



### Using the SPIRIT1 transceiver under EN 300 220 at 169 MHz

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#### 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 and 915 MHz.

This application note outlines the expected performance when using SPIRIT1 under EN 300 220-1 (v2.3.1, 2012-02) [2] in the 169.400 - 169.475 MHz band, meter reading and tracking and tracing applications. The maximum allowed output power in this sub-band is +27 dBm (500 mW), but this application note focuses on applications having output power of +10 dBm (10 mW).

For details on the regulatory limits in the 169.400 - 169.475 MHz SRD frequency bands, please refer to ETSI EN 300 220-1 v2.3.1 [2] and ERC Recommendation 70-03 [3]. These documents can be downloaded from [www.etsi.org](http://www.etsi.org) and [www.ero.dk](http://www.ero.dk).

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# 1 Application circuit

[Figure 1](#) shows the SPIRIT1 application board photo. The application consists of two boards: a daughterboard and a motherboard. The daughterboard holds SPIRIT1 with the circuits necessary for its operation. In order to function correctly, the daughterboard must be plugged into the motherboard (see [Figure 2](#)) using two header 5x2 connectors (J6 and J7).

The motherboard is provided with a 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 SPIRIT1.

The daughterboard is provided with a 25 MHz crystal to provide the correct oscillator to SPIRIT1. The W-MBUS N-mode application, built expressly for the 169 MHz band, needs a frequency tolerance that cannot be achieved with a quartz oscillator. A dedicated W-MBUS application at 169 MHz with a range extender to +27 dBm has been developed and it is described in a dedicated application note for general-purpose applications that work in the 169.400 - 169.475 MHz bandwidth.

SPIRIT1 has an internal SMPS that drastically reduces power consumption, making SPIRIT1 the best-in-class for applications 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 an antenna or to instruments to verify the correct functionality and verify the ETSI standard request.

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

To reduce the application cost SPIRIT1 has been designed to work without an external antenna switch. This daughterboard has been designed to show the SPIRIT1 functionality in this condition. Clearly, an application with an antenna switch can exist, but this case is not described in this document.

Figure 1. SPIRIT1 application daughterboard

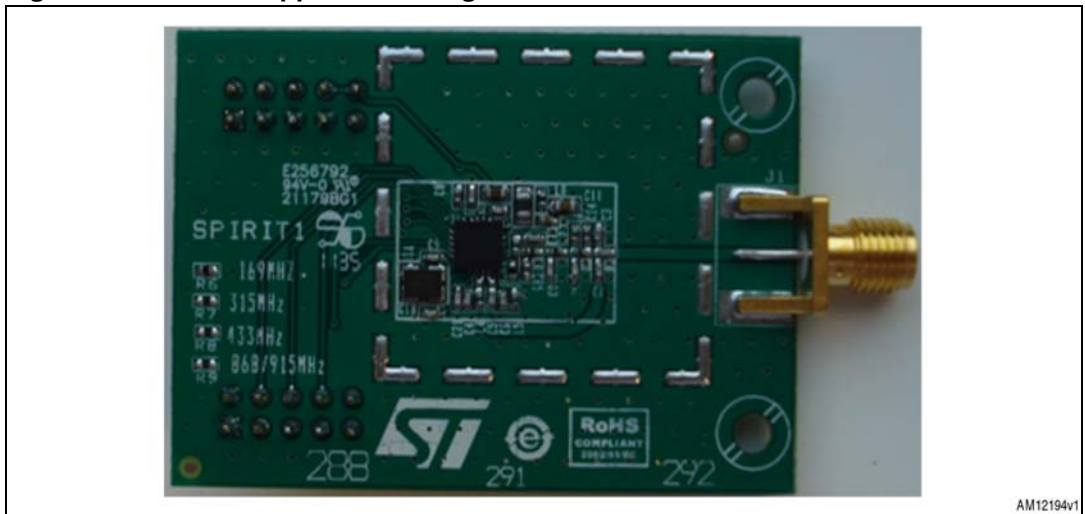
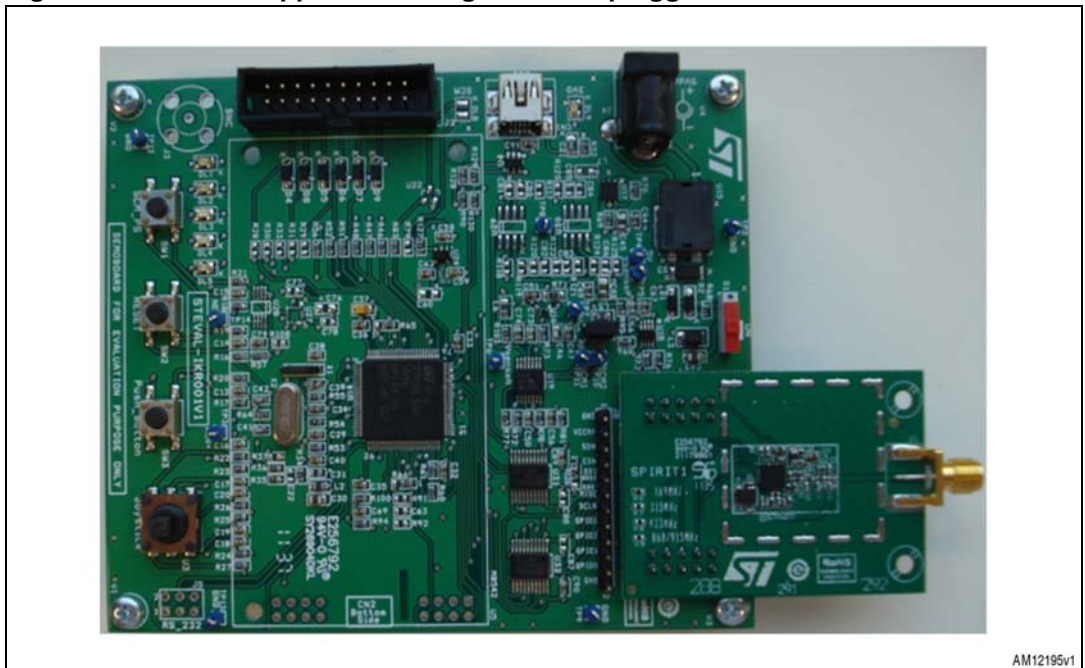
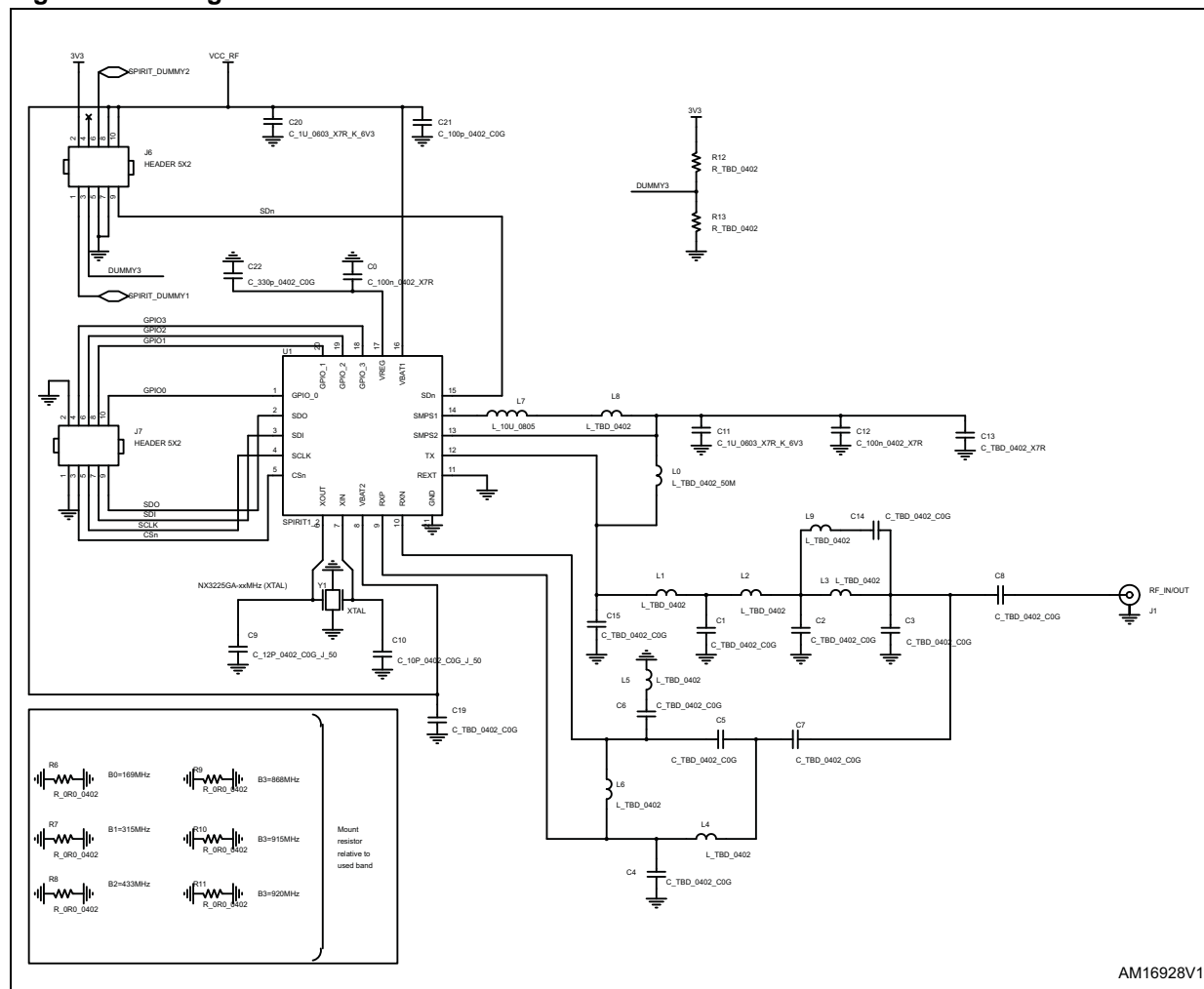


Figure 2. SPIRIT1 application daughterboard plugged into the motherboard



**Figure 3. Daughterboard schematic**



## 2 Transmitter parameters

All the measurements given in the following sections have been measured under these conditions:  $T_c = 25\text{ }^{\circ}\text{C}$ ,  $V_{DD} = 3.0\text{ V}$ ,  $f = 169.400\text{ MHz}$ .

The measurements concerning adjacent channel power, modulation bandwidth and unwanted emissions in the spurious domain are given in the following sections. These measurements have been taken according to EN 300 220 v1 [2] paragraphs 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. These measurements are applicable to narrowband systems (eg. applications or equipment) used in a non-channelized continuous frequency band with a channel bandwidth less than or equal to 25 kHz, or systems used in a channelized frequency band with a channel spacing less than or equal to 25 kHz.

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.

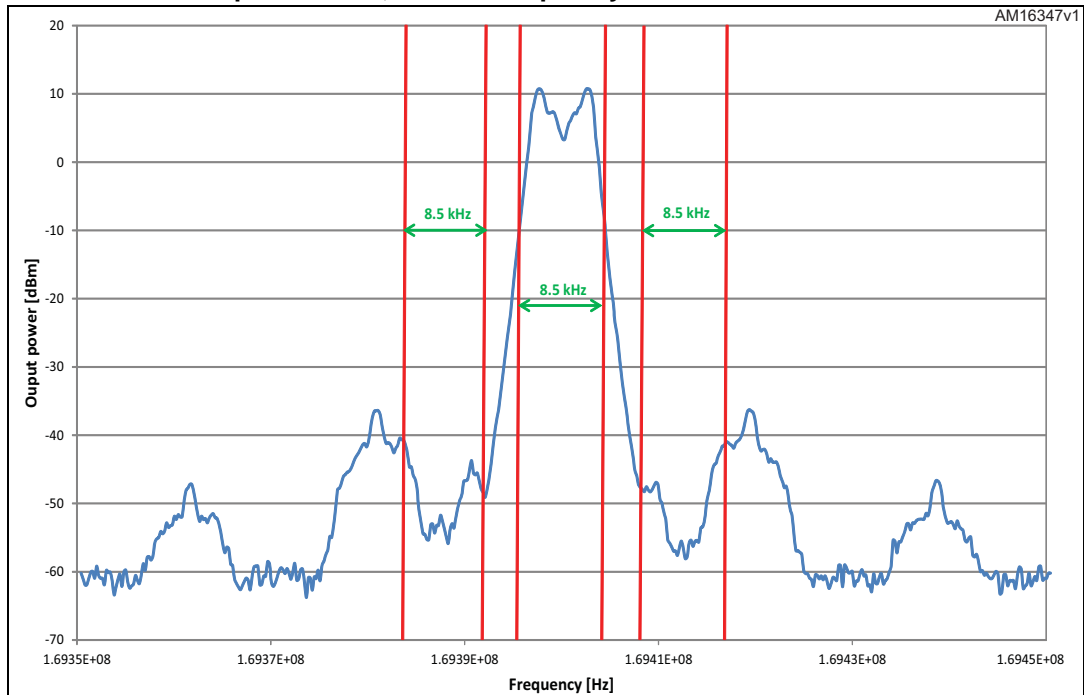
In this application note the ACP measured with 12.5 kHz channel spacing is investigated. For this measurement the integrated bandwidth of the adjacent channel is 8.5 kHz and the ETSI limit for the ACP is 10  $\mu\text{W}$  (-20 dBm).

*Figure 4* and *Figure 5* illustrate the measured ACP at the center frequency of 169.4 MHz. The data rate is set to 2.4 kbps, the frequency deviation is set to 2.4 kHz, the modulation is set to Gaussian FSK (GFSK) with a BT = 0.5 in *Figure 4*. The data rate is set to 4.8 kbps, the frequency deviation is set to 1.2 kHz, the modulation is set to Gaussian FSK (GFSK) with a BT = 0.5 in *Figure 5*. These modulation settings are extracted from the CEN/TC 294 prEN 13757-4:2011.10 draft version, "communication systems for meters and remote reading of meters - Part 4: wireless meter readout (radio meter reading for operation in SRD bands) [4]. This document describes the characteristics of the W-MBUS mode-N standard for radio metering.

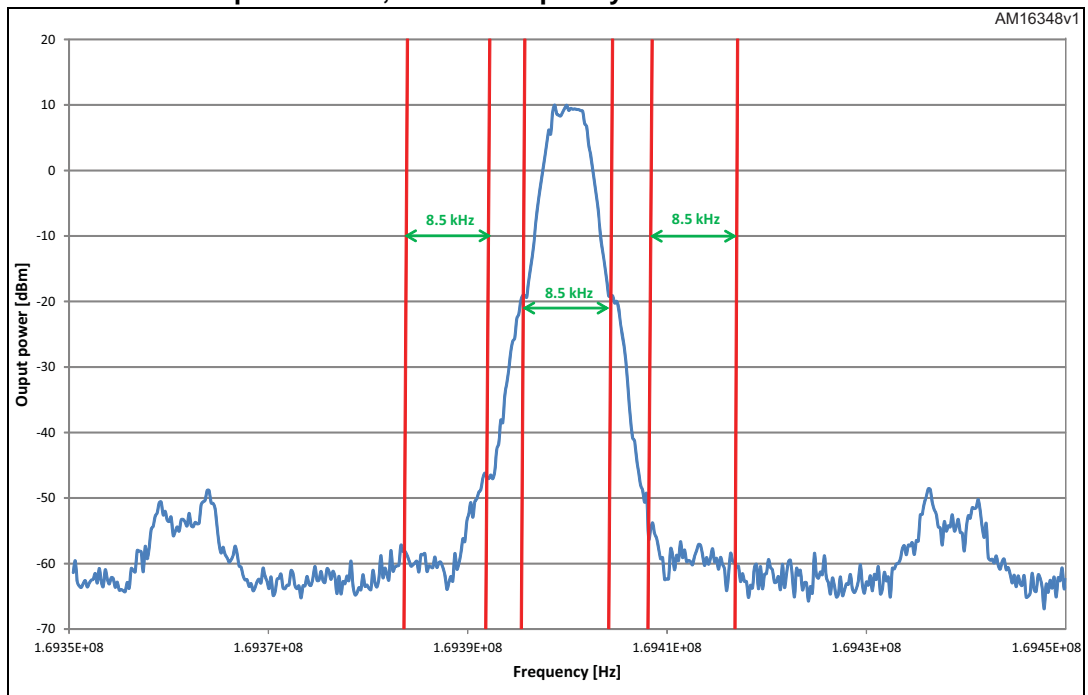
The output power integrated around the carrier is 11 dBm in the 8.5 kHz bandwidth and with average detection. With this power the ACP is -39 dBm in the first case and -45 dBm in the second case. The two measured values are well below the ETSI limit of -20 dBm.

SPIRIT1 is fully compliant with the ETSI transmitter adjacent channel power requirements by a large margin.

**Figure 4. Adjacent power measurement, 12.5 kHz narrowband channel spacing, 2.4 kbps data rate, 2.4 kHz frequency deviation**



**Figure 5. Adjacent power measurement, 12.5 kHz narrowband channel spacing, 4.8 kbps data rate, 1.2 kHz frequency deviation**



## 2.2 Modulation bandwidth

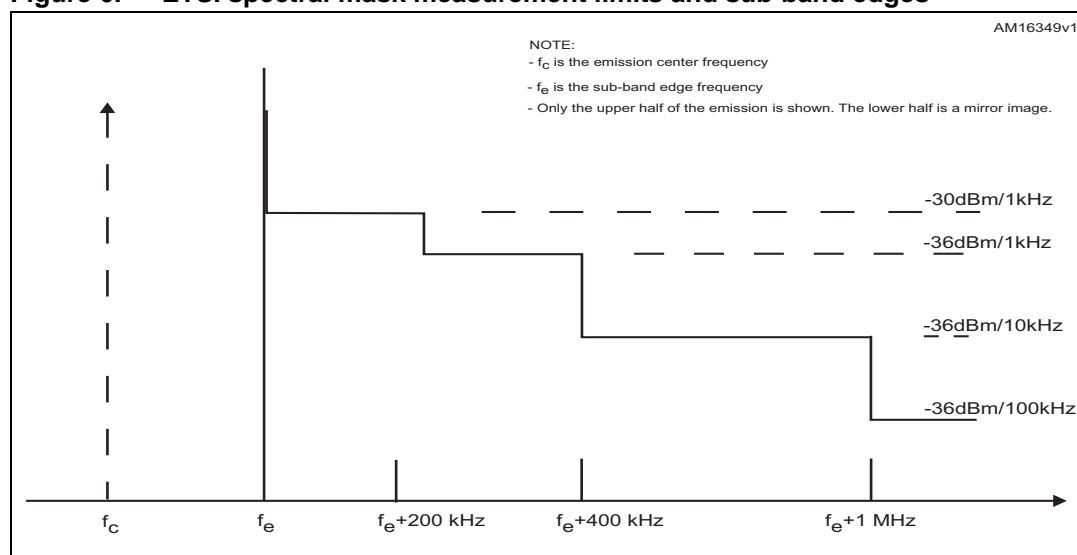
The range of the modulation bandwidth includes all associated side bands above the appropriate emissions level and the frequency error or drift under extreme test conditions. The frequency drift in extreme test conditions primarily depends on the crystal quality, which is not included in this report.

This measurement applies to equipment not covered by adjacent channel power measurement for the narrowband systems. In the 169.400 MHz to 169.475 MHz band it is possible to work with a band  $\leq 50$  kHz (the narrowband system has a band  $\leq 25$  kHz), so standard conformity with a bandwidth  $\geq 25$  kHz is necessary.

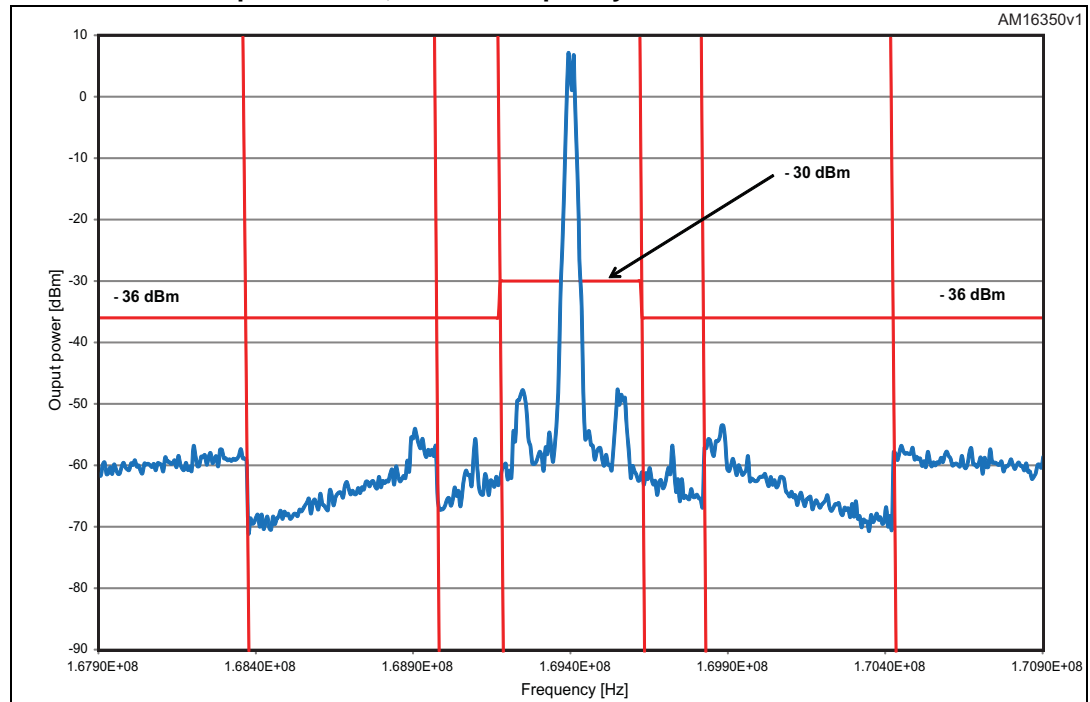
Figure 6 illustrates the ETSI spectral mask with which the radio must comply at the sub-band edges. Basically, there are only two limit thresholds, what changes is the bandwidth of integration at the different offset regions.

The same spectral mask is shown in Figure 7 as well. The device center frequency is 169.4 MHz, the data rate is set to 20 kbps, the frequency deviation is set to 10 kHz, the modulation is set to Gaussian FSK (GFSK) with a BT = 0.5. The applied output power is set to 11 dBm. With these parameters, the spectral mask of SPIRIT1 complies with ETSI [2] subclause 7.7.

**Figure 6. ETSI spectral mask measurement limits and sub-band edges**



**Figure 7. Spectral mask measurement, 12.5 kHz narrowband channel spacing, 4.8 kbps data rate, 1.2 kHz frequency deviation**



## 2.3 Unwanted emissions in the spurious domain

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

A spectrum analyzer is used as an external receiver. The measurement is performed setting SPIRIT1 without modulation and observing until 4 GHz as described in the ETSI [2] subclause 7.8.

The measurement is split between two figures, showing the frequency ranges above and below 1 GHz. In [Figure 8](#) the unwanted spurious emission for frequencies below 1 GHz is shown. This measurement is performed by setting the instrument with a resolution bandwidth of 100 kHz, as requested in ETSI [2]. In [Figure 9](#) the unwanted spurious emission for frequencies from 1 GHz to 4 GHz is shown. This measurement is performed by setting the instrument with a resolution bandwidth of 1 MHz, as requested in ETSI [2]. In the two figures the mask request from ETSI is also shown. Also, for the narrowband equipment, the unwanted emission in the spurious domain test has to be done at all frequencies except the channel on which the transmitter is intended to operate and its adjacent and alternate channels. A zoom of the zone near the carrier is taken in [Figure 10](#), [Figure 11](#) and [Figure 12](#) just to show that the ETSI specification is also met near the carrier.

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

Figure 8. Unwanted spurious emission below 1 GHz

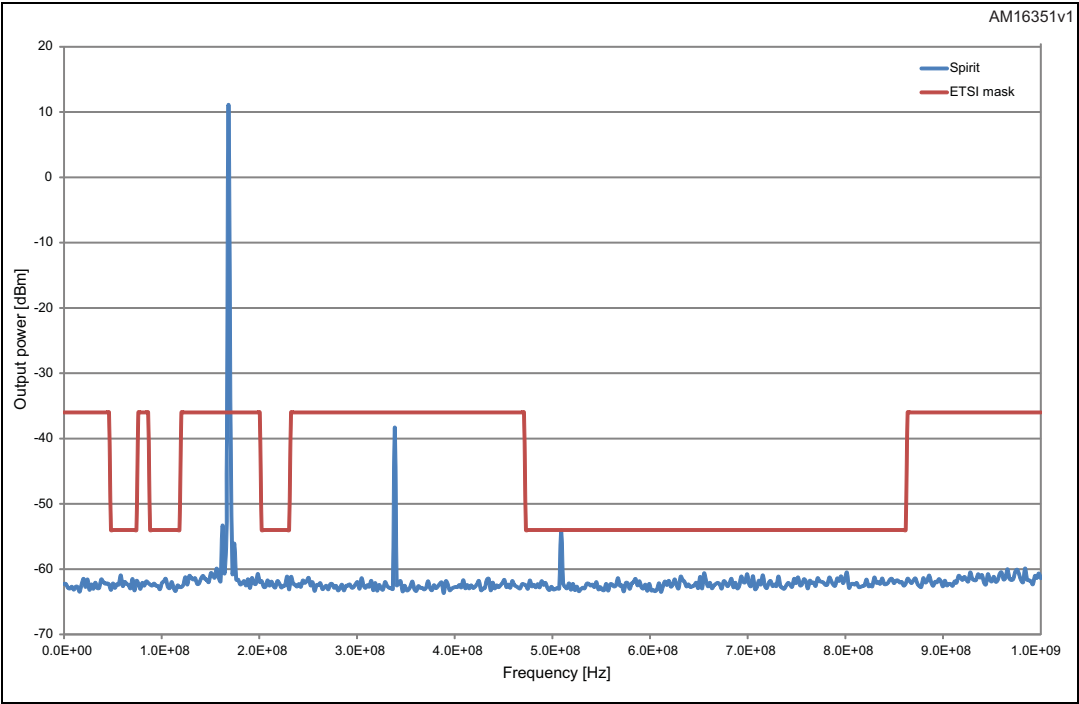


Figure 9. Unwanted spurious emission above 1 GHz

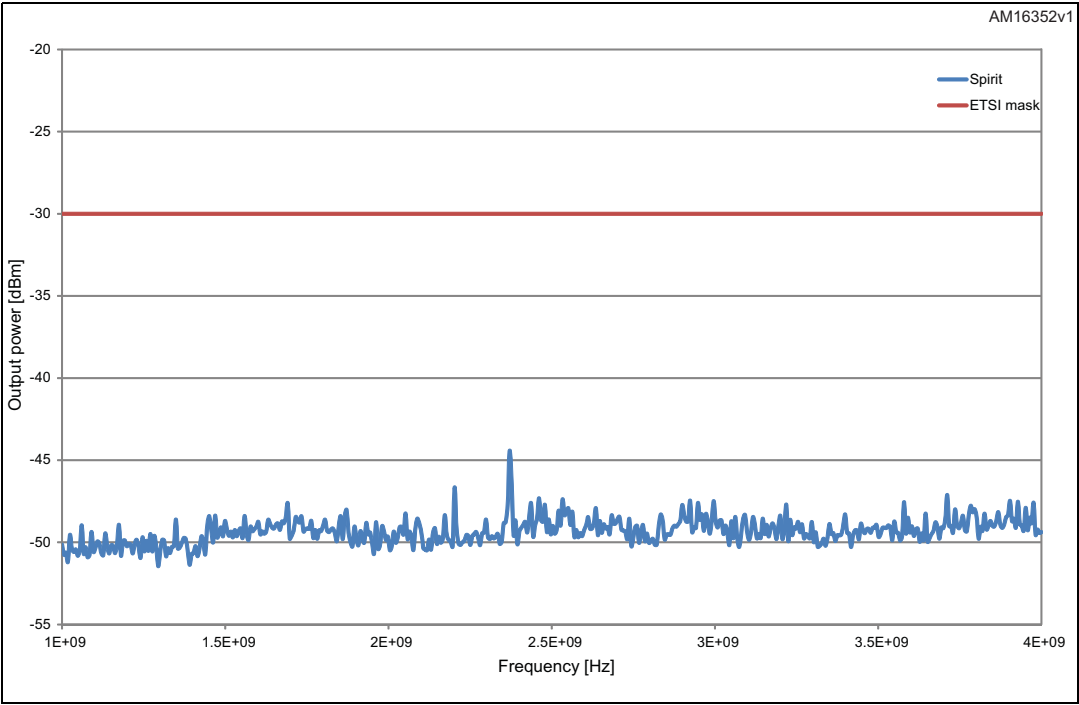


Figure 10. Unwanted spurious emission in 10 MHz band

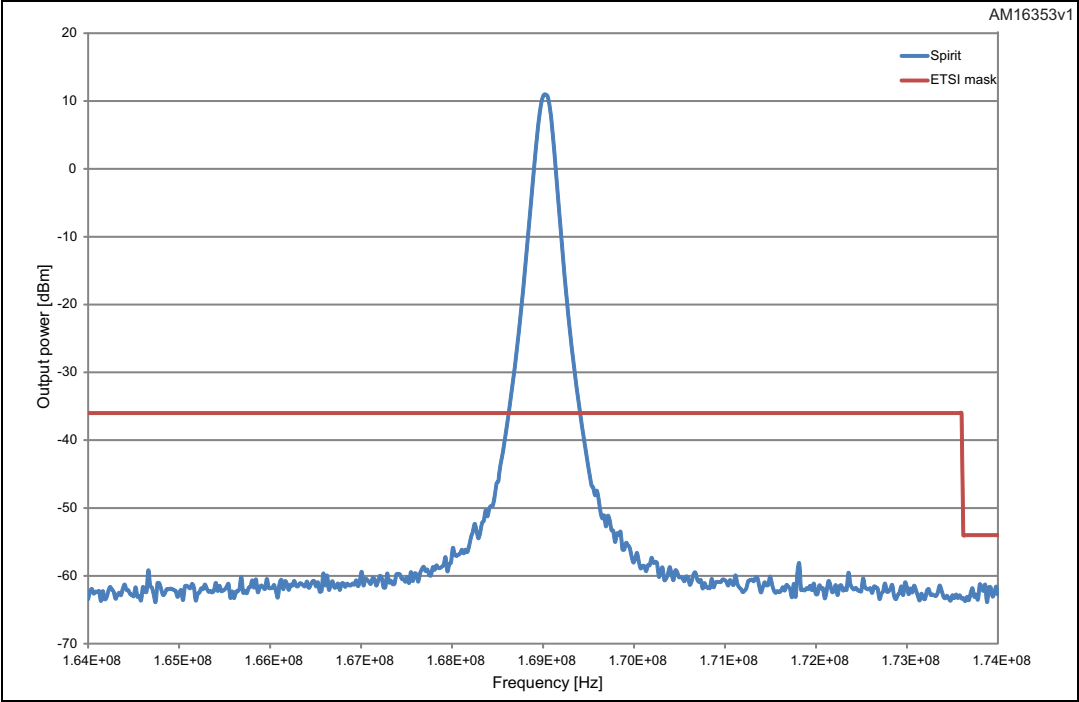


Figure 11. Unwanted spurious emission in 500 kHz band

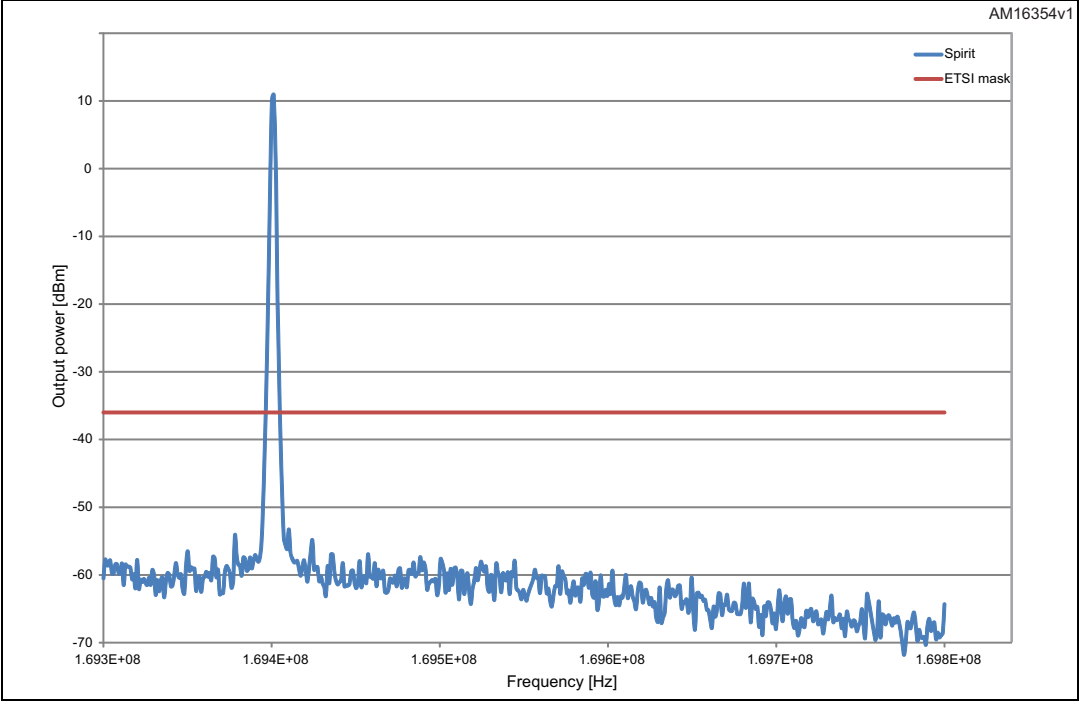
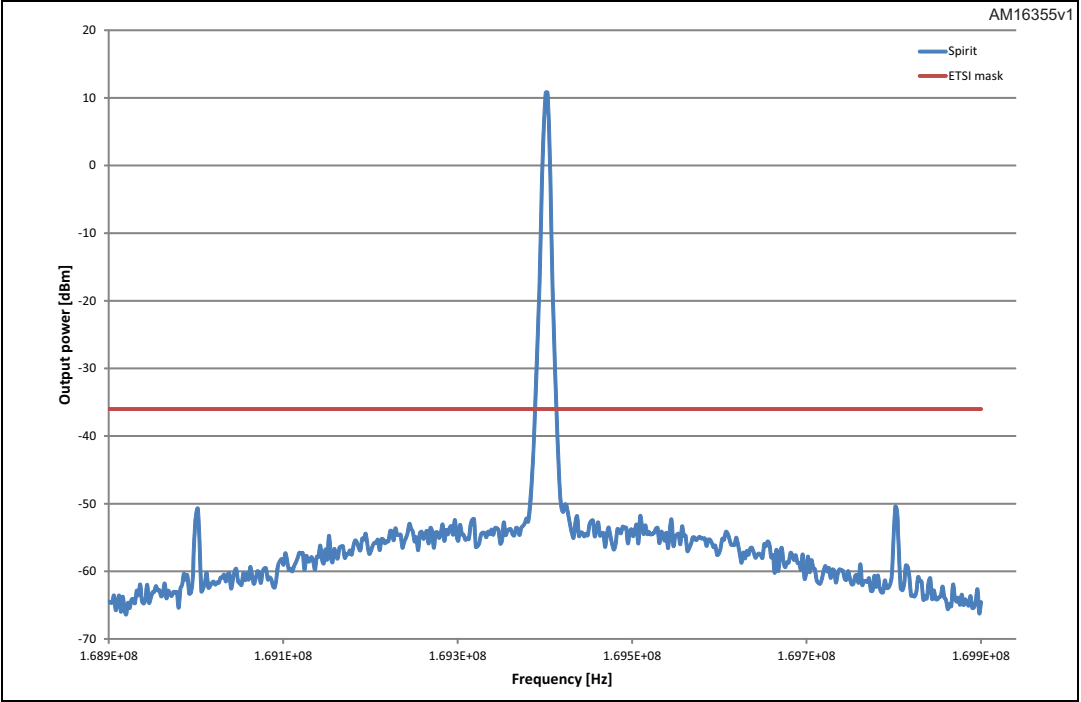


Figure 12. Unwanted spurious emission in 1 MHz band



### 3 Receiver parameters

All the measurements given in the following sections have been measured under these conditions:  $T_c = 25\text{ }^{\circ}\text{C}$ ,  $V_{DD} = 3.0\text{ V}$ ,  $f = 169.400\text{ MHz}$ .

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 the receiver category by the equipment provider. SPIRIT1 is a transceiver meeting the requirements of receiver category 2. This category is defined as medium reliable SRD communication media that can cause inconvenience to persons, which cannot simply be overcome by other means.

The main parameters that have to be measured for the category 2 devices are the sensitivity, the blocking and the receiver spurious radiation. The adjacent channel selectivity, receiver saturation at adjacent channel and spurious response rejection measurements fall within the receiver category 1, so SPIRIT1 does not have to meet these requirements.

#### 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 maximum usable sensitivity for 25 kHz channel spacing equipment with a 16 kHz bandwidth shall not exceed -107 dBm. If the RX bandwidth is not 16 kHz, the sensitivity limit is modified according to the following formula:

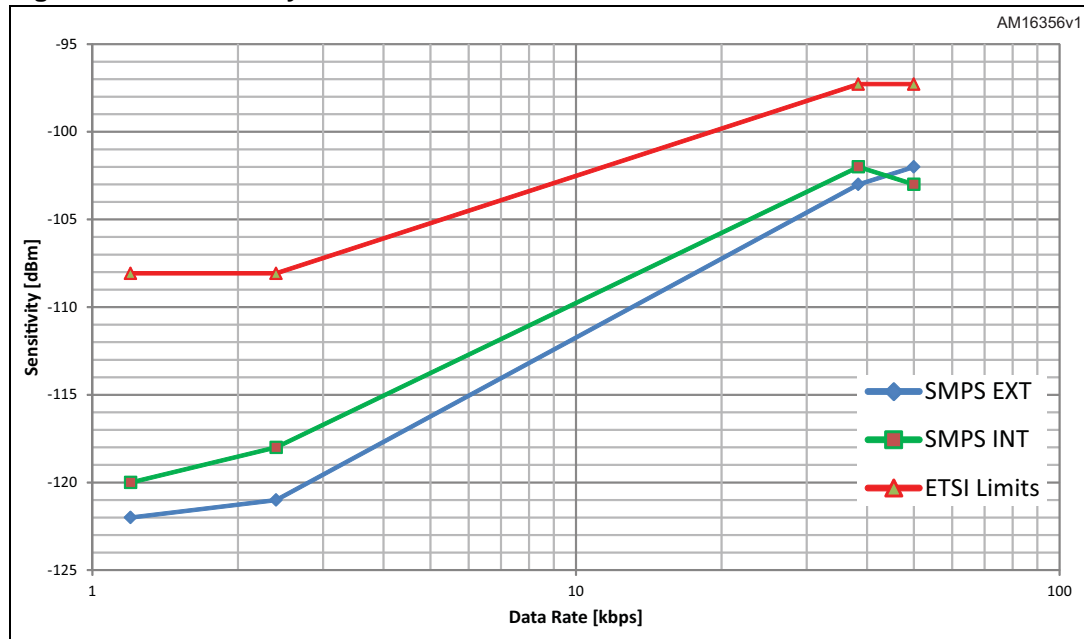
##### Equation 1

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

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

To reduce the power consumption an internal SMPS is integrated in SPIRIT1. [Figure 13](#) demonstrates the ETSI 1% BER sensitivity limit (red line) and the SPIRIT1 sensitivity for different data rates with internal and external SMPS. This application note outlines the expected performance when using SPIRIT1 under EN 300 220-1 (v2.3.1, 2012-02) [\[2\]](#) in the 169.400 - 169.475 MHz band, with the maximum channel spacing  $\leq 50\text{ kHz}$ . Just to show the real performance of the SPIRIT1 transceiver, a data rate greater than 50 kbps is shown.

The SPIRIT1 is fully compliant with the ETSI class 2 receiver sensitivity requirements by a large margin.

**Figure 13. Sensitivity vs. data rate with 1 % BER**

## 3.2 Blocking

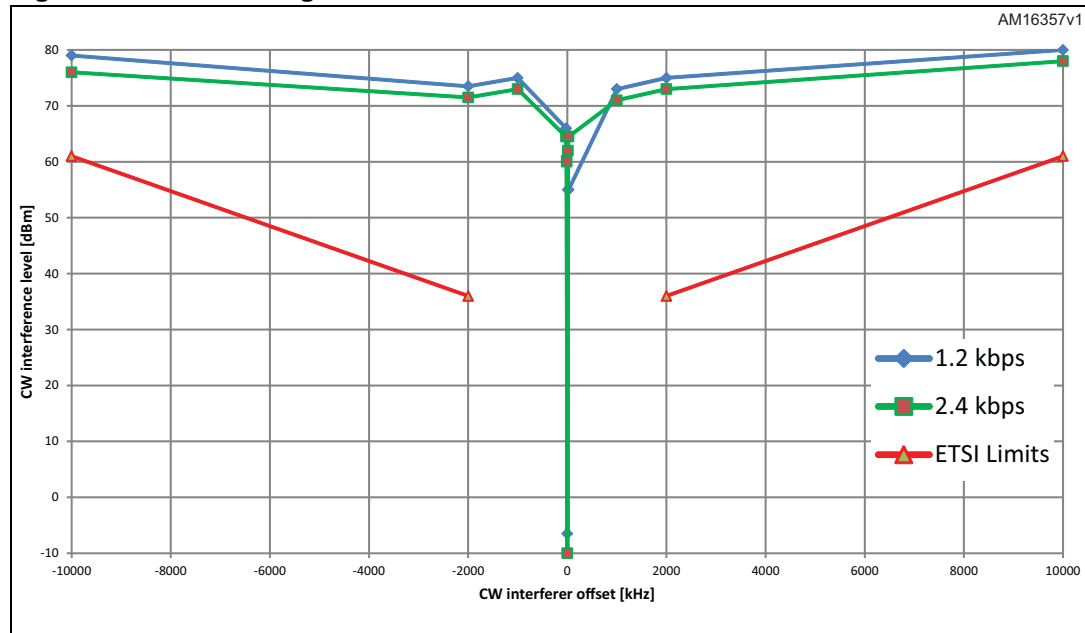
Blocking is a measure of the capability of the receiver to receive a desired modulated signal without exceeding a given degradation due to the presence of an unwanted input signal at any frequency other than those of the spurious responses or the adjacent channels or bands.

All the blocking results are measured by positioning the input power 3 dB above the measured sensitivity limit given in the previous paragraph with a primary signal source generator. A second generator with an unmodulated signal is used as the interferer, 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 value at two points:  $\pm 2$  MHz and  $\pm 10$  MHz. The limit for class 2 receiver at  $\pm 2$  MHz is 36 dB, and at  $\pm 10$  MHz it is 61 dB.

SPIRIT1 is fully compliant with the ETSI class 2 receiver blocking requirements by a large margin.

In the ETSI EN300 220 [2] standard the adjacent channel selectivity is defined as well as the measure of the capability of the receiver to operate satisfactorily in the presence of an unwanted signal, which differs in frequency from the desired signal by an amount equal to the adjacent channel separation for which the equipment is intended. This parameter has to be evaluated only for devices that comply with the ETSI class 1 which is not the case for SPIRIT1.

**Figure 14. RX blocking vs. CW interferer offset with 1 % BER**

### 3.3 Receiver spurious radiation

Spurious radiation from the receiver come from components at any frequency, radiated by the equipment and antenna.

A spectrum analyzer is used as the external receiver. The measurement is performed setting SPIRIT1 without modulation and observing until 4 GHz as described in ETSI [2] subclause 8.6.

The measurement is split between two figures, showing the frequency ranges above and below 1 GHz. [Figure 15](#) indicates the unwanted spurious emission for frequencies below 1 GHz. This measurement is performed by setting the instrument with a resolution bandwidth of 100 kHz, as requested in ETSI [2]. In [Figure 16](#) the spurious radiation from the receiver for frequencies from 1 GHz to 4 GHz is shown. This measurement is performed by setting the instrument with a resolution bandwidth of 1 MHz, as requested in ETSI [2]. In the two figures the mask request from ETSI is also indicated.

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

Figure 15. Receiver spurious radiation below 1 GHz

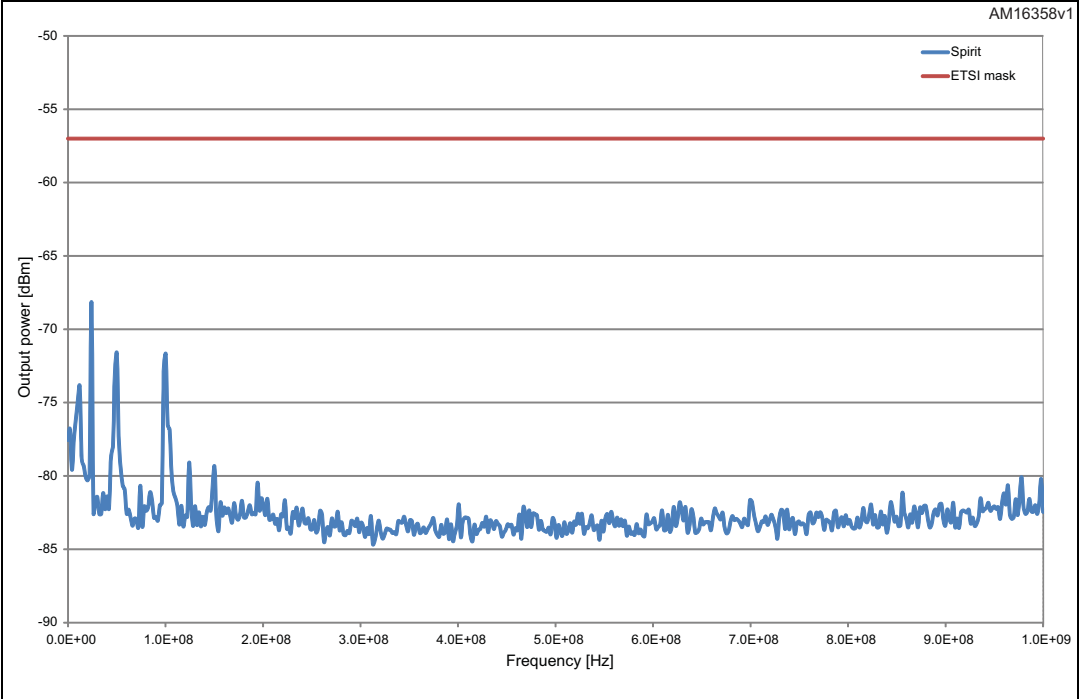
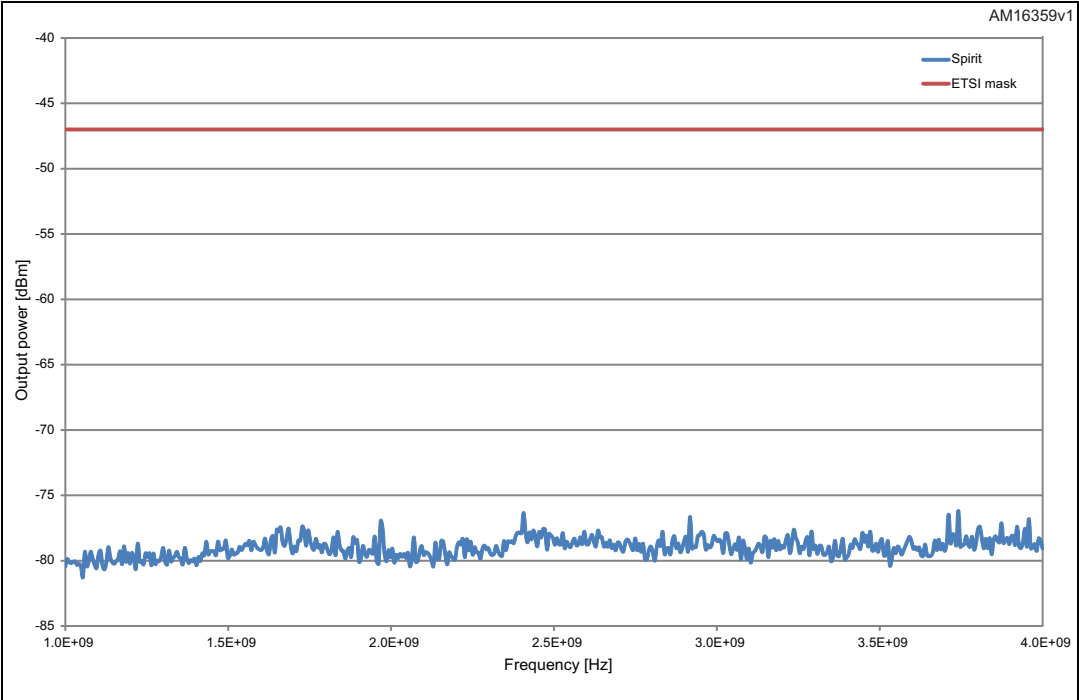


Figure 16. Receiver spurious radiation above 1 GHz



## 4 Measurement equipment

The following equipment was used for the measurements.

**Table 1. Instruments**

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

## 5 References

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
14-May-2013	1	Initial release.

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