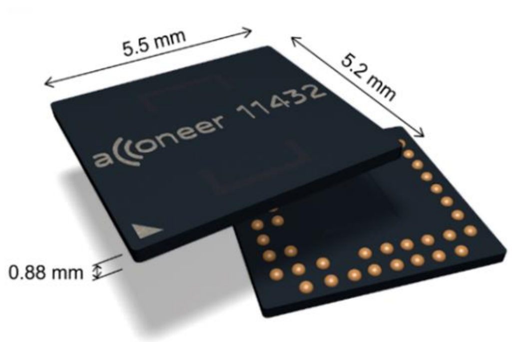
A111-003 – Pulsed Coherent Radar

Operational description, User manual, and Installation instruction



A111-003 Overview

The A111-003 (hereafter referred to as A111) is a radar system based on pulsed coherent radar (PCR) technology and is setting a new benchmark for power consumption and distance accuracy – fully integrated in a small package of 29 mm^2.

The A111 60 GHz radar system is optimized for high precision and ultra-low power, delivered as a one package solution with integrated Baseband, RF front-end and Antenna in Package (AiP). This will enable easy integration into any portable battery driven device.

The A111 is based on leading-edge patented sensor technology with pico-second time resolution, capable of measuring absolute distance with mm accuracy up to a range of 2 m (1) and with configurable update rate.

The A111 60 GHz radar remains uncompromised by any natural source of interference, such as noise, dust, color and direct or indirect light.

Applications

- High precision distance measurements with mm accuracy and high update rate
- Ultra-low power consumption, e.g. average power consumption 0.2 mW at 0.1 Hz update rate, 3 mW at 10 Hz update rate and 20 mW at 100 Hz update rate
- Proximity detection with high accuracy and the possibility to define multiple proximity zones
- Motion detection, Speed detection
- Enables material detection
- High precision object tracking, enabling gesture control
- High precision tracking of 3D objects
- Monitor vital life signs such as breathing and pulse rate
- Only for factory installation in the interior of new passenger motor vehicles

Features

- **Fully integrated sensor**
  - 60 GHz Pulsed Coherent Radar (PCR)
  - Integrated Baseband, RF front-end and Antenna in Package (AiP)
  - 5.5 x 5.2 x 0.88 mm fcCSP, 0.5 mm pitch
- **Accurate distance ranging and movements**
  - Measures absolute range up to 2 m (1)
    - Absolute accuracy in mm
  - Relative accuracy in µm
  - Possible to recognize movement and gestures for several objects
  - Support continuous and single sweep mode
  - HPBW of 80 (H-plane) and 40 degrees (E-plane) , possible to adapt beam pattern using dielectric lens
- **Easy integration**
  - One chip solution with integrated Baseband and RF
  - Can be integrated behind plastic or glass without any need for a physical aperture
  - Single reflowable component
  - 1.8 V single power supply, enable with Power on Reset (PoR)
  - Clock input for crystal or external reference clock, 20-80 MHz
  - SPI interface for data transfer, up to 50 MHz SPI clock support
  - INTERRUPT support

(1) 2m ranging is guaranteed for an object size, shape and dielectric properties corresponding to a spherical corner reflector of 5 cm radius.

Table of Contents

1 Revision History

Revision	Comment
V1.0	Released version

2 Description

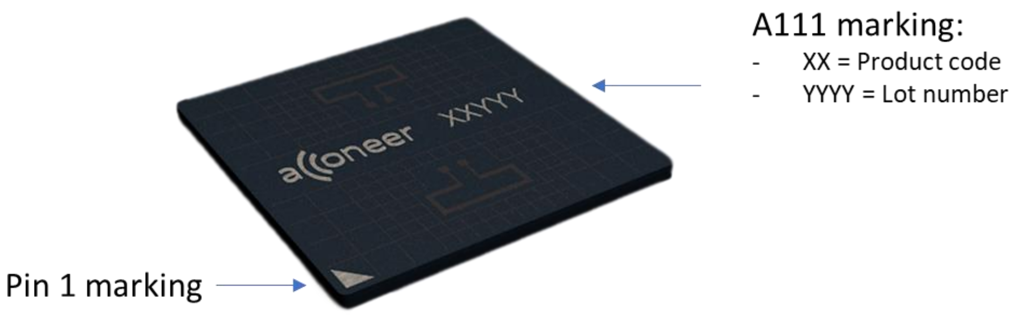
The A111-003 (hereafter referred to as A111) is an optimized low-power, high-precision, 60 GHz radar sensor with integrated Baseband, an RF front-end and an Antenna in Package (AIP).

The sensor is based on pulsed coherent radar (PCR) technology, featuring a leading-edge patented solution with picosecond time resolution. The A111 is the perfect choice for implementing high-accuracy, high-resolution sensing systems with low-power consumption.

Ordering information

Part number	Package	Size (nom)	Primary component container
A111-003-T&R	fcCSP50	5.2 x 5.5 x 0.88 mm	Tape & reel
A111-003-TY	fcCSP50	5.2 x 5.5 x 0.88 mm	13” Tray

Acconeer A111 marking



2.1 Functional Block Diagram

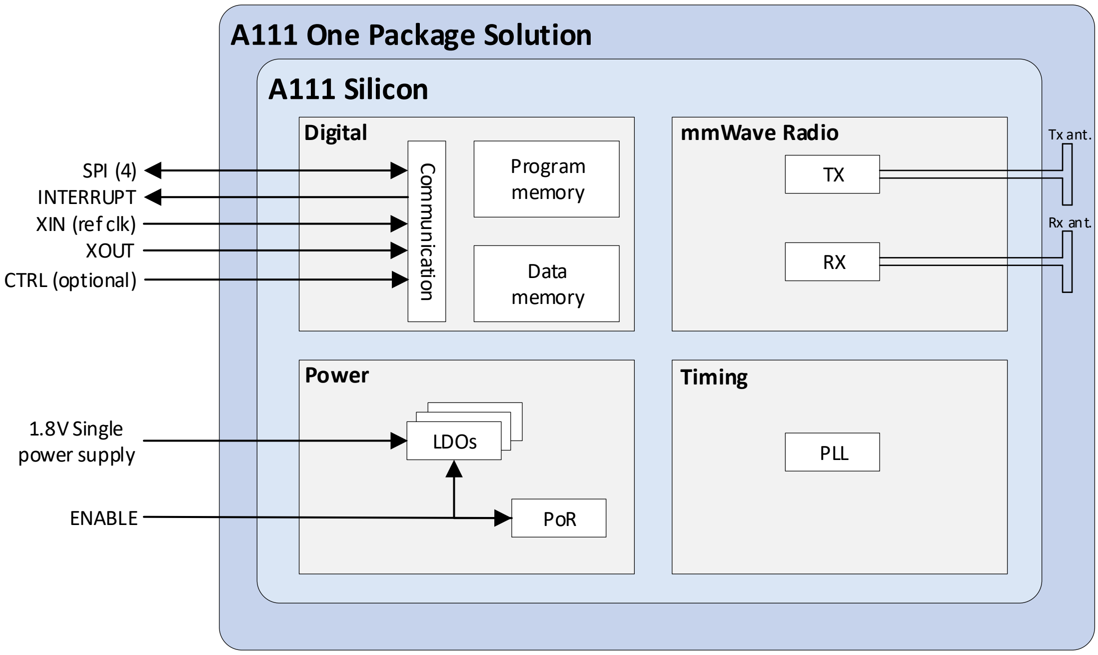


Figure 2.1. The A111 functional block diagram.

The A111 silicon is divided into four functional blocks: Power, Digital, Timing and mmWave radio.

The Power functional block includes LDOs and a Power on Reset (PoR) block. Each LDO creates its own voltage domain. The PoR block generates a Reset signal on each power-up cycle. The host interfaces the Power functional block of the sensor via 1.8V Single power supply and ENABLE.

The Digital functional block includes sensor control. The data memory stores the radar sweep data from the ADC. The host interfaces the Sensor via an SPI interface, a Clock (XIN, XOUT), INTERRUPT signal and optional CTRL signal.

The Timing block includes the timing circuitry. The PLL digital clock output is used to drive digital logic and is synthesized from external crystal (XIN/XOUT) or external reference frequency (XIN ref clk). The operational oscillator (XIN) frequency range is 20-80 MHz.

The mmWave radio functional block generates and receives radar pulses and includes transmitter (TX), receiver (RX) and interfaces toward the integrated antennas. The A111 operates in the 57-64 GHz band.

3 Pin Configuration and Functions

The below figure shows the A111 pin configuration, top view:

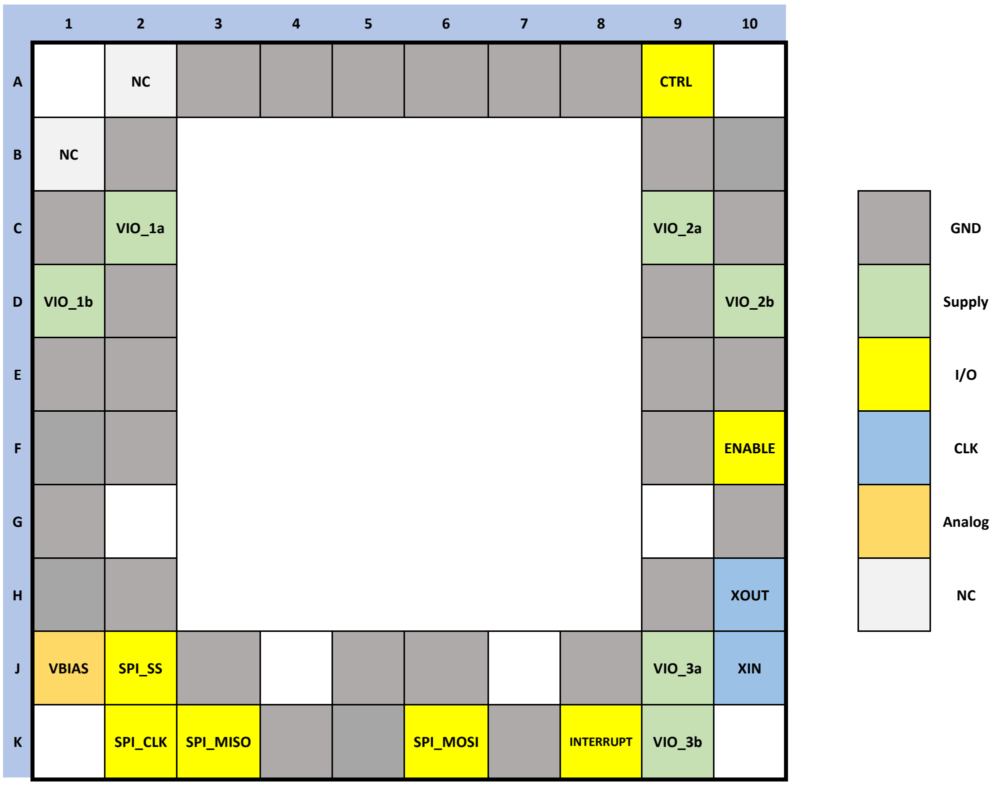


Figure 3.1. Pin configuration of the A111 sensor, top view.

The below table shows the A111 total number of 50 pins:

Pin	Pin name	Pin type	Description	Comment
A2	NC		Must no connect	
A3-A8	GND	Ground	Must be connected to solid ground plane	
A9	CTRL	I/O	Optional control signal. Must be connected to either host MCU or ground	optional
B1	NC		Must no connect	
B2, B9	GND	Ground	Must be connected to solid ground plane	
B10	GND	Ground	Must be connected to solid ground plane	
C1	GND	Ground	Must be connected to solid ground plane	
C2	VIO_1a	Supply voltage	Supply voltage, RF part (1)	
C9	VIO_2a	Supply voltage	Supply voltage, RF part (1)	
C10	GND	Ground	Must be connected to solid ground plane	
D1	VIO_1b	Supply voltage	Supply voltage, RF part (1)	
D2, D9	GND	Ground	Must be connected to solid ground plane	
D10	VIO_2b	Supply voltage	Supply voltage, RF part (1)	
E1, E2, E9, E10	GND	Ground	Must be connected to solid ground plane	

Pin	Pin name	Pin type	Description	Comment
F1	GND	Ground	Must be connected to solid ground plane	
F2, F9	GND	Ground	Must be connected to solid ground plane	
F10	ENABLE	I/O	Must be connected to host MCU available GPIO. ENABLE is active high	
G1, G10	GND	Ground	Must be connected to solid ground plane	
H1	GND	Ground	Must be connected to solid ground plane	
H2, H9	GND	Ground	Must be connected to solid ground plane	
H10	XOUT	CLK	XTAL out	No connect if no XTAL
J1	VBIAS	Analog	The analog VBIAS must be connected to VIO_3	
J2	SPI_SS	I/O	SPI slave select, active low select.	
J3, J5, J6, J8	GND	Ground	Must be connected to solid ground plane	
J9	VIO_3a	Supply voltage	Supply voltage, digital part (1)	
J10	XIN	CLK	XTAL input OR external ref clk input	1.1V domain
K2	SPI_CLK	I/O	SPI Serial Clock	
K3	SPI_MISO	I/O	Master Input – Slave Output	
K4	GND	Ground	Must be connected to solid ground plane	
K5	GND	Ground	Must be connected to solid ground plane	
K6	SPI_MOSI	I/O	Master Output – Slave Input	
K7	GND	Ground	Must be connected to solid ground plane	
K8	INTERRUPT	I/O	Interrupt signal, that is used as an interrupt in the host, more details are found in section 7, *Description*.	mandatory
K9	VIO_3b	Supply voltage	Supply voltage, digital part (1)	

Table 3.1. A111 sensor pin list

(1) VIO_1a and VIO_1b are short circuit inside the sensor. VIO_2a and VIO_2b are short circuit inside the sensor. VIO_3a and VIO_3b are short circuit inside the sensor.

4 Specifications

4.1 Absolute Maximum Ratings

The below table shows the A111 absolute maximum ratings over operating temperature range, on package, unless otherwise noted:

Parameter	Description	Min.	Max.	Unit
VIO_1 (2)	1.8 V RF power supply	0	2.0	V
VIO_2 (2)	1.8 V RF power supply	0	2.0	V
VIO_3	1.8 V digital power supply	0	2.0	V
XIN (1)	Clock input port for crystal or reference clock	-0.5	1.6	V
I/O	I/O supply voltage	-0.5	VIO_3+0.5	V
T_{OP}	Operating temperature range	-40	85	°C
T_{STG}	High temperature storage		150	°C

Table 4.1. Absolute maximum ratings

(1) XIN input may not exceed 0V when ENABLE is low.
(2) VIO_1 and VIO_2 must never exceed VIO_3.

Stresses beyond those listed in table 4.1 may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions or at any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods of time may affect device reliability.

4.2 Environmental Sensitivity

The below table shows the A111 environmental sensitivity:

Parameter	Standard	Max.	Unit
Storage temperature	JESD22-A103 (1)	150(1)	ºC
Reflow soldering temperature (1)	J-STD-020 (1)	260	ºC
Moisture Sensitivity Level	JESD22-A113 (1)	MSL3	
ESD, Charge Device Model (CDM)	JS-002, Class C2	500	V
ESD, Human Body Model (HBM)	JS-001, Class 1C	1000	V
Latch-up	JESD78, Class I	Pass	

Table 4.2 Environmental sensitivity

(1) For reference only. The package is generically qualified by the manufacturer. Acconeer does not guarantee adherence to standard.

4.3 Recommended Operating Conditions

The below table shows the A111 recommended operating conditions, on package:

Parameter	Min.	Typ.	Max.	Unit
Operating power supply voltage, VIO_1	1.71	1.8	1.89	V
Operating power supply voltage, VIO_2	1.71	1.8	1.89	V
Operating power supply voltage, VIO_3	1.71	1.8	1.89	V
I/O operating range	-0.3		VIO_3+0.3	V
XIN operating range (1)	-0.3		1.2	V
Operating temperature (T_{op})	-40		85	ºC

Table 4.3. Recommended operating conditions

(1) XIN input must not exceed 0V when ENABLE is low.

4.4 Electrical Specification

The below table shows the A111 electrical DC specification conditions, on package, T_{op} = -40ºC to 85ºC:

Parameter	Min.	Typ.	Max.	Unit
Current into any power supply	0		100	mA
I/O V_{IL} Low-level input voltage	-0.3		0.10*VIO_3	V
I/O V_{IH} High-level input voltage	0.90*VIO_3		VIO_3+0.3	V
I/O V_{OL} Low-level output voltage	0		0.4	V
I/O V_{OH} High-level output voltage	1.6		VIO_3	V
I/O I_{OL} (VOL = 0.4V)	4.56	7.8	12.4	mA
I/O I_{OH} (VOH = VIO_3-0.4)	3.42	5.8	9.16	mA
I/O I_{IL} Low-level input current			<1	µA
I/O I_{IH} High-level input current			<1	µA
XIN V_{IL} Low-level input voltage	-0.3		0.4	V
XIN V_{IH} High-level input voltage	1.0		1.2	V
XIN I_{IL} Low-level input current			<1	µA
XIN I_{IH} High-level input current			<1	µA

Table 4.4. Electrical DC conditions

The below table shows the A111 electrical AC specification conditions, on package, at T_{op} = -40ºC to 85ºC:

Parameter	Min.	Typ.	Max.	Unit
I/O output operating frequency(2)	0		100	MHz
I/O minimum positive and negative pulse	6.25			ns
XIN operating frequency	20		80(1)	MHz

Table 4.5 Electrical AC conditions

(1) The maximum external reference clock frequency is 80 MHz and the maximum XTAL frequency is 50 MHz.
(2) Load capacitance 2 pF.

4.5 Power Consumption Summary

Table 4.6 summarizes the steady-state current consumption for the sensor states, average current ratings at all power terminals (VIO_1, VIO_2, VIO_3), VIO 1.8 V, at T_{op} = -40ºC to 85ºC:

Parameter		Typ.	Max.	Unit
OFF	VIO_1	29	139	µA
OFF	VIO_2	31	158	µA
OFF	VIO_3	0	23	µA
HIBERNATE	VIO_1	29	139	µA
HIBERNATE	VIO_2	31	158	µA
HIBERNATE	VIO_3	410	2064	µA
SLEEP	VIO_1	764	1069	µA
SLEEP	VIO_2	767	1082	µA
SLEEP	VIO_3	1.59	3.48	mA
READY	VIO_1	1.32	1.90	mA
READY	VIO_2	768	1085	µA
READY	VIO_3	31.0	41.6	mA
ACTIVE	VIO_1	2.85	4.00	mA
ACTIVE	VIO_2	1.34	1.91	mA
ACTIVE	VIO_3	60.8	79.9	mA
MEASURE, PROFILE 1	VIO_1	3.94	5.32	mA
MEASURE, PROFILE 1	VIO_2	2.31	3.08	mA
MEASURE, PROFILE 1	VIO_3	61.8	81.1	mA
MEASURE, PROFILE 2	VIO_1	4.01	5.40	mA
MEASURE, PROFILE 2	VIO_2	2.37	3.16	mA
MEASURE, PROFILE 2	VIO_3	61.8	81.1	mA
MEASURE, PROFILE 3	VIO_1	4.30	5.76	mA
MEASURE, PROFILE 3	VIO_2	2.80	3.67	mA
MEASURE, PROFILE 3	VIO_3	62.4	81.8	mA

MEASURE, PROFILE 4	VIO_1	5.20	6.86	mA
MEASURE, PROFILE 4	VIO_2	4.18	5.32	mA
MEASURE, PROFILE 4	VIO_3	62.4	81.8	mA
MEASURE, PROFILE 5	VIO_1	6.37	8.29	mA
MEASURE, PROFILE 5	VIO_2	6.06	7.61	mA
MEASURE, PROFILE 5	VIO_3	62.4	81.7	mA

Table 4.6. Average current ratings at power terminals for the sensor states.

5 Timing Requirements

5.1 Serial Peripheral Interface

The Serial Peripheral Interface (SPI) is a 4-wire serial bus, used for configuration and reading output from the A111 radar sensor. The A111 radar sensor is an SPI slave device connected to the SPI master, as described in figure 5.1. The A111 allows several devices to be connected on the same SPI bus, with a dedicated slave-select signal. Daisy-chain is not supported.

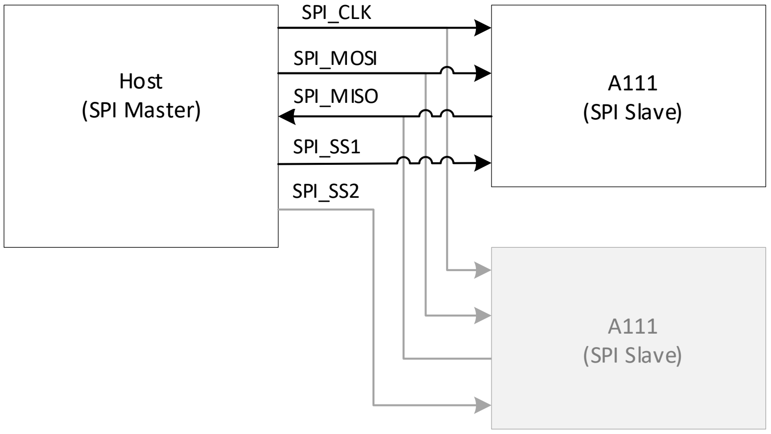


Figure 5.1. SPI master-slave connection

The serial data transfer input (MOSI) and output (MISO) to the A111 are synchronized by the SPI_CLK. The Slave Select signal (SS) must be low before and during transactions. The MOSI is always read on the rising edge of SCLK and the MISO changes value on the falling edge of SPI_CLK (SPI mode 0, CPOL/CPHA = 0). SS requires release in between transactions. See figure 5.2 and table 5.1 for timing characteristics.

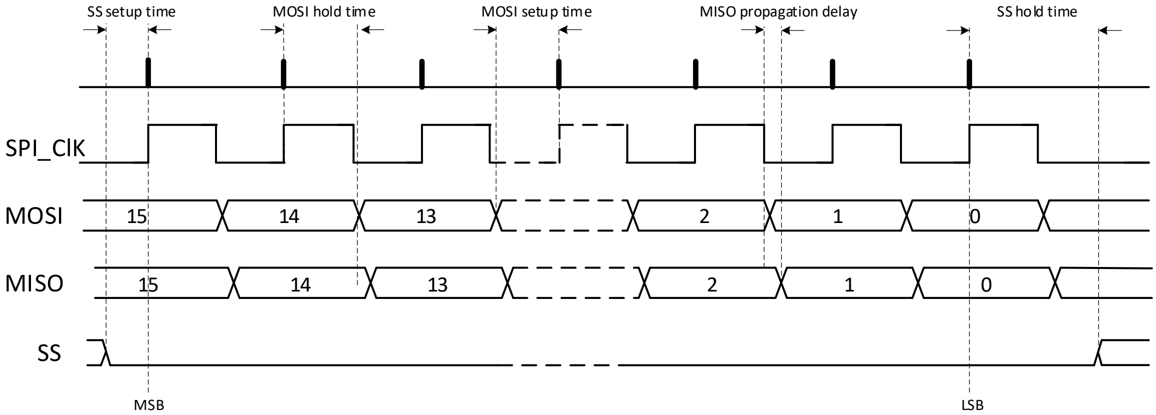


Figure 5.2: Timing diagram of SPI, CPOL=0 and CPHA=0.

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Parameter	Min.	Typ.	Max.	Unit
Clock frequency (1)			50	MHz
SS setup time	1.0			ns
SS hold time	2.0			ns
MOSI setup time	1.0			ns
MOSI hold time	2.5			ns
MISO propagation delay (2)			5.5	ns

Table 5.1 SPI timing characteristics

(1) The 50 MHz clock frequency requires that the reference clock is at least 20.625 MHz
(2) 10pF load on SPI_MISO

6 Typical Characteristics

6.1 Radar Loop Gain Pattern

The Radar Loop Gain pattern includes the gain in both the TX and RX radar path and is defined as the angular separation between the two points at which the gain has decreased by 3dB relative to the maximum main lobe value, when the radar itself is used to measure the reflected power. For details regarding the measurement setup, refer to “Hardware and physical integration guideline”, chapter 1.2.

Conditions: T_A = 25 ºC, V_{DD} = 1.8 V. Tested on 5 XR112 devices.

The below figure shows the Radar Loop Gain Radiation Pattern normalized to Free Space Sensor Boresight at Elevation plane (E-plane).

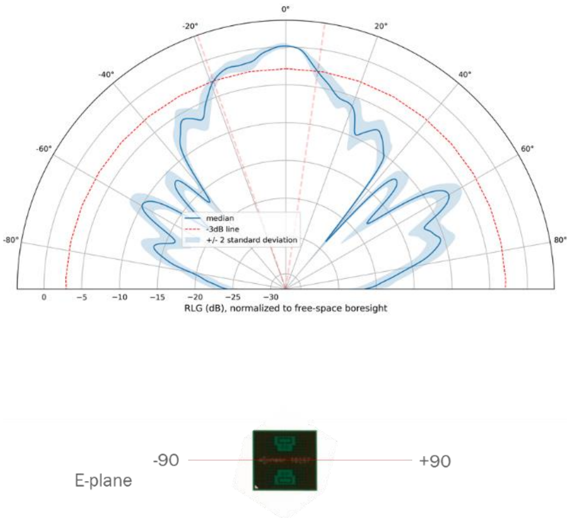

Figure 6.1. Normalized radar loop gain radiation pattern at E-plane.

The below figure shows the Radar Loop Gain Radiation Pattern normalized to Free Space Sensor Boresight at Horizontal plane (H-plane).

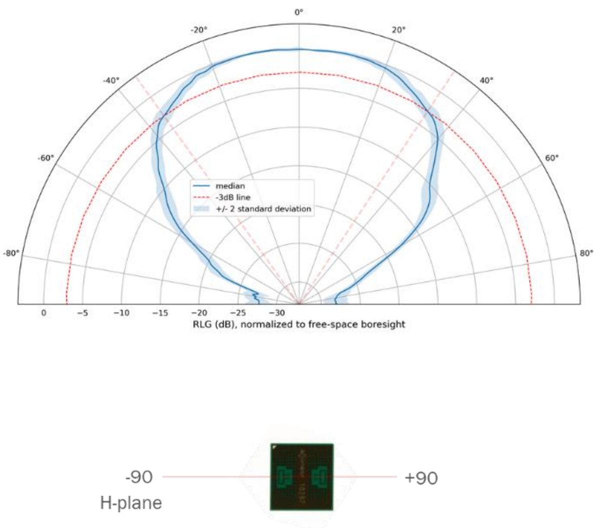

Figure 6.2. Normalized radar loop gain radiation pattern at H-plane

6.2 Relative Phase Accuracy

Conditions: T_A = 25 ºC, V_{DD} = 1.8 V. Statistical result based on sweep count 100, 20 tested devices.

Standard deviation of phase estimation, measured at a distance of 0.35 m. Object metal cylinder, 40 mm in diameter.

Average STD of relative phase estimation:

6.1 degrees in relative phase accuracy, translates to 42 µm in relative distance accuracy.

7 Functional Description

The below figure shows the A111 system integration with Host MCU:

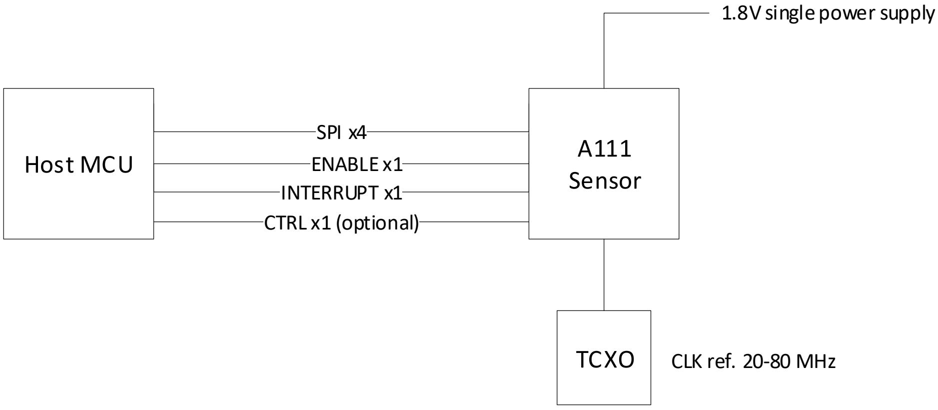

Figure 7.1. System integration

The Acconeer software is executed on Host MCU that handles sensor initiation, configuration, sweep acquisition and signal processing.

The Serial Peripheral Interface (SPI) is a 4-wire serial bus, used for configuration and reading output from the A111 radar sensor. The A111 radar sensor is an SPI slave device, connected to the SPI master (Host MCU), and allows several devices to be connected on same SPI bus, with a dedicated slave-select signal. Daisy-chain is not supported.

The sensor provides support for ENABLE and INTERRUPT as interrupt signal, always output, that is used as an interrupt in the Host MCU. The sensor supports an optional control signal: CTRL, which is configured through software, e.g. for controlling the operating state of the sensor to idle in Hibernate.

7.1 Acconeer Software

The Acconeer software has been written in C and is portable to any OS and HW platform. The Acconeer software is executed on Host MCU and delivered as binaries, except for integration software that is delivered as source code.

The below figure shows the A111 software offer.

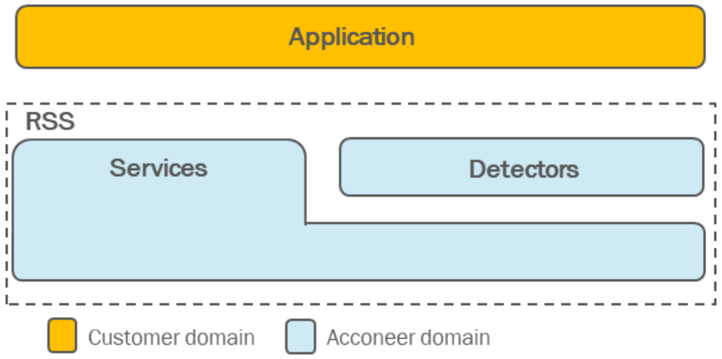

Figure 7.2. Acconeer Software offer

The RSS (Radar System Software) provides output at two different levels, Service and Detector. RSS provides an API (Application Programming Interface) for Application utilization of various Services and Detectors.

The Service output is pre-processed sensor data as a function of distance E.g. Envelope data (amplitude of sensor data), Power bin data (integrated amplitude data in pre-defined range intervals), IQ modulated data (representation in cartesian) etc.

Detectors are built on Service data as input and the output is a result E.g. Distance detector that presents distance and amplitude result based on envelope Service etc.

Customer can either use Acconeer detector or develop their own signal processing based on Service data.

Acconeer provides several example applications to support customer own application development. Also, customer guidelines are provided for application development utilizing the Acconeer RSS API.

Acconeer provides several reference drivers as source code, e.g. Support for Cortex M4, Cortex M7 MCU's.

7.2 Software Integration

Integration software shall implement functions defined in a definitions file provided in Acconeer Software offer. This includes handling of SPI, ENABLE, INTERRUPT and CTRL, as well as potential OS functions.

See reference HAL - User Guide for guideline on software integration and HAL implementation (https://www.acconeer.com/products).

7.3 Power Sequences

The power-up sequence is described using the recommended integration shown in the below figure:

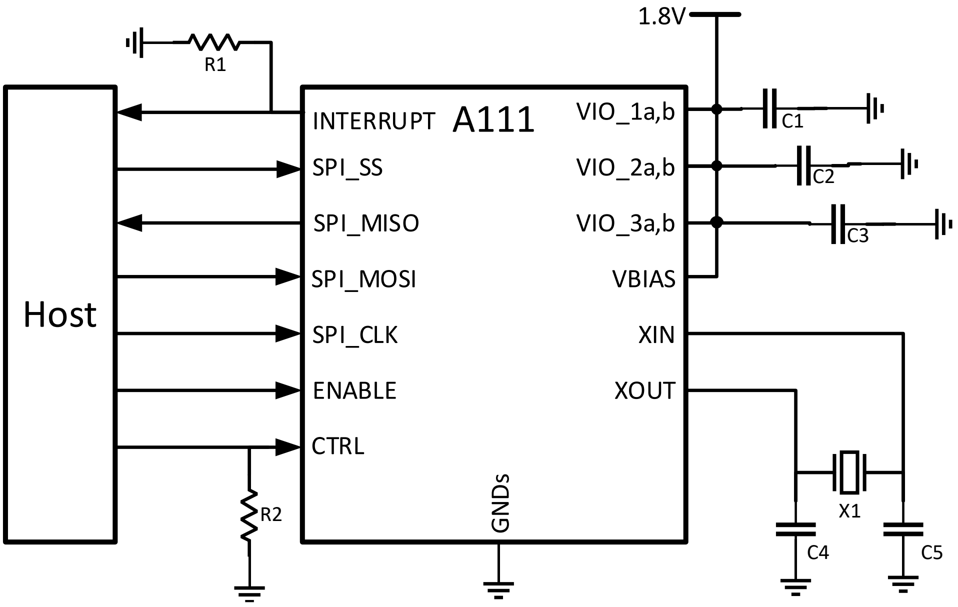

Figure 7.3. Recommended integration of the A111 radar sensor.

The power up sequence is shown in below figure.

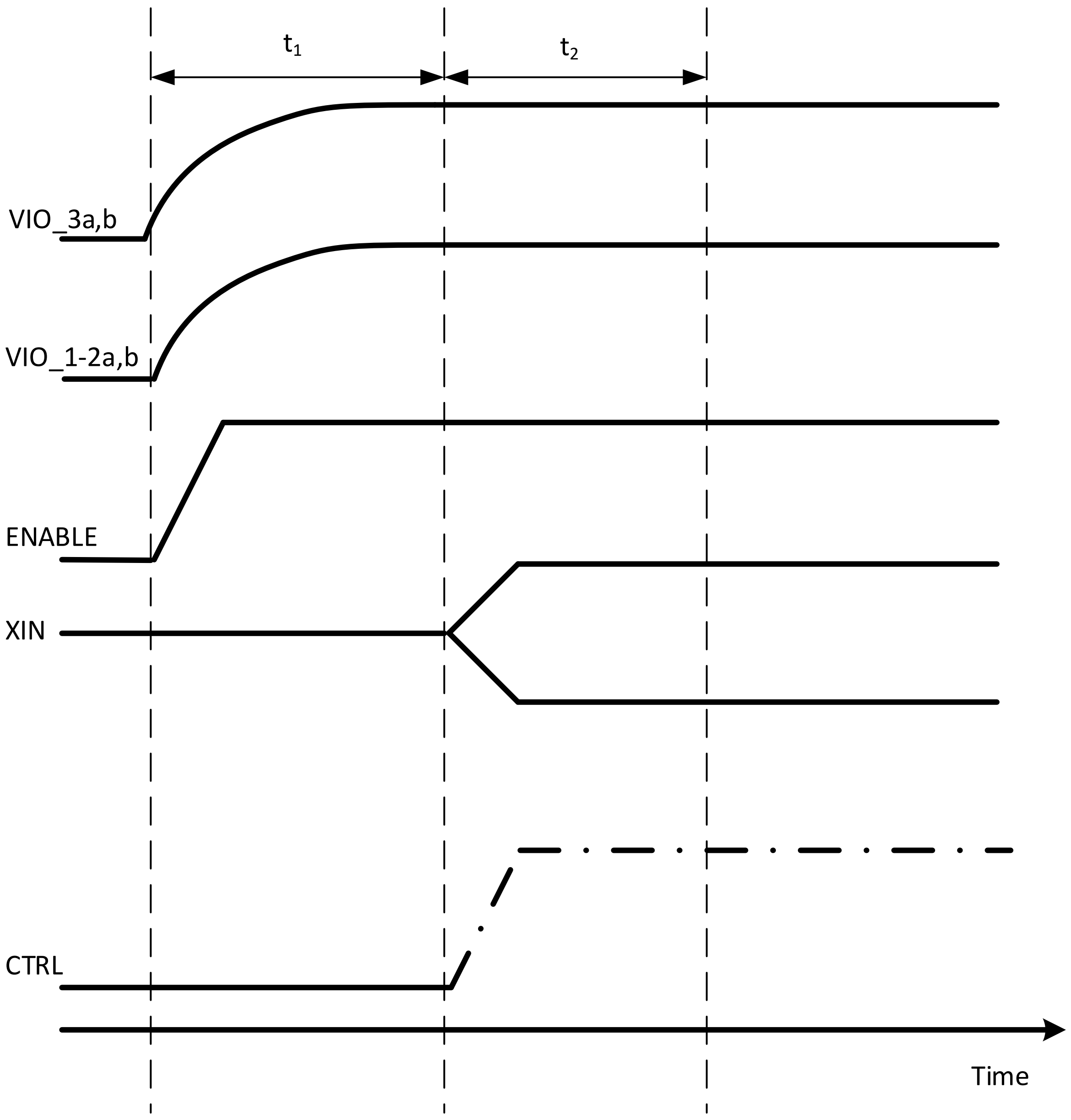

Figure 7.4. Power up sequence

The power up sequence is initiated by turning on VIO_3a,b. It must be turned on before or simultaneously with ENABLE and VIO_1-2a,b. ENABLE and VIO_1-2a,b can be turned on in any order and independently of each other. A111 should however not be considered as in state "ON" until all supply voltage levels are stable and ENABLE is high. The time constant t_1 in figure 7.4 denotes this time. The actual value of t_1 depends on the power supply and the decoupling capacitors used. If the CTRL signal is used, it must be held at 0V during time t_1.

Next step in the power up sequence is to have a settling time for the XTAL oscillator to stabilize, shown as time t_2 in figure 7.4. This may take up to several milliseconds depending on the XTAL performance. The sensor does not require any settling time if it is integrated using an external reference clock. It is advised to have the clock inactive at 0 V while ENABLE is inactive.

Now the A111 radar sensor is ready for SPI communication.

After power up is complete, the sensor is loaded with a program. Up until the point where the sensor's program is started, the INTERRUPT is high impedance. However, after the sensor's program has started the INTERRUPT is configured to a push-pull CMOS output. It is therefore required that the host I/O is configured as input before any programs are started on the sensor.

The power down sequence is described in Figure 7.5.

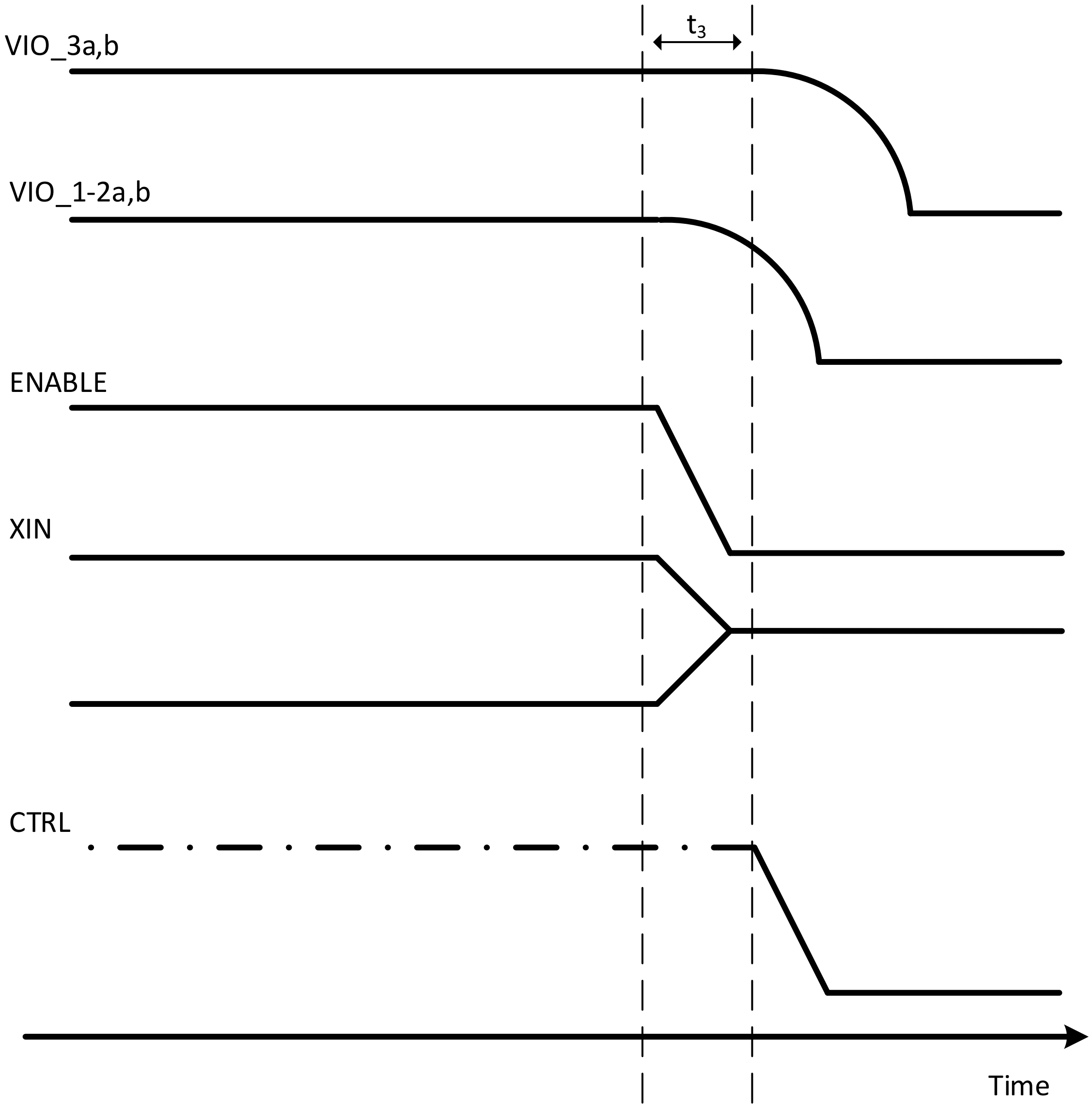

Figure 7.5. The power down sequence

The power down sequence is initiated by setting "ENABLE" low. The crystal oscillator will be disabled when ENABLE is set low. If an external reference clock is used, it is advised to disable it simultaneously with ENABLE.

After that, VIO_1-2a,b can be turned off. Time constant t_3 (refer to Figure 7.5) later, VIO_3a,b can be disabled. The constant t_3 >=0. The I/O inputs on A111 (including CTRL if it is being used) must be set to 0V before or simultaneously with VIO_3a,b going low, otherwise the internal ESD protection diodes will draw current from the I/O source.

8 Layout Recommendations

A111 sensor free space integration should take the following into consideration:

- Any material above the sensor should have as low permittivity and loss as possible, e.g. plastic or glass with low permittivity.
- To conclude on optimum distance from the sensor, a simulation/measurement investigation is required.

The sensor antennas are of a folded dipole type, with its ground reference in the package ground plane, extending over the whole area of the sensor. To further enhance the directivity of the sensor, the package ground plane should be extended to the package by soldering all GND connections of the sensor to the board top layer ground. This top layer ground plane below the sensor should be continuous and should have low impedance.

The below table shows the sensor gain loss versus solid ground plane area.

Ground plane area	Sensor gain loss
625 mm^2	0 dB
425 mm2	-0.2 dB
225 mm^2	-0.4 dB
127 mm^2	-2.2 dB
29 mm^2	-4.0 dB

Table 8.1 Simulated relative maximum gain as function of extended solid ground plane area. The area is quadratic.

It is recommended to keep the layout around XIN and XOUT symmetrical to the XTAL and capacitors.

VIO_1a and VIO_1b are short circuit inside the sensor and are recommended to be connected to each other on the PCB as well. VIO_2a and VIO_2b are short circuit inside the sensor and are recommended to be connected to each other on the PCB as well. VIO_3a and VIO_3b are short circuit inside the sensor and are recommended to be connected to each other on the PCB as well. It is recommended to have decoupling capacitors on the supplies placed as close as possible to the supply terminals. It is recommended as minimum 100 nF in parallel with 1 uF decoupling capacitance on each supply.

8.1 Bill of Material (BoM)

The below table shows BOM for integration of the A111:

Component	Value	Description
C1, C2, C3	1 µF	VIO_1, VIO_2, VIO_3 decoupling
R1, R2	100 kΩ	INTERRUPT and CTRL pull down resistor
X1		XTAL 24 MHz, Epson TSX-3225 (optional)
C4, C5	8 pF (1)	XTAL freq. tuning capacitor (optional)

Table 8.2 BOM list

(1) See details in chapter 7.1 XTAL for C4, C5 value calculation.

See figure 8.1 that shows the optional XTAL populated.

8.2 XTAL

The input clock can origin from a crystal (XTAL), connected to XIN and XOUT.

The A111 sensor has a built-in XTAL oscillator and by adding an external XTAL component, as shown in the below figure 8.1, a reference design without any external clock reference supplied is possible. Note however, that the external clock reference still is supported and if used instead of an external XTAL, it is connected to XIN.

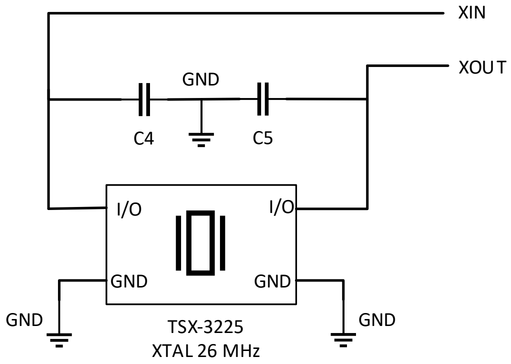

Figure 8.1. External XTAL schematics.

To enable the internal XTAL oscillator to drive the external resonator, the relation in equation 1 must be fulfilled.

Equation 1

$$f * C_{pin}^{0.8} * R_{ESR}^{0.61} < 0.7$$

Equation 2

$$C = 2(C_L - C_{stray})$$

Equation 3

$$C_{pin} = C + C_{stray} * 2$$

The capacitance values are calculated in equation 2. C_L and R_{ESR} are XTAL parameters and vary from XTAL to XTAL. The stray capacitance is the sum of the capacitance between XIN and XOUT, which are found in the traces on PCB and in the package; 2 to 5 pF is a general estimation.

Example:

- f = 26 MHz
- C_L = 9 pF
- R_{ESR} = 40 ohm

Assuming that C_{stray} = 5 pF gives C4, C5 = 8 pF and that the condition is met with the result 0.63 < 0.7.

8.3 External Clock Source

The input clock can origin from an external clock source connected to XIN, with XOUT left open.

As an example given in table 8.3, maximum phase noise figures are given using 40 MHz external clock reference.

Offset frequency (Hz)	Min.	Typ.	Max.	Unit
1000			-80	dBc/Hz
10 000			-100	dBc/Hz
100 000			-120	dBc/Hz
1 000 000			-140	dBc/Hz
10 000 000			-155	dBc/Hz

Table 8.3. Phase noise using 40 MHz external clock reference

8.4 Power Supply

The A111 sensor has got three power supplies where the VIO_3 power supply is sensitive to power supply ripple. Power supply ripple on VIO_3 may degrade performance since VIO_3 supplies the internal clock generation blocks. Table 8.4 provides the required power supply ripple specification for VIO_3.

Frequency (Hz)	Min.	Typ.	Max.	Unit
10 000			18.7	mV_{pp}
100 000			2.6	mV_{pp}
1 000 000			0.26	mV_{pp}
3 000 000			0.09	mV_{pp}
10 000 000			0.23	mV_{pp}
100 000 000			3.0	mV_{pp}

Table 8.4: Required power supply ripple specification for VIO_3

<u>Low-cost LC filter solution</u>

Acconeer provides recommended low-cost LC filter solution, the recommended filter is displayed in figure 8.2. The values of the component demonstrate an example filter design, exact values depend on switching frequency and ripple amplitude of the supply regulator. However, be aware of LC filter peaking at the series resonance frequency 1/(2π*sqrt(LC)). A small resistor, 250 mΩ in the example filter, can be inserted to lower the Q factor of the filter. In certain applications, where disturbances at the series resonance frequency is present, the filter may not be an optimal solution and an external LDO such as TPS7A8801 or equal is recommended to use instead of the low-cost LC filter.

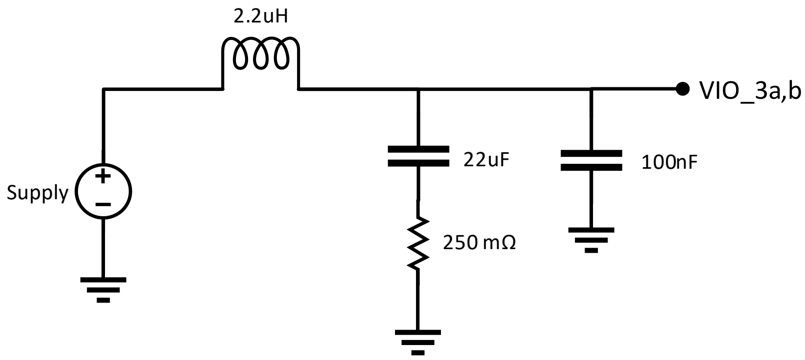

Figure 8.2: Low cost LC supply filter

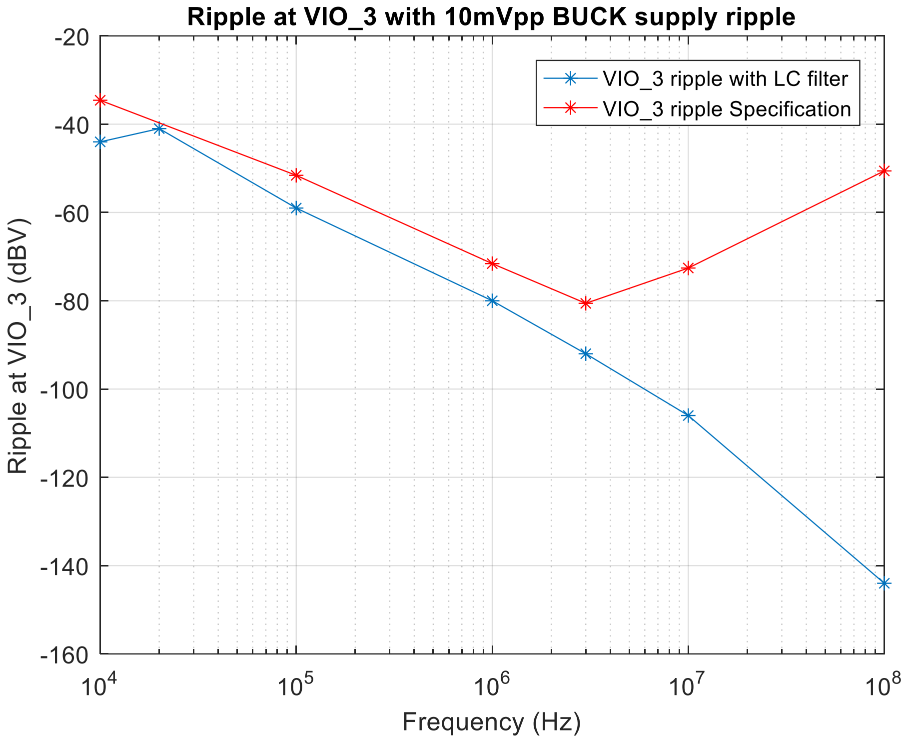

Figure 8.3: Simulated performance with 10mV$_{pp}$ supply ripple with low cost LC supply filter.

9 Regulatory Approval

To be noted is that some regulatory specifications also specify the usage of the sensor, so users of the sensor must check regulatory requirements for their own use case and determine if the regulatory approvals described below are sufficient.

9.1 ETSI

Hereby, Acconeer declares that the A111 sensor is compliant with directive 2014/53/EU.

9.1.1 EU type examination certificate

EU Type Examination Certificate

CTC advanced
member of RWTÜV group

Bundesnetzagentur

BNetzA-bS-02/51-52

authorized by the German Government to act as Notified Body in accordance with the RE Directive 2014/53/EU of 16 April 2014.

Certificate Holder: Acconeer AB
Ideon Gateway, Scheelevägan 27
223 70 Lund
Sweden

Product Manufacturer: See Certificate Holder

Product Designation: A111

Product Description: 60 GHz Module for SRD Radar

Conformity Assessment:

Essential requirements	Examined documentation	Result
Radio spectrum RED, Article 3.2	Technical documentation including test report	conform

EU Type Examination Certificate:
In accordance with Annex III of the European Council Directive 2014/53/EU on radio equipment, our opinion is that this equipment type complies with the essential requirements stated above.

Marking:
The product shall be marked with the CE marking as required in the Council Directive 2014/53/EU.

Annexes:
The certificate is only valid in conjunction with the following number of annexes: 1

Validity:
Conformity is provided unless changes/modifications have been done to the standard and/or assessed type of equipment.

GERMAN NOTIFIED BODY
EUROPEAN ID-NO. 0682

Certificate Registration No.: T818606L-01-TEC

CE 0682

CTC advanced GmbH

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Authorized signature / title

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Untertuerkheimer Str. 6–10 | 66117 Saarbruecken | Germany | www.ctcadvanced.com

9.2 Declaration of conformity FCC

Hereby, Acconeer declares that the A111-003 sensor has limited single-modular transmitter approval granted by FCC. Acconeer has not approved any changes to this device. Any changes or modifications to this device could invalid the FCC approval.

The host manufacturer should refer to guidance in KDB 996369. In addition, the host manufacturer must seek guidance and approval from Acconeer to ensure that the module limiting conditions are fulfilled for the host product and that the installation instructions provided by Acconeer in this document has been followed. In section “9.2.1 Host integrator instructions” of this User manual it is explicitly stated what the host manufacturer must do to ensure that the waiver conditions are fulfilled for the product being installed in the interior of new passenger motor vehicles. Acconeer will review test data, host design, and host documentation prior to giving manufacturer approval. Changes or modifications not expressly approved by the Acconeer could void the user’s authority to operate the equipment. The host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification.

The A111-003 sensor meets the title 47 of the Code of Federal Regulations, part 15 section 15.255 for intentional radiators operating in the 57-71 GHz band, with the addition of the waiver conditions outlined in DA 21-814 and listed here below. Intended uses are restricted to vehicle-bound applications like passenger presence detection to include children inadvertently left in vehicles in hot weather; seat belt reminder/airbag suppression; intruder alarm; and automotive access gesture control to detect foot movement to close a sliding door.

- The Acconeer pulse-coherent radar shall be certified for compliance with all the technical specifications applicable to operation under 47 CFR Part 15, with the exception of the following provisions in 47 CFR §§ 15.255(a)(2) and (c)(3), which are waived to allow the device to operate as a radar on new passenger motor vehicles in the 57-64 GHz band at 5% duty cycle, evaluated in 0.125 μs time-averaged windows, at a 3 dBm average EIRP evaluated in 0.125 μs time-averaged windows, and a pulse duration not to exceed 6 ns.
- The radar shall be restricted to factory installation in the interior of new passenger motor vehicles for the primary purpose of in-cabin monitoring functions and shall not be marketed in after-market add-on products. The grantee shall include clear and complete installation instructions that explain this restriction and a copy of these instructions shall be submitted along with the application for equipment authorization. If the radar is installed such that it is not visible (e.g., behind the headliner), then the required equipment labeling in accordance with the provisions of 47 CFR §§ 2.925 and 15.19 shall be provided in the vehicle’s Owner’s Manual. The certification grant shall specify these restrictions.
- Operations under this waiver may not be used to transmit data.
- Users of Acconeer radars must be made aware through a disclosure in the vehicle Owner’s Manual or an equivalent means that that operation is subject to the conditions that no harmful interference is caused and that any interference must be accepted.
- This waiver and its conditions shall apply only to Acconeer radars intended for installation in passenger motor vehicles as described herein and are not to be considered to apply generally to any other radars or field disturbance sensors that will operate in different environments where further analysis would be necessary to assess the potential for impact to other authorized users.
- The waiver conditions granted herein are not transferable to any third party via §2.933 or any other means of technology transfer.
- The waiver is explicitly conditioned on any changes to our rules that may be adopted in a future rulemaking proceeding in accordance with the terms of this order.

9.2.1 Host integrator instructions

This section provides guidance to the host integrator per sub section of chapter “2.0 INTEGRATION INSTRUCTIONS” KDB 996369 D03 and lists what the host integrator must do for Acconeer to give manufacturer approval that the host product complies with title 47 of the Code of Federal Regulations, part 15 section 15.255 for intentional radiators operating in the 57-71 GHz band, with the addition of the waiver conditions outlined in DA 21-814.

2.2 List of applicable FCC rules

The A111-003 module meets the title 47 of the Code of Federal Regulations, part 15 section 15.255 for intentional radiators operating in the 57-71 GHz band, with the addition of the waiver conditions outlined in DA 21-814, and presented in section 9.2 of this User manual.

2.3 Summarize the specific operational use conditions

The A111-003 module shall be restricted to factory installation in the interior of new passenger motor vehicles for the primary purpose of in-cabin monitoring functions and shall not be marketed in after-market add-on products. Intended uses are restricted to vehicle-bound applications like passenger presence detection to include children inadvertently left in vehicles in hot weather; seat belt reminder/airbag suppression; intruder alarm; and automotive access gesture control to detect foot movement to close a sliding door.

One or several of these modules may be installed per vehicle, within the interior of the vehicle. Installers must safeguard that modules are installed in a manner than ensures that passengers will not have access to the modules. Figure 9.1 shows an example of how the modules can be installed for the allowed use in passenger motor vehicles (i.e., passenger presence detection; seat belt reminder/airbag suppression; intruder alarm; and automotive access gesture control to detect foot movement to close a sliding door). This module integration example fulfills the requirement that the module is integrated in the interior of new passenger motor vehicles for the primary purpose of in-cabin monitoring functions.

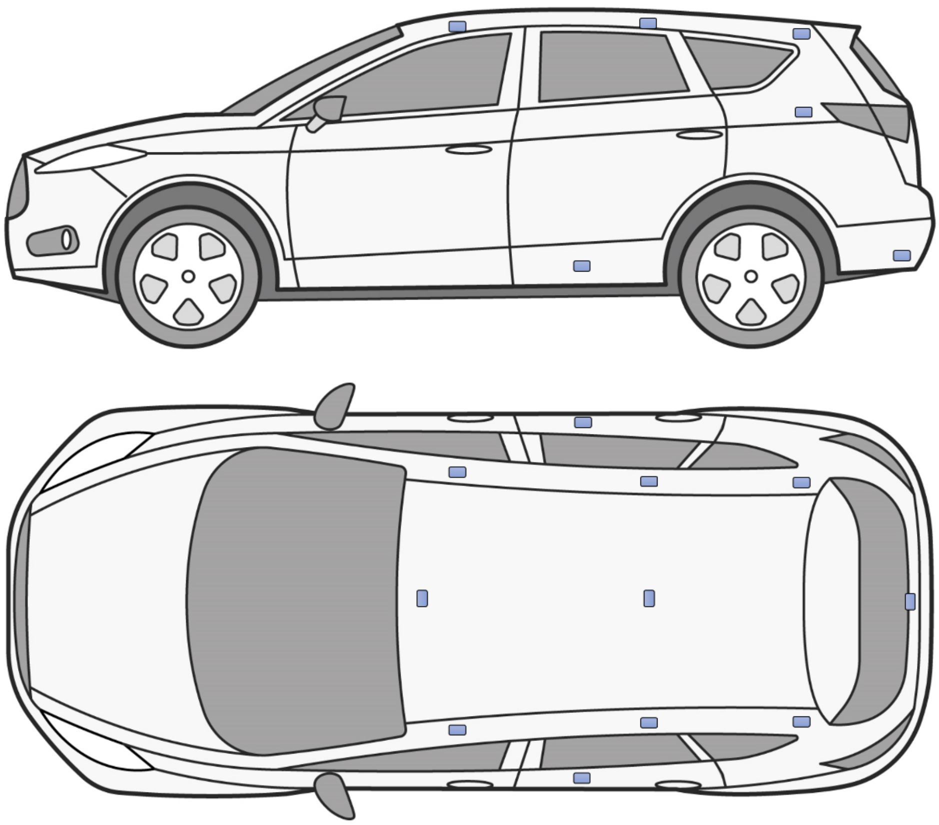

Figure 9.1: Example of how the modules can be installed for the allowed use in passenger motor vehicles.

The module may not be used to transmit data. The design does have data inputs and there is no possibility for the user to modulate data on the transmitted signal

2.4 Limited module procedures

The A111-003 module has limited single-modular transmitter approval granted by FCC. Host product manufacturers are responsible to follow the integration guidance and to perform a limited set of transmitter module verification testing, to ensure that the end product is in compliance with the FCC rules.

The host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification.

2.5 Trace antenna designs

The product has integrated antennas in package, it is not possible to connect trace antenna.

2.6 RF exposure considerations

MPE RF exposure testing is not needed as the available maximum time-averaged power of the module is no more than 1 mW, according to 47 CFR 1.1307(b)(3)(i)(A). Co-location of this module with other transmitters that operate simultaneously are required to be evaluated using the FCC multi-transmitter procedures.

2.7 Antennas

The modular approval covers use with dielectric lens that converge or diverge the electromagnetic waves at least in one plane of radiation (E or H plane).

2.8 Label and compliance information

The host device shall be labelled to identify the modules within the host device, which means that the host device shall be labelled to display the FCC ID of the module preceded by words "Contains transmitter module" or "Contains", E.g.

Contains FCC ID: 2AQ6KA1003

If the module is installed such that it is not visible (e.g., behind the headliner), then the required equipment labeling in accordance with the provisions of 47 CFR §§ 2.925 and 15.19 shall be provided in the vehicle's Owner's Manual.

The module integrator must include below interference statement to vehicle Owner's manual:

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

2.9 Information on test modes and additional testing requirements

Testing for the modular approval of the A111-003 has been performed using a binary file which represents highest Tx emission configuration. This test binary is available in the software provided by Acconeer and can be used for that the module as installed in a host complies with FCC requirements.

2.10 Additional testing, Part 15 Subpart B disclaimer

The host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification.

10 Mechanical Data

The A111 is available in fcCSP package for mounting on a substrate. The below table shows mechanical data:

Parameter	Min.	Typ.	Max	Unit
Body X	5.15	5.20	5.25	mm
Body Y	5.45	5.50	5.55	mm
Body Z (height)		0.821	0.899	mm
Ball pitch	0.45	0.50	0.55	mm
Ball diameter	0.25	0.30	0.35	mm
Ball height	0.15	0.24		mm
Ball count		50		#

Table 10.1. Mechanical data

The A111 footprint is shown in Figure 10.1.

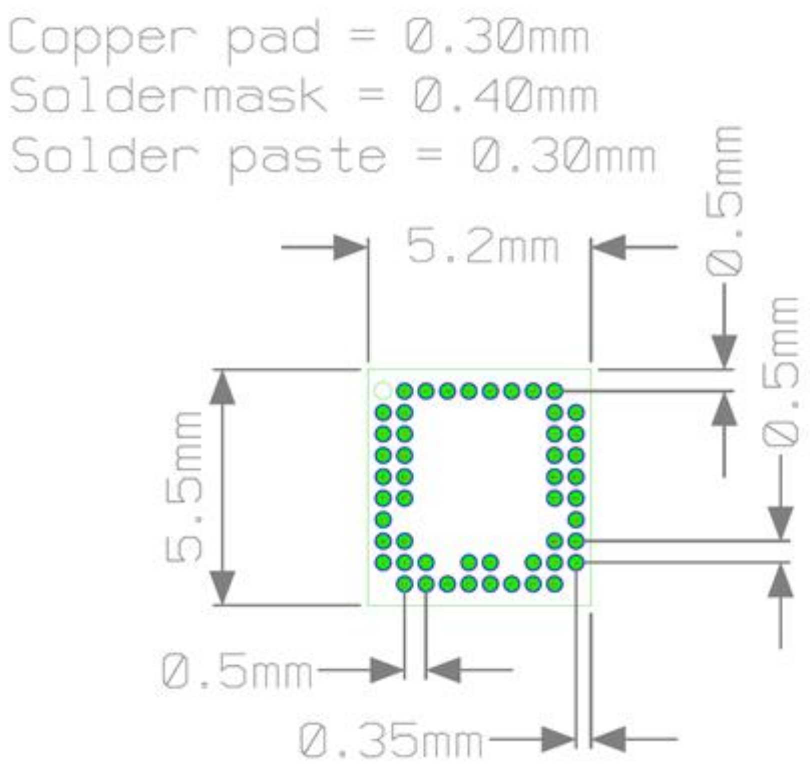

Figure 10.1. A111 footprint

The physical layout of the A111 sensor is shown in Figure 10.2, 10.3 and 10.4.

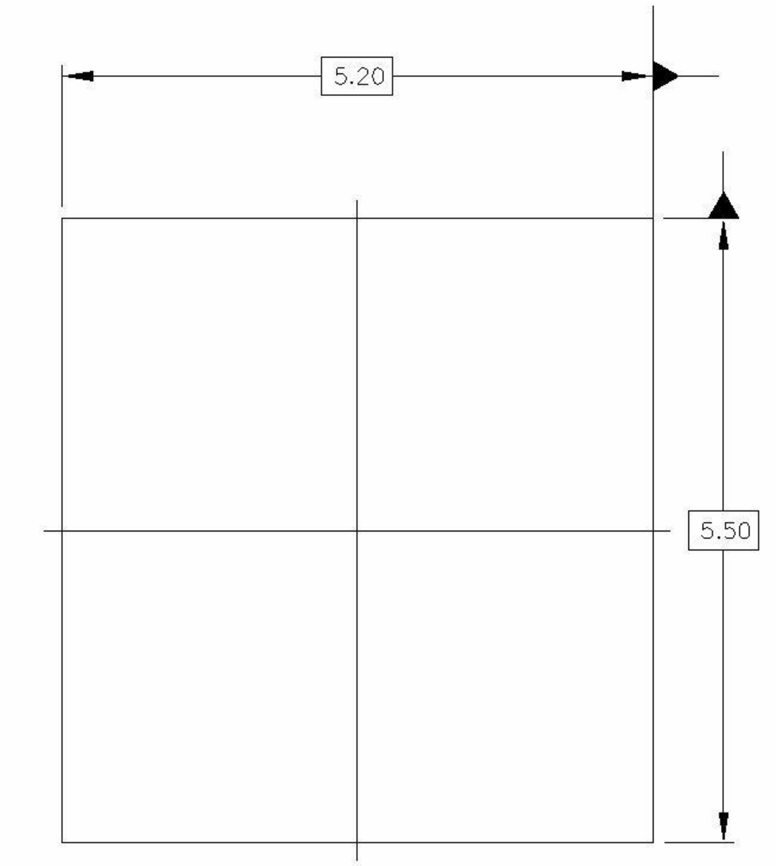

Figure 10.2. Physical layout of the A111 sensor, top view.

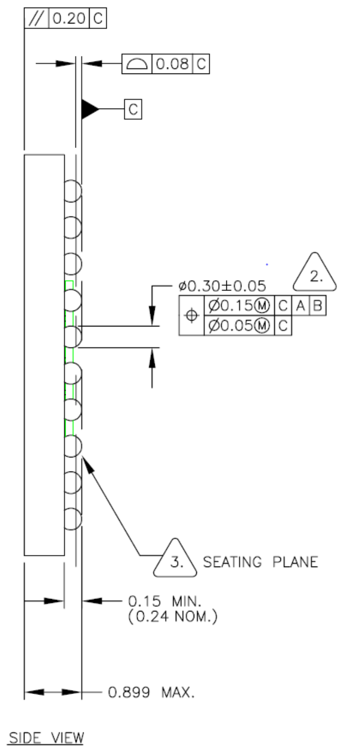

Figure 10.3. Physical layout of the A111 sensor, side view.

Primary datum C and seating plane are defined by the spherical crowns of the solder balls. Dimension is measured at the maximum solder ball diameter, parallel to primary datum C. All dimensions and tolerances conform to ASME Y14.5 – 2009.

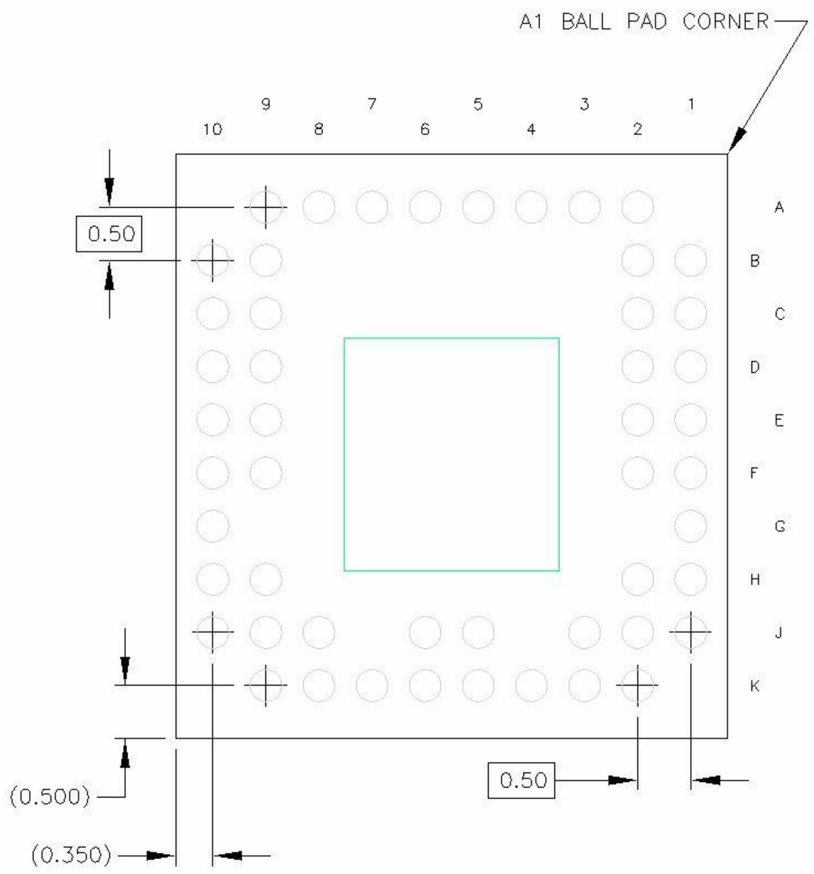

Figure 10.4. Physical layout of the A111 sensor, bottom view.

The bottom view shows 50 solder balls. The pitch of the BGA balls is 500 µm, the ball diameter is 300 µm ±5 µm and the collapsed ball height is 0.244 ± 0.050 mm.

10.1 Moisture Sensitivity Level and Recommended Reflow Profile

Acconeer A111 sensor is a Moisture Sensitive Devices (MSD) in accordance to the IPC/JEDEC specification. The Moisture Sensitivity Level (MSL) relates to the packaging and handling precautions required. A111 sensor is rated at MSL level 3.

Maximum number of reflow passes recommended for A111 is 2.

Soldering process qualified during qualification with “Preconditioning MSL 3: 30°C. 60%r.h., 192h, according to JEDEC JSTD20”, and qualified for soldering heat resistance according to JEDEC J-STD-020.

10.2 RoHS and REACH Statement

Acconeer A111 sensor meet the requirements of Directive 2011/65/EC of the European Parliament and of the Council on the Restriction of Hazardous Substances (RoHS) and the requirements of the REACH regulation (EC 1907/2006) on Registration, Evaluation, Authorization and Restriction of Chemicals.

11 Abbreviations

ADC	Analog digital converter
AiP	Antenna in package
API	Application programming interface
BGA	Ball grid array
BOM	Bill of materials
CE	"Conformité Européene" (which literally means "European Conformity")
CPHA	Clock phase
CPOL	Clock polarity
EIRP	Equivalent isotropically radiated power
ESD	Electrostatic discharge
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
fcCSP	Flip-chip chip-scale package
GND	Ground
HAL	Hardware abstraction layer
HPBW	Half power beamwidth
LDO	Low-dropout regulator
MCU	Microcontroller unit
MISO	Master input, slave output
MOSI	Master output, slave input
NC	No connect
PCR	Pulse coherent radar
PLL	Phase locked loop
PoR	Power on reset
RCS	Radar cross section
RF	Radio frequency
RX	Receiver
SPI	Serial peripheral interface
SS	Slave select
STD	Standard deviation
TCXO	Temperature compensated crystal oscillator
TX	Transceiver
XTAL	Crystal

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