AN4953
Application note

Using the S2-LP transceiver under ARIB STD-T108 in the 920 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 both in the license-free ISM and SRD frequency bands at 433, 868, 915 and 920 MHz.

The ARIB (Japanese Association of Radio Industries and Businesses) was established in response to several trends such as the growing internationalization of telecommunications, the convergence of telecommunications and broadcasting, and the need for promotion of radio related industries. The scope of the ARIB organism is defined the basic technical requirements for standard specifications of radio equipment.

This application note outlines the expected performance when using the S2-LP under ARIB STD-T108 *[2]* in the 920 MHz band. For details on the regulatory limits in the 920 MHz frequency band, please, refer to the ARIB STD-T108 regulation *[2]*.

These can be downloaded from *www.arib.or.jp/english/index.html* .

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1 An overview of ARIB STD-T108 regulation

Radio equipment defined in this standard utilizes 915 to 930 MHz bandwidth. The ARIB STD-T108 defined two different types of possible categories of application:

1. Convenience radio stations
2. Low-power radio stations

A short description of the two different categories is given in the following sections. The main difference concerns the output power and used band frequency.

1.1 Convenience radio stations

Devices that operate to convenience radio stations work in one way, simplex, duplex, semi-duplex or broadcast methods. The contents of communications are primarily the signals for telemetry, telecontrol and data transmission systems.

Key parameters and functionality of the convenience radio stations are:

- Frequency band = 920.5 MHz – 923.5 MHz
- Transmission power < 250 mW that is +24 dBm on a 50 ohm load, +27 dBm EIRP considering an antenna of 3 dBi gain
- Transmission content = data signal
- Transmission modulation system = not specified

A radio channel consists of up to 5 consecutive unit radio channels. A unit channel is 200 kHz wide, the permissible value for occupied bandwidth is:

- (200 x n) kHz or less with n = integer from 1 to 5

An adjacent channel leakage power is permitted. Two different channel masks are defined, functions of the usable bandwidth and of the output power as following:

- From 920.5 MHz to 922.3 MHz (3-1 of *[2]*)
- From 922.3 MHz to 923.5 MHz (3-2 of *[2]*)

For the transmitter a permissible value for unwanted emission intensity is defined (see *Table 1: "Permissible values for unwanted emission intensity"*).

For the receiver a limit for the secondary radiated emissions is defined (see *Table 2: "Limit on secondary radiated emissions, etc. at receiver"*).

Table 1: Permissible values for unwanted emission intensity

Frequency band	Spurious emission strength (average power)	Reference bandwidth
f ≤ 710 MHz	-36 dBm	100 kHz
710 MHz < f ≤ 900 MHz	-55 dBm	1 MHz
900 MHz < f ≤ 915 MHz	-55 dBm	100 kHz
915 MHz < f ≤ 920.3 MHz	-36 dBm	100 kHz
920.3 MHz < f ≤ 924.3 MHz (except for |f-fc| <= (200+100xn) kHz)	-29 dBm for 20mW < P ≤ 250mW -36 dBm for P ≤ 20 mW	100 kHz
924.3 MHz < f ≤ 930 MHz	-36 dBm	100 kHz
930 MHz < f ≤ 1000 MHz	-55 dBm	100 kHz
1000 MHz < f ≤ 1215 MHz	-45 dBm	1 MHz

Frequency band	Spurious emission strength (average power)	Reference bandwidth
1215 MHz < f	-30 dBm	1 MHz

Table 2: Limit on secondary radiated emissions, etc. at receiver

Frequency band	Limit on secondary radiated emissions, etc. (antenna input)	Reference bandwidth
f ≤ 710 MHz	-54 dBm	100 kHz
710 MHz < f ≤ 900 MHz	-55 dBm	1 MHz
900 MHz < f ≤ 915 MHz	-55 dBm	100 kHz
915 MHz < f ≤ 930 MHz	-54 dBm	100 kHz
930 MHz < f ≤ 1000 MHz	-55 dBm	100 kHz
1000 MHz < f	-47 dBm	1 MHz

1.2 Low power radio stations

Low power radio stations differ from the convenience radio station for two parameters: output power and usable frequency band.

Key parameters and functionality of the low power radio stations are:

- Frequency band = 915.9 MHz – 916.9 MHz and 920.5 MHz – 929.7 MHz
- Transmission power:
  - < 20 mW that is +13 dBm (+16 dBm considering an antenna of 3 dBi gain) on a 50 Ohm load for 920.5 MHz – 928.15 MHz bandwidth
  - < 1 mW that is 0 dBm (+3 dBm considering an antenna of 3 dBi gain) on a 50 ohm load for 916.0 MHz – 916.8 MHz and 928.15 MHz – 929.65 MHz bandwidths
- Transmission content = data signal
- Transmission modulation system = not specified

As for the convenience radio stations, a radio channel consists of up to 5 consecutive unit radio channels. A unit channel is 100 kHz or 200 kHz wide depending on the frequency band as following:

- 916.0 MHz – 916.8 MHz → 200 kHz
- 920.6 MHz – 928.0 MHz → 200 kHz
- 928.15 MHz – 929.65 MHz → 100 kHz

The permissible value for occupied bandwidth is:

- (200 x n) kHz or less with n = integer from 1 to 5
- (100 x n) kHz or less with n = integer from 1 to 5

An adjacent channel leakage power is permitted. Five different channel masks are defined, functions of the usable bandwidth and of the output power as following:

- From 915.9 MHz to 916.9 MHz (3-1 of *[2]*)
- From 920.5 MHz to 922.3 MHz (3-2 of *[2]*)
- From 922.3 MHz to 928.1 MHz (for transmission power < 0 dBm, 3-3 of *[2]*)

- From 922.3 MHz to 928.1 MHz (for transmission power between 0 dBm and 13 dBm, 3-4 of *[2]*)
- From 928.1 MHz to 929.7 MHz (3-5 of *[2]*)

For the transmitter a permissible value for unwanted emission intensity is defined (see *Table 3: "Permissible values for unwanted emission intensity"*).

For the receiver a limit for the secondary radiated emissions is defined (see *Table 4: "Limit on secondary radiated emissions, etc. at receiver"*).

Table 3: Permissible values for unwanted emission intensity

Frequency band	Spurious emission strength (average power)	Reference bandwidth
f ≤ 710 MHz	-36 dBm	100 kHz
710 MHz < f ≤ 900 MHz	-55 dBm	1 MHz
900 MHz < f ≤ 915 MHz	-55 dBm	100 kHz
915 MHz < f ≤ 930 MHz (Except for |f-fc| ≤ (200+100xn) kHz if bandwidth of unit radio channel is 200 kHz, except for |f-fc| ≤ (100+50xn) kHz if the bandwidth of unit radio channel is 100 kHz. Except for |f-fc| ≤ (100+100xn) kHz if frequency band is 915.9 MHz ≤ f ≤ 916.9 MHz and 920.5 MHz ≤ f ≤ 922.3 MHz. Where n is a number of unit radio channels constituting the radio channel and is an integer from 1 to 5).	-36 dBm	100 kHz
930 MHz < f ≤ 1000 MHz	-55 dBm	100 kHz
1000 MHz < f ≤ 1215 MHz	-45 dBm	1 MHz
1215 MHz < f	-30 dBm	1 MHz

Table 4: Limit on secondary radiated emissions, etc. at receiver

Frequency band	Limit on secondary radiated emissions, etc. (antenna input)	Reference bandwidth
f ≤ 710 MHz	-54 dBm	100 kHz
710 MHz < f ≤ 900 MHz	-55 dBm	1 MHz
900 MHz < f ≤ 915 MHz	-55 dBm	100 kHz
915 MHz < f ≤ 930 MHz	-54 dBm	100 kHz
930 MHz < f ≤ 1000 MHz	-55 dBm	100 kHz
1000 MHz < f	-47 dBm	1 MHz

2 Application circuit

An application board has been designed to evaluate the RF performances and to develop the connected firmware of 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"* shows the S2-LP application board photo.

The daughterboard is provided with a 50 MHz xtal to provide the correct oscillator to the S2-LP.

The S2-LP has an internal SMPS that drastically reduce 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 provide to the device a programmable voltage (1.5 V usually). An SMA connector is present to connect the board at antenna or at instrumentation to verify the correct functionality and verify the compatibility with the requested standards.

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

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

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

Figure 1: S2-LP application daughterboard

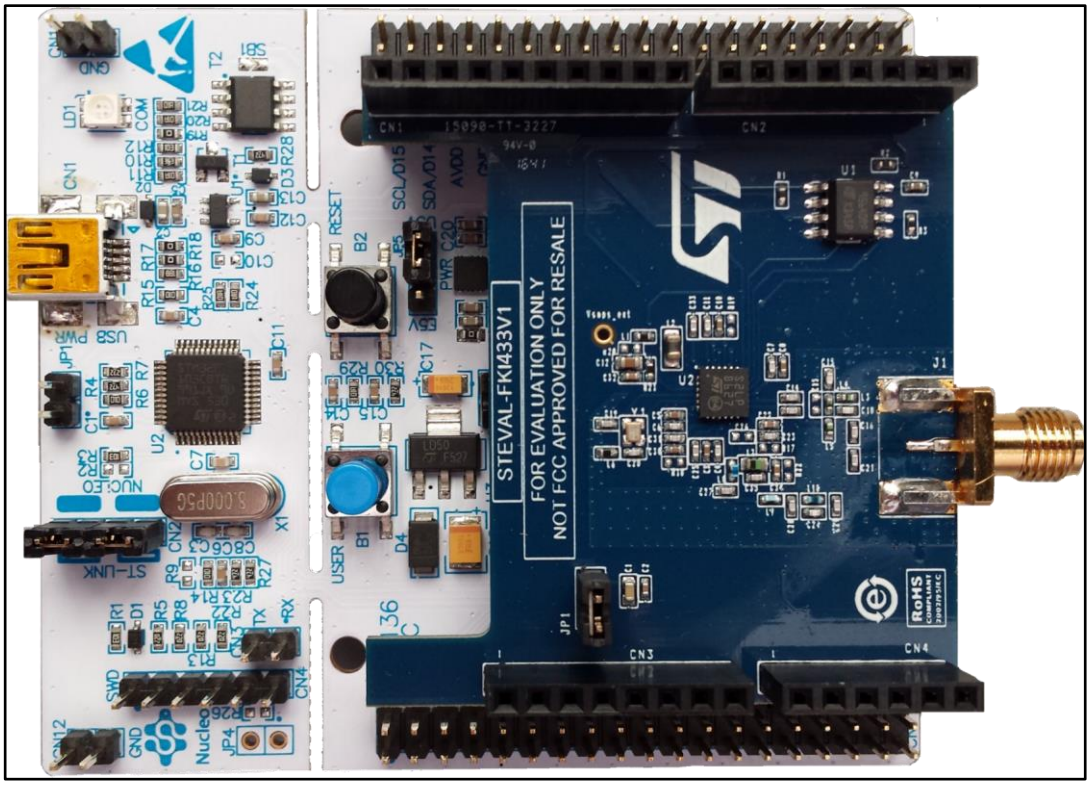
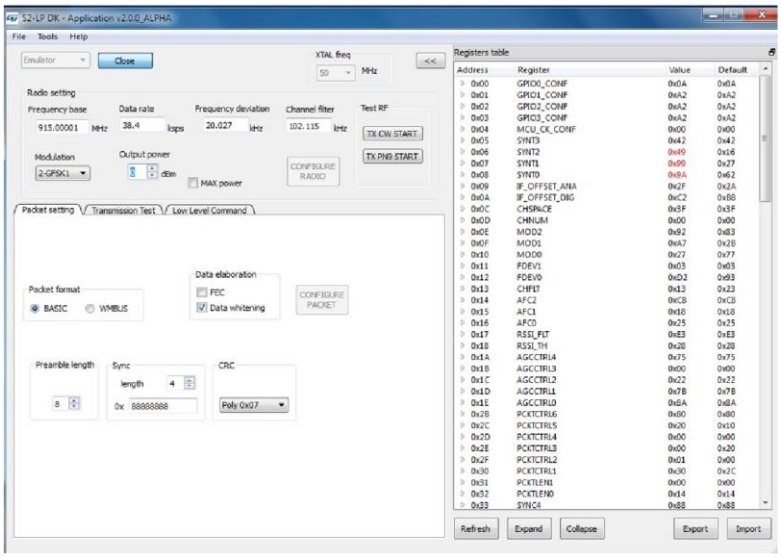


Figure 2: S2-LP application GUI



3 Transmitter parameters

All the measurement here reported are measured using the following parameters: Tc = 25 °C, Vdd = 3.3 V, unless otherwise specified.

The maximum output power of the S2-LP in this band is +14 dBm, so all the measurements for the convenience radio stations and low power radio stations with +24 dBm output power will be performed at +14 dBm. All the other cases will be carried out with the correct output power.

A radio channel consist of up to 5 consecutive unit radio channels which are defined that their center frequency are located from 920.6 MHz to 923.4 MHz with 200 kHz separation and their bandwidth are 200 kHz. S2-LP fully supports the center frequency, separation and bandwidth requirements. No measurement in that sense will be done.

There are no specific requirements for the modulation method, while the permissible value for occupied bandwidth is (200 x n) kHz or less, where n is the number of unit radio channels constituting the radio channel and is an integer from 1 to 5.

The measurement will be performed with the following S2-LP settings:

- Data rate = 38.4 kbps
- Frequency deviation = 20 kHz
- Modulation = GFSK with BT = 0.5

and

- Data rate = 100 kbps
- Frequency deviation = 50 kHz
- Modulation = GFSK with BT = 0.5

Different combinations of modulation, data rate, and frequency deviation creates signals that have a bandwidth different from 200 kHz: a dedicated check has to be done case by case.

There are no specific requirements in the standard about the setting of the spectrum analyzer. The following settings will be used as defined in [*3*]:

- Detection function = peak
- Trace = max hold

The RBW and VBW settings are defined in each paragraph.

3.1 Adjacent channel leakage power

The adjacent channel leakage power is defined as the amount of the modulated RF signal power which falls within a given adjacent channel. This power is the sum of the mean power produced by the modulation, hum and noise of the transmitter.

A dedicated discussion has to be done about the resolution bandwidth (RBW) setting. All the adjacent channel leakage powers and masks are defined in a 100 kHz reference bandwidth. In this case it is not appropriate to use an RBW = 100 kHz due to the proximity of the modulation bandwidth of the desired signal. So the following settings are used:

- RBW = 1 kHz
- VBW = 1 kHz

In this case the measurement limits are adjusted downwards by 10xlog (100 kHz/1kHz) = 20 dB.

Different masks are defined for the two types of working modes. For the convenience radio stations the following masks are defined:

- 920.5 MHz to 922.3 MHz band → *Figure 3: "Convenience radio station channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz"*
- 922.3 MHz to 923.5 MHz band → *Figure 5: "Convenience radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 923.5 MHz"*

The max output power permitted for the convenience radio station is 250 mW (+24 dBm), the S2-LP does not support this output power, so the mask compliance is verified with an output power of 14 dBm. An external PA should be used to reach the maximum output power.

The following results are obtained:

- *Figure 4: "Convenience radio station channel mask of a radio channel at 922 MHz"* shows the compliance measurement in the 920 MHz to 922.3 MHz convenience band. The masks reported in the picture are for n = 1, 2 and 3. The compliance is obtained with n = 3 with no margin. A larger n (4 or 5) or a lower output power are suggested to have margin.
- *Figure 6: " Convenience radio station channel mask of a radio channel at 923 MHz"* shows the compliance measurement in the 922.3 MHz to 923.5 MHz convenience band. The masks reported in the picture are for n = 1 and 2. The compliance is obtained with n = 2 with no margin. A larger n (3, 4 or 5) or a lower output power are suggested to have margin.

For the low-power radio stations the masks printed in the corresponding figures below are defined:

- 915.9 MHz to 916.9 MHz band → *Figure 7: "Low-power radio station channel mask of a radio channel whose frequency is from 915.9 MHz to 916.9 MHz"* 1 mW (0 dBm) max output power.
- 920.5 MHz to 922.3 MHz band *Figure 9: "Low-power radio station channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz"* 20 mW (+13 dBm) max output power.
- 922.3 MHz to 928.1 MHz band *Figure 11: "Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is 1 mW or less)"* 1 mW (0 dBm) max output power.
- 922.3 MHz to 928.1 MHz band → *Figure 13: "Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is more than 1 mW and 20 mW or less)"*, output power between 1 mW (0 dBm) and 20 mW (+13 dBm).
- 928.1 MHz to 929.7 MHz band → *Figure 15: "Low-power radio station channel mask of a radio channel whose frequency is from 928.1 MHz to 929.7 MHz"*, 1 mW (0 dBm) max output power.

The following results are obtained:

- *Figure 8: " Low-power radio station channel mask of a radio channel at 916.5 MHz"* shows the compliance measurement in the 915.9 MHz to 916.9 MHz low power band at 0 dBm output power. The masks reported in the picture are for n = 1 and 2. The compliance is obtained with n = 1 for the data rate of 38.4 kbps and n = 2 for the data rate of 100 kbps with margin.
- *Figure 10: " Low-power radio station channel mask of a radio channel at 921.5 MHz"* shows the compliance measurement in the 920.5 MHz to 922.3 MHz low power band at +14 dBm output power. The masks reported in the picture are for n = 1, 3 and 4. The compliance is obtained with n = 4 with limited margin. A larger n (5) can be used.
- *Figure 12: " Low-power radio station channel mask of a radio channel at 928 MHz"* shows the compliance measurement in the 922.3 MHz to 928.1 MHz low power band

at 0 dBm output power. The mask reported in the picture are for n = 1. The compliance is obtained with limited margin. A larger n (2, 3, 4 or 5) can be used.

- *Figure 14: " Low-power radio station channel mask of a radio channel at 925 MHz"* shows the compliance measurement in the 922.3 MHz to 928.1 MHz low power band at +13 dBm output power. The masks reported in the picture are for n = 1, 3 and 4. The compliance is obtained with n = 4 with no margin. A larger n (5) or a lower power are suggested to have margin.
- *Figure 16: " Low-power radio station channel mask of a radio channel at 929 MHz"* shows the compliance measurement in the 928.1 MHz to 929.7 MHz low power band at 0 dBm output power. The masks reported in the picture are for n = 1 and 2. The compliance is obtained with n = 2 with margin. A larger n (3, 4 or 5) can be used.

Figure 3: Convenience radio station channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz

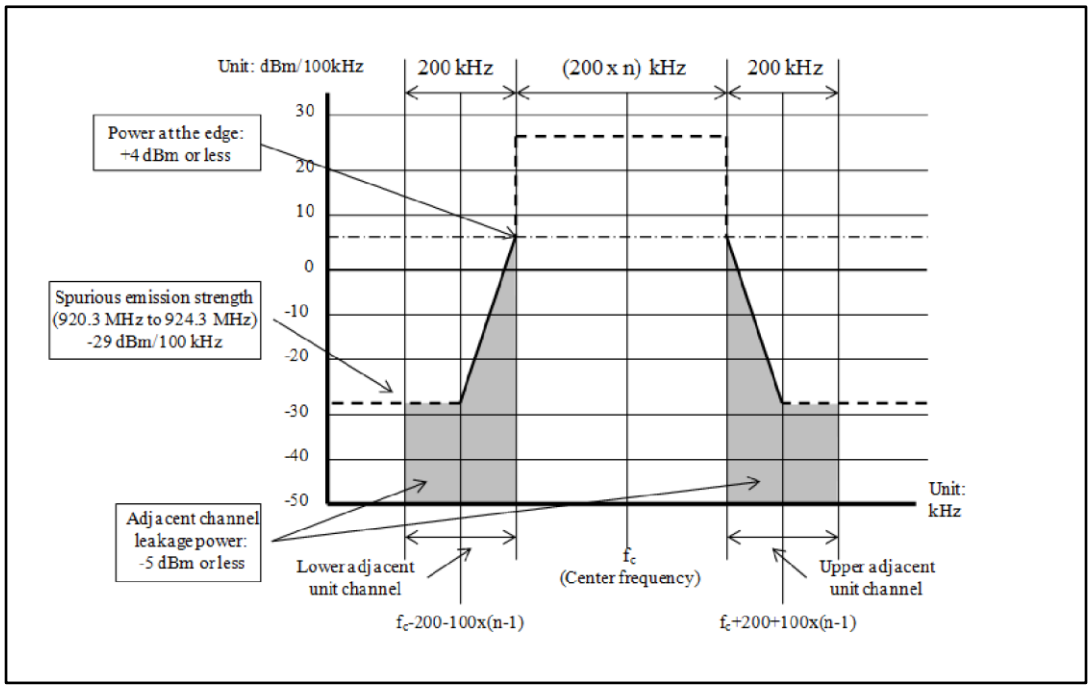


Figure 4: Convenience radio station channel mask of a radio channel at 922 MHz

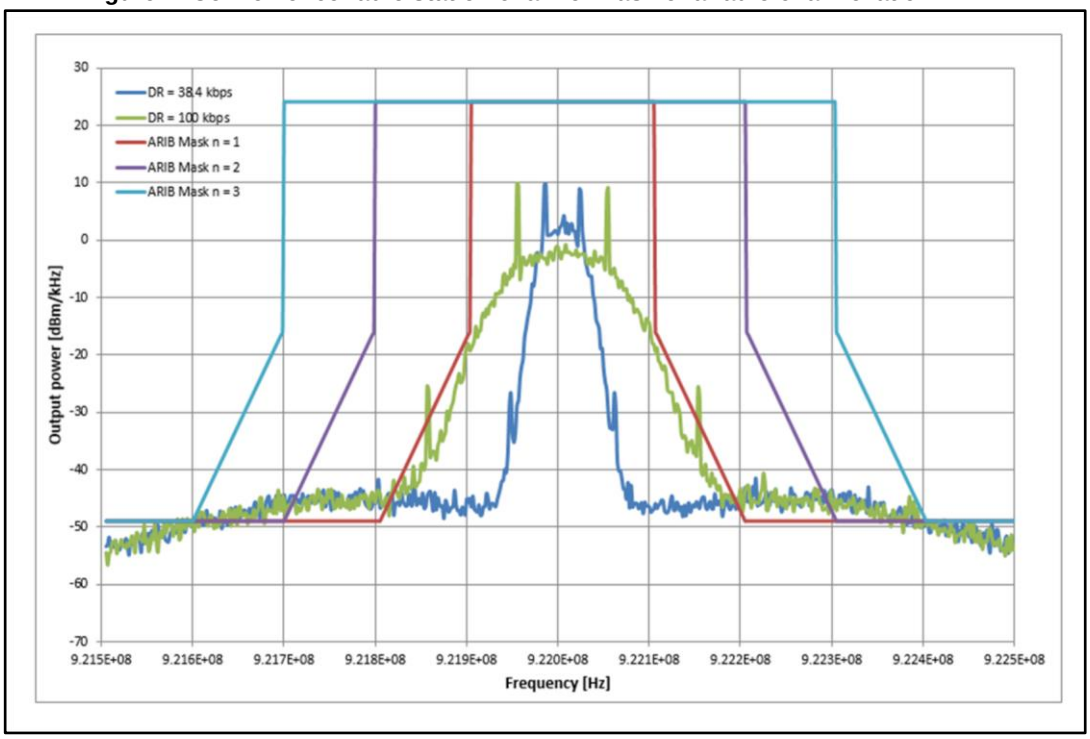


Figure 5: Convenience radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 923.5 MHz

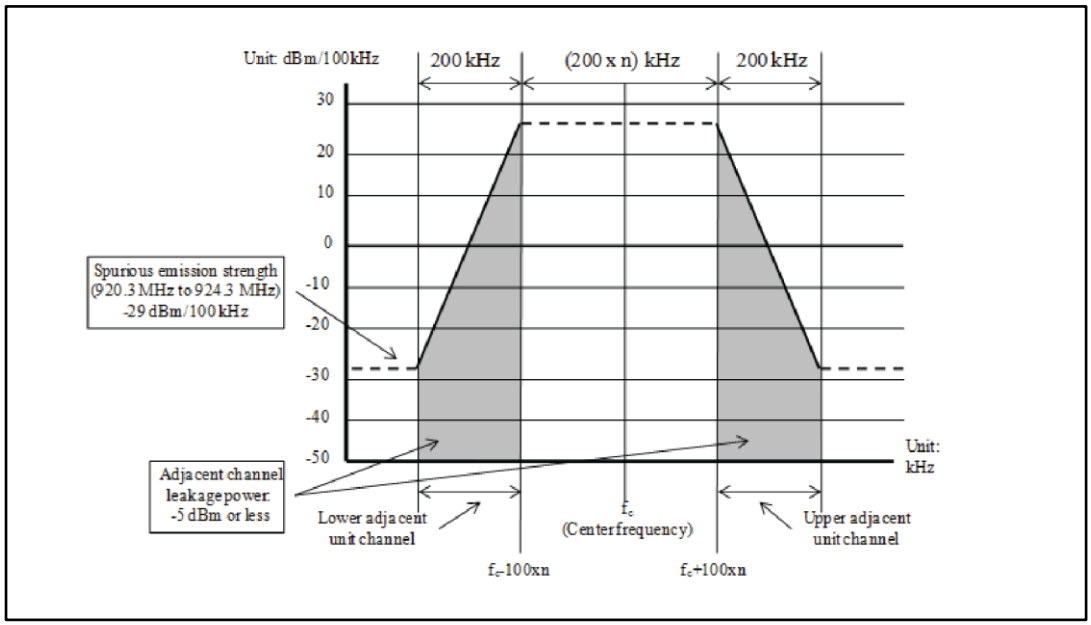


Figure 6: Convenience radio station channel mask of a radio channel at 923 MHz

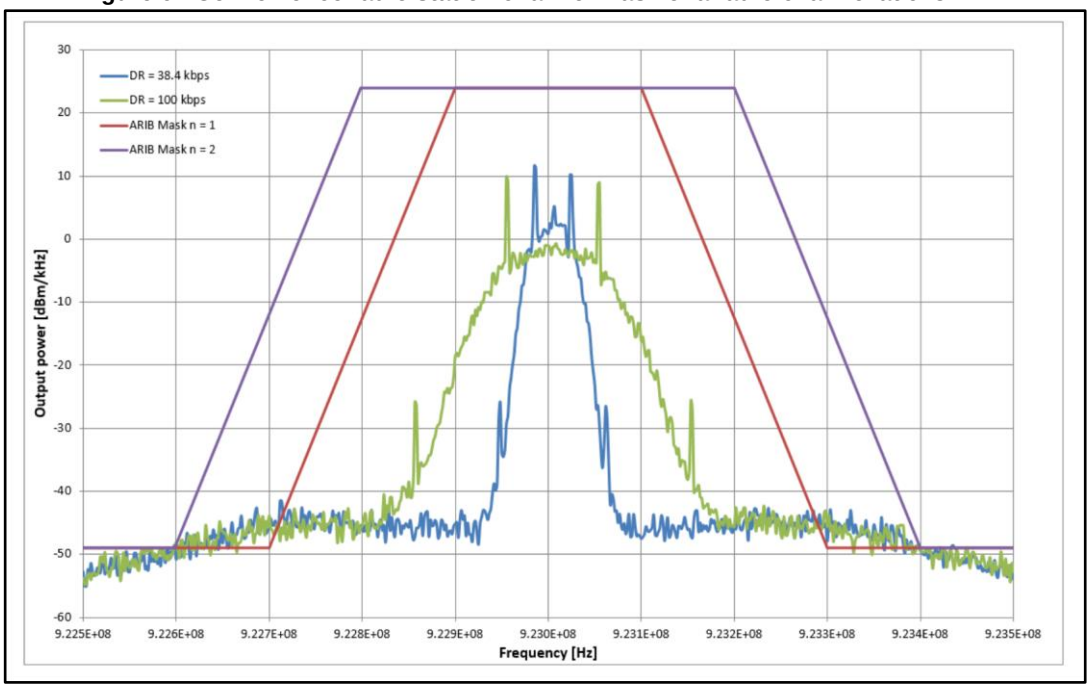


Figure 7: Low-power radio station channel mask of a radio channel whose frequency is from 915.9 MHz to 916.9 MHz

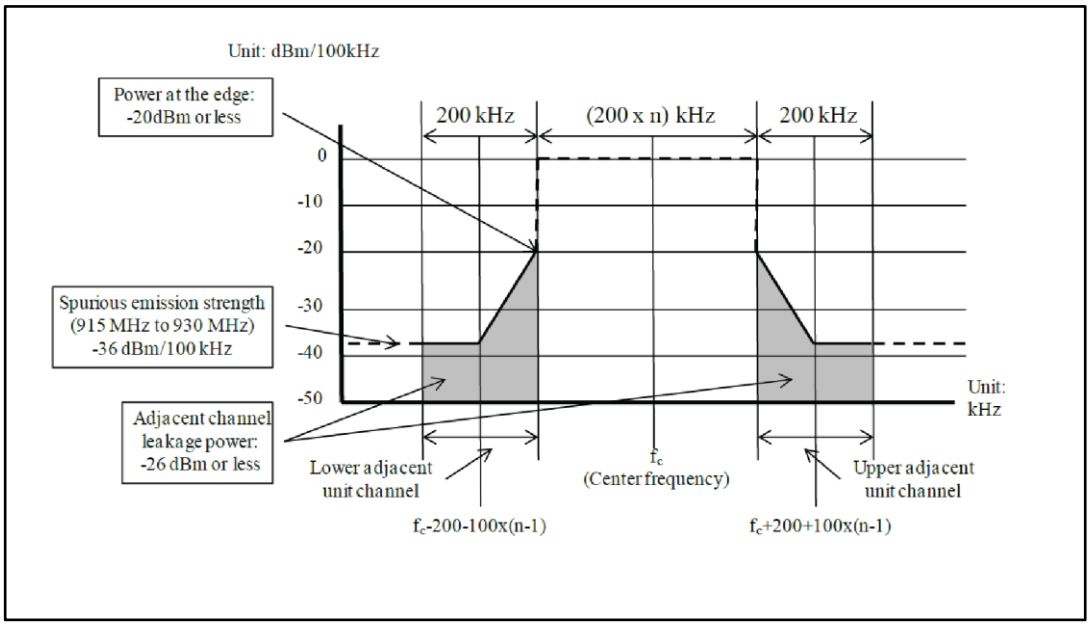


Figure 8: Low-power radio station channel mask of a radio channel at 916.5 MHz

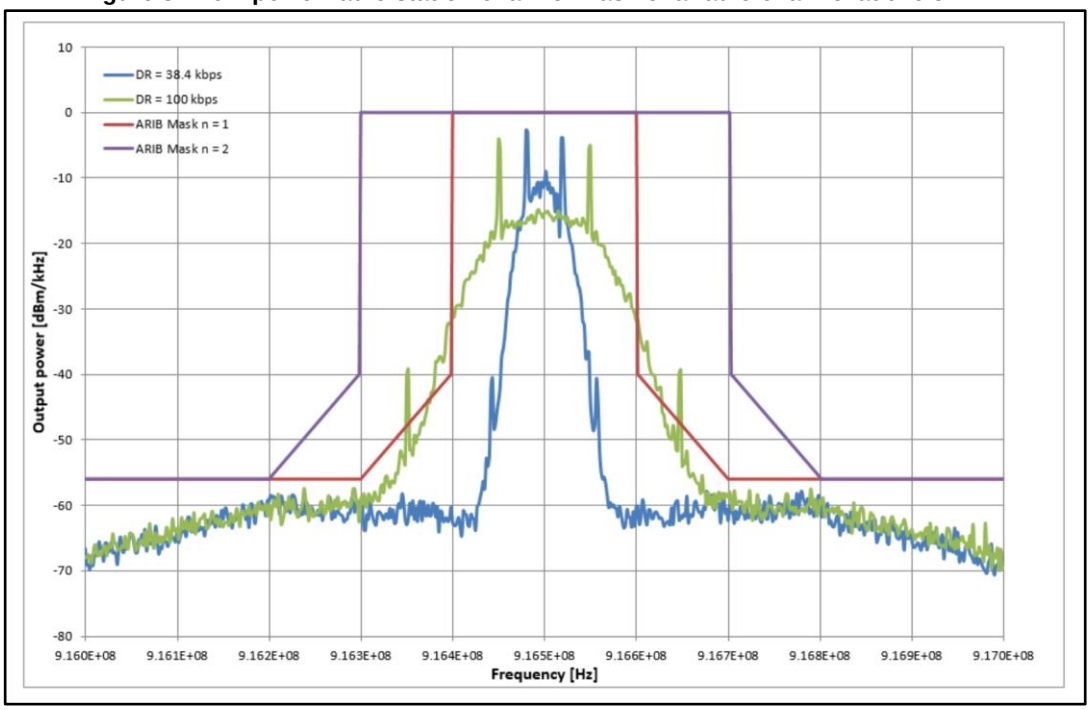


Figure 9: Low-power radio station channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz

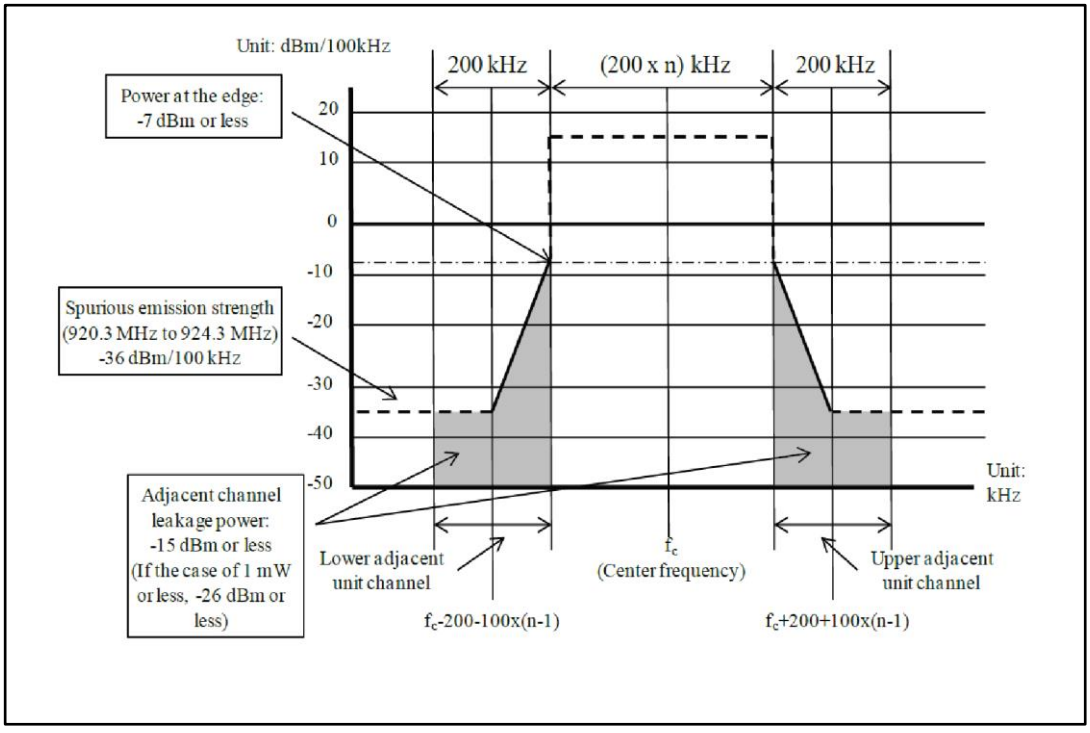


Figure 10: Low-power radio station channel mask of a radio channel at 921.5 MHz

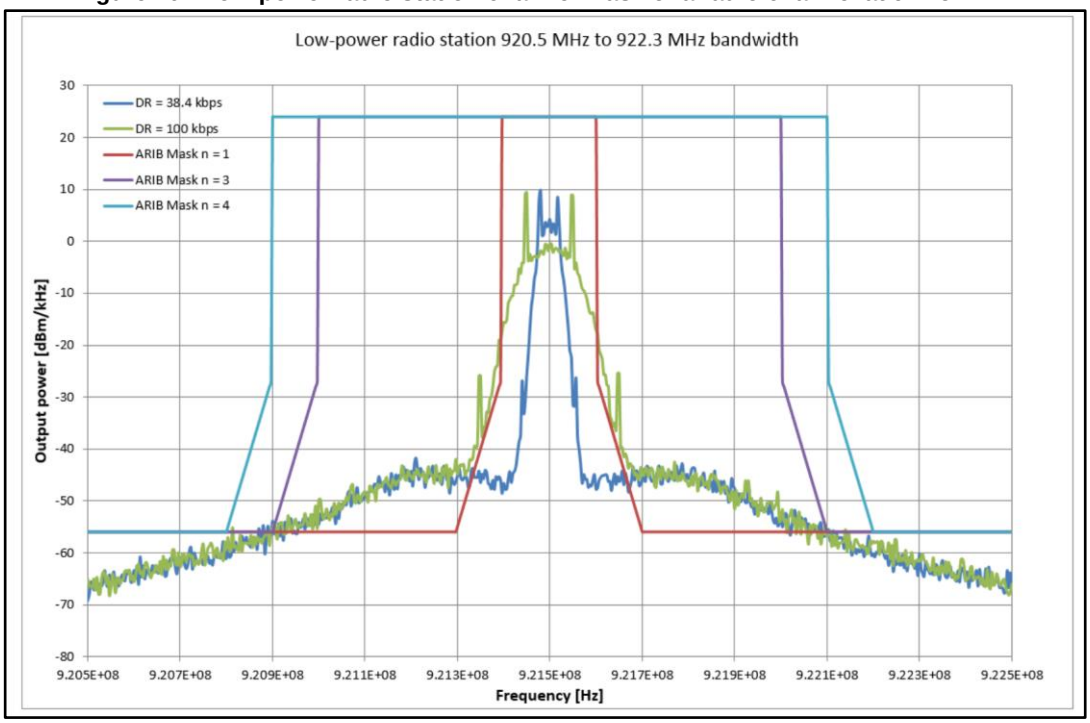


Figure 11: Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is 1 mW or less)

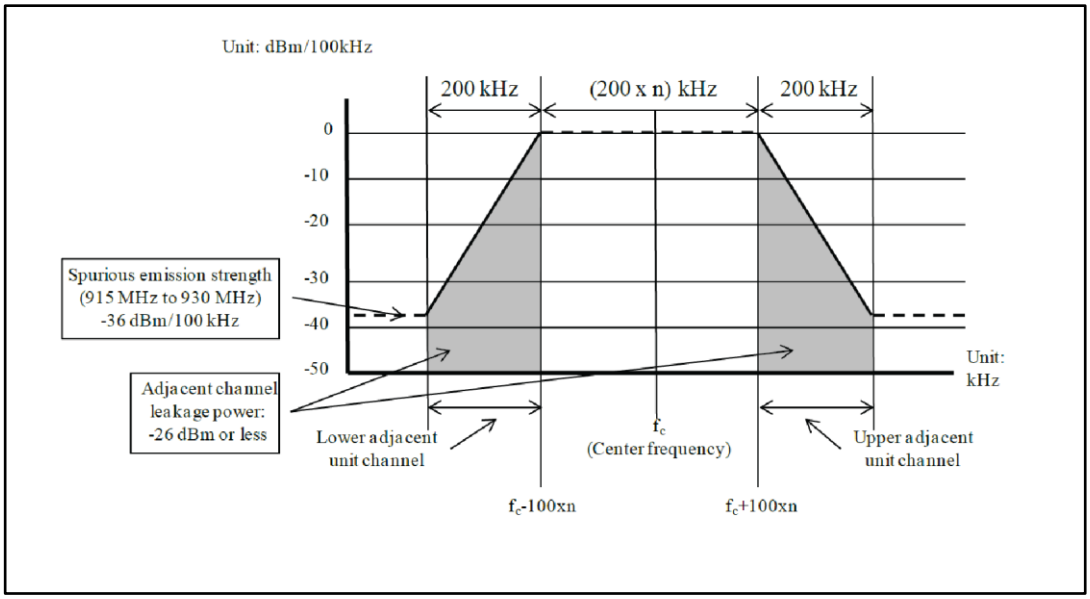


Figure 12: Low-power radio station channel mask of a radio channel at 928 MHz

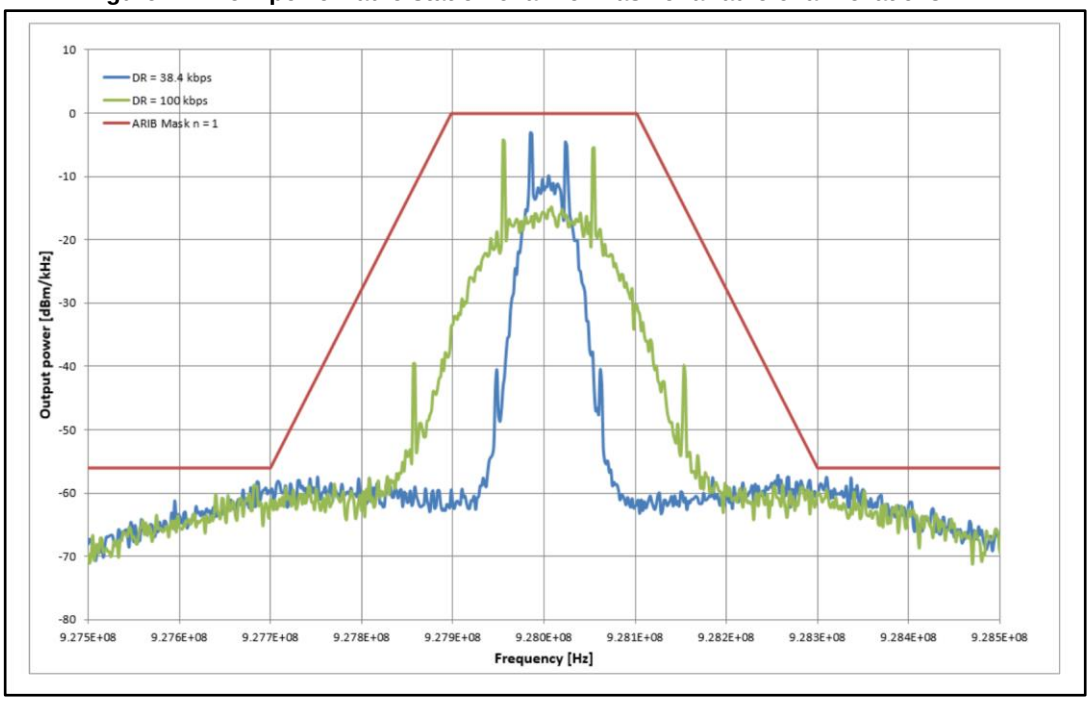


Figure 13: Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is more than 1 mW and 20 mW or less)

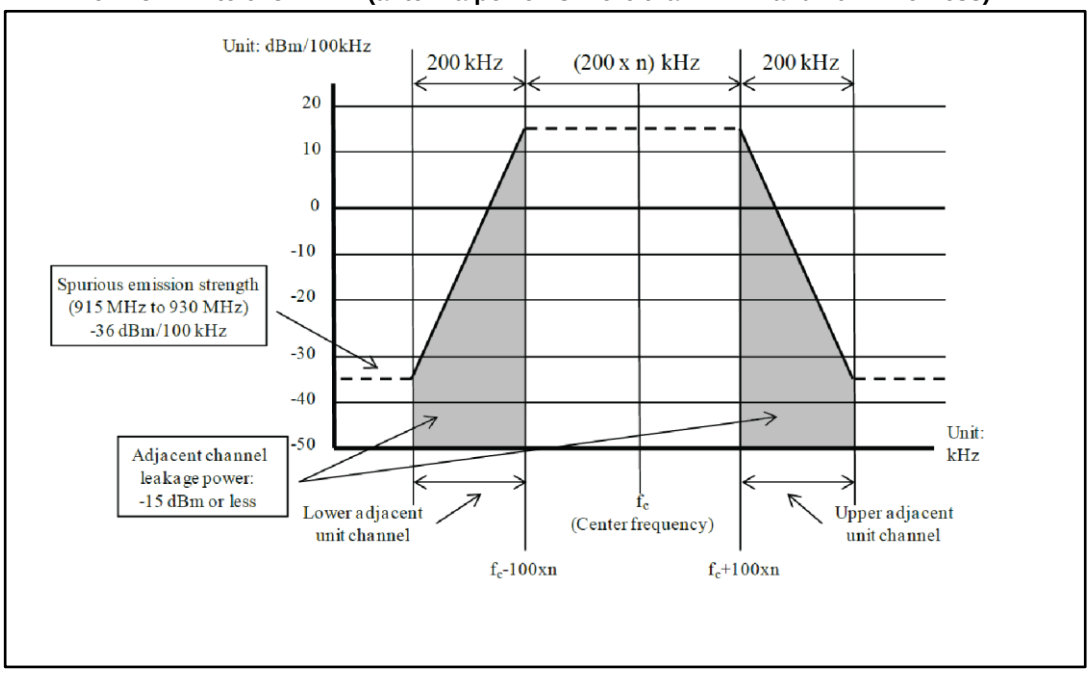


Figure 14: Low-power radio station channel mask of a radio channel at 925 MHz

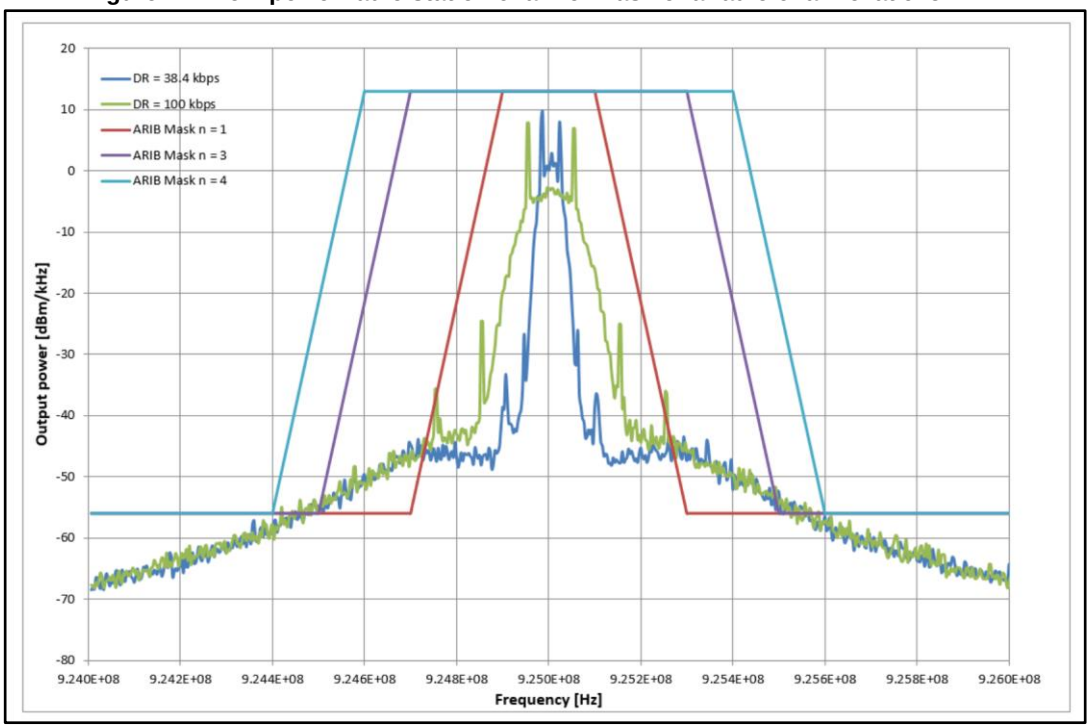


Figure 15: Low-power radio station channel mask of a radio channel whose frequency is from 928.1 MHz to 929.7 MHz

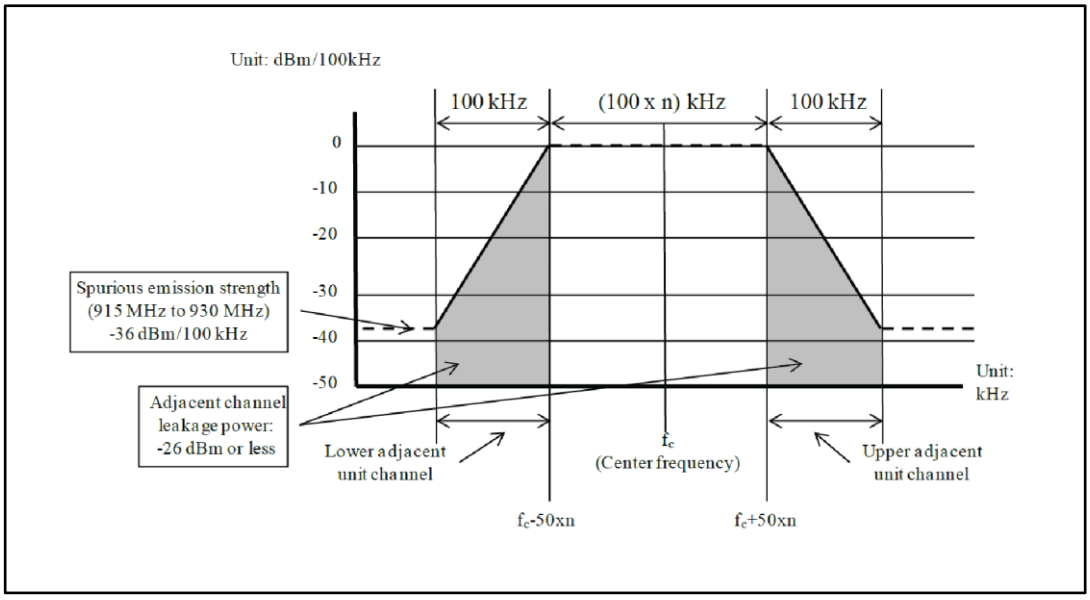
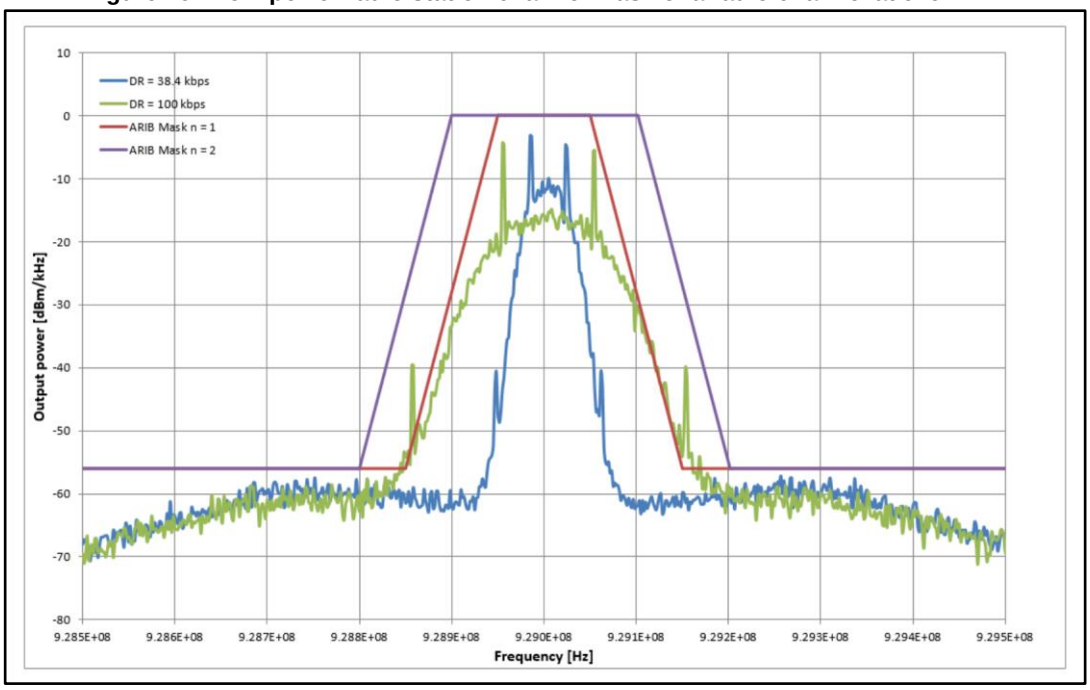


Figure 16: Low-power radio station channel mask of a radio channel at 929 MHz



3.2 Permissible values for unwanted emission intensity

Unwanted emissions in the spurious domain are emissions at a frequency other than those of the wanted carrier frequency and its sidebands associated with normal test modulation.

The spurious emission strength at the antenna input has to be less than values in *Table 1: "Permissible values for unwanted emission intensity"* for the convenience radio stations and *Table 3: "Permissible values for unwanted emission intensity"* for the low-power radio station. The measurements for the convenience radio station are done with the carrier set to 922 MHz. The measurements for the low-power radio station are done with the carrier set to 916.5 MHz.

The measurements performed for the convenience radio station are provided from figure 17 to figure 26 where it is possible to observe that the entire requirements are met.

The measurements performed for the low-power radio station are given from figure 27 to figure 32 where for the low-power case the full requirements are met.

Figure 17: Convenience radio station emission in the 10 - 710 MHz bandwidth

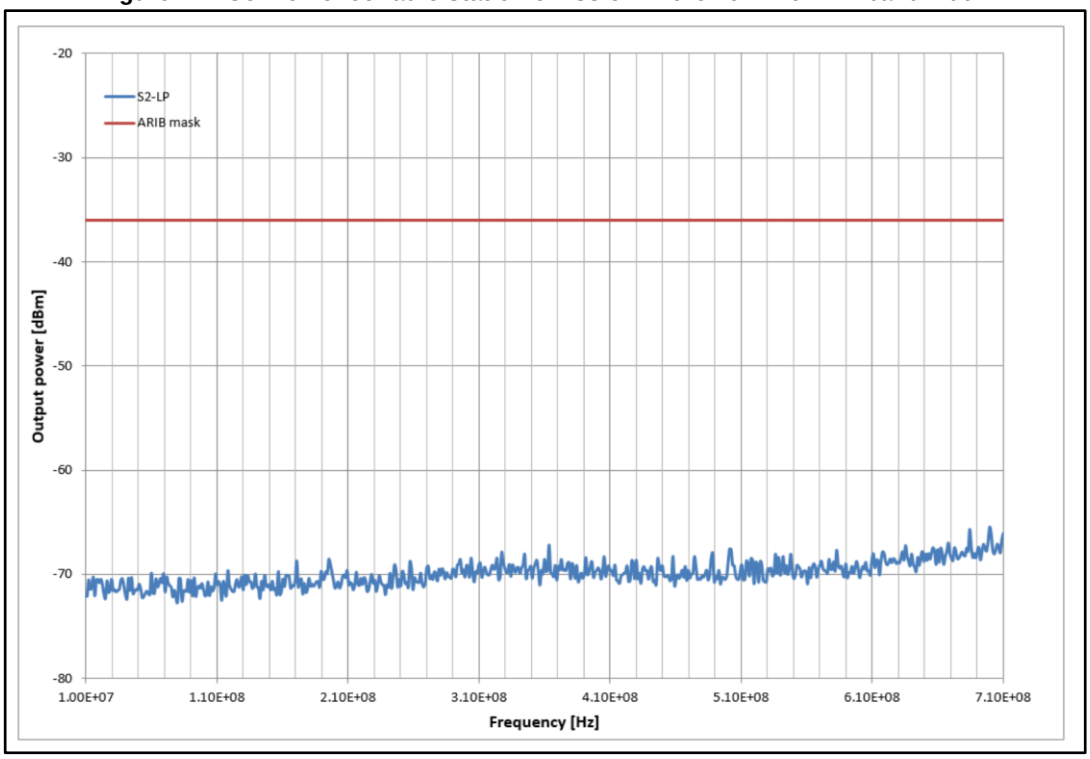


Figure 18: Convenience radio station emission in the 710 - 900 MHz bandwidth

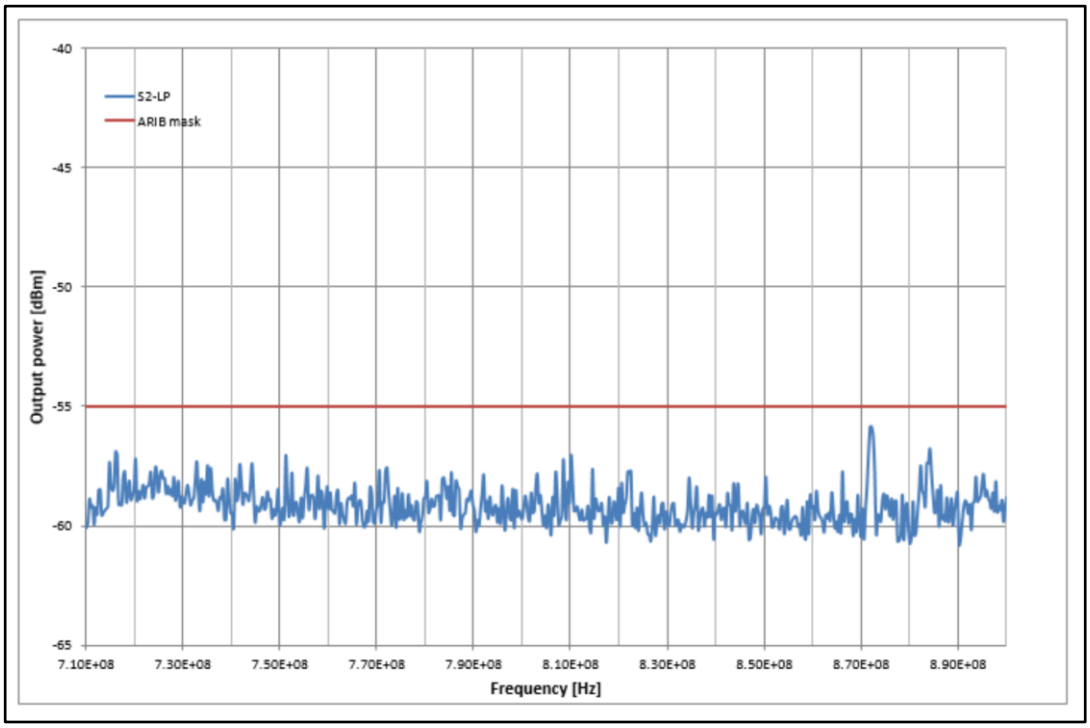


Figure 19: Convenience radio station emission in the 900 - 915 MHz bandwidth

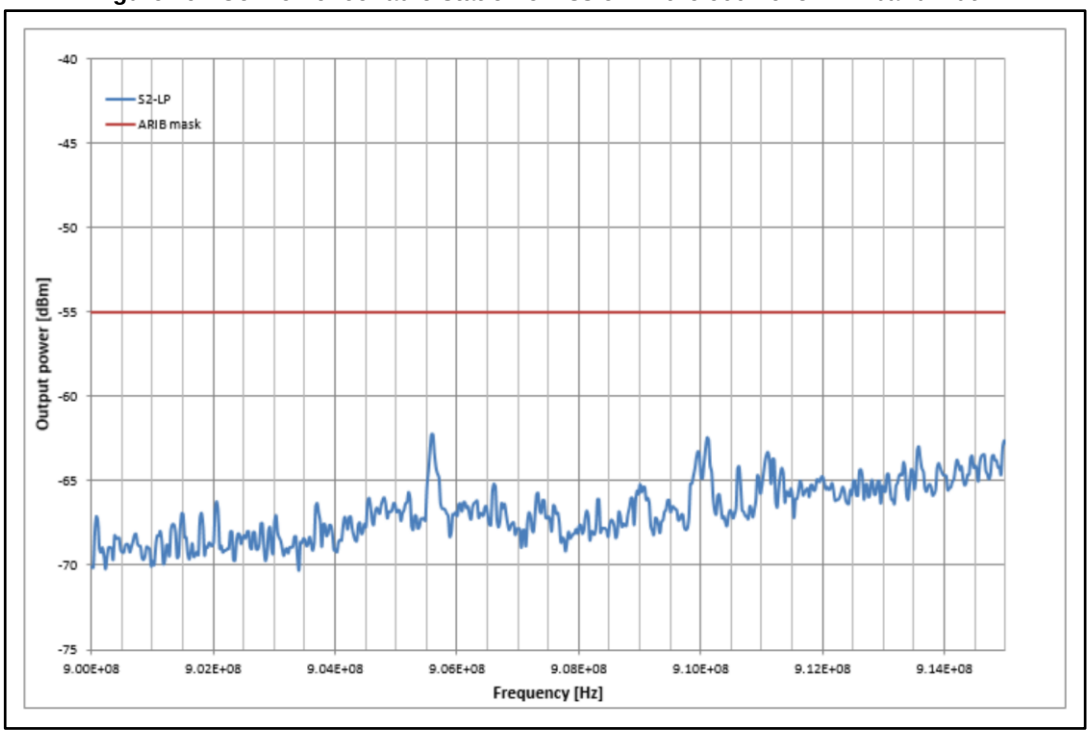


Figure 20: Convenience radio station emission in the 915 – 920.3 MHz bandwidth

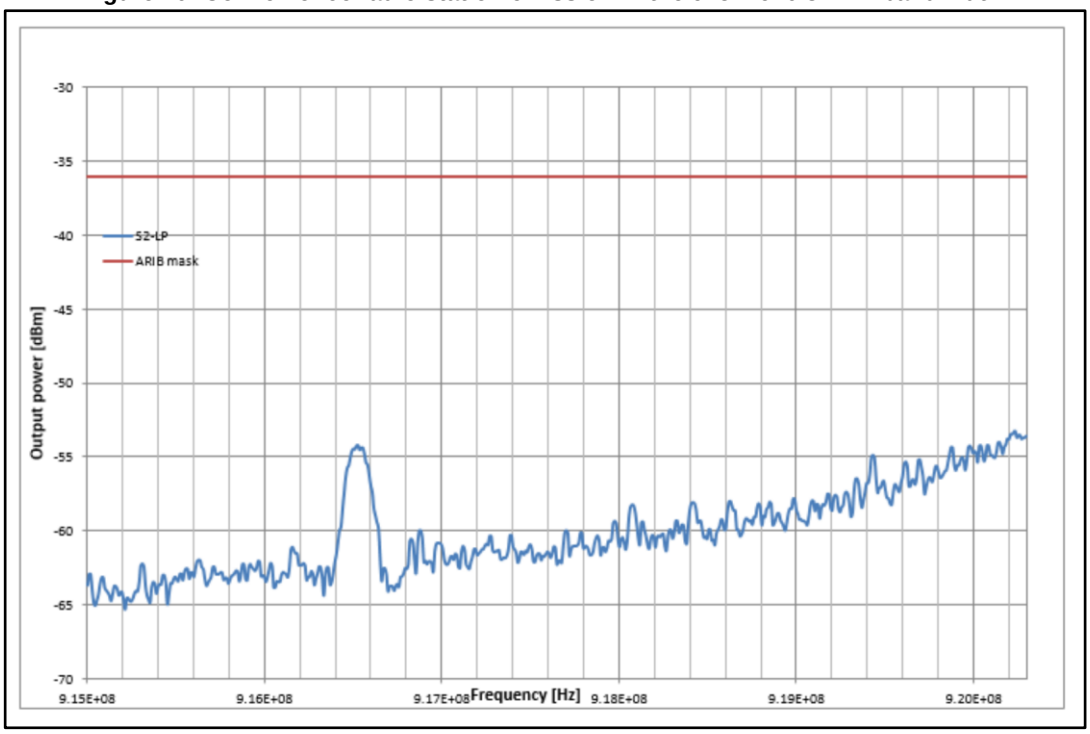


Figure 21: Convenience radio station emission in the 920.3 – 924.3 MHz bandwidth

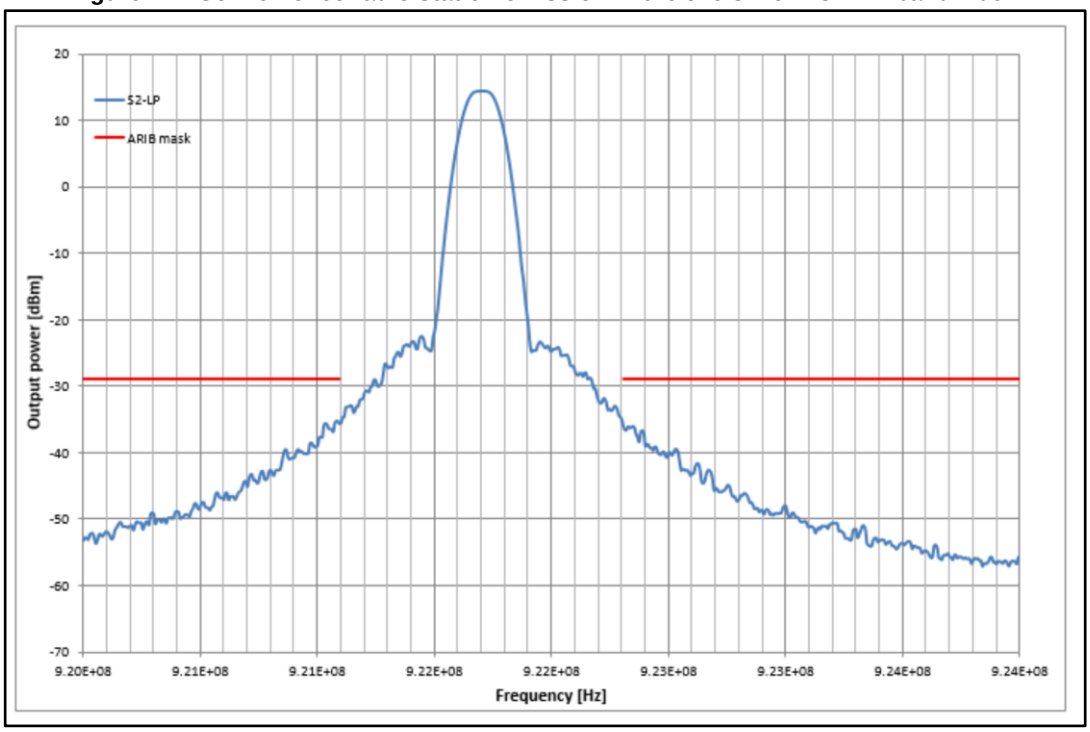


Figure 22: Convenience radio station emission in the 924.3 – 930 MHz bandwidth

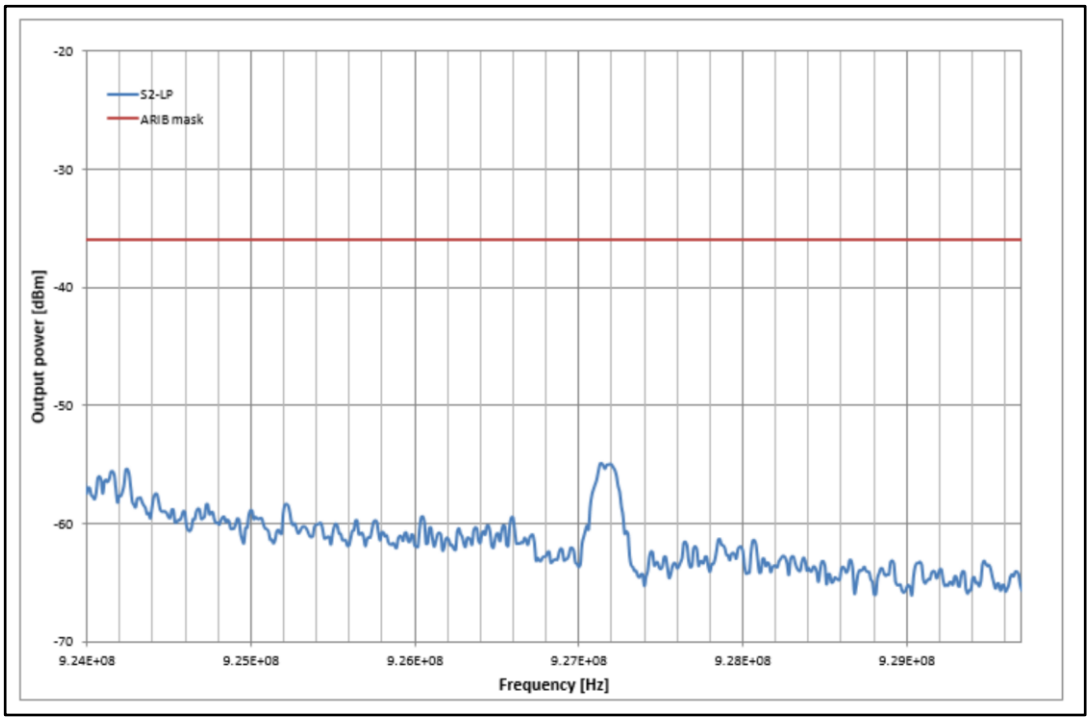


Figure 23: Convenience radio station emission in the 930 – 1000 MHz bandwidth

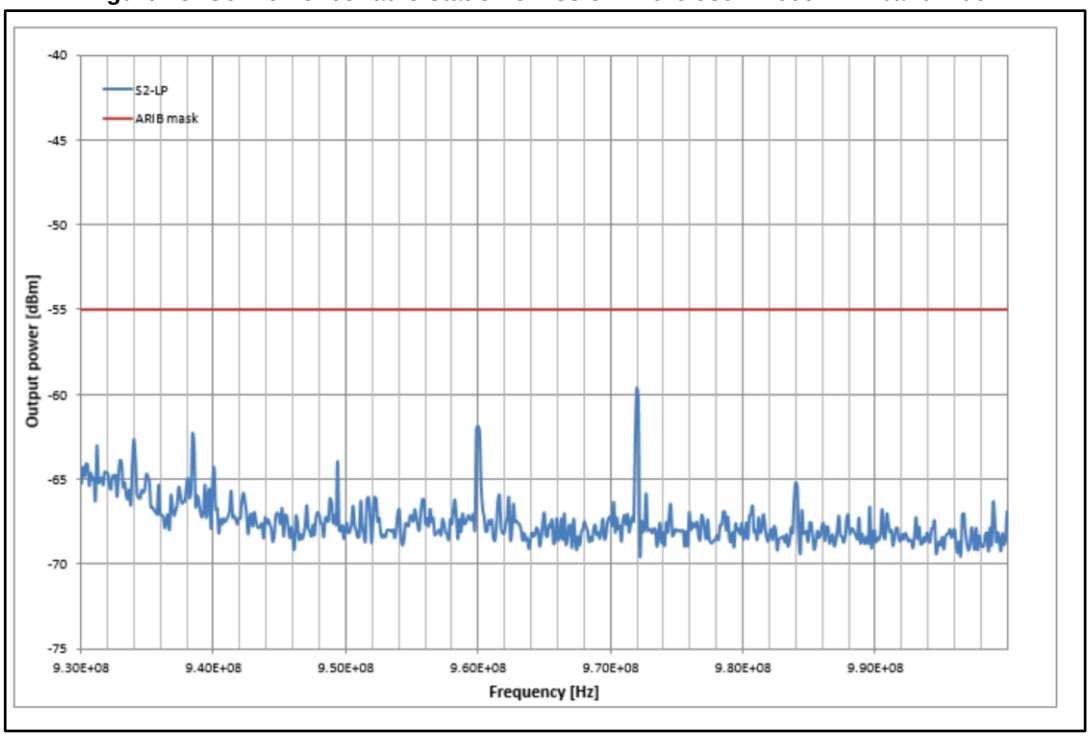


Figure 24: Convenience radio station emission in the 1 – 1.215 GHz bandwidth

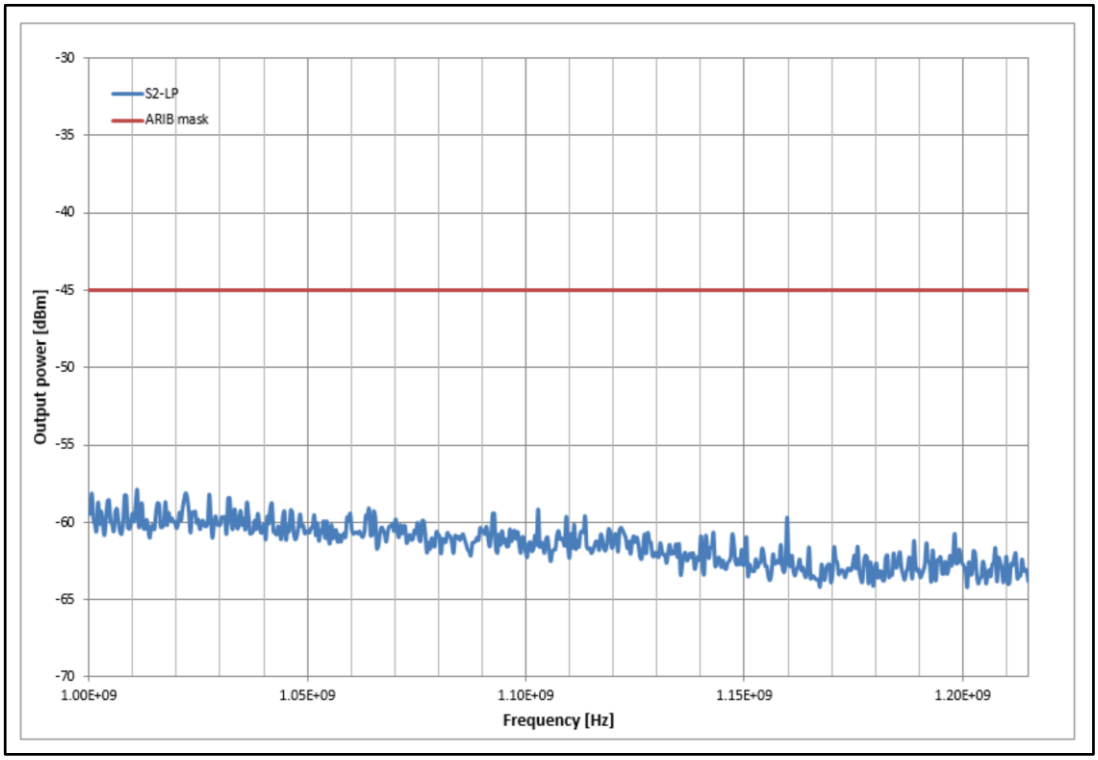


Figure 25: Convenience radio station emission in the 1.215 – 12 GHz bandwidth

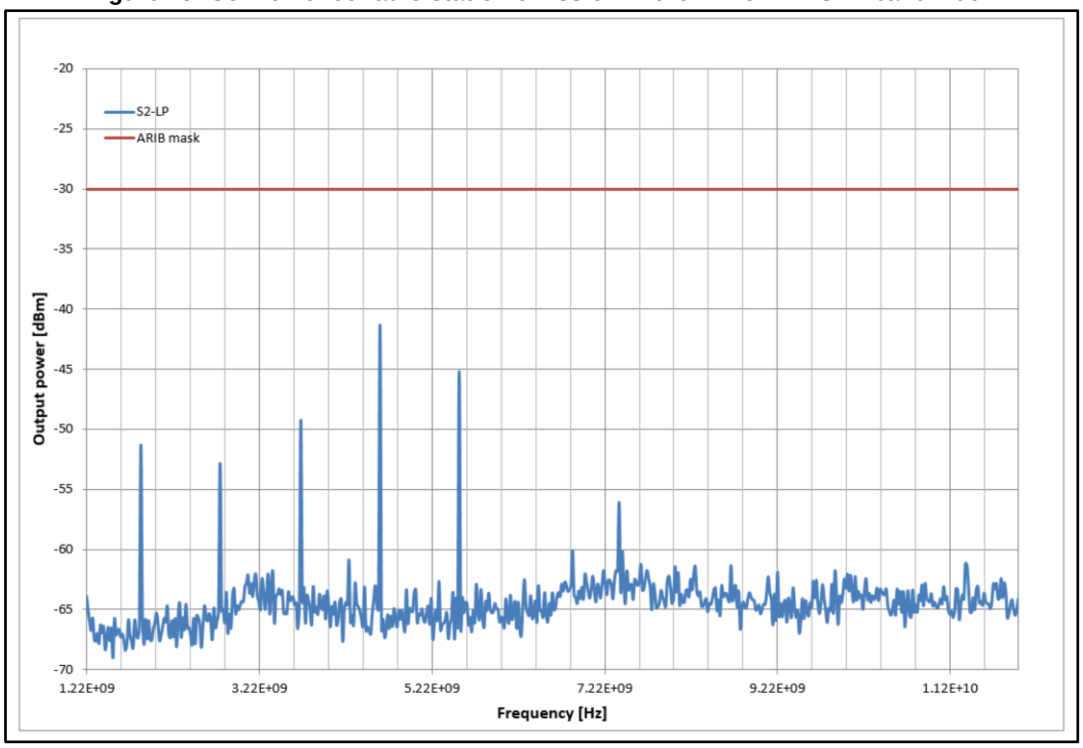


Figure 26: Low-power radio station emission in the 10 – 710 MHz bandwidth

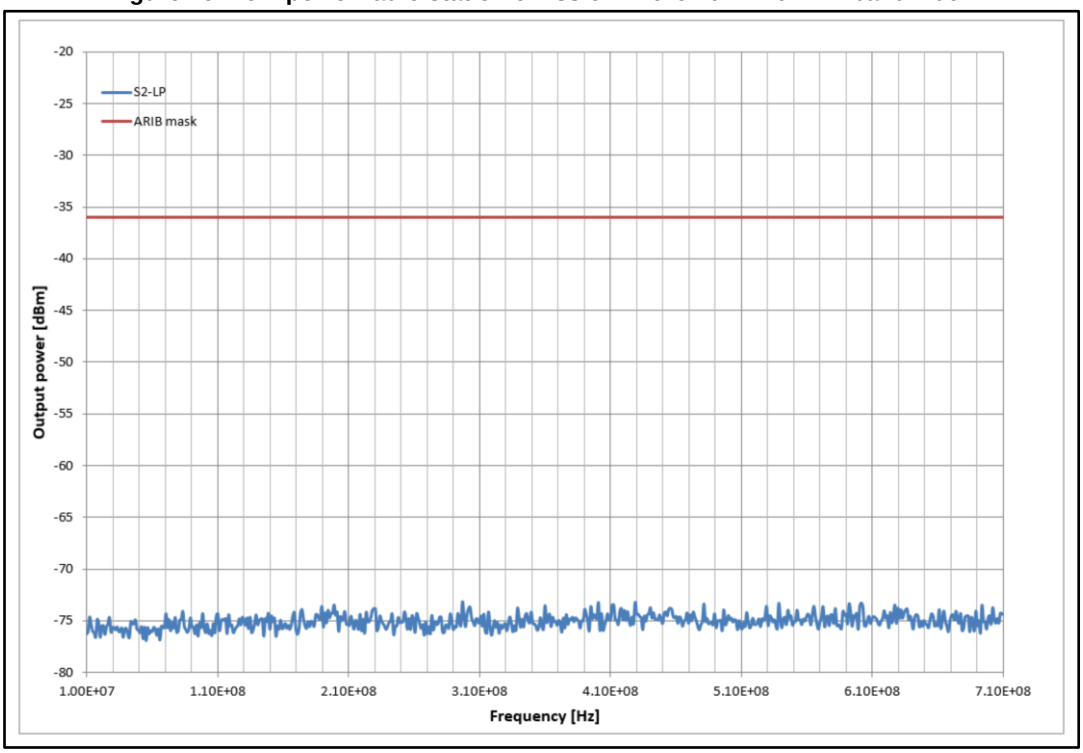


Figure 27: Low-power radio station emission in the 710 – 900 MHz bandwidth

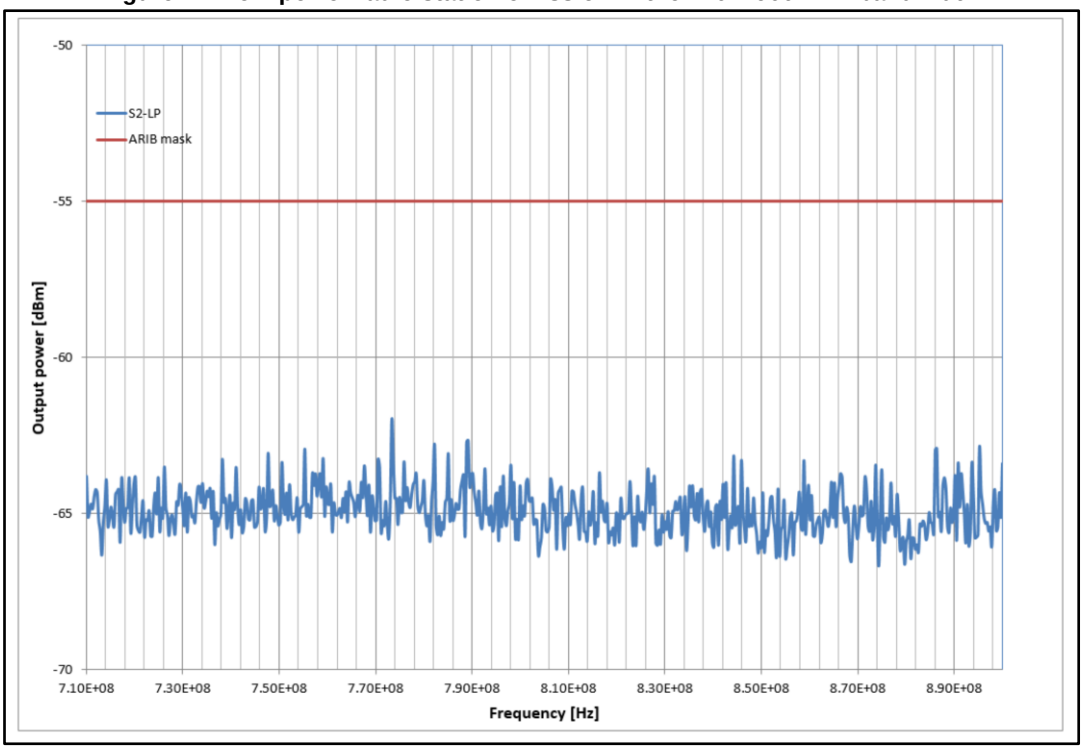


Figure 28: Low-power radio station emission in the 900 – 915 MHz bandwidth

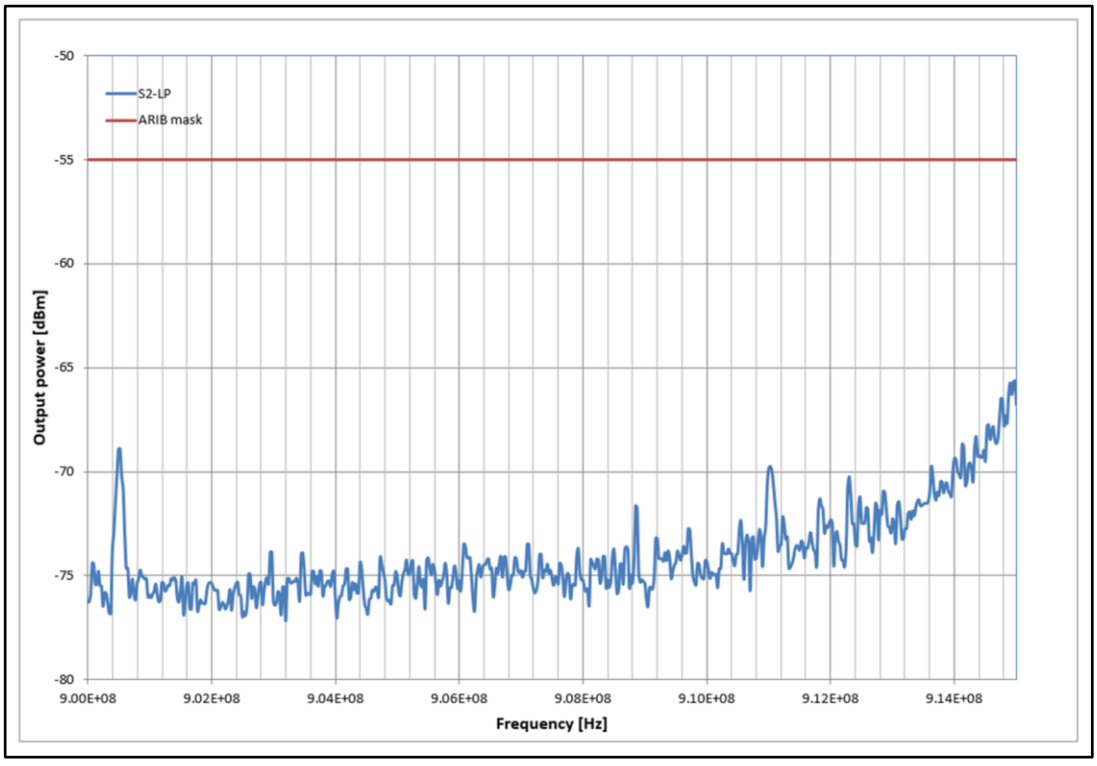


Figure 29: Low-power radio station emission in the 915 – 930 MHz bandwidth

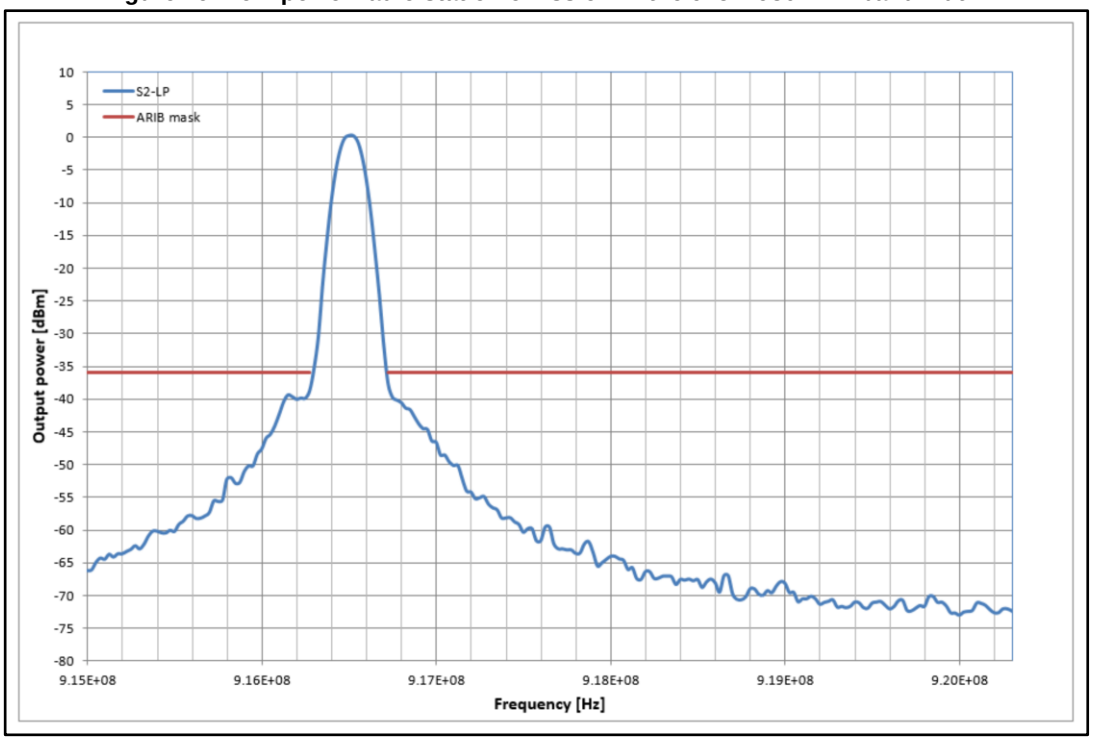


Figure 30: Low-power radio station emission in the 930 MHz– 1 GHz bandwidth

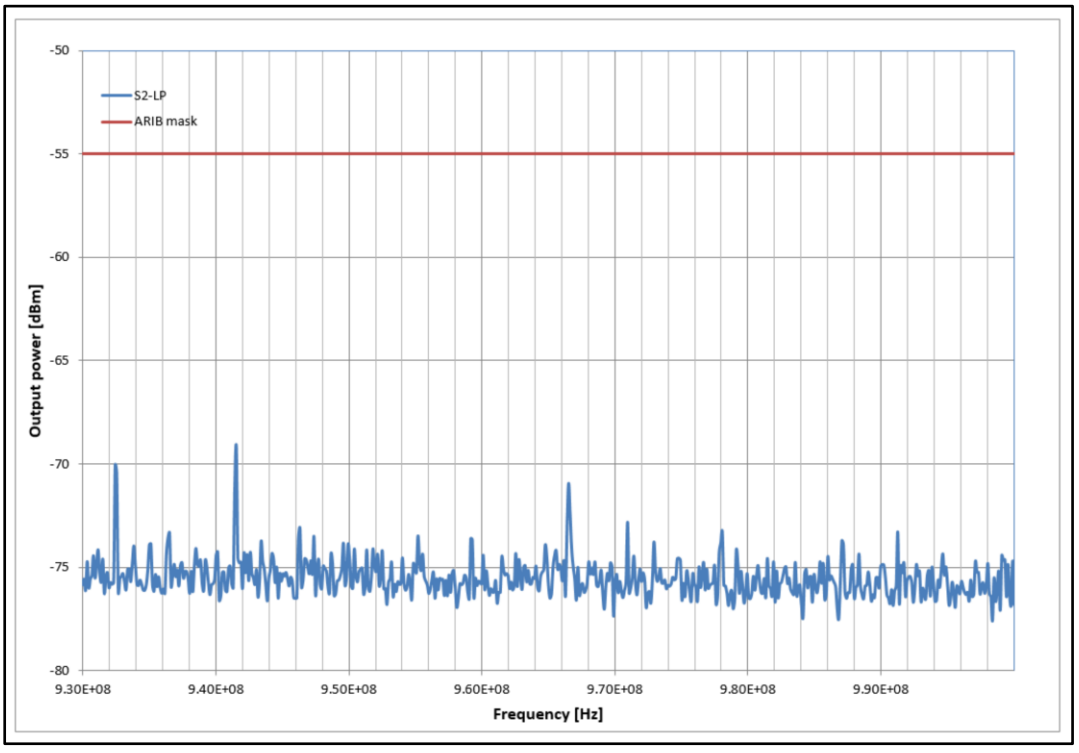


Figure 31: Low-power radio station emission in the 1 – 1.215 GHz bandwidth

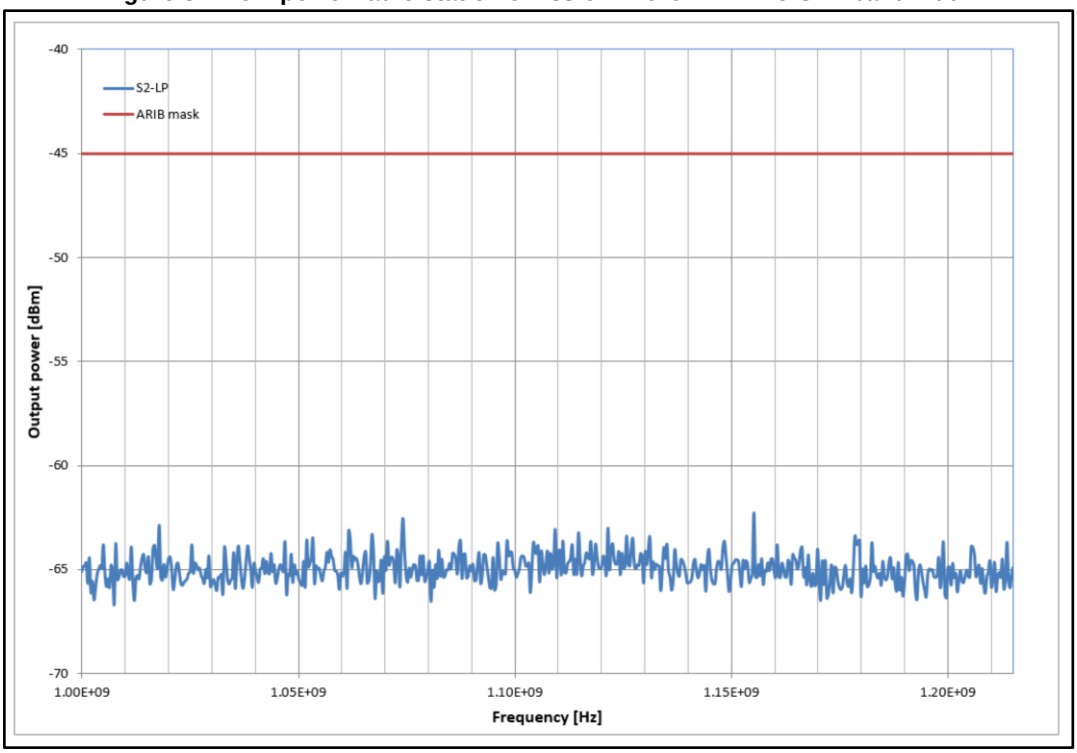
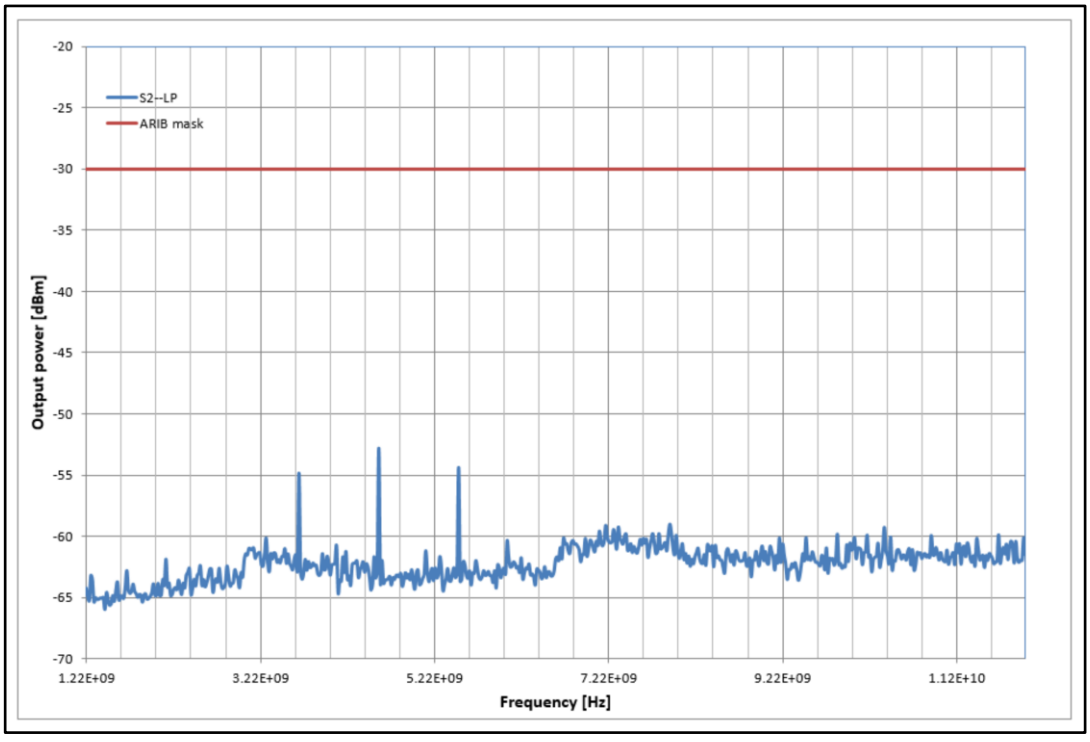


Figure 32: Low-power radio station emission in the 1.215 – 12 GHz bandwidth



4 Receiver parameter

Only a measurement is required for the receiver, the limit on secondary radiated emission. The measurement is performed with the following parameters: Tc = 25 °C, Vdd = 3.0 V, f = 922 MHz (middle frequency of the useful bandwidth).

4.1 Limit on secondary radiated emission

Spurious radiations from the receiver are components at any frequency, radiated by the equipment. The spurious emission strength at the antenna input has to be less than values in *Table 2: "Limit on secondary radiated emissions, etc. at receiver"* for the convenience radio stations and *Table 4: "Limit on secondary radiated emissions, etc. at receiver"* for the low-power radio station. The two tables are the same, so only a measurement campaign is done with the receiver set to 922 MHz, maximum gain.

The measurement results are given in the following figures. The entire standard requirements are met from the S2-LP in receiver mode.

Figure 33: Receiver radiated emission in the 10 – 710 MHz bandwidth

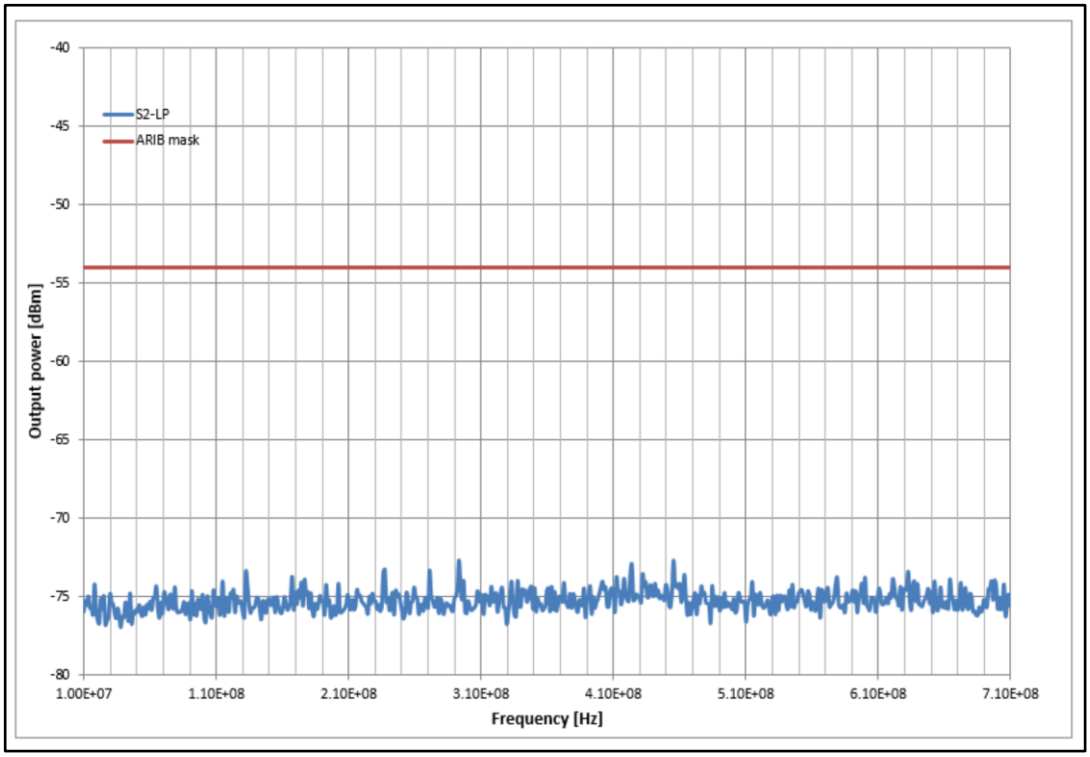


Figure 34: Receiver radiated emission in the 710 – 900 MHz bandwidth

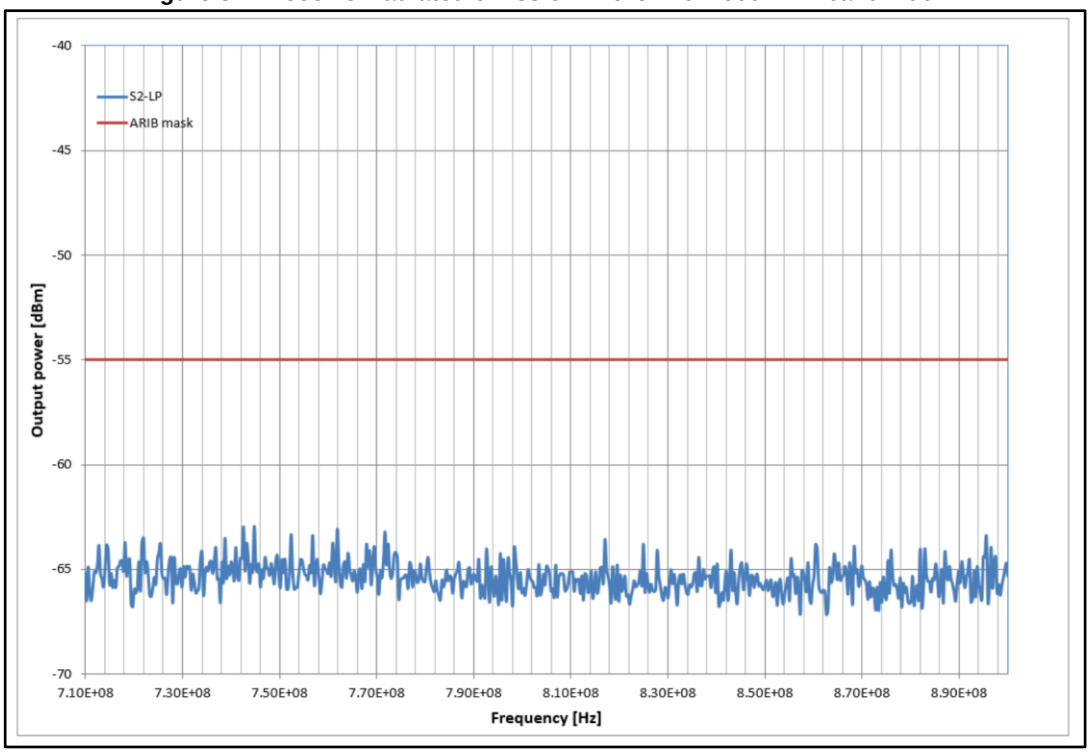


Figure 35: Receiver radiated emission in the 900 – 915 MHz bandwidth

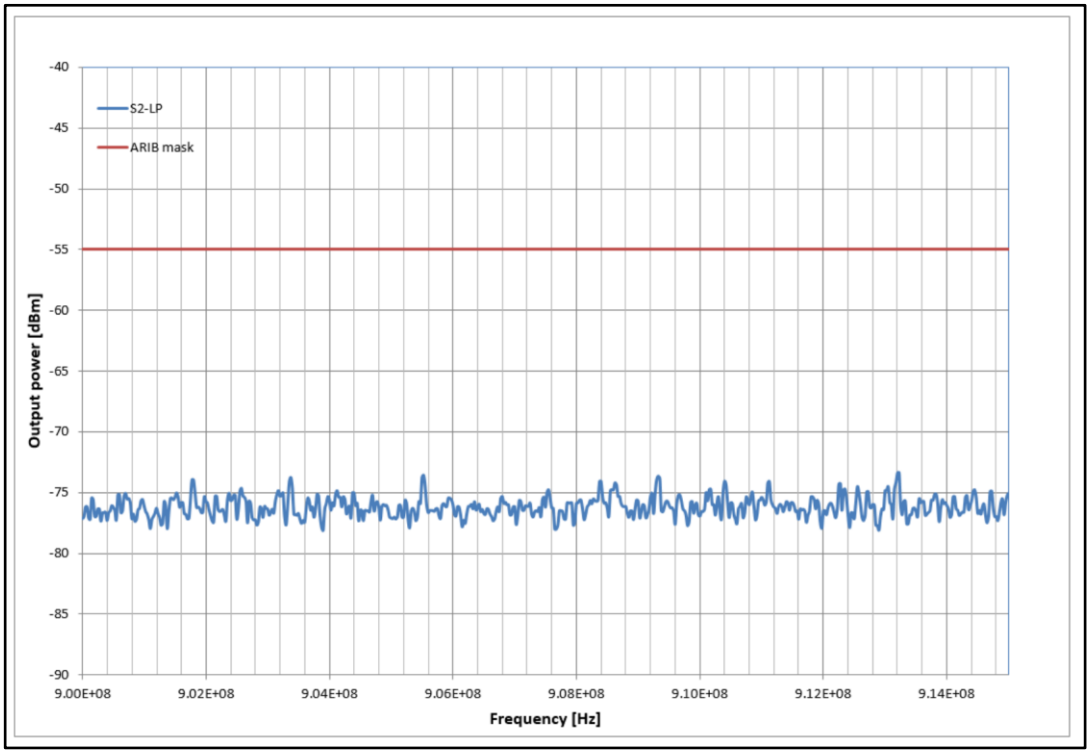


Figure 36: Receiver radiated emission in the 915 – 930 MHz bandwidth

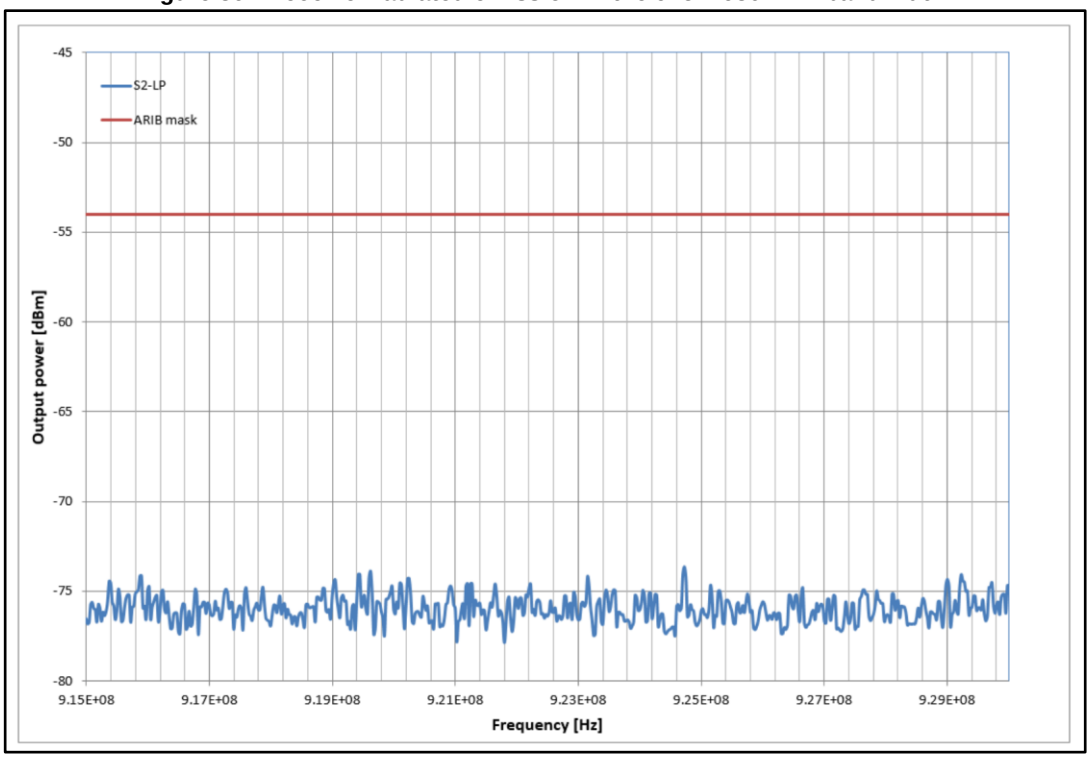


Figure 37: Receiver radiated emission in the 930 – 1000 MHz bandwidth

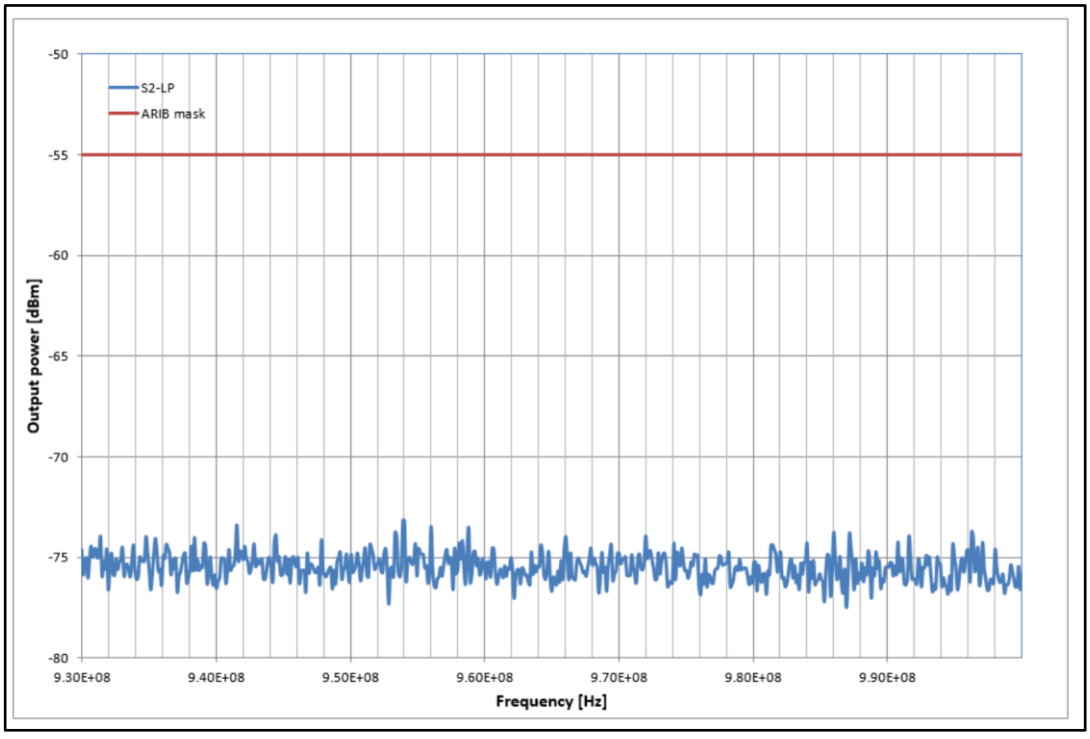
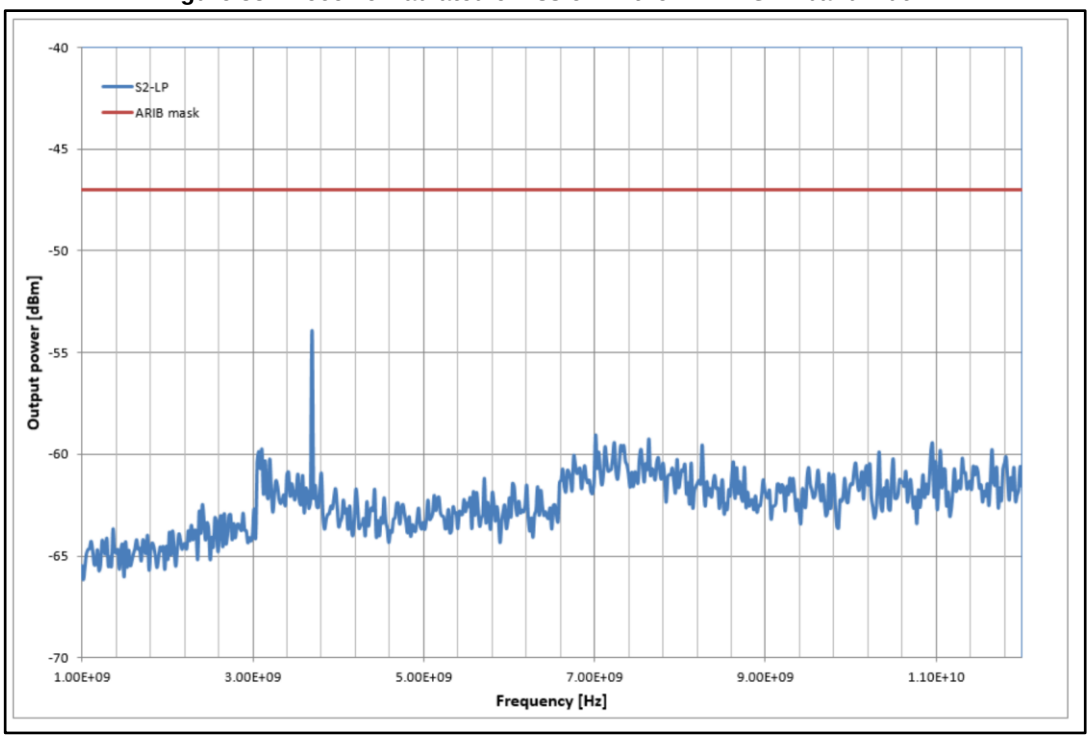


Figure 38: Receiver radiated emission in the 1 – 12 GHz bandwidth



5 References

1. S2-LP Datasheet
2. ARIB STD-T108: “920 MHz band telemeter, telecontrol and data transmission radio equipment”.
3. TELEC T245 measurements method.

6 Revision history

Table 5: Document revision history

Date	Version	Changes
19-Dec-2016	1	Initial release.

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