RF-BM-S02, RF-BM-S02A and RF-BM-S02I

CC254X Series

Bluetooth Low Energy Module

Version 1.0

Shenzhen RF-star Technology Co., Ltd.

May 26th, 2023

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1 Device Overview

1.1 Module Series

There is a series of RF-BM-S02x Bluetooth Low Energy modules. All of them are based on TI CC254X (CC2540 and CC2541) SoC series. Because the CC254X series ICs are compatible in package, pins, and peripherals, those modules are pin-to-pin compatible with each other as well.

Table 1. Module Series of RF-BM-S02x

Model	Antenna Output Mode	Chip Model	TX Power	FLASH	RAM	Peripherals
S02	PCB onboard	CC2540	+4 dBm	256 KB	8 KB	USB, PWM, ADC, IR, WATCHDOG
S02I	IPEX connector					
S02A	PCB onboard	CC2541	0 dBm	256 KB	8 KB	I2C, PWM, ADC, IR, WATCHDOG

1.2 Description

RF-BM-S02, RF-BM-S02A, and RF-BM-S02I are Bluetooth Low Energy (BLE) module based on TI CC254X (CC2540 and CC2541), an 8051 core BLE System-on-Chip (SoC). This PCB module integrates a 32 MHz crystal, a 32.768 kHz crystal, an LC balun, an RF matching filter, and a meander line PCB antenna (S02 and S02A) or an IPEX connector (S02I). It is pre-programmed with the BLE 4.0 stack and an application communication protocol Very low-power sleep modes are available. Short transition times between operating modes further enable low power consumption. RF-BM-S02 is pin-compatible with the RF-BM-S02A and RF-BM-S02I in SMT package, if the USB is not used on the RF-BM-S02 & RF-BM-S02I and the I^2C/extra I/O is not used on the RF-BM-S02A. Compared to the RF-BM-S02 and RF-BM-S02I, the RF-BM-S02A provides lower RF current consumption. The RF-BM-S02A does not have the USB interface of the RF-BM-S02 and RF-BM-S02I, and provides lower maximum output power in TX mode. The RF-BM-S02A also adds a HW I^2C interface.

1.3 Key Features

- RF
  - Bluetooth low energy compatible protocol stack for single-mode
  - Excellent link budget (up to 97 dBm), Enabling long-range applications without external front end
  - Accurate Digital Received Signal-Strength Indicator (RSSI)
- Microcontroller
  - High-performance and low-power 8051 microcontroller core
  - In-system-programmable flash of 256 KB
  - 8-KB SRAM
- Peripherals

- 12 Bit ADC with eight channels and configurable resolution
- Integrated high-power op-amp and ultra-low power comparator
- General-purpose timers (one 16-bits, two 8-bits)
- 13 General-purpose I/O pins
- 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
- RF-BM-S02/S02I:
  - Full speed USB interface
  - Each CC2540 contains a unique 48-bit IEEE address
- RF-BM-S02A:
  - I^2C interface
  - 2 I/O pins have LED driving capabilities

- Low Power
  - Active mode RX down to 19.6 mA
  - Active mode TX (–6 dBm): 24 mA
  - Power mode 1 (3-μs wake-up): 235 μA
  - Power mode 2 (sleep timer on): 0.9 μA
  - Power mode 3 (external interrupts): 0.4 μA
  - Wide supply voltage range (2 V ~ 3.6 V)
  - Full RAM and register retention in all power modes
- Dimension: 15.2 mm x 11.2 mm SMT Package

1.4 Applications

- 2.4-GHz Bluetooth low energy system
- Mobile phone accessories
- Sports and leisure equipment
- Consumer electronics
- Human interface devices
- Keyboard, mouse
- Remote control
- USB dongles
- Health care and medical
- Smart lighting

1.5 Functional Block Diagram

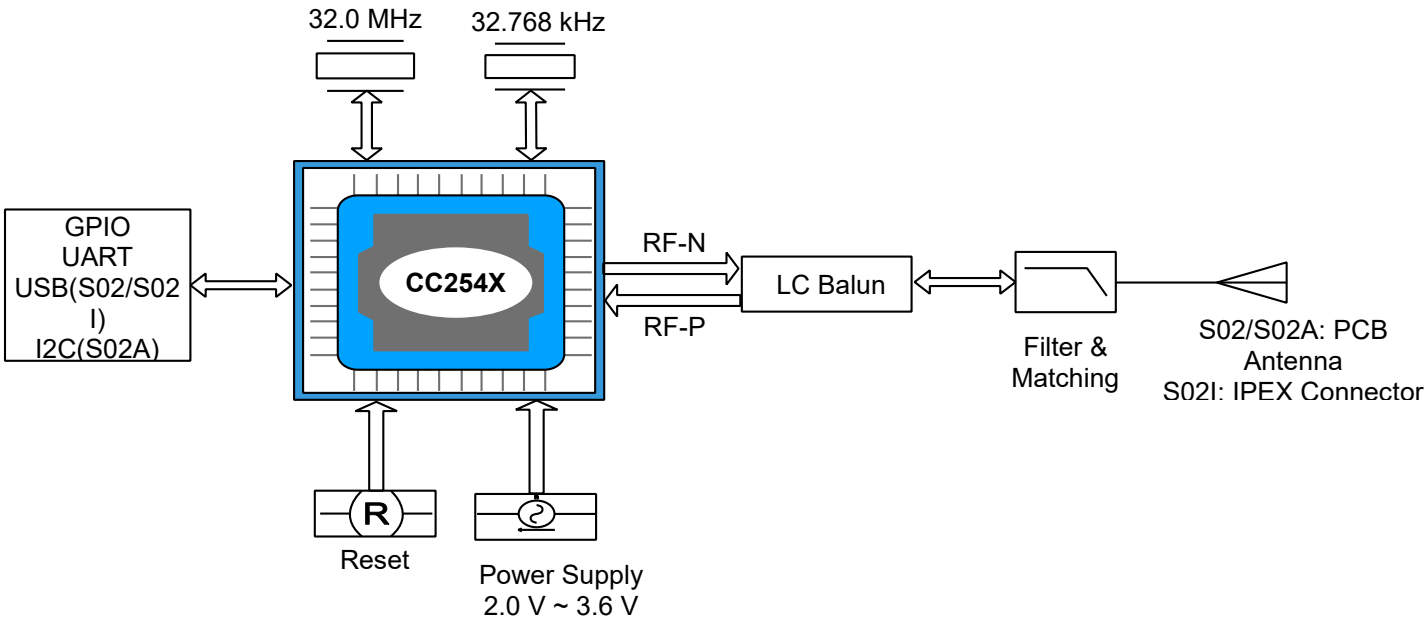


Figure 1. Functional Block Diagram of RF-BM-S02x

1.6 Part Number Conventions

The part numbers are of the form of RF-BM-S02x where the fields are defined as follows:

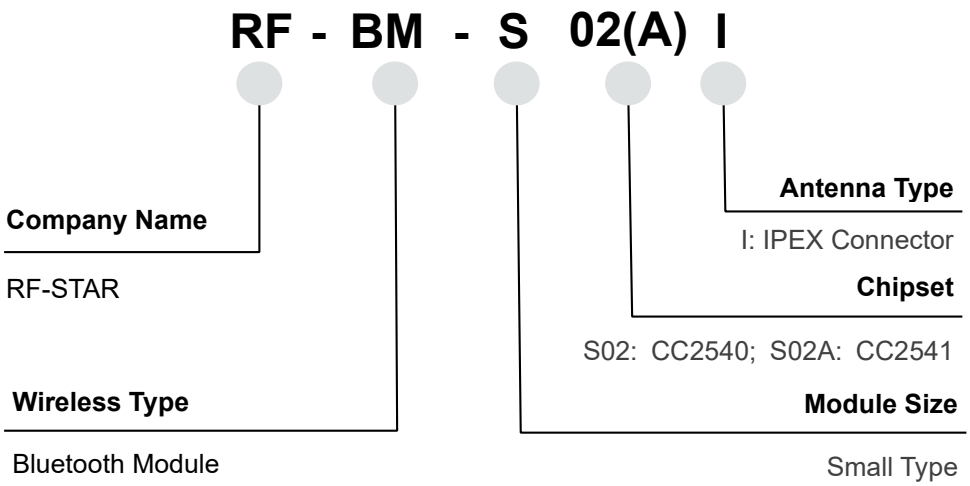


Figure 2. Part Number Conventions of RF-BM-S02x

Table of Contents

1 Device Overview 1
1.1 Module Series 1
1.2 Description 1
1.3 Key Features 1
1.4 Applications 2
1.5 Functional Block Diagram 2
1.6 Part Number Conventions 3
Table of Contents 4
2 Module Configuration and Functions 6
2.1 Module Parameters 6
2.2 Module Pin Diagram 7
2.3 Pin Functions 8
3 Specifications 9
3.1 Recommended Operating Conditions 9
3.2 Handling Ratings 9
4 Application, Implementation, and Layout 10
4.1 Module Photos 10
4.2 Recommended PCB Footprint 11
4.3 Schematic Diagram 12
4.4 Reference Design 12
4.5 Antenna 13
4.5.1 Antenna Design Recommendation 13
5.4.2 IPEX Connector Specification 14
4.6 Basic Operation of Hardware Design 14
4.7 Trouble Shooting 15
4.7.1 Unsatisfactory Transmission Distance 15
4.7.2 Vulnerable Module 16
4.7.3 High Bit Error Rate 16
4.8 Electrostatics Discharge Warnings 16
4.9 Soldering and Reflow Condition 16
5 Optional Package Specification 18

6 Certification 20
6.1 FCC 20
6.2 CE 20
6.3 RoHS 21
6.4 Reach 21
7 Revision History 22
8 Contact Us 23

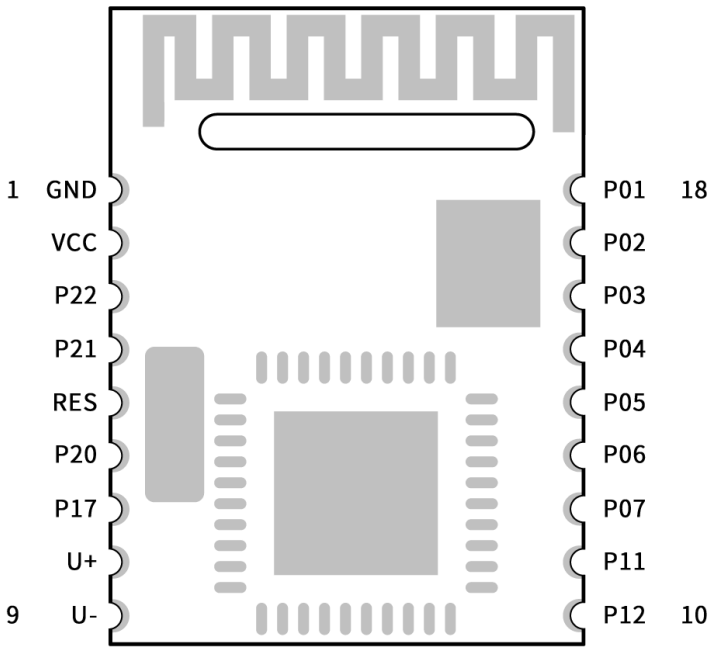
2 Module Configuration and Functions

2.1 Module Parameters

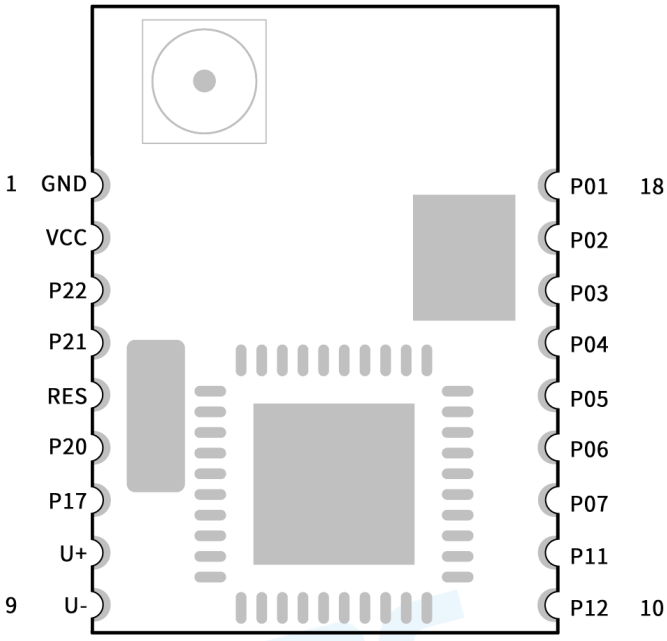
Table 2. Parameters of RF-BM-S02x

Chipset	RF-BM-S02/S02I: CC2540 RF-BM-S02A: CC2541
Supply Power Voltage	2.0 V ~ 3.6 V, recommended to 3.3 V
Frequency	2402 MHz ~ 2480 MHz
Transmit Power	RF-BM-S02/S02I: -23.0 dBm ~ +4.0 dBm RF-BM-S02A: -23.0 dBm ~ 0 dBm
Receiving Sensitivity (low-gain mode)	-87 dBm
Receiving Sensitivity (high-gain mode)	-93 dBm
GPIO	13
Crystal	32 MHz
RAM	8 KB
Flash	256 KB
Package	SMT Packaging (1.27-mm half-hole pitch stamp stick)
Frequency Error	±20 kHz
Dimension	15.2 mm x 11.2 mm x 1.7 mm
Type of Antenna	PCB Antenna
Operating Temperature	-40 ℃ ~ +85 ℃
Storage Temperature	-40 ℃ ~ +125 ℃
RX Current	19.6 mA
TX Current (-6 dBm)	24.0 mA
Power mode 1 (3-μs wake-up)	235 μA
Power mode 2 (sleep timer on)	0.9 μA
Power mode 3 (external interrupts)	0.4 μA

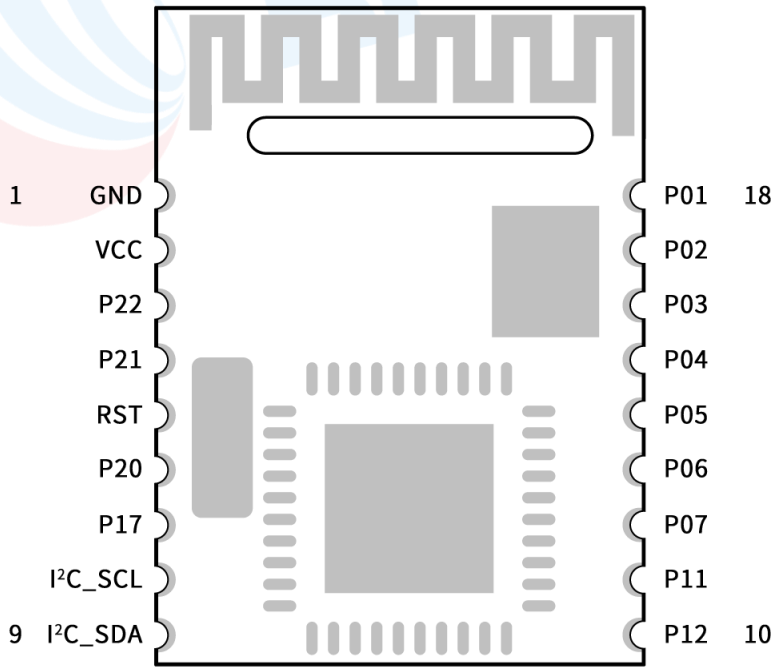
2.2 Module Pin Diagram



RF-BM-S02



RF-BM-S02I



RF-BM-S02A

Figure 3. Pin Diagram of RF-BM-S02x

2.3 Pin Functions

Table 3. Pin Functions of RF-BM-S02x

Pin	Name	Chip Pin	Pin Type	Description
1	GND	-	GND	Ground
2	VCC	-	Power	Power supply 2.0 V ~ 3.6 V
3	P22	P2_2	I/O	
4	P21	P2_1	I/O	
5	RESET	RST	RESET	Reset, active low.
6	P20	P2_0	I/O	
7	P17	P1_7	I/O	
8	USB_P	USB+	USB+	USB+ (For RF-BM-S02 and RF-BM-S02I)
	I2C_SCL	I2C_SCL	I/O	I2C_SCL (For RF-BM-S02A)
9	USB_N	USB-	USB-	USB- (For RF-BM-S02 and RF-BM-S02I)
	I2C_SDA	I2C_SDA	I/O	I2C_SDA (For RF-BM-S02A)
10	P12	P1_2	I/O	
11	P11	P1_1	I/O	
12	P07	P0_7	I/O	
13	P06	P0_6	I/O	
14	P05	P0_5	I/O	
15	P04	P0_4	I/O	
16	P03	P0_3	I/O	
17	P02	P0_2	I/O	
18	P01	P0_1	I/O	

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 4. Recommended Operating Conditions of RF-BM-S02x

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 5. Handling Ratings of RF-BM-S02x

Items	Condition	Min.	Typ.	Max.	Unit
Storage Temperature	Tstg	-40	+25	+125	℃
Human Body Model	HBM		±2000		V
Moisture Sensitivity Level			3		
Charged Device Model			±750		V

4 Application, Implementation, and Layout

4.1 Module Photos

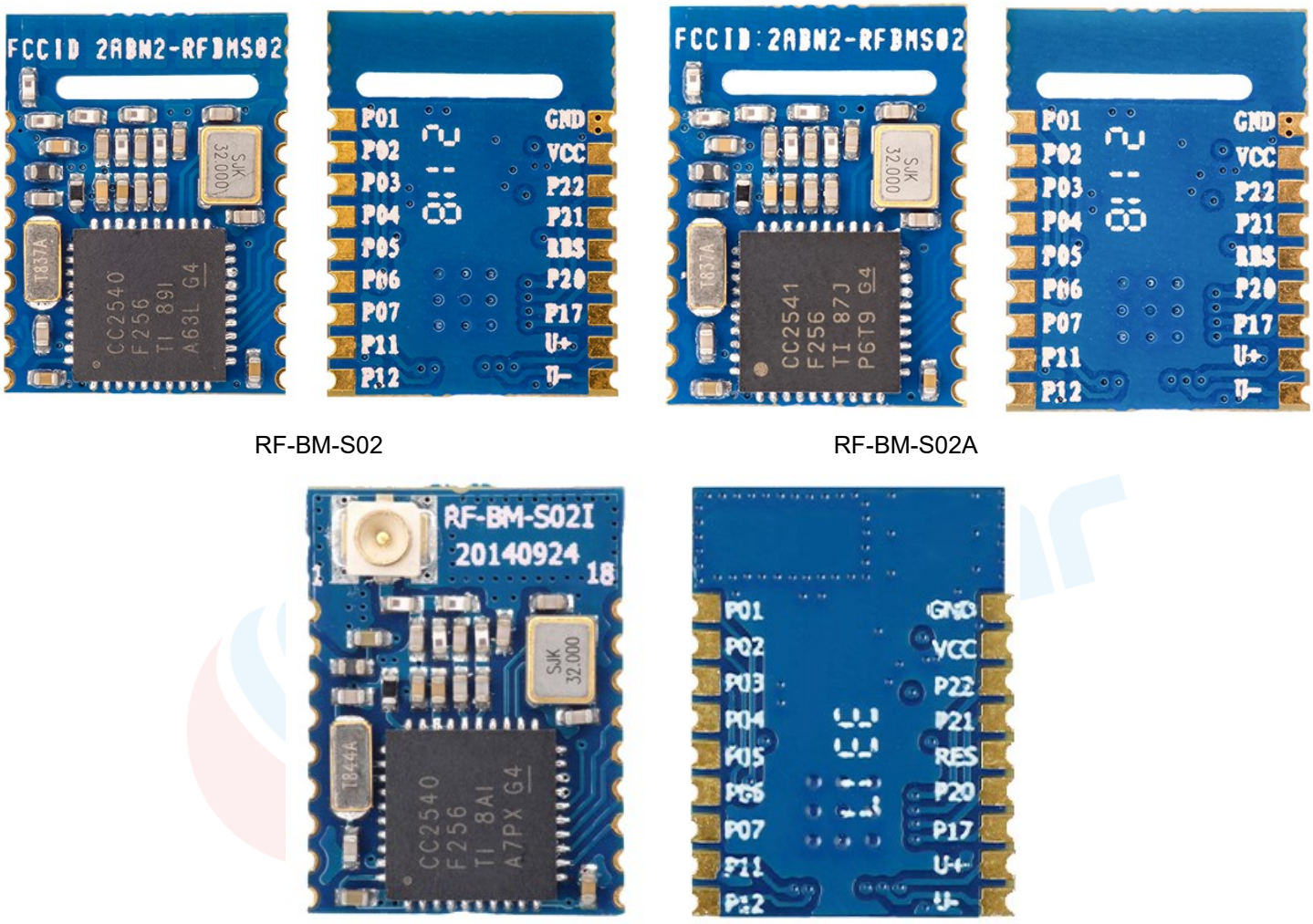
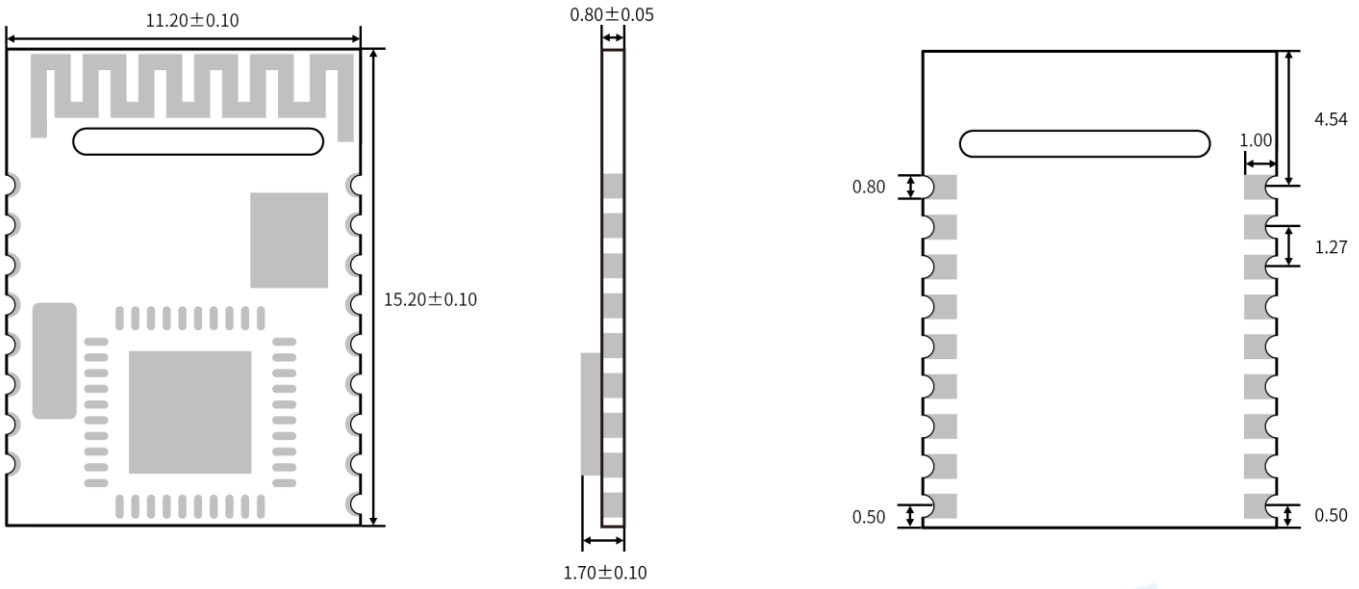
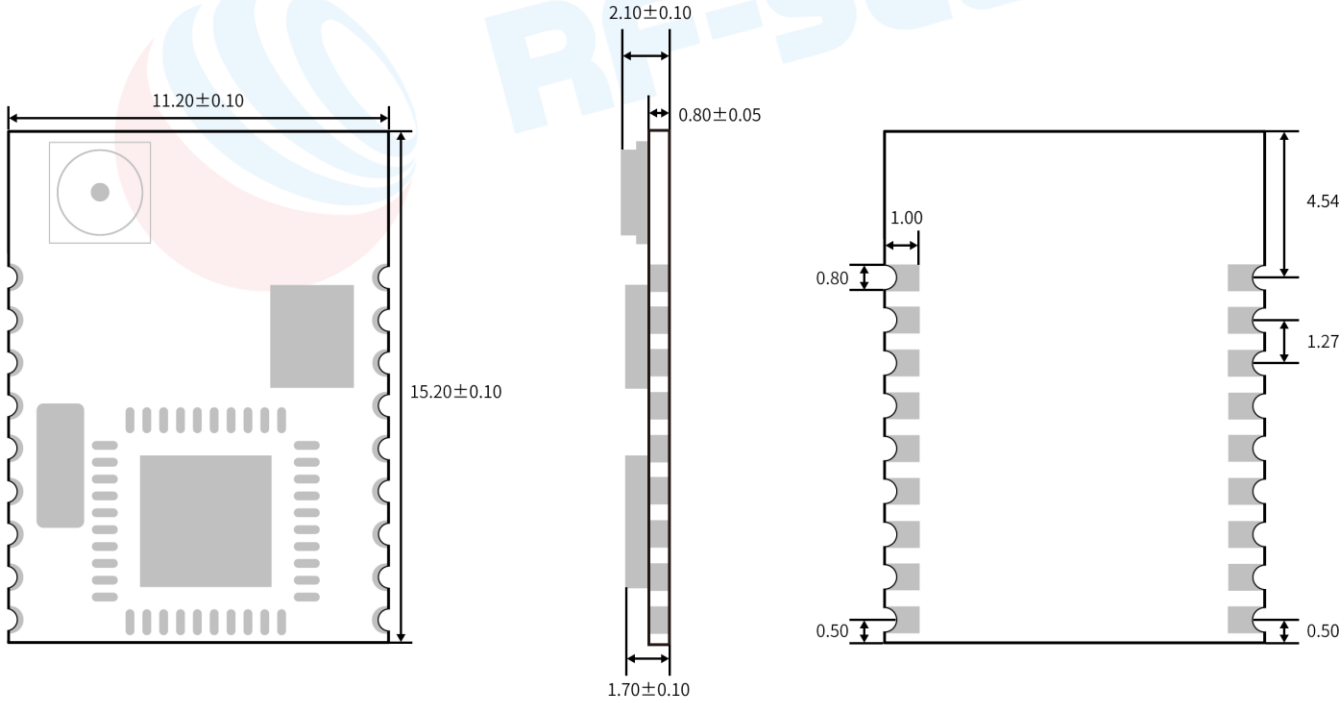


Figure 4. Photos of RF-BM-S02x

4.2 Recommended PCB Footprint



RF-BM-S02(A)



RF-BM-S02I

Figure 5. Recommended PCB Footprint of RF-BM-S02 (mm)

4.3 Schematic Diagram

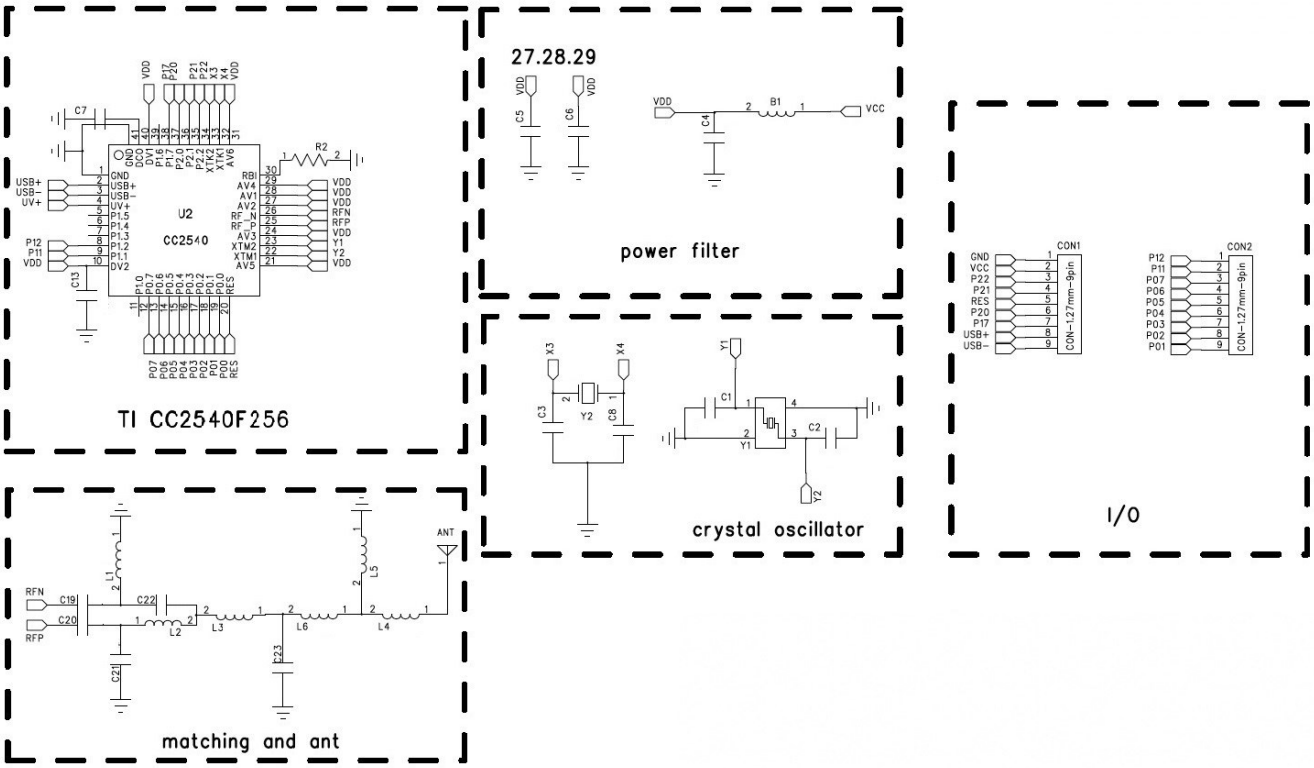


Figure 6. Schematic Diagram of RF-BM-S02x

4.4 Reference Design

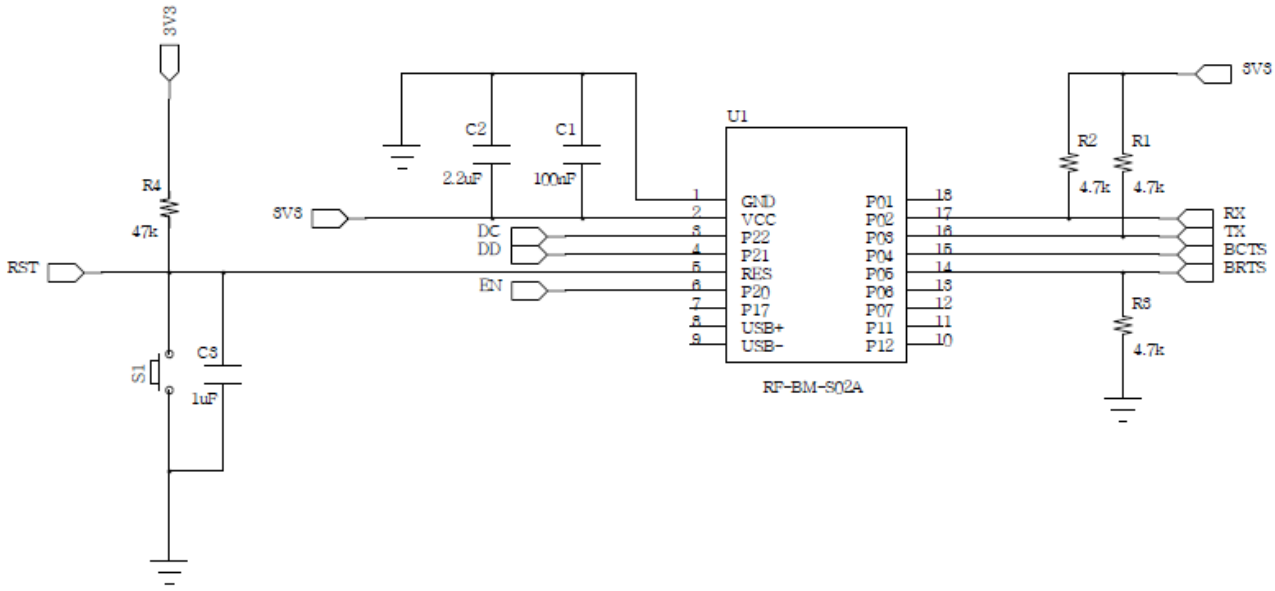


Figure 7. Reference Design of RF-BM-S02x

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.

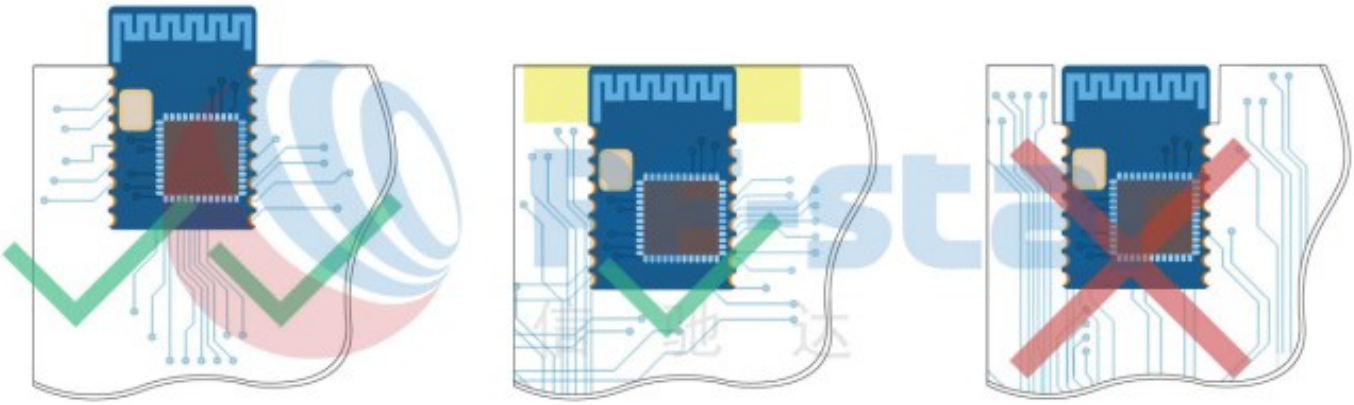


Figure 8. Recommendation of Antenna Layout

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

5.4.2 IPEX Connector Specification

RF-BM-S02I module is integrated the IPEX version 1 antenna seat, the specification of the antenna seat is as follows:

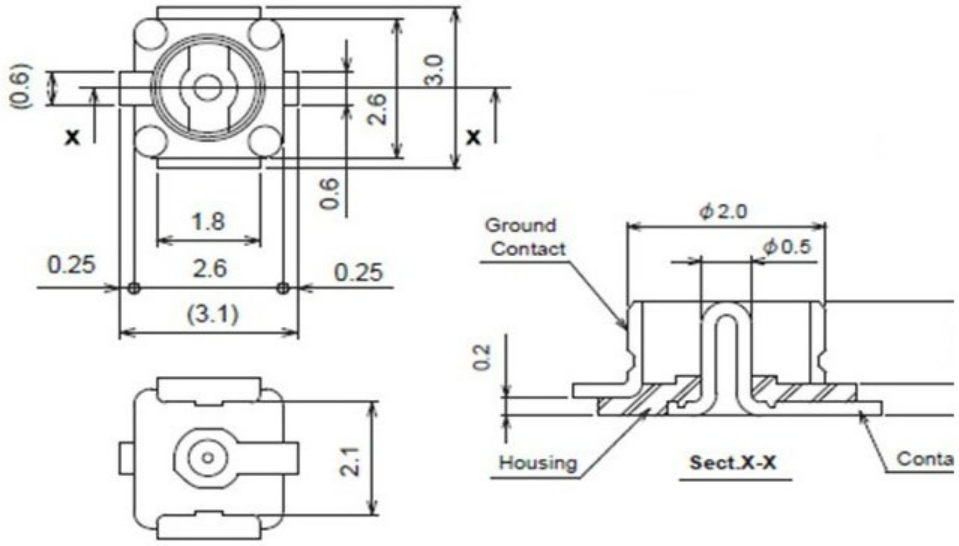


Figure 9. Specification of Antenna Seat

The specification of the IPEX wire end is as follows:

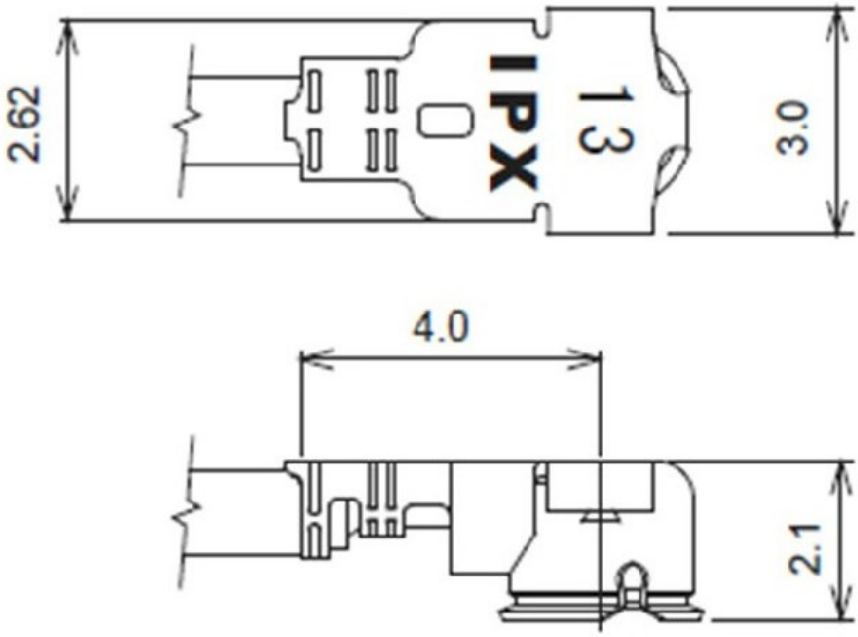


Figure 10. Specification of IPEX Wire

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 the 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 the 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 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 ℃.

Table 6. 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

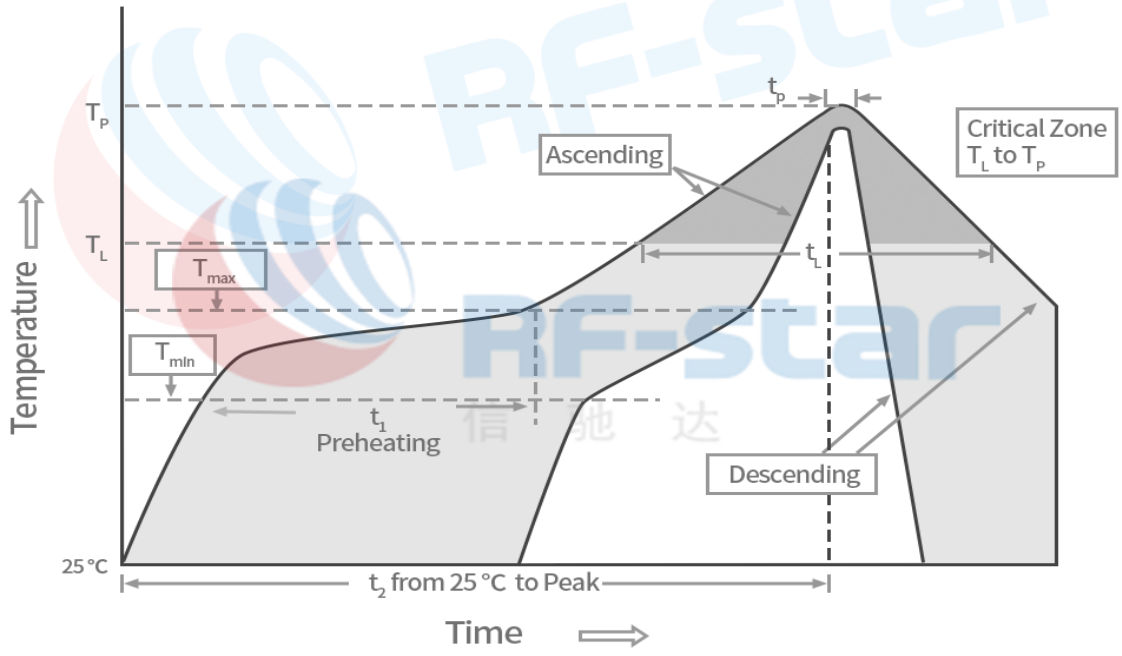


Figure 11. Recommended Reflow for Lead-Free Solder

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.

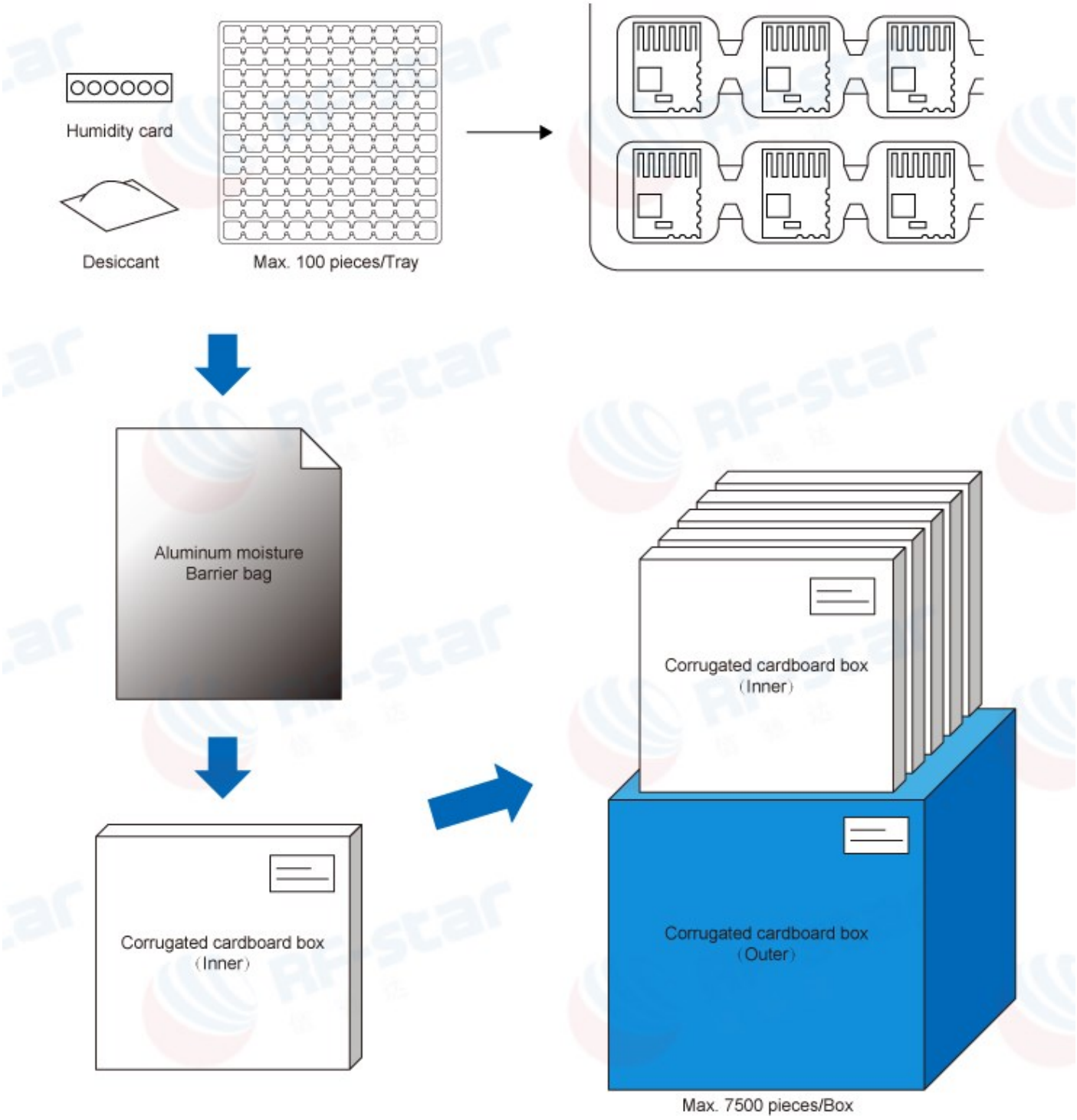


Figure 12. Default Package by Tray

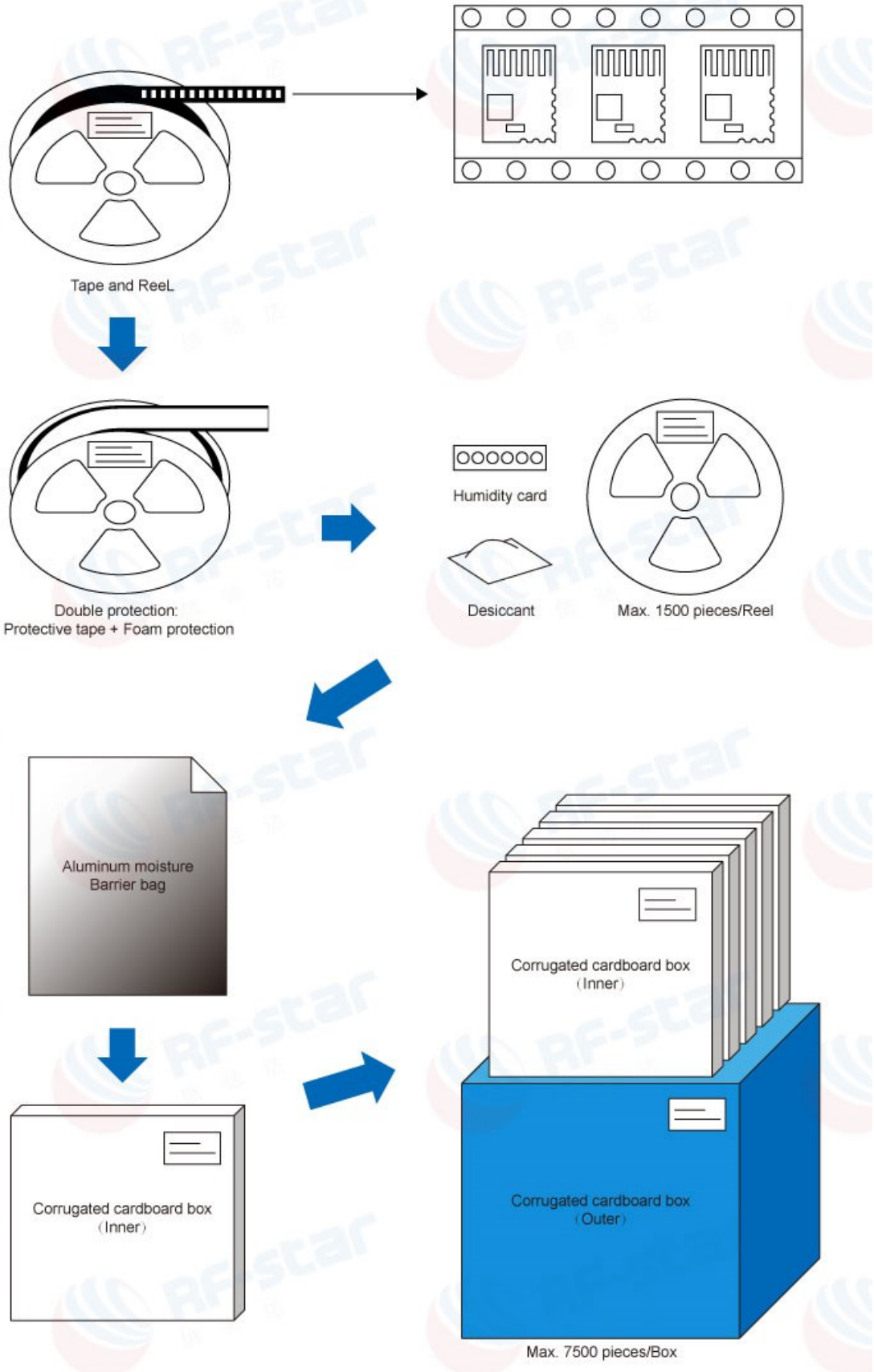


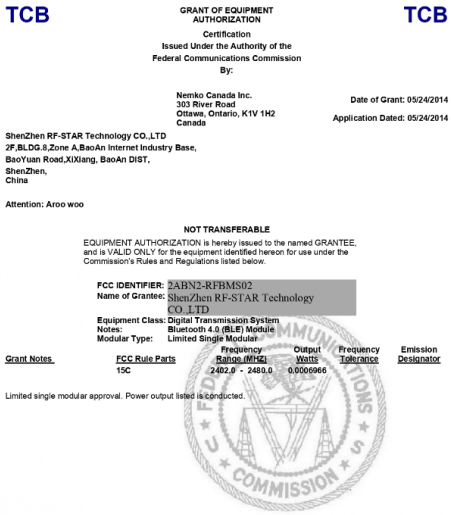
Figure 13. Package by Tape & Reel

6 Certification

6.1 FCC

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.

FCC ID: 2ABN2-RFBMS02



TCB GRANT OF EQUIPMENT AUTHORIZATION TCB

Certification
Issued Under the Authority of the
Federal Communications Commission
By:

Nemko Canada Inc.
303 River Road
Ottawa, Ontario, K1V 1H2
Canada

Date of Grant: 05/24/2014
Application Dated: 05/24/2014

ShenZhen RF-STAR Technology CO.,LTD
2F,BLDG.8,Zone A,BaoAn Internet Industry Base,
BaoYuan Road,XiXiang, BaoAn DIST,
ShenZhen,
China

Attention: Aroo woo

NOT TRANSFERABLE

EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.

FCC IDENTIFIER: 2ABN2-RFBMS02
Name of Grantee: ShenZhen RF-STAR Technology CO.,LTD
Equipment Class: Digital Transmission System
Notes: Bluetooth 4.0 (BLE) Module
Modular Type: Limited Single Modular

Grant Notes	FCC Rule Parts	Frequency Range (MHz)	Output Watts	Frequency Tolerance	Emission Designator
	15C	2402.0 - 2480.0	0.0006966		

Limited single modular approval. Power output listed is conducted.

Figure 14. FCC Certificate

6.2 CE

Verification No.: CCISE170703301V

CCIS Shenzhen Zhongjian Nanfang Testing Co., Ltd.

VERIFICATION OF CONFORMITY

Verification No:	CCISE170703301V
Applicant:	SHENZHEN RF STAR TECHNOLOGY CO., LTD.
Address of Applicant:	2F, Block8, Dist.A, Internet Industry Base, Baoyuan Road, Baoan Dist, Shenzhen, China
Product Name:	Bluetooth Module
Model No.:	RF-BM-S02, RF-BM-S02A
Trade Mark:	RF-star
Applicable standards:	Sufficient samples of the product have been tested and found to be in conformity with Test ETSI EN 301 489-1 V2.2.0 (2017-03), Test ETSI EN 301 489-17 V3.2.0 (2017-03), ETSI EN 300 328 V2.1.1 (2016-11), EN 62479:2010, EN 60950-1: 2006+ A11:2009 + A1:2010+ A12:2011+A2:2013
As shown in the Test report number(s):	CCISE170703301, CCISE170703302, CCISE170703303, CCISS170704001

Based on a review of the test report detailed above, this apparatus has met the requirements of the above standards and hence has been properly demonstrated that the requirement of the directive have been fulfilled. The product is in conformity with the article 3.1(a) the requirements of safety and article 3.1(b) the requirements of EMC and article 3.2 requirements of radio equipment in Directive 2014/53/EU.

The CE mark as shown below can be used, under the responsibility of the manufacturer, after completion of an EC Declaration of Conformity and compliance with all relevant EC Directives. The affixing of the CE marking presumes in addition that the conditions in all relative Directives are fulfilled.

Bruce Zhang
Laboratory Manager
02 Aug., 2017

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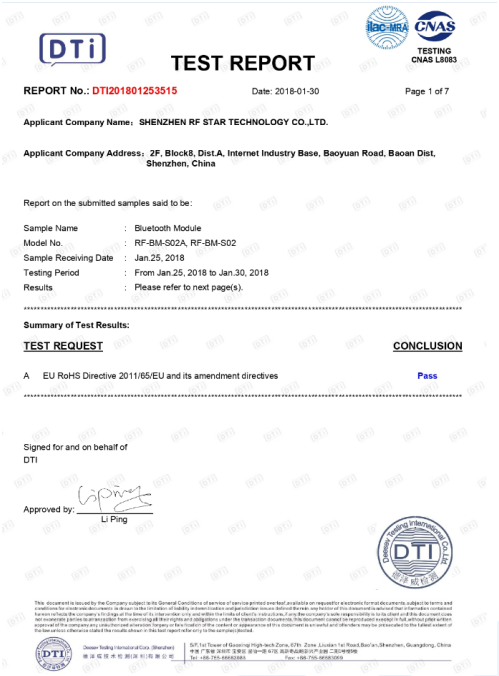
Address: No. B-C, 1/F., Building 2, Laodong No.2 Industrial Park, Xixiang Road, Bao'an District, Shenzhen, Guangdong, China
Telephone: +86 (0) 755 2311 8282, Fax: +86 (0) 755 2311 6366, Website: www.ccis-cb.com

Figure 15. CE Certificate

6.3 RoHS

Report No.: DTI201801253515



TEST REPORT

REPORT No.: DTI201801253515 Date: 2018-01-30 Page 1 of 7

Applicant Company Name：SHENZHEN RF STAR TECHNOLOGY CO.,LTD.

Applicant Company Address：2F, Block8, Dist.A, Internet Industry Base, Baoyuan Road, Baoan Dist, Shenzhen, China

Report on the submitted samples said to be:

Sample Name : Bluetooth Module
Model No. : RF-BM-S02A, RF-BM-S02
Sample Receiving Date : Jan.25, 2018
Testing Period : From Jan.25, 2018 to Jan.30, 2018
Results : Please refer to next page(s).

Summary of Test Results:

TEST REQUEST		CONCLUSION
A	EU RoHS Directive 2011/65/EU and its amendment directives	Pass

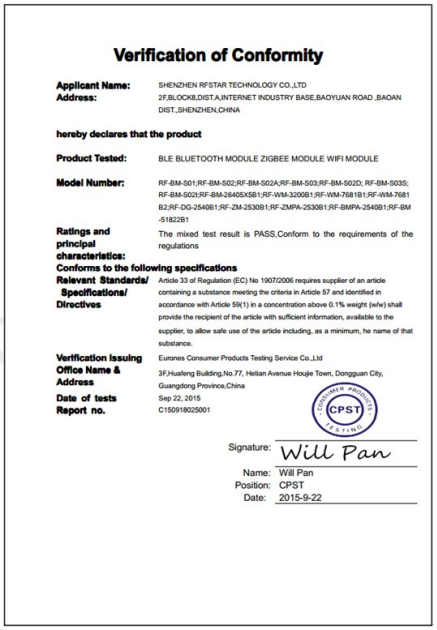
Signed for and on behalf of DTI

Approved by: Li Ping

Figure 16. RoHS Certificate

6.4 Reach

Reach Test Report No.: C150918025001



Verification of Conformity

Applicant Name: SHENZHEN RFSTAR TECHNOLOGY CO.,LTD
Address: 2F,BLOCK8,DIST.A,INTERNET INDUSTRY BASE,BAOYUAN ROAD ,BAOAN DIST.,SHENZHEN,CHINA

hereby declares that the product

Product Tested: BLE BLUETOOTH MODULE ZIGBEE MODULE WIFI MODULE

Model Number: RF-BM-S01;RF-BM-S02;RF-BM-S02A;RF-BM-S03;RF-BM-S02D; RF-BM-S03S; RF-BM-S02I;RF-BM-26405X5B1;RF-WM-3200B1;RF-WM-7681B1;RF-WM-7681 B2;RF-DG-2540B1;RF-ZM-2530B1;RF-ZMPA-2530B1;RF-BMPA-2540B1;RF-BM -5182B1

Ratings and principal characteristics: The mixed test result is PASS,Conform to the requirements of the regulations

Conforms to the following specifications

Relevant Standards/ Specifications/ Directives Article 33 of Regulation (EC) No 1907/2006 requires supplier of an article containing a substance meeting the criteria in Article 57 and identified in accordance with Article 59(1) in a concentration above 0.1% weight (w/w) shall provide the recipient of the article with sufficient information, available to the supplier, to allow safe use of the article including, as a minimum, he name of that substance.

Verification Issuing Office Name & Address Eurones Consumer Products Testing Service Co.,Ltd 3F,Husfeng Building,No.77, Hetian Avenue Houjie Town, Dongguan City, Guangdong Province,China

Date of tests Sep 22, 2015
Report no. C150918025001

Signature: Will Pan
Name: Will Pan
Position: CPST
Date: 2015-9-22

Figure 17. Reach Certificate

7 Revision History

Date	Version No.	Description
2018.01.23	V1.0	The initial version is released.
2018.02.07	V1.0	Update module picture.
2018.02.26	V1.0	Update module operating and storage temperature range. Add CE certificate.
2018.08.02	V1.0	Update company address.
2023.05.26	V1.0	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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Email: sunny@szrfstar.com, sales@szrfstar.com

Web.: www.rfstariot.com, www.szrfstar.com