AN4305
Application note

Using the SPIRIT1 transceiver with range extender under EN 300 220 at 169 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 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 the SPIRIT1 with a range extender under EN 300 220-1 (v2.3.1, 2012-02) [*2.*] in the 169.400 - 169.475 MHz band, meter reading, tracking and tracing applications. The maximum allowed output power in this sub-band is +27 dBm (500 mW), this application note relates to an application designed to reach the maximum permitted power, while respecting ETSI requirements.

This application note also relates to CEN/TC 294 prEN 13757-4:2011.10 [*4.*] requirements for the W-MBUS N-mode standard in the 169.400 - 169.475 MHz band.

For details on the regulatory limits in the 169.400 - 169.475 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.

Contents

1 Application circuit

Figure 1 shows the SPIRIT1 with range extender application board photo. The application is made up of 2 boards: a daughterboard and a motherboard. The daughterboard holds the SPIRIT1 with the circuits necessary for its function. For correct operation, the daughterboard must be plugged into the motherboard (see *Figure 2*) by two header 5x2 connectors (J6 and J7).

The motherboard is equipped 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 for programming of the SPIRIT1.

The daughterboard includes a 25 MHz TCXO to provide the correct oscillator to the SPIRIT1. The W-MBUS N-mode application, expressly tailored for the 169 MHz band, requires a frequency tolerance that cannot be achieved with a crystal oscillator, so this application board is designed with an external TCXO. Due to the TCXO power consumption, its power on/off is controlled by a GPIO of the STM32L152VBT6 microcontroller to power on only in the Ready, TX and RX SPIRIT1 states.

The SPIRIT1 has an internal SMPS that drastically reduce the power consumption making the SPIRIT1 the best in class for the application on this bandwidth. The SMPS is fed from the battery (1.8 V to 3.6 V) and provide to the device a programmable voltage (1.4 V usually).

A few passive devices (inductors and capacitors) are used as matching/filtering for the SPIRIT1 power amplifier (PA) and balun network for the receiver.

A SAW filter is recommended to attenuate the spurious and harmonics emissions above the carrier frequency, which would otherwise violate spurious emissions limits under ETSI 300 220 [*2.*]. The SAW filter used is a Tai-Saw Technology CO., LTD. TA0437 169 MHz SAW filter [*6.*].

An external FEM (front-end module) is used to improve the output power at the +27 dBm requested. The FEM utilized is a Skyworks SKY66100 [5]. The device includes a power amplifier (PA) capable of about +27 dBm of transmitted output power. The receive chain consists of a low-loss single-pole, triple-throw switch, which provides an insertion loss of approximately 0.5 dB.

A low power amplifier (LNA) is inserted in the RX path. This one, a CEL µPD5740T6N [*8.*], is inserted to improve the application sensitivity.

A few passive devices (inductors and capacitors) are used as matching/filtering between the SAW filter and PA, between the PA and switch and after the switch.

An SMA connector, after the FEM, is provided to connect the board to the antenna or to instrumentation in order to verify correct functionality and confirm the ETSI standard required.

Figure 1. SPIRIT1 with range extender application daughterboard

Figure 2. SPIRIT1 application daughterboard plugged into the motherboard

Figure 3. Daughterboard circuit schematic (1 of 2)

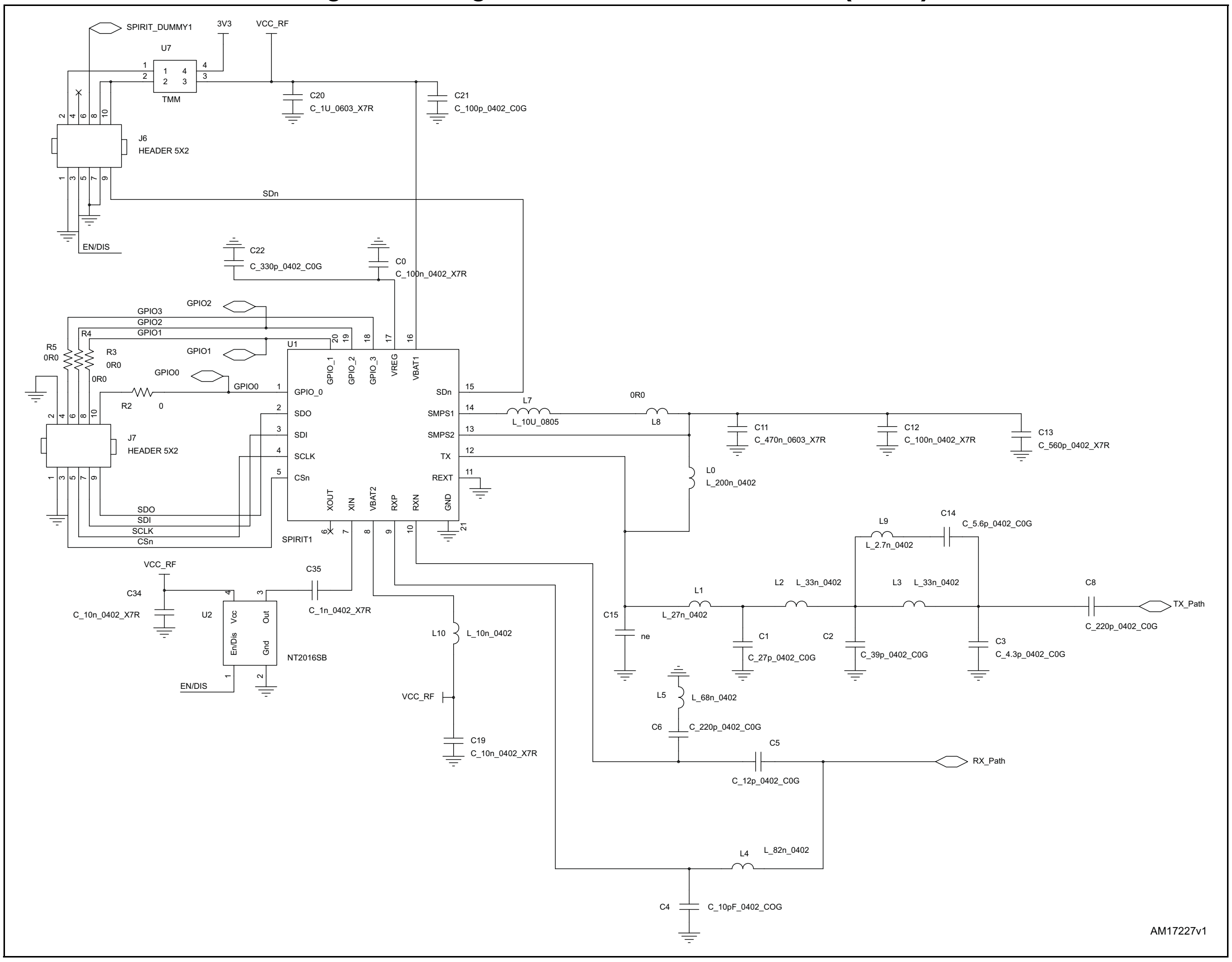
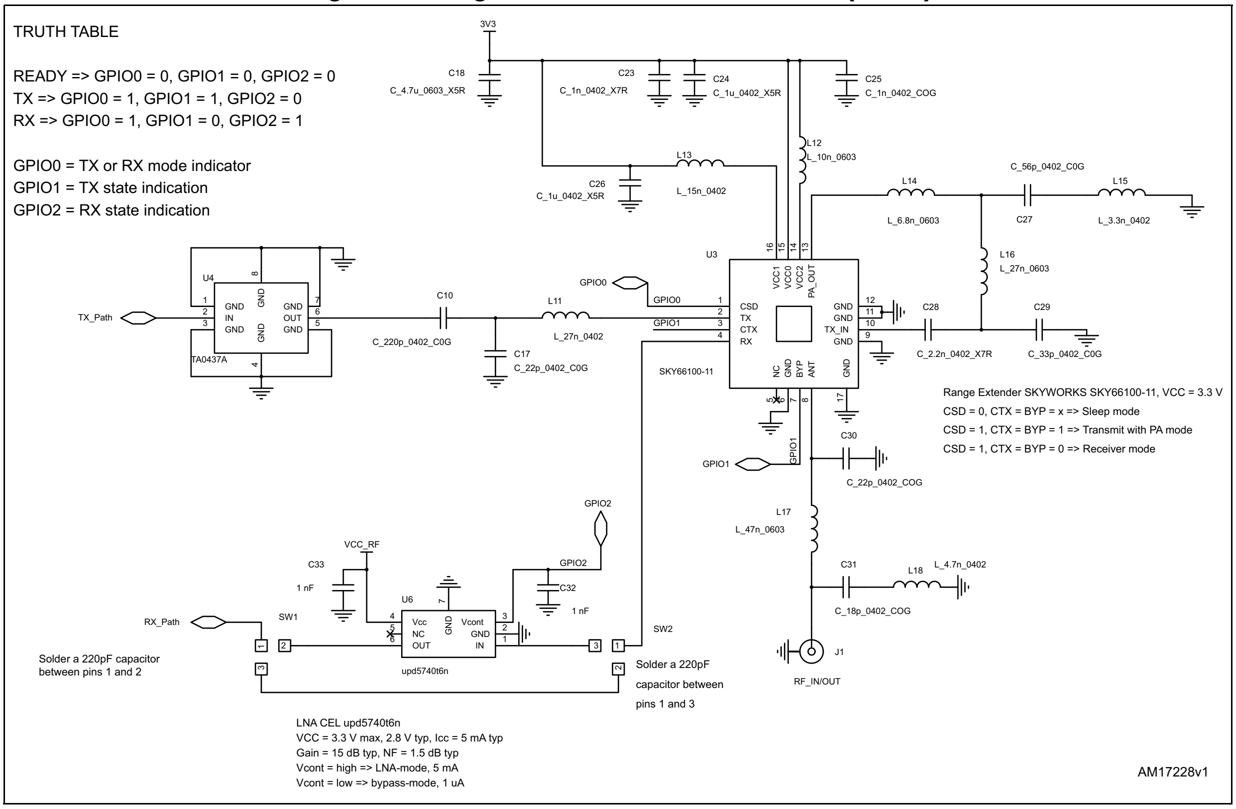


Figure 4. Daughterboard circuit schematic (2 of 2)



2 Transmitter parameters

All the measurements reported here have been measured with the following parameters: T_C = 25 °C, V_{DD} = 3.3 V, f = 169.400 MHz.

This application is specifically designed to work with the W-MBUS N-mode standard, as defined in the CEN/TC 294 prEN 13757-4:2011.10 [4]. In this case the maximum targeted channel spacing is 12.5 kHz. In the ETSI EN 300 220-1 v2.3.1 [2] standard the equipment used in non-channelized frequency band with a channel bandwidth of equal or less than 25 kHz is considered “narrow band”, so all the measurements for the transmitter reported in this application note are done for the narrow band systems.

The configuration used is: 2.4 kbps as data rate, 2.4 kHz as frequency deviation and GFSK modulation with BT = 0.5 or 4.8 kbps as data rate, 1.2 kHz as frequency deviation and GMSK modulation with BT = 0.5.

For the narrow band systems, the adjacent channel power and the unwanted emissions in the spurious domain measurements must be reported. The measurements are performed in accordance with EN 300 220 v1 [*2.*] paragraphs 7.6 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 test measures the power transmitted in the adjacent channel during continuous modulation. The ACP is measured with a spectrum analyzer conforming to the requirements given in the 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. The ETSI limits for the ACP is 10 µW (-20 dBm).

The resolution bandwidth of the spectrum analyzer is set to 100 Hz and the power of all the 100 Hz sub-band measurements over a total bandwidth of 8.5 kHz are integrated, as described in the EN 300 220-1 v2.3.1 (2010-02) [*2.*] annex B.

Figure 5 and *Figure 6* illustrate the measured ACP at the 169.4 MHz center frequency. 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 5*, while the data rate is 4.8 kbps with GMSK modulation (BT=0.5) in *Figure 6*. 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.*].

The output power integrated around the carrier is 26.5 dBm. With this power the ACP in the two different modulation conditions are respectively -30 dBm, which is 10 dB lower than the ETSI limit, and -38 dBm, which is 16 dB lower than the ETSI limit.

The SPIRIT1 is fully compliant with the ETSI transmitter adjacent channel power requirements.

Figure 5. Adjacent power measurement, GFSK BT = 0.5, 2.4 kbps data rate, 2.4 kHz frequency deviation

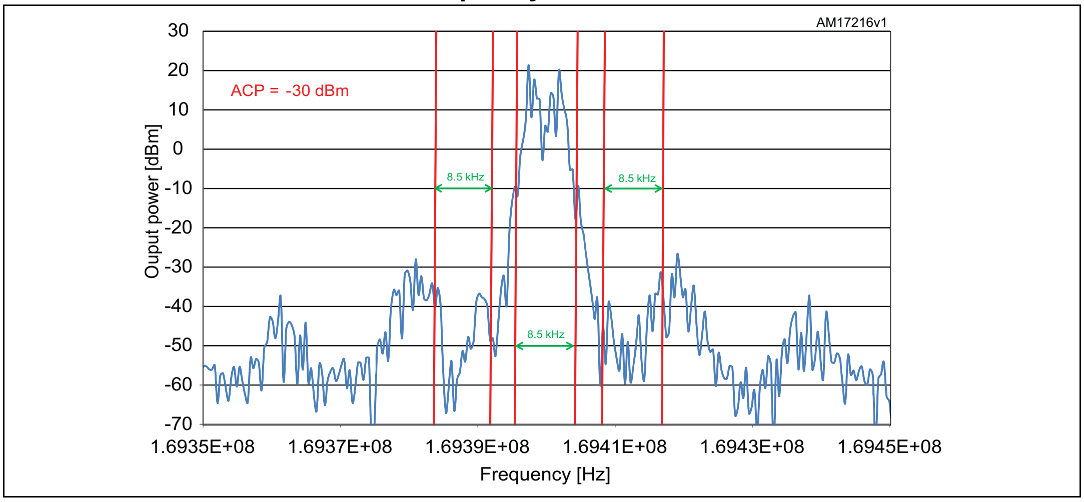
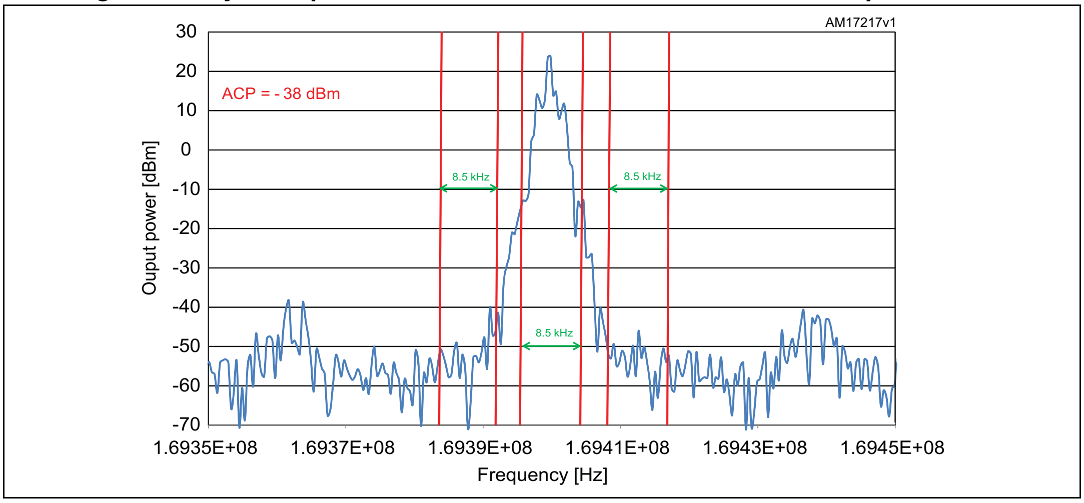


Figure 6. Adjacent power measurement, GMSK BT = 0.5, 4.8 kbps data rate



2.2 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 external receiver. The measurement is performed setting the SPIRIT1 with modulation and observing it over the frequency range of 9 kHz to 4 GHz, as described in the ETSI [2.] sub-clause 7.8. Since the equipment is tested under clause 7.6 of the ETSI [2.] standard, the tests are made on all frequencies except the channel on which the transmitter is intended to operate, and its adjacent and alternate channels.

For the measurement below 1 GHz, the RMS detector of the spectrum analyzer must be set. In this case, the measuring receiver bandwidth must be 100 kHz. If the measurement bandwidth of the measuring receiver needs to be narrower, a conversion formula must be applied:

$$B = A + 10 \log (BWref/BWmeasured)$$

where:

– B is the value referred to the reference bandwidth

– A is the value at the narrower measurement bandwidth

The measured value A must be used directly if the measured spectrum is a discrete spectral line. A discrete spectrum line is defined as a narrow peak with a level of at least 6 dB above the average level inside the measurement bandwidth.

For measurements above 1 GHz, the peak value shall be measured, the “max hold” function of the spectrum analyzer shall be used. In this case the reference bandwidth for the measurement receiver must be 1 MHz.

The measurement is split into six figures: in *Figure 7* the unwanted spurious emission for frequencies below 1 GHz is shown. The measurement is performed setting the instrument to max hold with a resolution bandwidth of 10 kHz. In *Figure 8* the unwanted spurious emission for frequencies from 1 GHz to 4 GHz is shown. The measurement is performed setting the instrument to max hold with a resolution bandwidth of 1 MHz, as required by ETSI [2.]. In the two graphs, the mask requirement from ETSI is reported also.

The spurious emissions near the modulated signals are also investigated. In *Figure 9* and *10* the spurious emissions with a span of 200 kHz for the two different cases are shown. The channel used, and its adjacent and alternate channels are not considered, as described in the ETSI [2.] subclause 7.8. In *Figure 11* and *12*, the spurious emissions with a span of 800 kHz for the two different cases are shown. The channel used, and its adjacent and alternate channels are also not considered.

The unwanted emissions in the spurious domain of the SPIRIT1 complies with ETSI [2.] sub-clause 7.8.

Figure 7. Unwanted emission in the spurious domain mask below 1 GHz

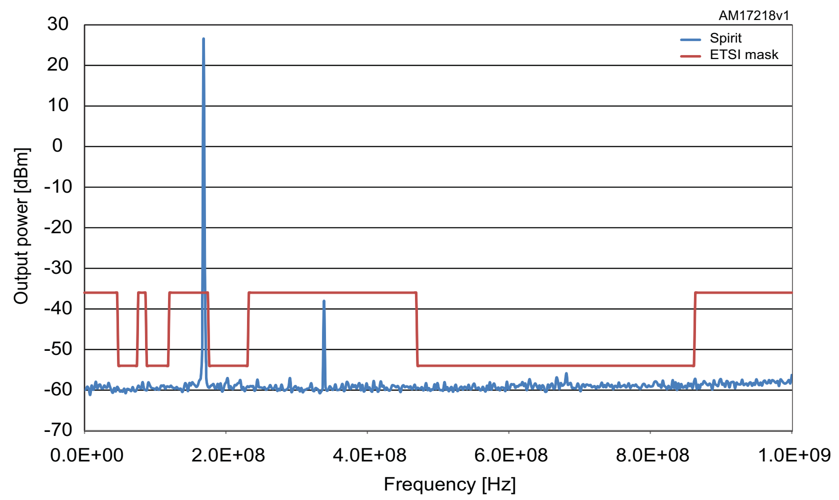


Figure 8. Unwanted emission in the spurious domain mask above 1 GHz

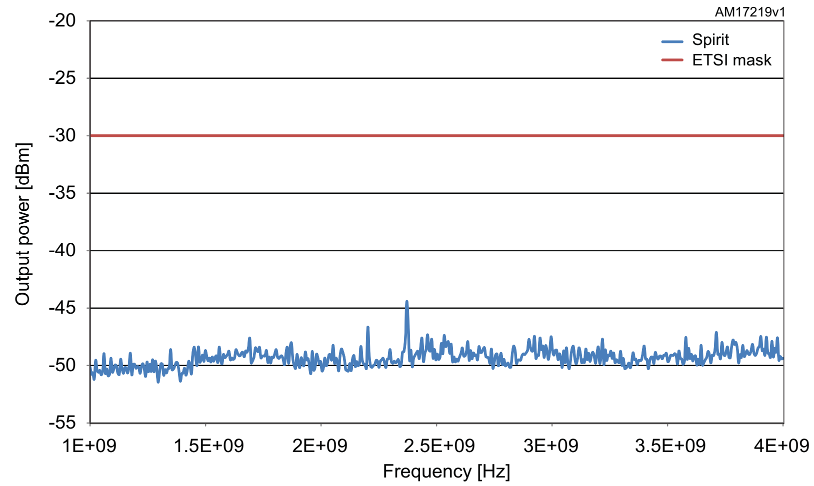


Figure 9. Unwanted emission in the spurious domain, GFSK modulation, 2.4 kbps data rate, 2.4 kHz frequency deviation, 200 kHz span

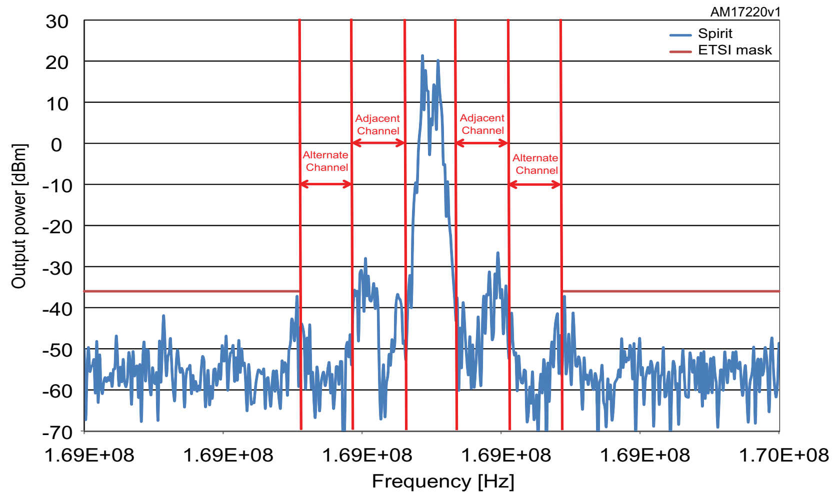


Figure 10. Unwanted emission in the spurious domain, GMSK modulation, 4.8 kbps data rate, 200 kHz span

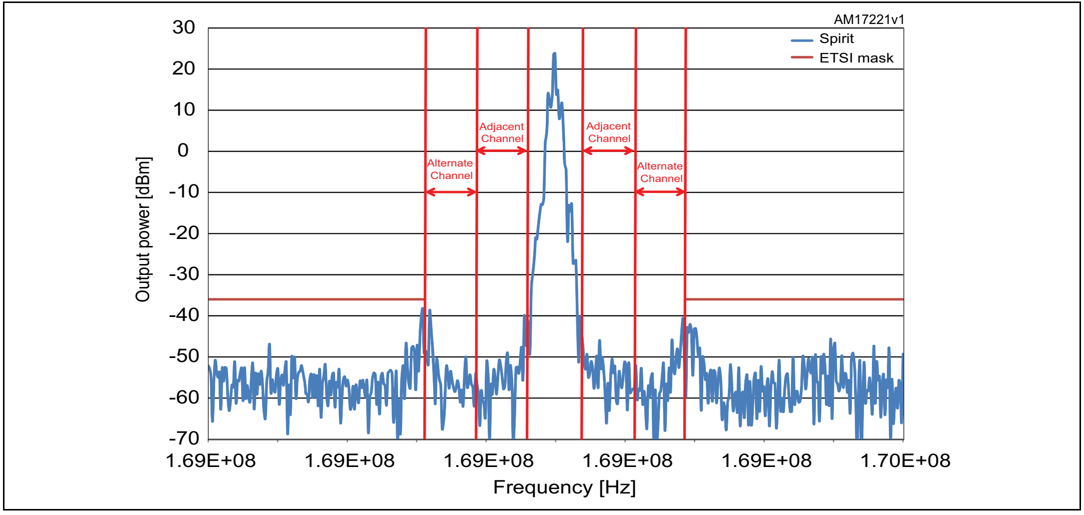


Figure 11. Unwanted emission in the spurious domain, GFSK modulation, 2.4 kbps data rate, 2.4 kHz frequency deviation, 800 kHz span

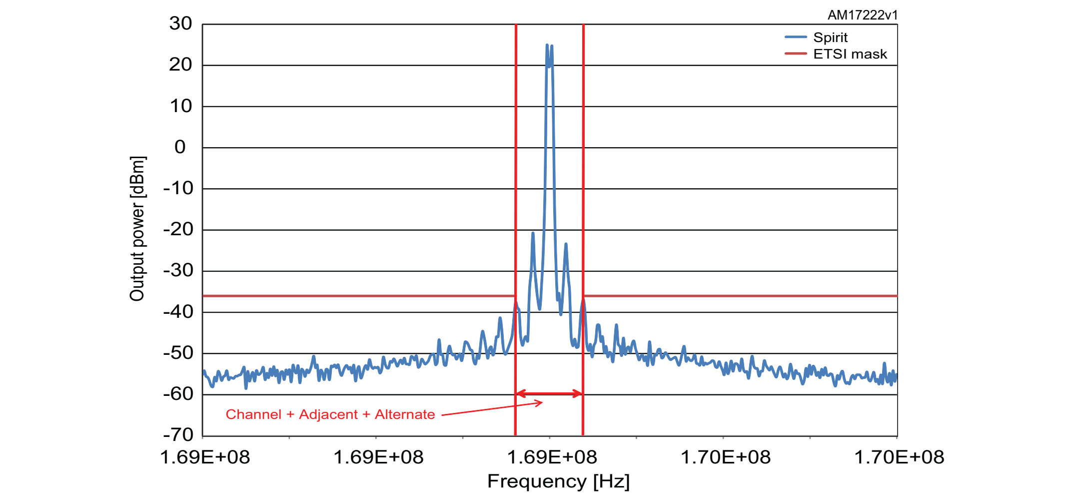
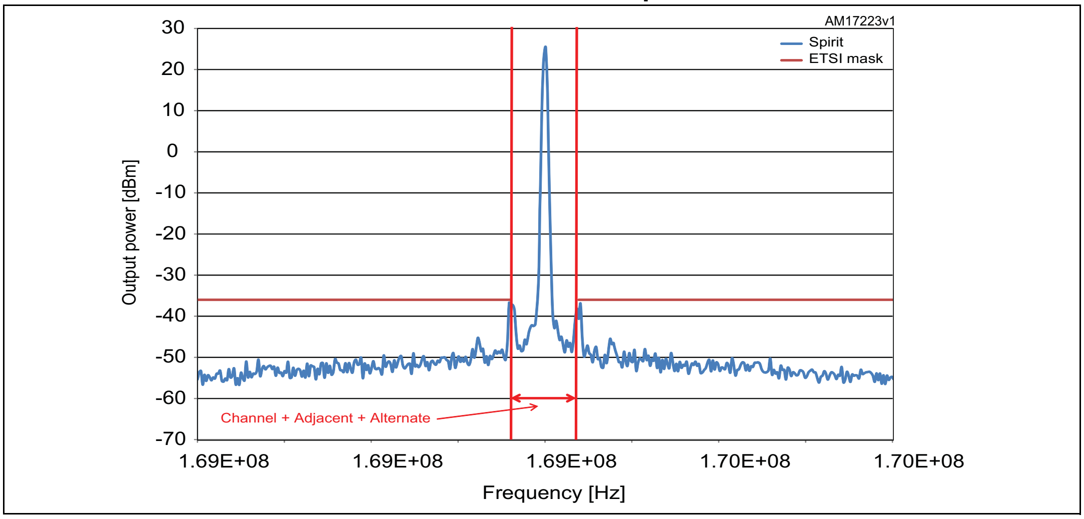


Figure 12. Unwanted emission in the spurious domain, GMSK modulation, 4.8 kbps data rate, 800 kHz span



3 Receiver parameters

All the measurement reported here are measured with the following parameters: T_C = 25 °C, V_{DD} = 3.3 V, f = 169.400 MHz.

The 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 the requirements of receiver category 2, which means 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.

3.1 Receiver sensitivity

Receiver sensitivity is the minimum level of the signal at receiver input, produced by a carrier at the nominal frequency of the receiver, modulated with the normal test signal modulation, which produces 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

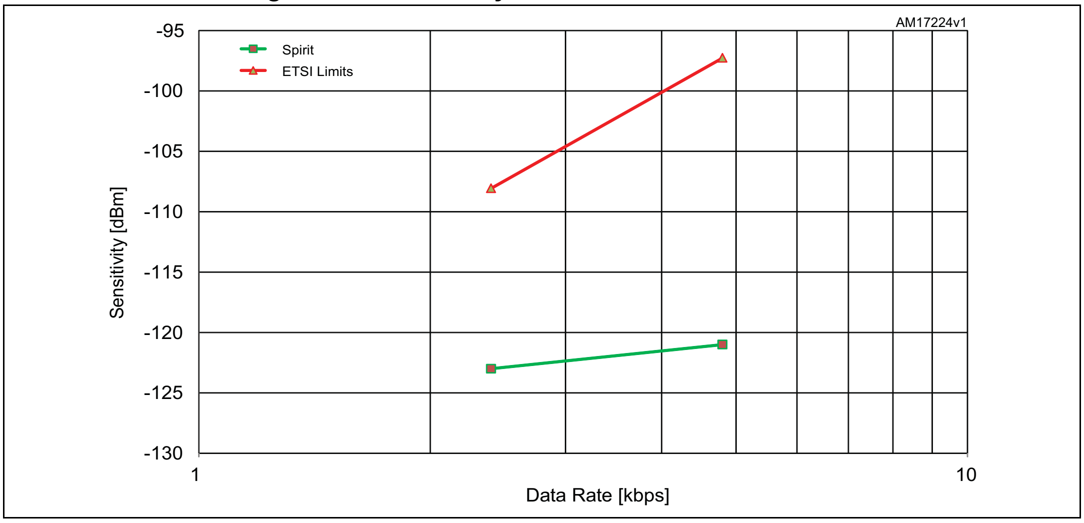
$$Sp[dBm] = 10\log\left(\frac{BW[kHz]}{16}\right) - 107$$

The measurement is performed using an RF signal source generator centered at the same receiver frequency 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 power consumption, an internal SMPS is integrated in the SPIRIT1. *Figure 13* demonstrates the ETSI 1% BER sensitivity limit (red line) and the SPIRIT1 sensitivity for the two investigated data rates with internal SMPS. This application note outlines the expected performance when using the SPIRIT1 under EN 300 220-1 (v2.3.1, 2012-02) [2.] in the 169.400 - 169.475 MHz band, with channel spacing of 12.5 kHz.

The SPIRIT1 with range extender application is fully compliant with ETSI class 2 receiver sensitivity requirements, with a large margin.

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



3.2 Blocking

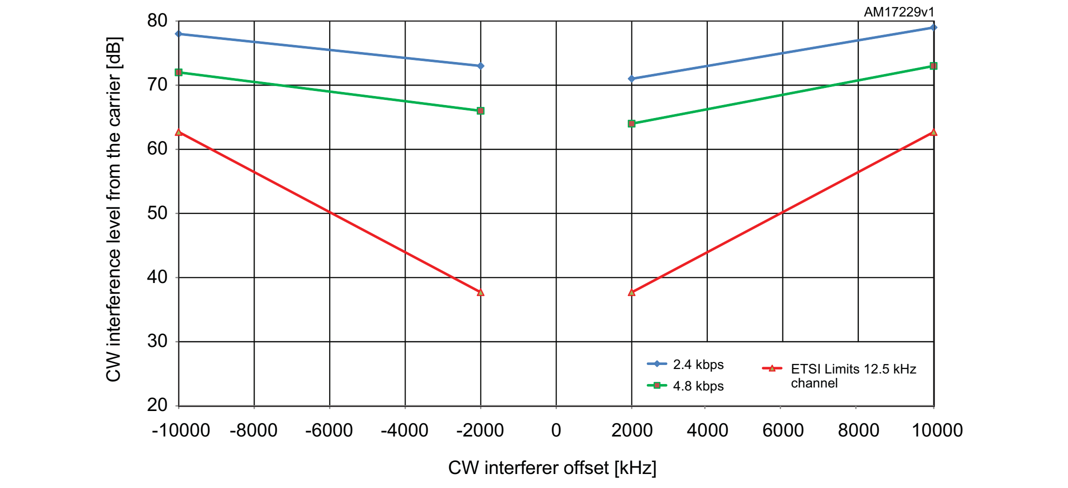
Blocking is a measure of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of an unwanted input signal at any frequency other than those of the spurious responses or the adjacent channels or bands.

All the blocking results are measured by positioning the input power 3 dB above the measured sensitivity limit reported in the previous paragraph with a primary signal source generator. A second generator with an un-modulated 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 at two points: ±2 and ±10 MHz. The limit for class 2 receiver at ±2 MHz is 37.7 dB from the 3 dB level above the sensitivity, and at ±10 MHz it is 62.7 dB from the 3 dB level above the sensitivity.

The SPIRIT1 with range extender is fully compliant with ETSI class 2 receiver blocking requirements, with a large margin.

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



3.3 Receiver spurious radiation

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

A spectrum analyzer is used as external receiver. The measurement is performed setting the SPIRIT1 in RX mode with modulation and observing it at up to 4 GHz as described in the ETSI [2.] sub-clause 8.6.

The measurement is split into two graphs: in *Figure 15* the unwanted spurious emission for frequencies below 1 GHz is shown. The measurement is performed setting the instrument to a resolution bandwidth of 100 kHz. In *Figure 16* the spurious radiation from the receiver for frequencies from 1 GHz to 4 GHz is shown. The measurement is performed setting the instrument to a resolution bandwidth of 1 MHz, as required by ETSI [2.]. In the two graphs, the mask required from the ETSI is reported also.

The receiver spurious radiation of the SPIRIT1 complies with ETSI [2.] sub-clause 8.6.

Figure 15. Receiver spurious radiation below 1 GHz

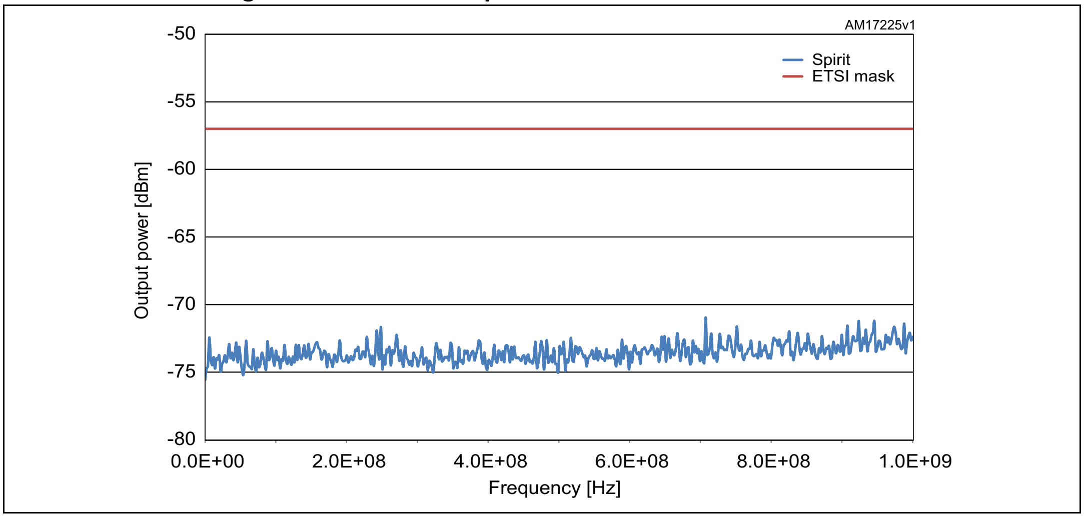
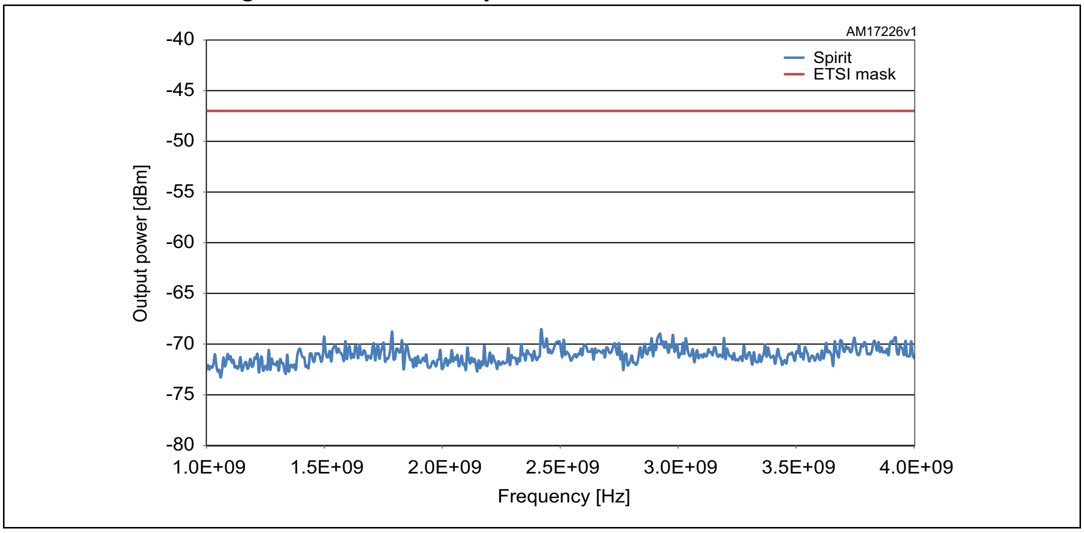


Figure 16. Receiver spurious radiation above 1 GHz



4 Measuring equipment

The following equipment was used to perform the measurements.

Table 1. Measuring equipment

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

5 Reference

1. STMicroelectronics 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)”
5. Skyworks SKY66100 datasheet
6. TAI-SAW Technology CO., LTD. TA0437A “SAW Filter 169 MHz” datasheet
7. Peregrine Semiconductor PE4259 datasheet
8. California Eastern Laboratories µPD5740T6N datasheet

6 Revision history

Table 2. Document revision history

Date	Revision	Changes
24-Oct-2013	1	Initial release.