BGT24ATR22 DPA shield

XENSIV™ 24 GHz radar system platform

Board version V2.0

About this document

Scope and purpose

This application note describes the function, circuitry, and performance of the XENSIV™ BGT24ATR22 24 GHz radar dual patch antenna (DPA) shield. The shield is the demo platform that accompanies Infineon's XENSIV™ BGT24ATR22 24 GHz radar sensor with an external two pairs of patch antennas. The shield offers a digital interface for configuration and transfer of the acquired radar data to a microcontroller board such as Radar Baseboard MCU7.

Intended audience

This document is intended for design engineers, technicians, and developers of electronic systems, working with Infineon's XENSIV™ BGT24ATR22 24 GHz low-power radar sensor.

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1 Introduction

1.1 24 GHz radar system platform

The 24 GHz radar system platform described in this application note demonstrates the operational parameters of Infineon's BGT24ATR22 24 GHz radar MMIC. The platform consists of two boards: the RF shield containing the MMIC and antennas, and Radar Baseboard MCU7.

This application note focuses on the BGT24ATR22 DPA shield. For detailed documentation on the radar baseboard, see AN599 - Radar Baseboard MCU7 application note [1].

Figure 1 shows the "DEMO BGT24ATR22 DPA" board, composed of the Radar Baseboard MCU7 with the plugged BGT24ATR22 DPA shield, forming together the "DEMO BGT24ATR22 DPA".

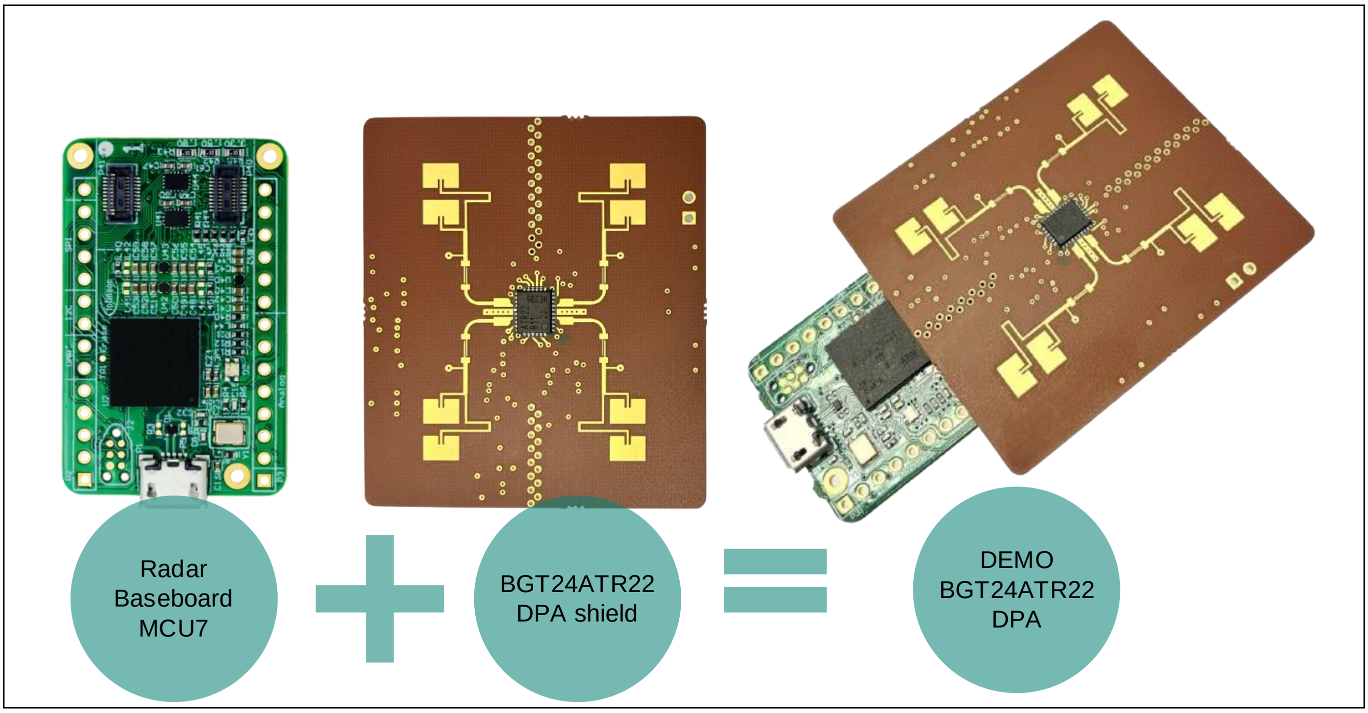

Figure 1 DEMO BGT24ATR22 DPA

1.2 Key features

The BGT24ATR22 shield is designed to showcase the capabilities of BGT24ATR22 in hands-free trunk opening applications, including motion detection and kick sensing, while requiring ultra-low power consumption.

The following features make BGT24ATR22 a perfect fit for these applications:

- 24 GHz radar, enabling good penetration of housing and little external/environmental attenuation
- Integrated finite state machine for ultra-low power operation
- On-chip radar data preprocessing including the frequency-shift-keying (FSK) feature
- Single-ended RF terminals with 2 Tx and Rx channels for custom antenna design
- Fully integrated low-phase-noise VCO
- Automatic frequency control
- Homodyne quadrature receiver

- Integrated analog baseband amplifiers
- Automatic DC offset compensation
- Integrated 12-bit ADC
- Fully ESD-protected device
- VQFN32-9 plastic package

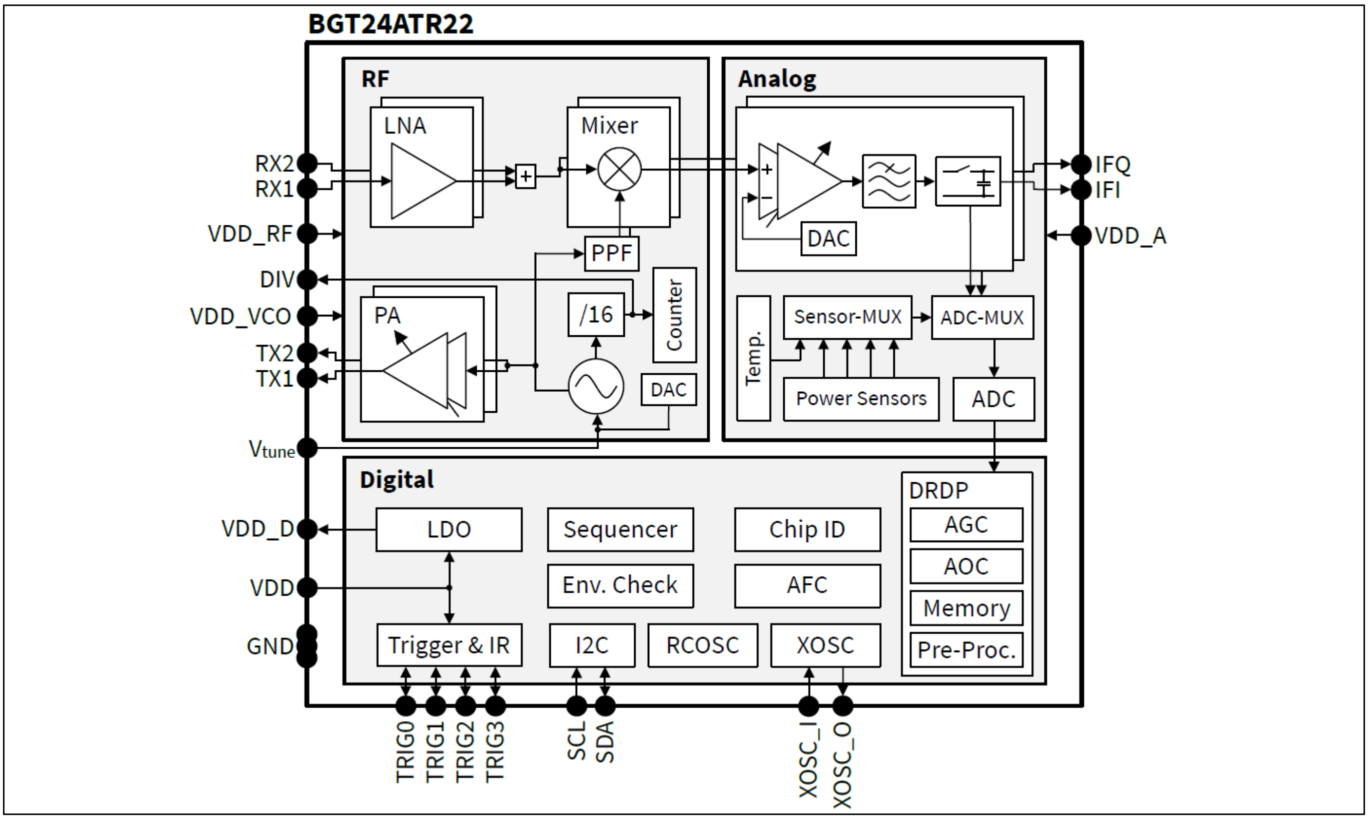

Figure 2 **Block diagram of BGT24ATR22**

2 Hardware specifications

2.1 Overview

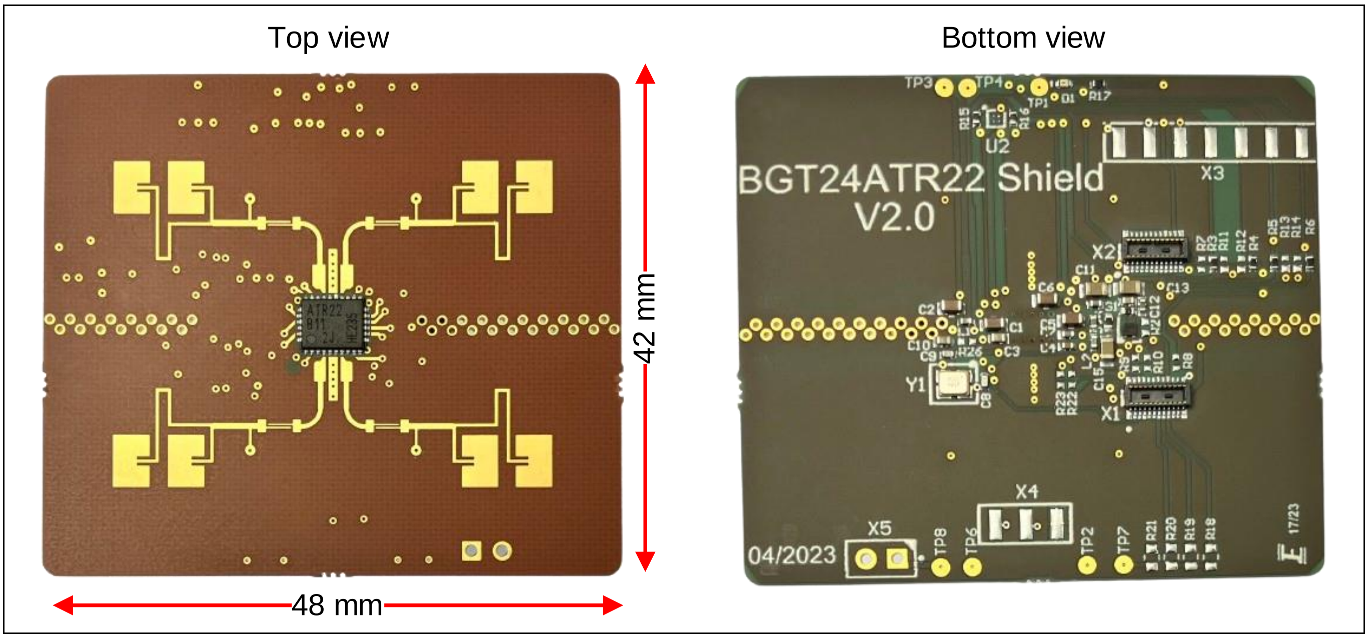

Figure 3 BGT24ATR22 shield v2.0 (top and bottom views)

The BGT24ATR22 DPA shield v2.0 has dimensions of 48 mm x 42 mm on a 4-layer board (see Section 2.9 for details of the layer stack). The MMIC is mounted on top of the board together with the matching structures for Tx and Rx ports and the antennas. For more details on the recommended footprint, antennas, and matching structures, see Section 3.1. The bottom side has the required external components, connectors to Radar Baseboard MCU7, and pin headers for debugging. For details, see Section 3.2.

2.2 Schematics

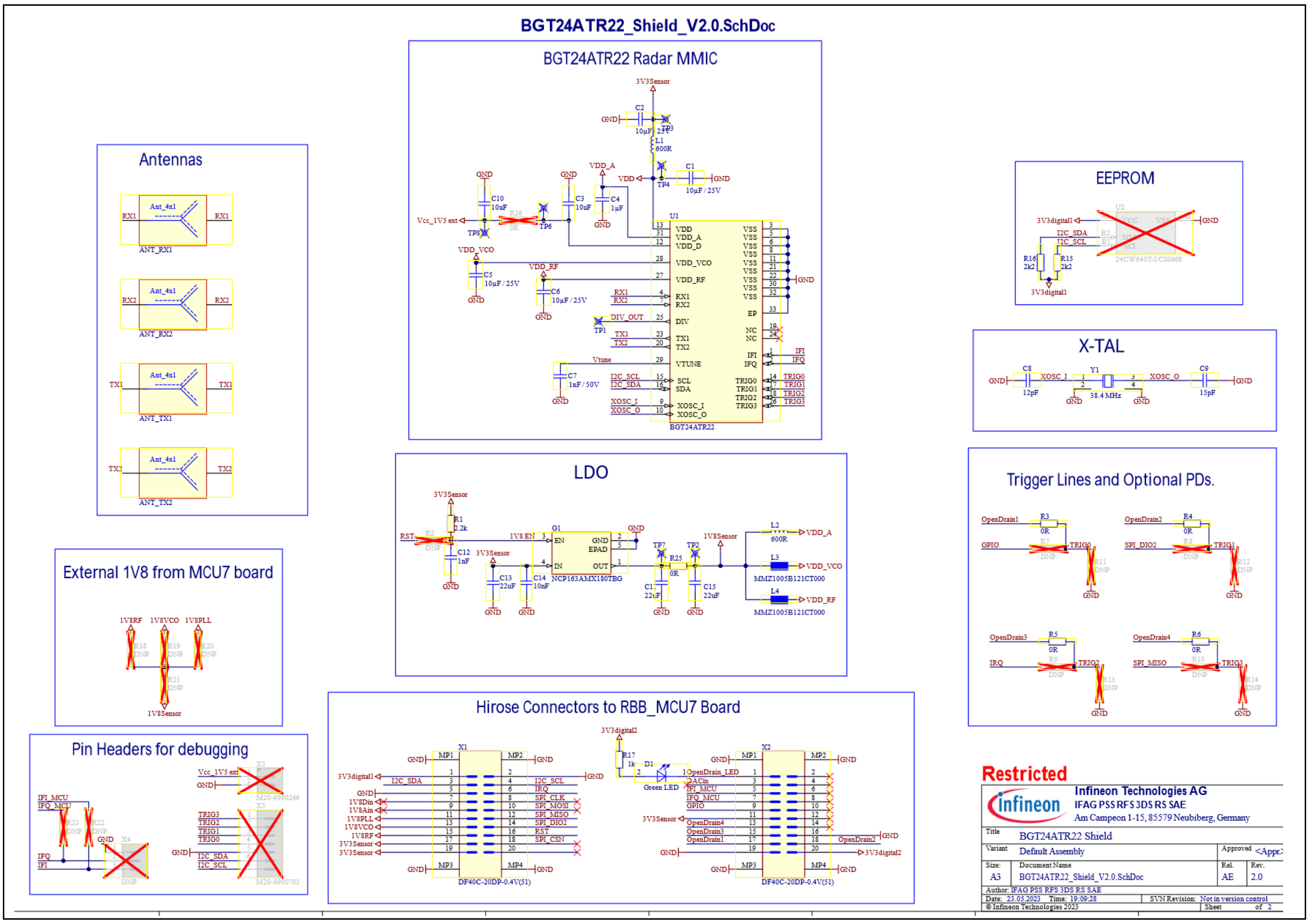

Figure 4 Overview of the schematic of the shield

2.3 Sensor supply

BGT24ATR22 supports 1.8 – 3.3 V as VDD and GPIO voltages, dependent on whether 1.8 V or 3.3 V are supplied. A chip-internal LDO generates 1.5 V as VDD_D as the digital supply. Because the Radar Baseboard MCU7 board uses a 3.3 V MCU, the VDD of BGT24ATR22 is supplied from an onboard LDO from Radar Baseboard MCU7 with 3.3 V. Because radar sensors are very sensitive to supply voltage fluctuations or crosstalk between different supply domains, a low-noise power supply with properly decoupled supply rails is recommended. Therefore, all analog supplies (i.e., VDD_RF, VDD_VCO, and VDD_A) are fed from one single external LDO placed on the RF shield that generates 1.8 V.

In order to measure the current supplied from the external LDO to the analog supplies, the 0-Ohm jumper R25 can be replaced with a very small high precision resistor. The voltage can be sensed between test point TP7 and TP2. Optionally, the LDO can be duty-cycled, if populated with R2.

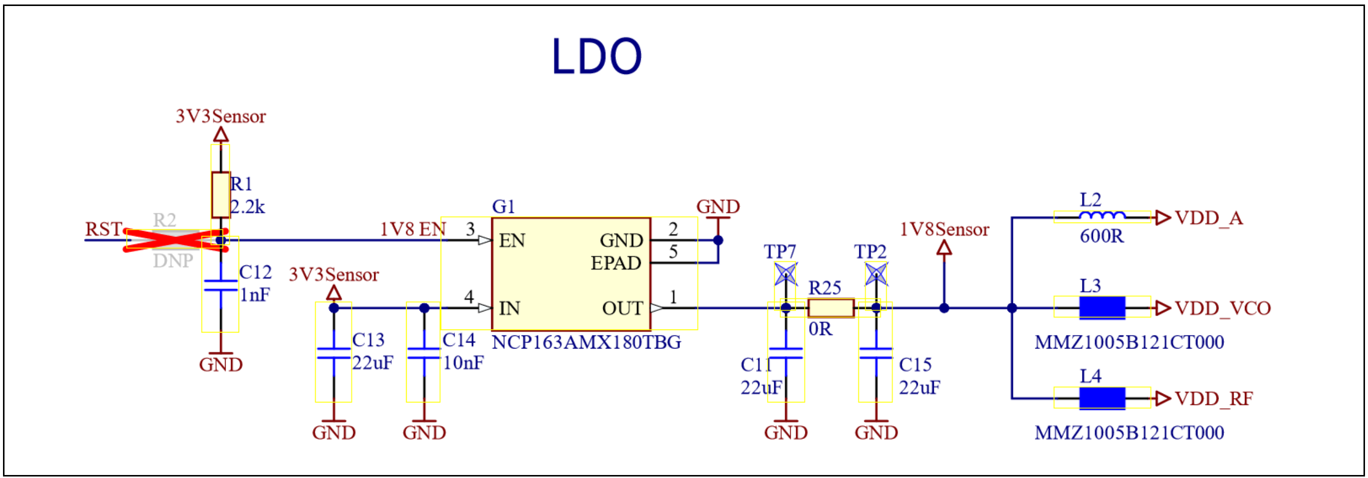

Figure 5 External LDO generating 1.8 V output as VDD (VDD_RF, VDD_VCO, VDD_A) from 3.3 V input

BGT24ATR22 is intended to be used in a heavy pulsed operational mode, showing high load transients for the supply current. To handle these current transients on the supply line, especially the LDO output, they have to be buffered by large capacitors. The LDO itself shows a load transient dip in supply voltage and cannot serve the current as fast as required. To reduce this effect, the required supply pulse charge is provided by the large (ceramic) buffer capacitors (MLCC).

The better the load transient characteristic of the used LDO is, the less critical the situation will be. Therefore, it is important for highly duty-cycled short-range radars to select a suitable LDO.

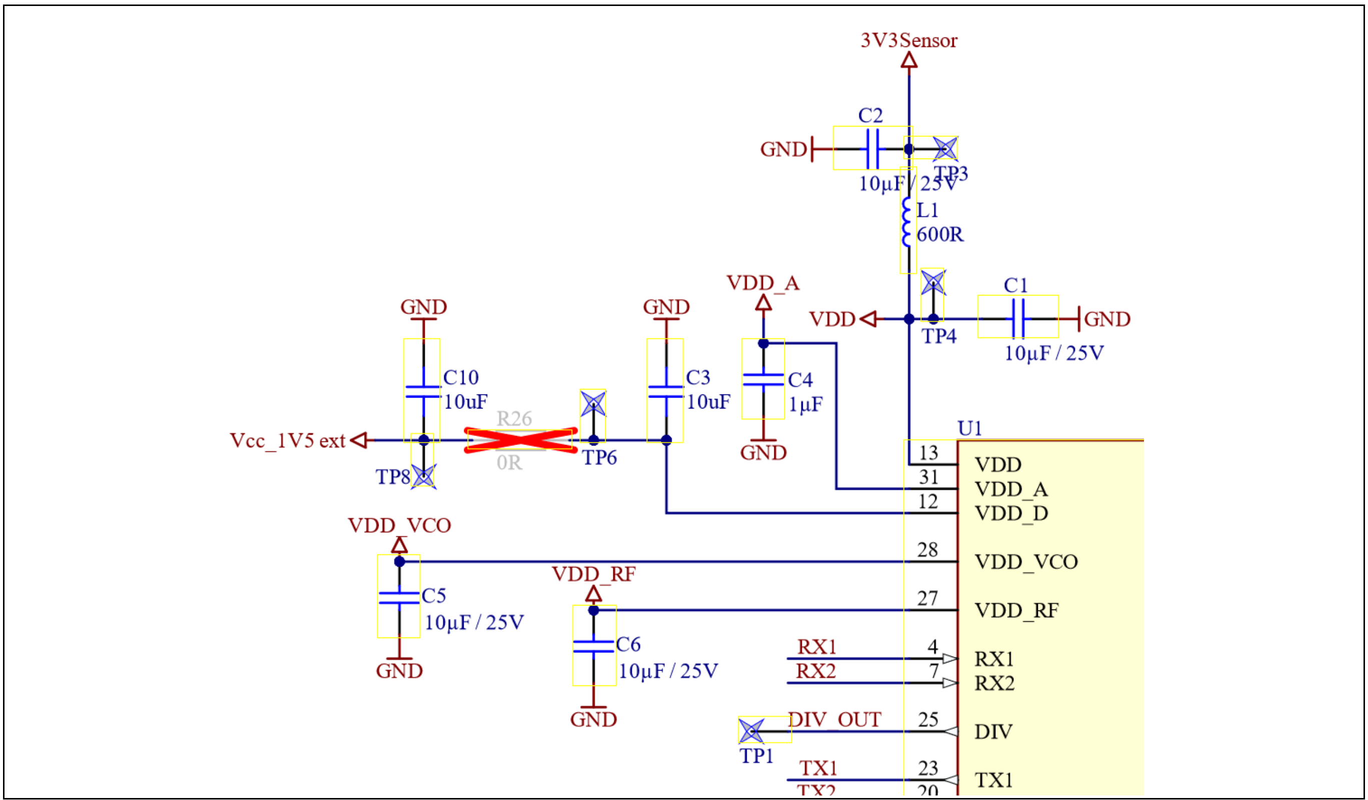

Figure 6 Schematic section of DC supply

2.4 Oscillator

The 38.4 MHz crystal serves as a high-precision time reference to calibrate the transmitted VCO frequency. The internal oscillator is based on a Pierce oscillator architecture, which usually requires symmetrical load capacitors. The values of the load capacitor are different because at XOSC_I, there are additional 5 pF on the chip. Instead of 11 pF and 16 pF, standard values of C8 = 12 pF and C9 = 15 pF can be chosen.

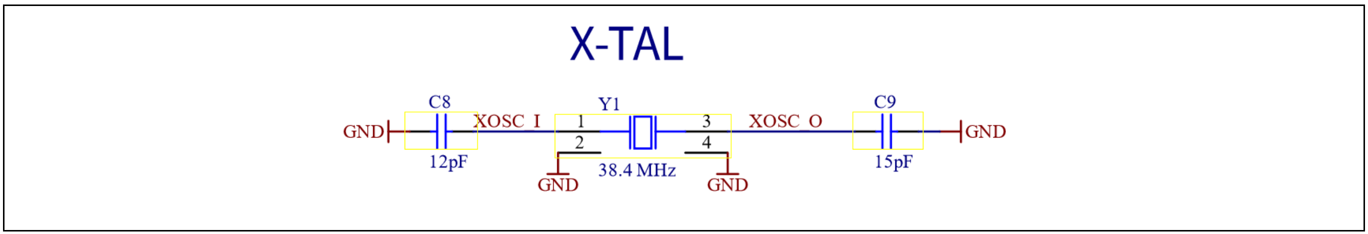

Figure 7 Crystal and load capacitors

2.5 Connectors

On the BGT24ATR22 DPA shield, there are micro connectors for connecting the RF shield to Radar Baseboard MCU7 and pin headers for debugging.

Figure 8 shows the two Hirose connectors that connect the RF shield to Radar Baseboard MCU7. The naming of the pins corresponds to the naming as given in AN599 [1]. The connections include the following:

- I2C communication (I2C_SDA, I2C_SCL)
- Connections of the trigger outputs to GPIO inputs of the MCU (OpenDrain1, 2, 3)
- 3.3 V voltage supply provided by an LDO onboard the Radar Baseboard MCU7.

In addition, there is the optional feature to sample the IFI/IFQ signal with an ADC integrated on the MCU, as described below.

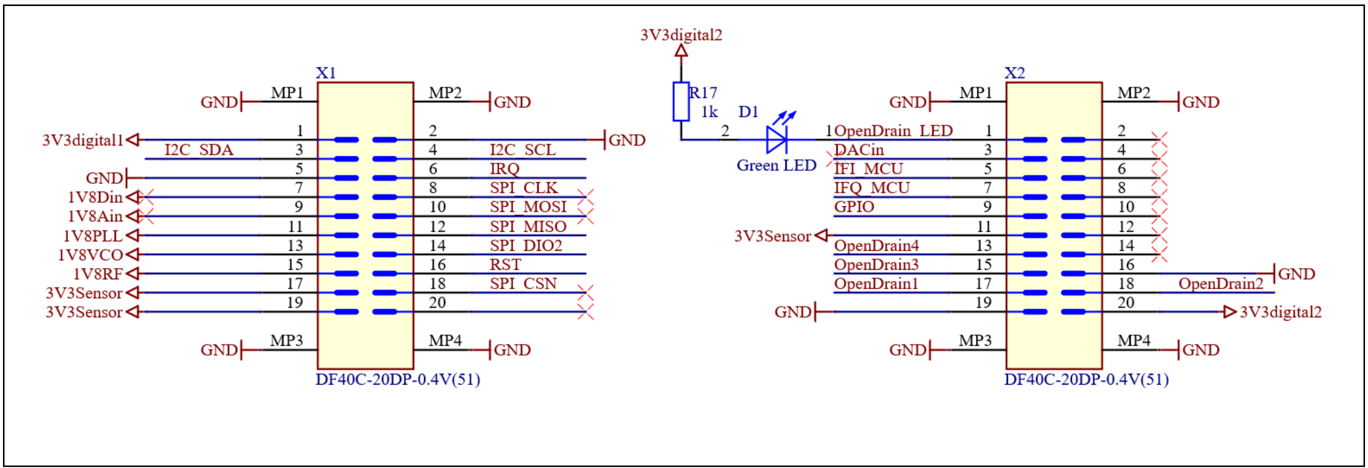

Figure 8 Hirose connectors to Radar Baseboard MCU7

The pin headers for debugging provide a simple way to monitor the digital interfaces between the RF shield and Radar Baseboard MCU7 and analog I/Q signals. The I/Q signals can be rerouted to the MCU's ADC inputs by placing zero-ohm resistors at R22 and R23.

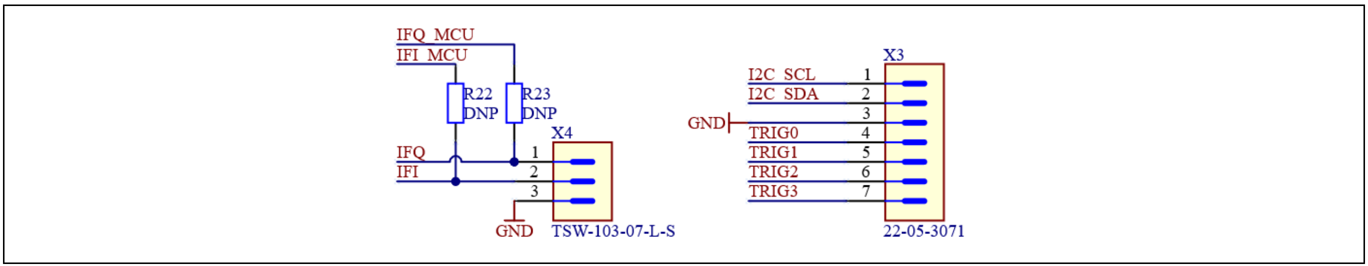

Figure 9 Pin headers for debugging

2.6 EEPROM and I2C pull-ups

Optionally, the BGT24ATR22 RF shield contains an EEPROM memory to store data such as the board identifier, with connections as shown in Figure 10. Note that even if the EEPROM is omitted, pull-up resistors must be placed on the I2C lines.

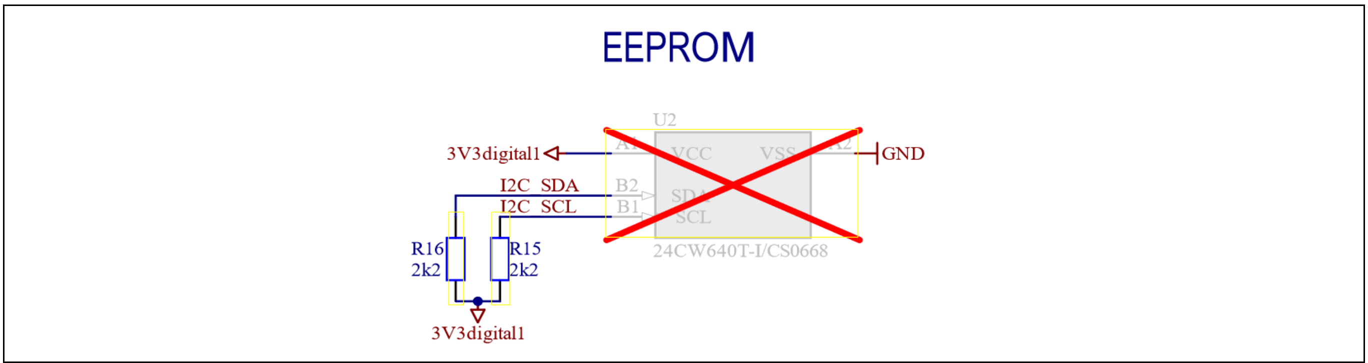

Figure 10 Schematic of the EEPROM

2.7 Trigger interface and compatibility features

Figure 11 shows the connection of the trigger pins to GPIOs of Radar Baseboard MCU7. Pull-down resistors for the four trigger pins and a jumper resistor for use of the shield with future baseboards are optionally available.

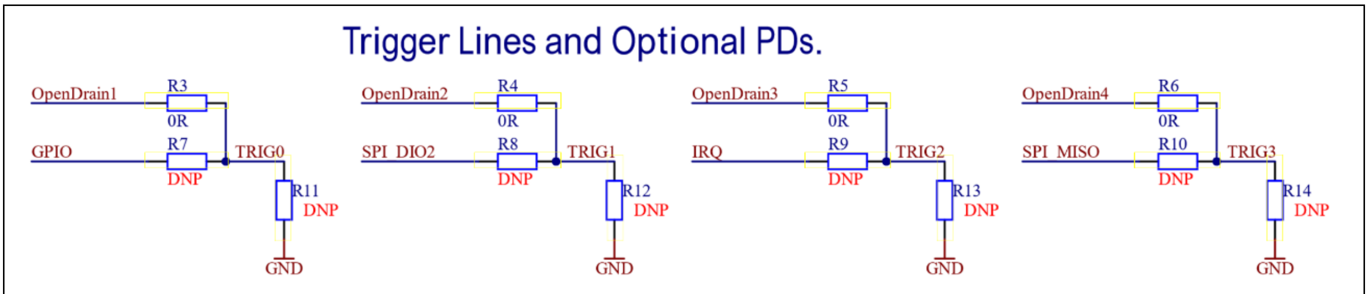

Figure 11 Trigger lines

The resistors shown in Figure 12 are for compatibility with future baseboards.

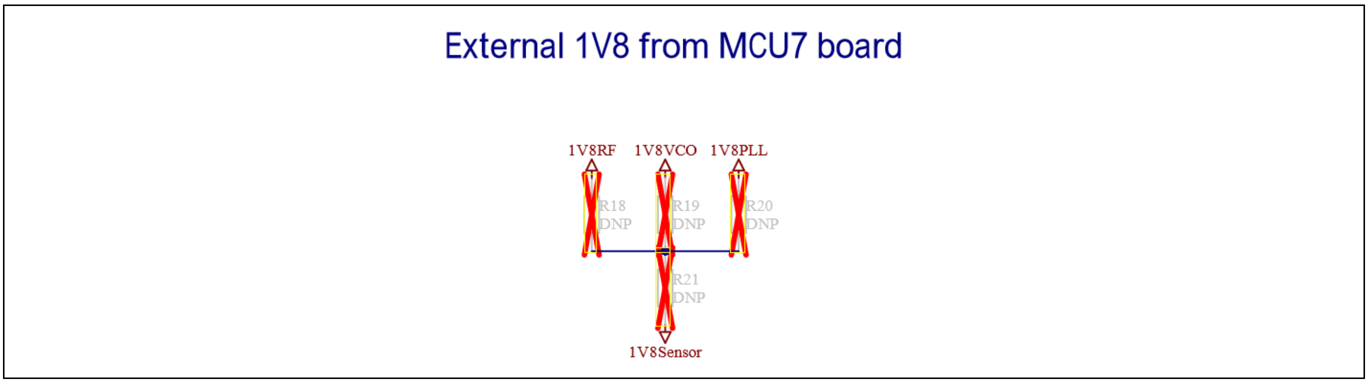

Figure 12 **Resistors connecting 1.8 V domain**

2.8 External filter capacitors

C3 and C7 shown in Figure 13 are filter capacitors. C3 reduces the noise generated by the internal 1.5 V LDO, while C7 stores the voltage generated by the DAC which controls the tuning voltage.

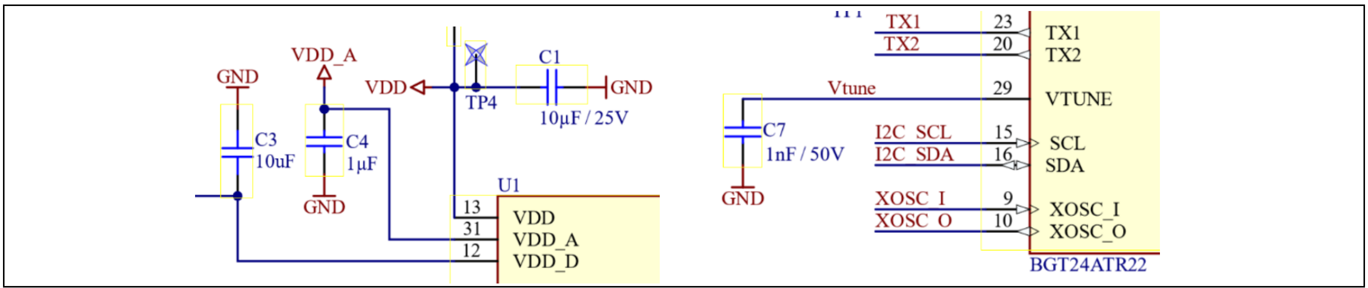

Figure 13 **External filter capacitors at VDD_D and VTUNE**

2.9 Layer stackup

Stackup		Layer stack			
Layer	Board layer stack	Name	Material	Thickness	Constant
1		Top Paste			
2		Top Overlay			
3		Top Solder	Solder Resist	0.025mm	3.5
4		L1_Top	Copper	0.018 or 0.035mm*	
5		Dielectric1	Elite EM-528	0.254mm	
6		L2_GND	Copper	0.018mm	
7		Dielectric2	Panasonic 2116 R1551W	0.230mm	
8		Dielectric1	Panasonic R1566W	0.710mm	3.5
9		L3_Sig	Copper	0.018mm	
10		Dielectric3	Panasonic 2116 R1551W	0.230mm	
11		L4_Bot	Copper	0.018 or 0.035mm*	3.5
12		Bottom Solder	Solder Resist	0.025mm	
13		Bottom Overlay			
14		Bottom Paste			
	Height: 1.546mm				

* 0.018mm or 0.035mm does not make a difference, choose what ever is cheaper.

Figure 14 **Layer stackup**

Surface finish is Electroless Nickel Immersion Gold (ENIG).

Note: *The RF shield design uses only through-hole vias. No blind vias are required.*

2.10 Metal layers

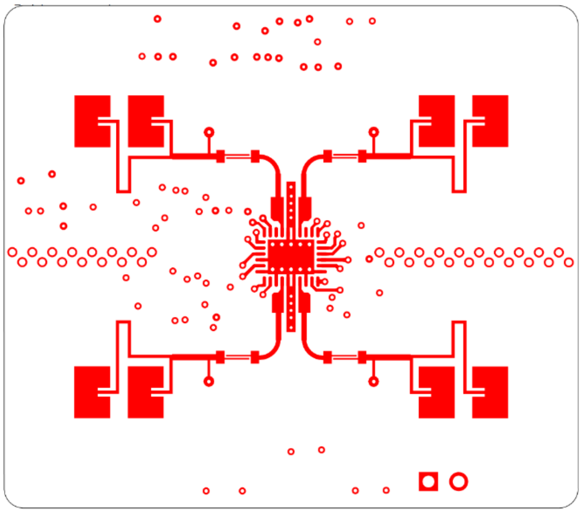

Figure 15 Top layer – Antennas and MMIC

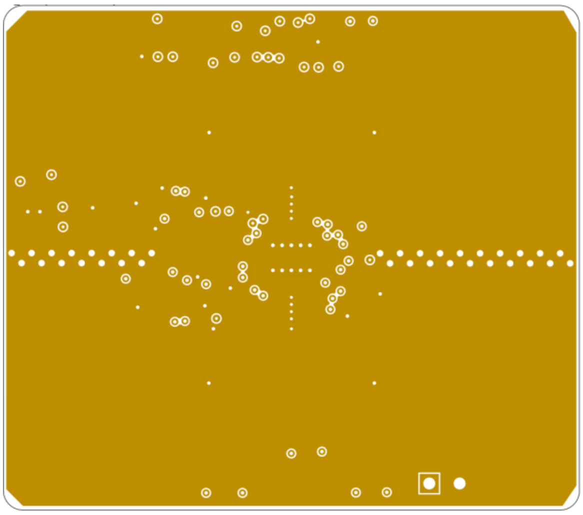

Figure 16 Layer 2 – GND plane

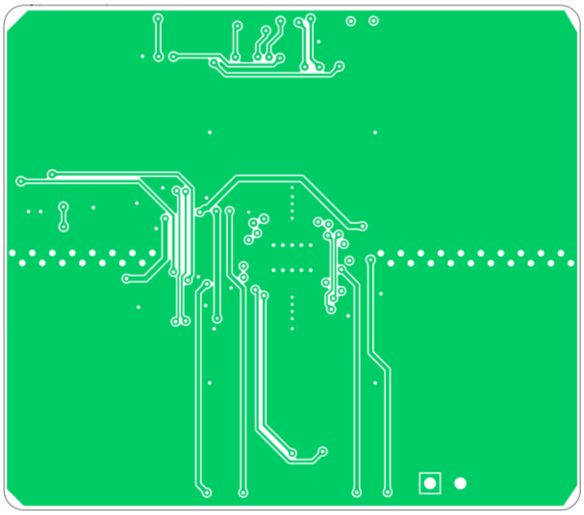

Figure 17 Layer 3 – Signal routing

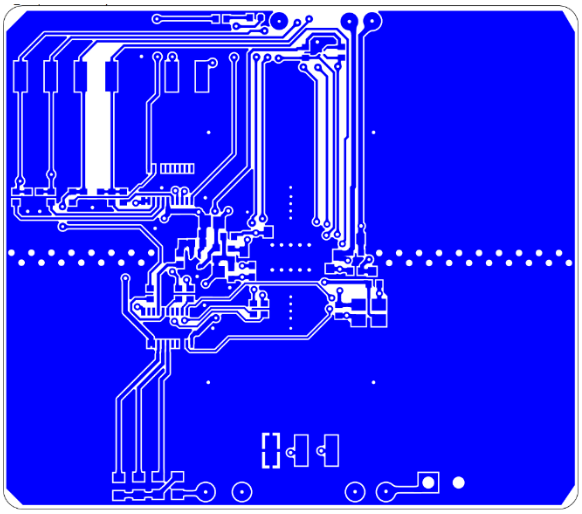

Figure 18 Bottom layer – Signal routing and supporting components

3 Layout overview

3.1 Top side with MMIC and antennas

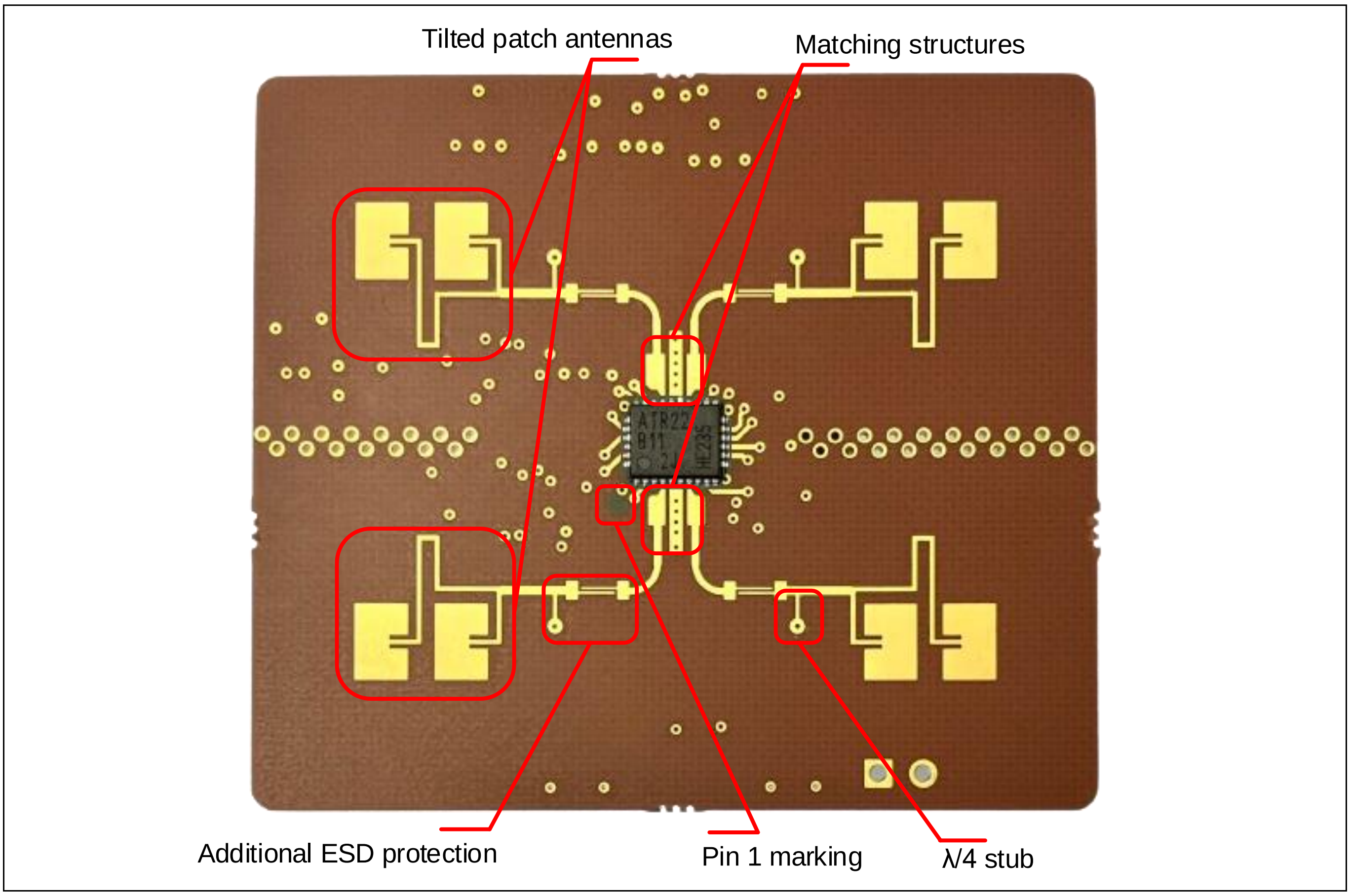

Figure 19 Layout elements on top side

The top side features all the RF-related structures and the MMIC.

3.1.1 MMIC footprint

It is recommended to use the exact footprint as shown in Figure 20 because this structure was optimized for use with BGT24ATR22 and recommended PCB material.

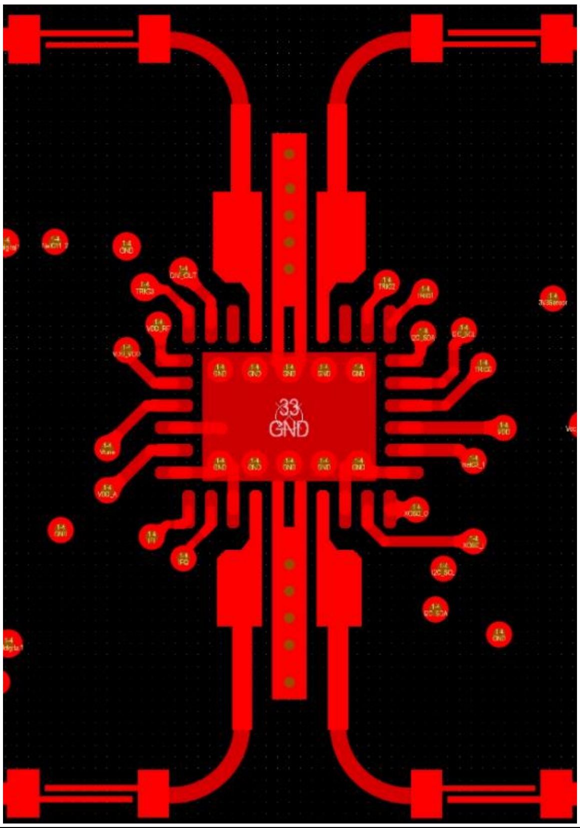

Figure 20 Recommended PCB footprint

3.1.2 Patch antennas

The antenna pattern of the patch antennas is designed in a way that the RF shield can be mounted in a position tilted approximately 45° towards the ground, in order to achieve easy mounting such as behind the bumper of a car. The antenna pattern of the two Tx-Rx antenna pairs is designed to be tilted in angle of roughly +/-30°, respectively. This way, one Tx-Rx antenna pair is facing down, while the second Tx-Rx pair is facing towards the area behind the trunk. The intended purpose of the Tx-Rx antenna pair facing the area behind the trunk is to detect motion. Once motion is detected, the microcontroller unit is woken up, and switches into kick-detection mode by enabling the second Tx-Rx antenna pair facing down towards the ground. The orientation of the antenna pattern may be better visualized with the 3D plots of the diagram, whereas the performance of the antenna may be better judged by the 2D polar plots.

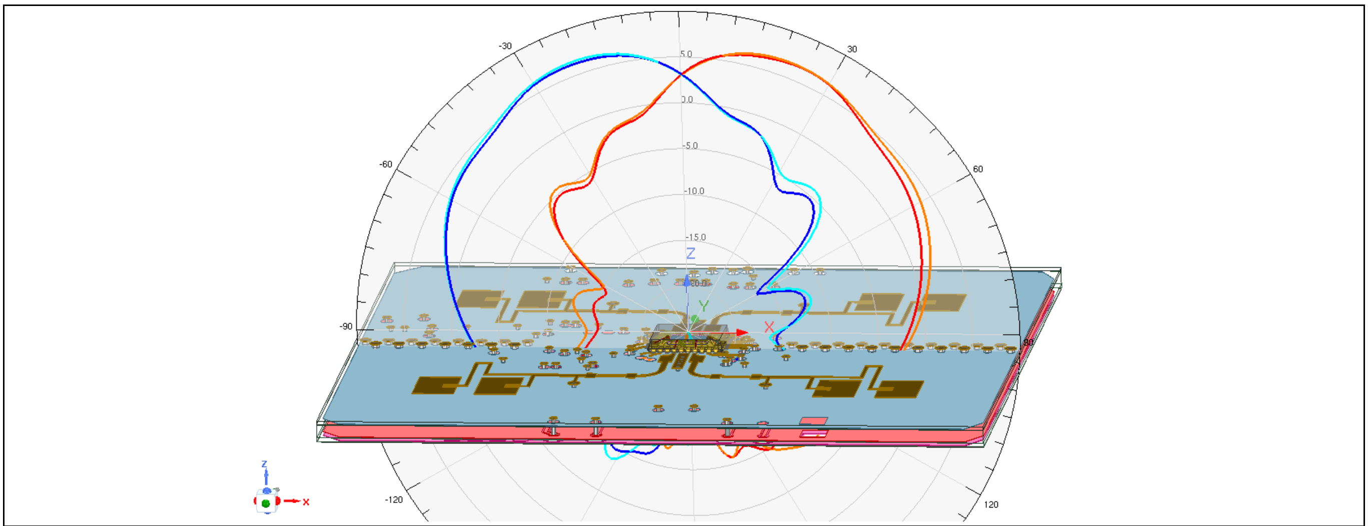

Figure 21 Simulated radiation pattern of patch antennas, E-plane, intended vertical plane when mounted behind the bumper

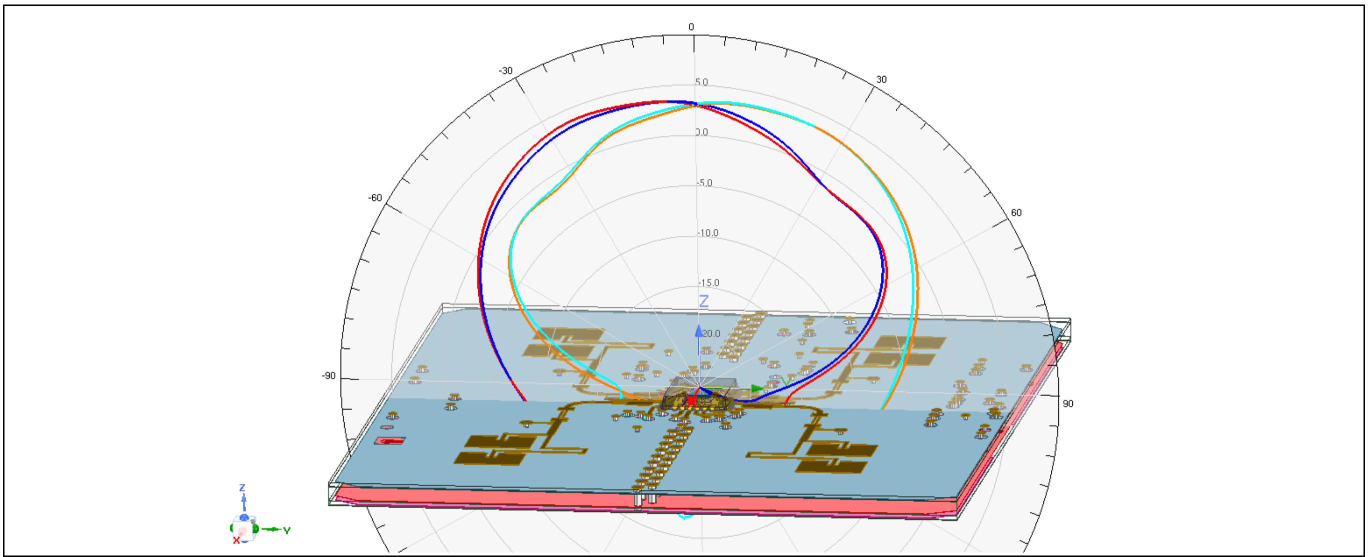

Figure 22 Simulated radiation pattern of patch antennas, H-plane, intended horizontal plane when mounted behind the bumper

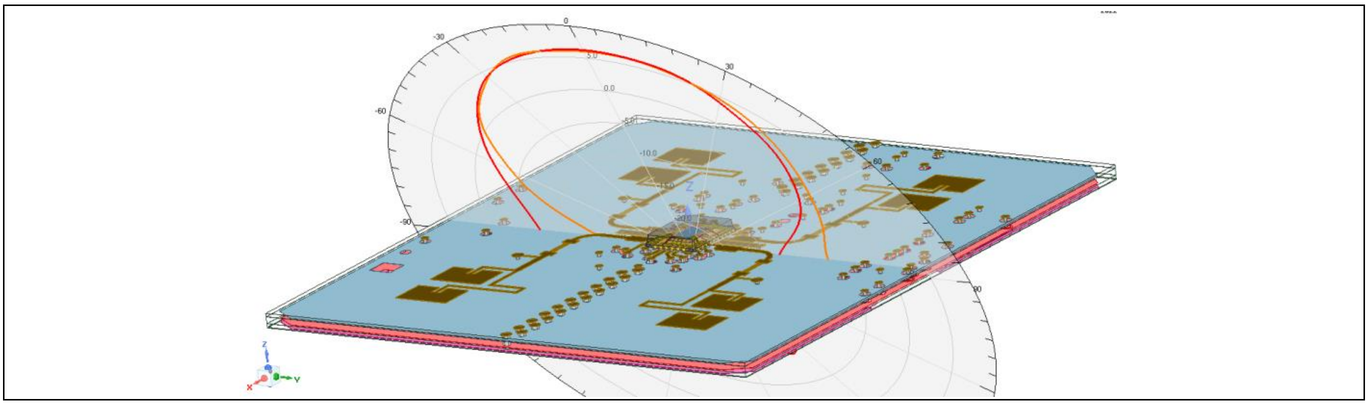

Figure 23 Simulated radiation pattern of patch antennas, intended vertical plane when mounted behind the bumper, at +30 degree main-lobe angle

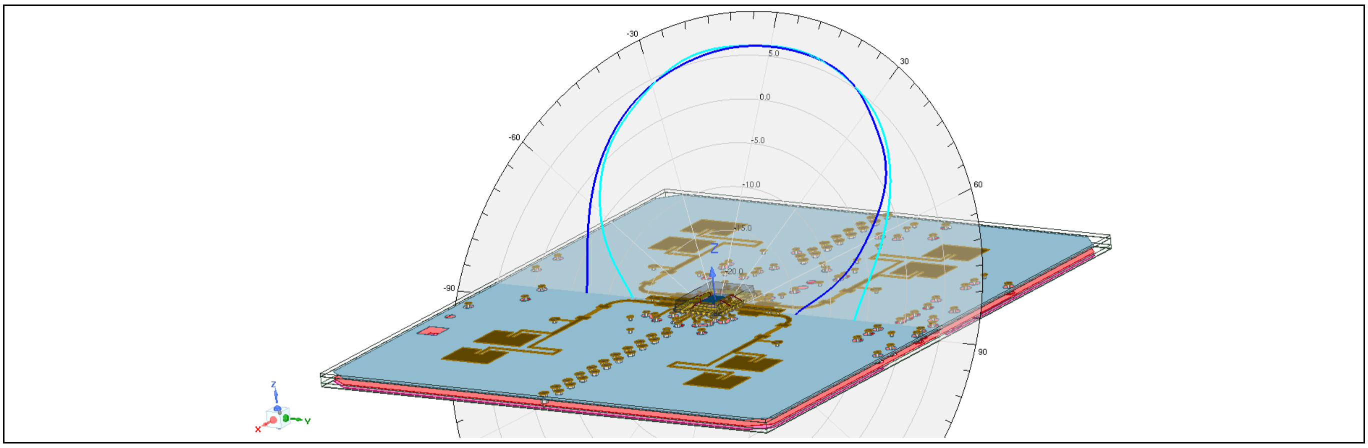

Figure 24 Simulated radiation pattern of patch antennas, intended vertical plane when mounted behind the bumper, at -30 degree main-lobe angle

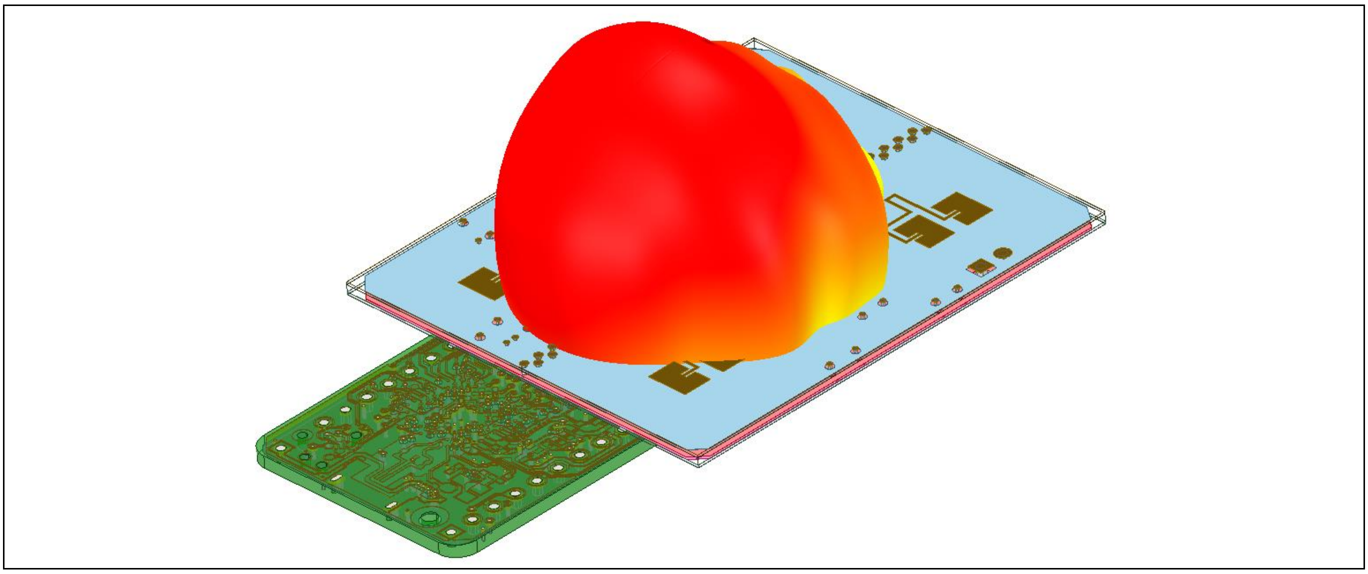

Figure 25 Simulated radiation pattern of patch antennas, Tx1/Rx1, 3D view

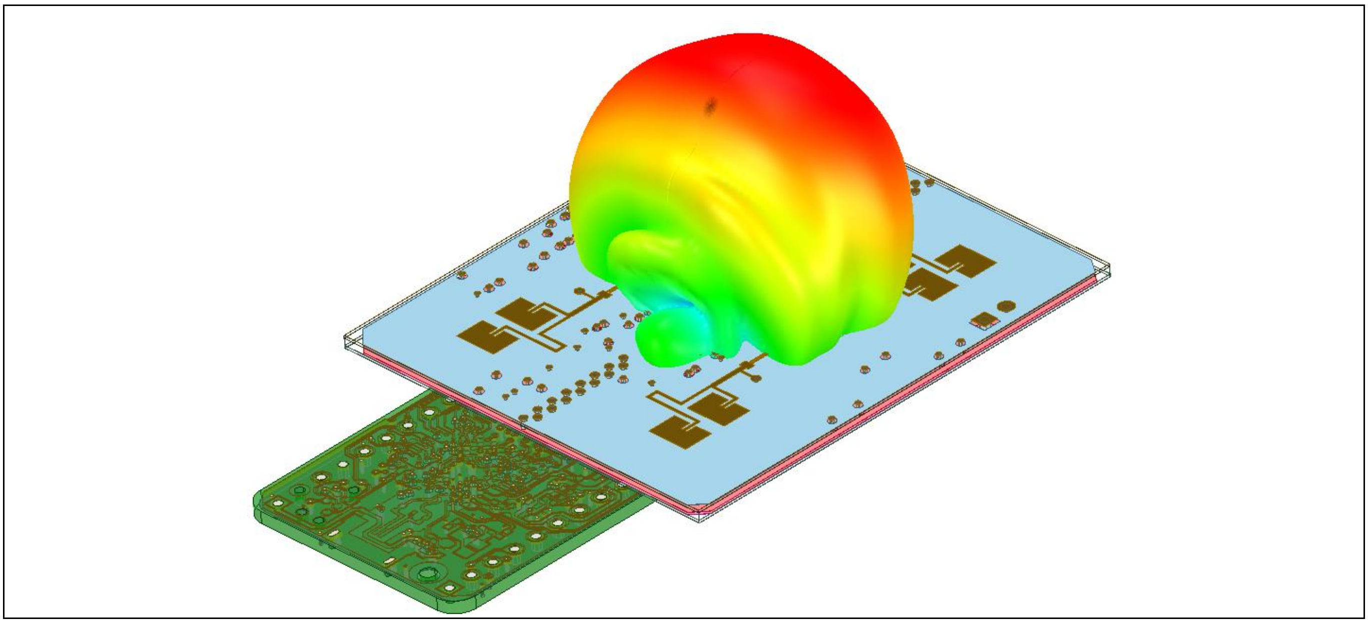

Figure 26 Simulated radiation pattern of patch antennas, Tx2/Rx2, 3D view

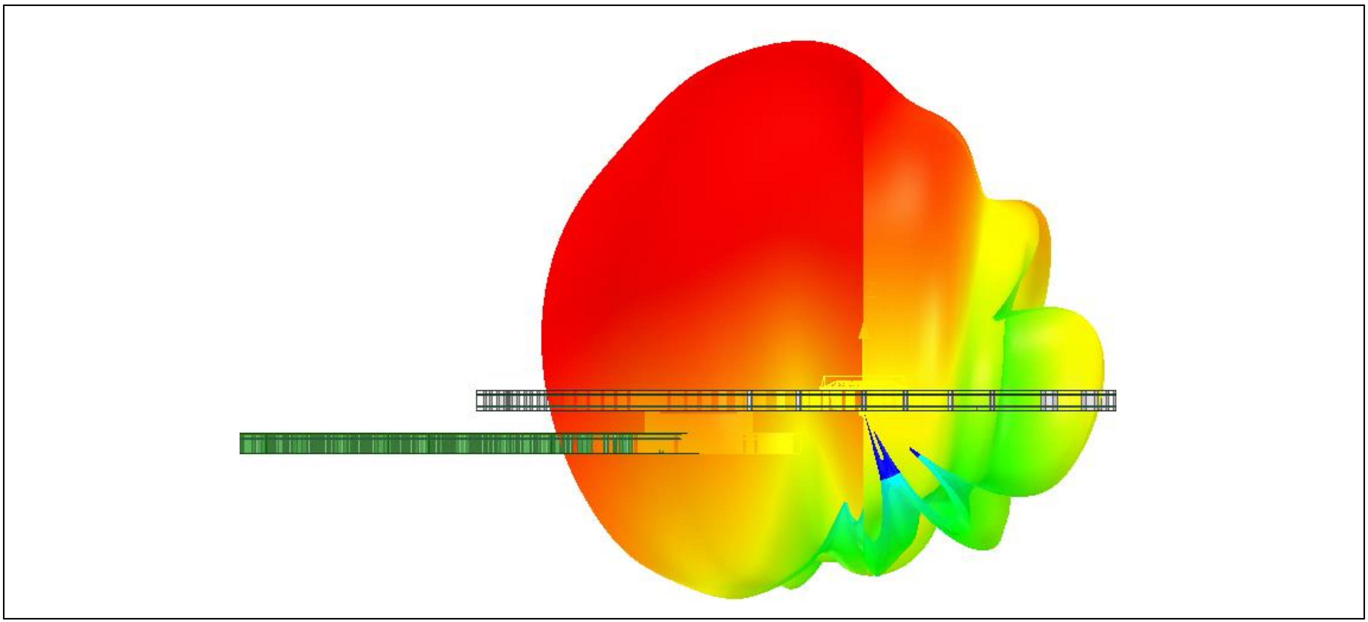

Figure 27 Simulated radiation pattern of patch antennas, Tx1/Rx1, side-view

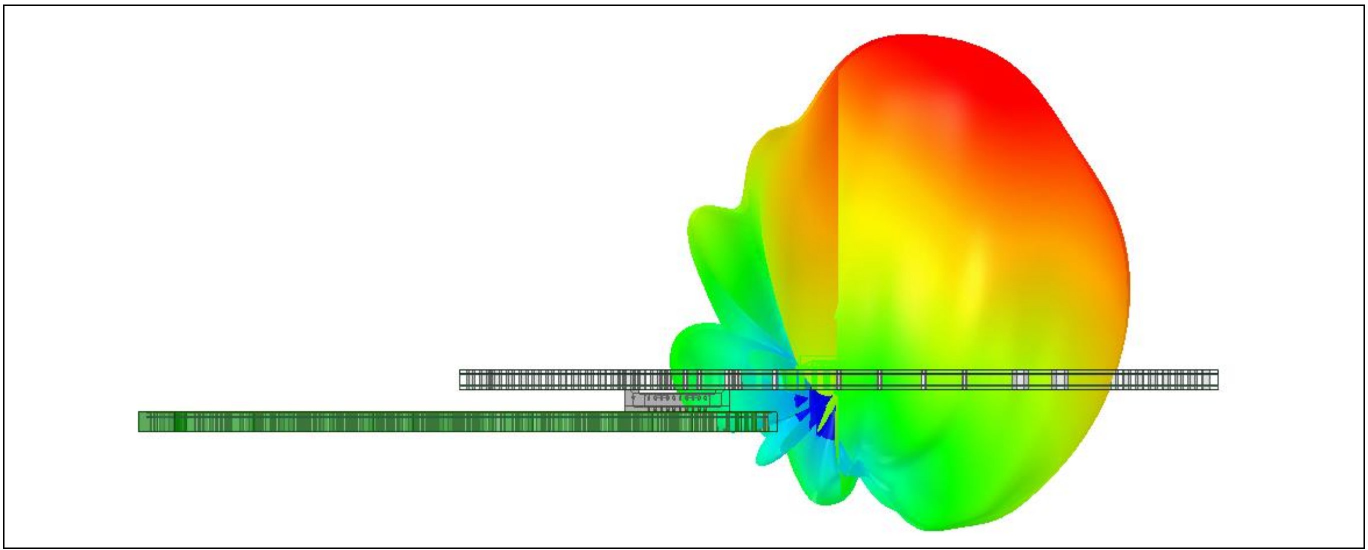

Figure 28 Simulated radiation pattern of patch antennas, Tx2/Rx2, side-view

3.2 Bottom side with supporting components

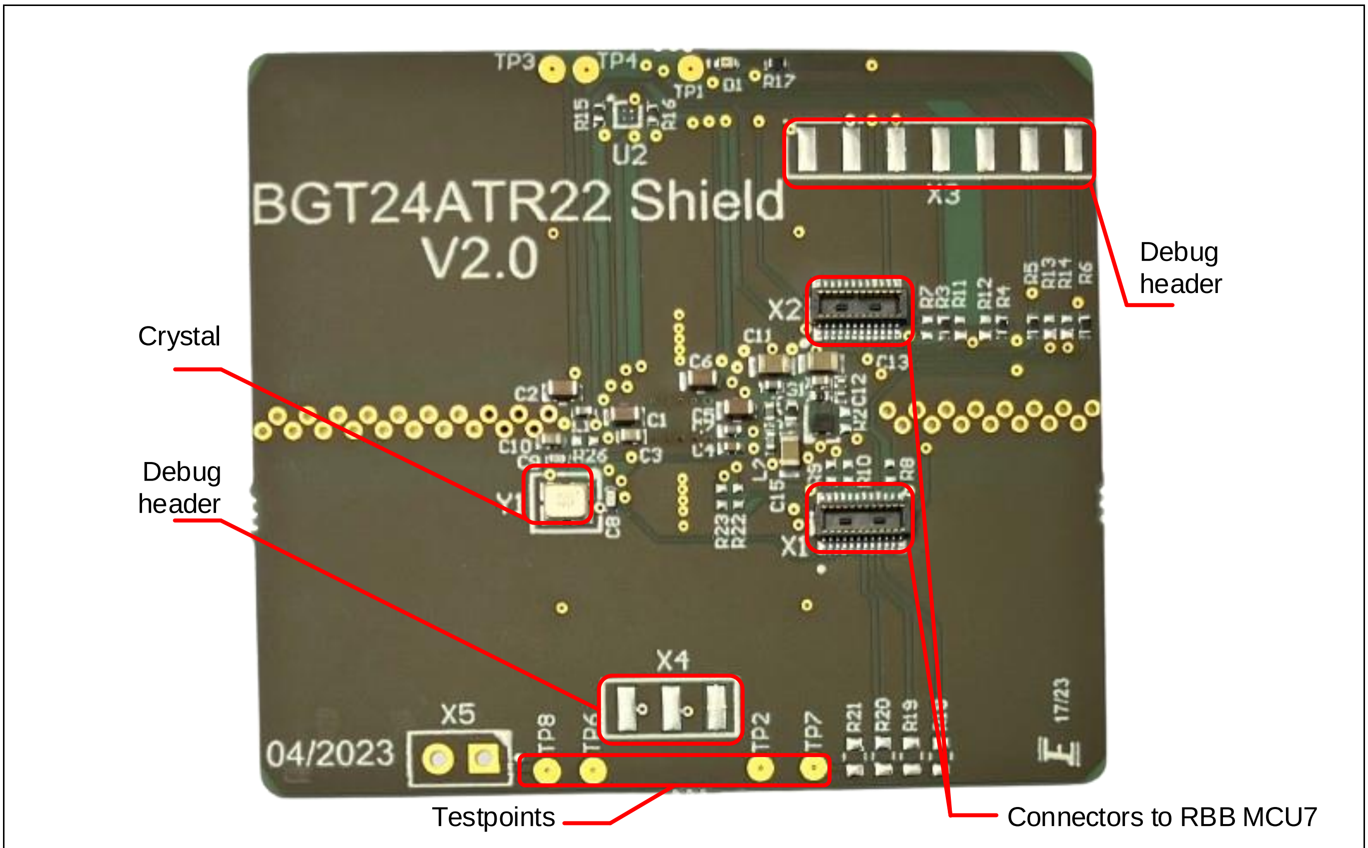

Figure 29 Components on bottom side

All external components except the MMIC are placed on the bottom side of the RF shield.

The main connector interface of the BGT24ATR22 DPA shield contains two Hirose DF40C-20DP-0.4V connectors. On the microcontroller side, Radar Baseboard MCU7 contains the corresponding DF40HC(3.5)-20DS-0.4V(51) connectors on its bottom side. The RF shield and Radar Baseboard MCU7 must be properly aligned as shown in Figure 1.

There is a risk of the Hirose connectors wearing out when regularly plugged into and unplugged from the shield. To prevent this, it is recommended not to lift the board out of the connector on the short side. Instead, simply pull on the long side of the board, thereby tilting the short side. This will significantly increase the operational lifetime of the connectors.

References

[1] Infineon Technologies AG: *AN599: Radar Baseboard MCU7*; Available online

Revision history

Document revision	Date	Description of changes
1.00	2024-06-13	Initial version

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Edition 2024-06-13

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference

AN121516