# AF65E

# Hardware Design

**Automotive Wi-Fi&Bluetooth Module Series**

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**At Quectel, our aim is to provide timely and comprehensive services to our customers. If you require any assistance, please contact our headquarters:**

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| | |
|---|---|
|  | Full attention must be paid 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 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. |
|  | Terminals or mobiles operating over radio signal and 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 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 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 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 |
|---|---|---|---|
| - | 2024-10-17 | Lorenzo LI/Starry CHEN | Creation of the document |
| 1.0.0 | 2024-10-17 | Lorenzo LI/Starry CHEN | Preliminary |
| 1.0 | 2025-02-25 | Lorenzo LI/Starry CHEN | |

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# 1 Introduction

This document describes the AF65E features, performance, and air interfaces and hardware interfaces connected to your applications. The document provides a quick insight into interface specifications, RF performance, electrical and mechanical specifications, and other module information, as well.

# 2 Product Overview

AF65E is a low-power, cost-effective Wi-Fi and Bluetooth module supporting IEEE 802.11a/b/g/n/ac/ax and Bluetooth 5.3 protocols. It features built-in power management unit, power amplifier, low noise amplifier and RF transceiver switch. The module has multiple interfaces including PCIe Gen 2, UART, and PCM for various applications.

The module is an SMD module with compact packaging.

**Table 1: Basic Information**

| Item | Description |
|---|---|
| Packaging type | LGA |
| Pin counts | 112 |
| Dimensions | (23.0 ±0.2) mm × (23.0 ±0.2) mm × (3.0 ±0.2) mm |
| Weight | Approx. 3.3 g |

## 2.1. Key Features

**Table 2: Key Features**

| Basic Information | |
|---|---|
| Protocols and Standard | ● Wi-Fi protocol: IEEE 802.11a/b/g/n/ac/ax<br>● Bluetooth protocol: Bluetooth 5.3<br>● All hardware components fully comply with EU RoHS directive |
| Supply Voltage | **VDD_CORE_VL Power Supply:**<br>● 0.9–1.2 V<br>● Typ.: 0.95 V<br>**VDD_CORE_VM Power Supply:**<br>● 1.30–1.42 V<br>● Typ.: 1.35 V |

| | |
|---|---|
| | **VDD_CORE_VH Power Supply:**<br>● 1.85–2.0 V<br>● Typ.: 1.9 V<br>**VDD_PA Power Supply:**<br>● 1.71–2.1 V<br>● Typ.: 1.8 V<br>**VDD_IO Power Supply:**<br>● 1.71–1.89 V<br>● Typ.: 1.8 V |
| Temperature Ranges | ● Normal operating temperature [1]: -40 to +85 °C<br>● Storage temperature: -40 to 90 °C |
| EVB | V2X&5G EVB [2] |
| **RF Antenna Interfaces** | |
| Wi-Fi Antenna Interfaces | ● ANT_WIFI0/BT<br>● ANT_WIFI1<br>● 50 Ω characteristic impedance |
| Bluetooth Antenna Interface | ● ANT_BT<br>● 50 Ω characteristic impedance |
| **Application Interfaces** | |
| Wi-Fi Application Interface | PCIe Gen 2 |
| Bluetooth Application Interfaces | UART, PCM |

# 3 RF Specifications

## 3.1. Wi-Fi Performances

**Table 3: Wi-Fi Performances**

| |
|---|
| **Operating Frequency** |

[1] Within this range, the module's indicators comply with IEEE and Bluetooth specification requirements.
[2] Quectel supplies a V2X&5G EVB with accessories to develop and test the module. For more details, see ***document [1]***.

- **2.4 GHz:** 2.400–2.4835 GHz
- **5 GHz:** 5.150–5.850 GHz
- **6 GHz:** 5.925–7.125 GHz

**Modulation**

DBPSK, DQPSK, CCK, BPSK, QPSK, 16QAM, 64QAM, 256QAM, 1024QAM

**Encryption Mode**

WEP, WPS, WPA_PSK, WPA2_PSK, WPA3_PSK, WPA_WPA2_PSK_BOTH, WPA_WPA2_WPA3_PSK_ALL

**Operating Mode**

- AP
- STA

**Transmission Data Rate**

- 802.11b: 1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps
- 802.11a/g: 6 Mbps, 9 Mbps, 12 Mbps, 18 Mbps, 24 Mbps, 36 Mbps, 48 Mbps, 54 Mbps
- 802.11n: HT20 (MCS 0–7), HT40 (MCS 0–7)
- 802.11ac: VHT20 (MCS 0–8), VHT40 (MCS 0–9), VHT80 (MCS 0–9), VHT160 (MCS 0–9)
- 802.11ax: HE20 (MCS 0–11), HE40 (MCS 0–11), HE80 (MCS 0–11), HE160 (MCS 0–11)

| **Condition (VDD_CORE_VL = 0.95 V; VDD_CORE_VM = 1.35 V; VDD_CORE_VH = 1.9 V; VDD_IO = 1.8 V; VDD_PA = 1.8 V; Temp.: 25 °C)** | | **EVM** | **Transmitting Power (Unit: dBm; Tolerance: ±3 dB)** | **Receiver Sensitivity (Unit: dBm)** | | |
|---|---|---|---|---|---|---|
| | | | **Typ.** | **Max. (Worst Case)** | **Typ.** | **Min. (Best Case)** |
| 2.4 GHz | 802.11b @ 1 Mbps | ≤ 35 % | 15.5 | -93 | -96 | -98.5 |
| | 802.11b @ 11 Mbps | | 15.5 | -85 | -88.5 | -90 |
| | 802.11g @ 6 Mbps | ≤ -5 dB | 14.5 | -89 | -92 | -94.5 |
| | 802.11g @ 54 Mbps | ≤ -25 dB | 13 | -71 | -75 | -76.5 |
| | 802.11n, HT20 @ MCS 0, BPSK | ≤-5 dB | 14.5 | -89 | -92.5 | -94 |
| | 802.11n, HT20 @ MCS 7, 64QAM | ≤ -27 dB | 12.5 | -69 | -73 | -74.5 |
| | 802.11n, HT40 @ MCS 0, BPSK | ≤ -5 dB | 14 | -86 | -89 | -91.5 |
| | 802.11n, HT40 @ MCS 7, 64QAM | ≤ -27 dB | 12 | -67 | -70.5 | -71.5 |
| | 802.11ax, HE20 @ MCS 0, BPSK | ≤ -5 dB | 14.5 | -89 | -93.5 | -95 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 802.11ax, HE20 @ MCS 11, 1024QAM | ≤ -35 dB | 11 | -59 | -63.5 | -65 |
| | 802.11ax, HE40 @ MCS 0, BPSK | ≤ -5 dB | 14 | -86 | -90.5 | -92 |
| | 802.11ax, HE40 @ MCS 11, 1024QAM | ≤ -35 dB | 9.5 | -55 | -61 | -62 |
| 5 GHz | 802.11a @ 6 Mbps | ≤ -5 dB | 13 | -88 | -91.5 | -94 |
| | 802.11a @ 54 Mbps | ≤ -25 dB | 11 | -70 | -73.5 | -75.5 |
| | 802.11n, HT20 @ MCS 0, BPSK | ≤ -5 dB | 13 | -88 | -91 | -93.5 |
| | 802.11n, HT20 @ MCS 7, 64QAM | ≤ -27 dB | 10.5 | -68 | -71.5 | -73.5 |
| | 802.11n, HT40 @ MCS 0, BPSK | ≤ -5 dB | 12.5 | -85 | -88 | -90.5 |
| | 802.11n, HT40 @ MCS 7, 64QAM | ≤ -27 dB | 10 | -65 | -68 | -71 |
| | 802.11ac, VHT20 @ MCS 0, BPSK | ≤ -5 dB | 13 | -88 | -91 | -93.5 |
| | 802.11ac, VHT20 @ MCS 8, 256QAM | ≤ -30 dB | 10.5 | -64 | -67.5 | -70 |
| | 802.11ac, VHT40 @ MCS 0, BPSK | ≤ -5 dB | 12.5 | -85 | -88 | -90.5 |
| | 802.11ac, VHT40 @ MCS 9, 256QAM | ≤ -32 dB | 9.5 | -59 | -63 | -65.5 |
| | 802.11ac, VHT80 @ MCS 0, BPSK | ≤ -5 dB | 12 | -82 | -85.5 | -87 |
| | 802.11ac, VHT80 @ MCS 9, 256QAM | ≤ -32 dB | 9 | -57 | -60 | -62.5 |
| | 802.11ac, VHT160 @ MCS 0, BPSK | ≤ -5 dB | 11.5 | -79 | -82 | -84 |
| | 802.11ac, VHT160 @ MCS 9, 256QAM | ≤ -32 dB | 7.5 | -54 | -58 | -58 |
| | 802.11ax, HE20 @ MCS 0, BPSK | ≤ -5 dB | 13 | -88 | -91.5 | -94 |
| | 802.11ax, HE20 @ MCS 11, 1024QAM | ≤ -35 dB | 8.5 | -59 | -62 | -64 |
| | 802.11ax, HE40 @ MCS 0, BPSK | ≤ -5 dB | 12.5 | -86 | -89 | -91.5 |
| | 802.11ax, HE40 @ MCS 11, 1024QAM | ≤ -35 dB | 8 | -56 | -58.5 | -61 |
| | 802.11ax, HE80 @ MCS 0, BPSK | ≤ -5 dB | 12 | -83 | -86 | -88 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 802.11ax, HE80 @ MCS 11, 1024QAM | ≤ -35 dB | 7 | -53 | -56.5 | -58.5 |
| | 802.11ax, HE160 @ MCS 0, BPSK | ≤ -5 dB | 11.5 | -79.5 | -82.5 | -85 |
| | 802.11ax, HE160 @ MCS 11, 1024QAM | ≤ -35 dB | 6 | -49 | -53.5 | -56 |
| 6 GHz | 802.11ax, HE20 @ MCS 0, BPSK | ≤ -5 dB | 12.5 | -88 | -90.5 | -94.5 |
| | 802.11ax, HE20 @ MCS 11, 1024QAM | ≤ -35 dB | 8 | -58 | -61.5 | -64.5 |
| | 802.11ax, HE40 @ MCS 0, BPSK | ≤ -5 dB | 12 | -85 | -88 | -91.5 |
| | 802.11ax, HE40 @ MCS 11, 1024QAM | ≤ -35 dB | 7.5 | -55 | -58.5 | -61.5 |
| | 802.11ax, HE80 @ MCS 0, BPSK | ≤ -5 dB | 11.5 | -82 | -84.5 | -87.5 |
| | 802.11ax, HE80 @ MCS 11, 1024QAM | ≤ -35 dB | 6.5 | -53 | -56 | -59.5 |
| | 802.11ax, HE160 @ MCS 0, BPSK | ≤ -5 dB | 11 | -78.5 | -81.5 | -85 |
| | 802.11ax, HE160 @ MCS 11, 1024QAM | ≤ -35 dB | 5.5 | -49.5 | -53 | -56.5 |

## 3.2. Bluetooth Performances

**Table 4: Bluetooth Performances**

| **Operating Frequency** | | |
|---|---|---|
| 2.400–2.4835 GHz | | |
| **Modulation** | | |
| GFSK, 8-DPSK, π/4-DQPSK | | |
| **Operating Mode** | | |
| ● Classic Bluetooth (BR + EDR)<br>● BLE | | |
| **Condition**<br>**(VDD_CORE_VL = 0.95 V;** | **Transmitting Power**<br>**(Unit: dBm; Tolerance: ±4 dB)** | **Receiver Sensitivity**<br>**(Unit: dBm)** |

| VDD_CORE_VM = 1.35 V;<br>VDD_CORE_VH = 1.9 V;<br>VDD_IO = 1.8 V;<br>Temp.: 25 °C) | Typ. | Max. (Worst Case) | Typ. | Min. (Best Case) |
|---|---|---|---|---|
| BR (GFSK) | 6 | -87 | -92 | -95 |
| EDR (π/4-DQPSK) | 2 | -82 | -90 | -96 |
| EDR (8-DPSK) | 2 | -82 | -90 | -96 |
| BLE (1 Mbps) | 6 | -90 | -94 | -98 |
| BLE (2 Mbps) | 6 | -90 | -94 | -98 |
| BLE (S = 2) | 6 | -90 | -98 | -101 |
| BLE (S = 8) | 6 | -90 | -98 | -105 |

# 4 Application Interface

## 4.1. Pin Definitions

**Table 5: Parameter Definition**

| Parameter | Description |
|---|---|
| AI | Analog Input |
| AO | Analog Output |
| AIO | Analog Input/Output |
| DI | Digital Input |
| DO | Digital Output |
| DIO | Digital Input/Output |
| OD | Open Drain |
| PI | Power Input |

DC characteristics include power domain and rated current.

**Table 6: Pin Description**

| Power Supply | | | | | |
|---|---|---|---|---|---|
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| VDD_CORE_VL | 79, 85, 86 | PI | Voltage for core, low voltage | Vmin = 0.9 V<br>Vnom = 0.95 V<br>Vmax = 1.2 V | It must be provided with sufficient current up to 1.0 A. |
| VDD_CORE_VM | 89 | PI | Voltage for core, medium voltage | Vmin = 1.30 V<br>Vnom = 1.35 V<br>Vmax = 1.42 V | It must be provided with sufficient current |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | up to 400 mA. |
| VDD_CORE_VH | 77, 83 | PI | Voltage for core, high voltage | Vmin = 1.85 V<br>Vnom = 1.9 V<br>Vmax = 2.0 V | It must be provided with sufficient current up to 400 mA. |
| VDD_IO | 71 | PI | Provide 1.8 V for the module's I/O pins | Vmin = 1.71 V<br>Vnom = 1.8 V<br>Vmax = 1.89 V | It must be provided with sufficient current up to 20 mA. |
| VDD_PA | 105, 106 | PI | Power supply for the module's RF part | Vmin = 1.71 V<br>Vnom = 1.8 V<br>Vmax = 2.1 V | It must be provided with sufficient current up to 1600 mA. |
| GND | 6, 11, 14, 17, 23, 26, 29, 36, 38, 43, 44, 46, 47, 52, 53, 55, 56, 67, 70, 78, 80–82, 84, 87, 88, 90–100, 103, 104, 107–112 | | | | Connect these pins to ground. |
| **Bluetooth Application Interfaces** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| PCM_DIN | 2 | DI | PCM data input | VDD_IO | |
| PCM_SYNC | 5 | DIO | PCM data frame sync | | In master mode, they are output signals;<br>In slave mode, they are input signals. |
| PCM_CLK | 4 | DIO | PCM clock | | |
| PCM_DOUT | 3 | DO | PCM data output | | Please ensure that it is high during boot-up.<br>See ***Table 12*** for more details. |
| BT_TXD | 74 | DO | Bluetooth UART transmit | | |
| BT_RXD | 75 | DI | Bluetooth UART receive | | |
| BT_RTS | 72 | DO | Request to send signal from the module | | |
| BT_CTS | 73 | DI | Clear to send signal to the module | | |
| BT_EN | 69 | DI | Bluetooth enable | VDD_IO | Reserve a 100 kΩ |

| | | | | | |
|---|---|---|---|---|---|
| | | | control | | external weak pull-down resistor, Active high. |
| **Wi-Fi Application Interfaces** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| WLAN_EN | 68 | DI | Wi-Fi function enable control | VDD_IO | Reserve a 100 kΩ external weak pull-down resistor, Active high. |
| PCIE_REFCLK_P | 19 | AI | PCIe reference clock (+) | | Require differential impedance of 85 Ω. |
| PCIE_REFCLK_M | 18 | AI | PCIe reference clock (-) | | |
| PCIE_TX_P | 15 | AO | PCIe transmit (+) | | |
| PCIE_TX_M | 16 | AO | PCIe transmit (-) | | |
| PCIE_RX_P | 12 | AI | PCIe receive (+) | | |
| PCIE_RX_M | 13 | AI | PCIe receive (-) | | |
| PCIE_CLKREQ_N | 9 | OD | PCIe clock request | VDD_IO | There are 10K pull-up resistors inside the module. |
| PCIE_WAKE_N | 8 | OD | PCIe wake up | | |
| PCIE_RST_N | 7 | DI | PCIe reset | | |
| **Control Signals** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| SW_CTRL | 10 | DO | Control PMIC output | VDD_IO | If unused, keep it open. |
| **Coexistence Interface** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| COEX_TXD | 76 | DO | LTE & Wi-Fi/Bluetooth coexistence transmit | VDD_IO | Please ensure that it is low during boot-up. See ***Table 12*** for more details. If unused, keep them open. |
| COEX_RXD | 1 | DI | LTE & Wi-Fi/Bluetooth | | If unused, keep them open. |

| | | | | | |
|---|---|---|---|---|---|
| | | | coexistence receive | | |
| **WLAN_SLP_CLK Interface** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| WLAN_SLP_CLK | 22 | DI | WLAN sleep clock | VDD_IO | The module is unable to boot up and work without sleep clock. |
| **RF Antenna Interfaces** | | | | | |
| **Pin Name** | **Pin No.** | **I/O** | **Description** | **DC Characteristics** | **Comment** |
| ANT_WIFI0/BT | 45 | AIO | Wi-Fi 0/Bluetooth antenna interface | | 50 Ω characteristic impedance. |
| ANT_WIFI1 | 54 | AIO | Wi-Fi 1 antenna interface | | |
| ANT_BT | 37 | AIO | Reserved dedicated Bluetooth antenna interface | | |
| **RESERVED Pins** | | | | | |
| **Pin Name** | **Pin No.** | | | | **Comment** |
| RESERVED | 20, 21, 24, 25, 27, 28, 30–35, 39–42, 48–51, 57–66, 101, 102 | | | | Keep them open. It is recommended to add an external 10 kΩ pull-up resistor for pin 30 and 10 kΩ pull-down resistor for pin 58 if they are connected to GPIO of the host. See ***Table 12*** for more details. |

**NOTE**

1. If the WLAN or Bluetooth function is not used, WLAN_EN or BT_EN cannot be kept open and a 10–100 kΩ pull-down resistor must be added.
2. To reduce the probability of module damage and extend module service life, do not power up and down frequently.

## 4.2. Reference Design for Power Supply

The module is powered by VDD_CORE (i.e., VDD_CORE_VL, VDD_CORE_VM, VDD_CORE_VH), VDD_PA and VDD_IO. VDD_CORE and VDD_IO supplies of the module can be powered by Quectel cellular modules AG59xE and AG59xH families. The following figure shows the reference design for these power pins which are powered by Quectel cellular modules.

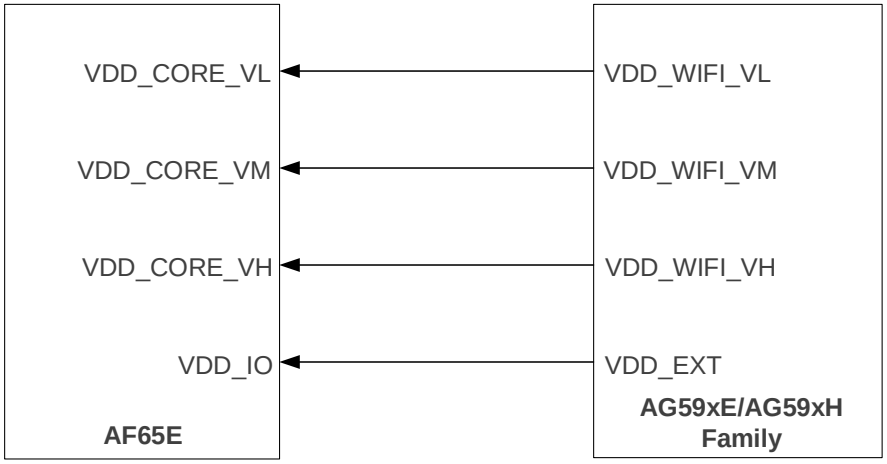



**Figure 1: Reference Design of Power Supply**

VDD_CORE and VDD_IO can also be powered by independent power chips. The maximum output current requirement of the supply chip for these power supply pins is as follows:

- 1000 mA for VDD_CORE_VL
- 400 mA for VDD_CORE_VM
- 400 mA for VDD_CORE_VH
- 20 mA for VDD_IO

The RF part of the module is powered by VDD_PA. VDD_PA is recommended to use a power supply chip with maximum output current up to 1600 mA. The following figure shows a reference design for VDD_PA which are controlled by WLAN_PWR_EN1 of the host.

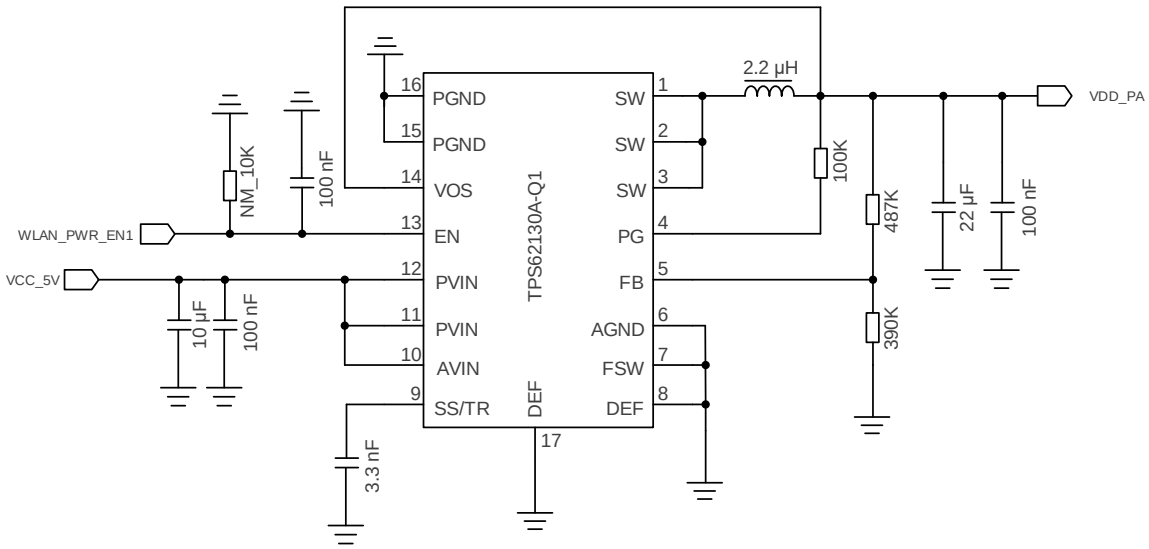



**Figure 2: Reference Design for VDD_PA**

### 4.2.1. Timing of Turn On and Turn Off

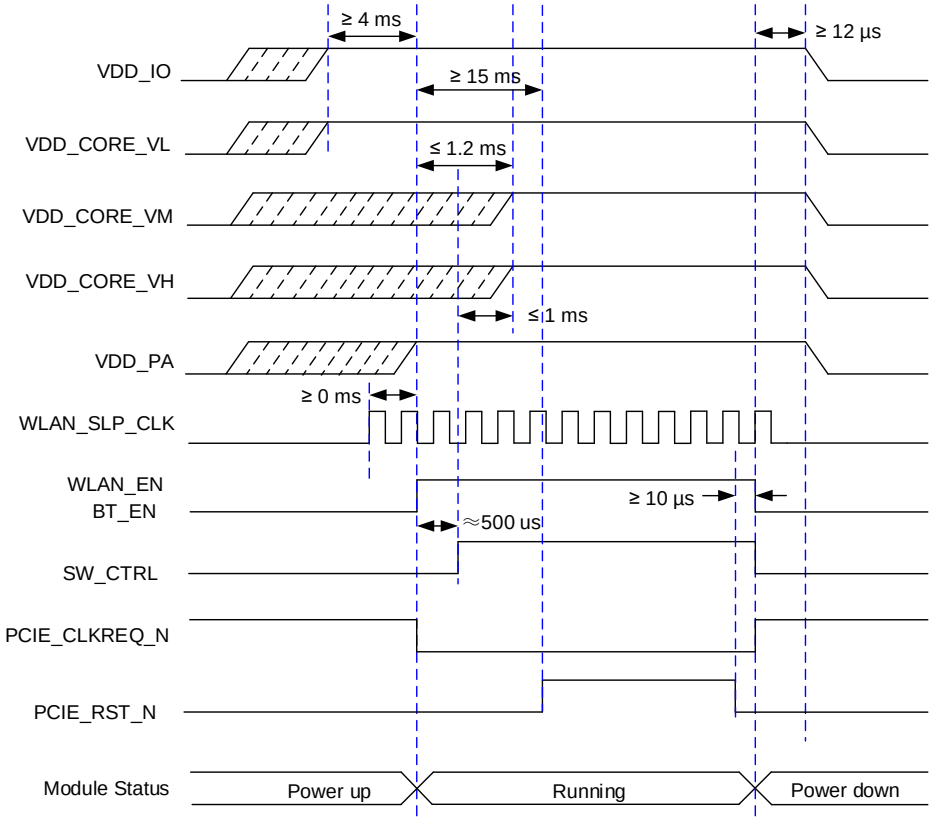



**Figure 3: Timing of Turn On and Turn Off**

## 4.3. Wi-Fi Application Interfaces

The Wi-Fi application interfaces connection between the module and the host is shown below:

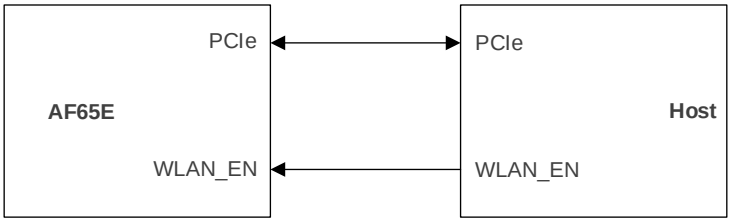



**Figure 4: Wi-Fi Application Interface Connection**

### 4.3.1. WLAN_EN

Wi-Fi function of the module is controlled by WLAN_EN.

WLAN_EN is the Wi-Fi function enable signal. When routing, keep it far away from power supply traces, crystal-oscillators, magnetic devices, sensitive signals and signals, such as RF signals, analog signals, and noise signals generated by clock and DC-DC.

### 4.3.2. PCIe Interface

The PCIe interface connection between the module and the host is shown below:

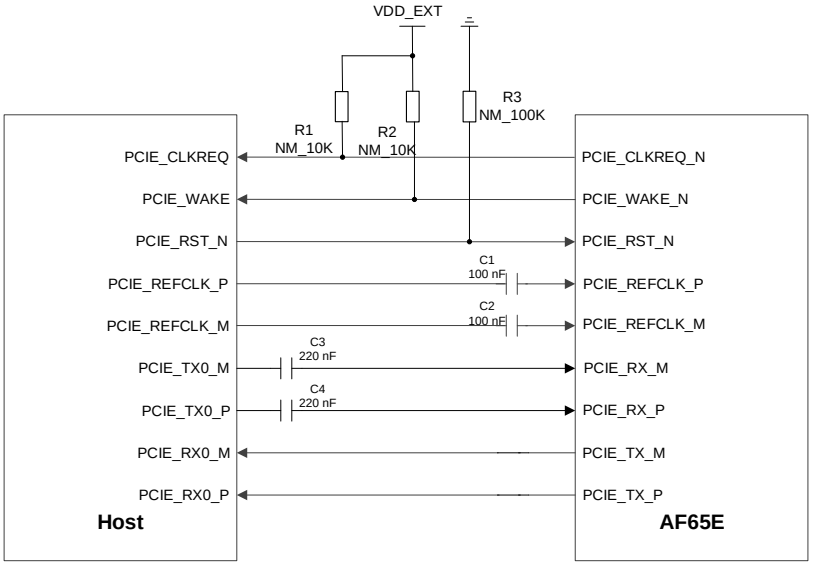



**Figure 5: PCIe Interface Connection**

To ensure the PCIe interface design meets PCIe Gen 2 specifications, you should follow the principles below:

- Route PCIe signal traces (Tx/Rx/REFCLK) as differential pairs at the inner-layer of PCB, and surround the traces with ground on that layer and with ground planes above and below. The differential impedance should be 85 Ω ±10 %. Meanwhile, protect them from interferences such as crystal-oscillators, VBAT traces, RF signal traces.
- For PCIe signal traces (Tx/Rx/REFCLK), the intra-lane length mismatch of each differential data pair should be less than 0.7 mm. and the maximum length of each differential data pair should be less than 250 mm.
- Spacings between Tx and Rx signal traces and that between Tx/Rx and all other signal traces should be wider than 3 and 4 times of the trace width respectively.
- Add capacitors in series on Rx traces to immune from leakage current (Tx already has 220 nF coupling capacitors inside the module). A couple of 100 nF capacitors (C1/C2) must be added when the host is i.MX serial, because the differential clock of i.MX serial does not meet PCIe compliance standard. Place C1 and C2 near the module and place C3 and C4 near the host, and keep the traces as short as possible to ensure the signal integrity of the PCIe interface.

**Table 7: PCIe Interface Trace Length Inside the Module (Unit: mm)**

| Pin Name | Pin No. | Length | Length Mismatch |
|---|---|---|---|
| PCIE_REFCLK_P | 19 | 10.2996 | 0.0981 |
| PCIE_REFCLK_M | 18 | 10.2015 | |
| PCIE_TX_P | 15 | 6.4003 | 0.0841 |
| PCIE_TX_M | 16 | 6.3162 | |
| PCIE_RX_P | 12 | 4.5654 | 0.0305 |
| PCIE_RX_M | 13 | 4.5959 | |

## 4.4. Bluetooth Application Interfaces

The Bluetooth application interface connection between the module and the host is shown below:

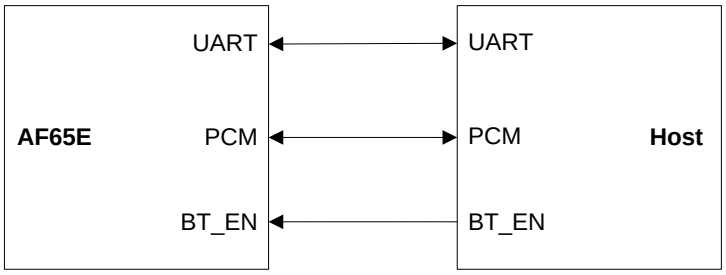



**Figure 6: Bluetooth Application Interface Connection**

### 4.4.1. BT_EN

Bluetooth function of AF65E is controlled by BT_EN.

BT_EN is the Bluetooth function enable signal. When routing, keep it far away from power supply traces, crystal-oscillators, magnetic devices, sensitive signals and signals, such as RF signals, analog signals, and noise signals generated by clock and DC-DC.

### 4.4.2. PCM Interface

The module provides a PCM interface for Bluetooth audio application. The PCM interface supports both master and slave modes and it operates in slave mode by default. Please note that the PCM_DIN is the data receive terminal (an input), the PCM_DOUT pin is the data transmit terminal (an output).

The following figure shows a reference design for PCM interface connection between AF65E and the host.

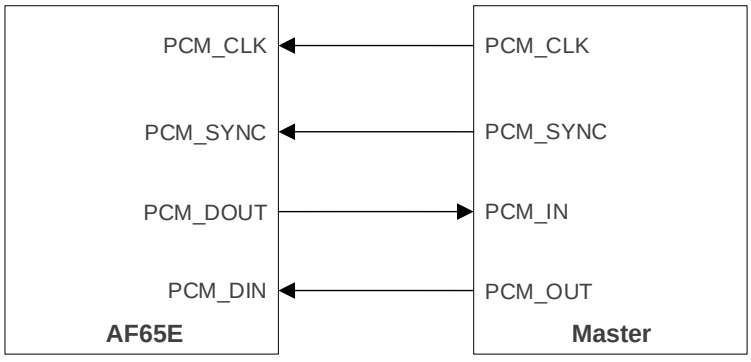



**Figure 7: PCM Interface Connection (Slave Mode)**

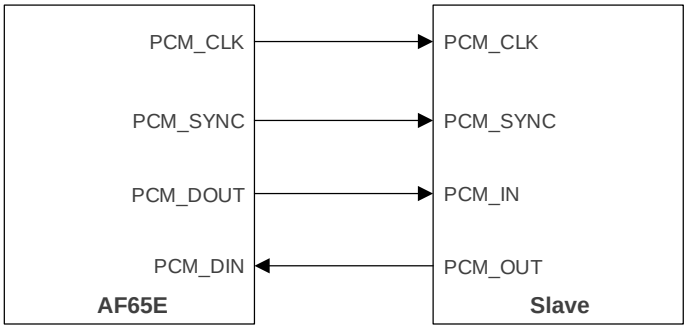



**Figure 8: PCM Interface Connection (Master Mode)**

The PCM timing and relevant parameters in slave mode are shown below:

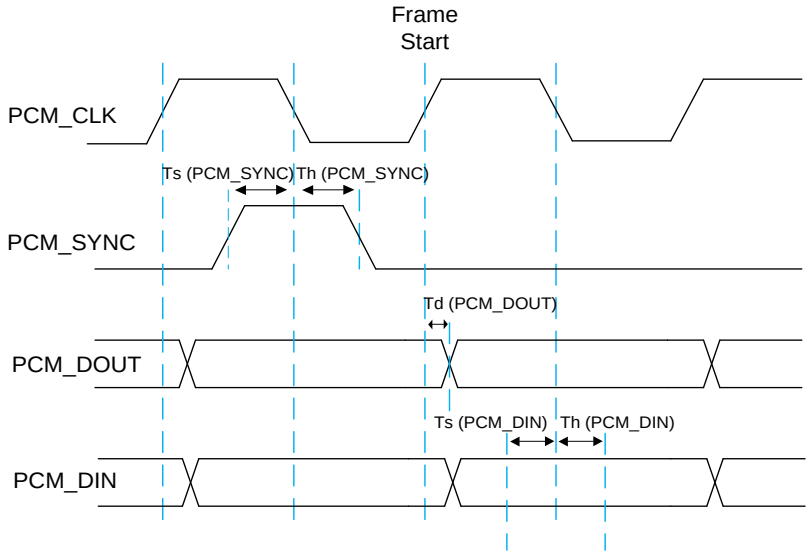



**Figure 9: PCM Interface Timing (Slave Mode)**

**Table 8: PCM Timing Parameters in Slave Mode**

| Parameter | Description | Max. | Typ. | Min. | Unit |
|---|---|---|---|---|---|
| - | Frequency of PCM_CLK | 64 | - | 2048 | kHz |
| Ts (PCM_SYNC) | Setup time PCM_SYNC to PCM_CLK fall | 0 | - | - | ns |
| Th (PCM_SYNC) | Hold time PCM_CLK fall to PCM_SYNC fall | 150 | - | - | ns |
| Td (PCM_DOUT) | Delay time from PCM_CLK rise to PCM_OUT | 0 | - | 150 | ns |
| Ts (PCM_DIN) | Setup time PCM_DIN to PCM_CLK fall | 0 | - | - | ns |

| | | | | | |
|---|---|---|---|---|---|
| Th (PCM_DIN) | Hold time PCM_DIN after PCM_CLK fall | 150 | - | - | ns |

The PCM timing and relevant parameters in master mode are shown below:

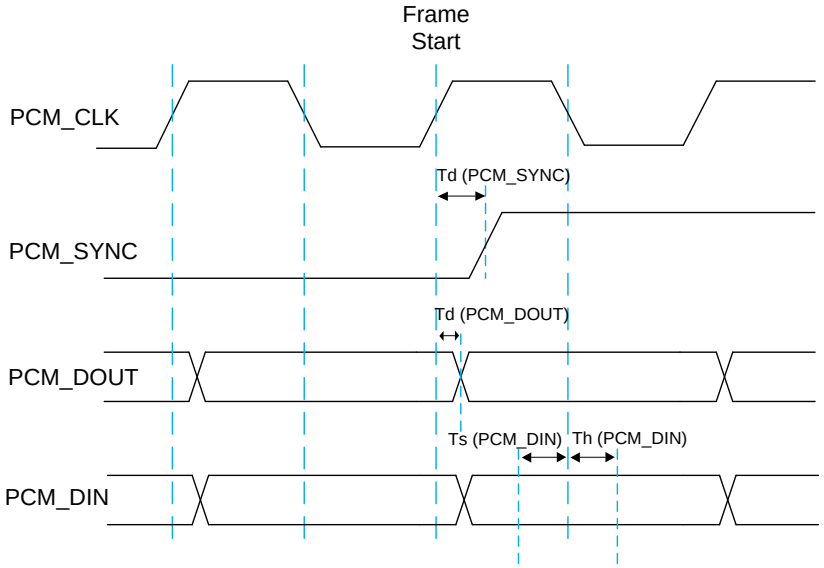



**Figure 10**: **PCM Interface Timing (Master Mode)**

**Table 9: PCM Timing Parameters in Master Mode**

| Parameter | Description | Max. | Typ. | Min. | Unit |
|---|---|---|---|---|---|
| - | Frequency of PCM_CLK | 64 | - | 2048 | kHz |
| Td (PCM_SYNC) | Delay time from PCM_CLK rise to long PCM_SYNC | -10 | -- | 50 | ns |
| Td (PCM_DOUT) | Delay time from PCM_CLK rise to PCM_DOUT | -10 | - | 50 | ns |
| Ts (PCM_DIN) | Setup time PCM_DIN to PCM_CLK fall | 50 | - | - | ns |
| Th (PCM_DIN) | Hold time PCM_DIN after PCM_CLK fall | 150 | - | - | ns |

### 4.4.3. Bluetooth UART Interface

The module supports HCI UART interface. The UART interface complies with the *Bluetooth Core Specification Version 4.0* and supports hardware flow control. It can be used for data transmission with a host and supports baud rates up to 3.2 Mbps.

The UART interface connection between the module and the host is shown below:

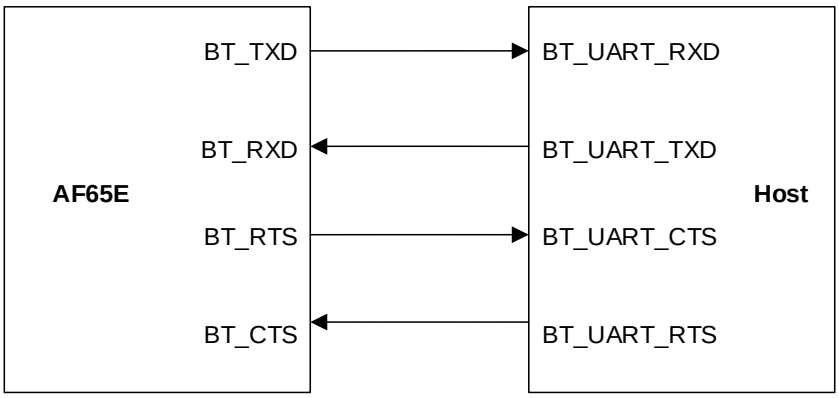



**Figure 11: UART Interface Connection**

**NOTE**

1. When paired with Quectel AG59xE/AG59xH Series modules, please note that the module's CTS is connected to the AG59x's CTS, and the module's RTS is connected to the AG59x's RTS.
2. To increase the stability of UART communication, it is recommended to add UART hardware flow control design.

The HCI UART transmitting timing and relevant parameters are shown below:

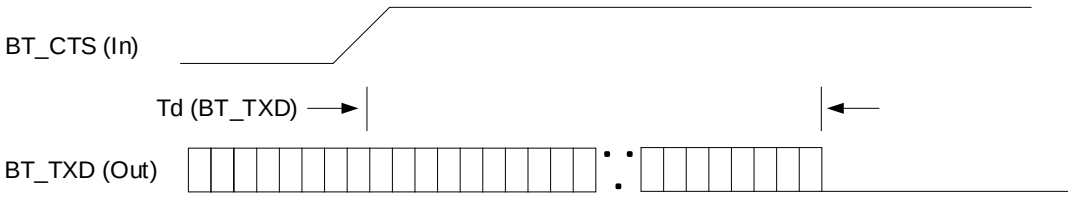



**Figure 12: HCI UART Transmitting Control Timing**

**Table 10: HCI UART Transmitting Control Timing Parameters**

| Parameter | Description | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| Td (BT_TXD) | Delay time from BT_CTS to BT_TXD stop bit | - | - | 1 | byte |

The HCI UART receiving timing and relevant parameters are shown below:

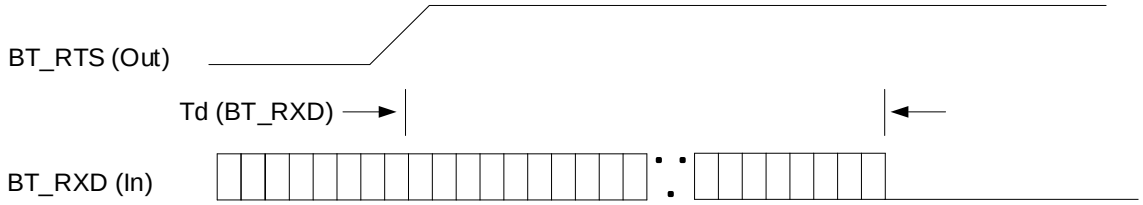



**Figure 13: HCI UART Receiving Control Timing**

**Table 11: HCI UART Receiving Control Timing Parameters**

| Parameter | Description | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| Td (BT_RXD) | Delay time from BT_RTS to BT_RXD stop bit | 16 | - | - | byte |

## 4.5. Bootstrap Pins

Bootstrap pins are essential for operational boot-up. If the pin level state is incorrect during the turn-on process, the module will go into an abnormal operational mode. Bootstrap pins are sampled within 100 ms after the first enable pin (either WLAN_EN or BT_EN) is pulled up, and the sampled bootstrap level will be latched, after which the pins are used as the defined function pins.

**Table 12: Bootstrap Pins**

| Pin Name | Pin No. | Resistor Inside the Module | Comment |
|---|---|---|---|
| PCM_DOUT | 3 | 10 kΩ; pull-up | Please ensure that it is high during boot-up, and it is not recommended to add an external pull-down resistor or connect it to GND. |
| COEX_TXD | 76 | - | Please ensure that it is low during boot-up, and it is recommended to add an external 10 kΩ pull-down resistor if it is connected to the host GPIO. |
| RESERVED | 30 | - | If unused, keep it open. It is recommended to add an external 10 kΩ pull-up resistor if it is connected to the host GPIO. |
| RESERVED | 58 | - | If unused, keep it open. It is recommended to add an external 10 kΩ pull-down resistor if it is connected to the host GPIO. |

**NOTE**

To avoid affecting the level status of Bootstrap pins, if they are connected to the host, level-shifting, A2B or other chips, please pay attention to the default status of the host or chip pins.

## 4.6. Other Interfaces

### 4.6.1. Coexistence Interface

The coexistence interface is used for the coexistence of LTE and Wi-Fi/Bluetooth. If unused, it can be kept unconnected.

When matched with a third-party host, COEX_TXD can be configured as BT_WAKE_HOST (active high), and COEX_RXD can be configured as HOST_WAKE_BT (active high). For more details, please contact Quectel Technical Support.

The following figure shows the coexistence interface connection between AF65E and the host.

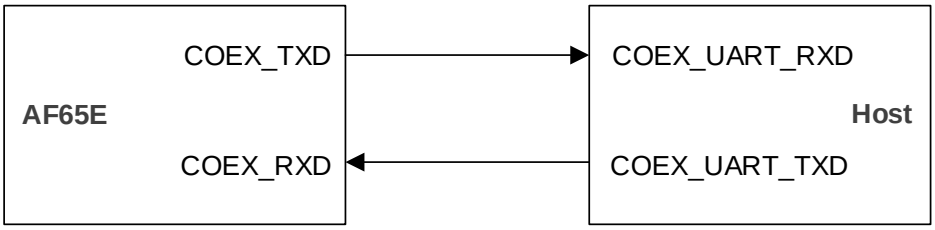



**Figure 14: Block Diagram of Coexistence Interface Connection**

### 4.6.2. WLAN_SLP_CLK

The 32.768 kHz sleep clock is used in low power consumption modes, such as power saving mode and sleep mode. It serves as a timer to determine when to wake up the module to receive signals in various power saving schemes, and to maintain basic logic operations when the module is in sleep mode. The module is unable to boot up and work without the sleep clock.

The following are the timing and recommended selection parameters for the recommended 32.768 kHz crystal:

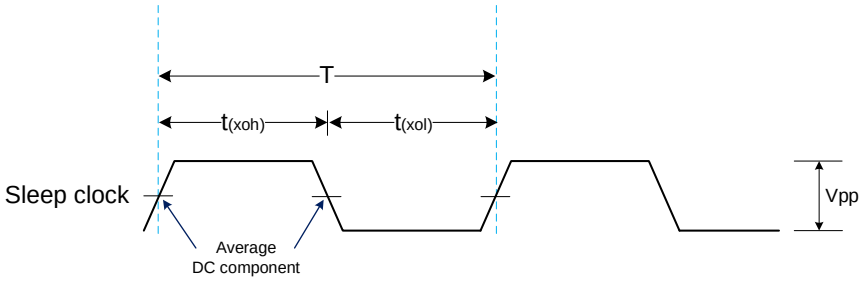



**Figure 15: External Sleep Clock Signal Timing**

**Table 13: Parameter Recommendation**

| Parameter | | Comment | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $t_{(xoh)}$ | sleep clock logic high | - | 4.58 | - | 25.94 | μs |
| $t_{(xol)}$ | sleep clock logic low | - | 4.58 | - | 25.94 | μs |
| T | sleep clock period | - | - | 30.5208 | - | μs |
| - | sleep clock frequency | F = 1/T | - | 32.768 | - | kHz |
| $V_{pp}$ | Peak to peak voltage | - | - | 1.8 | - | V |

### 4.6.3. SW_CTRL

The following figure shows the SW_CTRL connection between AF65E and the host. The SW_CTRL only can be used with Quectel AG59xE/AG59xH Series modules.

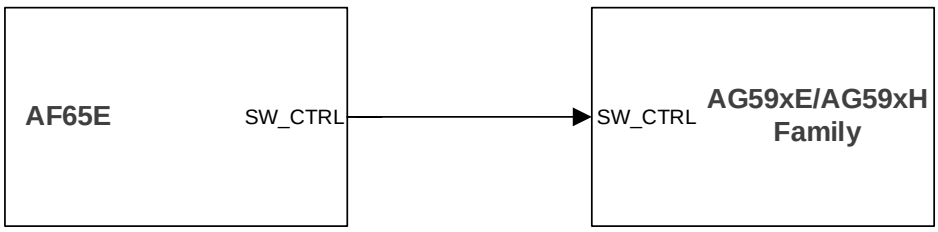



**Figure 16: SW_CTRL Connection**

## 4.7. RF Antenna Interfaces

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.

### 4.7.1. Reference Design

The circuit of RF antenna interface is shown below. For better RF performance, it is recommended to reserve a dual L-type circuit. The reserved matching components (C1, C2, R1, D1) should be placed as close to the antenna as possible and mounted or not based on the actual situation. By default, ESD protection components are mounted. C1 and C2 is not mounted, and only a 0 Ω resistor is mounted at R1.

The following reference design takes ANT_WIFI0/BT as an example, and the reference designs of other antenna interfaces are the same.

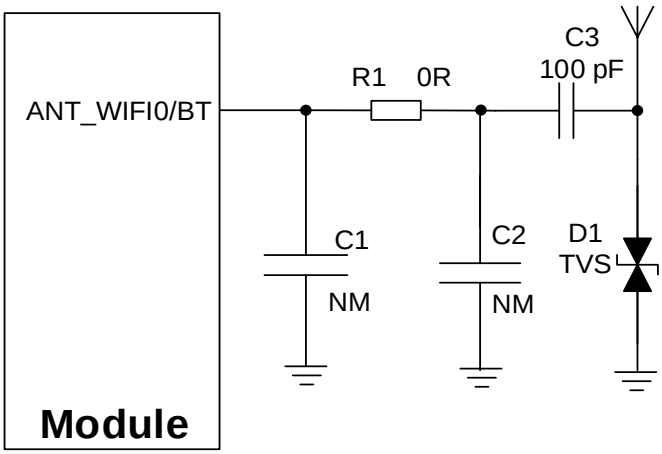



**Figure 17**: **Reference Design of Antenna Interface (ANT_WIFI0/BT)**

**NOTE**

1. ESD protection components need to be added close to the antenna to effectively prevent static electricity. Junction capacitance of ESD protection components on the antenna interfaces is recommended to be 0.05 pF.
2. C3 is used for DC-blocking and the capacitance value is recommended to be 100 pF.

### 4.7.2. Requirements for Antenna Design

**Table 14: Requirements for Antenna Design**

| Parameter | Requirements [3] |
|---|---|
| Frequency Range (GHz) | ● **2.4 GHz**：2.400–2.4835 GHz<br>● **5 GHz**：5.150–5.850 GHz<br>● **6 GHz:** 5.925–7.125 GHz |
| Cable Insertion Loss (dB) | < 1 |
| VSWR | ≤ 2 (Typ.) |
| Gain (dBi) | 1.6 (Typ.) |
| Max. Input Power (W) | 50 |
| Input Impedance (Ω) | 50 |
| Polarization | Vertical polarization |

**NOTE**

1. Maximize the distance among Wi-Fi 0/Bluetooth antenna, Wi-Fi 1 antenna and Bluetooth antenna.
2. Antenna isolation:
   > 20 dB @ above 1000 MHz;
   > 15 dB @ 600–1000 MHz;
   > 10 dB @ 400–600 MHz.
3. The isolation between each antenna traces on PCB is recommended to be over 75 dB.

### 4.7.3. RF Routing Guidelines

For user's PCB, the characteristic impedance of all RF traces should be controlled as 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 the RF traces and the ground (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.

[3] For more information about RF characteristics, see ***Chapter 3***.

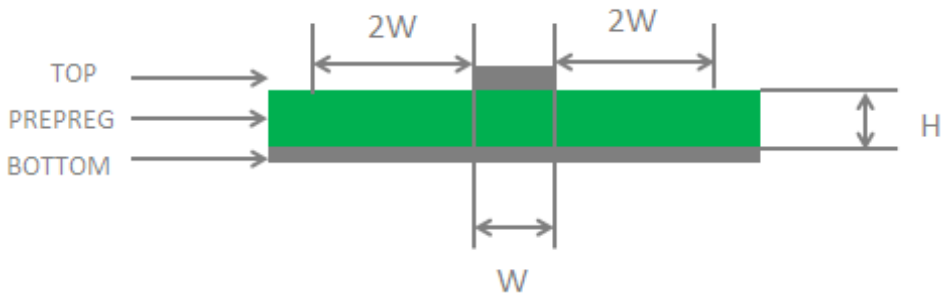



**Figure 18: Microstrip Design on a 2-layer PCB**

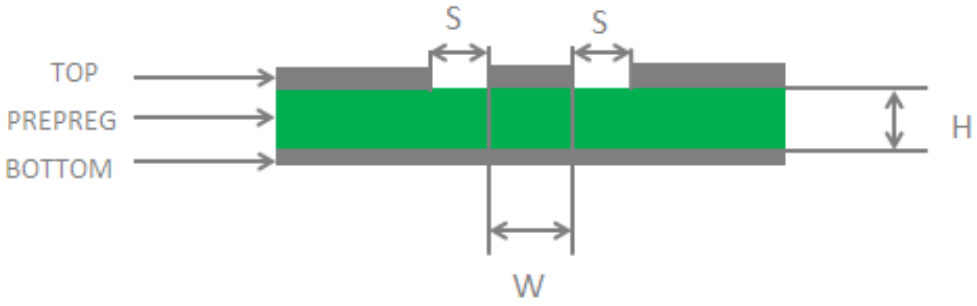



**Figure 19: Coplanar Waveguide Design on a 2-layer PCB**

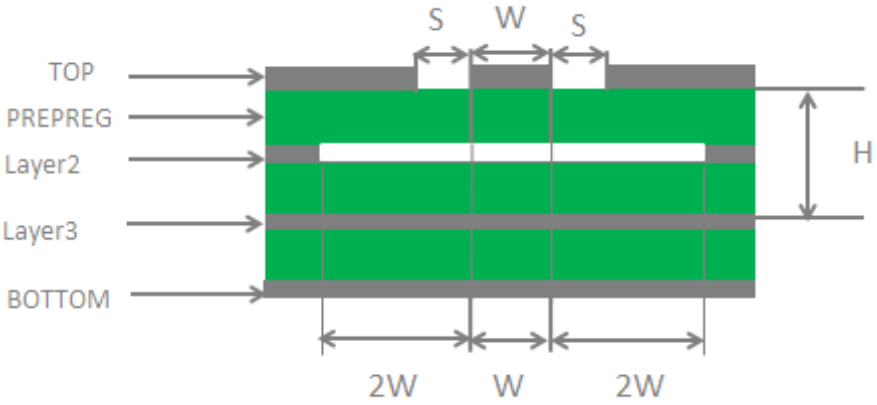



**Figure 20: Coplanar Waveguide Design on a 4-layer PCB (Layer 3 as Reference Ground)**

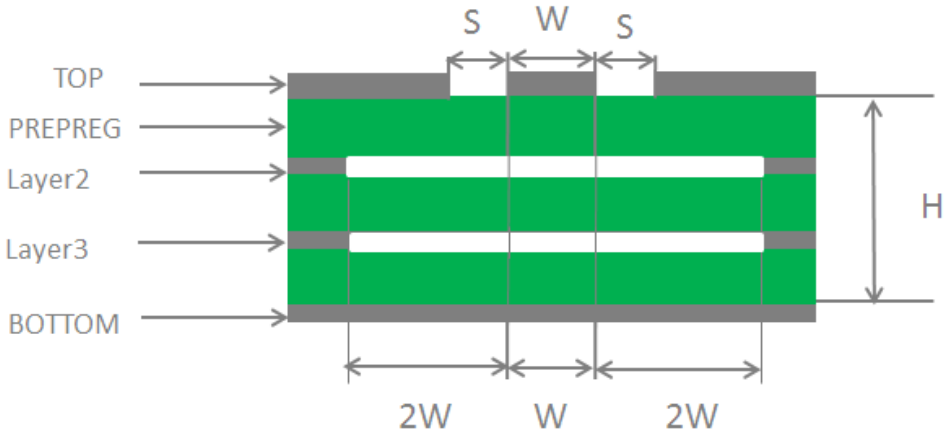



**Figure 21: Coplanar Waveguide Design on a 4-layer PCB (Layer 4 as Reference Ground)**

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 at least twice the width of RF signal traces (2 × W).
- Keep RF traces away from interference sources (such as DC-DC, (U)SIM/USB/SDIO high frequency digital signals, display signals, and clock signals), and avoid intersection and paralleling between traces on adjacent layers.

For more details about RF layout, see ***document [2].***

### 4.7.4. RF Connector Recommendation

If RF connector is used for antenna connection, it is recommended to use the HFM connector provided by Rosenberger.

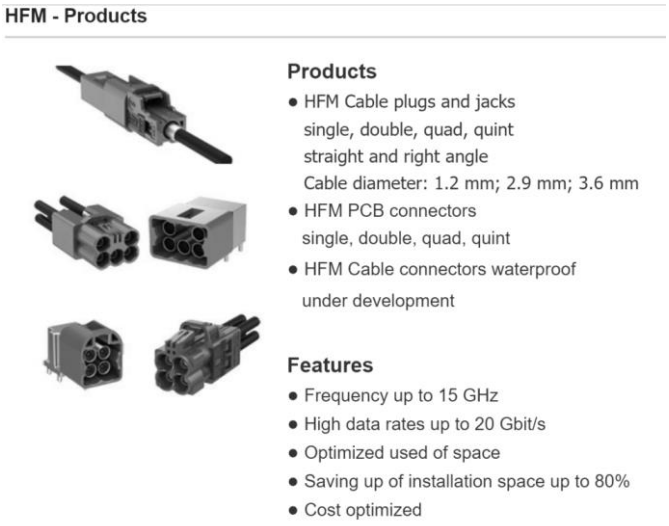



**Figure 22: HFM Connector**

For more details, visit https://www.rosenbergerap.com.

# 5 Electrical Characteristics and Reliability

## 5.1. Absolute Maximum Ratings

**Table 15: Absolute Maximum Ratings (Unit: V)**

| Parameter | Min. | Max. |
|---|---|---|
| VDD_CORE_VL | -0.3 | 2.1 |
| VDD_CORE_VM | -0.3 | 2.1 |
| VDD_CORE_VH | -0.3 | 2.1 |
| VDD_IO | -0.3 | VDD_IO + 0.2 |
| VDD_PA | -0.3 | VDD_PA + 0.4 |
| Digital I/O Input Voltage | -0.3 | VDD_IO + 0.2 |

## 5.2. Power Supply Ratings

**Table 16: Module's Power Supply Ratings (Unit: V)**

| Parameter | Description | Condition | Min. | Typ. | Max. |
|---|---|---|---|---|---|
| VDD_CORE_VL | Provide 0.95 V for Wi-Fi or Bluetooth modules | The actual input voltages must be kept between the minimum and maximum values. | 0.9 | 0.95 | 1.2 |
| VDD_CORE_VM | Provide 1.35 V for Wi-Fi or Bluetooth modules | | 1.30 | 1.35 | 1.42 |

| | | | | |
|---|---|---|---|---|
| VDD_CORE_VH | Provide 1.9 V for Wi-Fi or Bluetooth modules | 1.85 | 1.9 | 2.0 |
| VDD_IO | Provide 1.8 V for the module's I/O pins | 1.71 | 1.8 | 1.89 |
| VDD_PA | Provide 1.8 V for the module's RF part. | 1.71 | 1.8 | 2.1 |

## 5.3. Power Consumption

### 5.3.1. Wi-Fi Power Consumption [4]

**Table 17: Wi-Fi Power Consumption in Non-signaling Mode (Unit: mA)**

| Condition | | | $I_{VDD\_CORE\_VL}$ (AVG) | $I_{VDD\_CORE\_VM}$ (AVG) | $I_{VDD\_CORE\_VH}$ (AVG) | $I_{VDD\_IO}$ (AVG) | $I_{VDD\_PA}$ (AVG) |
|---|---|---|---|---|---|---|---|
| 2.4 GHz (2 × 2 MIMO) | 802.11n | Tx HT20 @ MCS 0 | 362 | 159 | 112 | 1.46 | 704 |
| | | Tx HT20 @ MCS 7 | 363 | 160 | 111 | 1.47 | 652 |
| | | Tx HT40 @ MCS 0 | 388 | 166 | 111 | 1.45 | 686 |
| | | Tx HT40 @ MCS 7 | 388 | 167 | 111 | 1.47 | 646 |
| | 802.11ax | Tx HE20 @ MCS 0 | 368 | 168 | 112 | 1.47 | 707 |
| | | Tx HE20 @ MCS 11 | 368 | 168 | 111 | 1.46 | 634 |
| | | Tx HE40 @ MCS 0 | 400 | 175 | 112 | 1.49 | 700 |
| | | Tx HE40 @ MCS 11 | 393 | 174 | 111 | 1.47 | 626 |
| 5 GHz (2 × 2 MIMO) | 802.11n | Tx HT20 @ MCS 0 | 395 | 209 | 95 | 1.34 | 827 |
| | | Tx HT20 @ MCS 7 | 397 | 209 | 94 | 1.30 | 771 |
| | | Tx HT40 @ MCS 0 | 427 | 216 | 94 | 1.27 | 815 |

[4] The Bluetooth function is disabled when the Wi-Fi power consumption is tested.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Tx HT40 @ MCS 7 | 423 | 216 | 94 | 1.30 | 762 |
| | 802.11ac | Tx VHT20 @ MCS 0 | 392 | 208 | 94 | 1.31 | 825 |
| | | Tx VHT20 @ MCS 8 | 393 | 209 | 94 | 1.31 | 768 |
| | | Tx VHT40 @ MCS 0 | 426 | 216 | 93 | 1.33 | 814 |
| | | Tx VHT40 @ MCS 9 | 422 | 216 | 94 | 1.33 | 756 |
| | | Tx VHT80 @ MCS 0 | 575 | 222 | 93 | 1.34 | 813 |
| | | Tx VHT80 @ MCS 9 | 570 | 221 | 93 | 1.36 | 757 |
| | | Tx VHT160 @ MCS 0 | 662 | 228 | 98 | 1.34 | 821 |
| | | Tx VHT160 @ MCS 9 | 659 | 227 | 96 | 1.34 | 754 |
| | 802.11ax | Tx HE20 @ MCS 0 | 403 | 209 | 105 | 1.40 | 832 |
| | | Tx HE20 @ MCS 11 | 400 | 209 | 102 | 1.37 | 745 |
| | | Tx HE40 @ MCS 0 | 433 | 217 | 105 | 1.33 | 818 |
| | | Tx HE40 @ MCS 11 | 427 | 216 | 102 | 1.36 | 741 |
| | | Tx HE80 @ MCS 0 | 585 | 222 | 104 | 1.33 | 819 |
| | | Tx HE80 @ MCS 11 | 578 | 221 | 102 | 1.33 | 740 |
| | | Tx HE160 @ MCS 0 | 674 | 227 | 98 | 1.34 | 823 |
| | | Tx HE160 @ MCS 11 | 672 | 226 | 97 | 1.34 | 743 |
| 6 GHz （2 × 2 MIMO） | 802.11ax | Tx HE20 @ MCS 0 | 415 | 221 | 201 | 1.24 | 860 |
| | | Tx HE20 @ MCS 11 | 411 | 220 | 193 | 1.21 | 735 |
| | | Tx HE40 @ MCS 0 | 451 | 227 | 193 | 1.23 | 830 |
| | | Tx HE40 @ MCS 11 | 438 | 227 | 193 | 1.21 | 726 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Tx HE80 @ MCS 0 | 582 | 225 | 187 | 1.22 | 785 |
| | Tx HE80 @ MCS 11 | 585 | 231 | 193 | 1.19 | 720 |
| | Tx HE160 @ MCS 0 | 663 | 235 | 183 | 1.22 | 746 |
| | Tx HE160 @ MCS 11 | 687 | 240 | 193 | 1.23 | 717 |

**NOTE**

1. Test conditions: ambient temperature 25 °C, and typical power domain.
2. The above power consumption data is the typical value for your reference only. Actual values may vary among different modules due to differences in internal components, software versions and test ambient temperatures. For more details, please contact Quectel Technical Support.

### 5.3.2. Bluetooth Power Consumption [5]

**Table 18: Bluetooth Power Consumption in Non-signaling Mode (Unit: mA)**

| Condition | $I_{VDD\_CORE\_VL}$ (AVG) | $I_{VDD\_CORE\_VM}$ (AVG) | $I_{VDD\_CORE\_VH}$ (AVG) | $I_{VDD\_IO}$ (AVG) |
|---|---|---|---|---|
| BR (GFSK) @ 6 dBm | 14 | 25 | 33 | 0.9 |
| EDR (π/4-DQPSK) @ 2 dBm | 14 | 29 | 32 | 0.9 |
| EDR (8-DPSK) @ 2 dBm | 14 | 29 | 32 | 0.9 |
| BLE (1 Mbps) @ 6 dBm | 10 | 24 | 44 | 0.9 |
| BLE (2 Mbps) @ 6 dBm | 8 | 16 | 26 | 0.9 |
| BLE (S = 2) @ 6 dBm | 12 | 27 | 55 | 0.9 |
| BLE (S = 8) @ 6 dBm | 10 | 20 | 40 | 0.9 |

**NOTE**

1. Test conditions: ambient temperature 25 °C, and typical power domain.

[5] The Wi-Fi function is disabled when the Bluetooth power consumption is tested.

2. The above power consumption data is the typical value for your reference only. Actual values may vary among different modules due to differences in internal components, software versions and test ambient temperatures. For more details, please contact Quectel Technical Support.

## 5.4. Digital I/O Characteristics

**Table 19: VDD_IO I/O Characteristics (Unit: V)**

| Parameter | Description | Min. | Max. |
|---|---|---|---|
| $V_{IH}$ | High-level input voltage | 0.7 × VDD_IO | VDD_IO + 0.2 |
| $V_{IL}$ | Low-level input voltage | -0.3 | 0.3 × VDD_IO |
| $V_{OH}$ | High-level output voltage | VDD_IO - 0.45 | VDD_IO |
| $V_{OL}$ | Low-level output voltage | 0 | 0.45 |
| $I_{iH}$ | High-level input leakage current | - | 1 |
| $I_{iL}$ | Low-level input leakage current | -1 | - |
| $I_{OH}$ | High-level output current | 2 | - |
| $I_{OL}$ | Low-level output current | - | -16 |

## 5.5. 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 20: ESD Characteristics (Temperature: 25-30 °C, Humidity: 40 ±5 %; Unit: kV)**

| Test Interfaces | Contact Discharge | Air Discharge |
|---|---|---|
| VDD_CORE_VL | ±6 | ±10 |

| | | |
|---|---|---|
| VDD_CORE_VM | ±6 | ±10 |
| VDD_CORE_VH | ±6 | ±10 |
| VDD_PA | ±6 | ±10 |
| VDD_IO | ±6 | ±10 |
| GND | ±6 | ±10 |
| All antenna interfaces | ±6 | ±10 |

## 5.6. Thermal Dissipation

The module exhibits the best performance when all internal chips are working within their designated operating temperature ranges. However, if any chip reaches or exceeds its maximum temperature, the module may still work but its performance and functionalities (such as RF output power and data rate) will be compromised. Therefore, the thermal design should be maximally optimized to ensure that all internal chips consistently remain within their recommended operating temperature ranges.

The following principles for thermal consideration are provided for reference:

- Keep the module away from heat sources on the PCB motherboard, 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.
- Expose the copper on the backside of the PCB where the module is mounted.
- Follow the principles below when designing the heatsink:
  - It is recommended to integrate the heatsink with the outer shell of telematic control unit (TCU) according to the module's application scenario. This allows for rapid transfer of the heat generated by the module to the outer shell, thus enhancing heat dissipation efficiency and eliminating the need for fixing the heatsink.
  - The entire shell of the TCU or the shell of the area where the module is located must be made of materials with excellent heat dissipation properties. It is recommended to use die-cast aluminum with higher thermal conductivity.
  - Based on the heat dissipation direction of the module, you can choose either of the following optional heatsink installation positions:
    a) The top surface of the module shielding cover;
    b) The bottom surface of the PCBA under the module;
    c) Both the top surface of the module shielding cover and the bottom surface of the PCBA under the module.

    If the heatsink is located only on one side, option a) is recommended; if the situation allows, option c) is recommended.

- The heatsink must meet the following requirements:
  a) The base plate area of the heatsink should be larger than the module area for full coverage;
  b) Choose a heatsink with adequate fins to ensure effective heat dissipation. The fins should be located within the area where the module is mounted.
- Since the heatsink is in contact with either the top surface of the shielding cover or the bottom surface of the PCBA through the thermal interface material (TIM), it is necessary to choose a TIM with high thermal conductivity, good flexibility, and good wettability.
- Fasten the shell (heatsink) with screws around the TCU to prevent the heatsink from falling off during the drop tests, shock and vibration tests, or transportation.

- Implement other auxiliary cooling methods, such as air cooling or liquid cooling.

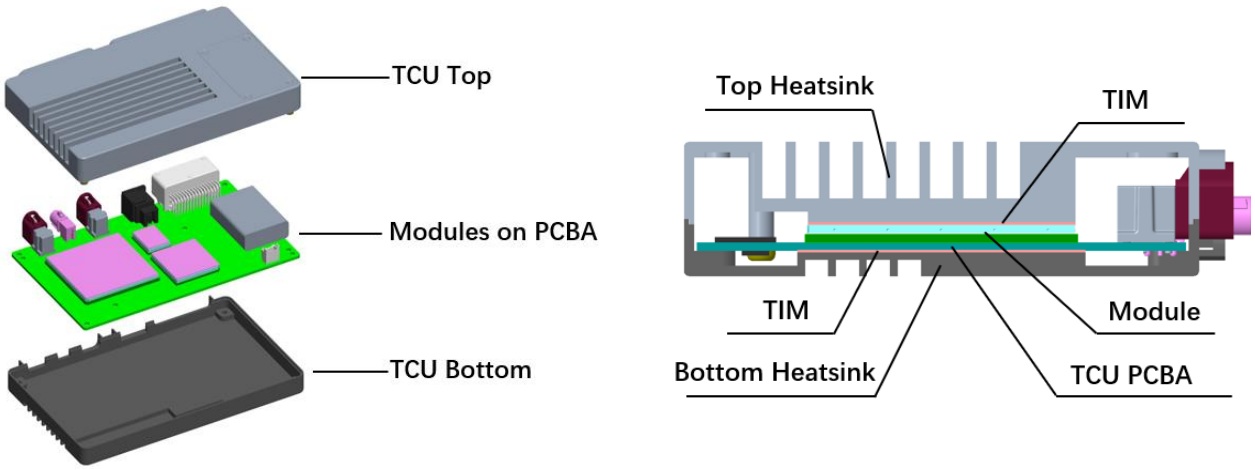



**Figure 23: Heatsink Design Example**

# 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

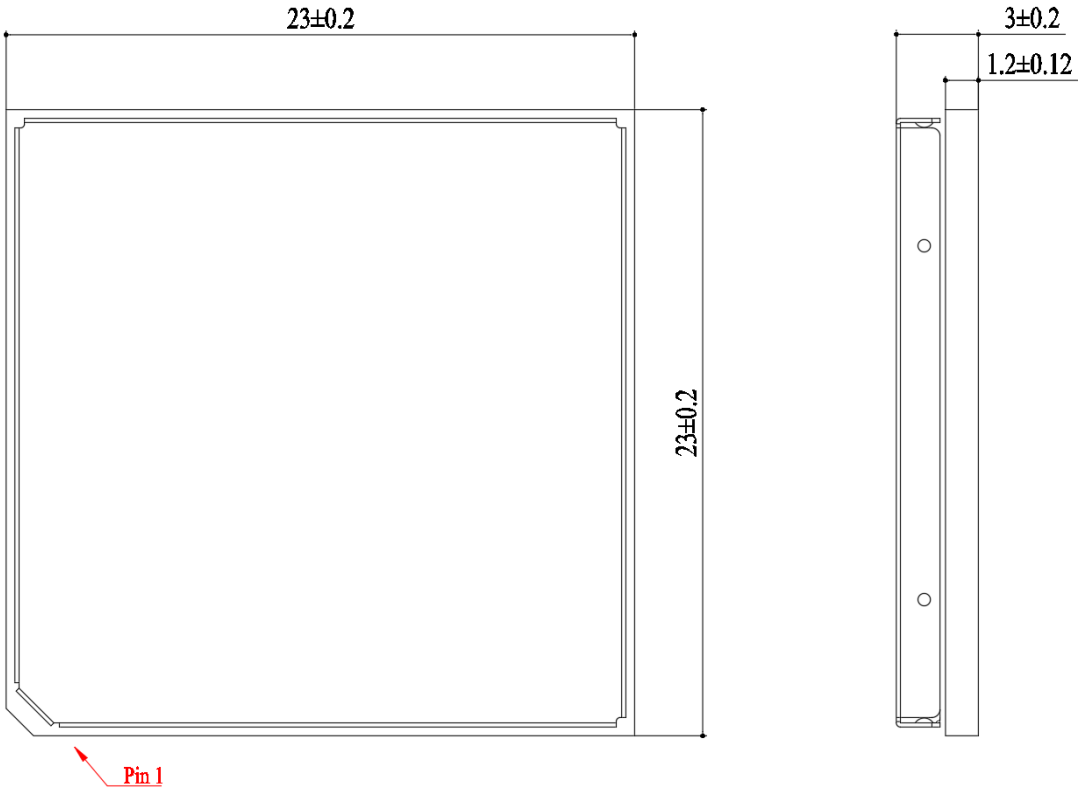



**Figure 24: Top and Side Dimensions**

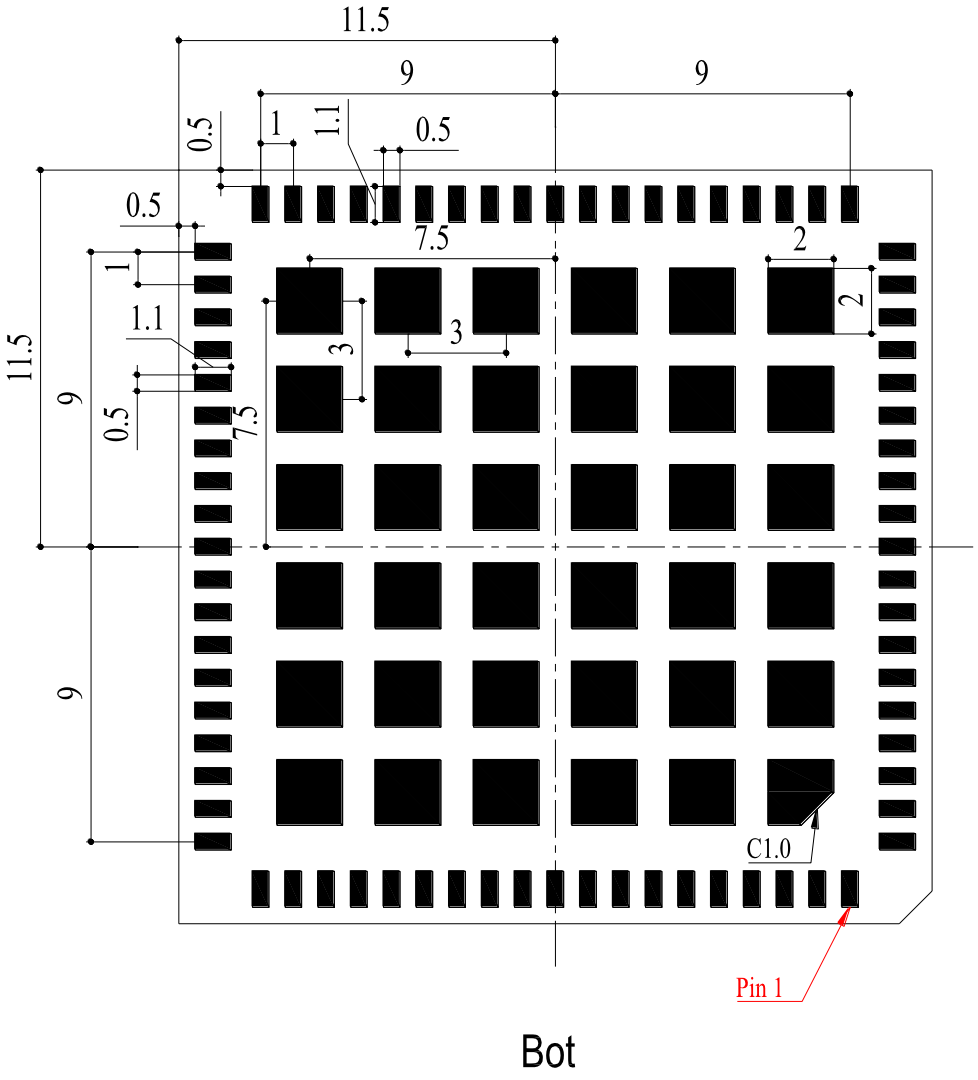



**Figure 25: Bottom Dimensions (Bottom View)**

**NOTE**

The module's coplanarity standard: ≤ 0.13 mm.

## 6.2. Recommended Footprint

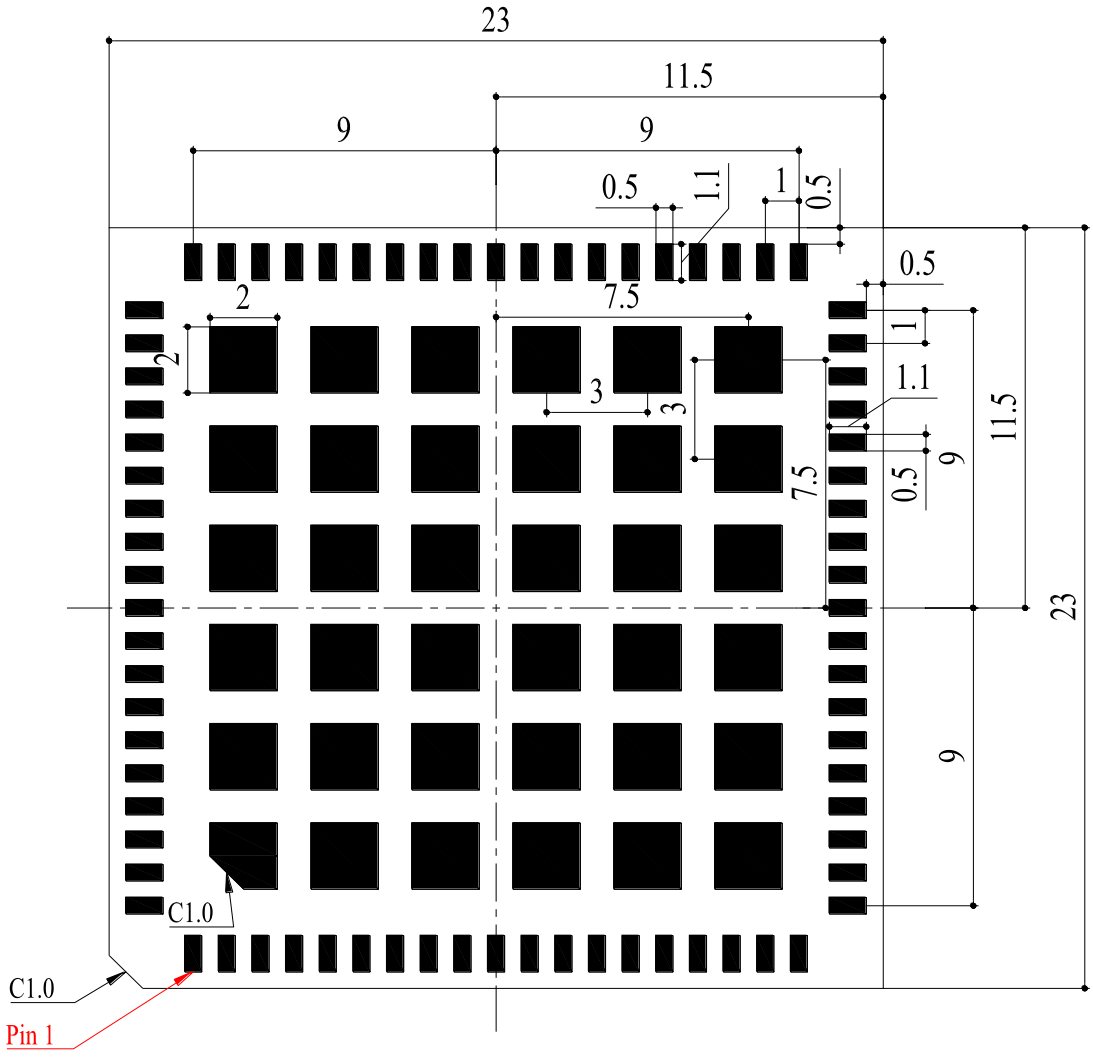



**Figure 26: Recommended Footprint**

**NOTE**

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

# 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 [6] 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;

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.

**NOTE**

1. To avoid blistering, layer separation and other soldering issues, extended exposure of the module to the air is forbidden.

[6] 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*. And do not unpack the modules in large quantities until they are ready for soldering.

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 0.12–0.15 mm. For more details, see ***document [3]***.

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:

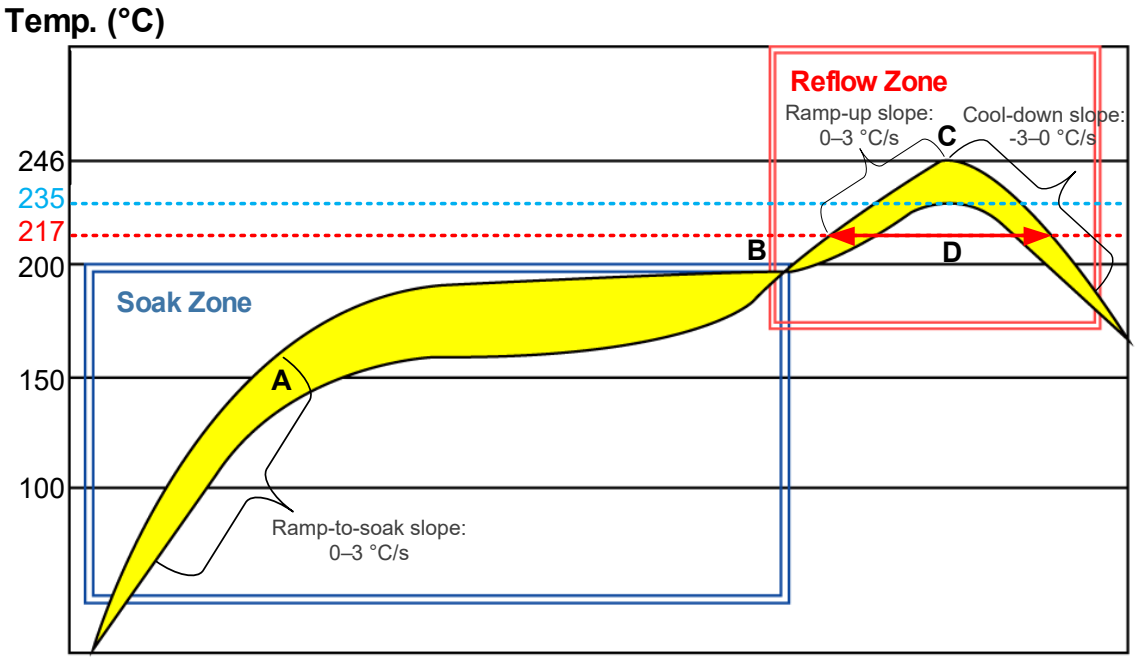



**Figure 27: Recommended Reflow Soldering Thermal Profile**

**Table 32: 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. Due to the large-size form factor, to avoid excessive temperature change, which may cause excessive thermal deformation of the metal shielding frame and cover, it is recommended to reduce the ramp-up and cool-down slopes in the liquid phase of the solder paste. If possible, please choose a reflow oven with more than 10 temperature zones during production so that there are more temperature zones to set up to meet the optimal temperature curve.
3. 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.
4. Avoid using ultrasonic technology for module cleaning since it can damage crystals inside the module.
5. Avoid using materials that contain mercury (Hg), such as adhesives, for module processing, even if the materials are RoHS compliant and their mercury content is below 1000 ppm (0.1 %).
6. Corrosive gases may corrode the electronic components inside the module, affecting their reliability and performance, and potentially leading to a shortened service life that fails to meet the designed lifespan. Therefore, do not store or use unprotected modules in environments containing corrosive gases such as hydrogen sulfide, sulfur dioxide, chlorine, and ammonia.
7. 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 [4].***

## 7.3. Packaging Specification

This chapter outlines the key packaging parameters and processes. All figures below are for reference purposes only, as the actual appearance and structure of packaging materials may vary in delivery.

The modules are packed in a tape and reel packaging as specified in the sub-chapters below.

### 7.3.1. Carrier Tape

Carrier tape dimensions are illustrated in the following figure and table:

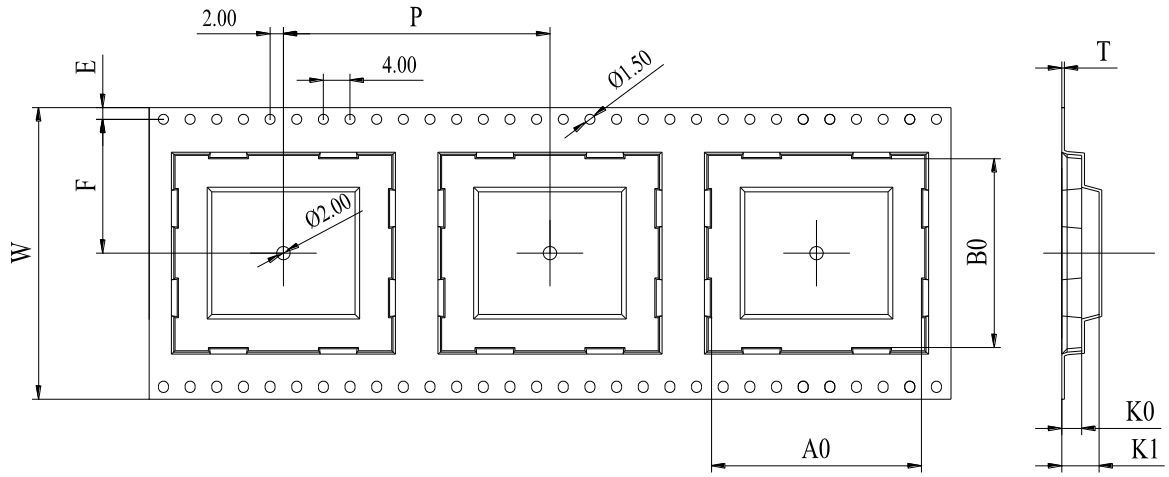



**Figure 28: Carrier Tape Dimension Drawing (Unit: mm)**

**Table 21: Carrier Tape Dimension Table (Unit: mm)**

| W | P | T | A0 | B0 | K0 | K1 | F | E |
|---|---|---|---|---|---|---|---|---|
| 44 | 32 | 0.4 | 23.5 | 23.5 | 3.5 | 6.8 | 20.2 | 1.75 |

### 7.3.2. Plastic Reel

Plastic reel dimensions are illustrated in the following figure and table:

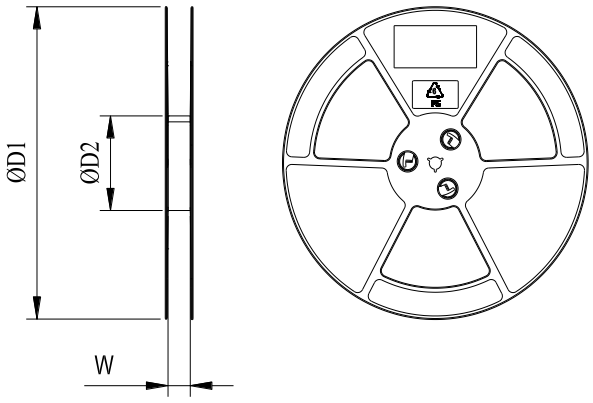



**Figure 29: Plastic Reel Dimension Drawing**

**Table 22: Plastic Reel Dimension Table (Unit: mm)**

| øD1 | øD2 | W |
|---|---|---|
| 330 | 100 | 44.5 |

### 7.3.3. Mounting Direction

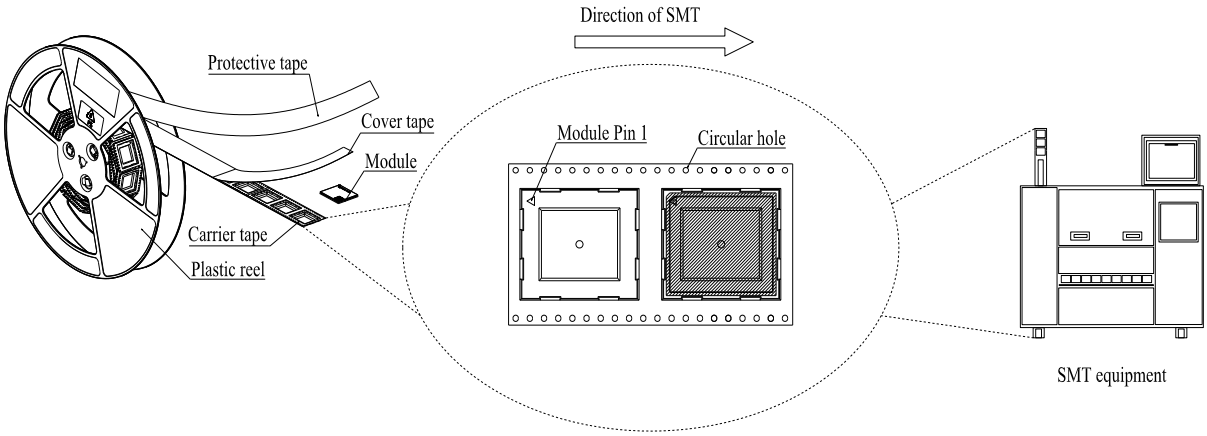
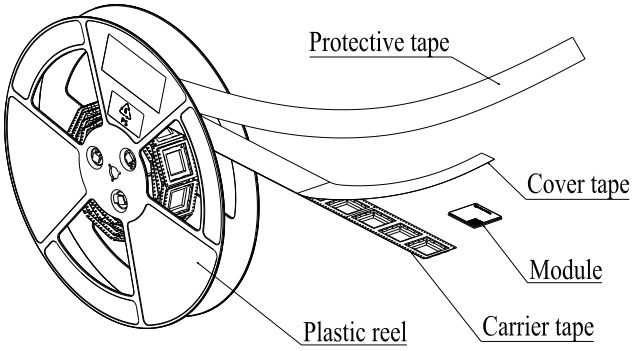


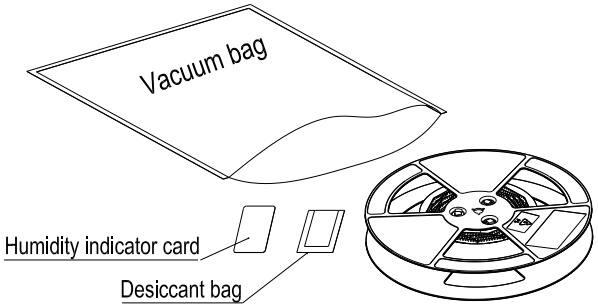

**Figure 30: Mounting Direction**

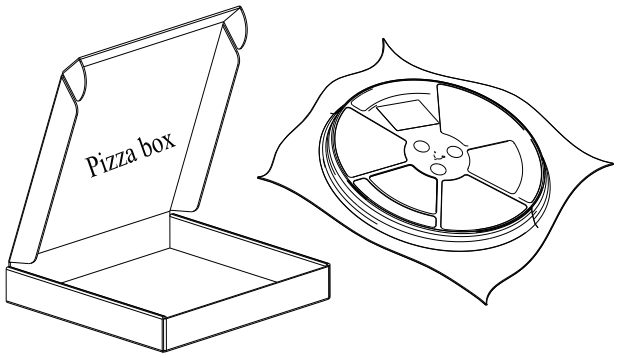
### 7.3.4. Packaging Process




Place the modules onto the carrier tape cavity and cover them securely with cover tape. Wind the heat-sealed carrier tape onto a plastic reel and apply a protective tape for additional protection. 1 plastic reel can pack 250 modules.

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




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

Place the 4 packaged pizza boxes into 1 carton and seal it. 1 carton can pack 1000 modules.

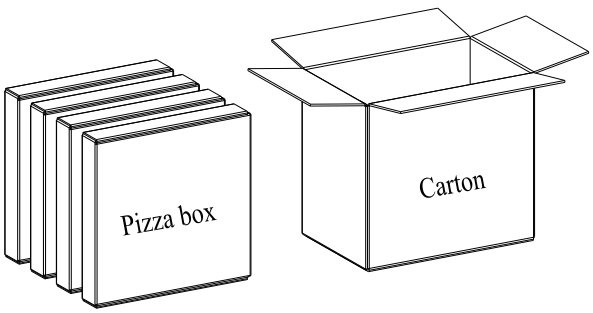



**Figure 31: Packaging Process**

# 8 Appendix References

**Table 35: Related Documents**

| Document Name |
|---|
| [1] Quectel_V2X&5G_EVB_User_Guide |
| [2] Quectel_RF_Layout_Application_Note |
| [3] Quectel_Module_Stencil_Design_Requirements |
| [4] Quectel_Module_SMT_Application_Note |

**Table 36: Terms and Abbreviations**

| Abbreviation | Description |
|---|---|
| AP | Application Processor |
| BLE | Bluetooth Low Energy |
| bps | Bits Per Second |
| BPSK | Binary Phase Shift Keying |
| BR | Basic Rate |
| CCK | Complementary Code Keying |
| CTS | Clear To Send |
| DBPSK | Differential Binary Phase Shift Keying |
| DPSK | Differential Phase Shift Keying |
| DQPSK | Differential Quadrature Phase Shift Keying |
| EDR | Enhanced Data Rate |
| GFSK | Gauss frequency Shift Keying |

| | |
|---|---|
| HCI | Host Controller Interface |
| I/O | Input/Output |
| LGA | Land Grid Array |
| LTE | Long Term Evolution |
| MCS | Modulation and Coding Scheme |
| MIMO | Multiple Input Multiple Output |
| PA | Power Amplifier |
| PCB | Printed Circuit Board |
| PCIe | Peripheral Component Interconnect Express |
| PCM | Pulse Code Modulation |
| PMIC | Power Management Integrated Circuit |
| QAM | Quadrature Amplitude Modulation |
| QPSK | Quadrature Phase Shift Keying |
| RF | Radio Frequency |
| Rx | Receive |
| STA | Station |
| TBD | To Be Determined |
| TRx | Transmit & Receive |
| Tx | Transmit |
| UART | Universal Asynchronous Receiver/Transmitter |
| VHT | Very High Throughput |
| Vmax | Maximum Voltage |
| Vnom | Nominal Voltage |
| Vmin | Minimum Voltage |
| WLAN | Wireless Local Area Network |

## CE

Hereby, [Quectel Wireless Solutions Co., Ltd.] declares that the radio equipment type [AF65E] is in compliance with Directive 2014/53/EU. The full text of the EU declaration of conformity is available at the following internet address: http://www.quectel.com/support/technical.htm

The device could be used with a separation distance of 20cm to the human body.

The device is restricted to indoor use only when operating in the 5250-5350 MHz frequency range.

| | | | | | | |
|---|---|---|---|---|---|---|
| AT | BE | BG | HR | CY | CZ | DK |
| EE | FI | FR | DE | EL | HU | IE |
| IT | LV | LT | LU | MT | NL | PL |
| PT | RO | SK | SI | ES | SE | UK(NI) |

## FCC

### OEM/Integrators Installation Manual

## Important Notice to OEM integrators

1. This module is limited to OEM installation ONLY.
2. This module is limited to installation in mobile or fixed applications, according to Part 2.1091(b).
3. The separate approval is required for all other operating configurations, including portable configurations with respect to Part 2.1093 and different antenna configurations
4. For FCC Part 15.31 (h) and (k): The host manufacturer is responsible for additional testing to verify compliance as a composite system. When testing the host device for compliance with Part15 Subpart B, the host manufacturer is required to show compliance with Part 15 Subpart B while the transmitter module(s) are installed and operating. The modules should be transmitting and the evaluation should confirm that the module's intentional emissions are compliant (i.e. fundamental and out of band emissions). The host manufacturer must verify that there are no additional unintentional emissions other than what is permitted in Part 15 Subpart B or emissions are complaint with the transmitter(s) rule(s).

The Grantee will provide guidance to the host manufacturer for Part 15 B requirements if needed.

## Important Note

notice that any deviation(s) from the defined parameters of the antenna trace, as described by the instructions, require that the host product manufacturer must notify to Quectel that they wish to change the antenna trace design. In this case, a Class II permissive change application is required to be filed by the USI, or the host manufacturer can take responsibility through the change in FCC ID (new application) procedure followed by a Class II permissive change application.

## End Product Labeling

When the module is installed in the host device, the FCC/IC ID label must be visible through a window on the final device or it must be visible when an access panel, door or cover is easily re-moved. If not, a

second label must be placed on the outside of the final device that contains the following text:
“Contains FCC ID: XMR2024AF65E”
“Contains IC: 10224A-2024AF65E”
The FCC ID/IC ID can be used only when all FCC/IC compliance requirements are met.

## Antenna Installation

(1) The antenna must be installed such that 20 cm is maintained between the antenna and users,
(2) The transmitter module may not be co-located with any other transmitter or antenna.
(3) Only antennas of the same type and with equal or less gains as shown below may be used with this module. Other types of antennas and/or higher gain antennas may require additional authorization for operation.

| Antenna type | 2400-2500MHz Peak Gain | 5150-5250MHz Peak Gain | 5250-5350MHz Peak Gain | 5470-5725MHz Peak Gain | 5725-5850MHz Peak Gain | 5925-7125MHz Peak Gain |
|---|---|---|---|---|---|---|
| Dipole | 0.2dBi | -0.7dBi | -0.8dBi | -1.2dBi | -1.5dBi | 1.6dBi |

(4) Antenna of VLP must be integral to the host device.
In the event that these conditions cannot be met (for example certain laptop configurations or co-location with another transmitter), then the FCC/IC authorization is no longer considered valid and the FCC ID/IC ID cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC/IC authorization.

## Manual Information to the End User

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user’s manual of the end product which integrates this module. The end user manual shall include all required regulatory information/warning as show in this manual.

## Federal Communication Commission Interference Statement

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.
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:
- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment. This transmitter must not be co-located or operating in

conjunction with any other antenna or transmitter.

## List of applicable FCC rules

This module has been tested and found to comply with part 15.247 and 15.407 requirements for Modular Approval.

The modular transmitter is only FCC authorized for the specific rule parts (i.e., FCC transmitter rules) listed on the grant, and that the host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification. If the grantee markets their product as being Part 15 Subpart B compliant (when it also contains unintentional-radiator digital circuity), then the grantee shall provide a notice stating that the final host product still requires Part 15 Subpart B compliance testing with the modular transmitter installed.

## This device is intended only for OEM integrators under the following conditions: (For module device use)

1) The antenna must be installed such that 20 cm is maintained between the antenna and users, and
2) The transmitter module may not be co-located with any other transmitter or antenna.

As long as 2 conditions above are met, further transmitter test will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed.

## Radiation Exposure Statement

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20 cm between the radiator & your body.

- The operation of this device is prohibited on oil platforms and aircraft, except that operation of this device in 5.925-6.425 GHz is permitted in large aircraft while flying above 10,000 feet.
- Installation on outdoor fixed infrastructure is prohibited.
- Controlling or communications with unmanned aircraft systems, including drones, is prohibited.

**IC: 10224A-2024AF65E**

## Industry Canada Statement

This device complies with Industry Canada’s licence-exempt RSSs. Operation is subject to the following two conditions:
(1) This device may not cause interference; and
(2) This device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:
(1) l'appareil ne doit pas produire de brouillage, et
(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement."

## Radiation Exposure Statement

This equipment complies with IC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20 cm between the radiator & your body.

## Déclaration d'exposition aux radiations:

Cet équipement est conforme aux limites d'exposition aux rayonnements ISED établies pour un environnement non contrôlé. Cet équipement doit être installé et utilisé avec un minimum de 20 cm de distance entre la source de rayonnement et votre corps.

## RSS-247 Section 6.4 (5) (6) (for local area network devices, 5GHz)

The device could automatically discontinue transmission in case of absence of information to transmit, or operational failure. Note that this is not intended to prohibit transmission of control or signaling information or the use of repetitive codes where required by the technology.

The device for operation in the band 5150–5250 MHz is only for indoor use to reduce the potential for harmful interference to co-channel mobile satellite systems;
The maximum antenna gain permitted for devices in the bands 5250–5350 MHz and 5470–5725 MHz shall comply with the e.i.r.p. limit; and
The maximum antenna gain permitted for devices in the band 5725–5825 MHz shall comply with the e.i.r.p. limits specified for point-to-point and non point-to-point operation as appropriate.

L'appareil peut interrompre automatiquement la transmission en cas d'absence d'informations à transmettre ou de panne opérationnelle. Notez que ceci n'est pas destiné à interdire la transmission d'informations de contrôle ou de signalisation ou l'utilisation de codes répétitifs lorsque cela est requis par la technologie.

Le dispositif utilisé dans la bande 5150-5250 MHz est réservé à une utilisation en intérieur afin de réduire le risque de brouillage préjudiciable aux systèmes mobiles par satellite dans le même canal;

Le gain d'antenne maximal autorisé pour les dispositifs dans les bandes 5250-5350 MHz et 5470-5725 MHz doit être conforme à la norme e.r.p. limite; et
Le gain d'antenne maximal autorisé pour les appareils de la bande 5725-5825 MHz doit être conforme à la norme e.i.r.p. les limites spécifiées pour un fonctionnement point à point et non point à point, selon le cas.

## This device is intended only for OEM integrators under the following conditions: (For module device use)

1) The antenna must be installed such that 20 cm is maintained between the antenna and users, and
2) The transmitter module may not be co-located with any other transmitter or antenna.
As long as 2 conditions above are met, further transmitter test will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed.

## Cet appareil est conçu uniquement pour les intégrateurs OEM dans les conditions suivantes: (Pour utilisation de dispositif module)

1) L'antenne doit être installée de telle sorte qu'une distance de 20 cm est respectée entre l'antenne et les utilisateurs, et
2) Le module émetteur peut ne pas être coïmplanté avec un autre émetteur ou antenne.

Tant que les 2 conditions ci-dessus sont remplies, des essais supplémentaires sur l'émetteur ne seront pas nécessaires. Toutefois, l'intégrateur OEM est toujours responsable des essais sur son produit final pour toutes exigences de conformité supplémentaires requis pour ce module installé.

## IMPORTANT NOTE:

In the event that these conditions cannot be met (for example certain laptop configurations or colocation with another transmitter), then the Canada authorization is no longer considered valid and the IC ID cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate Canada authorization.

## NOTE IMPORTANTE:

Dans le cas où ces conditions ne peuvent être satisfaites (par exemple pour certaines configurations d'ordinateur portable ou de certaines co-localisation avec un autre émetteur), l'autorisation du Canada n'est plus considéré comme valide et l'ID IC ne peut pas être utilisé sur le produit final. Dans ces circonstances, l'intégrateur OEM sera chargé de réévaluer le produit final (y compris l'émetteur) et l'obtention d'une autorisation distincte au Canada.

## End Product Labeling

This transmitter module is authorized only for use in device where the antenna may be installed such that 20 cm may be maintained between the antenna and users. The final end product must be labeled in a visible area with the following: “Contains IC: 10224A-2024AF65E”.

## Plaque signalétique du produit final

Ce module émetteur est autorisé uniquement pour une utilisation dans un dispositif où l'antenne peut être installée de telle sorte qu'une distance de 20cm peut être maintenue entre l'antenne et les utilisateurs. Le produit final doit être étiqueté dans un endroit visible avec l'inscription suivante: "Contient des IC: 10224A-2024AF65E".

## Manual Information To the End User

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user's manual of the end product which integrates this module.
The end user manual shall include all required regulatory information/warning as show in this manual.

## Manuel d'information à l'utilisateur final

L'intégrateur OEM doit être conscient de ne pas fournir des informations à l'utilisateur final quant à la façon d'installer ou de supprimer ce module RF dans le manuel de l'utilisateur du produit final qui intègre ce module.
Le manuel de l'utilisateur final doit inclure toutes les informations réglementaires requises et avertissements comme indiqué dans ce manuel.

Devices shall not be used for control of or communications with unmanned aircraft systems.
Devices shall not be used on oil platforms.
Devices shall not be used on aircraft, except for the low-power indoor access points, indoor subordinate devices, low-power client devices, and very low-power devices operating in the 5925-6425 MHz band, that may be used on large aircraft as defined in the Canadian Aviation Regulations, while flying above 3,048 metres (10,000 feet).

Les dispositifs ne doivent pas être utilisés pour le contrôle ou les communications avec les systèmes d'aéronef sans pilote.
Les dispositifs ne doivent pas être utilisés sur les plates-formes pétrolières.
Les dispositifs ne doivent pas être utilisés à bord des aéronefs, sauf pour les points d'accès intérieurs à faible puissance, les dispositifs subalternes intérieurs, les dispositifs clients à faible puissance et les dispositifs à très faible puissance fonctionnant dans la bande de 5925 à 6425 MHz, qui peuvent être utilisés sur les gros aéronefs au sens du règlement de l'aviation canadien, alors qu'ils volent à plus de 3048 mètres (10 000 pieds).