77 GHz CRN Radar Sensor

Operational Description

Product Model: 77V125CRN

Table of Contents

Table of Figures

1 Scope and Definition

1.1 Scope

The scope of this document is to provide the required information for radio frequency type approval of Veoneer's Gen1.25 77GHz radar sensor. This document covers the functional aspects, and also hardware aspects of the module, focusing on the radio frequency related part.

1.2 List of Terminology and Acronyms

A/D	Analog to Digital Converter
ADC	Analog to Digital Converter
BSD	Blind Spot Detection
CAN	Controller Area Network
DSP	Digital Signal Processor
ECU	Electronic Control Unit (CAN bus Master located in the automobile)
EMC	Electro Magnetic Compliance (regulatory standards)
EPWM	Enhanced Pulse Width Modulation
ESD	Electro Static Discharge
FM	Frequency Modulation
GHz	Giga-Hertz (10^9)
HP	Host Processor
ICAN	Internal Controller Area Network
IF	Intermediate Frequency
I/Q	In-phase / Quadrature (baseband demodulated signals)
ISM	Industrial Scientific Medical (EMC regulatory mode)
LCA	Lane Change Assist
LDO	Low Drop Out regulator
LNA	Low Noise amplifier
LO	Local Oscillator
MMIC	Monolithic Microwave Integrated Circuit
MCU	Micro Controller Unit
NB	Narrow Band
PCB	Printed Circuit Board
PLL	Phase Lock Loop
PWM	Pulse Width Modulation
RADAR	RAdio Detection And Ranging
RCTA	Rear Cross Traffic Alert
RF	Radio Frequency (or Microwave)
RX	Receive
SPI	Serial Peripheral Interface

TBD	To Be Decided (not presently specified)
TX	Transmit
VCAN	Vehicle Controller Area Network
VGA	Variable Gain amplifier

2 Product Overview

2.1 Product Description

The products described here are part of a family of radars offered by Veoneer. They are intended for automotive use, operating in the 76-77 GHz band.

The radars are fully integrated devices, with the RF part and DSP part on two different PCBs. The DSP board controls the signal processing, as well as vehicle communications through CAN and diagnosis functions. The RF PCB generates the FMCW waveform and transmit/receive the radio signal through patch antennae.

The radars are integrated into a vehicle to enhance vehicle safety systems. They can be integrated as a standalone sensor or sensors, or as part of more complex system that also may include cameras, lidar, and other type of sensors to provide features like Automatic Cruise Control, Automatic Emergency Break, Free space detections and other Autonomous Driving functions.

2.2 Product Application Examples

The product can be used to support following applications among others:

- **Blind Spot Monitoring (BSM)** - The BSM algorithm detects and reports “Objects of Interest" on either side of the vehicle, within a specified “blind spot” zone. The feature generates an output a signal on the CAN Bus.

- **Lane Change Warning/Assist (LCW/A)** - The LCW/A algorithm detects and reports to the driver that a highway licensable vehicle is rapidly approaching the host vehicle in one of the adjacent lanes. The feature generates a signal which is used to drive a visual display placed in the outside view mirror and/or request a chime or vibrating seat cushion, to alert the driver to the approach of objects of interest within the defined LCA zone. The signal can also be used by the ADAS system to engage/dis-engage lane change, as per described in UN R79.

- **Rear Cross Traffic Alert/Break (RCTA/B)** - The RCTA/B algorithm detects and reports “Objects of Interest” behind the host vehicle, within a specified RCTA/B coverage zone when going backward. The feature generates a signal which is used to drive a visual display to alert the driver of the presence of objects of interest that may cause a collision with the host vehicle within the defined RCTA zone. The signal can also be used to control the break.

The product can be used, but is not limited to the following applications

- Autonomous drive systems
- Automatic braking systems
- Adaptive cruise control
- Collision prevention systems
- Pedestrian and Bicycle collision prevention
- Etc.

3 Typical Installation

The radar is typically installed in the positions of the vehicle depicted in Figure 1. The unit is mounted behind the front/rear bumper of the vehicle.

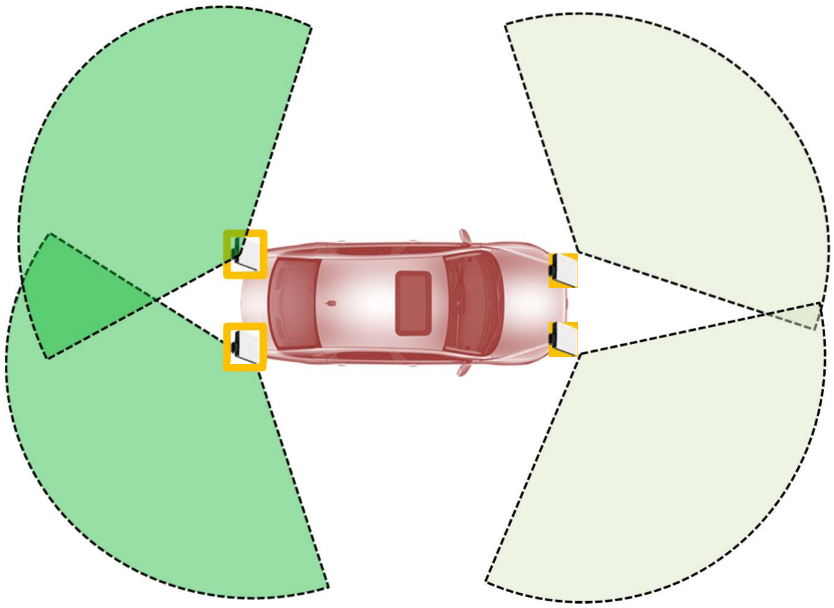

Figure 1: Typical Vehicle Installation

4 Hardware Description

The radar assembly consists of 2 PCB boards, one containing all the RF components, antenas and analog to digital converters and the other containing all what is necessary for signal processing and communications with the vehicle and power.

The boards are assembled in to a plastic housing that is laser welded toghether. The sensor has no servisable parts and can't be opened without permanent damage.

4.1 Antenna

The radar sensor antenna arrangement is show in Figure 2. There are 4 receive antenna, and 3 transmit antennas.

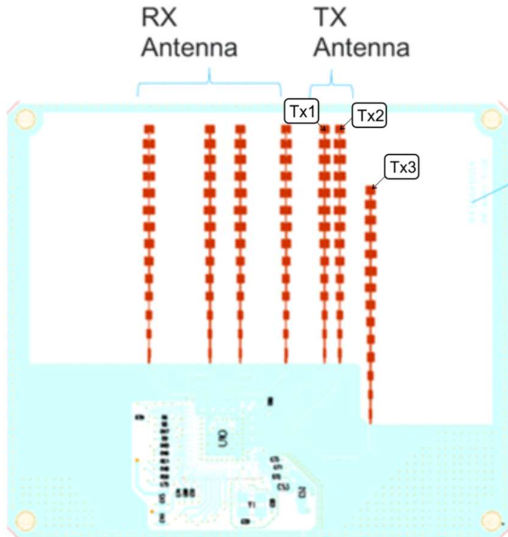

Figure 2: Antenna arrangement

The antenna are linear fed patch array type, using a vertical polarization.
All antennas have the same number of patches and the patches have the same size. The gain pattern of each individual antenna are close, however there are slight differences due to the coupling. Especially Tx1 and Tx2 show a lower gain compared to Tx3 because of the coupling.
The detailed antenna radiation patterns are shown in Section 5.2.

4.2 Electrical blocks

Figure 3 is a block diagram of the radar, showing the ICs used for each main functionnality. We descibe below the main block related to RF.

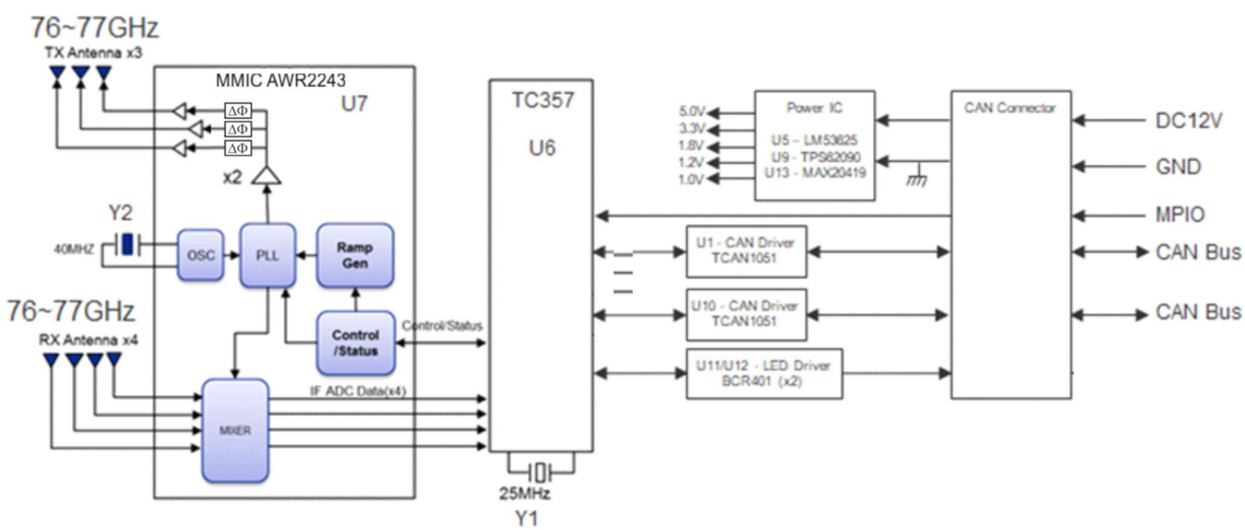

Figure 3: Radar sensor block diagram

4.2.1 RF part

The RF part of the sensor is based on one MMIC, the AWR2243 (U7), that contains the waveform generator circuit, the transmit power amplifier, and the receiver circuits.
The MMIC is using an external crystal (Y2) at 40MHz as source for the clock generation.
The 76-77GHz RF signal is generated internally by a PLL running between 19GHz and 19.25GHz, and a multiplier by 4 circuit.

4.2.2 Power Supply

The power supplies for each blocks are generated from the 12V input of the sensor. Figure 4 shows is simplified power tree.
From the 12V battery voltage, internal 3.3V is created with the LM53625 (U5). The 3.3V is used to create 5.0V, 1.8V and 1.2V with the MAX20419 (U13), as well as 1.0V with the TPS62090 (U9).

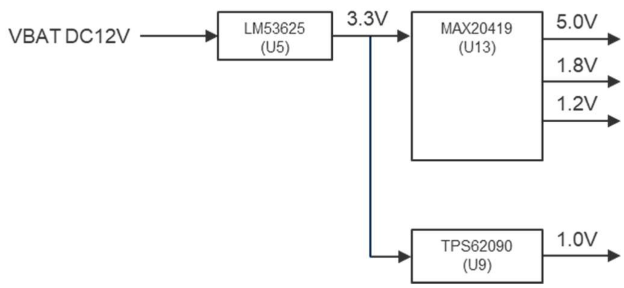

Figure 4: Power Tree

4.2.3 Main processor

The MCU main processor, TC357 (U6), is using an external oscillator (Y1) at 25MHz as base clock. Communication with the MMIC is done through a LVDS link.

4.2.4 CAN

For communication between the vehicle and the sensor, there are 2 CAN interface circuits. Both uses the TCAN1051 (U1/U10) as a CAN driver.
Depending on the customer requirement an internal terminasion is implemented or not.

4.3 Mechanicals

The boards are assembled into a plastic housing that is laser welded together. The sensor has no serviceable parts and cannot be opened without permanent damage.

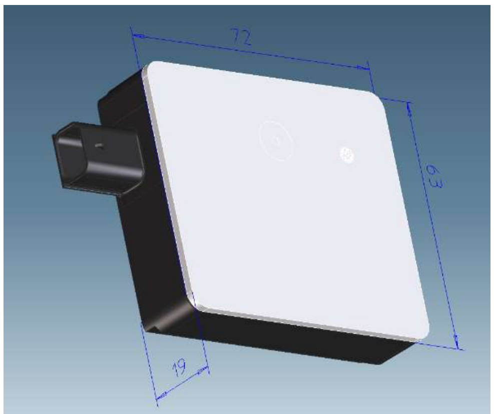

Figure 5: Mechanical View

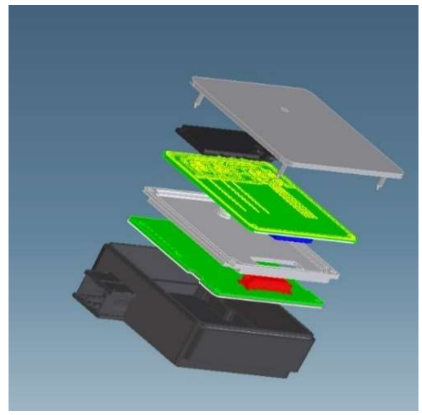

Figure 6: Sensor Exploded View

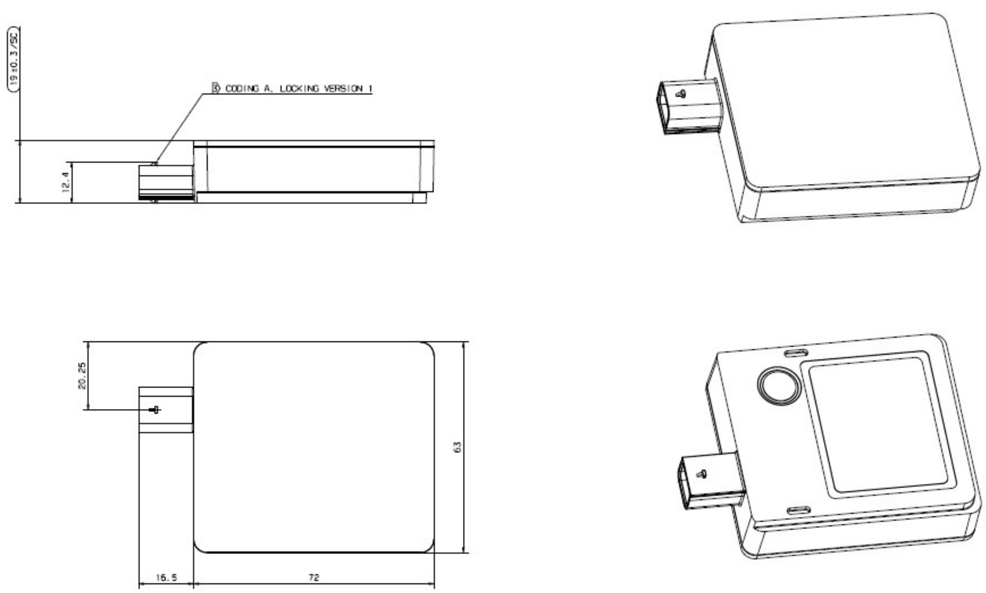

Figure 7: Dimension

4.4 External Interface

4.4.1 CAN Connector pin-out

The sensor uses an 8 pins CAN connector for external connection to the vehicle. This connector contains the power supply pins, the 2 CAN interface, the LED output control signal and a pin to indicate mounting position.

The sensor uses a NanoMQS 2x4 CAN connector. Detailed pin-out is presented in the table below and in the following description.

Signal	Pin	I/O Type	Description
GND	1	Ground	Ground
CAN1_L	2	Signal	CAN (Negative).
CAN1_H	3	Signal	CAN (Positive)
BAT	4	Power	+12V Power
AUX / ADD 0	5	Signal	CAN address 0. Leave open or GND
AUX / ADD 1	6	Signal	CAN address 1. Leave open or GND
NC	7		No Connect or Aux
NC	8		No Connect or Aux

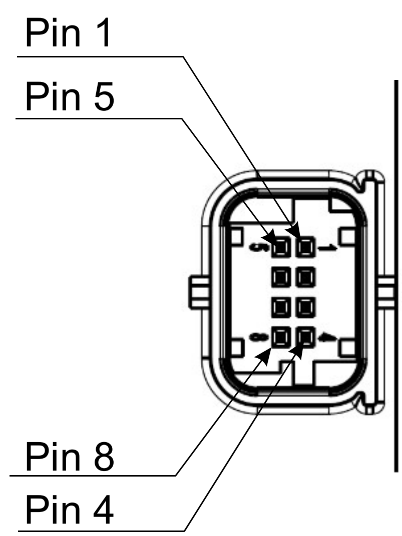

Figure 8: Pin location

4.4.2 Power & Ground

The sensor is connected to the host vehicle power and ground through the CAN connector. The typical voltage is 12VDC. The sensor operates in a voltage range of 8 to 16VDC.

The input is reverse polarity protected and filtered against transients as per ISO 16750-2.

4.4.3 CAN Bus

The communication between the sensor and the host vehicle is using a CAN or CAN-FD protocol as per ISO 11898 / SAE J2284 standards. CAN will have a 500kbps rate, whereas CAN-FD will support up to 2MBps.
The vehicle send to the sensor messages containing speed or other vehicles dynamic parameters required for detection processing. The sensor outputs its status as well as the detected objects information.
The sensor can also receive engineering commands trough the CAN interface to set or evaluate specific modes.

4.4.4 Address selection pin

This pin is used to differentiate left and right sensor connected to the same harness. The pin can be either grounded or left unconnected (open).

For example, in the front of the car, the left side would be grounded, and the right side would be left unconnected. The actual configuration depends on customer requirements.

Note: depending on the SW implementation, the sensor saves the installation position at line calibration in its internal memory and compare to the cable connection. When there is a mismatch a fault will occur.

4.5 Generic Specifications

Sensor Specifications & Functions	Value	Unit
Sensor		
Input Operating Voltage	8 – 16	V
Power Dissipation	5.5	W
Operating Temperature	-40 to 85	C
Size	72x63x19	mm
Weight	<150	g
IP Class	IPX9K	
Vehicle Physical Interface	2x4 Nano MQS	
DSP		
Vehicle Interface	CAN/CAN-FD	
Cycle Time	50	ms
MCU Reference Clock	25	MHz
RF		
Frequency Band	76-77	GHz
Waveform	Fast chirp FMCW	
ITU Emissions Designator	925MQ0N	
Number of Antenna Channels		
- Transmit	3	
- Receive	4	
Antenna Array Max Realized Gain	Tx1+Tx2: 17.7	dBi
Conducted Output Power (=Antenna Input Power)	10	dBm
Production Tune Up Tolerance (+/- dBm)	2	dBm
Max. EIRP (Transmit Output Power)	Tx1+Tx2: 29.7	dBm
Antenna Polarization	Vertical	
Return Loss at Antenna Port	-6	dB
Feeding Network Loss (ball to antenna port)	2	dB
Antenna Impedance	50	Ohm
Number of Parallel Receiver Channels to the ADC	4	
Interference Mitigation	Yes	
MMIC Reference Clock	40	MHz
Feature and Functions		
Field of View (azimuth)	-70 to +70	deg
Detection range	130	m
Minimum range	0.2	m
Horizontal Auto Alignment	Yes	
Vertical Auto Alignment	Yes	
Blockage Detection	Yes	
Sensor ASIL Level	ASIL B	
AutoSAR support	Yes (4.X)	

5 Waveform

5.1 Waveform description

The radar sensors utilize FMCW modulation.

The radar has a data cycle of 50ms. Within one cycle, the radar will send and receive 10 bursts of modulated signal. Each burst has a repetition rate of 5ms.

Within each burst, there are 2 sequences of FMCW chirps. Each sequence is made by selecting which of the 2 different transmitters are turned ON at a given time and by relative phase setting between the transmitters.

- Sequence 1 (SUM): 16 ramps with Tx1 and Tx2 simultaneously ON and with a 180-degree phase shift.
- Sequence 2 (DELTA): 16 ramps with Tx1 and Tx2 simultaneously ON and with phase shift applied (Variant 1: 85°; Variant 2: 258°)

Figure 9 represent the waveform and sequence used.

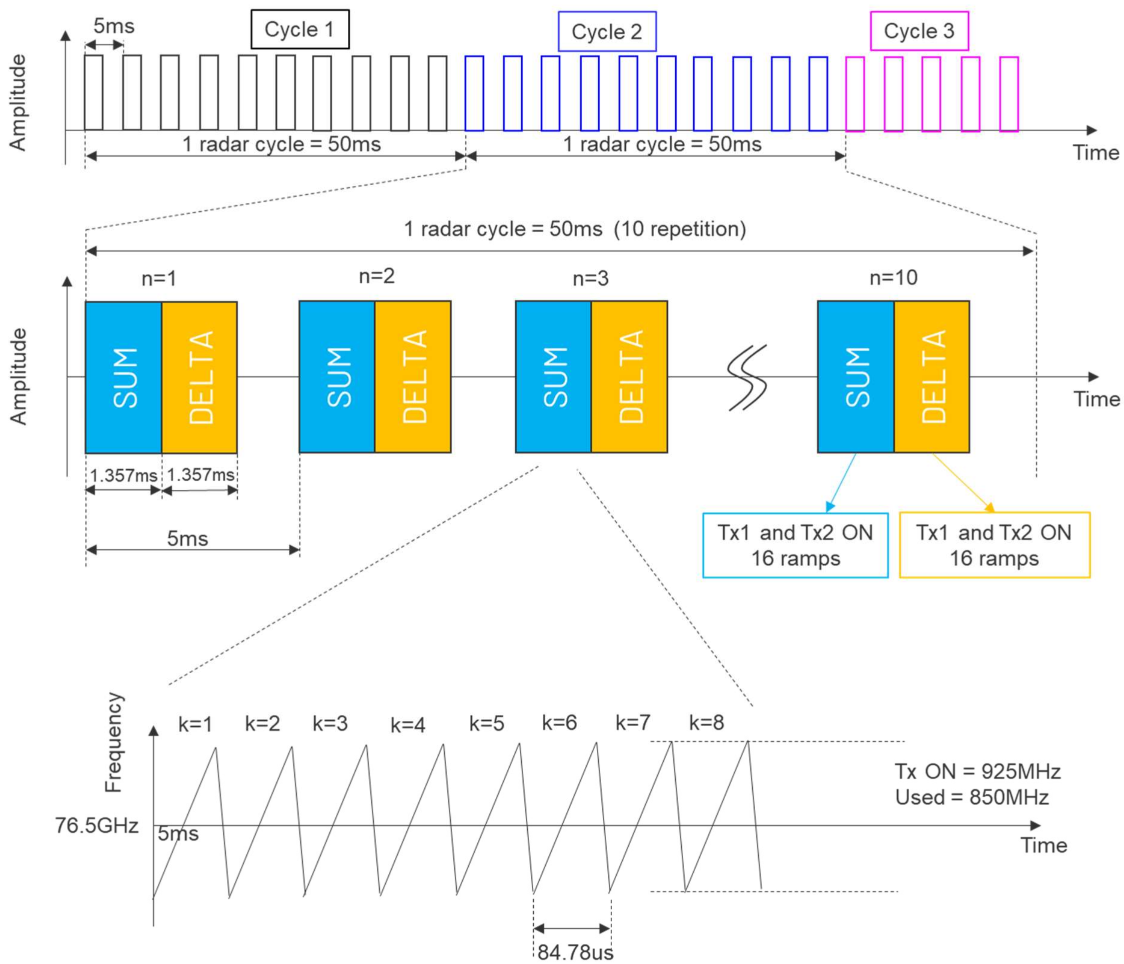

Figure 9: Transmit Waveform

Each ramp used are the same and have a frequency sweep of 925MHz.
The repetition time of the ramp is 84.78us, and the Tx is turned ON during 66.80us within one ramp. After the ramp sequences are sent, the Tx are OFF until the next burst starts.
The total Tx ON time within one burst is 2.14ms, which gives a duty of 42.8%.
Note: that this duty value does not consider the directivity of each sequence.

The following table summarize the waveform parameters.

Antennas Used	Tx1, Tx2
Center Frequency	76.5GHz
Bandwidth	925 MHz
Radar cycle	50ms
Burst repetition	5ms
Sequence 1 (Sum) antenna used	Tx1 and Tx2 simultaneously ON with 180-degree phase difference
Sequence 1 (Sum) number of ramps	16
Sequence 2 (Delta) antenna used	Tx1 and Tx2 simultaneously ON with phase shift applied Variant 1: 85-degree phase shift Variant 2: 258-degree phase shift
Sequence 2 (Delta) number of ramps	16
Tx ON/OFF within one ramp	66.80us/17.98us
Duty Cycle within one burst	42.8%

5.2 Antenna pattern

The antenna pattern is dependent of the sequence as different antenna combination are used.

The following table summarize the realized gain for each sequence.

Variant 1:

Sequence	TX Antenna Configuration	Gain [dBi]
Sequence 1 (Sum)	Tx1+Tx2 @180° Phaseshift	15.7dBi at 40° / -40°deg
Sequence 2 (Delta)	Tx1+Tx2 @ 85° Phaseshift	16.7dBi at +30deg

The antenna pattern in Azimuth for both sequences and Elevation for Sequence 2 (Delta) is shown in Figure 10. The power is maximum for Sequence 2 at 30° off boresight.

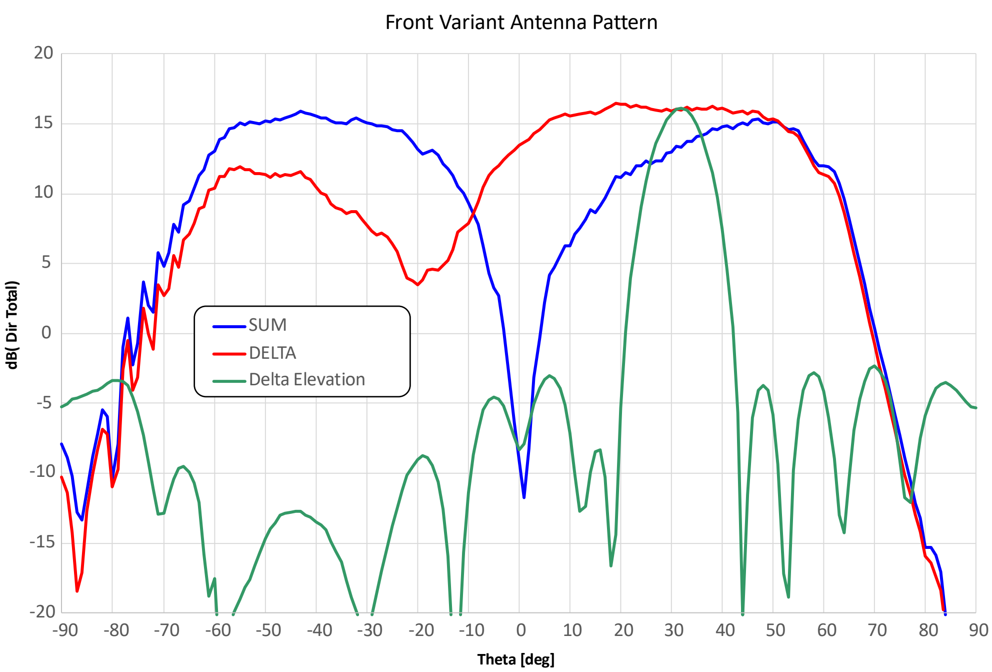

Figure 10: Sequence 1 (Delta) and Sequence 2 (Sum) antenna radiation pattern

Variant 2:

Sequence	TX Antenna Configuration	Gain [dBi]
Sequence 1 (Sum)	Tx1+Tx2 @180° Phaseshift	16.7dBi at 40° / -40°deg
Sequence 2 (Delta)	Tx1+Tx2 @ 258° Phaseshift	17.7dBi at -15deg

The antenna pattern in Azimuth for both sequences and Elevation for Sequence 2 (Delta) is shown in Figure 101. The power is maximum for Sequence 2 at -15° off boresight.

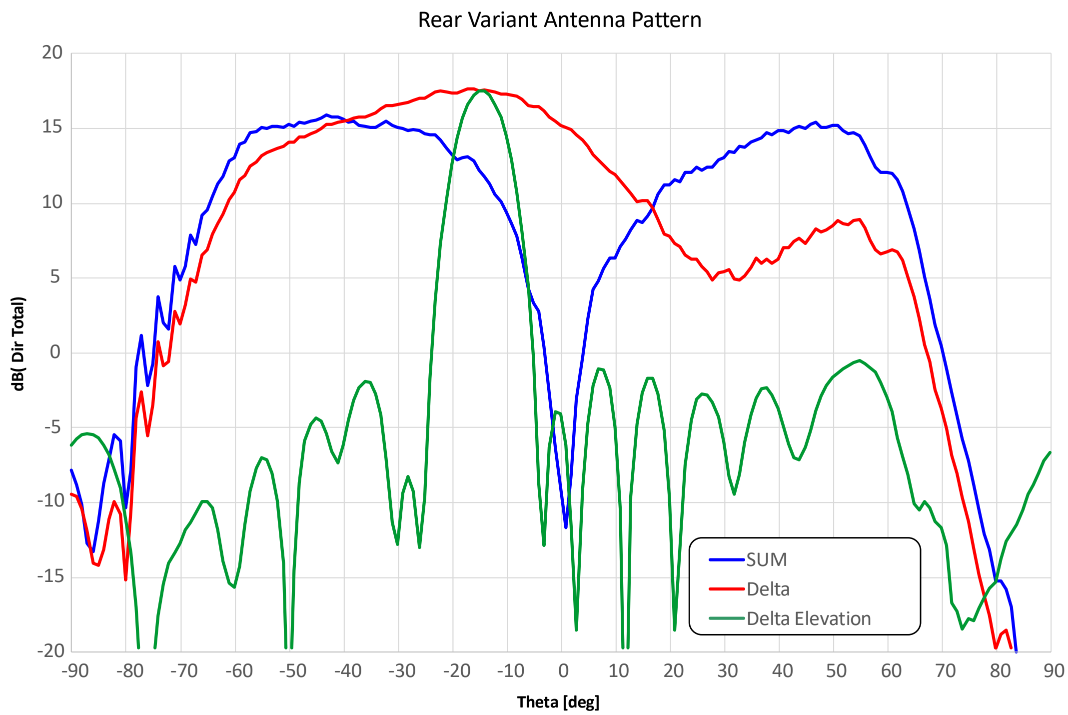

Figure 11: Sequence 1 (Delta) and Sequence 2 (Sum) antenna radiation pattern

6 *Fail Safe Features*

6.1 Fail Safe Features

The sensor has several fail safe features implemented using combination of HW and SW reactions.

1. Standard Features
   - Reverse Polarity Protection
   - ESD Protection
   - Other – as required by OEM
2. ASIL-C rated power supplies with redundant references, precision UV/OV monitors, and BIST
3. Windowed Watchdog
4. ASIL-D rated processor which provides:
   - Redundant Die Temp Monitors
   - ADCs for voltage monitoring and Power Management System for monitoring critical processor rails
   - Safety Management Unit to provide transitions to safe states for processor errors
   - Internal Watchdog
   - BIST
5. Redundant Sensor I/O connectivity at the Aurix for protection against broken BGA balls
6. RF MMIC with:
   - Redundant Die Temp Monitors
   - ADCs for voltage monitoring
   - CRC on ADC data lanes
   - Built-in BIST Processor
7. Redundant (series) input capacitor on I/O lines between connector and first series elements for increased robustness/protection against direct shorts from Battery to GND due to capacitor cracks
8. Current limiting on LED driver output for variants with LED support

The following sections present some of the diagnostic features that can have external reasons. Most of the others are related to sensor internal monitoring and thus are not easily visible from the outside.

6.1.1 Power supply protection

The sensor includes protection against several fault conditions on power supply, such as reverse bias protection, ESD protection, over/under voltage protection.

The over/under voltage is a double protection with a SW reaction coming first, and a HW shutdown to protect the unit integrity.

The sensor will go into a failure mode is the input voltage gets lower than 7.8V or higher than 16.2V.

The detailed behavior can be adapted to the customer requirements, with for example DTC assertion, warning on the CAN messages or partial function turn off.

Note: All the internally generated voltages are also monitored. If the value changed out of the designed range the sensor will automatically take protective reactions.

6.1.2 Temperature protection

The MMIC and CPU devices contain internal temperature monitor functions that are used for diagnosis. When internal temperatures are too low or too high the sensor will enter in fail-safe mode. The detailed behavior can be adapted to the customer requirements, with for example DTC assertion, warning on the CAN messages or partial function turn off.

7 Conformance Statement

7.1 USA

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

CAUTION TO USERS Changes or modifications not expressly approved by the party responsible for compliance could void the user`s authority to operate the equipment.

Additionally, it should be mentioned, that the integrator is advised to have this statement in their user manual as well.

7.2 Canada

This device contains license-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada’s license-exempt RSS(s). Operation is subject to the following two conditions: (1) This device may not cause interference. (2) This device must accept any interference, including interference that may cause undesired operation of the device.

L’émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d’Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L’exploitation est autorisée aux deux conditions suivantes : 1) L’appareil ne doit pas produire de brouillage; 2) L’appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d’en compromettre le fonctionnement.

7.3 E.U.

Simplified Declaration of Conformity – RE Directive 2014/53/EU

Hereby, Veoneer US, Inc. declares that the radio equipment type 77V125CRN is in compliance with Directive 2014/53/EU.

The full text of the EU declaration of conformity is available at the following internet address: *https://www.veoneer.com/en/regulatory*

Manufacturer: Veoneer US, Inc.

Address: 26360 American Drive, Southfield, Michigan, 48034, United States of America

Model: 77V125CRN

Operation frequency: 76 - 77GHz

Maximum Output Power: less than 55dBm peak EIRP

8 Revision History

The revision number in table below is the PLM revision and version number. The Description/Comment is the same description that is found in PLM in check comment.

Revision	Date	Author(s)	Description/comment
000 v1	2020-07-17	P. LoRé	Draft
000 v2	2020-12-11	H. Henftling	Updates to add details