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

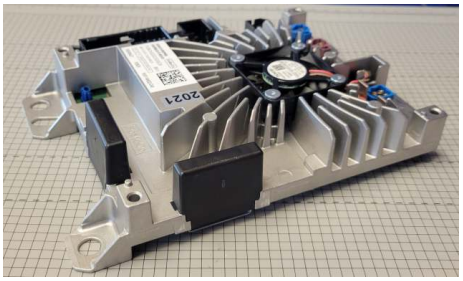
SG5PHX-WR2301NA2G
Issued: **February 27, 2023**

WLAN DTS Test Report

regarding

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

for



SG5PHX

Category: Vehicular Domain Controller

Judgments:
FCC 15.247, ISED RSS-247v2 Compliant
Testing Completed: February 27, 2023

TESTING
NVLAP LAB CODE 200129-0

Prepared for:

Ford Motor Company

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Date of Issue: February 27, 2023

Revision History

Rev. No.	Date	Details	Revised By
r0	February 27, 2023	Initial Release.	J. Brunett
r1	May 3, 2023	Updates per TCB comments.	J. Brunett
r2	May 31, 2023	Sum MIMO spur.	J. Brunett

Contents

List of Tables

List of Figures

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 March 2033.

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. Any data in this report that is not covered under the laboratory's scope is clearly identified.

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
EMI Receiver	R & S / ESW26	101313	RSESW2601	RS / October-2023
Spec. Analyzer 70GHz	Anritsu / MS2760A	1705006	ANMS2760A1	ANR / Sept-2023
Pk/Avg Pwr Mtr	BK Prec. / RFP3008	620C22101	BKPM300801	BK / Mar-2024
Power Meter	R & S / NRP50S	101087	RSNRP50	RS / Nov-2024

2 Test Specifications and Procedures

2.1 Test Specification and General Procedures

The goal of Ford Motor Company 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 Ford Motor Company SG5PHX 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"
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 "
KDB 662911 D01v02r01	"Emissions Testing of Transmitters with Multiple Outputs in the Same Band"
KDB 662911 D02 v01	"MIMO with Cross-Polarized Antenna"
TP0102RA	"AHD Internal Document TP0102 - Radiated Emissions Test Procedure"

3 Configuration and Identification of the Equipment Under Test

3.1 Description and Declarations

The equipment under test is a vehicle entertainment and information system containing Bluetooth, BLE, and 2x2 WiFi. The EUT is approximately 15 x 22 x 4 cm in dimension, and is depicted in Figure 1. It is powered by 13.5 VDC nominal vehicular power system. In use, this device is a vehicle entertainment module permanently installed into Ford motor vehicles. Table 3 outlines provider declared EUT specifications.

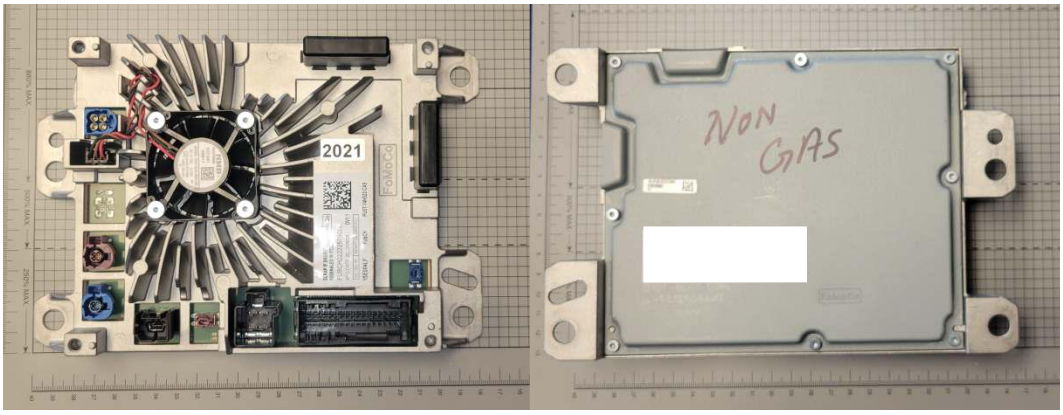


Figure 1: Photos of EUT.

Table 3: EUT Declarations.

General Declarations	
Equipment Type:	Vehicular Domain Controller
Country of Origin:	Not Declared
Nominal Supply:	13.5 VDC nominal
Oper. Temp Range:	-40^{o}C to $+75^{o}$C
Frequency Range:	BT/BLE/2G WLAN (2400 – 2483.5 MHz)
Antenna Dimension:	Integral
Antenna Type:	PCB Trace
Antenna Gain:	4.3 dBi max. (2400 – 2483.5 MHz)
Number of Channels:	2G WLAN, B/G/N20 (1-11)
Channel Spacing:	2G WLAN 5 MHz
Alignment Range:	Not Declared
Type of Modulation:	2G WLAN: 802.11 B,G (SISO), N(20)SISO+MIMO
United States	
FCC ID Number:	KMH-SG5PHX
Classification:	DTS
Canada	
IC Number:	1422A-SG5PHX
Classification:	Vehicle Entertainment/Network Device

3.1.1 EUT Configuration

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

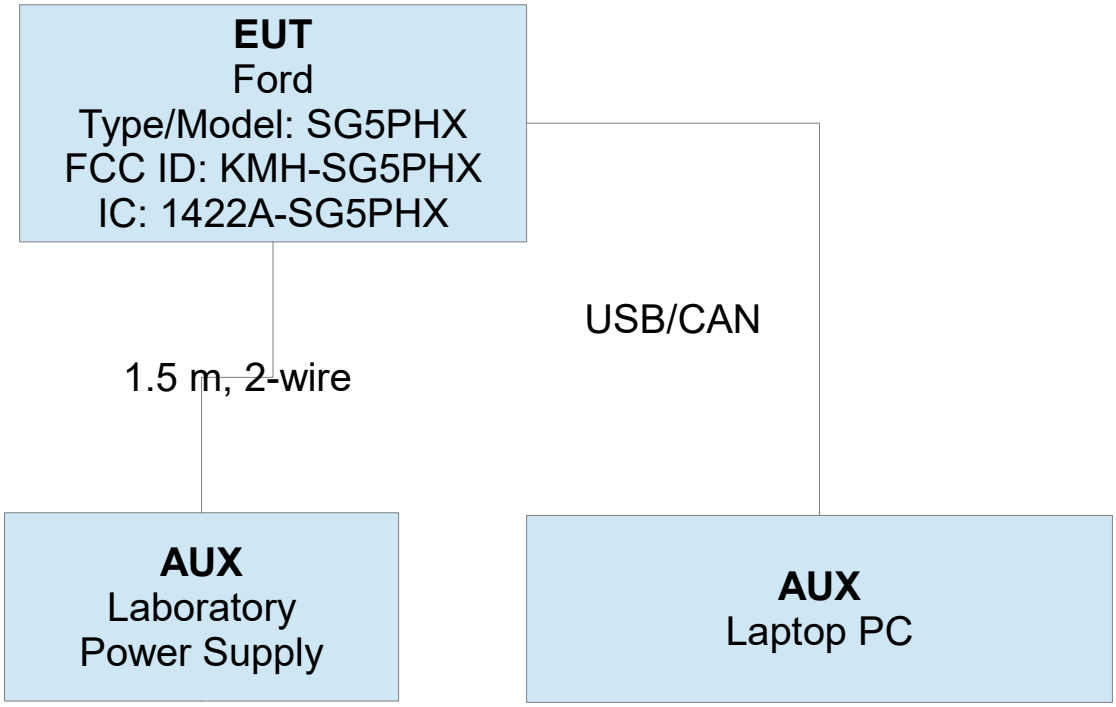


Figure 2: EUT Test Configuration Diagram.

3.1.2 Modes of Operation

The EUT employs two radio paths (PATH A and PATH B), over six modes (BT, BLE, 2G-BG-STA, 2G-N-STA, 5G-STA, 5G-AP). This report addresses only the following two modes: **MODE 2G-BG-STA**: In this mode the EUT operates as a 802.11B or 802.11G CLIENT ONLY radio in the 2.4-2.4835 GHz band. This mode only employs SISO PATH A or SISO PATH B, but not both simultaneously. **MODE 2G-N-STA**: In this mode the EUT operates as a 802.11N 20MHz channel CLIENT ONLY radio in the 2.4-2.4835 GHz band. This mode employs SISO PATH A, SISO PATH B, or MIMO PATH A + B.

3.1.3 Variants

There is only a single variant of the EUT, as tested.

3.1.4 Test Samples

Four samples of the EUT were provided in total, two normal (production ready) samples (SN: 2020, 2021) with integral antennas and two with the antennas replaced by coaxial cable connections (SN:2016, 1376). Each sample provided was capable of receiving radio instructions via CAN + USB interface to a personal computer. The manufacturer provided software tools and firmware need to place the EUT radio into test and normal operating modes.

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, conducted RF emissions pretesting indicated that the EUT power setting in 802.11g and 802.11n modes had to be set to a power rating of 15 dBm to remain in compliance with the band-edge restricted band limit at 2483.5 MHz. This power setting was selected by the manufacturer for final testing.

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 permanently installed in a transportation vehicle. As such, digital emissions are exempt from US and Canadian digital emissions regulations (per FCC 15.103(a) and IC correspondence on ICES-003). General spurious emissions (cabinet emissions with the EUT antenna ports terminated) are reported in the associated spurious emission test report for this product.

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.

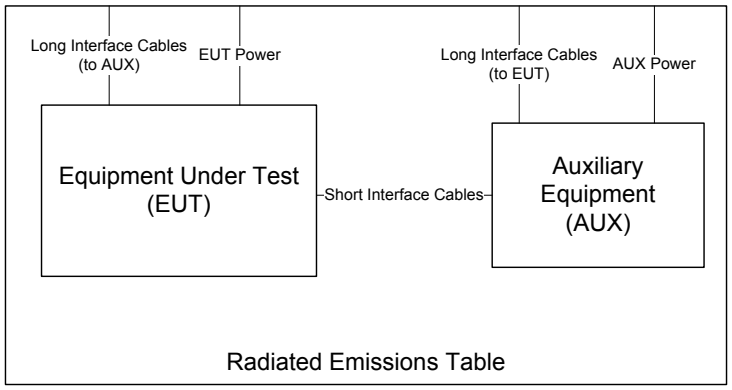


Figure 3: Radiated Emissions Diagram of the EUT.

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 regulation. Shielded loops are placed at a 1 meter receive height at the desired measurement distance. For exposure in this band, 10cm diameter single-axis broadband probes meeting the requirements of ISED SPR-002 section 5.2 are employed. Measurements are repeated and summed over three axes, and the entire frequency range is measured with and without the EUT transmitting.

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.

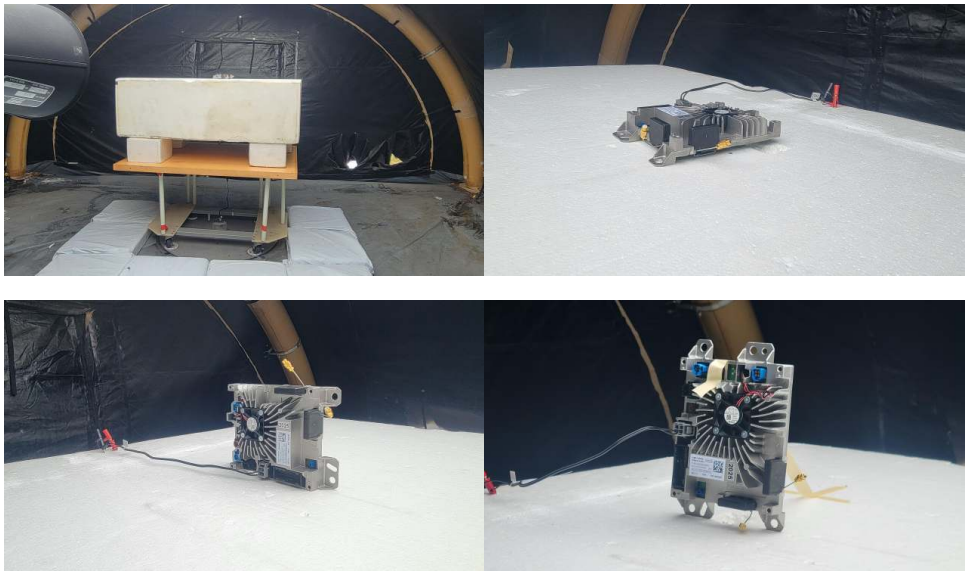


Figure 4: Radiated Emissions Test Setup Photograph(s).

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.

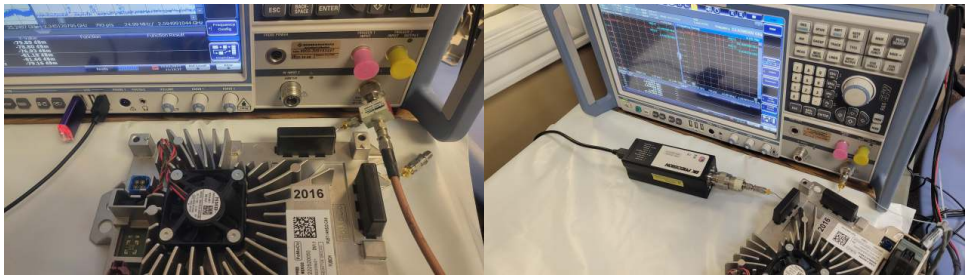


Figure 5: Conducted RF Test Setup Photograph(s).

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. Plots showing the measurements made to obtain these values are provided in Figure 6.

Table 4: Pulsed Emission Characteristics (Duty Cycle).

Test Date: 23-Feb-23
Test Engineer: Joseph Brunett
EUT Ford SG5PHX
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	802.11b SISO	1.0	13.4	2437.0	3.7120	3.8150	97	0.1
R2	802.11g SISO	6.0	13.4	2437.0	4.6300	4.7220	98	0.1
R3	802.11n(20) SISO	HT0	13.4	2437.0	3.8700	3.9700	97	0.1
R4	802.11n(20) MIMO	HT0	13.4	2412.0	0.6922	0.7928	87	0.6
#	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.

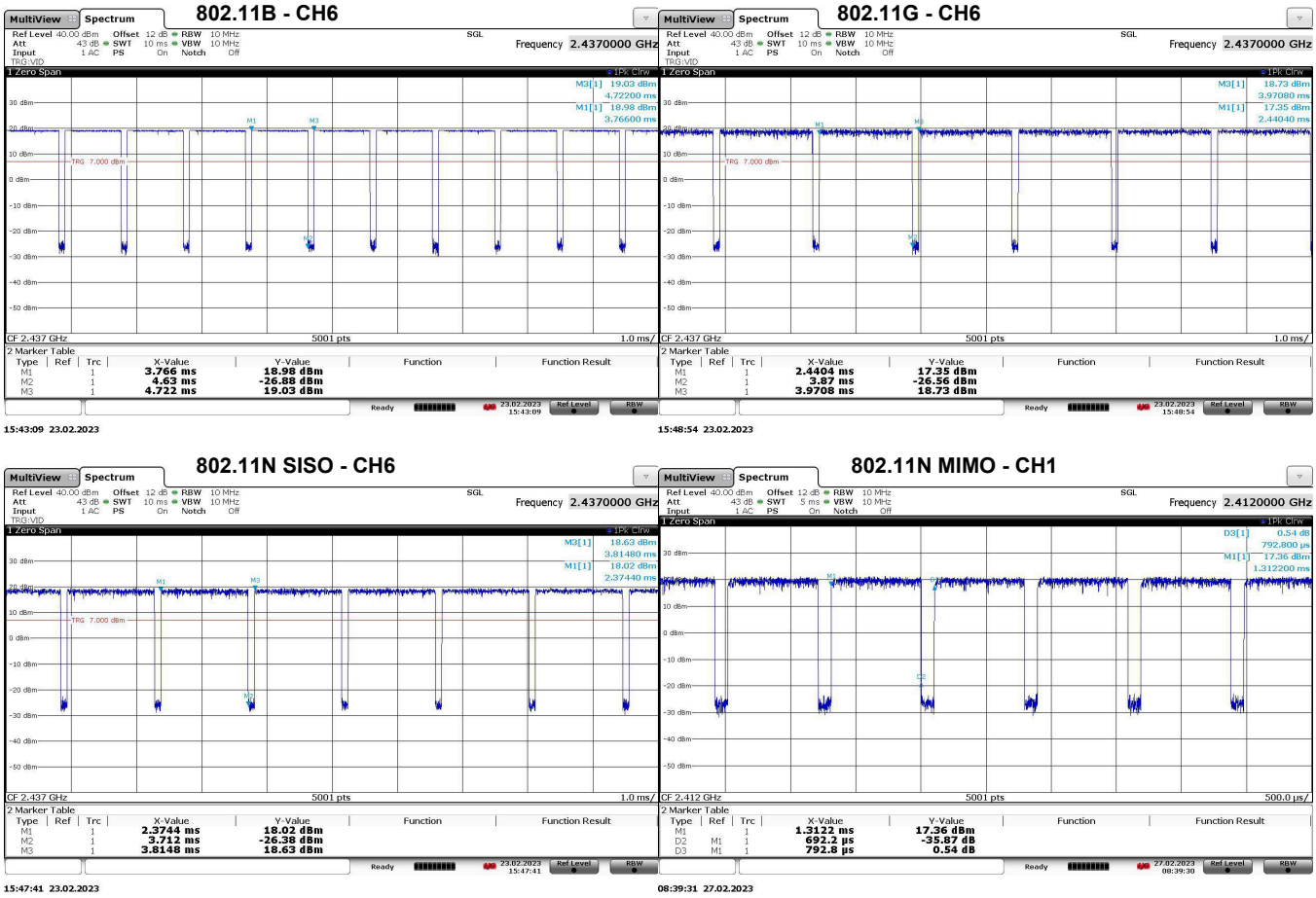


Figure 6: Example Pulsed Emission Characteristics (Duty Cycle).

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 7.

Table 5: Intentional Emission Bandwidth.

Test Date: 27-Feb-23
Test Engineer: Joseph Brunett
EUT Ford SG5PHX
Meas. Distance: Conducted

	Occupied Bandwidth								
#	Transmit Mode	Data Rate (Mbps)	Path A / B	Voltage (V)	Oper. Freq (MHz)	6 dB BW (MHz)	6 dB BW Limit (MHz)	99% OBW (MHz)	Pass/Fail
R1	802.11B SISO	1.0	A	13.4	2412.0	**7.94**	0.50	**12.06**	Pass
R2					2437.0	8.66	0.50	11.98	Pass
R3					2462.0	7.70	0.50	11.67	Pass
R4		1.0	B	13.4	2412.0	8.30	0.50	12.01	Pass
R5					2437.0	7.22	0.50	11.94	Pass
R6					2462.0	7.55	0.50	11.73	Pass
R7	802.11G SISO	6.0	A	13.4	2412.0	15.14	0.50	16.88	Pass
R8					2437.0	13.82	0.50	16.73	Pass
R9					2462.0	14.92	0.50	16.62	Pass
R10		6.0	B	13.4	2412.0	**15.05**	0.50	**16.89**	Pass
R11					2437.0	15.01	0.50	16.69	Pass
R12					2462.0	14.76	0.50	16.60	Pass
R13	802.11n(20) SISO	HT0	A	13.4	2412.0	15.11	0.50	17.42	Pass
R14					2437.0	15.16	0.50	17.39	Pass
R15					2462.0	15.05	0.50	17.40	Pass
R16		HT0	B	13.4	2412.0	15.17	0.50	17.41	Pass
R17					2437.0	15.37	0.50	17.63	Pass
R18					2462.0	15.02	0.50	17.39	Pass
R19	802.11n(20) MIMO	HT0	A	13.4	2412.0	**17.73**	0.50	**18.19**	Pass
R20					2437.0	16.33	0.50	18.00	Pass
R21					2462.0	15.97	0.50	17.78	Pass
R22		HT0	B	13.4	2412.0	17.32	0.50	18.00	Pass
R23					2437.0	16.45	0.50	17.86	Pass
R24					2462.0	15.96	0.50	17.45	Pass
#	C1	C2	C3	C4	C5	C6	C7	C8	C9

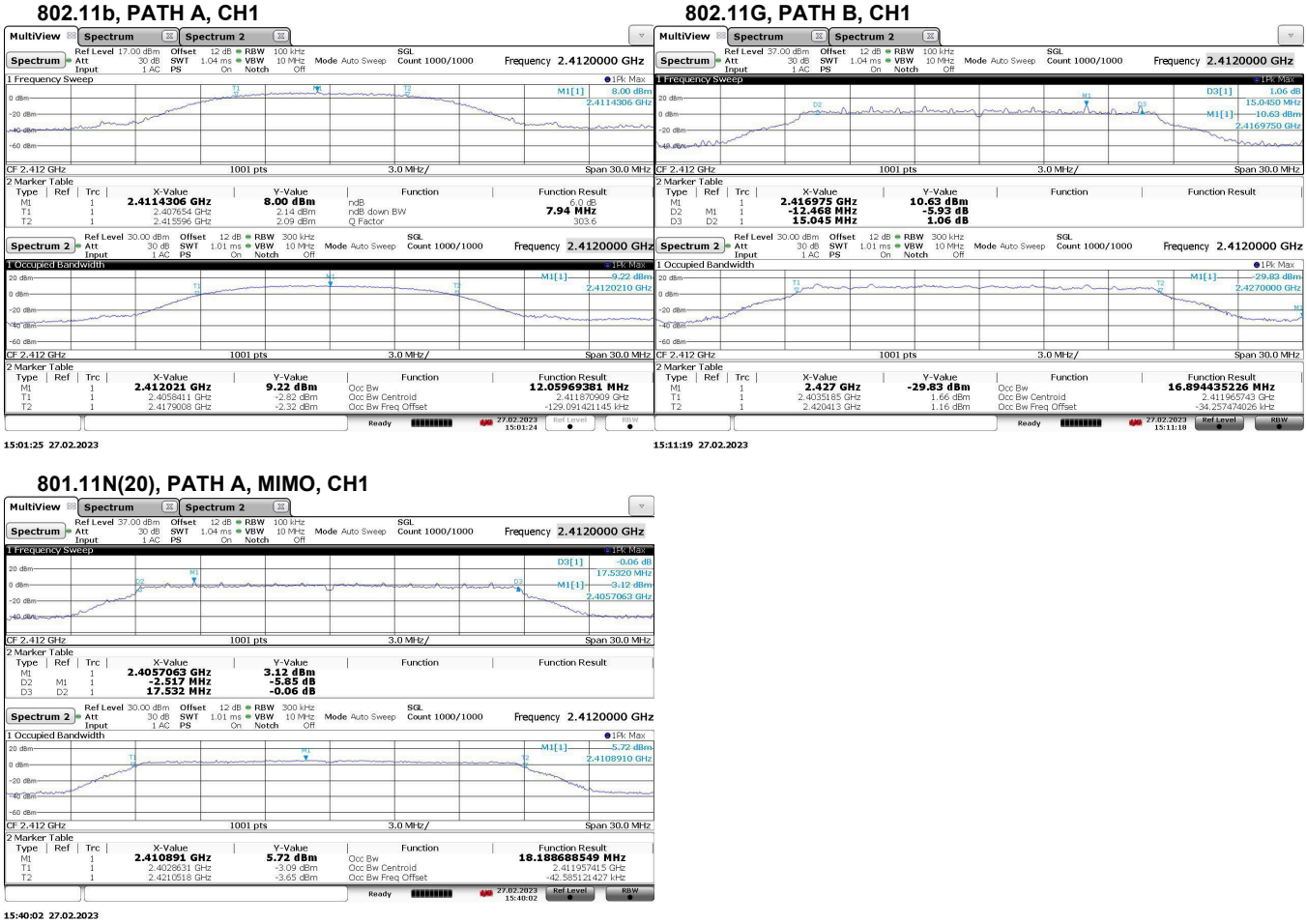


Figure 7: Example Intentional Emission Bandwidth Plots.

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:	1-Feb-23
Test Engineer:	Joseph Brunett
EUT:	Ford SG5PHX
Meas. Distance:	Conducted

	Fundamental Power												
#	Mode	Channel	Freq. MHz	Path A / B	Pout (Pk) meas. dBm	Pout (Avg) meas. dBm	Duty dB	Pout(Avg) + Duty dBm	Ant Gain dBi	EIRP (Pk) Calc. dBm	EIRP (Avg) Limit dBm	Pass dB	Comments
R1	802.11B SISO	1	2412.0	A	19.5	15.6	0.1	19.6	4.3	23.9	36.0	12.1	
R2		6	2437.0		20.0	16.3	0.1	20.1	4.3	24.4	36.0	11.6	
R3		11	2462.0		19.6	15.9	0.1	19.7	4.3	24.0	36.0	12.0	
R4		1	2412.0	B	20.5	16.6	0.1	20.6	4.3	24.9	36.0	11.1	
R5		6	2437.0		20.8	17.1	0.1	20.9	4.3	25.2	36.0	10.8	
R6		11	2462.0		20.2	16.6	0.1	20.3	4.3	24.6	36.0	11.4	
R7	802.11G SISO	1	2412.0	A	21.3	13.0	0.1	21.4	4.3	25.7	36.0	10.3	
R8		6	2437.0		21.7	13.8	0.1	21.8	4.3	26.1	36.0	9.9	
R9		11	2462.0		21.5	13.5	0.1	21.6	4.3	25.9	36.0	10.1	
R10		1	2412.0	B	22.7	14.4	0.1	22.8	4.3	27.1	36.0	8.9	
R11		6	2437.0		23.3	15.4	0.1	23.4	4.3	27.7	36.0	8.3	
R12		11	2462.0		23.4	15.4	0.1	23.5	4.3	27.8	36.0	8.2	
R13	802.11n(20) SISO	1	2412.0	A	21.1	13.0	0.1	21.2	4.3	25.5	36.0	10.5	
R14		6	2437.0		21.7	13.6	0.1	21.8	4.3	26.1	36.0	9.9	
R15		11	2462.0		21.6	13.3	0.1	21.7	4.3	26.0	36.0	10.0	
R16		1	2412.0	B	21.0	12.9	0.1	21.1	4.3	25.4	36.0	10.6	
R17		6	2437.0		20.9	12.8	0.1	21.0	4.3	25.3	36.0	10.7	
R18		11	2462.0		21.2	12.9	0.1	21.3	4.3	25.6	36.0	10.4	
R19	802.11n(20) MIMO	1	2412.0	A	21.3	13.2	0.6	21.9	4.3	26.2	36.0	9.8	
R20		6	2437.0		21.6	13.6	0.6	22.2	4.3	26.5	36.0	9.5	
R21		11	2462.0		21.7	13.4	0.6	22.3	4.3	26.6	36.0	9.4	
R22		1	2412.0	B	21.0	12.9	0.6	21.6	4.3	25.9	36.0	10.1	
R23		6	2437.0		21.7	13.7	0.6	22.3	4.3	26.6	36.0	9.4	
R24		11	2462.0		21.4	13.1	0.6	22.0	4.3	26.3	36.0	9.7	
R25		1	2412.0	A+B	24.2	16.1	0.6	24.8	4.3	29.1	36.0	6.9	
R26		6	2437.0		24.7	16.7	0.6	25.2	4.3	29.5	36.0	6.5	
R27		11	2462.0		24.6	16.3	0.6	25.2	4.3	29.5	36.0	6.5	
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13

ROW	COLUMN	
All	C6	Measured conducted from radio conducted sample. Avg Power measured per DTS Guidance 558074 D01 v5 r02 Section 8.3.2.2 / ANSI C63.10 11.9.2.3.1 (AVGPM)
All	C5	Measured conducted from radio conducted sample. Pk Power measured per DTS Guidance 558074 D01 v5 r02 Section 8.3.1.3 / ANSI C63.10 11.9.1.3 (PKPM1)
All	C9	Maximum Antenna Gain across Band. For MIMO, Gain = SISO Gain_dBi because MIMO completely uncorrelated.

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 8.

Table 7: Power Spectral Density Results.

Frequency Range	Detector	IF Bandwidth	Video Bandwidth		
2400-2483.5	Pk	3 kHz	10 kHz	**Test Date:**	26-Jan-23
				Test Engineer:	Joseph Brunett
				EUT:	Ford SG5PHX
				Meas. Distance:	Conducted

Power Spectral Density										
R0	Mode	Path A / B	Channel	Frequency (MHz)	Ant. Used	PK PSDcond (meas) (dBm/3kHz)	Duty (dB)	PSDcond (calc) (dBm/3kHz)	PSD Limit (dBm/3kHz)	Pass By (dB)
R1	802.11B SISO	A	1	2412.0	Cond.	-6.9		-6.9	8.00	14.9
R2			6	2437.0	Cond.	-5.6		-5.6	8.00	13.6
R3			11	2462.0	Cond.	-6.3		-6.3	8.00	14.3
R4		B	1	2412.0	Cond.	-5.8		-5.8	8.00	13.8
R5			6	2437.0	Cond.	-4.9		-4.9	8.00	**12.9**
R6			11	2462.0	Cond.	-5.5		-5.5	8.00	13.5
R7	802.11G SISO	A	1	2412.0	Cond.	-14.9		-14.9	8.00	22.9
R8			6	2437.0	Cond.	-14.5		-14.5	8.00	22.5
R9			11	2462.0	Cond.	-15.0		-15.0	8.00	23.0
R10		B	1	2412.0	Cond.	-14.4		-14.4	8.00	22.4
R11			6	2437.0	Cond.	-13.9		-13.9	8.00	**21.9**
R12			11	2462.0	Cond.	-15.0		-15.0	8.00	23.0
R13	802.11n(20) SISO	A	1	2412.0	Cond.	-9.1		-9.1	8.00	17.1
R14			6	2437.0	Cond.	-8.7		-8.7	8.00	16.7
R15			11	2462.0	Cond.	-8.0		-8.0	8.00	16.0
R16		B	1	2412.0	Cond.	-7.8		-7.8	8.00	15.8
R17			6	2437.0	Cond.	-7.1		-7.1	8.00	**15.1**
R18			11	2462.0	Cond.	-8.8		-8.8	8.00	16.8
R19	802.11n(20) MIMO	A	1	2412.0	Cond.	-7.3		-7.3	8.00	15.3
R20			6	2437.0	Cond.	-7.2		-7.2	8.00	**15.2**
R21			11	2462.0	Cond.	-7.1		-7.1	8.00	15.1
R22		B	1	2412.0	Cond.	-7.2		-7.2	8.00	15.2
R23			6	2437.0	Cond.	-7.1		-7.1	8.00	**15.1**
R24			11	2462.0	Cond.	-7.1		-7.1	8.00	15.1
R25		A+B	1	2412.0	Cond.	-5.4		-5.4	8.00	13.4
R26			6	2437.0	Cond.	-5.3		-5.3	8.00	13.3
R27			11	2462.0	Cond.	-5.1		-5.1	8.00	13.1
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10

ROW	COLUMN	
All	C6	PSD measured conducted following DTS guidance 558074 D01 v5 r02 8.4 / ANSI C63.10 11.10 PKPSD procedure.
All	C7	Not applicable for PKPSD measurements
R25-27	C8	Per 662911 D01 Multiple Transmitter Output v02r01, PSD linear sum of paths for MIMO operation

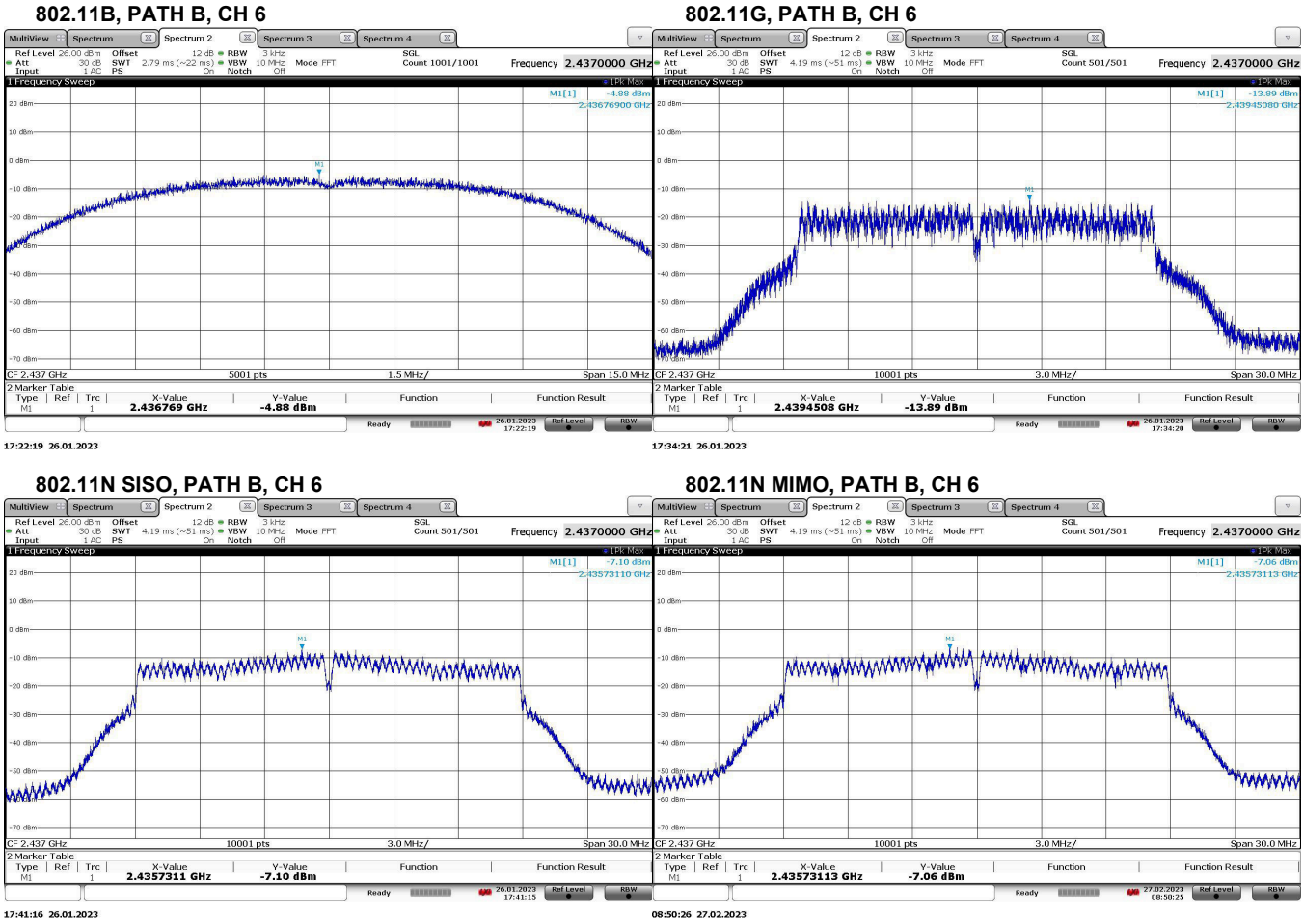


Figure 8: Power Spectral Density Plots.

4.3 Unintentional Emissions

4.3.1 Restricted Band Transmit Chain 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
30 >= f > 1000 MHz	Pk/QPk	100 kHz	300 kHz
f < 1000 MHz	Pk/Avg	1 MHz	3 MHz

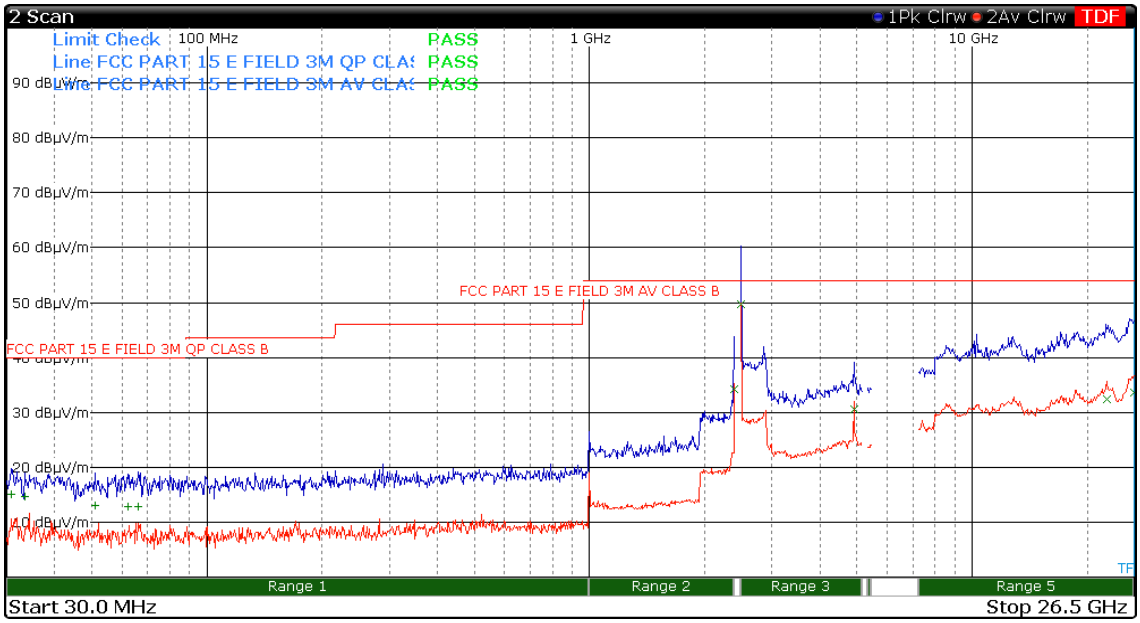
Test Date:	22-Feb-23
Test Engineer:	J. Brunett
EUT:	Ford SG5PHX
Meas. Distance:	Conducted

Transmitter Spurious in Restricted Bands FCC/IC

#	Mode	Path	Frequency Start	Frequency Stop	Output Power Pk	Output Power Avg	Ant Gain	GR Factor	Avg Duty Factor	Electric Field @ 3m Calc. Pk	Electric Field @ 3m Limit Pk	Electric Field @ 3m Calc. Avg	Electric Field @ 3m Limit Qpk/Avg	Pass	Comments
		A / B	MHz	MHz	dBm	dBm	dBi	dB	dB	dBuV/m	dBuV/m	dBuV/m	dBuV/m	dB	
R1	Fundamental Restricted Band Edge (Low Side)														
R2	802.11B	A	2390.0	2390.0	-46.8	-59.9	4.3	0.0	0.1	52.7	74.0	39.8	54.0	14.2	max all - L,M,H channels
R3	802.11B	B	2390.0	2390.0	-46.4	-57.6	4.3	0.0	0.1	53.1	74.0	42.1	54.0	**12.0**	max all - L,M,H channels
R4	Fundamental Restricted Band Edge (High Side)														
R5	802.11B	A	2483.5	2483.5	-47.1	-57.3	4.3	0.0	0.1	52.4	74.0	42.3	54.0	11.7	max all - L,M,H channels
R6	802.11B	B	2483.5	2483.5	-47.2	-57.6	4.3	0.0	0.1	52.3	74.0	42.0	54.0	**12.0**	max all - L,M,H channels
R7															
R8	802.11B	max	30	88	-84.8		4.3	4.7	0.1	19.4			40	20.6	max all - L,M,H channels
R9	802.11B	max	88	216	-80.8		4.3	4.7	0.1	23.4			43	19.6	max all - L,M,H channels
R10	802.11B	max	216	1000	-81.3		4.3	4.7	0.1	22.9			46	23.1	max all - L,M,H channels
R14	802.11B	max	1000.0	4000.0	-59.3	-68.5	4.3	0.0	0.1	40.2	75.0	31.1	55.0	23.9	max all - L,M,H channels
R15	802.11B	max	4824.0	4824.0	-58.3	-66.8	4.3	0.0	0.1	41.2	76.0	32.8	56.0	23.2	
R16	802.11B	max	4874.0	4874.0	-63.2	-75.9	4.3	0.0	0.1	36.3	77.0	23.7	57.0	33.3	
R17	802.11B	max	4924.0	4924.0	-62.3	-79.6	4.3	0.0	0.1	37.2	77.0	20.0	57.0	37.0	
R18	802.11B	max	4000.0	6000.0	-58.3	-66.8	4.3	0.0	0.1	41.2	74.0	32.8	54.0	21.2	max all - L,M,H channels
R19	802.11B	max	6000.0	8400.0	-60.3	-69.5	4.3	0.0	0.1	39.2	74.0	30.1	54.0	23.9	max all - L,M,H channels
R20	802.11B	max	8400.0	12500.0	-57.8	-67.6	4.3	0.0	0.1	41.7	74.0	32.0	54.0	22.0	max all - L,M,H channels
R21	802.11B	max	12500.0	26000.0	-56.0	-65.7	4.3	0.0	0.1	43.5	74.0	33.9	55.0	21.1	max all - L,M,H channels
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15

ROW	COLUMN	
All	C5/C6	Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6, 8.7 / ANSI C63.10 11.10, 11.11, 11.12
All	C8	Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)
All	C10/C12	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
30 >= f > 1000 MHz	Pk/QPk	100 kHz	300 kHz
f < 1000 MHz	Pk/Avg	1 MHz	3 MHz

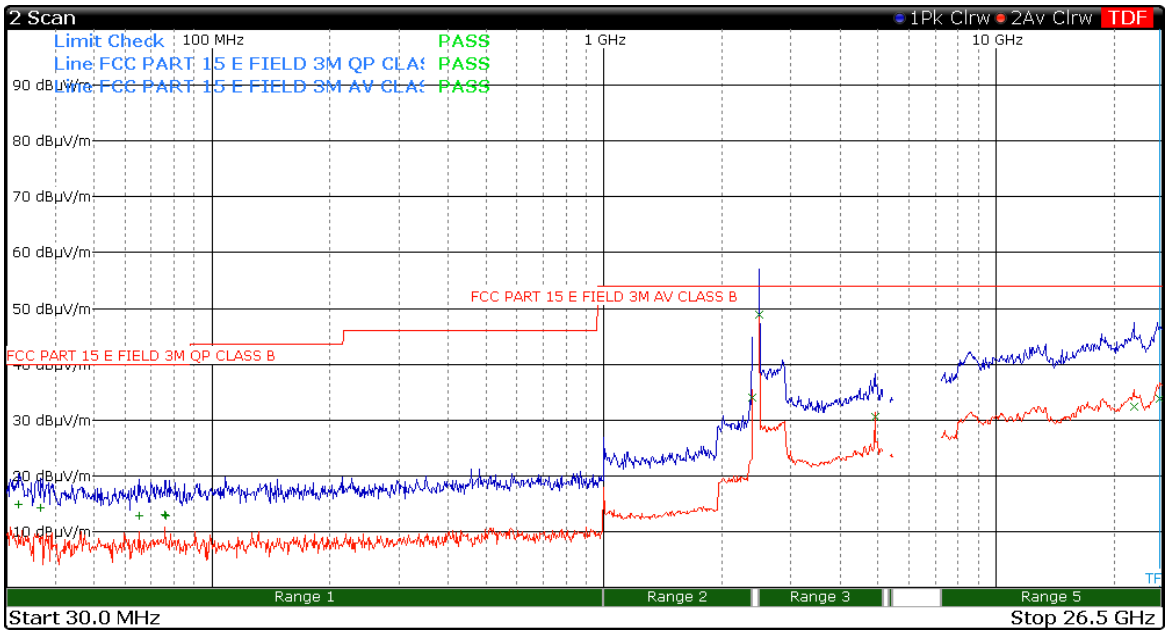
Test Date:	22-Feb-23
Test Engineer:	J. Brunett
EUT:	Ford SG5PHX
Meas. Distance:	Conducted

Transmitter Spurious in Restricted Bands FCC/IC

#	Mode	Path A / B	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 Calc. Pk dBuV/m	Electric Field @ 3m Limit Pk dBuV/m	Electric Field @ 3m Calc. Avg dBuV/m	Electric Field @ 3m Limit Qpk/Avg dBuV/m	Pass dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)														
R2	802.11G	A	2390.0	2390.0	-45.7	-55.8	4.3	0.0	0.1	53.8	74.0	43.8	54.0	10.2	max all - L,M,H channels
R3	802.11G	B	2390.0	2390.0	-48.1	-57.9	4.3	0.0	0.1	51.4	74.0	41.6	54.0	12.4	max all - L,M,H channels
R4	Fundamental Restricted Band Edge (High Side)														
R5	802.11G	A	2483.5	2483.5	-40.3	-49.9	4.3	0.0	0.1	59.2	74.0	49.7	54.0	**4.3**	max all - L,M,H channels
R6	802.11G	B	2483.5	2483.5	-43.7	-53.7	4.3	0.0	0.1	55.8	74.0	45.9	54.0	8.1	max all - L,M,H channels
R7															
R8	802.11G	max	30	88	-83.8		4.3	4.7	0.1	20.4			40	19.6	max all - L,M,H channels
R9	802.11G	max	88	216	-81.3		4.3	4.7	0.1	22.9			43	20.1	max all - L,M,H channels
R10	802.11G	max	216	1000	-82.6		4.3	4.7	0.1	21.6			46	24.4	max all - L,M,H channels
R14	802.11G	max	1000.0	4000.0	-59.3	-68.5	4.3	0.0	0.1	40.2	75.0	31.1	55.0	23.9	max all - L,M,H channels
R15	802.11G	max	4824.0	4824.0	-58.6	-66.7	4.3	0.0	0.1	40.9	76.0	32.9	56.0	23.1	
R16	802.11G	max	4874.0	4874.0	-60.6	-68.2	4.3	0.0	0.1	38.9	77.0	31.4	57.0	25.6	
R17	802.11G	max	4924.0	4924.0	-59.3	-69.0	4.3	0.0	0.1	40.2	77.0	30.6	57.0	26.4	
R18	802.11G	max	4000.0	6000.0	-58.6	-66.7	4.3	0.0	0.1	40.9	74.0	32.9	54.0	21.1	max all - L,M,H channels
R19	802.11G	max	6000.0	8400.0	-59.9	-69.5	4.3	0.0	0.1	39.6	74.0	30.1	54.0	23.9	max all - L,M,H channels
R20	802.11G	max	8400.0	12500.0	-58.1	-67.6	4.3	0.0	0.1	41.4	74.0	32.0	54.0	22.0	max all - L,M,H channels
R21	802.11G	max	12500.0	26000.0	-56.5	-65.7	4.3	0.0	0.1	43.0	74.0	33.9	55.0	21.1	max all - L,M,H channels
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15

ROW	COLUMN	
All	C5/C6	Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6, 8.7 / ANSI C63.10 11.10, 11.11, 11.12
All	C8	Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)
All	C10/C12	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
30 >= f > 1000 MHz	Pk/QPk	100 kHz	300 kHz
f < 1000 MHz	Pk/Avg	1 MHz	3 MHz

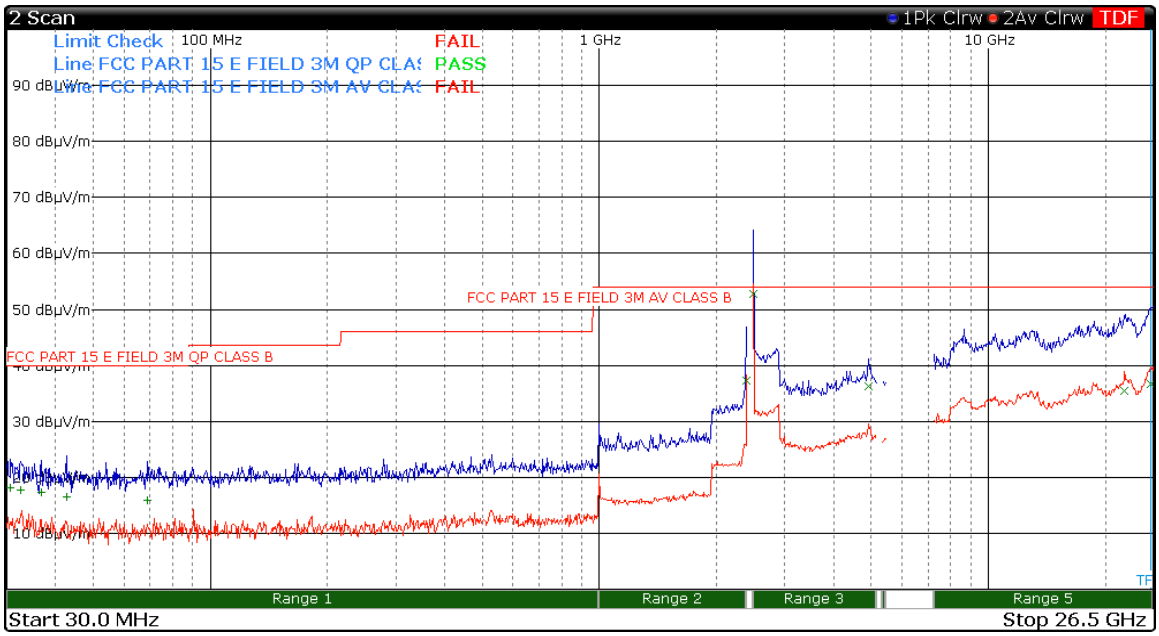
Test Date:	22-Feb-23
Test Engineer:	J. Brunett
EUT:	Ford SG5PHX
Meas. Distance:	Conducted

Transmitter Spurious in Restricted Bands FCC/IC

#	Mode	Path A / B	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 Calc. Pk dBuV/m	Electric Field @ 3m Limit Pk dBuV/m	Electric Field @ 3m Calc. Avg dBuV/m	Electric Field @ 3m Limit Qpk/Avg dBuV/m	Pass dB	Comments
R1	Fundamental Restricted Band Edge (Low Side)														
R2	802.11n(20) SISO	A	2390.0	2390.0	-44.3	-54.1	4.3	0.0	0.1	55.2	74.0	45.5	54.0	8.5	max all - L,M,H channels
R3	802.11n(20) SISO	B	2390.0	2390.0	-46.7	-56.8	4.3	0.0	0.1	52.8	74.0	42.9	54.0	11.2	max all - L,M,H channels
R4	Fundamental Restricted Band Edge (High Side)														
R5	802.11n(20) SISO	A	2483.5	2483.5	-40.7	-50.8	4.3	0.0	0.1	58.8	74.0	48.8	54.0	**5.2**	max all - L,M,H channels
R6	802.11n(20) SISO	B	2483.5	2483.5	-47.7	-57.0	4.3	0.0	0.1	51.8	74.0	42.7	54.0	11.4	max all - L,M,H channels
R7															
R8	802.11n(20) SISO	max	30	88	-83.8		4.3	4.7	0.1	20.4			40	19.6	max all - L,M,H channels
R9	802.11n(20) SISO	max	88	216	-81.3		4.3	4.7	0.1	22.9			43	20.1	max all - L,M,H channels
R10	802.11n(20) SISO	max	216	1000	-82.6		4.3	4.7	0.1	21.6			46	24.4	max all - L,M,H channels
R14	802.11n(20) SISO	max	1000.0	4000.0	-59.3	-68.5	4.3	0.0	0.1	40.2	75.0	31.1	55.0	23.9	max all - L,M,H channels
R15	802.11n(20) SISO	max	4824.0	4824.0	-58.6	-66.6	4.3	0.0	0.1	40.9	76.0	33.0	56.0	23.0	
R16	802.11n(20) SISO	max	4874.0	4874.0	-60.6	-68.4	4.3	0.0	0.1	38.9	77.0	31.2	57.0	25.8	
R17	802.11n(20) SISO	max	4924.0	4924.0	-59.3	-69.0	4.3	0.0	0.1	40.2	77.0	30.6	57.0	26.4	
R18	802.11n(20) SISO	max	4000.0	6000.0	-58.6	-66.6	4.3	0.0	0.1	40.9	74.0	33.0	54.0	21.0	max all - L,M,H channels
R19	802.11n(20) SISO	max	6000.0	8400.0	-60.3	-69.5	4.3	0.0	0.1	39.2	74.0	30.1	54.0	23.9	max all - L,M,H channels
R20	802.11n(20) SISO	max	8400.0	12500.0	-57.5	-67.6	4.3	0.0	0.1	42.0	74.0	32.0	54.0	22.0	max all - L,M,H channels
R21	802.11n(20) SISO	max	12500.0	26000.0	-56.6	-65.7	4.3	0.0	0.1	42.9	74.0	33.9	55.0	21.1	max all - L,M,H channels
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15

ROW	COLUMN	
All	C5/C6	Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6, 8.7 / ANSI C63.10 11.10, 11.11, 11.12
All	C8	Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)
All	C10/C12	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
30 >= f > 1000 MHz	Pk/QPk	100 kHz	300 kHz
f < 1000 MHz	Pk/Avg	1 MHz	3 MHz

Test Date:	22-Feb-23
Test Engineer:	J. Brunett
EUT:	Ford SG5PHX
Meas. Distance:	Conducted

Transmitter Spurious in Restricted Bands FCC/IC

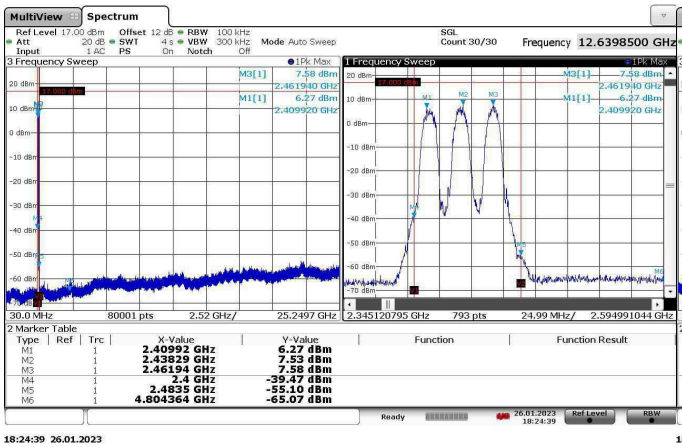
#	Mode	Path	Frequency Start	Frequency Stop	Output Power Pk	Output Power Avg	Ant Gain	GR Factor	Avg Duty Factor	Electric Field @ 3m Calc. Pk	Electric Field @ 3m Limit Pk	Electric Field @ 3m Calc. Avg	Electric Field @ 3m Limit Qpk/Avg	Pass	Comments
		A / B	MHz	MHz	dBm	dBm	dBi	dB	dB	dBuV/m	dBuV/m	dBuV/m	dBuV/m	dB	
R1	Fundamental Restricted Band Edge (Low Side)														
R2	802.11n(20) MIMO	A	2390.0	2390.0	-44.6	-54.4	4.3	0.0	0.6	57.5	74.0	48.0	54.0	6.0	max all - L,M,H channels
R3	802.11n(20) MIMO	B	2390.0	2390.0	-45.4	-55.9	4.3	0.0	0.6		74.0		54.0		max all - L,M,H channels
R4	Fundamental Restricted Band Edge (High Side)														
R5	802.11n(20) MIMO	A	2483.5	2483.5	-39.7	-50.3	4.3	0.0	0.6	61.0	74.0	51.2	54.0	**2.8**	max all - L,M,H channels
R6	802.11n(20) MIMO	B	2483.5	2483.5	-44.6	-54.4	4.3	0.0	0.6		74.0		54.0		max all - L,M,H channels
R7															
R8	802.11n(20) MIMO	A+B	30	88	-83.3		4.3	4.7	0.6	20.9			40	19.1	max all - L,M,H channels
R9	802.11n(20) MIMO	A+B	88	216	-81.6		4.3	4.7	0.6	22.6			43	20.4	max all - L,M,H channels
R10	802.11n(20) MIMO	A+B	216	1000	-83.1		4.3	4.7	0.6	21.1			46	24.9	max all - L,M,H channels
R14	802.11n(20) MIMO	A+B	1000.0	4000.0	-62.3	-72.0	4.3	0.0	0.6	37.2	75.0	28.1	55.0	26.9	max all - L,M,H channels
R15	802.11n(20) MIMO	A+B	4824.0	4824.0	-61.6	-70.1	4.3	0.0	0.6	37.9	76.0	30.0	56.0	26.0	
R16	802.11n(20) MIMO	A+B	4874.0	4874.0	-63.6	-75.7	4.3	0.0	0.6	35.9	77.0	24.4	57.0	32.6	
R17	802.11n(20) MIMO	A+B	4924.0	4924.0	-62.3	-71.7	4.3	0.0	0.6	37.2	77.0	28.4	57.0	28.6	
R18	802.11n(20) MIMO	A+B	4000.0	6000.0	-61.6	-70.1	4.3	0.0	0.6	37.9	74.0	30.0	54.0	24.0	max all - L,M,H channels
R19	802.11n(20) MIMO	A+B	6000.0	8400.0	-62.6	-73.0	4.3	0.0	0.6	36.9	74.0	27.1	54.0	26.9	max all - L,M,H channels
R20	802.11n(20) MIMO	A+B	8400.0	12500.0	-60.5	-71.1	4.3	0.0	0.6	39.0	74.0	29.0	54.0	25.0	max all - L,M,H channels
R21	802.11n(20) MIMO	A+B	12500.0	26000.0	-57.1	-67.7	4.3	0.0	0.6	42.4	74.0	32.4	55.0	22.6	max all - L,M,H channels
#	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15

ROW	COLUMN	
All	C5/C6	Conducted measurements were made in line with DTS guidance 558074 D01 v5 r02 sections 8.5, 8.6, 8.7 / ANSI C63.10 11.10, 11.11, 11.12
All	C7	MIMO paths uncorrelated, MIMO Antenna Gain = SISO Antenna Gain
All	C8	Ground Reflection Factor as described in ANSI C63.10-2013 section 11.12.2.2 (c)
All	C10/C12	Computed according to ANSI C63.10-2013 section 11.12.2.2 (e), summed per 11.12.2.2 (d)

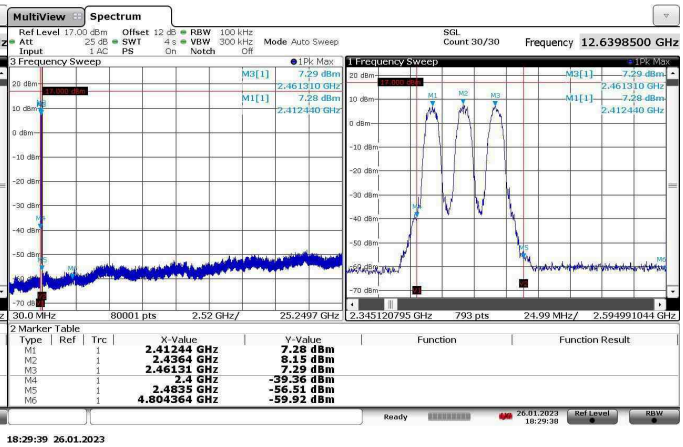
4.3.2 OOB Transmit Chain Spurious Emissions

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) in the worst cases are provided in Figure 9 below.

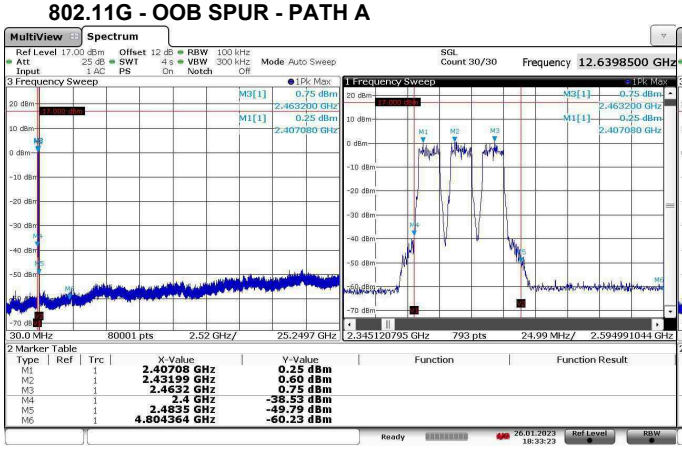
802.11B - OOB SPUR - PATH A



802.11B - OOB SPUR - PATH B



802.11G - OOB SPUR - PATH A



802.11G - OOB SPUR - PATH B

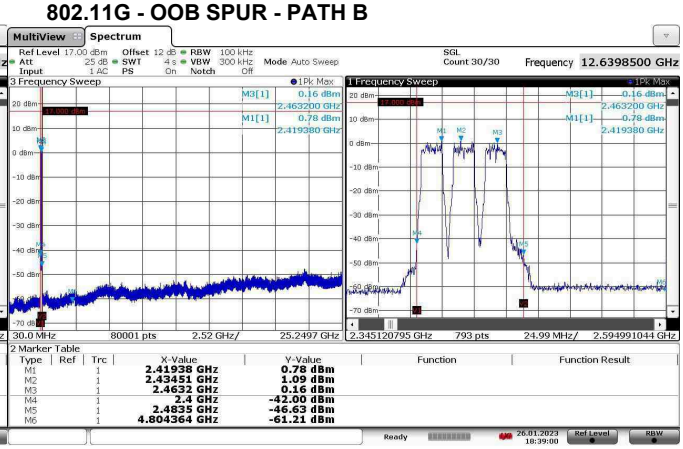
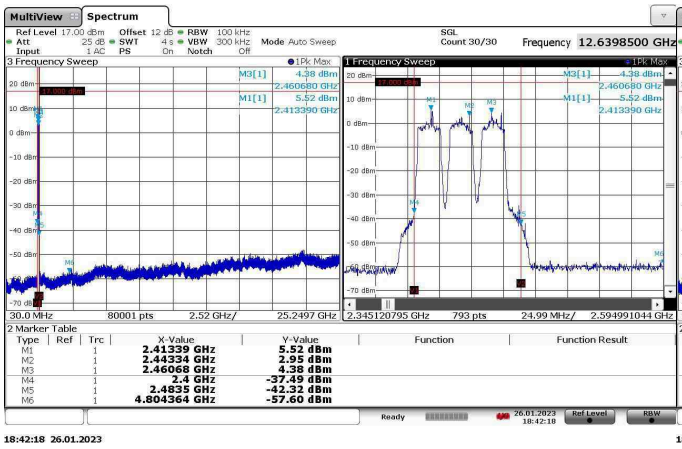
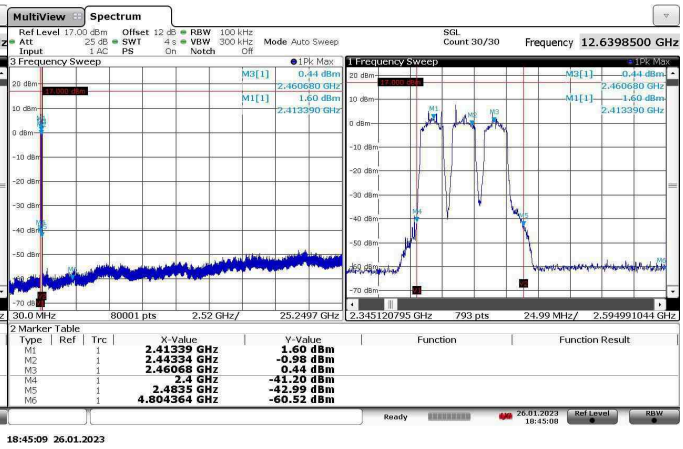


Figure 9(a): Worst Case Transmitter OOB Emissions Measured.

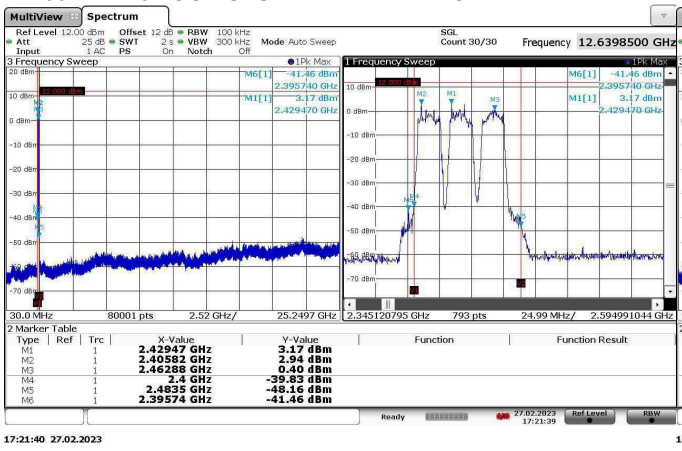
802.11N20 - OOB SPUR - PATH A - SISO



802.11N20 - OOB SPUR - PATH B - SISO



802.11N20 - OOB SPUR - PATH A - MIMO



802.11N20 - OOB SPUR - PATH B - MIMO

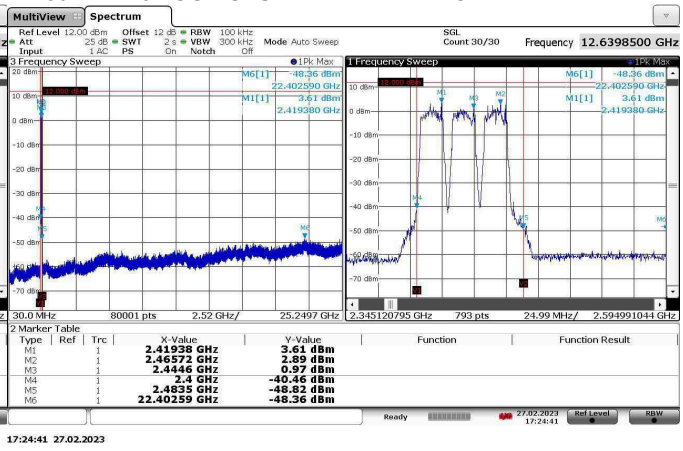


Figure 9(b): Worst Case Transmitter OOB Emissions Measured.

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 9: 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).

2022-06-28 through 2023-06-30
Effective Dates

For the National Voluntary Laboratory Accreditation Program

Figure 10: Accreditation Documents