



## A111 – Pulsed Coherent Radar (PCR)

Datasheet v1.7



## A111 Overview

The 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<sup>2</sup>.

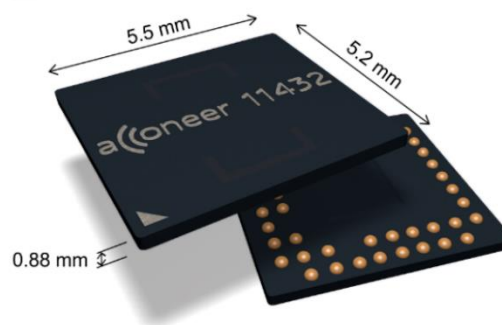
The A111 60 GHz radar system is optimized for high precision and ultra-low power, delivered as a one package solution with integrated Baseband, RF front-end and Antenna in Package (AiP). This will enable easy integration into any portable battery driven device.

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<sup>(1)</sup> and with a continuous sweep update frequency fully configurable up to 1500 Hz<sup>(2)</sup>.

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 frequency
- 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



## 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<sup>(1)</sup>
    - Absolute accuracy in mm
  - Relative accuracy in  $\mu\text{m}$
  - Possible to recognize movement and gestures for several objects
  - Support continuous and single sweep mode
  - Continuous sweep update rate up to 1500 Hz<sup>(2)</sup>
  - HPBW of 80 (H-plane) and 40 degrees (E-plane)
- **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

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

<sup>(2)</sup> System integration dependent – e.g. Host MCU and SPI performance.



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# 1 Revision History

Revision	Comment
V1.0	Released version
V1.1	Minor reference correction in chapter 5.1. A111 marking info added in chapter 2.
V1.2	Relative phase accuracy added in chapter 6.3
V1.3	Ordering information added in chapter 2. Equation corrected in XTAL chapter 8.1.
V1.4	<ul style="list-style-type: none"><li>- EU declaration of conformity added, chapter 9.0.</li><li>- Pin configuration alphabetically order corrected, chapter 3.</li><li>- Acconeer Software chapter 7.1 updated including updated software integration info, chapter 7.2.</li></ul>
V1.5	Removed introduced error in chapter 3, pin configuration.
V1.6	FCC modular approval added, chapter 9.2.
V1.7	Power supply specification added, chapter 8.4.



## 2 Description

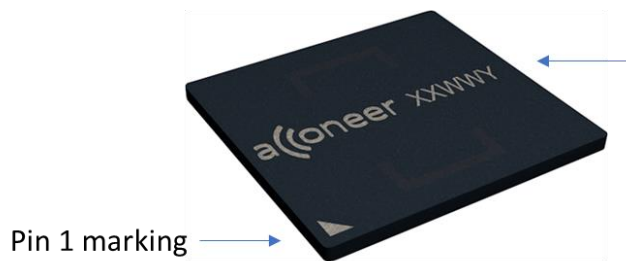
The A111 is an optimized low-power, high-precision, 60 GHz radar sensor with integrated Baseband, an RF front-end and an Antenna in Package (AIP).

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
A111-001-T&R	fcCSP50	5.2 x 5.5 x 0.88 mm	Tape & reel
A111-001-TY	fcCSP50	5.2 x 5.5 x 0.88 mm	13" Tray

### Acconeer A111 marking



#### A111 marking:

- XX = Product code
- WW = Manufacturing week
- Y = Manufacturing year



## 2.1 Functional Block Diagram

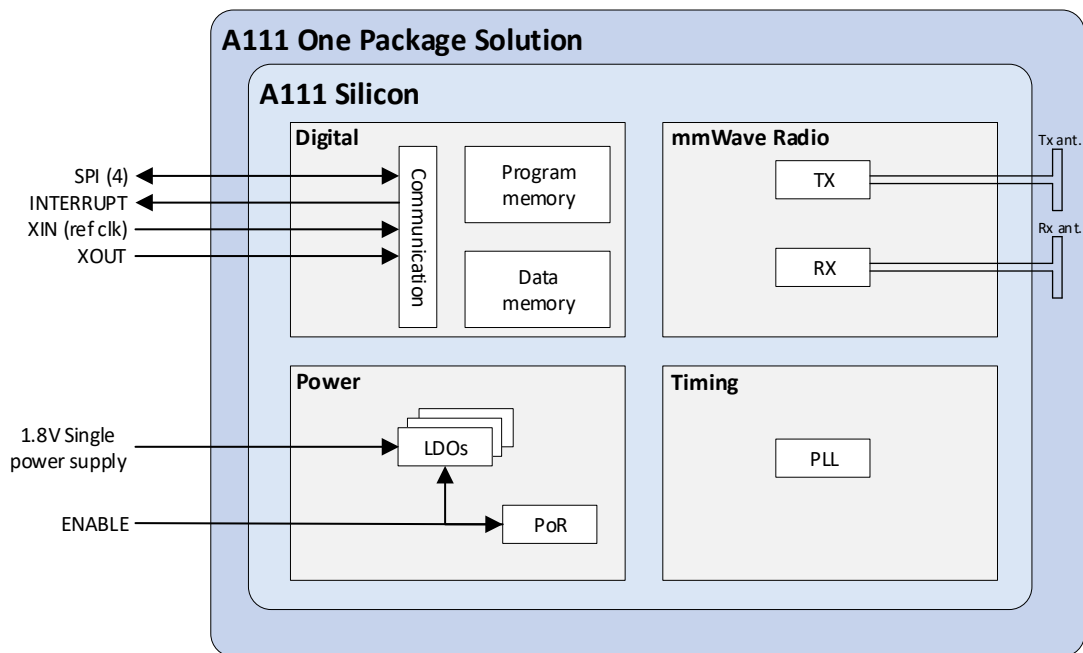


Figure 2.1. The A111 functional block diagram.

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) and INTERRUPT signal.

The Timing block includes the timing circuitry.

The mmWave radio functional block generates and receives radar pulses and includes transmitter (TX), receiver (RX) and interfaces toward the integrated antennas.



### 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		No connect	
A3-A8	GND	Ground	Must be connected to solid ground plane	
A9	GND	Ground	Must be connected to solid ground plane	
B1	NC		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 <sup>(1)</sup>	
C9	VIO_2a	Supply voltage	Supply voltage, RF part <sup>(1)</sup>	
C10	GND	Ground	Must be connected to solid ground plane	
D1	VIO_1b	Supply voltage	Supply voltage, RF part <sup>(1)</sup>	
D2, D9	GND	Ground	Must be connected to solid ground plane	
D10	VIO_2b	Supply voltage	Supply voltage, RF part <sup>(1)</sup>	
E1, E2, E9, E10	GND	Ground	Must be connected to solid ground plane	
F1	GND	Ground	Must be connected to solid ground plane	



Pin	Pin name	Pin type	Description	Comment
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 <sup>(1)</sup>	
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, <i>Description</i> .	mandatory
K9	VIO_3b	Supply voltage	Supply voltage, digital part <sup>(1)</sup>	

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 <sup>(2)</sup>	1.8 V RF power supply	0	2.0	V
VIO_2 <sup>(2)</sup>	1.8 V RF power supply	0	2.0	V
VIO_3	1.8 V digital power supply	0	2.0	V
XIN <sup>(1)</sup>	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 <sub>OP</sub>	Operating temperature range	-40	85	°C
T <sub>STG</sub>	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 <sup>(1)</sup>	150 <sup>(1)</sup>	°C
Reflow soldering temperature <sup>(1)</sup>	J-STD-020 <sup>(1)</sup>	260	°C
Moisture Sensitivity Level	JESD22-A113 <sup>(1)</sup>	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 <sup>(1)</sup>	-0.3		1.2	V
Operating temperature	-40		85	°C

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, at T<sub>A</sub> = 25°C:

Parameter	Min.	Typ.	Max.	Unit
Current into any power supply			100	mA
I/O V <sub>IL</sub> Low-level input voltage	-0.3		0.10*VIO_3	V
I/O V <sub>IH</sub> High-level input voltage	0.90*VIO_3		VIO_3+0.3	V
I/O V <sub>OL</sub> Low-level output voltage			0.4	V
I/O V <sub>OH</sub> High-level output voltage	1.6			V
I/O I <sub>OL</sub> (VOL = 0.4V)		7.8		mA
I/O I <sub>OH</sub> (VOH = VIO_3-0.4)		5.8		mA
I/O I <sub>IL</sub> Low-level input current		<1		µA
I/O I <sub>IH</sub> High-level input current		<1		µA
XIN V <sub>IL</sub> Low-level input voltage	-0.3		0.4	V
XIN V <sub>IH</sub> High-level input voltage	1.0		1.2	V
XIN I <sub>IL</sub> Low-level input current		<1		µA
XIN I <sub>IH</sub> 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  $T_A = 25^\circ\text{C}$ :

Parameter	Min.	Typ.	Max.	Unit
I/O output operating frequency			100	MHz
I/O load capacitance			20	pF
XIN operating frequency	20		80 <sup>(1)</sup>	MHz
XIN capacitance		0.2		pF

Table 4.5 Electrical AC conditions

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

## 4.5 Power Consumption Summary

The below table summarizes the power consumption, maximum current ratings and average current ratings at all power terminals (VIO\_1, VIO\_2, VIO\_3), at  $T_A = 25^\circ\text{C}$ , VIO 1.8 V:

Parameter	Min.	Typ.	Max.	Unit
Current consumption, continuous TX active mode		71		mA
Average power consumption, 0.1 Hz sweep rate <sup>(2)</sup>		0.2 <sup>(1)</sup>		mW
Average power consumption, 10 Hz sweep rate <sup>(2)</sup>		3 <sup>(1)</sup>		mW
Average power consumption, 100 Hz sweep rate		20 <sup>(1)</sup>		mW
Current leakage at ENABLE low		66		$\mu\text{A}$

Table 4.6. Maximum and Average current ratings at power terminals.

(1) Measuring window set to 0.24 m, configuration with maximize on depth resolution used. Leakage current in ENABLE low not removed.

(2) Supply voltage turned off in between measurements.

## 4.6 RF Specification

The below table shows the A111 RF specification:

Parameter	Min.	Typ.	Max.	Unit
Center frequency $f_c$		60.5		GHz
EIRP			10	dBm
HPBW, elevation plane <sup>(1)</sup>		40		degrees
HPBW, horizontal plane <sup>(1)</sup>		80		degrees
Update frequency (configurable) <sup>(2)</sup>			1500	Hz

Table 4.7 A111 RF specification

(1) See chapter 6 Typical Characteristics for elevation (E-plane) and horizontal (H-plane) HPBW.

(2) System integration dependent e.g. Host MCU and SPI performance.



## 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.

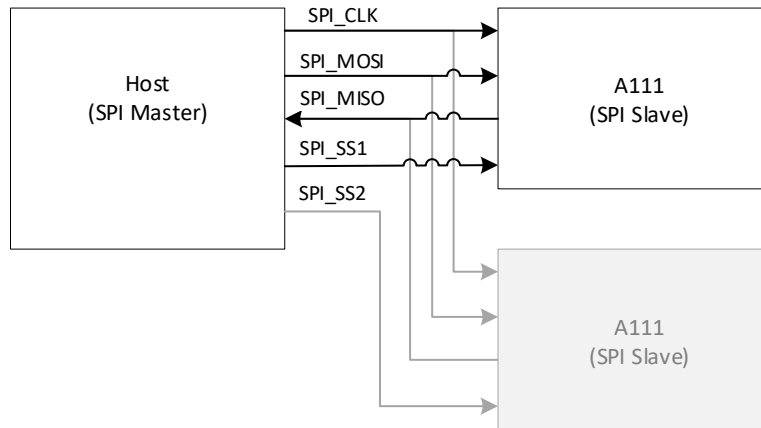


Figure 5.1. SPI master-slave connection

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.

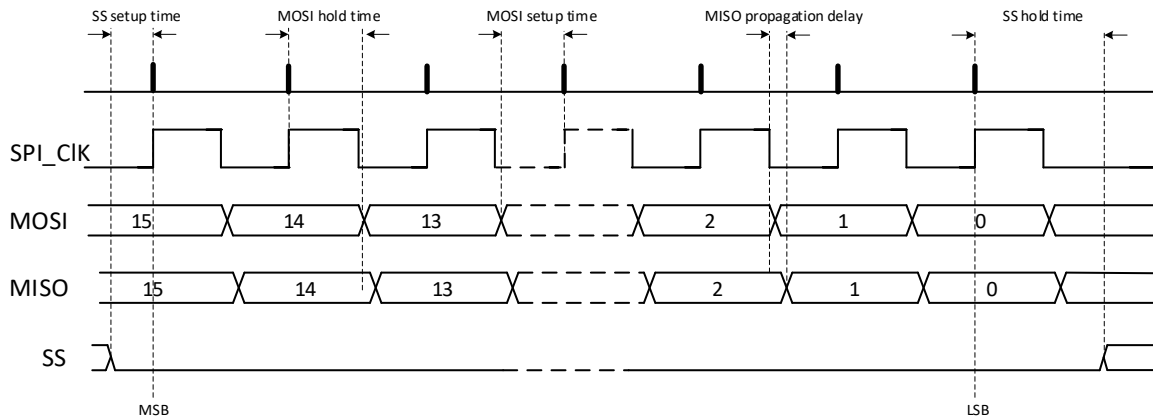


Figure 5.2: Timing diagram of SPI, CPOL=0 and CPHA=0.



Parameter	Min.	Typ.	Max.	Unit
Clock frequency <sup>(1)</sup>			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 <sup>(2)</sup>			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 Distance Accuracy

Conditions:  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 1.8\text{ V}$ . Statistical result based on sweep count 100, 20 tested devices.

The below figure shows the standard deviation of distance estimation, configuration using envelope service with maximize depth resolution profile, 0.06-0.30 m. Object metal cylinder, 40 mm in diameter.

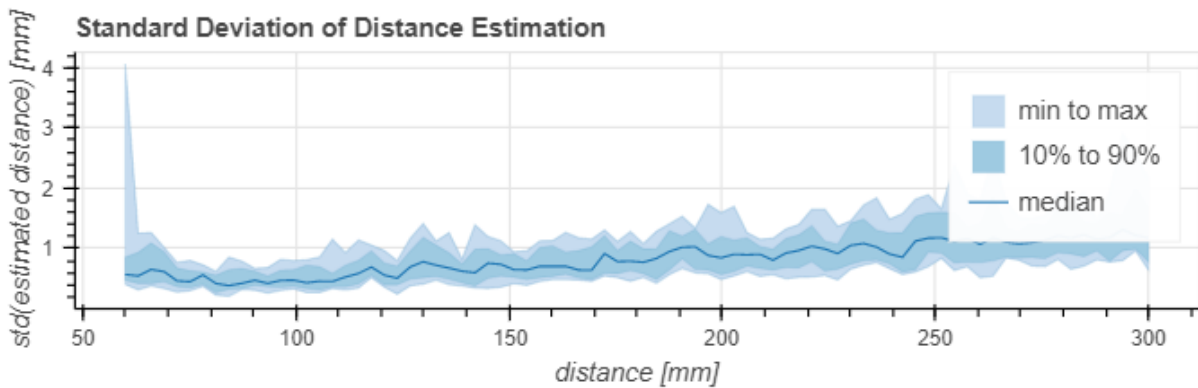


Figure 6.1. Standard deviation of distance estimation, maximize on depth resolution 0.06-0.30 m.

The below figure shows the standard deviation of distance estimation, configuration using envelope service with maximize SNR profile, 1.76-2.0 m. Object 50 mm radius spherical metal corner reflector.

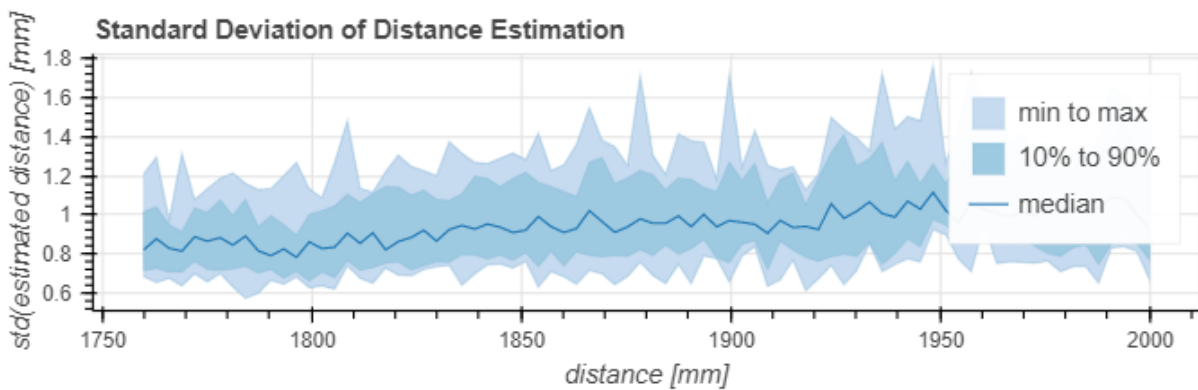


Figure 6.2. Standard deviation of distance estimation, maximize on SNR 1.76-2.0 m



## 6.2 Amplitude Accuracy

Conditions:  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 1.8\text{ V}$ . Statistical result based on sweep count 100, 20 tested devices.

The below figure shows the standard deviation of amplitude estimation, configuration using envelope service with maximize depth resolution profile, 0.06-0.30 m. Object metal cylinder 40 mm diameter.

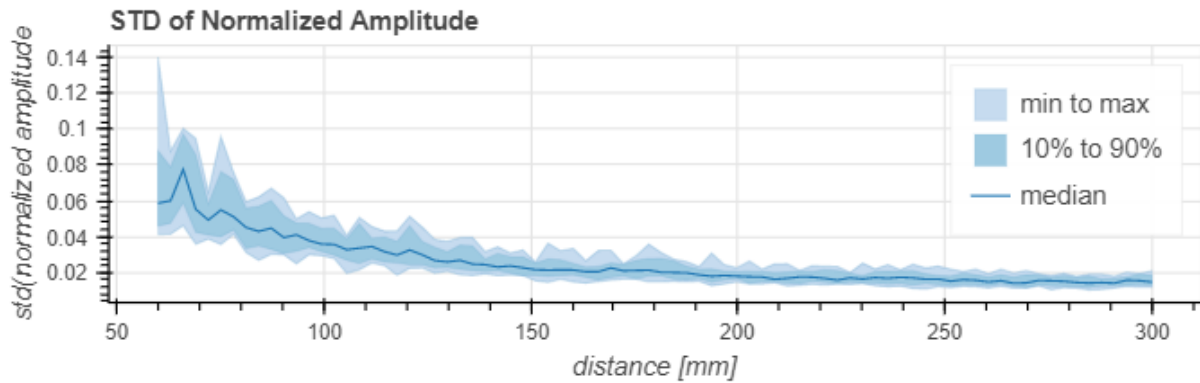


Figure 6.3. Standard deviation of amplitude estimation, maximize on depth resolution 0.06-0.30 m.

The below figure shows the standard deviation of amplitude estimation, configuration using envelope service with maximize SNR profile, 1.76-2.0 m. Object 5 cm radius spherical metal corner reflector.

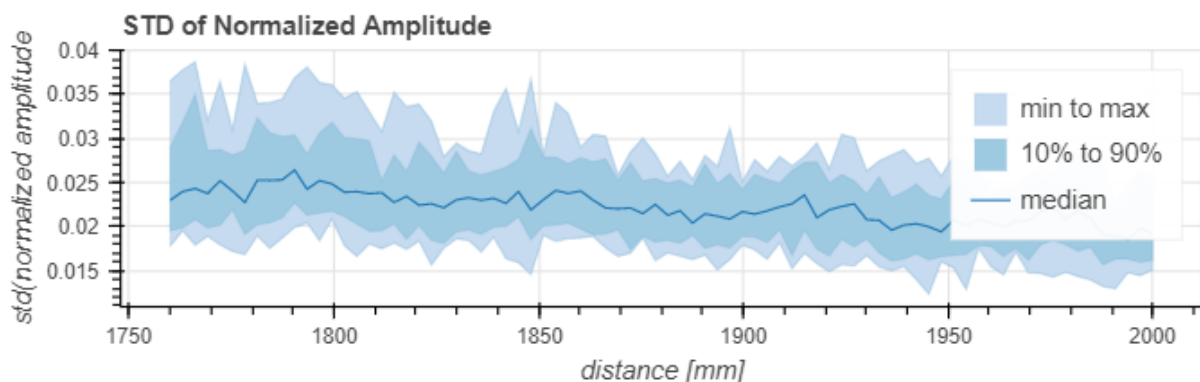


Figure 6.4. Standard deviation of amplitude estimation, maximize on SNR 1.76-2.0 m.

## 6.3 Relative Phase Accuracy

Conditions:  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 1.8\text{ V}$ . 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  $\mu\text{m}$  in relative distance accuracy.



## 6.4 Half Power Beamwidth (HPBW)

Conditions:  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 1.8\text{ V}$ . Statistical result based on sweep count 100 (20 tested devices).

This section shows the A111 Elevation plane (E-plane) and Horizontal plane (H-plane) radiation pattern.

The below figure shows the normalized radiation pattern at E-plane, configuration using envelope service with maximize depth resolution profile, with a 5 cm radius spherical metal corner reflector. HPBW for E-plane is  $\pm 20$  degrees, as shown in the below figure.

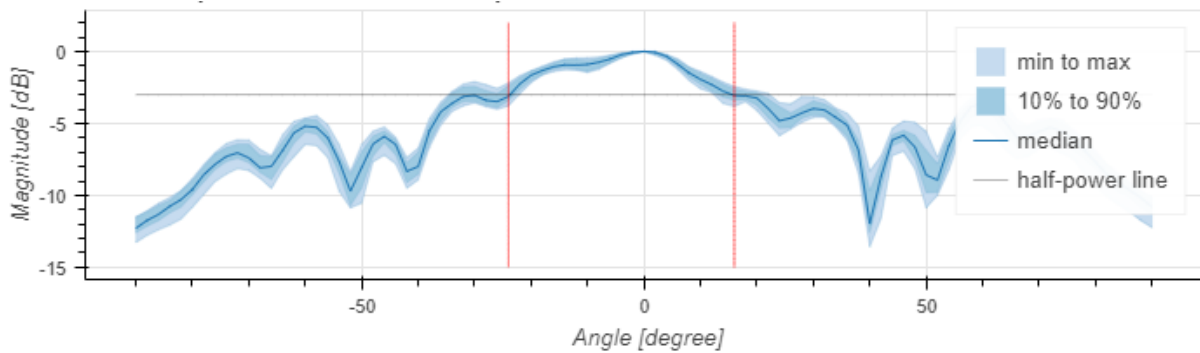


Figure 6.5. Normalized radiation pattern at E-plane.

The below figure shows the normalized radiation pattern at H-plane, configuration using envelope service with maximize depth resolution profile, with a 5 cm radius spherical metal corner reflector. The HPBW for H-plane is  $\pm 40$  degrees, as shown in the below figure.

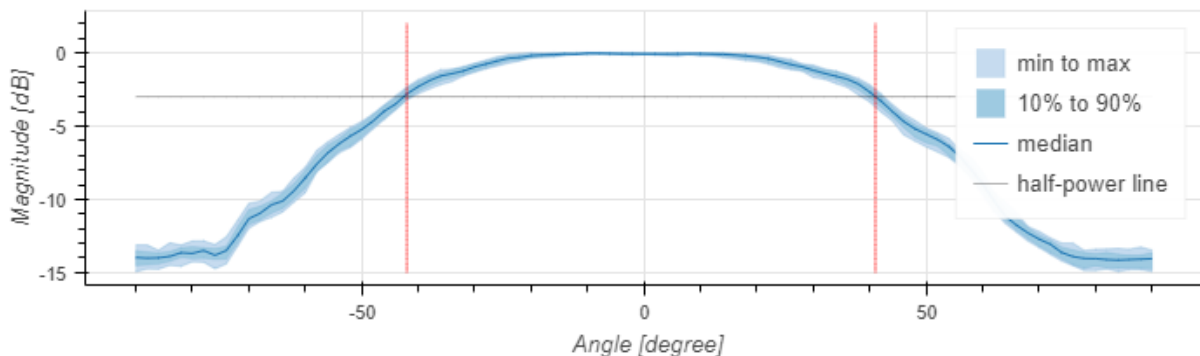


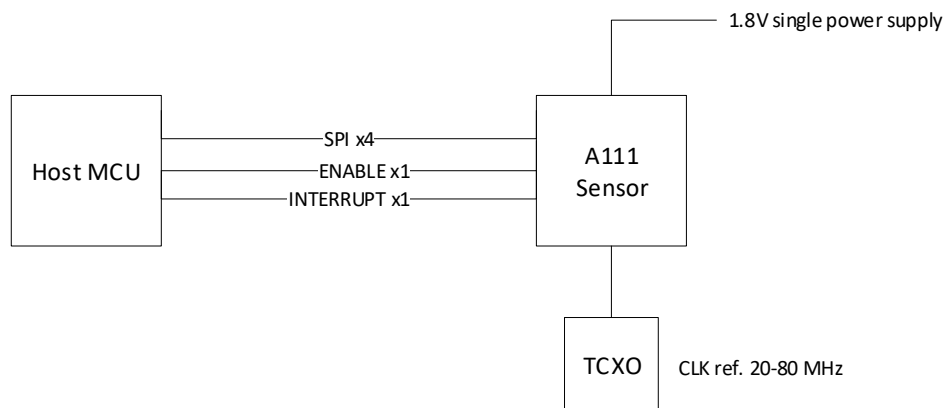
Figure 6.6. Normalized radiation pattern at H-plane





## 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.

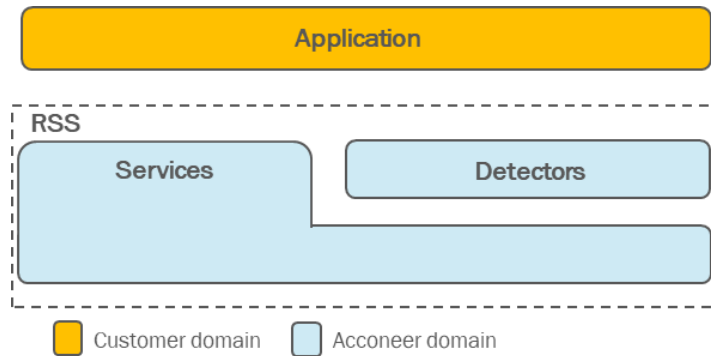
The sensor provides support for ENABLE and INTERRUPT as interrupt signal, always output, that is used as an interrupt in the Host MCU.



## 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 and INTERRUPT 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 Up Sequence

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

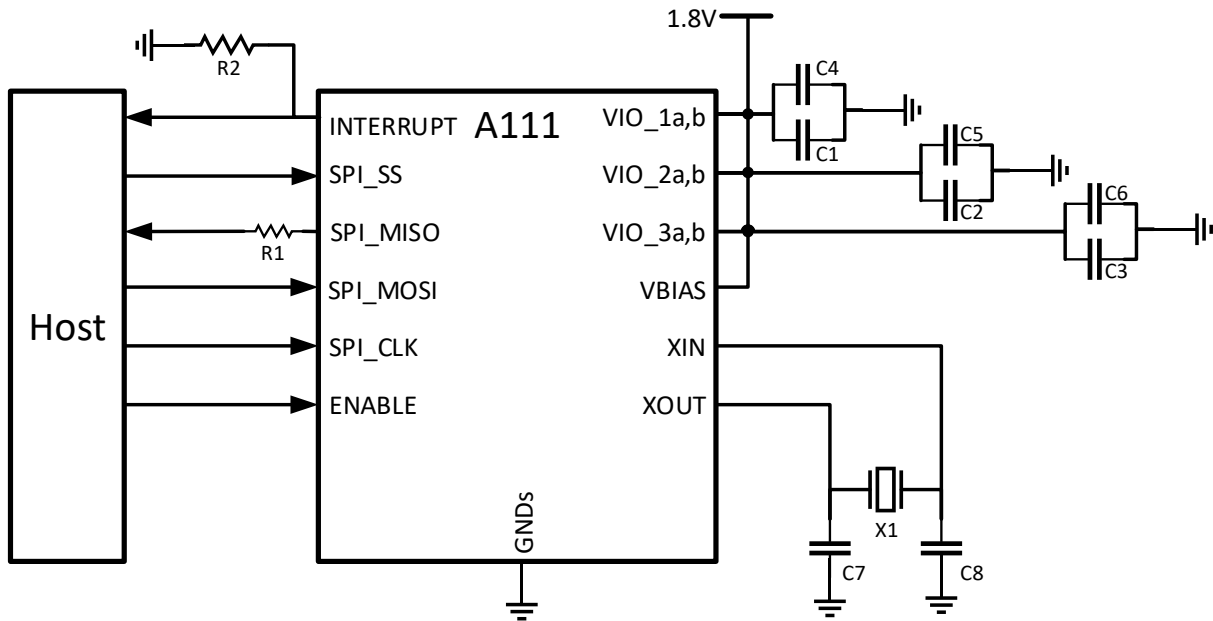


Figure 7.3. Recommended integration of the A111 radar sensor.

The power up sequence is shown in below figure.

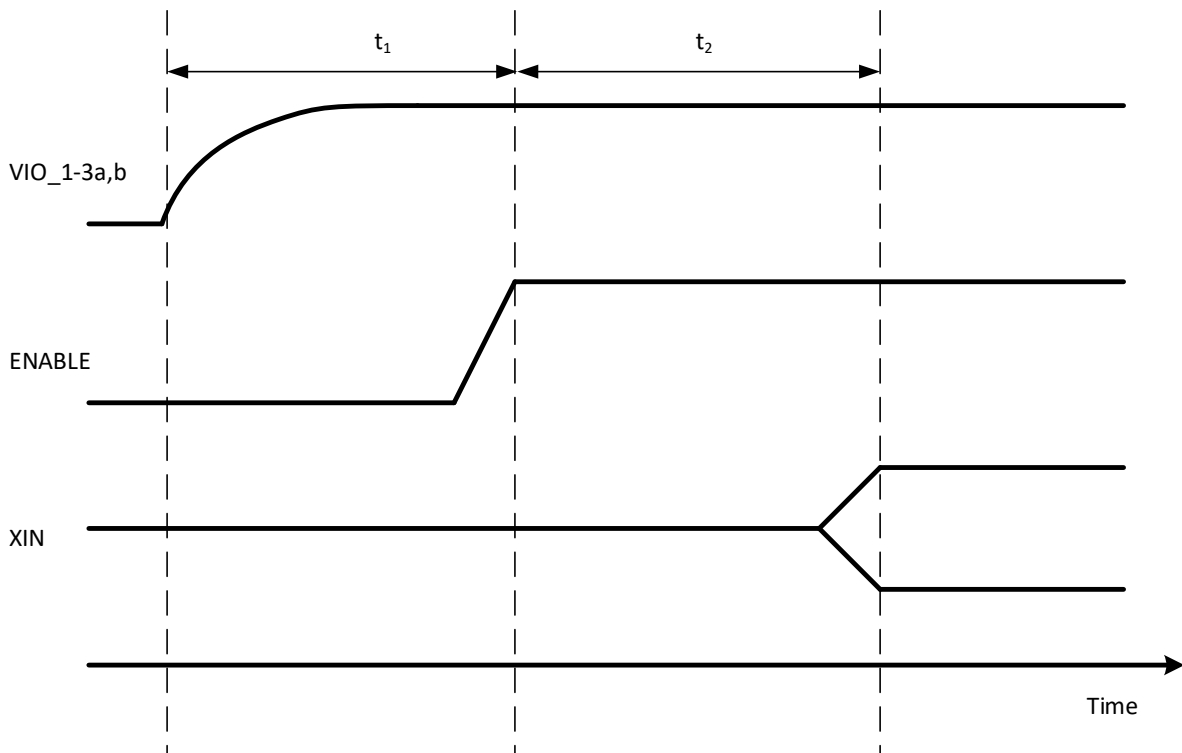


Figure 7.4. Power up sequence



It is recommended to allow the supply voltage on the sensor to stabilize before activating ENABLE. That is shown as the time  $t_1$  in figure 7.4 and the actual time depends on the power supply and the value of the decoupling capacitors.

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. All I/Os must never exceed VIO\_3 voltage, accordingly if VIO\_3 voltage is set to 0V between sensor usage then all I/Os must also be set to 0V. Otherwise, the internal ESD protection diodes will draw current from the I/O source.

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. Therefore it is required that the host I/O is configured as input before any programs are started on the sensor.

The power down sequence is recommended to be executed in the reverse order as the power up sequence: First ensure that all I/O inputs are at 0V which includes ENABLE, after that all VIO1\_3a,b can be turned off.

VIO\_1 and VIO\_2 must never have higher voltage than VIO\_3, and it is recommended to enable/disable the three supplies simultaneously.

External clock reference, if used, needs always to be available to sensor.



## 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 <sup>2</sup>	0 dB
425 mm <sup>2</sup>	-0.2 dB
225 mm <sup>2</sup>	-0.4 dB
127 mm <sup>2</sup>	-2.2 dB
29 mm <sup>2</sup>	-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	100 nF	VIO_1, VIO_2, VIO_3 decoupling
C4, C5, C6	1 $\mu$ F	VIO_1, VIO_2, VIO_3 decoupling
R2	100 k $\Omega$	INTERRUPT pull down resistor
R1	30 $\Omega$	SPI_MISO series resistance (optional)
X1		XTAL 24 MHz, Epson TSX-3225 (optional)
C7, C8	8 pF <sup>(1)</sup>	XTAL freq. tuning capacitor (optional)

*Table 8.2 BOM list*

(1) See details in chapter 7.1 XTAL for C7, C8 value calculation.

See figure 7.3 that shows the optional XTAL populated.



## 8.2 XTAL

The input clock can originate 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.

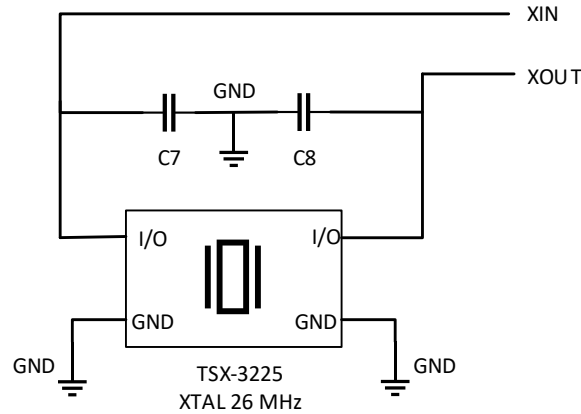


Figure 8.1. External XTAL schematics.

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:

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

Assuming that  $C_{stray} = 5 \text{ pF}$  gives  $C7, C8 = 8 \text{ pF}$  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 <sub>pp</sub>
100 000			2.6	mV <sub>pp</sub>
1 000 000			0.26	mV <sub>pp</sub>
3 000 000			0.09	mV <sub>pp</sub>
10 000 000			0.23	mV <sub>pp</sub>
100 000 000			3.0	mV <sub>pp</sub>

Table 8.4: Required power supply ripple specification for VIO\_3

### Low-cost LC filter solution

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  $1/(2\pi*\sqrt{LC})$ . 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.

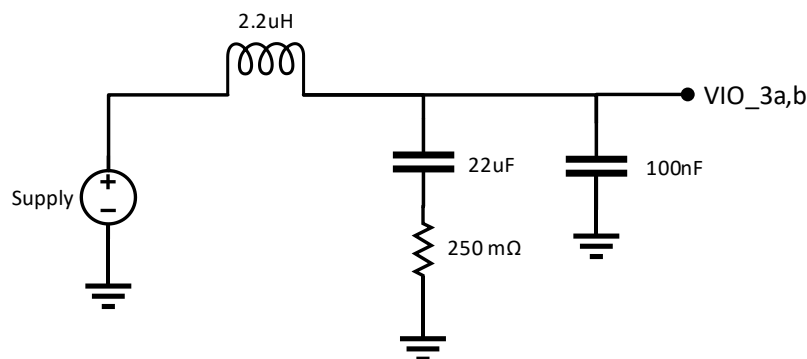


Figure 8.2: Low cost LC supply filter

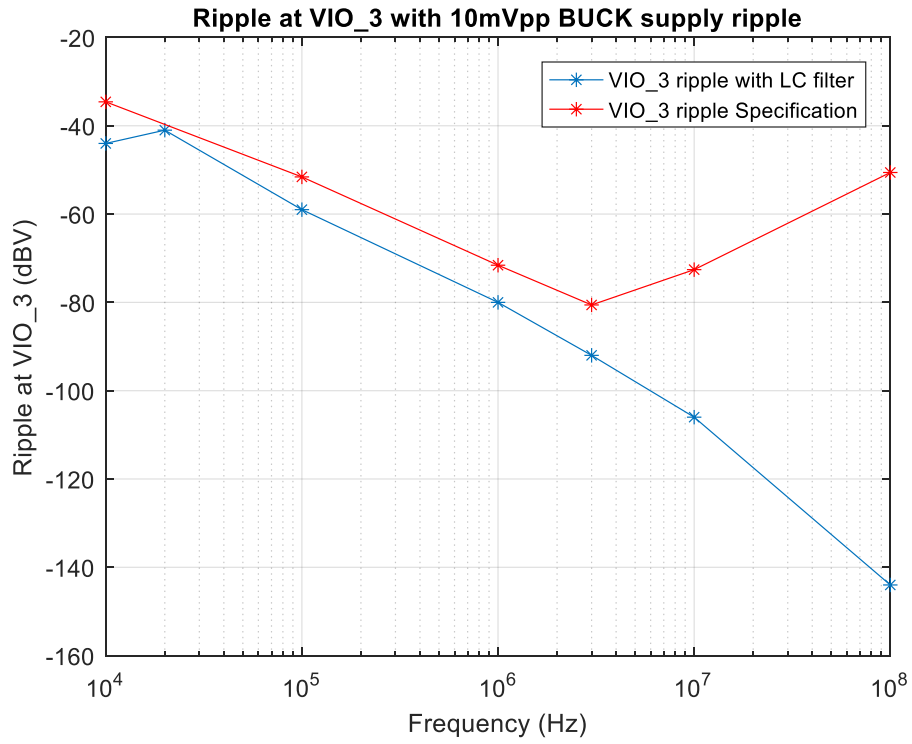


Figure 8.3: Simulated performance with 10mV<sub>pp</sub> supply ripple with low cost LC supply filter.



## 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 for the following software configuration profiles:

- Maximize depth resolution
- Maximize SNR

#### 9.1.1 EU declaration of conformity

The image shows an EU Type Examination Certificate for the CTC advanced A111 Pulsed Coherent Radar (PCR). The certificate is issued by CTC advanced, a member of the RWTÜV group, and is authorized by the German Government as a Notified Body. The certificate holder is Acconeer AB, located in Lund, Sweden. The product is a 60 GHz Pulsed Coherent Radar (PCR). The certificate includes a table of essential requirements and a section for the conformity assessment. The certificate is valid for 10 years and is marked with the CE marking 0682. The certificate is issued in Saarbrücken, Germany.

**CTC advanced**  
member of RWTÜV group

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

**Product Manufacturer:** see Certificate Holder

**Product Designation:** A111

**Product Description:** 60 GHz Pulsed Coherent Radar (PCR)

**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.

**Certificate Registration No.:** T818345F-02-TEC

**CE 0682**

Saarbrücken

CTC advanced GmbH  
Unter den Eichen Str. 6-10 | 66117 Saarbrücken | Germany | www.ctcadvanced.com

CTC advanced GmbH (formerly CETECOM ICT Services GmbH)  
Unter den Eichen Str. 6-10 | 66117 Saarbrücken | Germany | www.ctcadvanced.com

GERMAN NOTIFIED BODY  
EUROPEAN ID-NO. 0682

Authorized signature / title



## 9.2 FCC Approval

Hereby, Acconeer declares that the A111 sensor has modular approval granted by FCC for the following software configuration profiles:

- Maximize depth resolution
- Maximize SNR

The A111 sensor meets the FCC part 15 requirements for intentional radiators operating in the 57-71 GHz band for the following type of applications.

- Field disturbance sensor employed for fixed operations.
- Short range device for interactive motion sensing.

Warning: The end user needs to maintain 20 cm distance to radiating parts of the device.

FCC ID: 2AQ6KA1

### 9.2.1 FCC Regulatory Notes

#### Modifications

Acconeer has not approved any changes to this device. Any changes or modifications to this device could invalidate the FCC approval.

#### Interference statement

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.

#### RF exposure

This device complies with the FCC radiation exposure limits set forth for an uncontrolled environment. The transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

The RF exposure has been calculated with a 20 cm separation distance I.e. Mobile devices.

#### Labelling requirements for the host device

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: 2AQ6KA1*



## 9.2.2 FCC Grant Authorization

<b>TCB</b>	<b>GRANT OF EQUIPMENT AUTHORIZATION</b>  Certification Issued Under the Authority of the <b>Federal Communications Commission</b>  By:  <b>CETECOM GmbH</b> Im Teelbruch 116 45219 Essen, Germany	<b>TCB</b>								
Acconeer AB mikael.rosenhed@acconeer.com mikael.egard@acconeer.com Lund, 22370 Sweden	Date of Grant: 03/28/2019  Application Dated: 03/28/2019									
<b>NOT TRANSFERABLE</b>  EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.										
FCC IDENTIFIER: 2AQ6KA1 Name of Grantee: Acconeer AB Equipment Class: Part 15 Low Power Transceiver, Rx Verified Notes: SRD (Short Range Device) Modular Type: Single Modular										
<u>Grant Notes</u>	<u>FCC Rule Parts</u>	<table border="0" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;"><u>Frequency Range (MHZ)</u></th> <th style="text-align: center;"><u>Output Watts</u></th> <th style="text-align: center;"><u>Frequency Tolerance</u></th> <th style="text-align: center;"><u>Emission Designator</u></th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">57000.0 - 64000.0</td> <td style="text-align: center;">0.00052</td> <td></td> <td></td> </tr> </tbody> </table>	<u>Frequency Range (MHZ)</u>	<u>Output Watts</u>	<u>Frequency Tolerance</u>	<u>Emission Designator</u>	57000.0 - 64000.0	0.00052		
<u>Frequency Range (MHZ)</u>	<u>Output Watts</u>	<u>Frequency Tolerance</u>	<u>Emission Designator</u>							
57000.0 - 64000.0	0.00052									
Single modular transmitter.  Output Power is EIRP.  RF exposure compliance is addressed for 1.1310 and 2.1091 MPE limits.  The final product operating with this transmitter must include operating instructions, for end-users and installers to satisfy RF exposure compliance requirements. The Grantee is responsible for providing the documentation required for modular use.										



## 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.

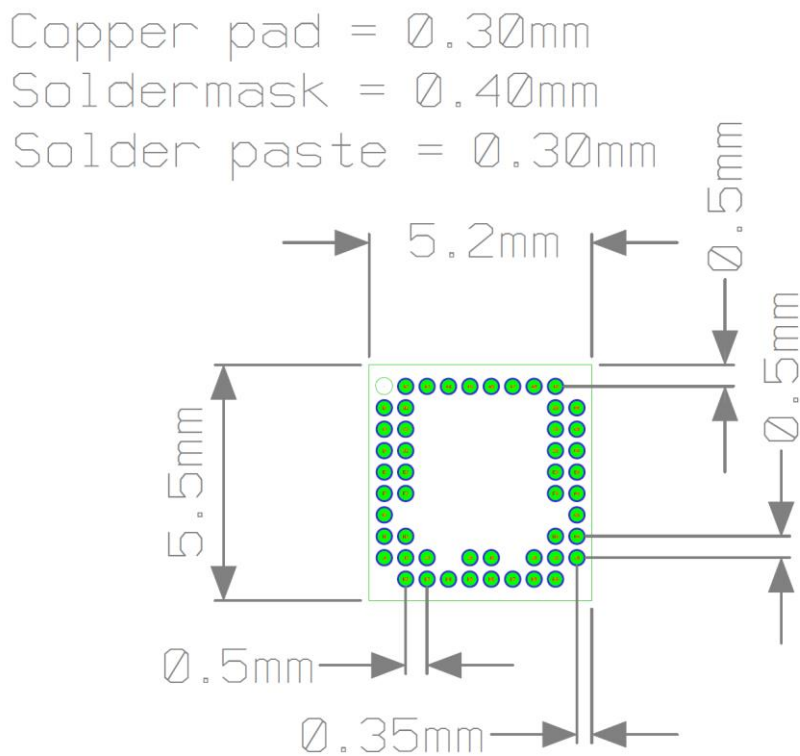


Figure 10.1. A111 footprint



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

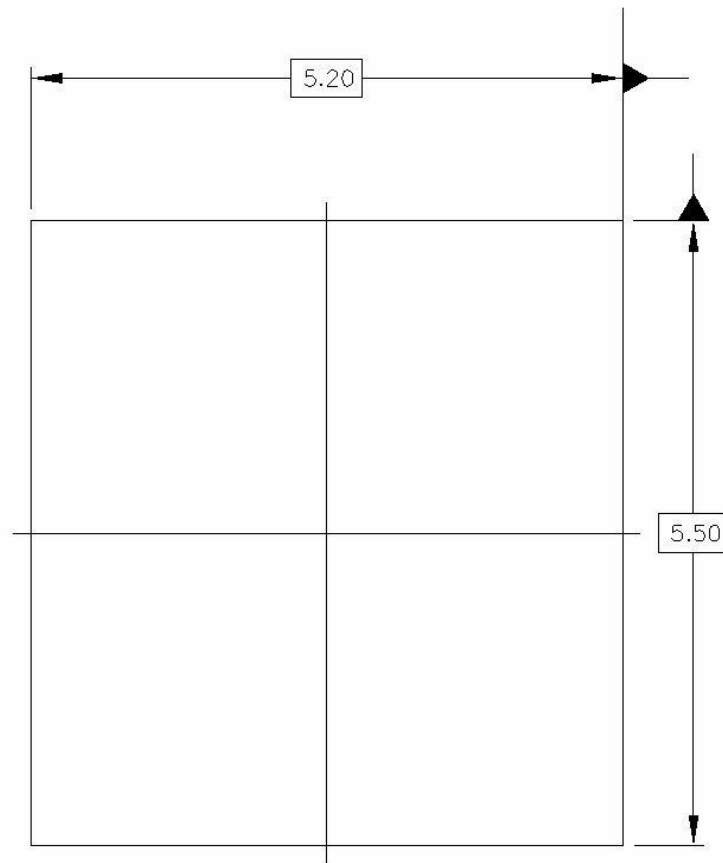


Figure 10.2. Physical layout of the A111 sensor, top view.

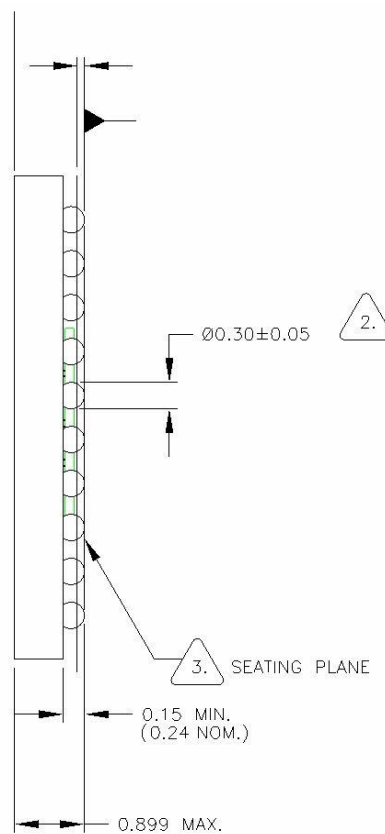


Figure 10.3. Physical layout of the A111 sensor, side view.



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.

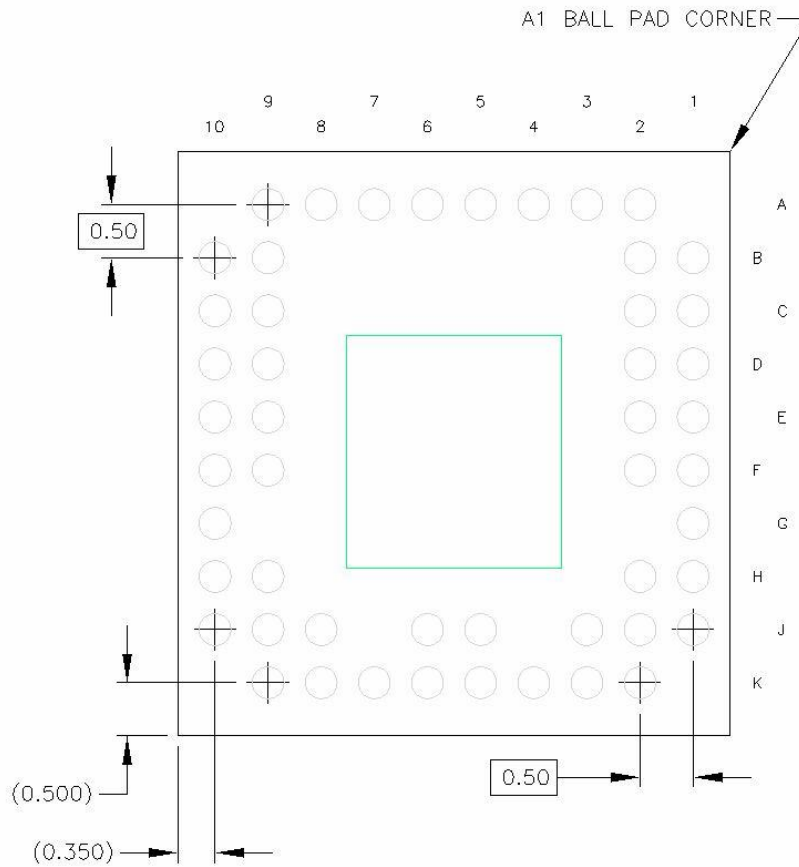


Figure 10.4. Physical layout of the A111 sensor, bottom view.

The bottom view shows 50 solder balls. The pitch of the BGA balls is 500  $\mu\text{m}$ , the ball diameter is 300  $\mu\text{m} \pm 5 \mu\text{m}$  and the collapsed ball height is  $0.244 \pm 0.050 \text{ mm}$ .

## 10.1 Recommended Reflow Profile

Reflow Profiles per JEDEC J-STD-020.





## 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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