



Test Report No. <i>Prüfbericht-Nr.:</i>	US24L0WX 001	Order No. <i>Auftrags-Nr.:</i>	P01387797 234057357	Page 1 of 123 <i>Seite 1 von 123</i>
Client Reference No.: <i>Kunden-Referenz-Nr.:</i>	2239931	Order date: <i>Auftragsdatum:</i>	02/15/2024	
Client: <i>Auftraggeber:</i>	Tokenize, Inc. 4545 East River Road W. Henrietta, NY 14586			
Identification/ Type No.: <i>Bezeichnung / Typ-Nr</i>	TokenRing V3, Token Biostick			
Order content: <i>Auftrags-Inhalt:</i>	FCC 15.247 and RSS-247 Issue 3 Compliance Evaluation			
Test specification: <i>Prüfgrundlage</i>	CFR Title 47 Subchapter A §Part 15.247 ISED RSS-247 Issue 3			
Date of sample receipt: <i>Wareneingangsdatum:</i>	TR3: 6/4/2024 & 8/26/2025 TBK: 8/15/2025 – 8/26/2025			
Test sample No: <i>Prüfmuster-Nr.:</i>	TR3: Test Sample Number: A003741573 Serial Number: 240802ZD2406 TBK: Test Sample Number: A004076538 Serial Number: K02BA15C00088			
Testing period: <i>Prüfzeitraum</i>	TR3: 6/4/2024 - 6/11/2024 & 7/26/2025 TBK: 8/15/2025 – 8/26/2025			
Place of testing: <i>Ort der Prüfung:</i>	TUV Rheinland of North America Inc. 5015 Brandin Ct Fremont CA 94538 USA			
Testing laboratory: <i>Prüflaboratorium</i>	TUV Rheinland of North America, Inc.			
Test result*: <i>Prüfergebnis*:</i>	Pass			
compiled by: <i>geprüft von:</i>	Nathaniel Beyer		Authorized by: <i>genehmigt von:</i>	Dieter Baldamus Paasche
Date: 8/26/2025 <i>Datum:</i>			Issue Date: 8/26/2025 <i>Ausstellungsdatum:</i>	
Position / Stellung:	Test Engineer		Position / Stellung:	Expert
Others / <i>Sonstiges:</i>				
Condition of the test item at delivery: In Order <i>Zustand des Prüfgegenstandes bei</i> <i>Anlieferung:</i>				
* Legend: P(ass) = passed a.m. test specification(s) F(ail) = failed a.m. test specification(s) N/A = not applicable N/T = not tested * Legende: P(ass) = entspricht o.g. Prüfgrundlage(n) F(ail) = entspricht nicht o.g. Prüfgrundlage(n) N/A = nicht anwendbar N/T = nicht getestet				
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Remarks
Anmerkungen

1	The equipment used during the specified testing period was calibrated according to our test laboratory calibration program. The equipment fulfils the requirements included in the relevant standards. The traceability of the test equipment used is ensured by compliance with the regulations of our management system. Detailed information regarding test conditions, equipment and measurement uncertainty is available in the test laboratory and could be provided on request. <i>Alle eingesetzten Prüfmittel waren zum angegebenen Prüfzeitraum gemäß eines festgelegten Kalibrierungsprogramms unseres Prüfhauses kalibriert. Sie entsprechen den in den Prüfprogrammen hinterlegten Anforderungen. Die Rückverfolgbarkeit der eingesetzten Prüfmittel ist durch die Einhaltung der Regelungen unseres Managementsystems gegeben.</i> <i>Detaillierte Informationen bezüglich Prüfkonditionen, Prüfequipment und Messunsicherheiten sind im Prüflabor vorhanden und können auf Wunsch bereitgestellt werden.</i>
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3	Test clauses with remark of * are subcontracted to qualified subcontractors and described under the respective test clause in the report. Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report. <i>Prüfklausel mit der Note * wurden an qualifizierte Unterauftragnehmer vergeben und sind unter der jeweiligen Prüfklausel des Berichts beschrieben.</i> <i>Abweichungen von Prüfspezifikation(en) oder Kundenanforderungen sind in der jeweiligen Prüfklausel im Bericht aufgeführt.</i>
4	Electromagnetic Compatibility Test Report. The above product was found to be Compliant to the above test standard(s).

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Product description
Produktbeschreibung

1	Product details: <i>Produktdetails:</i>	TokenRing V3, Token Biostick
2	Dimensions / Weight: <i>Maße / Gewicht:</i>	30mm x 30mm x 15mm
3	Operating elements: <i>Bedienelemente:</i>	5V DC
4	Equipment / Accessories: <i>Ausstattung / Zubehör:</i>	N/A
5	Used materials: <i>Verwendete Materialien:</i>	N/A
6	Other: <i>Sonstiges:</i>	Test sample(s), as well sample information, description, product details and intended usage was provided by customer.
7	Test sample obtaining: <i>Prüfmusterbereitstellung:</i>	☒ Sending by customer ☐ Sampling by TÜV Rheinland Group ☐ others:

Revisions

[illegible]

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1 Executive Summary

1.1 Scope

This report is intended to document the status of conformance with the requirements of CFR Title 47 Subchapter A §Part 15.247 & ISSED RSS-247 Issue 3, based on the results of testing performed on 6/4/2024 to 6/11/2024 on TokenRing V3, Token Biostick manufactured by Tokenize, Inc.. This report only applies to the specific samples tested under the stated test conditions. It is the responsibility of the manufacturer to assure that additional production units of this model are manufactured with identical or EMI equivalent electrical and mechanical components. This report is further intended to document changes and modifications to the EUT throughout its life cycle. All documentation will be included as a supplement.

1.2 Purpose

Testing was performed to evaluate the EMC performance of the EUT in accordance with the applicable requirements, procedures, and criteria defined in the application of regulations and application of standards listed in this report. The 2400 MHz to 2483.5 MHz frequency band is covered in this document.

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1.3 Summary of Test Results

Table 1: Summary of Test Results

Test	Test Method ANSI C63.10: 2013	Worst Case (Measured)	Result
Spurious Emission in Transmitted Mode	CFR47 15.209, CFR47 15.247 (d) RSS-Gen section 8.9 RSS-247 Section 5.5	17981.77 MHz 2.82 dB	Complied
Restricted Bands of Operation	CFR47 15.205 RSS-Gen Section 8.10	2484 MHz 35.10 dBuV/m	Complied
AC Power Conducted Emission	CFR47 15.207 RSS-Gen Section 8.8	--	N/A⁴
Occupied Bandwidth	CFR47 15.247 (a) RSS-247 Section 5.2 a)	2442 MHz 664.3 kHz	Complied
Emissions Bandwidth	RSS-Gen Section 6.7	2442 MHz 1.044 MHz	Complied
Maximum Output Power	CFR47 15.247 (b) RSS-247 Section 5.4 d)	2480 MHz 6.39 dBm	Complied
Peak Power Spectral Density	CFR47 15.247 €, RSS-247 Section 5.2 (b)	2480 MHz 6.38 dBm/100kHz	Complied
Out of Band Emission	CFR47 15.247 (d) RSS-247 Section 5.5	2.4GHz -48.61 dBm	Complied
RF Exposure	CFR47 15.247 (i), 2.1093 RSS-102 Issue 6	--	Note 2
Note: 1. This test report covers 2400 MHz to 2483.5 MHz band. 2. FCC RF Exposure evaluation is covered in a separate report (US244BIF.001). 3. ISSED RF Exposure evaluation is covered in a separate report (US240YZF.001). 4. The manufacturer does not provide an AC Power Supply with product, test was not applicable.			

1.4 Special Accessories

None

1.5 Equipment Modifications

None

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2 Laboratory Information

2.1 Accreditations & Endorsements

2.1.1 US Federal Communications Commission, US1131



TUV Rheinland of North America EMC test facilities located at 1279 Quarry Lane, Ste. A, Pleasanton, CA, 94566, and 5015 Brandin Ct, Fremont, CA. 94538, are recognized by the Commission for performing testing services for the general public on a fee basis. These laboratory test facilities have been fully described in reports submitted to and accepted by the FCC (Pleasanton Registration No. US1131, Fremont Registration No. US1131). The laboratory Scopes of Accreditation include Title 47 CFR Parts 15, 18 and 90. The accreditations are updated every three years.

2.1.2 NIST / A2LA, Testing Cert #3331.02



TUV Rheinland of North America EMC test facilities are accredited by the American Association for Laboratory Accreditation (A2LA). The laboratories have been assessed and accredited by A2LA in accordance with ISO Standard 17025:2017 (Testing Certificate #3331.02). The Scope of Laboratory Accreditation includes emission and immunity testing. The accreditations are updated annually.

2.1.3 Canada – Innovation, Science and Economic Development (ISED), 2932M



TÜV Rheinland of North America at the 1279 Quarry Ln, Pleasanton, CA 94566 address is accredited by Industry Canada for performing testing services for the general public on a fee basis. This laboratory test facilities have been fully described in reports submitted to and accepted by Industry Canada (File Number 2932M). The accreditation is updated every 3 years.

2.1.4 Japan – VCCI



The Voluntary Control Council for Interference by Information Technology Equipment (VCCI) is a group that consists of Information Technology Equipment (ITE) manufacturers and EMC test laboratories. The purpose of the Council is to take voluntary control measures against electromagnetic interference from Information Technology Equipment, and thereby contribute to the development of a socially beneficial and responsible state of affairs in the realm of Information Technology Equipment in Japan. TÜV Rheinland of North America at 1279 Quarry Ln, Pleasanton, CA 94566 has been assessed and approved in accordance with the Regulations for Voluntary Control Measures.

VCCI Registration No. for Fremont: A-0409

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2.1.5 Acceptance by Mutual Recognition Arrangement



The United States has an established agreement with specific countries under the Asia Pacific Laboratory Accreditation Corporation (APLAC) Mutual Recognition Arrangement. Under this agreement, all TÜV Rheinland at 1279 Quarry Ln, Pleasanton, CA 94566 test results and test reports within the scope of the laboratory NIST/ A2LA accreditation will be accepted by each member

country.

2.2 Test Facilities

Test facilities are located at 5015 Brandin Ct, Fremont, California, 94538, USA and 1279 Quarry Lane, Pleasanton, California 94566, USA (Fremont is the Pleasanton Annex).

2.2.1 Emission Test Facility

The Semi-Anechoic Chambers and AC Line Conducted measurement facilities used to collect radiated and conducted emissions data have been constructed in accordance with ANSI C63.7:1992. The Fremont 10 meter semi-anechoic chamber has been measured in accordance with and verified to comply with the theoretical volumetric normalized site attenuation of ANSI C63.4:2014 and SVSWR requirements of CISPR 16-1-4 Consol. Ed. 3.0 (2010-04), at test distances of 3 and 10 meters. This site has been described in reports dated November 1st, 2006, submitted to the FCC, and accepted by letter dated November 28, 2006. The site is listed with the FCC and accredited by A2LA (Testing Certificate #3331.02). The Pleasanton 5 meter semi-anechoic chamber has been verified to comply with the theoretical volumetric normalized site attenuation of ANSI C63.4:2009 and SVSWR requirements of CISPR 16-1-4 Consol. Ed. 3.0 (2010-04) at a test distance of 3 meters. This site has been described in reports dated November 1st, 2006, submitted to the FCC, and accepted by letter dated November 28, 2006. The site is listed with the FCC and accredited by A2LA (Testing Certificate #3331.02).

2.3 Measurement Uncertainty

Two types of measurement uncertainty are expressed in this report, per *ISO Guide To The Expression Of Uncertainty In Measurement*, 1st Edition, 1995.

The Combined Standard Uncertainty is the standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities; it is equal to the positive square root of the sum of the variances or co-variances of these other quantities, weighted according to how the measurement result varies with changes in these quantities. The term *standard uncertainty* is the result of a measurement expressed as a standard deviation.

The Expanded Uncertainty defines an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurement and the fraction may be viewed as the coverage probability or level of confidence of the interval.

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2.3.1 Sample Calculation – radiated & conducted emissions

The field strength is calculated by subtracting the Amplifier Gain and adding the Cable Loss and Antenna Correction Factor to the measured reading. The basic equation is as follows:

$$\text{Field Strength (dB}\mu\text{V/m)} = \text{RAW} - \text{AMP} + \text{CBL} + \text{ACF}$$

Where: RAW = Measured level before correction (dB μ V)

AMP = Amplifier Gain (dB)

CBL = Cable Loss (dB)

ACF = Antenna Correction Factor (dB/m)

$$\mu\text{V/m} = 10^{\frac{\text{dB}\mu\text{V} / \text{m}}{20}}$$

Sample radiated emissions calculation @ 30 MHz

Measurement +Antenna Factor–Amplifier Gain+Cable loss=Radiated Emissions (dB μ V/m)

$$25 \text{ dB}\mu\text{V/m} + 17.5 \text{ dB} - 20 \text{ dB} + 1.0 \text{ dB} = 23.5 \text{ dB}\mu\text{V/m}$$

2.3.2 Measurement Uncertainty

Per CISPR 16-4-2	U _{lab}	U _{usp}
Radiated Disturbance @ 10 meters		
30 – 1,000 MHz	2.25 dB	4.51 dB
Radiated Disturbance @ 5 meters		
30 – 1,000 MHz	2.26 dB	4.52 dB
1 – 6 GHz	2.12 dB	4.25 dB
6 – 18 GHz	2.47 dB	4.93 dB
Conducted Disturbance @ Mains Terminals		
150 kHz – 30 MHz	1.09 dB	2.18 dB
Disturbance Power		
30 MHz – 300 MHz	3.92 dB	4.3 dB

Voltech PM6000A

The estimated combined standard uncertainty for harmonic current and flicker measurements is $\pm 5.0\%$.	Per CISPR 16-4-2 Methods
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2.3.3 Measurement Uncertainty Immunity

The estimated combined standard uncertainty for ESD immunity measurements is $\pm 8.2\%$.	Per IEC 61000-4-2
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The estimated combined standard uncertainty for radiated immunity measurements is ± 4.10 dB.	Per IEC 61000-4-3
The estimated combined standard uncertainty for conducted immunity measurements with CDN is ± 3.66 dB	Per IEC 61000-4-6
The estimated combined standard uncertainty for power frequency magnetic field immunity is $\pm 2.9\%$.	Per IEC 61000-4-8

Thermo KeyTek EMC Pro

The estimated combined standard uncertainty for EFT fast transient immunity measurements is $\pm 2.6\%$.
The estimated combined standard uncertainty for surge immunity measurements is $\pm 2.6\%$.
The estimated combined standard uncertainty for voltage variation and interruption measurements is $\pm 1.74\%$.

The expanded uncertainty at a level of 95% confidence is obtained by multiplying the combined standard uncertainty by a coverage factor of 2. Compliance criteria are not based on measurement uncertainty.

2.4 Calibration Traceability

All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Measurement method complies with ANSI/NCSL Z540-1-1994 and ISO Standard 17025:2017. Equipment calibration records are kept on file at the test facility.

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3 EMC Test Plan

3.1 Introduction

This section provides a description of the Equipment Under Test (EUT), configurations, operating conditions, and performance acceptance criteria. It is an overview of information provided by the manufacturer so that the test laboratory may perform the requested testing.

3.2 Customer

Table 2: Customer Information

Client	Tokenize, Inc.
Address 1	4545 East River Road W. Henrietta, NY 14586
Contact Person	Timothy Harrington
Telephone	585-214-9587
E-Mail	Timothy.Harrington@tokenring.com

Table 3: Technical Contact Information

Contact Person	Timothy Harrington
Telephone	585-214-9587
E-Mail	Timothy.Harrington@tokenring.com

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3.3 Equipment Under Test (EUT)

Table 4: EUT Specifications

EUT Specifications	
Dimensions	30mm x 30mm x 15mm
Power Input	5V
Operating Temperature Range:	15 to 120 F -9 to 49 C
Multiple Feeds:	☐ Yes and how many ☒ No
Hardware Version/Model	TokenRing V3, Token Biostick
Firmware Version	TR3: 0.9, TBK: 1.2.3
RF Software Version	1.16.0.0
Product Marketing Name	TR3 & TBK
Operating Mode	Bluetooth Low Energy (BLE)
Transmitter Frequency Band	2400 – 2480 MHz (BLE)
Antenna Manufacturer	Tokenize, Inc.
Antenna Type	BLE: PCB Trace Antenna (Pole)
Antenna Gain	TR3: -0.3dBi, TBK: 2.2dBi
Modulation Type	GFSK
Data Rate	1Mbps 2Mbps
TX/RX Chain (s)	1
Directional Gain Type	N/A
Type of Equipment	☒ Table Top ☐ Wall-mount ☐ Floor standing cabinet ☐ Other: Indoor/Residential
Note: None.	

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Table 5: EUT Test Samples

Equipment	Manufacturer	Model	Serial	Used for
Token Ring	Tokenize	TR3	240802ZD2406	Radiated Conducted Emissions Testing
Dev Board	Tokenize	TR3	240701ZD0024	Conducted Testing
Token Biostick	Tokenize	TBK	K02BA15C00088	Additional Radiated Testing ¹
Note: 1. See Appendix 10 for additional spot check testing.				

Table 6: Channerl Power Settting/Specifcation

Freq. (MHz)	BLE 1Mbps	BLE 2Mbps	--	--	--	--	--	--
2400 – 2480	+7 dBm	+7dBm	--	--	--	--	--	--

Table 7: General Product Infromation

Dimensions	Height:	30mm	Width:	30mm	Length:	15mm
Weight	--		Fork-lift Needed:	No		
Note: None						

Table 8: Electrical Power Type

Name	Type	Voltage		Frequency (Hz)	Current (A)
		Min	Max		
TokenRing V3	DC	5V	5V	--	--
Token Biostick	DC	5V	5V	--	--
Note: None					

Table 9: EUT Interface/Port Specifications

EUT Port	Connect To	Location	Length	Shielded/ Unshielded
N/A	--	--	--	--

4 Product Information

4.1 Product Description

Token Ring 3rd Generation and Token Biostick.

4.2 Equipment Configuration

A description of the equipment configuration is given in the Test Plan Section. The EUT was tested as called for in the test standard and was configured and operated in a manner consistent with its intended use. The placement of the EUT system components was guided by the test standard and selected to represent typical installation conditions.

In the case of an EUT that can operate in more than one configuration, preliminary testing was performed to determine the configuration that produced maximum radiation.

The final configuration was selected to produce the worst-case radiation for emissions testing.

4.3 Operating Mode

A description of the operation mode is given in the Test Plan Section. In the case of an EUT that can operate in more than one state, preliminary testing was performed to determine the operating mode that produced maximum radiation.

The final operating mode was selected to produce the worst-case radiation for emissions testing.

4.4 Unique Antenna Connector

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 CFR47 Parts 15.211, 15.213, 15.217, 15.219, 15.221 and LP0002 Section 2.2.

4.4.1 Results

The EUT contains a PCB trace antenna which connects via a UFL connection. The devices are professionally installed and will not be touch by an end-user.

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4.4.2 Duty Cycle

The duty cycle of the device was determined before testing was performed in order to choose the appropriate test methodology. Duty cycle was measured with a spectrum analyzer in zero span and calculated as the percentage between the transmitters on time over the signal period.

$$\text{Duty cycle \%} = (\text{Transmitter on time} / \text{Signal Period}) * 100$$

4.4.3 Results

Test Condition:	Conducted, Normal Temperature	Date:	06/04/2024 06/05/2024
Antenna Type:	BLE: PCB Trace Antenna (Pole)	Power Level:	See Table 6
Ambient Temperature:	25	Relative Humidity:	41
Max. Antenna Gain:	-0.3dBi	Test Engineer	Nathaniel Beyer
Signal State: Modulated			
1Mbps			
Frequency (MHz)	On-Time (µs)	Signal Period (µs)	Duty Cycle (%)
2402	406	626	65
2442	--	--	--
2480	--	--	--
2Mbps			
Frequency (MHz)	On-Time (µs)	Signal Period (µs)	Duty Cycle (%)
2402	407	627	65
2442	--	--	--
2480	--	--	--
Note:			
1. All insertion loss and corrections are accounted for in the measurement plots. 2. Mid Channel and High Channel were verified but not reported. 3. Duty cycle correction: $10 \log(1/d) = 1.87\text{dB}$ where $d = \text{duty cycle}$.			

5 Emissions

Testing was performed in accordance with CFR 47 Part 15.247/RSS-247 Issue 3. These test methods are listed under the laboratory's A2LA Scope of Accreditation. This test measures the levels emanating from the EUT, thus evaluating the potential for the EUT to cause radio frequency interference to other electronic devices. Procedures described in section 8 of the standard were used.

5.1 Output Power Requirements

The maximum output power requirement is the maximum equivalent isotropic radiated power delivering at the transmitting antenna under specified conditions of measurements in the presence of modulation.

The maximum output power and harmonics shall not exceed CFR47 Part 15.247 (b), RSS 247 Sect. 5.4 d.

The maximum transmitted powers are:

Band 2400-2483.5 MHz: the maximum peak conducted output power shall not exceed 1 W and the E.R.I.P shall not exceed 4 W.

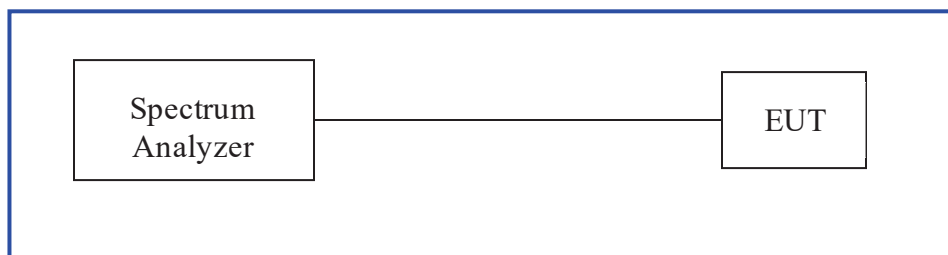
5.1.1 Test Method

The ANSI C63.10 section 11.9.1.1 conducted method was used to measure the channel power output. The measurements were conducted on 3 channels in each operating range per CFR47 Part 15.247(b): 2017. The device was connected to the spectrum analyzer with the following setting:

1. Span ≥ 1.5 times the OBW
2. Sweep Trigger = Free Run
3. RBW = RBW > DTS Bandwidth
4. VBW $\geq 3 \times$ RBW
5. Detector = Peak
6. Trace Mode = Max Hold
7. Sweep Time = auto couple

The trace was allowed to maximize, and the peak search function was used to determine the maximum power. All measurement system losses have been accounted for and inputted into the analyzer.

Test Setup:



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5.1.2 Results

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 10: RF Output Power at the Antenna Port – Test Results

Test Condition:	Conducted, Normal Temperature	Date:	06/04/2024 – 06/05/2024
Antenna Type:	BLE: PCB Trace Antenna (Pole)	Power Level:	See Table 6
Ambient Temperature:	26	Relative Humidity:	41
Max. Antenna Gain:	-0.3dBi	Test Engineer	Nathaniel Beyer
Signal State: Modulated			
1Mbps			
Frequency (MHz)	Maximum Power (dBm)	Limit (dBm)	Margin (dB)
2402	4.34	30	25.66
2442	4.27	30	25.73
2480	4.23	30	25.77
2Mbps			
Frequency (MHz)	Maximum Power (dBm)	Limit (dBm)	Margin (dB)
2402	5.95	30	24.05
2442	4.25	30	25.75
2480	6.39	30	23.61
Note:			
1. All insertion loss and corrections are accounted for in the measurement plots.			

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5.1.2.1 Analyzer Data

5.1.2.1.1 Modulation: 1Mbps



RF Output Power 2402 MHz, 1Mbps



RF Output Power 2442 MHz, 1Mbps

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RF Output Power 2480 MHz, 1Mbps

5.1.2.1.2 Modulation: 2 Mbps



RF Output Power 2402 MHz, 2Mbps

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RF Output Power 2442 MHz, 2Mbps



RF Output Power 2480 MHz, 2Mbps

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5.2 Occupied Bandwidth (Emission Bandwidth) and DTS Bandwidth (X dB bandwidth)

The occupied bandwidth is measured at an amplitude level reduced from the reference level by a specified ratio. The reference level is the level of the highest amplitude signal observed from the transmitter at the fundamental frequency.

The 99% bandwidth is the bandwidth in which 99% of the transmitted power occupied.

The minimum 6 dB bandwidth shall be at least 500 kHz.

5.2.1 Test Method

The conducted method was used to measure the occupied bandwidth according to ANSI C63.10 section 11.8 The measurement was performed with modulation per CFR47 15.247(a) (2) and RSS-247 section 5.2 on three channels operating between frequency range; 2400 MHz to 2483.5 MHz.

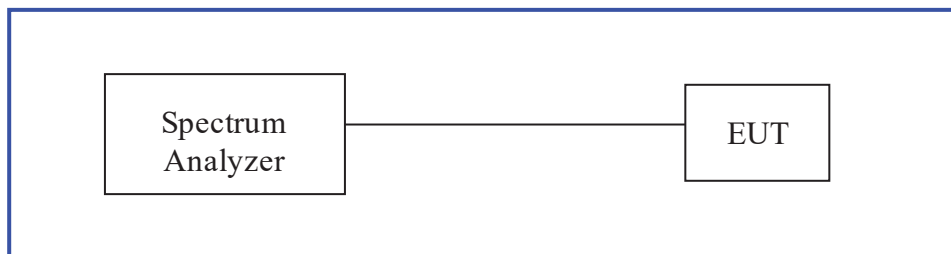
5.2.1.1 6 dB bandwidth & Emission Bandwidth (99%)

The device was connected to the spectrum analyzer with the following setting:

1. RBW = 100 kHz
2. VBW = 3 x RBW
3. Detector = Peak
4. Sweep = auto couple

The trace was allowed to maximize, and the peak emission was determined. For 99% occupied bandwidth, the spectrum analyzer's internal occupied bandwidth measurement function was used. For 6 dB bandwidth, the bandwidth was measured from the two outermost amplitude points that were attenuated by 6 dB. Emission bandwidth used the analyzer bandwidth function to calculate the bandwidth. All measurement system losses have been accounted for and inputted into the analyzer.

Test Setup:



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5.2.2 Results

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 11: Occupied Bandwidth – Test Results

Test Condition:	Conducted, Normal Temperature		Date:	06/04/2024 – 06/05/2024
Antenna Type:	BLE: PCB Trace Antenna (Pole)		Power Level:	See Table 6
Ambient Temperature:	25		Relative Humidity:	41
Max. Antenna Gain:	-0.3dBi		Test Engineer	Nathaniel Beyer
Signal State: Modulated				
1Mbps				
Frequency (MHz)	6 dB Bandwidth (kHz)	99% Bandwidth (MHz)	6 dB BW Limit (kHz)	Pass/Fail
2402	664.3	1.019	500	Pass
2442	664.3	1.044	500	Pass
2480	652.2	1.01	500	Pass
2Mbps				
Frequency (MHz)	6 dB Bandwidth (kHz)	99% Bandwidth (MHz)	6 dB BW Limit (kHz)	Pass/Fail
2402	652.2	0.98	500	Pass
2442	652.2	1	500	Pass
2480	649.7	980.3	500	Pass
Note:				
1. All insertion loss and corrections are accounted for in the measurement plots.				

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5.2.2.1 Analyzer Data

5.2.2.1.1 Modulation: 1Mbps



6 dB Bandwidth 2402 MHz, 1Mbps



6 dB Bandwidth 2442 MHz, 1Mbps

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6 dB Bandwidth 2480 MHz, 1 Mbps

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Modulation: 1 Mbps



99% Occupied Bandwidth 2402 MHz, 1Mbps



99% Occupied Bandwidth 2442 MHz, 1Mbps

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99% Occupied Bandwidth 2480 MHz, 1Mbps

5.2.2.1.2 Modulation: 2 Mbps



6 dB Bandwidth 2402 MHz, 2Mbps

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6 dB Bandwidth 2442 MHz, 2Mbps



6 dB Bandwidth 2480 MHz, 2 Mbps

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5.2.2.1.3 Modulation: 2 Mbps



99% Occupied Bandwidth 2402 MHz, 2Mbps



99% Occupied Bandwidth 2442 MHz, 2Mbps

Test report no.: US24L0WX 001
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99% Occupied Bandwidth 2480 MHz, 2Mbps

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5.3 Peak Power Spectral Density

According to the CFR47 Part 15.247 (e) and RSS-247 section 5.2 b) Issue 3, 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.

5.3.1 Test Method

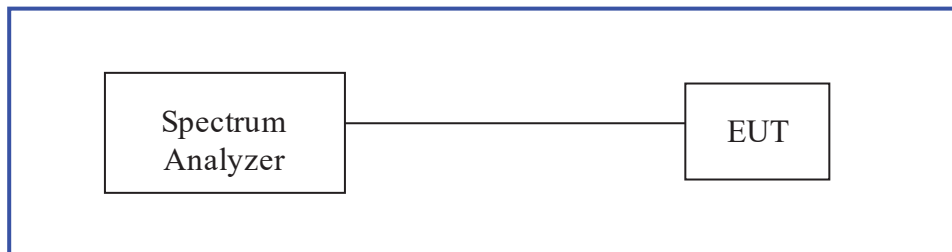
The conducted method was used to measure the channel power output per ANSI C63.10-2013 Section 11.10.2. The measurement was performed with modulation per CFR47 Part 15.247(e), RSS-247 section 5. The device was connected to the spectrum analyzer with the following setting:

1. Span = 1.5 x DTS Bandwidth
2. RBW = 3 kHz
3. VBW $\geq$ 3 x RBW
4. Detector = Peak
5. Sweep time = auto couple
6. Trace Mode = Max Hold

The trace is allowed to maximize, and the peak marker function is used to find the peak power spectral density.

All measurement system losses have been accounted for and inputted into the analyzer.

Test Setup:



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5.3.2 Results

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 12: Peak Power Spectral Density – Test Results

Test Condition:	Conducted, Normal Temperature	Date:	06/04/2024 – 06/05/2024		
Antenna Type:	BLE: PCB Trace Antenna (Pole)	Power Level:	See Table 6		
Ambient Temperature:	26	Relative Humidity:	41		
Max. Antenna Gain:	-0.3dBi	Test Engineer	Nathaniel Beyer		
Signal State: Modulated					
1Mbps					
Frequency (MHz)	Power Spectral Density (dBm/100kHz)	Correction (dB)	Power Spectral Density (dBm/3kHz)	Limit (dBm/3KHz)	Margin (dB)
2402	4.21	-15.23	-11.02	8	19.02
2442	4.25	-15.23	-10.98	8	18.98
2480	4.21	-15.23	-11.02	8	19.02
2Mbps					
Frequency (MHz)	Power Spectral Density (dBm/100kHz)	Correction (dB)	Power Spectral Density (dBm/3kHz)	Limit (8dBm/3KHz)	Margin (dB)
2402	5.93	-15.23	-9.3	8	17.3
2442	4.23	-15.23	-11	8	19
2480	6.38	-15.23	-8.85	8	16.85
Note:					
1. All insertion loss and corrections are accounted for in the measurement plots.					

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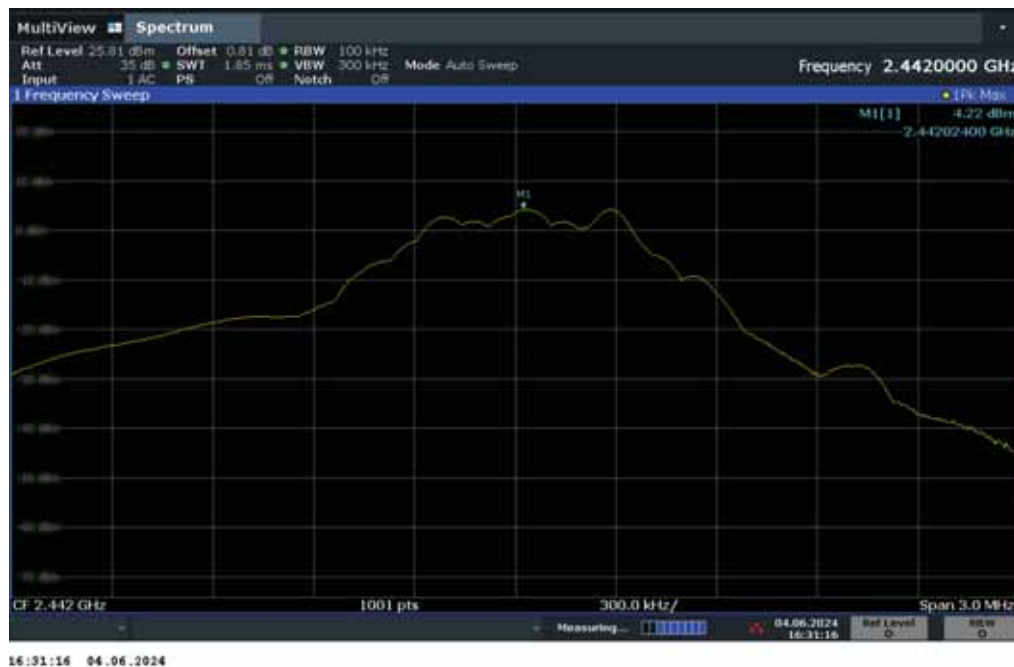
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5.3.2.1 Analyzer Data

5.3.2.1.1 Modulation: 1 Mbps



Power Spectral Density 2402 MHz, 1Mbps



Power Spectral Density 2442 MHz, 1Mbps

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Power Spectral Density 2480 MHz, 1Mbps

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Modulation: 2 Mbps



Power Spectral Density 2402 MHz, 2Mbps



Power Spectral Density 2442 MHz, 2Mbps

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Power Spectral Density 2480 MHz, 2Mbps

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5.4 Out of Band Emissions: Non-Restricted Band

Transmitter spurious emissions are emissions outside the frequency range of the equipment when the equipment is in transmitting mode; per requirement of CFR47 2.1051, 15.247(d), RSS-247 section 5.5.

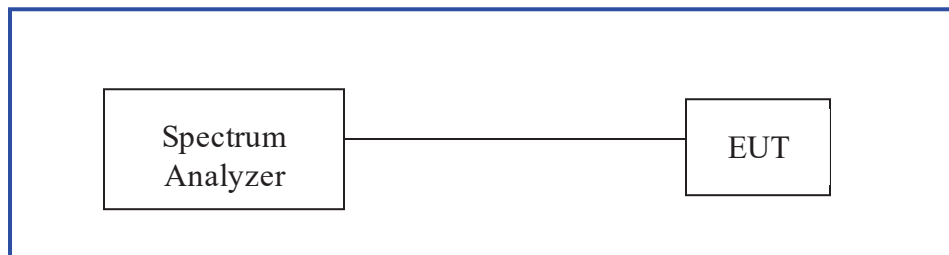
5.4.1 Test Method

ANSI C63.10 section 11.11 was used. The level (20 dBc or 30 dBc) was determined from the maximum PSD reference level procedure of section 11.11.2 of ANSI C63.10. The device was directly connected to a spectrum analyzer with the following settings:

1. Span set to encompass 30 MHz to the 10th harmonic of the fundamental
2. RBW = 100 kHz
3. VBW = 300 kHz
4. Detector: Peak
5. Sweep Time = auto couple
6. Trace Mode = max hold

The trace was allowed to maximize and maximum emissions reported. All measurement system losses have been accounted for and inputted into the analyzer.

Test Setup:



5.4.2 Results

As originally tested, the EUT was found to compliant to the requirements of the test standard(s).

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Table 13: Emissions at the Band-Edge – Test Results

Test Condition:	Conducted, Normal Temperature	Date:	06/04/2024 – 06/05/2024		
Antenna Type:	BLE: PCB Trace Antenna (Pole)	Power Level:	See Table 6		
Ambient Temperature:	26	Relative Humidity:	41		
Max. Antenna Gain:	-0.3dBi	Test Engineer	Nathaniel Beyer		
Signal State: Modulated					
1Mbps					
Test Frequency: 2402 MHz					
Emission (GHz)	Power (dBm)	Duty Cycle Correction (dB)	Corrected Power (dBm)	Limit (dB)	Margin (dB)
2.37	-54.65	--	-54.65	-15.790	38.86
2.34	-53.99	--	-53.99	-15.790	38.2
2.32	-54.03	--	-54.03	-15.790	38.24
1Mbps					
Test Frequency: 2480 MHz					
Emission (GHz)	Power (dBm)	Duty Cycle Correction (dB)	Corrected Power (dBm)	Limit (dB)	Margin (dB)
2.4835	-55.97	--	-55.97	-25.768	30.20
2.5	-60.83	--	-60.83	-25.768	35.06
2Mbps					
Test Frequency: 2402 MHz					
Emission (GHz)	Power (dBm)	Duty Cycle Correction (dB)	Corrected Power (dBm)	Limit (dB)	Margin (dB)
2.4	-48.61	--	-48.61	-24.052	24.558
2.31	-61.17	--	-61.17	-24.052	37.118
2Mbps					
Test Frequency: 2480 MHz					
Emission (GHz)	Power (dBm)	Duty Cycle Correction (dB)	Corrected Power (dBm)	Limit (dB)	Margin (dB)
2.4835	-54	--	-54	-23.61	30.39
2.5	-61.91	--	-61.91	-23.61	38.3
Note:					
1. All insertion loss and corrections are accounted for in the measurement plots.					

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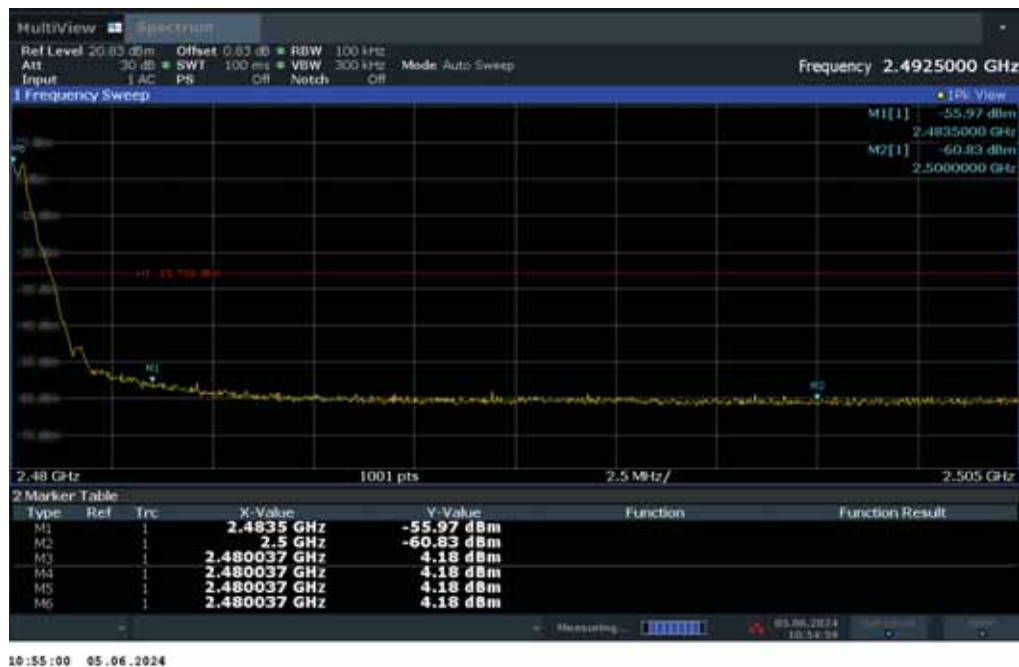
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5.4.2.1 Analyzer Data

5.4.2.1.1 Conducted Bandedge: 1 Mbps



2310 to 2390 MHz Bandedge

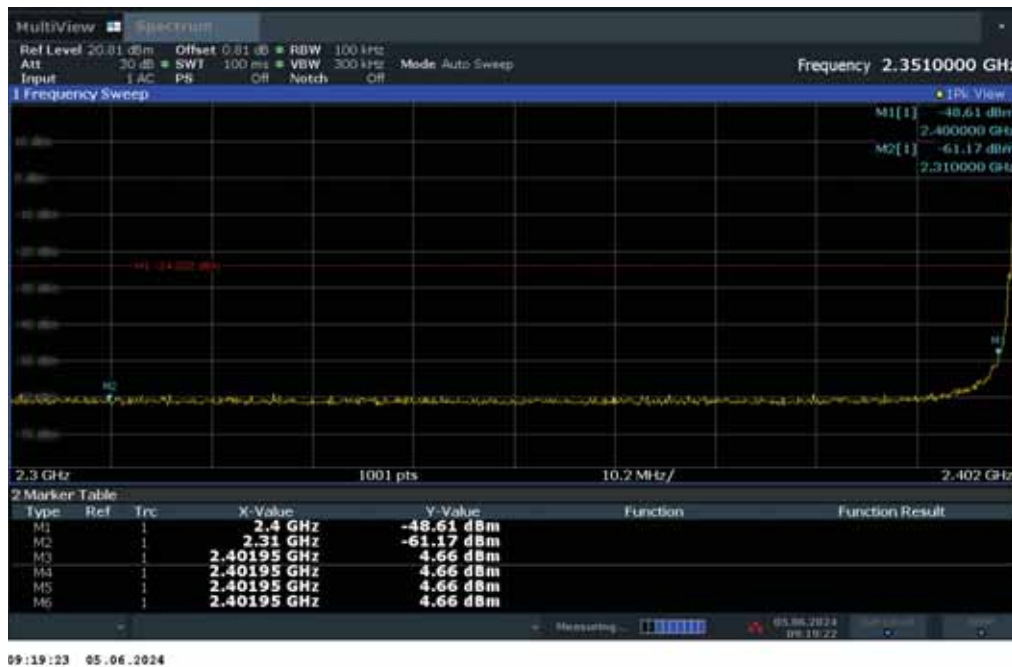


2483.5 to 2500 MHz Bandedge

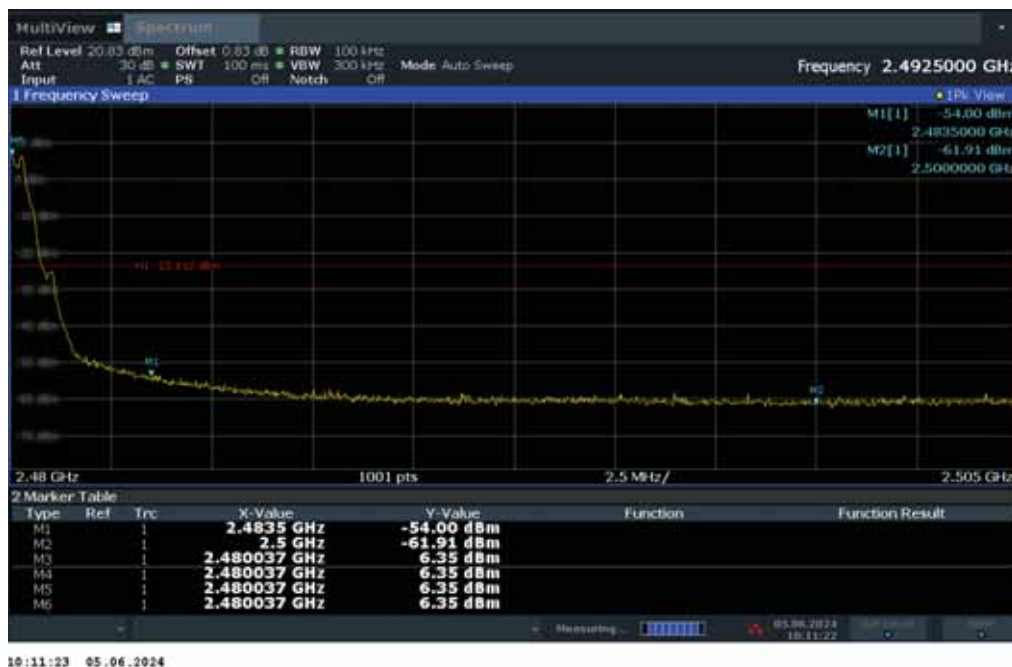
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5.4.2.1.2 Conducted Bandedge: 2 Mbps



2310 to 2390 MHz Bandedge



2483.5 to 2500 MHz Bandedge

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5.4.2.1.3 Modulation: 1 Mbps



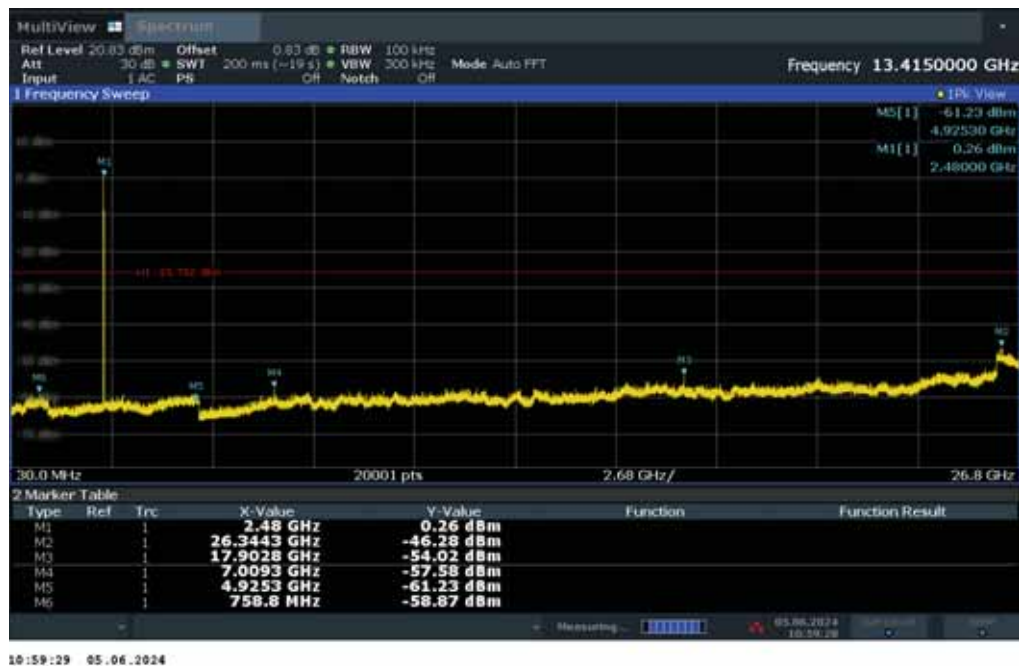
Conducted Emission: Non-Restricted Band 2402 MHz, 1Mbps



Conducted Emission: Non-Restricted Band 2442 MHz, 1Mbps.

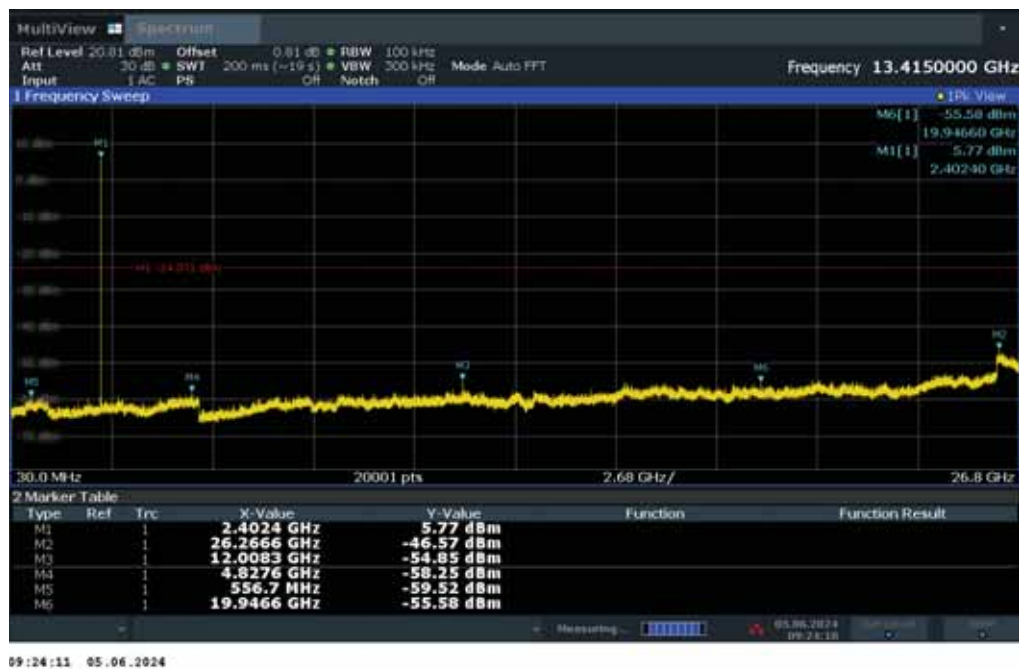
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Conducted Emission: Non-Restricted Band 2480 MHz, 1Mbps.

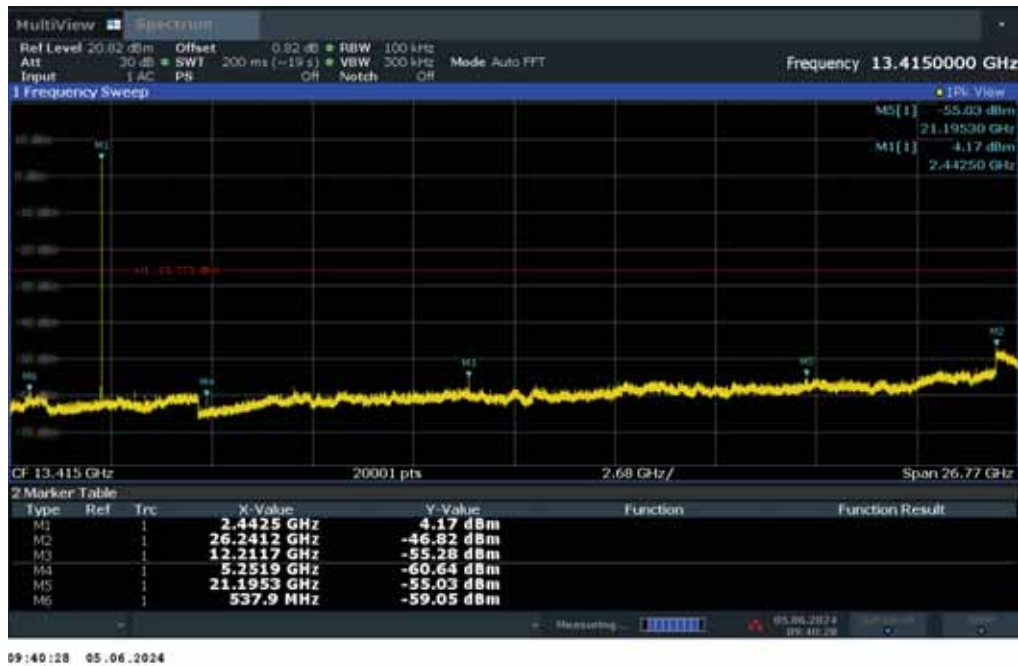
5.4.2.1.4 Modulation: 2 Mbps



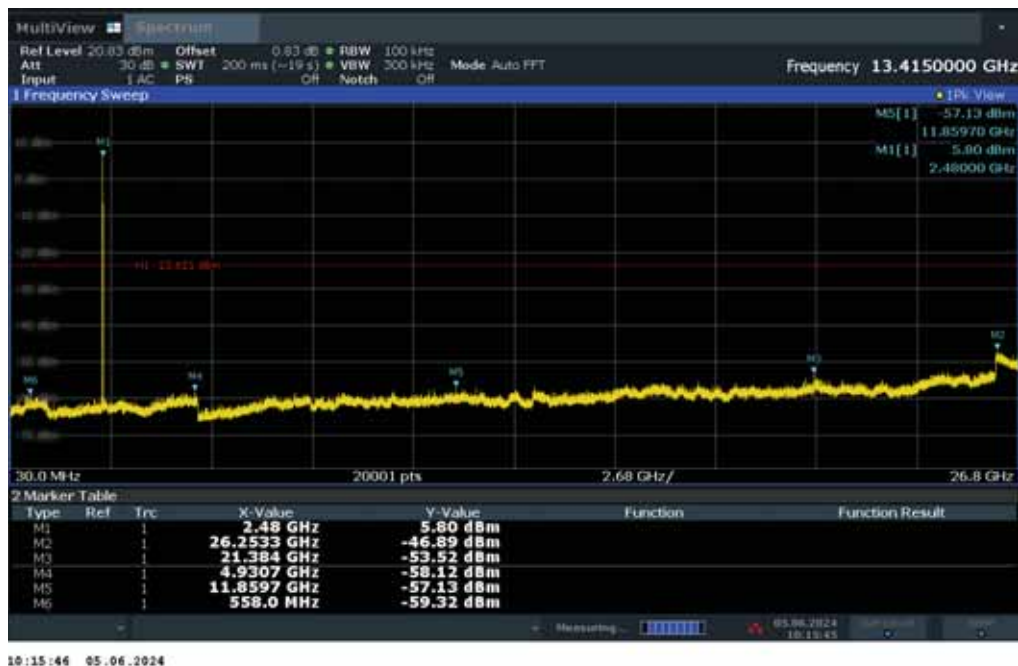
Conducted Emission: Non-Restricted Band 2402 MHz, 2Mbps.

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Conducted Emission: Non-Restricted Band 2442 MHz, 2Mbps.



Conducted Emission: Non-Restricted Band 2480 MHz, 2Mbps.

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5.5 Transmit Spurious Emissions

Transmitter spurious emissions are emissions outside the frequency range of the equipment when the equipment is in transmit mode; per requirement of CFR47 15.205, 15.209, 15.247(d), RSS 247 Sect.5.5.

5.5.1 Test Methodology

5.5.1.1 Preliminary Test

A test program that controls instrumentation and data logging was used to automate the preliminary RF emission test procedure. The frequency range of interest was divided into sub-ranges to yield a frequency resolution of approximately 120 kHz and provide a reading at each frequency for no more than 12° of turntable rotation. For each frequency sub-range the turntable was rotated 360° while peak emission data was recorded and plotted over the frequency range of interest in horizontal and vertical antenna polarization's.

Preliminary emission profile testing was performed inside the anechoic chamber. The EUT was placed on a 1.0m x 1.5m non-conductive table 80cm (<1 GHz) and 150cm (>1 GHz) above the floor. The EUT was positioned as shown in the setup photographs. The receiving antenna was placed at a distance of 3m at a fixed height of 1m. Measurement equipment was located outside of the chamber. A video camera was placed inside the chamber to view the EUT.

Pre-scans were performed to determine the worst data rate/chains.

5.5.1.2 Final Test

For each frequency measured, the peak emission was maximized by manipulating the receiving antenna from 1 to 4 meters above the ground plane and placing it at the position that produced the maximum signal strength reading. The turntable was then rotated through 360° while observing the peak signal and placing the EUT at the position that produced maximum radiation. The six highest emissions relative to the limit were measured unless such emissions were more than 20 dB below the limit. If less than six emissions are within 20 dB of the limit, then the noise level of the receiver is measured at frequencies where emissions are expected. Multiples of all oscillator and microprocessor frequencies were also checked.

Final testing was performed on an NSA compliant test site. The EUT was placed on a 1.0m x 1.5m non-conductive table 80cm (<1 GHz) and 150cm (>1 GHz) above the ground plane. The placement of EUT and cables were the same as for preliminary testing and is shown in the setup photographs.

The resolution bandwidth of the measurement analyzer is chosen based on either peak

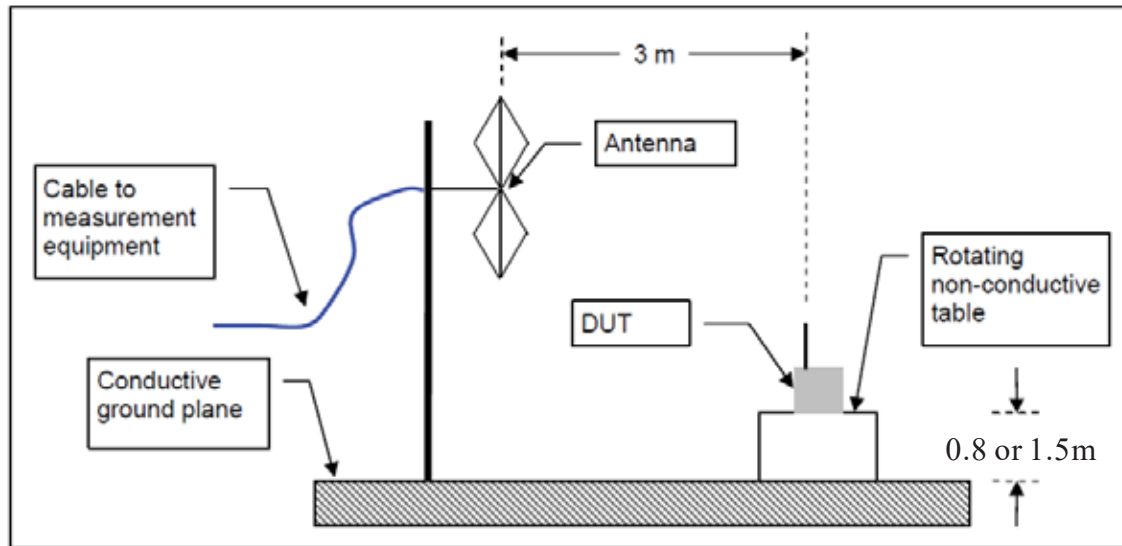
5.5.1.3 Deviations

None.

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Test Setup:



5.5.2 Transmitter Spurious Emission Limit

The spurious emissions of the transmitter shall not exceed the values in CFR47 Part 15.205, 15.209: 2023 and RSS Gen Sect. 8.9 and 8.10: 2018.

Frequency (MHz)	Field Strength (microvolts/meter)	Measurement Distance (Meters)
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30.0	30	30
30.0 – 88	100	3
88 – 216	150	3
216 – 960	200	3
Above 960	500	3

All harmonics and spurious emission which are outside of the restricted band shall be 20dB below the in-band emission.

5.5.3 Test Results

The final measurement data was taken under the worst case operating modes, configurations, and/or cable positions. It also reflects the results including any modifications and/or special accessories listed in Sections 1.4 and test plan.

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

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5.5.3.1 Bandedge Data

Table 14: Bandedge: Restricted band 2310 MHz to 2390 MHz

Test Condition:		Radiated, Normal Temperature			Date:		06/05/2024 – 06/06/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)			Power Level:		See Table 6		
Ambient Temperature:		23			Relative Humidity:		35		
Max. Antenna Gain:		-0.3dBi			Test Engineer:		Nathaniel Beyer		
Signal State: Modulated									
1Mbps									
Test Frequency: 2402 MHz									
Freq. (MHz)	Peak (dBμV/m)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
2350	23.22	--	54	30.78	100	400	H	206	3.2
2Mbps									
Test Frequency: 2402 MHz									
2389	23.17	--	54	30.83	100	100	V	139	3.2
Note: None									

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5.5.3.2 Bandedge Data

Table 15: Bandedge: Restricted band 2483.5MHz to 2500MHz

Test Condition:		Radiated, Normal Temperature			Date:		06/05/2024 – 06/06/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)			Power Level:		See Table 6		
Ambient Temperature:		23			Relative Humidity:		35		
Max. Antenna Gain:		-0.3dBi			Test Engineer:		Nathaniel Beyer		
Signal State: Modulated									
1Mbps									
Test Frequency: 2480 MHz									
Freq. (MHz)	Peak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
2484	30.56	--	54	23.44	100	300	H	147	3.2
2Mbps									
Test Frequency: 2480 MHz									
2484	35.10	--	54	18.9	100	300	H	52	3.2
Note: None									

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5.5.3.3 Transmitter Spurious Emissions: 30 MHz – 1000 MHz

Table 16: Transmit Spurious Emission 30 – 1000 MHz – 2402 MHz, 1Mbps

Test Condition:		Radiated, Normal Temperature				Date:		06/07/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:		See Table 6		
Ambient Temperature:		24				Relative Humidity:		39		
Max. Antenna Gain:		-0.3dBi				Test Engineer		Nathaniel Beyer		
Signal State: Modulated										
1Mbps										
Test Frequency: 2402 MHz										
Freq. (MHz)	Quasi-Peak (dBμV/m)	Peak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
30.53	14.43	---	40	25.57	10000	120	100	V	253	-15.7
96.85	16.52	---	43.52	27	10000	120	154	H	338	-14.9
120.66	20.54	---	43.52	22.98	10000	120	154	H	338	-16.2
121.38	19.25	---	43.52	24.27	10000	120	153	H	-5	-16.4
217.19	22.27	---	46.02	23.75	10000	120	100	H	217	-15.4
434.49	23.3	---	46.02	22.72	10000	120	100	H	32	-11.2
Note: None										

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Table 17: Transmit Spurious Emission 30 – 1000 MHz – 2442 MHz, 1 Mbps

Test Condition:		Radiated, Normal Temperature				Date:		06/07/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:		See Table 6		
Ambient Temperature:		24				Relative Humidity:		39		
Max. Antenna Gain:		-0.3dBi				Test Engineer		Nathaniel Beyer		
Signal State: Modulated										
1Mbps										
Test Frequency: 2442 MHz										
Freq. (MHz)	Quasi-Peak (dBµV/m)	Peak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
30.05	14.1	---	40	25.9	10000	120	100	V	313	-15.6
96.82	15.96	---	43.52	27.56	10000	120	153	H	-5	-14.9
120.01	19.58	---	43.52	23.94	10000	120	154	H	-5	-16.1
120.68	21.19	---	43.52	22.33	10000	120	153	H	-5	-16.2
217.26	22.33	---	46.02	23.69	10000	120	100	H	208	-15.4
362.12	19.7	---	46.02	26.32	10000	120	100	V	258	-12.6
Note: None										

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Table 18: Transmit Spurious Emission 30 – 1000 MHz – 2480 MHz, 1Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/07/2024			
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6			
Ambient Temperature:		24				Relative Humidity:	39			
Max. Antenna Gain:		-0.3dBi				Test Engineer	Nathaniel Beyer			
Signal State: Modulated										
1Mbps										
Test Frequency: 2480 MHz										
Freq. (MHz)	Quasi-Peak (dBµV/m)	Peak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
30.00	15.02	---	40	24.98	10000	120	100	V	224	-15.6
96.75	13.1	---	43.52	30.42	10000	120	153	H	-5	-14.9
119.99	19.64	---	43.52	23.88	10000	120	154	H	-5	-16.1
120.69	21.29	---	43.52	22.23	10000	120	153	H	-5	-16.2
217.21	21.37	---	46.02	24.65	10000	120	100	H	208	-15.4
434.39	15.53	---	46.02	30.49	10000	120	153	H	22	-11.2
Note: None										

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Table 19: Transmit Spurious Emission 30 – 1000 MHz – 2402 MHz, 2 Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/07/2024			
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6			
Ambient Temperature:		24				Relative Humidity:	39			
Max. Antenna Gain:		-0.3dBi				Test Engineer	Nathaniel Beyer			
Signal State: Modulated										
2 Mbps										
Test Frequency: 2402 MHz										
Freq. (MHz)	Quasi-Peak (dBμV/m)	Peak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
30.76	12.95	---	40	27.05	10000	120	100	V	-5	-15.7
96.83	15.75	---	43.52	27.77	10000	120	354	H	-2	-14.9
119.98	19.3	---	43.52	24.22	10000	120	155	H	-5	-16.1
120.69	20.96	---	43.52	22.56	10000	120	153	H	-5	-16.2
121.38	18.79	---	43.52	24.73	10000	120	153	H	-5	-16.4
217.21	20.75	---	46.02	25.27	10000	120	103	H	201	-15.4
Note: None										

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Table 20: Transmit Spurious Emission 30 – 1000 MHz – 2442 MHz, 2 Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/07/2024			
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6			
Ambient Temperature:		24				Relative Humidity:	40			
Max. Antenna Gain:		-0.3dBi				Test Engineer	Nathaniel Beyer			
Signal State: Modulated										
2 Mbps										
Test Frequency: 2442 MHz										
Freq. (MHz)	Quasi-Peak (dBµV/m)	Peak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
96.11	7.18	---	43.52	36.34	10000	120	250	H	235	-15
205.49	5.78	---	43.52	37.74	10000	120	100	H	197	-15.7
217.65	9.9	---	46.02	36.12	10000	120	100	H	292	-15.4
265.46	7.04	---	46.02	38.98	10000	120	250	H	215	-14.1
291.93	6.8	---	46.02	39.22	10000	120	100	H	193	-13.8
329.27	8.72	---	46.02	37.3	10000	120	104	H	196	-12.8
Note: None										

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Table 21: Transmit Spurious Emission 30 – 1000 MHz – 2480 MHz, 2 Mbps

Test Condition:		Radiated, Normal Temperature				Date:		06/07/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:		See Table 6		
Ambient Temperature:		24				Relative Humidity:		40		
Max. Antenna Gain:		-0.3dBi				Test Engineer		Nathaniel Beyer		
Signal State: Modulated										
2 Mbps										
Test Frequency: 2480 MHz										
Freq. (MHz)	Quasi-Peak (dBµV/m)	Peak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
46.05	10.26	---	40	29.74	10000	120	350	V	308	-12
189.24	4.5	---	43.52	39.02	10000	120	250	H	267	-16.1
270.75	6.81	---	46.02	39.21	10000	120	250	H	334	-14.1
299.85	6.91	---	46.02	39.11	10000	120	254	H	184	-13.7
472.76	7.89	---	46.02	38.13	10000	120	100	V	199	-11.2
510.54	7.83	---	46.02	38.19	10000	120	350	V	162	-11.1
513.07	8.07	---	46.02	37.95	10000	120	100	V	189	-11
537.99	8.31	---	46.02	37.71	10000	120	353	V	305	-10.8
559.84	9.71	---	46.02	36.32	10000	120	350	H	178	-9.6
Note: None										

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5.5.3.4 Transmitter Spurious Emissions: 1 GHz – 18 GHz

Table 22: Transmit Spurious Emission 1 – 18 GHz – 2402 MHz, 1Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/06/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6		
Ambient Temperature:		24				Relative Humidity:	36		
Max. Antenna Gain:		-0.3dBi				Test Engineer:	Nathaniel Beyer		
Signal State: Modulated									
1Mbps									
Test Frequency: 2402 MHz									
Freq. (MHz)	Peak (dBμV/m)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
1074.99	30.61	---	74	43.39	1000	350	V	235	-8
1074.99	---	17.86	54	36.14	1000	350	V	235	-8
1419.95	30.47	---	74	43.53	1000	104	V	292	-7.2
1419.95	---	17.37	54	36.63	1000	104	V	292	-7.2
3220.10	37.6	---	74	36.4	1000	150	H	265	0.7
3220.10	---	23.73	54	30.27	1000	150	H	265	0.7
4810.92	37.41	---	74	36.59	1000	155	H	261	5.3
4810.92	---	23.89	54	30.11	1000	155	H	261	5.3
8515.00	---	35.43	54	18.57	1000	100	V	62	13.3
8515.00	47.85	---	74	26.15	1000	100	V	62	13.3
14604.00	53.9	---	74	20.1	1000	105	V	201	21.3
14604.00	---	41.93	54	12.07	1000	105	V	201	21.3
17974.76	64.36	---	74	9.64	1000	355	H	144	30.7
17974.76	---	53.01	54	0.99	1000	355	H	144	30.7
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle.									

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Table 23: Transmit Spurious Emission 1 – 18 GHz – 2442 MHz, 1Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/06/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6		
Ambient Temperature:		24				Relative Humidity:	36		
Max. Antenna Gain:		-0.3dBi				Test Engineer:	Nathaniel Beyer		
Signal State: Modulated									
1Mbps									
Test Frequency: 2442 MHz									
Freq. (MHz)	Peak (dBμV/m)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
1110.15	31.52	---	74	42.48	1000	155	V	216	-7.8
1110.15	---	18.45	54	35.55	1000	155	V	216	-7.8
1119.00	---	17.88	54	36.12	1000	354	H	313	-7.9
1119.00	30.34	---	74	43.66	1000	354	H	313	-7.9
1550.72	---	18.32	54	35.68	1000	350	V	179	-6.7
1550.72	31.56	---	74	42.44	1000	350	V	179	-6.7
2196.00	33.9	---	74	40.1	1000	255	V	208	-3.7
2196.00	---	20.93	54	33.07	1000	255	V	208	-3.7
4143.50	38.13	---	74	35.87	1000	250	V	229	3
4143.50	---	24.76	54	29.24	1000	250	V	229	3
6379.00	41.36	---	74	32.64	1000	250	V	81	7.7
6379.00	---	28.73	54	25.27	1000	250	V	81	7.7
14051.19	53.79	---	74	20.21	1000	350	V	81	20.2
14051.19	---	42.25	54	11.75	1000	350	V	81	20.2
17926.67	64.69	---	74	9.31	1000	334	H	265	30.5
17926.67	---	52.53	54	1.48	1000	334	H	265	30.5
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle.									

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Table 24: Transmit Spurious Emission 1 – 18 GHz – 2480 MHz, 1 Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/06/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6		
Ambient Temperature:		24				Relative Humidity:	36		
Max. Antenna Gain:		-0.3dBi				Test Engineer:	Nathaniel Beyer		
Signal State: Modulated									
1Mbps									
Test Frequency: 2480 MHz									
Freq. (MHz)	Peak (dBμV/m)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
1055.82	30.04	---	74	43.96	1000	250	V	329	-8.3
1055.82	---	16.98	54	37.02	1000	250	V	329	-8.3
1175.50	29.75	---	74	44.25	1000	155	V	185	-7.8
1175.50	---	16.84	54	37.16	1000	155	V	185	-7.8
1491.42	30.78	---	74	43.22	1000	237	V	185	-7
1491.42	---	18.5	54	35.5	1000	237	V	185	-7
3201.51	---	21.51	54	30.62	1000	103	V	263	0.5
3201.51	36.59	---	74	37.41	1000	103	V	263	0.5
8850.00	---	36.15	54	17.85	1000	350	V	212	13.6
8850.00	47.84	---	74	26.16	1000	350	V	212	13.6
13470.70	53.25	---	74	20.75	1000	250	V	108	20
13470.70	---	41.16	54	12.84	1000	250	V	108	20
14246.69	---	42.02	54	11.98	1000	150	H	267	20.8
14246.69	53.42	---	74	20.58	1000	150	H	267	20.8
17910.00	---	52.28	54	1.72	1000	104	V	135	30.4
17910.00	63.8	---	74	10.2	1000	104	V	135	30.4
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle.									

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Table 25: Transmit Spurious Emission 1 – 18 GHz – 2402MHz, 2 Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/06/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6		
Ambient Temperature:		24				Relative Humidity:	39		
Max. Antenna Gain:		-0.3dBi				Test Engineer:	Nathaniel Beyer		
Signal State: Modulated									
2Mbps									
Test Frequency: 2402 MHz									
Freq. (MHz)	Peak (dBμV/m)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
1070.72	30.37	---	74	43.63	1000	254	H	208	-8.1
1070.72	---	17.71	54	36.29	1000	254	H	208	-8.1
1076.97	30.53	---	74	43.47	1000	355	V	152	-8
1076.97	---	17.96	54	36.04	1000	355	V	152	-8
1094.00	---	18.27	54	35.73	1000	103	V	79	-7.9
1094.00	31.14	---	74	42.86	1000	103	V	79	-7.9
1423.50	---	17.67	54	36.33	1000	350	H	319	-7
1423.50	30.22	---	74	43.78	1000	350	H	319	-7
1784.67	32.38	---	74	41.62	1000	250	H	312	-5
1784.67	---	19.65	54	34.35	1000	250	H	312	-5
2877.50	---	22.35	54	31.65	1000	250	H	315	-1.2
2877.50	34.95	---	74	39.05	1000	250	H	315	-1.2
4285.41	37.19	---	74	36.81	1000	250	H	315	3
4285.41	---	24.5	54	29.5	1000	250	H	315	3
7524.04	43.8	---	74	30.2	1000	334	H	65	11.2
7524.04	---	32.14	54	21.86	1000	334	H	65	11.2
14044.35	---	42.18	54	11.82	1000	236	H	278	20.4
14044.35	53.93	---	74	20.07	1000	236	H	278	20.4
17981.77	64.68	---	74	9.32	1000	350	V	169	30.7
17981.77	---	53.05	54	0.95	1000	350	V	169	30.7
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle.									

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Table 26: Transmit Spurious Emission 1 – 18 GHz – 2442MHz, 2Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/06/2024		
/Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6		
Ambient Temperature:		24				Relative Humidity:	39		
Max. Antenna Gain:		-0.3dBi				Test Engineer:	Nathaniel Beyer		
Signal State: Modulated									
2Mbps									
Test Frequency: 2442 MHz									
Freq. (MHz)	Peak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azim uth (deg)	Corr. (dB)
1195.24	29.82	---	74	44.18	1000	250	V	225	-7.7
1195.24	---	17.15	54	36.85	1000	250	V	225	-7.7
1357.00	31.07	---	74	42.93	1000	150	H	330	-7.1
1357.00	---	18.38	54	35.62	1000	150	H	330	-7.1
3818.53	36.94	---	74	37.06	1000	350	V	204	2.9
3818.53	---	24.14	54	29.86	1000	350	V	204	2.9
13459.91	52.61	---	74	21.39	1000	155	H	334	20
13459.91	---	41.06	54	12.94	1000	155	H	334	20
14167.94	---	42.14	54	11.86	1000	350	H	306	20.6
14167.94	53.99	---	74	20.01	1000	350	H	306	20.6
17933.85	---	52.51	54	1.49	1000	150	V	309	30.5
17933.85	64.58	---	74	9.42	1000	150	V	309	30.5
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle.									

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Table 27: Transmit Spurious Emission 1 – 18 GHz – 2480 MHz, 2 Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/06/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6		
Ambient Temperature:		24				Relative Humidity:	39		
Max. Antenna Gain:		-0.3dBi				Test Engineer:	Nathaniel Beyer		
Signal State: Modulated									
2Mbps									
Test Frequency: 2480 MHz									
Freq. (MHz)	Peak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
1380.21	---	18.24	54	35.76	1000	100	H	210	-7
1380.21	30.87	---	74	43.13	1000	100	H	210	-7
3252.50	36.41	---	74	37.59	1000	337	V	176	0.9
3252.50	---	23.57	54	30.43	1000	337	V	176	0.9
3774.48	37.34	---	74	36.66	1000	355	H	209	2.7
3774.48	---	24.69	54	29.31	1000	355	H	209	2.7
13079.50	51.65	---	74	22.35	1000	354	V	178	19.7
13079.50	---	40.18	54	13.82	1000	354	V	178	19.7
14097.93	53.56	---	74	20.44	1000	354	V	102	20.4
14097.93	---	42.13	54	11.87	1000	354	V	102	20.4
17979.00	---	53	54	1	1000	353	V	277	30.7
17979.00	64.62	---	74	9.38	1000	353	V	277	30.7
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle.									

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5.5.3.5 Transmitter Spurious Emissions: 18 GHz – 26.5 GHz

Table 28: Transmit Spurious Emission 18 – 26.5 GHz – 2402 MHz, 1 Mbps

Test Condition:		Radiated, Normal Temperature				Date:		06/07/2024	
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:		See Table 6	
Ambient Temperature:		23				Relative Humidity:		40	
Max. Antenna Gain:		-0.3dBi				Test Engineer:		Nathaniel Beyer	
Signal State: Modulated									
1Mbps									
Test Frequency: 2402 MHz									
Freq. (MHz)	Peak (dBμV/m)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azimuth (deg)	Corr. (dB)
18004.50	49.13	---	74	24.87	1000	100	V	72	-2.9
18004.50	---	37.2	54	16.8	1000	100	V	72	-2.9
20743.00	---	36.12	54	17.88	1000	154	V	211	-0.2
20743.00	47.95	---	74	26.05	1000	154	V	211	-0.2
21831.50	47.95	---	74	26.05	1000	154	V	354	0.2
21831.50	---	36.3	54	17.7	1000	154	V	354	0.2
22698.62	48.3	---	74	25.7	1000	150	V	200	0.1
22698.62	---	36.1	54	17.9	1000	150	V	200	0.1
25054.91	48.99	---	74	25.01	1000	254	V	41	2.6
25054.91	---	37.02	54	16.98	1000	254	V	41	2.6
25518.17	---	37.52	54	16.48	1000	105	V	25	3.5
25518.17	48.92	---	74	25.08	1000	105	V	25	3.5
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle.									

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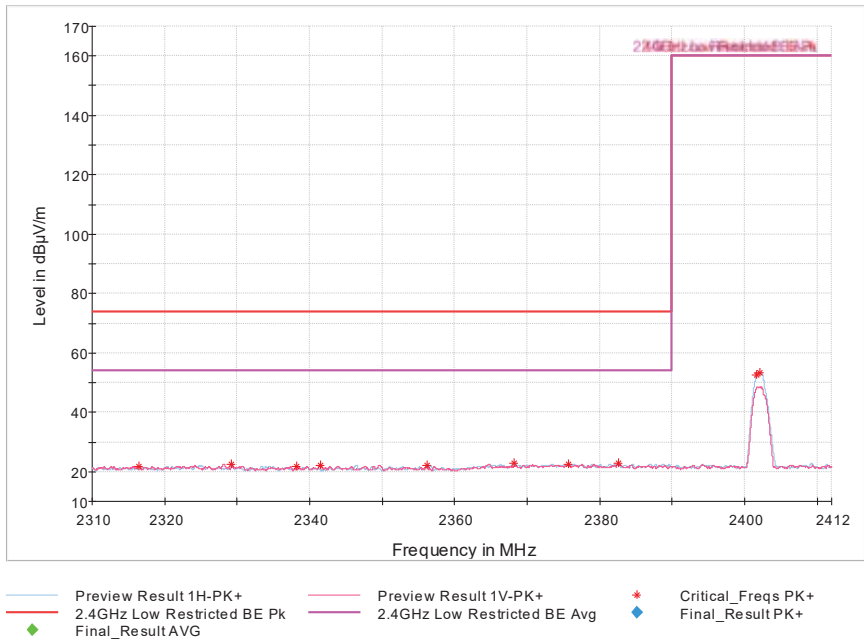
Table 29: Transmit Spurious Emission 18 – 26.5 GHz – 2480 MHz, 2 Mbps

Test Condition:		Radiated, Normal Temperature				Date:	06/07/2024		
Antenna Type:		BLE: PCB Trace Antenna (Pole)				Power Level:	See Table 6		
Ambient Temperature:		23				Relative Humidity:	40		
Max. Antenna Gain:		-0.3dBi				Test Engineer:	Nathaniel Beyer		
Signal State: Modulated									
2Mbps									
Test Frequency: 2480 MHz									
Freq. (MHz)	Peak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	BW (kHz)	Height (cm)	Pol (V/H)	Azim uth (deg)	Corr. (dB)
18072.53	48.66	---	74	25.34	1000	250	V	26	-2.8
18072.53	---	37	54	17	1000	250	V	26	-2.8
19061.50	---	36.22	54	17.78	1000	250	H	48	-2
19061.50	48.13	---	74	25.87	1000	250	H	48	-2
19840.00	48.17	---	74	25.83	1000	250	H	344	-1
19840.00	---	36.05	54	17.95	1000	250	H	344	-1
20312.26	48.26	---	74	25.74	1000	255	H	112	-0.4
20312.26	---	36.32	54	17.68	1000	255	H	112	-0.4
21453.35	---	36.54	54	17.46	1000	353	H	113	0.2
21453.35	48.37	---	74	25.63	1000	353	H	113	0.2
25051.00	48.68	---	74	25.32	1000	103	H	262	2.6
25051.00	---	37.02	54	16.98	1000	103	H	262	2.6
Note: Duty Cycle Correction added final reported Average value using equation 10log(1/d) where d = duty cycle. High Channel at 2Mbps worst case reported.									

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5.5.3.6 Analyzer Data

5.5.3.6.1 Restricted Band 2310 – 2390 MHz – Bandedge



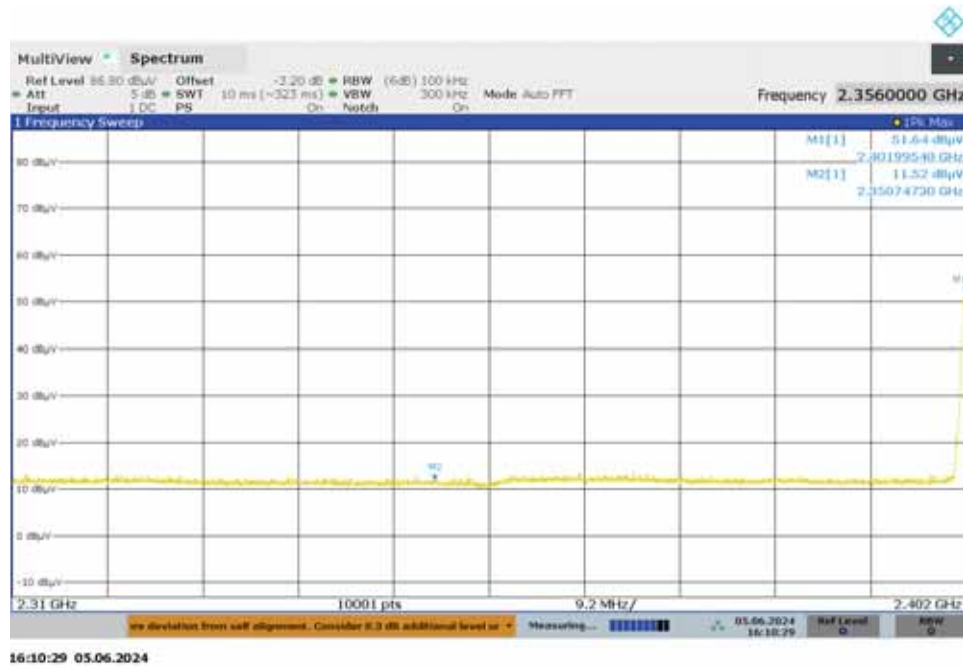
2402 MHz, 1Mbps



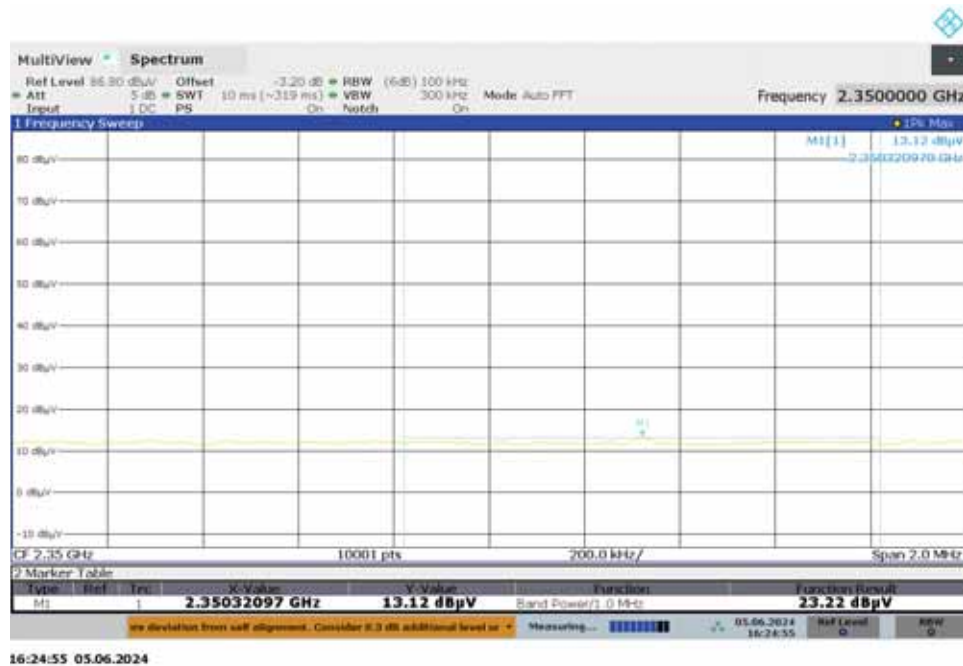
2402 MHz, 1Mbps

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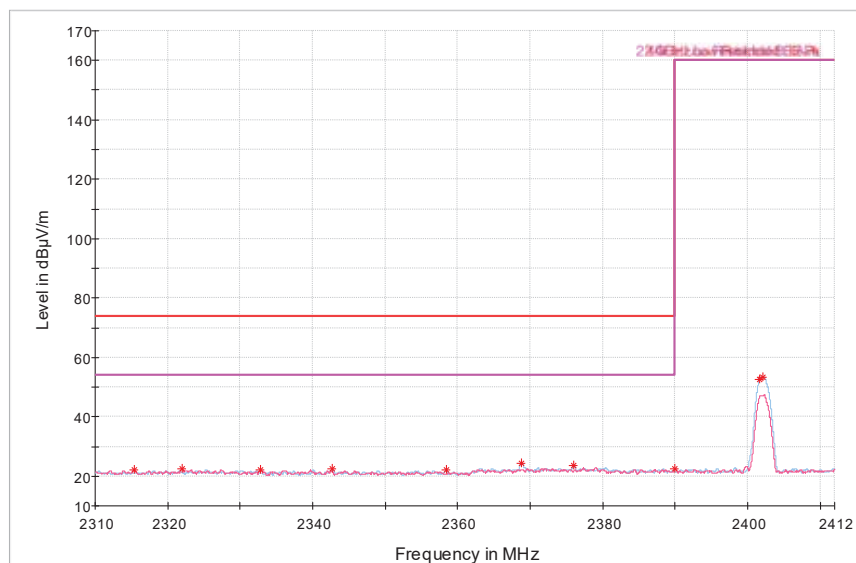
2402 MHz, 1Mbps



2402 MHz, 1Mbps

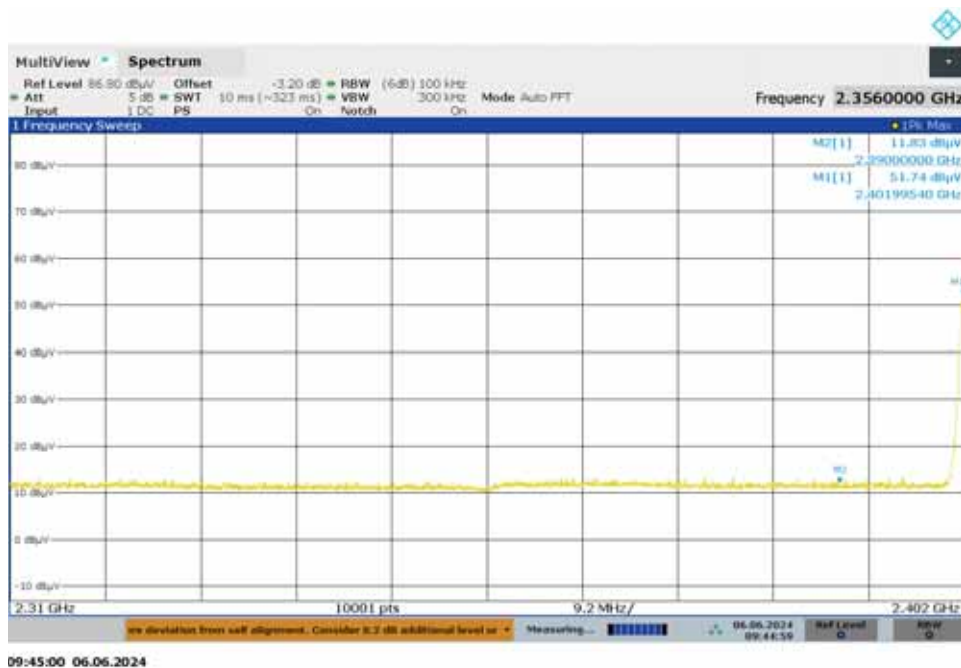
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Preview Result 1H-PK+ Preview Result 1V-PK+ Critical_Freqs PK+
2.4GHz Low Restricted BE PK 2.4GHz Low Restricted BE Avg Final_Result PK+
Final_Result AVG ◆

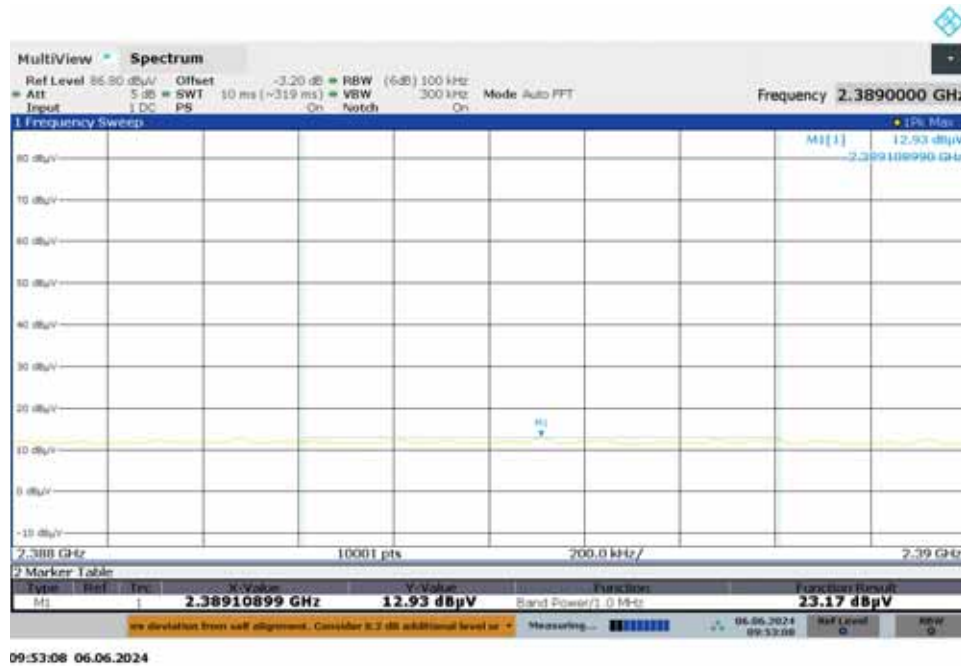
2402 MHz, 2 Mbps



2402 MHz, 2 Mbps

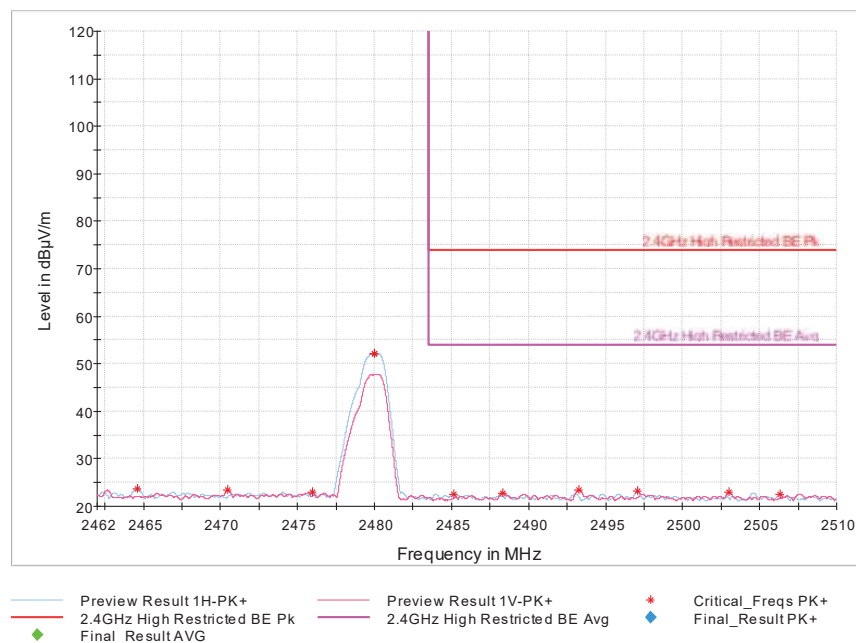
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2402 MHz, 2 Mbps

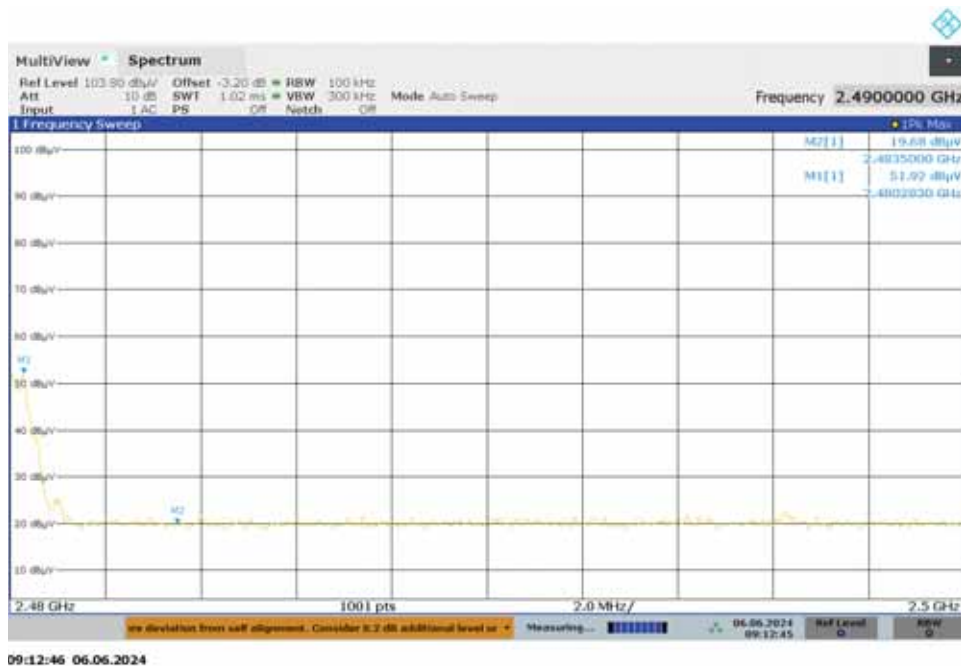
5.5.3.6.2 Restricted Band 2310 – 2390 MHz – Bandedge



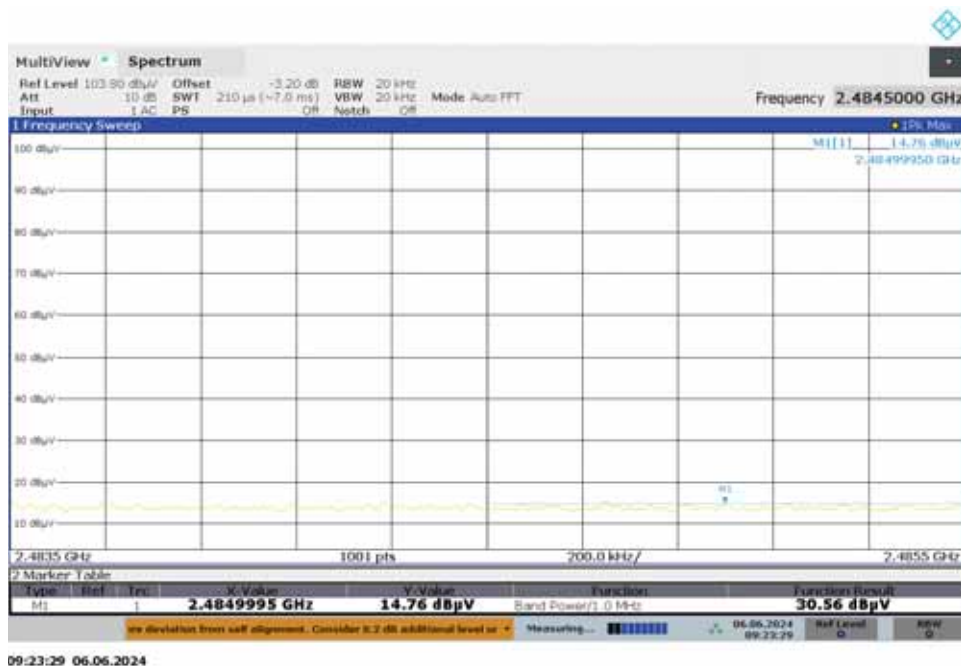
2480 MHz, 1Mbps

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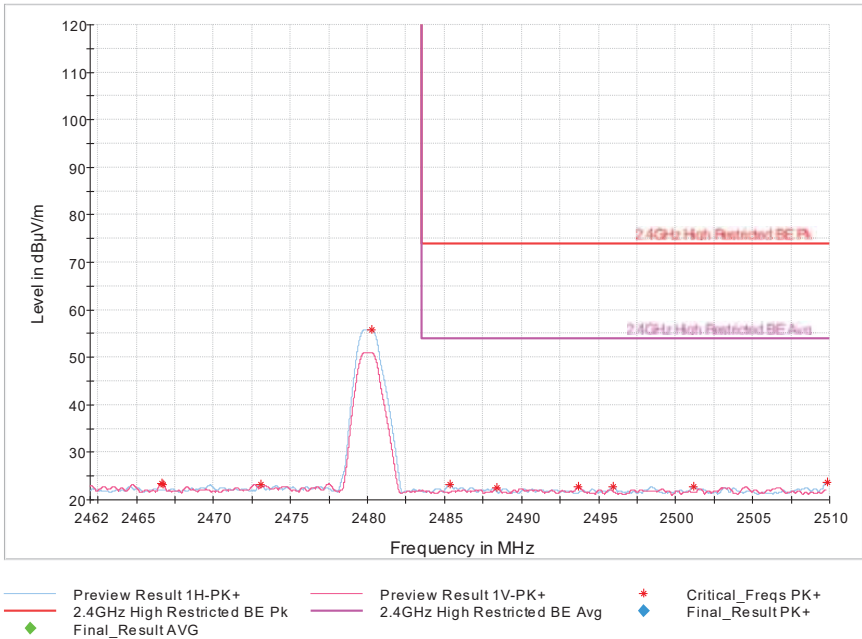


2480 MHz, 1Mbps

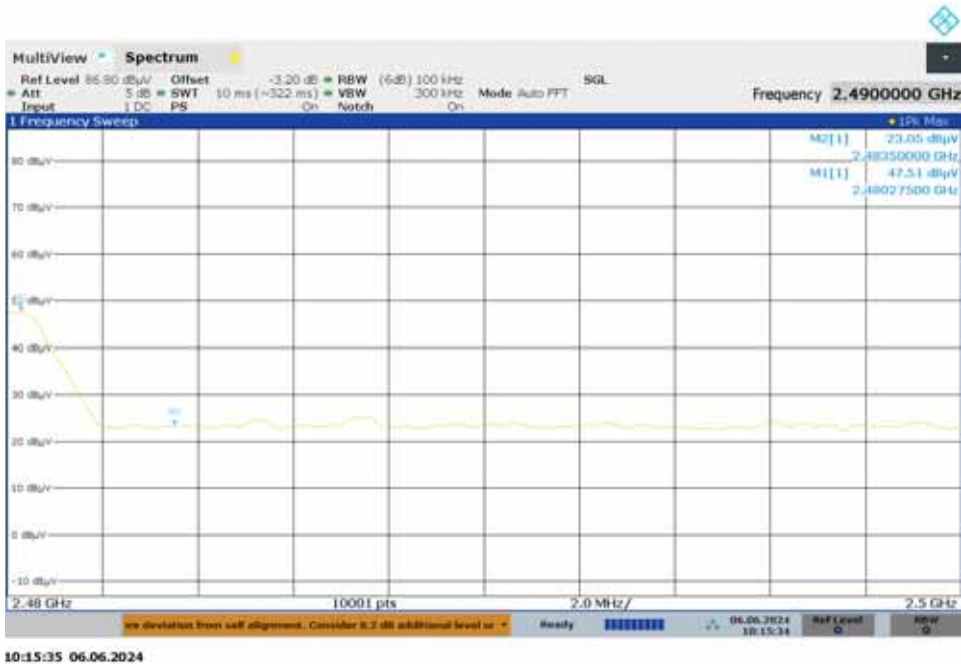


2480 MHz, 1Mbps

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2480 MHz, 2 Mbps



2480 MHz, 2 Mbps

Test report no.: US24L0WX 001
Prüfbericht-Nr.:



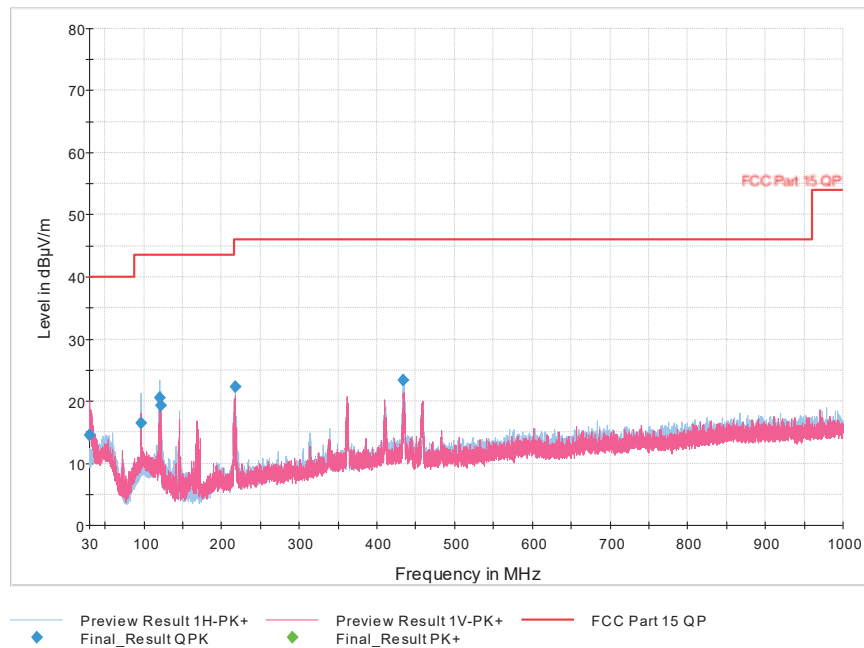
10:36:26 06.06.2024

2480 MHz, 2 Mbps

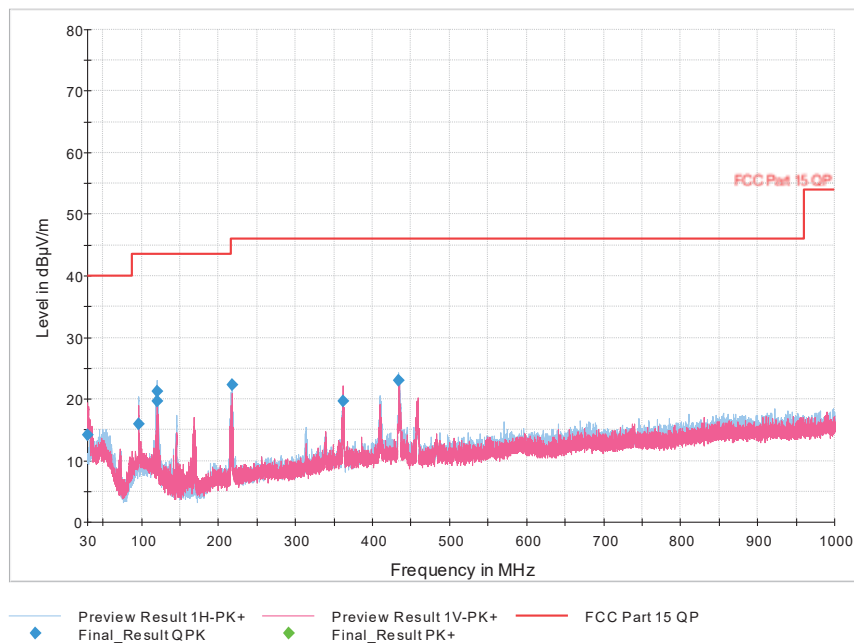
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5.5.3.6.3 Spurious Emissions 30 MHz to 1000 MHz



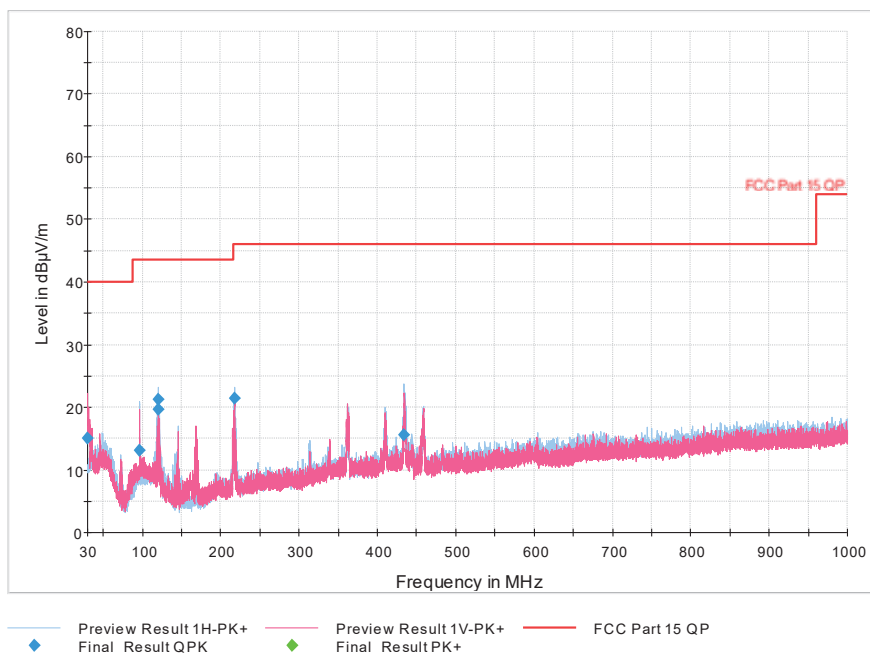
2402 MHz, 1 Mbps



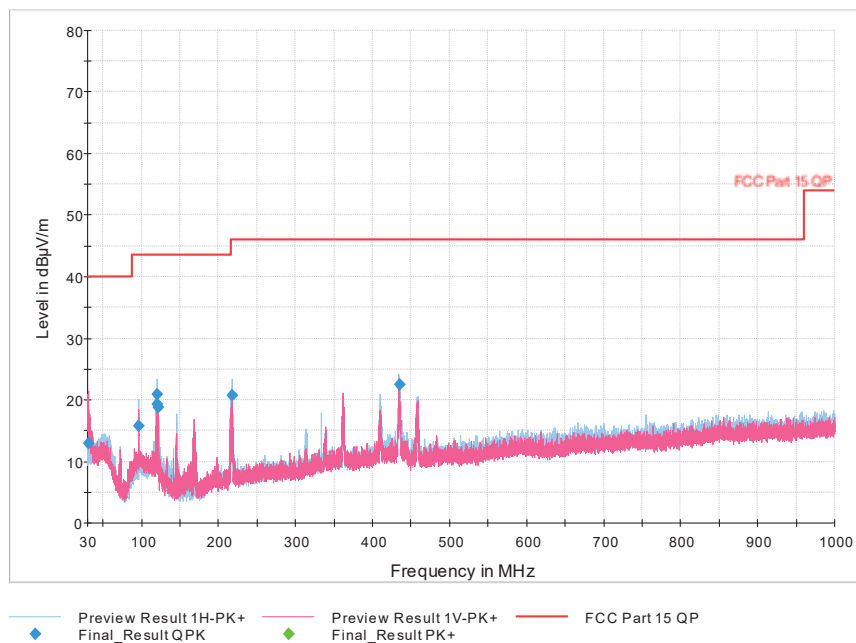
2442 MHz, 1 Mbps

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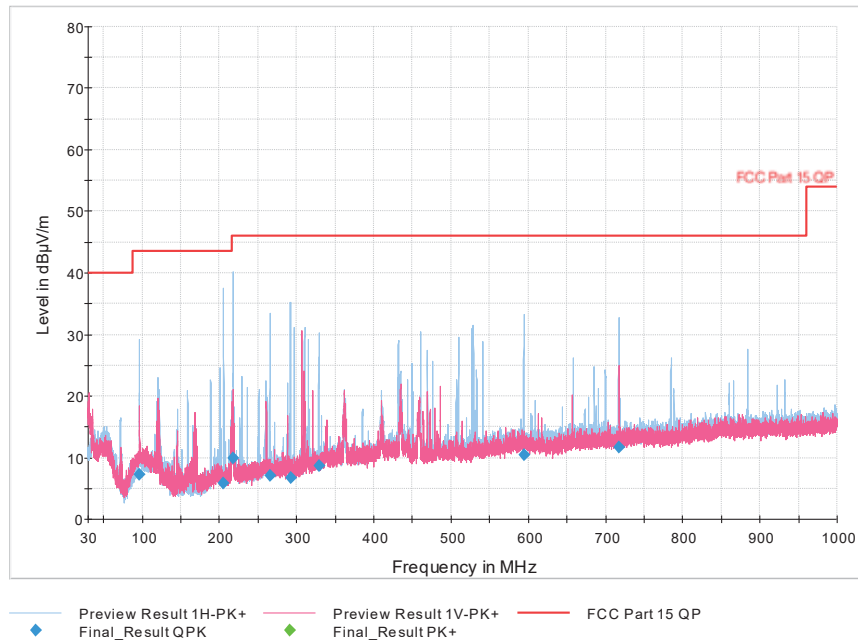
2480 MHz, 1 Mbps



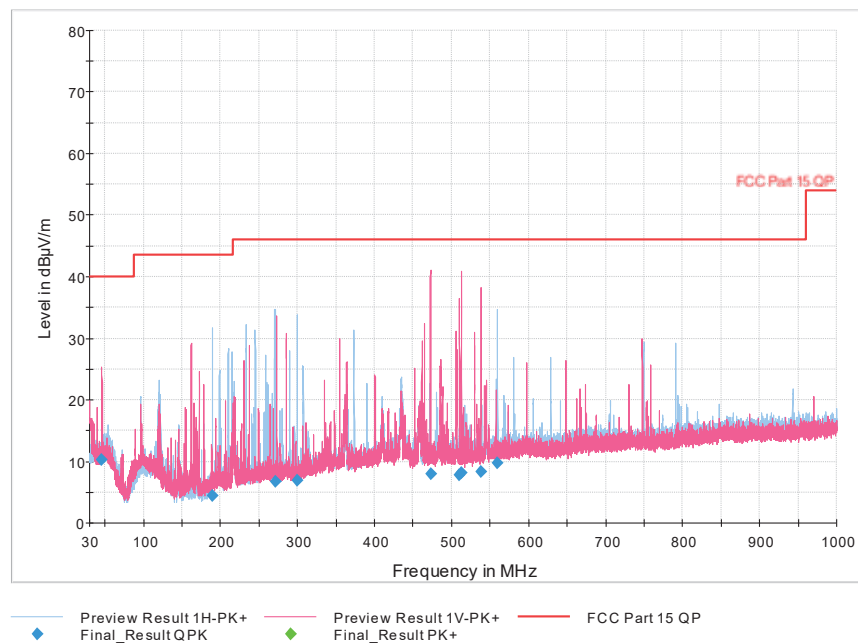
2402 MHz, 2 Mbps

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2442 MHz, 2 Mbps

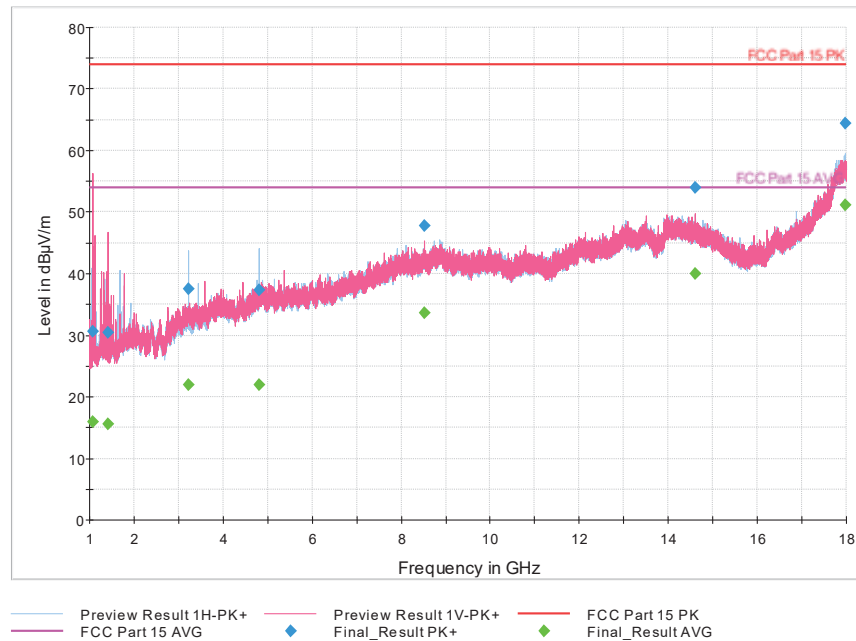


2480 MHz, 2 Mbps

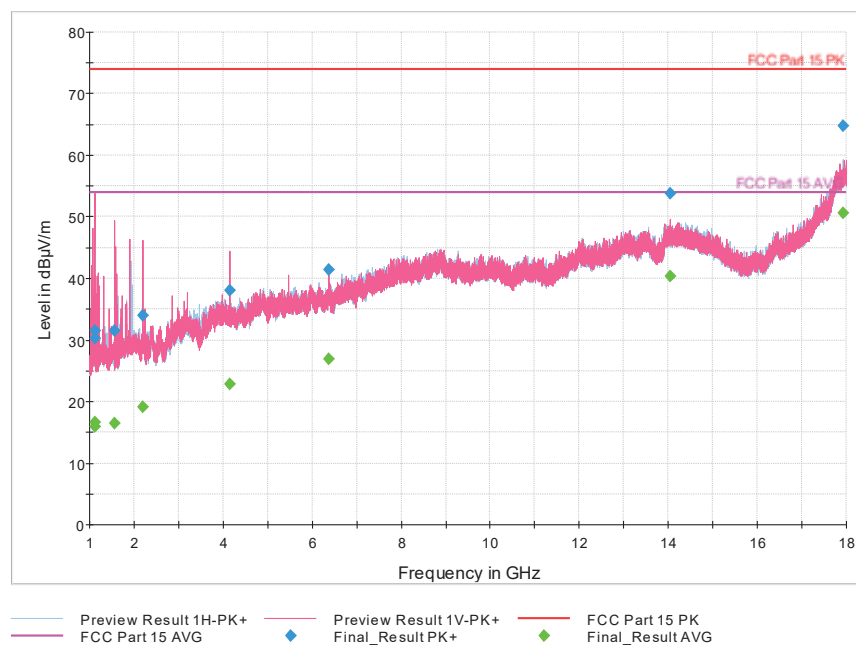
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5.5.3.6.4 Spurious Emissions 1 GHz to 18 GHz



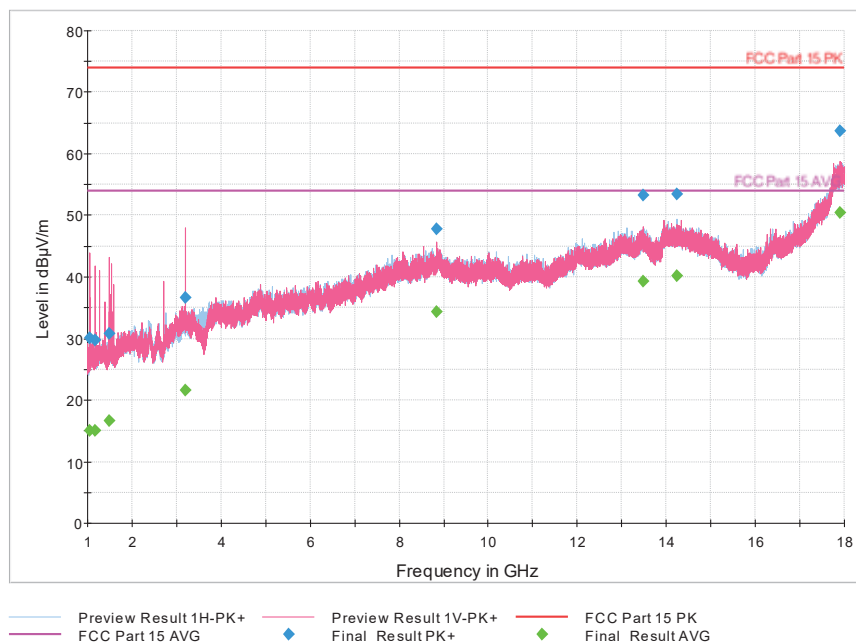
2402 MHz, 1 Mbps



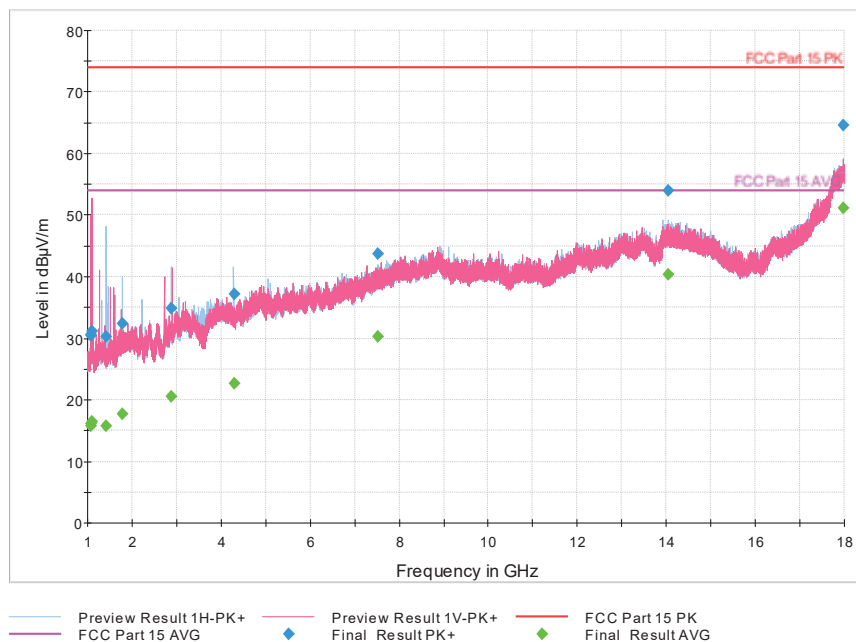
2442 MHz, 1 Mbps

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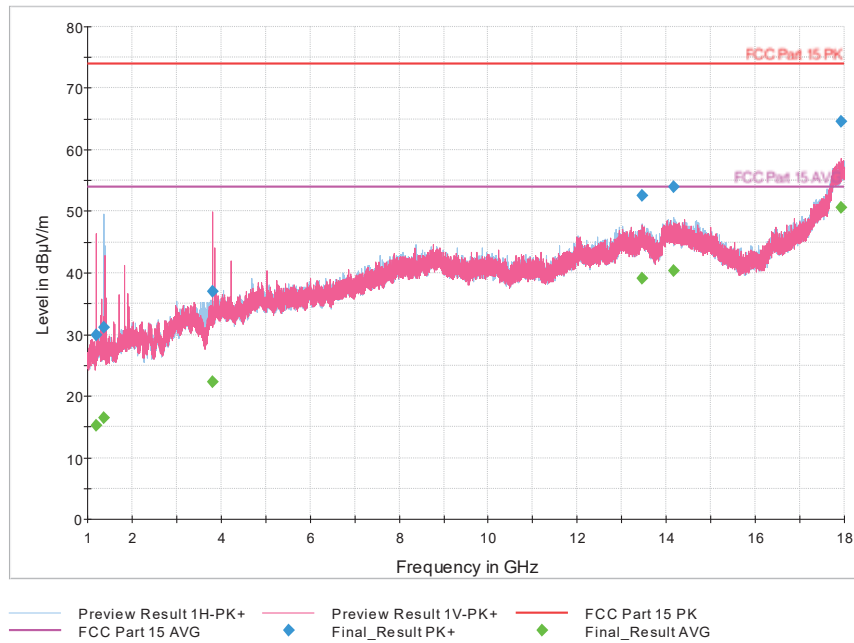
2480 MHz, 1 Mbps



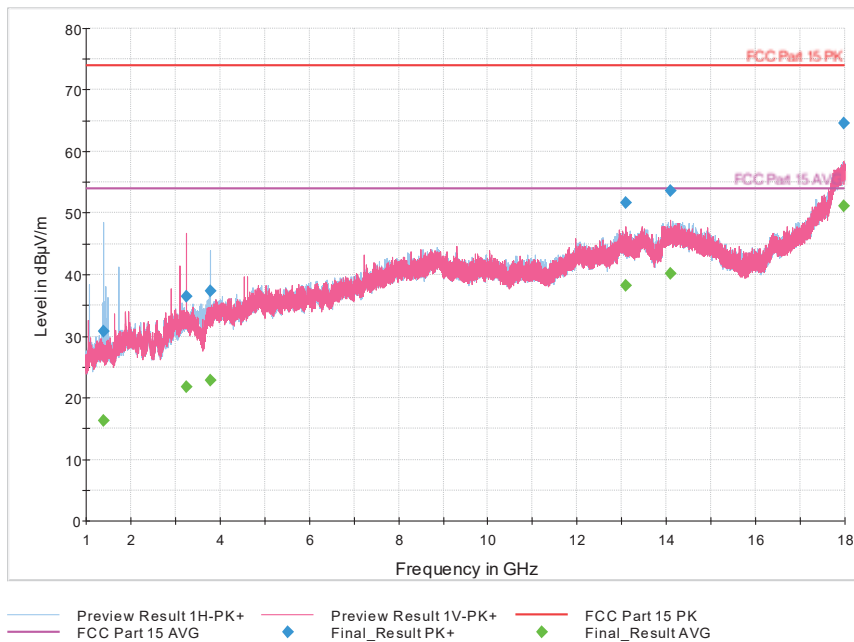
2402 MHz, 2 Mbps

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2442 MHz, 2 Mbps

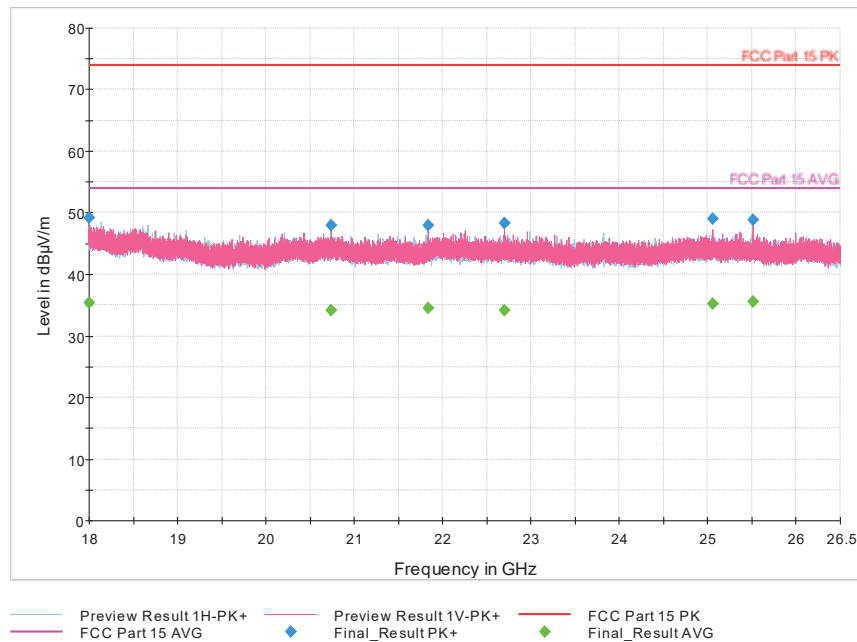


2480 MHz, 2 Mbps

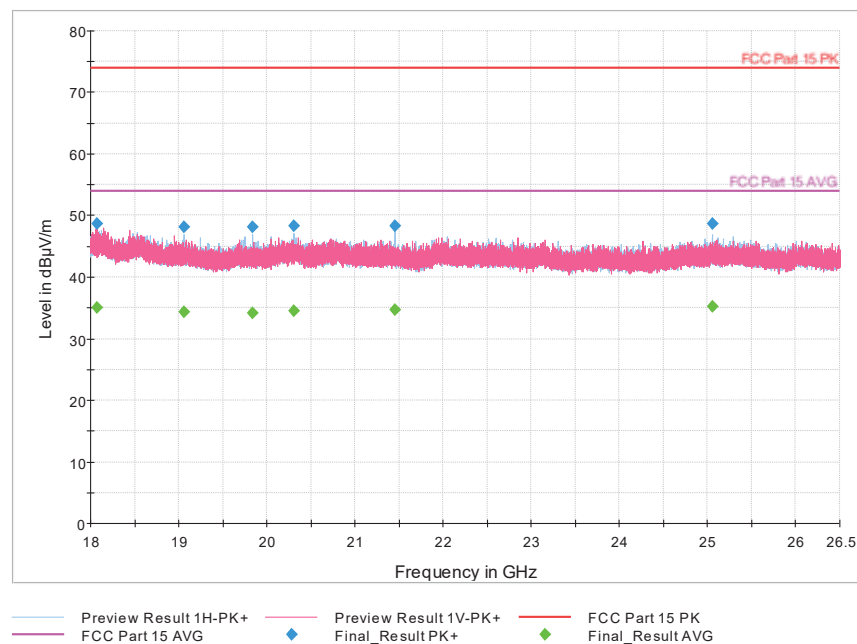
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5.5.3.6.5 Spurious Emissions 18 GHz to 26.5 GHz



2402 MHz, 1 Mbps



2480 MHz, 2 Mbps

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5.6 AC Conducted Emissions

Testing was performed in accordance with ANSI C63.4:2020. These test methods are listed under the laboratory's A2LA Scope of Accreditation.

This test measures the levels emanating from the EUT's AC input port, thus evaluating the potential for the EUT to cause radio frequency interference to other electronic devices.

The AC conducted emissions of equipment under test shall not exceed the values in CFR47 Part 15.207 and RSS-Gen Section 8.8.

5.6.1 Test Methodology

A test program that controls instrumentation and data logging was used to automate the AC Power Line Conducted emission test procedure. The frequency range of interest was divided into sub-ranges such as to yield a frequency resolution of 9 kHz. Each phase and neutral of the AC power line were measured with respect to ground. Measurements were performed using a set of 50µH / 50Ω LISNs.

The setup photographs clearly identify which site was used. The vertical ground plane used is a 2m x 2m solid aluminum frame and panel, and it is bonded to the horizontal ground plane.

In the case of tabletop equipment, the EUT is placed on a 1.0m x 1.5m non-conductive table 80cm above the ground plane and 40cm from a vertical ground reference plane. The rear of the EUT was positioned flush with the backside of the table and directly over the LISNs. The power and I/O cables were routed over the edge of the table and bundled approximately 40cm from the ground plane. Support equipment was powered from a separate LISN.

The radio's were transmitting when testing was performed.

5.6.2 Conducted Emission Limits

The emissions of the EUT shall not exceed the limits required by the applicable rule parts as described below.

Table 28: AC Conducted Emission limits

Frequency of Emission (MHz)	Conducted Limit (dBµV)	
	Quasi-Peak	Average
0.15 – 0.5	66 to 56 ¹	56 to 46 ¹
0.5 – 5	56	46
5 – 30	60	50
Note: 1. Decreases with the logarithm of the frequency.		

5.6.3 Deviations

There were no deviations from this test methodology.

5.6.4 Test Results

The device passed as configured.

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5.6.4.1 Test Data

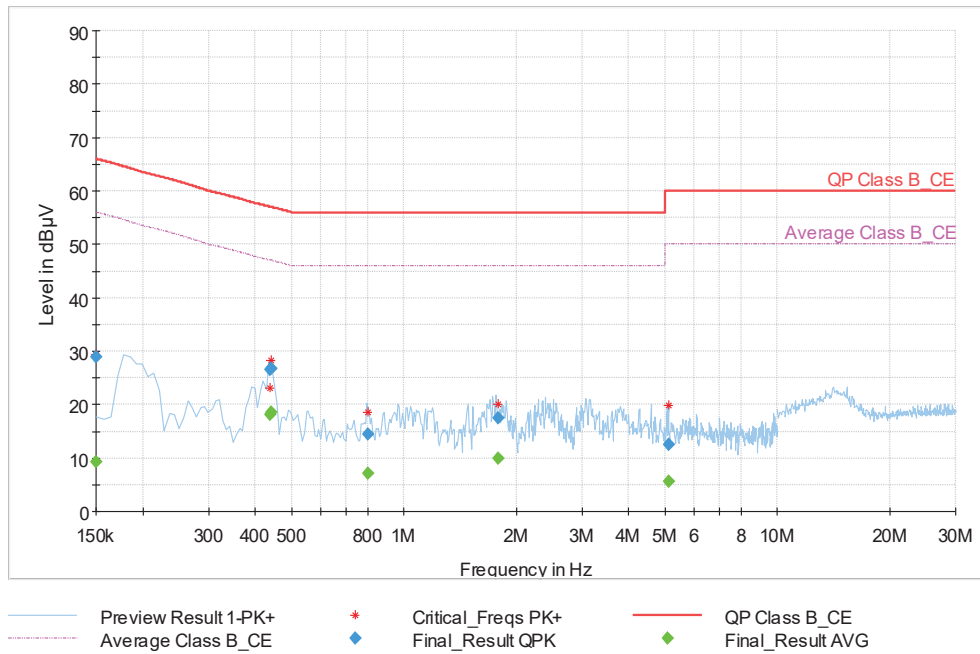
5.6.4.1.1 Conducted Emissions

Table 29: Conducted Emission – 2480 MHz, Line

Test Condition:		Radiated, Normal Temperature			Date:	08/26/2025		
Antenna Type:		PCB Trace Antenna (Pole)			Power Level:	See Table 6		
Ambient Temperature:		23°C			Relative Humidity:	40%		
Max. Antenna Gain:		-0.3dBi			Test Engineer	Nathaniel Beyer		
Signal State: Modulated								
Freq. (MHz)	Quasi-Peak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Line	PE	Corr. (dB)
0.15	---	9.2	56	46.8	10000	L1	GND	10.1
0.15	28.95	---	66	37.05	10000	L1	GND	10.1
0.44	---	18.15	47.02	28.87	10000	L1	GND	10
0.44	26.51	---	57.02	30.51	10000	L1	GND	10
0.44	---	18.59	46.98	28.4	10000	L1	GND	10
0.44	26.73	---	56.98	30.26	10000	L1	GND	10
0.80	---	7.17	46	38.83	10000	L1	GND	10
0.80	14.43	---	56	41.57	10000	L1	GND	10
1.79	---	9.95	46	36.06	10000	L1	GND	10
1.79	17.54	---	56	38.46	10000	L1	GND	10
5.11	---	5.61	50	44.39	10000	L1	GND	10.1
5.11	12.52	---	60	47.48	10000	L1	GND	10.1
Note: None								

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Conducted Emissions: Line

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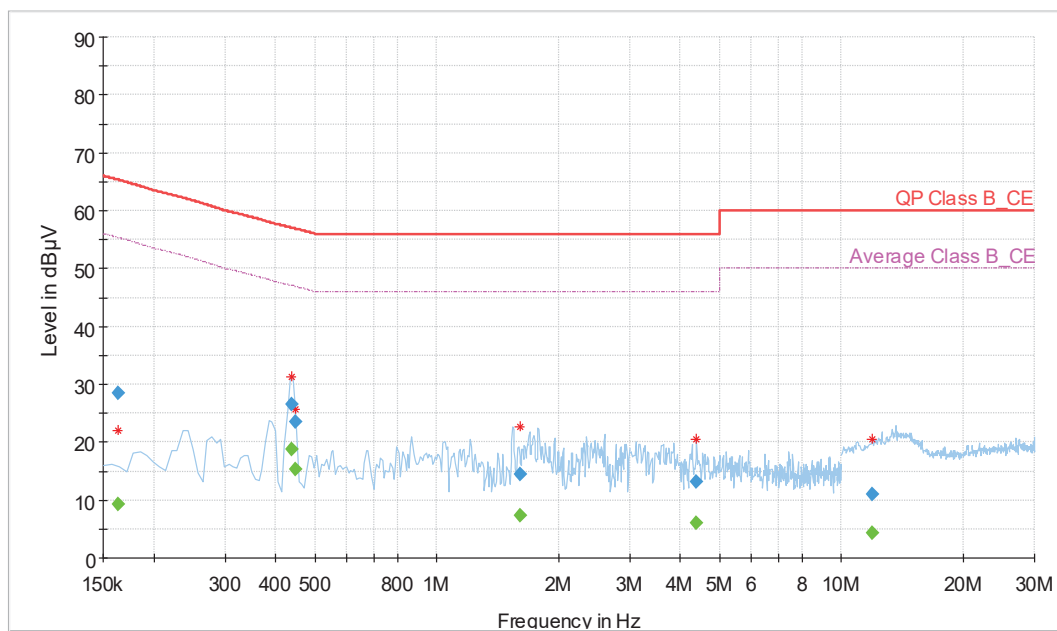
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Table 30: Conducted Emissions – 2480 MHz, Neutral

Test Condition:		Radiated, Normal Temperature			Date:	08/26/2025		
Antenna Type:		PCB Trace Antenna (Pole)			Power Level:	See Table 6		
Ambient Temperature:		23°C			Relative Humidity:	40%		
Max. Antenna Gain:		-0.3dBi			Test Engineer	Nathaniel Beyer		
Signal State: Modulated								
Freq. (MHz)	Quasi-Peak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Line	PE	Corr. (dB)
0.16	---	9.29	55.33	46.03	10000	N	GND	10.1
0.16	28.4	---	65.33	36.92	10000	N	GND	10.1
0.44	26.46	---	57.04	30.58	10000	N	GND	10
0.44	---	18.76	47.04	28.27	10000	N	GND	10
0.45	23.44	---	56.87	33.43	10000	N	GND	10
0.45	---	15.42	46.87	31.45	10000	N	GND	10
1.61	---	7.33	46	38.67	10000	N	GND	10
1.61	14.56	---	56	41.44	10000	N	GND	10
4.37	---	6.1	46	39.9	10000	N	GND	10.1
4.37	13.2	---	56	42.8	10000	N	GND	10.1
11.89	---	4.33	50	45.67	10000	N	GND	10.1
11.89	11.01	---	60	48.99	10000	N	GND	10.1
Note: None								

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— Preview Result 1-PK+ * Critical_Freqs PK+ — QP Class B_CE
— Average Class B_CE ◆ Final_Result QPK ◆ Final_Result AVG

Conducted Emissions: Neutral

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6 Test Equipment List

6.1 Equipment List

Table 31: Equipment List

Equipment	Type	Inventory number	Manufacturer	Last calibration	Calibration due date
Radiated Emissions					
EMI Test Receiver	ESW44	9018108	Rohde & Schwarz	21.02.2024	21.02.2025
Preamplifier 30MHz – 8 GHz	TS-PR8	9017639	Rohde & Schwarz	22.02.2024	22.02.2025
Preamplifier 1GHz – 18GHz	TS-PR18	9018047	Rohde & Schwarz	27.02.2024	27.02.2025
Horn Antenna 1GHz – 18GHz	3115	9038283	EMCO	14.09.2023	14.09.2025
Trilog Antenna 30MHz – 7GHz	VULB 9162	9017943	Schwarzbeck; Huber+ Suhner	24.03.2023	24.03.2025
Conducted RF					
EMI Test Receiver	ESW44	90229914	Rohde & Schwarz	20.02.2024	20.02.2025
DC Power Supp DC Power Supply ly	E36104B	9066184	Keysight	--	--
Conducted Emissions					
EMI Test Receiver	ESW44	9022991	Rohde & Schwarz	02.04.2025	02.04.2026
LISN	LI-215	G1700229	Com-Power	18.02.2025	18.02.2026
Transient Limiter	11947A	G1701026	Agilent	18.02.2025	18.02.2026
Note: Initial testing on TR3 from 6/4/2024 - 6/11/2024 & 8/26/2025					

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Table 32: Equipment List

Equipment	Type	Inventory Number	Manufacturer	Last calibration	Calibration due date
Radiated Emissions					
EMI Test Receiver	ESW44	9018108	Rohde & Schwarz	21.02.2024	21.02.2025
Preamplifier 30MHz – 8 GHz	TS-PR8	9017639	Rohde & Schwarz	22.02.2024	22.02.2025
Trilog Antenna 30MHz – 7GHz	VULB 9162	9017943	Schwarzbeck; Huber+ Suhner	24.03.2023	24.03.2025
Loop Antenna 10 kHz – 30 MHz	6502	G1700997	EMCO	23.05.2024	23.05.2026
Conducted Emissions					
EMI Test Receiver	ESW44	9022991	Rohde & Schwarz	02.04.2025	02.04.2026
LISN	LI-215	G1700229	Com-Power	18.02.2025	18.02.2026
Transient Limiter	11947A	G1701026	Agilent	18.02.2025	18.02.2026
Note: Additional testing on TBK on 8/15/2025 – 08/26/2025					

6.2 Testing Software

Table 33: Testing Software

Manufacturer	Name	Version	Test
Rohde & Schwarz	EMC32	3m – 10.60.10	Radiated Emissions
Rohde & Schwarz	EMC32	CE - 10.50.10	Conducted Emissions

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--- Ende des Prüfberichts / End of Test Report ---