AN4133
Application note

Using the SPIRIT1 transceiver under ARIB STD-T108 in the 920 MHz band

By Placido De Vita

Introduction

SPIRIT1 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 169, 315, 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 ARIB organism defines the basic technical requirements for standard specifications of radio equipment.

This application note outlines the expected performance when using the Spirit1 under ARIB STD-T108 (see *References on page 33*) 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 in *References on page 33*.

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 defines 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 band frequency used.

1.1 Convenience radio stations

Devices that operate in convenience radio stations will work in using either a simplex, duplex, or semi-duplex broadcast method. The contents of communications are primarily the signals for telemetry, telecontrol and data transmission systems. The operating frequency band is between 920.5 MHz and 923.5 MHz. The maximum permitted antenna power is 250 mW (+24 dBm on a 50 ohm load, +27 dBm EIRP considering an antenna of 3 dBi gain). A radio channel consists of up to 5 consecutive unit radio channels which are defined such that their center frequency is located from 920.6 MHz to 923.4 MHz with 200 kHz separation and a bandwidth of 200 kHz. There aren't 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 entire radio channel and is an integer from 1 to 5.

An adjacent channel leakage power is permitted: two different channel masks are defined, one for systems that work in the 920.5 MHz to 922.3 MHz band and a second one for the systems that work in the 922.3 to 923.5 MHz band. For the two different masks refer to the figures 3-1 and 3-2 of the ARIB STD-T108 regulation cited in *References on page 33*.

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

For the receiver a limit for the secondary radiated emissions is defined (see *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)	-55 dBm	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 convenience radio stations in output power and usable frequency band.

Regarding the output power, two different values are permitted as follows.

- An output power of 1 mW (0 dBm on a 50 ohm load, +3 dBm EIRP considering an antenna of 3 dBi gain) is permitted in the band greater than or equal to 915.9 MHz to less than or equal to 916.9 MHz , and greater than or equal to 920.5 MHz and less than or equal to 929.7 MHz.
- An output power of 20 mW (+13 dBm on a 50 ohm load, +16 dBm EIRP considering an antenna of 3 dBi gain) is permitted in the band greater than or equal to 920.5 MHz to less than or equal to 928.1 MHz.

As for convenience radio stations, an entire radio channel consists of up to 5 consecutive unit radio channels which are defined such that their center frequency is located from 916.0 MHz to 916.8 MHz and from 920.6 MHz to 928.0 MHz with 200 kHz separation and a bandwidth of 200 kHz, or which are defined such that their center frequency is located from 928.15 MHz to 929.65 MHz with 100 kHz separation and a bandwidth of 100 kHz. There aren't specific requirements for the modulation method, while the permissible value for the occupied bandwidth is (200 x n) kHz or less, where n is the number of unit radio channels constituting the entire radio channel and is an integer from 1 to 5. In the case that the center frequency is from 928.15 MHz to 929.65 MHz, it shall be (100 x n) kHz or less.

An adjacent channel leakage power is permitted: five different channel masks are defined, functions of the usable bandwidth and of the output power. For the five different masks refer to the figures 3-1 to 3-5 of the ARIB STD-T108 regulation, see *References on page 33*.

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

For the receiver a limit for the secondary radiated emissions is defined (see *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

Figure 1 shows the SPIRIT1 application board. The application is composed of two boards: a daughterboard and a motherboard. The daughterboard holds the SPIRIT1 with the circuits necessary for operation. In order to function properly the daughterboard has to be plugged into the motherboard (see *Figure 2*) using two header 5x2 connectors (J6 and J7).

The motherboard is provided with an STM32L152VBT6 microcontroller to correctly program the transceiver. The microcontroller is programmed with firmware developed for the SPIRIT1 application. A graphical user interface (GUI) has been developed to correctly program the SPIRIT1.

The daughterboard is provided with a 52 MHz crystal to provide the correct oscillator to the SPIRIT1.

The SPIRIT1 has an internal SMPS that drastically reduces power consumption making the SPIRIT1 the best in class for the application in this bandwidth. The SMPS is fed from the battery (1.8 V to 3.6 V) and provides a programmable voltage (1.4 V usually) to the device. An SMA connector is present to connect the board to the antenna or to the instrumentation to verify the correct functionality and verify the ETSI standard request.

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

To reduce the application cost the SPIRIT1 is designed to work without an external antenna switch. This daughterboard is designed to show the functionality of the SPIRIT1 in this condition. Of course an application with antenna switch can be implemented, but this isn't described in this document.

Figure 1. SPIRIT1 application daughterboard

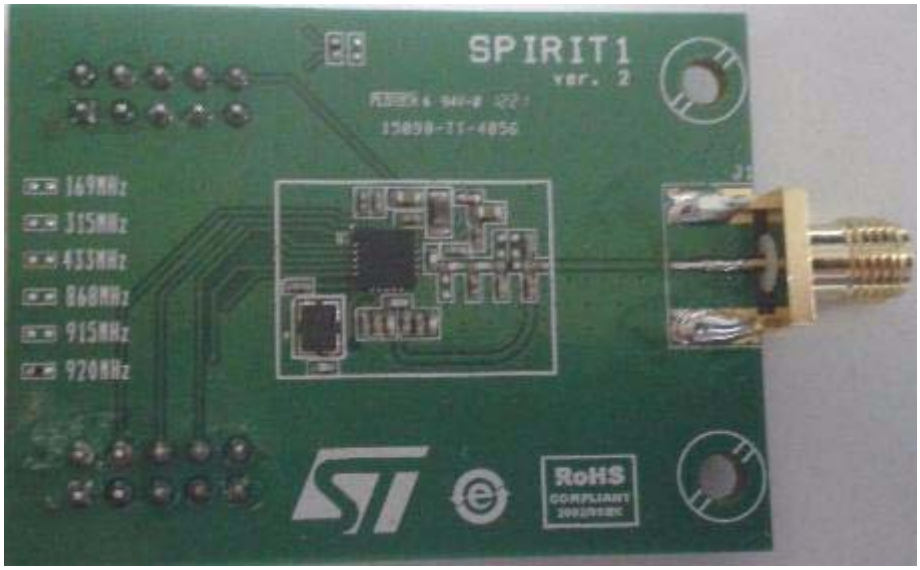


Figure 2. SPIRIT1 application daughterboard plugged into the motherboard

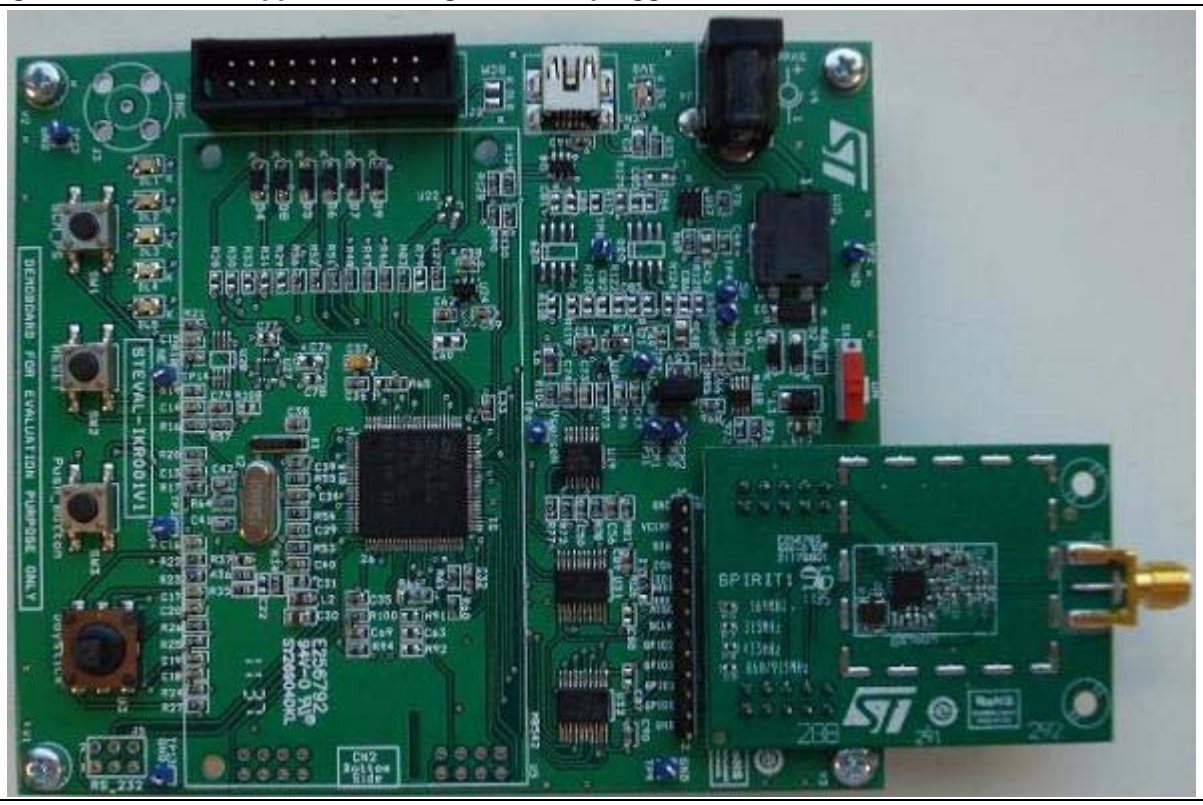
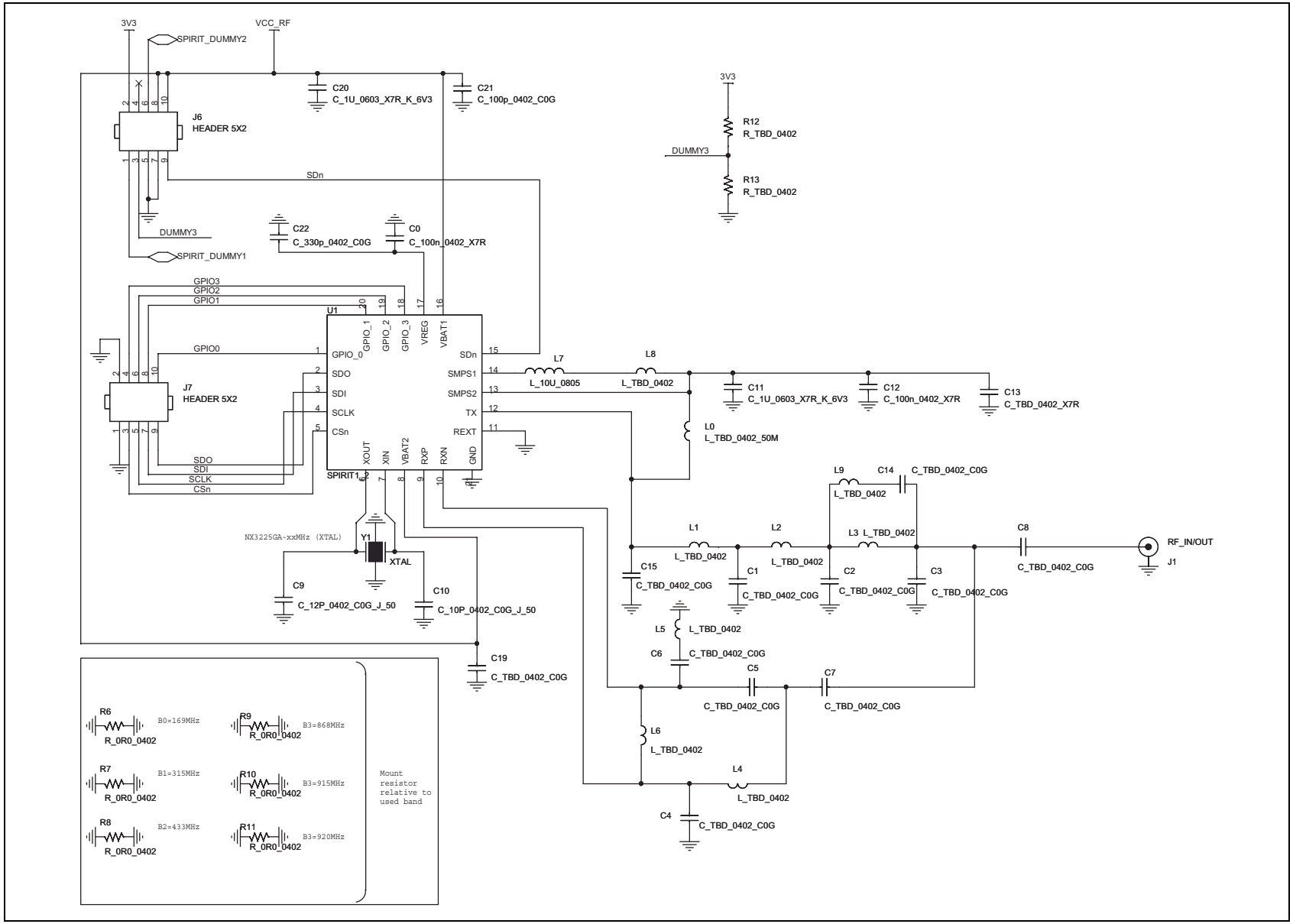


Figure 3. Daughterboard schematic



3 Transmitter

All the measurements given are measured under the following conditions: Tc = 25 °C, Vdd = 3.0 V, f = 922 MHz (middle frequency of the bandwidth used), unless otherwise specified.

The maximum output power of the SPIRIT1 in this band is 10 dBm, so all the measurements for the convenience radio stations and low-power radio stations with +24 dBm or +13 dBm output power will be performed at +10 dBm. Low-power radio stations with output power of 0 dBm will be performed with the correct output power.

A radio channel consists of up to 5 consecutive unit radio channels which are defined such that their center frequency is located from 920.6 MHz to 923.4 MHz with 200 kHz separation and a bandwidth of 200 kHz. SPIRIT1 fully supports the center frequency, separation and bandwidth requirements. No measurement in that sense will be done.

There aren't specific requirements for the modulation method, while the permissible value for the occupied bandwidth is (200 x n) kHz or less, where n is the number of unit radio channels constituting the entire radio channel and is an integer from 1 to 5. The measurement in this case will be done with a GFSK (BT = 0.5) modulation with 100 kbps data rate, 50 kHz frequency deviation. Different combinations of modulation, data rate and frequency deviation creates signals that have a bandwidth lower than 200 kHz: a specific check has to be done for each case.

There are no specific requirements in the standard about setting the detector, resolution bandwidth (RBW) or video bandwidth (VBW) of the spectrum analyzer. The detector will be set to peak, the resolution and video bandwidths will be set sufficiently large to ensure the correctness of the measurement, and the display will be set to peak hold.

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.

Different masks are defined for the two types of operating modes. For the convenience radio stations the masks given in *Figure 4* and *6* are defined. The first one defines the channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz. The second one defines the 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 SPIRIT1 doesn't support this output power, so the mask compliance is verified with an output power of 10 dBm. An external PA should be used to reach the maximum output power.

Figure 5 and *7* show the compliance measurement with the two masks and that the SPIRIT1 complies. If an external power amplifier is used to burst the output power to +24 dBm a verification of the channel masks has to be done. If the mask requirements aren't met, a reduction of the data rate and/or frequency deviation is necessary.

For the low-power radio stations the masks printed in *Figure 8*, *10*, *12*, *14*, and *16* are defined.

Figure 8 defines the channel mask of a radio channel whose frequency is from 915.9 MHz to 916.9 MHz. In this case the maximum permitted output power is 1 mW (0 dBm), so the measurement is performed with this output power level. *Figure 9* shows the SPIRIT1

compliance with the mask, the measurement is performed with the center frequency set to 916.5 MHz.

Figure 10 defines the channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz. The max output power permitted for this bandwidth is 20 mW (+13 dBm), the SPIRIT1 doesn't support this output power, so the mask compliance is verified with an output power of 10 dBm. In *Figure 11* the SPIRIT1 compliance mask is shown. The output power is set to 7 dBm to enter on the mask. To work with a higher output power, a reduction of the data rate and/or frequency deviation is necessary. The center frequency is set to 921.5 MHz.

Figure 12 and *14* define the channel masks of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz. The compliance mask measurements are shown respectively in *Figure 13* and*15*. The measurements are performed with the center frequency set to 928 MHz and 925 MHz respectively.

The mask in *Figure 16* is defined for maximum permitted output power of 1 mW (0 dBm) of a radio channel whose frequency is from 928.1 MHz to 929.7 MHz. The measurement is performed with SPIRIT1 set to provide this output power level. *Figure 17* shows the compliance with the mask. The measurement is performed with the center frequency set to 929 MHz.

Figure 4. Convenience radio station channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz

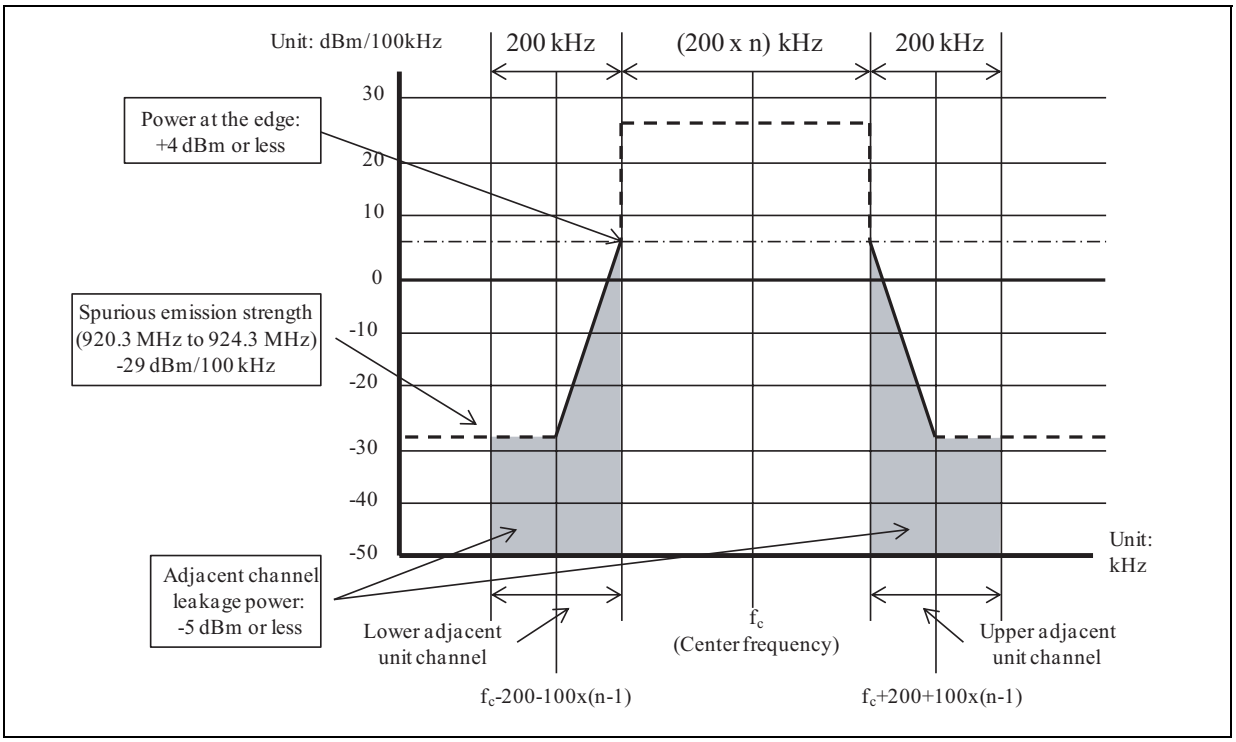


Figure 5. Convenience radio station channel mask of a radio channel at 922 MHz

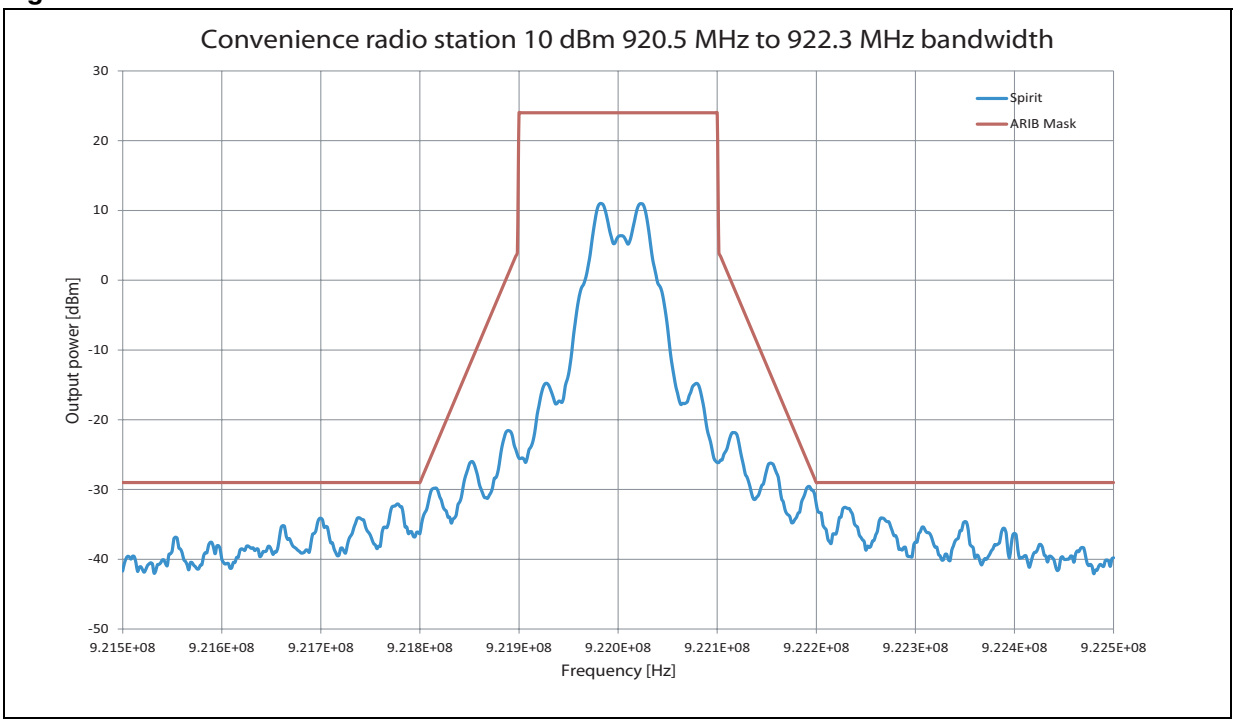


Figure 6. Convenience radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 923.5 MHz

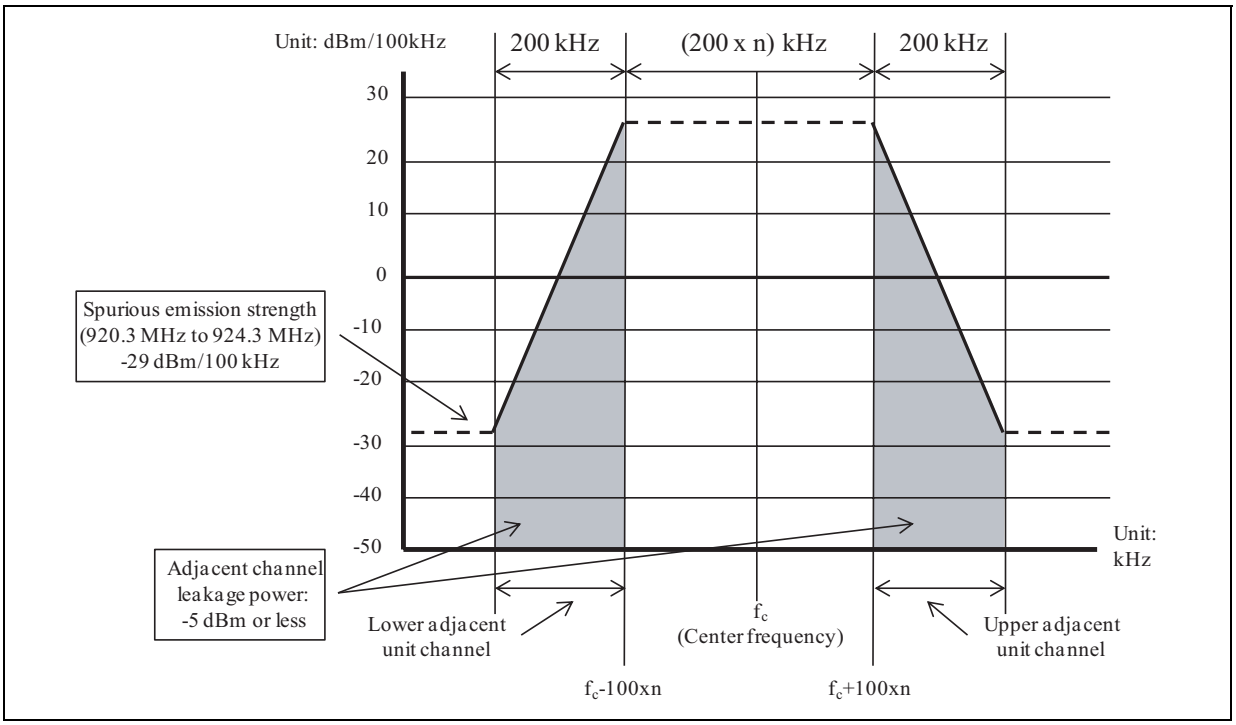


Figure 7. Convenience radio station channel mask of a radio channel at 923 MHz

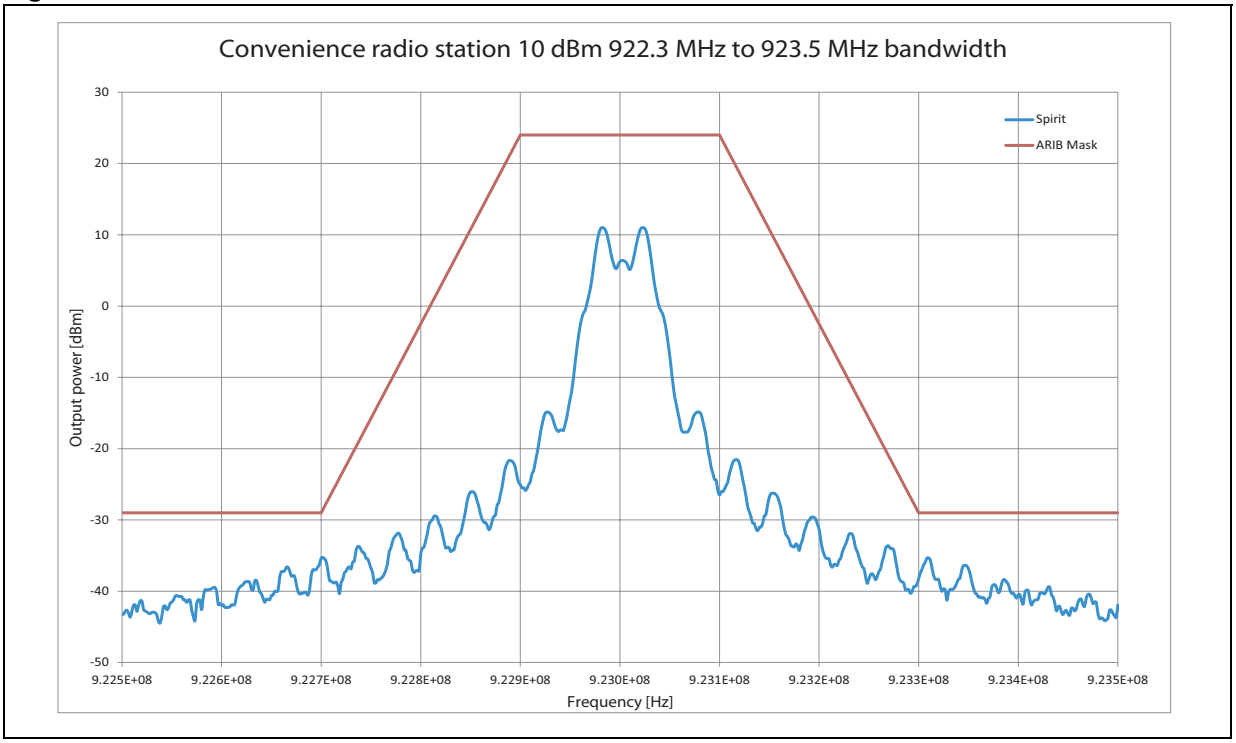


Figure 8. Low-power radio station channel mask of a radio channel whose frequency is from 915.9 MHz to 916.9 MHz

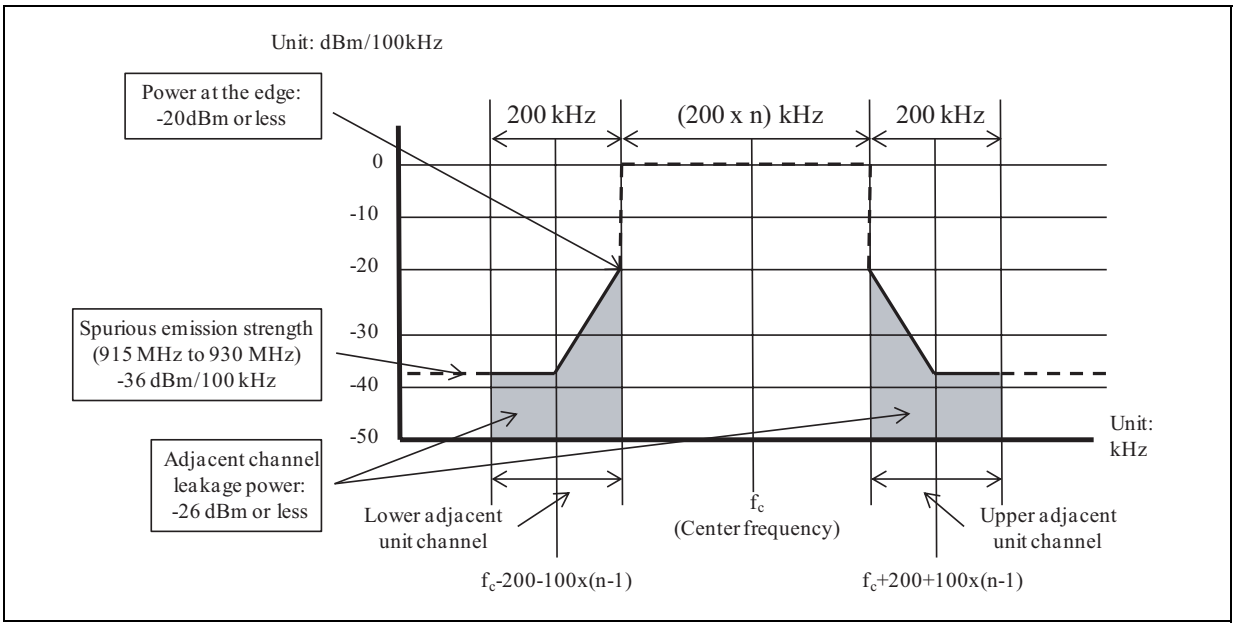


Figure 9. Low-power radio station channel mask of a radio channel at 916.5 MHz

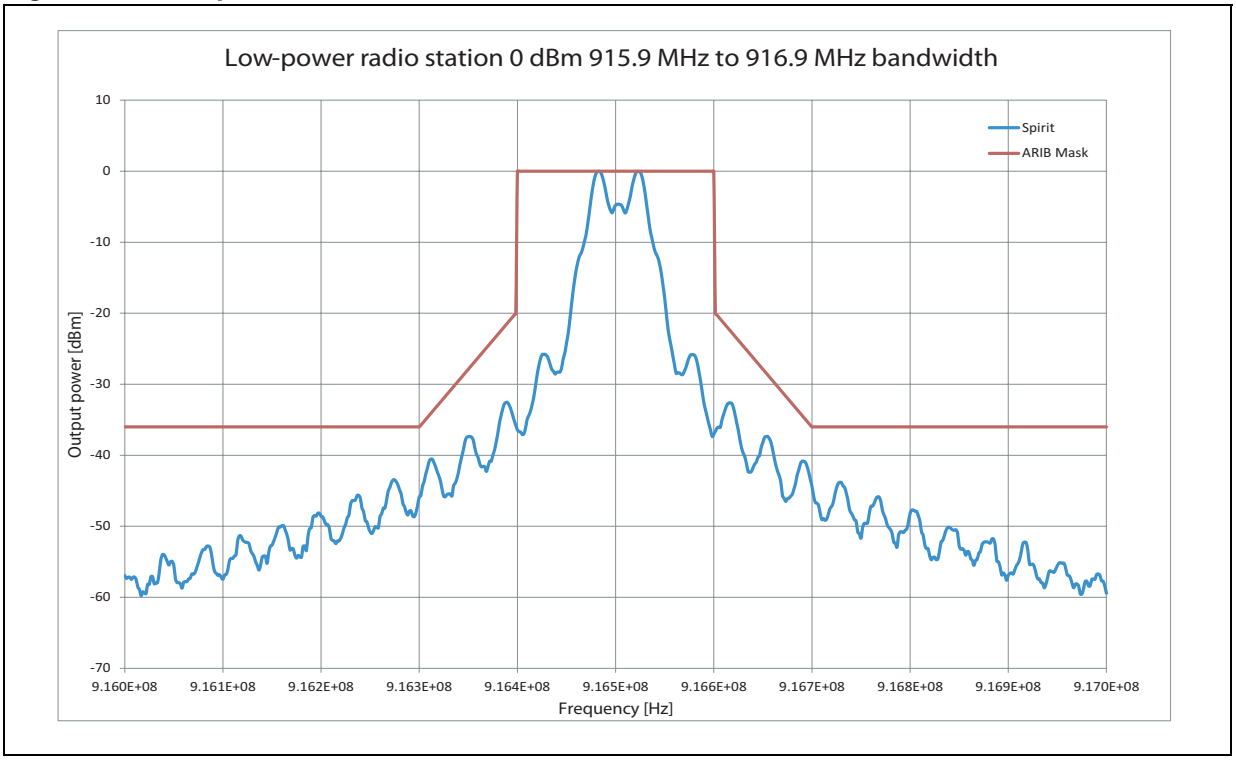


Figure 10. Low-power radio station channel mask of a radio channel whose frequency is from 920.5 MHz to 922.3 MHz

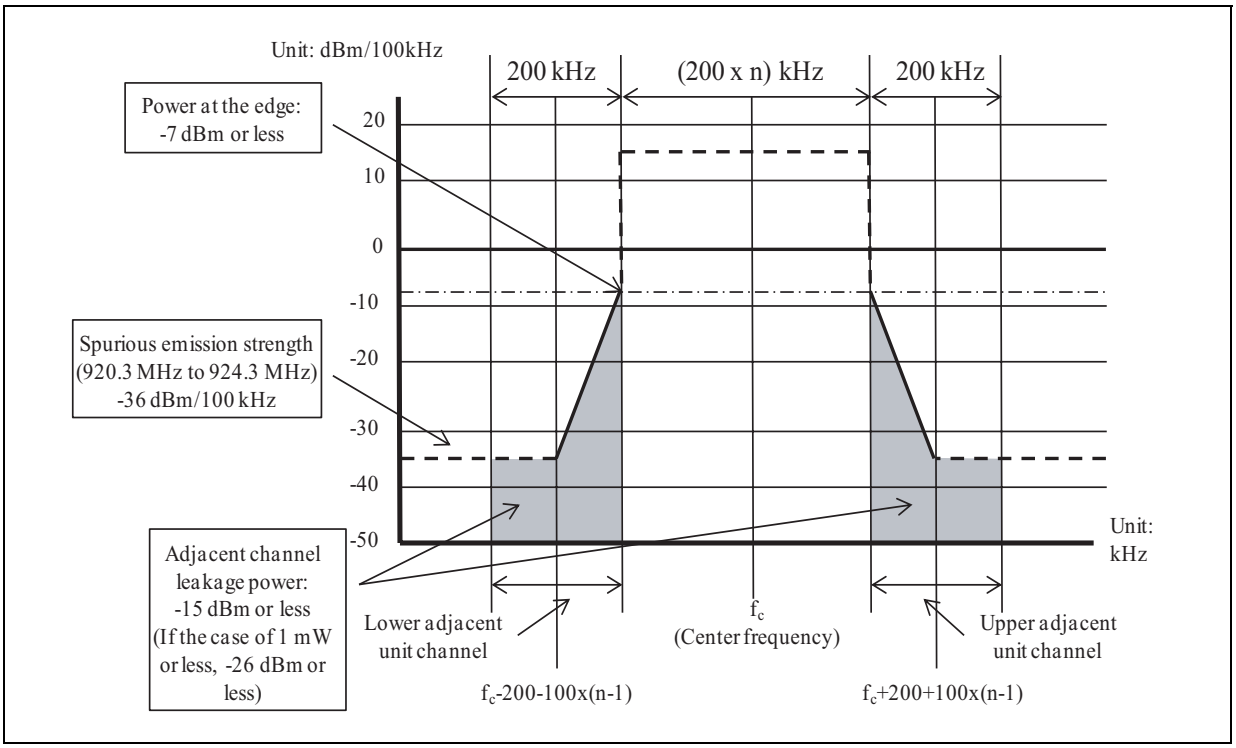


Figure 11. Low-power radio station channel mask of a radio channel at 921.5 MHz

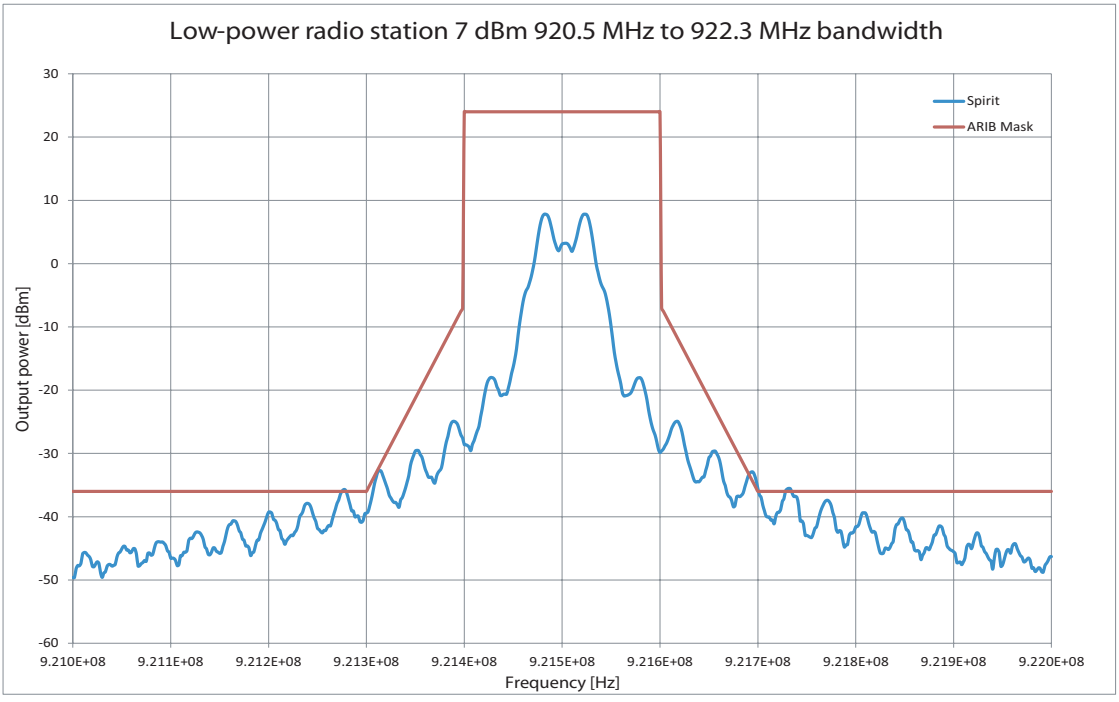


Figure 12. Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is 1 mW or less)l

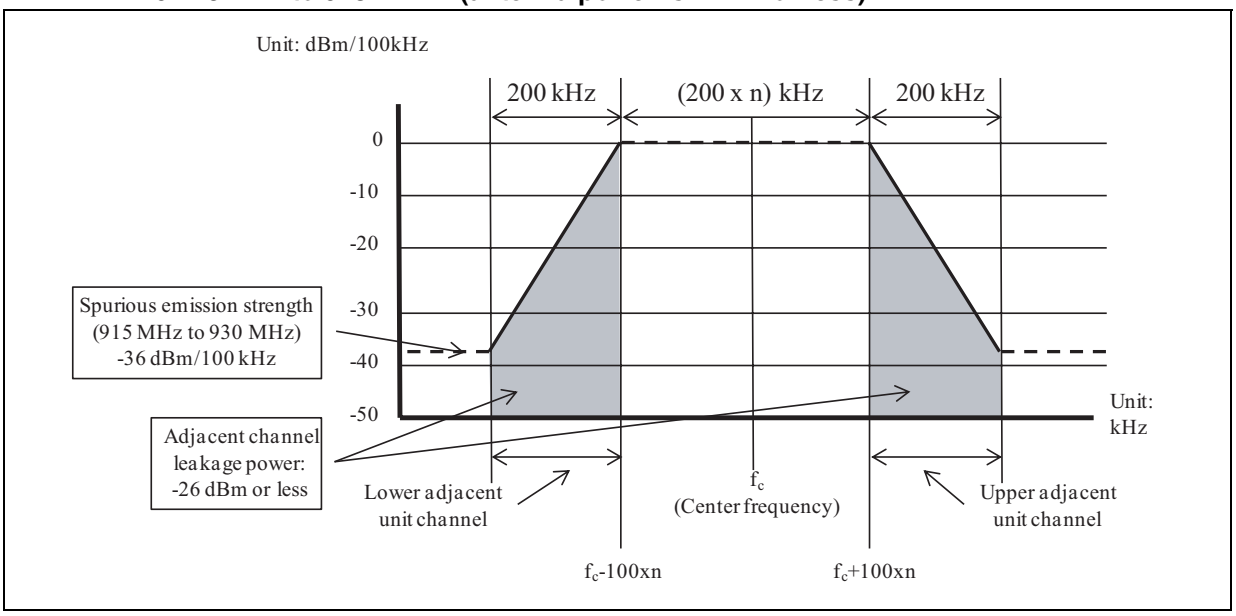


Figure 13. Low-power radio station channel mask of a radio channel at 928 MHz

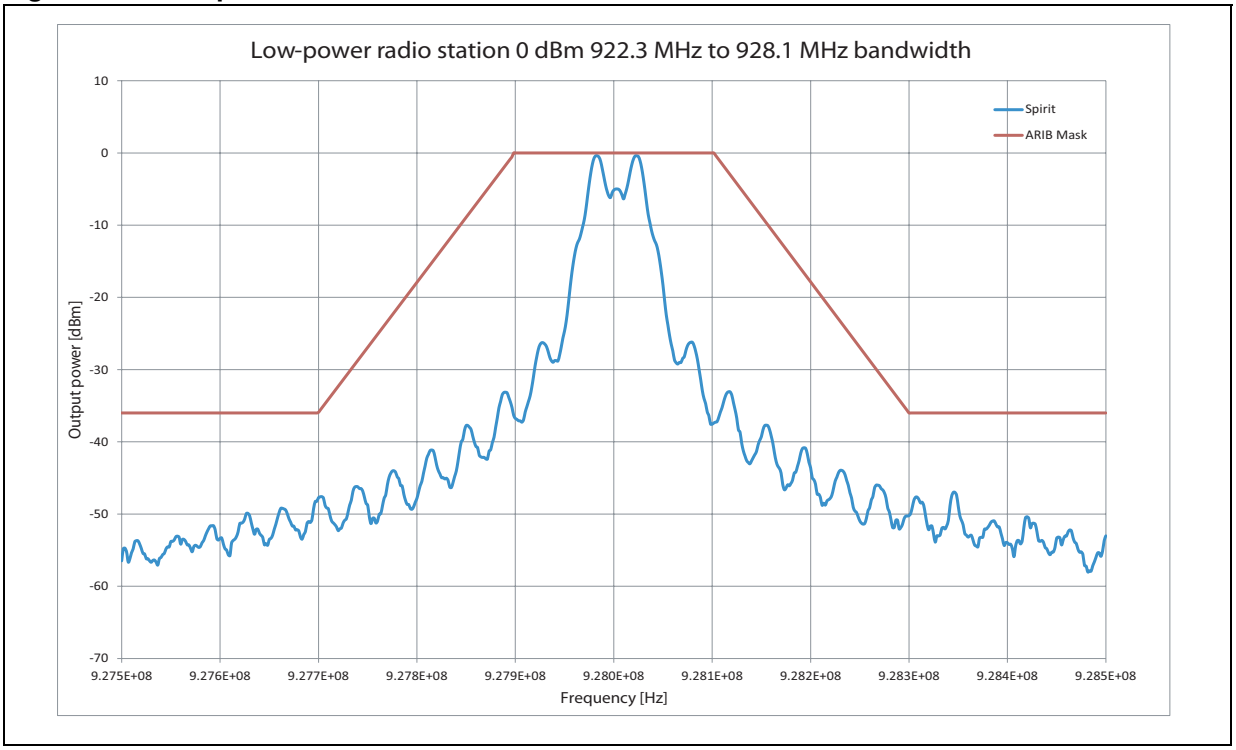


Figure 14. Low-power radio station channel mask of a radio channel whose frequency is from 922.3 MHz to 928.1 MHz (antenna power is more than 1 mW and 20 mW or less)

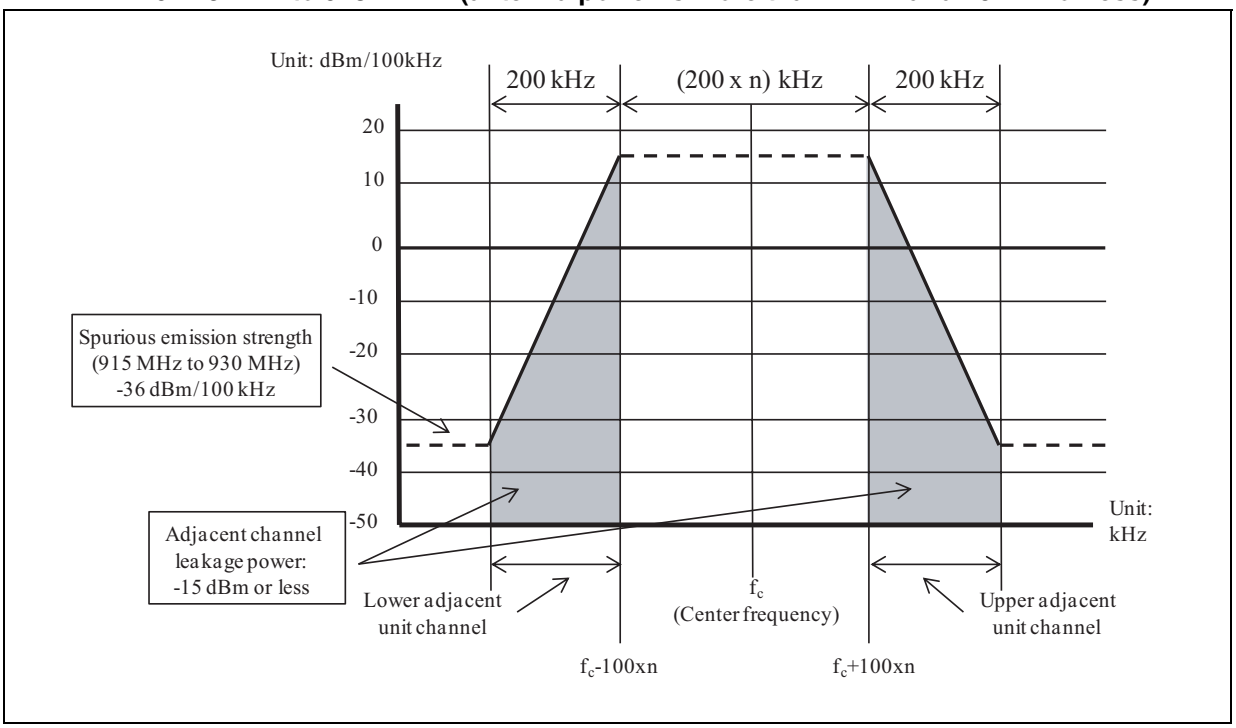


Figure 15. Low-power radio station channel mask of a radio channel at 925 MHz

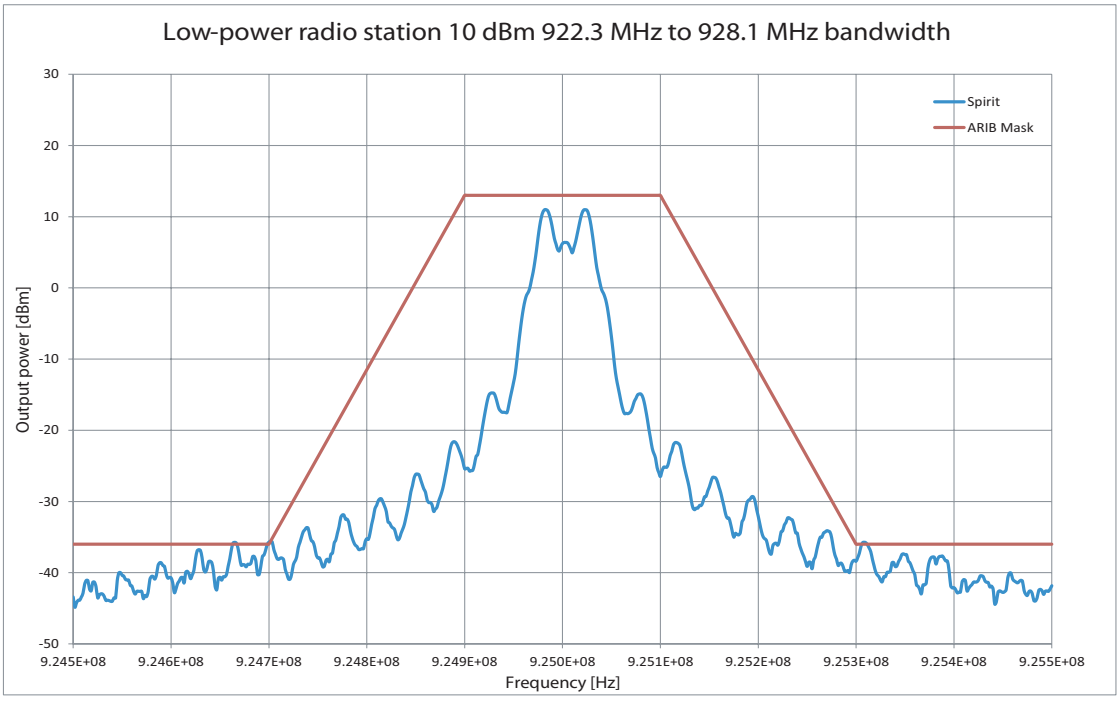


Figure 16. Low-power radio station channel mask of a radio channel whose frequency is from 928.1 MHz to 929.7 MHz

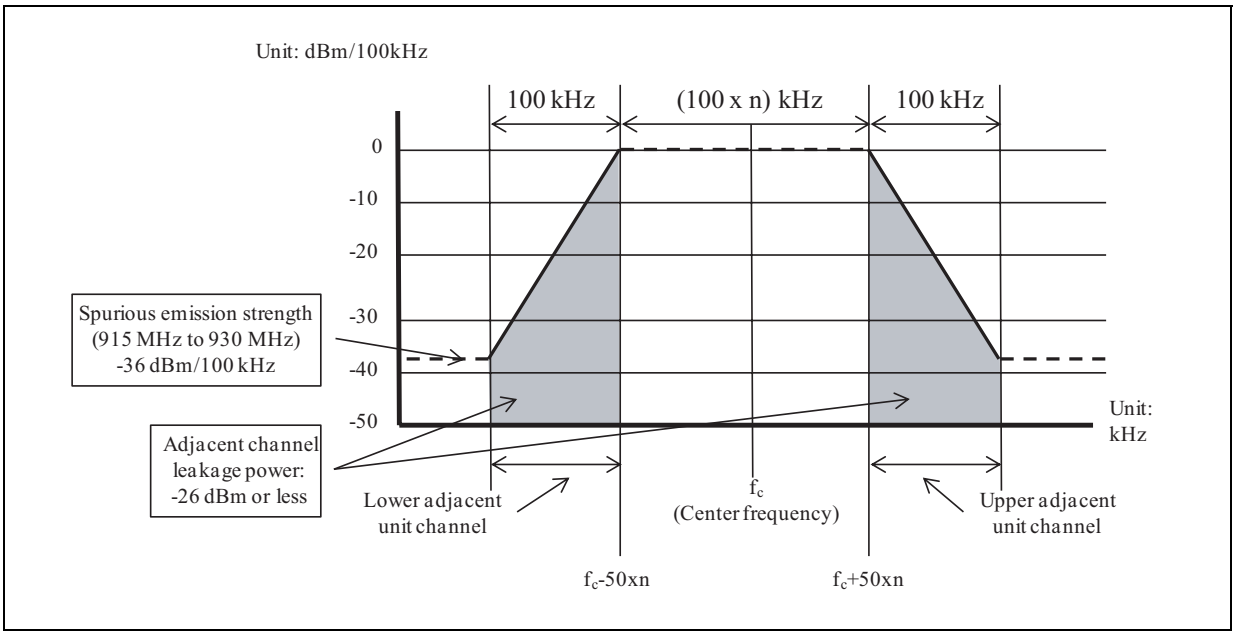
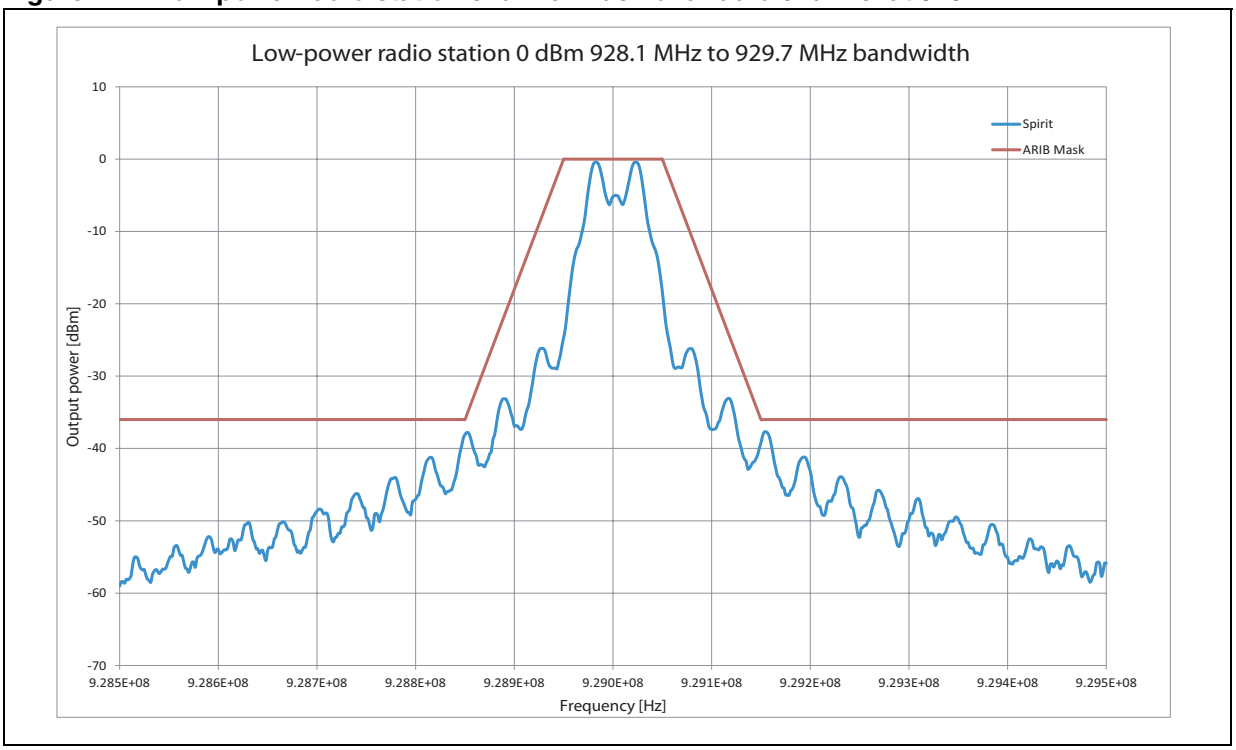


Figure 17. Low-power radio station channel mask of a radio channel at 929 MHz



4 Permissible values for unwanted emission intensity

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

The spurious emission strength at the antenna input has to be less than the values in *Table 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. 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 given in *Figure 18* to *26* which show that all requirements are met. Special attention must be given to the requirement in the 920.3 to 924.3 MHz band. In this band the levels of the spurious have to be lower than -55 dBm on 100 kHz band without considering the channel occupied bandwidth. This value is in obvious contradiction with the value reported in the convenience radio station channel masks (*Figure 4* and *6*) where for the same spurious a maximum level of -29 dBm integrated in 100 kHz bandwidth is given. In *Figure 22* the two different masks are shown and it is clear that the second requirement is much less stringent than the first one.

The measurements performed for the low-power radio station are given in *Figure 27* to *33*. For the low-power case the full requirements are met.

Figure 18. Convenience radio station emission in the 10 - 710 MHz bandwidth

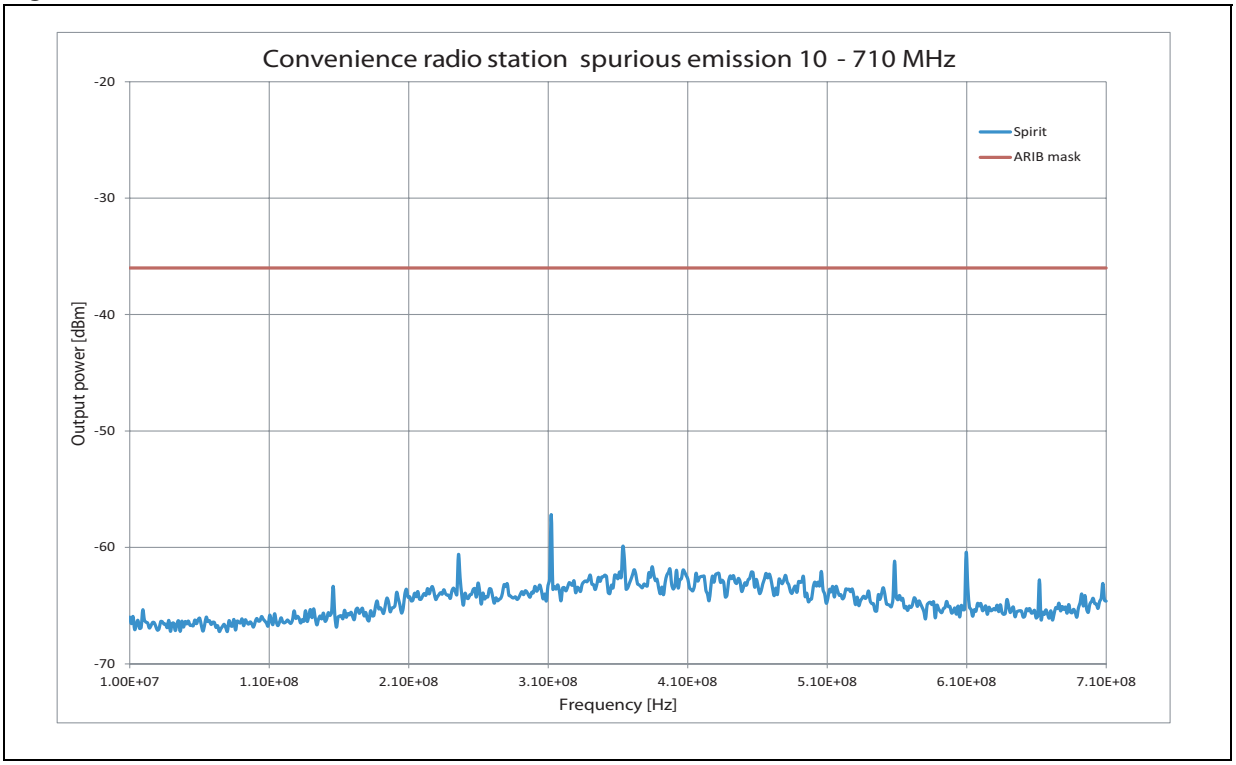


Figure 19. Convenience radio station emission in the 710 - 900 MHz bandwidth

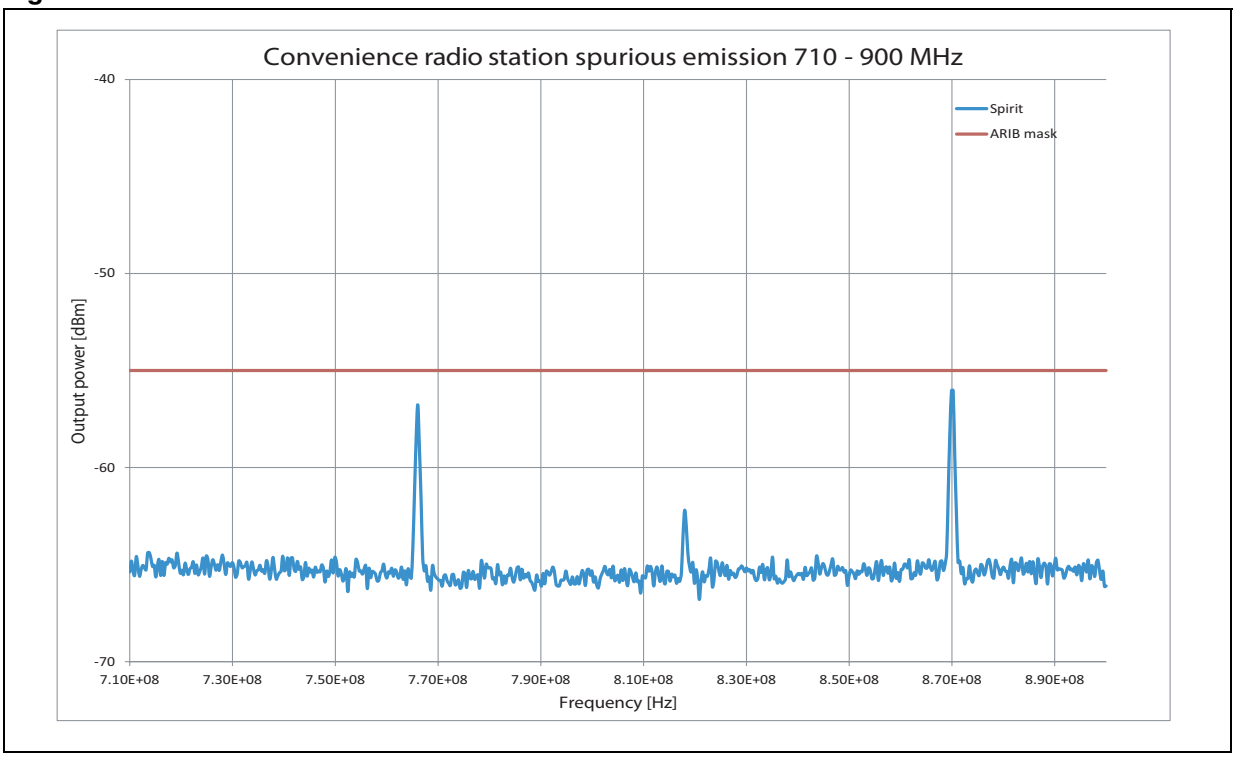


Figure 20. Convenience radio station emission in the 900 - 915 MHz bandwidth

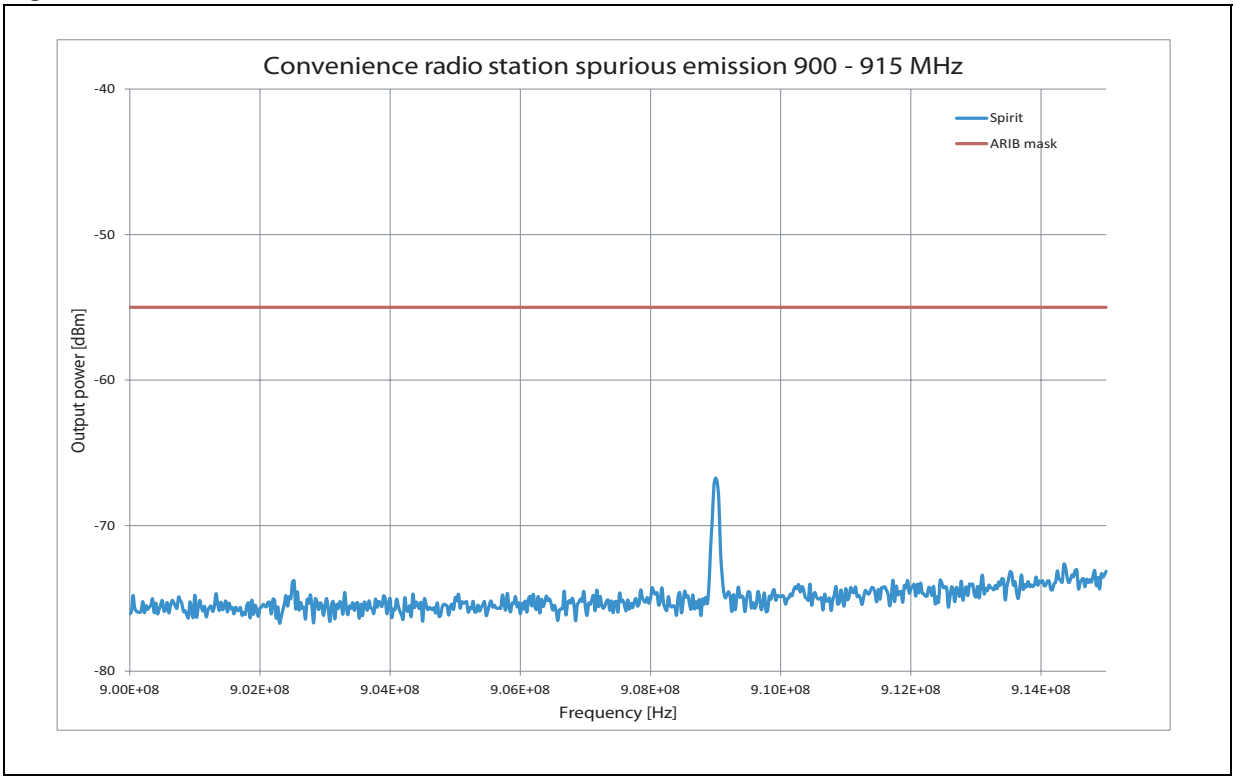


Figure 21. Convenience radio station emission in the 915 - 920.3 MHz bandwidth

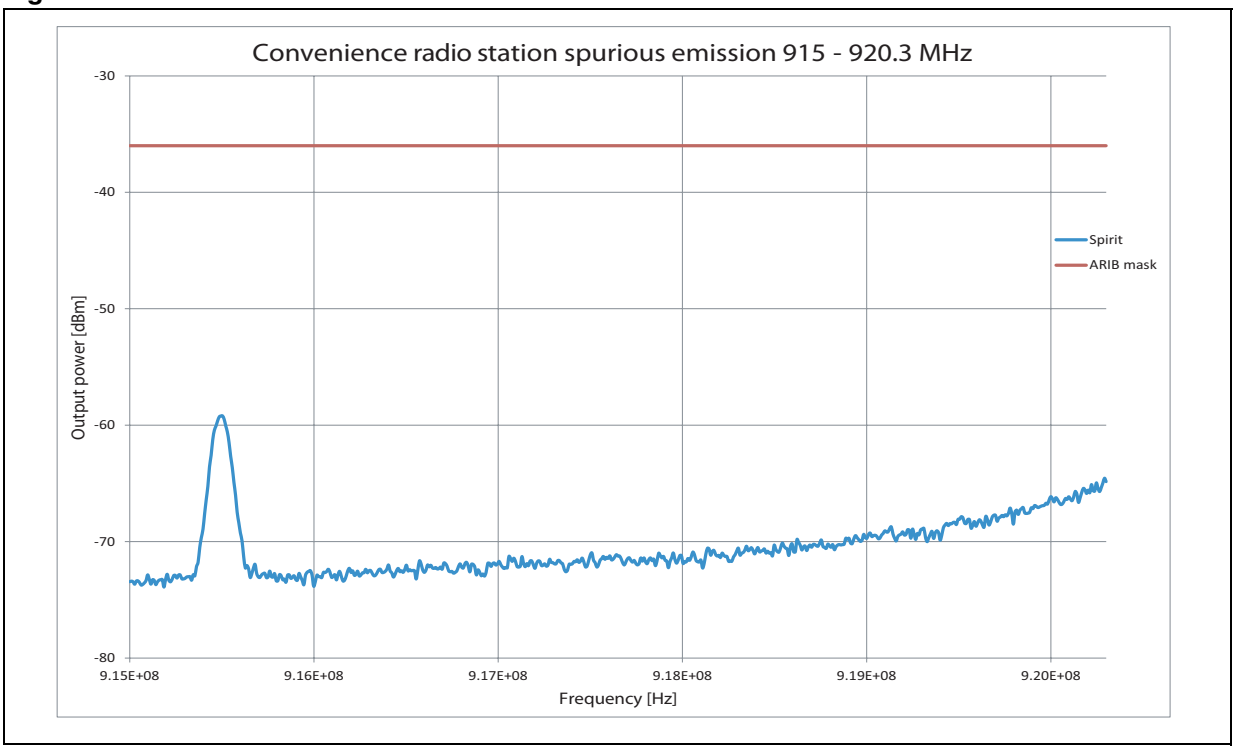


Figure 22. Convenience radio station emission in the 920.3 - 924.3 MHz bandwidth

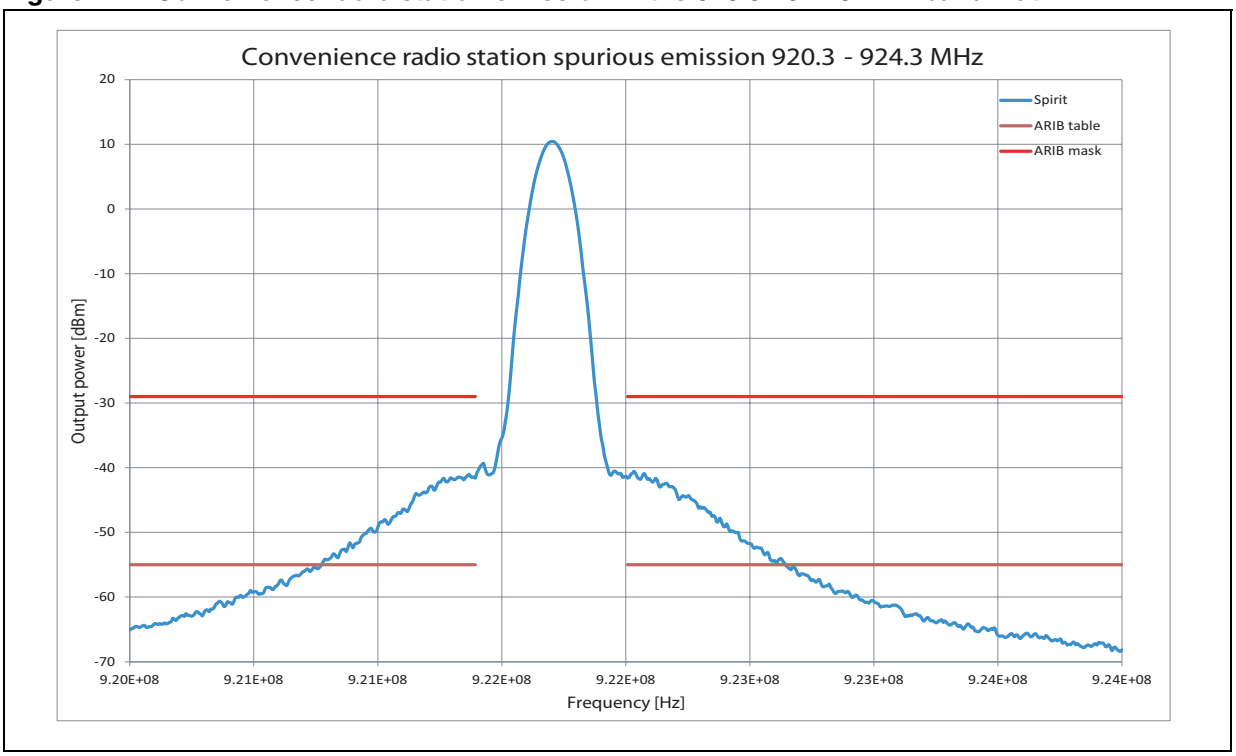


Figure 23. Convenience radio station emission in the 924.3 - 930 MHz bandwidth

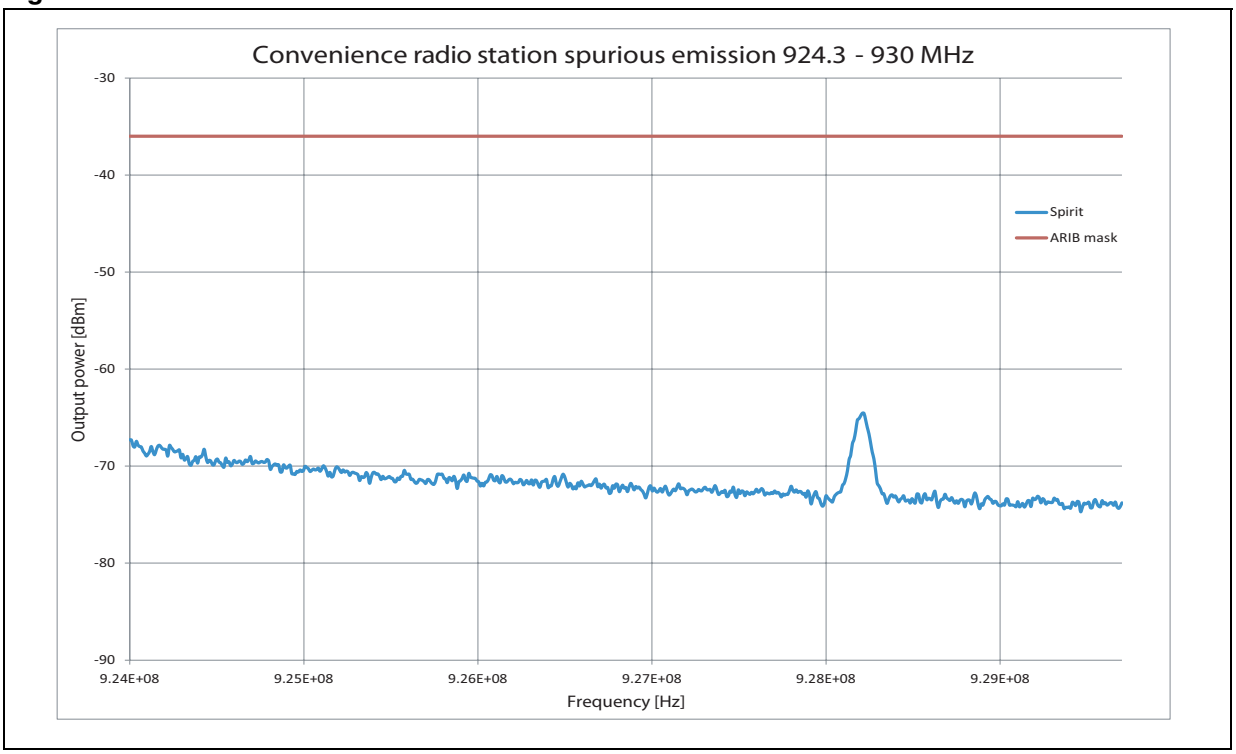


Figure 24. Convenience radio station emission in the 930 - 1000 MHz bandwidth

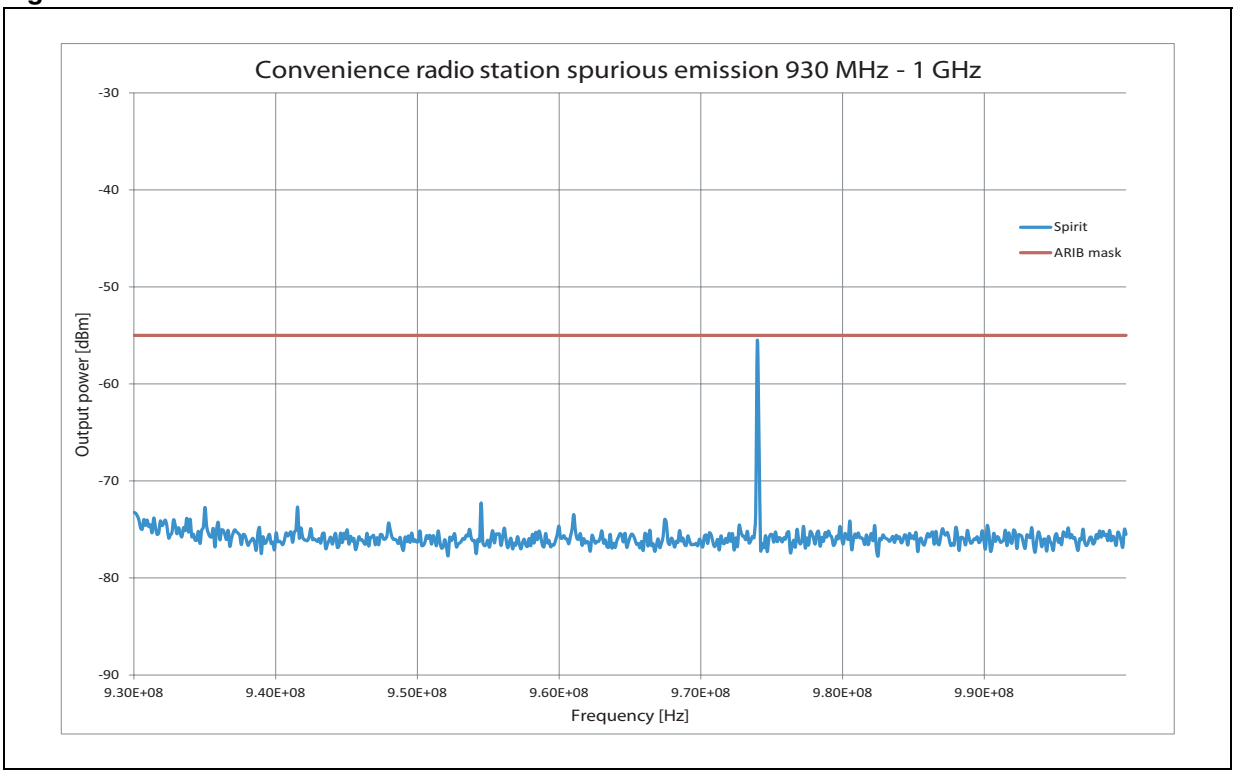


Figure 25. Convenience radio station emission in the 1 - 1.215 GHz bandwidth

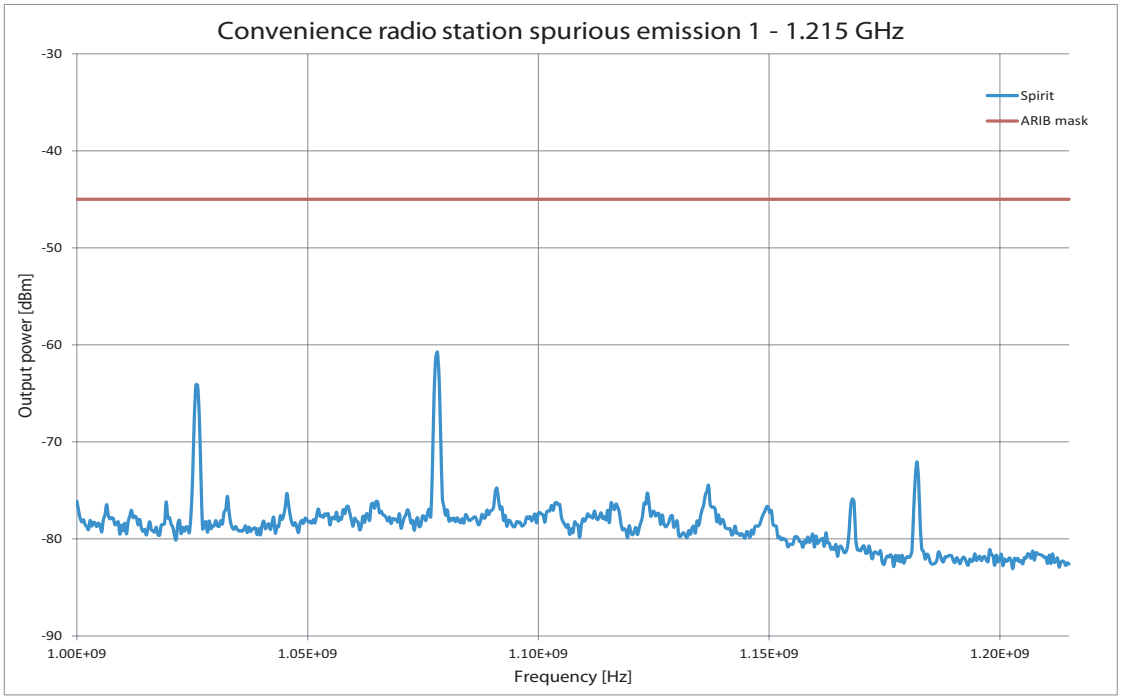


Figure 26. Convenience radio station emission in the 1.215 - 6 Hz bandwidth

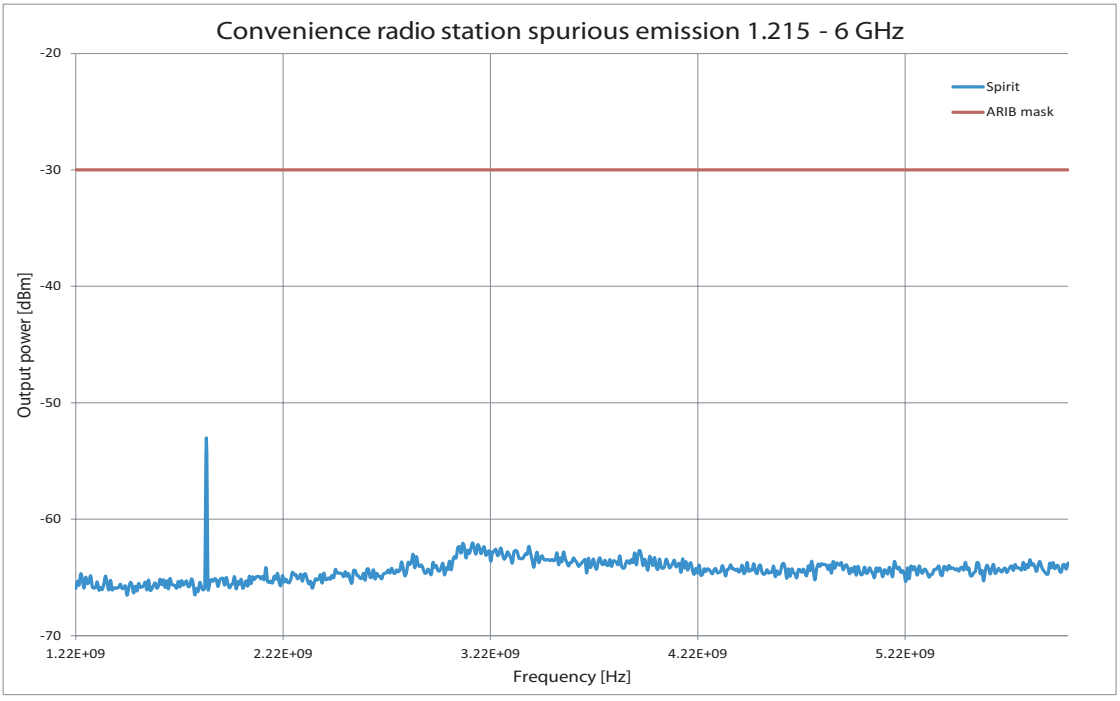


Figure 27. Low-power radio station emission in the 10 - 710 MHz bandwidth

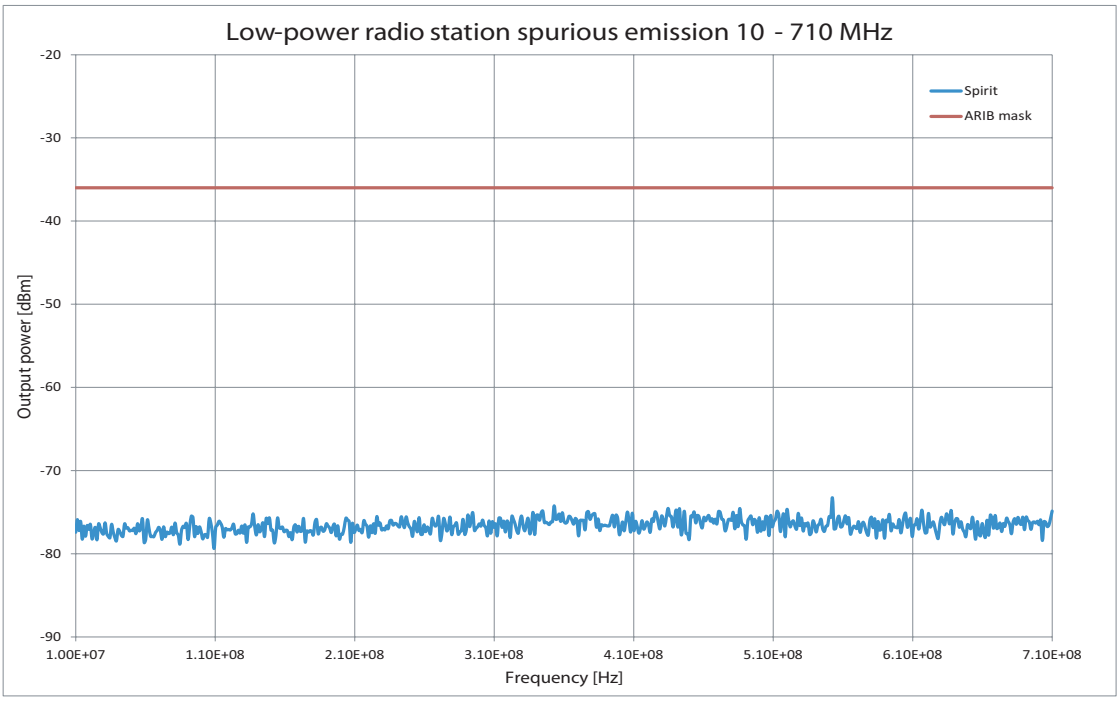


Figure 28. Low-power radio station emission in the 710 - 900 MHz bandwidth

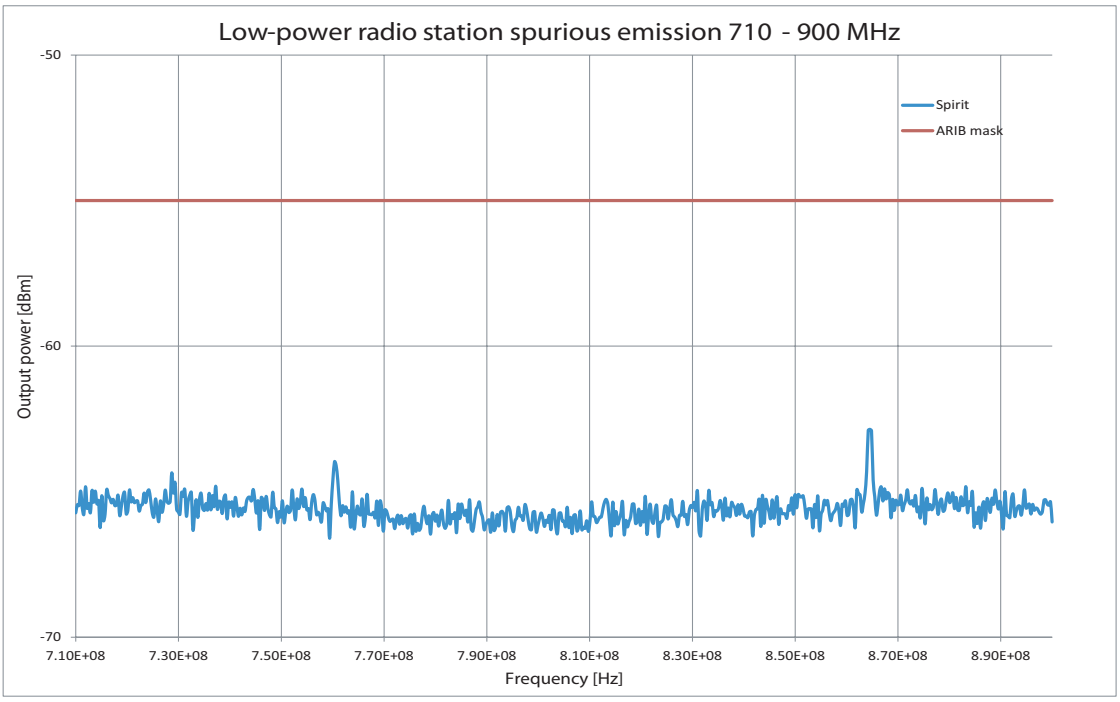


Figure 29. Low-power radio station emission in the 900 - 915 MHz bandwidth

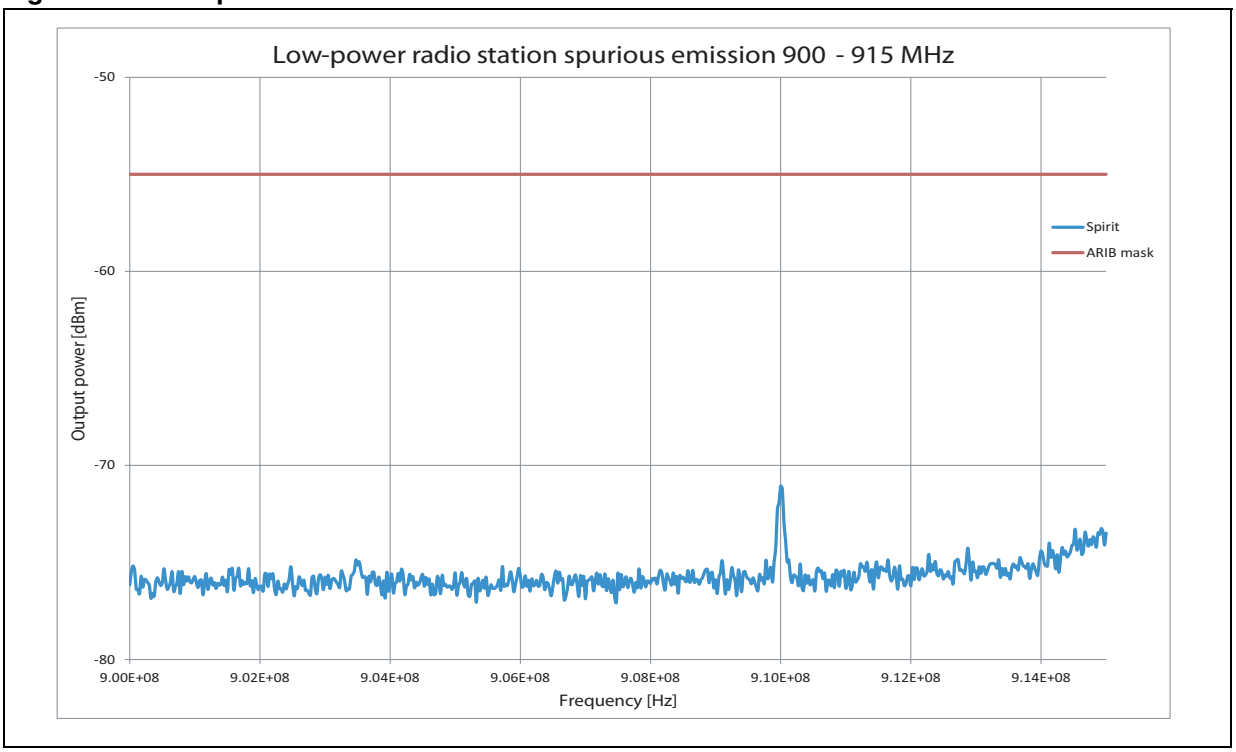


Figure 30. Low-power radio station emission in the 915 - 930 MHz bandwidth

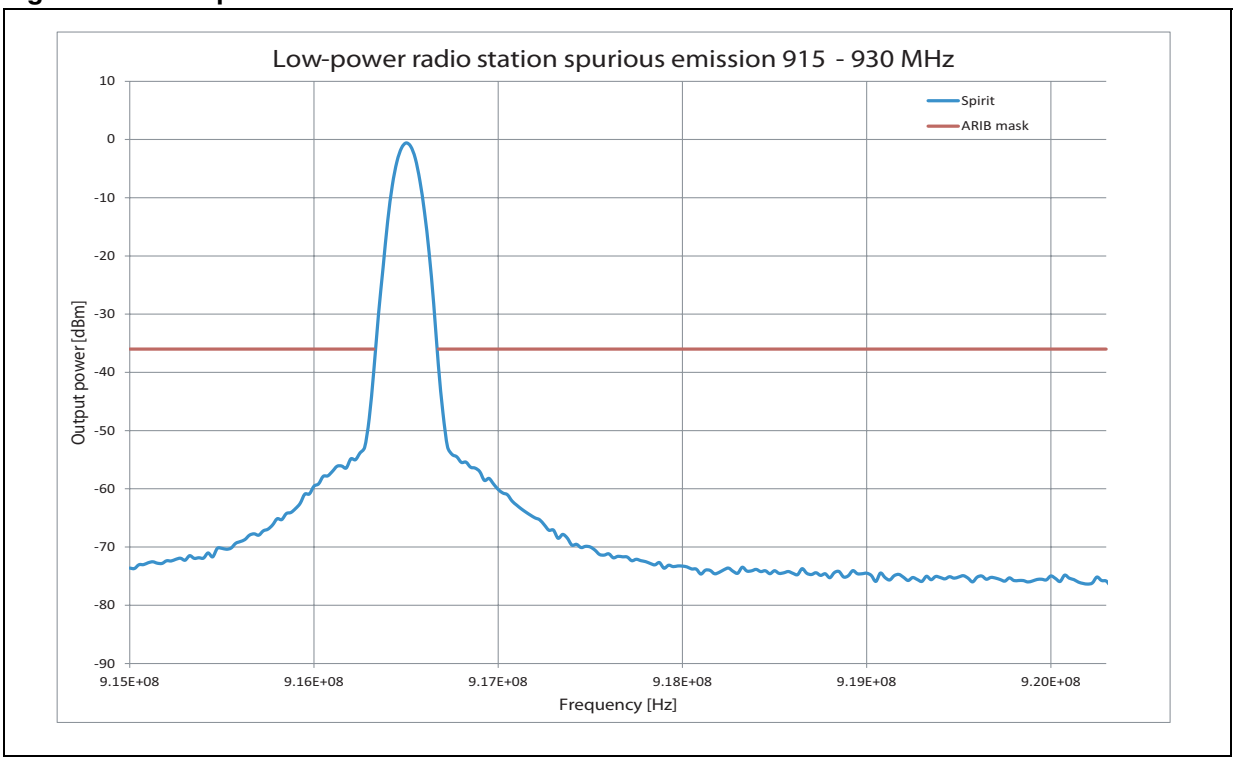


Figure 31. Low-power radio station emission in the 930 - 1000 MHz bandwidth

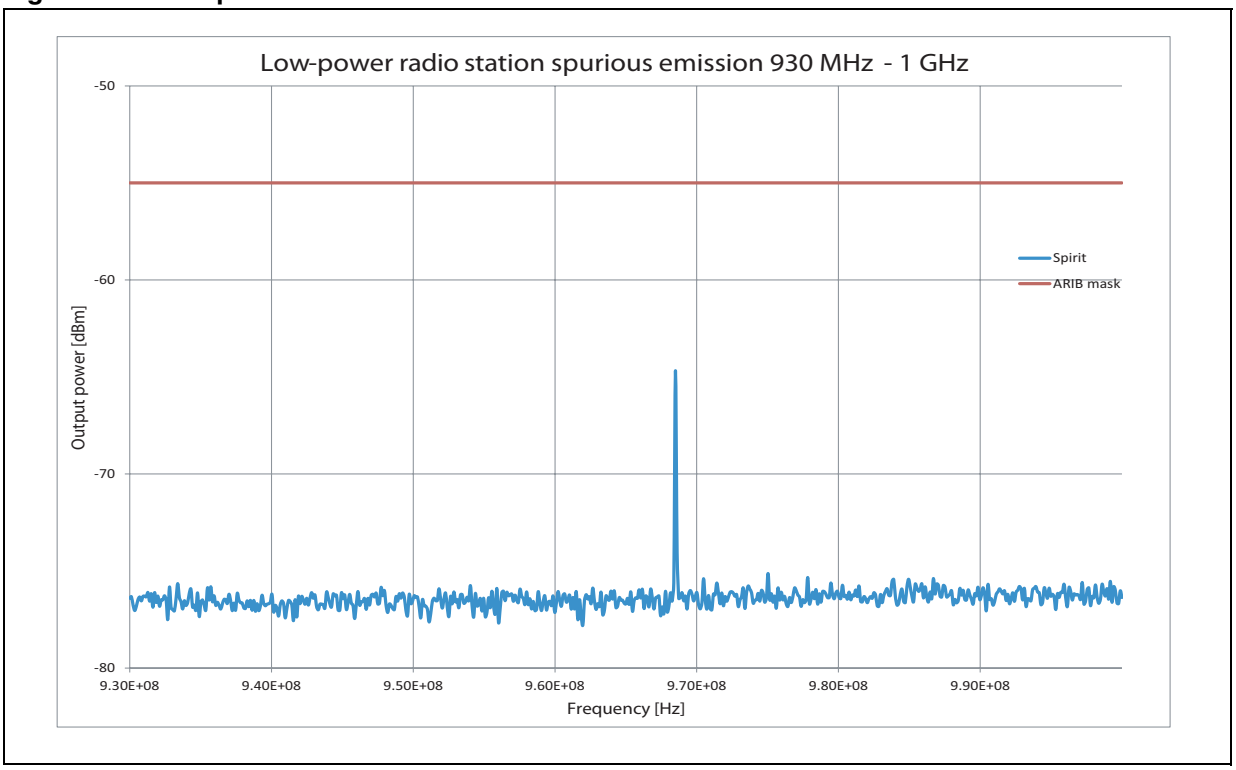


Figure 32. Low-power radio station emission in the 1 - 1.215 GHz bandwidth

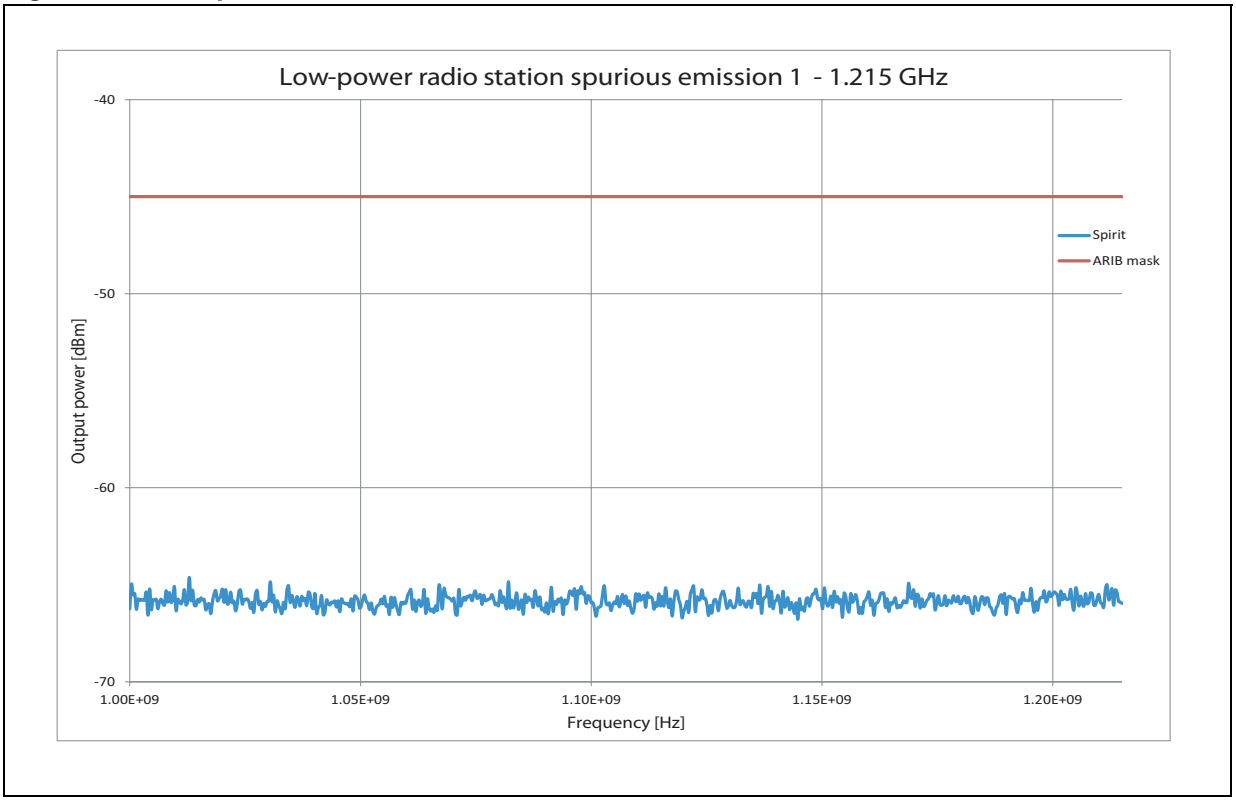
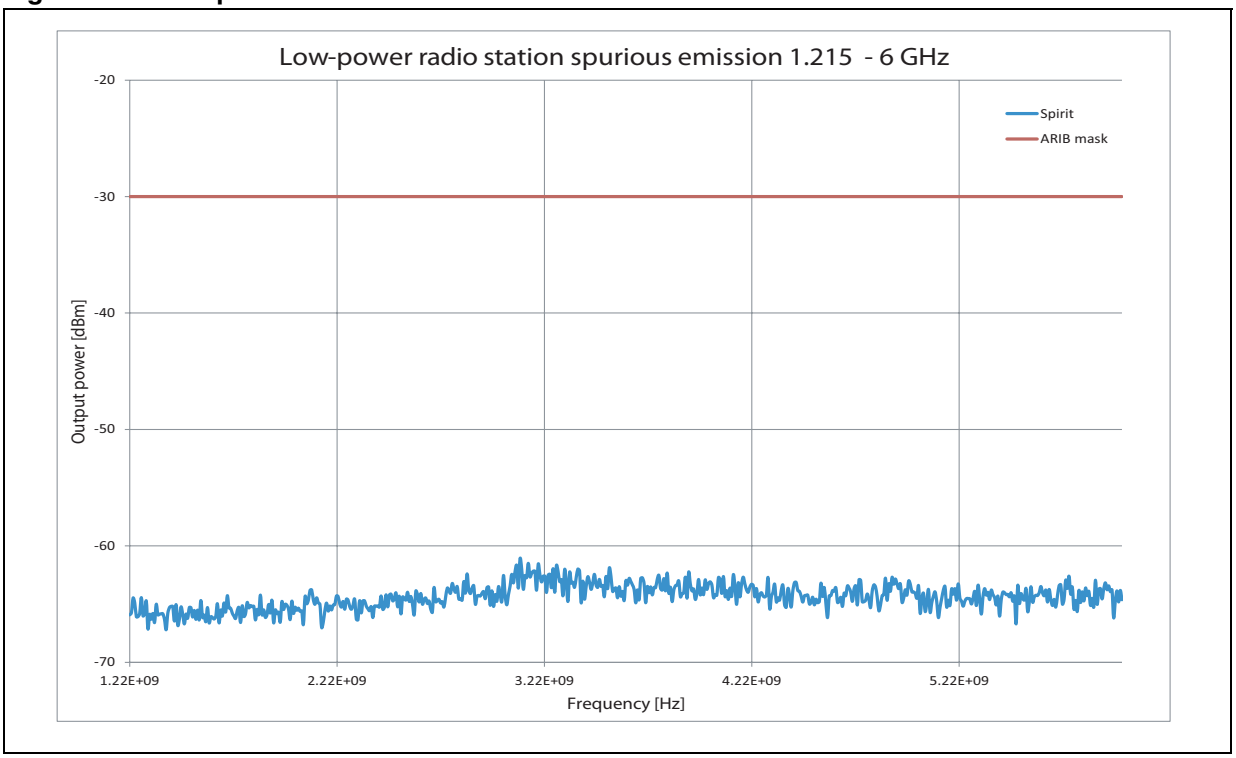


Figure 33. Low-power radio station emission in the 1.215 - 6 GHz bandwidth



5 Receiver

Only one measurement is required for the receiver, the limit on secondary radiated emission. This measurement is performed under the following conditions: Tc = 25 °C, Vdd = 3.0 V, f = 922 MHz (middle frequency of the bandwidth used).

5.1 Limit on secondary radiated emission

Spurious radiation from the receiver includes components at any frequency, radiated by the equipment. The spurious emission strength at the antenna input has to be less than the values in *Table 2* for the convenience radio stations and *Table 4* for the low-power radio stations. The two tables are the same, so the measurement is performed only once, setting the receiver to 922 MHz, maximum gain.

The measurement results are given in *Figure 34* to *39*. The entire standard requirements are met from the SPIRIT1 in receiver mode.

Figure 34. Receiver radiated emission in the 10 - 710 MHz bandwidth

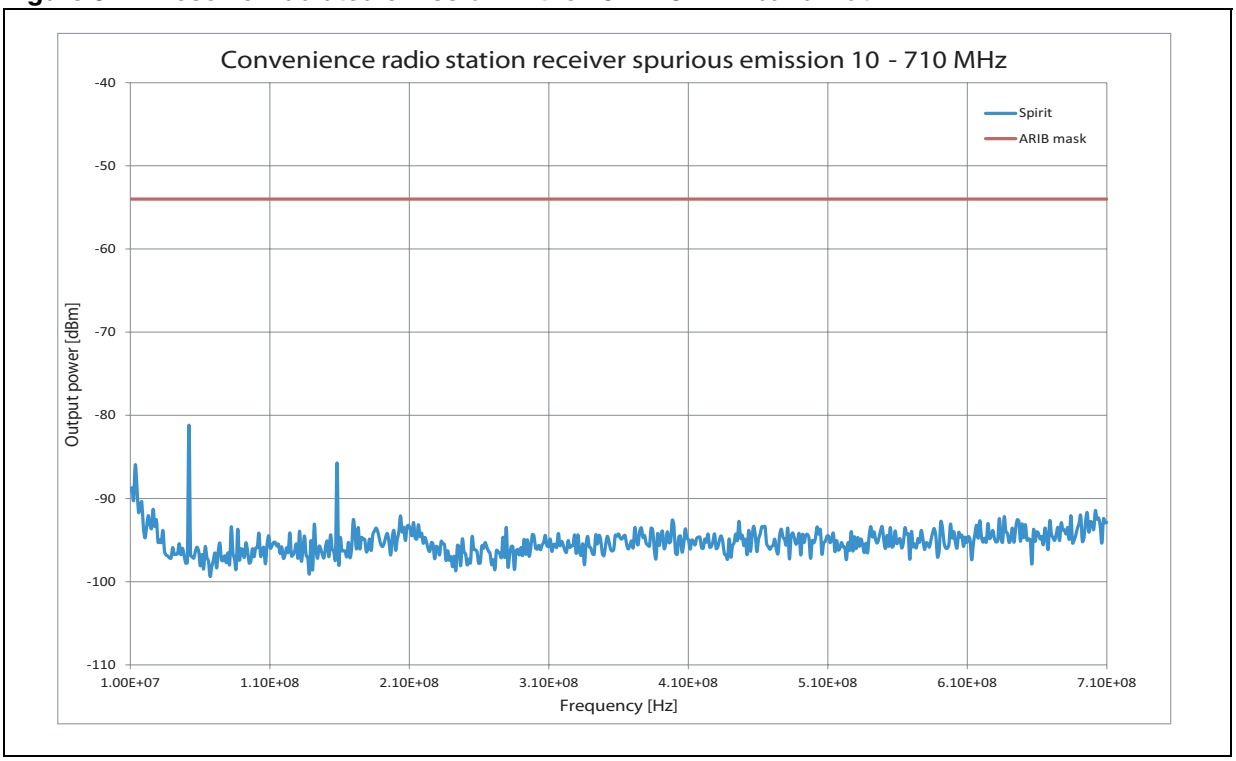


Figure 35. Receiver radiated emission in the 710 - 900 MHz bandwidth

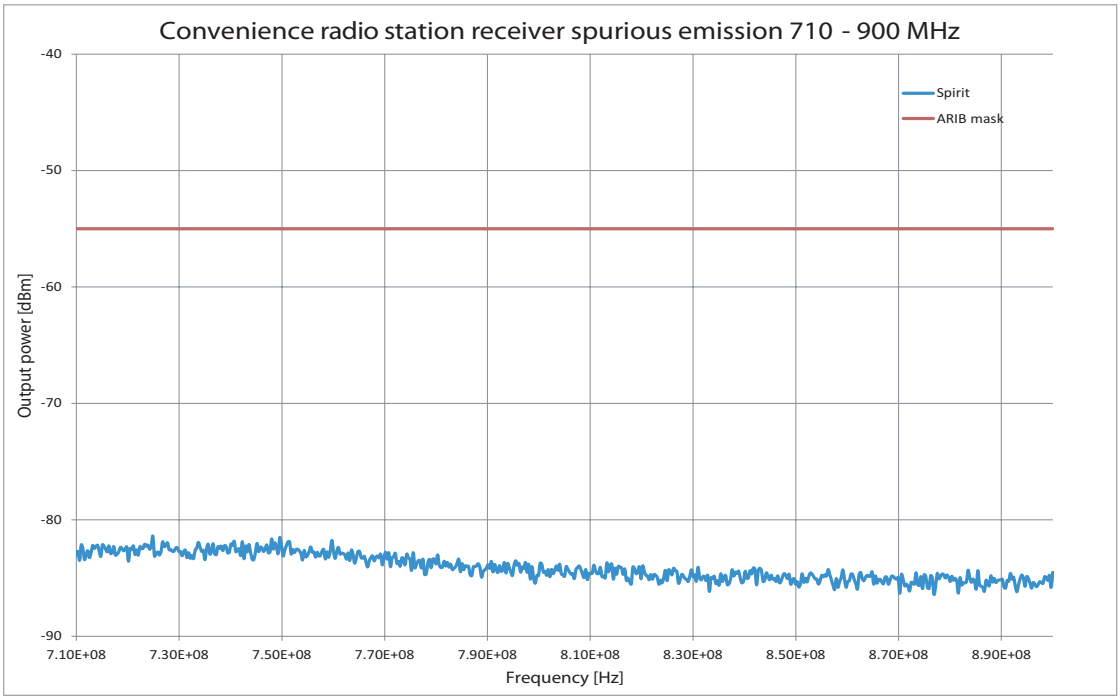


Figure 36. Receiver radiated emission in the 900 - 915 MHz bandwidth

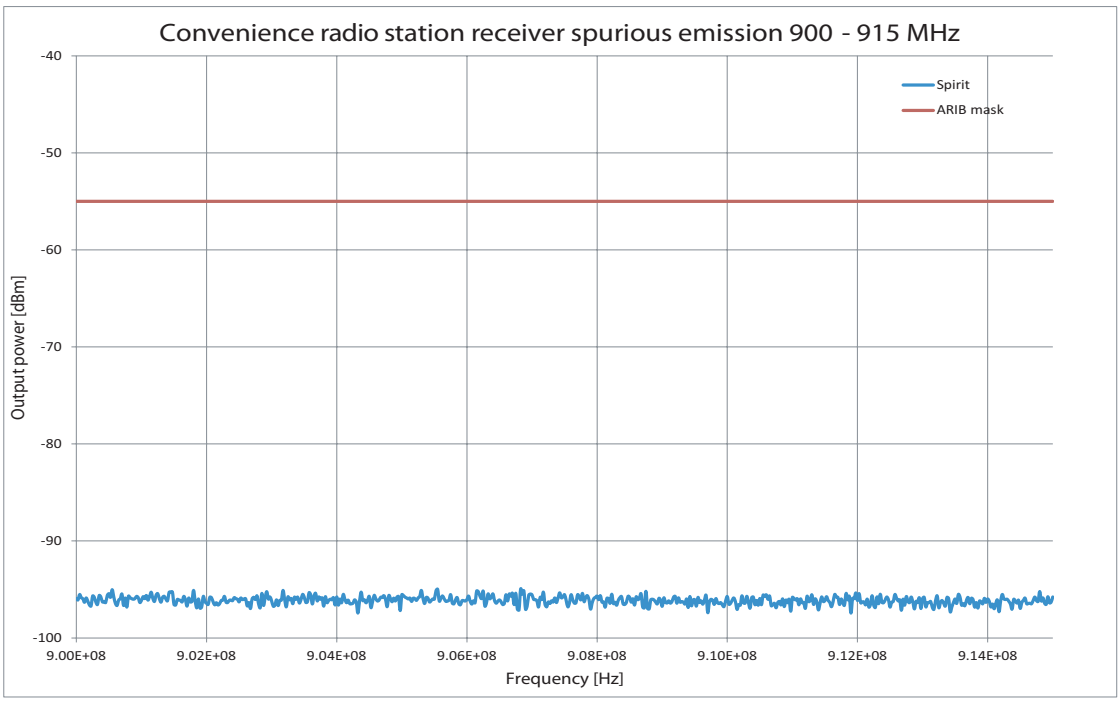


Figure 37. Receiver radiated emission in the 915 - 930 MHz bandwidth

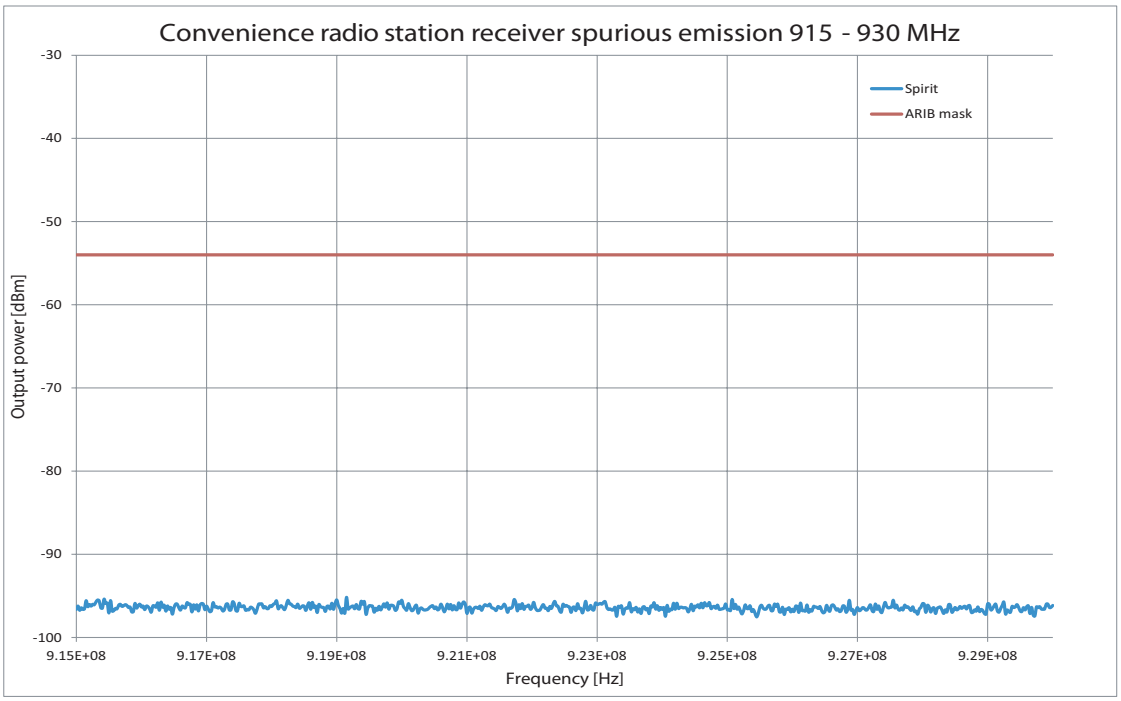


Figure 38. Receiver radiated emission in the 930 - 1000 MHz bandwidth

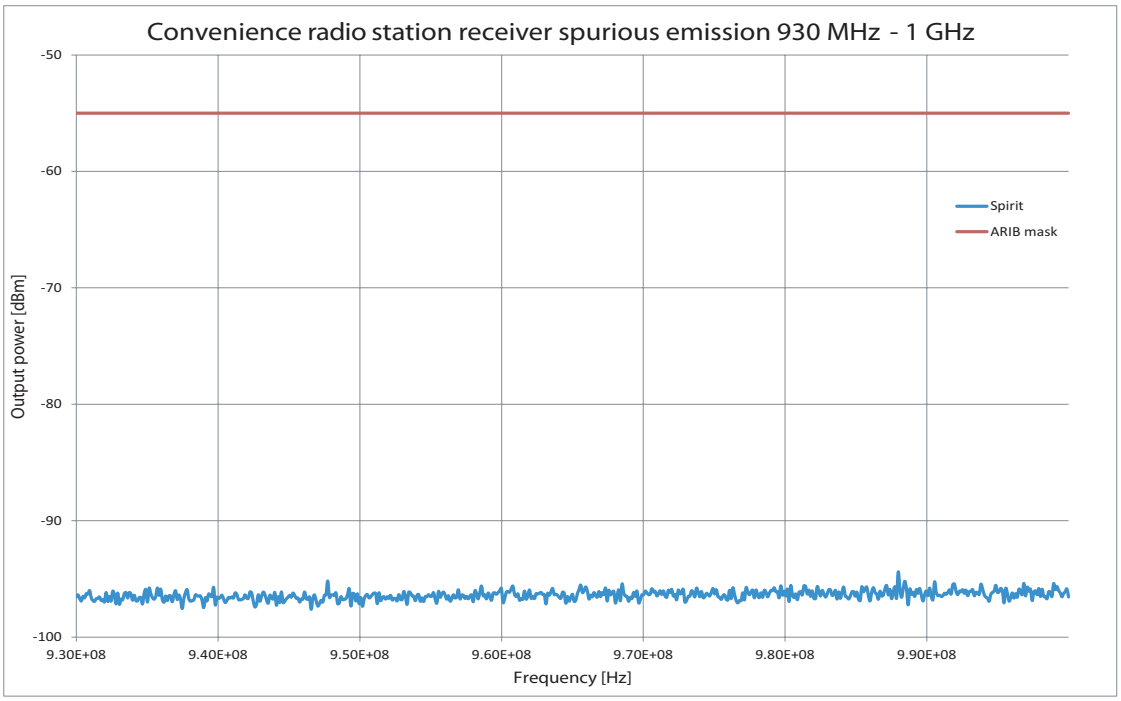
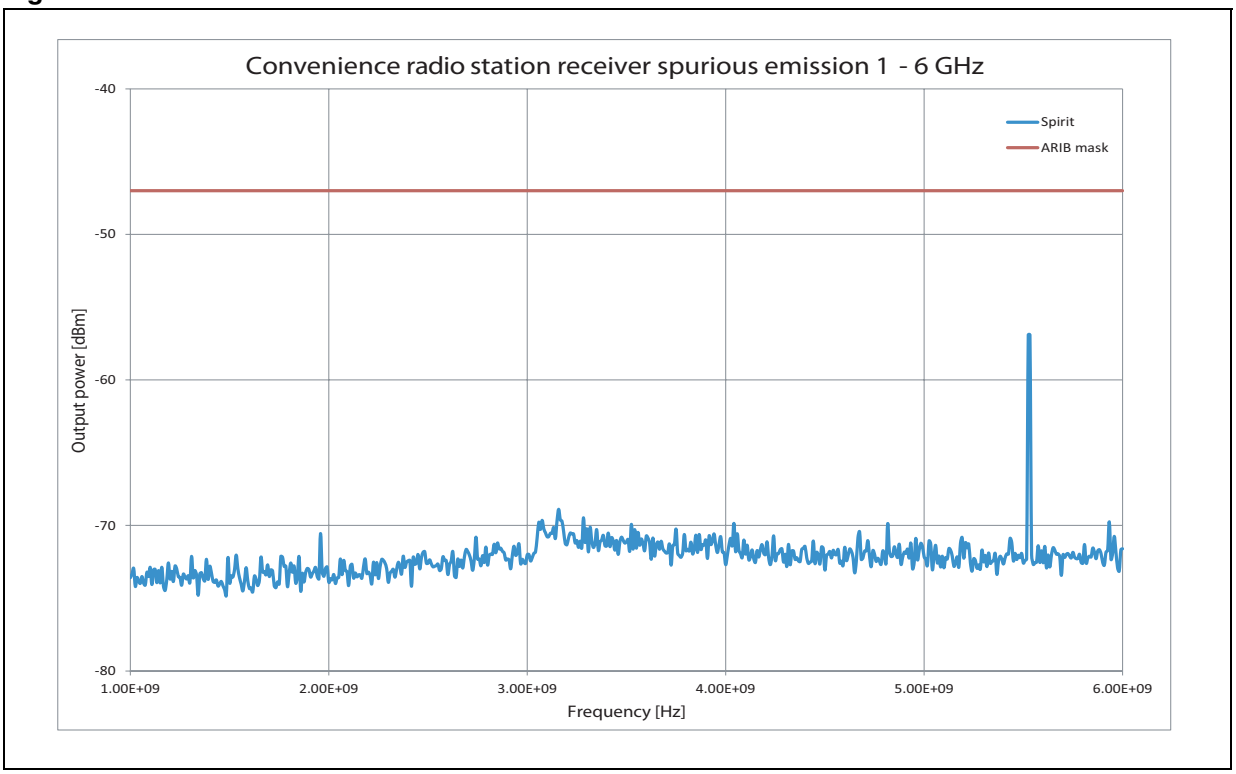


Figure 39. Receiver radiated emission in the 1 - 6 GHz bandwidth



6 References

1. SPIRIT1 datasheet
2. ARIB STD-T108: "920 MHz band telemeter, telecontrol and data transmission radio equipment"

7 Revision history

Table 5. Document revision history

Date	Revision	Changes
12-Jul-2012	1	Initial release.