Amber Helm Development L.C.
92723 Michigan Hwy-152
Sister Lakes, Michigan 49047 USA
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GRIDTS-WR2111TX
Issued: **May 25, 2021**

DTS EMC Test Report

regarding

USA: CFR Title 47, Part 15.247 (Emissions)
Canada: IC RSS-247/GENe (Emissions)

for

GC-ESP32-ETH

Category: WLAN+BLE Module

Judgments:
FCC 15.247, ISED RSS-247v2 Compliant
Testing Completed: October 8, 2021

TESTING
NVLAP LAB CODE 200129-0

Prepared for:

Grid Connect, Inc.

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Reviewed by: Gordon Helm, EMC-002401-NE

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Date of Issue: May 25, 2021

Revision History

Rev. No.	Date	Details	Revised By
r0	May 25, 2021	Initial Release.	J. Brunett
r1	October 8, 2021	Add DTS OBW + Voltage Reg.	J. Brunett

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1 Test Report Scope and Limitations

1.1 Laboratory Authorization

Test Facility description and attenuation characteristics are on file with the FCC Laboratory, Columbia, Maryland (FCC Reg. No: US5348 and US5356) and with ISED Canada, Ottawa, ON (File Ref. No: 3161A and 24249). Amber Helm Development L.C. holds accreditation under NVLAP Lab Code 200129-0.

1.2 Report Retention

For equipment verified to comply with the regulations herein, the manufacturer is obliged to retain this report with the product records for the life of the product, and no less than ten years. A copy of this Report will remain on file with this laboratory until May 2031.

1.3 Subcontracted Testing

This report does not contain data produced under subcontract.

1.4 Test Data

This test report contains data included within the laboratory's scope of accreditation.

1.5 Limitation of Results

The test results contained in this report relate only to the item(s) tested. Any electrical or mechanical modification made to the test item subsequent to the test date shall invalidate the data presented in this report. Any electrical or mechanical modification made to the test item subsequent to this test date shall require reevaluation.

1.6 Copyright

1.7 Endorsements

This report shall not be used to claim product endorsement by any accrediting, regulatory, or governmental agency.

1.8 Test Location

The EUT was fully tested by **Amber Helm Development L.C.**, headquartered at 92723 Michigan Hwy-152, Sister Lakes, Michigan 49047 USA. Table 1 lists all sites employed herein. Specific test sites utilized are also listed in the test results sections of this report where needed.

Table 1: Test Site List.

Description	Location	Quality Num.
OATS (3 meter)	3615 E Grand River Rd., Williamston, Michigan 48895	OATSC

1.9 Traceability and Equipment Used

Pertinent test equipment used for measurements at this facility is listed in Table 2. The quality system employed at Amber Helm Development L.C. has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to the SI through NIST, other recognized national laboratories, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards.

Table 2: Equipment List.

Description	Manufacturer/Model	SN	Quality Num.	Cal/Ver By / Date Due
Spectrum Analyzer	R & S / FPC1000	101060	RSFPC1K01	RS / Jan-2022
Spectrum Analyzer	R & S / FSW26	101873	RSFSW2601	RS / Sept-2021
Pk Pwr Telecom	Anritsu / MT8870A	6201282278	ANMT8870A	AHD / Jul-2021
Biconical	EMCO / 93110B	9802-3039	BICEMCO01	Keysight / Aug-2023
Log Periodic Antenna	EMCO / 3146	9305-3614	LOGEMCO01	Keysight / Aug-2023
Quad Ridge Horn	Singer / A6100	C35200	HQR1TO18S01	Keysight / Aug-2022
BNC-BNC Coax	WRTL / RG58/U	001	CAB001-BLACK	AHD / Oct-2021
3.5-3.5MM Coax	PhaseFlex / PhaseFlex	001	CAB015-PURP	AHD / Jul-2022
K-Band Horn	JEF / NRL Std.	001	HRNK01	AHD / Jul-2022
LISN	Solar / 8012-50-R-24-BNC	970917	LISNB	AHD / March-2022

2 Test Specifications and Procedures

2.1 Test Specification and General Procedures

The goal of Grid Connect, Inc. is to demonstrate that the Equipment Under Test (EUT) complies with the Rules and/or Directives below. Detailed in this report are the results of testing the Grid Connect, Inc. GC-ESP32-ETH for compliance to:

Country/Region	**Rules or Directive**	**Referenced Section(s)**
United States	Code of Federal Regulations	CFR Title 47, Part 15.247
Canada	ISED Canada	IC RSS-247/GENe

It has been determined that the equipment under test is subject to the rules and directives above at the date of this testing. In conjunction with these rules and directives, the following specifications and procedures are followed herein to demonstrate compliance (in whole or in part) with these regulations.

ANSI C63.4:2014	"Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz"
ANSI C63.10:2013	"American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices"
TP0102RA	"AHD Internal Document TP0102 - Radiated Emissions Test Procedure"
ISED Canada	"The Measurement of Occupied Bandwidth"
ICES-003; Issue 7 (2020)	"Information Technology Equipment (ITE) - Limits and methods of measurement"

3 Configuration and Identification of the Equipment Under Test

3.1 Description and Declarations

The EUT is wireless transceiver module. The EUT is approximately 3.4 x 2.2 x 0.3 cm in dimension, and is depicted in Figure 1. It is powered by 3.3 VDC external supply. This product is used as modular transceiver with WLAN, BLE, and Bluetooth modes. Table 3 outlines provider declared EUT specifications.

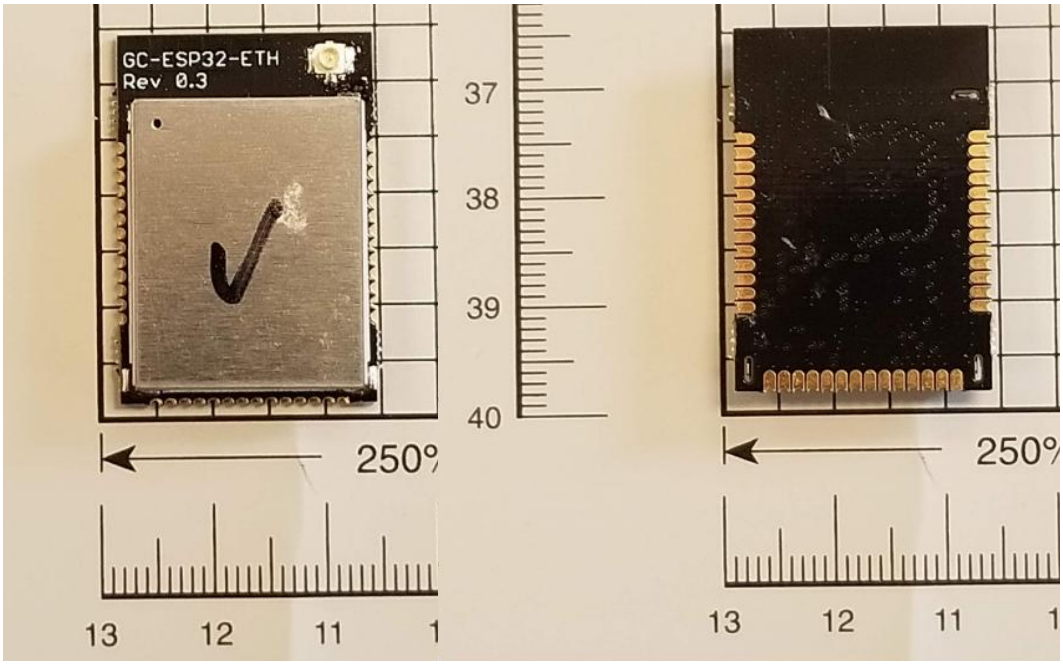


Figure 1: Photos of EUT.

Table 3: EUT Declarations.

General Declarations	
Equipment Type:	WLAN+BLE Module
Country of Origin:	Not Declared
Nominal Supply:	3.3 VDC
Oper. Temp Range:	not declared
Frequency Range:	2402 – 2480 MHz
Antenna Dimension:	Integral
Antenna Type:	Whip, Trace
Antenna Gain:	Whip(5dBi), Trace(3.8dBi) declared
Number of Channels:	40(BLE), 11(WLAN), 6(N40)
Channel Spacing:	2 MHz(BLE), 5 MHz(WLAN)
Alignment Range:	Not Declared
Type of Modulation:	GFSK, OFDM

United States	
FCC ID Number:	2AFC3ESP32P001
Classification:	DTS

Canada	
IC Number:	22503-ESP32P001
Classification:	Spread Spectrum (24002483.5 MHz)

3.1.1 EUT Configuration

The EUT is configured for testing as depicted in Figure 2.

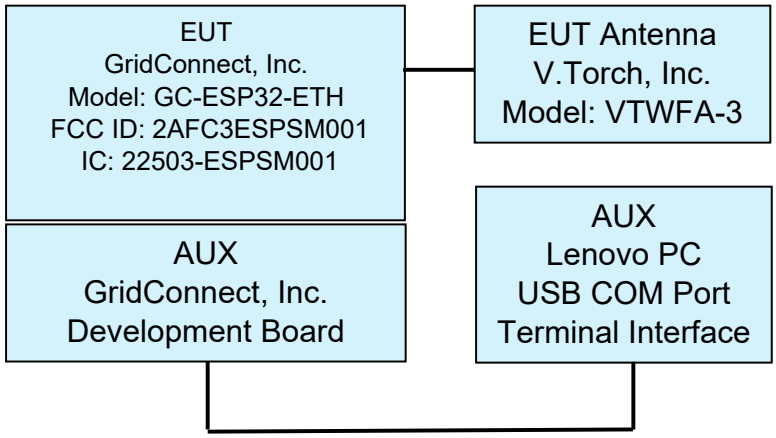


Figure 2: EUT Test Configuration Diagram.

3.1.2 Modes of Operation

The EUT is capable of operating in BLE (1Mbps) or WLAN 802.11 b, g, n(20), or n(40) SISO modes. Test samples were placed into worst-case operating states (highest data rate, highest operating power that may be employed in each mode) using a PC serial UART interface that could be attached and detached from the EUT development/interface board. The EUT could not be placed into full continuous transmission for the BLE mode, so duty cycle is measured and applied to measured data in line with DTS guidelines in that mode. The EUT was placed into full continuous transmission mode for the 802.11 b, g, n(20), n(40) modes.

3.1.3 Variants

There is only a single version of the EUT.

3.1.4 Test Samples

Two samples of the EUT were provided for emissions testing. Both sample modules were tested when mounted onto a development PCB which provided UART and dc power interface to the module.

3.1.5 Functional Exerciser

Normal functionality was confirmed by measurement of transmitted signals.

3.1.6 Modifications Made

There were no modifications made to the EUT by this laboratory. However, in order to bring the device into compliance with band edge and harmonic emissions limits, the manufacturer chose to have the power setting attenuation value on the WLAN chipset for the 802.11 n(40) mode adjusted linearly according to data rate as follows: MCS0 = 20 (5dB attenuation below max power), MCS4 = 12 (3 dB attenuation below max power) and MCS7 = 4 (1dB attenuation below max power). The manufacturer states all modules manufactured will be firmware limited with power setting levels equal to those noted herein.

3.1.7 Production Intent

The EUT appears to be a production ready sample.

3.1.8 Declared Exemptions and Additional Product Notes

The EUT is also capable of Bluetooth Classic FHSS protocols, which are addressed in a separate test report. There is only one RFIC radio populated on this product and thus only a single radio mode may be active at a given time. Testing also demonstrated that the EUT ceases to function below a voltage of 2.3V (turns off) and above a voltage of 3.6V the EUT overheats within a few seconds and is rendered inoperable.

4 Emissions

4.1 General Test Procedures

4.1.1 Radiated Test Setup and Procedures

Radiated electromagnetic emissions from the EUT are first pre-scanned in our screen room. Spectrum and modulation characteristics of all emissions are recorded. Instrumentation, including spectrum analyzers and other test equipment as detailed in Section 1.8 are employed. After pre-scan, emission measurements are made on the test site of record. If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in relevant test standards are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed if the resulting emissions appear to be worst-case in such a configuration. See Figure 3. All intentionally radiating elements that are not fixed-mounted in use are placed on the test table lying flat, on their side, and on their end (3-axes) and the resulting worst case emissions are recorded. If the EUT is fixed-mounted in use, measurements are made with the device oriented in the manner consistent with installation and then emissions are recorded. If the EUT exhibits spurious emissions due to internal receiver circuitry, such emissions are measured with an appropriate carrier signal applied.

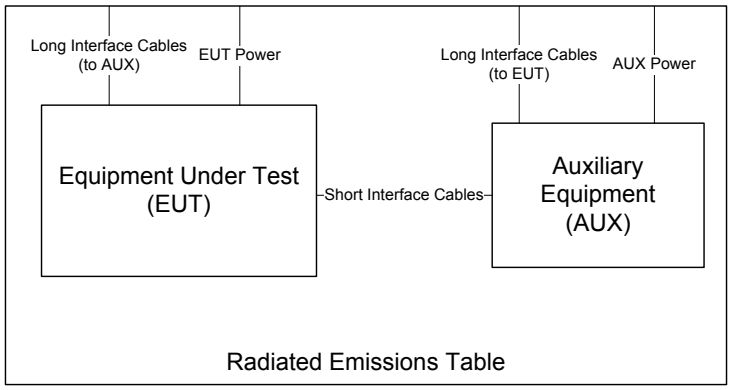


Figure 3: Radiated Emissions Diagram of the EUT.

For devices with intentional emissions below 30 MHz, a shielded loop antenna and/or E-field and H-Field broadband probes are used depending on the regulations. Shielded loops are placed at a 1 meter receive height at the desired measurement distance. For exposure in this band, the broadband probes employed are 10cm diameter single-axis shielded transducers and measurements are repeated and summed over three axes.

Emissions between 30 MHz and 1 GHz are measured using calibrated broadband antennas. For both horizontal and vertical polarizations, the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected. The EUT is then rotated through 360^o in azimuth until the highest emission is detected. The test antenna is then raised and lowered one last time from 1 to 4 m and the worst case value is recorded. Emissions above 1 GHz are characterized using standard gain or broadband ridge-horn antennas on our OATS with a 4×5 m rectangle of ECCOSORB absorber covering the OATS ground screen and a 1.5m table height. Care is taken to ensure that test receiver resolution and video bandwidths meet the regulatory requirements, and that the emission bandwidth of the EUT is not reduced. Photographs of the test setup employed are depicted in Figure 4.

Where regulations allow for direct measurement of field strength, power values (dBm) measured on the test receiver / analyzer are converted to dBμV/m at the regulatory distance, using

$$E_{dist} = 107 + P_R + K_A - K_G + K_E - C_F$$

where P_R is the power recorded on spectrum analyzer, in dBm, K_A is the test antenna factor in dB/m, K_G is the combined pre-amplifier gain and cable loss in dB, K_E is duty correction factor (when applicable) in dB, and C_F is a distance conversion (employed only if limits are specified at alternate distance) in dB. This field strength value is then compared with the regulatory limit. If effective isotropic radiated power (EIRP) is computed, it is computed as

$$EIRP(dBm) = E_{3m}(dB\mu V/m) - 95.2.$$

When presenting data at each frequency, the highest measured emission under all possible EUT orientations (3-axes) is reported.

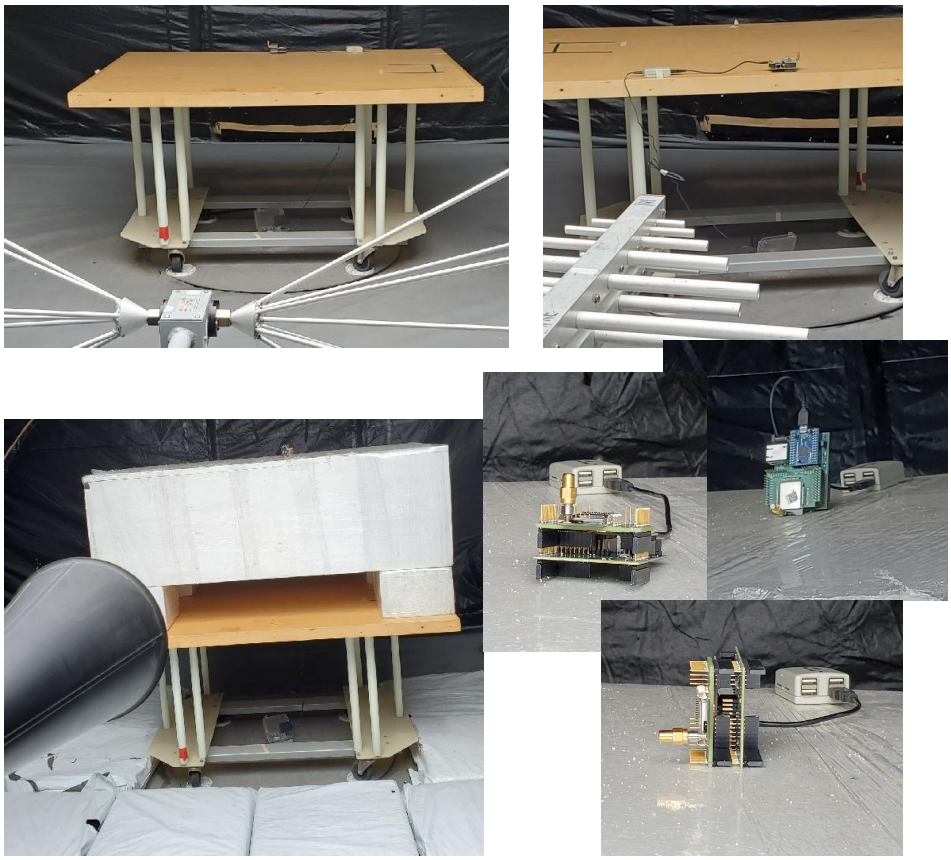


Figure 4: Radiated Emissions Test Setup Photograph(s).

4.1.2 Conducted Emissions Test Setup and Procedures

Transmit Antenna Port Conducted Emissions At least one sample EUT supplied for testing was provided with a 50Ω antenna port. Conducted transmit chain emissions measurements (where applicable) are made by connecting the EUT antenna port directly to the test receiver port. Photographs of the test setup employed are depicted in Figure 5.

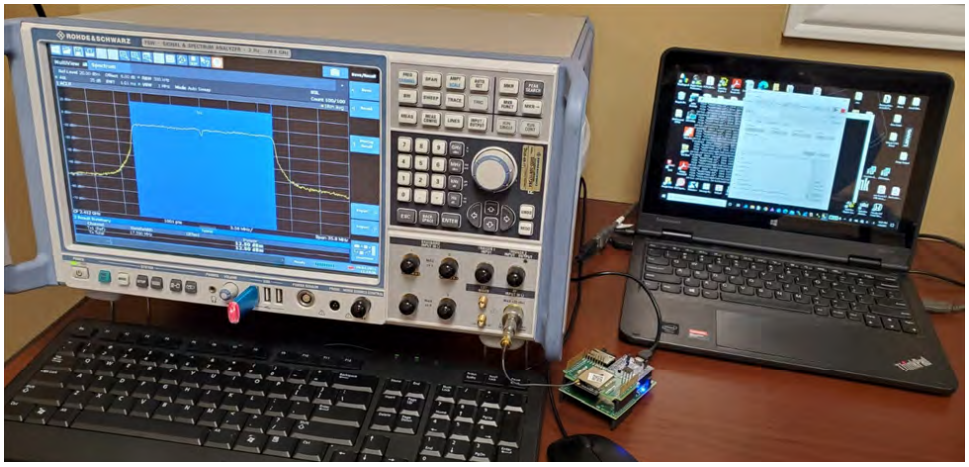


Figure 5: Conducted RF Test Setup Photograph(s).

AC Port Conducted Spurious For this device, AC power line conducted emissions are measured in our screen room. If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 / CISPR 22 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration. See Figure 6.

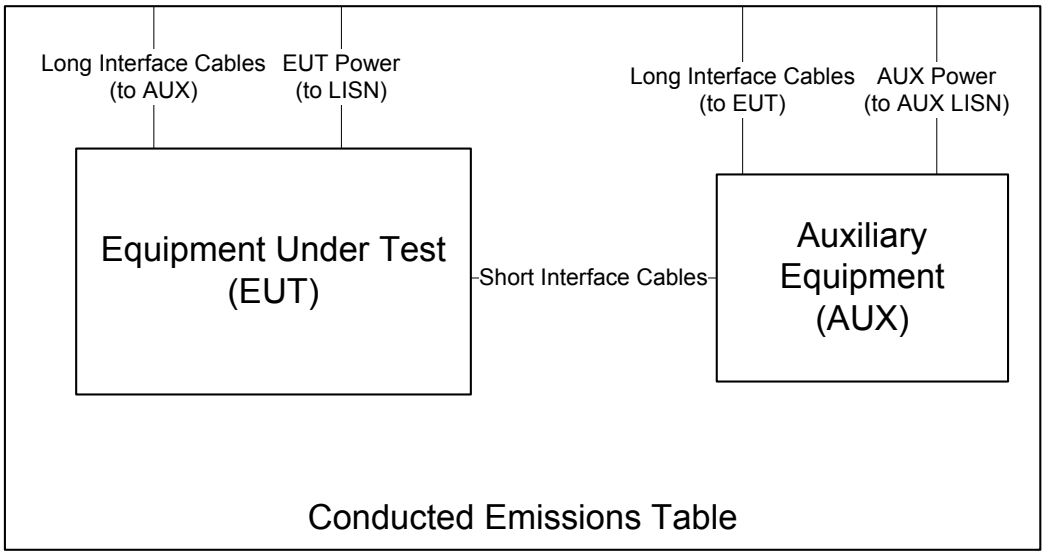


Figure 6: Conducted Emissions Setup Diagram of the EUT.

Conducted emissions are measured and recorded for each AC mains power source over the spectrum 0.15 MHz to 30 MHz for both the ungrounded (HI/PHASE) and grounded (LO/GND) conductors with the EUT placed in its highest current draw operating mode(s). The test receiver is set to peak-hold mode in order to record the peak emissions throughout the course of functional operation. Only if an emission exceeds or is near the limit are quasi-peak and average detection applied. Photographs of the test setup employed are depicted in Figure 7.

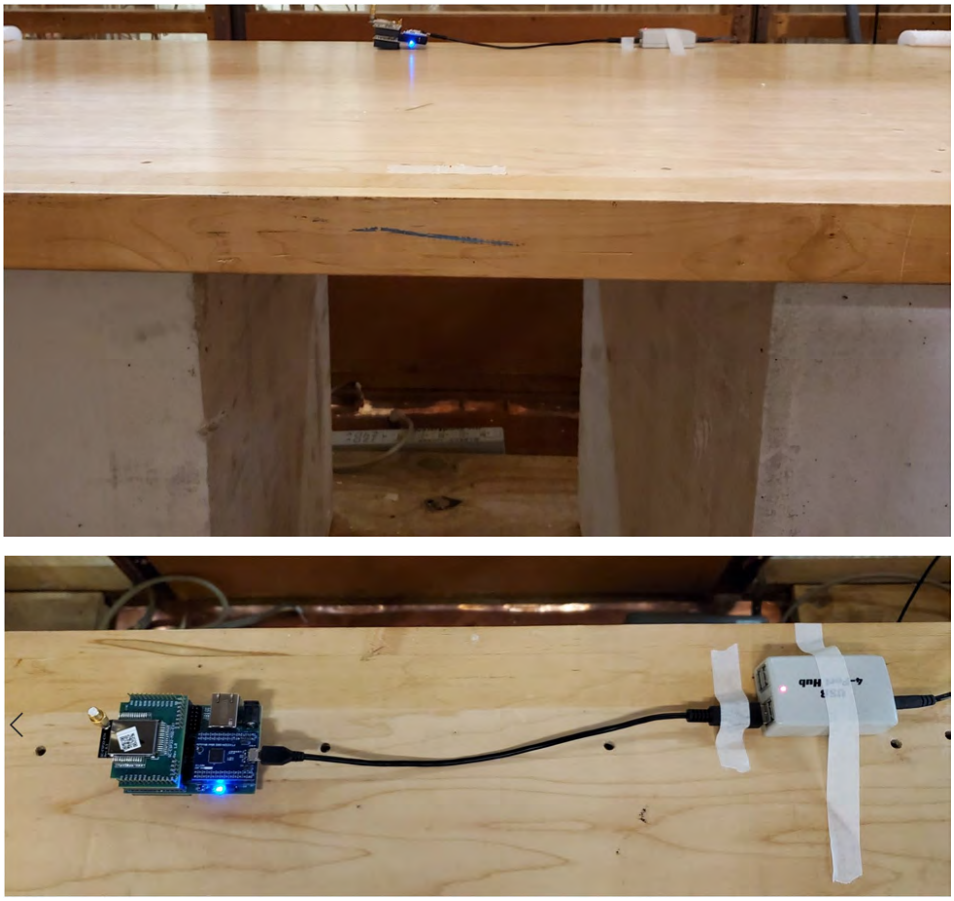


Figure 7: Conducted Emissions Test Setup Photograph(s).

4.1.3 Power Supply Variation

Tests at extreme supply voltages are made if required by the procedures specified in the test standard, and results of this testing are detailed in this report.

In the case of this EUT, measurements of the worst-case radiated emissions are performed with the supply voltage varied by no less than 85% and 115% of the nominal rated value for devices connecting to AC power mains.

4.2 Intentional Emissions

4.2.1 Duty and Transmission Cycle, Pulsed Operation

The details and results of testing the EUT for pulsed operation are summarized in Table 4. Plots showing the measurements made to obtain these values are provided in Figure 8.

Table 4: Pulsed Emission Characteristics (Duty Cycle).

Test Date: 23-Apr-21
Test Engineer: Joseph Brunett
EUT GridConnect ESP32-ETH
Meas. Distance: Conducted

	Test Mode Pulsed Operation / Average Measurement Duty Cycle							
#	Mode	Data Rate Mbps	Voltage V	Oper. Freq MHz	Pulse Length	Pulse Period	Duty Cycle %	Power Duty Correction dB
R1	BLE	1.0	3.3	2440.0	8.4	10.6	79.1	-1.0
R2	802.11b	11.0	3.3	2437.0	1.0	1.0	100.0	0.0
R3	802.11g	54.0	3.3	2437.0	1.0	1.0	100.0	0.0
R4	802.11n(20)	65.0	3.3	2437.0	1.0	1.0	100.0	0.0
R5	802.11n(40)	135.0	3.3	2437.0	1.0	1.0	100.0	0.0
R6								
R7	NOTE: SUPPLY VOLTAGE TO THE EUT WAS VARIED FROM 2 V TO 4 V DC. BELOW 2.6 VDC THE EUT DID NOT OPERATE. ABOVE							
R8	3.6 VDC THE EUT OVERHEATED AND STOPED OPERATING. WORST CASE EMISSIONS OBSERVED AT NOMINAL 3.3 VDC.							
#	C1	C3	C4	C5	C6	C7	C8	C9

* Duty Cycle is measured in line with DTS guidance 558074 D01 v5 r02 section 6(b) for averaging only over full-power transmission pulses.

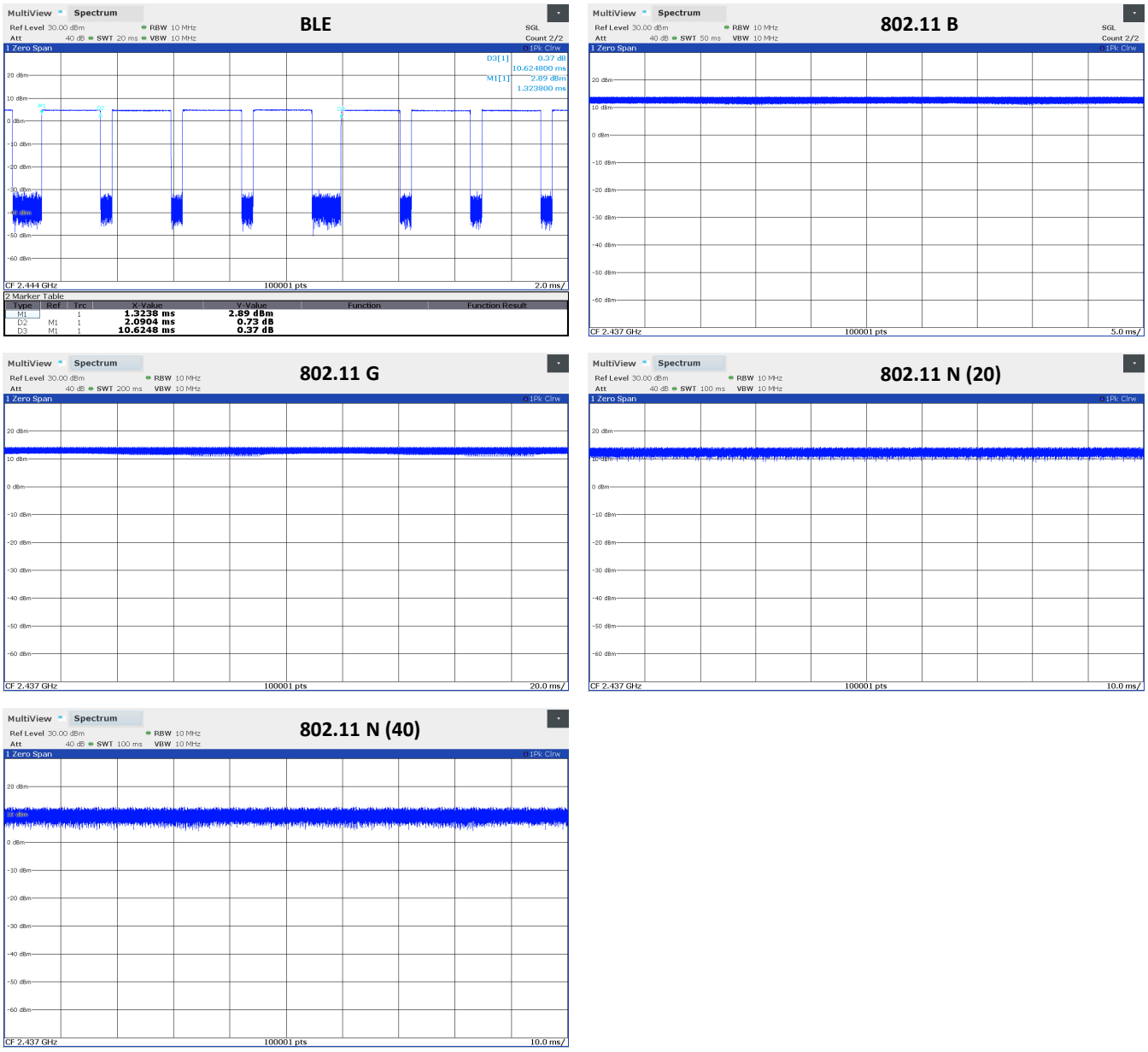


Figure 8: Pulsed Emission Characteristics (Duty Cycle).

4.2.2 Fundamental Emission Bandwidth

Emission bandwidth (EBW) of the EUT is measured with the device placed in the test mode(s) with the shortest available packet length and minimum packet spacing. Radiated emissions are recorded following the test procedures listed in Section 2.1. The 6 dB bandwidth is measured for the lowest, middle, and highest channels available. The 99% emission bandwidth per IC test procedures is also reported. The results of this testing are summarized in Table 5. Plots showing measurements employed obtain the emission bandwidths reported are provided in Figure 9.

Table 5: Intentional Emission Bandwidth.

Test Date: 04/23/2021, 10/08/2021
Test Engineer: Joseph Brunett
EUT GridConnect ESP32-ETH
Meas. Distance: Conducted

				Occupied Bandwidth					
#	Transmit Mode	Data Rate (Mbps)	Voltage (V)	Oper. Freq (MHz)	6 dB BW (MHz)	6 dB BW Limit (MHz)	99% OBW (MHz)	20 dB BW (MHz)	Pass/Fail
R1	BLE	1.0	3.3	2402.0	0.723	0.50	1.17	1.04	Pass
R2				2440.0	0.723	0.50	1.17	1.04	Pass
R3				2480.0	0.723	0.50	1.17	1.05	Pass
R4	802.11b	11.0	3.3	2412.0	9.43	0.50	15.64	13.35	Pass
R5				2437.0	9.73	0.50	15.5	13.15	Pass
R6				2462.0	8.75	0.50	15.47	13.15	Pass
R7	802.11g	54.0	3.3	2412.0	16.68	0.50	18.17	16.64	Pass
R8				2437.0	16.68	0.50	18.17	16.64	Pass
R9				2462.0	16.68	0.50	18.2	16.63	Pass
R10	802.11n(20)	65.0	3.3	2412.0	17.88	0.50	18.95	17.6	Pass
R11				2437.0	17.88	0.50	19	17.61	Pass
R12				2462.0	17.88	0.50	19	17.6	Pass
R13	802.11n(40)	135.0	3.3	2412.0	36.56	0.50	39.8	36.44	Pass
R14				2437.0	36.52	0.50	39.78	36.43	Pass
R15				2462.0	36.51	0.50	39.79	36.42	Pass
#	C1	C2	C3	C4	C5	C6	C7	C8	C9

ROW (R1-R15) COLUMN (C5) NOTE DTS Bandwidth measured with RBW = 100 kHz per ANSI C63.10 11.8.1

BLE (1Mbps) 802.11 B

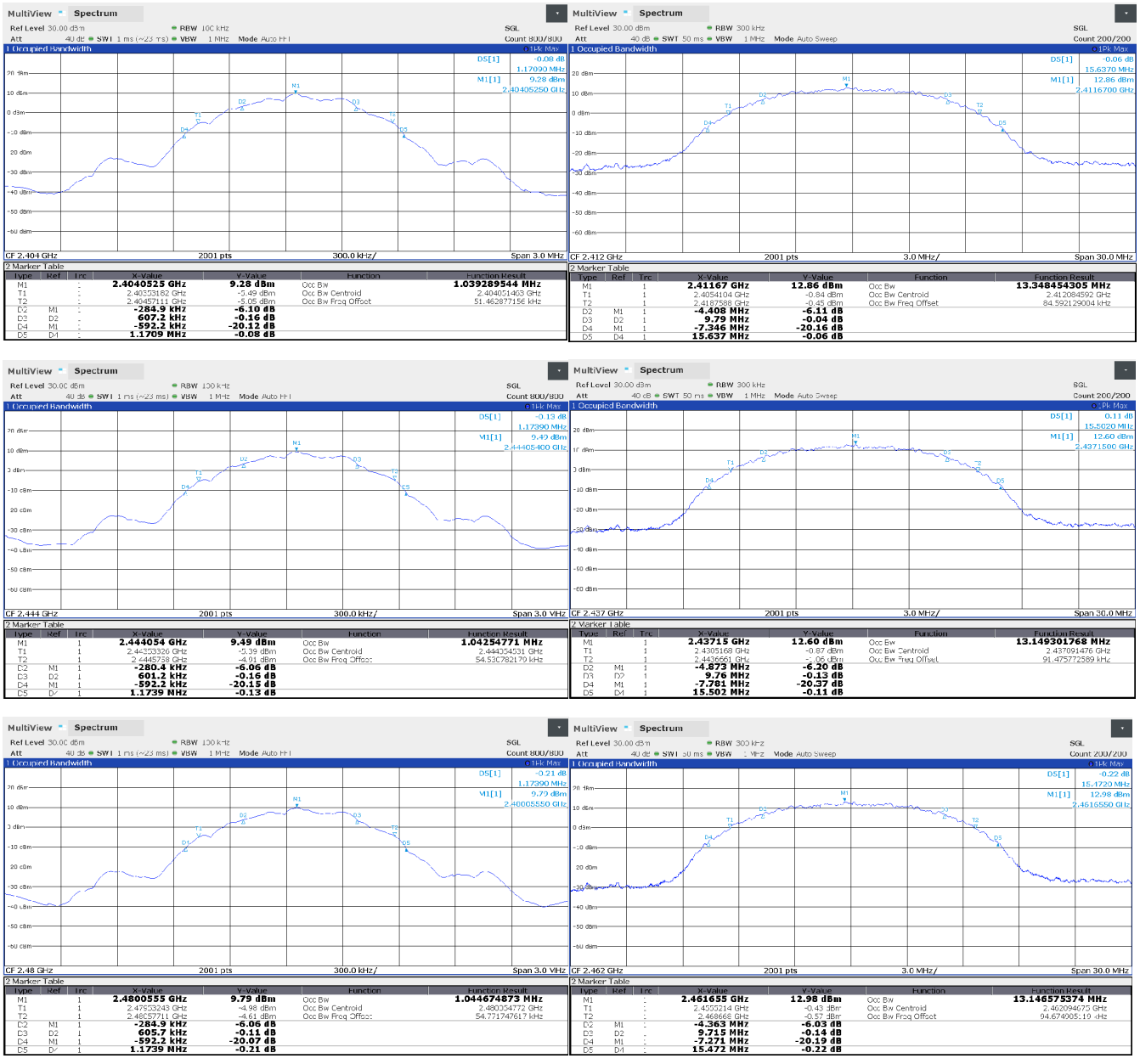


Figure 9(a): Intentional Emission Bandwidth.

802.11 G 802.11 N (20)

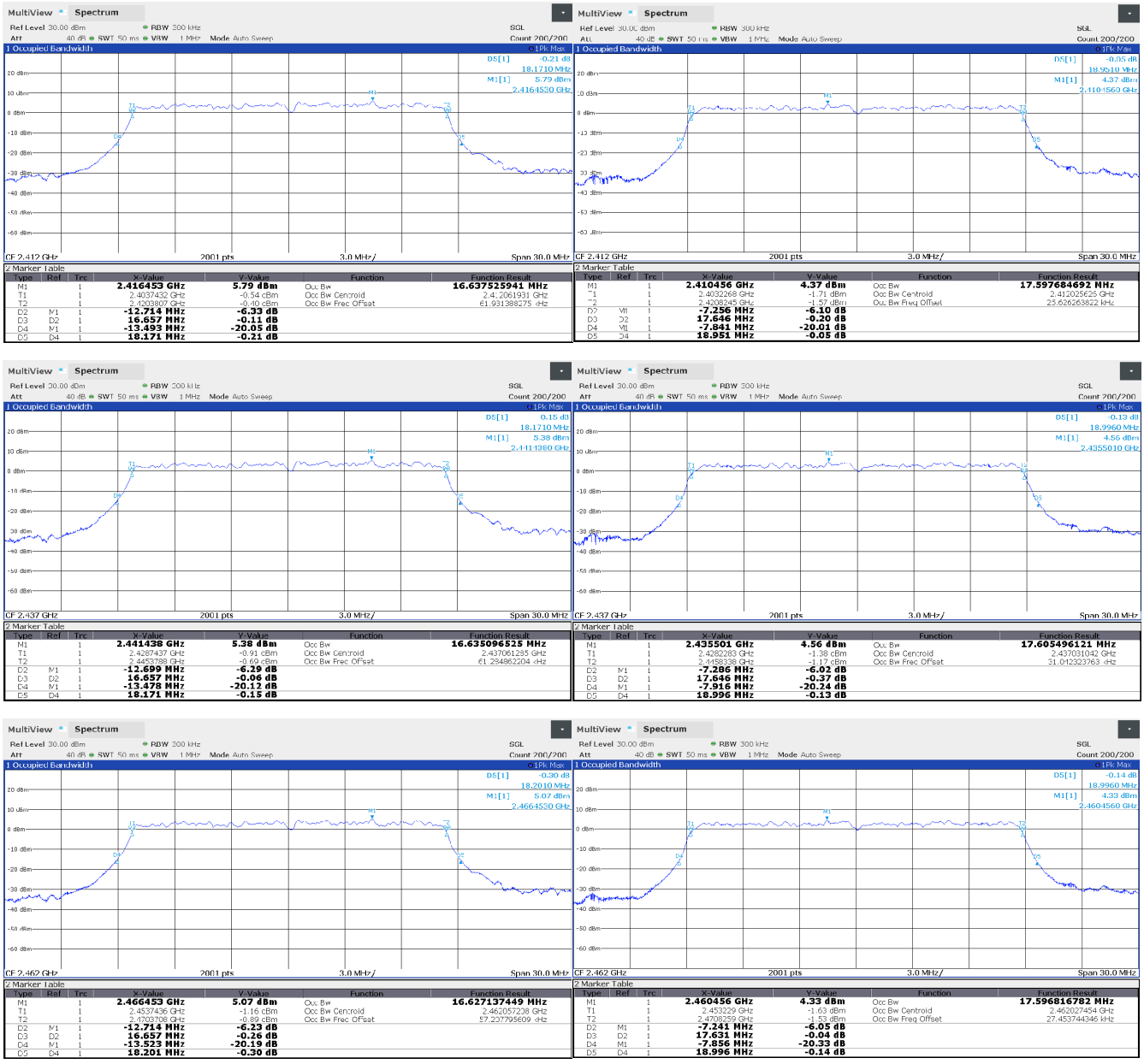
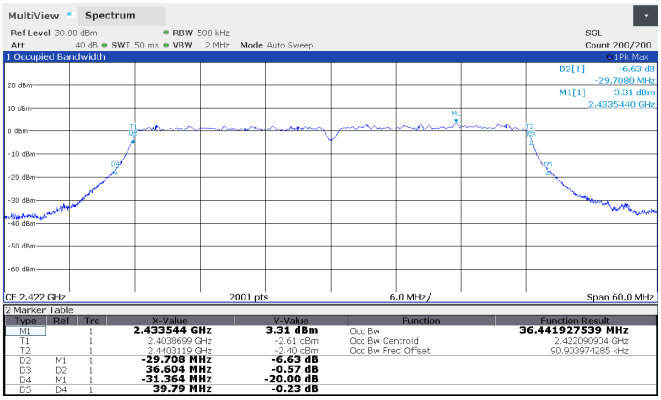
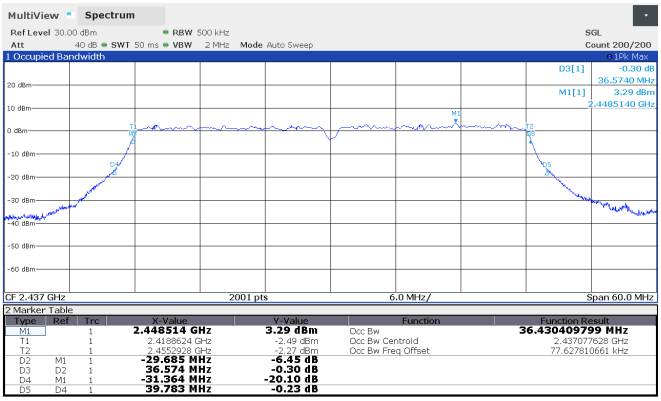


Figure 9(b): Intentional Emission Bandwidth.

802.11 N (40)





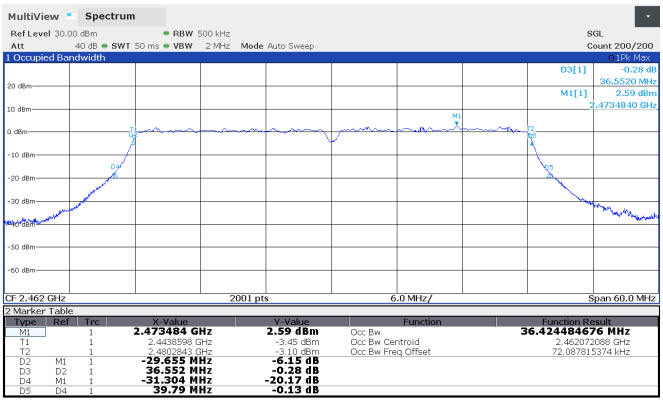


Figure 9(c): Intentional Emission Bandwidth.

BLE (1Mbps) 802.11 B

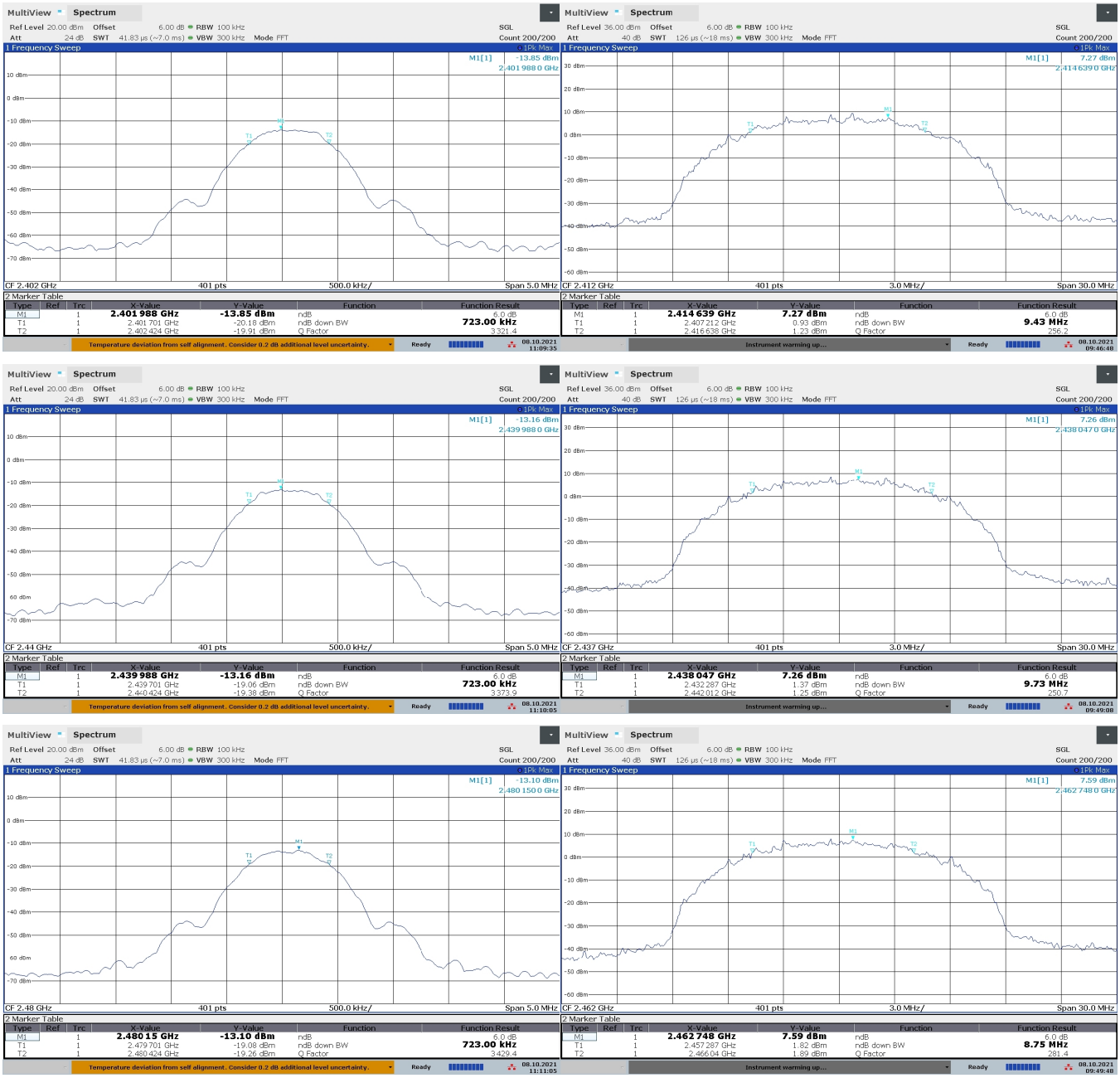


Figure 9(d): Intentional Emission Bandwidth.

802.11 G 802.11 N (20)

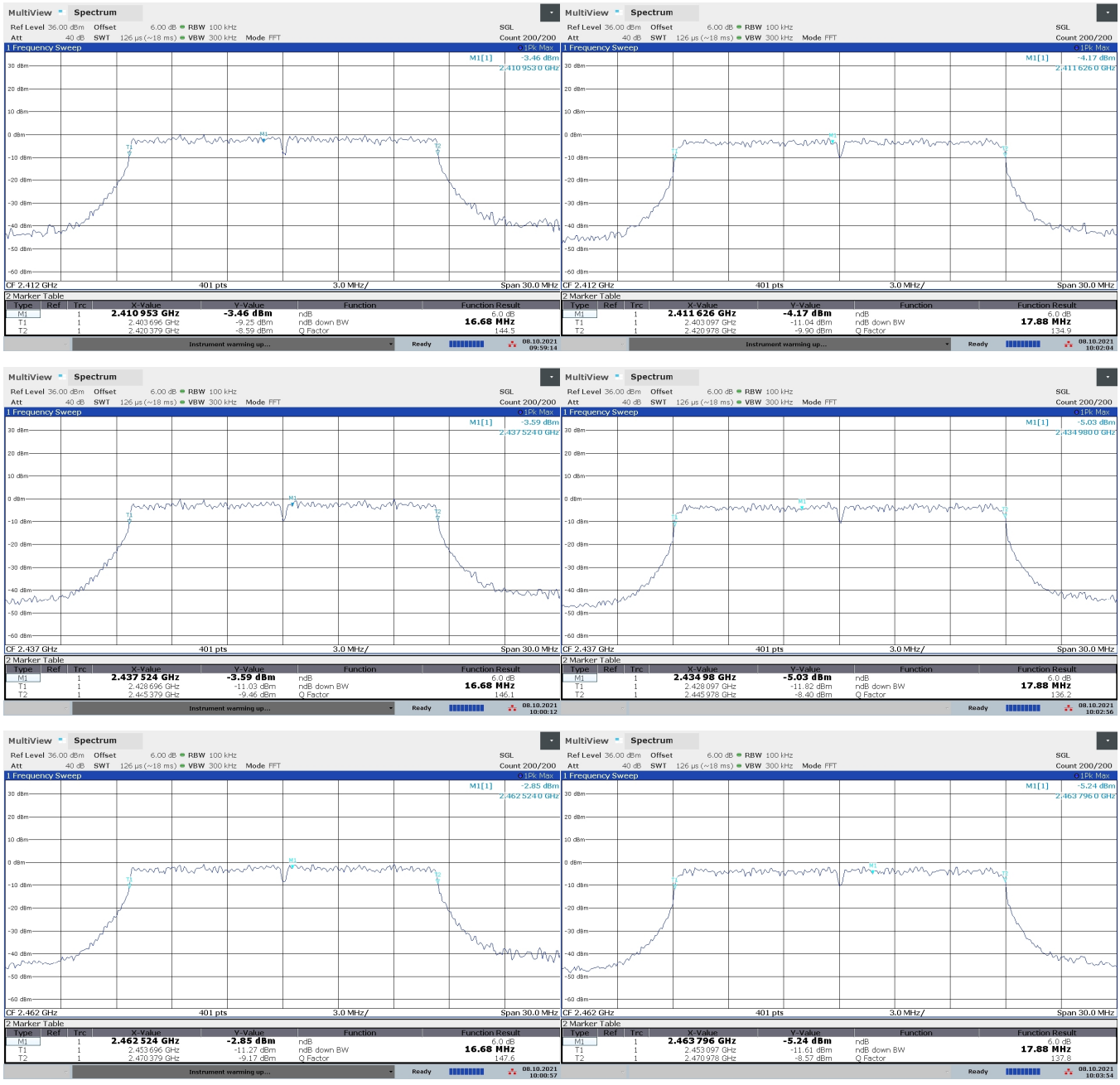


Figure 9(e): Intentional Emission Bandwidth.

802.11 N (40)

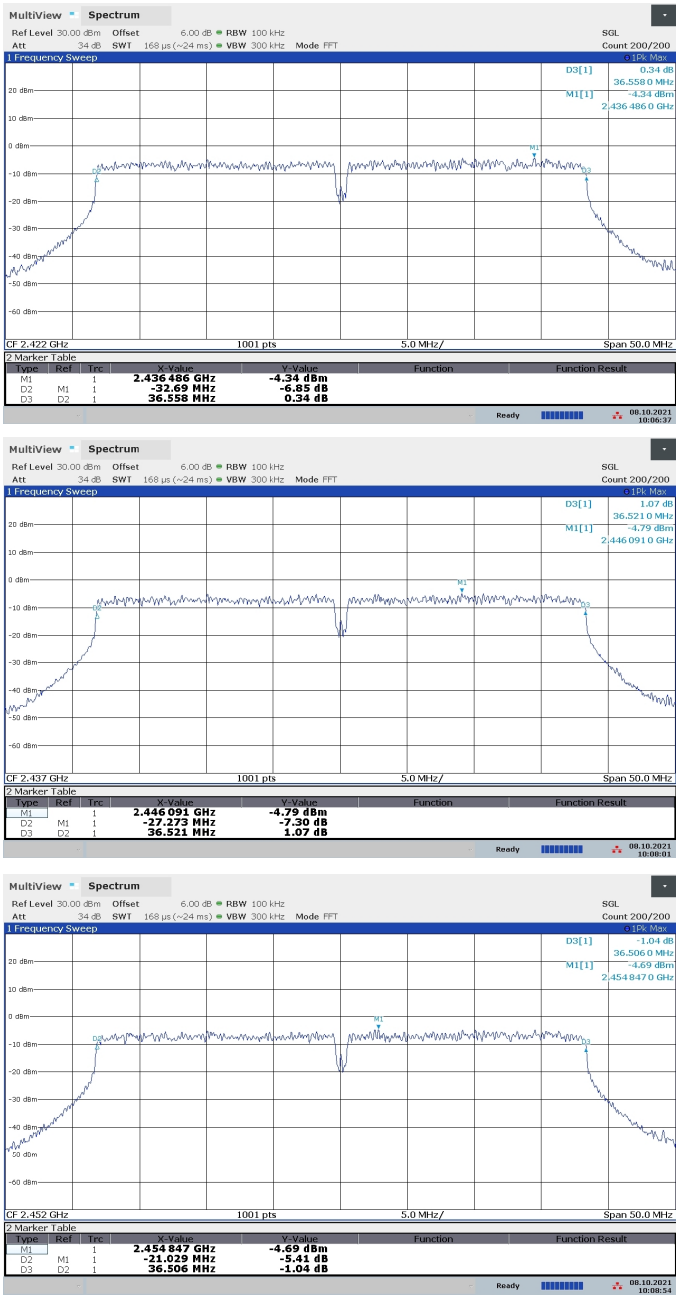


Figure 9(f): Intentional Emission Bandwidth.

4.2.3 Effective Isotropic Radiated Power

The EUT's radiated power is computed from antenna port conducted power measurements and the gain of the EUT antenna(s). Where the EUT is not sold with an antenna connector, a modified product has been provided including such. The results of this testing are summarized in Table 6.

Table 6: Radiated Power Results.

Test Date: 23-Apr-21
Test Engineer: J. Brunett
EUT: Err:501
Meas. Distance: Conducted

	Fundamental Power										
#	Mode	Channel	Freq. MHz	Pout (Avg) dBm	Duty dB	Pout + Duty dBm	Ant Gain*** dBi	EIRP (Avg) dBm	EIRP (Avg) Limit dBm	Pass dB	Comments
R1	BLE (1MBPS)*		2402.0	9.2	1.0	10.2	5.0	15.2	36.0	20.8	
R2		19	2440.0	9.1	1.0	10.1	5.0	15.1	36.0	20.9	
R3		39	2480.0	**9.3**	1.0	10.3	5.0	15.3	36.0	20.7	
R4	802.11B*	1	2412.0	18.4		18.4	5.0	23.4	36.0	12.6	
R5		6	2437.0	18.4		18.4	5.0	23.4	36.0	12.6	
R6		11	2462.0	**18.5**		18.5	5.0	23.5	36.0	**12.5**	
R7	802.11G*	1	2412.0	17.5		17.5	5.0	22.5	36.0	13.6	
R8		6	2437.0	17.6		17.6	5.0	22.6	36.0	13.4	
R9		11	2462.0	**17.8**		17.8	5.0	22.8	36.0	13.2	
R10	802.11N(20)*	1	2412.0	17.9		17.9	5.0	22.9	36.0	13.1	
R11		6	2437.0	17.8		17.8	5.0	22.8	36.0	13.2	
R12		11	2462.0	**17.9**		17.9	5.0	22.9	36.0	13.1	
R13	802.11N(40)**	3	2422.0	**9.1**		9.1	5.0	14.1	36.0	21.9	
R14		6	2437.0	6.4		6.4	5.0	11.4	36.0	24.6	
R15		9	2452.0	8.4		8.4	5.0	13.4	36.0	22.6	
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11

* Measured conducted from the radio using conducted test sample. Avg Power measured following DTS Guidance 558074 D01 v5 r02 Section 8.3.2.2 (AVGSA-1)
** Measured conducted from the radio using conducted test sample. Pk Power measured following DTS Guidance 558074 D01 v5 r02 Section 8.3.1.3 (PKPM1)
*** Worst Case Antenna Gain as declared by Manufacturer (antenna data sheet)

4.2.4 Power Spectral Density

For this test, the EUT was attached directly to the test receiver. Following FCC DTS measurement procedures, the emission spectrum is first scanned for maximum spectral peaks, the span and receiver bandwidth are then reduced until the power spectral density is measured in the prescribed receiver bandwidth. The results of this testing are summarized in Table 7. Plots showing how these measurements were made are depicted in Figure 10.

Table 7: Power Spectral Density Results.

Frequency Range	**Detector**	**IF Bandwidth**	**Video Bandwidth**	**Test Date:**	20-Apr-21
2400-2483.5	Pk	3 kHz	10 kHz	**Test Engineer:**	Joseph Brunett
				EUT:	GridConnect ESP32
				Meas. Distance:	Conducted

3kHz Power Spectral Density							
#	Mode	Channel	Frequency (MHz)	Ant. Used	PSDcond (meas)* (dBm/3kHz)	PSD Limit (dBm/3kHz)	Pass By (dB)
R1	BLE		2402.0	Cond.	-6.4	8.00	14.4
R2		19	2440.0	Cond.	-6.4	8.00	14.4
R3		39	2480.0	Cond.	-6	8.00	14.0
R4	802.11b	1	2412.0	Cond.	-5.3	8.00	13.3
R5		6	2437.0	Cond.	-4.9	8.00	12.9
R6		11	2462.0	Cond.	-4.7	8.00	**12.7**
R7	802.11g	1	2412.0	Cond.	-10.7	8.00	18.7
R8		6	2437.0	Cond.	-10.4	8.00	18.4
R9		11	2462.0	Cond.	-10.9	8.00	18.9
R10	802.11n(20)	1	2412.0	Cond.	-10.2	8.00	18.2
R11		6	2437.0	Cond.	-10.7	8.00	18.7
R12		11	2462.0	Cond.	-11.1	8.00	19.1
R13	802.11n(40)	3	2422.0	Cond.	-12.5	8.00	20.5
R14		6	2437.0	Cond.	-12.7	8.00	20.7
R15		9	2452.0	Cond.	-13	8.00	21.0
#	C1	C2	C3	C4	C5	C6	C7

* PSD measured conducted out the EUT antenna port following ANSI C63.10 11.10.2

BLE (1Mbps) 802.11 B

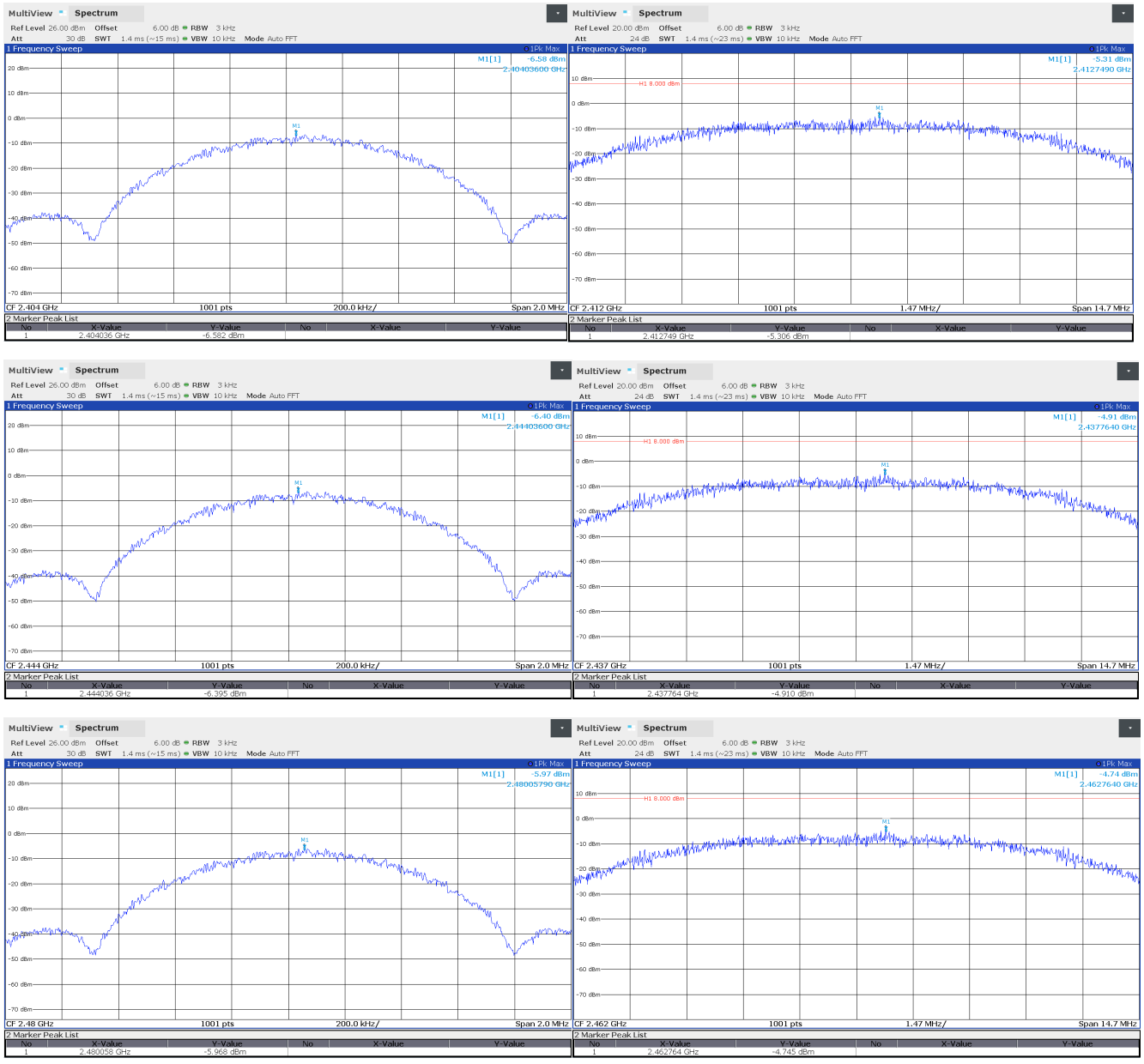


Figure 10(a): Power Spectral Density Plots.

802.11 G 802.11 N (20)

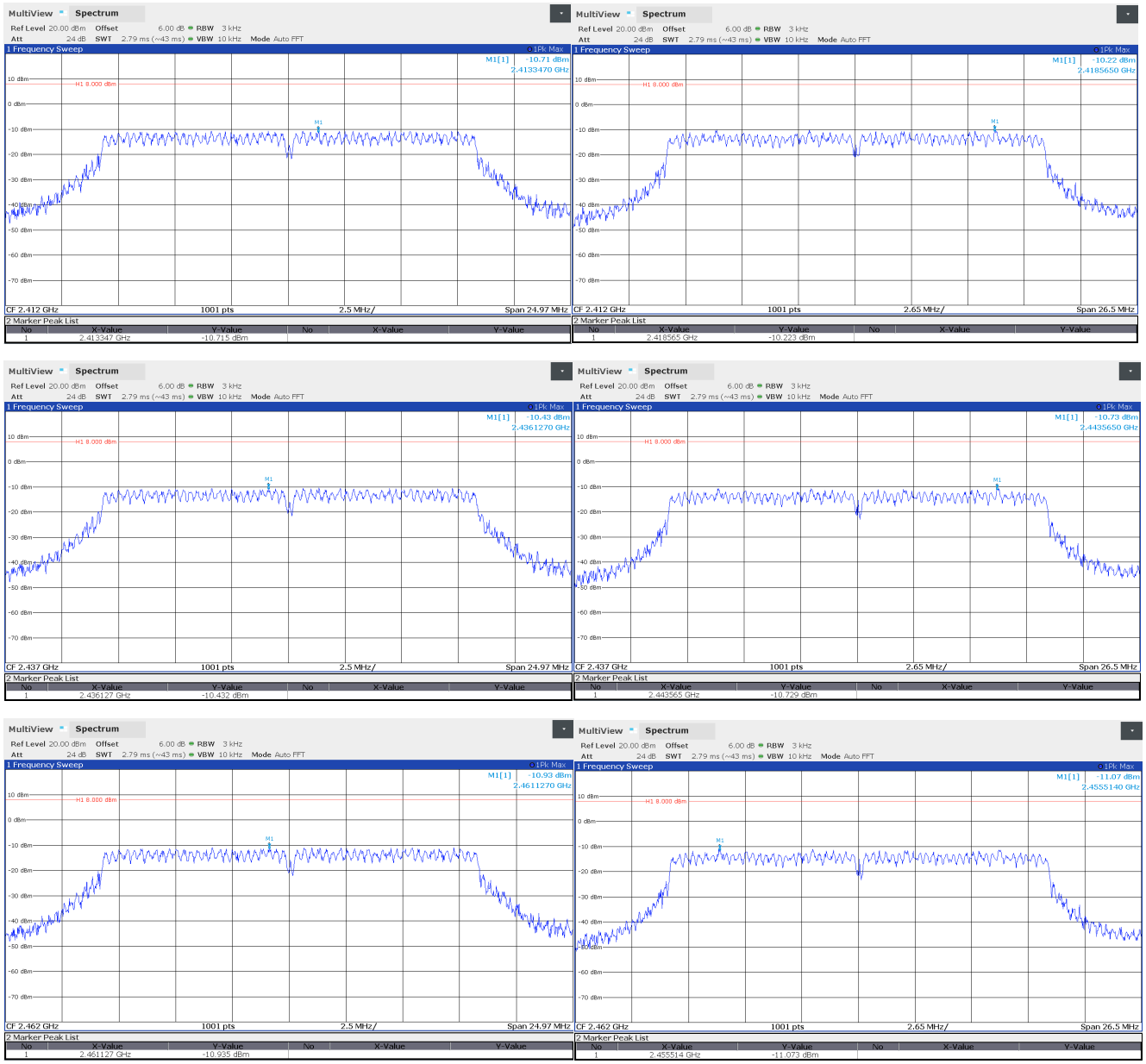


Figure 10(b): Power Spectral Density Plots.

802.11 N (40)

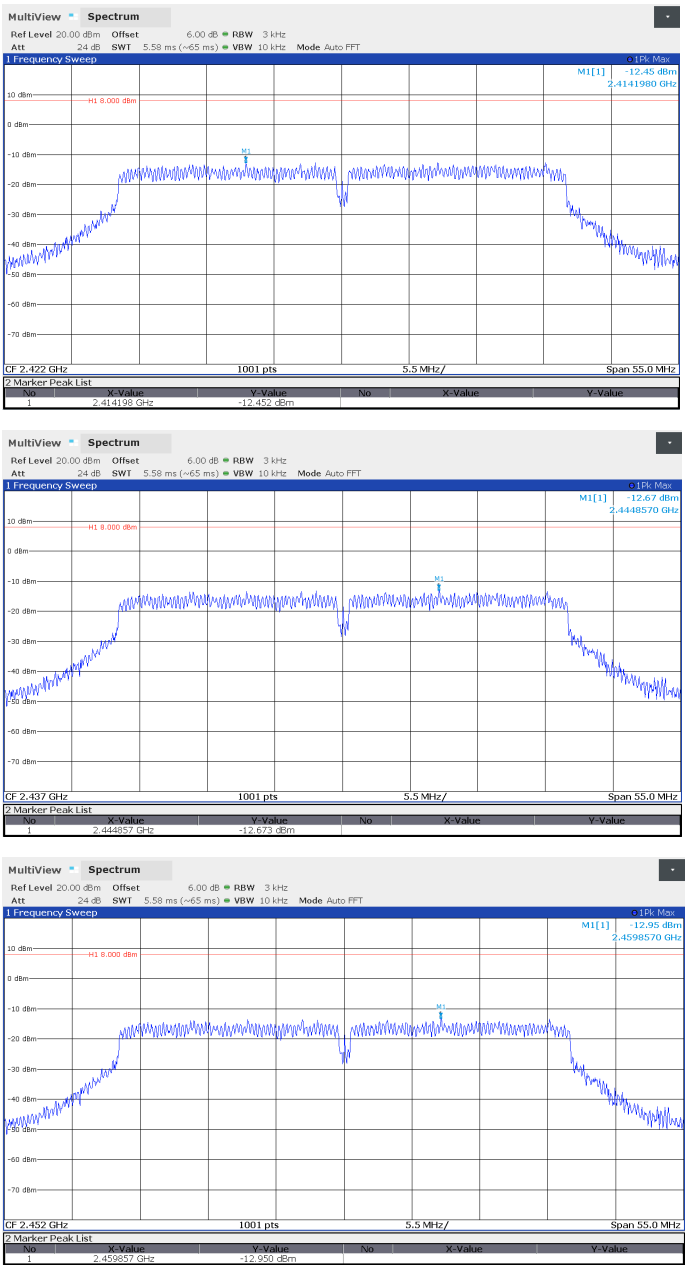


Figure 10(c): Power Spectral Density Plots.

4.3 Unintentional Emissions

4.3.1 Transmit Chain Radiated Spurious Emissions

The results for the measurement of transmit chain spurious emissions at the nominal voltage and temperature are provided in Table 8. Measurements are performed to 10 times the highest fundamental operating frequency.

Table 8(a): Transmit Chain Spurious Emissions.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
f > 1 000 MHz	Pk/Avg	1 MHz	3 MHz	**Test Date:**	12-Apr-21
				Test Engineer:	J. Brunett
				EUT:	GridConnect ESP32
				Meas. Distance:	Conducted

Transmitter Spurious														FCC/IC
		Frequency		Output Power		Ant	***GR Factor	Avg Duty	Electric Field @ 3m				Pass	
	Mode	Start	Stop	Pk	Avg	Gain		Factor	Meas. Pk	Limit Pk	Meas. Avg	Limit Avg		
#		MHz	MHz	dBm	dBm	dBi	dB	dB	dBuV/m	dBuV/m	dBuV/m	dBuV/m	dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)													
R2	BLE	2390.0	2390.0	-47.4	-58.3	5.0	0.0	1.0	52.8	74.0	43.0	54.0	11.0	max all - L,M,H channels
R3	Fundamental Restricted Band Edge (High Side)													
R4	BLE	2483.5	2483.5	-46.6	-55.7	5.0	0.0	1.0	53.6	74.0	45.6	54.0	8.4	max all - L,M,H channels
R5	Restricted Bands Emissions													
R6	BLE	30	88	-67.9		5.0	6.0	0.0	38.3			40	**1.7**	
R7	BLE	88	216	-69.5		5.0	6.0	0.0	36.7			43	6.3	
R8	BLE	216	1000	-75.3		5.0	6.0	0.0	30.9			46	15.1	
R9	BLE	4804.0	4804.0	-48.2	-58.9	5.0	0.0	1.0	52.0	74.0	42.4	54.0	11.6	CH Low channel or noise
R10	BLE	4888.0	4888.0	-48.0	-59.1	5.0	0.0	1.0	52.2	74.0	42.1	54.0	11.9	CH Med channel or noise
R11	BLE	4960.0	4960.0	-46.6	-56.5	5.0	0.0	1.0	53.6	74.0	44.8	54.0	9.2	CH High channel or noise
R12	BLE	4000.0	6000.0	-46.6	-56.5	5.0	0.0	1.0	53.6	74.0	44.8	54.0	9.2	max L,M,H channels or noise
R13	BLE	6000.0	8400.0	-65.4	-75.1	5.0	0.0	1.0	34.8	74.0	26.2	54.0	27.8	max L,M,H channels or noise
R14	BLE	8400.0	12500.0	-66.9	-76.9	5.0	0.0	1.0	33.3	74.0	24.4	54.0	29.6	max L,M,H channels or noise
R15	BLE	12500.0	26000.0	-58.3	-68.3	5.0	0.0	1.0	41.9	74.0	33.0	54.0	21.0	max L,M,H channels or noise
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14

* Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6 and 8.7 respectively.

** Measured according to ANSI C63-10-2013 section 6.10.5.2

*** Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)

*** Computed according to ANSI C63.10-2013 section 11.12.2.2 (e)

Table 8(b): Transmit Chain Spurious Emissions.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
f > 1 000 MHz	Pk/Avg	1 MHz	3 MHz	**Test Date:**	12-Apr-21
				Test Engineer:	J. Brunett
				EUT:	GridConnect ESP32
				Meas. Distance:	Conducted

Transmitter Spurious														FCC/IC
		Frequency		Output Power		Ant	***GR Factor	Avg Duty	Electric Field @ 3m				Pass	
	Mode	Start	Stop	Pk	Avg	Gain		Factor	Meas. Pk	Limit Pk	Meas. Avg	Limit Avg		
#		MHz	MHz	dBm	dBm	dBi	dB	dB	dBuV/m	dBuV/m	dBuV/m	dBuV/m	dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)													
R2	802.11B	2390.0	2390.0	-40.5	-51.0	5.0	0.0	0.0	59.7	74.0	49.3	54.0	4.7	max all - L,M,H channels
R3	Fundamental Restricted Band Edge (High Side)													
R4	802.11B	2483.5	2483.5	-44.0	-53.2	5.0	0.0	0.0	56.2	74.0	47.1	54.0	6.9	max all - L,M,H channels
R5	Restricted Bands Emissions													
R6	802.11B	30	88	-73.8		5.0	6.0	0.0	32.4			40	7.6	
R7	802.11B	88	216	-68.6		5.0	6.0	0.0	37.6			43	5.4	
R8	802.11B	216	1000	-77		5.0	6.0	0.0	29.2			46	16.8	
R9	802.11B	4824.0	4824.0	-46.9	-53.9	5.0	0.0	0.0	53.3	74.0	46.4	54.0	7.6	CH Low channel or noise
R10	802.11B	4874.0	4874.0	-48.3	-57.4	5.0	0.0	0.0	51.9	74.0	42.8	54.0	11.2	CH Med channel or noise
R11	802.11B	4924.0	4924.0	-47.2	-57.4	5.0	0.0	0.0	53.0	74.0	42.8	54.0	11.2	CH High channel or noise
R12	802.11B	4000.0	6000.0	-46.9	-53.9	5.0	0.0	0.0	53.3	74.0	46.4	54.0	7.6	max L,M,H channels or noise
R13	802.11B	6000.0	8400.0	-55.0	-66.0	5.0	0.0	0.0	45.3	74.0	34.3	54.0	19.7	max L,M,H channels or noise
R14	802.11B	8400.0	12500.0	-59.1	-69.4	5.0	0.0	0.0	41.1	74.0	30.9	54.0	23.1	max L,M,H channels or noise
R15	802.11B	12500.0	26000.0	-55.2	-65.2	5.0	0.0	0.0	45.0	74.0	35.1	54.0	18.9	max L,M,H channels or noise
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14

* Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6 and 8.7 respectively.

** Measured according to ANSI C63-10-2013 section 6.10.5.2

*** Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)

*** Computed according to ANSI C63.10-2013 section 11.12.2.2 (e)

Table 8(c): Transmit Chain Spurious Emissions.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
f > 1 000 MHz	Pk/Avg	1 MHz	3 MHz	**Test Date:**	12-Apr-21
				Test Engineer:	J. Brunett
				EUT:	GridConnect ESP32
				Meas. Distance:	Conducted

Transmitter Spurious														FCC/IC
		Frequency		Output Power		Ant	***GR Factor	Avg Duty	Electric Field @ 3m				Pass	
	Mode	Start	Stop	Pk	Avg	Gain		Factor	Meas. Pk	Limit Pk	Meas. Avg	Limit Avg		
#		MHz	MHz	dBm	dBm	dBi	dB	dB	dBuV/m	dBuV/m	dBuV/m	dBuV/m	dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)													
R2	802.11G	2390.0	2390.0	-34.6	-50.4	5.0	0.0	0.0	65.6	74.0	49.9	54.0	4.1	max all - L,M,H channels
R3	Fundamental Restricted Band Edge (High Side)													
R4	802.11G	2483.5	2483.5	-36.7	-49.0	5.0	0.0	0.0	63.5	74.0	51.3	54.0	2.7	max all - L,M,H channels
R5	Restricted Bands Emissions													
R6	802.11G	30	88	-73.8		5.0	6.0	0.0	32.4			40	7.6	
R7	802.11G	88	216	-68.6		5.0	6.0	0.0	37.6			43	5.4	
R8	802.11G	216	1000	-77		5.0	6.0	0.0	29.2			46	16.8	
R9	802.11G	4824.0	4824.0	-49.1	-58.8	5.0	0.0	0.0	51.1	74.0	41.5	54.0	12.5	CH Low channel or noise
R10	802.11G	4874.0	4874.0	-47.1	-59.1	5.0	0.0	0.0	53.1	74.0	41.2	54.0	12.8	CH Med channel or noise
R11	802.11G	4924.0	4924.0	-47.9	-52.4	5.0	0.0	0.0	52.3	74.0	47.9	54.0	6.1	CH High channel or noise
R12	802.11G	4000.0	6000.0	-47.1	-52.4	5.0	0.0	0.0	53.1	74.0	47.9	54.0	6.1	max L,M,H channels or noise
R13	802.11G	6000.0	8400.0	-55.3	-66.4	5.0	0.0	0.0	44.9	74.0	33.9	54.0	20.1	max L,M,H channels or noise
R14	802.11G	8400.0	12500.0	-53.4	-64.1	5.0	0.0	0.0	46.8	74.0	36.1	54.0	17.9	max L,M,H channels or noise
R15	802.11G	12500.0	26000.0	-55.2	-65.2	5.0	0.0	0.0	45.0	74.0	35.1	54.0	18.9	max L,M,H channels or noise
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14

* Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6 and 8.7 respectively.

** Measured according to ANSI C63-10-2013 section 6.10.5.2

*** Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)

*** Computed according to ANSI C63.10-2013 section 11.12.2.2 (e)

Table 8(d): Transmit Chain Spurious Emissions.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
f > 1 000 MHz	Pk/Avg	1 MHz	3 MHz	**Test Date:**	12-Apr-21
				Test Engineer:	J. Brunett
				EUT:	GridConnect ESP32
				Meas. Distance:	Conducted

Transmitter Spurious														FCC/IC
		Frequency		Output Power		Ant	***GR Factor	Avg Duty	Electric Field @ 3m				Pass	
	Mode	Start	Stop	Pk	Avg	Gain		Factor	Meas. Pk	Limit Pk	Meas. Avg	Limit Avg		
#		MHz	MHz	dBm	dBm	dBi	dB	dB	dBuV/m	dBuV/m	dBuV/m	dBuV/m	dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)													
R2	802.11N20	2390.0	2390.0	-40.0	-51.2	5.0	0.0	0.0	60.2	74.0	49.1	54.0	4.9	max all - L,M,H channels
R3	Fundamental Restricted Band Edge (High Side)													
R4	802.11N20	2483.5	2483.5	-33.6	-49.2	5.0	0.0	0.0	66.6	74.0	51.1	54.0	2.9	max all - L,M,H channels
R5	Restricted Bands Emissions													
R6	802.11N20	30	88	-73.8		5.0	6.0	0.0	32.4			40	7.6	
R7	802.11N20	88	216	-68.6		5.0	6.0	0.0	37.6			43	5.4	
R8	802.11N20	216	1000	-77		5.0	6.0	0.0	29.2			46	16.8	
R9	802.11N20	4824.0	4824.0	-48.1	-58.9	5.0	0.0	0.0	52.1	74.0	41.4	54.0	12.6	CH Low channel or noise
R10	802.11N20	4874.0	4874.0	-49.5	-59.1	5.0	0.0	0.0	50.7	74.0	41.2	54.0	12.8	CH Med channel or noise
R11	802.11N20	4924.0	4924.0	-47.4	-52.4	5.0	0.0	0.0	52.8	74.0	47.9	54.0	6.1	CH High channel or noise
R12	802.11N20	4000.0	6000.0	-47.4	-52.4	5.0	0.0	0.0	52.8	74.0	47.9	54.0	6.1	max L,M,H channels or noise
R13	802.11N20	6000.0	8400.0	-55.3	-66.5	5.0	0.0	0.0	44.9	74.0	33.8	54.0	20.2	max L,M,H channels or noise
R14	802.11N20	8400.0	12500.0	-52.3	-63.5	5.0	0.0	0.0	47.9	74.0	36.8	54.0	17.2	max L,M,H channels or noise
R15	802.11N20	12500.0	26000.0	-55.2	-65.2	5.0	0.0	0.0	45.0	74.0	35.1	54.0	18.9	max L,M,H channels or noise
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14

* Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6 and 8.7 respectively.

** Measured according to ANSI C63-10-2013 section 6.10.5.2

*** Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)

*** Computed according to ANSI C63.10-2013 section 11.12.2.2 (e)

Table 8(e): Transmit Chain Spurious Emissions.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
f > 1 000 MHz	Pk/Avg	1 MHz	3 MHz	**Test Date:**	12-Apr-21
				Test Engineer:	J. Brunett
				EUT:	GridConnect ESP32
				Meas. Distance:	Conducted

Transmitter Spurious														FCC/IC
		Frequency		Output Power		Ant	***GR Factor	Avg Duty	Electric Field @ 3m				Pass	
	Mode	Start	Stop	Pk	Avg	Gain		Factor	Meas. Pk	Limit Pk	Meas. Avg	Limit Avg		
#		MHz	MHz	dBm	dBm	dBi	dB	dB	dBuV/m	dBuV/m	dBuV/m	dBuV/m	dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)													
R2	802.11N40	2390.0	2390.0	-32.3	-47.6	5.0	0.0	0.0	67.9	74.0	52.7	54.0	**1.3**	max all - L,M,H channels
R3	Fundamental Restricted Band Edge (High Side)													
R4	802.11N40	2483.5	2483.5	-49.5	-49.5	5.0	0.0	0.0	50.7	74.0	50.8	54.0	3.2	max all - L,M,H channels
R5	Restricted Bands Emissions													
R6	802.11N40	30	88	-73.8		5.0	6.0	0.0	32.4			40	7.6	
R7	802.11N40	88	216	-68.6		5.0	6.0	0.0	37.6			43	5.4	
R8	802.11N40	216	1000	-77		5.0	6.0	0.0	29.2			46	16.8	
R9	802.11N40	4824.0	4824.0	-48.5	-58.9	5.0	0.0	0.0	51.7	74.0	41.4	54.0	12.6	CH Low channel or noise
R10	802.11N40	4874.0	4874.0	-47.6	-58.9	5.0	0.0	0.0	52.6	74.0	41.3	54.0	12.7	CH Med channel or noise
R11	802.11N40	4924.0	4924.0	-46.3	-52.4	5.0	0.0	0.0	53.9	74.0	47.9	54.0	6.1	CH High channel or noise
R12	802.11N40	4000.0	6000.0	-46.3	-52.4	5.0	0.0	0.0	53.9	74.0	47.9	54.0	6.1	max L,M,H channels or noise
R13	802.11N40	6000.0	8400.0	-54.9	-66.8	5.0	0.0	0.0	45.3	74.0	33.4	54.0	20.6	max L,M,H channels or noise
R14	802.11N40	8400.0	12500.0	-57.3	-68.8	5.0	0.0	0.0	42.9	74.0	31.5	54.0	22.5	max L,M,H channels or noise
R15	802.11N40	12500.0	26000.0	-55.2	-65.2	5.0	0.0	0.0	45.0	74.0	35.1	54.0	18.9	max L,M,H channels or noise
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14

* Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6 and 8.7 respectively.

** Measured according to ANSI C63-10-2013 section 6.10.5.2

*** Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)

*** Computed according to ANSI C63.10-2013 section 11.12.2.2 (e)

4.3.2 Relative Transmit Chain Spurious Emissions

The results for the measurement of transmit chain spurious emissions relative to the fundamental in a 100 kHz receiver bandwidth (at the nominal voltage and temperature) are provided in Figure 11 below.

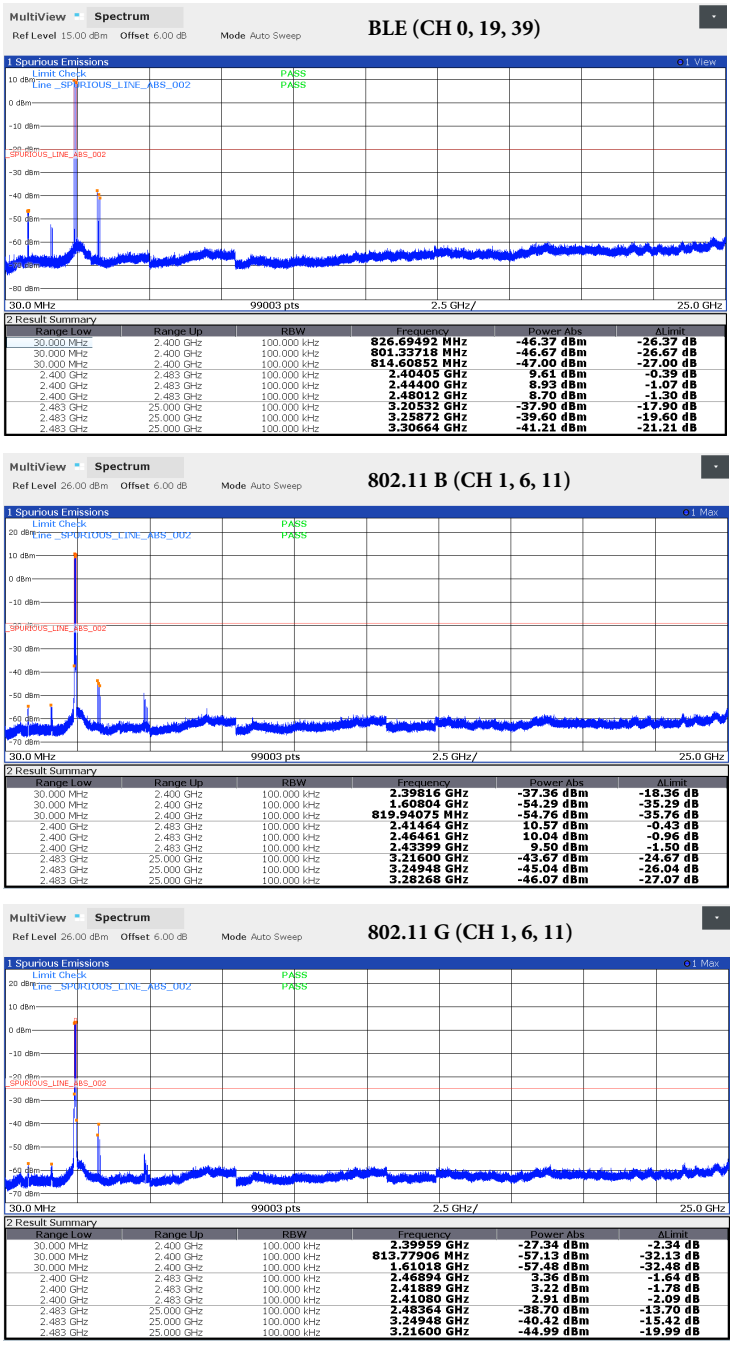
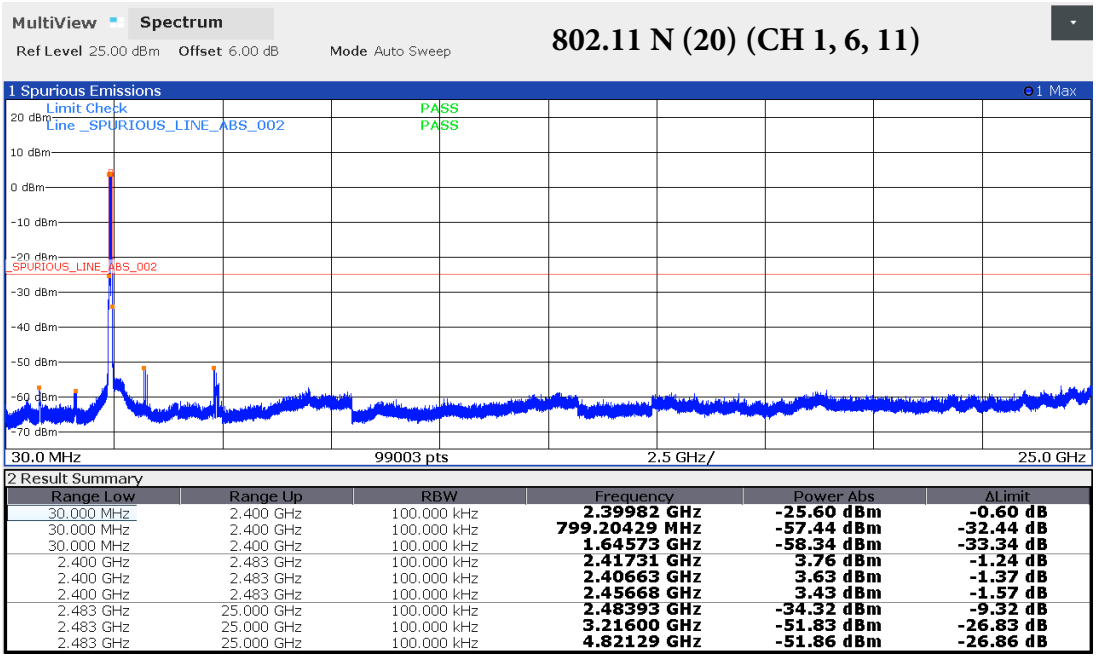


Figure 11(a): Conducted Transmitter Emissions Measured.



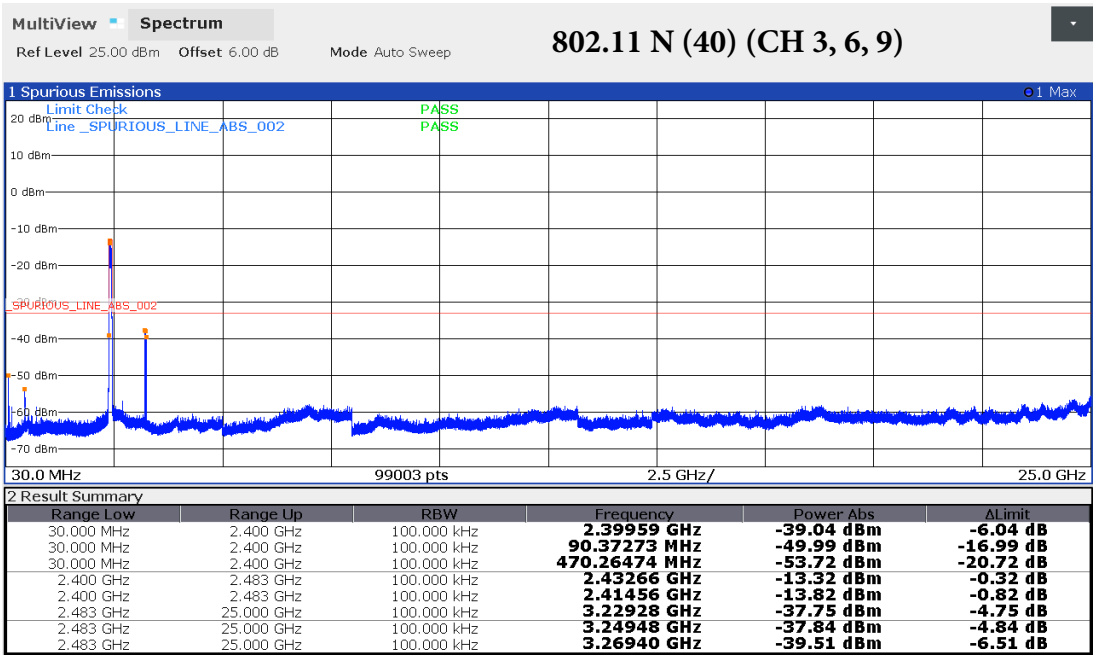


Figure 11(b): Conducted Transmitter Emissions Measured.

4.3.3 General Radiated Spurious

The results for the measurement of general spurious emissions (emissions arising from digital circuitry) at the nominal voltage and temperature are provided in Table 9. Radiation from digital components are measured up to 1000 MHz or to the highest frequency required by the applied standards, whichever is greater.

Table 9: Radiated Digital Spurious Emissions.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
25 MHz ≤ f ≤ 1 000 MHz	Pk/QPk	120 kHz	300 kHz	**Test Date:**	20-Apr-21
f > 1 000 MHz	Avg/RMS	1 MHz	3 MHz	**Test Engineer:**	J. Brunett
				*** **EUT:**	Grid Connect ESP32
				EUT Mode:	Active
				Meas. Distance:	3 m
				Temperature:	4.3C
				Rel. Humidty:	39%

Digital Spurious Emissions																FCC/IC + EU(CISPR)
	Test	Antenna				E-Field @ 3m**		FCC/IC Class B		EU 55032 Class B		FCC/IC Class A		EU 55032 Class A		
	Freq.	QN	Test	Ka	Kg	Pk	QPk/Avg	E3lim	Pass	E3lim	Pass	E3lim	Pass	E3lim	Pass	
#	MHz	Used	Pol.	dB/m	dB	dBµV/m	dBµV/m	dBµV/m	dB	dBµV/m	dB	dBµV/m	dB	dBµV/m	dB	Comments
1	160.0	BICEMCO01	H	13.1	-.7	38.9	35.9	43.5	7.6	40.5	4.6	54.0	18.1	50.5	14.6	
2	160.0	BICEMCO01	V	13.1	-.7	32.1	26.8	43.5	16.7	40.5	13.7	54.0	27.2	50.5	23.7	
3	181.0	BICEMCO01	H	14.2	-.8	24.7	19.2	43.5	24.3	40.5	21.3	54.0	34.8	50.5	31.3	
4	181.0	BICEMCO01	V	14.2	-.8	27.6	21.3	43.5	22.2	40.5	19.2	54.0	32.7	50.5	29.2	
5	199.0	BICEMCO01	H	14.7	-.8	25.7	19.4	43.5	24.1	40.5	21.1	54.0	34.6	50.5	31.1	
6	199.0	BICEMCO01	V	14.7	-.8	29.9	23.4	43.5	20.1	40.5	17.1	54.0	30.6	50.5	27.1	
7	320.0	LOGEMCO01	H	14.2	-1.2	33.7	31.1	46.0	14.9	47.5	16.4	56.9	25.8	57.5	26.4	
8	320.0	LOGEMCO01	V	14.2	-1.2	30.4	26.0	46.0	20.0	47.5	21.5	56.9	30.9	57.5	31.5	
9	480.2	LOGEMCO01	H	17.1	-1.7	40.3	34.8	46.0	11.2	47.5	12.7	56.9	22.1	57.5	22.7	
10	480.2	LOGEMCO01	V	17.1	-1.7	31.1	25.7	46.0	20.3	47.5	21.8	56.9	31.2	57.5	31.8	
11	962.1	LOGEMCO01	H	23.4	-3.0	38.5	32.9	54.0	21.1	47.5	14.6	60.0	27.1	57.5	24.6	
12	962.1	LOGEMCO01	V	23.4	-3.0	39	32.8	54.0	21.2	47.5	14.7	60.0	27.2	57.5	24.7	
13																
14	No other spurious emissions observed within 20 dB of the regulatory limit.															
15																

*QPk detection below 1 GHz, Avg detection at or above 1 GHz with receiver bandwidth as specified at top of table.

** When E-field is reported directly from Spectrum Analyzer, Antenna Factors and Cable losses are included directly in SA settings.

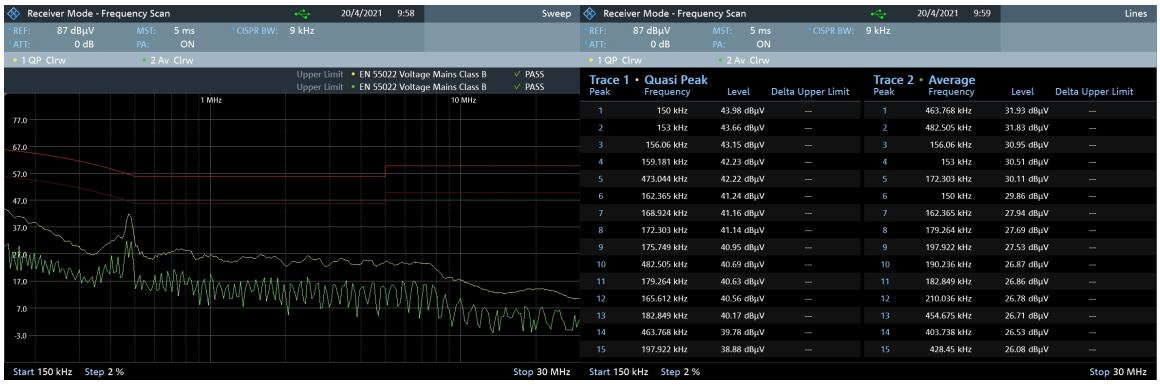
*** The EUT was tested as provided and declared by the customer.

4.3.4 Conducted Emissions Test Results - AC Power Port(s)

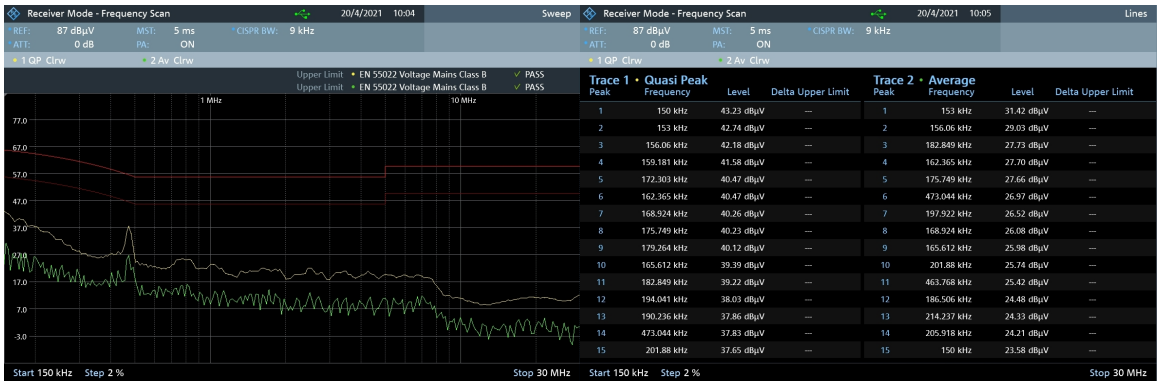
The results of emissions from the EUT's AC mains power port(s) are reported in Table 10.

Table 10: AC Mains Power Conducted Emissions Results.

AC MAINS CONDUCTED - NEUTRAL



AC MAINS CONDUCTED - L1



5 Measurement Uncertainty and Accreditation Documents

The maximum values of measurement uncertainty for the laboratory test equipment and facilities associated with each test are given in the table below. This uncertainty is computed for a 95.45% confidence level based on a coverage factor of $k = 2$.

Table 11: Measurement Uncertainty.

Measured Parameter	Measurement Uncertainty†
Radio Frequency	$\pm(f_{Mkr}/10^7 + RBW/10 + (SPN/(PTS-1))/2 + 1\,\text{Hz})$
Conducted Emm. Amplitude	$\pm 1.9\,\text{dB}$
Radiated Emm. Amplitude ($f < 30\,\text{MHz}$)	$\pm 3.1\,\text{dB}$
Radiated Emm. Amplitude ($30 - 200\,\text{MHz}$)	$\pm 4.0\,\text{dB}$
Radiated Emm. Amplitude ($200 - 1000\,\text{MHz}$)	$\pm 5.2\,\text{dB}$
Radiated Emm. Amplitude ($f > 1000\,\text{MHz}$)	$\pm 3.7\,\text{dB}$

†Ref: CISPR 16-4-2:2011+A1:2014


United States Department of Commerce
National Institute of Standards and Technology

NVLAP® ilac-MRA

Certificate of Accreditation to ISO/IEC 17025:2017

NVLAP LAB CODE: 200129-0

AHD (Amber Helm Development, L.C.)
Sister Lakes, MI

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

Electromagnetic Compatibility & Telecommunications

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).

2020-06-23 through 2021-06-30
Effective Dates

For the National Voluntary Laboratory Accreditation Program

Figure 12: Accreditation Documents