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# FCC/ISED Test Report

| | |
|---|---|
| **Prepared for:** | **RealmFive, Inc.** |
| **Address:** | **3300 Folkways Cir.<br>Lincoln, NE 68504** |
| **Product:** | **Gateway** |
| **Test Report No:** | **R20171017-22-01D** |
| **Approved By:** | **Nic S. Johnson, NCE<br>Technical Manager<br>iNARTE Certified EMC Engineer #EMC-003337-NE** |
| **DATE:** | **8 June 2021** |
| **Total Pages:** | **54** |



ACCREDITED
TESTING LABORATORY
CERTIFICATE NO. 1953.01

## REVISION PAGE

| Rev. No. | Date | Description |
|---|---|---|
| 0 | 1 October 2018 | Original – NJohnson<br>Prepared by KVepuri |
| A | 26 October 2020 | Updated Section 4.2 to state that intermodulation testing was performed and pre-testing with all cable configs. -NJ |
| B | 4 March 2021 | Section 4.7 –A note was added below Figure 29 to explain the hop channel plot. |
| C | 13 May 2021 | Section 4.7 – Note was modified to state device acts as a solicited device only |
| D | 8 June 2021 | Page 50, note corrected to state plot show dwell time per channel is 291ms. |

## CONTENTS

## TABLES OF FIGURES

**Figure Number** **Page**

## TABLE OF TABLES

**Table Number** **Page**

## 1.0 SUMMARY OF TEST RESULTS

The EUT has been tested according to the following specifications:

| APPLIED STANDARDS AND REGULATIONS | | |
|---|---|---|
| **Standard Section** | **Test Type** | **Result** |
| FCC Part 15.35<br>RSS Gen, Issue 4, Section 6.10 | Duty Cycle | Pass |
| FCC Part 15.247(a)(1)<br>RSS-247 Issue 2 Section 5.2 | Peak output power | Pass |
| FCC Part 15.247(a)(1)<br>RSS-247 Issue 2 Section 5.2 | Bandwidth | Pass |
| FCC Part 15.209<br>RSS-Gen Issue 4, Section 7.1 | Receiver Radiated Emissions | Pass |
| FCC Part 15.209 (restricted bands), 15.247 (unrestricted)<br>RSS-247 Issue 2 Section 5.5, RSS-Gen Issue 4, Section 8.9 | Transmitter Radiated Emissions | Pass |
| FCC Part 15.247(a)(1)<br>RSS-247 Issue 2 Section 5.2 | Power Spectral Density | Pass |
| FCC 15.247(a) (1) (i)<br>RSS-247, 5.1(c) | Frequency Hopping System | Pass |
| FCC Part 15.209, 15.247(d)<br>RSS-247 Issue 2 Section 11.13 | Band Edge Measurement | Pass |
| FCC Part 15.207<br>RSS-Gen Issue 4, Section 7.1 | Conducted Emissions | Not applicable. Battery power only, no charger. |
| FCC 15.203 | Unique Antenna Requirement | Pass |

See Section 4 for details on the test methods used for each test.

# 2.0 EUT DESCRIPTION

## 2.1 EQUIPMENT UNDER TEST

The Equipment Under Test (EUT) was a wireless gateway module used to collect data from sensors and transmit it. It has transmitted and receive capabilities.

| | |
|---|---|
| EUT | Gateway |
| EUT Received | 6 December 2017 |
| EUT Tested | 6 December 2017 - 28 March 2018 |
| Model No. | Rev. 6 |
| Serial No. | NCEETEST1 (Assigned) |
| Operating Band | 902.0 – 928.0 MHz |
| Device Type | Hybrid |
| Power Supply | Internal Battery/ Solar Powered |

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 | 902.3 |
| Middle | 908.5 |
| High | 914.9 |

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 |
| NCC CAB Identification No: | US0177 |

Environmental conditions varied slightly throughout the tests:

Relative humidity of 35 ± 4%
Temperature of 22 ± 3° Celsius

## 3.2 TEST PERSONNEL

All testing was performed by Karthik Vepuri of NCEE Labs. The results were reviewed by Nic Johnson.

## 3.3 TEST EQUIPMENT

| DESCRIPTION AND MANUFACTURER | MODEL NO. | SERIAL NO. | LAST CALIBRATION DATE | CALIBRATION DUE DATE |
|---|---|---|---|---|
| Rohde & Schwarz Test Receiver | ES126 | 100037 | 30 Jan 2018 | 30 Jan 2019 |
| Rohde & Schwarz Test Receiver | ES17 | 100007 | 31 Jul 2017 | 31 Jul 2018 |
| EMCO Biconilog Antenna | 3142B | 1647 | 02 Aug 2017 | 02 Aug 2018 |
| EMCO Horn Antenna | 3115 | 6416 | 26 Jan 2018 | 26 Jan 2020 |
| EMCO Horn Antenna | 3116 | 2576 | 31 Jan 2018 | 31 Jan 2020 |
| Rohde & Schwarz Preamplifier | TS-PR18 | 3545700803 | 09 Mar 2018* | 09 Mar 2019* |
| Trilithic High Pass Filter | 6HC330 | 23042 | 09 Mar 2018* | 09 Mar 2019* |
| Rohde & Schwarz LISN | ESH3-Z5 | 836679/010 | 25 Jul 2017 | 25 Jul 2018 |
| RF Cable (preamplifier to antenna) | MFR-57500 | 01-07-002 | 09 Mar 2018* | 09 Mar 2019* |
| RF Cable (antenna to 10m chamber bulkhead) | FSCM 64639 | 01E3872 | 09 Mar 2018* | 09 Mar 2019* |
| RF Cable (10m chamber bulkhead to control room bulkhead) | FSCM 64639 | 01E3874 | 09 Mar 2018* | 09 Mar 2019* |
| RF Cable (Control room bulkhead to RF switch) | FSCM 64639 | 01E3871 | 09 Mar 2018* | 09 Mar 2019* |
| RF Cable (RF switch to test receiver) | FSCM 64639 | 01F1206 | 09 Mar 2018* | 09 Mar 2019* |
| RF switch – Rohde and Schwarz | TS-RSP | 1113.5503.14 | 09 Mar 2018* | 09 Mar 2019* |
| N connector bulkhead (10m chamber) | PE9128 | NCEEBH1 | 09 Mar 2018* | 09 Mar 2019* |
| N connector bulkhead (control room) | PE9128 | NCEEBH2 | 09 Mar 2018* | 09 Mar 2019* |

*Internal Characterization

# 4.0 DETAILED RESULTS

## 4.1 DUTY CYCLE

## 4.2 RADIATED EMISSIONS

**Test Method**: ANSI C63.10:2013, Section 6.5, 6.6, 11.11, 11.12

**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 and higher.

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.

h. The EUT was tested with each combination of the radios operating simultaneously. In cases where intermodulation products were detected, they were reported in the results of this section.

**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:**

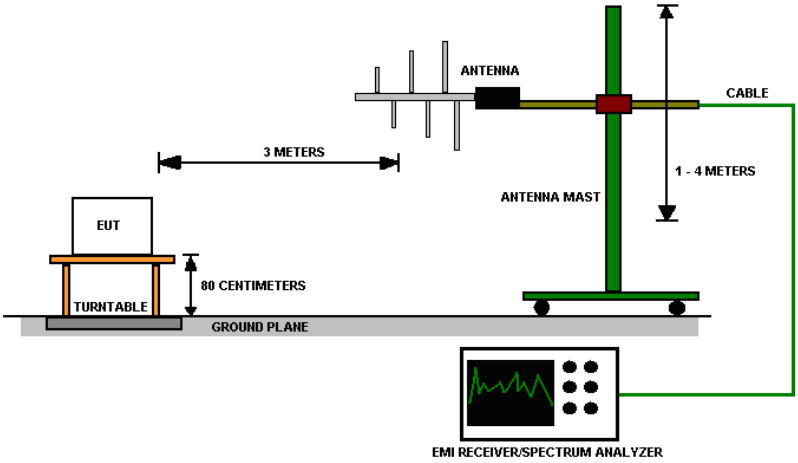


Figure 1 - Radiated Emissions Test Setup

**EUT operating conditions**

The EUT was powered by 6.4 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 was performed with all potential accessories including cables. Pre-scans indicated that the cables had no effect on the results presented in this report.

**Test results:**

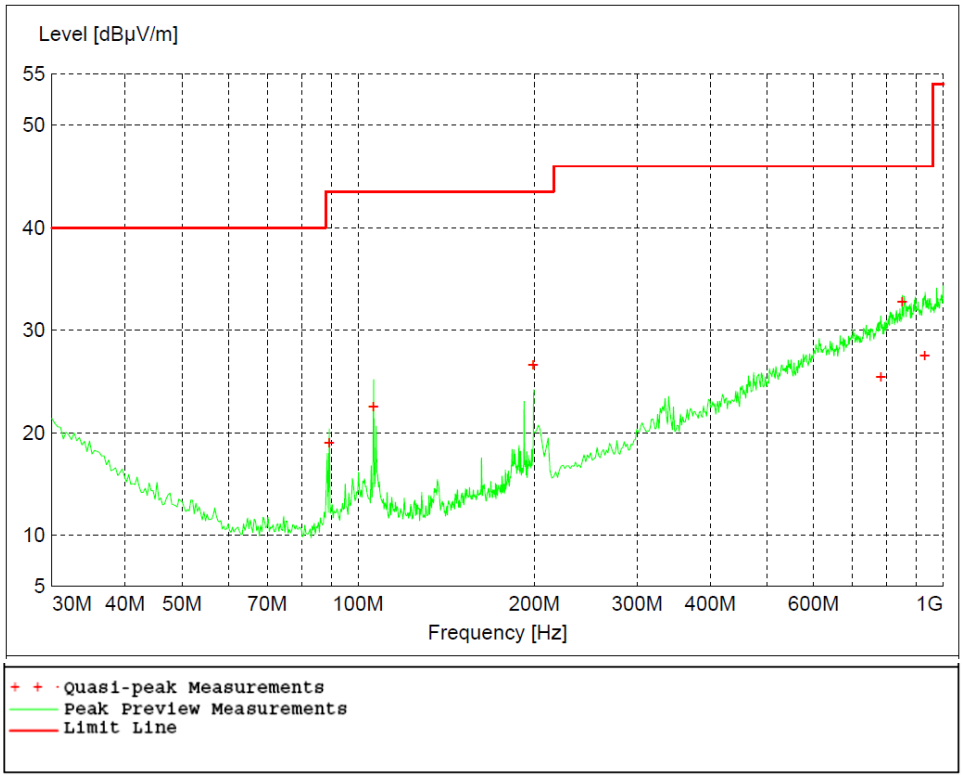


Figure 2 - Radiated Emissions Plot, Receive

Table 1 - Radiated Emissions Quasi-peak Measurements, Receive

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 89.280000 | 19.02 | 43.50 | 24.50 | 322 | 117 | VERT | X |
| 106.320000 | 22.48 | 43.50 | 21.00 | 115 | 15 | HORI | X |
| 199.320000 | 26.60 | 43.50 | 16.90 | 176 | 280 | HORI | X |
| 782.340000 | 25.42 | 46.00 | 20.60 | 357 | 335 | VERT | X |
| 850.980000 | 32.77 | 46.00 | 13.20 | 186 | 169 | VERT | X |
| 929.640000 | 27.47 | 46.00 | 18.50 | 233 | 124 | VERT | X |

Table 2 - Radiated Emissions Peak Measurements vs. Average Limit, Receive

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 1795.000000 | 32.77 | 54.00 | 21.20 | 114 | 360 | VERT | X |
| 2718.400000 | 33.31 | 54.00 | 20.70 | 397 | 307 | HORI | X |
| 3612.800000 | 38.06 | 54.00 | 15.90 | 397 | 337 | HORI | X |
| 4499.000000 | 40.20 | 54.00 | 13.80 | 146 | 114 | VERT | X |

Peak measurements were compared to average limit and found to be compliant so average measurements were not performed

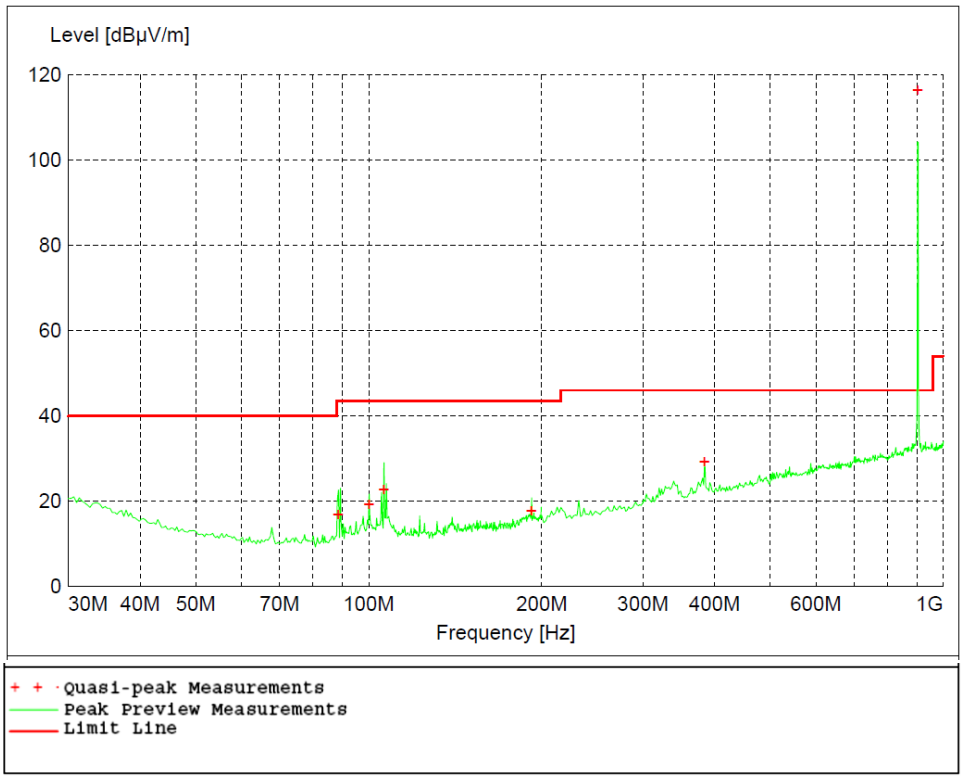


Figure 3 - Radiated Emissions Plot, Low Channel

Table 3 - Radiated Emissions Quasi-peak Measurements, Low Channel

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 88.560000 | 16.80 | 43.50 | 26.70 | 391 | 306 | HORI | X |
| 100.200000 | 19.20 | 43.50 | 24.30 | 337 | 166 | HORI | X |
| 106.320000 | 22.76 | 43.50 | 20.80 | 364 | 240 | HORI | X |
| 192.000000 | 17.69 | 43.50 | 25.80 | 100 | 119 | HORI | X |
| 384.000000 | 29.20 | 46.00 | 16.80 | 100 | 182 | HORI | X |
| 902.300000 | 116.37 | NA | NA | 123 | 241 | VERT | X |

Table 4 - Radiated Emissions Peak Measurements vs. Average Limit, Low Channel

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 1804.600000 | 36.46 | 54.00 | 17.50 | 101 | 221 | HORI | X |
| 2707.000000 | 35.99 | 54.00 | 18.00 | 99 | 241 | VERT | X |
| 3618.200000 | 38.11 | 54.00 | 15.90 | 394 | 288 | HORI | X |
| 4511.000000 | 40.58 | 54.00 | 13.40 | 113 | 5 | VERT | X |
| 5404.600000 | 41.45 | 54.00 | 12.60 | 395 | 224 | HORI | X |
| 6307.400000 | 43.31 | 54.00 | 10.70 | 395 | 258 | HORI | X |
| 7222.400000 | 43.07 | 54.00 | 10.90 | 100 | 185 | HORI | X |
| 8099.200000 | 45.10 | 54.00 | 8.90 | 394 | 360 | HORI | X |
| 8998.200000 | 46.61 | 54.00 | 7.40 | 157 | 34 | VERT | X |

Peak measurements were compared to average limit and found to be compliant so average measurements were not performed

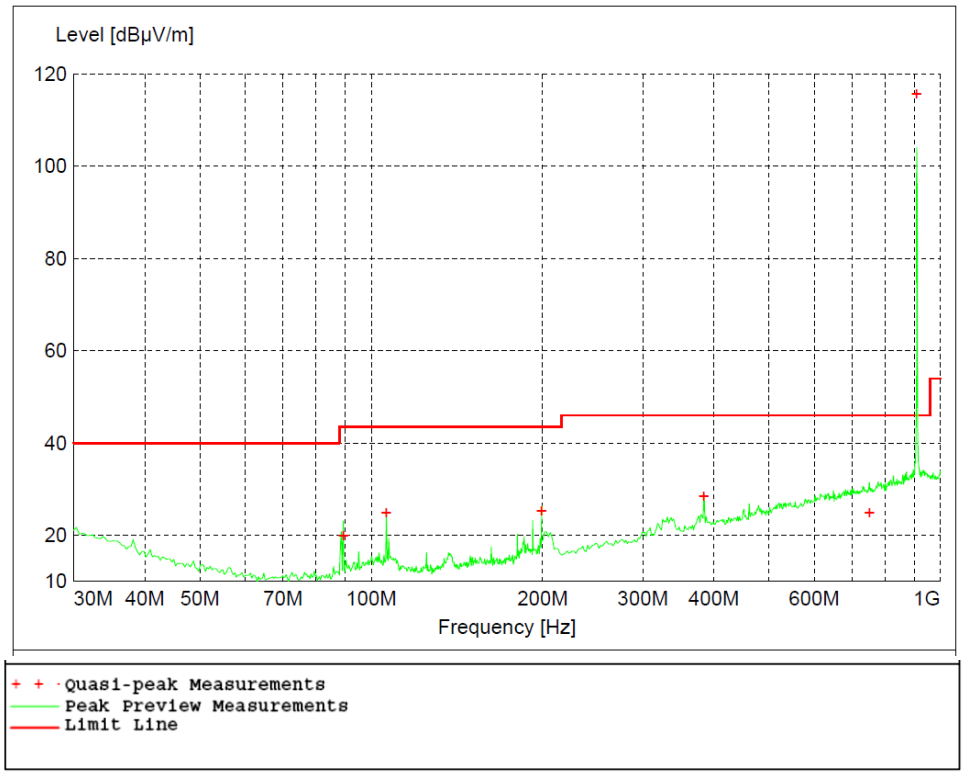


Figure 4 - Radiated Emissions Plot, Mid Channel

Table 5 - Radiated Emissions Quasi-peak Measurements, Mid Channel

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 89.340000 | 19.92 | 43.50 | 23.60 | 400 | 182 | VERT | X |
| 106.320000 | 24.81 | 43.50 | 18.70 | 135 | 309 | HORI | X |
| 199.320000 | 25.12 | 43.50 | 18.40 | 170 | 290 | HORI | X |
| 384.000000 | 28.46 | 46.00 | 17.50 | 99 | 187 | HORI | X |
| 750.300000 | 24.84 | 46.00 | 21.20 | 210 | 170 | VERT | X |
| 908.500000 | 115.54 | NA | NA | 112 | 228 | VERT | X |

Table 6 - Radiated Emissions Peak Measurements vs. Average Limit, Mid Channel

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 1826.400000 | 33.62 | 54.00 | 20.40 | 140 | 3 | VERT | X |
| 2725.600000 | 37.34 | 54.00 | 16.70 | 173 | 217 | VERT | X |
| 3633.800000 | 42.07 | 54.00 | 11.90 | 190 | 113 | VERT | X |
| 4542.000000 | 40.57 | 54.00 | 13.40 | 100 | 15 | VERT | X |
| 5459.400000 | 41.31 | 54.00 | 12.70 | 397 | 139 | HORI | X |
| 6355.200000 | 41.92 | 54.00 | 12.10 | 395 | 29 | VERT | X |
| 7262.600000 | 42.60 | 54.00 | 11.40 | 398 | 203 | HORI | X |
| 8177.600000 | 45.26 | 54.00 | 8.70 | 337 | 309 | HORI | X |
| 9085.200000 | 45.43 | 54.00 | 8.60 | 336 | 128 | VERT | X |
| 10018.000000 | 45.42 | 54.00 | 8.60 | 231 | 160 | HORI | X |

Peak measurements were compared to average limit and found to be compliant so average measurements were not performed

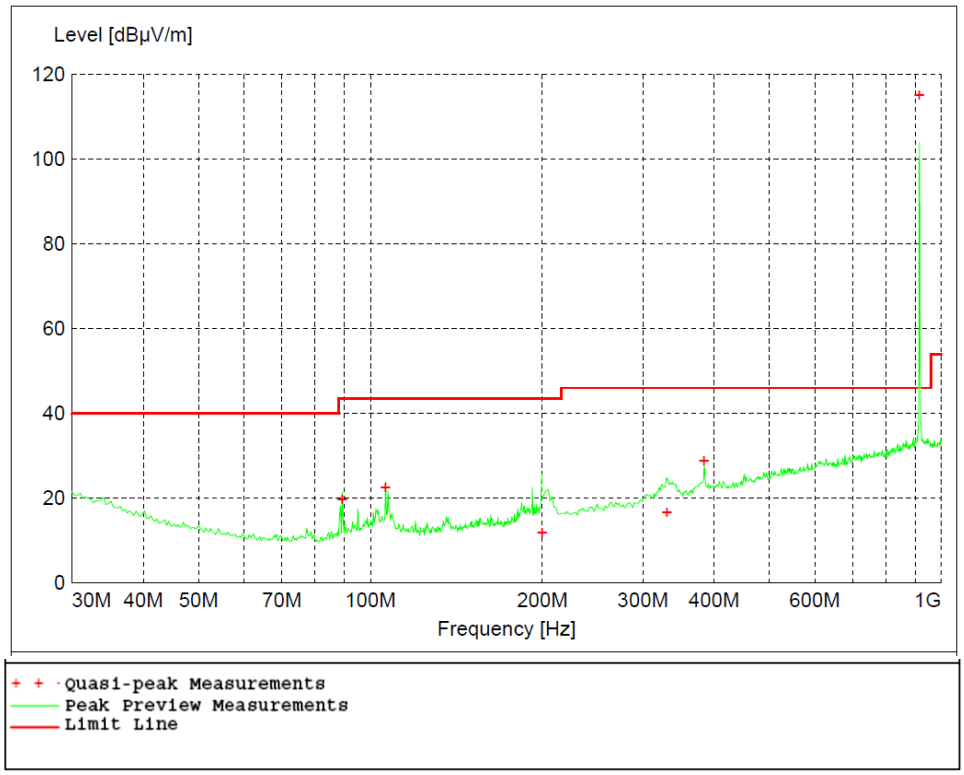


Figure 5 - Radiated Emissions Plot, High Channel

Table 7 - Radiated Emissions Quasi-peak Measurements, High Channel

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 89.280000 | 19.72 | 43.50 | 23.80 | 401 | 0 | VERT | X |
| 106.260000 | 22.54 | 43.50 | 21.00 | 388 | 236 | HORI | X |
| 199.980000 | 11.78 | 43.50 | 31.70 | 140 | 329 | HORI | X |
| 330.420000 | 16.57 | 46.00 | 29.40 | 101 | 360 | HORI | X |
| 384.000000 | 28.81 | 46.00 | 17.20 | 99 | 192 | HORI | X |
| 914.900000 | 115.08 | NA | NA | 109 | 229 | VERT | X |

Table 8 - Radiated Emissions Peak Measurements vs. Average Limit, High Channel

| Frequency | Level | Limit | Margin | Height | Angle | Pol | Axis |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dB | cm. | deg. | | |
| 1829.600000 | 34.62 | 54.00 | 19.40 | 100 | 186 | VERT | X |
| 2749.800000 | 34.47 | 54.00 | 19.50 | 396 | 178 | VERT | X |
| 3659.600000 | 42.63 | 54.00 | 11.40 | 101 | 121 | VERT | X |
| 4575.000000 | 41.10 | 54.00 | 12.90 | 396 | 23 | VERT | X |
| 5504.800000 | 41.88 | 54.00 | 12.10 | 98 | 124 | VERT | X |
| 6395.800000 | 42.59 | 54.00 | 11.40 | 395 | 261 | HORI | X |
| 7315.000000 | 41.97 | 54.00 | 12.00 | 157 | 58 | VERT | X |
| 8232.800000 | 45.28 | 54.00 | 8.70 | 137 | 268 | VERT | X |
| 9130.200000 | 45.87 | 54.00 | 8.10 | 180 | 275 | HORI | X |

Peak measurements were compared to average limit and found to be compliant so average measurements were not performed

**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 orthagonal 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

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

**Test procedures:**
The EUT was connected to the spectrum analyzer directly with a low-loss shielded coaxial cable with 10 MHz RBW and 10 MHz VBW. The RBW was set to a value larger than the DTS bandwidth.

**Deviations from test standard:**
No deviation.

**Test setup:**

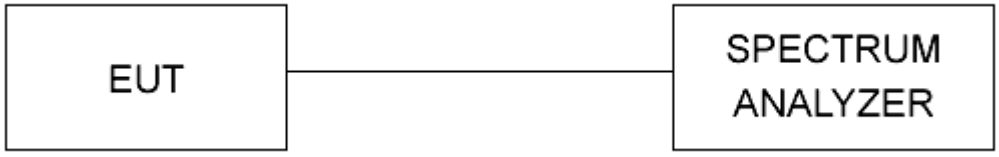


**Figure 6 – Peak Output Power Measurements Test Setup**
*1.1 dB of cable loss was used and it was accounted for in the plots

**EUT operating conditions:**
The EUT was powered by 6.4 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:**

**Peak Output Power**

| CHANNEL | CHANNEL FREQUENCY (MHz) | PEAK OUTPUT POWER (dBm) | Method | RESULT |
|---|---|---|---|---|
| Low | 902.3 | 17.81 | Conducted | PASS |
| Middle | 908.5 | 17.68 | Conducted | PASS |
| High | 914.9 | 17.43 | Conducted | PASS |

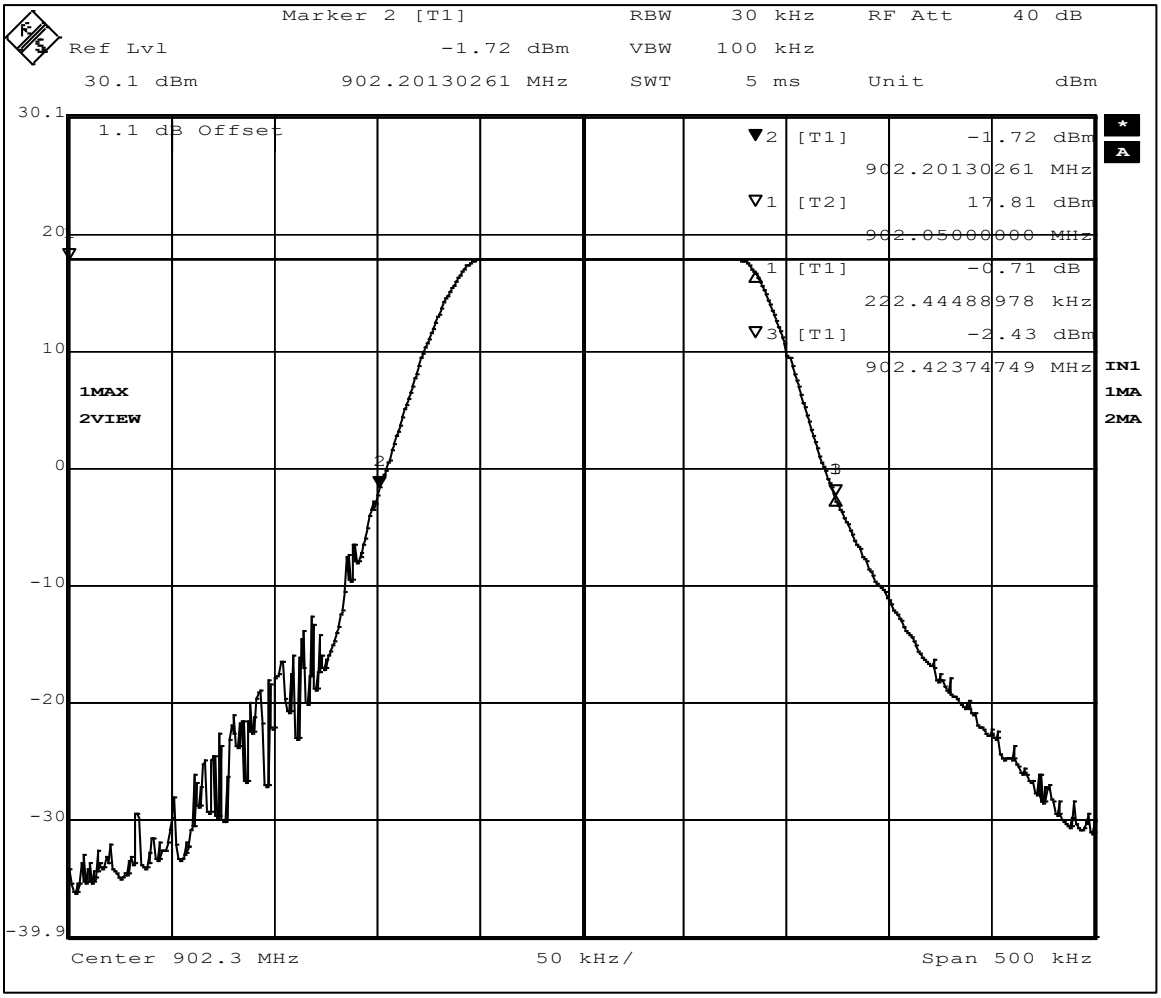


**Figure 7 – Output Power, Low Channel**

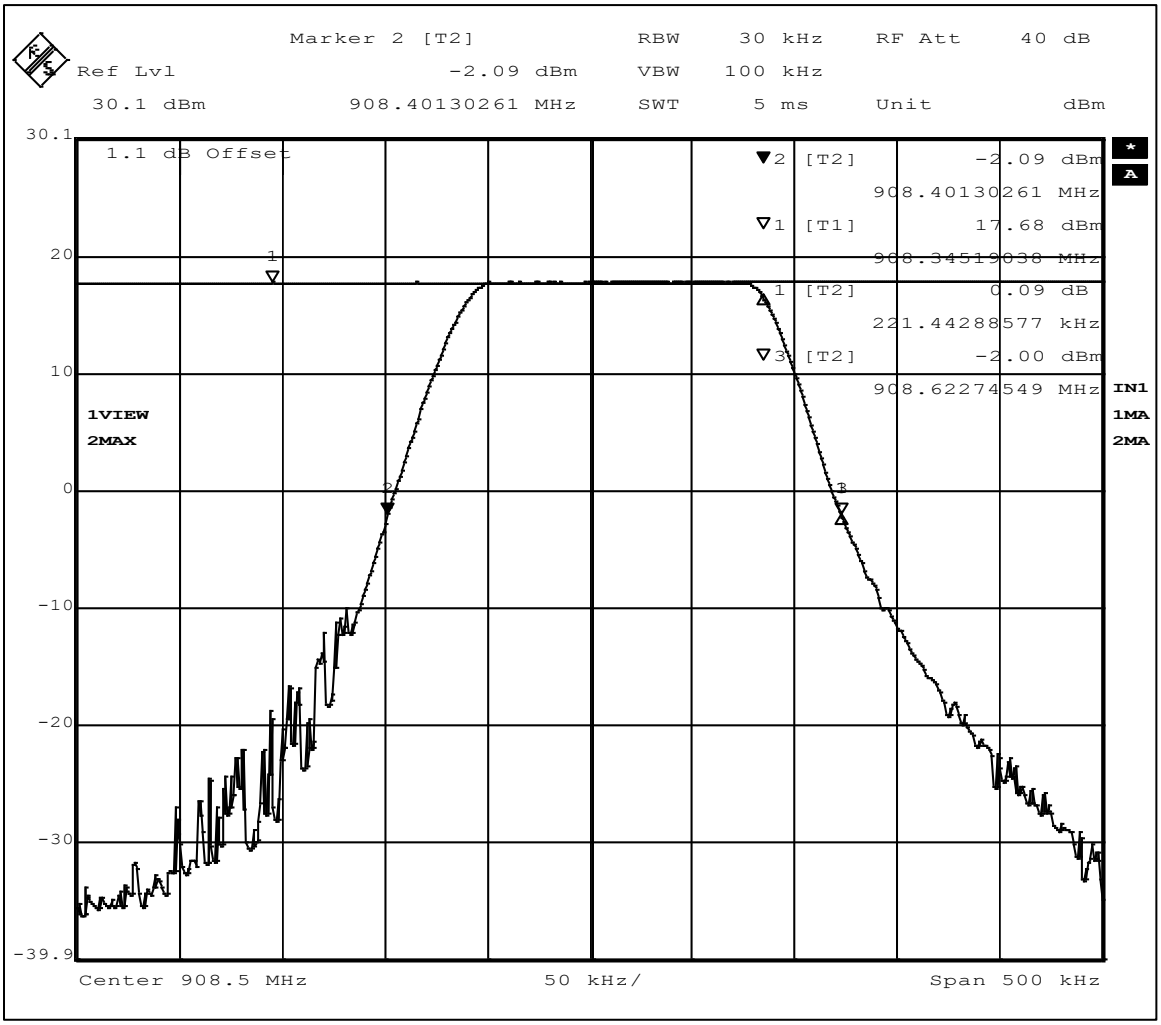


**Figure 8 - Output Power, Mid Channel**

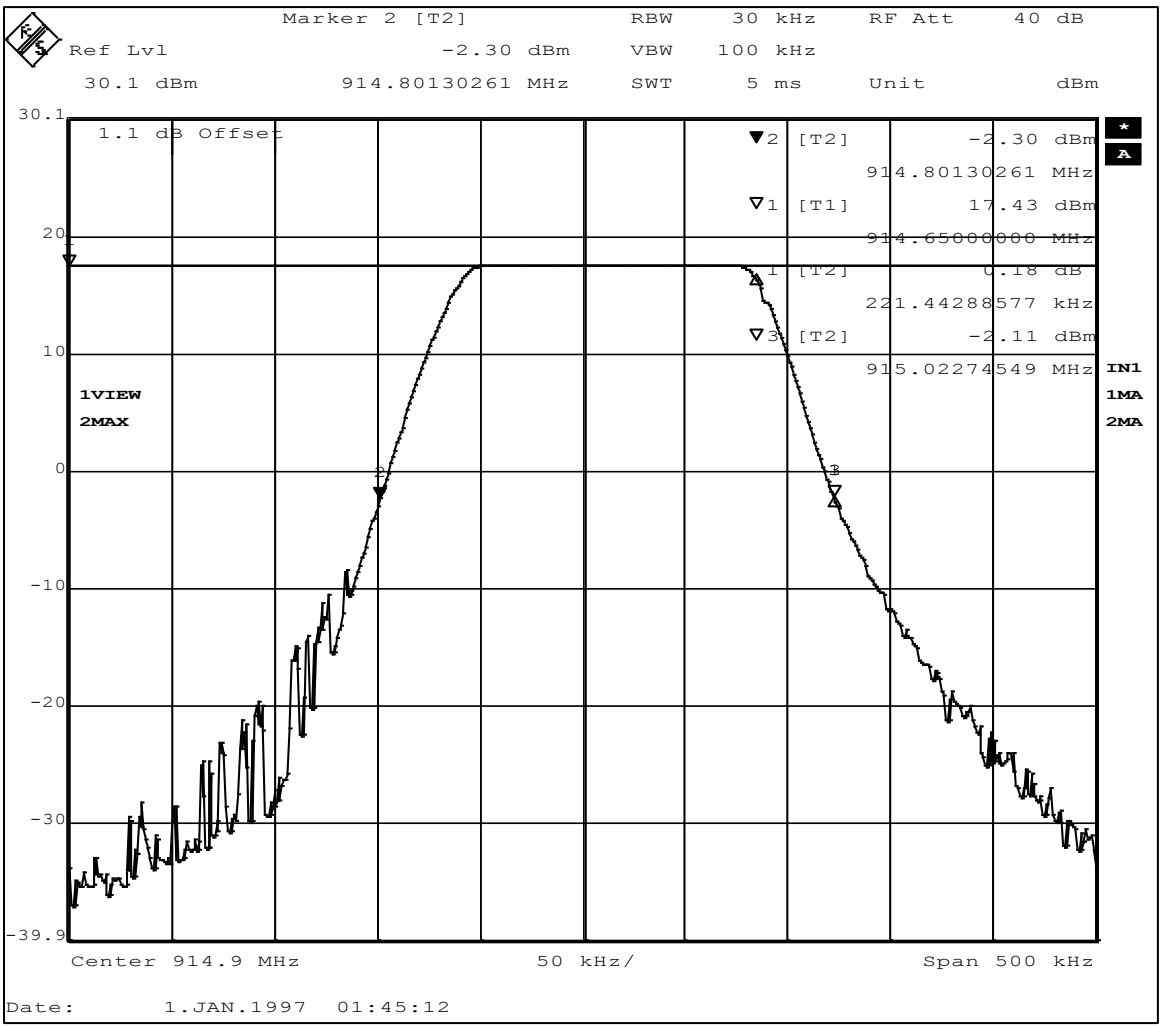


**Figure 9 - Output Power, High Channel**

## 4.4 BANDWIDTH

**Test Method:** ANSI C63.10, Section(s) 11.8.1

**Limits of bandwidth measurements:**
The 99% occupied bandwidth and peak output powers are displayed. The maximum allowed peak output power is 30 dBm.

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

**Test procedures:**
The EUT was connected to the spectrum analyzer directly with a low-loss shielded coaxial cable. The bandwidth of the fundamental frequency was measured by spectrum analyzer with 100 kHz RBW and 300 kHz VBW.

The 99% occupied is defined as the bandwidth at which 99% of the signal power is found. This corresponds to 20dB down from the maximum power level. The maximum power was measured with the largest resolution bandwidth possible (10MHz) and this value was recorded. The signal was then captured with a 1 MHz resolution bandwidth and the frequencies where the measurements were 20dB below the maximum power were marked. The bandwidth between these frequencies was recorded as the 99% occupied bandwidth.

The 6 dB bandwidth is defined as the bandwidth of which is higher than peak power minus 6dB.

For peak output power measurements, the EUT was connected to the spectrum analyzer directly with a low-loss shielded coaxial cable with 3 MHz RBW and 10 MHz VBW.

**Deviations from test standard:**
No deviation.

**Test setup:**

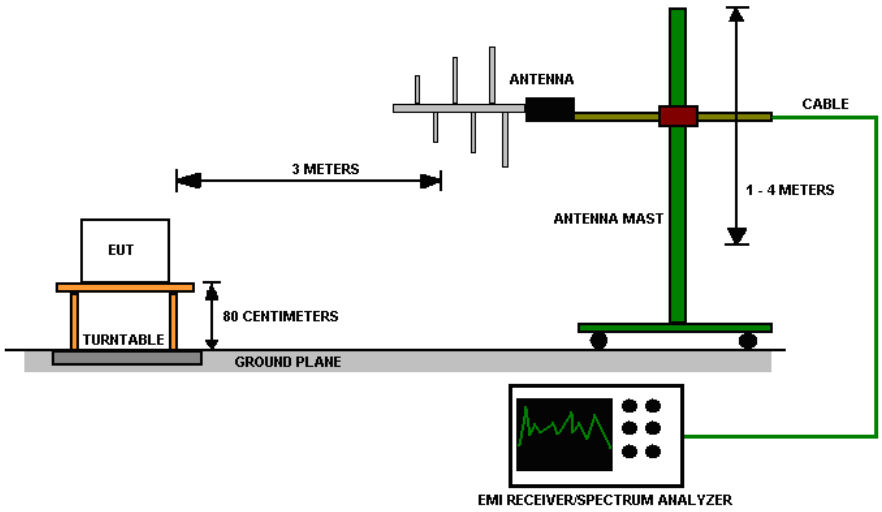


Figure 10 - Bandwidth Measurements Test Setup

**EUT operating conditions:**

The EUT was powered by 6.4 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:**

**99% Occupied Bandwidth**

| CHANNEL | CHANNEL FREQUENCY (MHz) | 99% Occupied BW (kHz) |
|---|---|---|
| 1 | 902.3 | 222.44 |
| 2 | 908.5 | 221.44 |
| 3 | 914.9 | 221.44 |

**6dB Bandwidth**

| CHANNEL | CHANNEL FREQUENCY (MHz) | 6 dB BW (kHz) |
|---|---|---|
| 1 | 902.3 | 168.34 |
| 2 | 908.5 | 167.33 |
| 3 | 914.9 | 169.34 |

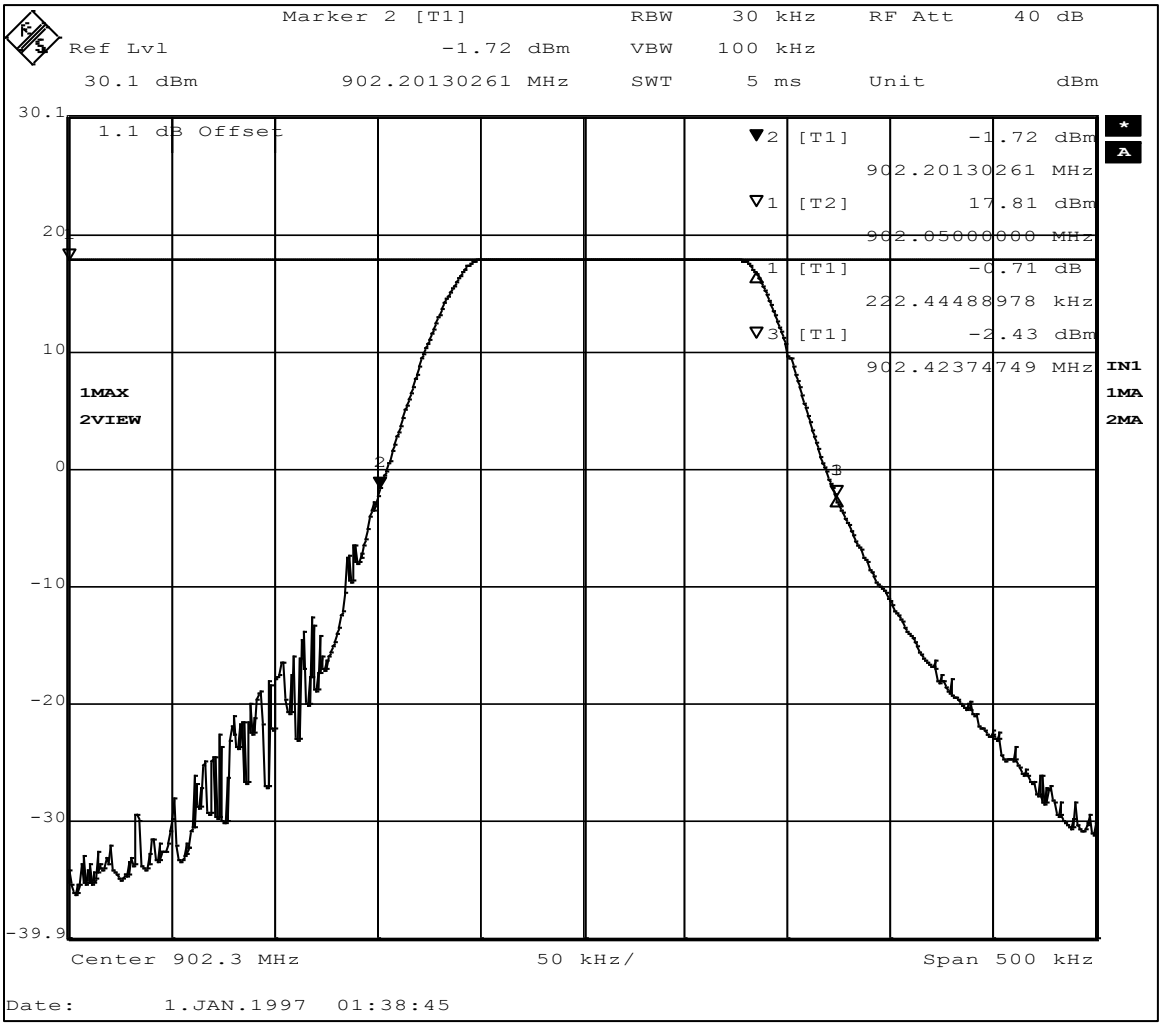


**Figure 11 - 99% Occupied Bandwidth, Low Channel**

Note: the trace at the top where Marker 1 is located was made with a 10MHz resolution bandwidth and saved on the screen. The trace on the bottom was made with a 100 kHz RBW.

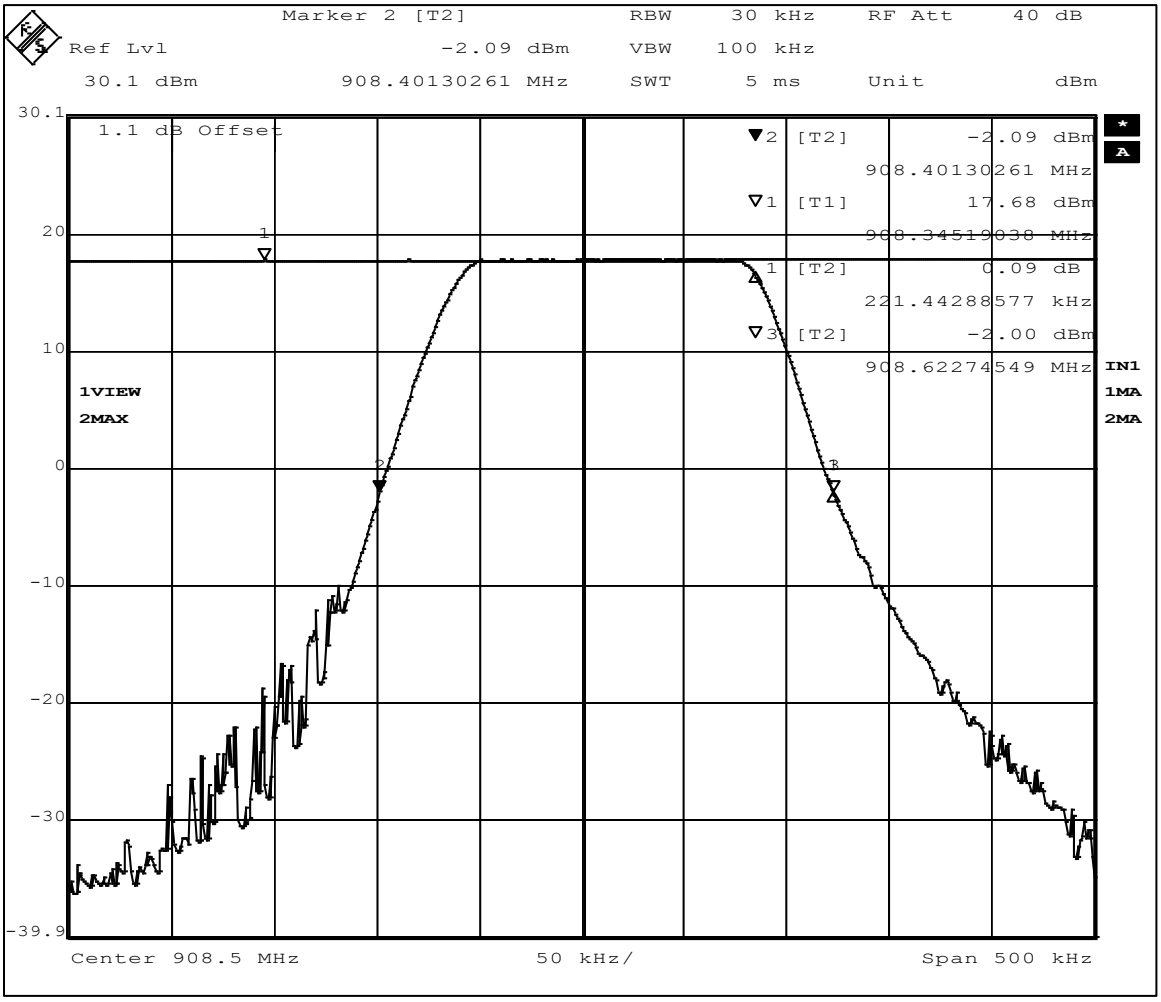


**Figure 12 - 99% Occupied Bandwidth, Mid Channel**

Note: the trace at the top where Marker 1 is located was made with a 10MHz resolution bandwidth and saved on the screen. The trace on the bottom was made with a 100 kHz RBW.

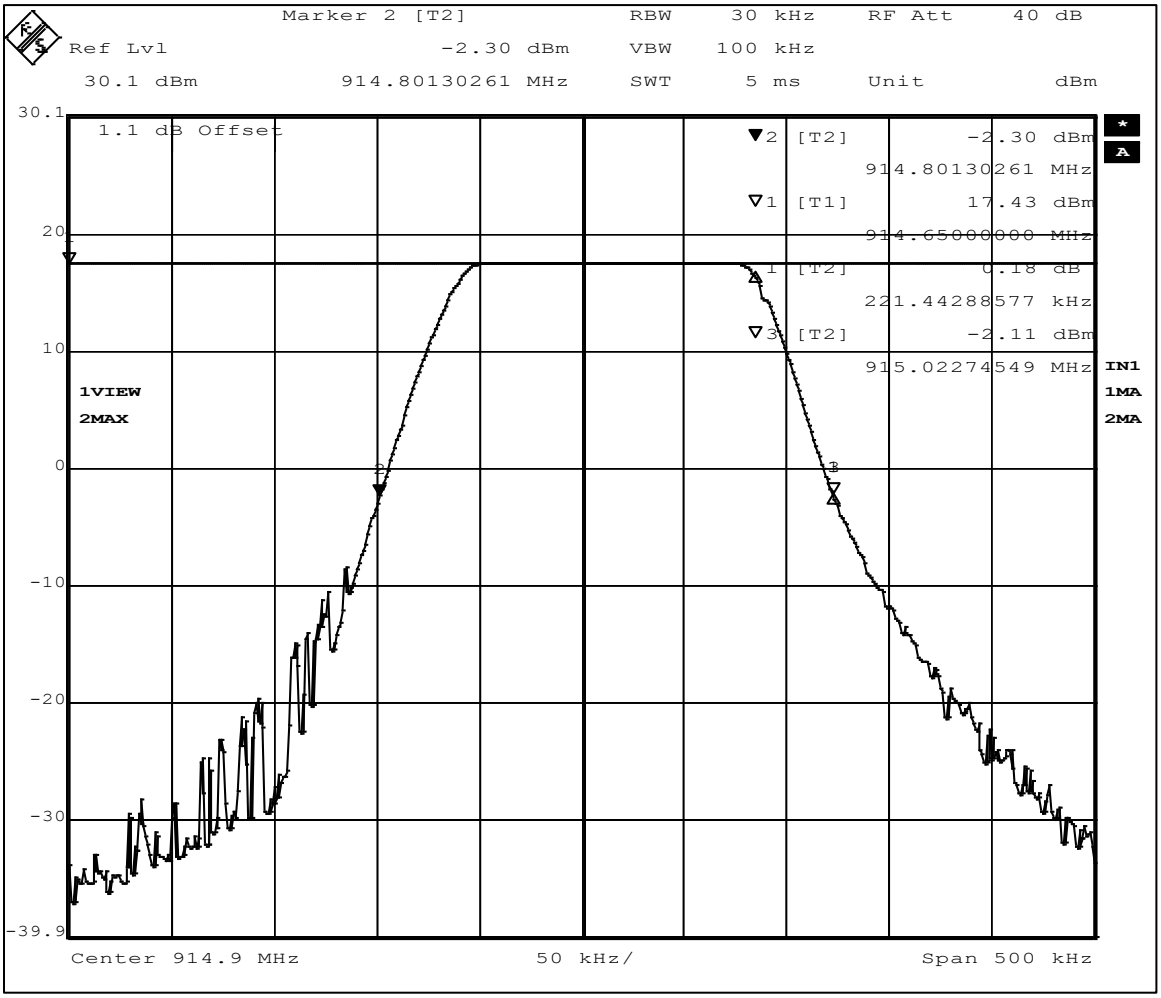


**Figure 13 - 99% Occupied Bandwidth, High Channel**

Note: the trace at the top where Marker 1 is located was made with a 10MHz resolution bandwidth and saved on the screen. The trace on the bottom was made with a 100 kHz RBW.

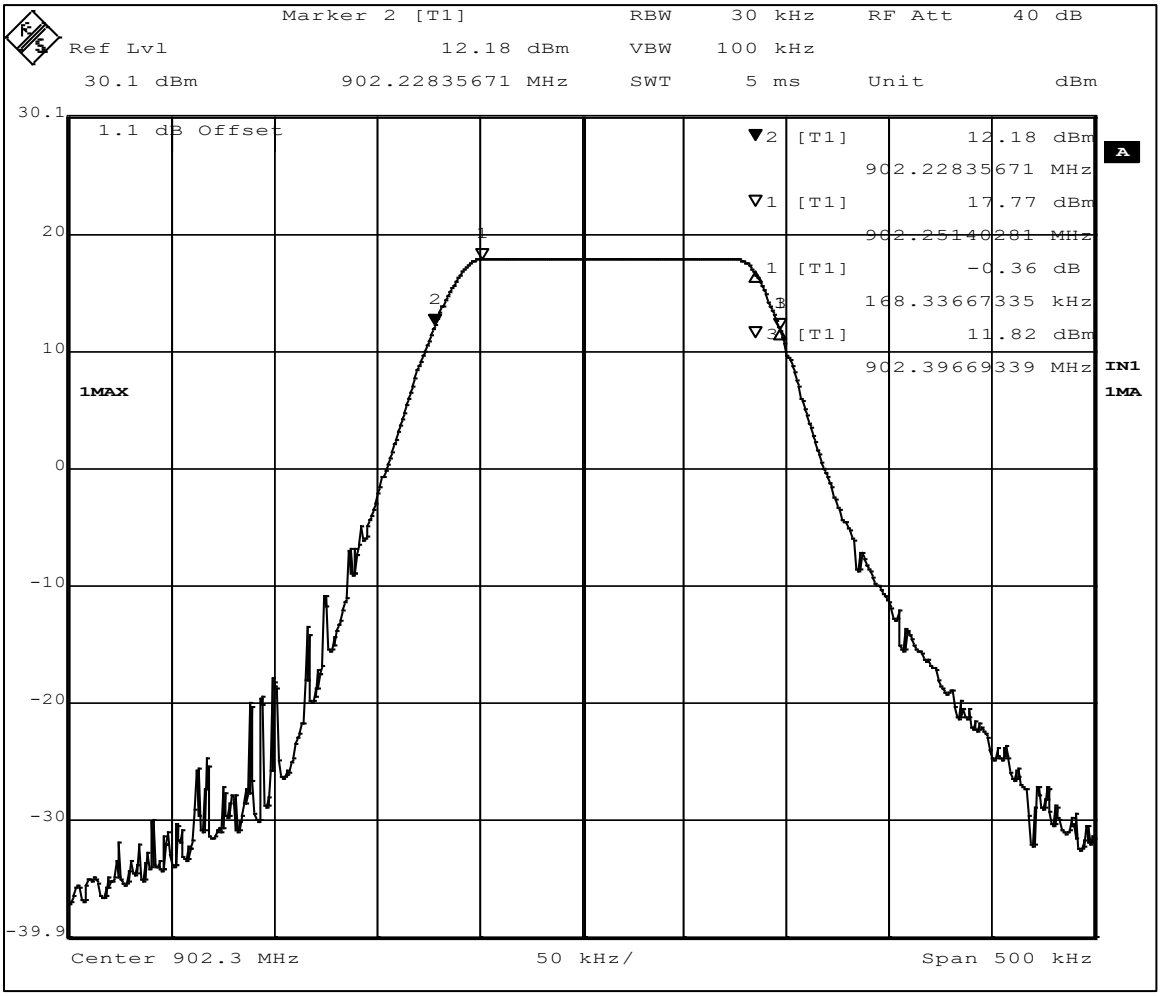


**Figure 14 - 6dB Bandwidth, Low Channel**

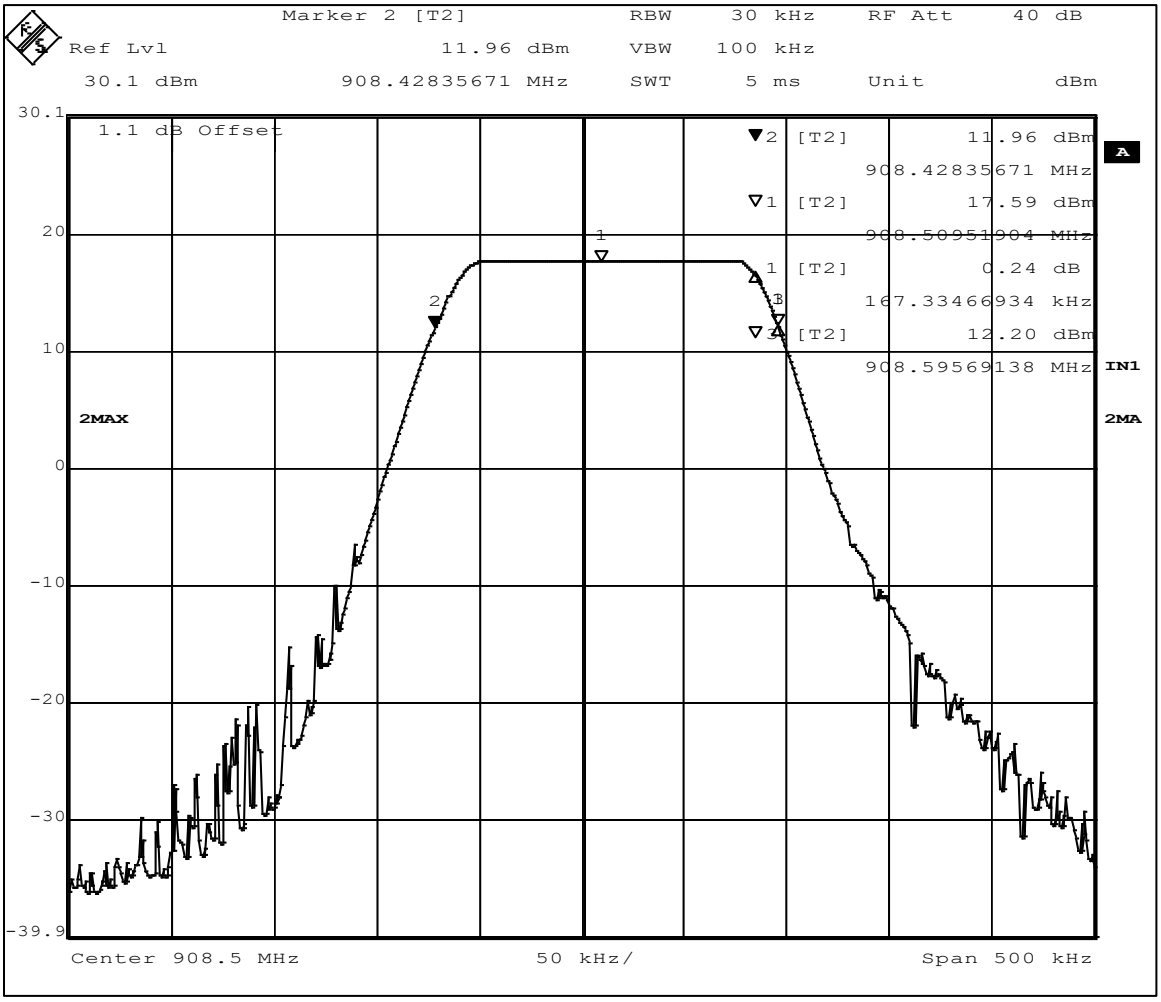


**Figure 15 - 6dB Bandwidth, Mid Channel**

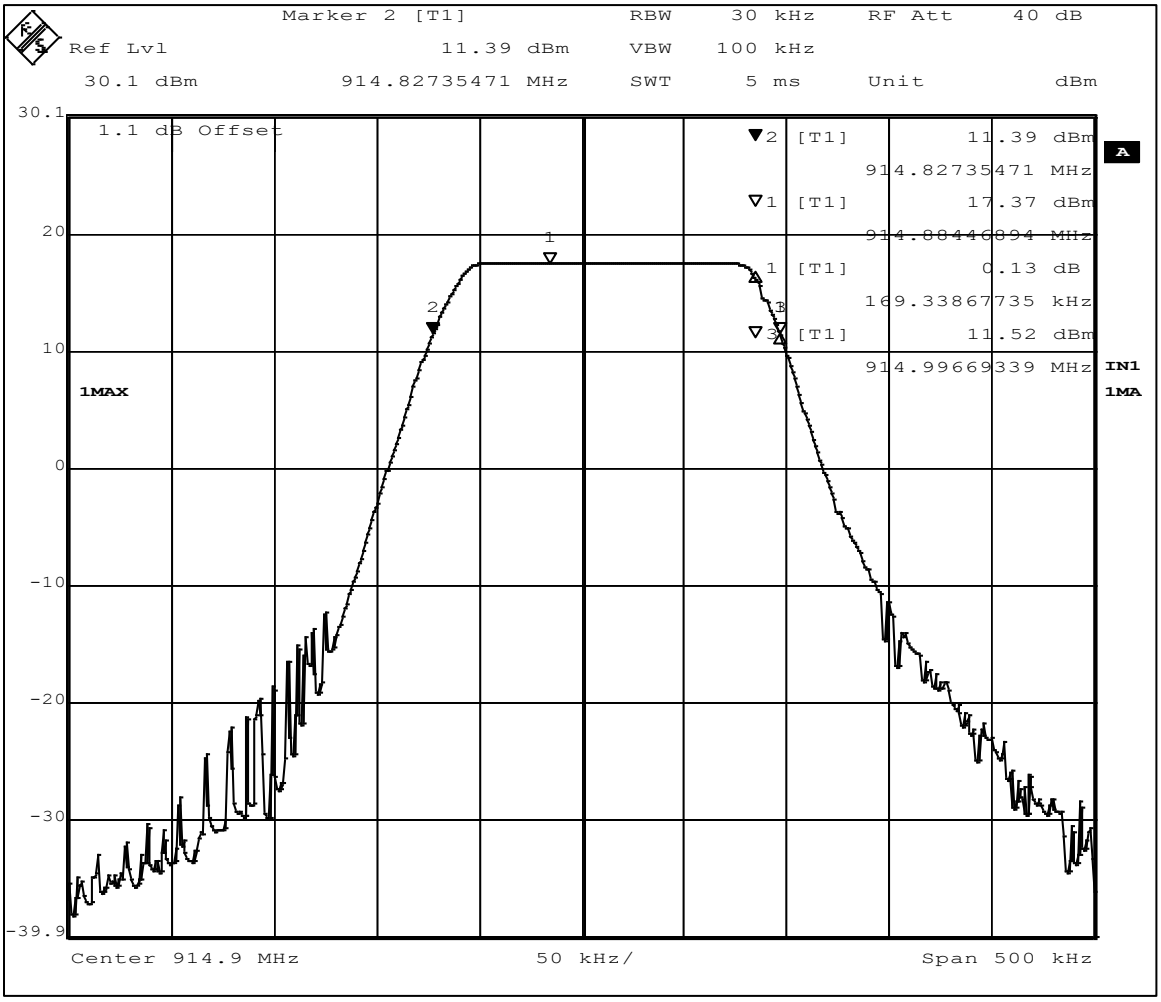


**Figure 16 - 6dB Bandwidth, High Channel**

## 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:**
The EUT was tested in the same method as described in section *4.4 - Bandwidth*. The EUT was oriented as to produce the maximum emission levels. The resolution bandwidth was set to 30kHz and the EMI receiver was used to scan from the bandedge to the fundamental frequency with a quasi-peak detector. The highest emissions level beyond the bandedge 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 while an operator was trying to activate the hopping sequence manually.

**EUT operating conditions:**
The EUT was powered by 6.4 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:**

Highest Out of Band Emissions, Restricted Band

| CHANNEL | Band edge /Measurement Frequency (MHz) | Relative Highest out of band level dBm | Relative Fundamental Level (dBm) | Delta | Min (dBc) | Result |
|---|---|---|---|---|---|---|
| Low, Continuous | 614.0 | -107.89 | -23.64 | 84.25 | 70.37 | PASS |
| High, Continuous | 960.0 | -106.05 | -24.27 | 81.78 | 69.08 | PASS |
| Low Hopping | 614.0 | -108.57 | -23.71 | 79.76 | 70.37 | PASS |
| High, Hopping | 960.0 | -106.42 | -24.83 | 80.70 | 69.08 | PASS |

Highest Out of Band Emissions, Unrestricted bands

| CHANNEL | Band edge /Measurement Frequency (MHz) | Relative Highest out of band level dBm | Relative Fundamental Level (dBm) | Delta | Min (dBc) | Result |
|---|---|---|---|---|---|---|
| Low, Continuous | 902.0 | -53.87 | -23.07 | 30.79 | 20.00 | PASS |
| High, Continuous | 928.0 | -80.14 | -23.92 | 56.22 | 20.00 | PASS |
| Low Hopping | 902.0 | -55.92 | -23.38 | 32.54 | 20.00 | PASS |
| High, Hopping | 928.0 | -71.39 | -24.33 | 47.06 | 20.00 | 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 902.3 MHz for low channel = 116.37 dBµV/m
Fundamental average field strength at 914.9 MHz for high channel = 115.08 dBµV/m

Low channel minimum delta = 116.37 – 46.0 dBµV/m = 70.37 dBc
High channel minimum delta = 115.08 – 46.0 dBµV/m = 69.08 dBc

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

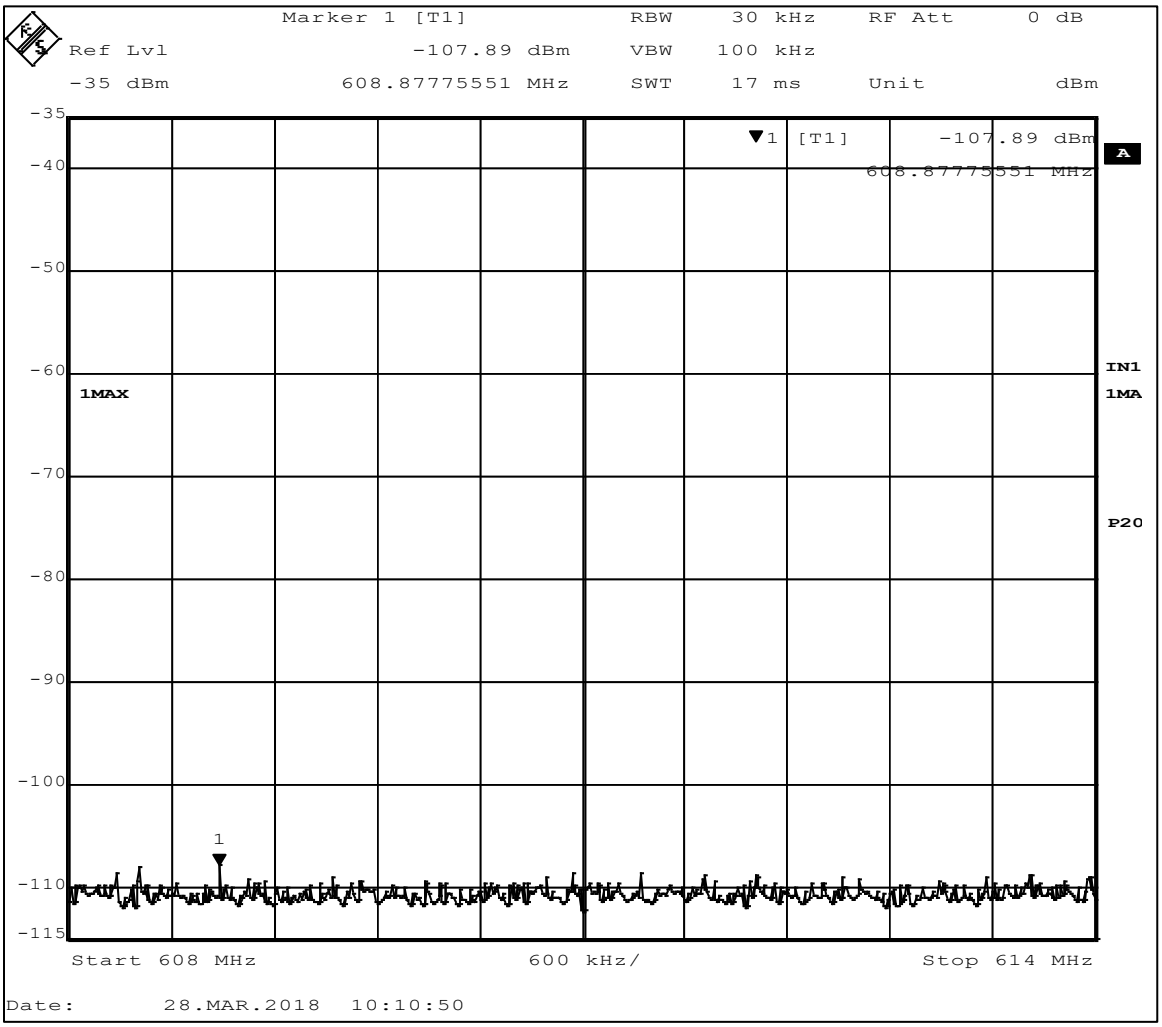


**Figure 17 - Band-edge Measurement, Low Channel, Restricted Frequency, Continuous Transmit**

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

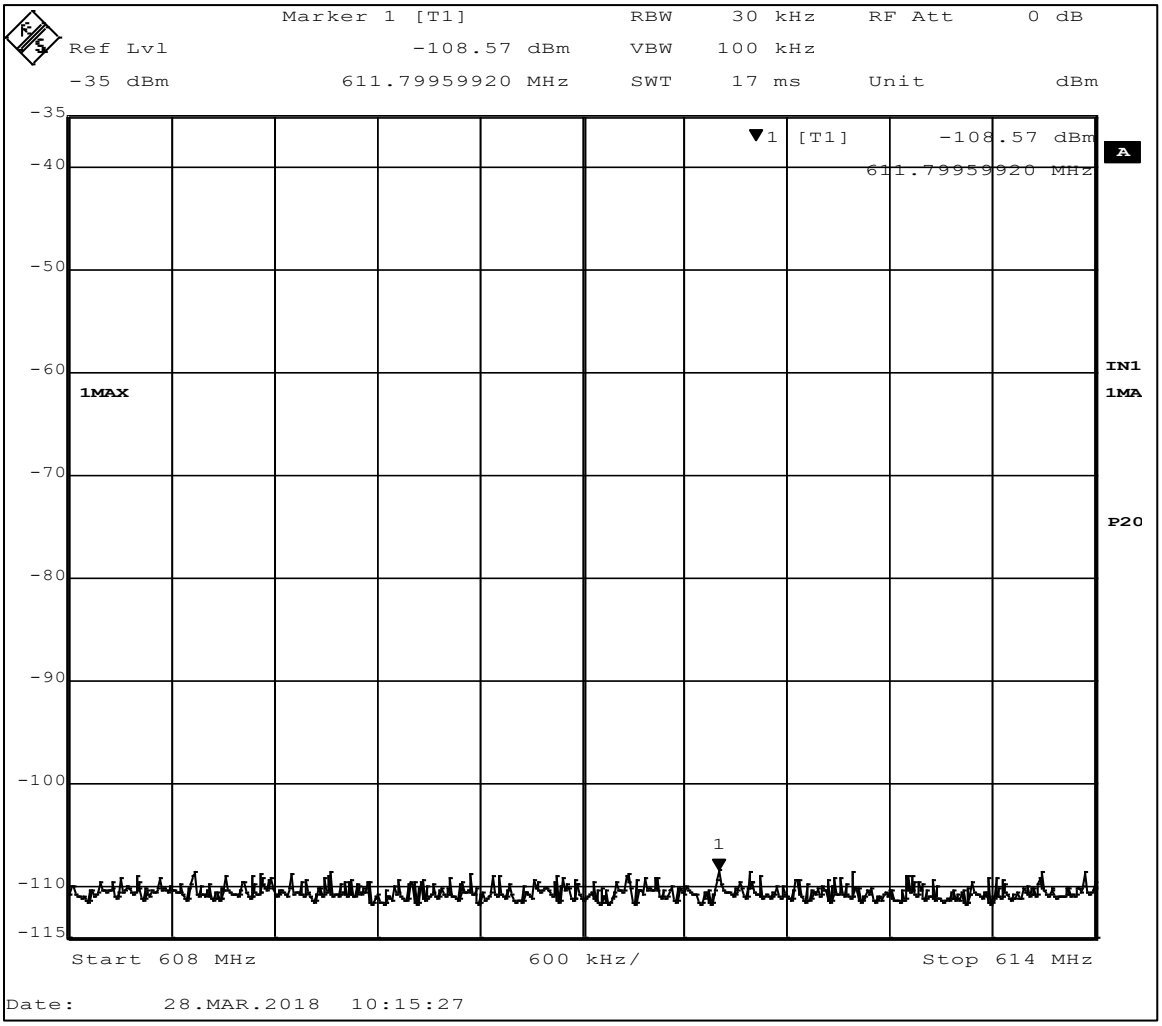


**Figure 18 - Band-edge Measurement, Low Channel, Restricted Frequency, Hopping**

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

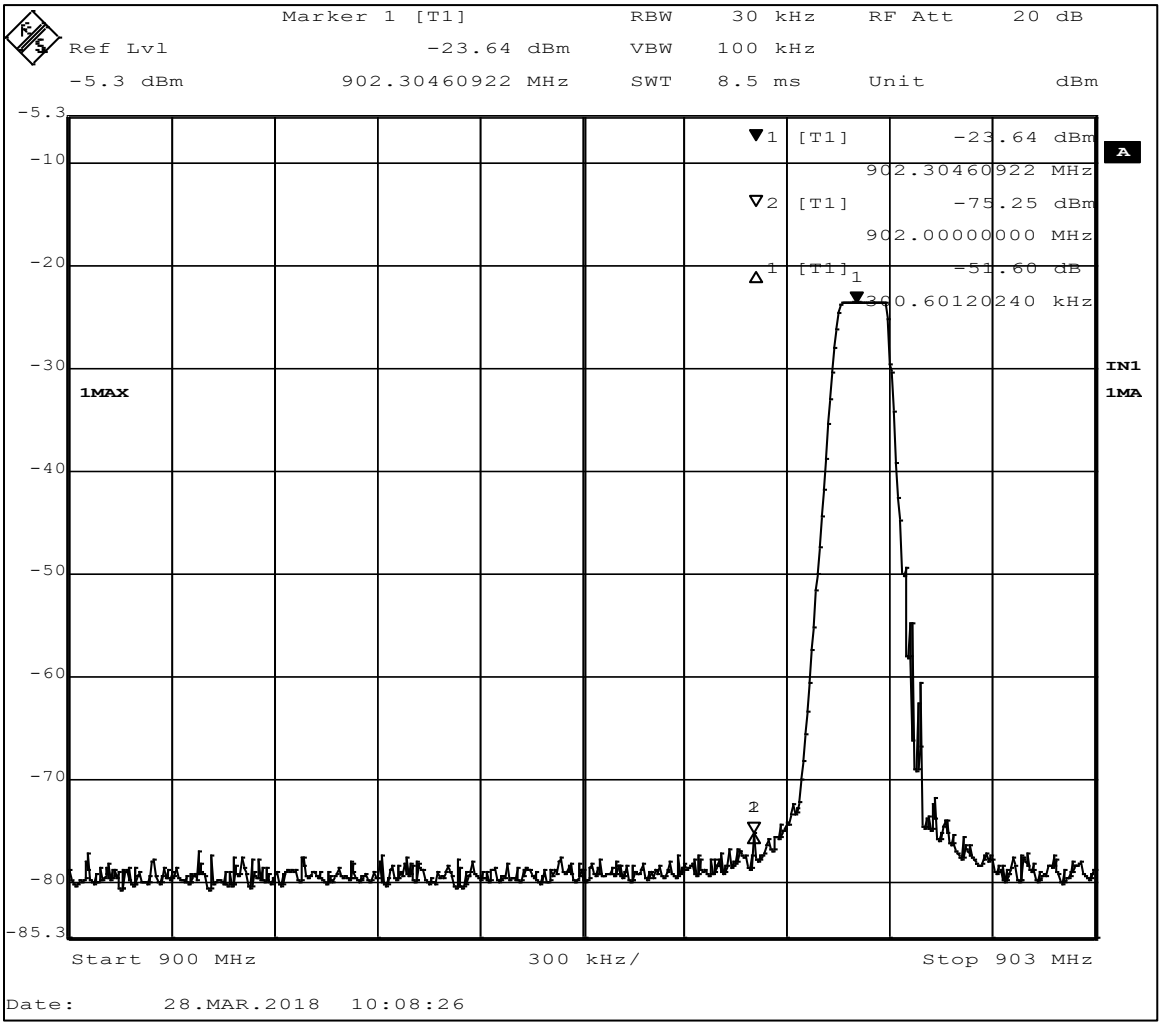


**Figure 19 - Band-edge Measurement, Low Channel, Fundamental, Continuous Transmit**

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

Delta = 51.60 dB > 20 dB minimum

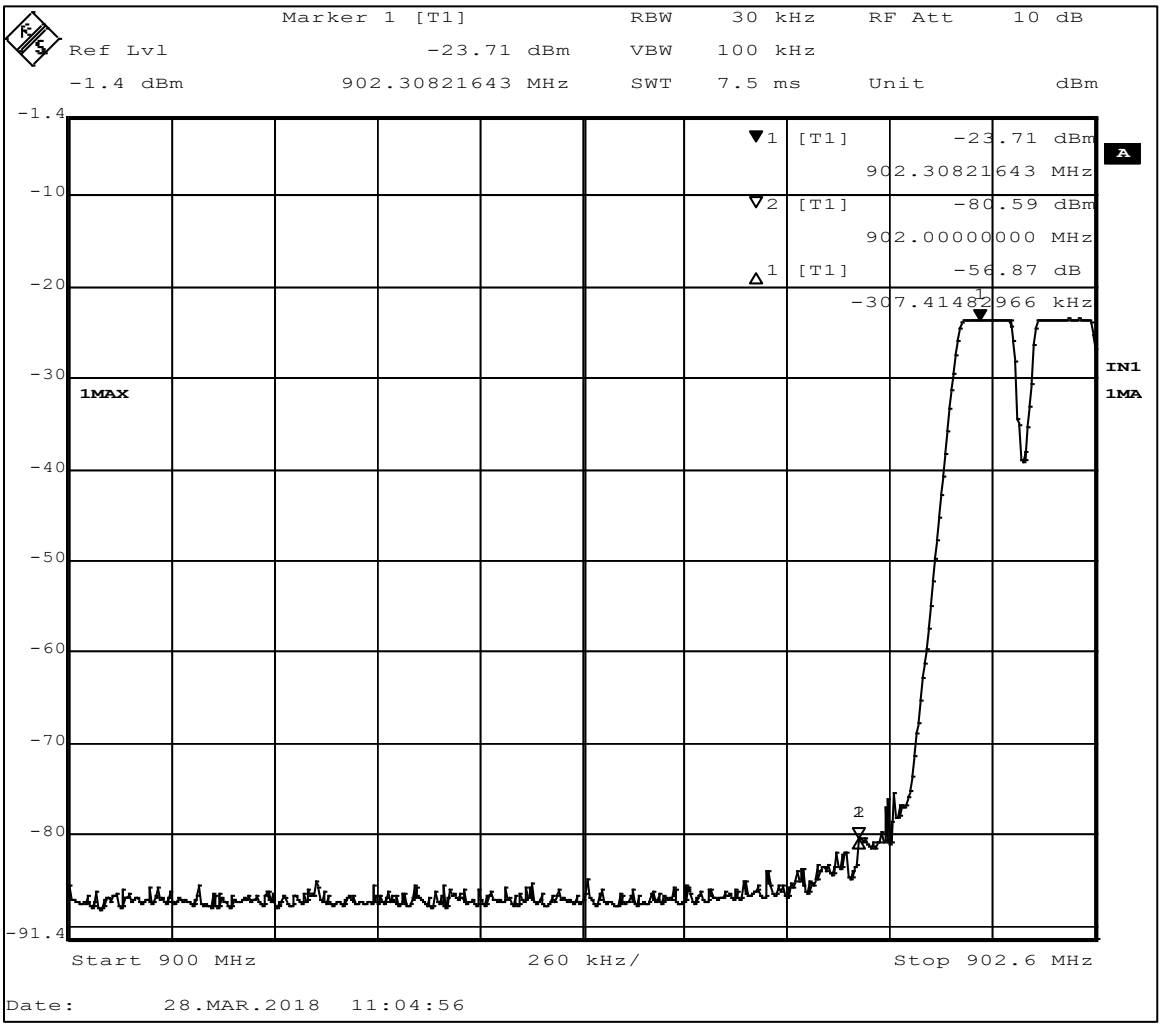


**Figure 20 - Band-edge Measurement, Low Channel, Fundamental, Hopping Transmit**

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

Delta = 56.87 dB > 20 dB minimum

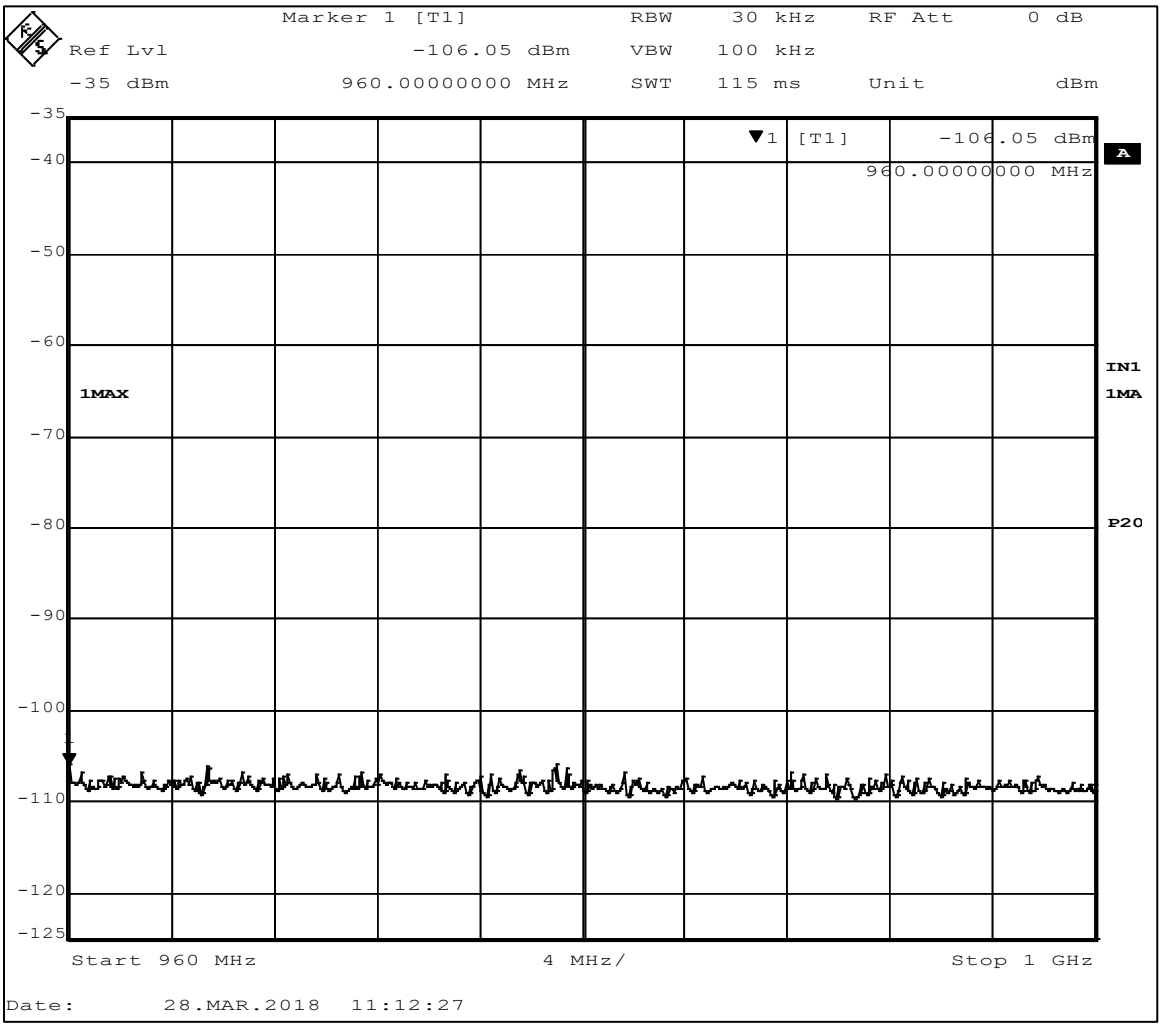


**Figure 21 - Band-edge Measurement, High Channel, Restricted Frequency, Continuous Transmit**

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

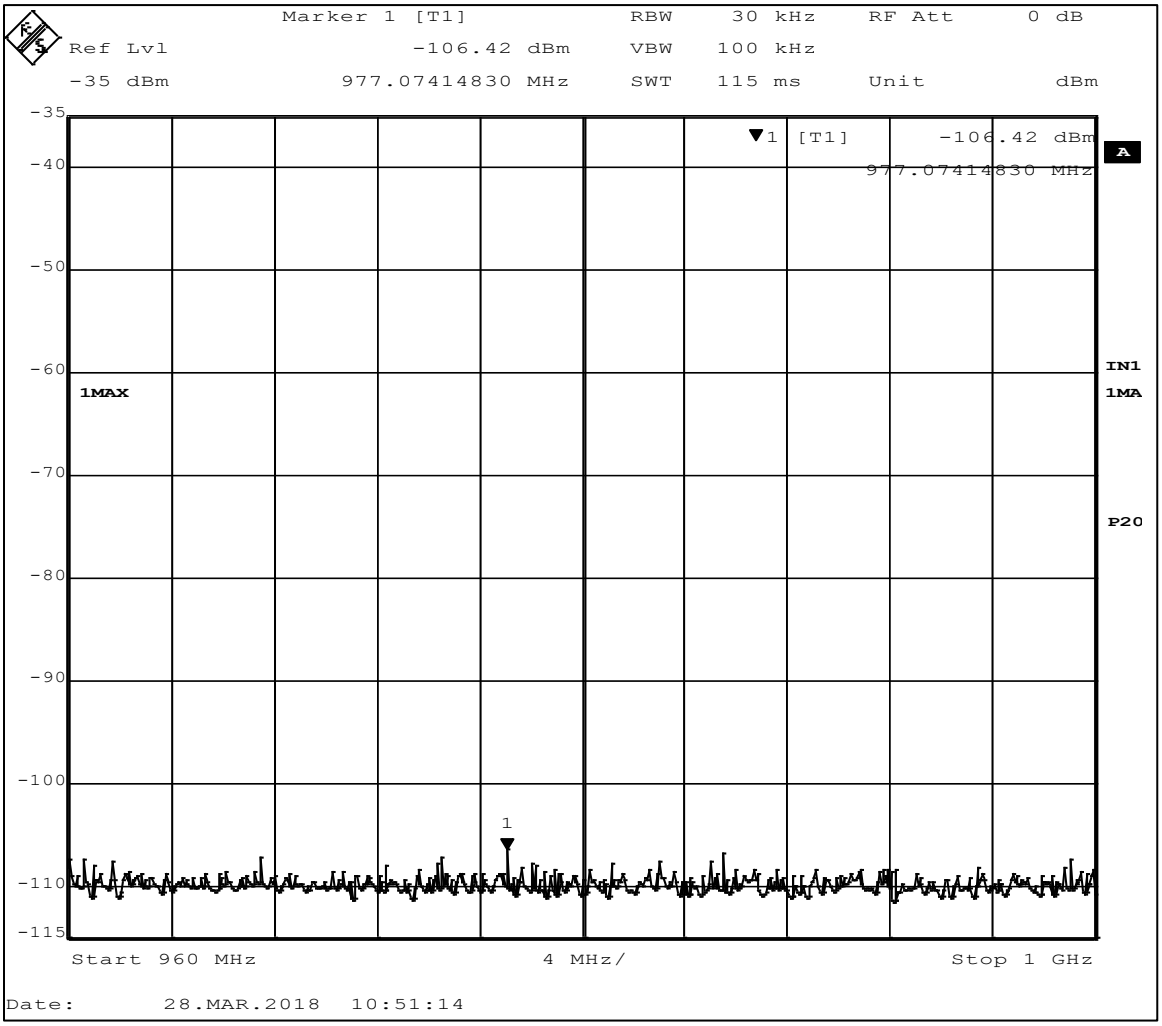


**Figure 22 - Band-edge Measurement, High Channel, Restricted Frequency, Hopping**

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

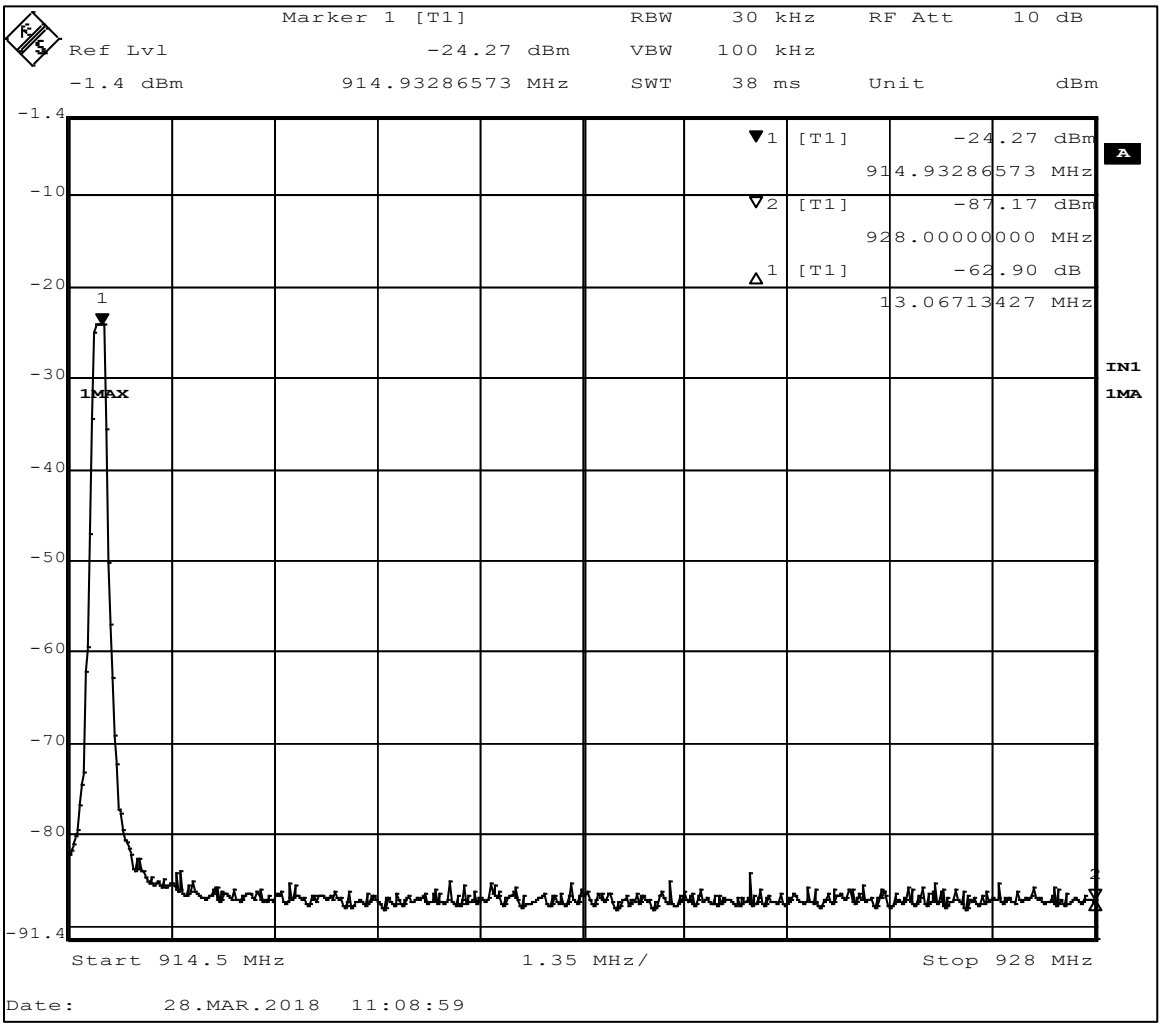


**Figure 23 - Band-edge Measurement, High Channel, Fundamental, Continuous Transmit**

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

Delta = 62.90 dB > 20 dB minimum

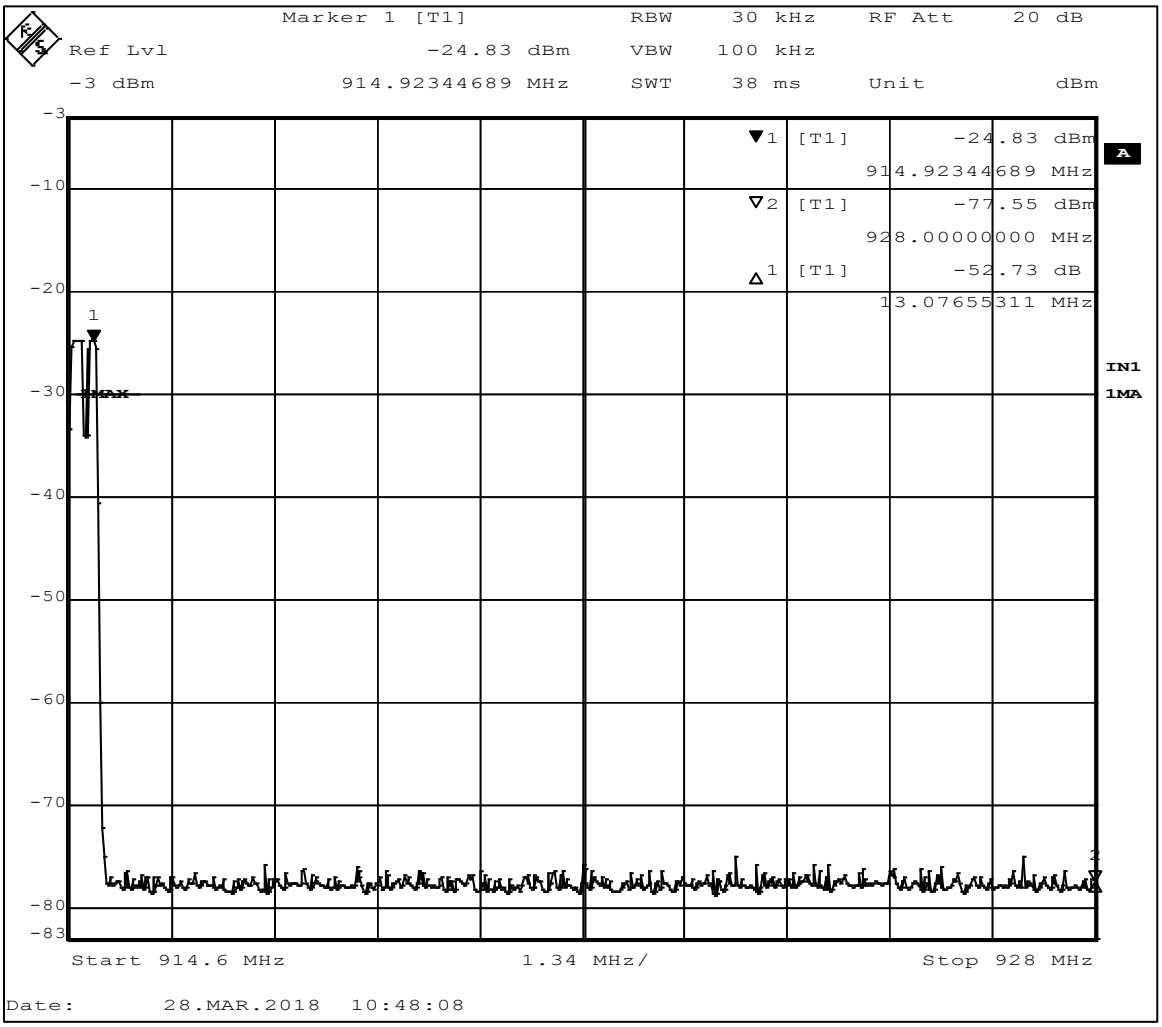


**Figure 24 - Band-edge Measurement, High Channel, Fundamental, Hopping Transmit**

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

Delta = 52.73 dB > 20 dB minimum

## 4.6 POWER SPECTRAL DENSITY

**Test Method**: ANSI C63.10, Section 11.10.2

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

**Test procedures:**
1. The EUT was connected to the spectrum analyzer directly with a low-loss shielded coaxial cable.

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 EUT was connected to the spectrum analyzer directly with a low-loss shielded coaxial cable on a bench top.

**EUT operating conditions:**
The EUT was powered by 6.4 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:**

**Power Spectral Density**

| CHANNEL | CHANNEL FREQUENCY (MHz) | EIRP RF POWER LEVEL IN # KHz BW (dBm) | Method | MAXIMUM POWER LIMIT (dBm) | RESULT |
|---|---|---|---|---|---|
| 1 | 902.3 | 1.76 | Conducted | 8.00 | PASS |
| 2 | 908.5 | 1.93 | Conducted | 8.00 | PASS |
| 3 | 914.9 | 1.71 | Conducted | 8.00 | PASS |

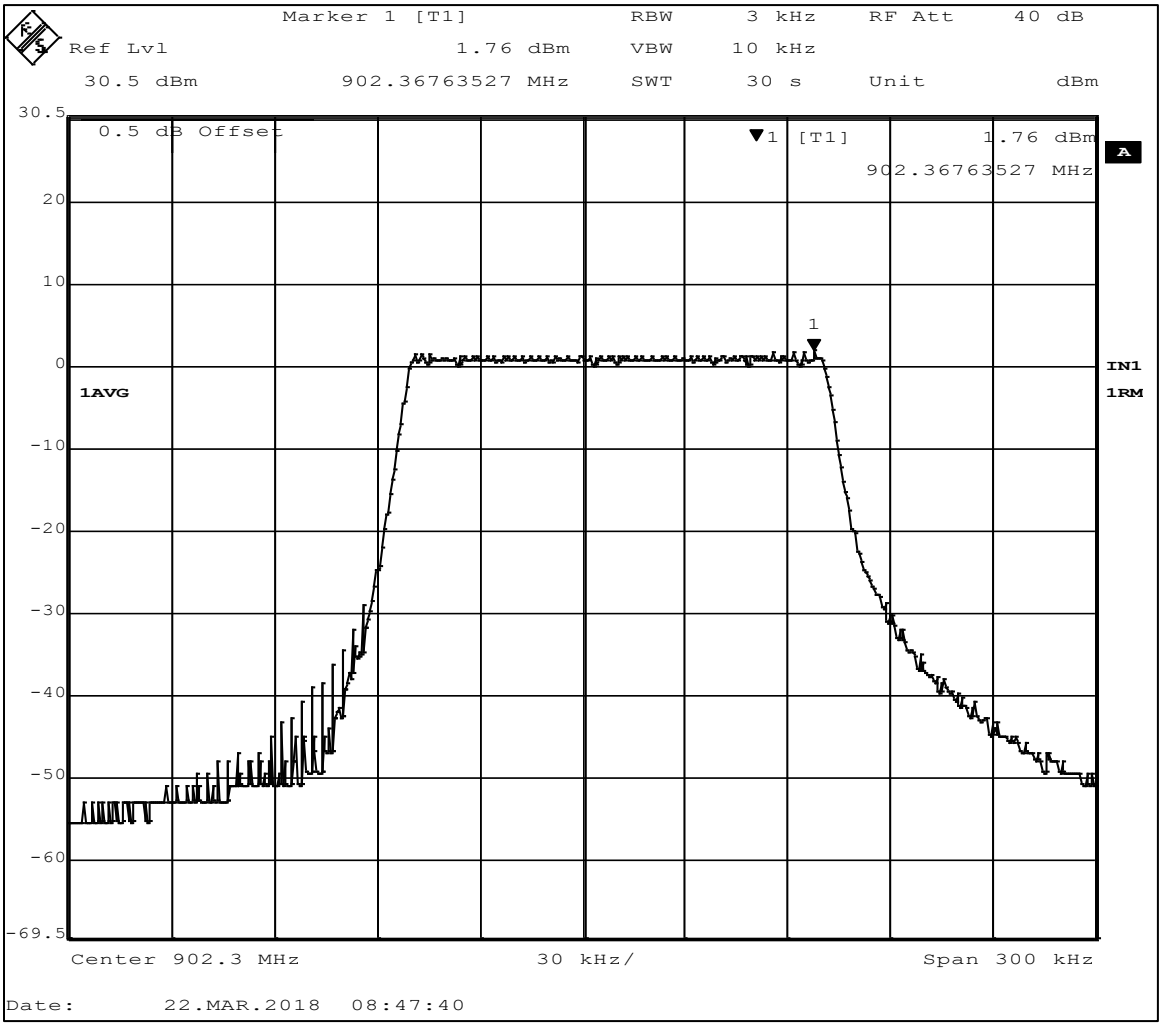


**Figure 25 - Power Spectral Density, Low Channel**

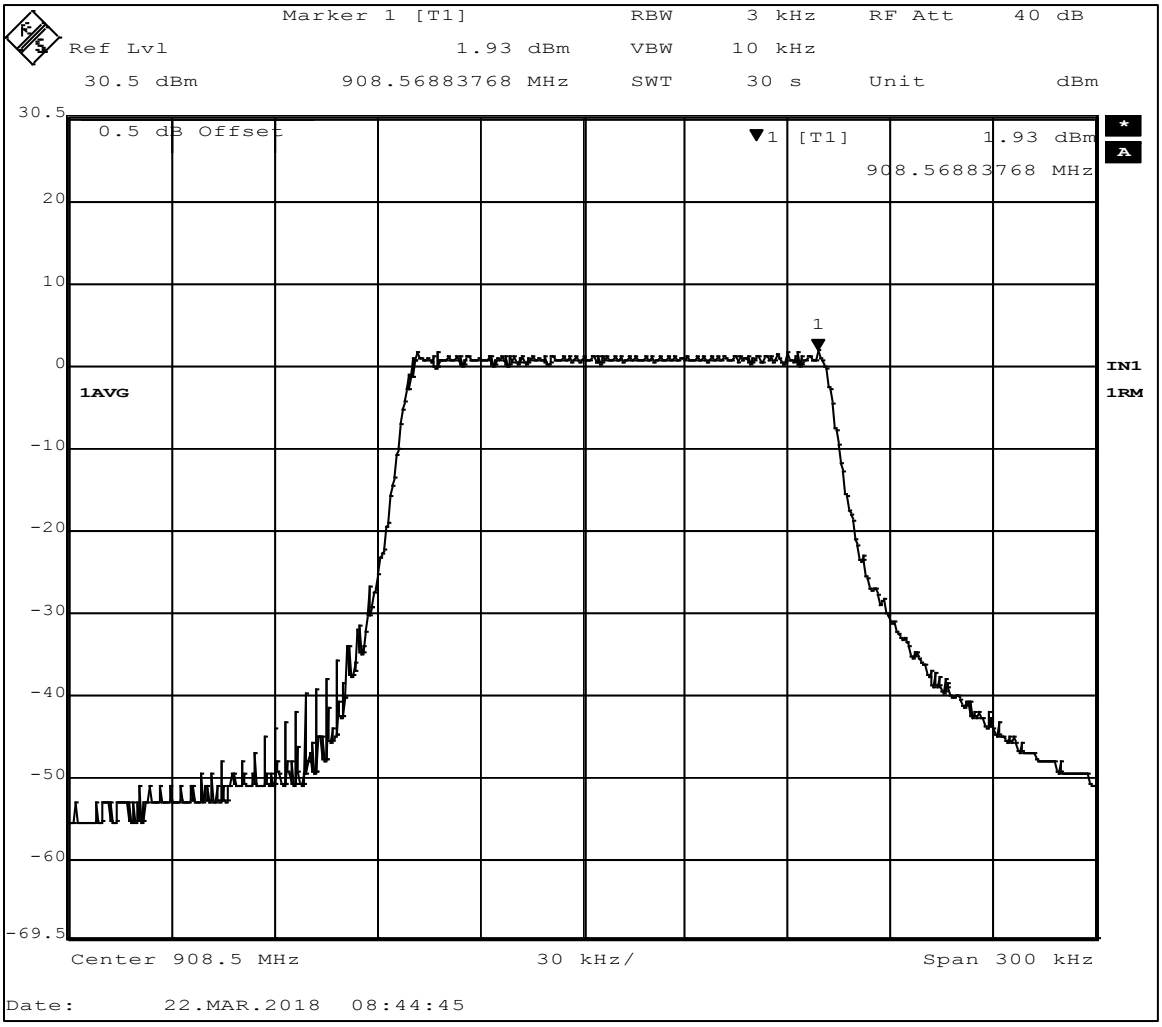


**Figure 26 - Power Spectral Density, Mid Channel**

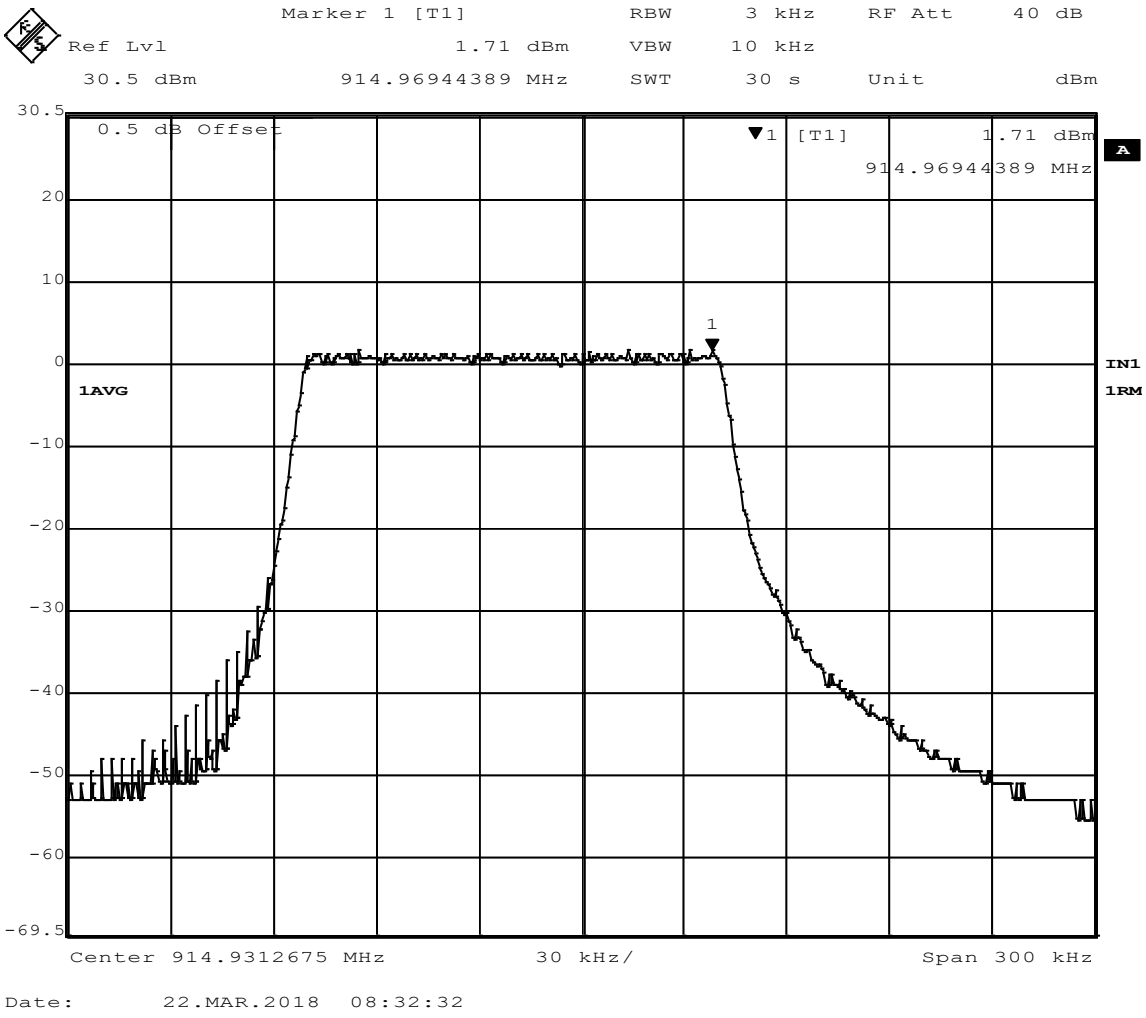


**Figure 27 - Power Spectral Density, High Channel**

## 4.7 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**
The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4.

**Test procedures:**
The method from FCC DA 00-705

**Test setup:**
All the measurements were done on the bench while an operator was trying to activate the hopping sequence manually.

**EUT operating conditions:**
The EUT was powered by 6.4 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.

This device operates only in solicited mode as described in the operational description.

**Test results:**

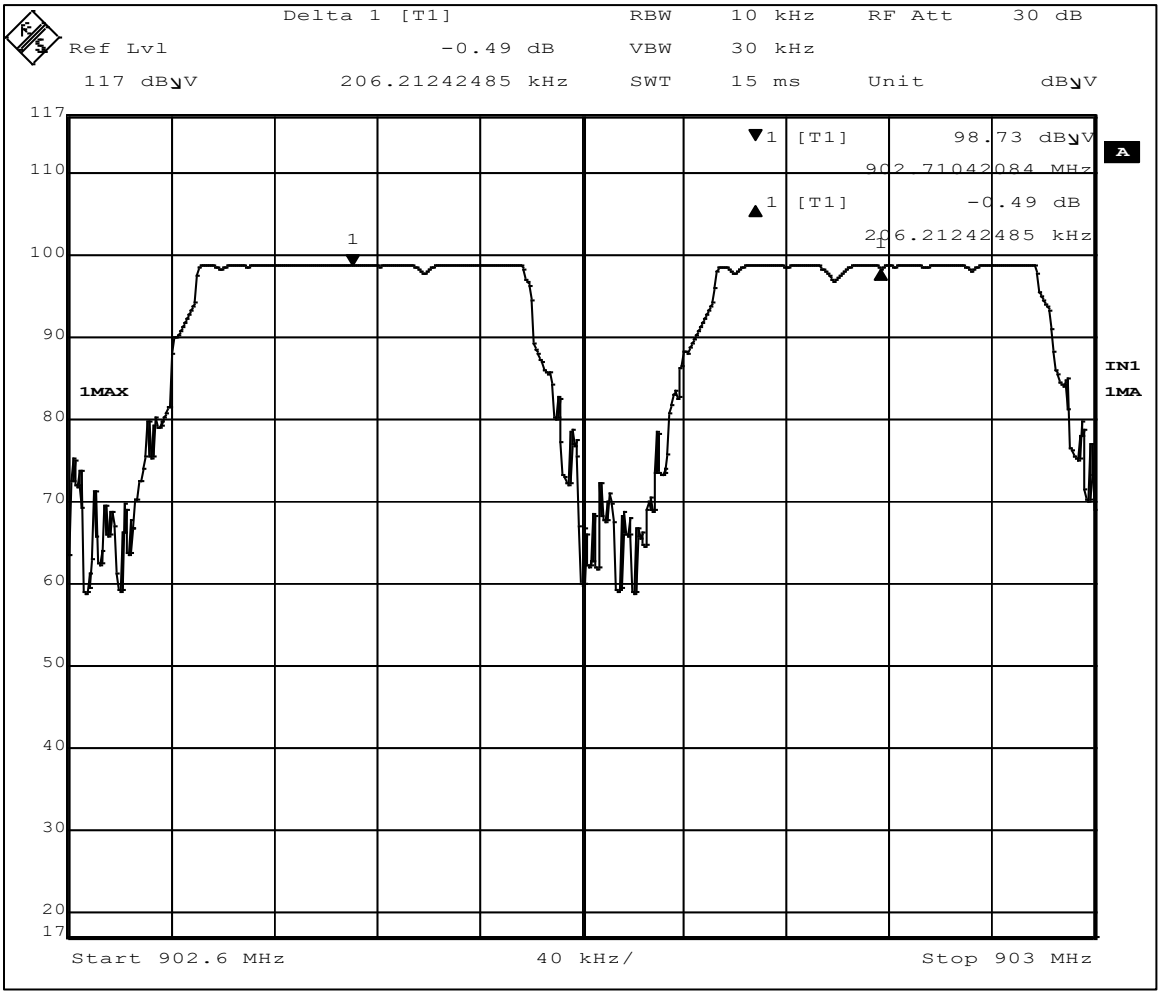


**Figure 28 – Frequency Separation, 206.21 kHz**

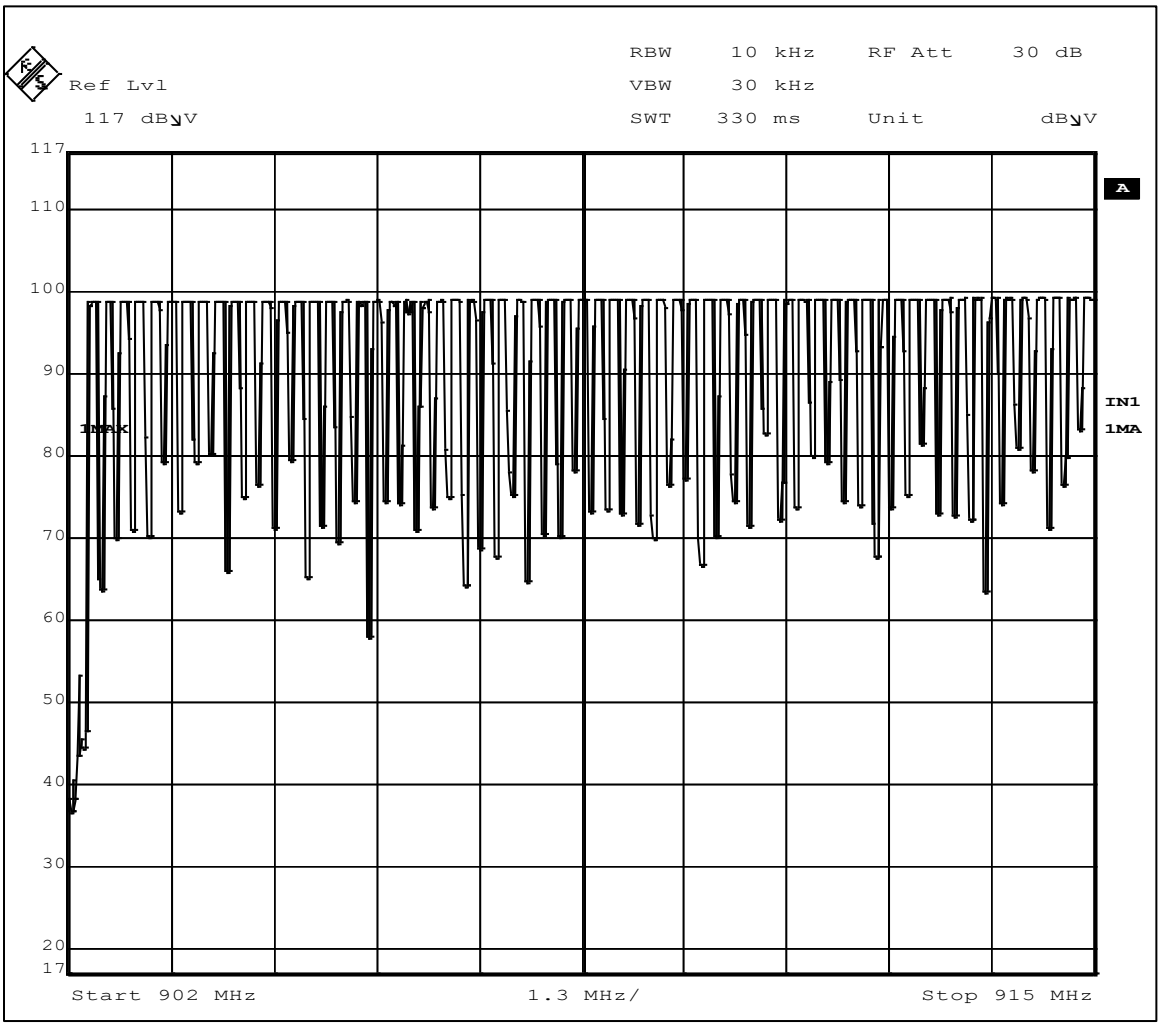


**Figure 29 – Hop Count, 63 Hops**

The plot above shows channel 0 as the leftmost hop channel. Channel 0 is only present in the test firmware and will not be used in production firmware and only channel 1 - 63 are used to transmit.

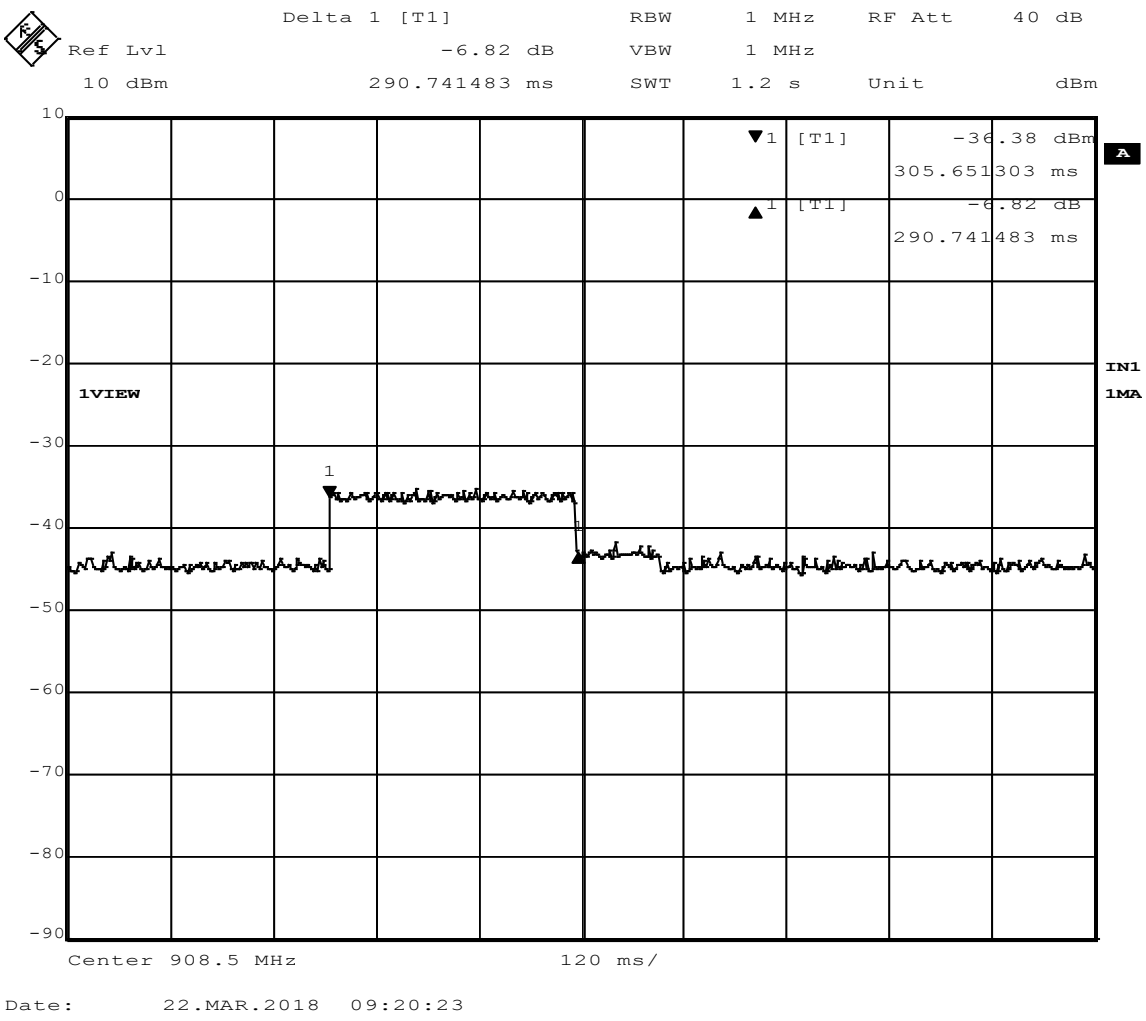


**Figure 30 – Time of Occupancy, On Time**

Show dwell time per channel is 291ms. See operational description for details.

# 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