AN4117
Application note

Using the SPIRIT1 transceiver under EN 300 220 at 434 MHz

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Introduction

The SPIRIT1 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 licence-free ISM and SRD frequency bands at 169, 315, 433, 868 and 915 MHz.

This application note outlines the expected performance when using the SPIRIT1 under EN 300 220-1 (v2.3.1, 2012-02) [2] in the 433.050 to 434.790 MHz band. There are no specific requirements in this band, no specific use and no channel spacing are defined. Devices supporting audio and video applications use a digital modulation method with a maximum bandwidth of 300 kHz. Devices supporting digital voice have a maximum bandwidth not exceeding 25 kHz. The maximum allowed output power is +10 dBm (10 mW).

For details of the regulatory limits in the 433.050 - 434.790 MHz SRD frequency bands, please refer to the ETSI EN 300 220-1 v2.3.1 [2] and ERC recommendation 70-03 [3]. These can be downloaded from www.etsi.org and www.ero.dk respectively.

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1 Application circuit

Figure 1 shows an image of the SPIRIT1 application daughterboard. The application is made up of two boards: a daughterboard and a motherboard. The daughterboard includes the SPIRIT1 with the circuits necessary for its functioning. For correct functionality, the daughterboard must be plugged into a motherboard (see *Figure 2*) by two header 5x2 connectors (J6 and J7).

The motherboard is provided with an STM32L152VBT6 micro to correctly program the transceiver. The micro is programmed with a 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 XTAL to provide the correct oscillator to the SPIRIT1.

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

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

To reduce application costs, the SPIRIT1 is designed to work without an external antenna switch. This daughterboard is designed to show the SPIRIT1 functions in this condition. An application with an antenna switch can certainly be realized but is not described in this document.

Figure 1. SPIRIT1 application daughterboard

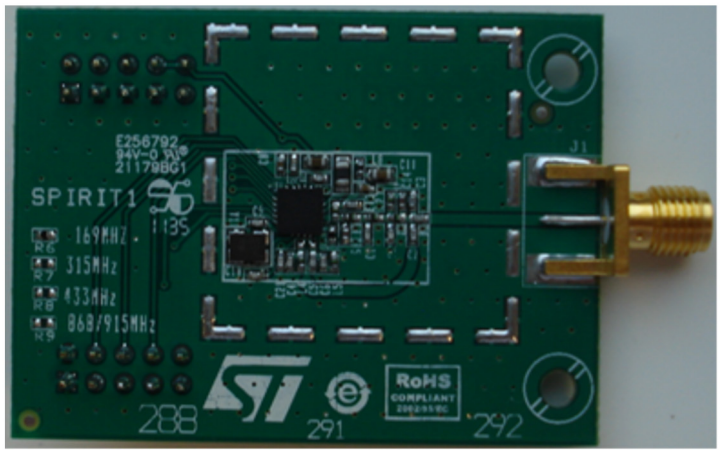


Figure 2. SPIRIT1 application daughterboard plugged into the motherboard

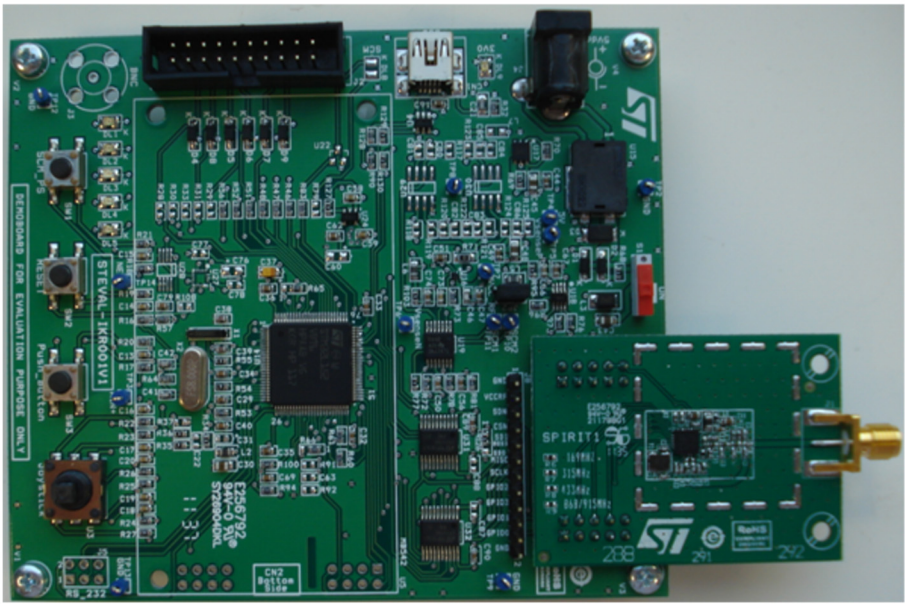
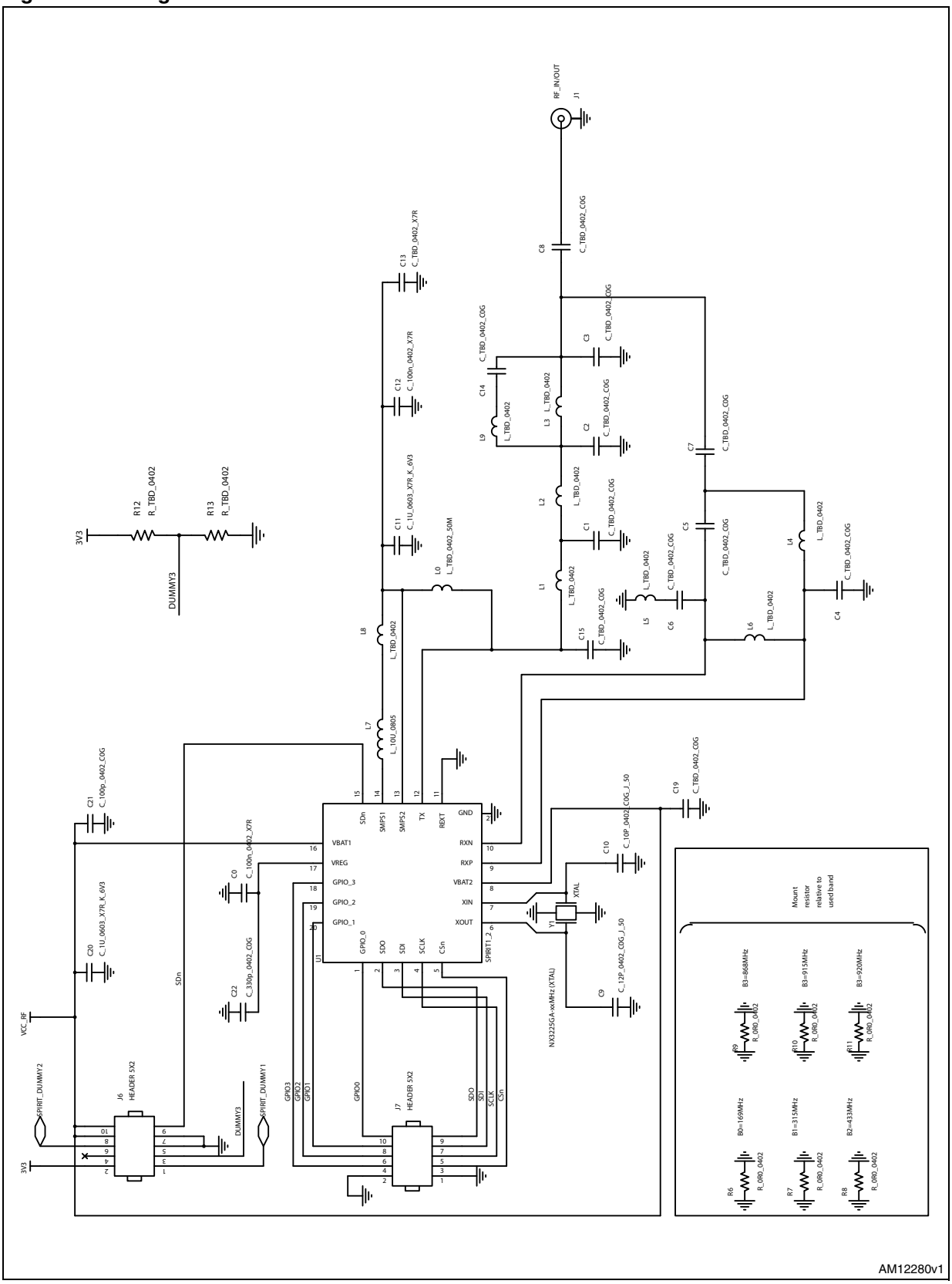


Figure 3. Daughterboard schematic



2 Transmitter parameters

All the measurements here reported are performed with the following parameters: Tc = 25 °C, Vdd = 3.0 V, f = 434.030 MHz. They are also measured with the reference design reported in EN 300 220 v1 [2] Annex A.1.

The modulation bandwidth, adjacent channel power, and unwanted emissions in the spurious domain measurements are here reported. The measurements are realized according to EN 300 220 v1 [2] sections 7.6, 7.7 and 7.8.

2.1 Adjacent channel power

The adjacent channel power (ACP) 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. This measurement is applicable only to narrowband systems.

This test measures the power transmitted in the adjacent channel during continuous modulation. The ACP is measured with a spectrum analyzer which conforms to the requirements given in EN 300 220-1 v2.3.1 (2010-02) [2] Annex C.

In this application note, ACP measured with 12.5 kHz and 25 kHz channel spacing are investigated. For these measurements the integrated bandwidths of the adjacent channel are 8.5 kHz and 16 kHz respectively. The ETSI limit for the ACP is 10 µW (-20 dBm) for 12.5 kHz channelization and 200 nW (-37 dBm) for 25 kHz channelization.

Figure 4 and *5* illustrate the measured ACP at the 434.3 MHz center frequency with 12.5 kHz channelization, *Figure 6* illustrates the measured ACP with 25 kHz channelization. The data rate for the modulated signal in *Figure 4* is set to 1.2 Kbps, the frequency deviation is set to 1 kHz, and the modulation is set to 2-FSK. The data rate for the modulated signal in *Figure 5* is set to 2.4 Kbps, the frequency deviation is set to 2.4 kHz, and the modulation is set to Gaussian FSK (GFSK) with BT = 0.5. The data rate for the modulated signal in *Figure 6* is set to 4.8 Kbps, the frequency deviation is set to 2.4 kHz, and the modulation is set to Gaussian FSK (GFSK) with BT = 0.5.

The output power integrated around the carrier is 12 dBm in the bandwidth and with average detection. With this power the ACP is -38 dBm in the first two cases and -43 dBm in the third case. The SPIRIT1 is fully compliant with the ETSI transmitter adjacent channel power requirements with margin.

Figure 4. Adjacent power measurement, 12.5 kHz narrowband channel spacing, 1.2 Kbps data rate, 1 kHz frequency deviation, 2-FSK modulation

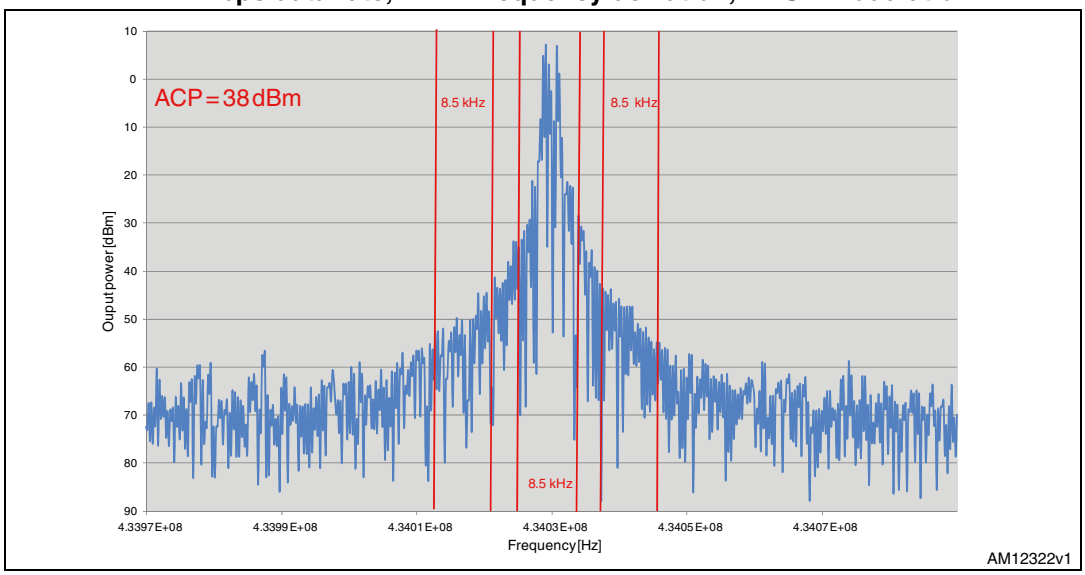


Figure 5. Adjacent power measurement, 12.5 kHz narrowband channel spacing, 2.4 Kbps data rate, 2.4 kHz frequency deviation, GFSK (BT=0.5) modulation

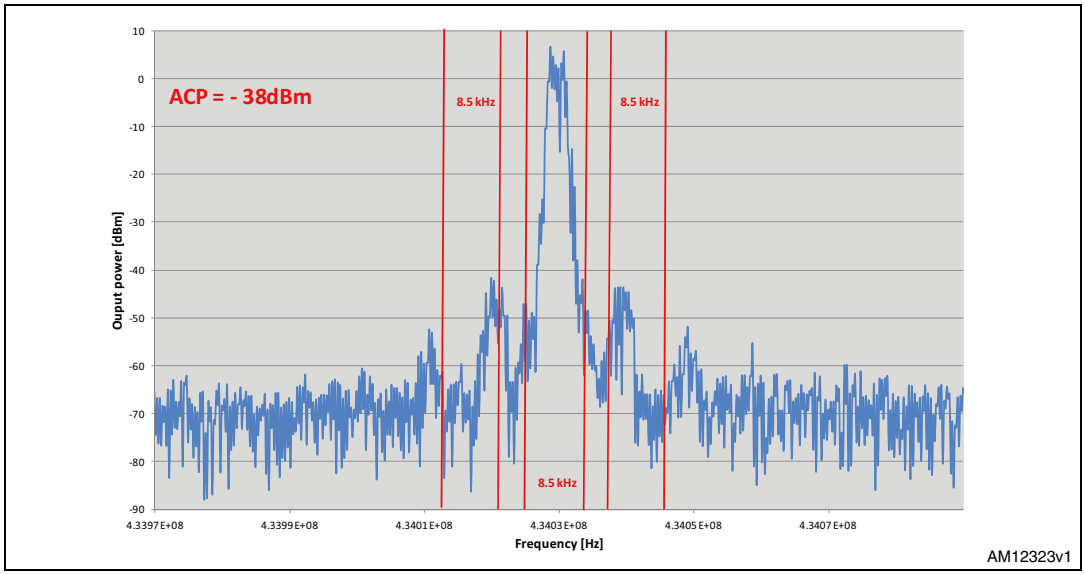
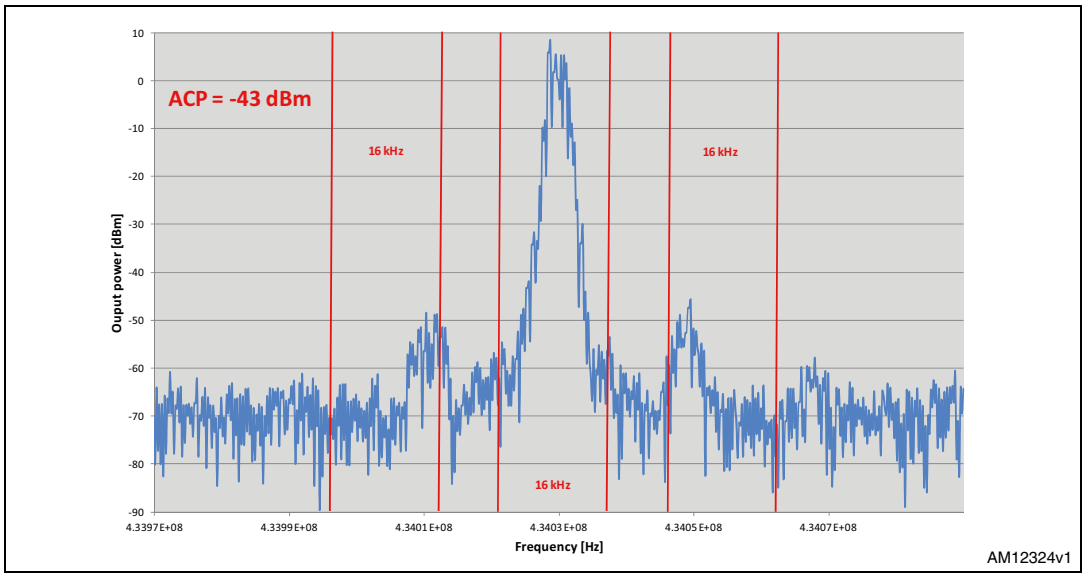


Figure 6. Adjacent power measurement, 25 kHz narrowband channel spacing, 4.8 Kbps data rate, 2.4 kHz frequency deviation, GFSK (BT=0.5) modulation



2.2 Modulation bandwidth

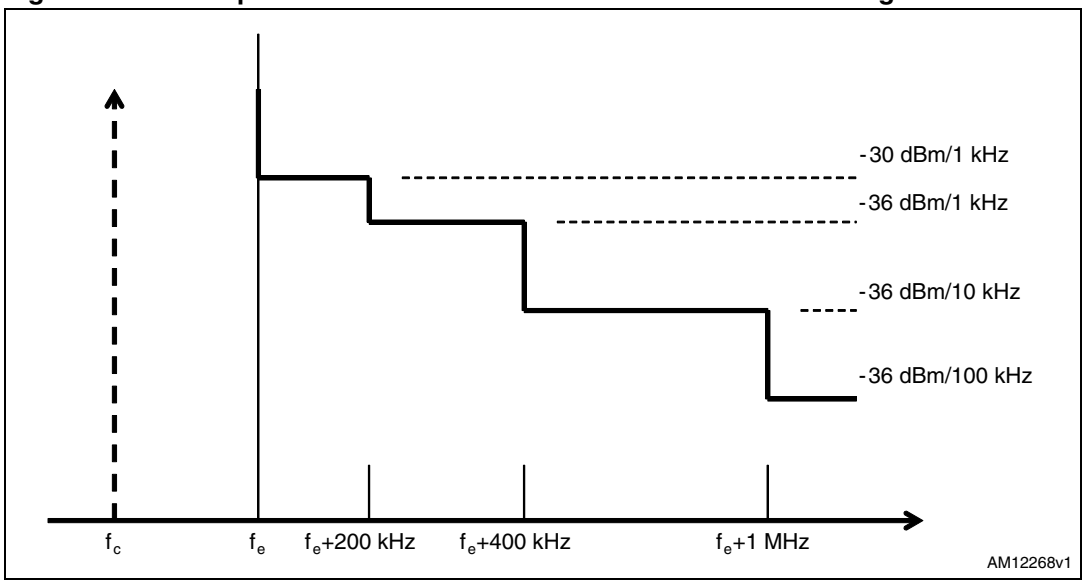
The range of the modulation bandwidth includes all associated side-bands above the appropriate emissions level and the frequency error or drift under extreme test conditions. The frequency drift in extreme test conditions primarily depends on the crystal quality, which is not included in this report.

Figure 7 illustrates the ETSI spectral mask with which the radio must comply at the sub-band edges. Basically, there are only two limit thresholds; what changes is the bandwidth of integration at the different offset regions.

The same spectral masks are reported in *Figure 8*, *9*, *10*, *11* and *12*. In *Figure 8* the data rate is set to 1.2 Kbps, the frequency deviation is set to 1 kHz and the modulation is set to 2-FSK (GFSK). In *Figure 9* the data rate is set to 2.4 Kbps, the frequency deviation is set to 2.4 kHz and the modulation is set to Gaussian FSK (GFSK) with a BT = 0.5. In *Figure 10* the data rate is set to 4.8 Kbps, the frequency deviation is set to 2.4 kHz and the modulation is set to Gaussian FSK (GFSK) with a BT = 0.5. In *Figure 11* the data rate is set to 38.4 Kbps, the frequency deviation is set to 20 kHz and the modulation is set to Gaussian FSK (GFSK) with a BT = 1. In *Figure 12* the data rate is set to 250 Kbps, the frequency deviation is set to 127 kHz and the modulation is set to Gaussian FSK (GFSK) with a BT = 1. The applied output power is set to 11 dBm.

With these parameters, the spectral masks of SPIRIT1 comply with ETSI [*2*] subclause 7.7.

Figure 7. ETSI spectral mask measurement limits and sub-band edges



Note: *f_c is the emission center frequency.*

f_e is the sub-band edge frequency.

Only the upper half of the emission is shown. The lower half is a mirror image.

Figure 8. Spectral mask measurement, 12.5 kHz narrowband channel spacing, 1.2 Kbps data rate, 1 kHz frequency deviation, 2-FSK modulation

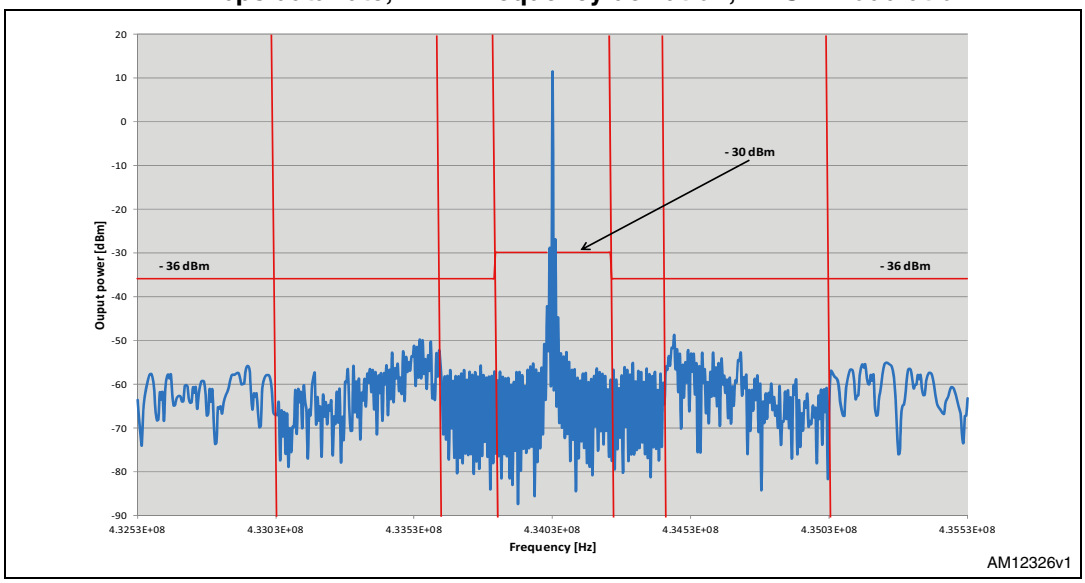


Figure 9. Spectral mask measurement, 12.5 kHz narrowband channel spacing, 2.4 Kbps data rate, 2.4 kHz frequency deviation, GFSK (BT=0.5) modulation

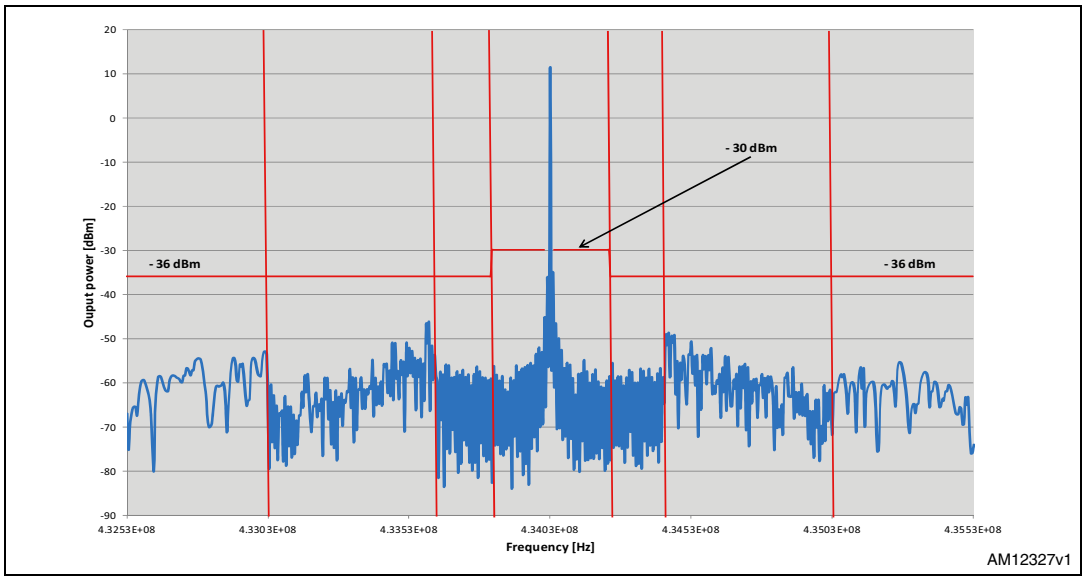


Figure 10. Spectral mask measurement, 25 kHz narrowband channel spacing, 4.8 Kbps data rate, 2.4 kHz frequency deviation, GFSK (BT=0.5) modulation

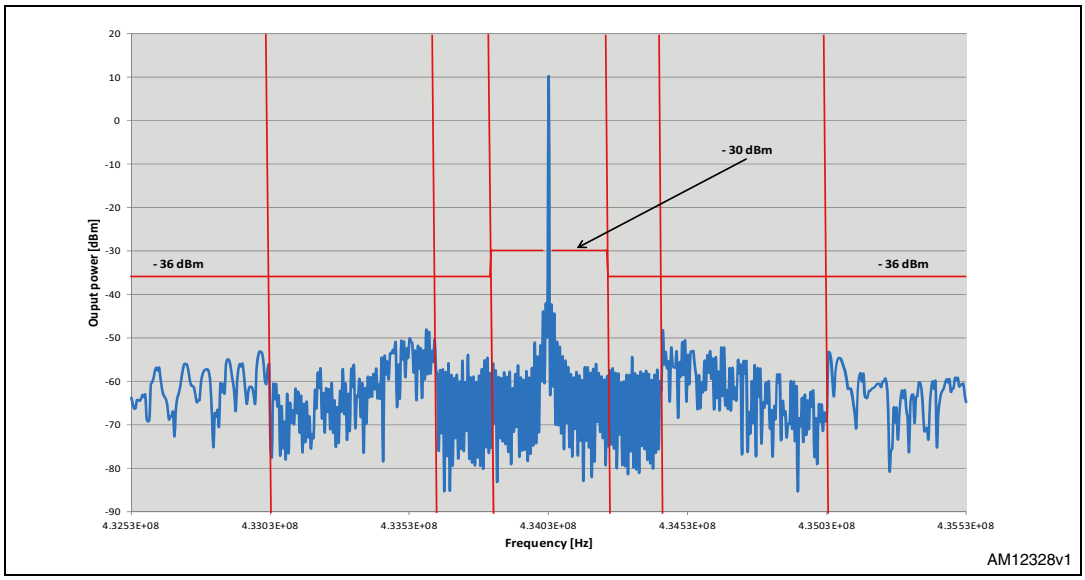


Figure 11. Spectral mask measurement, 100 kHz channel spacing, 38.4 Kbps data rate, 20 kHz frequency deviation, GFSK (BT=1) modulation

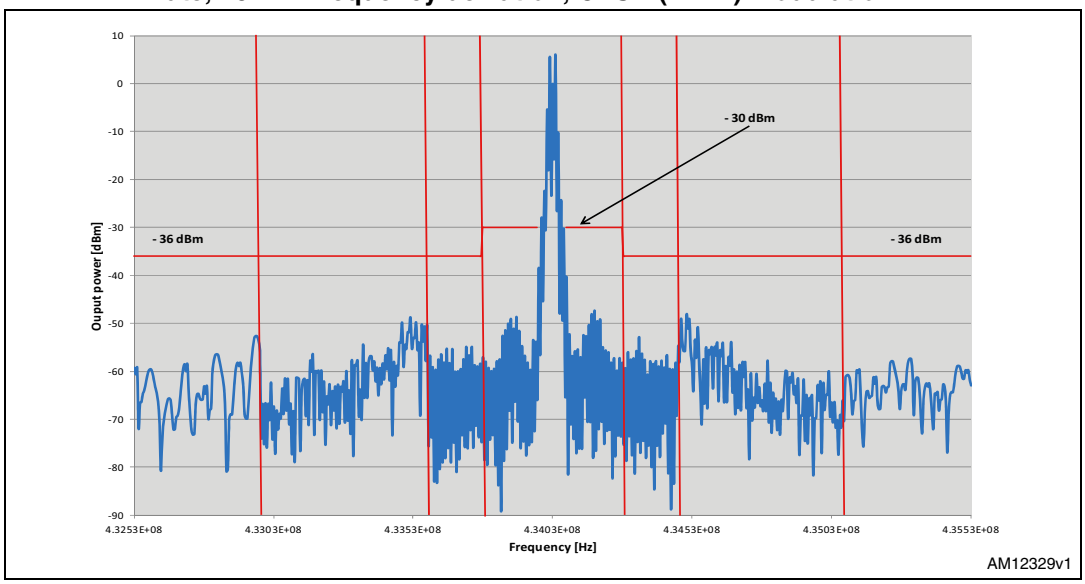
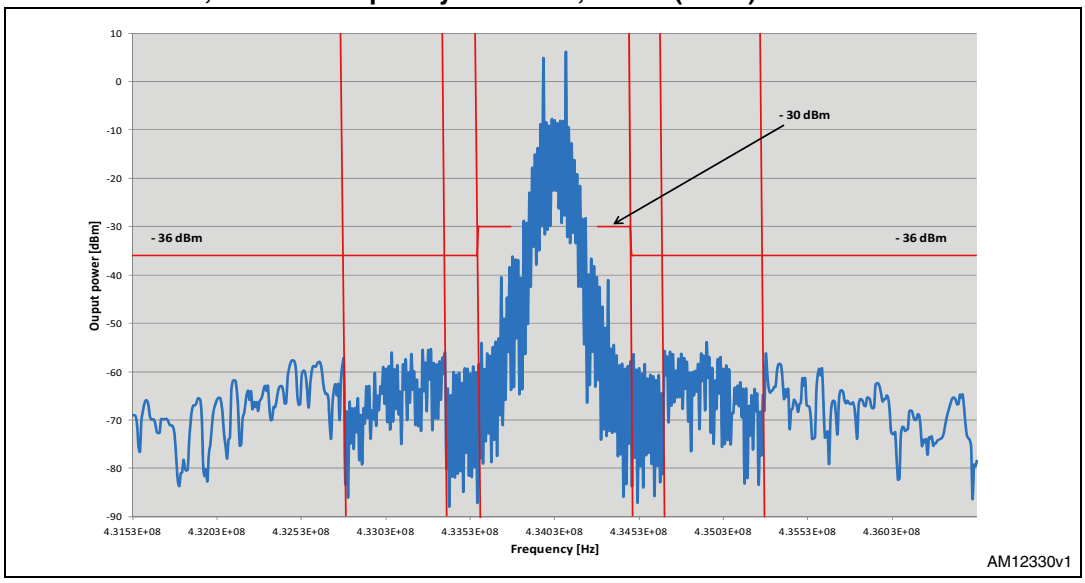


Figure 12. Spectral mask measurement, 500 kHz channel spacing, 250 Kbps data rate, 127 kHz frequency deviation, GFSK (BT=1) modulation



2.3 Unwanted emissions in the spurious domain

Spurious emissions are unwanted emissions in the spurious domain at frequencies other than those of the wanted carrier frequency and its side-bands associated with normal test modulation.

A spectrum analyzer is used as external receiver. The measurement is performed setting the SPIRIT1 with modulation and checking unwanted spurious emissions up to 4 GHz, as described in ETSI [2] subclause 7.8.

The measurement is split into two figures: in *Figure 13* the unwanted spurious emission for a frequency below 1 GHz is shown. The measurement is performed setting the instrument in max. hold with a resolution bandwidth of 100 kHz, as requested in ETSI [2]. In *Figure 14* the unwanted spurious emission for frequencies from 1 GHz to 4 GHz is shown. The measurement is performed setting the instrument in max. hold with a resolution bandwidth of 1 MHz, as requested in ETSI [2]. In the two images the mask request from ETSI is also reported.

The unwanted emissions in the spurious domain of SPIRIT1 comply with ETSI [2] subclause 7.8.

Figure 13. Unwanted emission in the spurious domain mask below 1 GHz

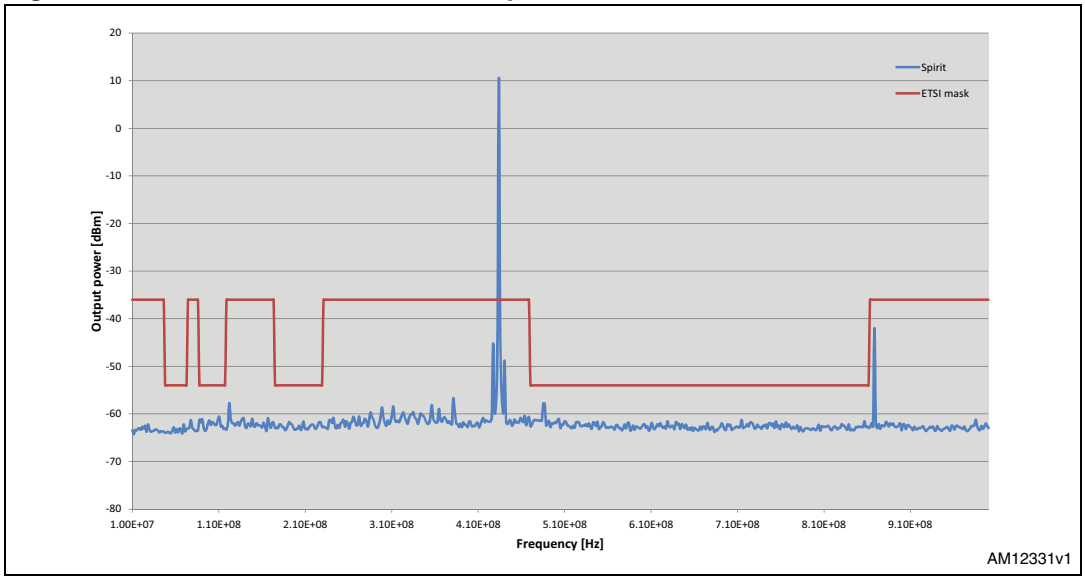
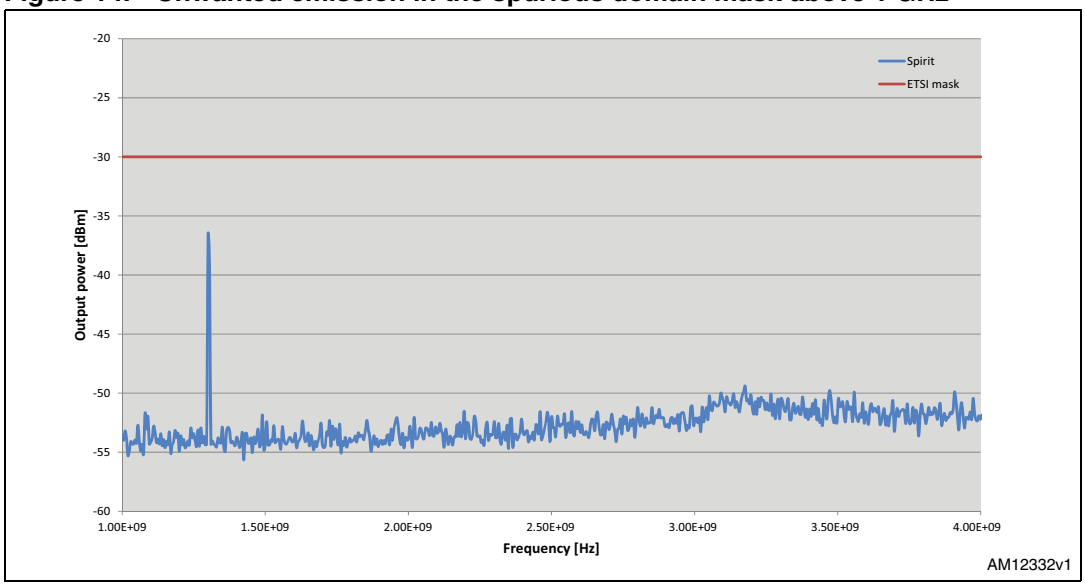


Figure 14. Unwanted emission in the spurious domain mask above 1 GHz



3 Receiver parameters

All the measurements here reported are performed with the following parameters: Tc = 25 °C, Vdd = 3.0 V, f = 434.300 MHz.

The product family of short range radio devices is divided into three receiver categories, each having a set of relevant receiver requirements and minimum performance criteria. The set of receiver requirements depends on the choice of receiver category by the equipment provider. The SPIRIT1 is a transceiver that meets receiver category 2. According to EN 300 220-1 (v2.3.1, 2012-02) [2], a category 2 receiver is described as “Medium reliable SRD communication media, e.g. causing inconvenience to persons, which cannot simply be overcome by other means”.

The main parameters that must be measured for category 2 devices are the sensitivity, the blocking, and the receiver spurious radiation. The adjacent channel selectivity is referred to receiver category 1, so it is not necessary for SPIRIT1 to meet this parameter.

3.1 Receiver sensitivity

The receiver sensitivity is the minimum level of the signal at the receiver input produced by a carrier at the nominal frequency of the receiver, modulated with the normal test signal modulation, which produces the performance of a bit error rate (BER) of 10^{-2} without correction.

Under normal test conditions, the value of the typical usable sensitivity for 25 kHz channel spacing equipment with a 16 kHz bandwidth should not exceed -107 dBm. If the RX bandwidth is not 16 kHz, the sensitivity limit is modified according to the following formula:

Equation 1

$$Sp[dBm] = 10\log\left(\frac{BW[kHz]}{16}\right) - 107$$

The measurement is performed using an RF signal source generator centered at the same receiver frequency with the wanted modulation signal. The demodulated data and clock are taken from the SPIRIT1 receiver and sent to the same generator to perform the BER measurement. The generator signal level is reduced and a BER of 1% is obtained.

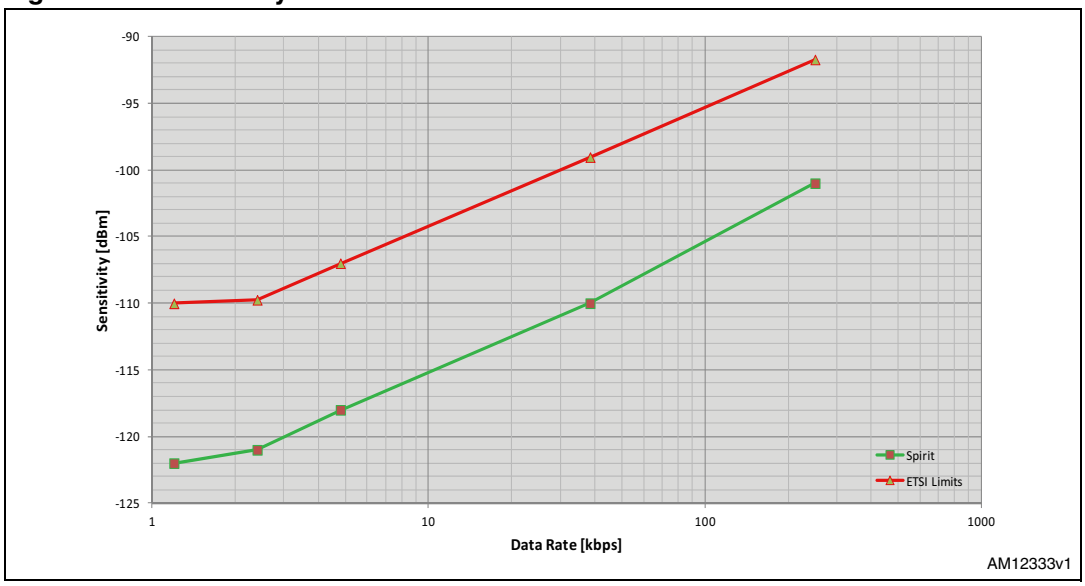
To reduce the power consumption, an internal SMPS is integrated into the SPIRIT1. *Figure 15* demonstrates the ETSI 1% BER sensitivity limit (red line) and the SPIRIT1 sensitivity for different data rates with SMPS. This application note outlines the expected performance when using the SPIRIT1 under EN 300 220-1 (v2.3.1, 2012-02) [2] at 434.3 MHz, without defining the maximum channel spacing. To show the real performance of the SPIRIT1 transceiver, different channel spacings are shown. The test conditions are:

- 2-FSK modulation, 1.2 kHz data rate, 1 kHz frequency deviation, 12.5 kHz channel spacing
- GFSK modulation with BT = 0.5, 2.4 kHz data rate, 2.4 kHz frequency deviation, 12.5 kHz channel spacing
- GFSK modulation with BT = 0.5, 4.8 kHz data rate, 2.4 kHz frequency deviation, 25 kHz channel spacing

- GFSK modulation with BT = 1, 38.4 kHz data rate, 20 kHz frequency deviation, 100 kHz channel spacing
- GFSK modulation with BT = 1, 250 kHz data rate, 127 kHz frequency deviation, 500 kHz channel spacing.

The SPIRIT1 is fully compliant with the ETSI category 2 receiver sensitivity requirements with large margin.

Figure 15. Sensitivity vs. data rate with 1% BER



3.2 Blocking

Blocking is a measurement of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of an unwanted input signal at any frequency other than those of the spurious responses or the adjacent channels or bands.

All the blocking results are measured by positioning the input power 3 dB above the measured sensitivity limit reported in the previous section with a primary signal source generator. A second generator with an unmodulated signal is used as the interferer and combined with the primary signal using a power combiner. The second interferer generator is placed at the desired frequency offset and the power is increased until the BER degradation of 1% is obtained.

ETSI specifies the blocking limits in absolute values at two points: ±2 and ±10 MHz. The limit for the category 2 receiver at ±2 MHz is ≥ 35 dB - 10log(BW_{kHz}/16 kHz), at ±10 MHz it is ≥ 60 dB - 10log(BW_{kHz}/16 kHz). *Figure 16* to *Figure 19* show the blocking curves with, respectively, 12.5 kHz, 25 kHz, 100 kHz, and 500 kHz channel bandwidth.

The SPIRIT1 is fully compliant with the ETSI category 2 receiver blocking requirements with large margin.

Figure 16. RX blocking vs. CW interferer offset with 1% BER, 12.5 kHz channel

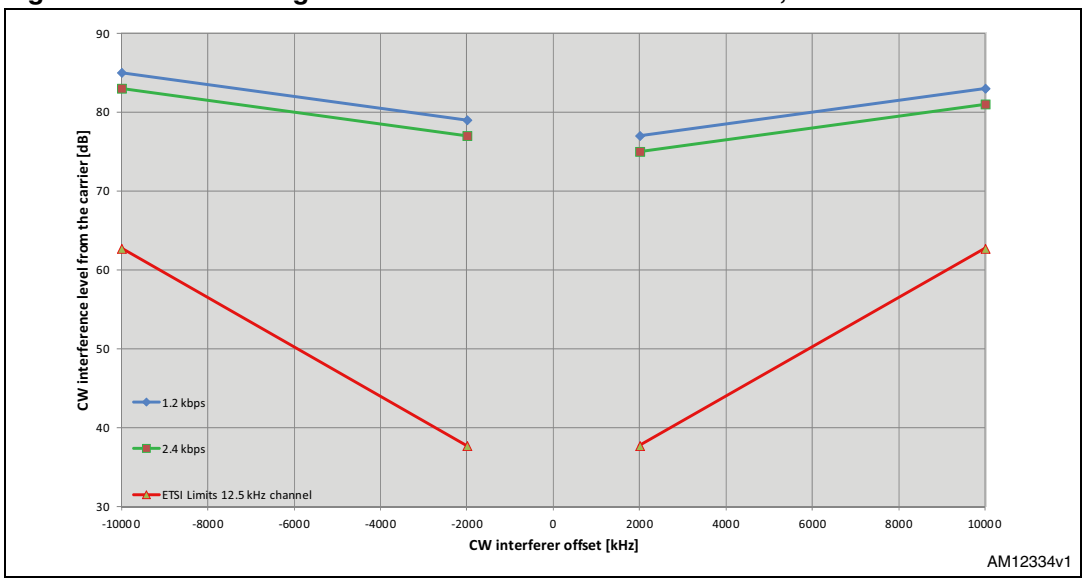


Figure 17. RX blocking vs. CW interferer offset with 1% BER, 25 kHz channel

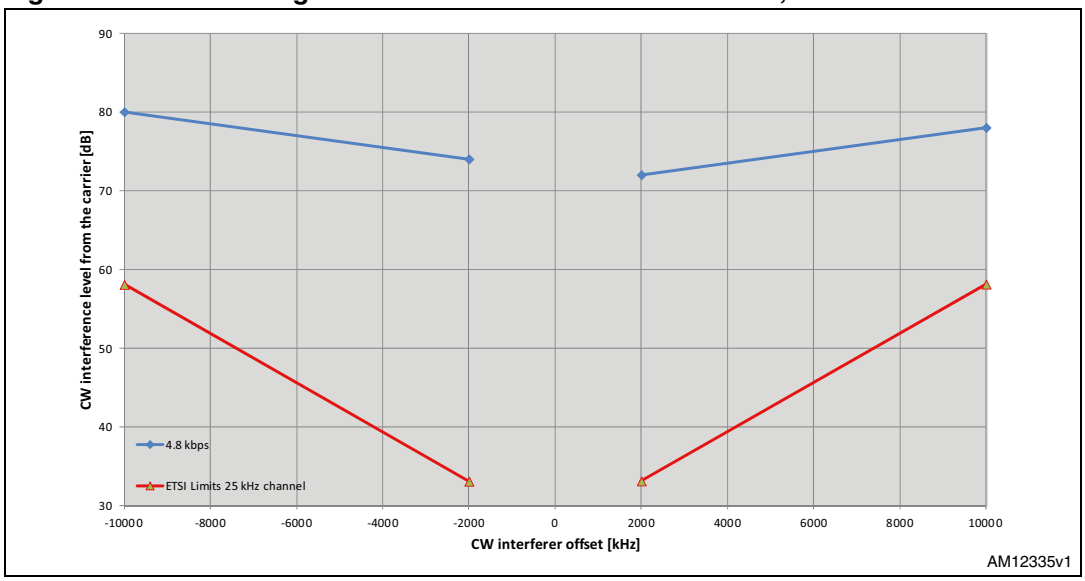


Figure 18. RX blocking vs. CW interferer offset with 1% BER, 100 kHz channel

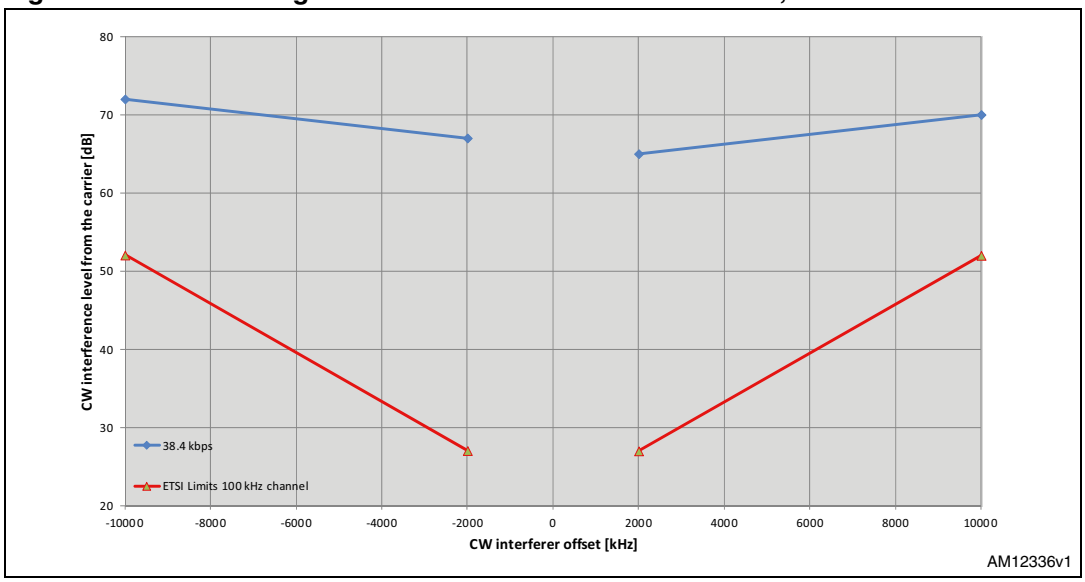
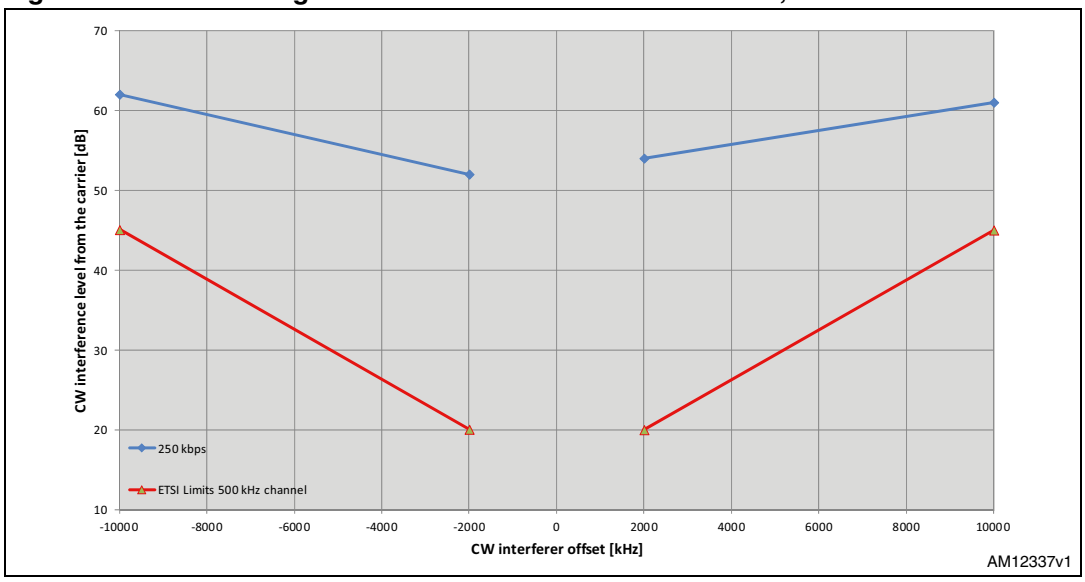


Figure 19. RX blocking vs. CW interferer offset with 1% BER, 500 kHz channel



3.3 Receiver spurious radiation

Spurious radiations from the receiver are components at any frequency, radiated by the equipment.

A spectrum analyzer is used as the external receiver. The measurement is performed setting the SPIRIT1 with modulation and checking receiver spurious emissions up to 4 GHz as described in ETSI [2] subclause 8.6.

The measurement is split into two figures: in *Figure 20* the spurious radiation for frequency below 1 GHz is shown. The measurement is performed setting the instrument in max. hold with a resolution bandwidth of 100 kHz, as requested in ETSI [2]. In *Figure 21* the spurious radiation for frequencies from 1 GHz to 4 GHz is shown. The measurement is performed

setting the instrument in max. hold with a resolution bandwidth of 1 MHz, as requested in ETSI [2]. In the two images the mask request from the ETSI is also reported.

The receiver spurious radiation of SPIRIT1 complies with ETSI [2] subclause 8.6.

Figure 20. RX spurious radiation below 1 GHz

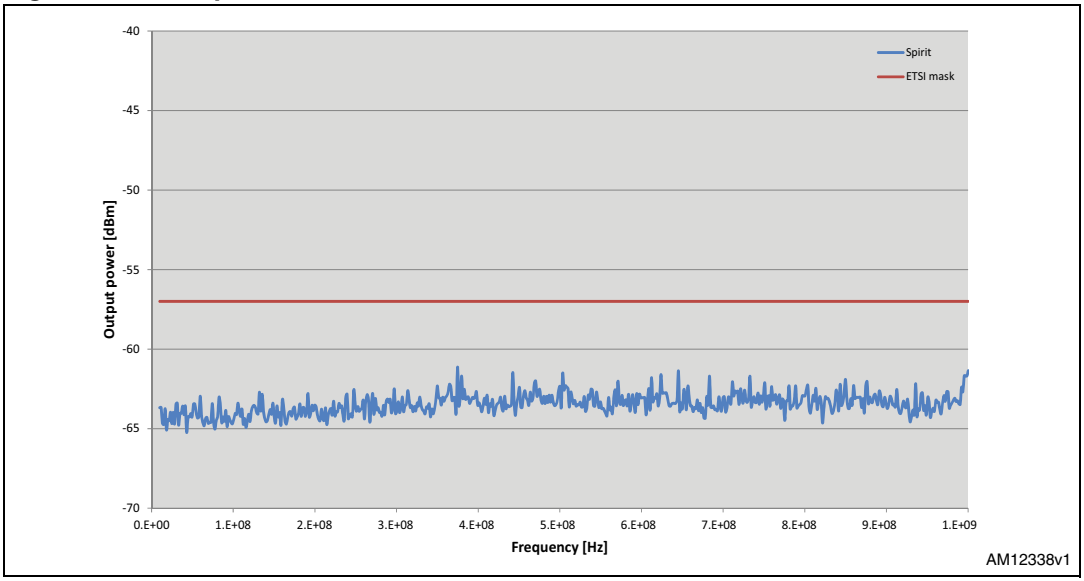
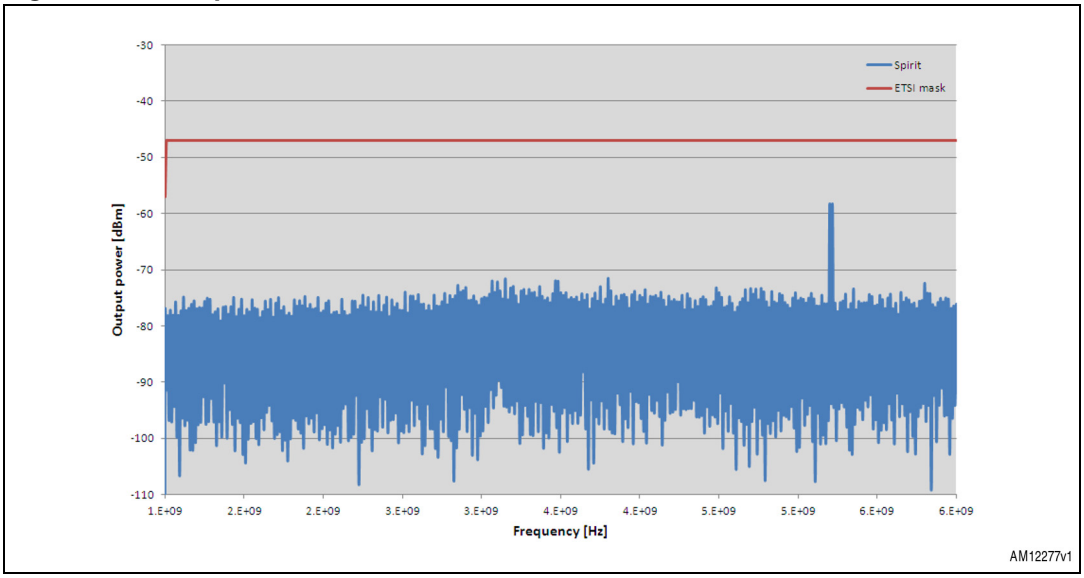


Figure 21. RX spurious radiation above 1 GHz



4 Measurement equipment

The following equipment was used for the measurements.

Table 1. Measurement equipment

Measurement	Instrument type	Instrument model
RX	Signal generator	Agilent ESG E4438C
TX	Signal analyzer	R&S FSIQ7

5 Reference

1. SPIRIT1 datasheet.
2. ETSI EN300 220 V2.3.1: “Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW”.
3. CEPT/ERC/Recommendation 70-03: “Relating to the use of Short Range Devices (SRD)”.
4. CEN/TC prEN 13757-4:2011.10: “Communication systems for meters and remote reading of meters - Part 4: Wireless meter readout (radio meter reading for operating in SRD bands)”.

6 Revision history

Table 2. Document revision history

Date	Revision	Changes
01-Oct-2012	1	Initial release.