

Test Report # 319384 A

Equipment Under Test: Radio Apparatus

Test Date(s): 8/10/2020 – 2/11/2021

Prepared for: Vermeer Manufacturing Company
Attn: Ty Gross
1716 Vermeer Rd East
Pella, IA 50219

Report Issued by: Shane Dock, EMC Engineer

Signature:



Date: 2/12/2020

Report Reviewed by: Adam Alger, Quality Manager

Signature: 

Date: 11/5/2020

Report Constructed by: Shane Dock, EMC Engineer

Signature:



Date: 9/24/2020

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CONTENTS

Contents.....	2
Laird Connectivity Test Services in Review	3
1 Test Report Summary	4
2 Client Information	5
2.1 Equipment Under Test (EUT) Information	5
2.2 Product Description	5
2.3 Modifications Incorporated for Compliance.....	5
2.4 Deviations and Exclusions from Test Specifications	5
2.5 Additional Information.....	5
2.6 Antenna Information	6
3 References	7
4 Uncertainty Summary	8
5 Test Data	9
5.1 Antenna Port Conducted Emissions.....	9
5.2 Radiated Emissions	36
5.3 AC Mains Conducted Emissions	45
6 Revision History	48

Laird Connectivity Test Services in Review

The Laird Connectivity, Inc. laboratory located at W66 N220 Commerce Court Cedarburg, Wisconsin, 53012 USA is recognized through the following organizations:



A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025:2017 with Electrical (EMC) Scope

A2LA Certificate Number: 1255.01

Scope of accreditation includes all test methods listed herein unless otherwise noted



Federal Communications Commission (FCC) – USA

Accredited Test Firm Registration Number: 953492

Recognition of two 3 meter Semi-Anechoic Chambers



Innovation, Science and Economic Development Canada

Accredited U.S. Identification Number: US0218

Recognition of two 3 meter Semi-Anechoic Chambers

Company: Vermeer Manufacturing Company	Page 3 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2

1 TEST REPORT SUMMARY

During **8/10/2020 – 2/12/2021** the Equipment Under Test (EUT), **Radio Apparatus**, as provided by **Vermeer Manufacturing Company** was tested to the following requirements:

Requirement	Description	Specification	Method	Result
FCC: 15.247 (a)(1) IC: RSS-247 5.1	Channel Separation, Number of Hopping frequencies, Time of Occupancy	FHSS	ANSI C63.10	Compliant
FCC: 2.1049 IC: RSS-GEN 6.7	Occupied Bandwidth	Reported	ANSI C63.10	Reported
FCC: 15.247 (b)(1) IC: RSS-247 5.4 (b)	Maximum Conducted Output Power	30 dBm	ANSI C63.10	Compliant
FCC: 15.247 (d) IC: RSS-247 5.5	RF Spurious Emissions at the Transmitter Antenna Terminal	20 dBc	ANSI C63.10	Compliant
FCC: 15.247 (d) IC: RSS-GEN 8.10	Spurious Radiated Emissions in Restricted Bands	FCC 15.209 RSS-GEN 8.9	ANSI C63.10	Compliant
FCC: 2.1055 (d) IC: RSS-GEN 6.11	Frequency Stability	Reported	ANSI C63.10	Compliant
FCC: 15.207 IC: RSS-GEN 8.8	Conducted AC Mains Emissions	Class B	ANSI C63.10	Compliant

Notice:

The results relate only to the item tested as configured and described in this report. Any additional configurations, modes of operation, or modifications made to the equipment under test after the specified test date(s) are at the decision of the client and may not apply to the data seen in this test report.

The decision rule for Pass / Fail assessment to the specification or standard listed in this test report has been agreed upon by the client and laboratory to be as follows:

Measurement Type	Rule
Emissions – Amplitude	2 dB below specified limit
Emissions – Frequency	1% less than the specification
Immunity	Tested at specified level

2 CLIENT INFORMATION

Company Name	Vermeer Corporation
Contact Person	Ty Gross
Address	1716 Vermeer Rd East Pella, IA 50219

2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

Product Name	Radio Apparatus
Model Number	VERMEER1
Serial Number	Engineering Samples
FCC/ISED ID:	FCC ID: 2AXF5-VERMEER1 IC: 26431-VERMEER1

2.2 Product Description

The Radio Apparatus is a 2.4 GHz Frequency Hopping Spread Spectrum (FHSS) Wireless Module used in OEM Host applications.

2.3 Modifications Incorporated for Compliance

None noted at time of test

2.4 Deviations and Exclusions from Test Specifications

None noted at time of test

2.5 Additional Information

The EUT is a module facilitated using a devkit (model: DVK-RM024-CE) powered by 120 VAC, 60 Hz. The Radio Apparatus houses a proprietary frequency hopping 2.4 GHz radio that operates from 2404 – 2466.9 MHz. Unit tested in the low mid, and high channels as shown below, and in the hopping mode as required for each test. Unit tested with a set of channels comprising 43 channels with 280kHz and 500 kHz data rates.

Low – 2404 MHz
Mid – 2435.5 MHz
High – 2466.9 MHz

Company: Vermeer Manufacturing Company	Page 5 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2

2.6 Antenna Information

This EUT was tested with a cabinet radiation method assuming a worst-case antenna gain of 4.6 dBi in accordance with FCC guidance.

The following antennas are to be used with this device:

Laird Connectivity TRA6927M3PBN-001 - Phantom 4.6dBi

PCTEL PCTCN24005 - Collinear 4.5dBi

Laird Connectivity TRAB24003P - Phantom 3.0 dBi

PCTEL BMLPV2400NGP - Phantom 3.0 DBi

Nearson S181FL-5(178)-PX-2450 - Half-Wave Dipole 2.0 dBi

Laird Connectivity MAF94045 - PCB Trace 2.0 dBi

Molex 2.4/5GHz Balance Flex Antenna – 3.0 dBi at 2.4 GHz

2.7 Duty Cycle Correction

Per the manufacturer of the Radio Apparatus, this device features a duty cycle of 9.47% in its normal operation. A duty cycle correction factor of 20.5 dB was used to adjust peak measurements for compare against the average limits (Factor derived from Report FR822301-03 for the RM024).

Company: Vermeer Manufacturing Company	Page 6 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2

3 REFERENCES

Publication	Edition	Date	AMD 1
FCC Title 47	-	2020	-
ANSI C63.10	-	2013	-
RSS-247	2	2017	-
RSS-GEN	5	2014	2019

4 UNCERTAINTY SUMMARY

Using the guidance of the following publications the calculated measurement uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of $k = 2$.

References	Version / Date
CISPR 16-4-1	Ed. 2 (2009-02)
CISPR 16-4-2	Ed. 2 (2011-06)
CISPR 32	Ed. 1 (2012-01)
ANSI C63.23	2012
A2LA P103	February 4, 2016
A2LA P103c	August 10, 2015
ETSI TR 100-028	V1.3.1 (2001-03)

Measurement Type	Configuration	Uncertainty $\pm$
Radiated Emissions	Biconical Antenna	5.0 dB
Radiated Emissions	Log Periodic Antenna	5.3 dB
Radiated Emissions	Horn Antenna	4.7 dB
AC Line Conducted Emissions	Artificial Mains Network	3.4 dB
Telecom Conducted Emissions	Asymmetric Artificial Network	4.9 dB
Disturbance Power Emissions	Absorbing Clamp	4.1 dB
Radiated Immunity	3 Volts/meter	2.2 dB
Conducted Immunity	CDN/EM/BCI	2.4/3.5/3.4 dB
EFT Burst/Surge	Peak pulse voltage	164 volts
ESD Immunity	15 kV level	1377 Volts

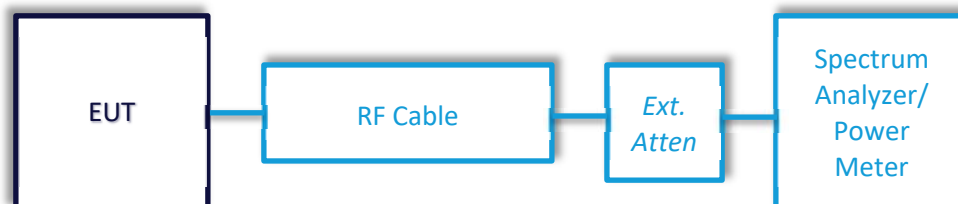
Parameter	ETSI U.C. $\pm$	U.C. $\pm$
Radio Frequency, from F0	1×10^{-7}	0.55×10^{-7}
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
Supply voltages	3 %	1 %

5 TEST DATA

Antenna Port Conducted Emissions

Description of Measurement	The direct measurement of emissions at the antenna port of the EUT is achieved by use of a RF connection to a spectrum analyzer or power meter. The cable and attenuator factors are loaded into the analyzer or power meter allowing for direct measurement readings without the need for further corrections.
Example Calculations	Measurement (dBm) + Cable factor (dB) + External Attenuator (dB) = Corrected Reading (dBm) Peak Corrected Reading (dBm) - Duty cycle correction factor (dB) + Ground Reflection factor (dB, if applicable) = Average Corrected Reading (dBm) Margin (dB) = Limit (dBm) – Corrected Reading (dBm)

Block Diagram



5.1.1 Antenna Port Conducted Emissions

Operator	Jon Dilley, Anthony Smith	QA	Shane Dock
Temperature	22.6°C	R.H. %	51.70%
Test Date	8/21/2020 – 1/15/2021	Location	Conducted RF Bench
Requirement	FCC Part 15.247	Method	ANSI C63.10 Sections 6.8, 6.9, 7.8.2, 7.8.3, 7.8.4, 7.8.5, 7.8.6, 7.8.8

Limits:

Frequency Separation	Number of Hopping Channels	Maximum Occupancy Time
>25 kHz or 20 dB Bandwidth	>15	0.4 seconds per 17.2 second period

Maximum Conducted Output Power (watts)	Maximum Conducted Output Power (dBm)
1	30

RF Spurious Limit
20 dBc

Frequency Stability Limit
<100 ppm

Test Parameters

Frequency	30-25000 MHz; 2400-2483.5 MHz	Setup	RM024 connected to Spectrum Analyzer via SMA cable.
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Instrumentation



Date : 6-Aug-2020 Test : 15,247 Tx (RM024) Job : C-3379
 PE : Shane Dock Customer : Vermeer Quote : 319384

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY 53400296	7/14/2020	7/14/2021	Active Calibration
2	AA 960143	Cable	Gore	EKD01D01048.0	5546519	12/9/2019	12/9/2020	Active Verification

January, 2021 Testing



Date : 6-Aug-2020 Test : Conducted RF - January Job : C-3379
 PE : Shane Dock Customer : Vermeer Quote : 319384

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960143	Cable	Gore	EKD01D01048.0	5546519	12/9/2019	2/9/2021	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY 53400296	7/14/2020	7/14/2021	Active Calibration

EUT Parameters

Input Power	7.5 VDC	Mode	Modulated Tx Mode Hopping Mode
Frequency	2404 MHz 2435.5 MHz 2466.9 MHz	Channel	Low, Mid, High Channel tested. All channels active in Hopping mode.
Notes	EUT tested at both 280 kHz and 500 kHz data rates. Display lines on plots may not be representative of test requirements		

Data

Tables – 280 kHz

Channel	Occupancy Time (ms)	Number of Transmissions	Occupancy time per (period) s (ms)
Low	0.6405	30	19.2
Mid	0.6405	30	19.2
High	0.6398	30	19.2

Channel	20 dB BW (kHz)	99% BW (kHz)
Low	854.0	831.6
Mid	811.6	817.6
High	868.7	857.0

Company: Vermeer Manufacturing Company	Page 11 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2

Channel	Measured Output Power (dBm)	Output Power Limit (dBm)	Margin (dB)
Low	8.1	30.0	21.9
Mid	8.6	30.0	21.4
High	8.8	30.0	21.2

Channel	Ref lvl (dBm)	Limit (dBm)
2404.0	7.9	-12.1
2435.4	8.3	-11.7
2466.9	8.5	-11.5

Frequency	Measurement (dBm)	Limit (dBm)	Margin (dB)	Channel
2247.9	-44.8	-12.1	32.7	Low
1714.9	-65.4	-12.1	53.3	Low
2560.0	-44.2	-12.1	32.1	Low
2716.0	-61.3	-12.1	49.2	Low
3054.0	-55.2	-12.1	43.1	Low
4807.8	-54.1	-12.1	42.0	Low
5496.4	-60.6	-12.1	48.5	Low
1720.5	-67.2	-11.7	55.5	Mid
2279.5	-50.2	-11.7	38.5	Mid
2513.5	-51.1	-11.7	39.4	Mid
3085.5	-54.7	-11.7	43.0	Mid
4871.1	-55.7	-11.7	44.0	Mid
5508.1	-61.6	-11.7	49.9	Mid
2623.0	-51.8	-11.5	40.3	High
3103.8	-55.2	-11.5	43.7	High
4933.6	-54.6	-11.5	43.1	High
5505.9	-63.4	-11.5	51.9	High
1817.0	-52.3	-11.5	40.8	High
2492.8	-46.6	-11.5	35.1	High
2310.9	-48.8	-11.5	37.3	High
2377.9	-52.3	-11.5	40.8	Low
2484.5	-49.7	-11.5	38.2	Low
2488.5	-47.9	-12.1	35.8	Hopping
2388.4	-51.0	-12.1	38.9	Hopping

Channel	6.4 VDC Freq. (Hz)	7.5 VDC Freq. (Hz)	8.6 VDC Freq. (Hz)	Deviation (Hz)
Low	2403978391	2403983008	2403981991	4617
Mid	2435442173	2435439390	2435441340	2783
High	2466899342	2466901942	2466898625	3317

Data

Tables – 500 kHz

Channel	Occupancy Time (ms)	Number of Transmissions	Occupancy time per (period) s (ms)
Low	0.4246	37.902	16.1
Mid	0.4263	37.902	16.2
High	0.4255	37.902	16.1

Channel	20 dB BW (kHz)	99% BW (kHz)
Low	1343.0	1090.5
Mid	1355.0	1100.1
High	1210.0	1167.1

Channel	Measured Output Power (dBm)	Output Power Limit (dBm)	Margin (dB)
Low	8.1	30.0	21.9
Mid	8.6	30.0	21.4
High	8.8	30.0	21.2

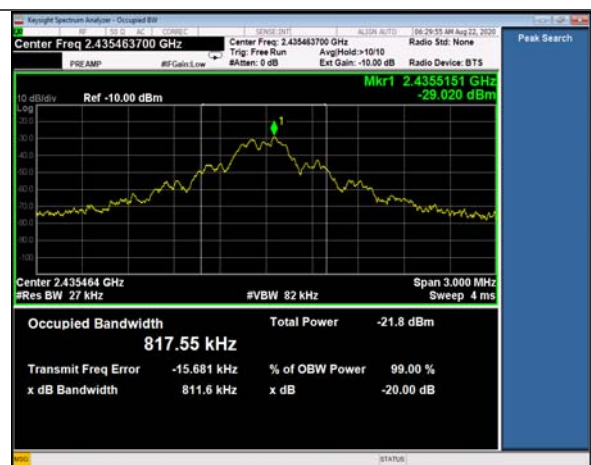
Channel	Ref lvl (dBm)	Limit (dBm)
2404.1	8.0	-12.0
2435.6	8.5	-11.5
2467.01	8.6	-11.4

Frequency (MHz)	Measurement (dBm)	Limit (dBm)	Margin (dB)	Channel
2248.0	-46.3	-12.0	34.3	Low
2279.6	-52.3	-11.5	40.8	Mid
1816.8	-55.8	-11.4	44.4	High
2545.0	-51.5	-11.4	40.1	High
3103.8	-55.6	-11.4	44.2	High
4933.6	-58.4	-11.4	47.0	High
2513.5	-51.2	-11.5	39.7	Mid
3072.3	-54.5	-11.5	43.0	Mid
4870.6	-56.4	-11.5	44.9	Mid
2560.0	-46.2	-12.0	34.2	Low
3054.0	-57.7	-12.0	45.7	Low
4807.8	-56.7	-12.0	44.7	Low
5506.1	-56.9	-12.0	44.9	Low
2378.0	-51.8	-12.0	39.8	Low
2310.8	-48.5	-11.4	37.1	High
2310.9	-51.1	-12.0	39.1	Hopping
2485.3	-47.3	-12.0	35.3	Hopping
2492.8	-46.8	-11.4	35.4	High
2483.6	-49.6	-12.0	37.6	Low
2400.0	-44.1	-12.0	32.1	Low
2390.0	-52.6	-12.0	40.6	Hopping

Plots – 280 kHz (Worst Case Shown)



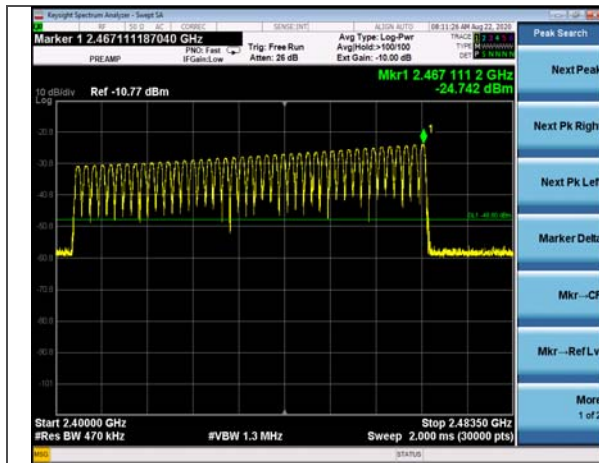
Low Channel



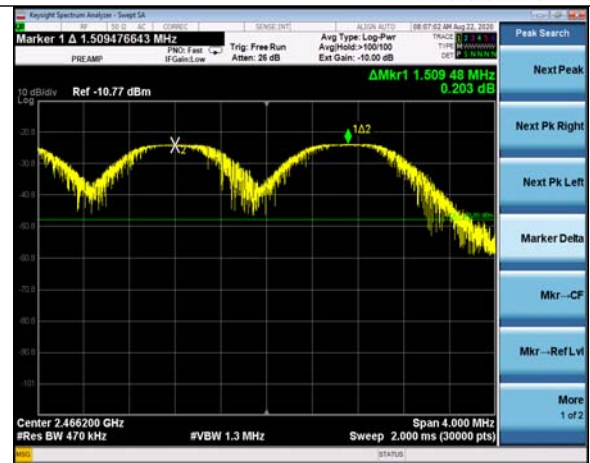
Mid Channel



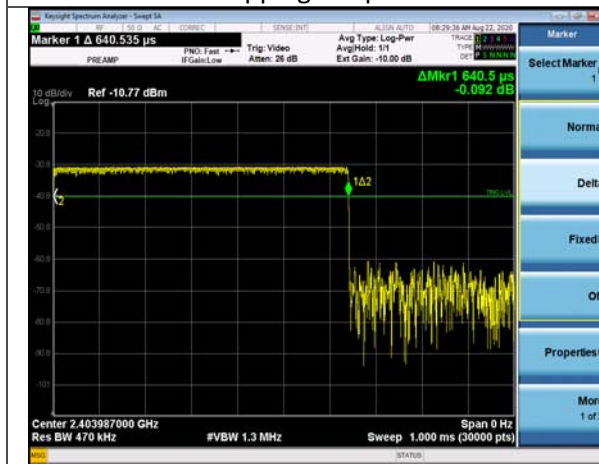
High Channel



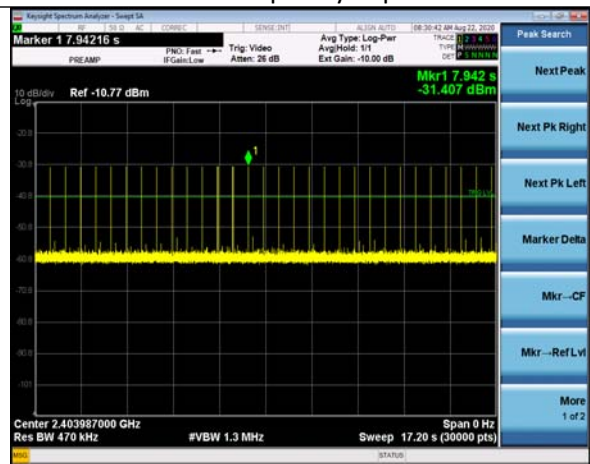
43 Hopping Frequencies



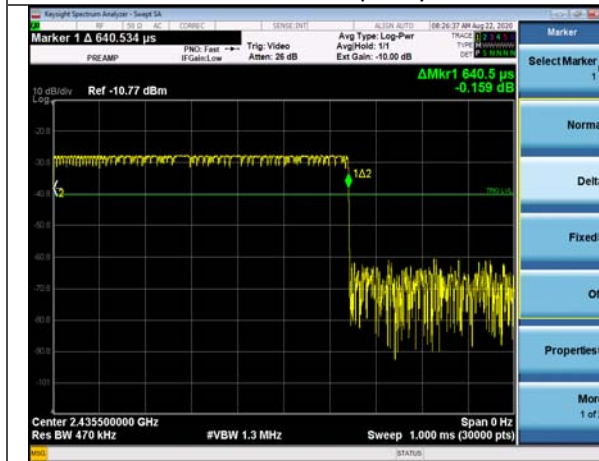
1.5 MHz Frequency Separation



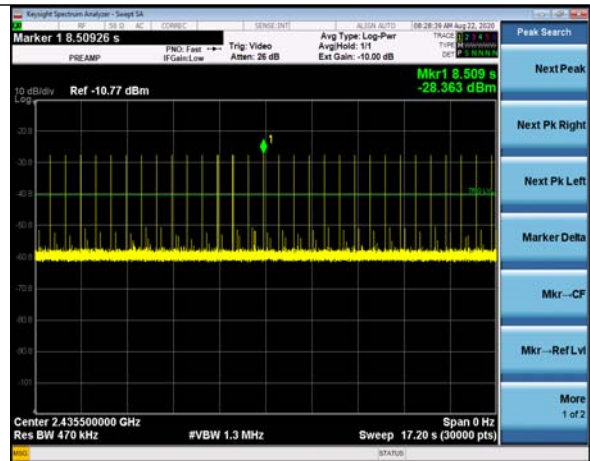
Low Channel Occupancy Time



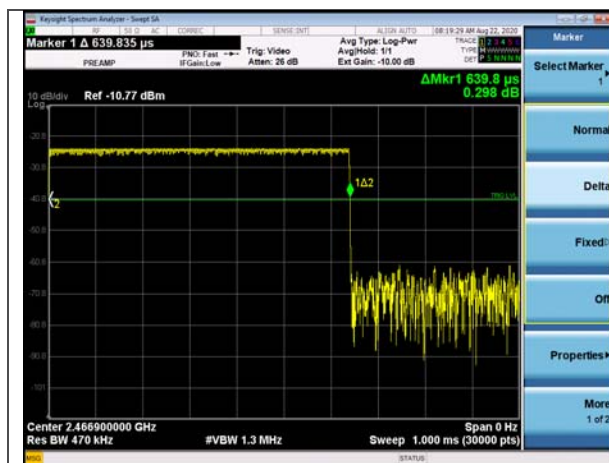
Low Channel over Observation Period



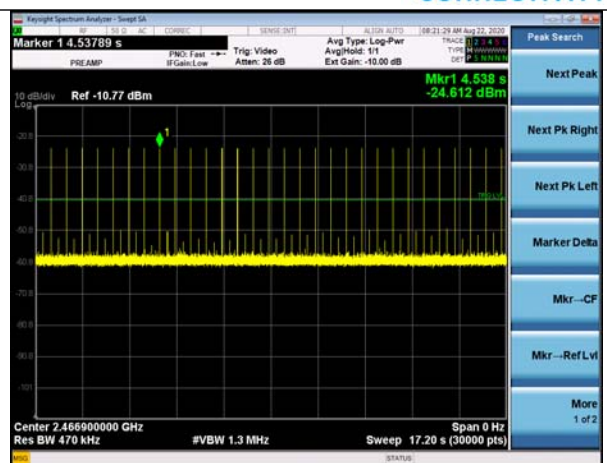
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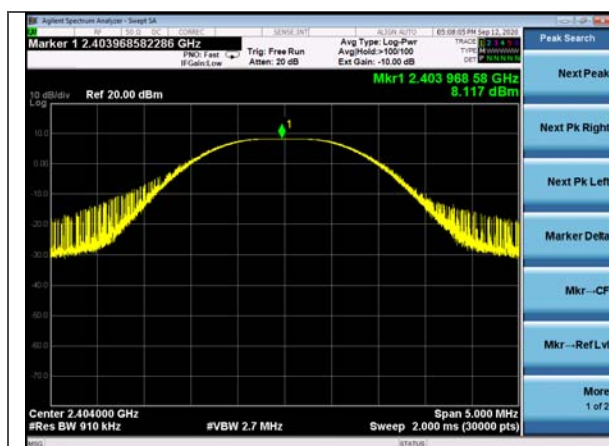
Mid Channel over Observation Period



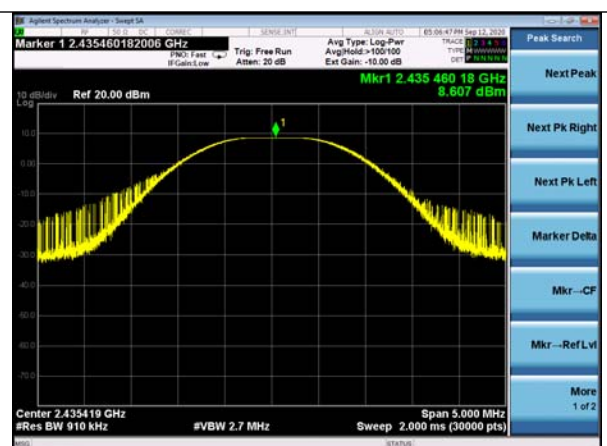
High Channel Occupancy Time



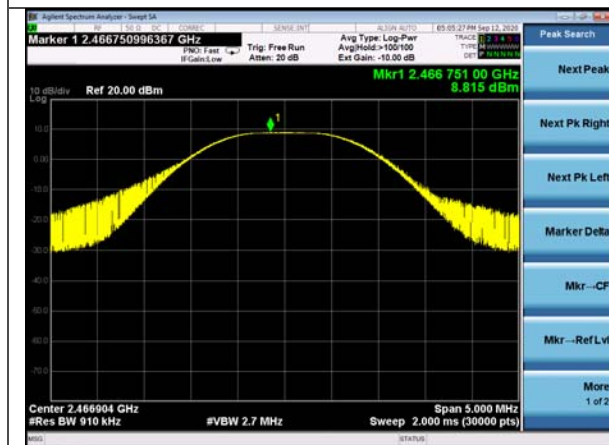
High Channel over Observation Period



Low Channel



Mid Channel



High Channel

Company: Vermeer Manufacturing
Company

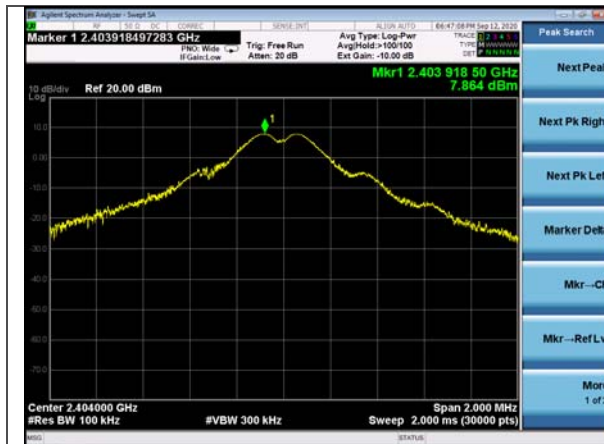
Report: 319384 A

Job: C-3379

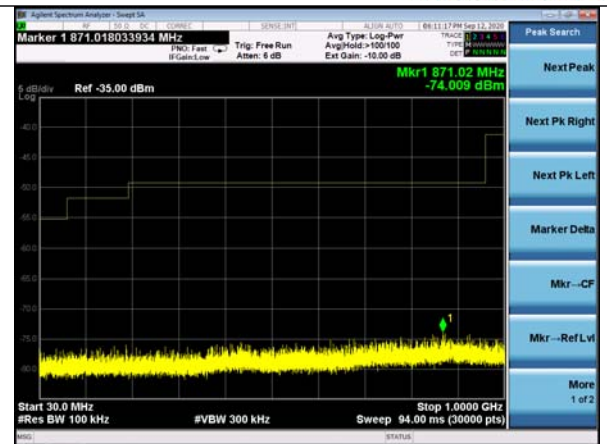
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Model: See Section 2

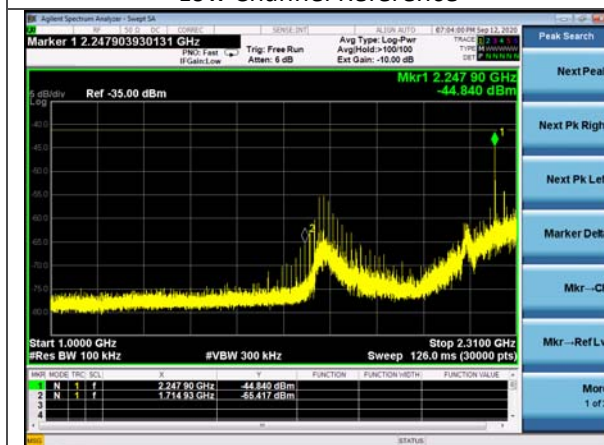
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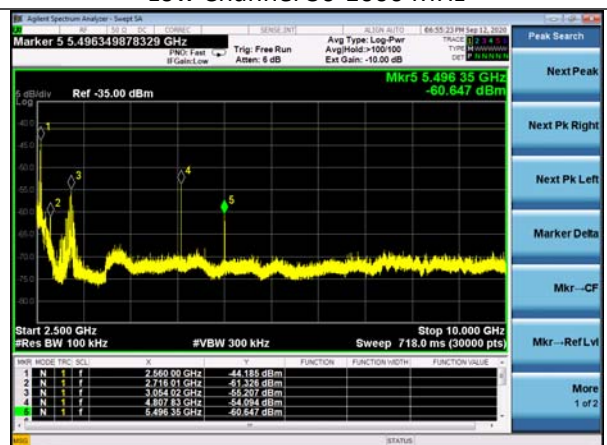
Low Channel Reference



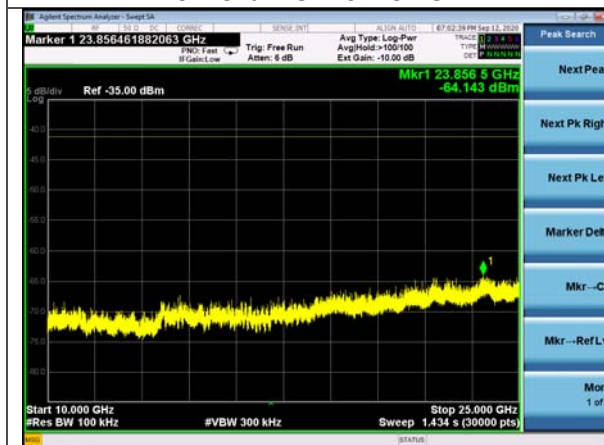
Low Channel 30-1000 MHz



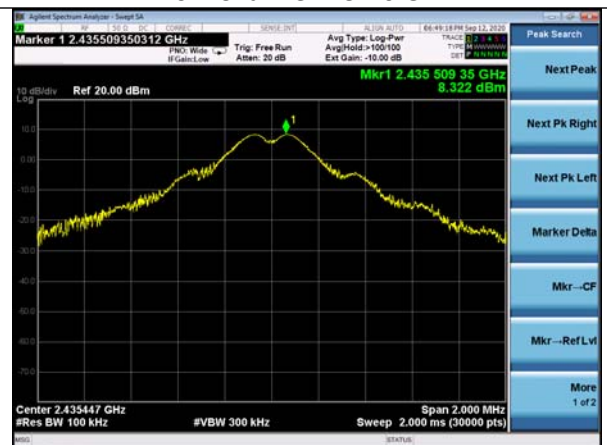
Low Channel 1.0-2.31 GHz



Low Channel 2.5-10 GHz



Low Channel 10-25 GHz



Mid Channel Reference

Company: Vermeer Manufacturing
Company

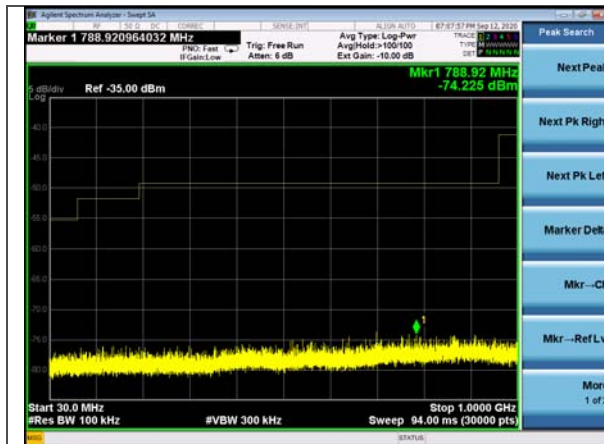
Report: 319384 A

Job: C-3379

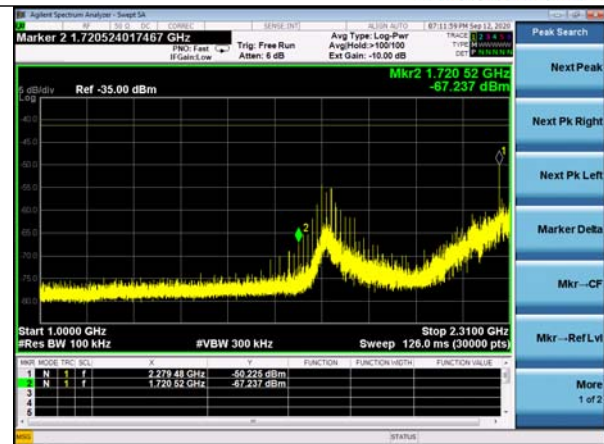
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Model: See Section 2

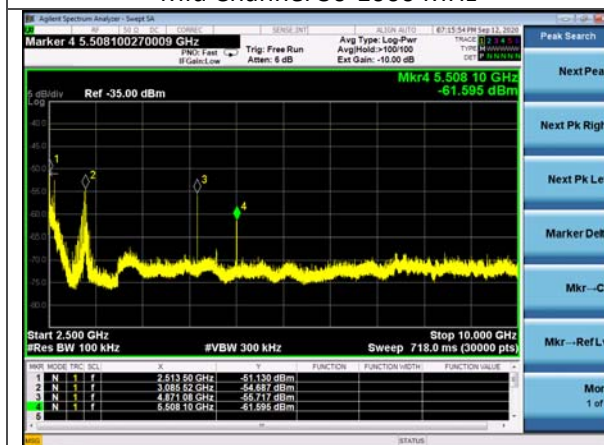
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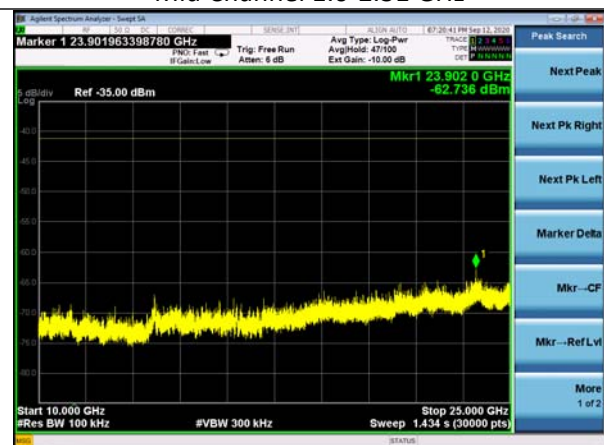
Mid Channel 30-1000 MHz



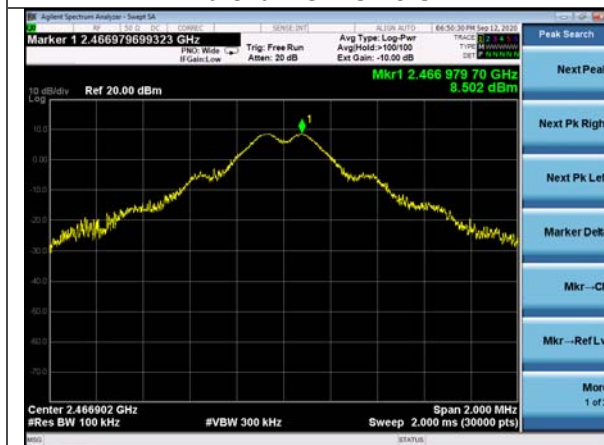
Mid Channel 1.0-2.31 GHz



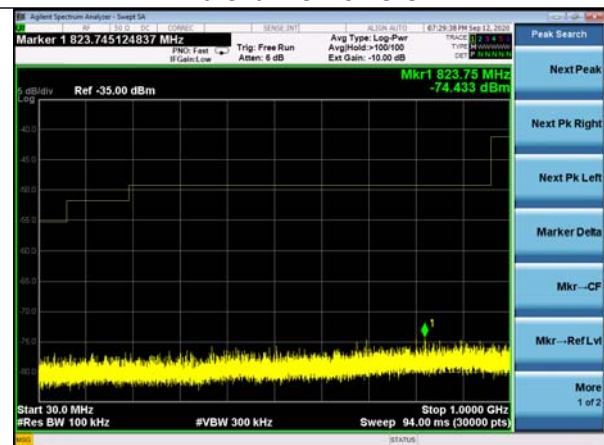
Mid Channel 2.5-10 GHz



Mid Channel 10-25 GHz



High Channel Reference



High Channel 30-1000 MHz

Company: Vermeer Manufacturing
Company

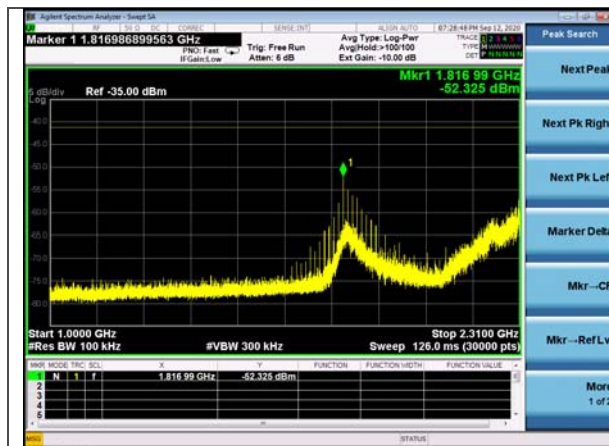
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Job: C-3379

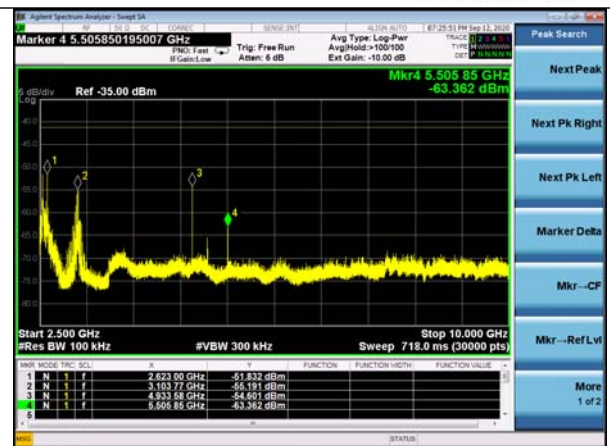
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Model: See Section 2

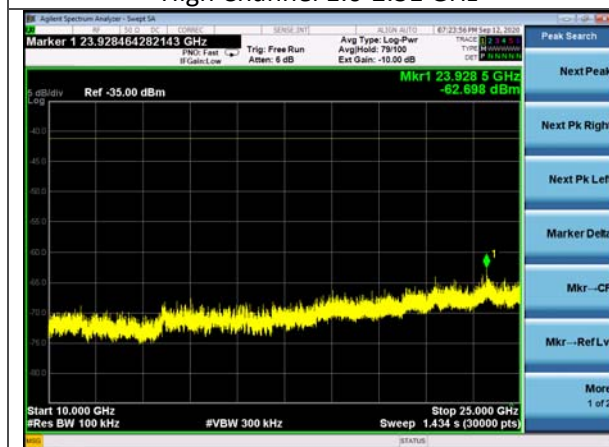
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High Channel 1.0-2.31 GHz



High Channel 2.5-10 GHz



High Channel 10-25 GHz

Company: Vermeer Manufacturing Company

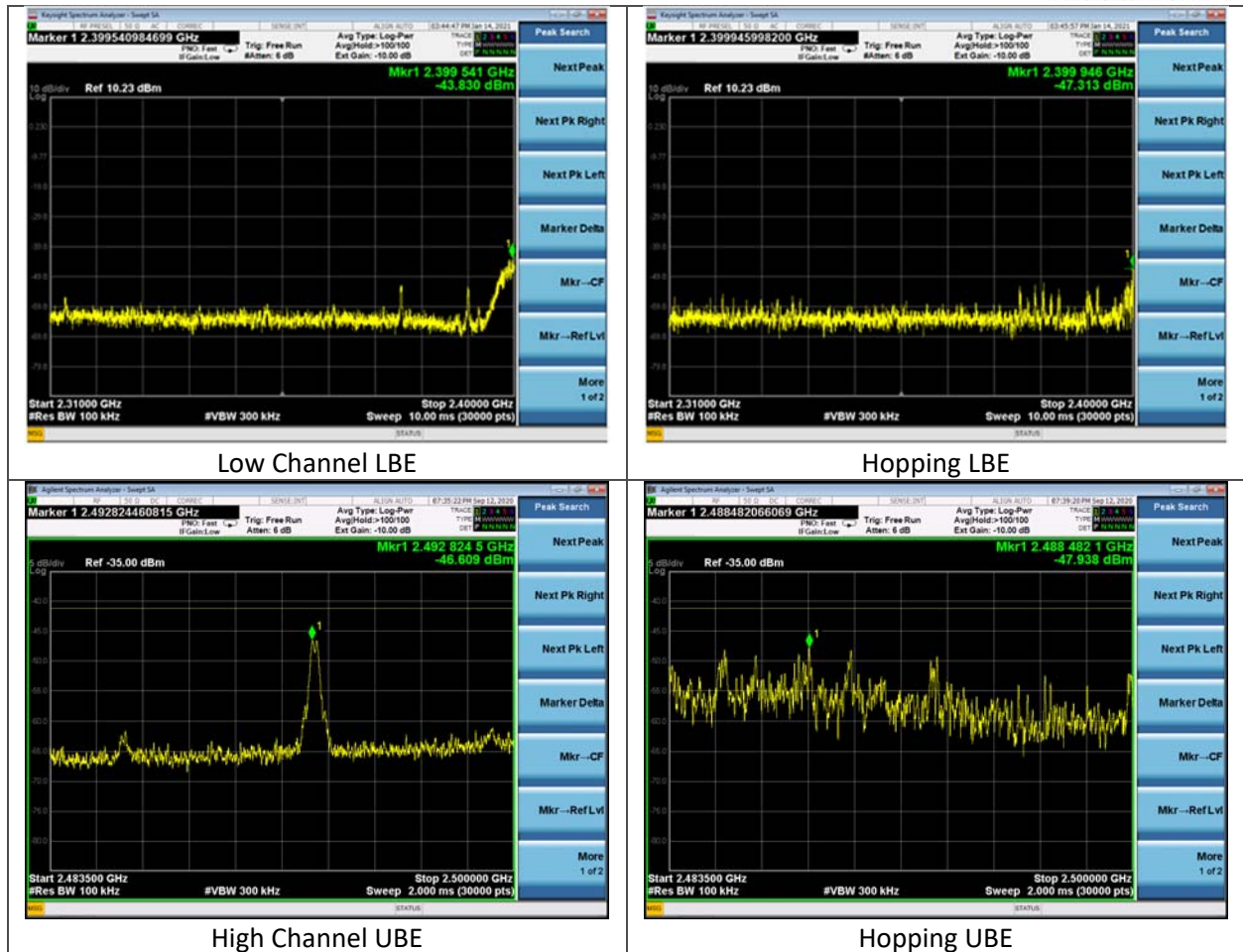
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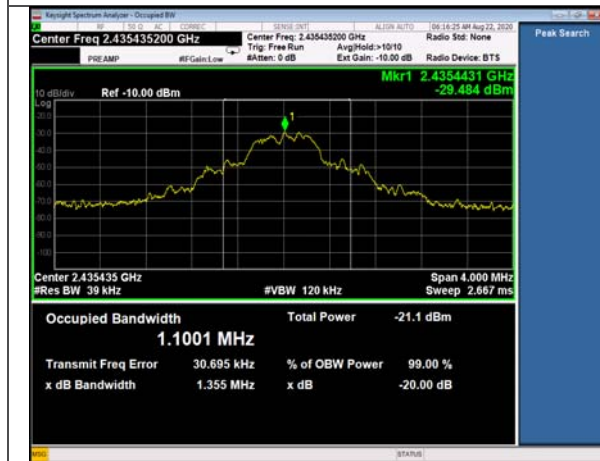
Plots – 500 kHz (Worst Case Shown)



99% BW Low Channel



20 dB BW Low Channel



99% BW Mid Channel



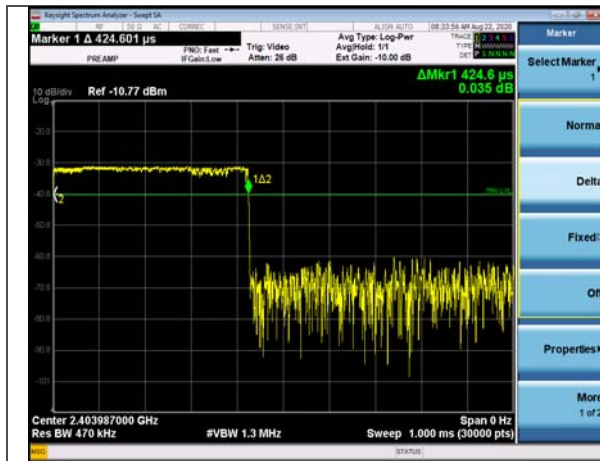
20 dB BW Mid Channel



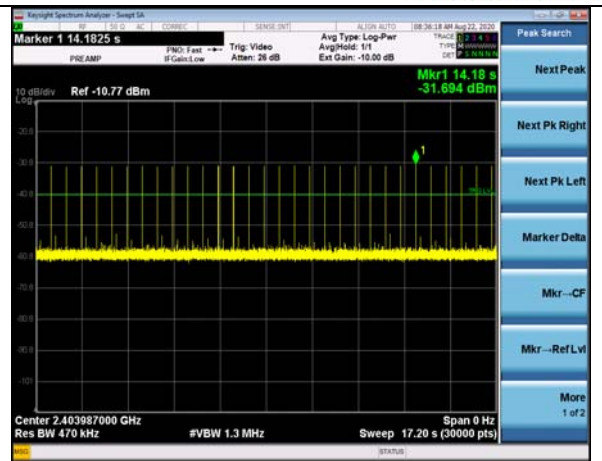
99% BW High Channel



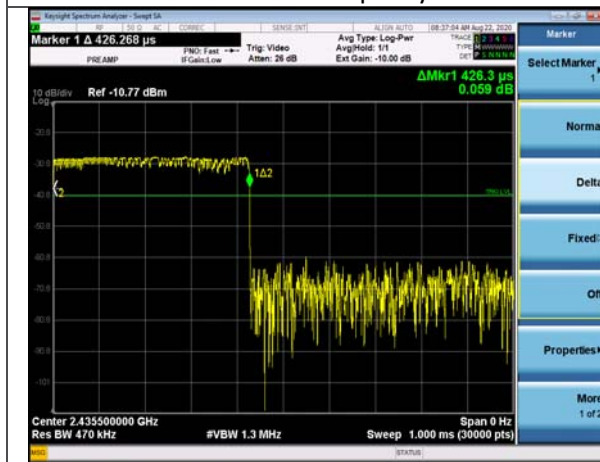
20 dB BW High Channel



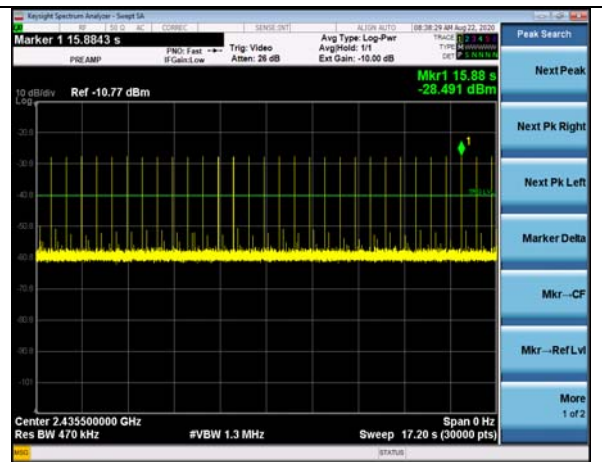
Low Channel Occupancy Time



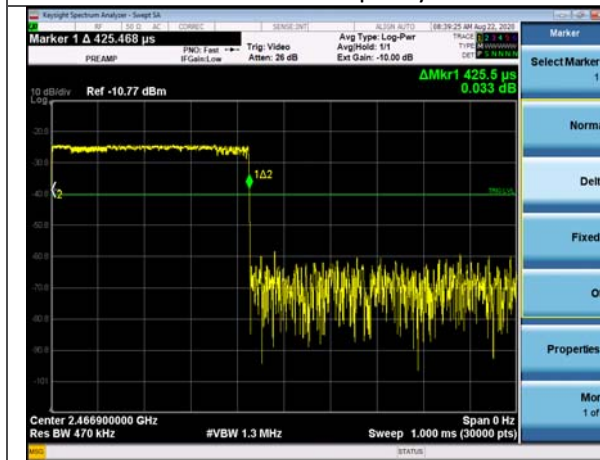
Low Channel over Observation Period



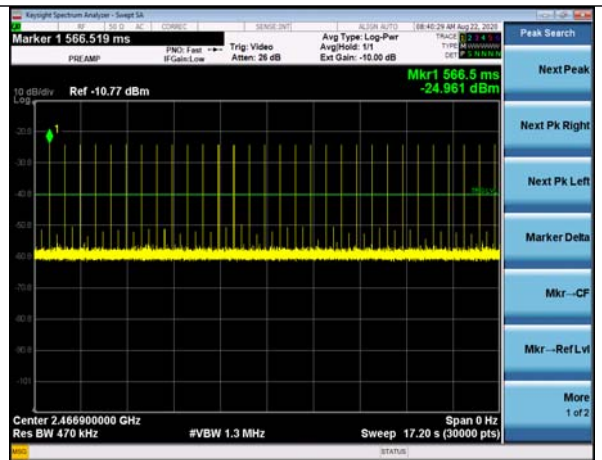
Mid Channel Occupancy Time



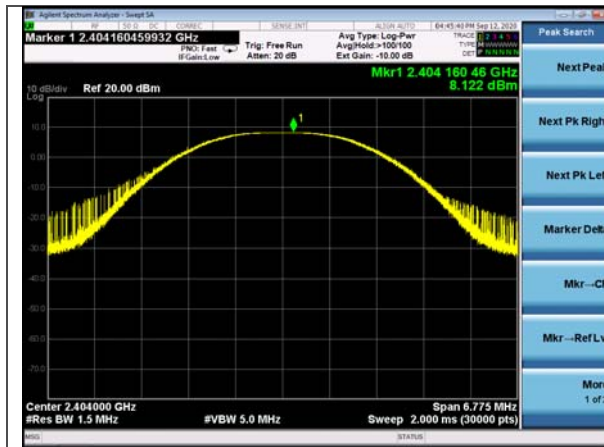
Mid Channel over Observation Period



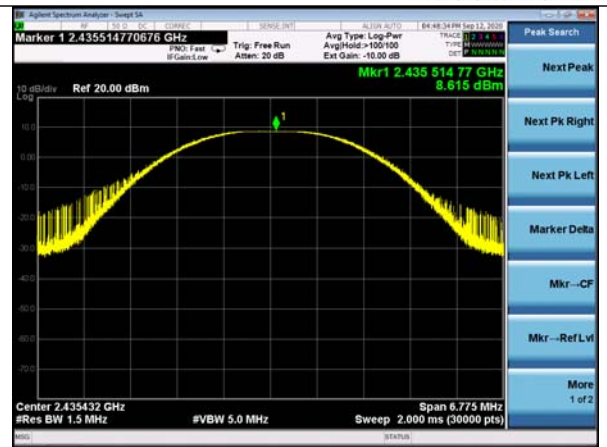
High Channel Occupancy Time



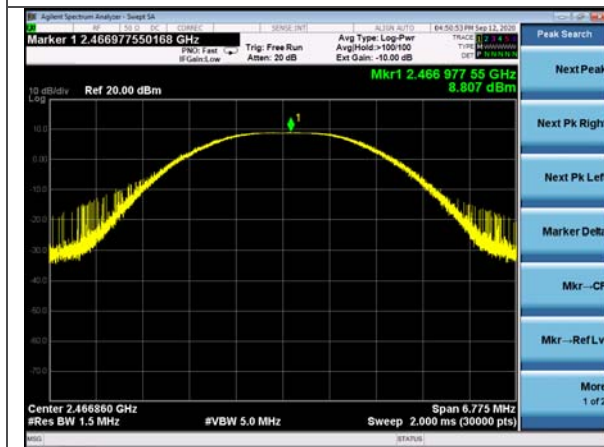
High Channel over Observation Period



Low Channel



Mid Channel



High Channel

Company: Vermeer Manufacturing
Company

Report: 319384 A

Job: C-3379

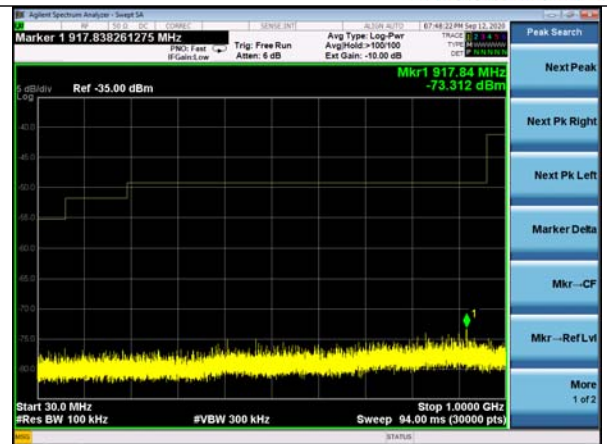
Name: Radio Apparatus

Model: See Section 2

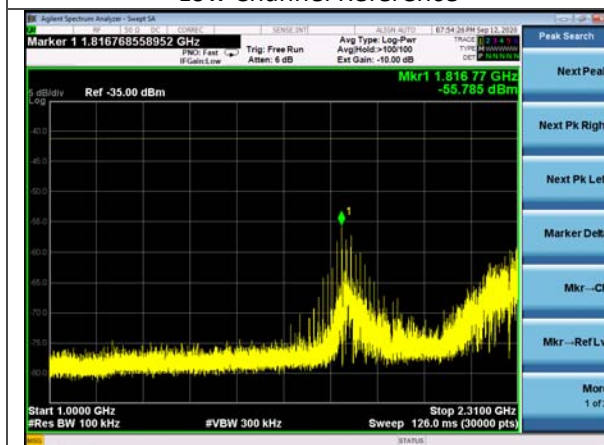
Serial: See Section 2



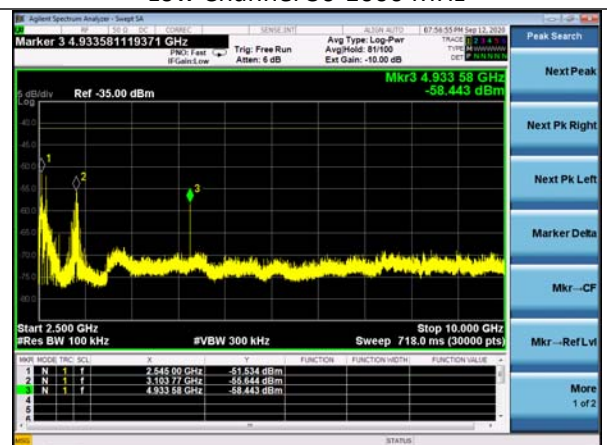
Low Channel Reference



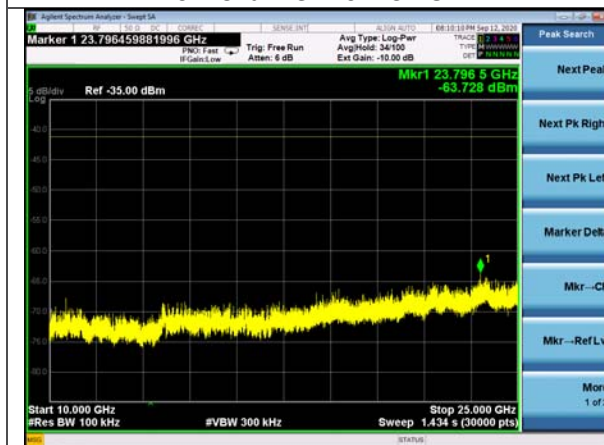
Low Channel 30-1000 MHz



Low Channel 1.0-2.31 GHz



Low Channel 2.5-10 GHz



Low Channel 10-25 GHz



Mid Channel Reference

Company: Vermeer Manufacturing Company

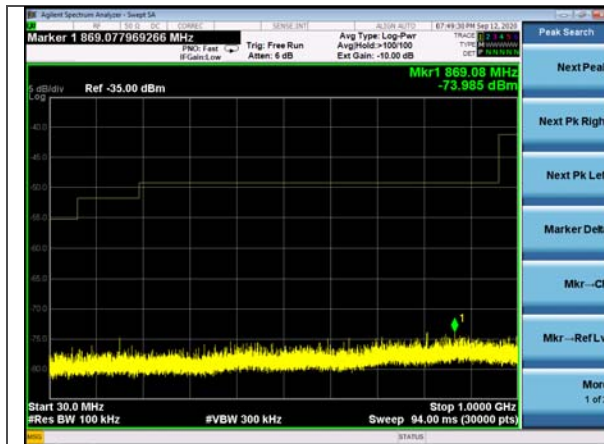
Report: 319384 A

Job: C-3379

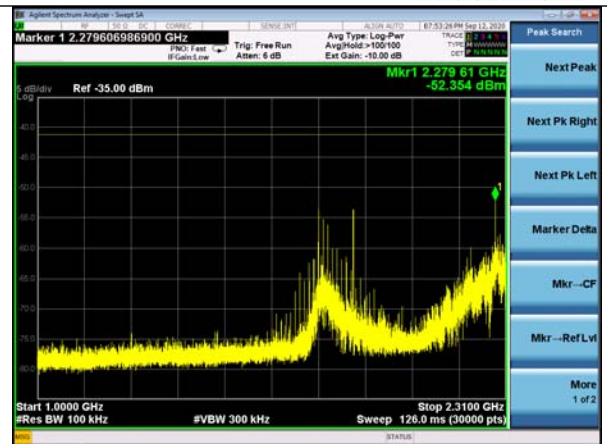
Name: Radio Apparatus

Model: See Section 2

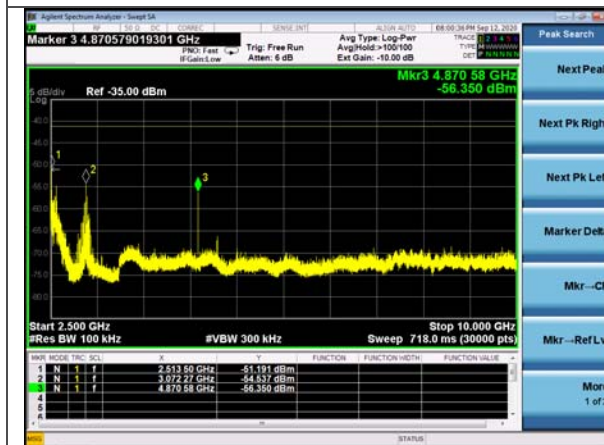
Serial: See Section 2



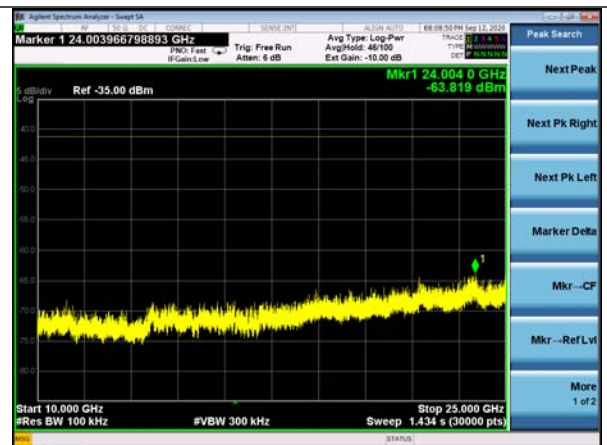
Mid Channel 30-1000 MHz



Mid Channel 1.0-2.31 GHz



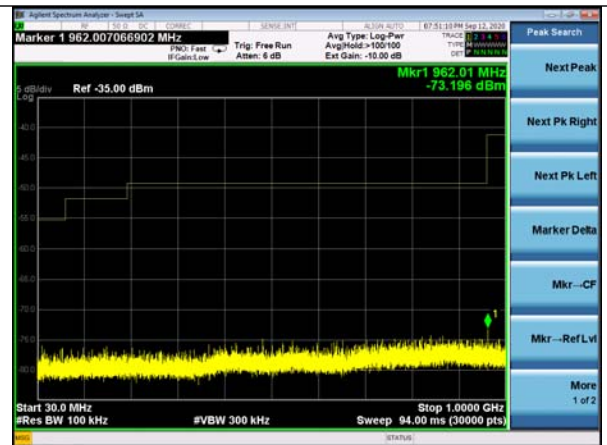
Mid Channel 2.5-10 GHz



Mid Channel 10-25 GHz



High Channel Reference



High Channel 30-1000 MHz

Company: Vermeer Manufacturing
Company

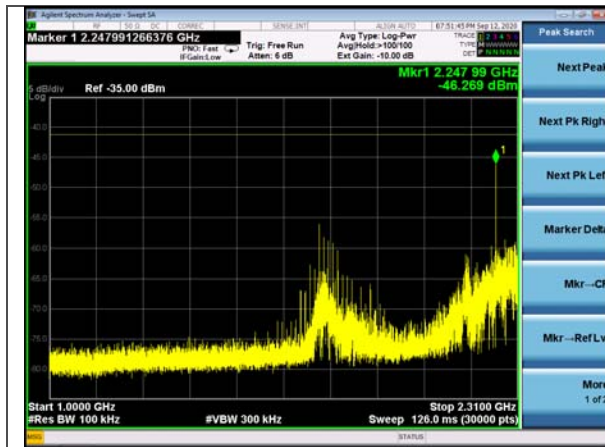
Report: 319384 A

Job: C-3379

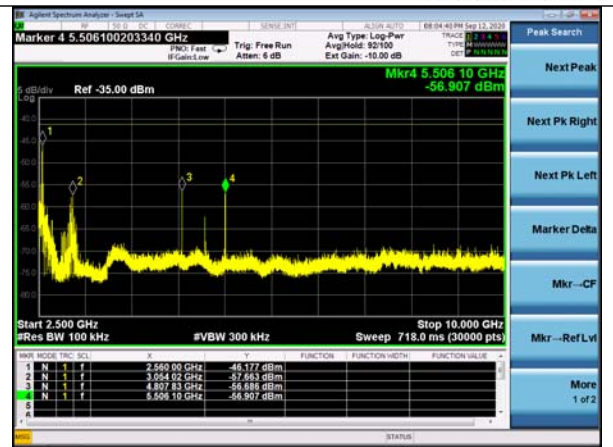
Name: Radio Apparatus

Model: See Section 2

Serial: See Section 2



High Channel 1.0-2.31 GHz



High Channel 2.5-10 GHz



High Channel 10-25 GHz

Company: Vermeer Manufacturing
Company

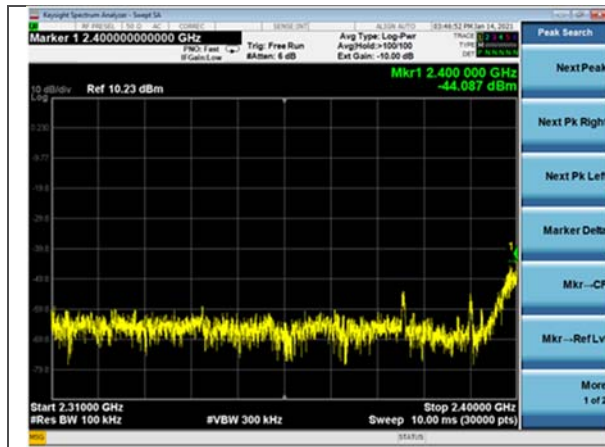
Report: 319384 A

Job: C-3379

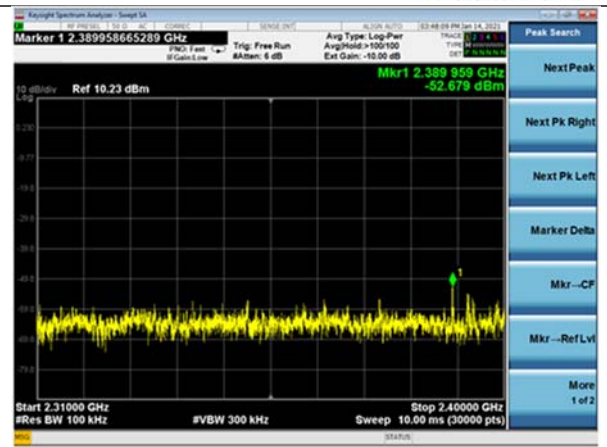
Name: Radio Apparatus

Model: See Section 2

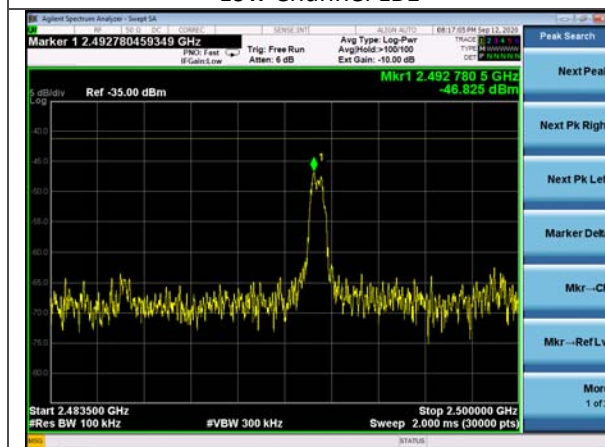
Serial: See Section 2



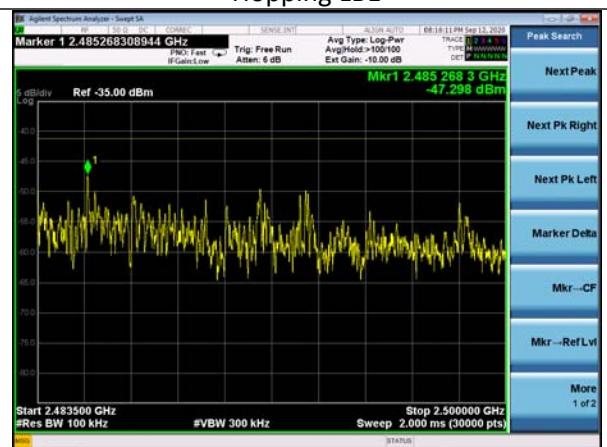
Low Channel LBE



Hopping LBE



High Channel UBE



Hopping UBE

5.1.2 Conducted RF Emissions – Cabinet Radiation

Operator	Anthony Smith	QA	Shane Dock
Temperature	22.3°C	R.H. %	51.70%
Test Date	9/3/2020	Location	Conducted RF Bench
Requirement	FCC 15.247	Method	ANSI C63.10

Limits:

Frequency (MHz)	EIRP (dBm) at 3 meters
30-88	-55.2
88-216	-51.7
216-960	-49.2
Above 960	-41.2

Limits shown above are 15.209 limits converted to EIRP with a 95.2 dB correction factor.
Example: at 1 GHz, 54 dBuV/m – 95.2 dB = -41.2 dBm.

Test Parameters

Frequency	30 – 25000 MHz	Setup	EUT connected to Spectrum Analyzer with an SMA cable
RBW	100 kHz (< 1 GHz) 1 MHz (> 1 GHz)	VBW	300 kHz (< 1 GHz) 3 MHz (> 1 GHz)
Detector(s)	Peak, Average	Note	Display lines on plots may not be representative of test requirements

Instrumentation



Date: 6-Aug-2020 Test: Cond RF Job: C-3379
PE: Shane Dock Customer: Vermeer Quote: 319384

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY 53400296	7/14/2020	7/14/2021	Active Calibration
2	AA 960143	Cable	Gore	EKD01D01048.0	5546519	12/9/2019	12/9/2020	Active Verification

EUT Parameters

Input Power	5V via USB	Mode	Modulated Tx
Frequency	2404 - 2466.9 MHz	Channel	Low, Mid, High Channels Hopping (All Channels)
Settings	280, 500k data rates.		

Company: Vermeer Manufacturing Company		Name: Radio Apparatus
Report: 319384 A	Page 30 of 48	Model: See Section 2
Job: C-3379		Serial: See Section 2

Data

Table – 280 kHz Peak

Frequency (MHz)	Peak Measurement (dBm)	Peak Measurement with Ant. Gain(dBm)	Limit (dBm)	Margin (dB)	Channel	Antenna Gain (dB)
962.0	-66.8	-62.2	-21.2	41.0	280k High	4.6
2247.9	-47.2	-42.6	-21.2	21.4	280k Low	4.6
2279.5	-49.3	-44.7	-21.2	23.5	280k Mid	4.6
4807.6	-48.0	-43.4	-21.2	22.2	280k Low	4.6
4871.0	-52.4	-47.8	-21.2	26.6	280k Mid	4.6
2499.9	-48.8	-44.2	-21.2	23.0	280k Mid	4.6
4933.8	-52.0	-47.4	-21.2	26.2	280k High	4.6
2325.9	-43.5	-38.9	-21.2	17.7	280k Low	4.6
2488.5	-40.9	-36.3	-21.2	15.1	280k Low	4.6
2357.3	-47.6	-43.0	-21.2	21.8	280k Mid	4.6
2388.9	-45.0	-40.4	-21.2	19.2	280k High	4.6
2493.0	-43.9	-39.3	-21.2	18.1	280k High	4.6
2380.2	-42.5	-37.9	-21.2	16.7	280k Hop	4.6
2485.1	-38.2	-33.6	-21.2	12.4	280k Hop	4.6

Values below 1 GHz have a 4.7 dB Ground Reflection value added.

Table – 280 kHz Average

Frequency (MHz)	Peak Measurement (dBm)	Corrected Average Measurement with Ant. Gain(dBm)	Limit (dBm)	Margin (dB)	Channel	Antenna Gain (dB)	Duty Cycle Correction Factor
962.0	-66.8	-82.7	-41.2	41.5	280k High	4.6	-20.5
2247.9	-47.2	-63.1	-41.2	21.9	280k Low	4.6	-20.5
2279.5	-49.3	-65.2	-41.2	24.0	280k Mid	4.6	-20.5
4807.6	-48.0	-63.9	-41.2	22.7	280k Low	4.6	-20.5
4871.0	-52.4	-68.3	-41.2	27.1	280k Mid	4.6	-20.5
2499.9	-48.8	-64.7	-41.2	23.5	280k Mid	4.6	-20.5
4933.8	-52.0	-67.9	-41.2	26.7	280k High	4.6	-20.5
2325.9	-43.5	-59.4	-41.2	18.2	280k Low	4.6	-20.5
2488.5	-40.9	-56.8	-41.2	15.6	280k Low	4.6	-20.5
2357.3	-47.6	-63.5	-41.2	22.3	280k Mid	4.6	-20.5
2388.9	-45.0	-60.9	-41.2	19.7	280k High	4.6	-20.5
2493.0	-43.9	-59.8	-41.2	18.6	280k High	4.6	-20.5
2380.2	-42.5	-58.4	-41.2	17.2	280k Hop	4.6	-20.5
2485.1	-38.2	-54.1	-41.2	12.9	280k Hop	4.6	-20.5

Table – 500 kHz Peak

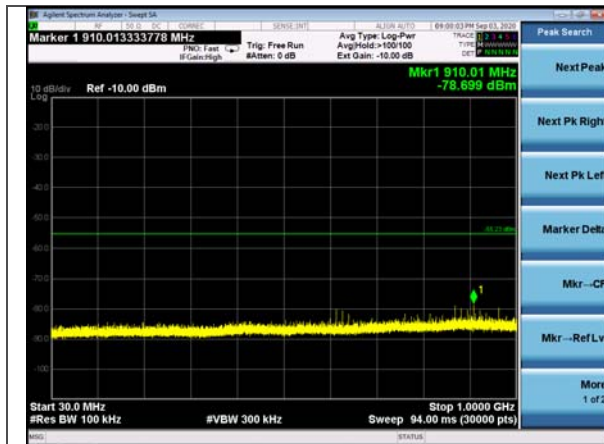
Frequency (MHz)	Peak Measurement (dBm)	Peak Measurement with Ant. Gain(dBm)	Limit (dBm)	Margin (dB)	Channel	Antenna Gain (dB)
1721.3	-66.9	-62.3	-21.2	41.1	High 500k	4.6
2272.1	-53.1	-48.5	-21.2	27.3	High 500k	4.6
2279.6	-49.1	-44.5	-21.2	23.3	Mid 500k	4.6
2247.8	-47.8	-43.2	-21.2	22.0	Low 500k	4.6
4933.5	-52.6	-48.0	-21.2	26.8	High 500k	4.6
4871.5	-52.5	-47.9	-21.2	26.7	Mid 500k	4.6
4807.5	-48.1	-43.5	-21.2	22.3	Low 500k	4.6
2361.3	-47.0	-42.4	-21.2	21.2	Mid 500k	4.6
2499.9	-48.8	-44.2	-21.2	23.0	Mid 500k	4.6
2325.8	-43.0	-38.4	-21.2	17.2	Low 500k	4.6
2485.0	-41.7	-37.1	-21.2	15.9	Low 500k	4.6
2389.1	-46.4	-41.8	-21.2	20.6	High 500k	4.6
2493.0	-43.5	-38.9	-21.2	17.7	High 500k	4.6
2378.2	-43.4	-38.8	-21.2	17.6	Hop 500k	4.6
2486.5	-38.5	-33.9	-21.2	12.7	Hop 500k	4.6

Table – 500 kHz Average

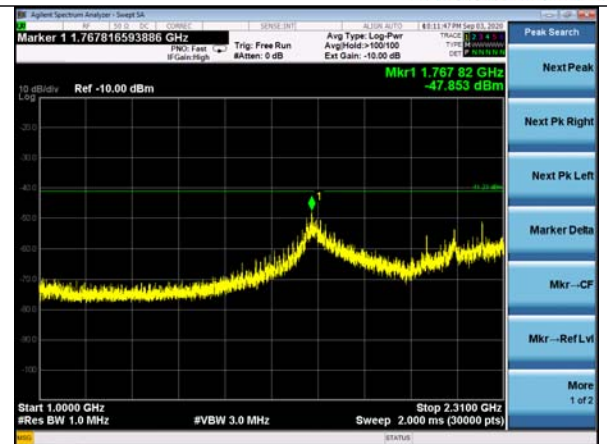
Frequency (MHz)	Peak Measurement (dBm)	Corrected Average Measurement with Ant. Gain(dBm)	Limit (dBm)	Margin (dB)	Channel	Antenna Gain (dB)	Duty Cycle Correction
1721.3	-66.9	-82.8	-41.2	41.6	High 500k	4.6	-20.5
2272.1	-53.1	-69.0	-41.2	27.8	High 500k	4.6	-20.5
2279.6	-49.1	-65.0	-41.2	23.8	Mid 500k	4.6	-20.5
2247.8	-47.8	-63.7	-41.2	22.5	Low 500k	4.6	-20.5
4933.5	-52.6	-68.5	-41.2	27.3	High 500k	4.6	-20.5
4871.5	-52.5	-68.4	-41.2	27.2	Mid 500k	4.6	-20.5
4807.5	-48.1	-64.0	-41.2	22.8	Low 500k	4.6	-20.5
2361.3	-47.0	-62.9	-41.2	21.7	Mid 500k	4.6	-20.5
2499.9	-48.8	-64.7	-41.2	23.5	Mid 500k	4.6	-20.5
2325.8	-43.0	-58.9	-41.2	17.7	Low 500k	4.6	-20.5
2485.0	-41.7	-57.6	-41.2	16.4	Low 500k	4.6	-20.5
2389.1	-46.4	-62.3	-41.2	21.1	High 500k	4.6	-20.5
2493.0	-43.5	-59.4	-41.2	18.2	High 500k	4.6	-20.5
2378.2	-43.4	-59.3	-41.2	18.1	Hop 500k	4.6	-20.5
2486.5	-38.5	-54.4	-41.2	13.2	Hop 500k	4.6	-20.5

Plots (Worst-Case Shown – 500 kHz)

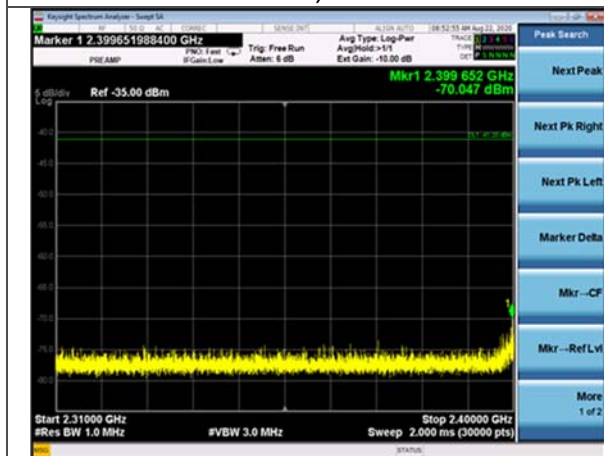
Company: Vermeer Manufacturing Company	Page 33 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2



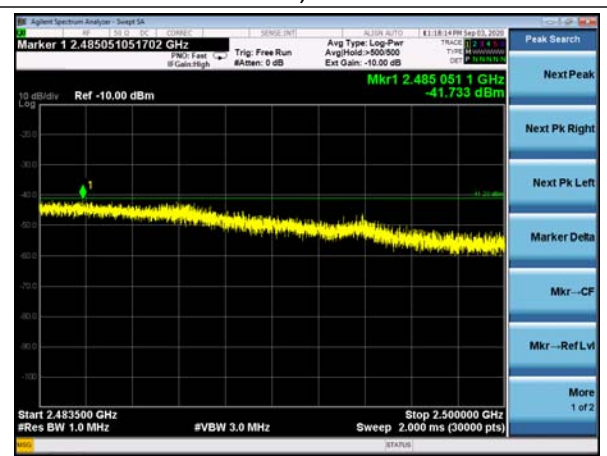
30-1000 MHz, Mid Channel



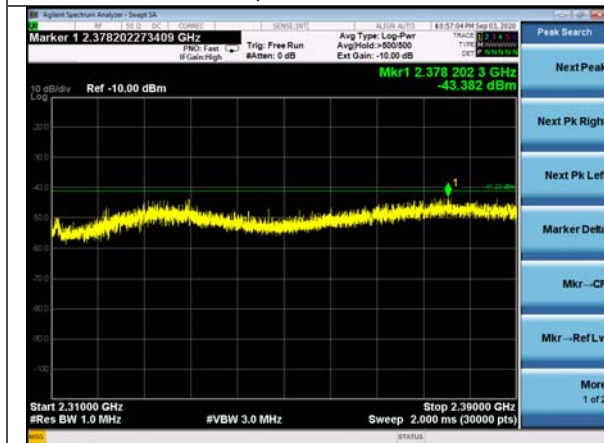
1.0-2.31 GHz, Low Channel



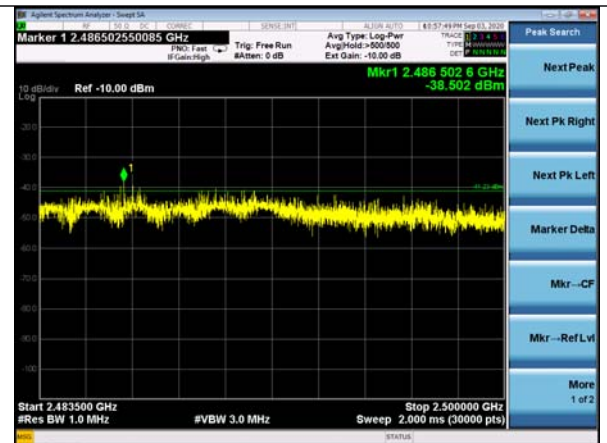
LBE, Low Channel



UBE, Low Channel



LBE, Hopping



UBE, Hopping

Company: Vermeer Manufacturing
Company

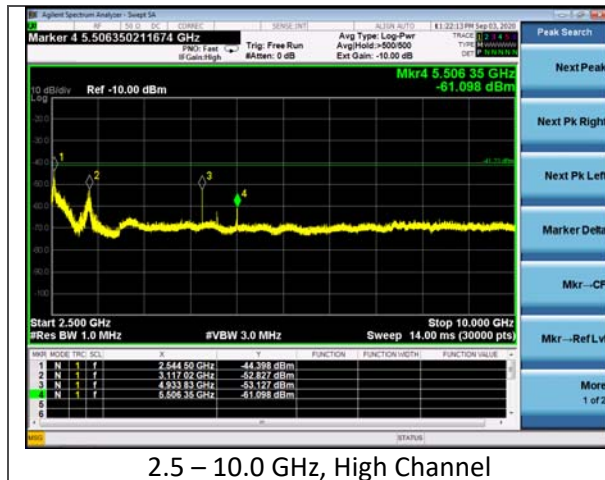
Report: 319384 A

Job: C-3379

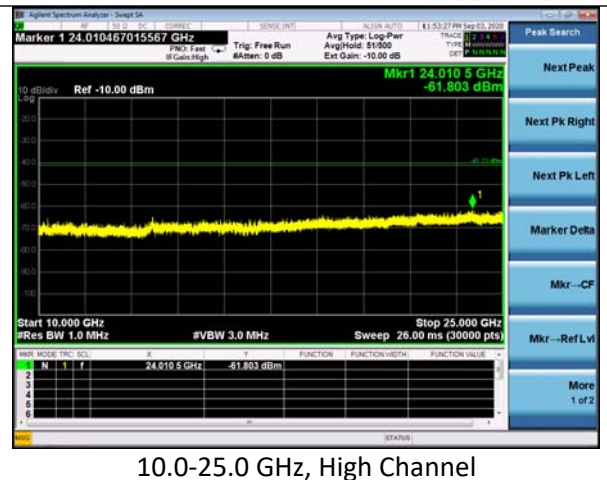
Name: Radio Apparatus

Model: See Section 2

Serial: See Section 2



2.5 – 10.0 GHz, High Channel



10.0-25.0 GHz, High Channel

5.2 Radiated Emissions

Description of Measurement	The frequency spectrum is investigated for intentional and / or unintentional signals emanating from the EUT by use of a standardized test site and measurement antenna. The antenna, cable, pre-amp, and other necessary measurement system correction factors are loaded onto the EMI receiver / spectrum analyzer when the measurements are performed allowing the data to be gathered and reported as corrected values. The maximum emissions from the EUT are determined by turn-table azimuth rotation (360°) and scanning of the measurement antenna. Maximized levels are noted at degree values of azimuth, measurement antenna height, and measurement antenna polarity.
Example Calculations	Measurement (dBμV) + Cable factor (dB) + Other (dB) + Antenna Factor (dB/m) = Corrected Reading (dBμV/m) Margin (dB) = Limit (dBμV/m) - Corrected Reading (dBμV/m) Example at 4000 MHz: Reading = 40 dBμV + 3.4 dB + 0.9 dB + 6.5 dB/m = 50.8 dBμV/m Average Limit = 20 log (500) = 54 dBμV/m Margin = 54 dBμV/m - 50.8 dBμV/m = 3.2 dB

Block Diagram



5.2.1 Radiated Emissions

Operator	Jon Dille, Anthony Smith, Braden Smith	QA	Shane Dock, Braden Smith, Anthony Smith
Temperature	23.1°C	R.H. %	56%
Test Date	8/7/2020 - 8/10/2020, 2/11/2021	Location	Chamber 3, 5
Requirement	FCC Part 15.247, RSS-247	Method	ANSI C63.10

Limits:

Frequency (MHz)	Field Strength (dBμV/m) at 3 meters
30-88	40.0
88-216	43.5
216-960	46.0
Above 960	54.0

Test Parameters

Frequency	30-1000 MHz, 1-25 GHz	Distance	3m
Detector(s)	Quasi-Peak (Under 1 GHz); Average, Peak (Above 1 GHz)	Table height	80 cm (Under 1 GHz); 150 cm (Above 1 GHz)
RBW	120 kHz (Under 1 GHz); 1 MHz (Above 1 GHz)	VBW	1.2 MHz (Below 1 GHz) 3 MHz (Above 1 GHz);
Notes	VBW reduced for screenshots above 1 GHz. Screenshots are informative in nature, while the tabulated data reflects Tx emissions measurements.		

Instrumentation



Date : 6-Aug-2020

Test : 15.247 Tx (RM024)

Job : C-3379

PE: Shane Dock

Customer: Vermeer

Quote : 319384

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960158	Antenna - Double Ridge Horn	ETS Lindgren	3117	109300	12/27/2019	12/27/2020	Active Calibration
2	AA 960154	Filter - High Pass 2.4 GHz	KWM	HFF-L-14186	7272-02	7/16/2020	7/16/2021	Active Calibration
3	EE 960159	Antenna - Low Noise Amplifier	Mini-Circuits	ZVA-213X-S+	691801732	12/27/2019	12/27/2020	Active Calibration
4	AA 960171	Cable	A.H. Systems, Inc	SAC-26G-6	386	12/9/2019	12/9/2020	Active Verification
5	EE 960085	Analyzer - EMI Receiver	Agilent	N9038A	MY51210148	7/13/2020	7/13/2021	Active Calibration
6	EE 960203	Analyzer - EMI Receiver	Keysight	N9038A	MY56400072	7/14/2020	7/14/2021	Active Calibration
7	AA 960081	Antenna - Double Ridge Horn	EMCO	3115	6907	10/18/2019	10/18/2020	Active Calibration
8	LSC-300	Cable	Chamber 3 Emissi -	-	-	12/9/2019	12/9/2020	Active Verification
9	AA 960195	Antenna - Log Periodic	A.H. Systems, Inc	SAS-512-2	557	7/24/2020	7/24/2021	Active Calibration
10	AA 960194	Antenna - Biconical	A.H. Systems, Inc	SAS-540	780	9/23/2019	9/23/2020	Active Calibration
11	LSC-500	Cable	Chamber 5 Emissi -	-	-	12/9/2019	12/9/2020	Active Verification

Company: Vermeer Manufacturing Company	Page 37 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2

February Testing



Date : 6-Aug-2020

Test : RE Check

Job : C-3379

PE : Shane Dock

Customer : Vermeer

Quote : 319384

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	LSC-500	Cable	Chamber 5 Emissi	-	-	9/14/2020	9/14/2021	Active Verification
2	EE 960203	Analyzer - EMI Receiver	Keysight	N9038A	MY 56400072	7/14/2020	7/14/2021	Active Calibration
3	AA 960194	Antenna - Biconical	A.H. Systems, Inc SAS-540		780	9/21/2020	9/22/2021	Active Calibration

EUT Parameters

Input Power	USB Powered through laptop. 120 VAC, 60 Hz provided to DVK.	Mode	Modulated Tx Mode
EUT	Low, Mid, High Channel	EUT	Worst-Case Reported
Notes	43 Channel Hopset used with 280 and 500 kHz data rates. Cabinet Radiation method used. Emissions below 1 GHz were investigated are not a function of the Tx.		

Table

Frequency (MHz)	Orient	Antenna Polarity	Height (cm)	Azimuth (degree)	Corrected Average Reading (dBμV/m)	Average Limit (dBμV/m)	Average Margin (dB)	Peak Reading (dBμV/m)	Peak Limit (dBμV/m)	Peak Margin (dB)	Channel
4870.9	Vertical	Horizontal	100	0	27.8	54.0	26.2	48.3	74.0	25.7	Mid
4870.9	Vertical	Vertical	276	0	28.9	54.0	25.1	49.4	74.0	24.6	Mid
4871.0	Horizontal	Vertical	138	355	27.2	54.0	26.8	47.7	74.0	26.3	Mid
4870.9	Horizontal	Horizontal	129	20	28.9	54.0	25.1	49.4	74.0	24.6	Mid
4870.9	Flat	Horizontal	355	350	28.1	54.0	25.9	48.6	74.0	25.4	Mid
4870.9	Flat	Vertical	285	0	25.2	54.0	28.8	45.7	74.0	28.3	Mid
4808.1	Vertical	Vertical	255	348	31.6	54.0	22.4	52.1	74.0	21.9	Low
4933.9	Vertical	Vertical	255	348	29.3	54.0	24.7	49.8	74.0	24.2	High

Company: Vermeer Manufacturing Company

Report: 319384 A

Job: C-3379

Name: Radio Apparatus

Model: See Section 2

Serial: See Section 2

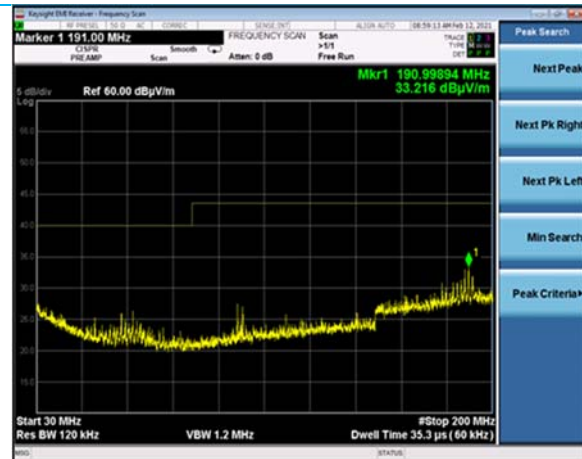
Table - Band Edges

Frequency (MHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Corrected Average Reading (dBμV/m)	Average Limit (dBμV/m)	Average Margin (dB)	Peak Reading (dBμV/m)	Peak Limit (dBμV/m)	Peak Margin (dB)	Channel	Note
2492.8	Horizontal	Horizontal	100	332	30.2	54.0	23.8	50.7	74.0	23.3	High	500 kHz Data Rate
2325.9	Horizontal	Horizontal	120	330	27.1	55.0	27.9	47.6	74.0	26.5	Low	500 kHz Data Rate
2379.9	Horizontal	Horizontal	120	329.6	27.5	56.0	28.5	48.0	74.0	26.0	Hopping	500 kHz Data Rate
2483.9	Horizontal	Horizontal	120	329.6	29.7	57.0	27.3	50.2	74.0	23.8	Hopping	500 kHz Data Rate
2492.9	Horizontal	Horizontal	120	328.5	29.8	58.0	28.2	50.3	74.0	23.7	Hopping	280 kHz Data Rate
2330.3	Horizontal	Horizontal	120	328.5	29.1	59.0	29.9	49.6	74.0	24.4	Hopping	280 kHz Data Rate
2492.9	Horizontal	Horizontal	120	330.7	29.5	60.0	30.5	50.0	74.0	24.0	High	280 kHz Data Rate
2326.0	Horizontal	Horizontal	125	332.8	28.3	61.0	32.7	48.8	74.0	25.2	Low	280 kHz Data Rate

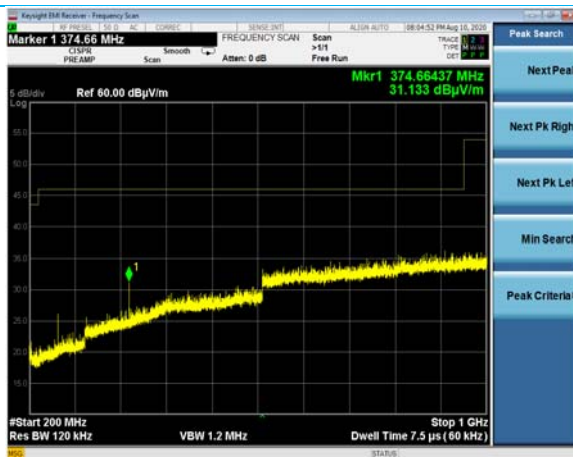
Plots



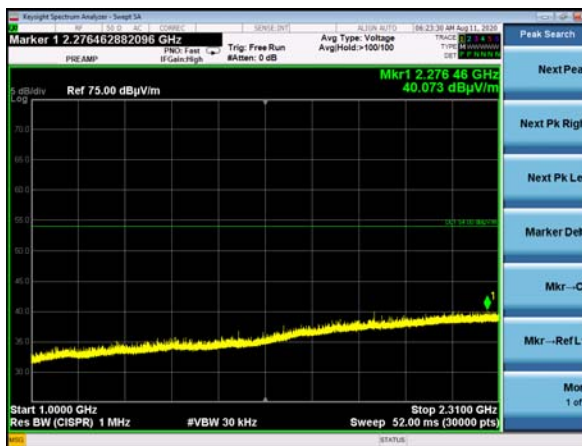
30-200 MHz, Vertical Polarization



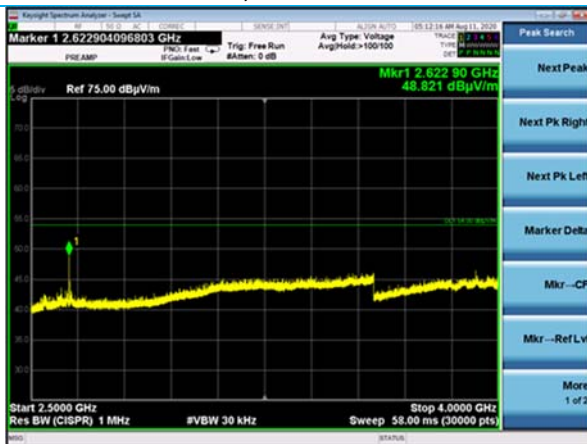
30-200 MHz, Vertical Polarization
EUT powered through AC Adapter



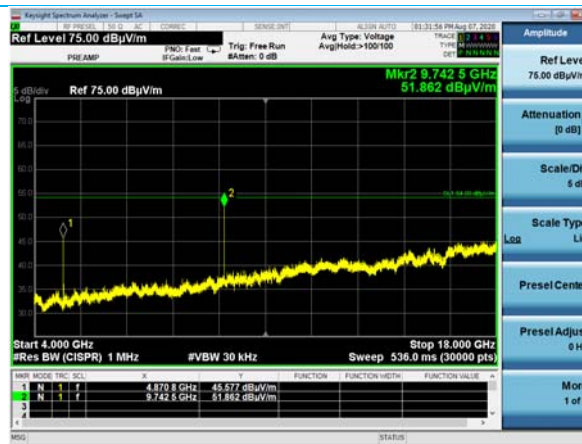
200-1000 MHz, Horizontal Polarization



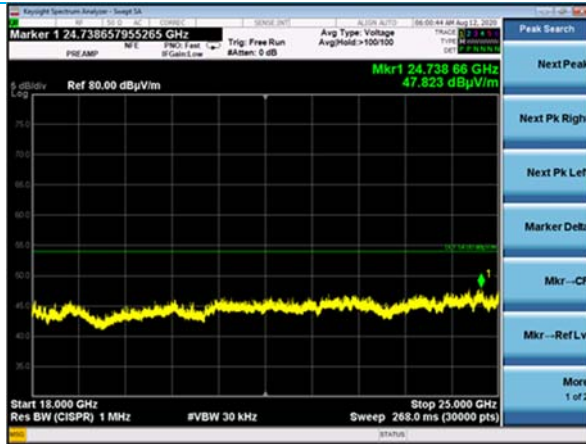
1-2.31 GHz, Vertical Polarization



2.5- 4 GHz, Vertical Polarization



4-18 GHz, Vertical Polarization



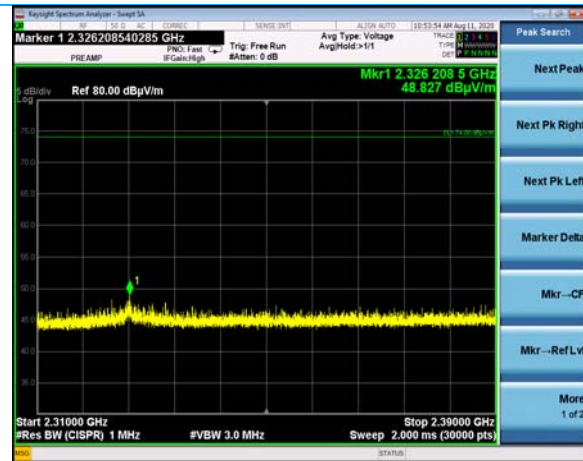
18-25 GHz, Vertical Polarization

Company: Vermeer Manufacturing Company	Page 41 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2

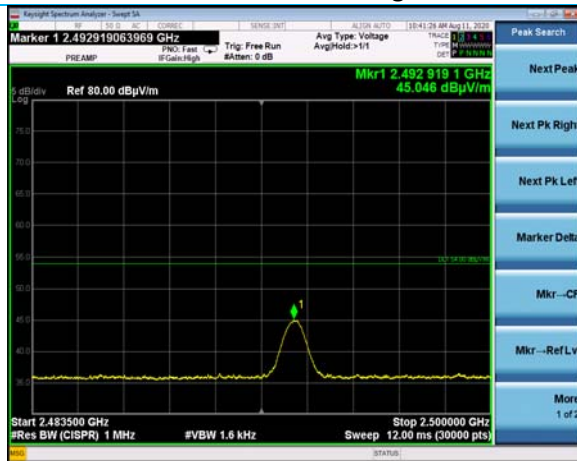
Plots, Band Edge



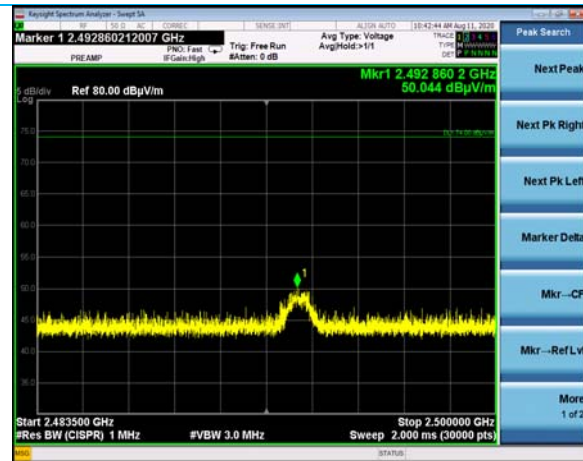
280 kHz LBE Average



280 kHz LBE Peak



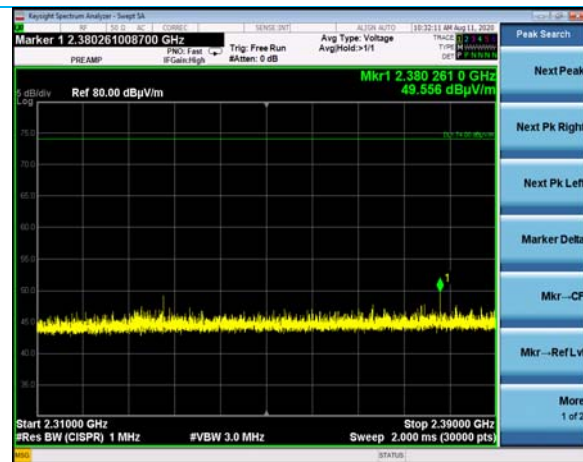
280 kHz UBE Average



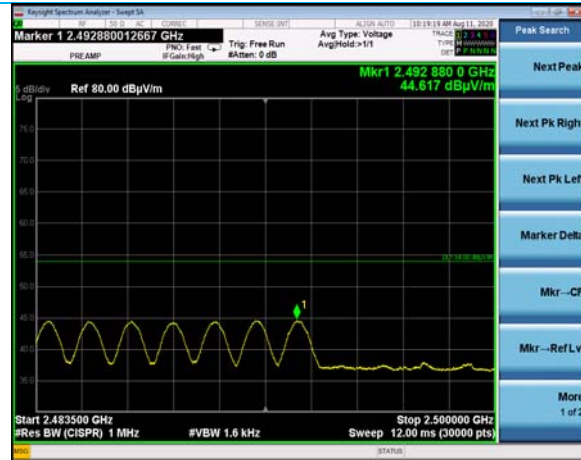
280 kHz UBE Peak



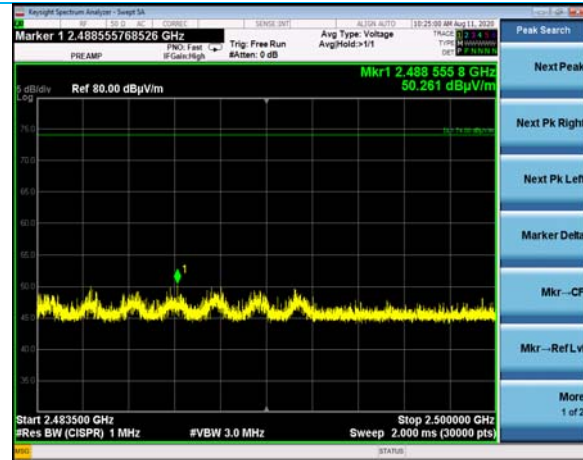
280 kHz LBE Average (Hopping)



280 kHz LBE Peak (Hopping)



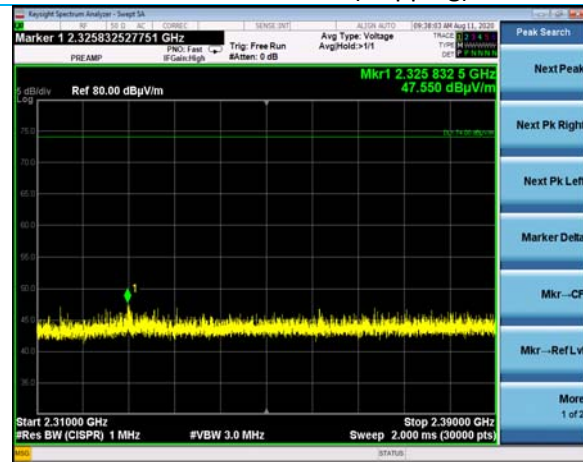
280 kHz UBE Average (Hopping)



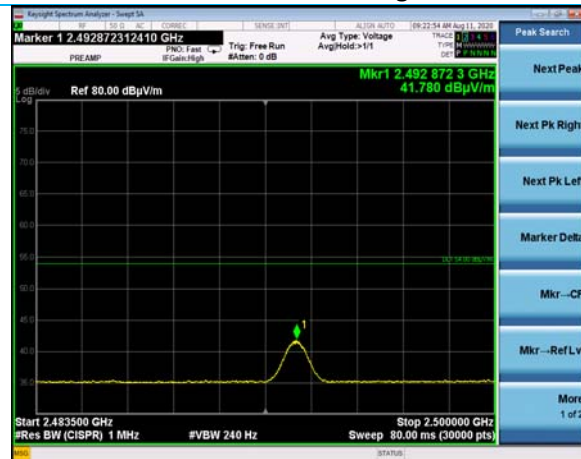
280 kHz UBE Peak (Hopping)



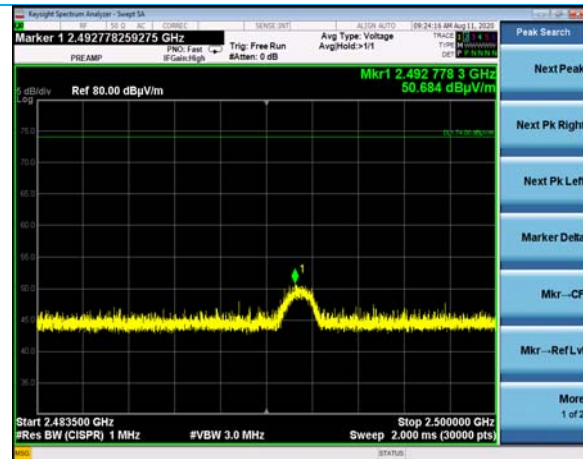
500 kHz LBE Average



500 kHz LBE Peak

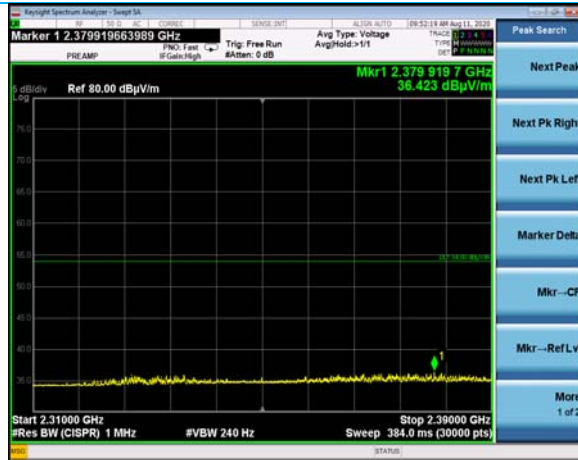


500 kHz UBE Average

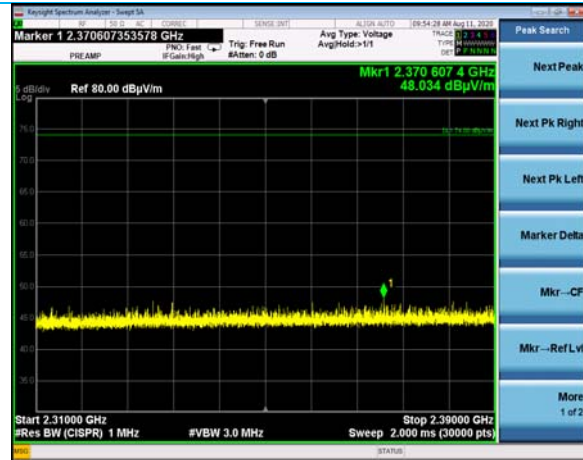


500 kHz UBE Peak

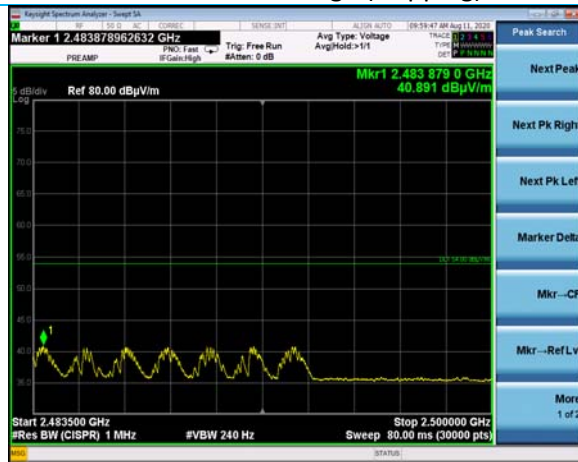
Company: Vermeer Manufacturing Company	Page 43 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2



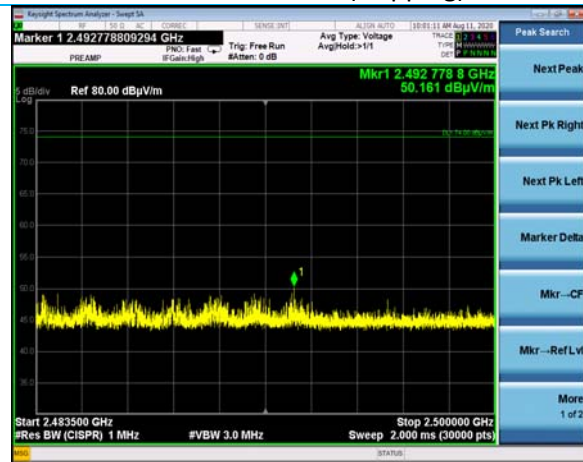
500 kHz LBE Average (Hopping)



500 kHz LBE Peak (Hopping)



500 kHz UBE Average (Hopping)



500 kHz UBE Peak (Hopping)

5.3 AC Mains Conducted Emissions

A line impedance stabilization network (LISN) or artificial mains network (AMN) allows the emissions of the power supply conductors to be measured while isolating the EUT from the supply mains.

Description of Measurement

The AMN, cable, and other necessary measurement system correction factors are loaded onto the EMI receiver when the measurements are performed. The data is gathered and reported as the corrected values.

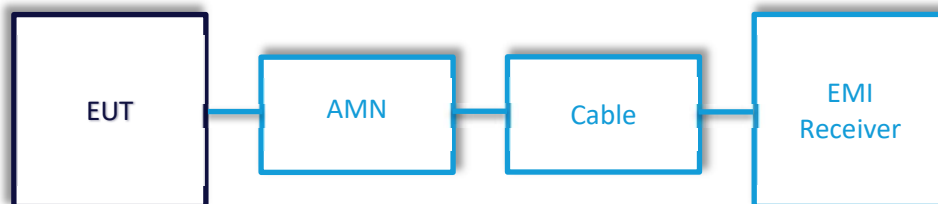
Maximum emissions are determined with a peak max hold trace then measurements at a selection of the highest points are made with quasi-peak and average detectors. Results are recorded and compared to limit for each line. (e.g. line and neutral)

Example Calculations

Measurement (dBμV) + Cable factor (dB) + Other (dB) = Corrected Reading (dBμV)

Margin (dB) = Limit (dBμV) - Corrected Reading (dBμV)

Block Diagram



5.3.1 AC Mains Conducted Emissions

Operator	Braden Smith	QA	Anthony Smith
Temperature	22.2°	R.H. %	52.70%
Test Date	9/1/2020	Location	Conducted Bench Area
Requirement	15.207	Method	ANSI C63.10 Section 6.2

Limits:

Frequency (MHz)	Conducted Limit (dBμV)	
	Quasi-Peak	Average
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

*Decreases logarithmically with frequency

Test Parameters

Frequency	0.15 - 30.0 MHz	Distance	80 cm from LISN, 40 cm from wall
Detector(s)	Quasi-Peak, Average	Table height	80 cm
RBW	9 kHz	VBW	90 kHz

Instrumentation



Date : 6-Aug-2020

Test : 15.247 Tx (RM024) CE

Job : C-3379

PE : Shane Dock

Customer : Vermeer

Quote : 319384

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	EE 960088	Analyzer - EMI Receiver	Agilent	N9038A	MY51210138	7/14/2020	7/14/2021	Active Calibration
2	EE 960162	LISN	COM-POWER	LI-215A	191969	7/13/2020	7/13/2021	Active Calibration
3	LSC-200	Cable	Micro-Coax	UFB311A-0-1440-70I	64639 224071-003	12/9/2019	12/9/2020	Active Verification

Company: Vermeer Manufacturing Company	Page 46 of 48	Name: Radio Apparatus
Report: 319384 A		Model: See Section 2
Job: C-3379		Serial: See Section 2

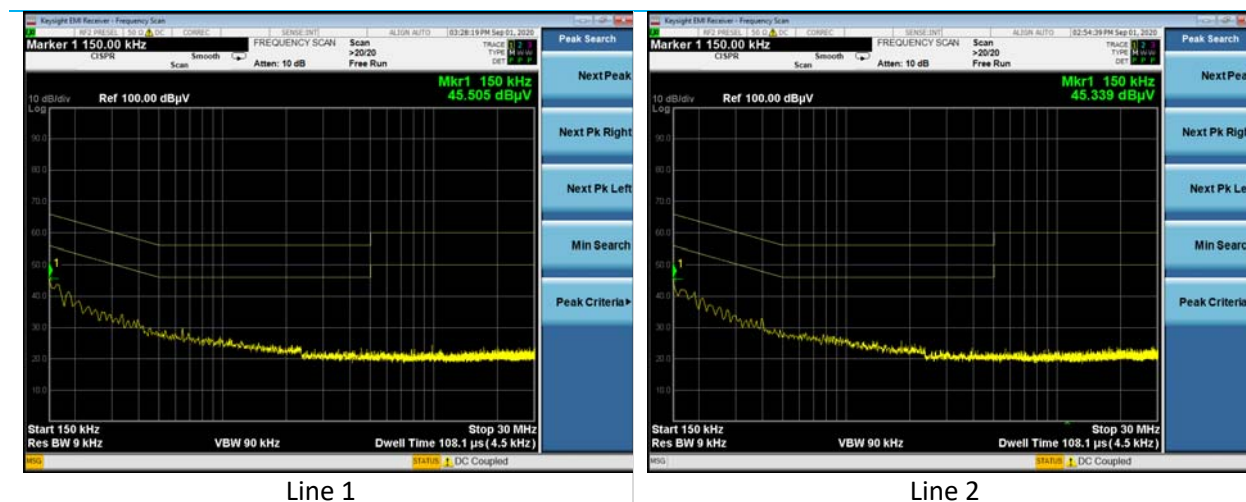
EUT Parameters

Input Power	120 VAC, 60 Hz	Mode	Modulated Tx Mode
EUT	Low, Mid, High Channel	EUT	Worst-Case Reported
Notes	43 Channel Hopset used with 280 data rate.		

Table

Line	Frequency (MHz)	Quasi-Peak Reading (dBμV)	Quasi-Peak Limit (dBμV)	Quasi-Peak Limit (dBμV)	Average Reading (dBμV)	Average Limit (dBμV)	Average Margin (dB)	Channel
1	0.1500	44.0	66.0	22.0	34.7	56.0	56.0	High
1	0.1725	42.8	64.8	22.0	32.7	54.8	54.8	High
1	3.1650	22.1	56.0	33.9	15.3	46.0	46.0	High
2	0.1500	38.0	66.0	28.0	26.4	56.0	56.0	High
2	0.3975	30.4	57.9	27.6	23.0	47.9	47.9	High
2	1.8190	19.0	56.0	37.0	12.1	46.0	46.0	High

Plots



6 REVISION HISTORY

Version	Date	Notes	Person
0	9/24/2020	First Draft	Shane Dock
1	11/2/2020	Updated Draft	Shane Dock
2	11/5/2020	Further Revision	Shane Dock
3	11/6/2020	Final Draft	Shane Dock
4	1/18/2021	TCB Updates	Shane Dock
5	2/3/2021	2 nd TCB Review	Shane Dock
6	2/5/2021	Address Change	Shane Dock
7	2/12/2021	TCB Responses	Shane Dock

END OF REPORT