

# TEST REPORT

of

FCC Part 15 Subpart C §15.247  
IC RSS-247 Issue 2 and RSS-Gen Issue 5

FCC ID: 2ADQJ-YSP88459SM  
IC Certification: 28512-YSP88459SM

Equipment Under Test : WiFi/BT Combo Module

Model Name : BWR-YSP88459-SMA

Variant Model Name(s) : BWR-YSP88459-SMA-LGA

FCC Applicant : ESSYS CO.,LTD.

IC Applicant : ESSYS CO.,LTD

Manufacturer : ESSYS CO.,LTD.

Date of Receipt : 2023.02.20

Date of Test(s) : 2023.02.20 ~ 2023.07.31

Date of Issue : 2023.08.03

In the configuration tested, the EUT complied with the standards specified above. This test report does not assure KOLAS accreditation.

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- 2) The SGS Korea is not responsible for the sampling, the results of this test report apply to the sample as received.
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- 4) The data marked \* in this report was provided by the customer and may affect the validity of the test results.

We are responsible for all the information of this test report except for the data(\*) provided by the customer.

Tested by:

  
Murphy Kim

Technical  
Manager:

  
Inho Park

**SGS Korea Co., Ltd. Gunpo Laboratory**

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## 1. General Information

### 1.1. Testing Laboratory

SGS Korea Co., Ltd. (Gunpo Laboratory)

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- 4, LS-ro 182beon-gil, Gunpo-si, Gyeonggi-do, Korea, 15807
- Designation number: KR0150

All SGS services are rendered in accordance with the applicable SGS conditions of service available on request and accessible at <http://www.sgs.com/en/Terms-and-Conditions.aspx>.

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### 1.2. Details of Applicant

FCC Applicant : ESSYS CO.,LTD.  
FCC Address : 55, Gaetbeol-ro, Yeonsu-gu, Incheon, South Korea, 21999  
IC Applicant : ESSYS CO.,LTD  
IC Address : 55, Gaetbeol-ro, Yeonsu-gu, Incheon, Korea(Republic Of), 21999  
Address : 55, Gaetbeol-ro, Yeonsu-gu, Incheon, South Korea, 21999  
Contact Person : Kim, Sung-hoon  
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### 1.3. Details of Manufacturer

Company : ESSYS CO.,LTD.  
Address : 55, Gaetbeol-ro, Yeonsu-gu, Incheon, Republic of Korea

### 1.4. Description of EUT

<b>Kind of Product</b>	WiFi/BT Combo Module
<b>Model Name</b>	BWR-YSP88459-SMA
<b>Variant Model Names</b>	BWR-YSP88459-SMA-LGA
<b>Serial Number</b>	Conducted Sample: C-001 Radiated Sample: R-001
<b>Power Supply</b>	DC 3.3 V
<b>Frequency Range</b>	2 402 MHz ~ 2 480 MHz (Bluetooth Low Energy)
<b>Modulation Technique</b>	GFSK
<b>Number of Channels</b>	40 channels (Bluetooth Low Energy)
<b>Antenna Type</b>	Pattern antenna
<b>Antenna Gain<sup>×</sup></b>	Core 0: 2.28 dB i
<b>H/W Version</b>	1.1
<b>S/W Version</b>	1.0
<b>FVIN</b>	N/A
<b>Power Setting</b>	Default

## 1.5. Test Equipment List

Equipment	Manufacturer	Model	S/N	Cal. Date	Cal. Interval	Cal. Due
Signal Generator	R&S	SMA100B	106887	Oct. 13, 2022	Annual	Oct. 13, 2023
Spectrum Analyzer	R&S	FSV30	103210	Dec. 07, 2022	Annual	Dec. 07, 2023
Spectrum Analyzer	Agilent	N9020A	MY53421758	Aug. 26, 2022	Annual	Aug. 26, 2023
Attenuator	AEROFLEX / INMET	40AH2W-10	40G-1	Jun. 14, 2023	Annual	Jun. 14, 2024
High Pass Filter	Wainwright Instrument GmbH	WHKX3.0/18G-10SS	21	Jun. 01, 2023	Annual	Jun. 01, 2024
High Pass Filter	Wainwright Instrument GmbH	WHNX7.5/26.5G-6SS	11	Oct. 24, 2022	Annual	Oct. 24, 2023
Low Pass Filter	Mini-Circuits	NLP-1200+	V 8979400903-2	Feb. 09, 2023	Annual	Feb. 09, 2024
Power Sensor	R&S	NRP-Z81	100669	May 16, 2023	Annual	May 16, 2024
DC Power Supply	Agilent	U8002A	MY49030063	Jan. 20, 2023	Annual	Jan. 20, 2024
DC Power Supply	R&S	HMP2020	019922876	Apr. 27, 2023	Annual	Apr. 27, 2024
Preamplifier	H.P.	8447F	2944A03909	Aug. 04, 2022	Annual	Aug. 04, 2023
Signal Conditioning Unit	R&S	SCU-18	10117	Jun. 15, 2023	Annual	Jun. 15, 2024
Preamplifier	TESTEK	TK-PA1840H	130016	Jan. 11, 2023	Annual	Jan. 11, 2024
Loop Antenna	Schwarzbeck Mess-Elektronik	FMZB 1519	1519-039	Aug. 23, 2021	Biennial	Aug. 23, 2023
Bilog Antenna	Schwarzbeck Mess-Elektronik	VULB 9163	01126	Feb. 09, 2023	Annual	Feb. 09, 2024
Horn Antenna	R&S	HF906	100326	Feb. 28, 2023	Annual	Feb. 28, 2024
Horn Antenna	Schwarzbeck Mess-Elektronik	BBHA 9170	9170-540	Nov. 30, 2022	Annual	Nov. 30, 2023
EMI Test Receiver	R&S	ESU26	100109	Jan. 18, 2023	Annual	Jan. 18, 2024
Turn Table	Innco systems GmbH	DS 1200 S	N/A	N.C.R.	N/A	N.C.R.
Controller	Innco systems GmbH	CONTROLLER CO3000/963/383 30516/L	CO3000/963/383 30516/L	N.C.R.	N/A	N.C.R.
Antenna Mast	Innco systems GmbH	MA4640-XP-ET	MA4640/536/383 30516/L	N.C.R.	N/A	N.C.R.
Anechoic Chamber	SY Corporation	L x W x H (9.6 m x 6.4 m x 6.6 m)	N/A	N.C.R.	N/A	N.C.R.
Coaxial Cable	RFONE	MWX221-NMSNMS (4 m)	J1023142	Apr. 04, 2023	Semi-Annual	Oct. 04, 2023
Coaxial Cable	Qualwave Inc.	QA500-18-NN-10 (10 m)	22200114	Apr. 04, 2023	Semi-Annual	Oct. 04, 2023
Coaxial Cable	RFONE	PL360P-292M292M-1.5 M-A	20200324002	Apr. 14, 2023	Semi-Annual	Oct. 14, 2023
Anechoic Chamber	SY Corporation	L x W x H (6.5 m x 3.5 m x 3.5 m)	N/A	N.C.R.	N/A	N.C.R.
Test Receiver	R&S	ESCI 7	100911	Feb. 24, 2023	Annual	Feb. 24, 2024
Two-Line V-Network	R&S	ENV216	100190	May 17, 2023	Annual	May 17, 2024

**Note:**

For equipment listed above that has a calibration date or calibration due date that falls within the test date range, care was taken to ensure that this equipment was used after the calibration date and before the calibration due date.

## 1.6. Summary of Test Results

The EUT has been tested according to the following specifications:

<b>APPLIED STANDARD: FCC Part15 Subpart C, RSS-247 Issue 2, RSS-Gen Issue 5</b>			
<b>Section in FCC</b>	<b>Section in IC</b>	<b>Test Item(s)</b>	<b>Result</b>
15.205(a) 15.209 15.247(d)	RSS-247 Issue 2 5.5 RSS-Gen Issue 5 8.9	Transmitter Radiated Spurious Emissions and Conducted Spurious Emission	Complied
15.247(a)(2)	RSS-247 Issue 2 5.2(a) RSS-Gen Issue 5 6.7	6 dB Bandwidth & 99 % Bandwidth	Complied
15.247(b)(3)	RSS-247 Issue 2 5.4(d)	Maximum Peak Conducted Output Power	Complied
15.247(e)	RSS-247 Issue 2 5.2(b)	Power Spectral Density	Complied
15.207	RSS-Gen Issue 5 8.8	AC Power Line Conducted Emission	Complied

## 1.7. Test Procedure(s)

The measurement procedures described in the American National Standard of Procedure for Compliance Testing of unlicensed Wireless Devices (ANSI C63.10-2013) and the guidance provided in KDB 558074 D01 15.247 Meas Guidance v05r02 were used in the measurement of the DUT.

## 1.8. Sample Calculation

Where relevant, the following sample calculation is provided:

### 1.8.1. Conducted Test

Offset value (dB) = Attenuator (dB) + Cable loss (dB)

### 1.8.2. Radiation Test

Field strength level (dB $\mu$ V/m) = Measured level (dB $\mu$ V) + Antenna factor (dB) + Cable loss (dB) - Amplifier gain (dB)  
+ Duty factor (dB)

## 1.9. Information of software for test

- Using the software of BLUETOOL(v1.9.5.3) to testing of EUT.

## 1.10. Measurement Uncertainty

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

Parameter	Uncertainty	
Maximum Peak Conducted Output Power	0.33 dB	
Power Spectral Density	0.64 dB	
99 % Bandwidth	0.01 MHz	
6 dB Bandwidth	0.01 MHz	
Conducted Spurious Emission	0.79 dB	
AC Power Line Conducted Emission	4.00 dB	
Radiated Emission, 9 kHz to 30 MHz	H	3.40 dB
	V	3.40 dB
Radiated Emission, below 1 GHz	H	4.50 dB
	V	5.10 dB
Radiated Emission, above 1 GHz	H	3.70 dB
	V	3.90 dB

All measurement uncertainty values are shown with a coverage factor of  $k=2$  to indicate a 95 % level of confidence.

## 1.11. Test Report Revision

Revision	Report number	Date of Issue	Description
0	F690501-RF-RTL004292	2023.08.03	Initial

### 1.12. Worst-Case Configuration and Test Mode (Bluetooth 5.1)

Model	Modulation	Mode	Frequency (MHz)	Packet length (Byte)	RF Output Power (dBm)	
Basic model	GFSK	PHY 1M	2 402	37	<u>6.08</u>	
				255	6.06	
Variant model		PHY 1M	2 440	37	<u>5.93</u>	
				255	5.50	

**Remark;**

The Bluetooth version of the EUT is 5.1 and only PHY 1M is supported

All modes were investigated.

For PHY 1M, 37 bytes is tested as worst condition.

Radiated emission below 1 GHz were performed with the EUT set to transmit at the channel with highest output power as worst-case scenario.

Radiated emission above 1 GHz was performed with the EUT set to transmit Low/Middle/High Channels as worst-case scenario.

Conducted tests were performed with the EUT set to transmit Low/Middle/High channels with highest RF output power.

### 1.13. Device Capabilities

Frequency	Mode	SISO		MIMO
		Core 0	Core 1	Core 0 + Core 1
2.4 GHz	Bluetooth & Bluetooth Low Energy	O	X	X
	802.11b/g/n	X	O	X
5 GHz	802.11a	O	O	X
	802.11n/ac	O	O	O

### 1.14. Information of Variant Models

Model Names		Description
Basic model	BWR-YSP88459-SMA	- Basic Model
Variant Model	BWR-YSP88459-SMA-LGA	- It is the same as the basic model except that the filter was changed on the Bluetooth path.

**Note;**

All the test were performed with the basic model and the variant model.

## 1.15. Duty Cycle of EUT

Regarding to KDB 558074 D01 15.247 Meas Guidance v05r02, 6, the maximum duty cycles of all modes were investigated and set the spectrum analyzer as below;

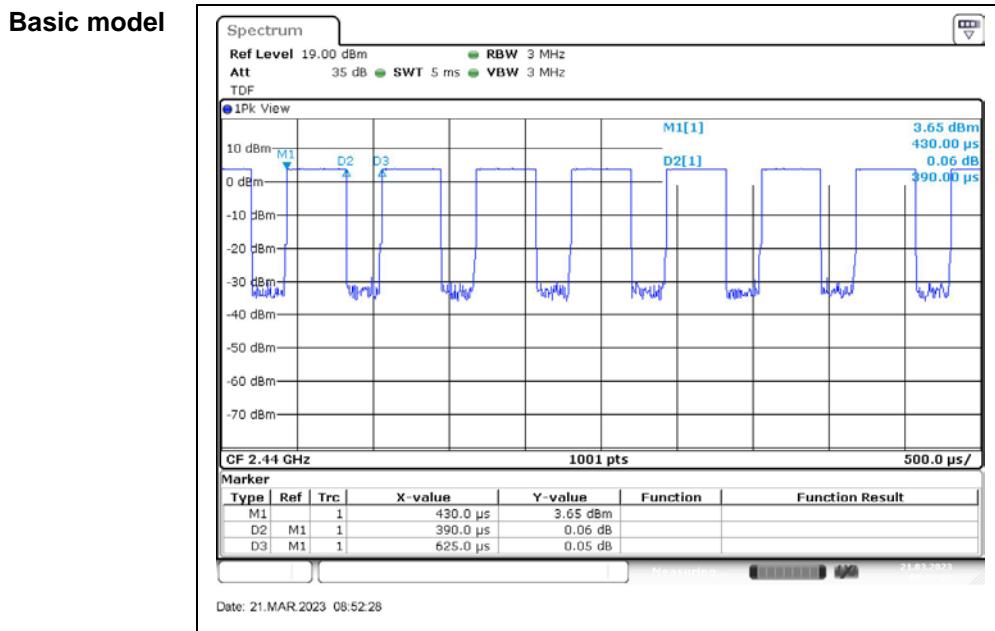
Set RBW  $\geq$  OBW if possible; otherwise, set RBW to the largest available value. Set detector = peak or average. The zero-span measurement method shall not be used unless both RBW and VBW are  $> 50/T$  and the number of sweep points across duration T exceeds 100.

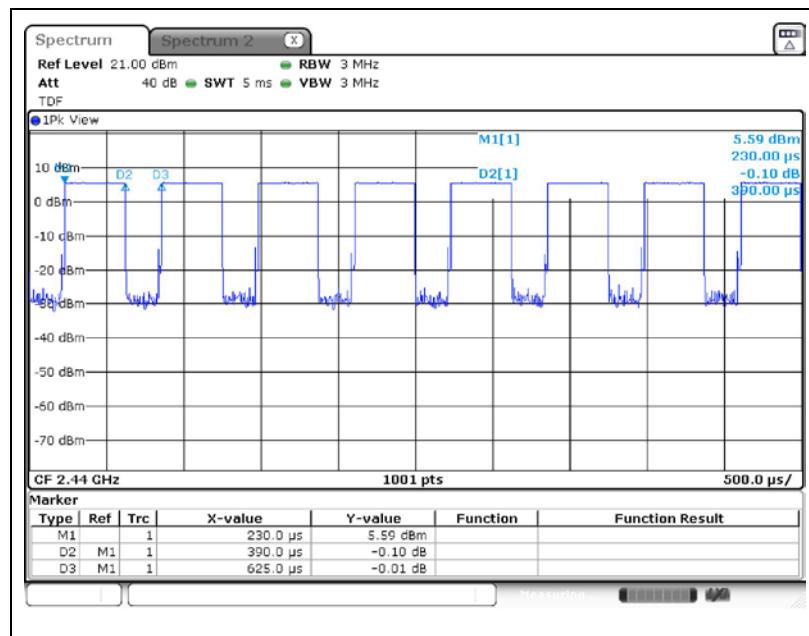
Model	Duty Cycle (%)	Correction factor (dB)
Basic model	62.40	2.05
Varian model	62.40	2.05

### Remark;

1. Duty Cycle (%) =  $(Tx \text{ on time} / Tx \text{ on + off time}) \times 100$
2. Correction Factor (dB) =  $10 \log (1 / \text{Duty Cycle})$

### - Test plots



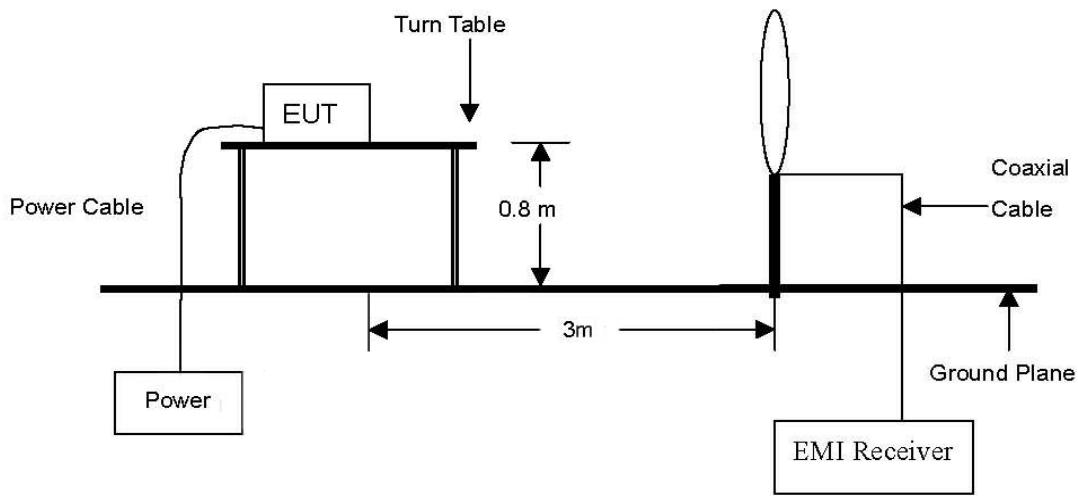
**Variant model**

## 2. Transmitter Radiated Spurious Emissions and Conducted Spurious Emission

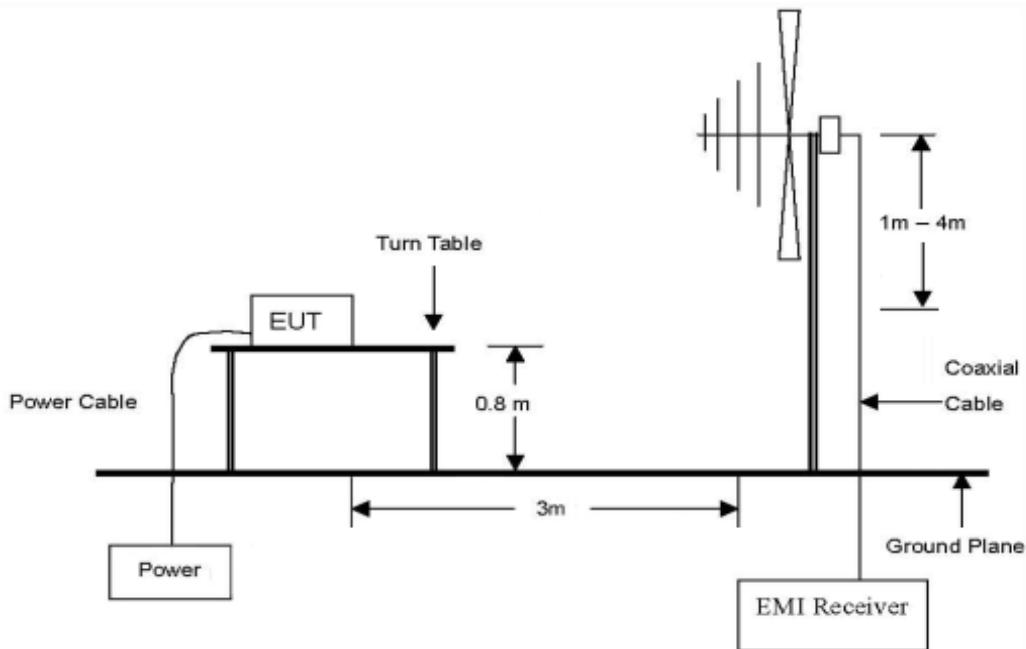
### 2.1. Test Setup

#### 2.1.1. Transmitter Radiated Spurious Emissions

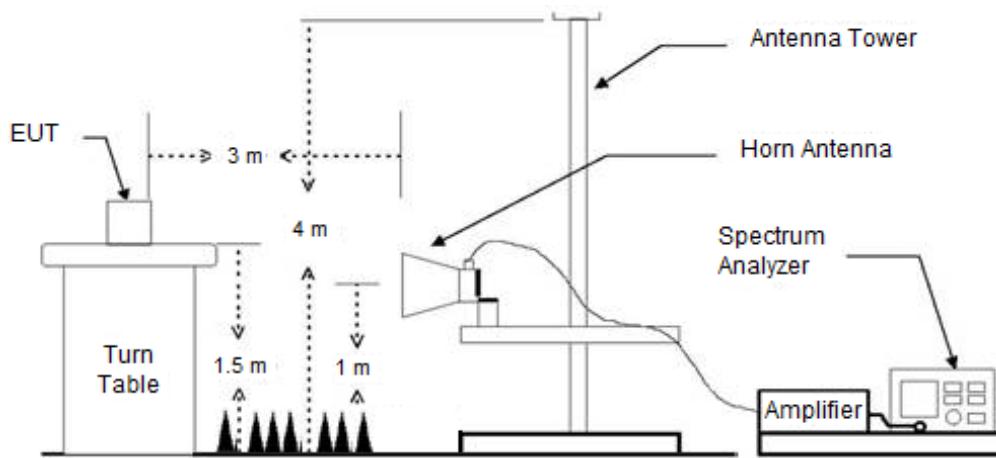
The diagram below shows the test setup that is utilized to make the measurements for emission from 9 kHz to 30 MHz emissions.



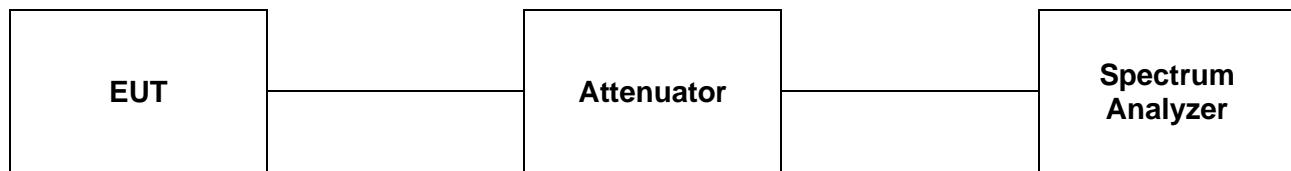
The diagram below shows the test setup that is utilized to make the measurements for emission from 30 MHz to 1 GHz Emissions.



The diagram below shows the test setup that is utilized to make the measurements for emission. The spurious emissions were investigated from 1 GHz to the 10<sup>th</sup> harmonic of the highest fundamental frequency or 40 GHz, whichever is lower.



### 2.1.2. Conducted Spurious Emission



## 2.2. Limit

### 2.2.1. FCC

According to §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 emission 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)).

According to §15.209(a), 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 (MHz)	Field Strength ( $\mu$ V/m)	Measurement Distance (Meters)
0.009-0.490	2 400/F(kHz)	300
0.490-1.705	24 000/F(kHz)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

\*\* Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§15.231 and 15.241.

### 2.2.2. IC

According to RSS-247 Issue 2, 5.5, in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

According to RSS-Gen Issue 5, 8.9, except where otherwise indicated in the applicable RSS, radiated emissions shall comply with the field strength limits shown in table 5 and table 6. Additionally, the level of any transmitter unwanted emission shall not exceed the level of the transmitter's fundamental emission.

**Table 5 – General Field Strength Limits at frequencies above 30 MHz**

Frequency (MHz)	Field Strength ( $\mu$ N/m at 3 m)
30-88	100
88-216	150
216-960	200
Above 960	500

**Table 6 – General Field Strength Limits at frequencies below 30 MHz**

Frequency	Magnetic Field Strength (H-Field) ( $\mu$ A/m)	Measurement Distance (meters)
9-490 kHz <sup>1</sup>	6.37/F (F in kHz)	300
490-1 705 kHz	63.7/F (F in kHz)	30
1.705-30 MHz	0.08	30

**Note<sup>1</sup>:** The emission limits for the ranges 9-90 kHz and 110-490 kHz are based on measurements employing a linear average detector.

## 2.3. Test Procedures

Radiated emissions from the EUT were measured according to the dictates in section 11.11 & 11.12 of ANSI C63.10-2013

### 2.3.1. Test Procedures for emission below 30 MHz

1. The EUT was placed on the top of a rotating table 0.8 meters above the ground at a 3 meter anechoic chamber test site. The table was rotated 360 degrees to determine the position of the highest radiation.
2. Then antenna is a loop antenna is fixed at one meter above the ground to determine the maximum value of the field strength. Both parallel and perpendicular of the antenna are set to make the measurement.
3. For each suspected emission, the EUT was arranged to its worst case and then the table was turned from 0 degrees to 360 degrees to find the maximum reading.
4. The test-receiver system was set to average or quasi peak detect function and Specified Bandwidth with Maximum Hold Mode.

### 2.3.2. Test Procedures for emission from above 30 MHz

1. The EUT was placed on the top of a rotating table 0.8 meters above the ground at a 3 meter anechoic chamber test site below 1 GHz and 1.5 meters above the ground at a 3 meter anechoic chamber test site above 1 GHz. The table was rotated 360 degrees to determine the position of the highest radiation.
2. During performing radiated emission below 1 GHz, the EUT was set 3 meters away from the interference receiving antenna, which was mounted on the top of a variable-height antenna tower. During performing radiated emission above 1 GHz, the EUT was set 3 meter away from the interference-receiving antenna.
3. The antenna is a bi-log antenna, a horn antenna and its height is varied from one meter to four meters above the ground to determine the maximum value of the field strength. Both horizontal and vertical polarizations of the antenna are set to make the measurement.
4. For each suspected emission, the EUT was arranged to its worst case and then the antenna was tuned to heights from 1 meter to 4 meters and the table was turned from 0 degrees to 360 degrees to find the maximum reading.
5. For measurements below 1 GHz resolution bandwidth is set to 100 kHz for peak detection measurements or 120 kHz for quasi-peak detection measurements. Peak detection is used unless otherwise noted as quasi-peak.
6. For measurements Above 1 GHz resolution bandwidth is set to 1 MHz, the video bandwidth is set to 3 MHz for peak measurements and as applicable for average measurements.

### 2.3.3. Test Procedures for Radiated Spurious Emissions

#### 1. Unwanted Emissions into Non-Restricted Frequency Bands

- The Reference Level Measurement refer to section 11.11.2

Set analyzer center frequency to DTS channel center frequency, SPAN  $\geq$  1.5 times the DTS bandwidth, the RBW = 100 kHz and VBW  $\geq$  3 x RBW, Detector = Peak, Sweep time = Auto couple, Trace = Max hold.

- Unwanted Emissions Level Measurement refer to section 11.11.3

Set the center frequency and span to encompass frequency range to be measured, the RBW = 100 kHz and VBW  $\geq$  3 x RBW, Detector = Peak, Sweep time = Auto couple, Trace = Max hold.

#### 2. Unwanted Emissions into Restricted Frequency Bands

- Peak Power measurement procedure refer to section 11.12.2.4

Set RBW = as specified in Table 9, VBW  $\geq$  3 x RBW, Detector = Peak, Sweep time = auto, Trace = Max hold.

**Table 9 – RBW as a function of frequency**

Frequency	RBW
9 kHz to 150 kHz	200 Hz to 300 Hz
0.15 MHz to 30 MHz	9 kHz to 10 kHz
30 MHz to 1 000 MHz	100 kHz to 120 kHz
> 1 000 MHz	1 MHz

If the peak – detected amplitude can be shown to comply with the average limit, then it is not necessary to perform a separate average measurement.

- Average Power measurements procedure refer to section 11.12.2.5.2

The EUT shall be configured to operate at the maximum achievable duty cycle.

Measure the duty cycle D of the transmitter output signal as described in section 11.6.

Set RBW = 1 MHz, VBW  $\geq$  3 x RBW, Detector = RMS, if span / (# of points in sweep)  $\leq$  (RBW/2).

Satisfying this condition may require increasing the number of points in the sweep or reducing the span. If this condition cannot be satisfied then the detector mode shall be set to peak.

Averaging type = power (i.e., RMS).

As an alternative the detector and averaging type may be set for linear voltage averaging.

Some instruments require linear display mode in order to use linear voltage averaging. Log or dB averaging shall not be used. Sweep time = auto, Perform a trace average of at least 100 traces.

A correction factor shall be added to the measurement results prior to comparing to the emission limit in order to compute the emission level that would have been measured had the test been performed at 100 percent duty cycle. The correction factor is computed as follows:

- 1) If power averaging (rms) mode was used in step f), then the applicable correction factor is  $[10 \log (1 / D)]$ , where D is the duty cycle.

#### 3. Definition of DUT Axis.

The radiation test of the EUT was investigated in three orthogonal orientations X, Y, and Z described in the test setup photo. All radiated testing of EUT was performed with worst case asix.

### 2.3.4. Test Procedures for Conducted Spurious Emissions

Per the guidance of ANSI C63.10-2013, section 11.11.1 & 11.11.2 & 11.11.3, the reference level for out of band emissions is established from the plots of this section since the band edge emissions are measured with a RBW of 100  $\text{kHz}$ . This reference level is then used as the limit in subsequent plots for out of band spurious emissions shown in section 2.4.3. The limit for out of band spurious emission at the band edge is 20 dB below the fundamental emission level measured in a 100  $\text{kHz}$  bandwidth.

#### 1. Conducted Emissions at Band Edge

- The Measurement refer to section 11.11.3

Set the center frequency and span to encompass frequency range to be measured, the RBW = 100  $\text{kHz}$  and  $\text{VBW} \geq 3 \times \text{RBW}$ , Detector = Peak, Sweep time = Auto couple, Trace mode = Max hold, The trace was allowed to stabilize.

#### 2. Conducted Spurious Emissions

- The Measurement refer to section 11.11.3

Start frequency was set to 9  $\text{kHz}$  and stop frequency was set to 25  $\text{GHz}$  (separated into two plots per channel), RBW = 1  $\text{MHz}$ ,  $\text{VBW} \geq 3 \times \text{RBW}$ , Detector = Peak, Sweep time = Auto couple, Trace = Max hold, The trace was allowed to stabilize.

#### 3. TDF function

- For plots showing conducted spurious emissions from 9  $\text{kHz}$  to 25  $\text{GHz}$ , all path loss of wide frequency range was investigated and compensated to spectrum analyzer as TDF function.  
So, the reading values shown in plots were final result.

## 2.4. Test Results

Ambient temperature :  $(23 \pm 1)^\circ\text{C}$

Relative humidity : 47 % R.H.

### 2.4.1. Radiated Spurious Emission below 1 000 MHz

#### 2.4.1.1. Basic model

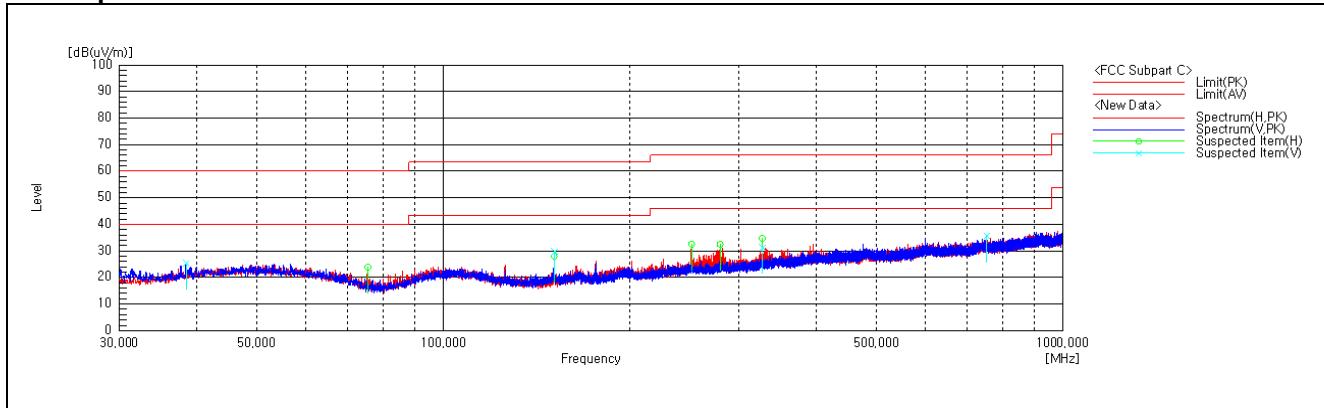
The frequency spectrum from 9 kHz to 1 000 MHz was investigated. All reading values are peak values.

Radiated Emissions			Ant	Correction Factors		Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ N)	Detect Mode	Pol.	AF (dB/m)	AMP + CL (dB)	Actual (dB $\mu$ N/m)	Limit (dB $\mu$ N/m)	Margin (dB)
38.45	35.30	Peak	V	17.93	-27.71	25.52	40.00	14.48
151.05	42.60	Peak	V	13.80	-26.71	29.69	43.50	13.81
251.81	39.90	Peak	H	18.60	-26.05	32.45	46.00	13.55
279.82	39.70	Peak	H	18.60	-25.79	32.51	46.00	13.49
327.10	40.40	Peak	H	19.76	-25.51	34.65	46.00	11.35
754.31	35.10	Peak	V	26.60	-26.02	35.68	46.00	10.32
Above 800.00	Not detected	-	-	-	-	-	-	-

#### Remark:

- Spurious emissions for all channels were investigated and almost the same below 1 GHz.
- Reported spurious emissions are in **PHY 1M / 37 bytes / Low channel** as worst case among other channels.
- Radiated spurious emission measurement as below.  
(Actual = Reading + AF + AMP + CL)
- According to §15.31(o), emission levels are not report much lower than the limits by over 20 dB.
- Test from 30 MHz to 1 000 MHz was performed using the software of EP5RE(V5.3.70) from TOYO.

#### - Test plot



#### 2.4.1.2. Variant model

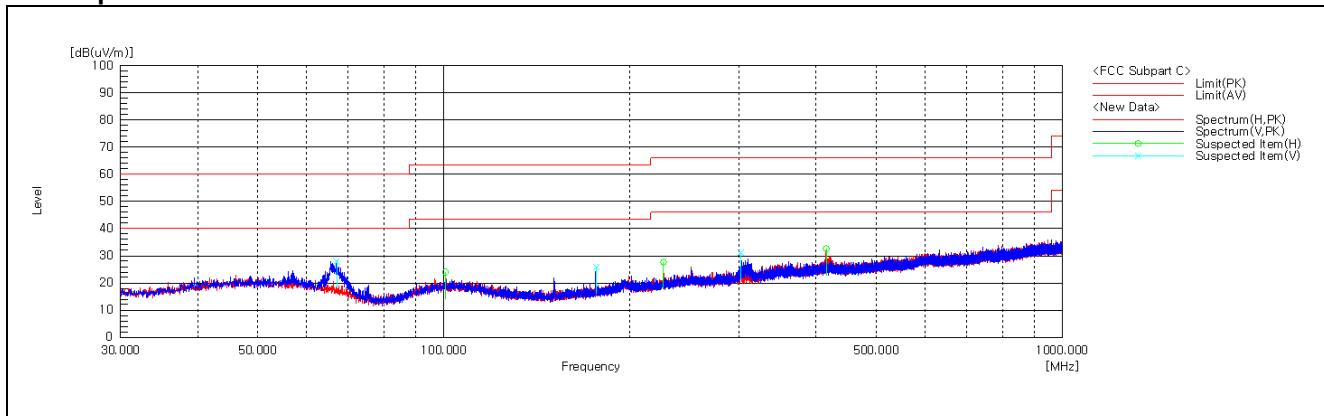
The frequency spectrum from 9 kHz to 1 000 MHz was investigated. All reading values are peak values.

Radiated Emissions			Ant	Correction Factors		Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ N)	Detect Mode	Pol.	AF (dB/m)	AMP + CL (dB)	Actual (dB $\mu$ N/m)	Limit (dB $\mu$ N/m)	Margin (dB)
67.18	38.90	Peak	V	16.23	-27.09	<u>28.04</u>	40.00	11.96
100.61	33.20	Peak	H	17.84	-27.06	23.98	43.50	19.52
176.23	37.30	Peak	V	14.82	-26.25	25.87	43.50	17.63
226.51	36.20	Peak	H	17.43	-25.91	27.72	46.00	18.28
301.96	37.70	Peak	V	19.00	-25.39	31.31	46.00	14.69
415.09	36.00	Peak	H	21.80	-25.15	32.65	46.00	13.35
Above 500.00	Not detected	-	-	-	-	-	-	-

#### Remark;

1. Spurious emissions for all channels were investigated and almost the same below 1 GHz.
2. Reported spurious emissions are in **PHY 1M / 37 bytes / Middle channel** as worst case among other channels.
3. Radiated spurious emission measurement as below.  
(Actual = Reading + AF + AMP + CL)
4. According to §15.31(o), emission levels are not report much lower than the limits by over 20 dB.
5. Test from 30 MHz to 1 000 MHz was performed using the software of EP5RE(V5.3.70) from TOYO.

#### - Test plot



## 2.4.2. Radiated Spurious Emission above 1 000 MHz

### 2.4.2.1. Basic model

The frequency spectrum above 1 000 MHz was investigated. All reading values are peak and average values.

Low Channel (2 402 MHz)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
*2 310.00	17.80	Peak	V	28.04	6.37	-	52.21	74.00	21.79
*2 310.00	7.67	Average	V	28.04	6.37	2.05	44.13	54.00	9.87
*2 349.06	19.81	Peak	V	28.20	6.42	-	54.43	74.00	19.57
*2 328.71	8.72	Average	V	28.11	6.36	2.05	45.24	54.00	8.76
*2 390.00	17.75	Peak	V	28.28	6.63	-	52.66	74.00	21.34
*2 390.00	7.88	Average	V	28.28	6.63	2.05	44.84	54.00	9.16

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
*4 987.90	44.79	Peak	V	33.20	-35.34	-	42.65	74.00	31.35
Above 5 000.00	Not detected	-	-	-	-	-	-	-	-

Middle Channel (2 440 MHz)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
*5 008.90	41.61	Peak	V	33.24	-35.27	-	39.58	74.00	34.42
Above 5 100.00	Not detected	-	-	-	-	-	-	-	-

## High Channel (2 480 MHz)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
*2 483.50	21.55	Peak	V	28.27	6.35	-	56.17	74.00	17.83
*2 483.50	8.54	Average	V	28.27	6.35	2.05	45.21	54.00	8.79
*2 484.31	22.32	Peak	V	28.27	6.35	-	56.94	74.00	17.06
*2 491.00	8.71	Average	V	28.28	6.34	2.05	<b>45.38</b>	54.00	8.62
*2 500.00	18.73	Peak	V	28.30	6.32	-	53.35	74.00	20.65
*2 500.00	8.28	Average	V	28.30	6.32	2.05	44.95	54.00	9.05

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
*4 999.80	42.55	Peak	V	33.20	-35.26	-	30.09	74.00	43.91
Above 5 000.00	Not detected	-	-	-	-	-	-	-	-

**2.4.2.2. Variant model**

The frequency spectrum above 1 000 MHz was investigated. All reading values are peak and average values.

Low Channel (2 402 MHz)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
*2 310.00	14.02	Peak	H	28.04	5.99	-	48.05	74.00	25.95
*2 310.00	3.28	Average	H	28.04	5.99	2.05	39.36	54.00	14.64
*2 345.26	15.67	Peak	H	28.18	6.37	-	50.22	74.00	23.78
*2 388.31	4.56	Average	H	28.28	6.20	2.05	41.09	54.00	12.91
*2 390.00	14.26	Peak	H	28.28	6.20	-	48.74	74.00	25.26
*2 390.00	4.26	Average	H	28.28	6.20	2.05	40.79	54.00	13.21

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

Middle Channel (2 440 MHz)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

High Channel (2 480 MHz)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
*2 483.50	15.79	Peak	H	28.27	6.40	-	50.46	74.00	23.54
*2 483.50	3.87	Average	H	28.27	6.40	2.05	40.59	54.00	13.41
*2 483.58	16.27	Peak	H	28.27	6.40	-	50.94	74.00	23.06
*2 486.17	4.70	Average	H	28.27	6.37	2.05	41.39	54.00	12.61
*2 500.00	14.56	Peak	H	28.30	6.19	-	49.05	74.00	24.95
*2 500.00	3.43	Average	H	28.30	6.19	2.05	39.97	54.00	14.03

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (MHz)	Reading (dB $\mu$ V)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

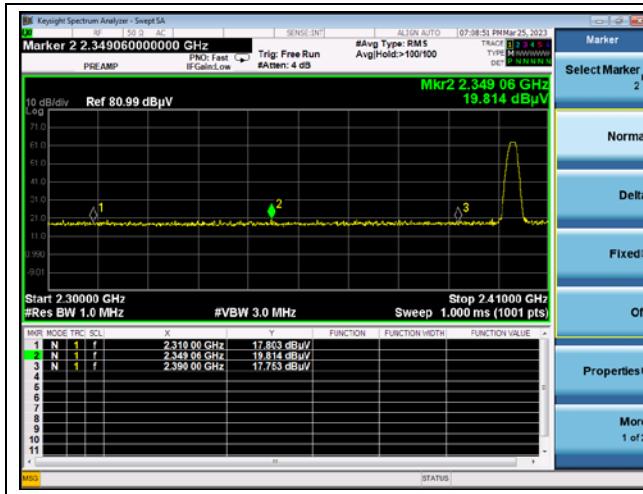
**Remarks:**

- \*\*\* means the restricted band.
- Measuring frequencies from 1 GHz to the 10<sup>th</sup> harmonic of highest fundamental frequency.
- Radiated emissions measured in frequency above 1 000 MHz were made with an instrument using peak/average detector mode.
- Actual = Reading + AF + CL + (DF) or Reading + AF + AMP + CL + (DF).
- According to § 15.31(o), emission levels are not reported much lower than the limits by over 20 dB.
- The maximized peak measured value complies with the average limit, to perform an average measurement is unnecessary.
- AF = Antenna Factor, CL = Cable Loss, DF = Duty Correction Factor.

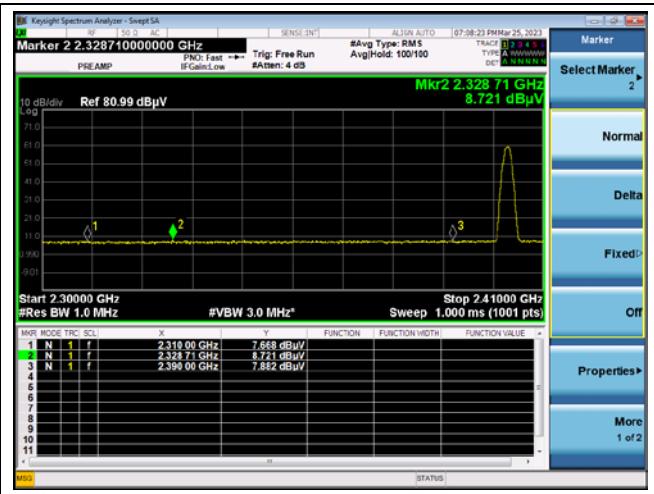
**- Test plots**

**- Basic model**

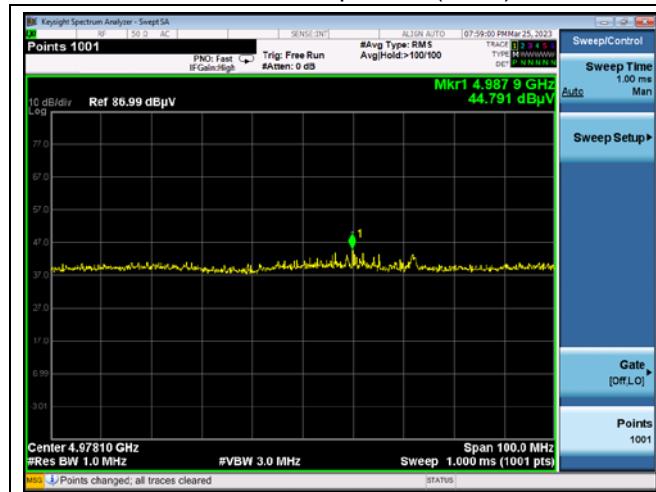
Low channel band edge (Peak)



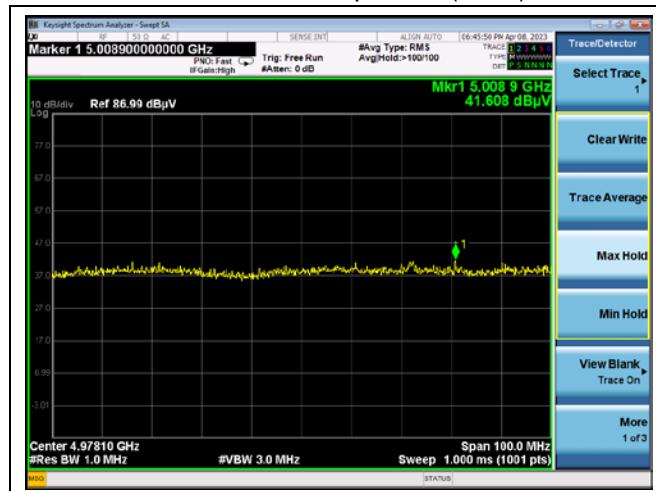
Low channel band edge (Average)



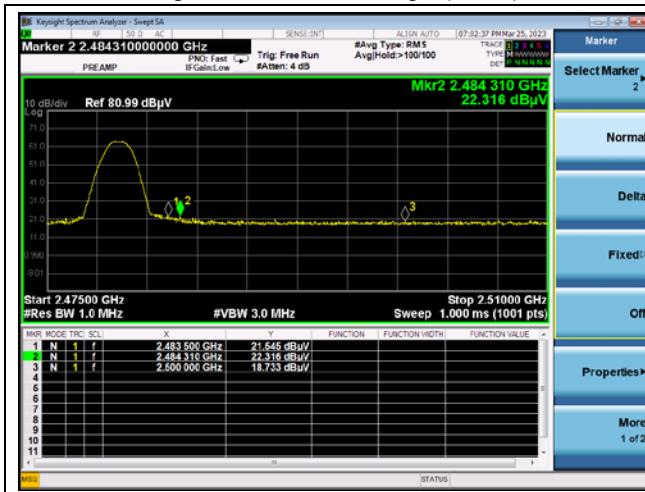
Low channel Spurious (Peak)



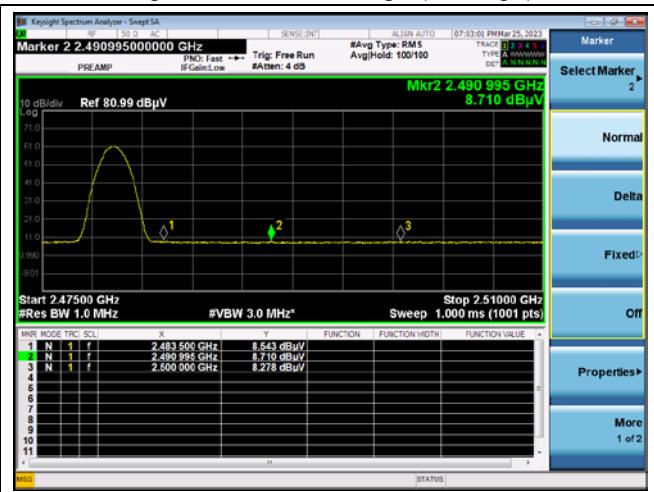
Middle channel Spurious (Peak)



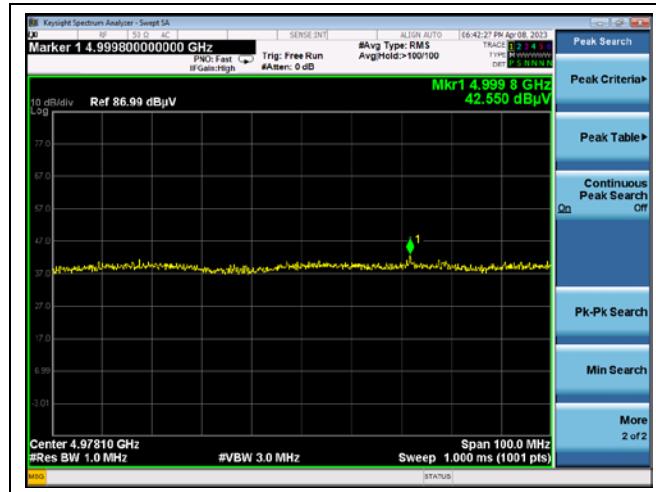
High channel band edge (Peak)



High channel band edge (Average)

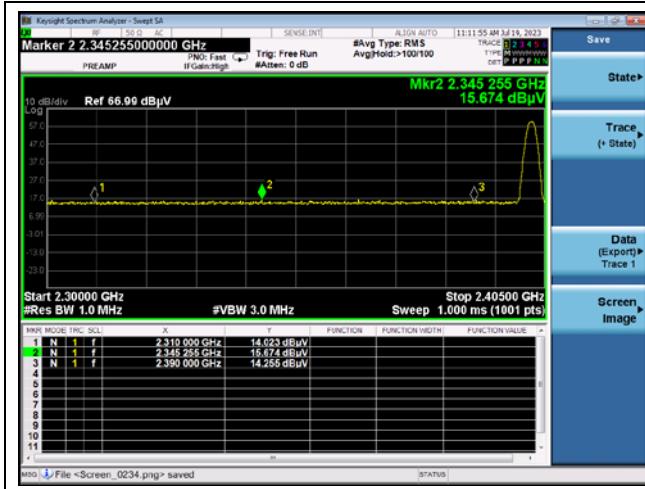


High channel Spurious (Peak)

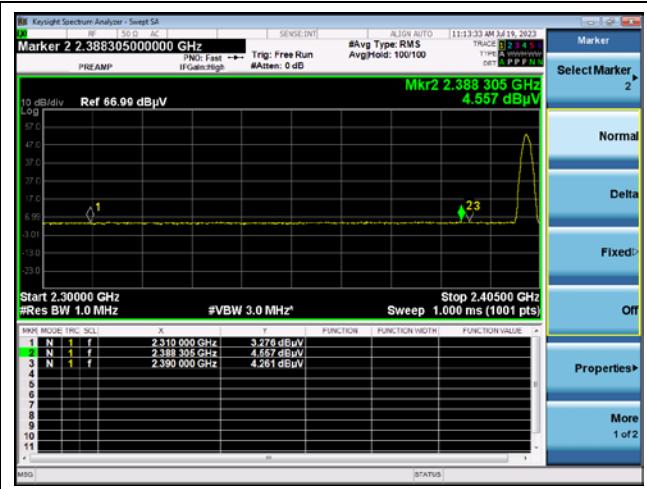


**- Variant model**

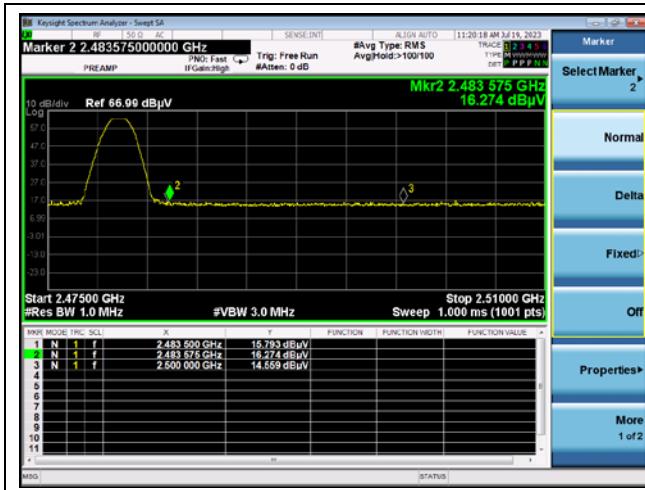
Low channel band edge (Peak)



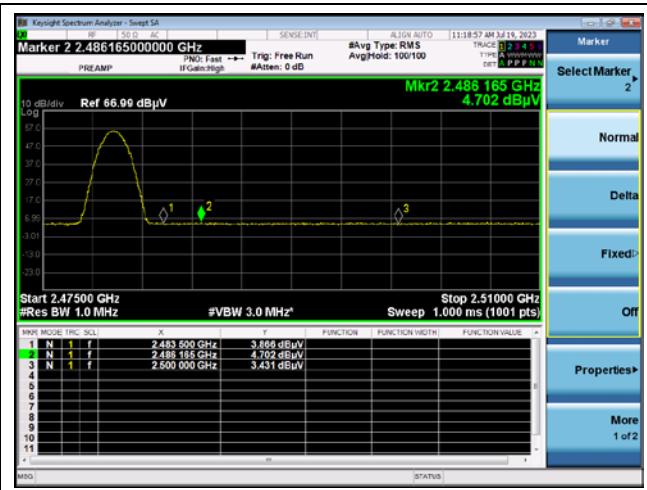
Low channel band edge (Average)



High channel band edge (Peak)



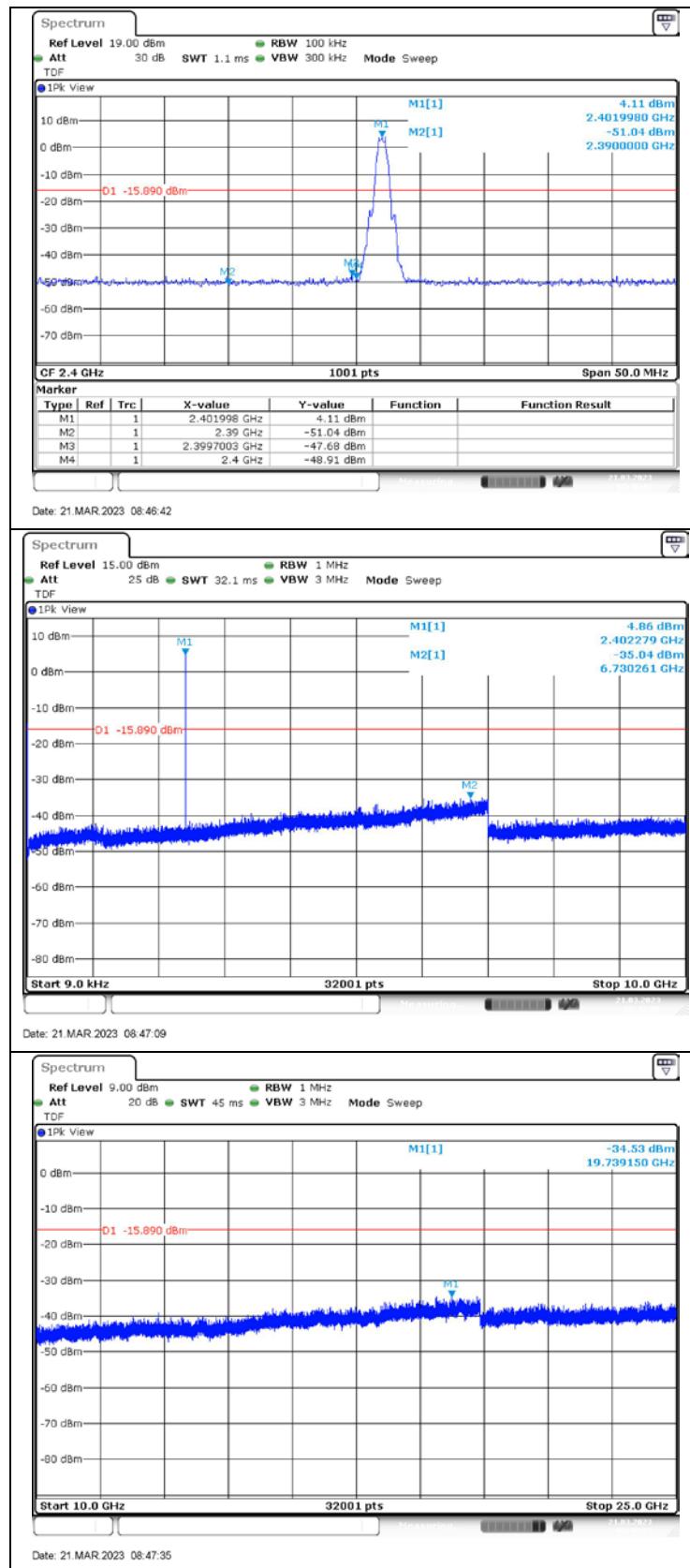
High channel band edge (Average)



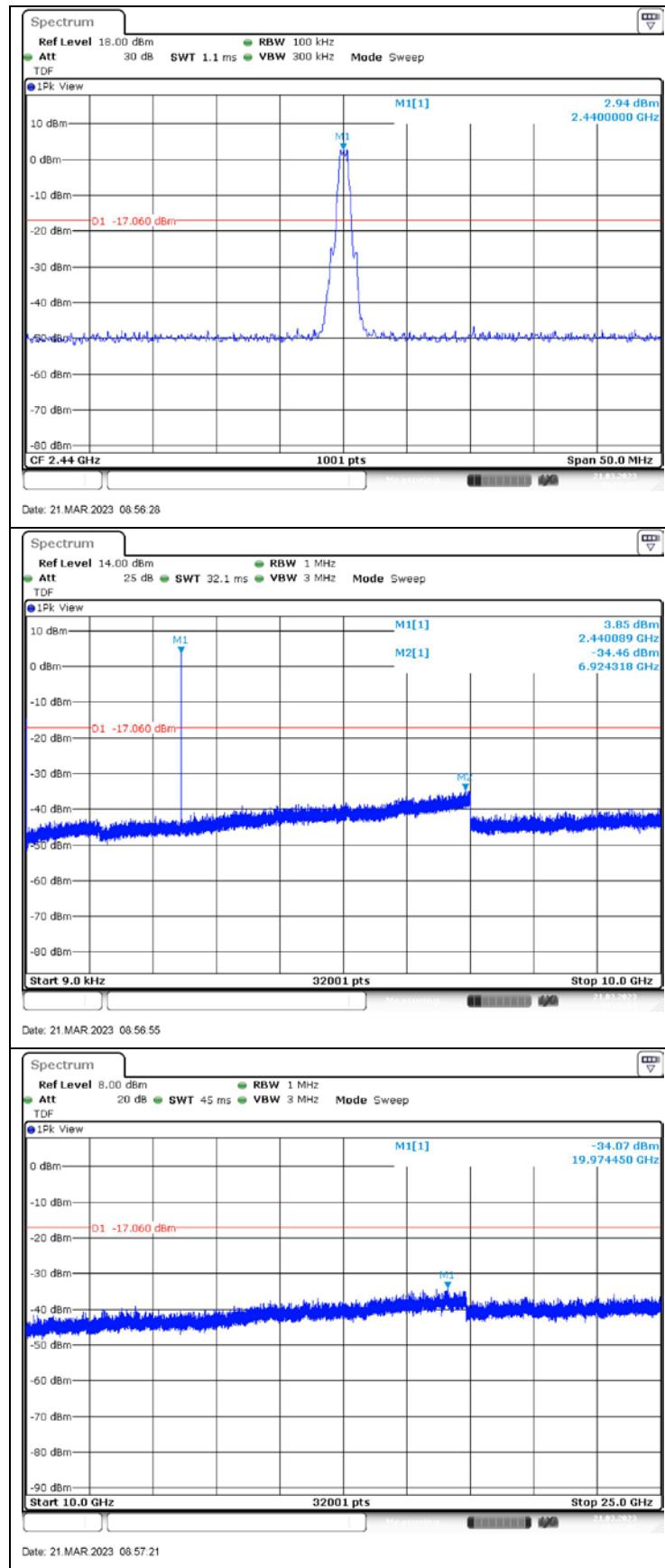
### 2.4.3. Plot of Conducted Spurious Emissions

#### 2.4.3.1. Basic model

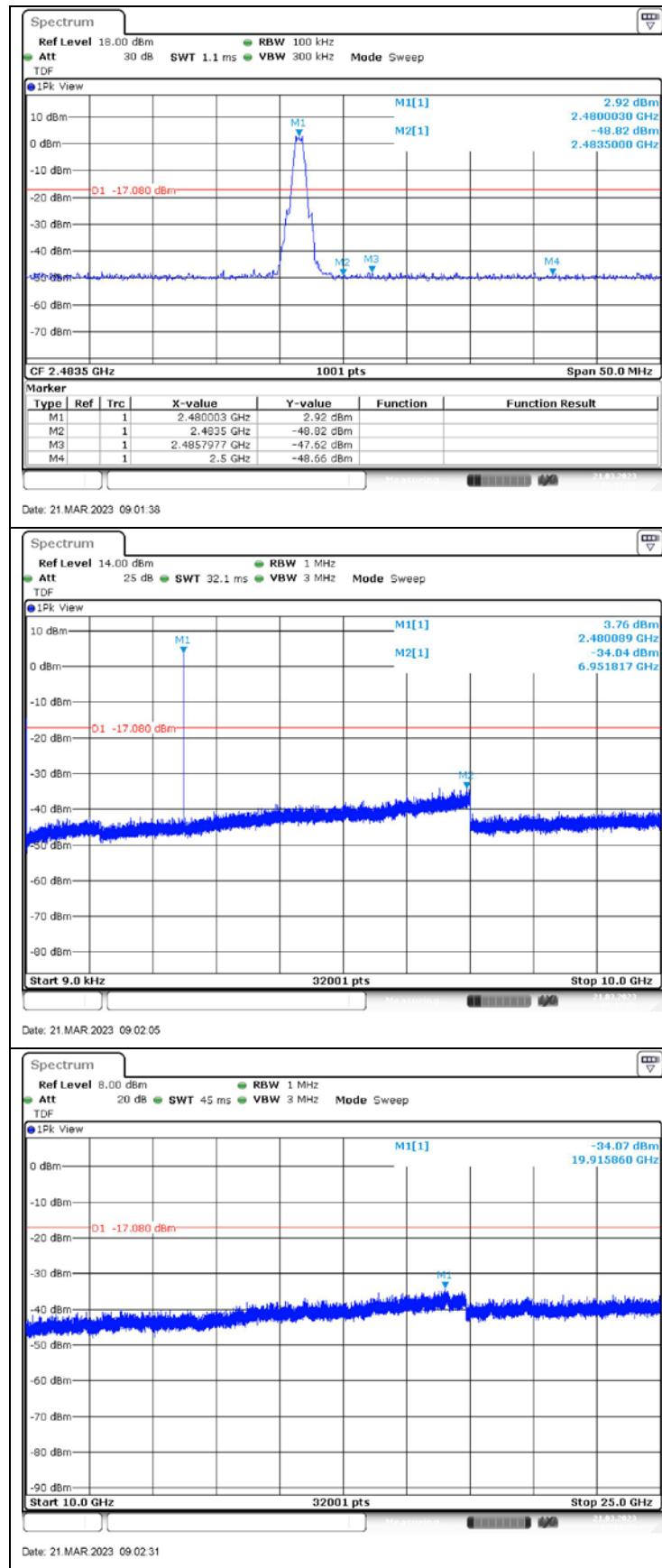
Low Channel



## Middle Channel

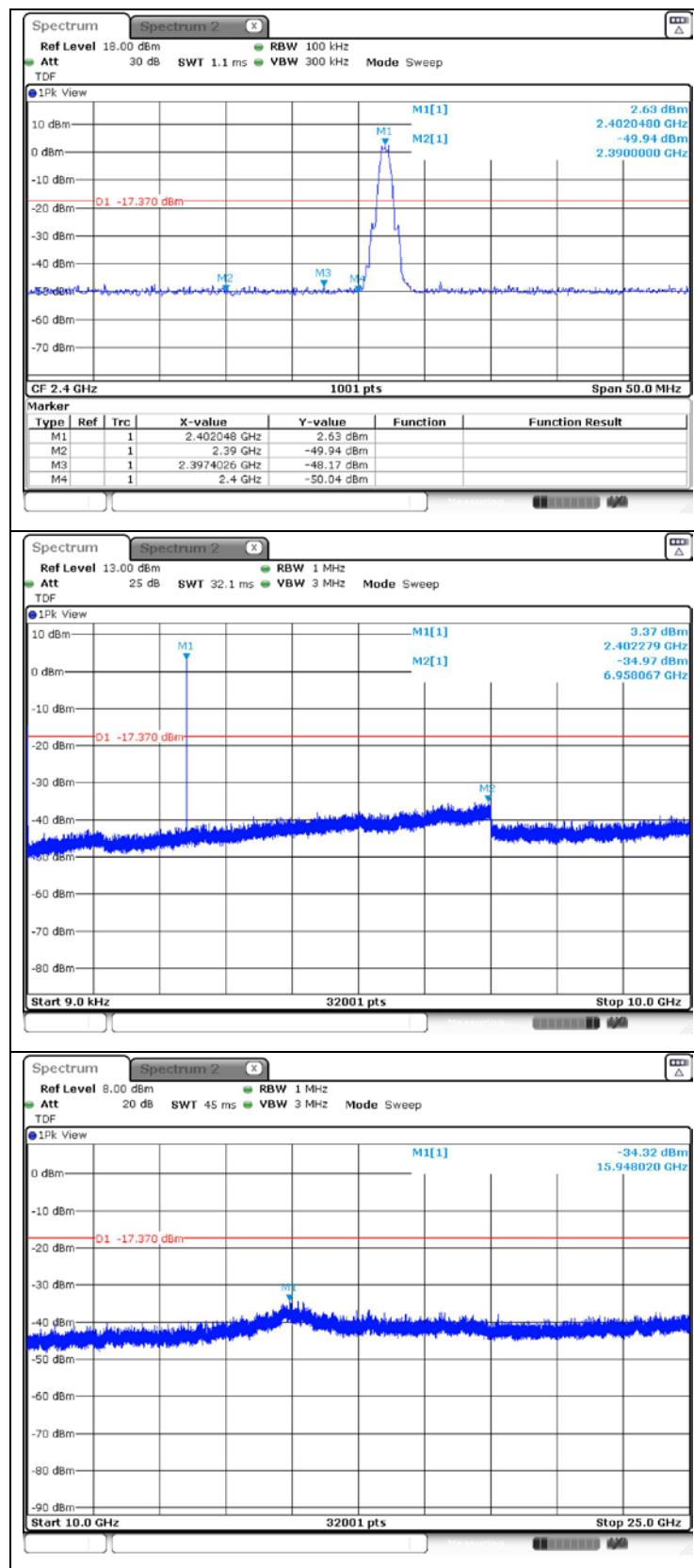


## High Channel

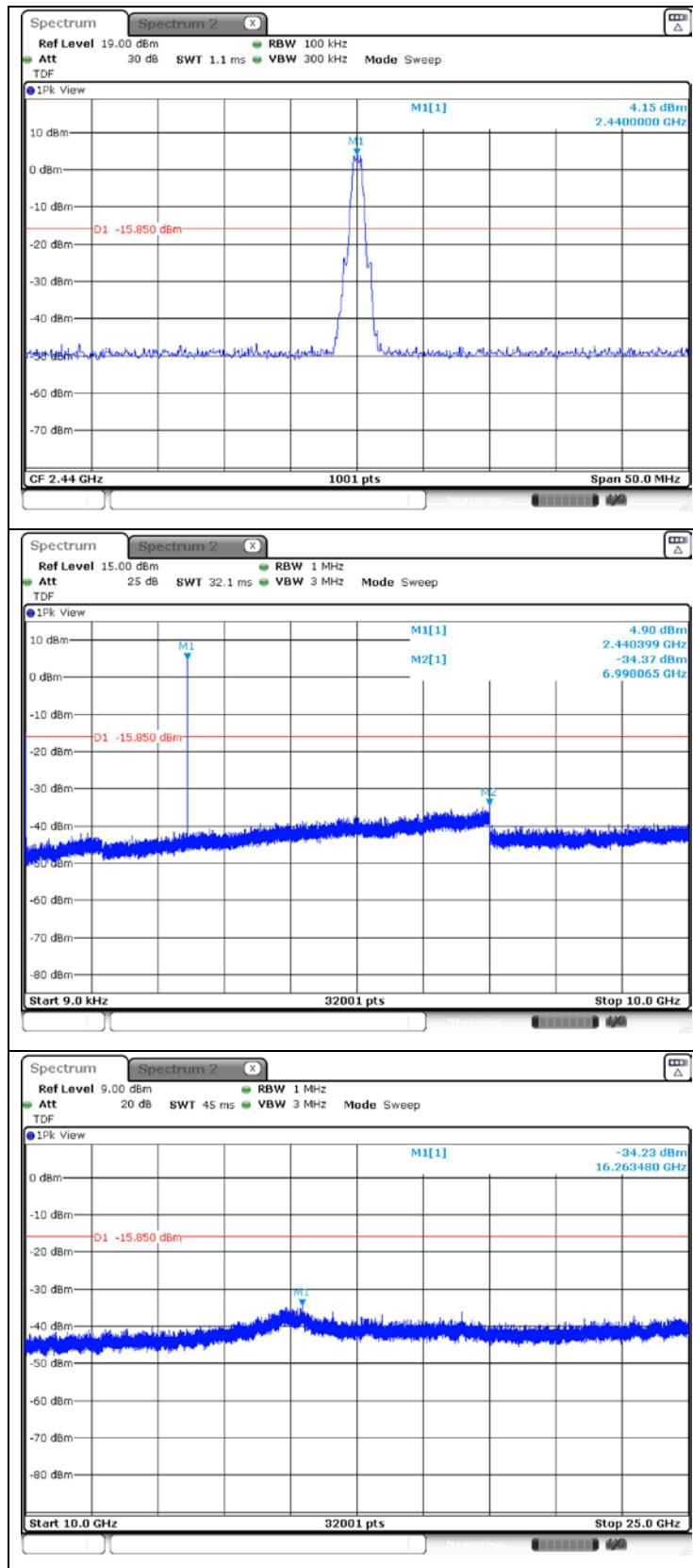


### 2.4.3.2. Variant model

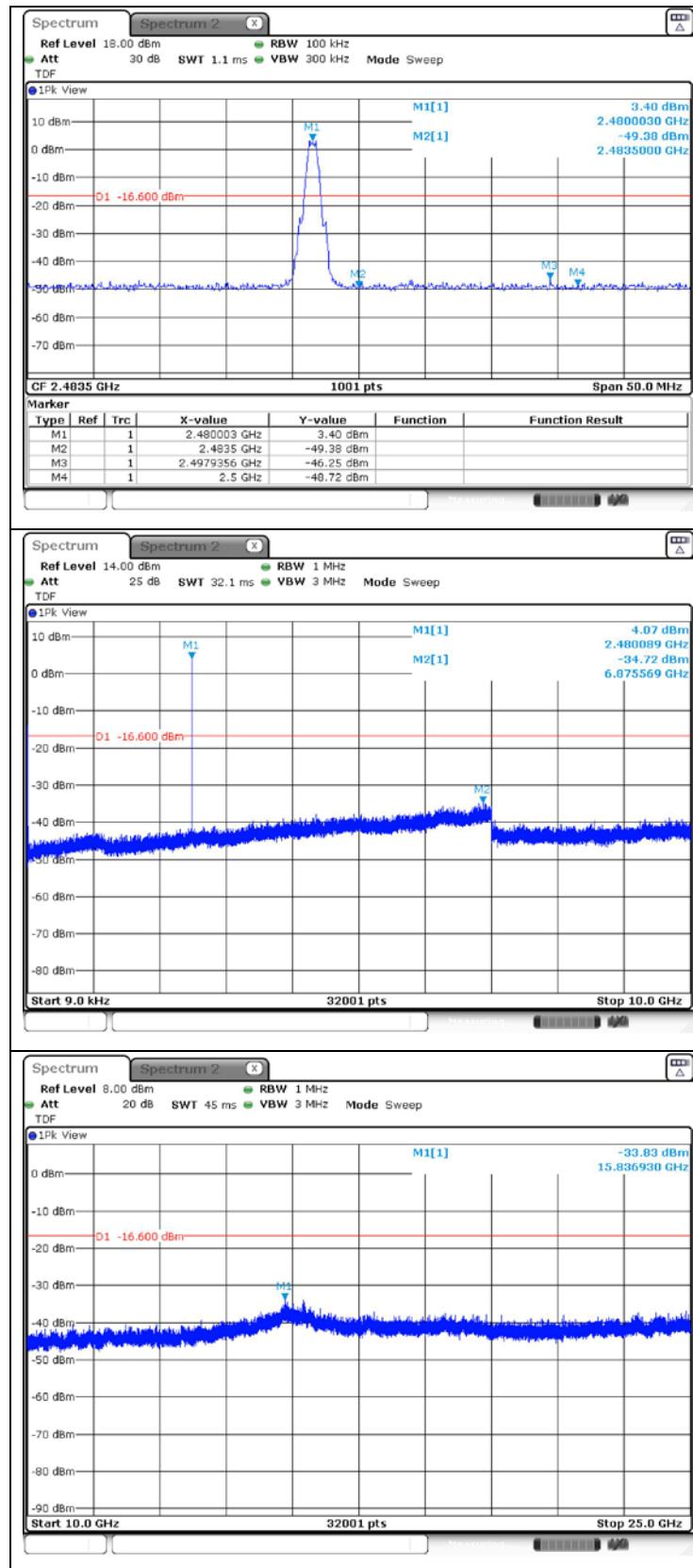
Low Channel



## Middle Channel



## High Channel



## 3.6 dB Bandwidth and 99 % Bandwidth

### 3.1. Test Setup



### 3.2. Limit

#### 3.2.1. FCC

According to §15.247(a)(2), systems using digital modulation techniques may operate in the 902-928 MHz, 2 400-2 483.5 MHz, and 5 725-5 850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

#### 3.2.2. IC

According to RSS-247 Issue 2, 5.2(a), the minimum 6 dB bandwidth shall be 500 kHz.

### 3.3. Test Procedure

The test follows section 11.8 DTS bandwidth of ANSI C63.10-2013.

Tests performed using section 11.8.1 Option 1.

#### 3.3.1. 6 dB Bandwidth

- Option 1:

1. Set RBW to = 100 kHz.
2. Set the VBW  $\geq [3 \times \text{RBW}]$ .
3. Detector = peak.
4. Trace mode = max hold.
5. Sweep = auto couple.
6. Allow the trace to stabilize.
7. 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.

### 3.3.2. 99 % Bandwidth

The following conditions shall be observed for measuring the occupied bandwidth and x dB bandwidth:

- The transmitter shall be operated at its maximum carrier power measured under normal test conditions.
- The span of the spectrum analyzer shall be set large enough to capture all products of the modulation process, including the emission skirts, around the carrier frequency, but small enough to avoid having other emissions (e.g. on adjacent channels) within the span.
- The detector of the spectrum analyzer shall be set to “Sample”. However, a peak, or peak hold, may be used in place of the sampling detector since this usually produces a wider bandwidth than the actual bandwidth (worst-case measurement). Use of a peak hold (or “Max Hold”) may be necessary to determine the occupied / x dB bandwidth if the device is not transmitting continuously.
- The resolution bandwidth (RBW) shall be in the range of 1 % to 5 % of the actual occupied / x dB bandwidth and the video bandwidth (VBW) shall not be smaller than three times the RBW value. Video averaging is not permitted.

**Note:** It may be necessary to repeat the measurement a few times until the RBW and VBW are in compliance with the above requirement.

For the 99 % emission bandwidth, the trace data points are recovered and directly summed in linear power level terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5 % of the total is reached, and that frequency recorded. The process is repeated for the highest frequency data points (starting at the highest frequency, at the right side of the span, and going down in frequency). This frequency is then recorded. The difference between the two recorded frequencies is the occupied bandwidth (or the 99 % emission bandwidth).

### 3.4. Test Results

Ambient temperature :  $(23 \pm 1)$  °C

Relative humidity : 47 % R.H.

#### - 6 dB Bandwidth

Model	Mode	Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Bandwidth (kHz)	
Basic model	GFSK	Low	2 402	0.713	500	
		Middle	2 440	0.713		
		High	2 480	0.713		
Variant model		Low	2 402	0.698		
		Middle	2 440	0.707		
		High	2 480	0.710		

#### - 99 % Bandwidth

Model	Mode	Channel	Frequency (MHz)	99 % Bandwidth (MHz)	Limit	
Basic model	GFSK	Low	2 402	1.058	-	
		Middle	2 440	1.058		
		High	2 480	1.061		
Variant model		Low	2 402	1.052		
		Middle	2 440	1.052		
		High	2 480	1.052		