



# **RF-BM-2651B1 CC2651R3 SimpleLink™**

## **Single-protocol 2.4 GHz Wireless Module**

**Version 1.0**

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## 1 Device Overview

### 1.1 Description

RF-BM-2651B1 is an RF module based on TI lower-power CC2651R3 SoC. It integrates a 48 MHz crystal and a 32.768 kHz crystal, 352 KB of in-system Programmable Flash, 8 KB of Cache SRAM, and 32 KB of ultra-low leakage SRAM. Its ARM® Cortex®-M4 core application processor can operate at an extremely low current at flexible power modes. Its single-protocol 2.4 GHz RF transceiver is compatible with Bluetooth 5.3 Low Energy, ZigBee, SimpleLink TI 15.4-stack and Proprietary. It features a small size, robust connection distance, and rigid reliability.

### 1.2 Key Features

- RF Features
  - Zigbee®
  - Bluetooth® 5.3 Low Energy
  - SimpleLink™ TI 15.4-stack
  - Proprietary systems
- Modulation
  - 2-(G)FSK
  - 4-(G)FSK
  - MSK
- TX power: up to +5 dBm with temperature compensation
- RF sensitivity
  - -100 dBm for 802.15.4 (2.4 GHz)
  - -104 dBm for Bluetooth 125 kbps (LE coded PHY)
- Microcontroller
  - Powerful 48 MHz ARM® Cortex®-M4 processor
  - EEBMC CoreMark® score: 148
  - 2-pin cJTAG and JTAG debugging
  - Support OTA upgrade
- Memory
  - 352 KB of in-system programmable flash
  - 8 KB of cache SRAM
  - 32 KB of ultra-low leakage SRAM
- Wide Operation Range
  - Power supply: 1.8 V to 3.8 V
  - Operating temperature: -40 °C to +85 °C
  - Storage temperature: -40 °C to +125 °C
- Wide Peripherals
  - Up to 31 GPIOs, digital peripherals can be routed to any GPIO
  - Four 32-bit or eight 16-bit general-purpose timers
  - 12-bit ADC, 200 kSamples/s, 8 channels
  - 8-bit DAC
  - Analog Comparator
  - UART, SSI, I2C, I2S
  - Real-time clock (RTC)
  - Integrated temperature and battery monitor
- Security Enablers
  - AES 128 and 256 bit Crypto accelerator
  - True random number generator (TRNG)
  - Additional cryptography drivers available in Software Development Kit (SDK)
- Dimension: 22.5 mm × 15.55 mm × 2.1 mm

### 1.3 Applications

- Home and building automation
- Smart grid and automatic meter reading
- Wireless sensor networks
- Factory automation
- Wireless healthcare applications
- Energy harvesting applications

- Asset tracking and management

- Electronic Shelf Label (ESL)

## 1.4 Functional Block Diagram

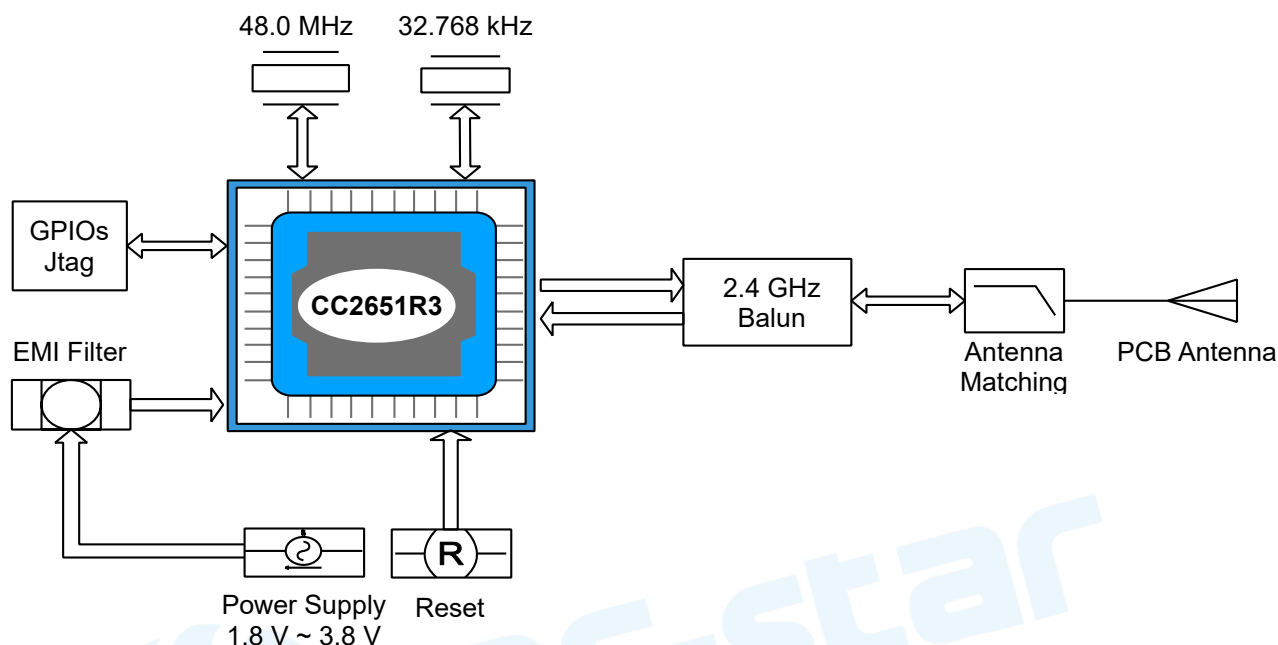


Figure 1. Functional Block Diagram of RF-BM-2651B1

## 1.6 Part Number Conventions

The part numbers are of the form of RF-BM-2651B1 where the fields are defined as follows:

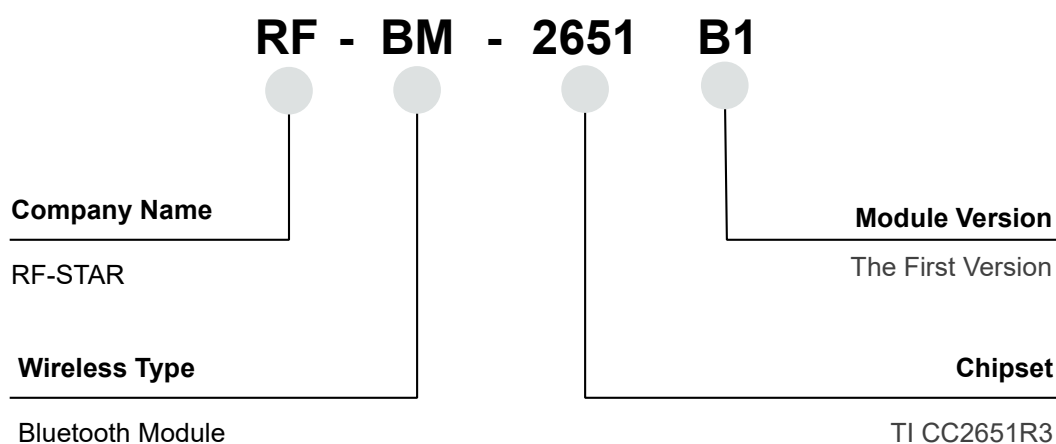


Figure 2. Part Number Conventions of RF-BM-2651B1

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## 2 Module Configuration and Functions

### 2.1 Module Parameters

Table 1. Parameters of RF-BM-2651B1

Chipset	CC2651R3
Supply Power Voltage	1.8 V ~ 3.8 V, 3.3 V is recommended
Frequency	2402 MHz ~ 2480 MHz
Maximum Transmit Power	+5.0 dBm
Receiving Sensitivity	-100 dBm @ 802.15.4 (2.4 GHz) -104 dBm @ Bluetooth 125 kbps (LE Coded PHY)
GPIO	23
Flash	352 KB
ROM	256 KB
SRAM	88 KB
Power Consumption	RX current: 6.4 mA TX current: 7.1 mA @ 0 dBm 9.5 mA @ 5 dBm MCU 48 MHz (CoreMark): 2.91 mA (61 $\mu$ A/MHz) Standby: 0.8 $\mu$ A Shutdown: 0.1 $\mu$ A
Support Protocol	Bluetooth 5.3 Low Energy, ZigBee, SimpleLink TI 15.4-stack, Proprietary
Crystal	48 MHz, 32.768 kHz
Package	SMT packaging (1.27-mm half-hole pitch stamp stick)
Dimension	22.5 mm × 15.55 mm × 2.1 mm
Type of Antenna	PCB antenna
Operating Temperature	-40 °C ~ +85 °C
Storage Temperature	-40 °C ~ +125 °C

## 2.2 Module Pin Diagram

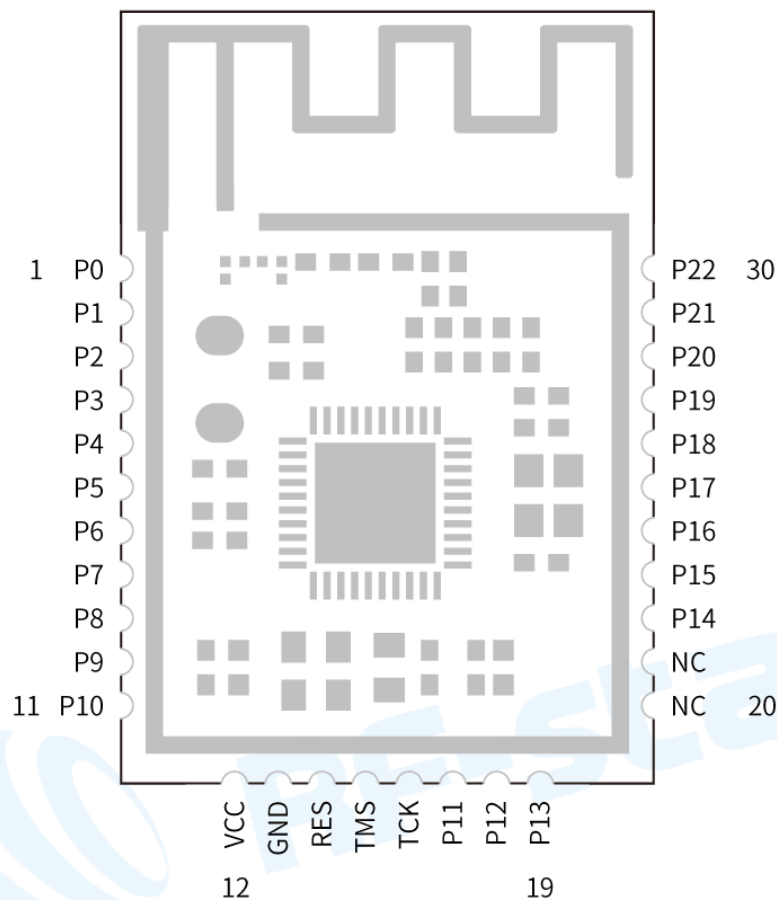


Figure 3. Pin Diagram of RF-BM-2651B1

## 2.3 Pin Functions

Table 2. Pin Functions of RF-BM-2651B1

Pin	Name	Chip Pin	Function	Description
1	P0	DIO_0	Digital	GPIO
2	P1	DIO_1	Digital	GPIO
3	P2	DIO_2	Digital	GPIO
4	P3	DIO_3	Digital	GPIO
5	P4	DIO_4	Digital	GPIO
6	P5	DIO_5	Digital	GPIO, high-drive capability
7	P6	DIO_6	Digital	GPIO, high-drive capability
8	P7	DIO_7	Digital	GPIO, high-drive capability
9	P8	DIO_8	Digital	GPIO
10	P9	DIO_9	Digital	GPIO

11	P10	DIO_10	Digital	GPIO, JTAG_TDO, high-drive capability
12	VCC	VCC		Power supply: 1.8 V ~ 3.8 V, recommend to 3.3 V
13	GND	Ground	Ground	Ground
14	RES	RES		Reset. Active pin.
15	TMS	JTAG_TMSC	Digital	JTAG TMS, high-drive capability
16	TCK	JTAG_TCKC	Digital	JTAG TCKC
17	P11	DIO_11	Digital	GPIO, JTAG_TDI, high-drive capability
18	P12	DIO_12	Digital	GPIO
19	P13	DIO_13	Digital	GPIO
20	NC			
21	NC			
22	P14	DIO_14	Digital	GPIO
23	P15	DIO_15	Digital or Analog	GPIO, analog capability
24	P16	DIO_16	Digital or Analog	GPIO, analog capability
25	P17	DIO_17	Digital or Analog	GPIO, analog capability
26	P18	DIO_18	Digital or Analog	GPIO, analog capability
27	P19	DIO_19	Digital or Analog	GPIO, analog capability
28	P20	DIO_20	Digital or Analog	GPIO, analog capability
29	P21	DIO_21	Digital or Analog	GPIO, analog capability
30	P22	DIO_22	Digital or Analog	GPIO, analog capability

### 3 Specifications

#### 3.1 Recommended Operating Conditions

The functional operation does not guarantee performance beyond the limits of the conditional parameter values in the table below. Long-term work beyond this limit will affect the reliability of the module more or less.

Table 3. Recommended Operating Conditions of RF-BM-2651B1

Items	Condition	Min.	Typ.	Max.	Unit
Operating Supply Voltage	/	1.8	3.3	3.8	V
Operating Temperature	/	-40	+25	+85	°C

#### 3.2 Handling Ratings

Table 4. Handling Ratings of RF-BM-2651B1

Items	Condition	Min.	Typ.	Max.	Unit
Storage Temperature	Tstg	-40	+25	+125	°C
Human Body Model	HBM		±2000		V
Moisture Sensitivity Level			3		
Charged Device Model			±500		V



## 4 Application, Implementation, and Layout

### 4.1 Module Photos

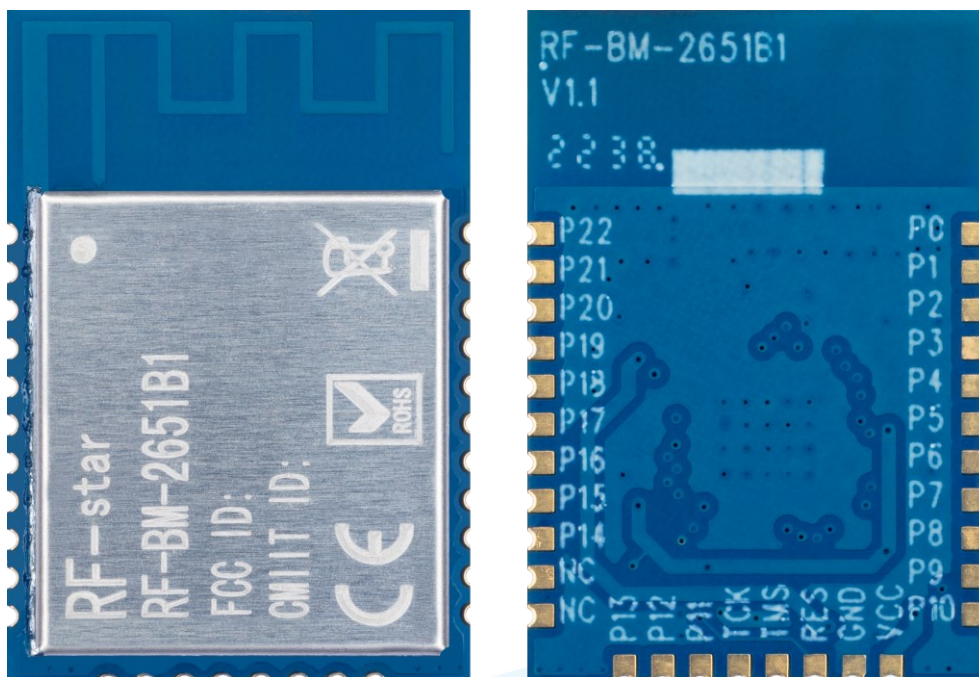


Figure 4. Photos of RF-BM-2651B1

### 4.2 Recommended PCB Footprint

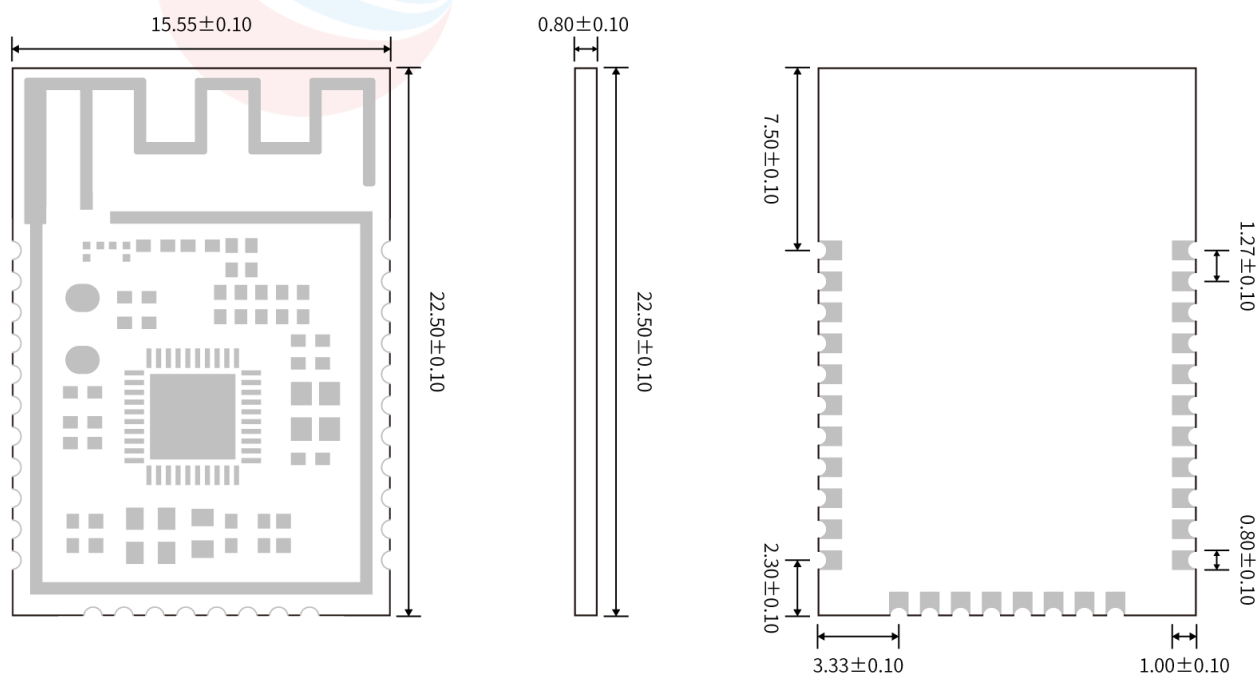


Figure 5. Recommended PCB Footprint of RF-BM-2651B1 (mm)

### 4.3 Schematic Diagram

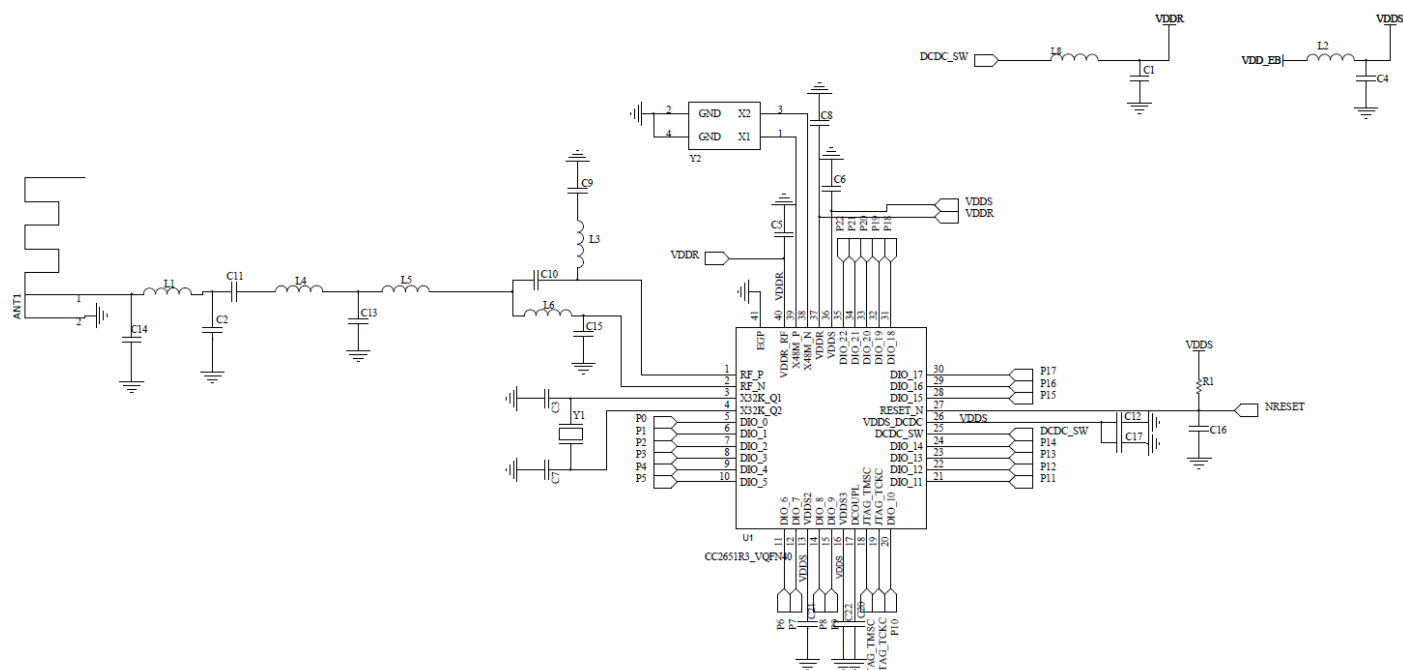


Figure 6. Schematic Diagram of RF-BM-2651B1

## 4.4 Reference Design

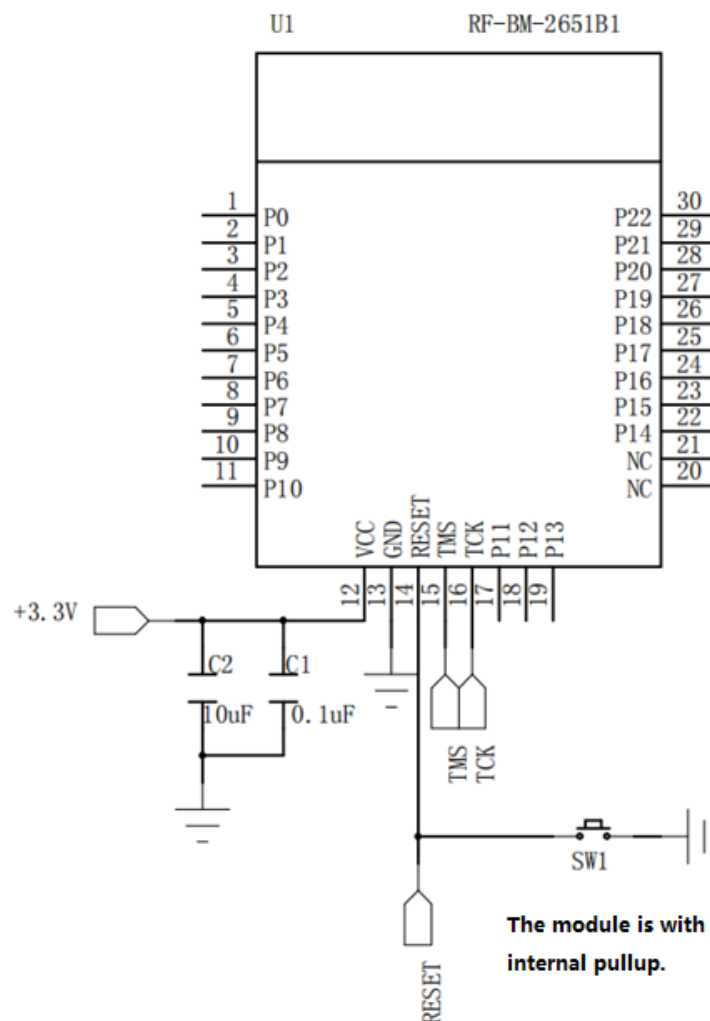


Figure 7. Reference Design of RF-BM-2651B1

## 4.5 Antenna

### 4.5.1 Antenna Design Recommendation

1. The antenna installation structure has a great influence on the module performance. It is necessary to ensure the antenna is exposed and preferably vertically upward. When the module is installed inside of the case, a high-quality antenna extension wire can be used to extend the antenna to the outside of the case.
2. The antenna must not be installed inside the metal case, which will cause the transmission distance to be greatly weakened.
3. The recommendation of antenna layout.

The inverted-F antenna position on PCB is free-space electromagnetic radiation. The location and layout of the antenna are key factors to increase the data rate and transmission range.

Therefore, the layout of the module antenna location and routing is recommended as follows:

- (1) Place the antenna on the edge (corner) of the PCB.
- (2) Make sure that there is no signal line or copper foil in each layer below the antenna.
- (3) It is best to hollow out the antenna position in the following figure to ensure that the S11 of the module is minimally affected.

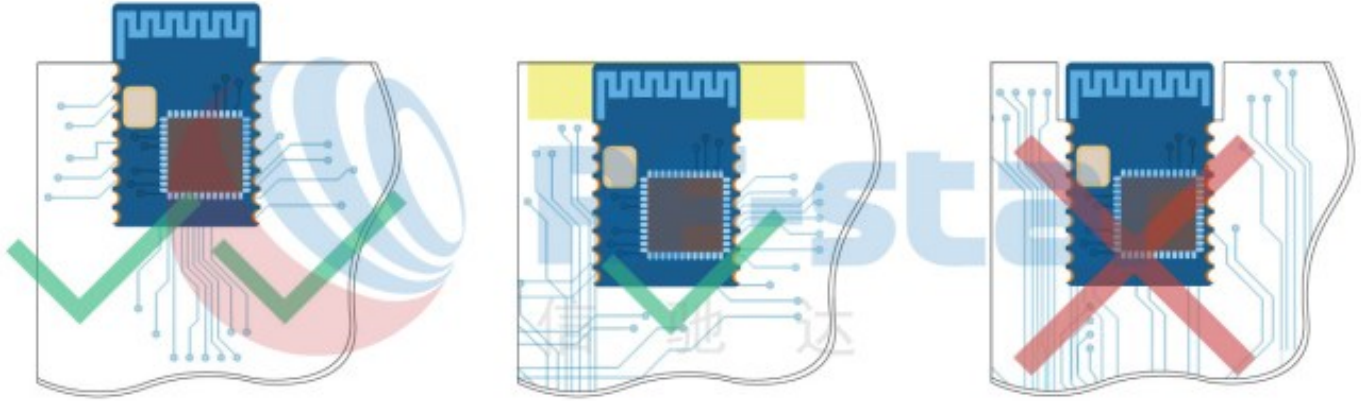


Figure 8. Recommendation of Antenna Layout

Note: The hollow-out position is based on the antenna used.

#### 4.6 Basic Operation of Hardware Design

1. It is recommended to offer the module a DC stabilized power supply, a tiny power supply ripple coefficient, and reliable ground. Please pay attention to the correct connection between the positive and negative poles of the power supply. Otherwise, the reverse connection may cause permanent damage to the module.
2. Please ensure the supply voltage is between the recommended values. The module will be permanently damaged if the voltage exceeds the maximum value. Please ensure a stable power supply and no frequently fluctuating voltage.
3. When designing the power supply circuit for the module, it is recommended to reserve more than 30% of the margin, which is beneficial to the long-term stable operation of the whole machine. The module should be far away from the power electromagnetic, transformer, high-frequency wiring, and other parts with large electromagnetic interference.
4. The bottom of the module should avoid high-frequency digital routing, high-frequency analog routing, and power routing. If it has to route the wire on the bottom of the module, for example, it is assumed that the module is soldered to the Top Layer, the copper must be spread on the connection part of the top layer and the module, and be close to the digital part of the module and routed in the Bottom Layer (all copper is well-grounded).
5. Assuming that the module is soldered or placed in the Top Layer, it is also wrong to randomly route the Bottom Layer or other layers, which will affect the spurs and receiving sensitivity of the module to some degree.
6. Assuming that there are devices with large electromagnetic interference around the module, which will greatly affect the module performance. It is recommended to stay away from the module according to the strength of the

interference. If circumstances permit, appropriate isolation and shielding can be done.

7. Assuming that there are routings of large electromagnetic interference around the module (high-frequency digital, high-frequency analog, power routings), which will also greatly affect the module performance. It is recommended to stay away from the module according to the strength of the interference. If circumstances permit, appropriate isolation and shielding can be done.
8. It is recommended to stay away from devices whose TTL protocol is the same 2.4 GHz physical layer, for example, USB 3.0.

## **4.7 Trouble Shooting**

### **4.7.1 Unsatisfactory Transmission Distance**

1. When there is a linear communication obstacle, the communication distance will be correspondingly weakened. Temperature, humidity, and co-channel interference will lead to an increase in the communication packet loss rate. The performance of ground absorption and reflection of radio waves will be poor when the module is tested close to the ground.
2. Seawater has a strong ability to absorb radio waves, so the test results by the seaside are poor.
3. The signal attenuation will be very obvious if there is metal near the antenna or if the module is placed inside the metal shell.
4. The incorrect power register set or the high data rate in the open air may shorten the communication distance. The higher the data rate, the closer the distance.
5. The low voltage of the power supply is lower than the recommended value at ambient temperature, and the lower the voltage, the smaller the power is.
6. The unmatchable antennas and modules or the poor quality of antenna will affect the communication distance.

### **4.7.2 Vulnerable Module**

1. Please ensure the supply voltage is between the recommended values. The module will be permanently damaged if the voltage exceeds the maximum value. Please ensure a stable power supply and no frequently fluctuating voltage.
2. Please ensure the anti-static installation and the electrostatic sensitivity of high-frequency devices.
3. Due to some humidity-sensitive components, please ensure the suitable humidity during installation and application. If there is no special demand, it is not recommended to use at too high or too low temperature.

### **4.7.3 High Bit Error Rate**

1. There are co-channel signal interferences nearby. It is recommended to be away from the interference sources or modify the frequency and channel to avoid interferences.

2. The unsatisfactory power supply may also cause garbled. It is necessary to ensure the power supply's reliability.
3. If the extension wire or feeder wire is of poor quality or too long, the bit error rate will be high.

## 4.8 Electrostatics Discharge Warnings

The module will be damaged by the discharge of static. RF-star suggests that all modules should follow the 3 precautions below:

1. According to the anti-static measures, bare hands are not allowed to touch modules.
2. Modules must be placed in anti-static areas.
3. Take the anti-static circuitry (when inputting HV or VHF) into consideration in product design.

Static may result in the degradation in performance of the module, even causing failure.

## 4.9 Soldering and Reflow Condition

1. Heating method: Conventional Convection or IR/convection.
2. Solder paste composition: Sn96.5/Ag3.0/Cu0.5
3. Allowable reflow soldering times: 2 times based on the following reflow soldering profile.
4. Temperature profile: Reflow soldering shall be done according to the following temperature profile.
5. Peak temperature: 245 °C.

Table 5. Temperature Table of Soldering and Reflow

Profile Feature	Sn-Pb Assembly	Pb-Free Assembly
<b>Solder Paste</b>	Sn63 / Pb37	Sn96.5 / Ag3.0 / Cu0.5
<b>Min. Preheating Temperature (<math>T_{min}</math>)</b>	100 °C	150 °C
<b>Max. Preheating Temperature (<math>T_{max}</math>)</b>	150 °C	200 °C
<b>Preheating Time (<math>T_{min}</math> to <math>T_{max}</math>) (<math>t_1</math>)</b>	60 s ~ 120 s	60 s ~ 120 s
<b>Average Ascend Rate (<math>T_{max}</math> to <math>T_p</math>)</b>	Max. 3 °C/s	Max. 3 °C/s
<b>Liquid Temperature (<math>T_L</math>)</b>	183 °C	217 °C
<b>Time above Liquidus (<math>t_L</math>)</b>	60 s ~ 90 s	30 s ~ 90 s
<b>Peak Temperature (<math>T_p</math>)</b>	220 °C ~ 235 °C	230 °C ~ 250 °C
<b>Average Descend Rate (<math>T_p</math> to <math>T_{max}</math>)</b>	Max. 6 °C/s	Max. 6 °C/s
<b>Time from 25 °C to Peak Temperature (<math>t_2</math>)</b>	Max. 6 minutes	Max. 8 minutes
<b>Time of Soldering Zone (<math>t_p</math>)</b>	20±10 s	20±10 s

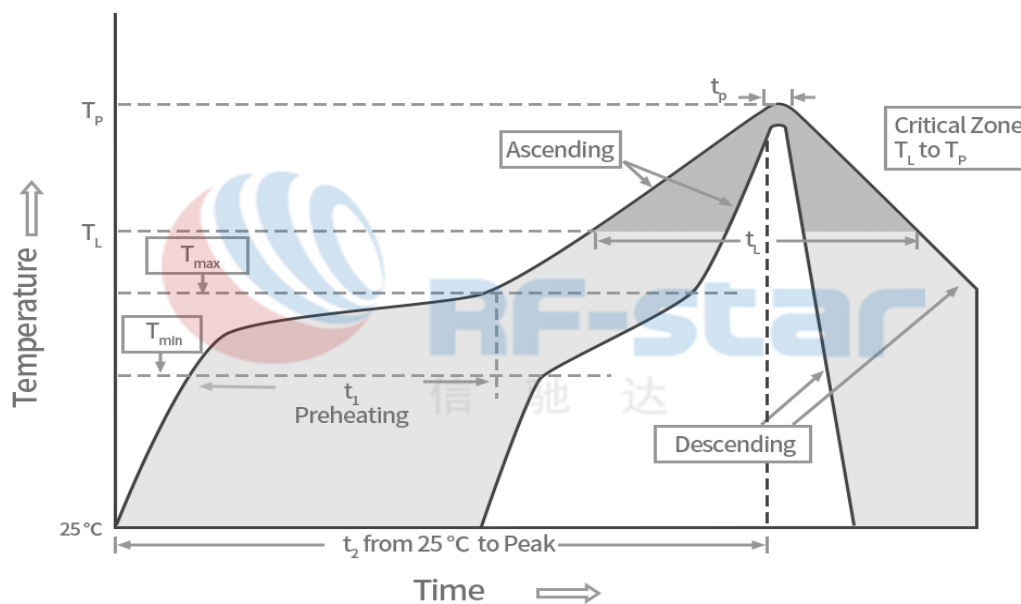


Figure 9. Recommended Reflow for Lead-Free Solder



## 5 Optional Package Specification

The default package method is **by tray**. If you need the modules to be shipped by tape & reel, pls contact us in advance.

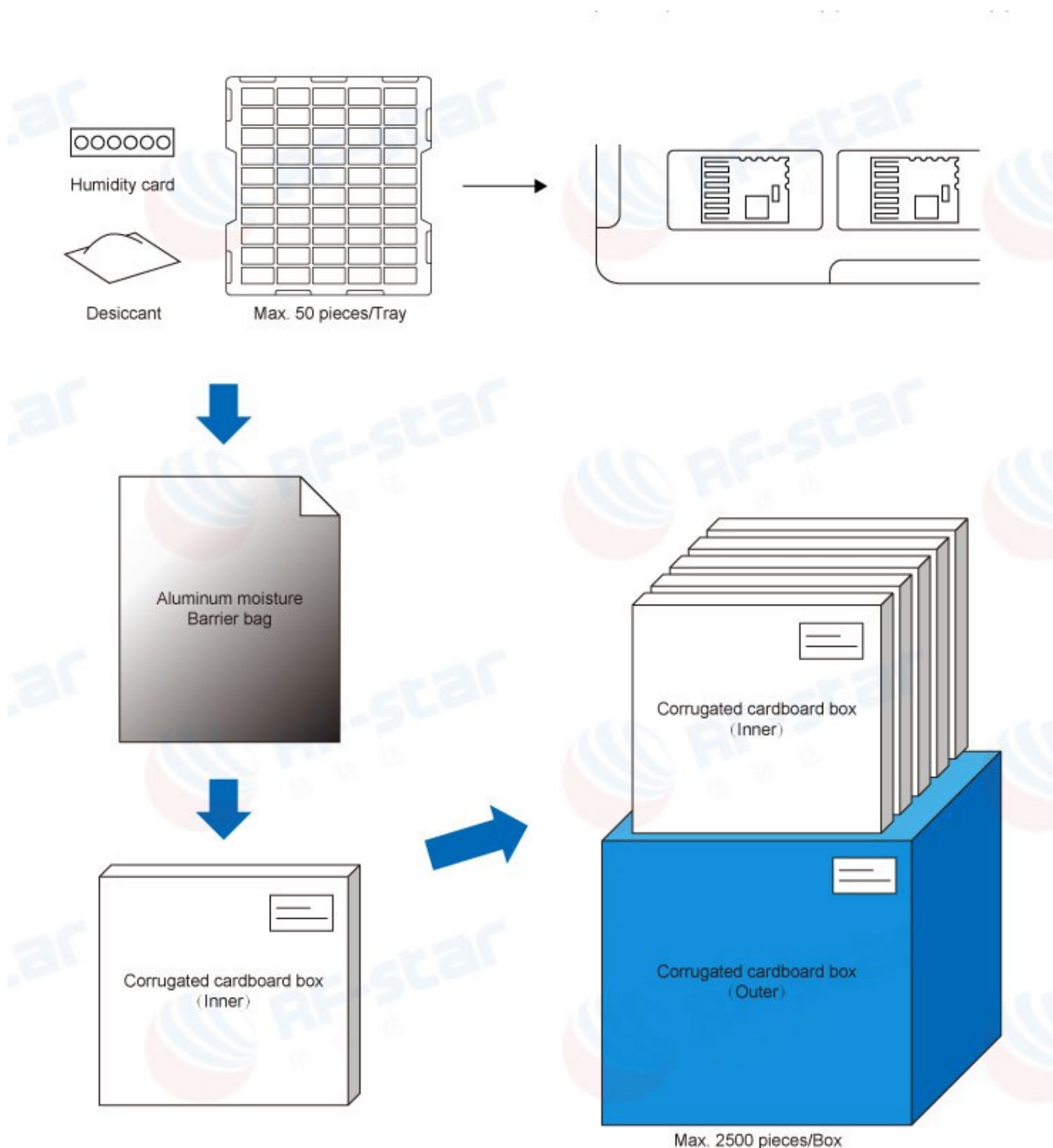


Figure 10. Default Package by Tray



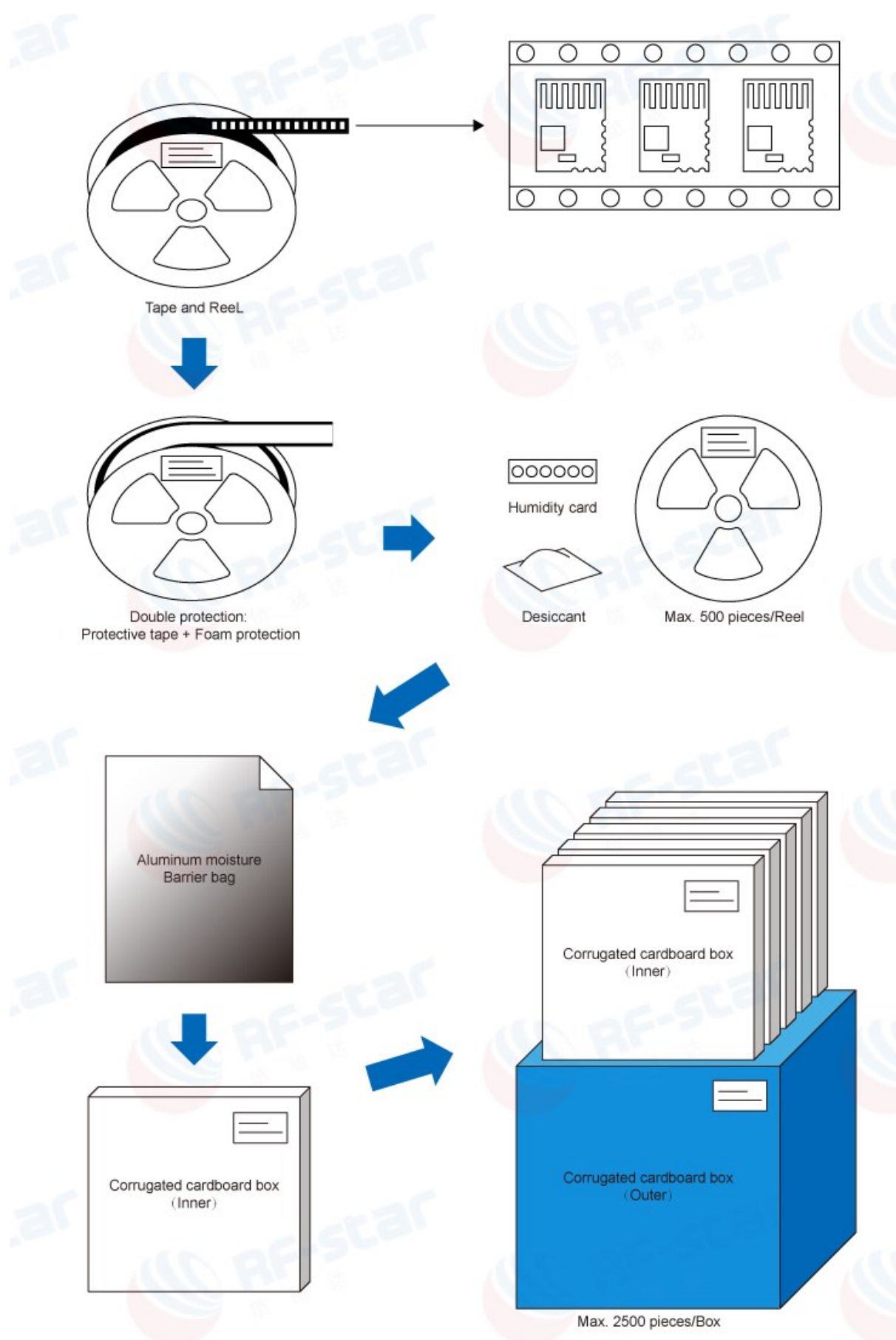


Figure 11. Package by Tape &amp; Reel

## 6 Revision History

Date	Version No.	Description
2023.03.21	V1.0	The initial version is released.
2023.05.25	V1.0	Update the mistake of pin description. Update the MSL level. Update the Shenzhen office address.

Note:

1. The document will be optimized and updated from time to time. Before using this document, please make sure it is the latest version.
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## 7 Contact Us

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