Antenna information: RR30 Radar Sensors (RF / TX Frontend)

Thema / Title	**Antenna information: R600V Radar Sensors (working principle of RF / TX frontend side)**	Innenauftrag / Internal order:	98000504
Ausgestellt für / Issued for:	CTC advanced GmbH and regulatory administrations in North America (FCC/ISED)	Aussteller / Issuer:	Baumer CH (F. Illi / R. Mauch)
FCC ID IC ID	PGP-RR30-01 24812-RR30V01		
Produktname: Product name: PMN	RR30.DAF0-11220109 RR30.DAF0-11220108 RR30.DAF0-11721820 RR30.DAF0-11230002 RR30.DAF0-11220160 RR30.DAJ2-11221309 RR30.DAJ2-11221333 RR30.DAJ2-11230003 RR30.DAJ2-11221334 RR30.DAJ2-11240769 RR30.DAJ2-11256805 RR30.DAJ2-11708433 RR30.DAJ5-11729773 RR30.DAO0-11221320 RR30.DAO0-11221321 RR30.DAO0-11221322 RR30.RAK0-11234882 RR30.RAQ0-11234883	Material-Nr.: HVIN	11220109-2 11220108-2 11721820-2 11230002-2 11220160-2 11221309-2 11221333-2 11230003-2 11221334-2 11240769-2 11256805-2 11708433-2 11729773-2 11221320-2 11221321-2 11221322-2 11234882-2 11234883-2

Verteiler / Distributor:

Name	Ort / Location	Name	Ort / Location	Name	Ort / Location
CTC advanced GmbH	Saarbrücken – Germany	ISED Regulatory administration CDN	Canada		
FCC Regulatory administration USA	USA				

Inhaltsverzeichnis/ Content

Berichtsversionsänderungen / Report Revision History

Revision / Revision	Datum / Date	Beschreibung / Description
1.0	July, 2024	First release
2.0	July, 2025	HVIN changed

1 Aim of this document

This document describes the Antenna of the RR30 radar sensors

2 Antenna

RF/TX part of the RR30 radar sensor is one integrated radar chip.
This chip has one integrated transmitting patch antenna (TX) and one integrated receiving patch antenna (RX) (see Figure **2-1**).

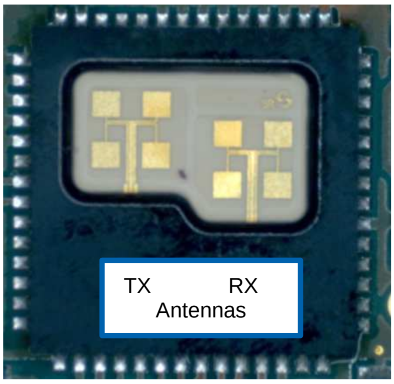


Figure 2-1: Integrated radar chip

3 Radar chip

As radar chip an integrated radar chip from Indie semiconductors is used:
TRX_120_067 – 120 GHz Radar Transceiver Front-end

4 Datasheet of radar MMIC

Following pages show data sheet of radar MMIC is now

indie Semiconductor FFO GmbH

To learn more about indie Semiconductor, please visit our website at
www.indiesemi.com

For customer support, please contact us at: dfo.support@indiesemi.com

indie Semiconductor FFO GmbH
Im Technologiepark 1
15236 Frankfurt (Oder)
+49 (335) 22 88 03 0

indie Semiconductor has acquired Indie Semiconductor FFO GmbH

TRX_120_067

120-GHz Highly Integrated IQ Transceiver with Antennas in Package
in Silicon Germanium Technology

Data Sheet

SILICON radar

TRX_120_067

120-GHz Highly Integrated IQ Transceiver with Antennas in Package
in Silicon Germanium Technology

Data Sheet

Status: Final	Date: 25-July-2023	Author: Indie Semiconductor FFO GmbH	Filename: Datasheet_TRX_120_067_V1.1	
Version: 1.1	Product number: TRX_120_067	Package: QFN56, 8 × 8 mm²	Marking: TRX067 YYWW	Page: 1 of

Document: Annex to VA_U03_01 Anlage 8_Template_Datenblatt_Rev F Date: 12-Dec-2023

Version Control

Version	Changed section	Description of change
0.1	Template, contents	Initial release
0.2	8 Measurement Results	Scale in figures 20 and 21 corrected
0.3	6.3 Evaluation Kit	Information regarding to SR’s new SiRad Easy® r4 platform
0.4	4.4 Electrical Characteristics 7 Reliability and Environmental Test	Notation of ‘IQ amplitude imbalance’ (Aimb) notation corrected. Status of all tests listed in Table 7 updated.
0.5	5.1 Outline Dimensions 8 Measurement Results	Figure 4, Position of Antenna Arrays… : Mold cap dimension corrected, and cross section added. Figure 8, Current Consumption vs. Temperature, and figure 16, TX Output Frequency vs. Temperature: shown temperature range extended.
1.0	4.4 Electrical Characteristics 7 Reliability and Environmental Test	Start and Stop Frequency limits changed to include latest test statistics. EIRP value added. All tests listed in Table 7 completed and passed.
1.1	4.4 Electrical Characteristics All sections	Update with data from serial test. Minor corrections to remove typos.

Table of Contents

1 Features

- Radar front end (RFE) with antennas in package for 122-GHz ISM band
- Single supply voltage of 3.3 V
- Fully ESD protected device
- Low power consumption of 380 mW in continuous operating mode
- Duty cycling is possible
- Integrated low phase noise push-push VCO
- Receiver with homodyne quadrature mixer
- RX and TX patch antennas
- Wide bandwidth of up to 6 GHz
- QFN56 leadless plastic package 8 × 8 mm²
- Package partly molded, MSL3 rated
- Pb-free, RoHS compliant package
- Replaces the TRX_120_001

1.1 Overview

The RFE is an integrated transceiver circuit for the 122-GHz ISM band with antennas in package. It includes a power amplifier (PA), low-noise amplifier (LNA), quadrature mixers, a poly-phase filter, a voltage-controlled oscillator, divide-by-32 outputs and transmit and receive antennas (see Figure 1). The RF signal from the oscillator is directed to both, the TX path via PA, and to the RX path via buffer circuits. The RX signal is amplified by the LNA and converted to baseband by two mixers with quadrature LO signal. The 120-GHz VCO has four analog tuning inputs with different tuning ranges and tuning slopes. The tuning inputs can be combined to obtain a wide frequency tuning range. The analog tuning inputs together with integrated frequency divider and external fractional-N PLL can be used for frequency modulated continuous wave (FMCW) radar operation. With fixed oscillator frequency it can be used in continuous wave (CW) mode. Other modulation schemes are possible as well by utilizing analog tuning inputs.
The IC is fabricated in a SiGe BiCMOS technology.

1.2 Applications

The main field of application for the 120-GHz transceiver radar frontend is in short range radar systems with a range up to about 10 meters. By using dielectric lenses or reflectors, the range can be increased considerably. The RFE can be used in FMCW mode as well as in CW mode. Although the chip is intended for use in the ISM band 122 GHz - 123 GHz, it is also possible to extend the bandwidth to the full tuning range of 6 GHz.

2 Block Diagram

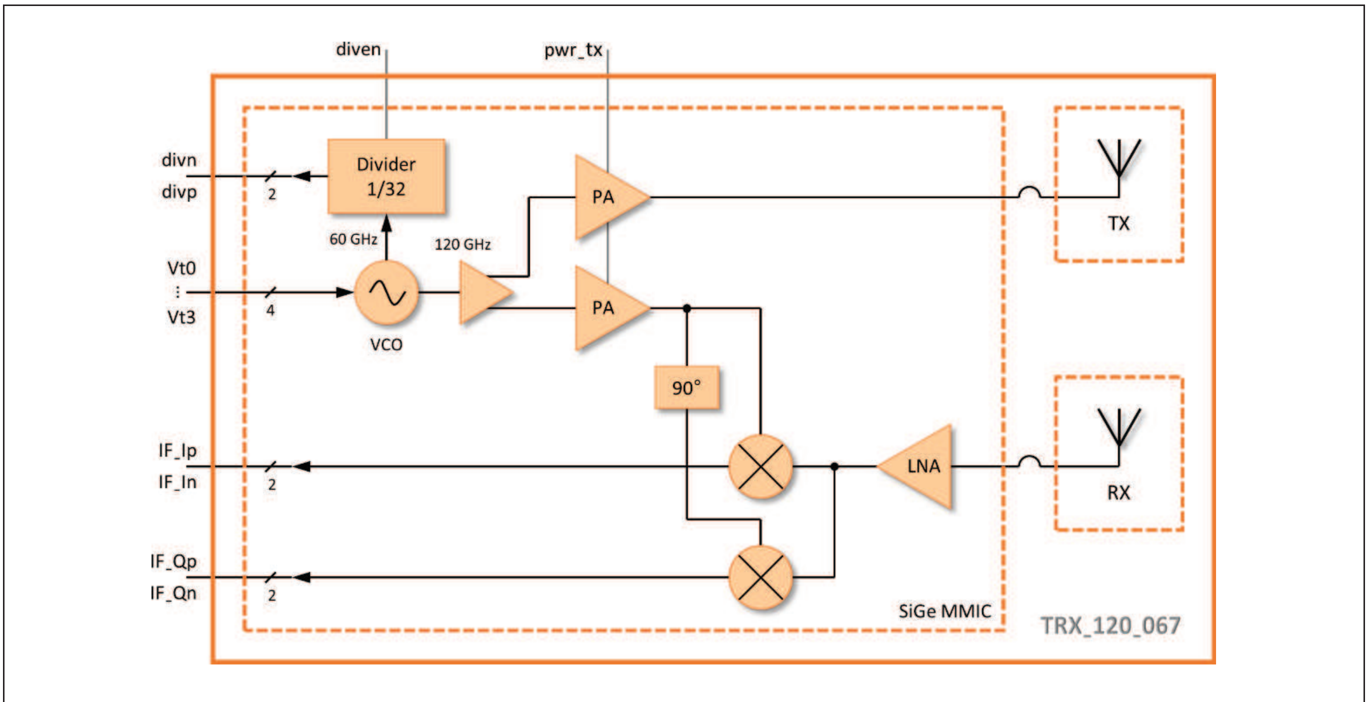


Figure 1 Block Diagram

3 Pin Configuration

3.1 Pin Assignment

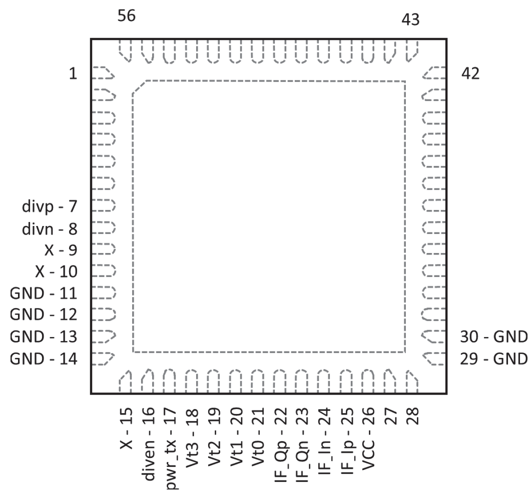


Figure 2 Pin Assignment (QFN56, top view)

3.2 Pin Description

Table 1 Pin Description

Pin		Description
No.	Name	
1 - 6	NC	Not connected
7	divp	Divider output with terminals for differential signal, matched to 50 Ω load, DC coupled, external decoupling capacitor required.
8	divn	
9, 10	X	Reserved. Do not make any connections.
11 - 14	GND	Connect to ground.
15	X	Reserved. Do not make any connections.
16	diven	Divider enable input: 1.2 V – enable, 0 – off. NMOS input, external pull-up resistor of 100 kΩ recommended.
17	pwr_tx	Transmitter power control input: 1.2 V – full, 0 – -3 dB. NMOS input, external pull-up resistor of 100 kΩ recommended.
18	Vt3	VCO tuning input 3 (0 – V_{CC})
19	Vt2	VCO tuning input 2 (0 – V_{CC})
20	Vt1	VCO tuning input 1 (0 – V_{CC})
21	Vt0	VCO tuning input 0 (0 – V_{CC})
22	IF_Qp	IF Q output with terminals for differential signal (DC coupled)
23	IF_Qn	
24	IF_In	IF I output with terminals for differential signal (DC coupled)
25	IF_Ip	
26	VCC	Supply voltage (3.3 V, 112 mA typ.)
27, 28	NC	Not connected
29, 30	GND	Ground pins, also connected to the exposed die attach pad.
31 - 56	NC	Not connected
(57)	GND	Exposed die attach pad of the QFN package, must be soldered to ground.

4 Specification

4.1 Absolute Maximum Ratings

Attempted operation outside the absolute maximum ratings of the part may cause permanent damage to the part. Actual performance of the IC is only guaranteed within the operational specifications, not at absolute maximum ratings.

Table 2 Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit	Remarks / Condition
Supply voltage	V_{CC}		3.6	V	to GND
DC voltage at tuning inputs	V_{Vt}	-0.3	V_{CC} + 0.3	V	Inputs Vt0, Vt1, Vt2, Vt3
DC voltage at enable inputs	V_{EN}	-0.3	1.5	V	Inputs diven, pwr_tx
Junction temperature	T_J	-50	150	°C	
Storage temperature range	T_{STG}		150	°C	
Floor life (out of bag) at factory ambient (30°C / 60% RH)	FL		168	h	IPC/JEDEC J–STD-033A MSL Level 3 Compliant [1)]
ESD robustness	V_{ESD}		500	V	Human body model, HBM [2)]

1) Device storage outside of the packaging is limited according to latest revision of JEDEC Standard IPC/JEDEC J–STD-033.
2) CLASS 1A according to ESDA/JEDEC Joint Standard for Electrostatic Discharge Sensitivity Testing, Human Body Model Component Level, ANSI/ESDA/JEDEC JS-001-2011

4.2 Operating Range

Table 3 Operating Range

Parameter	Symbol	Min	Max	Unit	Remarks / Condition
Ambient temperature	T_A	-40	85	°C	
Supply voltage	V_{CC}	3.13	3.47	V	(3.3 V ± 5%)
DC voltage at tuning inputs	V_{Vt}	0	V_{CC}	V	Inputs Vt0 – Vt3
DC voltage at enable inputs	V_{EN}	0	1.2	V	Inputs diven, pwr_tx

Note: Do not drive input signals without power supplied to the device.

4.3 Thermal Resistance

Table 4 Thermal Resistance

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Condition
Thermal resistance, junction-to-ambient	R_{thja}			30	K/W	JEDEC JESD51-5

4.4 Electrical Characteristics

T_A = -40°C to +85°C unless otherwise noted. Typical values measured at T_A = 25°C and V_{CC} = 3.3 V.

Table 5 Electrical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Condition
DC Parameters						
Supply current consumption	I_{CC}	100	112	128	mA	TX on, CW mode
Enable input voltage, low level	V_{EN_L}	0		0.3	V	Inputs diven, pwr_tx
Enable input voltage, high level	V_{EN_H}	0.9		1.2	V	Inputs diven, pwr_tx
VCO tuning voltage	V_{Vt}	0		V_{CC}	V	Inputs Vt0 – Vt3
RF Parameters						
VCO start frequency	f_{TX_start}	116.2	119.3	120.8	GHz	all Vt_0,1,2,3 = 0, Note 3
VCO stop frequency	f_{TX_stop}	123.3	125.4	128.9	GHz	all Vt_0,1,2,3 = 3.3 V, Note 3
VCO tuning full bandwidth	Δf_{TX}	5.5	6.3	8.2	GHz	Vt0 – Vt3 interconnected
Number of adjustable frequency bands	N		8			Vt1 – Vt3 used for band switching
Pushing VCO	$\Delta f_{TX}/\Delta V_{CC}$		27		MHz/V	
Phase noise	P_N		-90	-88	dBc/Hz	at 1 MHz offset
Transmitter output power	P_{TX}	-7	-3	1	dBm	Measured without antennas, V(pwr_tx) = 1.2 V
EIRP RMS Power	$P_{TX\ EIRP\ RMS}$		7.7		dBm	Measured at T_A = 25°C, FMCW, Duty Cylce 100%, Note 2
Divider ratio of TX signal	N_{div}		64			
Divider output power	P_{div}	-10		-7	dBm	Note 1
Divider output frequency	f_{div}	1.84		1.99	GHz	
Receiver gain	g_{RX}		8	10	dB	Measured without antennas
IF frequency range	f_{IF}	0		200	MHz	
IF output impedance	Z_{OUT}		500		Ω	Differential outputs
IQ amplitude imbalance	Aimb	-1.5		+1.5	dB	
IQ phase imbalance	PHimb	-10		10	deg	
Noise figure (DSB)	NF		8.7		dB	Simulated, at f_{IF} = 1 MHz
Input compression point	1dB ICP		-20		dBm	Measured without antennas

Note 1: Measured single-ended. Divider outputs are loaded with 50 Ω, external decoupling capacitors are required. 50-Ω match is not required in application.

Note 2: FMCW band width = 1.0 GHz

Note 3: Operation within world-wide ISM Band and over the entire ambient temperature range. Further information available.

5 Packaging

5.1 Outline Dimensions

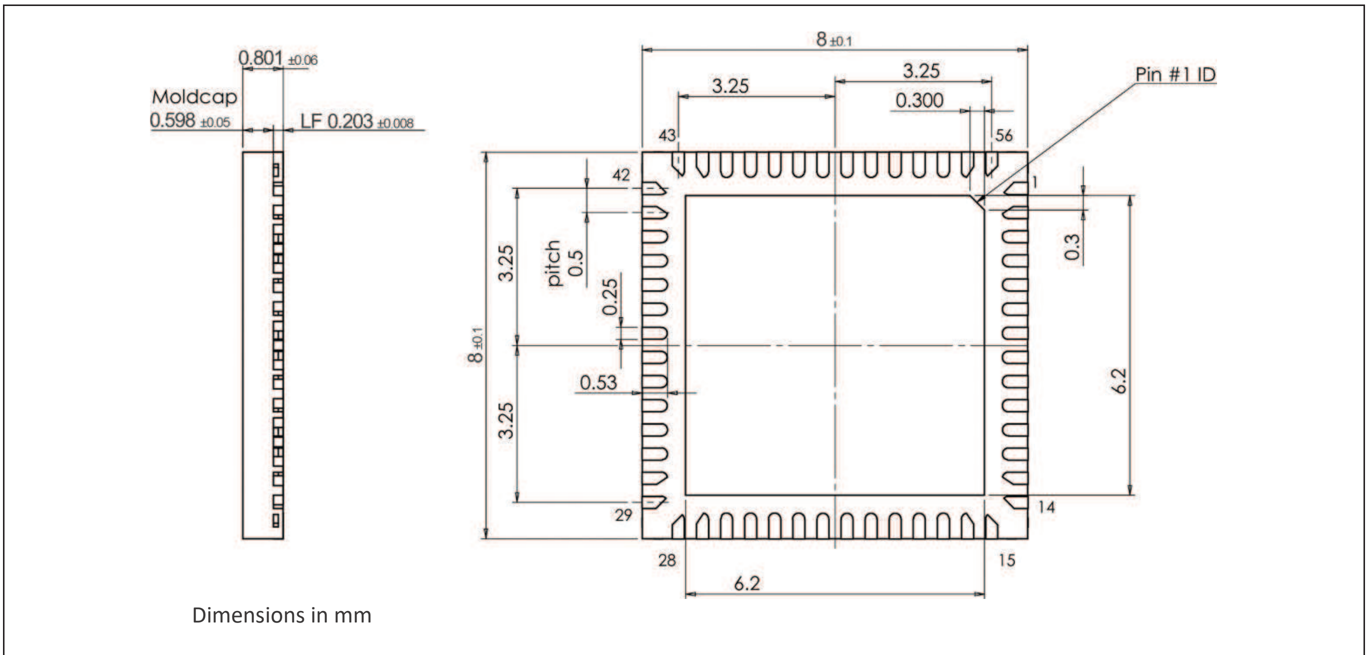


Figure 3 Outline Dimensions of QFN56, 0.5 mm Pitch, 8 mm × 8 mm

5.2 Package Code

Top-Side Markings	TRX067 YYWW

5.3 Antenna Position

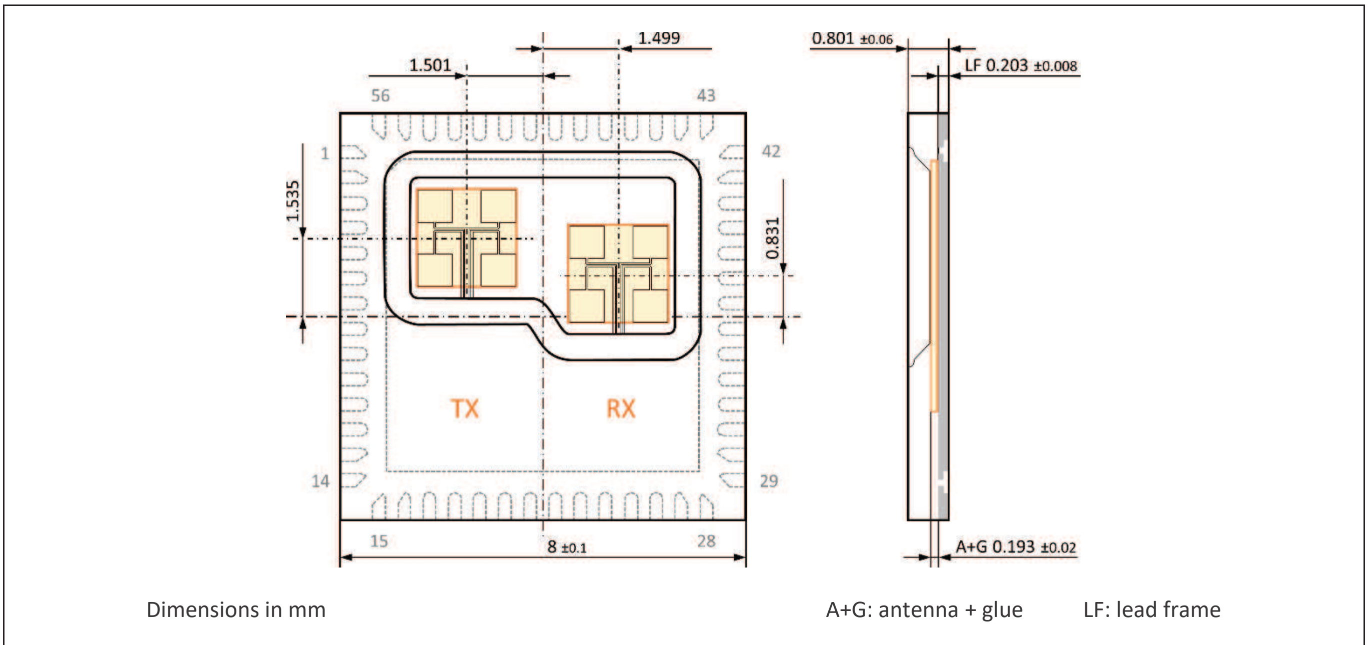


Figure 4 Position of Antenna Arrays (top view) and Cross Section (through RX Antenna)

6 Application

6.1 Application Circuit Schematic

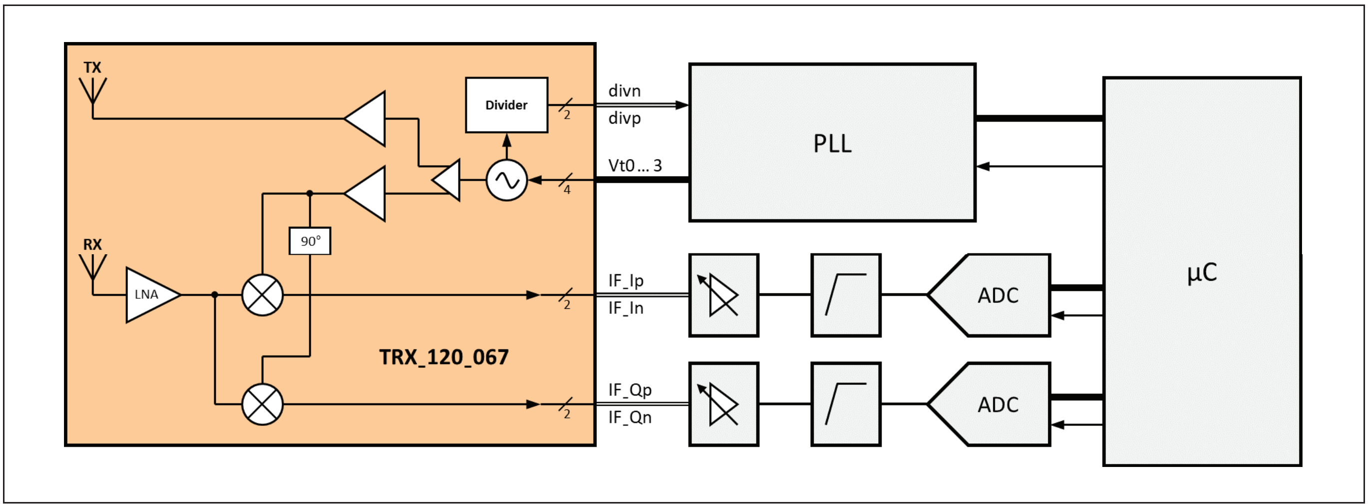


Figure 5 Application Circuit

6.2 Power Cycling

It is possible to reduce power consumption by power cycling the radar front end. Rapid power cycling with voltage rise times between 10 µs and 100 µs is possible. At power-up, it must be ensured that no input signal is driven high before the supply voltage is stable. At power-down, all input signals must be pulled low before the supply voltage is switched off.

6.3 Evaluation Kit

Silicon Radar offers evaluation kits for speeding up radar development. Please review our website and product sheets for more information: https://www.siliconradar.com/evalkits/.
The *SiRad Easy® r4* platform supports development for many of Silicon Radar's integrated IQ transceivers including radar front end boards for TRX_120_067. It serves as reference hardware and provides a design environment including a graphical user interface for parameter setting. Its functionality and communication protocol are adaptable to development projects.

6.4 Input / Output Stages

The following figures show the simplified circuits of the input and output stages. It is important that the voltage applied to the input pins never exceeds V_{CC} by more than 0.3 V. Otherwise, the supply current may be conducted through the upper ESD protection diode connected at the pin.

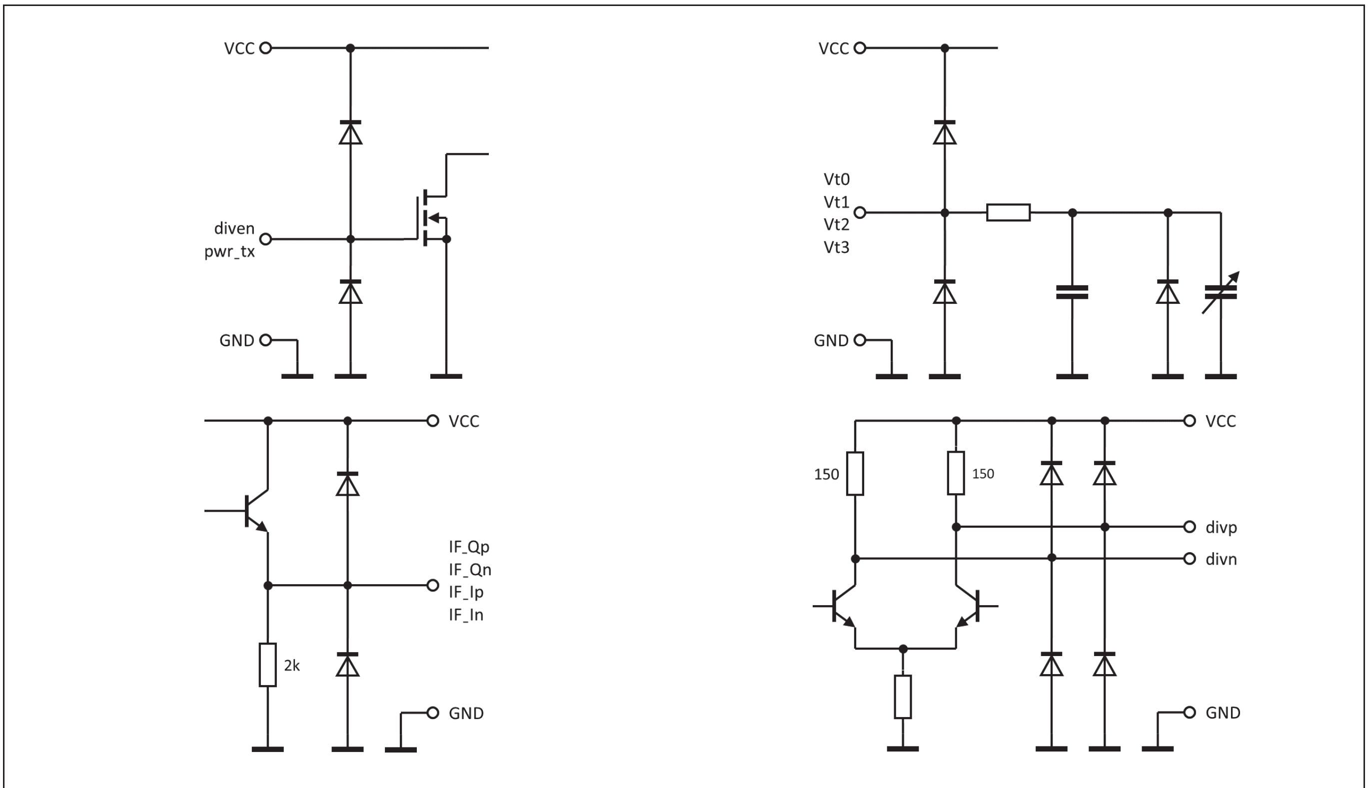


Figure 6 Equivalent I/O Circuits

6.5 VCO Tuning Inputs

The VCO tuning inputs Vt0 – Vt3 are of analog nature but can be switched digitally as well. The tuning inputs differ in their tuning ranges (tuning bandwidth) and slopes, whereby Vt3 has the widest tuning range, and Vt0 the narrowest.

Table 6 Typical VCO Tuning Bandwidth and Slope

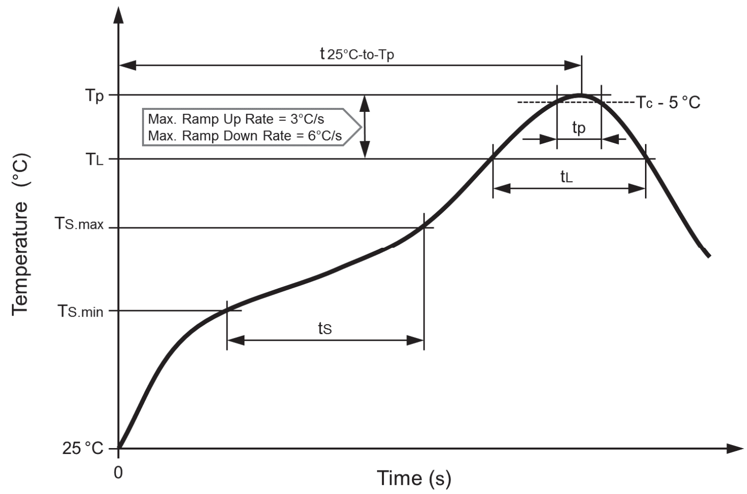
Input	VCO tuning bandwidth (MHz)		Middle band slope (MHz/V)	
Vt0	Δf_{TX_Vt0}	720	$\Delta f_{TX} / \Delta V_{Vt0}$	290
Vt1	Δf_{TX_Vt1}	750	$\Delta f_{TX} / \Delta V_{Vt1}$	300
Vt2	Δf_{TX_Vt2}	1580	$\Delta f_{TX} / \Delta V_{Vt2}$	630
Vt3	Δf_{TX_Vt3}	3450	$\Delta f_{TX} / \Delta V_{Vt3}$	1380

The VCO tuning range of a specific tuning input can be increased by connecting it to another tuning input. All combinations of the four tuning inputs are allowed. Unused tuning inputs must be set to a fixed potential (between 0 and V_{CC}). The interconnection of all inputs Vt0 – Vt3 leads to the maximum tuning bandwidth. For example, if Vt0 is used as tuning input, the variation of the potential at Vt1, Vt2, Vt3 in all logical combinations of 0 and V_{CC}, results in offsetting the tuning curve (see Figure 10).

7 Reliability and Environmental Test

Table 7 Reliability and Environmental Test according to JEDEC Standards

Qualification Test	JEDEC Standard	Condition	Pass / Fail
MSL3	J-STD-020E	Reflow simulation 3 times at 260°C	pass
Temperature Cycling	JESD22-A104	850 cycles at -40°C … 125°C	pass
HTSL	JESD22-A103	1,000 h at 150°C	pass
HTOL	JESD22-A108	1,000 h at 85°C	pass
THB	JESD22-A101	1,000 h at 85°C and 85% RH	pass



$T_p \le T_c = 260°C$
$t_p \le 30$ s
$T_{S.min} = 150°C$
$T_{S.max} = 200°C$
$t_S = 60$ s – 120 s
$T_L = 217°C$
$t_L = 60$ s – 150 s
$t_{25°C\text{-to-}Tp} \le 480$ s

Figure 7 Reflow Profile for Pb-Free Assembly according to JEDEC Standard J-STD-020E

8 Measurement Results

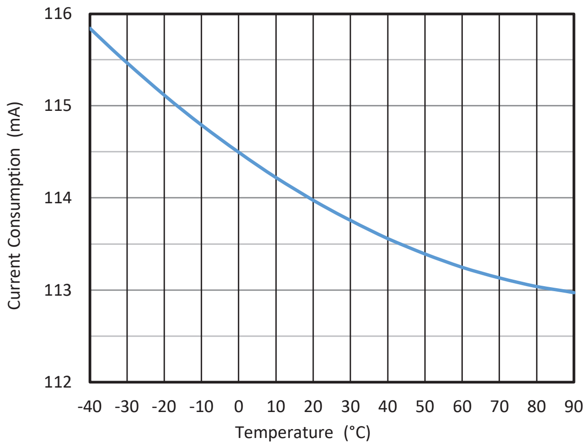


Figure 8 Current Consumption vs. Temperature

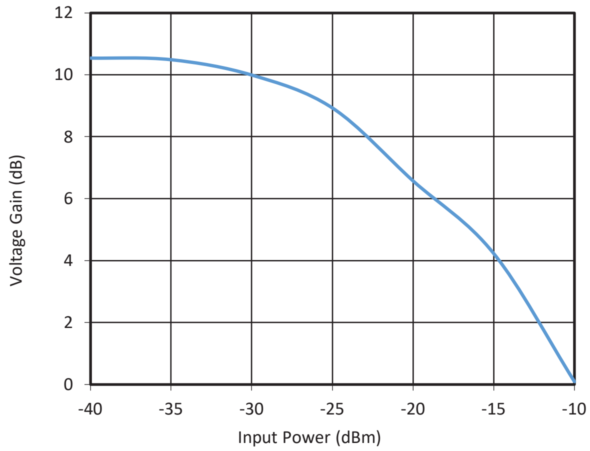


Figure 9 Measured Conversion Gain of the Receiver without antenna

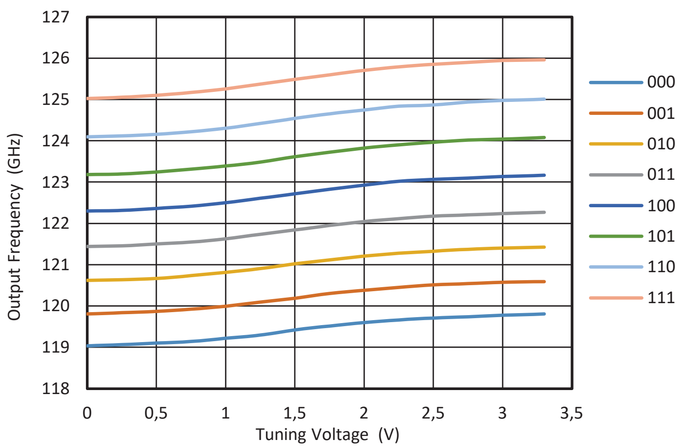


Figure 10 VCO Tuning Curves. Vt0 is varied, while Vt1, Vt2 and Vt3 are driven high or low. For example, 011 means Vt3 = 0, Vt2 = 3.3 V, and Vt1 = 3.3 V.

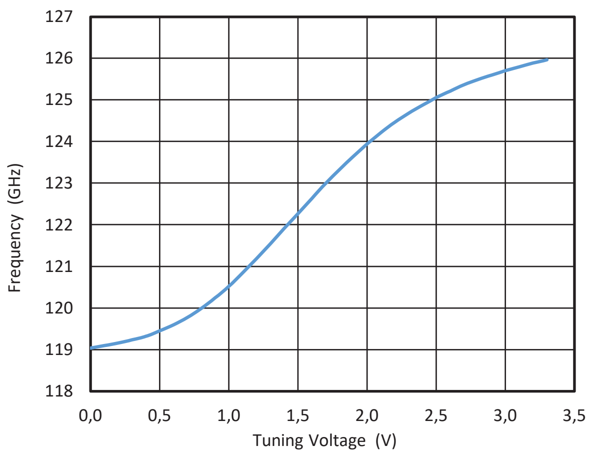


Figure 11 Full Bandwidth VCO Tuning.
Vt0, Vt1, Vt2, Vt3 are interconnected.
(Vt0 = Vt1 = Vt2 = Vt3)

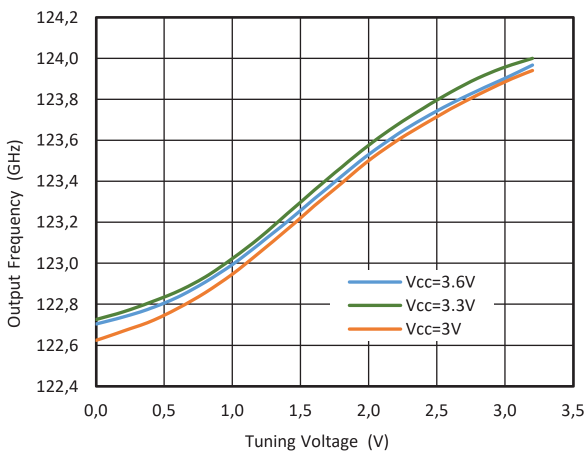


Figure 12 VCO Pushing - V_{CC} ± 300 mV
Vt0 = sweep, Vt1 = Vt2 = 0, Vt3 = 3.3 V

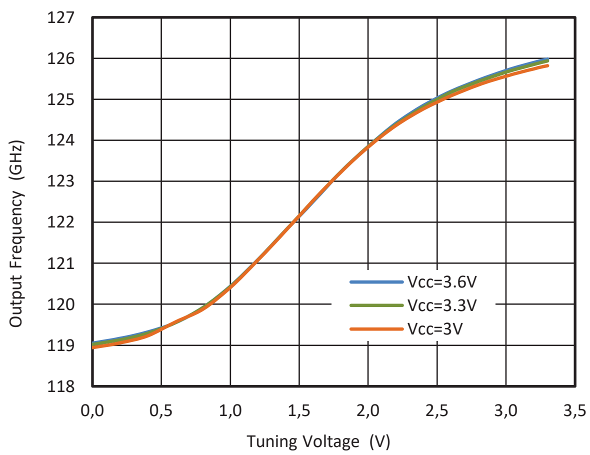


Figure 13 VCO Pushing - Full Bandwidth Operation.
All tuning voltages, Vt0 = Vt1 = Vt2 = Vt3

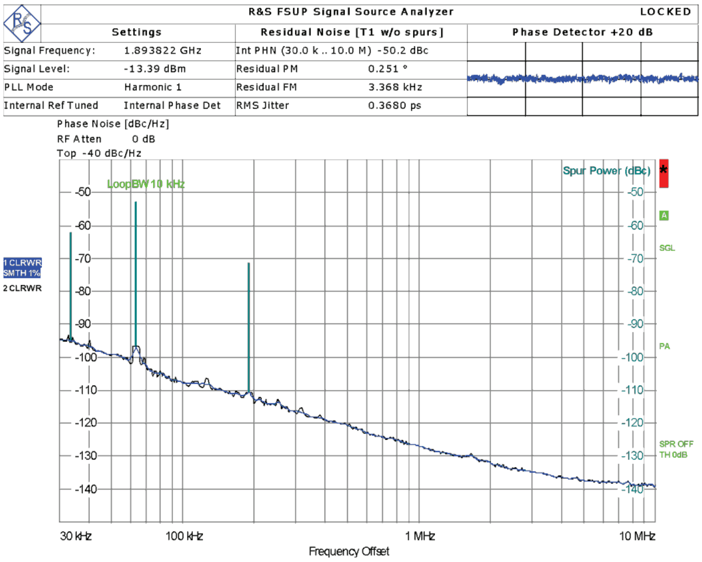


Figure 14 Phase Noise of the Integrated Oscillator Measured at Divider Output (1.89 GHz)

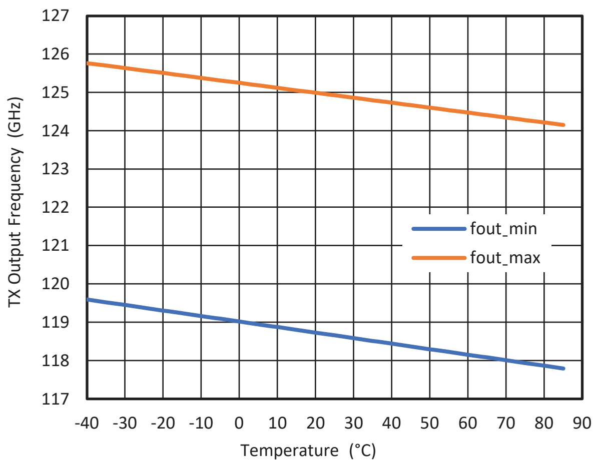


Figure 15 TX Output Frequency vs. Temperature

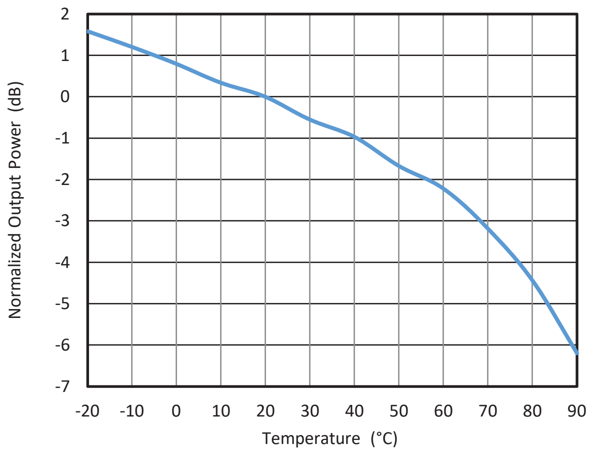
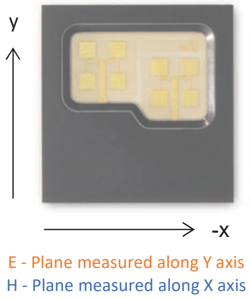


Figure 16 TX Output Power vs. Temperature (Normalized to 20°C)



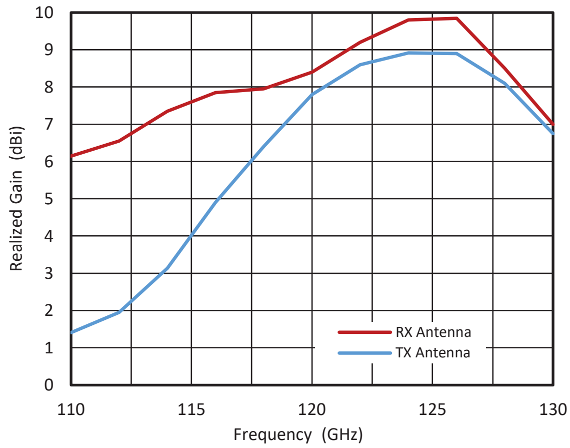


Figure 17 MMIC Orientation for Antenna Measurements

Figure 18 Simulated Single Antenna Gain vs. Frequency (Broad Side Direction)

The result of the measurements of the radiation patterns of TX and RX patch antennas at different frequencies are shown in Figure 19. The power levels are normalized separately for RX and TX measurements.

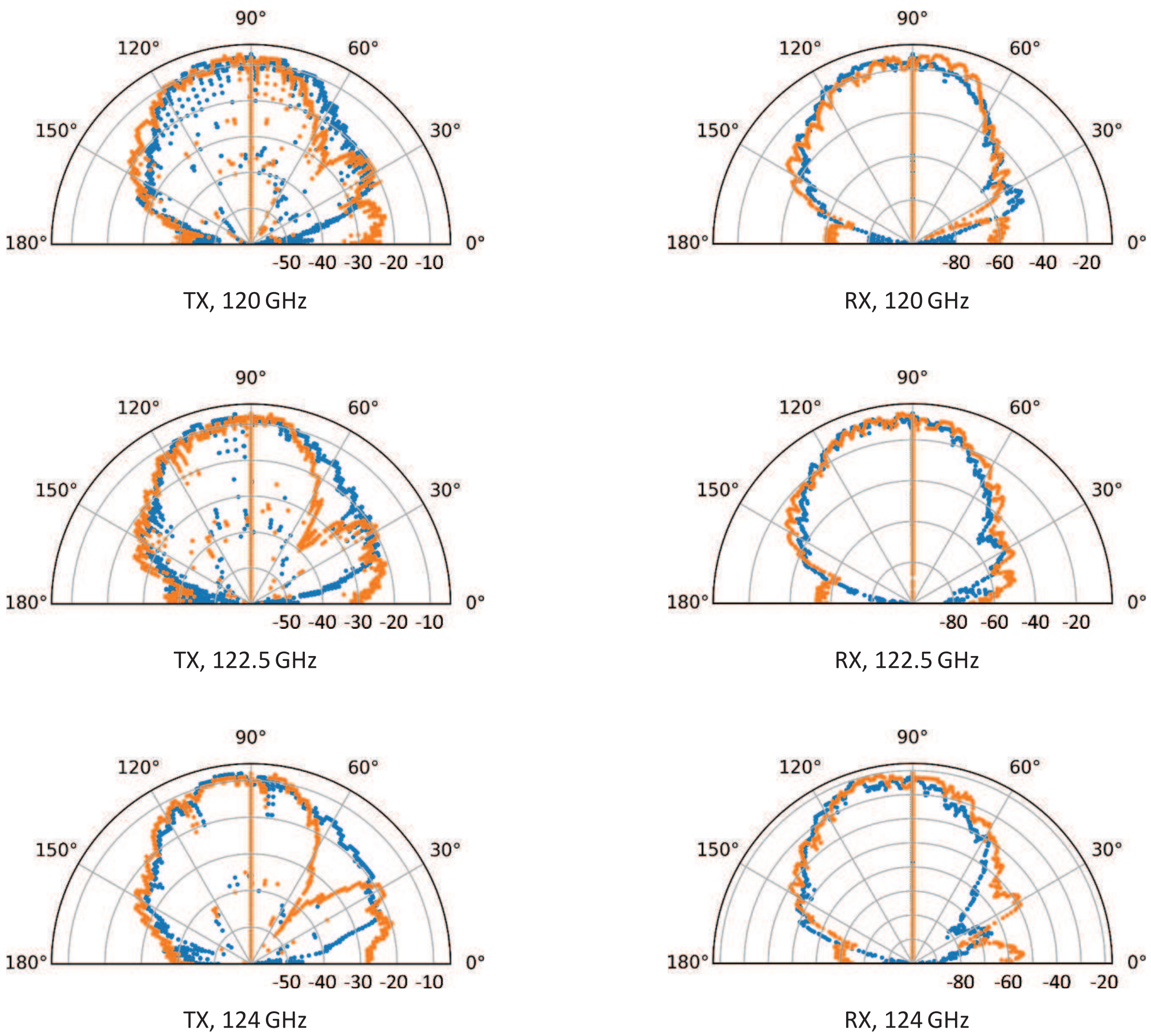
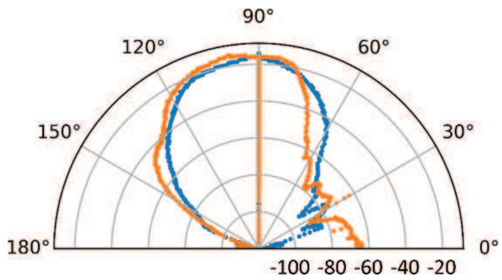
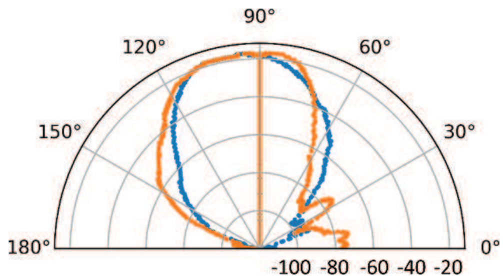


Figure 19 Radiation Pattern of TX and RX Patch Antennas, measured at different frequencies – H-Plane (blue), E-Plane (orange)

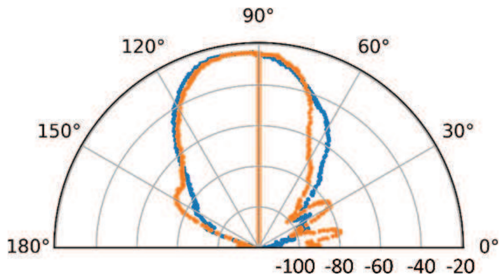
The combined normalized radiation patterns of RX and TX antenna for FMCW operation are shown in Figure 20. During the measurement, the IC was operated in FMCW mode with a bandwidth of 1 GHz. A corner reflector was used as the target. The frequency of the measurement refers to the start frequency of the sweep.



FMCW, 119.3 GHz



FMCW, 122 GHz



FMCW, 123.2 GHz

Figure 20 Combined Radiation Pattern of TX and RX Patch Antennas, measured in FMCW mode with 1-GHz modulation bandwidth at different frequencies − H-Plane (blue), E-Plane (orange)

Disclaimer

Indie Semiconductor FFO GmbH 2023. The information contained herein is subject to change at any time without notice.
Indie Semiconductor FFO GmbH assumes no responsibility or liability for any loss, damage or defect of a product which is caused in whole or in part by

(i) use of any circuitry other than circuitry embodied in a Indie Semiconductor FFO GmbH product,
(ii) misuse or abuse including static discharge, neglect, or accident,
(iii) unauthorized modifications or repairs which have been soldered or altered during assembly and are not capable of being tested by Indie Semiconductor FFO GmbH under its normal test conditions, or
(iv) improper installation, storage, handling, warehousing, or transportation, or
(v) being subjected to unusual physical, thermal, or electrical stress.

Disclaimer: Indie Semiconductor FFO GmbH makes no warranty of any kind, express or implied, with regard to this material, and specifically disclaims any and all express or implied warranties, either in fact or by operation of law, statutory or otherwise, including the implied warranties of merchantability and fitness for use or a particular purpose, and any implied warranty arising from course of dealing or usage of trade, as well as any common-law duties relating to accuracy or lack of negligence, with respect to this material, any Silicon Radar product and any product documentation. Products sold by Silicon Radar are not suitable or intended to be used in a life support applications or components, to operate nuclear facilities, or in other mission critical applications where human life may be involved or at stake. All sales are made conditioned upon compliance with the critical uses policy set forth below.

CRITICAL USE EXCLUSION POLICY: BUYER AGREES NOT TO USE INDIE SEMICONDUCTOR FFO GMBH'S PRODUCTS FOR ANY APPLICATIONS OR IN ANY COMPONENTS USED IN LIFE SUPPORT DEVICES OR TO OPERATE NUCLEAR FACILITIES OR FOR USE IN OTHER MISSION-CRITICAL APPLICATIONS OR COMPONENTS WHERE HUMAN LIFE OR PROPERTY MAY BE AT STAKE.