RF-BMPA-2541B1

Bluetooth Low Energy Module

Version 1.1

Shenzhen RF-star Technology Co., Ltd.

May 26th, 2023

1 Device Overview

1.1 Description

RF-BMPA-2541B1 is a Bluetooth Low Energy (BLE) module based on TI CC2541F256, an 8051 core BLE System-on-Chip (SoC) and a PA of CC2592. This PCB module integrates one 32 MHz crystal, one 32.768 kHz crystal, an LC balun, a chip matching, a high-performance PCB antenna, an IPEX connector, and half-hole antenna interface for different customer needs to develop. It is pre-programmed with the BLE 4.0 stack and an application communication protocol over its serial interface. It enables users to quickly connect their application MCUs to build reliable BLE connection from their products to smart phones.

1.2 Key Features

- RF
  - 2.4 GHz Bluetooth low energy 4.0 compatible and proprietary RF system-on-chip
  - Supports 250 kbps, 500 kbps, 1 Mbps, 2 Mbps data rates
  - Excellent link budget, enabling long-range applications without external front end
  - Excellent receiver sensitivity (-94 dBm at 1 Mbps), selectivity, and Blocking performance
  - Suitable for systems targeting compliance with worldwide radio frequency regulations: ETSI EN 300 328 and EN 300 440 Class 2 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T66 (Japan)
- Microcontroller
  - High-performance and low-power 8051 microcontroller core with code prefetch
  - In-system-programmable flash of 256 KB
  - 8-KB RAM with retention in all power modes
  - Hardware debug support
  - Extensive baseband automation, including auto-acknowledgment and address decoding
  - Retention of all relevant registers in all power modes
- Layout
  - Few external components
  - 31.4 mm x 13.7 mm in SMT Package
- Peripherals
  - Powerful five-channel DMA
  - 12 Bit ADC with eight channels and configurable resolution
  - Integrated high-power comparator
  - General-purpose timers (one 16-bits, two 8-bits)
  - 19 General-purpose I/O pins (21 × 4 mA, 2 × 20 mA)
  - 32 kHz sleep timer with capture
  - Two powerful USARTs with support for several serial protocols
  - IR generation circuity
  - AES security coprocessor
  - Battery monitor and temperature sensor
  - I2C interface
  - 2 I/O pins have LED driving capabilities
  - Watchdog timer

1.3 Applications

- 2.4-GHz Bluetooth low energy system
- Mobile phone accessories
- Sports and leisure equipment
- Consumer electronics
- Human interface devices
- Keyboard, mouse

- Remote control
- Smart lighting
- Health care and medical

1.4 Functional Block Diagram

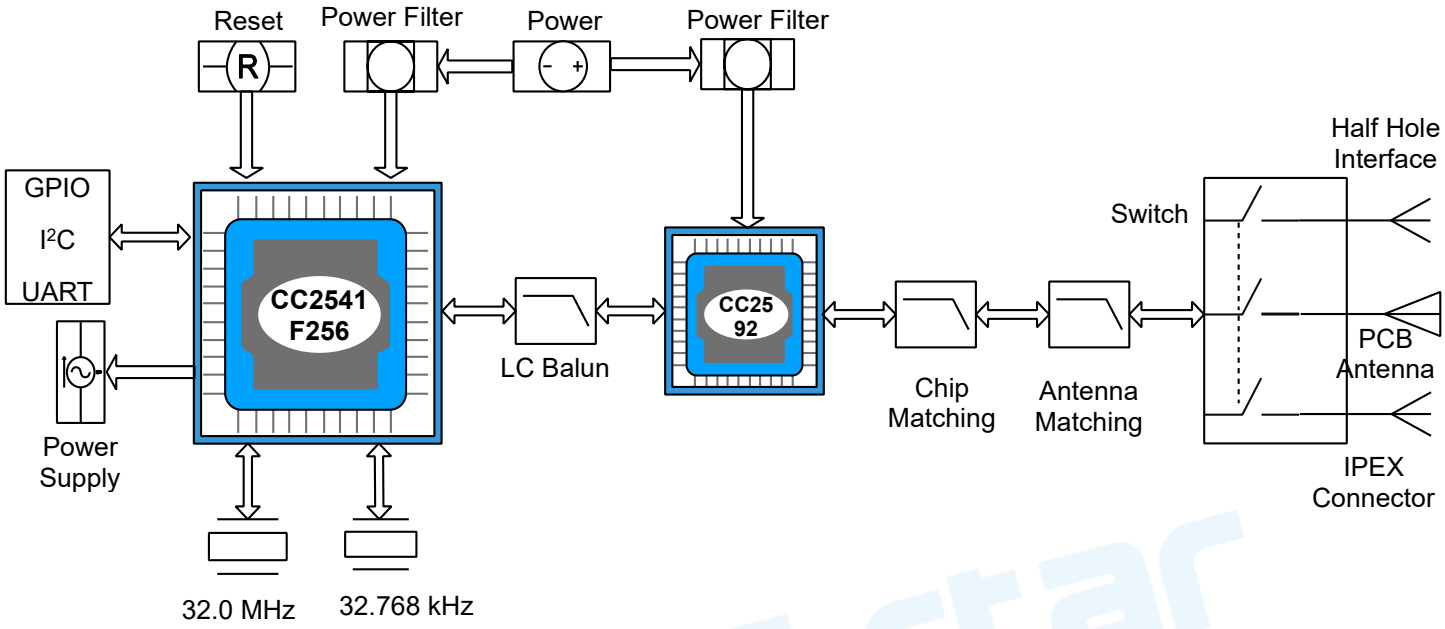

Figure 1. Functional Block Diagram of RF-BMPA-2541B1

1.5 Part Number Conventions

The part numbers are of the form of RF-BMPA-2541B1 where the fields are defined as follows:

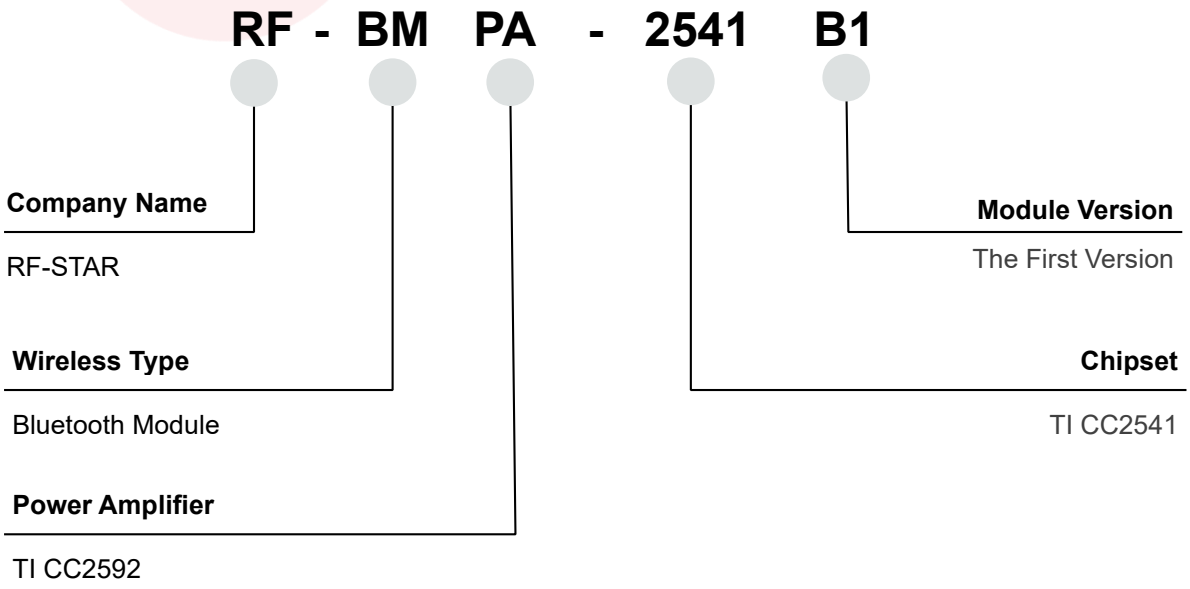

Figure 2. Part Number Conventions of RF-BMPA-2541B1

Table of Contents

2 Module Configuration and Functions

2.1 Module Parameters

Table 1. Parameters of RF-BMPA-2541B1

Chipset	CC2541F256+CC2592
Supply Power Voltage	2.0 V ~ 3.6 V, recommended to 3.3 V
Frequency	2402 MHz ~ 2480 MHz
Transmit Power	Programmable: -3.0 dBm ~ +19.0 dBm
Receiving Sensitivity (high gain mode)	-93 dBm
GPIO	19
Crystal	32 MHz, 32.768 kHz
RAM	8 KB
Flash	256 KB
Package	SMT Packaging (1.27-mm half-hole pitch stamp stick)
Frequency Error	±20 kHz
Dimension	31.40 mm x 13.7 mm x 2.1 mm
Type of Antenna	PCB Antenna / IPEX connector / Half-hole antenna interface
Operating Temperature	-40 ℃ ~ +85 ℃
Storage Temperature	-40 ℃ ~ +125 ℃

2.2 Module Pin Diagram

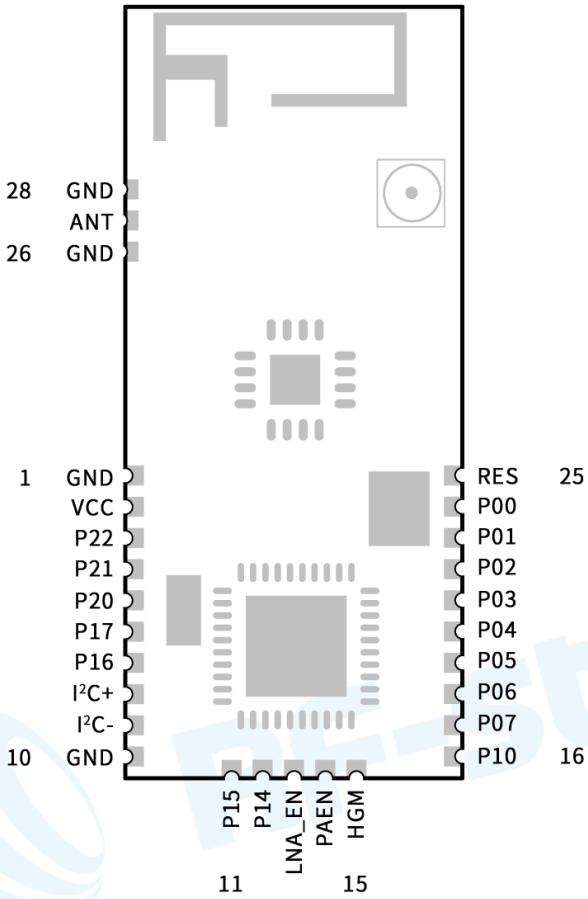

Figure 3. Pin Diagram of RF-BMPA-2541B1

2.3 Pin Functions

Table 2. Pin Functions of RF-BMPA-2541B1

Pin	Name	Chip Pin	Pin Type	Description
1	GND	—	GND	Suitable for long distance requirements
2	VCC	—	Power supply	
3	P22	P2.2	Debug DC	Debug DC
4	P21	P2.1	Debug DD	Debug DD
5	P20	P2.0	I/O	
6	P17	P1.7	I/O	
7	P16	P1.6	I/O	
8	I2C+	I2C+	I2C+	I2C+
9	I2C-	I2C-	I2C-	I2C-
10	GND	GND	Ground	

11	P15	P1.5	I/O	
12	P14	P1.4	I/O	
13	P13	P1.3	I/O @ LNA EN	Control CC2592 LNA enable
14	P12	P1.2	I/O @ PA EN	Control CC2592 PA enable
15	P11	P1.1	I/O @ gain	Control CC2592 LNA high & low gain
16	P10	P1.0	I/O	
17	P07	P0.7	I/O	
18	P06	P0.6	I/O	
19	P05	P0.5	I/O	
20	P04	P0.4	I/O	
21	P03	P0.3	I/O	
22	P02	P0.2	I/O	
23	P01	P0.1	I/O	
24	P00	P0.0	I/O	
25	RESET	RST	RESET	Active low
26	GND	-	GND	Ground
27	ANT	-	ANT	External antenna
28	GND	-	GND	Ground

3 Specifications

3.1 Recommended Operating Conditions

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-BMPA-2541B1

Items	Condition	Min.	Typ.	Max.	Unit
Operating Supply Voltage	Battery Mode	2.0	3.3	3.6	V
Operating Temperature	/	-40	+25	+85	℃
Environmental Hot Pendulum	/	-20		+20	℃/min

3.2 Handling Ratings

Table 4. Handling Ratings of RF-BM-ND04

Items	Condition	Min.	Typ.	Max.	Unit
Storage Temperature	Tstg	-40	+25	+125	℃
Human Body Model	HBM		±1000		V
Moisture Sensitivity Level			3		
Charged Device Model			±500		V

3.3 Current Consumption

Table 5. Table of Current Consumption

When measured on the RF-BMPA-2541B1 reference design with T A = 25 ℃, V BAT = 3.3 V, Fc = 2440 MHz with DC/DC enabled unless otherwise noted.

Event	Average Current (Integral Computed[1])	Average Current (Ammeter Measured[2])	Duration	Testing Conditions
Sleeping	0 mA	0 mA	/	EN is in high low
Broadcasting	0.79 mA	0.6 mA ~ 1.3 mA	4.42 ms	Broadcasting cycle: 200 ms
Connection	1.8 mA	1.9 mA ~2.1 mA	2.73 ms	Connection interval: 100 ms
Module receiving UART data and send to APP	0.95 mA	9.1 mA	0.512 ms	20 bytes,10 times/s
Module receiving APP data and send to MCU	0.94 mA	8.8 mA ~ 8.9 mA	0.512 ms	20 bytes,10 times/s

Note:

1. The official test method: Connect in series a 10 Ω resistor in the circuit with power supply, and intercept voltage waveform with oscilloscope and perform integration.
2. Multi-meter test method: Connect multi-meter (set at μA or mA level) in series between the battery and the module to check the value displayed, with the test voltage of 3.3 V.

3.4 RF Test

Table 6. Table of RF Test

When measured on the RF-BMPA-2541B1 reference design with T A = 25 ℃, V BAT = 3.3 V with DC/DC, channel of 39th (2442 MHz) enabled unless otherwise noted.

Test Item	Parameter	Test Value	Unit
Transmitter	Power	19.0	dBm
	Frequency Error	±20	kHz
	Transmission Distance	350	m
Receiver	Sensitivity (8% PER)	-93	dBm

4 Application, Implementation, and Layout

4.1 Module Photos

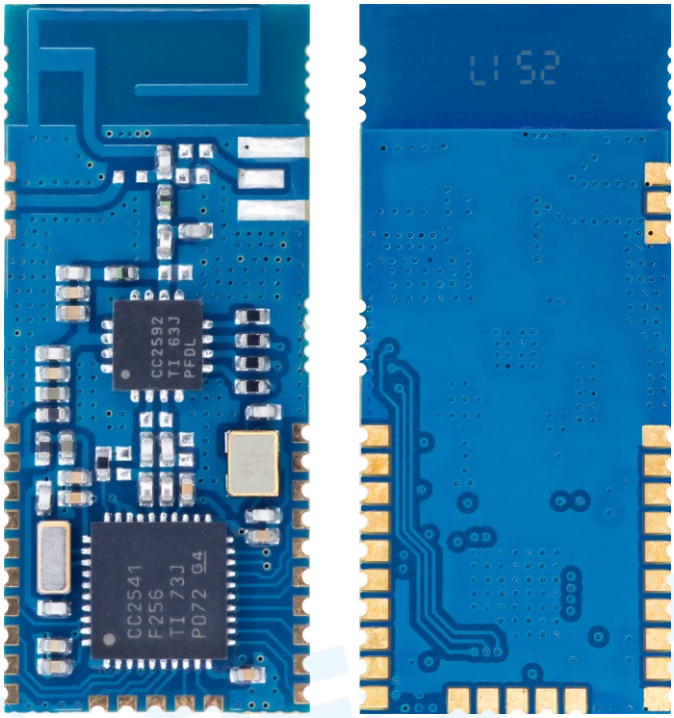

Figure 4. Photos of RF-BMPA-2541B1

4.2 Recommended PCB Footprint

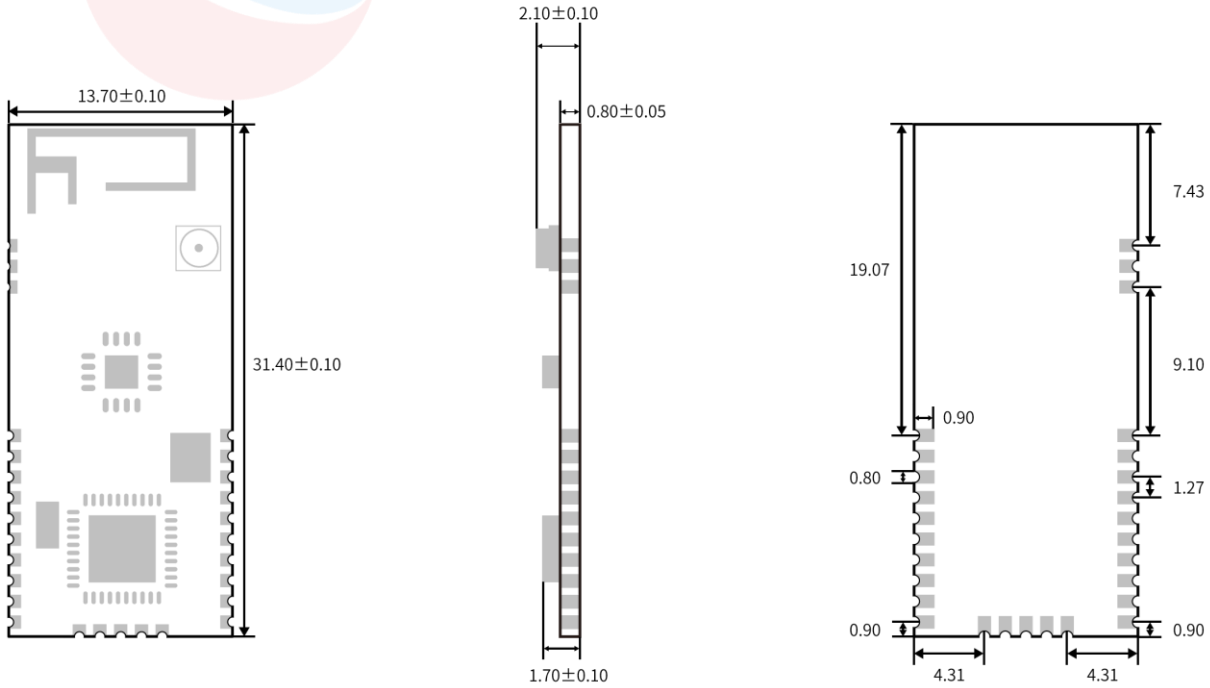

Figure 5. Recommended PCB Footprint of RF-BMPA-2541B1 (mm)

4.3 Schematic Diagram

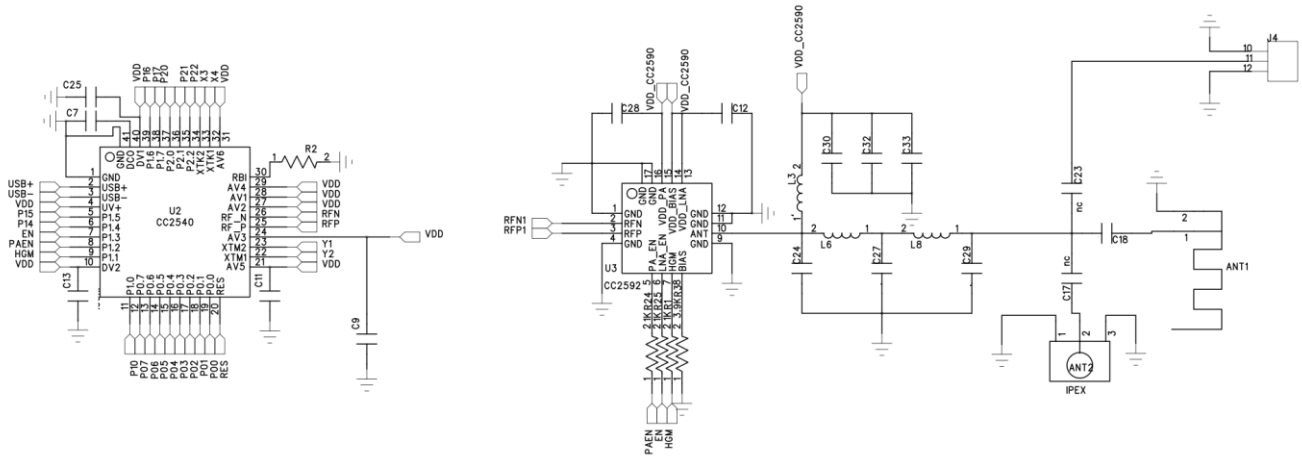

Figure 6. Schematic Diagram of RF-BMPA-2541B1

4.4 Antenna

4.4.1 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.

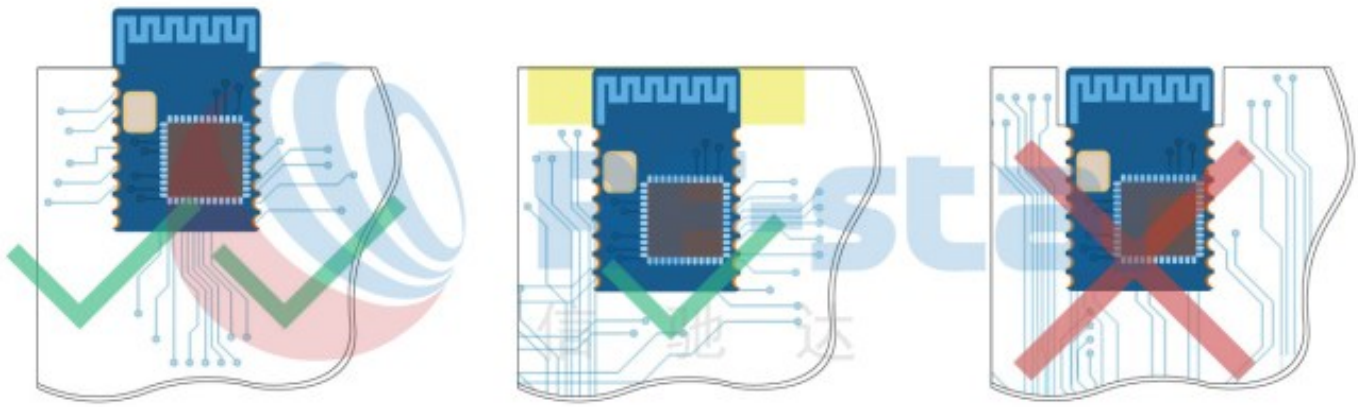

Figure 7. Recommendation of Antenna Layout

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

4.4.2 IPEX Connector Specification

Attentions:

1. The module is shipped as the version with onboard inverted-F antenna by default. Under this version, C23 and C17 are disconnected, and C18 is welded.
2. If IPEX antenna output is needed, C18 is disconnected, and C17 and C23 are welded.
3. IF half hole antenna output is needed, C17 is disconnected, and C18 and C23 are welded.

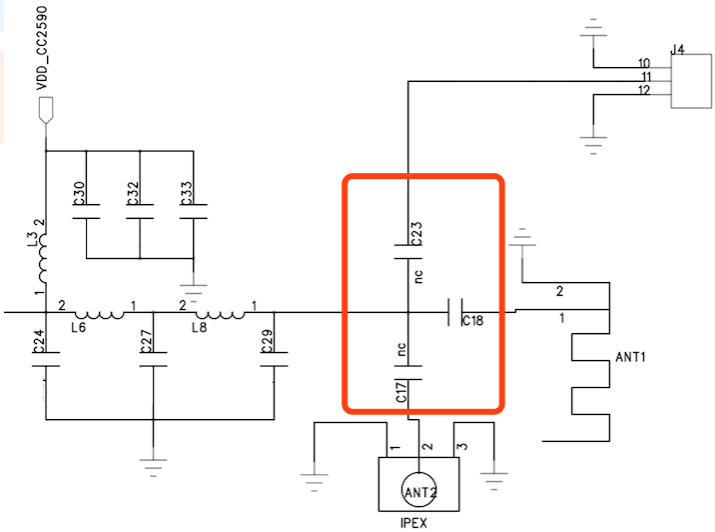

Figure 8. Location of C17, C18 and C23

RF-BMPA-2541B1 module is integrated the IPEX version 1 antenna seat, the specification of antenna seat is as follow:

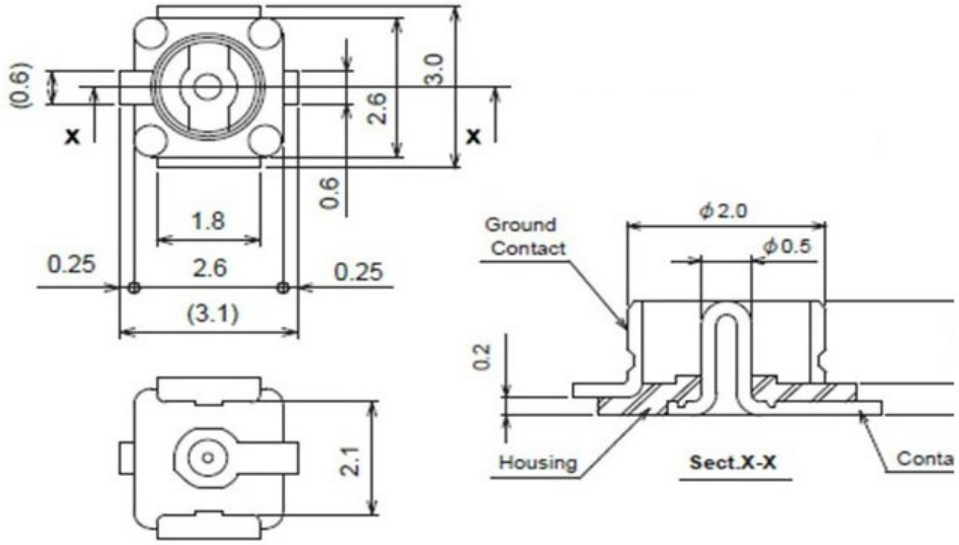

Figure 9. Specification of Antenna Seat

The specification of IPEX wire end is as follow:

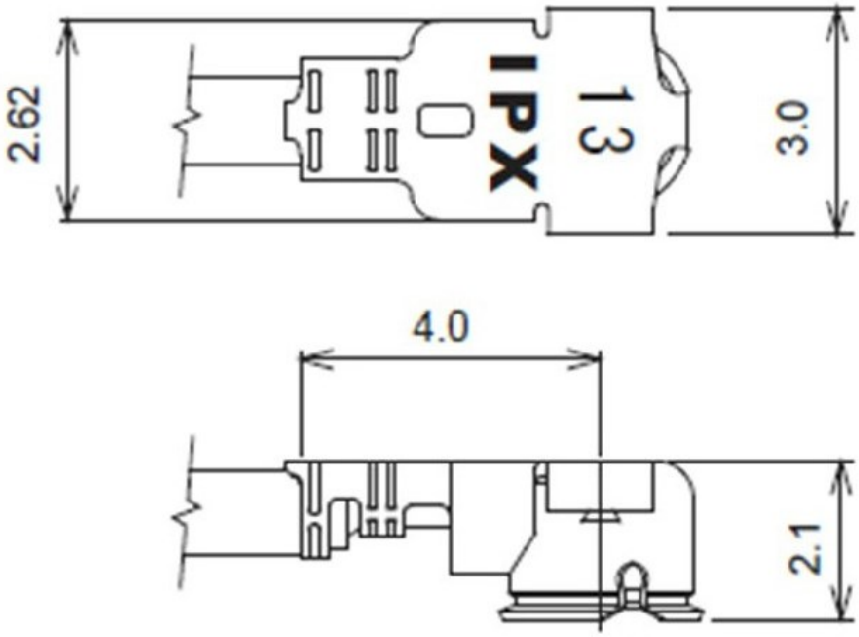

Figure 10. Specification of IPEX Wire

4.4.3 External Antenna Design Recommendation of the Half-Hole ANT Pin

1. A Π-type matching circuit is reserved for the antenna, and 50 Ω impedance control is performed on the RF traces. The traces are as short as possible, and 135° or arc traces are used as much as possible. No vias are used to change layers. More GND vias are placed around the RF traces.

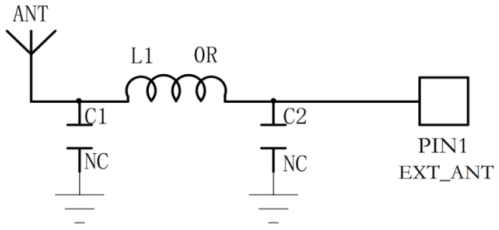

Figure 11. Reference Design of the External Antenna

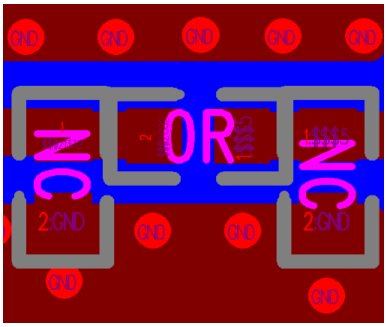

Figure 12. Reference Design of the External Antenna Traces

2. The RF trace width and copper-clad spacing can be calculated by SI9000 software, and the impedance is controlled to 50 Ω according to the actual board thickness, number of layers, plate, dielectric thickness, dielectric constant, copper thickness, line width, line spacing, and solder mask thickness.

   Example: FR4 is a double-layer board with a thickness of 1.0 mm. Through calculation, the width of the trace is 0.8254 mm, and the spacing between traces and copper is 0.22 mm.

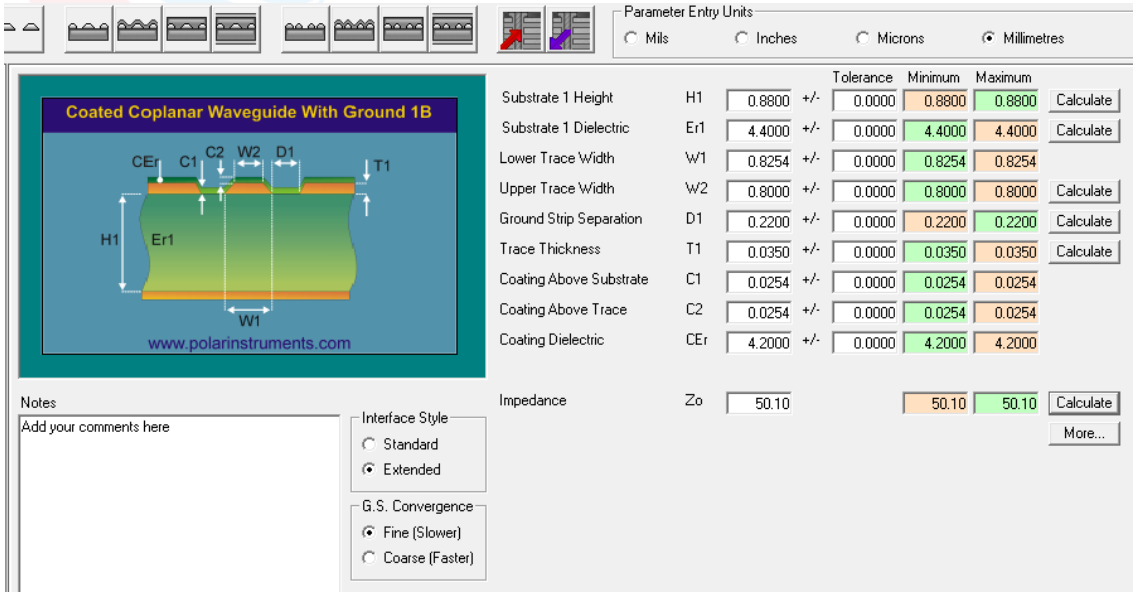

Figure 13. SI9000 Impedance Calculation Diagram

4.5 Basic Operation of Hardware Design

4. It is recommended to offer the module with a DC stabilized power supply, a tiny power supply ripple coefficient and the 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;

5. 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 the stable power supply and no frequently fluctuated voltage.
6. 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.
7. The bottom of 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 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 module and routed in the Bottom Layer (all copper is well grounded).
8. 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 degrees;
9. 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.
10. 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.
11. It is recommended to stay away from the devices whose TTL protocol is the same 2.4 GHz physical layer, for example: USB 3.0.

4.6 Trouble Shooting

4.6.1 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 communication packet loss rate. The performances 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 seaside are poor.
3. The signal attenuation will be very obvious, if there is a metal near the antenna or the module is placed inside of the metal shell.
4. The incorrect power register set or the high data rate in an 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 module or the poor quality of antenna will affect the communication distance.

4.6.2 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 the stable power supply and no frequently fluctuated 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.

4.6.3 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 reliability.
3. If the extension wire or feeder wire is of poor quality or too long, the bit error rate will be high.

4.7 Electrostatics Discharge Warnings

The module will be damaged for the discharge of static. RF-star suggest 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 module, even causing the failure.

4.8 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 ℃.

Table 7. Temperature Table of Soldering and Reflow

Profile Feature	Sn-Pb Assembly	Pb-Free Assembly
Solder Paste	Sn63 / Pb37	Sn96.5 / Ag3.0 / Cu0.5
Min. Preheating Temperature (T_{min})	100 ℃	150 ℃
Max. Preheating Temperature (T_{max})	150 ℃	200 ℃
Preheating Time (T_{min} to T_{max}) (t_1)	60 s ~ 120 s	60 s ~ 120 s
Average Ascend Rate (T_{max} to T_p)	Max. 3 ℃/s	Max. 3 ℃/s

Liquid Temperature (T_L)	183 ℃	217 ℃
Time above Liquidus (t_L)	60 s ~ 90 s	30 s ~ 90 s
Peak Temperature (T_p)	220 ℃ ~ 235 ℃	230 ℃ ~ 250 ℃
Average Descend Rate (T_p to T_{max})	Max. 6 ℃/s	Max. 6 ℃/s
Time from 25 ℃ to Peak Temperature (t_2)	Max. 6 minutes	Max. 8 minutes
Time of Soldering Zone (t_P)	20±10 s	20±10 s

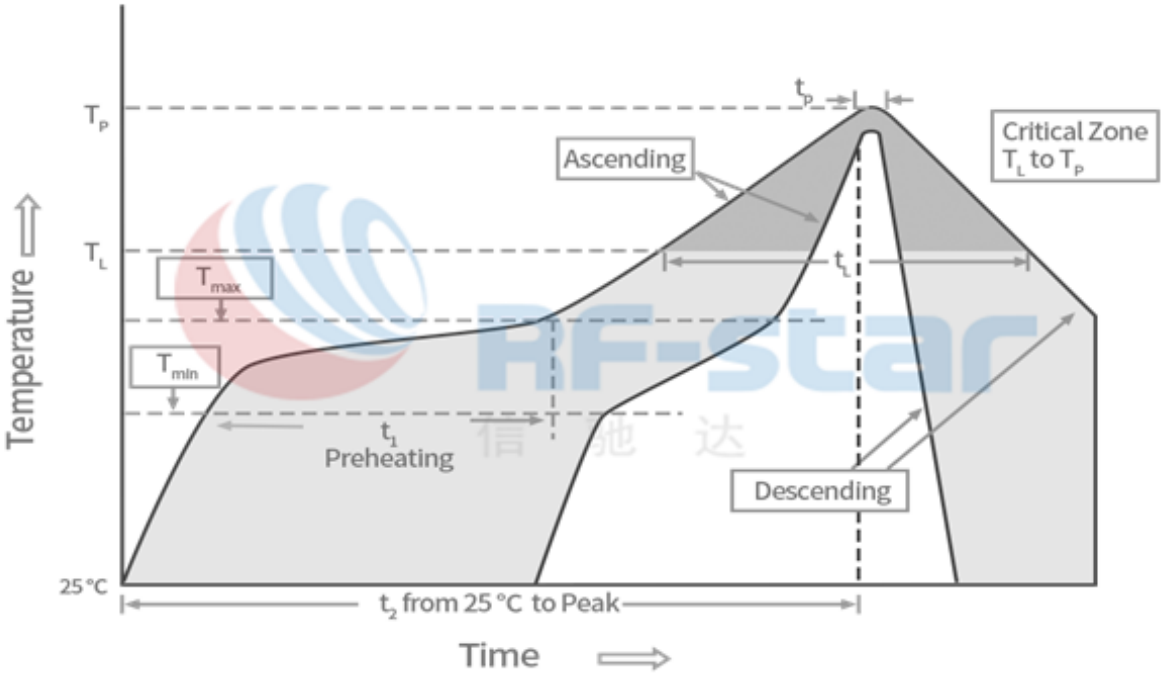

Figure 14. Recommended Reflow for Lead Free Solder

4 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.

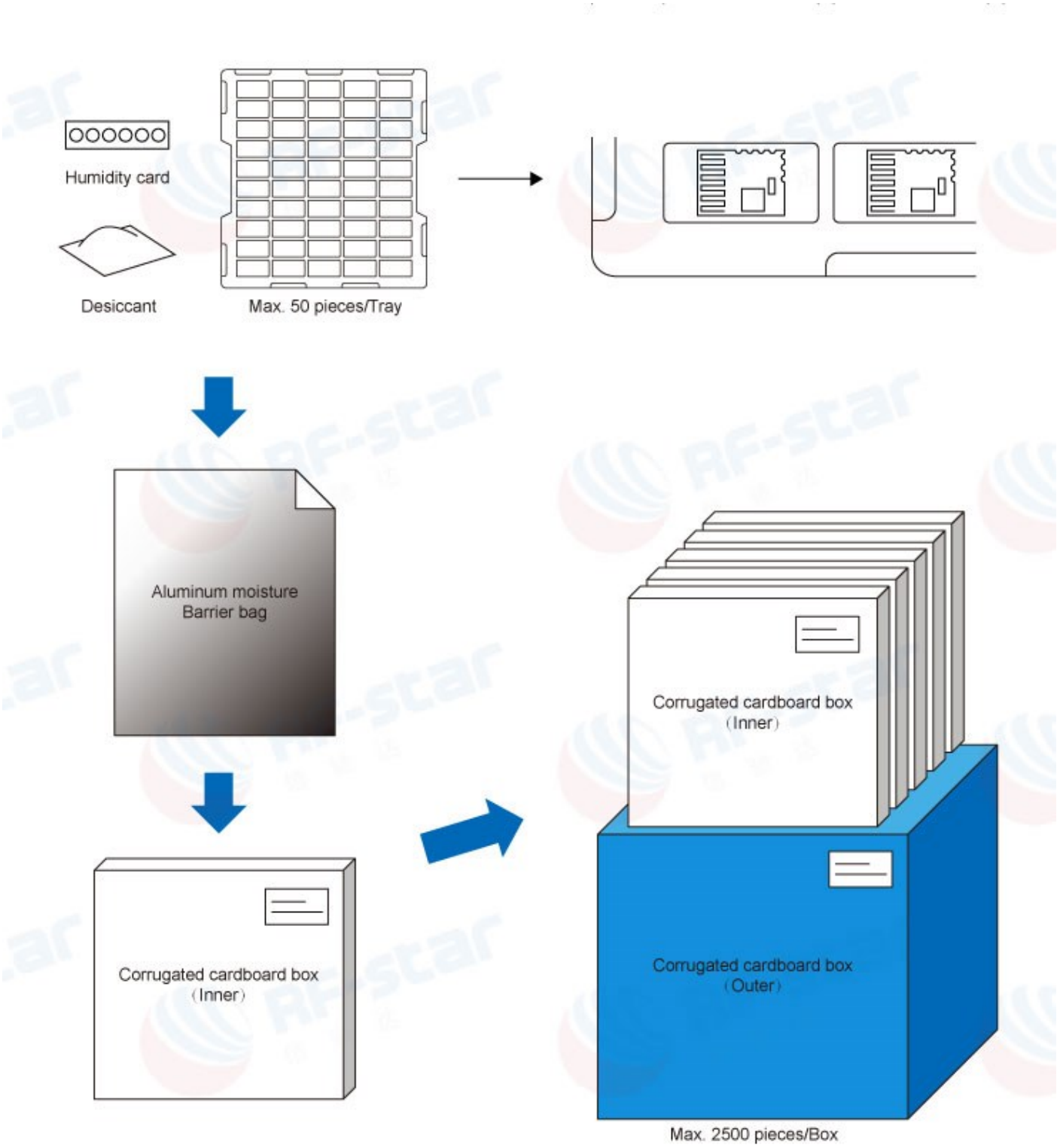

Figure 15. Default Package by Tray

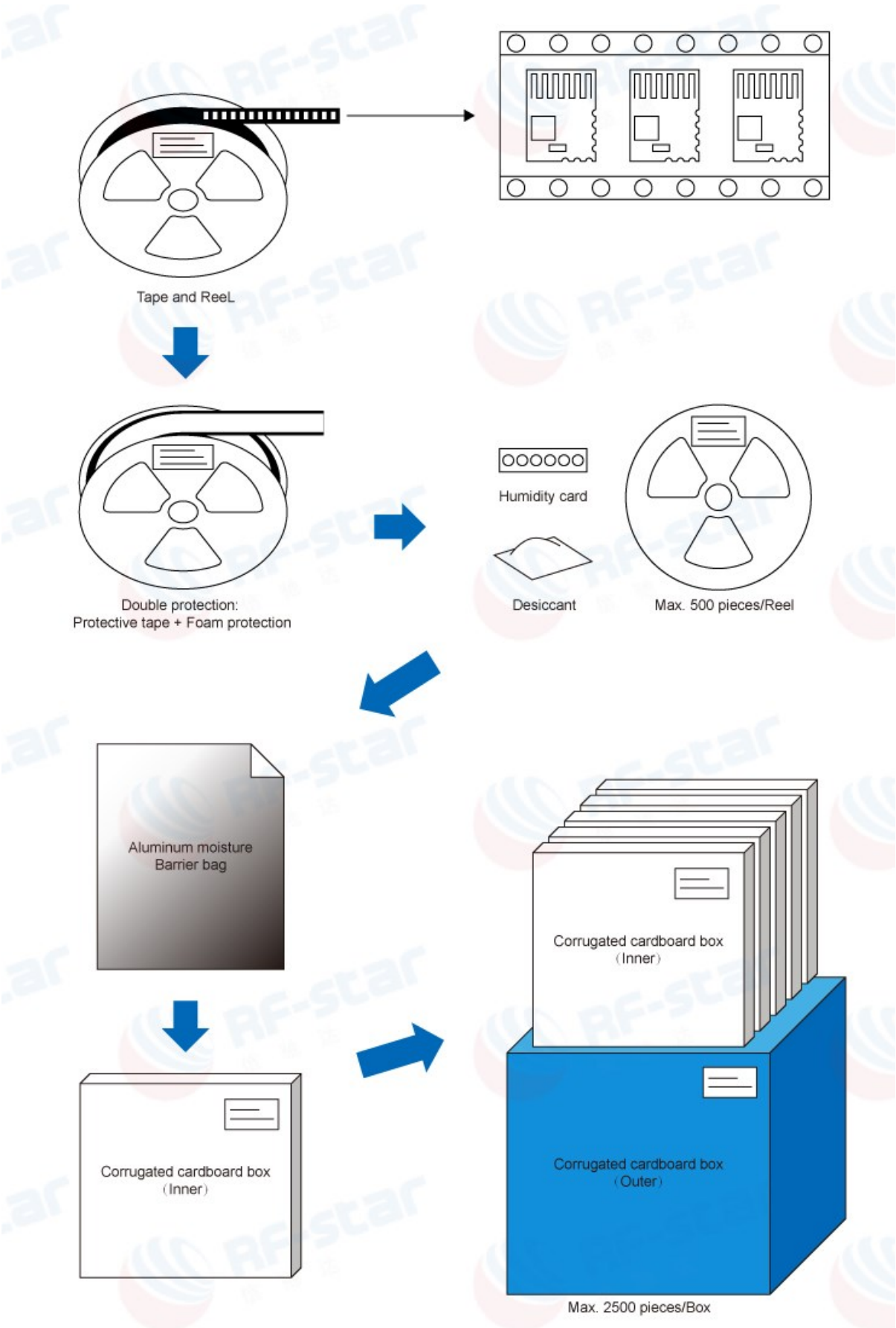

Figure 16. Package by Tape & Reel

6 Certification

6.1 RoHS

BLUE ASIA

Report No.: BLA-C-201811-A04-01 Date: Nov.30, 2018 Page 1 of 8

Applicant : ShenZhen RF-STAR Technology CO.,LTD

Address : 2F,BLDG.8,Zone A,BaoAn Internet Industry Base, BaoYuan Road,XiXiang, BaoAn DIST, ShenZhen, China

Report on the submitted sample said to be:

Sample Name : Nordic BLE module

Model No. : RF-BMPA-2541B1

Sample Received Date : Nov.23, 2018

Testing Period : Nov.23, 2018 to Nov.29, 2018

Test Site : 5 Floor, 6 Building, Second Guanlong Industrial Park, Xili Town, Nanshan District, Shenzhen, China

Test Requested		Result
1	As specified by the client, to determine Pb, Cd, Hg, Cr(VI), PBBs & PBDEs, DBP, BBP, DEHP, DIBP content in the submitted sample in accordance with EU Directive 2011/65/EU (ROHS 2.0)& (EU)2015/863	Pass

******FOR FURTHER DETAILS, PLEASE REFER TO THE FOLLOWING PAGE(S)******

Tested by: Murray Reviewed by: Michelle

Approved by: Marco Lab manager Date :

Figure 17. RoHS Certificate

7 Revision History

Date	Version No.	Description
2015.10.29	V1.0	The initial version is released.
2016.20.08	V1.0	Update pin functions.
2016.10.12	V1.0	Update IPEX connector specification.
2018.08.02	V1.0	Update company address.
2023.05.26	V1.1	Update 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.
2. To obtain the latest document, please download it from the official website: www.rfstariot.com and www.szrfstar.com.

8 Contact Us

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