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## Test Report

### Certification

<b>FCC ID</b>	SZV-TCM515B
<b>Equipment Under Test</b>	TCM515B
<b>Test Report Serial No</b>	V064178_01
<b>Dates of Test</b>	May 9 and July 9, 2022
<b>Report Issue Date</b>	July 27, 2022

<b>Test Specifications:</b>	<b>Applicant:</b>
FCC Part 15, Subpart C	EnOcean GmbH Kolpingring 18A Oberhaching 82041 Germany



## Certification of Engineering Report

This report has been prepared by VPI Laboratories, Inc. to document compliance of the device described below with the requirements of Federal Communications Commission (FCC) Part 15, Subpart C. This report may be reproduced in full. Partial reproduction of this report may only be made with the written consent of the laboratory. The results in this report apply only to the sample tested.

<b>Applicant</b>	EnOcean, GmbH
<b>Manufacturer</b>	EnOcean, GmbH
<b>Brand Name</b>	EnOcean
<b>Model Number</b>	TCM515B
<b>FCC ID</b>	SZV-TCM515B

On this 27<sup>th</sup> day of July 2022, I, individually and for VPI Laboratories, Inc., certify that the statements made in this engineering report are true, complete, and correct to the best of my knowledge, and are made in good faith.

Although NVLAP has accredited the VPI Laboratories, Inc. EMC testing facilities, this report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

VPI Laboratories, Inc.



Tested by: Benjamin N. Antczak



Reviewed by: Jason Stewart

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<b>Revision History</b>		
<b>Revision</b>	<b>Description</b>	<b>Date</b>
01	Original Report Release	July 27, 2022

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## 1 Client Information

### 1.1 Applicant

<b>Company Name</b>	EnOcean, GmbH Kolpingring 18A Oberhaching 82041 Germany
<b>Contact Name</b>	Armin Anders
<b>Title</b>	VP Business Development

### 1.2 Manufacturer

<b>Company Name</b>	EnOcean, GmbH Kolpingring 18A Oberhaching 82041 Germany
<b>Contact Name</b>	Armin Anders
<b>Title</b>	VP Business Development

## 2 Equipment Under Test (EUT)

### 2.1 Identification of EUT

<b>Brand Name</b>	EnOcean
<b>Model Number</b>	TCM515B
<b>Serial Number</b>	N/A
<b>Dimensions (cm)</b>	4.0 x 3.5 x 2.5
<b>Mfr. Declared Antenna Gain (dBi)</b>	-3.2

### 2.2 Customer Supplied Data (if applicable)

#### 2.2.1 Disclaimer

This test report contains customer supplied data that may influence the validity of the results presented. The customer maintains responsibility for the accuracy of these results.

### 2.3 Description of EUT

TCM 515B provides radio transceiver functionality (telegram transmission and reception) according to the Bluetooth Low Energy standard in the 2.4 GHz radio band. TCM 515B receives and transmits radio telegrams based on a whip or PCB antenna connected via the host PCB. The device's Bluetooth LE capability is limited to 2Mbit modulation only. The EUT was mounted to a carrier PCB that contained the -3.2 dBi trace antenna, and a 3.6VDC battery to keep the system transmitting.

EUT can operate on the following channels: bolded channels are evaluated in this report:

Channel	Frequency (MHz)	Channel	Frequency (MHz)	Channel	Frequency (MHz)	Channel	Frequency (MHz)
<b>1</b>	<b>2402</b>	11	2422	21	2442	31	2462
2	2404	12	2424	22	2444	32	2464
3	2406	<b>13</b>	<b>2426</b>	23	2446	33	2466
4	2408	14	2428	24	2448	34	2468
5	2410	15	2430	25	2450	35	2470
6	2412	16	2432	26	2452	36	2472
7	2414	17	2434	27	2454	37	2474
8	2416	18	2436	28	2456	38	2476
9	2418	19	2438	29	2458	39	2478
10	2420	20	2440	30	2460	<b>40</b>	<b>2480</b>

This report covers the circuitry of the devices subject to FCC Part 15, Subpart C.

### 2.4 EUT and Support Equipment

The EUT and support equipment used during the test are listed below.

<b>Brand Name</b> <b>Model Number</b> <b>Serial Number</b>	<b>Description</b>	<b>Name of Interface Ports / Interface Cables</b>
BN: EnOcean MN: TCM515B (Note 1) SN: N/A	Wireless Transceiver	See Section 2.4

Notes: (1) EUT

(2) Interface port connected to EUT (See Section 2.4)

The support equipment listed above was not modified in order to achieve compliance with this standard.

## 2.5 Interface Ports on EUT

There are no interface ports on the EUT.

## 2.6 Modification Incorporated/Special Accessories on EUT

There were no modifications or special accessories required to comply with the specification.

## 2.7 Deviation from Test Standard

There were no deviations from the test specification.

### 3 Test Specification, Methods and Procedures

#### 3.1 Test Specification

<b>Title</b>	FCC PART 15, Subpart C (47 CFR 15) 15.203, 15.207, and 15.247 Limits and methods of measurement of radio interference characteristics of radio frequency devices.
<b>Purpose of Test</b>	The tests were performed to demonstrate initial compliance

#### 3.2 Methods & Procedures

##### 3.2.1 §15.203 Antenna Requirement

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of Sections 15.211, 15.213, 15.217, 15.219, or 15.221. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with Section 15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this Part are not exceeded.

##### 3.2.2 §15.207 Conducted Limits

(a) Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 μH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

Frequency range (MHz)	Limit (dBμV)	
	Quasi-peak	Average
0.15 to 0.50*	66 to 56*	56 to 46*
0.50 to 5	56	46
5 to 30	60	50

\*Decreases with the logarithm of the frequency.

**Table 1: Limits for conducted emissions at mains ports of Class B ITE.**

##### 3.2.3 §15.247 Operation within the bands 902 – 928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz

- a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions.



- 1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400 – 2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.
    - i. For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.
    - ii. Frequency hopping systems operating in the 5725-5850 MHz band shall use at least 75 hopping frequencies. The maximum 20 dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.
    - iii. Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 non-overlapping channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 non-overlapping channels are used.
  - 2) 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.
- b) The maximum peak output power of the intentional radiator shall not exceed the following:
- 1) For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.
  - 2) For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

- 3) For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725 – 5850 MHz bands: 1 watt. As an alternative to a peak power measurement, compliance with the Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.
  - 4) The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.
- c) Operation with directional antenna gains greater than 6 dBi.
- 1) Fixed point-to-point operation:
    - i. Systems operating in the 2400-2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.
    - ii. Systems operating in the 5725-5850 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi without any corresponding reduction in transmitter peak output power.
    - iii. Fixed, point-to-point operation, as used in paragraphs (b)(4)(i) and (b)(4)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.
  - 2) In addition to the provisions in paragraphs (b)(1), (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400-2483.5 MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:
    - i. Different information must be transmitted to each receiver.

- ii. If the transmitter employs an antenna system that emits multiple directional beams but does not emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna /antenna array exceeds 6 dBi. The directional antenna gain shall be computed as follows:
    - A. The directional gain shall be calculated as the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.
    - B. A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.
  - iii. If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8 dB.
  - iv. Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.
- 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 Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).
- e) For digitally modulated systems, the 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. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.
- f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned off, shall have an

average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The digital modulation operation of the hybrid system, with the frequency hopping turned off, shall comply with the power density requirements of paragraph (d) of this section.

- g) Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.
- h) The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hops to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.
- i) Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines. See § 1.1307(b)(1) of this Chapter.

Note: Spread spectrum systems are sharing these bands on a noninterference basis with systems supporting critical Government requirements that have been allocated the usage of these bands, secondary only to ISM equipment operated under the provisions of Part 18 of this Chapter. Many of these Government systems are airborne radiolocation systems that emit a high EIRP which can cause interference to other users. Also, investigations of the effect of spread spectrum interference to U. S. Government operations in the 902-928 MHz band may require a future decrease in the power limits allowed for spread spectrum operation.

### **3.3 Test Procedure**

VPI Laboratories, Inc. is accredited by National Voluntary Laboratory Accreditation Program (NVLAP); NVLAP Lab Code: 100272-0, which is effective until September 30, 2022. VPI Laboratories, Inc. carries FCC Accreditation Designation Number US5263. VPI Laboratories main office is located at 313 W 12800 S, Suite 311, Draper, UT 84020. The testing was performed according to the procedures in ANSI C63.10-2013, KDB 558074, and 47 CFR Part 15.

## 4 Operation of EUT During Testing

### 4.1 Operating Environment

Power Supply	3.6 VDC Lithium Battery
AC Mains Frequency	N/A

### 4.2 Operating Modes

The transmitter was tested on 3 orthogonal axes while in a constant transmit mode at the upper, middle, and lower channels. A new battery was installed for testing. Measured values in this report are at the worst-case axis, see Photograph 5, Section 8 below.

### 4.3 EUT Exercise Software

Internal EnOcean software was used to control the EUT. Single button-press on the EUT switches transmission between low middle and high channels.

## 5 Summary of Test Results

### 5.1 FCC Part 15, Subpart C

#### 5.1.1 Summary of Tests

Section	Environmental Phenomena	Frequency Range (MHz)	Result
15.203	Antenna Requirements	Structural requirement	Complied
15.207	Conducted Disturbance at Mains Ports	0.15 to 30	Not Applicable (1)
15.247(a)	Bandwidth Requirement	2400 to 2483.5	Complied
15.247(b)	Peak Output Power	2400 to 2483.5	Complied
15.247(d)	Spurious Emissions	0.009 – 25000	Complied
15.247€	Peak Power Spectral Density	2400 to 2483.5	Complied
Note 1: The EUT does not have provisions for connecting to AC Mains.			

### 5.2 Result

In the configuration tested, the EUT complied with the requirements of the specification.

## 6 Measurements, Examinations and Derived Results

### 6.1 General Comments

This section contains the test results only. Details of the test methods used and a list of the test equipment used during the measurements can be found in Section 7 of this report. Measurement hardcopies are provided in Section 9 of this report.

When calculations in this report require EUT antenna gains, those values have been provided by the manufacturer unless otherwise noted.

### 6.2 Test Results

#### 6.2.1 §15.203 Antenna Requirements

The EUT uses a PCB Trace Antenna with a manufacturer declared maximum in-band gain of -3.2dBi (see Section 8, Photograph 3).

#### Result

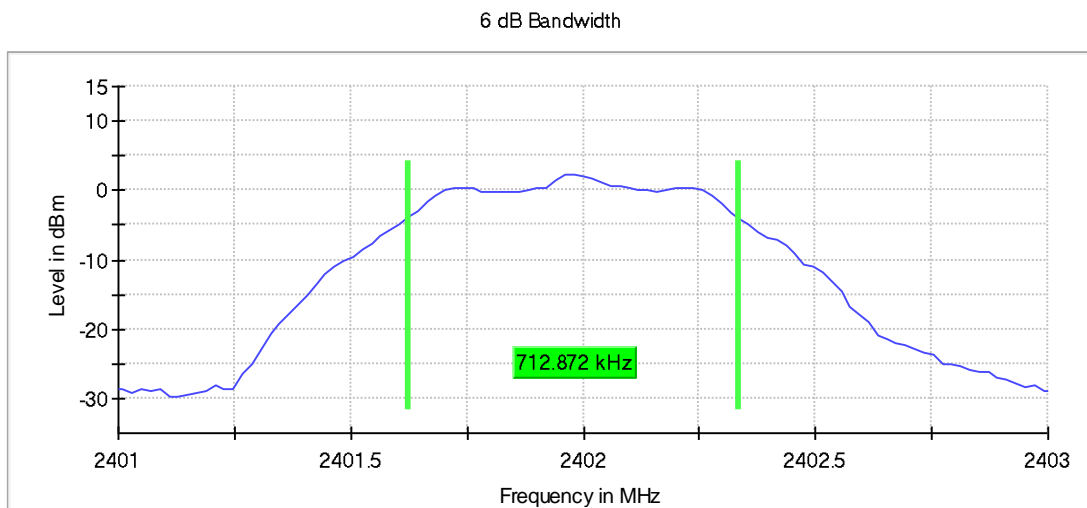
The EUT complied with the specification.

#### 6.2.2 §15.247(a)(2) Emissions Bandwidth

Frequency (MHz)	Emissions 6 dB bandwidth (kHz)
2402	712.9
2426	752.5
2480	712.9

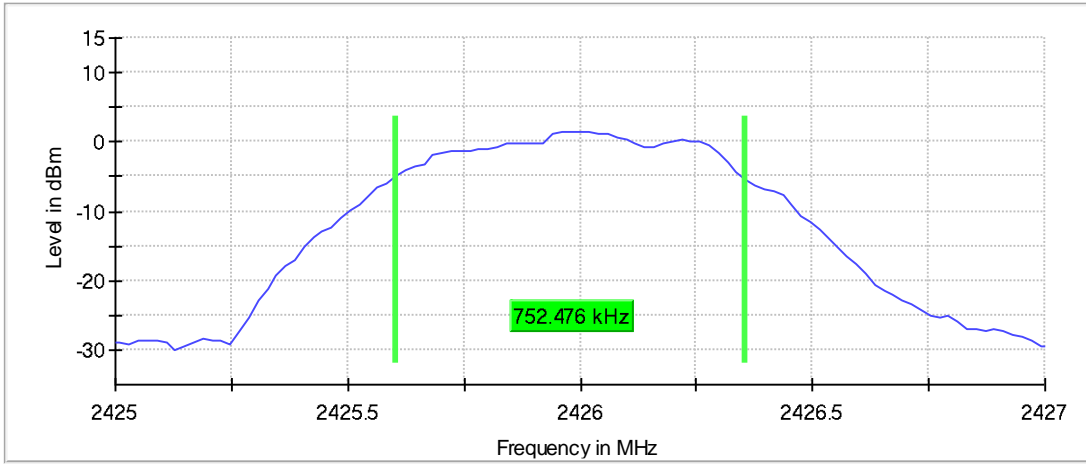
#### Result

In the configuration tested, the 6 dB bandwidth was greater than 500 kHz; therefore, the EUT complied with the requirements of the specification (see Section 9 for hard copies).



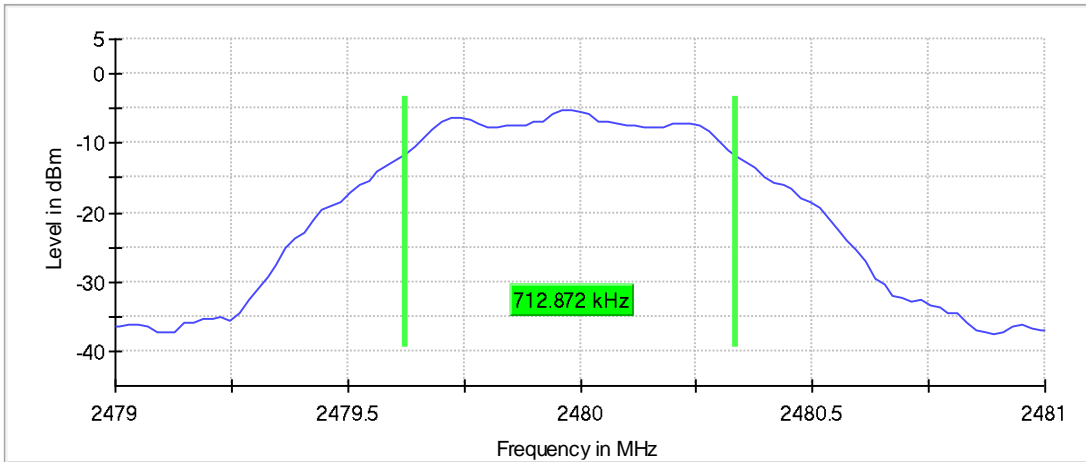
**Graph 1: Lowest Channel 6dB Bandwidth**

6 dB Bandwidth



**Graph 2: Middle Channel 6dB Bandwidth**

6 dB Bandwidth



**Graph 3: Highest Channel 6dB Bandwidth**



### 6.2.3 §15.247(b)(3) Peak Output Power

The maximum peak RF Conducted output power measured for this device was measured was 4.1 dBm or 2.6 mW. The limit is 30 dBm or 1 Watt when using antennas with 6 dBi or less gain. The antenna has a maximum in-band gain of -3.2 dBi as declared by the Manufacturer.

Equations G.7-G.9 of Annex G of C63.10 are utilized to calculate the EIRP Power from a 3 meter radiated test setup:

$$EIRP = P_R + L_P \tag{G.7}$$

where  $P_R$  is the Adjusted Receiver Reading in dBm (equivalent to  $dB\mu V-107$ ) and  $L_P$  is the basic free-space propagation pass loss in dB. The free space loss,  $L_P$  is calculated Equation G.8:

$$L_P = 20\log F + 20\log d - 27.5 \tag{G.8}$$

where  $F$  is the center frequency of the DUT signal in MHz and  $d$  is the measurement distance, 3 meters.

The adjusted received power,  $P_R$ , is calculated from the Receiver Reading,  $P_{meas}$ , here in dBm:

$$P_R = P_{meas} - G_R + L_C + L_{atten} - G_{amp} \tag{G.9}$$

where  $P_{meas}$  is the Receiver Reading,  $G_R$  is the measurement antenna’s isotropic gain (dBi),  $L_C$  is the loss introduced by the measurement cable (dB), and  $L_{atten}$  and  $G_{amp}$  are additional attenuation or gain (dB) utilized for the test in the form of in-line attenuators or amplifiers.  $L_C$ ,  $G_R$ ,  $L_{atten}$ , and  $G_{amp}$  are shown in the table below as “CF.”

For Example, given a Receiver Reading ( $P_{meas}$ ) is 65.0  $dB\mu V$ , the equivalent in dBm is  $65-107=-42$  dBm. Given a cable loss of -3 dB ( $C_L$ ) and a measurement antenna gain of 9 dBi ( $G_R$ ), the Correction Factor (CF) is calculated to be  $3-9 = -6$  dB. Adding the CF to  $P_{meas}$ ,  $-42 + (-6) = -48$ , results in  $P_R$ , the Adjusted Reading of -48 dBm. The EIRP is calculated by adding the Free Space Loss,  $L_P$  (given a frequency of 2402 MHz and a distance of 3 meters,  $L_P = 49.7$ ) to  $P_R$ :  $-48 + 49.7 = 1.7$ dBm.

Frequency (MHz)	Receiver Reading (dBμV)	Receiver Reading (dBm)	CF (dB)	P <sub>R</sub> (dBm)	L <sub>P</sub> (dB)	EIRP (dBm)
2402	62.7	-44.3	-6.1	-50.4	49.7	-0.7
2426	63.9	-43.1	-5.9	-49.0	49.7	0.7
2480	63.7	-43.3	-5.7	-49.0	49.9	0.9

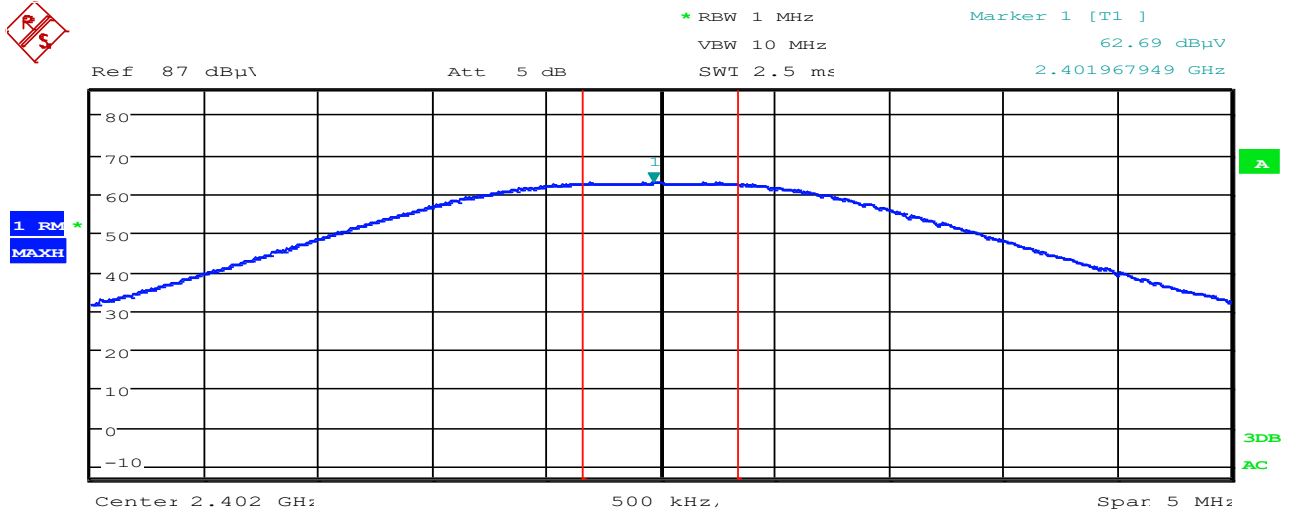
Maximum conducted power is derived from EIRP by subtracting the EUT’s transmit antenna gain in dBi. For example, given an EIRP of 1.7dBm and a transmit antenna gain of 1.5dBi, Conducted Output Power is:  $1.7 - 1.5 = 0.2$ dBm.

The EUT’s transmit antenna’s maximum in-band gain in dBi as declared by the manufacturer is -3.2dBi.

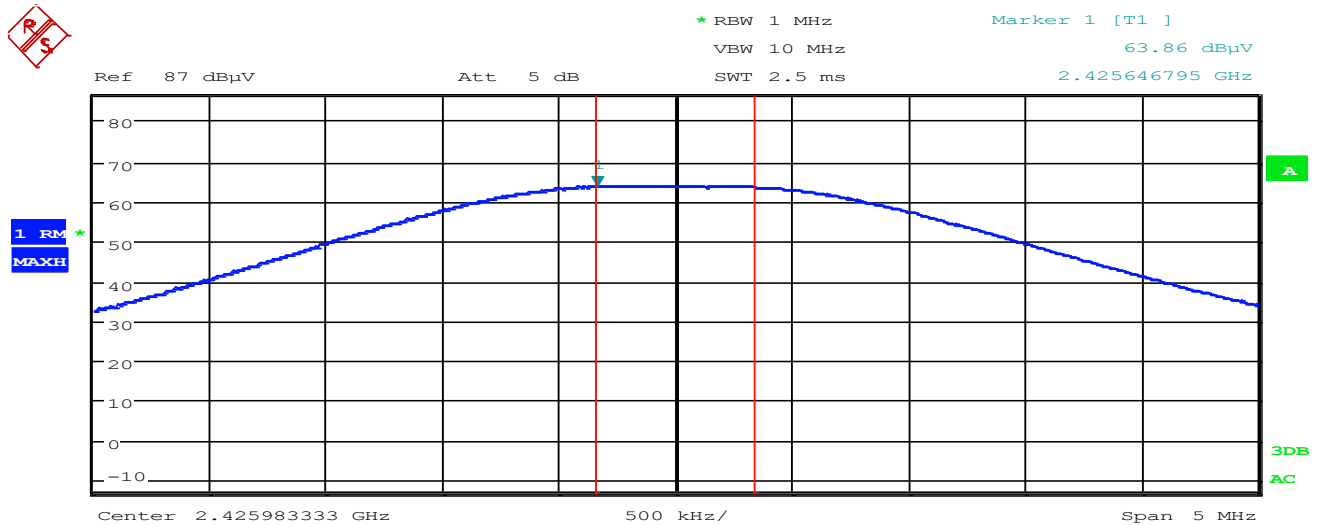
Frequency (MHz)	EIRP (dBm)	EUT In-Band Gain (dBi)	Conducted Output Power (dBm)	Conducted Output Power (mW)
2402	-0.7	-3.2	2.5	1.8
2426	0.7	-3.2	3.9	2.5
2480	0.9	-3.2	4.1	2.6

### Result

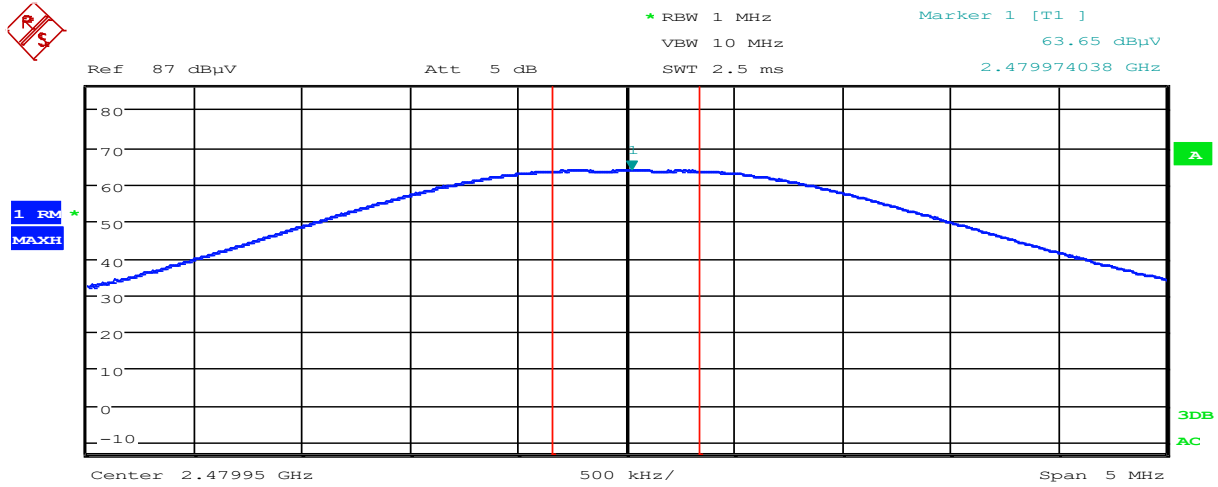
In the configuration tested, the RF peak output power was less than 1 Watt; therefore, the EUT complied with the requirements of the specification (see spectrum analyzer plots below).



**Graph 4: Lowest Channel Output Power Plot**



**Graph 5: Middle Channel Output Power**



**Graph 6: Highest Channel Output Power Plot**

## 6.2.4 §15.247(d) Spurious Emissions

### Conducted Spurious Emissions

The frequency range from the lowest frequency generated or used in the device to the tenth harmonic of the highest fundamental frequency was investigated to measure any antenna-conducted emissions. The tables show the measurement data from spurious emissions noted across the frequency range when transmitting at the lowest frequency, middle frequency, and upper frequency. Shown below are plots with the EUT tuned to the upper and lower channels. These demonstrate compliance with the provisions of this section at the band edges.

The emissions must be attenuated 20 dB below the highest power level measured within the authorized band as measured with a 100 kHz RBW. The highest power measured in was 4.1 dBm; therefore, the criteria is  $4.1 - 20 = -15.9$  dBm.

### Result

Conducted spurious emissions were attenuated 20 dB or more below the fundamental; therefore, the EUT complies with the specification.

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
4804	-43.4	-15.9	-27.5
7206	-54.6	-15.9	-38.7
9608*	-55.0	-15.9	-39.1
12010*	-54.8	-15.9	-38.9
14412*	-52.3	-15.9	-36.4
16814*	-54.5	-15.9	-38.6
19216*	-53.2	-15.9	-37.3
21618*	-53.5	-15.9	-37.6
24020*	-52.1	-15.9	-36.2
*No emissions were detected above the measurement noise floor at this frequency			

**Table 2: Transmitting on the Lowest Channel**

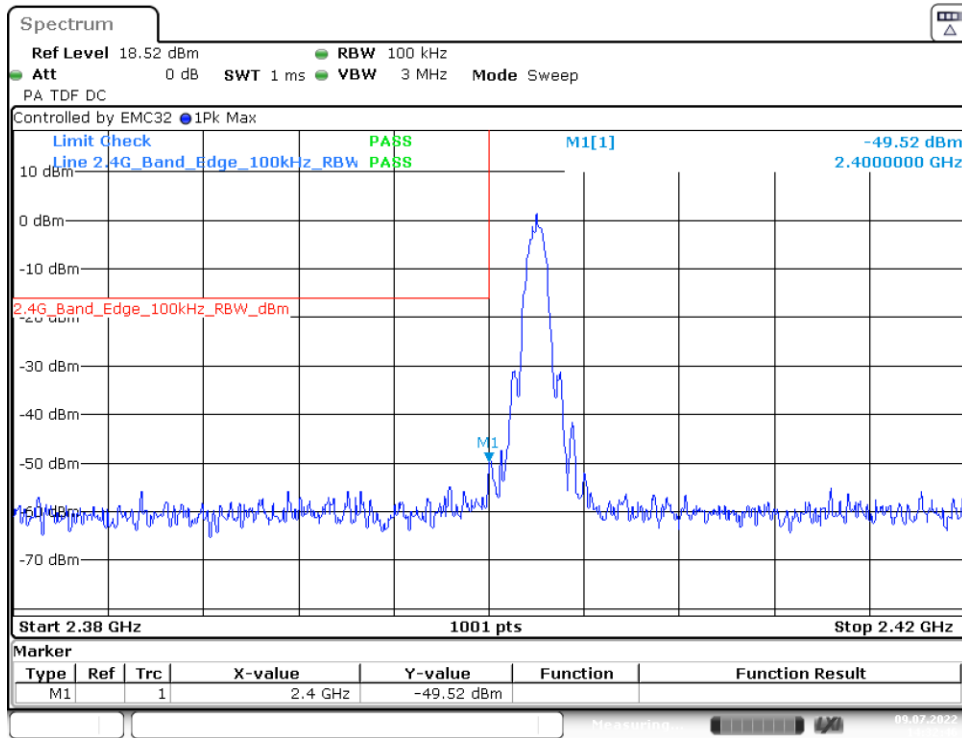
Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
4852	-41.7	-15.9	-25.8
7278	-55.1	-15.9	-39.2
9704*	-54.8	-15.9	-38.9
12130*	-54.3	-15.9	-38.4
14556*	-51.7	-15.9	-35.8
16982*	-54.1	-15.9	-38.2

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
19408*	-53.8	-15.9	-37.9
21834*	-53.5	-15.9	-37.6
24260*	-51.7	-15.9	-35.8
*No emissions were detected above the measurement noise floor at this frequency			

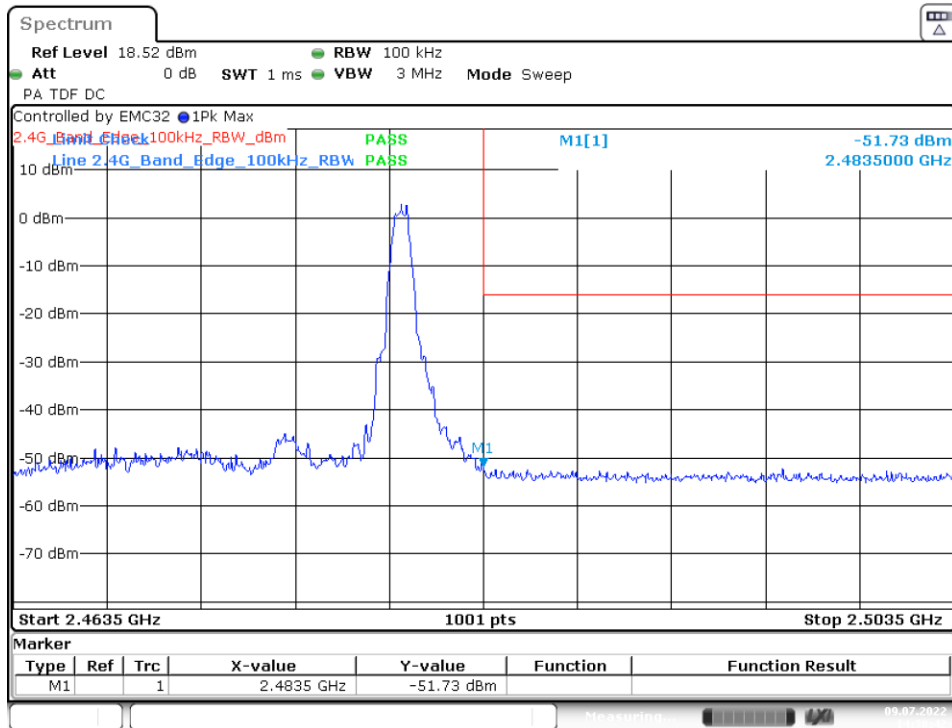
**Table 3: Transmitting on the Middle Channel**

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
4960	-39.1	-15.9	-23.2
7440	-55.5	-15.9	-39.6
9920*	-56.1	-15.9	-40.2
12400*	-53.4	-15.9	-37.5
14880*	-55.1	-15.9	-39.2
17360*	-54.3	-15.9	-38.4
19840*	-52.5	-15.9	-36.6
22320*	-52.7	-15.9	-36.8
24800*	-50.5	-15.9	-34.6
*No emissions were detected above the measurement noise floor at this frequency			

**Table 4: Transmitting on the Highest Channel**



**Graph 7: 100kHz RBW Lower Band Edge Plot**



**Graph 8: 100kHz RBW Upper Band Edge Plot**

## Radiated Spurious Emissions in the Restricted Bands of §15.205

The frequency range from the lowest frequency generated or used in the device to the tenth harmonic of the highest fundamental emission was investigated to measure any radiated emissions in the restricted bands. The following tables show measurements of any emission that fell into the restricted bands of §15.205. The tables show the worst-case emission measured from the EUT. For frequencies above 18.0 GHz, a measurement distance of 1 meter was used. The noise floor was a minimum of 6 dB below the limit. The emissions in the restricted bands must meet the limits specified in §15.209. Tabular data for each of the spurious emissions is shown below for each of the units. Plots of the band edges are also shown.

### Result

All emissions in the restricted bands of §15.205 met the limits specified in §15.209; therefore, the EUT complies with the specification.

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
2392.9	Peak	Horizontal	19.7	31.8	51.5	74.0	-2.5
2392.9	Average	Horizontal	0.3	31.8	32.1	54.0	-21.9
2400.0	Peak	Horizontal	18.1	31.9	50.0	74.0	-4.0
2400.0	Average	Horizontal	-0.2	31.9	31.7	54.0	-22.3
4804.0	Peak	Horizontal	11.6	38.8	50.4	74.0	-23.6
4804.8	Average	Horizontal	10.2	38.8	49.0	54.0	-5.0

**Table 5: Transmitting at the Lowest Frequency**

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
4852.1	Peak	Horizontal	12.9	39.1	52.2	74.0	-22.0
4852.1	Average	Horizontal	12.9	39.1	52.2	54.0	-1.8

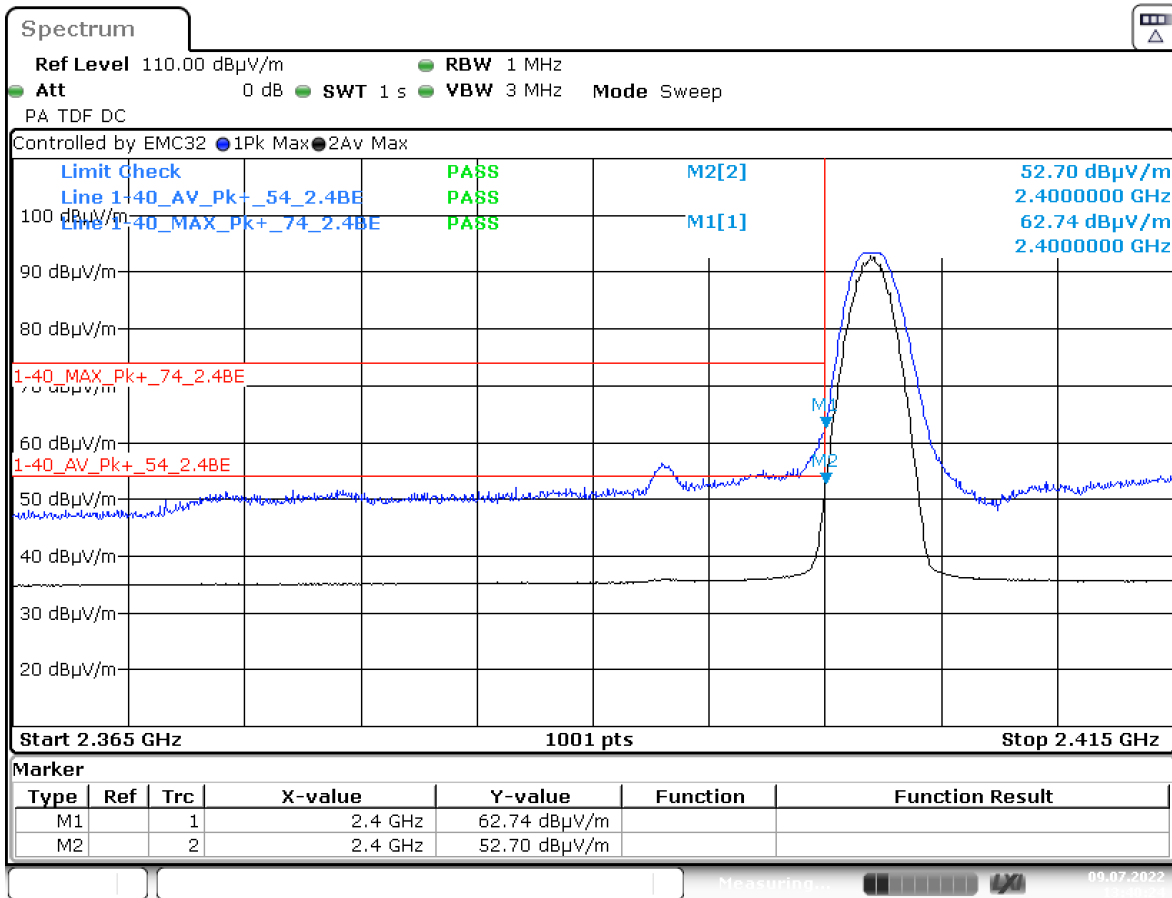
**Table 6: Transmitting at the Middle Frequency**

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
2483.5	Peak	Horizontal	16.3	32.4	48.7	74.0	-25.3
2483.5	Average	Horizontal	35.0	32.4	35.0	54.0	-19.0
2484.6	Peak	Horizontal	18.2	32.4	50.6	74.0	-23.4
2484.6	Average	Horizontal	3.1	32.4	35.5	54.0	-18.5
2493.0	Peak	Horizontal	17.9	32.4	50.3	74.0	-23.7

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
2493.0	Average	Horizontal	2.7	32.4	35.1	54.0	-18.4
4960.0	Peak	Horizontal	15.8	39.4	55.2	74.0	-18.5
4960.0	Average	Horizontal	13.0	39.4	52.4	54.0	-23.7

**Table 7: Transmitting at the Highest Frequency**

No other emissions were seen in the restricted bands.



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**Graph 9: 1MHz RBW Lower Band Edge**





### 6.2.5 §15.247(e) Peak Power Spectral Density

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. Results are calculated from a 3 meter radiated test setup.

Equations G.7-G.9 of Annex G of C63.10 was utilized to calculate the EIRP from a radiated test setup:

$$EIRP = P_R + L_P \tag{G.7}$$

where  $P_R$  is the Adjusted Receiver Reading in dBm (equivalent to  $dB\mu V - 107dB$ ) and  $L_P$  is the basic free-space propagation pass loss in dB. The free space loss,  $L_P$  is calculated Equation G.8:

$$L_P = 20\log F + 20\log d - 27.5 \tag{G.8}$$

where  $F$  is the center frequency of the DUT signal in MHz and  $d$  is the measurement distance, 3 meters.

The adjusted received power,  $P_R$ , is calculated from the Receiver Reading,  $P_{meas}$ , here in dBm:

$$P_R = P_{meas} - G_R + L_C + L_{atten} - G_{amp} \tag{G.9}$$

where  $P_{meas}$  is the Receiver Reading,  $G_R$  is the measurement antenna’s isotropic gain (dBi),  $L_C$  is the loss introduced by the measurement cable (dB), and  $L_{atten}$  and  $G_{amp}$  are additional attenuation or gain (dB) utilized for the test in the form of in-line attenuators or amplifiers.  $L_C$ ,  $G_R$ ,  $L_{atten}$ , and  $G_{amp}$  are shown in the table below as “CF.”

For Example, given a Receiver Reading ( $P_{meas}$ ) is 65.0  $dB\mu V$ , the equivalent in dBm is  $65 - 107 = -42$  dBm. Given a cable loss of -3 dB ( $L_C$ ) and a measurement antenna gain of 9 dBi ( $G_R$ ), the Correction Factor (CF) is calculated to be  $3 - 9 = -6$  dB. Adding the CF to  $P_{meas}$ ,  $-42 + (-6) = -48$ , results in  $P_R$ , the Adjusted Reading of -48 dBm. The EIRP is calculated by adding the Free Space Loss,  $L_P$  (given a frequency of 2402 MHz and a distance of 3 meters,  $L_P = 49.7$ ) to  $P_R$ :  $-48 + 49.7 = 1.7$  dBm.

Frequency (MHz)	Receiver Reading (dBμV)	Receiver Reading (dBm)	CF (dB)	P <sub>R</sub> (dBm)	L <sub>P</sub> (dB)	EIRP (dBm)
2402	52.1	-54.9	-6.1	-61.0	49.7	-11.3
2426	49.9	-57.1	-5.9	-63.0	49.7	-13.3
2480	50.9	-56.1	-5.7	-61.8	49.9	-11.9

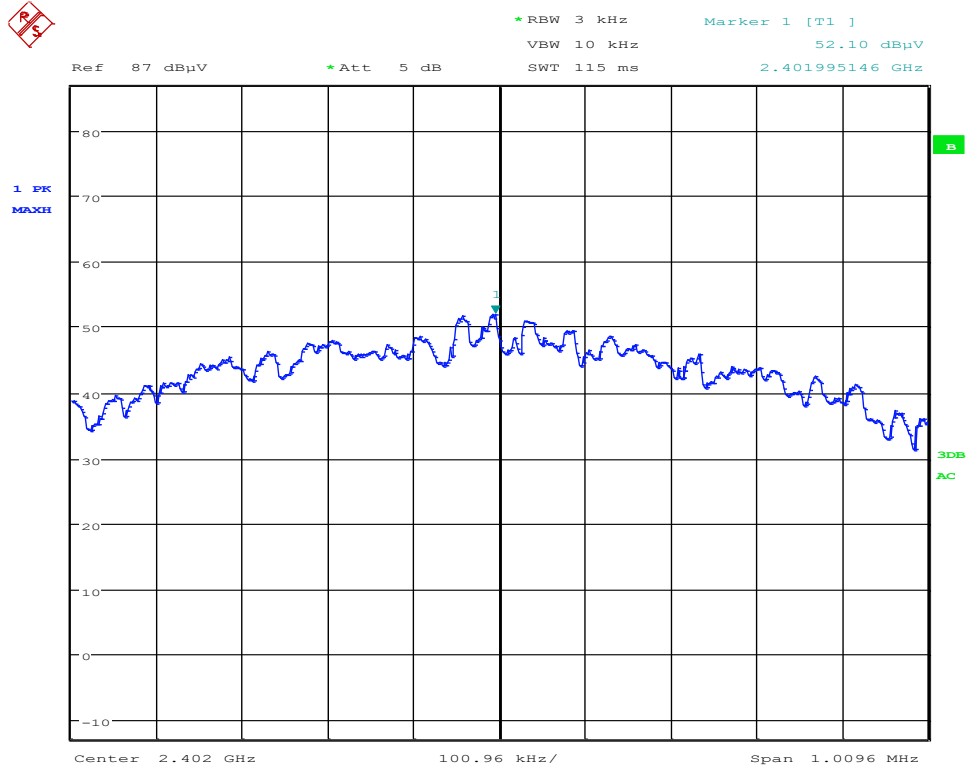
Maximum conducted PSD is derived from EIRP by subtracting the EUT’s transmit antenna gain in dBi. For example, given an EIRP of 1.7dBm and a transmit antenna gain of 1.5dBi, Conducted PSD is:  $1.7 - 1.5 = 0.2$  dBm.

The EUT’s transmit antenna’s maximum in-band gain in dBi as declared by the manufacturer is -3.2dBi.

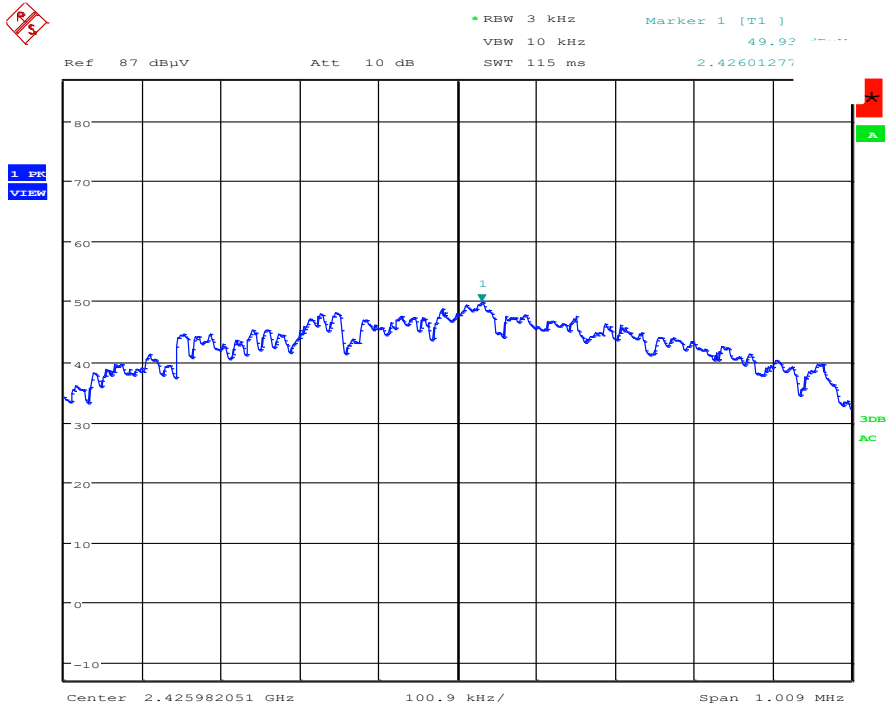
Frequency (MHz)	EIRP (dBm)	EUT In-Band Gain (dBi)	Conducted Peak PSD (dBm)	Criteria (dBm)
2402	-11.3	-3.2	-8.1	8.0
2426	-13.3	-3.2	-10.1	8.0
2480	-11.9	-3.2	-8.7	8.0

### Result

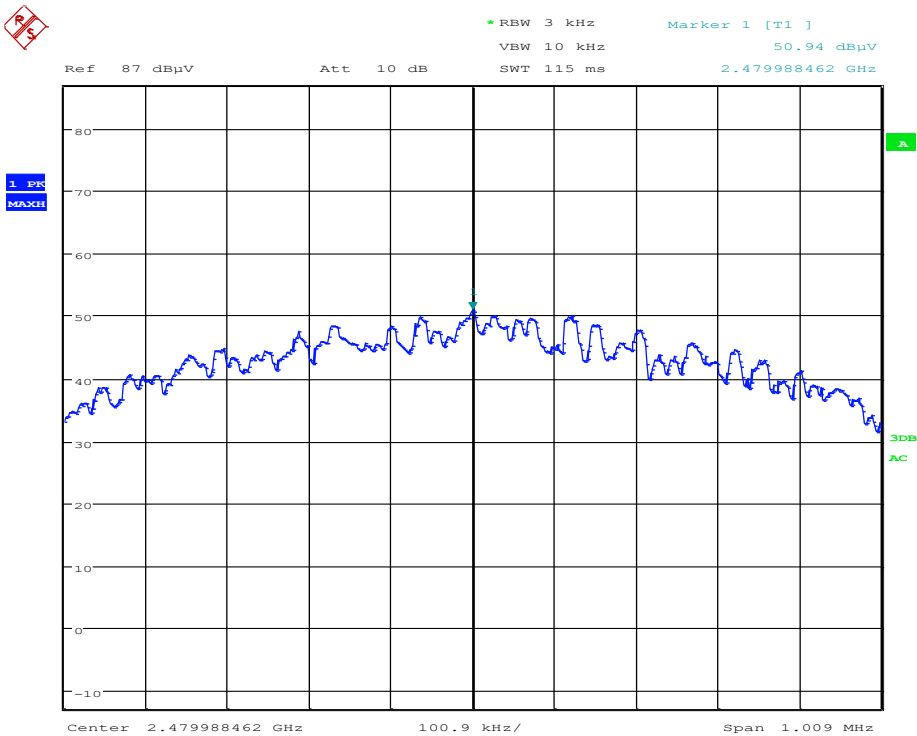
The maximum peak power spectral density was less than the limit of 8 dBm; therefore, the EUT complies with the specification.



**Graph 11: Lowest Channel 3 kHz PSD Plot**



**Graph 12: Middle Channel 3 kHz PSD Plot**



**Graph 13: Highest Channel Output 3 kHz PSD Plot**

## 6.3 Sample Measurement Calculations

### 6.3.1 General Field Strength Calculations for Band Edges and Spurious Emissions

The field strength is calculated by adding the *Correction Factor* (*Antenna Factor* + *Cable Factor*), to the measured level from the receiver. The receiver amplitude reading is compensated for any amplifier gain. When an average measurement requires an average measurement correction value, it is also accounted for. The basic equation with a sample calculation is shown below:

$$\text{Receiver Amplitude Reading} = \text{Receiver Reading} - \text{Amplifier Gain}$$

$$\text{Correction Factor} = \text{Antenna Factor} + \text{Cable Factor}$$

$$\text{Field Strength} = \text{Receiver Amplitude Reading} + \text{Correction Factor} [+ \text{Average Correction Value}]$$

#### Example

Assuming a *Receiver Reading* of 42.5 dB $\mu$ V is obtained from the receiver, the *Amplifier Gain* is 26.5 dB, the *Antenna Factor* is 4.5 dB, and the *Cable Factor* is 4.0 dB. The *Field Strength* is calculated by subtracting the *Amplifier Gain* and adding the *Correction Factor*, giving a *Field Strength* of 24.5 dB $\mu$ V/m.

$$\text{Receiver Amplitude Reading} = 42.5 - 26.5 = 16.0 \text{ dB}\mu\text{V/m}$$

$$\text{Correction Factor} = 4.5 + 4.0 = 8.5 \text{ dB}$$

$$\text{Field Strength} = 16.0 + 8.5 = 24.5 \text{ dB}\mu\text{V/m}$$

## 7 Test Procedures and Test Equipment

### 7.1 Radiated Emissions

The radiated emissions from the EUT were measured using a spectrum analyzer with a quasi-peak adapter for peak and quasi-peak readings.

A preamplifier with a fixed gain of 51 dB was used to increase the sensitivity of the measuring instrumentation. The quasi-peak adapter uses a bandwidth of 120 kHz, with the spectrum analyzer's resolution bandwidth set at 1 MHz, for readings in the 30 to 1000 MHz frequency ranges. For frequencies below 30 MHz, a 9 kHz resolution Bandwidth was used.

A loop antenna was used to measure frequencies below 30 MHz. A biconilog antenna was used to measure the frequency range of 30 to 1000 MHz, at a distance of 3 meters from the EUT. The readings obtained by these antennas are correlated to the levels obtained with a tuned dipole antenna by adding antenna factors. A double-ridged guide antenna was used to measure the emissions at frequencies above 1000 MHz at a distance of 3 and/or 1 meter from the EUT.

The configuration of the EUT was varied to find the maximum radiated emission. The EUT was connected to the peripherals listed in Section 2.3 via the interconnecting cables listed in Section 2.4. A technician manually manipulated these interconnecting cables to obtain worst-case radiated emissions. The EUT was rotated 360 degrees, and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission. Where there were multiple interface ports all of the same type, cables are either placed on all of the ports or cables added to these ports until the emissions do not increase by more than 2 dB.

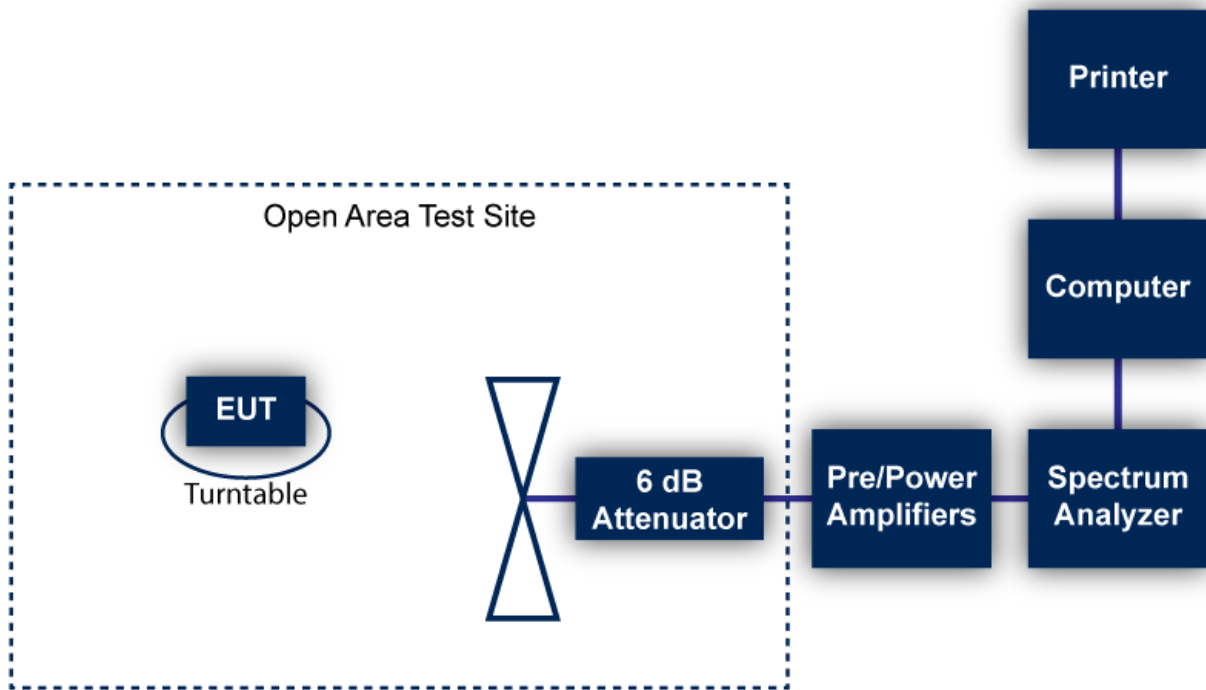
Desktop EUT are measured on a non-conducting table 0.8 meters above the ground plane. For frequencies above 1000 MHz, the EUT is placed on a table 1.5 meters above the ground plane. The table is placed on a turntable, which is level with the ground plane. For equipment normally placed on floors, the equipment shall be placed directly on the turntable.

For radiated emissions testing that is performed at distances closer than the specified distance; an inverse proportionality factor of 20 dB per decade is used to normalize the measured data for determining compliance.

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
Spectrum Analyzer/Receiver	Rohde & Schwarz	ESU40	V033119	08/26/2021	08/26/2022
Spectrum Analyzer/Receiver	Rohde & Schwarz	FSV40	V044352	03/08/2022	03/08/2023
Loop Antenna	EMCO	6502	V034216	02/03/2021	02/03/2023
Biconilog Antenna	EMCO	3142E	V057461	07/21/2021	07/21/2023
Double Ridged Guide Antenna	EMCO	3115	V033469	01/25/2021	01/25/2023
Standard Gain Horn	ETS-Lindgren	3160-09	V034223	ICO	ICO
High Frequency Amplifier	Miteq	AFS4-001018000-35-10P-4	V033997	01/10/2022	01/10/2023
900 MHz High Pass Filter	Micro-Tronics	HPM50108-03	V034185	01/10/2022	01/10/2023

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
2.4 GHz High Pass Filter	Micro-Tronics	HPM50111-03	V034183	01/10/2022	01/10/2023
2.4 GHz Notch Filter	Micro-Tronics	BRM50702-03	V034213	01/10/2022	01/10/2023
6' High Frequency Cable	Microcoax	UFB197C-0-0720-000000	V033638	01/10/2022	01/10/2023
20' High Frequency Cable	Microcoax	UFB197C-1-3120-000000	V033979	01/10/2022	01/10/2023
3 Meter Radiated Emissions Cable Wanship Upper Site	Microcoax	UFB205A-0-4700-000000	V033639	01/10/2022	01/10/2023
EMC32 Measurement Software	Rohde & Schwarz	11.40	N/A	N/A	N/A

**Table 8: List of equipment used for radiated emissions testing.**



**Figure 1: Radiated Emissions Test**

## 7.2 Equipment Calibration

All applicable equipment is calibrated using either an independent calibration laboratory or VPI Laboratories, Inc. personnel at intervals defined in ANSI C63.4:2014 following outlined calibration procedures. All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Supporting documentation relative to tractability is on file and is available for examination upon request.

### 7.3 Measurement Uncertainty

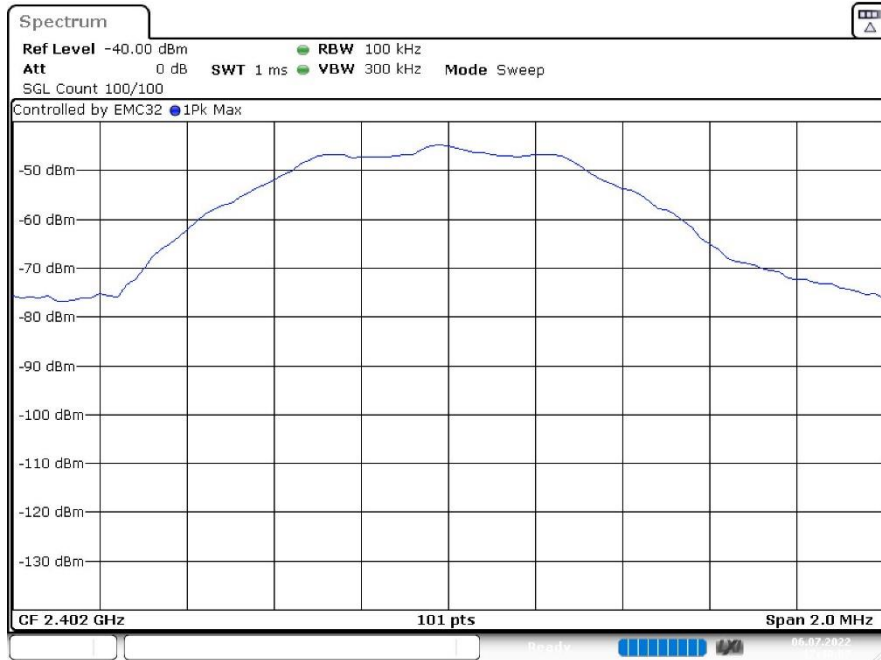
Test	Uncertainty ( $\pm$ dB)	Confidence (%)
Conducted Emissions	2.8	95
Radiated Emission (9 kHz to 30 MHz)	3.3	95
Radiated Emissions (30 MHz to 1 GHz)	3.4	95
Radiated Emissions (1 GHz to 18 GHz)	5.0	95
Radiated Emissions (18 GHz to 40 GHz)	4.1	95



## **8 Photographs**

**All Photographs are contained in an exhibit external to this report.**

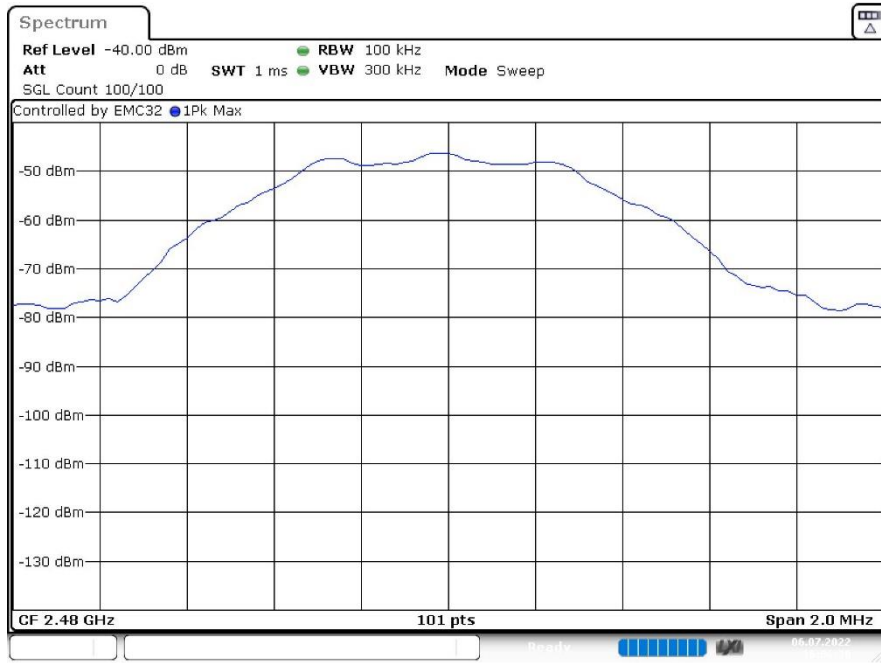
## 9 Measurement Hard Copies



**Hard Copy 1: Low Channel 6dB Bandwidth**



**Hard Copy 2: Middle Channel 6dB Bandwidth**



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**Hard Copy 3: High Channel 6dB Bandwidth**

**--- End of Report ---**