FCC / ISED Test Report

FOR:
CalAmp

Model Number:
TTU2900MB

Product Description:
Solar-based telematics gateway

FCC ID: APV-2900MB
IC ID: 5843C-2900MB

Applied Rules and Standards:
47 CFR Part 15.247 (DTS)
RSS-247 Issue 2 (DTS) & RSS-Gen Issue 5

REPORT #: EMC_CALAM-118-21001_15.247_BT_DTS

DATE: 2021-02-23

A2LA Accredited

IC recognized #
3462B-1
CABID: US0187

***CETECOM* Inc.**
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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.

No deviations were ascertained.

Company	Description	Model #
CalAmp	Solar-based telematics gateway	TTU2900MB

Responsible for Testing Laboratory:

Date	Section	Name	Signature
2021-02-23	Compliance	Cindy Li (EMC Lab Manager)	Cindy Li Digitally signed by cindy.li@cetecom.com DN: CN=cindy.li@cetecom.com Reason: I have reviewed this document Location: Date: 2021-02-24 11:23:06

Responsible for the Report:

Date	Section	Name	Signature
2021-02-23	Compliance	Yuchan Lu (Test Engineer)	Yuchan Lu Digitally signed by: Yuchan Lu DN: CN = Yuchan Lu email = Yuchan.Lu@cetecom.com C = US O = CETECOM Inc. OU = EMC Date: 2021.02.23 12:17:19 -08'00'

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
EMC Lab Manager:	Cindy Li
Responsible Project Leader:	Cathy Palacios

2.2 Identification of the Client

Client's Name:	CalAmp
Street Address:	2200 Faraday Avenue, Suite 220
City/Zip Code:	Carlsbad, CA 92008
Country:	USA

2.3 Identification of the Manufacturer

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

3 Equipment Under Test (EUT)

3.1 EUT Specifications

Model No:	TTU2900MB
HW Version :	REV A
SW Version :	8.5
FCC-ID:	APV-2900MB
IC-ID:	5843C-2900MB
HVIN:	TTU2900MB
PMN:	TTU2900MB
Product Description:	Solar-based telematics gateway
Frequency Range / number of channels:	Manufacture: Texas Instruments Module name/number: CC2640 Nominal band: 2400 MHz – 2483.5 MHz; Center to center: 2402 MHz (ch 0) – 2480 MHz (ch 39), 40 channels
Type(s) of Modulation:	Bluetooth Low Energy, using Dynamic Sequence Spread Spectrum with GFSK modulation.
Modes of Operation:	Bluetooth LE in both advertising and connected mode of operation
Antenna Information as declared:	• 1.88 dBi
Max. Peak Output Power:	Conducted Power 5.1 dBm
Power Supply/ Rated Operating Voltage Range:	Vmin: 8 VDC/ Vnom: 12 VDC / Vmax: 32 VDC
Operating Temperature Range:	Low -30ºC, Nominal 25ºC, High 70ºC
Other Radios included in the device:	❖ GSM, LTE • Manufacture: Quectel • Module name/number: BG96 • FCC ID: XMR201707BG96 • IC ID: 10224A-201709BG96
Sample Revision:	☐Prototype Unit; ☐ Production Unit; ■ Pre-Production

3.2 EUT Sample details

EUT #	Serial Number	HW Version	SW Version	Notes/Comments
1	6002001035	REV A	8.5	Radiated Emissions
2	6002001045	REV A	8.5	Conducted RF

3.3 Accessory Equipment details

AE #	Type	Model	Manufacturer	Serial Number
1	Charging and communication cable	-	-	-

3.4 Support Equipment

SE #	Description
1	Laptop, Dell Latitude 7490

3.5 Test Sample Configuration

EUT Set-up #	Combination of AE used for test set up	Comments
1	EUT#1 + AE#1	Special commands through Tera Term used to configure the Bluetooth LE radio to low, mid and high channels and co-transmitting with LTE CAT M1 Band 25 mid Channel (1882.5 MHz) provided by the client that will not be available to the end user. For radiated measurements, the internal antenna was connected.
2	EUT#2 + AE#1	Special commands through Tera Term used to configure the Bluetooth LE radio to low, mid and high channel provided by the client that will not be available to the end user. For conducted measurements, the equipment was connected to 50 ohm RF port of the EUT.

3.6 Justification for Worst Case Mode of Operation

During the testing process, the EUT was tested with transmitter sets on low, mid and high channels, and co-transmitting with LTE CAT M1 Band 25 mid Channel (1882.5 MHz). Based on client declaration, the EUT was configured to the highest duty cycle and maximum output power.
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.

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 of ISED Canada.

Testing procedures are based on 558074 D01 DTS Meas Guidance v05r02 – "GUIDANCE FOR PERFORMING COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEMS (DTS) OPERATING UNDER SECTION 15.247" - April 2, 2019, 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
§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	☐	☐	■	Note 2

Note1: NA= Not Applicable; NP= Not Performed.
Note2: The EUT is powered by 12 VDC.

6 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 30 MHz	±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

According to TR 102 273 a multiplicative propagation of error is assumed for RF measurement systems. For this reason the RMS method is applied to dB values and not to linear values as appropriate for additive propagation of error. Also used: http://physics.nist.gov/cuu/Uncertainty/typeb.html. The above calculated uncertainties apply to direct application of the Substitution method. The Substitution method is always used when the EUT comes closer than 3 dB to the limit.

6.1 Environmental Conditions during Testing:

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

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

6.2 Dates of Testing:

01/12/2021-02/04/2021

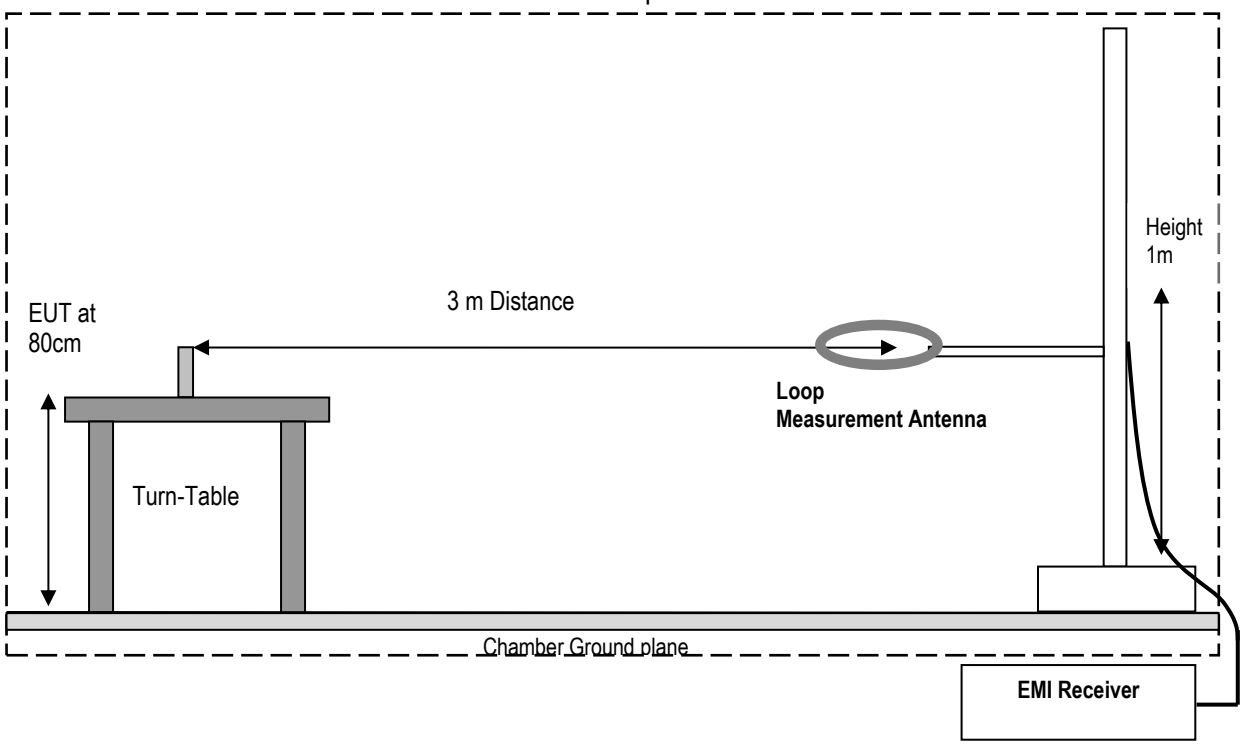
7 Measurement Procedures

7.1 Radiated Measurement

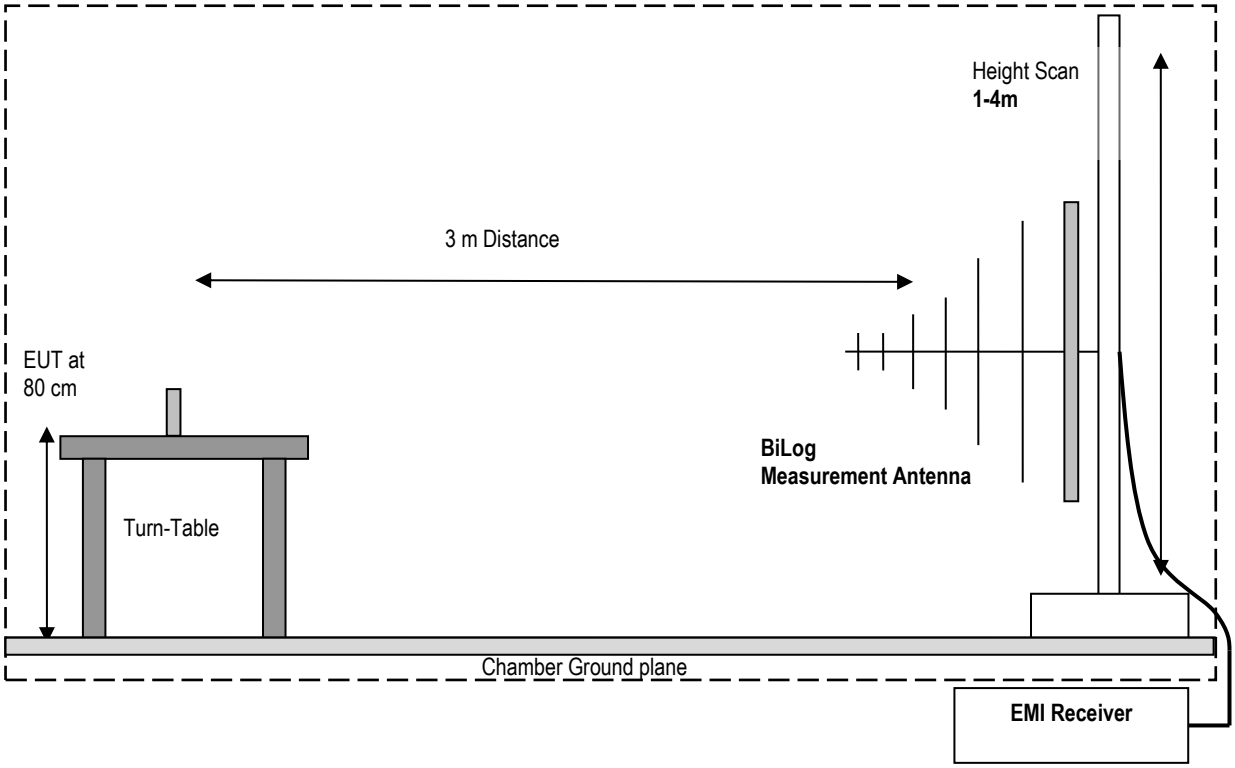
The radiated measurement is performed according to ANSI C63.10 (2013)

- 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.

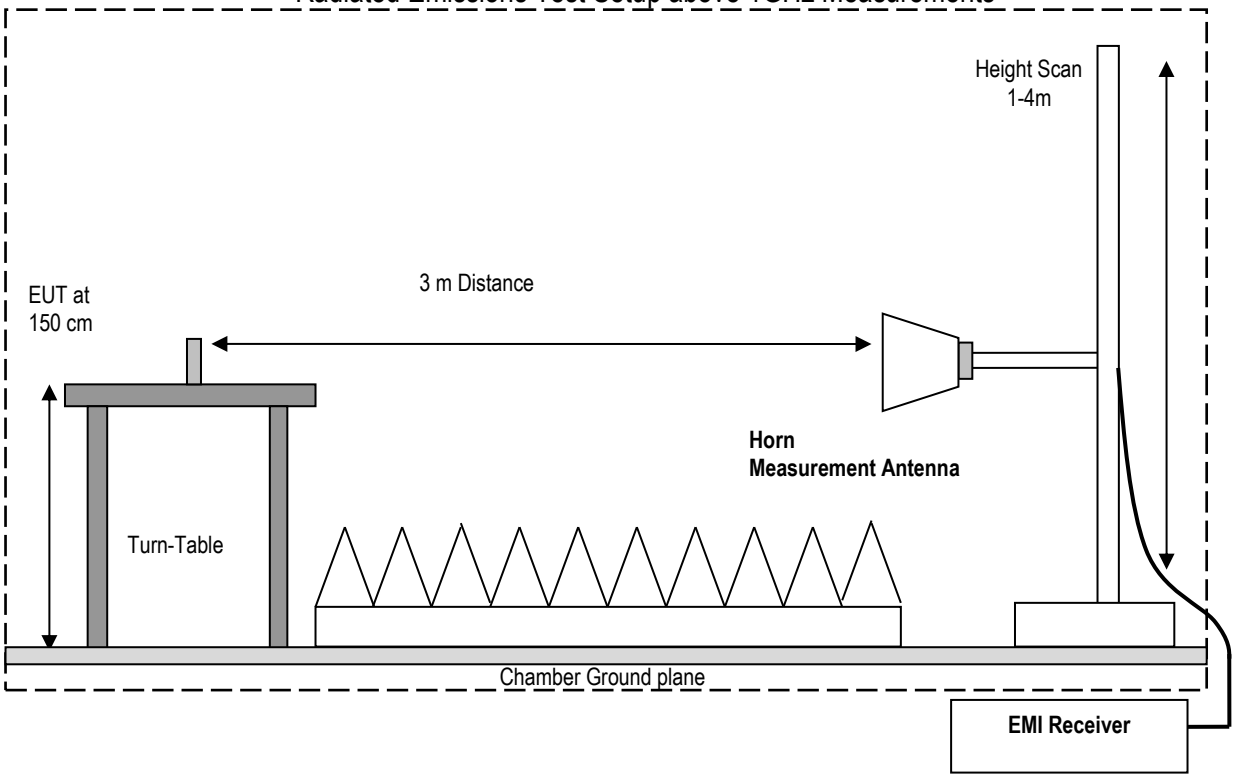
Radiated Emissions Test Setup below 30MHz Measurements



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 RF Conducted Measurement Procedure

Testing procedures are based on 558074 D01 DTS Meas Guidance v05r02 – "GUIDANCE FOR PERFORMING COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEMS (DTS) OPERATING UNDER SECTION 15.247" - April 2, 2019, by the Federal Communications Commission, Office of Engineering and Technology, Laboratory Division.

- 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.
- Calculate the conducted power by taking into account attenuation of the cable and the attenuator

8 Test Result Data

8.1 Maximum Peak Conducted Output Power

8.1.1 Measurement according to FCC 558074 D01 DTS Meas Guidance v05r02

Spectrum Analyzer settings:

- RBW ≥ DTS bandwidth
- VBW ≥ 3 x RBW
- Span ≥ 3 x RBW
- Sweep = Auto couple
- Detector function = Peak
- Trace = Max hold
- Use peak marker function to determine the peak amplitude level

8.1.2 Limits:

Maximum Peak Output Power:

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

8.1.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22° C	2	GFSK continuous fixed channel	12 VDC	1.88 dBi

8.1.4 Measurement result:

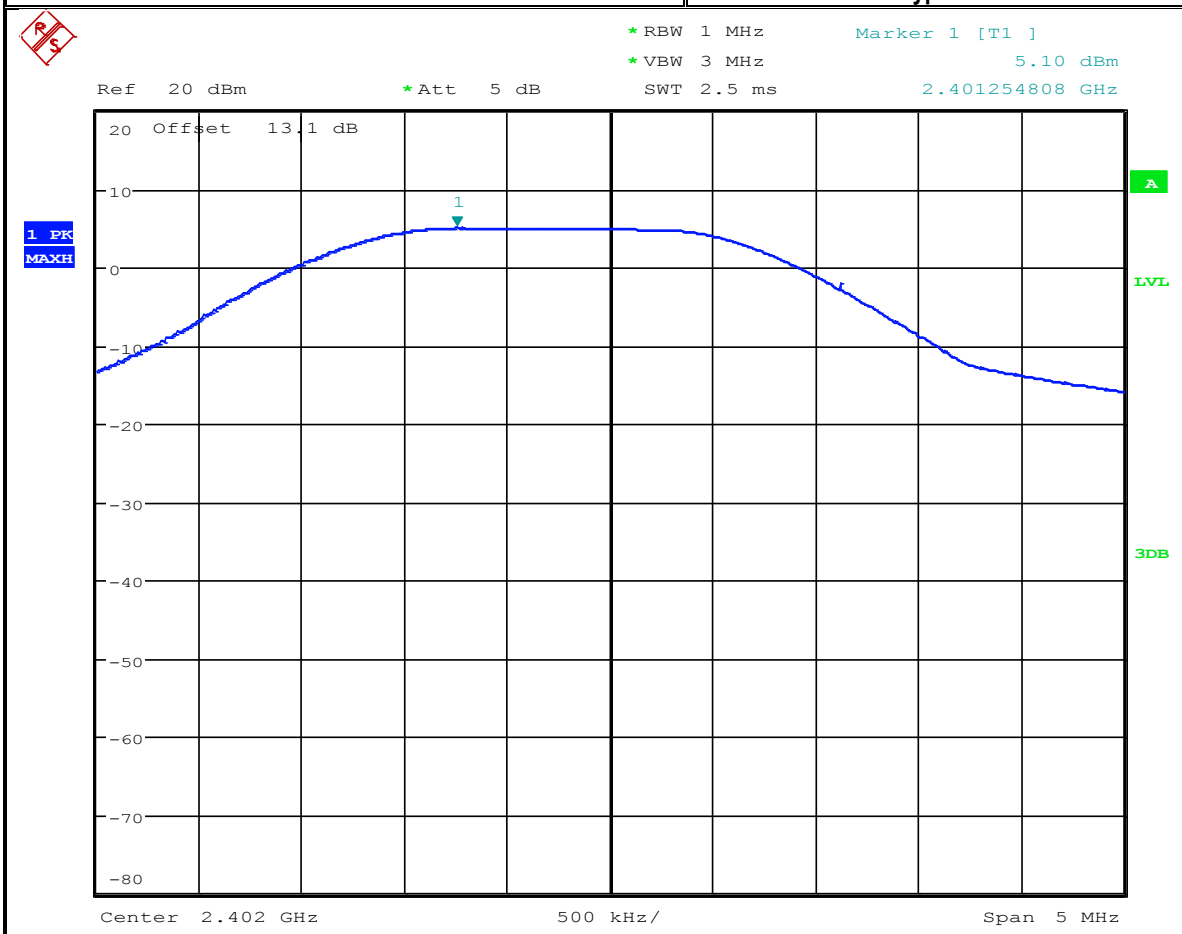
Attenuation of cable and attenuator (already taken into account): 13.1 dB

Plot #	Frequency (MHz)	Maximum Peak Conducted Output Power (dBm)	EIRP (dBm)	Limit (dBm)	Result
1	2402	5.1	6.98	30 (Pk) / 36 (EIRP)	Pass
2	2442	5.06	6.94	30 (Pk) / 36 (EIRP)	Pass
3	2480	4.92	6.80	30 (Pk) / 36 (EIRP)	Pass

8.1.5 Measurement Plots:

Plot #1

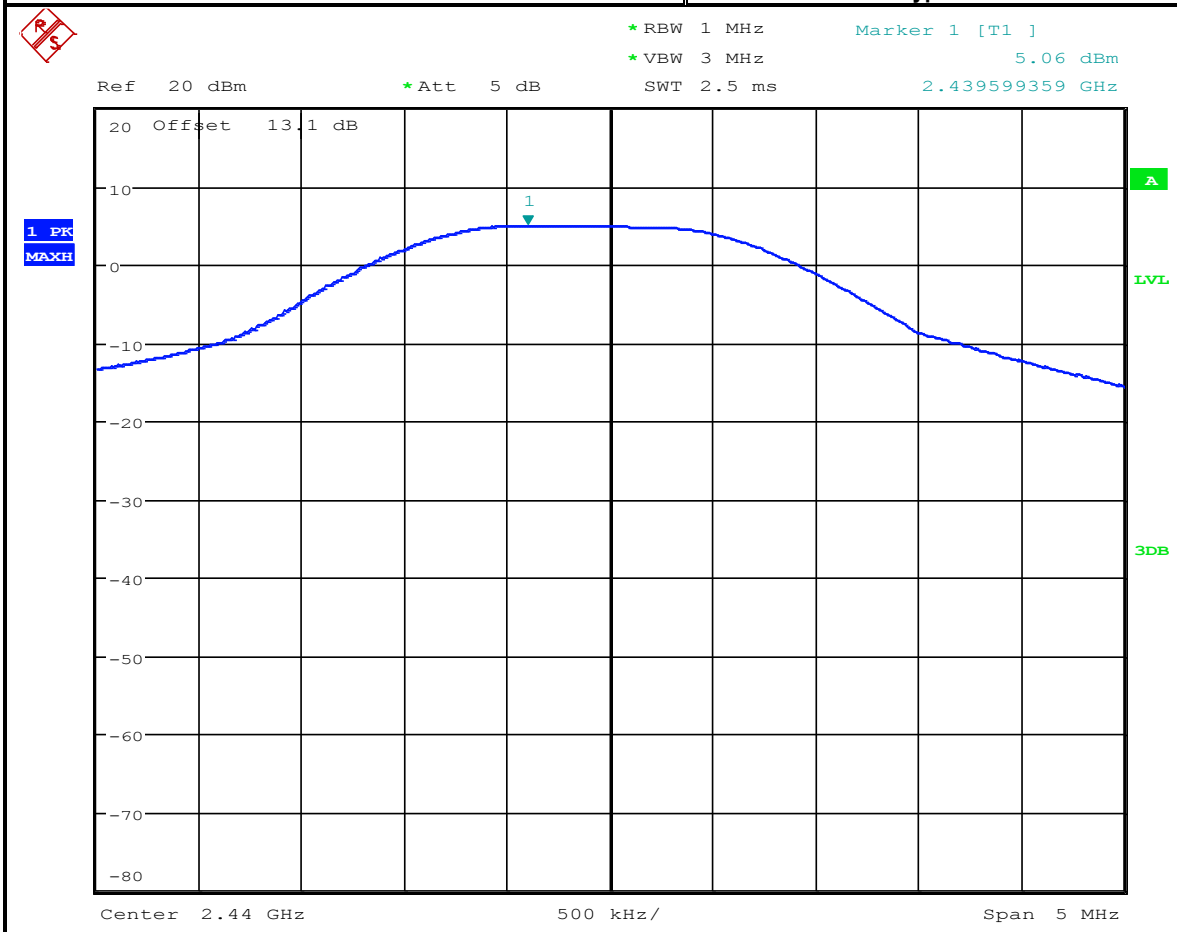
Low channel	Modulation/Packet Type: GFSK



Date: 12.JAN.2021 16:20:15

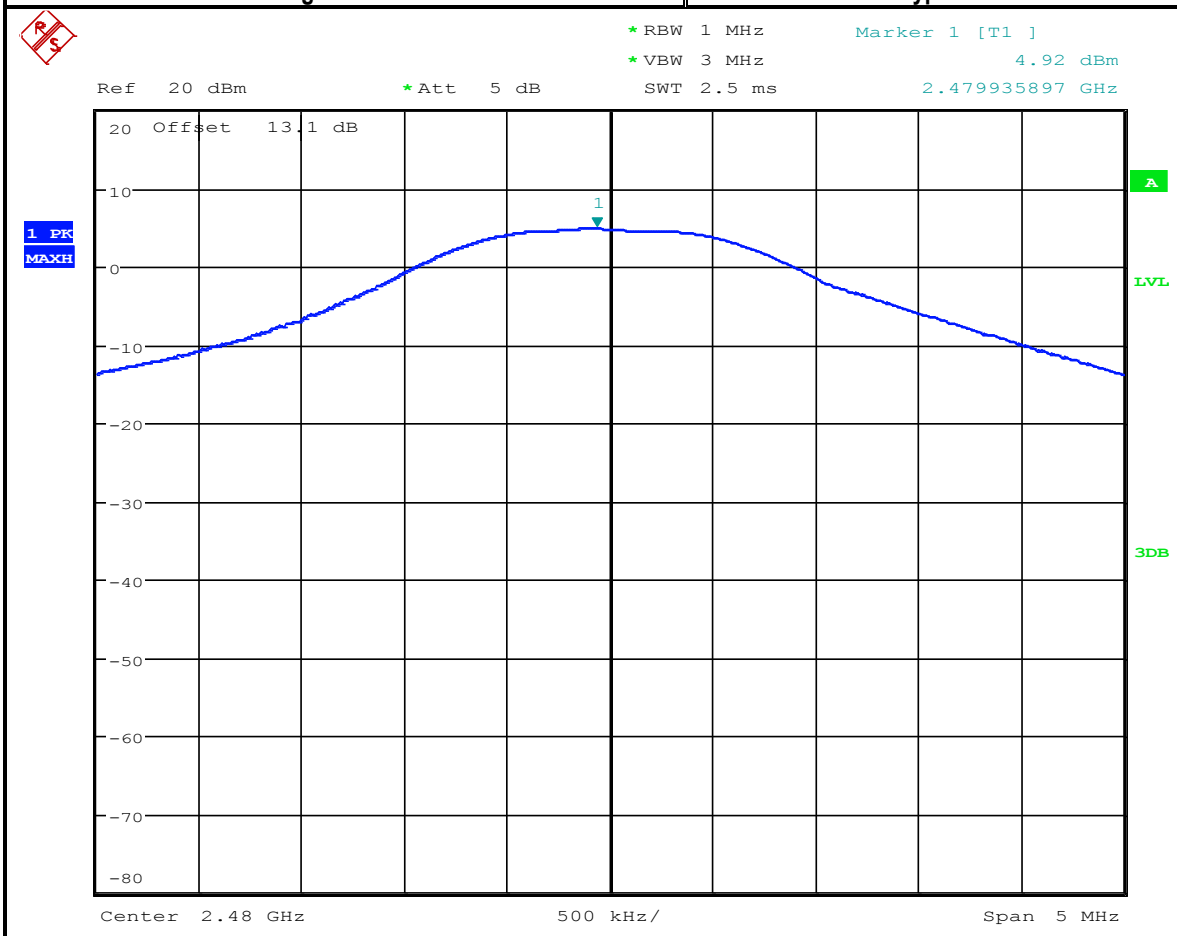
Plot #2

Mid channel | **Modulation/Packet Type: GFSK**



Plot #3

High channel | **Modulation/Packet Type: GFSK**



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8.2 Power Spectral Density

8.2.1 Measurement according to FCC 558074 D01 DTS Meas Guidance v05r02

Spectrum Analyzer settings for Peak PSD method:

- Set analyzer center frequency to DTS channel center frequency
- Set the span to 1.5 x 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

8.2.2 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.

8.2.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
23° C	2	GFSK continuous fixed channel	12 VDC	1.88 dBi

8.2.4 Measurement result:

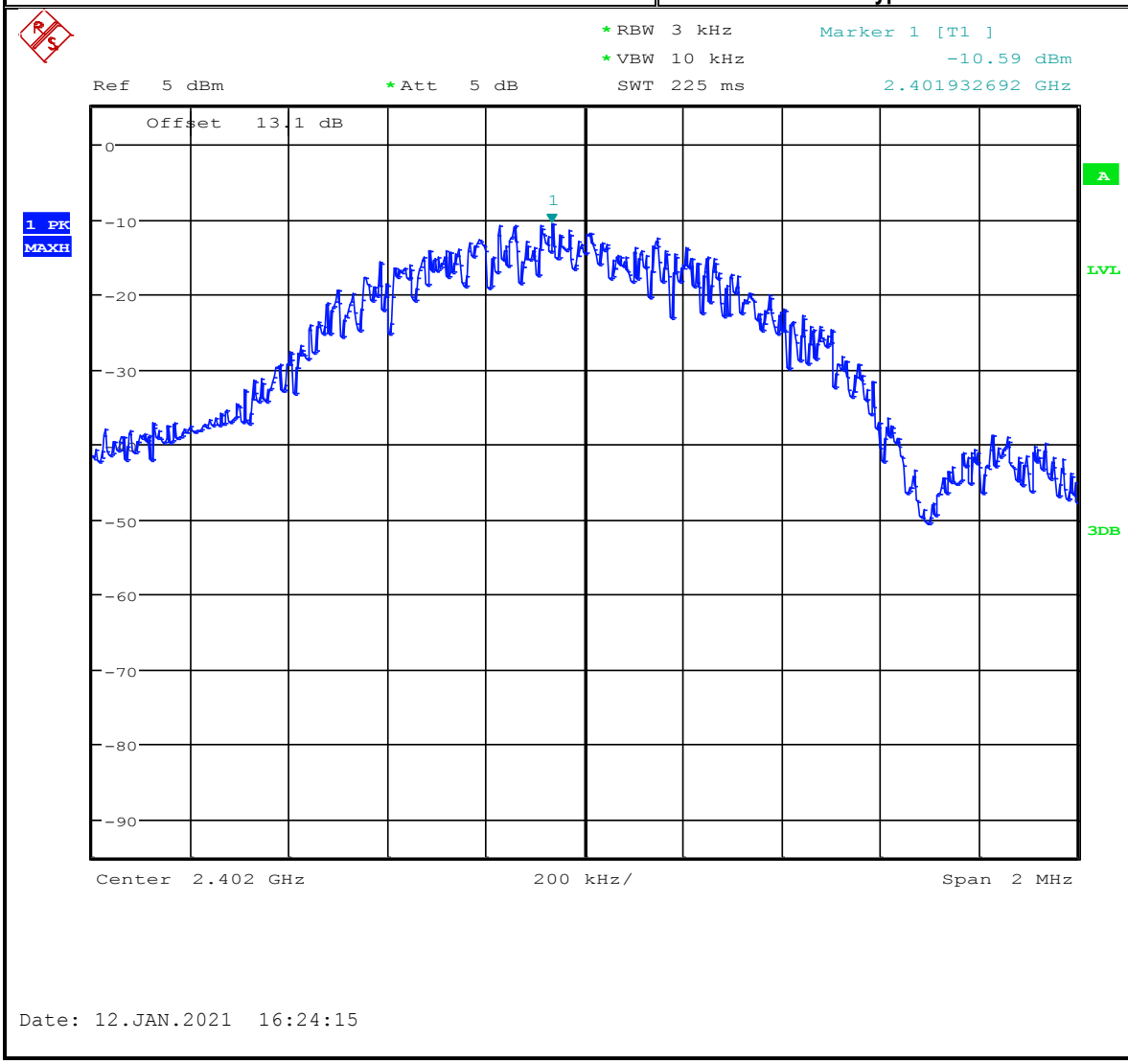
Attenuation of cable and attenuator (already taken into account): 13.1 dB

Plot #	Frequency (MHz)	Maximum Power Spectral Density (dBm/3 kHz)	Limit (dBm / 3 kHz)	Result
4	2402	-10.59	8	Pass
5	2442	-10.96	8	Pass
6	2480	-10.10	8	Pass

8.2.5 Measurement Plots:

Plot #4

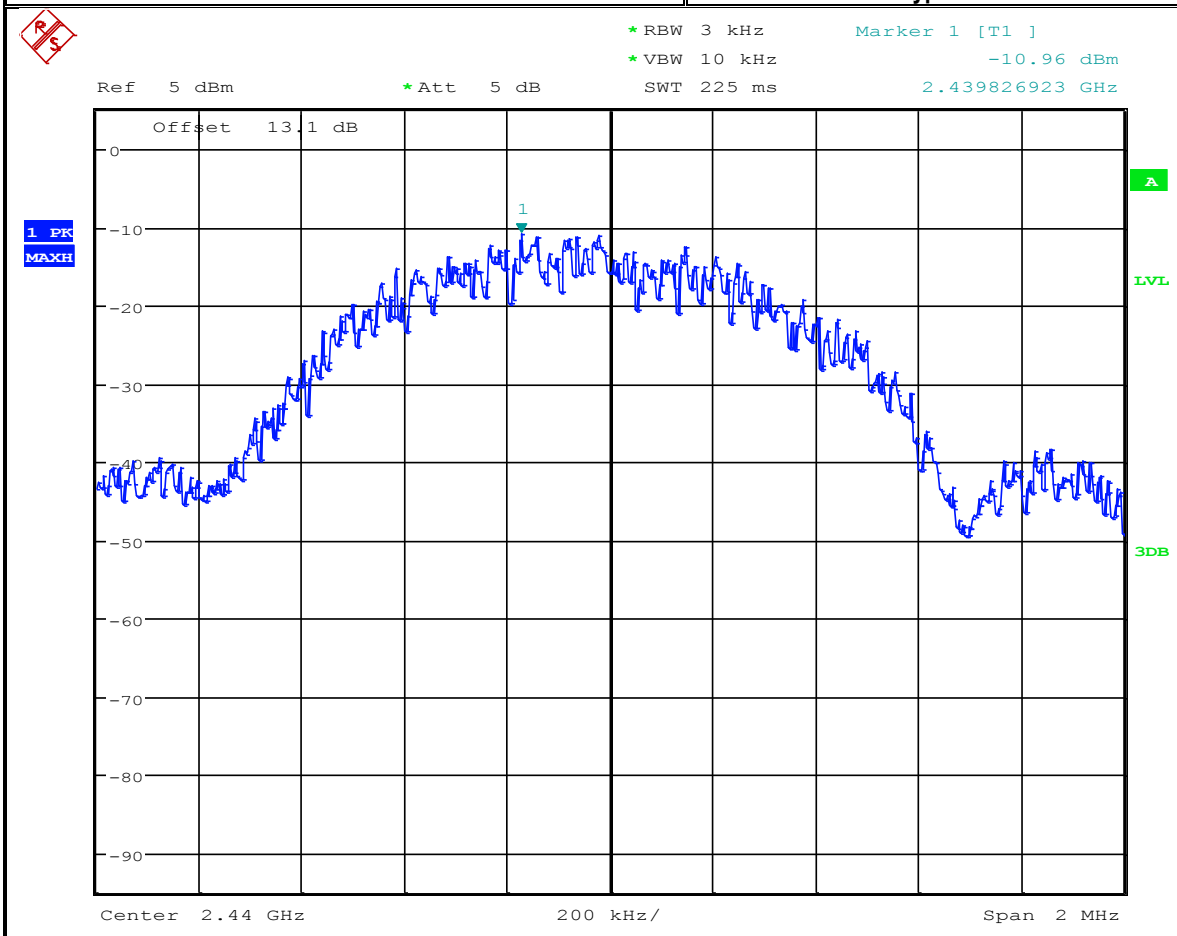
Low channel	Modulation/Packet Type: GFSK



Date: 12.JAN.2021 16:24:15

Plot #5

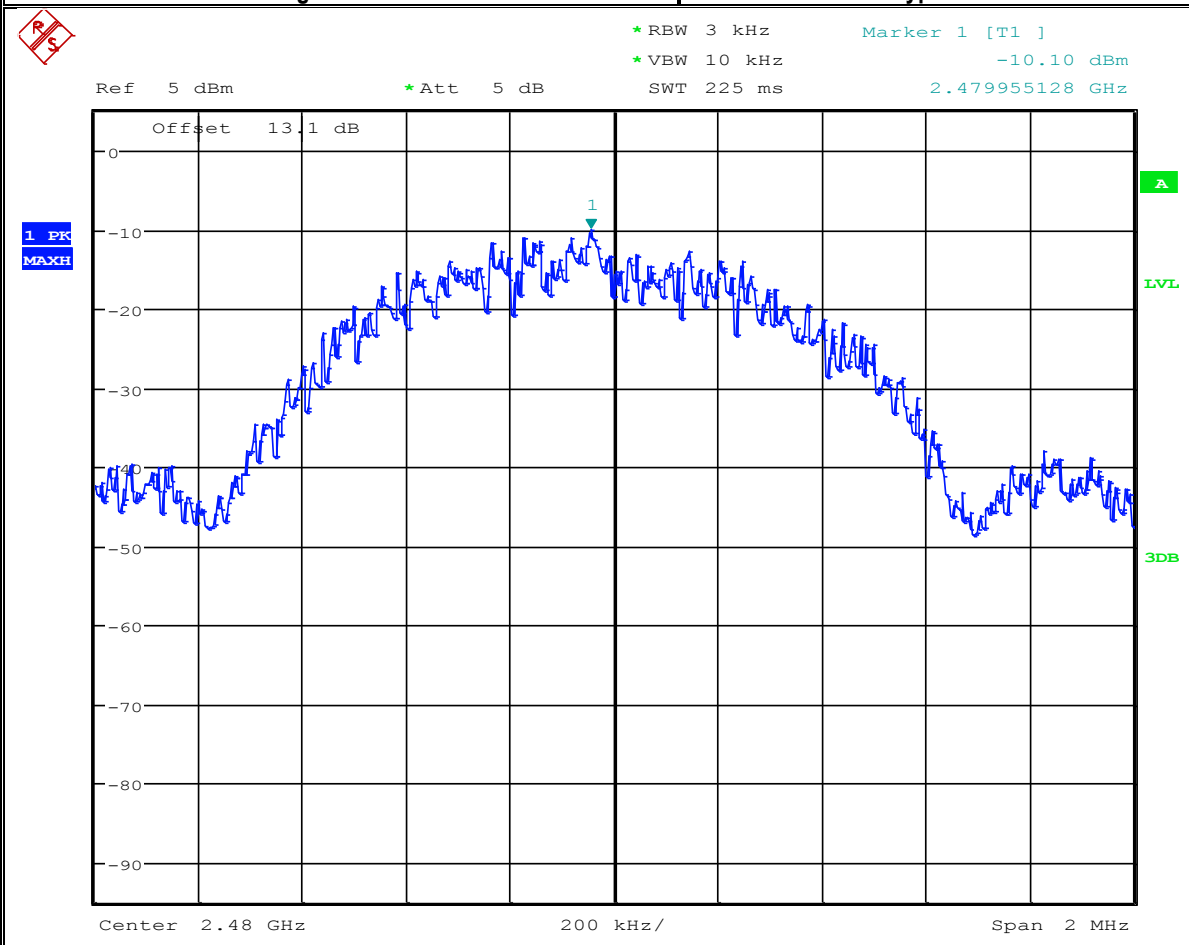
Mid channel	Modulation/Packet Type: GFSK



Date: 12.JAN.2021 16:23:22

Plot #6

High channel	Modulation/Packet Type: GFSK



Date: 12.JAN.2021 16:22:26

8.3 Duty cycle

8.3.1 Measurement according to FCC 558074 D01 DTS Meas Guidance v05r02

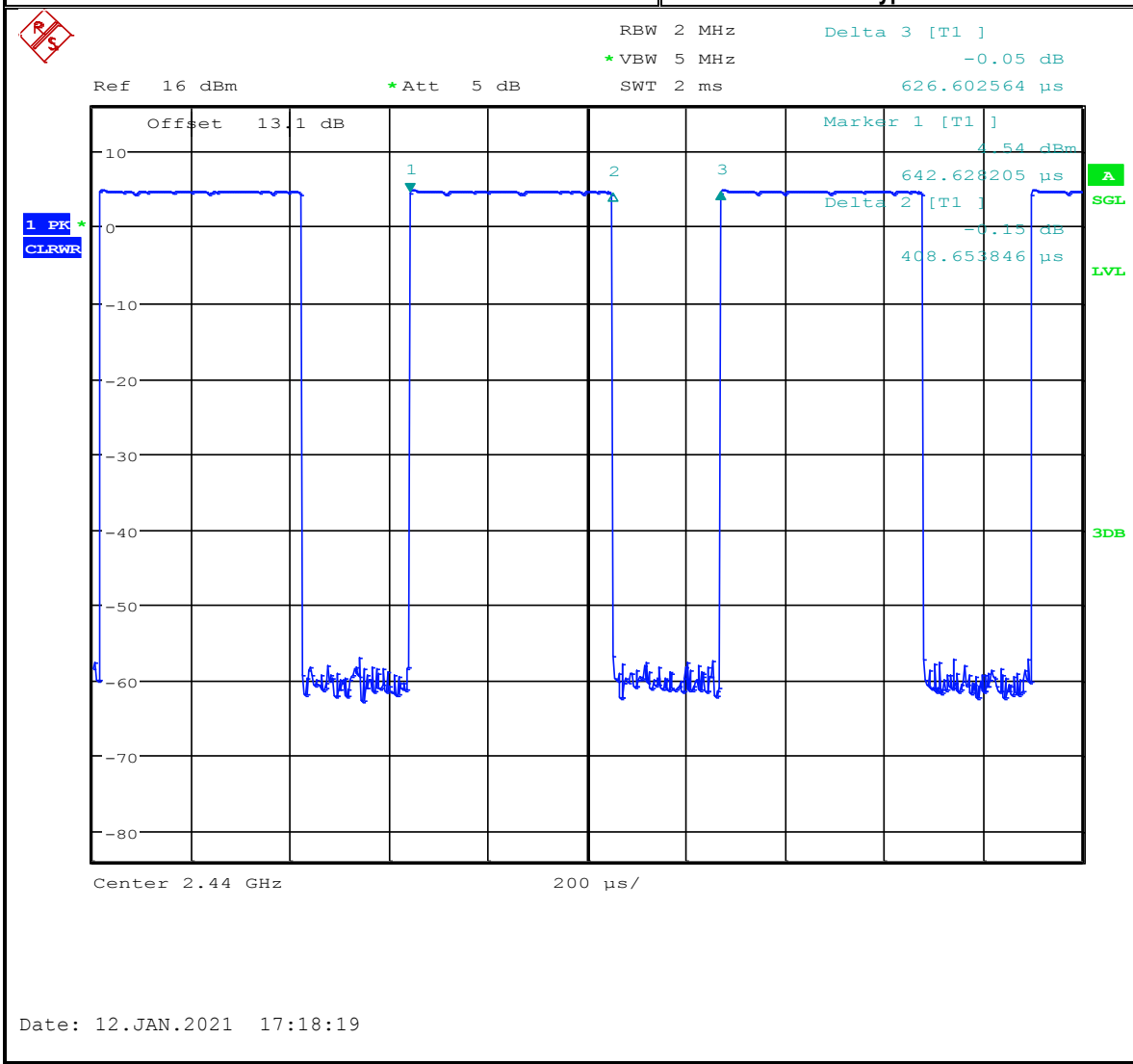
Spectrum Analyzer settings:

- Set the center frequency and of the instrument to the center frequency of the transmission
- Zero span
- Set RBW >=OBW if possible; otherwise, set RBW to the largest available value
- Detector = Peak or average

8.3.2 Measurement result

Duty cycle measurement

Mid channel / 2440 MHz	Modulation/Packet Type: GFSK



Duty cycle =63.59%
Duty cycle correction factor =10*log(1/0.6359) = 1.97 dB

8.4 Band Edge Compliance

8.4.1 Measurement according to FCC 558074 D01 DTS Meas Guidance v05r02

Spectrum Analyzer settings for 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

8.4.2 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

8.4.3 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:

(b)

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			

8.4.4 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22° C	2	GFSK continuous fixed channel	12 VDC	1.88 dBi

8.4.5 Measurement result:

Plot #	EUT operating mode	Band Edge	Band Edge Delta (dBc)	Limit (dBc)	Result
7, 8	GFSK continuous fixed channel	Lower, Non-restricted	-26.24	-20	Pass

Plot #	EUT operating mode	Band Edge	Measured Peak Value (dBm)	Corrected by duty cycle	Corrected by Antenna Gain (dBm)	Limit (dBm)	Result
9	GFSK continuous fixed channel	Lower Restricted peak	-32.34	N/A	-30.34	-21.23 Peak	Pass
10	GFSK continuous fixed channel	Lower Restricted Average	-60.79	-58.82	-56.82	-41.23 AVG	Pass
11	GFSK continuous fixed channel	Upper Restricted peak	-23.57	N/A	-21.57	-21.23 Peak	Pass
12	GFSK continuous fixed channel	Upper Restricted Average	-57.79	-55.82	-53.82	-41.23 AVG	Pass

Note: According to ANSI C63.10 §11.12.2.6, if Antenna Gain is less than 2 dBi, then 2 dBi should be used to determine the EIRP.

8.4.6 Measurement Plots:

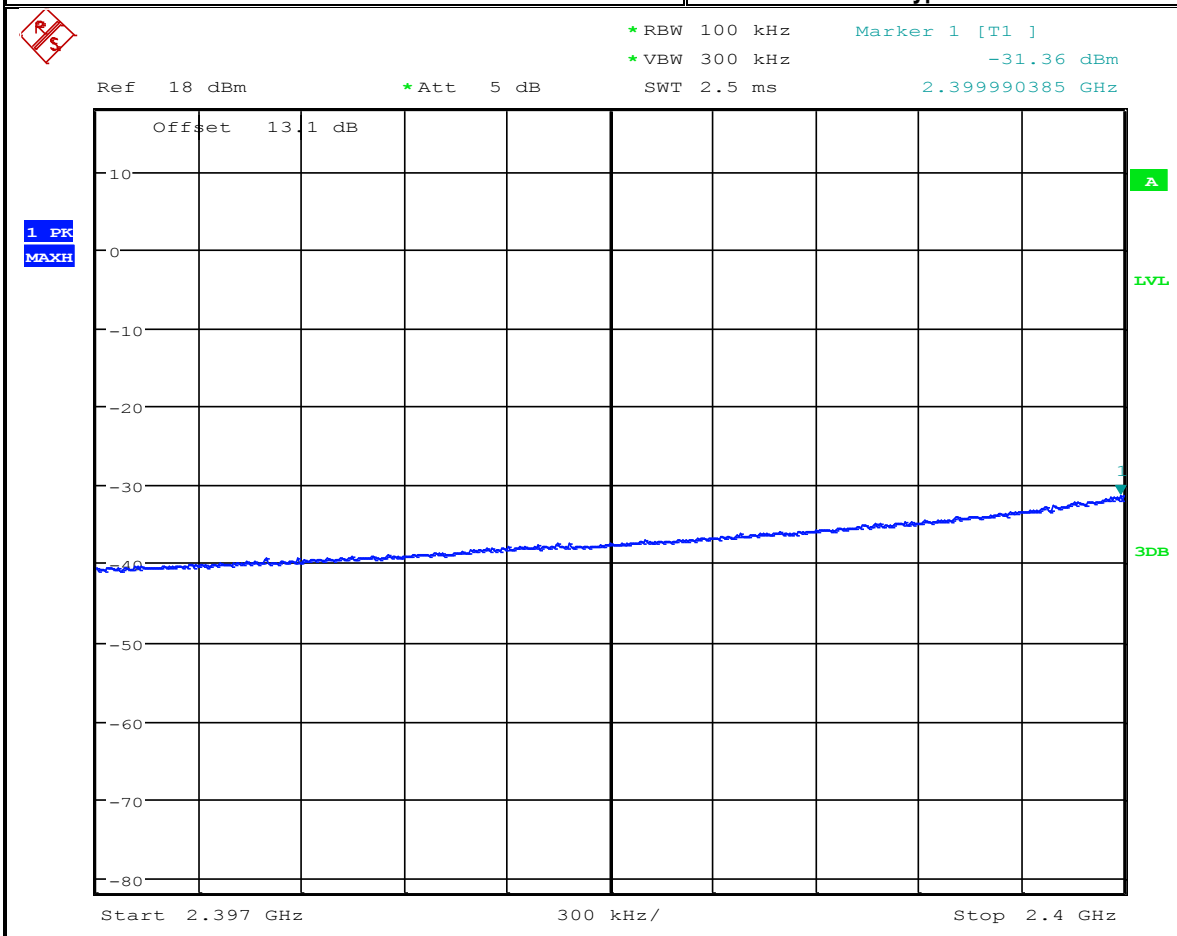
Plot #7

Low channel / 2402 MHz	Modulation/Packet Type: GFSK

Date: 12.JAN.2021 16:59:29

Plot #8

Low channel / 2402 MHz	Modulation/Packet Type: GFSK



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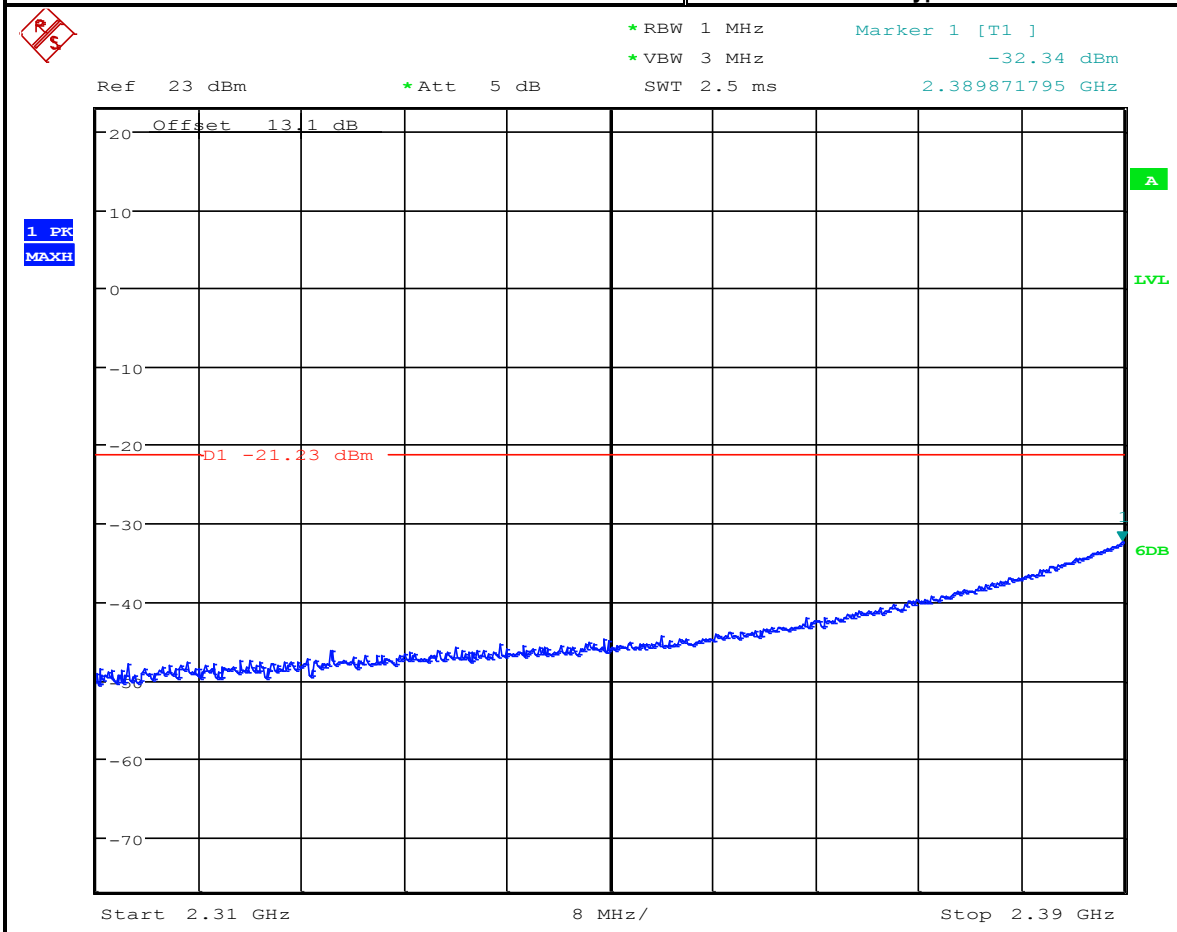
Plot #9

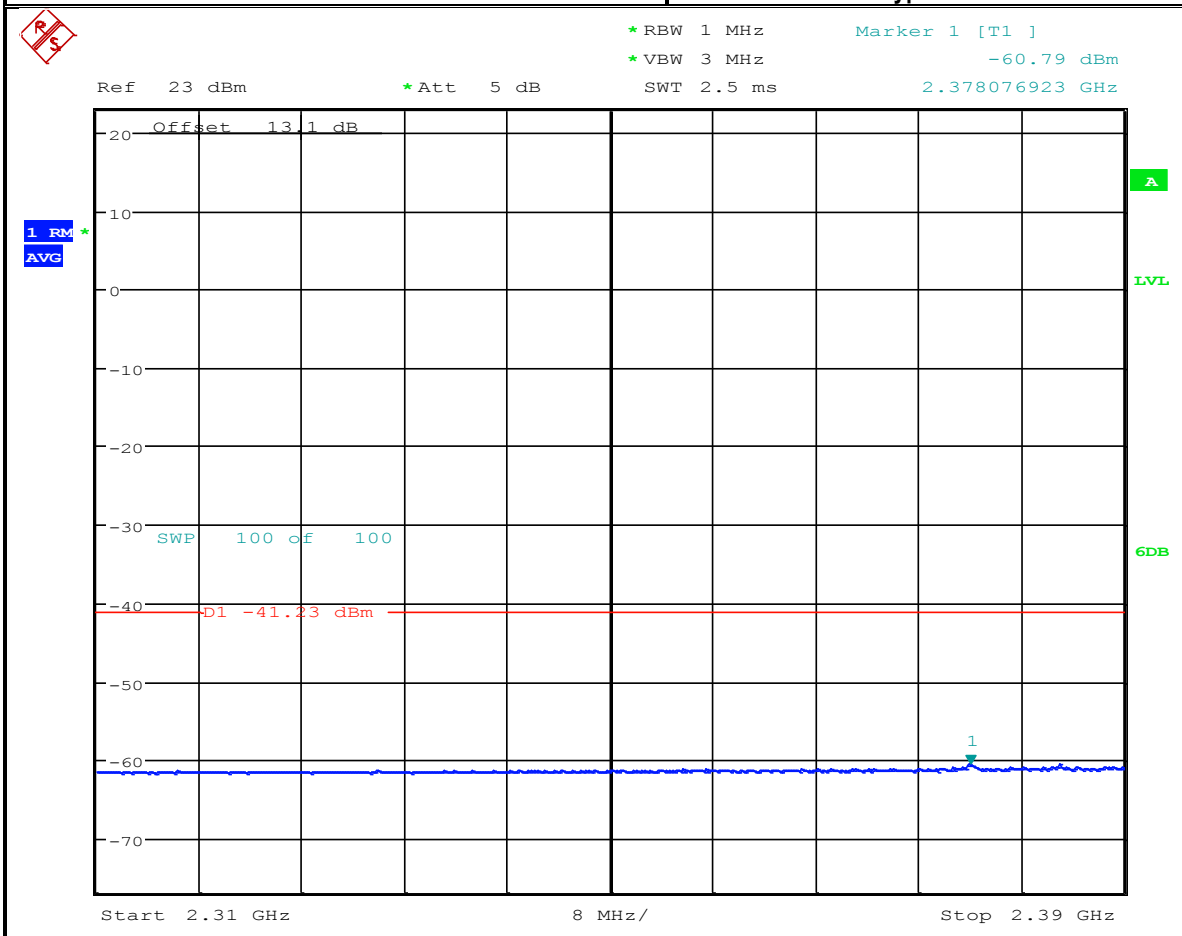
Low channel 2402 MHz | **Modulation/Packet Type: GFSK**



Date: 13.JAN.2021 12:20:42

Plot #10

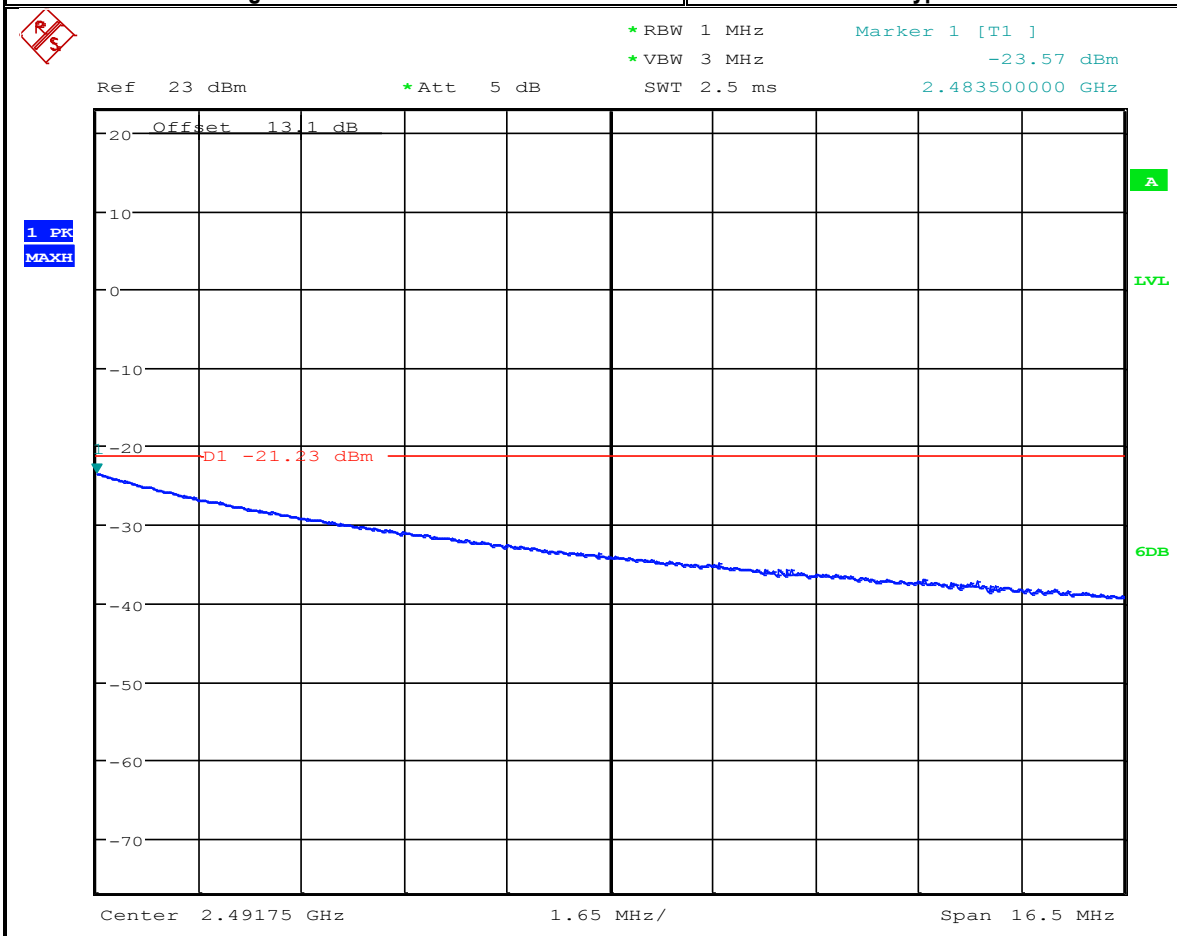
Low channel 2402 MHz | **Modulation/Packet Type: GFSK**



Date: 13.JAN.2021 12:22:01

Plot #11

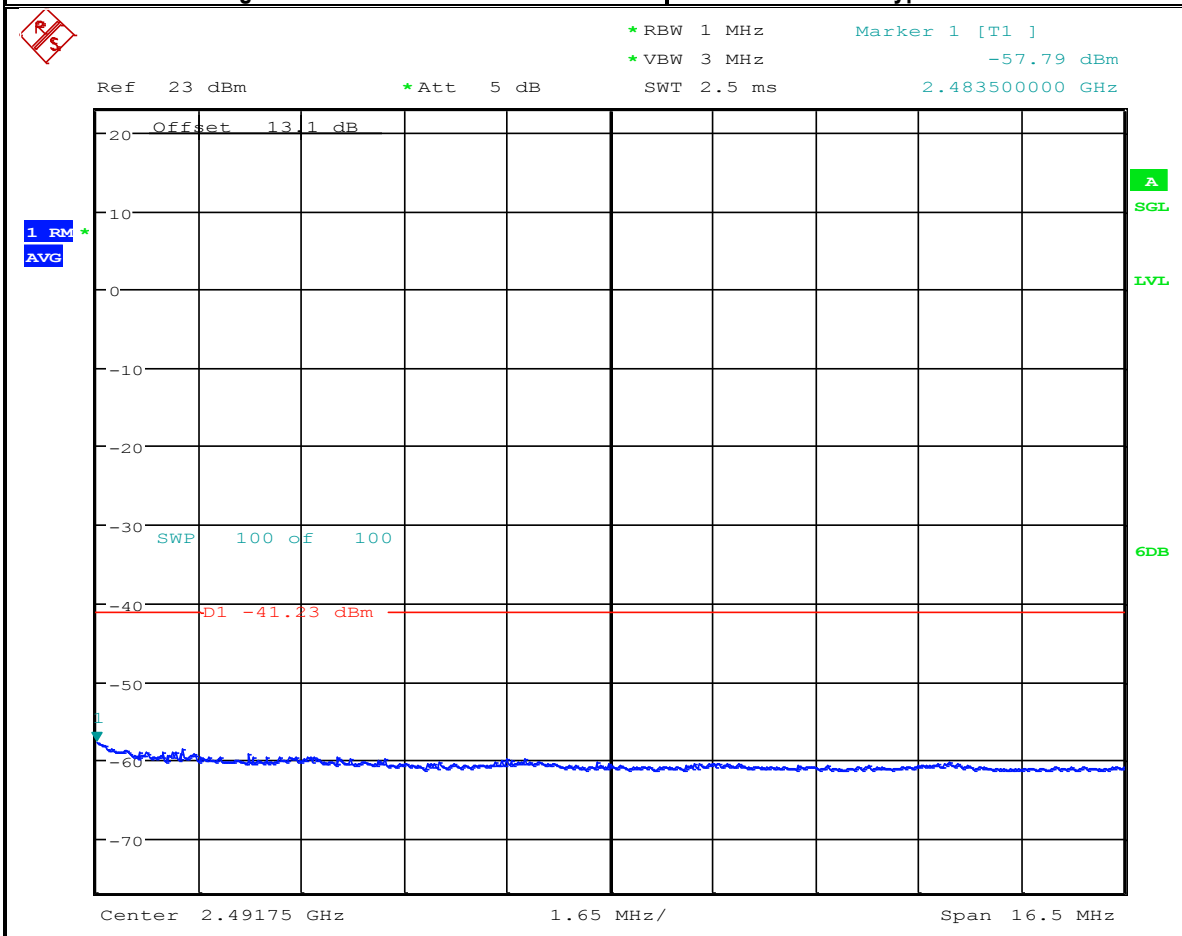
High channel 2480 MHz	Modulation/Packet Type: GFSK



Date: 12.JAN.2021 18:23:19

Plot #12

High channel 2480 MHz | **Modulation/Packet Type: GFSK**



Date: 15.JAN.2021 19:34:46

8.5 Emission Bandwidth 6 dB and 99% Occupied Bandwidth

8.5.1 Measurement according to FCC 558074 D01 DTS Meas Guidance v05r02

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.

8.5.2 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.

8.5.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22° C	2	GFSK continuous fixed channel	12 VDC

8.5.4 Measurement result:

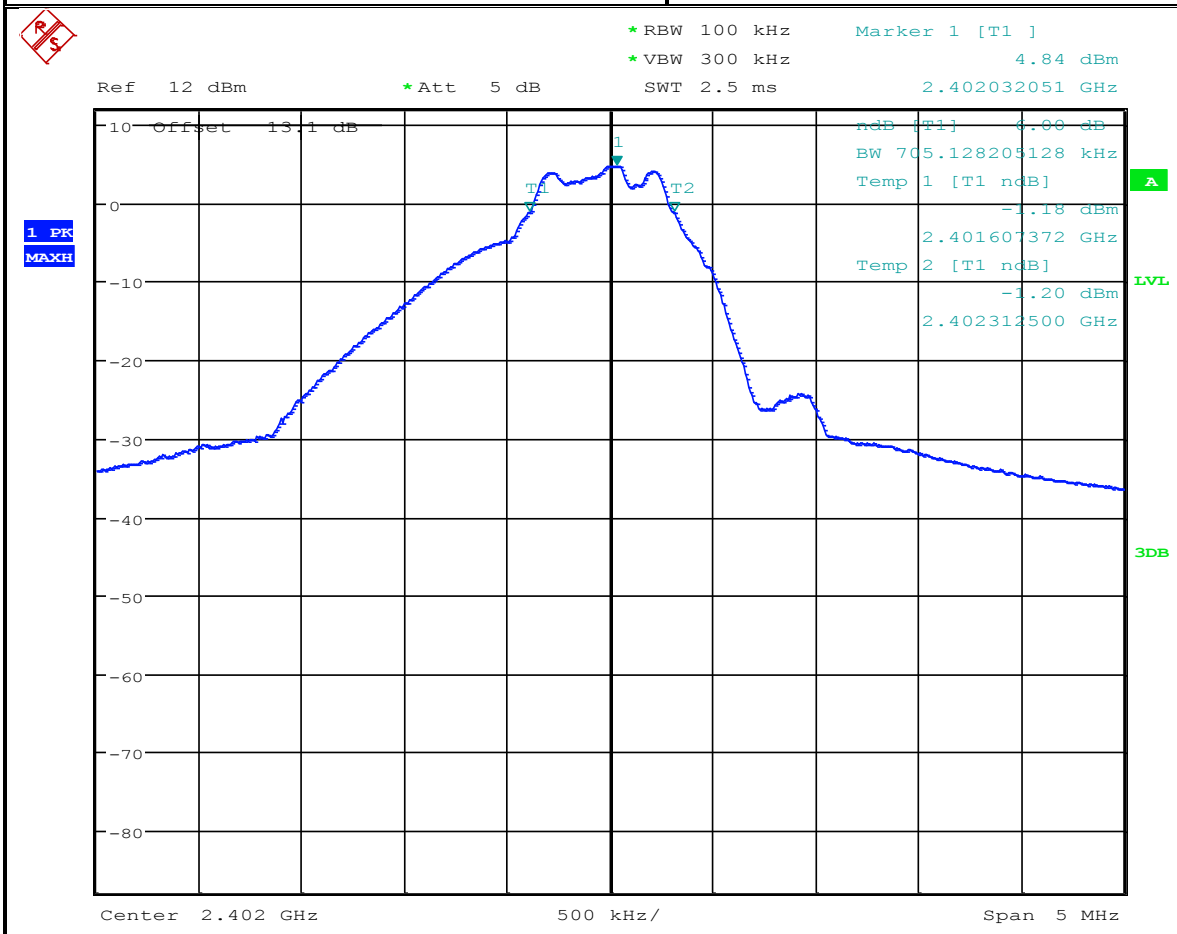
Plot #	Frequency (MHz)	6 dB Emissions Bandwidth (MHz)	Limit (MHz)	Result
11	2402	0.705	> 0.5	Pass
12	2440	0.713	> 0.5	Pass
13	2480	0.713	> 0.5	Pass

Plot #	Frequency (MHz)	99% Occupied Bandwidth (MHz)	Limit (MHz)	Result
14	2402	1.122	> 0.5	Pass
15	2440	1.122	> 0.5	Pass
16	2480	1.122	> 0.5	Pass

8.5.5 Measurement Plots:

Plot #13

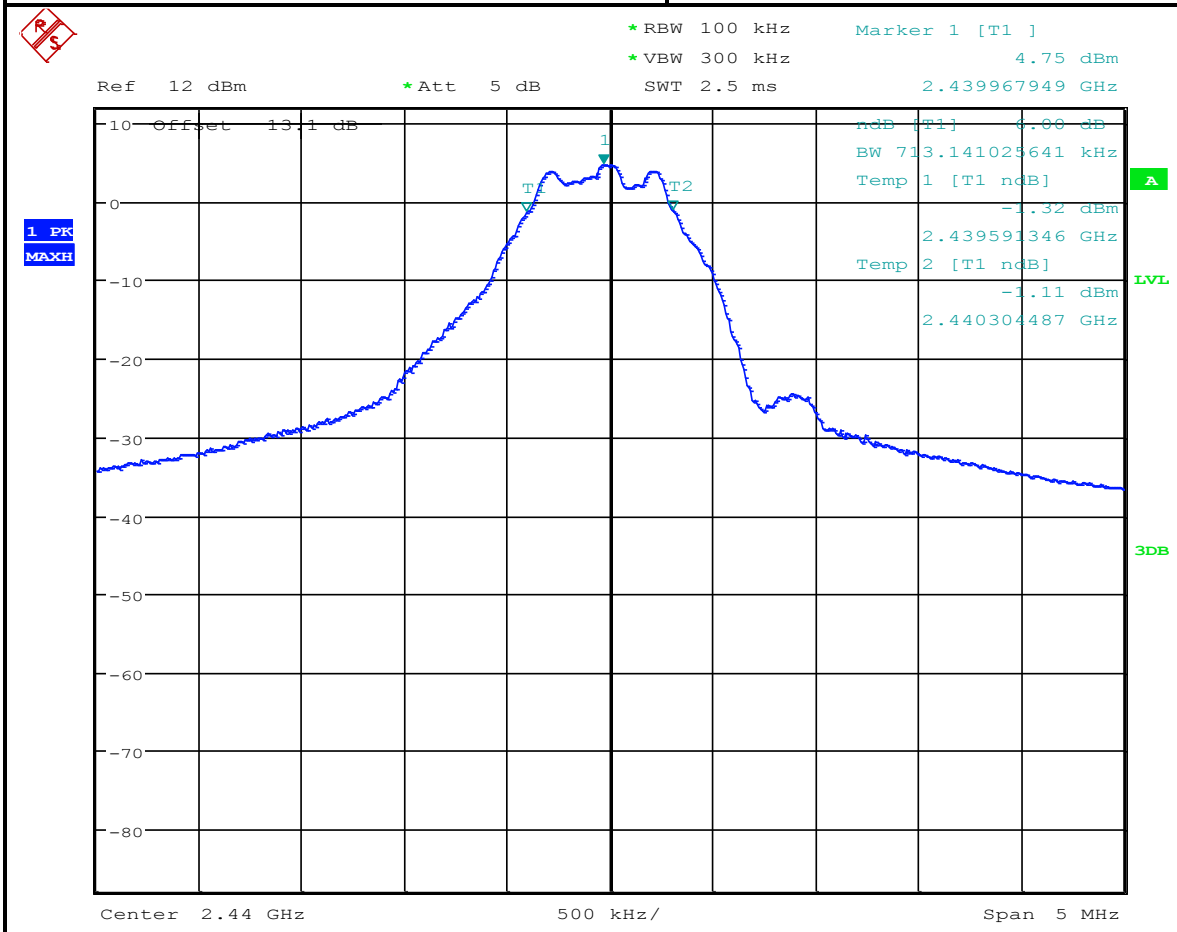
Low channel	Mode: GFSK



Date: 12.JAN.2021 16:37:20

Plot #14

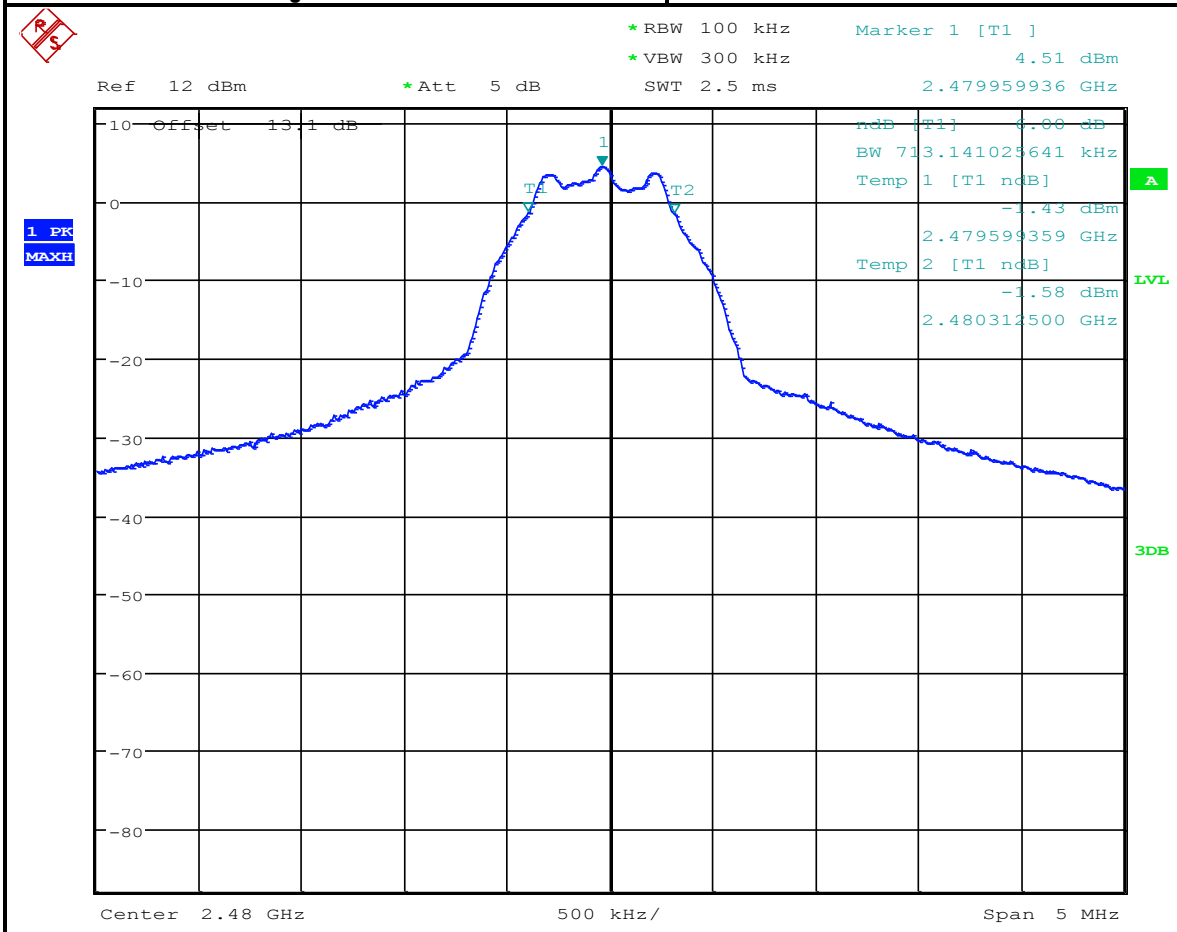
Mid channel | **Mode: GFSK**



Date: 12.JAN.2021 16:29:25

Plot #15

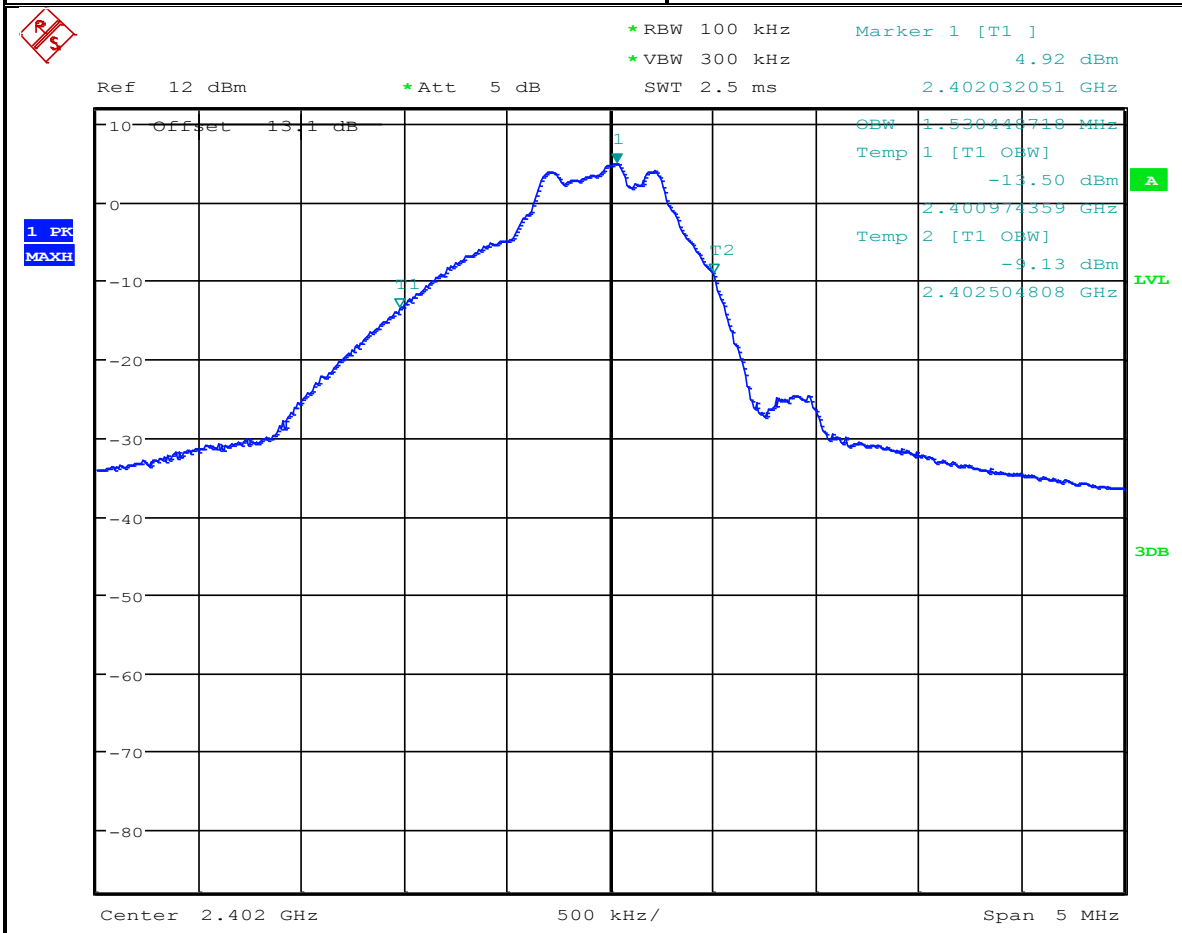
High channel | **Mode: GFSK**



Date: 12.JAN.2021 16:28:04

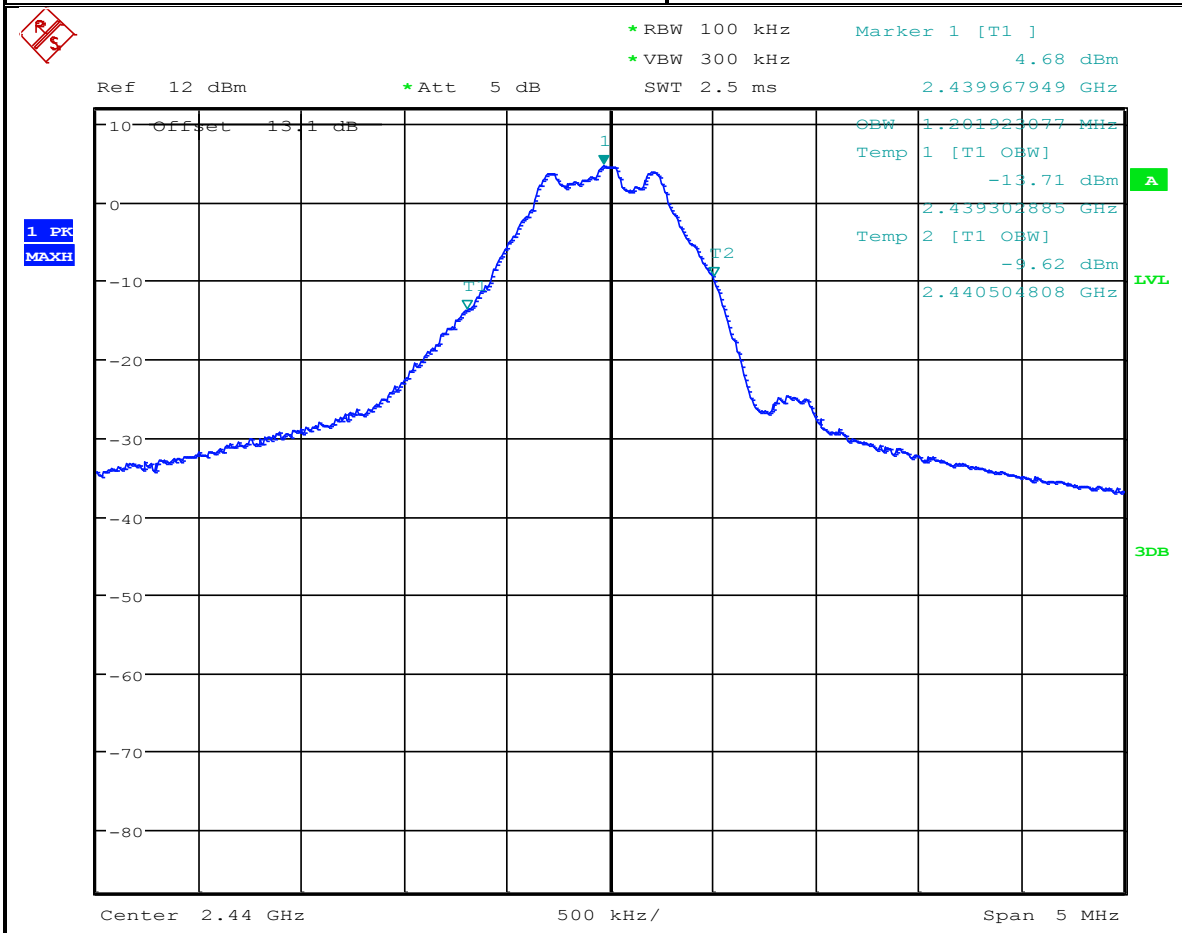
Plot #16

Low channel	Mode: GFSK



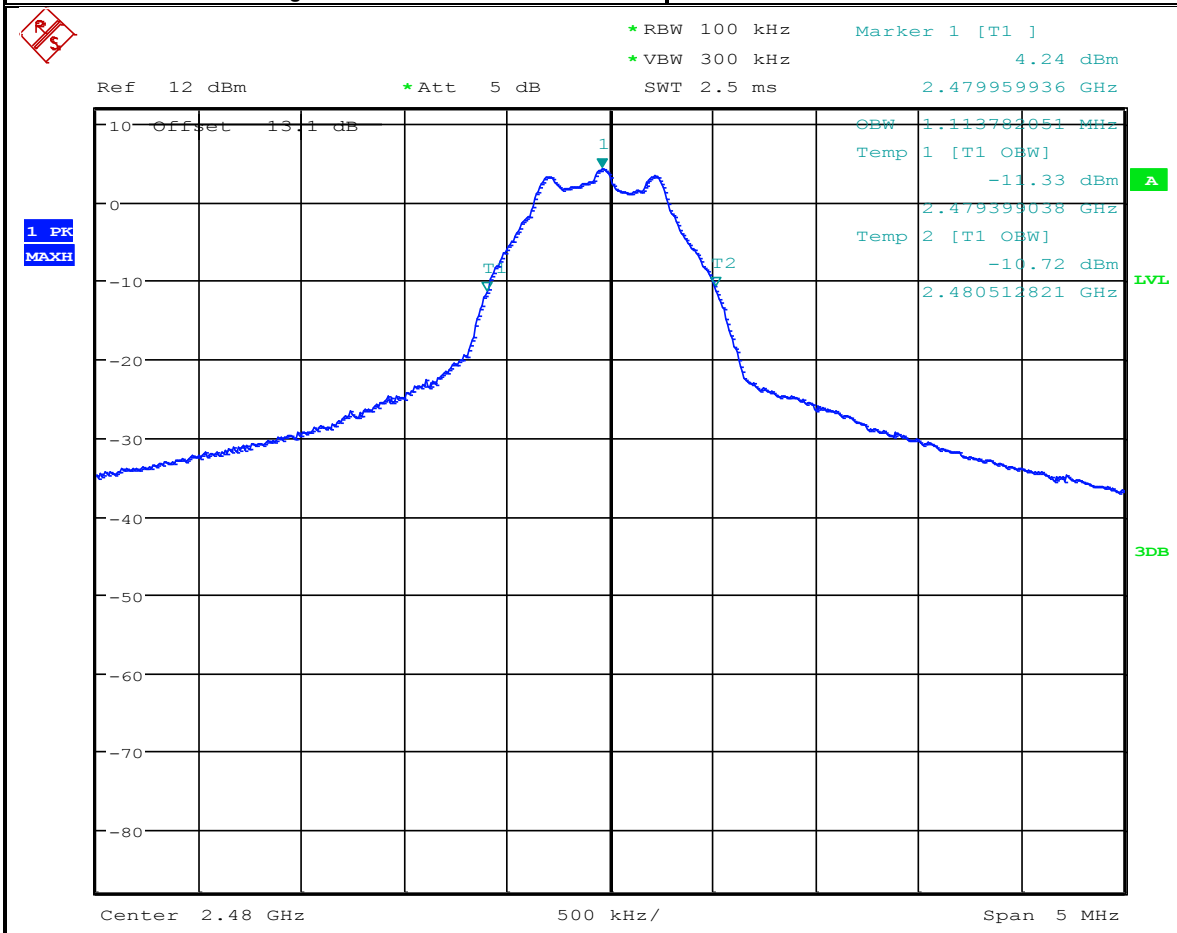
Plot #17

Mid channel	Mode: GFSK



Plot #18

High channel	Mode: GFSK



Date: 12.JAN.2021 16:54:42

8.6 Transmitter Frequency Stability

8.6.1 Measurement according to FCC 558074 D01 DTS Meas Guidance v05r02

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.

8.6.2 Limits:

FCC §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. In the case of intentional radiators operating under the provisions of subpart E, the emission bandwidth may span across multiple contiguous frequency bands identified in that subpart. 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 in 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.

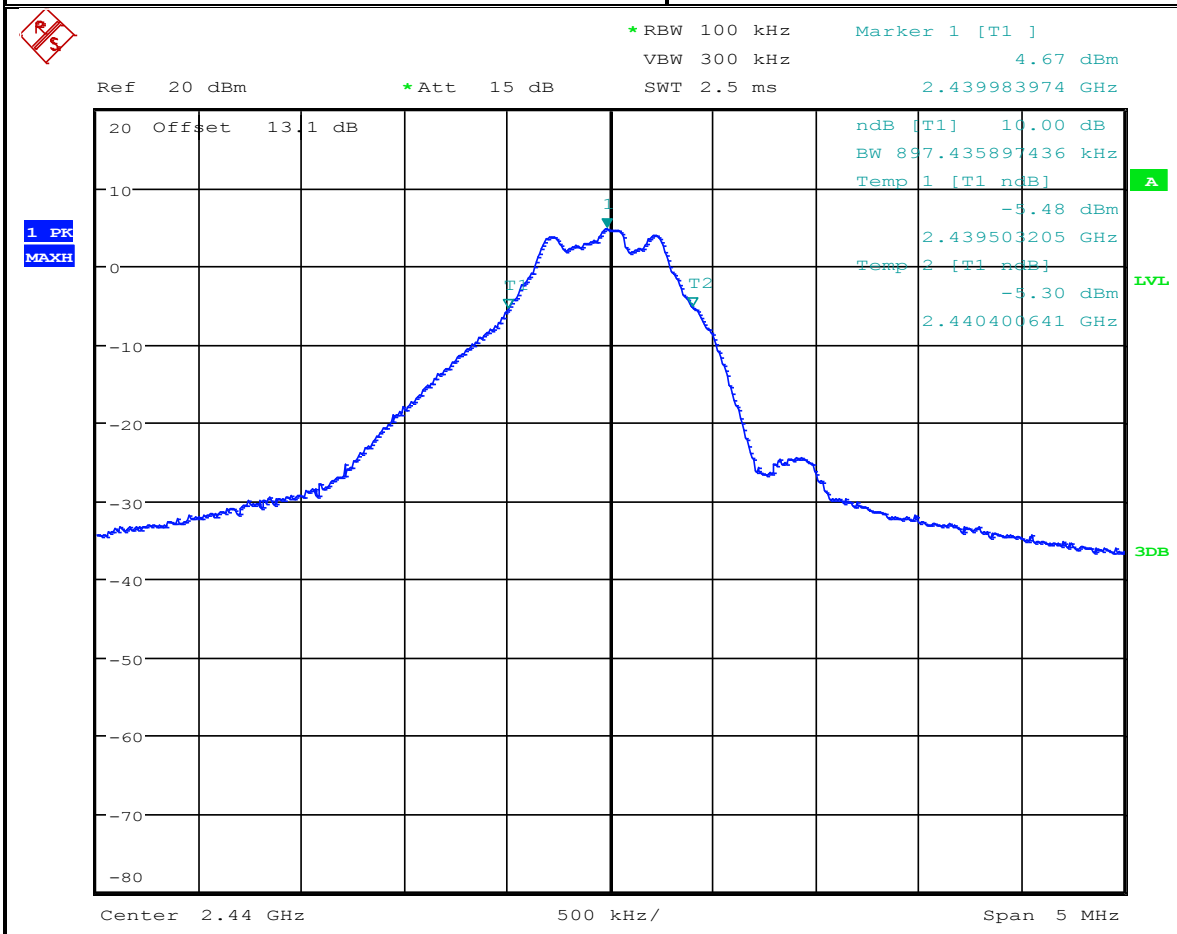
RSS Gen 6.11
When the measurement method of transmitter frequency stability is not stated in the applicable RSS or reference standards, the following conditions apply:
The reference temperature for radio transmitters is +20°C (+68°F).
A hand-held device that is only capable of operating using internal batteries shall be tested at the battery's nominal voltage, and again at the battery's operating end-point voltage, which shall be specified by the equipment manufacturer. For this test, either a battery or an external power supply can be used.
The operating carrier frequency shall be set up in accordance with the manufacturer's published operation and instruction manual prior to the commencement of these tests. No adjustment of any frequency-determining circuit element shall be made subsequent to this initial set-up.
For licence-exempt devices, the following conditions apply:
At the temperatures of -20°C (-4°F), +20°C (+68°F) and +50°C (+122°F), and at the manufacturer's rated supply voltage.
At the temperature of +20°C (+68°F) and at ±15% of the manufacturer's rated supply voltage.

Plot	Temperature(° C)	Calculated Center Frequency(MHz)	Variation	PPM
19	-20	2.43995	-0.000005	2.049222
20	20	2.43996	0	0
21	50	2.43995	-0.000010	4.098453

Plot	Voltage(V)	Calculated Center Frequency(MHz)	Variation	PPM
22	10.2	2.43996	0	0
20	12	2.43996	0	0
23	13.8	2.43996	0	0

Plot #19

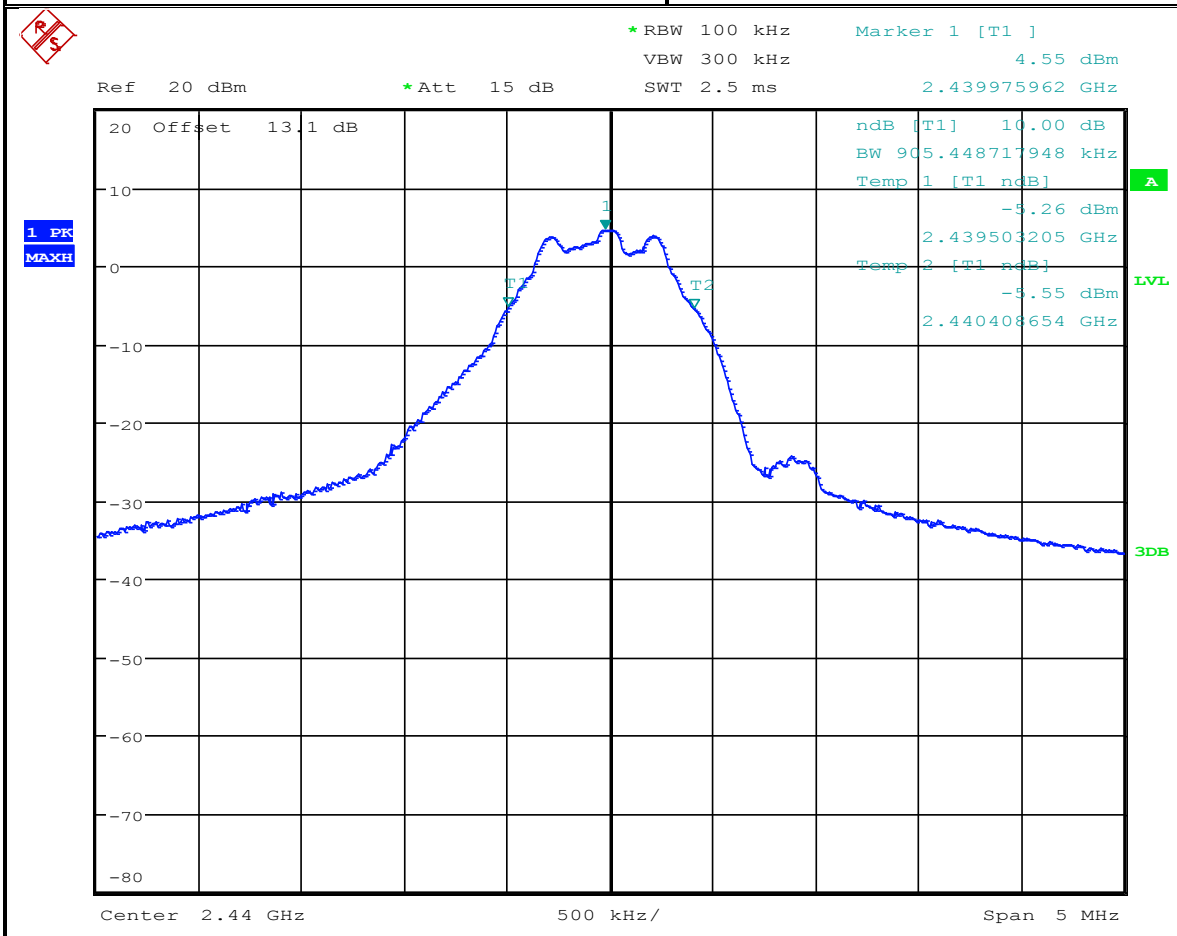
Mid channel	Mode: GFSK



Date: 4.FEB.2021 19:09:54

Plot #20

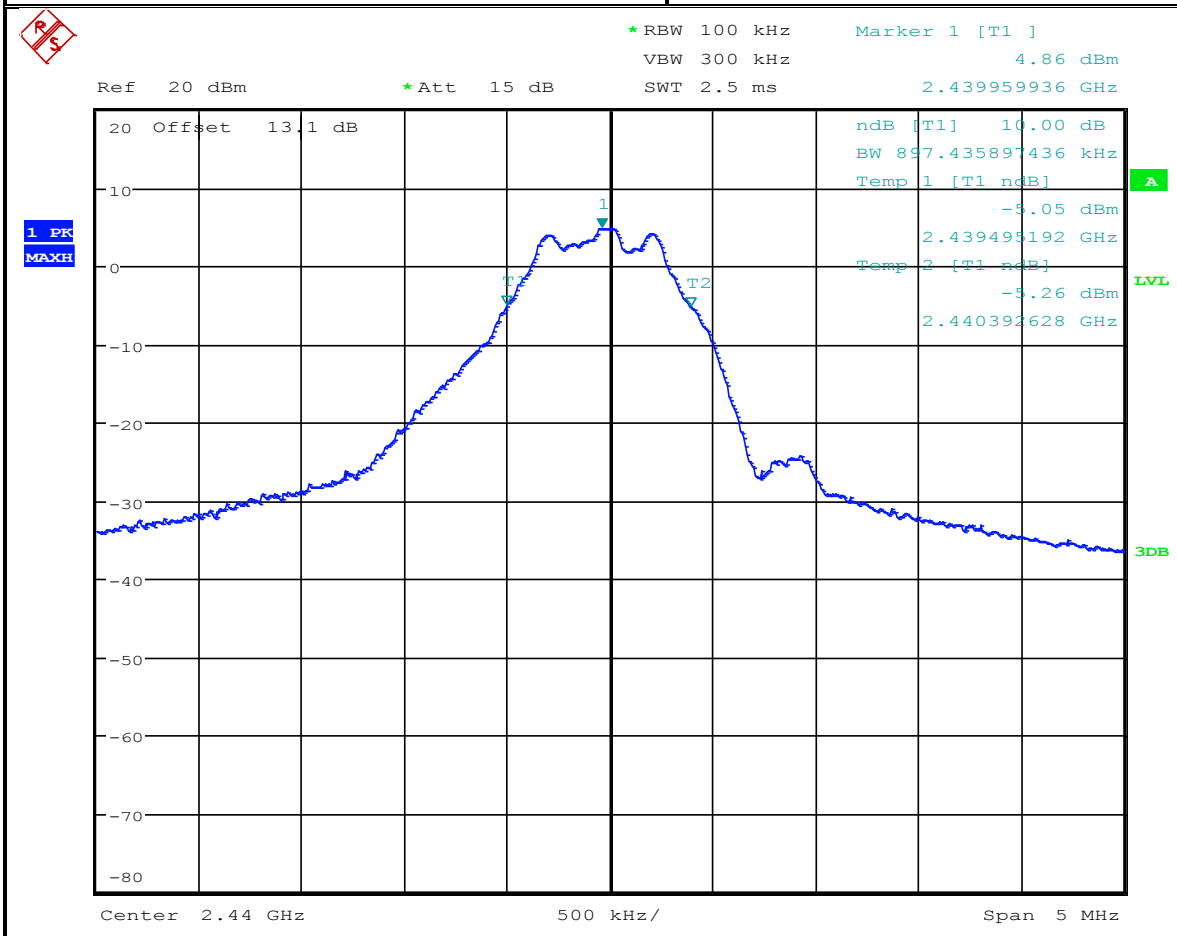
Mid channel	Mode: GFSK



Date: 4.FEB.2021 18:01:06

Plot #21

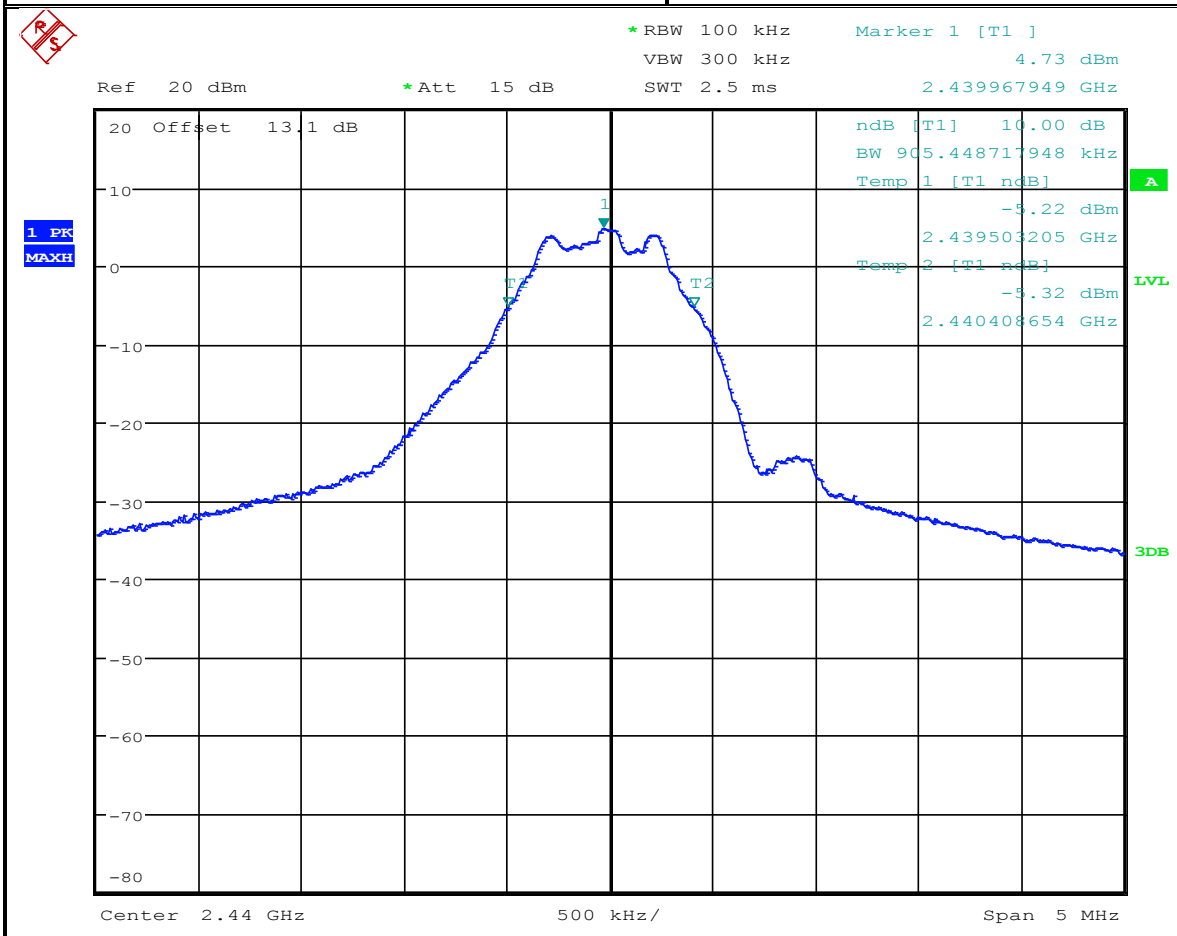
Mid channel	Mode: GFSK



Date: 4.FEB.2021 19:28:14

Plot #22

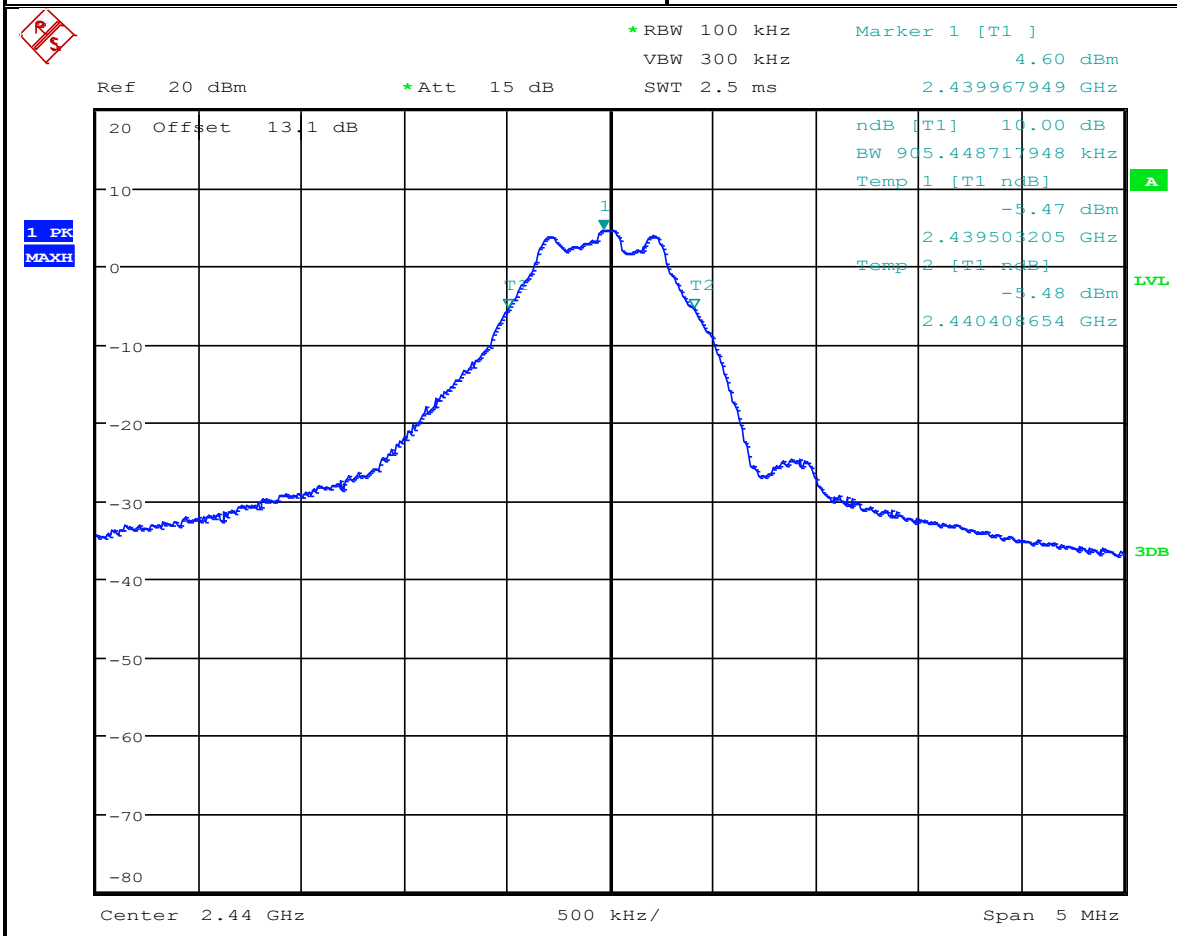
Mid channel	Mode: GFSK



Date: 4.FEB.2021 18:07:37

Plot #23

Mid channel	Mode: GFSK



8.7 Radiated Transmitter Spurious Emissions and Restricted Bands

8.7.1 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 = 1 MHz

- 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

8.7.2 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= 74 dBµV/m
  *AVG. LIMIT= 54 dBµV/m

8.7.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
23° C	1	GFSK continuous fixed channel	12 VDC

8.7.4 Measurement result:

Plot #	Channel #	Scan Frequency	Limit	Result
24-26	Low	30 MHz – 18 GHz	See section 8.7.2	Pass
27-31	Mid	9 kHz – 26 GHz	See section 8.7.2	Pass
32-34	High	30 MHz – 18 GHz	See section 8.7.2	Pass

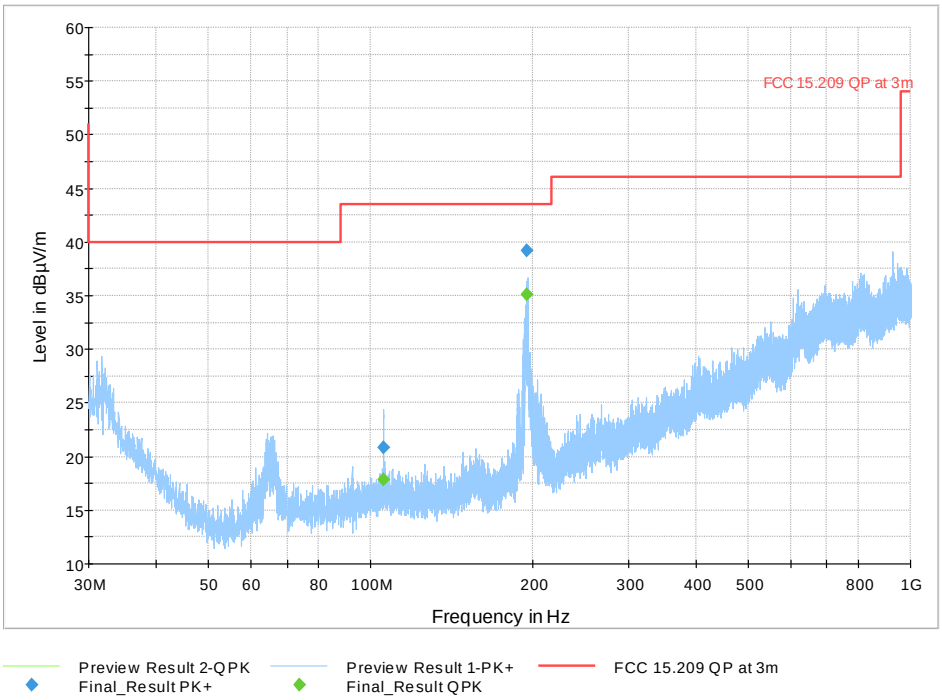
8.7.5 Measurement Plots:

Plot #24 Radiated Emissions: 30 MHz – 1GHz

Modulation: GFSK	Channel: Low	63.59% Duty Cycle

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
105.660	---	17.80	---	---	500.0	120.000	140.0	H	31.0	13.2	
105.660	20.88	---	43.50	22.62	500.0	120.000	140.0	H	31.0	13.2	
194.900	---	35.12	---	---	500.0	120.000	152.0	H	63.0	14.0	
194.900	39.26	---	43.50	4.24	500.0	120.000	152.0	H	63.0	14.0	

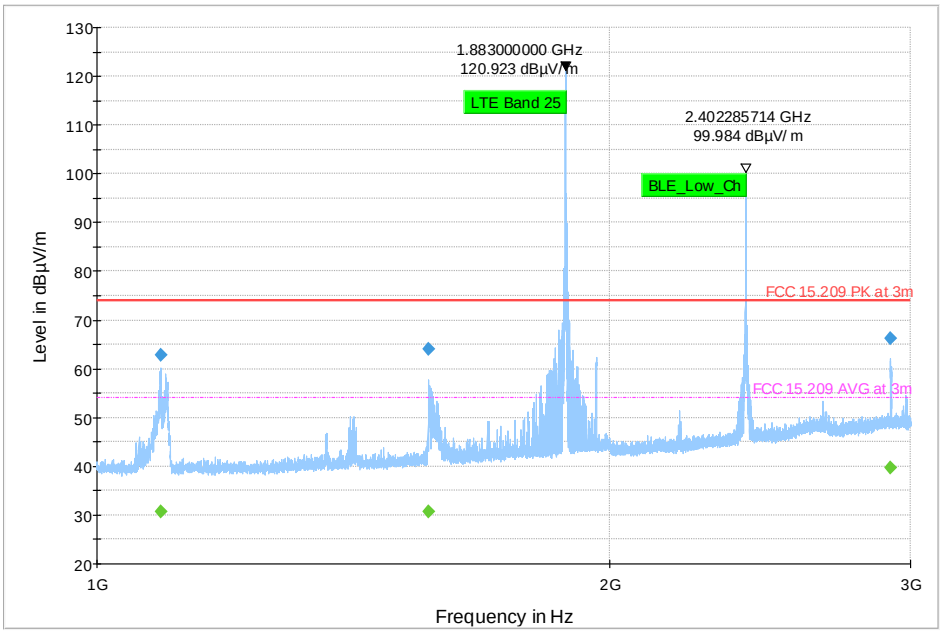


Plot #25 Radiated Emissions: 1-3 GHz

Modulation: GFSK	Channel: Low	63.59% Duty Cycle

Final_Result

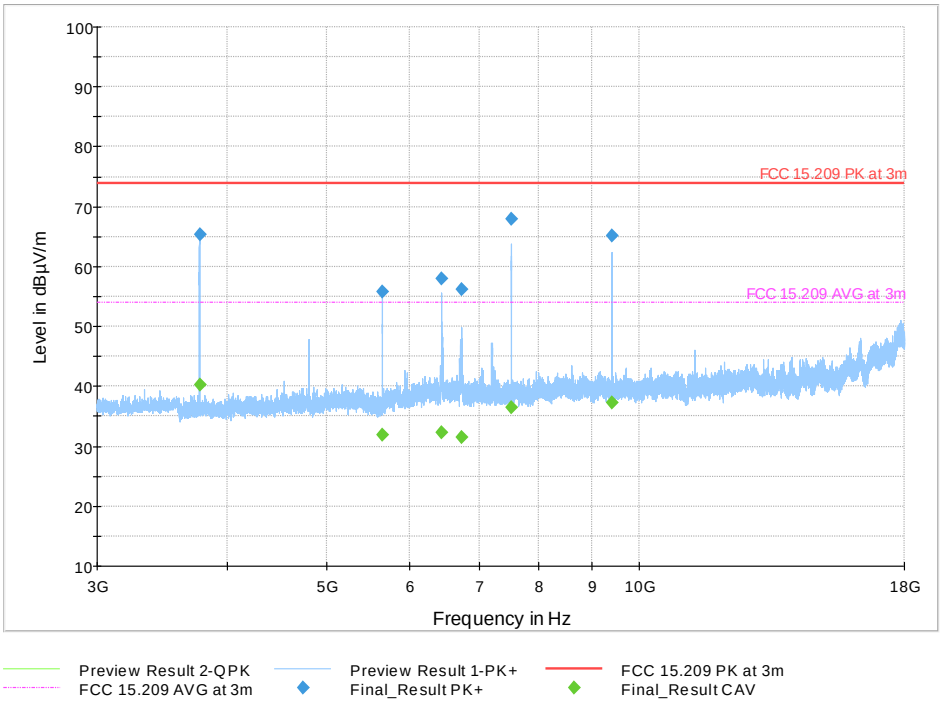
Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
1090.143	---	30.67	53.98	23.31	500.0	1000.000	185.0	V	195.0	4.1	
1090.143	62.93	---	73.98	11.05	500.0	1000.000	185.0	V	195.0	4.1	
1564.714	64.04	---	73.98	9.94	500.0	1000.000	185.0	H	346.0	5.8	
1564.714	---	30.82	53.98	23.16	500.0	1000.000	185.0	H	346.0	5.8	
2921.571	66.31	---	73.98	7.67	500.0	1000.000	274.0	V	36.0	11.6	
2921.571	---	39.71	53.98	14.27	500.0	1000.000	274.0	V	36.0	11.6	



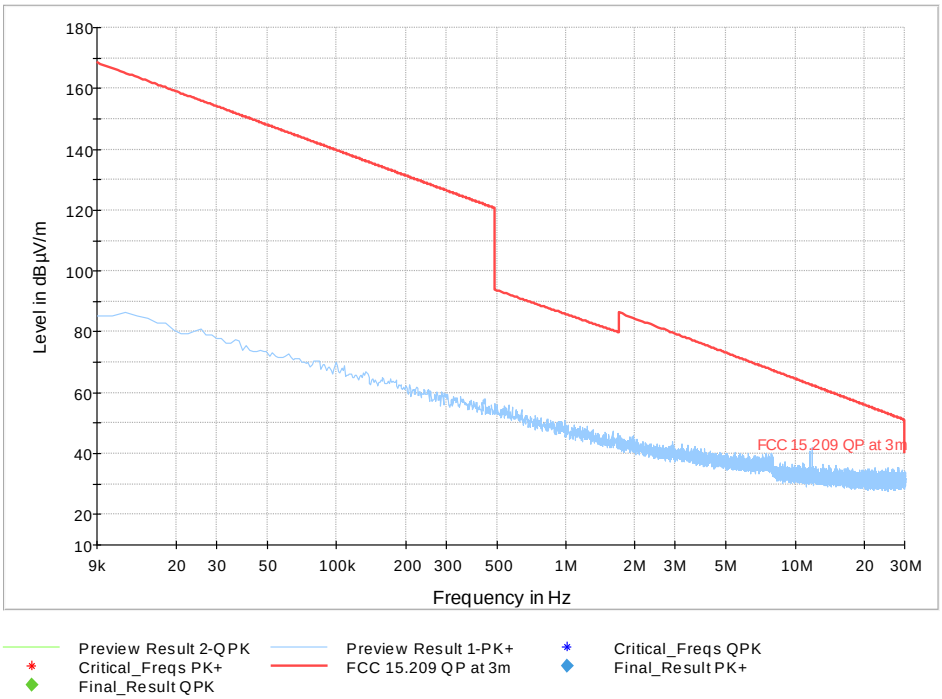
Plot #26 Radiated Emissions: 3-18 GHz		
Modulation: GFSK	**Channel: Low**	**63.59% Duty Cycle**

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
3765.500	65.44	---	73.98	8.54	500.0	1000.000	207.0	V	29.0	-6.6	
3765.500	---	40.20	53.98	13.78	500.0	1000.000	207.0	V	29.0	-6.6	
5649.000	55.81	---	73.98	18.17	500.0	1000.000	165.0	V	36.0	-4.2	
5649.000	---	31.91	53.98	22.07	500.0	1000.000	165.0	V	36.0	-4.2	
6444.500	58.00	---	73.98	15.98	500.0	1000.000	176.0	H	352.0	-0.5	
6444.500	---	32.33	53.98	21.65	500.0	1000.000	176.0	H	352.0	-0.5	
6738.000	56.21	---	73.98	17.77	500.0	1000.000	140.0	V	131.0	-0.4	
6738.000	---	31.54	53.98	22.44	500.0	1000.000	140.0	V	131.0	-0.4	
7530.000	---	36.53	53.98	17.45	500.0	1000.000	140.0	V	309.0	0.0	
7530.000	67.90	---	73.98	6.08	500.0	1000.000	140.0	V	309.0	0.0	
9414.500	---	37.35	53.98	16.63	500.0	1000.000	140.0	V	25.0	1.8	
9414.500	65.07	---	73.98	8.91	500.0	1000.000	140.0	V	25.0	1.8	



Plot #27 Radiated Emissions: 9 KHz – 30 MHz		
Modulation: GFSK	**Channel: Mid**	**63.59% Duty Cycle**

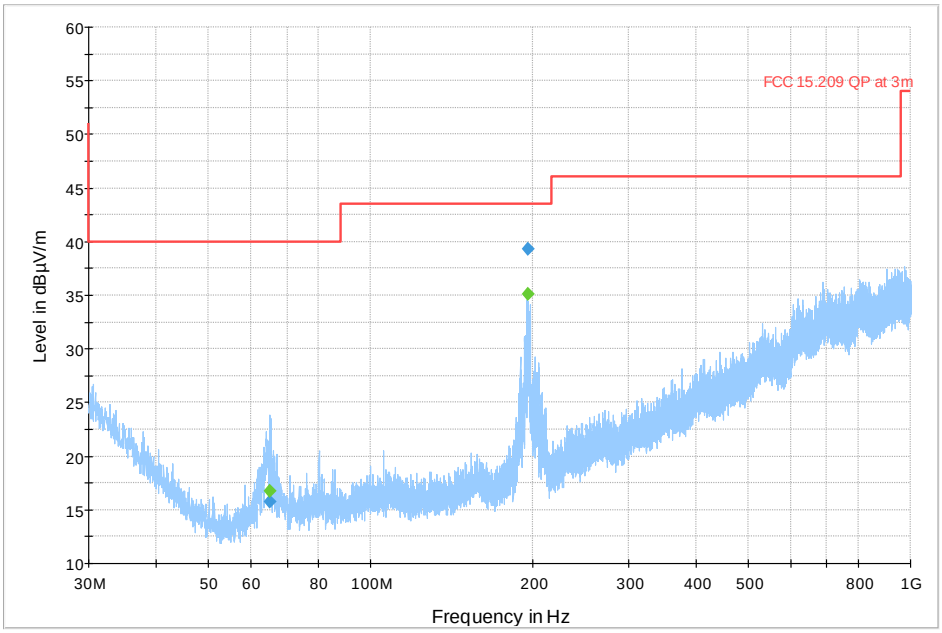


Plot #28 Radiated Emissions: 30 MHz – 1GHz

Modulation: GFSK	Channel: Mid	63.59% Duty Cycle

Final_Result

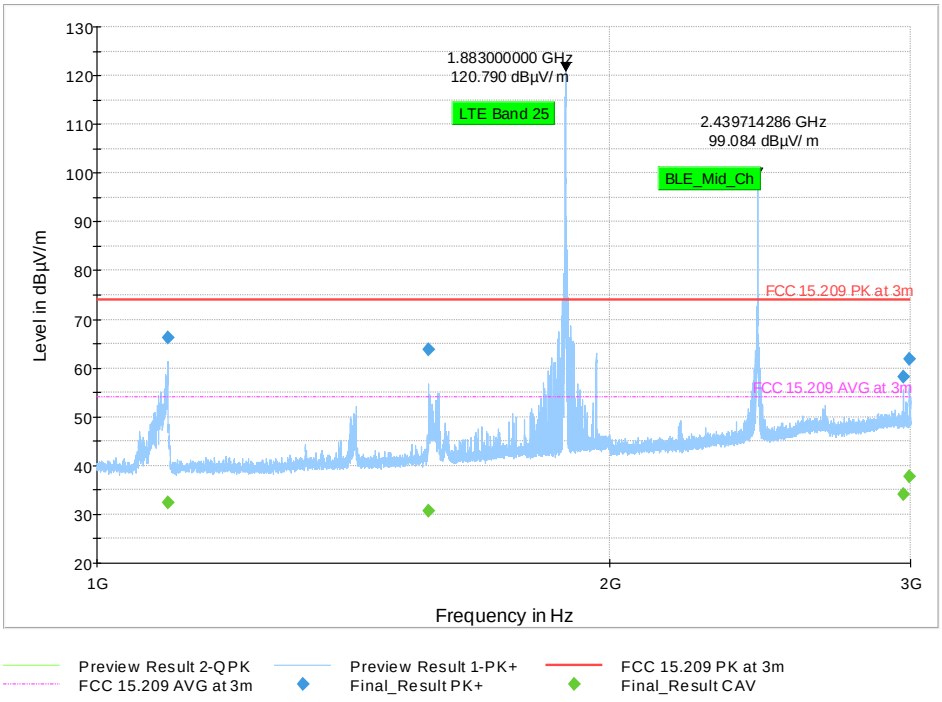
Frequency (MHz)	MaxPeak (dBµV/m)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
64.888	15.77	---	40.00	24.23	500.0	120.000	163.0	V	29.0	11.0	
64.888	---	16.76	---	---	500.0	120.000	163.0	V	29.0	11.0	
195.482	39.28	---	43.50	4.22	500.0	120.000	153.0	H	63.0	14.1	
195.482	---	35.13	---	---	500.0	120.000	153.0	H	63.0	14.1	



Plot #29 Radiated Emissions: 1-3 GHz		
Modulation: GFSK	**Channel: Mid**	**63.59% Duty Cycle**

Final_Result

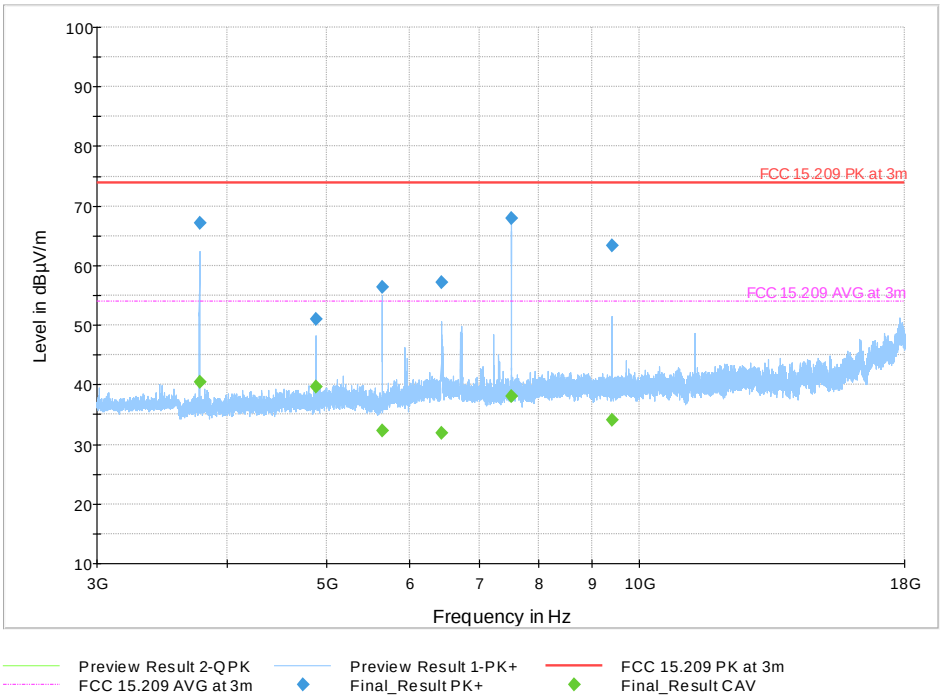
Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
1100.143	66.19	---	73.98	7.79	500.0	1000.000	164.0	H	152.0	4.1	
1100.143	---	32.41	53.98	21.57	500.0	1000.000	164.0	H	152.0	4.1	
1565.000	63.87	---	73.98	10.11	500.0	1000.000	185.0	H	-12.0	5.8	
1565.000	---	30.76	53.98	23.22	500.0	1000.000	185.0	H	-12.0	5.8	
2973.286	---	34.03	53.98	19.95	500.0	1000.000	140.0	V	3.0	11.8	
2973.286	58.32	---	73.98	15.66	500.0	1000.000	140.0	V	3.0	11.8	
2997.143	---	37.65	53.98	16.33	500.0	1000.000	288.0	V	34.0	11.9	
2997.143	61.93	---	73.98	12.05	500.0	1000.000	288.0	V	34.0	11.9	



Plot #30 Radiated Emissions: 3-18 GHz		
Modulation: GFSK	**Channel: Mid**	**63.59% Duty Cycle**

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
3766.000	67.18	---	73.98	6.80	500.0	1000.000	206.0	V	29.0	-6.6	
3766.000	---	40.37	53.98	13.61	500.0	1000.000	206.0	V	29.0	-6.6	
4880.500	---	39.66	53.98	14.32	500.0	1000.000	175.0	V	211.0	-5.0	
4880.500	51.03	---	73.98	22.95	500.0	1000.000	175.0	V	211.0	-5.0	
5649.000	---	32.30	53.98	21.68	500.0	1000.000	207.0	V	340.0	-4.2	
5649.000	56.47	---	73.98	17.51	500.0	1000.000	207.0	V	340.0	-4.2	
6442.000	57.11	---	73.98	16.87	500.0	1000.000	196.0	H	-12.0	-0.5	
6442.000	---	31.84	53.98	22.14	500.0	1000.000	196.0	H	-12.0	-0.5	
7532.000	67.89	---	73.98	6.09	500.0	1000.000	152.0	V	71.0	0.0	
7532.000	---	38.03	53.98	15.95	500.0	1000.000	152.0	V	71.0	0.0	
9413.500	63.37	---	73.98	10.61	500.0	1000.000	140.0	V	-25.0	1.8	
9413.500	---	34.16	53.98	19.82	500.0	1000.000	140.0	V	-25.0	1.8	

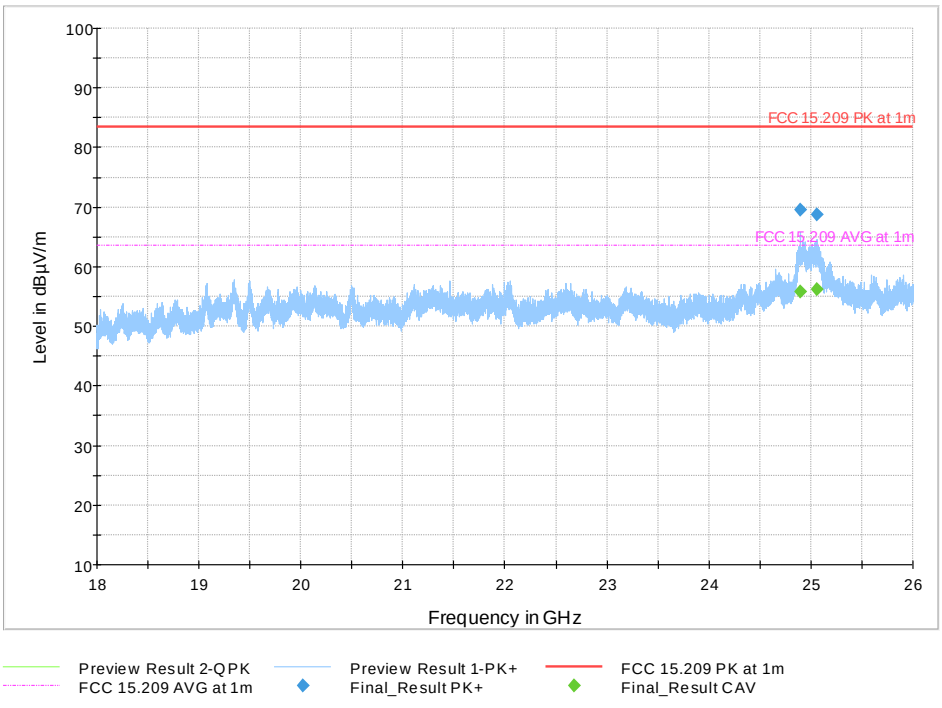


Plot #31 Radiated Emissions: 18-26 GHz

Modulation: GFSK	Channel: Mid	63.59% Duty Cycle

Final_Result

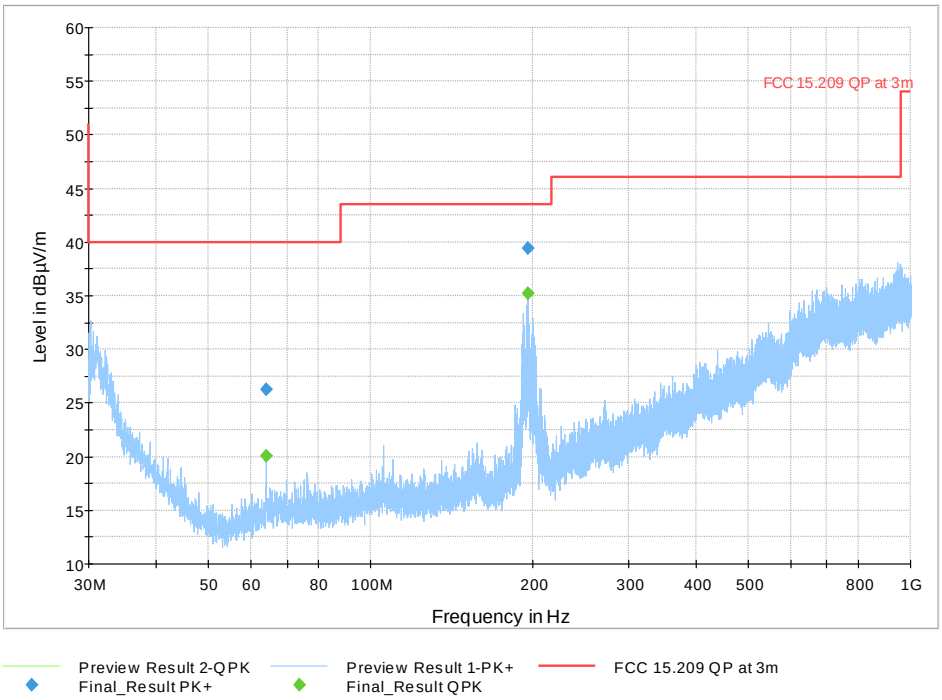
Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
24892.703	69.53	---	83.50	13.97	500.0	1000.000	100.0	V	4.0	30.3	
24892.703	---	55.82	63.50	7.68	500.0	1000.000	100.0	V	4.0	30.3	
25060.844	68.65	---	83.50	14.85	500.0	1000.000	100.0	H	140.0	30.3	
25060.844	---	56.18	63.50	7.32	500.0	1000.000	100.0	H	140.0	30.3	



Plot #32 Radiated Emissions: 30 MHz – 1GHz		
Modulation: GFSK	**Channel: High**	**63.59% Duty Cycle**

Final_Result

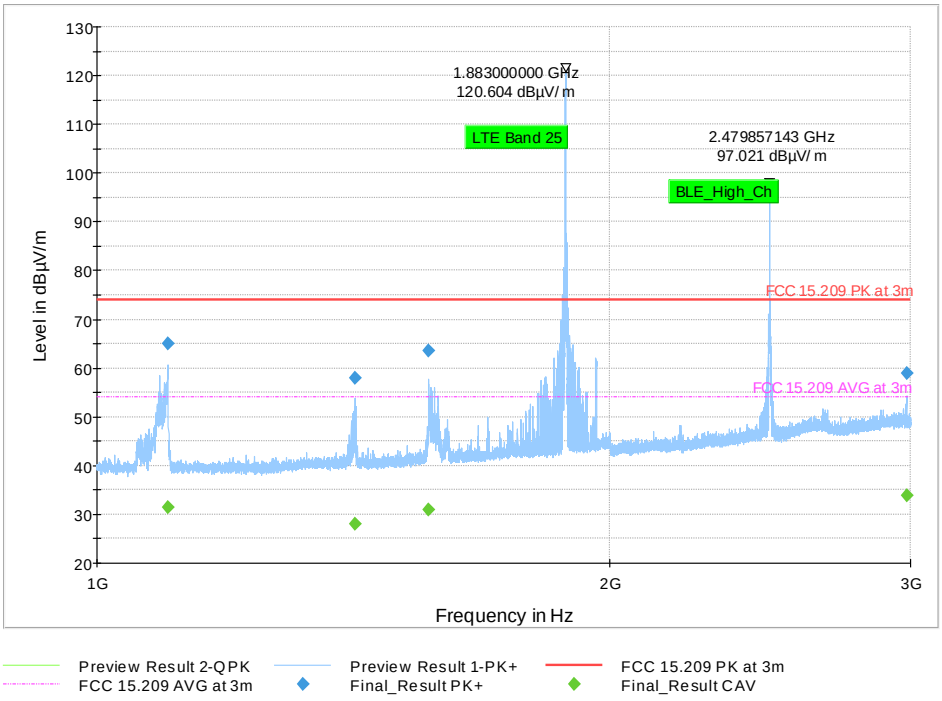
Frequency (MHz)	MaxPeak (dBµV/m)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
63.982	26.22	---	40.00	13.78	500.0	120.000	140.0	V	107.0	10.8	
63.982	---	20.10	---	---	500.0	120.000	140.0	V	107.0	10.8	
195.482	39.44	---	43.50	4.06	500.0	120.000	195.0	H	62.0	14.1	
195.482	---	35.24	---	---	500.0	120.000	195.0	H	62.0	14.1	



Plot #33 Radiated Emissions: 1-3 GHz		
Modulation: GFSK	**Channel: High**	**63.59% Duty Cycle**

Final_Result

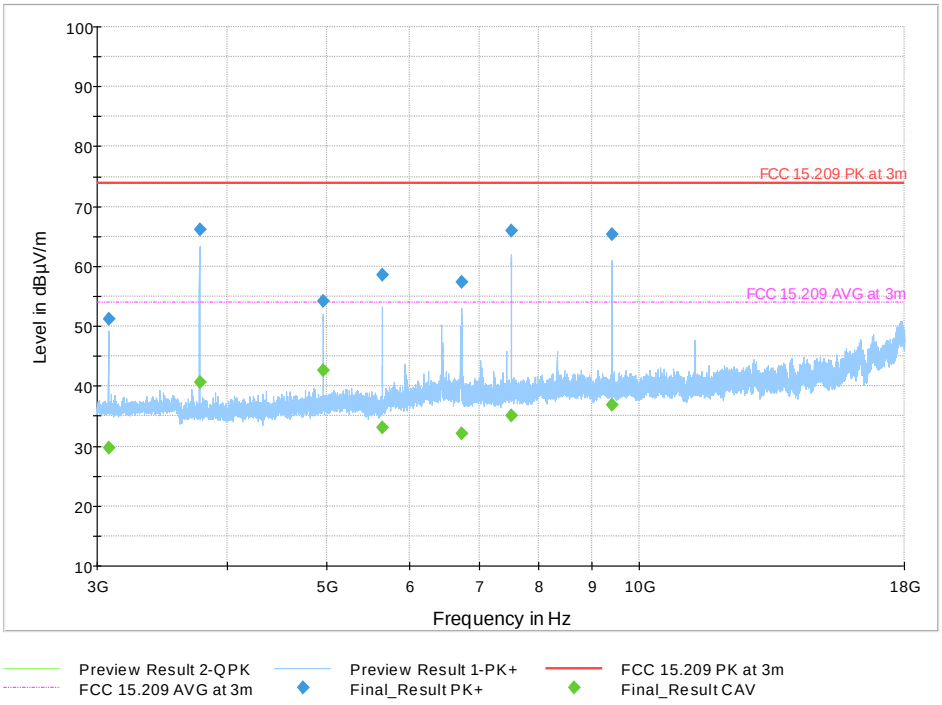
Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
1100.286	64.97	---	73.98	9.01	500.0	1000.000	152.0	H	234.0	4.1	
1100.286	---	31.48	53.98	22.50	500.0	1000.000	152.0	H	234.0	4.1	
1417.000	57.96	---	73.98	16.02	500.0	1000.000	215.0	H	18.0	5.3	
1417.000	---	27.96	53.98	26.02	500.0	1000.000	215.0	H	18.0	5.3	
1565.286	---	30.87	53.98	23.11	500.0	1000.000	185.0	H	351.0	5.8	
1565.286	63.61	---	73.98	10.37	500.0	1000.000	185.0	H	351.0	5.8	
2983.286	---	33.85	53.98	20.13	500.0	1000.000	297.0	V	45.0	11.8	
2983.286	58.89	---	73.98	15.09	500.0	1000.000	297.0	V	45.0	11.8	



Plot #34 Radiated Emissions: 3-18 GHz		
Modulation: GFSK	**Channel: High**	**63.59% Duty Cycle**

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
3077.500	51.22	---	73.98	22.76	500.0	1000.000	285.0	H	303.0	-9.0	
3077.500	---	29.64	53.98	24.34	500.0	1000.000	285.0	H	303.0	-9.0	
3765.500	---	40.72	53.98	13.26	500.0	1000.000	209.0	V	29.0	-6.6	
3765.500	66.18	---	73.98	7.80	500.0	1000.000	209.0	V	29.0	-6.6	
4960.500	---	42.74	53.98	11.24	500.0	1000.000	153.0	V	244.0	-4.5	
4960.500	54.16	---	73.98	19.82	500.0	1000.000	153.0	V	244.0	-4.5	
5649.000	---	33.12	53.98	20.86	500.0	1000.000	140.0	H	13.0	-4.2	
5649.000	58.50	---	73.98	15.48	500.0	1000.000	140.0	H	13.0	-4.2	
6736.000	---	32.19	53.98	21.79	500.0	1000.000	140.0	V	299.0	-0.4	
6736.000	57.47	---	73.98	16.51	500.0	1000.000	140.0	V	299.0	-0.4	
7529.500	---	35.09	53.98	18.89	500.0	1000.000	286.0	V	240.0	0.0	
7529.500	65.90	---	73.98	8.08	500.0	1000.000	286.0	V	240.0	0.0	
9415.000	65.41	---	73.98	8.57	500.0	1000.000	140.0	V	296.0	1.8	
9415.000	---	36.96	53.98	17.02	500.0	1000.000	140.0	V	296.0	1.8	



9 Test setup photos

Setup photos are included in supporting file name: "EMC_CALAM-118-21001_Setup_Photos.pdf"

10 Test Equipment and Ancillaries Used For Testing

Equipment Type	Manufacturer	Model	Serial #	Calibration Cycle	Last Calibration Date
ACTIVE LOOP ANTENNA	ETS LINDGREN	6507	00161344	3 YEARS	10/30/2020
BILOG ANTENNA	A.H.Systems	3049	569	3 YEARS	09/24/2020
HORN ANTENNA	ETS.LINDGREN	3115	00035111	3 YEARS	04/17/2019
HORN ANTENNA	ETS LINDGREN	3117	00169547	3 YEARS	09/01/2020
HORN ANTENNA	ETS LINDGREN	3116	00070497	3 YEARS	11/23/2020
WIDEBAND RADIO COMMUNICATION	R&S	CMW500	109825	3 YEARS	02/12/2018
SPECTRUM ANALYZER	R&S	FSU26	200065	3 YEARS	07/16/2019
SIGNAL ANALYZER	R&S	FSV 40	101022	3 YEARS	07/15/2019
COMPACT DIGITAL BAROMETER	CONTROL COMPANY	10510-922	200236891	3 YEARS	04/13/2020
DIGITAL THRMOMETER	CONTROL COMPANY	36934-164	191871994	3 YEARS	01/10/2019

Note: Equipment used meets the measurement uncertainty requirements as required per applicable standards for 95% confidence levels. 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
2021-02-23	EMC_CALAM_118_21001_15.247_BT_DTS	Initial version	Yuchan Lu

<<The End>>