FCC / ISED Canada Test Report

FOR:

KS Technologies

Model Name:

KST1020

Product Description:

Bluetooth Low Energy Sensor Module

FCC ID: 2AA3A-UNITYV8
IC ID: 11487S-UNITYV8

Applied Rules and Standards:
47 CFR Part 15.247 (DTS)
RSS-247 Issue 1 (DTSs)
RSS-Gen Issue 4

REPORT #: EMC_KSTEC-003-17001_15.247_DTS Rev 1

DATE: 2017-04-28

A2LA Accredited

IC recognized #
3462B-1

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1 Assessment

The following device was evaluated against the applicable criteria specified in FCC rules Parts 15.247 of Title 47 of the Code of Federal Regulations and the relevant ISED Canada standard RSS-247 Issue 1, and RSS-Gen Issue 4.

Company	Description	Model #
KS Technologies	Bluetooth Low Energy Sensor Module	KST1020

Responsible for Testing Laboratory:

Date	Section	Name	Signature
2017-04-28	Compliance	Peter Nevermann (Director Radio Communications and EMC)	Digitally signed by CETECOMCA1\PNevermann DN: cn=CETECOMCA1\PNevermann Date: 2017.04.30 19:15:35 -07'00'

Responsible for the Report:

Date	Section	Name	Signature
2017-04-28	Compliance	Kris Lazarov (EMC Engineer)	Kris Lazarov Digitally signed by Kris Lazarov DN: cn=Kris Lazarov, c=US, o=CETECOM Date: 2017.04.28 20:00:10 -07'00'

2 Administrative Data

2.1 Identification of the Testing Laboratory Issuing the EMC Test Report

Company Name:	CETECOM Inc.
Department:	Compliance
Street Address:	411 Dixon Landing Road
City/Zip Code	Milpitas, CA 95035
Country	USA
Telephone:	+1 (408) 586 6200
Fax:	+1 (408) 586 6299
Director Radio Com. and EMC:	Peter Nevermann
Responsible Project Leader:	Kris Lazarov

2.2 Identification of the Client

Applicant's Name:	KS Technologies
Street Address:	1910 Vindicator Drive Suite 100
City/Zip Code	Colorado Springs, CO 80919
Country	USA
Contact Person:	Mark Rieker
Phone No.	(719) 694-8193
e-mail:	mark.rieker@kstechnologies.com

2.3 Identification of the Manufacturer

Manufacturer's Name:	Same as Applicant
Manufacturers Address:	-------
City/Zip Code	-------
Country	-------

3 Equipment Under Test (EUT)

3.1 EUT Specifications

Model No:	KST1020
HW Version :	Rev E See note 1
SW Version :	Nrf52832_xxaa.hex
FCC-ID :	2AA3A-UNITYV8
IC-ID:	11487S-UNITYV8
HVIN:	KST1020
PMN:	Unity V8 Sensor Engine
Product Description:	Bluetooth Low Energy Sensor Module
Frequency Range / number of channels:	Nominal band: 2402 MHz – 2480 MHz; Center to center: 2402 MHz (Ch 0) – 2480 MHz (Ch 39), 40 channels
Type(s) of Modulation:	Bluetooth version 4.0, Low Energy, GFSK modulation.
Modes of Operation:	Bluetooth LE
Declared Antenna Information:	Chip antenna max gain = 5.3 dBi
Max. Output Powers:	Peak Conducted Power = 4 dBm
Power Supply/ Rated Operating Voltage Range:	Battery pack V min: 1.7 V dc/ V nom: 3.0 V dc / V max: 3.6 V dc
Operating Temperature Range	-40 ºC to 85 ºC
Other Radios included in the device:	N/A
Sample Revision	☐Prototype Unit ☑Production Unit ☐Pre-Production

Note 1: RSE testing was conducted with rev D sample followed up by a spot-check retest from 1 GHz to 40 GHz on mid channel with rev E sample. For the list of hardware changes from rev D to rev E see table below.

Hardware changes from Rev D to Rev E:

Description of Change	Reason for Change	How the Change is Implemented
LIS2DH changed from I2C to SPI	Improves battery performance of product	Connected one new signal from the LIS2DH to the primary microcontroller. No BOM Change. No component placement or orientation change.
GPIO2, GPIO3, GPIO4 Now Assigned as SPI Bus	Allowed us to change the LIS2DH communications from I2C to SPI	Firmware change only; no change was made to the hardware.
32.768kHz crystal changed to new P/N in Nordic DK	Part was no longer available.	This is a BOM change only for a form/fit/function direct crystal replacement (same frequency, same footprint, no hardware change, etc.)

3.2 EUT Sample details

EUT #	Serial Number	HW Version	SW Version	Notes/Comments
1	Engineering Sample 1	Rev D	Nrf52832_xxaa.hex	Radiated testing
2	Engineering Sample 2	Rev E	Nrf52832_xxaa.hex	Radiated spot-check testing
3	Engineering Sample 3	Rev E	Nrf52832_xxaa.hex	Conducted testing

3.3 Accessory Equipment (AE) details

AE #	Type	Model	Manufacturer	Serial Number
1	3 V Battery pack	2 x AAA Batteries	N/A	N/A

3.4 Test Sample Configuration

EUT Set-up #	Combination of AE used for test set up	Comments
1	EUT#1 + AE#1	Radiated testing
2	EUT#2 + AE#1	Radiated spot-check testing
3	EUT#3 + AE#1	Conducted testing

3.5 Justification for Worst Case Mode of Operation

During the testing process the EUT was tested with transmitter sets on low, mid and high channels. For radiated measurements, all data in this report shows the worst case between horizontal and vertical antenna polarizations and for all orientations of the EUT.

The channels and modulation scheme of the EUT was set with diagnostic software (not available to the end user), and the transmitter output power was measured using spectrum analyzer (Peak Power).

The application called J-Link RTT Viewer from Segger, was used to program the sample to low, mid and high carrier channel with the following parameters.

- Output power to +4dBm, the maximum allowable by the product.
- Data Rate to 1Mb/s, the standard for Bluetooth Low Energy.

4 Subject of Investigation

The objective of the measurements done by CETECOM Inc. was to assess the performance of the EUT according to the relevant requirements specified in FCC rules Part 15.247 of Title 47 of the Code of Federal Regulations and Radio Standard Specification RSS-247 Issue 1 of ISED Canada.

This test report is to support a request for new equipment authorization under the FCC ID: 2AA3A-UNITYV8 and IC ID: 11487S-UNITYV8

Testing procedures are based on 558074 D01 DTS Meas Guidance v04 – "GUIDANCE FOR PERFORMING COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEMS (DTS) OPERATING UNDER SECTION 15.247" - April 5, 2017, by the Federal Communications Commission, Office of Engineering and Technology, Laboratory Division.

5 Measurement Results Summary

Test Specification	Test Case	Temperature and Voltage Conditions	Mode	Pass	NA	NP	Result
§15.247(a)(1) RSS-247 5.2(1)	Emission Bandwidth	Nominal	BTLE	■	☐	☐	Complies
§15.247(e) RSS-247 5.2(2)	Power Spectral Density	Nominal	BTLE	■	☐	☐	Complies
§2.1055; RSS-133 6.3	Frequency Stability	Extreme Temperature and Voltage	BTLE	■	☐	☐	Complies
§15.247(b)(1) RSS-247 5.4(4)	Maximum Conducted Output Power and EIRP	Nominal	BTLE	■	☐	☐	Complies
§15.247(d) RSS-247 5.5	Band edge compliance Unrestricted Band Edges	Nominal	BTLE	■	☐	☐	Complies
§15.247; 15.209; 15.205 RSS-Gen 8.9; 8.10	Band edge compliance Restricted Band Edges	Nominal	BTLE	■	☐	☐	Complies
§15.247(d); §15.209 RSS-Gen 6.13	TX Spurious emissions-Radiated	Nominal	BTLE	■	☐	☐	Complies
§15.207(a) RSS Gen 8.8	AC Conducted Emissions	Nominal	BTLE	☐	■	☐	Complies

Note: NA= Not Applicable; NP= Not Performed.

6 Measurements

6.1 Measurement Uncertainty

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus, with 95% confidence interval (in dB delta to result), based on a coverage factor k=1.

Radiated measurement

9 kHz to 30MHz	±2.5 dB (Magnetic Loop Antenna)
30 MHz to 1000 MHz	±2.0 dB (Biconilog Antenna)
1 GHz to 40 GHz	±2.3 dB (Horn Antenna)

Conducted measurement

150 kHz to 30 MHz	±0.7 dB (LISN)

RF conducted measurement	±0.5 dB

6.2 Environmental Conditions during Testing:

The following environmental conditions were maintained during the course of testing:

- Ambient Temperature: 20-25°C
- Relative humidity: 40-60%

6.3 Dates of Testing:

2/08/2017 – 4/28/2017

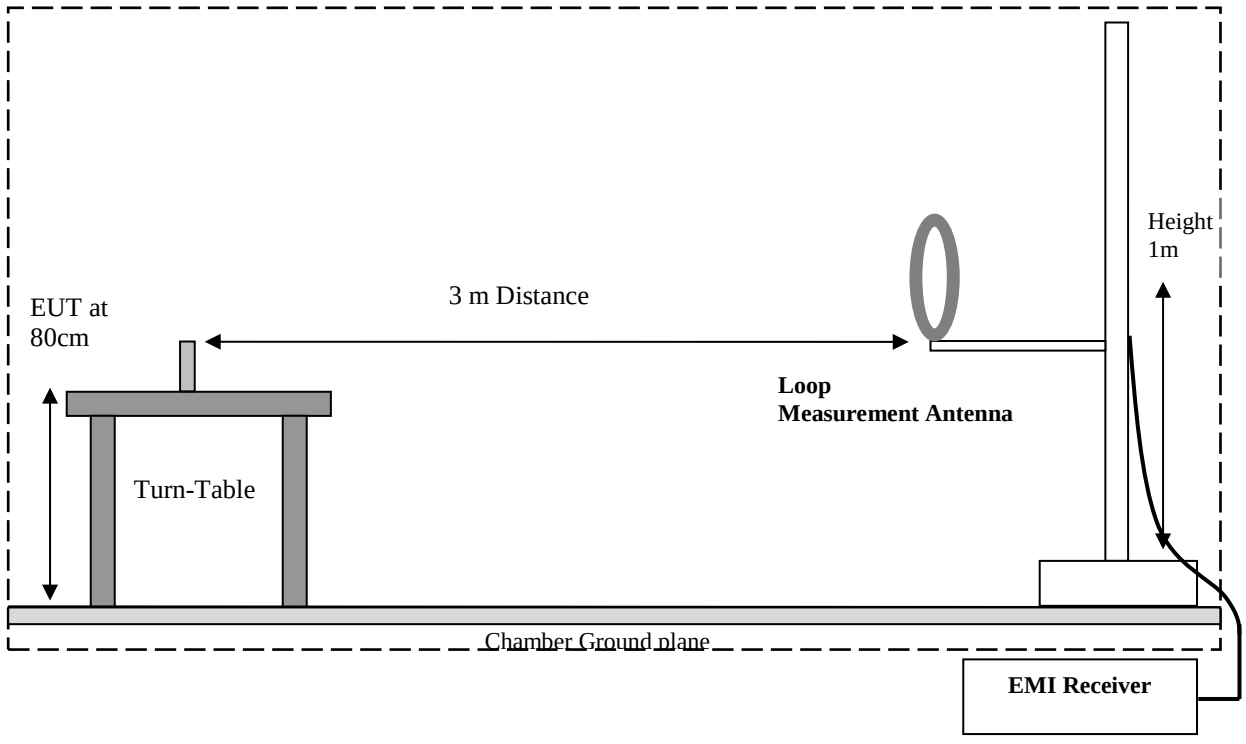
7 Measurement Procedures

7.1 Radiated Measurement

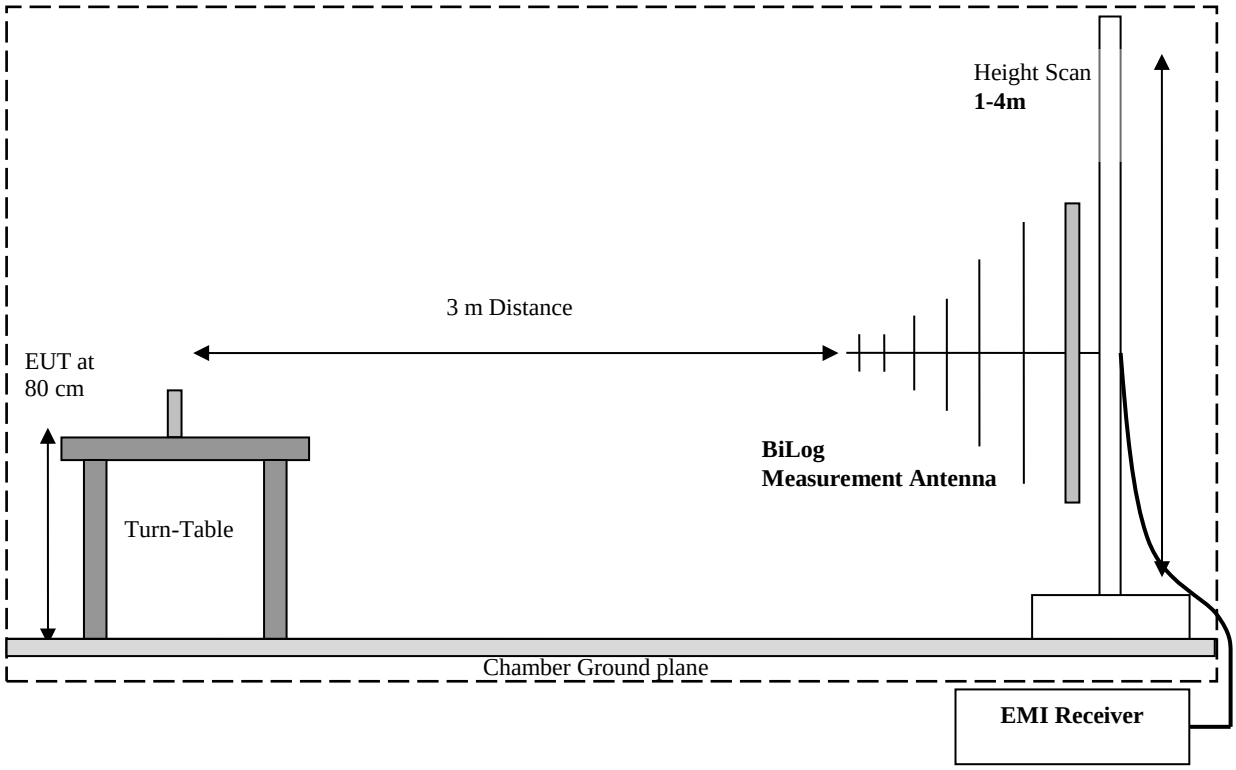
The radiated measurement is performed according to: ANSI C63.10 (2013)

- The exploratory measurement is accomplished by running a matrix of 16 sweeps over the required frequency range with R&S Test-SW EMC32 for 4 positions of the turntable, two orthogonal positions of the EUT and both antenna polarizations. This procedure exceeds the requirement of the above standards to cover the 3 orthogonal axis of the EUT. A max peak detector is utilized during the exploratory measurement. The Test-SW creates an overall maximum trace for all 12 sweeps and saves the settings for each point of this trace. The maximum trace is part of the test report.
- The 10 highest emissions are selected with an automatic algorithm of EMC32 searching for peaks in the noise floor and ensuring that broadband signals are not selected multiple times.
- The maxima are then put through the final measurement and again maximized in a 90deg range of the turntable, fine search in frequency domain and height scan between 1m and 4m.
- The above procedure is repeated for all possible ways of power supply to EUT and for all supported modulations.
- In case there are no emissions above noise floor level only the maximum trace is reported as described above.
- The results are split up into up to 4 frequency ranges due to antenna bandwidth restrictions. A magnetic loop is used from 9 kHz to 30 MHz, a Biconilog antenna is used from 30 MHz to 1 GHz, and two different horn antennas are used to cover frequencies up to 40 GHz.

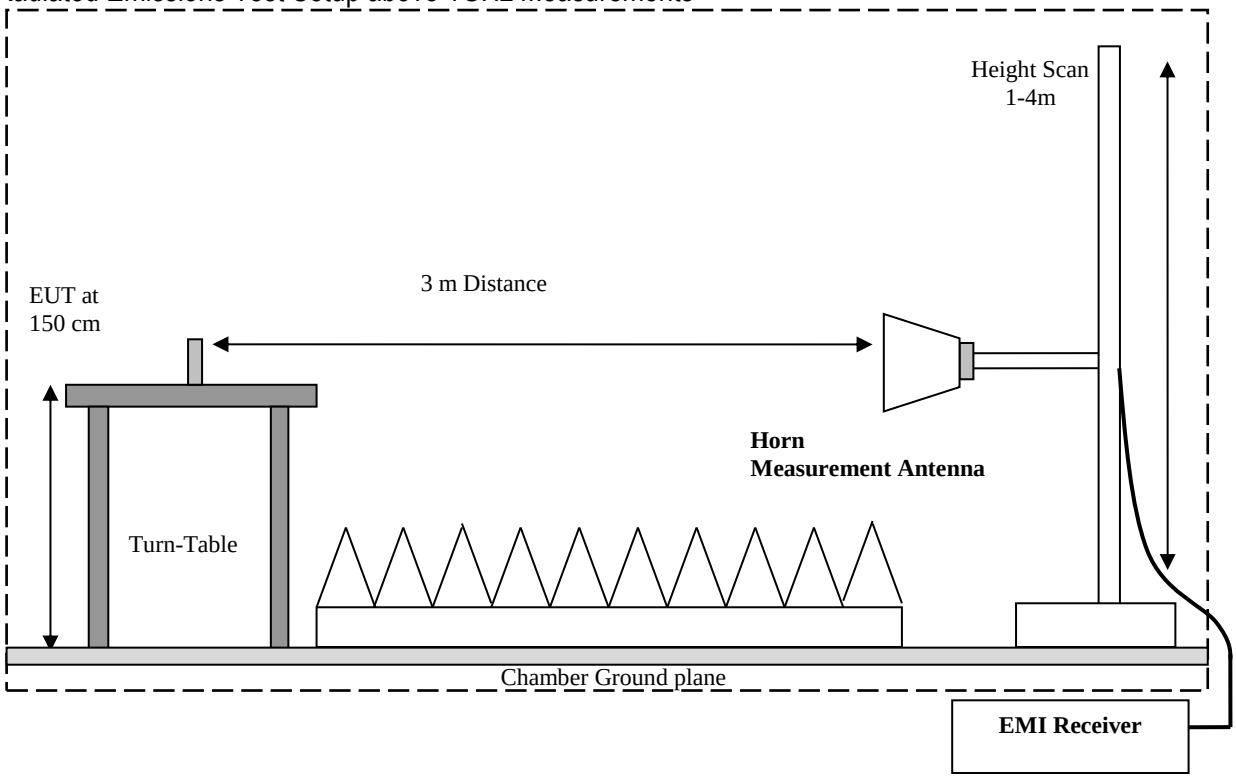
Radiated Emissions Test Setup below 30MHz Measurements



Radiated Emissions Test Setup 30MHz-1GHz Measurements



Radiated Emissions Test Setup above 1GHz Measurements



7.1.1 Sample Calculations for Field Strength Measurements

Field Strength is calculated from the Spectrum Analyzer/ Receiver readings, taking into account the following parameters:

1. Measured reading in dBµV
2. Cable Loss between the receiving antenna and SA in dB and
3. Antenna Factor in dB/m

All radiated measurement plots in this report are taken from a test SW that calculates the Field Strength based on the following equation:

FS (dBµV/m) = Measured Value on SA (dBµV)- Cable Loss (dB)+ Antenna Factor (dB/m)

Example:

Frequency (MHz)	Measured SA (dBµV)	Cable Loss (dB)	Antenna Factor Correction (dB)	Field Strength Result (dBµV/m)
1000	80.5	3.5	14	98.0

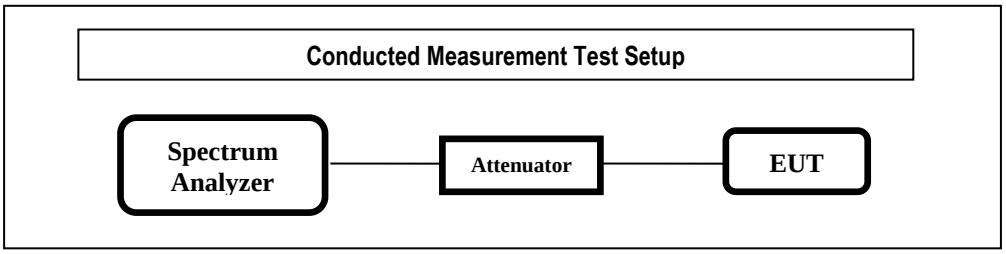
7.2 Power Line Conducted Measurement Procedure

AC Power Line conducted emissions measurements performed according to: ANSI C63.10 (2013)

7.3 RF Conducted Measurement Procedure

Testing procedures are based on 558074 D01 DTS Meas Guidance v04 – "GUIDANCE FOR PERFORMING COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEMS (DTS) OPERATING UNDER SECTION 15.247" - April 5, 2017, by the Federal Communications Commission, Office of Engineering and Technology, Laboratory Division.

7.4 Conducted Setup Block diagram



- Connect the equipment as shown in the above diagram.
- Adjust the settings of the SA (Rohde-Schwarz Spectrum Analyzer) to connect the EUT at the required mode of test.
- Measurements are to be performed with the EUT set to the low, middle and high channels and for worst case modulation schemes.

8 Test Result Data

8.1 Frequency Stability

8.1.1 Measurement according to: FCC: CFR 47 Part 2.1055

The center frequency of transmission on middle channel was measured at the low and high supply voltage specified for the equipment in the range of 0 ºC to 50 ºC' at 10 ºC intervals. The frequency stability was calculated using the following equation:

$$ppm\ error = \left(\frac{MCF_{MHz}}{ACF_{MHz}} - 1 \right) * 10^6$$

where

MCF_{MHz} is the Measured Carrier Frequency in MHz
ACF_{MHz} is the Assigned Carrier Frequency in MHz

Spectrum Analyzer settings:

- RBW =30 kHz
- VBW ≥ 300Hz
- Set span = 10MHz
- Sweep time = auto couple
- Detector = Pk
- Trace mode = Clear Write
- Marker Stepsize = SWP POINTS
- Sweep Points = 10000 points
- Measure the frequency at the low and high edge (F low and F high)
- Calculate the center frequency MCF = F low + (F high – F low)/2

8.1.2 Test conditions and setup:

Ambient Temperature (C)	EUT Set-Up #	EUT operating mode	Power Input (VDC)
-30°C and 50°C	3	BT LE	1.7 and 3.6

8.1.3 Measurement result:

Temperature (°C)	Supply Power (V)	MCF (GHz)	ACF (GHz)	Frequency Stability (ppm)
-30	1.7	2.44098	2.441	-8.5
-30	3.6	2.440979	2.441	-8.1
-20	1.7	2.440992	2.441	-3.2
-20	3.6	2.440992	2.441	-3.2
-10	1.7	2.441001	2.441	0.3
-10	3.6	2.441002	2.441	0.7
0	1.7	2.441004	2.441	1.6
0	3.6	2.441005	2.441	2
10	1.7	2.441004	2.441	1.6
10	3.6	2.441005	2.441	2
20	1.7	2.441001	2.441	0.4
20	3.6	2.441001	2.441	0.5
30	1.7	2.440997	2.441	-1.1
30	3.6	2.440998	2.441	-0.7
40	1.7	2.440994	2.441	-2.5
40	3.6	2.440995	2.441	-2.1
50	1.7	2.440993	2.441	-2.8
50	3.6	2.440994	2.441	-2.4

8.2 Emission Bandwidth

8.2.1 Measurement according to FCC KDB 558074 D01 DTS Meas Guidance v04

Spectrum Analyzer settings:

- Set RBW = 100 kHz
- Set the video bandwidth (VBW) ≥ 3 x RBW
- Detector = Peak
- Trace mode = max hold
- Sweep = auto couple
- Allow the trace to stabilize
- Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission.

8.2.2 Limits:

FCC §15.247(a)(1) and RSS-247 5.2(1)

- Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

8.2.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Measurement Path Loss (dB)	Antenna Gain (dBi)
24° C	3	BT LE	3 VDC	16	5.3

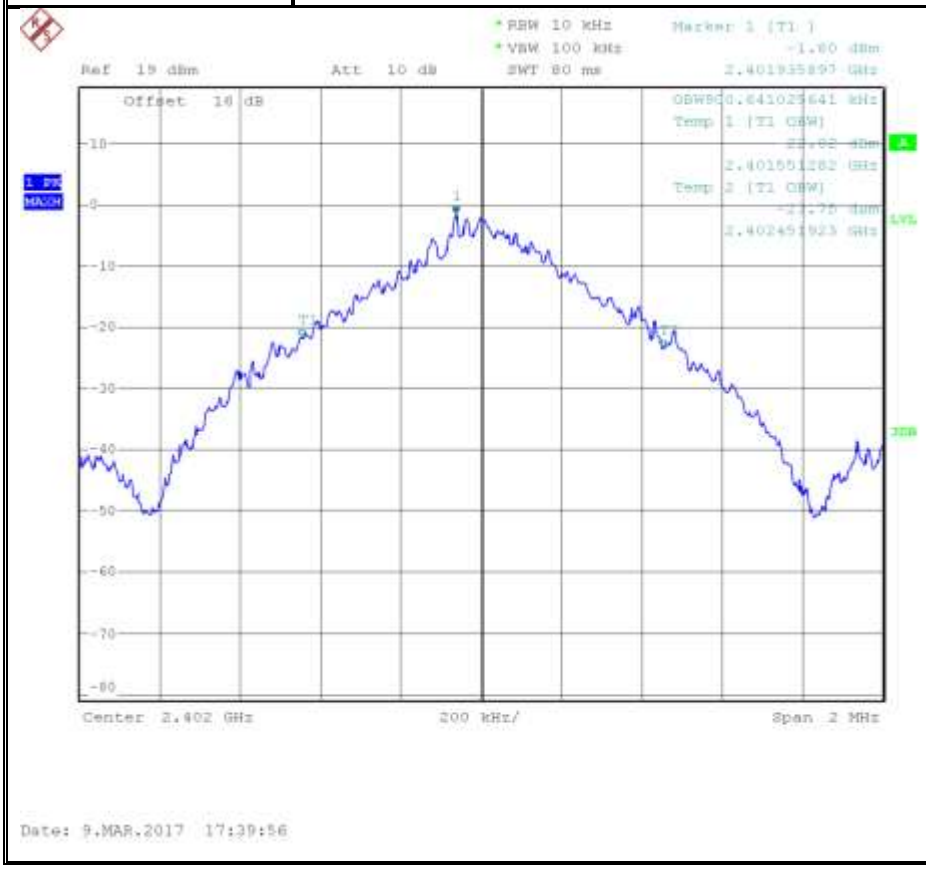
8.2.4 Measurement result:

Plot #	Frequency (MHz)	99% Emissions Bandwidth (MHz)	Limit (MHz)	Result
1	2402	0.9	> 0.5	Pass
2	2442	0.891	> 0.5	Pass
3	2480	0.916	> 0.5	Pass

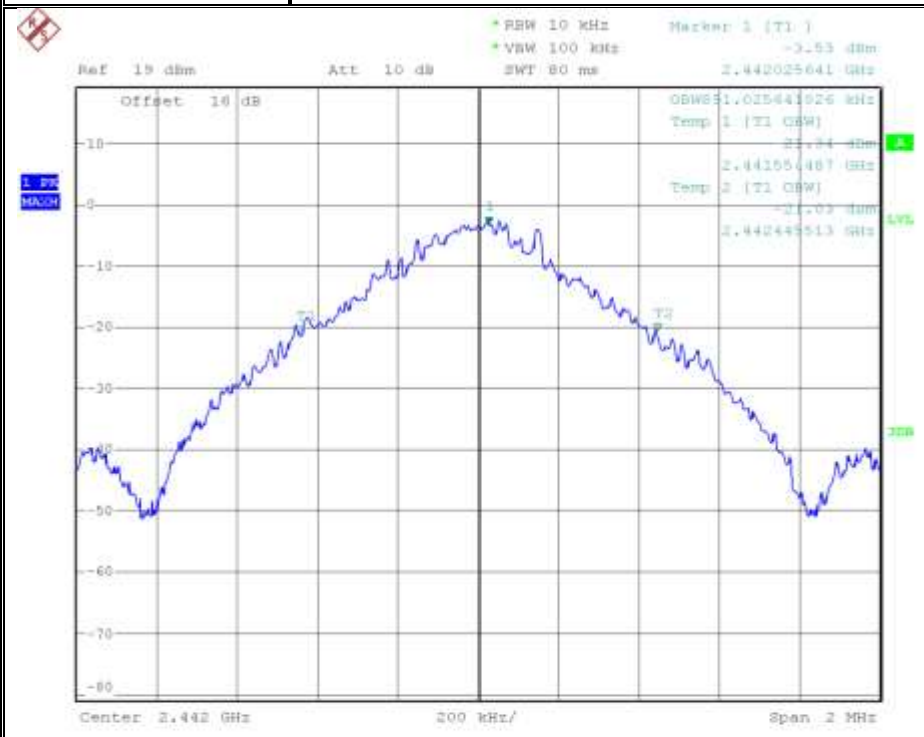
8.2.5 Measurement Plots:

Plot #1 99% Bandwidth

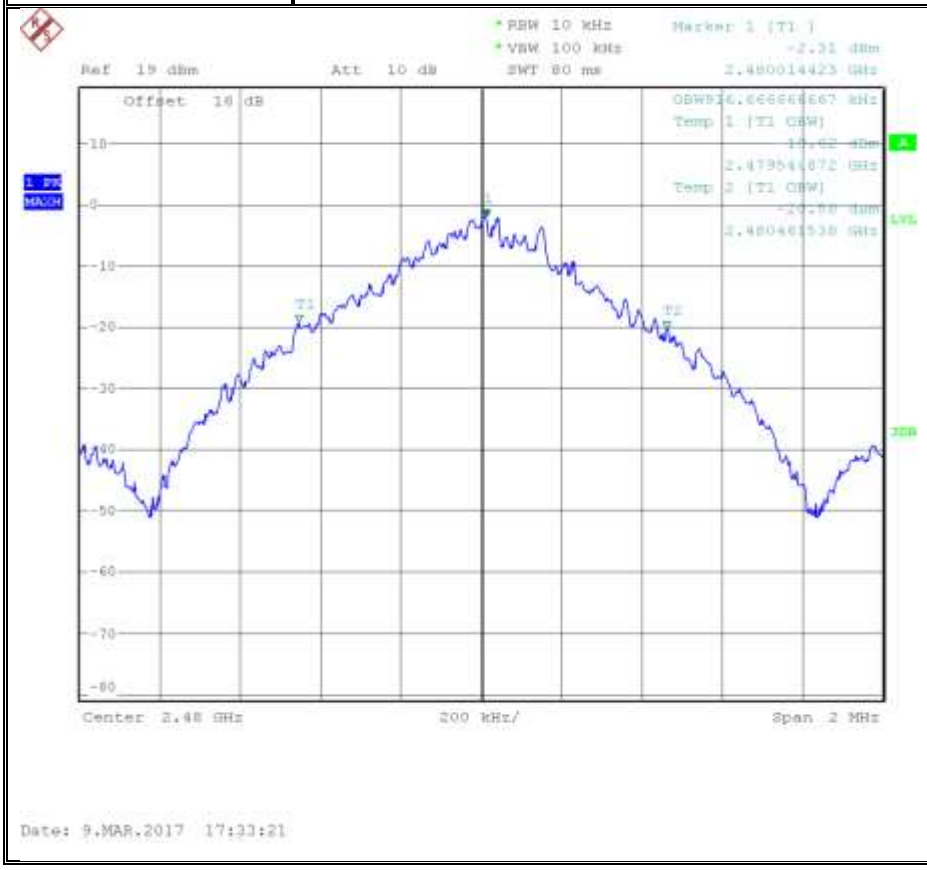
2402MHz	**Mode:** Bluetooth LE



Plot #2 99% Bandwidth	
2442	**Mode:** Bluetooth LE



Plot #3 99% Bandwidth	
2480	**Mode:** Bluetooth LE



8.3 Maximum Peak Conducted Output Power

8.3.1 Measurement according to FCC KDB 558074 D01 DTS Meas Guidance v04

Spectrum Analyzer settings:

- Span = approximately 5 times the 20 dB bandwidth
- RBW > the 20 dB bandwidth of the emission being measured
- VBW ≥ RBW
- Sweep = Auto couple
- Detector function = Peak
- Trace = Max hold
- Use peak marker function to determine the peak amplitude level.

8.3.2 Limits:

Maximum Peak Output Power:

- FCC §15.247 (b): 1 W
- IC RSS-247: 1 W

8.3.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Measurement Path Loss (dB)	Antenna Gain (dBi)
22° C	3	BT LE	3 VDC	16	5.3

8.3.4 Measurement result:

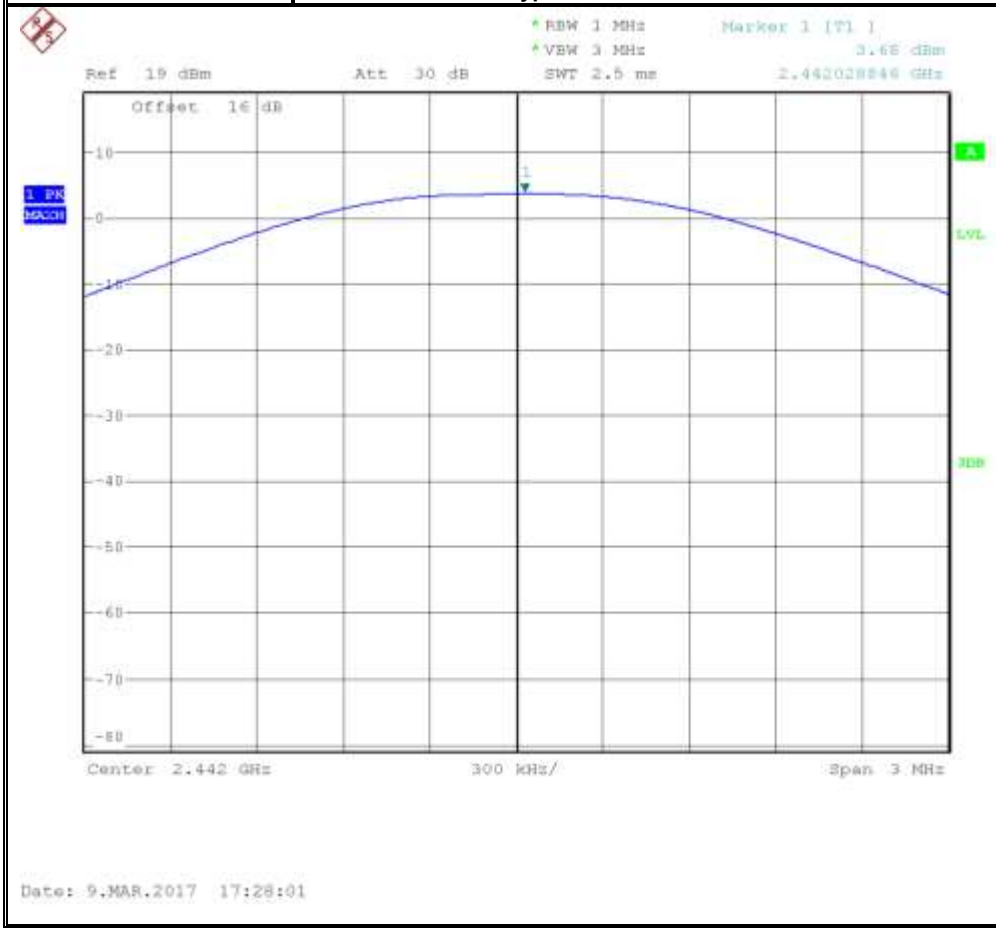
Plot #	Frequency (MHz)	Maximum Peak Conducted Output Power (dBm)	EIRP (dBm)	Limit (dBm)	Result
1	2402	3.45	8.75	20.99(Pk) / 26.99(EIRP)	Pass
2	2442	3.68	8.98	20.99(Pk) / 26.99(EIRP)	Pass
3	2480	3.89	9.19	20.99(Pk) / 26.99(EIRP)	Pass

8.3.5 Measurement Plots:

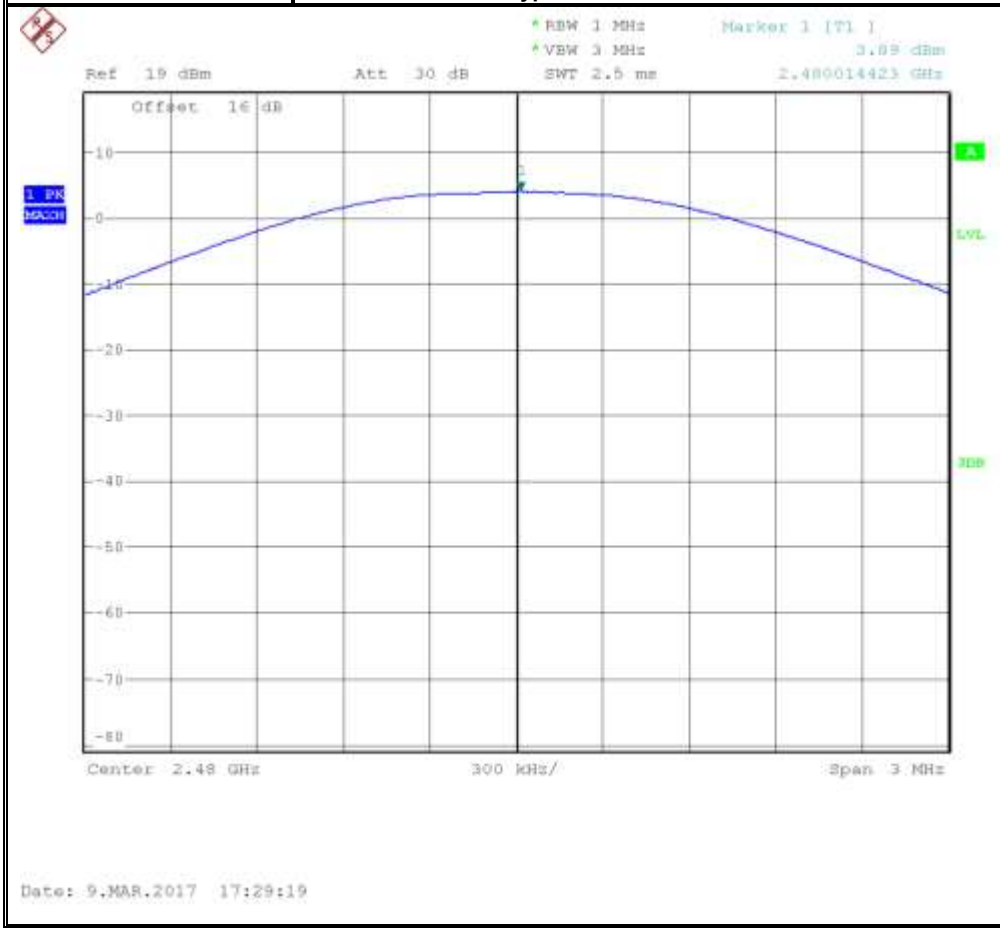
Plot #1

2402 MHz | **Modulation/Packet Type:** Bluetooth LE

Plot #2	
2442 MHz	**Modulation/Packet Type:** Bluetooth LE



Plot #3	
2480 MHz	**Modulation/Packet Type:** Bluetooth LE



8.4 Power Spectral Density

8.4.1 Measurement according to FCC KDB 558074 D01 DTS Meas Guidance v04

Spectrum Analyzer settings for Peak PSD method:

- Set analyzer center frequency to DTS channel center frequency.
- Set the span to 1.5 times the DTS bandwidth
- Set RBW to: 3 kHz ≤ RBW ≤ 100 kHz.
- Set the VBW ≥ 3 x RBW.
- Detector = Peak.
- Sweep time = Auto couple.
- Trace mode = Max hold.
- Allow trace to fully stabilize.
- Use the peak marker function to determine the maximum amplitude level within the RBW.
- If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.

8.4.2 Limits:

FCC§15.247(e) & RSS-247 5.2(2)

- For digitally modulated systems, the peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

8.4.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Measurement Path Loss (dB)	Antenna Gain (dBi)
22° C	3	BT LE	3 VDC	16	5.3

8.4.4 Measurement result:

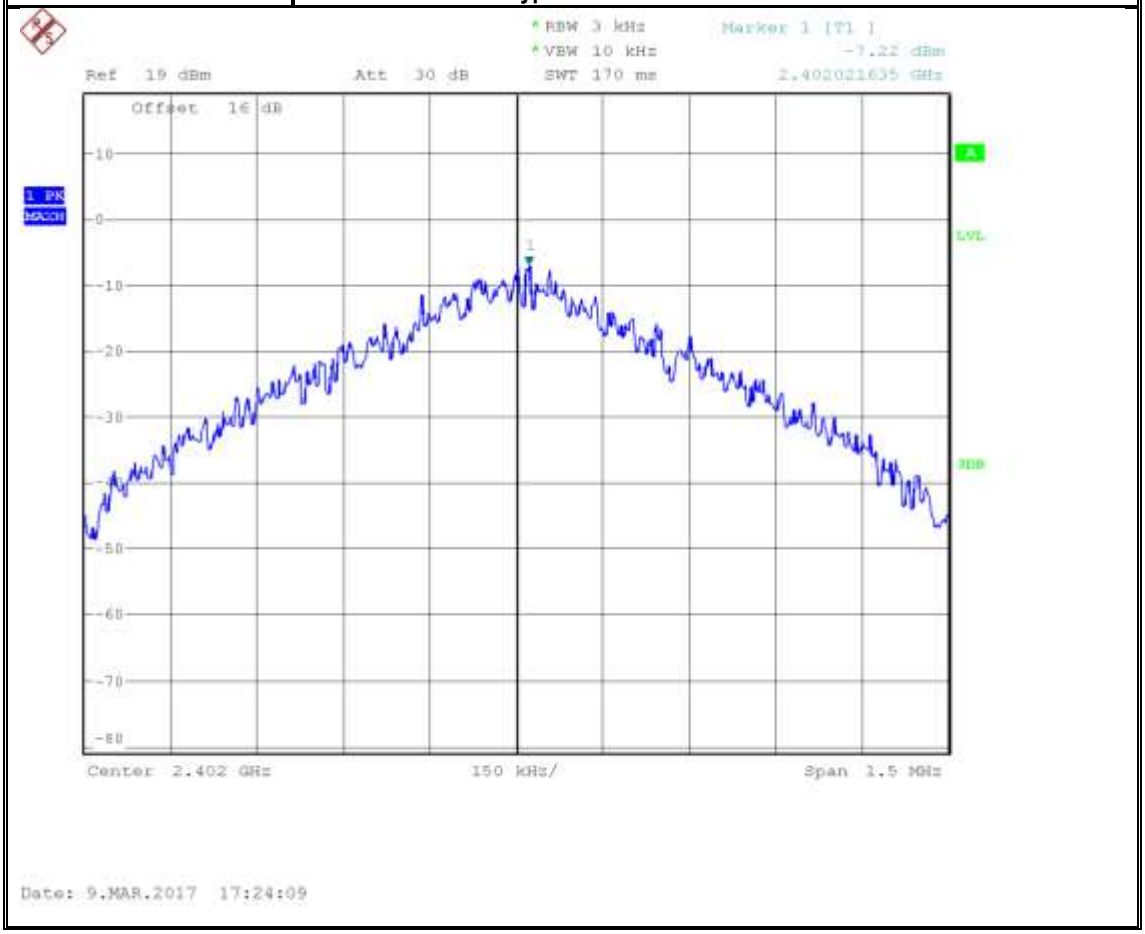
Plot #	Frequency (MHz)	Maximum Power Spectral Density (dBm / 3kHz)	Limit (dBm / 3kHz)	Result
1	2402	-1.92	8	Pass
2	2440	-3.07	8	Pass
3	2480	-2.62	8	Pass

Note: PSD results were adjusted to include antenna gain.

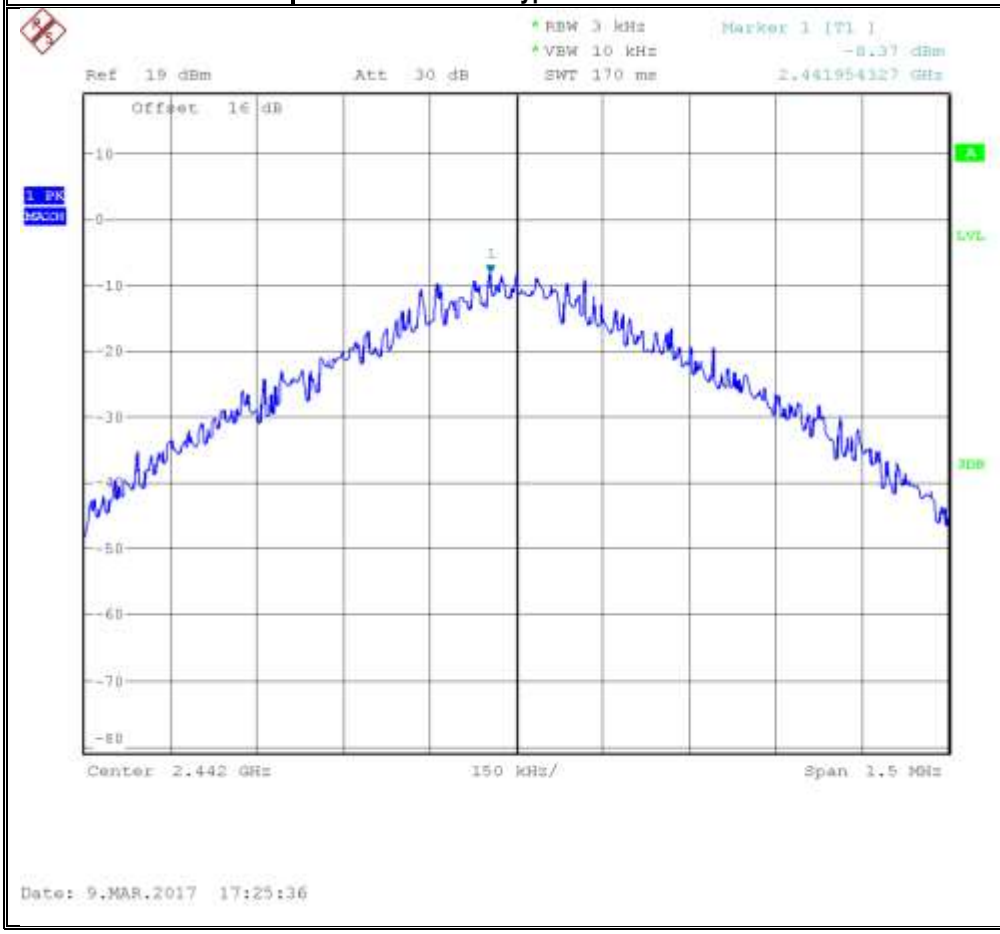
8.4.5 Measurement Plots:

Plot #1

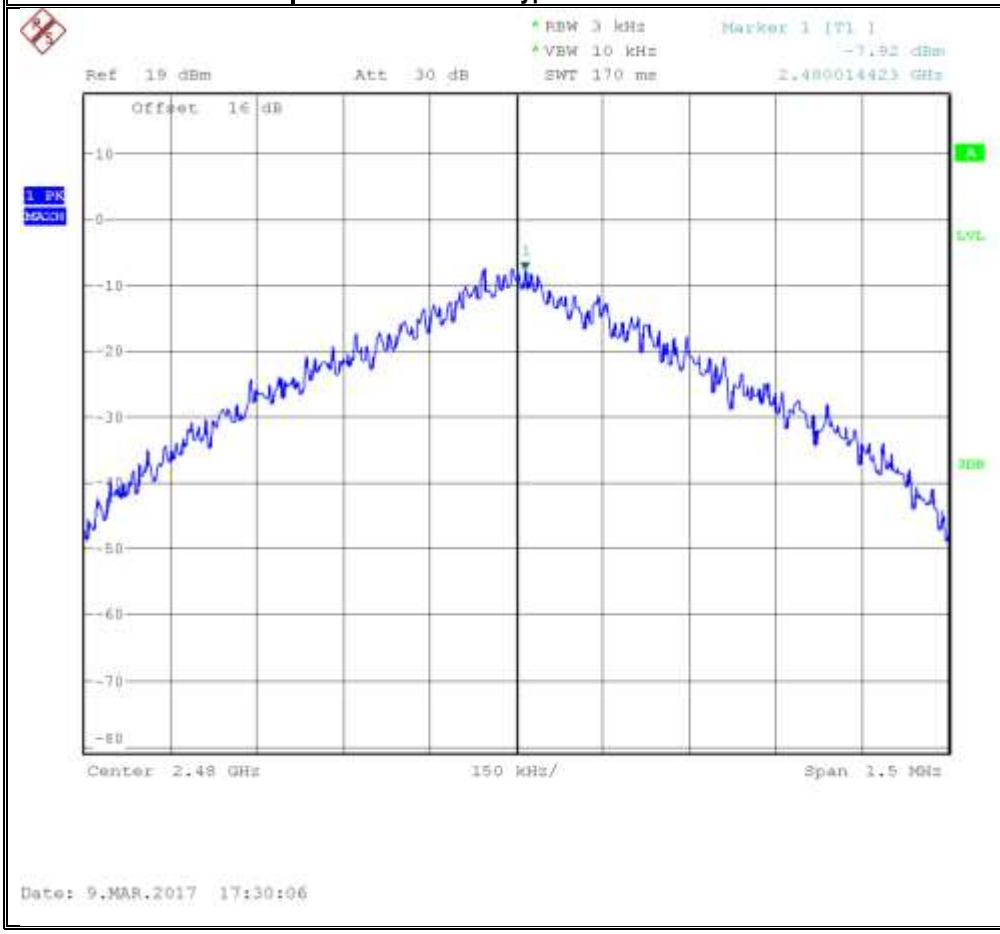
2402 MHz | **Modulation/Packet Type:** Bluetooth LE



Plot #2	
2440 MHz	**Modulation/Packet Type:** Bluetooth LE



Plot #3	
2480 MHz	**Modulation/Packet Type:** Bluetooth LE



8.5 Band Edge and Restricted Band Compliance

8.5.1 Measurement according to FCC KDB 558074 D01 DTS Meas Guidance v04

Spectrum Analyzer settings for non-restricted band edge:

- Set the center frequency and span to encompass frequency range to be measured
- RBW = 100 kHz
- VBW ≥ 3 x RBW
- Sweep Time: Auto couple
- Detector = Peak
- Trace = Max hold
- Allow trace to fully stabilize
- Use the peak marker function to determine the maximum amplitude level
- Set the marker on the emission at the band edge, or on the highest modulation product outside of the band, if this level is greater than that at the band edge

8.5.2 Limits non restricted band:

FCC§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. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

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- 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 30dB instead of 20dB.

Spectrum Analyzer settings for restricted band:

- Peak measurements are made using a peak detector and RBW=1 MHz

8.5.3 Limits restricted band §15.247/15.209/15.205 and RSS-Gen 8.9/8.10

- *PEAK LIMIT= 74 dBµV/m @3m =-21.23 dBm
- *AVG. LIMIT= 54 dBµV/m @3m =-41.23 dBm
- Start frequency & stop frequency according to frequency range specified in the restricted band table in FCC section 15.205 & RSS-Gen 8.10
- Measurements with a peak detector were used to show compliance to average limits, thus showing compliance to both peak and average limits.

(a) Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
[1]0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2690-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	Above 38.6
13.36-13.41			

8.5.4 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Measurement Path Loss (dB)	Antenna Gain (dBi)
22° C	3	BT LE	3 VDC	16	5.3

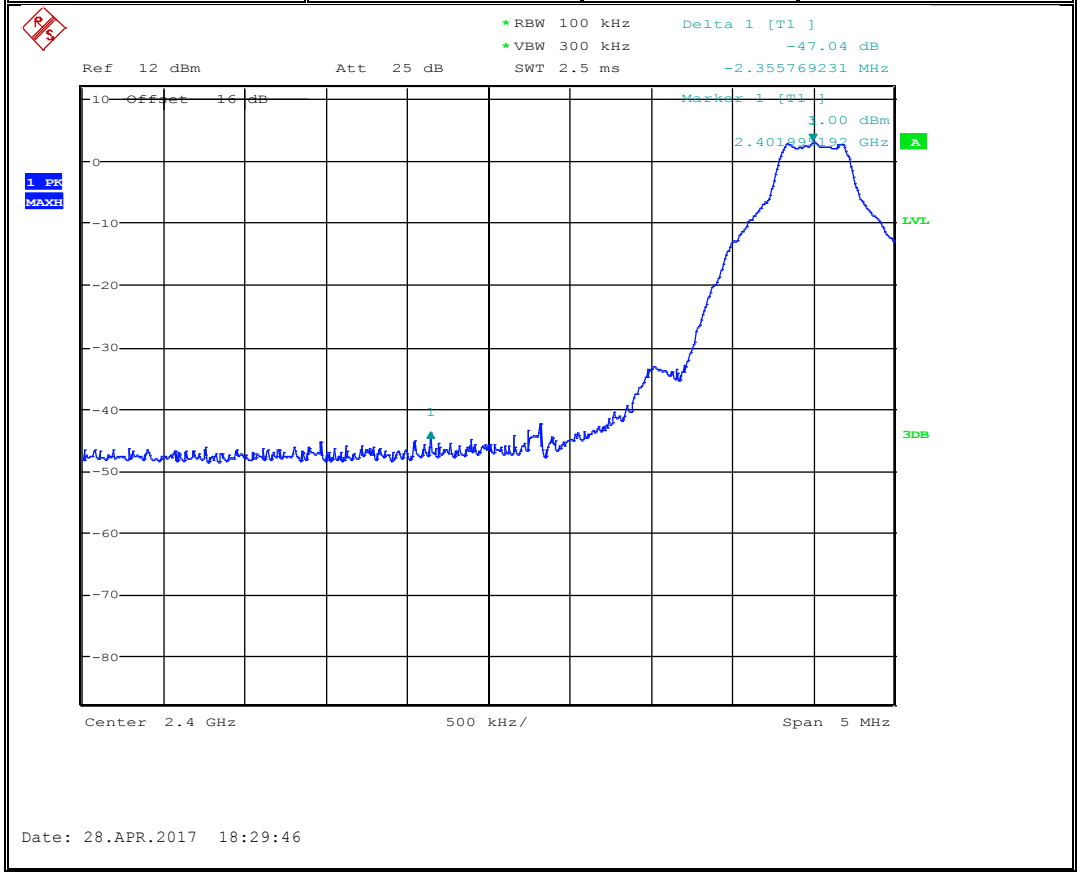
8.5.5 Measurement result:

Plot #	Band Edge	Band Edge Delta (dBc)	Limit (dBc)	Result
1	Lower non restricted	47.04	> 20	Pass

Plot #	EUT operating mode	Band Edge	Measured Value (dBm)	Corrected by Ant. Gain (dBm)	Limit (dBm)	Result
2	BT LE	Upper restricted peak	-39.01	-33.71	-21.23	Pass
3	BT LE	Upper restricted average	-55.65	-50.35	-41.23	Pass

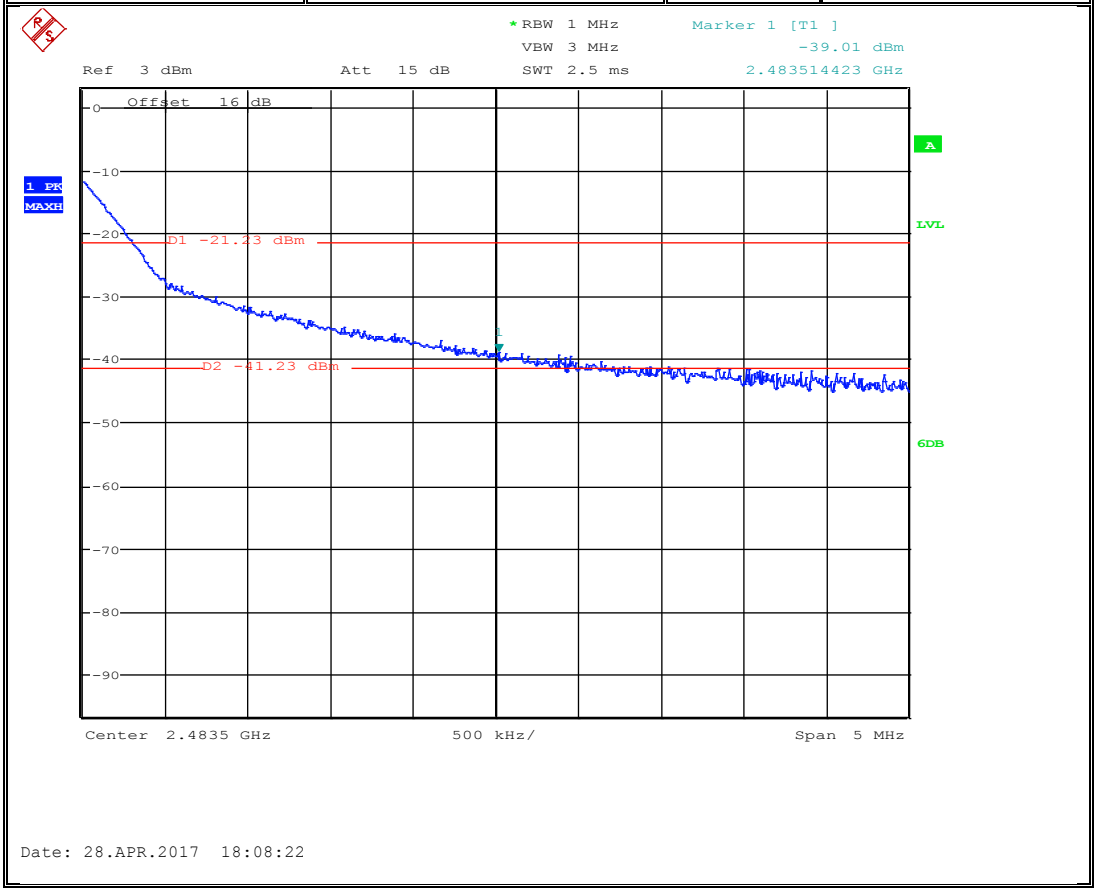
8.5.6 Measurement Plots:

Plot #1 Lower Band Edge non restricted continuous			
2400MHz	Bluetooth LE	Peak	GFSK



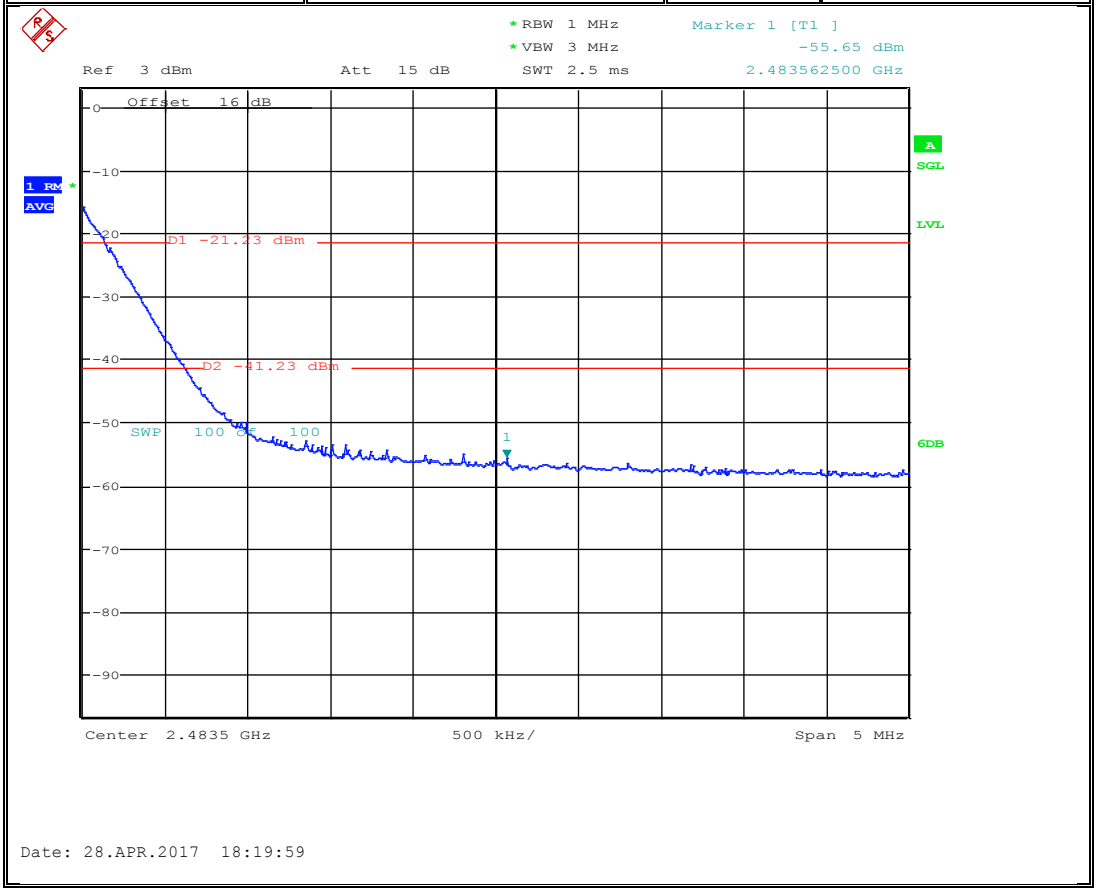
Plot #2 Upper Restricted Band

2483.5MHz	Bluetooth LE	Peak	GFSK



Plot #3 Upper Restricted Band

2483.5MHz	Bluetooth LE	AVG	GFSK



8.6 Radiated Transmitter Spurious Emissions

8.6.1 Measurement according to ANSI C63.10 (2013)

Spectrum Analyzer Settings:

- Frequency = 9 KHz – 30 MHz
- RBW = 9 KHz
- Detector: Peak

- Frequency = 30 MHz – 1 GHz
- Detector = Peak / Quasi-Peak
- RBW=120 KHz (<1GHz)

- Frequency > 1 GHz
- Detector = Peak / Average
- RBW= 1MHz

- Radiated spurious emissions shall be measured for the transmit frequencies, transmit power, and data rate for the lowest, middle and highest channel in each frequency band of operation and for the highest gain antenna for each antenna type, and using the appropriate parameters and test requirements.
- The highest (or worst-case) data rate shall be recorded for each measurement.
- For testing at distance other than the specified in the standard, the limit conversion is calculated by using 40 dB/decade extrapolation factor as follow: Conversion factor (CF) = 40 log (D/d) = 40 log (300m / 3m) = 80dB

8.6.2 Limits:

FCC §15.247

- 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. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

FCC §15.209 & RSS-Gen 8.9

- Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency of emission (MHz)	Field strength (µV/m)	Measurement Distance (m)	Field strength @ 3m (dBµV/m)
0.009–0.490	2400/F(kHz) / ---------	300	-
0.490–1.705	24000/F(kHz) / --------	30	-
1.705–30.0	30 / (29.5)	30	-
30–88	100	3	40 dBµV/m
88–216	150	3	43.5 dBµV/m
216–960	200	3	46 dBµV/m
Above 960	500	3	54 dBµV/m

FCC §15.205 & RSS-Gen 8.10

- Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
[1]0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2690-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	Above 38.6
13.36-13.41			

- Radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).
  *PEAK LIMIT= 74dBµV/m
  *AVG. LIMIT= 54dBµV/m

8.6.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain (dBi)
23° C	1 and 2	BT LE	3 VDC	5.3

8.6.4 Measurement result:

Plot #	Channel #	EUT Set-Up #	Scan Frequency	Limit	Result
1-3	Low	1	30 MHz – 18 GHz	See section 8.6.2	Pass - See Note 2
4-5	Mid	1	9 kHz – 1 GHz	See section 8.6.2	Pass
6-8	Mid	2 - See Note 1	1 GHz – 40 GHz	See section 8.6.2	Pass - See Note 2
9-11	High	1	30 MHz – 18 GHz	See section 8.6.2	Pass - See Note 2

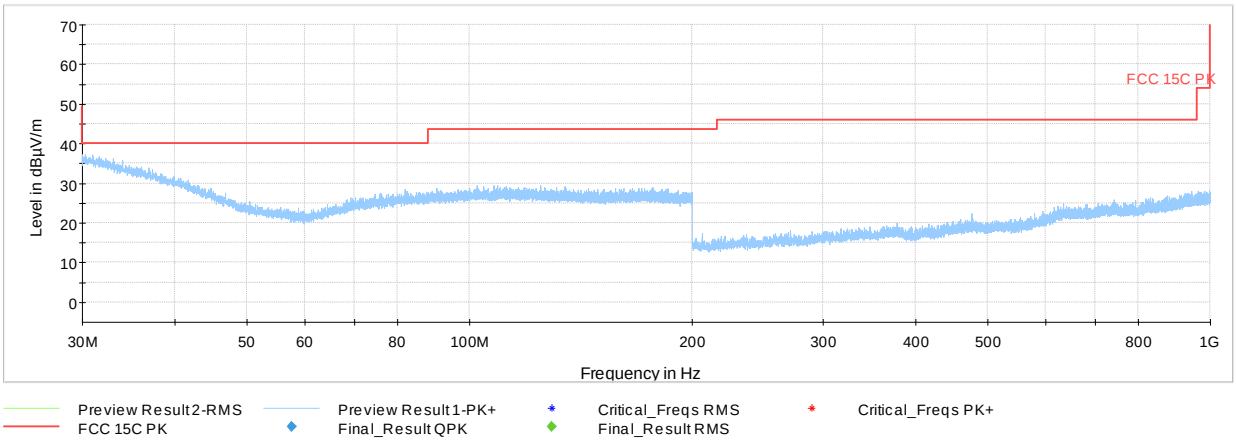
Note1: Spot-check RSE was conducted with the rev E sample.

Note2: The average field strength in the test results from 1 GHz to 18 GHz was calculated by applying -11.5 dB duty cycle correction to the peak measurement, corresponding to the maximum duty cycle of 7% for Bluetooth LE hopping over minimum of 15 channels. The Duty cycle correction factor was calculated using the following formula, CF = 10 log .07 = -11.5 dB

8.6.5 Measurement Plots:

Plots reported here represent the worst case emissions for horizontal and vertical antenna polarizations and for three orientations of the EUT. Unless mentioned otherwise, the emissions outside the limit lines in the plots are from the transmit signal.

Plot #1 Radiated Emissions: 30 MHz – 1GHz	
Modulation: BT LE	**Channel: Low**



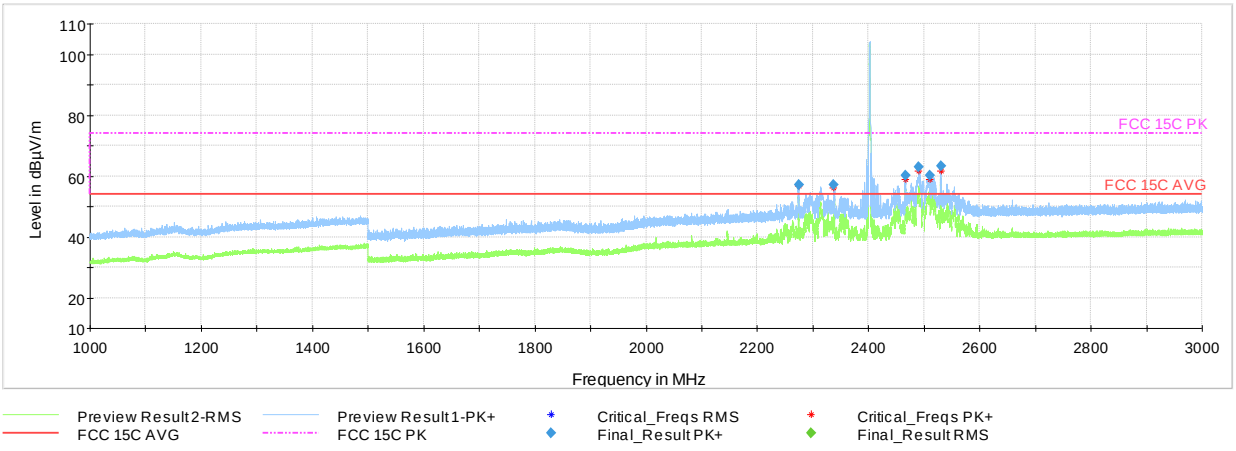
Plot # 2 Radiated Emissions: 1-3 GHz

Modulation: BT LE	**Channel: Low**

Final Measurement Result

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Comments
2274.35	57.23	73.99	16.76	147	H	36	13	Pass
2337.9	57.21	73.99	16.78	150	H	40	13.5	Pass
2466.45	60.04	73.99	13.95	104	H	36	14.2	Pass
2490.15	62.81	73.98	11.17	100	H	36	14.2	Pass
2510.1	60.2	73.99	13.79	129	H	34	14.4	Pass
2530.35	63.2	73.99	10.79	129	H	32	14.3	Pass

Frequency (MHz)	RMS (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. for 7% DC (dB)	Comments
2274.35	45.73	53.98	8.25	147	H	36	-11.5	Pass
2337.9	45.71	53.98	8.27	150	H	40	-11.5	Pass
2466.45	48.54	53.98	5.44	104	H	36	-11.5	Pass
2490.15	51.31	53.98	2.67	100	H	36	-11.5	Pass
2510.1	48.7	53.98	5.28	129	H	34	-11.5	Pass
2530.35	51.7	53.98	2.28	129	H	32	-11.5	Pass

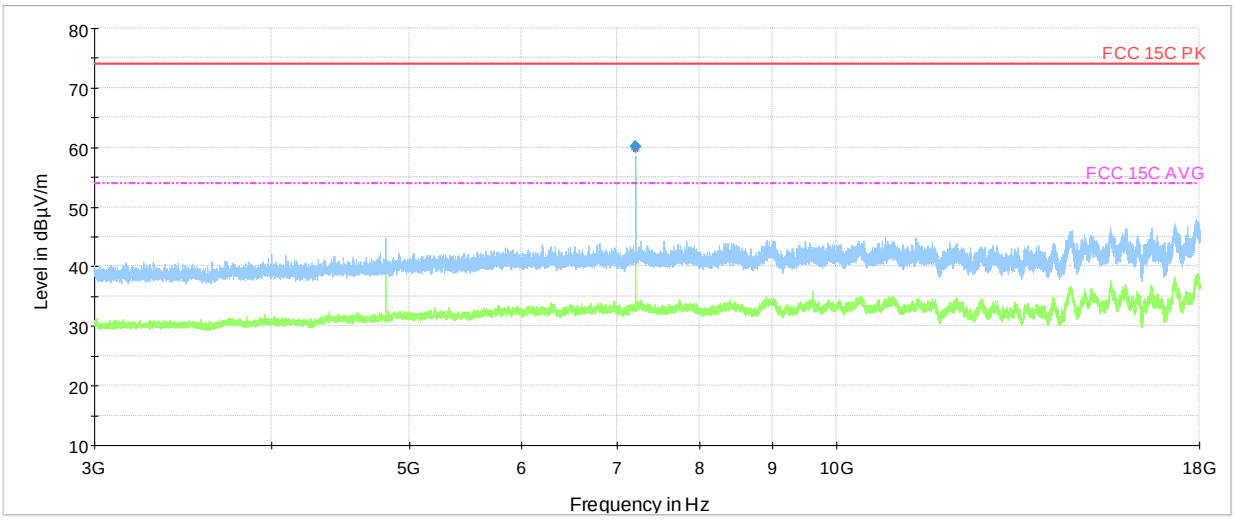


Plot # 3 Radiated Emissions: 3-18 GHz	
Modulation: BT LE	**Channel: Low**

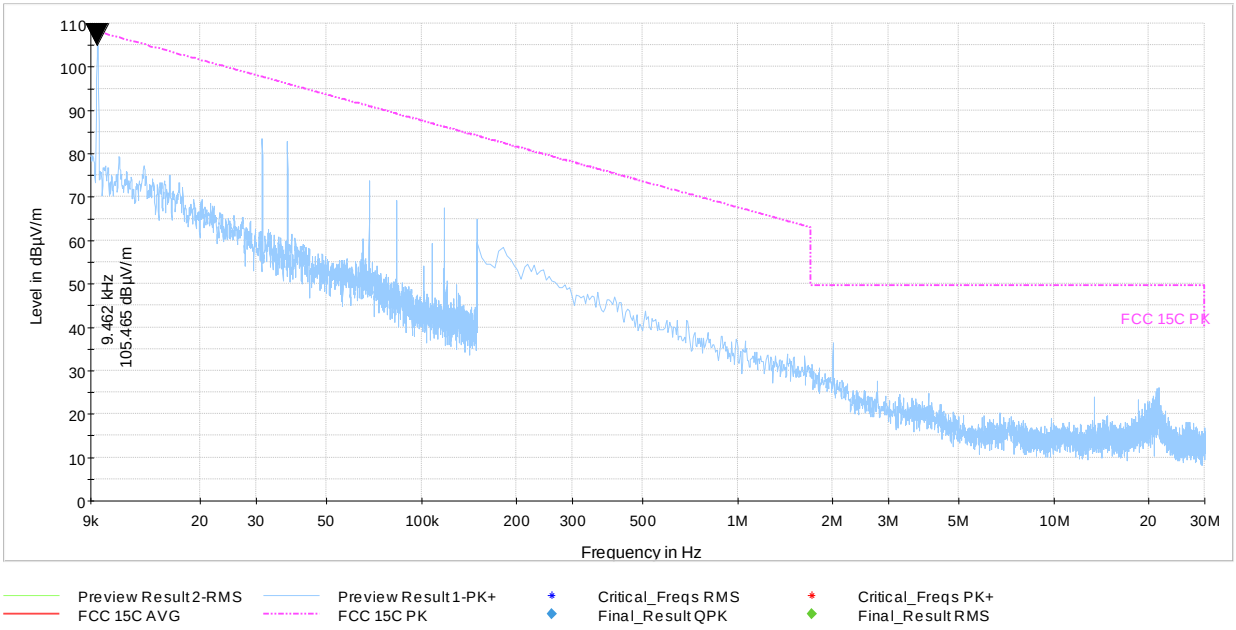
Final Measurement Result

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Comments
7212.51	60.09	73.99	13.9	118	H	47	-20.5	Pass

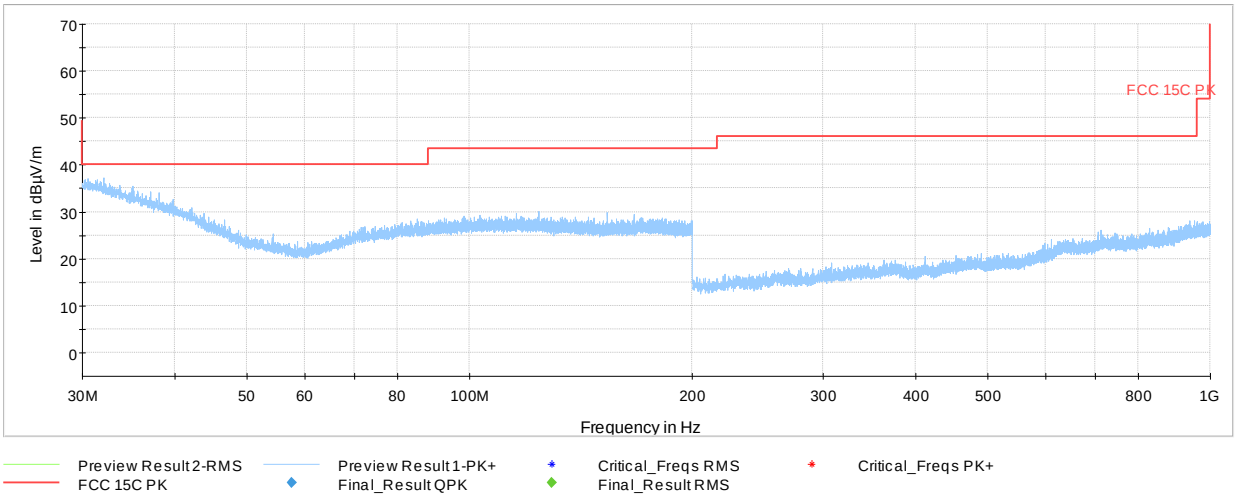
Frequency (MHz)	RMS (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. for 7% DC (dB)	Comments
2274.35	48.59	53.98	5.39	118	H	47	-11.5	Pass



Plot # 4 Radiated Emissions: 9 KHz - 30 MHz	
Modulation: BT LE	**Channel: Mid**



Plot #5 Radiated Emissions: 30 MHz – 1GHz	
Modulation: BT LE	**Channel: Mid**



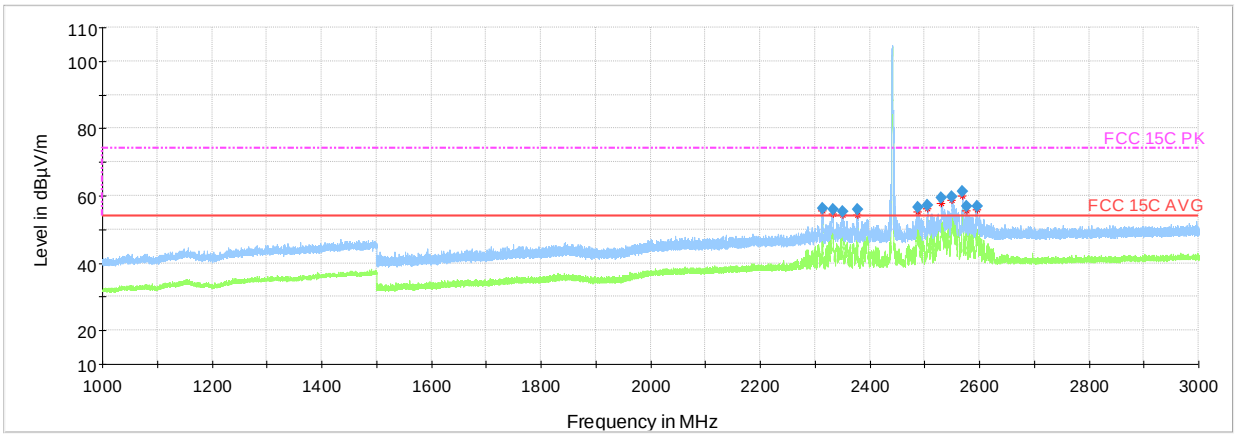
Plot #6 Radiated Emissions: 1-3 GHz

Modulation: BT LE | **Channel: Mid**

Final Measurement Result

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Comments
2313.2	56.23	73.99	17.76	175	H	131	13.3	Pass
2332.45	55.8	73.99	18.19	170	H	128	13.5	Pass
2351.4	55.4	73.99	18.59	127	H	129	13.6	Pass
2377	55.87	73.99	18.12	174	H	129	13.7	Pass
2487.05	56.45	73.99	17.54	185	H	128	14.2	Pass
2504.9	57.24	73.99	16.75	144	H	124	14.3	Pass
2531.4	59.35	73.99	14.64	191	H	124	14.2	Pass
2549.85	59.83	73.99	14.16	159	H	125	14.4	Pass
2569.1	61.24	73.99	12.75	131	H	134	14.6	Pass
2576.85	56.78	73.99	17.21	200	H	118	14.6	Pass
2595.2	56.76	73.99	17.23	195	H	132	14.7	Pass

Frequency (MHz)	RMS (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. for 7% DC (dB)	Comments
2313.2	44.73	53.98	9.25	175	H	131	-11.5	Pass
2332.45	44.3	53.98	9.68	170	H	128	-11.5	Pass
2351.4	43.9	53.98	10.08	127	H	129	-11.5	Pass
2377	44.37	53.98	9.61	174	H	129	-11.5	Pass
2487.05	44.95	53.98	9.03	185	H	128	-11.5	Pass
2504.9	45.74	53.98	8.24	144	H	124	-11.5	Pass
2531.4	47.85	53.98	6.13	191	H	124	-11.5	Pass
2549.85	48.33	53.98	5.65	159	H	125	-11.5	Pass
2569.1	49.74	53.98	4.24	131	H	134	-11.5	Pass
2576.85	45.28	53.98	8.7	200	H	118	-11.5	Pass
2595.2	45.26	53.98	8.72	195	H	132	-11.5	Pass

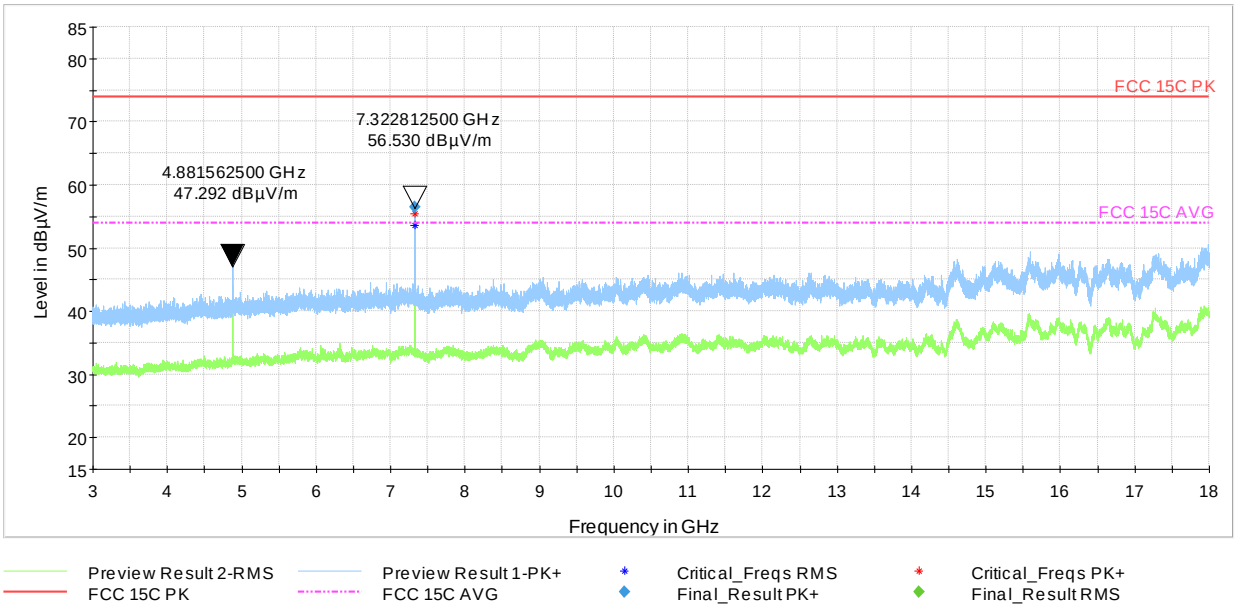

110
100
80
60
40
20
10
Level in dBµV/m
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Frequency in MHz
FCC 15C PK
FCC 15C AVG
Preview Result 2-RMS
FCC 15C AVG
Preview Result 1-PK+
FCC 15C PK
Critical_Freqs RMS
Final_Result PK+
Critical_Freqs PK+
Final_Result RMS

Plot #7 Radiated Emissions: 3-18 GHz	
Modulation: BT LE	**Channel: Mid**

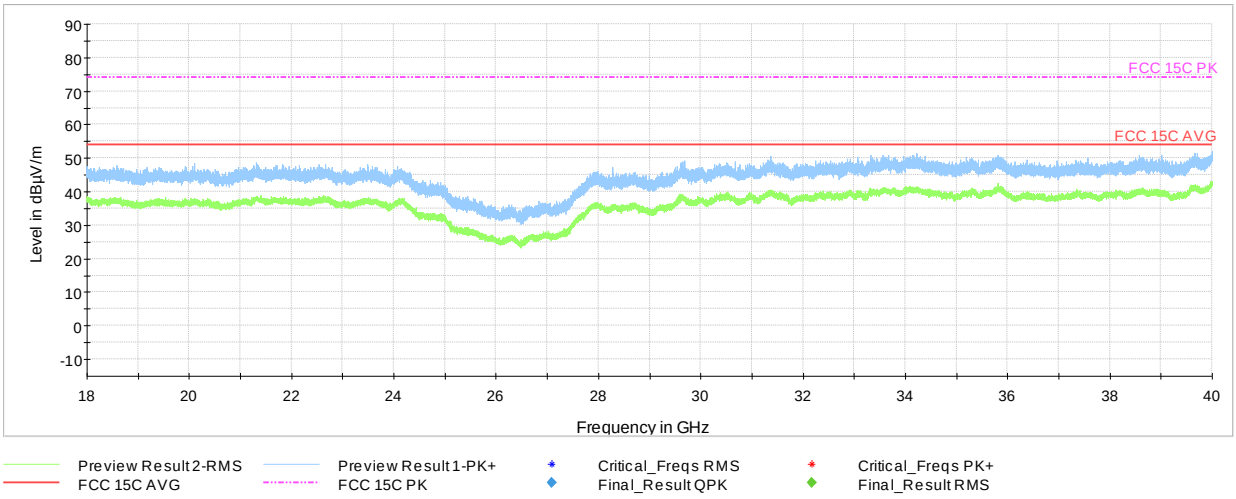
Final Measurement Result

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Comments
7322.8125	56.53	73.99	17.46	104	H	313	-20.8	Pass

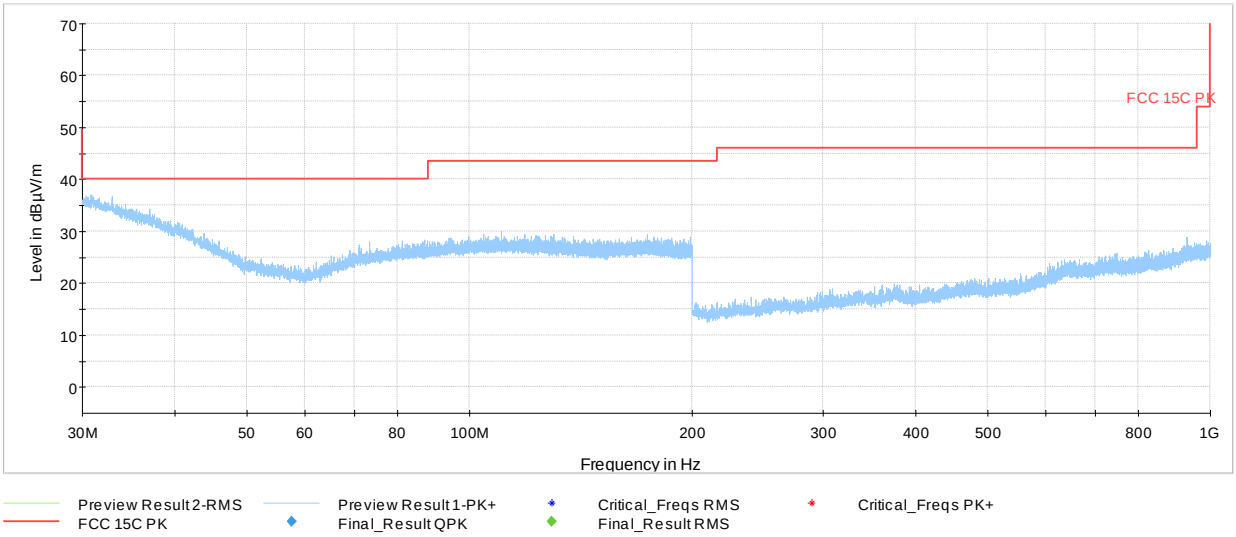
Frequency (MHz)	RMS (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. for 7% DC (dB)	Comments
7322.8125	45.03	53.98	8.95	104	H	313	-11.5	Pass



Plot #8 Radiated Emissions: 18-26 GHz	
Modulation: BT LE	**Channel: Mid**



Plot #9 Radiated Emissions: 30 MHz – 1GHz	
Modulation: BT LE	**Channel: High**



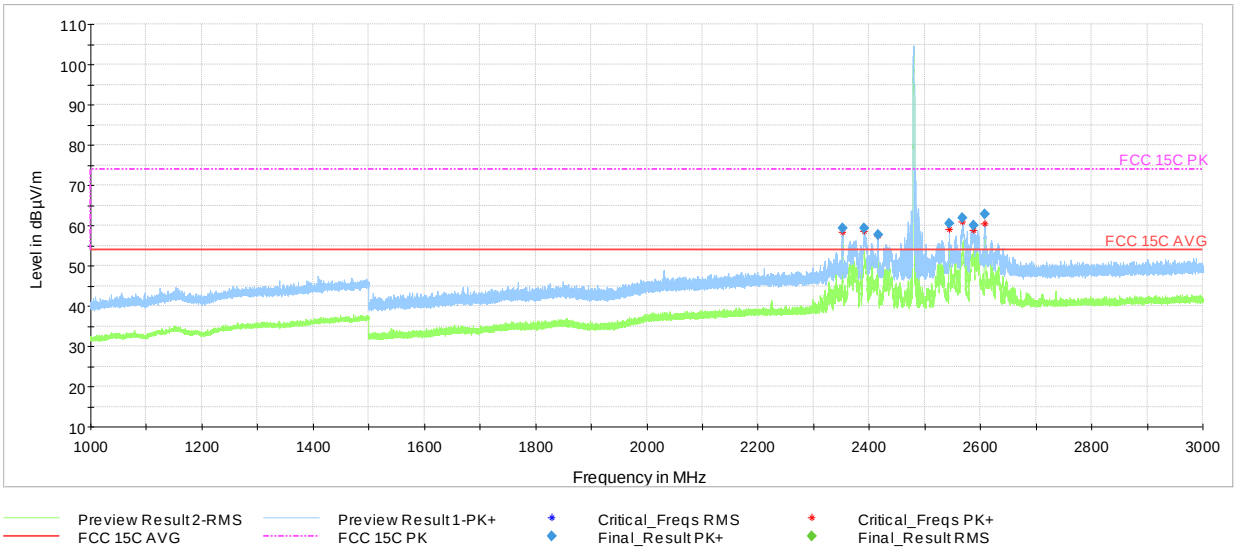
Plot # 10 Radiated Emissions: 1-3 GHz and Restricted Bands

Modulation: BT LE | **Channel: High**

Final Measurement Result

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Comments
2352.1	59.26	73.99	14.73	154	H	105	13.6	Pass
2391.9	59.24	73.99	14.75	152	H	104	13.9	Pass
2415.7	57.56	73.99	16.43	295	H	113	13.8	Pass
2543.95	60.42	73.99	13.57	145	H	100	14.3	Pass
2568.15	61.96	73.99	12.03	129	H	113	14.6	Pass
2587.55	60.03	73.99	13.96	167	H	108	14.6	Pass
2608.15	62.8	73.99	11.19	122	H	109	14.7	Pass

Frequency (MHz)	RMS (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. for 7% DC (dB)	Comments
2352.1	47.76	53.98	6.22	154	H	105	-11.5	Pass
2391.9	47.74	53.98	6.24	152	H	104	-11.5	Pass
2415.7	46.06	53.98	7.92	295	H	113	-11.5	Pass
2543.95	48.92	53.98	5.06	145	H	100	-11.5	Pass
2568.15	50.46	53.98	3.52	129	H	113	-11.5	Pass
2587.55	48.53	53.98	5.45	167	H	108	-11.5	Pass
2608.15	51.3	53.98	2.68	122	H	109	-11.5	Pass

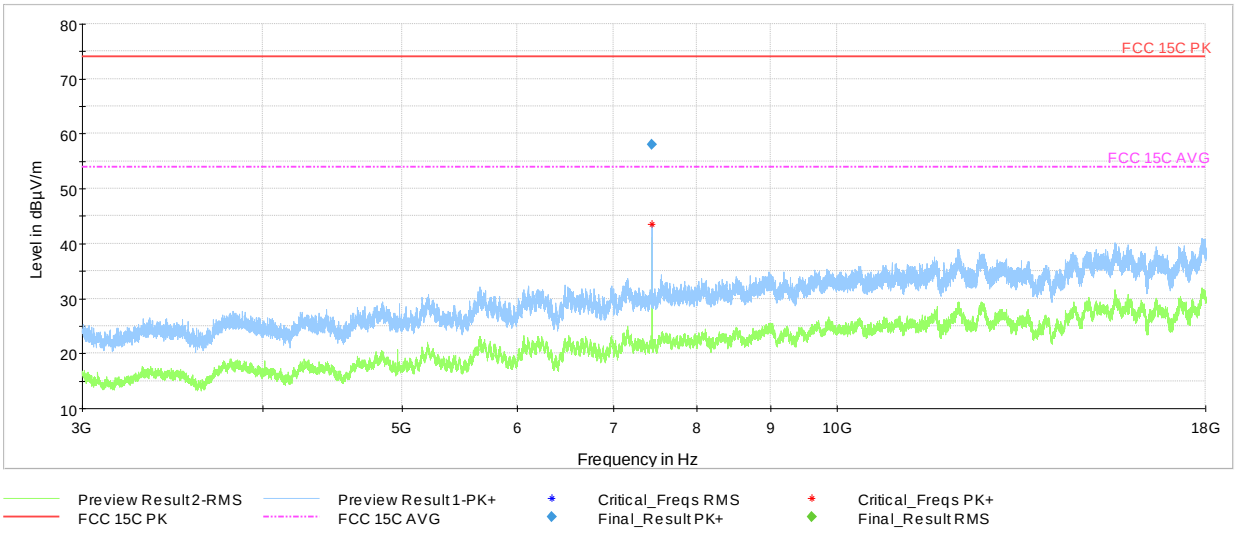


Plot #11 Radiated Emissions: 3-18 GHz	
Modulation: GFSK	**Channel: High**

Final Measurement Result

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Comments
7439.5313	58.01	73.99	15.98	180	H	159	-21	Pass

` (MHz)	RMS (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. for 7% DC (dB)	Comments
7439.5313	46.51	53.98	7.47	180	H	159	-11.5	Pass



9 Test setup photos

Setup photos are included in supporting file name: "EMC_KSTEC-003-17001_15.247_DTS_Setup_Photos.pdf"

10 Test Equipment And Ancillaries Used For Testing

Item Name	Equipment Type	Manufacturer	Model	Serial #	Calibration Cycle	Last Calibration Date
Antenna Biconilog 3142E	Biconlog Antenna	EMCO	3142E	166067	3 years	6/14/2014
Antenna Loop 6512	Loop Antenna	ETS Lindgren	6512	49838	3 years	3/13/2014
Antenna Horn 3115 SN 35111	Horn Antenna	EMCO	3115	35111	3 years	7/24/2015
Antenna Horn 3116	Horn Antenna	ETS Lindgren	3116	70497	3 years	7/22/2015
Digital Barometer	Compact Digital Barometer	Control Company	35519-055	91119547	2 Years	4/7/2015
FSU26	Spectrum Analyzer	R&S	FSU26	200065	3 years	7/4/2015
FSU26	Spectrum Analyzer	R&S	FSU26	200302	3 years	7/4/2015
Thermometer Humidity TM320	Thermometer Humidity	Dickson	AY1072	0528	1 Year	11/2/2016

Note:
1. Equipment used meets the measurement uncertainty requirements as required per applicable standards for 95% confidence levels.
2. Calibration due dates, unless defined specifically, falls on the last day of the month. Items indicated "N/A" for cal status either do not specifically require calibration or is internally characterized before use.

11 Revision History

Date	Report Name	Changes to report	Report prepared by
2017-03-29	EMC_KSTEC-003-17001_15.247_DTS	Initial Version	Kris Lazarov
2017-04-28	EMC_KSTEC-003-17001_15.247_DTS Rev 1	Updated the conducted test procedure to 558074 D01 DTS Meas Guidance v04 on various locations. Updated the Band Edge section	Kris Lazarov