DATASHEET

TRAFFIC MANAGEMENT SENSOR

TRUGRD® Stream

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CONTENT

1 USER SAFETY WARNING

Please read the entire document carefully before using the sensor.

INSTALLATION

Please pay attention to the details below before installing and connecting the sensor:

- Only use provided or approved equipment for the installation. Use stainless screws with the given metric thread. If other brackets than those provided are used, screw lengths must be adapted.
- Only skilled and instructed persons shall install and connect the sensor. Proper experience in working with mains voltage, electrical and electronic devices is required.
- Do not connect the sensor directly to the mains voltage; instead use the voltage specified for the product.
- Do not wire any connections when power is applied to the device.
- Ground devices carefully to prevent electrical shock.
- All connectors are pin-coded and fit in only one position. Also note the arrow indicating the top side of the sensor.
- Only use fully functional equipment (ladders, aerial work platform, etc.) when working above ground. Staff shall be capable of working at heights.
- Be cautious when installing the sensor on or around active roadways and pay attention to moving traffic.
- Mount the sensor carefully to prevent it from shifting or dropping.
- The sensor must be mounted to a stiff and solid support. Vibration, oscillation or other movement will reduce the sensor performance.
- Make sure that installation methods are in accordance with local safety policies and procedures as well as company practices.

OPERATION

Do not operate the sensor if the device itself or any cables are damaged.

Transmission of radio frequency waves starts after the sensor is powered up and stops when it is disconnected from power.

Using a J-Box or SRO does not influence the sensor performance. It is recommended that only one connection interface is used at a time.

For testing purposes, the sensor may be laid on its face when it is powered up, given that the surface or connectors will not be damaged this way. Be careful not to damage the camera. Please note that this position is not intended for permanent use.

The sensor may become hot during operation. Proper hand protection is recommended for maintenance work.

Do not dispose electrical and electronic equipment in household trash.

TECHNICAL SERVICE

Only use provided or approved equipment for operation. People other than authorized and approved electrical technicians shall NOT attempt to connect the device to a power supply, the COM HUB or other controllers, as there is a risk of electrical shock by unsafe handling of the power source.

Do not attempt to service or repair this device:

- No user-maintainable parts are contained in the device.
- To avoid electrical shock, do not remove or open the cover.
- Unauthorized opening will void all warranties.
- smartmicro is not liable for any damages or harms caused by unauthorized attempts to open or repair the device.

RADIATION

This product has been tested and found to comply with Part 15 Subpart C of the Federal Communications Commission (FCC) or the European RED directive, or other national rules, depending on the country where it may be in use.

Operation is subject to the following two conditions:

- This device may not cause harmful interference.
- This device must accept any interference received, including interference that may cause undesired operation.

This device generates radio frequency energy. There are strict limits on continuous emission power levels to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment.

- Human exposure to transmitted waves from this device is generally considered as safe. Still, it is considered good practice that humans are not subject to higher radiation levels than necessary.

This device may interfere with other devices using the same frequency band.

2 SENSOR SPECIFICATIONS

TRUGRD (UMRR-12 Type 48) is a 24GHz radar sensor for multi-lane, multi-object tracking traffic management applications that features 3D/UHD⁺ technology.

The antenna Type 48 aims at long range and wide horizontal angular coverage.

The video camera and the radar are integrated into one housing. The radar sensor and the video camera act as independent devices. The radar sensor carries out the detection.

The camera stream functions as an additional sensor modality to get an overview of the current traffic situation and to visually validate the output of the radar sensor.

2.1 MEASUREMENT PRINCIPLE

The sensor measures range, radial speed, horizontal and vertical angle, reflectivity and more parameters of multiple stationary and moving reflectors (targets) simultaneously. It is capable of ultra-high definition (3D/UHD⁺). Through MIMO antenna operation and super resolution algorithms, the sensor achieves a particularly high azimuth angular separation capability (UHD⁺) and elevation measurement, depending on its configuration.

The sensor is almost unaffected by weather, temperature and lighting conditions.

smartmicro radars employ a patented A/B fast chirp-sequence frequency-modulated continuous wave (A/B CS-FMCW) modulation.

FMCW radars can natively separate targets in two dimensions: Range and speed. Transmitting, receiving, and processing a single linear frequency ramp (chirp) enables the radar to detect and separate multiple targets within the radar's field of view.

CS-FMCW radars use multiple chirps as part of one measurement (one radar cycle). The results from multiple chirped range measurements are coherently processed, allowing the radar to measure the Doppler frequency of a target over the measurement time (typically in the order of 10-40ms). High-speed, slow-speed and even stationary targets are detected by the smartmicro radar.

smartmicro's patented A/B CS-FMCW technology then allows for direct unambiguous Doppler measurement (covering the complete specified speed interval) in one single measurement cycle.

The patented waveform and the high-performance signal processing allow to precisely measure the range and the speed of any target and even allows resolving multiple targets that are at the same range from the radar but traveling at different radial velocities or vice versa.

smartmicro radars employ multiple transmit, and receive antennas, adding a spatial component to the measurement process. In addition to range and speed, smartmicro 4D radars can measure the direction of any target separately in Azimuth (horizontal) and Elevation (vertical) angles.

3D/UHD+ MEASUREMENT

A 3D Doppler based radial motion detection principle is integrated:

a) Direct unambiguous Doppler measurement (speed)
b) Direct range measurement
c) Direct azimuth angle measurement (horizontal angle)

Moving reflectors with an absolute radial speed component of typically >0.1m/s (>0.32ft/s) can be detected as well as stationary objects.

With its multi-target capability, the sensor can *detect* many reflectors within the field of view at a time (max. 256[1]). The field of view typically covers up to 12 lanes. Additionally, filter algorithms are implemented for the tracking of all detected reflectors over time. Those tracking algorithms are integrated in the sensor. Multiple objects (max. 256[1]) can be *tracked* simultaneously. Depending on the selected communication interface, the number of *reported* targets and objects may be limited, for example when using RS485 interface. Both, targets and objects, are sorted by range; those with short range are reported first.

The result of tracking is an object list with the following parameters:

- X-position
- Y-position
- Absolute velocity
- Heading angle
- Length
- Object ID and more

The sensor reports such a list of all tracked objects in every measurement cycle of typically 50 or 100ms length, depending on the application.

ULTRA-HIGH DEFINITION RESOLUTION - OBJECT SEPARATION PERFORMANCE

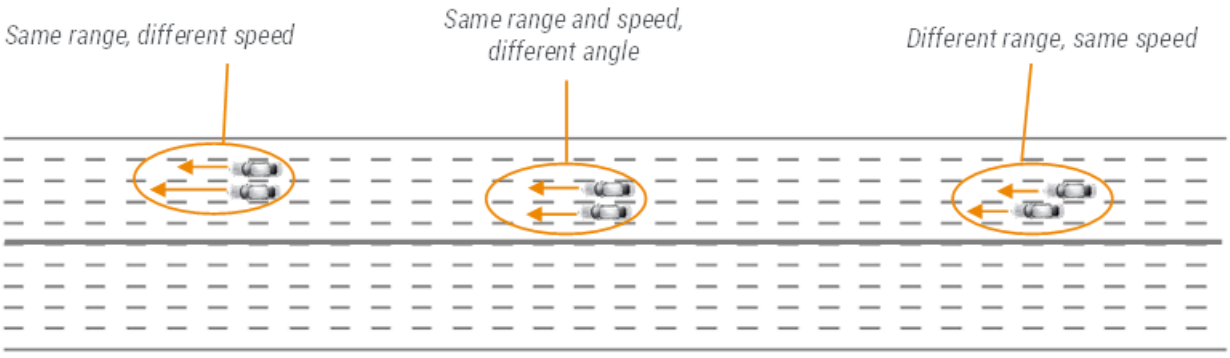
The sensor can separate objects even in areas where many vehicles are closely spaced: for example, in multi-lane scenarios with dense traffic like traffic jams, stop-and-go traffic or at busy intersections. The sensor measures object parameters in 3 dimensions: range, radial speed and azimuth angle – depending on the operational mode. It also separates in range cells, Doppler cells, and azimuth beams (UHD+).

Individual reflectors are separated by detection algorithms if having either:

- A different radial speed value or
- A different range value or
- A different azimuth angular position

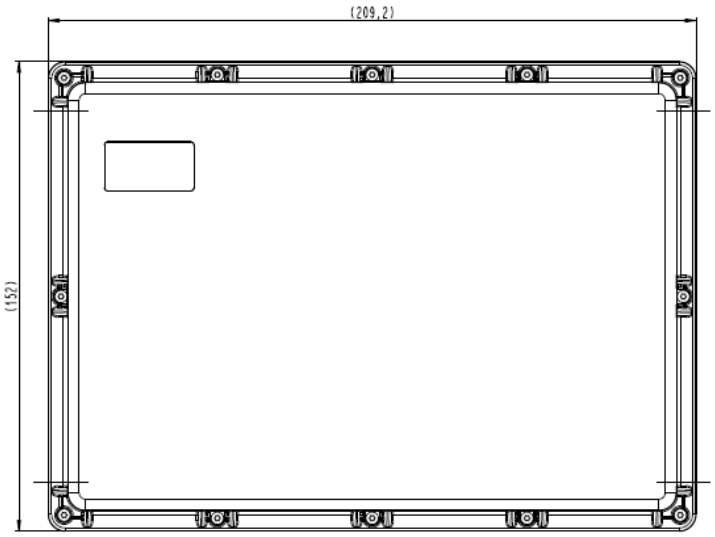
Tracking algorithms and the data base further support the separation of objects.

[1] Depending on the configuration.

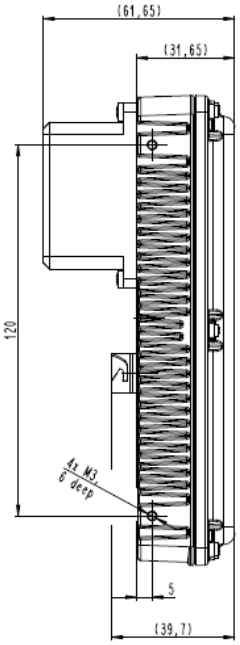


2.2 SENSOR DIMENSIONS

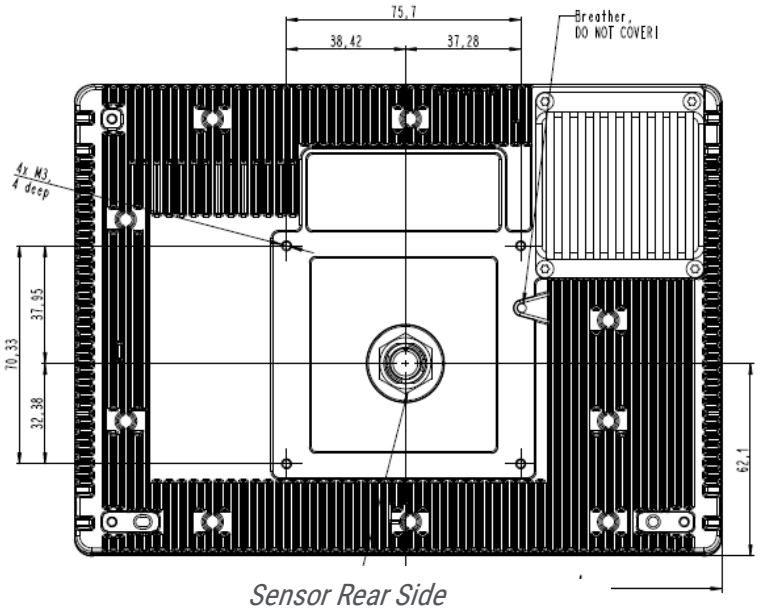
All values are given in mm.



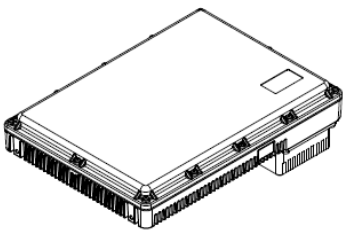
Sensor Front Side

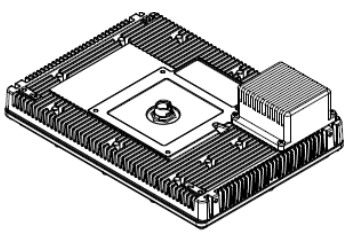


Left Side



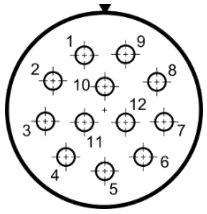
Sensor Rear Side





2.3 SENSOR CONNECTOR

The sensor connector is a 12-pin male (plug) circular bayonet type connector (waterproof IP67, series LF10WBRB-12PD, manufacturer Hirose, Japan). A female counterpart (socket), e.g. LF10WBP-12S,



must be used to connect with the sensor.

View on solder cup side of socket showing the pin numbering
(rear view of female counterpart to be connected to sensor)

Sensor connector pin out model giving pin descriptions:

Pin No.	**Function**	**Wire Color** (MEDI type #KU110C12J002)
1	Sensor Ethernet TX H	Gray / red
2	Sensor Ethernet TX L	Red / blue
3	Sensor RS485 RX L	Pink
4	Sensor RS485 RX H	Gray
5	Sensor RS485 TX L	Brown
6	Sensor RS485 TX H	White
7	Sensor_GND	Blue
8	Sensor_Vcc	Red
9	Sensor Ethernet RX L	Black
10	Sensor Ethernet RX H	Purple
11	CAN H	Green
12	CAN L	Yellow

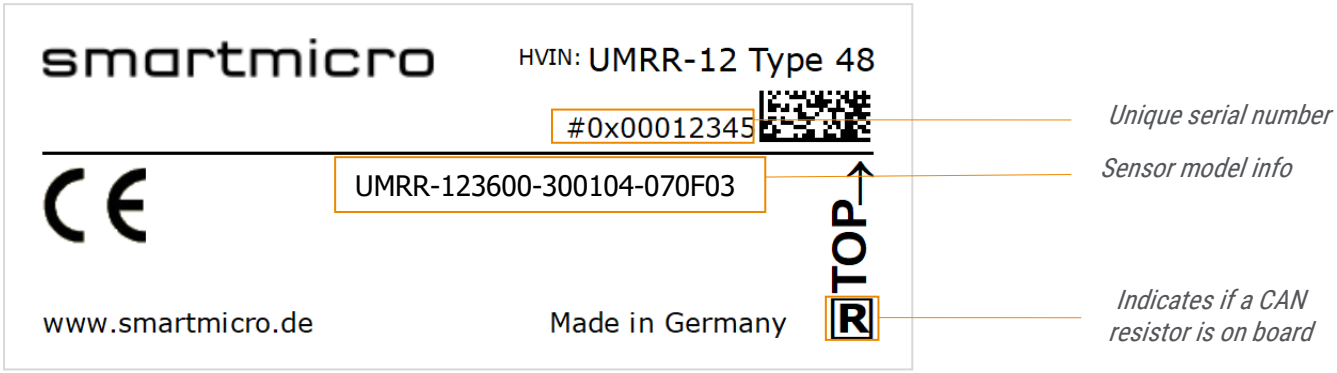
Please note that in the standard configuration the sensor does have a 120 Ohms resistor on board (CAN bus termination between CAN L and CAN H). Likewise, for the RS485 data interface there is a 120 Ohms resistor on board of the sensor. This resistor is required at either end of a CAN / RS485 bus.

Several cable sets for initial operation and test purposes are offered by smartmicro, to deliver a fast set-up of a sensor system. Among those preconfigured ready-to-run cables as well as cable stumps (pig tail cables or various lengths) which carry the connector on one side and open wires on the other.

2.4 SENSOR AND HARDWARE IDENTIFICATION

The sensor housing is tagged with a type sticker containing the product description and the serial number. It also indicates which side of the sensor is the top side.

Sticker example:



Additionally, the DSP board and the RF board have their own unique serial numbers.

3 GENERAL PERFORMANCE DATA

The video camera is mechanically integrated into the housing of the radar sensor. The radar sensor and the video camera act as independent devices.

Mechanical Details	
Weight	~ 1380g | ~ 48.7oz
Dimensions (H/W/D)	209.2 x 152 x 31.65mm | 8.24 x 5.98 x 1.25in (plus camera module and connector)

MECHANICAL INTEGRATION

The video camera and the radar sensor have the same azimuth angle. The elevation angle between the camera and the radar, however, is offset by three degree, because the camera is aligned to show the details at short distance (steeper elevation angle), while the radar sensor is aligned to detect targets at further distances.

MOUNTING POSITION

The device is usually mounted on a vertical pole at the roadside; no setback is required. Other mounting positions (gantry, mast arm, luminaire) are possible.

START-UP TIME

After powering up or resetting, device readings meet the specified performance in <30s.

3.1 RADAR SENSOR PERFORMANCE DATA

Parameter		Typical Values at 12.7dBm	Typical Values at 20dBm
Operating Frequency[2]		24.0…24.25GHz	
Range[3]	Minimum[4]	1.5m | 4.9ft	
	Max.: Pedestrian[5]	90m | 295ft	125m | 410ft
	Max.: Bike[5]	130m | 426ft	180m | 590ft
	Max.: Passenger Car[5]	200m | 656ft	260m | 853ft
	Max.: Truck[5]	300m | 984ft	
	Instrumented[4, 6]	150, 200 or 300m | 492, 656 or 984ft	
	Separation[4]	2 or 4m | 6.6 or 13ft	
	Accuracy[7]	±0.25 or ±0.5m | ±0.82 or ±1.64ft	
Speed[4]	Min. Abs. Radial Speed	0.1m/s | 0.3ft/s [0 for stationary target detection]	
	Min./Max.	-210…+210 or -320…+320km/h | -130.5…+130.5 or -198.6…+198.6mph	
	Separation	0.23 or 0.78m/s | 0.75 or 0.56 ft/s	
	Accuracy[8]	< ±0.1 or < ±0.28m/s; or ± 1% (bigger of)	
Angle	Field of View: Azimuth[9]	-55…+55°	
	Field of View: Elevation[9]	-10…+10°	
	Separation: Azimuth[10]	< 6°	
	Accuracy: Azimuth[11]	< 0.5°	

Mechanical Details		
Weight	~ 1380g | ~ 48.7oz	
Dimensions (H/W/D)	209.2 x 152 x 31.65mm | 8.24 x 5.98 x 1.25in (plus connector)	
Further Information		
Initialization Time	< 30s	
Processing Latency	4 cycles	
Operating Voltage[12]	7…32V	
Power Consumption[13]	14W	
Bandwidth	< 250MHz	
Max. Transmit Power (EIRP)	< 12.7dBm	< 20dBm
Operating & Storage Temperature	-40…+74°C | -40…+165°F	
Interfaces[14]	RS485 full duplex; Ethernet 10/100; CAN V2.0b (passive)	
Connector	Hirose LF10 series	
Shock / Vibration	$100g_{rms}$ / $14g_{rms}$	
Relative Humidity	0…95% (non-condensing)	
IP[15]	67	
Pressure or Transport Altitude	0…10000m | 0…32800ft	

3.1.1 SELF-DIAGNOSIS

The sensor cyclically reports a status message providing the following information: sensor run time, sensor cycle time, sensor mode and diagnosis information.

The sensor has a self-diagnosis feature to allow limited fail-safe capabilities, detecting for example:

- Sensor blindness
- Rain
- Detection and automatic suppression of RF interference (signals from other radar sensors in same frequency band)

Additionally, the radar is equipped with a sensor that facilitates measuring roll and pitch alignment.

3.1.2 SENSOR NETWORK

Sensors are typically used standalone. However, at intersections up to four sensors can be connected to one TMIB (interface board to intersection controllers; available as accessory) or COM HUB using separate configurable frequency channels, which avoid mutual interference.

[2] In certain regions, the frequency interval starts at 24.05GHz.
[3] Depending on the configuration.
[4] Depending on the waveform.
[5] Typical values; all values given for bore sight; they may vary depending on the clutter environment. Please note that the radar system can neither achieve a detection probability of 100% nor a false alarm rate equal to zero.
[6] The instrumented range indicates the maximum range at which the sensor can effectively process detections.
[7] Typical value, depending on the mode.
[8] The speed accuracy is measured at bore sight on an object with a constant radial speed.
[9] The total field of view is an angle interval in which reflectors can be detected; 3dB field of view is narrower.
[10] At 30dB S/N.
[11] The typical value is measured at a target output level at bore sight, for a point reflector showing >23dB SNR. Errors may increase towards larger angles.
[12] Measured at the connector for min. voltage slew rate of 500V/s or max. voltage rise time of 15ms. The supply source impedance is 0.5 Ohms.
[13] May vary between 12…20W depending on supply voltage and temperature; power consumption increases with supply voltage and with temperature. The typical value is given for 12V at 25°C.
[14] It is recommended to use an external surge protection for power, CAN, RS485, Ethernet and other interface ports.
[15] IP67 only when connector or cap is attached.

3.2 VIDEO CAMERA PERFORMANCE DATA

Parameter	Typical Values
Camera Module	
Resolution	2 megapixels (1920 x 1080 pixel)
Color Filter	Color camera with IR Cut Filter
Video Codec	H.265, H.264, MJPEG
Frame Rate	Up to 30 fps in 1920 x 1080 resolution
Standards	Supporting ONVIF Profile S
Operating Conditions[16]	-34…+74°C | -29…+165°F
Lens	
Angle Field of View	56°

CAMERA FIELD OF VIEW

Using the integrated camera, the camera field of view is designed to be four lanes wide (16m horizontal width) at a distance of 25m (distance of the sensor to the stop bar). At longer distances, it covers a larger horizontal width (more than 4 lanes).

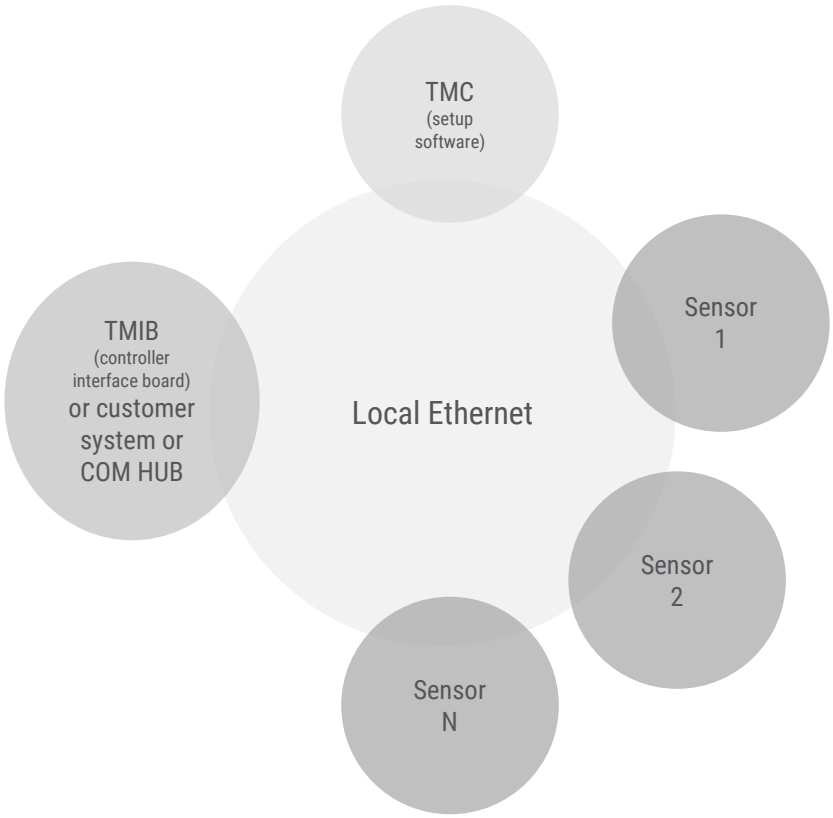
[16] Extreme temperatures may reduce the camera performance.

3.3 ETHERNET CONNECTION

The sensor supports UDP via Ethernet in a Local Area Network (LAN). Communication over low bandwidth environments or routed networks such as the world wide web are not supported.

Features:

- Ethernet standards IPv4, ARP, IGMP, IP multicast and UDP
- Support of DHCP
- smartmicro's proprietary communication protocol "smartmicro transport protocol" with:
    - IP/UDP Multicast based discovery protocol
    - Client ID based setup
    - Sensor data transmission

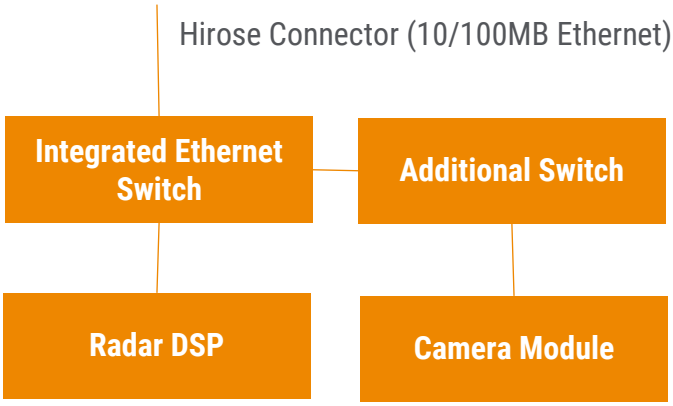


3.4 CONNECTION OF THE RADAR SENSOR AND THE CAMERA

The camera that is integrated into the radar sensor sends image data over a network with configurable resolution, framerate and video codecs. The camera can be accessed over the same Ethernet adapter as the radar sensor, but under a different IP address. The video camera can be configured through its webserver.

Note: The sensor can only be connected via the Ethernet adapter and not via RS485 or CAN.

Internal block diagram:



OUTPUT DATA

The output of the camera module is an encoded video stream transmitted over RTSP. The properties of the stream can be configured to meet different constraints, for example, as H.264.

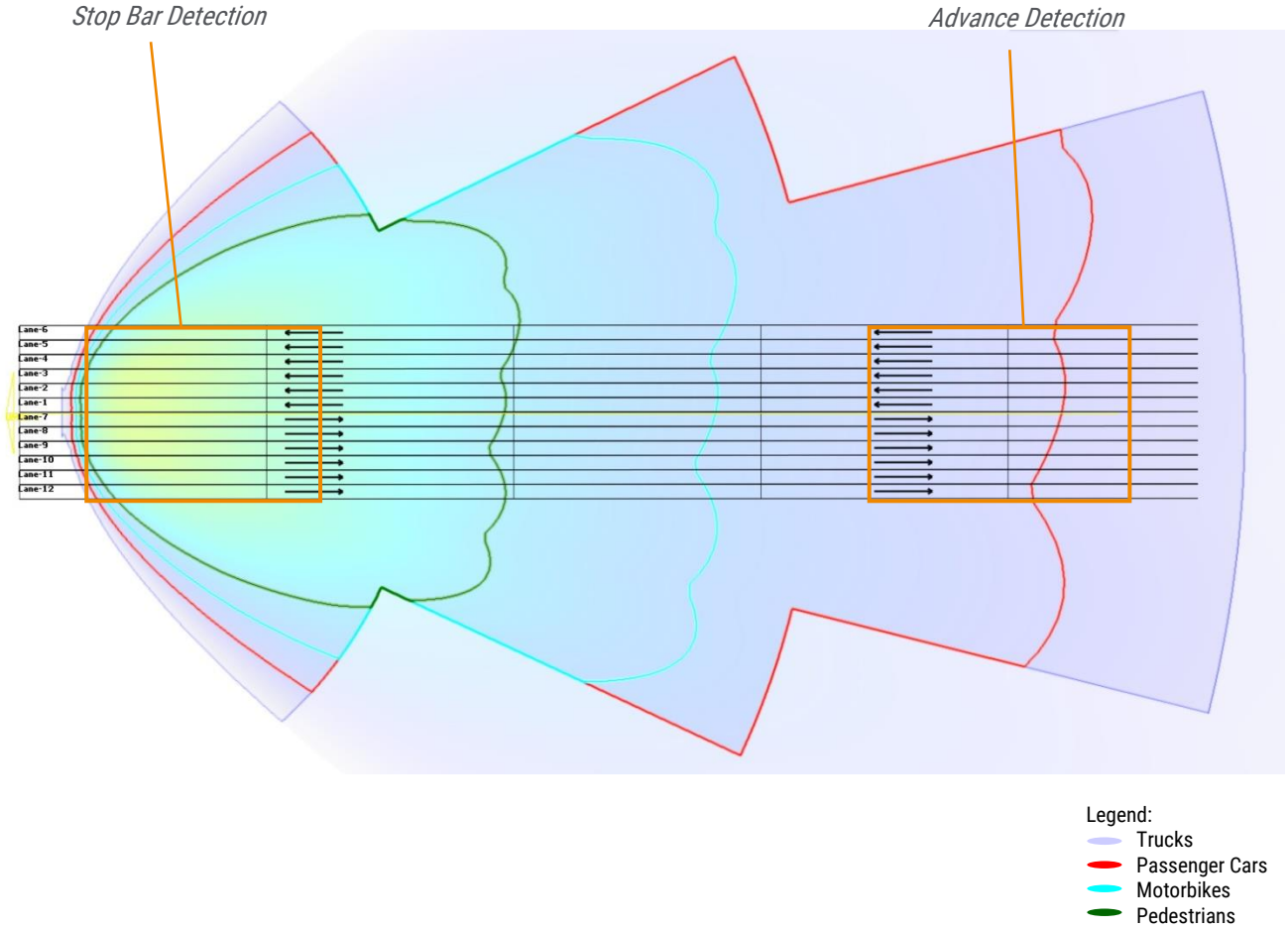
4 APPLICATION-SPECIFIC CHARACTERISTICS

The sensor can be used for the following different applications: intersection management, highway management and enforcement.

4.1 INTERSECTION MANAGEMENT: STOP+ADVANCE

At intersections the sensor is typically used for combined stop bar detection (true presence detection) and lane-specific advance detection (exploiting the long-range). Other features of the sensor are:

- Queue length measurement
- Custom trigger conditions (e.g. location, vehicle speed, classification)
- ETA measurement
- Speed measurement



For all configurations:

Parameter		Typical Values (min…max.)
Mounting Height[17]		6m (1…10m) | 20ft (3…33ft)
Angle[18]	Sensor Azimuth Angle	-10° (-25…+25°)
	Sensor Elevation Angle[19]	-2° (-9…0°)
Stop Bar Setting[20]		25m (20…90m) | 82ft (66…295ft)
Advance Detection Setting		110m (40…170m) | 295ft (164…492ft)

Overview of configurations; all configurations listed are also available with high power mode (20dBm) for increased range:

Application	EIRP	Bandwidth	Range Separation	Instrumented Range	Sensitivity (Passenger Car)	Speed Interval	Cycle Time[21]
Stop+Advance 3D/UHD+	12.7dBm	100MHz	4m	300m	200m	-210…+210km/h	100ms
Stop+Advance 3D/UHD+	12.7dBm	200MHz	2m	200m	200m	-200…+200km/h	100ms

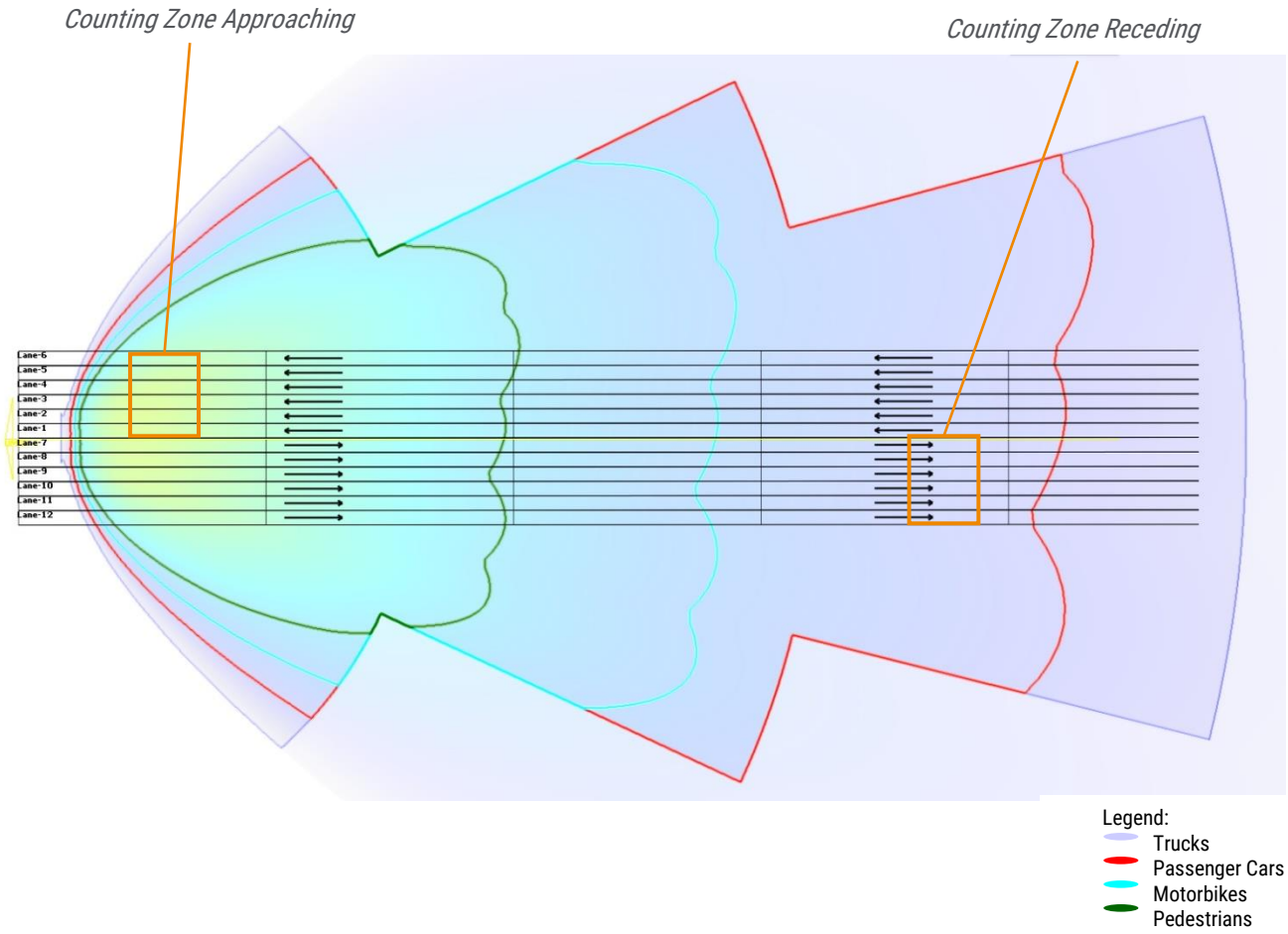
[17] The mounting height may affect the maximum detection range. Occlusion needs to be considered.
[18] The best performance is typically achieved at the center of the given angular range.
[19] These values are application specific. For gantry mounting a steeper elevation angle is possible, but this limits the maximum range. A negative elevation angle means that the sensor is pointing towards the pavement.
[20] Do not use stop bar distances below 20m (at max. sensor elevation mounting angle -9°). Outside the recommended range, vehicle drops are more likely.
[21] Typical value; may be higher depending on the number of detected radar targets.

4.2 HIGHWAY MANAGEMENT: FORWARD+

On highways and country roads, the sensor can be utilized to count and classify traffic. Usually, statistic details are selected and reported in configurable intervals. Otherwise, already collected statistic data can be retrieved in push mode. Every vehicle can be displayed as per vehicle record (PVR) in real-time.

Other features of the sensor are wrong way detection, support of incident detection and speed measurement. The sensor delivers the following data:

- Classification
- Volume
- Occupancy
- Average speed
- Vehicle presence
- 85 percentile speed
- Headway
- Gap
- Wrong-way detection



For all configurations:

Parameter		Typical Values (min…max.)
Mounting Height[22]		6m (1...10m) | 20ft (3...33ft)
Angle[23]	Sensor Azimuth Angle	-10° (-25...+25°)
	Sensor Elevation Angle[24]	-2° (-9…0°)
Counting Line Setting[25]	Approaching	30m (20m…90m) | 98ft (66…295ft)
	Receding	120m (70m…130m) | 394ft (230…427ft)
Setback		1m (0…10m) | 3ft (0…33ft)
Further Information		
Counting Accuracy[26]		> 95%
Classification Accuracy[26]		> 80%
Classes		7 (Pedestrian, Bicycle, Motorbike, Passenger Car, Transporter, Truck/Bus, Long Truck)

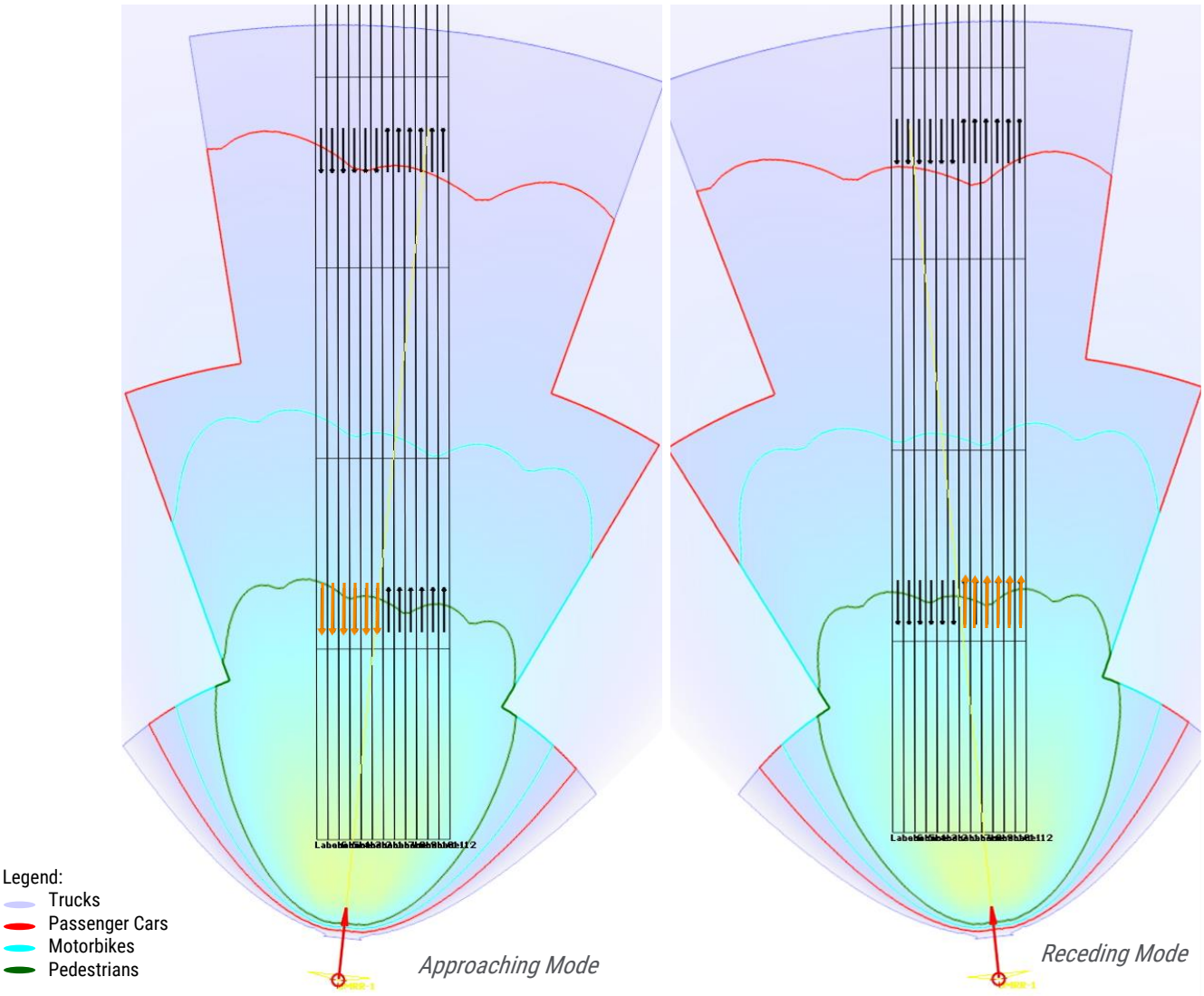
Overview of configurations; all configurations listed are also available with high power mode (20dBm) for increased range:

Application	EIRP	Bandwidth	Range Separation	Instrumented Range	Sensitivity (Passenger Car)	Speed Interval	Cycle Time[27]
Forward+ 3D/UHD+	12.7dBm	100MHz	4m	300m	200m	-210…+210km/h	100ms
Forward+ 3D/UHD+	12.7dBm	200MHz	2m	200m	200m	-200…+200km/h	100ms

[22] The mounting height may affect the maximum detection range. Occlusion needs to be considered.
[23] The best performance is typically achieved at the center of the given angular range.
[24] These values are application specific. For gantry montage a steeper elevation angle is possible but limiting the maximum range. A negative elevation angle means that the sensor is pointing towards the road.
[25] Outside the recommended range, vehicle drops are more likely.
[26] This is a typical value for a sensor that is properly installed at a suitable location. The counting and classification accuracy mainly depend on the mounting height and the traffic density as well as other factors.

4.3 TRAFFIC ENFORCEMENT: RED-LIGHT AND SPEED ENFORCEMENT

For traffic enforcement purposes the sensor can be used for combined lane-specific speed and red-light enforcement. The sensor can track up to 256 objects simultaneously.



For all configurations:

Parameter		Typical Values (min…max.)	
		Approaching Mode	Receding Mode
Mounting Height[28]		4m/6m (1…10m) | 13/20ft (3…33ft)	4m (1…10m)[28] | 13ft (3…33ft)
Angle[29]	Sensor Azimuth Angle	20° (-35…+35°)	20° (-35…+35°)
	Sensor Elevation Angle[30]	-6° (-9…0°)	-6° (-9…0°)
Photo Trigger Setting[31]		35m (20…50m) | 115ft (66…164ft)	45m (20…50m) | 148ft (66…164ft)
Further Information			
Speed Accuracy[32]		< ±0.28m/s or ±1% (bigger of)	
Track Initialization Time		6…10 cycles	

Overview of configurations; all configurations listed are also available with high power mode (20dBm) for increased range:

Application	EIRP	Bandwidth	Range Separation	Instrumented Range	Sensitivity (Passenger Car)	Speed Interval	Cycle Time[33]
Red-Light Enforcement 3D/UHD+	12.7dBm	100MHz	4m	150m	160m	-325…+325km/h	50ms
Speed Enforcement 3D/UHD+	12.7dBm	200MHz	2m	150m	160m	-325…+325km/h	50ms

[28] The mounting height may affect the maximum detection range. Occlusion needs to be considered.
[29] The best performance is typically achieved at the center of the given angular range.
[30] These values are application specific. For gantry montage a steeper elevation angle is possible but limiting the maximum range. A negative elevation angle means that the sensor is pointing towards the road.
[31] Outside the recommended range, vehicle drops are more likely.
[32] The speed accuracy is measured on an object having a constant radial speed, at bore sight.

5 COMPLIANCES

The sensor model complies with the following EU directives:

- RED 2014/53/EU
- RoHS 2011/65/EU
- EC 1907/2006 REACH

Applied Standards:

- Spectrum Usage:
  - EN 300 440 V2.1.1
- EMC:
  - EN 301 489-1 V2.2.0
  - EN 301 489-3 V2.1.1
- Health and Safety:
  - EN 62311: 2008
  - EN 62368-1: 2014 + AC: 2015

With regard to operating conditions like temperature, vibration etc., this sensor model was tested and certified by independent test labs to comply with:

- NEMA TS-2 2003

Regarding spectrum usage, this sensor model was tested and certified by independent test labs (formally approved by a test lab or notified body):

- EU RED directive
- FCC part 15.245 and 15.249
- RSS-310
- RSS-210

This sensor model is also generally compliant with the following regional regulations (but may not be formally tested/approved):

- SRRC
- KCC
- MIIT
- NCC

Note: This statement of compliance means that the sensor allows operation compliant to the listed standards. However, not all standards are certified through test labs. Formal frequency approval or registration is not accomplished for all countries. In certain countries or regions, a customer-specific local frequency approval is reasonable. smartmicro supports customers throughout this process.

For certain configurations of this sensor the accuracy of the speed (and other) measured values was tested by the Swiss Federal Institute of Metrology METAS.

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