5.5 Unwanted Emissions

▣ Test Requirements

- Part 15.407(b)

Undesirable emission limits. Except as shown in paragraph (b)(7) of this section, the maximum emissions outside of the frequency bands of operation shall be attenuated in accordance with the following limits:

(1) For transmitters operating in the **5.15 GHz - 5.25 GHz band**: all emissions outside of the **5.15 GHz - 5.35 GHz band** shall not exceed an **EIRP of -27 dBm/MHz**.

(2) For transmitters operating in the **5.25 GHz - 5.35 GHz band**: all emissions outside of the **5.15 GHz - 5.35 GHz band** shall not exceed an **EIRP of -27 dBm/MHz**.

(3) For transmitters operating in the **5.47 GHz - 5.725 GHz band**: all emissions outside of the **5.47 GHz - 5.725 GHz band** shall not exceed an **EIRP of -27 dBm/MHz.**

(4) For transmitters operating in the **5.725 GHz - 5.85 GHz band**: (i) All emissions shall be limited to a level of −27 dBm/MHz at 75 MHz or more above or below the band edge increasing linearly to 10 dBm/MHz at 25 MHz above or below the band edge, and from 25 MHz above or below the band edge increasing linearly to a level of 15.6 dBm/MHz at 5 MHz above or below the band edge, and from 5 MHz above or below the band edge increasing linearly to a level of 27 dBm/MHz at the band edge. The emission measurements shall be performed using a minimum resolution bandwidth of 1 MHz. A lower resolution bandwidth may be employed near the band edge, when necessary, provided the measured energy is integrated to show the total power over 1 MHz.

(5) Unwanted emissions **below 1 GHz** must comply with the general field strength limits set forth in **Section 15.209**.
Further, any U-NII devices using an **AC power line** are required to comply also with the conducted limits set forth in **Section 15.207**.

- Part 15.209: General requirements

Frequency (MHz)	FCC Limit (uV/m)	Measurement Distance (m)
0.009 – 0.490	2 400 / F (kHz)	300
0.490 – 1.705	2 4000 / F (kHz)	30
1.705 – 30.0	30	30

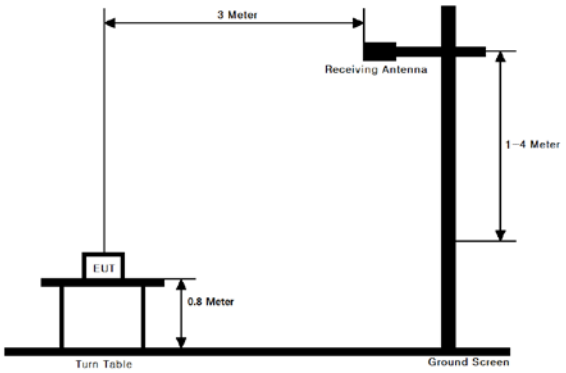
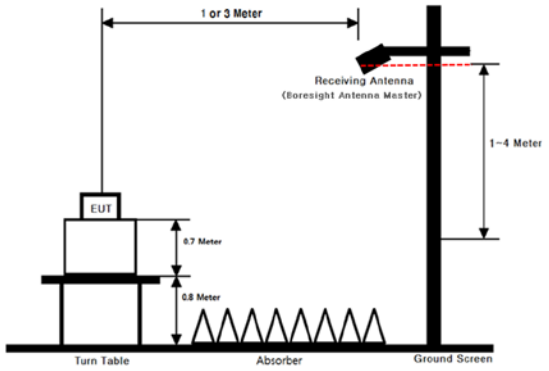
Frequency (MHz)	FCC Limit (uV/m)	Measurement Distance (m)
30 ~ 88	100 **	3
88 ~ 216	150 **	3
216 ~ 960	200 **	3
Above 960	500	3

**Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§15.231 and 15.241.

- Part 15.205(a): Restricted band of operation

MHz	MHz	MHz	MHz	GHz	GHz
0.009 ~ 0.110	8.414 25 ~ 8.414 75	108 ~ 121.94	1 300 ~ 1 427	4.5 ~ 5.15	14.47 ~ 14.5
0.495 ~ 0.505	12.29 ~ 12.293	123 ~ 138	1 435 ~ 1 626.5	5.35 ~ 5.46	15.35 ~ 16.2
2.173 5 ~ 2.190 5	12.519 75 ~ 12.520 25	149.9 ~ 150.05	1 645.5 ~ 1 646.5	7.25 ~ 7.75	17.7 ~ 21.4
4.125 ~ 4.128	12.576 75 ~ 12.577 25	156.524 75 ~ 156.525 25	1 660 ~ 1 710	8.025 ~ 8.5	22.01 ~ 23.12
4.177 25 ~ 4.177 75	13.36 ~ 13.41	156.7 ~ 156.9	1 718.8 ~ 1 722.2	9.0 ~ 9.2	23.6 ~ 24.0
4.207 25 ~ 4.207 75	16.42 ~ 16.423	162.012 5 ~ 167.17	2 200 ~ 2 300	9.3 ~ 9.5	31.2 ~ 31.8
6.215 ~ 6.218	16.694 75 ~ 16.695 25	167.72 ~ 173.2	2 310 ~ 2 390	10.6 ~ 12.7	36.43 ~ 36.5
6.267 75 ~ 6.268 25	16.804 25 ~ 16.804 75	240 ~ 285	2 483.5 ~ 2 500	13.25 ~ 13.4	Above 38.6
6.311 75 ~ 6.312 25	25.5 ~ 25.67	322 ~ 335.4	2 655 ~ 2 900		
8.291 ~ 8.294	37.5 ~ 38.25	399.90 ~ 410	3 260 ~ 3 267		
8.362 ~ 8.366	73 ~ 74.6	608 ~ 614	3 332 ~ 3 339		
8.376 25 ~ 8.386 75	74.8 ~ 75.2	960 ~ 1240	3 345.8 ~ 3 358		
			3 600 ~ 4 400		

▣ Test Configuration

Below 1 GHz	Above 1 GHz
	

▣ Test Procedure

1. The EUT is placed on a non-conductive table. For emission measurements at or below 1 GHz, the table height is 80 cm. For emission measurements above 1 GHz, the table height is 1.5 m.
2. The turn table shall be rotated for 360 degrees to determine the position of maximum emission level.
3. EUT is set 1 m or 3 m away from the receiving antenna, which is varied from 1 m to 4 m to find out the highest emissions.
4. Maximum procedure was performed on the six highest emissions to ensure EUT compliance.
5. And also, each emission was to be maximized by changing the polarization of receiving antenna both horizontal and vertical.
6. Repeat above procedures until the measurements for all frequencies are complete.

Radiated spurious emission measured using following Measurement Procedure **of KDB789033 D02v02r01**

► General Requirements for Unwanted Emissions Measurements

The following requirements apply to all unwanted emissions measurements, both in and outside of the restricted bands:

- EUT Duty Cycle

(1) The EUT shall be configured or modified to **transmit continuously** except as stated in (ii), below. The intent is to test at 100 percent duty cycle; however a small reduction in duty cycle (**to no lower than 98 percent**) is permitted if required by the EUT for amplitude control purposes. Manufacturers are expected to provide software to the test lab to permit such continuous operation.

(2) If **continuous transmission (or at least 98 percent duty cycle) cannot be achieved** due to hardware limitations of the EUT (e.g., overheating), the following additions to the measurement and reporting procedures are required:

- The EUT shall be configured to operate at the maximum achievable duty cycle.
- Measure the duty cycle, x, of the transmitter output signal.
- Adjustments to measurement procedures (e.g., increasing test time and number of traces averaged) shall be performed as described in the procedures below.
- The test report shall include the following additional information:
  - The reason for the duty cycle limitation.
  - The duty cycle achieved for testing and the associated transmit duration and interval between transmissions.
  - The sweep time and the amount of time used for trace stabilization during max-hold measurements for peak emission measurements.

(3) Reduction of the measured emission amplitude levels to account for operational duty factor is not permitted. Compliance is based on emission levels occurring during transmission - not on an average across on and off times of the transmitter.

► **Measurements below 1 000 MHz**

a) Follow the requirements in section II.G.3, “General Requirements for Unwanted Emissions Measurements”.

b) Compliance shall be demonstrated using **CISPR quasi-peak detection**; however, **peak detection** is permitted as an alternative to quasi-peak detection.

► **Measurements Above 1 000 MHz (Peak)**

a) Follow the requirements in section II.G.3, “General Requirements for Unwanted Emissions Measurements”.

b) Peak emission levels are measured by setting the analyzer as follows:

(i) **RBW = 1 MHz.**

(ii) **VBW ≥ 3 MHz.**

(iii) **Detector = Peak.**

(iv) Sweep time = Auto.

(v) Trace mode = Max hold.

(vi) Allow sweeps to continue until the trace stabilizes. Note that if the transmission is not continuous, the time required for the trace to stabilize will increase by a factor of approximately 1/x, where x is the duty cycle. For example, at 50 percent duty cycle, the measurement time will increase by a factor of two relative to measurement time for continuous transmission.

► **Measurements Above 1000 MHz (Method AD)**

(i) **RBW = 1 MHz.**

(ii) **VBW ≥ 3 MHz.**

(iii) **Detector = RMS**, if span / (# of points in sweep) ≤ RBW / 2. Satisfying this condition may require increasing the number of points in the sweep or reducing the span. If the condition is not satisfied, the detector mode shall be set to peak.

(iv) Averaging type = power (i.e., RMS)

• As an alternative, the detector and averaging type may be set for linear voltage averaging. Some analyzers require linear display mode in order to use linear voltage averaging. Log or dB averaging shall not be used.

(v) Sweep time = Auto.

(vi) Perform a trace average of at least 100 traces if the transmission is continuous. If the transmission is not continuous, the number of traces shall be increased by a factor of 1/x, where x is the duty cycle. For example, with 50 percent duty cycle, at least 200 traces shall be averaged.

(vii) If tests are performed with the EUT transmitting at a duty cycle less than 98 percent, a correction factor shall be added to the measurement results prior to comparing to the emission limit in order to compute the emission level that would have been measured had the test been performed at 100 percent duty cycle. The correction factor is computed as follows:

• **If power averaging (RMS) mode was used in step (iv) above, the correction factor is 10 log(1/x), where x is the duty cycle.** For example, if the transmit duty cycle was 50 percent, then 3 dB must be added to the measured emission levels.

• If linear voltage averaging mode was used in step (iv) above, the correction factor is 20 log (1/x), where x is the duty cycle. For example, if the transmit duty cycle was 50 percent, then 6 dB must be added to the measured emission levels.

• If a specific emission is demonstrated to be continuous (100 percent duty cycle) rather than turning on and off with the transmit cycle, no duty cycle correction is required for that emission.

Duty Cycle Correction factor

Test Mode	Date rate	T_{on}(ms)	T_{on+off} (ms)	x = T_{on} / (T_{on+off})	DCCF = 10 log(1/x) (dB)
TM 1	6 Mbps	2.064	2.166	0.952 9	0.21
TM 2	MCS 0	1.920	2.022	0.949 6	0.22
TM 3	MCS 0	0.944	1.046	0.902 9	0.44
TM 4	MCS 0	0.460	0.562	0.818 9	0.87

Note1: Where, T = Transmission duration / x = Duty cycle

Note2: Please refer to the appendix II for duty cycle plots.

▣ Test Results

Test Notes

1. The radiated emissions were investigated 9 kHz to 40 GHz. And no other spurious emissions were found below listed frequencies.
2. Information of Distance Correction Factor
   For finding emissions, measurements may be performed at a distance closer than that specified in the regulations.
   In this case, the distance factor is applied to the result.
   - Calculation of distance correction factor
   At frequencies below 30 MHz = 40 log(tested distance / specified distance)
   At frequencies at or above 30 MHz = 20 log(tested distance / specified distance)
   When distance factor is “N/A”, the measurements were performed at the specified distance and distance factor is not applied.
3. Sample Calculation.
   Margin = Limit – Result / Result = Reading + TF+ DCCF + DCF / TF = AF + CL + HL + AL – AG
   Where, TF = Total Factor, AF = Antenna Factor, CL = Cable Loss, AG = Amplifier Gain, HL = High pass filter Loss, AL = Attenuator Loss, DCCF = Duty Cycle Correction Factor, DCF = Distance Correction Factor
4. The limit is converted to field strength.
   E(dBuV/m) = EIRP(dBm) + 95.2 dB = -27 dBm + 95.2 = 68.2 dBuV/m

Unwanted Emissions data(9 KHz ~ 40 GHz) : *TM1*

Band	Tested Frequency (MHz)	Freq. (MHz)	ANT Pol	EUT Position (Axis)	Detector Mode	Reading (dBuV)	TF (dB/m)	DCCF (dB)	DCF (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)
U-NII 1	5 180	5 149.51	H	X	PK	62.42	2.67	N/A	N/A	65.09	74.00	8.91
		5 149.71	H	X	AV	47.15	2.67	0.21	N/A	50.03	54.00	3.97
		10 358.82	V	X	PK	42.79	8.48	N/A	N/A	51.27	68.20	16.93
	5 200	10 400.55	V	X	PK	43.82	8.44	N/A	N/A	52.26	68.20	15.94
	5 240	10 479.15	V	X	PK	43.91	8.56	N/A	N/A	52.47	68.20	15.73
U-NII 3	5 745	5 648.53	H	X	PK	51.77	3.23	N/A	N/A	55.00	68.20	13.20
		5 691.83	H	X	PK	56.49	3.24	N/A	N/A	59.73	99.15	39.42
		11 489.78	V	X	PK	46.66	8.56	N/A	N/A	55.22	74.00	18.78
		11 489.97	V	X	AV	39.05	8.56	0.21	N/A	47.82	54.00	6.18
	5 785	11 569.91	V	X	PK	44.96	8.60	N/A	N/A	53.56	74.00	20.44
		11 569.99	V	X	AV	35.94	8.60	0.21	N/A	44.75	54.00	9.25
	5 825	5 881.16	H	X	PK	53.54	3.36	N/A	N/A	56.90	100.64	43.74
		5 931.82	H	X	PK	51.36	3.79	N/A	N/A	55.15	68.20	13.05
		11 650.38	V	X	PK	45.71	8.84	N/A	N/A	54.55	74.00	19.45
		11 650.01	V	X	AV	37.26	8.84	0.21	N/A	46.31	54.00	7.69

Unwanted Emissions data(9 KHz ~ 40 GHz) : *TM2*

Band	Tested Frequency (MHz)	Freq. (MHz)	ANT Pol	EUT Position (Axis)	Detector Mode	Reading (dBuV)	TF (dB/m)	DCCF (dB)	DCF (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)
U-NII 1	5 180	5 147.26	H	X	PK	66.90	2.66	N/A	N/A	69.56	74.00	4.44
		5 147.94	H	X	AV	48.55	2.67	0.22	N/A	51.44	54.00	2.56
		10 360.15	V	X	PK	43.76	8.48	N/A	N/A	52.24	68.20	15.96
	5 200	10 399.78	V	X	PK	44.71	8.44	N/A	N/A	53.15	68.20	15.05
	5 240	10 479.72	V	X	PK	43.69	8.56	N/A	N/A	52.25	68.20	15.95
U-NII 3	5 745	5 640.53	H	X	PK	52.22	3.23	N/A	N/A	55.45	68.20	12.75
		5 716.50	H	X	PK	68.44	3.24	N/A	N/A	71.68	109.82	38.14
		11 489.57	V	X	PK	46.66	8.55	N/A	N/A	55.21	74.00	18.79
		11 489.88	V	X	AV	38.57	8.56	0.22	N/A	47.35	54.00	6.65
	5 785	11 569.33	V	X	PK	44.81	8.60	N/A	N/A	53.41	74.00	20.59
		11 569.76	V	X	AV	35.86	8.60	0.22	N/A	44.68	54.00	9.32
	5 825	5 878.46	H	X	PK	55.26	3.34	N/A	N/A	58.60	102.64	44.04
		5 935.81	H	X	PK	51.12	3.82	N/A	N/A	54.94	68.20	13.26
		11 649.71	V	X	PK	46.02	8.84	N/A	N/A	54.86	74.00	19.14
		11 650.00	V	X	AV	36.73	8.84	0.22	N/A	45.79	54.00	8.21

Unwanted Emissions data(9 KHz ~ 40 GHz) : *TM3*

Band	Tested Frequency (MHz)	Freq. (MHz)	ANT Pol	EUT Position (Axis)	Detector Mode	Reading (dBuV)	TF (dB/m)	DCCF (dB)	DCF (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)
U-NII 1	5 190	5 149.62	H	X	PK	60.83	2.67	N/A	N/A	63.50	74.00	10.50
		5 149.93	H	X	AV	47.40	2.67	0.45	N/A	50.52	54.00	3.48
		10 379.78	V	X	PK	43.52	8.46	N/A	N/A	51.98	68.20	16.22
	5 230	10 459.86	V	X	PK	44.69	8.51	N/A	N/A	53.20	68.20	15.00
U-NII 3	5 755	5 642.38	H	X	PK	52.91	3.23	N/A	N/A	56.14	68.20	12.06
		5 670.33	H	X	PK	54.06	3.24	N/A	N/A	57.30	83.24	25.94
		11 509.80	V	X	PK	46.80	8.58	N/A	N/A	55.38	74.00	18.62
		11 509.94	V	X	AV	37.91	8.58	0.45	N/A	46.94	54.00	7.06
	5 795	5 877.76	H	X	PK	52.76	3.34	N/A	N/A	56.10	103.16	47.06
		5 931.56	H	X	PK	52.27	3.79	N/A	N/A	56.06	68.20	12.14
		11 589.67	V	X	PK	44.72	8.64	N/A	N/A	53.36	74.00	20.64
		11 589.91	V	X	AV	36.03	8.64	0.45	N/A	45.12	54.00	8.88

Unwanted Emissions data(9 KHz ~ 40 GHz) : *TM4*

Band	Tested Frequency (MHz)	Freq. (MHz)	ANT Pol	EUT Position (Axis)	Detector Mode	Reading (dBuV)	TF (dB/m)	DCCF (dB)	DCF (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)
U-NII 1	5 210	5 147.44	H	X	PK	59.66	2.66	N/A	N/A	62.32	74.00	11.68
		5 147.86	H	X	AV	47.27	2.67	0.87	N/A	50.81	54.00	3.19
		10 419.84	V	X	PK	45.47	8.45	N/A	N/A	53.92	68.20	14.28
U-NII 3	5 775	5 643.50	H	X	PK	53.73	3.23	N/A	N/A	56.96	68.20	11.24
		5 683.85	H	X	PK	53.08	3.24	N/A	N/A	56.32	93.25	36.93
		5 895.96	H	X	PK	52.09	3.49	N/A	N/A	55.58	89.69	34.11
		5 932.29	H	X	PK	50.91	3.79	N/A	N/A	54.70	68.20	13.50
		11 549.91	V	X	PK	45.43	8.57	N/A	N/A	54.00	74.00	20.00
		11 549.72	V	X	AV	36.23	8.57	0.87	N/A	45.67	54.00	8.33

5.6 AC Power-Line Conducted Emissions

▣ Test Requirements, §15.207

An intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 uH/50 ohm line impedance stabilization network (LISN).

Compliance with the provision of this paragraph shall on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower applies at the boundary between the frequency ranges.

Frequency Range (MHz)	Conducted Limit (dBuV)	
	Quasi-Peak	Average
0.15 ~ 0.5	66 to 56 *	56 to 46 *
0.5 ~ 5.0	56	46
5 ~ 30	60	50

* Decreases with the logarithm of the frequency

Compliance with this provision shall be based on the measurement of the radio frequency voltage between each power line (LINE and NEUTRAL) and ground at the power terminals.

▣ Test Configuration

NA

▣ Test Procedure

Conducted emissions from the EUT were measured according to the ANSI C63.10-2013.

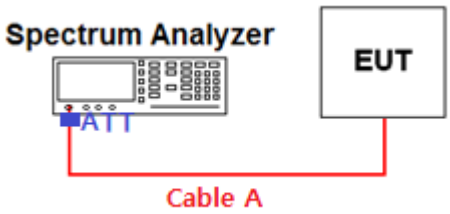
1. The test procedure is performed in a 6.5 m × 3.5 m × 3.5 m (L × W × H) shielded room. The EUT along with its peripherals were placed on a 1.0 m (W) × 1.5 m (L) and 0.8 m in height wooden table and the EUT was adjusted to maintain a 0.4 meter space from a vertical reference plane.
2. The EUT was connected to power mains through a line impedance stabilization network (LISN) which provides 50 ohm coupling impedance for measuring instrument and the chassis ground was bounded to the horizontal ground plane of shielded room.
3. All peripherals were connected to the second LISN and the chassis ground also bounded to the horizontal ground plane of shielded room.
4. The excess power cable between the EUT and the LISN was bundled. The power cables of peripherals were unbundled. All connecting cables of EUT and peripherals were moved to find the maximum emission.

▣ Test Results: NA

APPENDIX I

Conducted Test set up Diagram

▪ Conducted Measurement



APPENDIX II

Duty Cycle Information

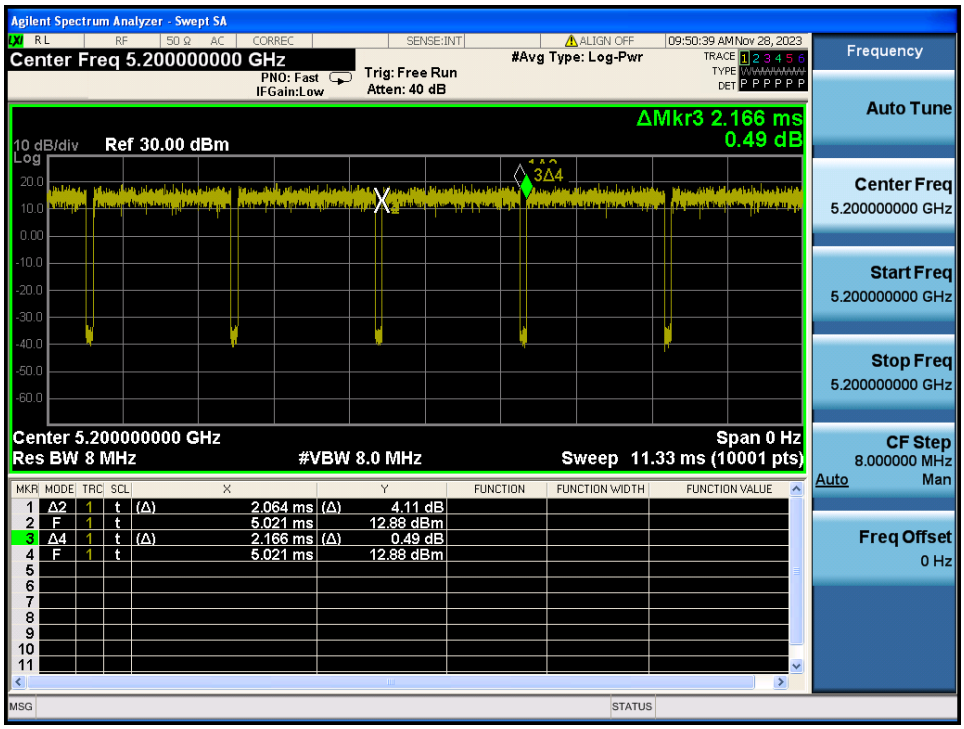
▣ Test Procedure

Duty Cycle [X = On Time / (On + Off time)] is measured using Measurement Procedure **of KDB789033 D02v02r01**

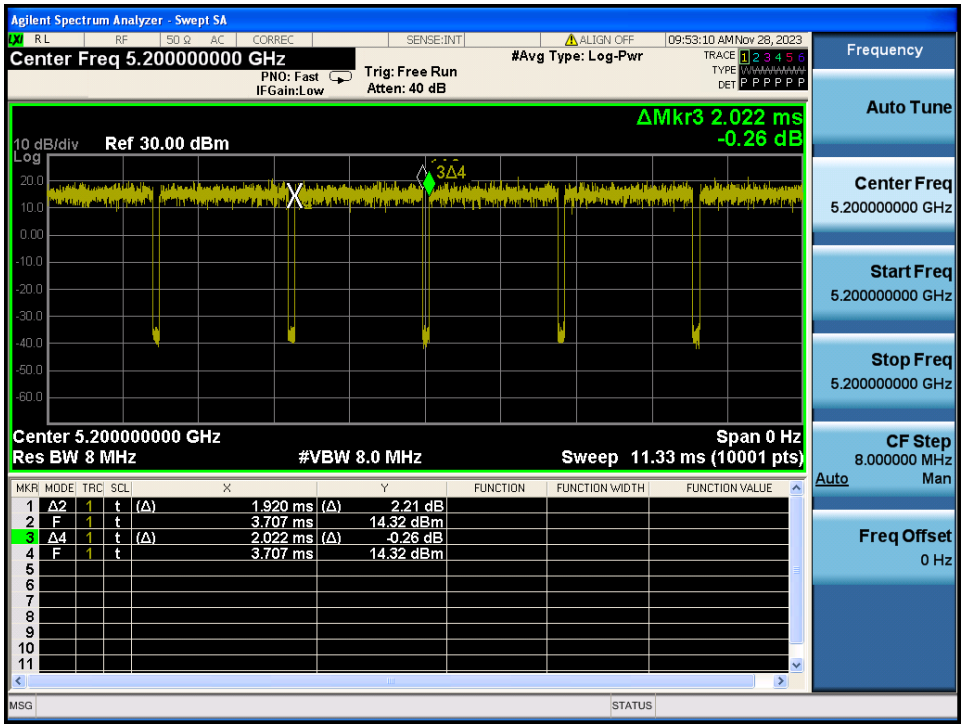
1. Set the center frequency of the spectrum analyzer to the center frequency of the transmission.
2. Set RBW ≥ EBW if possible; otherwise, set RBW to the largest available value.
3. Set VBW ≥ RBW. Set detector = peak.
4. Note : The zero-span measurement method shall not be used unless both **RBW and VBW are > 50 / *T***, where *T* is defined in section II.B.1.a), and **the number of sweep points across duration *T* exceeds 100**. (For example, if VBW and/or RBW are limited to 3 MHz, then the zero-span method of measuring duty cycle shall not be used if *T* ≤ 16.7 microseconds.)

T : The minimum transmission duration over which the transmitter is on and is transmitting at its maximum power control level for the tested mode of operation.
(***T* = On time** of the above table since the EUT operates with above fixed Duty Cycle and it is the minimum On time)

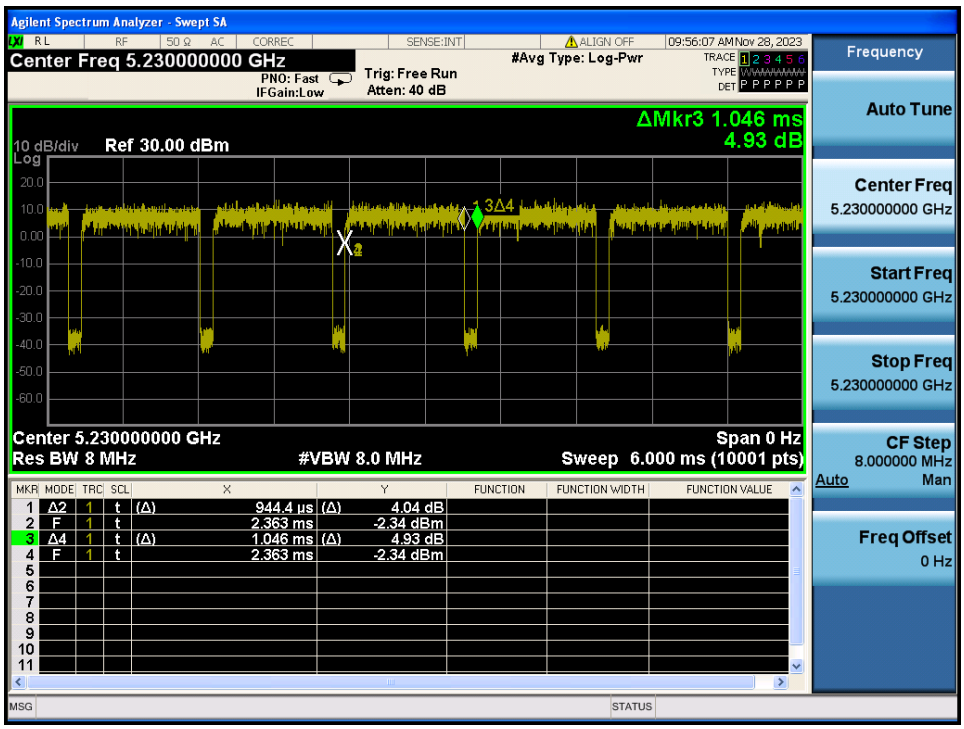
Duty Cycle Test Mode: TM1 & Ch.40



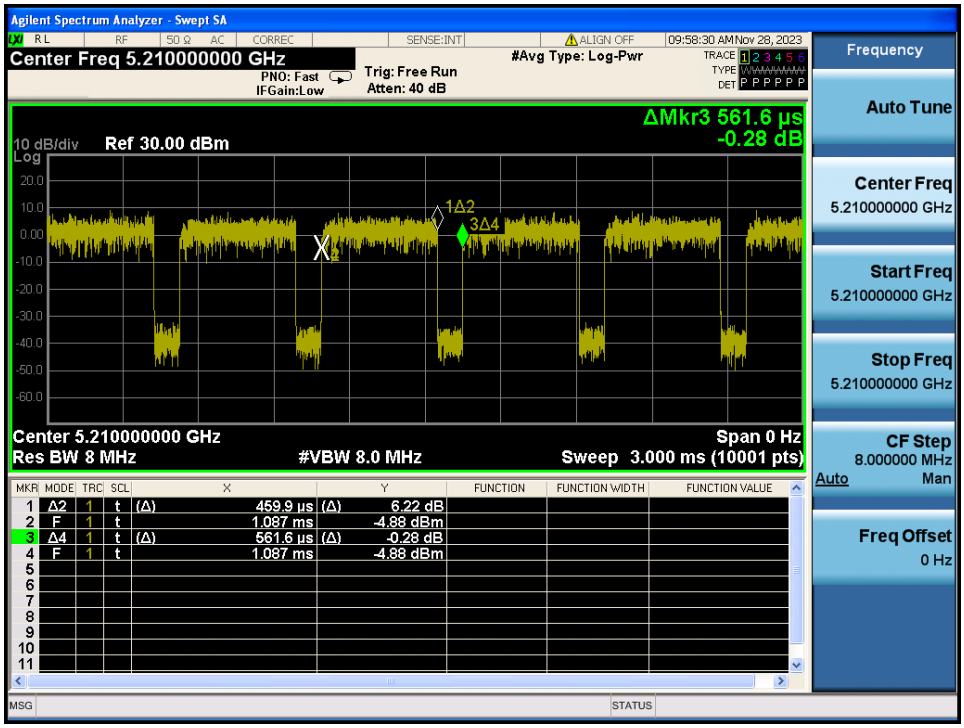
Duty Cycle Test Mode: TM 2 & Ch.40



Duty Cycle Test Mode: TM 3 & Ch.46



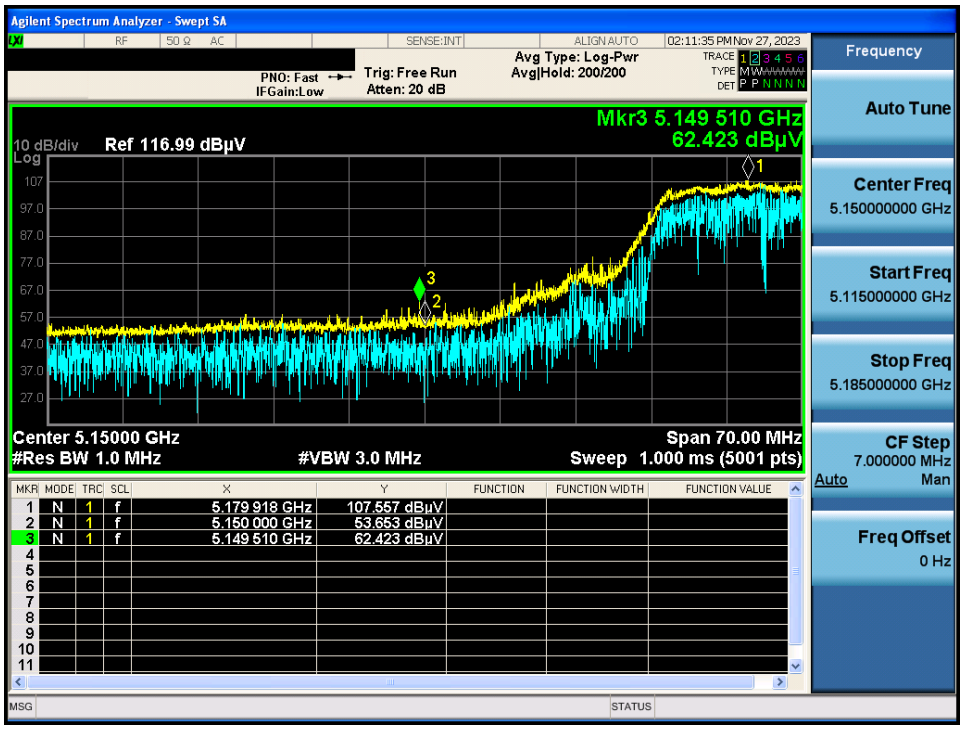
Duty Cycle Test Mode: TM 4 & Ch.42



APPENDIX III

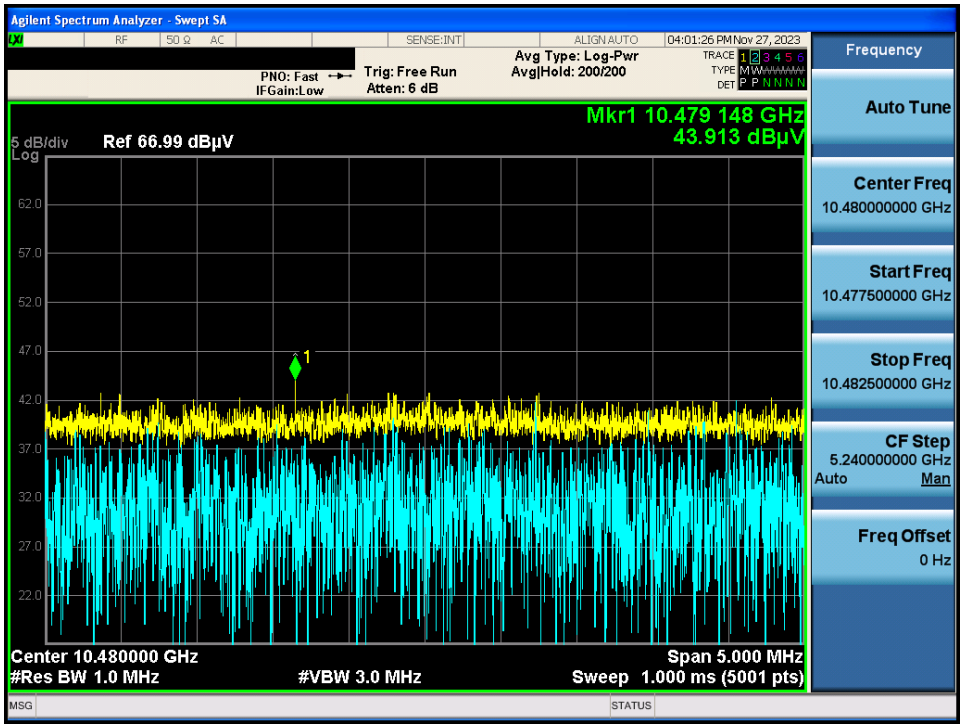
Unwanted Emissions (Radiated) Test Plot:

TM 1 & U-NII 1 & 5 180 & X axis & Hor **Detector Mode : PK**

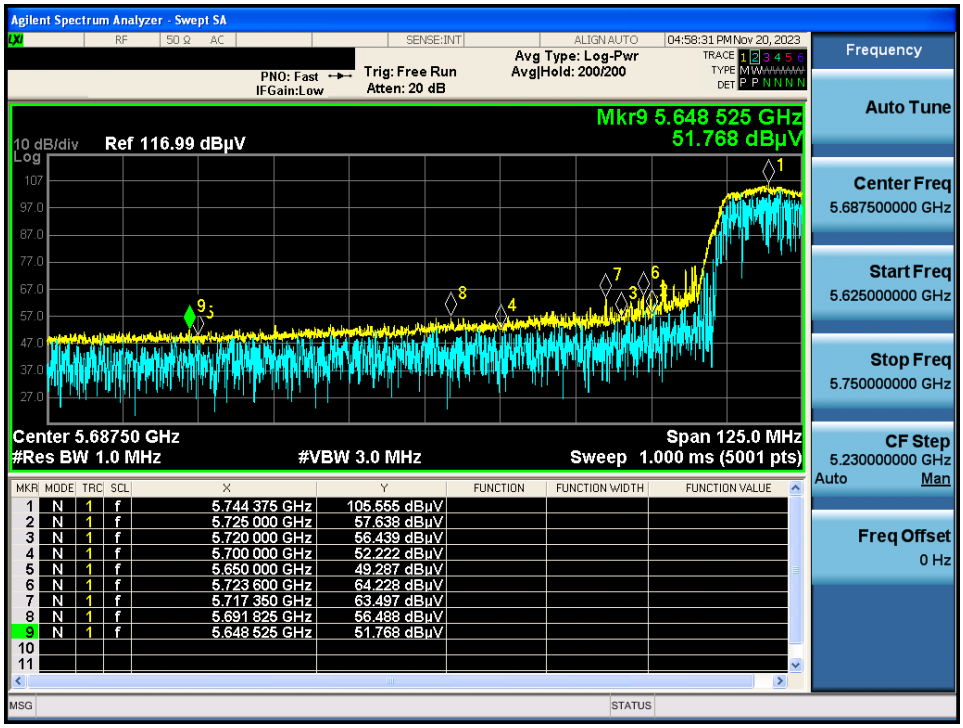


TM 1 & U-NII 1 & 5 180 & X axis & Hor **Detector Mode : AV**

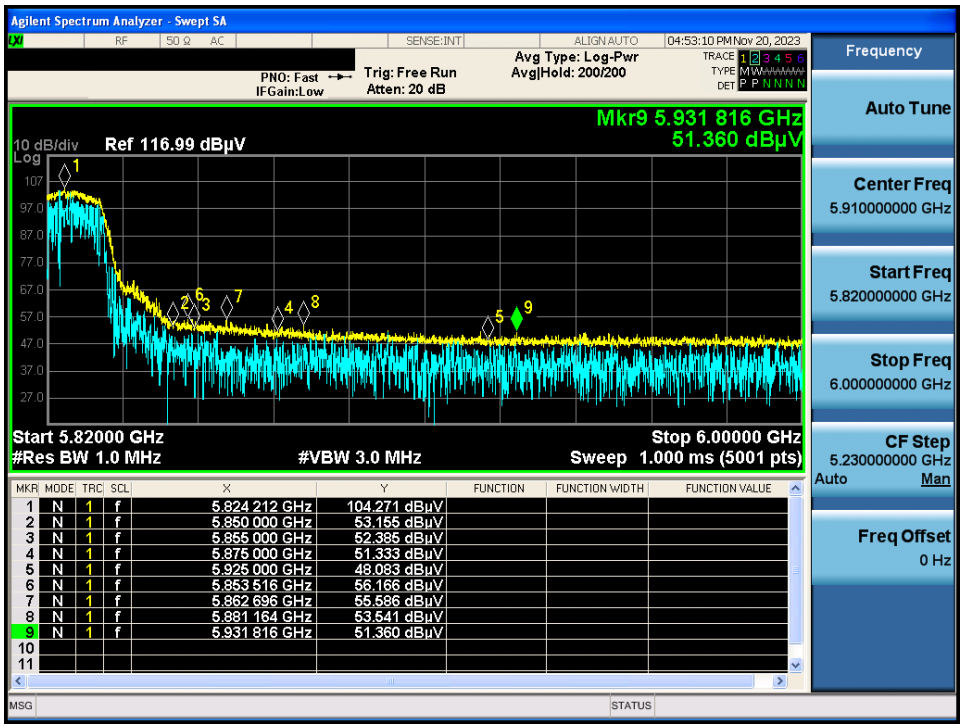
TM 1 & U-NII 1 & 5 240 & X axis & Ver **Detector Mode : PK**



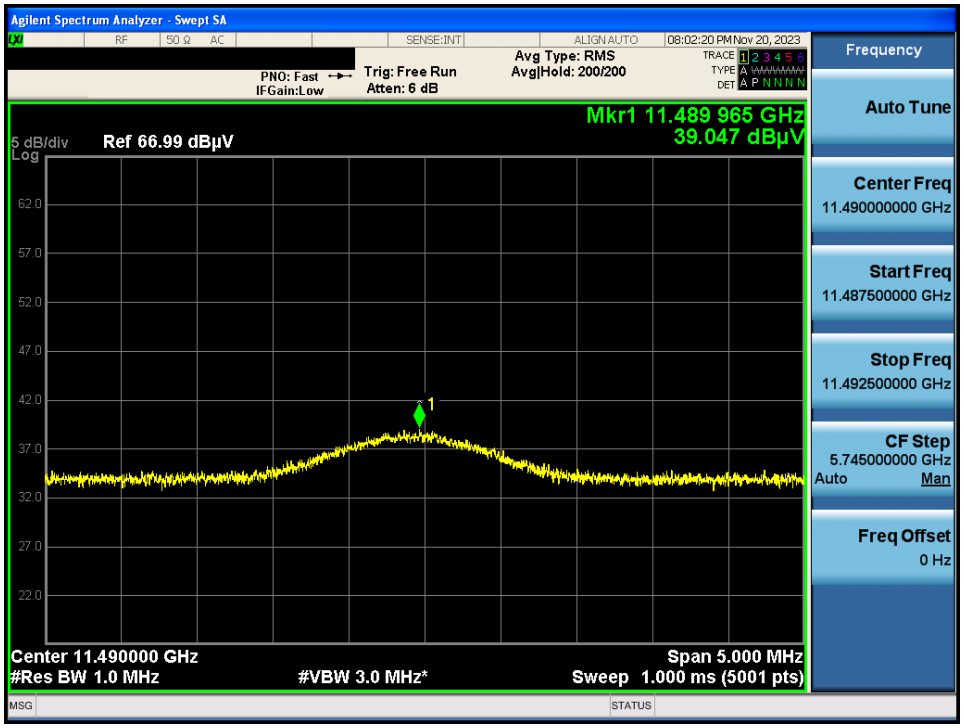
TM 1 & U-NII 3 & 5 745 & X axis & Hor **Detector Mode : PK**



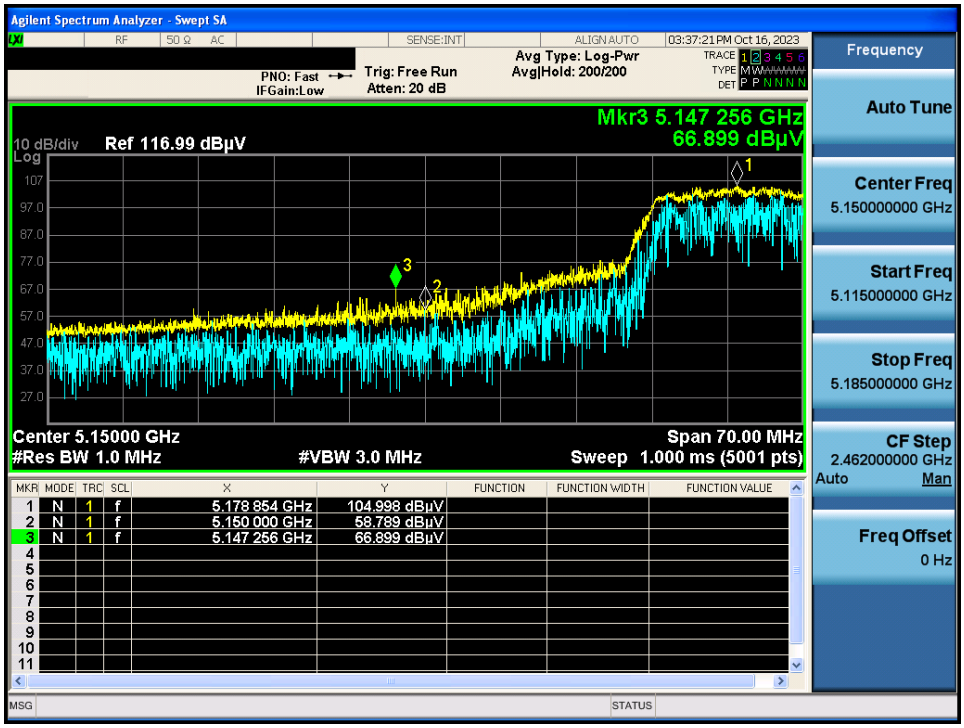
TM 1 & U-NII 3 & 5 825 & X axis & Hor **Detector Mode : PK**



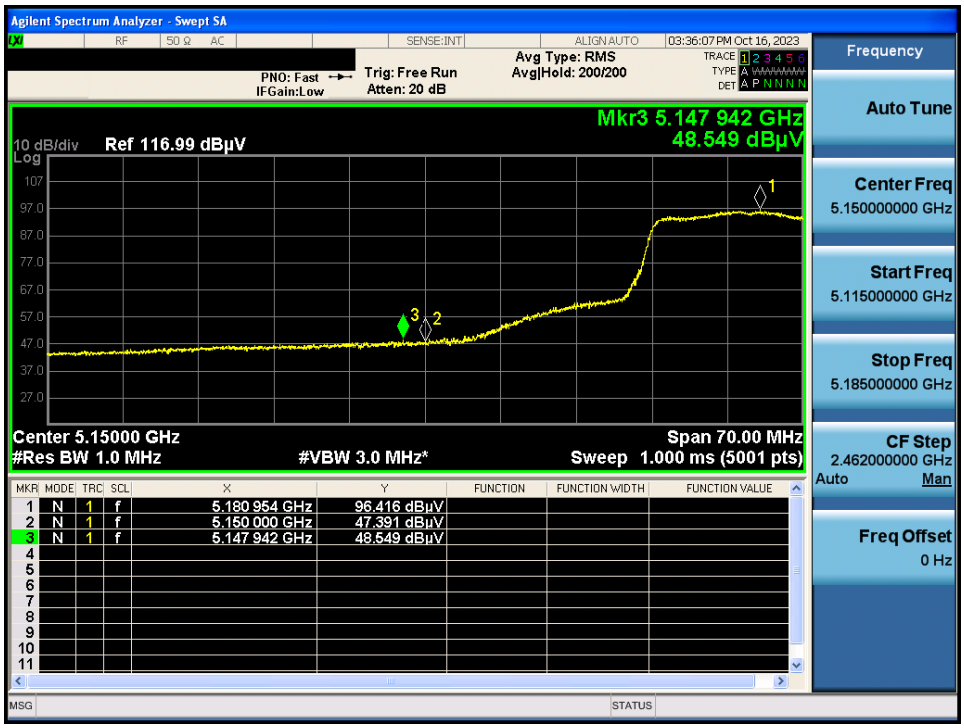
TM 1 & U-NII 3 & 5 745 & X axis & Ver **Detector Mode : AV**



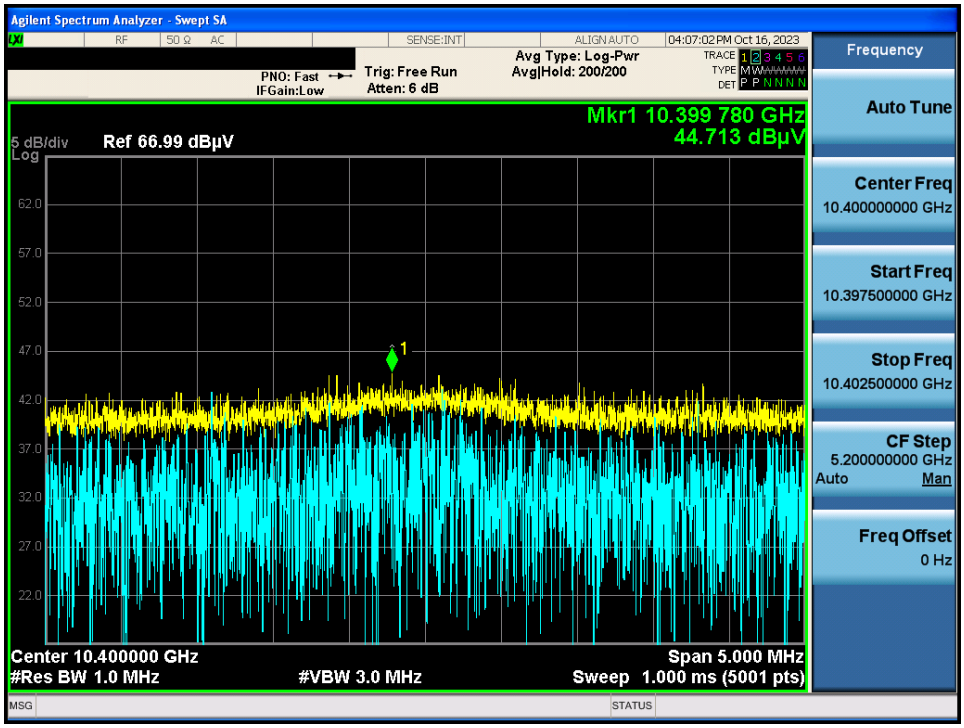
TM 2 & U-NII 1 & 5 180 & X axis & Hor **Detector Mode : PK**



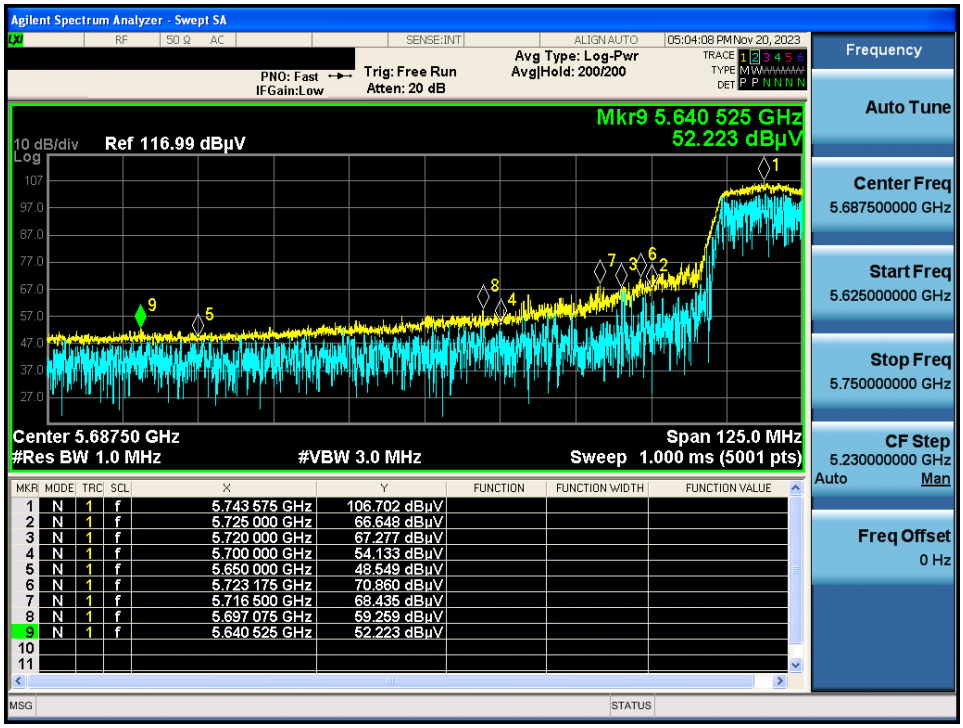
TM 2 & U-NII 1 & 5 180 & X axis & Hor **Detector Mode : AV**



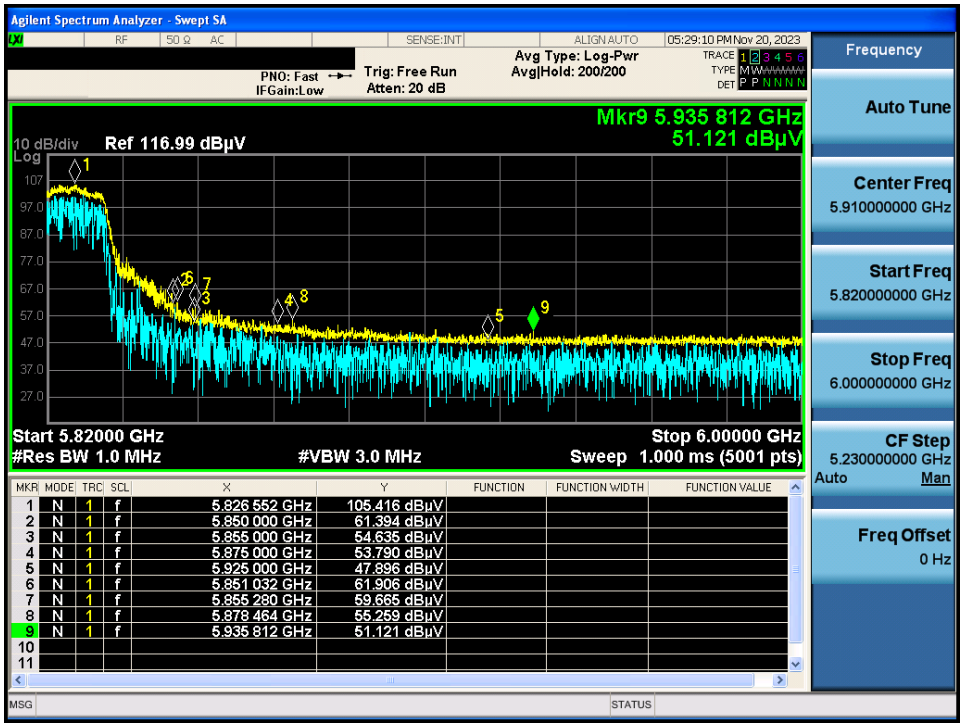
TM 2 & U-NII 1 & 5 200 & X axis & Ver **Detector Mode : AV**



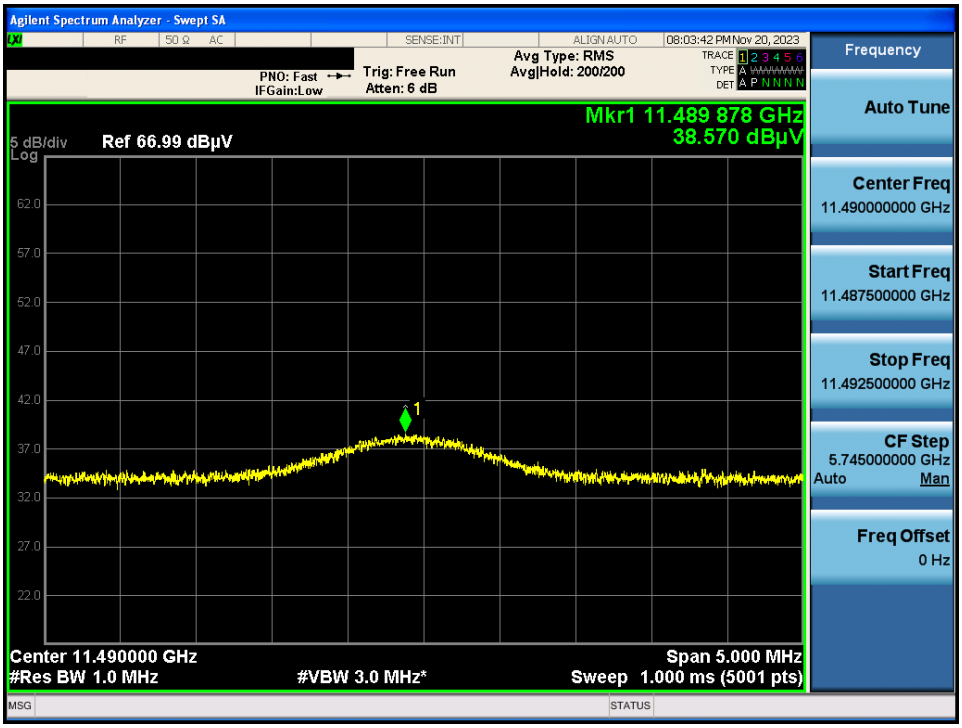
TM 2 & U-NII 3 & 5 745 & X axis & Hor **Detector Mode : PK**



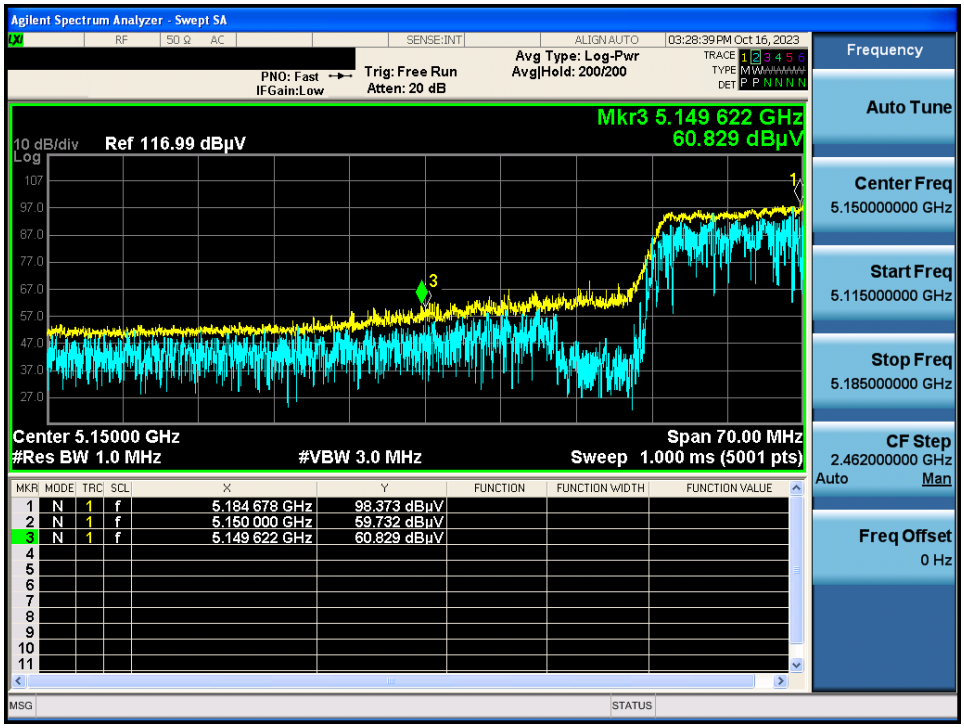
TM 2 & U-NII 3 & 5 825 & X axis & Hor **Detector Mode : PK**



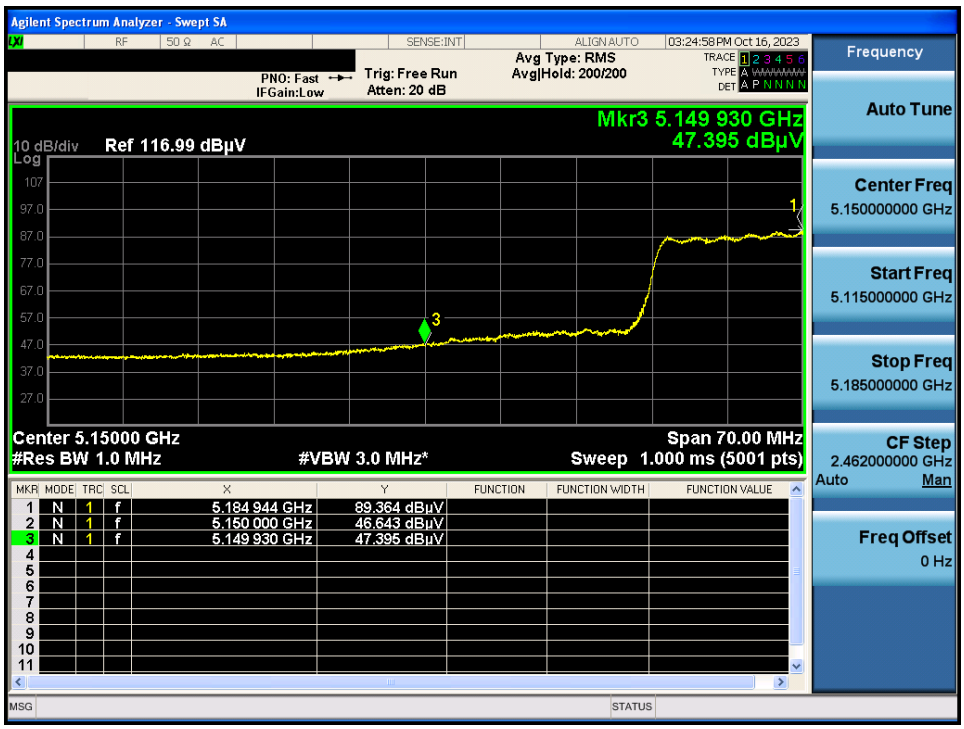
TM 2 & U-NII 3 & 5 745 & X axis & Ver **Detector Mode : AV**



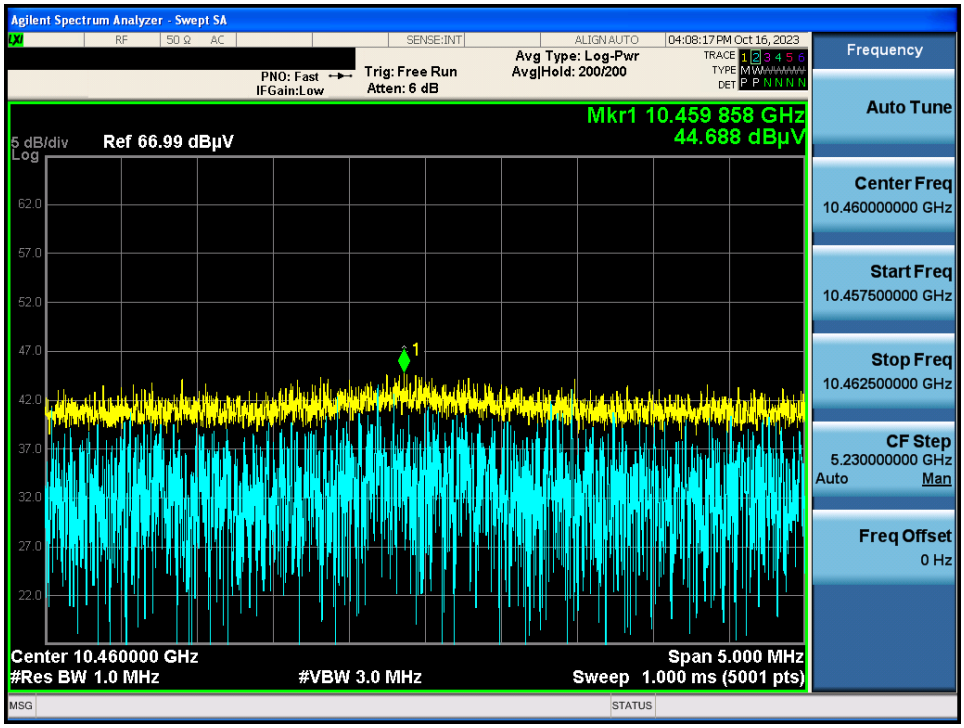
TM 3 & U-NII 1 & 5 190 & X axis & Hor **Detector Mode : PK**



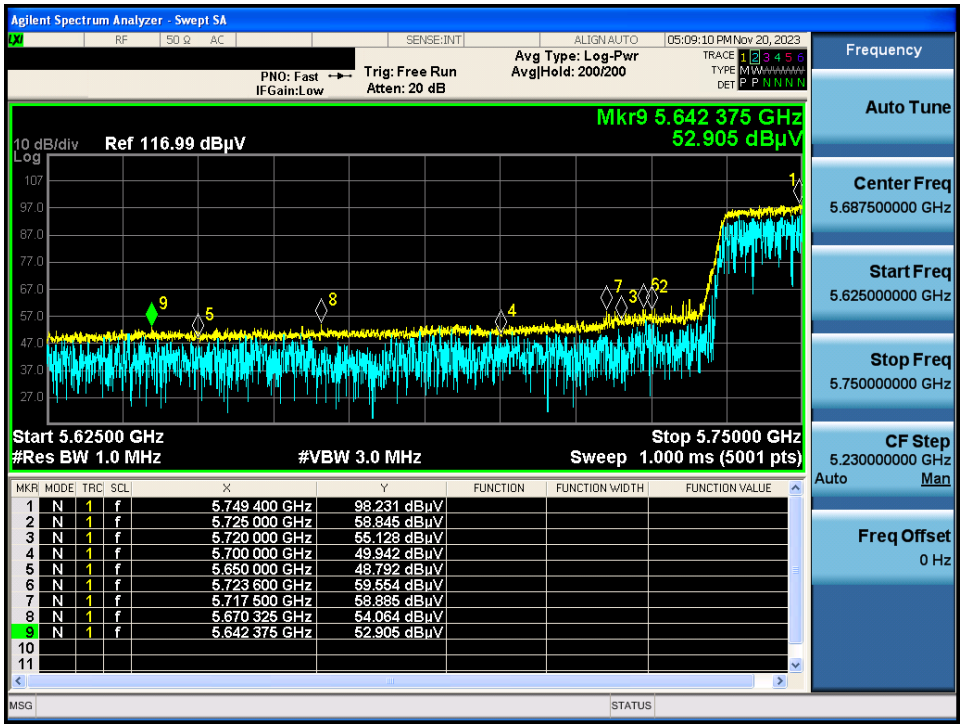
TM 3 & U-NII 1 & 5 190 & X axis & Hor **Detector Mode : AV**



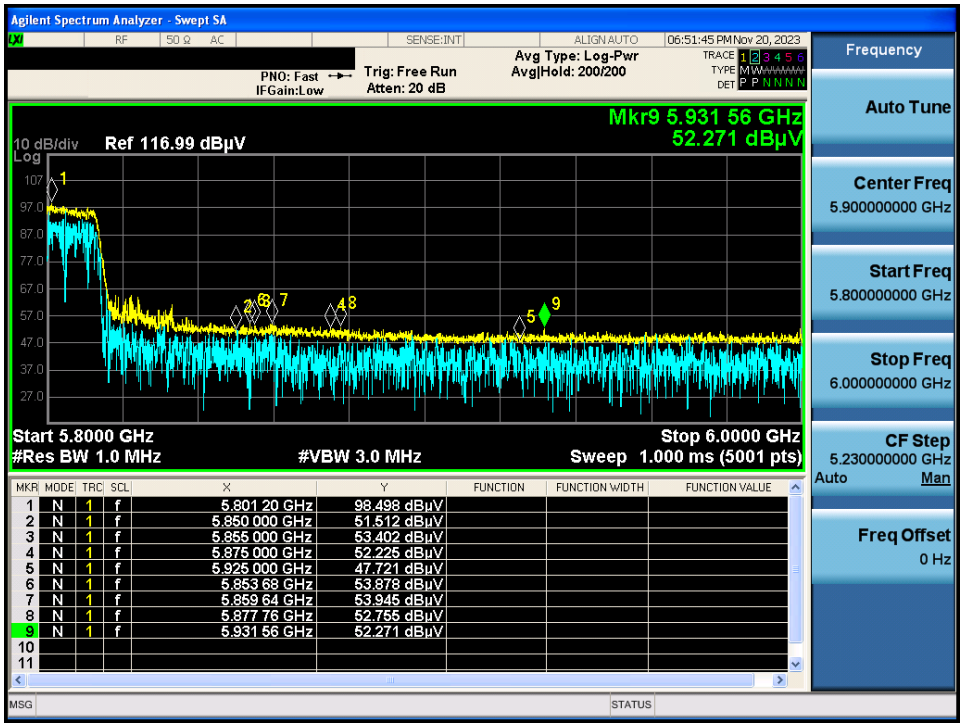
TM 3 & U-NII 1 & 5 230 & X axis & Ver **Detector Mode : AV**



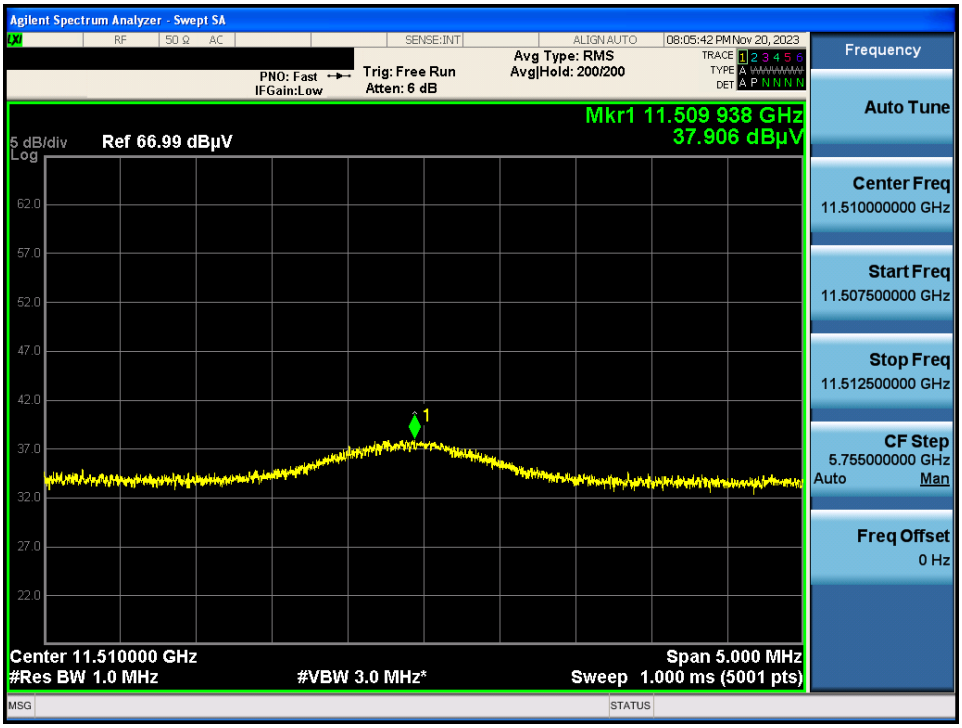
TM 3 & U-NII 3 & 5 755 & X axis & Hor **Detector Mode : PK**



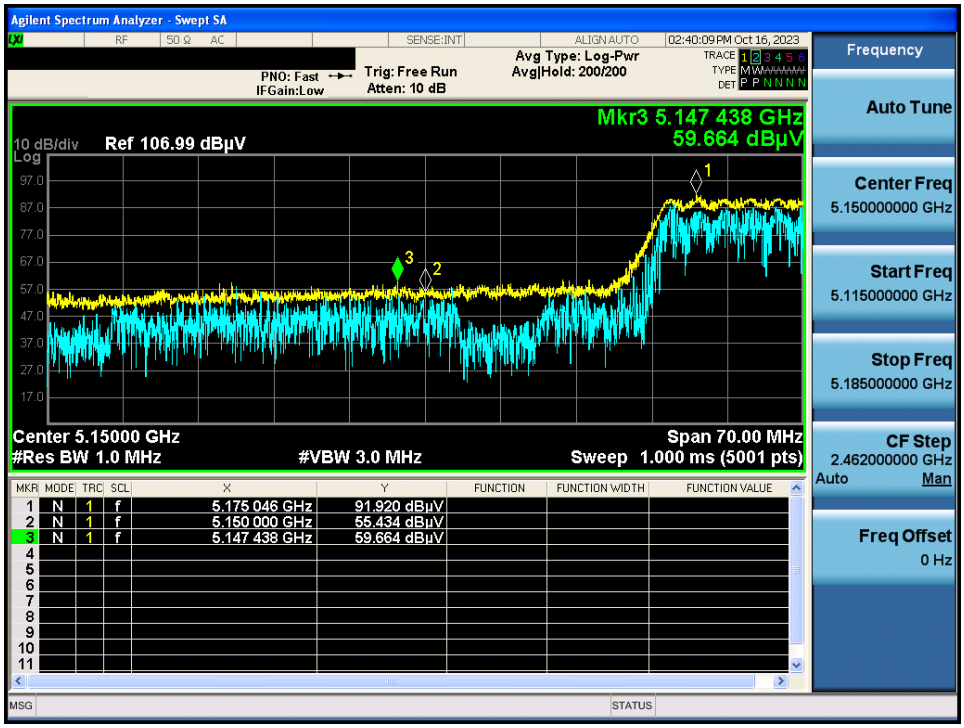
TM 3 & U-NII 3 & 5 795 & X axis & Hor **Detector Mode : PK**



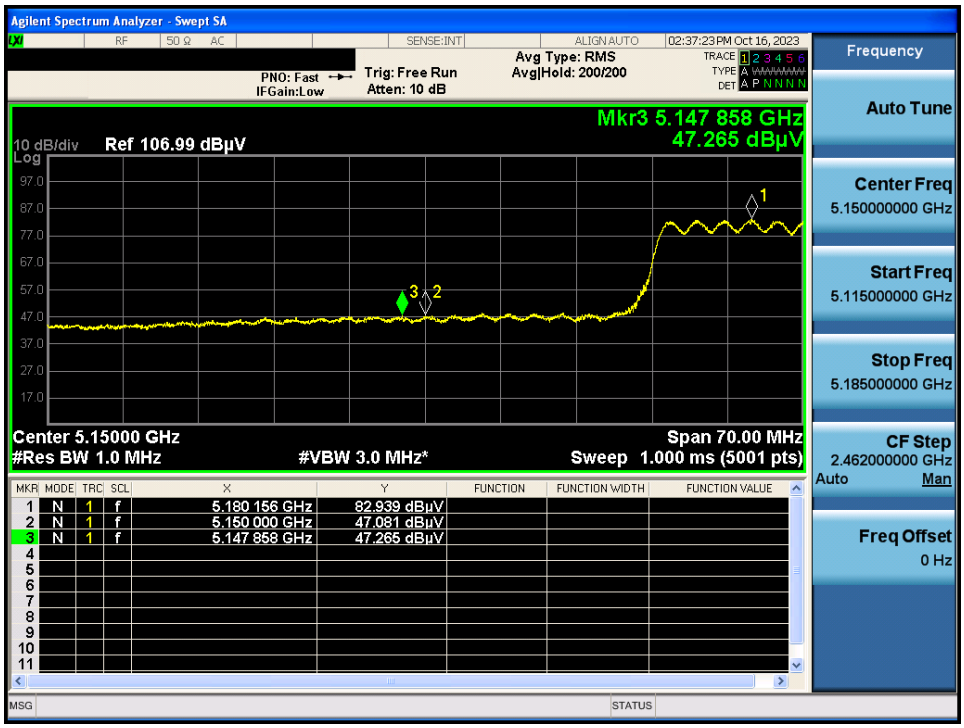
TM 3 & U-NII 3 & 5 755 & X axis & Ver **Detector Mode : AV**



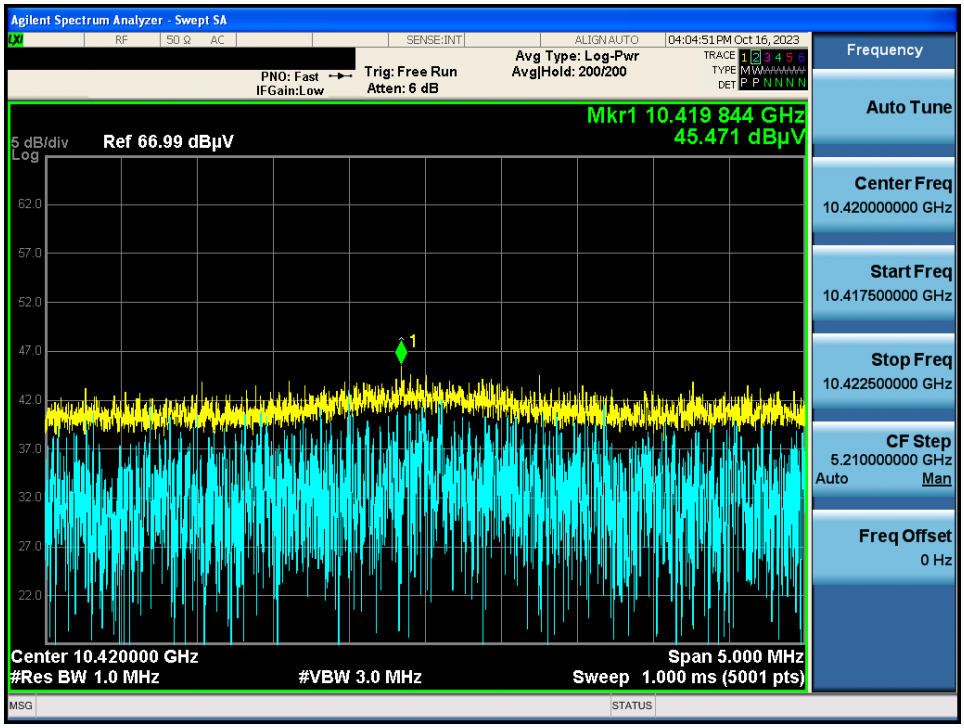
TM 4 & U-NII 1 & 5 210 & X axis & Hor **Detector Mode : PK**



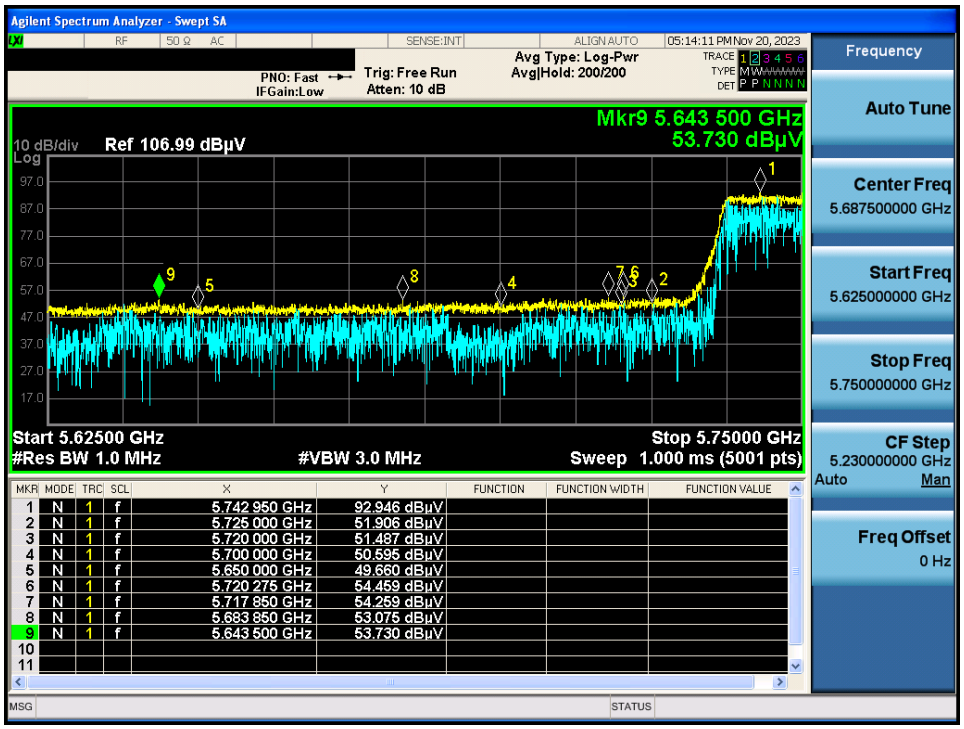
TM 4 & U-NII 1 & 5 210 & X axis & Hor **Detector Mode : AV**



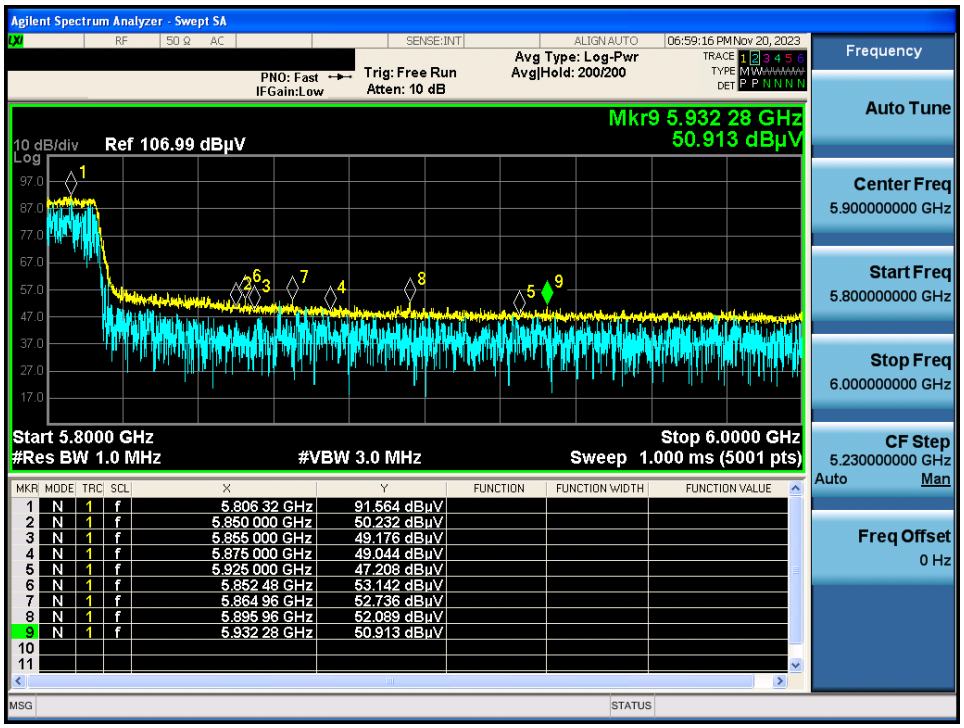
TM 4 & U-NII 1 & 5 210 & X axis & Ver **Detector Mode : AV**



TM 4 & U-NII 3 & 5 775 & X axis & Hor **Detector Mode : PK**



TM 4 & U-NII 3 & 5 775 & X axis & Hor **Detector Mode : PK**



TM 4 & U-NII 3 & 5 775 & X axis & Ver **Detector Mode : AV**