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Amended

FCC/ISED Test Report

Prepared for: **Retail Aware**

Address: **808 Conagra Drive 401**
Omaha, NE 68102

Product: **Base Station (RAIS2)**

Test Report No: **R20191205-21-E2C**

Approved by:

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

DATE: **14 July 2020**

Total Pages: **33**

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REVISION PAGE

Rev. No.	Date	Description
0	27 February 2020	Original – NJohnson Prepared by KVepuri
A	25 June 2020	Updated calibration table, Note in Section 2.2, add note to Page 12a, corrected PSD and BW measurements to conducted. Includes NCEE Labs report R20191205-21-E2 and its amendment in full.
B	30 June 2020	Added note to Section 2.2. Corrected PSD plot. Updated calibration table. Corrected average measurements for spurious emissions. Includes NCEE Labs report R20191205-21-E2A and its amendment in full.
C	17 July 2020	Corrected duty cycle to -38.56 dB on page 14. Includes NCEE Labs report R20191205-21-E2B and its amendment in full.

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1.0 SUMMARY OF TEST RESULTS

The worst-case measurements were reported in this report. The EUT has been tested according to the following specifications:

APPLIED STANDARDS AND REGULATIONS		
Standard Section	**Test Type**	**Result**
FCC Part 15.35 RSS Gen, Issue 5, Section 6.10	Duty Cycle	Pass
FCC Part 15.247(a)(1) RSS-247 Issue 2 Section 5.2	Peak output power	Pass
FCC Part 15.247(a)(1) RSS-247 Issue 2 Section 5.2	Bandwidth	Pass
FCC Part 15.209 RSS-Gen Issue 5, Section 7.1	Receiver Radiated Emissions	Pass
FCC Part 15.209 (restricted bands), 15.247 (unrestricted) RSS-247 Issue 2 Section 5.5, RSS-Gen Issue 4, Section 8.9	Transmitter Radiated Emissions	Pass
FCC Part 15.247(a)(1) RSS-247 Issue 2 Section 5.2	Power Spectral Density	Pass
FCC Part 15.209, 15.247(d) RSS-247 Issue 2 Section 11.13	Band Edge Measurement	Pass
FCC Part 15.207 RSS-Gen Issue 5, Section 7.1	Conducted Emissions	Pass

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

The Equipment Under Test (EUT) was a wireless transmitter from Retail Aware Inc. EUT contains a pre certified WIFI Module with FCC ID: 2AC7Z-ESPWROOM02.

EUT	Base Station (RAIS2)
EUT Received	2/19/2020
EUT Tested	2/19/2020 - 2/26/2020
Serial No.	NCEETEST2 (Assigned by the lab)
Operating Band	902.0 – 928.0 MHz
Device Type	DTS
Power Supply	5 VDC

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
Only Channel	914.88

These is the only representative channel 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. For duty cycle, the highest possible duty cycle was used. For other transmitter testes, the transmitter was set to transmit continuously.

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	Fox Lane	EMC Technician	Testing
2	Karthik Vepuri	EMC Test Engineer	Testing
3	Nic Johnson	Technical Manager	Review of Results

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
Software Version 1.60	ESK-1	2575	N/A	N/A
Keysight MXE Signal Analyzer	N9038A	MY59050109	23 Apr 2019	23 Apr 2021
Keysight EXA Signal Analyzer	N9010A	MY56070862	14 Dec 2018	14 Dec 2020
SunAR RF Motion	JB1	A082918-1	15 Oct 2018	15 Oct 2020
EMCO Horn Antenna	3115	6416	26 Jan 2018	26 Jan 2021
EMCO Horn Antenna	3116	2576	31 Jan 2018	31 Jan 2021
Rohde & Schwarz Preamplifier	TS-PR18	3545700803	09 Mar 2018*	09 Mar 2020*
Trilithic High Pass Filter	6HC330	23042	09 Mar 2018*	09 Mar 2020*
Rohde & Schwarz LISN	ESH3-Z5	836679/010	25 Jul 2019	25 Jul 2020
TDK Emissions Lab Software	V11.25	700307	NA	NA
RF Cable (preamplifier to antenna)	MFR-57500	01-07-002	09 Mar 2018*	09 Mar 2020*
RF Cable (antenna to 10m chamber bulkhead)	FSCM 64639	01E3872	09 Mar 2018*	09 Mar 2020*
RF Cable (10m chamber bulkhead to control room bulkhead)	FSCM 64639	01E3874	09 Mar 2018*	09 Mar 2020*
RF Cable (Control room bulkhead to RF switch)	FSCM 64639	01E3871	09 Mar 2018*	09 Mar 2020*
RF Cable (RF switch to test receiver)	FSCM 64639	01F1206	09 Mar 2018*	09 Mar 2020*
RF switch – Rohde and Schwarz	TS-RSP	1113.5503.14	09 Mar 2018*	09 Mar 2020*
N connector bulkhead (10m chamber)	PE9128	NCEEBH1	09 Mar 2018*	09 Mar 2020*
N connector bulkhead (control room)	PE9128	NCEEBH2	09 Mar 2018*	09 Mar 2020*
Mini Circuits 1700 – 5000Mhz High Pass Filter***	15542	31618	09 Mar 2018*	09 Mar 2020*

*Internal Characterization
**Used for radiated measurements above 1GHz
***Used for measurements from 1 GHz - 6GHz
****Used for measurements above 3 GHz

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

4.0 DETAILED RESULTS

4.1 DUTY CYCLE

Since the device featured pulsed emissions, a duty cycle correction factor was applied to peak measurements to calculate the average measurement per ANSI C63.10-2013, Section 7.5.

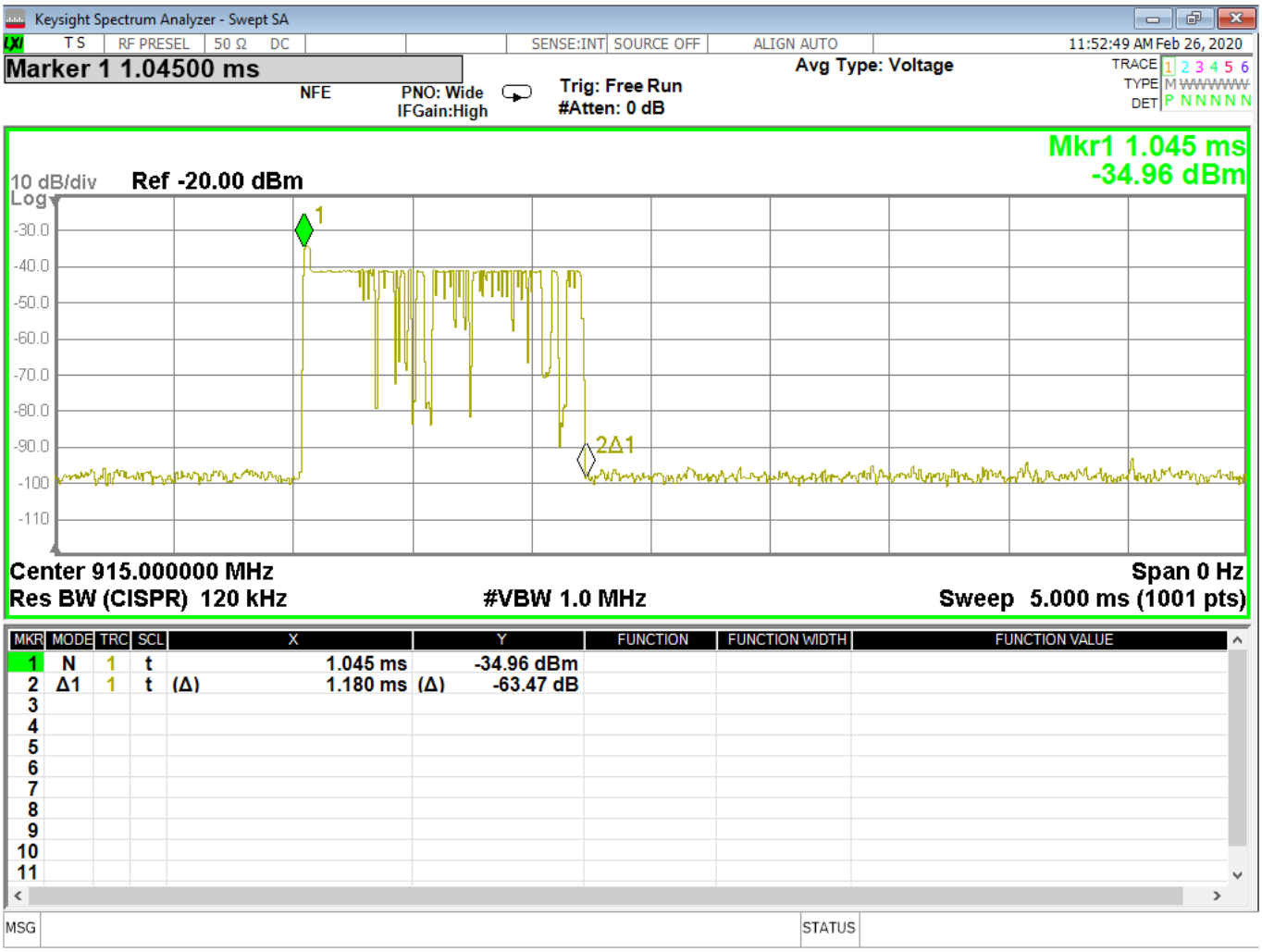


Figure 1 – ON Time

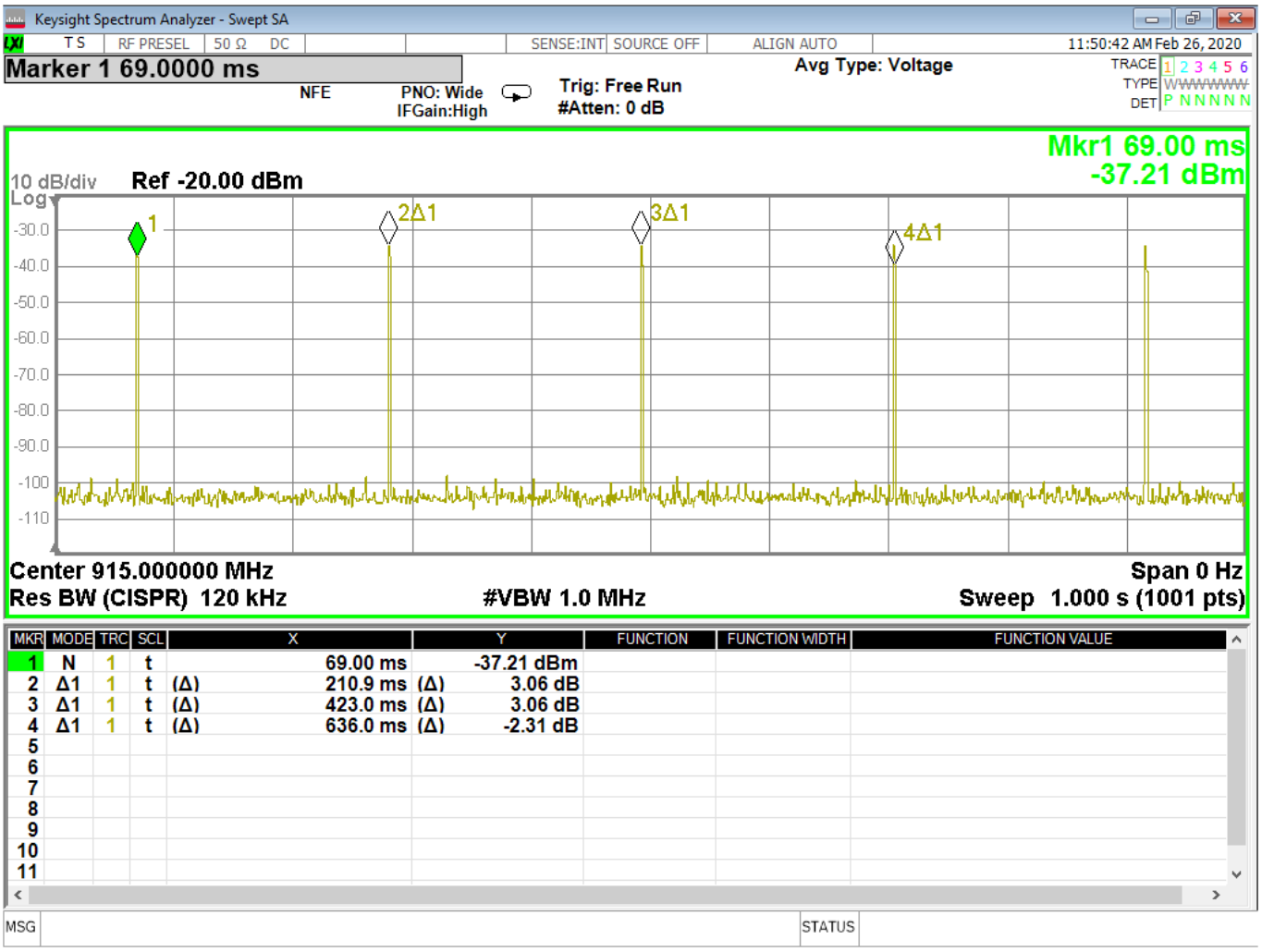


Figure 2 – Period

Duty Cycle Correction=20log ((1.18 (Duty Cycle))/100 (Max Period)) =-38.56 dB=-20 dB (Maximum usable)

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 25 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:

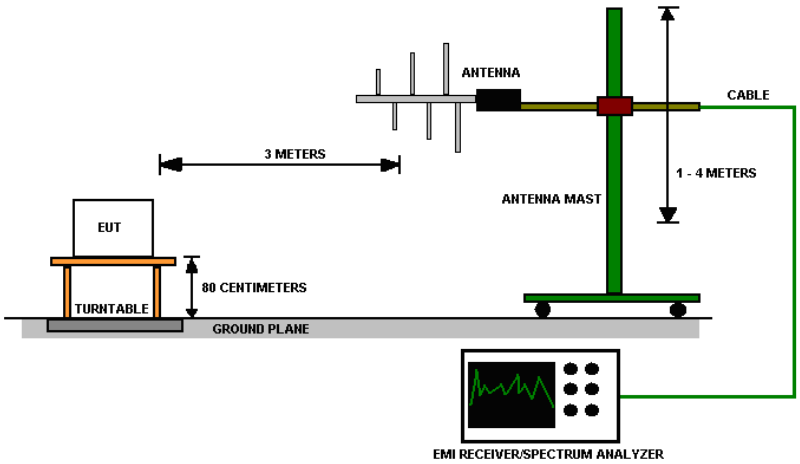


Figure 3 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by 5 VDC unless specified and set to transmit continuously.

Test results:

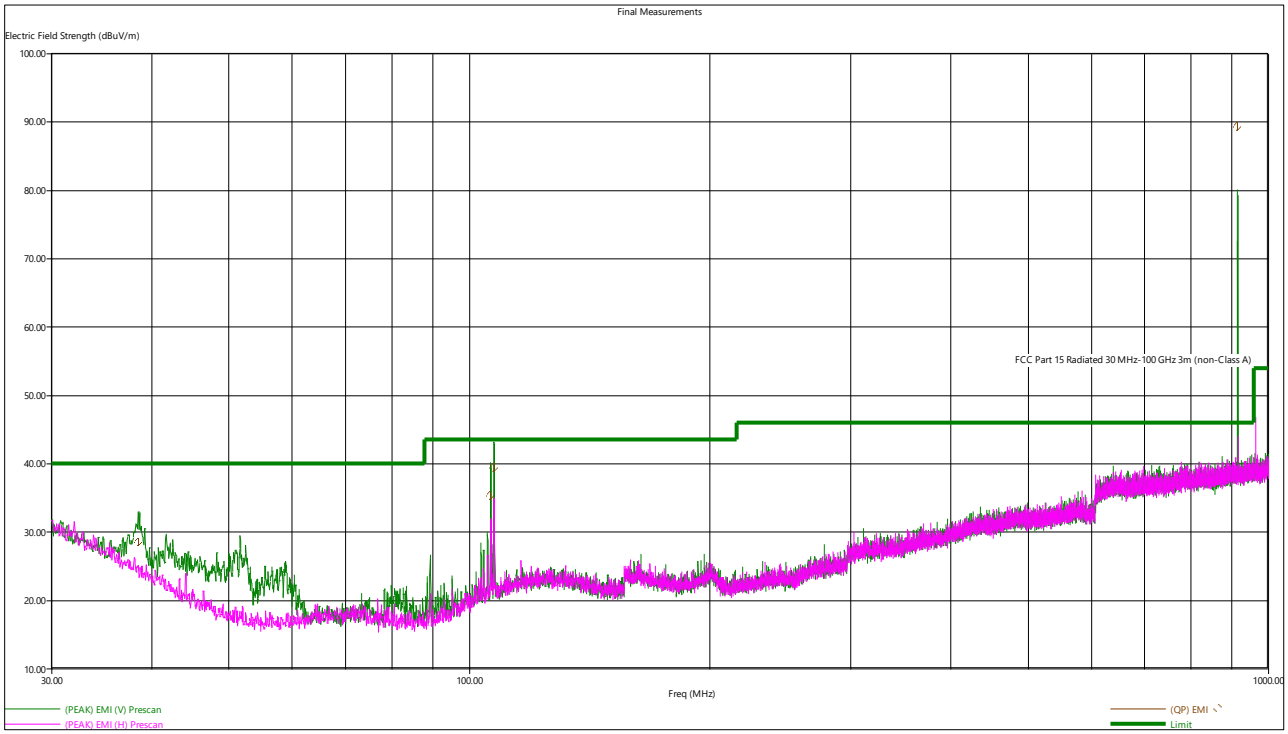


Figure 4 - Radiated Emissions Plot

Table 1 - Radiated Emissions Quasi-peak Measurements

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
38.35	28.55	40.00	11.45	123.00	284.00	V	X-Axis
106.27	35.33	43.52	8.19	107.00	280.00	V	X-Axis
107.29	39.36	43.52	4.16	107.00	53.00	V	X-Axis
914.88	89.32	NA	NA	109.00	163.00	V	X-Axis

Table 2 - Radiated Emissions Average Measurements

Frequency	Level	Limit	Margin	Pol	Axis
MHz	dBµV/m	dBµV/m	dB		
1829.50	14.54	54.00	20.90	H	X axis
2744.50	25.37	54.00	10.07	H	X Axis

*Duty cycle correction of -38.56 was used to determine the average measurements.

Table 3 - Radiated Emissions Peak Measurements

Frequency	Level	Limit	Margin	Pol	Axis
MHz	dBµV/m	dBµV/m	dB		
1829.50	53.10	74.00	20.90	H	X axis
2744.50	63.93	74.00	10.07	H	X Axis

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 axis. It was found that the Y-axis produced the highest emissions, and this orientation was used for all testing. See the test setup photo exhibit for details on the orientations.

4.3 PEAK OUTPUT POWER

Test Method: ANSI C63.10, Section(s) 11.9.1.1 “RBW ≥ DTS Bandwidth”

Limits of bandwidth measurements:
The maximum allowed peak output power is 30 dBm.

Test procedures:
Bandwidth measurement was taken at a distance of 3m from the EUT. The bandwidth of the fundamental frequency was measured by spectrum analyzer with 3 MHz RBW and 8 MHz VBW.

Deviations from test standard:
No deviation.

Test setup:

See Section 4.2

EUT operating conditions:
The EUT was powered by 5 VDC unless specified and set to transmit continuously.

Test results:

Peak Output Power

CHANNEL FREQUENCY (MHz)	PEAK OUTPUT POWER (dBm)	Method	RESULT
914.88	3.391	EIRP	PASS

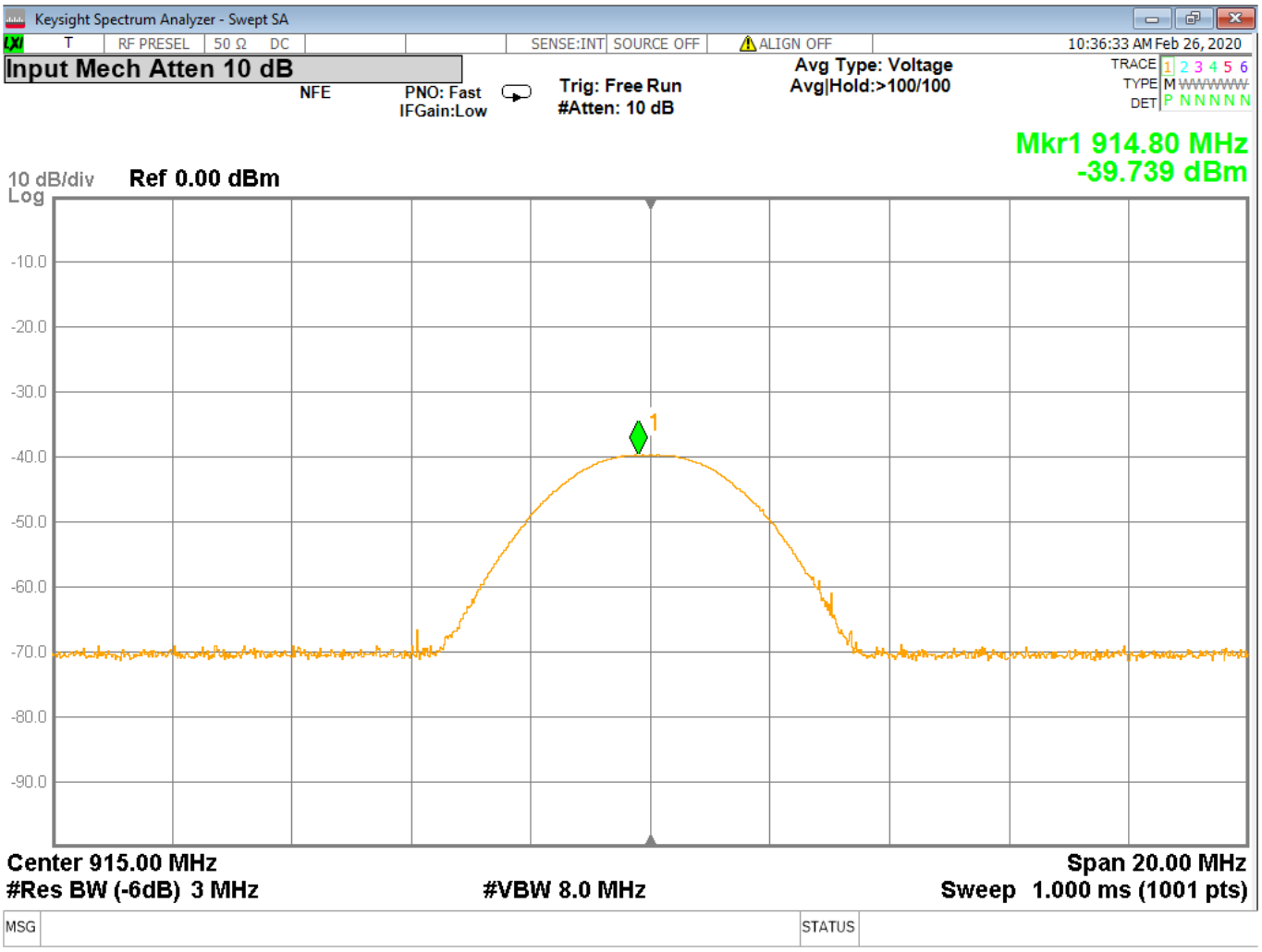


Figure 5 – Output Power

Maximum power = -39.739 dBm + 107 + CL + AF - 95.23 = 3.391 dBm
CL = cable loss = 5.06 dB
AF = antenna factor = 26.30 dB
107 = conversion from dBm to dBµV on a 50Ω measurement system
-95.23 = Conversion from field strength (dBµV/m) to EIRP (dBm) at a 3m measurement distance.

4.4 BANDWIDTH

Test Method: ANSI C63.10, Section(s) 11.8.1 “DTS Bandwidth, Option 1”

Limits of bandwidth measurements:
The 99% occupied bandwidth is displayed.

The 6dB bandwidth of the signal must be greater than 500 kHz.

Test procedures:
The bandwidth of the fundamental frequency was measured by spectrum analyzer with 100 kHz RBW and 300 kHz VBW. Automated functionality of the spectrum analyzer was used to make the OBW measurements.
The 6 dB bandwidth is defined as the bandwidth of which is higher than peak power minus 6dB.

Deviations from test standard:
No deviation.

Test setup:
The antenna output from the device was connected directly to the spectrum analyzer with a 50 ohm connector.

EUT operating conditions:
The EUT was powered by 5 VDC unless specified and set to transmit continuously.

Test results:

6 dB Bandwidth

CHANNEL FREQUENCY (MHz)	6dB BW (kHz)
914.88	521.00

Occupied Bandwidth

CHANNEL FREQUENCY (MHz)	OBW (kHz)
914.88	593.25

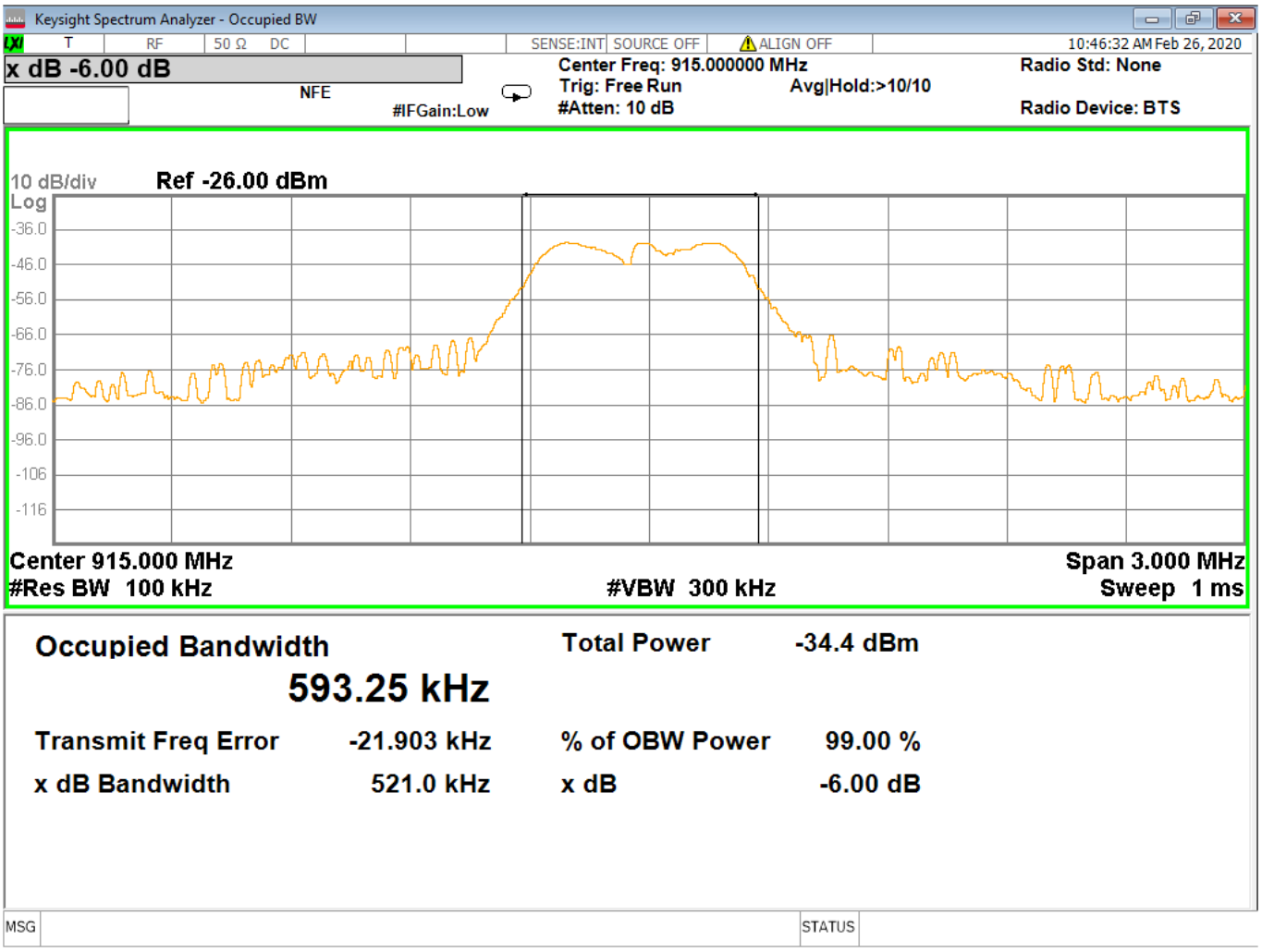


Figure 6 – Occupied Bandwidth

4.5 BANDEDGES

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

Limits of bandedge 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:
Bandwidth measurement was taken at a distance of 3m from the EUT. The bandwidth of the fundamental frequency was measured by spectrum analyzer with 100 kHz RBW and 300 kHz VBW.

The EUT was oriented as to produce the maximum emission levels. 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. All band edge measurements were evaluated to the general limits in Part 15.209.

Deviations from test standard:
No deviation.

Test setup:
All the measurements were done at 3m test distance.

EUT operating conditions:
The EUT was powered by 5 VDC unless specified and set to transmit continuously.

Test results:

Highest Out of Band Emissions

CHANNEL	Band edge /Measurement Frequency (MHz)	Relative Highest out of band level dBm	Relative Fundamental Level (dBm)	Delta	Min (dBc)	Result
Lowand high, Continuous (Unrestricted)	902.0	-93.814	-39.637	54.177	20.00	PASS
Low, Continuous (Restricted)	614.0	-91.210	-39.637	51.573	43.32	PASS
High, Continuous (Restricted)	960.0	-93.147	-39.637	53.510	43.32	PASS

*Minimum delta = [highest fundamental peak field strength from Section 4.2] – [Part 15.209 radiated emissions limit.]

From Section 4.2

Fundamental average field strength at 914.88 MHz = 89.32 dBµV/m

minimum delta = 89.32 – 46.0 dBµV/m = 43.32 dBc

Measurements do not include correction factors and are intended to be relative measurements only.

Figure 7 - Band-edge Measurement, Fundamental, Continuous Transmit

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

Worst Delta = 54.899 dB (lower band edge) > 20 dB Passing unrestricted band-edge

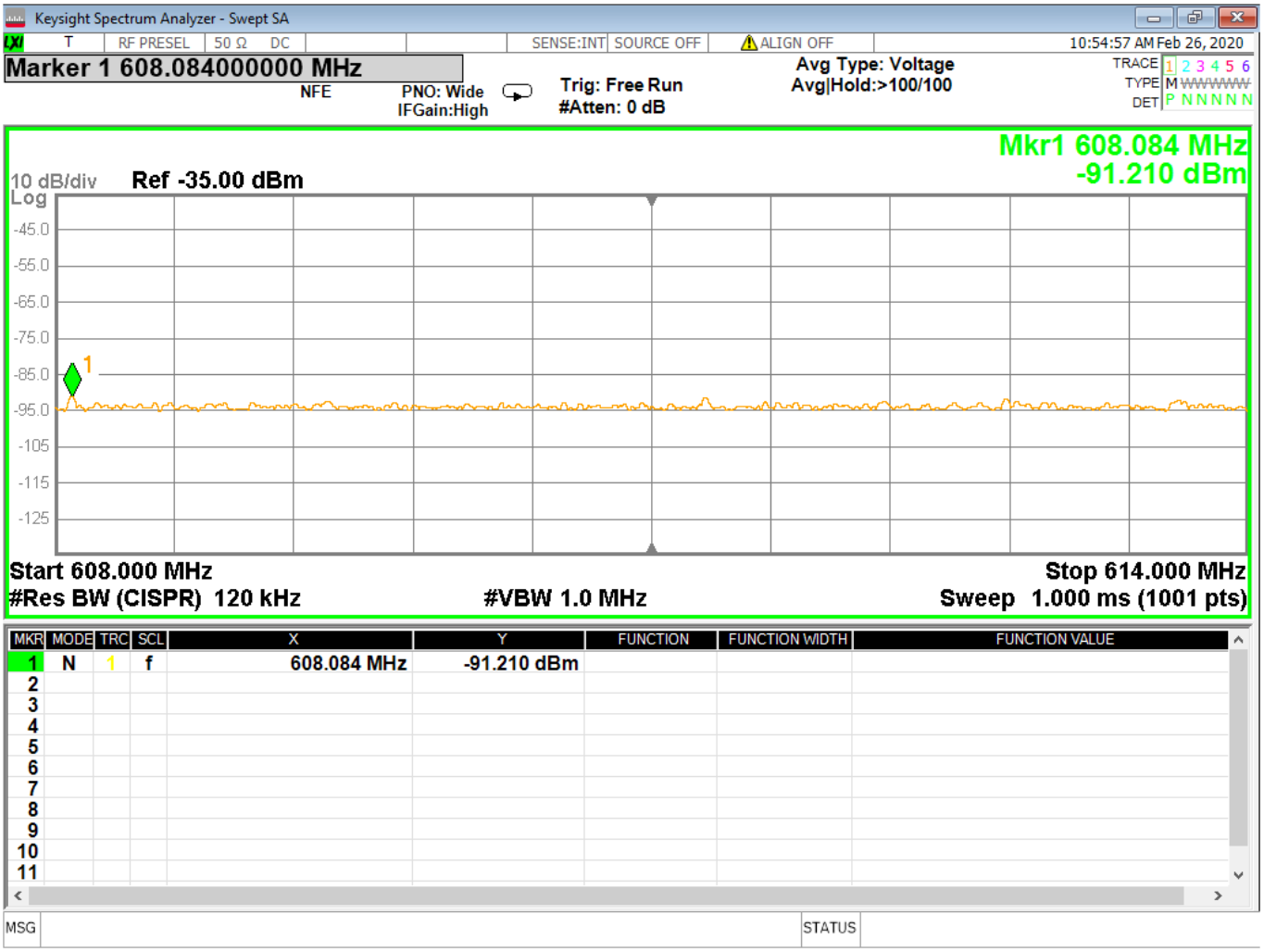


Figure 8 - Band-edge Measurement, Low Channel, Restricted Frequency, Continuous Transmit

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

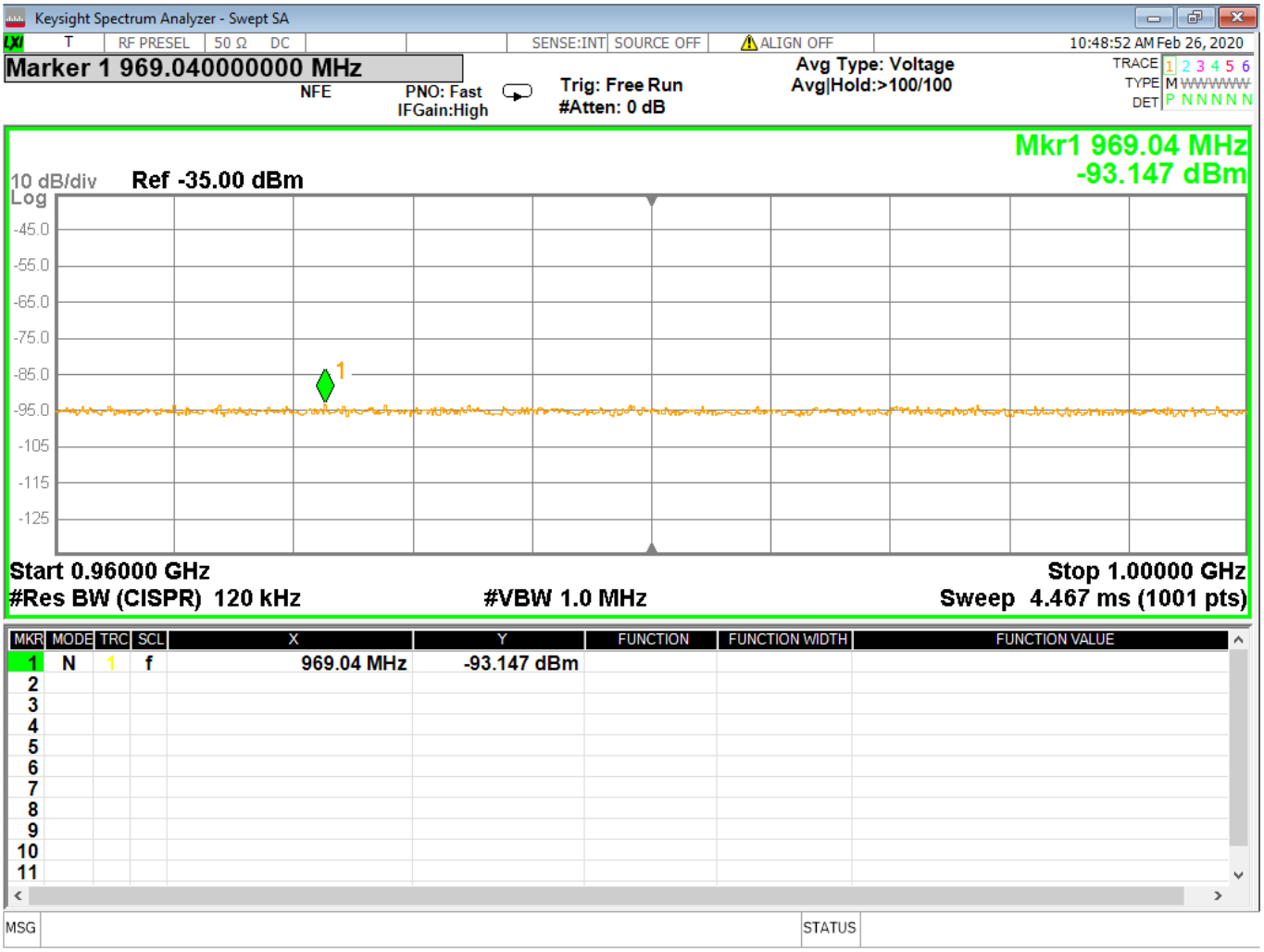


Figure 9 - Band-edge Measurement, High Channel, Restricted Frequency, Continuous Transmit

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

4.6 POWER SPECTRAL DENSITY

Test Method: ANSI C63.10,
1. Section 11.10.2 “Method PKPSD (peak PSD)”

Limits of power measurements:
The maximum PSD allowed is 8 dBm.

Test procedures:
1. The EUT was tested conducted

2. The resolution bandwidth was set to 3 kHz and the video bandwidth was set to 10 kHz to capture the signal. The analyzer used a peak detector in max hold mode.

Test setup:
The antenna output from the device was connected directly to the spectrum analyzer with a 50 ohm connector.

EUT operating conditions:
The EUT was powered by 5 VDC unless specified and set to transmit continuously.

Test results:

Power Spectral Density

CHANNEL FREQUENCY (MHz)	PEAK PSD(dBm)	Method	Limit (dBm)	RESULT
914.88	6.587	Conducted	8.00	PASS

Figure 10 - Power Spectral Density

4.7 CONDUCTED AC MAINS EMISSIONS

Test Method: ANSI C63.10-2013, Section(s) 6.2

Limits for conducted emissions measurements:

FREQUENCY OF EMISSION (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

Notes:
1. The lower limit shall apply at the transition frequencies.
2. The limit decreases in line with the logarithm of the frequency in the range of 0.15 to 0.50 MHz
3. All emanations from a class A/B digital device or system, including any network of conductors and apparatus connected thereto, shall not exceed the level of field strengths specified above.

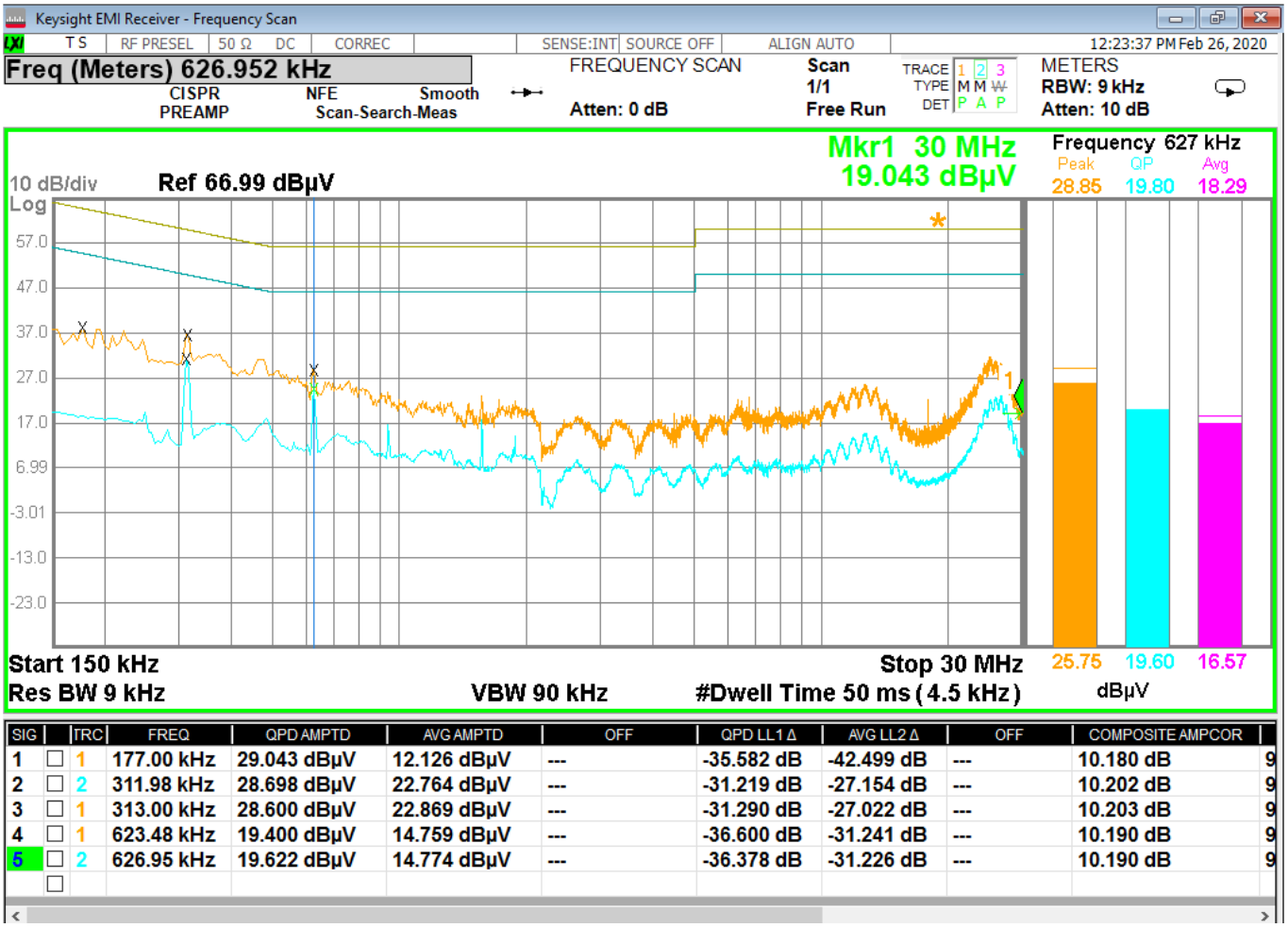
Test Procedures:

a. The EUT was placed 0.8m above a ground reference plane and 0.4 meters from the conducting wall of a shielded room with EUT being connected to the power mains through a line impedance stabilization network (LISN). The LISN provides 50 ohm/ 50uH of coupling impedance for the measuring instrument.
b. Both lines of the power mains connected to the EUT were checked for maximum conducted interference as well as the ground.
c. The frequency range from 150 kHz to 30 MHz was searched. Emission levels over 10dB under the prescribed limits are not reported.
d. Results were compared to the 15.207 limits.

Deviation from the test standard:
No deviation

EUT operating conditions:
The EUT was powered by 5 VDC unless specified and set to transmit continuously.

Test Results:



SIG	TRC	FREQ	QPD AMPTD	AVG AMPTD	OFF	QPD LL1 Δ	AVG LL2 Δ	OFF	COMPOSITE AMPCOR
1	1	177.00 kHz	29.043 dBµV	12.126 dBµV	---	-35.582 dB	-42.499 dB	---	10.180 dB
2	2	311.98 kHz	28.698 dBµV	22.764 dBµV	---	-31.219 dB	-27.154 dB	---	10.202 dB
3	1	313.00 kHz	28.600 dBµV	22.869 dBµV	---	-31.290 dB	-27.022 dB	---	10.203 dB
4	1	623.48 kHz	19.400 dBµV	14.759 dBµV	---	-36.600 dB	-31.241 dB	---	10.190 dB
5	2	626.95 kHz	19.622 dBµV	14.774 dBµV	---	-36.378 dB	-31.226 dB	---	10.190 dB

Figure 11 - Conducted Emissions, Line

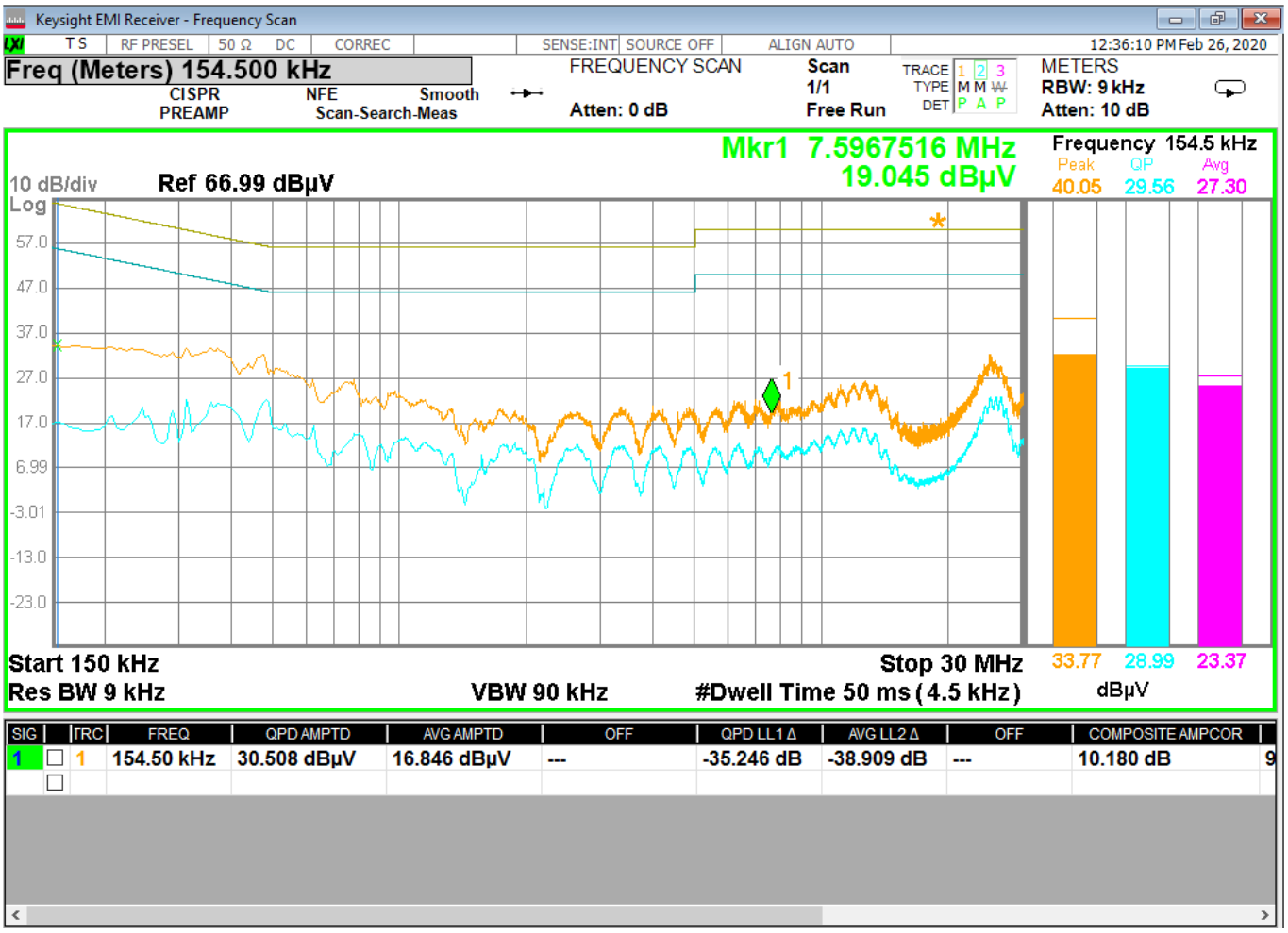


Figure 12 - Conducted Emissions, Neutral

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