CC1020/1021 - Reducing Spurious Emission

By S. Hellan

Keywords

- *Spurious emission*
- *EN 300 220*
- *ACP*
- *Selectivity*

1 Introduction

The CC1020/1021 reference frequency, f_{ref}, is the crystal oscillator clock frequency divided by REF_DIV + 1, where REF_DIV is a number between 1 and 7.

When operating the CC1020/1021 transceiver in the (European) 868 – 870 MHz frequency band in Tx mode with 14.7456 MHz crystal frequency and REF_DIV = 1, the highest spurious components have been found at frequencies around 650 MHz, 760 MHz and 862 MHz.

The spurious components around 862 MHz are close to the –54 dBm level specified by ETSI EN 300 220.

This application note presents a solution that reduces the spurious emission close to 862 MHz by increasing REF_DIV from 1 to 7 in Tx mode.

Table of Contents

KEYWORDS.......... 1
1 INTRODUCTION.......... 1
2 ABBREVIATIONS.......... 2
3 TEST SETUP.......... 3
3.1 SYSTEM PARAMETERS.......... 3
3.2 PLL LOOP FILTER.......... 3
3.3 TEST CASES.......... 4
3.3.1 Register settings for TEST 1.......... 5
3.3.2 Register settings for TEST 2.......... 6
3.3.3 Register settings for TEST 3.......... 7
4 TEST RESULTS AND DISCUSSIONS.......... 8
4.1 TRANSMIT MODE.......... 8
4.1.1 Adjacent channel power (ACP).......... 8
4.1.2 Spurious emission.......... 8
4.2 RECEIVE MODE.......... 9
4.2.1 Sensitivity.......... 9
4.2.2 Blocker rejection.......... 9
5 CONCLUSIONS.......... 10
6 GENERAL INFORMATION.......... 11
6.1 DOCUMENT HISTORY.......... 11
6.2 DISCLAIMER.......... 11
6.3 TRADEMARKS.......... 11
6.4 LIFE SUPPORT POLICY.......... 11
7 ADDRESS INFORMATION.......... 12

2 Abbreviations

ACP	Adjacent Channel Power
EIRP	Effective Isotropic Radiated Power
LO	Local Oscillator (in receive mode)
PLL	Phase Locked Loop
RBW	Resolution Bandwidth (for spectrum analyzer)
Tx	Transmit (mode)
VBW	Video Bandwidth (for spectrum analyzer)

3 Test setup

3.1 System parameters

Figure 1 shows the system parameters used for CC1020.

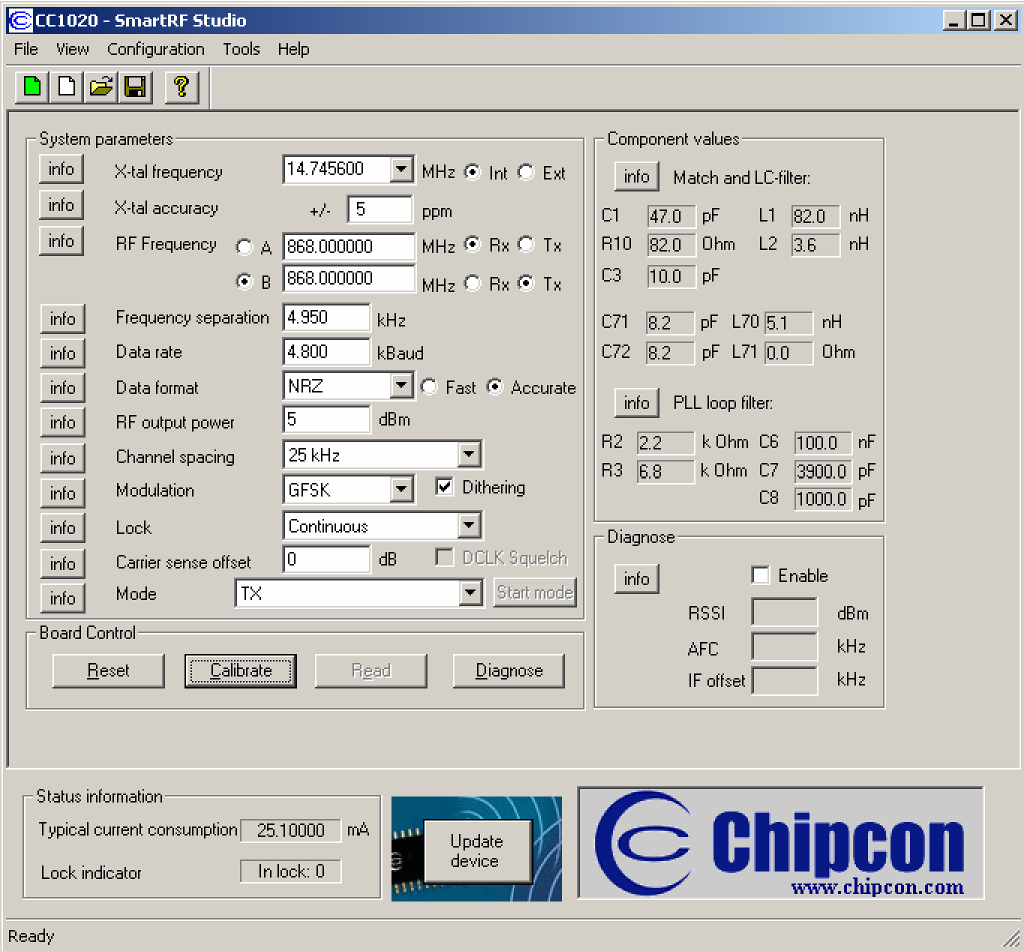

Figure 1. CC1020 system parameters

3.2 PLL loop filter

The reference frequency, f_{ref}, is the crystal oscillator clock frequency divided by REF_DIV (3 bits in the CLOCK_A or CLOCK_B register) + 1.

$$f_{ref} = \frac{f_{xosc}}{REF\_DIV + 1} \tag{1}$$

For a given PLL loop filter bandwidth, the loop filter resistor values decrease and the capacitor values increase with increasing f_{ref}. Furthermore, for a given set of loop filter component values the PLL loop filter bandwidth is proportional to the charge pump current. The charge pump current is set by the PLL_BW register (note that a PLL calibration needs to be performed for the PLL_BW register setting to take effect). The PLL_BW can be found from

$$PLL\_BW = 174 + 16 \log_2(f_{ref} / 7.126) \tag{2}$$

where f_{ref} is the reference frequency (in MHz). The PLL loop filter bandwidth increases with increasing PLL_BW setting. If the PLL_BW setting is changed by Δx decimal, the charge pump changes by a factor $2^{\Delta x/16}$. As an example, if PLL_BW changes by 32 decimal the charge pump current changes with a factor 4.

The loop filter component values given as "Loop filter 1" in Table 1 are recommended by SmartRF® Studio when operating at 4.8 kBaud and 25 kHz channel spacing (19.2 kHz receiver filter bandwidth) with REF_DIV = 1. If REF_DIV is increased to 7, the reference frequency is reduced by a factor 4 (Equation 1). "Loop filter 2" in Table 1 gives the loop filter component values in this case.

Component	Loop filter 1	Loop filter 2	Unit
C6	100	22	nF
C7	3900	1000	pF
C8	1000	270	pF
R2	2.2	10	kΩ
R3	6.8	27	kΩ
REF_DIV	1	7	decimal
f_{ref}	7.3728	1.8432	MHz

Table 1. Loop filter components value

If the "Loop filter 2" component values are used with REF_DIV = 1 instead of REF_DIV = 7, the charge pump current should be reduced by a factor 4 to give the same PLL loop filter bandwidth in both cases. That is, PLL_BW should be reduced with 32 decimal when REF_DIV = 1 compared to when REF_DIV = 7.

3.3 Test cases

Three tests were performed:

- **TEST 1:** REF_DIV = 1 in Rx and Tx and "Loop filter 1"
- **TEST 2:** REF_DIV = 7 in Rx and Tx and "Loop filter 2"
- **TEST 3:** REF_DIV = 1 in Rx and REF_DIV = 7 in Tx and "Loop filter 2"

3.3.1 Register settings for TEST 1

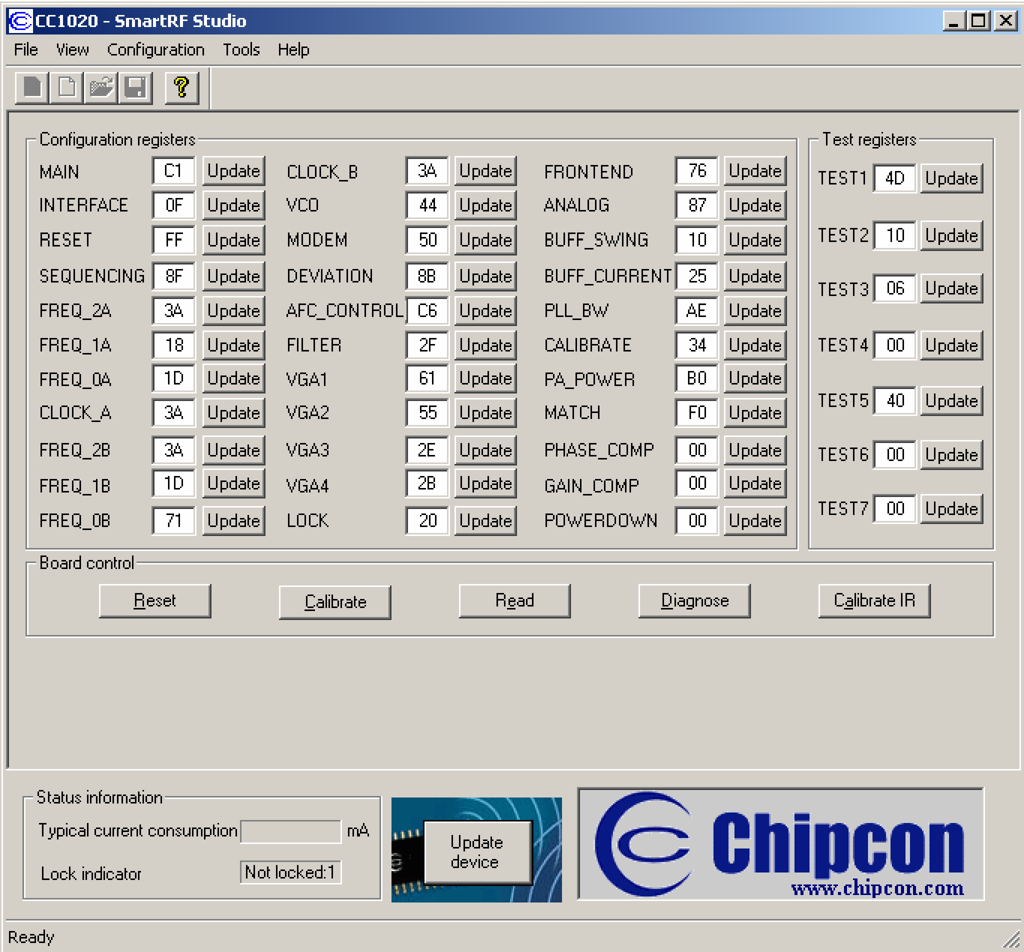

Figure 2. CC1020 register settings for TEST 1

- Registers FREQ_2A to FREQ_0A sets up the receiver LO frequency with REF_DIV = 1
- Register CLOCK_A sets up the data rate in receive with REF_DIV = 1
- Registers FREQ_2B to FREQ_0B sets up the transmit RF frequency with REF_DIV = 1
- Register CLOCK_B sets up the data rate in transmit with REF_DIV = 1
- Register DEVIATION sets up the frequency deviation with REF_DIV = 1
- Register PLL_BW = AE_h sets up the charge pump current in receive and transmit mode

3.3.2 Register settings for TEST 2

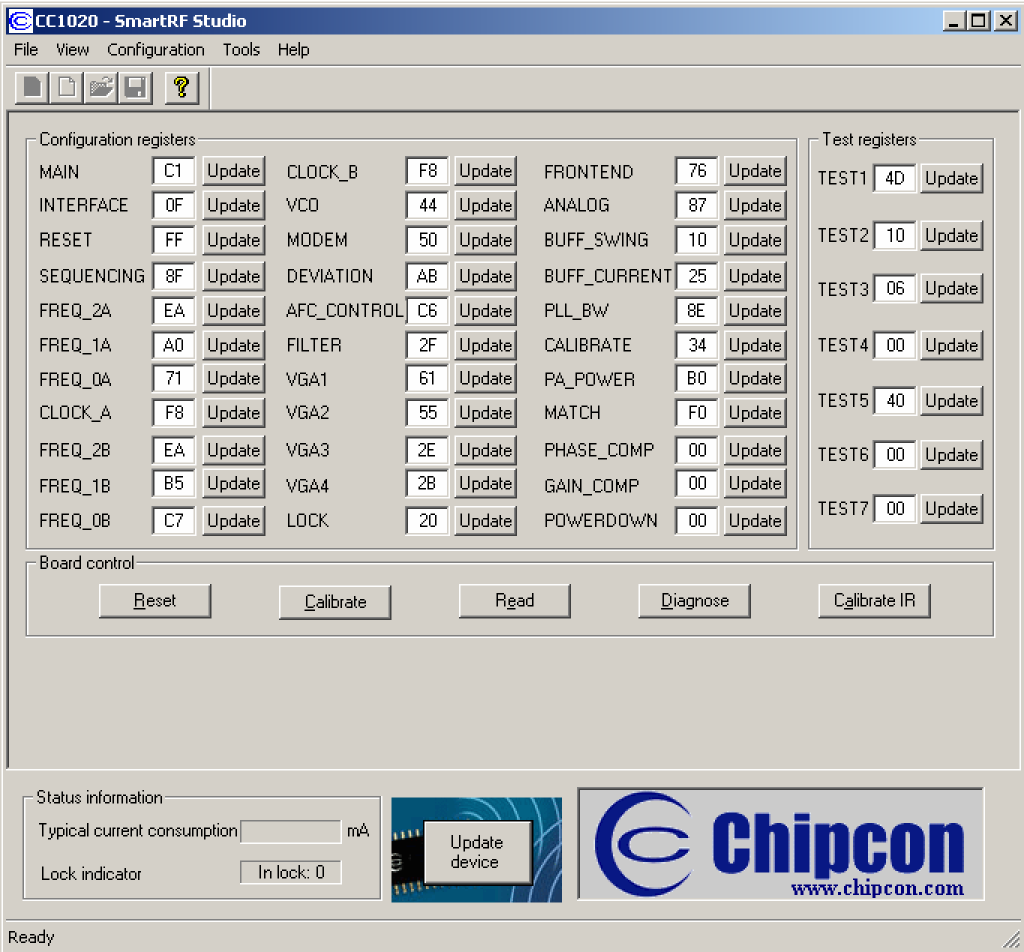

Figure 3. CC1020 register settings for TEST 2

- Registers FREQ_2A to FREQ_0A sets up the receiver LO frequency with REF_DIV = 7
- Register CLOCK_A sets up the data rate in receive with REF_DIV = 7
- Registers FREQ_2B to FREQ_0B sets up the transmit RF frequency with REF_DIV = 7
- Register CLOCK_B sets up the data rate in transmit with REF_DIV = 7
- Register DEVIATION sets up the frequency deviation with REF_DIV = 7
- Register PLL_BW = $8E_h$ sets up the charge pump current in receive and transmit mode

3.3.3 Register settings for TEST 3

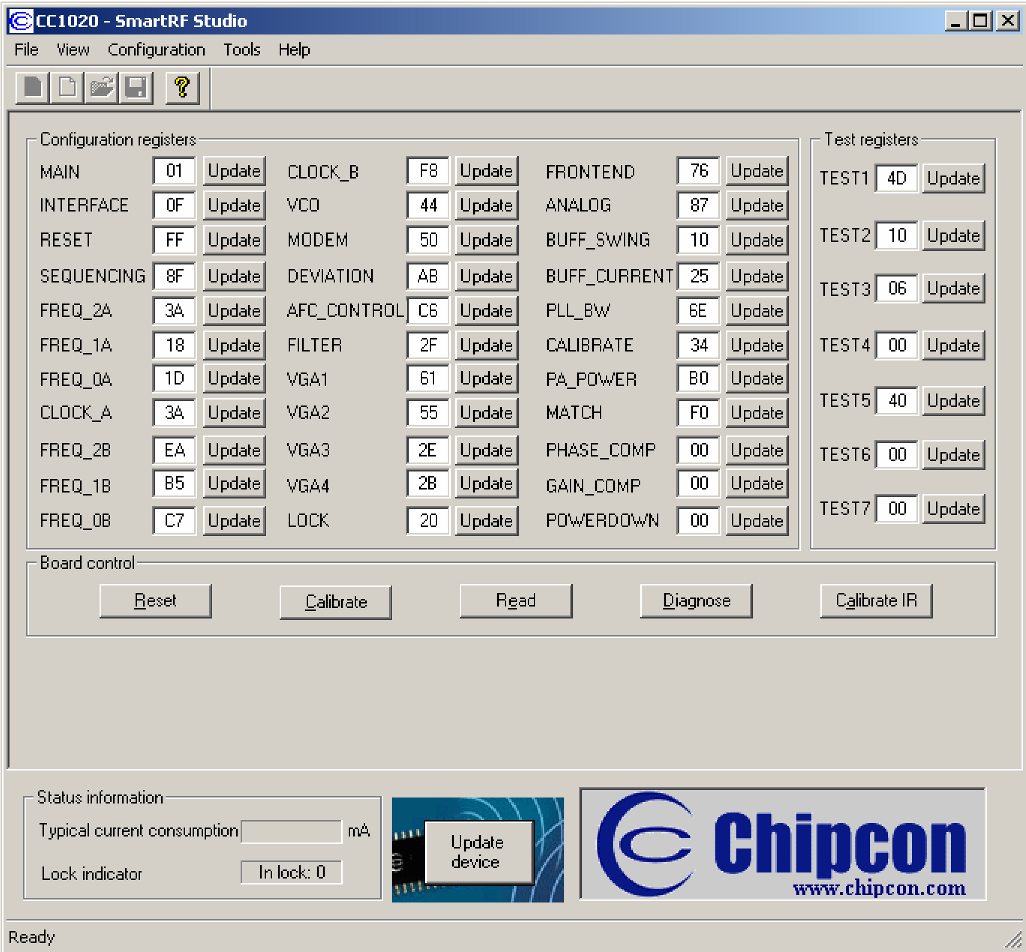

Figure 4. CC1020 register settings for TEST 3 in Rx (in Tx PLL_BW = 8E$_h$)

- Registers FREQ_2A to FREQ_0A sets up the receiver LO frequency with REF_DIV = 1
- Register CLOCK_A sets up the data rate in receive with REF_DIV = 1
- Registers FREQ_2B to FREQ_0B sets up the transmit RF frequency with REF_DIV = 7
- Register CLOCK_B sets up the data rate in transmit with REF_DIV = 7
- Register DEVIATION sets up the frequency deviation with REF_DIV = 7
- Register PLL_BW = 6E$_h$ sets up the charge pump current in receive mode with REF_DIV = 1
- Register PLL_BW = 8E$_h$ sets up the charge pump current in transmit mode with REF_DIV = 7

4 Test results and discussions

- All measurements were performed at 3V, 27°C
- 4 separate CC1020 transceivers were tested using Chipcon's CC1020EMX 2-layer PCB reference design
- The spectrum analyser used was an Anritsu MS2665C

4.1 Transmit mode

4.1.1 Adjacent channel power (ACP)

The ACP was measured using the spectrum analyzer set up with a 140 kHz span and RBW = VBW = 1 kHz. The ACP was measured at 25 kHz and 50 kHz channel spacings with a channel bandwidth of 17 kHz. The ACP was measured as the average of 8 measurements and the internal CC1020 PN9 generator was used. The CC1020 output power was set to +5 dBm.

	TEST 1	TEST 2/3	Unit
ACP, 25 kHz offset	-48.5	-47	dBc
ACP, 50 kHz offset	-58.5	-57	dBc
f_{ref}	7.3728	1.8432	MHz

Table 2. ACP (average of 4 modules)

From Table 2 we see that the ACP is degraded by typically 1.5 dB when using the lower reference frequency. TEST 2/3 employs larger resistor values in the PLL loop filter and lower charge pump current than TEST 1. Thus, the phase noise in TEST 2/3 is slightly higher than for TEST 1 and the ACP will therefore be degraded.

For 25 kHz channel spacing systems as defined by EN 300 220 the ACP requirement is –37 dBm. Thus, for narrowband systems complying with EN 300 220 the output power can not exceed +10 dBm.

4.1.2 Spurious emission

The *conducted* spurious emission was measured using a spectrum analyzer set up with RBW = 100 kHz and peak detector. The CC1020 output power was set to +5 dBm.

Frequency range [MHz]	TEST 1	TEST 2/3	Unit
470 – 600	-59.1	-67.3	dBm
600 – 700	-50.4	-45.7	dBm
700 – 820	-59.4	-59.7	dBm
820 – 862	-55.4	-63.8	dBm
862	-55.4	-69.6	dBm
f_{ref}	7.3728	1.8432	MHz

Table 3. Conducted spurious emissions (maximum of 4 modules)

Spurious emission can be measured as EIRP according to EN 300 220 and the antenna will then play a part in attenuating the spurious emission. The requirement in the 470 – 862 MHz frequency band is that the spurious emissions shall be below – 54 dBm.

From Table 3 we see that the spurious emissions close to 862 MHz are significantly reduced in the 820 - 862 MHz frequency range when using a lower reference frequency. A design not being fully optimised using the 7.3728 MHz reference frequency could lead to significant yield loss or call for an expensive SAW filter.

The highest spur in the 600 – 700 MHz range in Table 3 appears at approximately 655 MHz. Although the antenna normally attenuates the spur at 655 MHz with a few dB's, an external SAW filter or LC bandpass filter most likely will be required to attenuate the spurious emission sufficiently at 655 MHz to be below –54 dBm when using the lower reference frequency.

The highest spur in the 700 – 820 MHz frequency range appears at approximately 760 MHz. Assuming the external filter discussed above attenuates the spurs below 800 MHz we see from Table 3 that the maximum output power can be increased by approximately 10 dB when using REF_DIV = 7 compared to using REF_DIV = 1. For 25 kHz channel spacing systems the ACP requirement sets the upper limit on the output power to +10 dBm, but for a wideband system the maximum output power can be increased to approximately +20 dBm.

4.2 Receive mode

4.2.1 Sensitivity

The cable loss is not accounted for in the below sensitivity measurements.

	TEST 1	TEST 2	TEST 3	Unit
Sensitivity	-110.5	-108.5	-110.5	dBm
f_{ref}	7.3728	1.8432	7.3728	MHz

Table 4. Sensitivity (average of 4 modules)

From Table 4 we see that the sensitivity is reduced by typically 2 dB when using the lower reference frequency (TEST 2). Using the same loop filter components in TEST 3 as in TEST 2, but increasing the reference frequency to the same frequency as used in TEST 1, we obtain the same sensitivity in TEST 1 and TEST 3.

4.2.2 Blocker rejection

The blocker rejection was measured with the wanted signal 3 dB above the sensitivity limit for BER = 10^{-3}. A 1 kHz sine, ±2.5 kHz deviation FM jammer was used as the interfering signal.

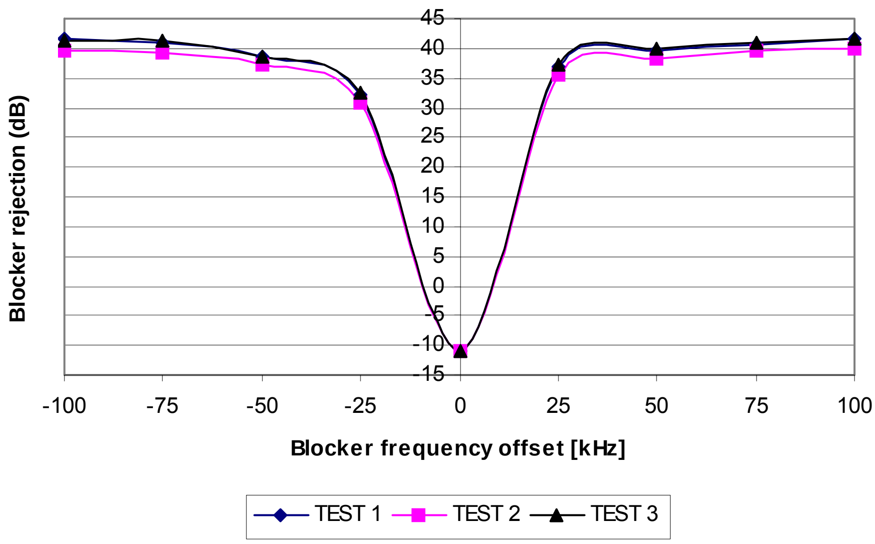

Figure 5. Blocker rejection (average of 4 modules)

From Figure 5 it can be observed that the blocker rejection is reduced by typically 2 dB when using the lower reference frequency (TEST 2). Using the same loop filter components in TEST 3 as in TEST 2, but increasing the reference frequency to the same frequency used in TEST 1, the same blocker rejection is obtained in TEST 1 and TEST 3.

5 Conclusions

Using the CC1020EMX reference design and the SmartRF® Studio default register values the output power can be up to +5 dBm and still meet ETSI's EN 300 220 ACP and spurious emission requirements for 25 kHz channel spacing systems operating in the European 868 – 870 MHz frequency range (see TEST 1 in Table 2 and Table 3).

For 25 kHz channel spacing systems operating in the 868 – 870 MHz frequency range the output power can be increased up to +10 dBm and still meet the EN 300 220 ACP and spurious emission requirements if the reference frequency is reduced from 7.3728 to 1.8432 MHz.

For wideband systems (> 25 kHz channel spacing) operating in the 868 – 870 MHz frequency range the output power can be increased up to +20 dBm and still meet the EN 300 220 spurious emission requirements if the reference frequency is reduced from 7.3728 to 1.8432 MHz.

The change of reference frequency requires changes to the external loop filter component values and to some of the register settings. An external power amplifier must be used to increase the output power up to +10/20 dBm. If an external power amplifier is used an external SAW or LC bandpass filter must be used to attenuate spurious emissions sufficiently to accommodate the EN 300 220 regulations.

Using a 1.8432 MHz reference frequency in receive mode degrades sensitivity and selectivity by approximately 2 dB compared to using a 7.3728 MHz reference frequency (see Table 4 and Figure 5).

To conclude: the CC1020EMX reference design and SmartRF® Studio default register values are recommended if the maximum output power is limited to +5 dBm. If the output power is increased above +5 dBm, an external power amplifier and a SAW or LC bandpass filter must be included in the design. The reference frequency in Tx mode should be 1.8432 MHz to minimize the spurious emissions close to 862 MHz. The reference frequency in Rx mode should be 7.3728 MHz for best sensitivity and selectivity. To obtain the same PLL loop filter bandwidth with different reference frequency in Rx and Tx the charge pump current is adjusted using the PLL_BW register.

6 General Information

6.1 Document History

Revision	Date	Description/Changes
1.0	2005-07-07	Initial release.

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7 Address Information

Web site:	http://www.chipcon.com
E-mail:	wireless@chipcon.com
Technical Support Email:	support@chipcon.com
Technical Support Hotline:	+47 22 95 85 45

Headquarters:

Chipcon AS
Gaustadalléen 21
N-0349 Oslo
NORWAY
Tel: +47 22 95 85 44
Fax: +47 22 95 85 46
E-mail: wireless@chipcon.com

US Offices:

Chipcon Inc., Western US Sales Office
1455 Frazee Road, Suite 800
San Diego, CA 92108
USA
Tel: +1 619 542 1200
Fax: +1 619 542 1222
Email: USsales@chipcon.com

Chipcon Inc., Eastern US Sales Office
35 Pinehurst Avenue
Nashua, New Hampshire, 03062
USA
Tel: +1 603 888 1326
Fax: +1 603 888 4239
Email: eastUSsales@chipcon.com

Sales Office Germany:

Chipcon AS
Riedberghof 3
D-74379 Ingersheim
GERMANY
Tel: +49 7142 9156815
Fax: +49 7142 9156818
Email: Germanysales@chipcon.com

Sales Office Asia:

Chipcon AS
Unit 503, 5/F
Silvercord Tower 2, 30 Canton Road
Tsimshatsui, Hong Kong
Tel: +852 3519 6226
Fax: +852 3519 6520
Email: Asiasales@chipcon.com

Sales Office Asia:

Chipcon AS
Unit 503, 5/F
Silvercord Tower 2, 30 Canton Road
Tsimshatsui
HONG KONG
Tel: +852 3519 6226
Fax: +852 3519 6520
Email:

Asiasales@chipcon.com (China, Hong Kong, Taiwan)

SEAsales@chipcon.com (Korea, South East Asia, India, Australia and New Zealand)

Sales Office Japan:

Chipcon AS
#403, Bureau Shinagawa
4-1-6, Konan, Minato-Ku
Tokyo, Zip 108-0075
JAPAN
Tel: +81 3 5783 1082
Fax: +81 3 5783 1083
Email: Japansales@chipcon.com

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