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FCC/ISED Test Report

Prepared for: RealmFive, Inc.

Address: 3300 Folkways Cir.
Lincoln, NE 68504

Product: TPM – Tower Pivot Monitor

Test Report No: R20171017-22-06E

Approved By:

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Technical Manager
iNARTE Certified EMC Engineer #EMC-003337-NE

DATE: 19 May 2023

Total Pages: 52

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ACCREDITED
TESTING LABORATORY
CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	20 December 2018	Original – NJohnson Prepared by KVepuri
A	9 May 2022	Amended report
B	8 May 2023	Added 20 dB BW Updated power limit
C	17 May 2023	Corrected typo in Section 4.3.
D	21 May 2023	Added note under Figure 28.
E	24 May 2023	Corrected minimum dBc on page 28

CONTENTS

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 RSS Gen, Issue 4, 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 4, 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 15.247(a) (1) (i) RSS-247, 5.1(c)	Frequency Hopping System	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 4, Section 7.1	Conducted Emissions	Pass
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

EUT	TPM – Tower Pivot Monitor
EUT Received	19 November 2018
EUT Tested	19 November 2018- 20 November 2018
Serial No.	NCEETEST1 (Assigned)
Operating Band	902.0 – 928.0 MHz
Device Type	Hybrid
Antenna Gain	6.4 dBi

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	902.30
Middle	908.46
High	914.90

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

The EUT was tested inside of a Davis weather station. The weather station enclosure was all plastic and was determined to have negligible effect on the radiated emissions from the device.

The device is typically installed within another sensor, but is itself a stand-alone transmitter that is capable or operating by itself with no sensor.

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
EMCO Biconilog Antenna	3142B	1647	02 Aug 2017	02 Aug 2018**
EMCO Horn Antenna	3115	6416	26 Jan 2018	26 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*
Mini Circuits 1700 – 5000Mhz High Pass Filter***	15542	31618	16 April 2018*	16 April 2019*
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
**Extended cal

4.0 DETAILED RESULTS

4.1 DUTY CYCLE

Not applicable

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 only one axis as it is intended to be placed in one orientation only. The results are presented in that axis.

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:

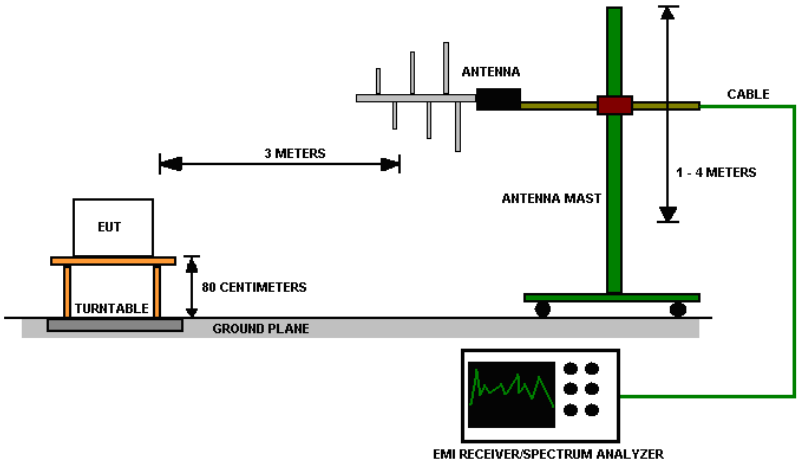

Figure 1 - Radiated Emissions Test Setup

EUT operating conditions

The EUT was powered by 120 VAC 60 Hz unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:

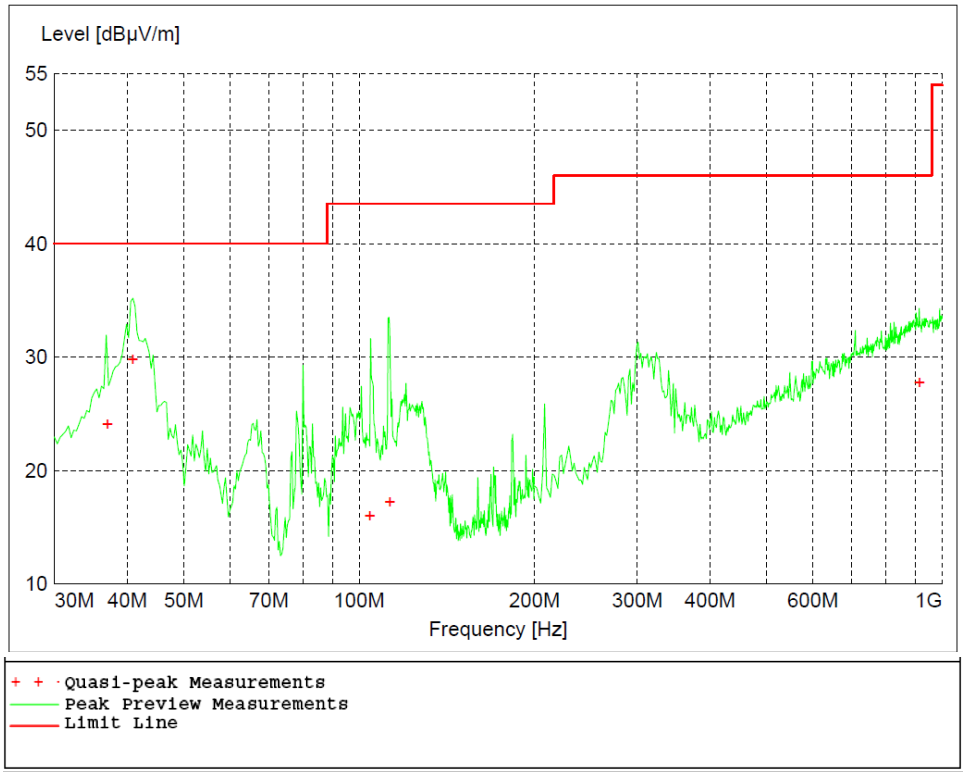

Figure 2 - Radiated Emissions Plot, Receive

Table 1 - Radiated Emissions Quasi-peak Measurements, Receive

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
37.020000	24.05	40.00	16.00	100	102	VERT
40.920000	29.76	40.00	10.20	119	65	VERT
104.400000	15.95	43.50	27.60	193	38	VERT
112.920000	17.17	43.50	26.40	117	42	VERT
914.700000	27.74	46.00	18.30	146	360	VERT

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

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
1830.4	35.07	54	18.9	119	282	HORI
2732.6	34.34	54	19.7	109	289	VERT

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

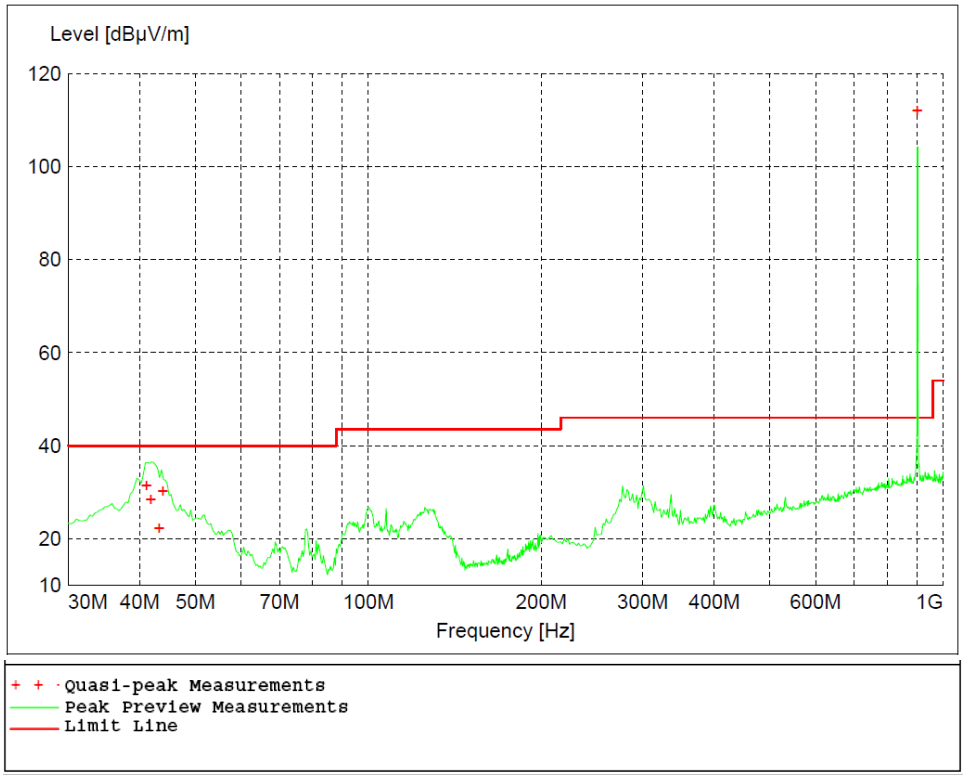

Figure 3 - Radiated Emissions Plot, Low Channel

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

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
41.100000	31.40	40.00	8.60	102	151	VERT
41.820000	28.40	40.00	11.60	241	210	VERT
43.260000	22.14	40.00	17.90	163	31	VERT
43.860000	30.16	40.00	9.80	108	0	VERT
902.300000	111.93	NA	NA	115	164	VERT

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

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
1804.600000	43.61	54.00	10.40	155	20	VERT
2707.200000	41.54	54.00	12.50	197	180	VERT
3609.400000	46.51	54.00	7.50	99	17	HORI
4506.800000	42.77	54.00	11.20	100	271	HORI

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

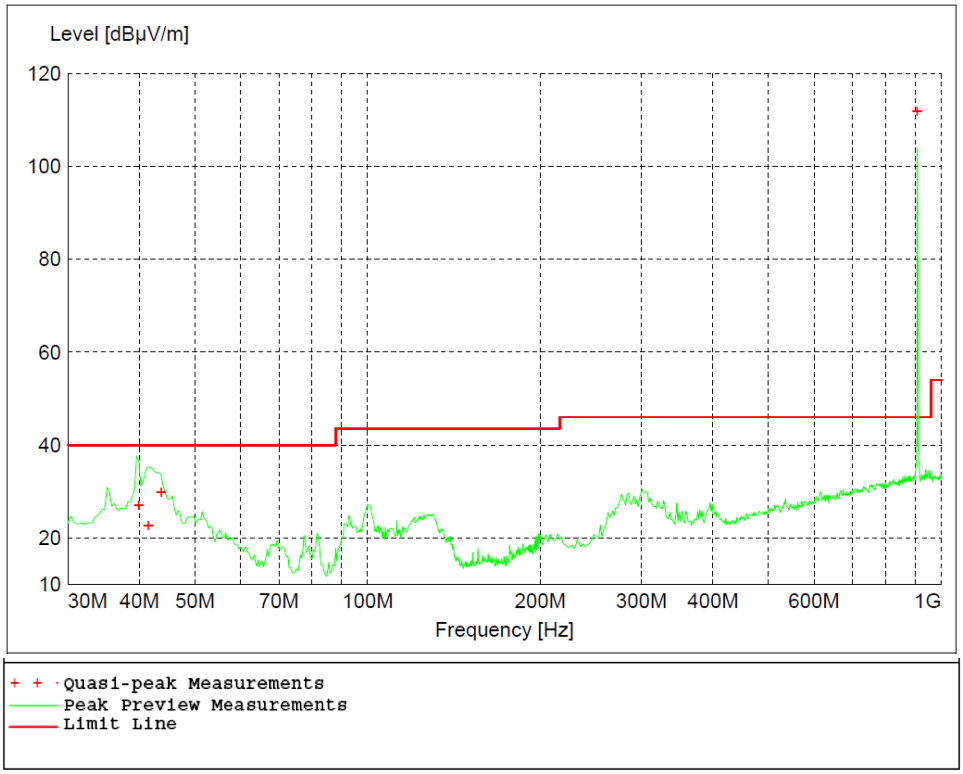

Figure 4 - Radiated Emissions Plot, Mid Channel

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

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
39.900000	26.99	40.00	13.00	99	80	VERT
41.460000	22.53	40.00	17.50	144	169	VERT
43.680000	29.85	40.00	10.10	98	57	VERT
908.500000	111.75	NA	NA	109	163	VERT

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

c	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
1816.800000	42.62	54.00	11.40	206	185	HORI
2725.400000	40.66	54.00	13.30	214	181	VERT
3634.400000	44.56	54.00	9.40	170	283	VERT
4547.200000	43.87	54.00	10.10	400	75	HORI

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

*Unrestricted band

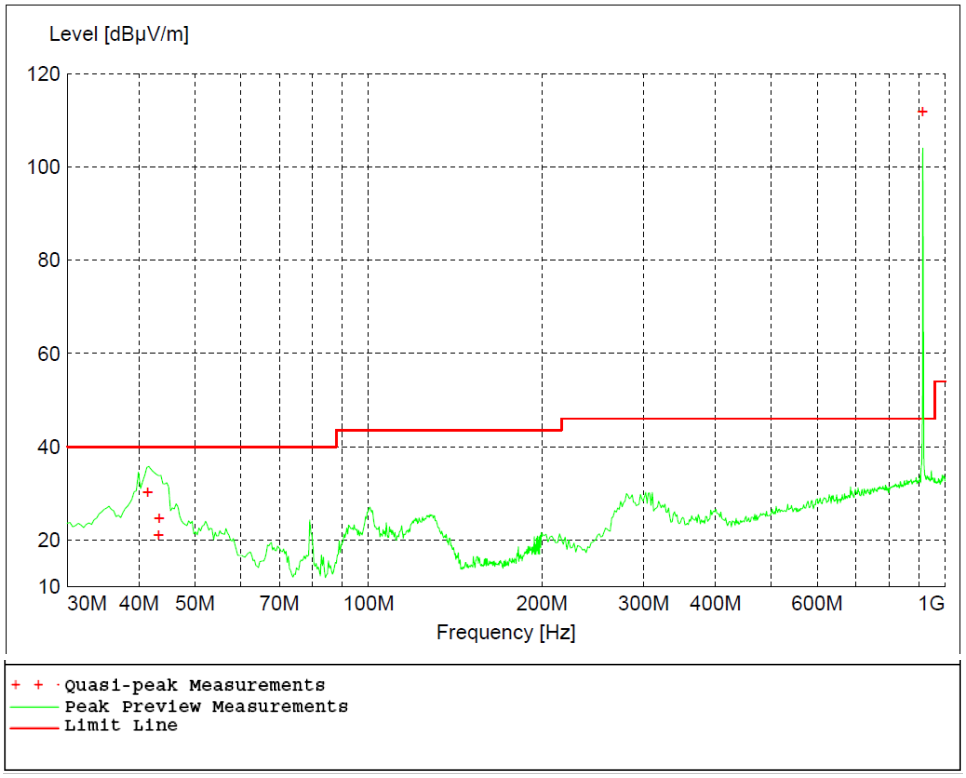

Figure 5 - Radiated Emissions Plot, High Channel

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

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
41.400000	30.26	40.00	9.70	99	270	VERT
43.260000	21.02	40.00	19.00	99	4	VERT
43.320000	24.55	40.00	15.40	265	73	VERT
914.900000	111.81	NA	NA	168	159	VERT

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

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
1829.800000	44.05	54.00	9.90	257	217	VERT
2744.600000	40.70	54.00	13.30	224	46	VERT
3659.800000	45.26	54.00	8.70	173	277	VERT
4567.000000	43.72	54.00	10.30	179	91	VERT

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

*Unrestricted band

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 29.6 dBm. (30 dBm – (6.4 – 6)). Maximum gain is reduced to account for antenna gain > 6 dBi

Test procedures:
All measurements were taken at a distance of 3m from the EUT.

Deviations from test standard:
No deviation.

Test setup:

See Section 4.2

EUT operating conditions:
The EUT was powered by 120 VAC 60 Hz 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	902.30	17.66	EIRP	Pass
Middle	908.46	16.76	EIRP	Pass
High	914.90	16.43	EIRP	Pass

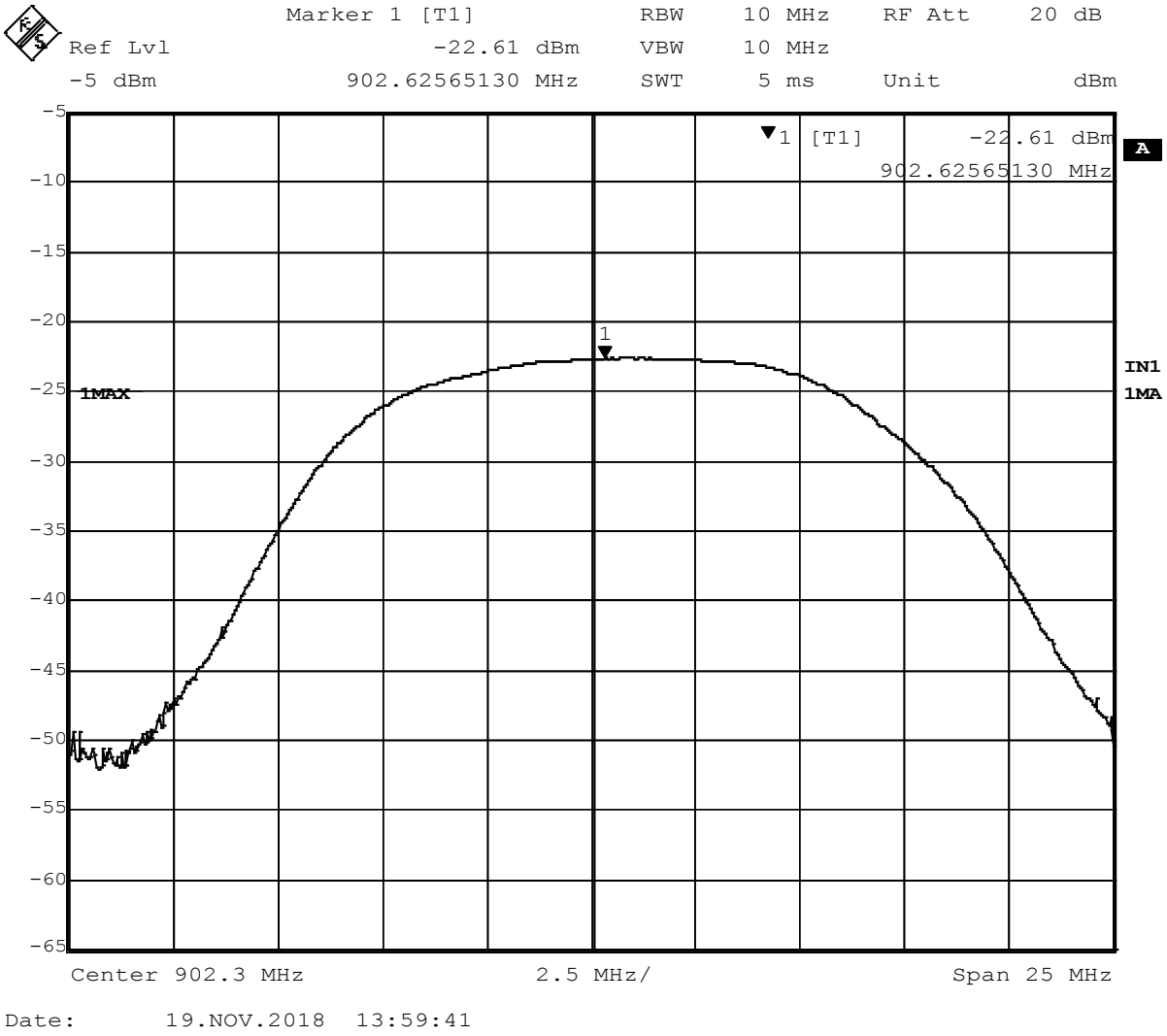

Figure 6 – Output Power, Low Channel

Maximum power = -22.61 dBm + 107 + CL + AF - 95.23 = 17.66 dBm

CL = cable loss = 4.70 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.

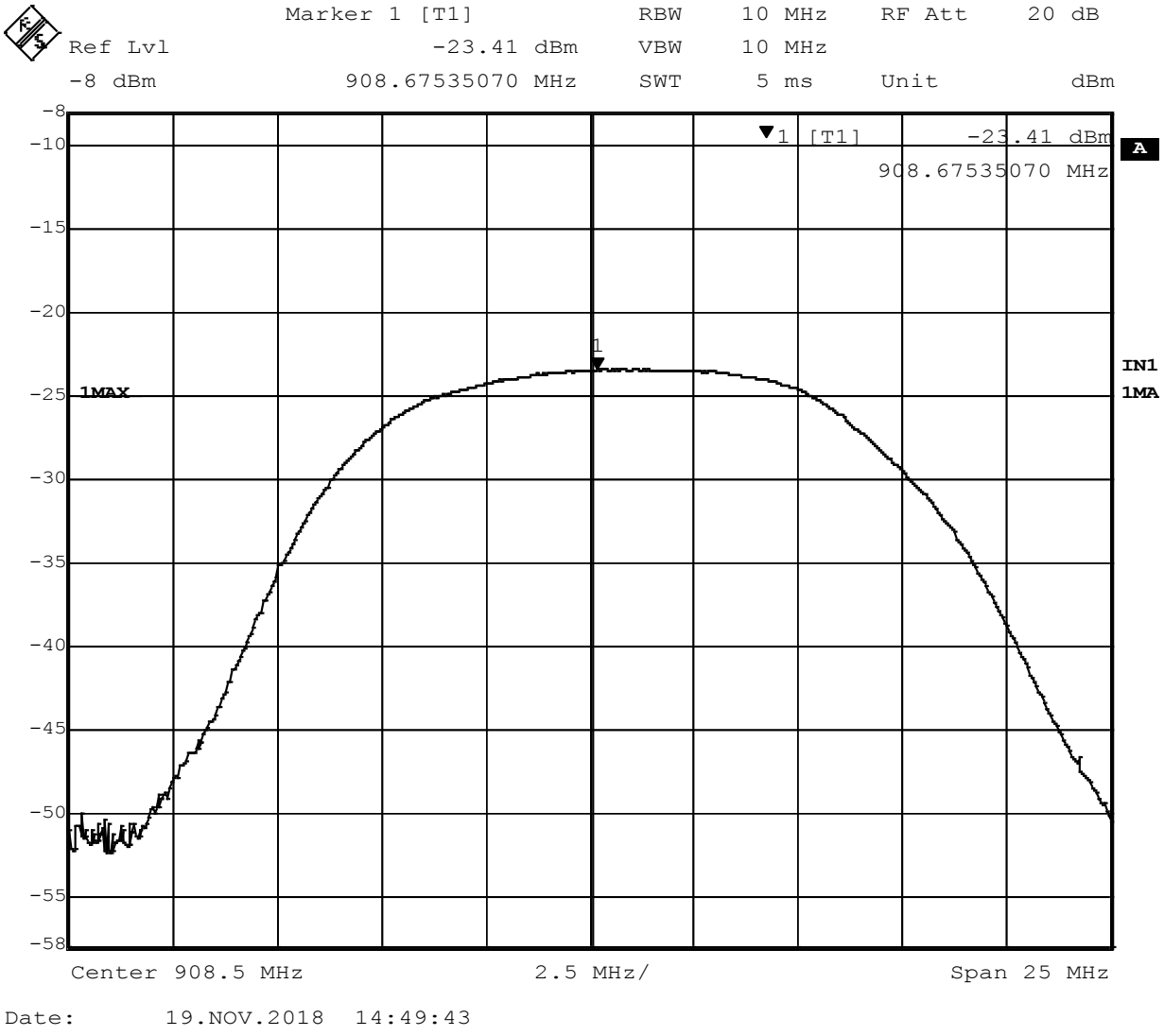

Figure 7 - Output Power, Mid Channel

Maximum power = -23.41 dBm + 107 + CL + AF - 95.23 = 16.76 dBm

CL = cable loss = 4.80 dB
AF = antenna factor = 23.60 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.

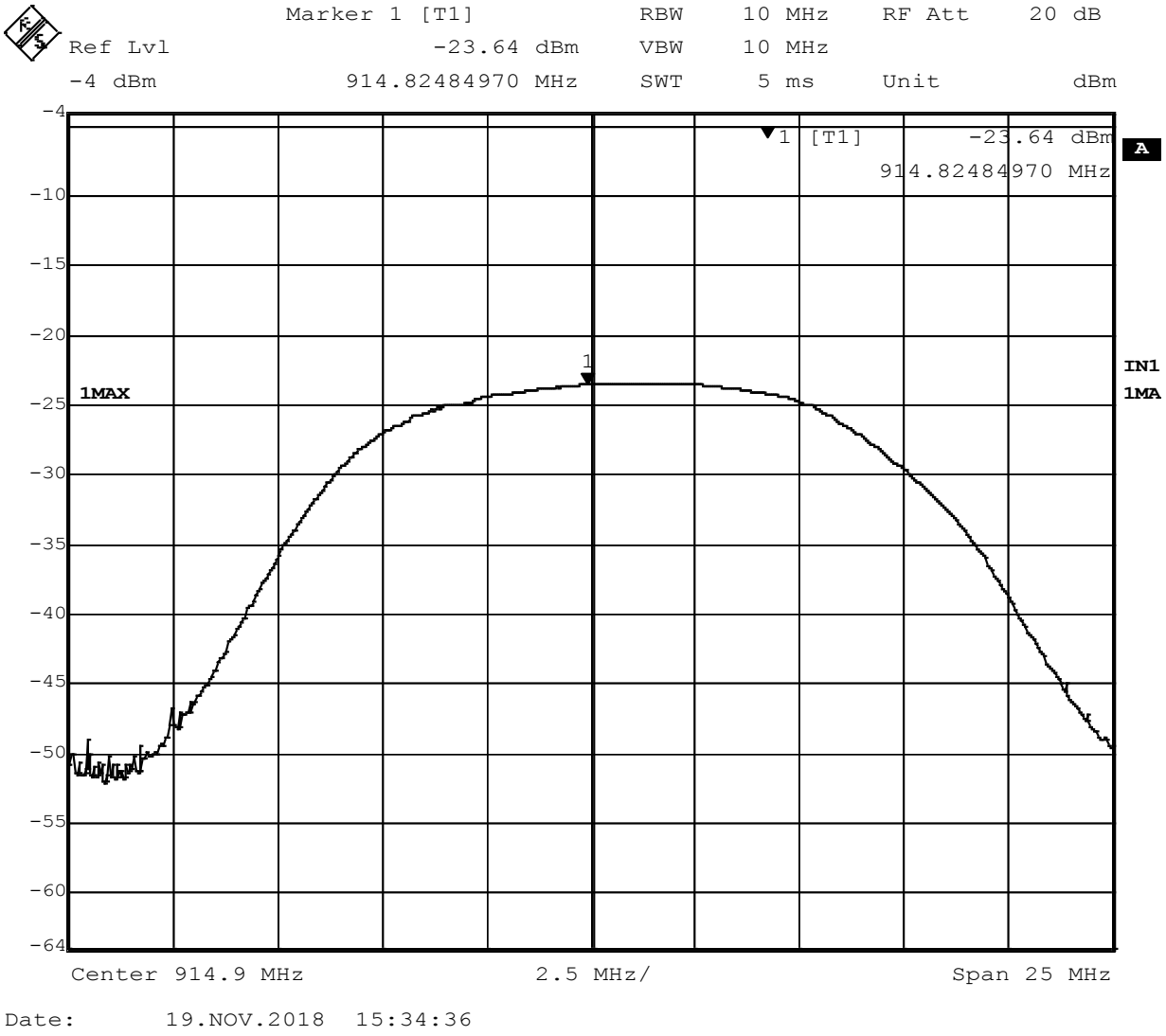

Figure 8 - Output Power, High Channel

Maximum power = -23.64 dBm + 107 + CL + AF - 95.23 = 16.43 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.

4.4 BANDWIDTH

Test Method: ANSI C63.10, Section(s) 6.9.2, 6.9.3

Limits of bandwidth measurements:
The Bandwidth measurements were reported for informational purposes only.

Test procedures:
The bandwidth of the fundamental frequency was measured by spectrum analyzer with 30 kHz RBW and 100 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.
99 % bandwidth function of the instrument was used to make this measurement.

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:

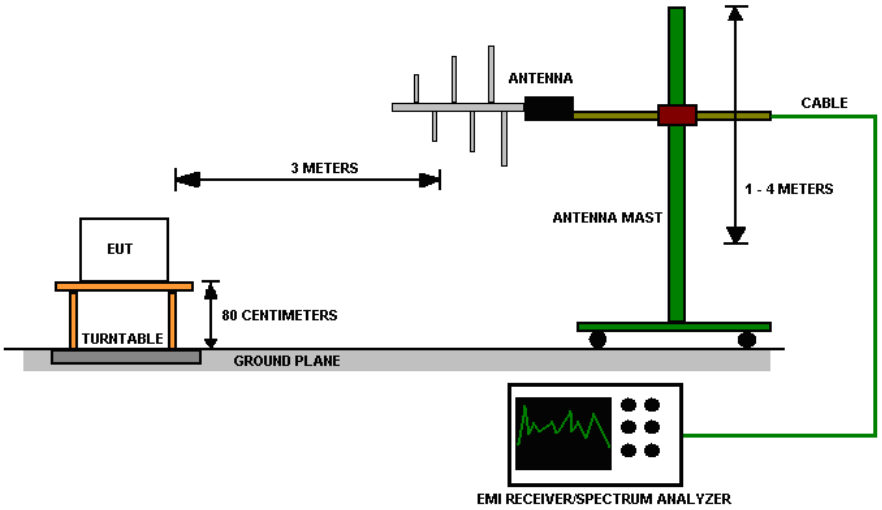

Figure 9 - Bandwidth Measurements Test Setup

EUT operating conditions:
The EUT was powered by 120 VAC 60 Hz 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)
LOW	902.30	185.37
MID	908.46	184.37
HIGH	914.90	186.37

6dB Bandwidth

CHANNEL	CHANNEL FREQUENCY (MHz)	6 dB BW (kHz)	20 dB BW* (kHz)
LOW	902.30	169.34	< 142.5
MID	908.46	168.34	< 142.5
HIGH	914.90	167.33	< 142.5

*20 dB bandwidth values were taken from PSD plots and overestimated from values on graph. The plots can be found in Figures 24 – 26, pages 38 – 40. Calculations are shown below each plot.

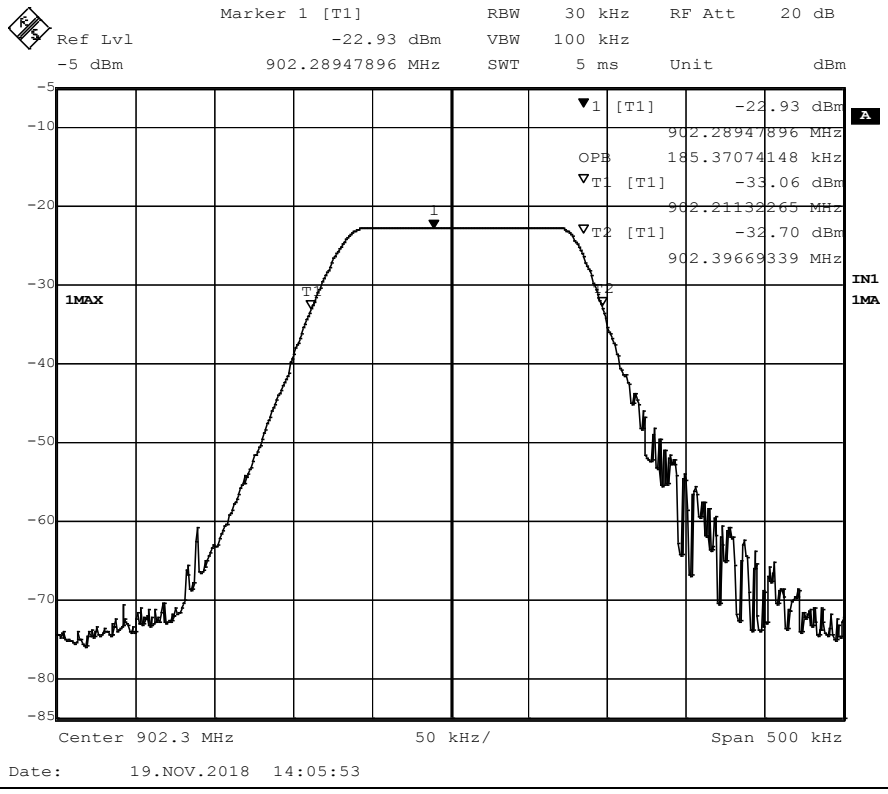

Figure 10 - 99% Occupied Bandwidth, Low Channel

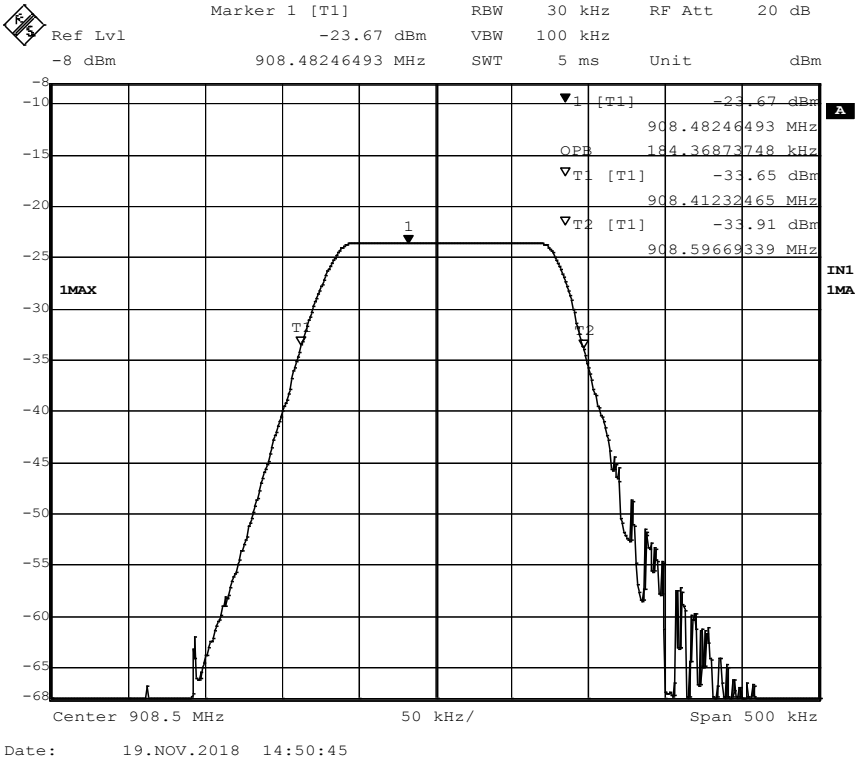

Figure 11 - 99% Occupied Bandwidth, Mid Channel

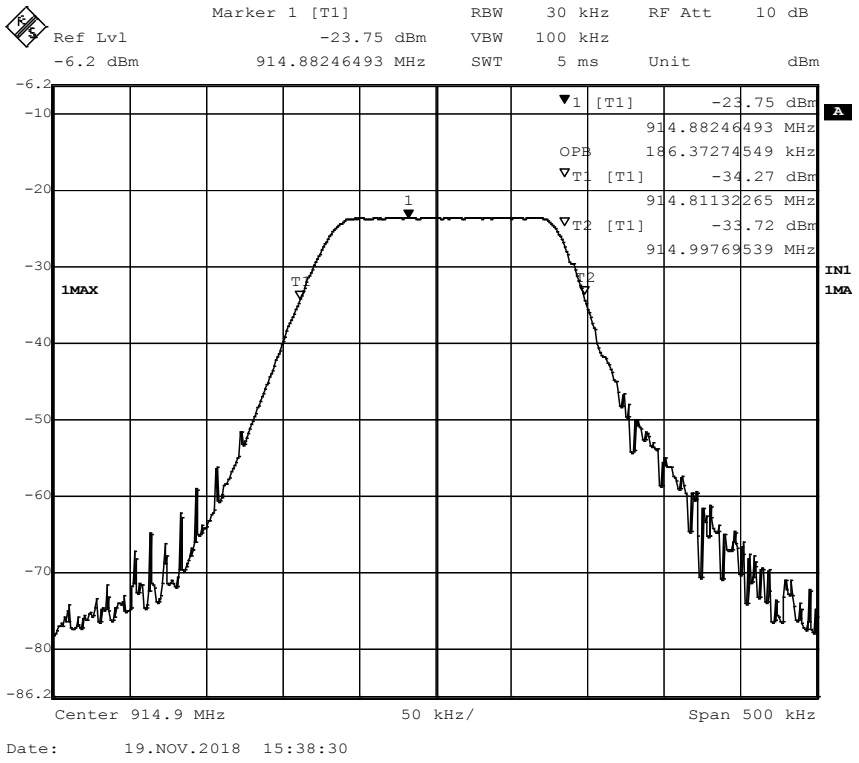

Figure 12 - 99% Occupied Bandwidth, High Channel

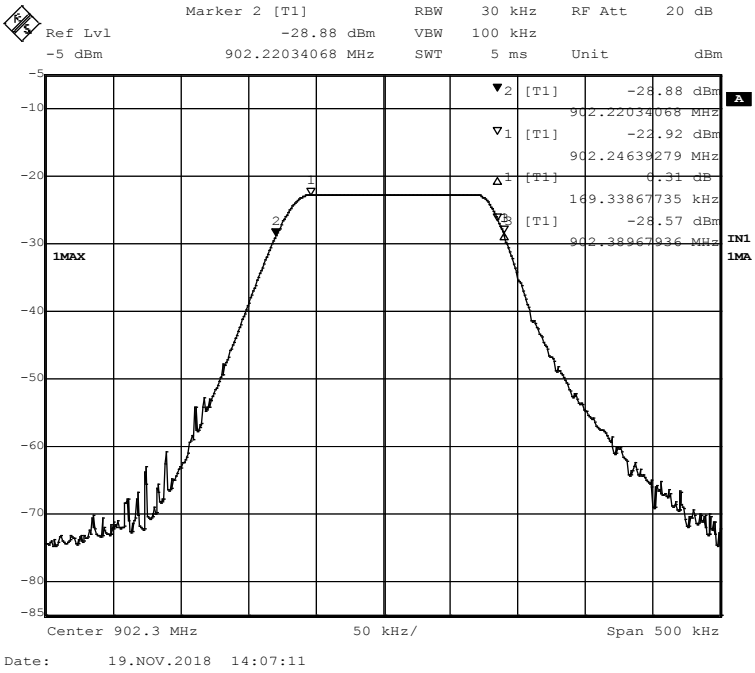

Figure 13 - 6dB Bandwidth, Low Channel

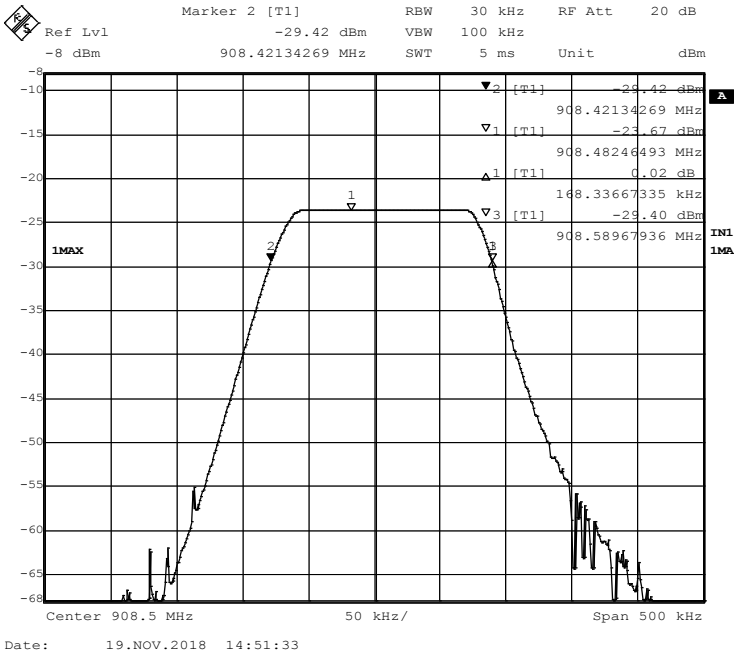

Figure 14 - 6dB Bandwidth, Mid Channel

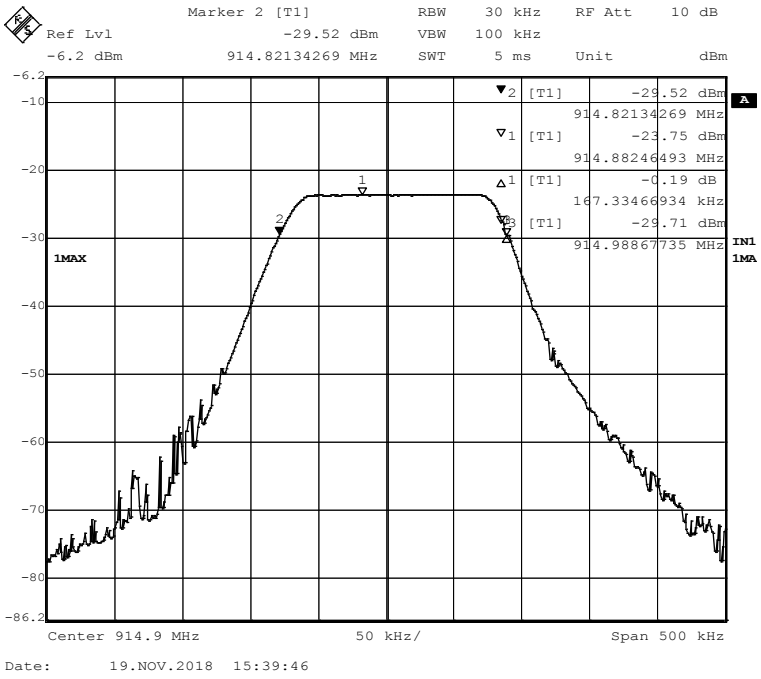

Figure 15 - 6dB Bandwidth, High Channel

4.5 BAND-EDGES

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

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

Test procedures:
The EUT was tested in the same method as described in section *4.4 - Bandwidth*. The EUT was oriented as to produce the maximum emission levels. The resolution bandwidth was set to 100 kHz and the EMI receiver was used to scan from the band-edge to the fundamental frequency with a 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:
See Section 4.2

EUT operating conditions:
The EUT was powered by 120 VAC 60 Hz 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	-101.76	-22.65	79.11	65.93	PASS
High, Continuous	960	-100.96	-23.60	77.36	65.81	PASS
Low Hopping	614.0	-101.41	-33.18	68.23	65.93	PASS
High, Hopping	960	-101.12	-32.00	69.12	65.81	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	-55.87	-22.65	33.22	20.00	PASS
High, Continuous	928.0	-69.91	-23.60	46.31	20.00	PASS
Low Hopping	902.0	-67.01	-33.18	33.83	20.00	PASS
High, Hopping	928.0	-80.49	-32.00	48.89	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 = 111.93 dBμV/m
Fundamental average field strength at 914.9 MHz for high channel = 111.81 dBμV/m

Low channel minimum delta = 111.93 – 46.0 dBμV/m = 65.93 dBc
High channel minimum delta = 111.81 – 46.0 dBμV/m = 65.81 dBc

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

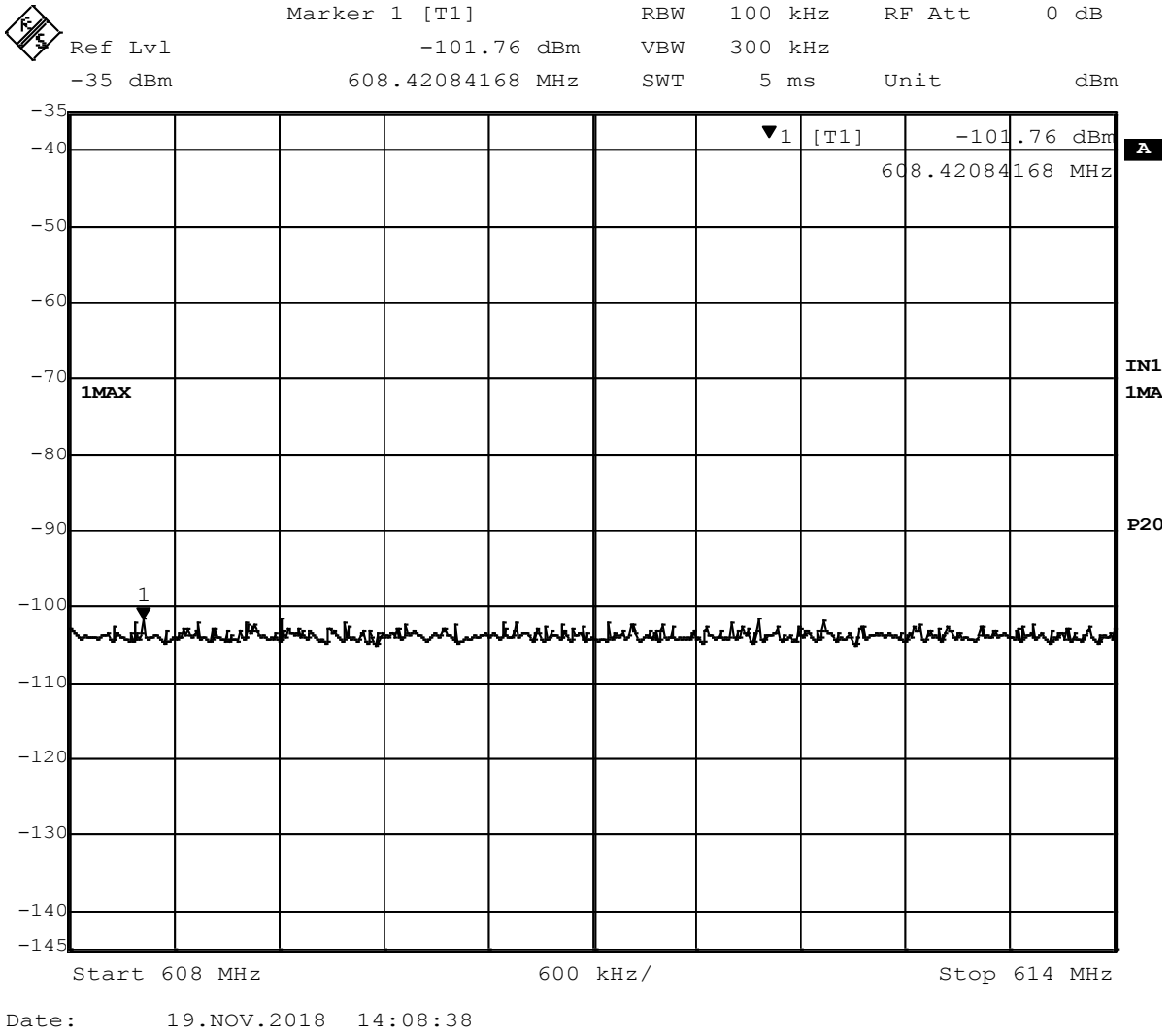

Figure 16 - Band-edge Measurement, Low Channel, Restricted Frequency, Continuous Transmit

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

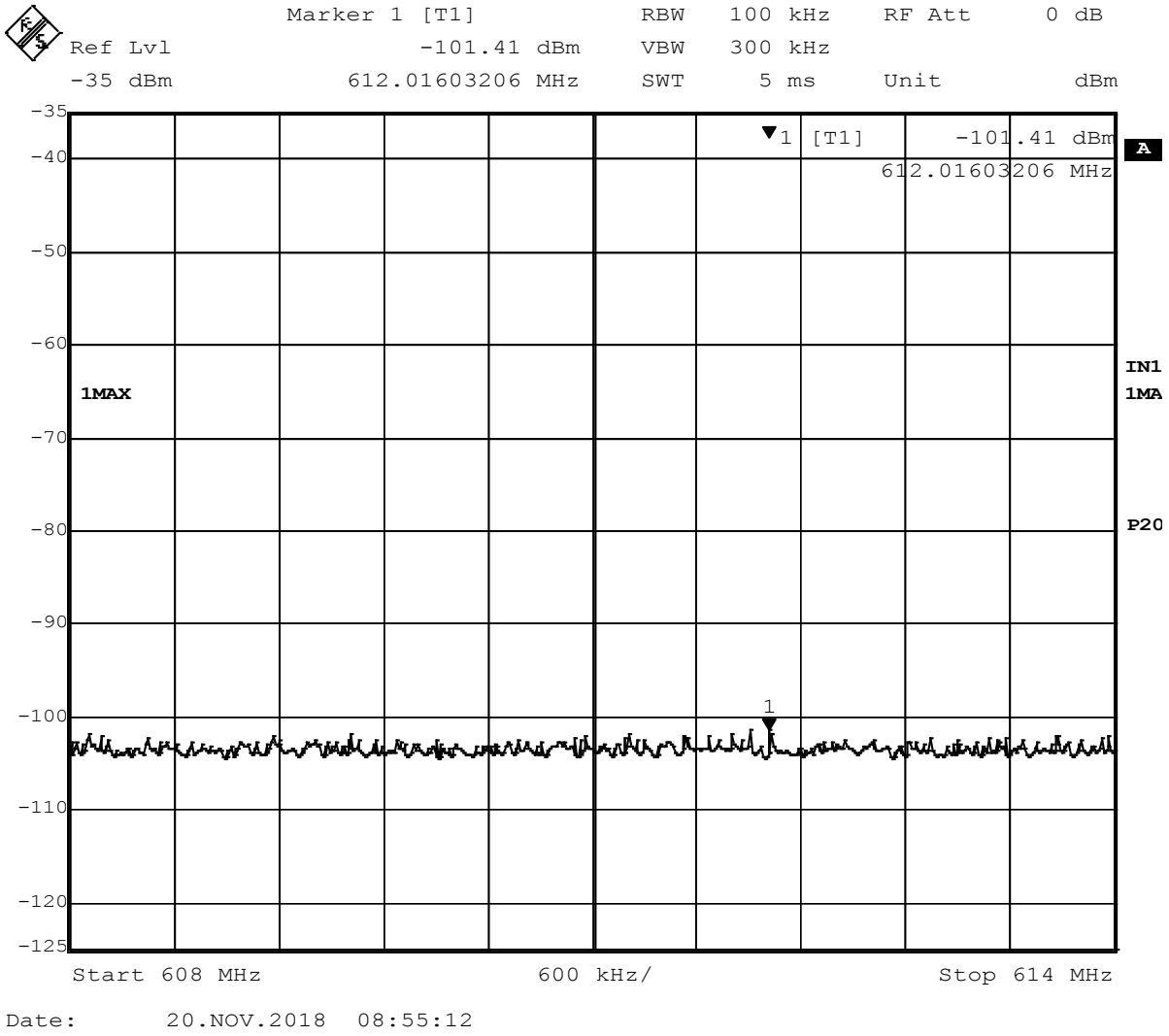

Figure 17 - Band-edge Measurement, Low Channel, Restricted Frequency, Hopping

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

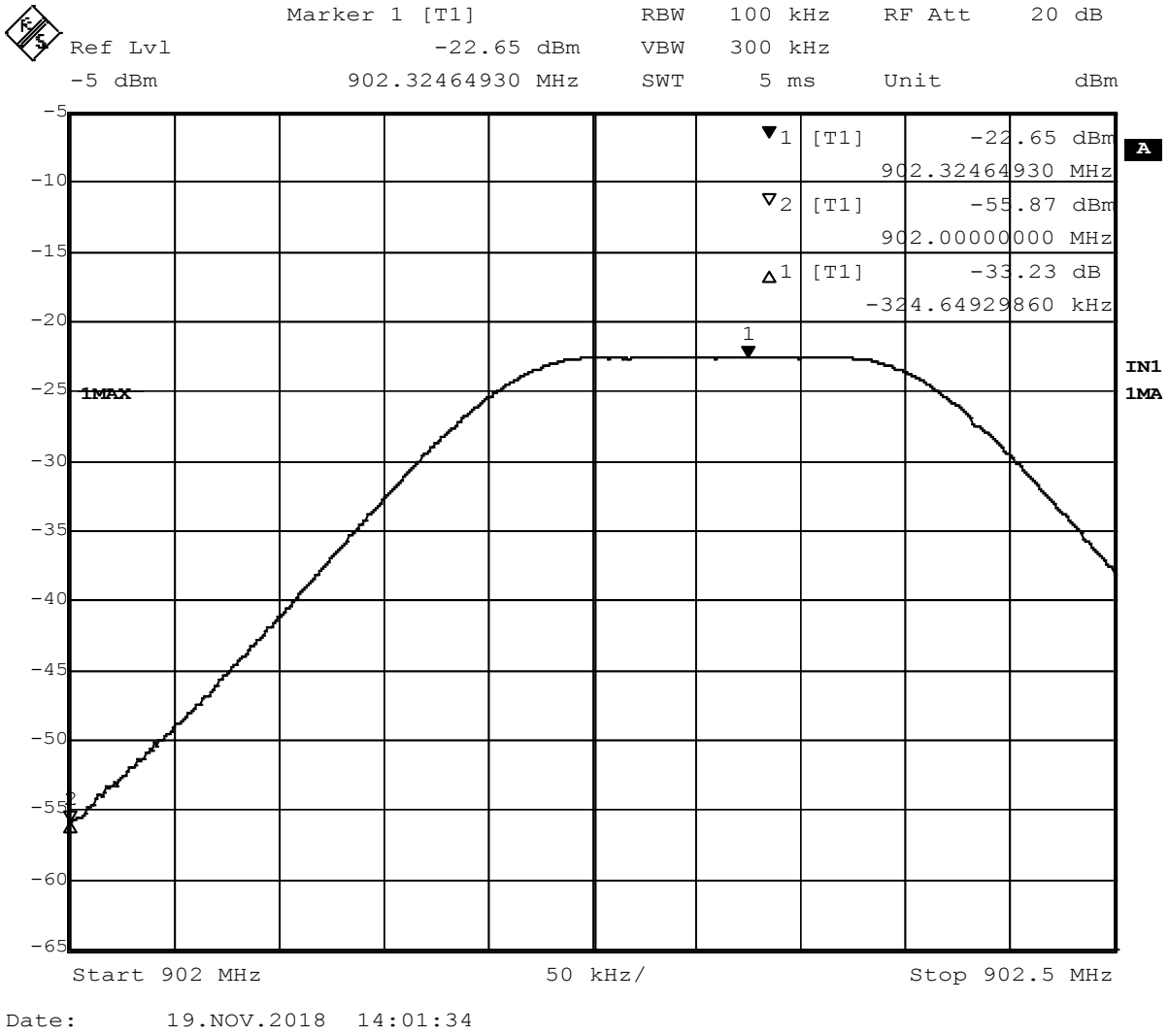

Figure 18 - Band-edge Measurement, Low Channel, Fundamental, Continuous Transmit

Figure 19 - Band-edge Measurement, Low Channel, Fundamental, Hopping Transmit

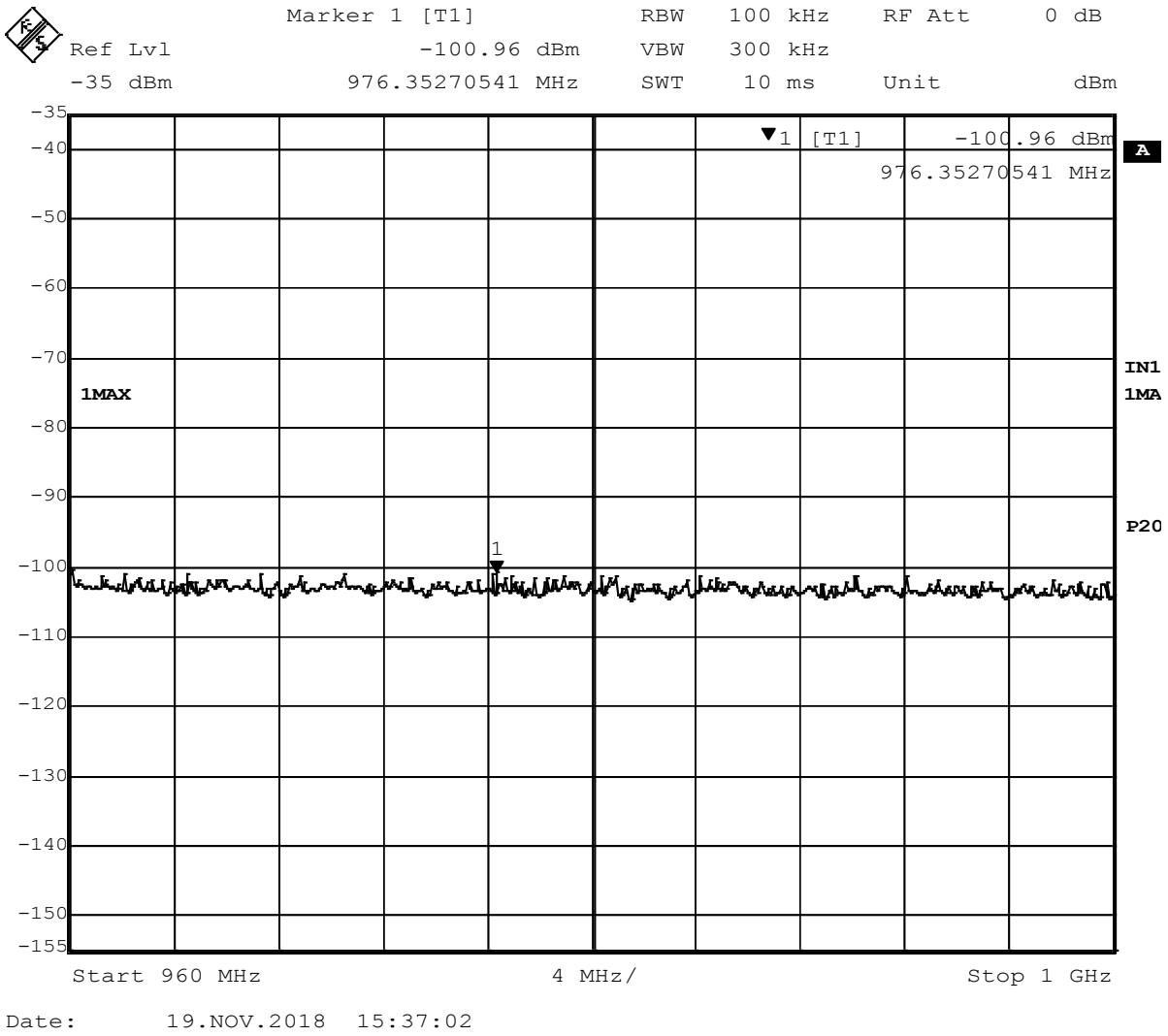

Figure 20 - Band-edge Measurement, High Channel, Restricted Frequency, Continuous Transmit

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

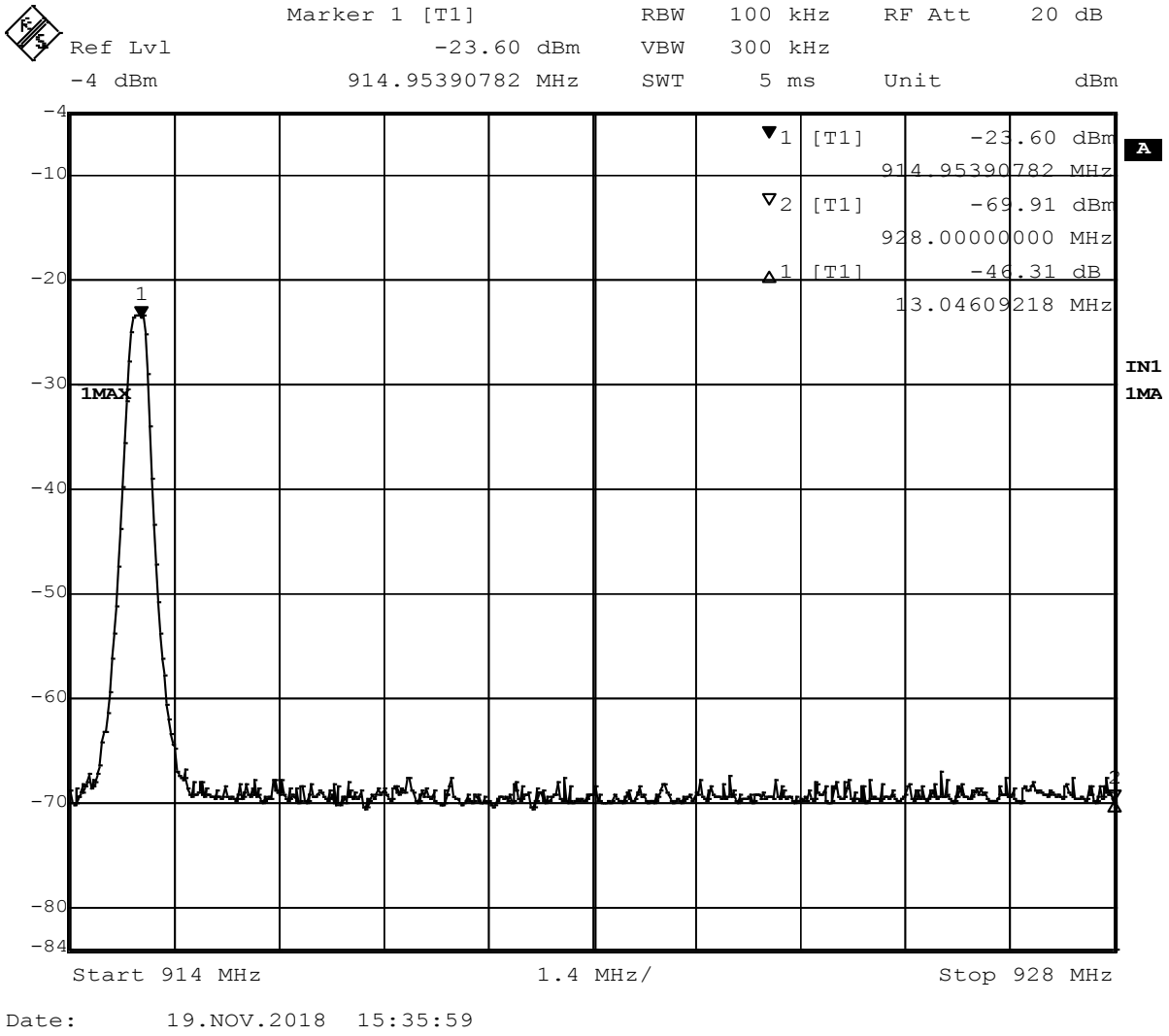

Figure 21 - Band-edge Measurement, High Channel, Fundamental, Continuous Transmit

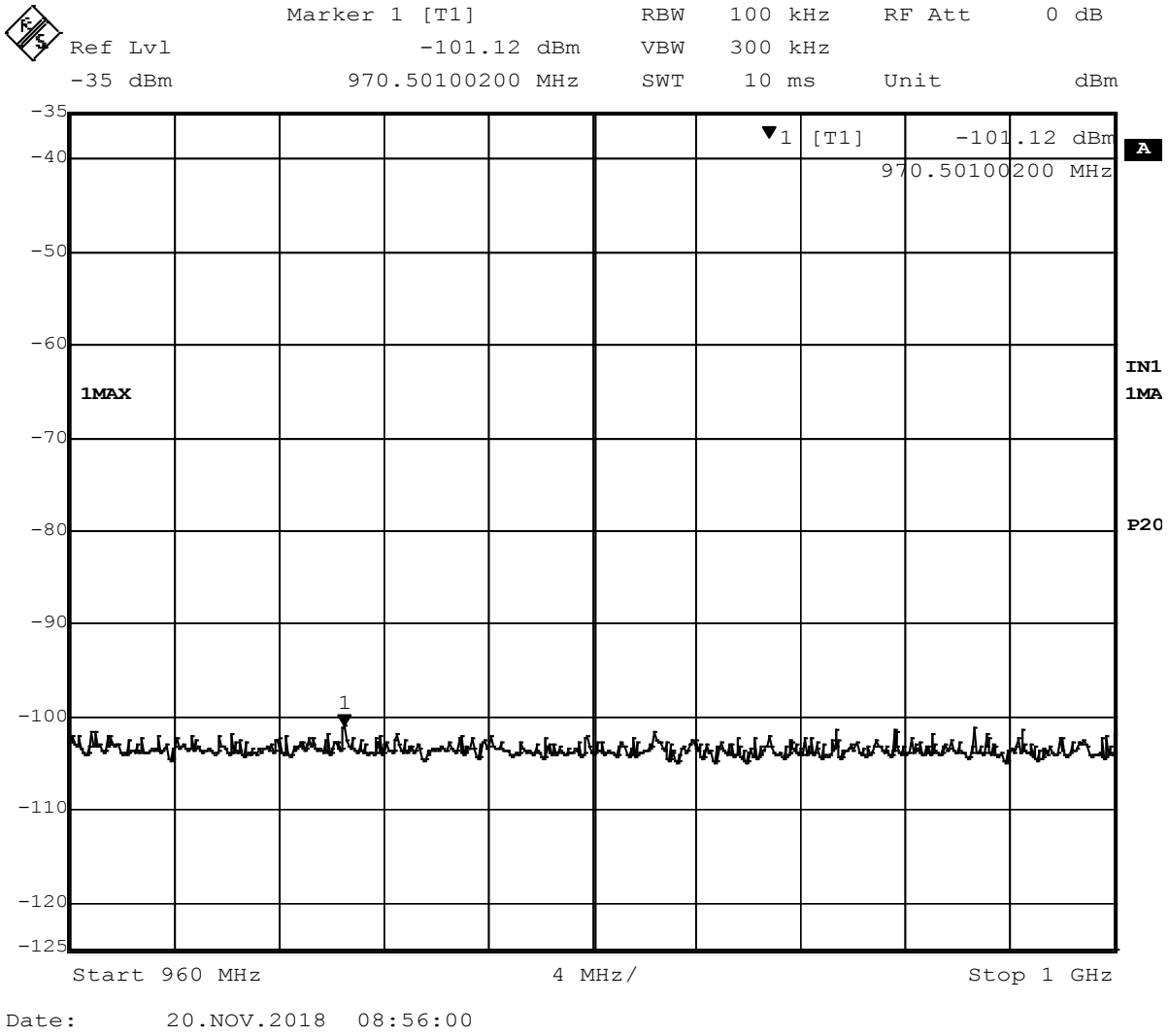

Figure 22 - Band-edge Measurement, High Channel, Restricted Frequency, Hopping

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

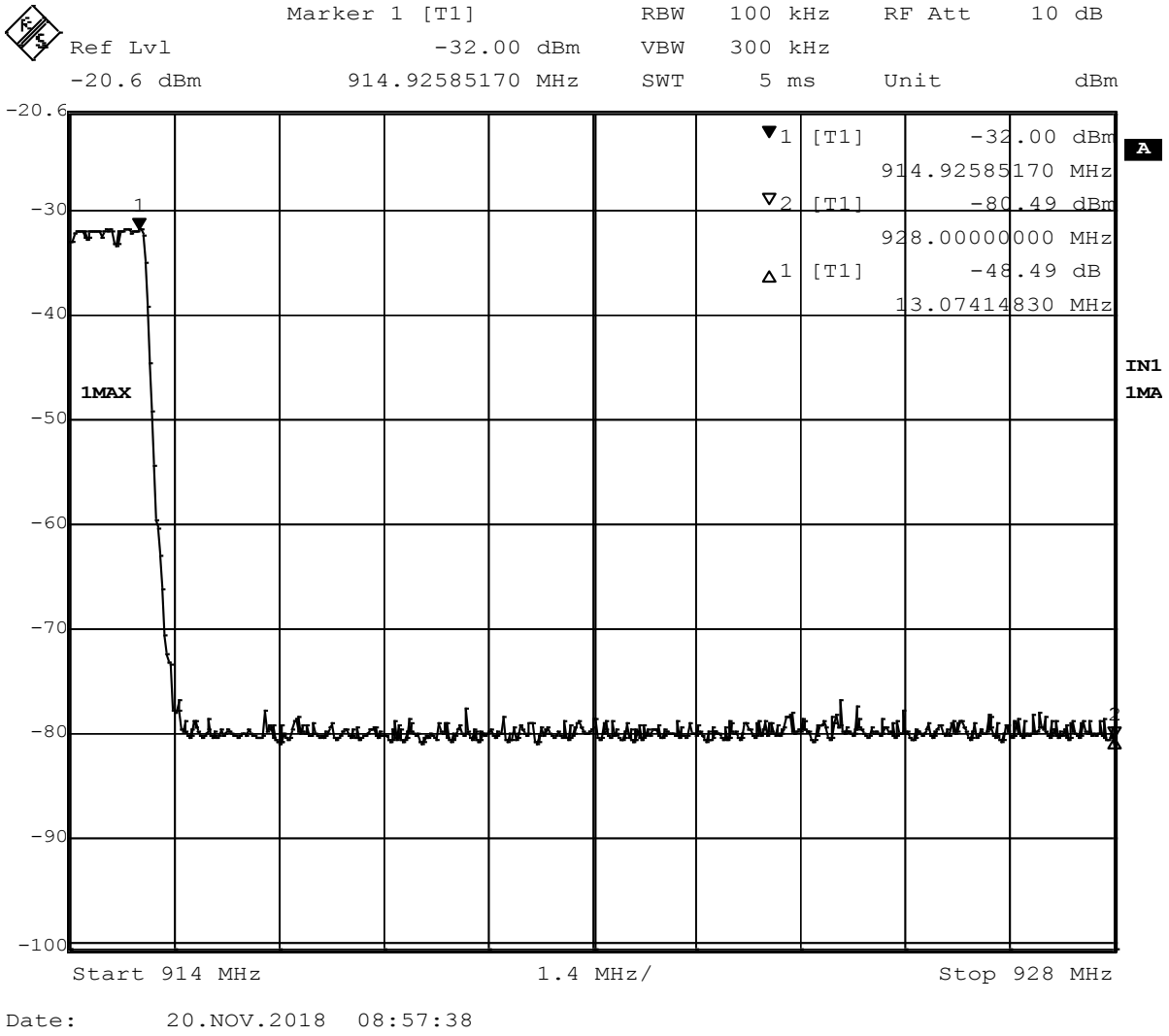

Figure 23 - Band-edge Measurement, High Channel, Fundamental, Hopping Transmit

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 tested at 3m test distance.

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:
See Section 4.2

EUT operating conditions:
The EUT was powered by 120 VAC 60 Hz 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 FREQUENCY (MHz)	EIRP RF POWER LEVEL IN # KHz BW (dBm)	Method	MAXIMUM POWER LIMIT (dBm)	RESULT
902.3	1.95	EIRP	8	Pass
908.5	1.58	EIRP	8	Pass
914.9	1.42	EIRP	8	Pass

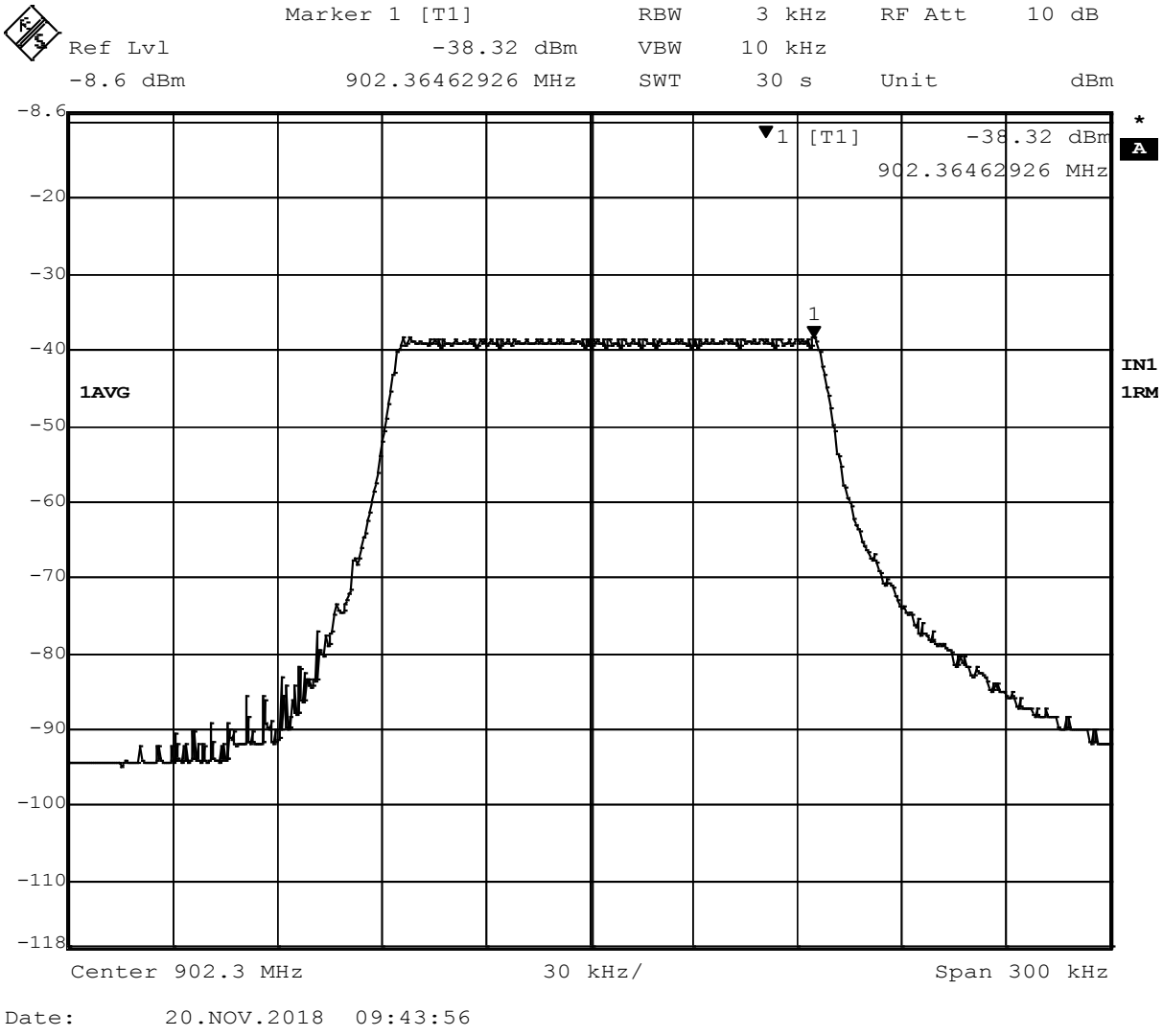

Figure 24 - Power Spectral Density, Low Channel

Maximum power = -38.32 dBm + 107 + CL + AF - 95.23 = 1.95 dBm

CL = cable loss = 4.70 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.

20 dB BW = < 135 kHz
value was taken from estimating to closest 0.25 delineation and rounding up to over-estimate
30 kHz per delineation x (4 + 0.25 + 0.5) = 142.5 kHz

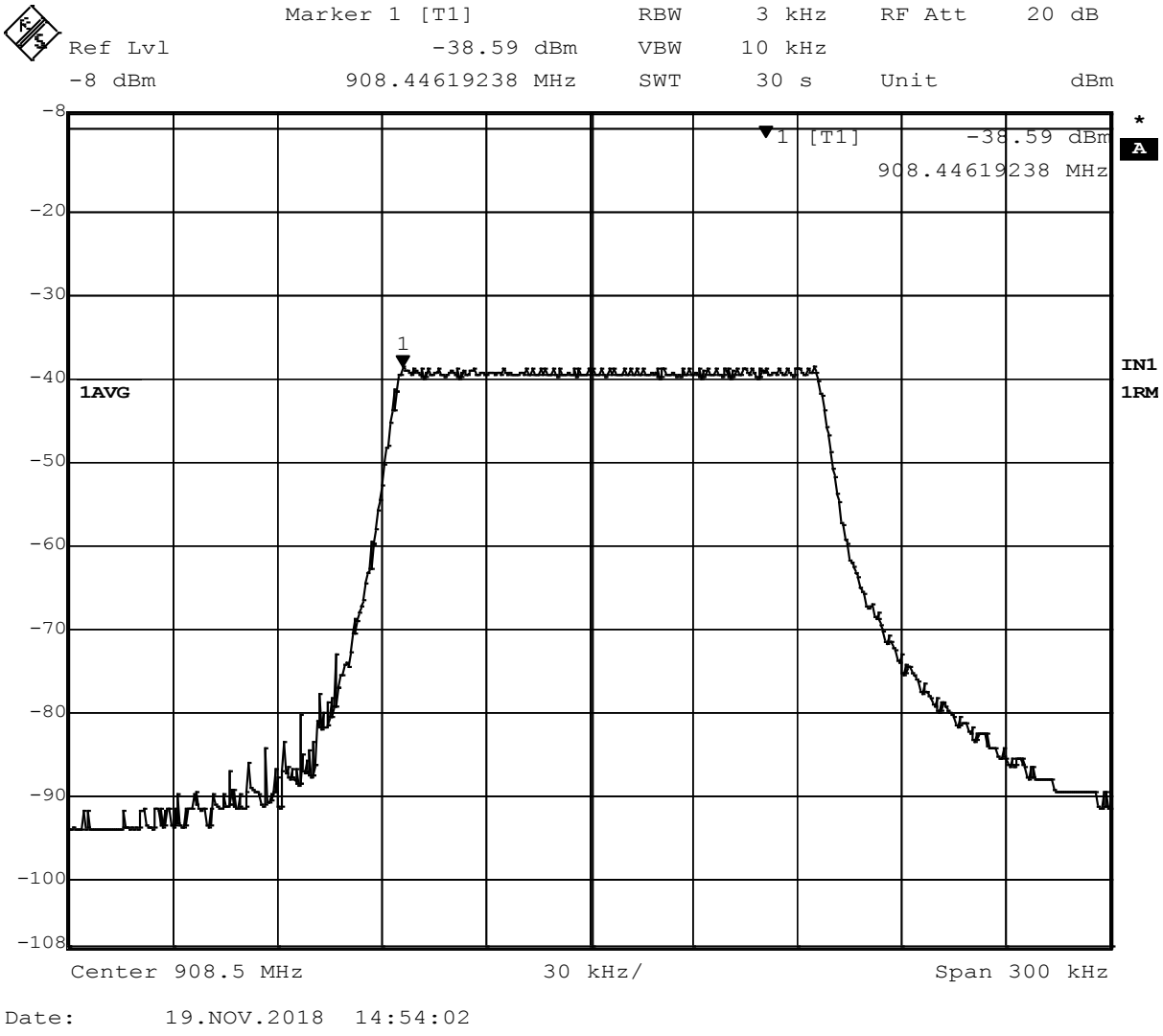

Figure 25 - Power Spectral Density, Mid Channel

Maximum power = -38.59 dBm + 107 + CL + AF - 95.23 = 1.58 dBm

CL = cable loss = 4.80 dB
AF = antenna factor = 23.60 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.

20 dB BW = < 135 kHz
value was taken from estimating to closest 0.25 delineation and rounding up to over-estimate
30 kHz per delineation x (4 + 0.25 + 0.5) = 142.5 kHz

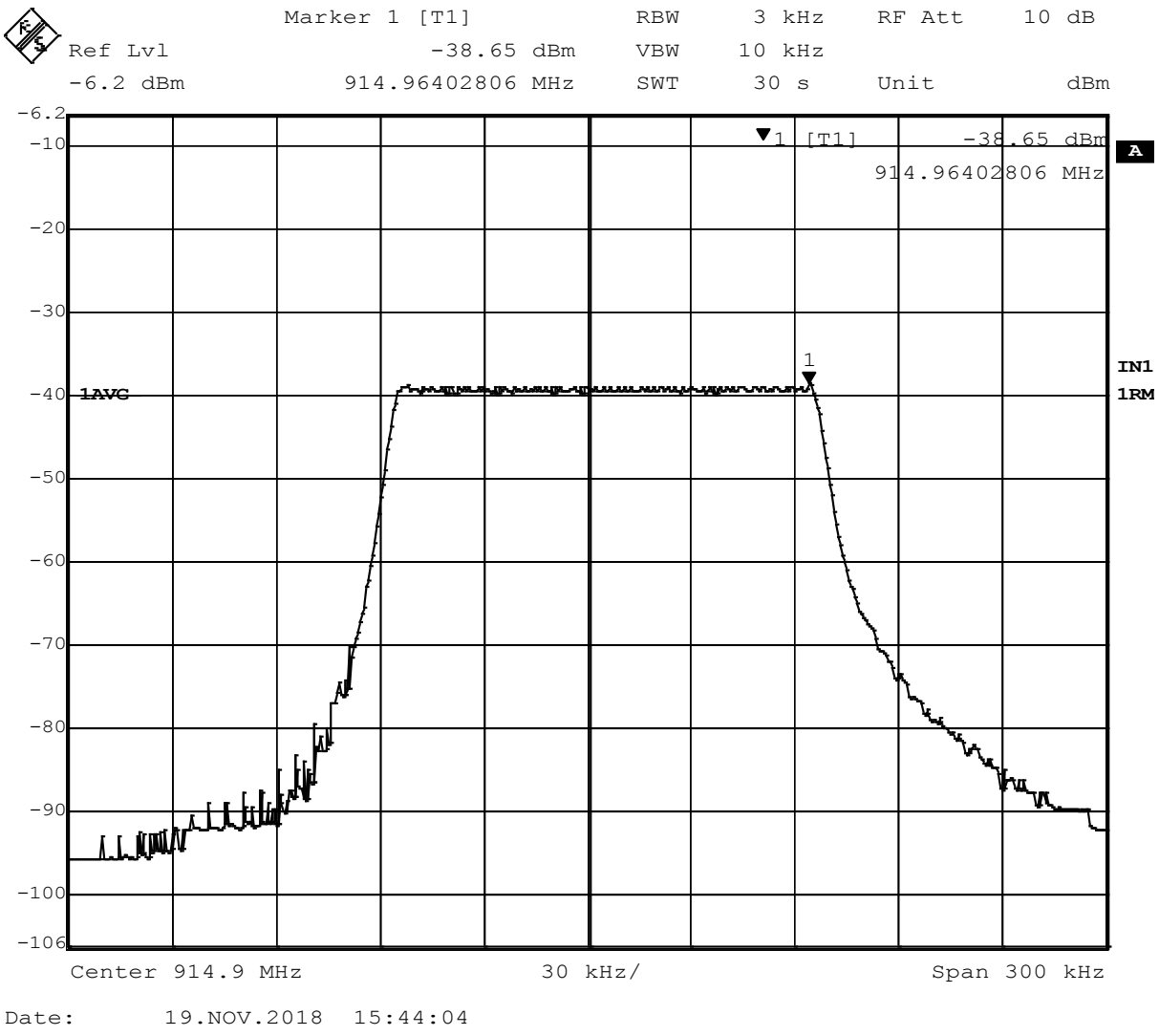

Figure 26 - Power Spectral Density, High Channel

Maximum PSD= -38.65 dBm + 107 + CL + AF - 95.23 = 1.42 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.

20 dB BW = < 135 kHz
value was taken from estimating to closest 0.25 delineation and rounding up to over-estimate
30 kHz per delineation x (4 + 0.25 +0.5) = 142.5 kHz

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:
See Section 4.2

EUT operating conditions:
The EUT was powered by 120 VAC 60 Hz 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:

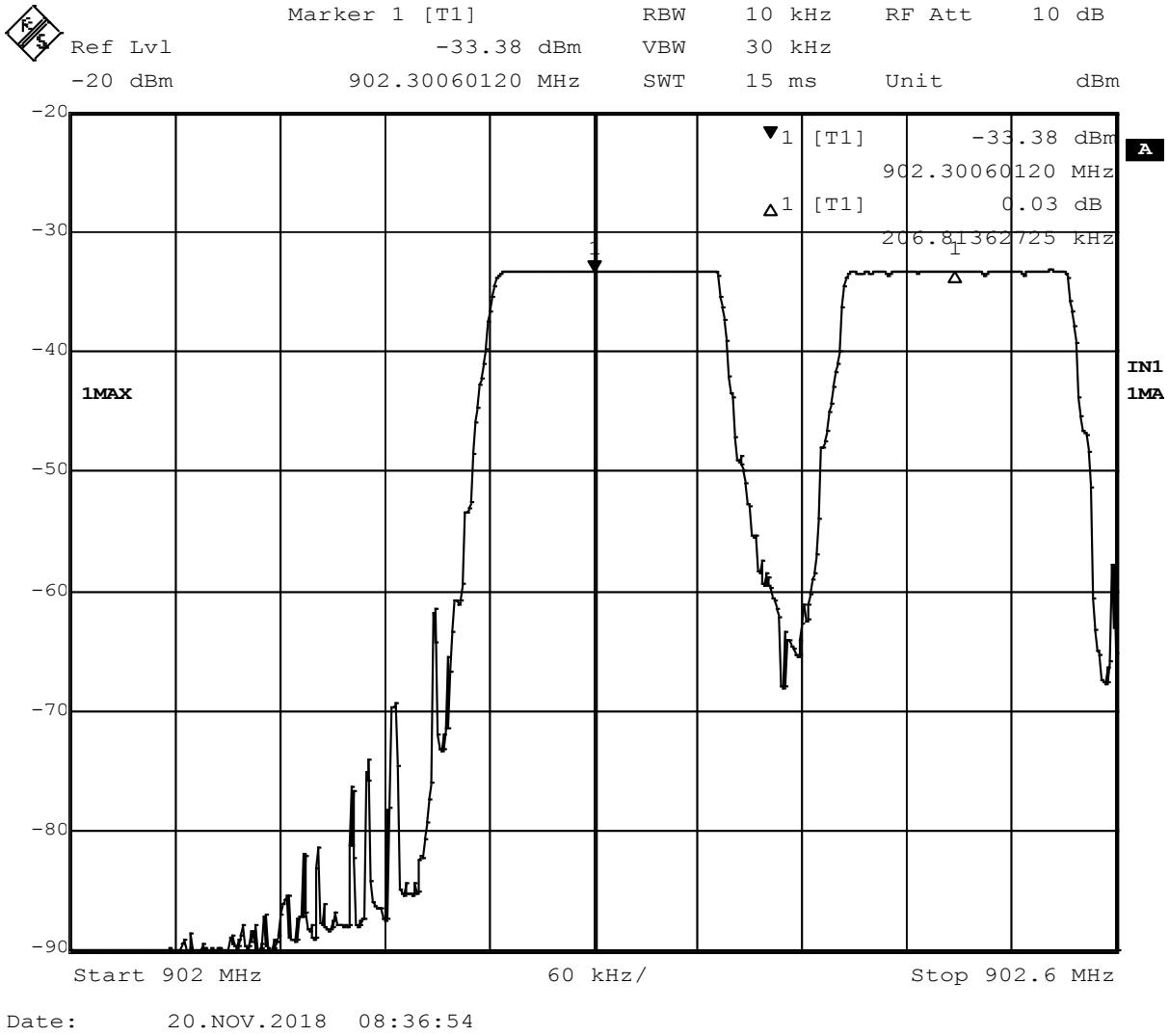

Figure 27 – Frequency Separation, 206.81 kHz

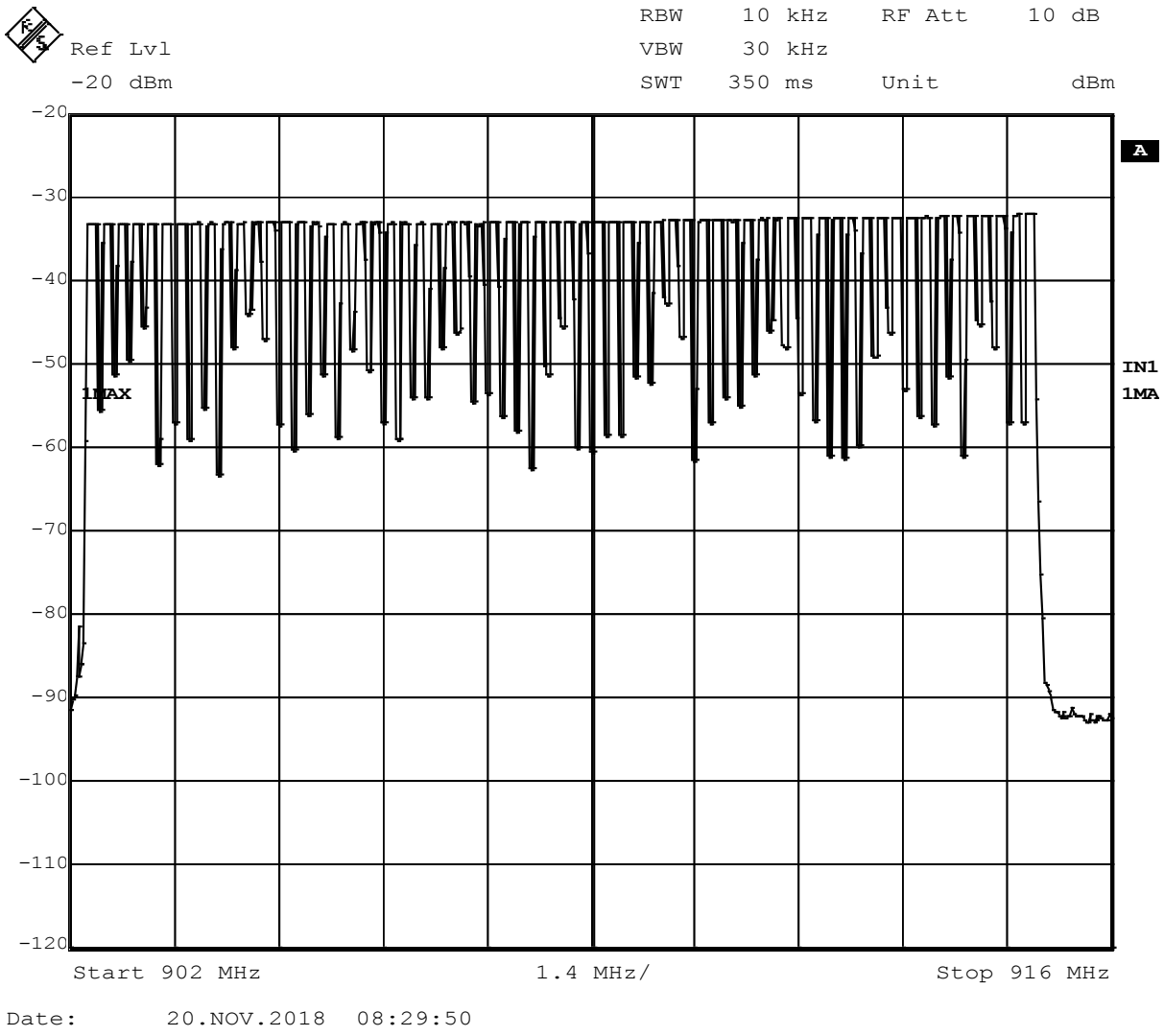

Figure 28 – Hop Count, 64 Hops

Note: Test firmware activated all 64 channels, so they were all tested. The final firmware will only use a subset of the measured channels and it will be locked in so that it cannot be changed by the end user.

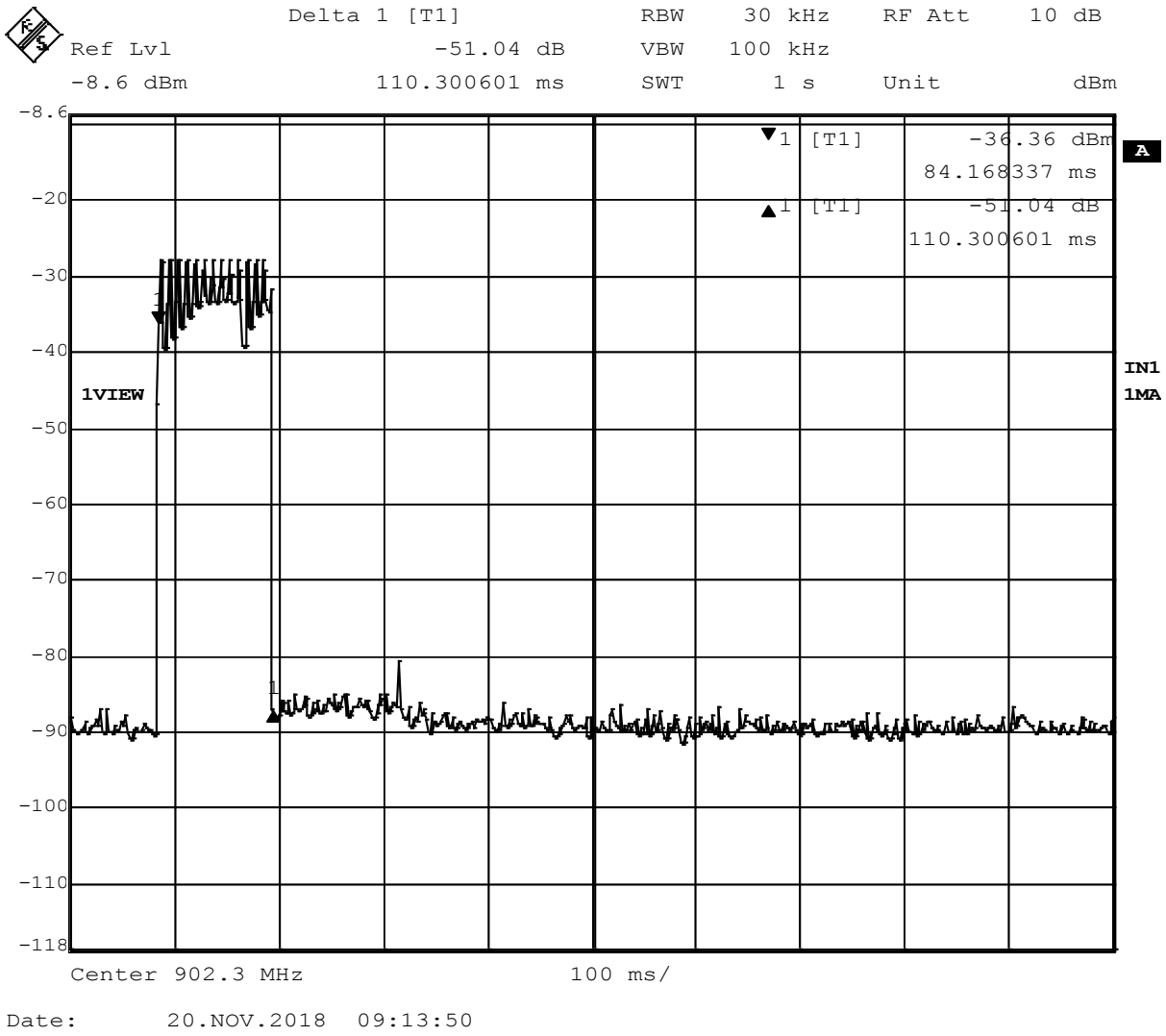

Figure 29 – Time of Occupancy, On Time, 110.30 ms

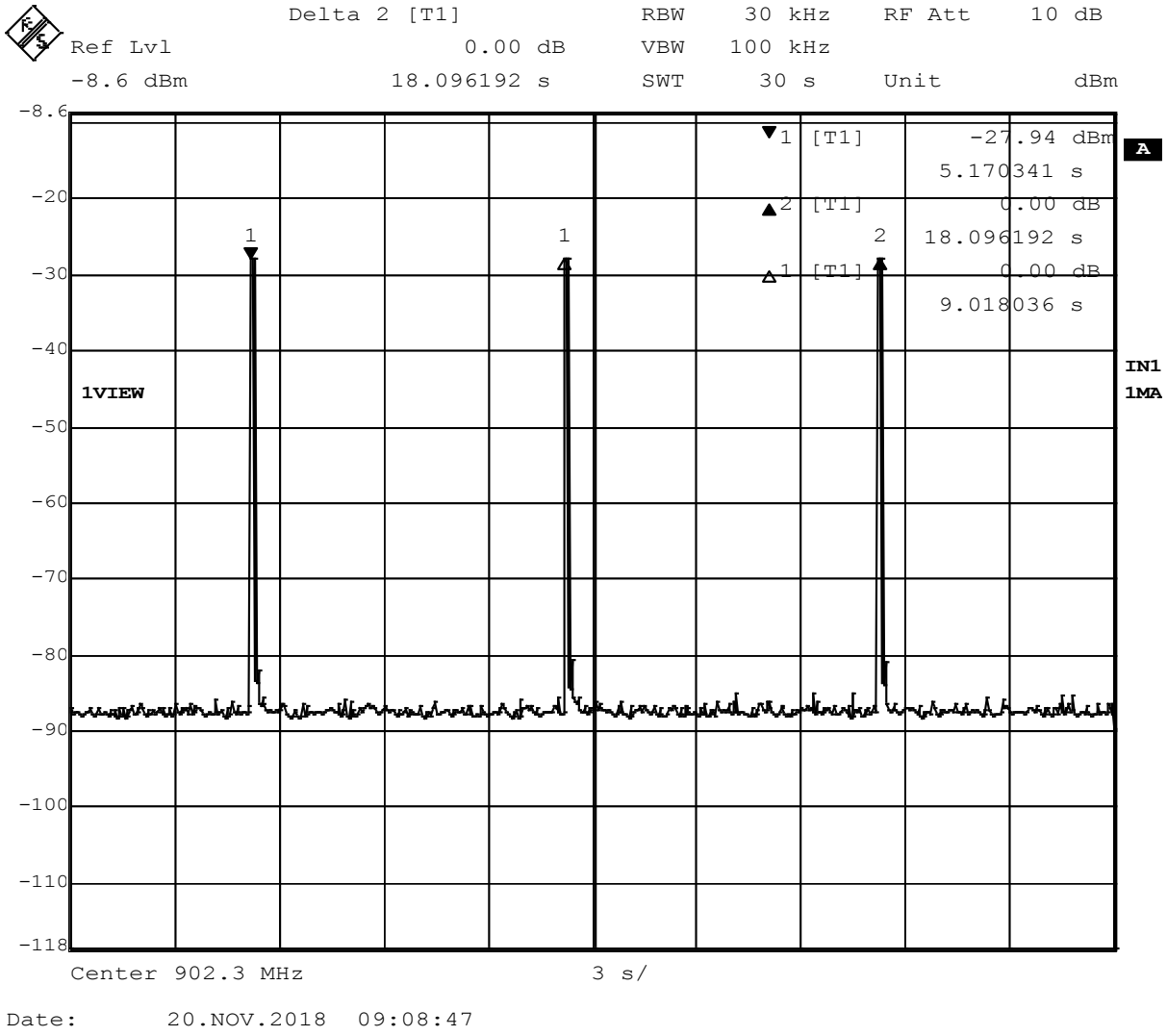

Figure 30 – Time of Occupancy, Period

*Maximum of 2 transmissions can occur in a given channel in any 10 s so the average time of occupancy is 110.30 ms x 2 =220.60 ms = 0.22 s < 0.4 s – Pass

Duty cycle = 22% in a 10 second period

4.8 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 120 VAC 60 Hz 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:

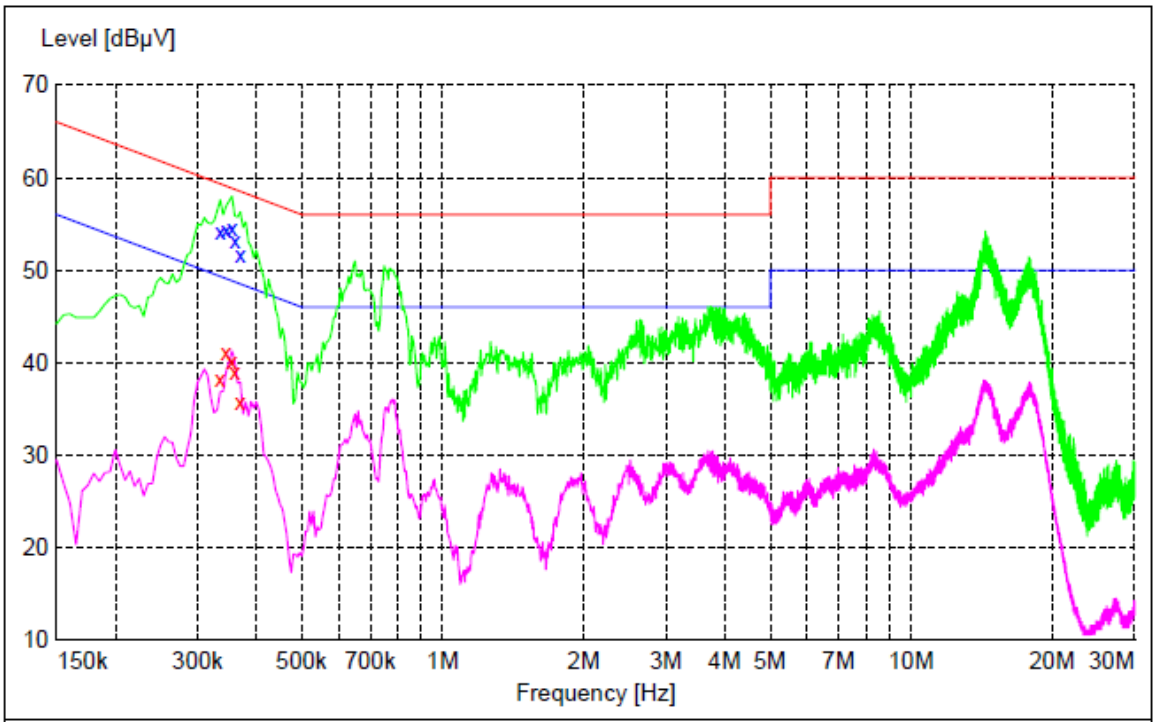

Figure 31 - Conducted Emissions Plot

Table 9 - Conducted Emissions Peak Measurements

Frequency	Level	Limit	Margin	Line	PE
MHz	dBµV/m	dBµV/m	dB		
0.335000	54.10	59.00	5.20	L2	GND
0.345000	54.40	59.00	4.70	L2	GND
0.355000	54.50	59.00	4.40	L2	GND
0.360000	53.20	59.00	5.60	L1	GND
0.370000	51.70	59.00	6.80	L2	GND

Table 10 - Conducted Emissions Average Measurements

Frequency	Level	Limit	Margin	Line	PE
MHz	dBµV/m	dBµV/m	dB		
0.335000	38.20	49.00	11.20	L1	GND
0.345000	41.20	49.00	7.80	L2	GND
0.355000	40.10	49.00	8.80	L1	GND
0.360000	39.00	49.00	9.70	L1	GND
0.370000	35.70	49.00	12.80	L1	GND

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