RFbeam Microwave GmbH

data sheet

V-MD3

digital 3D radar transceiver

Features

- 61 GHz 3D FMCW radar with digital signal processing
- Measures speed, direction, distance and angle of multiple static or moving objects
- Typical detection distance: 30 m for persons / 80 m for cars
- Target list output over 100BASE-T Ethernet
- Integrated range Doppler processing with tracking
- 2 configurable digital outputs with overcurrent protection
- Wide power supply range from 8 to 32V
- 3 TX and 4 RX patch antennas with 60°/36° beam aperture
- Rugged water-proof housing with M12 connectors for harsh conditions

Applications

- People counting
- Area surveillance
- Collision avoidance
- Security applications
- Industrial measurements
- Level measurements
- Traffic analysis and classification

Description

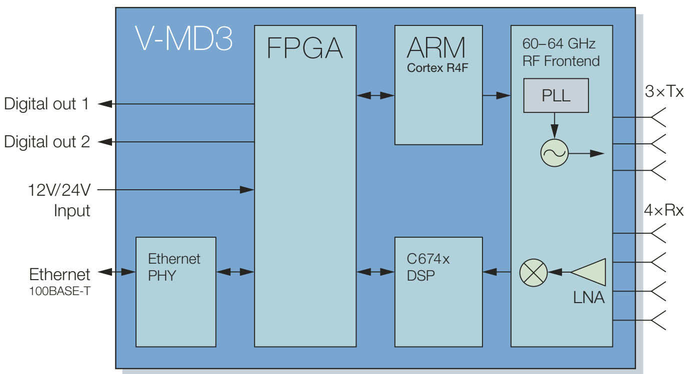
The V-MD3 is a high-end 3D radar transceiver with integrated signal processing and tracking algorithms. It can measure the speed, direction, distance and angle (in azimuth and elevation) of moving and static objects. The digital structure and wide power supply range make it very easy to use this sensor in any stand-alone or MCU based application.

The sensor contains a radar front end with 3 TX and 4 RX patch antennas paired with a powerful FPGA signal processing chain. It has an Ethernet connection for reading out data and for sensor configuration as well as two configurable digital outputs for simple area surveillance or collision avoidance systems. It is possible to read out sensor data from different processing stages, which offers maximum flexibility for easy integration in different customer environments.

There is no need to write own signal processing algorithms or handle small and noisy signals. This module comes with comprehensive functionalities for quick and simplified object detection, observation and measurements. The IP-65 housing with M12 plugs further simplifies integration in harsh environments.

Block Diagram

Figure 1: block diagram



CHARACTERISTICS

Parameter	Conditions/Notes	Symbol	Min	Typ	Max	Unit
Operating Conditions						
Supply voltage		V_{cc}	8.0	12.0/24.0	32.0	V
Supply current @ 12V	Depending on radar setting	$I_{cc@12V}$		300		mA
Peak current		$I_{peak@12V}$			600	mA
Operating temperature		T_{Op}	-20		+85	°C
Storage temperature		T_{St}	-40		+105	°C
Transmitter						
Transmitter frequency	T_{amb} = -20 °C .. +85 °C	f_{TX}	60.0		64.0	GHz
Output power	EIRP	P_{TX}		15	20	dBm
Frequency stability		Δf		50		ppm
Phase noise	@100 kHz	P_N		-80		dBc
Spurious emissions	According to ETSI 305 550	P_{Spur}		-30		dBm
Antenna						
Polarisation				Vertical		
TX antenna gain	f_{TX} = 62.0 GHz	G_{antTX}		9.5		dBi
TX horizontal -3dB beamwidth	E-Plane	$W_{\varphi TX}$		60		°
TX vertical -3dB beamwidth	H-Plane	$W_{\theta TX}$		36		°
RX antenna gain	f_{TX} = 62.0 GHz	G_{antRX}		9.5		dBi
RX horizontal -3dB beamwidth	E-Plane	$W_{\varphi RX}$		60		°
RX vertical -3dB beamwidth	H-Plane	$W_{\theta RX}$		36		°
RX horizontal spacing	E-Plane	$l_{\varphi RX}$		2.464		mm
RX vertical spacing	H-Plane	$l_{\theta RX}$		2.464		mm
Receiver						
Receiver sensitivity		P_{RX}		-141		dBm
Overall sensitivity	S/N = 12 dB	S		-144		dBc
Signal Processing						
Modulation				FMCW		
Speed range	Depending on radar setting	r_{speed}	0.1		100	km/h
Speed resolution	Depending on radar setting	Δr_{speed}	0.3		3.1	km/h
Distance range	Depending on radar setting	$r_{distance}$	0.3		100	m
Distance resolution	Depending on radar setting	$\Delta r_{distance}$	4.7		78.2	cm
Angular resolution		Δr_{angle}		1		°
Number of raw targets		N_{raw}	0		150	
Update rate	Depending on radar setting			130		ms
Output						
Ethernet output				100BASE-T		
Digital output high level		$V_{OH@10mA}$		VCC-0.8V		V
Digital output low level		$V_{OL@10mA}$		0.8V		V
Digital output source/sink current		I_{OH}, I_{OL}	-300		300	mA
Electrostatic discharge	IEC 61000-4-2	V_{ESD}			6	kV
Surge immunity	IEC 61000-4-4	V_{Surge}			3	kV
Burst immunity	ICE 61000-4-5	V_{Burst}			1.5	kV
Body						
Outline dimensions				76 × 56 × 27.6		mm^3
Weight				112		g
Connector				2 × 4pin M12		
Rating case				IP-65		

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ANTENNA DIAGRAM CHARACTERISTICS

This diagram shows module sensitivity in both azimuth and elevation directions. It incorporates the transmitter and receiver antenna characteristics and is identical for all RX and TX antennas.

Figure 2: Antenna characteristics

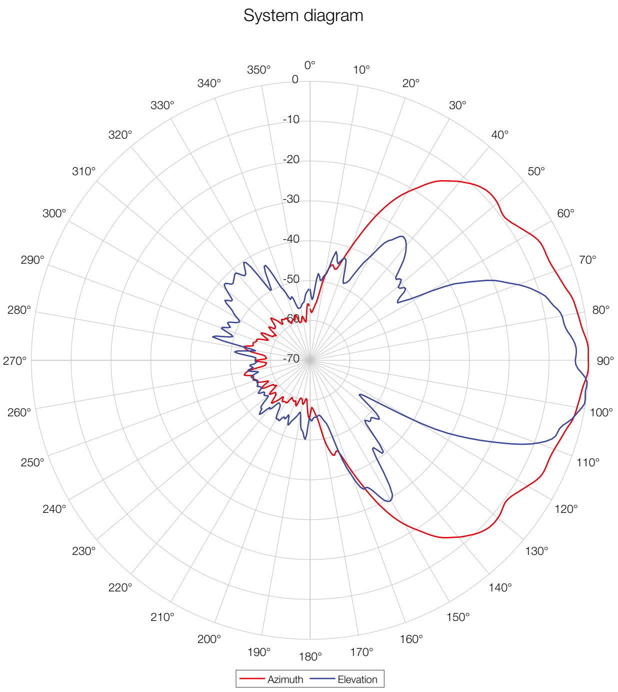
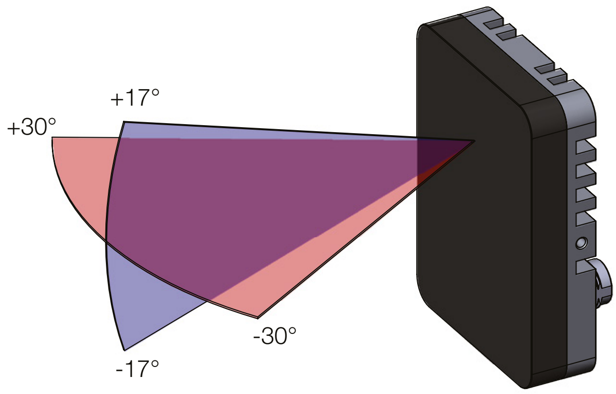


Figure 3: Antenna orientation



PIN CONFIGURATIONS AND FUNCTIONS

Figure 4: Pin configuration

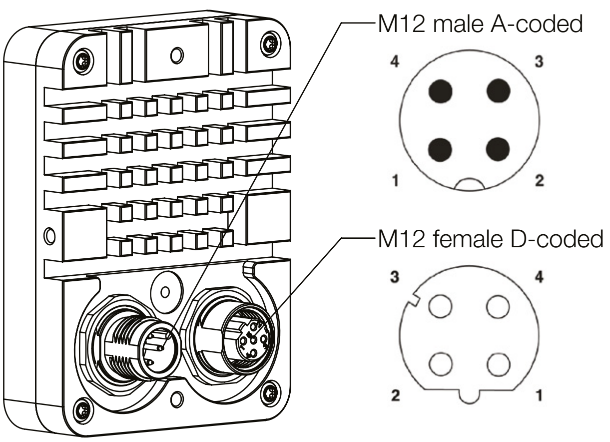


Table 1: Pin function description

Connector	Pin. No.	Name	Description
M12 male A-coded	1	VCC	Power supply pin (8 to 32V)
	2	Digital out 1	Digital detection output. The function is programmable over the instruction set.
	3	GND	Ground pin
	4	Digital out 2	Digital detection output. The function is programmable over the instruction set.
M12 female D-coded	1	TX+	Ethernet TX+ pin
	2	RX+	Ethernet RX+ pin
	3	TX-	Ethernet TX- pin
	4	RX-	Ethernet RX- pin

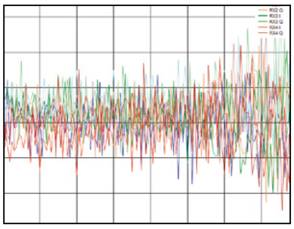
THEORY OF OPERATION

Overview

The V-MD3 is a digital 3D FMCW radar that consists of a 61GHz RF front end and a FPGA for signal processing and communication via Ethernet. In addition, it has two configurable digital outputs to ease area monitoring. The RF front end sends a frame of FMCW chirps and samples the received signals for all receiving antennas. The FPGA calculates a range Doppler map based on the sampled data. The further processing allows the measurement and tracking of speed, direction, distance and 2D angle of several moving and static objects in front of the sensor.

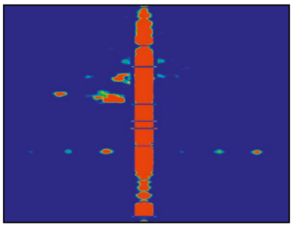
Processing

The processing of the V-MD3 is based on the raw ADC signals that are generated by a frame of several FMCW chirps of the RF front end, which is described in more detail in the next chapters. The sensor uses different processing stages to measure and track the speed, direction, distance and 2D angle of objects in front of the sensor. To get full control in an application, the data of each processing step can be read out via the Ethernet interface.



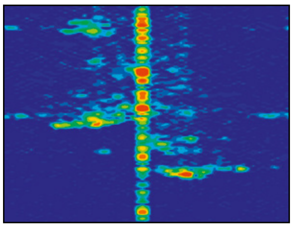
Raw ADC data (RADC)

- Samples ADC data from all 4 RX antennas directly in the RF front end for each frame
- Sends data to the FPGA for further processing



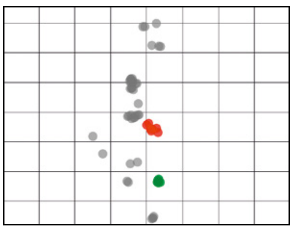
Raw Range-Doppler (RFFT)

- Calculates the raw range Doppler map for all 4 RX antennas



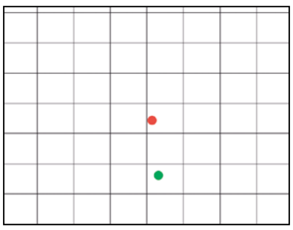
Mean Range-Doppler (RMRD)

- Averages the raw range Doppler map of all 4 RX antennas
- Logarithmises the averaged range Doppler map



Raw Target Data (PDAT)

- Searchs up to 150 targets in the range Doppler map
- Calculates the angle for the raw targets



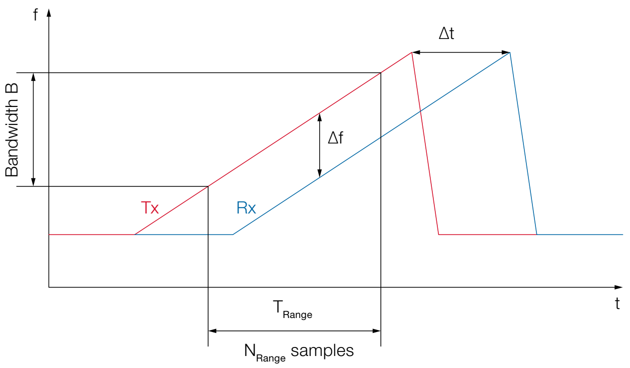
Tracking Data (TDAT)

- Assigns objects to tracking channels
- Predicts momentary lost objects

Distance and speed measurement

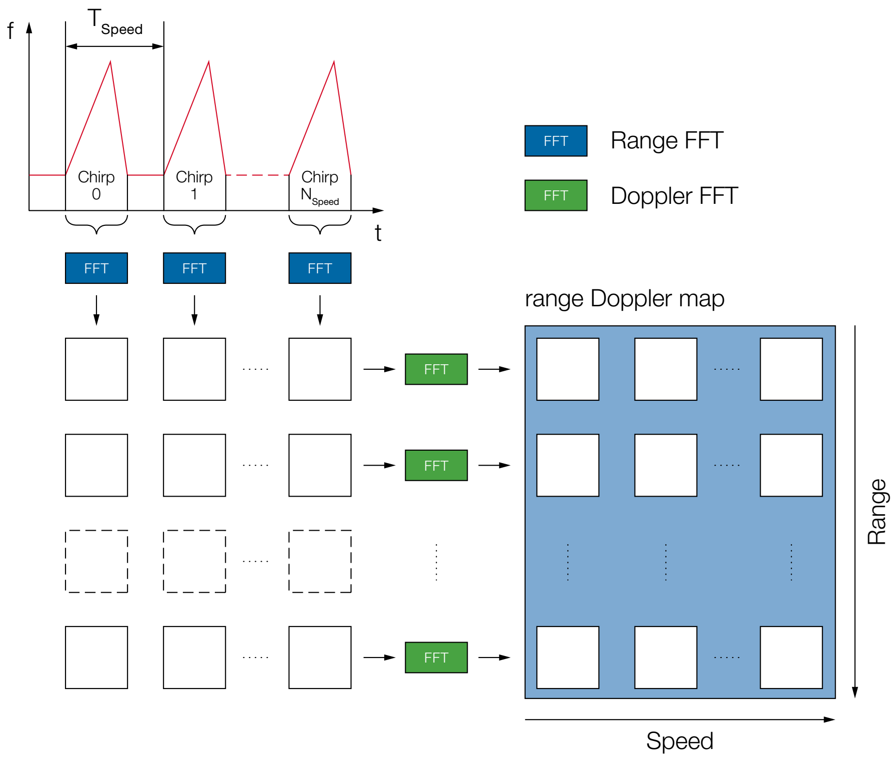
The V-MD3 measures the distance to static and moving objects using FMCW modulation. In a typical FMCW radar system, the TX carrier frequency is modulated with a digitally generated linear ramp with N_{Range} steps, also known as chirp. A chirp that is reflected on an object is received again after Δt, which is proportional to the distance to the object. This delay generates a constant frequency difference Δf in the demodulated signal. At every step in the ramp, the reflected signal is demodulated and sampled by the ADC for each RX antenna. Objects with different distances thus generate different frequencies in the sampled time domain signal. An FFT is used to transform the ADC samples into the frequency domain. The FFT magnitude spectrum contains the reflections of all objects in front of the sensor, which are represented by different frequencies. The higher the frequency, the further away the object is.

Figure 5: FMCW TX and RX chirp example



To measure the speed the V-MD3 sends N_{Speed} FMCW range chirps spaced with the time T_{Speed}. These multiple chirps are called a frame. Each reflected chirp is processed by means of a FFT to detect the range of the objects as described in the last chapter (range-FFT). The range-FFT corresponding to each chirp will have magnitude peaks in the same location, but with a different phase. The measured phase difference between the chirps corresponds to a motion of the objects. A second FFT, called Doppler-FFT, is performed over the phase information of each range bin over the number of chirps. The output of this Doppler-FFT allows the measurement of the speed and direction of the objects. The sensor then combines the range- and Doppler-FFT to an array called range Doppler map with the resolution $N_{Range} \times N_{Speed}$ Pixels.

Figure 6: Range Doppler map processing

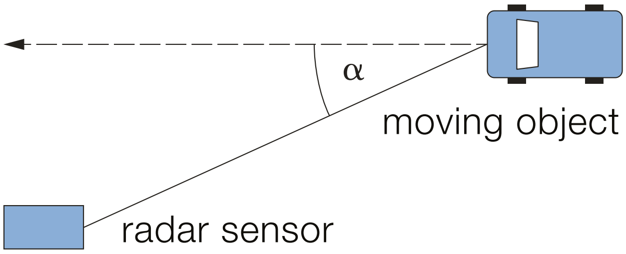


Speed compensation

The measured speed is only accurate if the direction of movement of the target is radial to the sensor. If the direction is tangential, the speed must be compensated with the formula below. This compensation has to be performed in azimuth and elevation to get the real speed of the moving object.

$$v_{real} = v_{measured} \cdot cos(\alpha)\ [km/h]$$

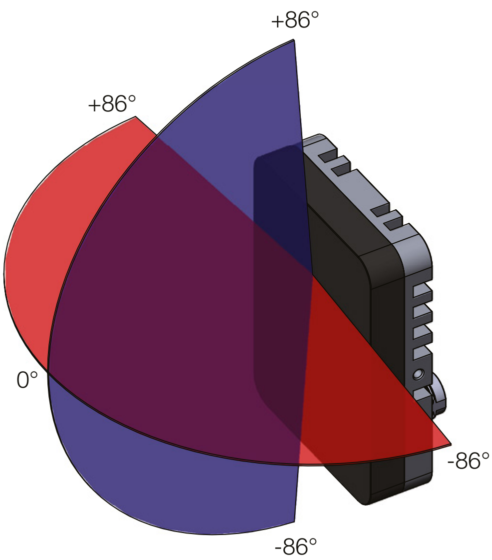
Figure 7: Tangential speed compensation



Angle measurement

The antenna pattern of the sensor enables angle measurement in azimuth and elevation. An algorithm searches for targets above a threshold in the range Doppler map and calculates the angles to the targets based on the phase difference generated by the physical locations of the TX and RX antennas.

Figure 8: Azimuth and elevation valid angle definition



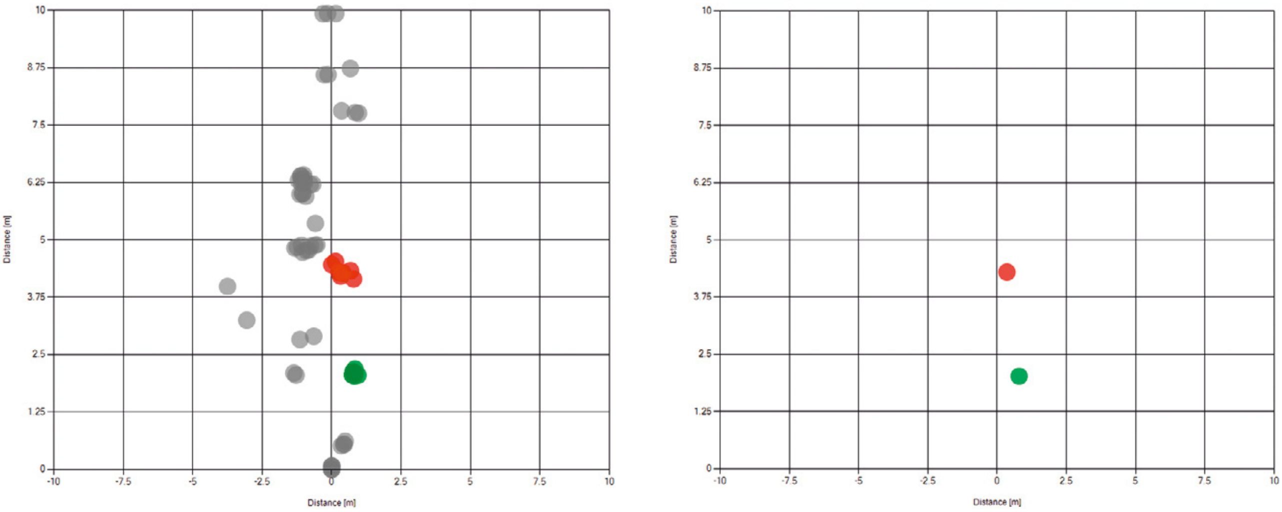
The angle is calculated in degrees and is valid between ±86°. If an object has an angle of zero in azimuth and elevation, it is directly in front of the sensor.

Raw targets and tracking filter

A real object does not just create one raw target point. For example, a moving person creates multiple raw target points at different speeds and distances that are created by the torso, legs and arms. This results in a so-called point cloud. Depending on the environment in which the sensor is used, more or less reflections are generated by the moving object. The number of raw targets can be controlled by adjusting the sensitivity setting of the sensor.

The sensor contains a tracking filter which provides a user-friendly output. The filter groups and tracks the dominant targets based on the point cloud of the raw targets and can predict temporarily lost targets, which allows good suppression of reflections and interferences.

Figure 9: Raw targets vs. tracked targets



APPLICATION INFORMATION

Stand-alone operation

With its standard settings, the V-MD3 can be used as simple area surveillance or collision avoidance sensor. Two digital outputs are available that can be used directly without a host. By default, the outputs are configured as follows:

The V-MD3 can also be factory configured with your settings. Please contact RFbeam for more information.

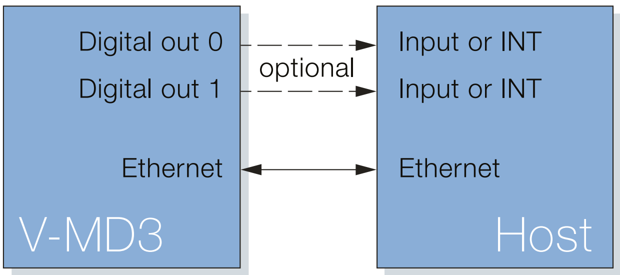
Table 2: Default digital output description

Connector	Pin	Name	Description
M12 male A-coded	2	Digital out 1	Monitors an area of 3 × 3m in the horizontal plane in front of the sensor. If an object is detected in this zone, the output switches to high.
M12 male A-coded	4	Digital out 2	Monitors an area of 1.5 × 1.5m in the horizontal plane in front of the sensor. If an object is detected in this zone, the output switches to high.

Host driven operation

By connecting the Ethernet interface to a host (e.g. MCU or PC), all sensor parameters can be configured. The complete processing data (RADC, RFFT, RMRD, PDAT, TDAT) can be read out in real time in order to obtain maximum flexibility when evaluating the data in your own signal processing. The sensor also features a firmware update function over this interface. This is the recommended use case and allows the user to easily optimize the sensor for different applications.

Figure 10: Host driven connection example



Radar settings

The V-MD3 comes with different predefined radar processing settings. The settings differ mainly with regard to the maximum measuring distance, the maximum measurable speed or whether the angle is only measured in azimuth (Angle setting 2D) or also in elevation (Angle setting 3D). The following table gives an overview of the different available settings:

Table 3: Predefined radar settings

Setting number	Max. range [m]	Max. speed [km/h]	Range samples N_{Range}	Speed samples N_{Speed}	Angle setting	Frame rate [ms]	Range resolution [cm]	Speed resolution [km/h]
1	6	10	128	64	2D	130	4.69	0.31
2	10	10	128	64	2D	130	7.82	0.31
3	30	30	128	64	2D	130	23.43	0.94
4	30	50	128	64	2D	130	23.43	1.56
5	50	50	128	64	2D	130	39.12	1.56
6	100	100	128	64	2D	130	78.18	3.14
7	6	10	128	32	3D	130	4.69	0.63
8	10	10	128	32	3D	130	7.82	0.63
9	30	30	128	32	3D	130	23.41	1.88

Maximum range

The setting for the maximum range defines the maximum possible measuring range without ambiguity. If there are objects in front of the sensor that are further away than the defined maximum range, the sensor measures the wrong distance. Therefore it is very important to choose a setting with a maximum range where targets are expected.

An approach to work with a lower maximum range setting is to change the sensor orientation to get a field of view without objects that are further away than the maximum range or to decrease the sensitivity in the detection settings.

Range resolution and samples

Range resolution defines the ability to separate two or more targets with different distances. If the distance difference between two objects is less than the defined range resolution, the sensor cannot separate the objects by the distance. It is defined by the maximum range divided by the number of range samples N_{Range} used in the range Doppler map processing as described in the chapter theory of operation.

Maximum speed

The setting for the maximum speed defines the maximum possible speed measuring without ambiguity. If there are objects in front of the sensor that are faster than the defined maximum range, the sensor measures the wrong speed. Therefore it is very important to choose a setting with a maximum speed where targets are expected.

It is possible to filter out targets by changing the minimum and maximum speed detection setting. This makes it very easy to filter out static objects or to filter out cars when you only want to measure persons.

Speed resolution and samples

Speed resolution defines the ability to distinguish two or more targets at different speeds. If the speed difference between two objects is less than the defined speed resolution, the sensor cannot separate the objects using the speed. It is defined by the maximum speed divided by the number of speed samples N_{Speed} used in the range Doppler map processing as described in the chapter theory of operation.

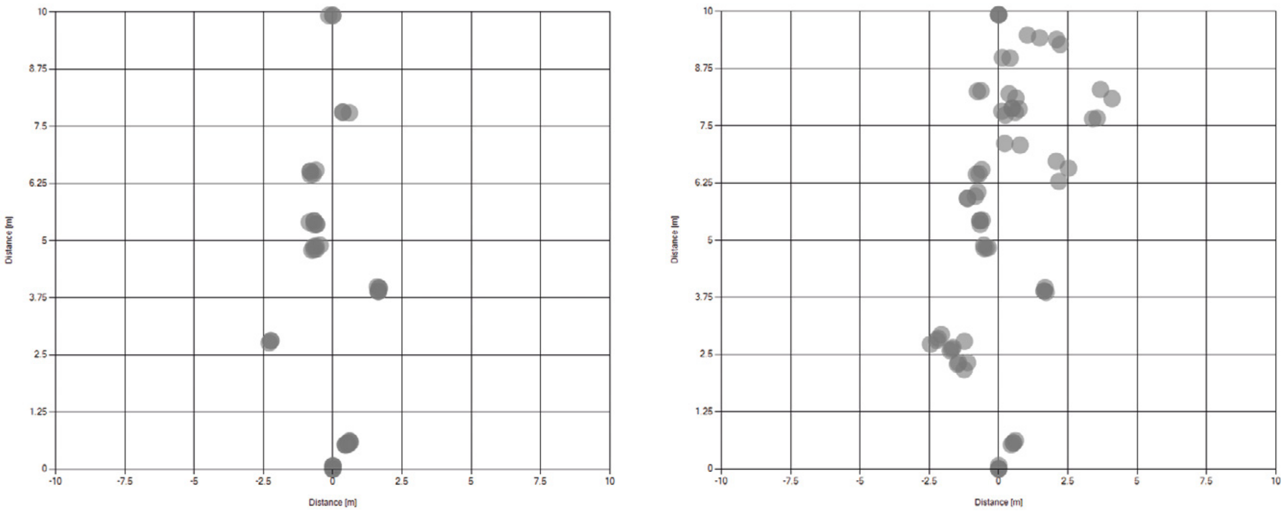
Detection settings

The algorithm for finding targets in the range Doppler map can be adapted via various parameters. The idea behind these parameters is to narrow down the PDAT raw targets before they are fed into the tracking filter. This allows the user to easily adapt the sensor to his requirements.

Sensitivity

The sensitivity of the sensor can be set in 16 steps using a parameter. A higher sensitivity setting produces more raw targets and a lower sensitivity setting reduces the number of raw targets in the PDAT output. This parameter can be used to reduce the number of targets in a short-range setting or to increase the maximum detection distance in a long-range setting.

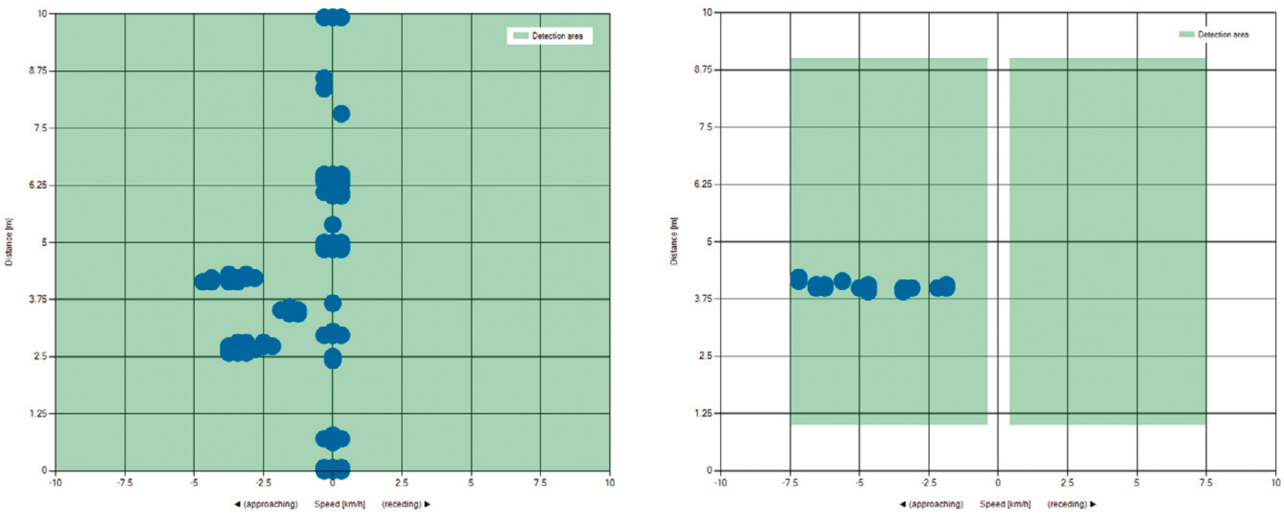
Figure 11: Influence of sensitivity in relation to raw targets



Distance and speed limitation

It is possible to limit the minimum and maximum distance and speed of the PDAT target search algorithm. By changing the minimum speed parameter, it is possible to filter out static targets or targets with low speeds such as persons. With the maximum speed parameter, fast objects such as cars can be filtered out. The same can be done by limiting the minimum or maximum distance.

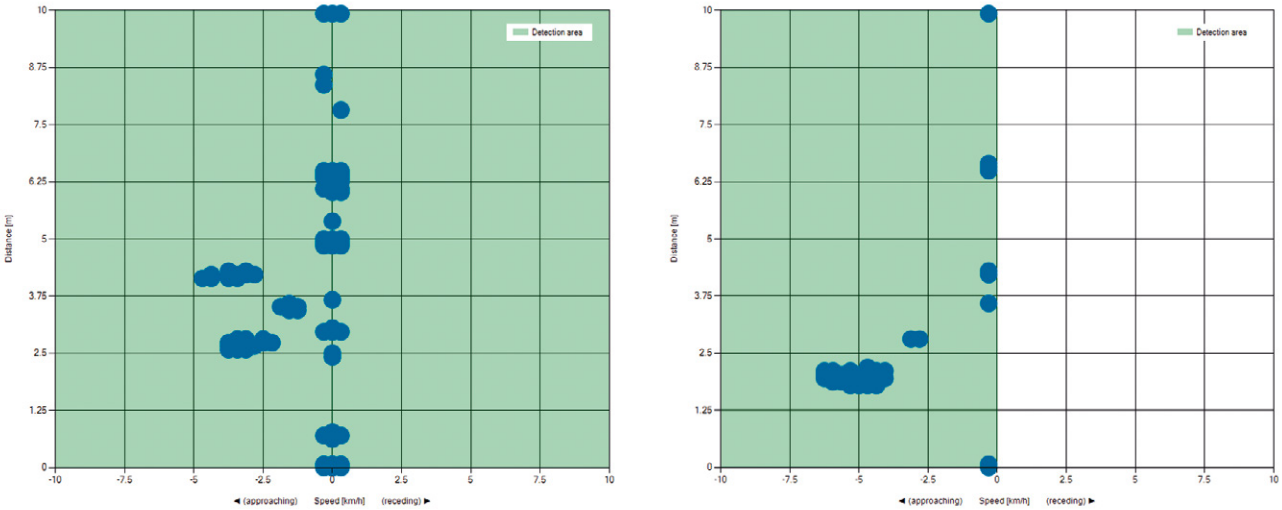
Figure 12: Influence of distance and speed limitation to raw targets



Detection direction

Using the parameter detection direction, it is very easy to restrict the PDAT target search algorithm so that it only searches for approaching or receding targets.

Figure 13: Influence of detection direction to raw targets



Tracking settings

The V-MD3 has a powerful tracking filter that groups and tracks different targets based on the PDAT raw targets. It is possible to adapt the tracking filter to the requirements of different applications using three parameters.

Table 4: Tracking filter parameters

Parameter name	Description
Minimum life time	The minimum life time defines how many frames are required before the tracking filter declares a target as valid and adds them to the TDAT package. Low value → The targets are recognized very quickly, with the disadvantage that the risk of incorrect detection increases. High value → It takes longer for targets to be recognized with the advantage of better suppression of false detections
Maximum life time	The maximum life time defines how many frames are required before the tracking filter declares a valid target as invalid and removes them from the TDAT package. Low value → The targets are lost very quickly when they are no longer available in the raw targets. High value → The targets are available for a longer period of time as the tracking filter predicts temporarily lost targets.
Static objects	With this parameter all static targets can be removed from the TDAT package.

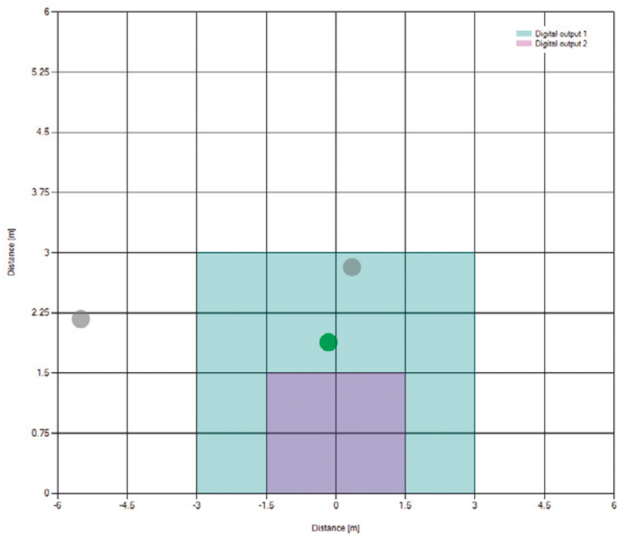
Digital outputs

The sensor has two digital outputs that can be used to indicate whether a PDAT/TDAT target is within a certain area in the azimuth plane. Each output has its own parameter set and can be configured to indicate a valid detection in a specific area. This can be used to implement simple area surveillance or collision avoidance applications without the need for an Ethernet connection.

Table 5: Digital outputs filter parameters

Parameter name	Description
Minimum and maximum width	Defines the minimum and maximum limit of the detection area in the X axis.
Minimum and maximum height	Defines the minimum and maximum limit of the detection area in the Y axis.
Polarity	With this parameter the polarity of the output can be set to high or low active.
Data basis	Defines whether the PDAT or TDAT data is used as the basis for the detection.

Figure 14: Default detection areas for digital outputs



Settings

It is possible to change the sensor‘s IP address using a command. This enables the use of different sensors in the same network area. Please refer to the instruction set description for more details on how to change the IP address.

The sensor also offers the option of resetting all parameters to the factory settings. This command can be very helpful to return to the default settings.

The V-MD3 can also be factory configured with your settings. Please contact RFbeam for more information.

INSTRUCTION SET DESCRIPTION

Transport Layer

The V-MD3 communicates via a 100 Base-T Ethernet interface. Commands to control the radar are sent over the TCP/IP protocol and data output messages from the radar are sent over the UDP protocol to the host.

> The host can configure the IP address and UDP port to connect to multiple sensors.

TCP/IP:
- Commands and responses
- Default server IP: 192.168.100.201
- Default server port number: 6172

UDP:
- Data output messages
- Default server port number: 4567

Presentation Layer

All commands and messages sent have the format described in the table below.

Table 6: Data packet format

Description	Datatype	Length
Header The header describes the command or message type (e.g. RADC, RMRD, …)	ASCII character	4 Bytes
Payload Length The payload length is always sent even if the payload is zero. It is sent as little endian (LSB first).	UINT32	4 Bytes
Payload The payload is message and command dependent. If the payload includes datatypes (e.g. UINT16, INT32, …) then they are sent as little endian (LSB first).	Binary data	0–196608 Bytes

Figure 15: Example INIT command

host to radar	Header: INIT				Length: 0Byte				Payload: Nothing			
	0x49	0x4E	0x49	0x54	0x00	0x00	0x00	0x00				
radar to host	Header: RESP				Length: 1Byte				Payload 1Byte: OK			
	0x52	0x45	0x53	0x50	0x01	0x00	0x00	0x00	0x00			

Figure 16: Example RDOT command

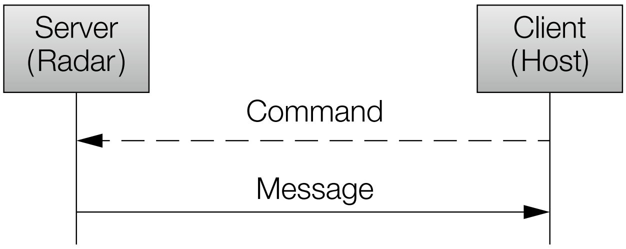
host to radar	Header: RDOT				Length: 4Byte				Payload 4Byte: DONE & PDAT			
	0x52	0x44	0x4F	0x54	0x04	0x00	0x00	0x00	0x28	0x00	0x00	0x00
radar to host	Header: RESP				Length: 1Byte				Payload 1Byte: OK			
	0x52	0x45	0x53	0x50	0x01	0x00	0x00	0x00	0x00			

Figure 17: Example PDAT message

radar to host	Header: PDAT				Length: 2000Byte				Payload 1500Byte: 150 Raw targets			
	0x50	0x44	0x41	0x54	0xD0	0x07	0x00	0x00	…	…	…	…

Client Server

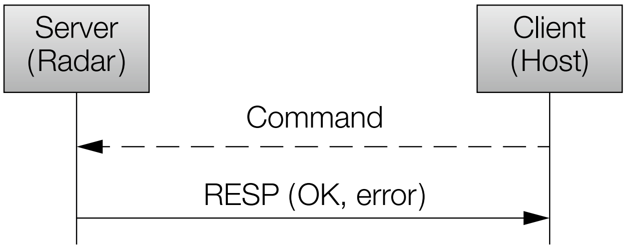
Figure 18: Client-Server model



The communication is based on a client-server model. There are two types of packets transmitted. Commands are sent from client to server and messages are sent from server to client.

Handshaking

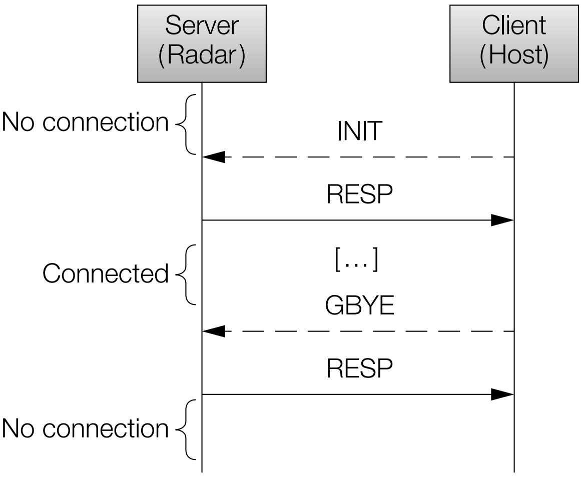
Figure 19: Handshaking



Every command sent by the client is acknowledged by the server with a response message (RESP). The response message includes information data about the success or failure of the received command.

Connection

Figure 20: Connection



To connect and disconnect from the radar module a connection procedure is used. The client has to send the INIT command over TCP/IP to establish a connection with the server. To disconnect from server the GBYE command must be sent from client.

Start-Up

The V-MD3 includes a boot loader which is able to update the application software. After power on, the boot loader starts up. If an INIT command is received within four seconds the radar module is ready for a firmware update. If no INIT command is received within four seconds the application is started.

Figure 21: Normal start-up with no connection to boot loader

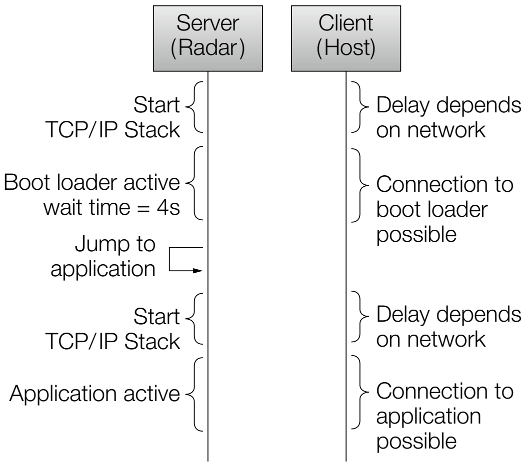
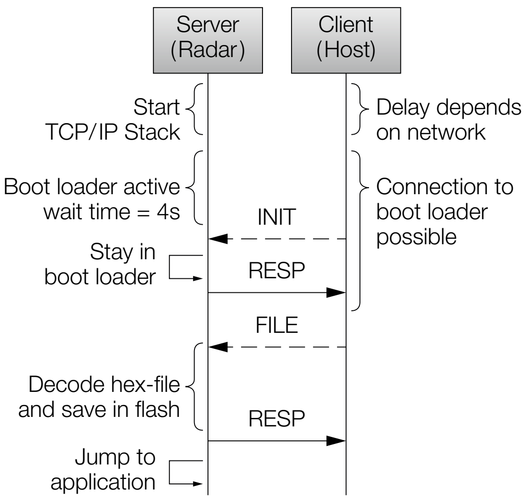


Figure 22: Start-up with connection to boot loader and firmware update



Bootloader

The boot loader starts up with a fixed IP and port. All its commands and messages are sent via the TCP/IP protocol.

– Default boot loader IP: 192.168.100.200
– Default boot loader port number: 6172

Commands

The following table shows all commands which can be sent by the client.

Table 7: Boot loader commands

Header	Payload Length	Description	Values
`INIT`	0	Start of connection	–
`GBLI`	0	Get boot loader information BLIN	–
`FILE`	Max. 2Mbyte	Hex-File for firmware update	Complete binary application hex-file (distributed by RFbeam Microwave GmbH)
`GBYE`	0	Disconnect	–

Messages

The following list shows all messages which are sent by the boot loader.

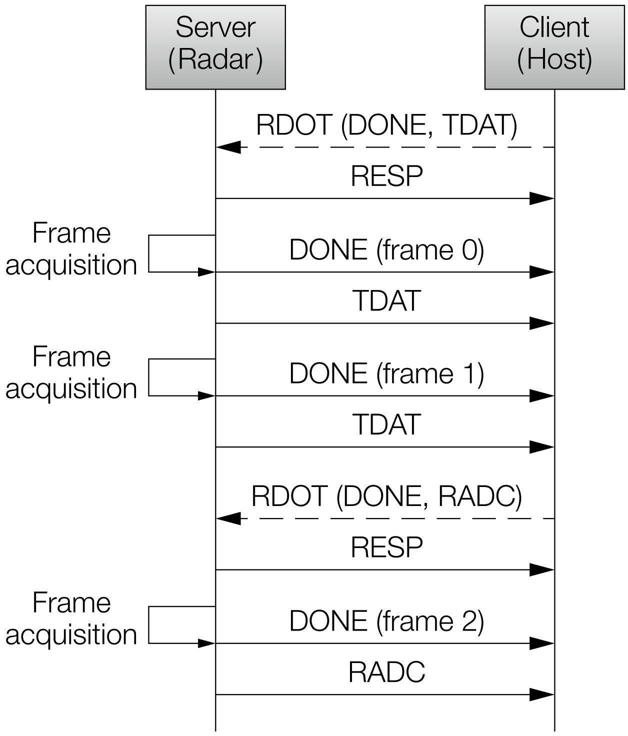
Table 8: Boot loader messages

<table>
<tr><th>Header</th><th>Payload Length</th><th>Description</th><th>Payload</th></tr>
<tr><td>RESP</td><td>1</td><td>Response</td><td>0 = OK
1–3 = Reserved
4 = Bootloader entry
5 = Invalid HEX checksum
6 = Invalid HEX record
7 = Not enough memory
8 = Flash error</td></tr>
<tr><td>BLIN</td><td>20</td><td>Boot loader information</td><td><table>
<tr><th>Description</th><th>Datatype</th><th>Length</th></tr>
<tr><td>Bootloader firmware description.
String terminated by 0x00.
(e.g. V-MD3_BTL-RFB-0100)</td><td>String</td><td>19</td></tr>
<tr><td>FPGA Version</td><td>UINT8</td><td>1</td></tr>
</table></td></tr>
</table>

Data output

When a connection between the server application and the client is established the client can enable and disable cyclic data output messages from client with the RDOT command. All data output messages are sent per UDP protocol.

Figure 23: Data output messages



Get and set parameter structure

The client can set every parameter with a separate command. There is also the possibility to collectively set all parameters within a parameter structure or read out this structure. Please refer to chapter "Parameter structure" for detailed description.

Figure 24: Get parameter structure

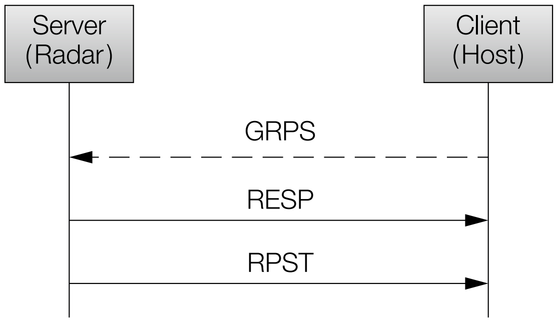
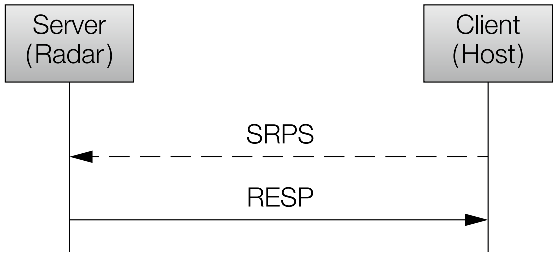


Figure 25: Set parameter structure



Parameter structure

The radar has a set of parameters which can be modified with single commands or all parameters can be set with the SRPS command. With the GRPS command all changeable parameters and a set of information parameters can be read out.

Table 9: Changeable parameters

Description	Datatype	Length	Values	Default
Software Version	STRING	19	Zero-terminated String	V-MD3_APP-RFB-XXXX
FPGA Version	UINT8	1	0..255	1
Radar settings	UINT8	1	0 = 2D, 6m, 10km/h, 128/64 1 = 2D, 10m, 10km/h, 128/64 2 = 2D, 30m, 30km/h, 128/64 3 = 2D, 30m, 50km/h, 128/64 4 = 2D, 50m, 50km*h, 128/64 5 = 2D, 100m, 100km/h, 128/64 6 = 3D, 6m, 10km/h, 128/32 7 = 3D, 10m, 10km/h, 128/32 8 = 3D, 30m, 30km/h, 128/32	6 = 3D, 6m, 10km/h, 128/32
Sensitivity	UINT8	1	0..15, 0 = Minimum sensitivity, 15 = Maximum sensitivity	10
Minimum detection distance	UINT8	1	0..100% of max range defined by used radar setting	5%
Maximum detection distance	UINT8	1	0..100% of max range defined by used radar setting	95%
Minimum detection speed	UINT8	1	0..100% of max speed defined by used radar setting	0%
Maximum detection speed	UINT8	1	0..100% of max speed defined by used radar setting	100%
Detection direction	UINT8	1	0 = Receding 1 = Approaching 2 = Both	2 = Both
Static objects for tracking	UINT8	1	0 = Disable 1 = Enable	1 = Enable
Tracking minimum life time	UINT8	1	0..100 frames	10 frames
Tracking maximum life time	UINT8	1	0..100 frames	10 frames
Digital output 1 Xmin	INT8	1	-100..100% of max range defined by used radar setting	-50%
Digital output 1 Xmax	INT8	1	-100..100% of max range defined by used radar setting	50%
Digital output 1 Ymin	UINT8	1	0..100% of max range defined by used radar setting	0%
Digital output 1 Ymax	UINT8	1	0..100% of max range defined by used radar setting	50%
Digital output 1 polarity	UINT8	1	0 = Low active 1 = High active	1 = High active
Digital output 2 Xmin	INT8	1	-100..100% of max range defined by used radar setting	-25%
Digital output 2 Xmax	INT8	1	-100..100% of max range defined by used radar setting	25%
Digital output 2 Ymin	UINT8	1	0..100% of max range defined by used radar setting	0%
Digital output 2 Ymax	UINT8	1	0..100% of max range defined by used radar setting	25%
Digital output 2 polarity	UINT8	1	0 = Low active 1 = High active	1 = High active
Digital output data basis	UINT8	1	0 = PDAT as data input 1 = TDAT as data input	1 = TDAT as data input

Table 10: Information parameter

Description	Datatype	Length	Values	Default
Start frequency	UINT16	2	57000..63999 MHz	60095 MHz
Slope	UINT16	2	1..65535 kHz/us	49970 kHz/us
Samples	UINT16	2	64..256	128
Sweeps	UINT16	2	32..128	32
Sample rate	UINT16	2	2000..12500 ksps	2000 ksps
Sweep repetition time	UINT16	2	10..65535 us/100	147.00 us
Frame repetition time	UINT16	2	20..1000 ms	130 ms
Transmit antenna index	UINT8	1	0 = 3D 1 = TX1 2 = TX2 3 = TX3	0 = 3D
Module is factory calibrated	UINT8	1	0 = Not calibrated 1 = Calibrated	1 = Calibrated

Commands

This chapter provides detailed information about the commands.

Table 11: Application commands

Header	Payload Length	Description	Values
INIT	0	Start of connection	–
RSET	4	Radar settings	0 = 2D, 6m, 10km/h, 128/64 1 = 2D, 10m, 10km/h, 128/64 2 = 2D, 30m, 30km/h, 128/64 3 = 2D, 30m, 50km/h, 128/64 4 = 2D, 50m, 50km/h, 128/64 5 = 2D, 100m, 100km/h, 128/64 6 = 3D, 6m, 10km/h, 128/32 7 = 3D, 10m, 10km/h, 128/32 8 = 3D, 30m, 30km/h, 128/32
RDOT	4	Data output configuration	Binary coded bit-field. 0=disabled, 1=enabled 0x01=RADC, 0x02=RFFT, 0x04=RMRD, 0x08=PDAT, 0x10=TDAT, 0x20=DONE
GRPS	0	Get radar parameter structure as shown in figure 24	–
SRPS	41	Set radar parameter structure as shown in figure 25	All changeable parameter as described in Table 9: Changeable parameter
SEIP	4	Set sensor IP address	IP address as ‚a.b.c.d' directly sent as four bytes ‚abcd'. The entire IP range except the IP of the bootloader (192.168.100.200) can be used. The sensor is automatically disconnected after changing the IP address. A reconnect via the INIT command is required.
UDPP	4	Set UDP port	4567..4667 UDP port is volatile and per default set to 4567.
STOB	4	Enable/Disable static objects for tracking	0 = Disable 1 = Enable
SENS	4	Sensitivity index	0..15, 0 = Minimum sensitivity, 15 = Maximum sensitivity
MIRA	4	Minimum detection distance	0..100% of max range defined by used radar setting
MARA	4	Maximum detection distance	0..100% of max range defined by used radar setting
MISP	4	Minimum detection speed	0..100% of max speed defined by used radar setting
MASP	4	Maximum detection speed	0..100% of max speed defined by used radar setting
DEDI	4	Detection direction index	0 = Receding 1 = Approaching 2 = Both
TVLT	4	Tracking minimum life time	0..100 frames
TDLT	4	Tracking maximum life time	0..100 frames
RFSE	0	Restore factory settings	–
D1XI	4	Digital output 1 Xmin	-100..100% of max range defined by used radar setting
D1XA	4	Digital output 1 Xmax	-100..100% of max range defined by used radar setting
D1YI	4	Digital output 1 Ymin	0..100% of max range defined by used radar setting
D1YA	4	Digital output 1 Ymax	0..100% of max range defined by used radar setting
D1PO	4	Digital output 1 polarity	0 = Low active 1 = High active
D2XI	4	Digital output 2 Xmin	-100..100% of max range defined by used radar setting
D2XA	4	Digital output 2 Xmax	-100..100% of max range defined by used radar setting
D2YI	4	Digital output 2 Ymin	0..100% of max range defined by used radar setting
D2YA	4	Digital output 2 Ymax	0..100% of max range defined by used radar setting
D2PO	4	Digital output 2 polarity	0 = Low active 1 = High active
DODA	4	Digital output data basis	0 = PDAT as data input 1 = TDAT as data input
GBYE	0	Disconnect	–

Messages

The following table lists all response messages which are sent by the sensor over TCP/IP protocol.

Table 12: Application response messages

Header	Payload Length	Description	Payload
RESP	1	Response	0 = OK 1 = Unknown command 2 = Invalid parameter value 3 = Invalid SRPS version
RPST	57	Radar parameter structure	Changeable parameter followed by information parameter Refer to 'Table 9: Changeable parameter' for a description of the changeable parameter and to 'Table 10: Information parameter' for a description of the information parameter

The following table lists data output messages which are sent over UDP protocol.

Table 13: Application data output messages

<table>
<tr><th>Header</th><th>Payload Length</th><th>Description</th><th>Payload</th></tr>
<tr><td>RADC</td><td>2D Mode:
131072
3D Mode:
196608</td><td>Raw ADC values</td><td>The RADC packet depends on 2D/3D mode defined by used radar setting. A packet consists of the data of a complete frame.
2D Mode:
A frame consists of 64 sweeps. For every sweep (0-63) the following structure will be sent:
<table>
<tr><th>Description</th><th>Datatype</th><th>Length</th></tr>
<tr><td>RX1 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>RX2 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>RX3 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>RX4 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
</table>
3D Mode:
A frame consists of 96 sweeps. For every sweep the transmit antenna will be changed. Therefore the following structure will be repeated 32 times for a frame:
<table>
<tr><th>Description</th><th>Datatype</th><th>Length</th></tr>
<tr><td>TX1, RX1 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX1, RX2 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX1, RX3 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX1, RX4 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX2, RX1 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX2, RX2 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX2, RX3 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX2, RX4 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX3, RX1 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX3, RX2 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX3, RX3 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
<tr><td>TX3, RX4 Sample 0-127: I/Q Value</td><td>INT16</td><td>512</td></tr>
</table>
</td></tr>
</table>

Header	Payload Length	Description	Payload
RFFT	2D Mode: 131072 3D Mode: 196608	Raw range Doppler FFT values	The RFFT packet depends on 2D/3D mode defined by used radar setting. A packet consists of the data of a complete frame. The FFT values are complex. 2D Mode:

Description:	Datatype	Length
RX1: Sample 0: Sweep 0-63: I/Q value …to Sample 127: Sweep 0-63: I/Q value	INT16	32768
RX2: Sample 0: Sweep 0-63: I/Q value …to Sample 127: Sweep 0-63: I/Q value	INT16	32768
RX3: Sample 0: Sweep 0-63: I/Q value …to Sample 127: Sweep 0-63: I/Q value	INT16	32768
RX4: Sample 0: Sweep 0-63: I/Q value …to Sample 127: Sweep 0-63: I/Q value	INT16	32768

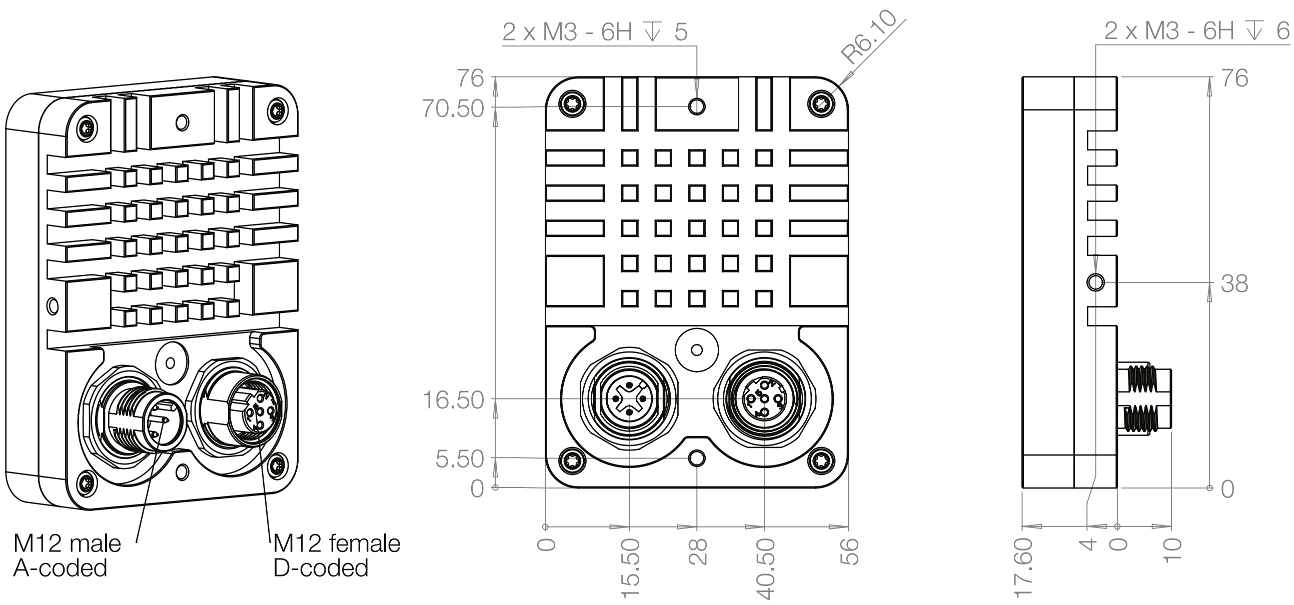
3D Mode:

Description:	Datatype	Length
TX1, RX1: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX1, RX2: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX1, RX3: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX1, RX4: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX2, RX1: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX2, RX2: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX2, RX3: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX2, RX4: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX3, RX1: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX3, RX2: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX3, RX3: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384
TX3, RX4: Sample 0: Sweep 0-31: I/Q value …to Sample 127: Sweep 0-31: I/Q value	INT16	16384

<table>
<tr><th>Header</th><th>Payload Length</th><th>Description</th><th>Payload</th></tr>
<tr><td>RMRD</td><td>2D Mode: 16384
3D Mode: 8192</td><td>Averaged mean range Doppler map</td><td>The RMRD packet depends on 2D/3D mode defined by used radar setting. It contains the averaged and logarithmized range Doppler maps based on the raw range Doppler maps.
2D Mode:
<table>
<tr><th>Description:</th><th>Datatype</th><th>Length</th></tr>
<tr><td>Sample 0: Sweep 0–63: Magnitude value
…to
Sample 127: Sweep 0–63: Magnitude value</td><td>UINT16</td><td>16384</td></tr>
</table>
3D Mode:
<table>
<tr><th>Description:</th><th>Datatype</th><th>Length</th></tr>
<tr><td>Sample 0: Sweep 0–31: Magnitude value
…to
Sample 127: Sweep 0–31: Magnitude value</td><td>UINT16</td><td>8192</td></tr>
</table></td></tr>
<tr><td>PDAT</td><td>0–1500</td><td>The array of detected raw targets</td><td>The following data structure will be added for every detected raw target:
<table>
<tr><th>Description</th><th>Datatype</th><th>Length</th></tr>
<tr><td>Distance [cm]</td><td>UINT16</td><td>2</td></tr>
<tr><td>Speed [km/h × 100]</td><td>INT16</td><td>2</td></tr>
<tr><td>Azimuth [degree × 100]</td><td>INT16</td><td>2</td></tr>
<tr><td>Elevation [degree × 100]</td><td>INT16</td><td>2</td></tr>
<tr><td>Magnitude of target</td><td>UINT16</td><td>2</td></tr>
</table></td></tr>
<tr><td>TDAT</td><td>0–1500</td><td>Tracked target structure</td><td>
<table>
<tr><th>Description</th><th>Datatype</th><th>Length</th></tr>
<tr><td>Distance [cm]</td><td>UINT16</td><td>2</td></tr>
<tr><td>Speed [km/h × 100]</td><td>INT16</td><td>2</td></tr>
<tr><td>Azimuth [degree × 100]</td><td>INT16</td><td>2</td></tr>
<tr><td>Elevation [degree × 100]</td><td>INT16</td><td>2</td></tr>
<tr><td>Magnitude of target</td><td>UINT16</td><td>2</td></tr>
</table></td></tr>
<tr><td>DONE</td><td>4</td><td>Frame done</td><td>Frame number since reset</td></tr>
</table>

OUTLINE DIMENSIONS

Figure 26: Outline dimensions in millimetre



ORDER INFORMATION

The ordering number consists of different parts with the structure below.

Figure 27: Ordering number structure

Product	–	Customer	–	HW variant	Supply	–	SW variant
= V-MD3_M12		**= RFB** for standard products		**= 00** for standard variant	**= A** for wide supply input version		**= 01** for standard variant

Table 14: Available ordering numbers

Ordering number	Description
V-MD3_M12-RFB-00A-01	Standard V-MD3 with M12 connectors, without connection cables, without power supply
V-MD3_M12-EVAL-RFB-00A	V-MD3 evaluation kit with powerful PC software, connection cables and power supply

DELIVERY CONTENT

V-MD3_M12

- V-MD3 sensor

V-MD3_M12-EVAL

- V-MD3 sensor
- Ethernet cable, 2m length, M12 male to RJ45 connector
- Power cable, 1.5m length, M12 female to open wires
- Power supply
- Control panel PC software
- Documentation
- Example readout scripts

REVISION HISTORY

05/2020 – Revision A: Initial Version