REPORT

Issued by an FCC listed Laboratory Reg. no. 93866.
The test site complies with RSS-Gen, file no: IC 3482A-2

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Date 2013-06-28 | Reference 3P03521-F15C Rev1 | Page 1 (1)

1002 ISO/IEC 17025

Rev 1: 2014-01-13

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Equipment Authorization measurements on F2M03GXA 2402-2480 MHz FHSS Transceiver Unit

(12 appendices)

Rev.1, 2014-01-13: Complementary tests of Dwell time and Band edge (radiated on a new sample #40) have been performed an also some corrections of other appendices. All the appendices have been revised.

Test object

Product name: F2M03GXA
Three different samples were used during the test:
Number: #34, #36, #40 (radiated samples)
Number: #35 (conducted sample, temporary antenna connector)

Summary

See appendix 1 for general information and appendix 12 for photos.
Emission measurements as specified below have been performed.

Standard	Compliant	Appendix	Remarks
FCC 47 CFR Part 15 C 15.247 Operation within the band 2400-2483.5 MHz	**Yes**		
IC RSS-210 Issue 8, December 2010	**Yes**		
Duty cycle measurements	N/A	2	
15.247 (a) (1) / RSS-210 A8.1(a) (b) Carrier frequency separation and 20 dB BW	Yes	3	
15.247 (a) (1) (iii) / RSS-210 A8.1(d) Number of hopping frequencies and dwell time	Yes	4	
15.247 (b) (1) / RSS-210 A8.4(2) Max peak conducted power	Yes	5	
15.247 (d) / RSS-210 A8.5 20 dBc below fundamental	Yes	6	
15.247 (d) / RSS-210 A8.5 Restricted bands of operation	Yes	7	
15.247 (i) / RSS-102 2.5.1 RF Safety	Yes	8	
15.215 (c) 20 dB bandwidth	Yes	9	
15.207 / RSS-Gen 7.2.4 Conducted emission limits	N/A		
2.1049 / RSS-Gen 4.6.1 Occupied bandwidth	Yes	10	
2.1049 / RSS-210 A8.5 Band Edge	Yes	11	

Note: Above RSS items are given as cross-reference only. Measurements were performed according to ANSI procedures referenced by FCC and covered by SP's accreditation.

SP Technical Research Institute of Sweden
Electronics - EMC

Performed by
Fredrik Isaksson

Examined by
Anders Nordlöf

Performance test and requirements

The tests were performed in order to verify that the F2M03GXA radio module meets the electromagnetic compatibility requirements of FCC 47 CFR part 15 C.

Test facility

The used anechoic chamber is compliant with the requirements of section 2.948 of the FCC rules and listed, registration number 96866, as a facility accepted for certification under parts 15 and 18. The site complies with RSS Gen, Issue 2 and is accepted by Industry Canada for the performance of radiated measurements, IC-file number 3482A-2.

Test object

Transceiver:	F2M03GXA FHSS transceiver module
Antenna:	Integral, PCB
Antenna gain:	2 dB
Frequency range:	2402-2480 MHz
Frequencies used during test:	2402 MHz 2441 MHz 2480 MHz
Modulations:	GFSK, π/4DQPSK, 8DPSK
Max power settings (used during the test):	
GFSK	+18 dBm (setting #30)
π/4DQPSK and 8DPSK	+5 dBm (setting #7)
Number of hopping frequencies:	79
Channel hopping separation:	1 MHz
Data rates:	
GFSK	1 Mbits/s
π/4 DQPSK	2 Mbit/s
8DPSK	3 Mbit/s
Supply voltage:	Nominal: 3.7 V DC

The EUT was powered by a Lithium hybrid battery cell.

Used samples

Radiated samples: #34, #36, #40
Conducted sample, temporary antenna connector: #35

Measurement	Appendix	Sample
Duty cycle measurements	2	#34, #36
Carrier frequency separation and 20 dB BW	3	#35
Number of hopping frequencies and dwell time	4	#35
Max peak conducted power	5	#35
20 dBc below fundamental	6	#35
Restricted bands of operation	7	#34, #35, #36
RF Safety	8	#35
20 dB bandwidth	9	#35
Occupied bandwidth	10	#35
Band Edge	11	#34; #36, #40

Measurement equipment

Measurement equipment	Calibration Due	SP number
Test site Edison	2013-11	504 114
R&S ESU40 Signal Analyser	2013-07	901 385
R&S ESU26 Signal Analyser	2013-12	902 210
R&S ESI40 Signal Analyser	2013-07 (2014-07 for measurements performed 2013-11-14)	503 125
Antenna Schaffner CBL 6143	2013-10	504 079
Horn antenna EMCO 3115	2014-01	501 548
Boonton power meter	2013-11	503 144
Boonton power sensor	2013-11	503 146
Standard gain horn Flann 16240-25	-	503 939
Standard gain horn Flann 18240-25	-	503 900
Standard gain horn Flann 20240-20	-	503 674
Low Noise Amplifier Miteq	2013-08	503 277
Low Noise Amplifier Miteq	2013-08	504 160
High pass filter Wainwright WHKY	2013-08	503 739
TTE Blocking filter	2013-07	503 575
High pass filter Wainwright	2013-08	504 200
Multimeter Fluke	2013-06	503 498
Multimeter Fluke 83	2013-06	501 522
Temperature and humidity meter Testo 625	2014-06	504 117
Temperature and humidity meter Testo	2013-06	503 418

Operational test mode

Justification measurements were performed with rotation of the EUT through three orthogonal axes, see photos in Appendix 12, and with the different modulations in order to determine worst case configuration. GFSK was deemed to represent worst case modulation.

The EUT was tested as a module powered by battery. The test was performed with GFSK modulation if not otherwise stated. Settings of the EUT were performed with an external computer with help of dedicated software.

For duty cycle measurements see appendix 2.
During test the EUT has a duty cycle of 77 %. The duty cycle correction factor was calculated to 20 log (2.89 / 3.75) = -2.3 dB. The PRF was calculated to PRF = 1/T = 1/3.75 ms = 270 Hz. Since the RBW of 1MHz is > PRF, QP-detector was used without any correction for pulse desensitization.

Uncertainties

Measurement and test instrument uncertainties are described in the quality assurance documentation ”SP QD 10885”. The measurement uncertainties can be found in the table below. The uncertainties are calculated with a coverage factor k=2 (95% level of confidence). The measurement uncertainties can be found in the table below:

Method	**Uncertainty**
Radiated emission, 30 – 1000 MHz	4.8/5.6 dB (V/H-pol)
Radiated emission, 1 – 40 GHz	2.6 dB

Compliancy evaluation is based on a shared risk principle with respect to the measurement uncertainty.

Reservation

The test results in this report apply only to the particular test object as declared in the report.

Delivery of test object

The test objects were delivered: 2013-05-29

Test participant

Peo Karlsson Free2move

Test engineers

Fredrik Isaksson, Martin Nilsson SP

Duty cycle measurements

Date	Temperature	Humidity
2013-06-18	21°C ± 3 °C	18 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009.

The test was performed with FHSS disabled, normal duty cycle and with GFSK modulation.

The radiated measurements were performed in a semi anechoic chamber. The measurements were performed with the EUT-axis, antenna at the position, polarization and the turntable in the position giving the highest level at the fundamental, see Appendix 5. The antenna distance was 3.0 m.

Measurement equipment	SP number
Semi anechoic chamber, Edison	504 114
Spectrum analyzer R&S ESU 26	902 210
Horn antenna EMCO 3115	501 548
Multimeter Fluke 83	501 522
Temperature and humidity meter Testo 625	504 117

Results

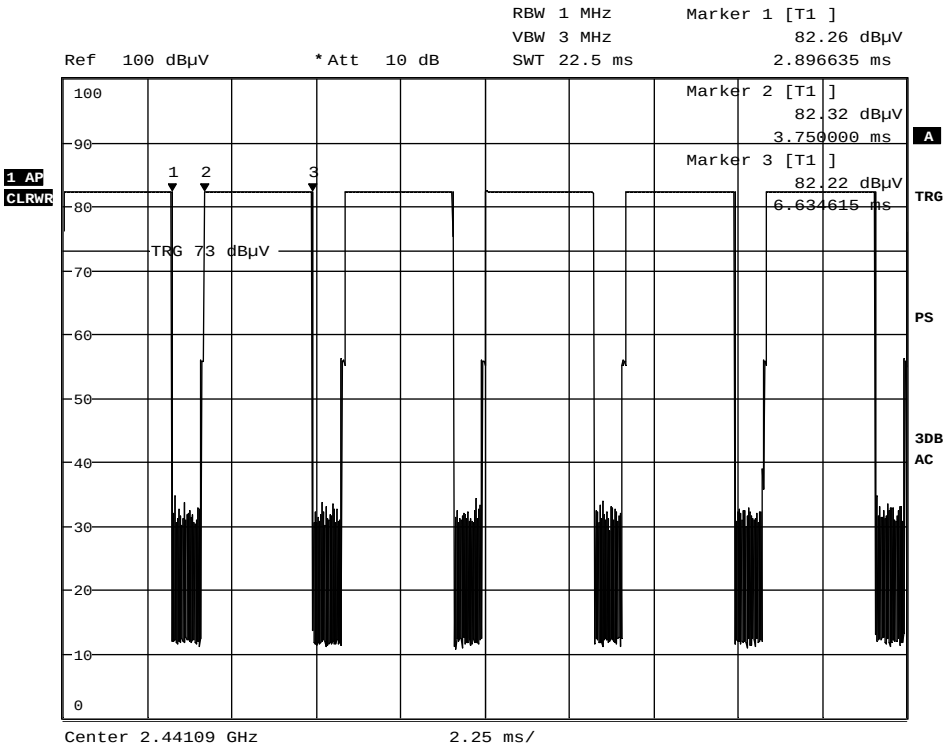
The duty cycle measurements can be found in the diagram below:

Diagram 1: Tx on: 2.89 ms

Period time: 3.75 ms

Complies?	N/A

Diagram 1



Date: 18.JUN.2013 11:32:26

Duty cycle: 2.89 ms/ 3.75 ms = 0.77

Carrier frequency separation measurements according to FCC 47 CFR part 15.247 (a) (1) / RSS-210 A8.1 (a) (b)

Date	Temperature	Humidity
2013-06-25	23°C ± 3 °C	51 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009 and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems, DA 00-705, released March 30, 2000.

Conducted measurements were performed at the antenna connector and with continuous transmission and with both GFSK and 8DPSK modulation and also with the FHSS function enabled.

Measurement equipment	SP number
Test site Hertz	15:116
R&S ESU40 Signal Analyser	901 385
Multimeter Fluke	503 498
Temperature and humidity meter Testo 625	503 418

Measurement uncertainty: 2.6 %

Results

The measurements can be found in the diagrams below:

Diagram 1	FHSS enabled	Channel separation (modulation independent) = 1.006 MHz
Diagram 2	FHSS enabled	2/3*20 dB BW GFSK = 671 kHz
Diagram 3	FHSS enabled	2/3*20 dB BW 8DPSK = 873 kHz

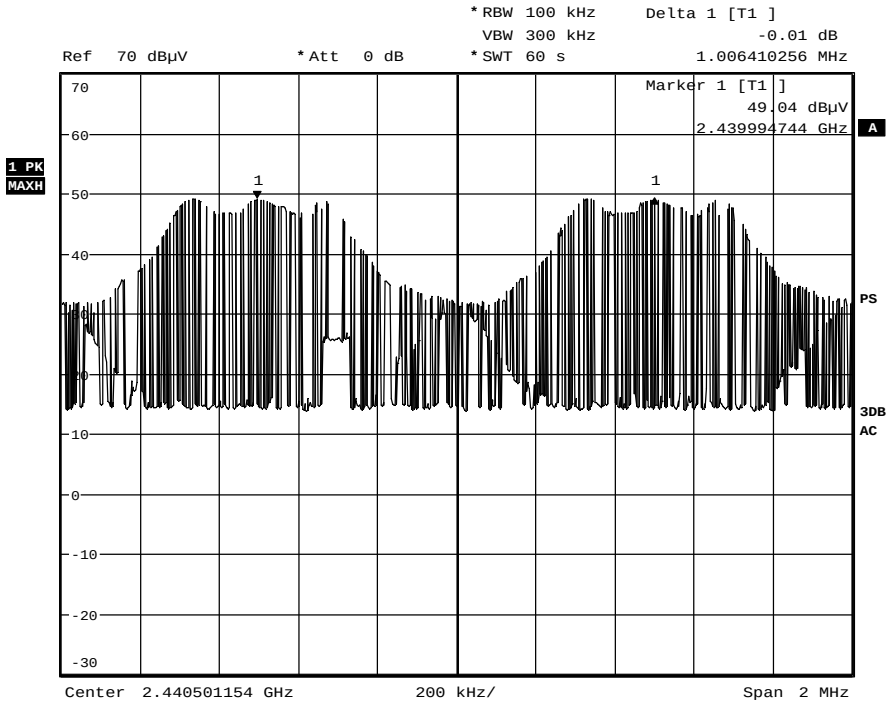
Limits

According to 47CFR 15.247(a)(1): Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or 2/3 of the 20 dB bandwidth of the hopping channel, whichever is the greater.

According to RSS-210 A8.1(a)(b): Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively,
frequency hopping systems operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the -20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.

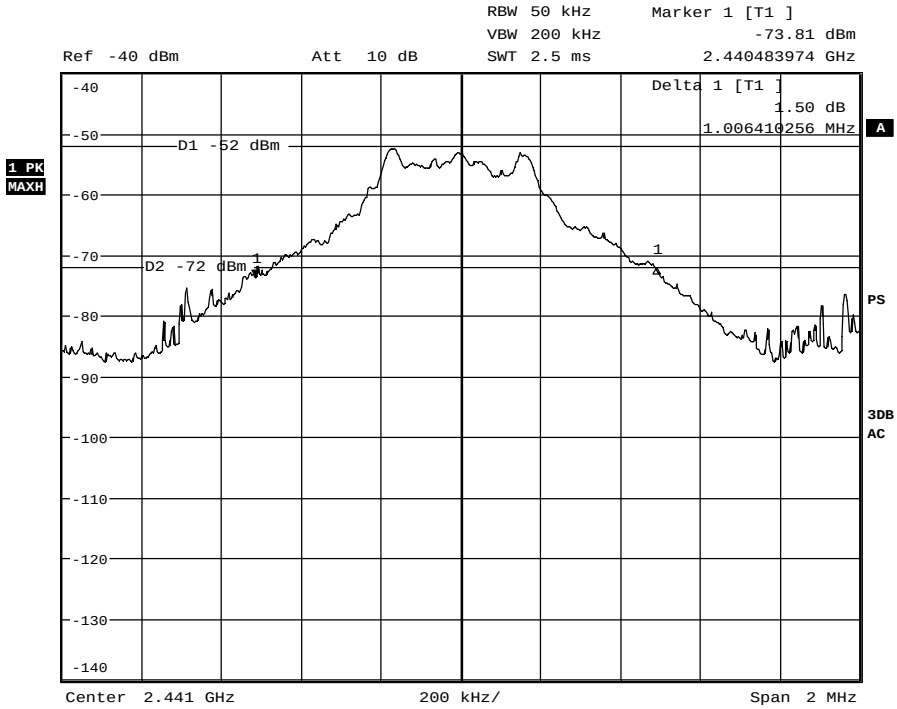
Complies?	Yes

Diagram 1



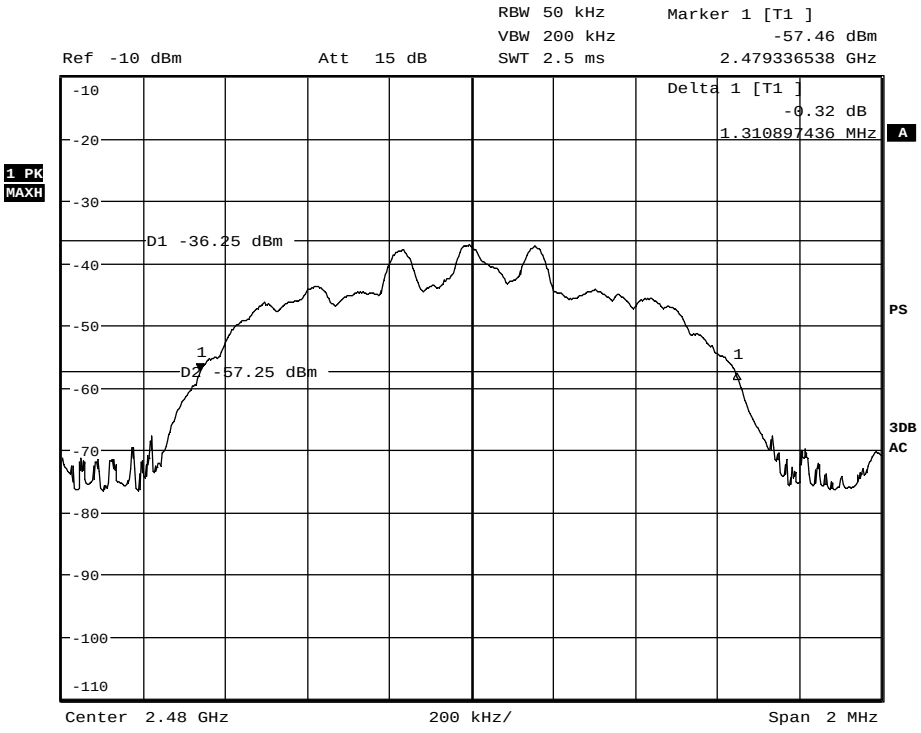
Date: 24.JUN.2013 12:27:20

Diagram 2



Date: 25.JUN.2013 07:24:51

Diagram 3



Date: 25.JUN.2013 08:56:48

‘

Number of hopping frequencies and dwell time measurements according to FCC 47 CFR part 15.247 (a) (1) (iii) / RSS-210 A8.1 (a) (d)

Date	Temperature	Humidity
2013-06-24	22 °C ± 3 °C	53 % ± 5 %
2013-11-14	23 °C ± 3 °C	33 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009 and according to Measurement Guidelines for Frequency Hopping Spread Spectrum Systems, DA 00-705, released March 30, 2000.

The number of hopping frequencies test were performed conducted measurements at the antenna connector and with the FHSS function enabled and GFSK modulation.

The dwell time measurements were performed radiated in a fully anechoic chamber. The antenna distance was 3.0 m.
The test was performed with GFSK modulation and the FHSS function enabled (=simplified hop sequence) and different time slots (DH1, DH3 and DH5).
The width of a single pulse was performed with the span set to 0 Hz.
The number of pulses was measured in a 3.16 second scan, to enable the resolution of each occurrence.
The average time of occupancy in the specified 31.6 second period (79 channels x 0.4 s) is equal to 10 x (# of pulses in 3.16 s) x pulse width.
The used test equipment was connected to an external 10 MHz reference standard during measurements

Measurement equipment	SP number
Test site Hertz	15:116
R&S ESI40 Signal Analyser	901 385
R&S ESU40 Signal Analyser	503 125
Multimeter Fluke	503 498
Temperature and humidity meter Testo	503 418

Measurement uncertainty: 1.3 %

Results

The measurements can be found in the diagrams below:

The number of hopping frequencies test:

Diagram 1	Number of hopping frequencies, hopping channel 1-18
Diagram 2	Number of hopping frequencies, hopping channel 18-36
Diagram 3	Number of hopping frequencies, hopping channel 36-54
Diagram 4	Number of hopping frequencies, hopping channel 54-72
Diagram 5	Number of hopping frequencies, hopping channel 72-78

The dwell time measurements:

Diagram 6	2402 MHz	DH1 time slot	Time of occupancy=10x32x0.417ms = 133.4 ms
Diagram 7	2441 MHz	DH1 time slot	Time of occupancy=10x32x0.415ms = 132.8 ms
Diagram 8	2480 MHz	DH1 time slot	Time of occupancy=10x32x0.419ms = 134.1 ms
Diagram 9	2402 MHz	DH3 time slot	Time of occupancy=10x16x1.672ms = 267.5 ms
Diagram 10	2441 MHz	DH3 time slot	Time of occupancy=10x16x1.672ms = 267.5 ms
Diagram 11	2480 MHz	DH3 time slot	Time of occupancy=10x16x1.672ms = 267.5 ms
Diagram 12	2402 MHz	DH5 time slot	Time of occupancy=10x11x2.926ms = 321.9 ms
Diagram 13	2441 MHz	DH5 time slot	Time of occupancy=10x11x2.926ms = 321.9 ms
Diagram 14	2480 MHz	DH5 time slot	Time of occupancy=10x11x2.916ms = 320.8 ms

Remark

FHSS could not be enabled with π/4DQPSK and 8DPSK, thus no measurements were performed.

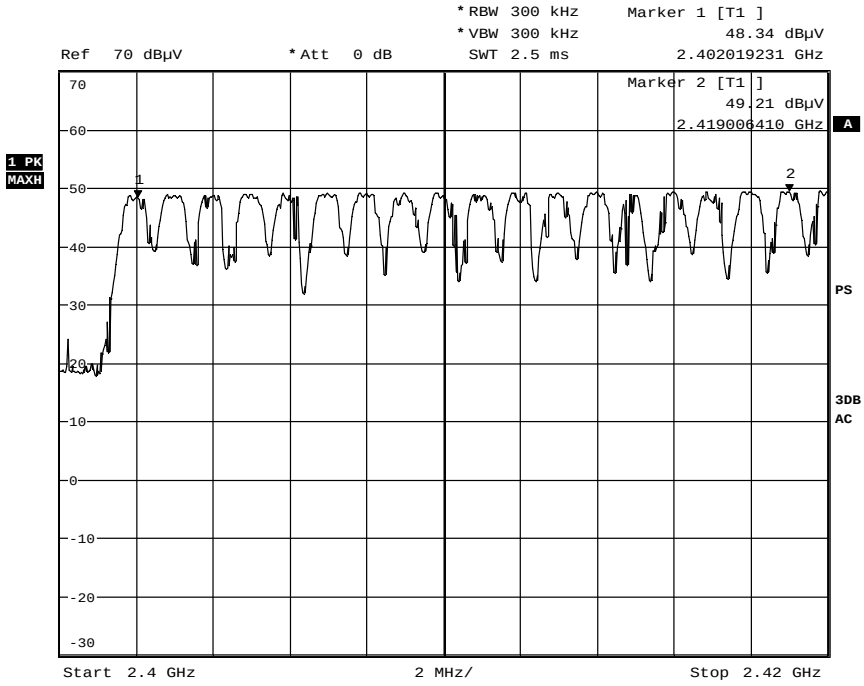
Limits

According to 47CFR 15.247(a)(1)(iii), Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used

According to RSS-210 A8.1(d), as above.

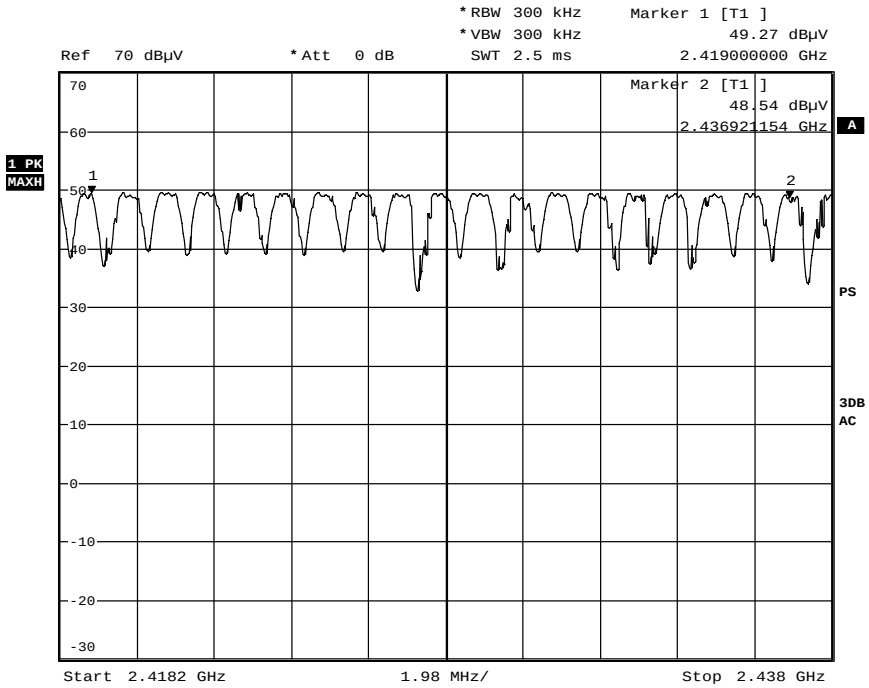
Complies?	Yes

Diagram 1



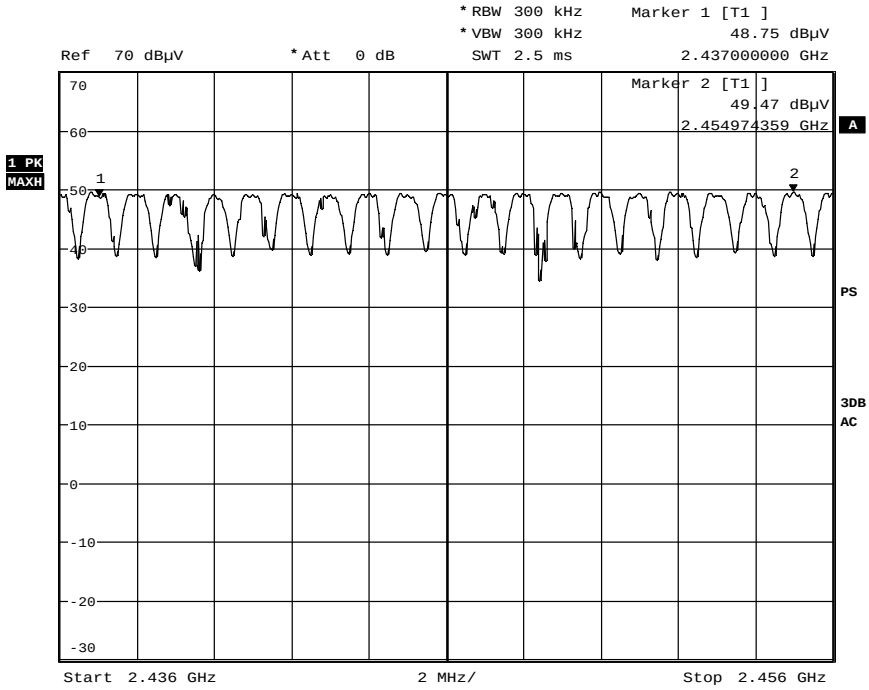
Date: 24.JUN.2013 12:39:41

Diagram 2



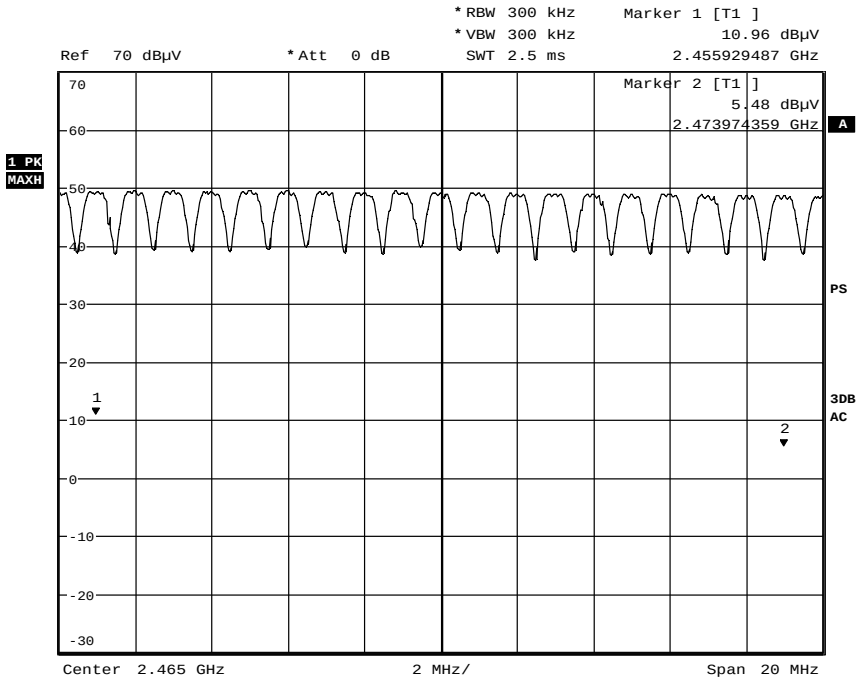
Date: 24.JUN.2013 12:52:25

Diagram 3



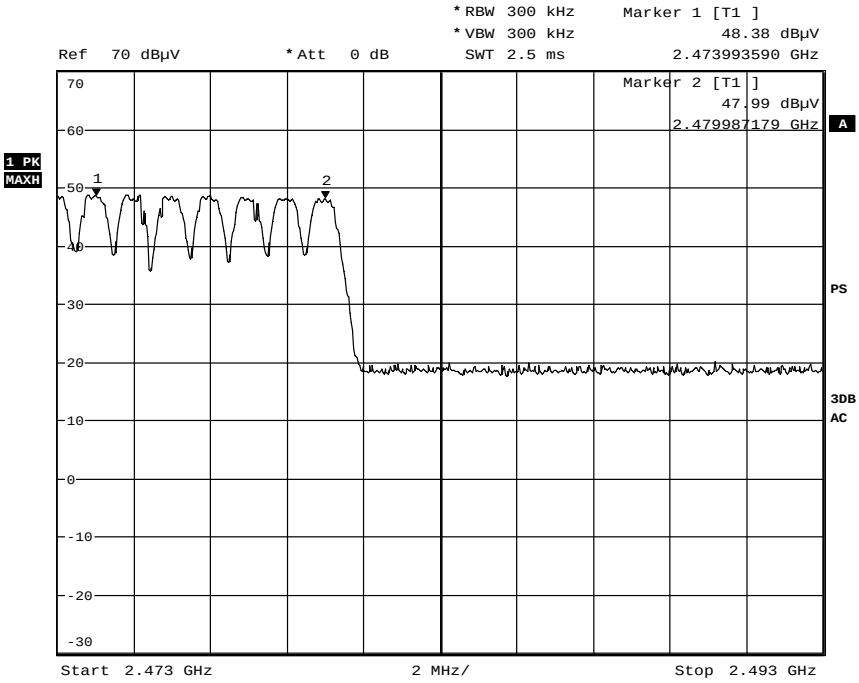
Date: 24.JUN.2013 13:08:29

Diagram 4



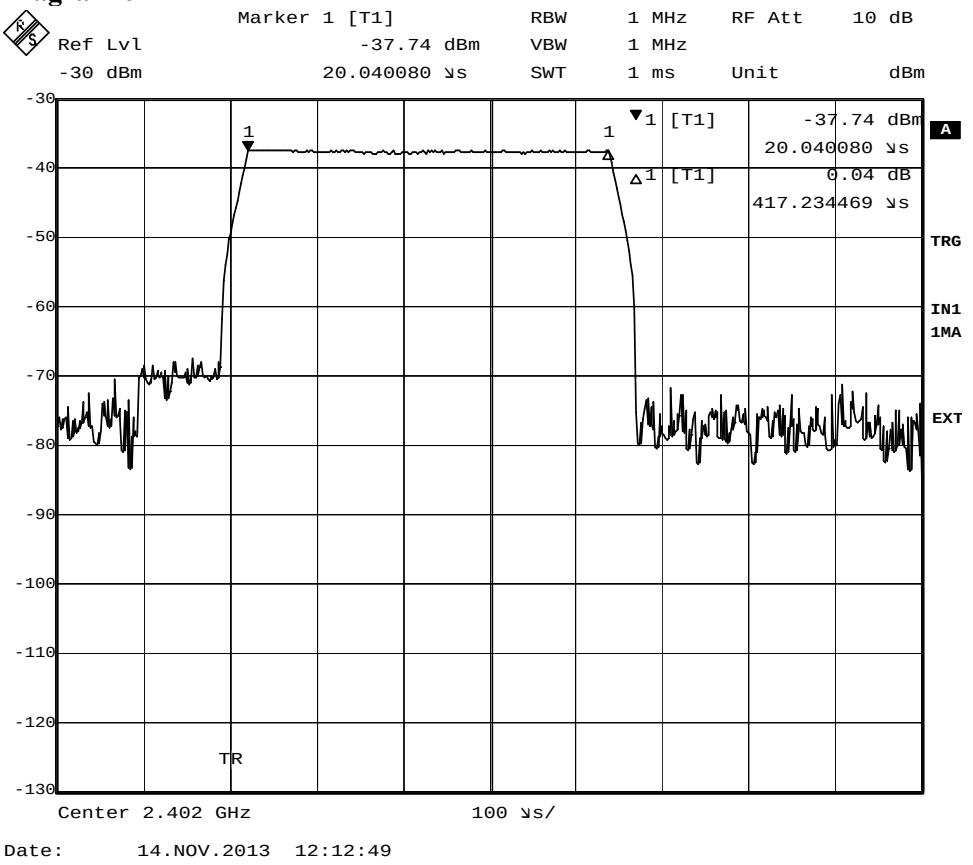
Date: 24.JUN.2013 13:39:02

Diagram 5



Date: 24.JUN.2013 13:54:54

Diagram 6


Marker 1 [T1]
RBW 1 MHz
RF Att 10 dB
Ref Lvl
-37.74 dBm
VBW 1 MHz
-30 dBm
20.040080 µs
SWT 1 ms
Unit dBm
1 [T1] -37.74 dBm
20.040080 µs
Δ1 [T1] 0.04 dB
417.234469 µs
A
TRG
IN1
1MA
EXT
TR
Center 2.402 GHz
100 µs/
Date: 14.NOV.2013 12:12:49

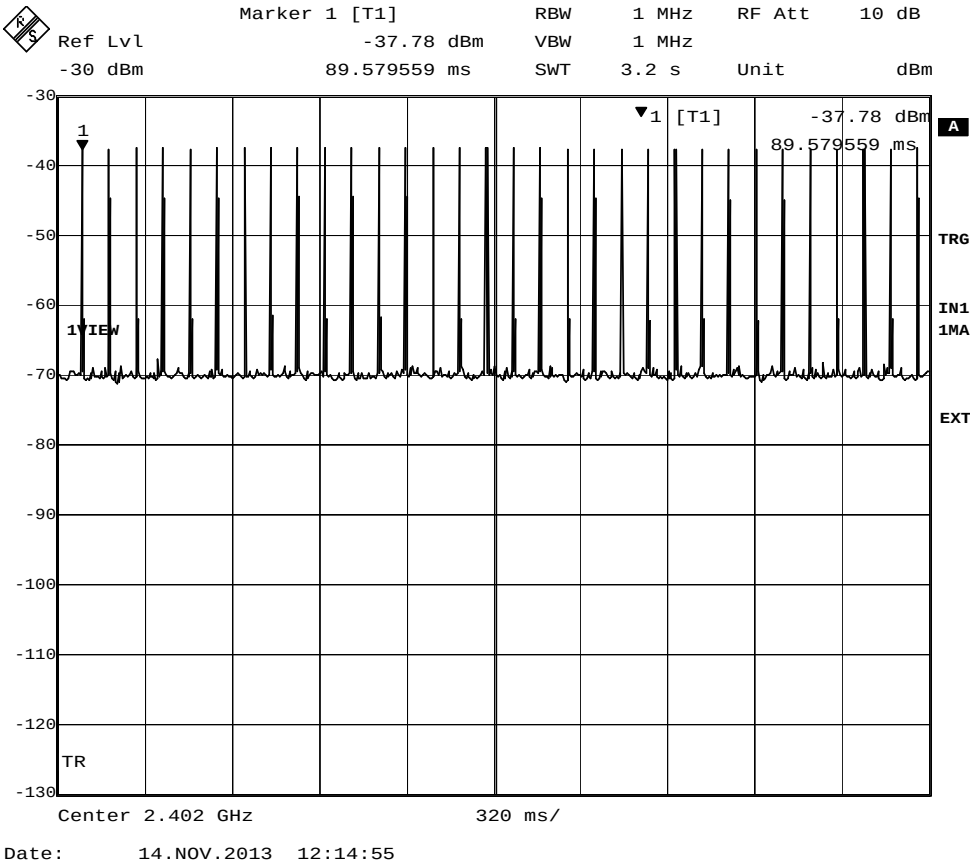
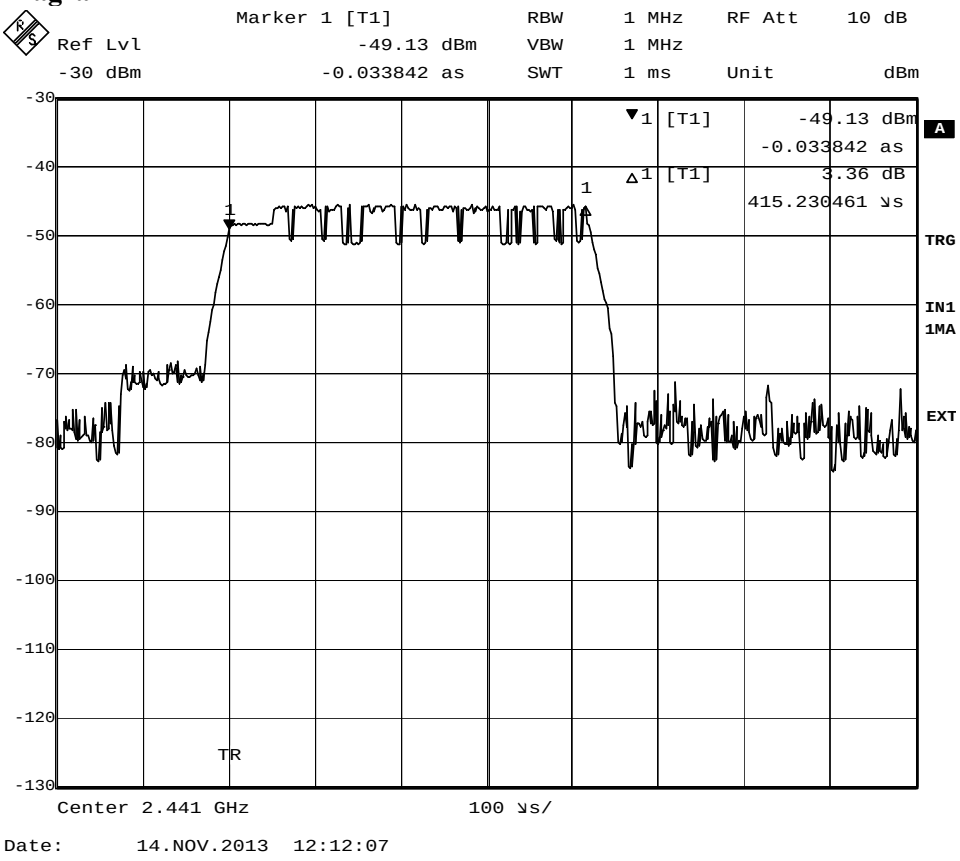
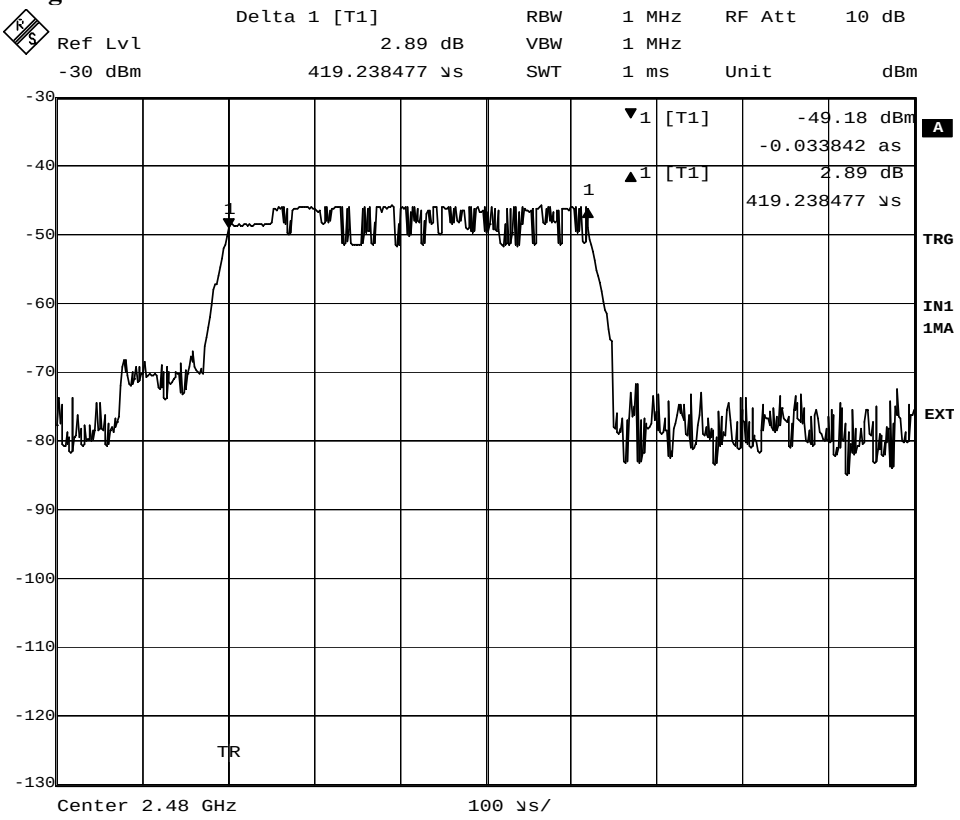

Marker 1 [T1]
RBW 1 MHz
RF Att 10 dB
Ref Lvl
-37.78 dBm
VBW 1 MHz
-30 dBm
89.579559 ms
SWT 3.2 s
Unit dBm
1 [T1] -37.78 dBm
89.579559 ms
A
TRG
IN1
1MA
EXT
1VIEW
TR
Center 2.402 GHz
320 ms/
Date: 14.NOV.2013 12:14:55

Diagram 7



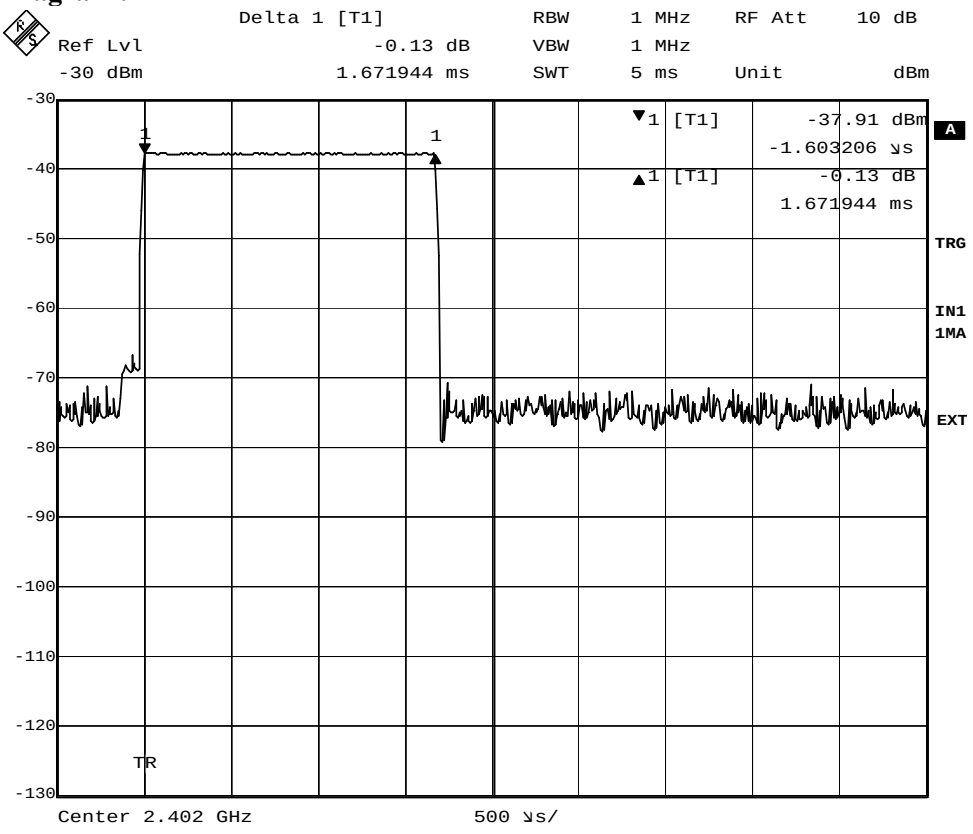
Date: 14.NOV.2013 12:12:07

Diagram 8



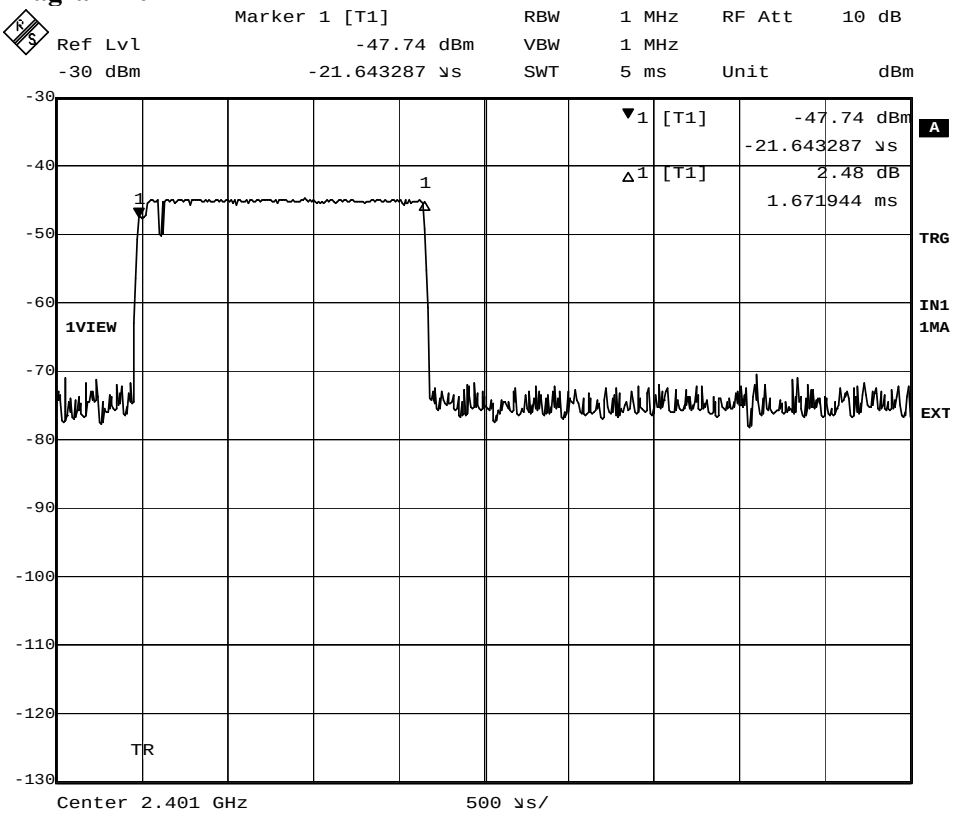
Date: 14.NOV.2013 12:11:34

Diagram 9



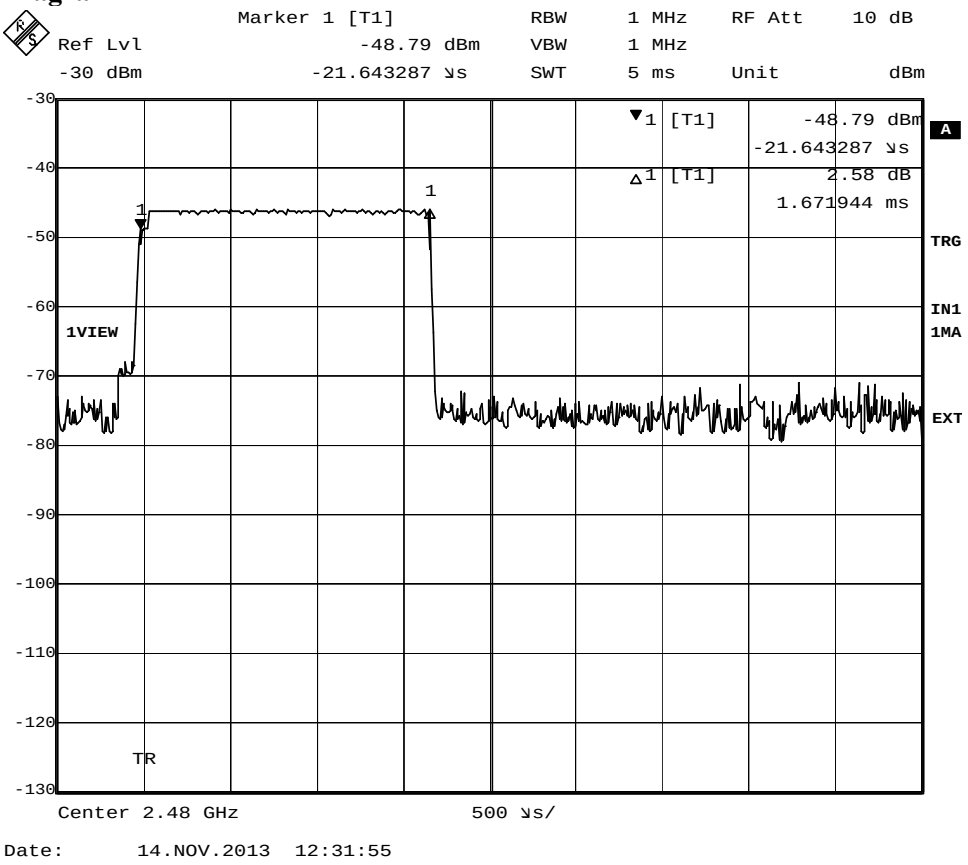
Date: 14.NOV.2013 12:30:47

Diagram 10



Date: 14.NOV.2013 12:31:30

Diagram 11


Marker 1 [T1]
RBW 1 MHz
RF Att 10 dB
Ref Lvl
-48.79 dBm
VBW 1 MHz
-30 dBm
-21.643287 µs
SWT 5 ms
Unit dBm
1 [T1] -48.79 dBm
-21.643287 µs
Δ1 [T1] 2.58 dB
1.671944 ms
1VIEW
TR
TRG
IN1
1MA
EXT
A
Center 2.48 GHz
500 µs/
Date: 14.NOV.2013 12:31:55

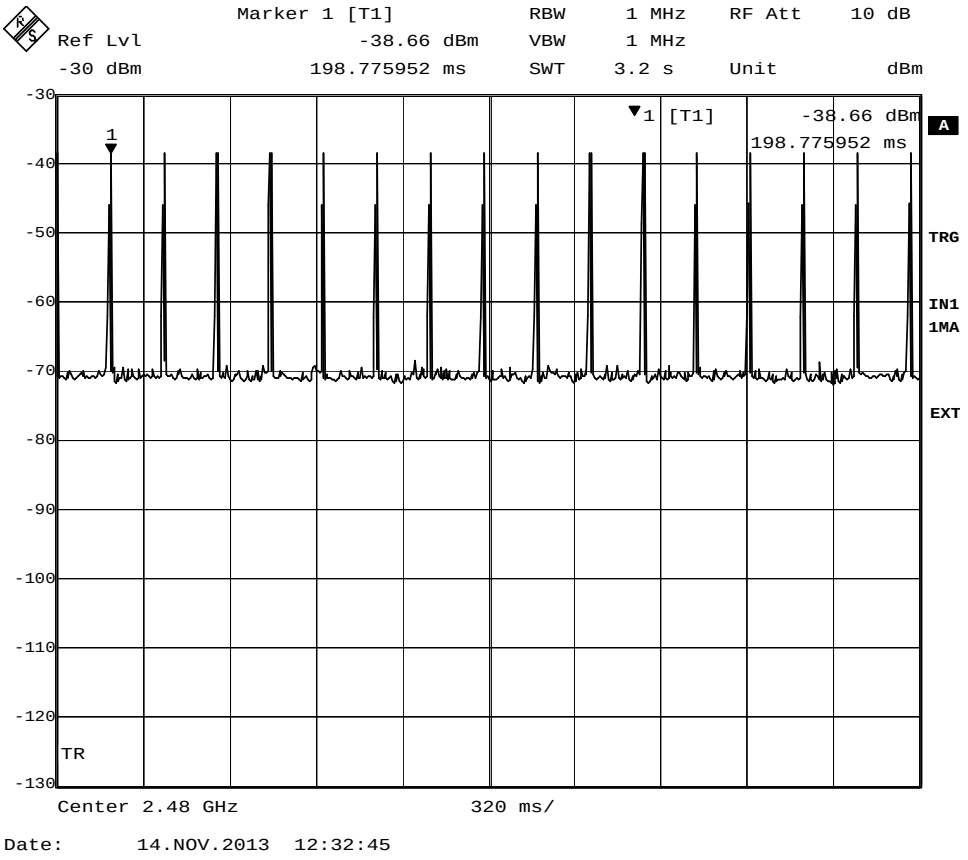
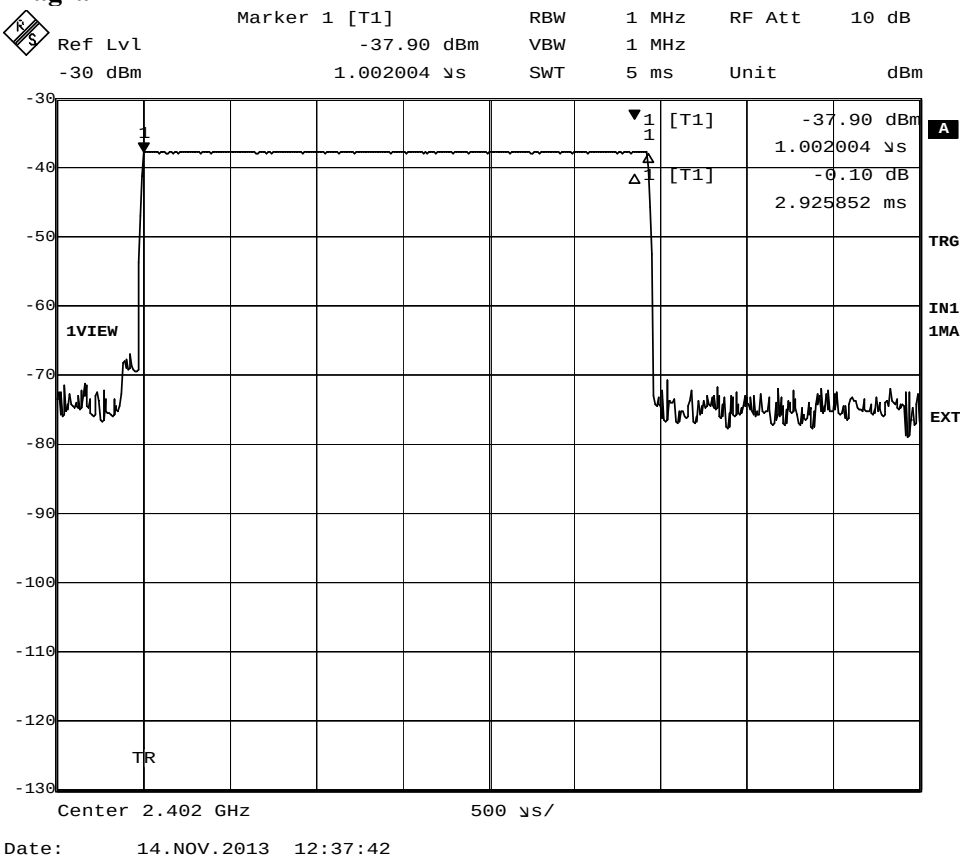
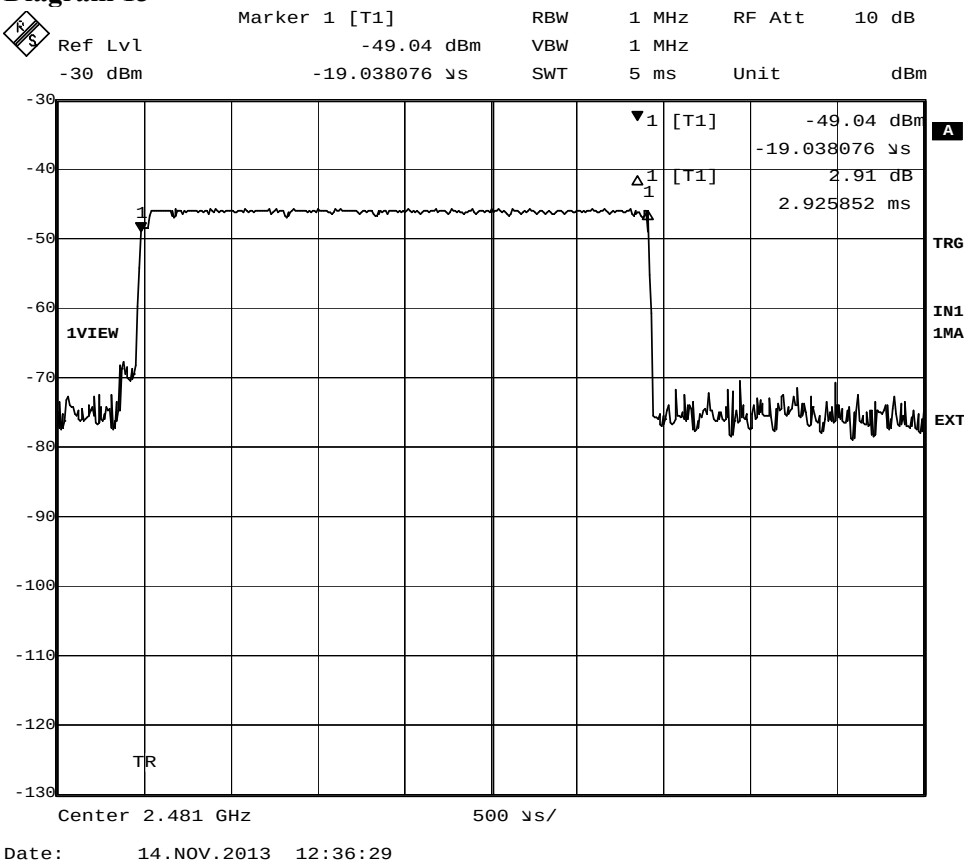

Marker 1 [T1]
RBW 1 MHz
RF Att 10 dB
Ref Lvl
-38.66 dBm
VBW 1 MHz
-30 dBm
198.775952 ms
SWT 3.2 s
Unit dBm
1 [T1] -38.66 dBm
198.775952 ms
TR
TRG
IN1
1MA
EXT
A
Center 2.48 GHz
320 ms/
Date: 14.NOV.2013 12:32:45

Diagram 12



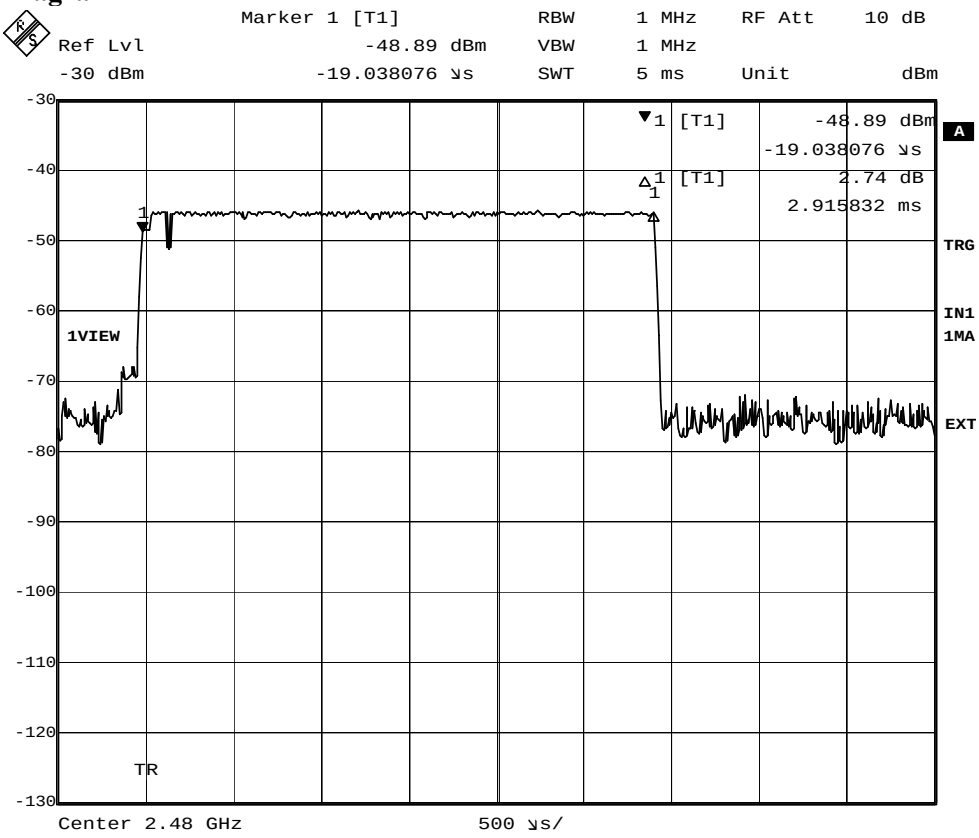
Date: 14.NOV.2013 12:37:42

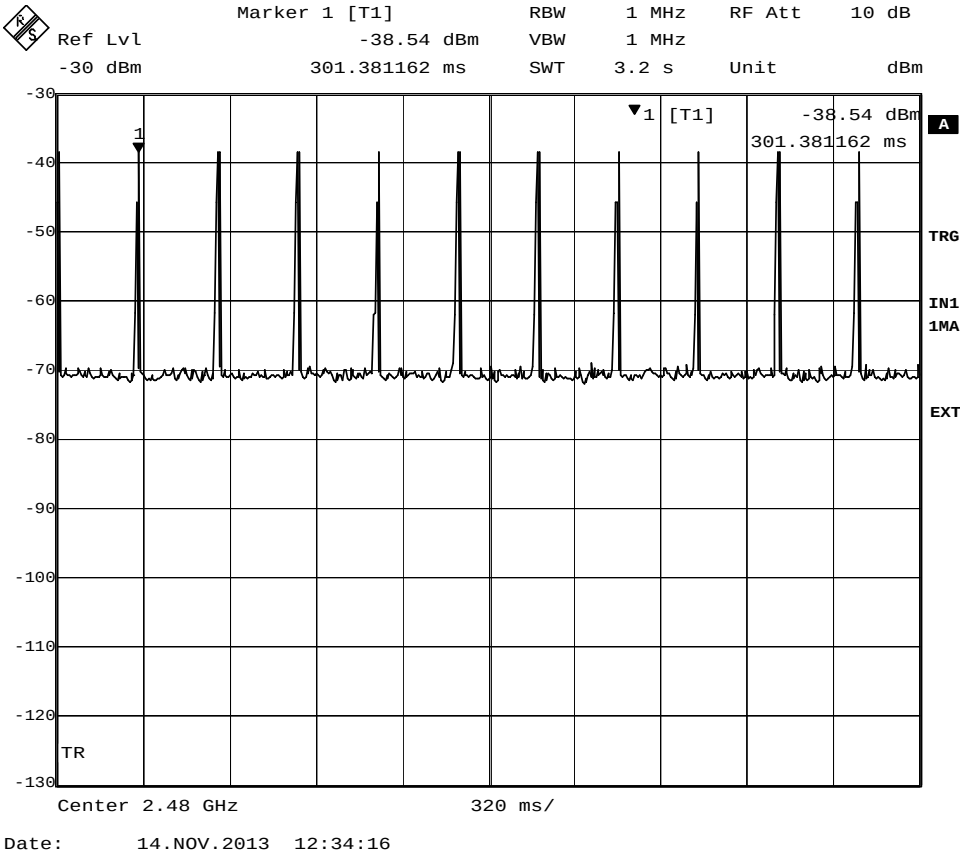
Diagram 13



Date: 14.NOV.2013 12:36:29

Diagram 14


Marker 1 [T1]
RBW 1 MHz
RF Att 10 dB
Ref Lvl
-48.89 dBm
VBW 1 MHz
-30 dBm
-19.038076 µs
SWT 5 ms
Unit dBm
1 [T1]
-48.89 dBm
-19.038076 µs
Δ1 [T1]
2.74 dB
2.915832 ms
A
TRG
IN1
1MA
EXT
1VIEW
TR
Center 2.48 GHz
500 µs/
Date: 14.NOV.2013 12:35:46


Marker 1 [T1]
RBW 1 MHz
RF Att 10 dB
Ref Lvl
-38.54 dBm
VBW 1 MHz
-30 dBm
301.381162 ms
SWT 3.2 s
Unit dBm
1 [T1]
-38.54 dBm
301.381162 ms
A
TRG
IN1
1MA
EXT
TR
Center 2.48 GHz
320 ms/
Date: 14.NOV.2013 12:34:16

Maximum peak conducted output power measurements according to FCC 47 CFR part 15.247 (b) (1) / RSS 210-210 A8.4(2)

Date	Temperature	Humidity
2013-06-19	23 °C ± 3 °C	50 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009 and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems, DA 00-705, released March 30, 2000.

The test was performed with continuous transmission (77% duty cycle) and both with GFSK and 8DPSK modulation.

The test was performed both radiated and conducted.
The test of radiated emission was performed in a semi anechoic chamber. The measurements were performed with both horizontal and vertical polarizations of the antenna. Measurement was performed with instrument RBW set to 1MHz. The fundamental was scanned with PEAK-detector with the antenna height was varied between 1-4 m and the turntable was rotated between 0-360 degrees for maximum response. The antenna distance during the measurements was 3.0 m.
Conducted power was measured with a Peak power analyzer in CDF-mode.

The radiated set-up photos during the tests can be found in Appendix 12.

Measurement equipment	SP number
Semi anechoic chamber, Edison	504 114
Spectrum analyzer R&S ESU 26	902 210
Boonton power meter	503 144
Boonton power sensor	503 146
EMI measurement computer	-
Software: R&S EMC32, ver. 8.52.0	503 745
Horn antenna EMCO 3115	501 548
Multimeter Fluke 83	501 522
Temperature and humidity meter Testo 625	504 117

Results

RBW=1 MHz GFSK		Max peak **radiated** output power , Note 1		
		2402 MHz	2441 MHz	2480 MHz
	EUT axes	X	X	X
	Antenna height	1.05	1.05	1.05
	Azimuth	278	278	278
	Polarization	Horizontal	Horizontal	Horizontal
T_{nom} 22°C	V_{nom} 3.7 V DC	112.8 dBµV/m	115.5 dBµV/m	104.3 dBµV/m
		Max peak **conducted** output power		
		2402 MHz	2441 MHz	2480 MHz
T_{nom} 22°C	V_{nom} 3.7 V DC GFSK	0.0537 W	0.0602 W	0.0549 W
T_{nom} 22°C	V_{nom} 3.7 V DC 8DPSK	0.0120 W	0.0150 W	0.0130 W

Note 1: According 47CFR 15.31(e), for intentional radiators, measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, shall be performed with the supply voltage varied between 85% and 115% of the nominal rated supply voltage. For battery operated equipment, the equipment tests shall be performed using a new battery.

Limits

According to 47CFR 15.247(b)(1), For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

According to RSS-210 A8.4(2), same as above.

Complies?	Yes

20 dBc below fundamental measurements according to FCC 47 CFR part 15.247 (d) / RSS-210 A8.5

Date	Temperature	Humidity
2013-07-03	23 °C ± 3 °C	53 % ± 5 %
2013-10-24	22 °C ± 3 °C	42 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009.

Conducted measurements were performed at the antenna connector and with continuous transmission (77% duty cycle) and with GFSK modulation.

The test was performed with peak detector and with RBW=100 kHz.
The used test equipment was connected to an external 10 MHz reference standard during measurements.

Measurement equipment	SP number
Test site Hertz	15:116
R&S FSIQ40 Signal Analyser	503 738
Multimeter Fluke 83	501 522
Temperature and humidity meter Testo 625	504 117

Measurement uncertainty: 2.6 dB

Results

The measurements can be found in the diagrams below:

Diagram 1:	2402 MHz	Fundamental
Diagram 2:	2402 MHz	9 kHz–150 kHz
Diagram 3:	2402 MHz	0.15 – 30 MHz
Diagram 4:	2402 MHz	30-1000 MHz
Diagram 5:	2402 MHz	1-2.4 GHz
Diagram 6:	2402 MHz	2.4-8 GHz
Diagram 7:	2402 MHz	8-18 GHz
Diagram 8:	2402 MHz	18-25 GHz

Diagram 9:	2441 MHz	Fundamental
Diagram 10:	2441 MHz	9 kHz–150 kHz
Diagram 11:	2441 MHz	0.15 – 30 MHz
Diagram 12:	2441 MHz	30-1000 MHz
Diagram 13:	2441 MHz	1-2.4 GHz
Diagram 14:	2441 MHz	2.4-4 GHz
Diagram 15:	2441 MHz	4-8 GHz
Diagram 16:	2441 MHz	8-18 GHz
Diagram 17:	2441 MHz	18-25 GHz

Diagram 18:	2480 MHz	Fundamental
Diagram 19:	2480 MHz	9 kHz–150 kHz
Diagram 20:	2480 MHz	0.15 – 30 MHz
Diagram 21:	2480 MHz	30-1000 MHz
Diagram 22:	2480 MHz	1-2.4 GHz
Diagram 23:	2480 MHz	2.4-8 GHz
Diagram 24:	2480 MHz	8-18 GHz
Diagram 25:	2480 MHz	18-25 GHz

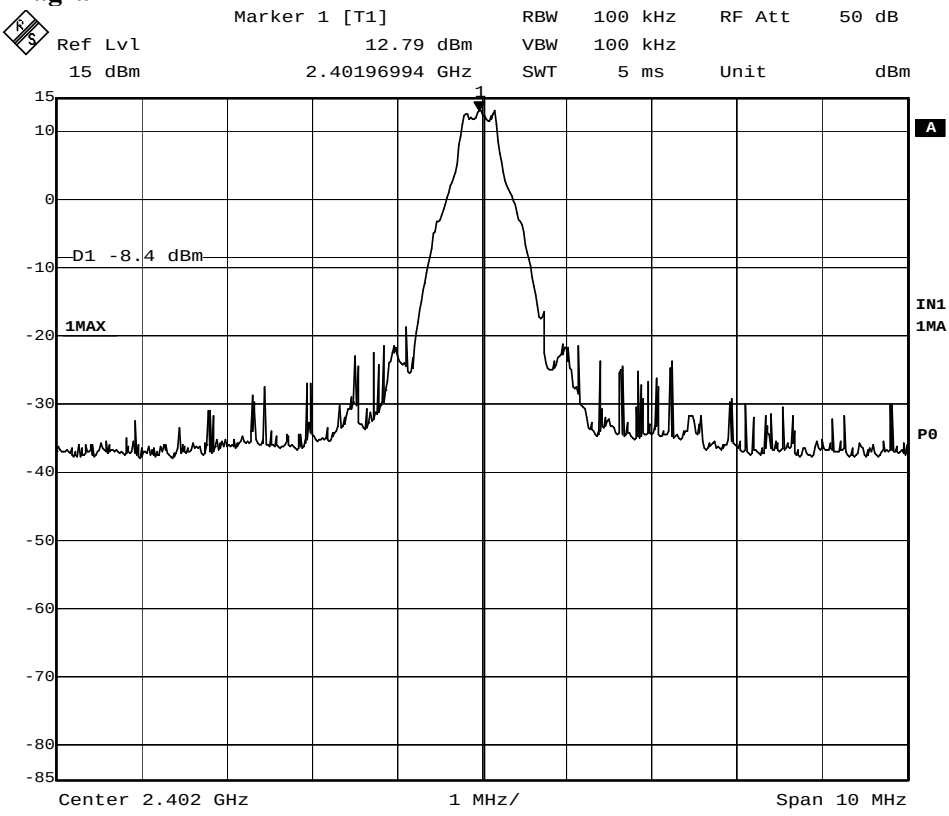
Limits

According to 47CFR 15.247(d), in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.
Radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section15.209(a).

According to RSS-210 A8.5, in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean square averaging over a time interval, as permitted under Section A8.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

Complies?	Yes

Diagram 1



2402MHz: Relative fundamental power=12,8 dBm > limit line@ -7.2 dBm.

Diagram 2

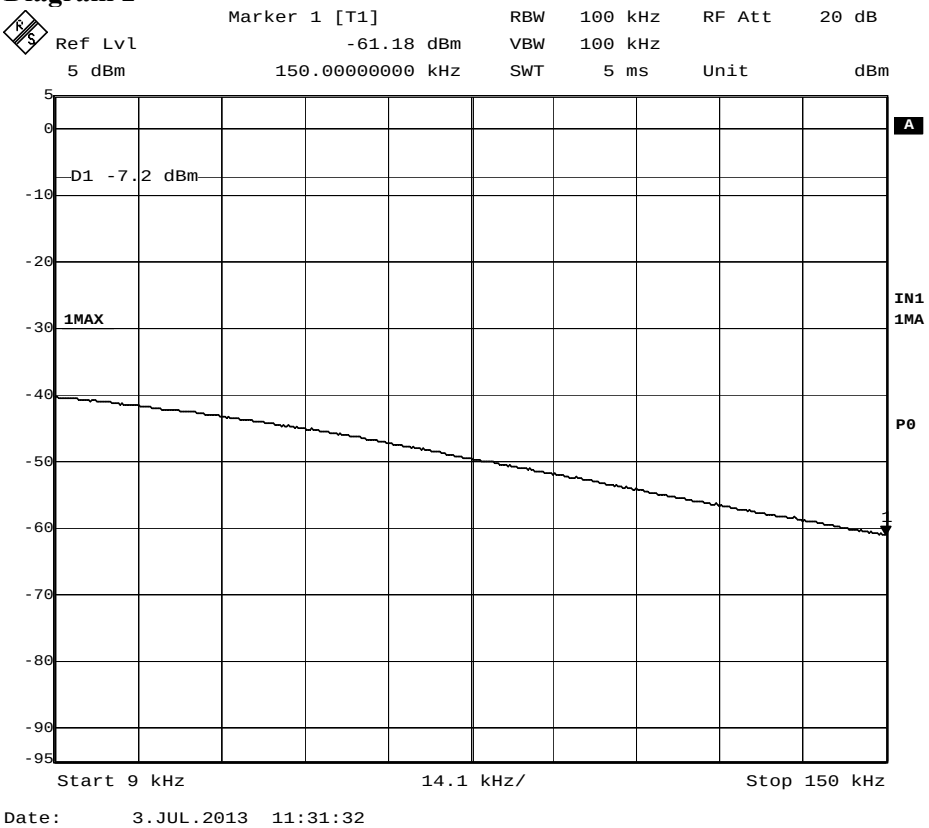
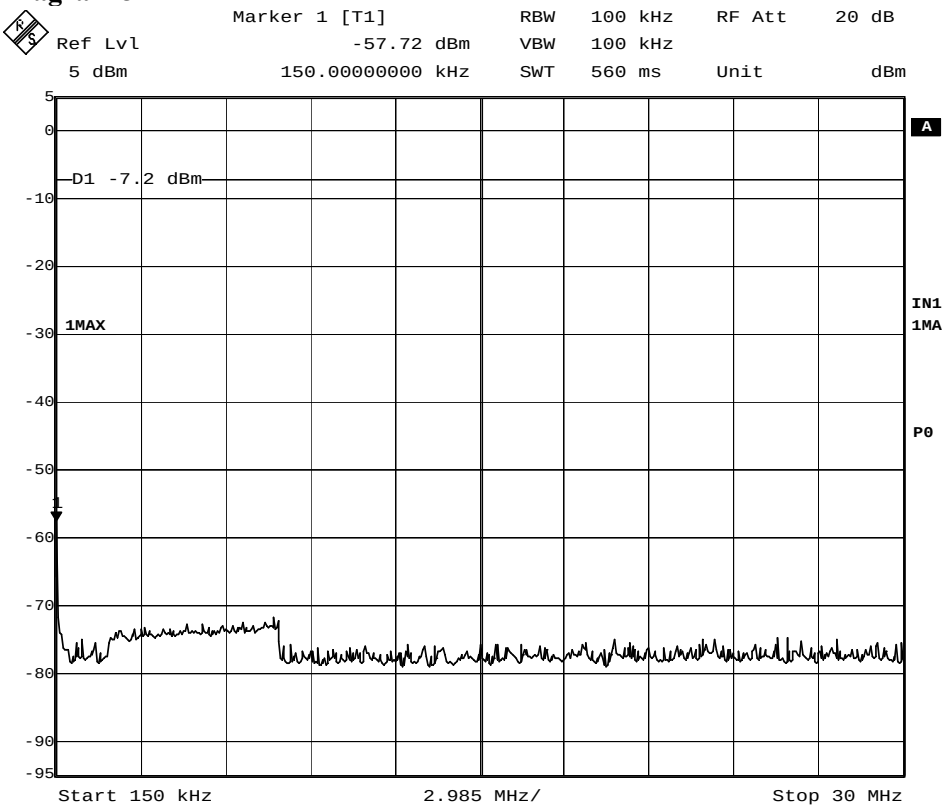
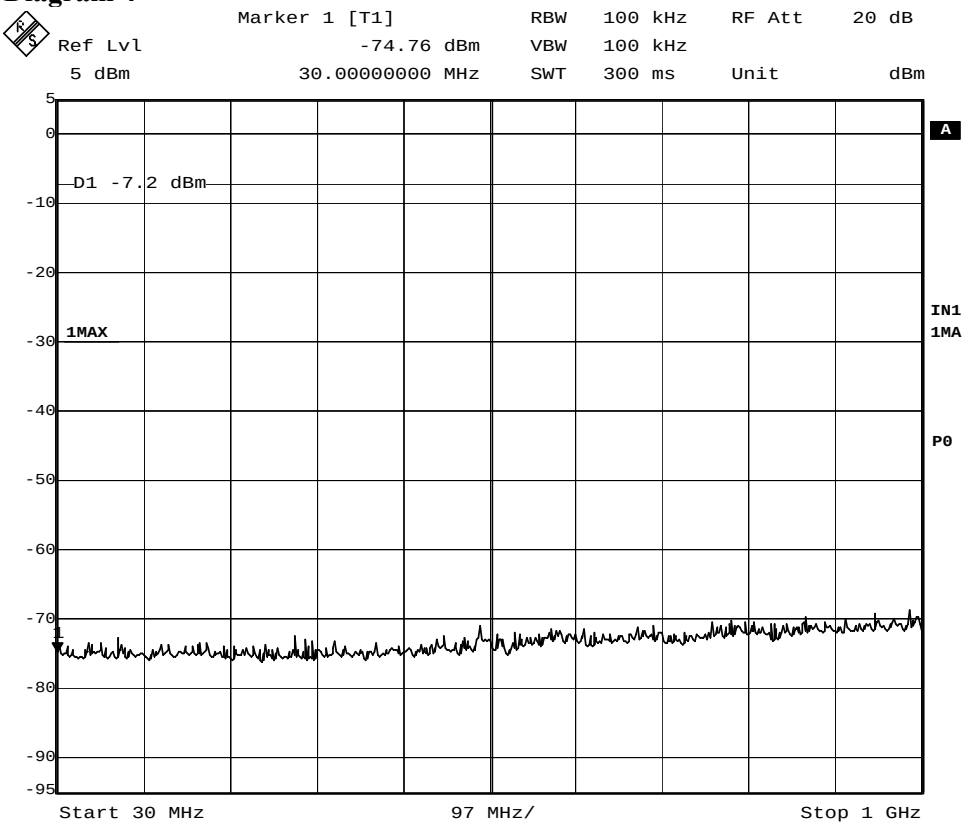


Diagram 3



Date: 3.JUL.2013 11:32:10

Diagram 4



Date: 3.JUL.2013 11:32:47

Diagram 5

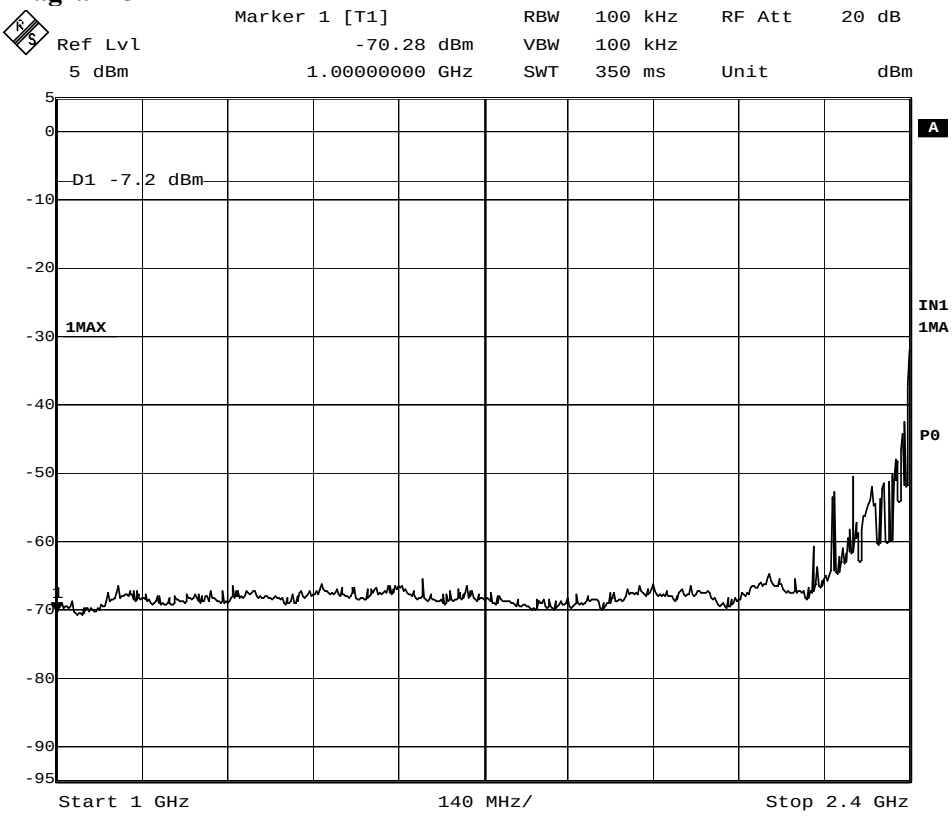


Diagram 6

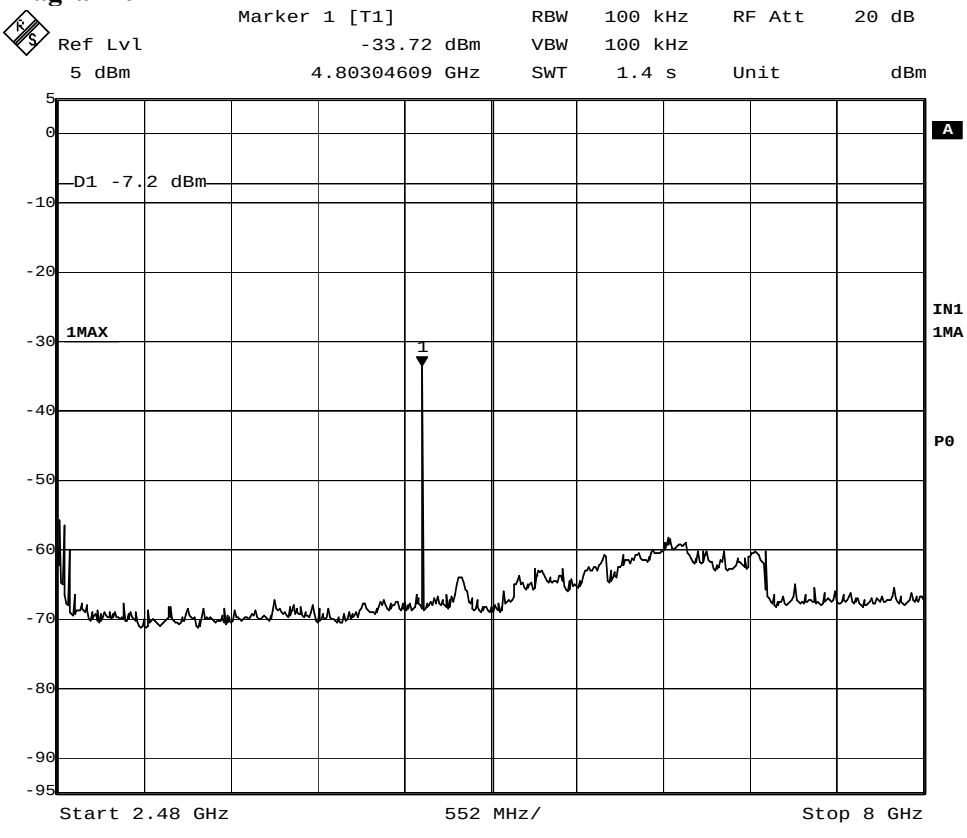
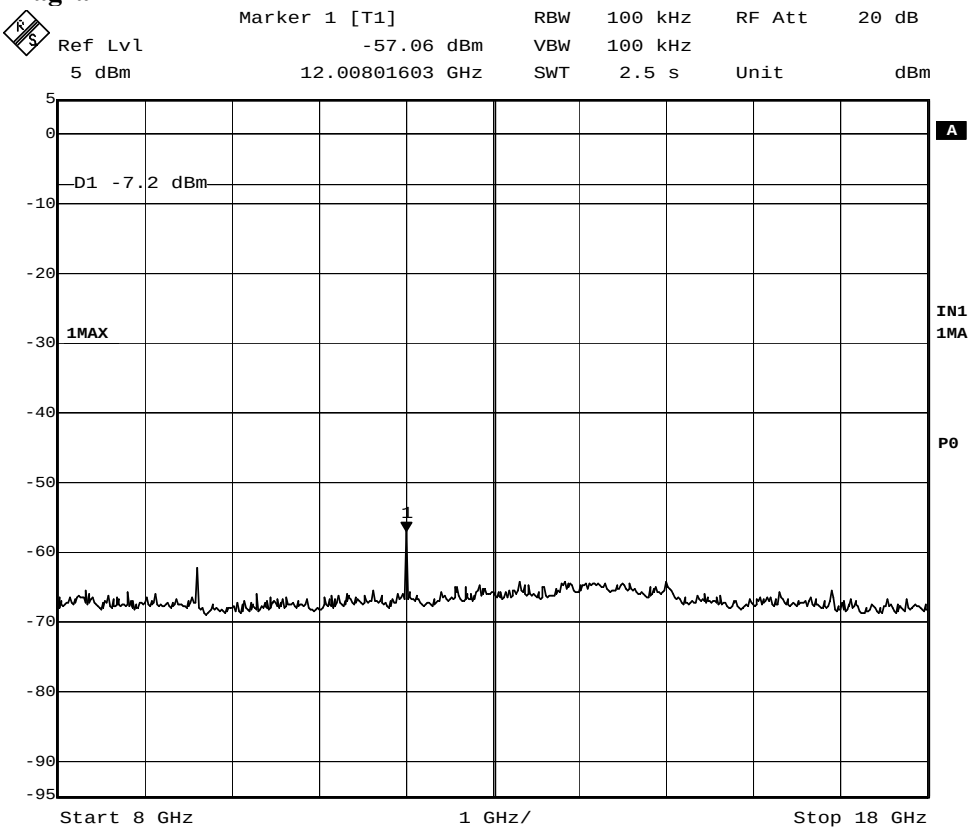
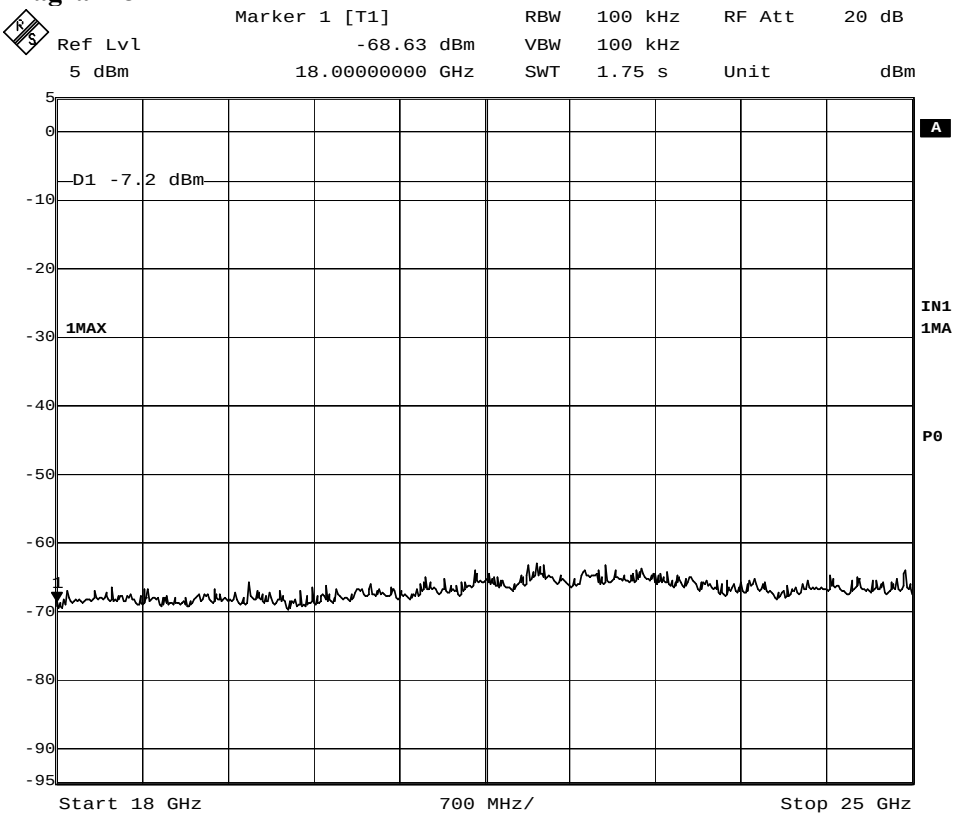


Diagram 7



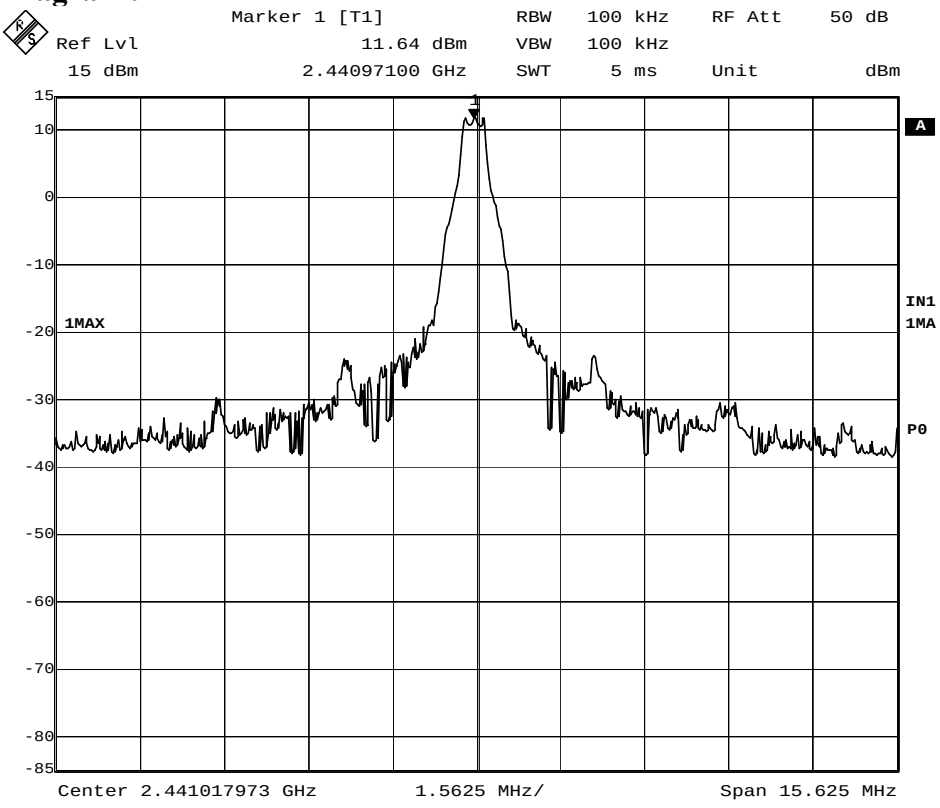
Date: 3.JUL.2013 11:34:59

Diagram 8



Date: 3.JUL.2013 11:35:27

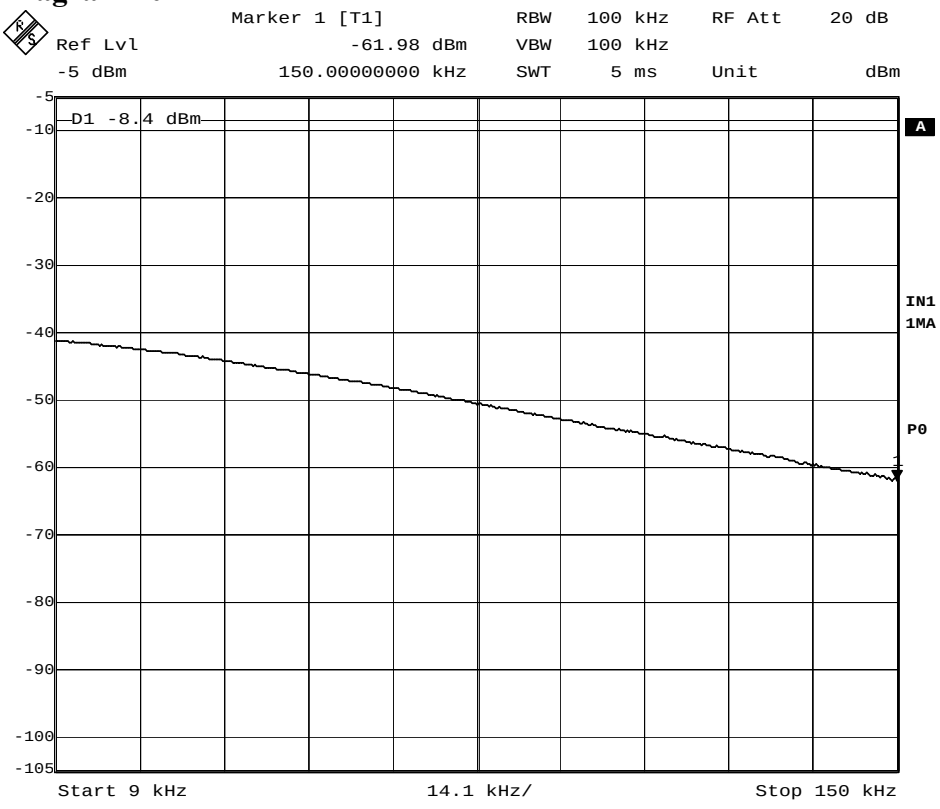
Diagram 9



Date: 3.JUL.2013 11:05:24

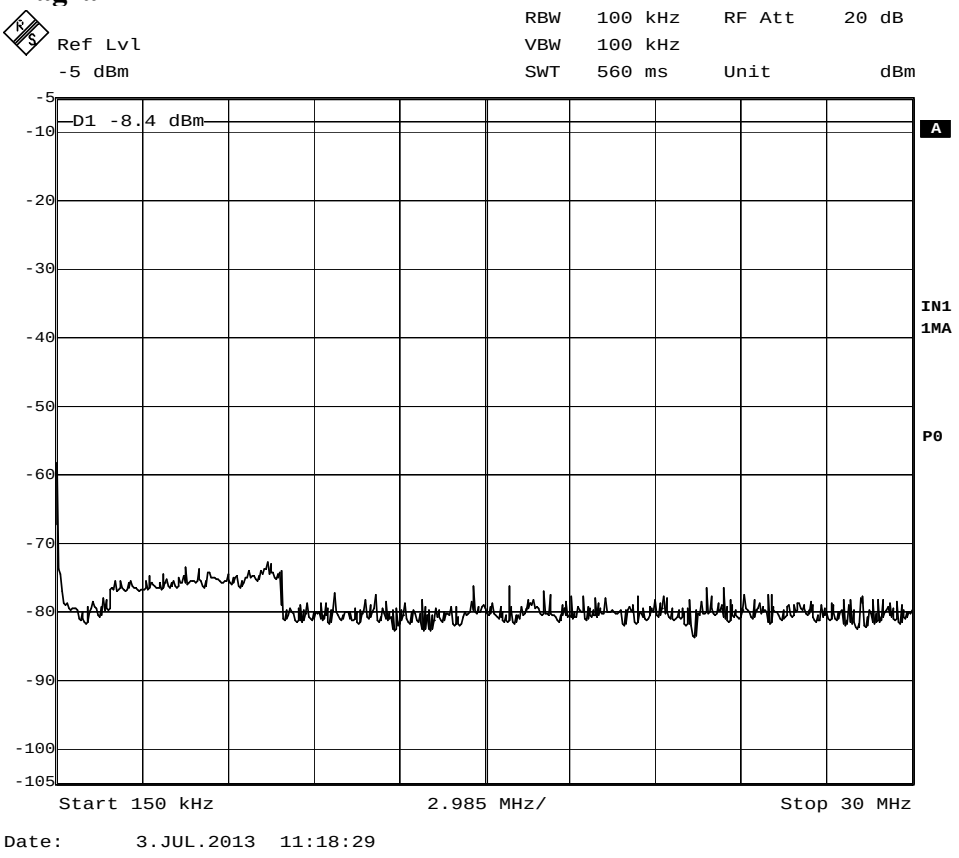
2441MHz: Relative fundamental power=11.6 dBm > limit line@ -8.4 dBm.

Diagram 10



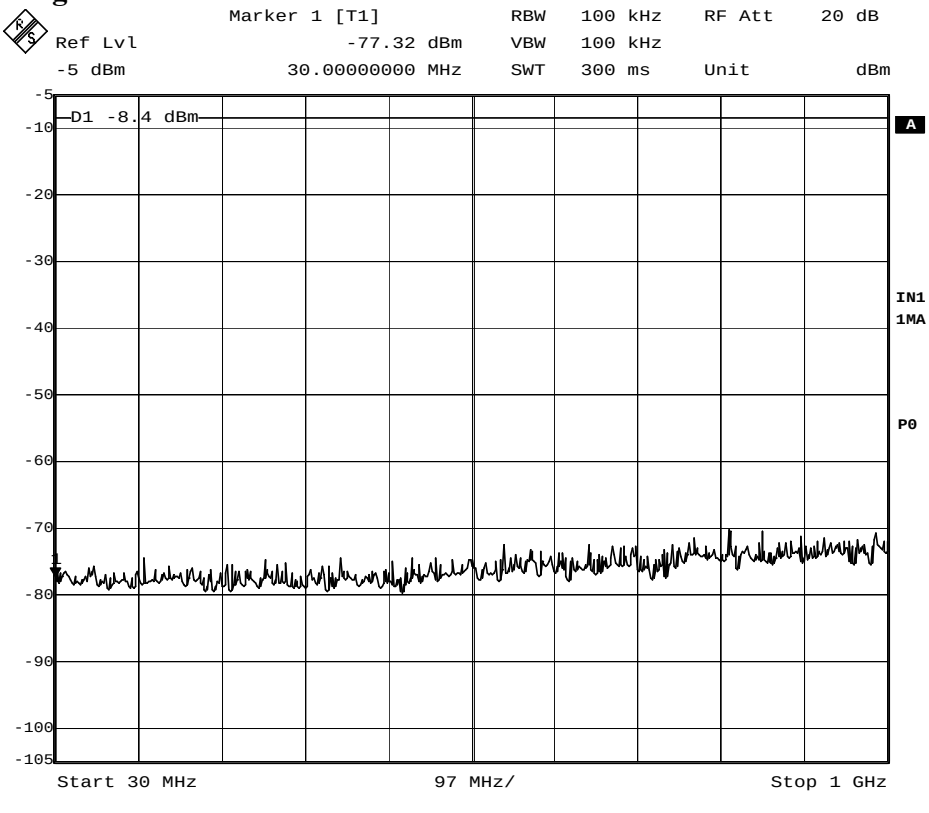
Date: 3.JUL.2013 11:16:49

Diagram 11



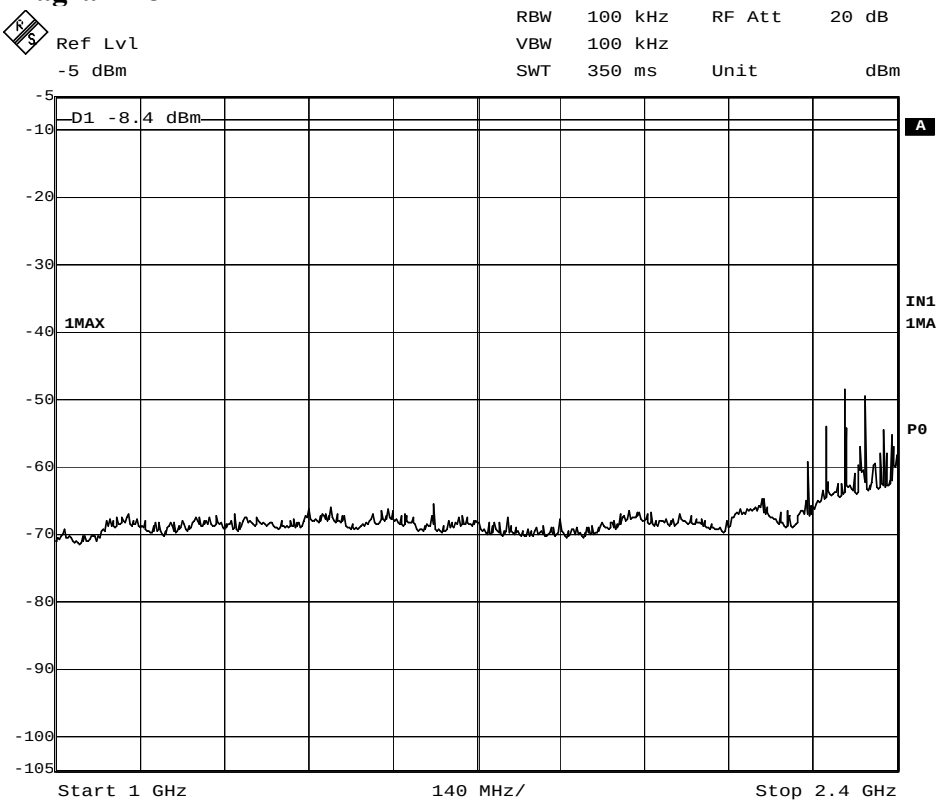
Date: 3.JUL.2013 11:18:29

Diagram 12



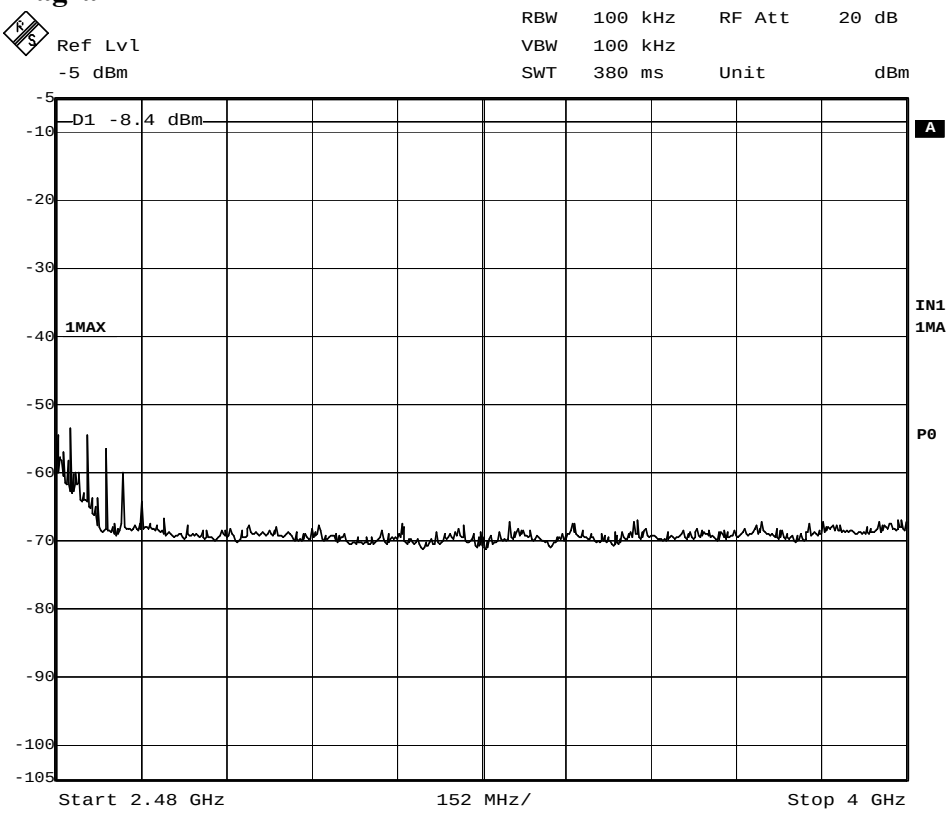
Date: 3.JUL.2013 11:19:26

Diagram 13



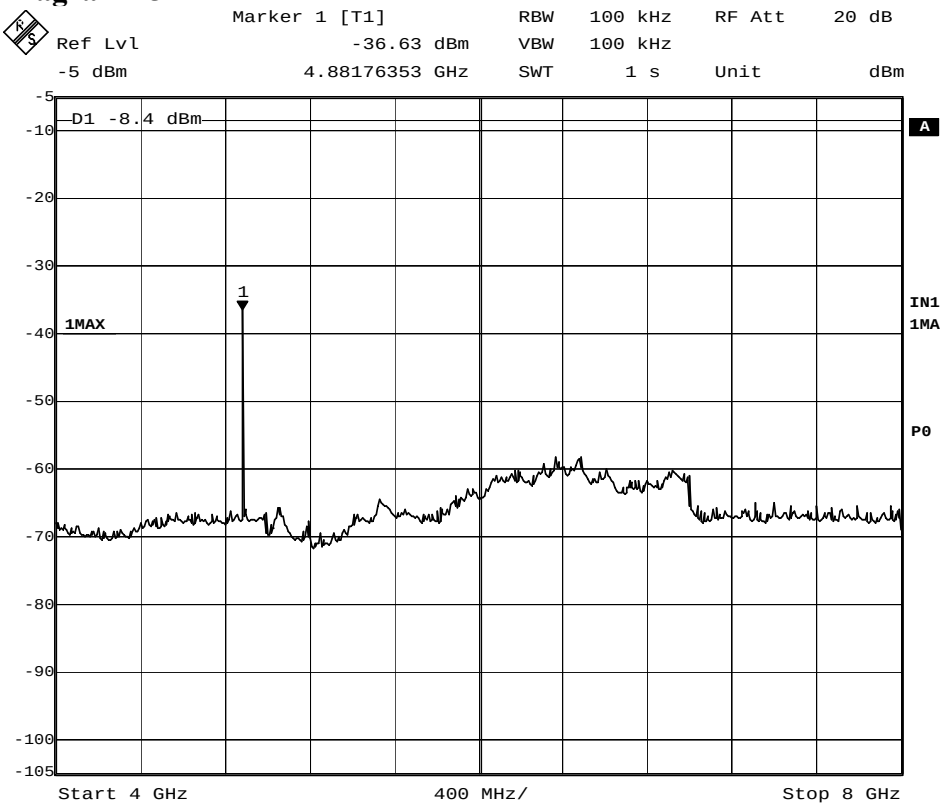
Date: 3.JUL.2013 11:21:08

Diagram 14



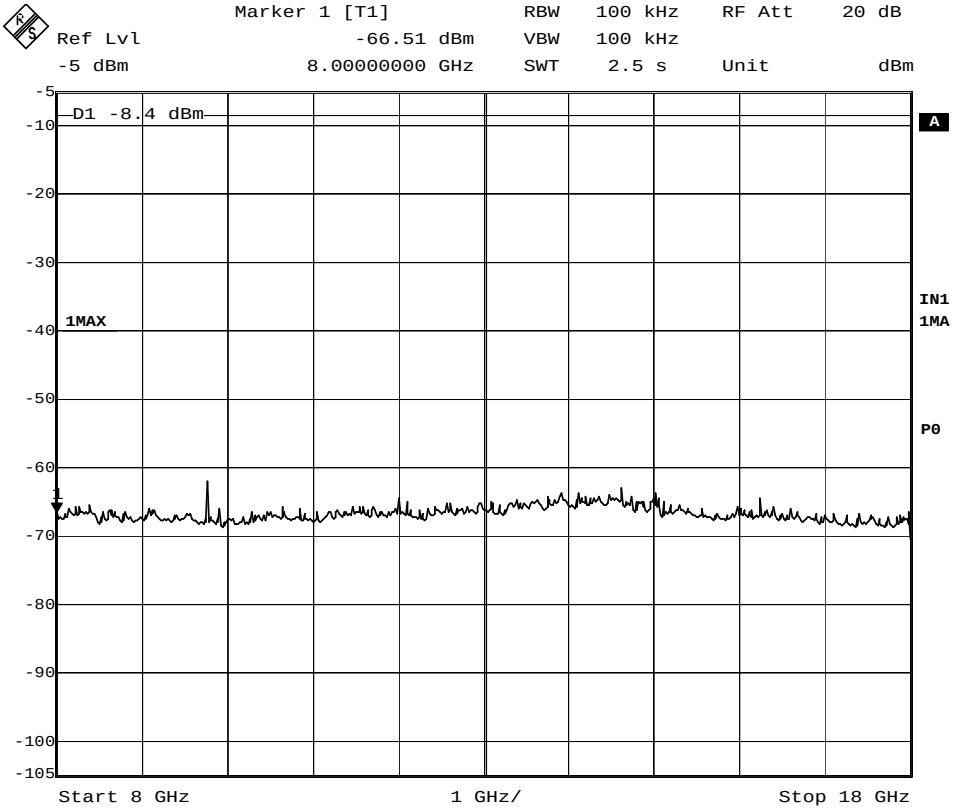
Date: 3.JUL.2013 11:21:51

Diagram 15



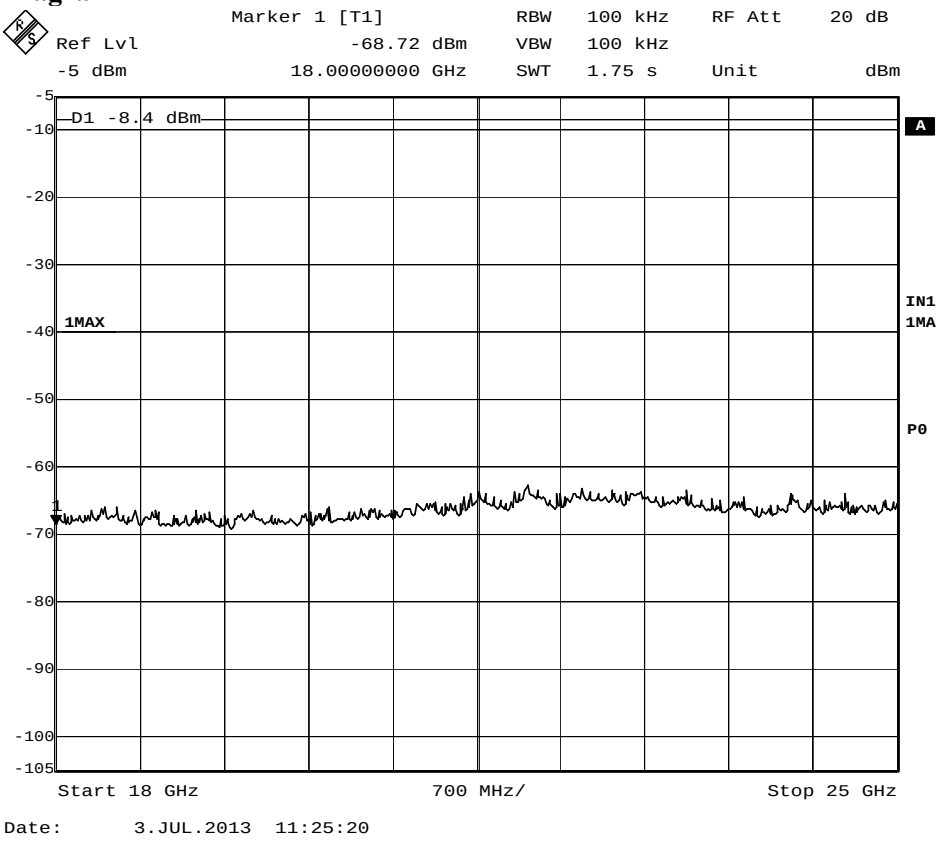
Date: 3.JUL.2013 11:23:05

Diagram 16



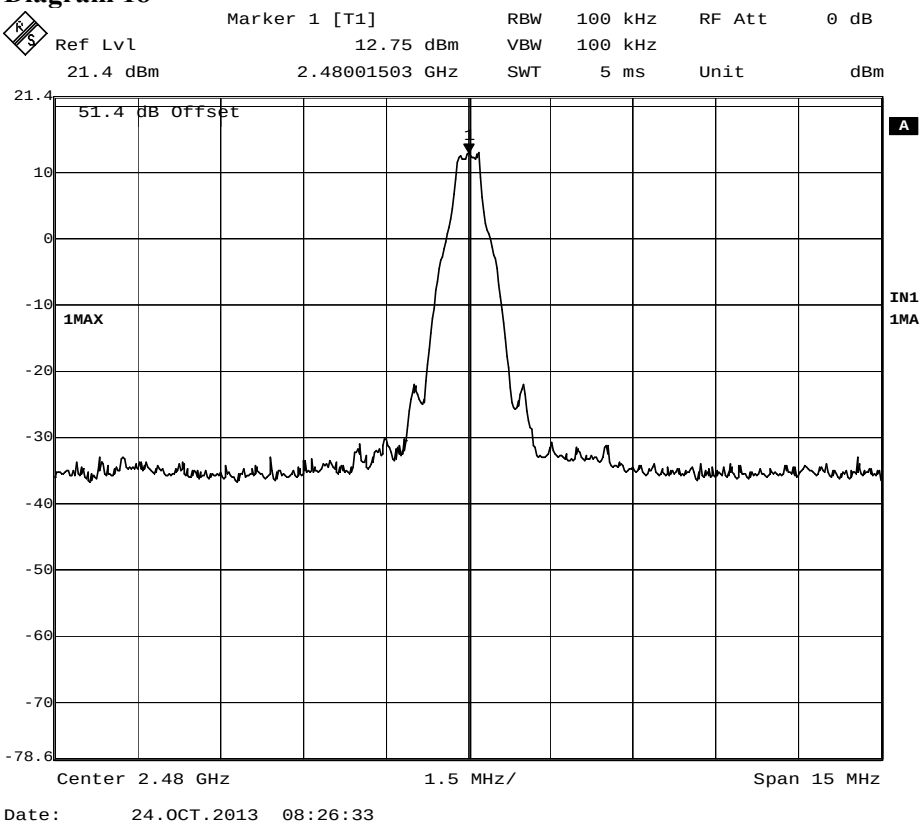
Date: 3.JUL.2013 11:24:07

Diagram 17



Date: 3.JUL.2013 11:25:20

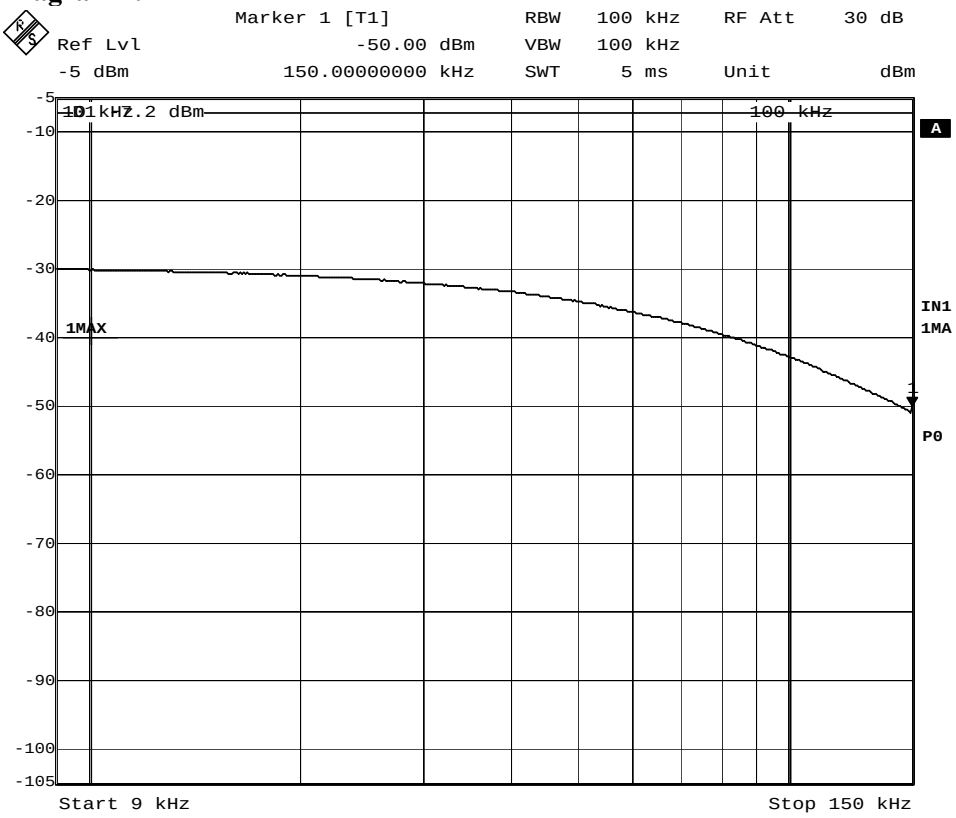
Diagram 18



Date: 24.OCT.2013 08:26:33

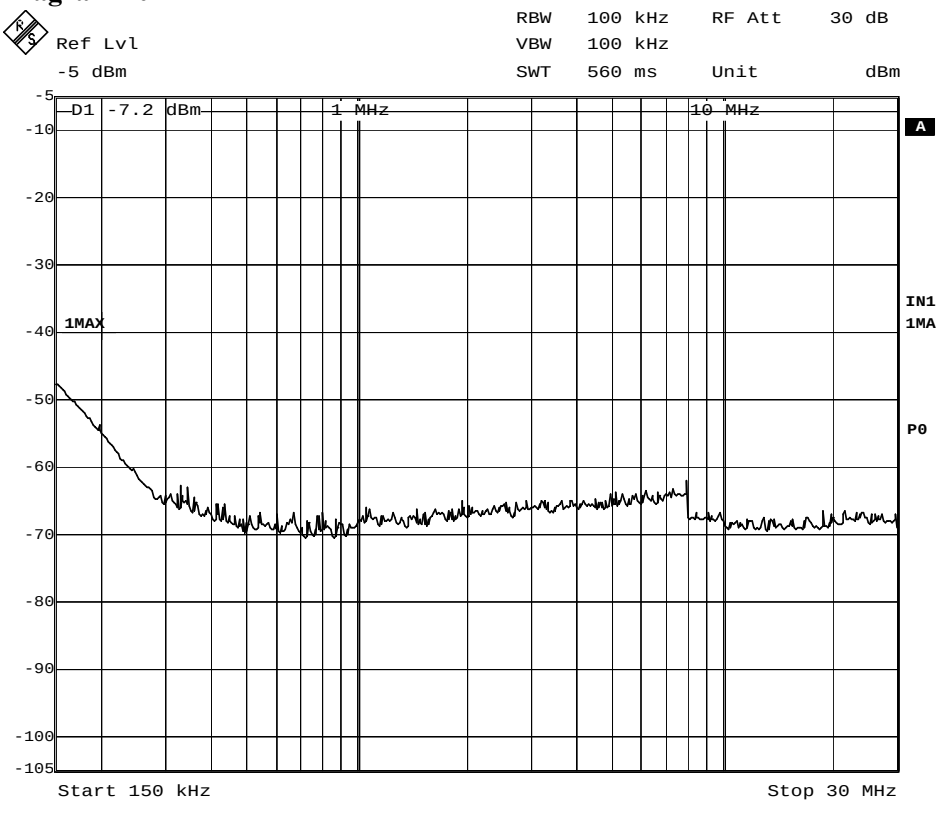
2480MHz: Relative fundamental power=12.8 dBm > limit line@ -7.2 dBm.

Diagram 19



Date: 3.JUL.2013 11:38:21

Diagram 20



Date: 3.JUL.2013 11:39:00

Diagram 21

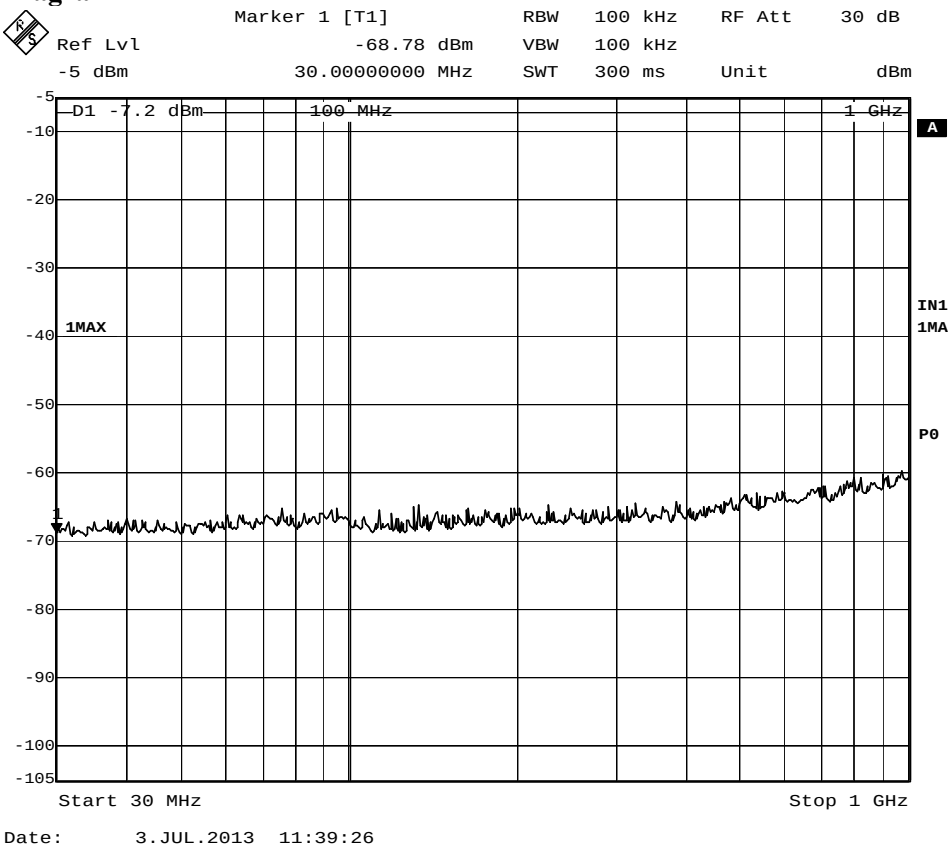


Diagram 22

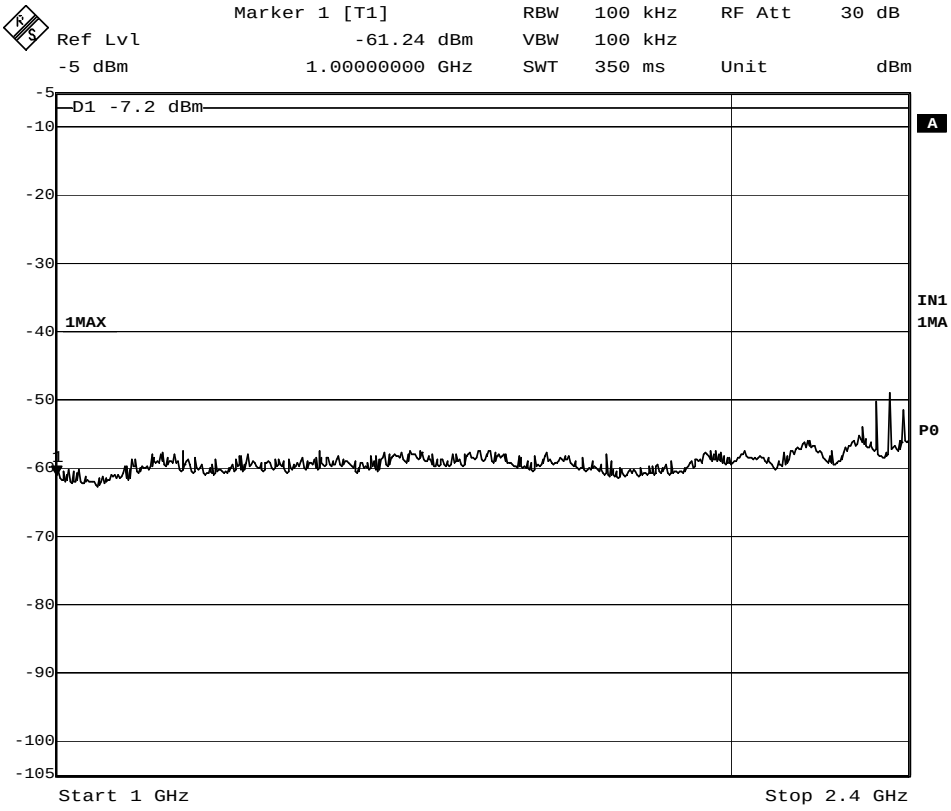


Diagram 23

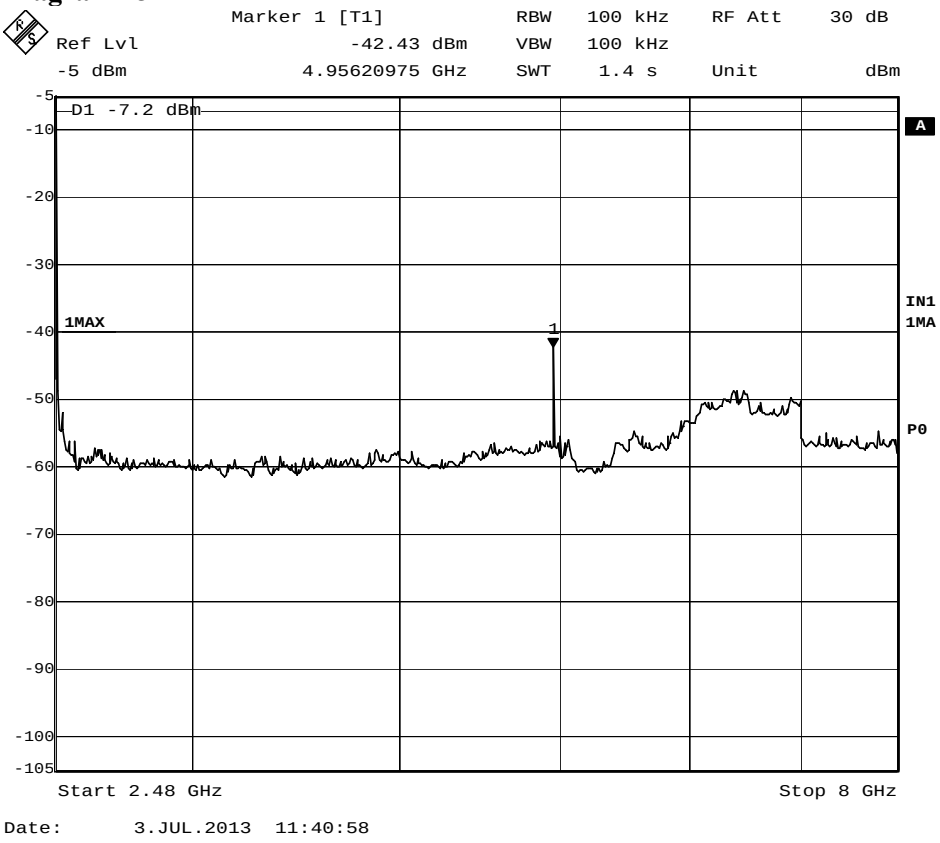


Diagram 24

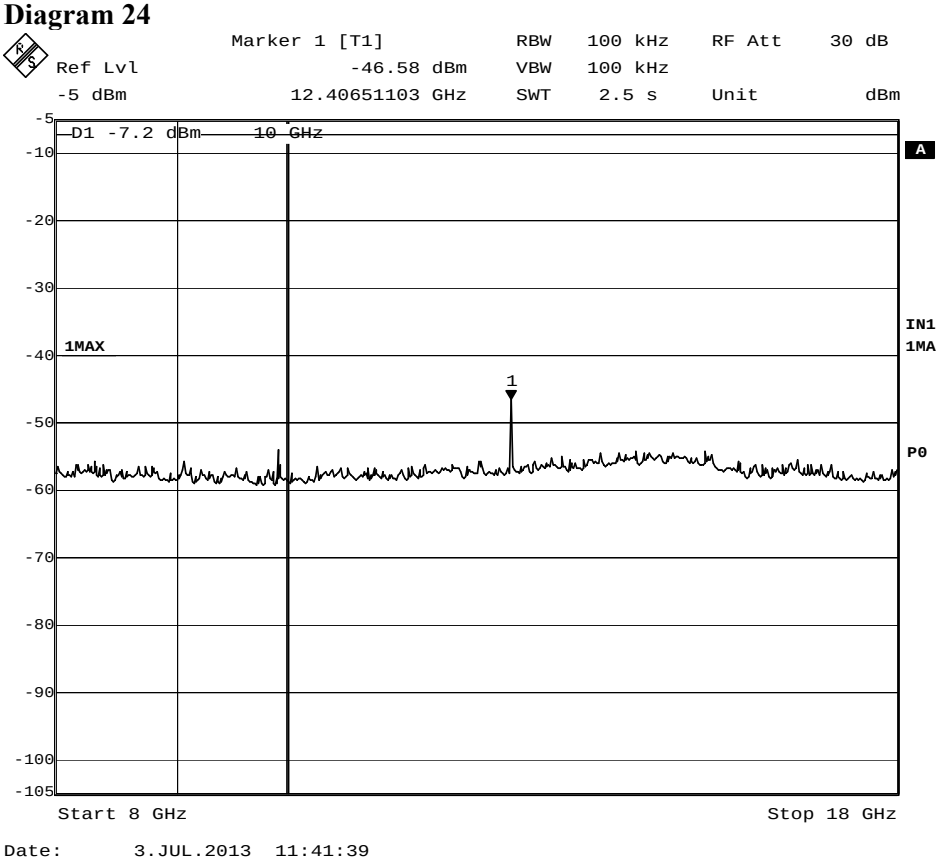
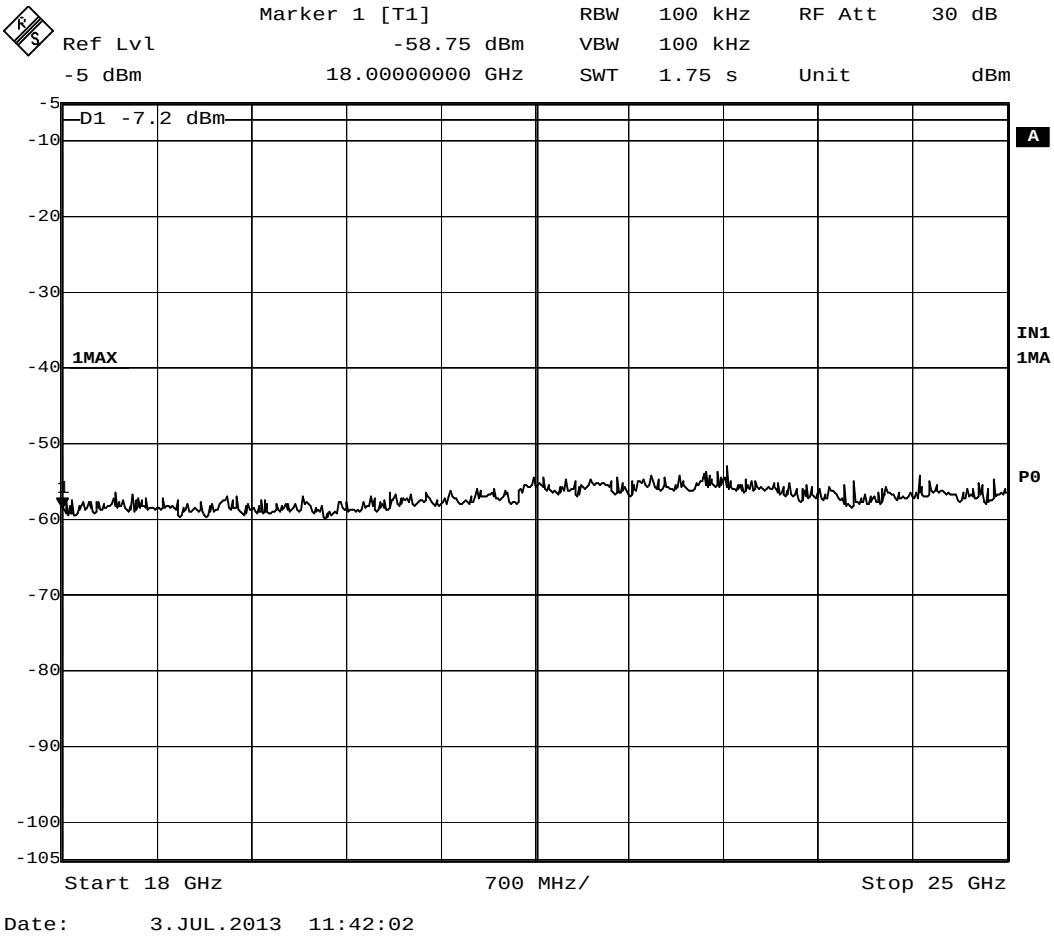


Diagram 25


Marker 1 [T1]
RBW 100 kHz
RF Att 30 dB
Ref Lvl
-58.75 dBm
VBW 100 kHz
-5 dBm
18.00000000 GHz
SWT 1.75 s
Unit dBm
D1 -7.2 dBm
1MAX
A
IN1
1MA
P0
-5
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-105
Start 18 GHz
700 MHz/
Stop 25 GHz
Date: 3.JUL.2013 11:42:02

Restricted bands of operation measurements according to FCC 47 CFR part 15.247 (d) / RSS-210 A8.5

Date	Temperature	Humidity
2013-06-18	22 °C ± 3 °C	49 % ± 5 %
2013-10-24	22 °C ± 3 °C	42 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009.

The test was performed with continuous transmission (77% duty cycle) and with GFSK modulation.

The test of radiated emission was performed in a semi anechoic chamber. The measurements were performed with both horizontal and vertical polarizations of the antenna. The antenna distance during the measurements was 3.0 m in the frequency range 30 MHz-18 GHz and 1.0 m in the frequency range 18-25 GHz.

The measurement procedure is as follows:

1. A pre-measurement is performed with peak detector. The test object is measured in eight directions with the antenna at three heights, 1.0 m, 1.5 m and 2.0 m.
2. If the emission is close or above the limit during the pre-measurement, the test object is scanned 360 degrees and the antenna height scanned from 1 to 4 m for maximum response. Then the emission is measured with the quasi-peak detector on frequencies below 1 GHz and with the average detector above 1 GHz.

The following RBW were used:
30 MHz-1 GHz: RBW=100 kHz
1-25 GHz: RBW=1 MHz

Test set-up photos during the tests can be found in Appendix 12.

Measurement equipment	SP number
Semi anechoic chamber, Edison	504 114
Spectrum analyzer R&S ESU 26	902 210
EMI measurement computer	-
Software: R&S EMC32, ver. 8.52.0	503 745
Antenna Schaffner Bilog CBL6143	504 079
Horn antenna EMCO 3115	501 548
Low Noise Amplifier Miteq	504 160
Low Noise Amplifier Miteq	503 277
Standard gain horn Flann 16240-25	503 939
Standard gain horn Flann 18240-25	503 900
Standard gain horn Flann 20240-20	503 674
High pass filter Wainwright WHKY	503 939
Multimeter Fluke 83	501 522
Temperature and humidity meter Testo 625	504 117

Results

The pre-measurement emission spectra can be found in the diagrams below:

Diagram 1	30-1000 MHz, 2441 MHz, vertical and horizontal polarization, X-axes
Diagram 2	1-3 GHz, 2441 MHz, vertical and horizontal polarization, X-axes
Diagram 3	3-8.2 GHz, 2441 MHz, vertical and horizontal polarization, X-axes
Diagram 4	8.2-12 GHz, 2441 MHz, vertical and horizontal polarization, X-axes
Diagram 5	12-18 GHz, 2441 MHz, vertical and horizontal polarization, X-axes
Diagram 6	18-25 GHz, 2441 MHz, vertical polarization, X-axes
Diagram 7	18-25 GHz, 2441 MHz, horizontal polarization, X-axes

Note: Worst-case plots are attached.

The highest detected levels during the final measurement in the frequency range 30 MHz-25 GHz are listed in the tables below.

2402 MHz

Frequency (MHz)	QP level (dBµV/m)	CISPRAV level (dBµV/m)	Peak level (dBµV/m)	Corr (dB)	Limit (dBµV/m)	Height (m)	Azimuth (deg)	Polarization
1627	N/A	25.2	36.3	20.6	53.9 (av)	100	216	Horizontal
9608	N/A	23.4	34.1	46.0	53.9 (av)	100	26	Horizontal
12010	N/A	21.3	33.3	8.7	53.9 (av)	100	60	Horizontal

2441 MHz

Frequency (MHz)	QP level (dBµV/m)	CISPRAV level (dBµV/m)	Peak level (dBµV/m)	Corr (dB)	Limit (dBµV/m)	Height (cm)	Azimuth (deg)	Polarization
1627	N/A	33.1	39.3	20.6	53.9 (av)	100	216	Horizontal
9764	N/A	36.1	46.0	15.2	53.9 (av)	100	26	Horizontal
12210	N/A	19.6	31.8	8.7	53.9 (av)	100	60	Horizontal

2480 MHz

Frequency (MHz)	QP level (dBµV/m)	CISPRAV level (dBµV/m)	Peak level (dBµV/m)	Corr (dB)	Limit (dBµV/m)	Height (cm)	Azimuth (deg)	Polarization
1627	N/A	32.6	37.8	20.6	53.9 (av)	100	216	Horizontal
9920	N/A	35.3	44.7	46.0	53.9 (av)	100	26	Horizontal
12400	N/A	45.3	56.3	8.7	53.9 (av)	100	60	Horizontal

Limits

According to 47CFR 15.247(d) Radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section15.209(a).

According to RSS-210 2.2 Category I licence exempt equipment is required to comply with the provisions in RSS-Gen with respect to emissions falling within restricted frequency bands. These restricted frequency bands are listed in RSS-GEN 7.2.2 and radiated emission should comply with limits specified RSS-GEN 7.2.5.

Complies?	Yes

Diagram 1

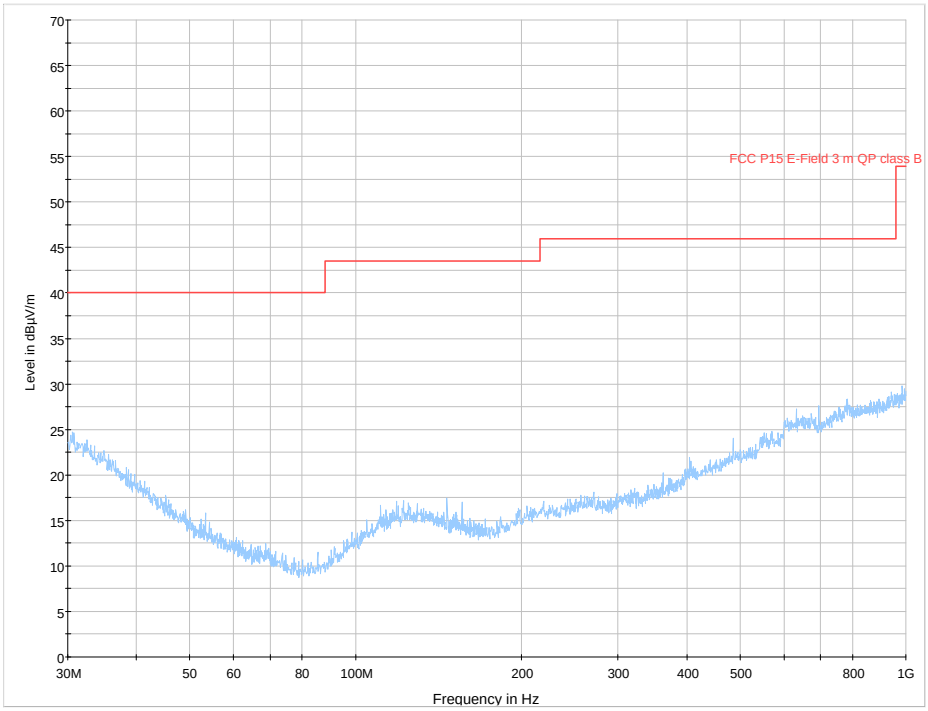


Diagram 2

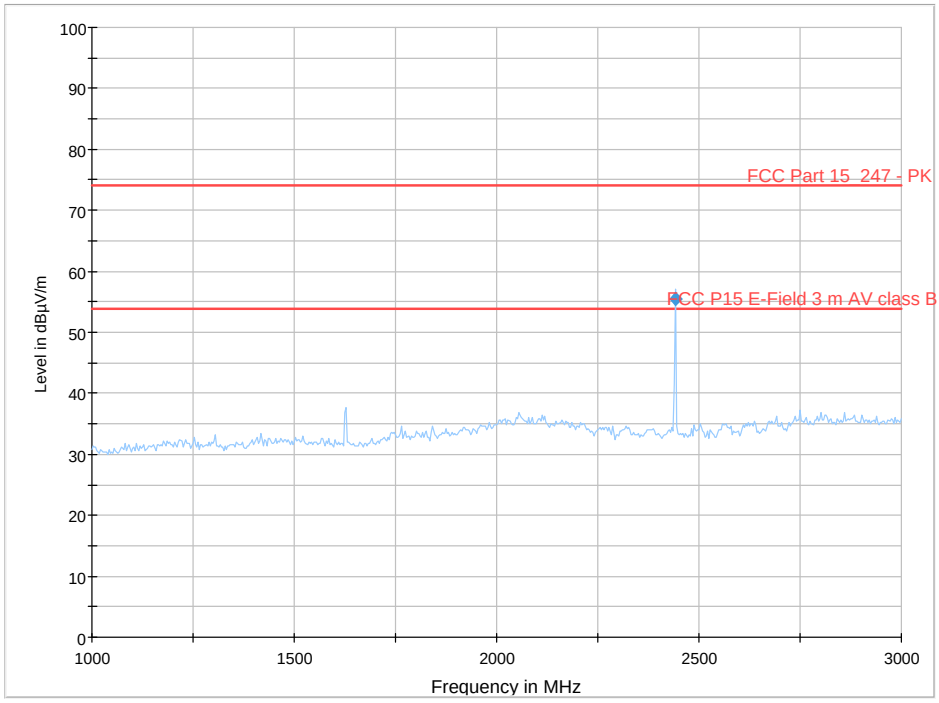


Diagram 3

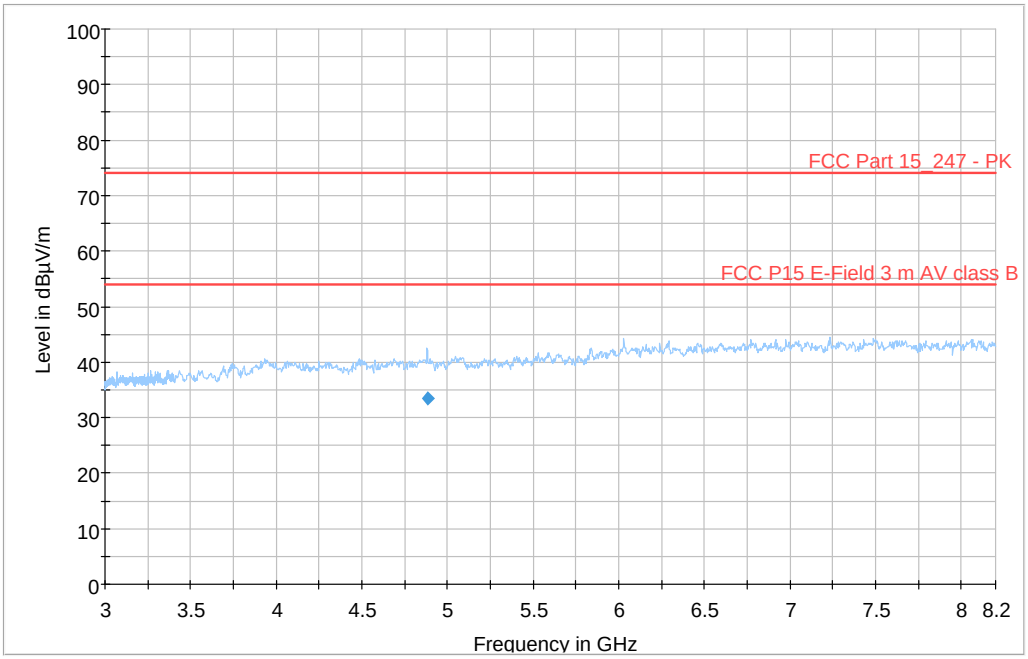


Diagram 4

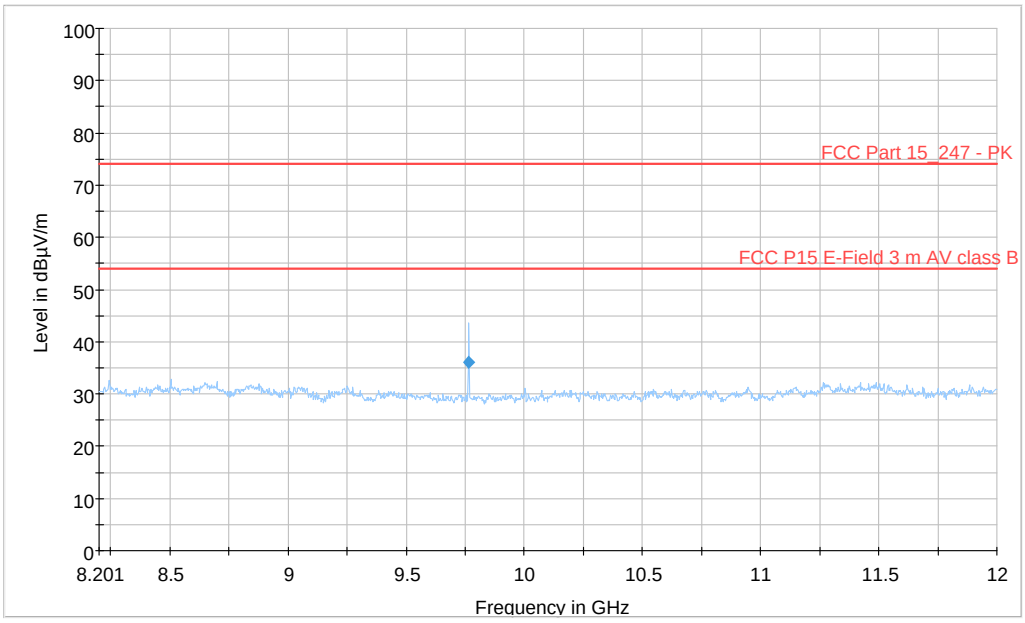


Diagram 5

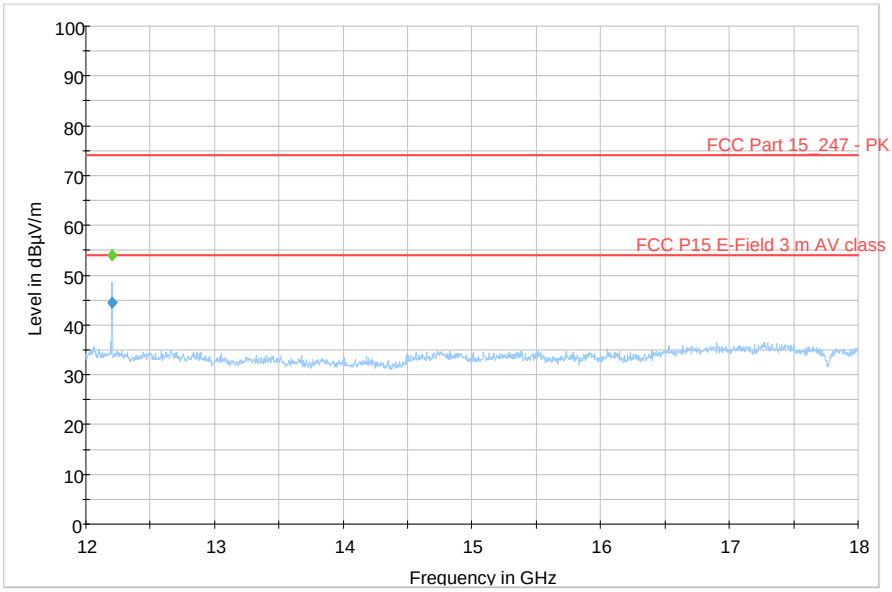


Diagram 6

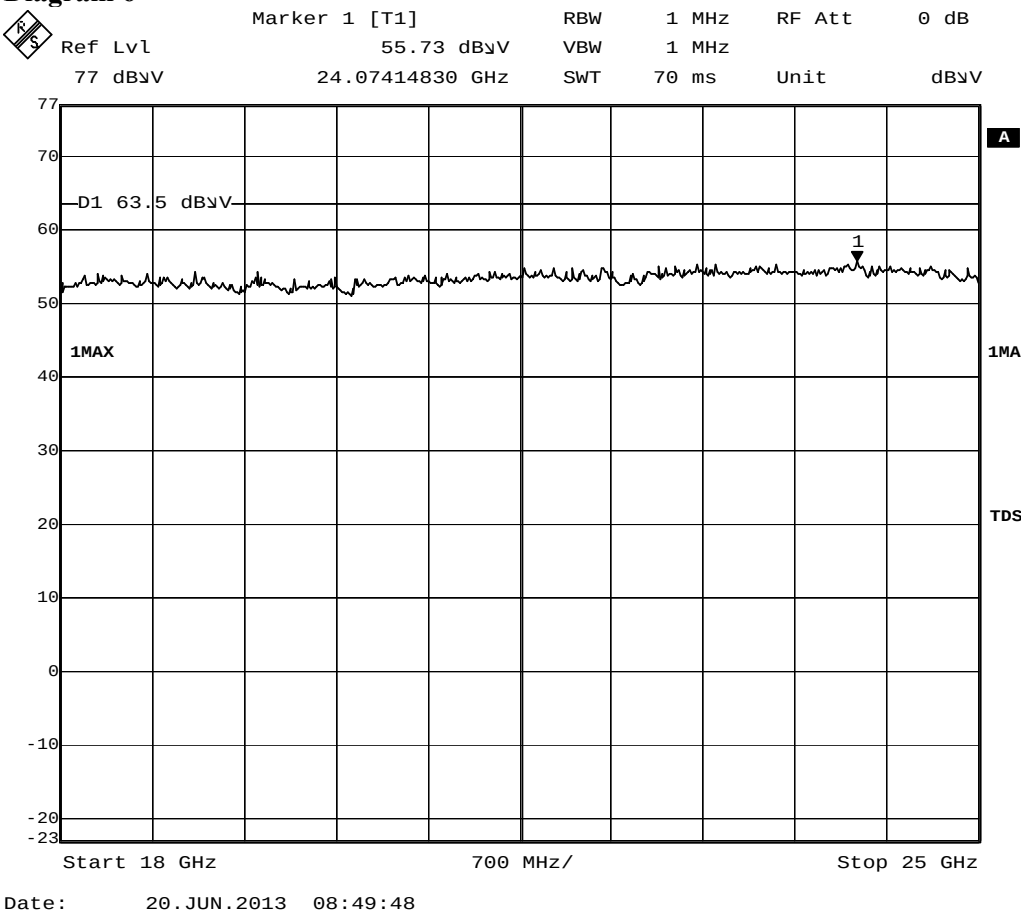
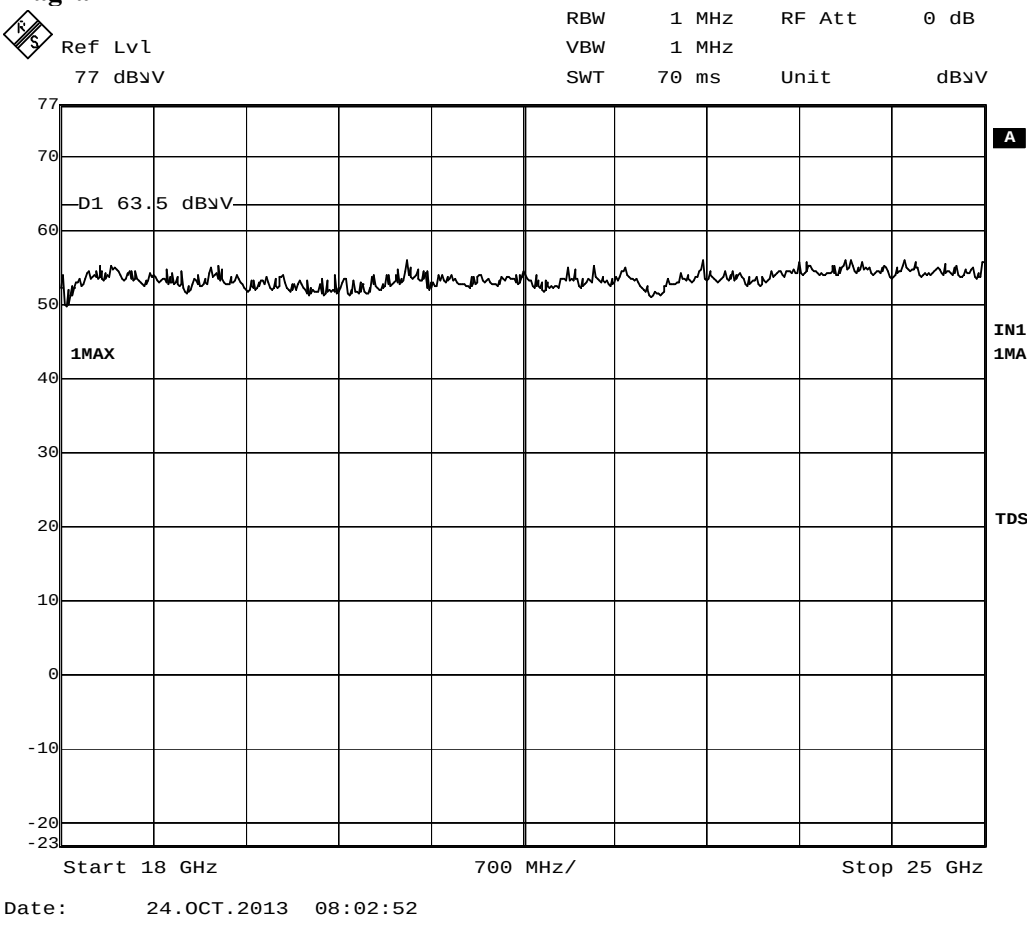


Diagram 7


RBW 1 MHz
RF Att 0 dB
VBW 1 MHz
Ref Lvl
77 dBµV
SWT 70 ms
Unit dBµV
77
70
60
50
40
30
20
10
0
-10
-20
-23
D1 63.5 dBµV
1MAX
A
IN1
1MA
TDS
Start 18 GHz
700 MHz/
Stop 25 GHz
Date: 24.OCT.2013 08:02:52

RF exposure evaluation: Mobile equipment FCC 47 CFR part 15.247 (i) / RSS-102 2.5.1

Date	Temperature	Humidity
2013-06-18	22 °C ± 3 °C	49 % ± 5 %

Procedure

Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess limit for maximum permissible exposure. In accordance with 47 CFR FCC Part 2 Subpart J, section 2.1091 this device has been defined as a mobile device whereby a distance of 0.2 m normally can be maintained between the user and the device.

Results

The following formula was used to calculate the RF exposure,
$Pd = Pout \times G/(4 \times \pi \times r^2_{cm})$

where,
Pd = power density in mW/cm^2
Pout = output power to antenna in mW
G = gain of antenna in linear scale
$\pi = 3.1416$
r = distance between observation and center of the radiator in cm

From the peak EUT RF output power, the minimum mobile separation distance, r=20 cm, as well as the gain of the used antenna, the RF power density can be obtained.

The maximum conducted peak output power from appendix 5 was used for calculation of MPE.

Antenna Gain (dBi)	Antenna Gain (numeric)	Peak output power (mW)	Power density, Pd [S] ($\mu W/cm^2$)	Limit of power density ($\mu W/cm^2$)
2	1.56	60.2	**0.089**	1000

Limits

(A) Limits for Occupational/Controlled Exposure

Frequency range (MHz)	Electric field strength [E] (V/m)	Magnetic field strength [H] (A/m)	Power density [S] (mW/cm^2)	Averaging time $|E|^2$, $|H|^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	(900/f)*	6
30-300	61.4	0.163	1.0	6
300-1500			F/300	6
1500-100,000			5	6

(B) Limits for General Population/Uncontrolled Exposure

Frequency range (MHz)	Electric field strength [E] (V/m)	Magnetic field strength [H] (A/m)	Power density [S] (mW/cm^2)	Averaging time $|E|^2$, $|H|^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	(180/f)*	30
30-300	27.5	0.073	0.2	30
300-1500			F/1500	30
1500-100,000			**1.0**	**30**

Note: f=frequency in MHz, *Plane-wave equivalent power density

According to RSS-102 2.5.1, SAR evaluation is required if the separation distance between the user and the radiating element of the device is less than or equal to 20 cm, except when the device operates as follows:

- above 2.2 GHz and up to 3 GHz inclusively, and with output power (i.e. the higher of the conducted or radiated (e.i.r.p.) source-based, time-averaged output power) that is less than or equal to 20 mW for general public use and 100 mW for controlled use.

Complies?	Yes

20 dB bandwidth measurements according to FCC 47 CFR part 15.215 (c)

Date	Temperature	Humidity
2013-06-25	23 °C ± 3 °C	51 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009.

Conducted measurements were performed at the antenna connector and with continuous transmission and with both GFSK and 8DPSK modulation and also with the FHSS function enabled.

Measurement equipment	SP number
Test site Hertz	15:116
R&S ESI40 Signal Analyser	503 125
Multimeter Fluke	503 418
Temperature and humidity meter Testo	503 498

Measurement uncertainty: 2.6 %

Results

The measurements can be found in the diagrams below:

GFSK

Diagram 1: 2402 MHz — 20 dB BW = **1.01 MHz**
Diagram 2: 2441 MHz — 20 dB BW = **1.01 MHz**
Diagram 3: 2480 MHz — 20 dB BW = **1.02 MHz**

8DPSK

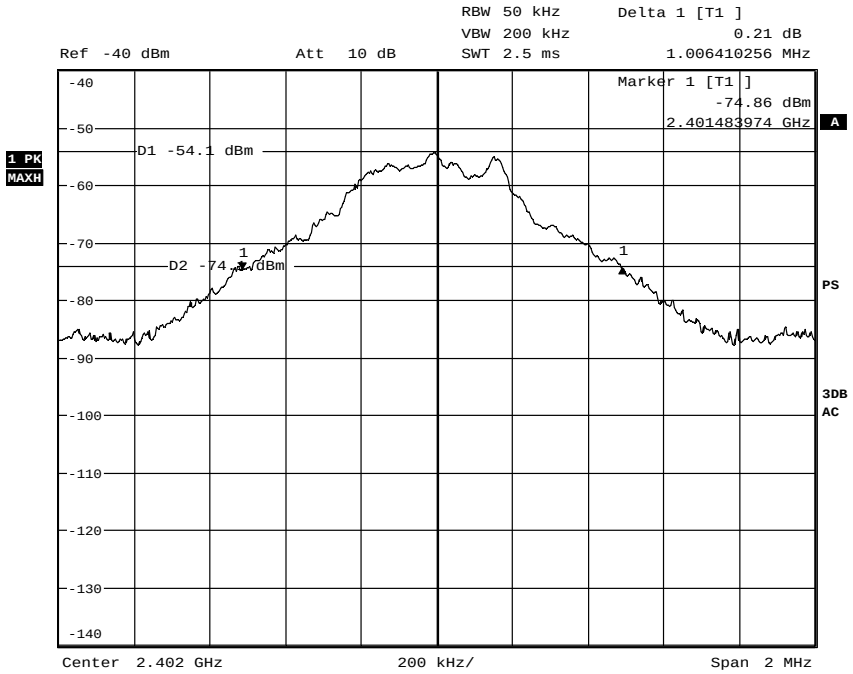
Diagram 4: 2402 MHz — 20 dB BW = **1.31 MHz**
Diagram 5: 2441 MHz — 20 dB BW = **1.31 MHz**
Diagram 6: 2480 MHz — 20 dB BW = **1.31 MHz**

Limits

According to 47CFR 15.215(c), intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§ 15.217 through 15.257 and in Subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified i the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

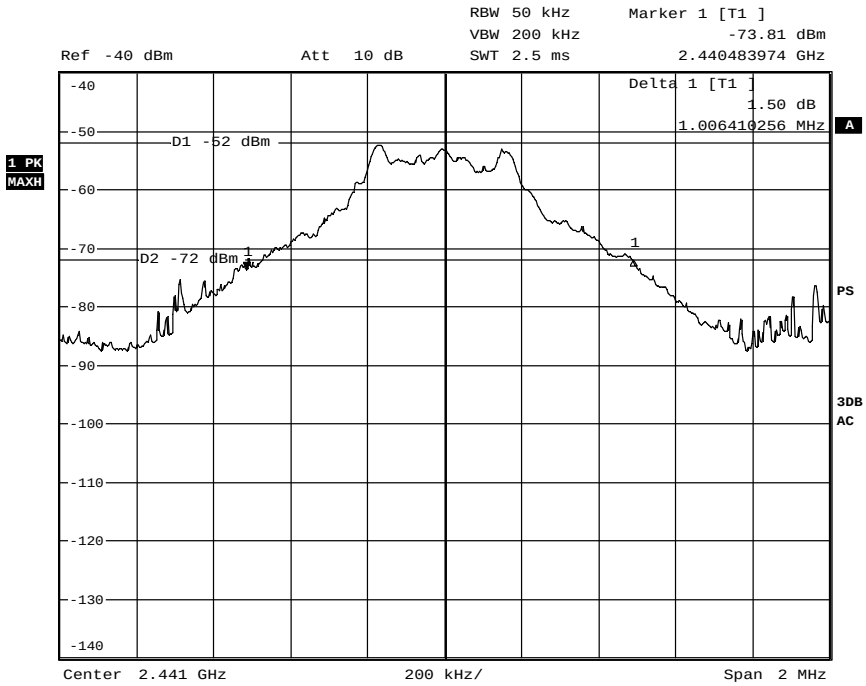
Complies?	Yes

Diagram 1



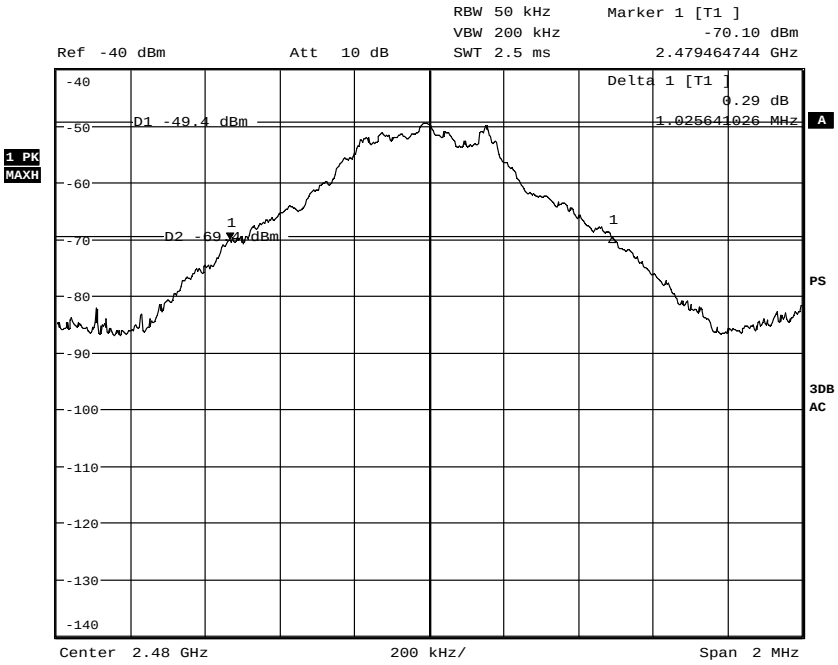
Date: 25.JUN.2013 07:45:30

Diagram 2



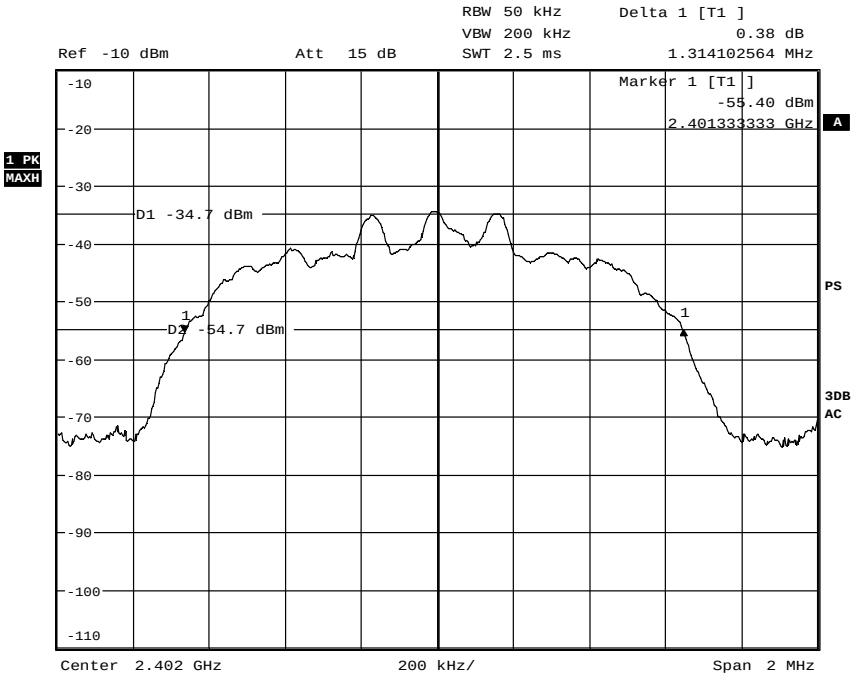
Date: 25.JUN.2013 07:24:51

Diagram 3



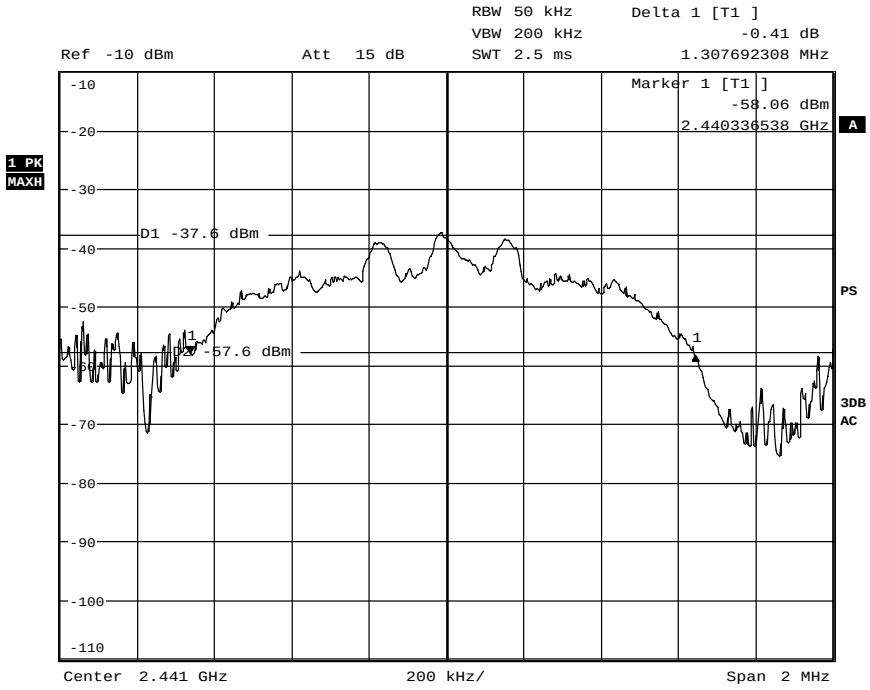
Date: 25.JUN.2013 07:51:34

Diagram 4



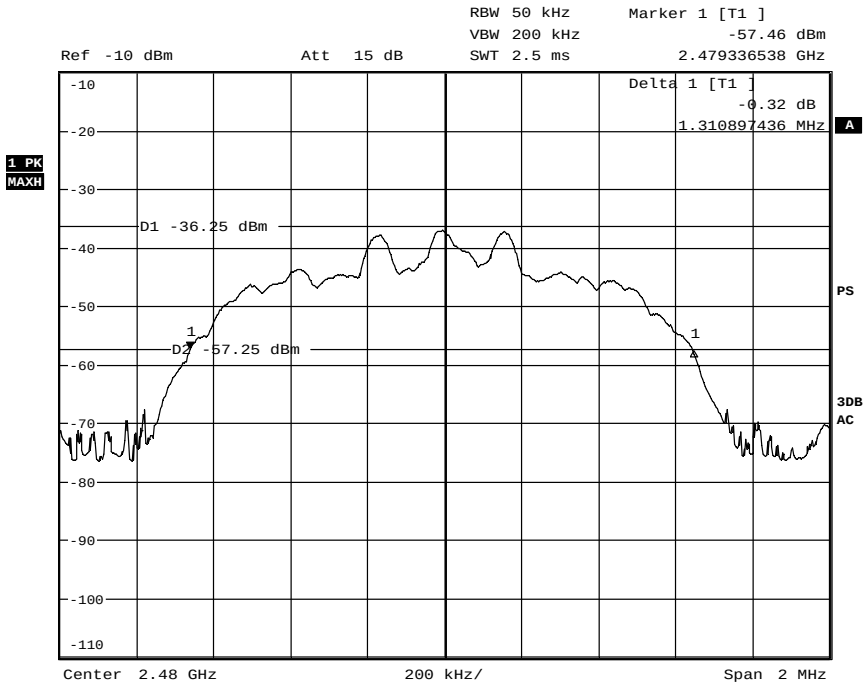
Date: 25.JUN.2013 09:12:03

Diagram 5



Date: 25.JUN.2013 09:00:33

Diagram 6



Date: 25.JUN.2013 08:56:48

Occupied bandwidth measurements according to 47CFR 2.1049 / RSS-Gen 4.6.1

Date	Temperature	Humidity
2013-09-10	22 °C ± 3 °C	46 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009.

Conducted measurements were performed at the antenna connector and with continuous transmission and with both GFSK and 8DPSK modulation and also with the FHSS function enabled.

Measurement equipment	SP number
Test site Hertz	15:116
R&S ESI40 Signal Analyser	503 125
Multimeter Fluke	503 418
Temperature and humidity meter Testo	503 498

Measurement uncertainty: 2.6 %

Results

The measurements can be found in the diagrams below:

GFSK

Diagram 1 2402 MHz OBW = **898 kHz (99%)**
Diagram 2 2441 MHz OBW = **886 kHz (99%)**
Diagram 3 2480 MHz OBW = **886 kHz (99%)**

8DPSK

Diagram 4 2402 MHz OBW = **1.22 MHz (99%)**
Diagram 5 2441 MHz OBW = **1.22 MHz (99%)**
Diagram 6 2480 MHz OBW = **1.22 MHz (99%)**

Complies?	Yes

Diagram 1

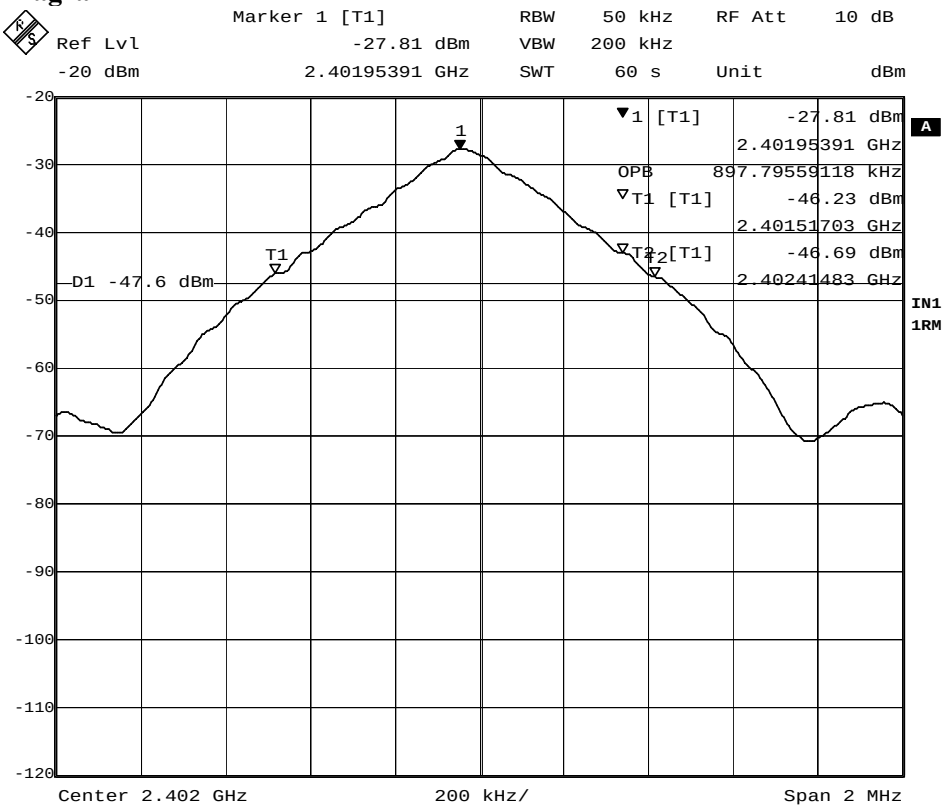


Diagram 2

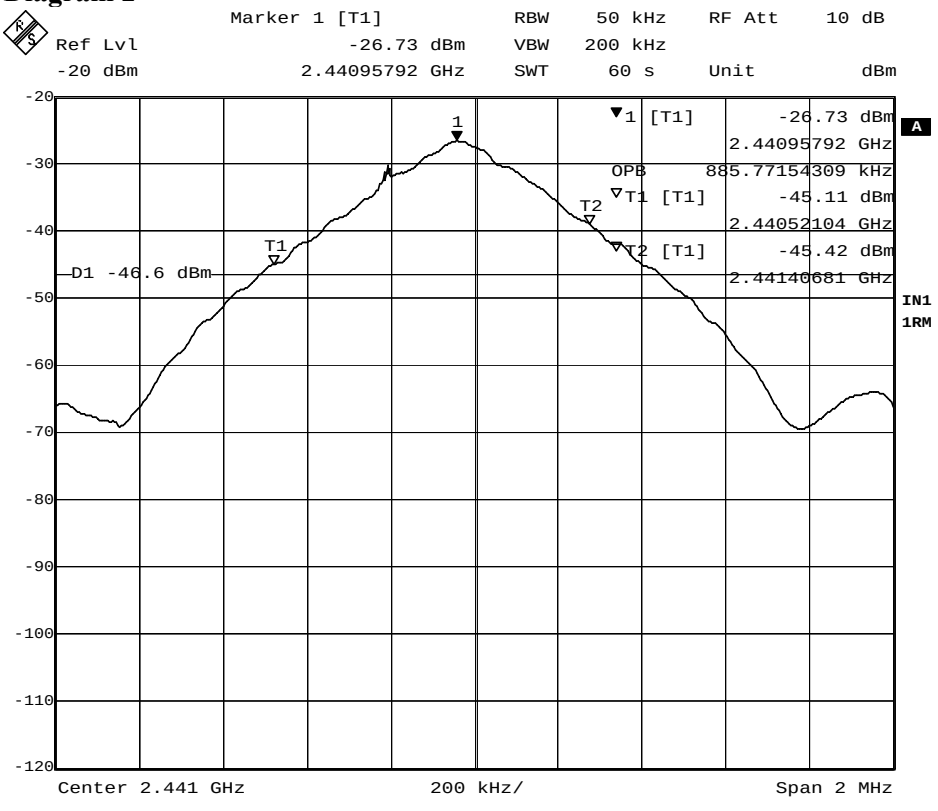


Diagram 3

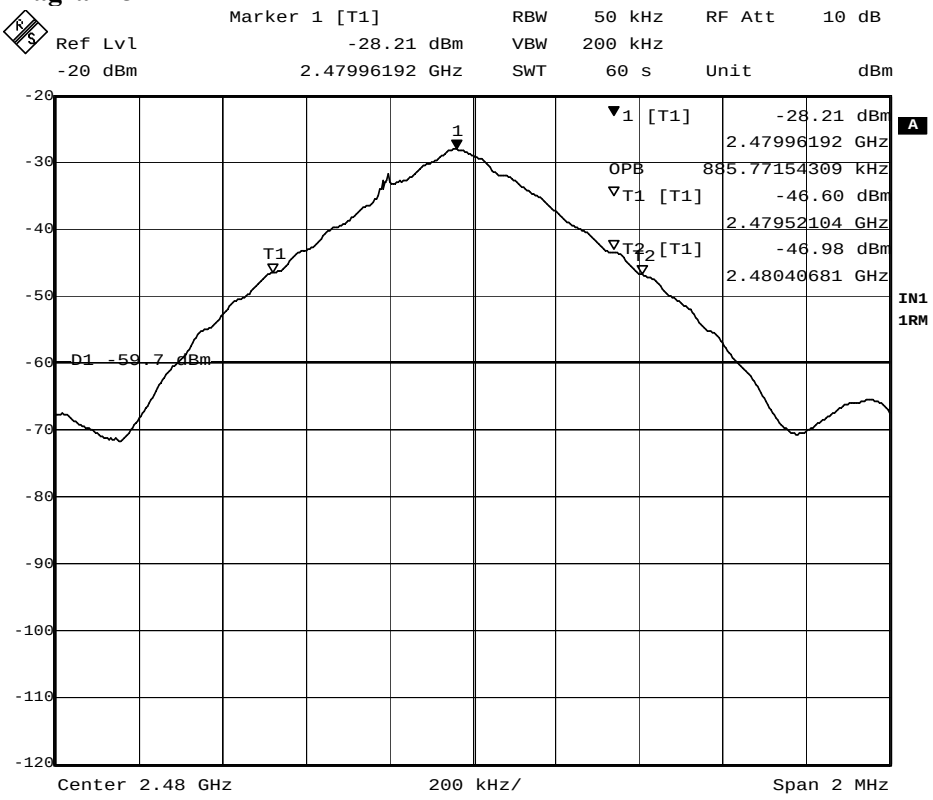


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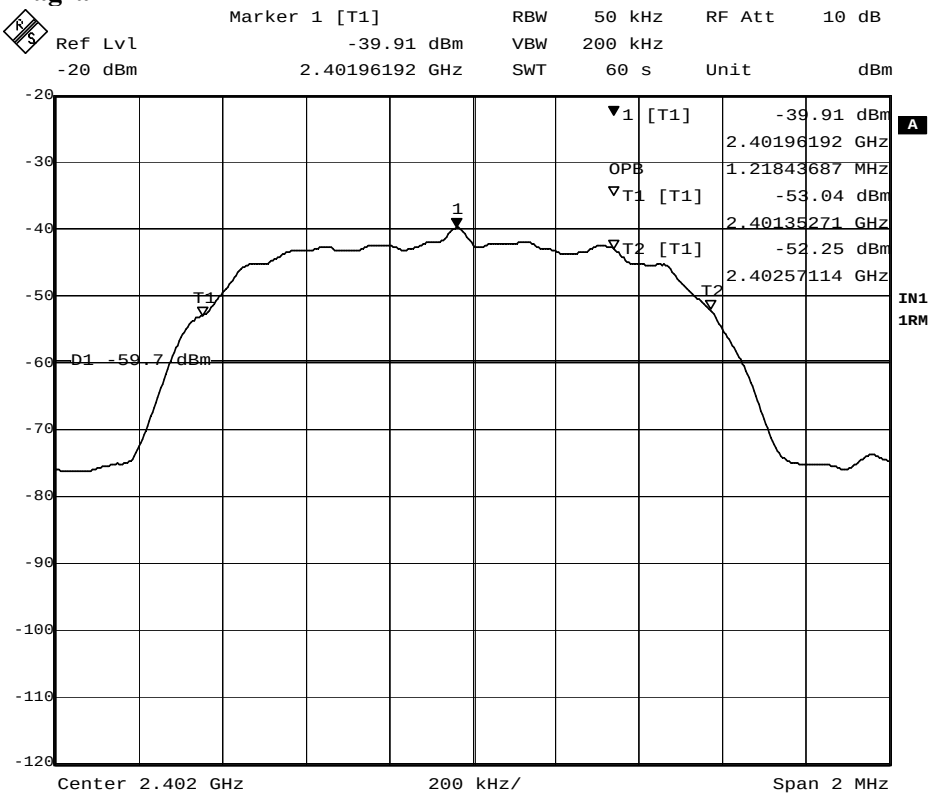
Diagram 4



Date: 10.SEP.2013 08:00:18

Diagram 5

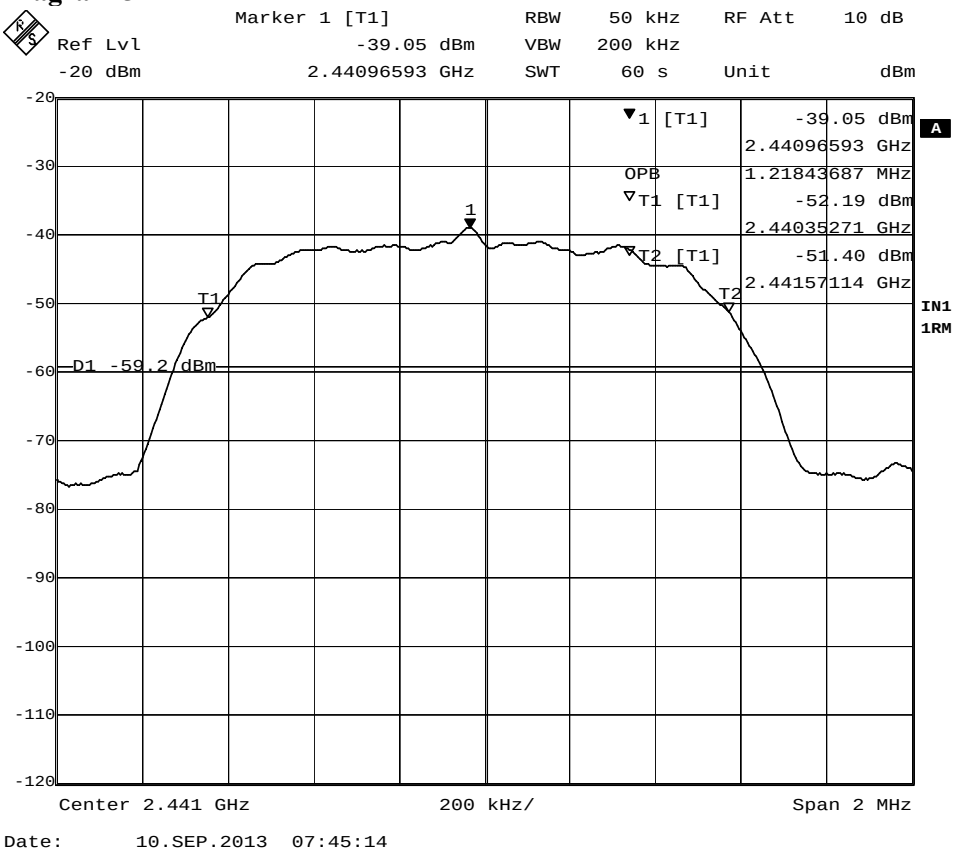
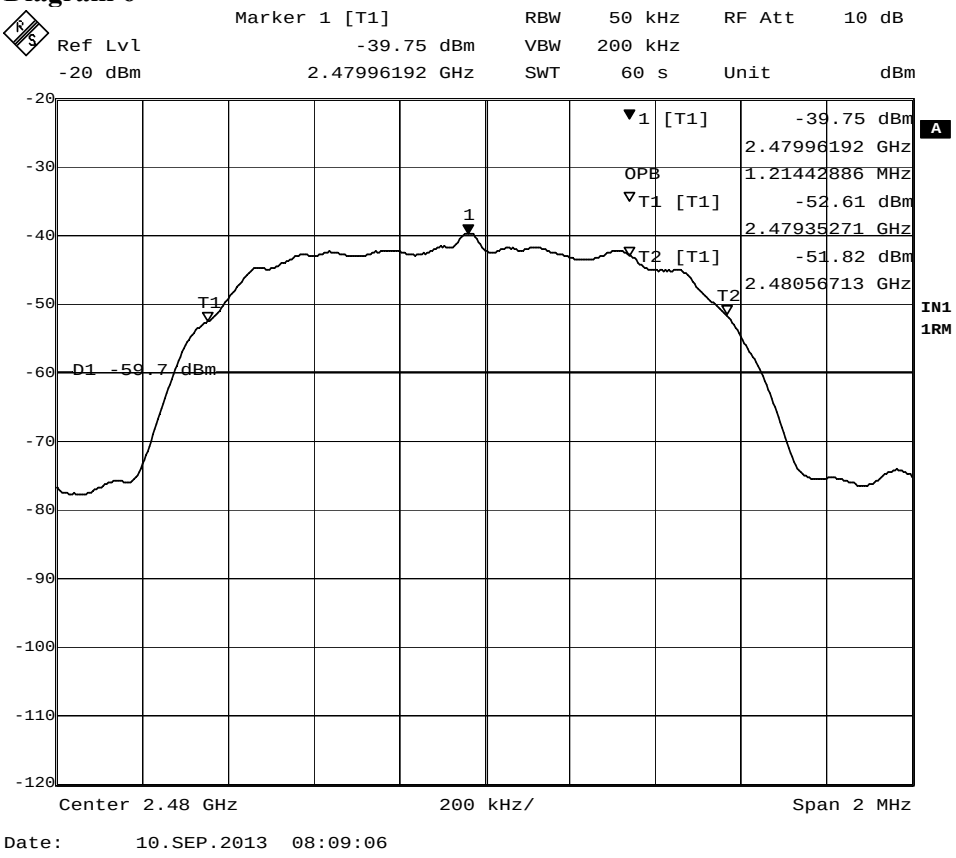


Diagram 6



Band edge measurements according to 47CFR 2.1049 / RSS-210 A8.5

Date	Temperature	Humidity
2013-11-14 (conducted tests)	23 °C ± 3 °C	33 % ± 5 %
2013-11-19 (radiated tests)	22 °C ± 3 °C	35 % ± 5 %

Test set-up and procedure

The measurements were performed according to ANSI C63.10-2009 and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems, DA 00-705, released March 30, 2000.

Both conducted (20 dBc) and radiated tests were performed.
The test was performed and both with continuous transmission and with both GFSK and 8DPSK modulation and also with FHSS disabled and enabled. With FHSS disabled the test was per formed with continuous transmission (77% duty cycle).

The radiated band edge measurements were performed in a semi anechoic chamber. The measurements were performed with the EUT-axis, antenna at the position, polarization and the turntable in the position giving the highest level at the fundamental, see Appendix 5. The antenna distance was 3.0 m.

Test set-up photos during the tests can be found in Appendix 12.

Measurement equipment	SP number
Semi anechoic chamber, Edison (radiated tests)	504 114
Spectrum analyzer R&S ESU 26	902 210
EMI measurement computer	-
Software: R&S EMC32, ver. 8.52.0	503 745
Horn antenna EMCO 3115	501 548
Multimeter Fluke 83	501 522
Temperature and humidity meter Testo 625	504 117
Test site Hertz (conducted tests)	15:116
R&S ESI40 Signal Analyser	503 125
Multimeter Fluke	503 418
Temperature and humidity meter Testo	503 498

Results

Operation band 2400-2483.5 MHz

For duty cycle measurements see Appendix 2.
During test with the FHSS disabled the duty cycle duty was 77 %.
The duty cycle correction factor was calculated to 20 log (2.89 / 3.75) = -2.3 dB.

The pre-measurements with peak detector can be found in the diagrams below:

<u>GFSK with FHSS disabled:</u>

Diagram 1 2402 MHz Band edge at 2390 MHz (limit=54.0 dBµV/m (Average))
(Restricted band)
CAverage level at 2390 MHz =34.1 dBµV/m (noise floor)
CAverage level at band edge due to the duty cycle:
34.1 dBµV/m-2.3 dB = **31.8 dBµV/m** (Average)

Diagram 2 2402 MHz Band edge at 2400 MHz (limit=20 dBc)
Delta dBc: fundamental vs. 2400 MHz = **50.8 dBc**

Diagram 3 2480 MHz Band edge at 2483.5 MHz (limit=54.0 dBµV/m (Average))
(Restricted band)
CAverage level at 2483.5 MHz =34.8 dBµV/m (noise floor)
CAverage level at band edge due to the duty cycle:
34.8 dBµV/m-2.3 dB = **32.5 dBµV/m** (Average)

<u>GFSK with FHSS enabled:</u>

Diagram 4 2402 MHz Band edge at 2390 MHz (limit=54.0 dBµV/m (Average))
(Restricted band)
CAverage level at 2390 MHz =**33.6 dBµV/m** (noise floor)

Diagram 5 2402 MHz Band edge at 2400 MHz (limit=20 dBc)
Delta dBc: fundamental vs. 2400 MHz = **55.4 dBc**

Diagram 6 2480 MHz Band edge at 2483.5 MHz (limit=54.0 dBµV/m (Average))
(Restricted band)
CAverage level at 2483.5 MHz =**33.8 dBµV/m** (noise floor)

<u>8DPSK with FHSS disabled:</u>

Diagram 7 2402 MHz Band edge at 2390 MHz (limit=54.0 dBµV/m (Average))
(Restricted band)
CAverage level at 2390 MHz =33.6 dBµV/m (noise floor)
CAverage level at band edge due to the duty cycle:
33.6 dBµV/m-2.3 dB = **31.3 dBµV/m** (Average)

Diagram 8 2402 MHz Band edge at 2400 MHz (limit=20 dBc)
Delta dBc: fundamental vs. 2400 MHz = **42.9 dBc**

Diagram 9 2480 MHz Band edge at 2483.5 MHz (limit=54.0 dBµV/m (Average))
(Restricted band)
CAverage level at 2483.5 MHz =34.2 dBµV/m (noise floor)
CAverage level at band edge due to the duty cycle:
34.2 dBµV/m-2.3 dB = **31.9 dBµV/m** (Average)

Remark

FHSS could not be enabled with 8DPSK, thus no measurements were performed.

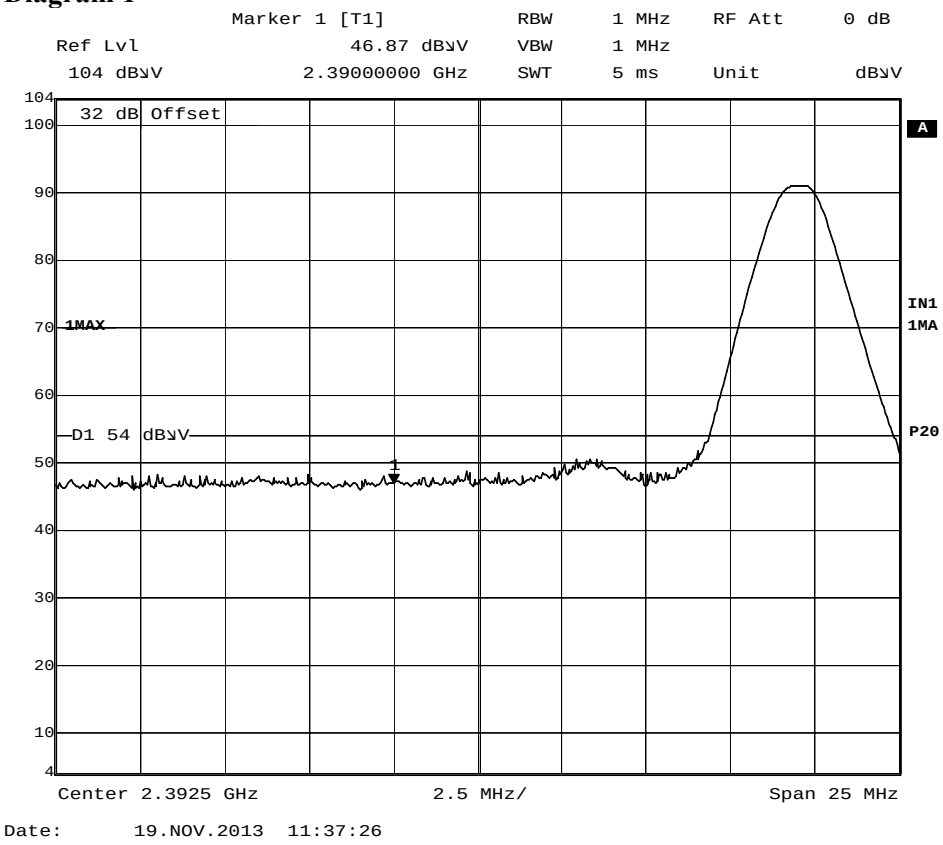
Limits

Band edge at 2390 MHz and 2483.5 MHz:
In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section15.209(a).

According to RSS-210 A8.5, in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean square averaging over a time interval, as permitted under Section A8.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

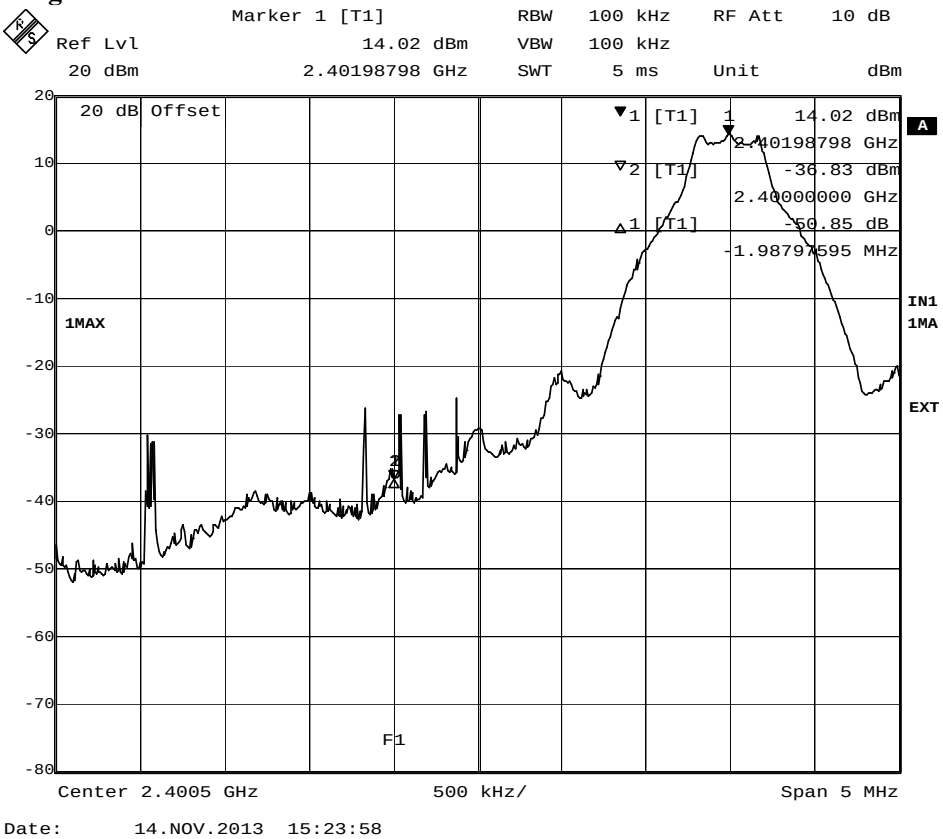
Complies?	Yes

Diagram 1



Date: 19.NOV.2013 11:37:26

Diagram 2



Date: 14.NOV.2013 15:23:58

Diagram 3

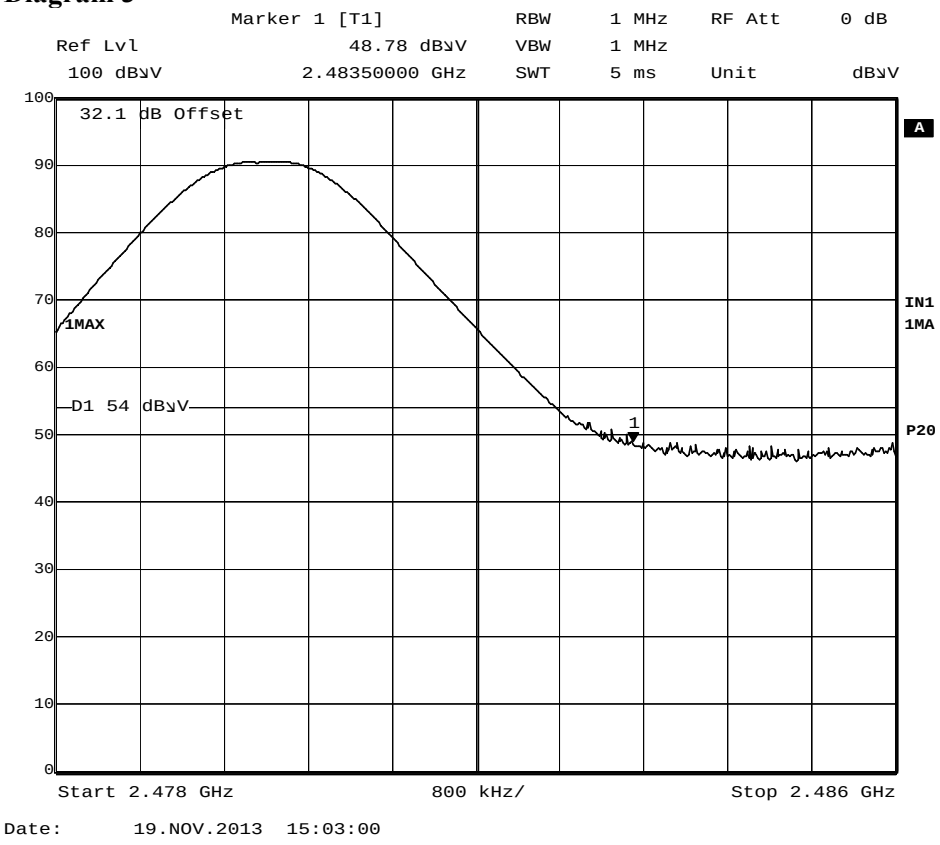
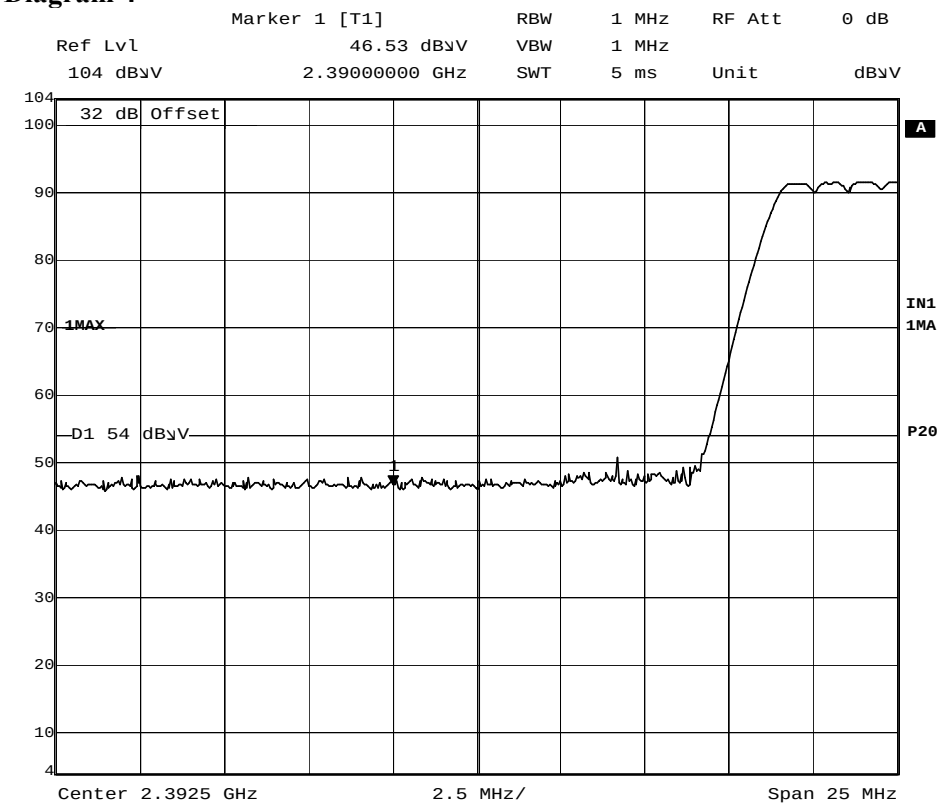
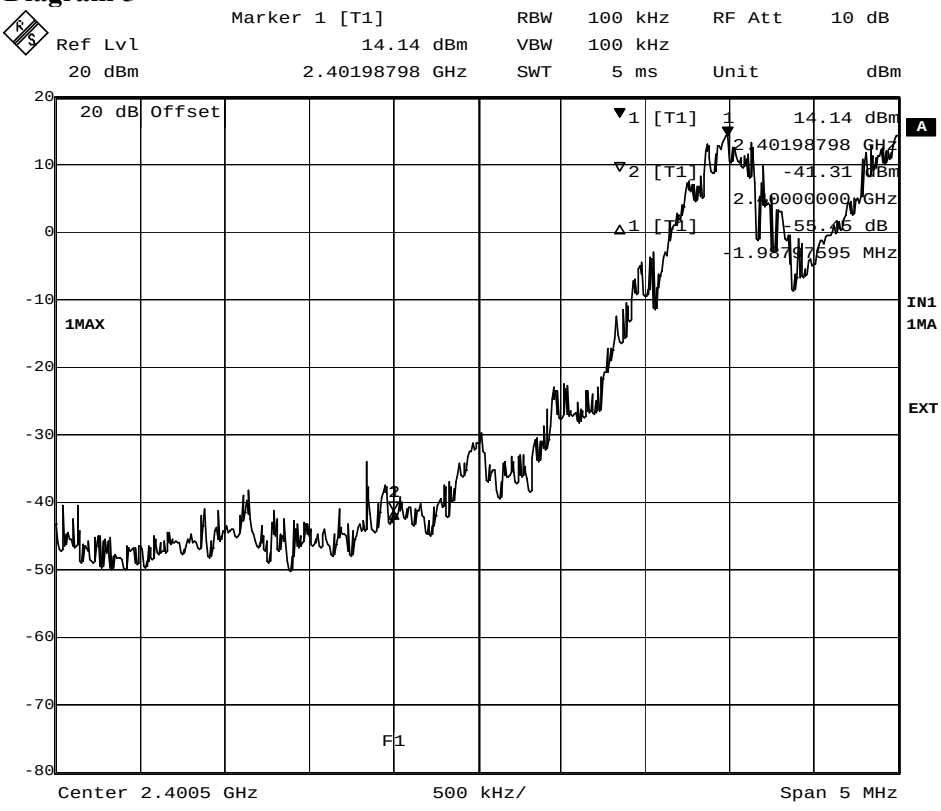

Marker 1 [T1]
RBW 1 MHz
RF Att 0 dB
Ref Lvl 48.78 dBµV
VBW 1 MHz
100 dBµV 2.48350000 GHz
SWT 5 ms
Unit dBµV
32.1 dB Offset
1MAX
D1 54 dBµV
1
A
IN1
1MA
P20
100
90
80
70
60
50
40
30
20
10
0
Start 2.478 GHz
800 kHz/
Stop 2.486 GHz
Date: 19.NOV.2013 15:03:00

Diagram 4



Date: 19.NOV.2013 13:22:18

Diagram 5



Date: 14.NOV.2013 15:31:05

Diagram 6

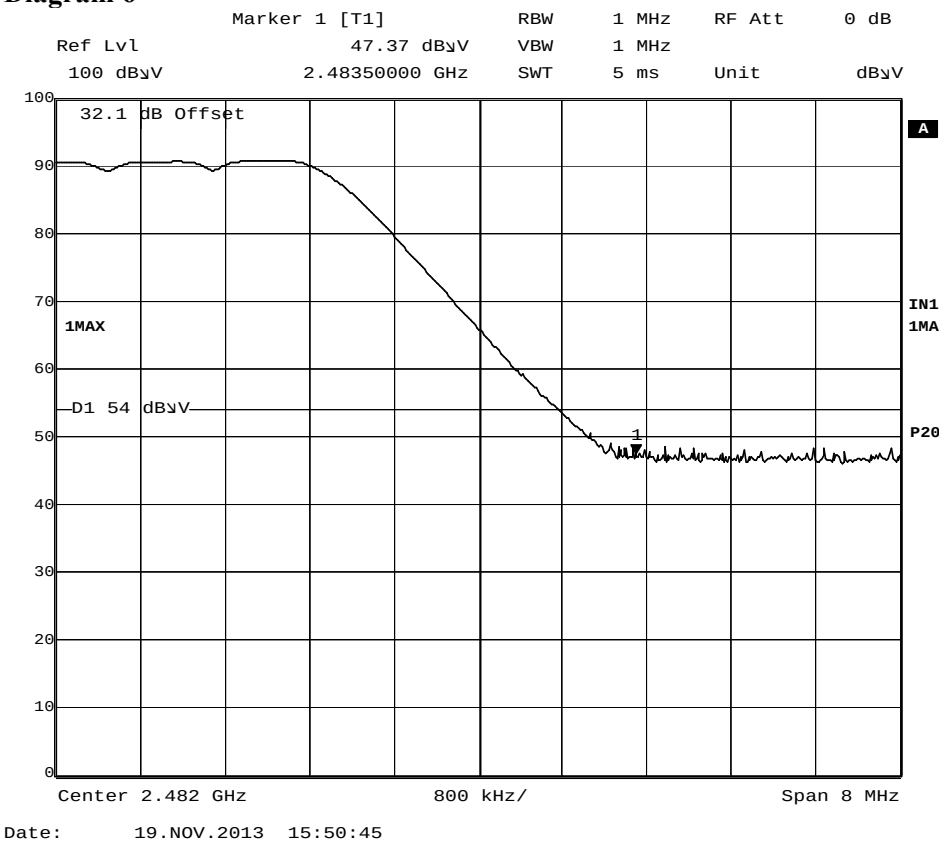
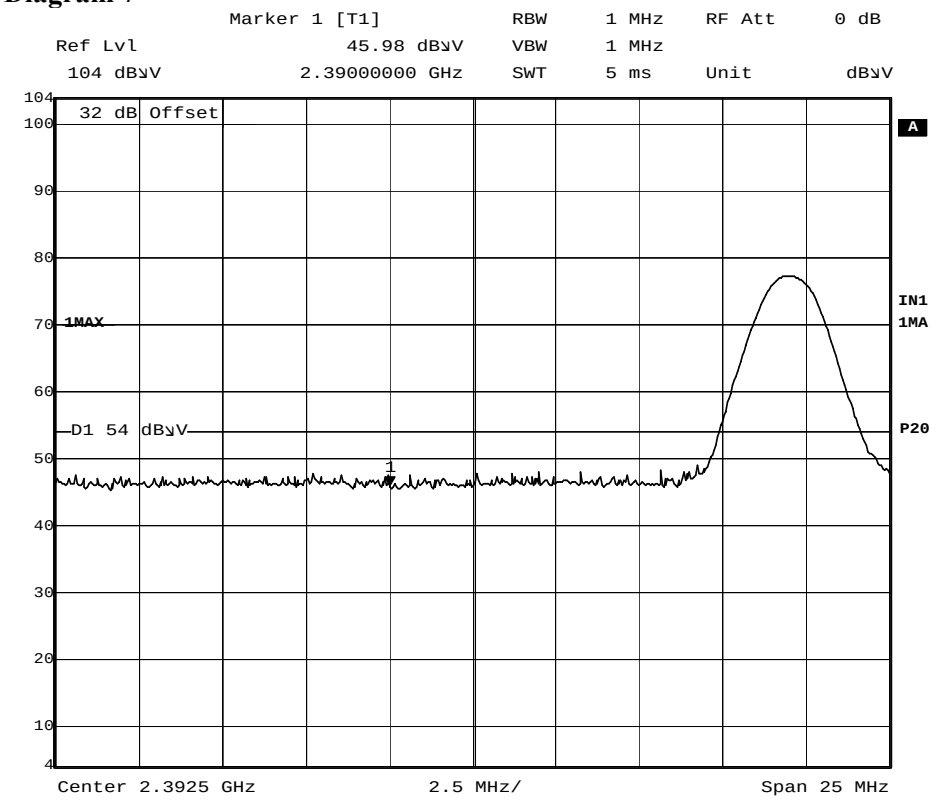
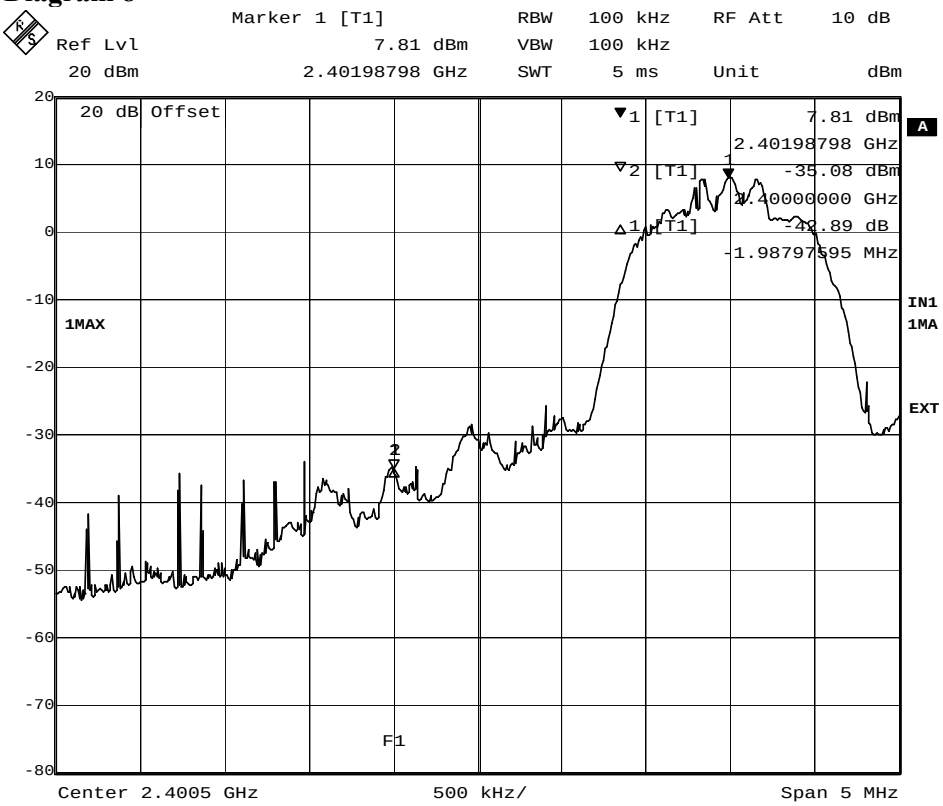

Marker 1 [T1]
RBW 1 MHz
RF Att 0 dB
Ref Lvl 47.37 dBµV
VBW 1 MHz
100 dBµV 2.48350000 GHz
SWT 5 ms
Unit dBµV
32.1 dB Offset
A
IN1
1MA
1MAX
D1 54 dBµV
P20
100
90
80
70
60
50
40
30
20
10
0
Center 2.482 GHz
800 kHz/
Span 8 MHz
Date: 19.NOV.2013 15:50:45

Diagram 7



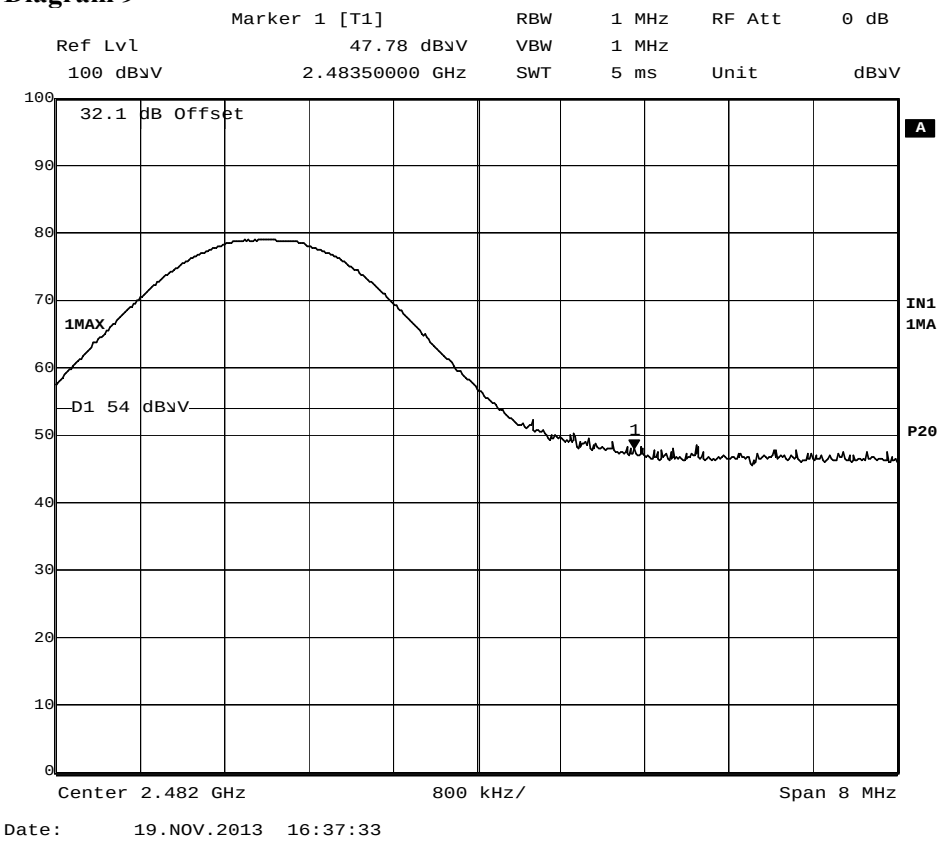
Date: 19.NOV.2013 13:56:48

Diagram 8



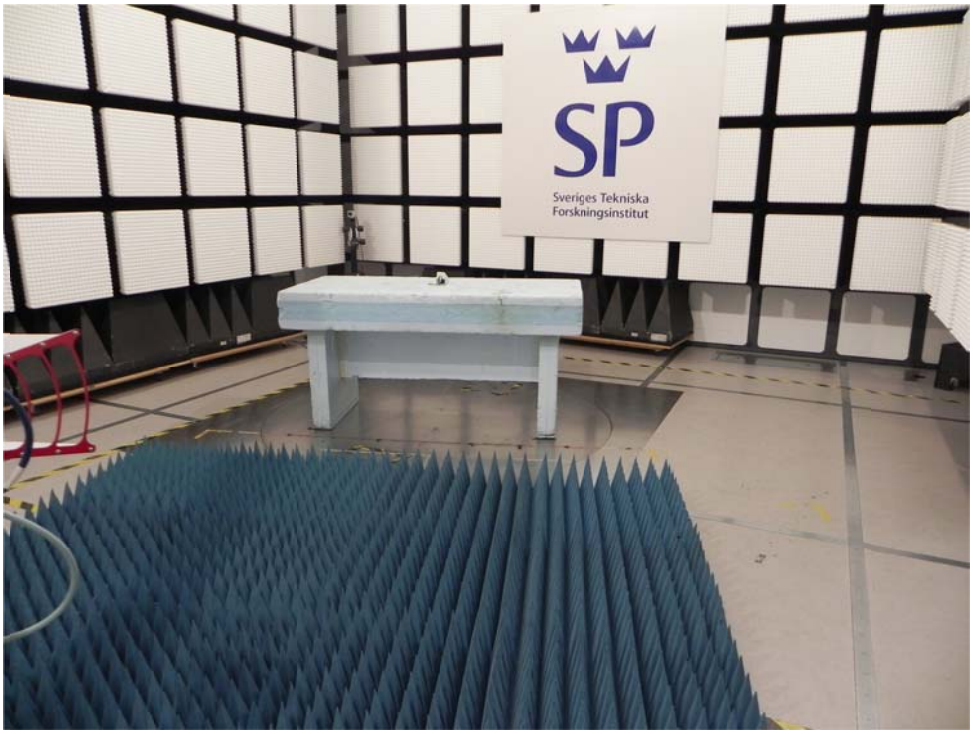
Date: 14.NOV.2013 16:02:02

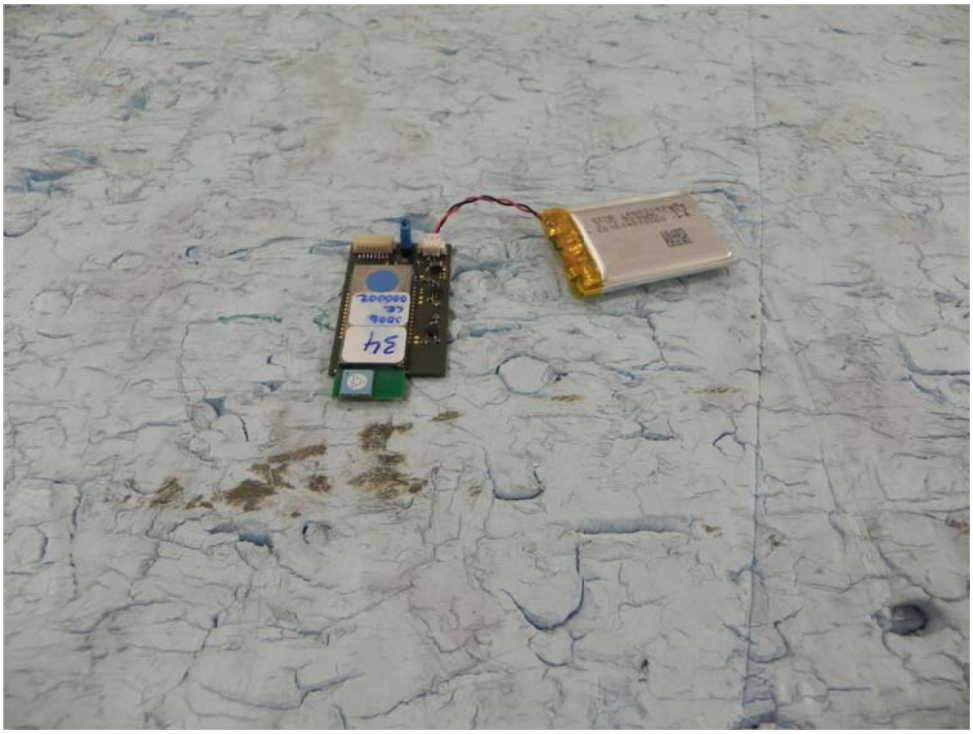
Diagram 9


Marker 1 [T1]
RBW 1 MHz
RF Att 0 dB
Ref Lvl
47.78 dBµV
VBW 1 MHz
100 dBµV
2.48350000 GHz
SWT 5 ms
Unit dBµV
32.1 dB Offset
A
IN1
1MA
P20
1MAX
D1 54 dBµV
Center 2.482 GHz
800 kHz/
Span 8 MHz
Date: 19.NOV.2013 16:37:33

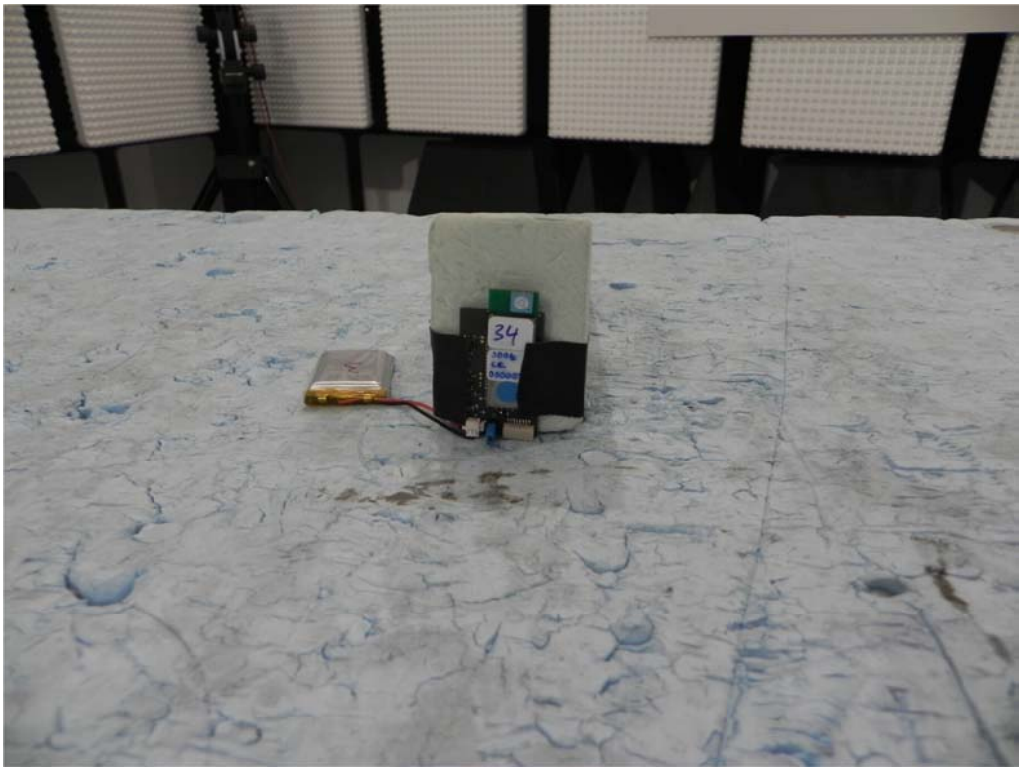
Photos

The test set-up during the radiated tests can be seen in the pictures below.

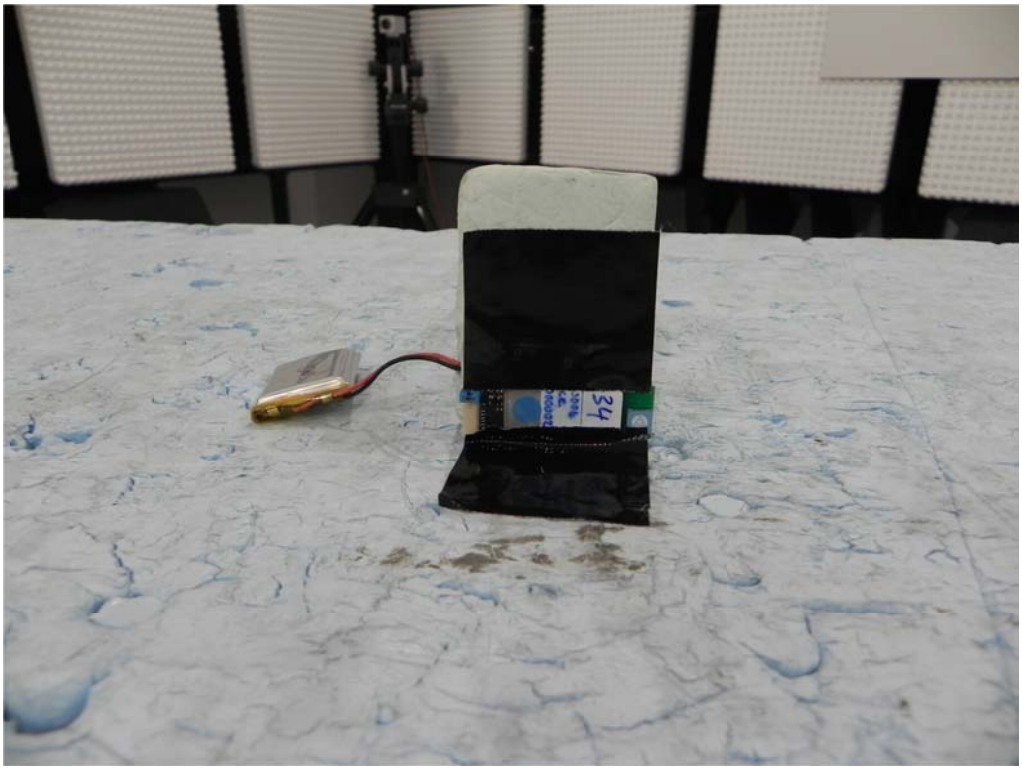




X-axis



Y-axis



Z-axis

EUT, radiated sample #36, conducted sample #35.