# FCS945R

# Hardware Design

**Wi-Fi&Bluetooth Module Series**

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# Safety Information

The following safety precautions must be observed during all phases of operation, such as usage, service or repair of any cellular terminal or mobile incorporating the module. Manufacturers of the cellular terminal should notify users and operating personnel of the following safety information by incorporating these guidelines into all manuals of the product. Otherwise, Quectel assumes no liability for customers' failure to comply with these precautions.

Full attention must be given to driving at all times in order to reduce the risk of an accident. Using a mobile while driving (even with a handsfree kit) causes distraction and can lead to an accident. Please comply with laws and regulations restricting the use of wireless devices while driving.

Switch off the cellular terminal or mobile before boarding an aircraft. The operation of wireless appliances in an aircraft is forbidden to prevent interference with communication systems. If there is an Airplane Mode, it should be enabled prior to boarding an aircraft. Please consult the airline staff for more restrictions on the use of wireless devices on an aircraft.

Wireless devices may cause interference on sensitive medical equipment, so please be aware of the restrictions on the use of wireless devices when in hospitals, clinics or other healthcare facilities.


Cellular terminals or mobiles operating over radio signal and cellular network cannot be guaranteed to connect in certain conditions, such as when the mobile bill is unpaid or the (U)SIM card is invalid. When emergency help is needed in such conditions, use emergency call if the device supports it. In order to make or receive a call, the cellular terminal or mobile must be switched on in a service area with adequate cellular signal strength. In an emergency, the device with emergency call function cannot be used as the only contact method considering network connection cannot be guaranteed under all circumstances.

The cellular terminal or mobile contains a transceiver. When it is ON, it receives and transmits radio frequency signals. RF interference can occur if it is used close to TV sets, radios, computers or other electric equipment.

In locations with explosive or potentially explosive atmospheres, obey all posted signs and turn off wireless devices such as mobile phone or other cellular terminals. Areas with explosive or potentially explosive atmospheres include fuelling areas, below decks on boats, fuel or chemical transfer or storage facilities, and areas where the air contains chemicals or particles such as grain, dust or metal powders.

# About the Document

## Revision History

| Version | Date | Author | Description |
|---|---|---|---|
| - | 2023-04-14 | Wain ZHAO | Creation of the document |
| 1.0.0 | 2023-04-14 | Wain ZHAO | Preliminary |

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# 1 Introduction

This document defines the FCS945R and describes its air interfaces and hardware interfaces which are connected with your applications. With this document, you can quickly understand module interface specifications, electrical and mechanical details, as well as other related information of the module.

## 1.1. Special Marks

**Table 1: Special Marks**

| Mark | Definition |
|---|---|
| * | Unless otherwise specified, when an asterisk (*) is used after a function, feature, interface, pin name, AT command, or argument, it indicates that the function, feature, interface, pin, AT command, or argument is under development and currently not supported; and the asterisk (*) after a model indicates that the sample of such model is currently unavailable. |
| […] | Brackets ([…]) used after a pin enclosing a range of numbers indicate all pins of the same type. For example, SDIO_DATA[0:3] refers to all four SDIO pins: SDIO_DATA0, SDIO_DATA1, SDIO_DATA2, and SDIO_DATA3. |

# 2 Product Overview

FCS945R is a small and high performance IEEE 802.11a/b/g/n Wi-Fi and Bluetooth 5.2 module which supports 1T1R. It provides a SDIO 2.0 interface for Wi-Fi functions and a UART and a PCM interface for Bluetooth functions.

Wi-Fi 1T1R has a theoretical throughput of up to 150 Mbps.

It is an SMD module with compact packaging. Related information is listed in the table below:

**Table 2: Basic Information**

| FCS945R | |
|---|---|
| Packaging type | LCC |
| Pin counts | 44 |
| Dimensions | (12.0 ±0.15) mm × (12.0 ±0.15) mm × (2.15 ±0.2) mm |
| Weight | 0.62g |
| Variants | FCS945R |

## 2.1. Key Features

**Table 3: Key Features**

| | |
|---|---|
| **Basic Information** | |
| Protocol and Standard | ● Wi-Fi protocols: IEEE 802.11 a/b/g/n<br>● Bluetooth protocol: Bluetooth 5.2<br>● All hardware components are fully compliant with EU RoHS directive |
| Power Supply | **VBAT Power Supply:**<br>● 3.0–3.6 V<br>● Typ.: 3.3 V<br>**VDD_IO Power Supply:**<br>● 1.62–3.6 V<br>● Typ.: 1.8/3.3 V |
| Temperature Ranges | ● Operating temperature [1] : 0 °C to +70 °C<br>● Storage temperature: -40 °C to +85 °C |
| EVB Kit | FCS945R-M.2 |
| **RF Antenna Interface** | |
| Wi-Fi/Bluetooth antenna interface | ● ANT_WIFI/BT<br>● 50 Ω characteristic impedance |
| **Application Interface** | |
| Wi-Fi Application Interface | SDIO 2.0 |
| Bluetooth Application Interfaces | ● UART<br>● PCM |

[1] To meet the normal operating temperature range requirements, it is necessary to ensure effective thermal dissipation, e.g., by adding passive or active heatsinks, heat pipes, vapor chambers, etc. Within this range, the module's indicators comply with IEEE and Bluetooth specification requirements.

## 2.2. Functional Diagram

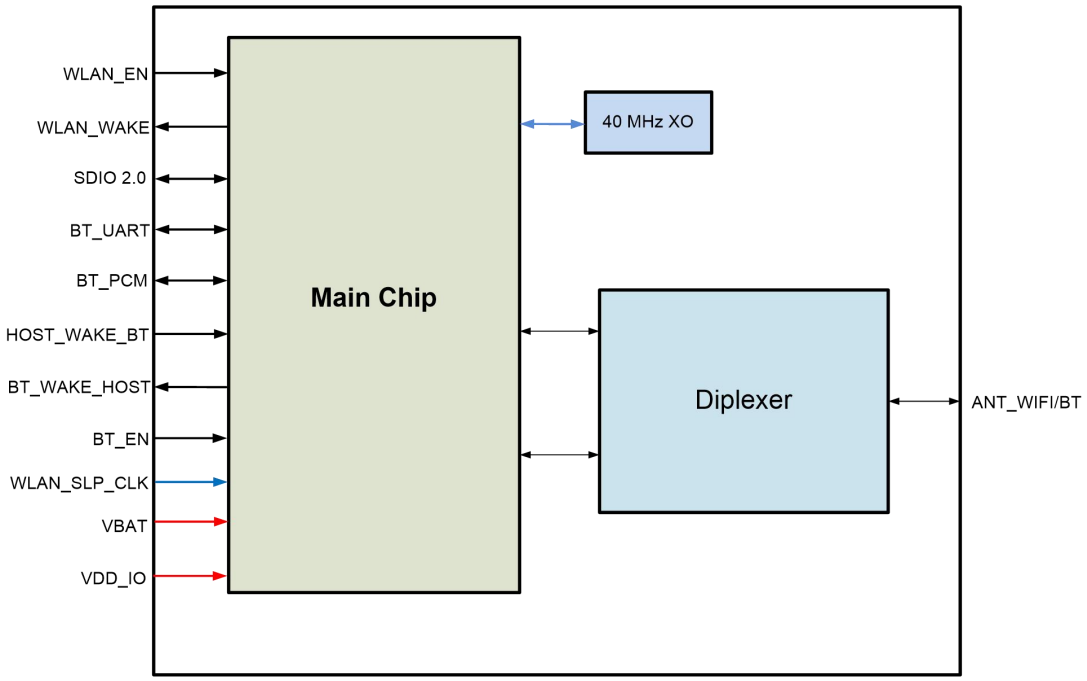



**Figure 1: FCS945R Functional Diagram**

# 3 RF Performances

## 3.1. Wi-Fi Performances

**Table 4: Wi-Fi Performances**

| **Operating Frequency** | | | | |
|---|---|---|---|---|
| **2.4 GHz:** 2.400–2.4835 GHz<br>**5 GHz:** 5.150–5.850 GHz | | | | |
| **Modulation** | | | | |
| CCK, BPSK, QPSK, DQPSK, 16QAM, 64QAM | | | | |
| **Operating Mode** | | | | |
| ● AP<br>● STA | | | | |
| **Transmission Data Rate** | | | | |
| ● 802.11b: 1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps<br>● 802.11a/g: 6 Mbps, 9 Mbps, 12 Mbps, 18 Mbps, 24 Mbps, 36 Mbps, 48 Mbps, 54 Mbps<br>● 802.11n: HT20 (MCS 0–7), HT40 (MCS 0–7) | | | | |
| **Condition** | | **EVM** | **Unit: dBm, Tolerance: ±2 dB** | |
| | | | **Transmitting Power @ Typ.** | **Receiving Sensitivity @ Typ.** |
| 2.4 GHz | 802.11b @ 1 Mbps | ≤ 35% | 18 | -94 |
| | 802.11b @ 11 Mbps | | 18 | -87 |
| | 802.11g @ 6 Mbps | ≤ -5 dB | 18 | -91 |
| | 802.11g @ 54 Mbps | ≤ -25 dB | 17 | -73 |
| | 802.11n, HT20 @ MCS 0 | ≤ -5 dB | 17 | -91 |
| | 802.11n, HT20 @ MCS 7 | ≤ -27 dB | 16 | -71 |
| | 802.11n, HT40 @ MCS 0 | ≤ -5 dB | 17 | -90 |

| | | | | |
|---|---|---|---|---|
| | 802.11n, HT40 @ MCS 7 | ≤ -27 dB | 16 | -70 |
| 5 GHz | 802.11a @ 6 Mbps | ≤ -15 dB | 18 | -90 |
| | 802.11a @ 54 Mbps | ≤ -25 dB | 17 | -72 |
| | 802.11n, HT20 @ MCS 0 | ≤ -15 dB | 17 | -90 |
| | 802.11n, HT20 @ MCS 7 | ≤ -28 dB | 16 | -71 |
| | 802.11n, HT40 @ MCS 0 | ≤ -15 dB | 17 | -87 |
| | 802.11n, HT40 @ MCS 7 | ≤ -28 dB | 16 | -68 |

## 3.2. Bluetooth Performances

**Table 5: Bluetooth Performances**

| **Operating Frequency** | | |
|---|---|---|
| 2.400–2.4835 GHz | | |
| **Modulation** | | |
| GFSK, π/4-DQPSK, 8-DPSK | | |
| **Operating Mode** | | |
| ● Classic Bluetooth (BR + EDR)<br>● Bluetooth Low Energy (BLE) | | |
| **Condition** | **Unit: dBm, Tolerance: ±2dB** | |
| | **Transmitting Power @ Typ.** | **Receiving Sensitivity @ Typ.** |
| BR | 5 | -93 |
| EDR (π/4-DQPSK) | 5 | -87 |
| EDR (8-DPSK) | 5 | -87 |
| BLE (1 Mbps) | 5 | -99 |
| BLE (2 Mbps) | 5 | -96 |
| BLE (S=2) | 5 | -102 |
| BLE (S=8) | 5 | -105 |

# 4 Application Interfaces

## 4.1. Pin Assignment

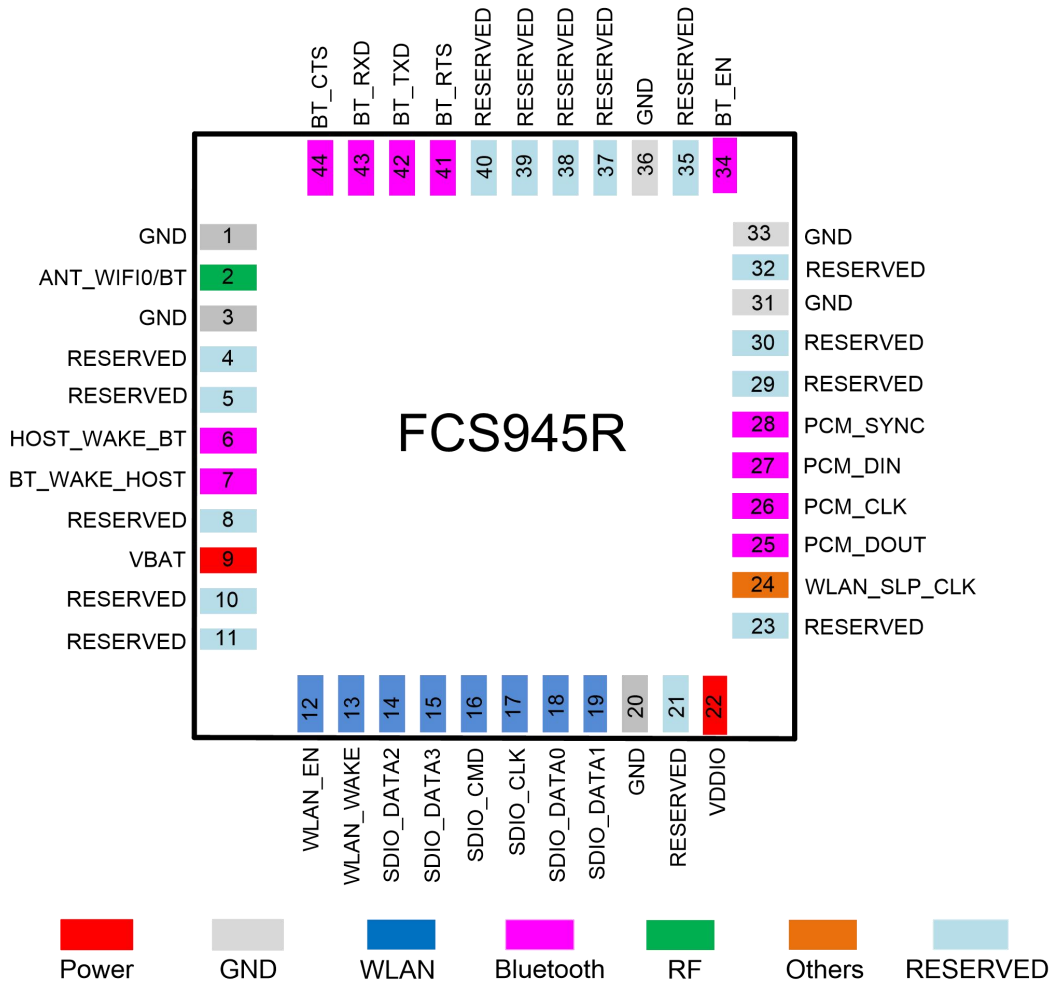



**Figure 2: Pin Assignment (Top View)**

**NOTE**

1. Keep all RESERVED and unused pins unconnected.
2. Keep all GND pins connected to the ground.

## 4.2. Pin Description

**Table 6: I/O Parameters Definition**

| Type | Description |
|---|---|
| AIO | Analog Input/Output |
| DI | Digital Input |
| DO | Digital Output |
| DIO | Digital Input/Output |
| PI | Power Input |

DC characteristics include power domain and rate current.

**Table 7: Pin Description**

| **Power Supply** | | | | | |
|---|---|---|---|---|---|
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| VBAT | 9 | PI | Power supply for the module | Vmin = 3.0 V<br>Vnom = 3.3 V<br>Vmax = 3.6 V | It must be provided with sufficient current up to 0.6 A. |
| VDD_IO | 22 | PI | Power supply for the module's I/O pins | Vmin = 1.62 V<br>Vnom = 1.8/3.3 V<br>Vmax = 3.6 V | It must be provided with sufficient current up to 0.1 A. |
| GND | 1, 3, 20, 31, 33, 36 | | | | |
| **Wi-Fi Application Interfaces** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| WLAN_EN | 12 | DI | WLAN enable control | 3.3 V | Active high. |
| WLAN_WAKE | 13 | DO | WLAN wakes up host | VDD_IO | |
| SDIO_DATA2 | 14 | DIO | SDIO data bit 2 | | |
| SDIO_DATA3 | 15 | DIO | SDIO data bit 3 | | |

| | | | | | |
|---|---|---|---|---|---|
| SDIO_CMD | 16 | DIO | SDIO command | | |
| SDIO_CLK | 17 | DI | SDIO clock | | |
| SDIO_DATA0 | 18 | DIO | SDIO data bit 0 | | |
| SDIO_DATA1 | 19 | DIO | SDIO data bit 1 | | |
| **Bluetooth Application Interfaces** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| BT_EN | 34 | DI | Bluetooth enable control | 3.3 V | Active high. |
| HOST_WAKE_BT | 6 | DI | Host wakes up Bluetooth | VDD_IO | If unused, keep them open. |
| BT_WAKE_HOST | 7 | DO | Bluetooth wakes up host | | |
| PCM_DOUT | 25 | DO | PCM data output | | |
| PCM_CLK | 26 | DI | PCM clock | | |
| PCM_DIN | 27 | DI | PCM data input | | |
| PCM_SYNC | 28 | DI | PCM data frame sync | | |
| BT_RTS | 41 | DO | Request to send signal from the module | | Internally connected to GND. |
| BT_TXD | 42 | DO | Bluetooth UART transmit | VDD_IO | If unused, keep them open. |
| BT_RXD | 43 | DI | Bluetooth UART receive | | |
| BT_CTS | 44 | DI | Clear to send signal to the module | | |
| **RF Antenna Interfaces** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| ANT_WIFI0/BT | 2 | AIO | Wi-Fi/Bluetooth antenna interface | | 50 Ω characteristic impedance. |
| **Other Interface** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| WLAN_SLP_CLK | 24 | DI | WLAN sleep clock | VDD_IO | 32.768 kHz sleep clock input. |

| | | |
|---|---|---|
| | | If unused, keep it open. |
| **RESERVED Pins** | | |
| **Pin Name** | **Pin No.** | **Comment** |
| RESERVED | 4, 5, 8, 10, 11, 21, 23, 29, 30, 32, 35, 37–40 | Keep them open. |

## 4.3. Power Supply

The module is powered by VBAT. It is recommended to use a 3.3 V power supply chip with sufficient up to 0.6 A. For better power supply performance, it is recommended to parallel a 100 µF decoupling capacitor, and 1 µF and 100 nF filter capacitors near the module's VBAT pin. In addition, it is recommended to add a TVS near the VBAT to improve the surge voltage bearing capacity of the module. In principle, the longer the VBAT trace is, the wider it should be.

VBAT reference circuit is shown below:

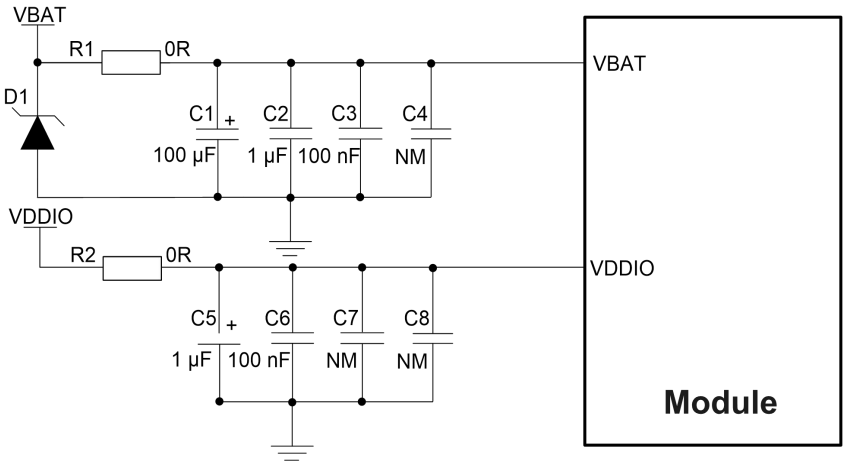



**Figure 3: Reference Circuit of Power Supply**

The power-up timing of the module is shown below.

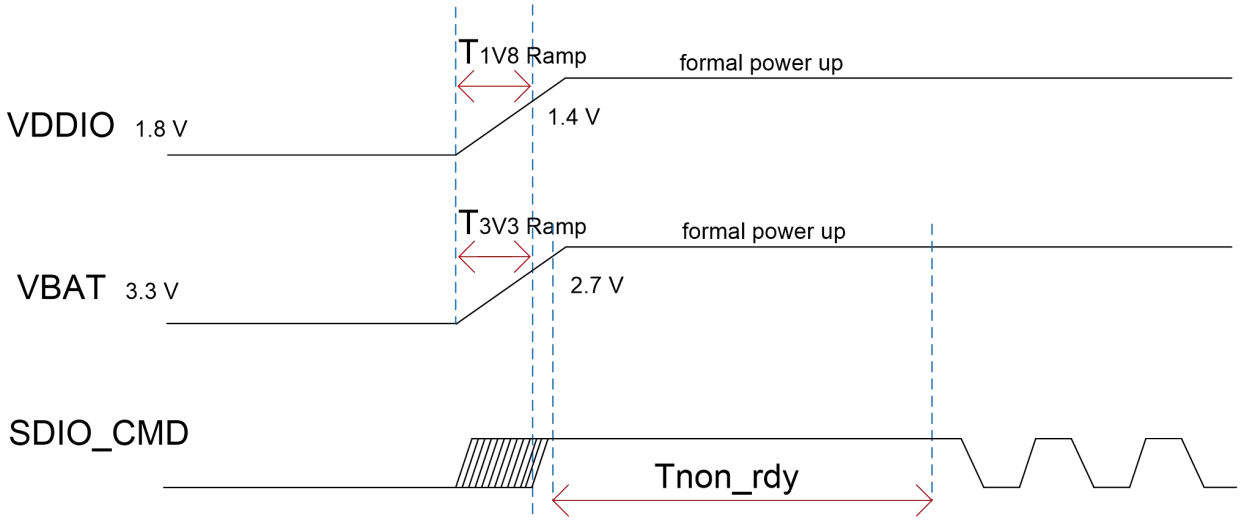



**Figure 4: Power-up Timing**

**NOTE**

Keep PCM_DIN at low level during the module power-up.

**Table 8:Power-on Timing Parameters**

| Parameter | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|
| T3V3 ramp | 0.2 | 0.5 | 2.5 | ms |
| T1V8 ramp | 0.2 | 0.5 | 2.5 | |
| Tnon-rdy | 1 | 2 | 10 | |

## 4.4. Wi-Fi Application Interface

Wi-Fi application interface connection between the module and the host is illustrated in the figure below.

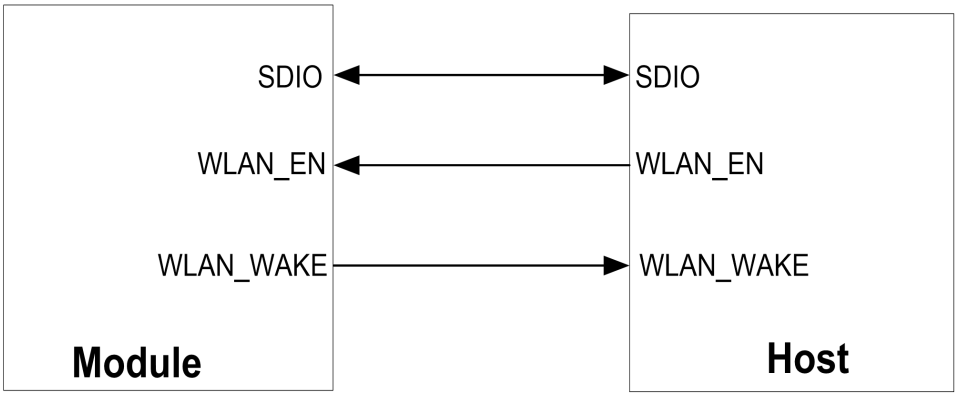



**Figure 5: Wi-Fi Application Interface Connection**

### 4.4.1. SDIO Interface

SDIO interface connection between the module and the host is illustrated in the following figure.

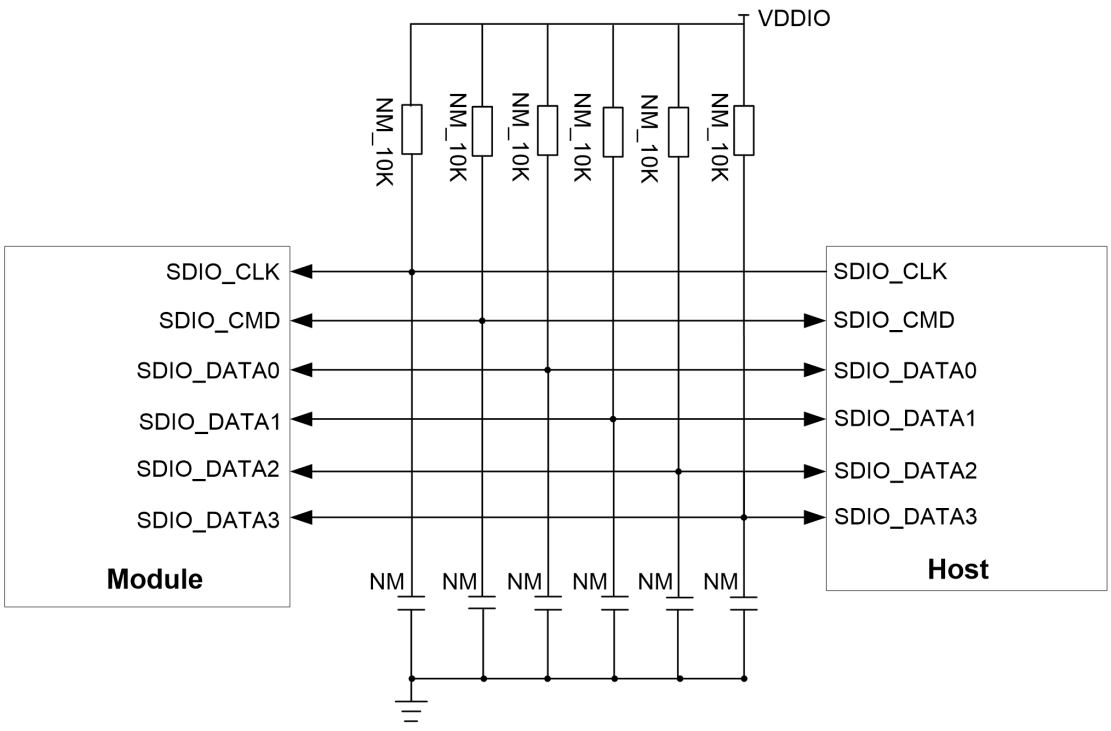



**Figure 6: SDIO Interface Connection**

To ensure compliance of interface design with the SDIO 2.0 specification, it is recommended to adopt the following principles:

- To avoid jitter of bus, pull up SDIO_CMD and SDIO_DATA_[0:3]/SDIO_CMD to VDD_IO with resistors respectively. Value range of these resistors should be 10–100 kΩ and the recommended value is 10 kΩ.
- The impedance of SDIO signal trace is 50 Ω ±10 %. Route the SDIO traces in inner layer of the PCB, and surround the traces with ground on that layer and with ground planes above and below.
- Keep SDIO signals far away from other sensitive circuits/signals such as RF circuits and analog signals, as well as noise signals such as clock signals and DC-DC signals.
- SDIO signal traces (SDIO_CLK and SDIO_DATA[0:3]/SDIO_CMD) need to be equal in length (the distance between the traces should be less than 1 mm).
- The distance between SDIO signals and other signals must be greater than twice the trace width, and the bus load capacitance must be less than 15 pF.

## 4.5. Bluetooth Application Interfaces

Bluetooth application interface connection between the module and the host is illustrated in the figure below.

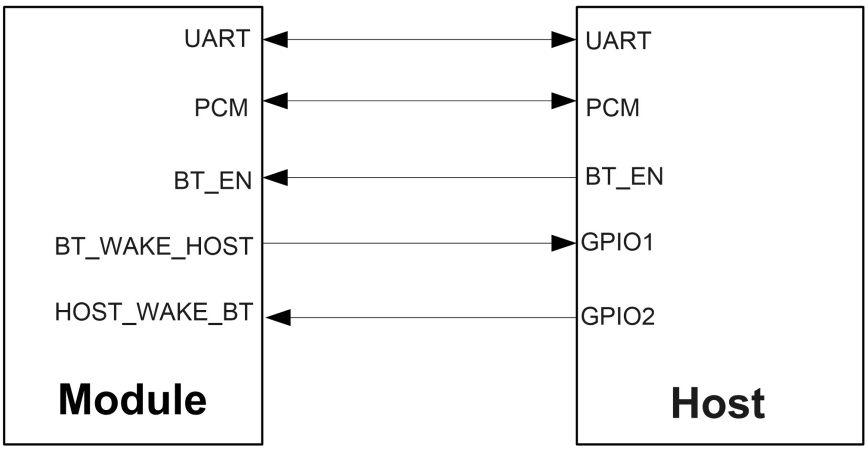



Figure 7: Bluetooth Application Interface Connection

### 4.5.1. PCM Interface

The module provides a PCM interface for Bluetooth audio application. It supports the following features:

- Supports Master and Slave mode
- Programmable long/short Frame Sync
- Supports 8-bit/16-bit linear PCM formats
- PCM Master Clock Output: 64 kHz, 128 kHz, 256 kHz, or 512 kHz
- Supports SCO/eSCO link

PCM interface timing is shown below:

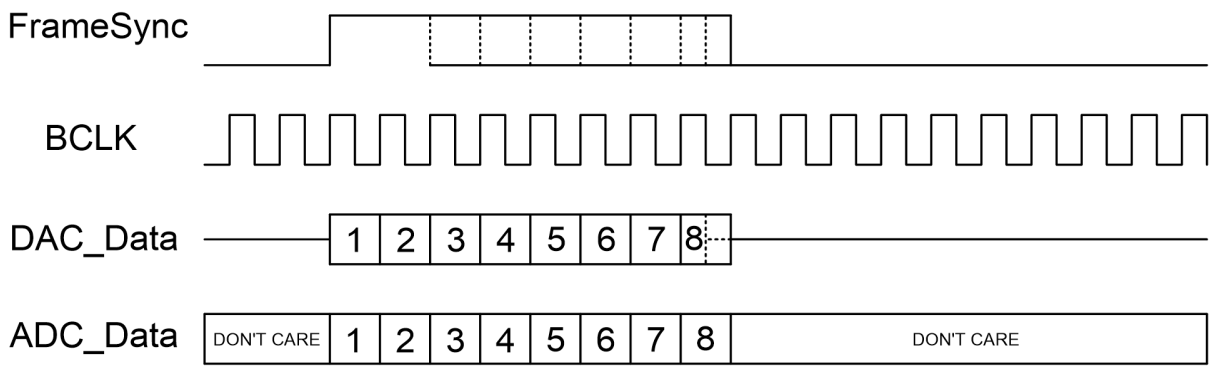



**Figure 8: PCM Interface (Long Frame Sync)**

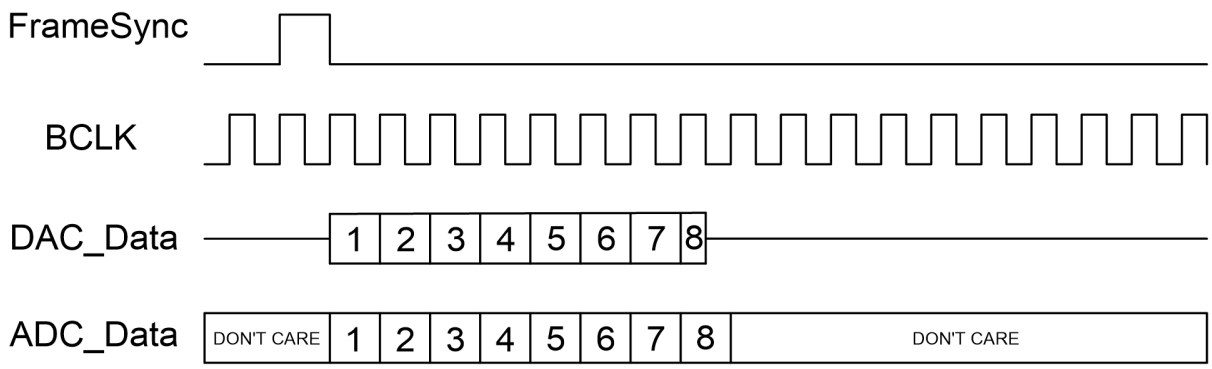



**Figure 9: PCM Interface (Short Frame Sync)**

**NOTE**

Keep PCM_DIN at low level during the module power-up.

### 4.5.2. UART

The Module supports Bluetooth HCI (Host Controller Interface) UART defined in *Bluetooth Core Specification Version 5.2*. It supports hardware flow control, and can be used for data transmission with the host.

Pin definitions of the UART interface is shown in the following table

The voltage range of the Bluetooth UART is determined by VDD_IO. It is necessary to monitor the consistency of the voltage range of the host and Bluetooth UART. If necessary, adopt a voltage-level translator.

The UART connection between the module and the host supporting hardware flow control is as below:

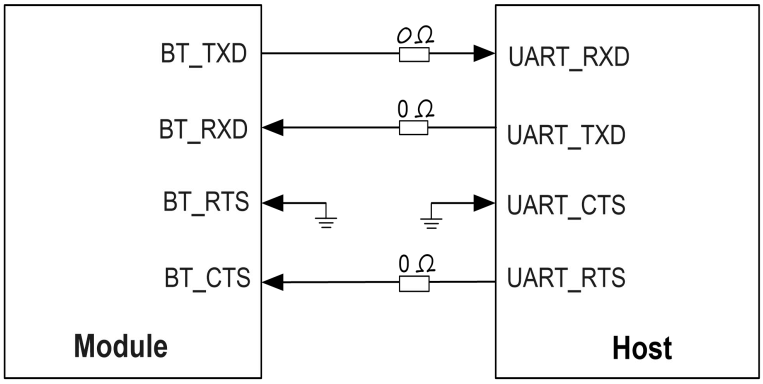



**Figure 10: UART Connection with Host Supporting Hardware Flow Control**

The UART connection between the module and the host not supporting hardware flow control is as below:

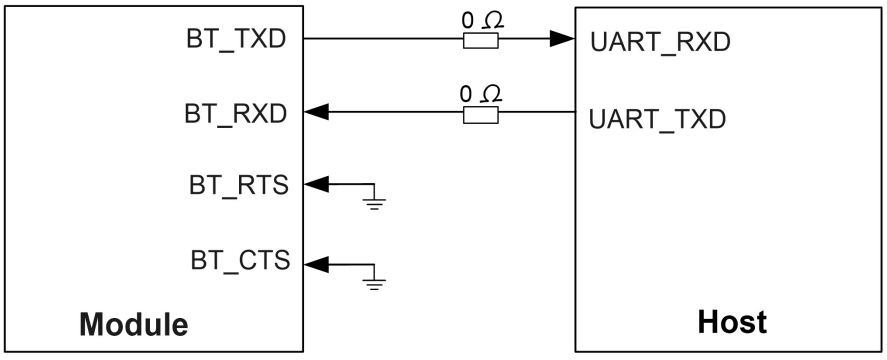



**Figure 11: UART Connection with Host Not Supporting Hardware Flow Control**

## 4.6. RF Antenna Interface

Appropriate antenna type and design should be used with matched antenna parameters according to specific application. It is required to perform a comprehensive functional test for the RF design before mass production of terminal products. The entire content of this chapter is provided for illustration only. Analysis, evaluation and determination are still necessary when designing target products.

For single-antenna module, ANT_ BT is unconnected.

### 4.6.1. Antenna Design Requirements

**Table 9: Antenna Design Requirements**

| Parameter | Requirement [2] |
|---|---|
| Frequency Ranges (GHz) | ● 2.400–2.4835<br>● 5.150–5.850 |
| Cable Insertion Loss (dB) | < 1 |
| VSWR | ≤ 2 (Typ.) |
| Gain (dBi) | 1 (Typ.) |
| Max Input Power (W) | 50 |
| Input Impedance (Ω) | 50 |
| Polarization Type | Vertical |

### 4.6.2. Reference Design

A reference circuit for the RF antenna interface is shown below. It is recommended to reserve a π-type matching circuit and add ESD protection components for better RF performance. Reserved matching components (R1, C1, C2, and D1) shall be placed as close to the antenna as possible. C1, C2 and D1 are not mounted by default. The parasitic capacitance of TVS should be less than 0.05 pF and R1 is recommended to be 0 Ω.

The following reference design is based on ANT_WIFI0/BT as an example, the reference design of other RF antenna interfaces is the same.

[2] For more details about the RF performances, see ***Chapter 3***.

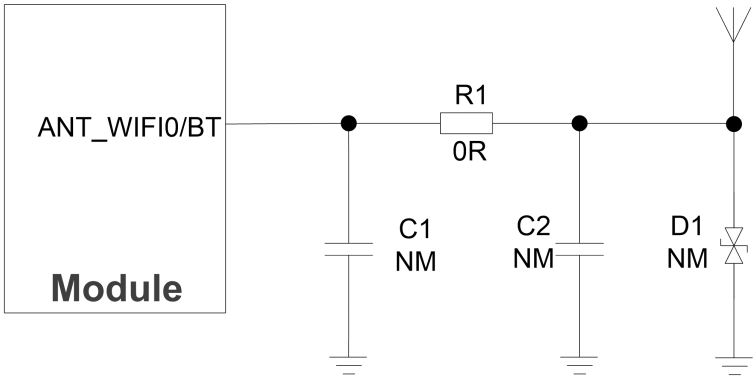



**Figure 12: Reference Circuit for RF Antenna Interface**

### 4.6.3. RF Routing Guidelines

For user's PCB, the characteristic impedance of all RF traces should be controlled to 50 Ω. The impedance of the RF traces is usually determined by the trace width (W), the materials' dielectric constant, the height from the reference ground to the signal layer (H), and the spacing between RF traces and grounds (S). Microstrip or coplanar waveguide is typically used in RF layout to control characteristic impedance. The following are reference designs of microstrip or coplanar waveguide with different PCB structures.

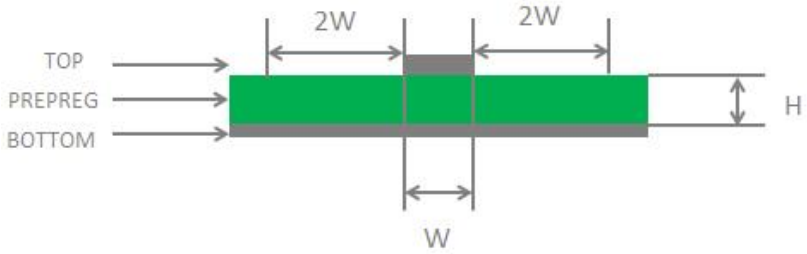



**Figure 13: Microstrip Design on a 2-layer PCB**

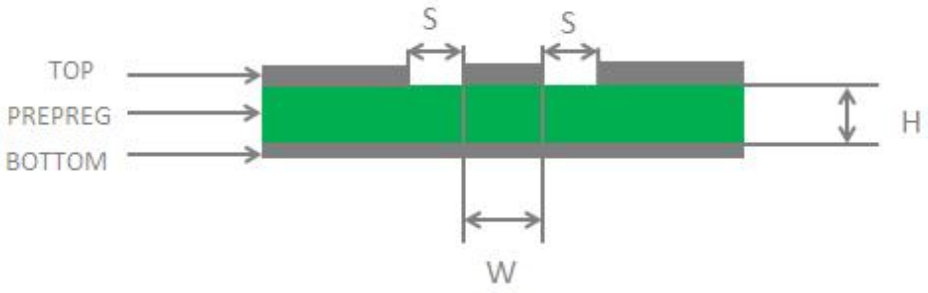



**Figure 14: Coplanar Waveguide Design on a 2-layer PCB**

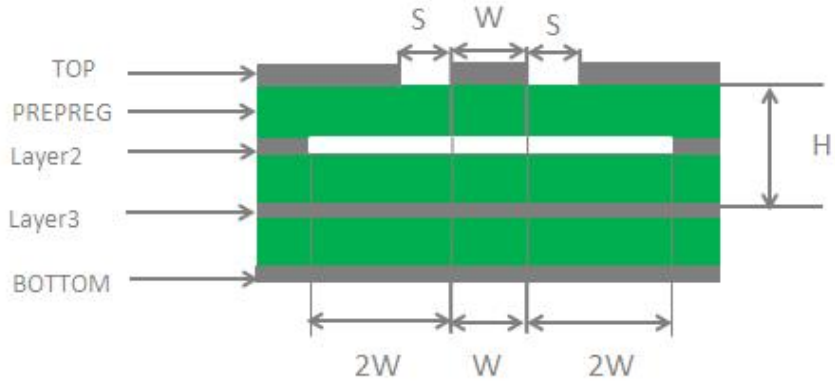



**Figure 15: Coplanar Waveguide Design on a 4-layer PCB (Layer 3 as Reference Ground)**

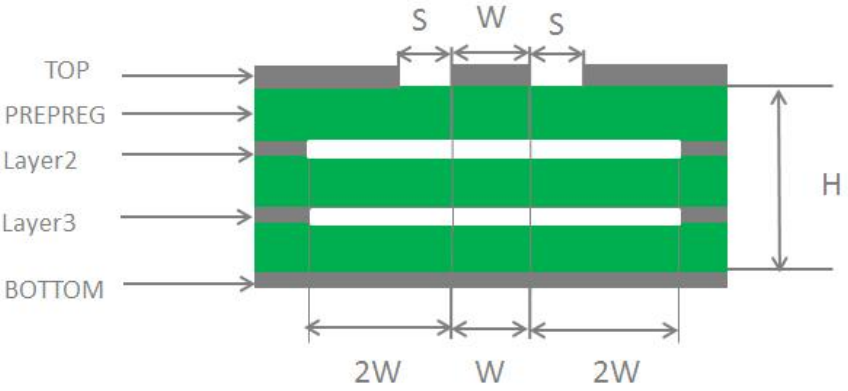



**Figure 16: Coplanar Waveguide Design on a 4-layer PCB (Layer 4 as Reference Ground)**

To ensure RF performance and reliability, follow the principles below in RF layout design:

- Use an impedance simulation tool to accurately control the characteristic impedance of RF traces to 50 Ω.
- The GND pins adjacent to RF pins should not be designed as thermal relief pads, and should be fully connected to ground.
- The distance between the RF pins and the RF connector should be as short as possible and all the right-angle traces should be changed to curved ones. The recommended trace angle is 135°.
- There should be clearance under the signal pin of the antenna connector or solder joint.
- The reference ground of RF traces should be complete. Meanwhile, adding some ground vias around RF traces and the reference ground could help to improve RF performance. The distance between the ground vias and RF traces should be not less than twice the width of RF signal traces (2 × W).
- Keep RF traces away from interference sources, and avoid intersection and paralleling between traces on adjacent layers.

For more details about RF layout, see ***document [1]***.

### 4.6.4. RF Connector Recommendation

If RF connector is used for antenna connection, it is recommended to use the U.FL-R-SMT connector provided by Hirose.

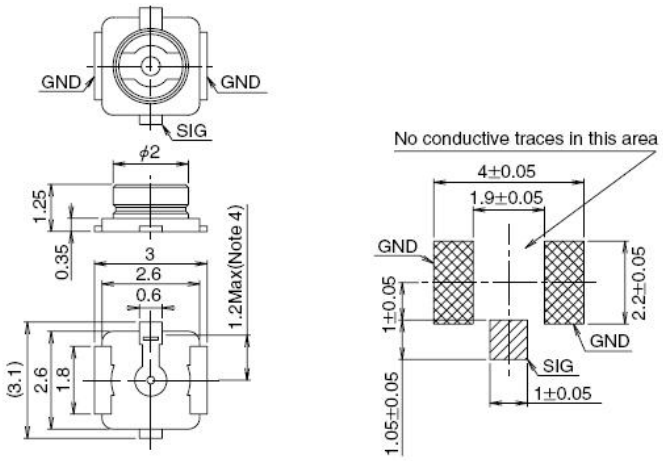



**Figure 17: Dimensions of the Receptacle (Unit: mm)**

U.FL-LP series mated plugs listed in the following figure can be used to match the U.FL-R-SMT connector.

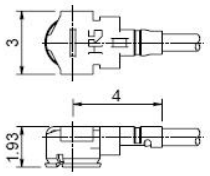
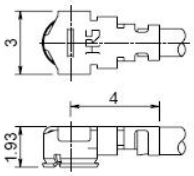
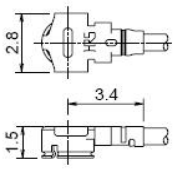
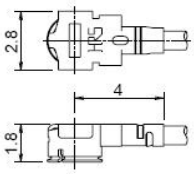
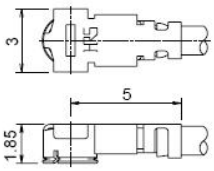
| Part No. | U.FL-LP-040 | U.FL-LP-066 | U.FL-LP(V)-040 | U.FL-LP-062 | U.FL-LP-088 |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| Mated Height | 2.5mm Max. (2.4mm Nom.) | 2.5mm Max. (2.4mm Nom.) | 2.0mm Max. (1.9mm Nom.) | 2.4mm Max. (2.3mm Nom.) | 2.4mm Max. (2.3mm Nom.) |
| Applicable cable | Dia. 0.81mm Coaxial cable | Dia. 1.13mm and Dia. 1.32mm Coaxial cable | Dia. 0.81mm Coaxial cable | Dia. 1mm Coaxial cable | Dia. 1.37mm Coaxial cable |
| Weight (mg) | 53.7 | 59.1 | 34.8 | 45.5 | 71.7 |
| RoHS | YES | | | | |

**Figure 18: Specifications of Mated Plugs**

The following figure describes the space factor of mated connectors.

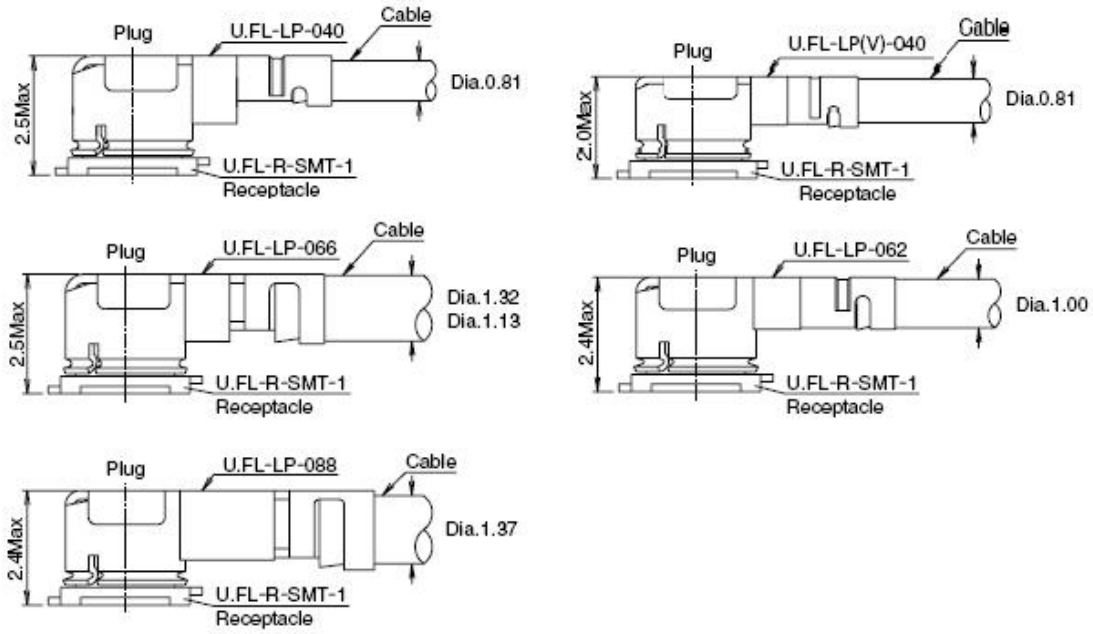



**Figure 19: Space Factor of Mated Connectors (Unit: mm)**

For more details, please visit http://www.hirose.com.

# 5 Electrical Characteristics & Reliability

## 5.1. Absolute Maximum Ratings

**Table 10: Absolute Maximum Ratings (Unit: V)**

| Parameter | Min. | Max. |
|---|---|---|
| VBAT | -0.3 | 6 |
| VDD_IO | -0.3 | 3.63 |

## 5.2. Power Supply Ratings

**Table 11: Module Power Supply Ratings (Unit: V)**

| Parameter | Description | Condition | Min. | Typ. | Max. |
|---|---|---|---|---|---|
| VBAT | Power supply for the module | The actual input voltages must be kept between the minimum and maximum values. | 3.0 | 3.3 | 3.6 |
| VDD_IO | Power supply for the module's I/O pins | - | 1.62 | 1.8/3.3 | 3.6 |

## 5.3. Power Consumption

**Table 12: Wi-Fi Power Consumption**

| Condition | | | $I_{VDD\_IO}$ | $I_{VBAT}$ | Unit |
|---|---|---|---|---|---|
| 2.4 GHz | 802.11b | Tx @ 1 Mbps | TBD | TBD | mA |
| | | Tx @ 11 Mbps | TBD | TBD | mA |
| | | Rx @ 1 Mbps | TBD | TBD | mA |
| | | Rx @ 11 Mbps | TBD | TBD | mA |
| | 802.11g | Tx @ 6 Mbps | TBD | TBD | mA |
| | | Tx @ 54 Mbps | TBD | TBD | mA |
| | | Rx @ 6 Mbps | TBD | TBD | mA |
| | | Rx @ 54 Mbps | TBD | TBD | mA |
| | 802.11n | Tx HT20 @ MCS 0 | TBD | TBD | mA |
| | | Tx HT20 @ MCS 7 | TBD | TBD | mA |
| | | Rx HT20 @ MCS 0 | TBD | TBD | mA |
| | | Rx HT20 @ MCS 7 | TBD | TBD | mA |
| | | Tx HT40 @ MCS 0 | TBD | TBD | mA |
| | | Tx HT40 @ MCS 7 | TBD | TBD | mA |
| | | Rx HT40 @ MCS 0 | TBD | TBD | mA |
| | | Rx HT40 @ MCS 7 | TBD | TBD | mA |
| 5 GHz | 802.11a | Tx @ 6 Mbps | TBD | TBD | mA |
| | | Tx @ 54 Mbps | TBD | TBD | mA |
| | | Rx @ 6 Mbps | TBD | TBD | mA |
| | | Rx @ 54 Mbps | TBD | TBD | mA |
| | 802.11n | Tx HT20 @ MCS 0 | TBD | TBD | mA |

| | | | | |
|---|---|---|---|---|
| | Tx HT20 @ MCS 7 | TBD | TBD | mA |
| | Rx HT20 @ MCS 0 | TBD | TBD | mA |
| | Rx HT20 @ MCS 7 | TBD | TBD | mA |
| | Tx HT40 @ MCS 0 | TBD | TBD | mA |
| | Tx HT40 @ MCS 7 | TBD | TBD | mA |
| | Rx HT40 @ MCS 0 | TBD | TBD | mA |
| | Rx HT40 @ MCS 7 | TBD | TBD | mA |

**Table 13: Bluetooth Power Consumption in Non-signalling Modes**

| Mode | Transmitting Power | $I_{VDD\_IO}$ | $I_{VBAT}$ |
|---|---|---|---|
| BR | TBD | TBD | TBD |
| EDR (π/4-DQPSK) | TBD | TBD | TBD |
| EDR (8-DPSK) | TBD | TBD | TBD |
| BLE (1 Mbps) | TBD | TBD | TBD |
| BLE (2 Mbps) | TBD | TBD | TBD |

## 5.4. ESD Protection

Static electricity occurs naturally and it may damage the module. Therefore, applying proper ESD countermeasures and handling methods is imperative. For example, wear anti-static gloves during the development, production, assembly and testing of the module; add ESD protection components to the ESD sensitive interfaces and points in the product design.

**Table 14: Electrostatics Discharge Characteristics (Unit: kV)**

| Model | Test Result | Standard |
|---|---|---|
| Human Body Model (HBM) | TBD | *ESDA/JEDEC JS-001-2017* |
| Charged Device Model (CDM) | TBD | *ESDA/JEDEC JS-002-2018* |

## 5.5. Digital I/O Characteristics

**Table 15: VDD_IO Low-level I/O Requirements (Unit: V)**

| Parameter | Description | Min. | Max. |
|---|---|---|---|
| $V_{IH}$ | High-level input voltage | 2.0 | 3.6 |
| $V_{IL}$ | Low-level input voltage | - | 0.5 |
| $V_{OH}$ | High-level output voltage | 2.97 | 3.6 |
| $V_{OL}$ | Low-level output voltage | 0 | 0.33 |

**Table 16: VDD_IO High-level I/O Requirements (Unit: V)**

| Parameter | Description | Min. | Max. |
|---|---|---|---|
| $V_{IH}$ | High-level input voltage | 1.3 | 2.0 |
| $V_{IL}$ | Low-level input voltage | - | 0.3 |
| $V_{OH}$ | High-level output voltage | 1.62 | 1.98 |
| $V_{OL}$ | Low-level output voltage | 0 | 0.18 |

## 5.6. Thermal Dissipation

The module offers the best performance when all internal IC chips are working within their operating temperatures. When the IC chip reaches or exceeds the maximum junction temperature, the module may still work but the performance and function (such as RF output power, data rate, etc.) will be affected to a certain extent. Therefore, the thermal design should be maximally optimized to ensure all internal IC chips always work within the recommended operating temperature range.

The following principles for thermal consideration are provided for reference:

- Keep the module away from heat sources on your PCB, especially high-power components such as processor, power amplifier, and power supply.
- Maintain the integrity of the PCB copper layer and drill as many thermal vias as possible.
- Follow the principles below when the heatsink is necessary:
  - Do not place large size components in the area where the module is mounted on your PCB to reserve enough place for heatsink installation.
  - Attach the heatsink to the shielding cover of the module; In general, the base plate area of the heatsink should be larger than the module area to cover the module completely;
  - Choose the heatsink with adequate fins to dissipate heat;
  - Choose a TIM (Thermal Interface Material) with high thermal conductivity, good softness and good wettability and place it between the heatsink and the module;
  - Fasten the heatsink with four screws to ensure that it is in close contact with the module to prevent the heatsink from falling off during the drop, vibration test, or transportation.

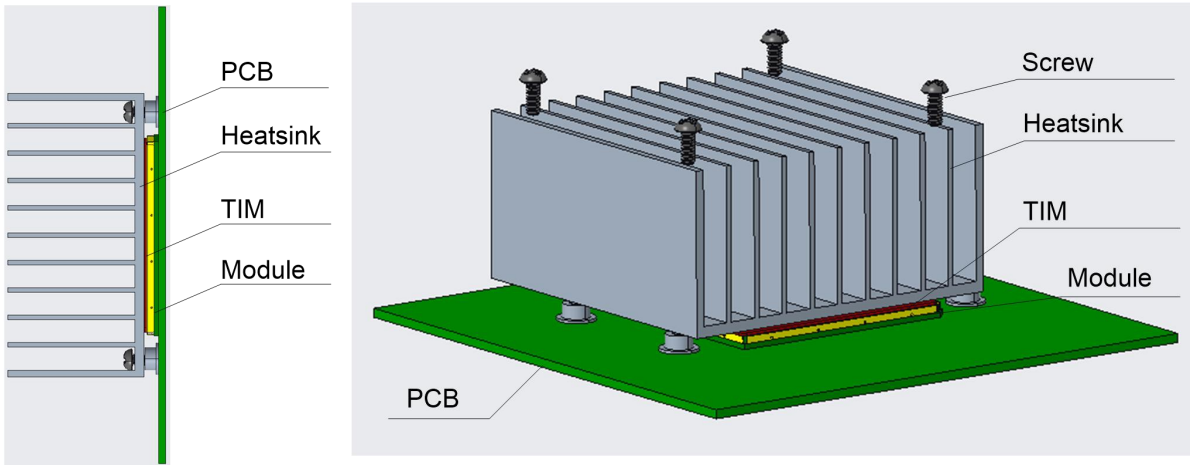



**Figure 20: Placement and Fixing of the Heatsink**

# 6 Mechanical Information

This chapter describes the mechanical dimensions of the module. All dimensions are measured in millimeter (mm), and the dimensional tolerances are ±0.2 mm unless otherwise specified.

## 6.1. Mechanical Dimensions

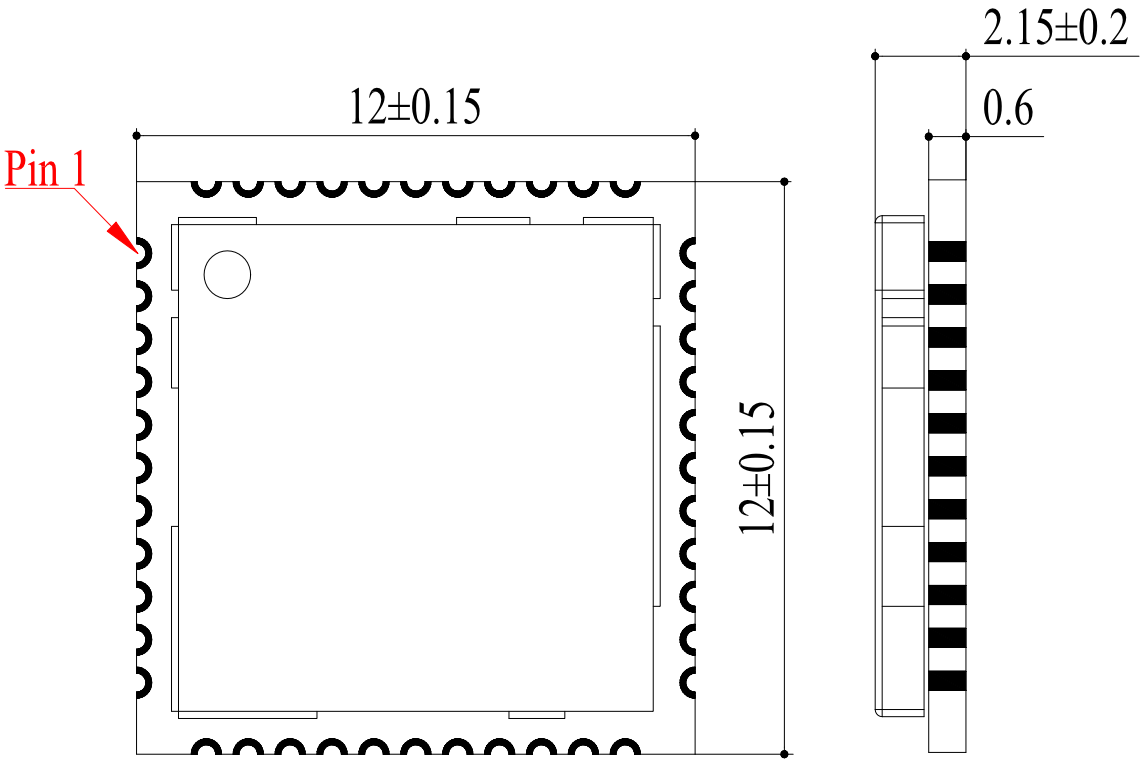



**Figure 21: Top and Side Dimensions**

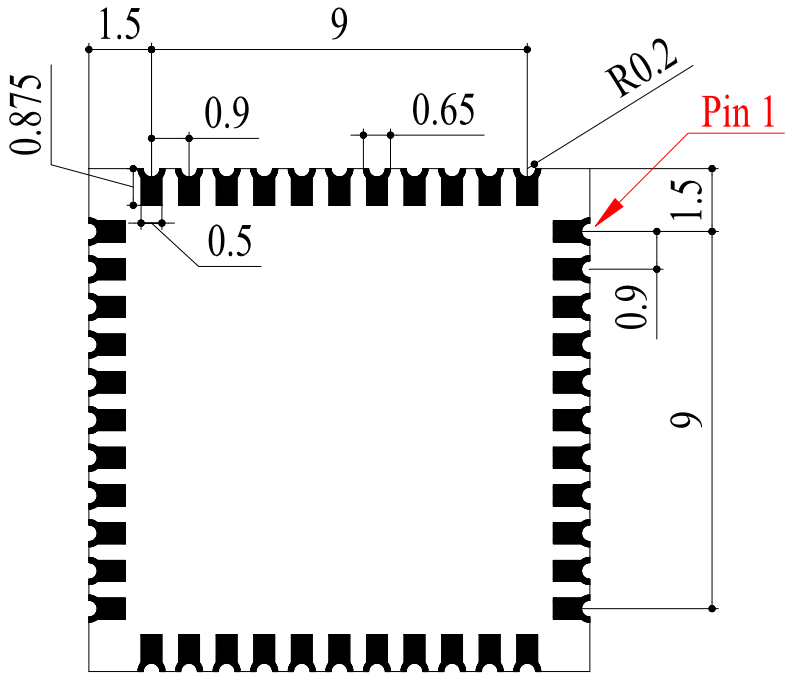



**Figure 22: Bottom Dimensions (Bottom View)**

**NOTE**

The package warpage level of the module conforms to *JEITA ED-7306* standard.

## 6.2. Recommended Footprint

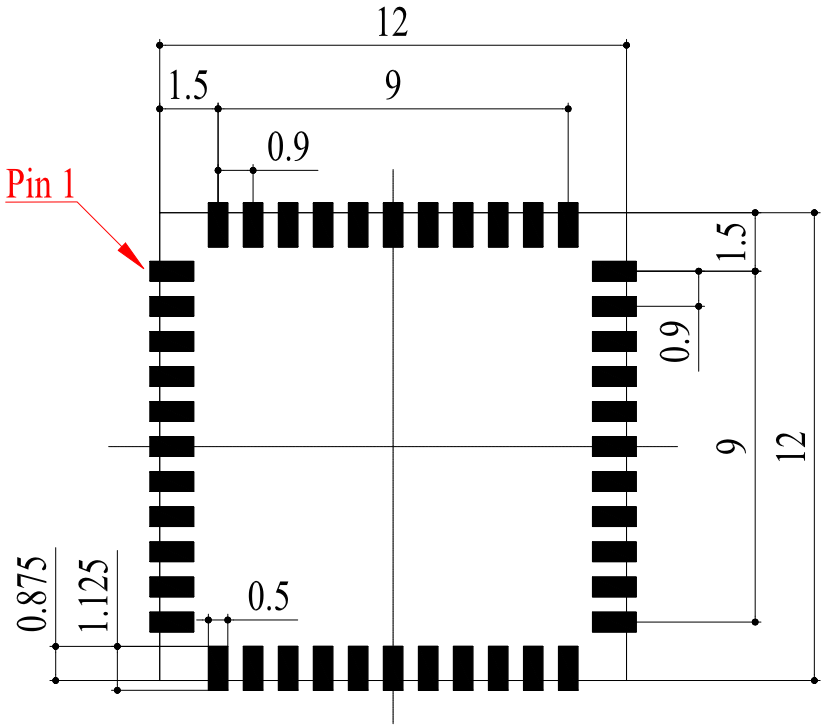



**Figure 23: Recommended Footprint**

**NOTE**

Keep at least 3 mm between the module and other components on the motherboard to improve soldering quality and maintenance convenience.

## 6.3. Top and Bottom Views

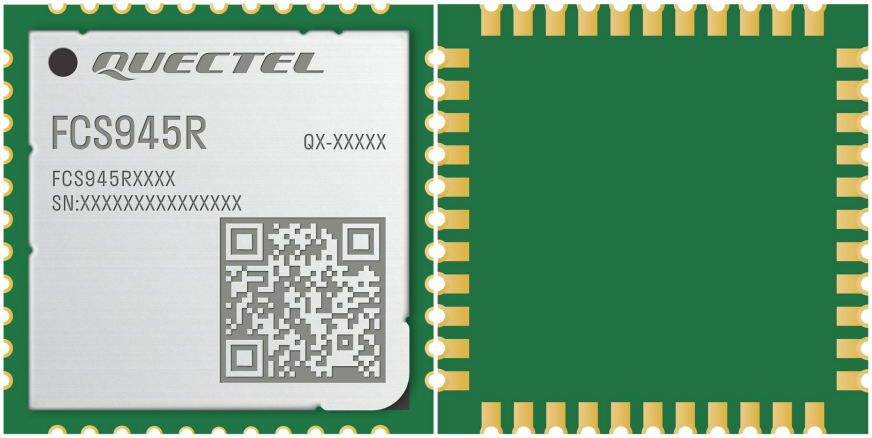



Figure 24: FCS945R Top and Bottom Views

**NOTE**

Images above are for illustrative purposes only and may differ from the actual module. For authentic appearance and label, please refer to the module received from Quectel.

# 7 Storage, Manufacturing & Packaging

## 7.1. Storage Conditions

The module is provided with vacuum-sealed packaging. MSL of the module is rated as 3. The storage requirements are shown below.

1. Recommended Storage Condition: the temperature should be 23 ±5 °C and the relative humidity should be 35–60 %.

2. Shelf life (in a vacuum-sealed packaging): 12 months in Recommended Storage Condition.

3. Floor life: 168 hours [3] in a factory where the temperature is 23 ±5 °C and relative humidity is below 60 %. After the vacuum-sealed packaging is removed, the module must be processed in reflow soldering or other high-temperature operations within 168 hours. Otherwise, the module should be stored in an environment where the relative humidity is less than 10 % (e.g., a dry cabinet).

4. The module should be pre-baked to avoid blistering, cracks and inner-layer separation in PCB under the following circumstances:

   - The module is not stored in Recommended Storage Condition;
   - Violation of the third requirement mentioned above;
   - Vacuum-sealed packaging is broken, or the packaging has been removed for over 24 hours;
   - Before module repairing.

5. If needed, the pre-baking should follow the requirements below:

   - The module should be baked for 8 hours at 120 ±5 °C;
   - The module must be soldered to PCB within 24 hours after the baking, otherwise it should be put in a dry environment such as in a dry cabinet.

[3] This floor life is only applicable when the environment conforms to IPC/JEDEC J-STD-033. It is recommended to start the solder reflow process within 24 hours after the package is removed if the temperature and moisture do not conform to, or are not sure to conform to *IPC/JEDEC J-STD-033*. Do not unpack the modules in large quantities until they are ready for soldering.

**NOTE**

1. To avoid blistering, layer separation and other soldering issues, extended exposure of the module to the air is forbidden.
2. Take out the module from the package and put it on high-temperature-resistant fixtures before baking. If shorter baking time is desired, see *IPC/JEDEC J-STD-033* for the baking procedure.
3. Pay attention to ESD protection, such as wearing anti-static gloves, when touching the modules.

## 7.2. Manufacturing and Soldering

Push the squeegee to apply the solder paste on the surface of stencil, thus making the paste fill the stencil openings and then penetrate to the PCB. Apply proper force on the squeegee to produce a clean stencil surface on a single pass. To guarantee module soldering quality, the thickness of stencil for the module is recommended to be 0.15–0.18 mm. For more details, see ***document [2]***.

The recommended peak reflow temperature should be 235–246 ºC, with 246 ºC as the absolute maximum reflow temperature. To avoid damage to the module caused by repeated heating, it is recommended that the module should be mounted only after reflow soldering for the other side of PCB has been completed. The recommended reflow soldering thermal profile (lead-free reflow soldering) and related parameters are shown below.

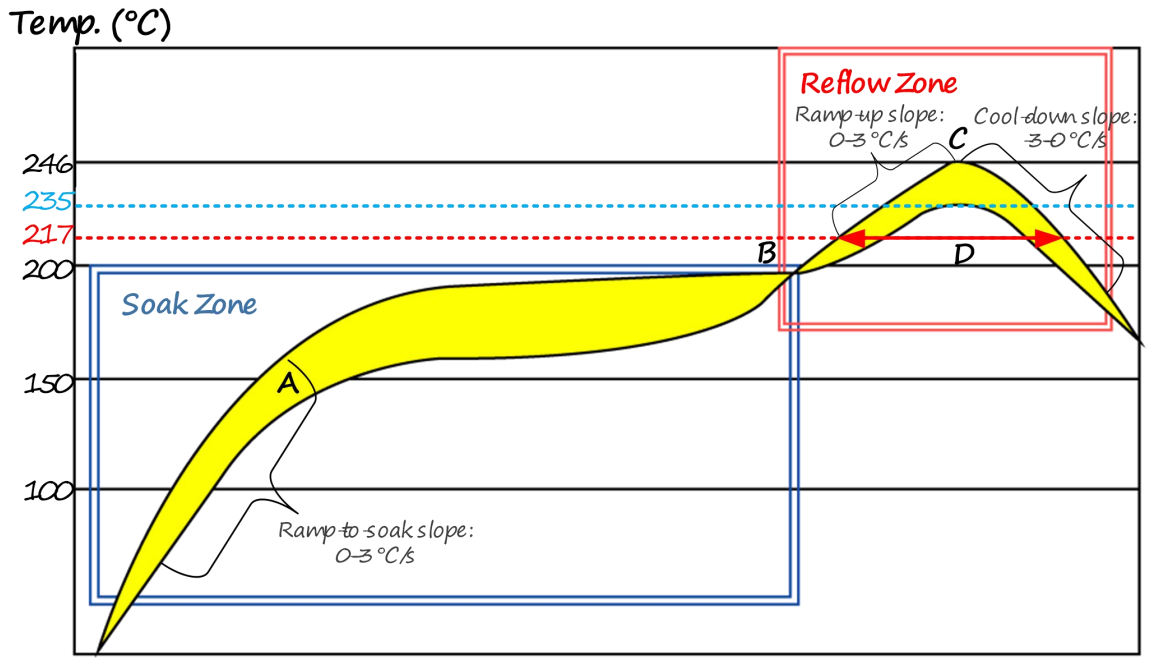



**Figure 25: Recommended Reflow Soldering Thermal Profile**

**Table 17: Recommended Thermal Profile Parameters**

| Factor | Recommended Value |
|---|---|
| **Soak Zone** | |
| Ramp-to-soak slope | 0–3 °C/s |
| Soak time (between A and B: 150 °C and 200 °C) | 70–120 s |
| **Reflow Zone** | |
| Ramp-up slope | 0–3 °C/s |
| Reflow time (D: over 217 °C) | 40–70 s |
| Max temperature | 235–246 °C |
| Cool-down slope | -3–0 °C/s |
| **Reflow Cycle** | |
| Max reflow cycle | 1 |

**NOTE**

1. The above profile parameter requirements are for the measured temperature of the solder joints. Both the hottest and coldest spots of solder joints on the PCB should meet the above requirements.
2. During manufacturing and soldering, or any other processes that may contact the module directly, NEVER wipe the module's shielding can with organic solvents, such as acetone, ethyl alcohol, isopropyl alcohol, trichloroethylene, etc. Otherwise, the shielding can may become rusted.
3. The shielding can for the module is made of Cupro-Nickel base material. It is tested that after 12 hours' Neutral Salt Spray test, the laser engraved label information on the shielding can is still clearly identifiable and the QR code is still readable, although white rust may be found.
4. If a conformal coating is necessary for the module, do NOT use any coating material that may chemically react with the PCB or shielding cover, and prevent the coating material from flowing into the module.
5. Avoid using ultrasonic technology for module cleaning since it can damage crystals inside the module.
6. Due to the complexity of the SMT process, please contact Quectel Technical Support in advance for any situation that you are not sure about, or any process (e.g. selective soldering, ultrasonic soldering) that is not mentioned in ***document [2]***.

## 7.3. Packaging Specifications

This chapter describes only the key parameters and process of packaging. All figures below are for reference only. The appearance and structure of the packaging materials are subject to the actual delivery.

The module adopts carrier tape packaging and details are as follow:

### 7.3.1. Carrier Tape

Dimension details are as follow:

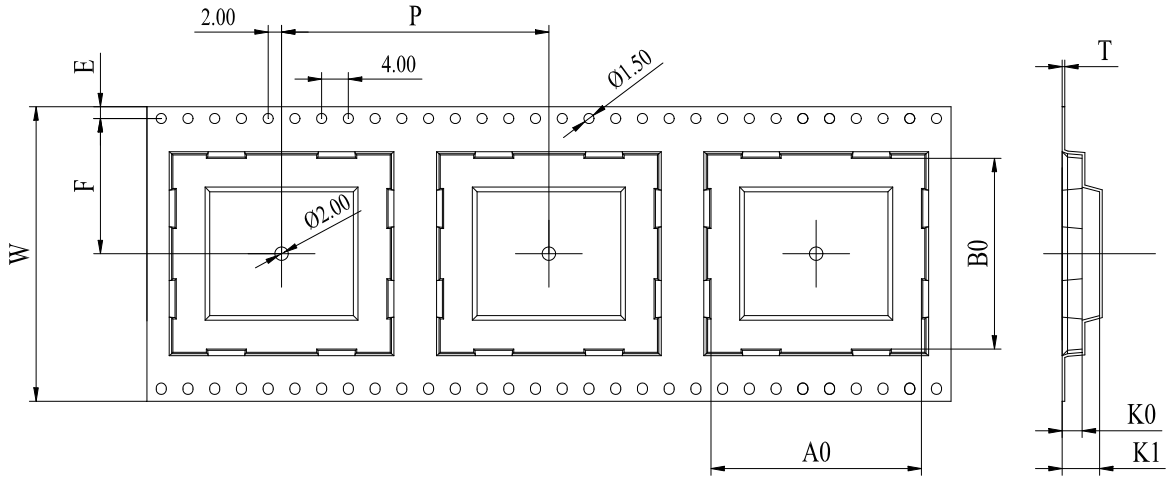



**Figure 26: Carrier Tape Dimension Drawing**

**Table 18: Carrier Tape Dimension Table (Unit: mm)**

| W | P | T | A0 | B0 | K0 | K1 | F | E |
|---|---|---|---|---|---|---|---|---|
| 24 | 16 | 0.3 | 12.4 | 12.4 | 2.6 | 4.0 | 11.5 | 1.75 |

### 7.3.2. Plastic Reel

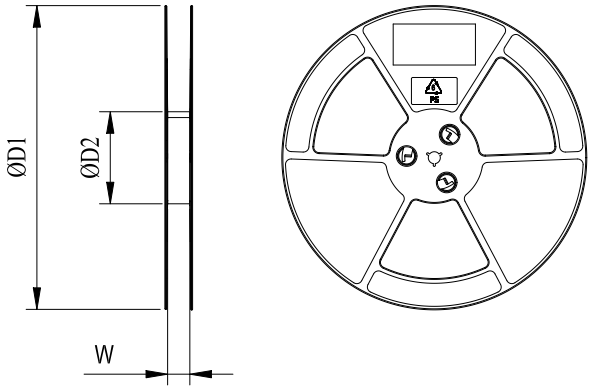



**Figure 27: Plastic Reel Dimension Drawing**

**Table 19: Plastic Reel Dimension Table (Unit: mm)**

| øD1 | øD2 | W |
|---|---|---|
| 330 | 100 | 32.5 |

### 7.3.3. Mounting Direction

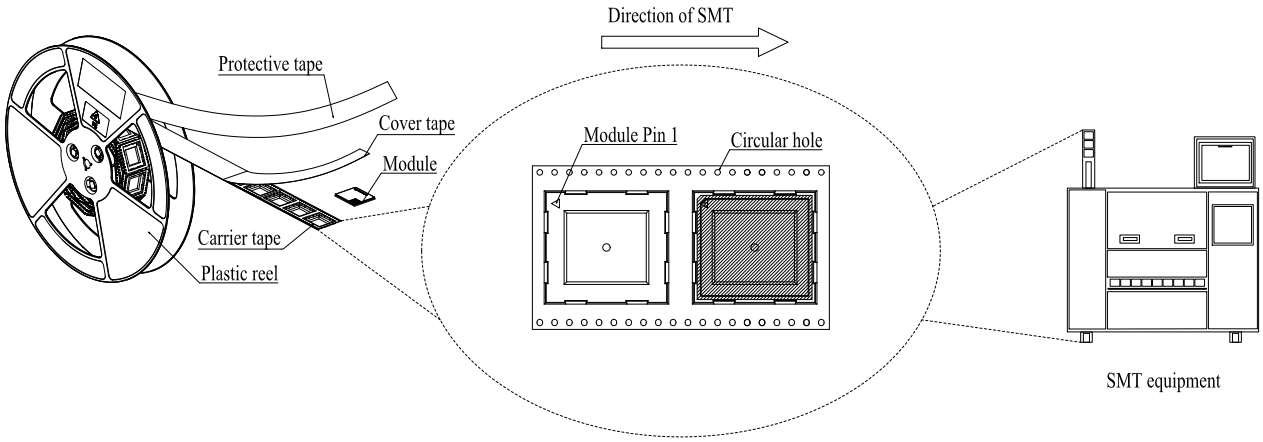
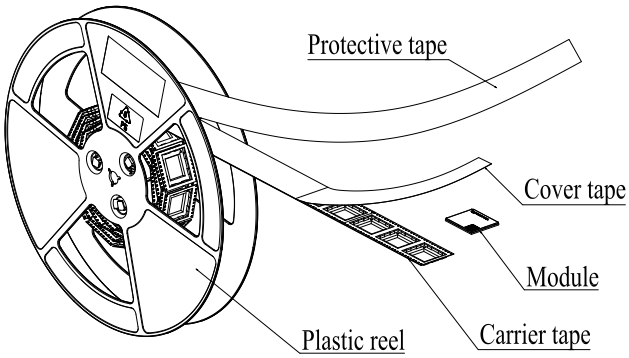


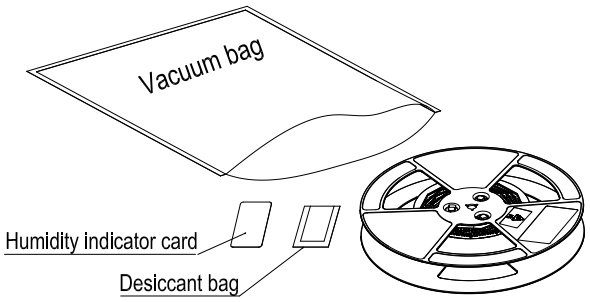

**Figure 28: Mounting Direction**

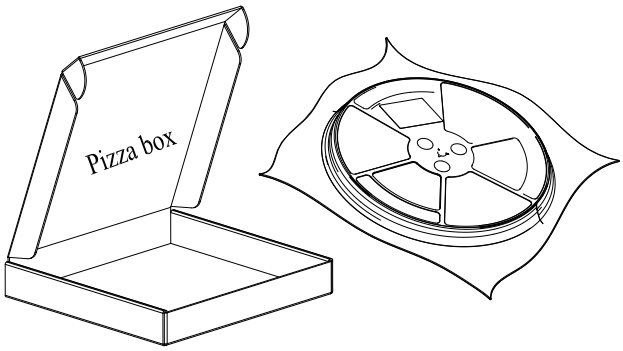
### 7.3.4. Packaging Process




Place the module into the carrier tape and use the cover tape to cover it; then wind the heat-sealed carrier tape to the plastic reel and use the protective tape for protection. 1 plastic reel can load 500 modules.

Place the packaged plastic reel, 1 humidity indicator card and 1 desiccant bag into a vacuum bag, vacuumize it.




Place the vacuum-packed plastic reel into the pizza box.

Put 4 packaged pizza boxes into 1 carton box and seal it. 1 carton box can pack 2000 modules.

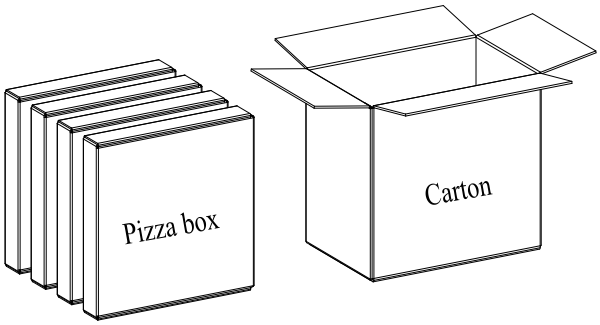



**Figure 29: Packaging Process**

# 8 Appendix References

**Table 20: Related Documents**

| Document Name |
|---|
| [1] Quectel_RF_Layout_Application_Note |
| [2] Quectel_Module_SMT_Application_Note |

**Table 21: Terms and Abbreviations**

| Abbreviation | Description |
|---|---|
| AP | Access Point |
| BLE | Bluetooth Low Energy |
| BPSK | Binary Phase Shift Keying |
| BR | Basic Rate |
| CCK | Complementary Code Keying |
| CTS | Clear To Send |
| CDM | Charged Device Model |
| DBPSK | Differential Binary Phase Shift Keying |
| DPSK | Differential Phase Shift Keying |
| DQPSK | Differential Quadrature Phase Shift Keying |
| EDR | Enhanced Data Rate |
| eSCO | Extended Synchronous Connection-Oriented |
| ESD | Electrostatic Discharge |
| EVB | Evaluation Board |

| | |
|---|---|
| EVM | Error Vector Magnitude |
| GFSK | Gauss frequency Shift Keying |
| GND | Ground |
| HBM | Human Body Model |
| HCI | Host Controller Interface |
| HT | High Throughput |
| IEEE | Institute of Electrical and Electronics Engineers |
| I/O | Input/Output |
| LCC | Leadless Chip Carrier (package) |
| Mbps | Million Bits Per Second |
| MCS | Modulation and Coding Scheme |
| MSL | Moisture Sensitivity Level |
| PCB | Printed Circuit Board |
| PCM | Pulse Code Modulation |
| QAM | Quadrature Amplitude Modulation |
| QPSK | Quadrature Phase Shift Keying |
| RF | Radio Frequency |
| RoHS | Restriction of Hazardous Substances |
| RTS | Request to Send |
| Rx | Receive |
| RXD | Receive Data |
| SCO | Synchronous Connection-Oriented |
| SDIO | Secure Digital Input/Output |
| SMT | Surface Mount Technology |
| STA | Station |

| | |
|---|---|
| TBD | To Be Determined |
| TVS | Transient Voltage Suppressor |
| Tx | Transmit |
| TXD | Transmit Data |
| UART | Universal Asynchronous Receiver/Transmitter |
| VHT | Very High Throughput |
| $V_{IH}$ | High-level Input Voltage |
| $V_{IL}$ | Low-level Input Voltage |
| Vmax | Maximum Voltage |
| Vmin | Minimum Voltage |
| Vnom | Nominal Voltage |
| $V_{OH}$ | High-level Output Voltage |
| $V_{OL}$ | Low-level Output Voltage |
| VSWR | Voltage Standing Wave Ratio |
| Wi-Fi | Wireless Fidelity |

FCC Certification Requirements.
According to the definition of mobile and fixed device is described in Part 2.1091(b), this device is a mobile device.
And the following conditions must be met:
1. This Modular Approval is limited to OEM installation for mobile and fixed applications only. The antenna installation and operating configurations of this transmitter, including any applicable source-based time-averaging duty factor, antenna gain and cable loss must satisfy MPE categorical Exclusion Requirements of 2.1091.
2. The EUT is a mobile device; maintain at least a 20 cm separation between the EUT and the user’s body and must not transmit simultaneously with any other antenna or transmitter.
3.A label with the following statements must be attached to the host end product: This device contains FCC ID: XMR2023FCS945R.
4.To comply with FCC regulations limiting both maximum RF output power and human exposure to RF radiation, maximum antenna gain (including cable loss) must not exceed:

- Bluetooth/Bluetooth LE/Wi-Fi 2.4G:≤0.52dBi
- Wi-Fi 5G:≤0.66 dBi

5. This module must not transmit simultaneously with any other antenna or transmitter
6. The host end product must include a user manual that clearly defines operating requirements and conditions that must be observed to ensure compliance with current FCC RF exposure guidelines.
For portable devices, in addition to the conditions 3 through 6 described above, a separate approval is required to satisfy the SAR requirements of FCC Part 2.1093
If the device is used for other equipment that separate approval is required for all other operating configurations, including portable configurations with respect to 2.1093 and different antenna configurations.
For this device, OEM integrators must be provided with labeling instructions of finished products. Please refer to KDB784748 D01 v07, section 8. Page 6/7 last two paragraphs:
A certified modular has the option to use a permanently affixed label, or an electronic label. For a permanently affixed label, the module must be labeled with an FCC ID - Section 2.926 (see 2.2 Certification (labeling requirements) above). The OEM manual must provide clear instructions explaining to the OEM the labeling requirements, options and OEM user manual instructions that are required (see next paragraph).
For a host using a certified modular with a standard fixed label, if (1) the module’s FCC ID is not visible when installed in the host, or (2) if the host is marketed so that end users do not have straightforward commonly used methods for access to remove the module so that the FCC ID of the module is visible; then an additional permanent label referring to the enclosed module: “Contains Transmitter Module FCC ID: XMR2023FCS945R.” or “Contains FCC ID: XMR2023FCS945R.” must be used. The host OEM user manual must also contain clear instructions on how end users can find and/or access the module and the FCC ID.
The final host / module combination may also need to be evaluated against the FCC Part 15B criteria for unintentional radiators in order to be properly authorized for operation as a Part 15 digital device.
The user’s manual or instruction manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. In cases where the manual is provided only in a form other

than paper, such as on a computer disk or over the Internet, the information required by this section may be included in the manual in that alternative form, provided the user can reasonably be expected to have the capability to access information in that form.
This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
Changes or modifications not expressly approved by the manufacturer could void the user’s authority to operate the equipment.
IC Certification Requirements.

This device contains licence-exempt transmitteris)/receivers) that comply with Innovation, Science and EconomicDevelopment 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.

To comply with IC regulations limiting both maximum RF output power and human exposure to RF radiation, maximum antenna gain (including cable loss) must not exceed:
❒ Bluetooth/Bluetooth LE/Wi-Fi 2.4G:≤0.52dBi
❒ Wi-Fi 5G:≤0.66 dBi

L'appareil contient un émetteur / récepteur exempté de licence conforme au CNR exempté de licence d'innovation, sciences et développement économique Canada. Les opérations sont soumises aux deux conditions suivantes:

1. Cet appareil peut ne pas causer d'interférence.

L'appareil doit accepter toute interférence, y compris celles qui peuvent entraîner un fonctionnement indésirable de l'appareil.

This equipment complies with ISED radiation exposure limits set forth for an uncontrolled environment. To comply with RSS-102 RF Exposure compliance requirements, this grant is applicable to only Mobile Configurations. The antennas used for the transmitter must be installed to provide a separation distance of at least 20cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

The user manual for LE-LAN devices shall contain instructions related to the restrictions mentioned in the abovesections, namely that:
i. the device for operation in the band 5150-5250 MHz is only for indoor use to reduce the potential for harmfulinterference to co-channel mobile satellite systems;
ii. for devices with detachable antenna(s), the maximum antenna gain permitted for devices in the bands 5250-5350 MHz and 5470-5725 MHz shall be such that the equipment still complies with the e.i.r.p. limit.

iii. for devices with detachable antennals), the maximum antenna gain permitted for devices in the band5725-5850 MHz shall be such that the equipment still complies with the e.i.r.p. limits as appropriate;
iv. where applicable, antenna type(s), antenna models(s), and worst-case tilt angle(s) necessary to remain compliantwith the e.iro. elevation mask reauirement set forth in section 6.2.2.3 shall be clearly indicated.

The host product shall be properly labelled to identify the modules within the host product.
The Innovation, Science and Economic Development Canada certification label of a module shall be clearly visible at all times when installed in the host product; otherwise, the host product must be labeled to display the Innovation, Science and Economic Development Canada certification number for the module, preceded by the word “Contains” or similar wording expressing the same meaning, as follows: “Contains IC: 10224A-2023FCS945R” or “where: 10224A-2023FCS945R is the module’s certification number”.