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FCC/ISED Test Report

Prepared for:	**Inovonics**
Address:	**397 S. Taylor Ave. Louisville, CO 80027**
Product:	**EN1221S-60**
Test Report No:	**R20180115-21**
Approved by:	**Nic S. Johnson, NCE Technical Manager iNARTE Certified EMC Engineer #EMC-003337-NE**
DATE:	**12 February 2018**
Total Pages:	**50**

ilac-MRA A2LA ACCREDITED TESTING LABORATORY CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	12 February 2018	Original – NJohnson Prepared by KVepuri

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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 4
(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	Pass	Pulsed emissions duty cycle was applied
FCC 15.209 RSS-Gen, 7.1	Receiver Radiated Emissions	NA	The EUT has no receiver functionality
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)(2) 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	Not applicable. Battery power only, no charger.

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

The Equipment Under Test (EUT) was a wireless FHSS transmitter. It has transmit capabilities only.

EUT	EN1221S-60
EUT Received	2/7/2018
EUT Tested	2/7/2018 - 2/9/2018
Serial No.	NCEE B1
Operating Band	902.0 – 928.0 MHz
Device Type	FHSS
Maximum 99% Occupied Bandwidth	316.63 kHz
Peak Output Power	16.64 dBm (EIRP) peak / 46.13 mW (EIRP) peak
Average Output Power	3.02 dBm (EIRP) peak / 2.00 mW (EIRP) peak
Highest spurious emissions level	59.34 dBµV/m peak
Power Supply	A 3 VDC - CR 2032 Coin Cell will be used in the final product (This was not used for testing as the power required for continuous transmission during the testing made this impractical to use) A 4.1 VDC power supply was used for the testing instead: BK Precision 1692 DC Power Supply SN: S940016438

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
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

No.	PERSONNEL	TITLE	ROLE
1	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
Rohde & Schwarz Test Receiver	ES126	100037	30 Jan 2018	30 Jan 2019
EMCO Biconilog Antenna	3142B	1647	02 Aug 2017	02 Aug 2018
EMCO Horn Antenna	3115	6416	25 Jan 2016	25 Jan 2019
Rohde & Schwarz Preamplifier	TS-PR18	3545700803	9 Feb 2017*	9 Feb 2018*
Trilithic High Pass Filter	6HC330	23042	9 Feb 2017*	9 Feb 2018*
Mini Circuits 1700 – 5000Mhz High Pass Filter***	15542	31618	9 Feb 2017*	9 Feb 2018*
RF Cable (preamplifier to antenna)	MFR-57500	01-07-002	09 Feb 2017*	09 Feb 2018*
RF Cable (antenna to 10m chamber bulkhead)	FSCM 64639	01E3872	09 Feb 2017*	09 Feb 2018*
RF Cable (10m chamber bulkhead to control room bulkhead)	FSCM 64639	01E3874	09 Feb 2017*	09 Feb 2018*
RF Cable (Control room bulkhead to RF switch)	FSCM 64639	01E3871	09 Feb 2017*	09 Feb 2018*
RF Cable (RF switch to test receiver)	FSCM 64639	01F1206	09 Feb 2017*	09 Feb 2018*
RF switch – Rohde and Schwarz	TS-RSP	1113.5503.14	09 Feb 2017*	09 Feb 2018*
N connector bulkhead (10m chamber)	PE9128	NCEEBH1	09 Feb 2017*	09 Feb 2018*
N connector bulkhead (control room)	PE9128	NCEEBH2	09 Feb 2017*	09 Feb 2018*

*Internal Characterization

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

4.0 DETAILED RESULTS

4.1 DUTY CYCLE

Test Method: ANSI C63.10:2013, Section 7.5

Limits for duty cycle:

As shown in FCC Part 15.35(b), and RSS-Gen, Section 6.1, 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.

(c) Unless otherwise specified, *e.g.,* §§15.255(b), and 15.256(l)(5), when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds. As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. The exact method of calculating the average field strength shall be submitted with any application for certification or shall be retained in the measurement data file for equipment subject to Supplier's Declaration of Conformity.

Test procedures:

Because the EUT did not have provisions for making conducted measurements, the duty cycle was measured in a 10m semi-anechoic chamber with the test receiver set to “Zero span” mode.

All field strength or power measurements shown in these plots are arbitrary and only the times and levels of the EUT relative to the remote are considered for compliance.

Deviations from test standard:

No deviation.

Test setup:

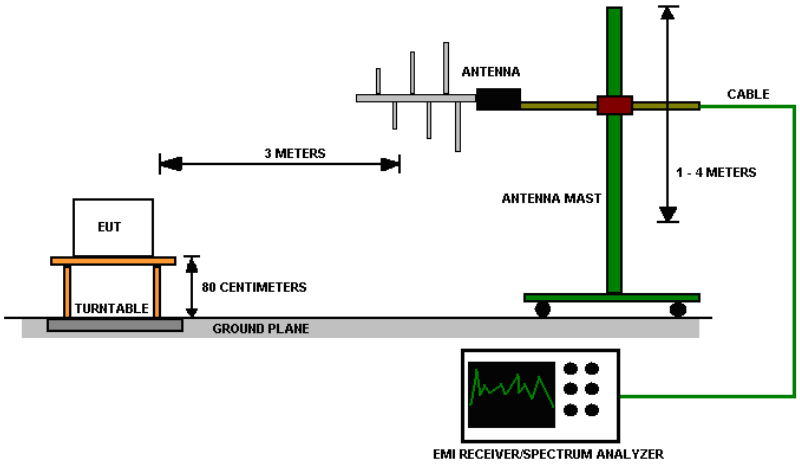

Figure 1 - Radiated Emissions Test Setup, 30MHz – 1GHz

EUT operating conditions:

The EUT was powered by 4.1 VDC unless specified. The duty cycle was only tested on the low channel as it will be identical for all channels.

The EUT will only transmit often when the alarm button on the pendant is activated. In order to measure the maximum possible duty cycle an operator was standing next to the EUT and was clicking this button during the test.

Test results:

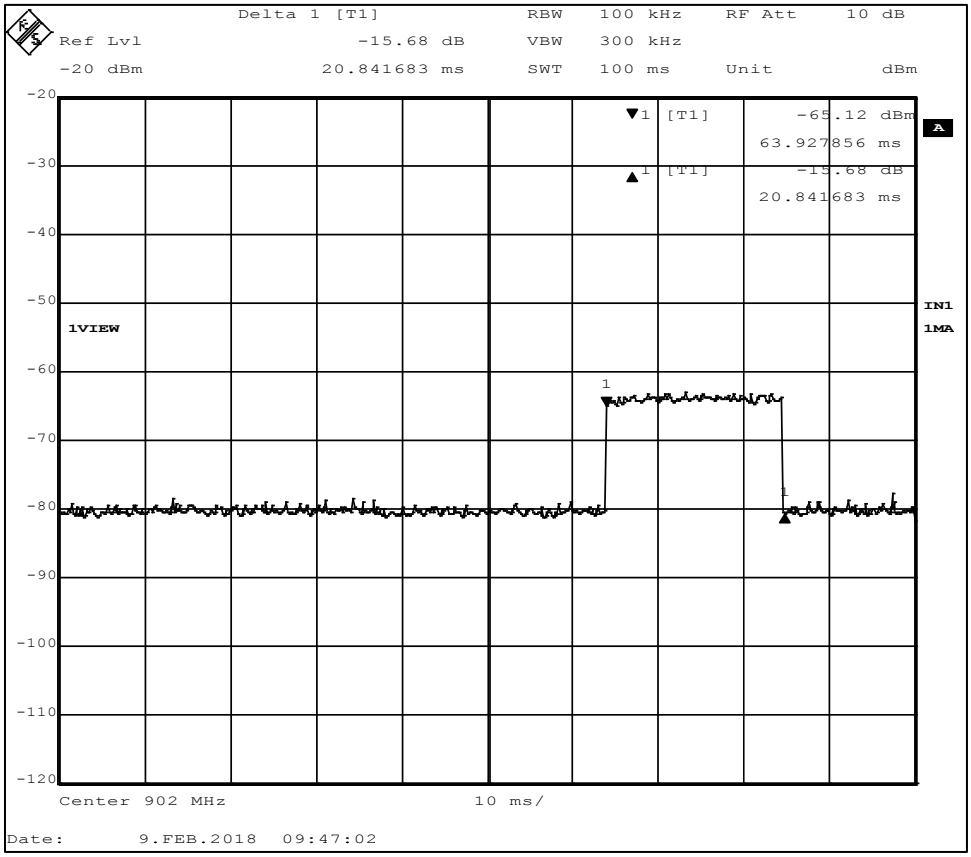

Figure 2 – Duty Cycle

Maximum of 1 pulse can occur in any 100 ms window on any one frequency channel.

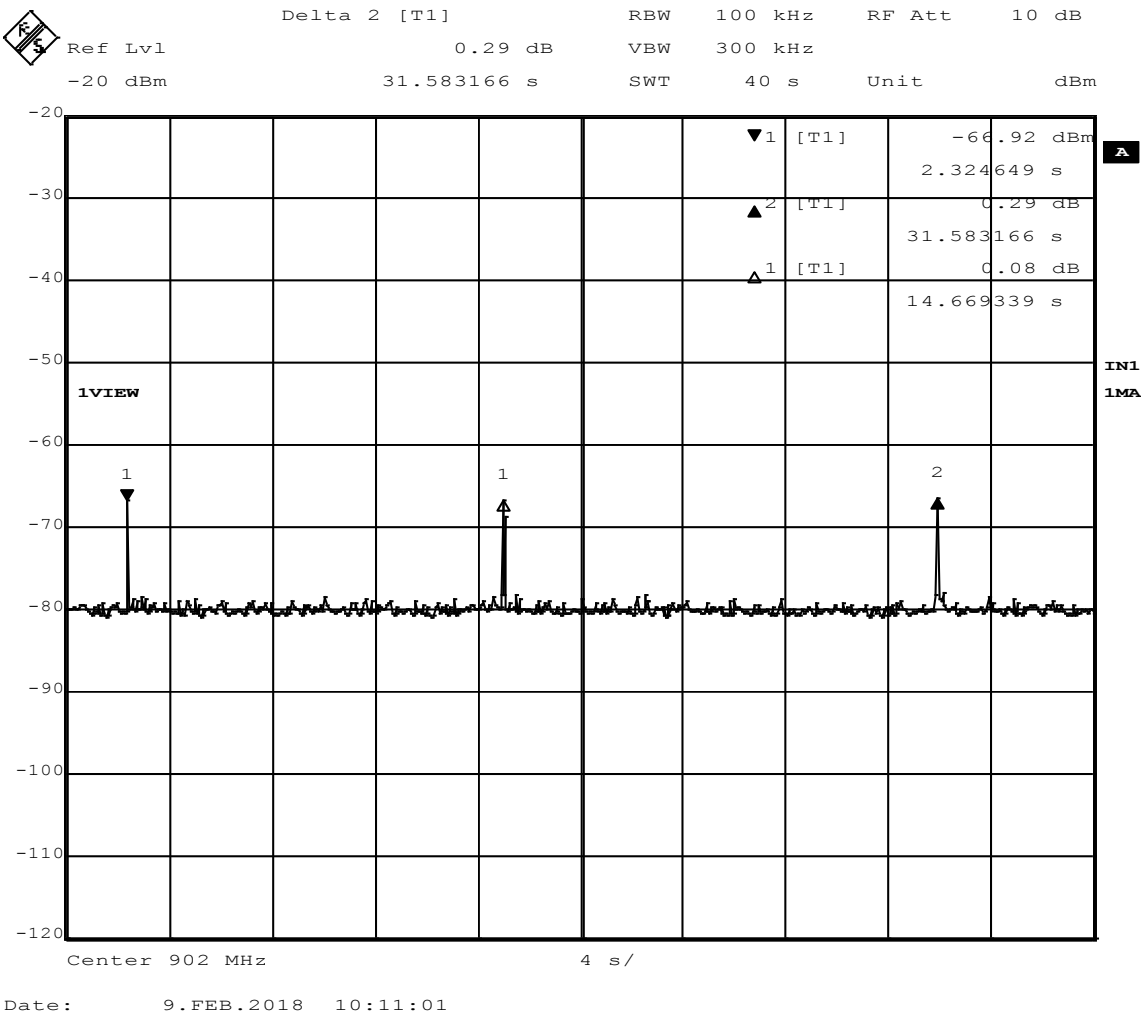

Figure 3 – Maximum Period

Duty cycle correction factor = 20*log(20.84)/100) **= -13.62 dB**

On time = 20.84 ms per Figure 2

Period = 100 ms (Max usable) (Figure 3 shows period greater than 14 s; maximum 100ms was used). Note that the device had to be activated manually to let it transmit again in the same channel.

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 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.

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:

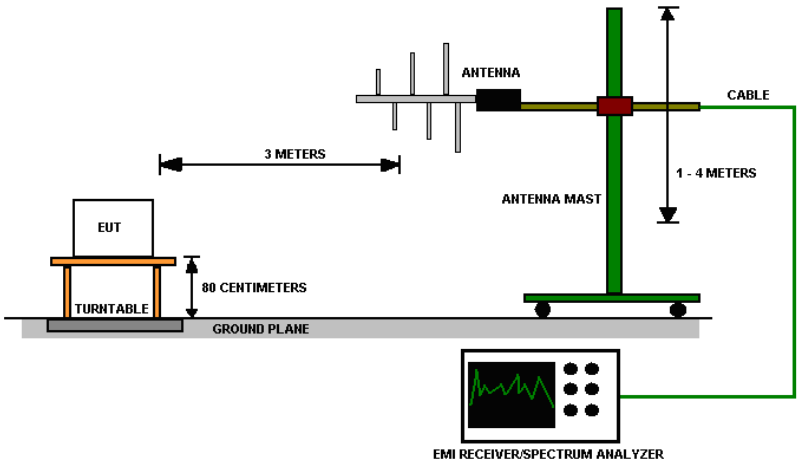

Figure 4 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by 4.1 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.

Since the EUT would drain the battery very quickly when transmitting continuously, it was tested with a thin wire run from a DC power supply to the battery input terminals for testing. Some additional preview scan measurements were performed to ensure the additional DC supply wire did not affect the test results. It was found to have no significant effect.

Test results:

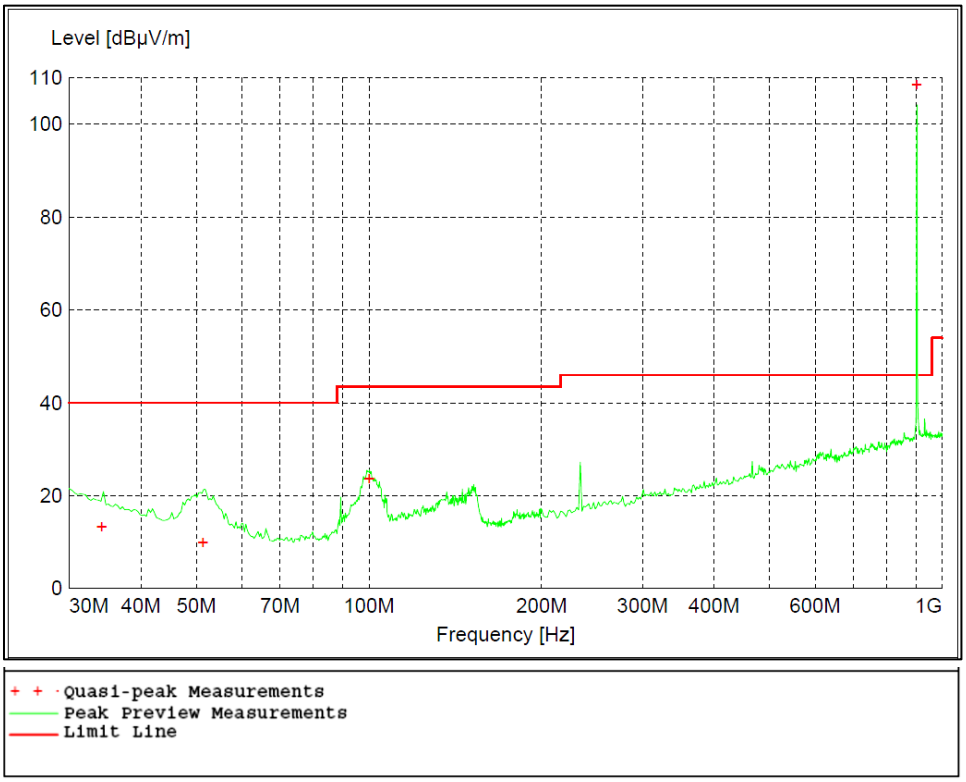

Figure 5 - Radiated Emissions Plot, Low Channel

Table 1 - Radiated Emissions Quasi-peak Measurements, Low Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
34.200000	13.15	40.00	26.90	370	26	HORI	X
51.360000	9.79	40.00	30.20	384	45	VERT	X
100.200000	23.61	43.50	19.90	99	128	VERT	X
902.400000	108.40	NA	NA	100	319	HORI	X

Table 2 - Radiated Emissions Average Measurements, Low Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
1804.800000	28.96	54.00	25.04	197	191	HORI	Z
2707.200000	31.38	54.00	22.62	197	231	VERT	Z
3609.600000	27.07	54.00	26.93	100	299	VERT	Z
4501.400000	26.76	54.00	27.24	354	360	VERT	Z
5414.400000	42.32	54.00	11.68	147	179	HORI	Z
6316.800000	30.77	54.00	23.23	150	204	HORI	Z
7219.200000	34.87	54.00	19.13	115	189	HORI	Z
8121.600000	38.30	54.00	15.70	127	0	VERT	Z
9025.000000	32.72	54.00	21.28	396	69	VERT	Z

Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is calculated in Figures 2, and 3. 13.62 dB was used.

Table 3 - Radiated Emissions Peak Measurements, Low Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
1804.800000	42.58	74.00	31.42	197	191	HORI	Z
2707.200000	45.00	74.00	29.00	197	231	VERT	Z
3609.600000	40.69	74.00	33.31	100	299	VERT	Z
4501.400000	40.38	74.00	33.62	354	360	VERT	Z
5414.400000	55.94	74.00	18.06	147	179	HORI	Z
6316.800000	44.39	74.00	29.61	150	204	HORI	Z
7219.200000	48.49	74.00	25.51	115	189	HORI	Z
8121.600000	51.92	74.00	22.08	127	0	VERT	Z
9025.000000	46.34	74.00	27.66	396	69	VERT	Z

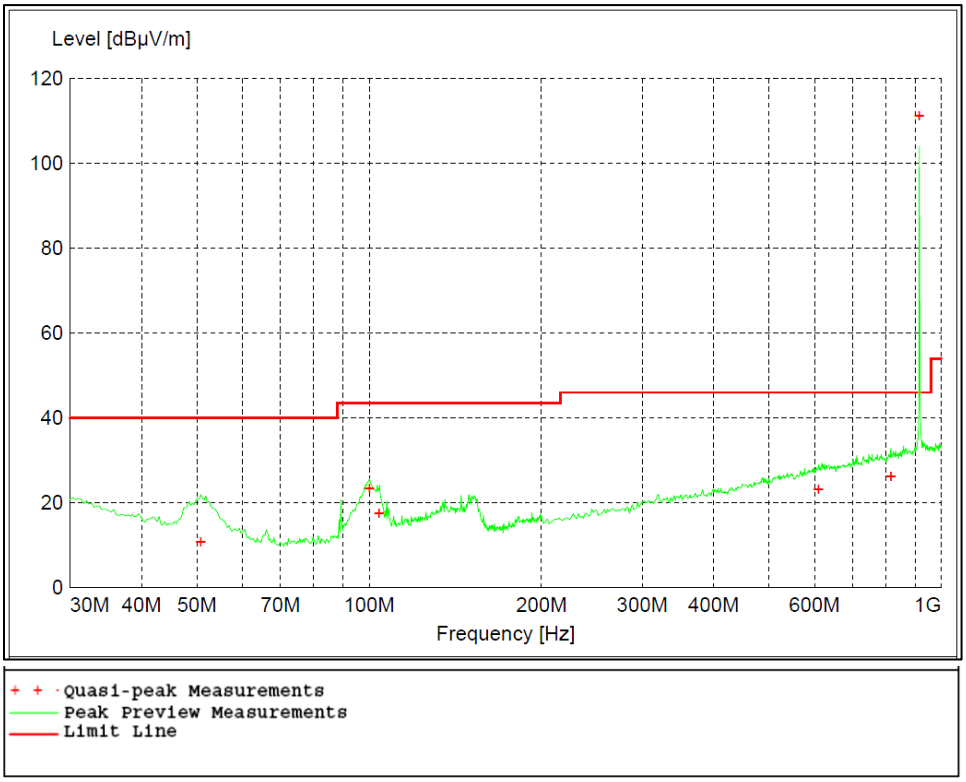

Figure 6 - Radiated Emissions Plot, Mid Channel

Table 4 - Radiated Emissions Quasi-peak Measurements, Mid Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
50.820000	10.81	40.00	29.20	374	122	VERT	X
100.200000	23.30	43.50	20.20	101	69	VERT	X
104.100000	17.51	43.50	26.00	99	79	VERT	X
609.480000	23.19	46.00	22.80	186	187	VERT	X
816.960000	26.25	46.00	19.70	349	221	VERT	X
914.800000	111.07	NA	NA	100	320	HORI	X

Table 5 - Radiated Emissions Average Measurements, Mid Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
1829.600000	24.37	54.00	29.63	100	219	HORI	Z
2744.400000	20.58	54.00	33.42	100	330	VERT	Z
3659.200000	33.54	54.00	20.46	154	292	VERT	Z
4573.800000	32.30	54.00	21.70	100	0	HORI	Z
5488.800000	45.15	54.00	8.85	157	173	HORI	Z
6403.600000	35.94	54.00	18.06	177	197	HORI	Z
7292.600000	28.47	54.00	25.53	100	230	HORI	Z
8233.200000	39.83	54.00	14.17	220	121	VERT	Z
9123.200000	32.95	54.00	21.05	146	339	HORI	Z

Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is calculated in Figures 2, and 3. 13.62dB was used.

Table 6 - Radiated Emissions Peak Measurements, Mid Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
1829.600000	37.99	74.00	36.01	100	219	HORI	Z
2744.400000	34.20	74.00	39.80	100	330	VERT	Z
3659.200000	47.16	74.00	26.84	154	292	VERT	Z
4573.800000	45.92	74.00	28.08	100	0	HORI	Z
5488.800000	58.77	74.00	15.23	157	173	HORI	Z
6403.600000	49.56	74.00	24.44	177	197	HORI	Z
7292.600000	42.09	74.00	31.91	100	230	HORI	Z
8233.200000	53.45	74.00	20.55	220	121	VERT	Z
9123.200000	46.57	74.00	27.43	146	339	HORI	Z

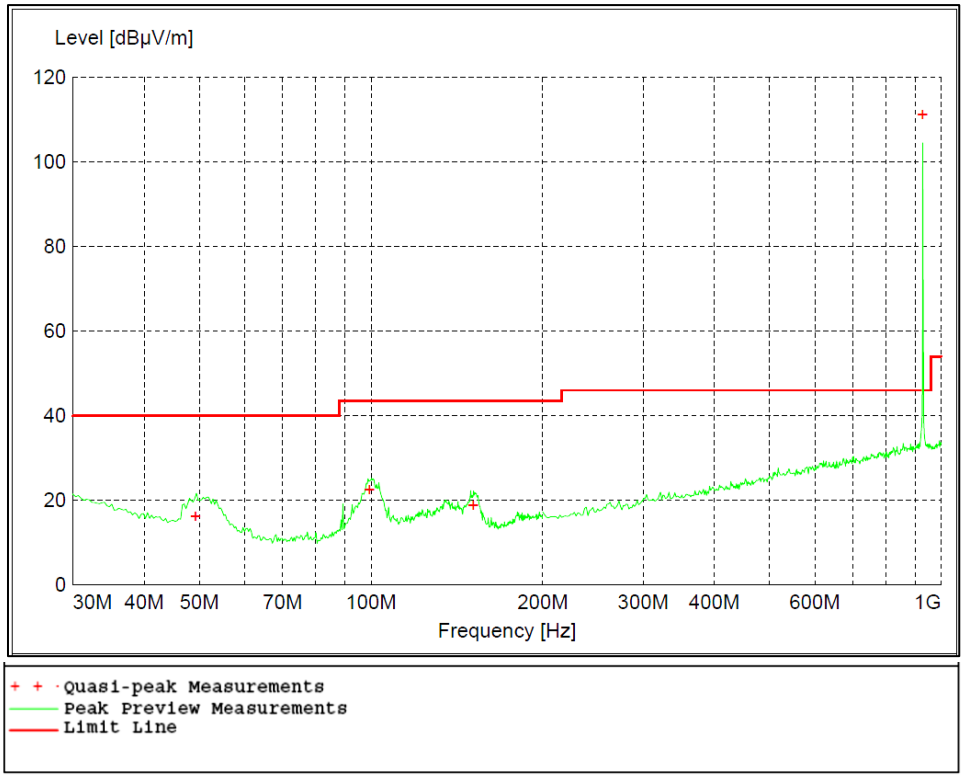

Figure 7 - Radiated Emissions Plot, High Channel

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.		
49.260000	16.14	40.00	23.90	99	46	VERT	X
99.360000	22.41	43.50	21.10	113	89	VERT	X
151.200000	18.83	43.50	24.70	100	79	VERT	X
927.600000	111.11	NA	NA	99	314	HORI	X

Table 8 - Radiated Emissions Average Measurements, High Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
1855.200000	32.28	54.00	21.72	101	61	VERT	Z
2782.800000	33.52	54.00	20.48	97	329	VERT	Z
3710.400000	28.73	54.00	25.27	134	280	VERT	Z
4638.000000	30.20	54.00	23.80	100	360	HORI	Z
5565.600000	45.72	54.00	8.28	147	178	HORI	Z
6493.200000	36.53	54.00	17.47	160	187	HORI	Z
7420.800000	32.03	54.00	21.97	104	216	HORI	Z
8348.400000	39.87	54.00	14.13	157	186	HORI	Z
9283.800000	30.91	54.00	23.09	396	290	VERT	Z

Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is calculated in Figures 2, and 3. 13.62dB was used.

Table 9 - Radiated Emissions Peak Measurements, High Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
1855.200000	45.90	74.00	28.10	101	61	VERT	Z
2782.800000	47.14	74.00	26.86	97	329	VERT	Z
3710.400000	42.35	74.00	31.65	134	280	VERT	Z
4638.000000	43.82	74.00	30.18	100	360	HORI	Z
5565.600000	59.34	74.00	14.66	147	178	HORI	Z
6493.200000	50.15	74.00	23.85	160	187	HORI	Z
7420.800000	45.65	74.00	28.35	104	216	HORI	Z
8348.400000	53.49	74.00	20.51	157	186	HORI	Z
9283.800000	44.53	74.00	29.47	396	290	VERT	Z

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) 7.8.5

Limits of bandwidth measurements:
The peak EIRP was measured using a 1 MHz RBW. For an FHSS system with 25 channels, the output power is required to be less than 250 mW or 24 dBm. EIRP was calculated from field strength measurements using ANSI C63.10:2013, Section 9.5, Equation (22). The field strength was measured at a 3m distance and maximized. The average EIRP was calculated by adding the Duty Cycle correction factor from Section 4.1.

Test procedures:
All measurements were taken at a distance of 3m from the EUT. The bandwidth of the fundamental frequency was measured by spectrum analyzer with 1 MHz RBW and 3 MHz VBW.

The EUT was maximized in all 3 orthogonal positions in a similar manner as described in Section 4.2.

Deviations from test standard:
No deviation.

Test setup:

See Section 4.2

EUT operating conditions:
The EUT was powered by 4.1 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	902.4	13.81	EIRP	PASS
Middle	914.8	16.64	EIRP	PASS
High	927.6	16.43	EIRP	PASS

Average Output Power

CHANNEL	CHANNEL FREQUENCY (MHz)	AVG OUTPUT POWER (dBm)	Method	RESULT
Low	902.4	0.19	EIRP	PASS
Middle	914.8	3.02	EIRP	PASS
High	927.6	2.81	EIRP	PASS

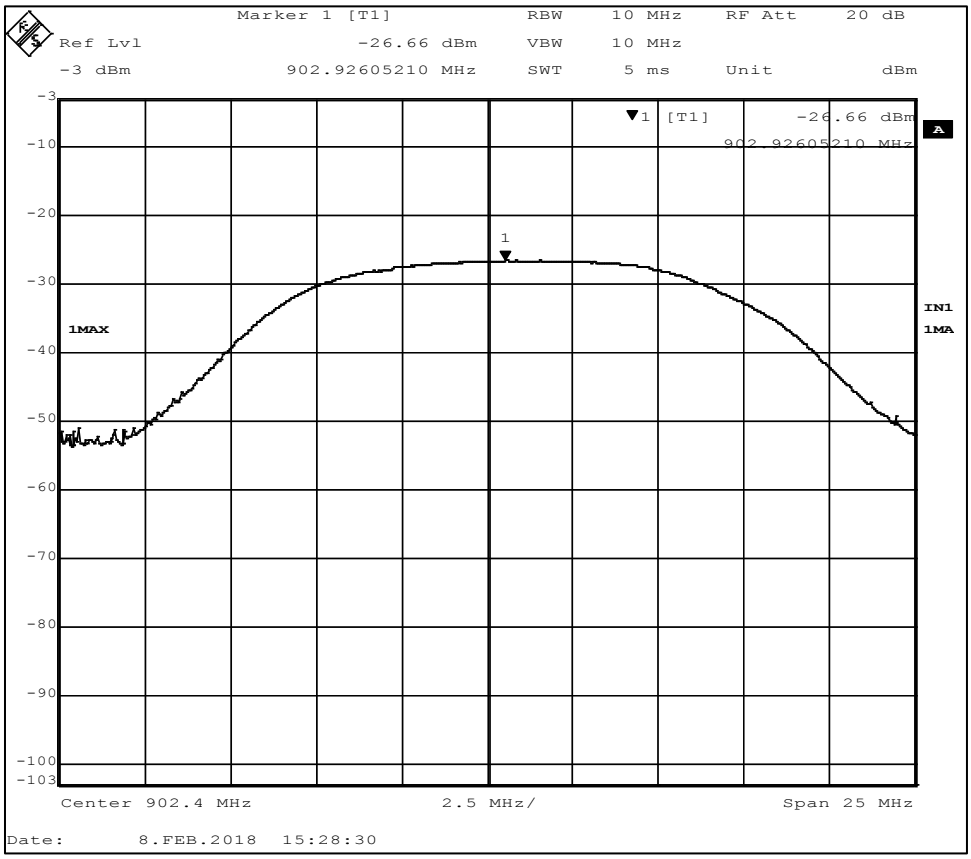

Figure 8 – Output Power, Low Channel

Maximum power = -26.66 dBm + 107 + CL + AF - 95.23 = 13.81 dBm
CL = cable loss = 4.90 dB
AF = antenna factor = 23.80 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.

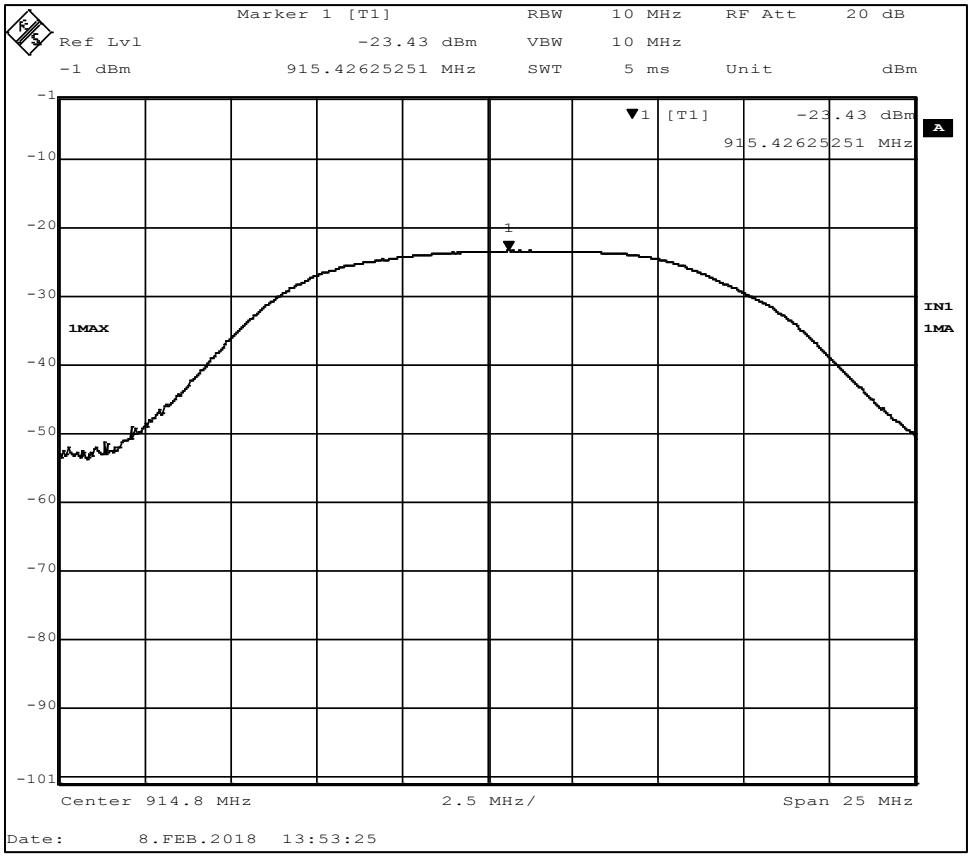

Figure 9 - Output Power, Mid Channel

Maximum power = -23.43 dBm + 107 + CL + AF - 95.23 = 16.64 dBm
CL = cable loss = 4.80 dB
AF = antenna factor = 23.50 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.

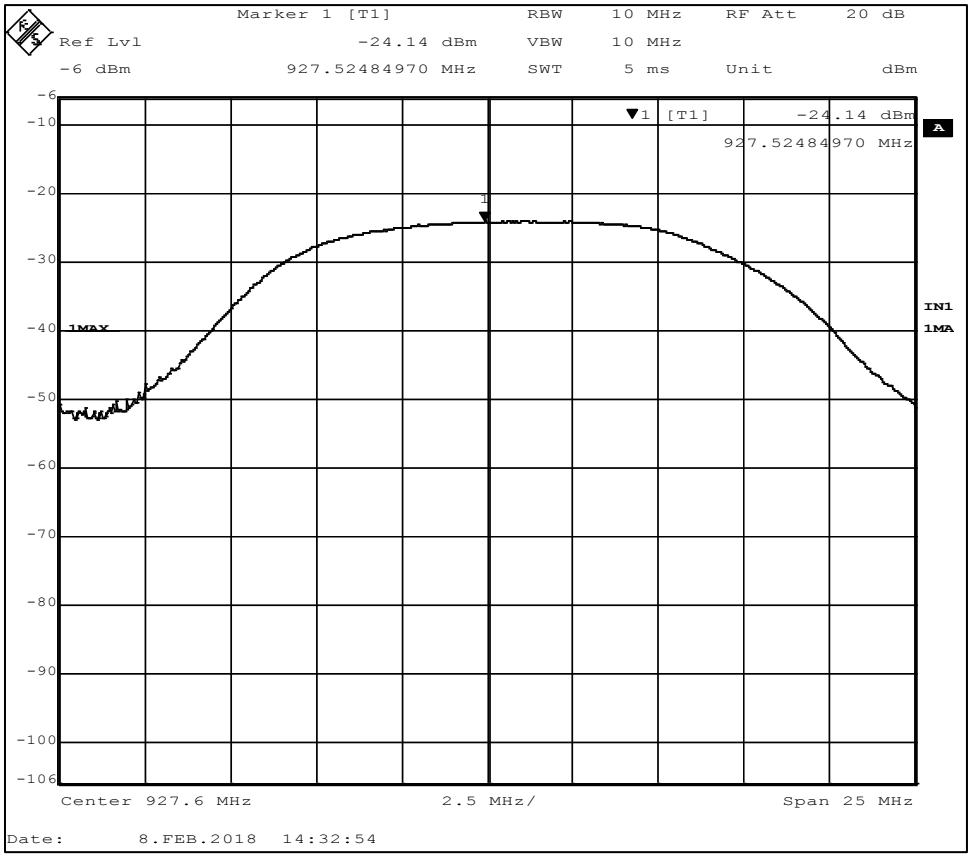

Figure 10 - Output Power, High Channel

Maximum power = -24.14 dBm + 107 + CL + AF - 95.23 = 16.43 dBm
CL = cable loss = 4.90 dB
AF = antenna factor = 23.90 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) 6.9.2
ANSI C63.10:2003 (measurement bandwidth) per FCC Report and Order 14-208, sections 83 and 84

Limits of bandwidth measurements:
From FCC Part 15.247 (1) (i) and RSS-247 5.1(c)

The maximum allowed 20 dB bandwidth of the hopping channel is 250 kHz.

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 100 kHz resolution bandwidth is allowed per FCC report and order 14-208, Section 83 and 84.

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

Test setup:

All the measurements were done at 3m test distance while an operator was trying to activate the hopping sequence manually. See Section 4.3 for more details.

Deviations from test standard:
No deviation.

Test setup:

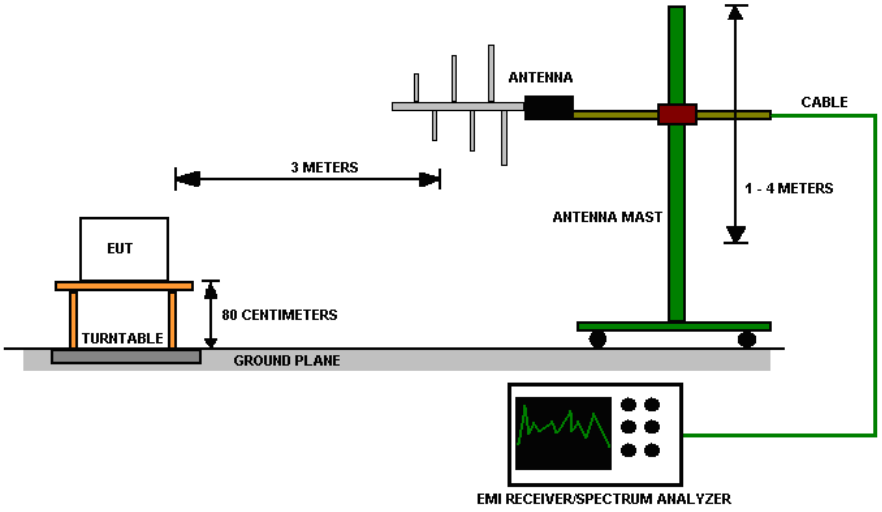

Figure 11 - Bandwidth Measurements Test Setup

EUT operating conditions:

The EUT was powered by 4.1 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:

20 dB Bandwidth

CHANNEL	CHANNEL FREQUENCY (MHz)	20dB BW (kHz)
Low	902.4	312.62
Mid	914.8	316.63
High	927.6	312.62

*The limit is 250 kHz minimum. The measurements were conducted at 100 kHz RBW and 300 kHz VBW according to FCC Report and Order FCC 14-208 from December 30, 2014, Paragraph 83.

99% Occupied Bandwidth

CHANNEL	CHANNEL FREQUENCY (MHz)	20dB BW (kHz)
Low	902.4	312.62
Mid	914.8	316.63
High	927.6	312.62

Because peak power measurements were within 0.5 dB of the peak measurements in the bandwidth plots, the 20 dB BW and 99% dB BW values are considered to be the same with a ±5% tolerance.

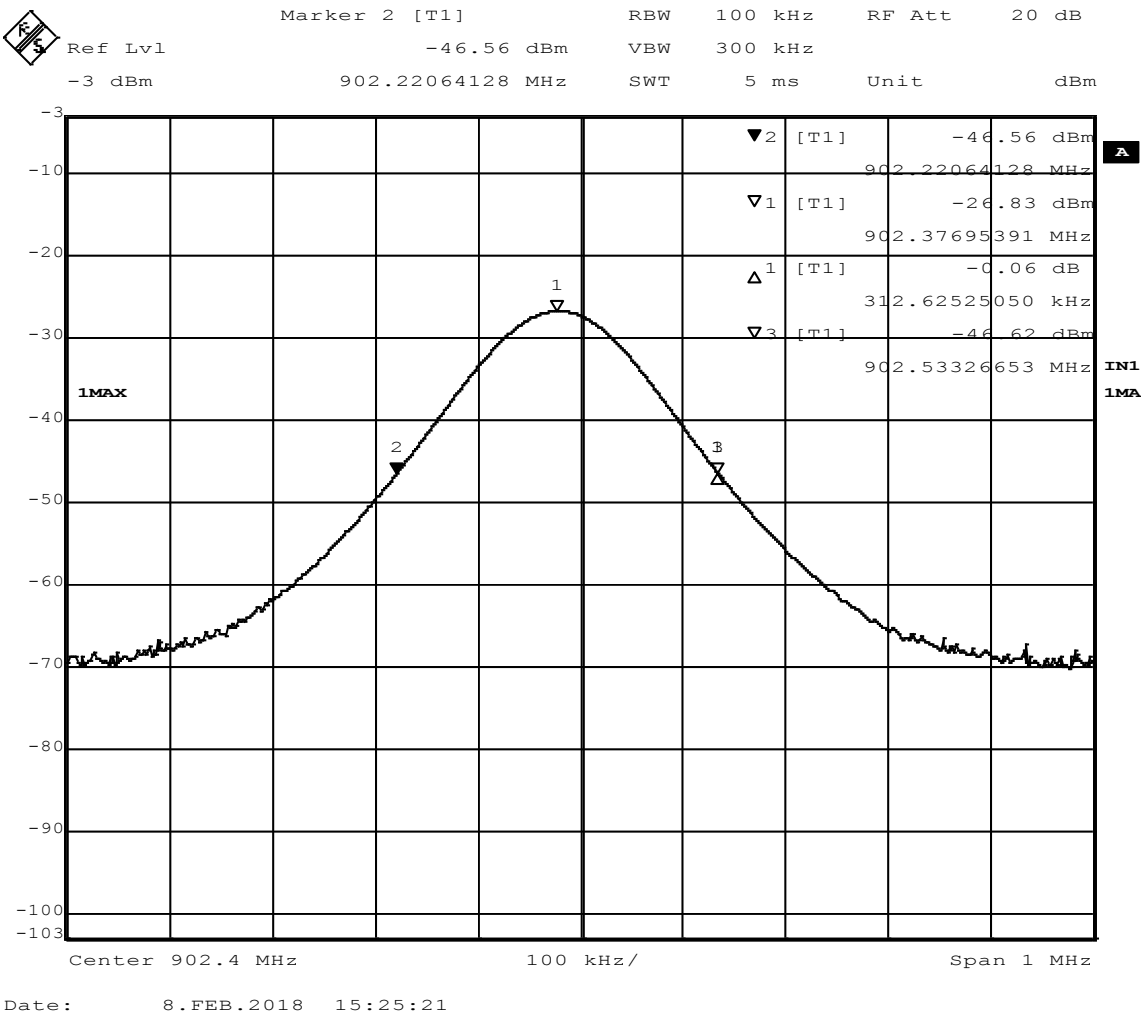

Figure 12 – 20 dB Bandwidth, Low Channel

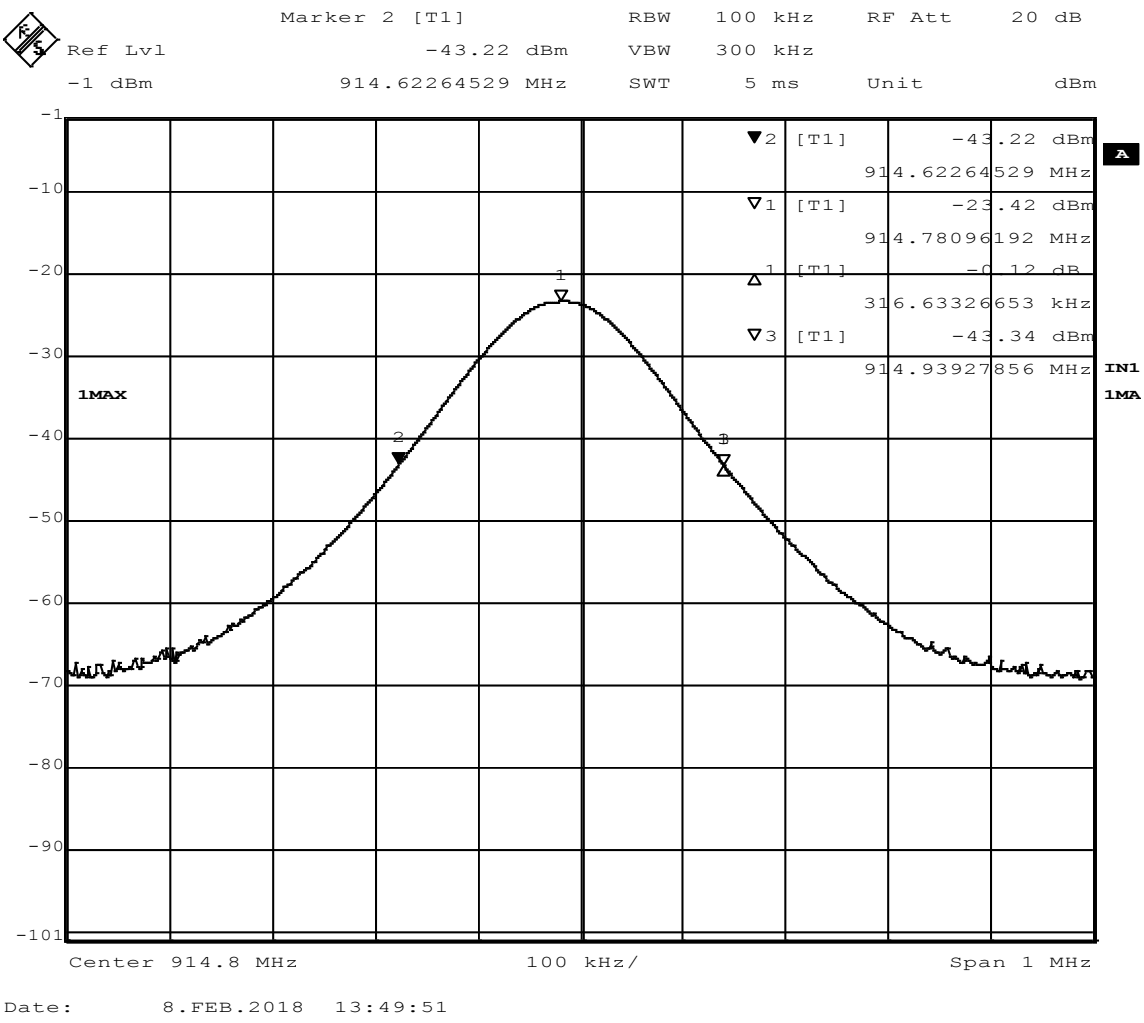

Figure 13 - 20 dB Bandwidth, Mid Channel

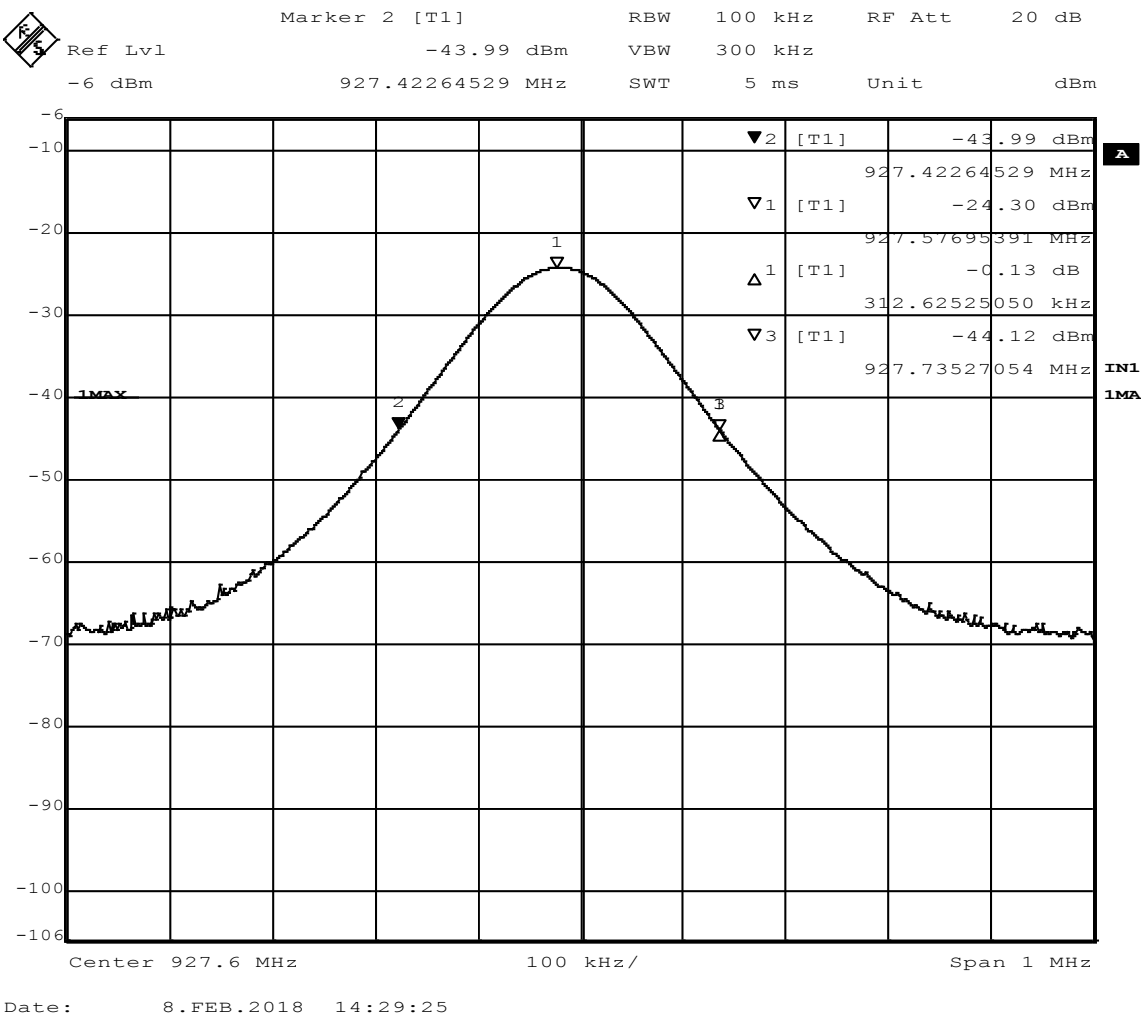

Figure 14 - 20 dB Bandwidth, High Channel

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 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:

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	-107.42	-27.54	79.88	62.40	PASS
High, Continuous	960.0	-105.98	-24.38	81.60	65.11	PASS
Low Hopping	614.0	-107.28	-27.52	79.76	62.40	PASS
High, Hopping	960.0	-107.26	-26.56	80.70	65.11	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	-78.70	-27.54	51.16	20.00	PASS
High, Continuous	928.0	-78.61	-24.38	54.23	20.00	PASS
Low Hopping	902.0	-77.96	-27.52	50.44	20.00	PASS
High, Hopping	928.0	-78.24	-26.56	51.68	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 902.4MHz for low channel = 108.40 dBµV/m
Fundamental average field strength at 927.6MHz for high channel = 111.11 dBµV/m

Low channel minimum delta = 108.40 – 46.0 dBµV/m = 62.40 dBc
High channel minimum delta = 111.11 – 46.0 dBµV/m = 65.11 dBc

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

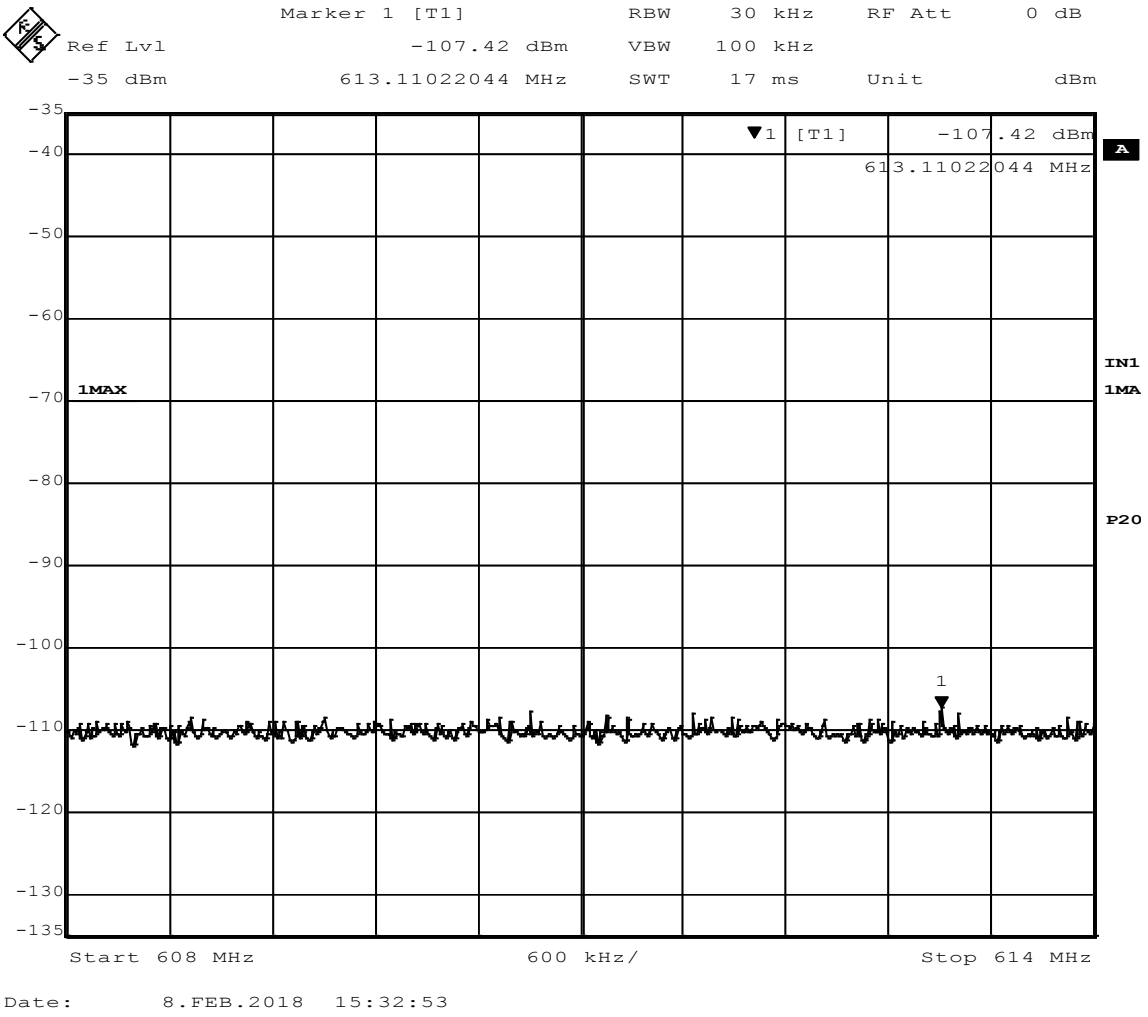

Figure 15 - Band-edge Measurement, Low Channel, Restricted Frequency, Continuous Transmit

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

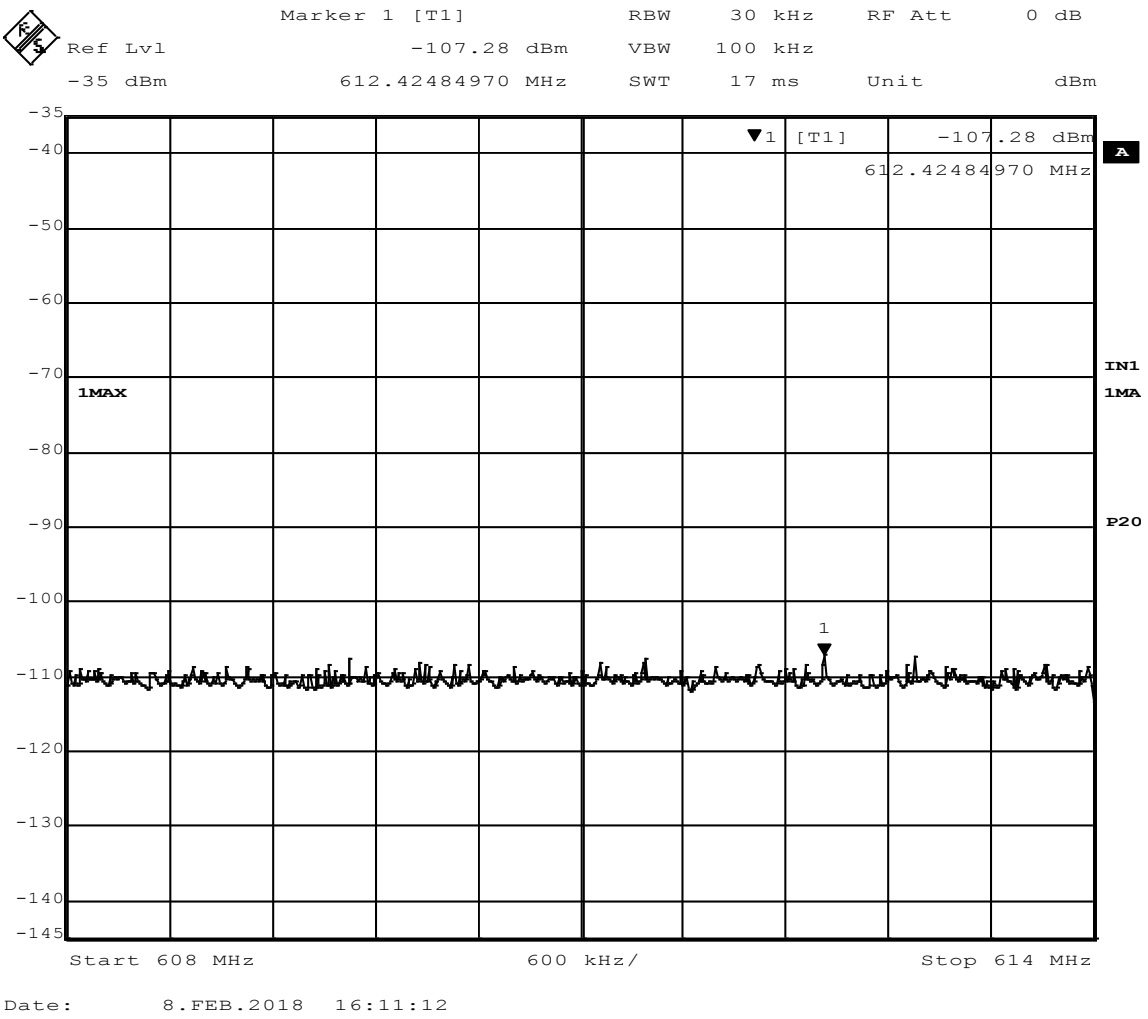

Figure 16 - Band-edge Measurement, Low Channel, Restricted Frequency, Hopping

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

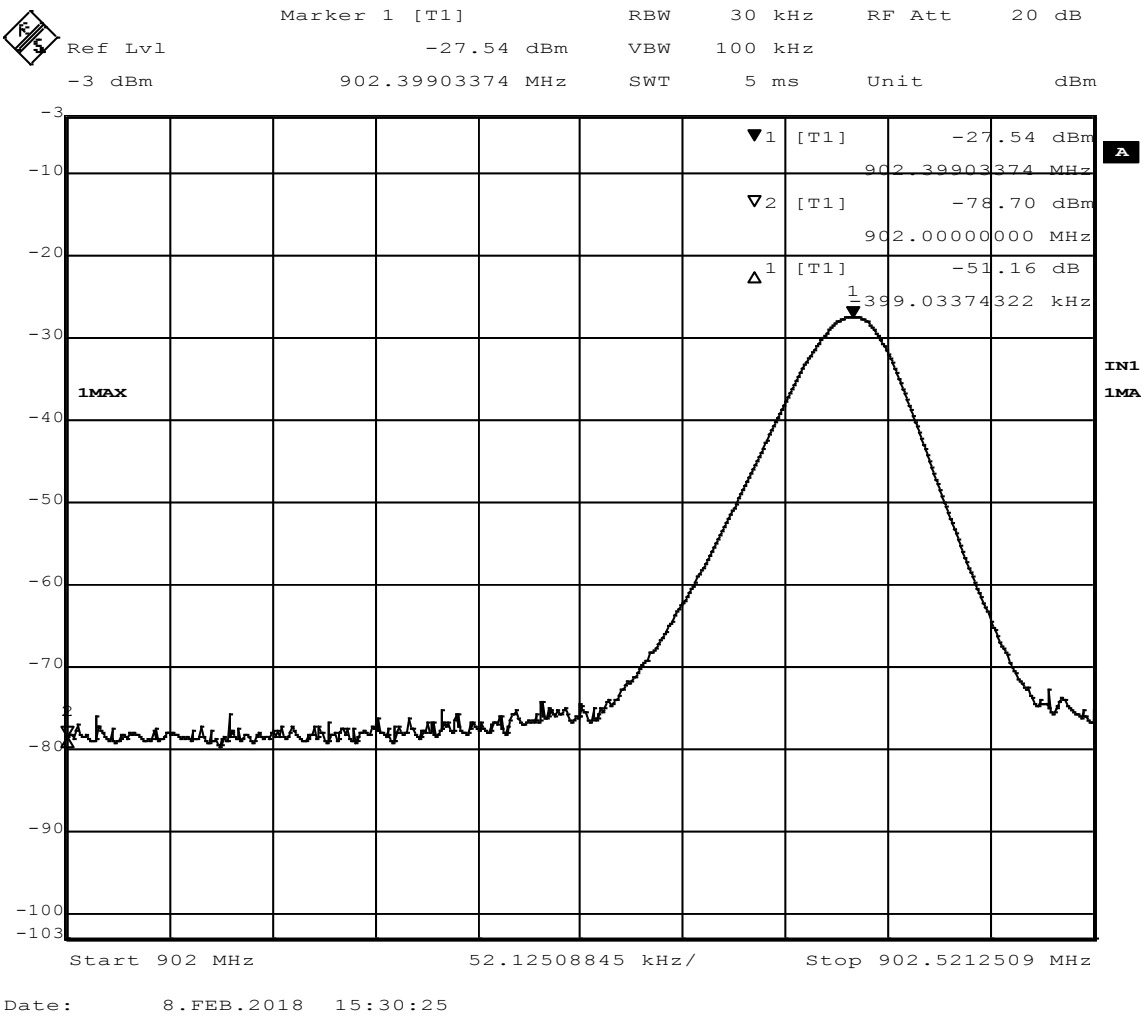

Figure 17 - Band-edge Measurement, Low Channel, Fundamental, Continuous Transmit

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

Delta = 51.16 dB > 20 dB minimum

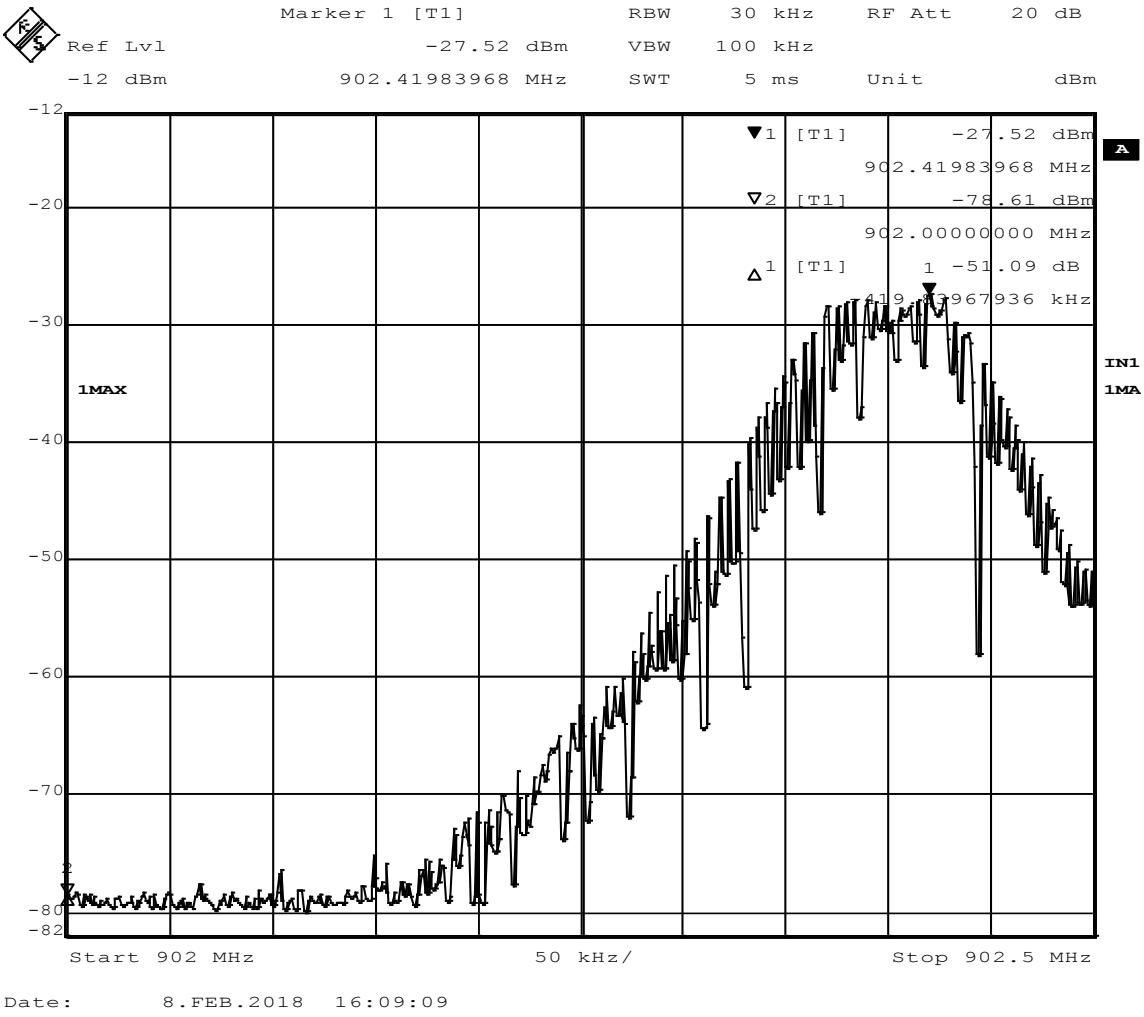

Figure 18 - Band-edge Measurement, Low Channel, Fundamental, Hopping Transmit

The plot shows an uncorrected measurement, used for relative measurements only.
Delta = 51.09 dB > 20 dB minimum

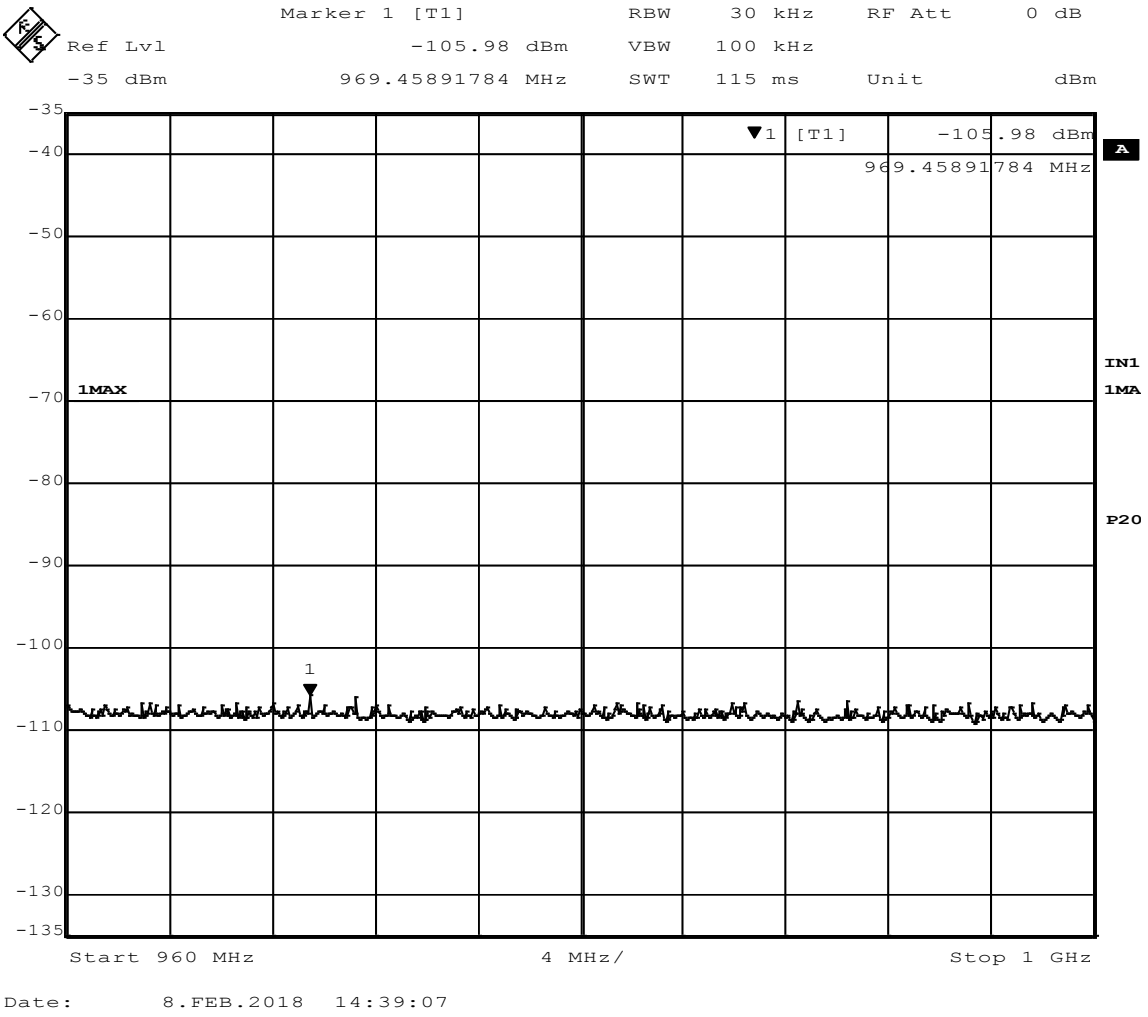

Figure 19 - Band-edge Measurement, High Channel, Restricted Frequency, Continuous Transmit

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

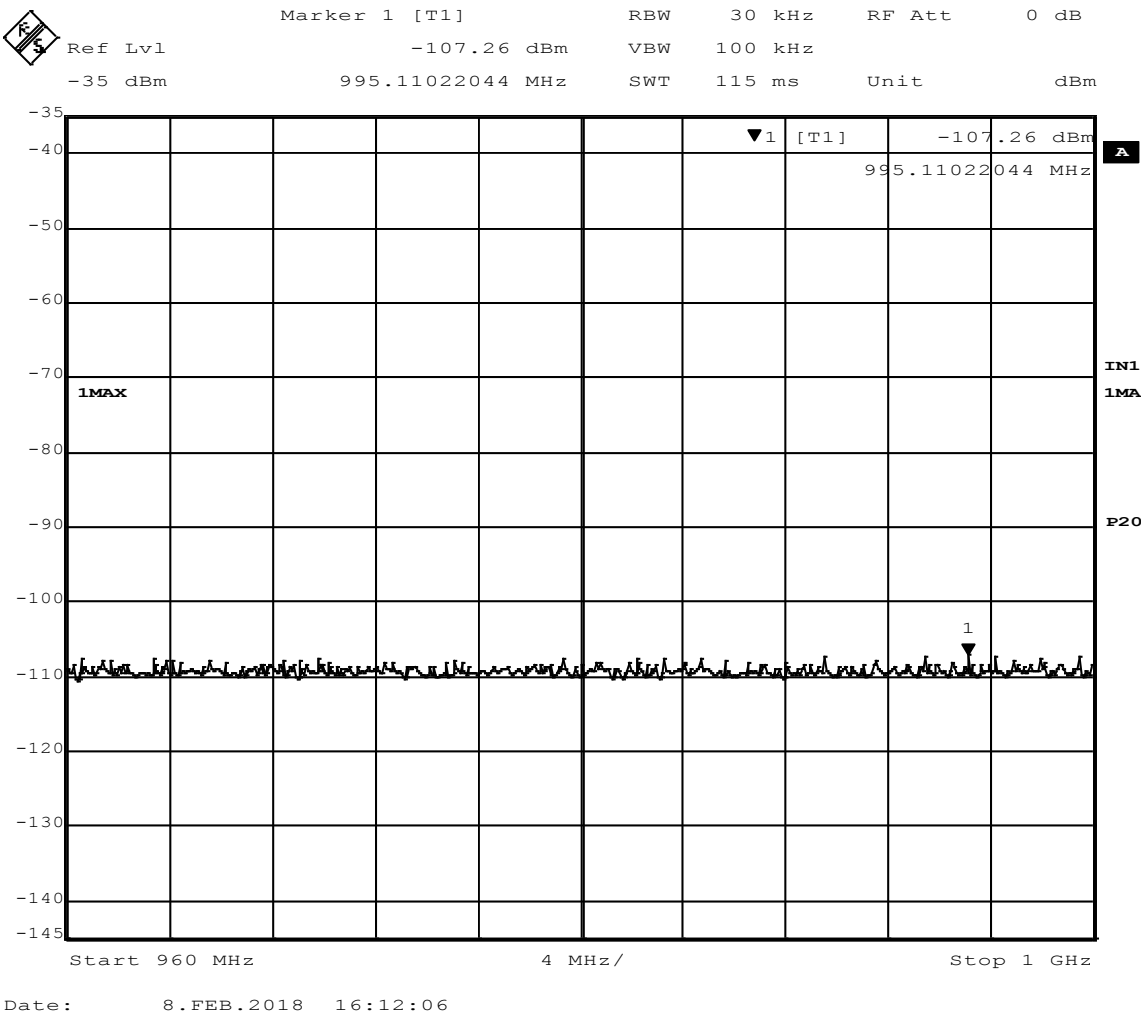

Figure 20 - Band-edge Measurement, High Channel, Restricted Frequency, Hopping

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

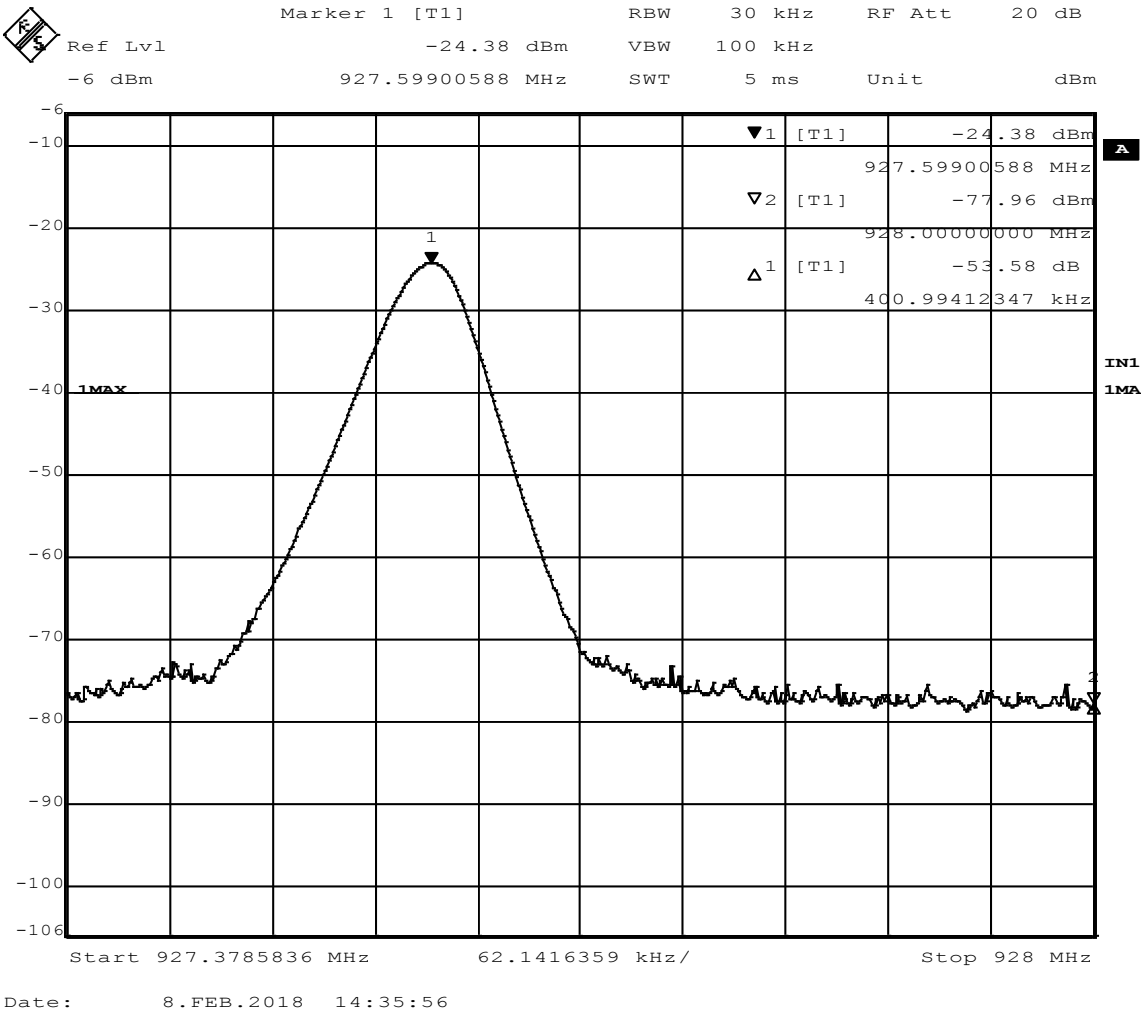

Figure 21 - Band-edge Measurement, High Channel, Fundamental, Continuous Transmit

The plot shows an uncorrected measurement, used for relative measurements only.
Delta = 53.58 dB > 20 dB minimum

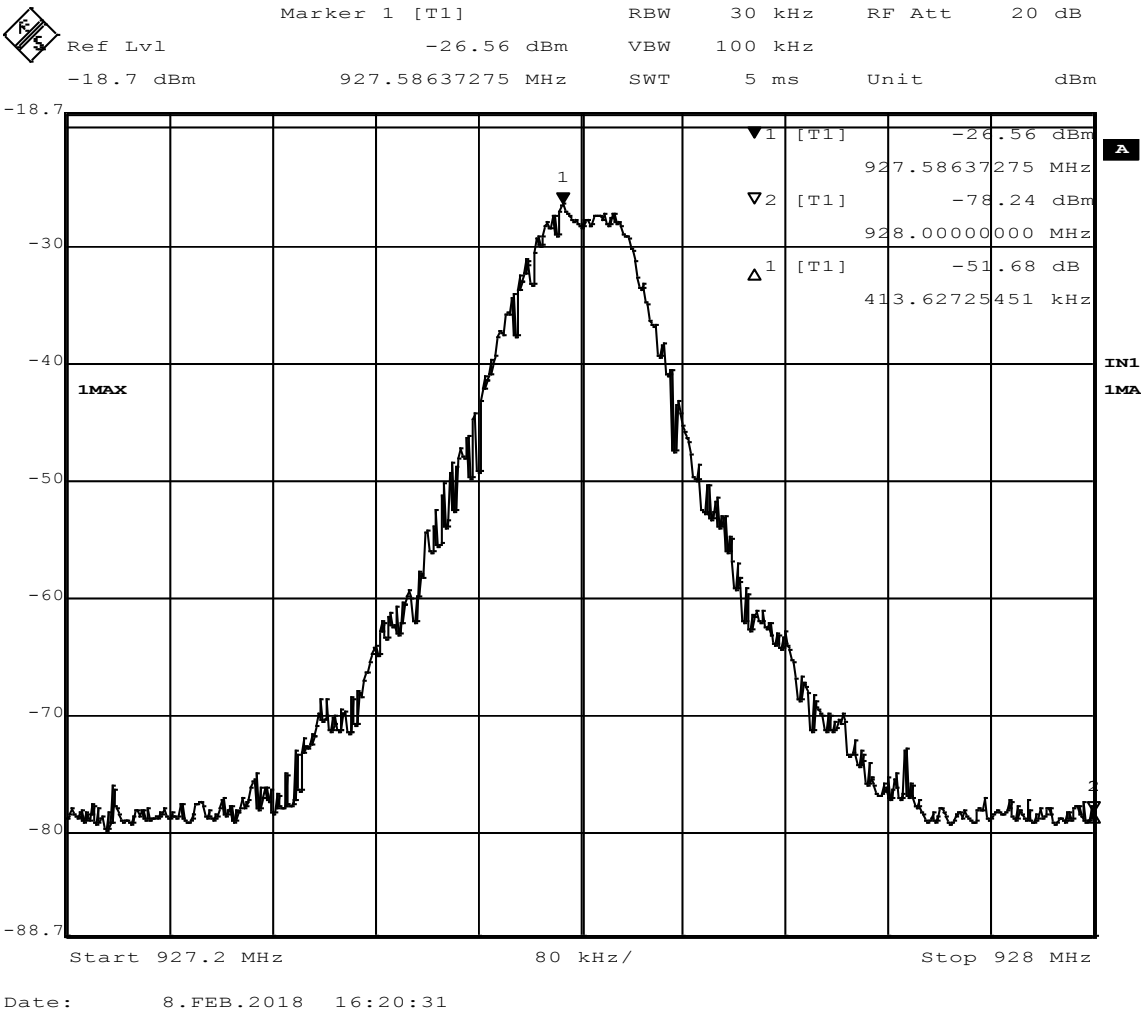

Figure 22 - Band-edge Measurement, High Channel, Fundamental, Hopping Transmit

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

Delta = 51.68 dB > 20 dB minimum

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 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 3VDC 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:

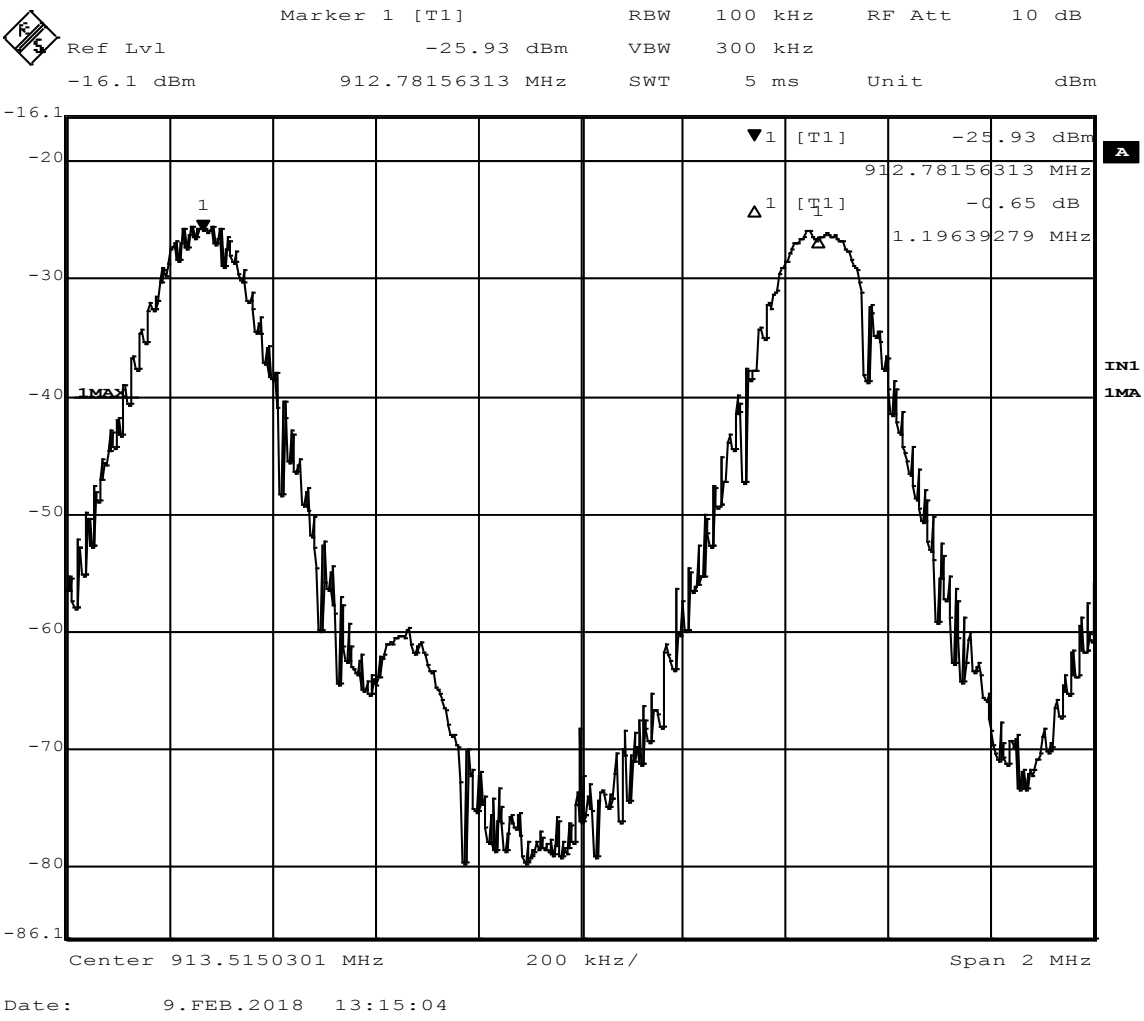

Figure 23 – Frequency Separation, 1.19 MHz

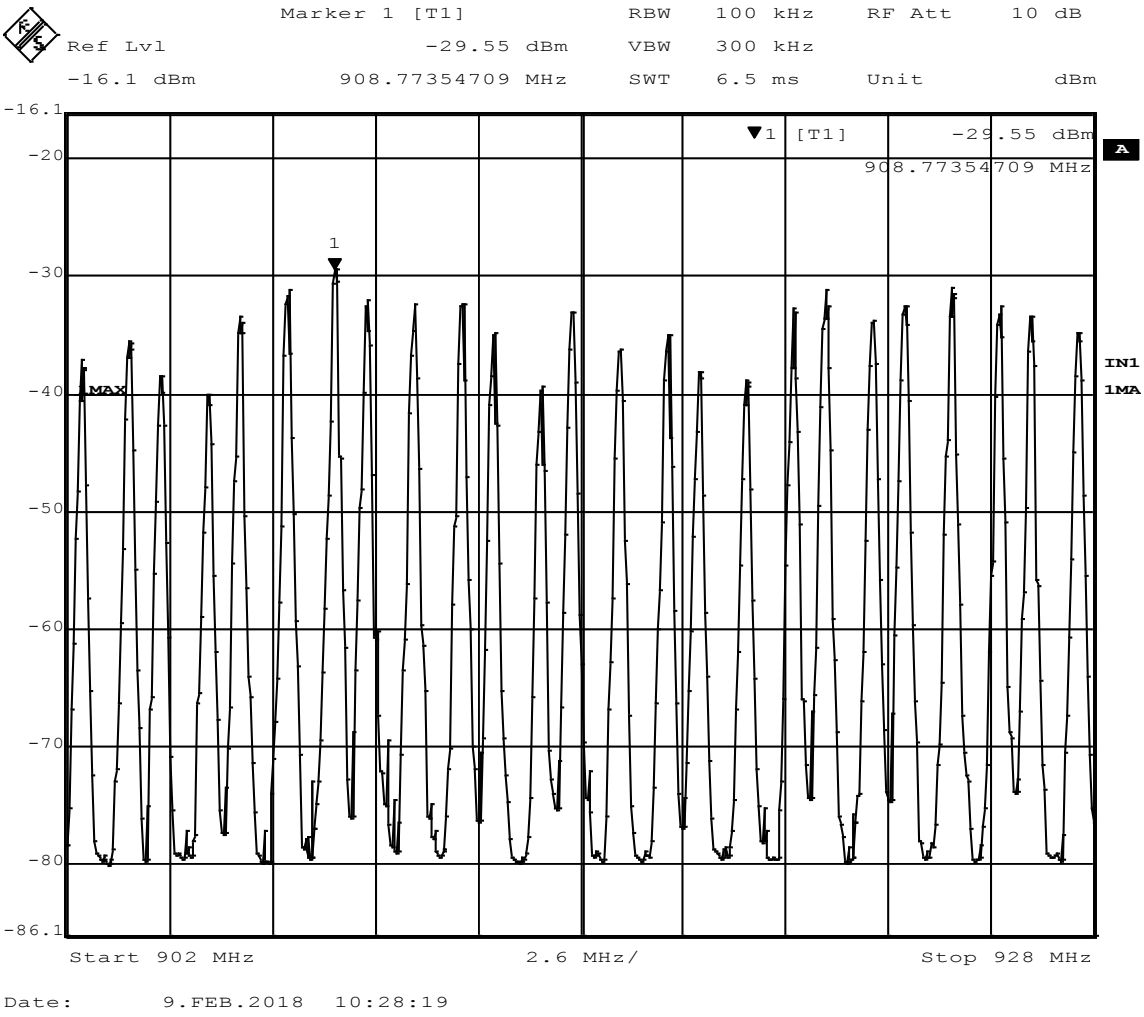

Figure 24 – Hop Count, 25 Hops

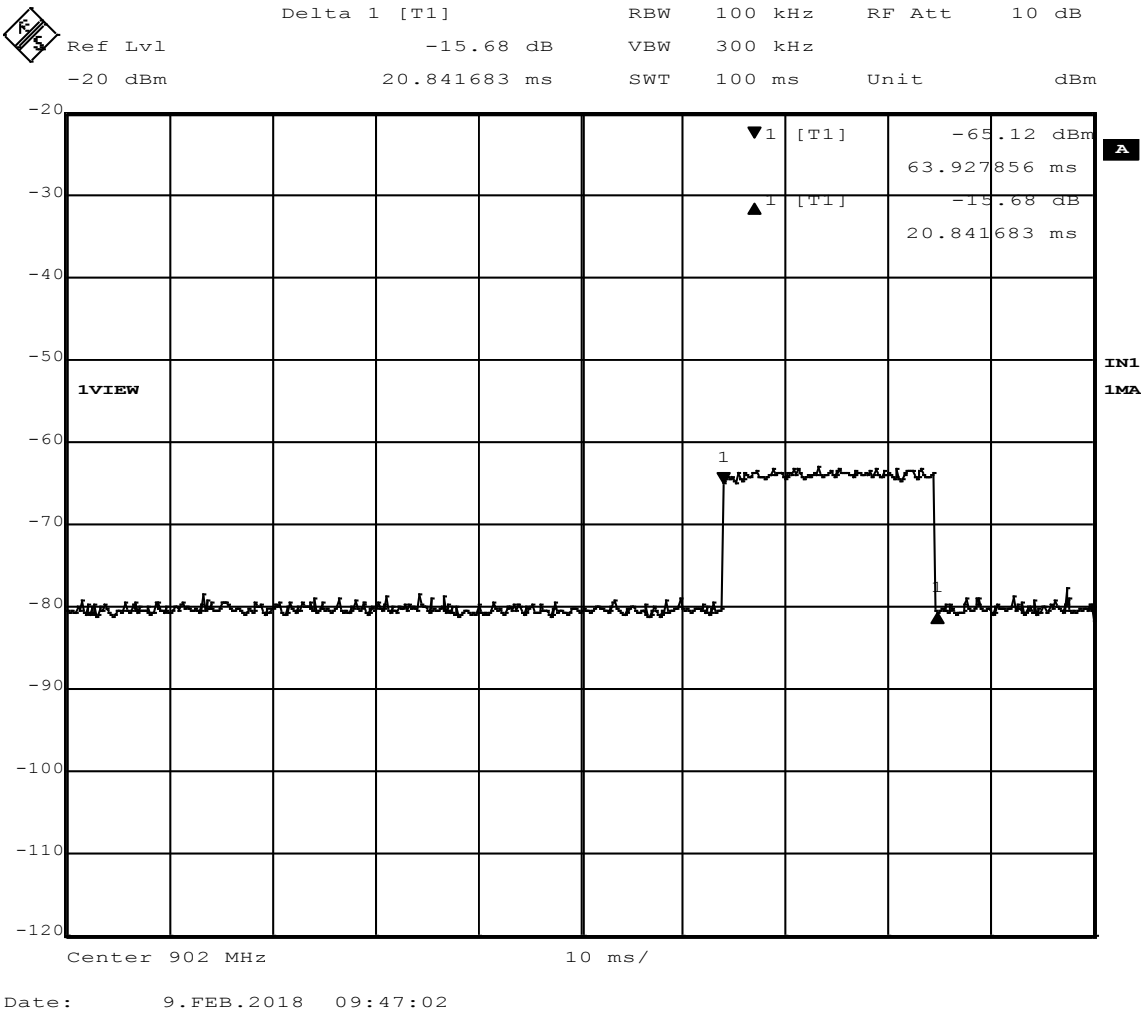

Figure 25 – Time of Occupancy, On Time

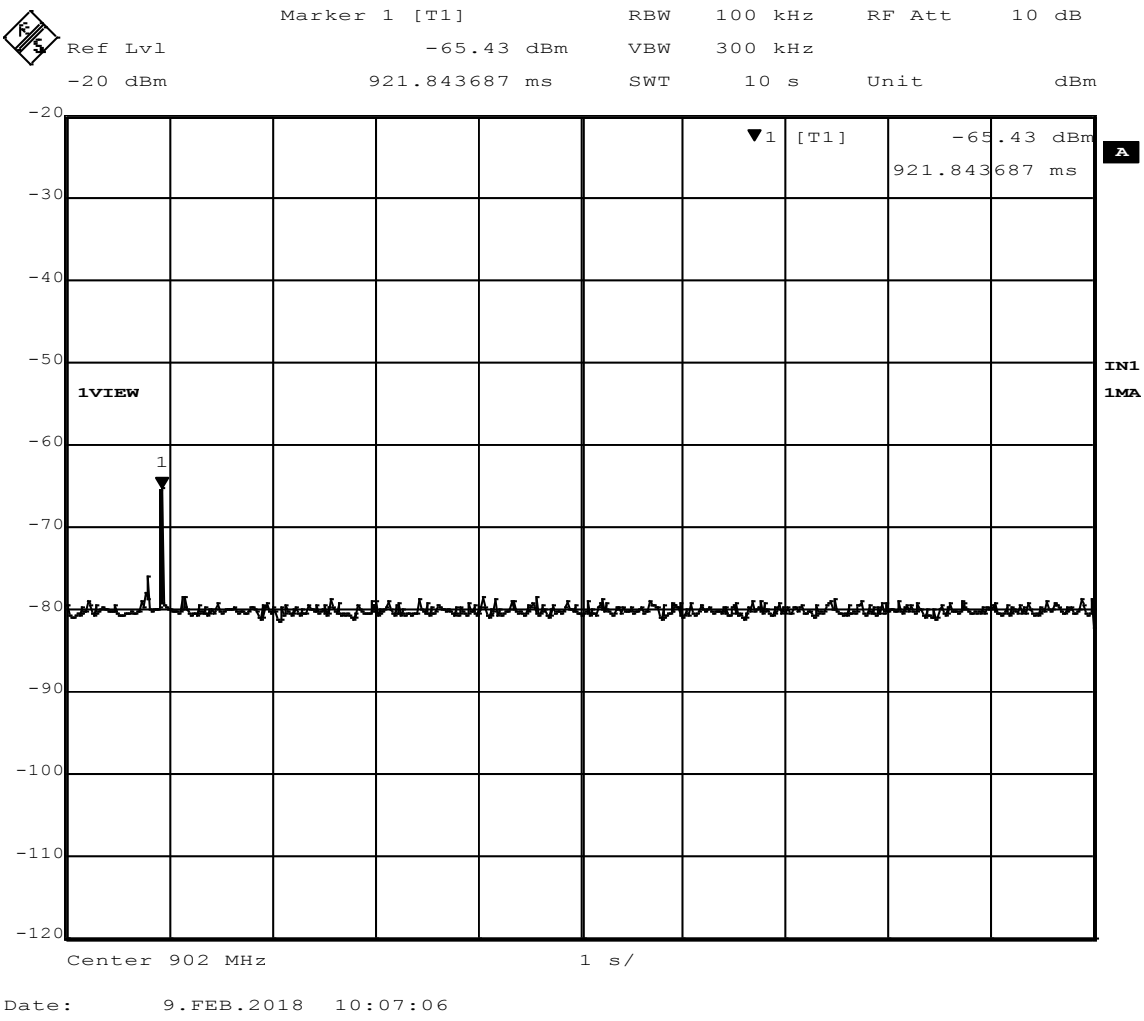

Figure 26 – Time of Occupancy, Period

*Maximum of 1 transmissions can occur in a given channel in any 10 s so the average time of occupancy is 20.84 ms x 1 =20.84 ms = 0.020 s < 0.4 s - Pass

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