AN4174
Application note

Using the SPIRIT1 transceiver under the ARIB STD-T67 standard in the 426 MHz band

By Placido De Vita

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, 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 to promote radio related industries. The scope of the ARIB organism is defined as the basic technical requirements for standard specifications of radio equipment.

This application note outlines the expected performance when using the SPIRIT1 under the ARIB STD-T67 [2] standard in the 426 MHz band. For details of regulatory limits in the 426 MHz frequency band, please refer to the ARIB STD-T67 standard [2].

This can be downloaded from www.arib.or.jp/english/index.html.

Contents

List of figures

1 An overview of the ARIB STD-T67 standard

This standard provides for telemetry radio equipment designed to automatically indicate and/or record the results obtained by measuring instruments located remotely by means of radio waves; telecontrol radio equipment, for the transmission of signals to activate, change, or deactivate the functions of devices located remotely by means of radio waves; and data transmission radio equipment, intended for the transmission of information to be processed primarily by machines, or of previously processed information.

The communication methods are those defined in *Table 1*. In the same table the operating frequency bands, the antenna powers and the transmission time restrictions are defined.

For the transmitter, the following parameters are defined.

The antenna power (the specified or rated power that is supplied from the transmitter to the feeder of an antenna system in normal operation and is averaged over a sufficiently long period of time compared to the cycle of the lowest frequency) is 0.01 W (+10 dBm) or less. However, for transmission units using a frequency between 426.025 MHz and 426.1375 MHz, the antenna power is 0.001 W (0 dBm) or less.

The frequency tolerance (the maximum allowable deviation of the center frequency of the band occupied by emission from the allocated frequency) is $\pm 4 \times 10^{-6}$ ($\pm$ 4 ppm). This is a very stringent requirement, a TCXO is necessary to meet the frequency tolerance requirement.

There are no specific requirements regarding modulation method, frequency deviation and modulation rate. In the general conditions of the ARIB STS-T67, the emission classes of the apparatus are defined. The emission class supported by the SPIRIT1 is the F1D, which is frequency modulation (F), one channel containing digital information, no subcarrier (1), data transmission, telemetry or telecommand (D). The choice of the data rate and frequency deviation is made to meet the bandwidth requirements described in *Table 1*.

An adjacent channel leakage power requirement, that is the power radiated in a certain band of the adjacent channel separated from the carrier frequency at the specified frequency interval, is defined. The power radiated into the ± 4.25 kHz band of the frequency, 12.5 kHz in distance from the carrier frequency, is lower than the carrier power by 40 dB or more. However, for transmitters that emit radio waves in an occupied bandwidth over 8.5 kHz and up to 16 kHz, the power radiated into the ± 8 kHz band of the frequency, 25 kHz in distance from the carrier frequency, is lower than the carrier power by 40 dB or more.

The permissible value for an occupied bandwidth (the bandwidth in which the mean powers radiated below its lower frequency limit and above its upper frequency limit are each equal to 0.5% of the total mean power radiated by a given emission) is 8.5 kHz. However, for transmitters emitting radio waves in an occupied bandwidth over 8.5 kHz and up to 16 kHz, the value is 16 kHz.

Spurious emission refers to the emissions on a frequency or frequencies which are outside the permitted bandwidth and the level of which may be reduced without affecting the corresponding transmission of information, including a high harmonic emission, a low harmonic emission, a parasitic emission and an intermodulation product but excluding an out-of-band emission.

Out-of-band emission refers to the emission which results from the modulation process on a frequency or frequencies outside the permitted bandwidth.

Unwanted emission refers to the emissions made up of the spurious emission and the out-of-band emission.

The permissible value of the unwanted emission intensity refers to the permissible value defined according to the mean power of unwanted emissions of each modulated frequency supplied to the feeder. The permissible value of the unwanted emission intensity is 2.5 µW (-26 dBm) or less, as measured in the average power.

For the receiver, the following parameters are defined.

The reference sensitivity (the necessary receiver input voltage in which the output bit error rate of the device is 1 x 10-2 when the desired wave modulated is applied) is 2 µV (-101 dBm on 50 ohm) or less for receivers with channel intervals of 12.5 kHz and 25 kHz, and 2.8 µV (-98 dBm on 50 Ω) or less for receivers with channel interval of 50 kHz.

The spurious response at effective selectivity (the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1 x 10-2 when an un-modulated jamming wave is applied in a state in which a desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied) is 40 dB or more.

The adjacent channel selectivity at effective selectivity (the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1 x 10^{-2} when a jamming wave that is modulated by a signal of repetitive binary pseudo noise with a code length of 32767 bits and is 12.5 kHz or 25 kHz in distance from the desired wave is applied to a device with channel interval of 12.5 kHz or 25 kHz, respectively, in a state in which the desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied) is 30 dB or more.

The frequency tolerance, as for the transmitter, is ±4 x 10^{-6} (± 4 ppm). This is a very stringent requirement, a TCXO is necessary to meet the frequency tolerance requirement.

The limit of the secondary radiated emission from the receiving equipment is, in terms of the power of a dummy antenna circuit that has the same electrical constant as the receiving antenna, 4 nW (-54 dBm) or lower.

Table 1. Communication method, operating frequencies and antenna power

Communication method	Operating frequency band [MHz]	Antenna power [W]	Transmission time restriction
One-way communication, simplex operation or broadcast communication	426.0250 - 426.1375 (12.5 kHz interval)	0.001 or less	TCT: 40 sec, TQT: 2 sec (Telemetry, data transmission) TCT: 5 sec, TQT: 2 sec (Telecontrol, data transmission)
	426.0375 - 426.1125 (25 kHz interval)		TCT: 40 sec, TQT: 2 sec (Telemetry, data transmission) TCT: 5 sec, TQT: 2 sec (Telecontrol, data transmission)
One-way communication, simplex operation or broadcast communication	429.1750 - 429.2375 (12.5 kHz interval)	0.01 or less	TCT: 40 sec, TQT: 2 sec
	429.2500 - 429.7375 (12.5 kHz interval)		Continuous transmission (intermittent communication possible)

Table 1. Communication method, operating frequencies and antenna power (continued)

Communication method	Operating frequency band [MHz]	Antenna power [W]	Transmission time restriction
One-way communication, simplex operation, broadcast communication, semi-duplex operation or duplex operation	429.8125 – 429.9125 (12.5 kHz interval)	0.01 or less	TCT: 40 sec, TQT: 2 sec
	429.9250 (12.5 kHz interval)		TCT: 0.2 sec, TQT: 2 sec
	449.7125 – 449.8125 (12.5 kHz interval)		TCT: 40 sec, TQT: 2 sec
	449.8250 (12.5 kHz interval)		TCT: 0.2 sec, TQT: 2 sec
	449.8375 – 449.8375 (12.5 kHz interval)		TCT: 40 sec, TQT: 2 sec
	449.8875 (12.5 kHz interval)		TCT: 0.2 sec, TQT: 2 sec
	469.4375 – 469.4750 (12.5 kHz interval)		TCT: 40 sec, TQT: 2 sec
	469.4875 (12.5 kHz interval)		TCT: 0.2 sec, TQT: 2 sec

Note: TCT: transmission continuous time.
TQT: transmission quiescence time.

2 Application circuit

Figure 1 shows the SPIRIT1 application board. The application is made up of 2 boards: a daughterboard and a motherboard. The daughterboard holds the SPIRIT1 with the circuits necessary for its functioning. For correct functionality, the daughterboard must be plugged on 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) is 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 the application 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 usually) to the device. An SMA connector is present to connect the board at antenna or at instrumentation to verify the correct functionality and to verify the ETSI standard request.

A few passive inductors and capacitors are used as matching/filtering for the power amplifier (PA) and 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 functionality in this condition. Clearly, an application with antenna switch can be realized, but this isn't described in this document.

Figure 1. SPIRIT1 application daughterboard

Figure 2. SPIRIT1 application daughterboard plugged on the motherboard

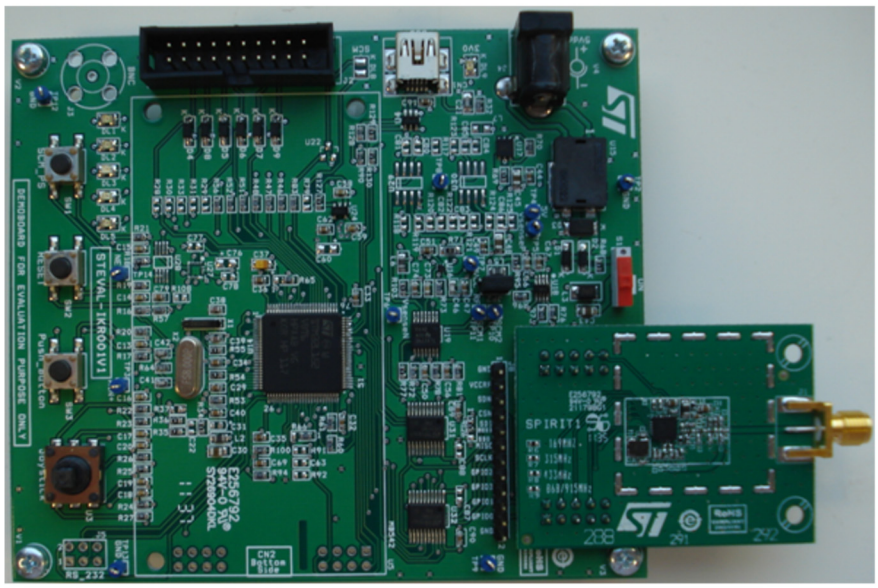
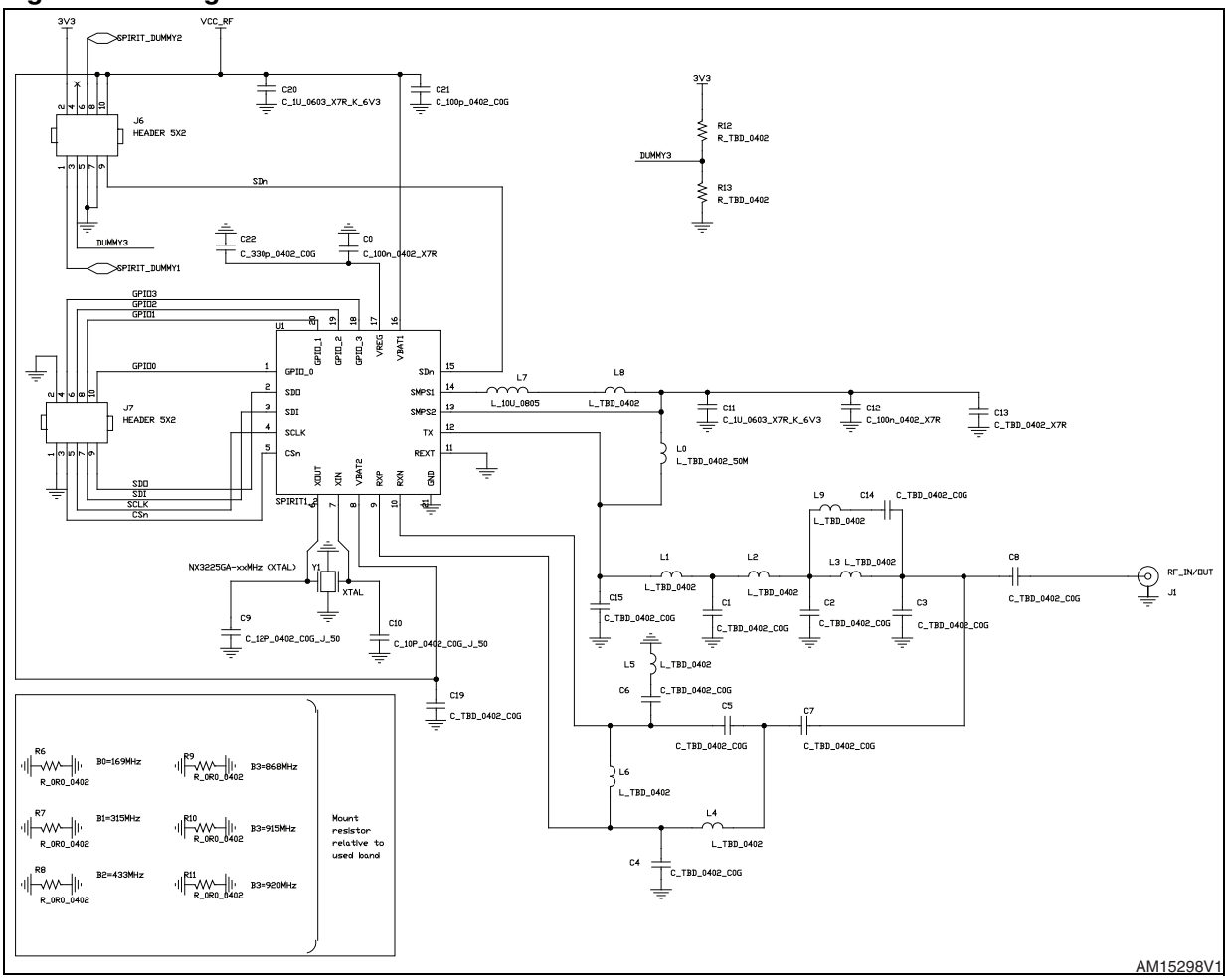


Figure 3. Daughterboard schematic



3 Transmitter

All the measurements here reported are measured with the following parameters: Tc = 25 °C, Vdd = 3.0 V, f = 426 MHz (middle frequency of the useful bandwidth), unless otherwise specified.

The maximum output power of the SPIRIT1 in this band is 11 dBm, so all power requirements in the different bands are met.

There are no specific requirements in the standard regarding setting the detector, resolution bandwidth (RBW) or video bandwidth (VBW) of the spectrum analyzer. The detector is set to peak, the resolution and video bandwidths are set sufficiently large to ensure correct measurements.

3.1 Adjacent channel leakage power

The adjacent channel leakage power requirement is the power radiated in a certain band of the adjacent channel separated from the carrier frequency at the specified frequency interval. The power radiated into the ± 4.25 kHz band of the frequency 12.5 kHz in distance from the carrier frequency is lower than the carrier power by 40 dB or more. However, for transmitters that emit radio waves in an occupied bandwidth over 8.5 kHz and up to 16 kHz, the power radiated into the ± 8 kHz band of the frequency 25 kHz in distance from the carrier frequency is lower than the carrier power by 40 dB or more.

Figures *4* to *7* show the adjacent channel power measurements in four different working conditions. The case with a data rate of 2.4 Kbps and frequency deviation of 2.4 kHz (12.5 kHz bandwidth) is reported in *Figure 4*: the measured ACP is 54 dB. The case with a data rate of 4.8 Kbps and frequency deviation of 2.4 kHz (12.5 kHz bandwidth) is reported in *Figure 5*: the measured ACP is 54 dB. The case with a data rate of 9.6 Kbps and frequency deviation of 2.4 kHz (25 kHz bandwidth) is reported in *Figure 6*: the measured ACP is 60 dB. Lastly, *Figure 7*, shows the case with the data rate set to 9.6 Kbps and the frequency deviation set to 4.8 kHz (25 kHz bandwidth). In this last case the measured ACP is 58 dB.

In all the considered cases the ARIB STD-T67 requirement is met with large margin.

Figure 4. Adjacent channel power, 2.4 Kbps data rate, 2.4 kHz frequency deviation

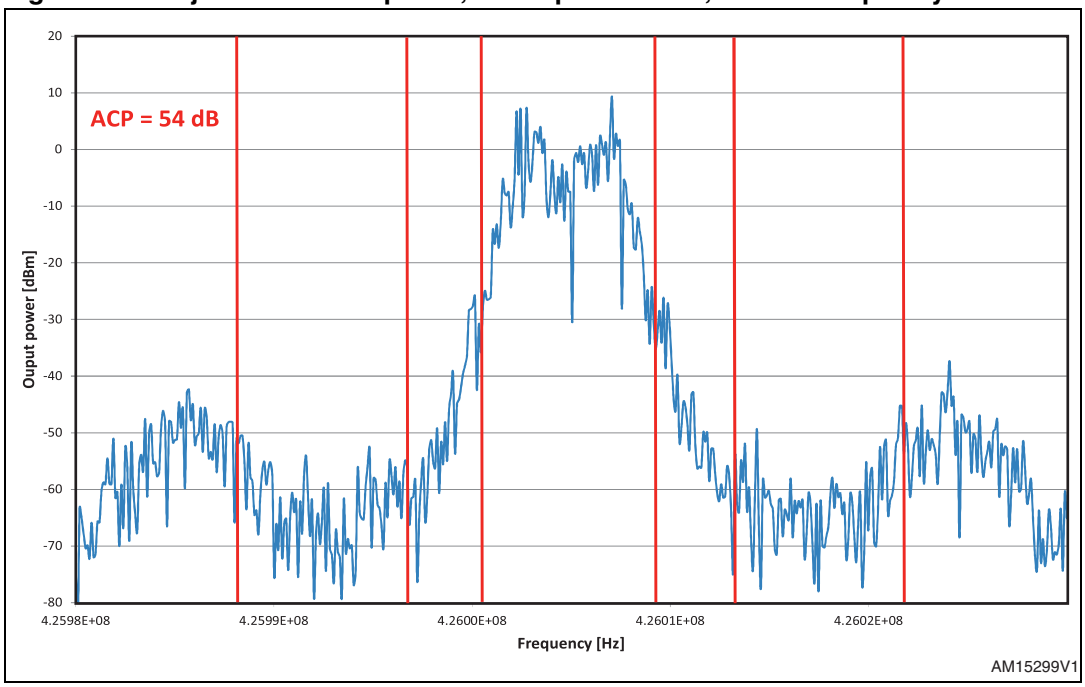


Figure 5. Adjacent channel power, 4.8 Kbps data rate, 2.4 kHz frequency deviation

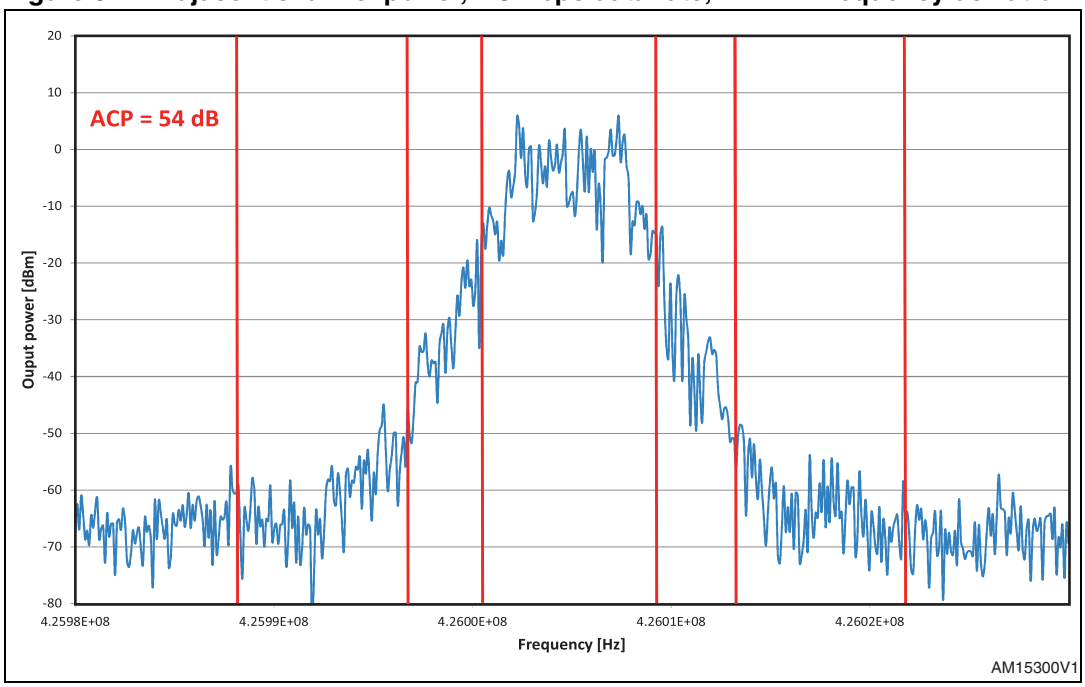


Figure 6. Adjacent channel power, 9.6 Kbps data rate, 2.4 kHz frequency deviation

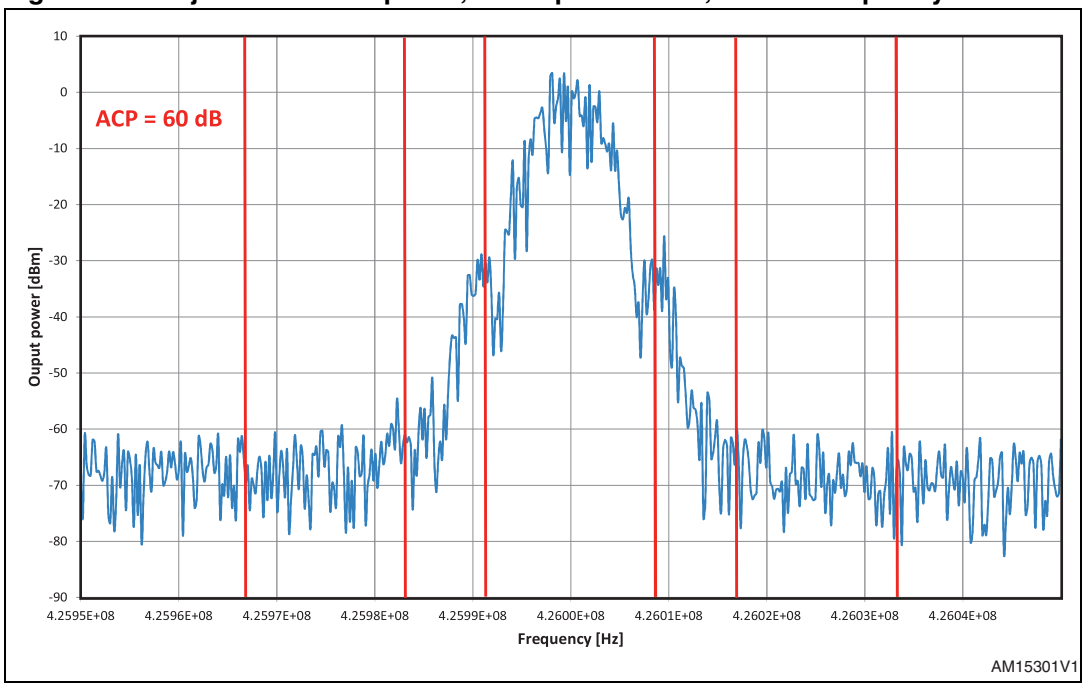
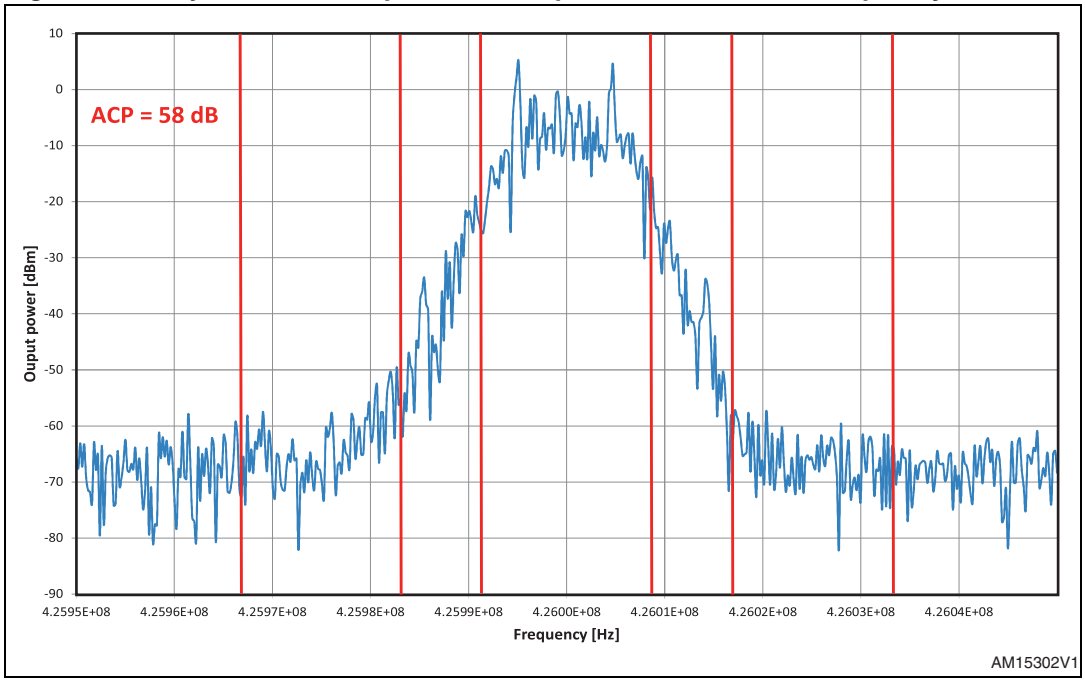


Figure 7. Adjacent channel power, 9.6 Kbps data rate, 4.8 kHz frequency deviation



3.2 Permissible value of the occupied bandwidth

The permissible value for an occupied bandwidth (the bandwidth in which the mean powers radiated below its lower frequency limit and above its upper frequency limit are each equal to 0.5% of the total mean power radiated by a given emission, which is 99% of the powers) is 8.5 kHz. However, for transmitters emitting radio waves in an occupied bandwidth over 8.5 kHz and up to 16 kHz, the value is 16 kHz.

The measurements of these parameters are reported in figures *4* to *7*. In *Figure 4* and *Figure 5* 99% of the emitted power is concentrated in 8.5 kHz, in *Figure 6* and *Figure 7* 99% of the emitted power is integrated in the 16 kHz bandwidth.

3.3 Permissible values of spurious emission or unwanted emission

Spurious emission refers to the emission on a frequency or frequencies which are outside the permitted bandwidth and the level of which may be reduced without affecting the corresponding transmission of information, including a high harmonic emission, a low harmonic emission, a parasitic emission and an intermodulation product, but excluding an out-of-band emission.

Out-of-band emission refers to the emission which results from the modulation process on a frequency or frequencies outside the permitted bandwidth.

Unwanted emission refers to the emission consisting of the spurious emission and the out-of-band emission.

The permissible value of the unwanted emission intensity refers to the permissible value defined according to the mean power of unwanted emissions of each modulated frequency supplied to the feeder. The permissible value of the unwanted emission intensity is 2.5 µW (-26 dBm) or lower, as measured in the average power.

The spurious emission measurements are reported in figures *8* and *9*. In *Figure 8* the spurious emission below 1 GHz is reported, in *Figure 9* spurious emission above 1 GHz is reported. In the two images the ARIB STD-T67 specification mask is also reported.

The SPIRIT1 meets the spurious emission requirements with margin.

Figure 8. TX spurious emission below 1 GHz

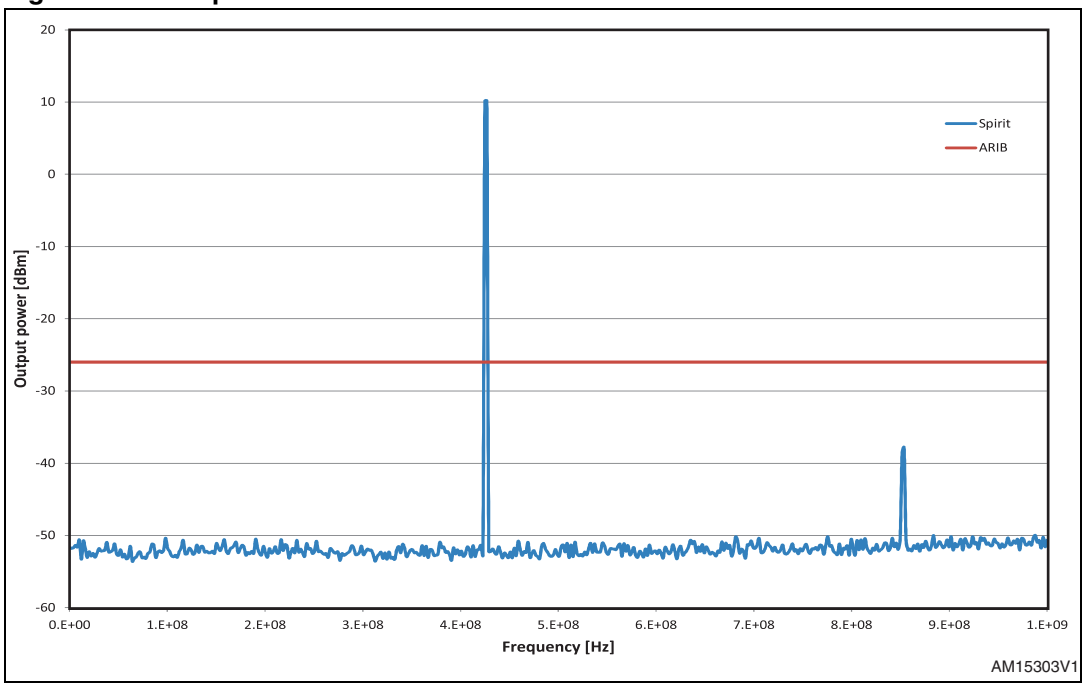
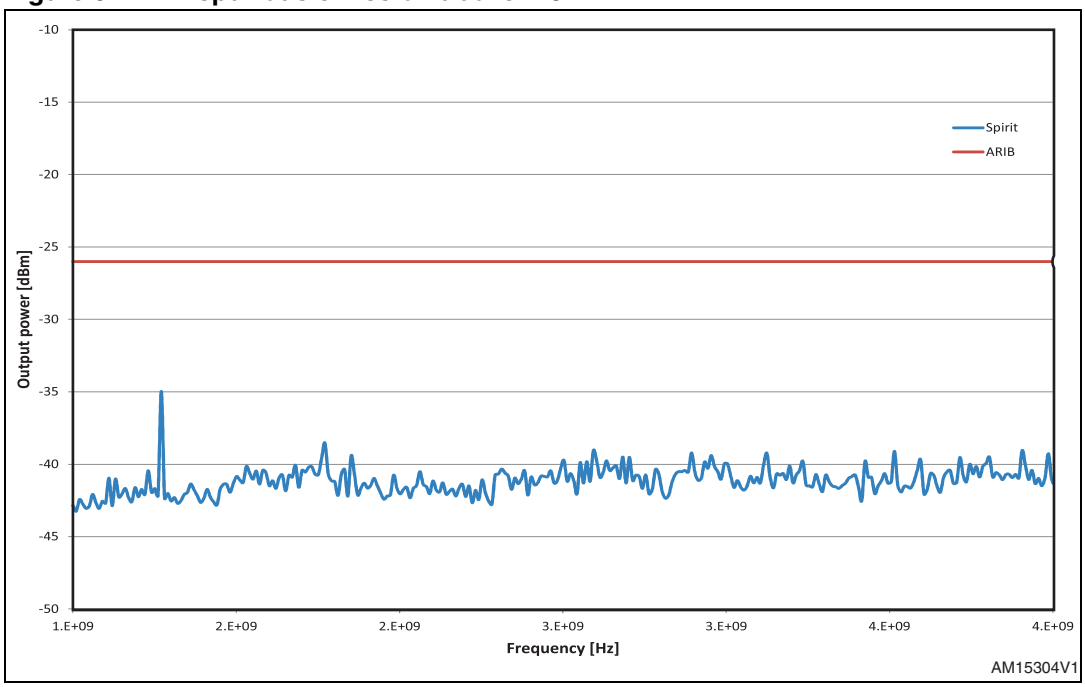


Figure 9. TX spurious emission above 1 GHz



4 Receiver parameter

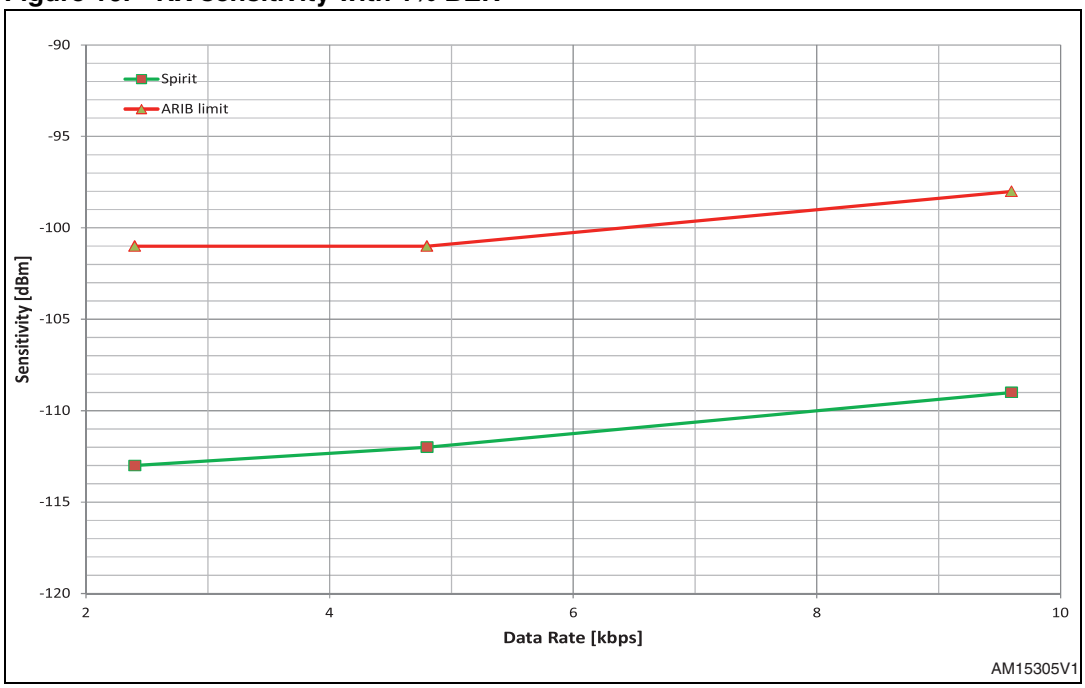
The measurements performed on the receiver are: encoding reference sensitivity, spurious response at effective selectivity, adjacent-channel selectivity at effective selectivity and limit on secondary radiated emission. The measurements are performed with the following parameters: Tc = 25 °C, Vdd = 3.0 V, f = 426 MHz (middle frequency of the useful bandwidth).

4.1 Encoding reference sensitivity

The reference sensitivity (the necessary receiver input voltage such that the output bit error rate of the device is 1 x 10-2 when the desired wave modulated is applied) is 2 µV (-101 dBm on 50 ohm) or less for receivers with channel intervals of 12.5 kHz and 25 kHz, and 2.8 µV (-98 dBm on 50 Ω) or less for receivers with channel interval of 50 kHz.

The receiver sensitivity measurements for three different cases of data rate are reported in *Figure 10*. The ARIB STD-T67 requirements are also reported in the same figure. The SPIRIT1 met the standard requirement with large margin.

Figure 10. RX sensitivity with 1% BER



4.2 Spurious response at effective selectivity

The spurious response at effective selectivity (the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1 x 10-2 when a un-modulated jamming wave is applied in a state in which a desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied) is 40 dB or more.

The measurement results are reported in *Table 2*. Three different data rate cases are reported. The measurement has been performed connecting two signal generators by a power combiner. The first generator has been set with the modulation data reported in the table and with PN9 as data. The level was set to be 3 dB higher than sensitivity. After that, the second generator was powered on with an un-modulated carrier set at ±12.5 kHz or ±25 kHz from the fundamental and its level was raised until 1% of BER was reached. The difference between the two levels was the searched value.

The ARIB STD-T67 requirement is also reported in the same table. The SPIRIT1 met the standard requirement with margin.

Table 2. Communication method, operating frequencies and antenna power

Modulation	Data rate [Kbps]	Deviation [kHz]	Channel filter [kHz]	Spurious response [dB]		
				-ΔCh	+ΔCh	ARIB
GFSK	2.4	2.4	8.5	53	56	40
GFSK	4.8	2.4	8.5	54	52	
GFSK	9.6	4.8	16	50	55	

4.3 Adjacent channel selectivity at effective selectivity

The adjacent channel selectivity at effective selectivity (the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1 x 10-2 when a jamming wave that is modulated by a signal of repetitive binary pseudo noise with a code length of 32767 bits and is 12.5 kHz or 25 kHz distant from the desired wave is applied to a device with channel interval of 12.5 kHz or 25 kHz, respectively, in a state in which the desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied) is 30 dB or more.

The measurement results are reported in *Table 3*. Three different data rate cases are reported. The measurement has been performed connecting two signal generators by a power combiner. The first generator has been set with the modulation data reported in the table and with PN9 as data. The level was set to be 3 dB higher than sensitivity. After that, the second generator was powered on with a modulated carrier (same modulation, data rate, frequency deviation and data of the fundamental) set at ±12.5 kHz or ±25 kHz from the fundamental and its level was raised until 1% of BER was reached. The difference between the two levels was the searched value.

The ARIB STD-T67 requirement is also reported in the same table. The SPIRIT1 met the standard requirement with margin.

Table 3. Communication method, operating frequencies and antenna power

Modulation	Data rate [Kbps]	Deviation [kHz]	Channel filter [kHz]	Adjacent channel selectivity [dB]		
				-ΔCh	+ΔCh	ARIB
GFSK	2.4	2.4	8.5	55	52	30
GFSK	4.8	2.4	8.5	50	36	
GFSK	9.6	4.8	16	48	45	

4.4 Limit on secondary radiated emissions

The limit of the secondary radiated emission from the receiving equipment is, in terms of the power of a dummy antenna circuit that has the same electrical constant as the receiving antenna, 4 nW (-54 dBm) or lower.

The receiver secondary radiated emissions measurements are reported in *Figure 11* and *Figure 12*. In *Figure 12* the radiated emission below 1 GHz is reported, in *Figure 12* the radiated emission above 1 GHz is reported. In the two figures the ARIB STD-T67 specification mask is also reported.

The SPIRIT1 met the spurious emission requirements with margin.

Figure 11. RX spurious emission below 1 GHz

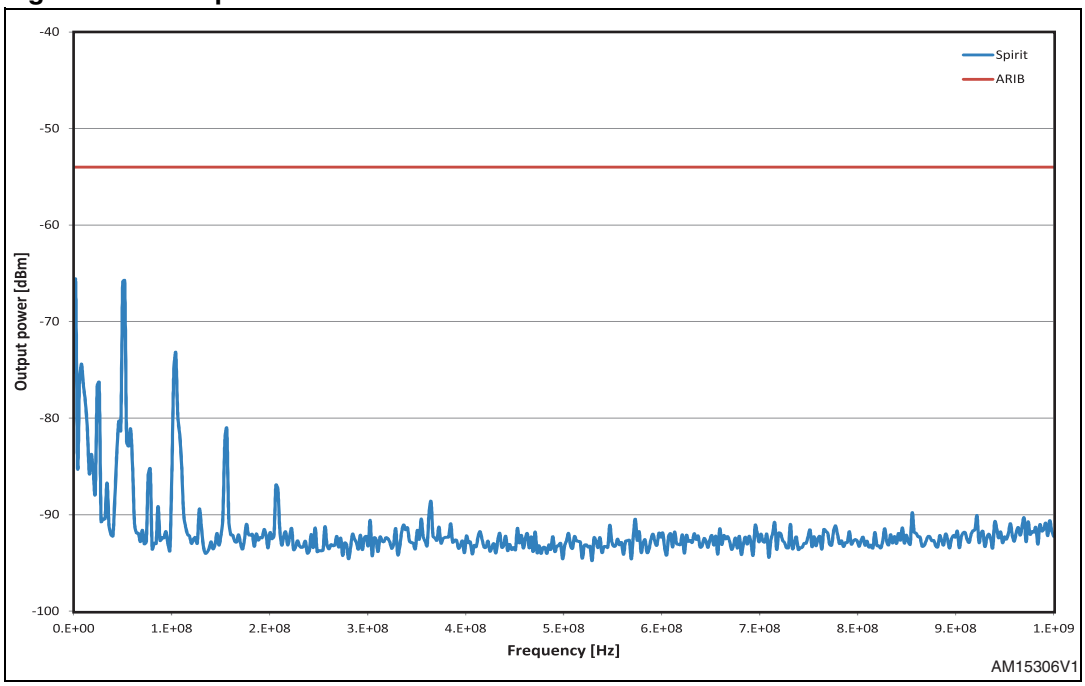
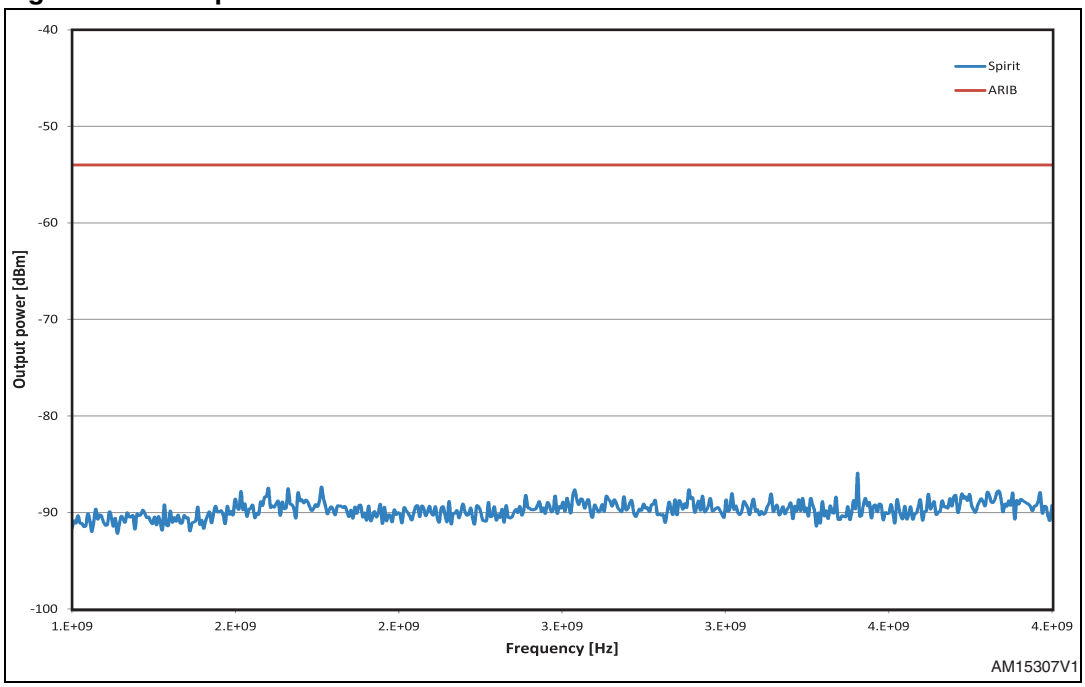


Figure 12. RX spurious emission above 1 GHz



5 Reference

1. SPIRIT1 datasheet.
2. ARIB STD-T67: “Telemeter, Telecontrol and data transmission radio equipment for specified low-power radio station”.

6 Revision history

Table 4. Document revision history

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