Using the CC1101 in the European 868 MHz SRD band

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Keywords

- *CC1101*
- *ETSI EN 300 220*

1 Introduction

The CC1101 is a truly low-cost, highly integrated and very flexible RF transceiver. The CC1101 is primarily designed for use in low-power applications in the 315, 433, 868 and 915 MHz SRD/ISM bands.

This application note describes how to use the CC1101 in the European 863 – 870 MHz SRD frequency bands in order to comply with EN 300 220 requirements.

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2 Abbreviations

ACP	Adjacent Channel Power
BOD	Brown-Out Detection
CEPT	European Conference of Postal and Telecommunications Administrations
EM	Evaluation module
ERC	European Radiocommunications Committee
ETSI	European Telecommunications Standards Institute
GFSK	Gaussian Frequency Shift Keying
ISM	Industrial, Scientific, Medical
MBW	Modulation Bandwidth
MCU	Microcontroller Unit
OBW	Occupied Bandwidth
PLL	Phase Locked Loop
ppm	Parts Per Million
RBW	Resolution Bandwidth
SRD	Short Range Device

3 Frequency Bands

The use of radio equipment in the European Union (EU) is regulated through the R&TTE directive. This directive sets the general essential requirements. The actual standards to follow are written by standardization bodies like CEPT and ETSI. The CEPT is an organ for the PTT (post-telephone -telegraph) authorities in the European countries and is responsible for the use of frequencies and output power. CEPT/ERC/70-03 describes the allocated frequency bands, maximum output power, channel spacing, and duty cycle for short-range devices (SRD) for countries within CEPT [2]. ERC/REC 70-03, annex 1, allows operation in the 863 - 870 MHz frequency band [2]. ETSI EN 300 220-1 V2.1.1 which is a harmonized European Norm, specifies the requirements and test methods to be used for declaration of conformity of license-free operated radio equipment [1].

This application note gives CC1101 RF system parameters, such as data rate and output power, that meets regulatory requirements for the frequency bands/configurations listed in Table 1.

g	863 - 870 MHz (note 3, 4 and 6)	≤ 25 mW e.r.p.	≤ 0.1% or LBT (note 1 and 5)	≤ 100 kHz for 47 or more channels (note 2)		FHSS modulation
		≤ 25 mW e.r.p (note 6) Power density : - 4.5 dBm/100 kHz (note 8)	≤ 0.1% or LBT (note 1, 5 and 6)	No spacing		DSSS and other wideband modulation other than FHSS
		≤ 25 mW e.r.p.	≤ 0.1% or LBT (note 1 and 5)	≤ 100 kHz, for 1 or more channels (note 2 and 7)		Narrow /wide-band modulation
g1	868.000 - 868.600 MHz (note 4)	≤ 25 mW e.r.p.	≤ 1% or LBT. (note 1)	No spacing, for 1 or more channels (note 2)	ERC DEC (01)04	Narrow / wide-band modulation No channel spacing, however the whole stated frequency band may be used
g2	868.700 - 869.200 MHz (note 4)	≤ 25 mW e.r.p.	≤ 0.1% or LBT. (note 1)	No spacing, for 1 or more channels (note 2)	ERC DEC (01)04	Narrow / wide-band modulation No channel spacing, however the whole stated frequency band may be used
g3	869.400 - 869.650 MHz (note 4)	≤ 500 mW e.r.p	≤ 10% or LBT. (note 1)	25 kHz (for 1 or more channels)	ERC DEC (01)04	Narrow / wide-band modulation The whole stated frequency band may be used as 1 channel for high speed data transmission
g4	869.700 - 870.000 MHz	≤ 5 mW e.r.p.	up to 100%	No spacing (for 1 or more channels)	ERC DEC (01)04	Narrow / wide-band modulation No channel spacing, however the whole stated frequency band may be used Audio applications excluded Voice applications allowed with LBT together with 1 minute carrier time-out timer

Note 1: For single frequency devices the duty cycle limit applies, unless LBT is used.
For FHSS, DSSS or AFA devices, the duty cycle applies to the total transmission unless LBT is used.

Note 2: The preferred channel spacing is 100 kHz allowing for a subdivision into 50 kHz or 25 kHz.

Note 3: Subbands for alarms are excluded (see ERC/REC 70–03 Annex 7).

Note 4: Audio and voice applications are excluded.

Note 5: Duty cycle may be increased to 1% if the band is limited to 865 – 868 MHz.

Note 6: For other wide-band modulation than FHSS and DSSS with a bandwidth of 200 kHz to 3 MHz, duty cycle can be increased to 1% if the band is limited to 865-868 MHz and power to ≤10 mW e.r.p.

Note 7: For other narrow-band modulation with a bandwidth of 50 kHz to 200 kHz, the band is limited to 865.5 – 867.5 MHz.

Note 8: The power density can be increased to +6.2 dBm/100 kHz and +0.8 dBm/100 kHz, if the band of operation is limited to 865 –868 MHz and 865-870 MHz respectively.

Table 1: Frequency bands considered in this application note. From [2].

For details on the regulatory limits in the 863 – 870 MHz SRD frequency bands, please refer to the ETSI EN 300 220-1 V2.1.1 standard [1] and ERC Recommendation 70-03 [2]. These can be downloaded from www.etsi.org and www.ero.dk.

The CC1101EM reference design [3] has been used for all measurements. The register settings used are available from the SmartRF® Studio sotware [4].

4 Comments to Requirements

EN 300 220-1 V2.1.1 specifies both tests of the RF performance and the protocol (SW). The latter is not considered in this application note.

4.1 Transmitter Parameters

4.1.1 Requirement 8.1: Frequency error or frequency drift

The frequency error or drift is due to crystal inaccuracies. This requirement is therefore a test of the crystal used and not covered in this application note. Note that ETSI EN 300 220-1 extreme condition is -10°C to +55°C.

4.1.2 Requirement 8.4: Spread spectrum modulation

This is a test of the protocol and not considered in this application note.

4.1.3 Requirement 8.5: Transient power

Transient power is the power falling into adjacent spectrum when switching the transmitter on/off during normal operation [1].

For a channelized system the transient power shall be measured at the channel that is two channels away (alternate channel) as well as at 4 and 10 times the channel spacing of the equipment. The alternate channel and 4^{th} and 10^{th} channel limits are in the middle of the respective channels as opposed to channel edges. As an example, for 100 kHz channel spacing alternate channel shall be measured at ±200 kHz, 4^{th} channel at ±400 kHz, and 10^{th} channel at ±1 MHz offsets.

For a non-channelized system EN 300 220-1 does not specify where to measure transient power. In this application note the whole sub-band is defined as the channel for a single channel system. As an example, operating at 869.5 MHz in the 869.4 – 869.65 MHz sub-band the transient power measurements are done at 869.5 MHz ±2·250 kHz, 869.5 MHz ±4·250 kHz, and 869.5 MHz ±10·250 kHz.

The spectrum analyzer RBW affects the transient power measurements. EN 300 220-1 states that a spectrum analyzer can be used if the RBW is equivalent to the filter characteristics defined in annex B [1].

FSQ and FSIQ7 Rhode&Schwartz spectrum analyzers were used to measure CC1101 transient power. The RBW was set to 10 kHz in the measurements. The filter response of the FSQ and FSIQ7 Rhode&Schwartz spectrum analyzers, with an RBW of 10 kHz, is a conservative choice in terms of meeting the filter characteristics defined in EN 300 220-1, annex B [1] .

4.1.4 Requirement 8.7: Modulation bandwidth for wideband equipment

The 99% occupied bandwidth (OBW) shall be measured. The difference between the upper and lower frequencies where the output power envelope crosses the –36 dBm spurious limit shall be measured (MBW_{36}).

The larger of these two measurements shall be used as the modulation bandwidth. The frequency error or drift shall be included so that the total modulation bandwidth (MBW_{tot}) is the sum of the frequency error and MBW_{36}/OBW.

The modulation bandwidth shall be measured in 300 Hz RBW. As an example, assuming a ±10 ppm initial crystal tolerance, and ±10 ppm temperature drift, the total error is 40 ppm. This corresponds to 868 MHz· 40 ppm = 35 kHz at 868 MHz operation.

4.1.5 Requirement 8.9: Frequency stability under low voltage conditions.

The operating equipment shall remain on channel while the supply voltage is decreased until it ceases to function.

In the measurements the CC1101 supply voltage was set to 1.8 / 3.0 / 3.6 V and the VCO and PLL calibrated for all sub-bands. The voltage was then stepped down in 10 mV steps towards zero for all three supply voltage settings, while the spectrum was monitored. The CC1101 remained on channel down to 1.5 V in all three cases.

Note that the CC1101 does not have a brown-out-detector (BOD) so the external MCU must turn off CC1101 before the supply voltage drops below 1.5 V.

4.1.6 Requirement 8.10: Duty cycle

This is a test of the protocol and not considered in this application note.

4.1.7 Requirement 8.11: Principle for Listen Before Talk (LBT)

This is a test of the protocol and not considered in this application note.

4.2 Receiver Parameters

4.2.1 Requirement 9.1: Maximum useable sensitivity (conducted)

The limit for useable sensitivity is given by

$$Sensitivity = 10\log\frac{BW}{16} - 107 \quad [\text{dBm}]$$

where BW is the RX filter bandwidth in kHz.

4.2.2 Requirement 9.2: Receiver LBT threshold and transmitter max on-time

The LBT threshold is the level at which the receiver determines if the channel is available for use or not. If the input signal is above this threshold the channel is busy. Conversely, if the input signal is below this threshold the channel is available for use.

Transmitter maximum on-time is not considered in this application as this is related to the protocol (SW).

4.2.3 Requirement 9.3: Adjacent channel selectivity

This is a requirement for receiver class 1 only. Receiver class 1 is for devices serving systems where failure may result in a physical risk to a person [1]. CC1101 does not meet receiver class 1 adjacent channel selectivity requirements.

5 863 - 870 MHz, FHSS with Channel Spacing of 100 kHz (g)

The adjacent channel power (ACP) limits the output power to +5 dBm in this frequency band (see Requirement 8.6: Adjacent channel power (ACP)).

The following system parameters were used for the tests referred to in this section:

Baud rate [kBaud]	Modulation format	Frequency deviation [kHz]	Output power [dBm]	RX channel filter bandwidth [kHz]
1.2	GFSK	5.2	+5	58
38.4	GFSK	14.3	+5	101

Table 2: System parameters for tests in the 863 - 870 MHz frequency band

5.1 Transmitter Parameters

5.1.1 Requirement 8.2: Carrier power (conducted)

Maximum +14 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

5.1.2 Requirement 8.3 Effective radiated power

Maximum +14 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

5.1.3 Requirement 8.5: Transient power

Figure 1 and Figure 2 show that the CC1101 is compliant for both 1.2 kBaud and 38.4 kBaud data rates. Alternate channel is at ±200 kHz, 4^{th} channel at ±400 kHz, and 10^{th} channel at ±1 MHz offsets. PA power ramp-up must be used to meet the transient power regulatory requirements, which are -27 dBm for the alternate channel and -36 dBm for the 4^{th} and 10^{th} channels.

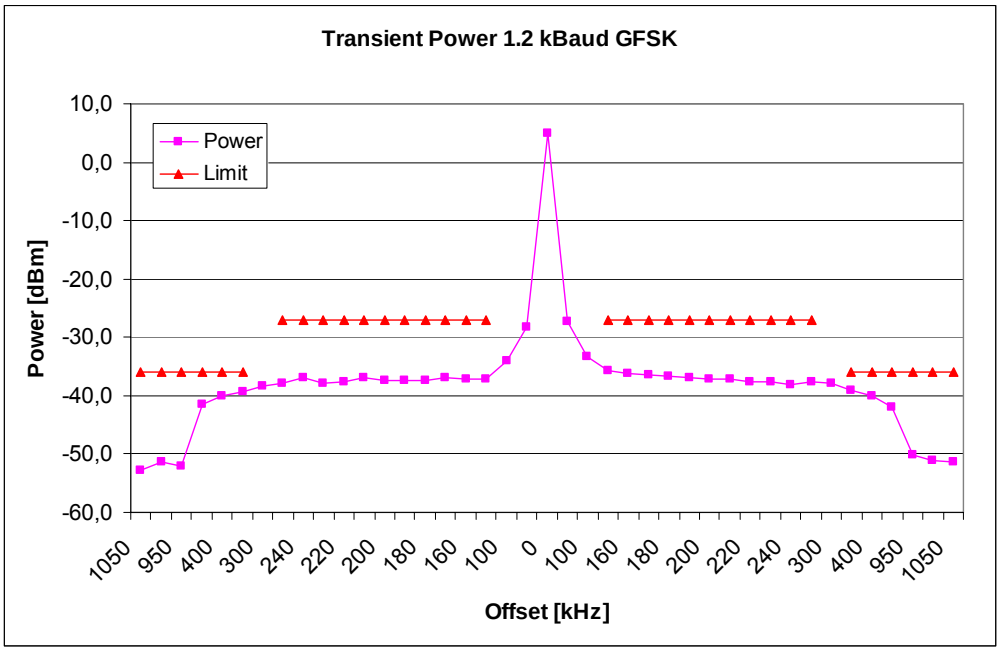

Figure 1: Typical transient power at +5 dBm output power, 1.2 kBaud data rate

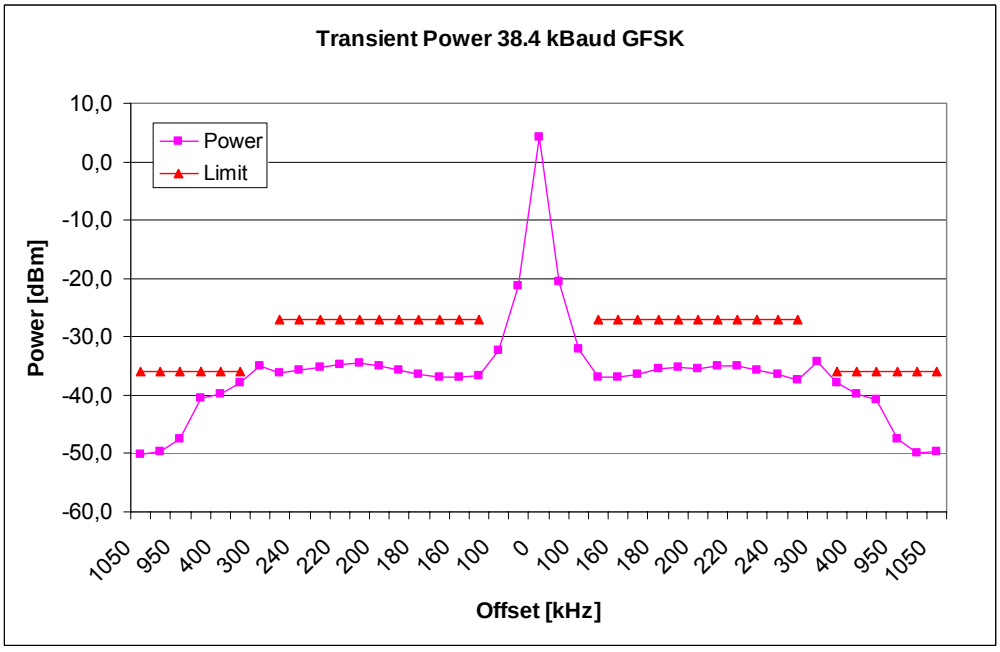

Figure 2: Typical transient power at +5 dBm output power, 38.4 kBaud data rate

5.1.4 Requirement 8.6: Adjacent channel power (ACP)

The limits for power in the adjacent channels are -37 dBm at normal conditions and -32 dBm at extreme conditions (-10°C to +55°C).

The ACP puts an upper limit on the output power with the spectrum analyzer RBW set to 100 Hz. The CC1101 ACP, with +5 dBm output power, is typically -38 dBm for 1.2 kBaud and 38.4 kBaud data rate.

5.1.5 Requirement 8.7: Modulation bandwidth for wideband equipment

This test only applies to channel spacing of >200 kHz.

5.1.6 Requirement 8.8: Spurious emission

The spurious emission is below the EN 300-220-1 requirements. Note that there is one spur at 699 MHz, which is close to limit at -54 dBm.

5.2 Receiver parameters

5.2.1 Requirement 9.1: Maximum useable sensitivity (conducted)

System parameters	CC1101 sensitivity [dBm]	Limit [dBm]
1.2 kBaud, GFSK, 5.2 kHz deviation, 58 kHz RX filter bandwidth	-111	-101.4
38.4 kBaud, GFSK, 14.3 kHz deviation, 101 kHz RX filter bandwidth	-103	-99

Table 3: Typical CC1101 sensitivity performance and EN 300 220 limits

5.2.2 Requirement 9.2: Receiver LBT threshold and transmitter max on-time

The LBT threshold limit is -90 dBm for a channel spacing of 100 kHz and output power less than 20 dBm [1]. Both 1.2 kBaud and 38.4 kBaud comply with this requirement. For a given AGCCTRL2.MAX_LNA_GAIN and AGCCTRL2.MAX_DVGA_GAIN register setting the absolute threshold can be adjusted ±7 dB in steps of 1 dB using CARRIER_SENSE_ABS_THR. See CC1101 data sheet for more details.

As an example, using the 1.2 kBaud register settings used for optimized sensitivity the sensitivity in RX mode is -111 dBm. In LBT mode it is better to have the threshold closer to the LBT threshold limit. The LBT threshold can be set to -104 dBm using CARRIER_SENSE_ABS_THR together with the register settings optimized sensitivity.

5.2.3 Requirement 9.4: Blocking or desensitization.

The wanted signal was set 3 dB above maximum useable sensitivity in requirement 9.1. The blocking performance was measured at ±2 MHz and ±10 MHz offsets. The measurement was repeated with the wanted signal

increased by 13 dB to 16 dB above the useable sensitivity limit. The latter test is only applicable for receivers with LBT.

System parameters	Wanted signal level [dBm]	Jammer offset [MHz]	Jammer signal level [dBm]	Limit [dBm]
1.2 kBaud, 58 kHz RX filter bandwidth. RX mode	-98.4	±2	-38	≥-69
		±10	-30	≥-44
1.2 kBaud, 58 kHz RX filter bandwidth. LBT mode	-85.4	±2	-26	≥-35
		±10	-24	≥-35
38.4 kBaud, 101 kHz RX filter bandwidth. RX mode	-98.4	±2	-47	≥-69
		±10	-37	≥-44
38.4 kBaud, 101 kHz RX filter bandwidth. LBT mode	-85.4	±2	-33	≥-35
		±10	-25	≥-35

Table 4: Typical CC1101 blocking performance and EN 300 220 limits

250kBaud:
868.3MHz +/-
127kHz in Tx
541.67kHz Rx filter

6 868 - 868.6 MHz, No Channel Spacing (g1)

The following system parameters were used for the tests referred to in this section:

Baud rate [kBaud]	Modulation format	Frequency deviation [kHz]	Output power [dBm]	RX channel filter bandwidth [kHz]
1.2	GFSK	5.2	+10	58
38.4	GFSK	20	+10	101
76.8	GFSK	32	+10	203
100	GFSK	47	+10	270
175	GFSK	95	+10	464

Table 5: System parameters for tests in the 868 - 868.6 MHz frequency band

6.1 Transmitter Parameters

6.1.1 Requirement 8.2: Carrier power (conducted)

Maximum +14 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

6.1.2 Requirement 8.3 Effective radiated power

Maximum +14 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

6.1.3 Requirement 8.5: Transient power

The 868 – 868.6 MHz sub-band is 600 kHz wide. The transient power measurements are performed at ±2·600 kHz, ±4·600 kHz, and ±10·600 kHz offsets.

At ±1.2 MHz offset the CC1101 has more than 10 dB margin to the -27 dBm limit.

6.1.4 Requirement 8.6: Adjacent channel power (ACP)

This only applies to narrowband systems with channel spacing <200 kHz.

6.1.5 Requirement 8.7: Modulation bandwidth for wideband equipment

Assuming a ±10 ppm initial crystal tolerance, and ±10 ppm temperature drift, 35 kHz shall be added to the measured MBW/OBW. This number shall be <600 kHz.

System parameters	99% OBW [kHz]	MBW [kHz]	MBW_{tot} [kHz]	Limit [kHz]
1.2 kBaud, GFSK, 5.2 kHz deviation	11	16	51	<600
38.4 kBaud, GFSK, 20 kHz deviation	66	116	151	<600
76.8 kBaud, GFSK, 32 kHz deviation	114	168	203	<600
100 kBaud, GFSK, 47 kHz deviation	167	300	335	<600
175 kBaud, GFSK, 95 kHz deviation	390	525	560	<600

Table 6: Typical CC1101 modulation bandwidth and EN 300 220 limits

6.1.6 Requirement 8.8: Spurious emission

The spurious emission is below the EN 300 220-1 requirements. Note that there is one spur at 699 MHz, which is close to limit at -54 dBm.

6.2 Receiver Parameters

6.2.1 Requirement 9.1: Maximum useable sensitivity (conducted)

System parameters	CC1101 sensitivity [dBm]	Limit [dBm]
1.2 kBaud, GFSK, 5.2 kHz deviation, 58 kHz RX filter bandwidth	-111	-101.4
38.4 kBaud, GFSK, 20 kHz deviation, 101 kHz RX filter bandwidth	-103	-99
76.8 kBaud, GFSK, 32 kHz deviation, 203 kHz RX filter bandwidth	-101	-96
100 kBaud, GFSK, 47 kHz deviation, 270 kHz RX filter bandwidth	-99	-94.7
175 kBaud, GFSK, 95 kHz deviation, 464 kHz RX filter bandwidth	-95	-92.4

Table 7: Typical CC1101 sensitivity performance and EN 300 220 limits

The sensitivity figures in Table 7 assume that register settings optimized for sensitivity being used.

6.2.2 Requirement 9.2: Receiver LBT threshold and transmitter max on-time

EN 300 220-1 has LBT threshold limits relative to channel spacing. A reasonable interpretation is that the 868 - 868.6 MHz sub-band has a “channel spacing” of 600 kHz and thus an LBT limit of -82 dBm when 1 channel is being used and the output power is less than 20 dBm [1].

For data rates >100 kBaud the register settings optimized for sensitivity cannot be used when doing listen before talk. The reason is that the LBT blocking requirements are then violated (covered in section 6.2.3).

For data rates ≤100 kBaud the LBT threshold can be set to a higher level than the sensitivity in Table 7 by programming CARRIER_SENSE_ABS_THR and still meet the LBT blocking requirements.

6.2.3 Requirement 9.4: Blocking or desensitization.

For receivers with LBT operating at data rates >100 kBaud it is recommended to use a higher MAX_LNA_GAIN register setting in LBT mode compared to RX mode to meet the -35 dBm limit at ±2 MHz and ±10 MHz offsets with the wanted signal 16 dB above the useable sensitivity limit. A higher MAX_LNA_GAIN register setting corresponds to a lower maximum LNA gain and hence lower sensitivity but better blocking performance.

In normal RX mode, the CC1101 meets the blocking performance at ±2 MHz and ±10 MHz offsets (-69 dBm and -44 dBm respectively) using the register settings optimized for sensitivity for all data rates.

7 868.7 - 869.2 MHz, No Channel Spacing (g2)

The following system parameters were used for the tests referred to in this section:

Baud rate [kBaud]	Modulation format	Frequency deviation [kHz]	Output power [dBm]	RX channel filter bandwidth [kHz]
1.2	GFSK	5.2	+10	58
38.4	GFSK	20	+10	101
76.8	GFSK	32	+10	203
100	GFSK	47	+10	270

Table 8: System parameters for tests in the 868.7 - 869.2 MHz frequency band

7.1 Transmitter Parameters

7.1.1 Requirement 8.2: Carrier power (conducted)

Maximum +14 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

7.1.2 Requirement 8.3 Effective radiated power

Maximum +14 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

7.1.3 Requirement 8.5: Transient power

The 868.7 – 869.2 MHz sub-band is 500 kHz wide. The transient power measurements are performed at ±2·500 kHz, ±4·500 kHz, and ±10·500 kHz offsets.

At ±1.0 MHz offset the CC1101 has approximately 15 dB margin to the -27 dBm limit.

7.1.4 Requirement 8.6: Adjacent channel power (ACP)

This only applies to narrowband systems with channel spacing <200 kHz.

7.1.5 Requirement 8.7: Modulation bandwidth for wideband equipment

By assuming a ±10 ppm initial crystal variation, and ±10 ppm temperature drift, 35 kHz shall be added to the measured MBW/OBW. This number shall be <500 kHz.

System parameters	99% OBW [kHz]	MBW [kHz]	MBW_{tot} [kHz]	Limit [kHz]
1.2 kBaud, GFSK, 5.2 kHz deviation	11	16	51	<500
38.4 kBaud, GFSK, 20 kHz deviation	66	116	151	<500
76.8 kBaud, GFSK, 32 kHz deviation	114	168	203	<500
100 kBaud, GFSK, 47 kHz deviation	167	300	335	<500

Table 9: Typical CC1101 modulation bandwidth and EN 300 220 limits

7.1.6 Requirement 8.8: Spurious emission

The spurious emission is below the EN 300-220 requirements. Note that there is one spur at 699 MHz, which is close to limit at -54 dBm.

7.2 Receiver Parameters

7.2.1 Requirement 9.1: Maximum useable sensitivity (conducted)

System parameters	CC1101 sensitivity [dBm]	Limit [dBm]
1.2 kBaud, GFSK, 5.2 kHz deviation, 58 kHz RX filter bandwidth	-111	-101.4
38.4 kBaud, GFSK, 20 kHz deviation, 101 kHz RX filter bandwidth	-103	-99
76.8 kBaud, GFSK, 32 kHz deviation, 203 kHz RX filter bandwidth	-101	-96
100 kBaud, GFSK, 47 kHz deviation, 270 kHz RX filter bandwidth	-99	-94.7

Table 10: Typical CC1101 sensitivity performance and EN 300 220 limits

7.2.2 Requirement 9.2: Receiver LBT threshold and transmitter max on-time

EN 300 220-1 has LBT threshold limits relative to channel spacing. A reasonable interpretation is that the 868.7 - 869.2 MHz sub-band has a “channel spacing” of 500 kHz and thus an LBT limit of -83 dBm when 1 channel is being used and the output power is less than 20 dBm [1].

For data rates ≤100 kBaud the LBT threshold can be set to a higher level than the sensitivity in Table 10 by programming CARRIER_SENSE_ABS_THR and still meet the LBT blocking requirements.

7.2.3 Requirement 9.4: Blocking or desensitization.

For receivers with LBT the blocking requirements are met using the register settings optimized for sensitivity for all data rates in Table 10.

In normal RX mode the blocking requirements are met using the register settings optimized for sensitivity for all data rates in Table 10.

8 869.4 - 869.65 MHz, No Channel Spacing (g3)

A 27 MHz crystal frequency is recommended used when operating in this frequency band for maximum CC1101 output power.

The following system parameters were used for the tests referred to in this section:

Baud rate [kBaud]	Modulation format	Frequency deviation [kHz]	Output power [dBm]	RX channel filter bandwidth [kHz]
1.2	GFSK	5.2	+10	58
38.4	GFSK	20	+10	101
76.8	GFSK	32	+10	203

Table 11: System parameters for tests in the 869.4 - 869.65 frequency band

8.1 Transmitter Parameters

8.1.1 Requirement 8.2: Carrier power (conducted)

Maximum +27 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

8.1.2 Requirement 8.3 Effective radiated power

Maximum +27 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

8.1.3 Requirement 8.5: Transient power

The 869.4 – 869.65 MHz sub-band is 250 kHz wide. The transient power measurements are performed at ±2·250 kHz, ±4·250 kHz, and ±10·250 kHz offsets.

At ±500 kHz offset the CC1101 has approximately 7 dB margin to the -27 dBm limit. At ±1 MHz offset the CC1101 has approximately 7 dB margin to the -36 dBm limit.

8.1.4 Requirement 8.6: Adjacent channel power (ACP)

This only applies to narrowband systems with channel spacing <200 kHz.

8.1.5 Requirement 8.7: Modulation bandwidth for wideband equipment

By assuming a ±10 ppm initial crystal variation, and ±10 ppm temperature drift, 35 kHz shall be added to the measured MBW/OBW. This number shall be <250 kHz.

System parameters	99% OBW [kHz]	MBW [kHz]	MBW_{tot} [kHz]	Limit [kHz]
1.2 kBaud, GFSK, 5.2 kHz deviation	11	16	51	<250
38.4 kBaud, GFSK, 20 kHz deviation	66	116	151	<250
76.8 kBaud, GFSK, 32 kHz deviation	114	168	203	<250

Table 12: Typical CC1101 modulation bandwidth and EN 300 220 limits

8.1.6 Requirement 8.8: Spurious emission

Close-in spurs increases in power as the frequency increases towards 870 MHz when using a 26 MHz crystal. The maximum output power is then limited to +7 dBm. With a 27 MHz crystal the maximumCC1101 output power of +10 dBm can be used.

8.2 Receiver Parameters

8.2.1 Requirement 9.1: Maximum useable sensitivity (conducted)

System parameters	CC1101 sensitivity [dBm]	Limit [dBm]
1.2 kBaud, GFSK, 5.2 kHz deviation, 58 kHz RX filter bandwidth	-111	-101.4
38.4 kBaud, GFSK, 20 kHz deviation, 101 kHz RX filter bandwidth	-103	-99
76.8 kBaud, GFSK, 32 kHz deviation, 203 kHz RX filter bandwidth	-101	-96

Table 13: Typical CC1101 sensitivity performance and EN 300 220 limits

8.2.2 Requirement 9.2: Receiver LBT threshold and transmitter max on-time

EN 300 220-1 has LBT threshold limits relative to channel spacing. A reasonable interpretation is that the 869.4 - 869.65 MHz sub-band has a “channel spacing” of 250 kHz and thus an LBT limit of approximately -86 dBm when 1 channel is being used and the output power is less than 20 dBm [1].

The data rates in Table 13 comply with this requirement. For a given AGCCTRL2.MAX_LNA_GAIN and AGCCTRL2.MAX_DVGA_GAIN register setting the absolute threshold can be adjusted ±7 dB in steps of 1 dB using CARRIER_SENSE_ABS_THR. See CC1101 data sheet for more details.

8.2.3 Requirement 9.4: Blocking or desensitization.

For receivers with LBT the blocking requirements are met using the register settings optimized for sensitivity for all data rates in Table 13.

In normal RX mode the blocking requirements are met using the register settings optimized for sensitivity for all data rates in Table 13.

9 869.7 - 870 MHz, No Channel Spacing (g4)

A 27 MHz crystal frequency is recommended used when operating in this frequency band for maximum CC1101 output power.

The following system parameters were used for the tests referred to in this section:

Baud rate [kBaud]	Modulation format	Frequency deviation [kHz]	Output power [dBm]	RX channel filter bandwidth [kHz]
1.2	GFSK	5.2	+10	58
38.4	GFSK	20	+10	101
76.8	GFSK	32	+10	203

Table 14: System parameters for tests in the 869.7 - 870 MHz frequency band

9.1 Transmitter Parameters

9.1.1 Requirement 8.2: Carrier power (conducted)

Maximum +7 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

9.1.2 Requirement 8.3 Effective radiated power

Maximum +7 dBm output power is allowed. The CC1101 has a maximum output power of +10 dBm.

9.1.3 Requirement 8.5: Transient power

The 869.7 – 870 MHz sub-band is 300 kHz wide. The transient power measurements are performed at ±2·300 kHz, ±4·300 kHz, and ±10·300 kHz offsets.

At ±600 kHz offset the CC1101 has approximately 10 dB margin to the -27 dBm limit. At ±1.2 MHz offset the CC1101 has approximately 4 dB margin to the -36 dBm limit.

9.1.4 Requirement 8.6: Adjacent channel power (ACP)

This only applies to narrowband systems with channel spacing <200 kHz.

9.1.5 Requirement 8.7: Modulation bandwidth for wideband equipment

By assuming a ±10 ppm initial crystal variation, and ±10 ppm temperature drift, 35 kHz shall be added to the measured MBW/OBW. This number shall be <300 kHz.

System parameters	99% OBW [kHz]	MBW [kHz]	MBW_{tot} [kHz]	Limit [kHz]
1.2 kBaud, GFSK, 5.2 kHz deviation	11	16	51	<300
38.4 kBaud, GFSK, 20 kHz deviation	66	116	151	<300
76.8 kBaud, GFSK, 32 kHz deviation	114	168	203	<300

Table 15: Typical CC1101 modulation bandwidth and EN 300 220 limits (measured with +10 dBm output power)

9.1.6 Requirement 8.8: Spurious emission

Close-in spurs increases in power as the frequency increases towards 870 MHz when using a 26 MHz crystal. The maximum output power is then limited to +5 dBm. With a 27 MHz crystal the maximum output power of +7 dBm can be used.

9.2 Receiver Parameters

9.2.1 Requirement 9.1: Maximum useable sensitivity (conducted)

System parameters	CC1101 sensitivity [dBm]	Limit [dBm]
1.2 kBaud, GFSK, 5.2 kHz deviation, 58 kHz RX filter bandwidth	-111	-101.4
38.4 kBaud, GFSK, 20 kHz deviation, 101 kHz RX filter bandwidth	-103	-99
76.8 kBaud, GFSK, 32 kHz deviation, 203 kHz RX filter bandwidth	-101	-96

Table 16: Typical CC1101 sensitivity performance and EN 300 220 limits

9.2.2 Requirement 9.2: Receiver LBT threshold and transmitter max on-time

EN 300 220-1 has LBT threshold limits relative to channel spacing. A reasonable interpretation is that the 869.7 - 870 MHz sub-band has a “channel spacing” of 300 kHz and thus an LBT limit of approximately -84.5 dBm when 1 channel is being used and the output power is less than 20 dBm [1].

The data rates in Table 16 comply with this requirement. For a given AGCCTRL2.MAX_LNA_GAIN and AGCCTRL2.MAX_DVGA_GAIN register setting the absolute threshold can be adjusted ±7 dB in steps of 1 dB using CARRIER_SENSE_ABS_THR. See CC1101 data sheet for more details.

9.2.3 Requirement 9.4: Blocking or desensitization.

For receivers with LBT the blocking requirements are met using the register settings optimized for sensitivity for all data rates in Table 16.

In normal RX mode the blocking requirements are met using the register settings optimized for sensitivity for all data rates in Table 16.

10 References

[1] ETSI EN 300 220 V2.1.1: 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"

[2] CEPT/ERC/Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)"

[3] CC1101EM 868 – 915 MHz Reference Design 2.0 (swrr044.zip)

[4] SmartRF® Studio (swrc046.zip)

11 General Information

11.1 Document History

Revision	Date	Description/Changes
SWRA146A	2007.10.25	Changed the maximum recommended data rate for sub band g1, g2, g3 and g4.
SWRA146	2007.06.28	Initial release.

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