RFbeam Microwave GmbH

user manual

K-MD2

Engineering Sample

radar transceiver
with integrated signal processing

Features

- 24 GHz FMCW radar with digital signal processing
- Angle of arrival in azimuth/elevation
- Serial target list output
- Detection distance: 100 m for persons/200 m for cars
- Distance range: 0–250 m, 1 m resolution
- Speed range: ± 130 km/h, 1 km/h resolution
- Angle range: ± 9.1° (elevation) ±16.4° (azimuth), 0.1° resolution
- Compact size: 120 × 72 × 15 mm

Applications

- Traffic analysis and classification
- Intersection management
- Security systems
- Object speed measurement systems
- Measurement and research applications
- Industrial sensors

Description

The K-MD2 is a high-end 3D radar transceiver with three receiving channels and a low phase noise, PLL controlled transmitter. The target information from the three receive antennas is digitized and the high speed digital signal processing performs range and doppler FFT's with an update rate of 20 measurements per second. Using the serial interface, many operating parameters such as frequency, bandwidth and repetition rate can be adjusted. Results are available in target list format as well as in raw range-doppler matrices. Ethernet and a serial communication interfaces are included.

Control Panel

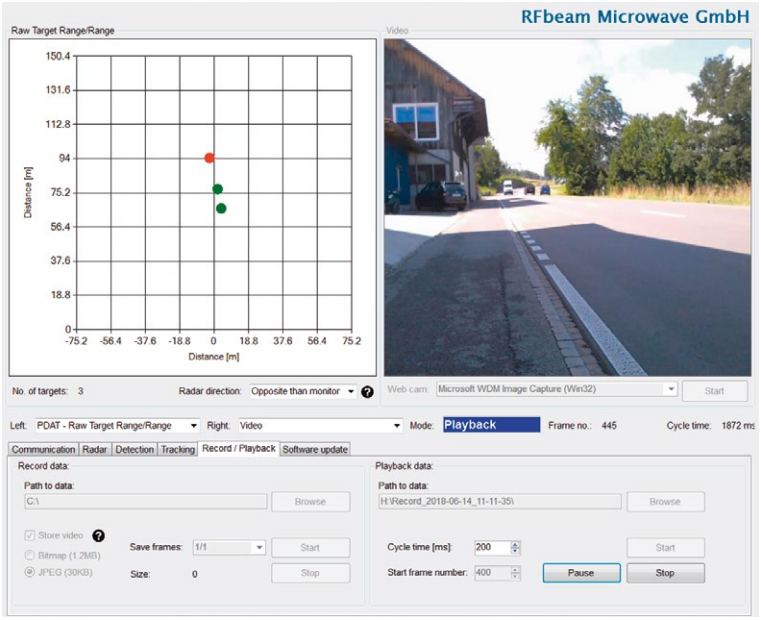

Figure 1: Control panel GUI overview

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INSTALLATION

Double-click the K-MD2_CTP-RFB-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 manufacturer's website.

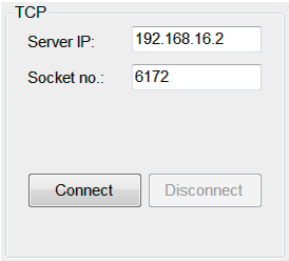


Figure 2: TCP area

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 K-MD2
2. Connect the ethernet cable to the K-MD2 and your computer
3. After some seconds the LED1 starts blinking
4. Change the IPV4 connection settings on your computer to a static setting with the following parameters:
   IP-Address: 192.168.16.1
   Subnet: 255.255.255.0
5. Open the cmd console and type in:
   `ping 192.168.16.2 <enter>`
6. The K-MD2 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.
7. Connect your webcam – wait until Windows has installed the webcam drivers.
8. Your K-MD2 is now connected with your computer – start the control panel.
9. Now click the "Connect" button in the TCP frame (Figure 2). If it does not connect immediately, click again until it successfully connects your K-MD2.
10. On a system with multiple cameras, the window Figure 3 will pop up. Select the camera you want to use.
11. After connecting, the control panel will display the following view of Figure 4.

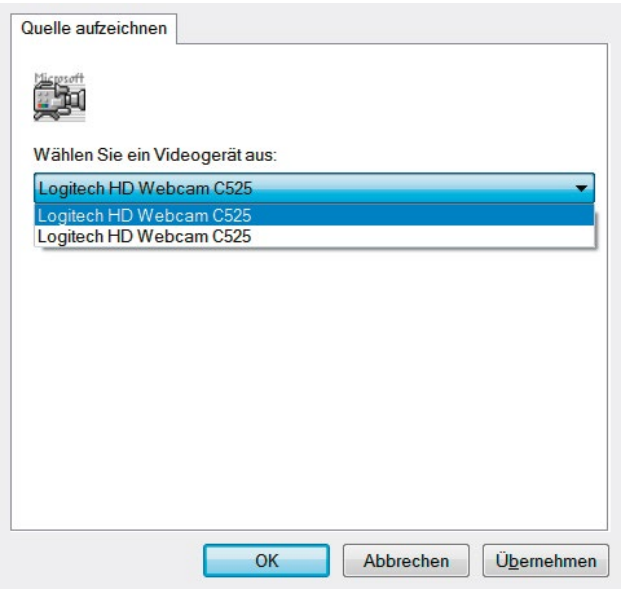


Figure 3: Camera selection window

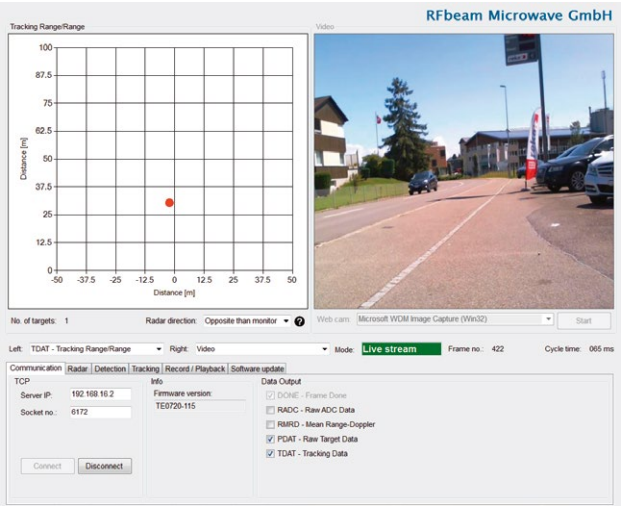
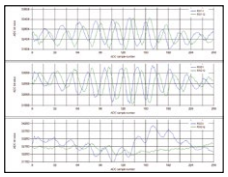


Figure 4: Default connected view

QUICK START

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

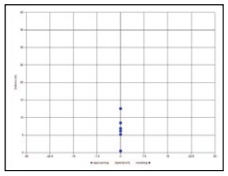


Raw ADC Data (RADC)

- Samples ADC data from all 3 RX antennas (1 Frame = 256 Samples x 256 Chirps)

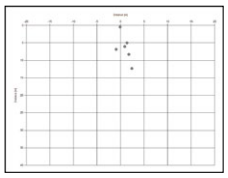
Mean Range-Doppler (RMRD)

- Calculates the range-doppler map for all 3 RX antennas
- Averages the range-doppler map of all 3 RX antennas



Raw Target (PDAT)

- Find targets over threshold
- Range compensation
- Filtering with an exponential moving average



Tracking Target (TDAT)

- Uses an alpha-beta-gamma tracker to track targets
- Assigns objects to tracking channels
- Predicts temporary lost objects

Figure 5: Signal processing workflow

The control panel is structured according to Figure 6.
Go to the same named chapter for further information.

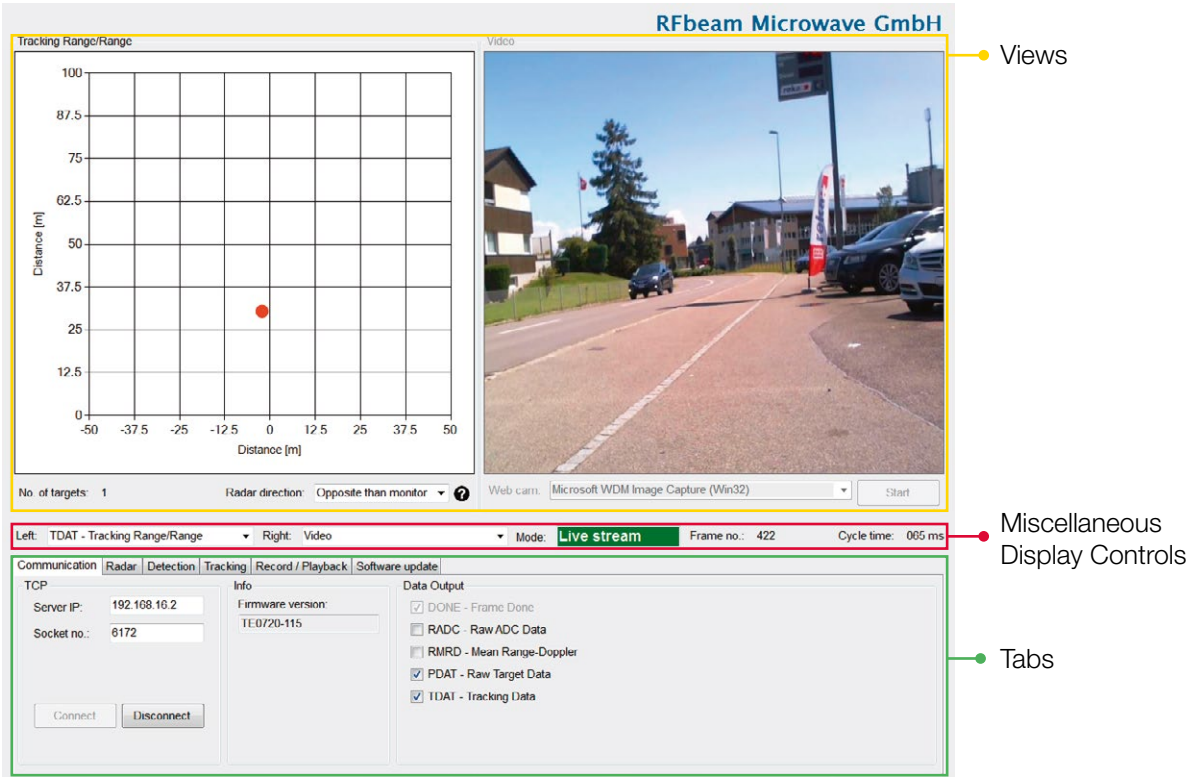


Figure 6: Overview control panel areas

There are many views to select, all of them with a preceded shortcut. The shortcuts are also preceded by the data output and therefore allows easy checking of whether the current view receives and shows data from the radar.

Example

By enabling “PDAT – Raw Target Data”
on the “Data Output”, the view:
- **PDAT** – Raw Target Speed/Range
- **PDAT** – Raw Target Azimuth/Range
- **PDAT** – Raw Target Elevation/Range
- **PDAT** – Raw Target Range/Range
- **PDAT** – Raw Target 3D

Start to update with radar data, also illustrated
in Figure 7.

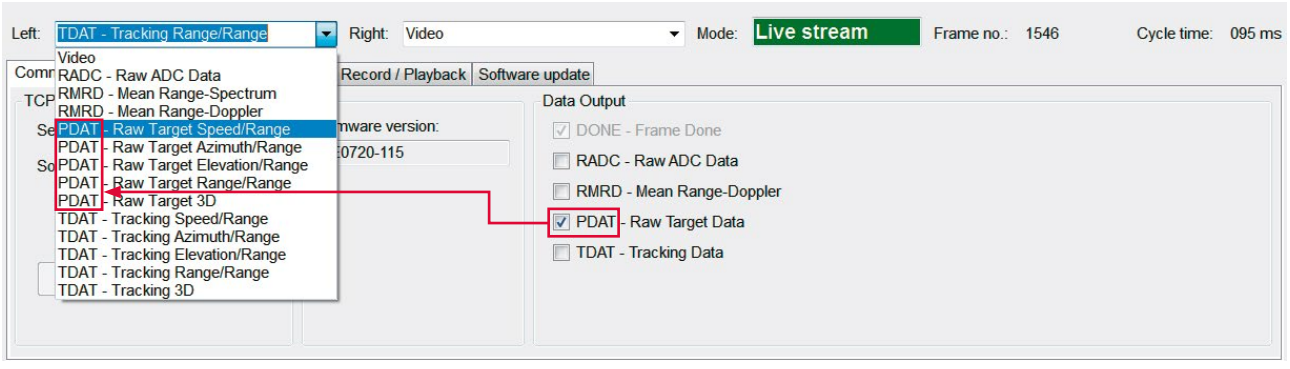


Figure 7: Data output example

Adjust the Settings

Although the K-MD2 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 K-MD2 device and are still available after power off/on.

Make sure the orientation of the device is as shown in Figure 8. Otherwise the azimuth and elevation angles are mirrored.

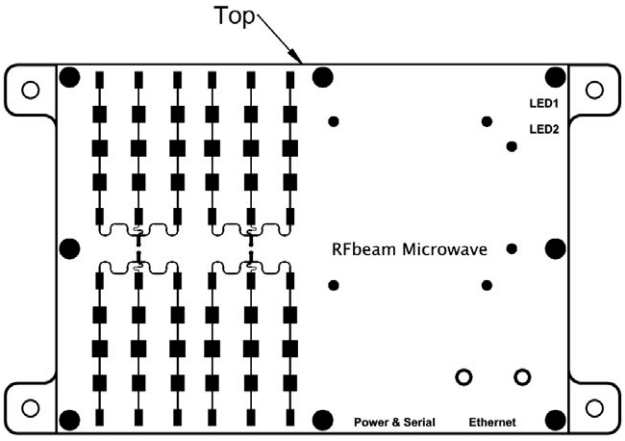


Figure 8: Device orientation

Radar Settings

On the radar tab the K-MD2 parameters can be set. Choose the following settings according to the application:

- Range
- Speed
- RX gain

Changing of these settings, especially the RX gain, can result in clipping of the ADC signals as shown in Figure 9. If this happens, reduce the RX gain in a way that the ADC signals don't clip anymore as shown in Figure 10.

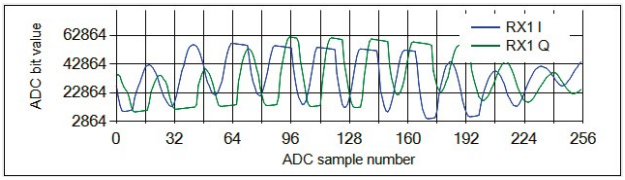


Figure 9: Clipping ADC signals

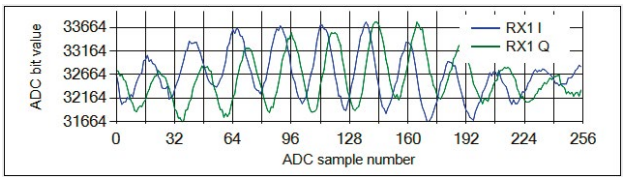


Figure 10: No clipping ADC signals

Clipping ADC signals will result in loss of sensitivity and therefore in worse target detections.

The range has to be set depending on the maximum distance which should be detected and the necessary distance resolution of the application. The speed setting is dependent of the maximum detectable speed of the application.

Detection Settings

Using the ADC data, which is now perfectly parameterized, the K-MD2 calculates three raw range-doppler maps (for each RX antenna) and subsequently averages them into one mean range-doppler map.

Targets over the “Peak threshold” are coloured red in the mean range-doppler map. Depending on the detection settings the raw targets are reported. Set the detection parameters according to your needs.

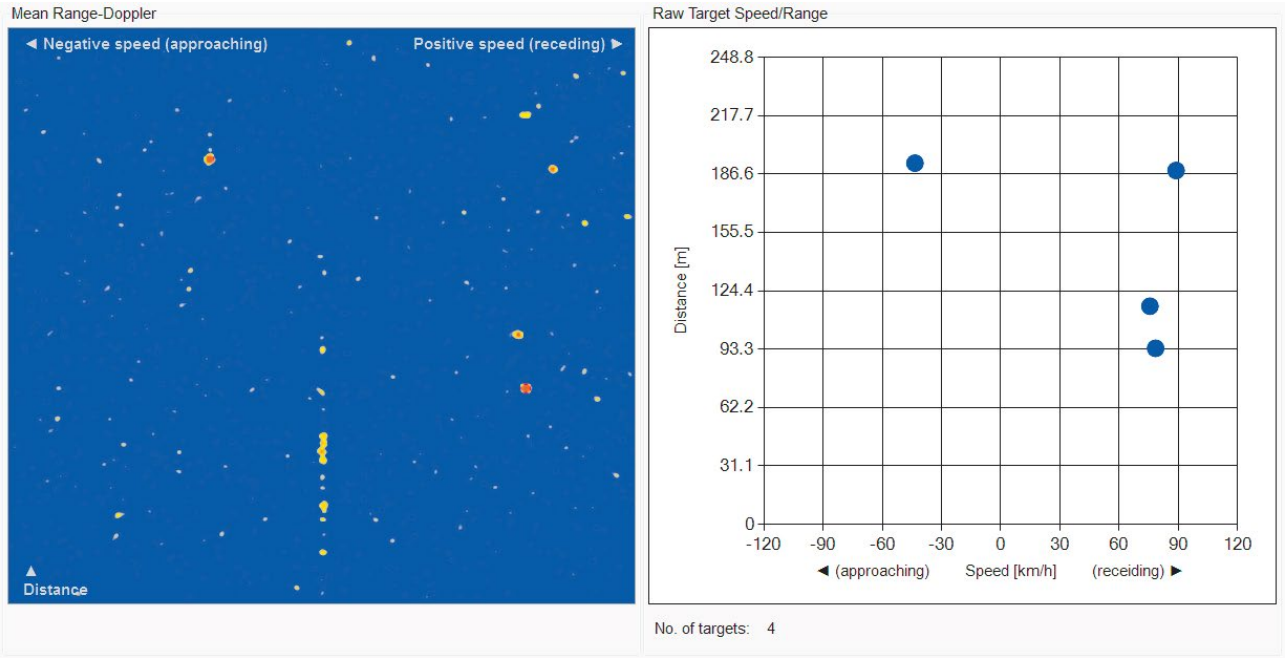


Figure 11: Mean range-doppler map to raw targets

Tracking Settings

On each frame the range, speed and direction of every track is updated. An alpha-beta-gamma tracker is used, where the speed is updated with the current acceleration estimate, and the range is updated with the current speed estimate. If a constant speed is assumed the acceleration is assumed to be zero, resulting in more reliable tracking for objects moving at a constant speed (e.g. towards or away from the radar). If the speed of the object is changing rapidly (e.g. passing across the radar field of view) it can be tracked if a constant speed is not assumed.

The list of detected peaks is compared with the updated list of known tracks. If a peak matches an existing track, it is marked as associated and the life of the track is increased. If no peak is found for the track, the life of the track is decreased. If there is no existing track for the peak, a new track is created. Once the life of a track reaches a minimum threshold it is reported as a confirmed track. The life of a track is limited, in that it will be lost if no detections are associated with it for the maximum track life. Adapt the given parameters to suit your needs.

As indicated in the following figure, the tracking filter reports only real targets and ignores reflections.

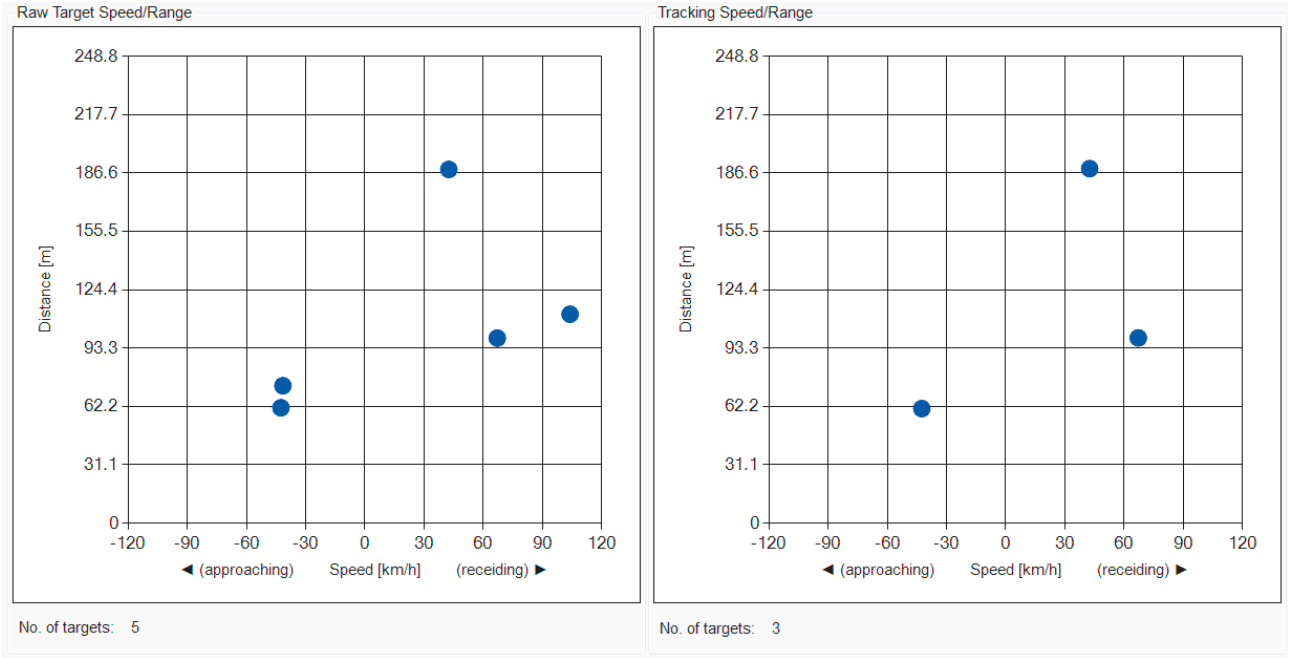


Figure 12: Raw targets to tracked targets

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.

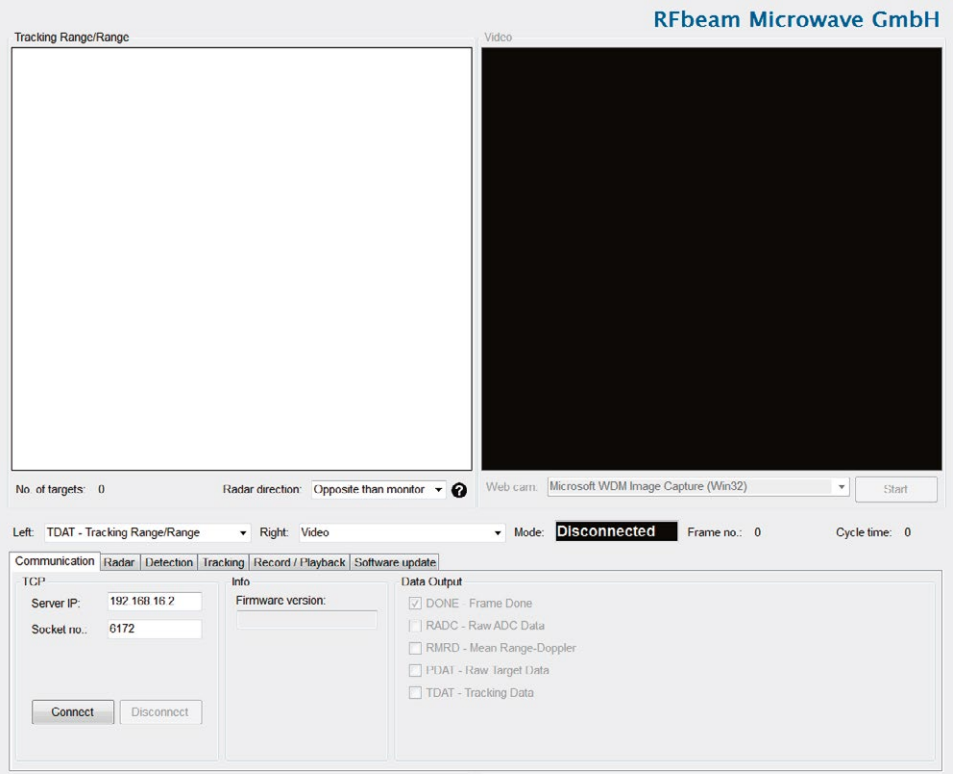
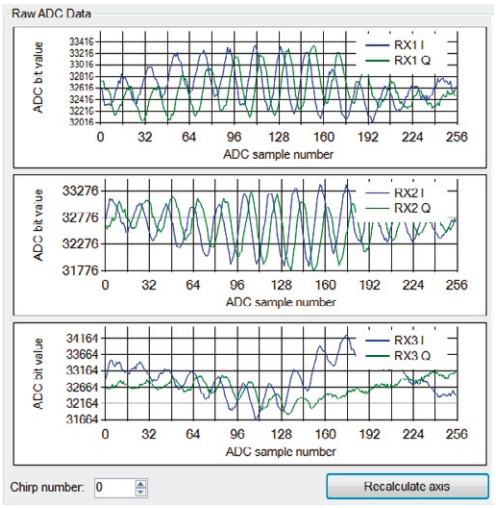


Figure 13: Start-up view of the control panel

Video

Start and stop the webcam video stream.



Raw ADC Data View

This view shows the ADC values recorded by the K-MD2. Use the «Recalculate axis button» to rescale when ADC signals are displayed very small or bigger than the current axis range.

Chirp number:
The K-MD2 is configured to sample 256 chirps. From all of these chirps the ADC signal of all three RX antennas can be shown (Figure 14).

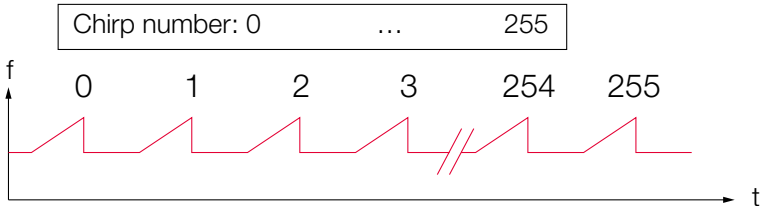
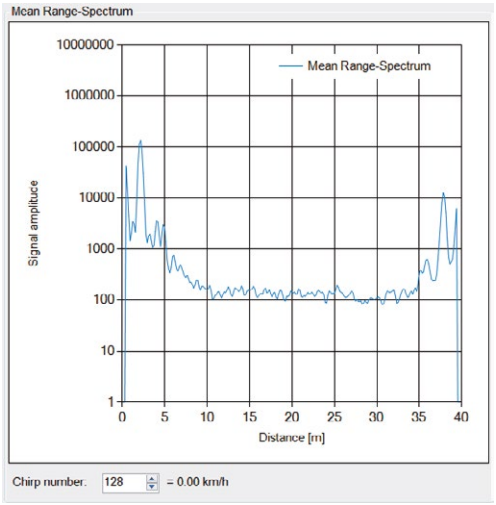


Figure 14: Chirps over time



Mean Range-Spectrum View

This is the cross spectrum of the mean range-doppler map.

Chirp number:
The mean range-spectrum of the selected chirp number is shown. The chirp number of zero speed is 128.

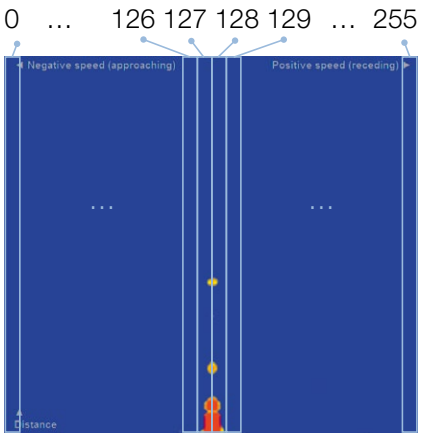
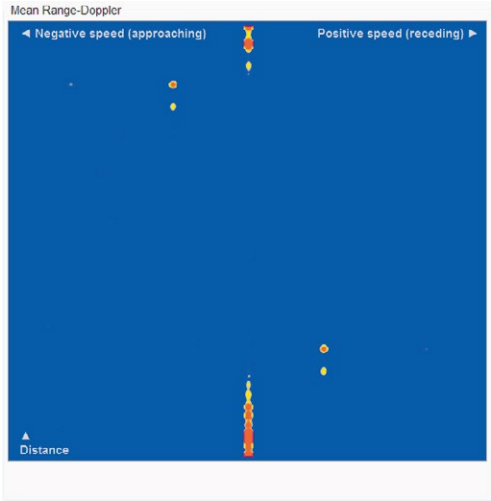


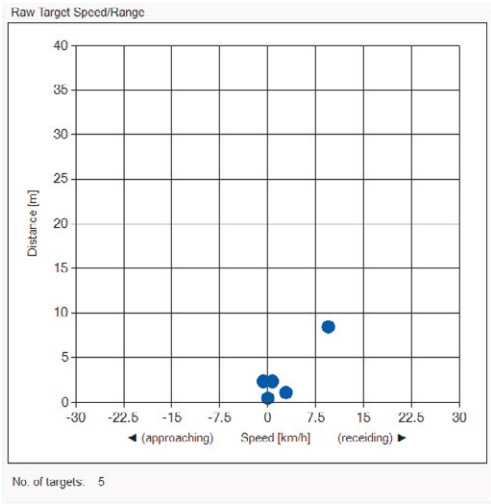
Figure 15: Chirp slices in the range-doppler map



Mean Range-Doppler View

In the mean 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. Targets over the “peak threshold” are shown red.

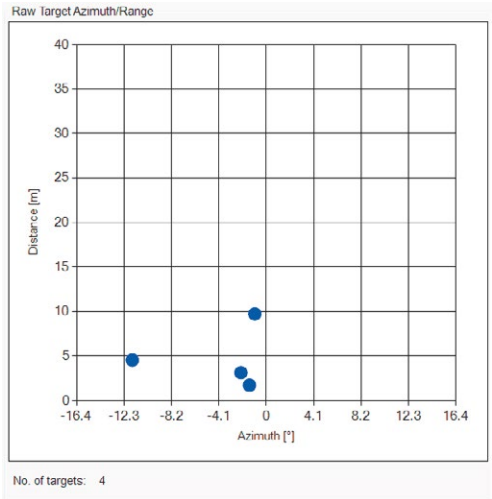
The ADC values are complex values (I-Channel and Q-Channel). Due to hardware coupling of these channels targets in the lower half of the distance are seen mirrored in the upper half of the distance but with less magnitude.



Raw Target Speed/Range View

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

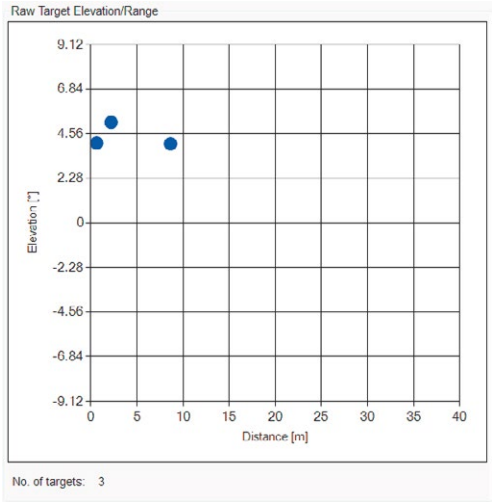
No. of targets:
Count of actually reported raw targets



Raw Target Azimuth/Range View

This view shows the azimuth angle and the distance of the raw targets in the same diagram. It is very helpful for angle measure-ments and to calibrate the azimuth angle.

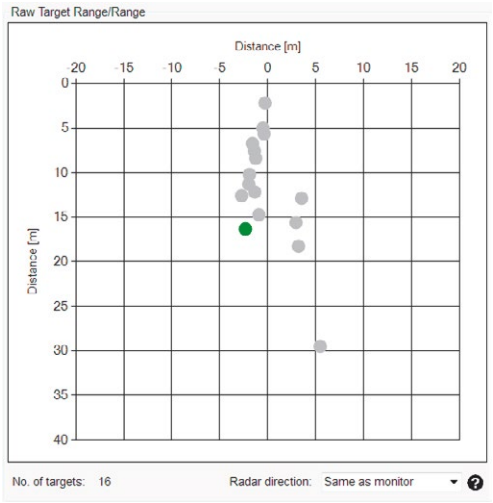
No. of targets:
Count of actually reported raw targets



Raw Target Elevation/Range View

This view shows the elevation angle and the distance of the raw targets in the same diagram. It is very helpful for angle measurements and to calibrate the elevation angle.

No. of targets:
Count of actually reported raw targets

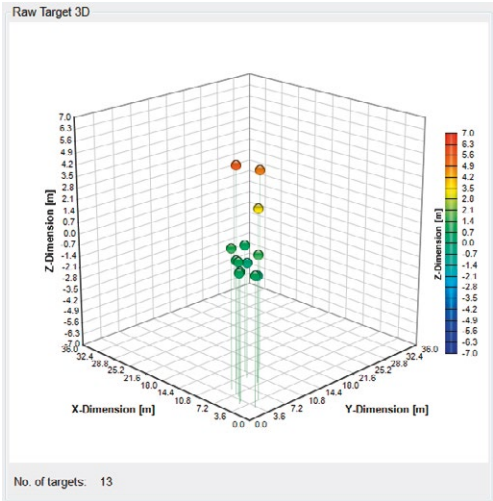


Raw Target Range/Range View

This is one of the most interesting views as the information of the raw targets is interpreted and shown in a two-dimensional map. The targets show the radar's view of the real world. Grey targets are static targets without any speed. Green targets are moving away from the radar and red targets are moving towards the radar.

No. of targets:
Count of actually reported raw targets

Radar direction:
This 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.

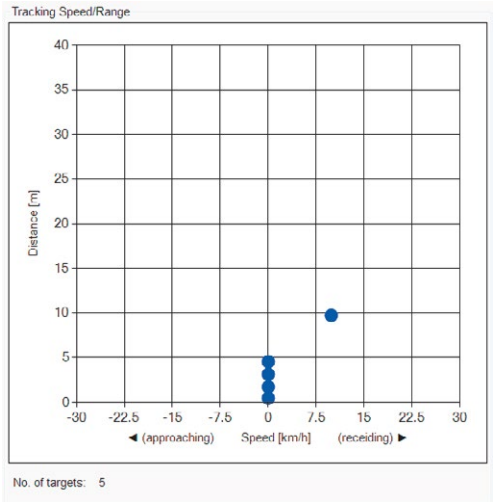


Raw Target 3D View

This view shows the raw targets in three dimensions. The information of the azimuth and elevation angles and the target distance are calculated to the location in a 3D-distance area. The targets are coloured pins and the colour suits to the Z-dimension (elevation).

No. of targets:
Count of actually reported raw targets

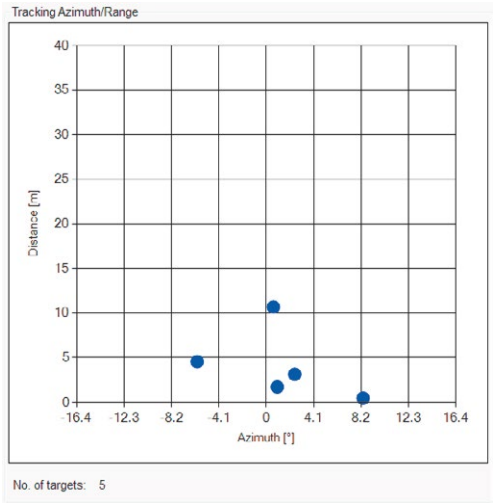
The 3D view can be turned around with the mouse to change the perspective.



Tracking Speed/Range View

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

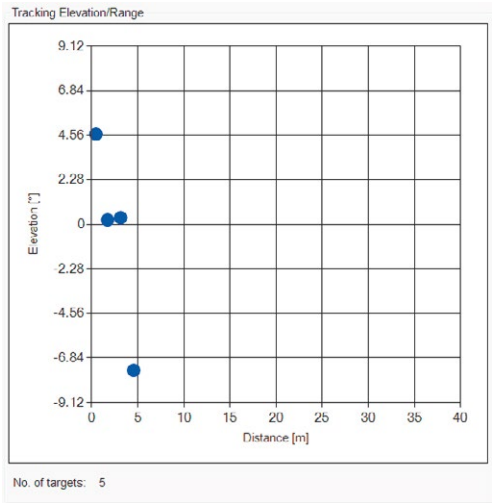
No. of targets:
Count of actually tracked targets



Tracking Azimuth/Range View

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

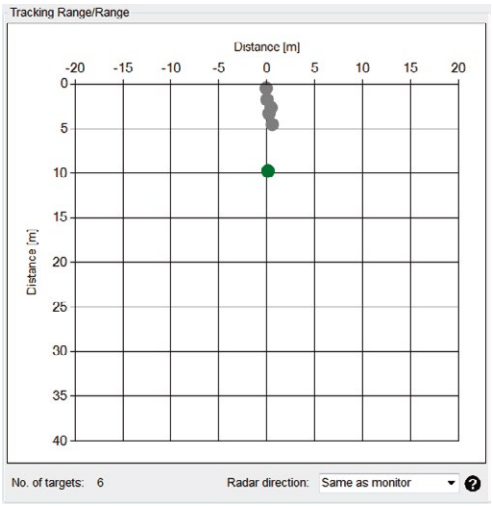
No. of targets:
Count of actually tracked targets



Tracking Elevation/Range View

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

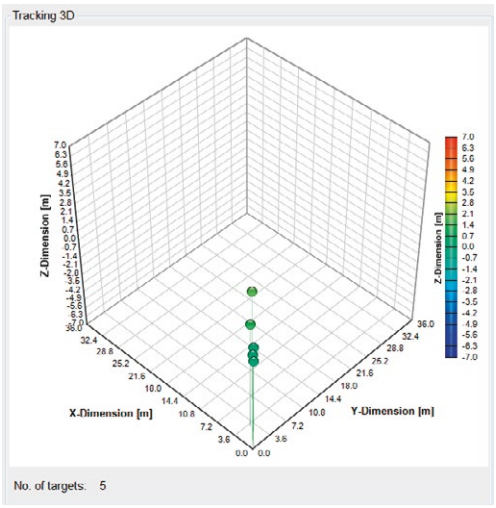
No. of targets:
Count of actually tracked targets



Tracking Range/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



Tracking 3D 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 3D view can be turned around with the mouse to change the perspective.

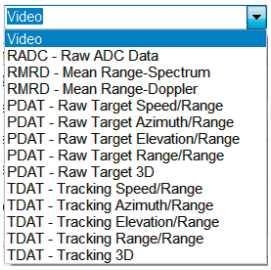


Figure 16: Display dropdown

Display Dropdown

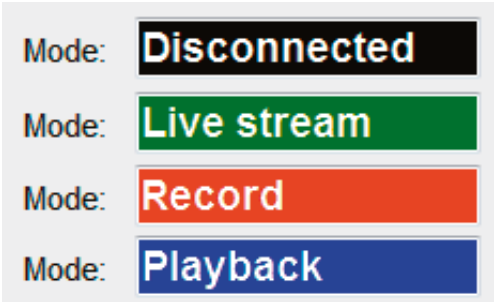
There are two display frames left and right where different views can be shown.

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

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

Dropdown label	Description
Video	Webcam video picture
RADC – Raw ADC Data	ADC values of all RX antennas
RMRD – Mean Range-Spectrum	Cross section of mean range-doppler map
RMRD – Mean Range-Doppler	Averaged range-doppler map of all RX antennas
PDAT – Raw Target Speed/Range	Raw target map speed vs. range
PDAT – Raw Target Azimuth/Range	Raw target map azimuth vs. range
PDAT – Raw Target Elevation/Range	Raw target map elevation vs. range
PDAT – Raw Target Range/Range	Raw target map range vs. range
PDAT – Raw Target 3D	Raw target map in three distance dimensions
TDAT – Tracking Speed/Range	Tracked target map speed vs. range
TDAT – Tracking Azimuth/Range	Tracked target map azimuth vs. range
TDAT – Tracking Elevation/Range	Tracked target map elevation vs. range
TDAT – Tracking Range/Range	Tracked target map range vs. range
TDAT – Tracking 3D	Tracked target map in three distance dimensions

Table 1: Dropdown labels



Modes

Disconnected:
No connection with the K-MD2.

Live stream:
The control panel is connected to the K-MD2 and receives data packets.

Record:
The control panel is connected to the K-MD2 and records the received data packets (saved to hard disk).

Playback:
Recorded data will be played and visualized.

Control Tabs

This chapter discusses the function of all control tabs.

Communication Tab

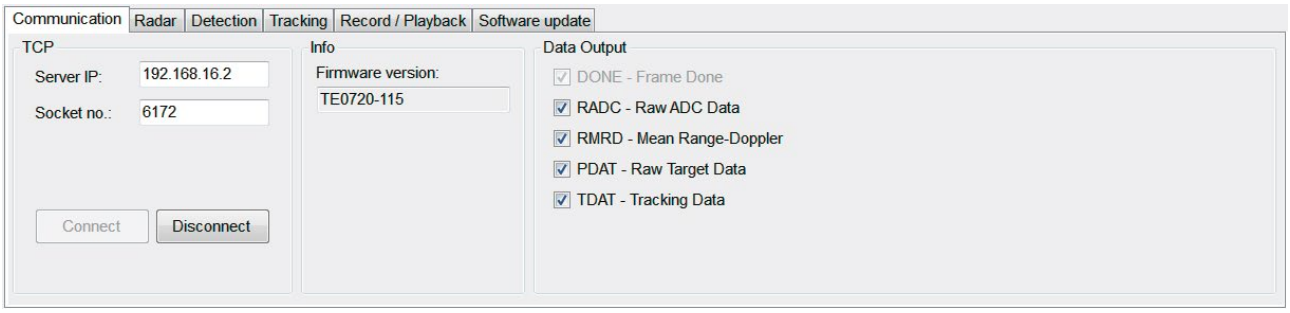


Figure 17: Communication tab

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 K-MD2.

Try several times to connect if the device isn't found. Sometimes the ethernet needs some time to establish the connection. If there is no connection after several times check the settings in the chapter "Installation".

Info

The actual firmware version of the connected K-MD2 is shown.

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 hard disk speed of the PC, it is possible that the cycle time will increase.

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

Radar Tab

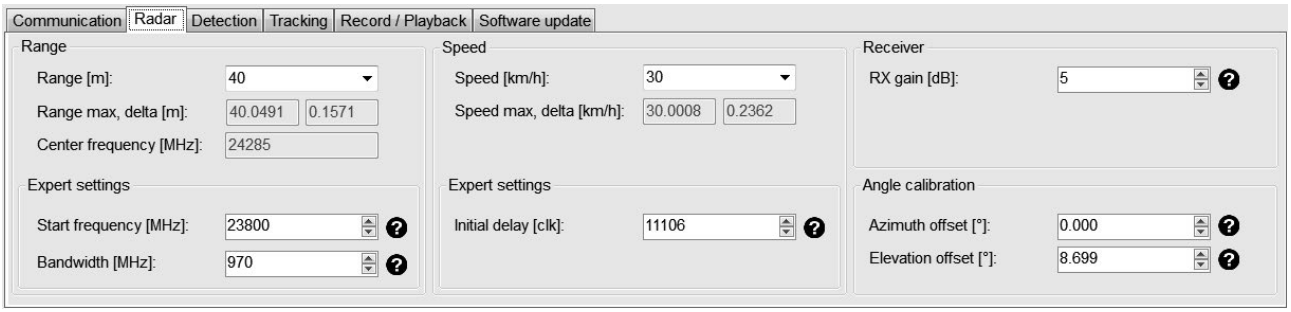


Figure 18: Radar tab

On this tab page, the radar properties can be changed.

Refer to datasheet for detailed description of the parameter.

Range

Range [m]

There are some presets for the range which can be chosen. Depending on this selection the parameters “Start frequency” and “Bandwidth” are changed to meet the specification.

Range max, delta [m]

Depending on the “Bandwidth” parameter, the maximal detectable range and the range resolution are calculated.

Refer to datasheet for calculation formula.

Center frequency [MHz]

Depending on the parameters “Start frequency” and “Bandwidth” the center frequency of the chirp ramp is calculated.

Start frequency [MHz]

This is the start frequency of the FMCW sweep. To reach other center frequencies than those defined by presets, change this parameter.

Bandwidth [MHz]

This is the bandwidth of the FMCW sweep. To reach other maximal ranges and range resolutions adjust the bandwidth.

Speed

Speed [km/h]

There are some presets for the range which can be chosen. Depending on this selection the parameters “Start frequency” and “Bandwidth” are changed to meet the specification.

Speed max, delta [km/h]

Depending on the “Initial delay” parameter the maximal detectable speed and the speed resolution is calculated.

Refer to datasheet for calculation formula.

Initial delay [clk]

This is the delay at every chirp before the ramp starts.
To reach other maximal speeds and speed resolutions adjust the initial delay.

Receiver

RX gain [dB]

Receiver gain in decibels.

Angle calibration

Azimuth offset [°]

To calibrate the device, add an offset to the azimuth angle.

Elevation offset [°]

To calibrate the device, add an offset to the elevation angle.

Detection Tab

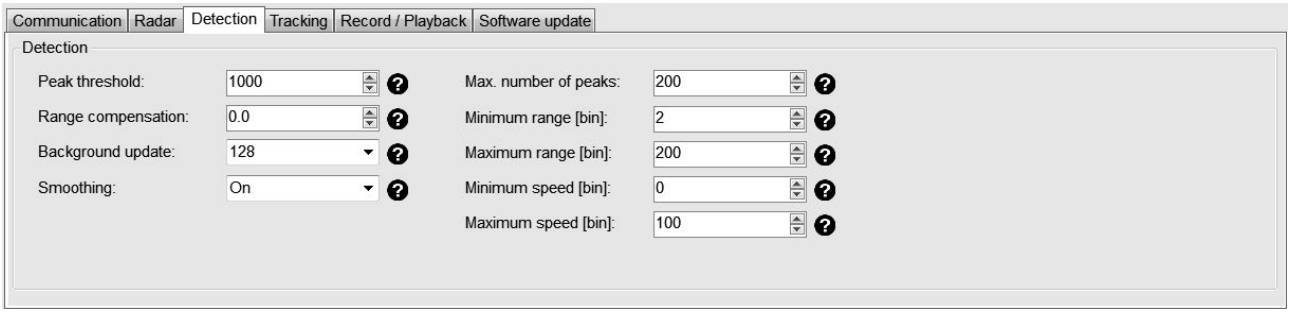


Figure 19: Detection tab

On this tab page, the detection algorithm properties are changeable.

Refer to datasheet for detailed description of the parameter.

Detection

Peak threshold

A peak is detected if it is more than the threshold higher than the exponential moving average (background).

Range compensation

The peak threshold can be adjusted to allow for the expected change in signal with range. The adjustment is made by dividing the threshold by the range to the power of this value.

Background update

The number of frames to average for the background range-doppler map. The background range-doppler is an exponential moving average against which each frame is compared.

Smoothing

Smooth the mean range-doppler map with a 3x3 Gaussian window.

Max. number of peaks

The maximum number of peaks to be detected. Close range peaks are found first.

Minimum range [bin]

The minimum range bin for finding peaks.

Maximum range [bin]

The maximum range bin for finding peaks.

Minimum speed [bin]

The minimum doppler bin for finding peaks.

Maximum speed [bin]

The maximum doppler bin for finding peaks.

Tracking Tab

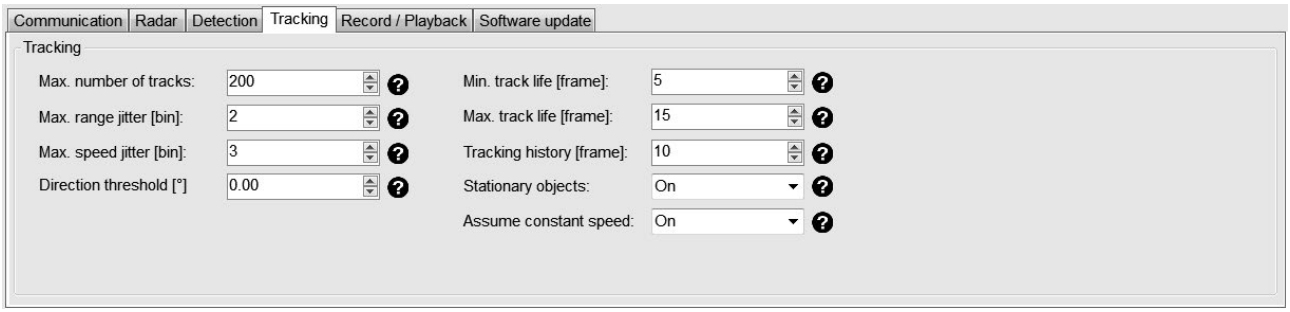


Figure 20: Tracking tab

On this tab page, the tracking properties can be changed.

Refer to datasheet for detailed description of the parameter.

Tracking

Max. number of tracks

The maximum number of tracks to be reported. The internal list length is the same as the maximum number of peaks to find.

Max. range jitter [bin]

Maximum difference in range bins between predicted range and range of the peak.

Max. speed jitter [bin]

Maximum difference in doppler bins between predicted speed and speed of the peak.

Direction threshold [°]

Maximum difference between predicted direction and measured direction of the peak.

Min. track life [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. track life [frame]

When no targets can be associated with a valid tracking channel for this amount of frames, the tracking channel becomes invalid and will no longer be reported.

Tracking history [frame]

Number of previous frames to use in tracking algorithm.

Stationary objects

Report non-moving tracks.

Assume constant speed

Assume constant speed in tracking algorithm.

Record/Playback Tab

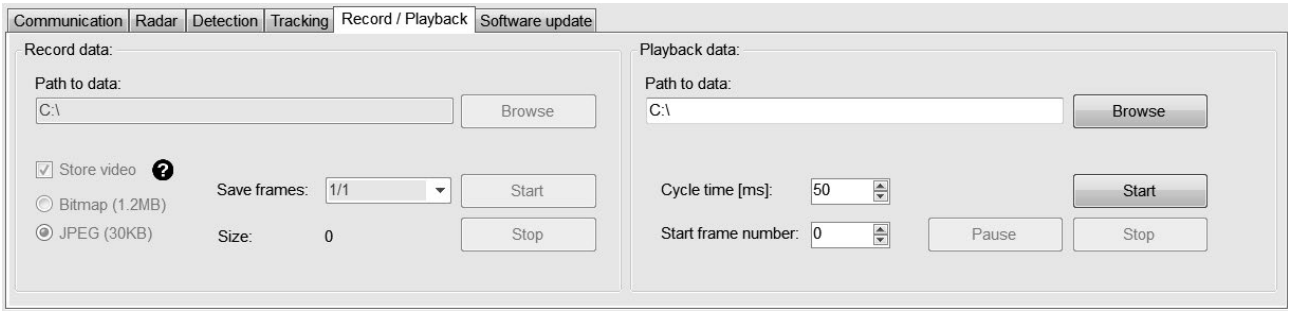


Figure 21: Record/Playback tab

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

Record 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

In the selected folder, a new subfolder is created for every recording. The subfolder contains a binary file where all received data packets are directly stored. If a webcam is available and the “Store video” is selected, a picture is saved for every received frame.

Refer to datasheet for detailed description of the data format and the messages.

In addition to the binary file and the pictures the control panel saves the following two files to the directory:
- sensor_server.conf → Actual configuration of the K-MD2 radar
- versions → Actual firmware versions

Refer to datasheet for detailed description of the configuration parameter.

Playback data

To playback the recorded data, the control panel must be disconnected. At start of playback the control panel loads the configuration of the “sensor_server.conf” file and displays the firmware version of the “versions” file. If there are pictures saved in the directory, the pictures are displayed in the video frame.

Cycle time:
Allows the playback to run faster or slower.

Start frame number:
Allows the recording to be viewed from a 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

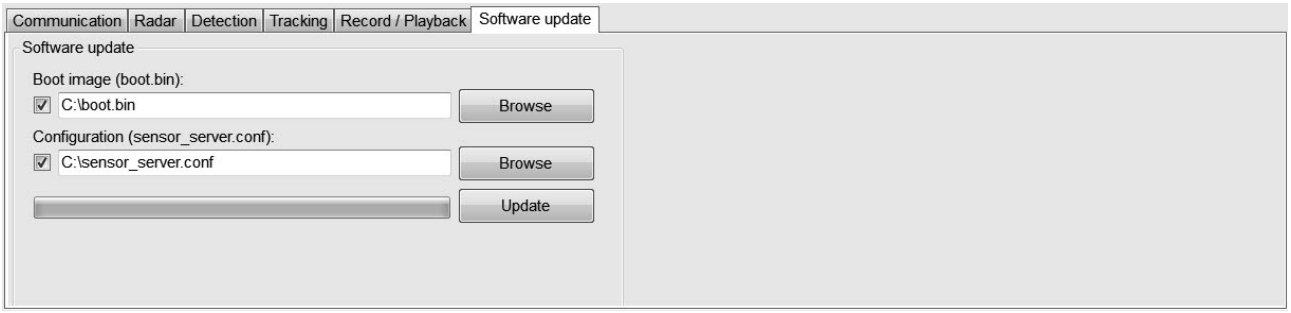


Figure 22: Software update tab

This tab allows the update of the firmware and the configuration file of the K-MD2 over ethernet. It is possible to update the firmware or the configuration file alone or both together. The updates are only possible if the control panel is connected to the K-MD2.

Firmware Update

Figure 23: Select boot image

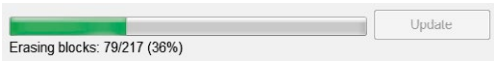


Figure 24: Update status

Figure 25: Update successful

For the firmware update the following procedure must be done:

1. Check the box of the boot image
2. Select a valid binary file of the boot image

Only boot images distributed by RFbeam Microwave GmbH are allowed and supported.

Don't interrupt the update process nor disconnect the ethernet or the power plug. An interruption can result in an irreparable state where the device has to be reprogrammed by RFbeam Microwave GmbH.

3. Start update with "Update" button
4. The update status is displayed above the progress bar
5. The updating procedure takes about a minute
6. After successful update the power of the device must be cycled off/on
7. Connect to the device after restart
8. Check the firmware version on the "Communication Tab"

Configuration Update

For updating the configuration the following procedure must be done:

1. Check the caption of the configuration
2. Select a valid configuration file

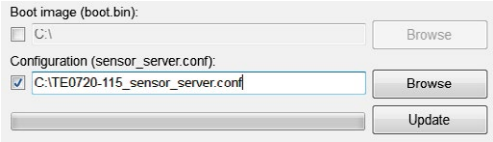


Figure 26: Select configuration file

Only configuration files distributed by RFbeam Microwave GmbH are allowed and supported.

Don't interrupt the update process nor disconnect the ethernet or the power plug. An interruption can result in an irreparable state where the device has to be re-programmed by RFbeam Microwave GmbH.

Figure 27: Update successful

3. Start update with "Update" button
4. The update status is displayed with the progress bar
5. The updating procedure takes about two seconds
6. After successful update the power of the device has to be cycled off/on
7. Connect to the device after restart
8. Check the parameters

SYSTEM REQUIREMENTS

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

REVISION HISTORY

06/2018 – Revision A: Initial Version