Amber Helm Development L.C.
92723 Michigan Hwy-152
Sister Lakes, Michigan 49047 USA
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EMC Test Report

GCESP-182249TX
Issued: **July 19, 2018**

regarding

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

for

GC-ESP32-PORT-N

Category: WLAN+BLE Module

Judgements:
FCC 15.247, ISED RSS-247 Compliant
Testing Completed: August 12, 2018

TESTING
NVLAP LAB CODE 200129-0

Prepared for:

GridConnect, Inc.

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Date of Issue: July 19, 2018

Revision History

Rev. No.	Date	Details	Revised By
r0	July 19, 2018	Initial Release.	J. Brunett
r1	August 15, 2018	Revised Conducted RF Plots	J. Brunett
r2	August 22, 2018	Assorted Corrections.	J. Brunett
r3	September 7, 2018	Assorted Corrections.	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 July 2028.

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 laboratories 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 (3m & 10m)	92723 Michigan Hwy-152, Sister Lakes, Michigan 49047 USA	OATSA

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.	Last Cal By / Date Due
BiconiLog Antenna	EMCO / 3142	1169	BILO3142	Lib.Labs / May-2019
(3m) RG8 Coax	CS-3227 / CS-3227	C060914	CS3227	AHD / Sept-2018
EMI Receiver	HP / 85460A/85462A	3704A00422, 3807A00465	HP8546A	Std and Cal / May-2019
(3m) LMR-400 Coax	AHD / LMR400	C090804	LMR400	AHD / Sept-2018
(LCI) DS Coax	AHD / RG58/U	920809	RG58U	AHD / Dec-2018
(10-m) Amelco Coax	AHD / RG213U	9903-10ab	RG213U	AHD / Sept-2018
Double Ridged Horn	EMCO / 3115	2788	RH3115	Lib.Labs. / July-2018
Double Ridged Horn	Cobham / H-1798	190	RHCOB1840	Lib.Labs. / Jul 2018
LISN	Solar / 8012-50-R-24-BNC	962137	LISN7	AHD / May-2019
LISN	Solar / 8012-50-R-24-BNC	962138	LISN7	AHD / April-2021

2 Test Specifications and Procedures

2.1 Test Specification and General Procedures

The ultimate goal of GridConnect, 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 GridConnect, Inc. GC-ESP32-PORT-N 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 (USA)	"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 6 (2016)	"Information Technology Equipment (ITE) Limits and methods of measuremen"

3 Configuration and Identification of the Equipment Under Test

3.1 Description and Declarations

The EUT is wireless transceiver. The EUT is approximately 1.5 x 1.8 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 and BLE modes. Table 3 outlines provider declared EUT specifications.

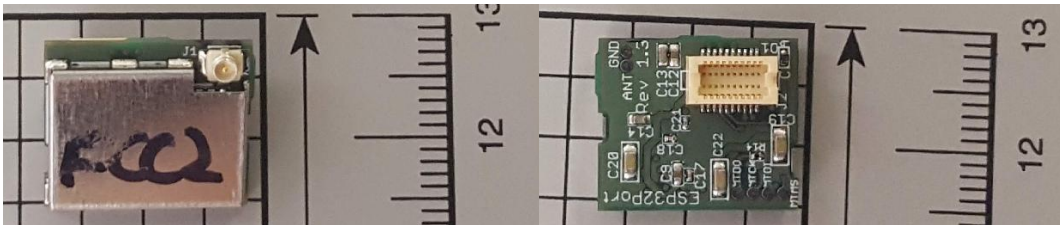


Figure 1: Photos of EUT.

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 (3 dBi), Trace (3.8 dBi)
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.

3.1.2 Modes of Operation

The EUT is capable of operating in BLE (1Mbps) or in 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 interface board. The EUT could not be placed into full continuous transmission, so duty cycle is measured and applied to measured data in line with DTS guidelines.

3.1.3 Variants

There is only a single version of the EUT.

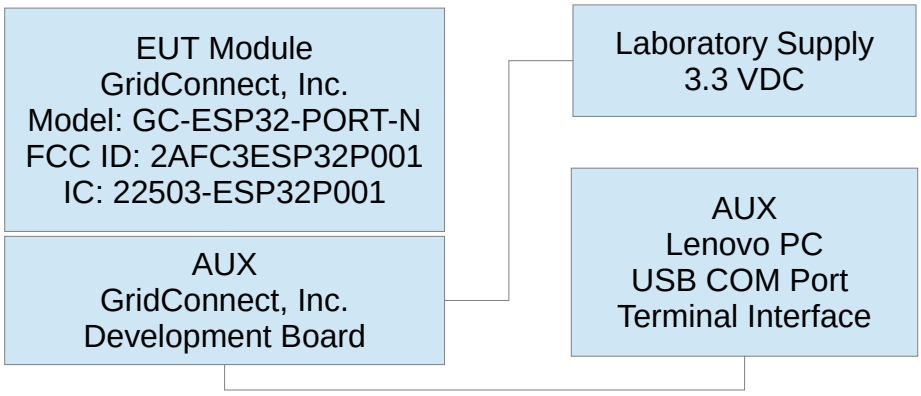


Figure 2: EUT Test Configuration Diagram.

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 maximum power setting on the WLAN chipset reduced to setting 2 (BK=-2) and the BLE power setting was reduced to setting 7 (2 less than max 9). 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

None.

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.

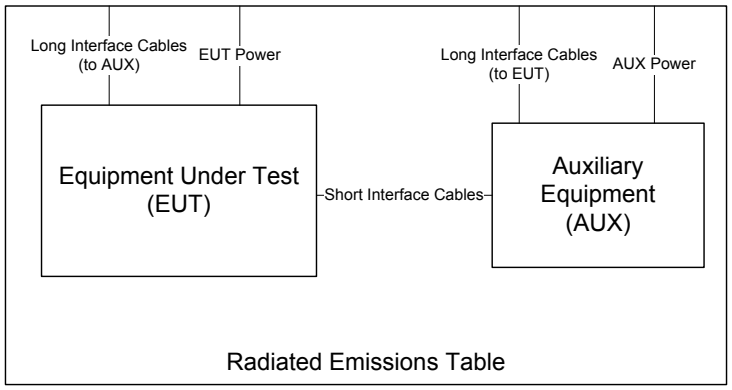


Figure 3: Radiated Emissions Diagram of the EUT.

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.

Where regulations call for substitution method measurements, the EUT is replaced by a substitution antenna if field strength measurements indicate the emission is close to the regulatory limit. This antenna is co-polarized with the test antenna and tuned (when necessary) to the emission frequency, after which the test antenna height is again optimized. The substitution antenna's signal level is adjusted such that its emission is equal to the level measured from the EUT. The signal level applied to the substitution antenna is then recorded. Effective isotropic radiated power (EIRP) and effective radiated power (ERP) in dBm are formulated from

$$EIRP = P_T - G_A = ERP + 2.16, \tag{1}$$

where P_T is the power applied to substitution antenna in dBm, including correction for cable loss, and G_A is the substitution antenna gain, in dBi.

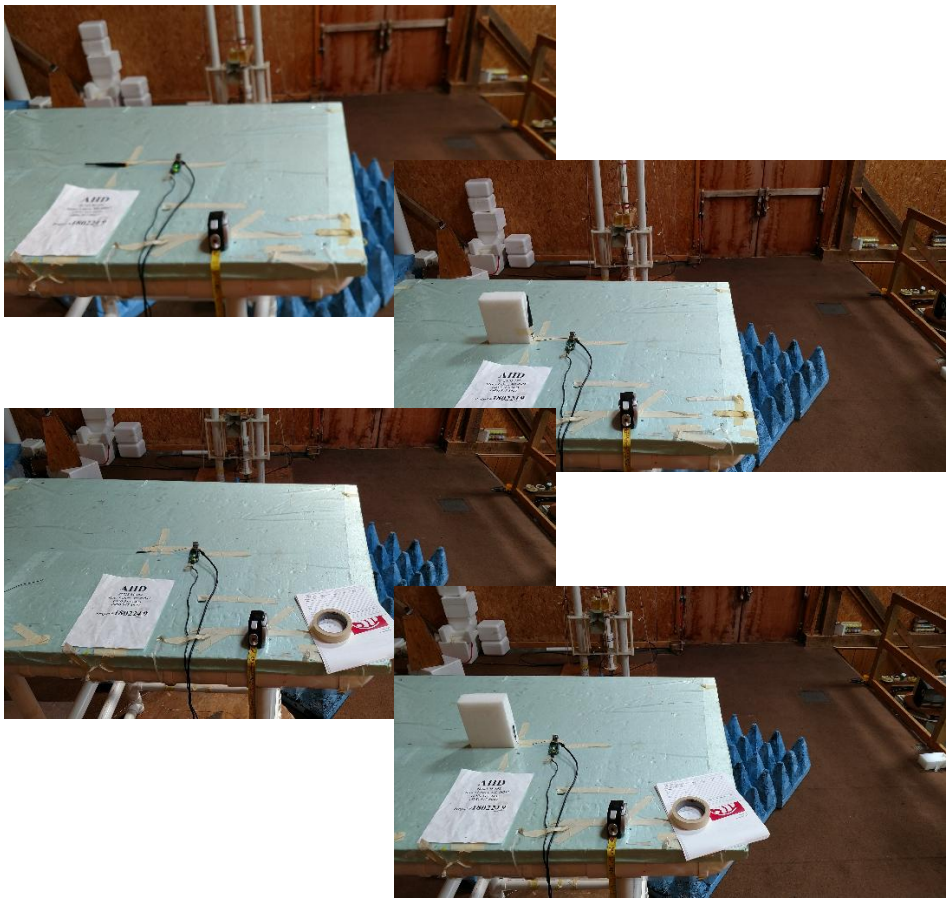


Figure 4: Radiated Emissions Test Setup Photograph(s).

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.

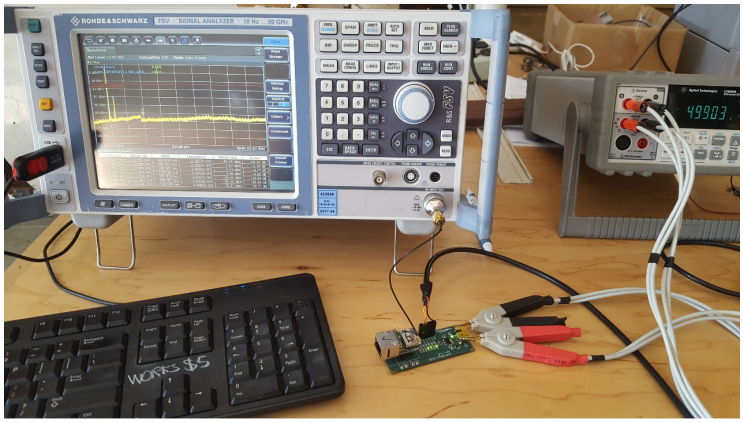


Figure 5: Conducted RF Test Setup Photograph(s).

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.

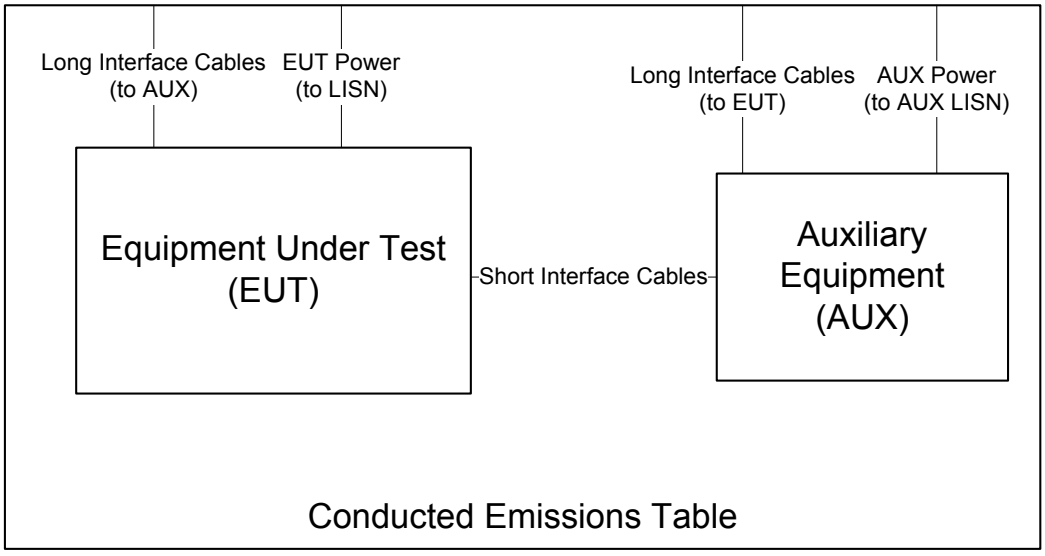


Figure 6: Conducted Emissions Setup Diagram of the EUT.

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 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.

Table 4: Pulsed Emission Characteristics (Duty Cycle).

Frequency Range	**Det**	**IFBW**	**VBW**
f > 1 000 MHz	Pk	1 MHz	28 MHz
f > 1 000 MHz	Pk	28 MHz	28 MHz

Test Date:	11-Jun-18
Test Engineer:	Joseph Brunett
EUT	GridConnect ESP32
Meas. Distance:	Conducted

Pulsed Operation / Duty Cycle						
Transmit Mode	Data Rate (Mbps)	Voltage (V)	Oper. Freq (MHz)	Pulse Length us	Pulse Period us	Worst Case Duty Factor (dB)
BLE	1.0	3.3	2440.0	132.0	625.6	-6.8
802.11b	11.0	3.3	2437.0	592.8	673.6	-0.6
802.11g	54.0	3.3	2437.0	185.2	230.0	-0.9
802.11n(20)	65.0	3.3	2437.0	201.6	246.8	-0.9
802.11n(40)	135.0	3.3	2437.0	201.2	247.2	-0.9

* Duty Cycle is measured in line with DTS procedures section 12.2.5.1 for averaging only over full-power transmission pulses.

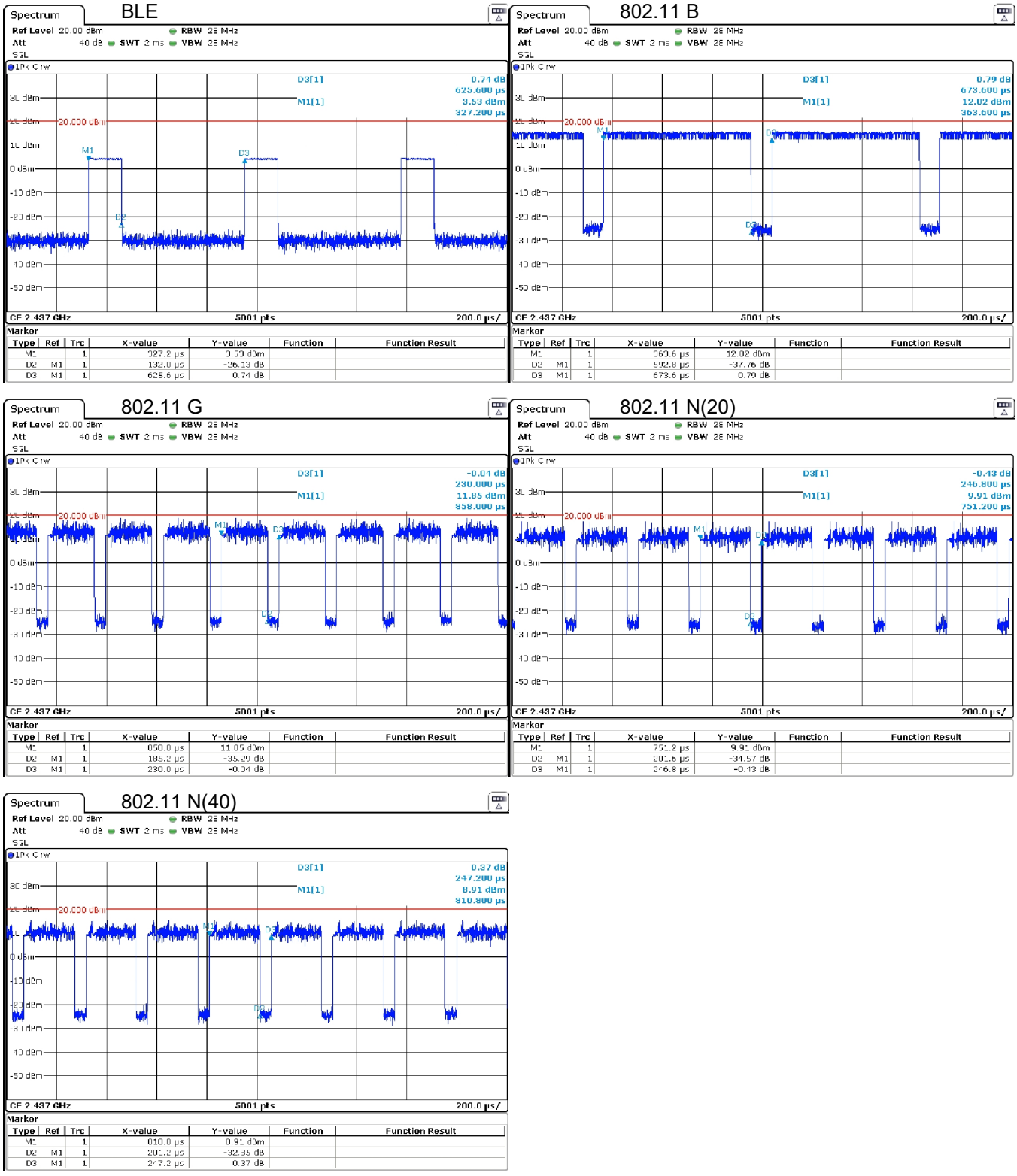


Figure 8: Pulsed Emission Characteristics (Duty Cycle).

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: 06/11/18
Test Engineer: Joseph Brunett
EUT GridConnect ESP32
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
BLE	1.0	3.3	2402.0	0.79	0.50	1.23	1.43	Pass
			2440.0	0.66	0.50	1.04	1.18	Pass
			2480.0	0.60	0.50	1.04	1.18	Pass
802.11b	11.0	3.3	2412.0	8.09	0.50	11.19	12.83	Pass
			2437.0	7.81	0.50	11.17	12.83	Pass
			2462.0	8.53	0.50	11.19	12.89	Pass
802.11g	54.0	3.3	2412.0	16.57	0.50	16.60	17.83	Pass
			2437.0	16.60	0.50	16.60	17.92	Pass
			2462.0	16.59	0.50	16.60	17.92	Pass
802.11n(20)	65.0	3.3	2412.0	17.35	0.50	17.53	18.70	Pass
			2437.0	17.41	0.50	17.56	18.75	Pass
			2462.0	17.41	0.50	17.56	18.67	Pass
802.11n(40)	135.0	3.3	2412.0	36.56	0.50	36.41	39.86	Pass
			2437.0	36.56	0.50	36.41	39.86	Pass
			2462.0	36.56	0.50	36.46	39.90	Pass

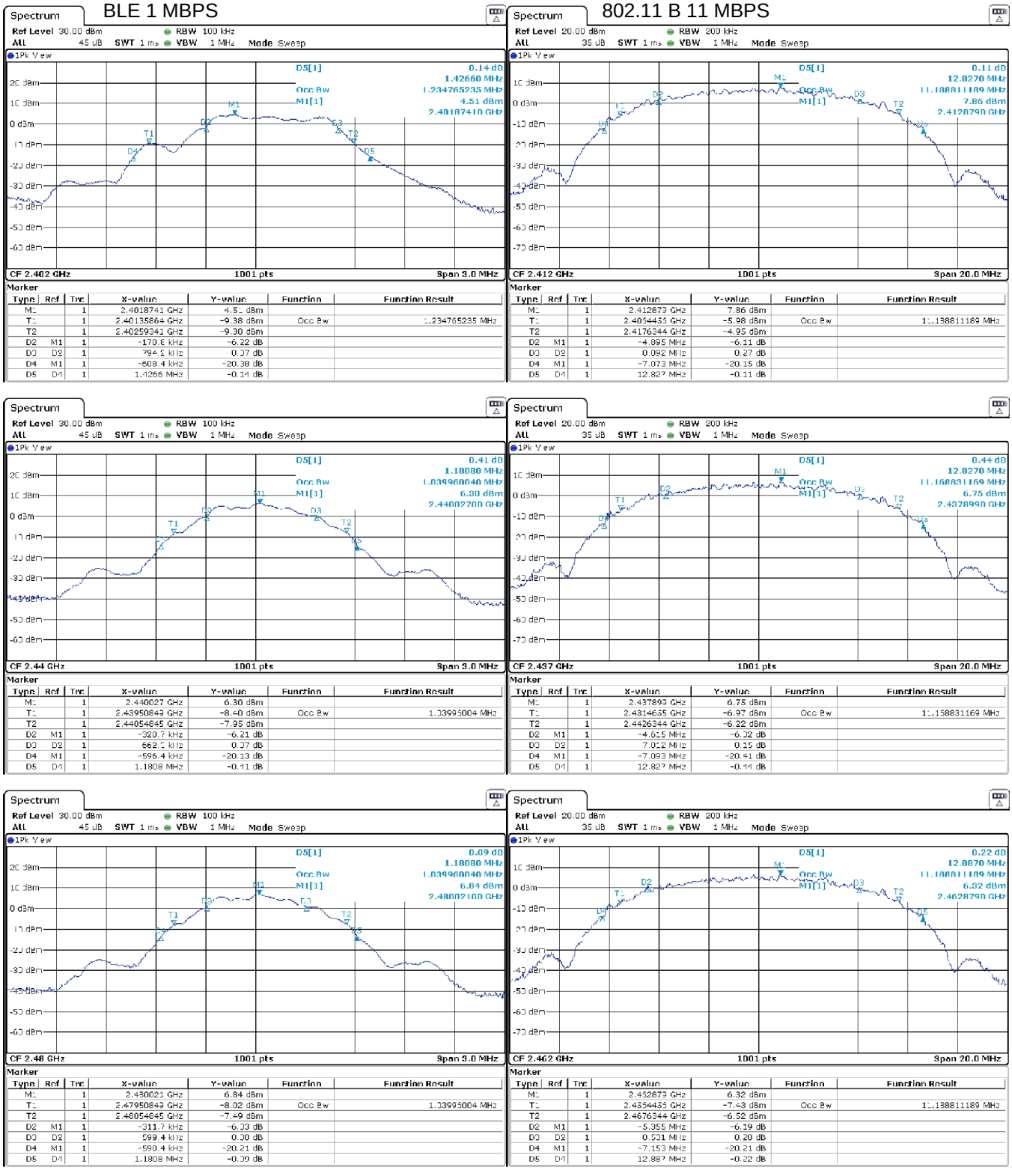


Figure 9(a): Intentional Emission Bandwidth.

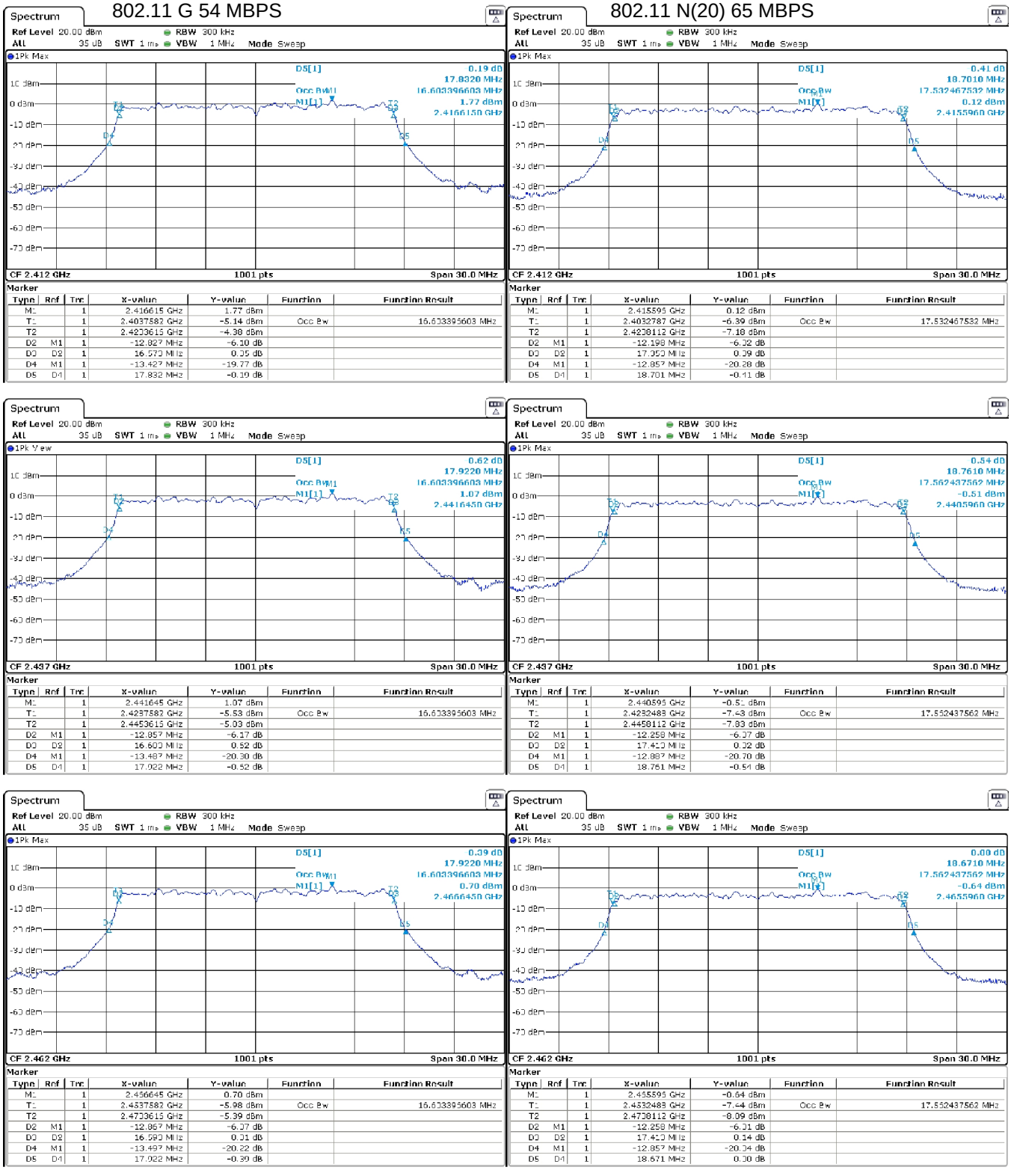
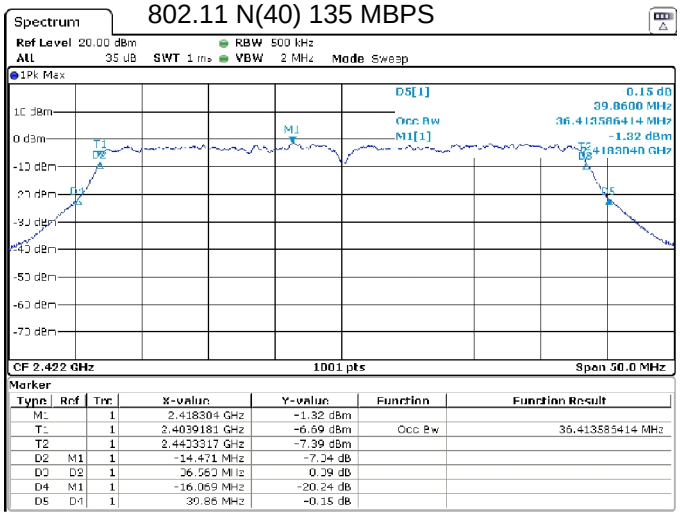
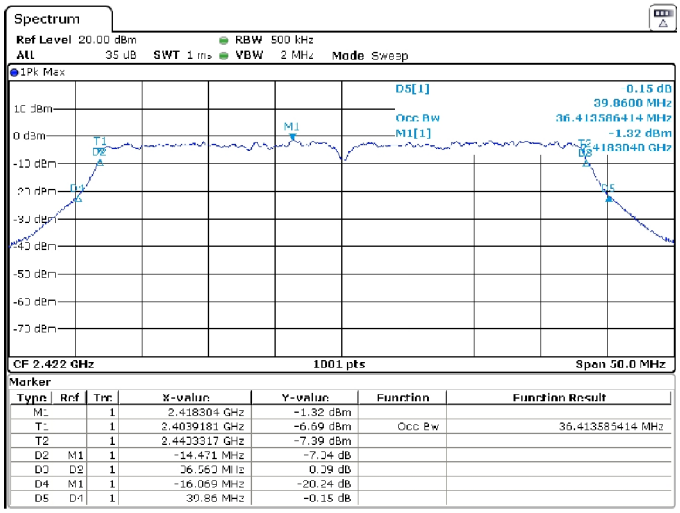


Figure 9(b): Intentional Emission Bandwidth.





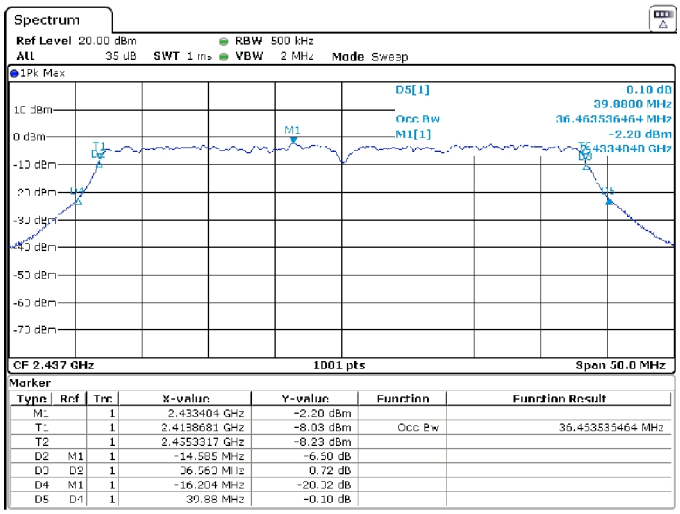


Figure 9(c): Intentional Emission Bandwidth.