The S2-LP transceiver with BALF-SPI2-01D3 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 Japanese Association of Radio Industries and Businesses (ARIB) 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 aim 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.

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:

- Convenience radio stations
- Low power radio stations

A short description of the two different categories is reported. The mainly difference is located in the output power and used band frequency.

1.1 Convenience radio stations

Those devices operating 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 the table below).

For the receiver a limit for the secondary radiated emissions is defined (see the table 2).

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 20 mW < P <= 250 mW -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
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 the table below).

For the receiver a limit for the secondary radiated emissions is defined (see the table 4).

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 performance of the S2-LP transceiver.

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 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 provide sto 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.

In this evaluation board an ultra-miniature balun, STMicroelectronics BALF-SPI-01D3, is used.

The BALF-SPI-01D3 integrates matching network and harmonics filters. Matching impedance has been customized for the S2-LP ST transceiver.

To reduce the application cost the S2-LP is designed to work without external antenna switch. This daughterboard is designed to show the 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 below.

Figure 1. **S2-LP validation daughterboard**

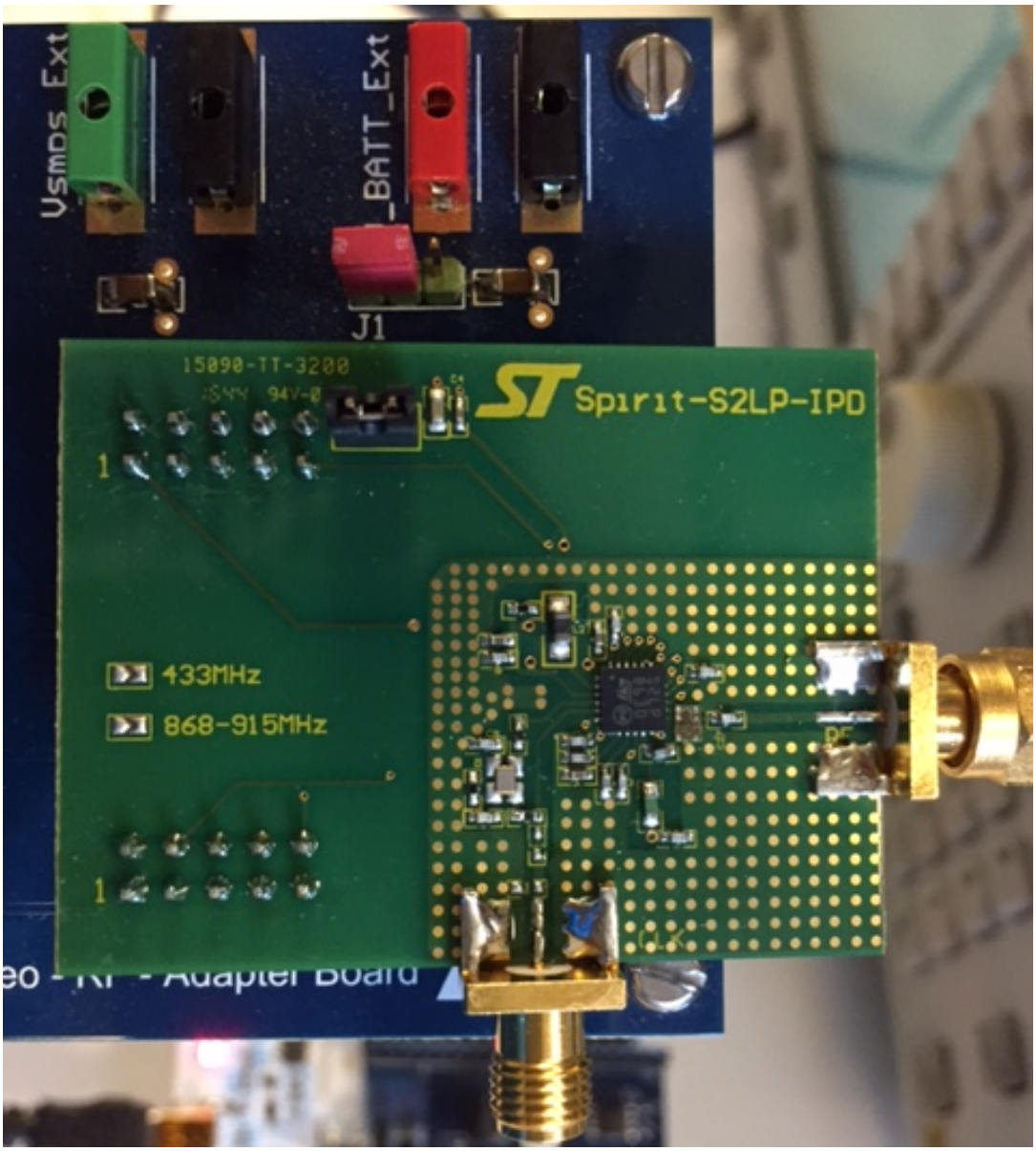
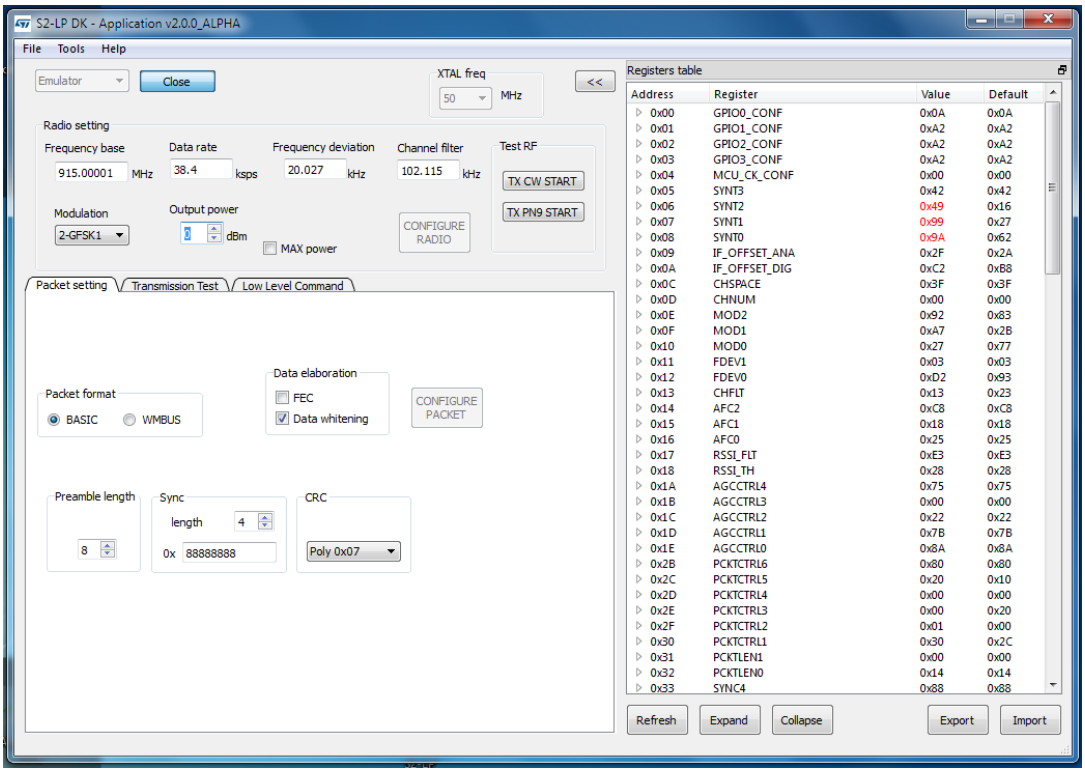


Figure 2. S2-LP application daughterboard plugged on the motherboard



3 Transmitter parameters

All the measurements here reported are measured with the following parameters: T_c = 25 °C, V_{dd} = 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 are performed at +14 dBm. All the other cases are performed with the correct output power.

A radio channel consists of up to 5 consecutive unit radio channels whose center frequencies are located from 920.6 MHz to 923.4 MHz with 200 kHz separation and their bandwidth is 200 kHz. The S2-LP fully supports the center frequency, separation and bandwidth requirements. No measurement in that sense is performed.

There are not 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 is done 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 create 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 setting of the spectrum analyzer. The following settings are 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) settings. All the adjacent channel leakage powers and masks are defined in a 100 kHz reference bandwidth.

3.1.1 Convenience radio stations

For the convenience radio stations the following masks are defined:

- 920.5 MHz to 923.5 MHz band see
- 922.3 MHz to 923.5 MHz band see

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:

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

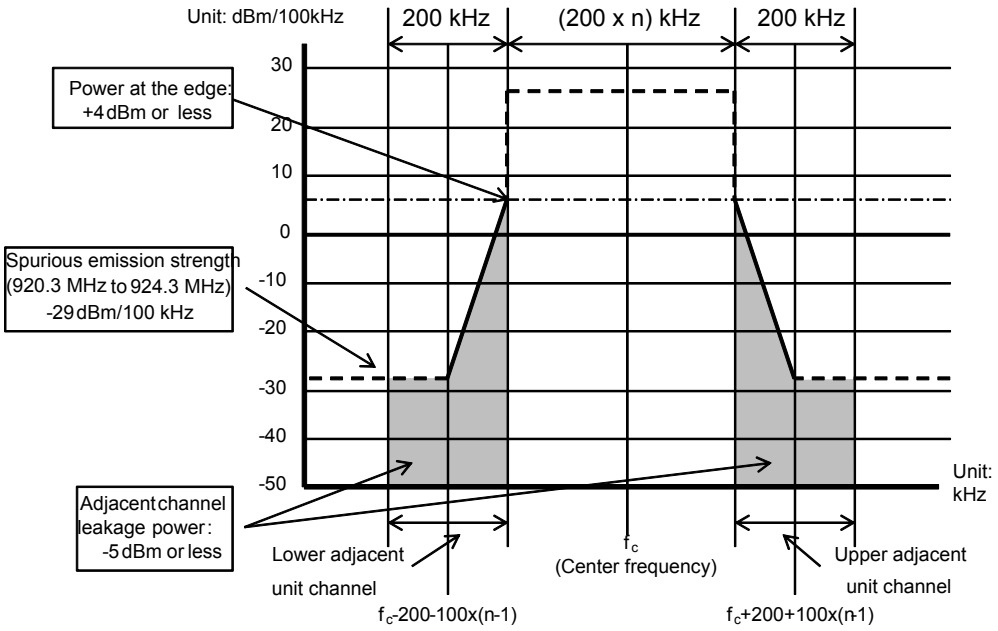


Figure 4. Convenience radio station channel mask of a radio channel at 922 MHz data rate 38.4 kbps

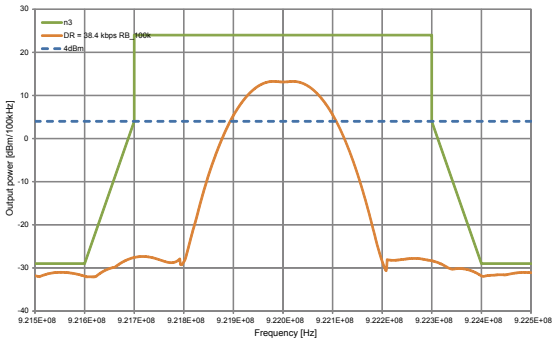


Figure 5. Convenience radio station channel mask of a radio channel at 922 MHz data rate 100 kbps

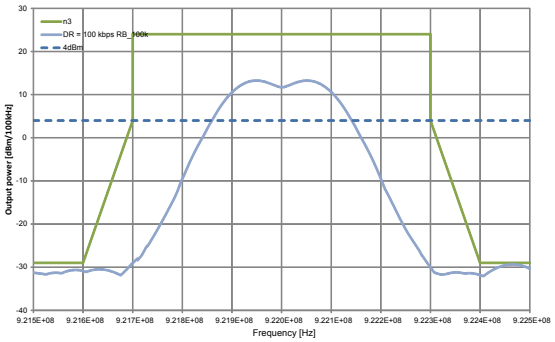


Figure 6. Convenience radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 923.5 MHz

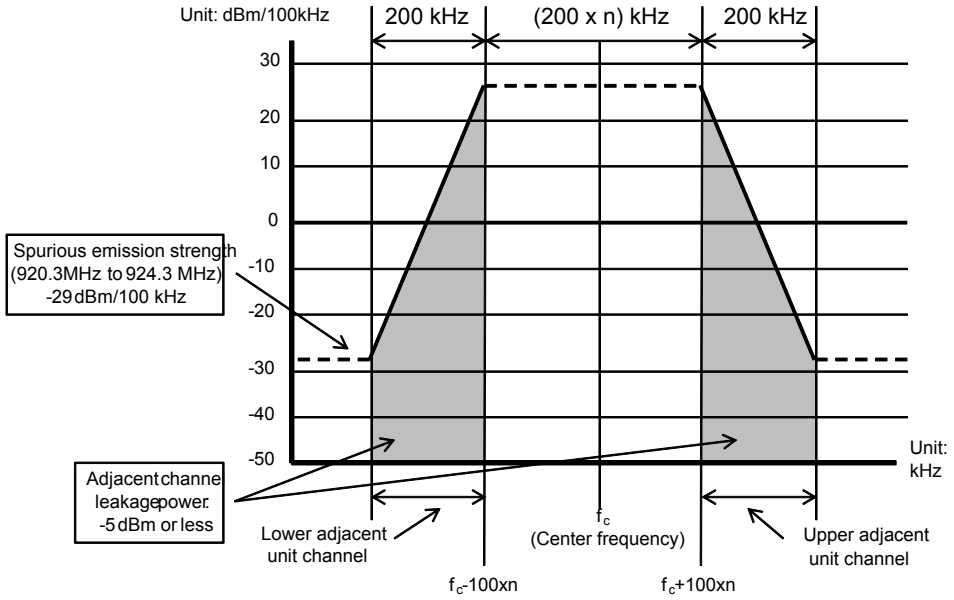


Figure 7. Convenience radio station channel mask of a radio channel at 923 MHz data rate 38.4 kbps

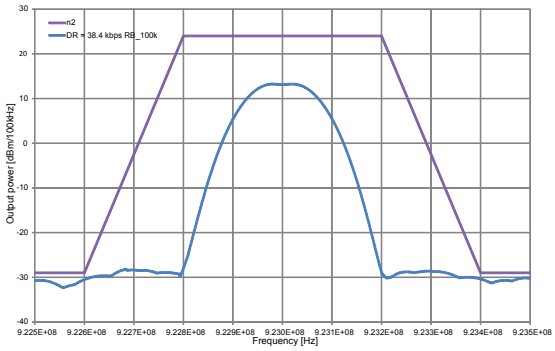


Figure 8. Convenience radio station channel mask of a radio channel at 923 MHz data rate100 kbps

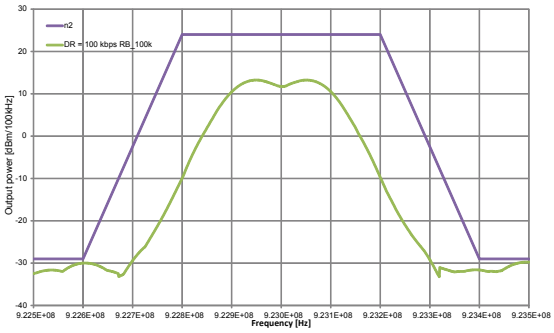


Table 5. Convenience station test results data rate 38.4 ksps frequency deviation 20 kHz

Convenience band	Output power	Results	n	Figure
920 MHz to 922.3 MHz	14 dBm	Pass	3	Figure 4
922.3 MHz to 923.5 MHz	14 dBm	Pass	2	Figure 6

Table 6. Convenience station test results data rate 100 ksps frequency deviation 50 kHz

Convenience band	Output power	Results	n	Figure
920 MHz to 922.3 MHz	14 dBm	Pass	3	Figure 4
922.3 MHz to 923.5 MHz	14 dBm	Pass	2	Figure 6

3.1.2 Low-power radio stations

Regarding to the low-power radio stations the masks printed in the figures 8, 10, 12, 14 and 16 are defined:

- 915.9 MHz to 916.9 MHz band => figure 8, 1 mW (0 dBm) max. output power
- 920.5 MHz to 922.3 MHz band => figure 10, 20 mW (+13 dBm) max. output power
- 922.3 MHz to 928.1 MHz band => figure 12, 1 mW (0 dBm) max. output power
- 922.3 MHz to 928.1 MHz band => figure 14, output power between 1 mW (0 dBm) and 20 mW (+13 dBm)
- 928.1 MHz to 929.7 MHz band => figure 16, 1 mW (0 dBm) max. output power

Figure 9. Low-power radio station channel mask of a radio channel whose frequency is from 915.9 MHz to 916.9 MHz

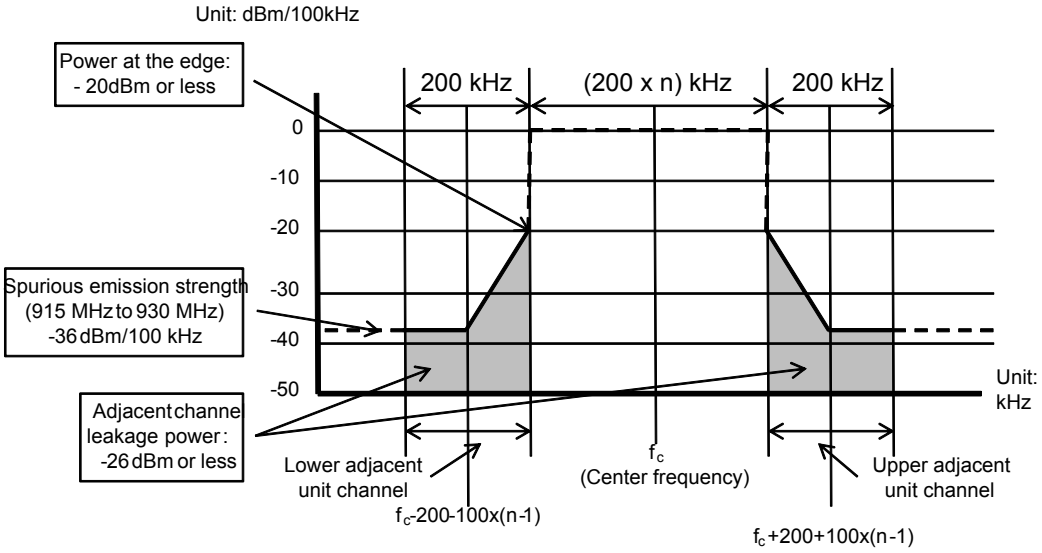


Figure 10. Low-power radio station channel mask of a radio channel at 916.5 MHz at 38.4 kbps

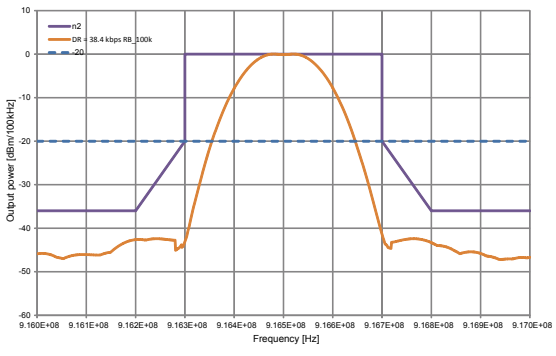


Figure 11. Low-power radio station channel mask of a radio channel at 916.5 MHz at 100 kbps

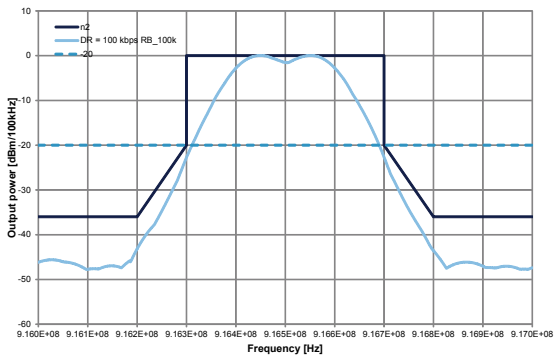


Figure 12. Low-power radio station channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz

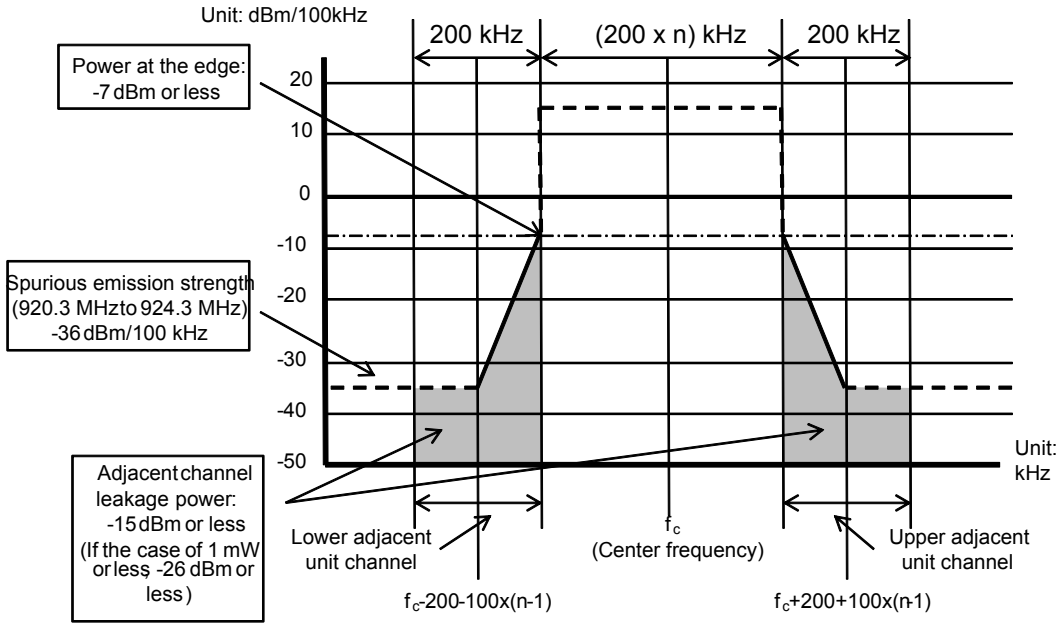


Figure 13. Low-power radio station channel mask of a radio channel at 921.5 MHz data rate 38.4 kbps

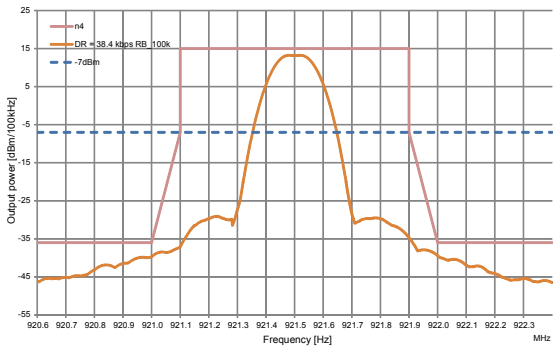


Figure 14. Low-power radio station channel mask of a radio channel at 921.5 MHz data rate 100 kbps

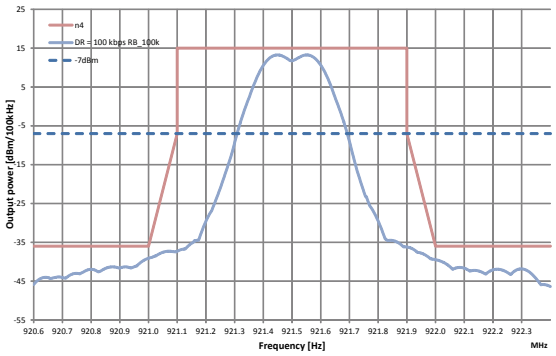


Figure 15. Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is 1 mW or less)

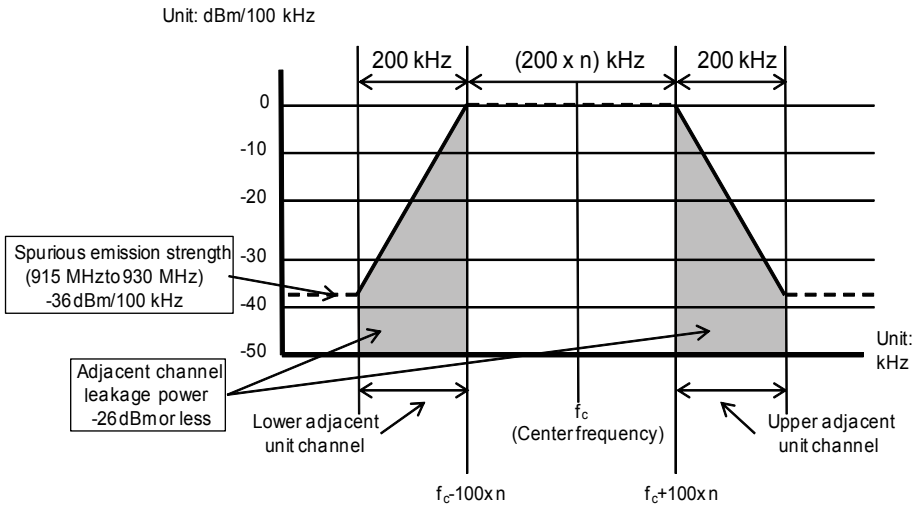


Figure 16. Low-power radio station at 928 MHz data rate 38.4 kbps

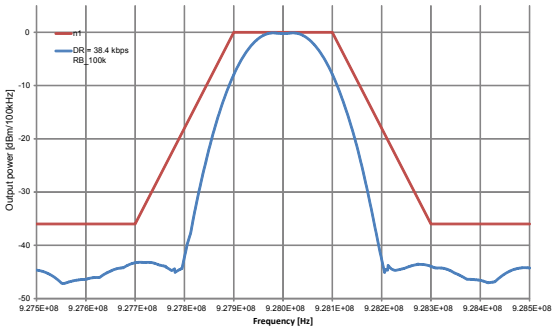


Figure 17. Low-power radio station at 928 MHz data rate 100 kbps

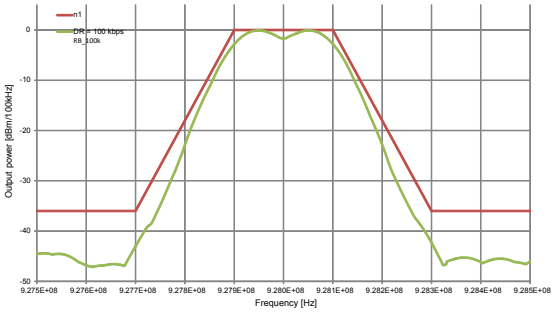


Figure 18. Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is more than 1 mW and 20 mW or less)

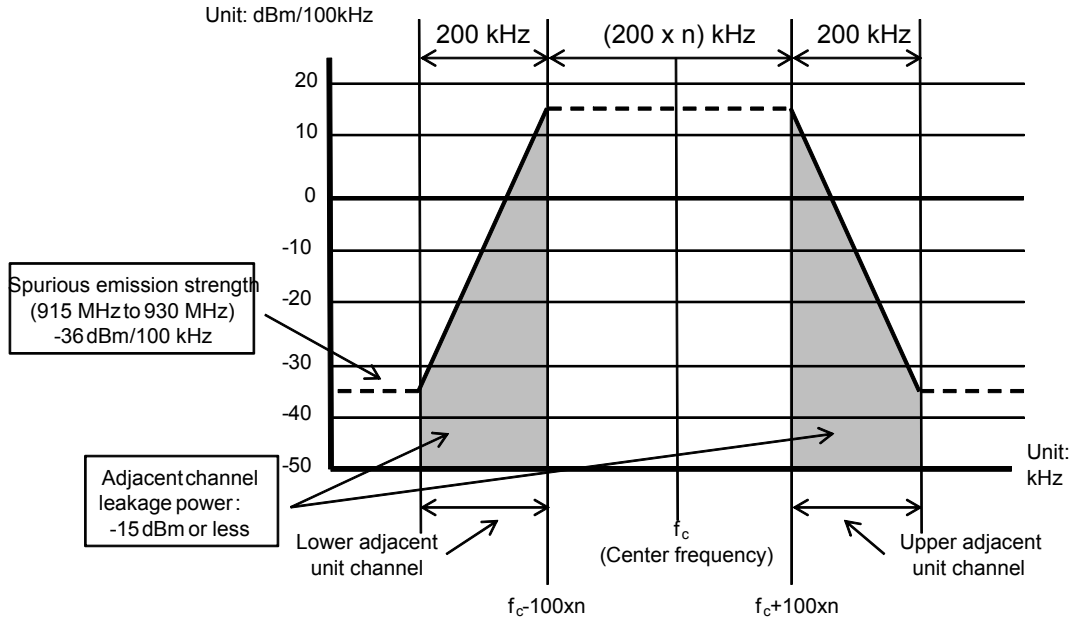


Figure 19. Low-power radio station at 925 MHz data rate 38.4 kbps

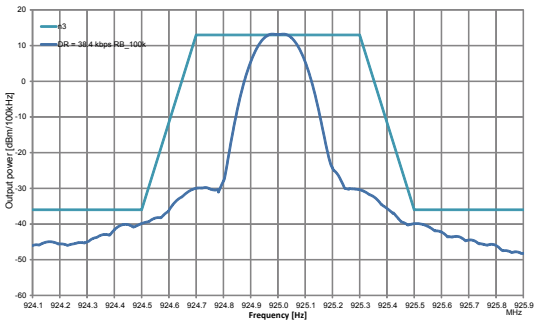


Figure 20. Low-power radio station at 925 MHz data rate 100 kbps

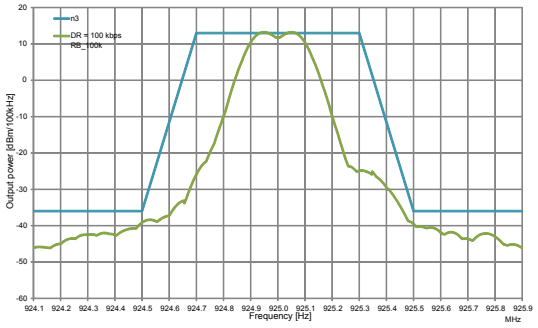


Figure 21. Low-power radio station channel mask of a radio channel whose frequency is from 928.1 MHz to 929.7 MHz

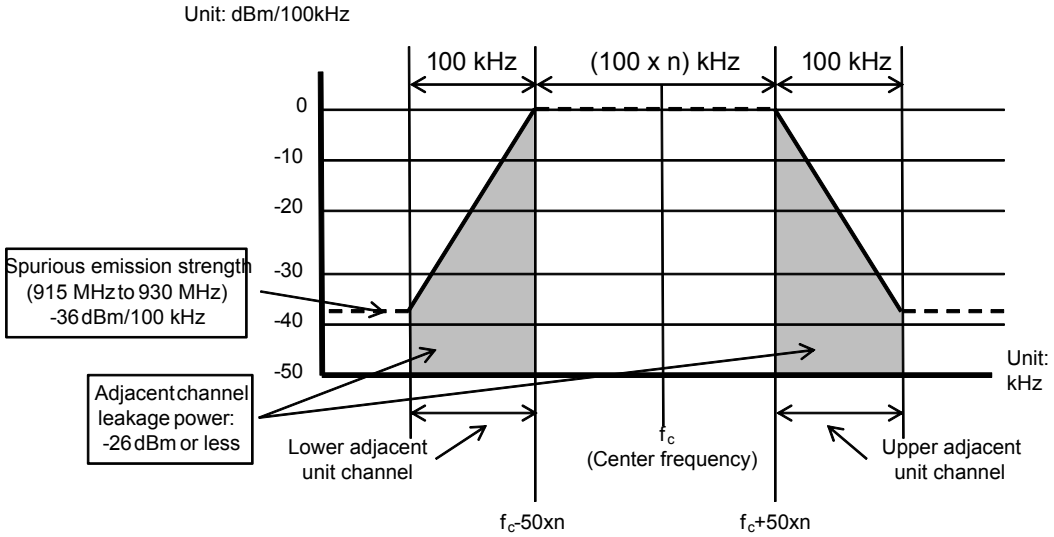


Figure 22. Low-power radio station at 929 MHz data rate 38.4 kHz

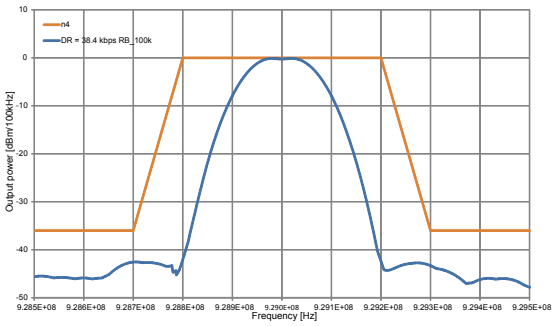


Figure 23. Low-power radio station at 929 MHz data rate 100 kHz

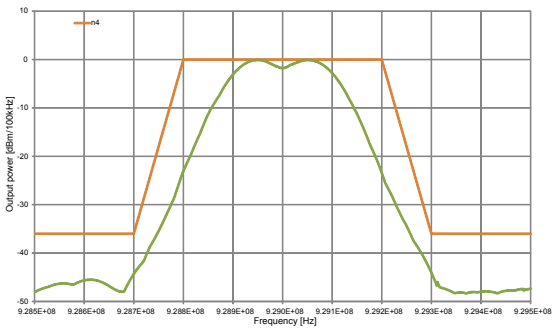


Table 7. Low power station test results data rate 38.4 ksps frequency deviation 20 kHz

Low power band	Output power	Results	n	Figure
915.9 MHz to 916.9 MHz	0 dBm	Pass	2	Figure 8
920.5 MHz to 922.3 MHz	13 dBm	Pass	4	Figure 10
922.3 MHz to 928.1 MHz	0 dBm	Pass	1	Figure 12
922.3 MHz to 928.1 MHz	13 dBm	Pass	3	Figure 14
928.1 MHz to 929.7 MHz	0 dBm	Pass	**2**	Figure 16

Table 8. **Low power station test results data rate 100 ksps frequency deviation 50 kHz**

Low power band	Output power	Results	n	Figure
915.9 MHz to 916.9 MHz	0 dBm	Pass	2	Figure 8
920.5 MHz to 922.3 MHz	13 dBm	Pass	4	Figure 10
922.3 MHz to 928.1 MHz	0 dBm	Pass	1	Figure 12
922.3 MHz to 928.1 MHz	13 dBm	Pass	3	Figure 14
928.1 MHz to 929.7 MHz	0 dBm	Pass	4	Figure 16

3.2 Permissible values for unwanted emission intensity

Unwanted emissions in the spurious domain are emissions at 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 the tables 1 for the convenience radio stations and table 3 for the low-power radio station. The measurements for the convenience radio station are done with the carrier set to 922 MHz at 13 dBm. The measurements for the low-power radio station are done with the carrier set to 916.5 MHz at 0 dBm.

The measurements performed for the convenience radio station are printed in the figures from 18 to 26. From these pictures it is possible to see that the entire requirements are met.

The measurements performed for the low-power radio station are printed in the figures from 27 to 33. For the low-power case the full requirement is met.

Figure 24. **Convenience radio station emission in the 10 - 710 MHz bandwidth**

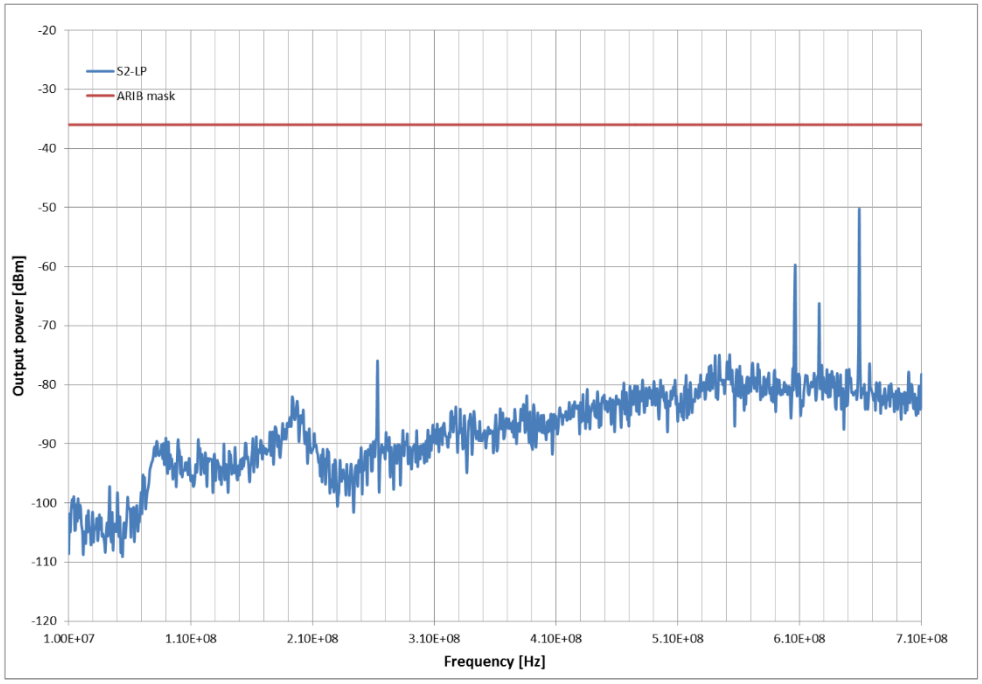


Figure 25. **Convenience radio station emission in the 710 - 900 MHz bandwidth**

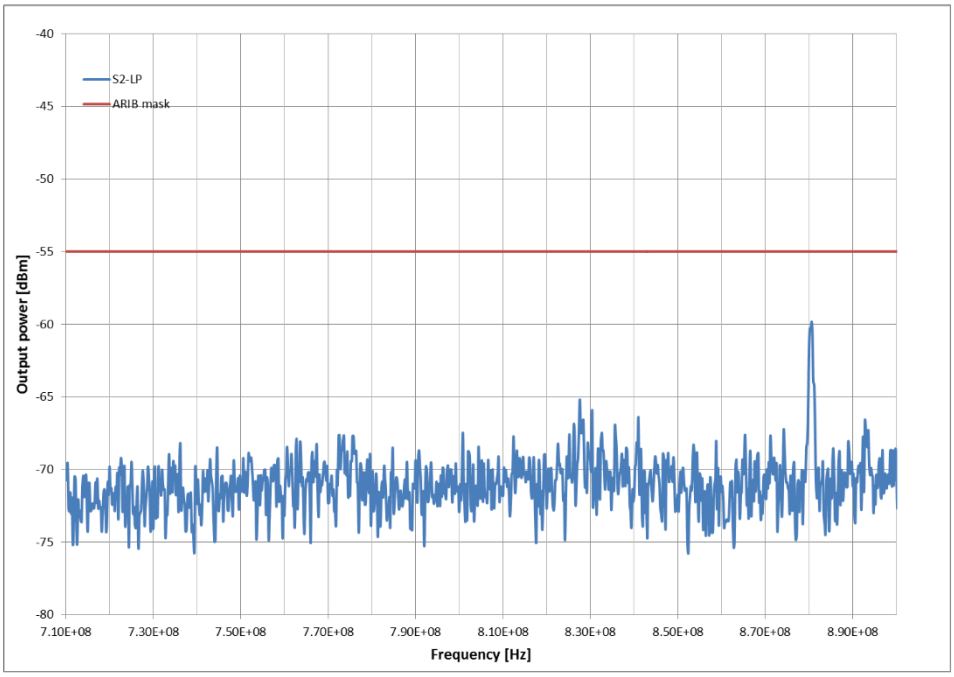


Figure 26. **Convenience radio station emission in the 900 - 915 MHz bandwidth**

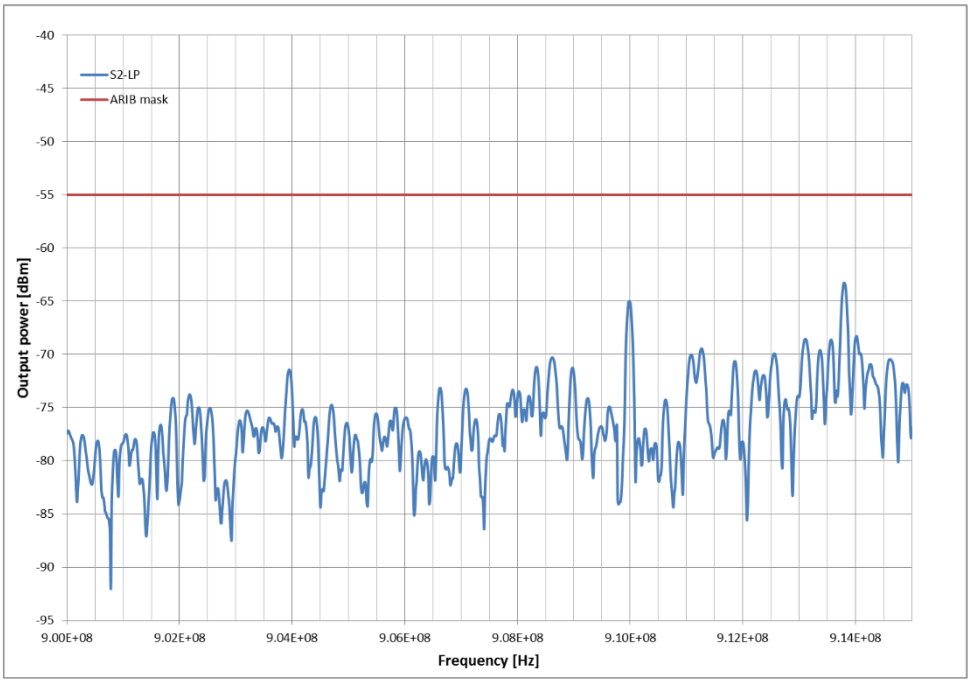


Figure 27. Convenience radio station emission in the 915 – 920.3 MHz bandwidth

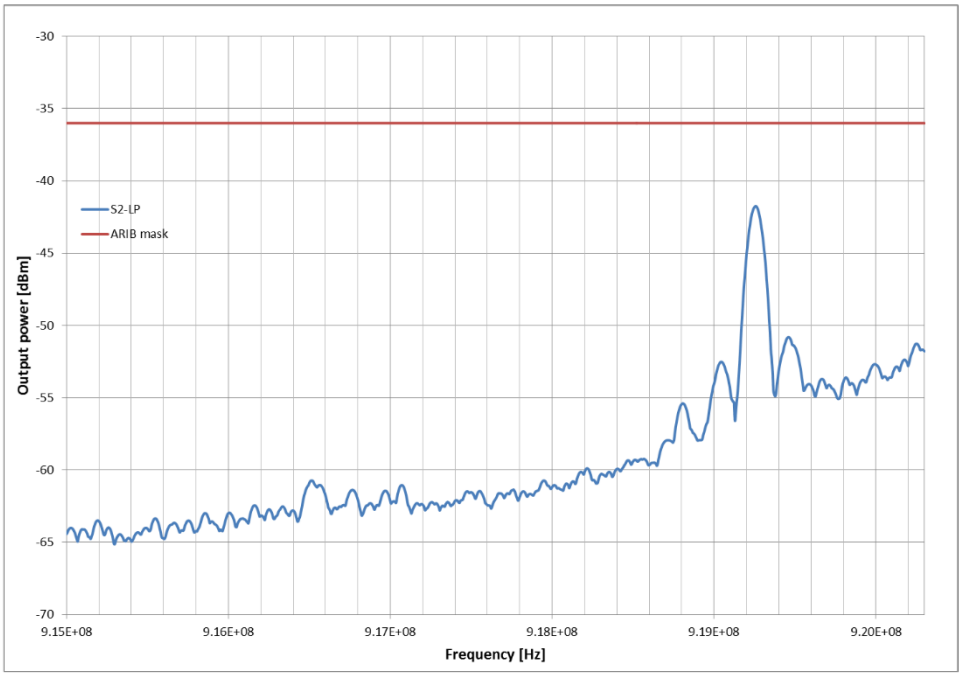


Figure 28. Convenience radio station emission in the 920.3 – 924.3 MHz bandwidth

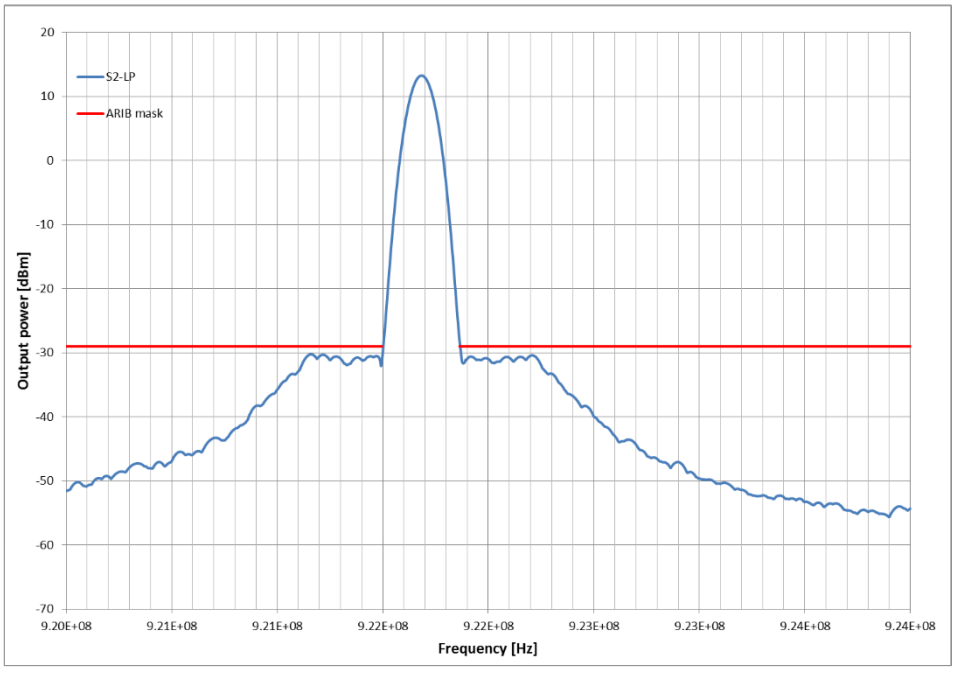


Figure 29. **Convenience radio station emission in the 924.3 – 930 MHz bandwidth**

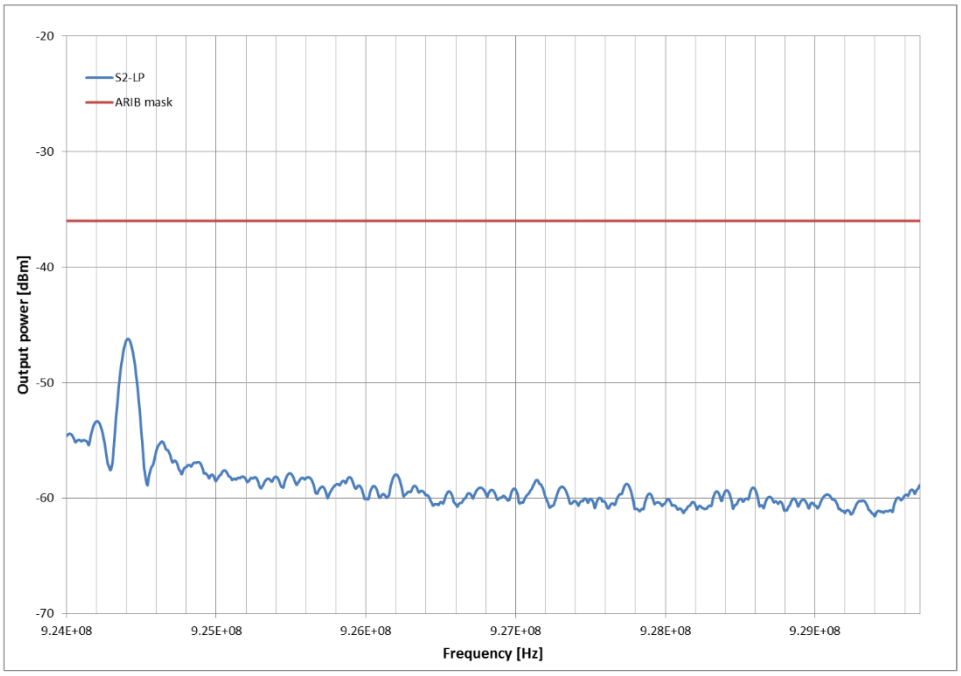


Figure 30. **Convenience radio station emission in the 930 – 1000 MHz bandwidth**

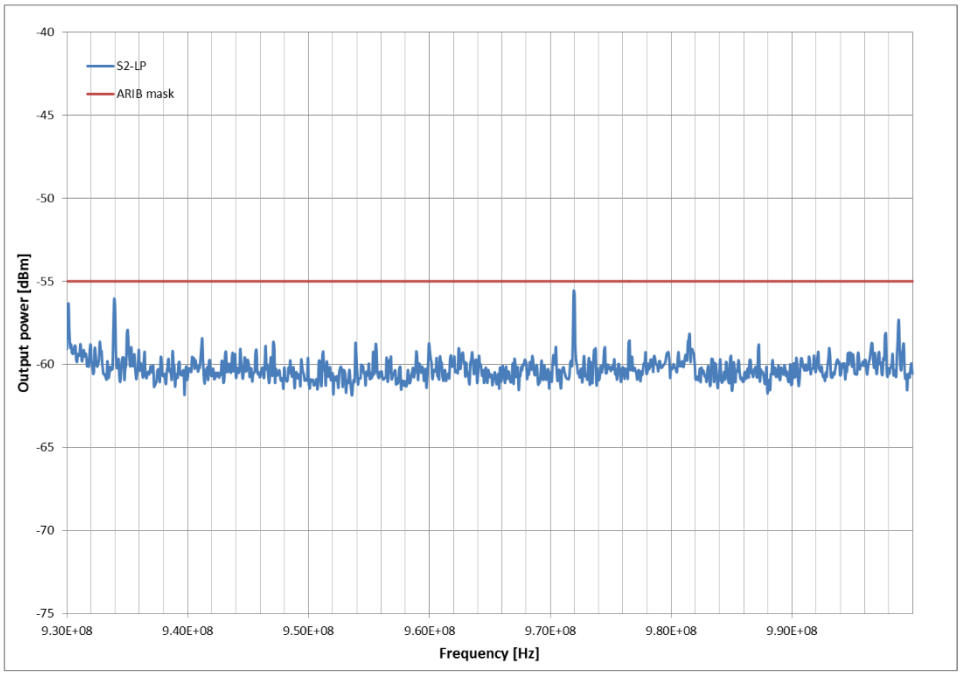


Figure 31. **Convenience radio station emission in the 1 – 1.215 GHz bandwidth**

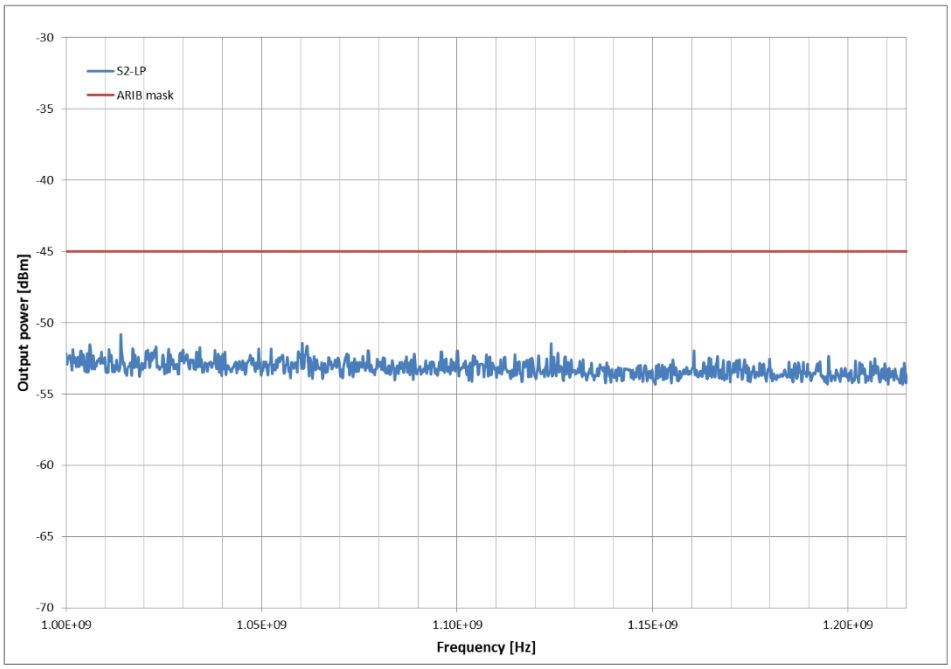


Figure 32. **Convenience radio station emission in the 1.215 – 12 GHz bandwidth**

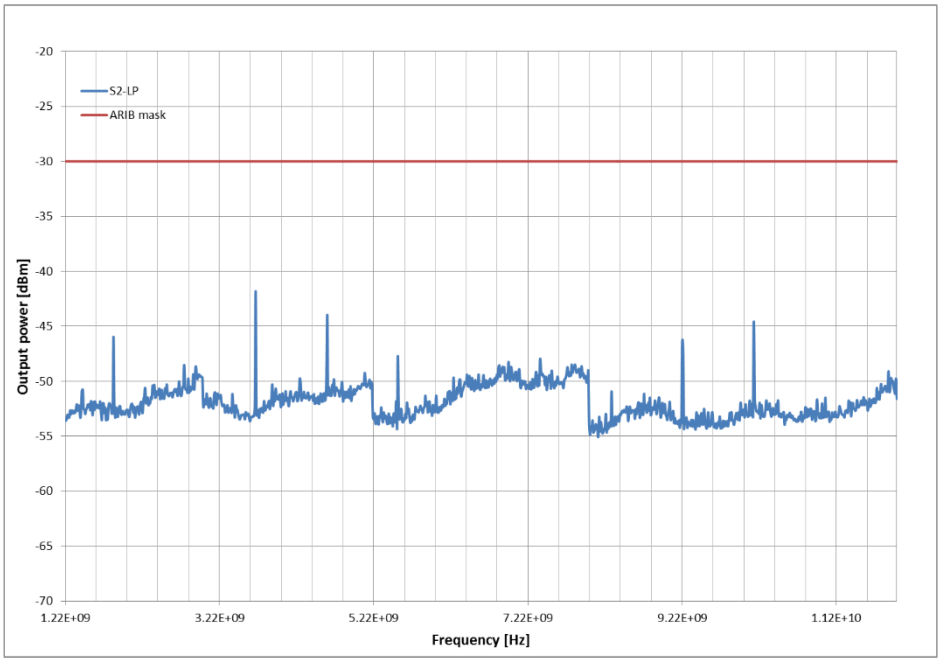


Figure 33. **Low-power radio station emission in the 10 – 710 MHz bandwidth**

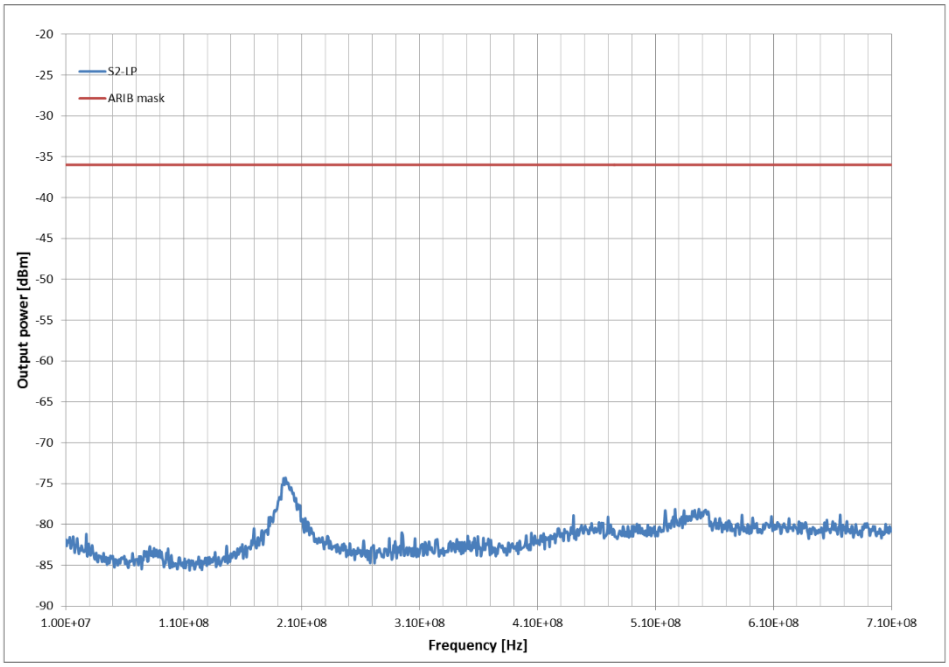


Figure 34. **Low-power radio station emission in the 710 – 900 MHz bandwidth**

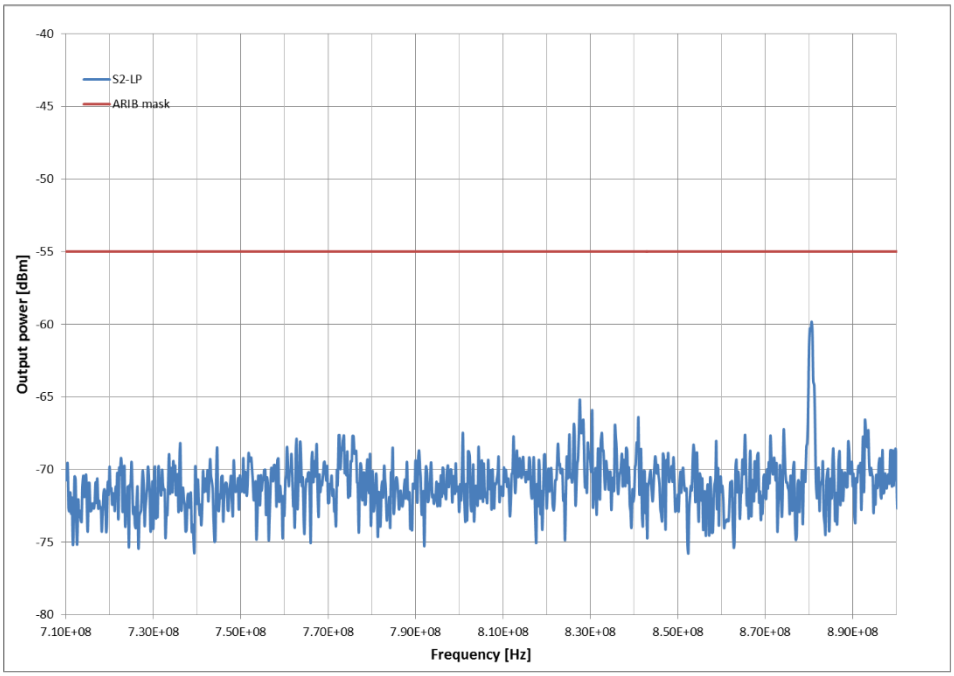


Figure 35. **Low-power radio station emission in the 900 – 915 MHz bandwidth**

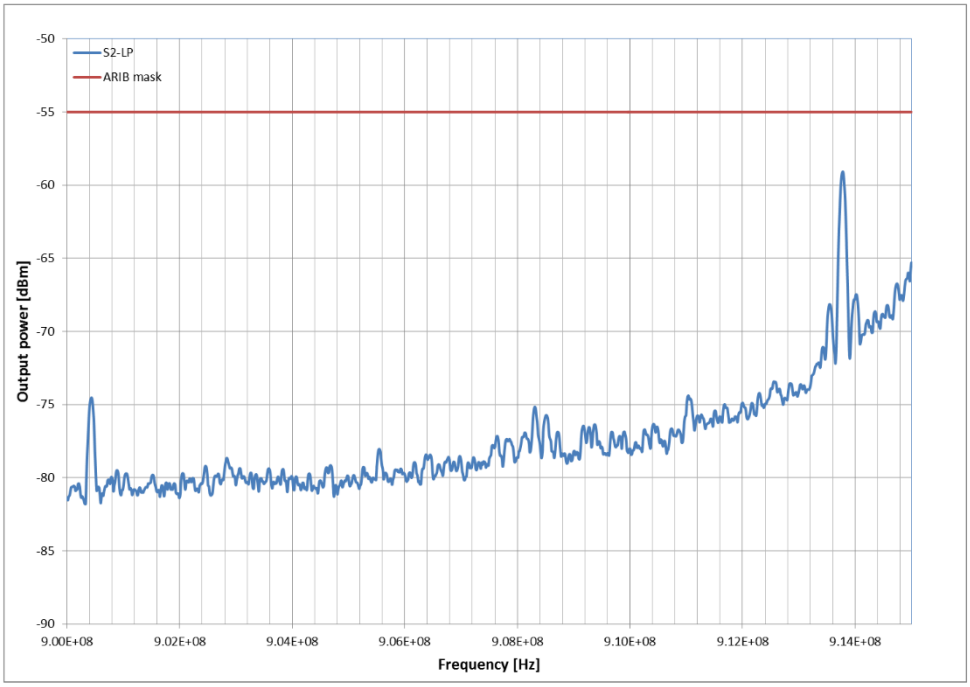


Figure 36. **Low-power radio station emission in the 915 – 930 MHz bandwidth**

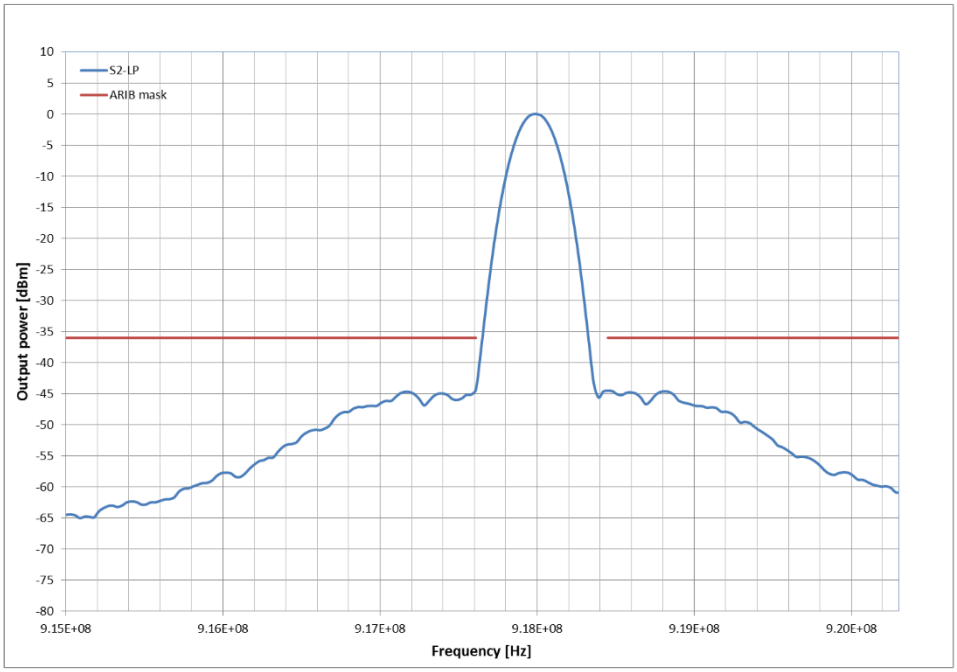


Figure 37. **Low-power radio station emission in the 930 – 1000 MHz bandwidth**

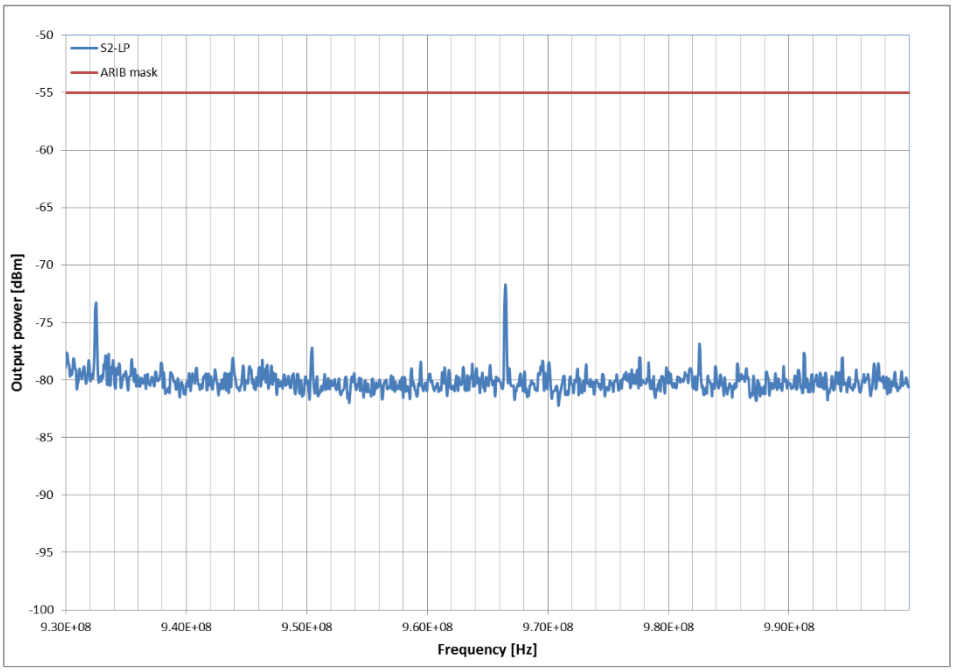


Figure 38. **Low-power radio station emission in the 1 – 1.215 GHz bandwidth**

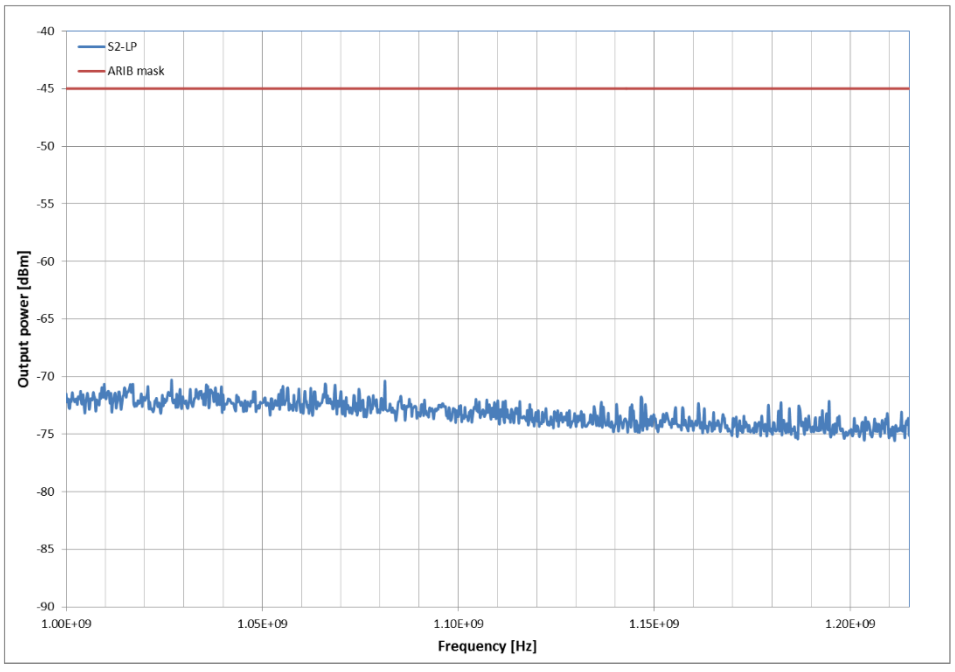
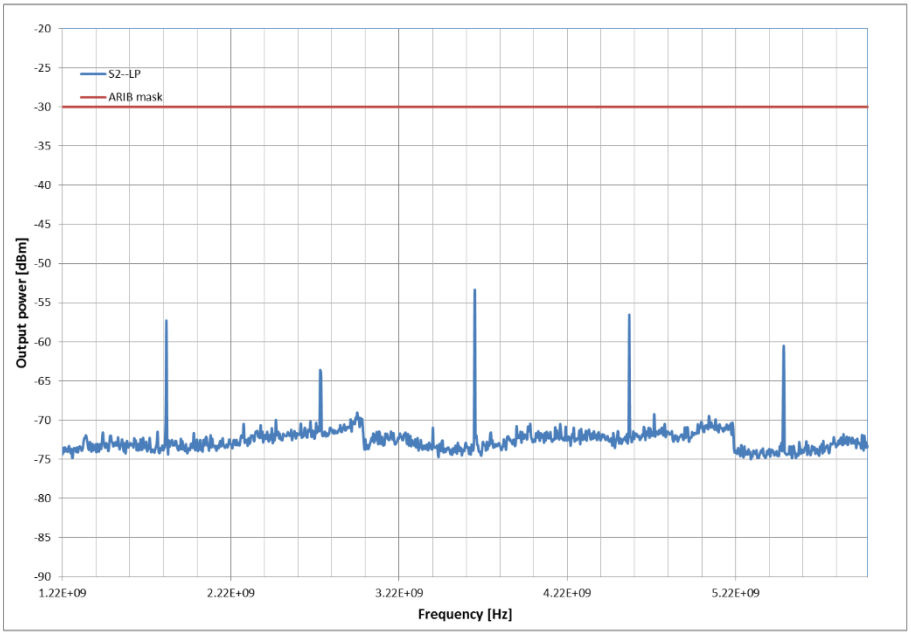


Figure 39. **Low-power radio station emission in the 1.215 – 6 GHz bandwidth**



4 Receiver parameters

Only a measure is required for the receiver, the limit on secondary radiated emission. The measure is performed with the following parameters: T_c = 25 °C, V_{dd} = 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 the tables 2 for the convenience radio stations and table 4 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 printed in the figures from 34 to 39. The entire standard requirements are met from the S2-LP in receiver mode.

Figure 40. Receiver radiated emission in the 10 – 710 MHz bandwidth

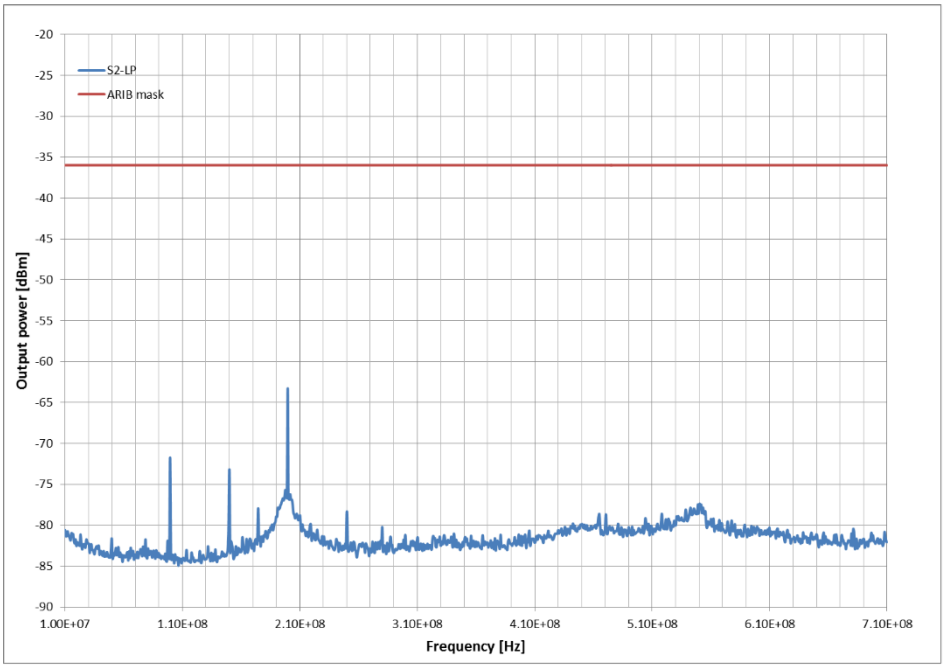


Figure 41. **Receiver radiated emission in the 710 – 900 MHz bandwidth**

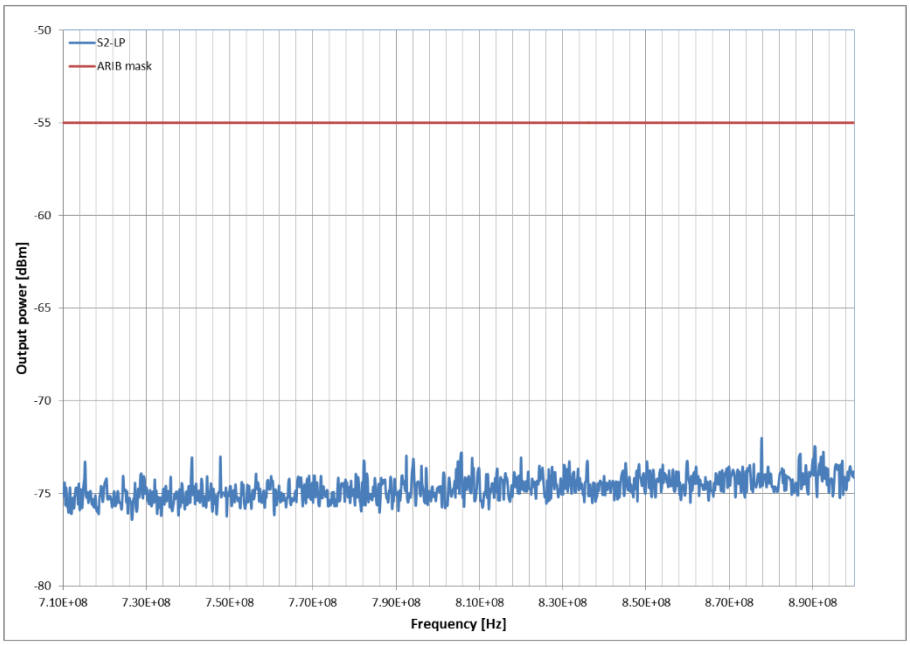


Figure 42. **Receiver radiated emission in the 900 – 915 MHz bandwidth**

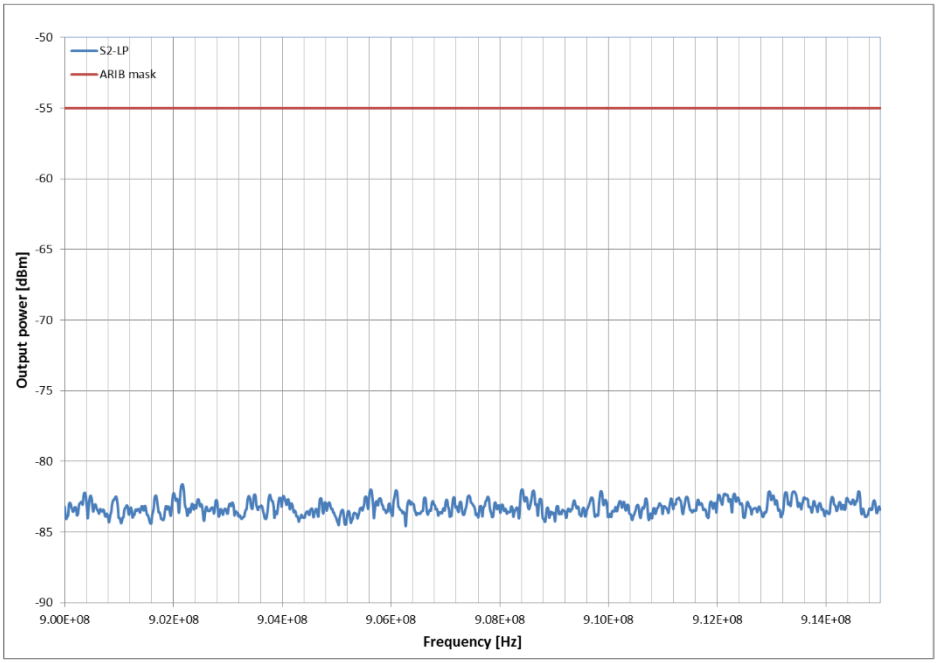


Figure 43. **Receiver radiated emission in the 915 – 930 MHz bandwidth**

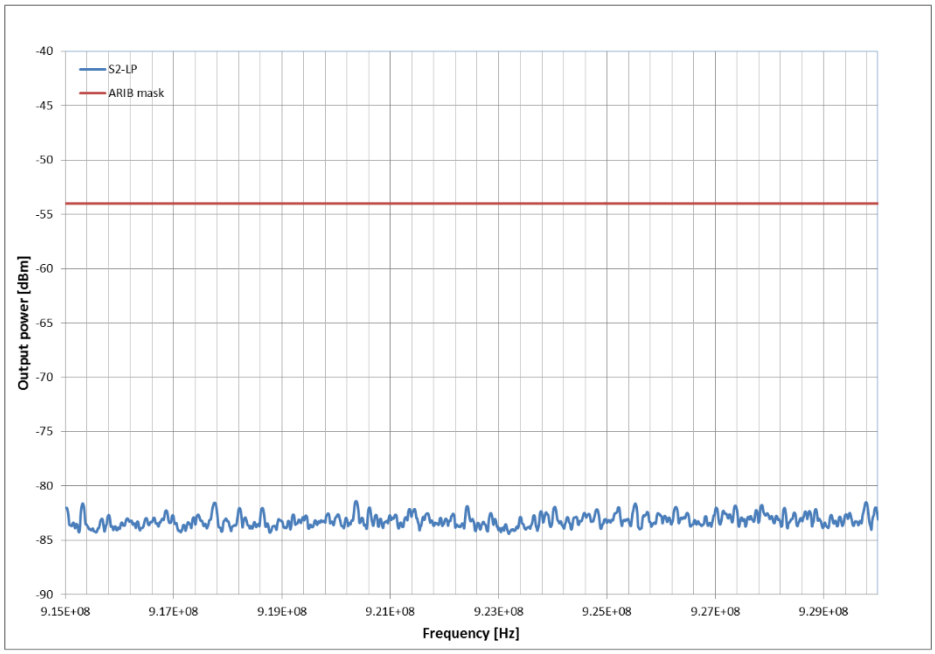


Figure 44. **Receiver radiated emission in the 930 – 1000 MHz bandwidth**

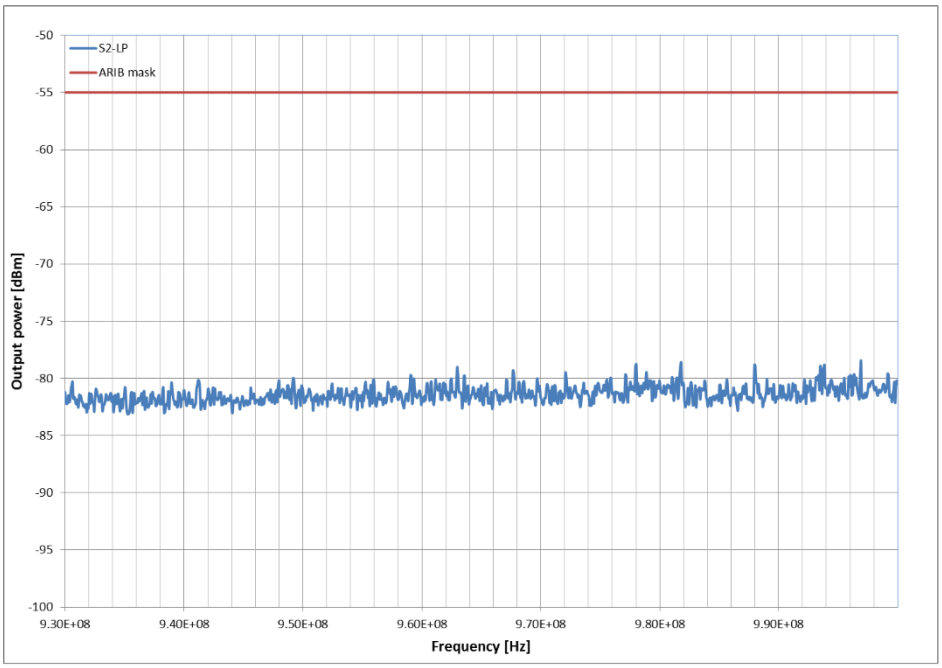
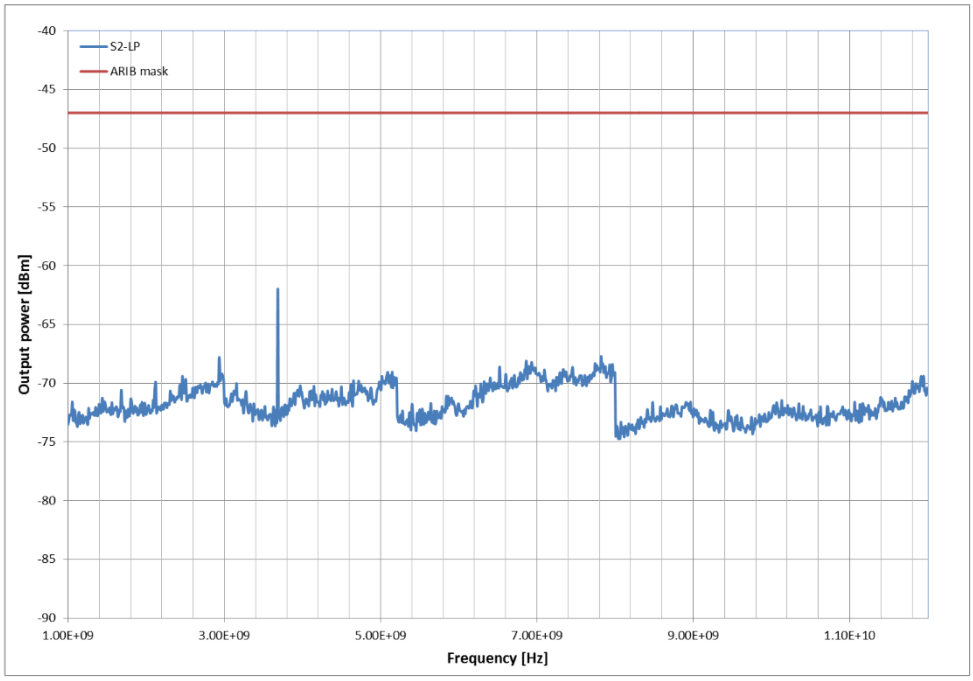


Figure 45. **Receiver radiated emission in the 1 – 12 GHz bandwidth**



A Reference

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

Revision history

Table 9. **Document revision history**

Date	Version	Changes
07-Nov-2018	1	Initial release.

Contents

List of tables

List of figures