to set them in Table 2.

Table 2: Triggering modes

Self-triggering (internal)	Manual (external) triggering
1. choose 'Self-trigger'	1. choose 'Manual trigger'
2. disable 'Pre-trigger'	2. optionally enable 'Pre-trigger'
3. optionally set a 'Trigger delay'	3. manually send triggers on the external trigger line (TR) - also see Section 3.2.3.1 - or by sending command frames (see the Protocol Description)

Self-trigger: activates the continuous measurement mode (default). The sensor triggers itself repeatedly for continuous measurements.

Manual trigger: deactivates the continuous measurement mode for manual external triggering. Use this setting for asynchronous triggering or synchronized measurements between multiple radar sensors. The sensor enters a low power mode after the transmission of measurement results and wakes up upon the next trigger. Also see the Protocol Description for manual trigger commands.

Pre-trigger: can be used to synchronize measurements between multiple radar sensors. If selected, and the sensor is not in self-trigger mode, the sensor expects two external trigger commands to execute one measurement. The two triggers have to be sent with a maximum delay of about 40ms or the second trigger is ignored. Also see the Protocol Description for the trigger commands.

Trigger delay: sets a delay time between two measurements when in self-trigger mode.

3.2.3.2 Frame options

DC cancellation: activates the DC offset compensation of the ADC data.

Range data: activates the transmission of the distance data frames, which contain the distance spectrum data in dB for each distance bin (magnitude of the complex FFT output).

CFAR data: activates the transmission of the CFAR data frames, which contain the threshold of the constant false alarm rate (CFAR) operator in dB for each distance bin. The CFAR operator is an adaptive algorithm to derive detection threshold for targets against noise.

Phase data: activates the transmission of the phase data frames, which contain the values of the phase angles for each distance bin (argument of the complex FFT output).

Target list data: activates the transmission of the target list data frames, which contain a list of targets including a target number, distance to the target, and their magnitude in dB and their phase. The speed field is reserved.

Status update data: activates the transmission of the status data update frames after every measurement. If deactivated, the status frame is only transmitted after the sensor settings changed. The status frame contains the distance unit (default: mm), the current maximum range of the sensor, the measurement accuracy of the current setting, the gain setting of the baseband amplifier for the last measurement, the update rate of the sensor and the bandwidth of the frequency ramps used in the current setup.

Extended mode: activates the transmission of the extended data frames (raw data) instead of the standard sensor data frames. Please be aware that the extended data frames are not supported by the WebGUI. No data will be shown in the WebGUI as long as the extended data mode is enabled. Please see the Protocol Description for more information about the 'Extended mode'.

3.2.3.3 Connection control

SER1: connect to the UART of the sensor though a USB port or to the WiFi module.

SER2: **<reserved>, no function for SiRad Simple® sensors.**

Please note that, if the wrong connection option is selected, the WebGUI will appear to be frozen because no data will be displayed. However, the sensor always listens on both serial ports, so reconfiguring is possible at any time.

3.2.3.4 Gain settings

AGC-Mode: activates the automatic gain control. If activated, the sensor uses two extra frequency ramps to detect and set the optimal gain setting. When AGC-Mode is turned on, the settings of the gain slider are overridden by the automatic gain control.

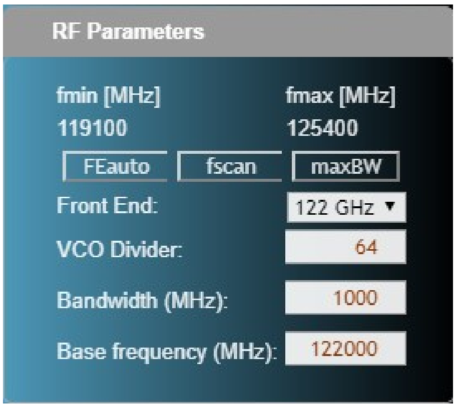
Gain: used to manually set one of 4 gain levels. The gain control is only used when the AGC-Mode is switched off. There are 4 gain modes, which depend on the hardware version of the sensors due to adaptations in the attenuation network and ADC lines of the baseband amplifier. The gain settings for the latest SiRad Simple® sensor (v2.2) are 8, 21, 43, 56 dB (left to right).

3.2.3.5 LED control

LED: switches the LED on or off. If switched on, the LED indicates the distance to the first detected target in rainbow colors.

3.2.4 Radar Front End Settings (RF Parameters Tab)

The ‘RF Parameters’ tab in Figure 15 is used to control the radar front end of the sensor. For each radar measurement, the front end is driven with one or more frequency ramps starting from a defined start frequency f_1 (base-frequency) to a higher frequency f_2 with the bandwidth BW = $f_2 - f_1$. The higher the bandwidth, the smaller is the detection range of the sensor due to Nyquist limitations. The start frequency is technically limited by the minimum frequency f_{min} supported by the front end. The bandwidth is limited by the maximum frequency f_{max} supported by the front end. **Please note, that in most countries, the permitted bandwidth is regulated by law to 1 GHz between 122 GHz and 123 GHz for field applications. Please check your local regulations.**



Setting	Description
fmin	shows the minimum supported frequency of the radar front end in MHz
fmax	shows the maximum supported frequency of the radar front end in MHz
FEscan	auto select the front end type
fscan	re-scan the minimum and maximum supported frequencies
max BW	auto set the maximum available bandwidth for the frequency ramps depending on the supported min and max frequencies
Front End	switch the presets for the used radar front end
VCO Divider	shows the VCO divider, fixed per front end type
Bandwidth	set the bandwidth used for the frequency ramps in MHz
Base-frequency	set the start frequency of the frequency ramps in MHz

Figure 15: RF Parameters tab of the Control Panel

fmin / fmax: displays the result of the frequency scan (done once automatically during startup) to find the minimum and maximum supported frequencies of the installed radar front end (f_{min} and f_{max}). The scan can be performed manually by using the 'fscan' feature.

FEauto: performs a manual scan of the mounted front end to determine the frequency range and basic front end settings (this feature is of less importance for the SiRad Simple® due to the fixed front end).

fscan: performs a manual min / max frequency scan for the installed front end. The frequencies supported by your front end should be approximately in the range of 119100 to 125900 MHz for the 122 GHz front end on the SiRad Simple® sensor.

max BW: sets the frequency ramp bandwidth to the maximum possible value for the installed front end. The maximum bandwidth is hardware dependent and may vary. The maximum useful bandwidth BW is (including a margin of 200 MHz):

$$\mathbf{BW_{max} = (f_{max} - 100\ MHz) - (f_{min} + 100\ MHz).}$$

Front End: switches the presets for the used radar front end. **Only the 122 GHz option is useful for the SiRad Simple® sensor. The other presets can lead to undefined behavior.**

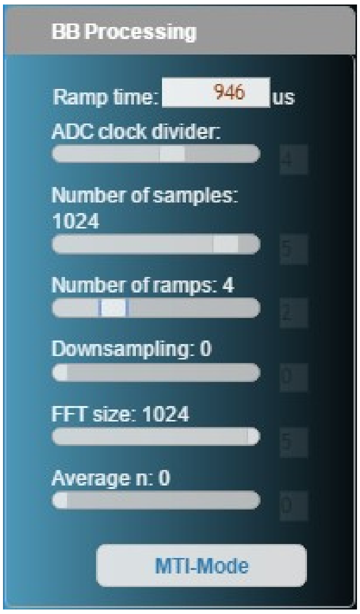
VCO Divider: is hardware dependent per front end type. **The VCO divider for the SiRad Simple® sensor (v2.2) is 64, fixed.**

Bandwidth: set the bandwidth (in MHz) used for the frequency ramps. The bandwidth should not exceed the maximum frequency f_{max} of the front end minus the minimum frequency f_{min} of the front end minus 200 MHz.

Base-frequency: set the start frequency of the frequency ramps (in MHz). The start frequency f_B should be at least 100 MHz larger than the minimum supported frequency f_{min} of the front end, and at least 100 MHz smaller than the maximum supported frequency of the front end f_{max} minus the desired bandwidth. **If the base-frequency and bandwidth are chosen in a way that the bandwidth exceeds the minimum and maximum supported frequencies of the front end, the voltage applied to the VCO for the voltage ramp may drive into saturation, which decreases the signal quality.**

3.2.5 Baseband Processing Settings (BB Processing Tab)

The 'BB Processing' tab shown in Figure 16 is used to control the baseband processing of the sensor to tune the SNR, accuracy, or processing speed.



Setting	Description
Ramp time	shows the calculated ramp time per ramp
ADC clock divider	adjust the sampling frequency indirectly
Number of samples	adjust the number of samples per ramp
Number of ramps	adjust the number of ramps used for SNR reduction
Downsampling	adjust the number of samples that are averaged after sampling
FFT size	adjust the number of FFT bins
Average n	adjust the number of FFTs to average
MTI-Mode	activate / deactivate the Moving Target Indicator mode

Figure 16: BB Processing tab of the Control Panel

Ramp time: is reported back by the sensor. The ramp time t is calculated using the selected sampling time t_{Smp}, the number of samples n_{Smp} and the clock frequency of the ADCs, like

$$\mathbf{t\ [us] = t_{Smp}\ [clock\ cycles] * (n_{Smp} + 85) / (36\ MHz)}$$

The sampling time t_{Smp} is an internal value that is controlled by the ADC Clock Divider setting according to Table 3. The sample frequency f_{Smp} is determined by the clock frequency of the ADCs (36 MHz) divided by the ADC sampling time t_{Smp}.

Table 3: Sampling time and sample frequency

ADC Clock Divider	ADC sampling time t_{Smp} [clock cycles * 10]	Sample frequency [MS/s]
0	14	2.5
1	15	2.4
2	17	2.1
3	20	1.8
4	32	1.1
5	74	0.4
6	194	0.1
7	614	0.05

ADC clock divider: sets the sampling time of the ADCs indirectly. A higher ADC clock divider means slower sampling, according to Table 3.

Number of samples: sets the number of samples taken per ramp.

Number of ramps: sets the number of ramps that are driven per measurement. All ramps are integrated to improve the SNR. Hence, higher values give slower measurements but better SNR. However, too many ramps may smear out the signal due to the phase noise of the system.

Downsampling: determines how many samples are averaged after sampling. Higher downsampling values improve the accuracy but reduce the maximum range of the sensor. Voids are filled with zeroes when downsampling. A downsampling of 0 means no downsampling, 1 means an average of 2 values, 2 an average of 4 values, etc.

FFT size: sets the number of FFT bins. Higher values mean better accuracy but slower calculation.

Average: determines the number of FFTs to average. An average of 0 means 1 FFT without averaging, 1 means an average of 2 FFTs, etc.

MTI-Mode: activates the Moving Target Indicator mode. When activated, the sensor displays the difference between the current measurement and the average of the previous measurements (set by the ‘Average n’ slider).

3.2.6 Target Recognition Settings (Target Recognition Tab)

The ‘Target Recognition’ tab shown in Figure 17 is used to control the CFAR-operator for the target recognition and the reported distance format / unit. Please also see Table 4 below for the valid format options. The CFAR-operator is explained in Figure 18. We use a simple CACFAR-operator that calculates the average from the reference cells for the CFAR.

Setting	Description
CFAR guard	adjust the number of guard cells before and after the cell under test
CFAR size	adjust the number of FFT bins used on either side of the guard cells
CFAR threshold	adjust the detection threshold in dB above the noise floor
Format	adjust the format in which the distance data is sent / displayed

Figure 17: Target Recognition tab of the Control Panel

Table 4: Format options

Format	Option	Description
0 - 3	Reserved	
4	bins	number of the distance bin which receives the data
5	mm	data is displayed in 'mm' depending on the accuracy
6	cm	data is displayed in 'cm' depending on the accuracy

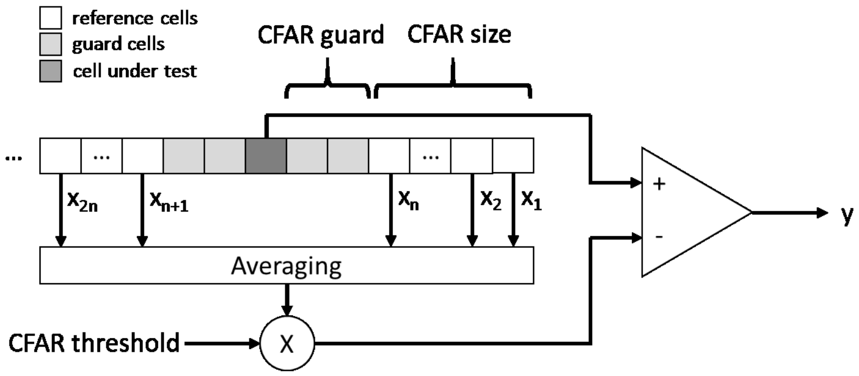
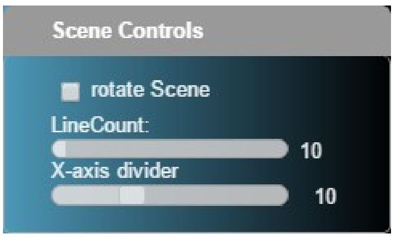


Figure 18: Schematic description of the CACFAR-operator

3.2.7 Scene Control Options (Scene Controls Tab)

You can control the scene with the settings shown on the 'Scene Control' tab shown in Figure 19.



Setting	Description
rotate Scene	rotates the view around the center of the drawing area
LineCount	adjust the number of datasets shown in the waterfall view (3D)
X-axis divider	adjust the number of data labels shown on the x-axis

Figure 19: Scene Controls tab of the Control Panel

3.2.8 Radar Hardware Information (System Info Tab)

The ‘System Info’ tab in Figure 20 (left) shows the unique hardware identification number of the SiRad Simple®, the firmware version, date of compilation, version identifier, and protocol version and specification date. You can press the ‘Update system info’ button to refresh this information from the sensor.

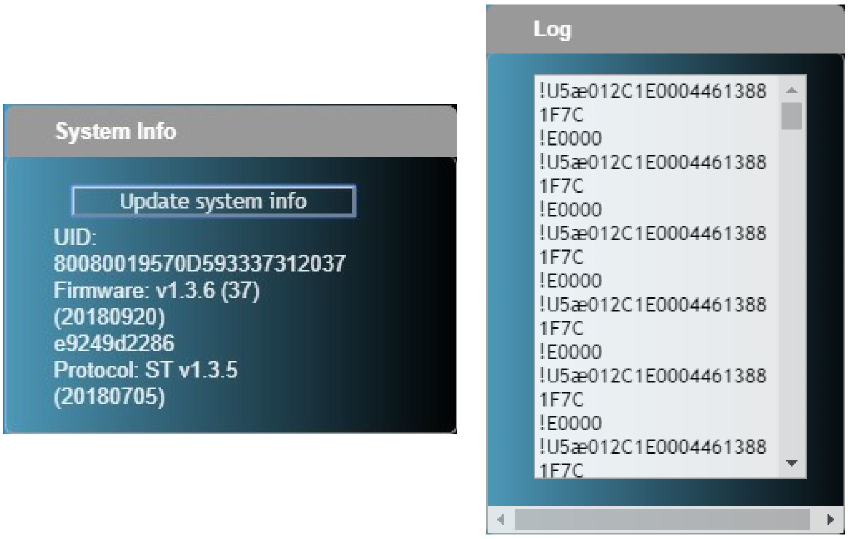


Figure 20: System Info tab (left) and Log tab (right) of the Control Panel

3.2.9 Recently Sent Control Frames (Log Tab)

Figure 20 (right) shows the Log tab which lists the latest control frames sent to the sensor. Also see the Protocol Description for further information about the sensor’s communication protocol.

3.3 Using the Main Menu

The main menu is shown in Figure 21. Here you can select how the data should be displayed. You have the following main options, which are explained in the following subsections:

- FFT-View: FFT (2D) and Waterfall (3D)
- Target-Timeline
- Spectrogram
- Options

Figure 21: Main menu of the WebGUI

3.3.1 FFT View

FFT (2D) chart (Figure 22):

The x-axis shows the distance and the y-axis shows the magnitude in dB at this distance.

Waterfall (3D) chart (Figure 23):

In the 3D view you can see the history of data, with the z-axis being the timeline. Older values move to the back (higher z-values). The x and y-axes behave like in the 2D view.

Figure 22: 2D view of the FFT data

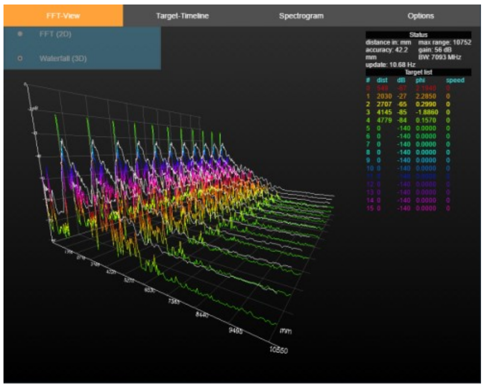


Figure 23: 3D view of the FFT data

3.3.2 Status Field and Target List

The 'Status' field shown in Figure 24, top, displays a couple of useful information about the current measurements.

distance: shows the used distance format of the sensor, for example, [mm, cm, bins].

max range: current maximal measurement range of the sensor in the chosen distance format.

accuracy: the width of one distance bin of the sensor after the formula

$$acc = c * n_{Smp} / (2 * BW * n_{FFT} * 2^{ndown})$$

where *c* is the speed of light, *BW* is the bandwidth, n_{Smp} is the number of samples, n_{FFT} is the FFT size, and n_{down} is the downsampling factor.

gain: current gain setting of the baseband amplifier in dB.

BW: the chirp's bandwidth.

update: calculated update rate from the TSLM-value („time since last measurement").

The 'Target list' shown in Figure 24, bottom part, is ordered by distance. With every new measurement having the CFAR operator enabled, the 'Target list' is updated. Where the distance bin crosses the CFAR threshold from below, the local maximum is searched and a target is generated. If two or more target peaks cross the CFAR threshold from below before the distance bin goes back underneath the CFAR threshold, only the first target is marked.

Status
distance in: mm max range: 18944
accuracy: 37.5 gain: 56 dB
mm BW: 1995 MHz
update: 5.93 Hz

Target list

#	dist	dB	phi	speed
0	2067	-27	-0.1910	0
1	2556	-52	1.4340	0
2	2856	-65	3.1230	0
3	3458	-75	2.2450	0
4	4097	-64	0.3990	0
5	4623	-83	-2.8350	0
6	6164	-95	-0.7100	0
7	0	-140	0.0000	0
8	0	-140	0.0000	0
9	0	-140	0.0000	0
10	0	-140	0.0000	0
11	0	-140	0.0000	0
12	0	-140	0.0000	0
13	0	-140	0.0000	0
14	0	-140	0.0000	0
15	0	-140	0.0000	0

Target list column	Description
num	indicates the number of the target
dist	the distance of the target in the selected format
db	magnitude of the target peak
phi	phase angle of the target, meaning the phase shift between the outgoing wave and the incoming wave; the value should change rapidly, if the target is moving
speed	radial velocity of the target [m/s] calculated as a distance difference since the last measurement

Figure 24: Target list with the status field at the top

3.3.3 Target-Timeline

The ‘Target-Timeline’ in Figure 25 shows the magnitudes of past targets. The x-axis shows the distances of the targets and the y-axis shows the magnitudes of the targets in dB. The z-axis shows the timeline of the data. Older values move to the back (higher z-values).

3.3.4 Spectrogram

The ‘Spectrogram’ shown in Figure 26 is another time dependent display of distance data.

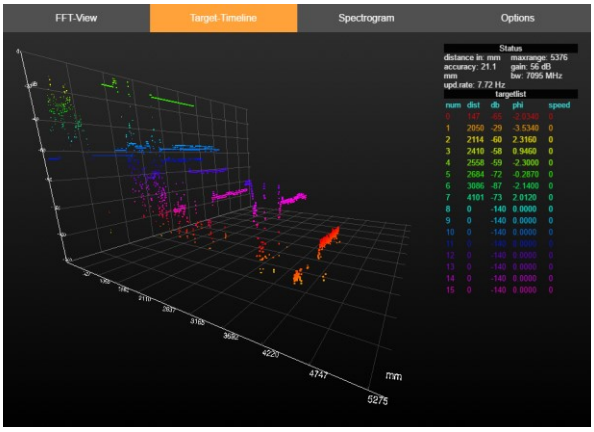


Figure 25: Target-Timeline

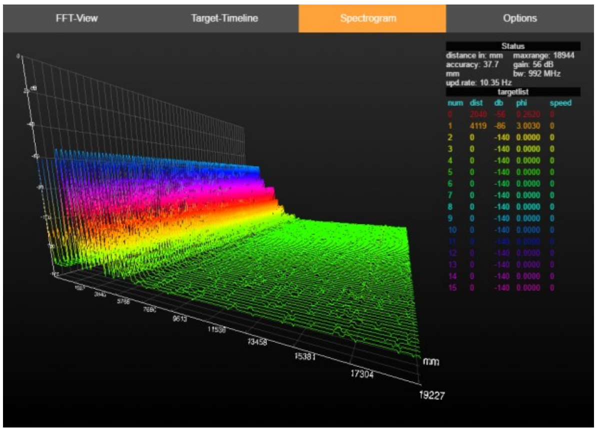


Figure 26: Spectrogram

3.3.5 Options

In the ‘Options’ menu, you can choose the coloring of the data between:

- Magnitude
- Range / target number
- Phase angles (the phase angles are only colorized if the magnitude is larger than -120 dB and when the Phase-frame transmission is enabled in the ‘System Configuration’ Tab)
- No coloring

Coloring examples are shown in Figure 27 to Figure 30. There is also an additional option to display phase markers above the detected targets. These markers show the phase angle of the detected target. The phase angle is very sensitive to slight changes of the target distance within one distance bin. It can be used to display relative motion in the µm range.

Figure 27: Magnitude coloring with phase markers

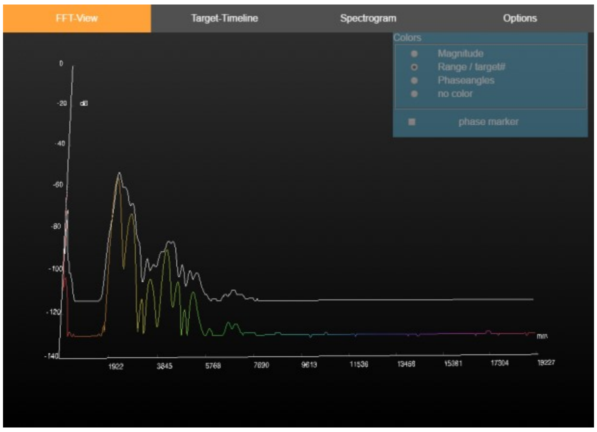


Figure 28: Range / target number coloring

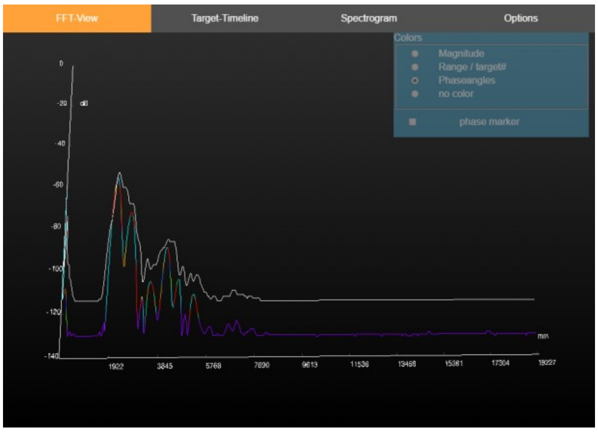


Figure 29: Phase coloring

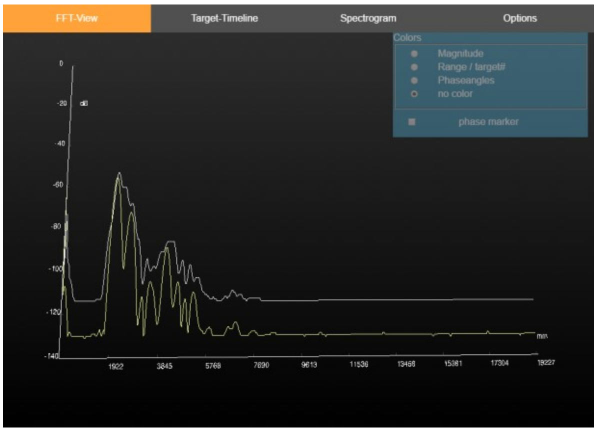


Figure 30: No color

3.4 Understanding the Configuration Info Field

The ‘config’ field shows the configuration that was send by the WebGUI to the sensor on connect. Those config words are further explained in the protocol description.

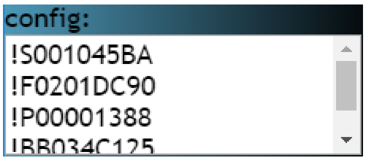


Figure 31: Configuration words

3.5 Camera Controls

Click on the

bar in the bottom left to show the camera controls. Here you can see and change the camera position and rotation of the view relative to the specified axis. The camera view can be changed using the mouse within the scene area. A left-click-drag pans the camera position. A right-click-drag changes the camera view angle. A middle-click-drag or moving the mouse wheel changes the zoom setting (z-coordinate) of the camera, also see Figure 32.

Camera control	Description
CamPosX	camera position on x-axis, move left (-) or right (+)
CamPosY	camera position on z-axis, move up (+) or down (-)
CamPosZ	camera position on z-axis, move to front(-) or back(+)
CamRotX	camera rotation on x-axis, rotate up(+) or down(-) relative to the x-axis
CamRotY	camera rotation on y-axis, rotate to left(+) or right(-) relative to the y-axis

Figure 32: Camera controls

3.6 Understanding the Error Info Field

The ‘Error’ info field is located in the top left of the WebGUI, see Figure 33.

Error flag	Description
CRC	UART transmission CRC checksum errors
RFE	radar front end configuration errors
PLL	PLL configuration errors
BB	baseband processing errors
PRC	errors in the signal processing

Figure 33: Error info field

Temporary errors are indicated in yellow. Temporary errors are errors that are raised during processing but will be auto corrected when the error disappears. The Detailed Errors Panel in Figure 34 shows the full error explanation. You can retrieve the full error information by clicking the refresh error info button.

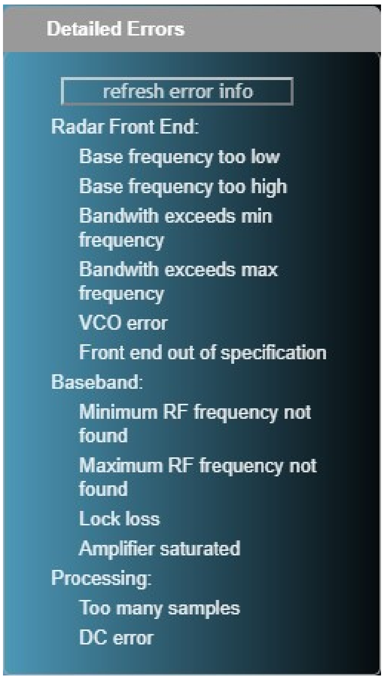


Figure 34: Detailed Error Panel

3.7 Understanding the Data View

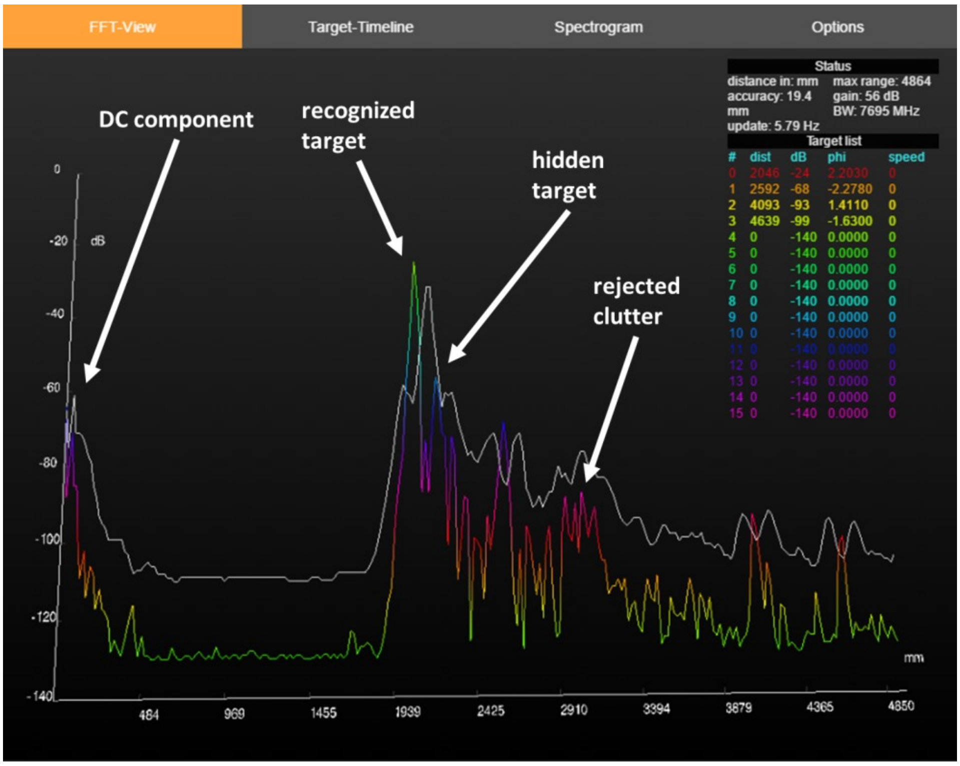


Figure 35: Data view with different elements in the display scene

Figure 35 shows a typical spectrum output of the sensor when placed on a tabletop and looking to the ceiling. Viewing a radar target spectrum for the first time might be confusing for the beginner. However, with some practice, it is easy to find targets and understand why some things work while others might not.

Targets:

The first ceiling echo is around 200 cm, which should be quite high versus the neighboring noise floor. Using a lens will make this target peak thinner and higher and more easily detectable by the CFAR operator. The next targets are around 260 cm, 410 cm, and 460 cm.

Due to the adaptive nature of the CFAR operator it might happen that if two targets are too near to each other or are very different in magnitude, one of them is rejected (hidden) by the CFAR operator, such a target may be hidden around 220 cm. Changing the target recognition settings might help in this situation.

DC component:

There is some DC component on the left side. If this DC offset is high, it might trigger a false target detection of the CFAR operator.

Clutter:

Around 290 cm to 330 cm there might be some clutter which is rejected by the CFAR operator.

4 Troubleshooting

Below you can find a number of questions often asked by our customers. If you still cannot find the answer to your specific question about SiRad Simple®, please write to support@siliconradar.com.

4.1 Drivers

4.1.1 Where can I get the driver to connect the SiRad Simple® ?

You need an FTDI cable (delivered with the sensor), also see Section 2.2.2. You can download the latest FTDI driver (VCP driver) for your FTDI cable from the FTDI Chip Website at https://www.ftdichip.com/Drivers/VCP.htm.

4.1.2 I installed the FTDI driver for the SiRad Simple® but it does not show up.

Please open the Device Manager in Windows and unfold the 'Ports (COM & LPT)' section. You should see a couple of ports there. Now unplug and plug your SiRad Simple® sensor. The sensor is installed properly if you can see another port show up, usually named 'USB Serial Port (COMx)' or similar. If this is not the case, please check your connection and if the device has power. Remove the FTDI driver and start over with the FTDI driver installation (see Section 2.2.2).

4.1.3 The FTDI driver for the SiRad Simple® does not work properly.

We recommend using a cable with FTDI chipset (delivered with the sensor) instead of cheaper alternatives since a lot of our customers found the cheaper alternatives to be very unstable, please also see Section 2.2.2.

4.2 WebGUI

4.2.1 I cannot store presets in the Preset tab.

Please make sure you are not working in the private mode of your browser and you have enabled cookies, since the presets are stored as cookies, also see Section 3.2.2.

4.2.2 I cannot see any output in the WebGUI window.

Please first set the SiRad Simple ® up for the USB connection. For that, check if the two dip switches on the SiRad Simple® are set to the off position and if the jumpers are set according to Section 2.1. If not, unplug the sensor, adjust the settings, and plug it in again. Also check the FTDI cable connection and if your device is powered properly. Then go to the 'System Configuration' tab and chose SER1, regardless whether you are using a WiFi or UART connection. The SER2 option is reserved for our SiRad Easy® Evaluation Kit. You can also toggle the 'Close' and 'Open' button of the Com2WebSocket tool without closing the WebGUI and see if that helps. Lastly, you can start over, close all WebGUI / Webbrowser and Com2WebSocket windows, disconnect the SiRad Simple® sensor and start over with connecting the sensor, connecting the Com2WebSocket tool and connecting the WebGUI.

4.2.3 The spectrum output jumps (partly).

First, if you are not using the WiFi connection, disable the WiFi module by disconnecting the power jumper J2. Sometimes it is necessary to turn the AGC-Mode off in the 'System Configuration' tab and manually choose one of the 4 gains using the gain slider. Further, you can try to manually set and increase the base-frequency in 100 MHz steps to see if that stabilizes the output.

4.2.4 How does the Auto Gain Control (AGC)-Mode work?

The AGC algorithm uses the first two ramps of each measurement to elaborate the highest gain setting without saturating the ADC or the baseband amplifier. In each of the two ramps the controller samples two gain stages while switching on an attenuation network during the first ramp. After that, the controller has 4 gain settings to choose from for the subsequent measurement.

4.2.5 Can I trigger the SiRad Simple® manually?

Yes. Please read Section 3.2.3.1 about the triggering options.

4.2.6 Can I use multiple SiRad Simple® sensors in parallel?

Yes. You can synchronize the sensors using the pre-trigger feature. We suggest either driving them in different frequency ranges so they do not interfere, or you trigger them manually to measure alternately. Please read Section 3.2.3.1 about the triggering options.

4.2.7 The LED goes off when I connect to the WebGUI.

This is because the WebGUI sends a different configuration to the sensor when it is connected. The LED will light again when the proper serial port (SER1 for the SiRad Simple®) is set in the 'System Configuration' tab and the LED mode is changed from off to 1st target rainbow.

4.2.8 The RF Parameters tab does not show the min / max frequencies properly.

You can try a manual min / max frequency scan by clicking the 'fscan' button three times.

4.2.9 How do I choose a base-frequency?

The base frequency should be at least 100 MHz above the minimum frequency and far away from the maximum frequency. For small bandwidths, you may choose the base frequency 500 MHz or more above the minimum frequency for an improved signal quality. **Please be aware, that in most countries the base frequency has to bet set between 122 GHz and 123 GHz for production purposes by law. Please check your local regulations.**

4.2.10 How do I set the maximum bandwidth in the RF Parameters tab?

Click the 'max BW' button to set the maximum possible bandwidth for the front end.

4.2.11 How do I choose a bandwidth?

The smaller the bandwidth, the greater will the range of the sensor become. However, with larger bandwidths the accuracy will decrease. **Please be aware, that in most countries the bandwidth is limited to 1 GHz between 122 GHz and 123 GHz for production purposes by law. Please check your local regulations.**

4.2.12 How can I choose the ramp time?

The ramp time can only be set indirectly by adjusting the ADC clock divider and the number of samples, please read Section 3.2.5.

4.2.13 What is the MTI-Mode?

The Moving Target Indicator mode. When activated, the sensor displays the difference between the current measurement and the average of the previous measurements (set by 'Average n' slider).

4.2.14 There are too many targets. The CFAR operator does not work.

You may experience that there are no targets detected by the CFAR operator although there are plenty of targets visible in the FFT output. If there are too many targets adjacent to each other in the field of view, the CFAR operator may treat those targets like noise floor and calculates an envelope around those targets. Increasing the number of guard cells may help in such a scenario.

4.2.15 How is the distance information calculated?

All calculations are done on the microcontroller on the SiRad Simple® sensor, so that the reported target distance is already in millimeters. The distance formula used is

$d = n_{Bin} * acc,$

where d is the distance to the target, n_{Bin} is the FFT bin of the target, and acc is the accuracy (see Section 3.3.2 for the formula).

4.2.16 The update rate of the sensor is very low. How can I improve it?

The update rate is dependent on the chosen parameters in the 'BB Processing' tab, in particular, on the ramp time, number of samples, number of ramps, and FFT size. Further, the amount of data that has to be transferred is important. You can select the transmitted frames in the 'System Configuration' tab. Using only the target list output, the sensor can reach about 50 Hz update rate.

4.3 Sensor Behavior, Range & Lens

4.3.1 How is the resolution defined?

We define the resolution as the ability to separate two targets in range. The resolution is only dependent on the selected bandwidth. With 1 GHz bandwidth the resolution is 15 cm, 6 GHz bandwidth equals 2.5 cm resolution. In practice, target recognition works from twice the resolution.

4.3.2 How is the accuracy defined?

We define accuracy as the maximum error of the measured distance to a single target. It is dependent on the number of samples, the bandwidth, the downsampling and the FFT size. If the FFT size is twice the number of samples, the accuracy is two times less than the resolution. We can reach about 1 mm accuracy, also see Section 3.3.2 for the formula.

4.3.3 Is there a minimum range / blind spot when using the SiRad Simple®?

The minimum range depends on the selected bandwidth. 1 GHz bandwidth works from about 30cm, 6 GHz bandwidth works from about 7cm. The blind spot is approximately as wide as once or twice the resolution.

4.3.4 Can something be detected within the minimum range / blind spot?

Going below the bandwidth-dictated minimum range leads to an increased DC-offset in the FFT output. It could be used to detect 'something is nearby' but this is very application-specific.

4.3.5 What is the maximum range of the SiRad Simple®?

The maximum range is dependent on the target. The SiRad Simple® Evaluation Kit reaches about 40 m with strong targets like buildings.

4.3.6 Can the range of the sensor be increased?

You can increase the range by assembling the lens delivered with the SiRad Simple® Evaluation Kit, however, the opening angle will decrease. Larger detection distances are possible using bigger lenses or well-designed patch array antennas.

4.3.7 How is the field of view of the SiRad Simple®?

The area covered by the radar over distance is dependent on the field of view of the sensor. Without a lens, the SiRad Simple® sensor has an opening angle of +/-30 degrees (-6dB). With the lens delivered with the sensor, this can be narrowed to about +/- 4 degrees.

4.3.8 How can I get directional information from the SiRad Simple®?

SiRad Simple® has a single radar transceiver chip, which is not capable of giving directional information directly. It is possible, however, to use more than one SiRad Simple® sensor to get rudimentary directional information.

4.4 Protocol & RAW data

4.4.1 Can I use the the SiRad Simple® with own or third-party software?

Yes. Please read the Protocol Description to get an idea how to control the sensor with your own software or third-party software like MATLAB.

4.4.2 Can I activate raw data only or FFT data only output?

Yes. Please read the Protocol Description about how to set up the sensor for raw data only or FFT data only output. You may choose between unwindowed raw data and windowed raw data as well as complex FFT data and magnitude / phase data output.

4.4.3 Can I use the sensor protocol with <any> device?

Yes. The protocol can be used to talk to the sensor from any device, it does not need to be a PC.

4.5 Schematics & Firmware

4.5.1 Where can I find the schematics for the SiRad Simple®?

You may apply for a non-disclosure agreement (NDA) with Silicon Radar to get the schematics.

4.5.2 Where can I get the source code for the SiRad Simple®?

The firmware on the SiRad Simple® is not freely available, however, we offer a free drivers library with a user friendly C programming API. We also provide the source code for the WebGUI and the Com2WebSocket tool.

5 Firmware Update

Please be careful when following this section. Silicon Radar is not responsible for any damages to your hardware or software that occurred during the flashing process.

5.1 Microcontroller

To update or change the microcontroller firmware, the board has to be set in bootloader mode, as shown in Figure 36. This is done by switching the DIP switch called MP to the ON position. Then connect the module to the PC via a USB to UART cable using the external header. Please read Section 2.1.1 about the external header connection. Connect cable TX to MR (microcontroller RX) and cable RX to MT (microcontroller TX). **Make sure to use a cable with 3.3V TTL levels!**

Find and install the flash tool stm32flash in the Firmware folder of the provided Install Package. Copy the desired firmware from the 'Firmware\SiRad_Simple' folder of the Install Package into the stm32flash folder. Edit the batch file stm32flash.bat and replace the COM port with the COM port of your USB to UART cable and the firmware name with the desired firmware, marked here:

stm32flash.exe -b 115200 -w <date>_SiRad_Simple_L8_<version>.bin -v -g 0x0 COMx

Run the batch file and the microcontroller gets programmed. After about 30 seconds the programming is finished. Switch the DIP switch MP back to the OFF position and do a power cycle to reset the module.

You can find the firmware <date>_SiRad_Simple_L8_<version>.bin in the provided Install Package in the folder 'Firmware\SiRad_Simple'.

5.2 WiFi Module

Connect the sensor using a USB to UART cable like shown in Figure 37 using the external header. Please read Section 2.1.1 about the external header connection. Switch the DIP switch called WP to the ON position. Then connect cable TX to WR (WiFi RX) and cable RX to WT (WiFi TX). **Make sure to use a cable with 3.3V TTL levels!** Now connect the power Jumper J2 to enable the supply voltage for the WiFi module.

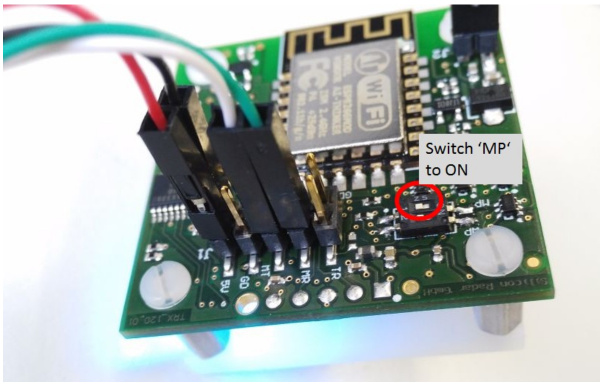


Figure 36: Firmware update configuration

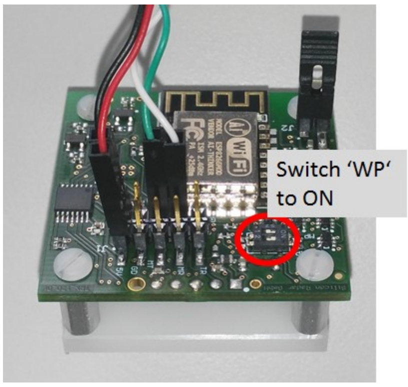


Figure 37: WiFi module update configuration

Find and install the esptool in the Firmware folder of the provided Install Package. Copy the firmware from the 'Firmware\WiFi_Module\websocket_mini' folder of the Install Package into the esptool folder. Edit the batch file esptool.bat and replace the COM port with the COM port of your USB to UART cable and the firmware name with the desired firmware, marked here:

esptool -bz 1M -cp COMx -cf websocket_mini.ino.generic.bin

Run the batch file and the WiFi module gets programmed, indicated by a flashing blue LED. After about 40 seconds programming is finished. Switch the DIP switch called WP back to the OFF position and connect a jumper between MT and WR and MR and WT.

6 Mechanical Drawing

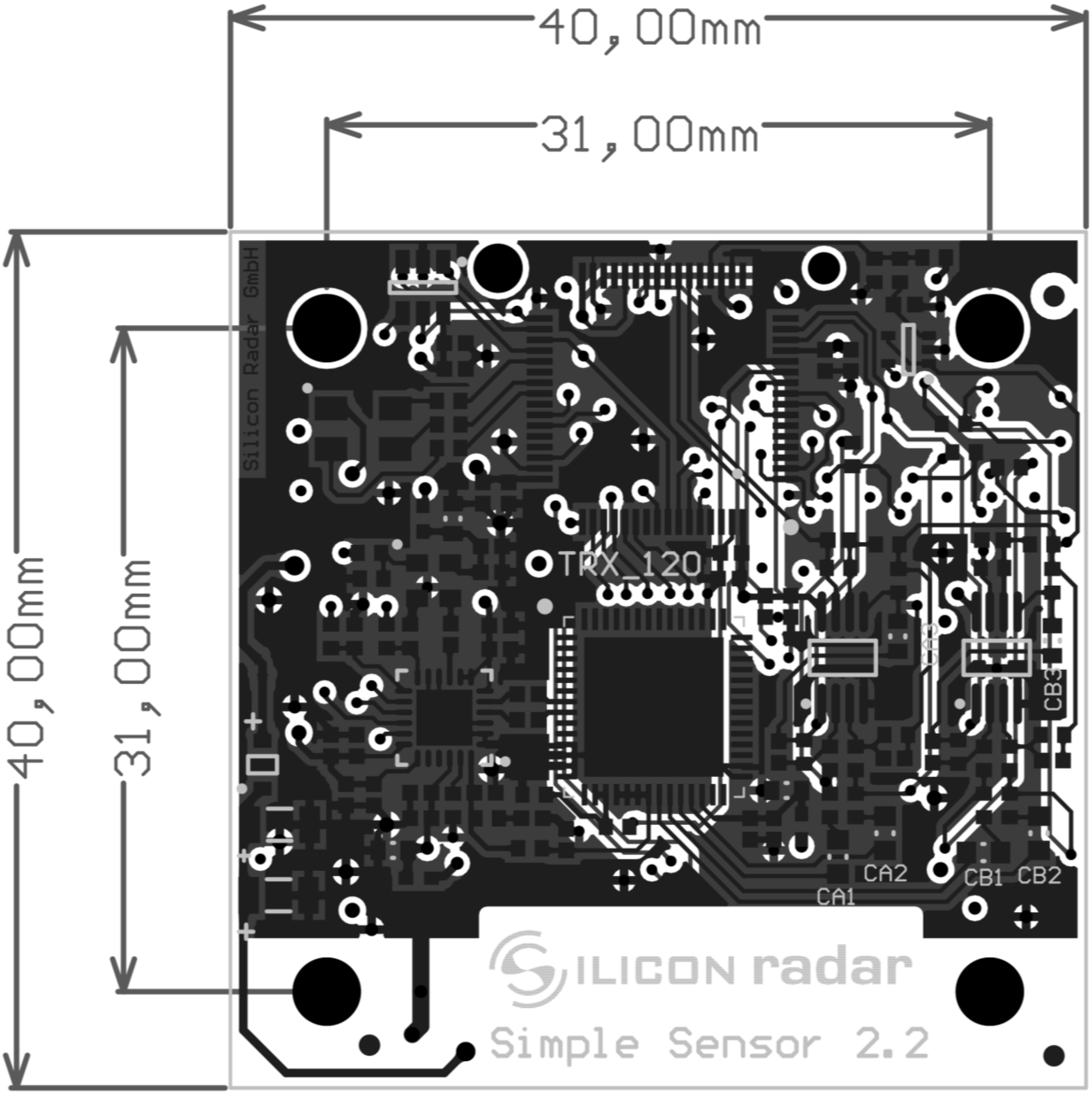


Figure 38: Mechanical drawing of the SiRad Simple® Evaluation Kit

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