Si4432 RF Performance and FCC Compliance Test Results

1. Introduction

This document provides measurement results and FCC compliance results for the Si4432B when operated from 902–928 MHz. The measurement results include receiver sensitivity, adjacent channel selectivity, blocking, transmit output power, transmit output spectrum, transmit deviation, and conducted harmonics. The FCC compliance results demonstrate a full FCC compliance scan to FCC 15.247. All tests are performed using an ISM-DK3 kit with a 4432-DKDB1 test card.The Wireless Development Suite (WDS) is used to control the test card. The results can be duplicated by using the same configuration and scripts available on the Silicon Labs website and referenced in the EZRadioPRO® Quick Start Guide.

All settings were used directly from the Excel Register Calculator worksheet provided on the Silicon Labs website. For measurement results with different RF parameters, contact customer support.

Silicon Labs has not attempted to obtain FCC certification on any RF reference design board using Si443x chips. FCC certification is obtained at the module level (and not the chip level), and thus any potential certification that would be obtained on Silicon Labs RF test cards would not be transferable to customer application modules. The compliance test results presented within this application note should be viewed as simply providing confidence to the customer that certification may be obtained, if the recommended RF design and layout practices are followed.

2. Relevant Measurements to comply with FCC

FCC compliance in the US only pertains to output power, emissions, and harmonics. There are no receive sensitivity, selectivity or blocking measurements to comply with FCC. Two sections pertain to operation in the 902-928 MHz band, 15.247 and 15.249. The maximum output power under FCC 15.247 is +30 dBm with Frequency Hopping Spread Spectrum. FCC 15.249 limits the maximum rms field strength to 50 mV/m at a 3 m distance which is equivalent to a radiated output power of –1.2 dBm EIRP for a non-hopping system. The TX measurements in this report assume a Frequency Hopping System operating at +20 dBm under 15.247.

3. RX Measurement Results

3.1. Sensitivity

Sensitivity measurements are done as bit error rate (BER) with BER <0.1%. To convert BER to PER it can be approximated by adding 3 dB (PER = BER+3 dB). A modulation index of H = 1 is used for all cases, with no additional allocation in the IF bandwidth for XTAL tolerance.

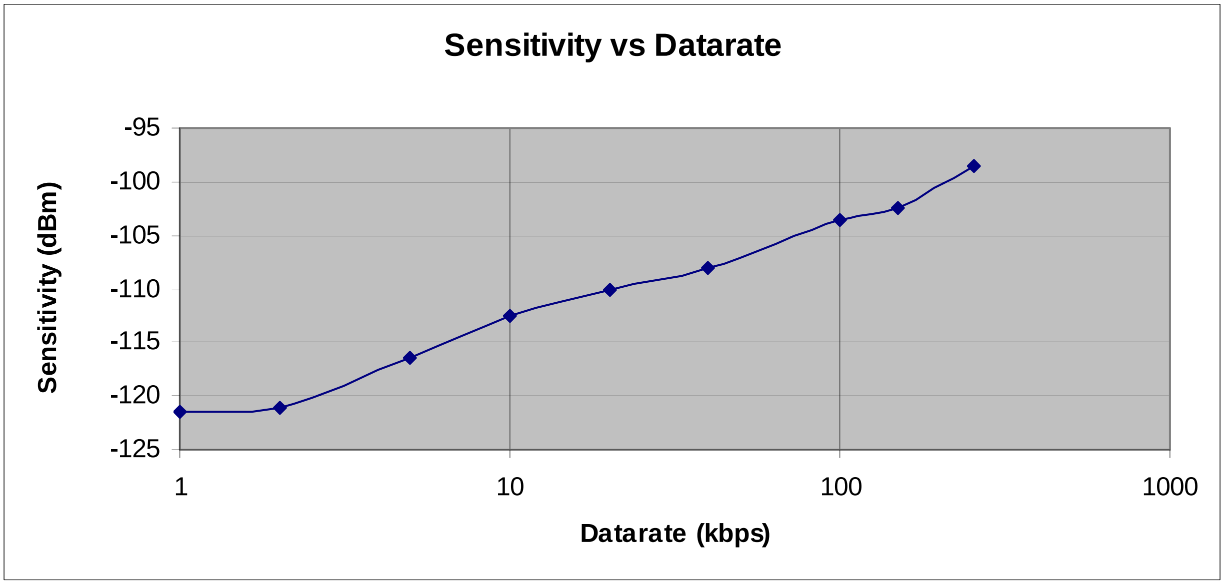

Figure 1. Sensitivity vs. Datarate

3.2. Adjacent Channel Selectivity

All selectivity results are done by positioning the input power 3 dB above sensitivity with the primary signal source generator. A second generator with an unmodulated signal is used as the interferer and combined with the primary signal using a power combiner (e.g., Mini-Circuits ZFSC-2-4-S+). The second interferer generator is placed at the desired frequency offset and then the power is increased until the BER degrades to 0.1% (1E-3). For example, the +1 MHz point in Figure 3 shows 62 dB of rejection. The sensitivity for 5 kbps is –116.5 dBm so the primary generator is set to –113.5 dBm. The secondary generator is set 1 MHz away from the primary generator and its power is increased to –51.5 dBm where the BER degrades to 0.1% which results in a rejection of the interferer by 62 dB.

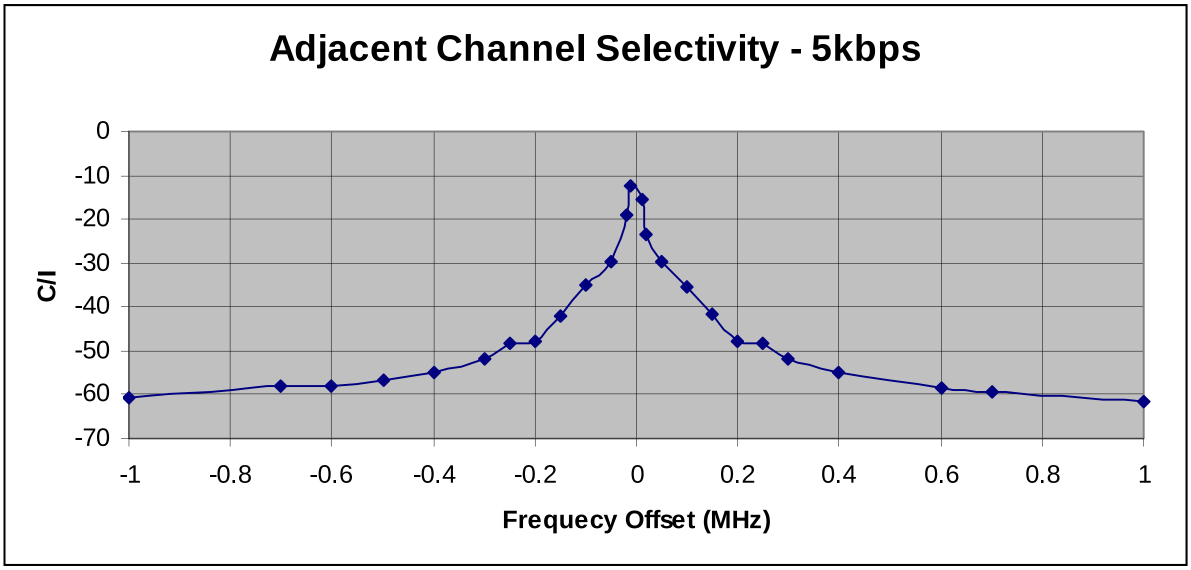

Figure 2. 5 kbps Adjacent Channel Selectivity

Datarate = 5 kbps, Deviation = 2.5 kHz, no allocation in BW for XTAL tolerance.

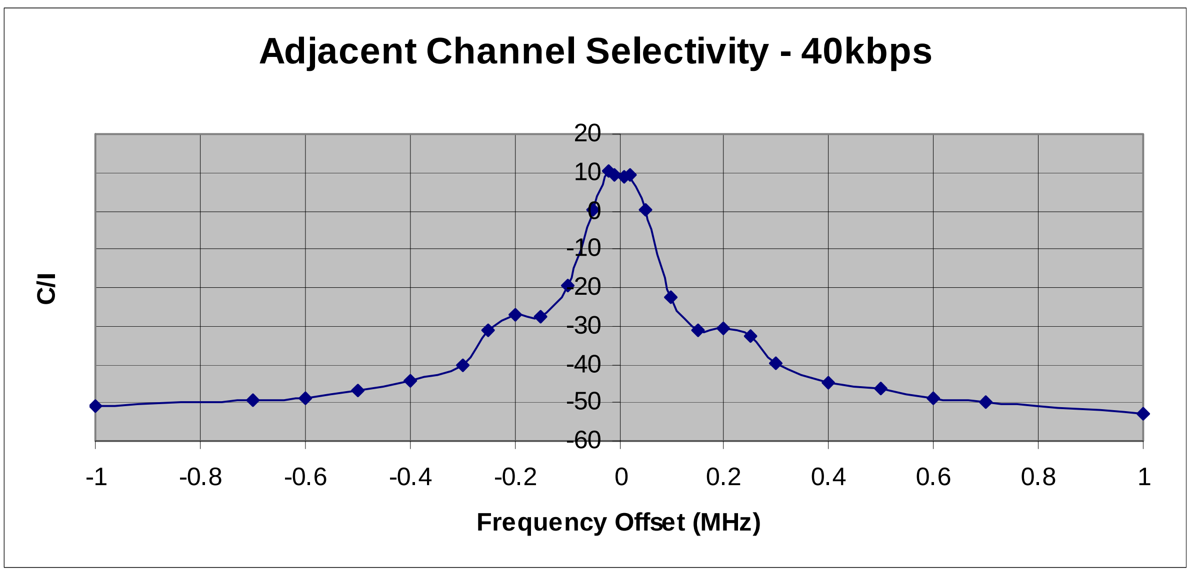

Figure 3. 40 kbps Adjacent Channel Selectivity

Datarate = 40 kbps, Deviation = 20 kHz, no allocation in BW for XTAL tolerance.

3.3. Blocking

Blocking measurements are done with the same measurement technique as described above for the adjacent channel selectivity but are performed at larger frequency offsets.

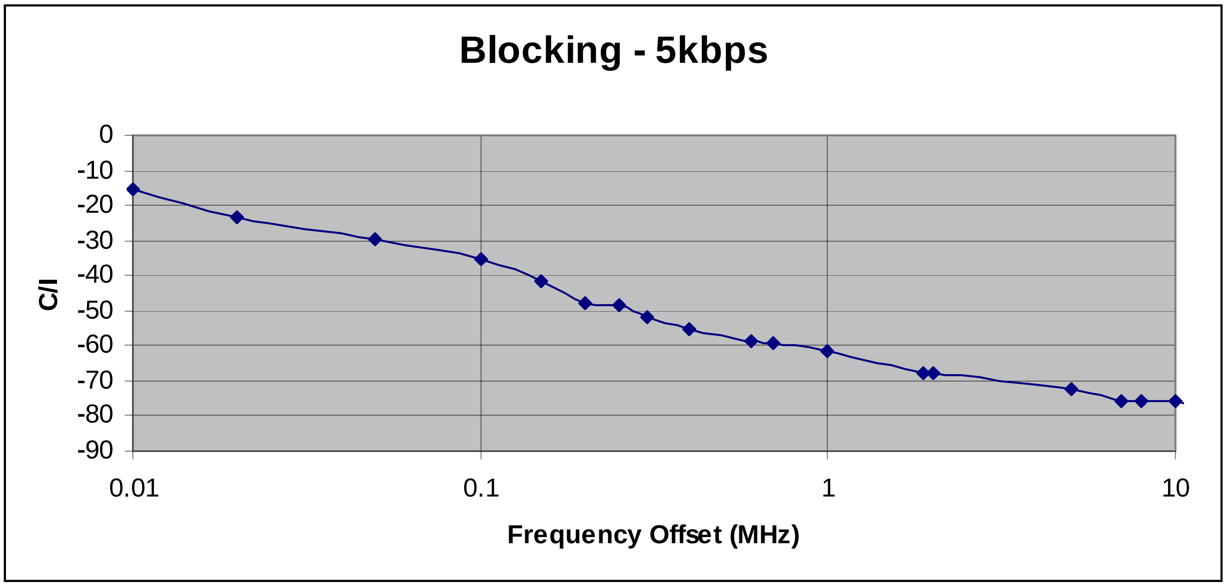

Figure 4. kbps Blocking

Datarate = 5 kbps, Deviation = 2.5 kHz, no allocation in BW for XTAL tolerance.

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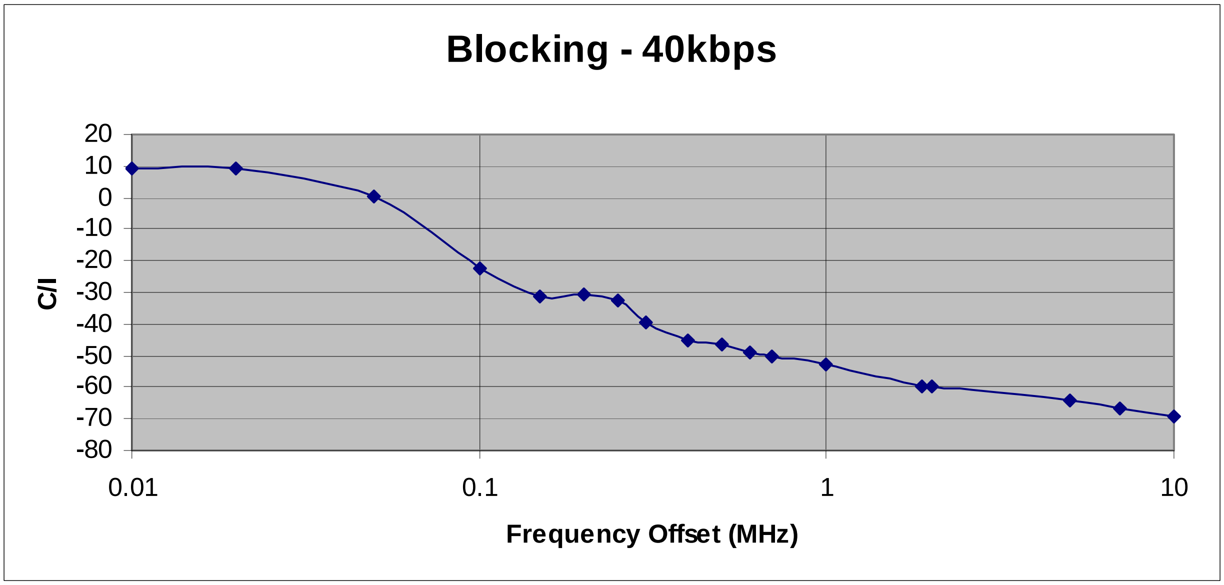

Figure 5. 40 kbps Blocking

Datarate = 40 kbps, Deviation = 20 kHz, no allocation in BW for XTAL tolerance.

3.4. Sensitivity vs. Frequency Offset

The Sensitivity vs. Frequency Offset measurements are referred to as bucket curves due to the shape of the curve. The receiver and generator frequencies are calibrated for zero frequency offset. The signal generator is then offset and the sensitivity measurement is repeated. The performance for this parameter is directly linked to the programmed receive bandwidth. With AFC disabled there is still internal modem compensation which corrects for offsets up to 0.25 x RX BW and with AFC enabled offsets can be corrected up to 0.35 BW. The modem parameters and receiver bandwidths were set using the Excel Register Calculator worksheet assuming a 20 ppm Crystal Tolerance on both the transmitter and receiver as shown in Figure 6.

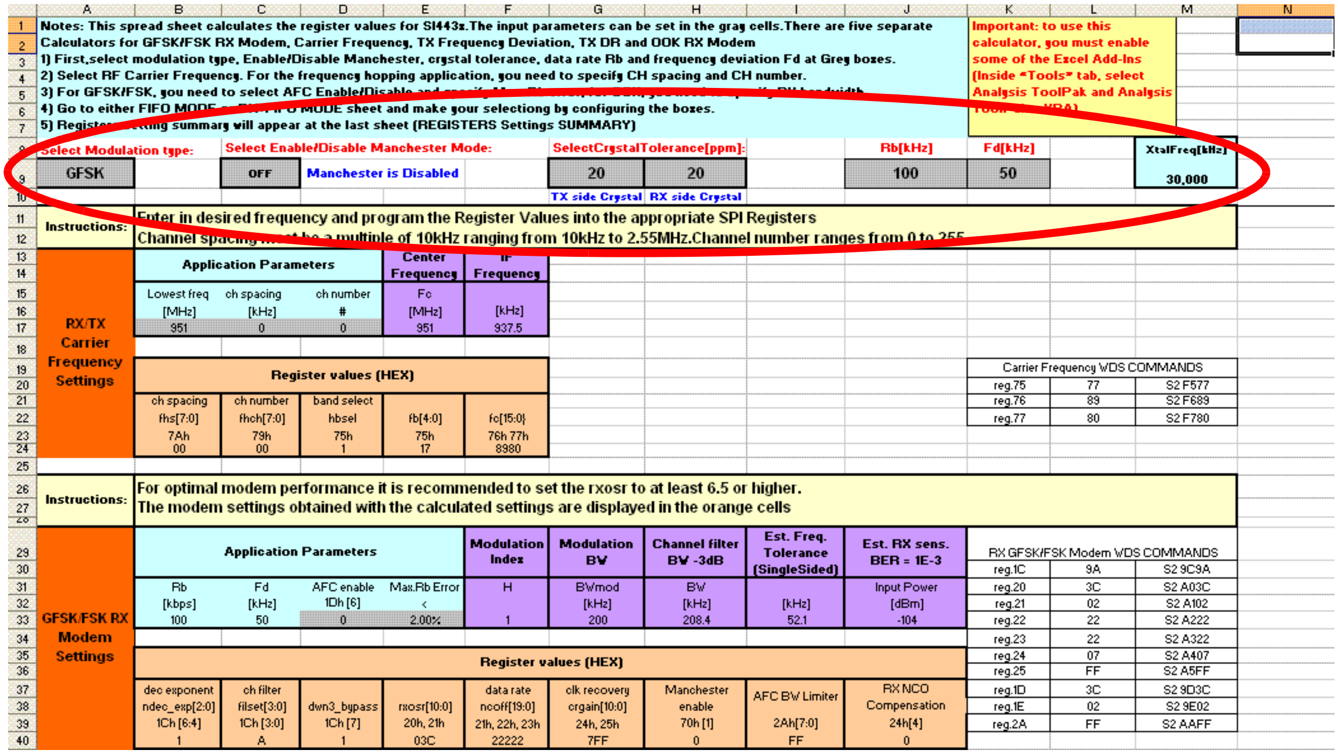

Figure 6. Excel Register Calculator Worksheet

Figure 7 demonstrates the performance for DR = 100 kbps, Dev = 50 kHz, and a BW of 208.4 kHz. For the AFC disabled (modem compensation only) case the frequency offset compensation can be calculated as 0.25 x 208.4 = 52.1 kHz which may be observed in Figure 7. For the AFC enabled case the frequency offset compensation can be calculated as 0.35 x 208.4 = 73 kHz. If more frequency offset compensation is desired then the RX bandwidth should be increased to a value greater than that shown in the Excel Register Calculator worksheet. This may be done by artificially increasing the value used for XTAL Tolerance.

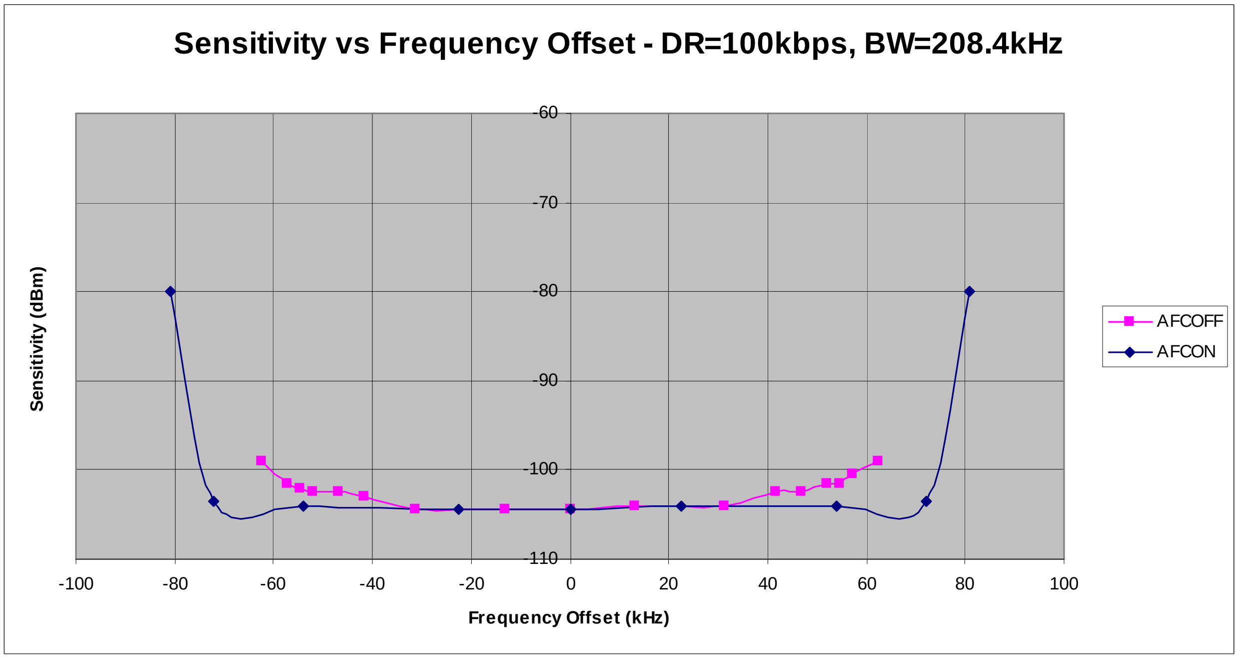

Figure 7. Selectivity vs. Frequency Offset, 100 kbps

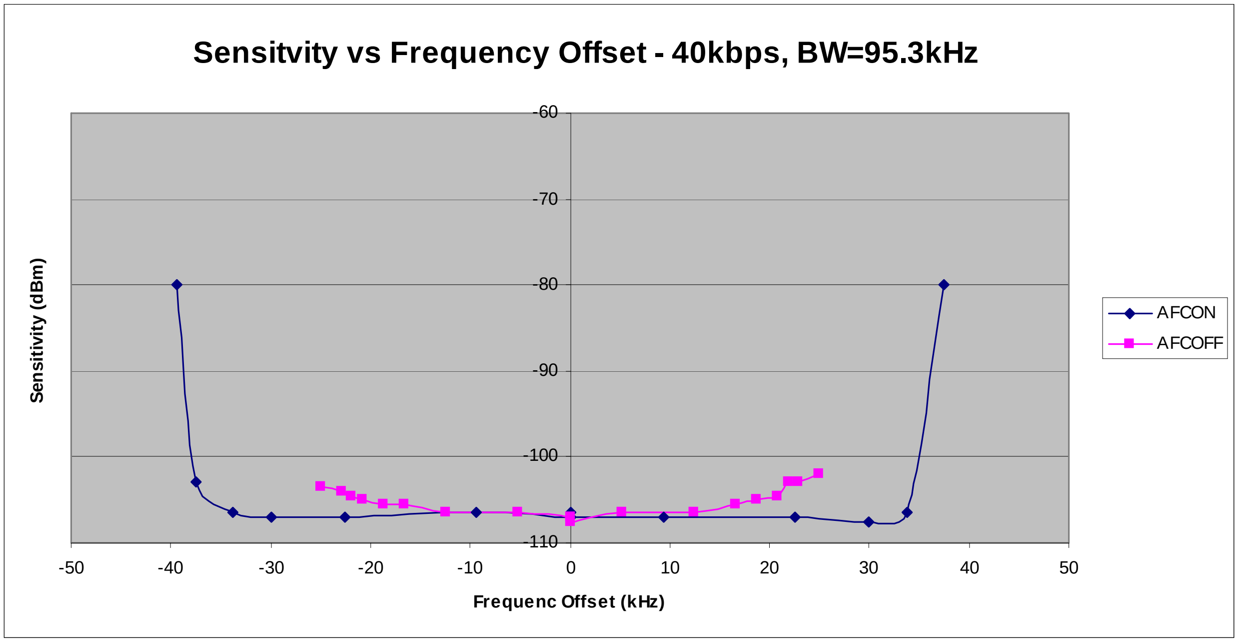

Figure 8. Selectivity vs. Frequency Offset, 40 kbps

4. TX Measurements

All TX Measurements unless otherwise specified are measured with V_{DD} = 3.3 V, txpow[2:0]=111, frequency = 913 MHz, using the scripts available on the Silicon Labs website and a 4432-DKDB1 test card. All measurements are done at the output of the lowpass filter at the TX SMA connector. The output power is ~1 dB higher at the TX pin of the chip before the lowpass filter.

4.1. Output Power and Spectrum

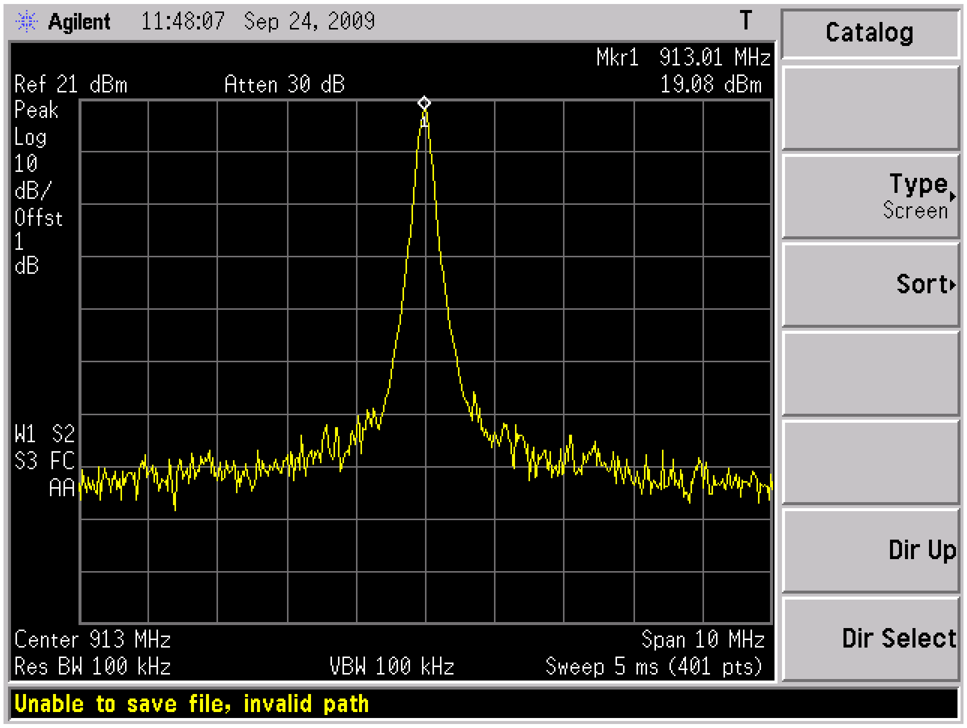

Figure 9. Output Power

4.2. Modulated Spectrum

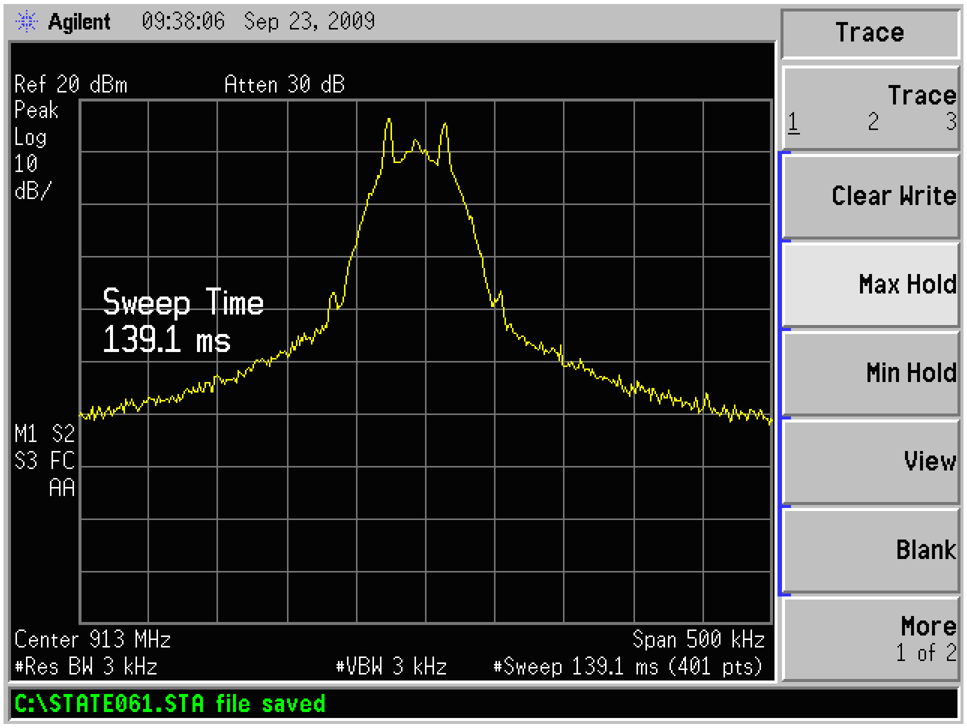

Figure 10. Modulated Spectrum—40 kbps/20 kHz Dev

4.3. TX Deviation

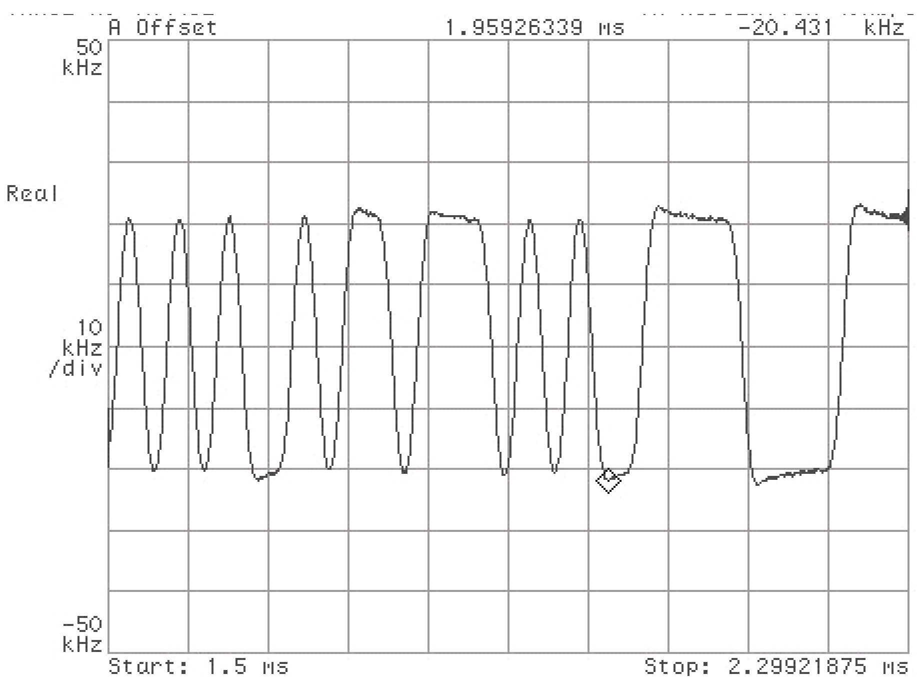

Figure 11. TX Modulation vs. Time—40 kbps/20 kHz Dev

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4.4. TX Output Power Variation vs. V_{DD} and Temperature

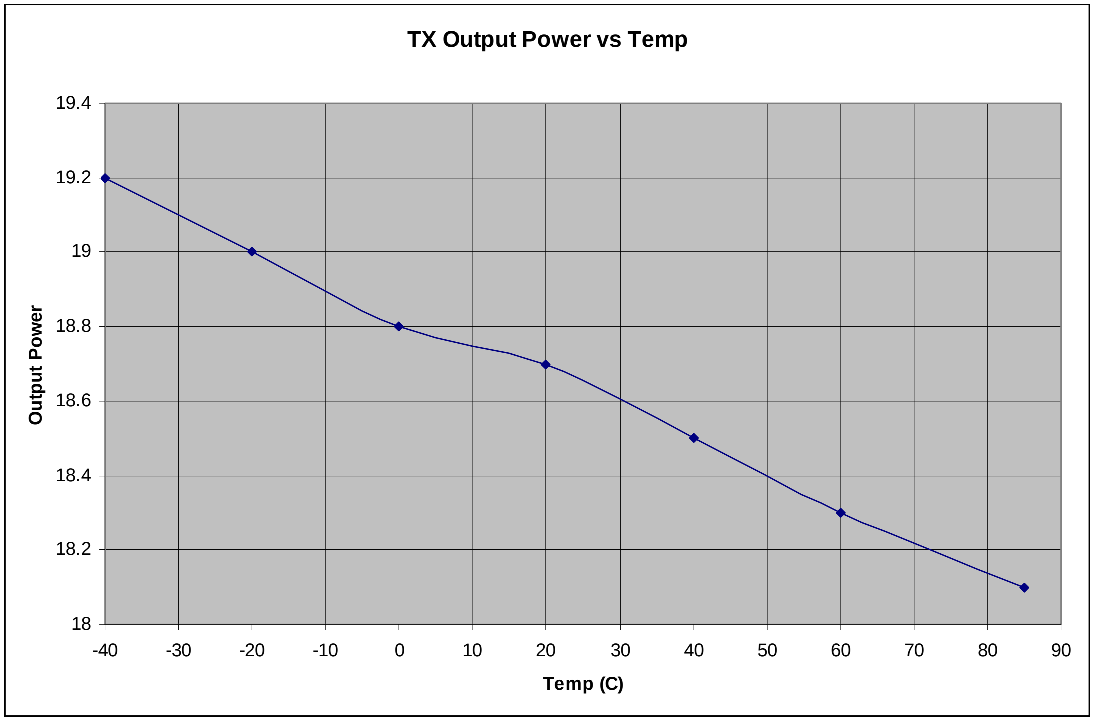

Figure 12. TX Output Power vs. Temperature

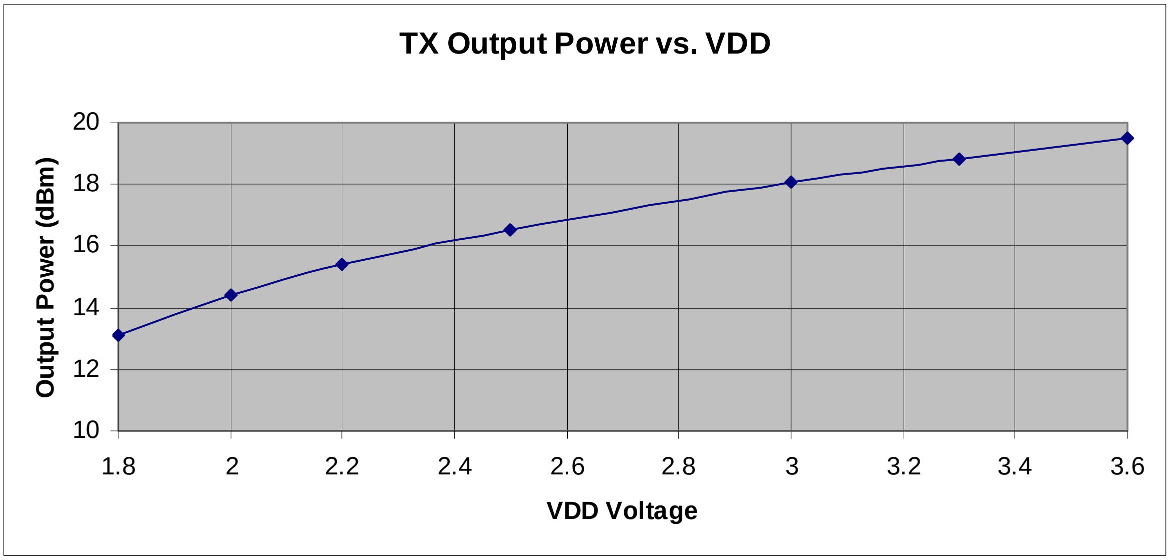

Figure 13. TX Output Power vs. V_{DD}

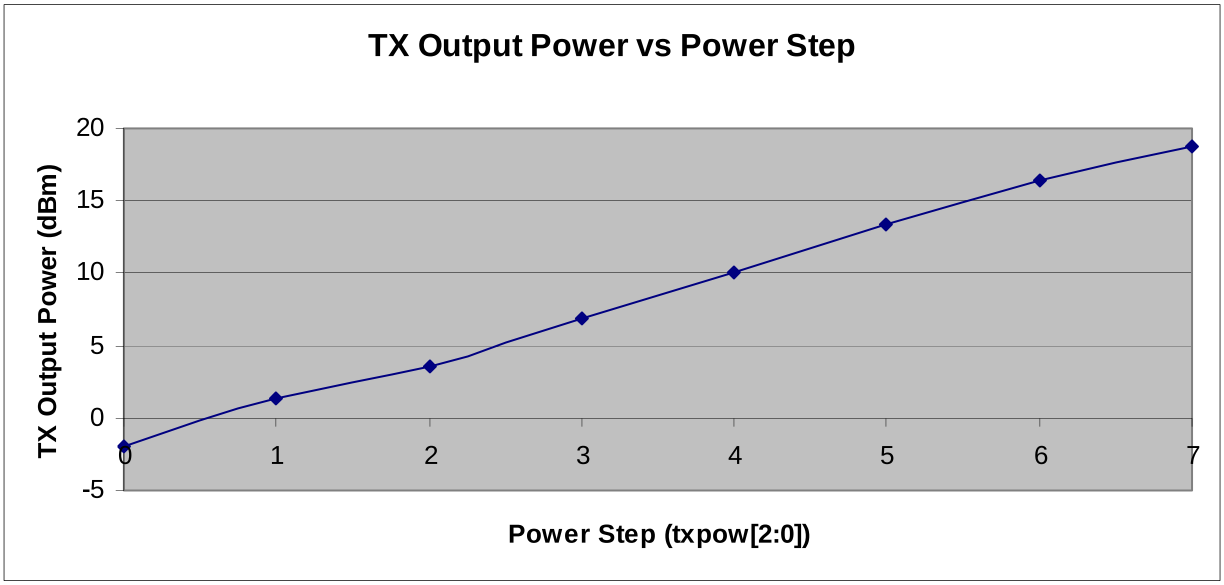

Figure 14. TX Output Power vs. Step (txpower[2:0])

4.5. Conducted Harmonics

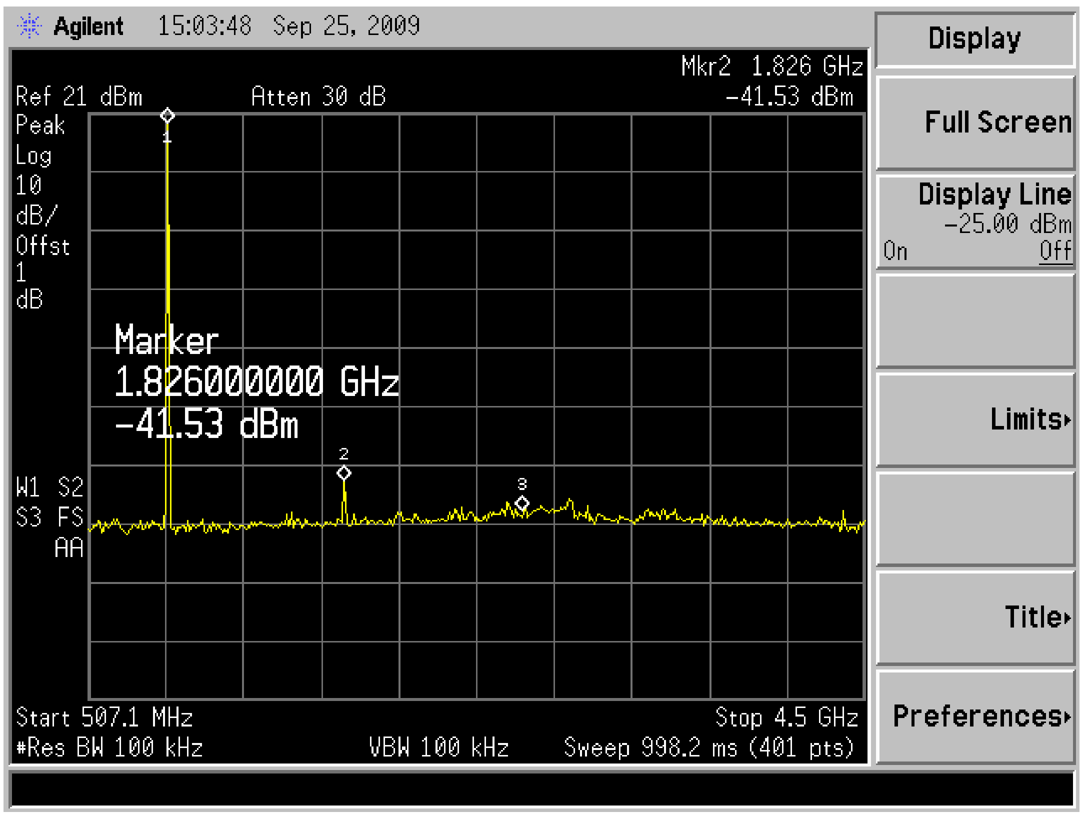

Figure 15. Conducted Harmonics

5. FCC Compliance

Silicon Labs has tested the Si4432B chip and 4432-DKDB1 TX/RX Split TRX Test Card for FCC Part 15.247 compliance in the 902–928 MHz frequency band, at an output power level of +20 dBm. These FCC compliance tests were performed by Elliott Labs, a FCC certified Electromagnetic Compatibility (EMC) test house. Per FCC Part 15.35, the radiated level of harmonic emissions at frequencies above 1000 MHz are to be measured using an average detector function, and thus there may be some advantage in using a burst-like packet structure rather than continuous transmission. FCC Part 15.35(c) states that if the packet length is less than 100 ms then time averaging can be applied which effectively relaxes the harmonic limits. If the packet structure is longer than 100 ms then time averaging cannot be used. The following test report is for a continuous-wave tone to test to the more stringent case of when a packet is longer than 100 ms. Explicit excerpt from FCC 15.35(c):

(c) *Unless otherwise specified, e.g.§ 15.255(b), when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds. As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value.*

6. EMC Test Data

Elliott An NTS company

EMC Test Data

Client:	Silicon Laboratories Inc.	Job Number:	J75170
Model:	915 MHz (North America, FCC Compliance in Pmax settings), 868 MHz (EU)	T-Log Number:	T75181
		Account Manager:	Deepa Shetty
Contact:	Hardy Schmidbauer		
Standard:	FCC 15.247, EN 300 220-1	Class:	N/A

RSS 210 and FCC 15.247 (DTS) Radiated Spurious Emissions

Test Specific Details

Objective: The objective of this test session is to perform engineering evaluation testing of the EUT with respect to the specification listed above.

Date of Test: 9/11/2009
Test Engineer: David Bare
Test Location: Fremont Chamber #4

Config. Used: 1
Config Change: None
EUT Voltage: 3.3V DC

General Test Configuration

The EUT and all local support equipment were located on the turntable for radiated spurious emissions testing.

For radiated emissions testing the measurement antenna was located 3 meters from the EUT.

Ambient Conditions:

Temperature: 26 °C
Rel. Humidity: 44 %

Summary of Results

Run #	Mode	Channel	Power Setting	Measured Power	Test Performed	Limit	Result / Margin
1	CWTX	915 MHz	Max	-	Radiated Emissions, Transmitter Harmonics	FCC Part 15.209 / 15.247(c)	51.5dBμV/m @ 8235.0MHz (-2.5dB)

Modifications Made During Testing

No modifications were made to the EUT during testing

Deviations From The Standard

No deviations were made from the requirements of the standard except that only 915 MHz was tested and the device can operate from 902-928 MHz for operation under FCC 15.247.

Elliott
An NTS company

EMC Test Data

Client:	Silicon Laboratories Inc.	Job Number:	J75170
Model:	915 MHz (North America, FCC Compliance in Pmax settings), 868 MHz (EU)	T-Log Number:	T75181
		Account Manager:	Deepa Shetty
Contact:	Hardy Schmidbauer		
Standard:	FCC 15.247, EN 300 220-1	Class:	N/A

Run #1: Radiated Spurious Emissions, Transmitter Harmonics (915 MHz)

Si4432_B0, SN: T13, CW TX 915 MHz, w/Antenna, VDD=3.3V, TXPWR7, 4-Layer Board w/Shield, PADUTY=2'b10

Frequency	Level	Pol	15.209 / 15.247		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
1829.940	62.7	V	94.0	-31.3	PK	328	1.4	RB 1 MHz; VB: 1 MHz
1829.990	62.6	V	74.0	-11.4	AVG	328	1.4	RB 1 MHz; VB: 10 Hz
1829.990	58.6	H	94.0	-35.4	PK	357	2.0	RB 1 MHz; VB: 1 MHz
1829.990	58.0	H	74.0	-16.0	AVG	357	2.0	RB 1 MHz; VB: 10 Hz
2744.920	49.0	V	74.0	-25.0	PK	40	1.2	RB 1 MHz; VB: 1 MHz
2744.960	46.5	V	54.0	-7.5	AVG	40	1.2	RB 1 MHz; VB: 10 Hz
2744.810	46.4	H	74.0	-27.6	PK	89	1.2	RB 1 MHz; VB: 1 MHz
2745.010	42.2	H	54.0	-11.8	AVG	89	1.2	RB 1 MHz; VB: 10 Hz
3659.930	49.6	V	74.0	-24.4	PK	342	1.7	RB 1 MHz; VB: 1 MHz
3660.010	46.8	V	54.0	-7.2	AVG	342	1.7	RB 1 MHz; VB: 10 Hz
3660.020	46.1	H	54.0	-7.9	AVG	229	1.8	RB 1 MHz; VB: 10 Hz
3660.070	49.5	H	74.0	-24.5	PK	229	1.8	RB 1 MHz; VB: 1 MHz
4575.080	48.5	V	74.0	-25.5	PK	260	1.2	RB 1 MHz; VB: 1 MHz
4575.040	44.4	V	54.0	-9.6	AVG	260	1.2	RB 1 MHz; VB: 10 Hz
4574.900	45.5	H	74.0	-28.5	PK	224	1.3	RB 1 MHz; VB: 1 MHz
4575.050	37.4	H	54.0	-16.6	AVG	224	1.3	RB 1 MHz; VB: 10 Hz
5489.860	49.7	V	74.0	-24.3	PK	342	1.1	RB 1 MHz; VB: 1 MHz
5490.000	45.9	V	54.0	-8.1	AVG	342	1.1	RB 1 MHz; VB: 10 Hz
5490.000	47.2	H	74.0	-26.8	PK	328	1.5	RB 1 MHz; VB: 1 MHz
5489.970	41.8	H	54.0	-12.2	AVG	328	1.5	RB 1 MHz; VB: 10 Hz
6404.980	51.0	V	94.0	-43.0	PK	201	1.6	RB 1 MHz; VB: 1 MHz
6405.000	47.4	V	74.0	-26.6	AVG	201	1.6	RB 1 MHz; VB: 10 Hz
6405.260	48.1	H	94.0	-45.9	PK	112	1.4	RB 1 MHz; VB: 1 MHz
6404.990	42.9	H	74.0	-31.1	AVG	112	1.4	RB 1 MHz; VB: 10 Hz
7320.310	50.0	V	74.0	-24.0	PK	23	1.3	RB 1 MHz; VB: 1 MHz
7319.980	40.9	V	54.0	-13.1	AVG	23	1.3	RB 1 MHz; VB: 10 Hz
7319.890	49.6	H	74.0	-24.4	PK	318	1.3	RB 1 MHz; VB: 1 MHz
7319.940	40.3	H	54.0	-13.7	AVG	318	1.3	RB 1 MHz; VB: 10 Hz
8235.080	55.4	V	74.0	-18.6	PK	211	1.6	RB 1 MHz; VB: 1 MHz
8234.980	51.5	V	54.0	-2.5	AVG	211	1.6	RB 1 MHz; VB: 10 Hz
8234.960	49.1	H	74.0	-24.9	PK	163	1.0	RB 1 MHz; VB: 1 MHz
8235.000	39.6	H	54.0	-14.4	AVG	163	1.0	RB 1 MHz; VB: 10 Hz
9149.960	48.0	V	74.0	-26.0	PK	89	1.1	RB 1 MHz; VB: 1 MHz
9150.140	37.2	V	54.0	-16.8	AVG	89	1.1	RB 1 MHz; VB: 10 Hz
9149.920	48.6	H	74.0	-25.4	PK	297	1.0	RB 1 MHz; VB: 1 MHz
9149.920	38.1	H	54.0	-15.9	AVG	297	1.0	RB 1 MHz; VB: 10 Hz

Note 1: For emissions in restricted bands, the limit of 15.209 was used. For all other emissions, the limit was set 20dB below the level of the fundamental and measured in 100kHz. (assumed to be 94 dBuV/m)

Document Change List

Revision 0.1 to Revision 0.2

- Added Section 6 with measured EMC test data.

Revision 0.2 to Revision 0.3

- Clarified aspects of FCC certification.

NOTES:

Simplicity Studio

One-click access to MCU tools, documentation, software, source code libraries & more. Available for Windows, Mac and Linux!

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Silicon Laboratories Inc.
400 West Cesar Chavez
Austin, TX 78701
USA

http://www.silabs.com