FCC / ISED & Test Report

For:

u-blox AG

Model Name:

SARA-R412M

Product Description:

Cellular Module

Applied Rules and Standards:

47 CFR Parts 24
RSS-Gen Issue 5; RSS-133 Issue 6

FCC ID: XPYUBX18ZO01
IC ID: 8595A-UBX18ZO01

REPORT #: EMC_CTSMC-003-18001_FCC_24_Rev_1
DATE: 2019-1-21

A2LA Accredited

IC recognized # 3462B-2

***CETECOM* Inc.**
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1 Assessment

The following device as further described in section 3 of this report was evaluated against the applicable criteria specified in the Code of Federal Regulations Title 47 parts 24, and ISED Standards: RSS-GEN, RSS-133 issue 6.

No deficiencies were ascertained.

Company Name	Product Description	Model #
u-blox AG	Cellular Module	SARA-R412M

Responsible for Testing Laboratory:

Date	Section	Name	Signature
2018-12-20	Compliance	Cindy Li (Lab Manager EMC)	Cindy Li Digitally signed by Cindy Li DN: cn=Cindy Li, o=Cetecom Inc., ou=EMC, email=cindy.li@cetecom.com, c=US Date: 2019.01.22 18:31:15 -08'00'

Responsible for the Report:

Date	Section	Name	Signature
2018-12-20	Compliance	Kris Lazarov (EMC Engineer)	Digitally signed by Kris Lazarov Date: 2019.01.22 17:15:40 -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
Lab Manager EMC:	Cindy Li
Responsible Project Leader:	Kris Lazarov

2.2 Identification of the Client

Applicant's Name:	u-blox AG
Street Address:	Zuercherstrasse 68
City/Zip Code	Thalwil, CH-8800
Country	Switzerland

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	SARA-R412M
HW Version	324A01
SW Version	M0.07.00
FCC-ID	XPYUBX18ZO01
IC-ID:	8595A-UBX18ZO01
HVIN:	SARA-R412M
PMN:	SARA-R412M
Product Description	Cellular Module
Transceiver Technology / Type(s) of Modulation	GSM 850 / 1900 / GMSK / 8PSK LTE Bands 2; 4; 5; 12; 13 / QPSK / 64-QAM
Frequency Range	GSM 850: Uplink: 824 – 850 MHz / Downlink: 869 – 894 MHz GSM 1900: Uplink: 1850 – 1910 MHz / Downlink: 1930 – 1990 MHz LTE Band 2: Uplink: 1850 – 1910 MHz / Downlink: 1930 – 1990 MHz LTE Band 4: Uplink: 1710 – 1755 MHz / Downlink: 2110 – 2155 MHz LTE Band 5: Uplink: 824 – 849 MHz / Downlink: 869 – 894 MHz LTE Band 12: Uplink: 699 – 716 MHz / Downlink: 729 – 746 MHz LTE Band 13: Uplink: 777 – 787 MHz / Downlink: 746 – 756 MHz
Max. antenna gain	GSM 850 = 1.71 dBi GSM 1900 = 2.32 dBi LTE Band 2 = 2.32 dBi LTE Band 4 = 1.57 dBi LTE Band 5 = 1.71 dBi LTE Band 12 = 2.83 dBi LTE Band 13 = 2.83 dBi
Power Supply/ Rated Operating Voltage Range	3.2VDC (Low) / 3.8VDC (Nominal) / 4.5VDC (Max)
Operating Temperature Range	–40°C ~ +85°C
Sample Revision	☐Prototype ■Production ☐ Pre-Production

3.2 EUT Sample details

EUT #	Serial Number	HW Version	SW Version	Comments
1	354679090052898	324A01	M0.07.00	-

3.3 Accessory Equipment (AE) details

AE #	Type	Model	Manufacturer	Serial Number
1	AC Adapter	UUX324-1215	UNIFIVE	Jo1-0058452
2	LTE I-Bar	LTE 700~2800MHz	Taoglas	N/A

3.4 Test Sample Configuration

Set-up #	EUT / AE used for set-up	Comments
1	EUT#1+AE#1	-
2	EUT#1+AE#1+AE#2	-

3.5 Operating Mode

Operating Mode #	Description	Comments
1	GSM	Established link with base station simulator in GSM mode.
2	CAT M1	Established link with base station simulator in CAT M1 mode.
3	NB IoT	Established link with base station simulator in NB IoT mode.

4 Subject of Investigation

The objective of the measurements done by CETECOM Inc. was to evaluate the compliance of the EUT against the relevant requirements specified in the Code of Federal Regulations Title 47 parts 24, and ISED Standards: RSS-133 issue 6.

4.1 Dates of Testing:

10/01/2018 - 10/20/2018

4.2 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

4.3 Environmental Conditions during Testing:

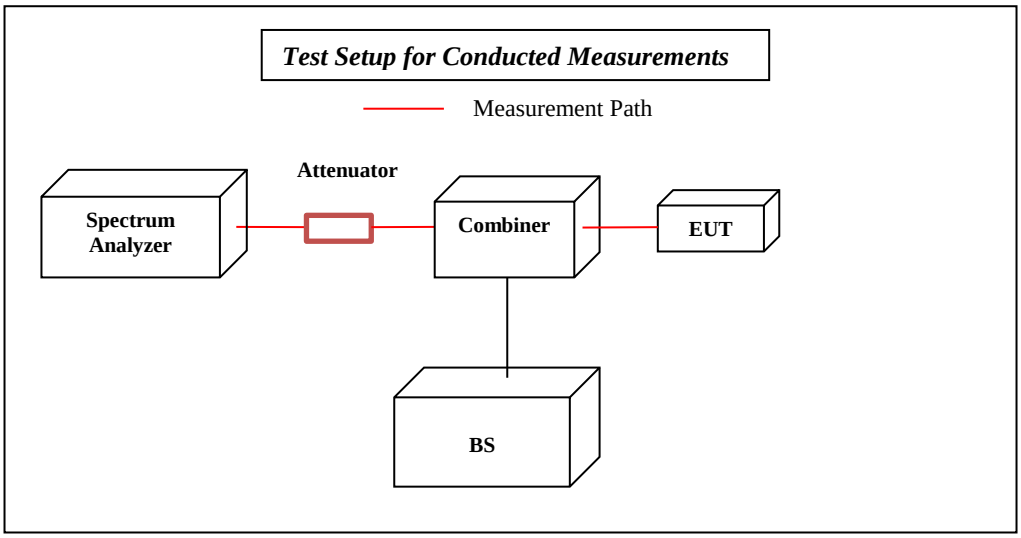
The following environmental conditions were maintained during the course of testing:

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

Deviating test conditions are indicated at individual test description where applicable.

5 Measurement Procedures

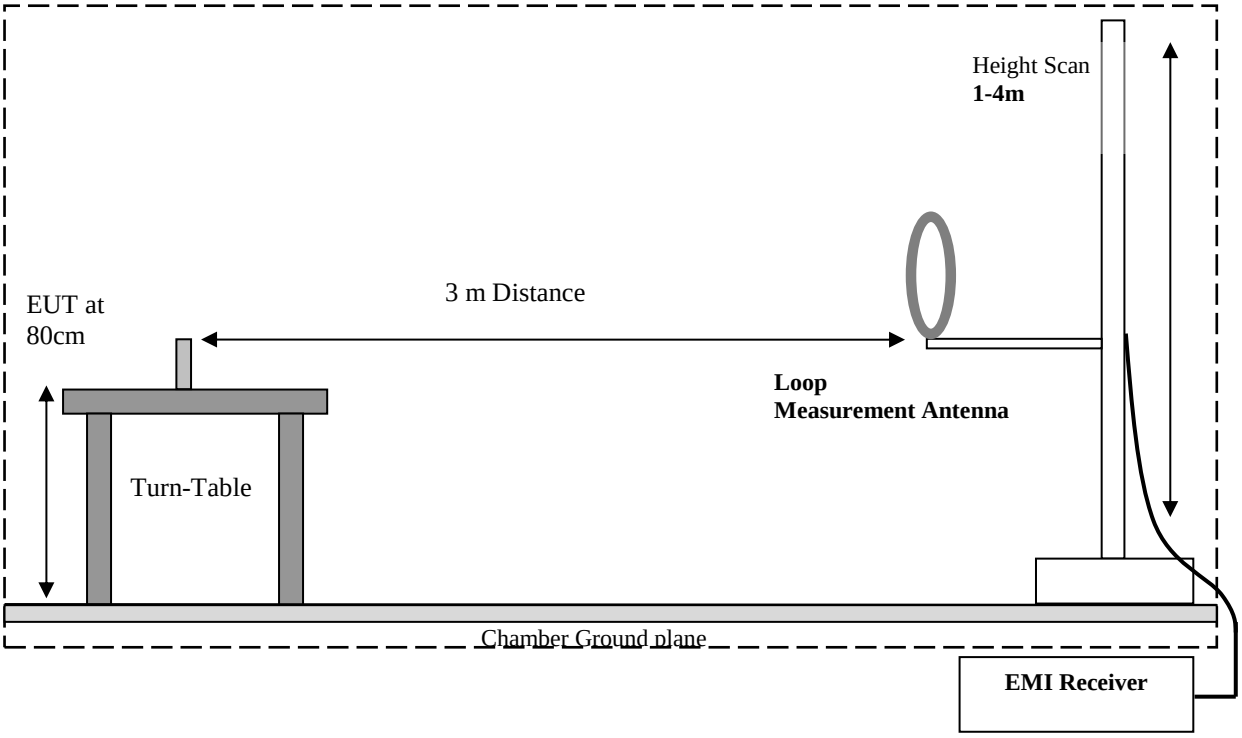
Testing is performed according to the guidelines provided in FCC publication (KDB) 971168 D01 and ANSI C63.26-2015 as detailed below.



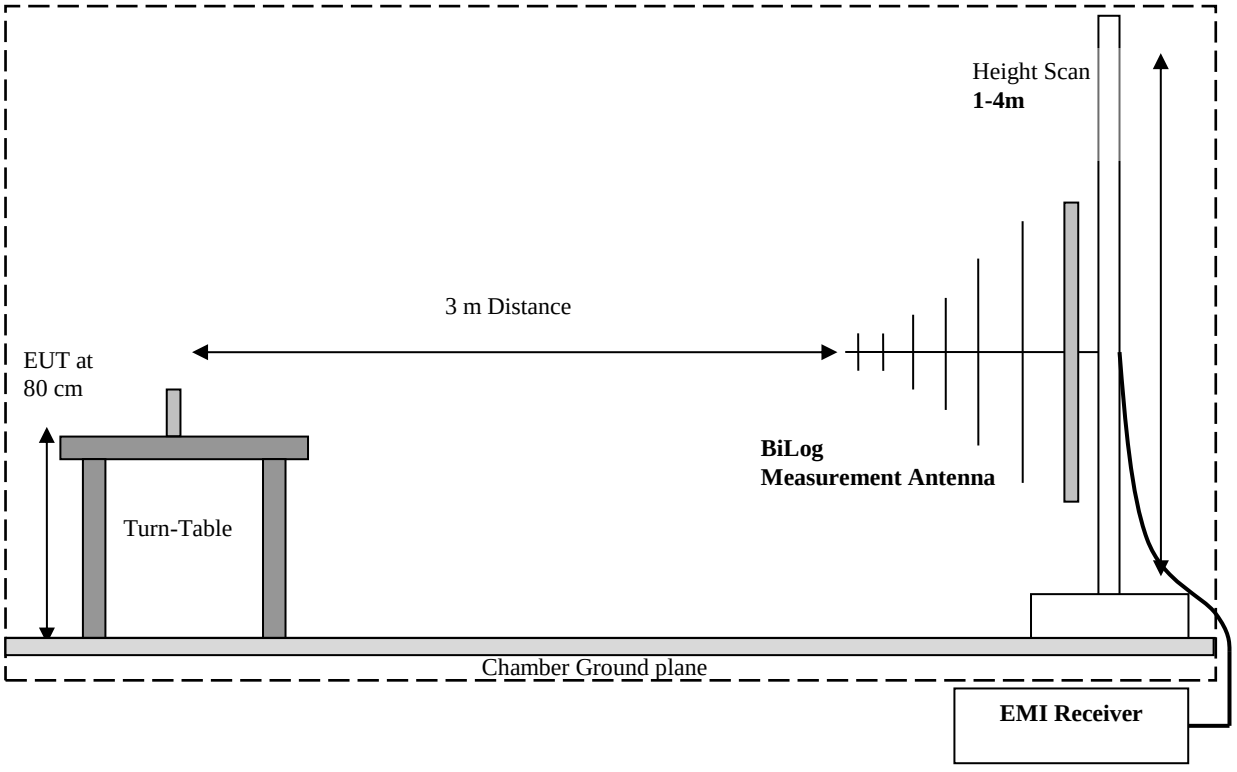
5.1 Radiated Measurement

- 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.

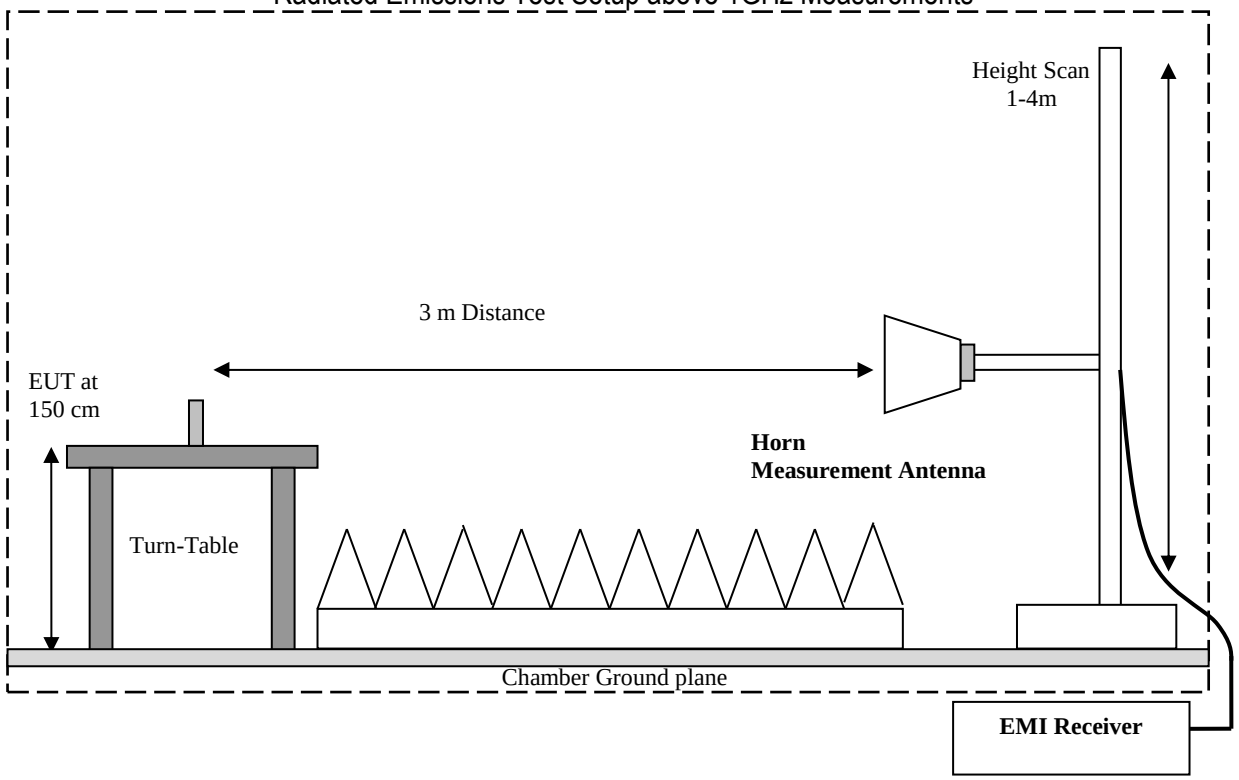
Radiated Emissions Test Setup below 30MHz Measurements



Radiated Emissions Test Setup 30MHz-1GHz Measurements



Radiated Emissions Test Setup above 1GHz Measurements



5.2 Sample Calculations for Field Strength Measurements

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

- Measured reading in dBµV
- Cable Loss between the receiving antenna and SA in dB and
- 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

6 Measurement Results Summary

Test Specification	Test Case	Temperature and Voltage Conditions	Mode	Pass	Fail	NA	NP	Result
§2.1046; §24.232 (a)	RF Output Power	Nominal	GSM CAT M1 NB IoT	■	☐	☐	☐	Complies
§2.1055; §24.235	Frequency Stability	Extreme Temperature and Voltage	GSM CAT M1 NB IoT	■	☐	☐	☐	Complies
§2.1049; §24.238	Occupied Bandwidth	Nominal	GSM CAT M1 NB IoT	■	☐	☐	☐	Complies
§2.1051; §24.238	Band Edge Compliance	Nominal	GSM CAT M1 NB IoT	■	☐	☐	☐	Complies
§2.1051; §24.238	Conducted Spurious Emissions	Nominal	GSM CAT M1 NB IoT	■	☐	☐	☐	Complies
§2.1053; §24.238	Radiated Spurious Emissions	Nominal	GSM CAT M1 NB IoT	■	☐	☐	☐	Complies

Note 1: NA= Not Applicable; NP= Not Performed.

Testing Notes

The RF output power and occupied bandwidth for GSM was tested with the TX configured to GMSK and 8PSK modulation. The results with GMSK were the highest, so this mode was used for the rest of testing and recorded in this report.

The RF output power and occupied bandwidth for LTE Cat M1 was tested with the TX configured to QPSK and 16QAM modulation. The results with 16QAM were the highest bandwidth, so this mode was used for the rest of testing and recorded in this report.

7 Test Result Data

7.1 RF Output Power

7.1.1 Conducted Measurement utilizing KDB 971168 D01 and ANSI C63.26-2015 Subclause 5.2.3.4

Spectrum Analyzer settings for CCDF procedure for PAPR measurements:

- RBW ≥ OBW
- Number of counts = 10000
- Sweep time ≥ 1ms
- Record the maximum PAPR level associated with a probability of 0.1%

7.1.2 Limits:

7.1.2.1 FCC Part 24.232

(c) Mobile and portable stations are limited to 2 watts EIRP (33 dBm) and the equipment must employ a means for limiting power to the minimum necessary for successful communications.

7.1.2.2 RSS-133 Part 6.4 Transmitter Output Power and Equivalent Isotropically Radiated Power

The equivalent isotropically radiated power (e.i.r.p.) for transmitters shall not exceed the limits given in SRSP-510. Moreover, base station transmitters operating in the band 1930-1995 MHz shall not have output power exceeding 100 watts. In addition, the transmitter's peak-to-average power ratio (PAPR) shall not exceed 13 dB for more than 0.1% of the time using a signal corresponding to the highest PAPR during periods of continuous transmission.

7.1.3 Test conditions and setup:

Ambient Temperature (C)	EUT Set-Up #	EUT operating mode	Power Input (V)	Measurement Path Correction (dB)
22	1	1, 2, and 3	110V / 60 Hz	35

7.1.4 Measurement result ERP / EIRP:

Plot #	Chanel #	Frequency (MHz)	Maximum AVG Conducted Output Power (dBm)	Antenna Gain (dBi)	Calc. ERP/EIRP (dBm)	Limit (dBm)	Result
1	GPRS 1900 / low	1850.2	28.89	2.32	31.21	< 33 EIRP	Pass
	EGPRS 1900 / low	1850.2	24.78	2.32	27.10	< 33 EIRP	Pass
2	GPRS 1900 / mid	1880	28.55	2.32	30.87	< 33 EIRP	Pass
	EGPRS 1900 / mid	1880	24.62	2.32	26.94	< 33 EIRP	Pass
3	GPRS 1900 / high	1909.8	28.19	2.32	30.51	< 33 EIRP	Pass
	EGPRS 1900 / high	1909.8	24.44	2.32	26.76	< 33 EIRP	Pass
4	CAT M1 B2 16QAM 6RB / low	1850.7	21.85	2.32	24.17	< 33 EIRP	Pass
	CAT M1 B2 16QAM 1RB / low	1850.7	23.51	2.32	25.83	< 33 EIRP	Pass
5	CAT M1 B2 16QAM 6RB / mid	1880	21.61	2.32	23.93	< 33 EIRP	Pass
	CAT M1 B2 16QAM 1RB / mid	1880	23.16	2.32	25.48	< 33 EIRP	Pass
6	CAT M1 B2 16QAM 6RB / high	1909.3	20.98	2.32	23.3	< 33 EIRP	Pass
	CAT M1 B2 16QAM 1RB / high	1909.3	22.40	2.32	24.72	< 33 EIRP	Pass
7	CAT M1 B2 QPSK 6RB / low	1850.7	21.78	2.32	24.10	< 33 EIRP	Pass
	CAT M1 B2 QPSK 1RB / low	1850.7	24.19	2.32	26.51	< 33 EIRP	Pass
8	CAT M1 B2 QPSK 6RB / mid	1880	21.54	2.32	23.86	< 33 EIRP	Pass
	CAT M1 B2 QPSK 1RB / mid	1880	23.69	2.32	26.01	< 33 EIRP	Pass
9	CAT M1 B2 QPSK 6RB / high	1909.3	20.85	2.32	23.17	< 33 EIRP	Pass
	CAT M1 B2 QPSK 1RB / high	1909.3	23.00	2.32	25.32	< 33 EIRP	Pass
10	NB IoT B2 / low	1850	20.22	2.32	22.54	< 33 EIRP	Pass
11	NB IoT B2 / mid	1880	20.46	2.32	22.78	< 33 EIRP	Pass
12	NB IoT B2 / high	1910	20.00	2.32	22.32	< 33 EIRP	Pass

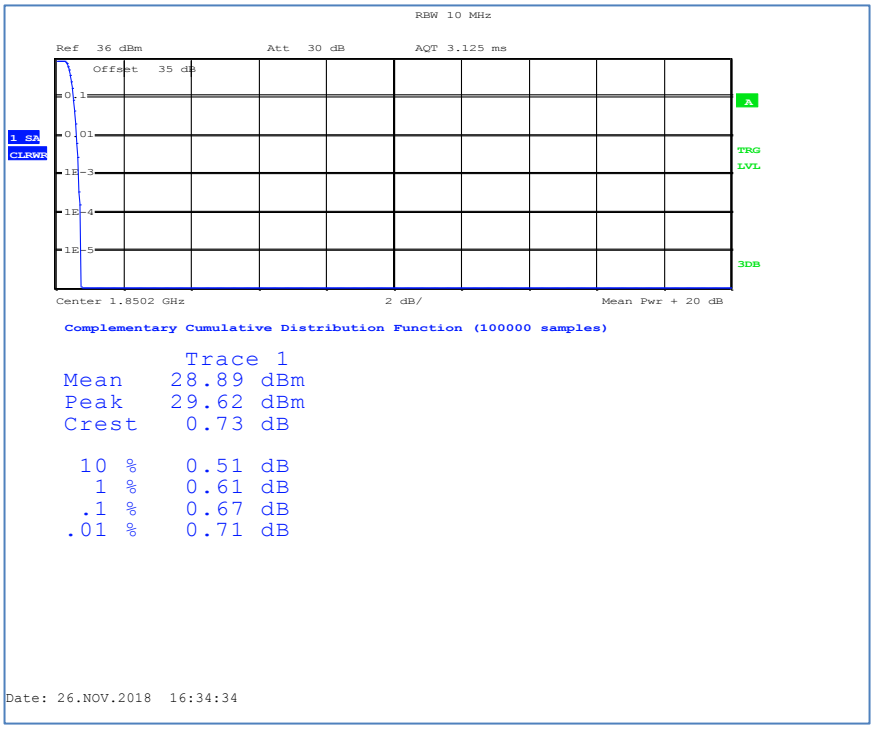
7.1.5 Peak-to-average power ratio:

Plot #	Chanel #	Frequency (MHz)	PAPR level at 0.1% probability (dB)	Limit (dB)	Result
1	GPRS 1900 / low	1850.2	0.67	< 13	Pass
	EGPRS 1900 / low	1850.2	3.62	< 13	Pass
2	GPRS 1900 / mid	1880	0.61	< 13	Pass
	EGPRS 1900 / mid	1880	3.53	< 13	Pass
3	GPRS 1900 / high	1909.8	0.61	< 13	Pass
	EGPRS 1900 / high	1909.8	3.33	< 13	Pass
4	CAT M1 B2 16QAM 6RB / low	1850.7	6.92	< 13	Pass
	CAT M1 B2 16QAM 1RB / low	1850.7	6.12	< 13	Pass
5	CAT M1 B2 16QAM 6RB / mid	1880	6.70	< 13	Pass
	CAT M1 B2 16QAM 1RB / mid	1880	5.93	< 13	Pass
6	CAT M1 B2 16QAM 6RB / high	1909.3	6.60	< 13	Pass
	CAT M1 B2 16QAM 1RB / high	1909.3	5.83	< 13	Pass
7	CAT M1 B2 QPSK 6RB / low	1850.7	5.99	< 13	Pass
	CAT M1 B2 QPSK 1RB / low	1850.7	5.29	< 13	Pass
8	CAT M1 B2 QPSK 6RB / mid	1880	5.99	< 13	Pass
	CAT M1 B2 QPSK 1RB / mid	1880	5.13	< 13	Pass
9	CAT M1 B2 QPSK 6RB / high	1909.3	5.74	< 13	Pass
	CAT M1 B2 QPSK 1RB / high	1909.3	5.03	< 13	Pass
10	NB IoT B2 / low	1850	8.78	< 13	Pass
11	NB IoT B2 / mid	1880	8.56	< 13	Pass
12	NB IoT B2 / high	1910	8.40	< 13	Pass

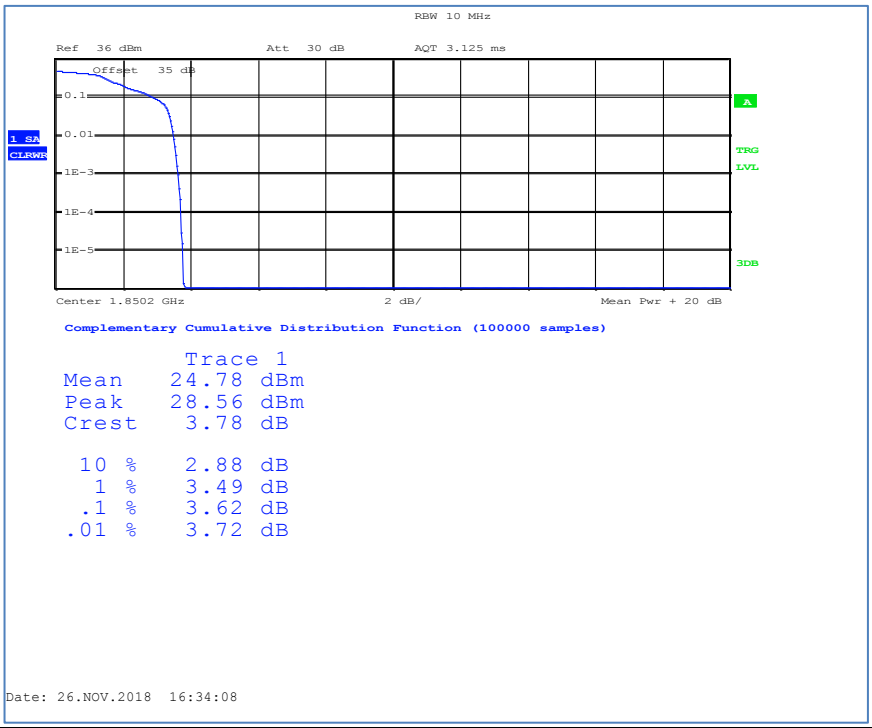
7.1.6 Measurement Plots:

Plot #1 Conducted Output Power

GPRS

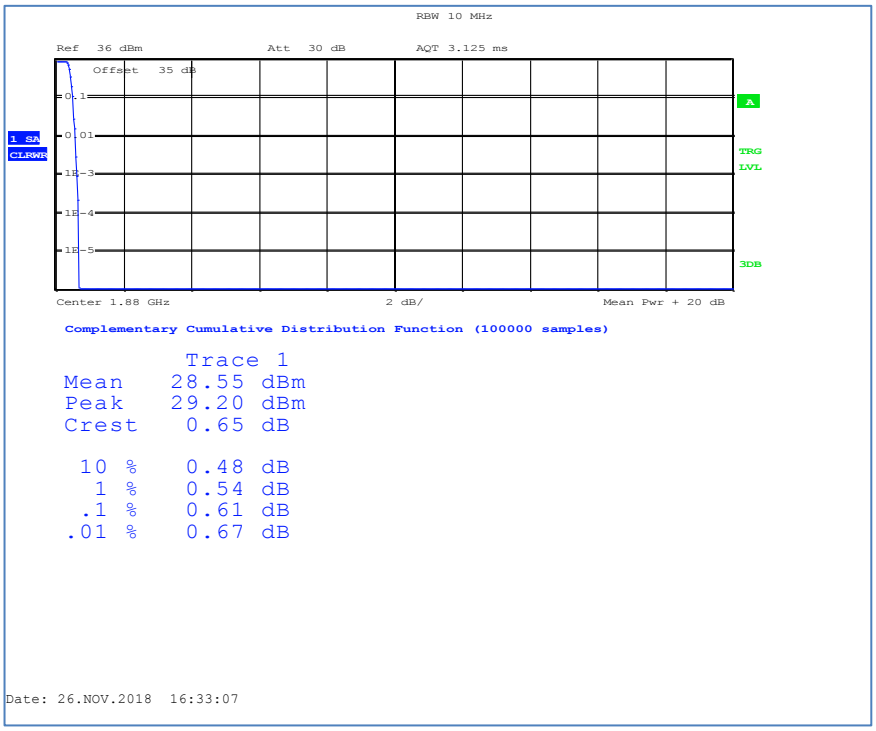


EGPRS



Plot #2 Conducted Output Power

GPRS

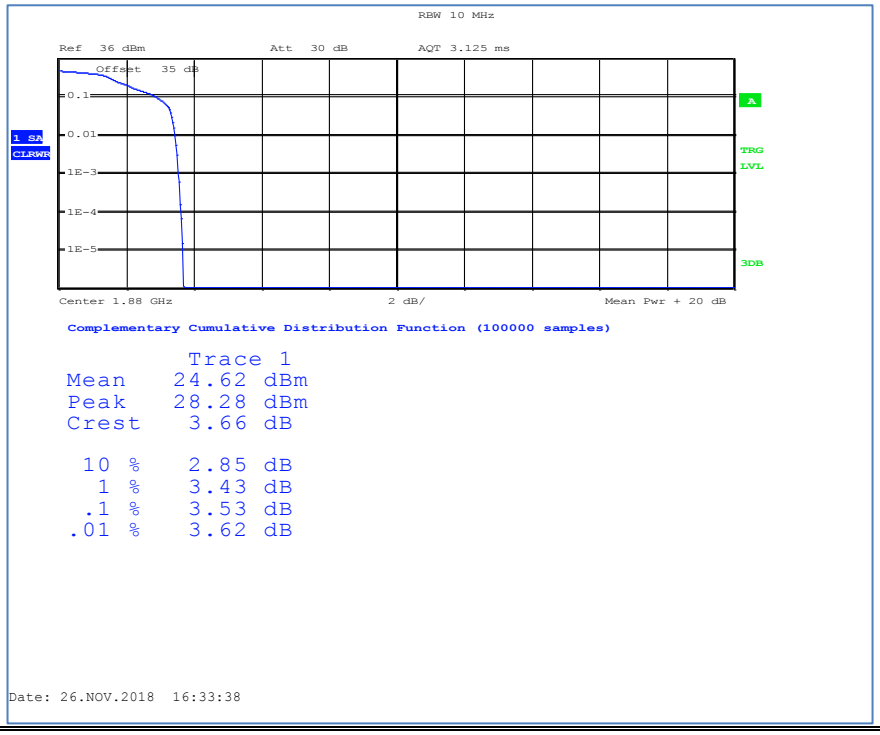


Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	28.55 dBm
Peak	29.20 dBm
Crest	0.65 dB
10 %	0.48 dB
1 %	0.54 dB
.1 %	0.61 dB
.01 %	0.67 dB

Date: 26.NOV.2018 16:33:07

EGPRS



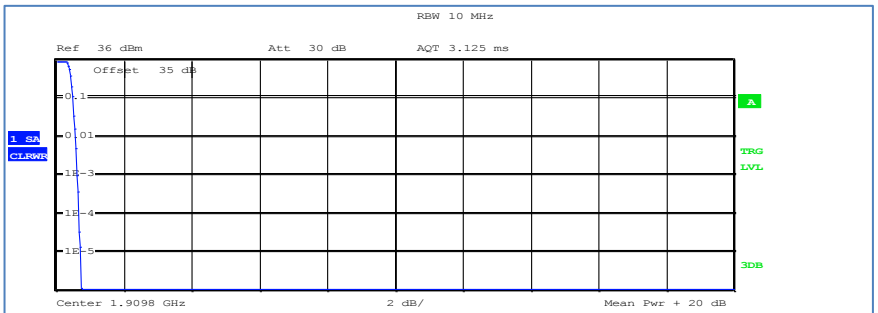
Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	24.62 dBm
Peak	28.28 dBm
Crest	3.66 dB
10 %	2.85 dB
1 %	3.43 dB
.1 %	3.53 dB
.01 %	3.62 dB

Date: 26.NOV.2018 16:33:38

Plot #3 Conducted Output Power

GPRS



Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	28.19 dBm
Peak	28.92 dBm
Crest	0.73 dB
10 %	0.48 dB
1 %	0.54 dB
.1 %	0.61 dB
.01 %	0.67 dB

Date: 26.NOV.2018 16:32:30

EGPRS

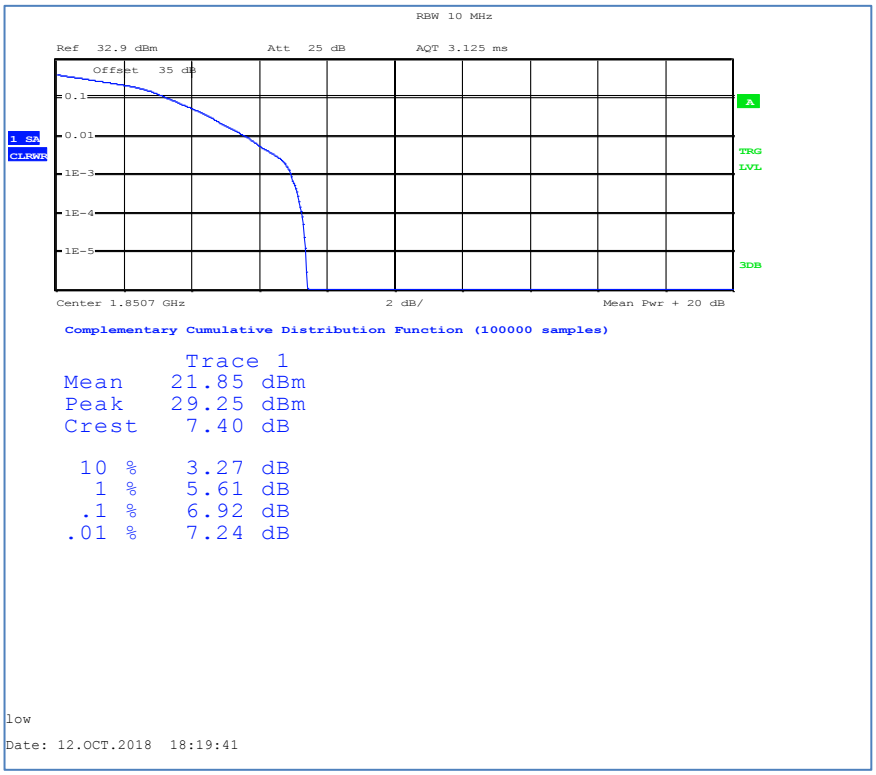
Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	24.44 dBm
Peak	27.93 dBm
Crest	3.48 dB
10 %	2.72 dB
1 %	3.24 dB
.1 %	3.33 dB
.01 %	3.40 dB

Date: 26.NOV.2018 16:32:08

Plot #4 Conducted Output Power

6RB



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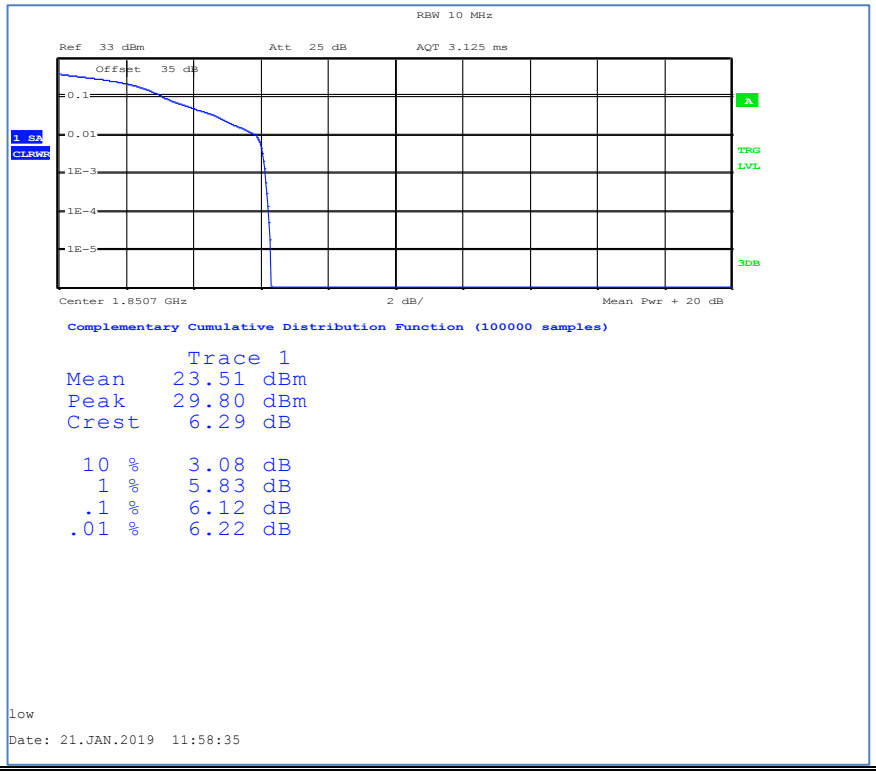
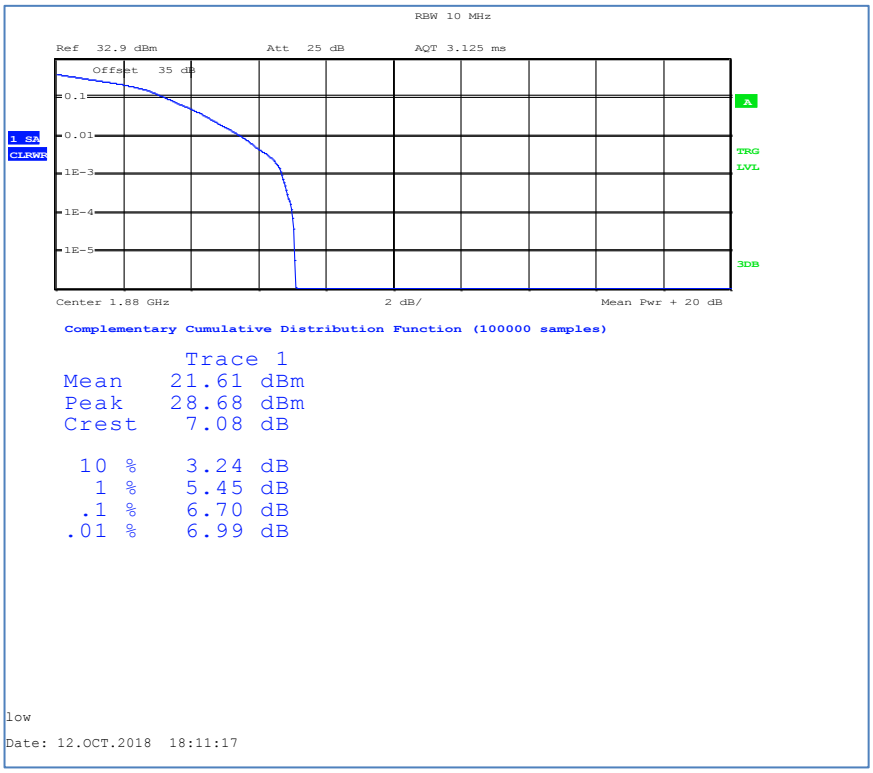
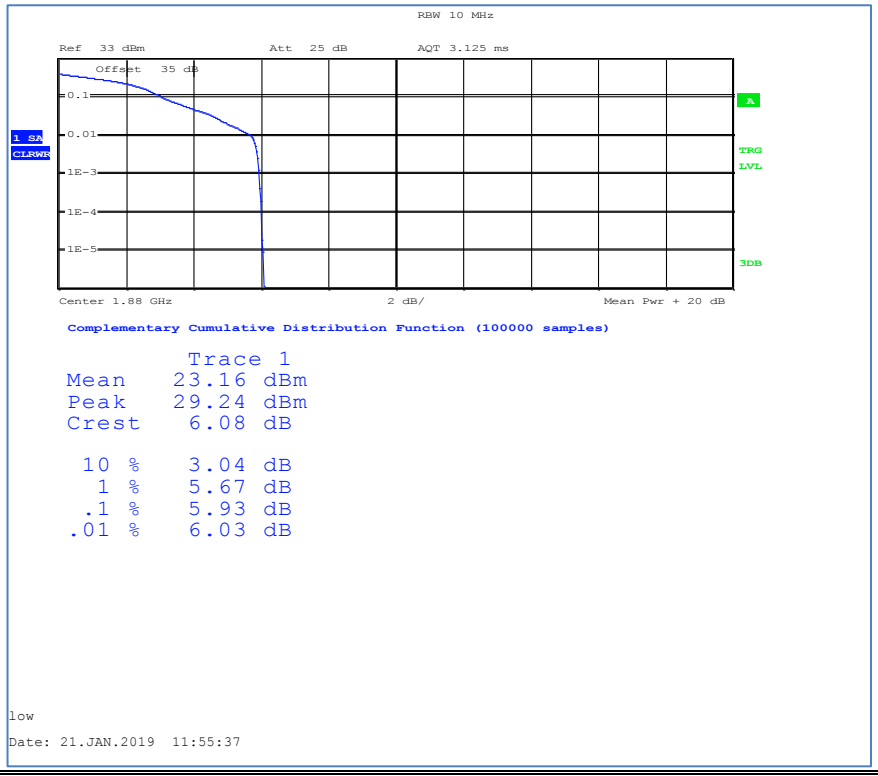


Plot #5 Conducted Output Power

6RB

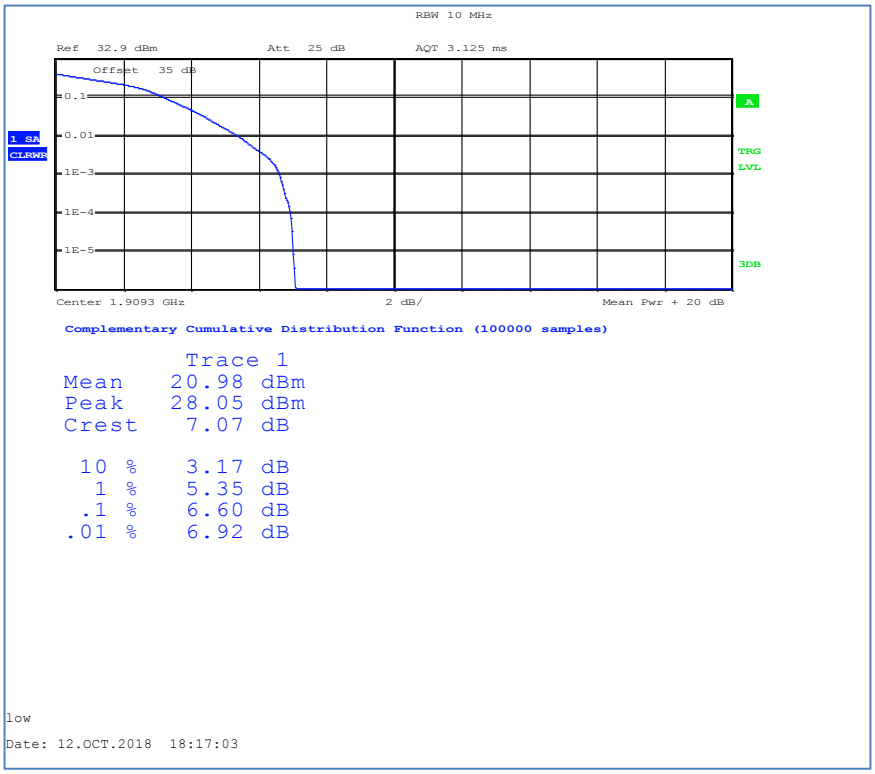


1RB



Plot #6 Conducted Output Power

6RB



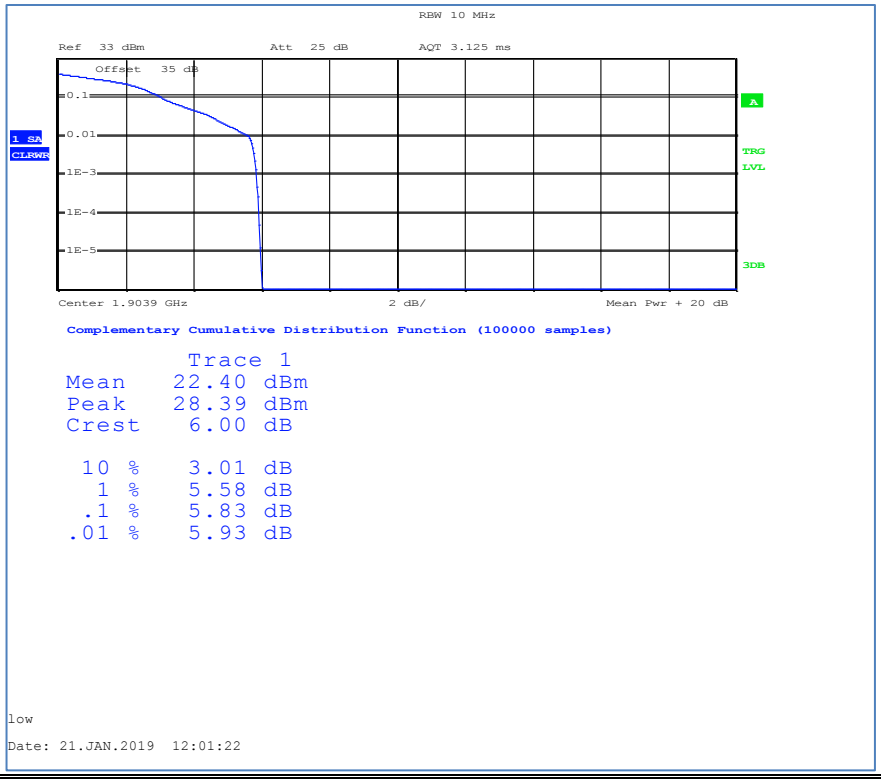
Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	20.98 dBm
Peak	28.05 dBm
Crest	7.07 dB
10 %	3.17 dB
1 %	5.35 dB
.1 %	6.60 dB
.01 %	6.92 dB

low

Date: 12.OCT.2018 18:17:03

1RB



Complementary Cumulative Distribution Function (100000 samples)

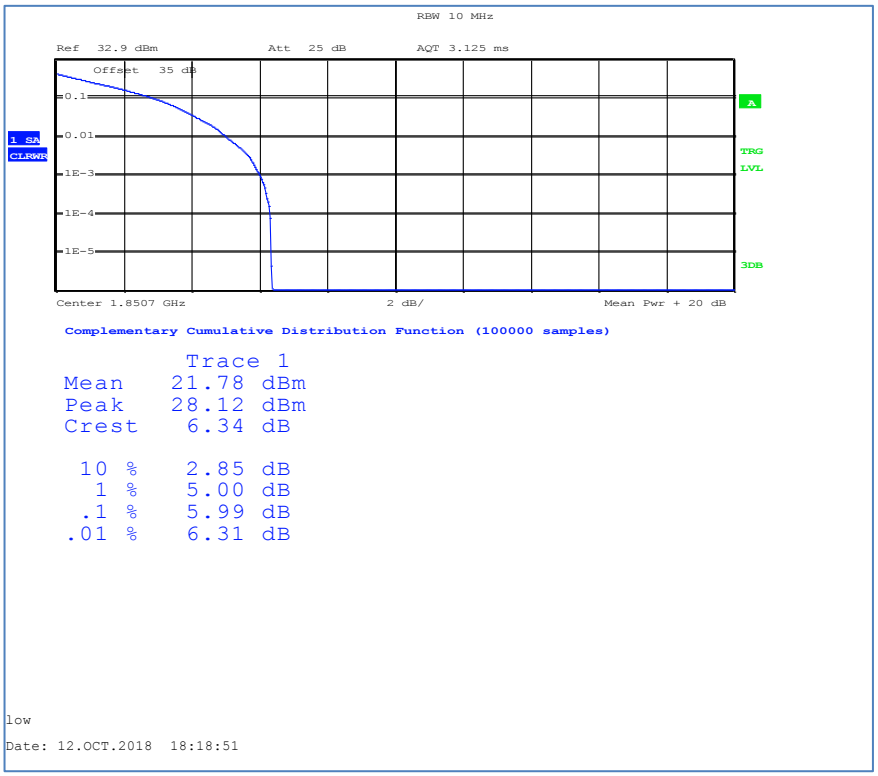
	Trace 1
Mean	22.40 dBm
Peak	28.39 dBm
Crest	6.00 dB
10 %	3.01 dB
1 %	5.58 dB
.1 %	5.83 dB
.01 %	5.93 dB

low

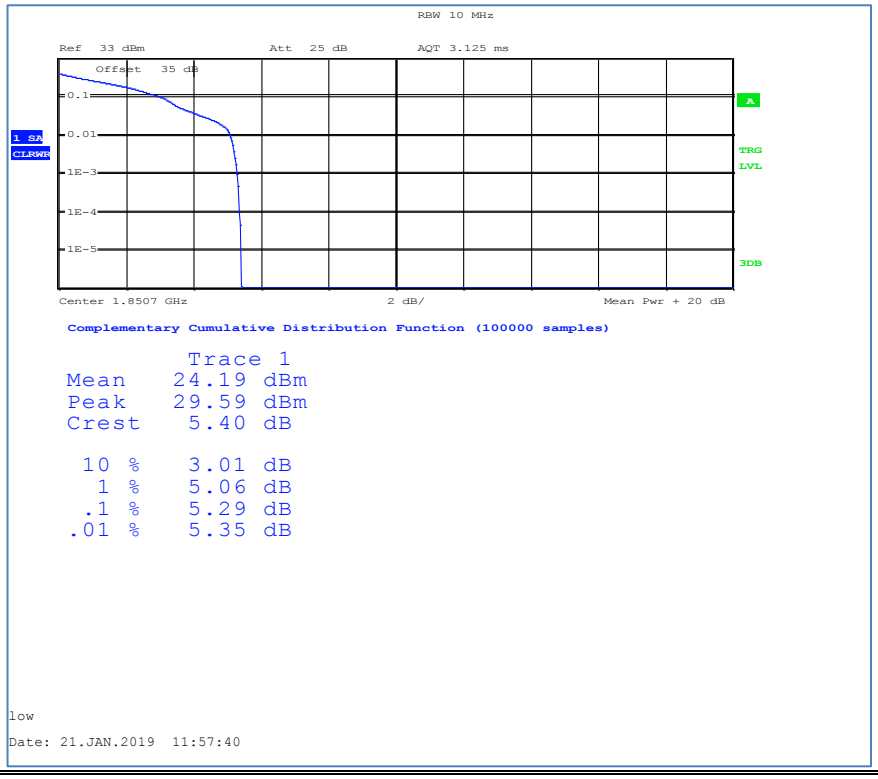
Date: 21.JAN.2019 12:01:22

Plot #7 Conducted Output Power

6RB

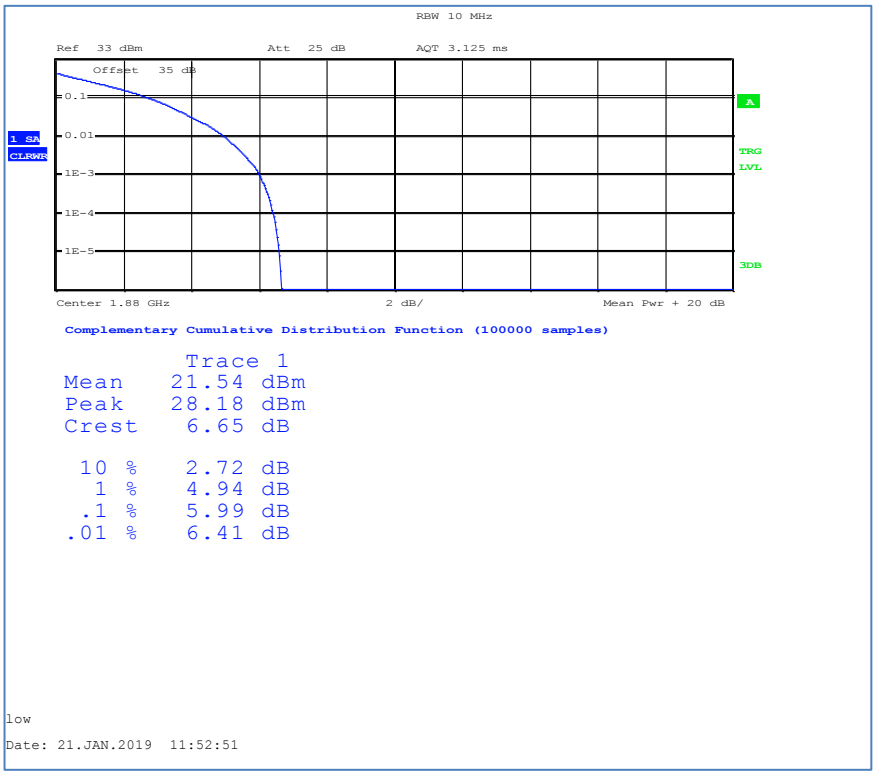


1RB



Plot #8 Conducted Output Power

6RB



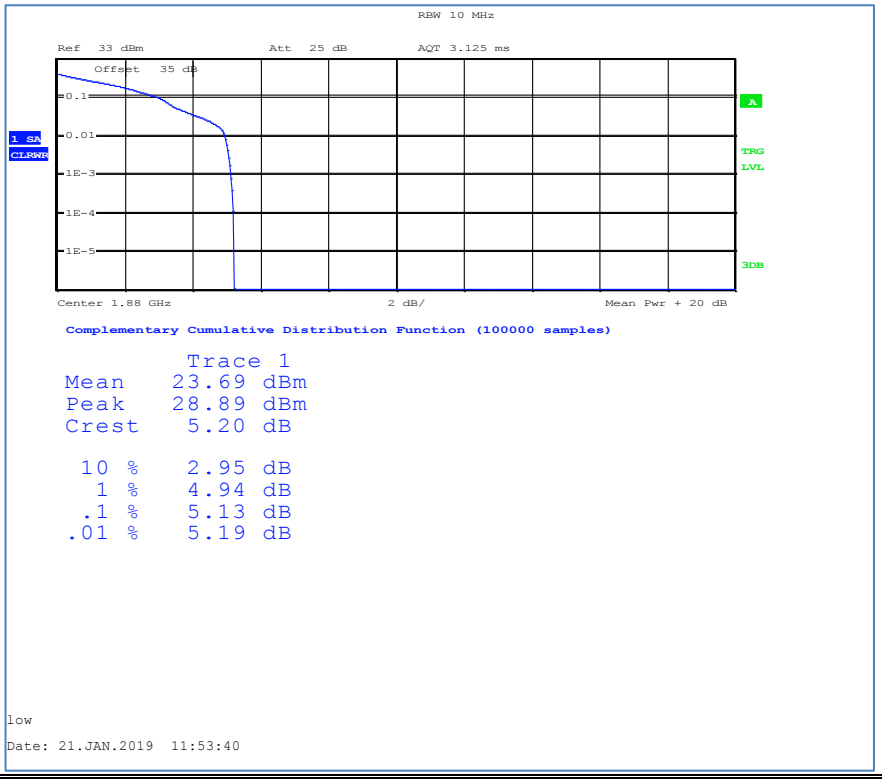
Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	21.54 dBm
Peak	28.18 dBm
Crest	6.65 dB
10 %	2.72 dB
1 %	4.94 dB
.1 %	5.99 dB
.01 %	6.41 dB

low

Date: 21.JAN.2019 11:52:51

1RB



Complementary Cumulative Distribution Function (100000 samples)

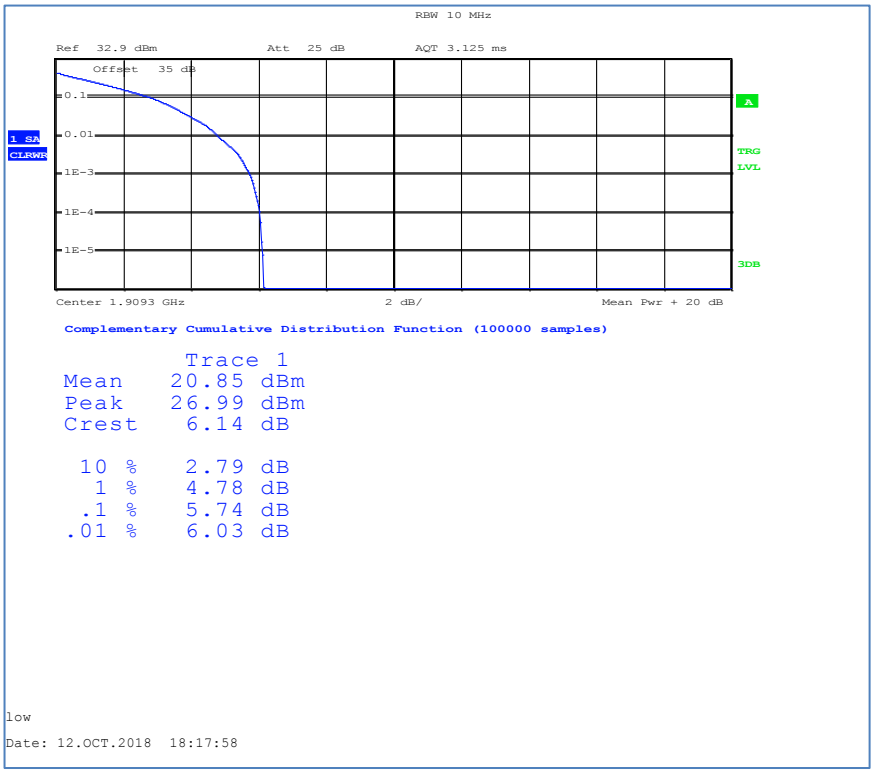
	Trace 1
Mean	23.69 dBm
Peak	28.89 dBm
Crest	5.20 dB
10 %	2.95 dB
1 %	4.94 dB
.1 %	5.13 dB
.01 %	5.19 dB

low

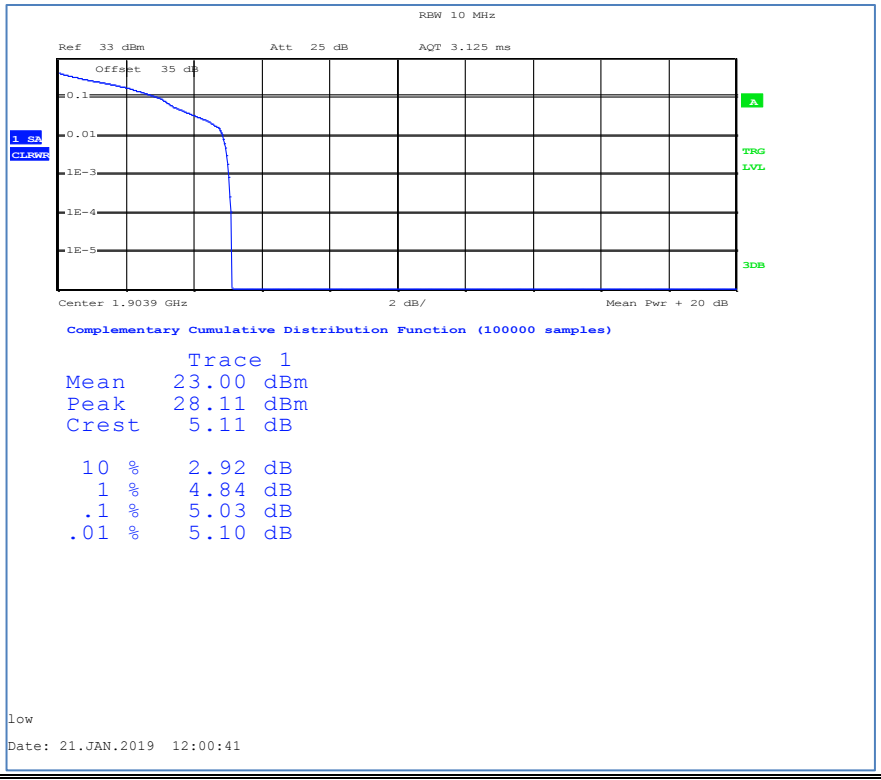
Date: 21.JAN.2019 11:53:40

Plot #9 Conducted Output Power

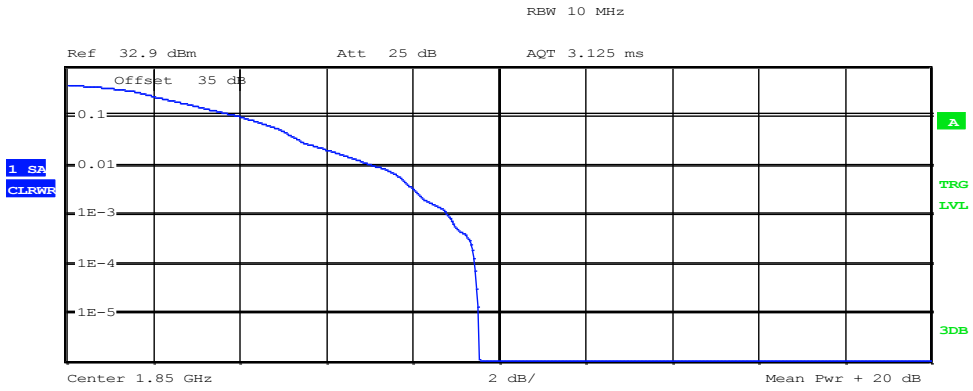
6RB



1RB



Plot #10 Conducted Output Power



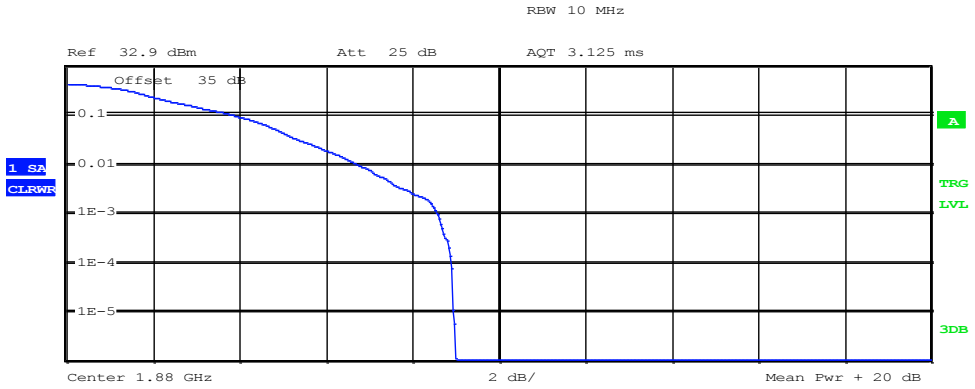
Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	20.22 dBm
Peak	29.74 dBm
Crest	9.53 dB
10 %	4.01 dB
1 %	7.12 dB
.1 %	8.78 dB
.01 %	9.42 dB

low

Date: 12.OCT.2018 19:16:07

Plot #11 Conducted Output Power



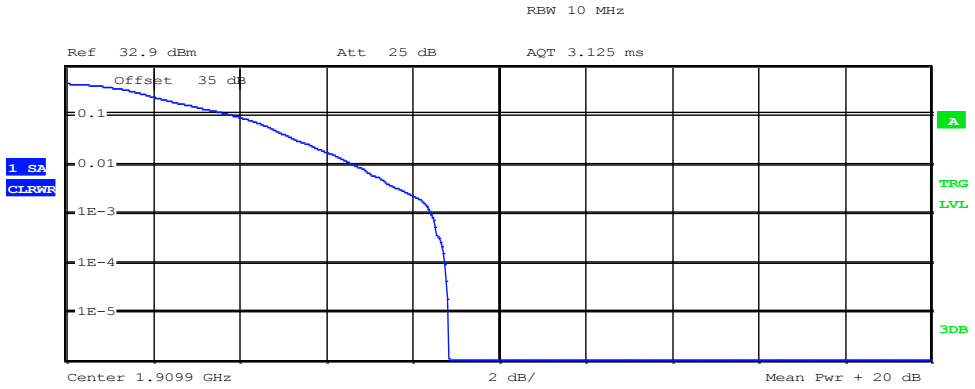
Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	20.46 dBm
Peak	29.46 dBm
Crest	9.00 dB
10 %	3.88 dB
1 %	6.73 dB
.1 %	8.56 dB
.01 %	8.91 dB

low

Date: 12.OCT.2018 19:14:12

Plot #12 Conducted Output Power



Complementary Cumulative Distribution Function (100000 samples)

	Trace 1
Mean	20.00 dBm
Peak	28.83 dBm
Crest	8.83 dB
10 %	3.85 dB
1 %	6.63 dB
.1 %	8.40 dB
.01 %	8.75 dB

low

Date: 12.OCT.2018 19:17:06

7.2 Frequency Stability

7.2.1 Measurement utilizing KDB 971168 D01 and ANSI C63.26-2015 Subclause 5.6

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 1

Spectrum Analyzer settings:

- RBW =30 kHz
- VBW ≥ 300Hz
- Set span = 10MHz
- Sweep time = auto couple
- Detector = Pk
- Trace mode = Max Hold
- 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

7.2.2 Limits:

7.2.2.1 Part 24.235 Frequency stability:

The frequency stability shall be sufficient to ensure that the fundamental emission stays within the authorized frequency block.

7.2.2.2 RSS-133 Part 6.3 Frequency Stability

The carrier frequency shall not depart from the reference frequency, in excess of ±2.5 ppm for mobile stations and ±1.0 ppm for base stations. In lieu of meeting the above stability values, the test report may show that the frequency stability is sufficient to ensure that the emission bandwidth stays within the operating frequency block when tested to the temperature and supply voltage variations specified in RSS-Gen.

7.2.3 Test conditions and setup:

Ambient Temperature (C)	EUT Set-Up #	EUT operating mode	Power Input (VDC)
22°C	1	1, 2, and 3	3.8

7.2.4 Measurement result:

Temperature Frequency Stability - GSM 1900					
Temperature (°C)	MCF (MHz)	ACF (MHz)	Frequency Stability (ppm)	Limit (ppm)	Result
-30	1879.9995	1880	0.27	2.5	Pass
-20	1879.9990	1880	0.53	2.5	Pass
-10	1879.9995	1880	0.27	2.5	Pass
0	1880.0000	1880	0.00	2.5	Pass
10	1880.0005	1880	0.27	2.5	Pass
20	1880.0000	1880	0.00	2.5	Pass
30	1880.0010	1880	0.53	2.5	Pass
40	1880.0010	1880	0.53	2.5	Pass
50	1880.0010	1880	0.53	2.5	Pass

Voltage Frequency Stability - GSM 1900					
Voltage(VDC)	MCF (MHz)	ACF (MHz)	Frequency Stability (ppm)	Limit (ppm)	Result
3.2V	1879.9980	1880	0.80	2.5	Pass
3.8V	1879.9985	1880	1.06	2.5	Pass
4.5V	1879.9985	1880	0.80	2.5	Pass

Temperature Frequency Stability– CAT M1 B2					
Temperature (°C)	MCF (MHz)	ACF (MHz)	Frequency Stability (ppm)	Limit (ppm)	Result
-30	1880.0025	1880	1.33	2.5	Pass
-20	1879.9967	1880	1.76	2.5	Pass
-10	1880.0015	1880	0.80	2.5	Pass
0	1880.0021	1880	1.12	2.5	Pass
10	1880.0018	1880	0.96	2.5	Pass
20	1880.0003	1880	0.16	2.5	Pass
30	1880.0018	1880	0.96	2.5	Pass
40	1880.0008	1880	0.43	2.5	Pass
50	1880.0013	1880	0.69	2.5	Pass

Voltage Frequency Stability - CAT M1 B2					
Voltage(VDC)	MCF (MHz)	ACF (MHz)	Frequency Stability (ppm)	Limit (ppm)	Result
3.2V	1880.0007	1880	0.37	2.5	Pass
3.8V	1880.0003	1880	0.16	2.5	Pass
4.5V	1880.0008	1880	0.43	2.5	Pass

Temperature Frequency Stability– NB IoT B2					
Temperature (°C)	MCF (MHz)	ACF (MHz)	Frequency Stability (ppm)	Limit (ppm)	Result
-30	1880.0032	1880	1.72	2.5	Pass
-20	1880.0024	1880	1.28	2.5	Pass
-10	1880.0017	1880	0.89	2.5	Pass
0	1880.0022	1880	1.14	2.5	Pass
10	1880.0013	1880	0.66	2.5	Pass
20	1880.0017	1880	0.90	2.5	Pass
30	1880.0016	1880	0.82	2.5	Pass
40	1880.0014	1880	0.73	2.5	Pass
50	1880.0012	1880	0.64	2.5	Pass

Voltage Frequency Stability - NB IoT B2					
Voltage(VDC)	MCF (MHz)	ACF (MHz)	Frequency Stability (ppm)	Limit (ppm)	Result
3.2V	1880.0014	1880	0.72	2.5	Pass
3.8V	1880.0003	1880	0.13	2.5	Pass
4.5V	1880.0024	1880	1.28	2.5	Pass

7.3 Occupied Bandwidth

7.3.1 Measurement utilizing KDB 971168 D01 and ANSI C63.26-2015 Subclause 5.4.4

Spectrum Analyzer settings:

- RBW ≥ 1 to 5 % of anticipated OBW.
- VBW ≥ 3 × RBW.
- Set span ≥ 2 to 5 times OBW
- Sweep time = auto couple.
- Detector = Peak
- Trace mode = Max hold.
- Allow trace to fully stabilize.
- Use the 99 % power bandwidth function of the spectrum analyzer (if available) and report the measured bandwidth.

7.3.2 Requirement: FCC Part 2.1049

7.3.2.1 FCC Part 2.1049

The occupied bandwidth, that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission shall be measured under the following conditions as applicable:
(h) Transmitters employing digital modulation techniques—when modulated by an input signal such that its amplitude and symbol rate represent the maximum rated conditions under which the equipment will be operated. The signal shall be applied through any filter networks, pseudo-random generators or other devices required in normal service. Additionally, the occupied bandwidth shall be shown for operation with any devices used for modifying the spectrum when such devices are optional at the discretion of the user.

7.3.2.2 RSS-133 Part 6.2; Types of Modulation

Equipment certified under this standard shall use digital modulation.

7.3.3 Test conditions and setup:

Ambient Temperature (C)	EUT Set-Up #	EUT operating mode	Power Input (VAC)
22	1	1, 2, and 3	110 V / 60 Hz

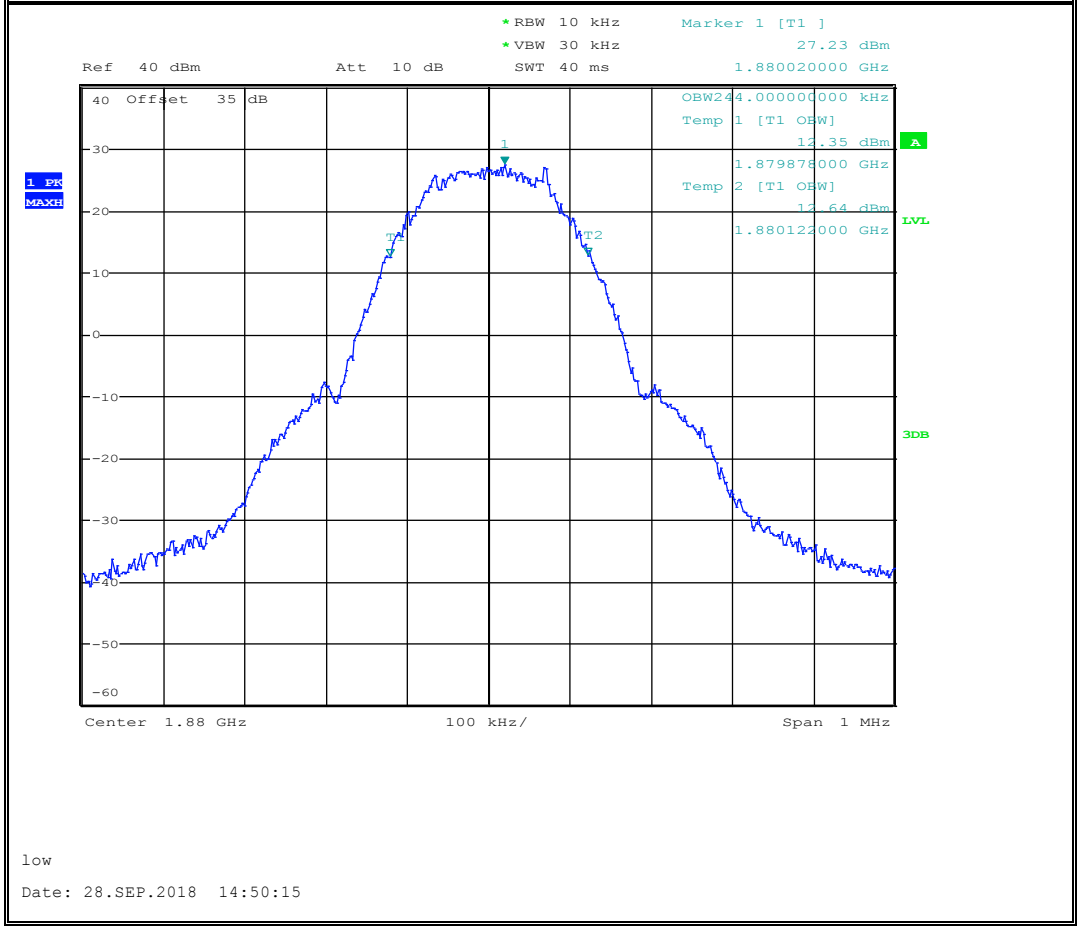
7.3.4 Measurement result:

Plot #	EUT operating mode / Modulation	OBW (MHz)
1	GSM 1900 / GMSK	0.244
2	GSM 1900 / 8PSK	0.244
3	CAT M1 B2 / QPSK	1.100
4	CAT M1 B2 / 16-QAM	1.110
5	NB IoT B2 / QPSK	0.189

7.3.5 Measurement Plots:

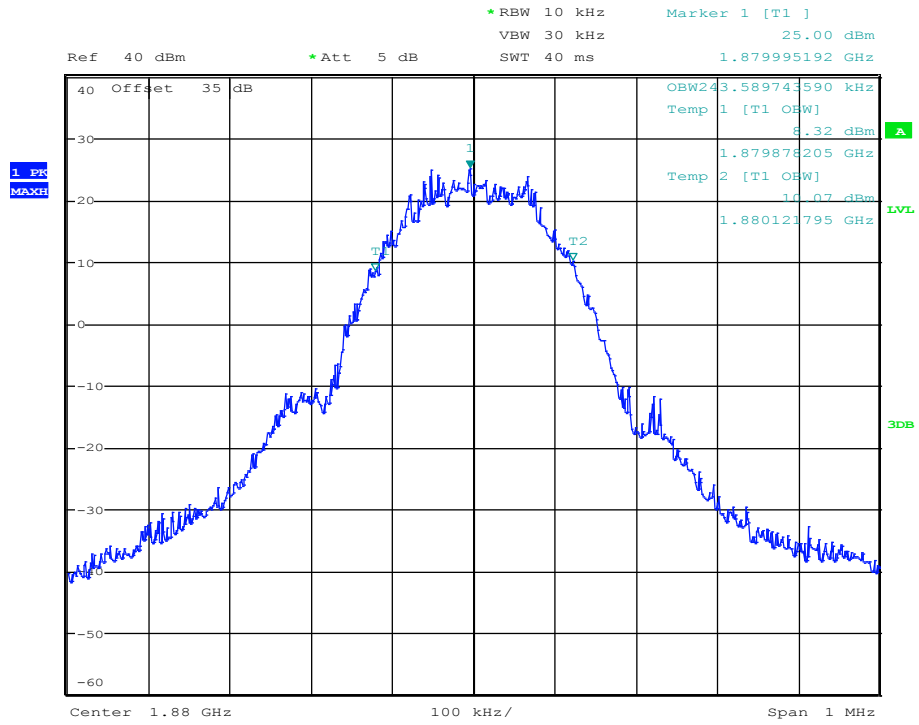
Plot #1

GSM 1900 Mid Channel



Plot #2

GSM 1900 Mid Channel

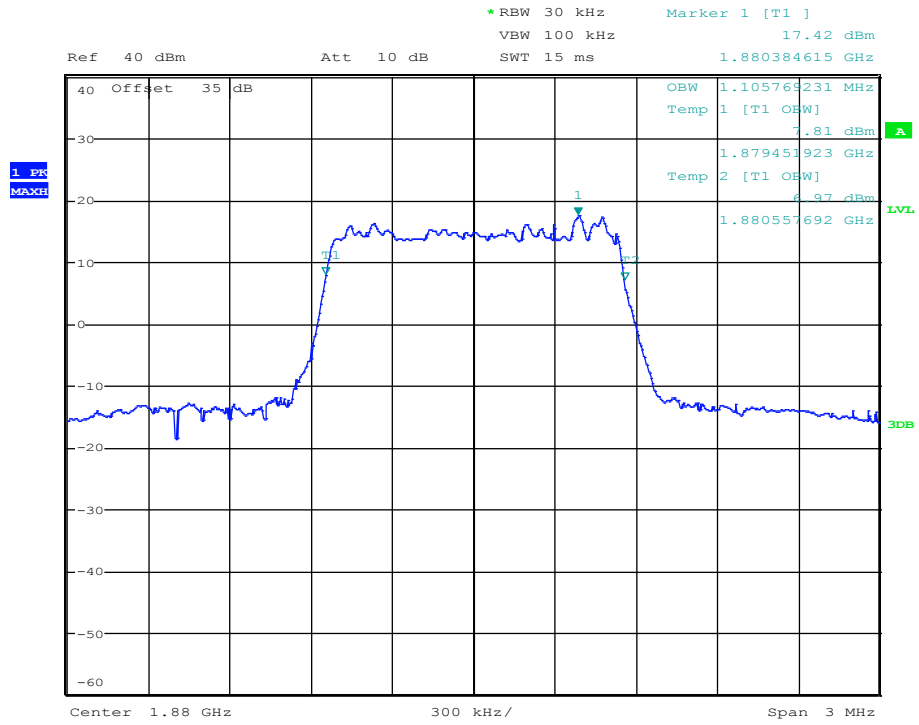


low

Date: 19.NOV.2018 18:37:05

Plot #3

CAT M1 B2 Mid Channel

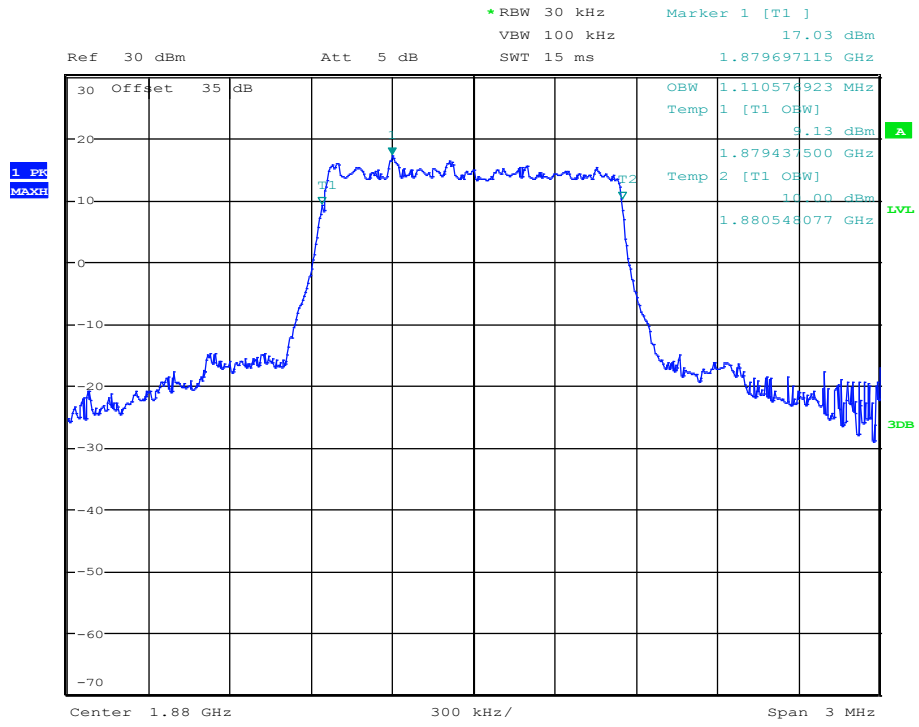


low

Date: 9.OCT.2018 12:37:17

Plot # 4

CAT M1 B2 Mid Channel

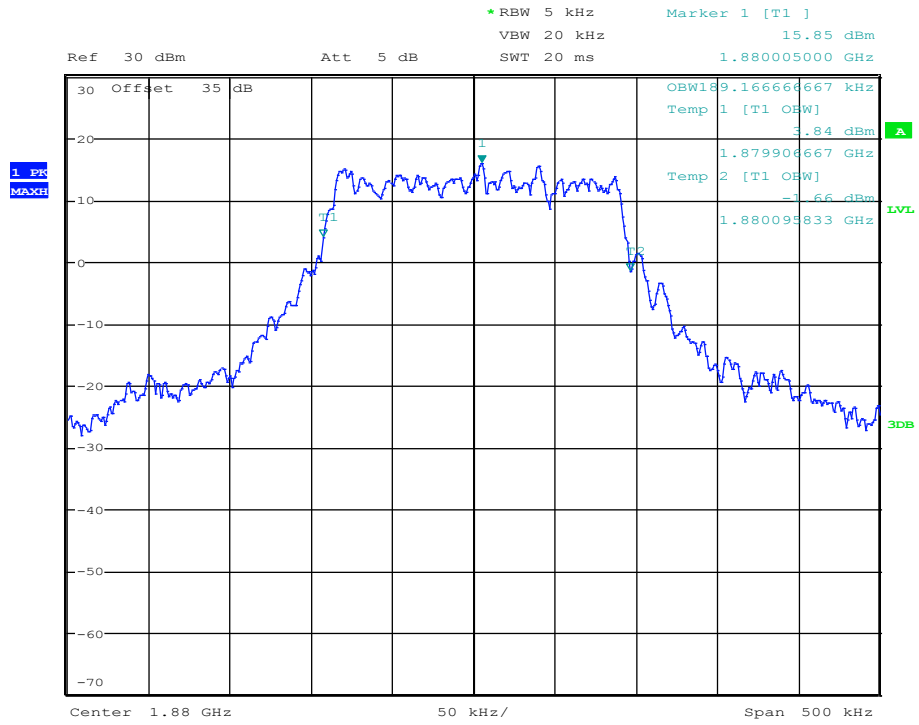


low

Date: 15.OCT.2018 12:25:02

Plot # 5

NB IoT B2 Mid Channel



low

Date: 15.OCT.2018 15:48:08

7.4 Band Edge Compliance

7.4.1 Measurement utilizing KDB 971168 D01 and ANSI C63.26-2015 Subclause 5.7.3

Spectrum Analyzer settings:

- RBW ≥ 1% of OBW
- VBW ≥ 3 × RBW
- Set span ≥ 1MHz
- Sweep time = auto couple
- Detector = RMS
- Trace mode = max hold
- Allow trace to fully stabilize
- Use the peak marker function to determine the peak amplitude level

7.4.2 Limits:

7.4.2.1 FCC Part 24.238

(a) Out of band emissions. The power of any emission outside of the authorized operating frequency ranges must be attenuated below the transmitting power (P) by a factor of at least 43 + 10 log(P) dB.

7.4.2.2 RSS-133 Part 6.5 Transmitter Unwanted Emissions

Mobile and base station equipment shall comply with the limits in (i) and (ii) below.
i.In the first 1.0 MHz band immediately outside and adjacent to each of the sub-bands specified in Section 5.1, the power of emissions per any 1% of the occupied bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least 43 + 10 log10p (watts).
ii.After the first 1.0 MHz immediately outside and adjacent to each of the sub-bands, the power of emissions in any 100 kHz bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least 43 + 10 log10 p (watts). If the measurement is performed using 1% of the occupied bandwidth, power integration over 100 kHz is required.

Note: The limit calculation result is a constant of -13dBm.

7.4.3 Test conditions and setup:

Ambient Temperature (C)	EUT Set-Up #	EUT operating mode	Power Input (VDC)	Measurement Path Correction (dB)
22	1	1, 2, and 3	110V / 60 Hz	35

7.4.4 Measurement result:

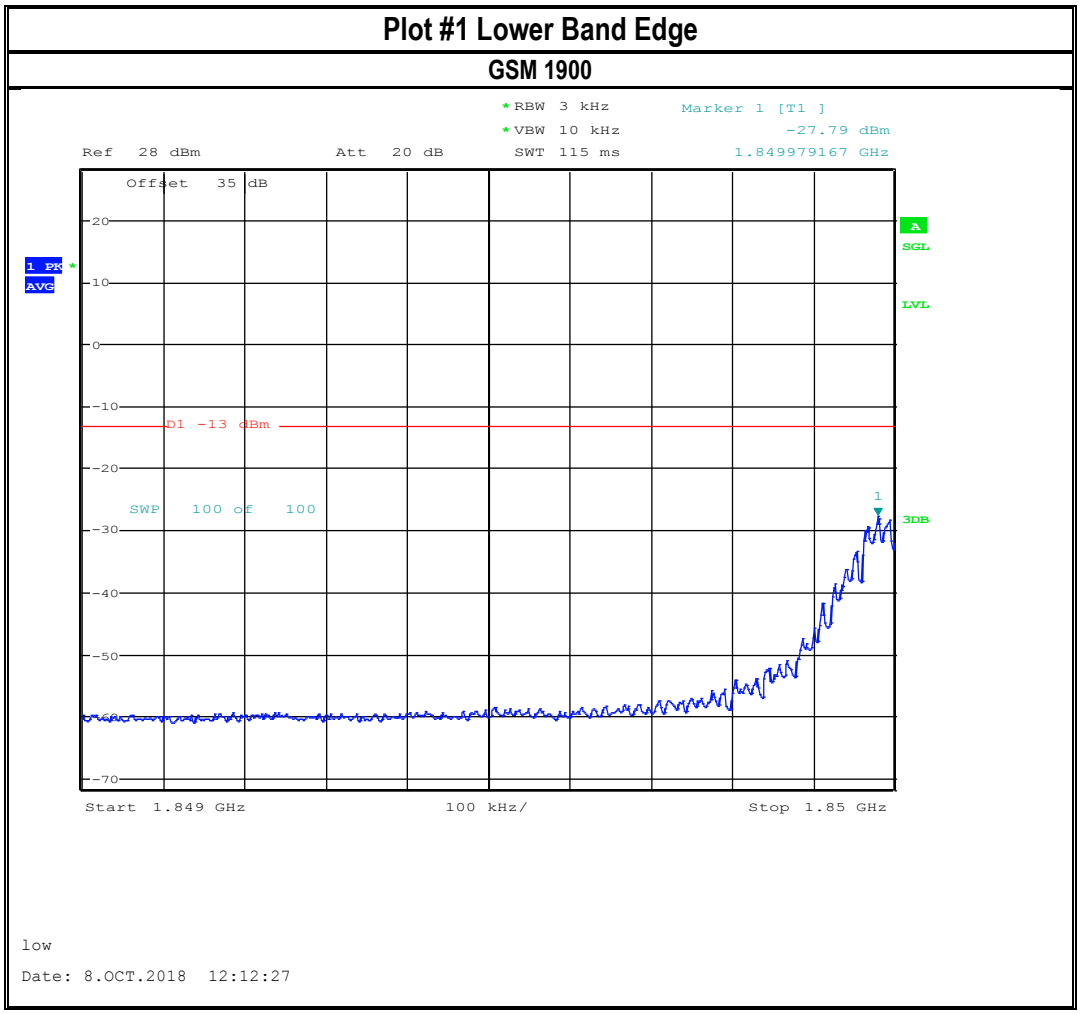
Plot #	EUT operating mode	Band Edge	RMS RF Power (dBm) See Note 1	Limit (dBm)	Result
1	GSM 1900	Lower Band Edge	-25.47	-13	Pass
2	GSM 1900	Upper Band Edge	-27.44	-13	Pass
3	CAT M1 B2	Lower Band Edge	-27.74	-13	Pass
4	CAT M1 B2	Upper Band Edge	-30.86	-13	Pass
5	NB IoT B2	Lower Band Edge	-28.69	-13	Pass
6	NB IoT B2	Upper Band Edge	-26.48	-13	Pass

Note 1: RF Power is adjusted for 2.32dBi antenna gain

7.4.5 Measurement Plots:

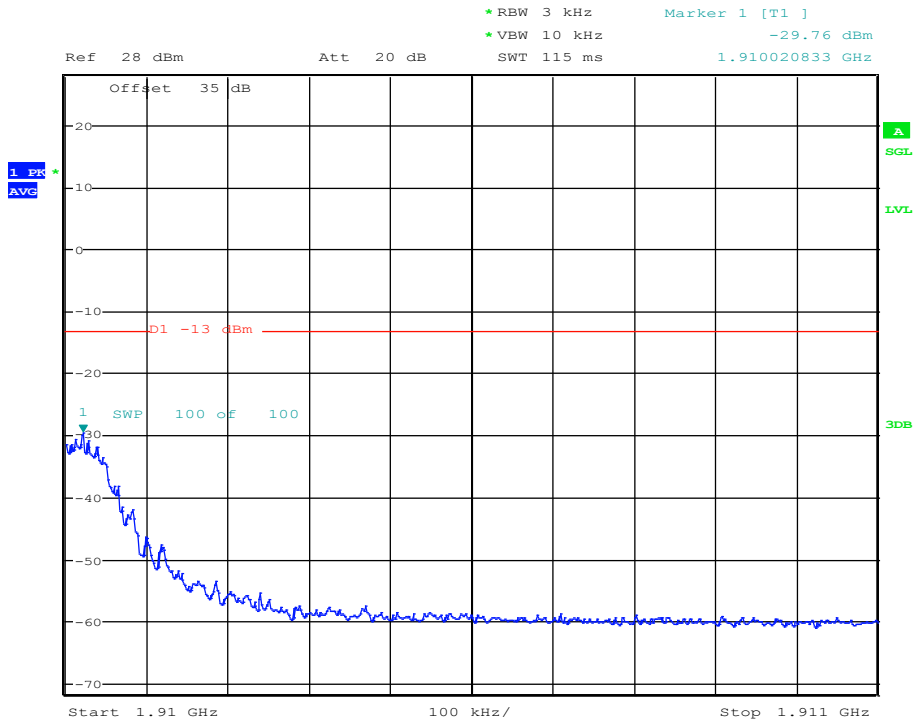
Plot #1 Lower Band Edge

GSM 1900



Plot #2 Upper Band Edge

GSM 1900

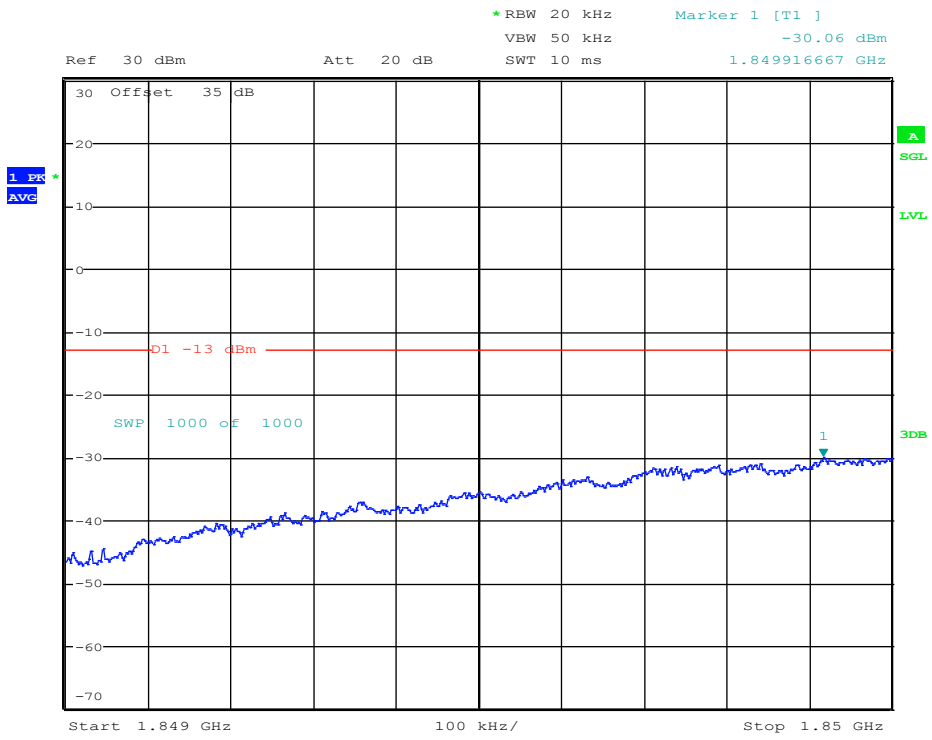


low

Date: 8.OCT.2018 12:10:17

Plot #3 Lower Band Edge

CAT M1 B2

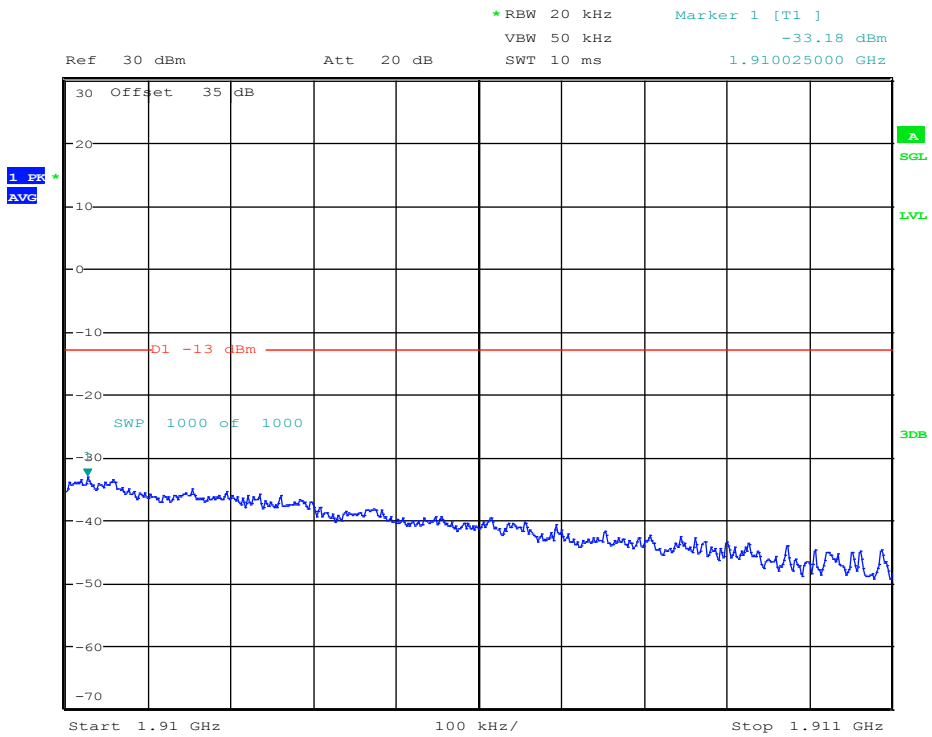


low

Date: 15.OCT.2018 13:18:57

Plot #4 Upper Band Edge

CAT M1 B2

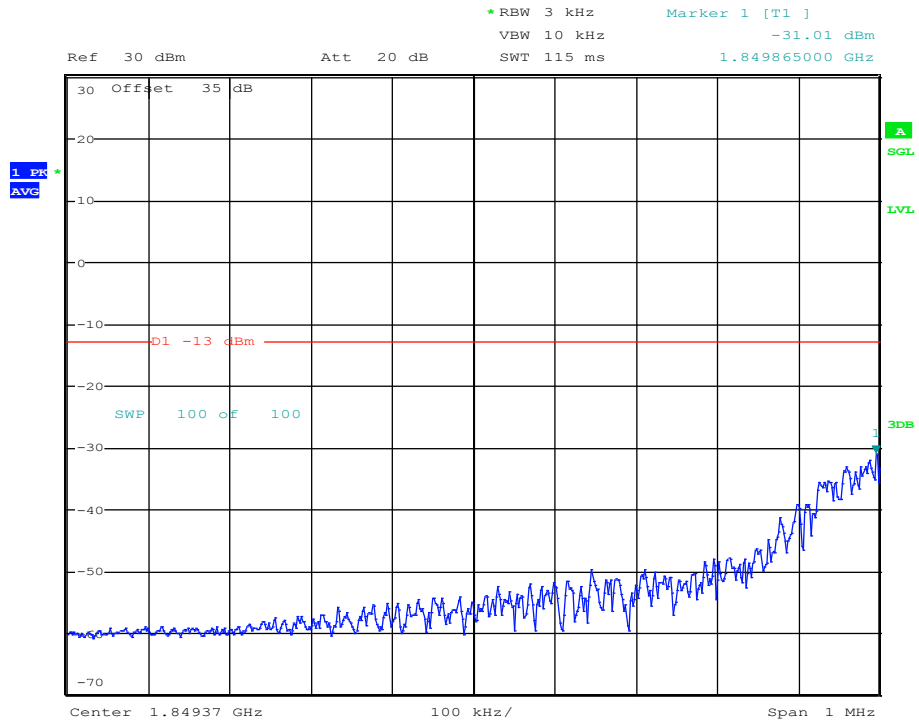


low

Date: 15.OCT.2018 13:21:29

Plot #5 Lower Band Edge

NB IoT B2

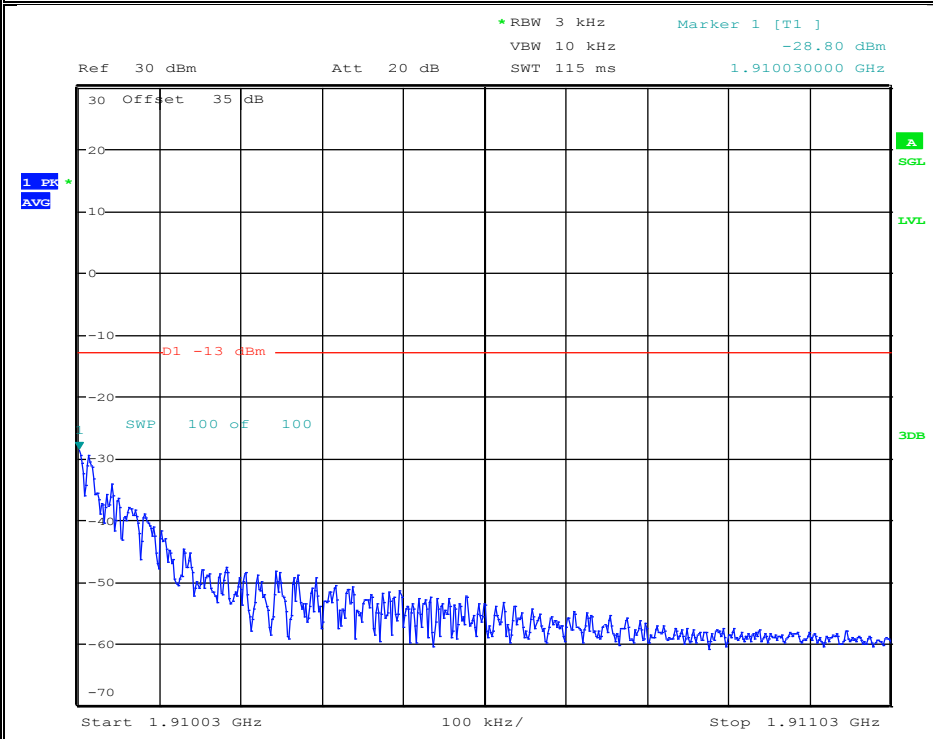


low

Date: 15.OCT.2018 16:43:56

Plot #6 Upper Band Edge

NB IoT B2



low

Date: 15.OCT.2018 16:51:18

7.5 Conducted Spurious Emissions

7.5.1 Measurement utilizing KDB 971168 D01 and ANSI C63.26-2015 Subclause 5.7.4

Spectrum Analyzer settings:

- RBW = 1 MHz
- VBW = 3 MHz
- Sweep time = Auto couple
- Detector = RMS
- Trace mode = Max Hold

7.5.2 Limits:

7.5.2.1 FCC Part 24.238

Out of band emissions. The power of any emission outside of the authorized operating frequency ranges must be attenuated below the transmitting power (P) by a factor of at least 43 + 10 log(P) dB.

7.5.2.2 RSS-133 Part 6.5; Transmitter Unwanted Emissions

Mobile and base station equipment shall comply with the limits in (i) and (ii) below.

i.In the first 1.0 MHz band immediately outside and adjacent to each of the sub-bands specified in Section 5.1, the power of emissions per any 1% of the occupied bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least 43 + 10 log10p (watts).

ii.After the first 1.0 MHz immediately outside and adjacent to each of the sub-bands, the power of emissions in any 100 kHz bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least 43 + 10 log10 p (watts). If the measurement is performed using 1% of the occupied bandwidth, power integration over 100 kHz is required.

Note: The limit calculation result is a constant of -13 dBm.

7.5.3 Test conditions and setup:

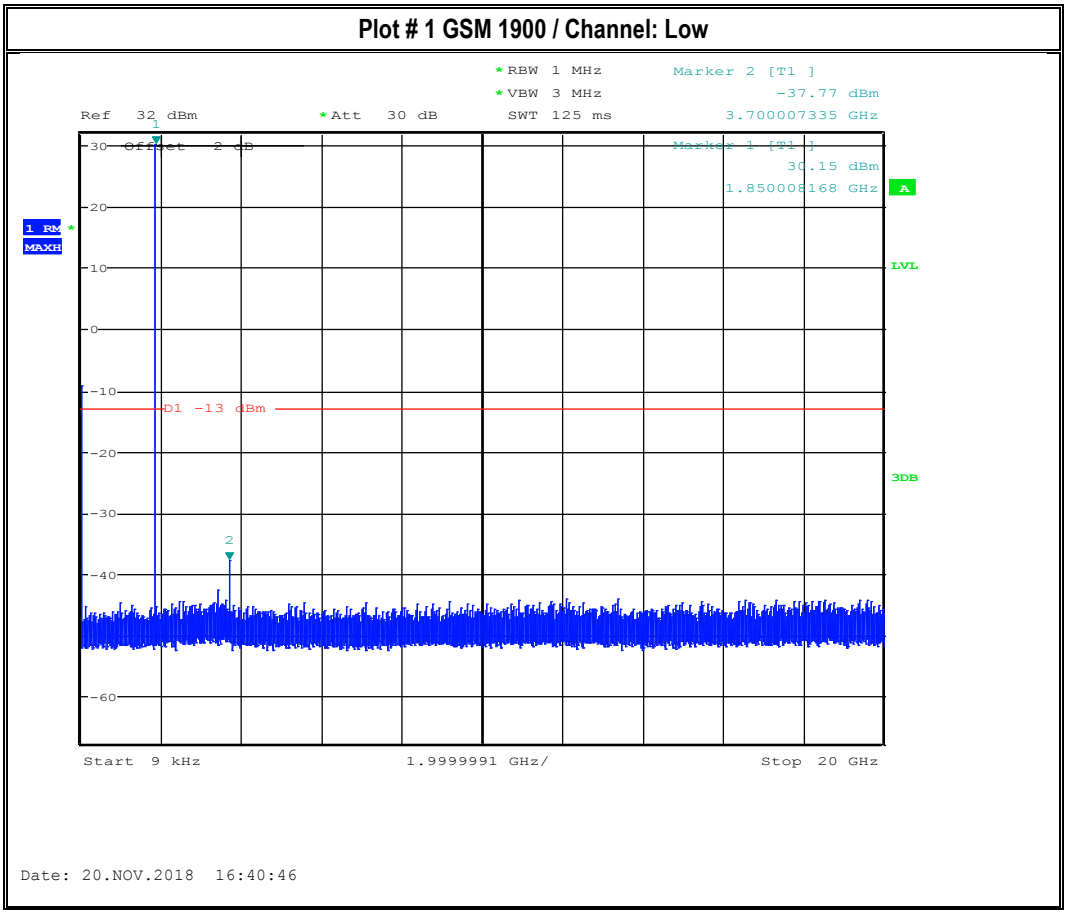
Ambient Temperature (C)	EUT Set-Up #	EUT operating mode	Power Input
22	1	1, 2, and 3	110 V / 60 Hz

7.5.4 Measurement result:

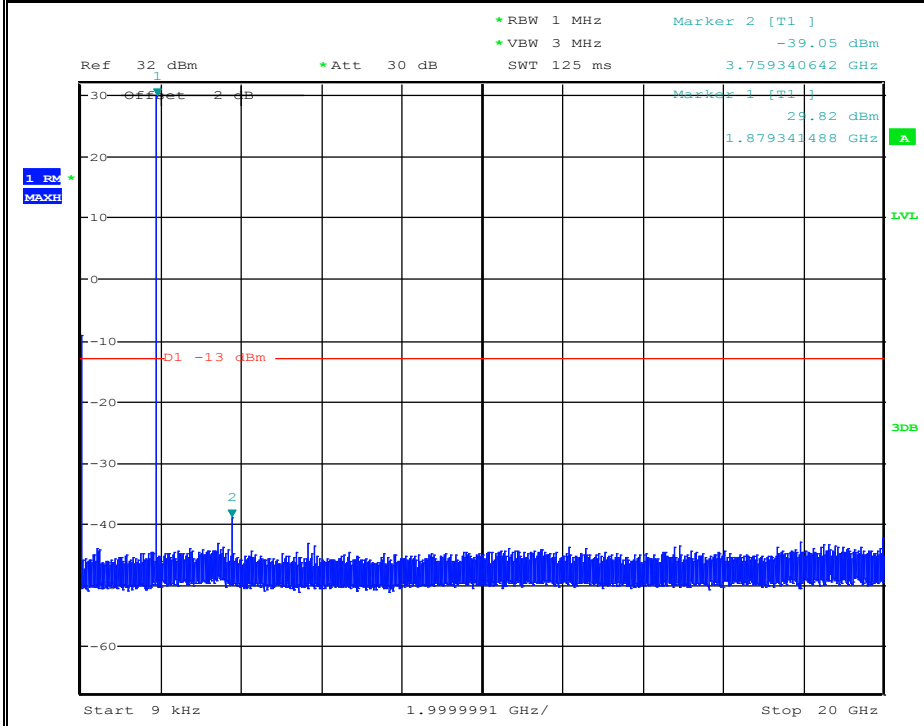
Plot #	Channel	EUT operating mode	Scan Frequency	Limit (dBm)	Result
1	Low	GSM 1900	9 kHz – 20 GHz	-13	Pass
2	Mid	GSM 1900	9 kHz – 20 GHz	-13	Pass
3	High	GSM 1900	9 kHz – 20 GHz	-13	Pass
4	Low	CAT M1 B2	9 kHz – 20 GHz	-13	Pass
5	Mid	CAT M1 B2	9 kHz – 22 GHz	-13	Pass
6	High	CAT M1 B2	9 kHz – 20 GHz	-13	Pass
7	Low	NB IoT B2	9 kHz – 20 GHz	-13	Pass
8	Mid	NB IoT B2	9 kHz – 22 GHz	-13	Pass
9	High	NB IoT B2	9 kHz – 20 GHz	-13	Pass

7.5.5 Measurement Plots:

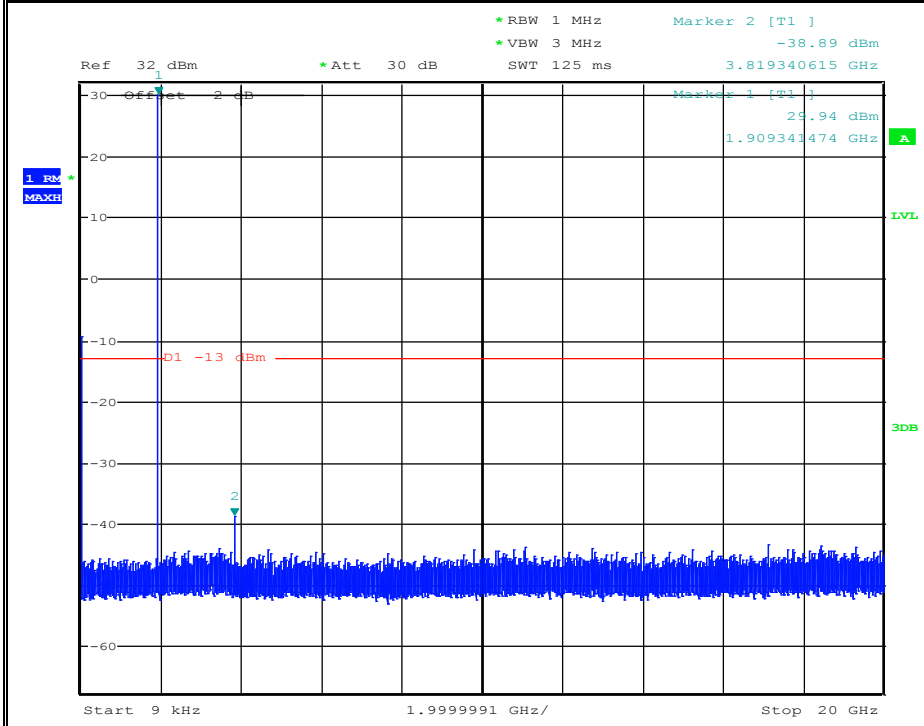
Plot # 1 GSM 1900 / Channel: Low



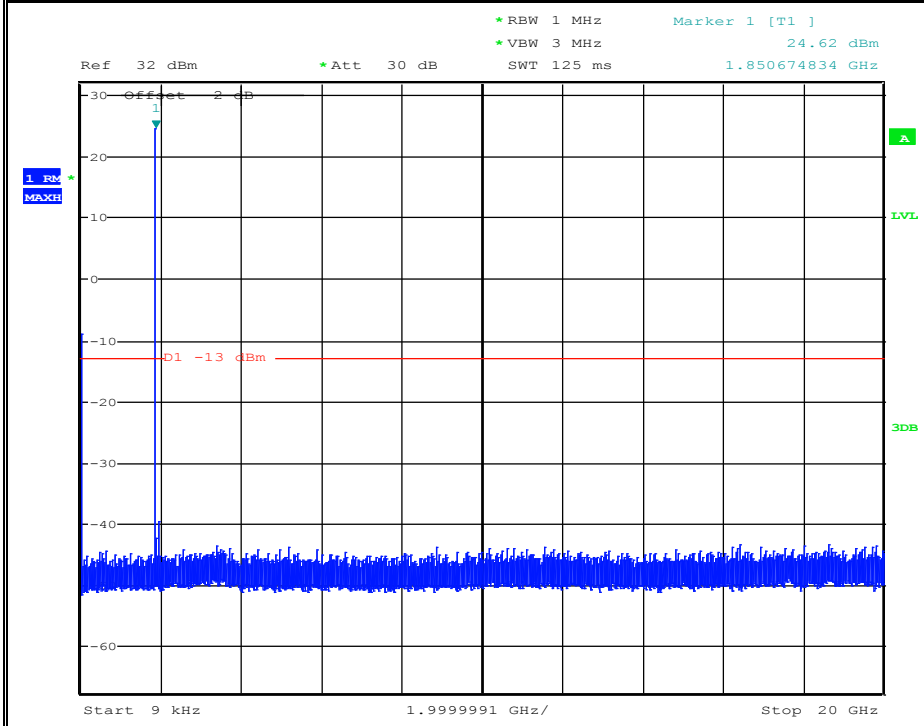
Plot # 2 GSM 1900 / Channel: Mid



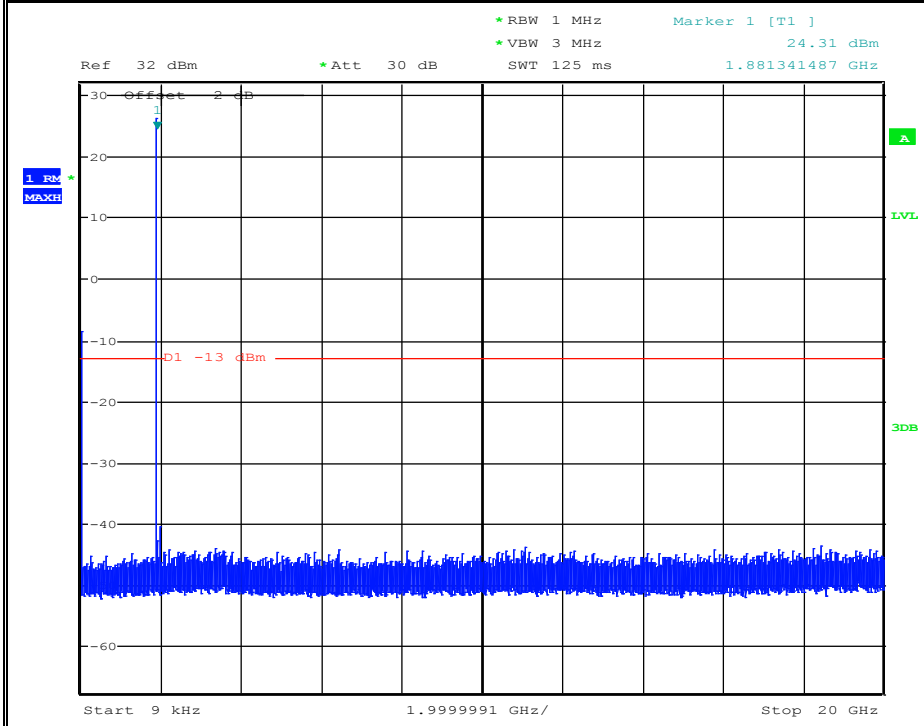
Plot # 3 GSM 1900 / Channel: Hi



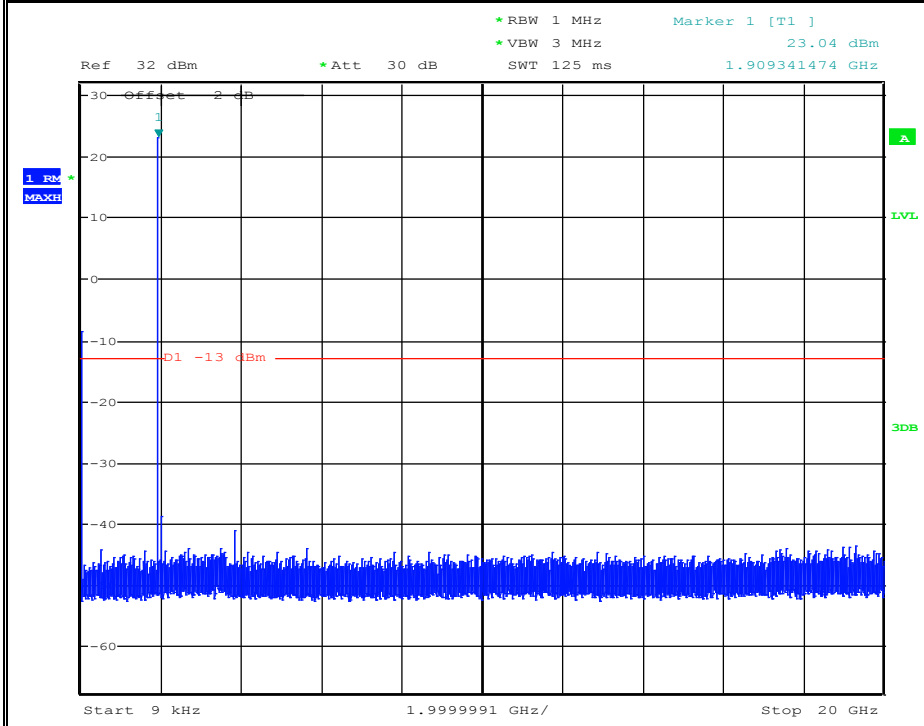
Plot # 4 CAT M1 B2 / Channel: Low



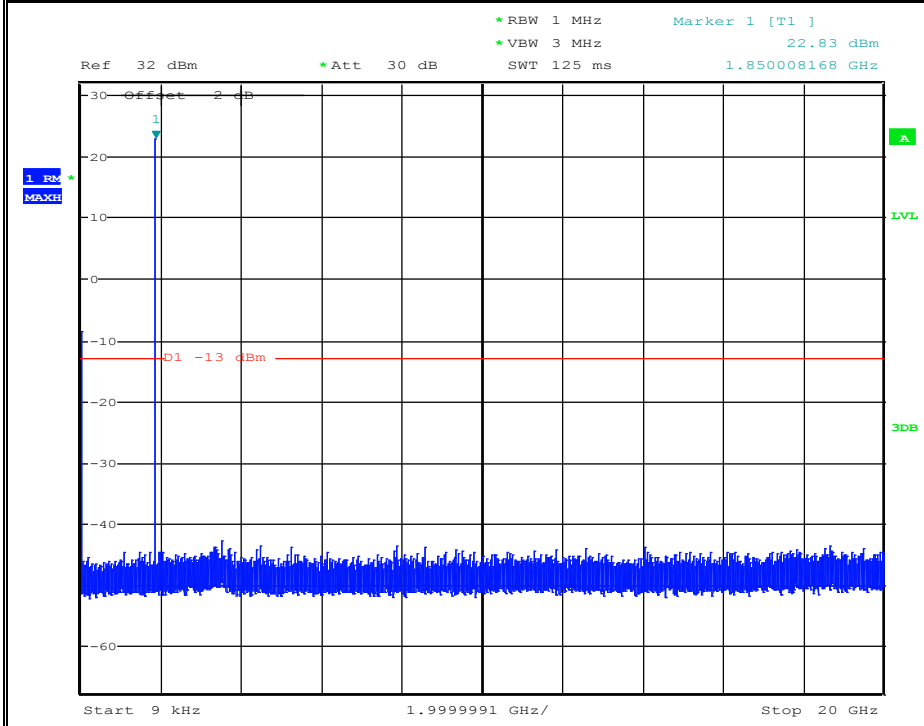
Plot # 5 CAT M1 B2 / Channel: Mid



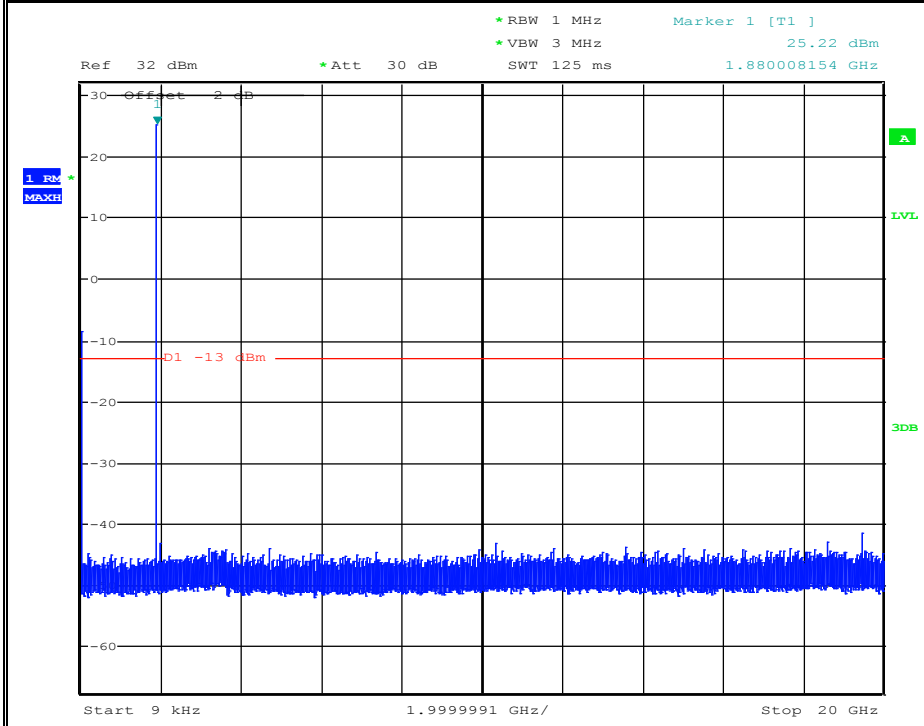
Plot # 6 CAT M1 B2 / Channel: Hi



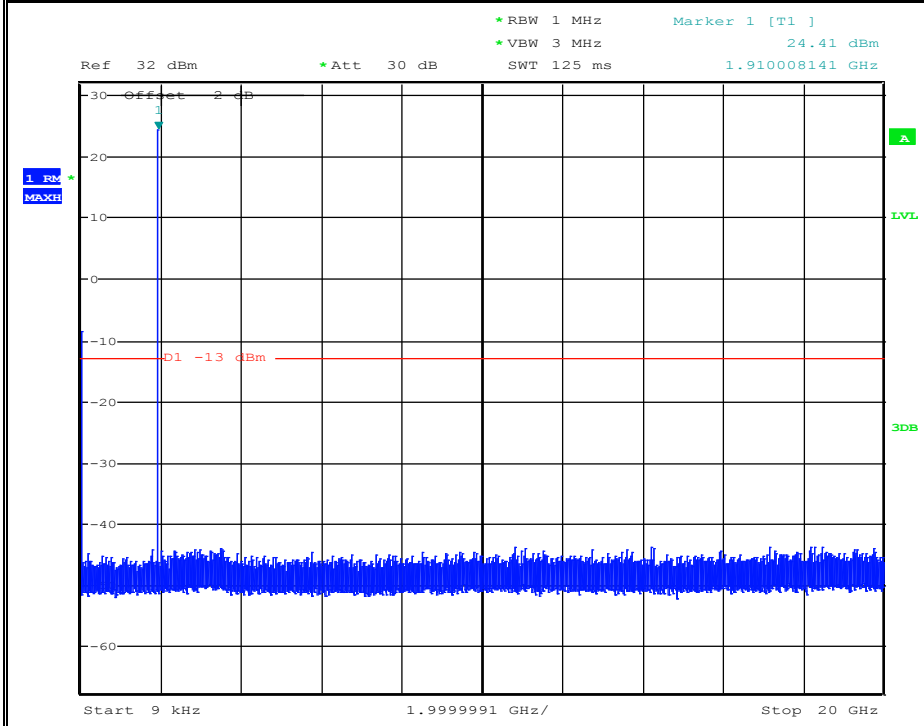
Plot # 7 NB IoT B2 / Channel: Low



Plot # 8 NB IoT B2 / Channel: Mid



Plot # 9 NB IoT B2 / Channel: Hi



7.6 Radiated Spurious Emissions

7.6.1 Measurement utilizing KDB 971168 D01 and ANSI C63.26-2015 Subclause 5.5.4

Spectrum Analyzer Settings for FCC 24

Frequency Range	30MHz – 1 GHz	1 – 2.7 GHz	2.7 – 18 GHz	18 – 19.1 GHz
Resolution Bandwidth	100 kHz	1 MHz	1 MHz	1 MHz
Video Bandwidth	100 kHz	1 MHz	1 MHz	1 MHz
Detector	Peak	Peak	Peak	Peak
Trace Mode	Max Hold	Max Hold	Max Hold	Max Hold
Sweep Time	Auto	Auto	Auto	Auto

7.6.2 Limits:

7.6.2.1 FCC Part 24.238

Out of band emissions. The power of any emission outside of the authorized operating frequency ranges must be attenuated below the transmitting power (P) by a factor of at least 43 + 10 log(P) dB.

7.6.2.2 RSS-133 Part 6.5; Transmitter Unwanted Emissions

Mobile and base station equipment shall comply with the limits in (i) and (ii) below.

i.In the first 1.0 MHz band immediately outside and adjacent to each of the sub-bands specified in Section 5.1, the power of emissions per any 1% of the occupied bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least 43 + 10 log10p (watts).

ii.After the first 1.0 MHz immediately outside and adjacent to each of the sub-bands, the power of emissions in any 100 kHz bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least 43 + 10 log10 p (watts). If the measurement is performed using 1% of the occupied bandwidth, power integration over 100 kHz is required.

Note: The limit calculation result is a constant of -13 dBm.

7.6.3 Test conditions and setup:

Ambient Temperature (C)	EUT Set-Up #	EUT operating mode	Power Input
22	2	1, 2, and 3	110 V / 60 Hz

7.6.4 Measurement result:

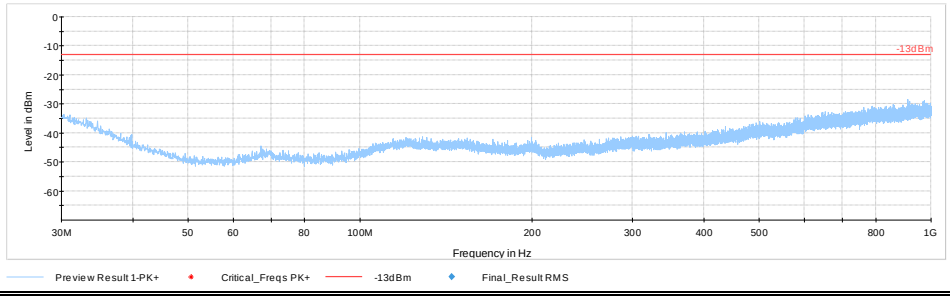
Plot #	Channel	EUT operating mode	Scan Frequency	Limit (dBm)	Result
1-3	Low	GSM 1900	30 MHz – 18 GHz	-13	Pass
4-8	Mid	GSM 1900	9 kHz – 22 GHz	-13	Pass
9-11	High	GSM 1900	30 MHz – 18 GHz	-13	Pass
12-14	Low	CAT M1 B2	30 MHz – 18 GHz	-13	Pass
15-19	Mid	CAT M1 B2	9 kHz – 22 GHz	-13	Pass
20-22	High	CAT M1 B2	30 MHz – 18 GHz	-13	Pass
23-25	Low	NB IoT B2	30 MHz – 18 GHz	-13	Pass
26-30	Mid	NB IoT B2	9 kHz – 22 GHz	-13	Pass
31-33	High	NB IoT B2	30 MHz – 18 GHz	-13	Pass

7.6.5 Measurement Plots:

7.6.6 GSM 1900

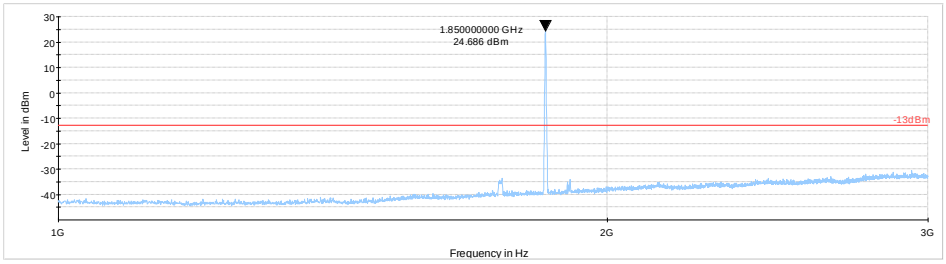
Plot #1 Radiated Emissions: 30 MHz – 1GHz

Channel: Low



Plot # 2 Radiated Emissions: 1-3 GHz

Channel: Low

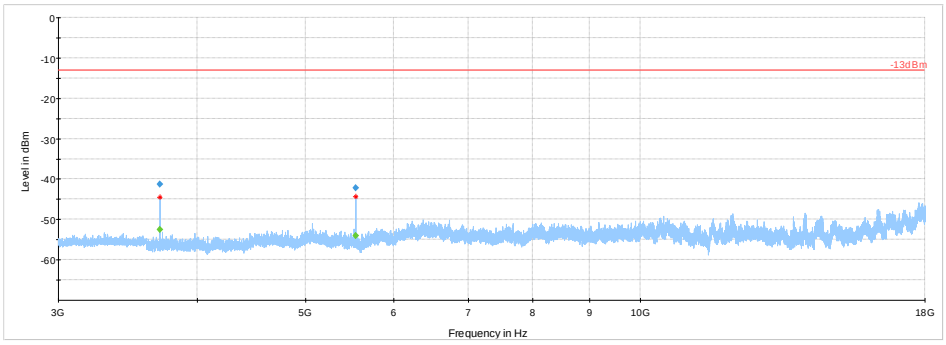


Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

Plot # 3 Radiated Emissions: 3-18 GHz

Channel: Low

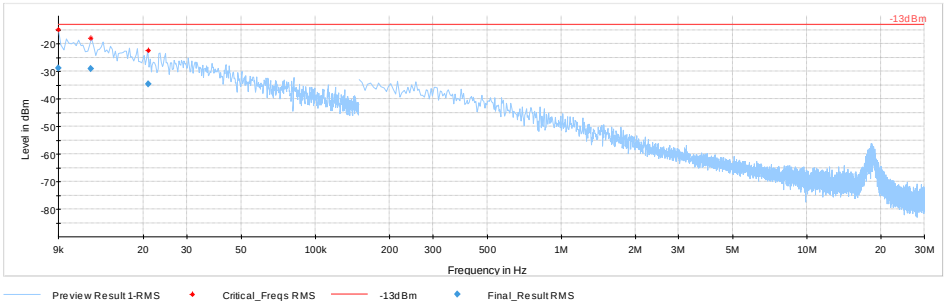
Frequency (MHz)	MaxPeak (dBm)	RMS (dBm)	Limit (dBm)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
3700.519500	-41.36	---	-13.00	28.36	264.0	V	238.0	-101.8
3700.519500	---	-52.47	---	---	264.0	V	238.0	-101.8
5550.407333	-42.19	---	-13.00	29.19	281.0	H	38.0	-99.7
5550.407333	---	-54.04	---	---	281.0	H	38.0	-99.7



Plot # 4 Radiated Emissions: 9 kHz-30 MHz

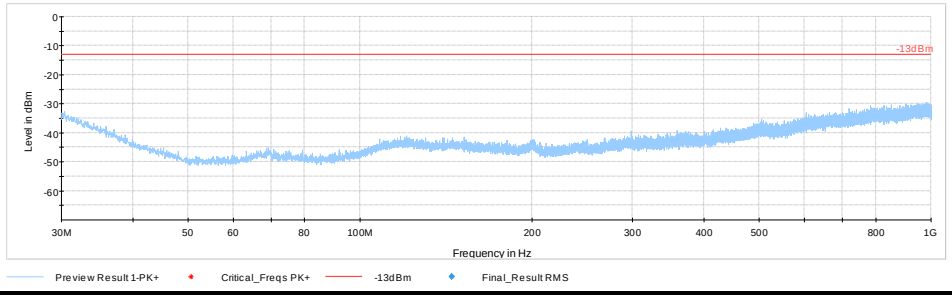
Channel: Mid

Frequency (MHz)	RMS (dBm)	Limit (dBm)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
0.00900	-28.89	-13.00	15.89	219.0	H	0.0	-64.3
0.01219	-29.11	-13.00	16.11	198.0	H	90.0	-66.4
0.02085	-34.77	-13.00	21.77	188.0	H	90.0	-70.8



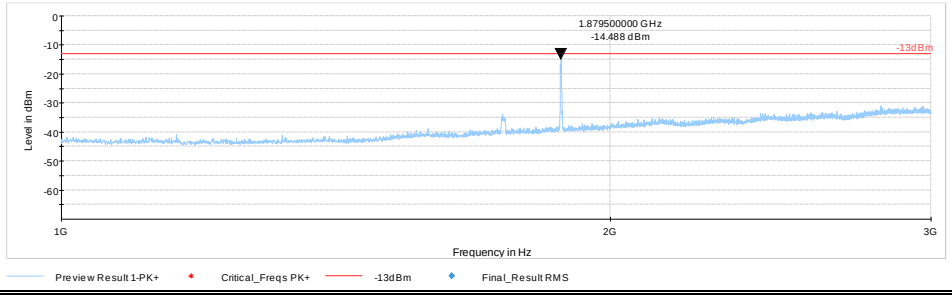
Plot #5 Radiated Emissions: 30 MHz – 1GHz

Channel: Mid



Plot #6 Radiated Emissions: 1-3 GHz

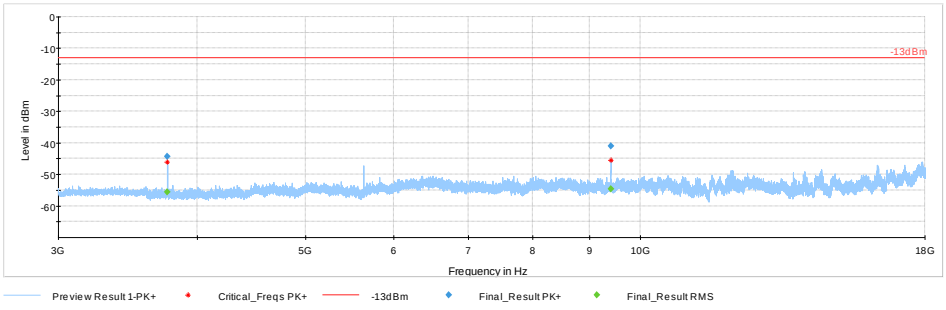
Channel: Mid



Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

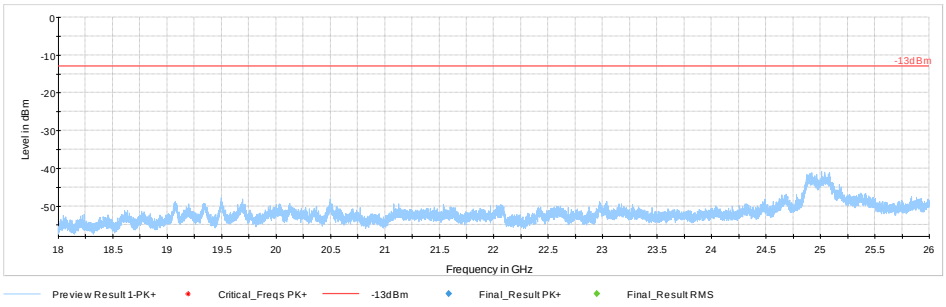
Plot #7 Radiated Emissions: 3-18 GHz

Channel: Mid



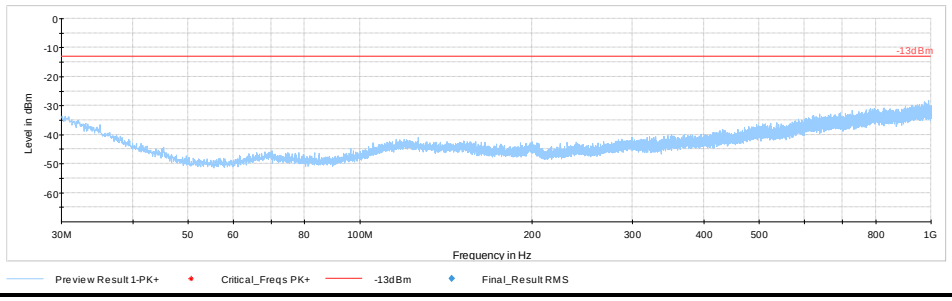
Plot #8 Radiated Emissions: 18-26 GHz

Channel: Mid



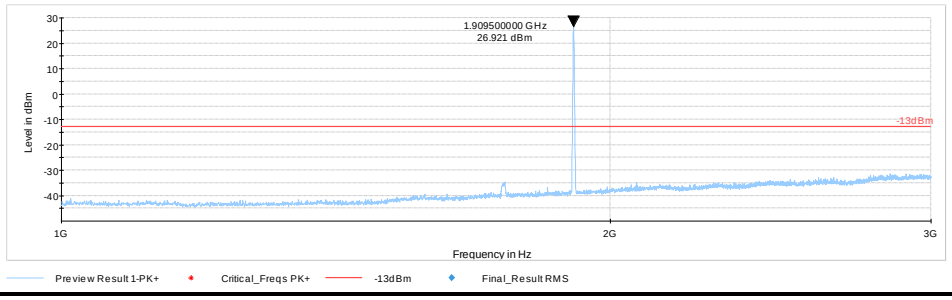
Plot #9 Radiated Emissions: 30 MHz – 1GHz

Channel: High



Plot #10 Radiated Emissions: 1-3 GHz

Channel: High

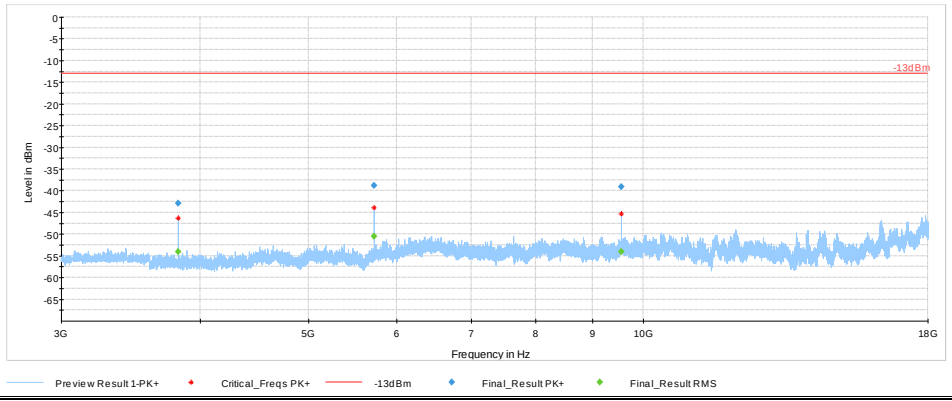


Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

Plot #11 Radiated Emissions: 3-18 GHz

Channel: High

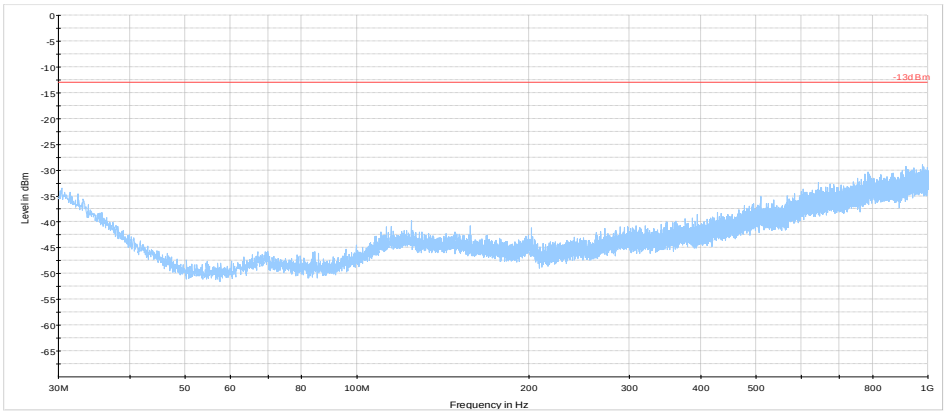
Frequency (MHz)	MaxPeak (dBm)	RMS (dBm)	Limit (dBm)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
3819.607333	---	-54.08	---	---	248.0	H	61.0	-101.7
3819.607333	-42.91	---	-13.00	29.91	248.0	H	61.0	-101.7
5729.583333	---	-50.59	---	---	325.0	V	82.0	-98.6
5729.583333	-38.78	---	-13.00	25.78	325.0	V	82.0	-98.6
9548.481500	---	-54.08	---	---	274.0	V	124.0	-93.2
9548.481500	-39.11	---	-13.00	26.11	274.0	V	124.0	-93.2



7.6.7 CAT M1 B2

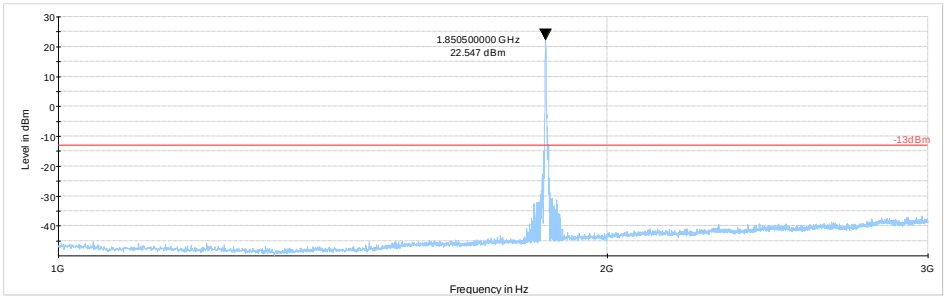
Plot #12 Radiated Emissions: 30 MHz – 1GHz

Channel: Low



Plot # 13 Radiated Emissions: 1-3 GHz

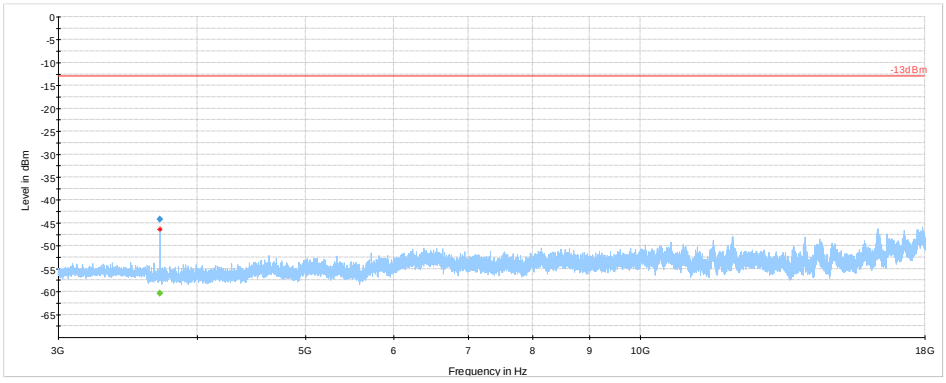
Channel: Low



Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

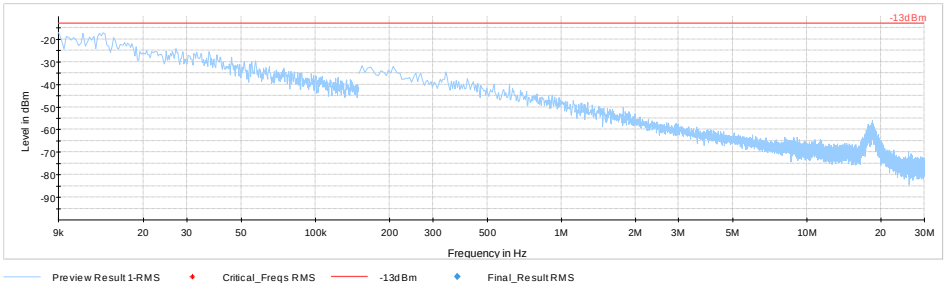
Plot # 14 Radiated Emissions: 3-18 GHz

Channel: Low



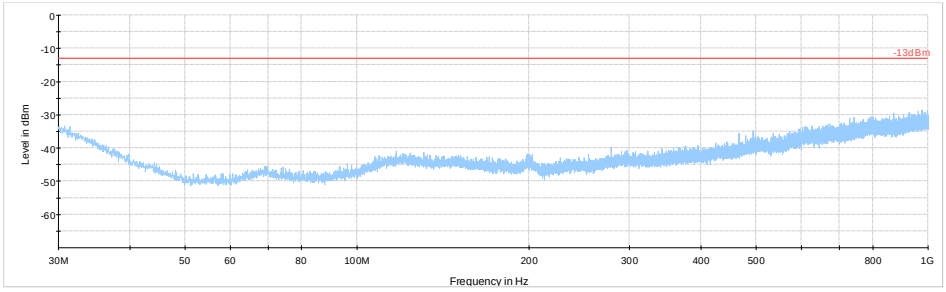
Plot # 15 Radiated Emissions: 9 kHz-30 MHz

Channel: Mid



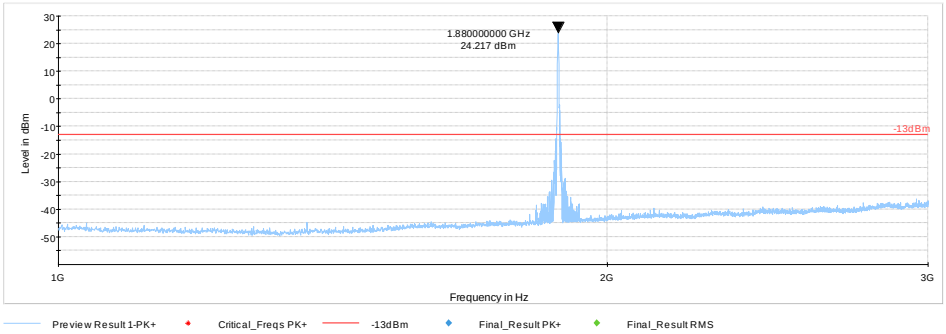
Plot #16 Radiated Emissions: 30 MHz – 1GHz

Channel: Mid



Plot #17 Radiated Emissions: 1-3 GHz

Channel: Mid

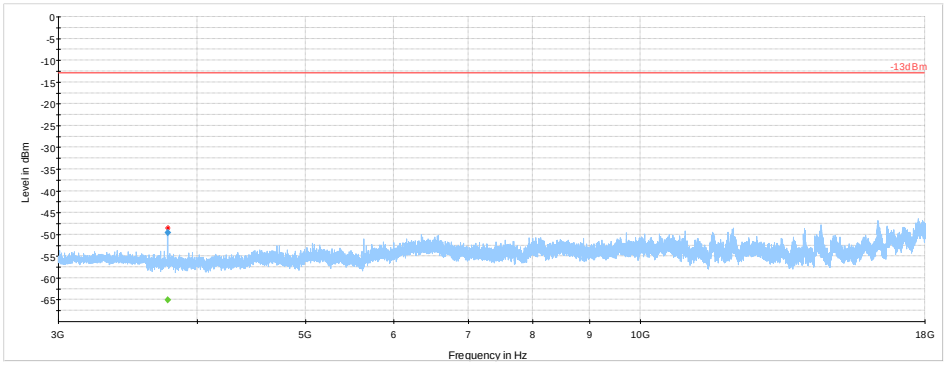


Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

Plot #18 Radiated Emissions: 3-18 GHz
GHz

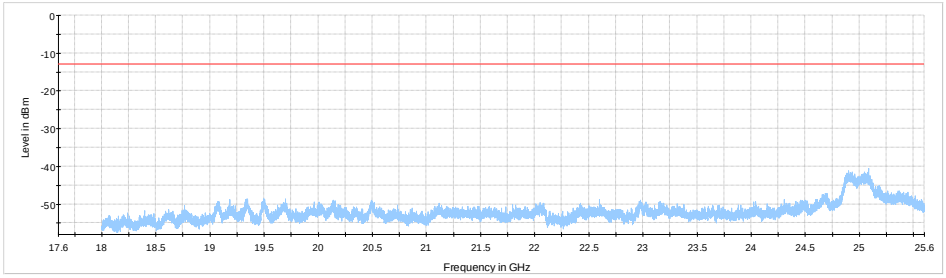
Channel: Mid

Frequency (MHz)	MaxPeak (dBm)	RMS (dBm)	Limit (dBm)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
3760.702000	---	-65.09	---	---	151.0	V	260.0	-101.6
3760.702000	-49.63	---	-13.00	36.63	151.0	V	260.0	-101.6



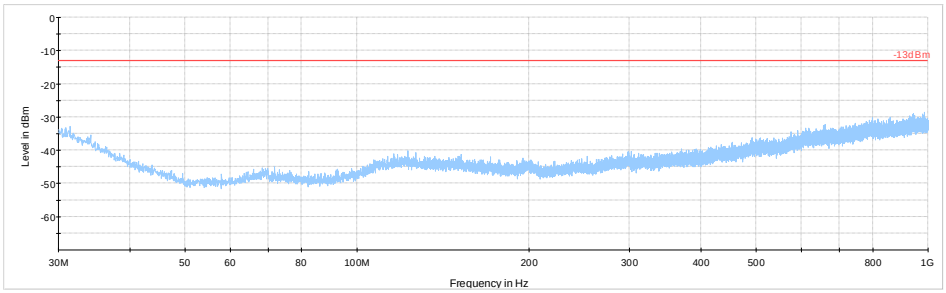
Plot #19 Radiated Emissions: 18-26 GHz
GHz

Channel: Mid



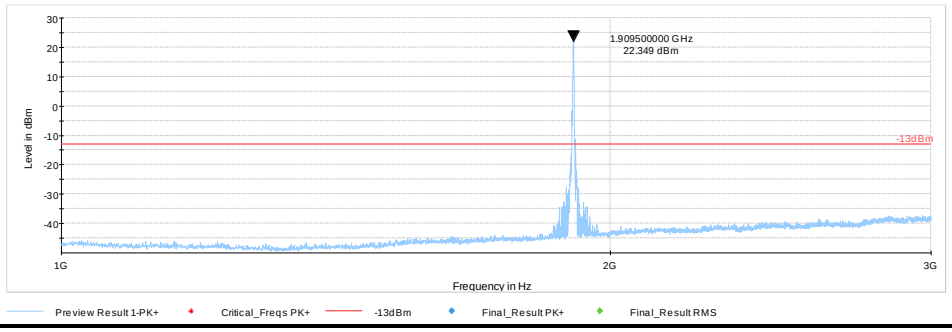
Plot #20 Radiated Emissions: 30 MHz – 1GHz

Channel: High



Plot #21 Radiated Emissions: 1-3 GHz

Channel: High

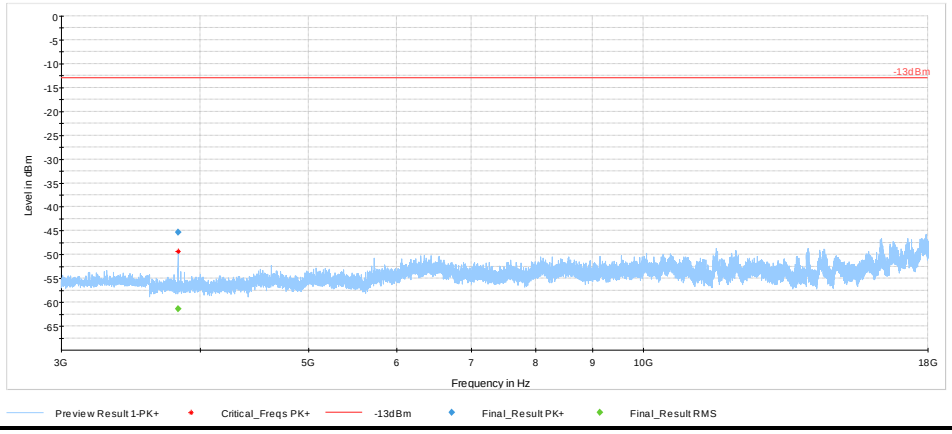


Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

Plot #22 Radiated Emissions: 3-18 GHz

Channel: High

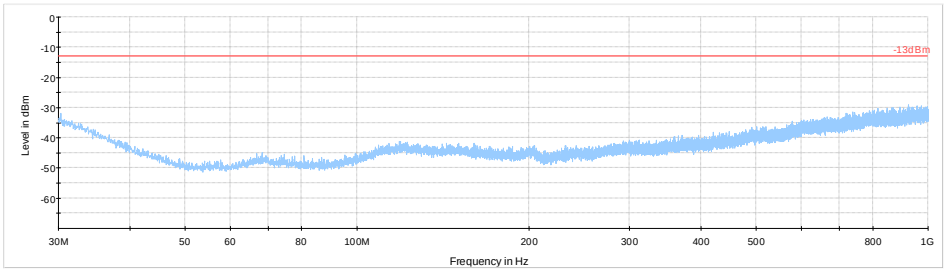
Frequency (MHz)	MaxPeak (dBm)	RMS (dBm)	Limit (dBm)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
3818.776000	---	-61.41	---	---	274.0	V	246.0	-101.7
3818.776000	-45.37	---	-13.00	32.37	274.0	V	246.0	-101.7



7.6.8 NB IoT B2

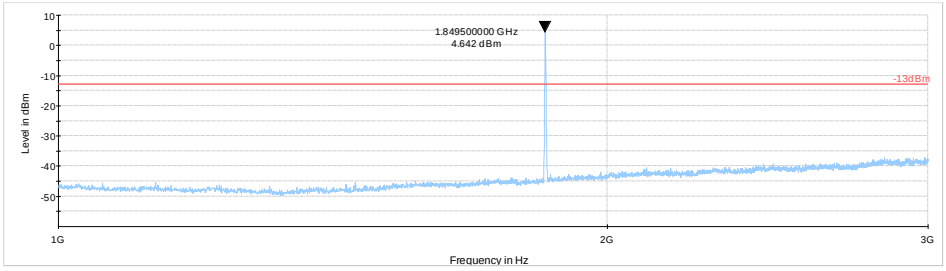
Plot #23 Radiated Emissions: 30 MHz – 1GHz

Channel: Low



Plot # 24 Radiated Emissions: 1-3 GHz

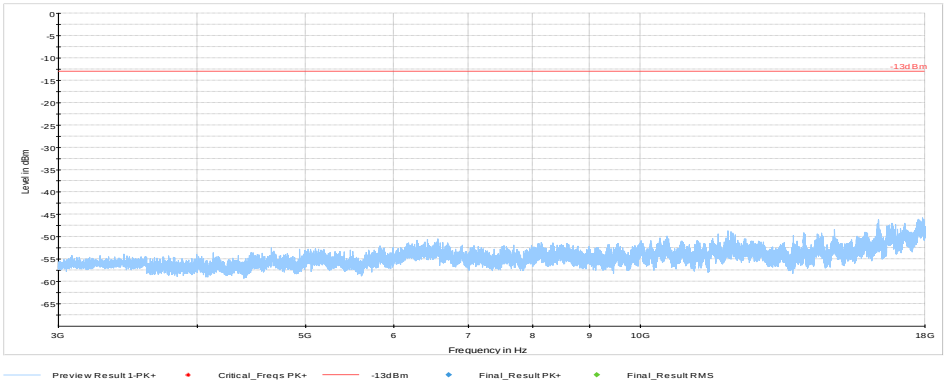
Channel: Low



Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

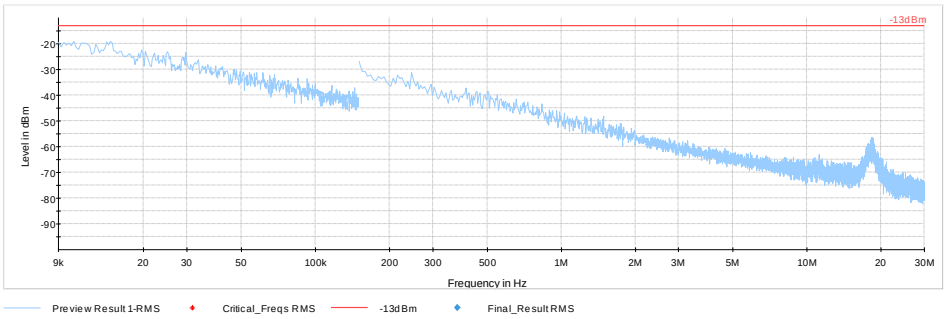
Plot # 25 Radiated Emissions: 3-18 GHz

Channel: Low



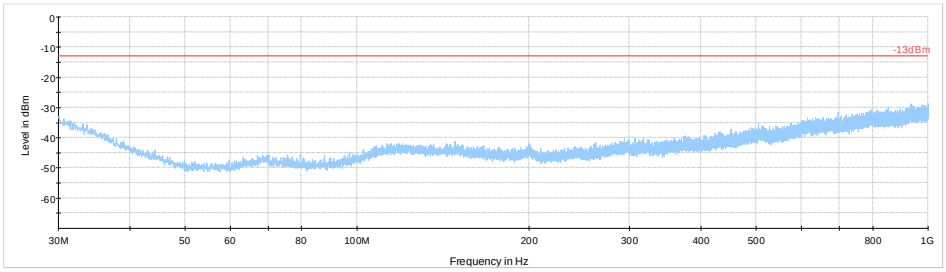
Plot # 26 Radiated Emissions: 9 kHz-30 MHz

Channel: Mid



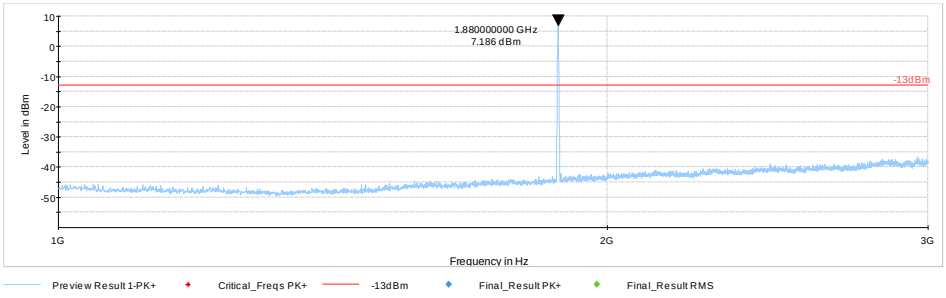
Plot #27 Radiated Emissions: 30 MHz – 1GHz

Channel: Mid



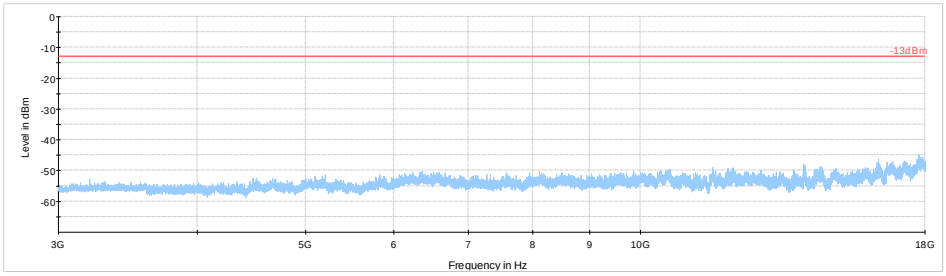
Plot #28 Radiated Emissions: 1-3 GHz

Channel: Mid

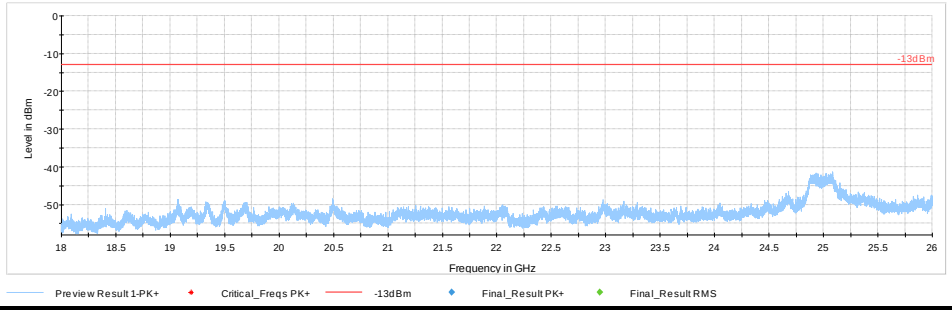


Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

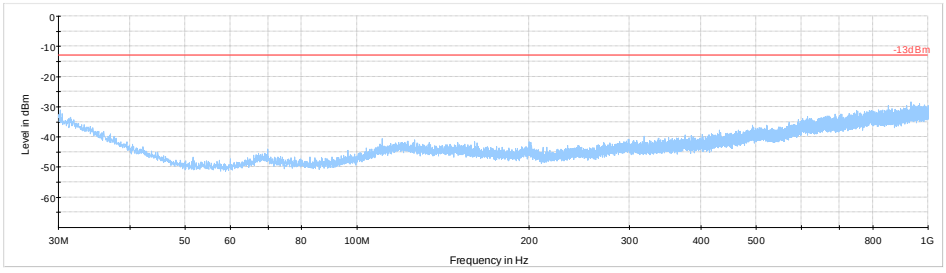
Plot #29 Radiated Emissions: 3-18 GHz
Channel: Mid



Plot #30 Radiated Emissions: 18-26 GHz
Channel: Mid

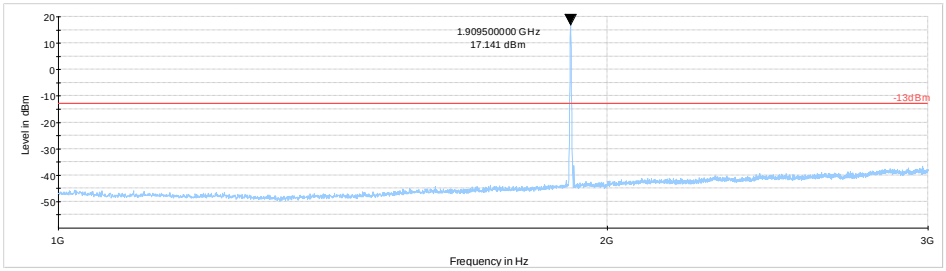


Plot #31 Radiated Emissions: 30 MHz – 1GHz
Channel: High



Plot #32 Radiated Emissions: 1-3 GHz

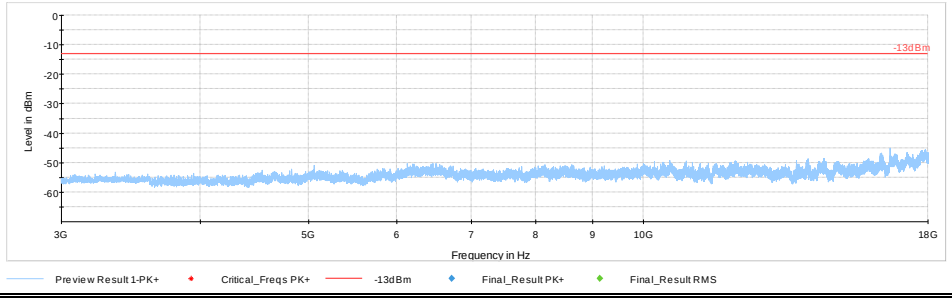
Channel: High



Note: Due to limited resolution during radiated measurements on the Band edges the manual conducted measurement from section 7.4 prevails.

Plot #33 Radiated Emissions: 3-18 GHz

Channel: High



8 Test setup photos

Setup photos are included in supporting file name: "EMC_ CTSMC-003-18001_FCC_Setup_photos.pdf"

9 Test Equipment And Ancillaries Used For Testing

Equipment Type	Manufacturer	Model	Serial #	Last Calibration Date
Loop Antenna	ETS Lindgren	6507	161344	10/26/2017
Biconlog Antenna	EMCO	3142E	166067	06/27/2017
Horn Antenna	EMCO	3115	35114	07/31/2017
Horn Antenna	ETS Lindgren	3117-PA	215984	01/26/2018
EMI Test Receiver	Rohde & Schwarz	ESU40	100251	01/31/2018
Spectrum Analyzer	Rohde & Schwarz	FSU40	101022	7/5/2017
Compact Digital Barometer	Control Company	35519-055	91119547	6/8/2017
Thermometer Humidity	Dickson	TM325	16253651	11/02/2017

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.

10 Revision History

Date	Report Name	Changes to report	Report prepared by
2018-11-26	EMC_CTSMC-003-18001_FCC_24	Initial Version	Kris Lazarov
2019-1-21	EMC_CTSMC-003-18001_FCC_24_Rev_1	Updated the power table in section 7.1.4 and 7.1.5 Updated the plots in section 7.1.6	Kris Lazarov