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Test Report

Prepared for: **Inovonics**

Address: **397 S. Taylor Ave.**
Louisville, CO 80027

Product: **EN 22XX**

Test Report No: **R20200701-21-E2C DSS**

Approved by:

Nic S. Johnson, NCE
Technical Manager
iNARTE Certified EMC Engineer #EMC-003337-NE

DATE: **2 June 2021**

Total Pages: **40**

ilac-MRA A2LA ACCREDITED TESTING LABORATORY CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	10 September 2020	Original – NJohnson Prepared by KVepuri
A	13 October 2020	Corrected calculation on Page 9 Includes NCEE Labs report R20200701-21-E2 and its amendment in full. -NJ
B	13 October 2020	Corrected calculation on Page 9 Includes NCEE Labs report R20200701-21-E2A and its amendment in full. -NJ
C	2 June 2021	Corrected table on pg 9 to state “DSS Radio Measurements” Includes NCEE Labs report R20200701-21-E2B and its amendment in full. -NJ

CONTENTS

1.0 SUMMARY OF TEST RESULTS

The EUT has been tested according to the following specifications:

(1) US Code of Federal Regulations, Title 47, Part 15
(2) ISED RSS-Gen, Issue 5
(3) ISED RSS-247, Issue 2

SUMMARY			
Standard Section	**Test Type and Limit**	**Result**	**Remark**
FCC 15.203	Unique Antenna Requirement	Pass	PCB antenna
FCC 15.35 RSS-Gen, 6.10	Duty cycle of pulsed emissions	NA	Pulsed emissions duty cycle was applied
FCC 15.209 RSS-Gen, 7.1	Receiver Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.247(a)(1)(i) RSS-247, 5.1(c)	Minimum Bandwidth, Limit: Min. 250kHz	Pass	Meets the requirement of the limit.
FCC 15.247(b)(1) RSS-247, 5.1	Maximum Peak Output Power, Limit: Max. 24 dBm	Pass	Meets the requirement of the limit.
FCC 15.209 RSS-Gen, 8.9 RSS-247, 5.5	Transmitter Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.247(a) (1) (i) RSS-247, 5.1(c)	Frequency hopping system, Limit: Max. 0.4 Seconds in 10 Second Period	Pass	Meets the requirement of the limit.
FCC 15.209, 15.205 RSS-Gen, 8.9 RSS-247, 5.5	Band Edge Measurement, Limit: 20dB less than the peak value of fundamental frequency	Pass	Meets the requirement of the limit.
FCC 15.207 RSS-Gen. 8.8	Conducted AC Emissions	NA	Battery powered equipment.

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

The Equipment Under Test (EUT) was a wireless FHSS transmitter.

EUT	EN 22XX
EUT Received	29 July 2020
EUT Tested	29 July 2020- 28 August 2020
Serial No.	0223300 (Used for power and all CW measurements); 0223340 (Used for all other measurements);
Operating Band	902.0 – 928.0 MHz
Device Type	FHSS
Power Supply / Voltage	3 VDC (CR 2 Battery)

NOTE: For more detailed features description, please refer to the manufacturer's specifications or user's manual.

2.2 DESCRIPTION OF TEST MODES

The EUT operates on, and was tested at the frequencies below:

Channel	Frequency
Low	902.4
Middle	914.8
High	927.6

These are the only three representative channels tested in the frequency range according to FCC Part 15.31 and RSS-Gen Table A1. See the operational description for a list of all channel frequency and designations.

This EUT was set to transmit in a worse-case scenario with modulation on. The manufacturer modified the unit to transmit continuously on the lowest, highest and one channel in the middle.

2.3 DESCRIPTION OF SUPPORT UNITS

None

3.0 LABORATORY DESCRIPTION

3.1 LABORATORY DESCRIPTION

All testing was performed at the following Facility:

The Nebraska Center for Excellence in Electronics (NCEE Labs)
4740 Discovery Drive
Lincoln, NE 68521

A2LA Certificate Number: 1953.01
FCC Accredited Test Site Designation No: US1060
Industry Canada Test Site Registration No: 4294A-1
CAB MRA Recognition Identification No: US0177

Environmental conditions varied slightly throughout the tests:
Relative humidity of 35 ± 4%
Temperature of 22 ± 3° Celsius

3.2 TEST PERSONNEL

No.	PERSONNEL	TITLE	ROLE
1	Nic Johnson	Technical Manager	Review of Results
2	Karthik Vepuri	EMC Test Engineer	Testing and Report
3	Fox Lane	EMC Test Engineer	Testing

Notes:
All personnel are permanent staff members of NCEE Labs. No testing or review was sub-contracted or performed by sub-contracted personnel.

3.3 TEST EQUIPMENT

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Keysight MXE Signal Analyzer	N9038A	MY59050109	April 23, 2019	April 23, 2021
SunAR RF Motion Hybrid Antenna	JB1	A091418	March 6, 2020	March 6, 2021
EMCO Horn Antenna	3115	6415	March 16, 2020	March 16, 2022
Rohde & Schwarz LISN	ESH3-Z5	836679/010	July 25, 2019	July 25, 2020
Rohde & Schwarz Preamplifier*	TS-PR18	3545700803	April 14, 2020	April 14, 2022
Trilithic High Pass Filter*	6HC330	23042	April 14, 2020	April 14, 2022
MiniCircuits High Pass Filter*	VHF-1320+	15542	April 14, 2020	April 14, 2022
RF Cable (preamplifier to antenna)*	MFR-57500	01-07-002	April 14, 2020	April 14, 2022
RF Cable (antenna to 10m chamber bulkhead)*	FSCM 64639	01E3872	April 14, 2020	April 14, 2022
RF Cable (10m chamber bulkhead to control room bulkhead)*	FSCM 64639	01E3874	April 14, 2020	April 14, 2022
RF Cable (control room bulkhead to test receiver)*	FSCM 64639	01F1206	April 14, 2020	April 14, 2022
N connector bulkhead (10m chamber)*	PE9128	NCEEBH1	April 14, 2020	April 14, 2022
N connector bulkhead (control room)*	PE9128	NCEEBH2	April 14, 2020	April 14, 2022
TDK Emissions Lab Software	V11.25	700307	NA	NA

*Internal Characterization

Notes:
All equipment is owned by NCEE Labs and stored permanently at NCEE Labs facilities.

4.0 RESULTS

DSS Radio Measurements							
CHANNEL	**Transmitter**	**Occupied Bandwidth (kHz)**	**20 dB Bandwidth (kHz)**	**PEAK OUTPUT POWER (dBm)**	**PEAK OUTPUT POWER (mW)**	**PSD (dBm)**	**RESULT**
Low	900MHz	251.17	259.10	17.718	59.13	NA	PASS
Mid	900MHz	251.59	260.60	18.914	77.88	NA	PASS
High	900MHz	243.27	253.90	18.275	67.22	NA	PASS
Occupied Bandwidth = N/A; 20 dB Bandwidth Limit = 250 kHz				Peak Output Power Limit = 24 dBm; PSD Limit = NA			

Unrestricted Band-Edge							
CHANNEL	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Relative Highest out of band level (dBm)**	**Relative Fundamental (dBµV/m)**	**Delta (dB)**	**Min Delta (dB)**	**Result**
Low	Hopping	902.00	42.38	115.71	73.33	20.00	PASS
High	Hopping	928.00	41.17	113.71	72.54	20.00	PASS

Peak Restricted Band-Edge							
CHANNEL	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Highest out of band level (dBuV/m @ 3m)**	**Measurement Type**	**Limit (dBuV/m @ 3m)**	**Margin**	**Result**
Low	Hopping	614.00	38.37	Peak	46.02	7.65	PASS
High	Hopping	960.00	41.17	Peak	54.00	12.83	PASS

*Limit shown is the peak limit taken from FCC Part 15.209; ** Corrections can be found under the graphs in Appendix C

4.1 DUTY CYCLE

NA

4.2 RADIATED EMISSIONS

Test Method: ANSI C63.10-2013, Section 6.5, 6.6

Limits for radiated emissions measurements:

Emissions radiated outside of the specified bands shall be applied to the limits in 15.209 as followed:

FREQUENCIES (MHz)	FIELD STRENGTH (µV/m)	MEASUREMENT DISTANCE (m)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	3
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

NOTE:
1. The lower limit shall apply at the transition frequencies.
2. Emission level (dBuV/m) = 20 * log * Emission level (µV/m).
3. As shown in 15.35(b), for frequencies above 1000MHz, the field strength limits are based on average detector, however, the peak field strength of any emission shall not exceed the maximum permitted average limits by more than 20dB under any condition of modulation.

Test procedures:

a. The EUT was placed on the top of a rotating table above the ground plane in a 10 meter semi-anechoic chamber. The table was rotated 360 degrees to determine the position of the highest radiation. The table was 0.8m high for measurements form 30MHz-1GHz and 1.5m for measurements from 1GHz to 10 GHz.

b. The EUT was set 3 meters away from the interference-receiving antenna, which was mounted on the top of a variable-height antenna tower.

c. The antenna was a broadband antenna, and its height is varied from one meter to four meters above the ground to determine the maximum value of the field strength. Both horizontal and vertical polarizations of the antenna are used to make the measurement.

d. For each suspected emission, the EUT was arranged to maximize its emissions and then the antenna height was varied from 1 meter to 4 meters and the rotating table was turned from 0 degrees to 360 degrees to find the maximum emission reading.

e. The test-receiver system was set to use a peak detector with a specified resolution bandwidth. For spectrum analyzer measurements, the composite maximum of several analyzer sweeps was used for final measurements.

f. If the emission level of the EUT in peak mode was 10dB lower than the limit specified, then testing could be stopped and the peak values of the EUT would be reported. Otherwise the emissions that did not have 10 dB margin would be re-tested one by one using peak, quasi-peak or average method as specified and then reported in a data sheet.

g. The EUT was maximized in all 3 orthogonal positions. The results are presented for the axis that had the highest emissions.

NOTE:
1. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120kHz for Peak detection (PK) and Quasi-peak detection (QP) at frequencies below 1GHz.

2. The resolution bandwidth 1 MHz for all measurements and at frequencies above 1GHz, A peak detector was used for all measurements above 1GHz. Measurements were made with an EMI Receiver.

Deviations from test standard:

No deviation.

Test setup:

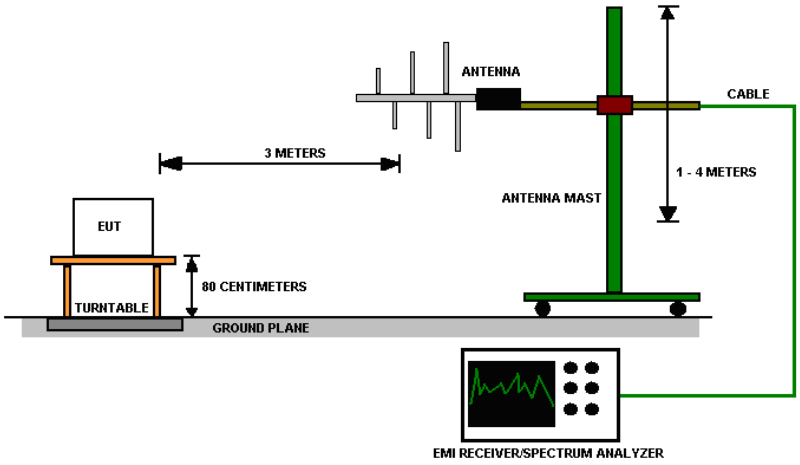

Figure 1 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by 3 VDC unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:

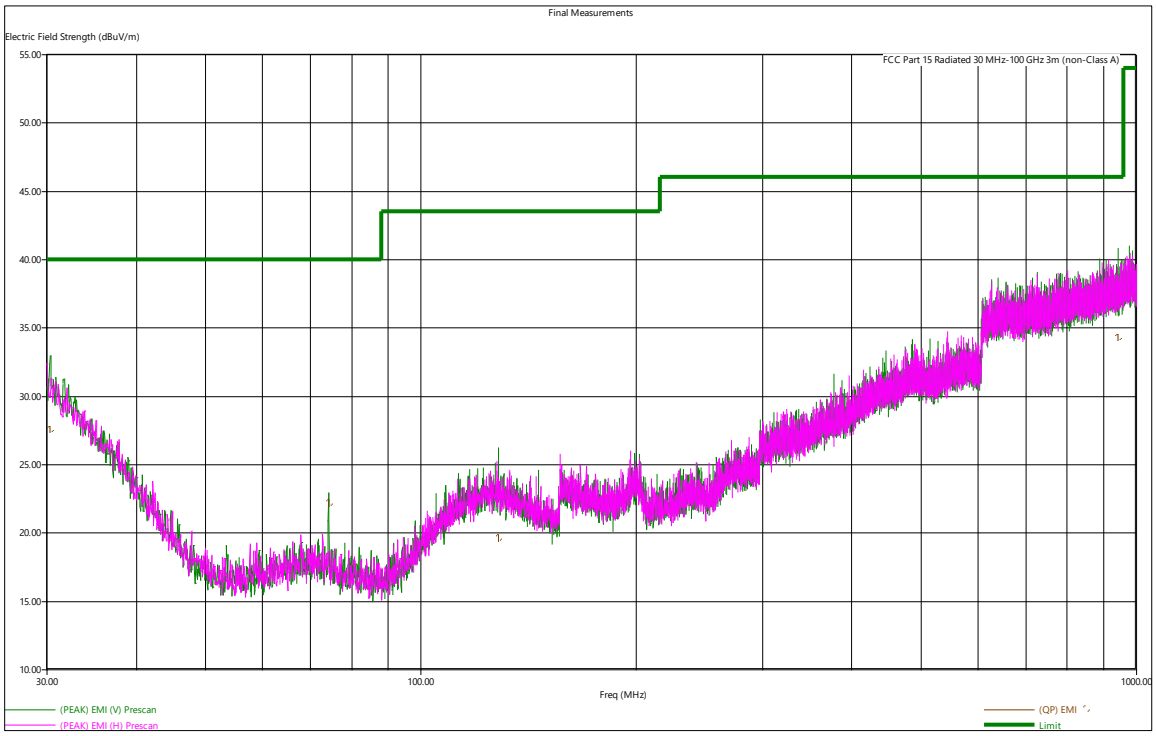

Figure 2 - Radiated Emissions Plot, Receive Channel

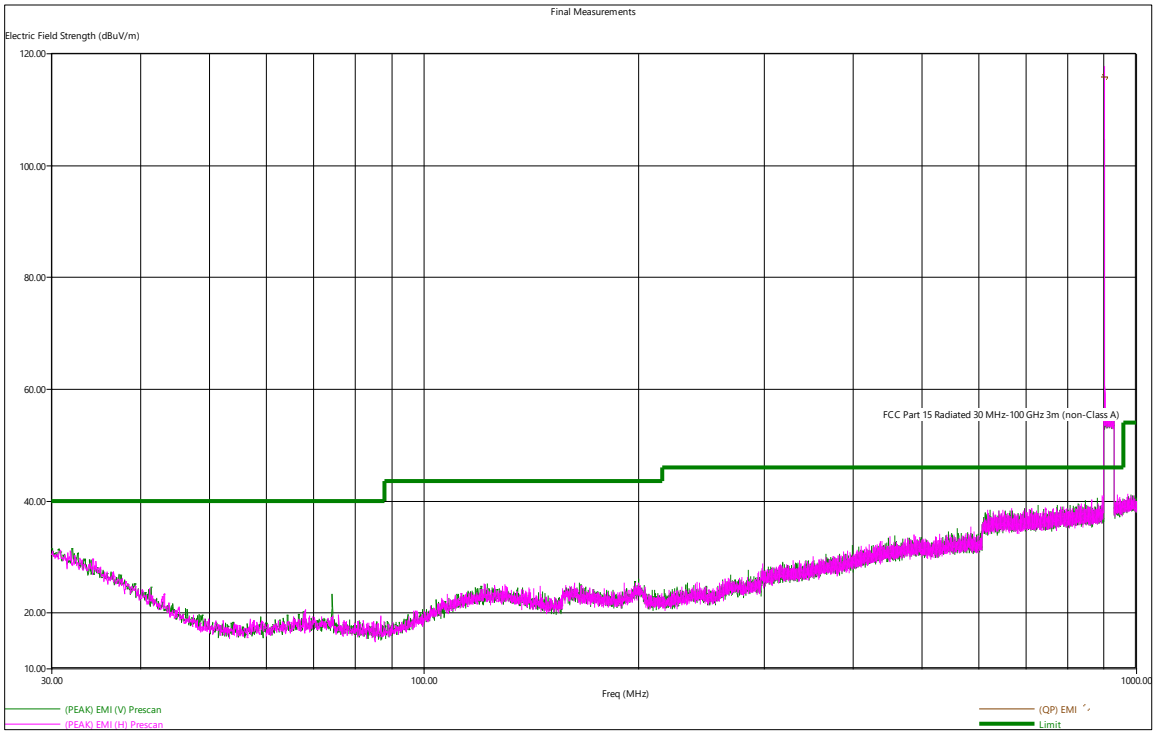

Figure 3 - Radiated Emissions Plot, Low Channel

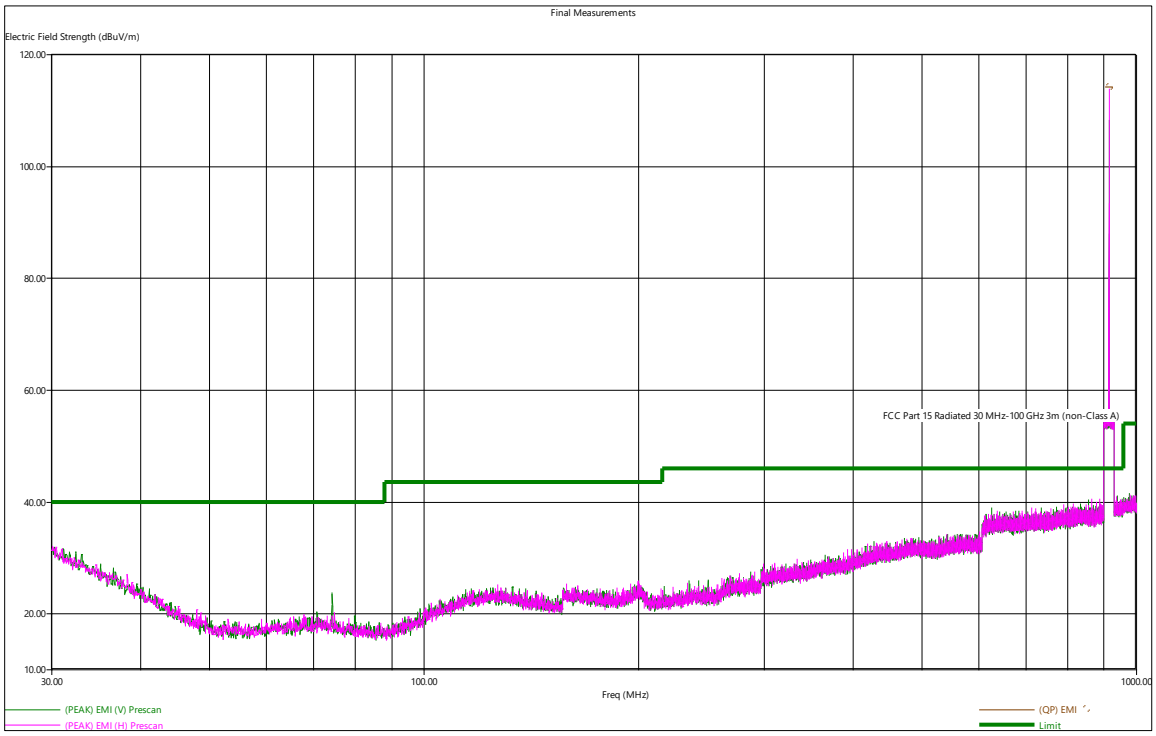

Figure 4 - Radiated Emissions Plot, Mid Channel

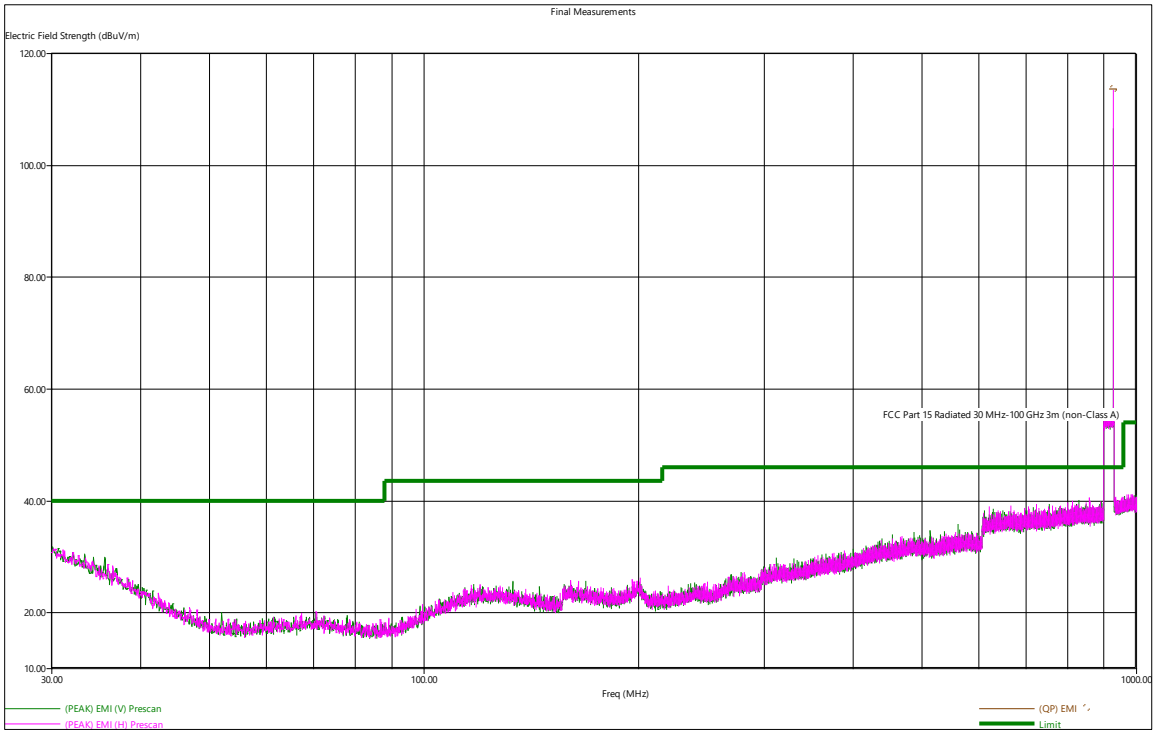

Figure 5 - Radiated Emissions Plot, High Channel

REMARKS:

1. Emission level (dBuV/m) = Raw Value (dBuV) + Correction Factor (dB)
2. Correction Factor (dB/m) = Antenna Factor (dB/m) + Cable Factor (dB)
3. The other emission levels were very low against the limit.
4. Margin value = Emission level – Limit value.
5. The EUT was measured in all 3 orthogonal axes. See the test setup photo exhibit for details on the orientations.

Quasi-Peak Measurements							
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**Channel**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**		
902.395200	115.71	NA	NA	105	67	H	Low
914.79912	114.07	NA	NA	104	5	H	Mid
927.59928	113.51	NA	NA	151	176	H	High
30.184320	27.52	40.00	12.48	201	353	V	Receive
74.262960	22.11	40.00	17.89	164	184	V	Receive
128.153760	19.63	43.52	23.89	370	0	V	Receive
942.070320	34.23	46.02	11.79	393	239	V	Receive

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the plots and tables above. If the measurements were found to be 10 dB below the limit, they were not reported.

Peak Measurements								
Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel	Modulation
MHz	dBµV/m	dBµV/m	dB	cm.	deg.			
1829.58	55.69	94.07	38.38	164	189	H	Mid	CW
2744.53	48.79	73.98	25.19	207	199	V	Mid	CW
2470.03	45.07	73.98	28.91	144	148	V	High	CW
2782.67	46.72	73.98	27.26	194	208	V	High	CW
1804.77	60.52	95.71	35.19	174	182	H	Low	CW
2707.07	44.24	73.98	29.74	130	163	H	Low	CW
2707.34	45.44	73.98	28.54	163	203	V	Low	CW
3609.56	51.67	73.98	22.31	199	181	V	Low	CW
5414.55	46.07	73.98	27.91	100	0	V	Low	CW
5488.73	51.18	73.98	22.8	200	87	H	Mid	CW
3659.31	48.96	73.98	25.02	200	169	V	Mid	CW
4637.97	47.97	73.98	26.01	200	22	H	High	CW
5564.95	44.66	73.98	29.32	200	78	H	High	CW
5595.52	43.28	73.98	30.7	199	358	H	High	CW
3711.04	42.41	73.98	31.57	199	199	V	High	CW

Average Measurements								
Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel	Modulation
MHz	dBµV/m	dBµV/m	dB	cm.	deg.			
1829.580000	54.94	94.07	39.13	164	189	H	Mid	CW
2744.530000	45.73	53.98	8.25	207	199	V	Mid	CW
2470.030000	24.58	53.98	29.4	144	148	V	High	CW
2782.670000	42.83	53.98	11.15	194	208	V	High	CW
1804.770000	59.97	95.71	35.74	174	182	H	Low	CW
2707.070000	39.48	53.98	14.5	130	163	H	Low	CW
2707.340000	41.3	53.98	12.68	163	203	V	Low	CW
3609.560000	49.15	53.98	4.83	199	181	V	Low	CW
5414.550000	38.46	53.98	15.52	100	0	V	Low	CW
5488.730000	47.96	53.98	6.02	200	87	H	Mid	CW
3659.310000	45.16	53.98	8.82	200	169	V	Mid	CW
4637.970000	43.24	53.98	10.74	200	22	H	High	CW
5564.950000	36.06	53.98	17.92	200	78	H	High	CW
5595.520000	29.46	53.98	24.52	199	358	H	High	CW
3711.040000	30.88	53.98	23.1	199	199	V	High	CW

4.3 PEAK OUTPUT POWER

Test Method: ANSI C63.10, Section(s) 7.8.5

Limits of bandwidth measurements:
Per FCC Part 15
For an FHSS system with 25 channels, the output power is required to be less than 250 mW or 24 dBm.

Test procedures:
Spectrum analyzer was set with a resolution bandwidth greater than occupied bandwidth and centered on the operating channel.

Deviations from test standard:
No deviation.

Test setup:
Device was connected to a spectrum analyzer with a low loss shielded cable. All attenuators and cables were accounted for.

EUT operating conditions:
The EUT was powered by 3 VDC unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:
*Refer to Section 4.0 for the summary table with results.

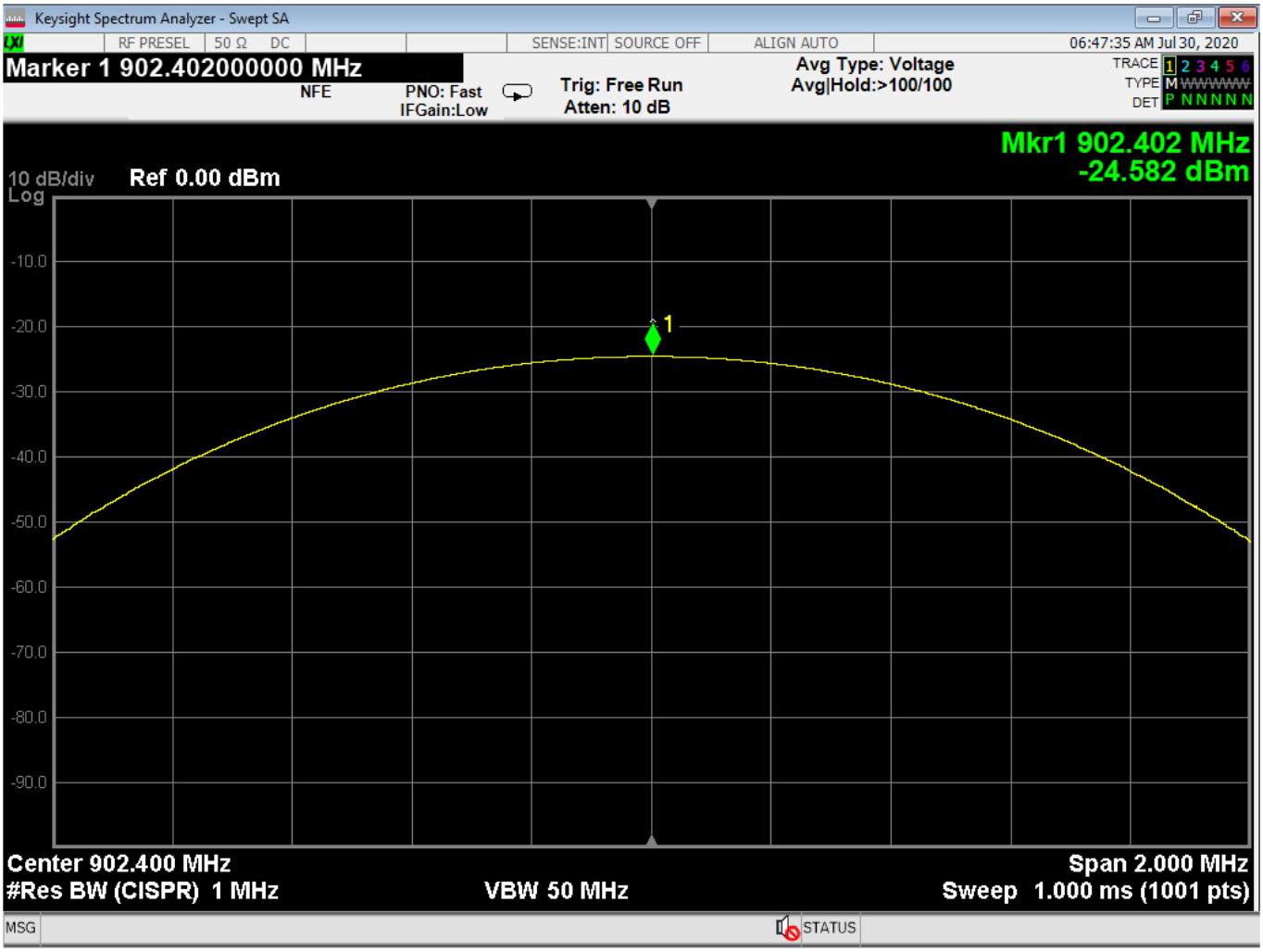

Figure 6 – Output Power, Low Channel

* Corrected EIRP Measurement = -24.582 (dBuV)+26.40 (Transducer in dB) +4.13 (Cable loss in dB) +107 (conversion from dBm to dBuV) -95.23 (EIRP conversion from 3m) = 17.718 dBm

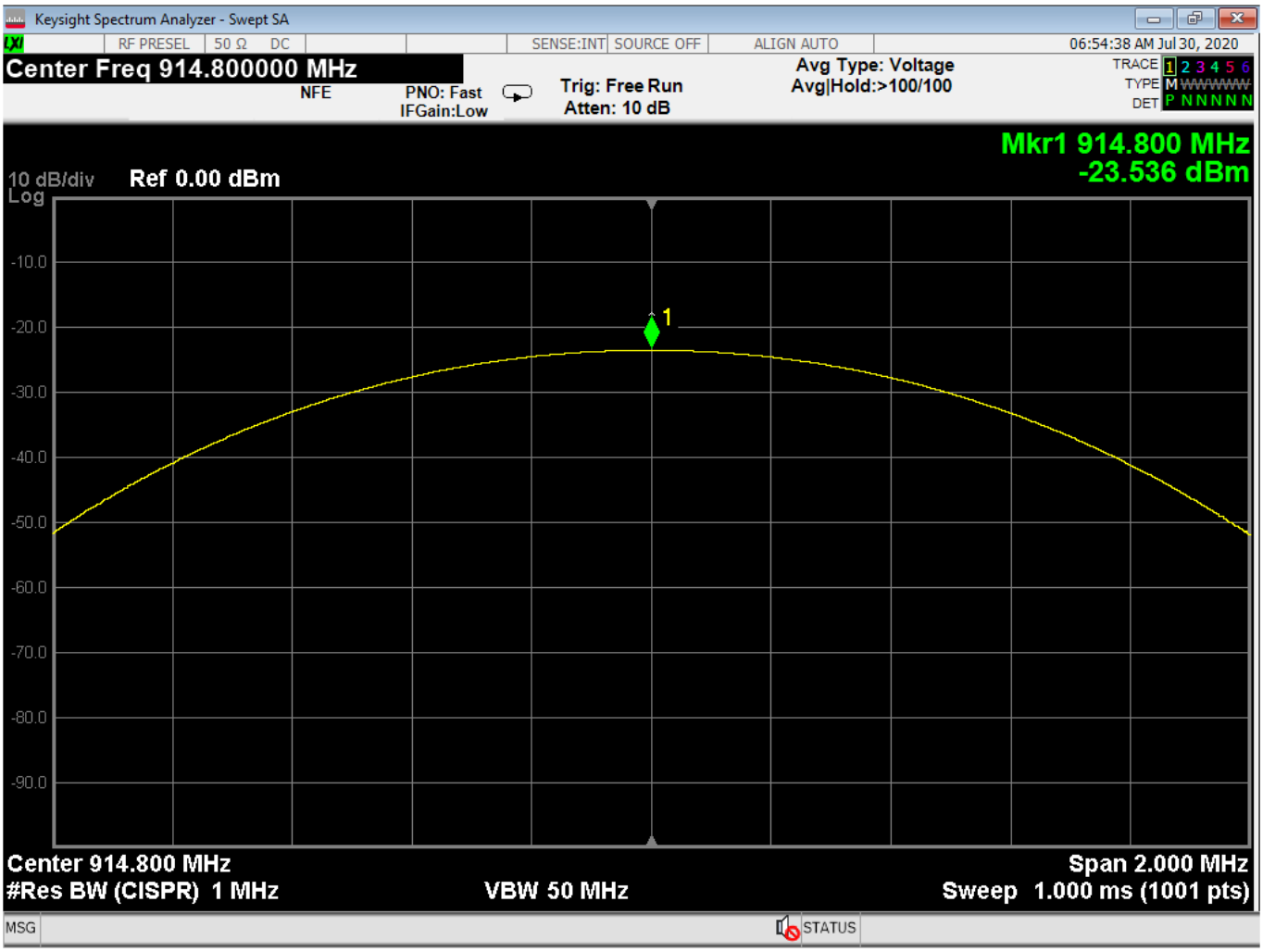

Figure 7 - Output Power, Mid Channel

* Corrected EIRP Measurement = -23.536 (dBuV)+26.60 (Transducer in dB) +4.08 (Cable loss in dB) +107 (conversion from dBm to dBuV) -95.23 (EIRP conversion from 3m) = 18.914 dBm

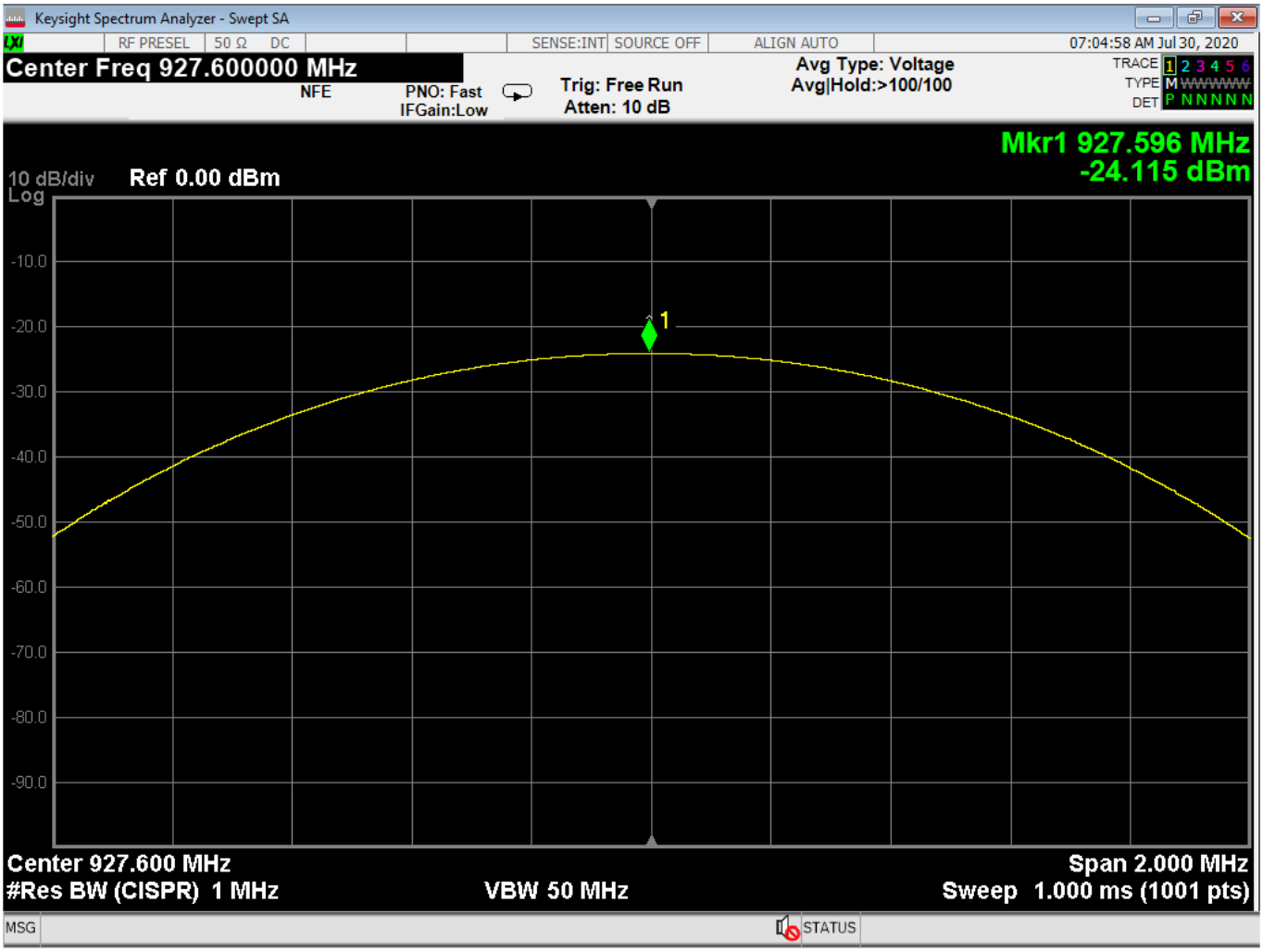

Figure 8 - Output Power, High Channel

* Corrected EIRP Measurement = -24.115 (dBuV)+26.60 (Transducer in dB) +4.02 (Cable loss in dB) +107 (conversion from dBm to dBuV) -95.23 (EIRP conversion from 3m) = 18.275 dBm

4.4 BANDWIDTH

Test Method: ANSI C63.10, Section(s) 6.9.2

Limits of bandwidth measurements:
The allowed 20 dB bandwidth of the hopping channel is 250 kHz ≤ BW ≤ 500 kHz.

Test procedures:
The bandwidth of the fundamental frequency was measured by spectrum analyzer with 9 kHz RBW and 30 kHz VBW.

The 20 dB bandwidth is defined as the bandwidth of which is higher than peak power minus 20dB. The 99% bandwidth is defined as the bandwidth that contains 99% of the power.

Deviations from test standard:
No deviation.

Test setup:
Device was connected to a spectrum analyzer with a low loss shielded cable. All attenuators and cables were accounted for.

EUT operating conditions:
The EUT was powered by 3 VDC unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:
*Refer to Section 4.0 for the summary table with results.

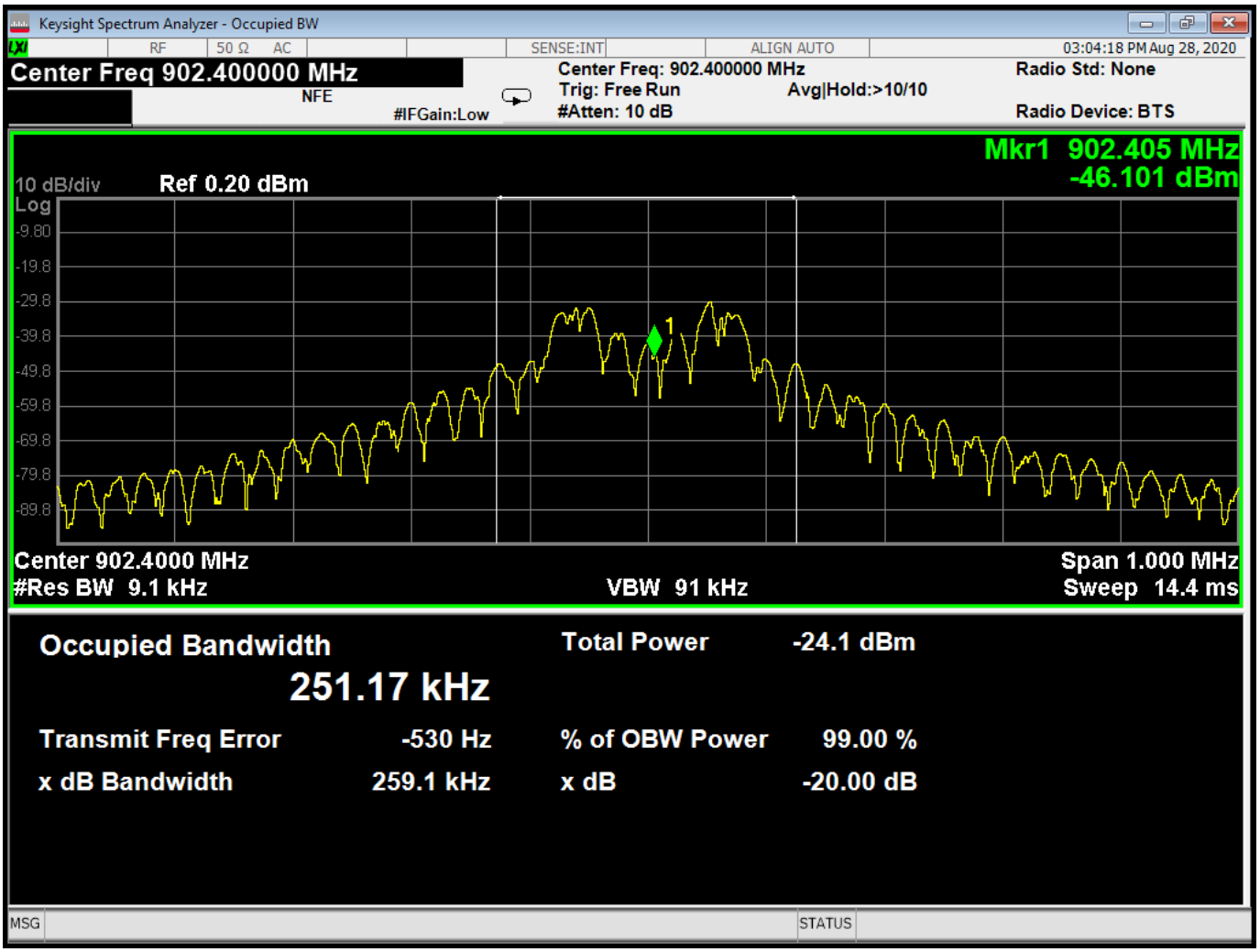

Figure 9 – Bandwidth, Low Channel

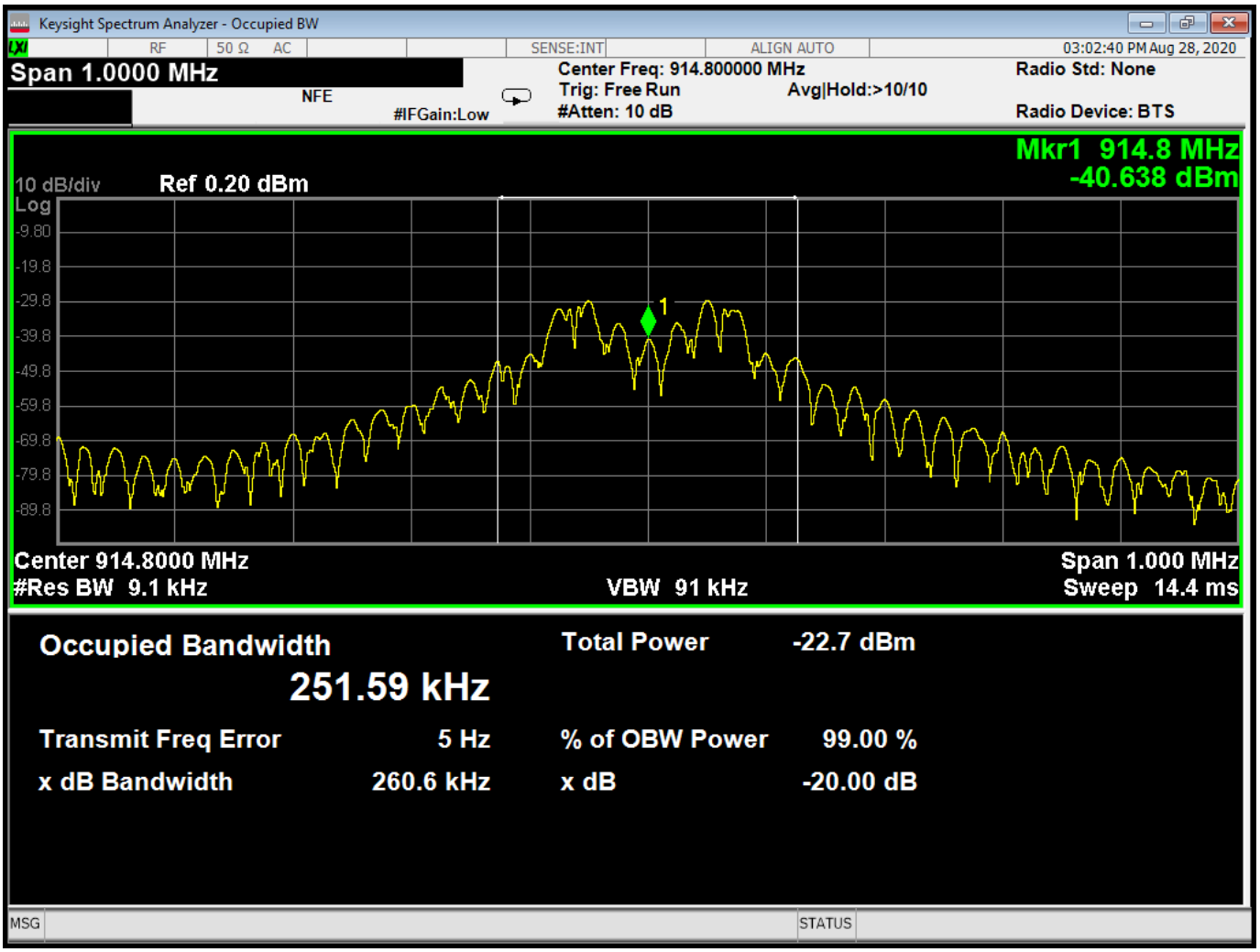

Figure 10 - Bandwidth, Mid Channel

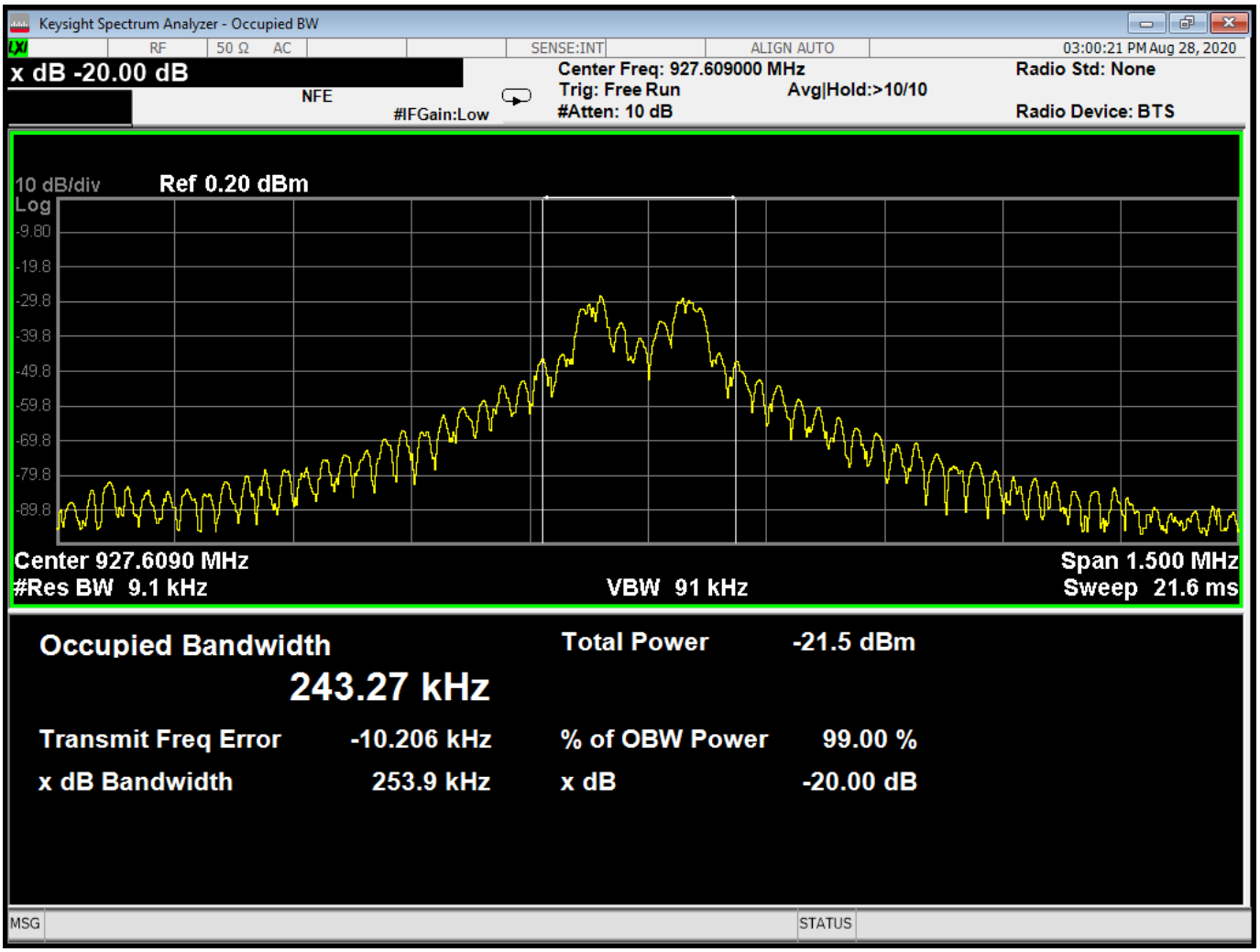

Figure 11 - Bandwidth, High Channel

4.5 BANDEDGES

Test Method: ANSI C63.10, Section(s) 6.10.6

Limits of band edge measurements:
For emissions outside of the allowed band of operation (902 – 928MHz), the emission level needs to be 20dB under the maximum fundamental field strength. However, if the emissions fall within one of the restricted bands from 15.205 the field strength levels need to be under that of the limits in 15.209.

Test procedures:
The EUT was tested in the same method as described in section *4.4 - Bandwidth*. The resolution bandwidth was set to 100kHz and the EMI receiver was used to scan from the band edge to the fundamental frequency with a quasi-peak detector. The highest emissions level beyond the band edge was measured and recorded. For restricted band edge measurements, the unit was tested to the same method as section 4.2 of this report.

Deviations from test standard:
No deviation.

Test setup:
The plots shown below indicate whether the measurement was performed radiated or conducted. For radiated setup, see section 4.2 of this report. For conducted setup, see section 4.3 of this report.

EUT operating conditions:
The EUT was powered by 3 VDC unless specified and set to transmit both continuously on the lowest and highest frequency channel and in normal hopping operation.

Test results:
*Refer to Section 4.0 for the summary table with results for tabular data.

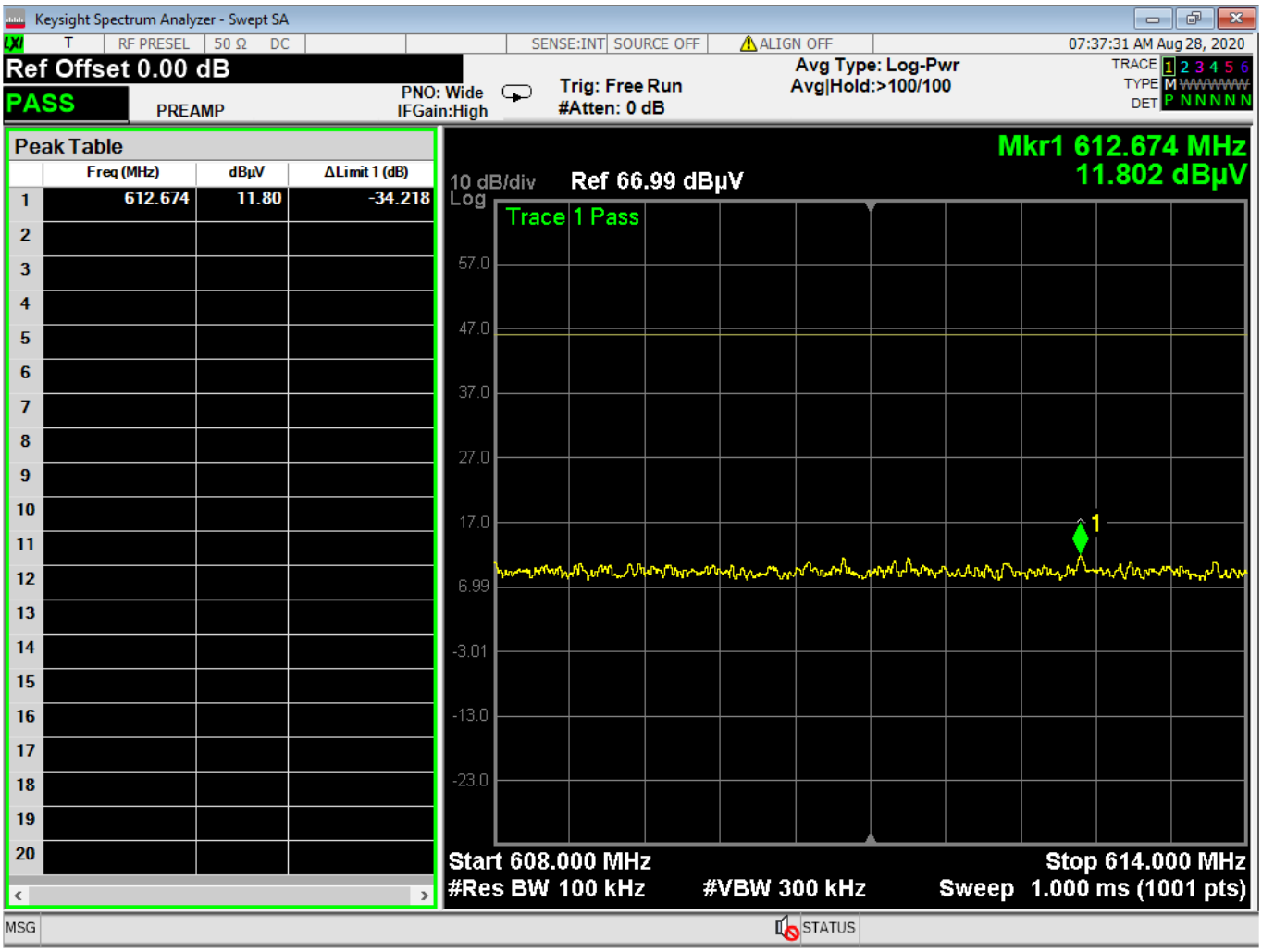

Figure 12 - Band-edge Measurement, Low Channel, Restricted Frequency, Hopping

* Corrected measurement at 3m = 11.802 (dBuV)+23.3 (Antenna Factor in dB) +3.27 (Cable Loss in dB) =38.372 (dBuV/m)

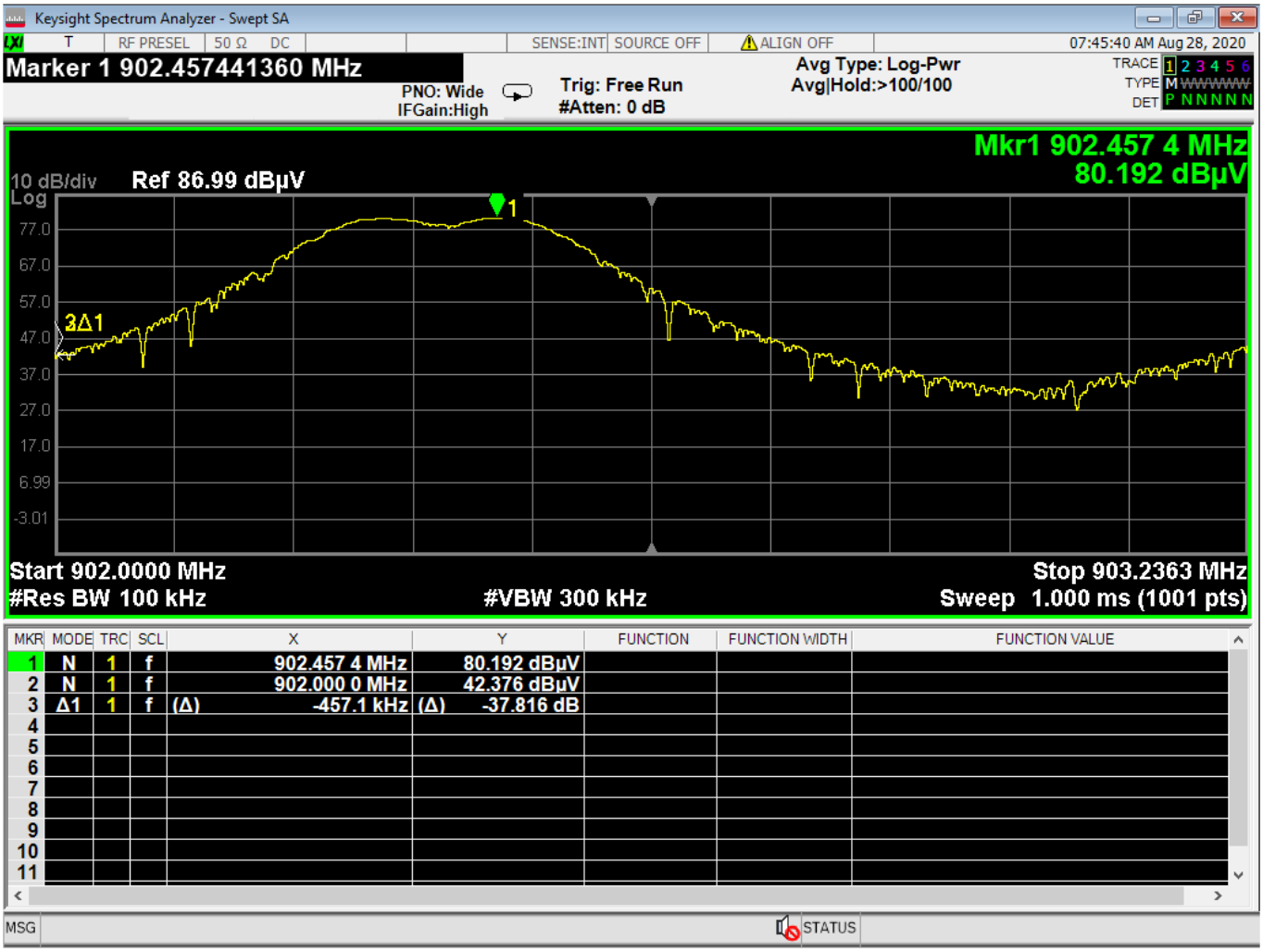

Figure 13 - Band-edge Measurement, Low Channel, Fundamental, Hopping Transmit

The plot shows an uncorrected measurement, used for relative measurements only.

Delta = 37.816 dB > 20 dB Passing unrestricted band edge

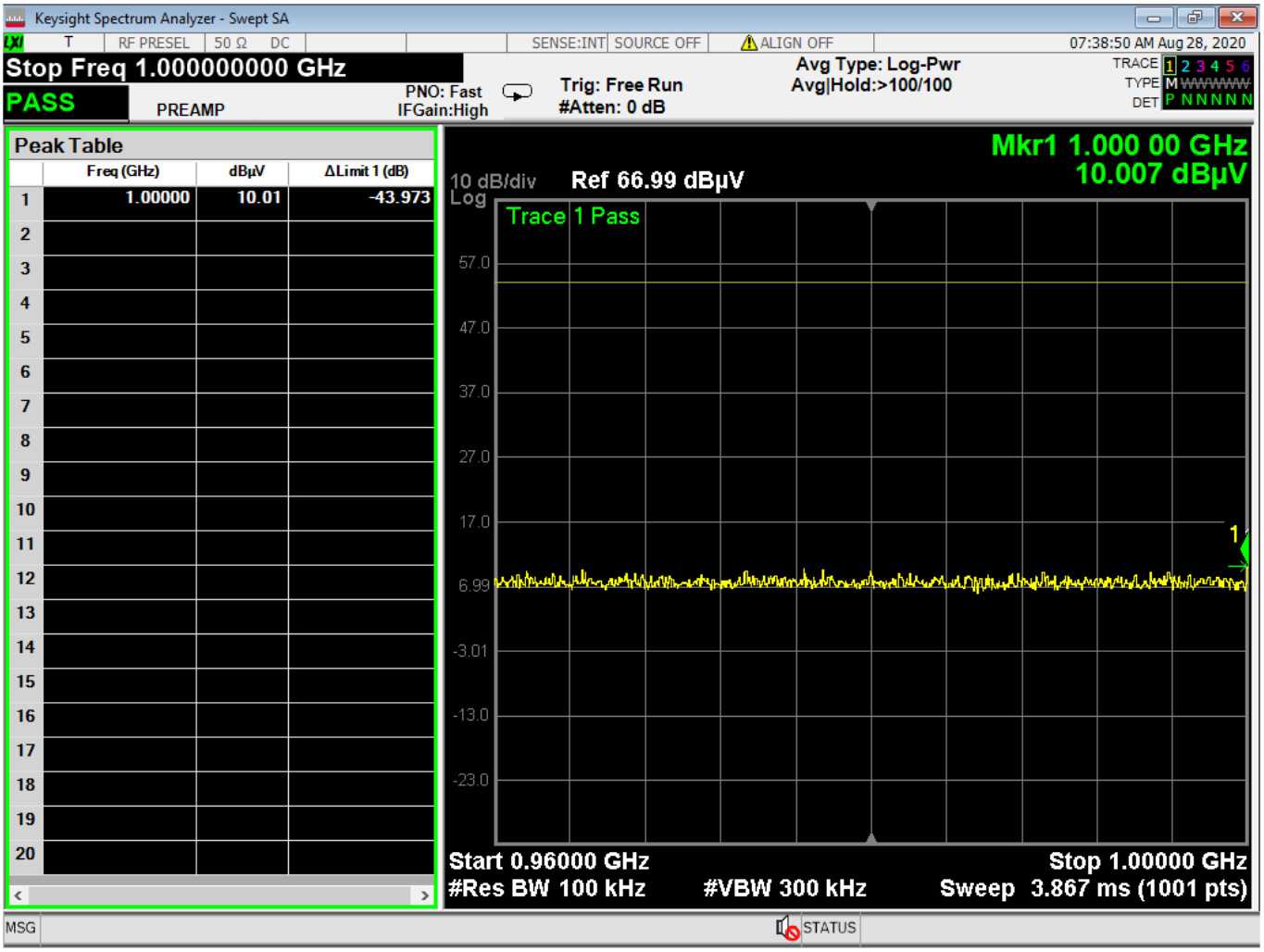

Figure 14 - Band-edge Measurement, High Channel, Restricted Frequency, Hopping

* Corrected measurement at 3m = 10.007 (dBuV)+23.3 (Antenna Factor in dB) +3.27 (Cable Loss in dB) =41.167 (dBuV/m)

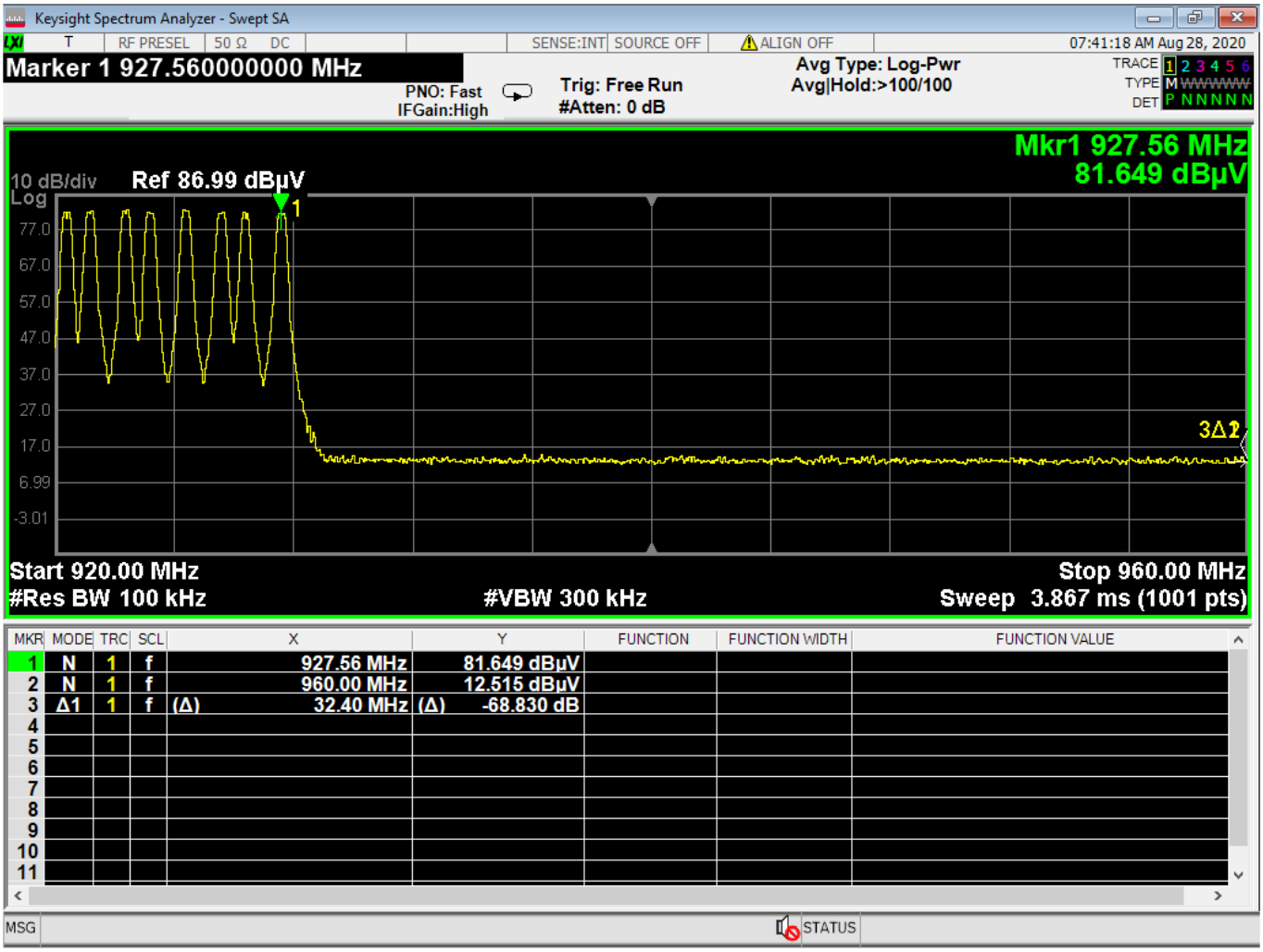

Figure 15 - Band-edge Measurement, High Channel, Fundamental, Hopping Transmit

The plot shows an uncorrected measurement, used for relative measurements only.

Delta =68.830 dB > 20 dB Passing unrestricted band edge

4.6 CARRIER FREQUENCY SEPERATION, NUMBER OF HOPPING CHANNELS, TIME OF OCCUPANCY

Test Method: ANSI C63.10, Section 7.8.2, 7.8.3, 7.8.4

Limits for Time of Occupancy
Average time of occupancy on any frequency, not to exceed 0.4 seconds within a 10 second period.

Test procedures:
The method from KDB 558074 D01 v05

Test setup:
All measurements were performed with the EUT connected directly to a spectrum analyzer with a low loss shielded cable and attenuator. All losses were accounted for.

EUT operating conditions:
The EUT was powered by 3 VDC unless specified and set to transmit while hopping.

Test results:

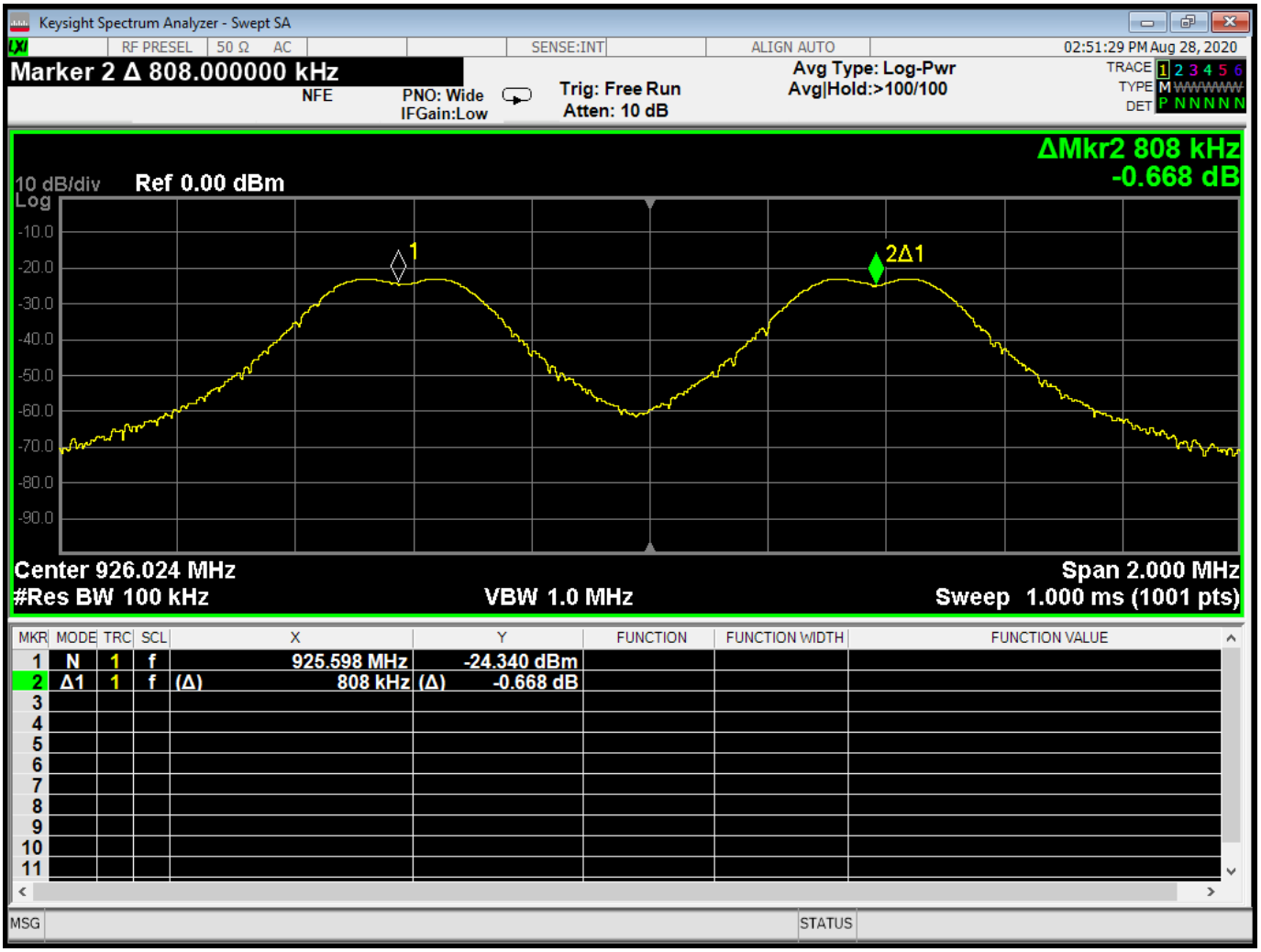

Figure 16 – Frequency Separation, Minimum

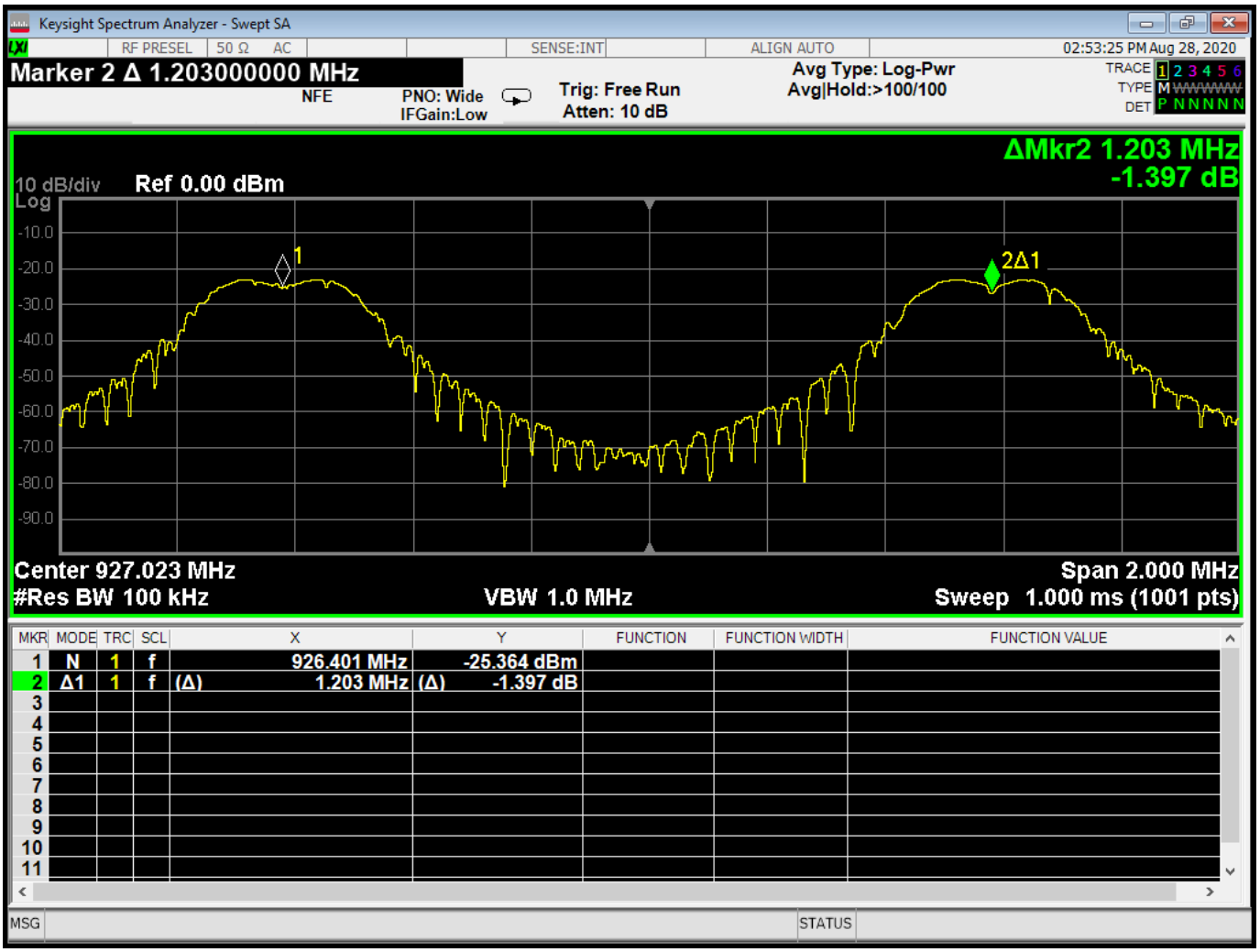

Figure 17 – Frequency Separation, Maximum

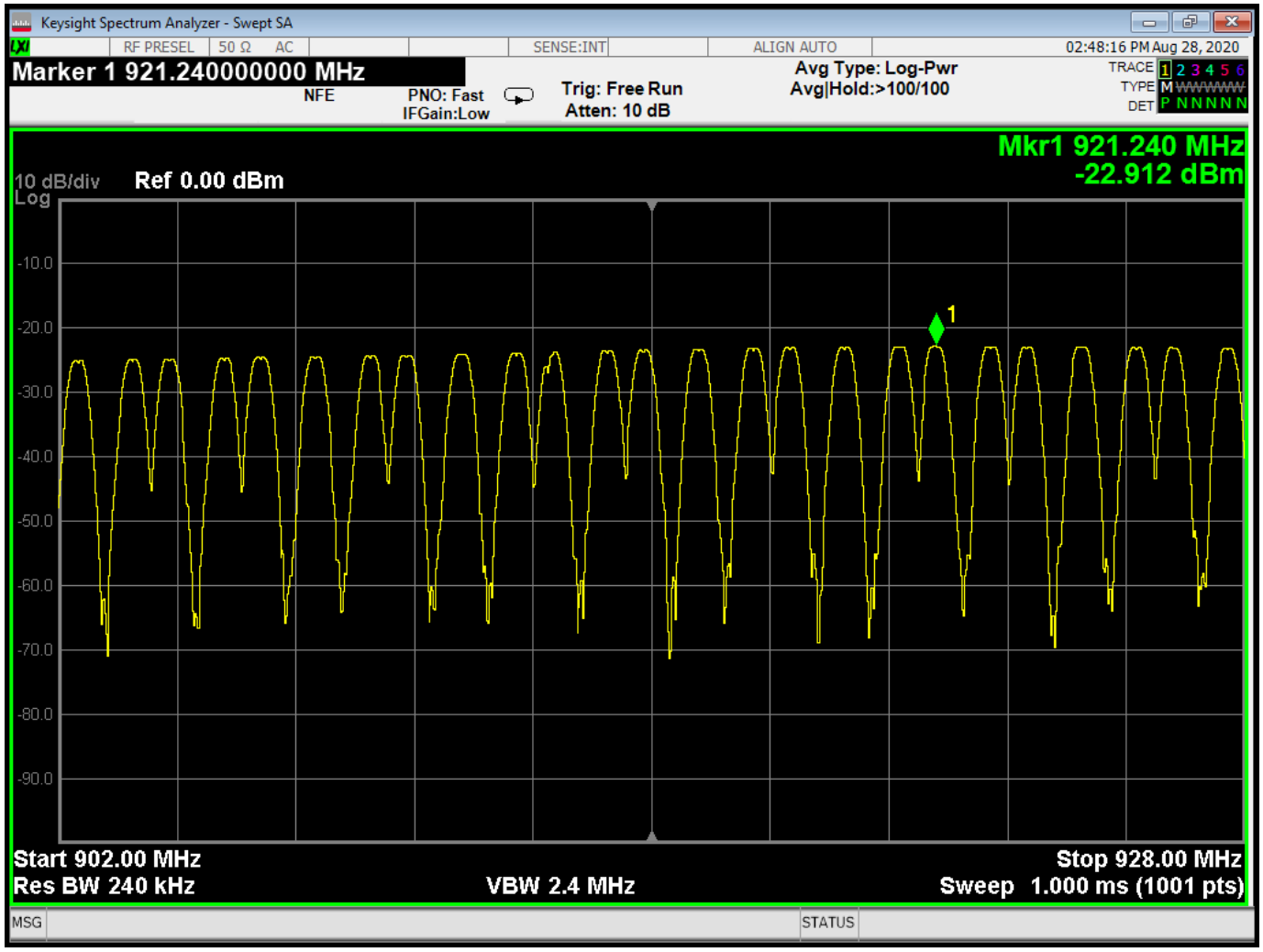

Figure 18 – Hop Count, 25 Hops

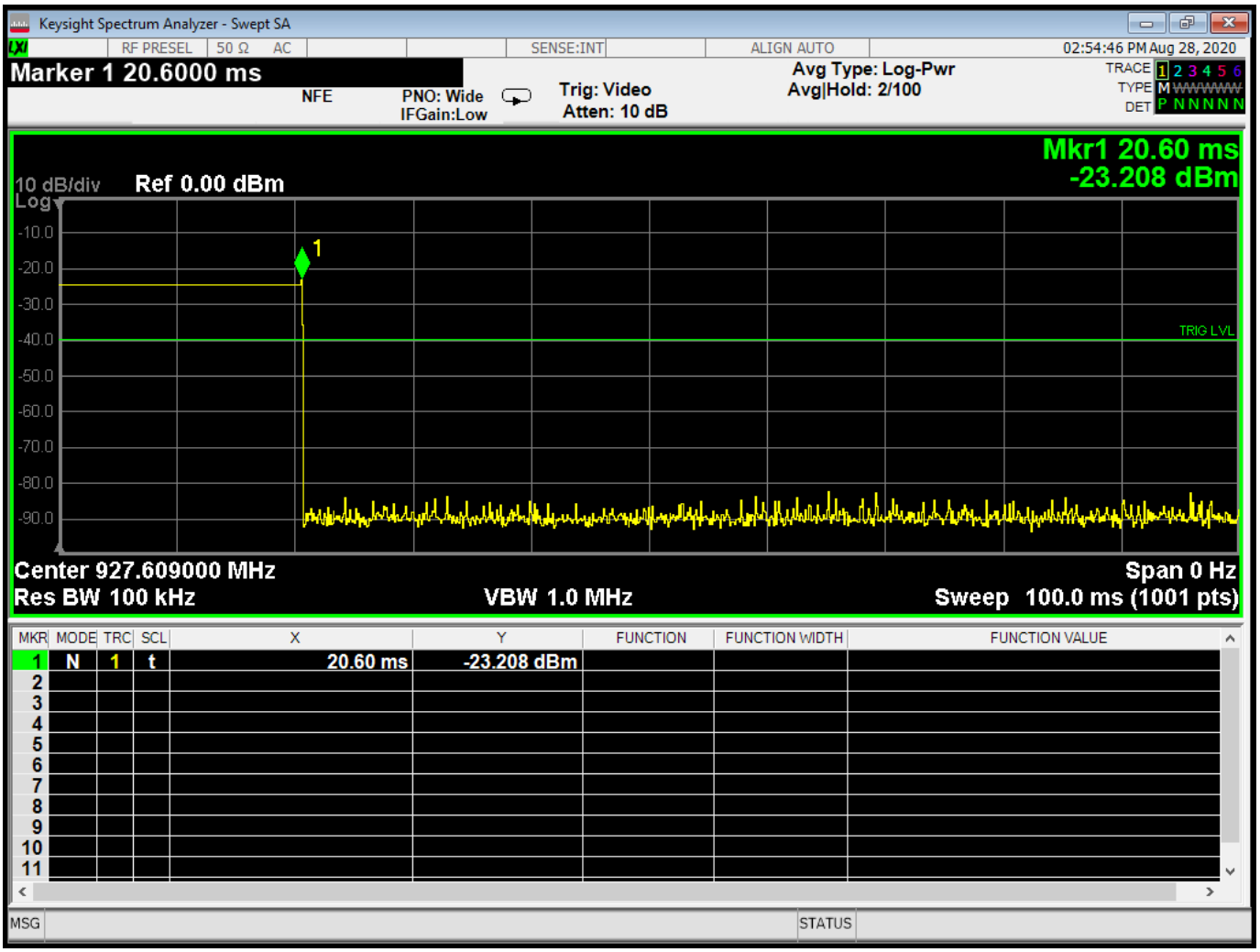

Figure 19 – Time of Occupancy, On Time

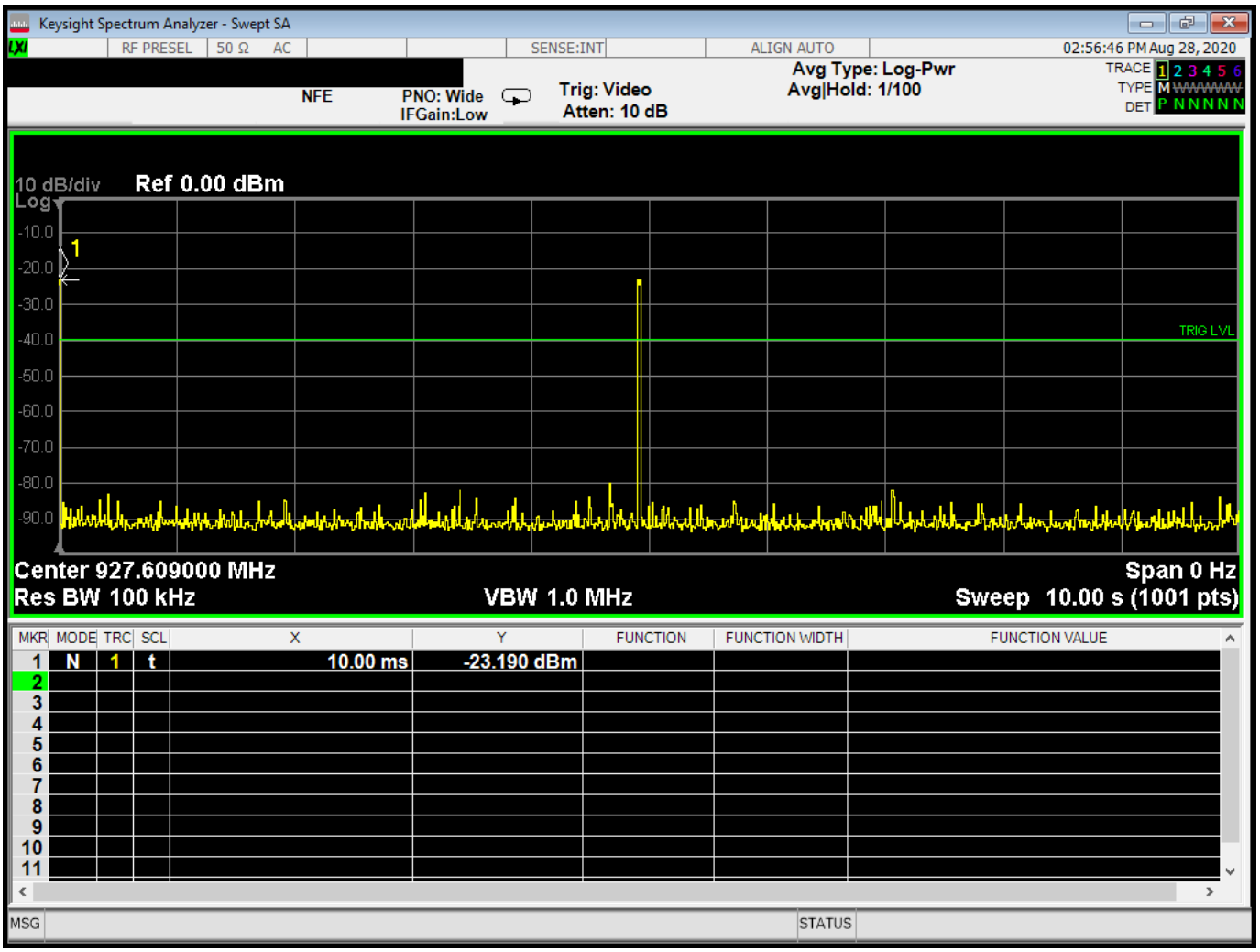

Figure 20 – Time of Occupancy, Period

*On time = 20.60 ms; in a given 10s window two transmissions are possible. Average time of occupancy is 0.04s < 0.4s; Passes the requirement.

APPENDIX A: SAMPLE CALCULATION

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

FS = RA + AF – (-CF + AG) + AV

where FS = Field Strength

RA = Receiver Amplitude

AF = Antenna Factor

CF = Cable Attenuation Factor

AG = Amplifier Gain

AV = Averaging Factor (if applicable)

Assume a receiver reading of 55 dBμV is obtained. The Antenna Factor of 12 and a Cable Factor of 1.1 is added. The Amplifier Gain of 20 dB is subtracted, giving a field strength of 48.1 dBμV/m.

FS = 55 + 12 – (-1.1 + 20) + 0 = 48.1 dBμV/m

The 48.1 dBμV/m value can be mathematically converted to its corresponding level in μV/m.

Level in μV/m = Common Antilogarithm [(48.1 dBμV/m)/20]= 254.1 μV/m

AV is calculated by the taking the 20*log(T_{on}/100) where T_{on} is the maximum transmission time in any 100ms window.

EIRP Calculations

In cases where direct antenna port measurement is not possible or would be inaccurate, output power is measured in EIRP. The maximum field strength is measured at a specified distance and the EIRP is calculated using the following equation;

EIRP (Watts) = [Field Strength (V/m) x antenna distance (m)]^2 / 30
Power (watts) = 10^[Power (dBm)/10] / 1000
Voltage (dBµV) = Power (dBm) + 107 (for 50Ω measurement systems)
Field Strength (V/m) = 10^[Field Strength (dBµV/m) / 20] / 10^6
Gain = 1 (numeric gain for isotropic radiator)
Conversion from 3m field strength to EIRP (d=3):

EIRP = [FS(V/m) x d^2]/30 = FS [0.3] for d = 3

EIRP(dBm) = FS(dBµV/m) – 10(log 10^9)+ 10log[0.3] = FS(dBµV/m) - 95.23

10log(10^9) is the conversion from micro to milli

APPENDIX B – MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been for tests performed in this test report:

Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	3.82
Radiated Emissions, 3m	1GHz - 18GHz	4.44
Emissions limits, conducted	30MHz – 18GHz	±3.30 dB

Expanded uncertainty values are calculated to a confidence level of 95%.

REPORT END