BGT60ATR24C ES shield

XENSIV™ 60 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 BGT60ATR24C shield (SHIELD_60ATR24ES_01) , part of Infineon's XENSIV™ 60 GHz radar system platform. The shield provides the supporting circuitry to the on-board BGT60ATR24C monolithic microwave integrated circuit (MMIC) Infineon's 60 GHz radar chipset with external antennas. The shield offers a digital interface for configuration and transfer of the acquired radar data to a microcontroller board, e.g., Radar Baseboard MCU7.

The MMIC-related parameters mentioned in the document are based on engineering samples (ES).

Intended audience

The intended audience for this document are design engineers, technicians, and developers of electronic systems, working with Infineon's XENSIV™ 60 GHz radar sensors, especially in automotive scenarios called in-cabin sensing (ICMS). Among the many applications it can be used for are– rear occupancy alert (ROA) and – left behind child (LBC) systems.

Related documents

Additional information can be found in the documentation provided with the Radar Development Kit tool in the Infineon Developer Center (IDC), or from www.infineon.com/60GHz.

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1 Introduction

1.1 60 GHz radar system platform

The 60 GHz radar system platform is the demo platform for Infineon's 60 GHz radar solutions. It consists of the Radar Baseboard MCU7 as the microcontroller board and a radar sensor board, like the BGT60ATR24C shield for Infineon's 60 GHz radar sensor chip. This application note focuses on the BGT60ATR24C shield. Detailed information about the Radar Baseboard MCU7 can be found in the corresponding application note [1].

Figure 1 illustrates the Radar Baseboard MCU7 with the BGT60ATR24C shield. The shield has to be plugged into the longer connectors on the baseboard's bottom side with an orientation as shown below.

a) Sensor board (antenna side) b) Radar Baseboard MCU7 (bottom side)

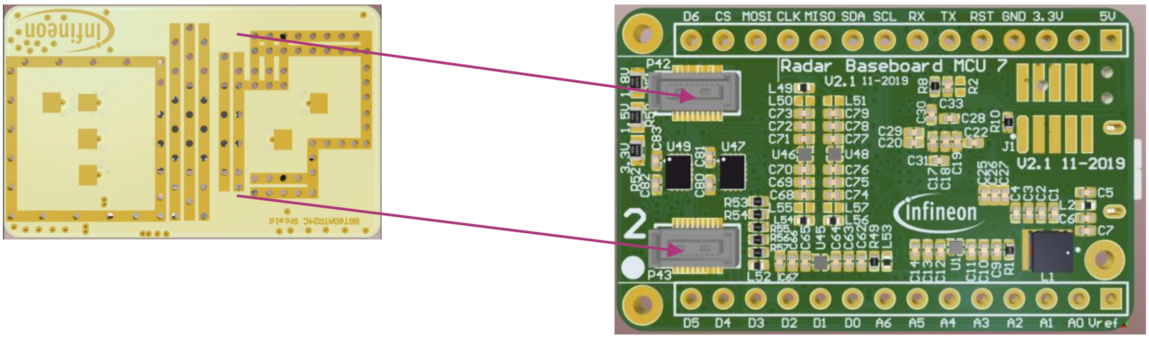


Figure 1 Radar Baseboard MCU7 with the BGT60ATR24C shield

1.2 Key features

The BGT60ATR24C shield is designed to showcase the capabilities of the BGT60ATR24C. This device offers customers design flexibility in terms of their desired antenna configuration. It consists of two transmit and four receive channels. The BGT60ATR24C shield facilitates fast prototyping and system integration, as well as initial product feature evaluation. This board offers developers the flexibility to choose their own platform depending on their preferred use cases. The sensor it incorporates various use cases, serving a broad array of applications – including presence detection, LBC, ROA, proximity sensing, people counting/tracking, gesture recognition, monitoring vital signs, etc. Presence detection may only require 1 mW of power in the sensor under certain circumstances. In an automotive context, it can be of value in ROA, LBC and dashboard control. Other areas where it might be applied are smart speakers, home/building automations and security/safety.

2 System specifications

2.1 Typical power consumption

The typical power consumption of the whole 60 GHz radar sensor platform, consisting of a Radar Baseboard MCU7 and a BGT60ATR24C shield, can be found in Table 1 and Table 2. The microcontroller on the Radar Baseboard MCU7 will change its mode of operation depending on the sensor that is plugged in and the signal processing that is required. This will be acutely reflected in the microcontroller's power consumption.

Table 1 Typical current consumption of the BGT60ATR24C shield

Condition	Power consumption of the BGT60ATR24C shield
Sensor attached but deactivated (BGT60ATR24C in deep sleep mode)	~ 0.25 mW (BGT) + ~ 10 mW (crystal osc.)
BGT60ATR24C shield attached and in CW operation (both TX on – maximum power consumption)	~ 500 mW

Table 2 Typical current consumption of the 60 GHz radar sensor platform

Condition	Power consumption of the radar system
MCU in reset	~ 10 mW
No sensor attached	~ 150 mW
Sensor attached but deactivated (BGT60ATR24C in deep sleep mode)	~ 550 mW
BGT60ATR24C shield attached and in CW operation (both TX on – maximum power consumption)	~ 1500 mW

3 Hardware description

This section of the document presents a detailed overview of the BGT60ATR24C shield's hardware specifications. It covers BGT60ATR24C considerations, as well as the power supply, oscillator and board interfaces.

3.1 Overview

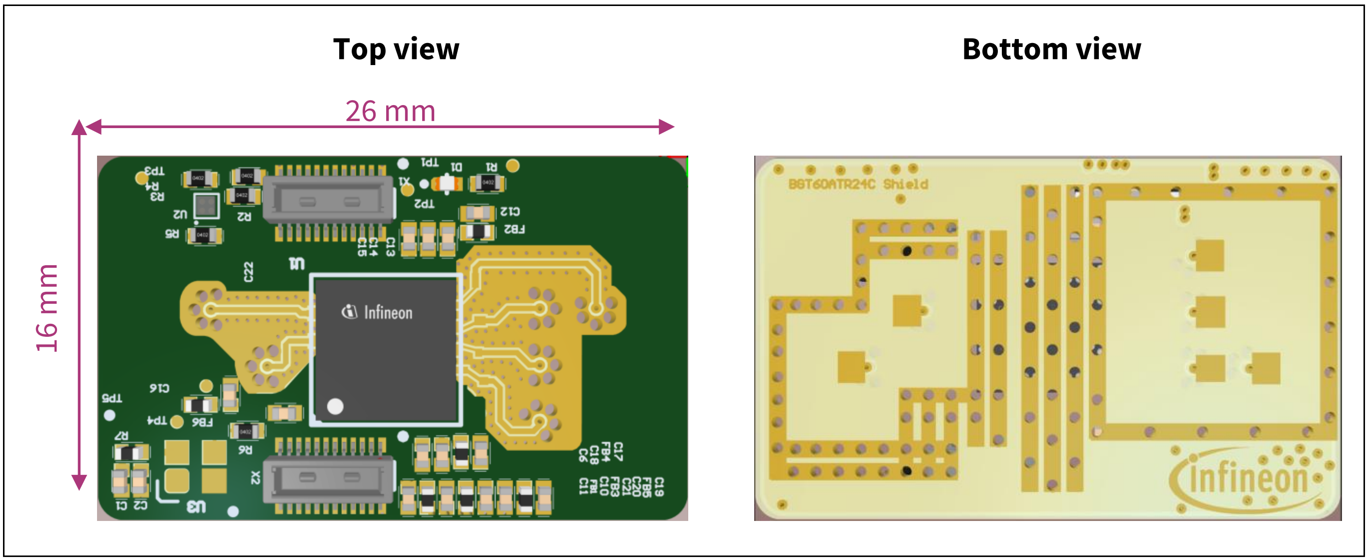


Figure 2 Top and bottom views of the BGT60ATR24C shield

The dimensions of the BGT60ATR24C shield are 26 mm x 16 mm. The BGT60ATR24C sensor is mounted on top of the PCB, while on the bottom patch antennas have been located. The current design of the shield uses two Rogers laminate layers for top and bottom (RO3003 top and RO4350B bottom). More details of the PCB stackup are mentioned in section 3.6.

To provide the correct level shifter voltage for the MCU board, the 1.8 V_{sensor} supply line is connected with $V_{digital}$ – refer to "Level shifters" section of application note AN599 [1]. When the shield is plugged into the Radar Baseboard MCU7, the sensor's supplies are initially deactivated. Only the EEPROM is powered. The microcontroller will read the content of the EEPROM's memory to determine which sensor is plugged into the sensor interface. Actually, it is not mandatory to use this EEPROM with the BGT60ATR24C, as it has an internal chip ID which can be read by SPI directly. The EEPROM is only for ensuring compatibility with other Infineon chips that do not have the chip ID feature.

Radar sensors are very sensitive to noise and cross-talk on the supply domains. Therefore, the different supply domains must be decoupled. On the BGT60ATR24C shield, this is realized by a pi-shaped low-pass filter on each supply domain (and the oscillator supply). Communication with the radar sensor is mainly performed via a serial peripheral interface (SPI) bus. Additionally, two more digital lines are required for operation. One line signals the microcontroller when new data needs to be fetched. The other allows the microcontroller to perform a hardware reset of the sensor. Furthermore, an LED indicator is mounted on the board. This allows the microcontroller to signal (for example) if the sensor is activated or deactivated at that time.

3.2 Sensor supply

Since radar sensors are very sensitive to supply voltage fluctuations or cross-talk between different supply domains, a low-noise power supply with properly decoupled supply rails will prove vital. The Radar Baseboard MCU7 provides a low-noise supply (see section 2.2 of application note AN599 for further details). Figure 3 depicts the schematics of the pi-shaped low-pass filters employed to decouple the supplies of the different power rails in the chip. High attenuation of voltage fluctuations in the MHz range is provided by ferrite beads. For example, the SPI (which runs at up to 50 MHz) induces voltage fluctuations in the digital domain. These fluctuations would then transfer into the analog domain if not for the decoupling filters incorporated. The ferrite beads are chosen because they can handle the maximum current of the sensor (approximately 200 mA) with a low DC resistance (below 0.25 Ω) and an elevated inductance. The high inductance figure will reduce the cut-off frequency of the low-pass filter, thereby providing better decoupling at lower frequencies.

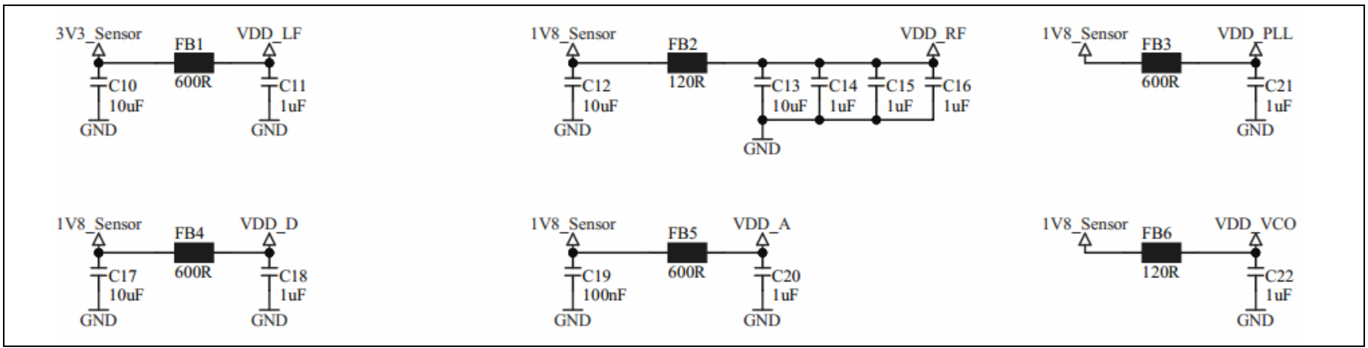


Figure 3 **Schematics of the low-pass filters**

3.3 Oscillator

Infineon's XENSIV™ BGT60ATR24C radar sensor requires an external 80 MHz oscillator with low phase jitter and low phase noise to provide a stable system reference clock. Therefore, the BGT60ATR24C shield employs an NDK NZ2520SHA quartz oscillator, as depicted in Figure 4. This oscillator source will output a stable 1.8 V digital signal. The most important parameters when choosing an oscillator are phase jitter and phase noise. Other oscillators should have similar phase jitter and phase noise to the NDK NZ2520SHA. The R6 series resistor reduces the RF level at the sensor so that it is at the optimal range for the BGT60ATR24C. If a redesign of the board contains a different signal source or a vastly different layout is implemented, the value of R1 (150 Ω) may have to be adjusted. A higher resistance results in a lower signal at the radar sensor. If the signal level is too low, the phase noise of the sensor will degrade. With a low resistance, the signal level at the sensor will be heightened. Consequently, in the range-Doppler illustration of the radar data, a peak (or ghost target) will appear for low distances.

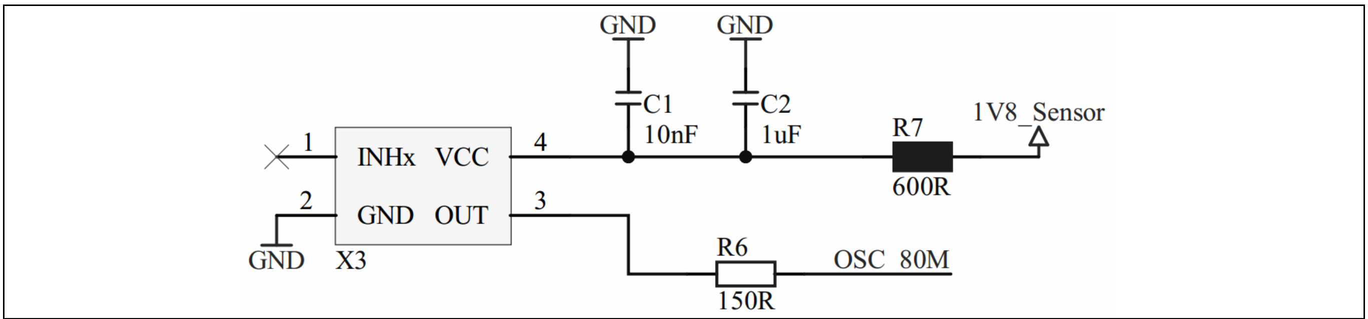


Figure 4 **The oscillator circuit on the BGT60ATR24C shield**

For this reason, the phase noise needs to be measured as well as the radar data. This can be illustrated with a range-Doppler plot to optimize the series resistance of the layout. The series resistance must be varied by soldering different resistors into the circuit. An optimized series resistance will show ideal phase noise behavior of the sensor, paired with a clean range-Doppler plot. If the phase noise behavior is non-ideal, the resistance value must be lower. If a peak appears in the range-Doppler plot, the resistance must be higher.

3.4 Connectors

The BGT60ATR24C shield is an extension board of Infineon's XENSIV™ 60 GHz radar system platform (without a microcontroller included). The shield must be connected to a microcontroller board, like the Radar Baseboard MCU7.

The main connector interface of the BGT60ATR24C shield contains two Hirose DF40C-20DP-0.4V connectors. On the microcontroller side, the Radar Baseboard MCU7 contains the corresponding DF40HC(3.5)-20DS-0.4V(51) connectors on its bottom side. Figure 5 describes the pin-out and the pad layout of the Hirose connectors on the BGT60ATR24C shield. To provide the information of the correct digital signal level to the host board, the line Vdigital is shorted with the 1.8 V supply. The RF shield and the MCU7 board have to be properly aligned, as depicted 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.

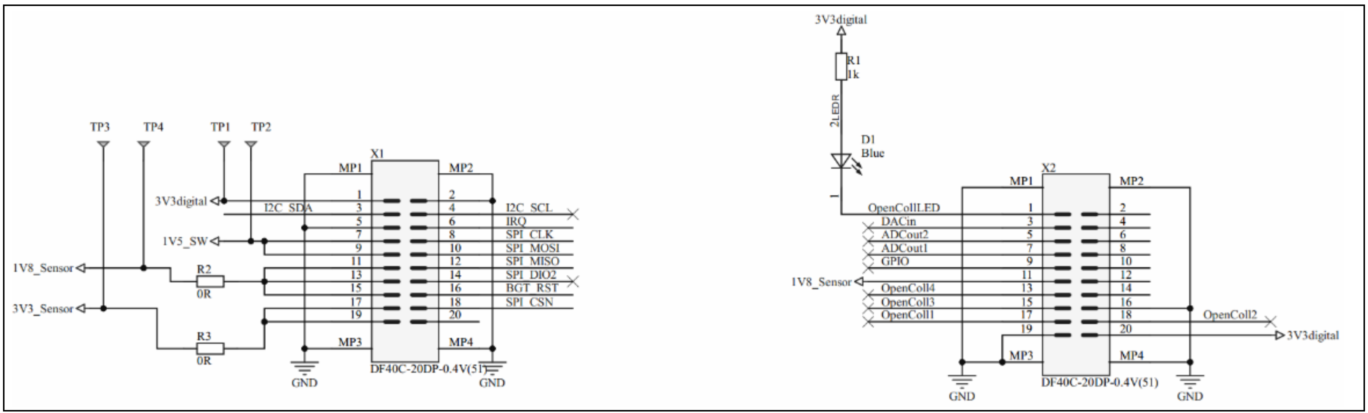


Figure 5 **Pin-out of the sensor connectors on the BGT60ATR24C shield**

3.5 EEPROM

The BGT60ATR24C shield contains an EEPROM memory to store data such as the board identifier. Its connections can be seen in Figure 6.

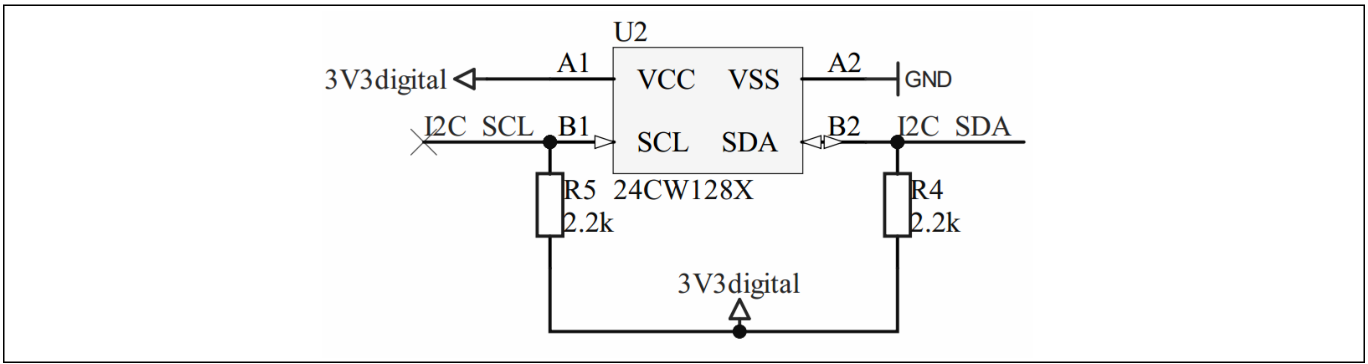
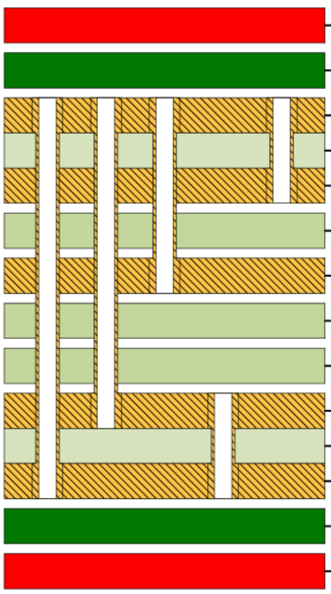


Figure 6 **Schematics of the EEPROM**

3.6 Layer stackup

Since the antennas are integrated on the PCB, the stackup must be chosen carefully. For low loss and enhanced performance, the stackup shown in Figure 7 is selected. All the vias in Figure 7 are mechanically drilled except for the blind vias between L1_Top and L2_GND, which are laser drilled.

Note: IS400 is similar to FR4 material



Material	Layer	Thickness	Dielectric Material	Type	Gerber
	Top Overlay			Legend	GTO
Surface Material	Top Solder	0.04mm	SM-001	Solder Mask	GTS
Copper	**L1_Top**	**0.02mm**		**Signal**	**GTL**
Core		*0.13mm*	*RO3003 R3 GHENT*	*Dielectric*	
Copper	**L2_GND**	**0.02mm**		**Signal**	**G1**
Prepreg		*0.12mm*	*2116 IS400*	*Dielectric*	
Copper	**L3_Signal**	**0.02mm**		**Signal**	**G2**
Prepreg		*0.10mm*	*IS400*	*Dielectric*	
Prepreg		*0.12mm*	*IS400*	*Dielectric*	
Copper	**L4_GND**	**0.02mm**		**Signal**	**G3**
Core		*0.40mm*	*RO4350b*	*Dielectric*	
Copper	**L5_Bot**	**0.02mm**		**Signal**	**GBL**
Surface Material	Bottom Solder	0.04mm	Solder Resist	Solder Mask	GBS
	Bottom Overlay			Legend	GBO

Total thickness: 1.02mm

Figure 7 Layer stackup and via types

3.7 Metal layers overview

Figure 8 through to Figure 12 show the different metal layers of the PCB. Layer 1 comprises SMD components, the BGT60ATR24C chipset and matching networks. Layer 2 consists of the ground plane for RF structures situated on Layer 1. Layer 3 consists of signal lines and power planes with the voltage domains required for BGT60ATR24C and other components. Layer 4 is the ground plane for the antennas that are placed on layer 5.

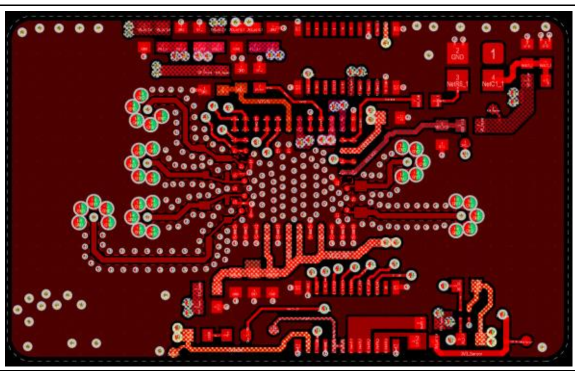


Figure 8 Layer 1 – RF layer, component side

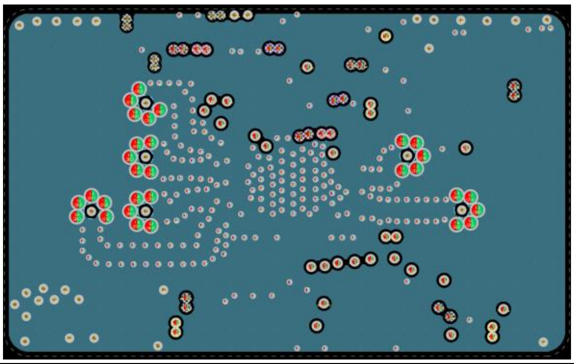


Figure 9 Layer 2 – GND plane for component side

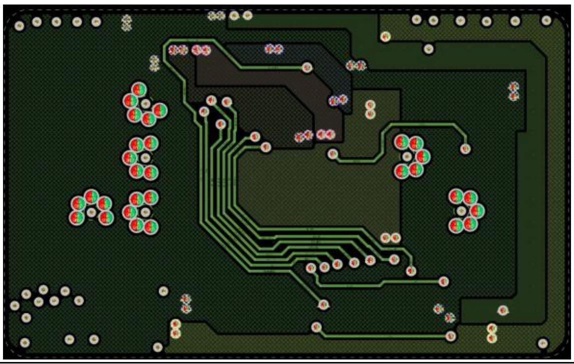


Figure 10 Layer 3 – signal/power layer

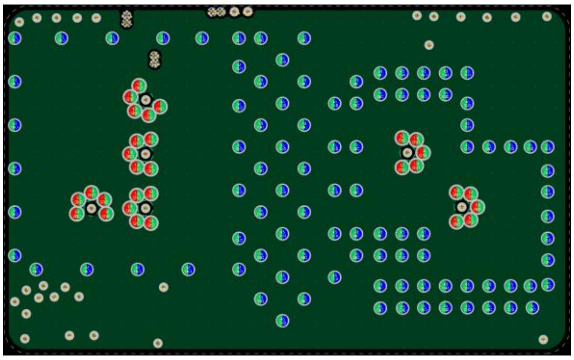


Figure 11 Layer 4 – GND plane for antenna side

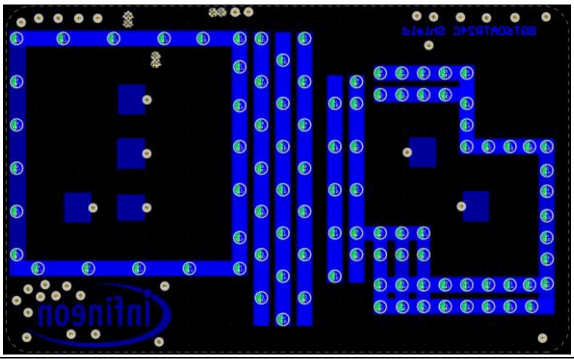


Figure 12 Layer 5 – RF layer, antenna side

4 Layout overview

4.1 Component side

Layer 1 is the component side. It comprises important elements for the RF performance of the shield.

- BGT60ATR24C radar chip
- TX matching structures
- RX matching structures
- Lines to the feed-throughs to the antenna side

The matching structures transform BGT60ATR24C's chip impedances at the package side into 50 Ω. The transmission lines to the feed-throughs correct for phase differences between the channels (see section 5.1) so that all RX channels and TX channels are in phase at the antenna side.

In order to work correctly, all these RF structures on the component side need a certain distance between the board and the other objects. Simulation has shown that this distance should be more than 1.8 mm. This is the reason why the shield should be plugged into the MCU7 board at the side with the higher connectors.

The copper areas between the matching structures and transmission lines, as well as the vias next to them, will help to increase the isolation between the single RX and TX channels.

The solder mask was removed in all RF relevant areas of the board, as otherwise it would degrade the RF performance.

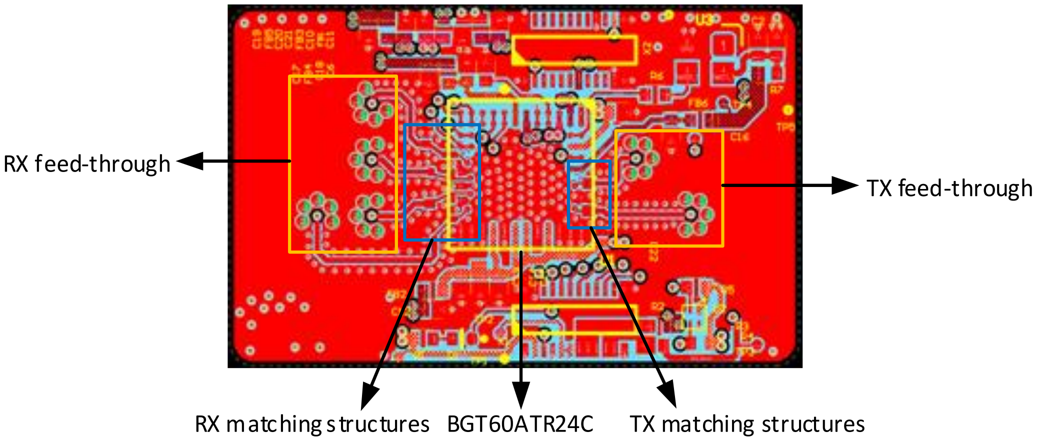


Figure 13 Top layer overview, component side

4.2 Antenna side

The antenna side consists of the six different antennas. The structures between the TX and RX side will increase the TX to RX isolation. The structures around the single sides prevent radiation in unwanted directions.

There is no solder mask on the antenna side, again in order to improve RF performance.

The single TX and RX antennas are placed in such a way that the board, if MIMO techniques are being used, has multiple virtual antennas - three for horizontal scanning, and four for vertical scanning. Figure 16 explains the principle behind this.

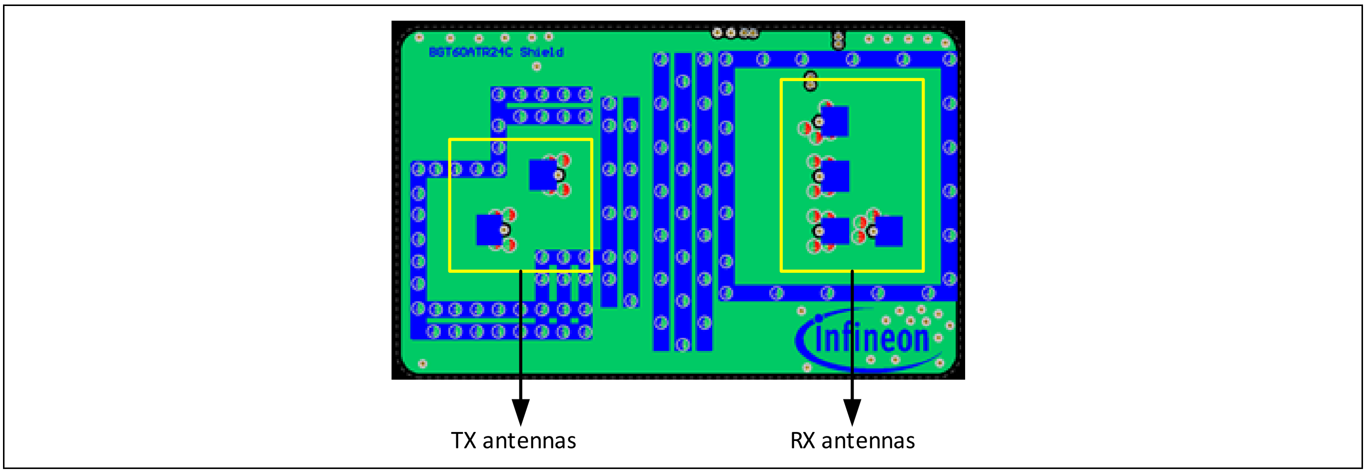


Figure 14 Bottom layer overview, antenna side

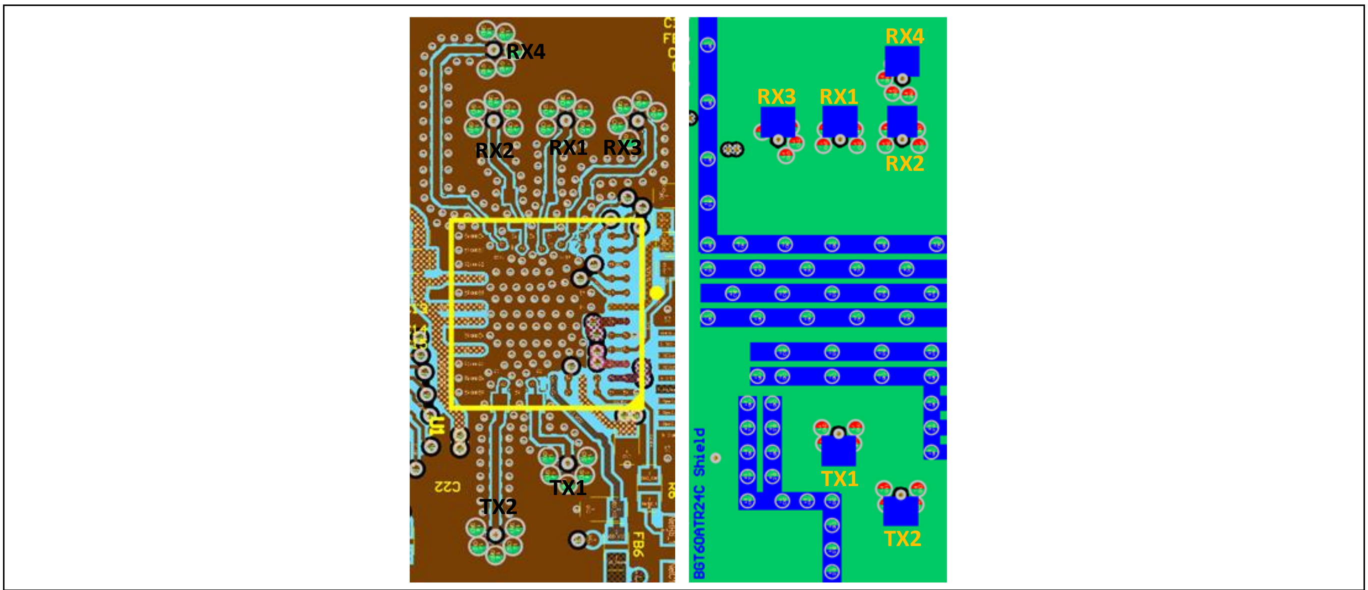


Figure 15 Antenna naming

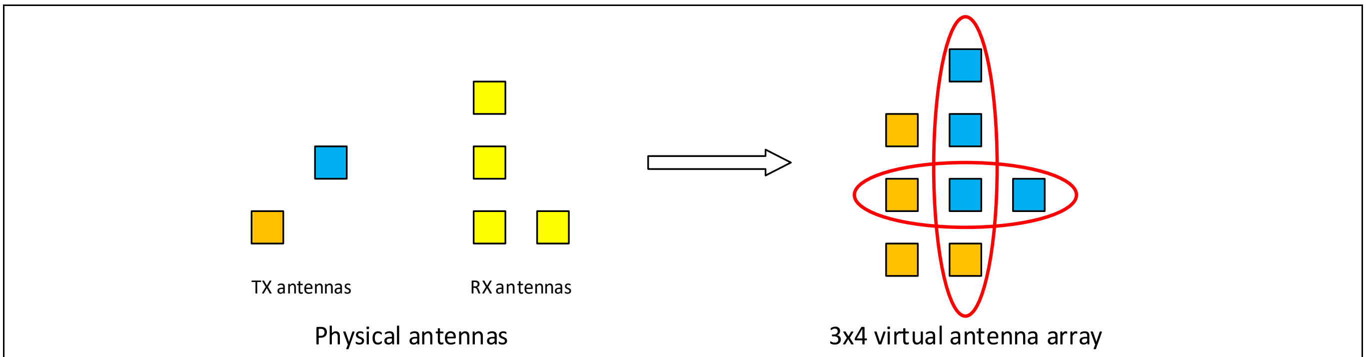


Figure 16 MIMO antenna array

5 TX and Rx channels

5.1 Phase relationship between RF channels

Due to BGT60ATR24C device's topology, the phase between single channels is partly shifted by 180°

5.1.1 TX outputs

The TX outputs have a phase difference of 180°, as shown in Figure 17.

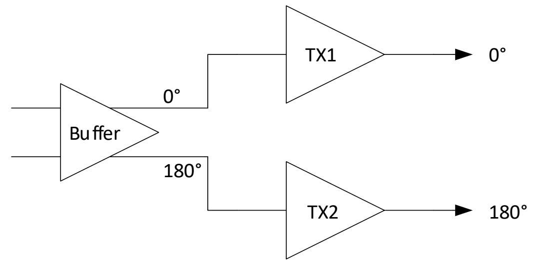


Figure 17 Phase relationship of TX outputs

5.1.2 RX channels

Due to the local oscillator (LO) distribution on the chip, single RX channels show a relative phase shift of 180° at the intermediate frequency (IF) side (Figure 18). In order to get phase correct results in signal processing, this phase shift needs to be compensated. This can be done either via hardware (by adding 180° phase on the RX side for the respective channels) or in software.

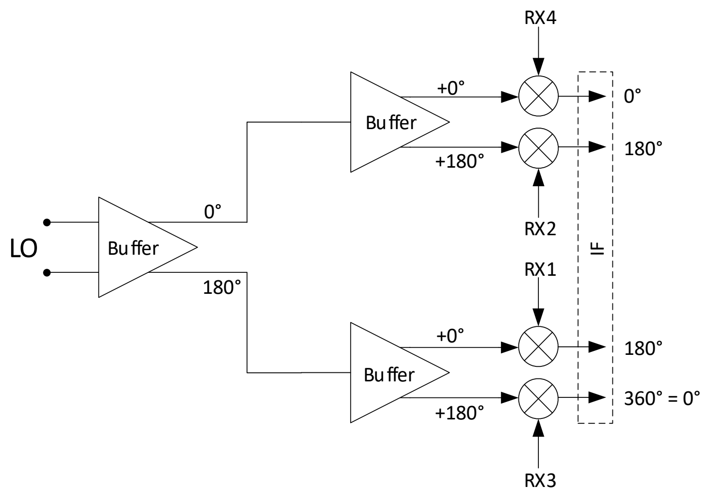


Figure 18 IF phase shift relative to LO signal

Table 3 Phase shift at IF outputs relative to LO

RX channel	Phase shift
RX1, RX2	180°
RX3, RX4	0°

6 Measurement results

6.1 Transmitter and receiver antenna matching

The antennas of this shield have been designed on a 0.4 mm Rogers RO4350B laminate substrate. This is a thicker substrate, when compared to the 0.127 mm thick substrate used for the top layer, it allows higher antenna bandwidths to be supported. All measurements include the feed-throughs from the top layer.

The achieved bandwidth here is over 4 GHz. The antennas' center frequency is shifted to higher frequencies but can be moved to the center of the BGT60ATR24C MMIC's frequency band by fine tuning.

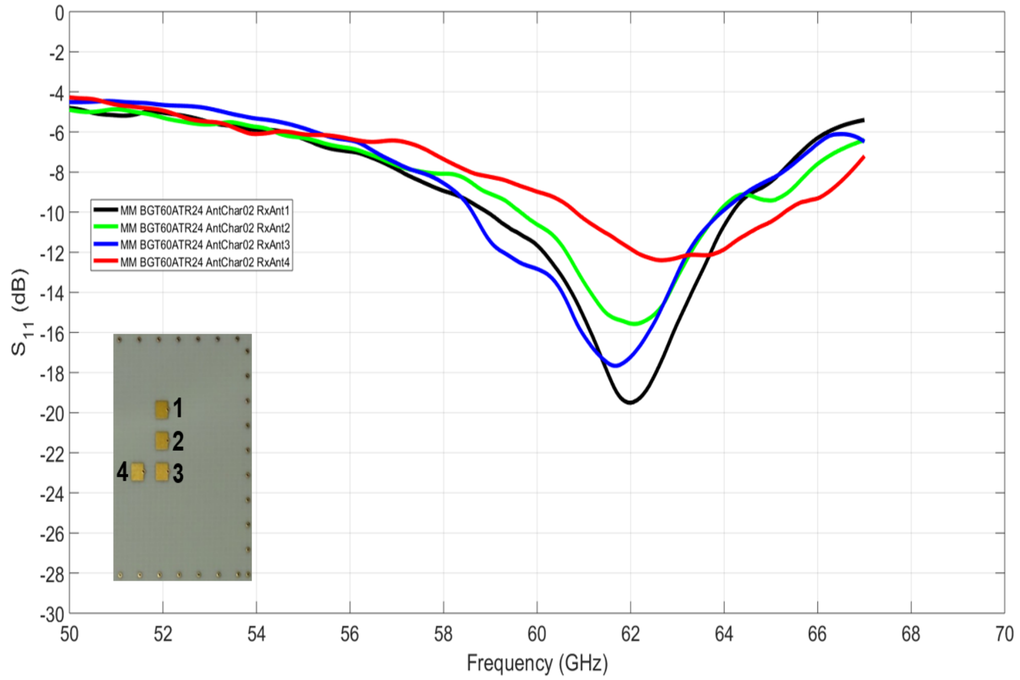


Figure 19 Measured RX antenna matching, including feed-throughs

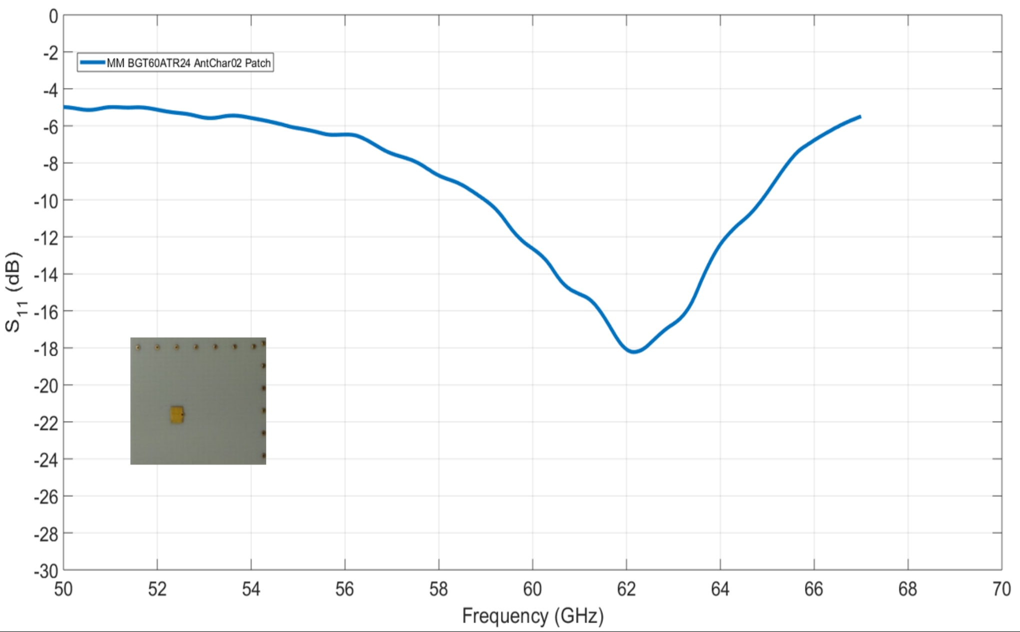


Figure 20 Measured TX antenna matching, including feed throughs

6.2 System radiation characteristics

The following graphs show the radiation characteristics of the complete board. The single TX channels have been used as signal sources. A corner reflector with 1 m^2 of radar cross section (RCS) has been used as a target. The single RX channels have been used as receivers. The RF shield was turned in 2° steps over the vertical and horizontal cut planes. Figure 21 shows the definition of these planes. Frequency-modulated continuous wave (FMCW) chirps of 500 MHz bandwidth were used as test signals. Start frequencies were changed in 500 MHz steps from 58 GHz to 62 GHz.

The received amplitudes were normalized to the peak value of the respective cut plane considering data from every RX channel.

The plots show that the system works well over the BGT60ATR24C MMIC's entire frequency range. The antennas will still need some fine tuning, especially RX2.

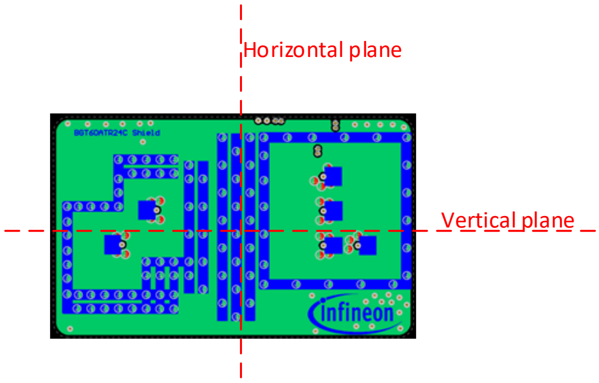


Figure 21 Horizontal and vertical cut planes

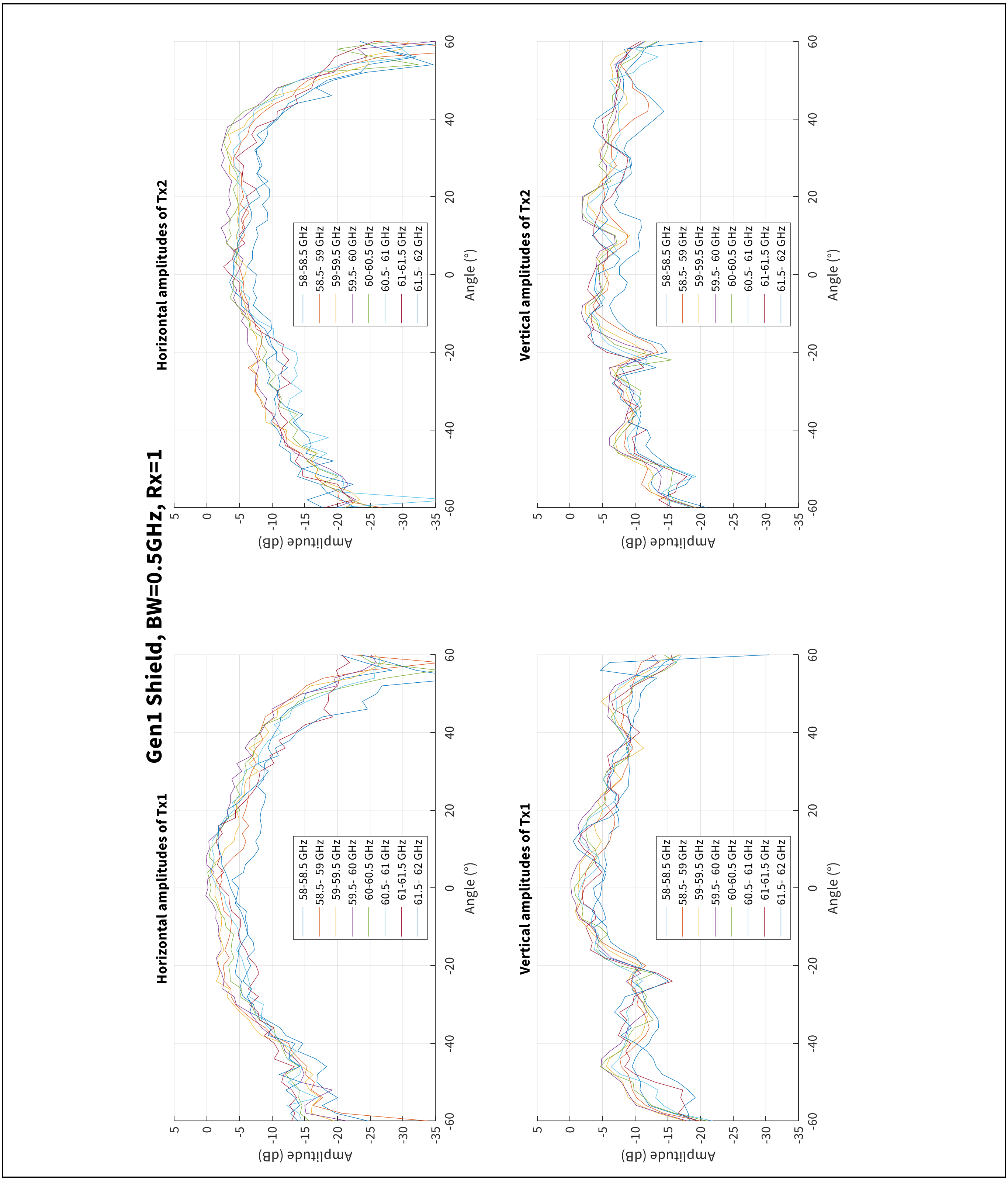


Figure 22 Amplitudes received by RX1 over angle, polarizations, transmitters, and frequency

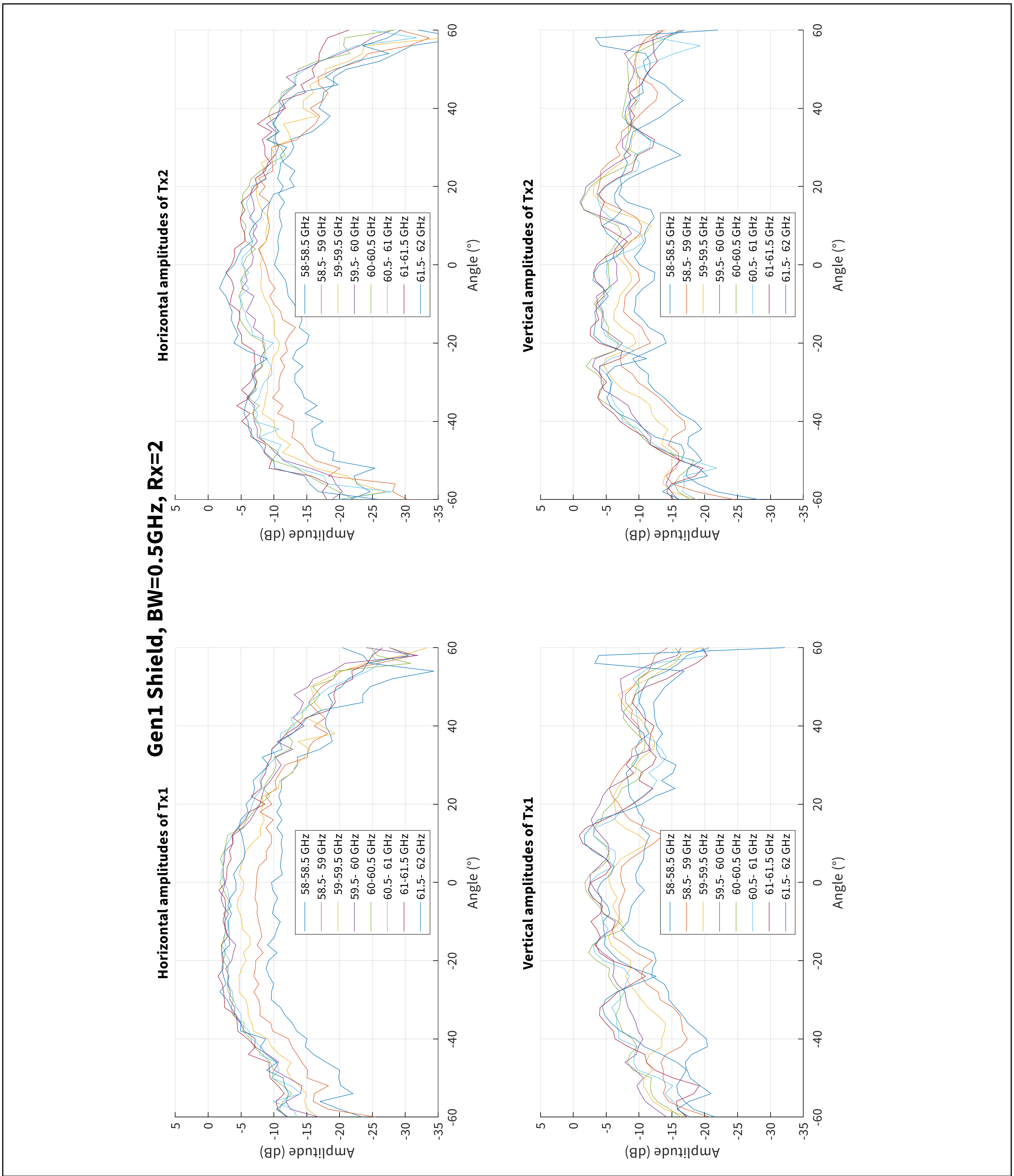


Figure 23 Amplitudes received by RX2 over angle, polarizations, transmitters, and frequency

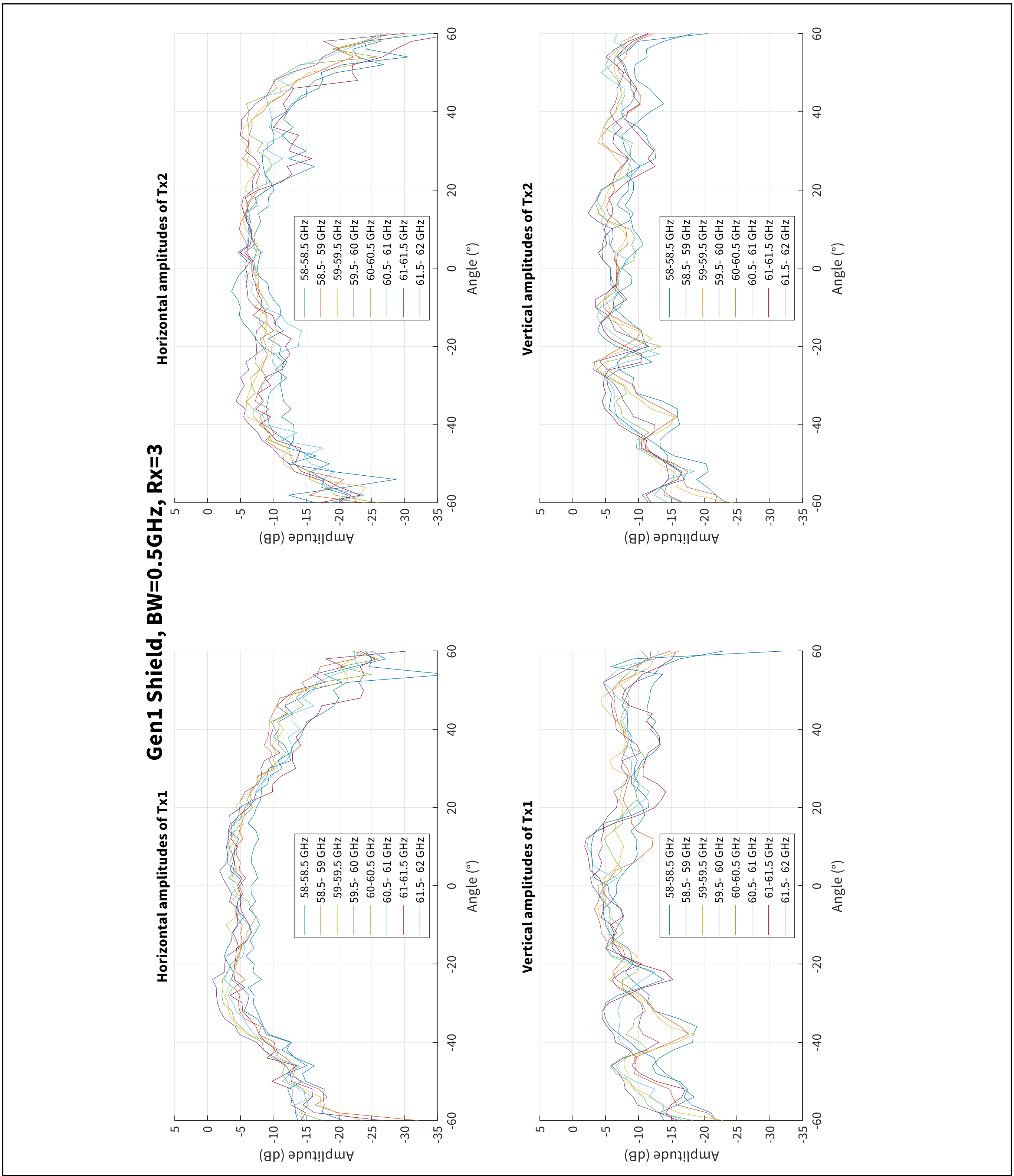


Figure 24 Amplitudes received by RX3 over angle, polarizations, transmitters, and frequency

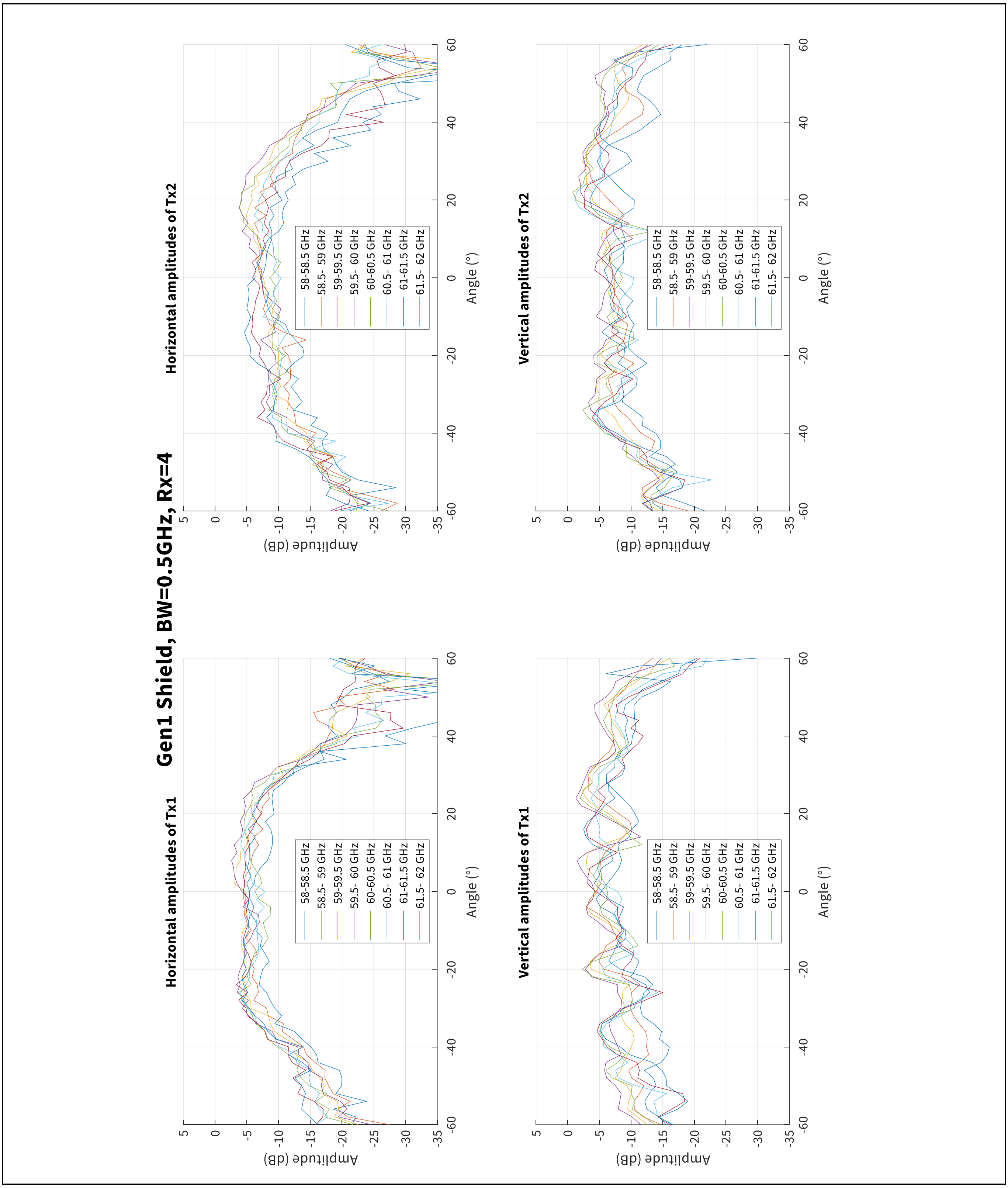


Figure 25 Amplitudes received by RX4 over angle, polarizations, transmitters, and frequency

References

[1] Infineon Technologies AG. AN599: Radar Baseboard MCU7

[2] Committee, E. C. (n.d.). ERC Recommendation. Retrieved 03 12, 2019, from https://www.ecodocdb.dk/download/25c41779-cd6e/Rec7003.pdf

[3] European Telecommunications Standards Institute. (n.d.). Retrieved 03 12, 2019, from https://www.etsi.org/

[4] Federal Communications Commission. (n.d.). Retrieved 03 12, 2019, from https://www.fcc.gov/

[5] Institute, E. T. (n.d.). EN 305 500. Retrieved 03 12, 2019, from https://www.etsi.org/deliver/etsi_en/305500_305599/305550/02.01.00_20/en_305550v020100a.pdf

[6] Regulations, E. C. (n.d.). §15.255. Retrieved 03 12, 2019, from https://www.ecfr.gov/cgi-bin/text-idx?SID=a484297320706bbafb187c022e7b3c0c&mc=true&node=se47.1.15_1255&rgn=div8

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1.10	2023-02-14	Miscellaneous document cleanup updates

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