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SiRad GUI v1.3
for *MIMO r2 and Easy r4*

SiRad MIMO r2 Firmware v1.1
SiRad Easy® r4 Firmware v1.5

User Guide

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Version Control

Version	Changed section	Description of change	Reason for change
1.0	all	Initial document	

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1 Start Settings

The evaluation kit provides a virtual COM port on the PC side. The GUI connects to this virtual COM port to read data from the kit and/or to send commands. When running the GUI, the **Start Settings** dialog is shown first, where initial serial port connection and parameter choices can be made. These settings are optional and can be also done later from the **Main Window** of the GUI.

For the *SiRad Easy® r4* kit, the serial connection is required for reading data and sending commands to the kit. For the *SiRad MIMO r2* kit, the serial connection is required for sending commands to the kit (the data transfer is done over a parallel Ethernet connection to the PC).
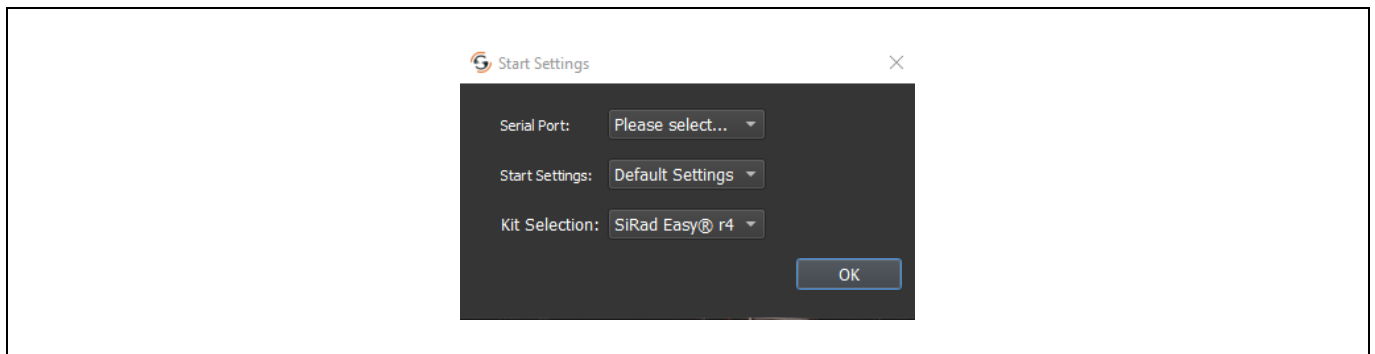
Figure 1   Start Settings Dialog

2 Main Window

The **Main Window** looks initially different for *SiRad Easy® r4* and *SiRad MIMO r2* kits. The menu bar and a toolbar are located at the top of the window. Below, the plot area is located. The plots are explained in Section 3.
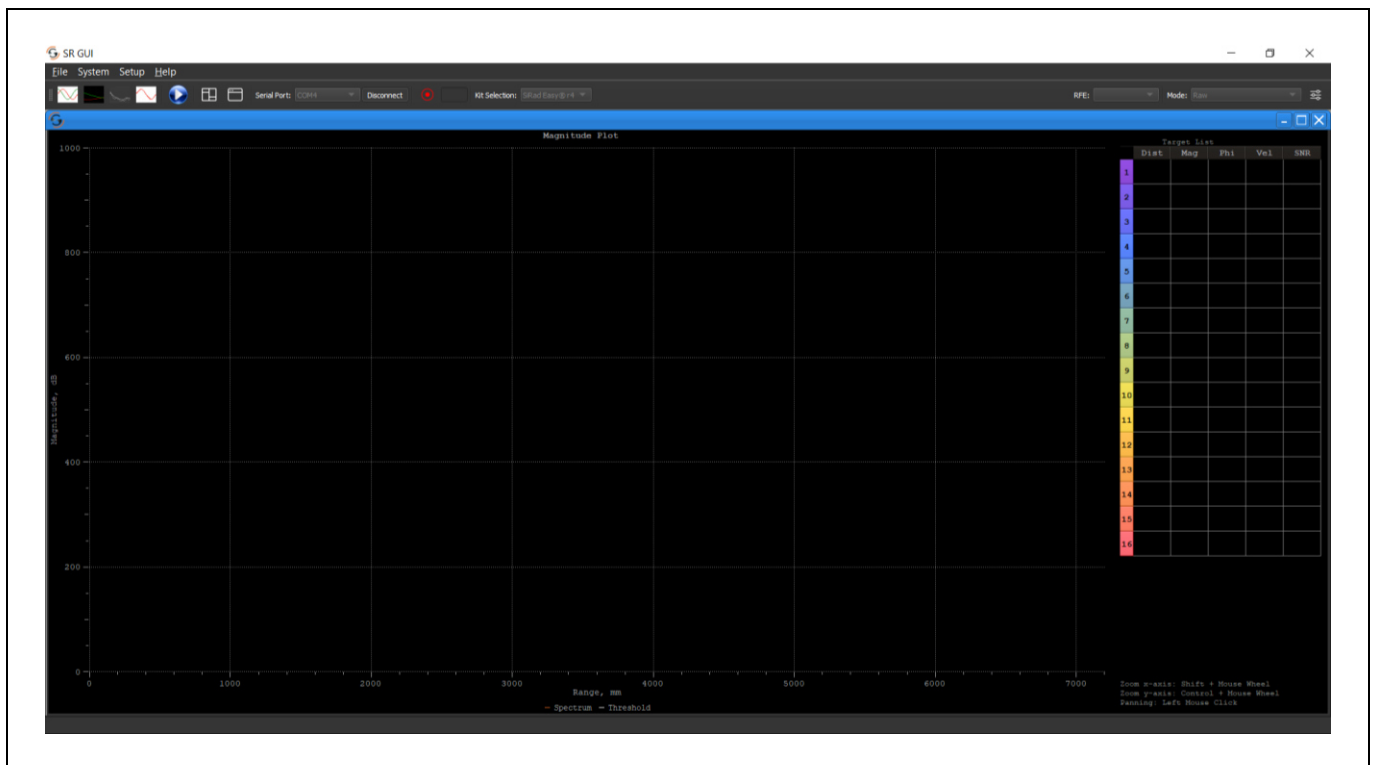
Figure 2   Main Window (Default Layout for *SiRad Easy® r4*)
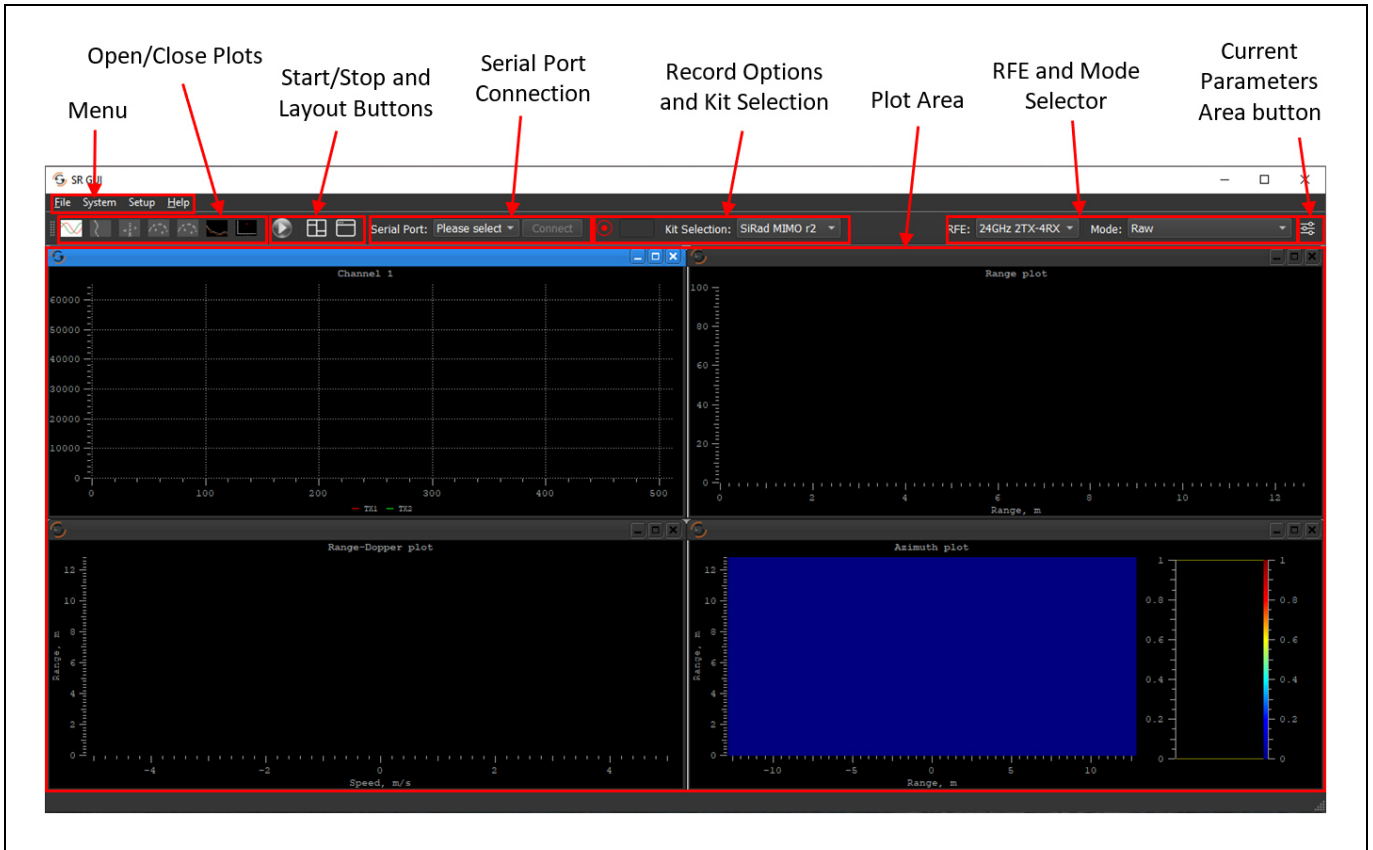
Figure 3   Main Window (Default Layout for *SiRad MIMO r2*)

By default, different layout appear upon startup of the GUI on **Main Window** for *SiRad MIMO r2* and *SiRad Easy® r4*, as shown in Figure 2 and Figure 3. Each plot has different purposes and detail explanation of plots are in Section 3.
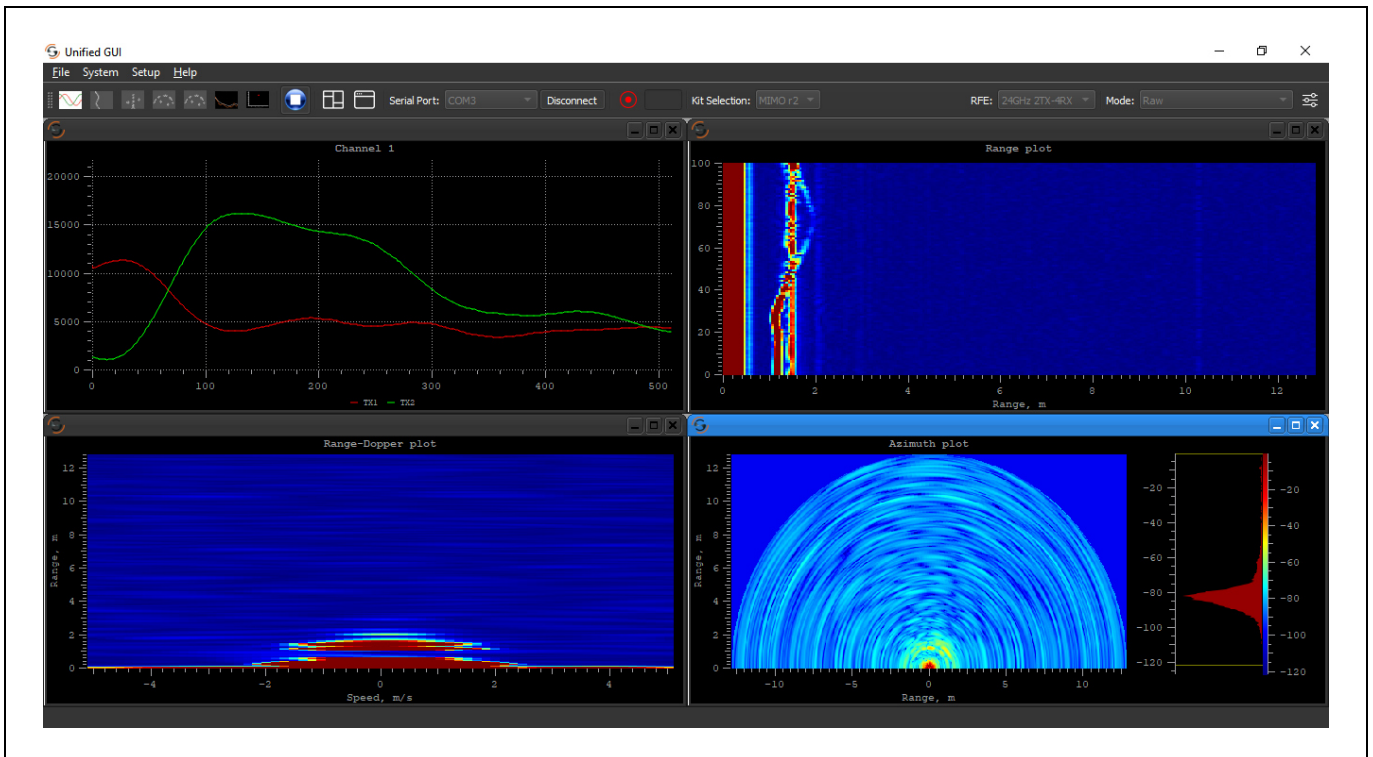
Figure 4   Main Window - Running System (*SiRad MIMO r2*)

2.1   Menu Bar

System contains the network setup options only for the *SiRad MIMO r2* kit. **Setup** will open a window containing radar and system parameters that can be set on both kits. For detailed information see Section 4.

2.2   Toolbar

2.2.1   Plot Icons

The plot icon area looks different with *SiRad Easy® r4* or *SiRad MIMO r2* connected because plots are kit specific and may not be available for both kits. The icons open and close the following plots for each kit.

SiRad MIMO r2
Raw Mode
For **raw mode** available plots are: Time, Range, Range-Doppler, Azimuth heat map, Elevation heat map and CFAR for multi-channel RFE boards. Multiple time plots can be opened for different channels and processing options. A target simulator is available for simulating the behavior of an artificial target (the rightmost icon). Detailed information about *SiRad MIMO r2* plots can be found in Section 3.3.
Preprocessing CFAR BF or CAPON Mode
When operating mode is switched to the Preprocessing CFAR BF or CAPON; another plot called **Preprocessing Range – Velocity/Azimuth** will be activated and it is the only plot option for this mode.

SiRad Easy® r4
For the *SiRad Easy® r4* kit available plots are ADC data, FFT, Magnitude-Distance and Phase plots. The data will be shown when the corresponding output data frame is activated in the **Setup** window. Detailed information about the *SiRad Easy® r4* plots can be found in Section 3.2 and about the output options available in the **Setup** window in Section 4.2.

2.2.2   Start/Stop Button

The Start/Stop Button operates differently for *SiRad Easy® r4* and *SiRad MIMO r2.* For both kits to operate properly, the serial com port connection must be established, otherwise the start/stop button will remain disabled.

For *SiRad MIMO r2,* the data transmission starts when the start button is pressed and stops when the stop button is pressed. The configurations that are set on the Setup Window will be sent just before the start of measurement cycle and if any of the values cannot be set on the kit properly, an error message will pop up. With *SiRad MIMO r2* kit, changing a setting during the runtime is not possible. To set new values, the system should be stopped first, and after the setup it can be started again.

For *SiRad Easy® r4,* data transmission starts when the kit is connected, however, GUI will start plotting when start button is pressed. Start/stop button can be used anytime. On contrary to *SiRad MIMO r2* any setting on the *SiRad Easy® r4* kit can be changed during the runtime.

2.2.3   Layout Options

The **Tile Windows** button (left) re-aligns the currently open windows, and the **Reset Layout** button (right) restores the plot area to its default setting.

2.2.4   Serial Port Connection

The serial port connection can be established in the **Start Settings** dialog as well as on the toolbar. There is one button for connecting and disconnecting the kit. A virtual COM port can be selected from the drop-down menu and the **Connect** button establishes the connection. The **Connect** button remains disabled until a COM port was selected in the drop-down menu. If the serial port connection was handled in the **Start Settings** window, no further action is needed to establish the connection in the **Main Window**.

Figure 5   Serial Port Connection: Not Connected (Left), Connected (Right)

2.2.5   Record Options

The record option allows to keep a log of the incoming frames. The log file will be saved under the *Logs* folder with the date information. There is one button to start and stop the recording. A duration of time in seconds can be entered to the text field next to the button. The recording will stop automatically after the given time. If no time was set, the recording can be stopped by pressing the **Stop Record** button.

Figure 6   Start Record Button and Duration (Left), Stop Record Button (Right)

2.2.6   RFE and Mode Selection (*SiRad MIMO r2 Only*)

For the *SiRad MIMO r2* kit, the **RFE Selector** is for choosing the radar front end. This selection is handled automatically when a serial port connection is established with an actual kit. Thus, this option is mainly useful for **Target Simulator** plot for *SiRad MIMO r2* kit. The behavior of the **Target Simulator** is changed for different types of RFEs with different antenna layouts or different number of transmit antennas. **RFE Selector** contains all the applicable RFEs for *SiRad MIMO r2* kit. Detailed information about **Target Simulator** plot can be found in Section 3.4.

The **Mode Selector** is for choosing the operating mode of the kit. *Raw* means all processing steps are calculated by the GUI. *Preprocessing CFAR BF* and *Preprocessing CFAR CAPON* means processing is done on the kit with the algorithms *Beamforming* or *Capon* respectively, and the *SiRad MIMO r2* kit transfers the Target List. When this mode is selected, Preprocessing Range – Velocity/Azimuth plot opens automatically. Detailed information about Preprocessing Range – Velocity/Azimuth plot can be found in Section 3.3.6.

2.3   Current Status of Parameters

The **Parameter Dialog** opens and closes on the right side of the **Main Window** when pressing the **Parameter Icon**. This dialog shows parameters, system information, errors and commands sent to the connected evaluation kit. It is different from the **Setup Window,** by taking the values directly from the kit. **System Info** gives information about the hardware and firmware of the kit. The **Errors** section shows the errors that are present on the kit. Title color of this tab will automatically turn red to indicate the error. When there is no error, the color of the title is white. The **Commands** section shows the commands that have been sent to the kit.

3 Data Plots

3.1 Zooming and Panning Options

Each of the plot windows can be dragged, resized, or closed as needed. More windows can be opened via the toolbar and right clicking on plots provides further options for the plot, such as selection of channel or more visualization options.

For heat map type of plots mouse wheel can be used for zooming options. For other plots, left mouse click is for panning and for zooming on x and y axis, shift key + mouse wheel and control key + mouse wheel is used respectively.

3.2 SiRad Easy® r4 Plots

For each plot of SiRad Easy® r4 certain data frames needed to be enabled, see Table 1. These frames can be enabled in the Setup Window Output Options tab, see Section 4.2.

Table 1   *SiRad Easy® r4* Plots and Connected Data Frames

SiRad Easy® r4 Plots	Data Frame to be enabled
Magnitude Plot	Magnitude, CFAR and Target Information Data Frame
Time Domain Plot	ADC Data Frame
FFT Plot	Complex FFT Data Frame
Phase Plot	Phase Data Frame

3.2.1 Time Domain Plot

IF time domain signals taken from the ADC are displayed in this plot.

Figure 7   Time Domain Plot (Raw ADC Data)
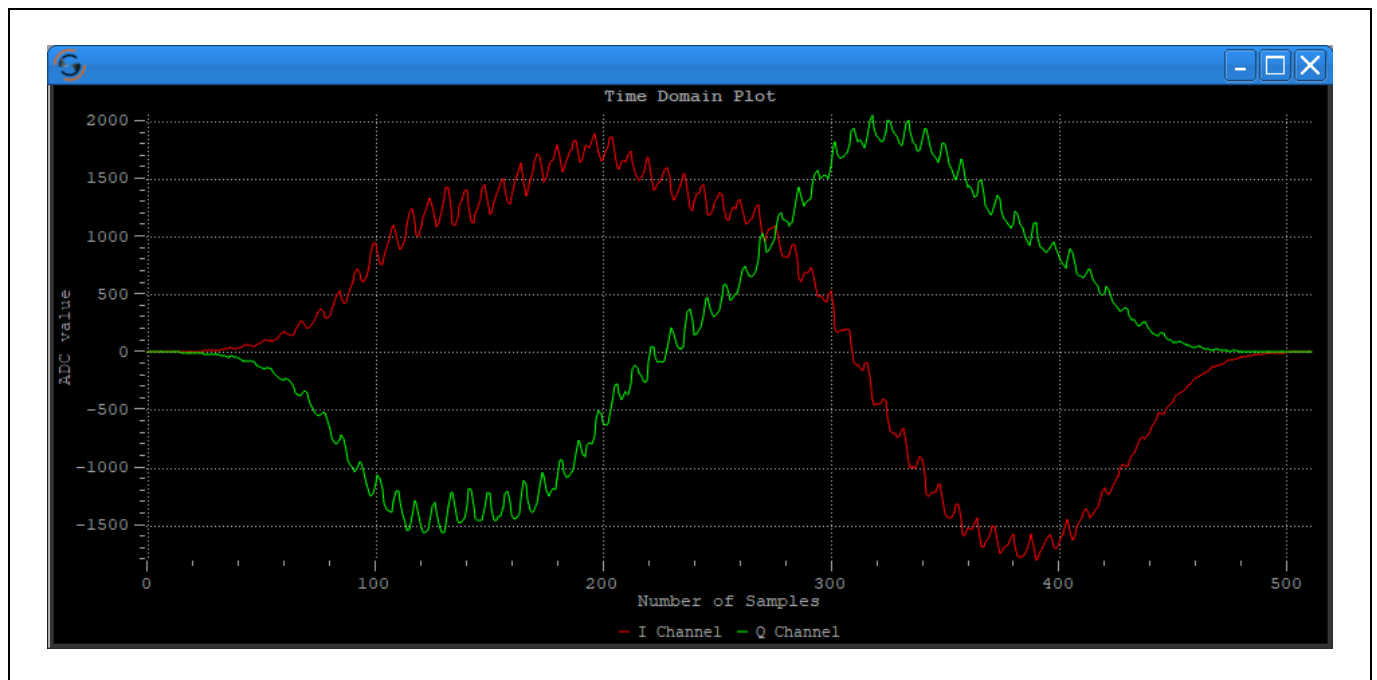
3.2.2 FFT Plot

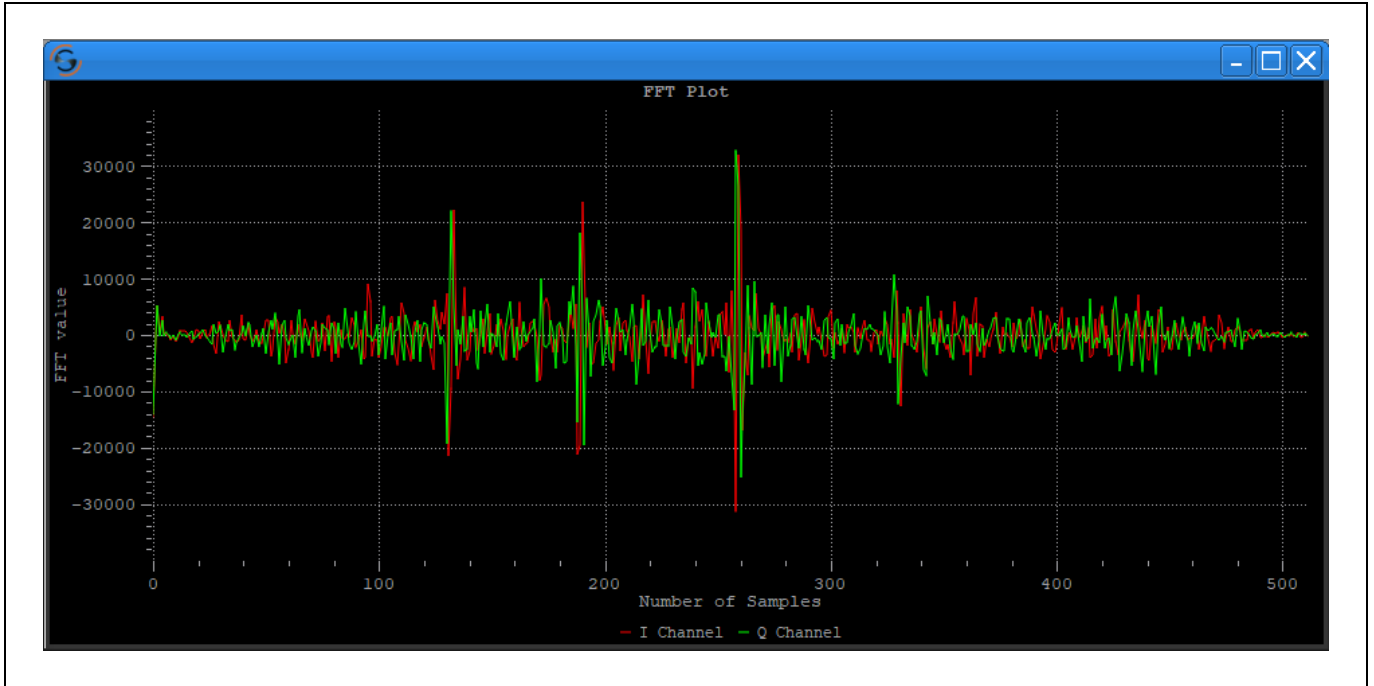**FFT plot** is obtained after performing FFT on IF time domain signals.

Figure 8   FFT Plot

3.2.3 Phase Plot

Phase frame contains the argument or phase of the FFT. The phase value is multiplied by 10000 in the evaluation kit firmware, therefore GUI plots phase values by dividing the same scaling factor to have +/- pi.
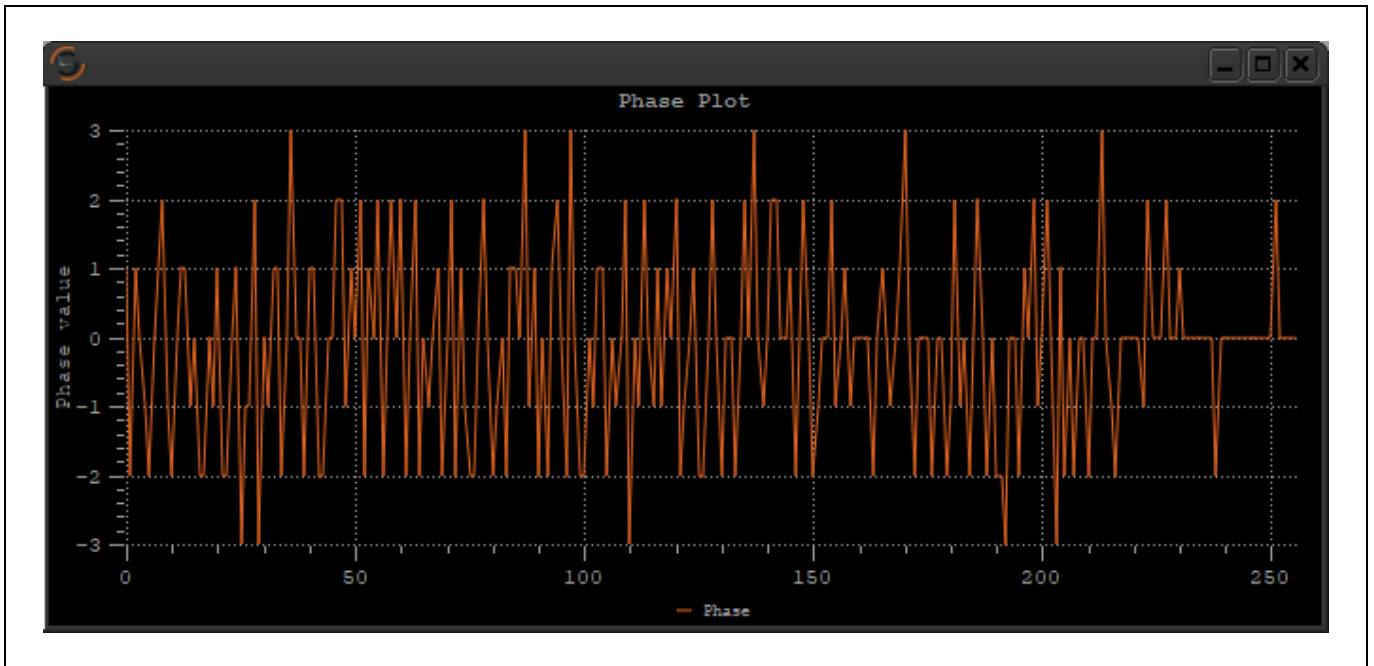
Figure 9   Phase Plot

3.2.4   Magnitude Plot

The **Magnitude plot** shows the distance in mm on the x-axis and the y-axis shows the magnitude in dB at this distance. The **Target List** on the right side contains information of distance, magnitude, phase, velocity, and signal to noise ratio of detected targets ordered by distance. The phase markers shown in the **Magnitude** plot are colored according to the target colors in the **Target List**. With every measurement, having the target information data frame enabled, the CFAR operator is calculated, and the **Target List** is updated. Where the magnitude of a distance bin crossed the CFAR threshold, the local maxima are searched, and targets generated.

Figure 10   Magnitude Plot with Phase Markers and Waterfall Plot

Figure 11   Magnitude Plot with Waterfall Plot in Plain Version

The **Waterfall** plot and **Phase Markers** can be activated with a right click on the **Magnitude** plot. The waterfall visualization can be changed between the original and the plain with a right click on **Wat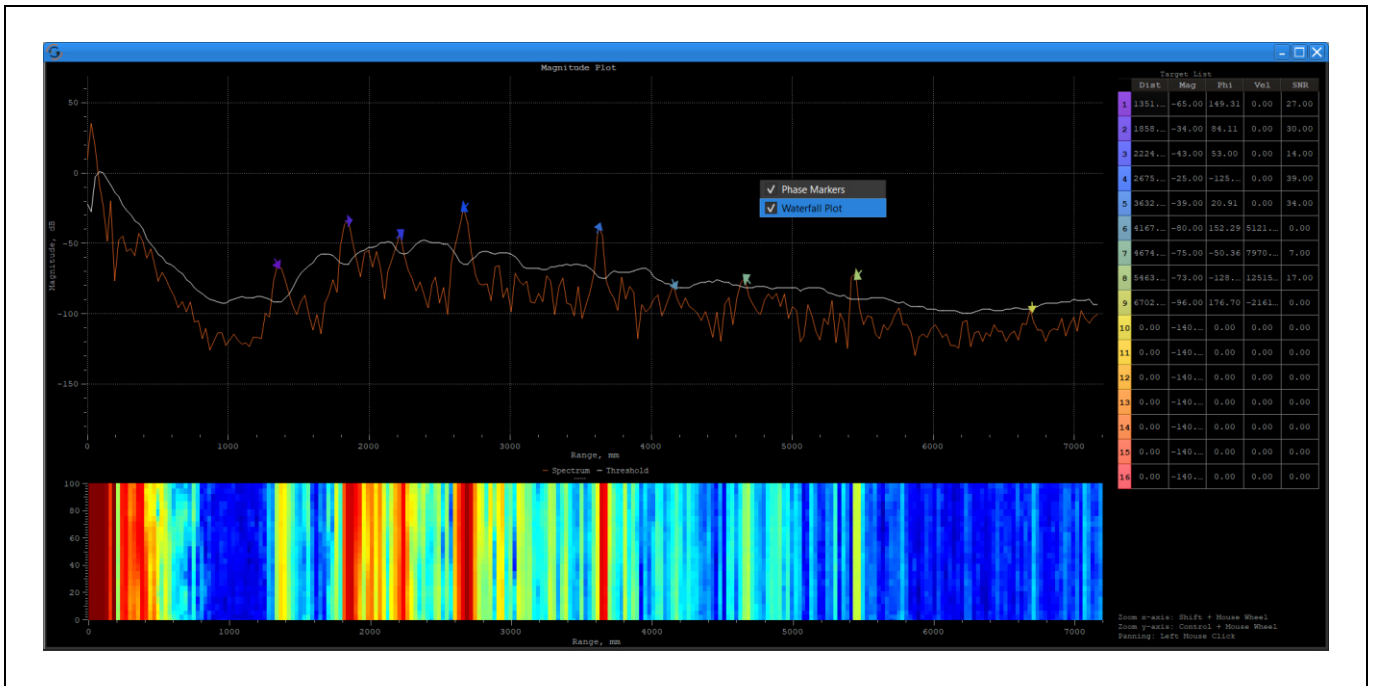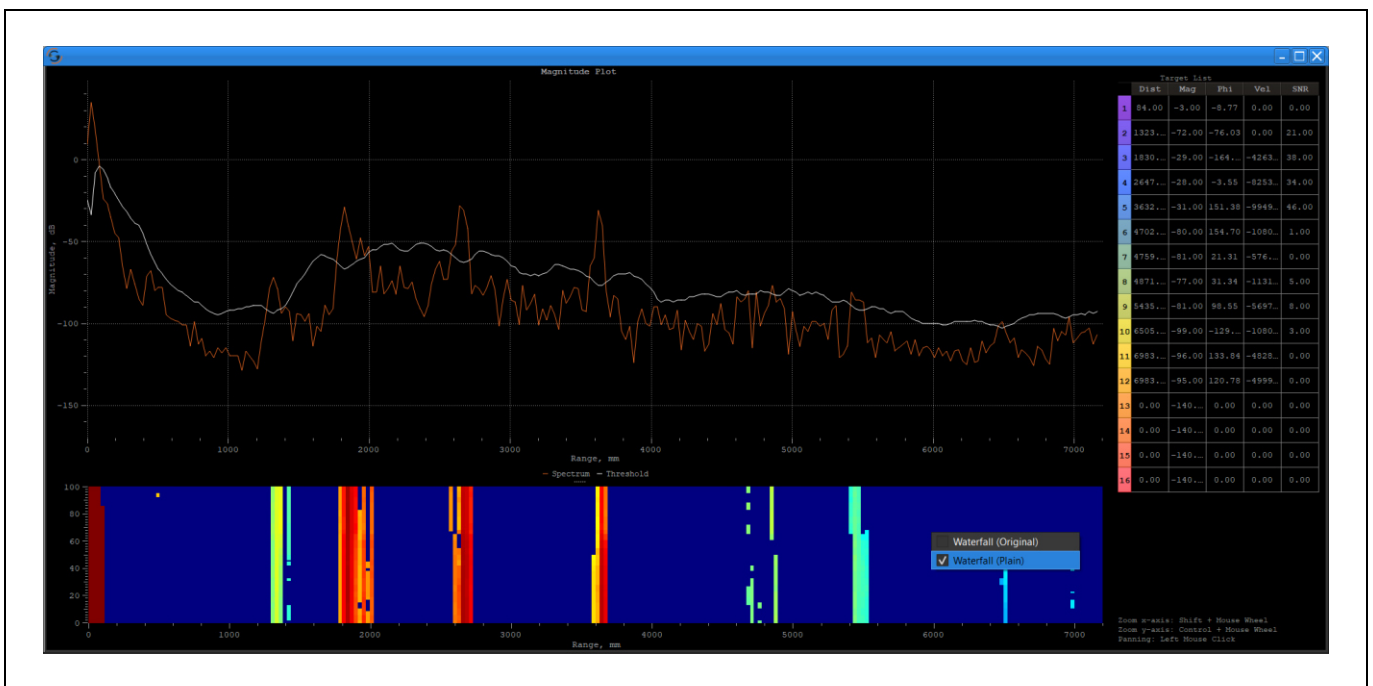erfall** plot. Original version is a visualization of whole spectrum and plain version only emphasizes the spectrum that is above the CFAR threshold.

In the **Waterfall** plot the history of data can be seen, with the x-axis being the timeline. Older values move upwards, while the y-axis behaves like in a 2D plot. The magnitude is represented by the waterfall heat map. Higher magnitude values represented in warm colors, on the other hand lower values represented in cold colors.

The **Phase 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.

3.3   SiRad MIMO r2 Plots

3.3.1   Time Domain Plot – ADC Raw Data (IF Data)

The **Time Domain Plot** shows the AD sampled raw time domain signals of the radar front end's receive (RX) and transmit (TX) channels. The plot shows 14-bit AD values on the y-axis over sample numbers displayed on the x-axis. A right click on the plot shows the channel selection, as well as the choice to apply an FFT on that specific channel's data to view a range profile. Clicking the **Time Domain Plot** icon in the tool bar allows multiple plots to be opened and is therefore useful for viewing multiple channels at once.
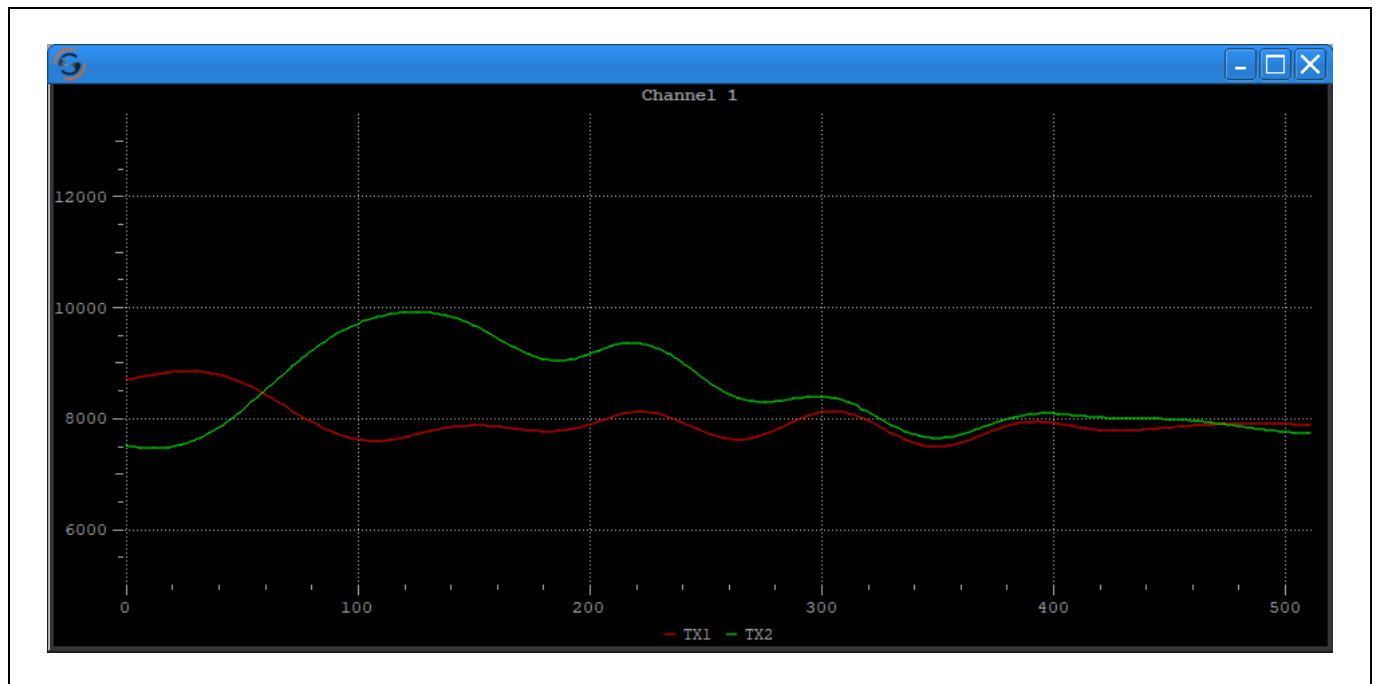
Figure 12   Time Domain Plot – ADC Raw Data (IF Data)
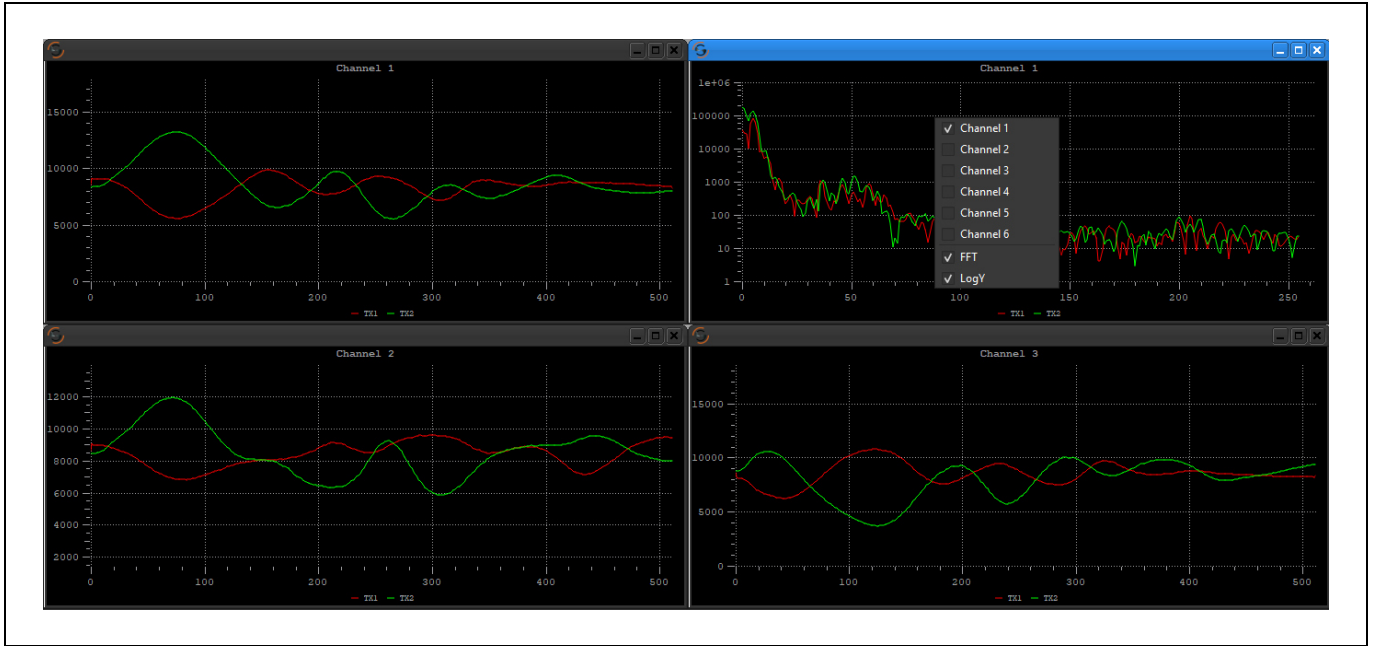
Figure 13   Time Domain Plot – ADC Raw Data (IF Data) with Different View Options Applied

The receive channels are mapped to the Time Domain plots as follows:
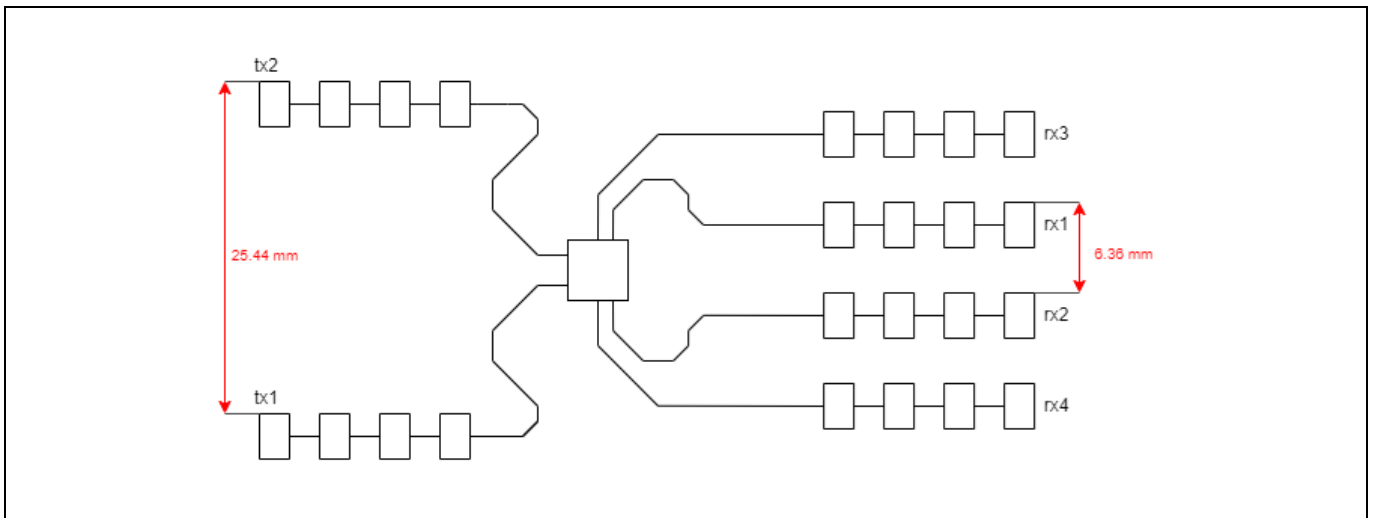
Figure 14   24 GHz RFE Antenna Layout (Not to Scale)

Table 2   *SiRad MIMO r2* Channels (24 GHz RFE)

Plot	Receiver	I / Q
Channel 1	Rx 3	I
Channel 2	Rx 2	I
Channel 3	Rx 3	Q
Channel 4	Rx 1	I
Channel 5	Rx 4	I
Channel 6	Rx 1	Q

3.3.2   Range Plot

The **Range plot** displays the aggregated range data across all virtual channels. The x-axis displays range in meters and the y-axis displays measurement cycle number. As such, it gives a visual reference of the range history as objects in the scene move towards or away from the radar.
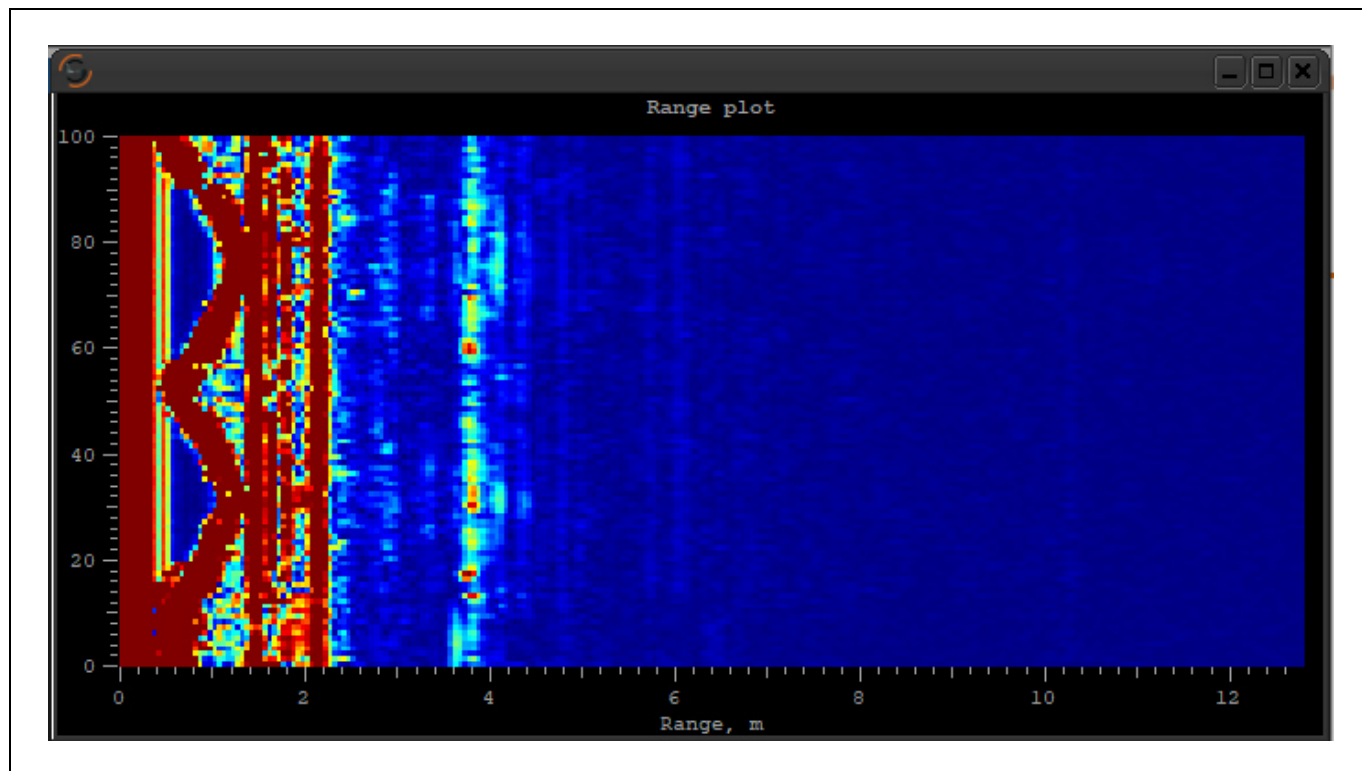
Figure 15   Range Plot

3.3.3   Range – Doppler Plot

The **Range-Doppler plot** visualizes the speed (as derived from the Doppler frequency) of the scene at every range bin in the range profile, with speed in meters per second on the x-axis and range in meters on the y-axis. The x-axis is centered on 0 m/s, meaning that static targets in the scene will appear along this line. Targets moving away from the radar will appear to move up (further in range) and to the left (with a negative speed) of the plot, whereas targets moving towards the radar will appear to move down (closer in range) and to the right (with a positive speed) of the plot.
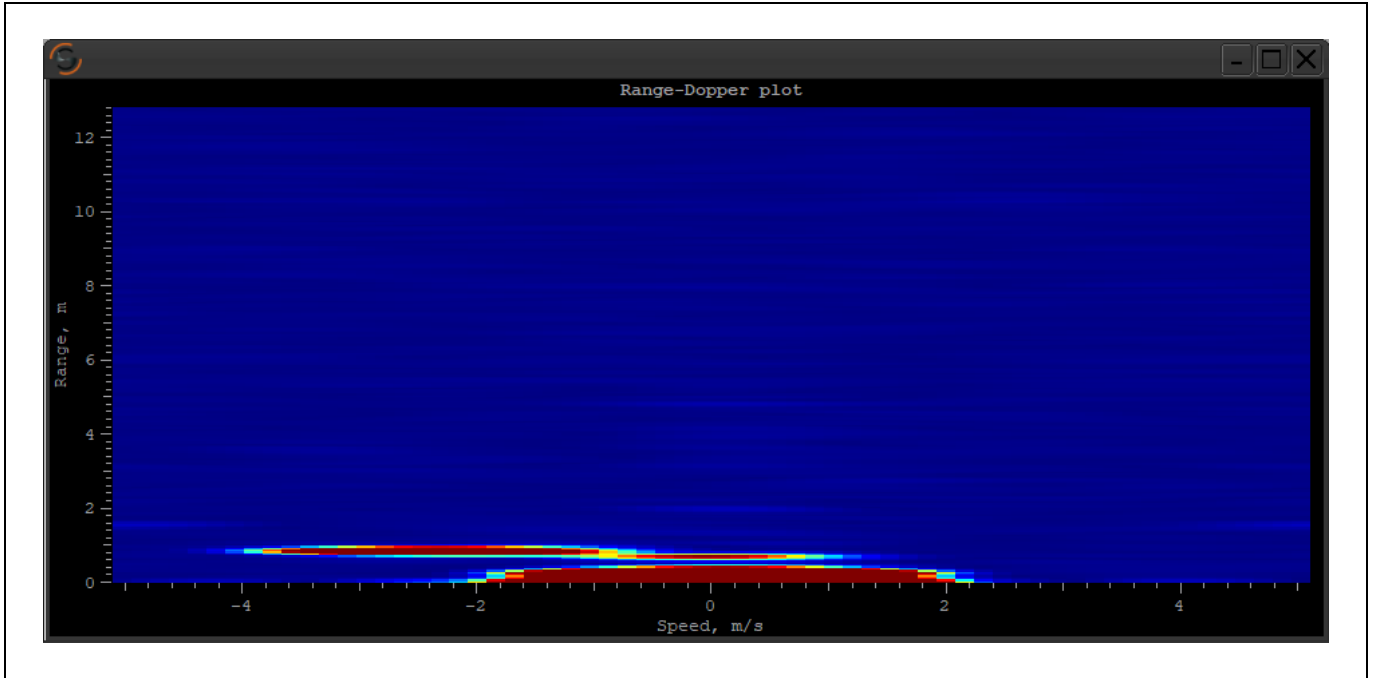
Figure 16   Range - Doppler Plot

3.3.4 Azimuth Plot

Azimuth plot visualize the scene radially. With respect to the radars position (bottom center of the plot), targets are displayed at angles relative to this point and their range being the distance from this point. As such, targets of an equal range are located on the same semicircular arc radiating from the radar position, and their azimuth being their location along this arc. The algorithm used to calculate the azimuth can be changed in the **Setup** window, the options are either *Classical Beamforming* or sub-space-based *CAPON*. Within the plot window is a slider to adjust the color range of the heat map to change the saturation of the plot.
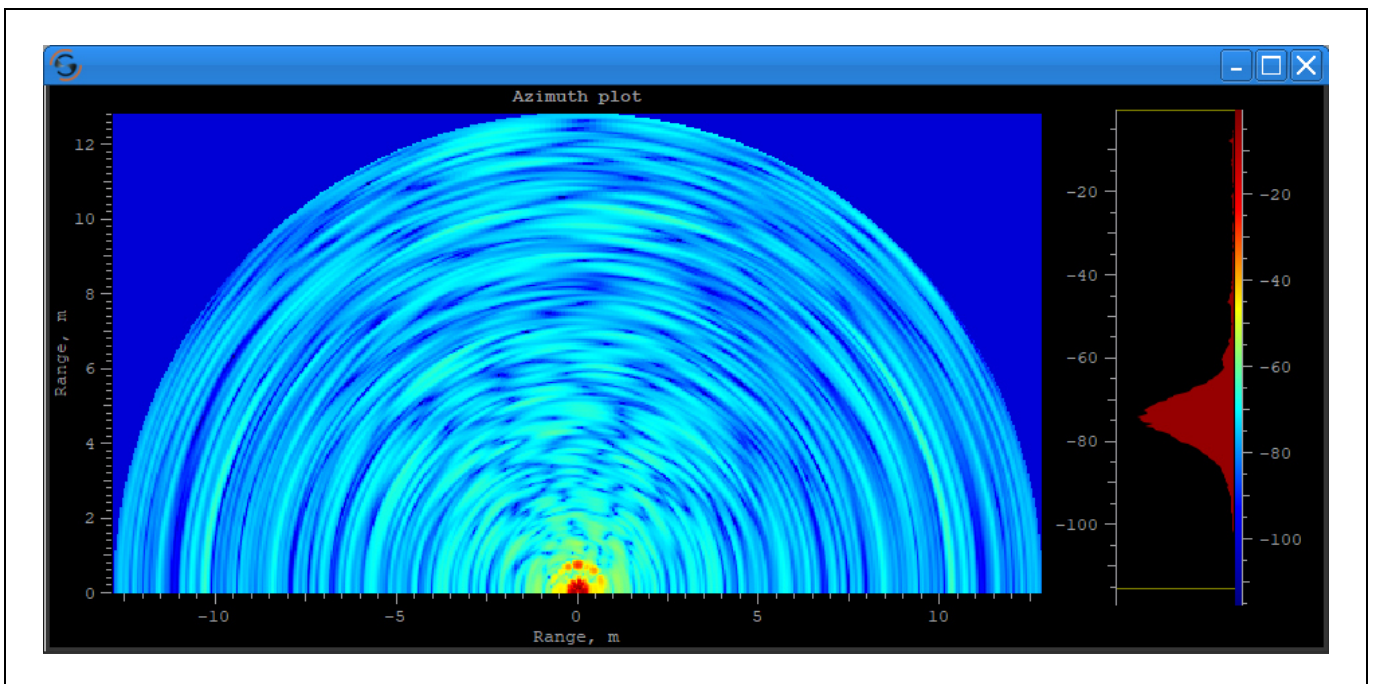
Figure 17   Azimuth Plot
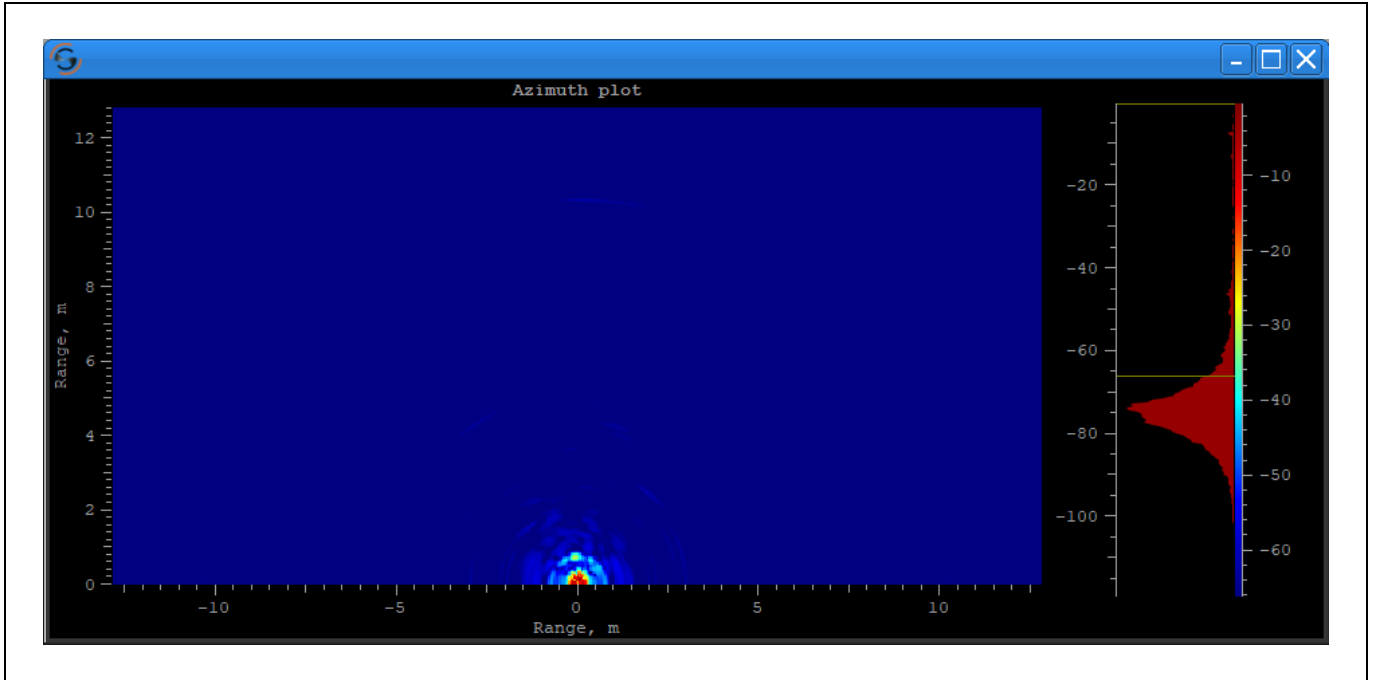
Figure 18   Azimuth Plot with Adjusted Heat Map

3.3.5   CFAR Plot

In the **CFAR plot**, the x-axis shows the distance in meters and y-axis shows the magnitude in dB at this distance. The magnitude and CFAR spectrum calculations are done in the GUI, only for *SiRad MIMO r2* kit when processing mode raw is selected. The CFAR parameters can be found in the **Setup window**, under **Target Recognition** tab (see Section 4).
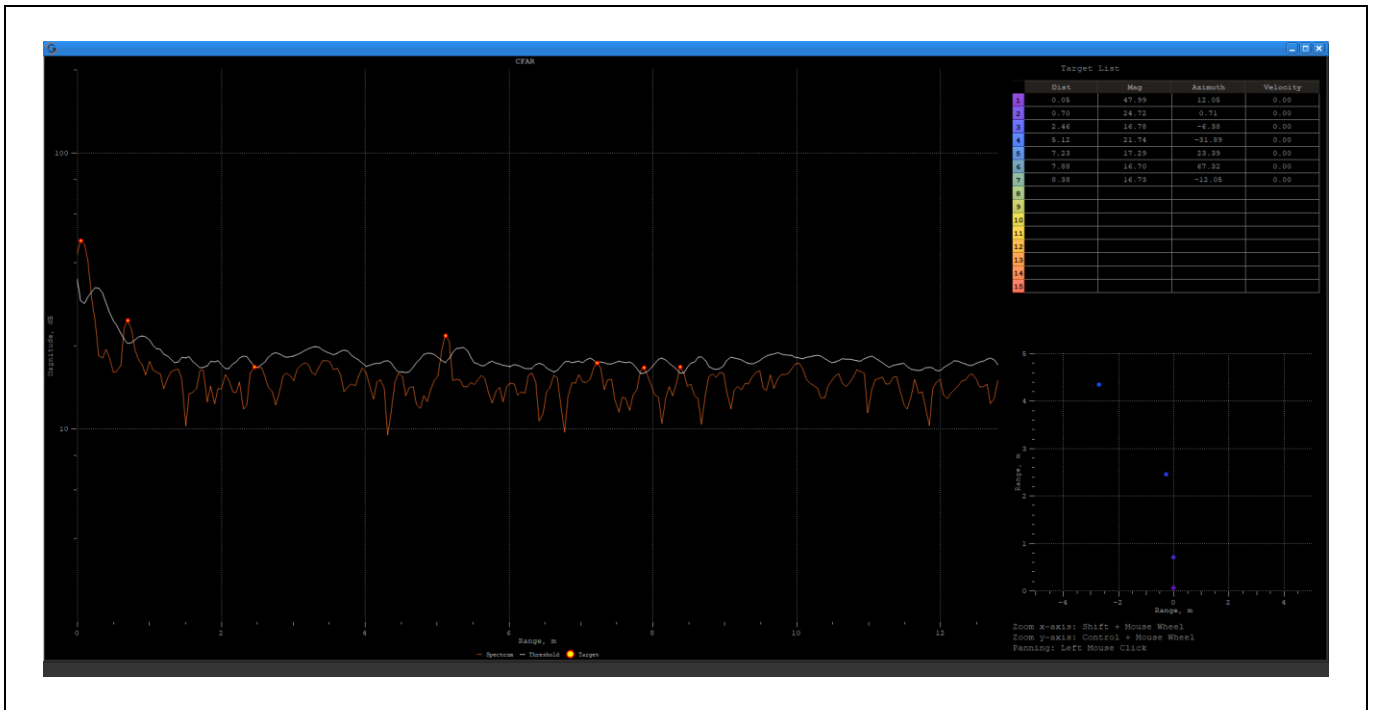
Figure 19   CFAR Plot

On the right side, under the target list, there is a **Range-Azimuth plot**. The points on this plot are colored respectively with the Target List. This plot uses results from the calculations of Azimuth heat map to see correct results in this range-azimuth graph, the azimuth heat map plot should be left open.

The **waterfall** plot shown in Figure 20 which can be activated with a right click on the **CFAR** plot, is a time dependent display of the distance data. When right clicked on, the waterfall gives two options of 'Original' (Figure 20) and 'Plain' (Figure 21). The plain version emphasizes the targets that are above the threshold line.

Figure 20   CFAR and Waterfall Plot

Figure 21   CFAR and Waterfall Plot (Plain)

3.3.6   Preprocessing Range – Velocity/Azimuth Plot

The **Range/Azimuth plot** (similar to the Azimuth plot explained in Section 3.3.4) visualize the scene radially. With respect to the radar's position (bottom center of the plot), targets are displayed at angles relative to this point and their range being the distance from this point. In the **Range/Velocity plot**, targets moving away from the radar will appear to move up (further in range) and to the left (with a negative speed), whereas targets which move towards the radar will appear to move down (closer in range) and to the right (with a positive speed). The targets are colored respectively with the target list on the right, in both plots.
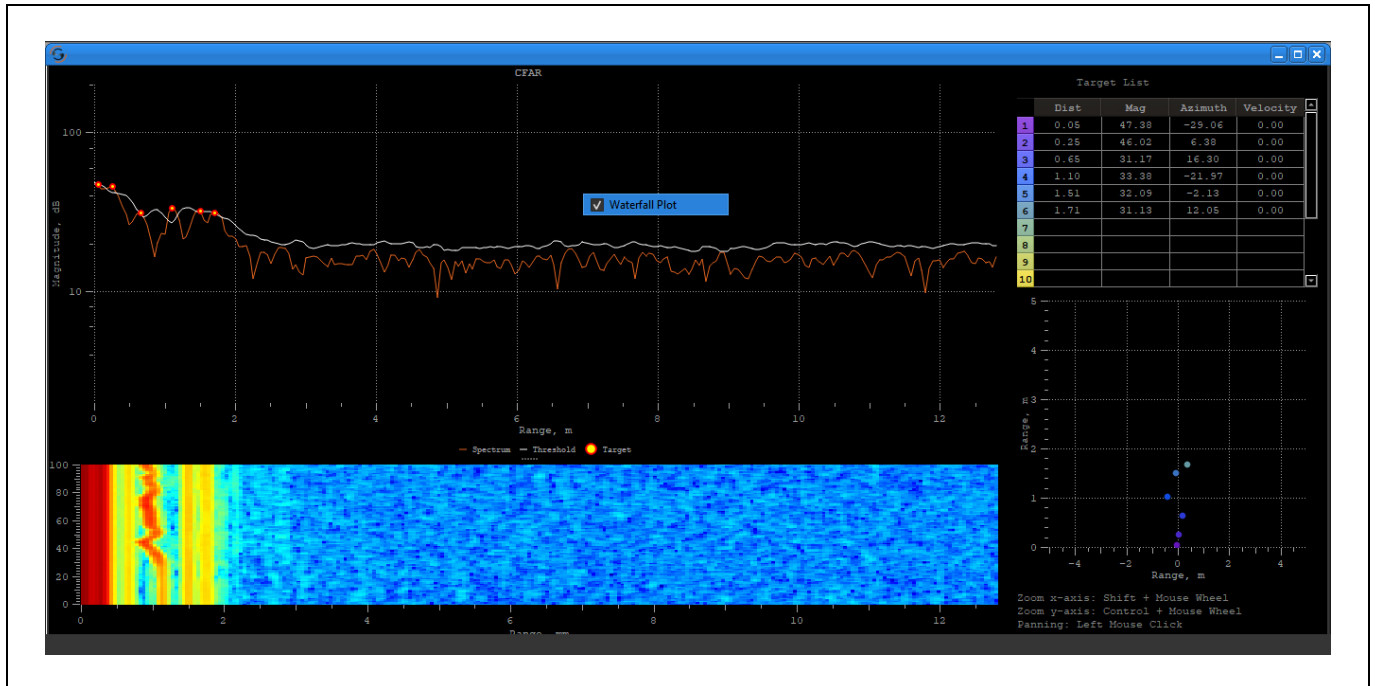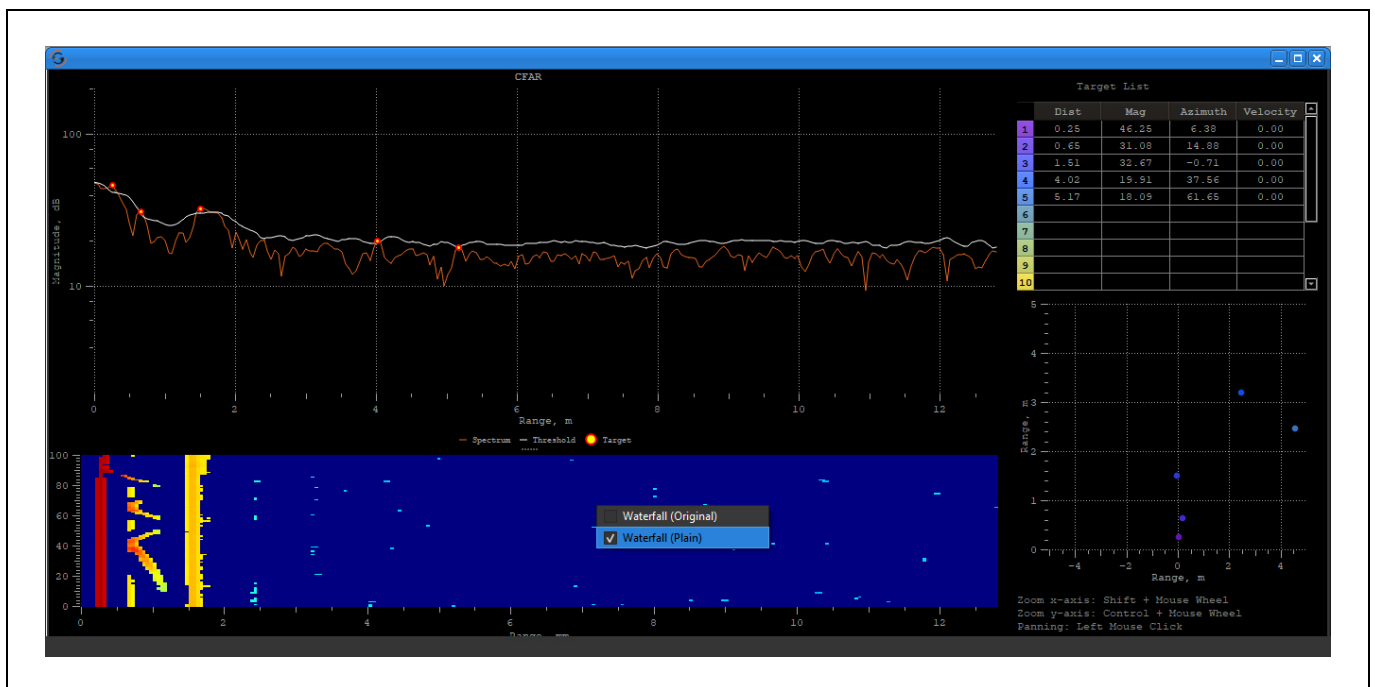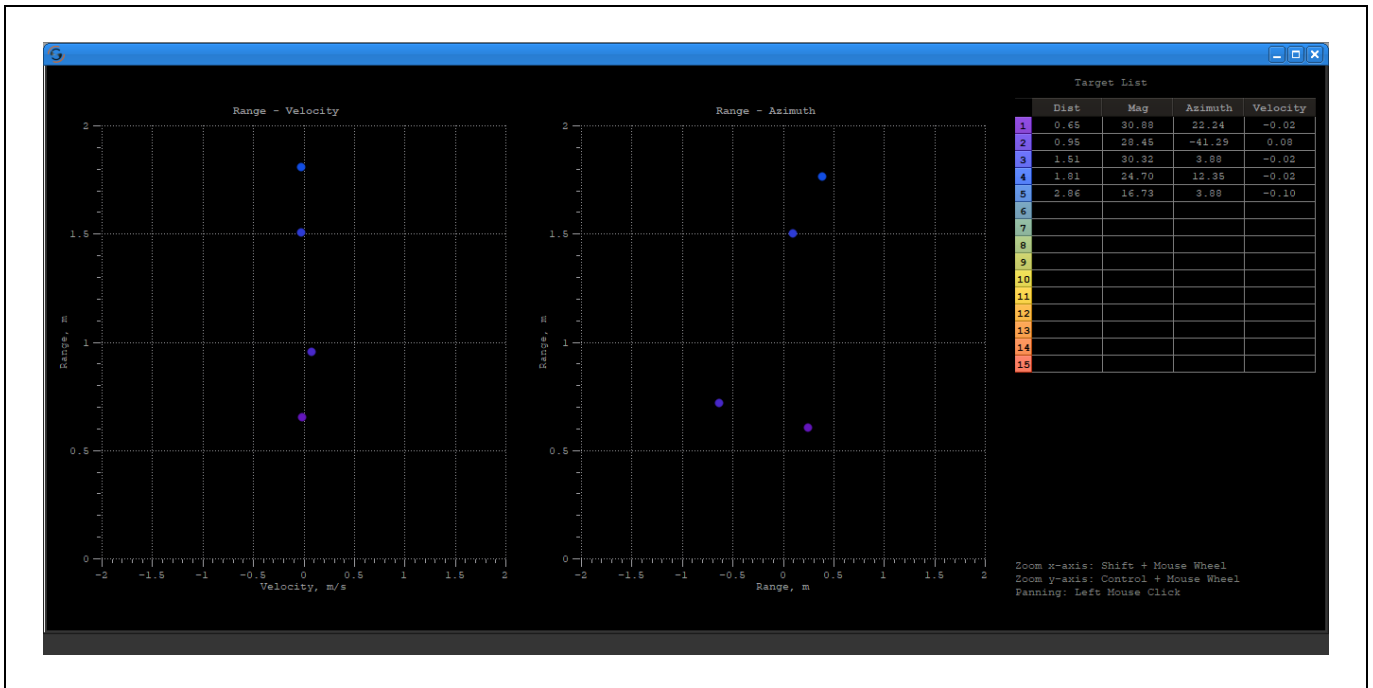

Figure 22   Preprocessing Range/Velocity (left) and Range/Azimuth (right) Plot

3.4   Target Simulator

Target Simulator only simulates the *SiRad MIMO r2* kit behavior.

The behavior of the system can be simulated by moving the red target dot with left mouse click in the **Target Simulator** plot. One ramp is simulated with the selected number of samples. Time domain plot and Azimuth plot is available with the Target Simulator. Detailed explanations of these plots can be found under Section 3.3.

Target Simulator will use the antenna geometry of selected RFE in the **RFE Selector** (and the antenna configuration selected from the **RFE Selector**). The algorithm for the Azimuth calculation can be changed in the **Setup window**.

The 2-dimensional **Target Simulator** will be activated when the 60 GHz RFE is selected from **RFE Selector** and besides the Time domain and Azimuth plot, Elevation plot is also available for this RFE. Unlike the 1-dimensional simulator, sliders are used for determining the target angles in 2 dimensions which are azimuth and elevation, and the target distance. For this target simulator, beamforming algorithm is used in processing.

Note that, 2-dimensional **Target Simulator** is in beta version, it may not work properly.

Figure 23   Target Simulator
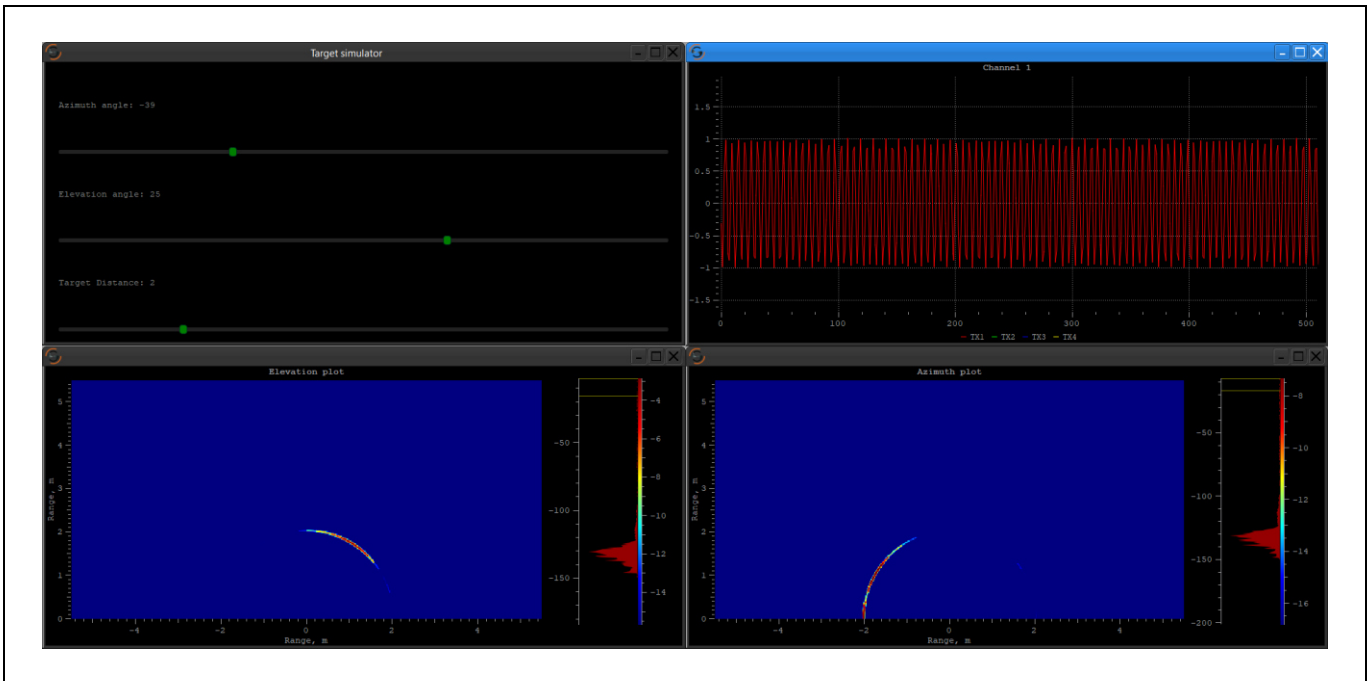
Figure 24   Target Simulator (Different View)

4 Setup Window

The Setup Window contains different tabs for different group of parameters that can be set on the kit.

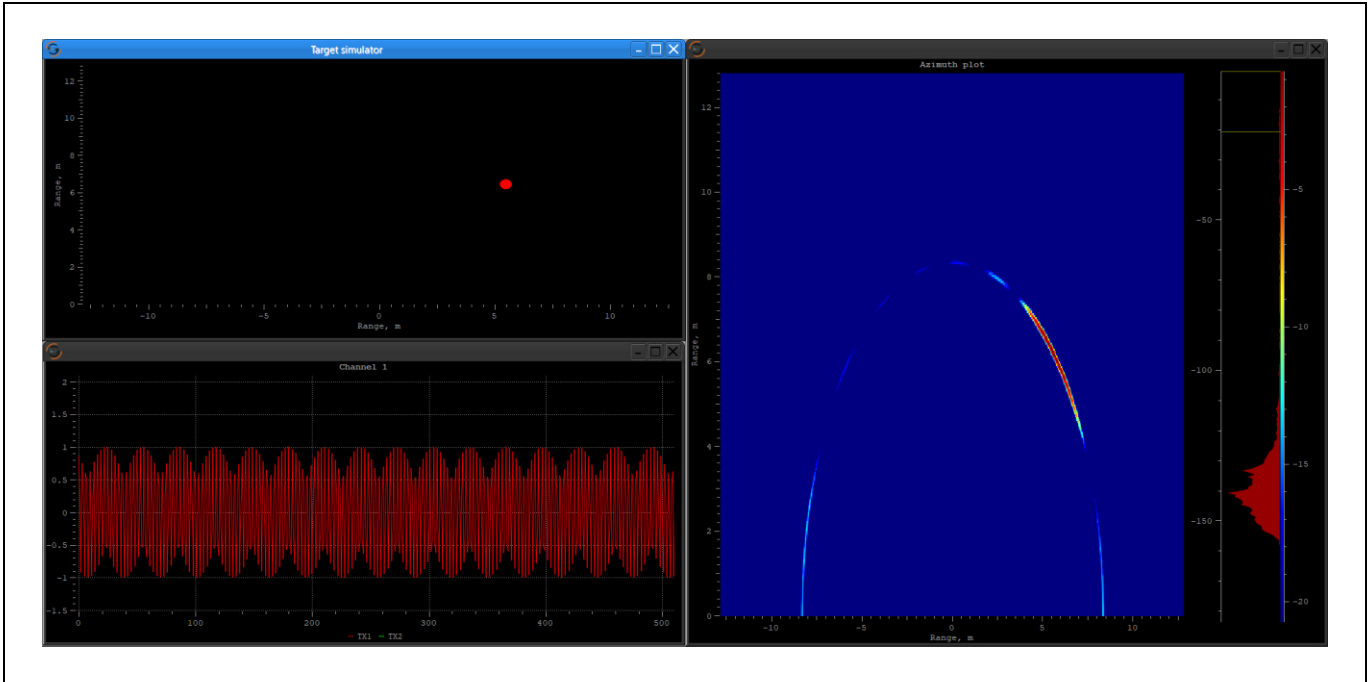Tabs in top and bottom area can be moved with the right click of the mouse.

Since the SiRad GUI can be used with two different evaluation kits, certain settings are enabled and disabled (grayed out) according to kits, RFEs and modes.

Please see those parameters and their influences in the measurement workflow description in the System/Protocol Description for *SiRad Easy® r4* [1] or User Guide for *SiRad MIMO r2* [2].

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 can decrease the signal quality.

Figure 25   Setup Window

Please note that in most countries the permitted start frequency and bandwidth is regulated by law for field applications. Please check your local regulations.

Table 3   Setup Window

GUI Element	Description
Presets	Load and save settings
RF Parameters	Radar front end settings
BB Processing	Baseband processing settings
Target Recognition	Target recognition and tracking settings
Output Data	Data protocol and output settings
Trigger Options	Triggering options

4.1 Presets Tab
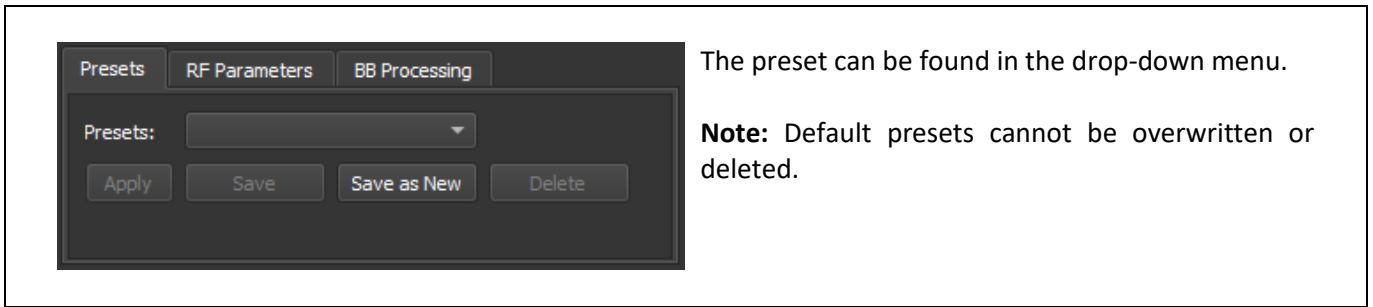
The preset can be found in the drop-down menu.

Note: Default presets cannot be overwritten or deleted.

Figure 26 Presets

Table 4 Presets

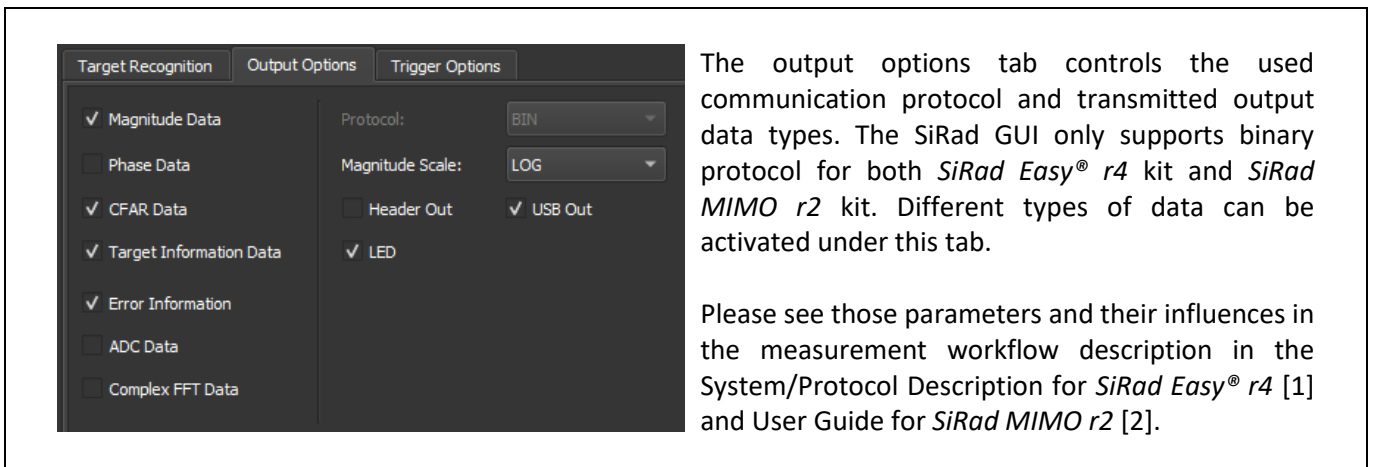| GUI Element	Description
Apply	Applies the selected preset on parameters.
Save	Overwrites the current configuration onto the selected preset.
Save as New	Saves the current configuration as a new preset.
Delete	Deletes the selected preset.

4.2 Output Options Tab

The output options tab controls the used communication protocol and transmitted output data types. The SiRad GUI only supports binary protocol for both *SiRad Easy® r4* kit and *SiRad MIMO r2* kit. Different types of data can be activated under this tab.

Please see those parameters and their influences in the measurement workflow description in the System/Protocol Description for *SiRad Easy® r4* [1] and User Guide for *SiRad MIMO r2* [2].

Figure 27 Output Options

Table 5 Output Options

GUI Element	Command	Description
Magnitude Data	OUTM	Enables the Magnitude / Range data frame
Phase Data	OUTP	Enables the Phase Data frame
CFAR Data	OUTC	Enables the CFAR Data frame
Target Information	OUTT	Enables the Target Information Data frame
Error Information	OUTE	Enables the Error Information frame
Raw ADC Data	OUTA	Enables the ADC raw data frame
Complex FFT Data	OUTF	Enables the Complex FFT data frame
Protocol	PRTL	Protocol type for data output; BIN
Mag Scale	MAGS	Sets scaling type of magnitude data; Logarithmic and Linear
Header Out	HDRO	Header bar connection on Easy r4
USB Out	USBO	USB connection on Easy r4
LED	LEDM	Enables the LED

5 Network Window

The IP address of the board and IP address and port of the Server can be setup in this window. The serial port connection must be established beforehand.

This window is only useable for *SiRad MIMO r2* kit.
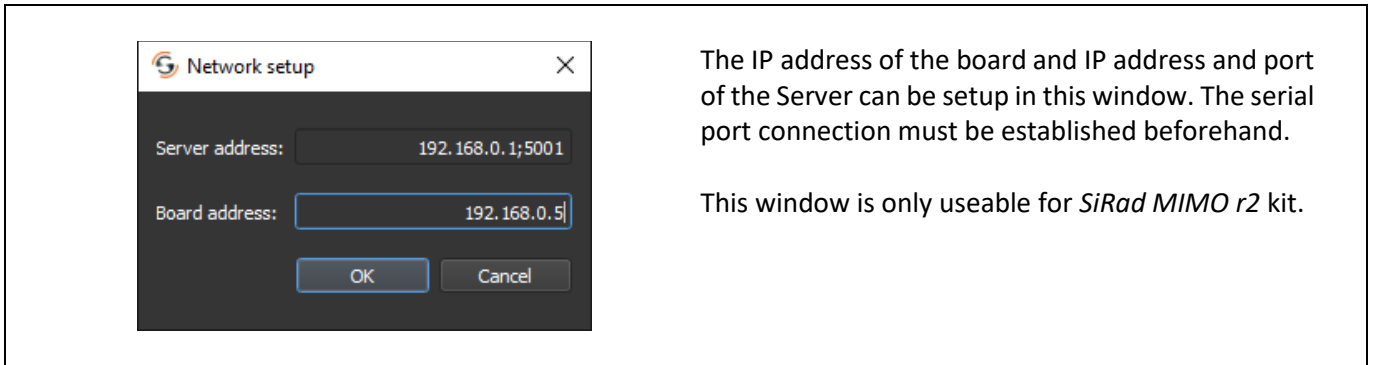
Figure 28   Network Setup

6 About Window

This window consists of the information related to the GUI and links to Silicon Radar Wiki page [3] and Download Area [4].
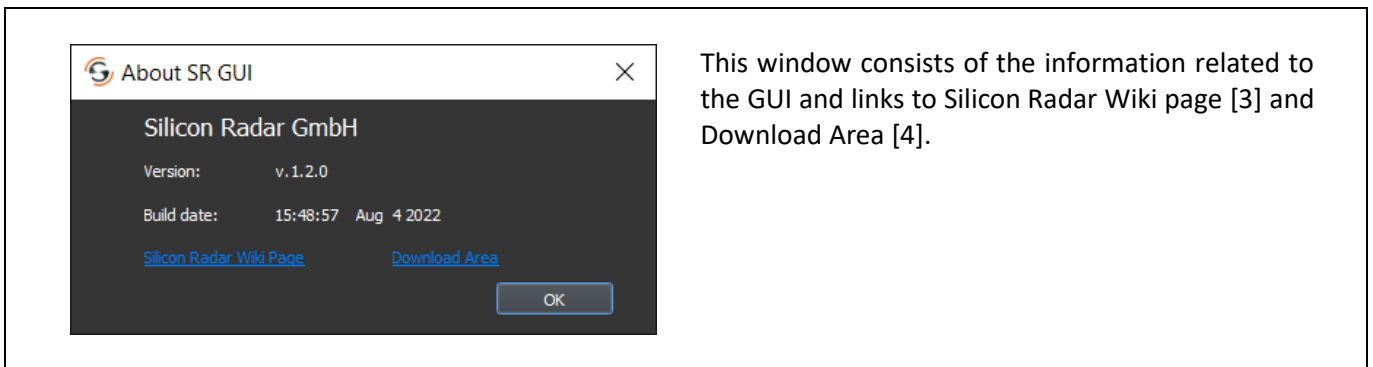
Figure 29   About Window

References

[1] https://siliconradar.com/datasheets/Protocol_Description_Easy_Simple.html
[2] https://siliconradar.com/datasheets/User_Guide_MIMO_r2.html
[3] https://wiki.siliconradar.com/
[4] https://login.siliconradar.com/

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