AN4997
Application note

Using the S2-LP transceiver under FCC Title 47 Part 15 in the 430 - 470 MHz band

Introduction

The S2-LP is a very low power RF transceiver, intended for RF wireless applications in the sub-1 GHz band. It is designed to operate in both the license-free ISM and SRD frequency bands at 433, 868, 915 and 920 MHz.

This application note outlines the expected performance when using the S2-LP under FCC Title 47 Part 15 in the 430 - 470 MHz band. There are no specific requirements in this band. No specific use and no channel spacing are defined.

For details on the regulatory limits in the 430 - 470 MHz band, please refer to the regulations in FCC Title 47 Part 15.

These regulations can be downloaded from:
http://wireless.fcc.gov/index.htm?job=rules_and_regulations.

Contents

1 An overview of FCC regulations

1.1 Part 15.231

Devices operating in the 430 - 470 MHz band must comply with section 15.231 of the FCC Title 47 Part 15 [2] regulations. The provisions in section 15.231 are restricted to periodic operation within the 40.66 - 40.70 MHz band and above 70 MHz. The intentional radiator is restricted to the transmission of a control signal such as those used with alarm systems, door openers, remote switches, etc. Continuous transmissions, voice, video and radio control of toys are not permitted. Data is permitted to be sent with a control signal.

To comply with the provisions for periodic operation, the following conditions must be met:

- A manually operated transmitter shall employ a switch that will automatically deactivate the transmitter within not more than 5 seconds of being released. A transmitter activated automatically shall cease transmission within 5 seconds after activation.
- Periodic transmissions at regular predetermined intervals are not permitted. However, polling or supervision transmissions, including data, to determine system integrity of transmitters used in security or safety applications are allowed if the total duration of transmissions does not exceed 2 seconds per hour.
- Intentional radiators which are employed for radio control purposes during emergencies involving fire, security and safety of life, when activated to signal an alarm, may operate during the pendency of the alarm condition.
- In addition to the provisions of 15.205, the field strength of emissions from intentional radiators operated under this section shall not exceed the values in *Table 1: "Field strength of emissions for normal working conditions"*. The field strength limits are specified at a distance of 3 meters.
- The limits on the field strength of the spurious emissions in *Table 1: "Field strength of emissions for normal working conditions"* are based on the fundamental frequency of the intentional radiator. Spurious emissions shall be attenuated to the average limits shown in this table or to the general limits shown in section 15.209, whichever limit permits higher field strength.
- The bandwidth of the emission shall be no wider than 0.25% of the center frequency. Bandwidth is determined at the points 20 dB down from the modulated carrier.
- Intentional radiators may operate at a periodic rate exceeding that specified in point 1 and may be employed for any type of operation, including operation prohibited in point 1. In this case, the max field strength is different and is shown in *Table 2: "Field strength of emissions for particular working conditions"*. The device operating in the condition described in this point shall be provided with a means for automatically limiting operation so that the duration of each transmission shall be at least 30 times the duration of the transmission, but in no case less than 10 seconds.

Table 1: Field strength of emissions for normal working conditions

Fundamental frequency [MHz]	Field strength of fundamental [µV/m]	Field strength of spurious emissions [µV/m]
40.66 – 40.70	2250	225
70 – 130	1250	125
130 – 174	1250 to 3750	125 to 375
174 – 260	3750	375
260 – 470	3750 to 12500	375 to 1250
Above 470	12500	1250

Table 2: Field strength of emissions for particular working conditions

Fundamental frequency [MHz]	Field strength of fundamental [µV/m]	Field strength of spurious emissions [µV/m]
40.66 – 40.70	1000	100
70 – 130	500	50
130 – 174	500 to 1500	50 to 150
174 – 260	1500	150
260 – 470	1500 to 5000	150 to 500
Above 470	5000	500

1.2 Part 15.205 and 15.209

As described in the previous paragraphs, radiated harmonics and spurious emissions of devices that comply with section 15.231 and which fall within the strict bands, as defined in FCC section 15.205 must comply with the radiated emission limits specified in FCC section 15.209. In addition to the provisions of 15.205, the field strength of emissions from intentional radiators operating under this section shall not exceed the values in *Table 1: "Field strength of emissions for normal working conditions"*. The field strength limits are specified at a distance of 3 meters.

Section 15.205 shows the bands where only spurious emissions are permitted. The field strength of emissions appearing within these frequency bands shall not exceed the limits shown in section 15.209. The following tables show the restricted bands as defined in section 15.205 and the radiated and conducted emission limits are defined in section 15.209.

Table 3: Restricted bands defined in section 15.205

[MHz]	[MHz]	[MHz]	GHz
0.090 – 0.110	16.42 – 16.423	399.9 – 410	4.5 – 5.15
0.495 – 0.505	16.69475 – 16.69525	608 – 614	5.35 – 5.46
2.1735 – 2.1905	16.80425 – 16.80475	960 – 1240	7.25 – 7.75
4.125 – 4.128	25.5 – 25.67	1300 – 1427	8.025 – 8.5
4.17725 – 4.17775	37.5 – 38.25	1435 – 1626.5	9.0 – 9.2
4.20725 – 4.20775	73 – 74.6	1645.5 – 1646.5	9.3 – 9.5
6.215 – 6.218	74.8 – 75.2	1660 – 1710	10.6 – 12.7
6.26775 – 6.26825	108 – 121.94	1718.8 – 1722.2	13.25 – 13.4
6.31175 – 6.31225	123 – 138	2200 – 2300	14.47 – 14.5
8.291 – 8.294	149.9 – 150.05	2310 – 2390	15.35 – 16.2
8.362 – 8.366	156.52475 – 156.52525	2483.5 – 2500	17.7 – 21.4
8.37625 – 8.38675	156.7 – 156.9	2690 – 2900	22.01 – 23.12
8.41425 – 8.41475	162.0125 – 167.17	3260 – 3267	23.6 – 24.0
12.29 – 12.293	167.72 – 173.2	3332 – 3339	31.2 – 31.8
12.51975 – 12.52025	240 – 285	3345.8 – 3358	36.43 – 36.5
12.57675 – 12.57725	322 – 335.4	3600 – 4400	Above 38.6
13.36 – 13.41	-	-	-

Table 4: Radiated and conducted emission limits defined in section 15.209

Frequency [MHz]	Field strength [µV/m]	Measurement distance [m]	Conducted [dBm]
0.009 – 0.490	2400/f[kHz]	300	12.4 – 20*log(f) kHz
0.490 – 1.705	24000/f[kHz]	30	12.4 – 20*log(f) kHz
1.705 – 30.0	30	30	– 46
30 – 88	100	3	– 56
88 – 216	150	3	– 52
216 – 960	200	3	– 49
960	500	3	– 41

2 Application circuit

An application board has been designed to evaluate the RF performance and to develop the connected firmware for the S2-LP transceiver. It is compatible with the Arduino UNO R3 connector layout and allows expansion of the STM32 Nucleo boards. *Figure 1: "S2-LP application daughterboard + STM32 Nucleo board"* shows an image of the S2-LP application board + STM32 Nucleo board. The daughterboard is equipped with a 50 MHz XTAL to provide the correct oscillator to the S2-LP.

The S2-LP has an internal SMPS that drastically reduces the power consumption, making the S2-LP the best-in-class for the application on this bandwidth. The SMPS is fed from the battery (1.8 V to 3.6 V) and provides to the device a programmable voltage (1.5 V typ). An SMA connector is present to connect the board to an antenna or instrumentation to verify the correct functionality and check compatibility with the required standards.

A few of passive components (inductors and capacitors) are used as matching/filtering for the power amplifier (PA) and balun network for the receiver.

To reduce application cost, the S2-LP is designed to work without an external antenna switch. This daughterboard is designed to show the S2-LP functionality in this condition. Clearly, an application with an antenna switch can be implemented, but this is not described in this document.

A dedicated graphical user interface (GUI) has been developed to correctly set of the S2-LP (see *Figure 2: "Graphical user interface"*).

Figure 1: S2-LP application daughterboard + STM32 Nucleo board

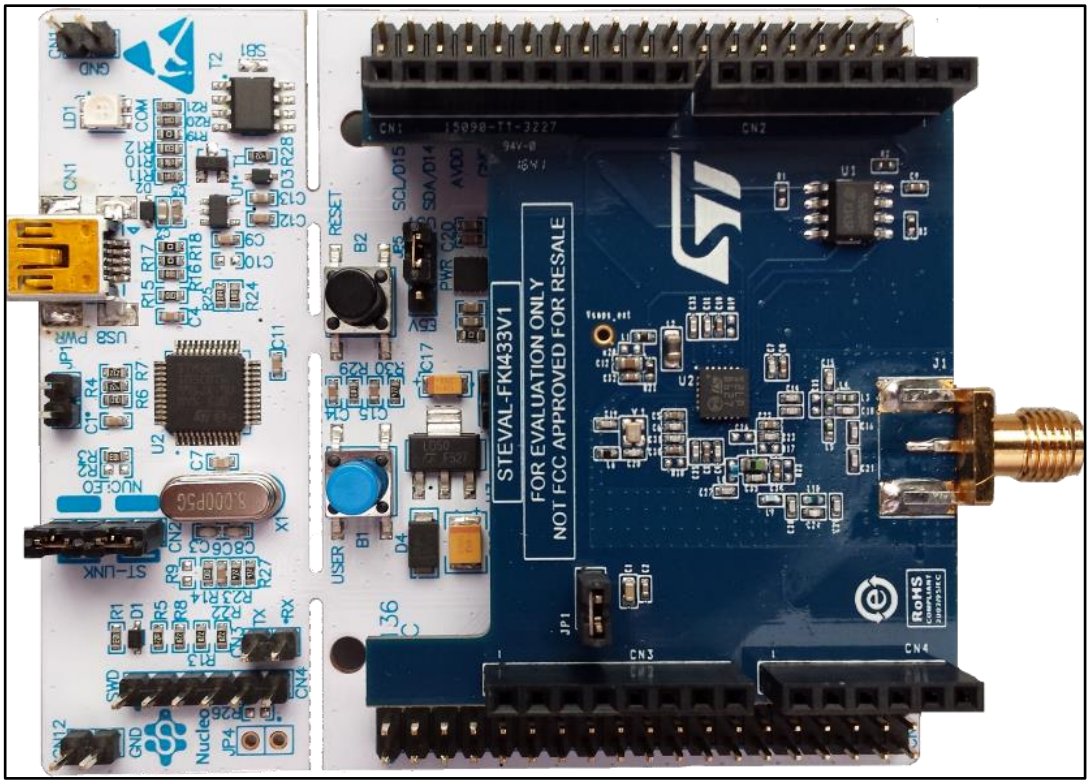
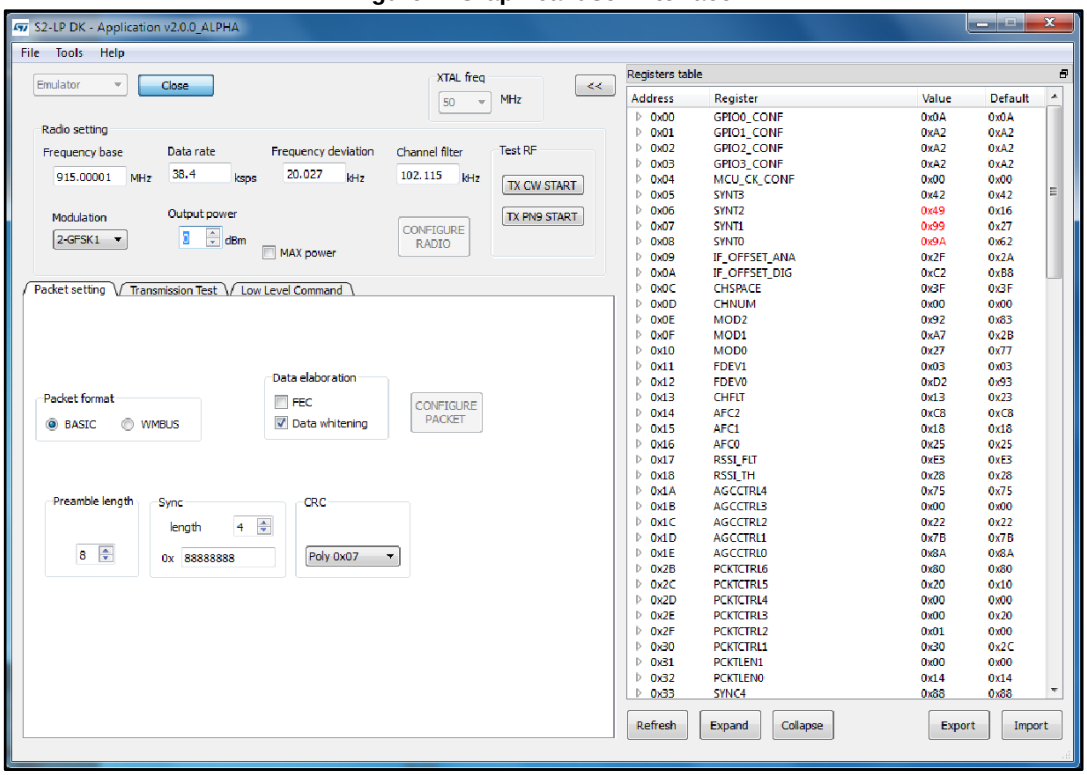


Figure 2: Graphical user interface



3 Transmitter parameters

All of the measurements reported here are measured using the following parameters:

T_c = 25 ° C,V_{dd} = 3.3 V, f = 450 MHz, unless otherwise specified.

Regarding the output power and emission, the standard specifies the maximum field strength (u V/m). Microvolts per meter (u V/m) are the units used to describe the strength of an electric field created by the operation of a transmitter. A particular transmitter that generates a constant level of power (watts) can produce electric fields of different strengths depending on the type of antenna connected to it. Because it is the electric field that causes interference to authorized radio communications, and since particular electric field strength does not directly correspond to a particular level of transmitter power, the emission limits of short range devices are specified in terms of field strength.

In order to simplify the testing environment, a conversion from the field strength to output power is performed, since the latter is easier to measure. Although the precise relationship between power and field strength can depend on a number of additional factors, a commonly-used equation to approximate the field strength (V/m) and the power (W) is:

Equation 1:

$$(\mathrm{P} * \mathrm{G})/(4 * \Pi * \mathrm{d}^2) = (\mathrm{E}^2)/(120 * \Pi)$$

where:

- P = transmitter power (EIRP) in watts
- G = gain of the transmitter antenna relative to an isotropic source
- d = distance of the measuring point from the electrical center of the antenna in meters
- E = field strength in volts/meter
- 4* P * d^2 = surface area of the sphere centered at the radiating source whose surface is d meters from the radiating source
- 120 * P = characteristic impedance of free space in Ohms, 377 Ω approximately Assuming a unity gain antenna (G = 1) and considering the measurement distance of 3 meters (d = 3), a formula can be summarized with:

Equation 2:

$$P = 0.3 * E^2$$

The field strength of the fundamental at 450 MHz is not given directly but must be calculated from the two values (260 to 470 MHz) defined in *Table 1: "Field strength of emissions for normal working conditions"*. The calculated value of the field strength of the fundamental at 450 MHz is 11666.67 u V/m which corresponds, applying the formula above, to a value of -13.9 dBm at a 3 m distance. In a similar manner, the field strength of the spurious emissions must be lower than 1166.67 u V/m which corresponds, applying the formula above, to a value of –33.9 dBm at a 3 m distance.

4 Spurious RF conducted emissions

According to FCC section 15.231, the field strength of all emissions from intentional radiators outside the fundamental and the band defined in section 15.205 must be lower than the values defined in *Table 1: "Field strength of emissions for normal working conditions"*. The field strength limits are specified at a distance of 3 meters. The limits on the field strength of the spurious emissions in *Table 1: "Field strength of emissions for normal working conditions"* are based on the fundamental frequency of the intentional radiator. Spurious emissions shall be attenuated to the average limits shown in this table or to the general limits shown in section 15.209, whichever limit permits higher field strength.

According to section 15.33, for an intentional radiator operating below 10 GHz, the frequency range of measurements must be up to the tenth harmonic of the highest fundamental or to 40 GHz, which ever is lower. The S2-LP highest fundamental frequency is 470 MHz, so the tenth harmonic is 4.70 GHz. The measurements are performed up to 6 GHz.

In *Figure 3: "Spurious conducted emissions below 1 GHz"* and *Figure 4: "Spurious conducted emissions above 1 GHz"* the spurious conducted emissions and the FCC emission mask are shown. The carrier is unmodulated. The S2-LP is fully compliant with the conducted spurious emission requirements.

Figure 3: Spurious conducted emissions below 1 GHz

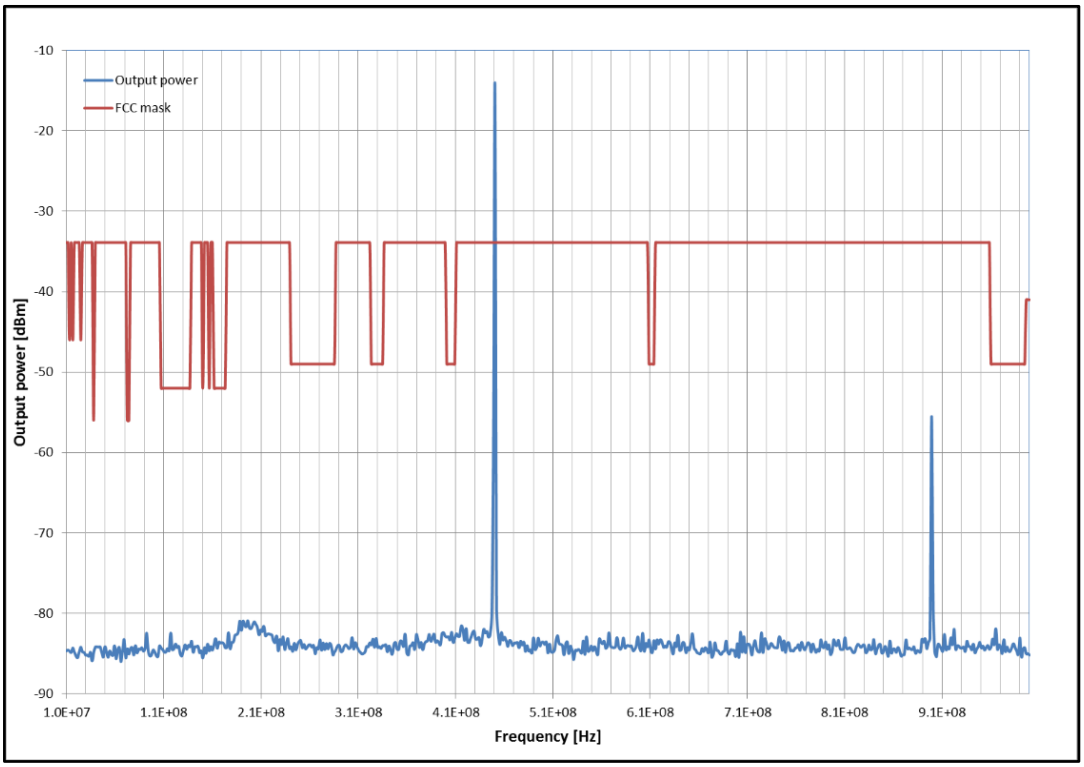
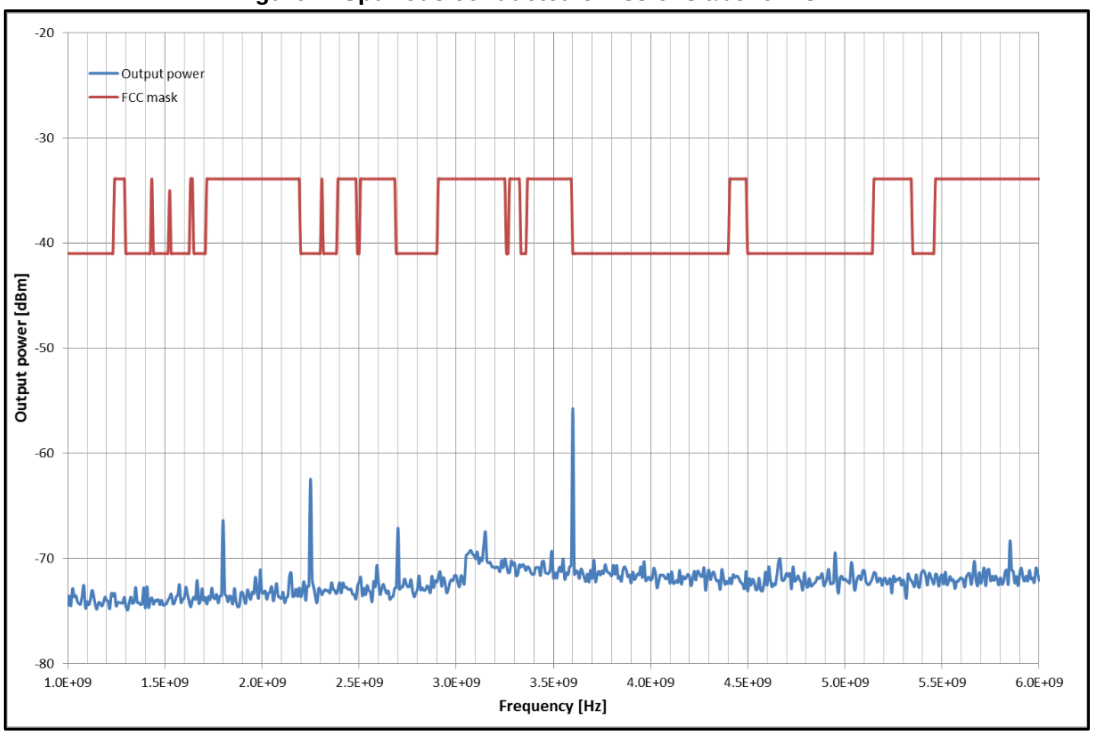


Figure 4: Spurious conducted emissions above 1 GHz



5 Receiver parameters

No specific requirements are defined for FCC compliance of the receiver in US FCC Title 47 Part 15 in the 430 - 470 MHz band. No measurements were taken for the receiver.

6 References

1. S2-LP datasheet
2. FCC Title 47 Part 15: "Radio frequency devices"

7 Revision history

Table 5: Document revision history

Date	Version	Changes
11-May-2017	1	Initial release.

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