Amber Helm Development L.C.
92723 Michigan Hwy-152
Sister Lakes, Michigan 49047 USA
Tel: 888-847-8027

GRIFHS-WR2110TX
Issued: **May 25, 2021**

FHHS EMC Test Report

regarding

USA:	**CFR Title 47, Part 15.247**	(Emissions)
Canada:	**IC RSS-247v2**	(Emissions)

for

GC-ESP32-ETH

Category: Bluetooth Module

Judgments:
FCC 15.247, ISED RSS-247v2 Compliant
Testing Completed: April 30, 2021

TESTING
NVLAP LAB CODE 200129-0

Prepared for:

Grid Connect, Inc.

1630 W. Diehl Rd., Naperville Illinois 60563 USA
Phone: 1 (630) 245-1445, Fax: +1 (630) 245-1717
Contact: Adam Justice, adamj@gridconnect.com

Data Recorded by: Dr. Joseph Brunett, EMC-002790-NE

Reviewed by: Gordon Helm, EMC-002401-NE

Prepared by: Dr. Joseph Brunett, EMC-002790-NE

Date of Issue: May 25, 2021

A copy of this report will remain on file until April 2031.

Revision History

Rev. No.	Date	Details	Revised By
r0	May 25, 2021	Initial Release.	J. Brunett
r1	October 8, 2021	Upd. Cond. Tables.	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 April 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

This report shall not be reproduced, except in full, without the written approval of Amber Helm Development L.C.

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
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-247v2

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"
KDB 558074 D01 v05r02	"GUIDANCE FOR COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEM, FREQUENCY HOPPING SPREAD SPECTRUM SYSTEM, AND HYBRID SYSTEM DEVICES OPERATING UNDER SECTION 15.247 OF THE FCC RULES "
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 a wireless transceiver. 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.

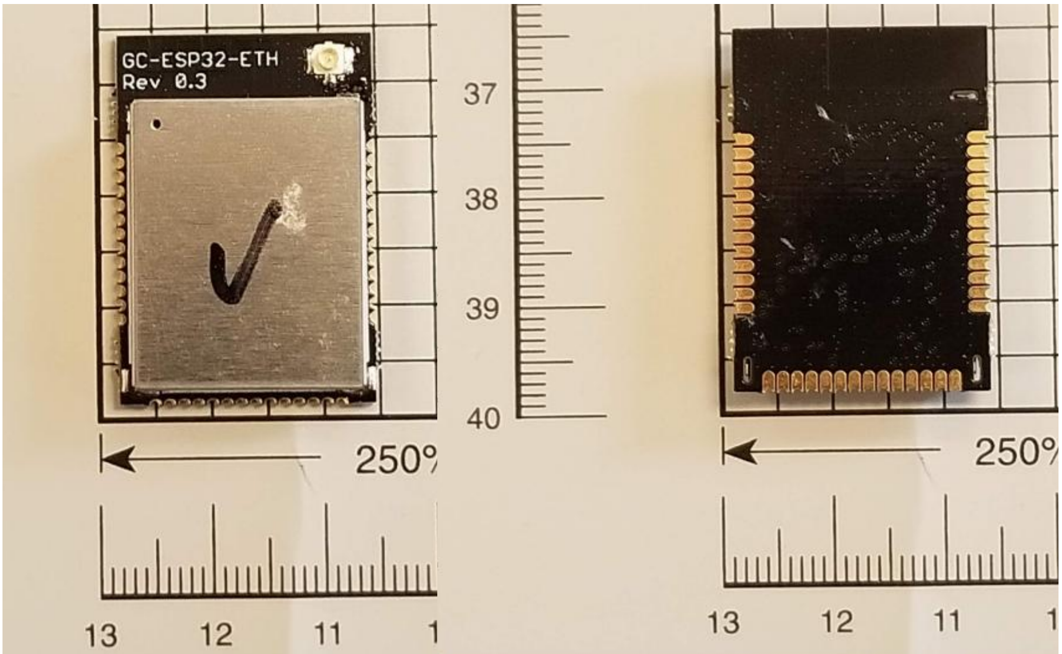

Figure 1: Photos of EUT.

Table 3: EUT Declarations.

General Declarations	
Equipment Type:	Bluetooth 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:	79
Channel Spacing:	1 MHz
Alignment Range:	Not Declared
Type of Modulation:	GFSK, pi/4-DPSK, 8DPSK
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.

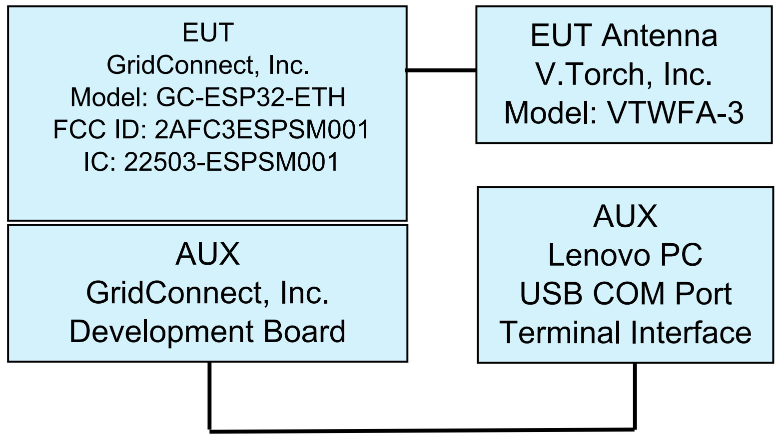

Figure 2: EUT Test Configuration Diagram.

3.1.2 Modes of Operation

The EUT is capable of operating as a Bluetooth 4.2 BR/EDR device employing GFSK, pi/4-DPSK, and 8DPSK modulations at 1, 2, and 3 Mbps data rates. 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 interface board.

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. Manufacturer states all modules manufactured will be firmware set with power setting levels equal to those tested 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 WLAN and BLE 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.

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.

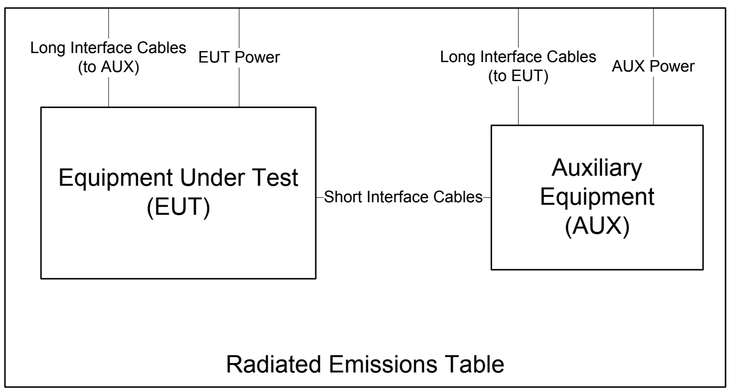

Figure 3: Radiated Emissions Diagram of the EUT.

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.

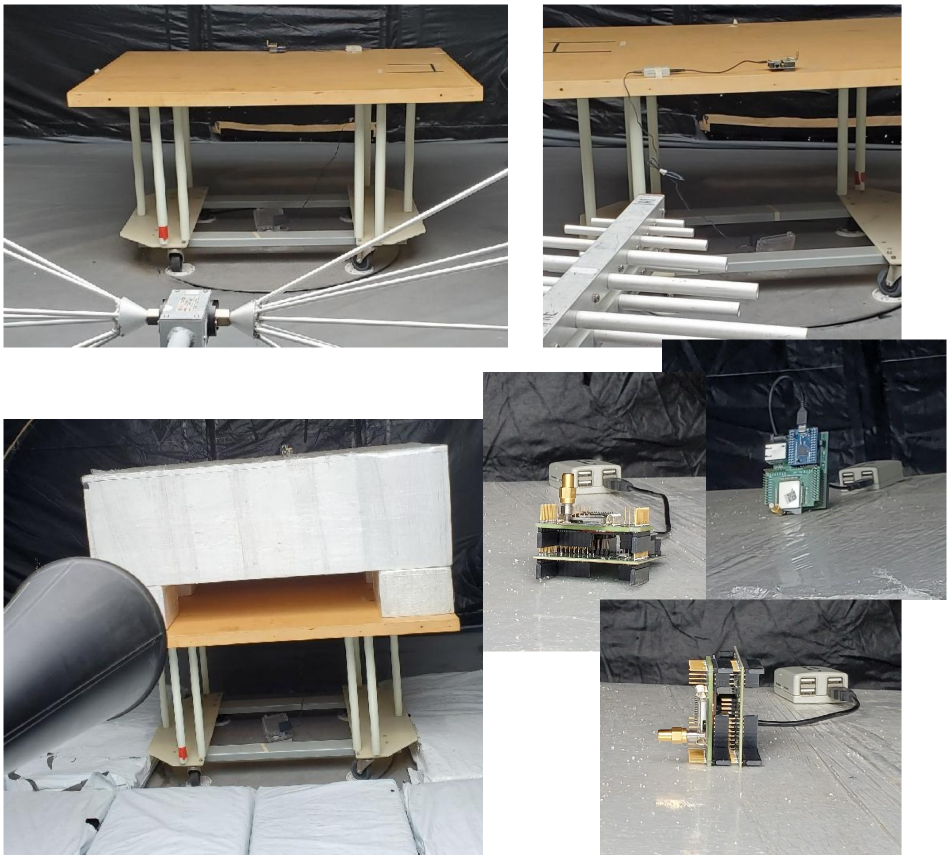

Figure 4: Radiated Emissions Test Setup Photograph(s).

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.

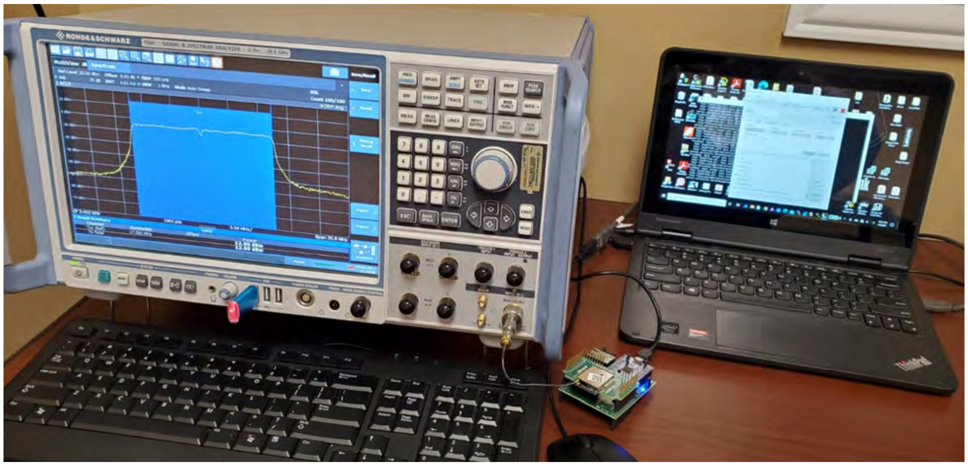

Figure 5: Conducted RF Test Setup Photograph(s).

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.

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.

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								
#	Transmit Mode	Symbol Rate Msym/s	Data Rate Mbps	Voltage V	Oper. Freq MHz	Tx Cycle Time* ms	On-Time* ms	Duty Cycle %	Power Duty Correction dB
R1	CM	1.000	GFSK (1 Mbps)	3.3	2441.0	10.000	5.800	58.0	-2.4
R2		1.000	Pi/4 DPSK (2 Mbps)	3.3	2441.0	10.025	5.800	57.9	-2.4
R3		1.000	8DPSK (3 Mbps)	3.3	2441.0	10.000	5.850	58.5	-2.3
R4	NOTE: SUPPLY VOLTAGE TO THE EUT WAS VARIED FROM 2 V TO 4 V DC. BELOW 2.3 VDC THE EUT DID NOT OPERATE. ABOVE 3.6								
R5	VDC THE EUT OVERHEATED AND STOPED OPERATING. WORST CASE EMISSIONS OBSERVED AT NOMINAL 3.3 VDC.								
#	C1	C2	C3	C4	C5	C6	C7	C8	C9

4.2.2 Hopping Channel Dwell Time

The average time of occupancy on any hopping channel must not be greater than 0.4 seconds within a 20 second period for FHSS device with 50 operating channels. For this test, the EUT was set for data transmission with hopping enabled. Results of this testing are depicted in Table 5. Plots showing example measurements made to obtain these values are provided in Figure 6.

Table 5: Hopping Channel Dwell Time.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
25 MHz ≤ f ≤ 1 000 MHz	Pk/QPk	100/120 kHz	300 kHz	**Test Date:**	23-Apr-21
f > 1 000 MHz	Pk	1 MHz	3 MHz	**Test Engineer:**	Joseph Brunett
				EUT:	GridConnect ESP32-ETH
				Meas. Distance:	Conducted

#	Dwell Time								
#	Packet Type	Frequency (MHz)	# Bursts #	Observation Time (sec)	Window (sec)	Active Time (sec)	Total On Time** (s)	Limit (s)	Pass/Fail
R1	DH1 (min)	2441.0	132	33.0	33.0	0.00039	0.0510	<0.4	Pass
R2	DH5 (max)	2441.0	87	33.0	33.0	0.00291	0.2532	<0.4	Pass
#	C1	C2	C3	C4	C5	C6	C7	C8	C9

* Dwell Time Observed with EUT placed into self-test hopping mode via PC interface.

**The measured dwell time may not indicate the actual single channel dwell time of the DUT. A dwell time of 0.3797 seconds in data mode is independent from the packet type (packet length) for all Bluetooth devices. Therefore, Bluetooth devices comply with the dwell time requirement.

Figure 6(a): Example Plots of Duty Cycle and Channel Dwell Time.

Dwell Time

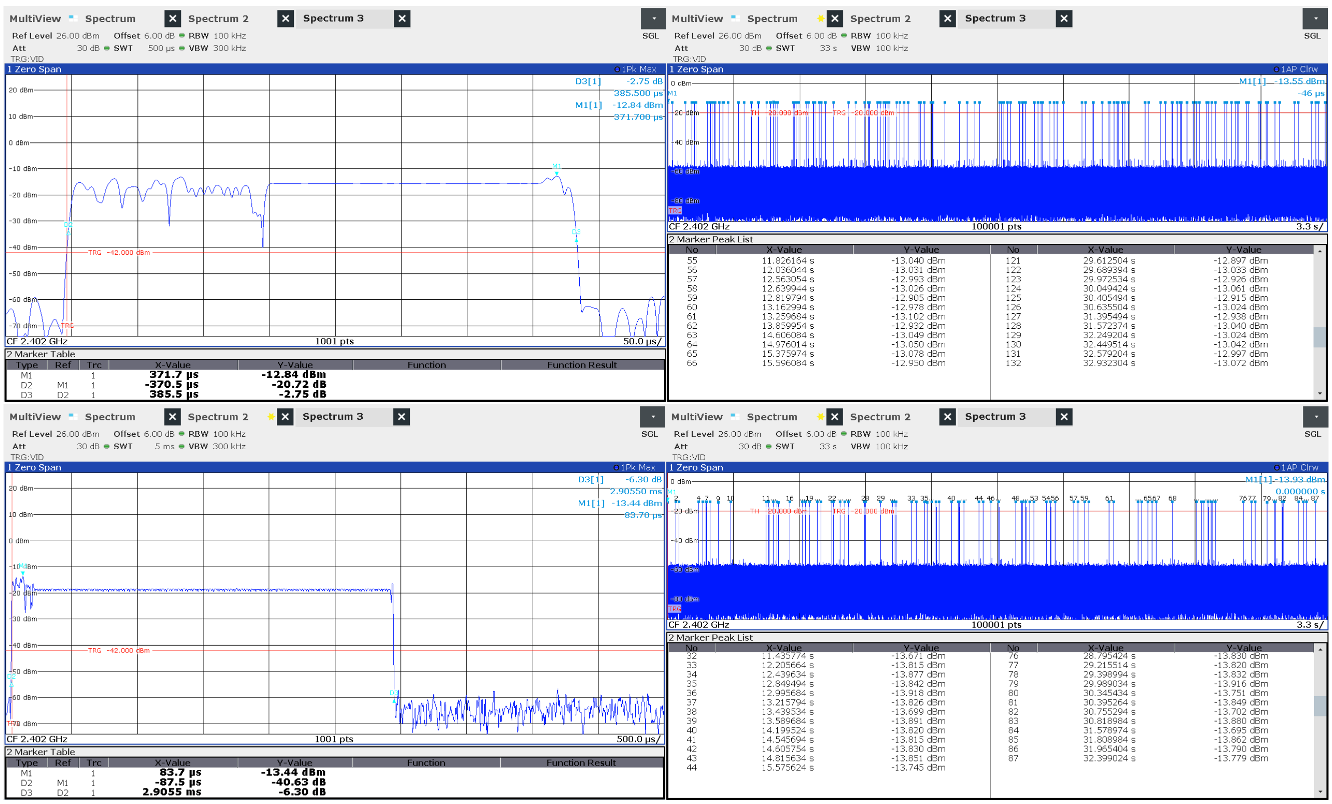

Figure 6(b): Example Plots of Duty Cycle and Channel Dwell Time.

4.2.3 Hopping Sequence and Spectrum Use

It is required that the EUT hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average. In addition, system receivers are required to have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and that shift frequencies in synchronization with the transmitted signals. Furthermore, the system must be designed to comply should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section. Finally, the incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopsets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted

The manufacturer has provided a separate exhibit addressing these items.

4.2.4 Channel Bandwidth

For this test, the EUT was set continuous data transmission (hopping disabled) in each modulation. The 20-dB bandwidth as well as 99% emission bandwidth were measured for the low, middle, and high channels. Results of these measurements are shown in Table 6. Plots showing example measurements employed to obtain this data are provided in Figure 9.

Table 6: Intentional Emission Bandwidth.

Frequency Range	Det	IFBW	VBW
f > 1 000 MHz	Pk	100 kHz	1 MHz

Test Date: 04/23/21
Test Engineer: Joseph Brunett
EUT GridConnect ESP32-ETH
Meas. Distance: Conducted

#	Occupied Bandwidth									
#	Transmit Mode	Symbol Rate (Msym/s)	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	GFSK	1	1.0	3.3	2402.0	-	-	0.912	1.071	Pass
R2					2441.0	-	-	0.905	1.041	Pass
R3					2480.0	-	-	0.901	1.048	Pass
R4	PI/4 DQPSK	1	2.0	3.3	2402.0	-	-	1.193	1.342	Pass
R5					2441.0	-	-	1.192	1.342	Pass
R6					2480.0	-	-	1.193	1.342	Pass
R7	8QPSK	1	3.0	3.3	2402.0	-	-	1.176	1.304	Pass
R8					2441.0	-	-	1.175	1.306	Pass
R9					2480.0	-	-	1.181	1.312	Pass
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10

* Over all modes of operation, the worst case (highest data rate) in each form of modulation was tested to demonstrate compliance. For GFSK, worst test pattern employed F0F0 dataset, for pi/4-DQPSK the PN15 dataset, for 8-DQPSK the PN15 dataset.

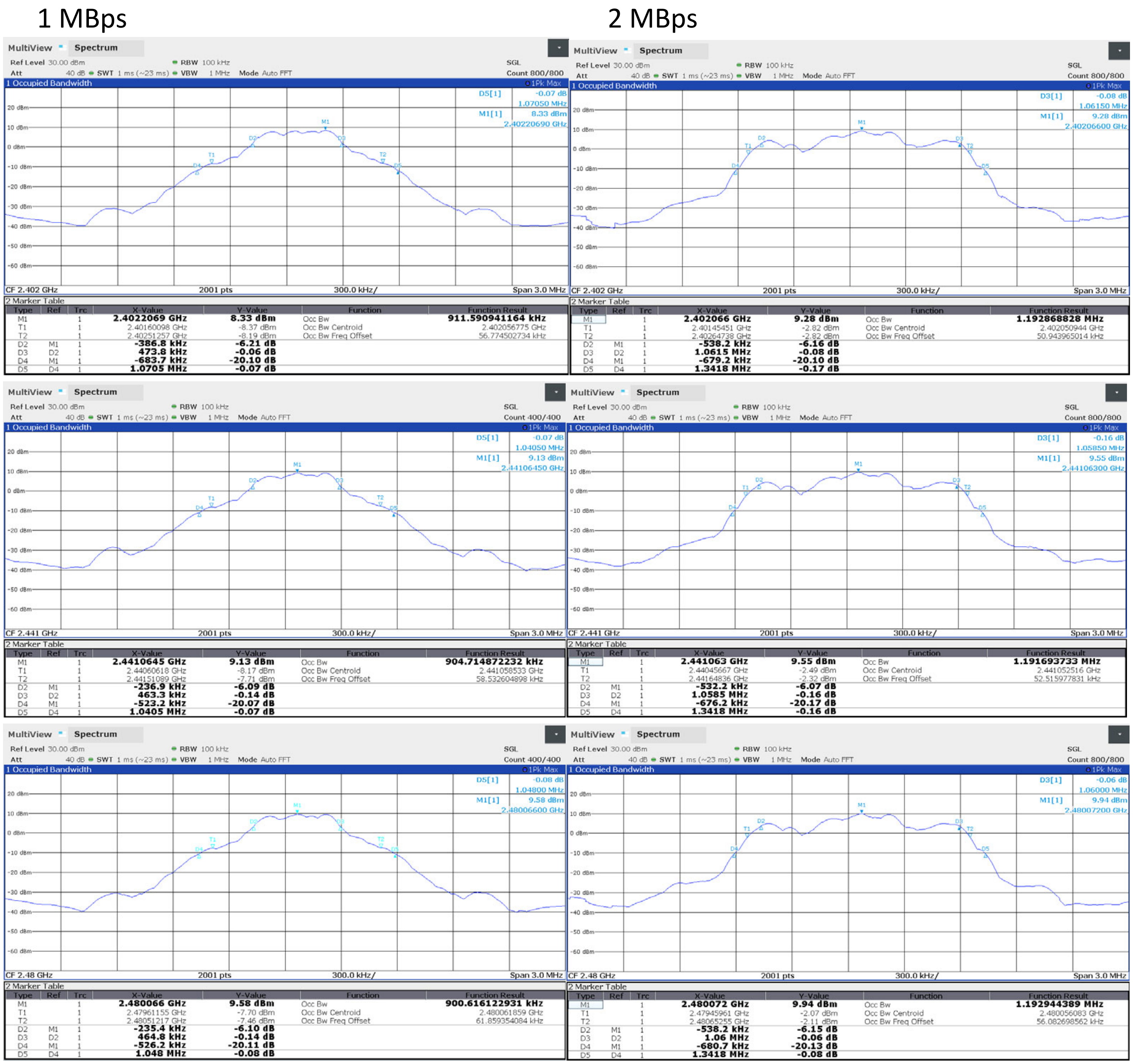

Figure 7(a): Intentional Emission Bandwidth.

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Figure 7(b): Intentional Emission Bandwidth.

4.2.5 Number of Hopping Channels

For this test, the EUT was enabled for data transmission with hopping. The number of channels measured is reported here in Table 7. Plots showing example measurements employed to obtain this data are provided in Figure 8.

Table 7: Measured Number of Hopping Channels.

Frequency Range	Det	IF Bandwidth	Video Bandwidth		
25 MHz ≤ f ≤ 1 000 MHz	Pk/QPk	100/120 kHz	300 kHz	**Test Date:**	23-Apr-21
f > 1 000 MHz	Pk	100 kHz	3 MHz	**Test Engineer:**	Joseph Brunett
				EUT:	GridConnect ESP32-ETH
				Meas. Distance:	Conducted

Number of Hopping Channels						
Mode	Start Frequency (MHz)	Stop Frequency (MHz)	Number of Channels Observed (#)	Total Number (#)	Limit (#)	Pass/Fail
GFSK Hopping	2400.0	2483.5	79	79	15.0	Pass

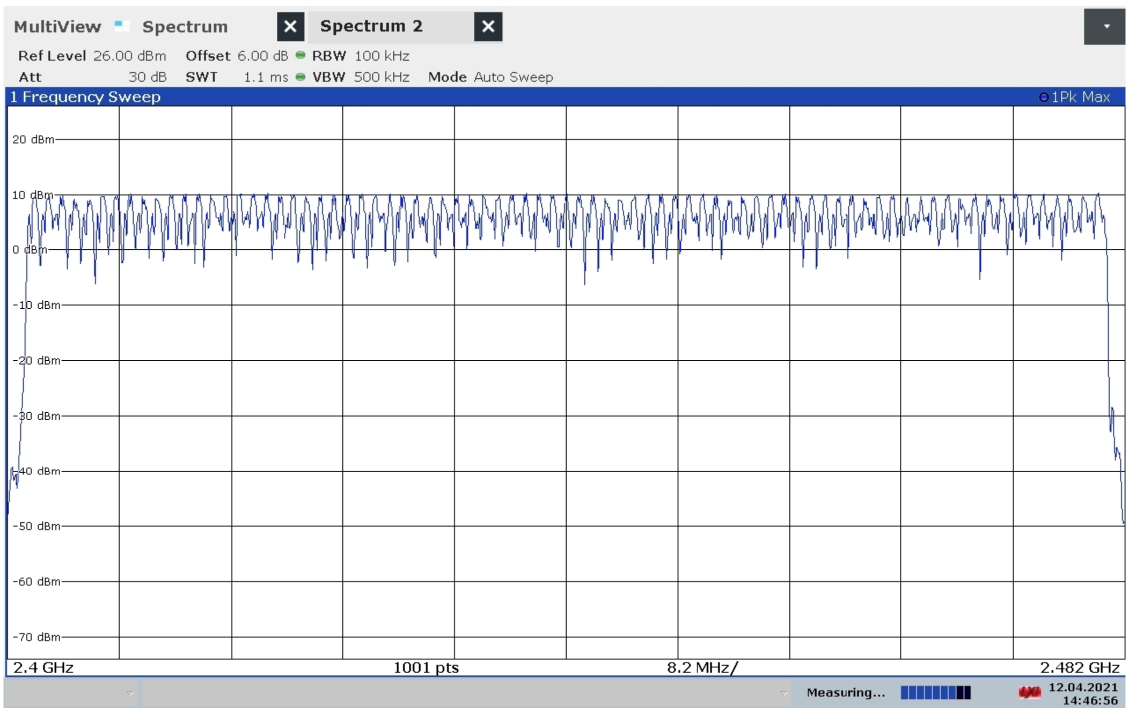


Figure 8: Measured Number of Hopping Channels.

4.2.6 Channel Separation

For this test, the EUT was enabled for data transmission with hopping. The Carrier Separation was measured for low, mid, and high channels. Results of these measurements are shown in Table 8.

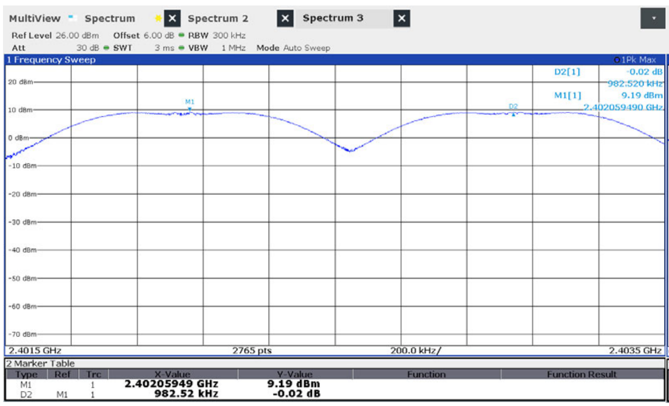
Table 8: Measured Channel Separation.

Frequency Range	**Det**	**IF Bandwidth**	**Video Bandwidth**	**Test Date:**	23-Apr-21
25 MHz ≤ f ≤ 1 000 MHz	Pk/QPk	100/120 kHz	300 kHz	**Test Engineer:**	Joseph Brunett
f > 1 000 MHz	Pk	100 kHz	3 MHz	**EUT**	GridConnect ESP32-ETH
				Meas. Distance:	Conducted

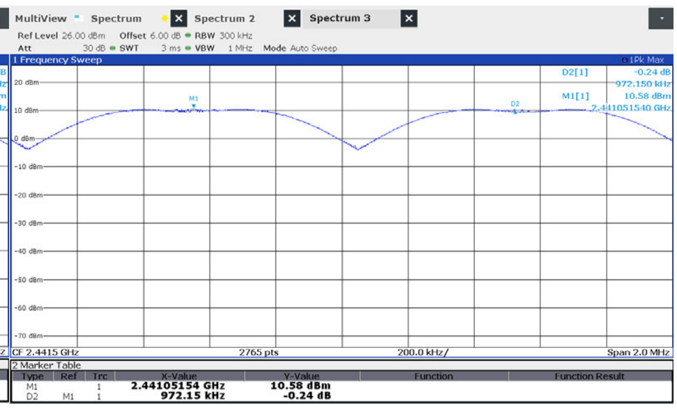
Hopping Frequency Separation					
Mode	Low Channel Frequency (MHz)	High Channel Frequency (MHz)	*Separation (MHz)	* *Separation Limit (kHz)	Pass/Fail
GFSK	2402.0	2403.0	0.983	>900	Pass
	2441.0	2442.0	0.972	>900	Pass
	2479.0	2480.0	1.040	>900	Pass
Pi/4DQPSK	Channel Separation is the same for all modulations in a Bluetooth transceiver. Only worst-case GFSK modulation was tested to demonstrate compliance.				
8DQPSK					

* Channel Separation Observed with the Device hopping over all available channels.
** Channel separation must be >2/3 20dB EBW according to §15.247 (a)(1)

CH 0



CH 39



CH 79

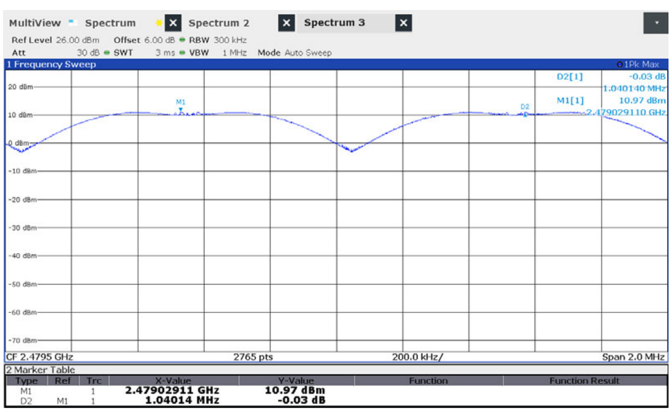


Figure 9: Measured Channel Separation.

4.2.7 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 9. Peak conducted output power was measured

Table 9: Radiated Power Results.

Frequency Range	**Det**	**Test Date:**	23-Apr-21
f > 1 000 MHz	Pk	**Test Engineer:**	J. Brunett
IFBW **VBW**		**EUT:**	GridConnect ESP32
2 MHz 5 MHz		**Meas. Distance:**	Conducted

#	Mode	Channel	Freq. MHz	*Pout (Pk) dBm	Ant Gain** dBi	EIRP (Pk) dBm	***EIRP (Avg) Limit dBm	Pass dB	FCC/IC Comments
R1	GFSK (1Mbps)		2402.0	9.7	5.0	14.7	27.0	12.3	
R2		39	2441.0	9.6	5.0	14.6	27.0	12.4	
R3		78	2480.0	9.8	5.0	14.8	27.0	12.3	
R4	Pi/4DQPSK (2Mbps)		2402.0	11.1	5.0	16.1	27.0	10.9	
R5		39	2440.0	11.1	5.0	16.1	27.0	10.9	
R6		78	2480.0	11.2	5.0	16.2	27.0	10.8	
R7	8QPSK (3Mbps)		2402.0	11.8	5.0	16.8	27.0	10.2	
R8		39	2440.0	11.8	5.0	16.8	27.0	10.2	
R9		78	2480.0	**11.9**	5.0	16.9	27.0	**10.1**	
#	C1	C2	C3	C4	C5	C6	C7	C8	C9

*Measured conducted from the radio using conducted test sample. Pk Power measured according to ANSI C63.10, section 7.8.5.

** Worst Case Antenna Gain as declared by Manufacturer (see antenna data sheet)

***Equivalent EIRP limit considering a conducted limit of 125mW (21dBm) and maximum allowed Antenna gain (6dBi)

directly from the EUT at the port where the antenna attaches. The test receiver bandwidth was set to be greater than the measured emission bandwidth of the EUT to capture the true peak. Antenna gain is either provided directly by the manufacturer or measured by comparison between calculated EIRP and conducted output power. Plots showing conducted measurements made are depicted in Figure 10.

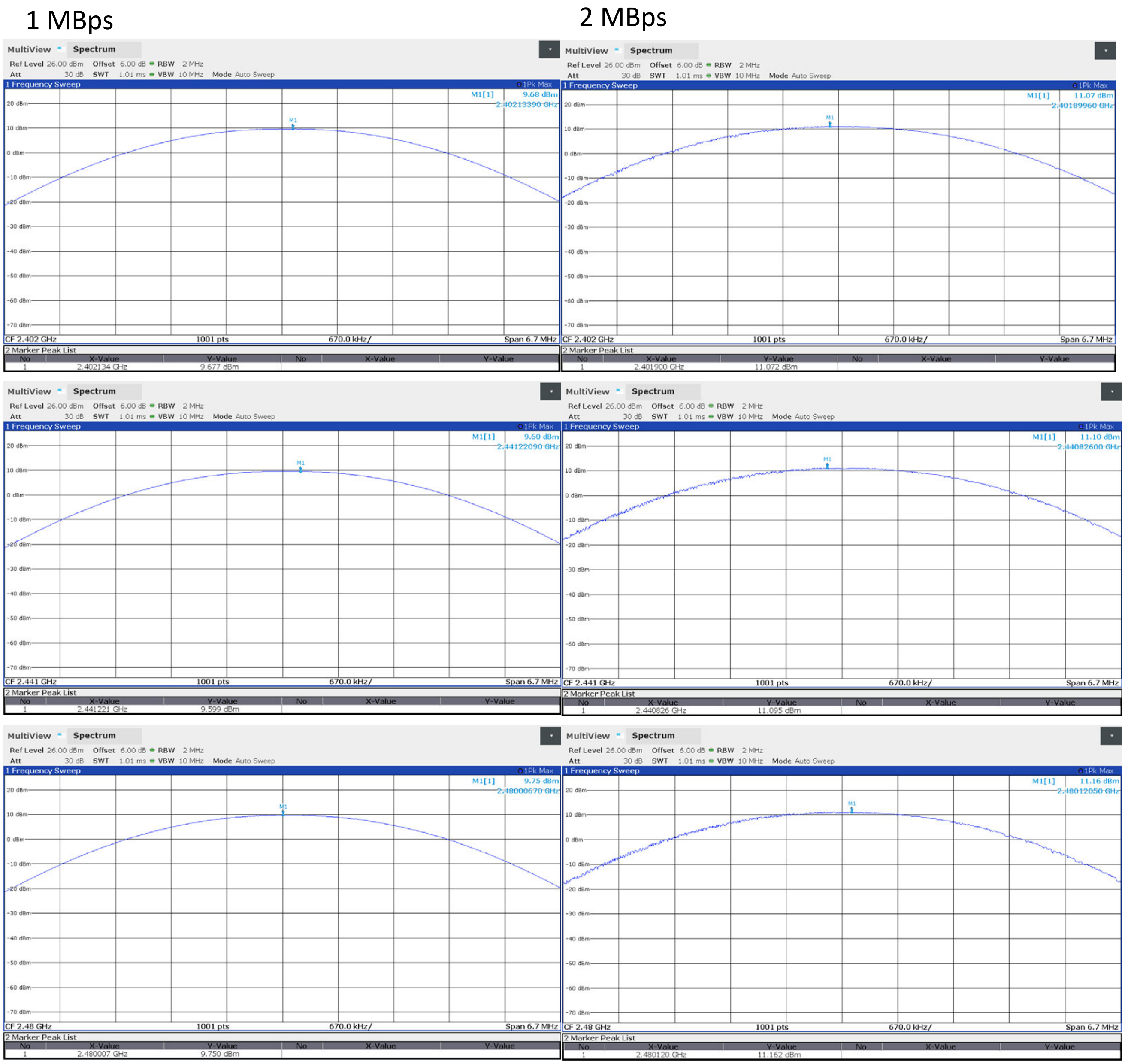


Figure 10(a): Conducted RF Power Plots

3 MBps

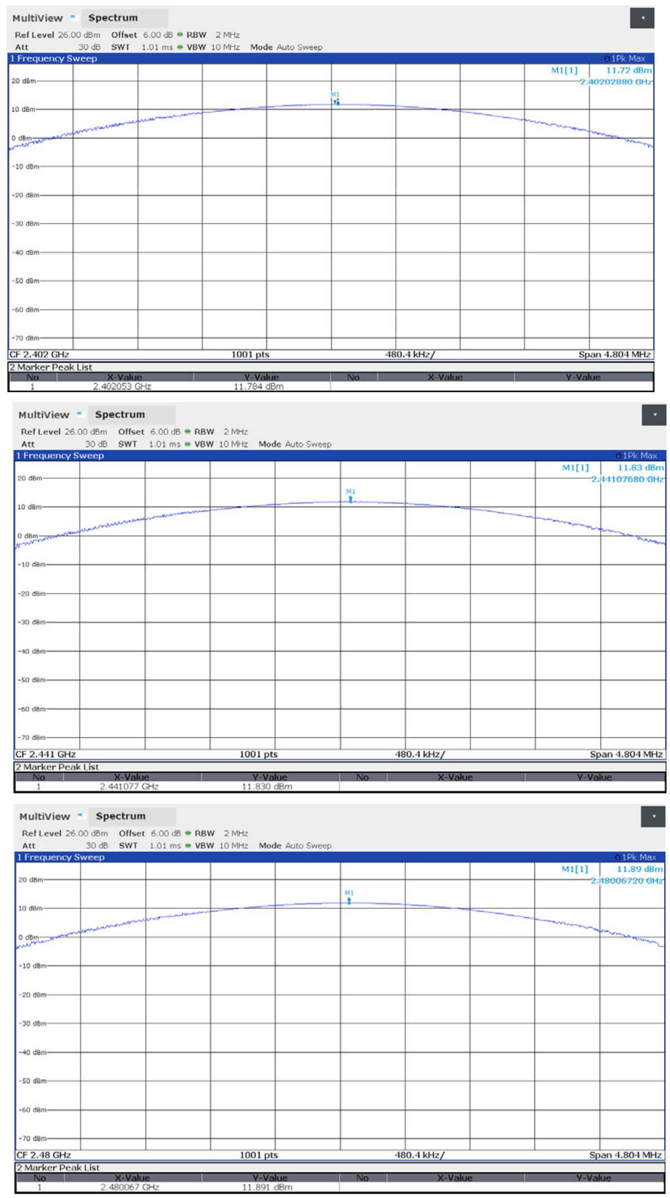


Figure 10(b): Conducted RF Power Plots

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 10. Measurements are performed to 10 times the highest fundamental operating frequency.

Table 10: 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

FCC/IC

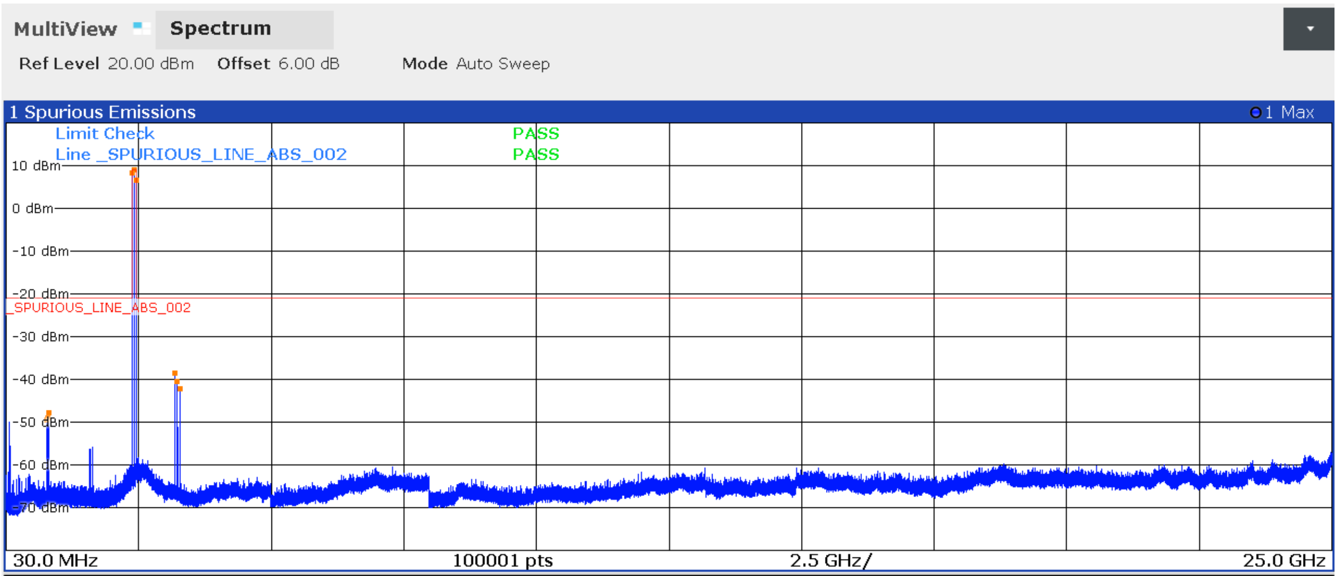
#	Mode	Frequency Start MHz	Frequency Stop MHz	Output Power Pk dBm	Output Power Avg dBm	Ant Gain dBi	***GR Factor dB	Avg Duty Factor dB	Electric Field @ 3m Meas. Pk dBuV/m	Limit Pk dBuV/m	Meas. Avg dBuV/m	Limit Avg dBuV/m	Pass dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)													
R2	Max all	2390.0	2390.0	-47.3	-58.6	5.0		2.4	52.9	74.0	44.1	54.0	9.9	max all - L,M,H channels
R3	Fundamental Restricted Band Edge (High Side)													
R4	Max all	2483.5	2483.5	-45.0	-58.6	5.0		2.4	55.2	74.0	44.1	54.0	9.9	max all - L,M,H channels
R5	Restricted Bands Emissions													
R6	Max all	30	88	-89.1		5.0	6.0		17.1			40.0	**22.9**	
R7	Max all	88	216	-81.8		5.0	6.0		24.4			43.0	18.6	
R8	Max all	216	1000	-71.9		5.0	6.0		34.3			46.0	11.7	
R9	Max all	4804.0	4804.0	-46.9	-58.8	5.0		2.4	53.3	74.0	43.9	54.0	10.1	CH Low channel or noise
R10	Max all	4888.0	4888.0	-48.3	-59.0	5.0		2.4	51.9	74.0	43.6	54.0	10.4	CH Med channel or noise
R11	Max all	4960.0	4960.0	-47.2	-58.9	5.0		2.4	53.0	74.0	43.7	54.0	10.3	CH High channel or noise
R12	Max all	4000.0	6000.0	-46.9	-58.8	5.0		2.4	53.3	74.0	43.9	54.0	10.1	max L,M,H channels or noise
R13	Max all	6000.0	8400.0	-59.3	-70.1	5.0		2.4	40.9	74.0	32.6	54.0	21.4	max L,M,H channels or noise
R14	Max all	8400.0	12500.0	-57.9	-68.6	5.0		2.4	42.3	74.0	34.1	54.0	19.9	max L,M,H channels or noise
R15	Max all	12500.0	26000.0	-55.1	-65.2	5.0		2.4	45.1	74.0	37.4	54.0	16.6	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.

Channels 0,39,78



2 Result Summary

Range Low	Range Up	RBW	Frequency	Power Abs	ΔLimit
30.000 MHz	2.400 GHz	100.000 kHz	**826.69492 MHz**	**-47.87 dBm**	**-26.87 dB**
30.000 MHz	2.400 GHz	100.000 kHz	**813.66057 MHz**	**-48.91 dBm**	**-27.91 dB**
30.000 MHz	2.400 GHz	100.000 kHz	**800.62622 MHz**	**-49.47 dBm**	**-28.47 dB**
2.400 GHz	2.483 GHz	100.000 kHz	**2.44108 GHz**	**8.98 dBm**	**-0.02 dB**
2.400 GHz	2.483 GHz	100.000 kHz	**2.40221 GHz**	**8.20 dBm**	**-0.80 dB**
2.400 GHz	2.483 GHz	100.000 kHz	**2.47987 GHz**	**6.68 dBm**	**-2.32 dB**
2.483 GHz	25.000 GHz	100.000 kHz	**3.20275 GHz**	**-38.43 dBm**	**-17.43 dB**
2.483 GHz	25.000 GHz	100.000 kHz	**3.25463 GHz**	**-40.57 dBm**	**-19.57 dB**
2.483 GHz	25.000 GHz	100.000 kHz	**3.30679 GHz**	**-42.31 dBm**	**-21.31 dB**

Figure 11: 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 11. Radiation from digital components are measured up to 1000 MHz or to the highest frequency required by the applied standards, whichever is greater.

Table 11: Radiated Digital Spurious Emissions.

Frequency Range	**Det**	**IF Bandwidth**	**Video Bandwidth**
25 MHz ≤ f ≤ 1 000 MHz	Pk/QPk	120 kHz	300 kHz
f > 1 000 MHz	Avg/RMS	1 MHz	3 MHz

Test Date:	20-Apr-21
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.

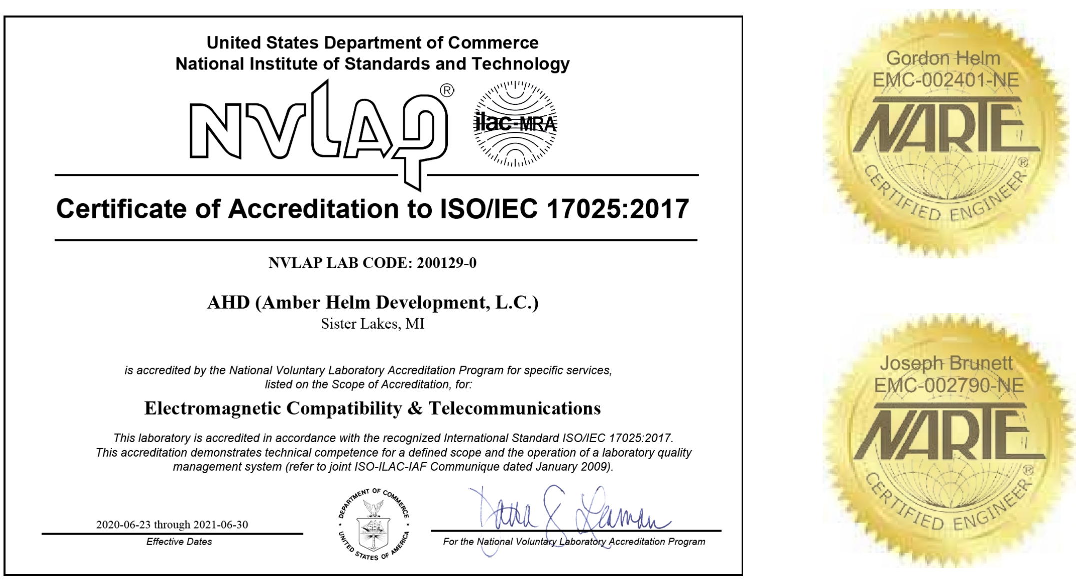
5 Measurement Uncertainty and Accreditation Documents

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 12: 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

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