User manual REF BGT60LTR11AIP

60 GHz pulsed Doppler Short Range Radar /Field Disturbing Sensor

About this document

Scope and purpose

This document briefly describes the function, circuitry, and performance of the 60 GHz autonomous reference design radar. The reference design provides the supporting circuitry to the on-board BGT60LTR11AIP monolithic microwave integrated circuit (SiP) Infineon's 60 GHz radar chipset with antenna-in-package (AIP). The board is fully functional in autonomous mode, for low cost and user-friendly applications.

1 Introduction

The BGT60LTR11AIP SiP is a fully integrated microwave motion sensor including Antenna in Package (AIP), built-in motion and direction of motion detectors.
The module „REF BGT60LTR11AIP" contains a NON RF section on FR4 carrier PCB and a RF section built by the mmW RF system in Package (SiP), where the BGT60LTR11 System on Chip (SoC) is extended by the package with mmW TX and RX antenna.
The RF section, based on the mmW "Short Range Radar" (SRR) SoC, called in FCC area often "Field disturbing sensor" (FDS). This SoC includes the entire mmW RF section with VCO, mixer, PA, freq control, the state machine for sequence control, crystal oscillator (w.o. crystal resonator) and the baseband signal processing...
The SoC is extended by the mmW TX and RX antenna on the top side of the package to become a full System in Package (SiP) solution.
In the non RF, section there are only some assisting components e.g. for clock generation (crystal resonator), LDO section, level shifter, hard coded QS pins to operate the autonomous working mode and Vcc filter elements.
The module is working without any external software.

This small-sized radar solution is a compelling, smart and cost-effective replacement for conventional passive infrared (PIR) sensors in low-power or battery-powered applications. The SiP is designed to operate as a Doppler motion sensor in the 60 GHz ISM-band. In order to save power, the Doppler radar is highly duty cycled (pulsed). RF on time can be restricted to e.g. 1%.

On this reference design, the SiP is working in autonomous mode, which can be selected via the QS1 pin. QS1 pin termination is fixed to act in the autonomous mode with internal signal processing to avoid the need of an external microcontroller.

Beside QS1, the SiP has three additional input pins (QS2-4) to control signal processing parameter (to tailor the performance to the application) in autonomous mode and to adjust the RF frequency inside the 61.0 - 61.5 band. These pins are used for configuration of the SiP as explained below.

In autonomous mode, the detection threshold (or sensitivity) is set via QS2 pin and has 15 different levels to select the targeted detection range from 0.5 m up to about 7 m for a typical human target Radar Cross-Section (RCS). The hold time is also configurable in 15 levels via QS3 pin, which allows detection status holding up to 30 minutes. The device operating frequency can be configured via QS4 pin and has 4 different possible frequencies between 61.1 and 61.4 GHz for BGT60LTR11AIP SiP. In this mode, the integrated detectors deliver digital output signals. One is indicating motion and the other one is indicating the direction of motion (approaching or departing) of a target.

2 Key features

The BGT60LTR11AIP autonomous reference design is optimized for fast prototyping designs and system integrations, as well as initial product feature evaluations. In addition, the sensor can be integrated into systems like laptops, tablets, TVs, speakers etc. to 'wake' them up based on detected motion (or direction of motion), put them to sleep or auto-lock the system when no motion is detected for a defined amount of time. Radar sensors offer the possibility to hide them inside the end product since they operate through non-metallic materials. Therefore, it enables a seamless integration of technology in our daily live.

Some key features of the BGT60LTR11AIP autonomous reference board are as follows:

- Form factor of 20 mm x 18 mm for the BGT60LTR11AIP autonomous reference design
- Features an AIP SiP of small size (6.7 mm x 3.3 mm x 0.56 mm), thereby eliminating antenna design complexity at the user end
- Detects motion and direction of movement (approaching or departing) for a human target
- Works standalone (autonomous mode)
- Quartz oscillator built on chip, only external quartz resonator required on the module.
  LDO on module (Vcc = VIN = 3V3)
- Configurable settings like operation mode, detector threshold, hold time, operating frequency via QS pins

2.1 Detection principle

In this autonomous mode operation, the SiP uses only internal detectors for motion (TD = Target Detect) and direction of motion (PD Phase Detect) indication. TD and PD output ports are available via castellation at the PCB edge. Furthermore the status of these pins are reported via LEDs.

2.2 Battery-powered operation

The Ref BGT60LTR11AIP autonomous reference board can operate independently with a battery that supplies to the VIN, and to the GND pin of the castellated holes or via other 2.7…4V power supply.
The Ref BGT60LTR11AIP module can be soldered on a carrier board with Vcc preprocessing for more input voltage flexibility and to get a input voltage of e.g. 3V3 V for the module itself.

2.3 Board layout and detection settings

The sensor configuration parameters are set via QS pins and external resistors. The BGT60LTR11AIP SiP has four quad-state inputs QS1-4. The default settings of these QS pins of the BGT60LTR11AIP autonoumous reference design are shown in figure 1, 2 and table 1, 2, 3.

2.4 Starting up the board

The BGT60LTR11 autonomous reference board can be used alone, or on the bigger carrier board.
For standalone use, a 3V3 power supply has to be connected to the 3V3 Vcc pad. For carrier board use, a Vcc of ~5-6V has to be connected to the 5V pin. The board is started up automatically in autonomous mode.

QS registers and other assisting registers are hard-coded in the design to select the pulsed autonomous mode (advanced level). More about the pulsed autonomous mode (advanced level) can be found in User´s guide to BGT60LTR11 AIP chapter 2 on Infineon Internet page.

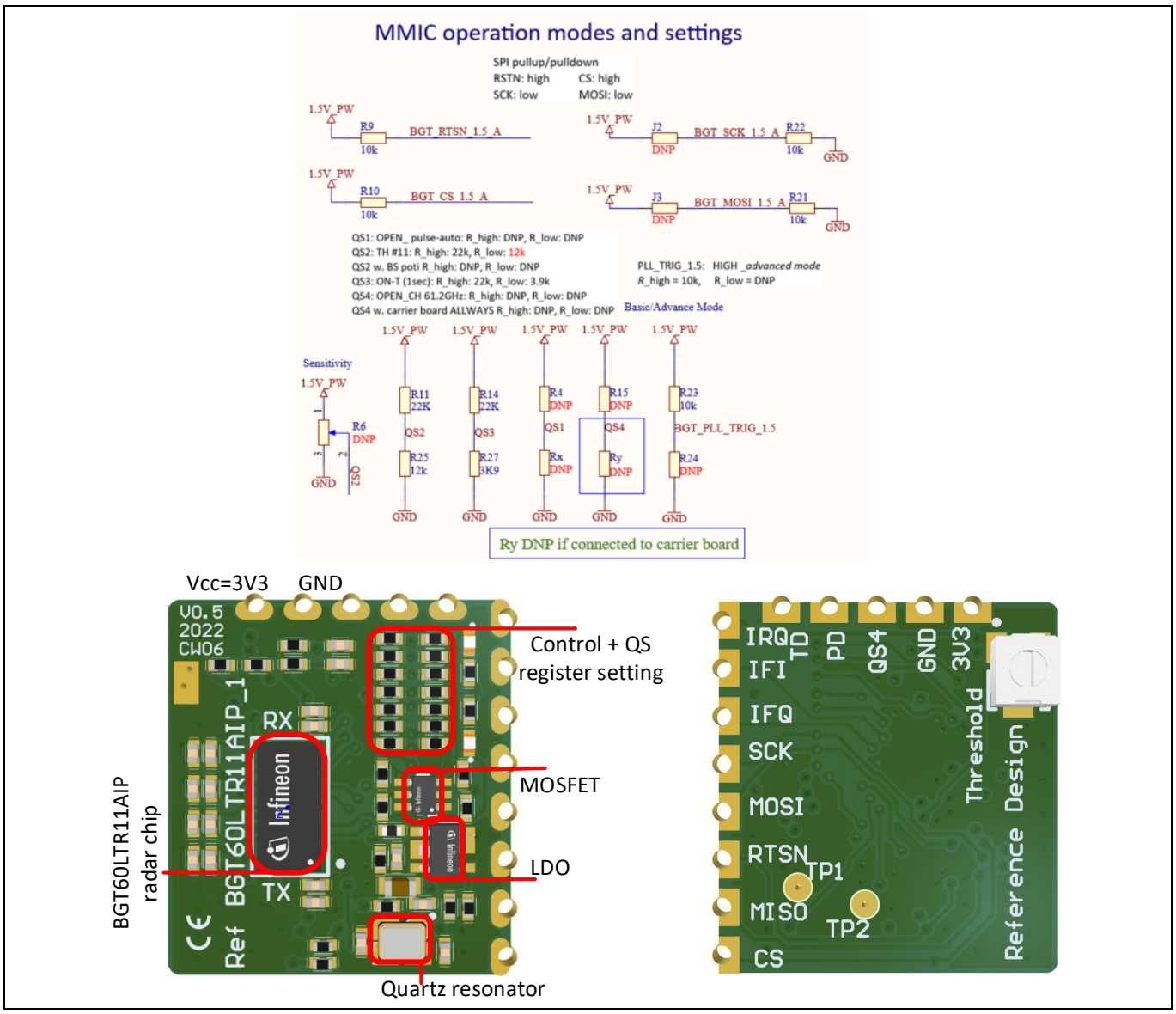

Figure 1 QS1 to QS4 schematic and layout connections

In following tables, the QS register programming resistors are called R_h (R_high) for the resistor between 1V5 Vcc and the mid point of the voltage divider (calls QSx) and R_l (R_low) for the resistor between the QSx node and GND.

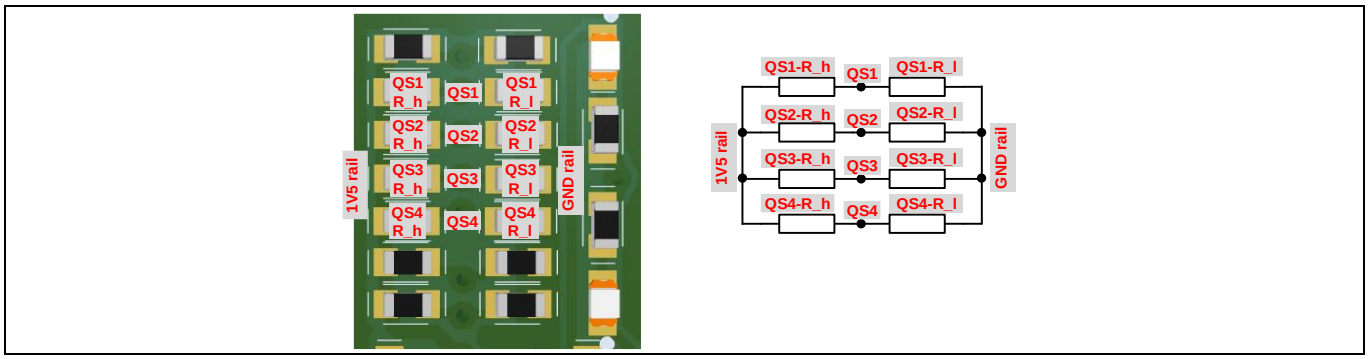

Figure 2 Placement of the QSx programming resistors

Key features

Table 1 QS1 settings

QS1	Operation mode of the SiP	PCB configuration	
ground	Autonomous (Continuous Wave) mode	R_low = 0 Ω	R_high = DNP*
Open (default)	Autonomous pulsed mode	R_low = DNP*	R_high = DNP*
100 kΩ to V_{DD}	SPI mode with external 9.6 MHz clock enabled	R_low = DNP*	R_high = 100 kΩ
V_{DD}	SPI mode	R_low = DNP*	R_high = 0 Ω

Table 2 QS4 settings

QS4	Device operating frequency	PCB configuration	
ground	61.1 GHz	R_low = 0 Ω	R_high = DNP*
Open (default)	61.2 GHz	R_low = DNP*	R_high = DNP*
100 kΩ to V_{DD}	61.3 GHz	R_low = DNP*	R_high = 100 kΩ
V_{DD}	61.4 GHz	R_low = DNP*	R_high = 0 Ω

DNP: Do Not Populate/Do Not Place

The default QS2 and QS3 setting on the board are set for detector threshold (good sensitivity, no false alarms) level 11 and level 13 for 1 second hold time. Table 3 shows the recommended resistor values for changing the QS2 and QS3 on the autonomous configuration of the board. Lower threshold means less range, but better immunity regarding false detections.

Table 3 Recommended resistor settings for QS2 (R_high, R_low) and QS3 (R_high, R_low)

Detector threshold (QS2)	Resistor setting	
	R_high	R_low
15 (highest)	Not supp.	Not supp
14	22 kΩ	2.2 kΩ
13	22 kΩ	3.9 kΩ
12	22 kΩ	5.6 kΩ
11	22 kΩ	8.2 kΩ
10 (default)	22 kΩ	12 kΩ
9	22 kΩ	15 kΩ
8	22 kΩ	18 kΩ
7	22 kΩ	27 kΩ
6	10 kΩ	15 kΩ
5	10 kΩ	18 kΩ
4	10 kΩ	27 kΩ
3	10 kΩ	39 kΩ
2	10 kΩ	47 kΩ
1	10 kΩ	100 kΩ
0 (lowest)	10 kΩ	270 kΩ

Hold time (QS3)	Resistor setting	
	R_high	R_low
100 ms	22 kΩ	680 Ω
500 ms	22 kΩ	2.2 kΩ
1 s (default)	22 kΩ	3.9 kΩ
2 s	22 kΩ	5.6 kΩ
3 s	22 kΩ	8.2 kΩ
5 s	22 kΩ	12 kΩ
10 s	22 kΩ	15 kΩ
30 s	22 kΩ	18 kΩ
45 s	10 kΩ	27 kΩ
1 min	10 kΩ	15 kΩ
90 s	10 kΩ	18 kΩ
2 min	10 kΩ	27 kΩ
5 min	10 kΩ	39 kΩ
10 min	10 kΩ	47 kΩ
15 min	10 kΩ	100 kΩ
30 min	10 kΩ	270 kΩ

2.5 Test modes and additional testing requirements

Autonomous (Continuous Wave) mode for testing without duty cycling can be selected via QS1 referring to table 1. The CW test mode is NOT the intended mode of use. This mode is only for test purpose.
The module enables the frequency toggling via QS4 pin. For details, refer to table 2.

2.6 Further information on BGT60LTR11AIP radar chip on the Infineon web.

BGT60LTR11 AIP chip entrance page

User´s guide to BGT60LTR11 AIP

2.7 Simulation results for the integrated patch antenna

To analyze the sensor radiation characteristics, the radiation pattern of the BGT60LTR11AIP autonomous reference design, is simulated along the H-plane and E-plane of the sensor. The realized gain of the transmitting antenna, in H-plane and E-plane at a frequency of 61 GHz, is shown at the left of the figure below. The antenna characteristics of the receiving antenna in H-plane and E-plane at a frequency of 61 GHz, is illustrated at the right of the figure below.

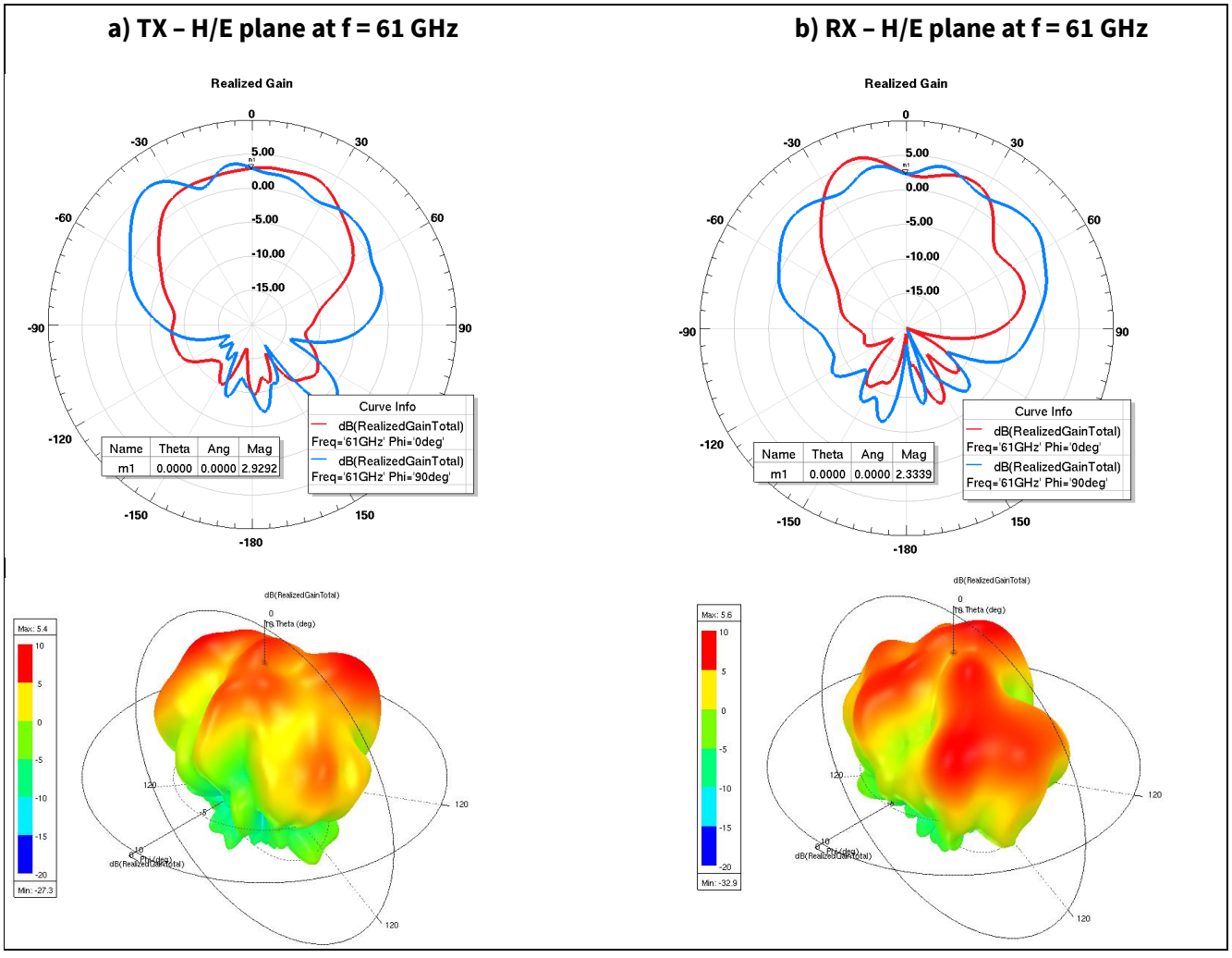

Figure 3 Radiation pattern simulations of the BGTL60TR11AIP autonomous reference design

2.7.1 Measurements results for the antenna pattern

• Hardware
Autonomous BGT60LTR11AIP Reference design, consisting of a BGT60LTR11AIP MMIC (which is configured by default in autonomous pulsed mode).

• Firmware
No firmware is needed for the autonomous reference design.

• Height
Board is placed at 1.2 m

• Scenario
Measure the max. detection range of a human target along the H-plane of the sensor, for different angles.

• Detection status
Is driven from the internal detector output (TDet). Figure 3 shows the measurement results in H-plane.

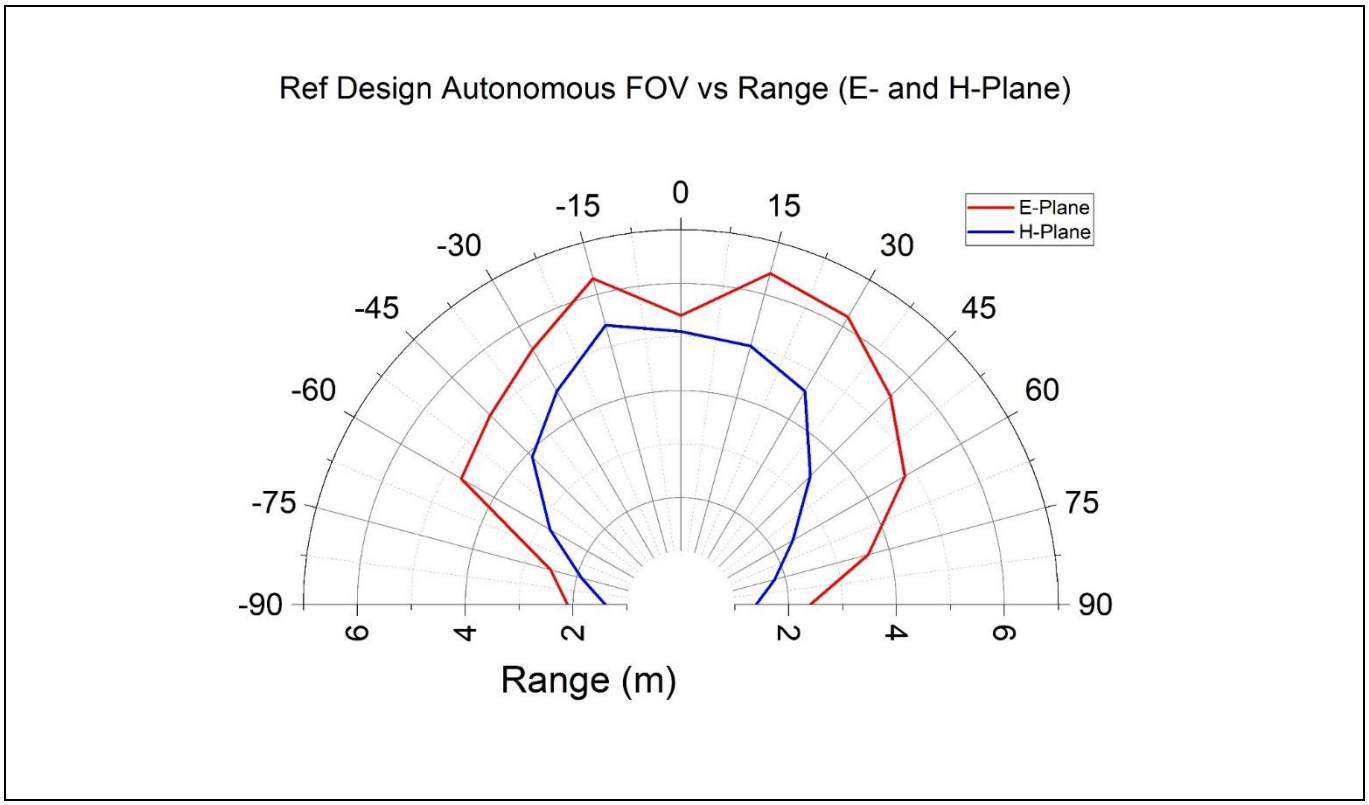

Figure 4 E/H-plane Human target detection area for BGT60LTR11AIP autonomous reference design

3 FCC / ISED considerations

The reference module has been certified at FCC according to the rules as stated below.

Host product manufacturers must immediately file a 2.933 Change-in-ID application to obtain their own FCC ID for the module, and then a C2P application to authorize the module in their specific host device(s).

Host product manufacturers are advised to carefully read this chapter 3 and follow the guidelines according to KDB 996369 D04, or the latest updates of it.

3.1 List of applicable FCC rules

The modular transmitter was tested according to the following rules:

- FCC Rules and Regulations Part 15, Subpart A – General (September 2019)
- Part 15, Subpart A, Section 15.31 Measurement standards
- FCC Rules and Regulations Part 15, Subpart C – Intentional Radiators (September 2019)
- Part 15, Subpart C, Section 15.203 Antenna requirements
- Part 15, Subpart C, Section 15.204 External radio frequency power amplifiers and antenna modifications
- Part 15, Subpart C, Section 15.205 Restricted bands of operation
- Part 15, Subpart C, Section 15.207 Conducted limits
- Part 15, Subpart C, Section 15.209 Radiated emission limits, general requirements
- Part 15, Subpart C, Section 15.255 Operation within the band 57 to 71 GHz.

The modular transmitter is **only** FCC authorized for the specific rule parts listed on the grant. The host product manufacturer is responsible for compliance with any other FCC rules that apply to the host not covered by the modular transmitter grant of certification.

3.2 Specific operational use conditions

- The module is classified for use in fixed equipment, refer to chapter 5.5.
- The module is FCC certified for the operating frequency range 61.0 to 61.5 GHz.
- There is NO software (SW) and firmware (FW) required. The module is running in autonomous mode, where all functions are implemented hard-coded on the silicon. RF section can not be modified, only 4 channels in the band 61.0-61.5MHz can be selected e.g. via jumper.

3.3 RF exposure considerations

- The performed human exposure evaluation is described in the *"Human exposure RF test report" No. : 80103696-02 Rev_0*
- The module is classified for use in fixed equipment.

The host product operating conditions must be such that there is a minimum separation distance of 20 cm (or possibly greater than 20 cm) between the module and nearby persons.

The host product manufacturer is required to provide the following text in its end user manual:
"In order to comply with FCC RF Exposure requirements, this device must be operated with a minimum separation distance of 20 cm between the equipment and a person's body."

3.4 Antennas / Trace antenna design

The antenna is integrated into the radar chip (on-chip antenna).
Type: Linear polarized strip patch array antenna; gain 5 dBi.
All measurements were performed radiated only. There is NO way to run a conducted measurement anyway.
NOT applicable - there are **NO antenna traces in the design**. Antenna are integrated on the mmW RF chip

3.5 Label and compliance information

The module does not have a FCC label attached on it because of missing space on the module.
To put the FCC ID, the IC number w.ith HIV into the user manual was approved by ISED.
The Module is approved according:
FCC ID: 2AYSQ60LTR11A1 and **IC: 28678-60LTR11A1 HVIN: Ref BGT60LTR11AIP_1**

The host product manufacturer is advised to provide a physical or e-label stating with the following information on it with following content with the finished product:
"Contains Transmitter Module **FCC ID: 2AYSQ60LTR11A1 IC: 28678-60LTR11A1**".
The manufacturer is advised to read "Guidelines for Labeling and User Information for RF Devices – KDB Publication 784748."
The label attached to the final product has to be visible from outside:

The label can look like (example in Arial bold 10 pt):

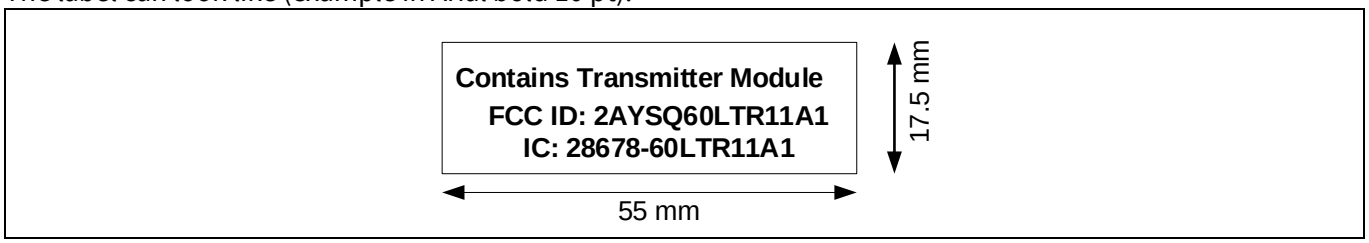

Figure 5 FCC ID label is mandatory to be placed on outside of customer´s end product enclosure on a location where it can be read easily.

3.6 Test modes and additional testing requirements

Refer to section **2.5** for the use of the test mode and the restriction of CW ode

3.7 Important notes

The host product manufacturer must provide the below text to the end-user:

Host product manufacturers must immediately file a 2.933 Change-in-ID application to obtain their own FCC ID for the module, and then a C2P application to authorize the module in their specific host device(s).

Host product manufacturers are advised to carefully read this chapter 3 and follow the guidelines according to KDB 996369 D04, or the latest updates of it.

Constrains according 47 CFR 15.255 :
(a) Operation under the provisions of this section is not permitted for the following products:

(1) Equipment used on satellites.

(2) Field disturbance sensors, including vehicle radar systems, unless the field disturbance sensors are employed for fixed operation, or used as short-range devices for interactive motion sensing. For the purposes of this section, the reference to fixed operation includes field disturbance sensors installed in fixed equipment, even if the sensor itself moves within the equipment.

(b Operation on aircraft is permitted under the following conditions:

(1) When the aircraft is on the ground.

(2) While airborne, only in closed exclusive on-board communication networks within the aircraft, with the following exceptions:

(i) Equipment shall not be used in wireless avionics intra-communication (WAIC) applications where external structural sensors or external cameras are mounted on the outside of the aircraft structure.

(ii) Equipment shall not be used on aircraft where there is little attenuation of RF signals by the body/fuselage of the aircraft. These aircraft include, but are not limited to, toy/model aircraft, unmanned aircraft, crop-spraying aircraft, aerostats, etc.

(h) Any transmitter that has received the necessary FCC equipment authorization under the rules of this chapter may be mounted in a group installation for simultaneous operation with one or more other transmitter(s) that have received the necessary FCC equipment authorization, without any additional equipment authorization. However, no transmitter operating under the provisions of this section may be equipped with external phase-locking inputs that permit beam-forming arrays to be realized.

(i) Measurement procedures that have been found to be acceptable to the Commission in accordance with § 2.947 of this chapter may be used to demonstrate compliance.

a) Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

b) This device complies with Part 15 of the FCC rules. Operation is subject to the following conditions:

- This device may not cause interference.
- This device must accept any interference, including interference that may cause undesired operation of the device.

FCC / ISED considerations

Constrains according RSS-GEN / 8.4

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s). Operation is subject to the following two conditions:
(1) This device may not cause interference
(2) This device must accept any interference, including interference that may cause undesired operation of the device.

Cet appareil contient des émetteurs / récepteurs exemptés de licence conformes aux RSS (RSS) d'Innovation, Sciences et Développement économique Canada. Le fonctionnement est soumis aux deux conditions suivantes:(1) Cet appareil ne doit pas causer d'interférences(2) Cet appareil doit accepter toutes les interférences, y compris celles susceptibles de provoquer un fonctionnement indésirable de l'appareil.

Constrains according RSS-210 Annex J:

(i) extends frequency bands from 57-64 GHz to 57-71 GHz
(ii) adds requirements for field disturbance sensors used as short-range devices for interactive motion sensing in the band 57-71 GHz
(iii) permits devices operating on aircraft under restricted conditions
Comment: The mentioned sensor is only working in the ISM band 61.0…61.5GHZ and occupies only maximum 500MHz bandwidth

4 Reference design

4.1 Integration of radar module into the host product to avoid interference

For integration of the Short-Range Radar device into the host application, it is important to ensure that the emissions from the host electronics are not inadvertently impacting the module and preventing proper operation. Conversely, the module emissions shall not prevent the rest of the host from operating properly. The complete host must still comply with applicable FCC regulations.

Therefore, a verification of the final product must be done, by at least spot-checking emissions from the device while operating the host as a complete system. This “module integrating” testing should be performed with the host product configured in typical operational modes to check the fundamental frequency and spurious emissions for compliance with all applicable rules.

To reduce the impact of the module on emissions, the host product manufacturer is advised to follow these guidelines:

Ensure that the maximum amount of the radar signal is indeed leaving the host device by ensuring that the signal is not unnecessarily reflected inside the host. See the Infineon “60 GHz radar radome design guide” for proper distances to housing surfaces and recommended housing materials.

Place the radar module inside the host as far away as technically feasible from other electronics that have been identified as susceptible to RF emissions, or identified to be a potential source of such emissions. Such potential sources include other intentional transmitters or digital electronics operating at MHz clock rates.

4.2 Integration of radar module to avoid distortion of antenna pattern

- The Short Range Radar Sensor (SRR sensor) must NOT be covered by any conducted material to avoid a blocking of transmitted and received mmW signal. A big break / cut out in conducting enclosure is mandatory. It is much better to avoid a conductive enclosure.
- The cover (non cond. and cond.) has to be in far field of the radar module. Far field starts in a distance of lambda/2 above the patch antennas. To be save we recommend a minimum distance of 1 x lambda between cover (w. appropriate cut out) and antenna structure. Optimal distance is N x lamda/2 to minimize unwanted reflections at the cover.
  For non conductive cover material showing a lower “er” causes less reflections and should be preferred. Lowest reflection in the non conductive material is given for a material thickness of lambda/2 in the material (= lambda @ air / SQRT “er”.
- Opening window especially for conductive cover material should be oversized to have an opening angle vs. the BGT60LTR11AIP chip edges of maximum -30°…+30° (minimum -60°…+60° vs. the vertical direction) to avoid a distortion of the antenna pattern.

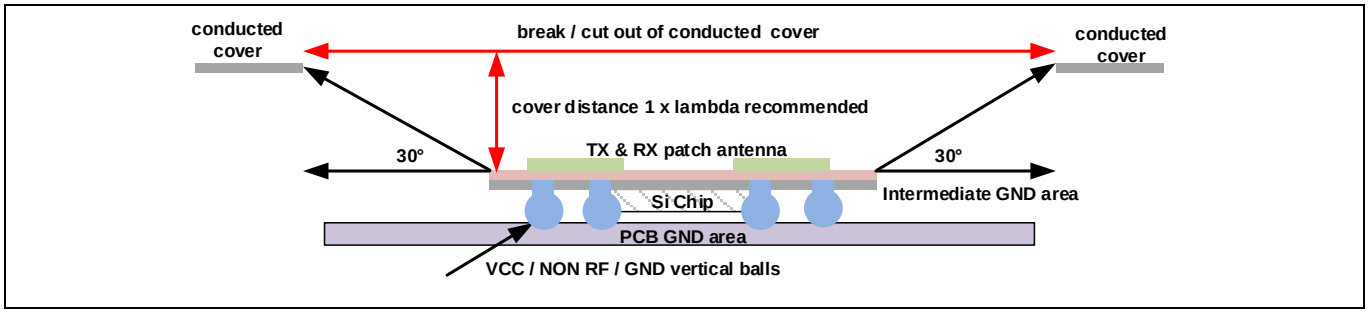

Figure 6 Defining the cut out area for the BGT60LTR11AIP chip.

4.3 Module information to place it on the customer´s main board

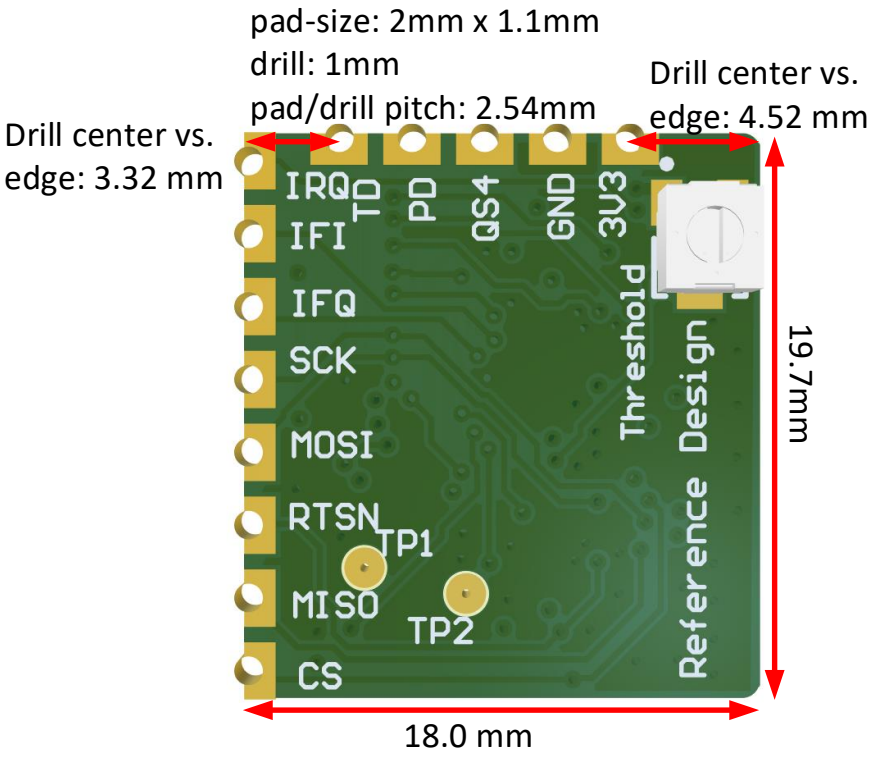

Figure 7 Module bottom side solder pads

5 Revision history

Document version	Date of release	Description of changes
V1.0	13.12.2022	1st release
V1.1	13.02.2023	Correction of minor errors

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