

# MR3003\_RD

radar transceiver  
with integrated signal processing



## Features

- Easy MR3003\_RD parameter setting over GUI
- Real-time streaming of all relevant radar processing data
- Record and playback function
- Firmware update per boot loader
- Saves time to market and reduces NRE

## Applications

- Optimize parameters of the MR3003 in your application
- Getting started with 77GHz radar
- Learn about radar signal processing and data interpretation

## Description

The MR3003\_RD is an advanced development kit for everyone, containing all the data processing from range-doppler to tracked two-dimensional targets, visualizing the environment as seen by the radar.

On the powerful control panel, every signal processing step is viewable and also comparable with the next or the one before. Recording and playback of data allows exact analysis of the data after the action. The integrated firmware update function enables you to keep your device up to date.

## Control Panel



Figure 1: Control panel GUI overview

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# INSTALLATION

Double click the MR3003\_CTP-NXP-01XX\_Setup.msi file to start the installation of the control panel. Follow the steps until installation is completed.

To use the integrated video function, the «Logitech HD Webcam C525» is recommended and supported by the control panel. Please download and install necessary drivers for the webcam from the manufacturers website.

## Setup for TCP (Ethernet)

Choose this option to connect the radar via TCP. To connect the radar with the computer via ethernet, follow these steps:

1. Plug in the delivered power supply (+12VDC) and connect it to the MR3003\_RD
2. The fan on the reverse must now run. If it doesn't check your power supply.
3. Connect the ethernet cable to the MR3003\_RD and your computer
4. Wait for 3 seconds
5. The light on the ethernet socket on the MR3003\_RD should now light green. If not check if the ethernet connector is plugged in correctly.
6. Change the IPV4 connection settings on your computer to a static one with the following parameters:  
IP-Address: 192.168.100.xx (xx must **not** be 5)  
Subnet: 255.255.255.0
7. Open the cmd console and type in:  
ping 192.168.100.5 <enter>
8. The MR3003\_RD should now respond to this ping. If there is no response at all, recheck your IP-address settings. If your IP-address settings are correct, please consider the possibility your firewall is blocking the connection.
9. Connect your webcam – wait until Windows has installed the webcam drivers.
10. Your MR3003\_RD is now connected with your computer – start the control panel.
11. Now click the «Connect» button in the TCP frame (Figure 2). If it does not connect immediately, click again until it successfully connects your MR3003\_RD.
12. On a system with multiple cameras, the window Figure 3 will pop up. Select the camera you want to use.
13. After connecting, the control panel will display the following View of Figure 4.

## Setup for CAN – not available for MR3003\_RD

The CAN interface function is currently not supported for the MR3003\_RD hardware and is reserved for future use.

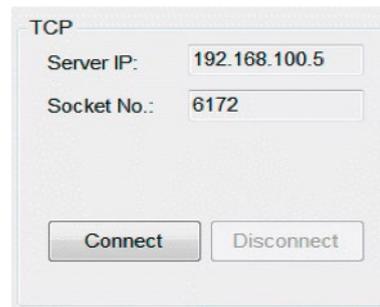


Figure 2: TCP area

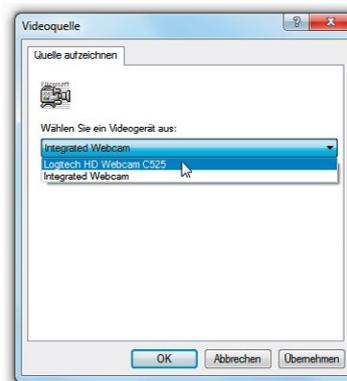


Figure 3: Camera selection window

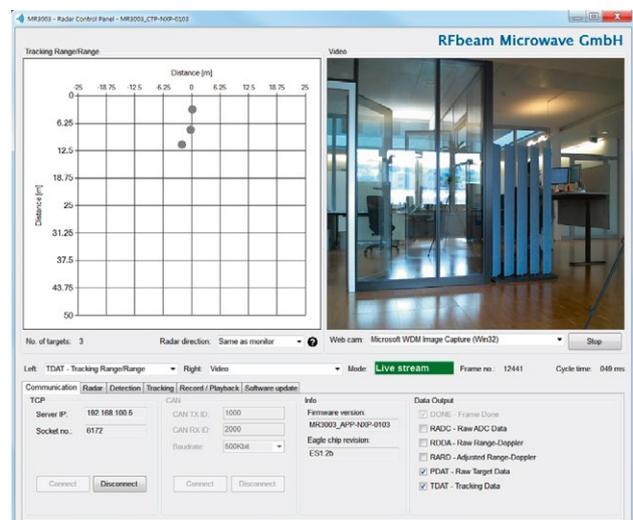


Figure 4: Default connected view

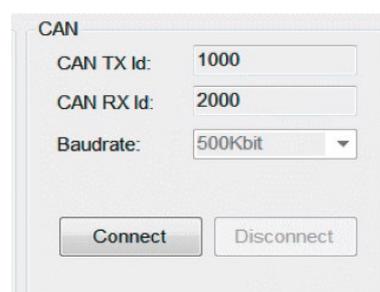
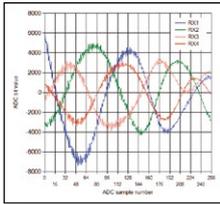


Figure 5: CAN area

# QUICK START

The control panel contains many setting options. The structure of the panel views is designed to guide you through the different steps of radar processing.



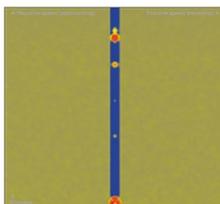
## Raw ADC Data (RADC)

- Samples ADC data from all 4 RX antennas directly in MR3003 (1 Frame = 256 Samples x 128 Chirps)
- Sends data to CPU S32R274 over digital MIPI interface



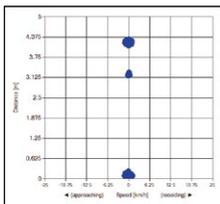
## Raw Range-Doppler (RDDA)

- Calculates the raw range-doppler map for each RX antenna



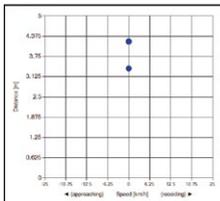
## Adjusted Range-Doppler (RARD)

- Averages the raw range-doppler map of all four RX antennas
- Normalises and adjusts the averaged range-doppler map
- Calculates automatically a threshold to detect targets



## Raw Target (PDAT)

- Finds targets over threshold
- Decides which target is reported in neighbourhood
- Filters targets (e.g. Clutter)



## Tracking (TDAT)

- Clusters raw target clouds to objects
- Assigns objects to tracking channels
- Predicts momentary lost objects

**Figure 6: Signal processing workflow**

The control panel is structured according to the following figure. Go to the same named chapter for further information.

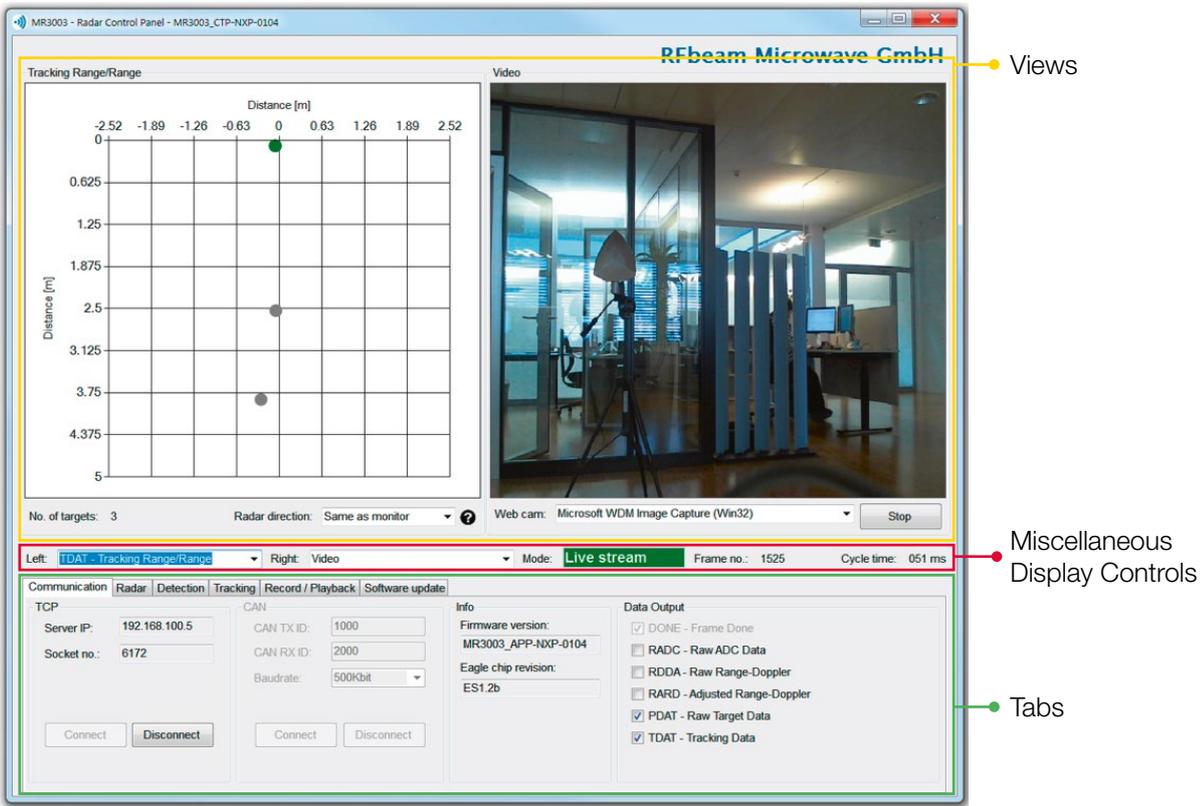


Figure 7: Overview control panel areas



There are many views to select, all of them have a preceded shortcut. This shortcut is also preceded by the data output and leads therefore to an easy check, if the current view receives data from the radar to show.

## Example

By enabling «PDAT – Raw Target Data» on the «Data Output», the view:

- **PDAT** – Raw Target Speed/Range
- **PDAT** – Raw Target Angle/Range
- **PDAT** – Raw Target Range/Range

start to update with radar data, also illustrated in Figure 8.

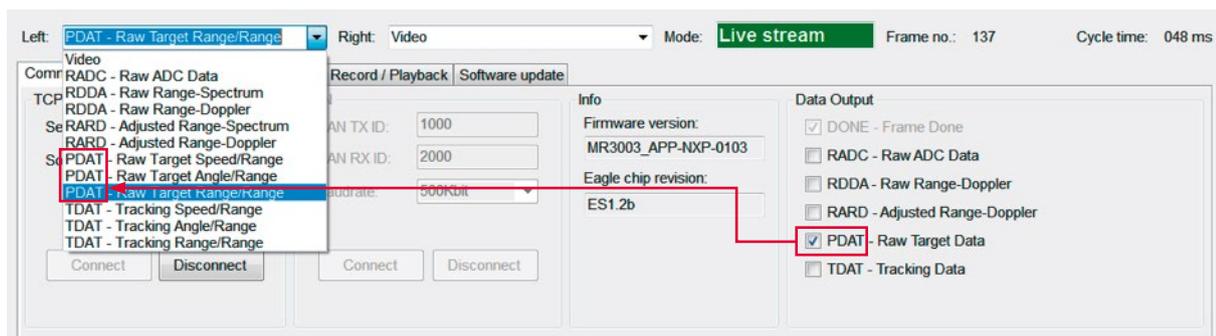


Figure 8: Data output example

## Adjust the Settings

Although the MR3003\_RD is pre-calibrated with useful parameters and the control panel assists in parameter selection, for a good result there are still many things to consider and set depending on your needs. This chapter is a guideline to lead you to usable results in the shortest possible time.

All changed parameters are saved on the MR3003\_RD device and are still available after power off/on.

### Radar settings

On the radar tab the MR3003 parameters can be set. Choose the following settings according to the application:

- Range/Speed
- TX antenna

 Check the orientation of the radar, otherwise the angles are all wrong.

When changing any setting on this tab it is essential to check the radar RX gain afterwards.

Set the left view to «RADC – ADC Data» and the right one to «RARD – Adjusted Range-Spectrum». Now the RX gain must be set to the minimum and increased step by step.

At each gain level,

- The RADC data must be checked for clipping, marked in Figure 10. The maximum ADC value for the MR3003\_RD is  $\pm 2^{14} = \pm 16384$ . Decrease until any clipping signals have been eliminated.
- The «RARD Adjusted Range Spectrum» must be checked for overflows. Due to fix and fast FFT calculations, the dynamic range is limited. When changing from one gain to the next higher gain, all signals should only rise by the same amount. By an overflow, a peak changes into a valley, as seen by the comparison of Figure 11 and Figure 12.

If clipping or overflows are seen, choose the next lower RX gain value.

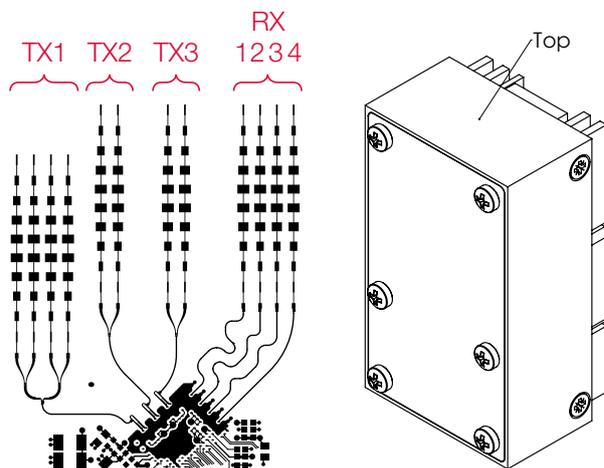


Figure 9: Antenna order

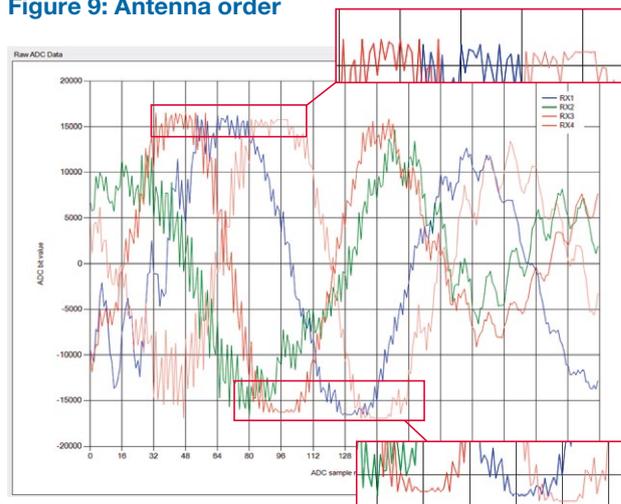


Figure 10: Clipping ADC signals

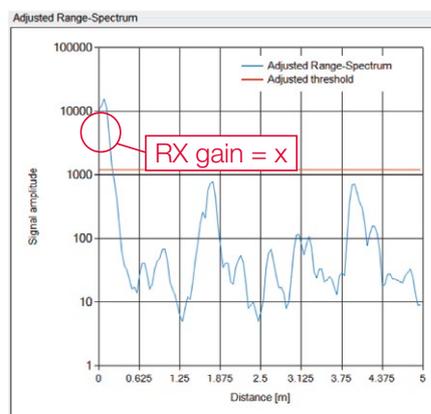


Figure 11: Peak is still peak

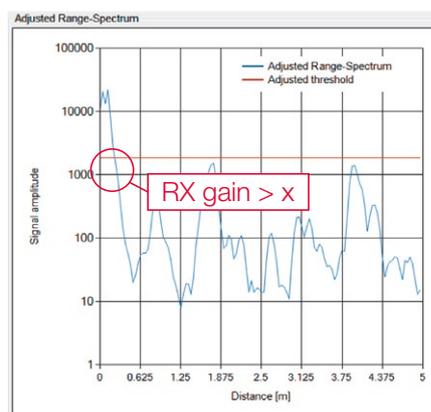


Figure 12: Peak gets valley

## Detection settings

Using the ADC data, which is now perfectly parameterized, the MR3003\_RD calculates four raw range-doppler maps (for each RX antenna) and subsequently averages them into one range-doppler map. This map is normalized and an automatic adjusted threshold is used to find potential targets. The potential target points are coloured red

in the adjusted range-doppler map. The detection algorithm applies criteria to the potential targets in the adjusted range-doppler map to find the raw targets.

Set the detection parameters according to your needs.

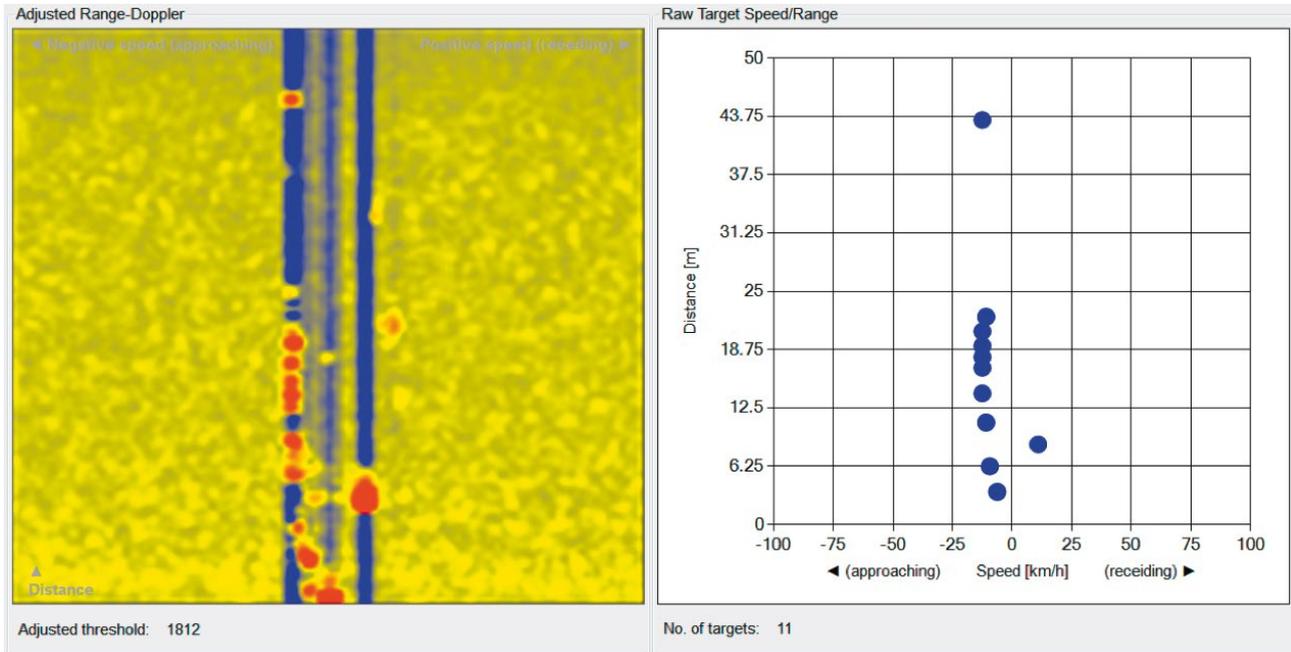


Figure 13: Adjusted range-doppler map to raw targets

## Tracking Settings

Depending on the tracking settings, the raw targets are added to the tracking algorithm. The tracking algorithm clusters raw targets, assigns them to tracking

channels, predicts and filters them. Adapt the given parameters to suit your needs.

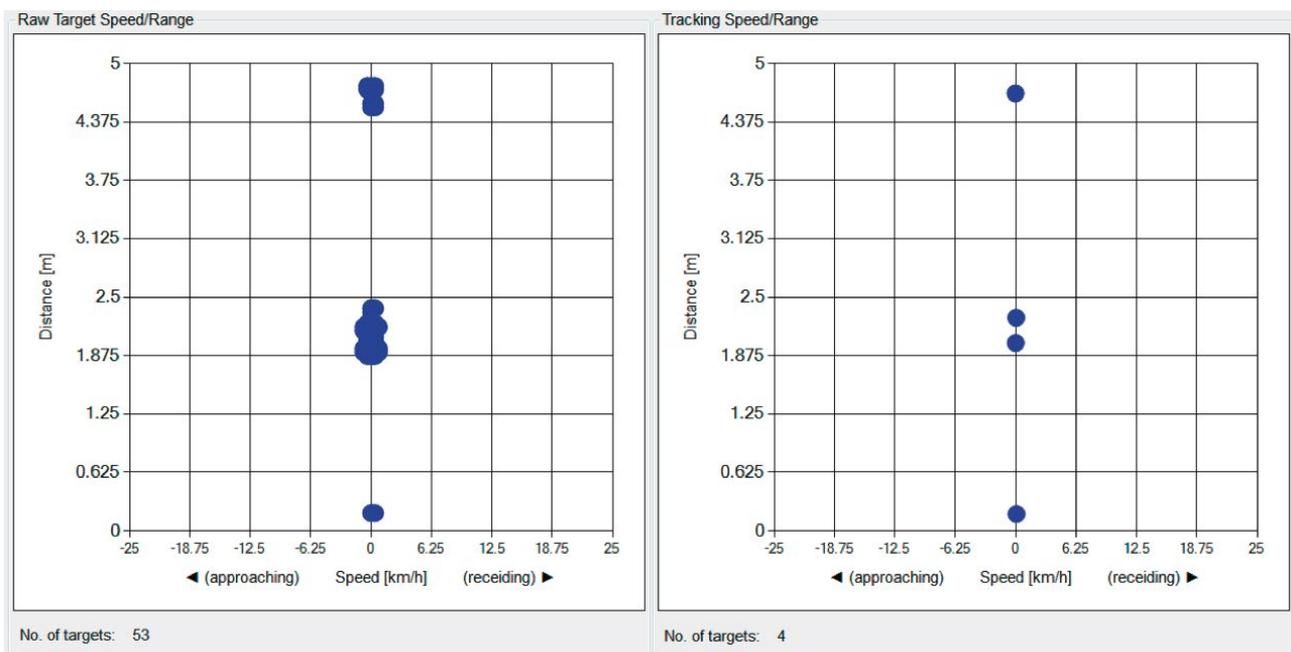


Figure 14: Tracking Settings

# CONTROL PANEL

This is the start-up view of the control panel. In this chapter all the graphical elements and the functions of the control panel are described.

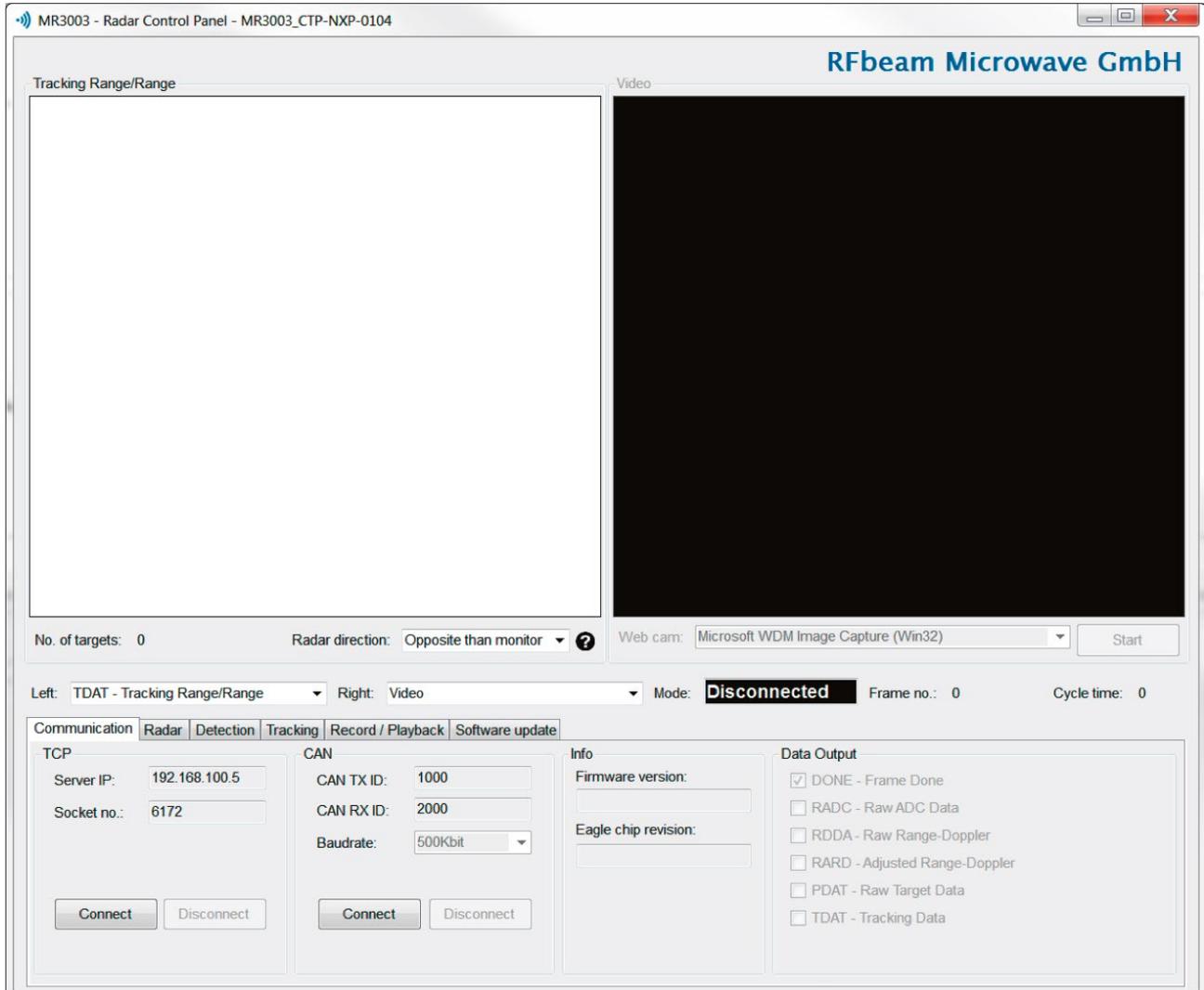
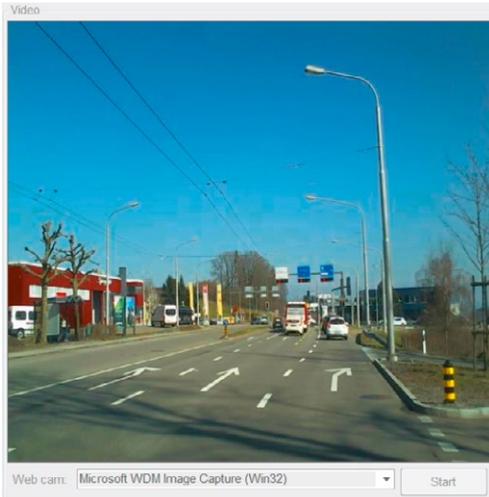


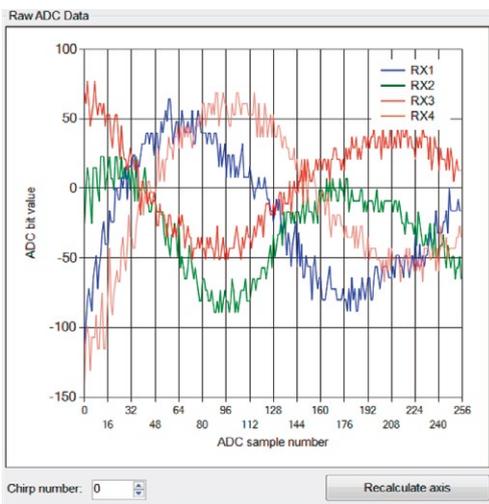
Figure 15: Start-up view of the control panel

# Views



## Start-up view of the control panel

Start and stop the webcam video stream.



## Raw ADC Data view

This view shows the ADC values recorded by the MR3003. Use the «Recalculate axis button» to rescale when ADC signals are displayed very small or bigger than the current axis range.

Chirp number:  
The MR3003 is configured for FMCW mode with 128 chirps (Fig. 16).

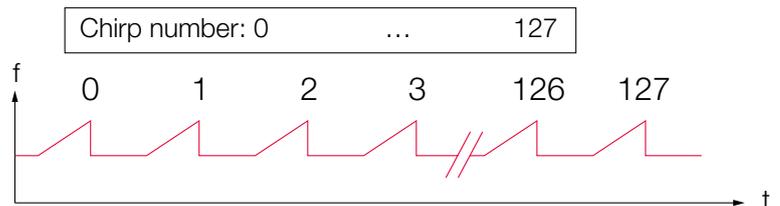
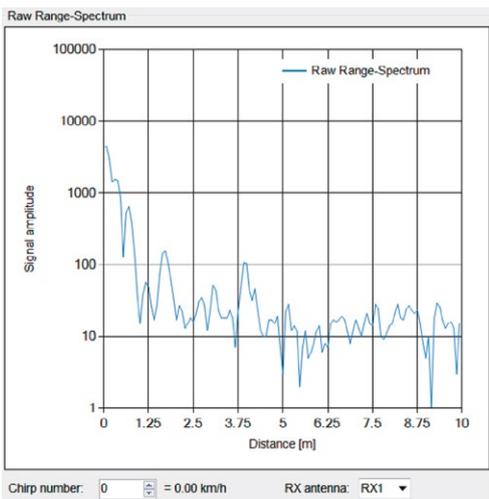


Figure 16: Chirps over time



## Raw Range-Spectrum

This is the cross-section of the raw range-doppler map.

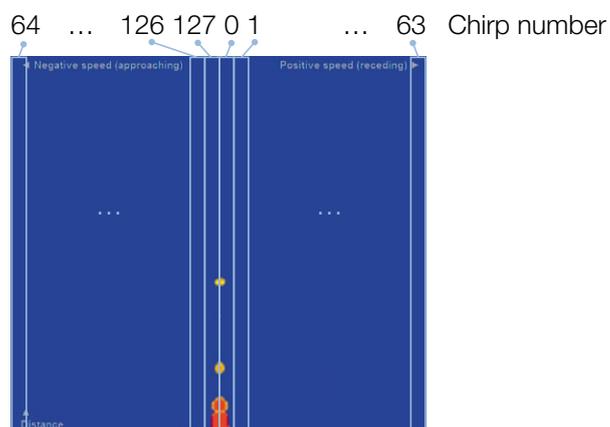
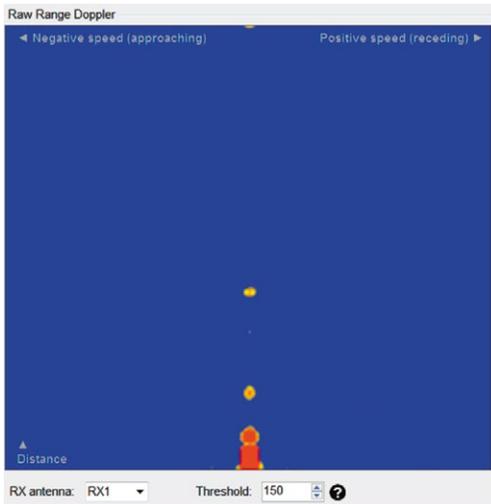


Figure 17: Chirp slices in the range-doppler map

Chirp number:  
The raw range-spectrum of the selected chirp number is shown.

RX antenna:  
The raw range-spectrum of the selected RX antenna is shown.



## Raw Range-Doppler view

In the raw range-doppler map targets are displayed in a speed vs. distance map. Range-doppler is popular amongst radar applications, as it can be efficiently calculated out of the raw ADC data.

RX antenna:

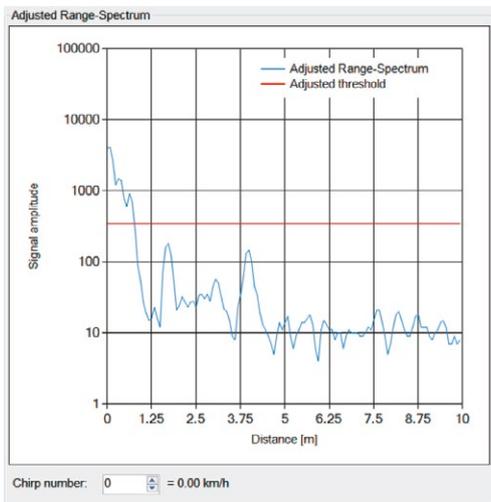
Shows the range-doppler map of the selected RX antenna.

Threshold:

Peaks over threshold are shown red.



The threshold must be set by hand and is only used for graphical use. It does not affect the target detection in any way.



## Adjusted Range-Spectrum view

This is the cross-section of the adjusted range-doppler.

64 ... 126 127 0 1 ... 63 Chirp number

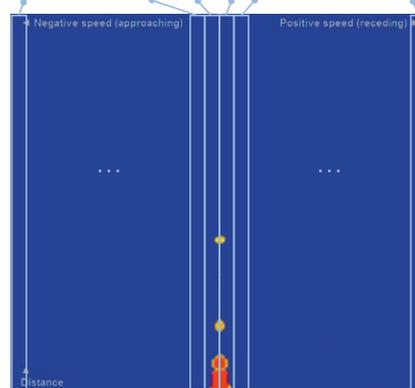
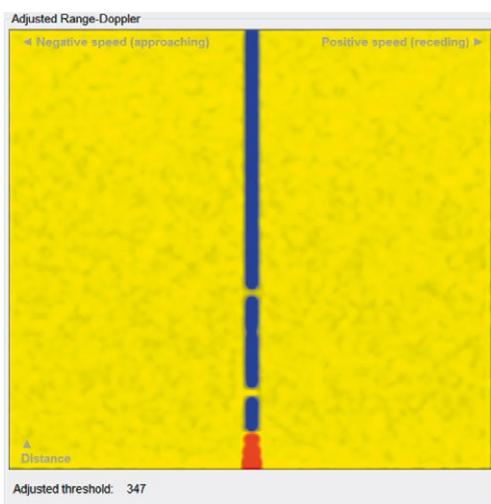


Figure 18: Chirp slices in the adjusted range-doppler map

Chirp number:

The raw range-spectrum of the selected chirp number is shown

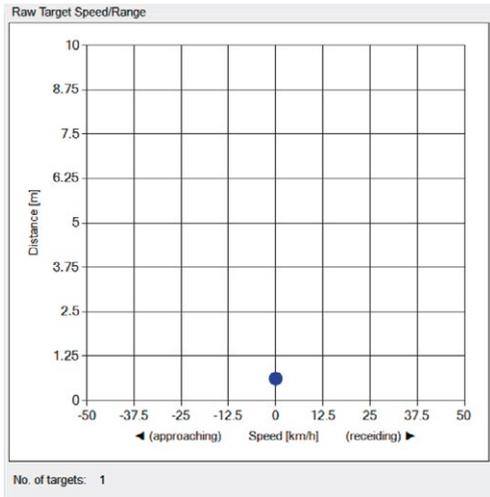


## Adjusted Range-Doppler view

The adjusted range-doppler map is calculated based on the raw range-doppler map. It is an adjusted and normalized result.

Adjusted threshold:

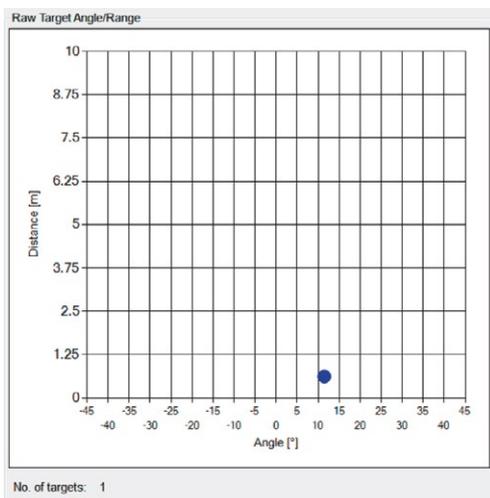
An automatic threshold algorithm always chooses the best possible threshold for the target detection.



### Raw Target Speed/Range view

This view contains the raw targets found with the same axis as the range-doppler view. It is helpful to compare this view with the adjusted range-doppler when tuning the detection parameters.

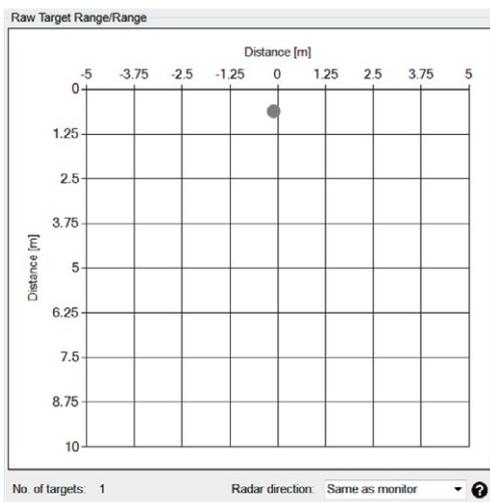
No. of targets:  
Count of actually reported raw targets



### Raw Angle/Range view

A very helpful view when doing angle measurements.

No. of targets:  
Count of actually reported raw targets

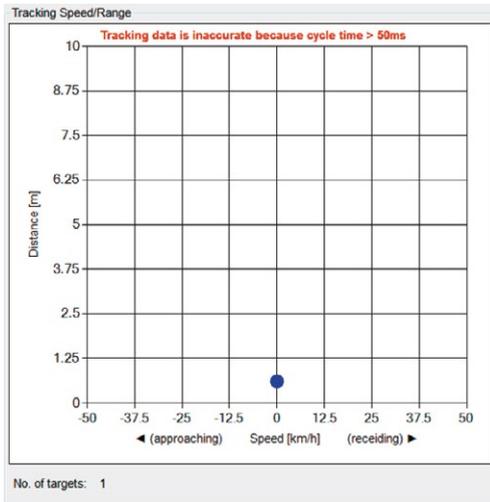


### Raw Target Range/Range view

This is one of the most interesting views, as the information of the targets is interpreted and shown in a two-dimensional map. The targets show the radar's view of the real world.

No. of targets:  
Count of actually reported raw targets

Radar direction:  
Defines the direction of the radar to the monitor. If «Same as monitor» is used, the webcam video has to be mirrored to correspond to the data.



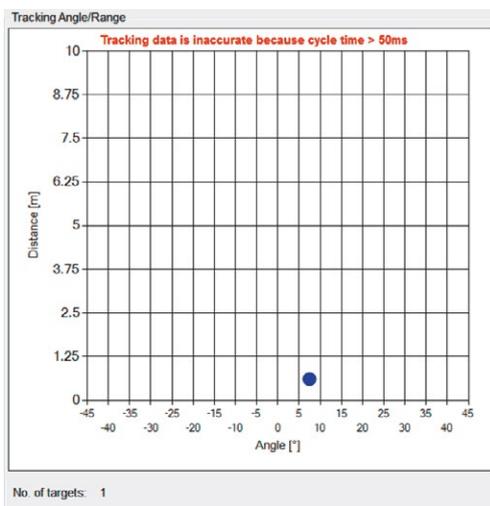
### Tracking Speed/Range view

Compare this view with the corresponding raw view to see the improvements of the tracking filter.

No. of targets:  
Count of actually tracked targets



The tracking filter requires a fixed cycle time, to work as expected. If the cycle time is too high, a warning is shown at the top of the chart. Reduce in this case the number of data outputs until the cycle time is about 50ms.



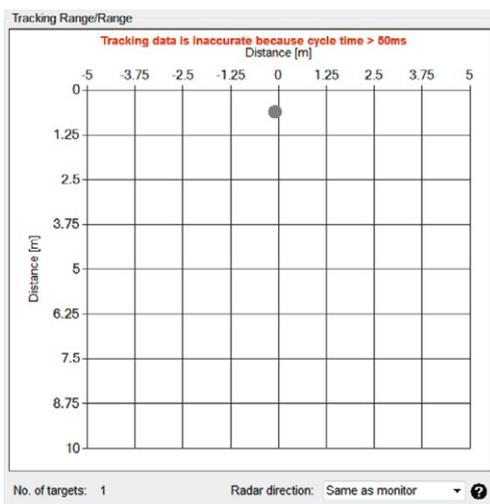
### Tracking Angle/Range view

Compare this view with the corresponding raw view to see the improvements with the tracking filter.

No. of targets:  
Count of actually tracked targets



The tracking filter requires a fixed cycle time, to work as expected. If the cycle time is too high, a warning is shown at the top of the chart. Reduce in this case the number of data outputs until the cycle time is about 50ms.



### Tracking Range/Range view

Compare this view with the corresponding raw view to see the improvements with the tracking filter.

No. of targets:  
Count of actually tracked targets



The tracking filter requires a fixed cycle time, to work as expected. If the cycle time is too high, a warning is shown at the top of the chart. Reduce in this case the number of data outputs until the cycle time is about 50ms.

# Miscellaneous Display Controls

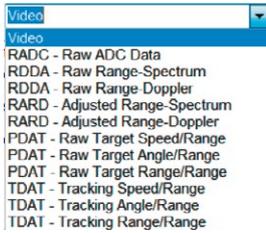


Figure 19: Display dropdown

 It is not possible to display the same view left and right at the same time

If the one of the windows (left/right) shows a white screen or is frozen, check that the chosen display setting matches with the selected data output.

Dropdown label	Meaning
Video	Webcam video picture
RADC – Raw ADC Data	ADC values of all RX antennas
RDDA – Raw Range-Spectrum	Cross section of raw range doppler map
RDDA – Raw Range-Doppler	Range doppler map of all RX channels
RARD – Adjusted Range-Spectrum	Cross section of adjusted range-doppler map
RARD – Adjusted Range-Doppler	Adjusted range-doppler map
PDAT – Raw Target Speed/Range	Raw target map speed vs. range
PDAT – Raw Target Angle/Range	Raw target map angle vs. range
PDAT – Raw Target Range/Range	Raw target map range vs. range
TDAT – Tracking Speed/Range	Tracked target map speed vs. range
TDAT – Tracking Angle/Range	Tracked target map angle vs. range
TDAT – Tracking Range/Range	Tracked target map range vs. range

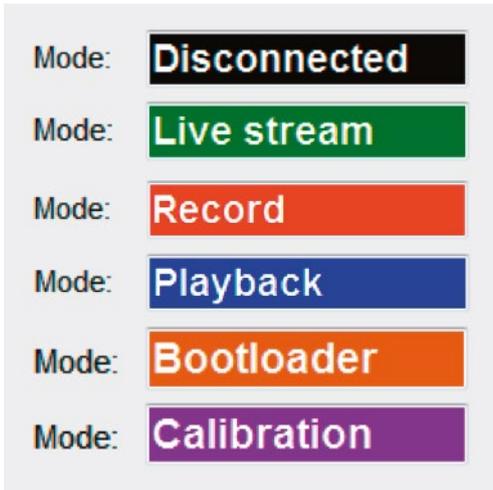


Figure 20: Different possible modes

## Modes

Disconnected:  
No connection with the MR3003\_RD.

Live stream:  
The control panel is connected to the MR3003\_RD and will receive data.

Record:  
Data from a connected sensor will be recorded (saved to harddisk).

Playback:  
Recorded data will be played and visualized.

Bootloader:  
The control panel is connected with the boot loader and is able to update the firmware of the MR3003\_RD.

Calibration:  
An angle calibration is on-going.

# Control Tabs

This chapter discusses the function of all control tabs.

## Communication Tab

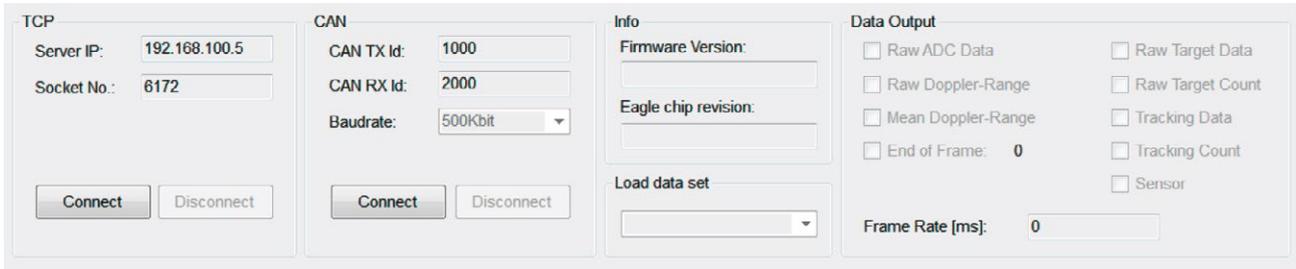


Figure 21: Different possible modes

In the communication tab, all settings for the communication with the radar can be set. On the following pages, each part of the communication tab is explained.

### TCP

Use TCP to connect to the MR3003\_RD.



Sometimes the «Connect» button must be clicked multiple times.

### CAN

CAN is not available for the MR3003\_RD and is reserved for future use.

### Info

Shows information about the firmware version and MR3003 chip revision

### Data Output

Select which output is sent from the radar to the control panel. Normally the frame cycle time is 50ms. Due to more enabled data outputs or the hddisk speed of the PC, it is possible that the cycle time will increase. It increases only in multiples of 50ms (50ms, 100ms, 150ms, ...).



TDAT Output is only correct, if cycle time is around 50ms, otherwise the tracking filter won't be able to track the targets correctly.



Only selected (transmitted) data can be shown and recorded.

## Radar Tab

Radar		Angle calibration	
Modulation mode:	FMCW	TX antenna:	TX3
Range/Speed [m, km/h]:	5m, 25km/h	TX power [dBm]:	15
CW frequency [MHz]:	76500	RX gain [dB]:	26

1. Enable "PDAT" messages  
2. Push "Start" button (two horizontal lines are shown)  
3. Put a target (e.g. corner reflector) in front of the sensor with an angle of zero degree and a distance between the lines  
4. Set the radar and detection parameter in a way that only one target is shown between the lines. Than the lines will turn green.  
5. Push "Calibrate" button

Start Calibrate Abort

Figure 22: Radar tab

On this tab page, the radar properties can be changed. The default values lead to good results for indoor short range walking tests.



All settings on this tab are radar commands. For further information refer the datasheet.

### Radar

#### Modulation mode

FMCW – Frequency modulated continuous wave  
CW – Continuous wave, for TX measurements only.  
Due to MR3003 internal filters, no doppler reaction is recognizable in CW mode.

#### Range/Speed [m, km/h]

Defines the maximum range and speed measurable. The sampling rate, chirp repetition rate and the bandwidth are changed to meet the selected specification

#### CW frequency [MHz]

Constant frequency in CW mode.

#### TX antenna

Specifies the active TX antenna. Only one TX antenna is active at any given time.

#### TX power [dBm]

Transmission power of the MR3003 chip

#### RX gain [dB]

RX gain of the MR3003 chip

### Angle calibration

Follow the steps stated to recalibrate the angles of the MR3003\_RD.



Your MR3003\_RD is pre-calibrated by RFbeam for best possible performance. You may recalibrate the MR3003\_RD by yourself, but make sure to use a point target else the angle accuracy of your MR3003\_RD will decrease drastically.

## Detection Tab

Detection	Filtering
Range neighbour delta [bin]: 0	Radar type: Static
Speed neighbour delta [bin]: 0	Static objects: On
Minimum range [bin]: 4	Collision time [s]: 2.00
	Minimum own speed [km/h]: 14.40
	Clutter band factor: 1.50 = ±0.59km/h

Figure 23: Detection tab

On this tab page, the detection algorithm properties are changeable. The default values lead to good results for indoor short range walking tests.



All settings on this tab are radar commands. For further information refer the datasheet.

### Detection

#### Range neighbour delta [bin]

When a value is set, only the strongest target in the range neighbourhood ( $\pm$  this value) will be reported. If this value is zero every detected target is reported.

For further information refer to the command table in the datasheet.

#### Speed neighbour delta [bin]

When a value is set, only the strongest target in the speed neighbourhood ( $\pm$  this value) will be reported. If this value is zero every detected target is reported. For further information refer to the command table in the datasheet.

#### Minimum range [bin]

Targets with a lower range value than this bin are filtered.

## Filtering

All peaks over the adjusted threshold are seen as valid detections. With the filters, it is possible to exclude areas in the mean range-doppler map or allow the position of the clutter to be detected and filtered automatically.

### Radar type

Static: The radar is standing still.

Moving: The radar is on a moving vehicle. With this option filters are enabled to reduce targets (clutter) of no interest.

### Static objects

Filter targets with no speed.



Only for static radar type.

### Collision time [s]

Filter targets which are at the radar position in less than the collision time.

→ Filtered area: time = distance/speed



Only for moving radar type.

### Minimum own speed [km/h]

The radar estimates its own speed. Depending on the minimum own speed, the radar decides whether the clutter filter is active or not.



Only for moving radar type.

### Clutter band factor

Due to leakage accuracy issues, not all clutter targets have exactly the same speed. The clutter factor filters targets around the own speed of the radar. The clutter band speed will be calculated as:

$$C_{BS} = O_S \pm C_{BF} \cdot S_R$$

$C_{BS}$  → clutter band speed

$O_S$  → own speed

$C_{BF}$  → clutter band factor

$S_R$  → speed resolution



Only for moving radar type.

## Tracking Tab



Tracking

Min. life time [frame]: 10

Max. life time [frame]: 15

**Figure 24: Tracking tab**

On this tab page, the tracking properties can be changed. The default values lead to good results for indoor short range walking tests.



It is of elementary importance, that the cycle time is about 50ms. The tracking filter needs exactly this time to accurately track the targets. If the frame cycle time is higher than 75ms disable some data outputs to decrease the cycle time to reach 50ms.



All settings on this tab are radar commands. For further information refer the datasheet.

### Tracking

#### **Min. life time [frame]**

When targets can be associated with a tracking channel for this amount of frames, the tracking channel becomes valid and will be reported.

#### **Max. life time [frame]**

When no targets can be associated with a valid tracking channel for this amount of frames, the tracking channel becomes invalid and won't be reported anymore.

## Record/Playback Tab

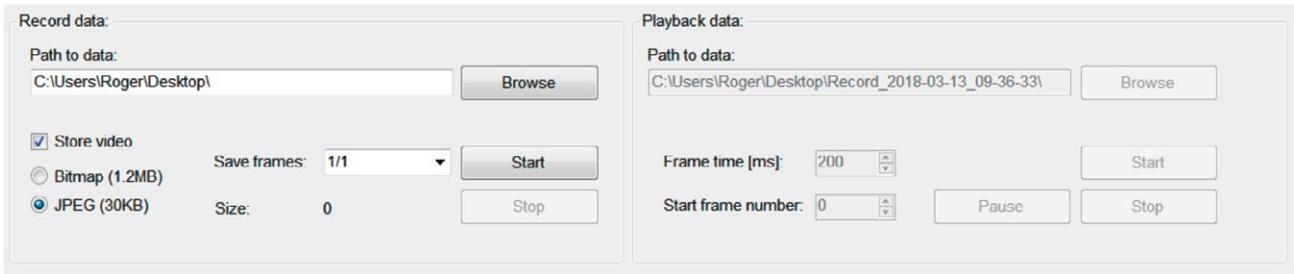


Figure 25: Record / Playback tab

This tab page can be used to record and playback data. When driving tests are done, this is useful to interpret the data afterwards.

### Recorded data

The performance of the recorded data is dependent on:

- The writing speed of the hard-disk of the computer being used
  - whether video is stored or not
- The enabled output data
- The chosen interface (CAN has only 500 kBit/s)

In the selected folder, for every recording a new subfolder is created.

The subfolder contains a binary file where all received data packets are directly stored. At the beginning of the recording the MR3003\_RD sends the «RPRM» packet which includes all actual parameter values.



Please refer to the datasheet for further information about the packet structure, commands and messages.

### Playback data

To playback the recorded data, the control panel must be disconnected.

Cycle time:

Lets the video run faster or slower.

Start frame number:

Allows the recording to be viewed from the specified frame.

The frame number is absolute. When it is set to zero the playback starts at the first frame found in the binary file.

## Software Update Tab

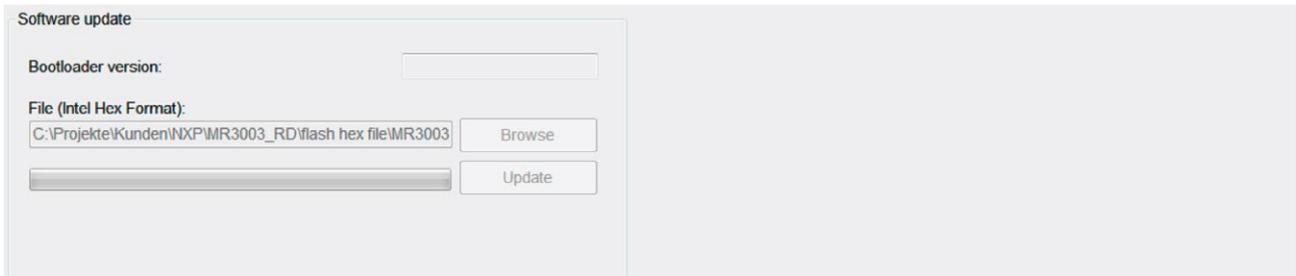


Figure 26: Software Update tab

This tab allows the update of the MR3003\_RD firmware over Ethernet.

Follow these steps to update your radar:

1. Power on the radar and connect it during the first 3s. If it is successfully connected with the boot loader, the control panel goes directly to the “Software update” tab. The boot loader version is shown.

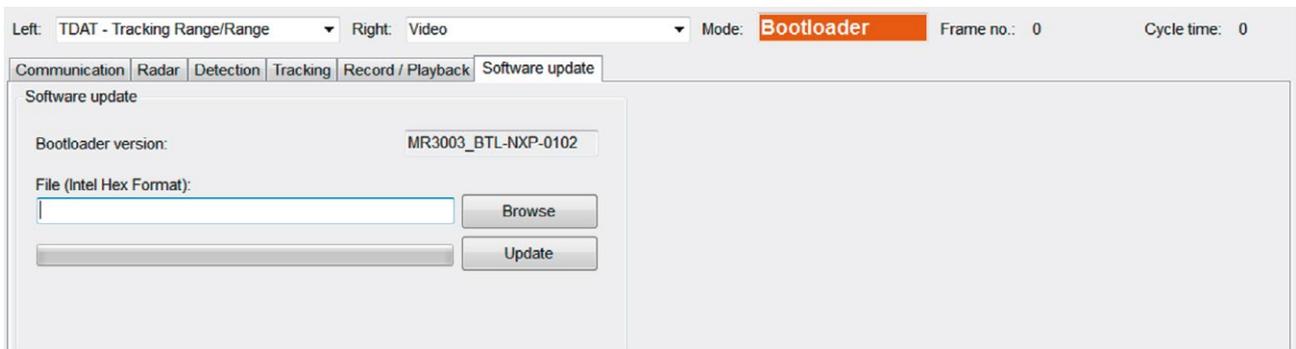


Figure 27: Software Update tab

2. Select the appropriate intel hex file you want to program using the browse button
3. Press update
4. Wait until the process has finished. A message box indicates if the update was successful

## SYSTEM REQUIREMENTS

- Windows 7 or Windows 10
- .NET Framework 4 Client Profile

## REVISION HISTORY

03/2018 – Revision A: Initial Version