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FCC/ISED Test Report

Prepared for: Garmin International Inc.

Address: 1200 E. 151st Street
Olathe, Kansas, 66062, USA

Product: A03645

Test Report No: R20181219-20-13B

Approved by:

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

DATE: 15 July 2019

Total Pages: 96

REVISION PAGE

Rev. No.	Date	Description
0	21 June 2019	Original – NJohnson Prepared by KVepuri/CFarrington
A	15 July 2019	Includes NCEE Labs report R20181219-20-13 and its amendment in full -NJ
B	13 August 2019	Includes NCEE Labs report R20181219-20-13A and its amendment in full. -NJ

CONTENTS

1.0 SUMMARY OF TEST RESULTS

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

APPLIED STANDARDS AND REGULATIONS		
Standard Section	**Test Type**	**Result**
FCC Part 15.35 RSS Gen, Issue 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 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

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

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

Summary

The Equipment Under Test (EUT) was a battery powered device. It features 802.11b, 802.11g, 802.11n, and has transmit and receives capabilities.

EUT	A03645
EUT Received	16 April 2019
EUT Tested	5 June 2019- 12 June 2019
Serial No.	3991631270 (radiated unit); 3991631460 (conducted unit)
Operating Band	2400 – 2483.5 MHz
Device Type	802.11 b, 802.11 g, 802.11 n
Power Supply	Internal Battery/ Charger: Garmin (Phi Hong) MN: PSAI10R-050Q (Representative Power Supply)

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	2412 MHz
Mid	2437 MHz
High	2462 MHz

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, middle and highest frequency channels.

The EUT was tested for spurious emissions while running off of battery power.

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	Nic Johnson	Technical Manager	Review/editing
2	Karthik Vepuri	Test Engineer	Testing and report
3	Caleb Farrington	Test Technician	Testing and report
4	Chase Jacobson	Test Technician	Testing and report

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 2020
Keysight EXA Signal Analyzer	N9010A	MY56070862	14 Dec 2018	14 Dec 2020
Rohde & Schwarz Test Receiver	ES17	100007	31 Jul 2017	31 Jul 2018
EMCO Biconilog Antenna	3142B	1647	02 Aug 2017	02 Aug 2019
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 2020*
Trilithic High Pass Filter	6HC330	23042	09 Mar 2018*	09 Mar 2020*
Rohde & Schwarz LISN	ESH3-Z5	836679/010	26 Jul 2018	26 Jul 2019
Rohde & Schwarz Test Software	ES-K1	12575	NA	NA
RF Cable (preamplifier to antenna)	MFR-57500	01-07-002	09 Mar 2018*	09 Mar 2020*
RF Cable (antenna to 10m chamber bulkhead)	FSCM 64639	01E3872	09 Mar 2018*	09 Mar 2020*
RF Cable (10m chamber bulkhead to control room bulkhead)	FSCM 64639	01E3874	09 Mar 2018*	09 Mar 2020*
RF Cable (Control room bulkhead to RF switch)	FSCM 64639	01E3871	09 Mar 2018*	09 Mar 2020*
RF Cable (RF switch to test receiver)	FSCM 64639	01F1206	09 Mar 2018*	09 Mar 2020*
RF switch – Rohde and Schwarz	TS-RSP	1113.5503.14	09 Mar 2018*	09 Mar 2020*
N connector bulkhead (10m chamber)	PE9128	NCEEBH1	09 Mar 2018*	09 Mar 2020*
N connector bulkhead (control room)	PE9128	NCEEBH2	09 Mar 2018*	09 Mar 2020*

*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: NA

4.2 OUTPUT POWER

Test Method: ANSI C63.10:

1. Section(s) 11.9.1.2 “Integrated Band Power Method”

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

Test procedures:
The EUT was connected to a spectrum analyzer directly with a low-loss shielded coaxial cable with 100 MHz RBW and 300 MHz VBW. Power was determined using an integrated channel power measurement.

Deviations from test standard:
No deviation.

Test setup:

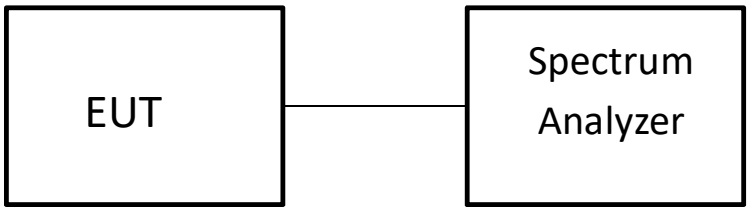

Figure 1 – Peak Output Power Measurements Test Setup

EUT operating conditions:
The EUT was powered by internal battery power unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range on each indicated modulation.

Test results:

The uncertainty for conducted peak power measurements is ±1.1 dB and average power is ±1.37 dB

Peak Output Power

CHANNEL	CHANNEL FREQUENCY (MHz)	PEAK OUTPUT POWER (dBm)	PEAK OUTPUT POWER (mW)	Method	RESULT	Transmitter
Low	2412	18.91	77.80	Conducted	PASS	b
Mid	2440	17.42	55.21	Conducted	PASS	b
High	2460	16.26	42.27	Conducted	PASS	b
Low	2412	20.88	122.46	Conducted	PASS	g
Mid	2440	19.87	97.05	Conducted	PASS	g
High	2460	19.38	86.70	Conducted	PASS	g
Low	2412	21.00	125.89	Conducted	PASS	n
Mid	2440	19.98	99.54	Conducted	PASS	n
High	2460	18.87	77.09	Conducted	PASS	n

Average Output Power

CHANNEL	CHANNEL FREQUENCY (MHz)	PEAK OUTPUT POWER (dBm)	PEAK OUTPUT POWER (mW)	Method	RESULT	Transmitter
Low	2412	11.07	12.79	Conducted	PASS	b
Mid	2440	10.34	10.81	Conducted	PASS	b
High	2460	10.25	10.59	Conducted	PASS	b
Low	2412	12.35	17.18	Conducted	PASS	g
Mid	2440	11.51	14.16	Conducted	PASS	g
High	2460	10.25	10.59	Conducted	PASS	g
Low	2412	13.62	23.01	Conducted	PASS	n
Mid	2440	12.34	17.14	Conducted	PASS	n
High	2460	11.11	12.91	Conducted	PASS	n

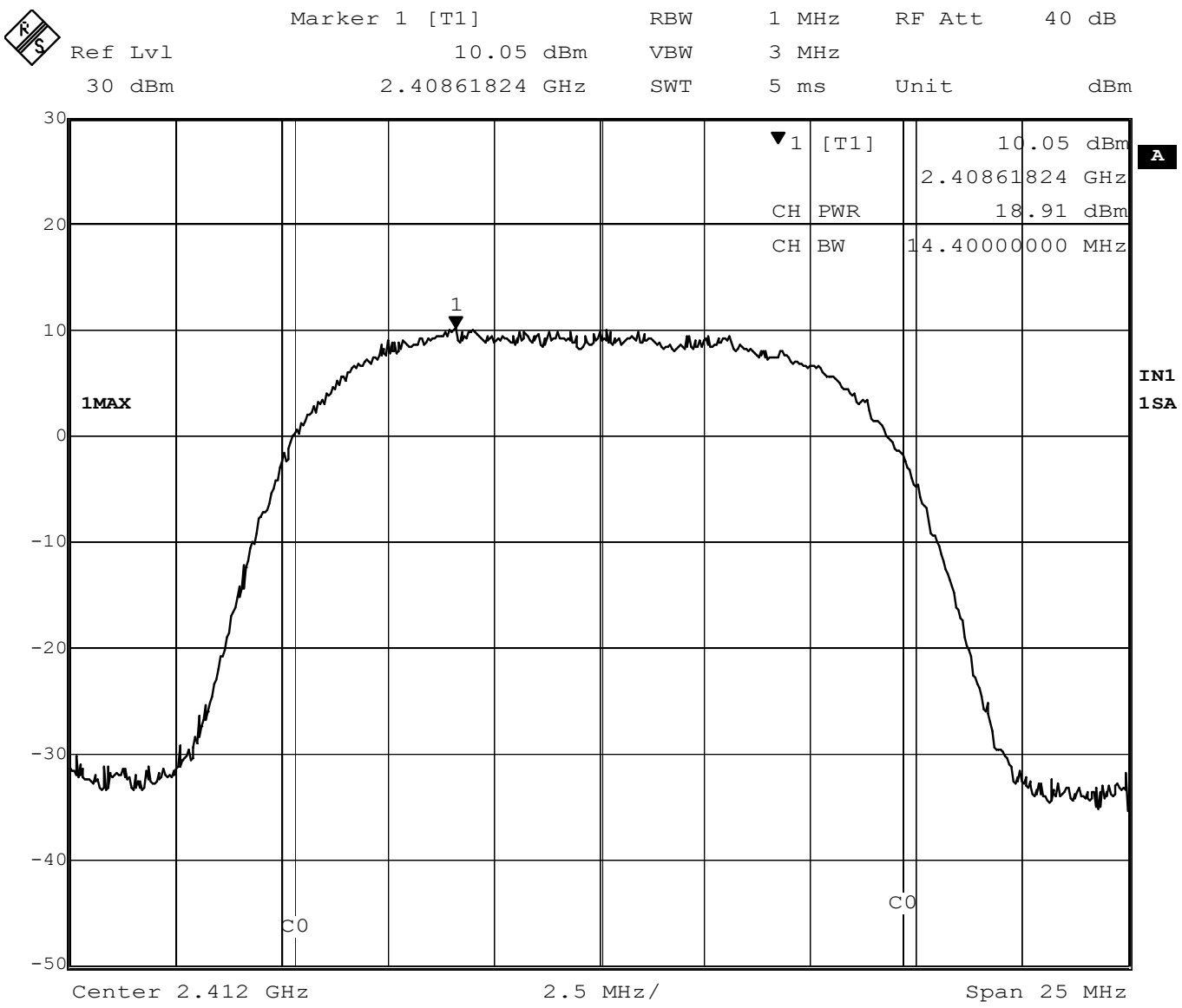

Figure 2 – Output Power Peak, Low Channel, 802.11b

Output power = 18.91 dBm

Cable loss was less than 0.1 dB and not included

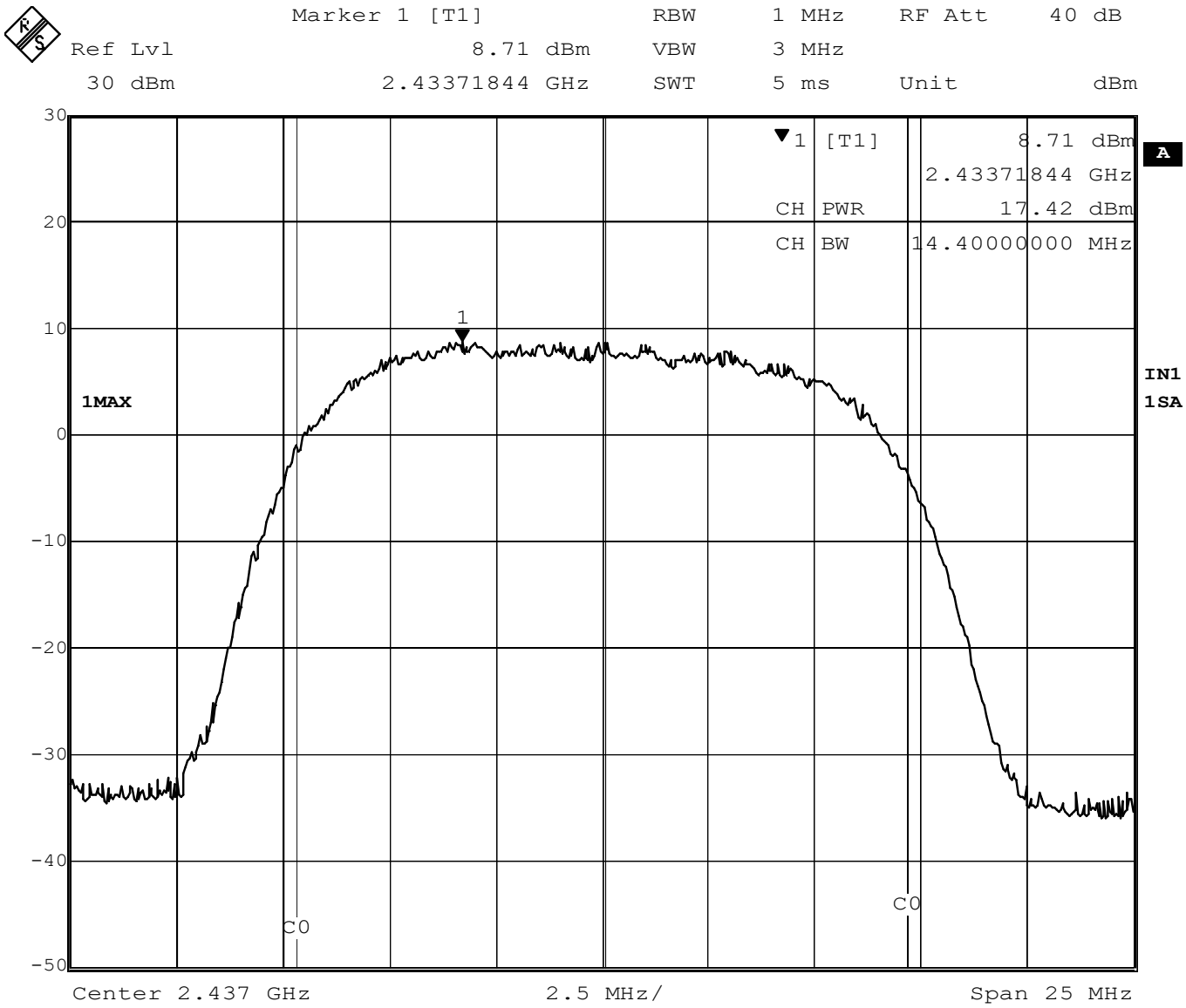

Figure 3 – Output Power Peak, Mid Channel, 802.11b

Output power = 17.42 dBm

Cable loss was less than 0.1 dB and not included

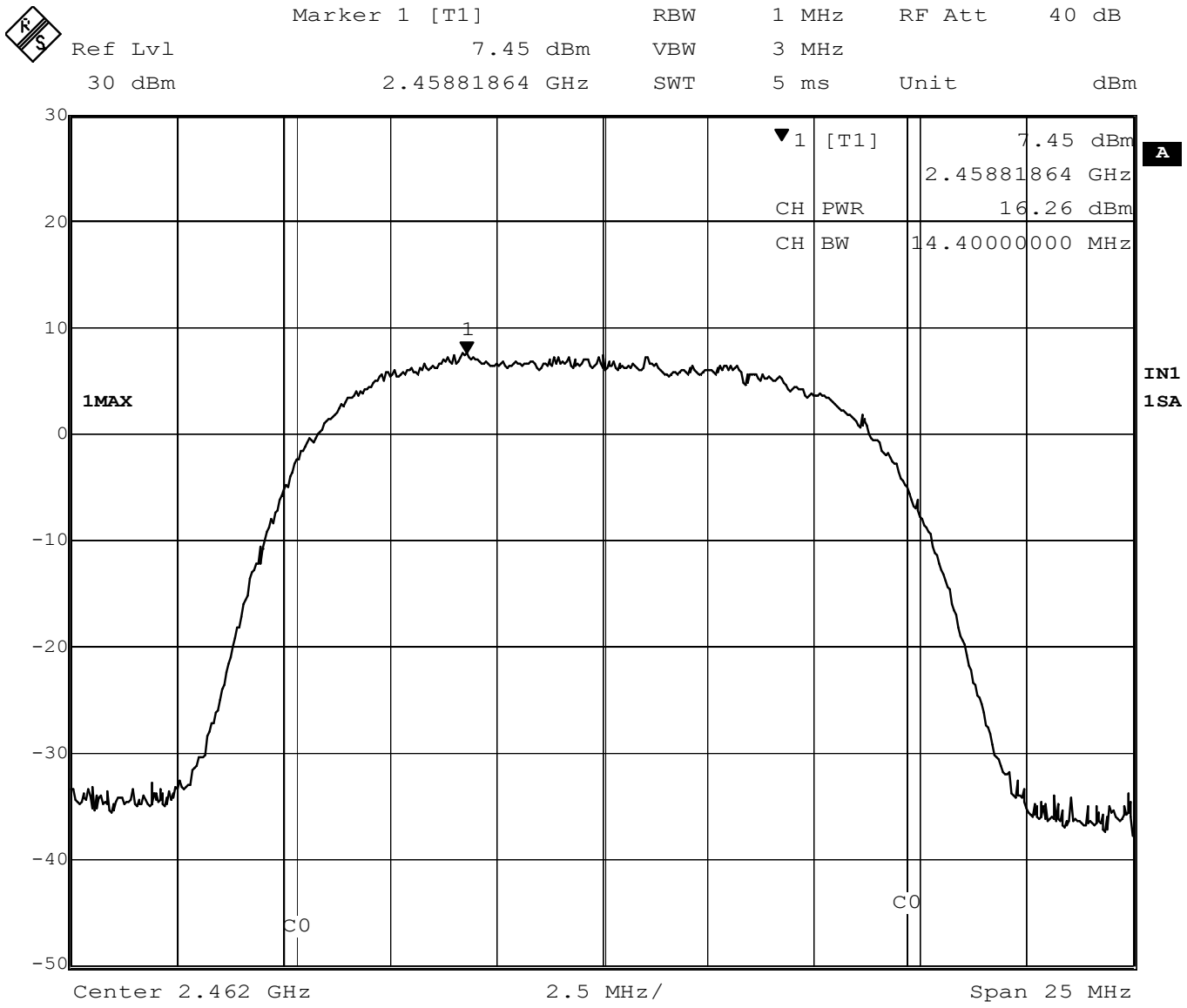

Figure 4 – Output Power Peak, High Channel, 802.11b

Output power = 16.26 dBm

Cable loss was less than 0.1 dB and not included

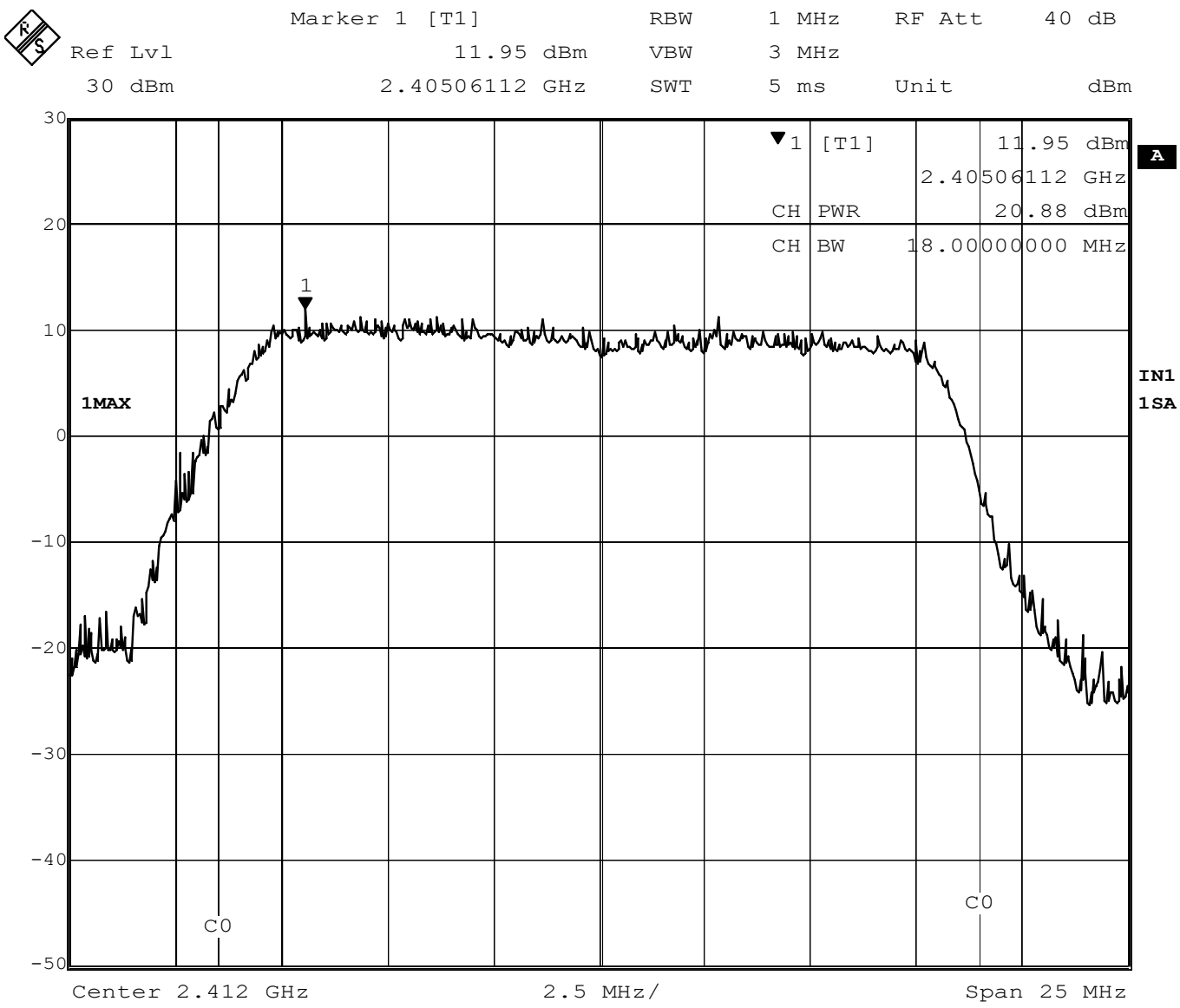

Figure 5 – Output Power Peak, Low Channel, 802.11g

Output power = 20.88 dBm

Cable loss was less than 0.1 dB and not included

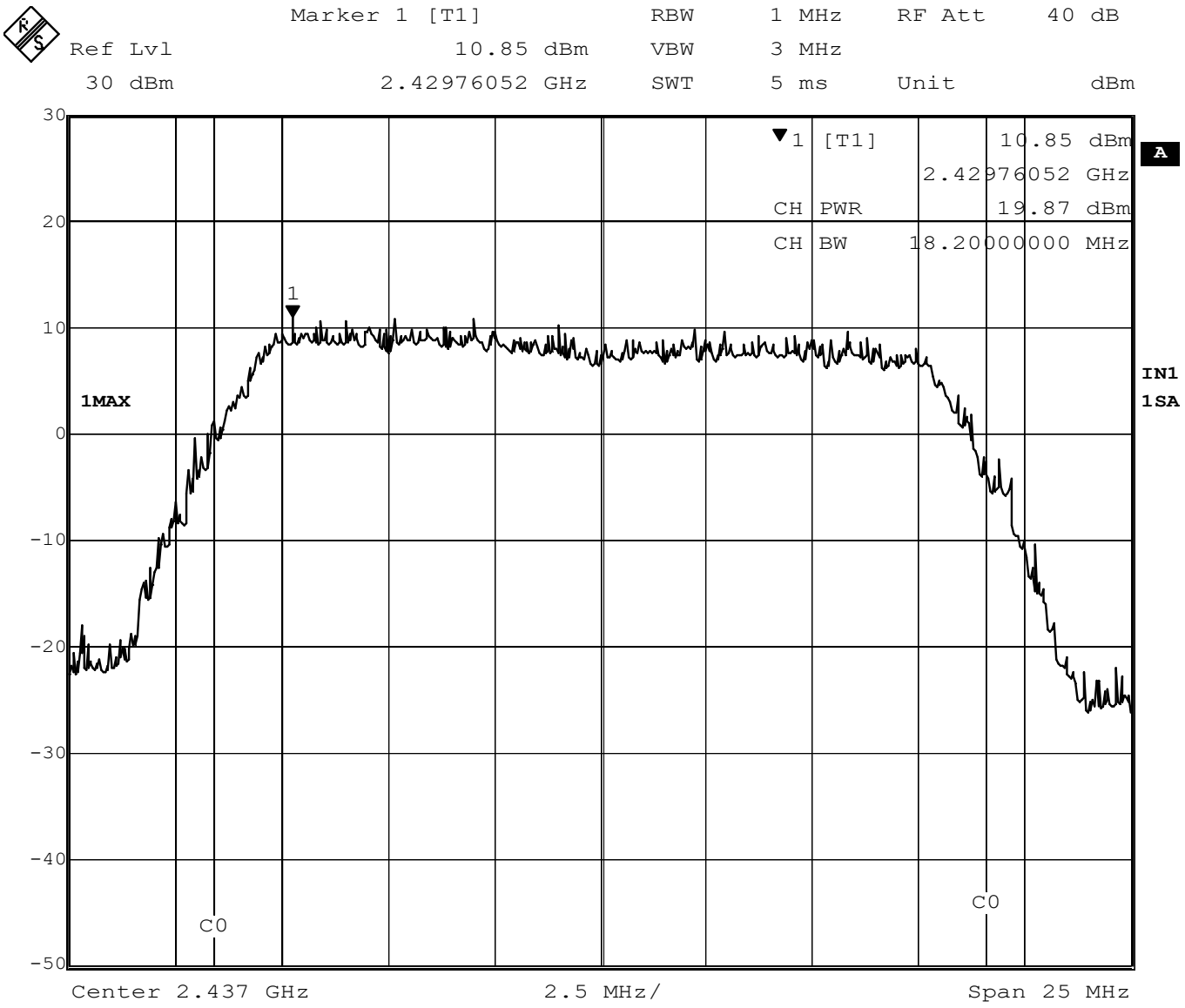

Figure 6 – Output Power Peak, Mid Channel, 802.11g

Output power = 19.87 dBm

Cable loss was less than 0.1 dB and not included

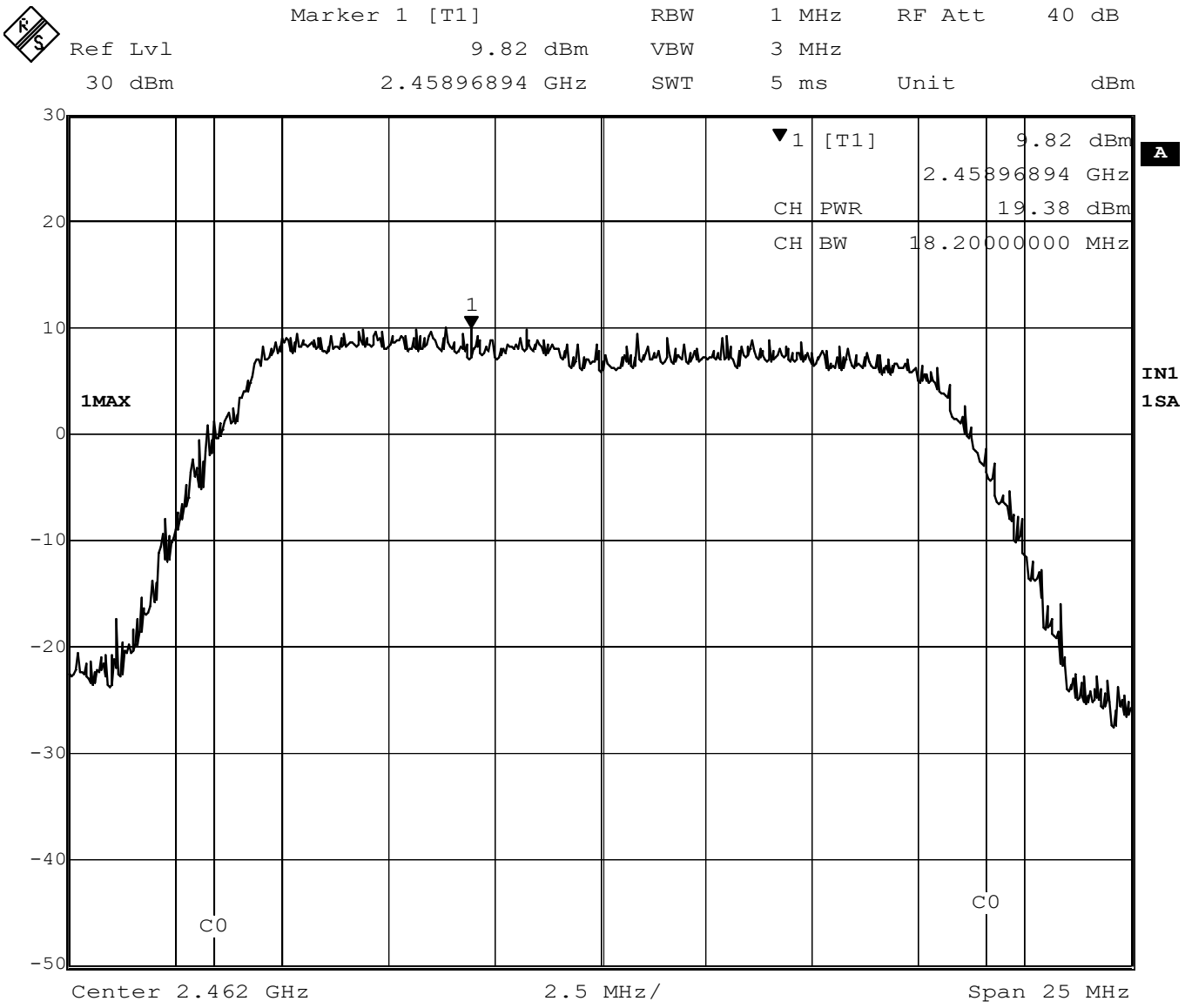

Figure 7 – Output Power Peak, High Channel, 802.11g

Output power = 19.38 dBm

Cable loss was less than 0.1 dB and not included

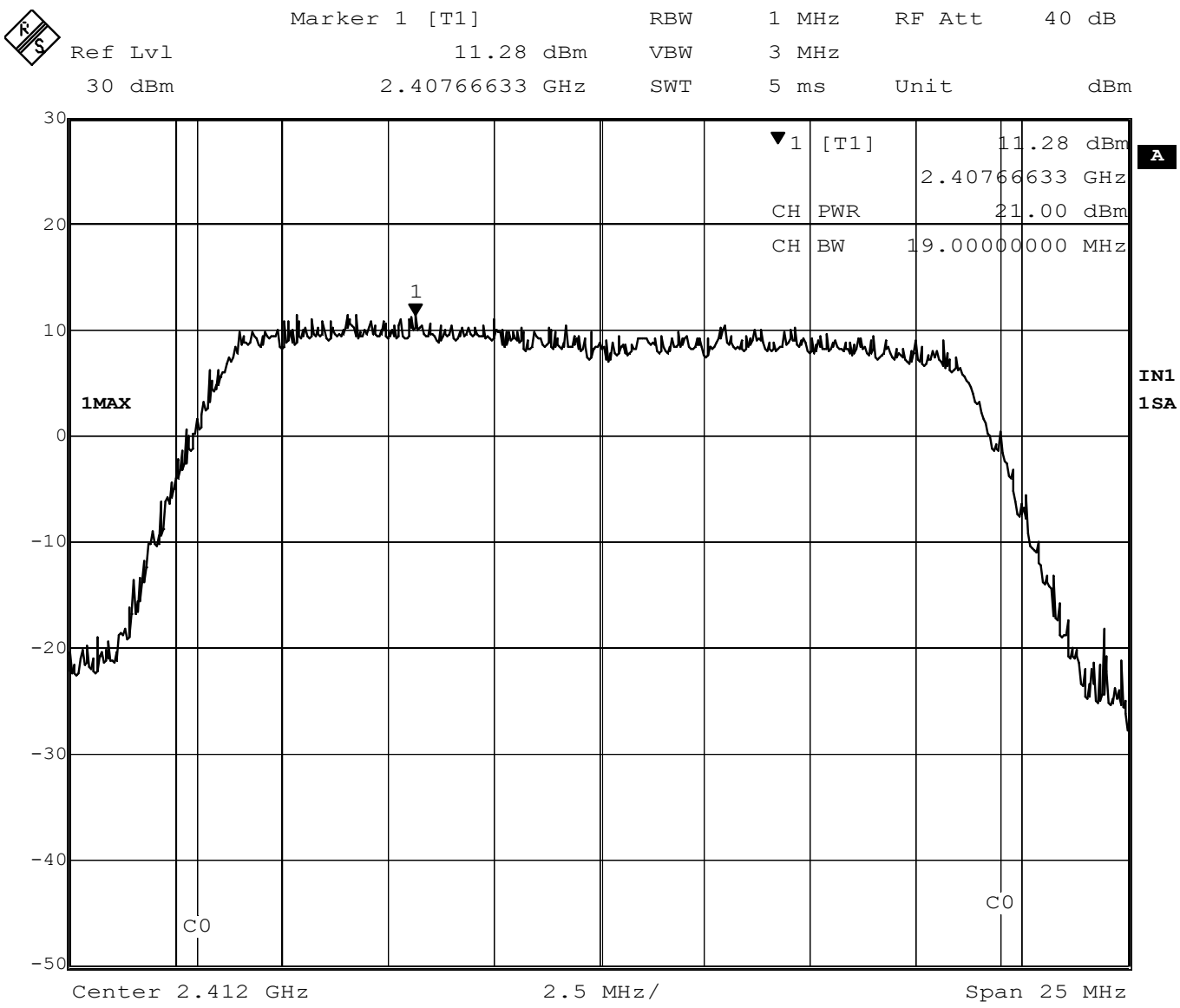

Figure 8 – Output Power Peak, Low Channel, 802.11n

Output power = 21.00 dBm

Cable loss was less than 0.1 dB and not included

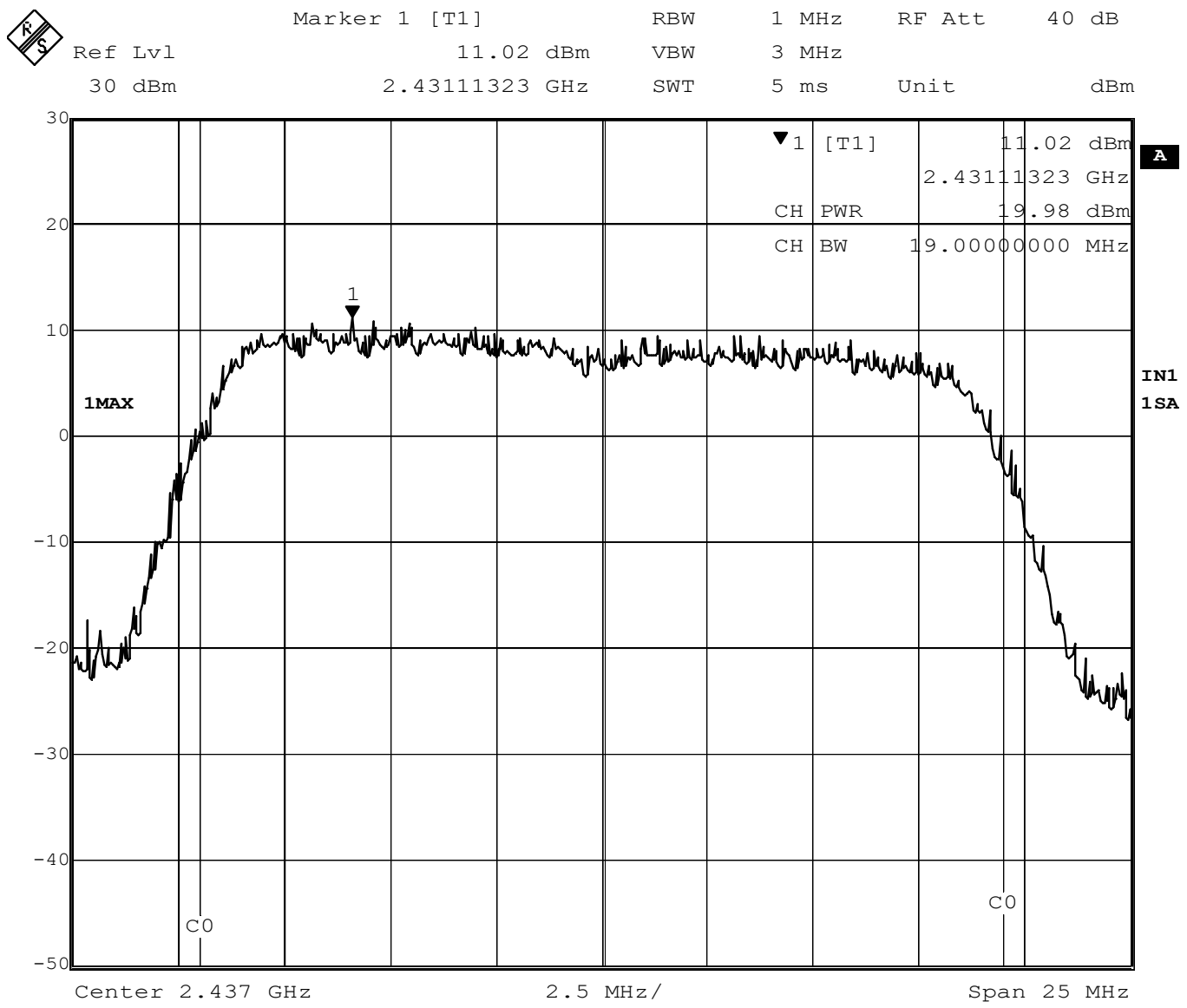

Figure 9 – Output Power Peak, Mid Channel, 802.11n

Output power = 19.98 dBm

Cable loss was less than 0.1 dB and not included

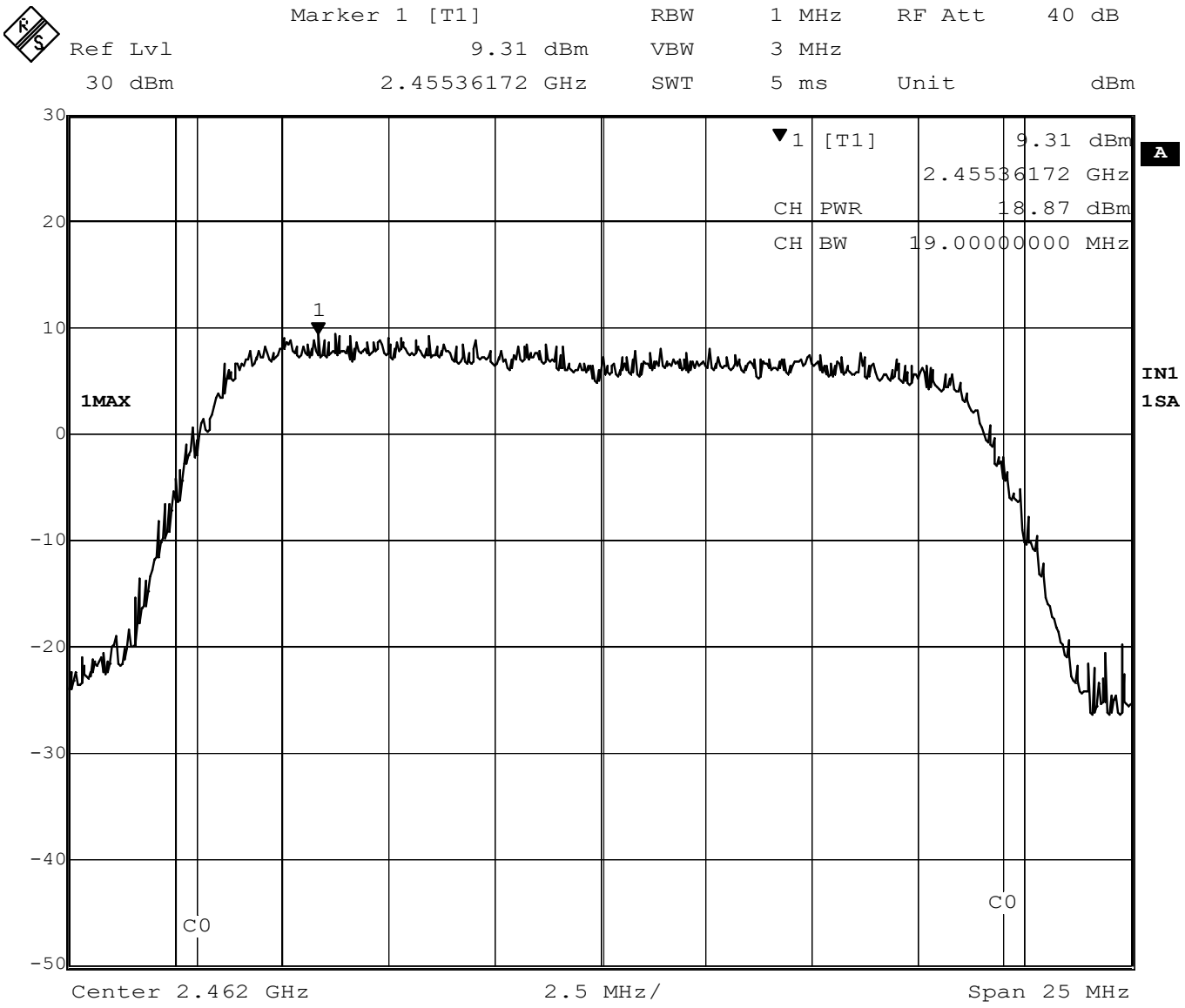

Figure 10 – Output Power Peak, High Channel, 802.11n

Output power = 18.87 dBm

Cable loss was less than 0.1 dB and not included

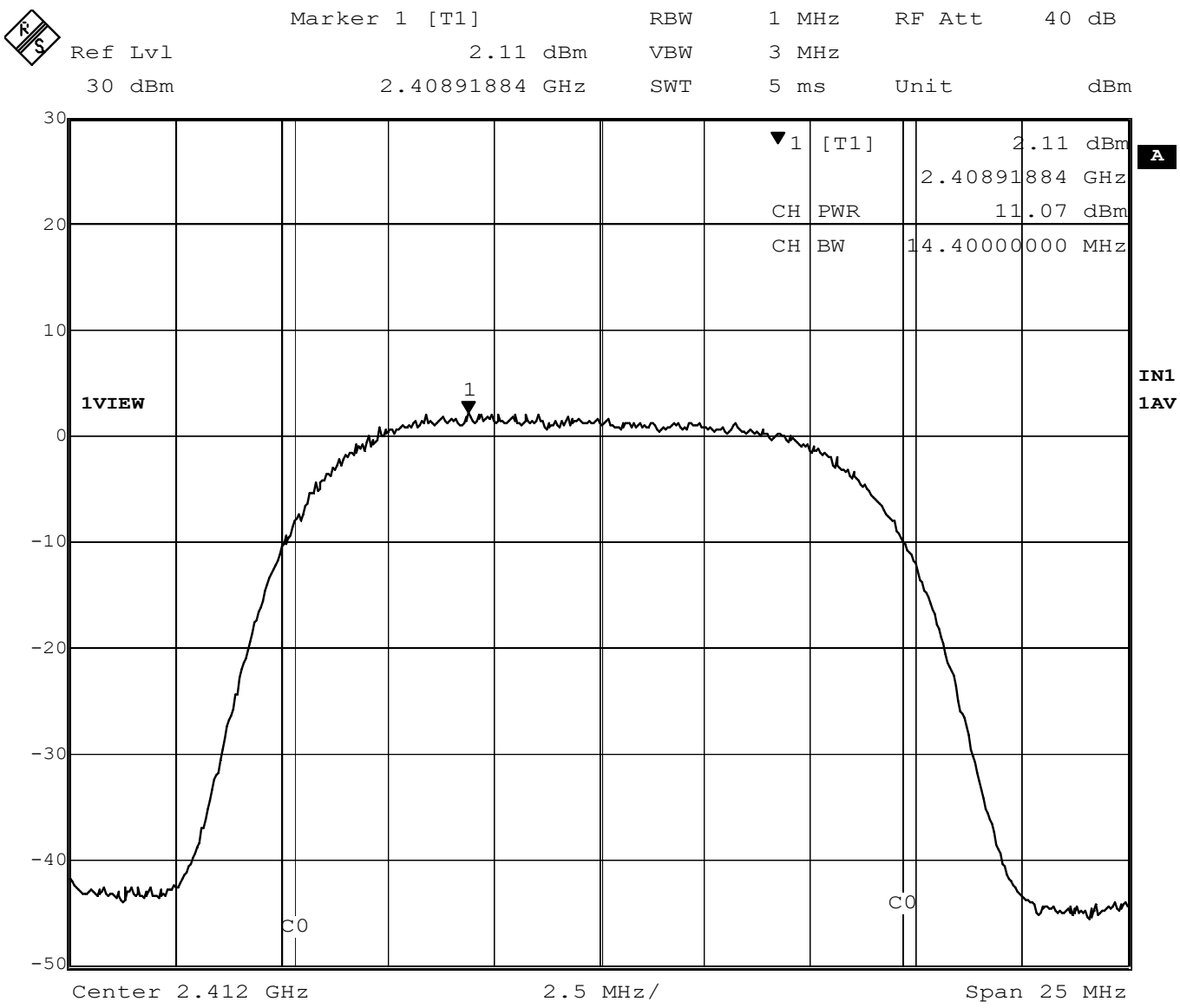

Figure 11 – Output Power Average, Low Channel, 802.11b

Output power 11.07 dBm

Cable loss was less than 0.1 dB and not included

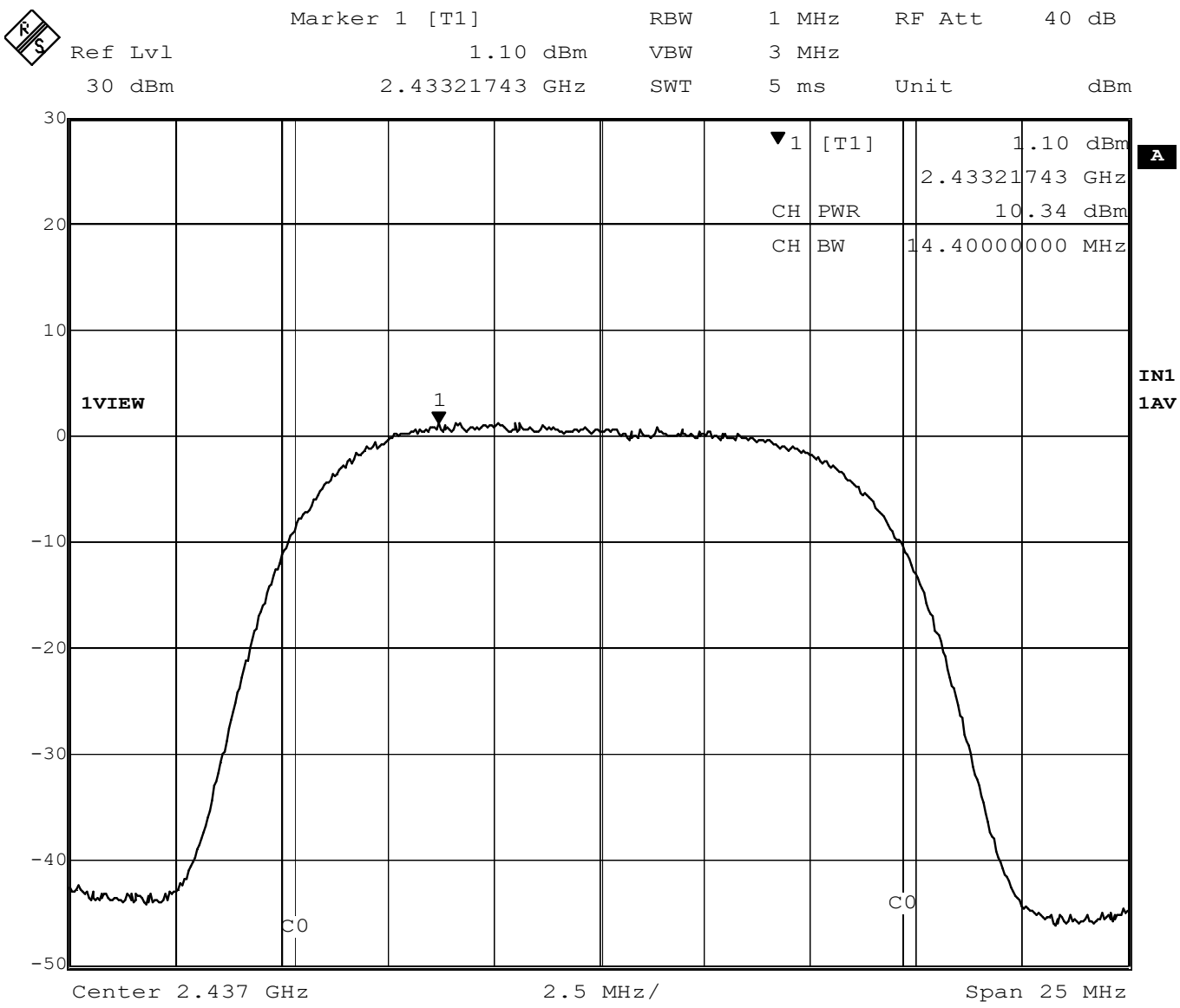

Figure 12 – Output Power Average, Mid Channel, 802.11b

Output power = 10.34 dBm

Cable loss was less than 0.1 dB and not included

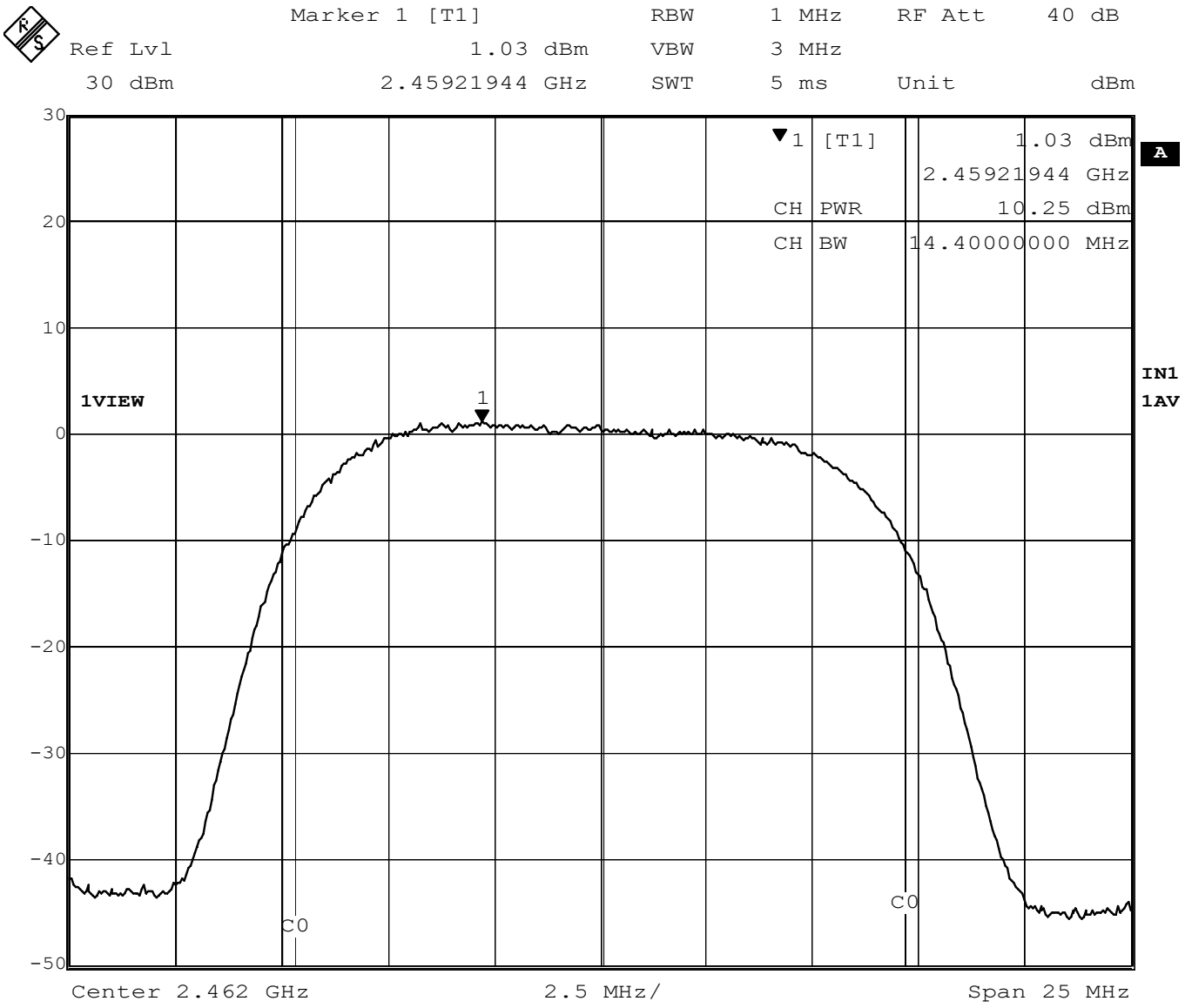

Figure 13 – Output Power Average, High Channel, 802.11b

Output power = 10.25 dBm

Cable loss was less than 0.1 dB and not included

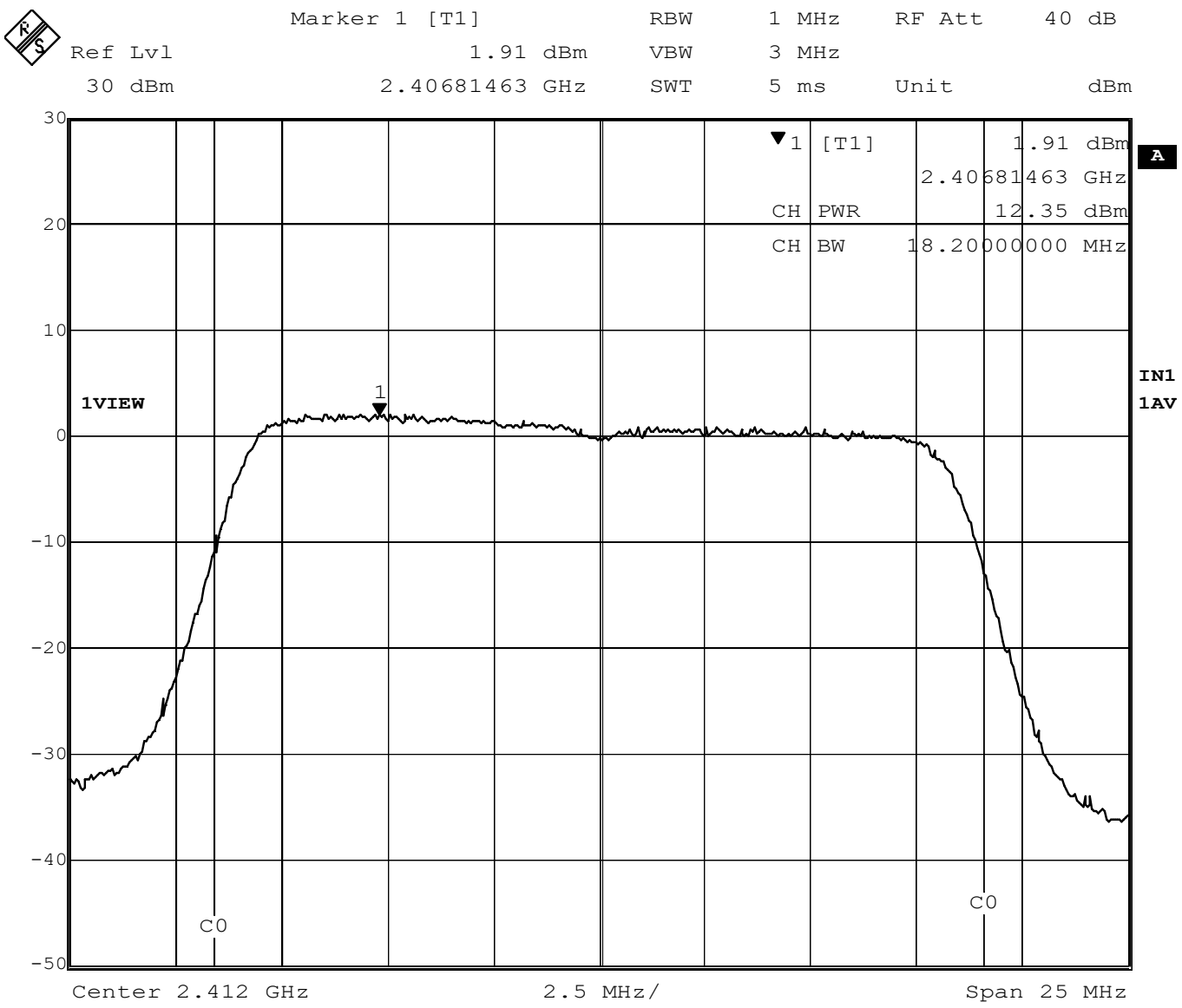

Figure 14 – Output Power Average, Low Channel, 802.11g

Output power 12.35 dBm

Cable loss was less than 0.1 dB and not included

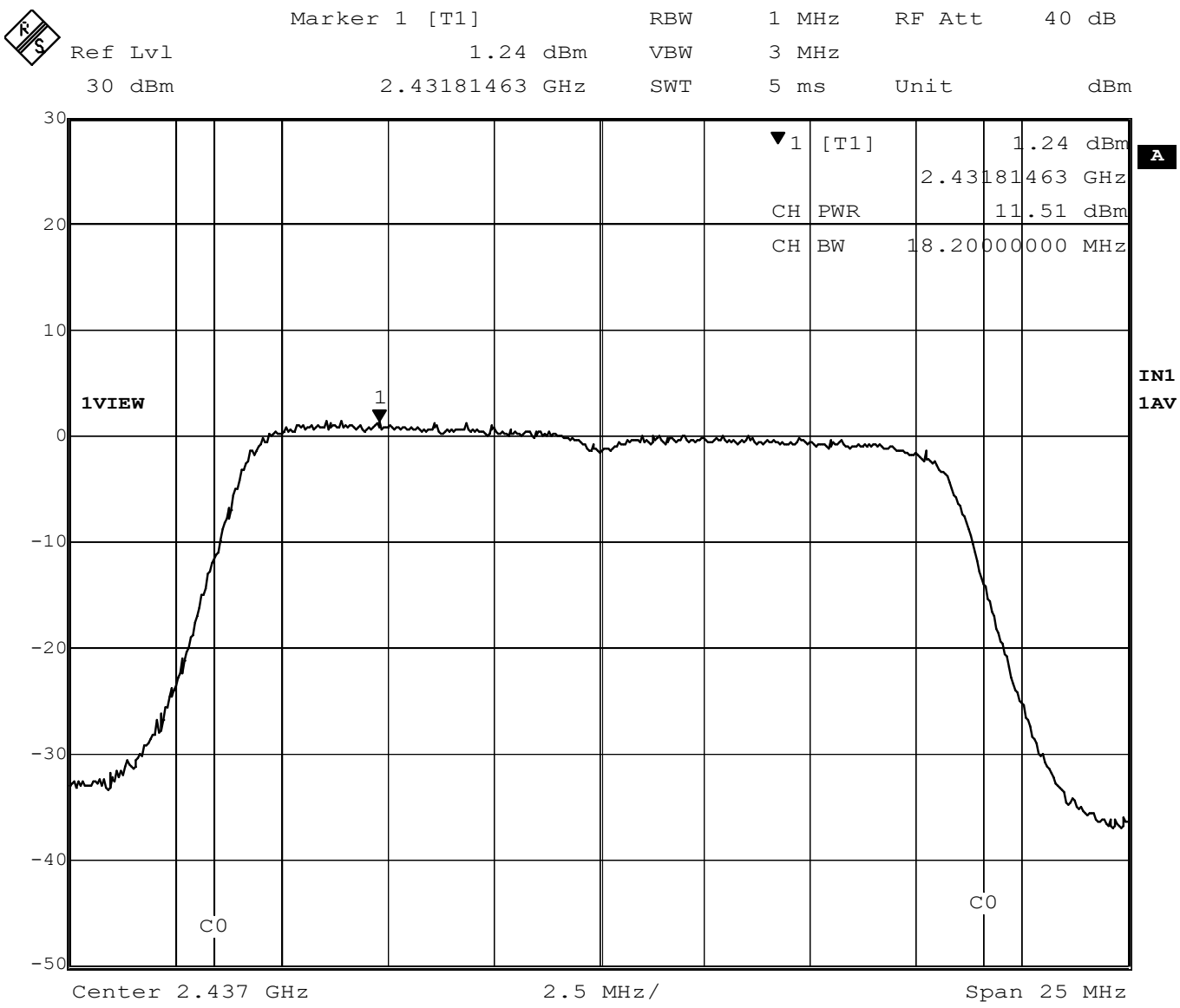

Figure 15 – Output Power Average, Mid Channel, 802.11g

Output power = 11.51 dBm

Cable loss was less than 0.1 dB and not included

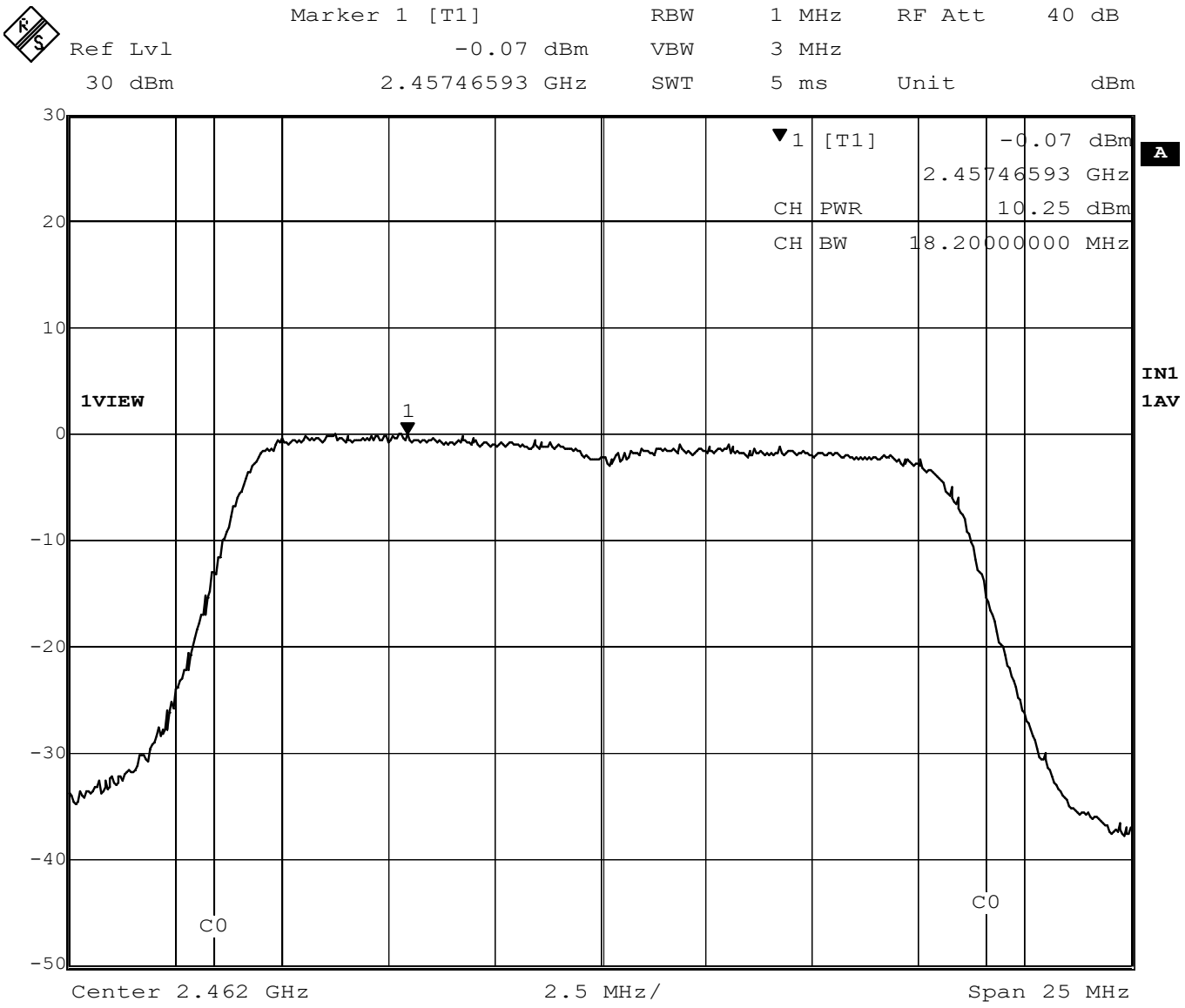

Figure 16 – Output Power Average, High Channel, 802.11g

Output power = 10.25 dBm

Cable loss was less than 0.1 dB and not included

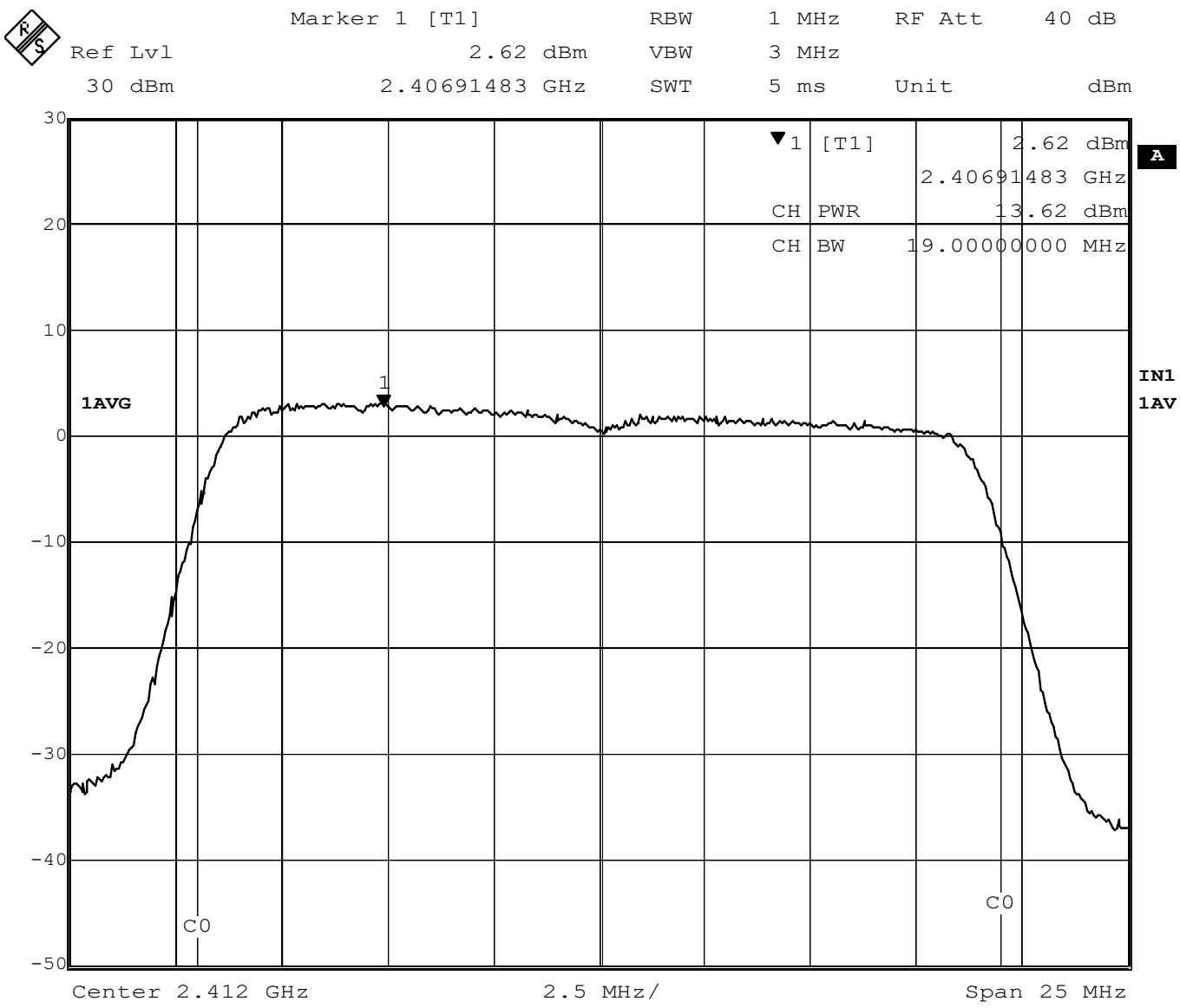

Figure 17 – Output Power Average, Low Channel, 802.11n

Output power 13.62 dBm

Cable loss was less than 0.1 dB and not included

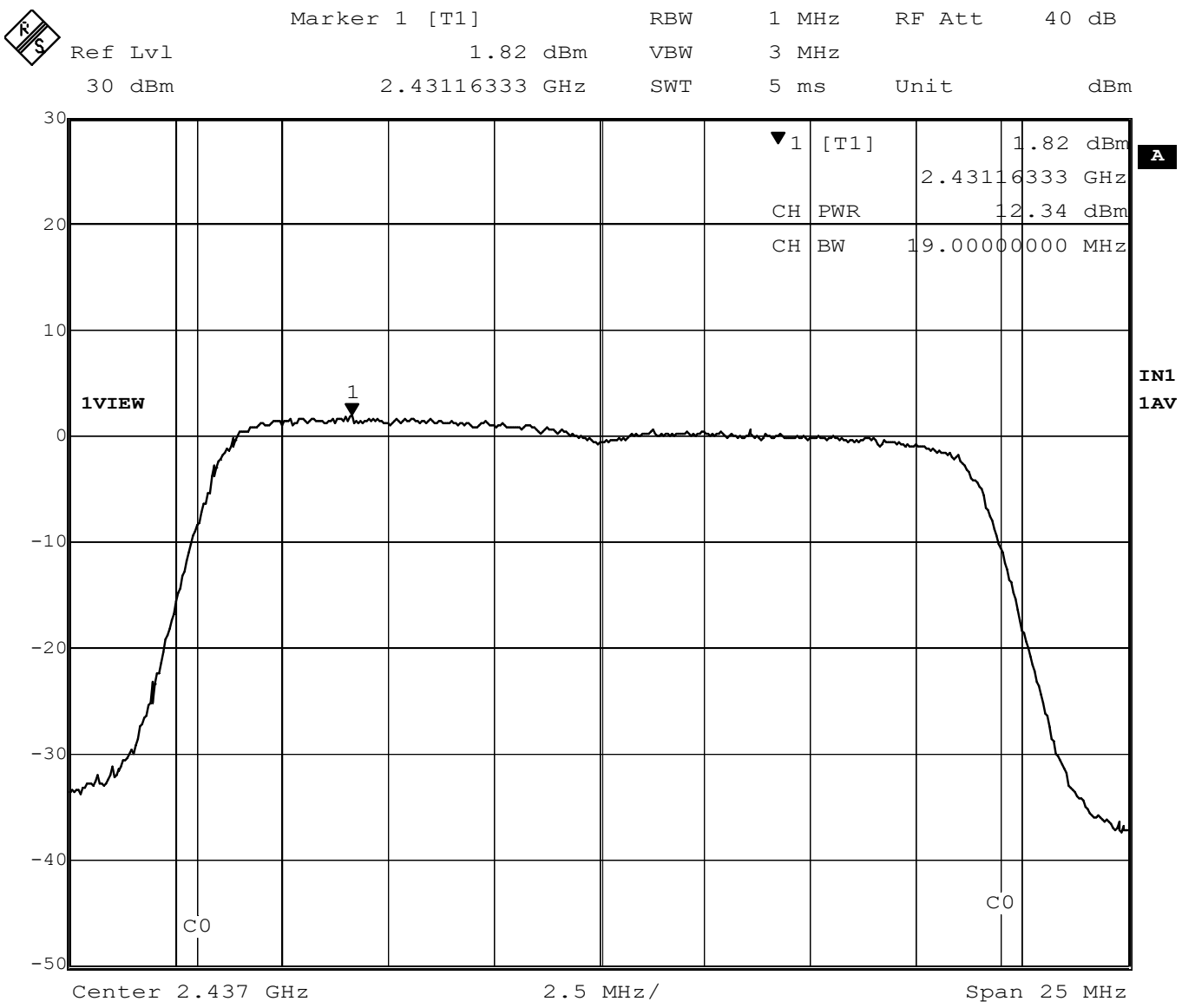

Figure 18 – Output Power Average, Mid Channel, 802.11n

Output power = 12.34 dBm

Cable loss was less than 0.1 dB and not included

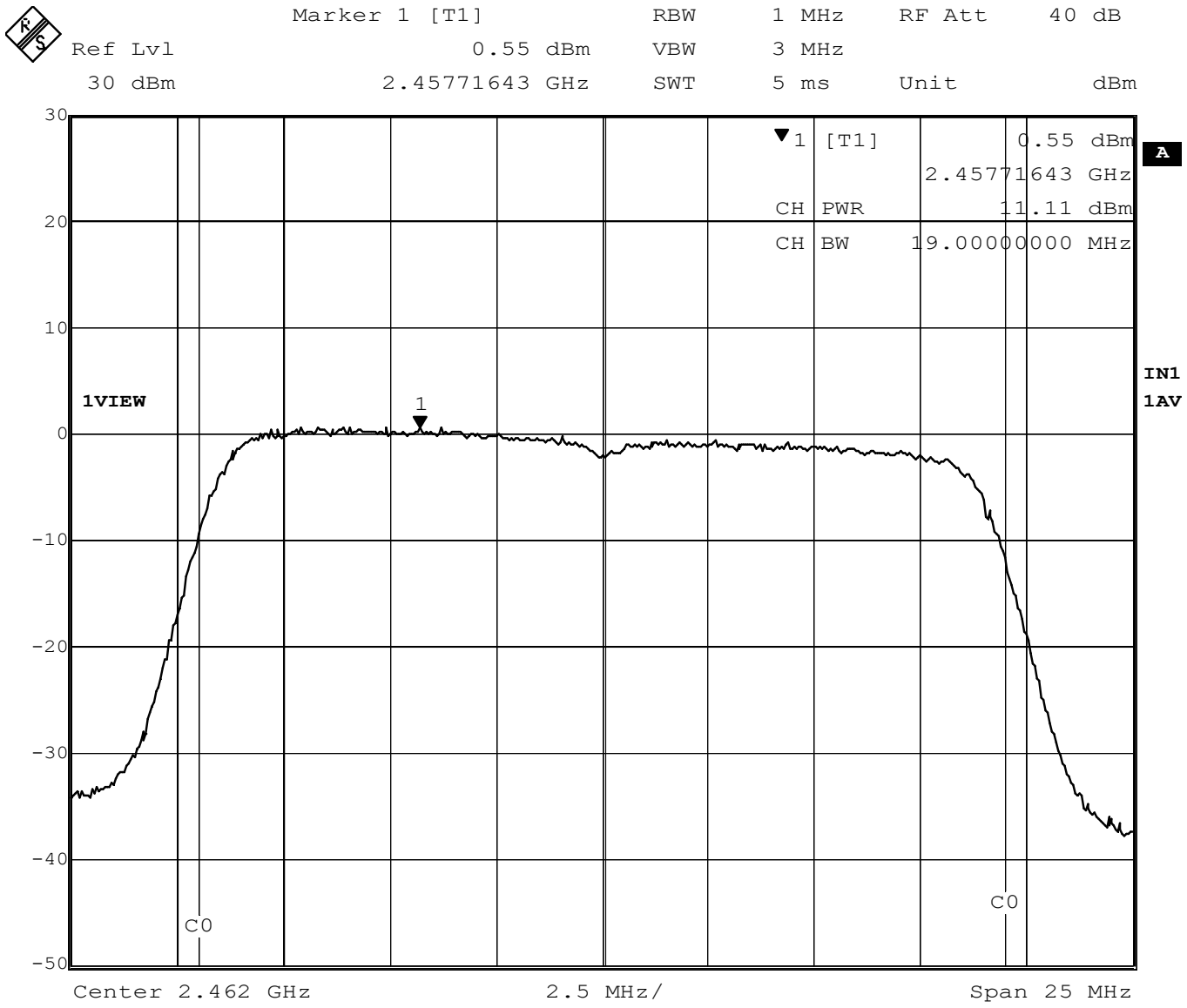

Figure 19 – Output Power Average, High Channel, 802.11n

Output power = 11.11 dBm

Cable loss was less than 0.1 dB and not included

4.3 BANDWIDTH

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

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

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

Test procedures:
The 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:

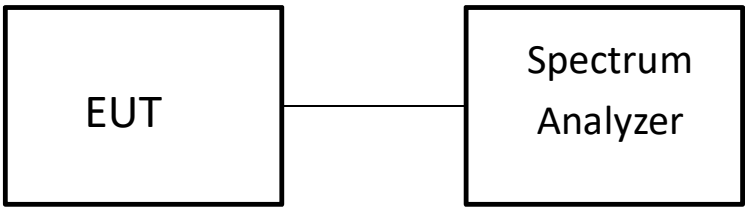

Figure 20 – Peak Output Power Measurements Test Setup

EUT operating conditions:
The EUT was powered by internal battery power unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range on each indicated modulation.

Test results:

Occupied Bandwidth

CHANNEL	Mode	CHANNEL FREQUENCY (MHz)	OBW (MHz)	RESULT
Low	802.11 b	2412	13.925	PASS
Mid	802.11 b	2440	13.937	PASS
High	802.11 b	2460	13.936	PASS
Low	802.11 g	2412	16.942	PASS
Mid	802.11 g	2440	16.993	PASS
High	802.11 g	2460	16.989	PASS
Low	802.11 n	2412	17.932	PASS
Mid	802.11 n	2440	17.996	PASS
High	802.11 n	2460	17.897	PASS

6dB Bandwidth

CHANNEL	Mode	CHANNEL FREQUENCY (MHz)	6dB BW (MHz)	RESULT
Low	802.11 b	2412	12.62	PASS
Mid	802.11 b	2440	12.63	PASS
High	802.11 b	2460	12.62	PASS
Low	802.11 g	2412	16.63	PASS
Mid	802.11 g	2440	16.63	PASS
High	802.11 g	2460	16.62	PASS
Low	802.11 n	2412	17.86	PASS
Mid	802.11 n	2440	17.87	PASS
High	802.11 n	2460	17.86	PASS

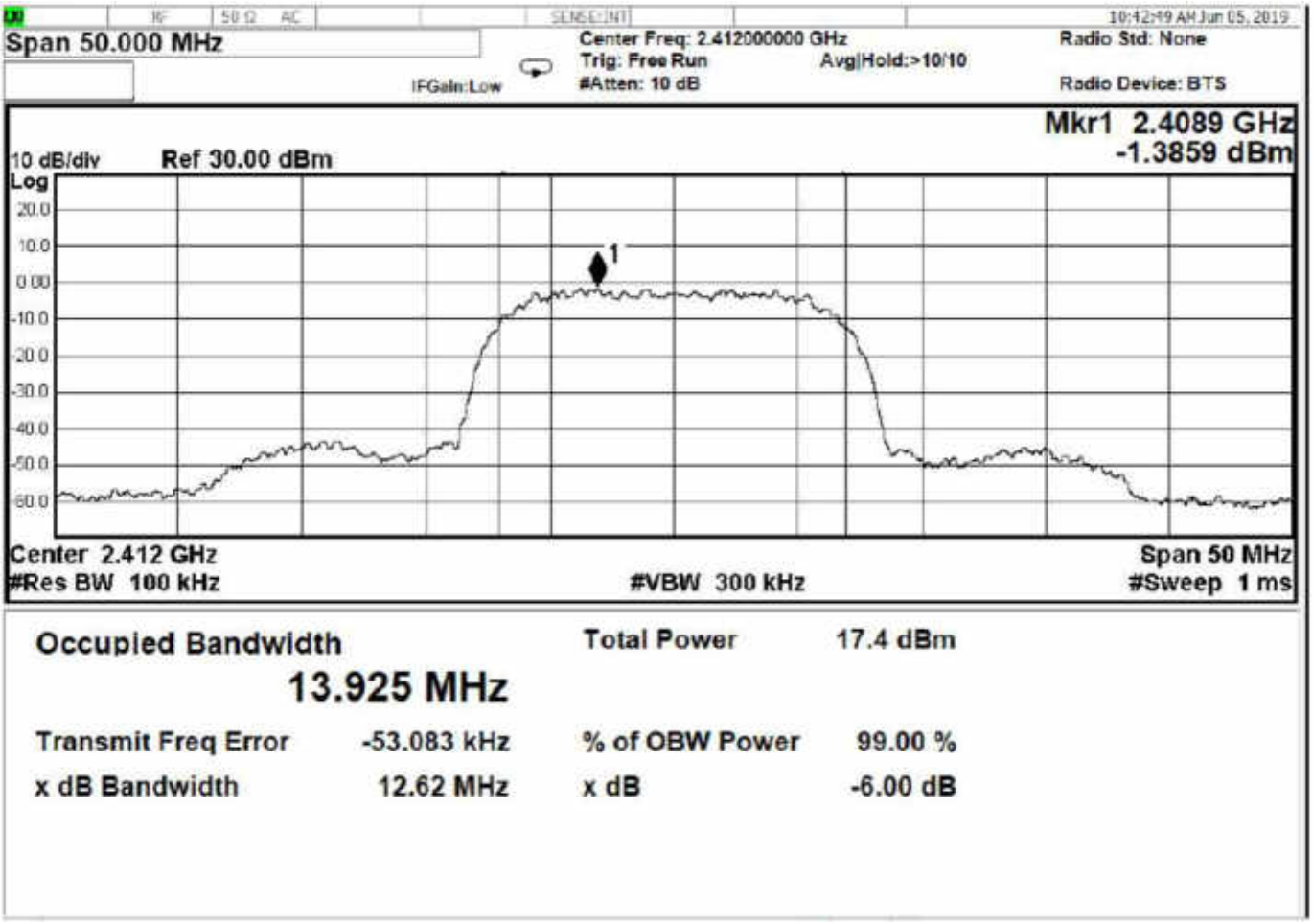

Figure 21 – Occupied Bandwidth and 6dB Bandwidth, Low Channel, 802.11b

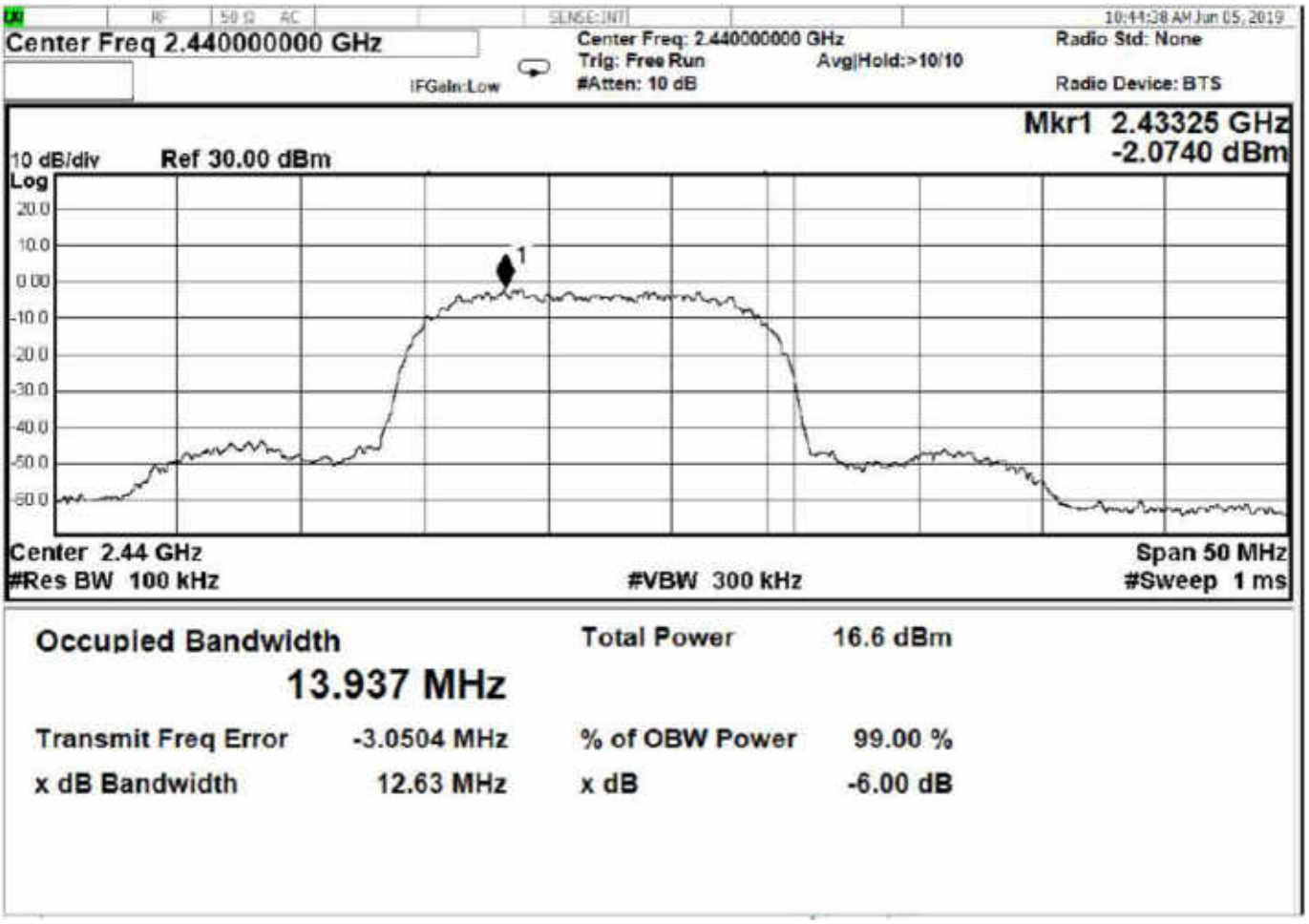

Figure 22 - Occupied Bandwidth and 6dB Bandwidth, Mid Channel, 802.11b

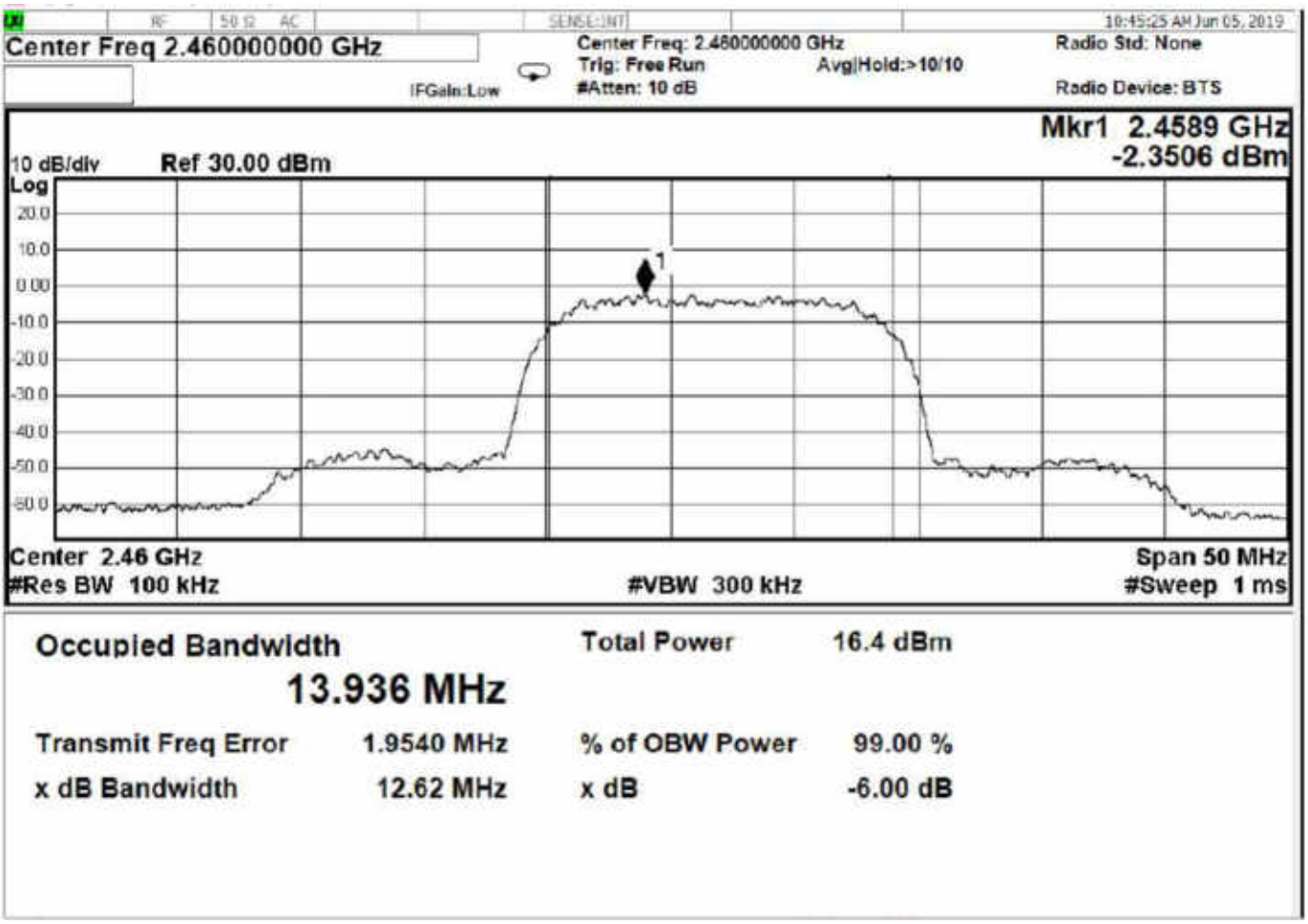

Figure 23 - Occupied Bandwidth and 6dB Bandwidth, High Channel, 802.11b

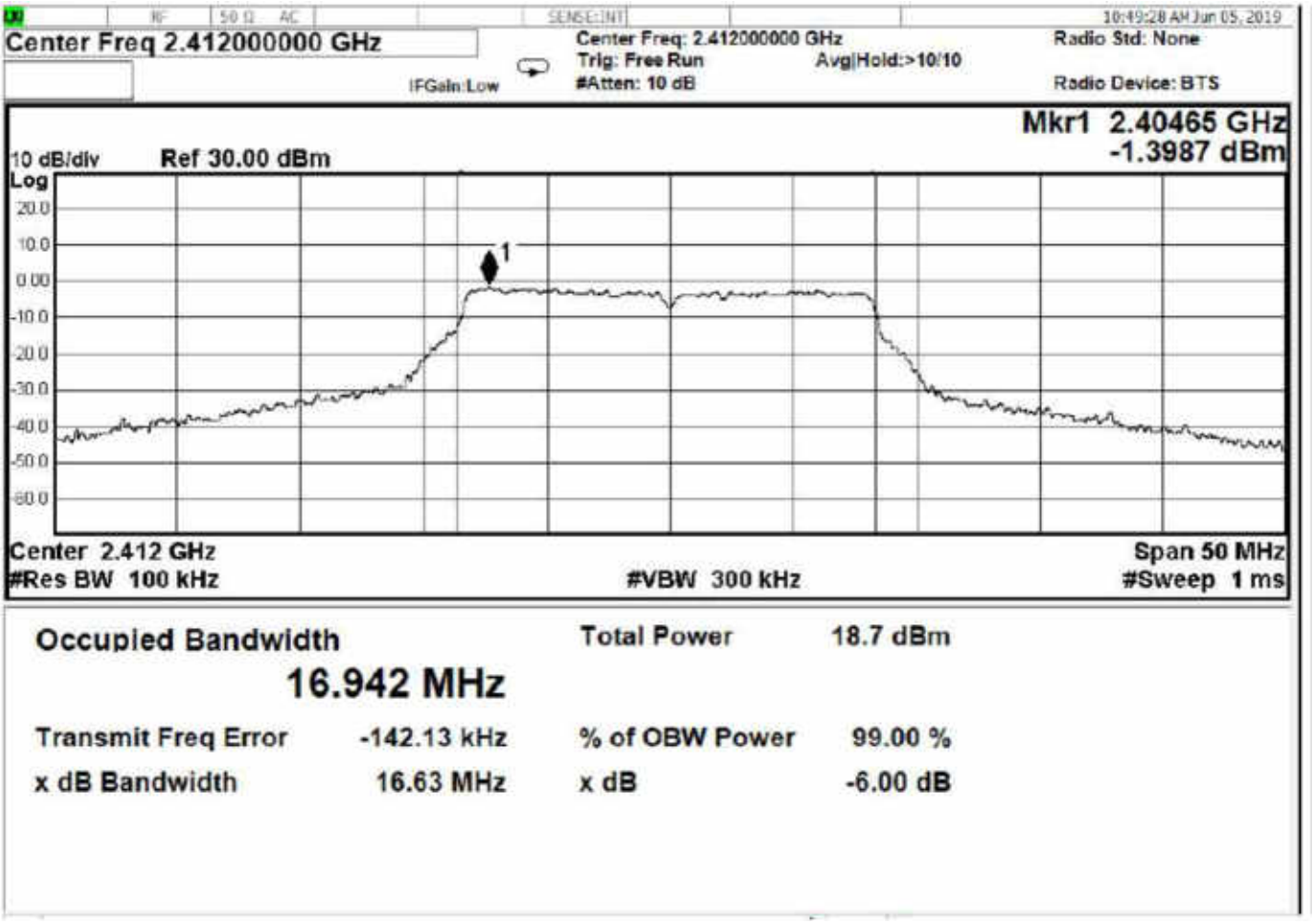

Figure 24 – Occupied Bandwidth and 6dB Bandwidth, Low Channel, 802.11g

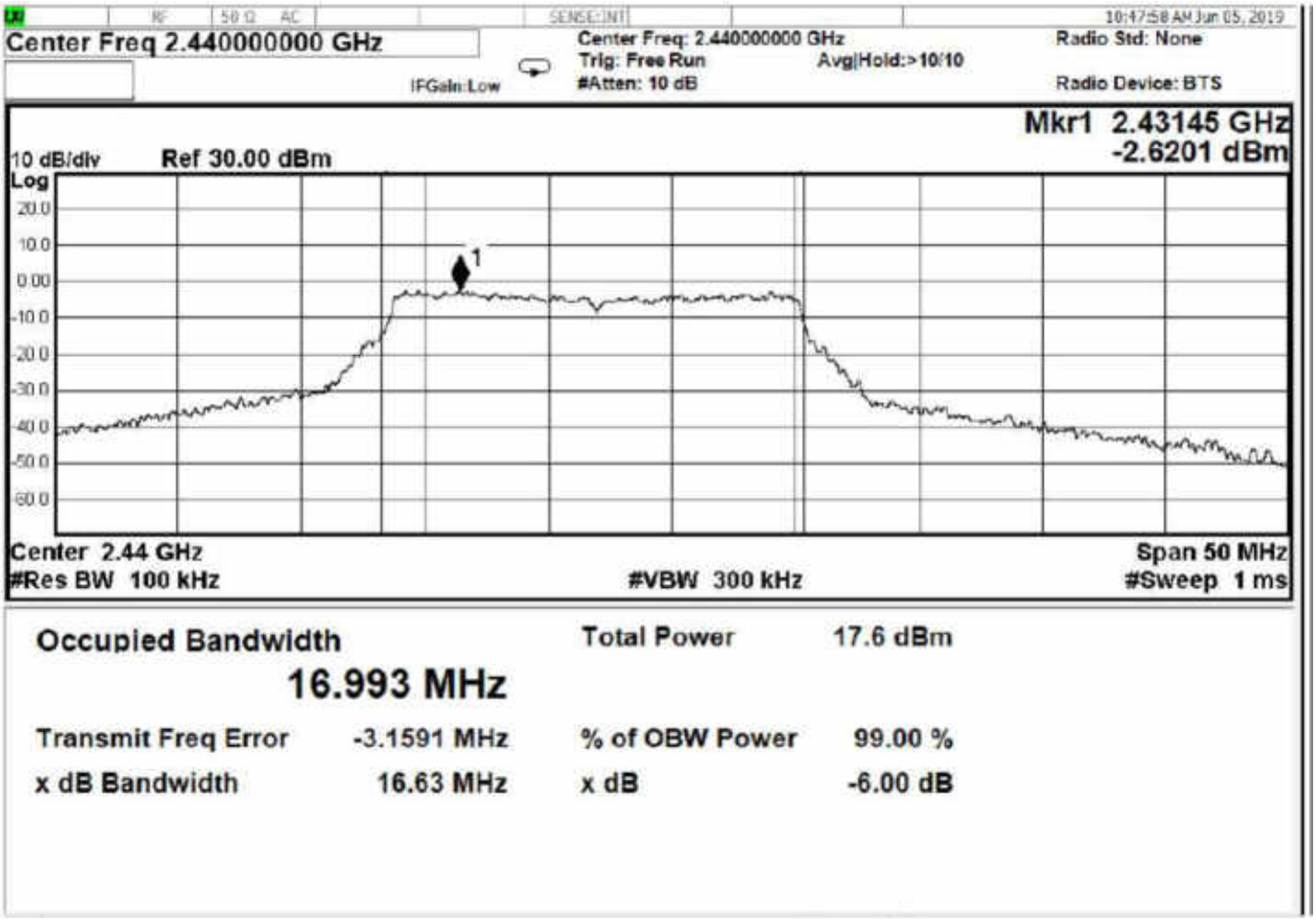

Figure 25 - Occupied Bandwidth and 6dB Bandwidth, Mid Channel, 802.11g

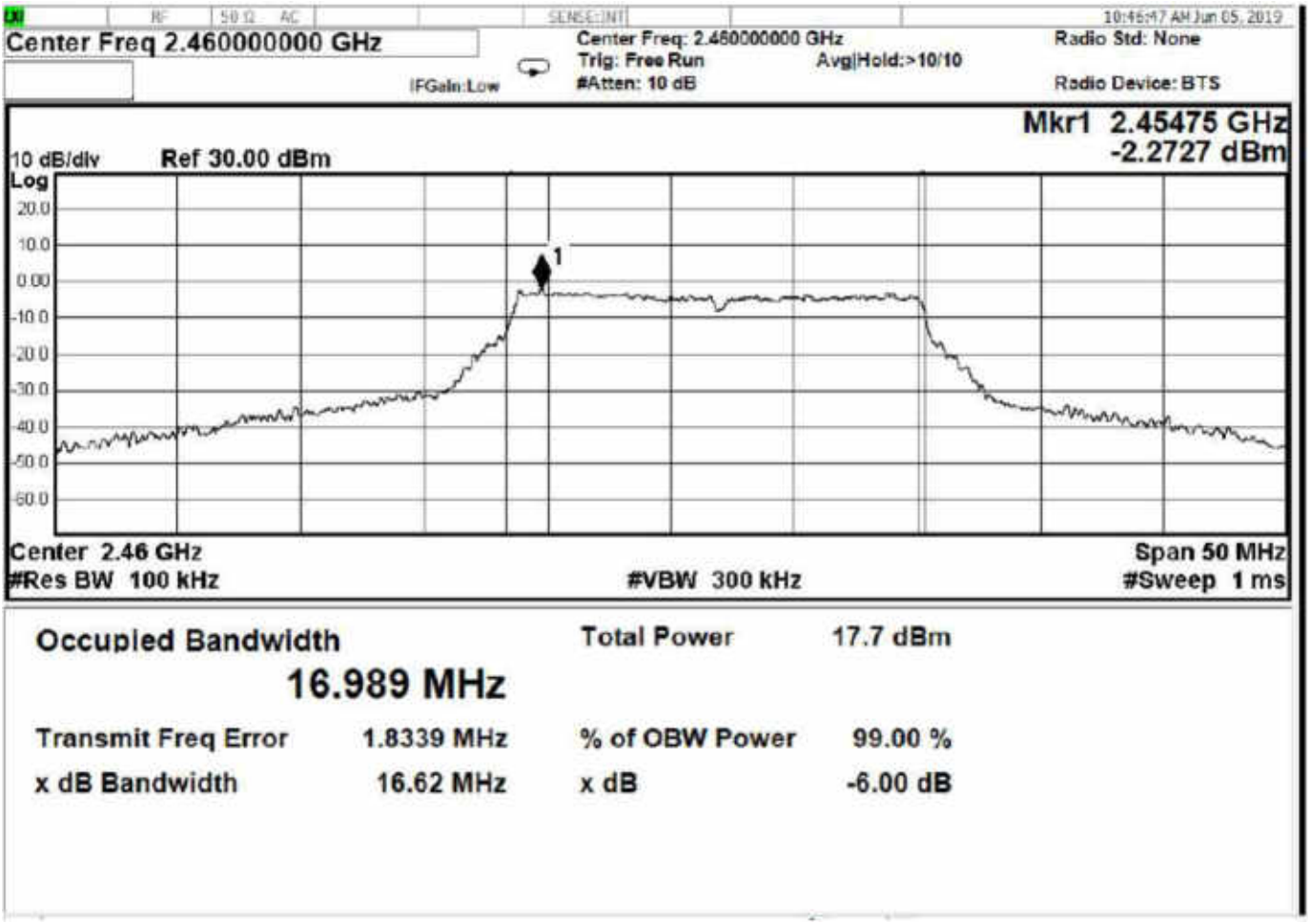

Figure 26 - Occupied Bandwidth and 6dB Bandwidth, High Channel, 802.11g

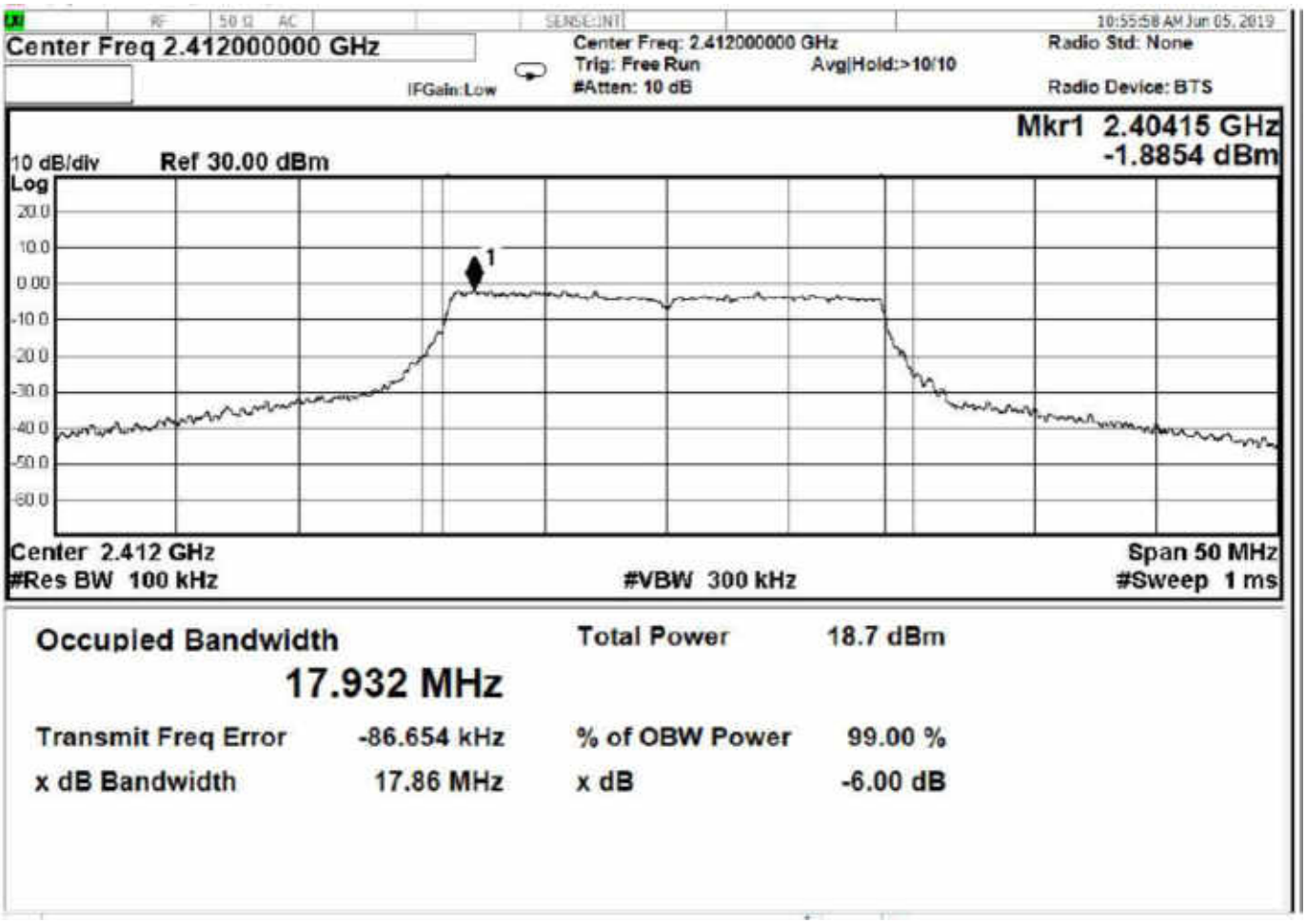

Figure 27 – Occupied Bandwidth and 6dB Bandwidth, Low Channel, 802.11n

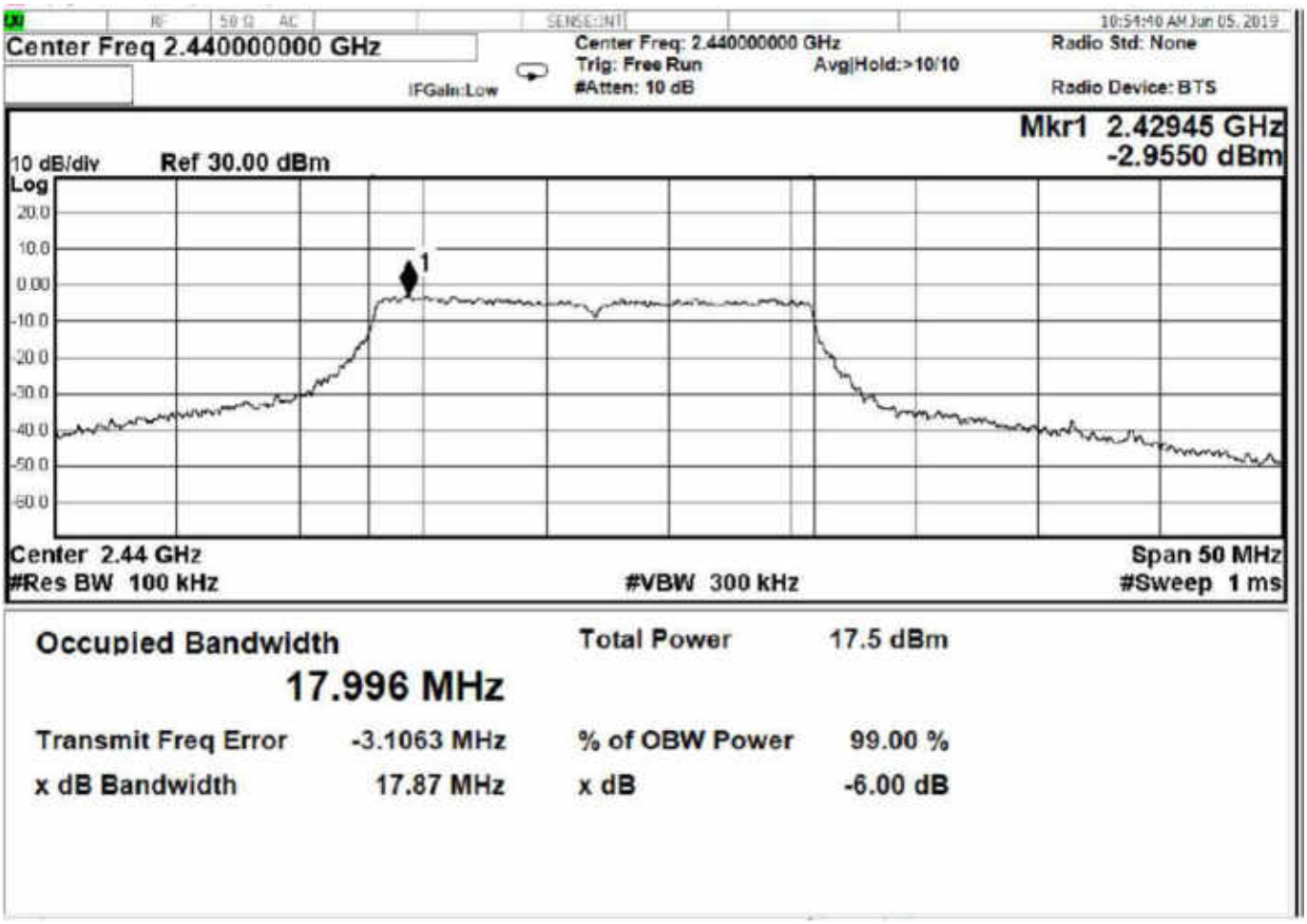

Figure 28 - Occupied Bandwidth and 6dB Bandwidth, Mid Channel, 802.11n

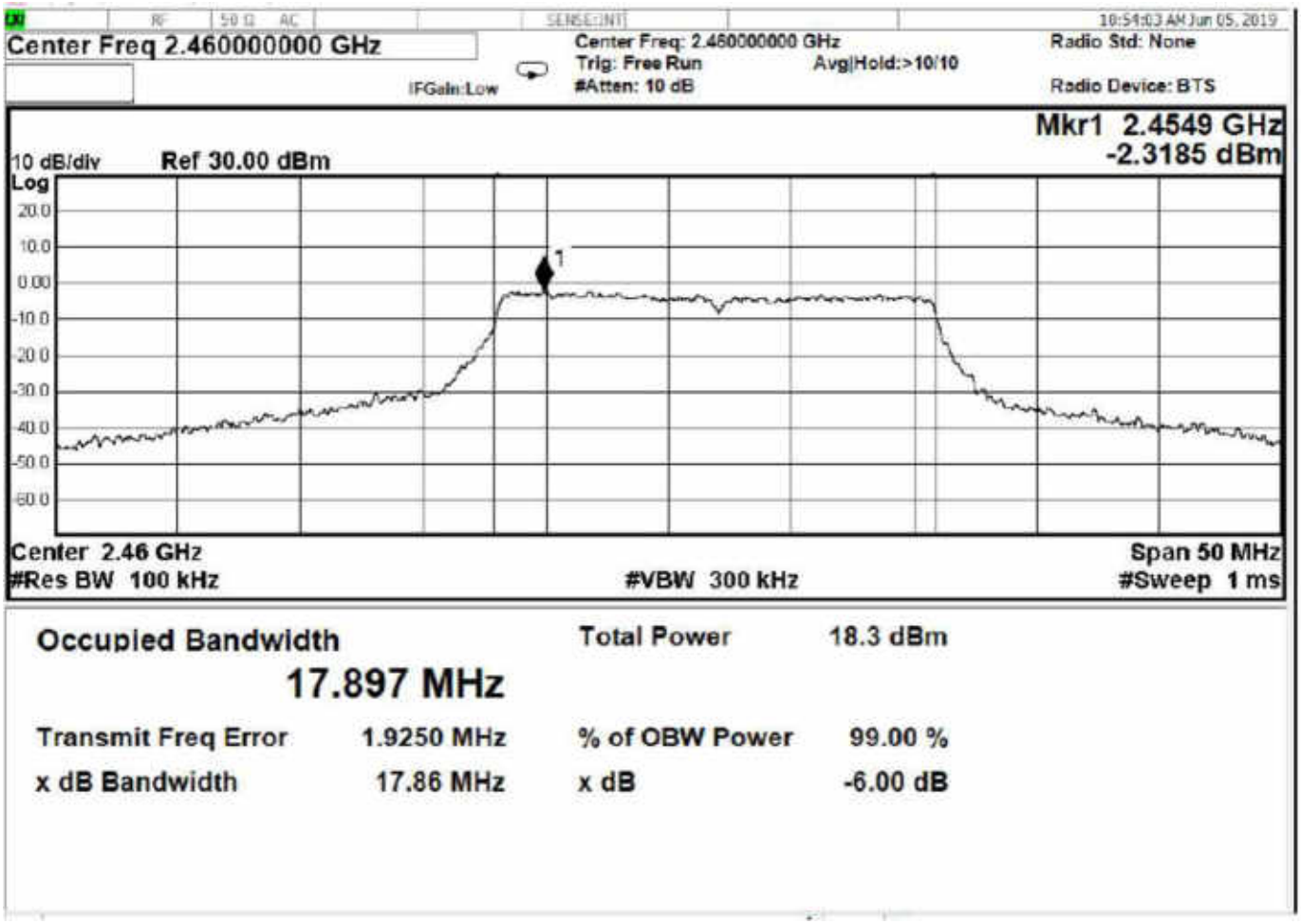

Figure 29 - Occupied Bandwidth and 6dB Bandwidth, High Channel, 802.11n

4.4 RADIATED EMISSIONS

Test Method: ANSI C63.10:2013:

1. Section 6.5, “Radiated emissions from unlicensed wireless devices in the frequency range of 30 MHz to 1000 MHz”
2. Section 6.6, “Radiated emissions from unlicensed wireless devices above 1 GHz”
3. Section 11.11, “Measurement in nonrestricted frequency bands”
4. Section 11.12, “Emissions in restricted bands”

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 about requirement from FCC Part 15.247(d) and RSS-247, Section 5.5:
In addition to the limits shown above, all emissions were also required to be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power. All measurements were performed with a 1 MHz bandwidth, but the bandwidth conversion from 1 MHz to 100 kHz would be equally applied to the highest emission and the spurious emissions, so it would not effect the delta measurement.

Since the fundamental emissions was at least 20 dB over the spurious emissions limtis from 15.209 and all spurious emissions were below the 15.209 limit, this requirement was met.

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. All 802.11 modes were examined (b, g, n, HT20) and it was found the 802.11n mode produced the highest emissions. All final measurements were performed with the EUT transmitting continuously in this mode.

h. Intermodulation products were investigated by measuring spurious emissions with each of the two 2.4 GHz radios running in parallel with the NFC radio. No intermodulation products were found above the labs system sensitivity.

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:

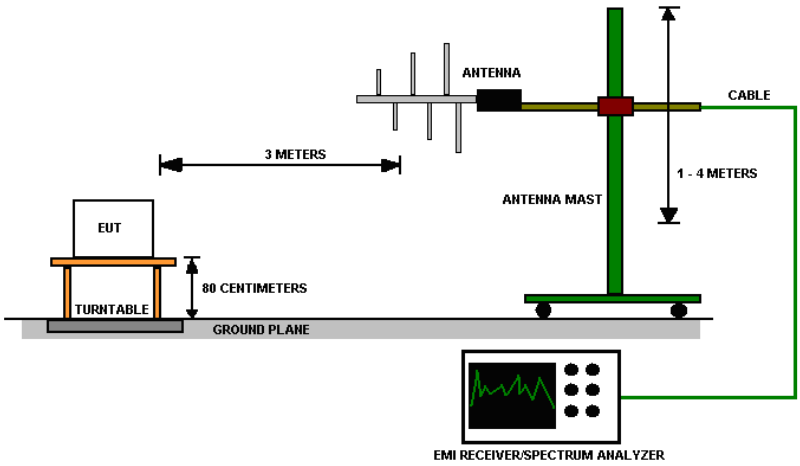

Figure 30 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by internal battery power unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range on each indicated modulation.

Test results:

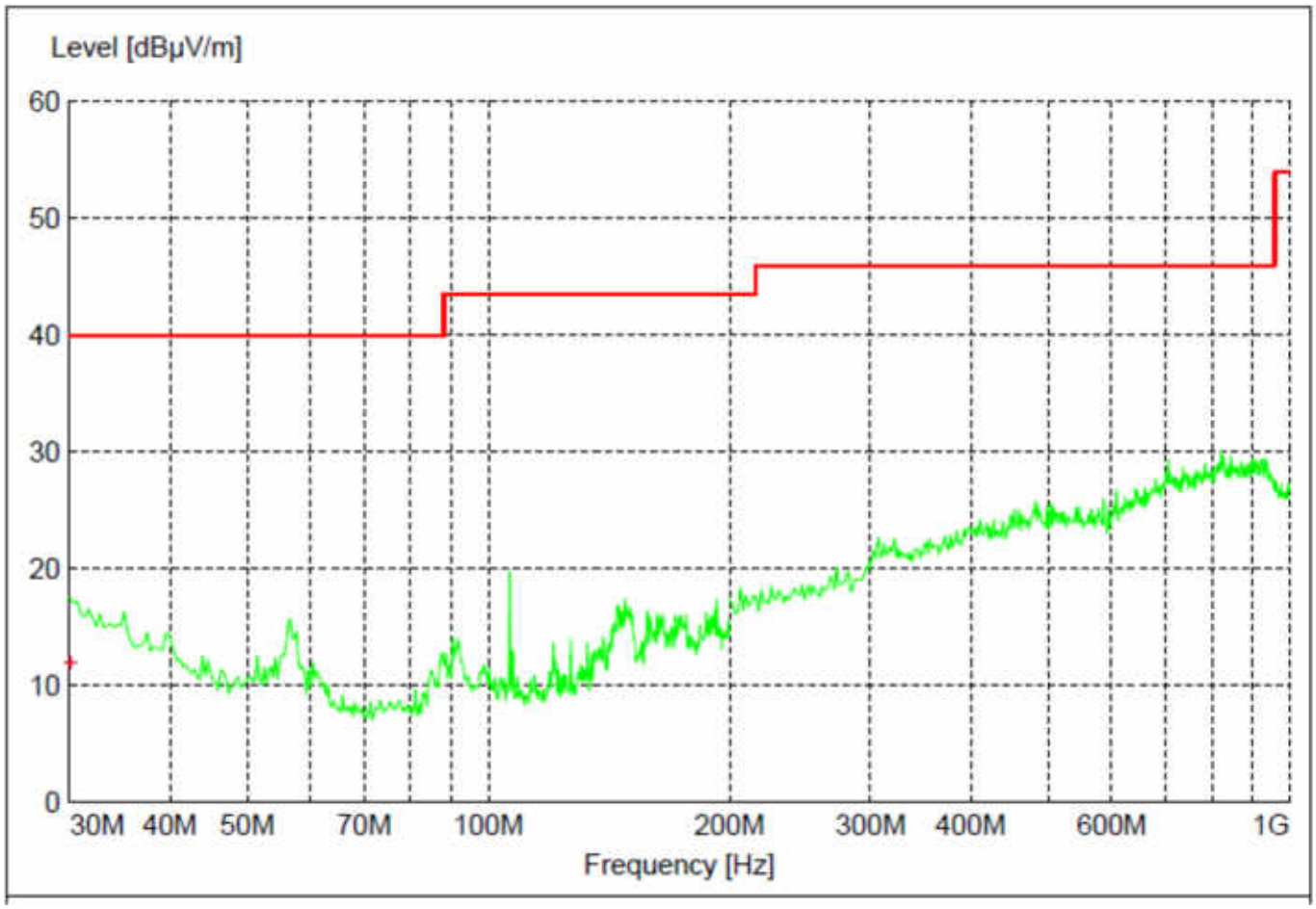

Figure 31 - Radiated Emissions Plot, Receive

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

Table 1 - Radiated Emissions Quasi-peak Measurements, Receive

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
30.060000	11.82	40.00	28.18	246.00	4.00	VERT

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.

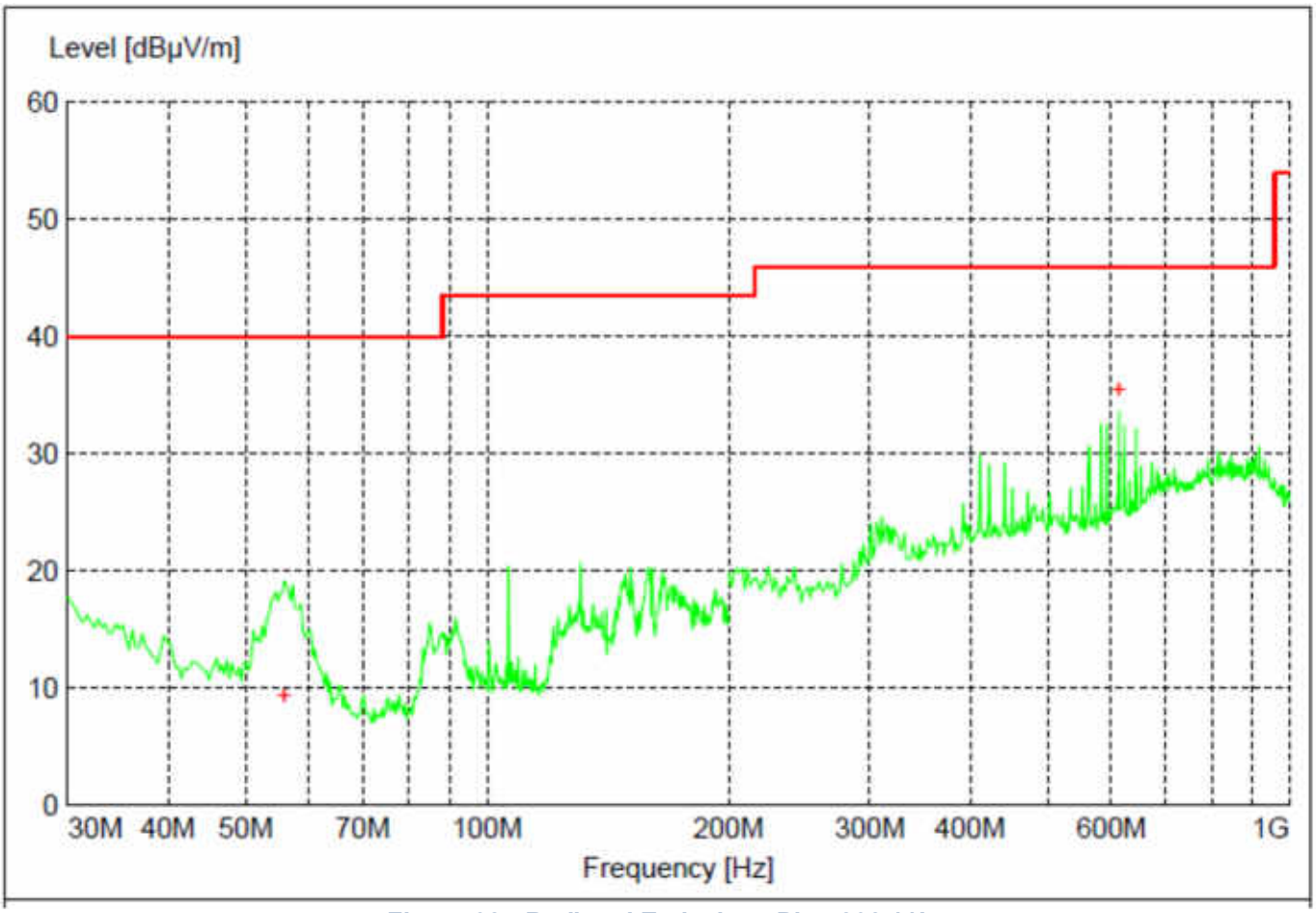

Figure 32 - Radiated Emissions Plot, 802.11b

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

Table 2 - Radiated Emissions Quasi-peak Measurements, 802.11b

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
55.860000	9.30	40.00	30.70	399	360	VERT
613.020000	35.52	46.00	10.48	173	182	HORI

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.

Table 3 - Radiated Emissions Average Measurements, 802.11b

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	89.34	NA	NA	197.00	10	VERT	Low
2440.000000	87.26	NA	NA	197.00	10	VERT	Mid
2480.000000	85.71	NA	NA	197.00	10	VERT	High
9648.000000*	57.71	69.34*	11.63	100.00	170	VERT	Low
9748.000000*	58.35	67.26*	8.91	100.00	165	VERT	Mid
9848.000000*	57.33	65.71*	8.38	100.00	168	VERT	High

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
*Unrestricted Band

Table 4 - Radiated Emissions Peak Measurements, 802.11b

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2412.000000	97.45	NA	NA	197	10	VERT	Low
2437.000000	95.50	NA	NA	197	10	VERT	Mid
2462.000000	93.98	NA	NA	197	10	VERT	High
9648.000000*	60.20	77.45*	17.25	100	170	VERT	Low
9748.000000*	60.66	75.50*	14.84	100	165	VERT	Mid
9848.000000*	59.81	73.98*	14.17	100	168	VERT	High

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.

*Unrestricted Band

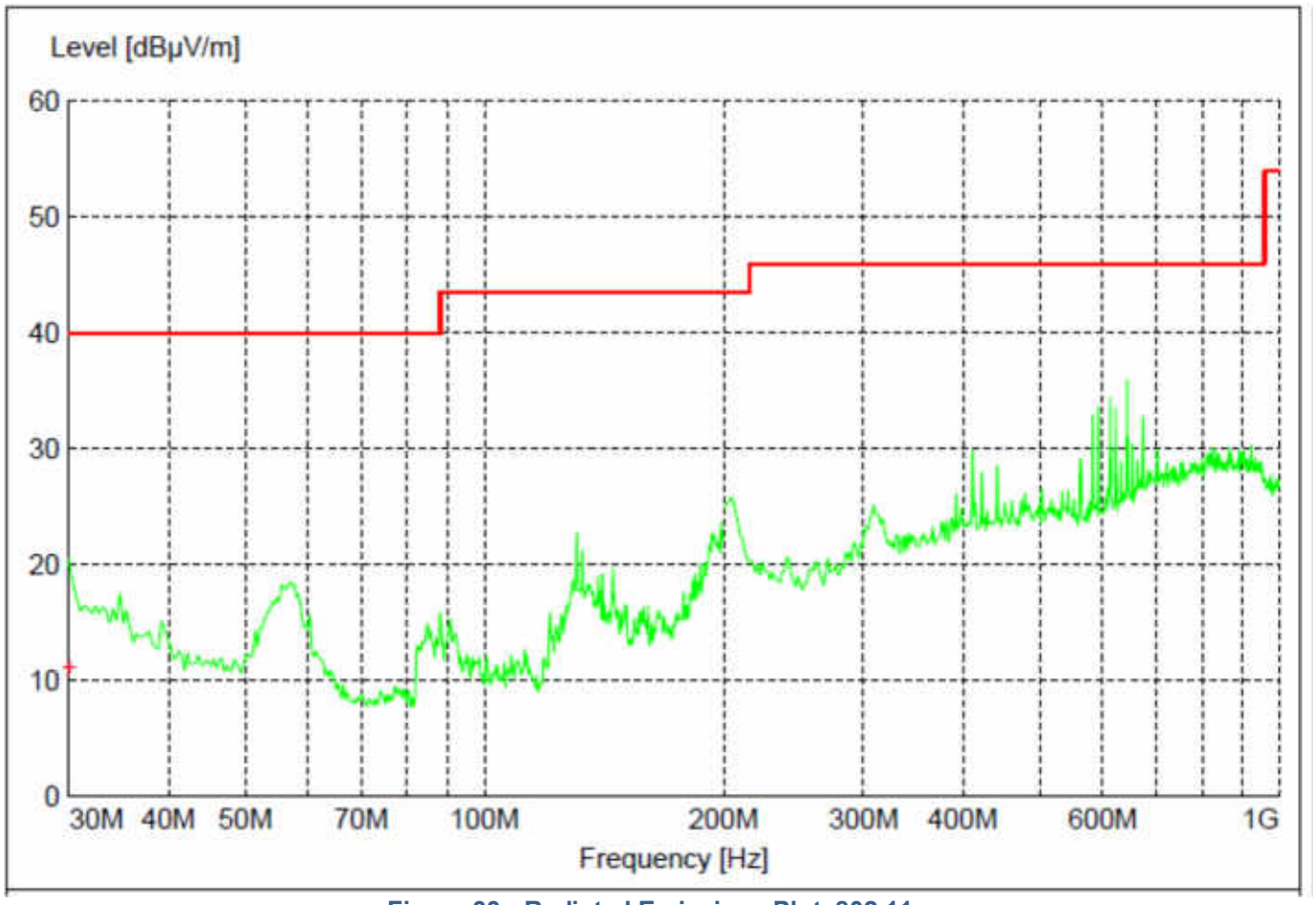

Figure 33 - Radiated Emissions Plot, 802.11g

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

Table 5 - Radiated Emissions Quasi-peak Measurements, 802.11g

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
30.000000	11.16	40.00	28.84	400	244	VERT

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.

Table 6 - Radiated Emissions Average Measurements, 802.11g

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	84.68	NA	NA	197	10	VERT	Low
2440.000000	84.90	NA	NA	197	10	VERT	Mid
2480.000000	83.70	NA	NA	197	10	VERT	High
9648.000000*	56.50	64.68*	8.18	98	166	VERT	Low
9748.000000*	57.40	64.90*	7.50	98	163	VERT	Mid
9848.000000*	58.10	63.70*	5.60	100	164	VERT	High

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
*Unrestricted Band

Table 7 - Radiated Emissions Peak Measurements, 802.11g

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2412.000000	103.37	NA	NA	197	10	VERT	Low
2437.000000	98.76	NA	NA	197	10	VERT	Mid
2462.000000	96.57	NA	NA	197	10	VERT	High
9648.000000*	59.68	83.37*	23.69	98	166	VERT	Low
9748.000000*	60.28	78.76*	18.48	98	163	VERT	Mid
9848.000000*	60.81	76.57*	15.76	100	164	VERT	High

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.

*Unrestricted Band

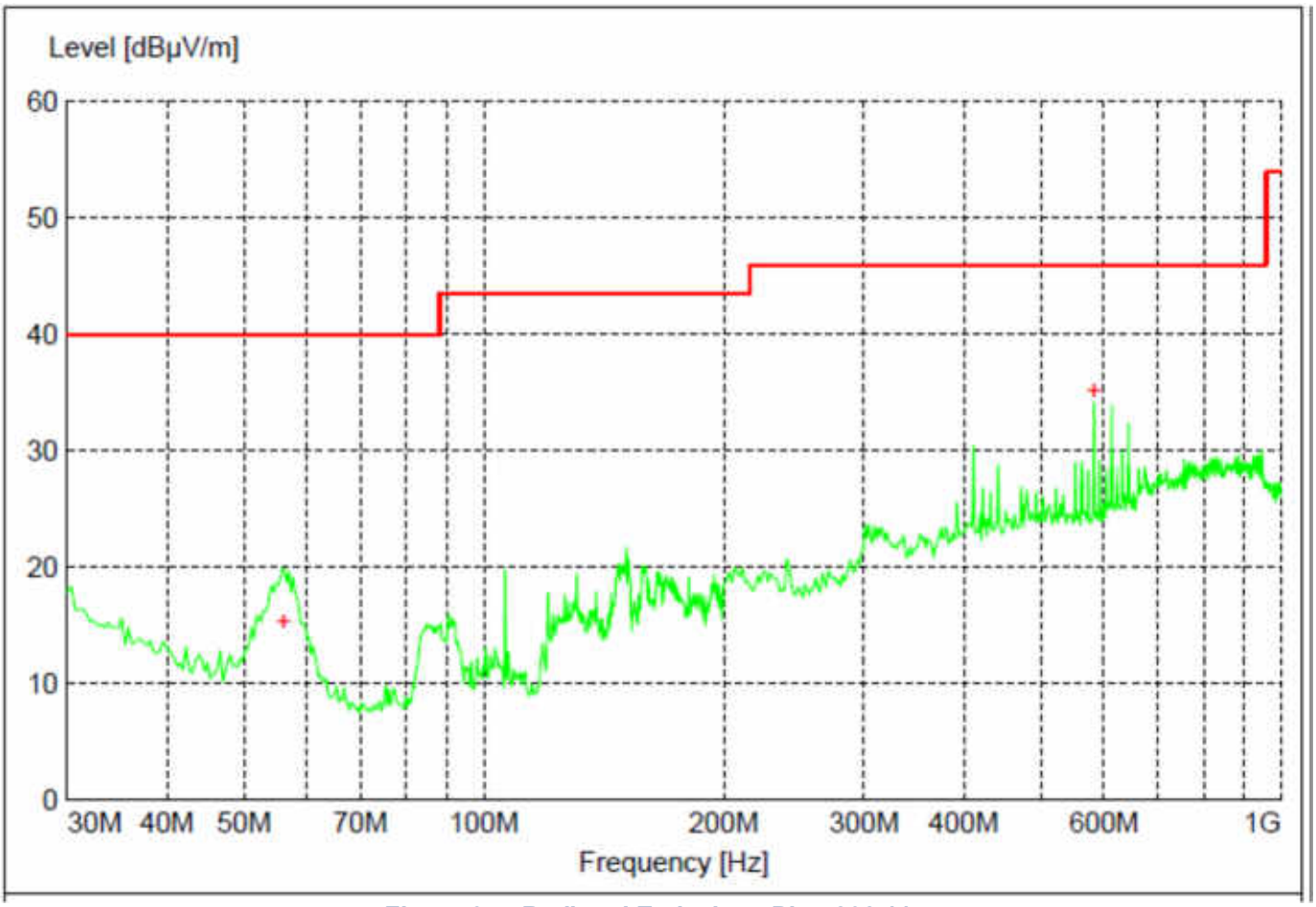

Figure 34 - Radiated Emissions Plot, 802.11n

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

Table 8 - Radiated Emissions Quasi-peak Measurements, 802.11n

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
56.100000	15.32	40.00	24.68	100.00	38.00	VERT
582.900000	35.15	46.00	10.85	169.00	226.00	HORI

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.

Table 9 - Radiated Emissions Average Measurements, 802.11n

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	86.07	NA	NA	197	10	VERT	Low
2440.000000	85.13	NA	NA	197	10	VERT	Mid
2480.000000	83.30	NA	NA	197	10	VERT	High
9648.000000*	57.19	66.07*	8.88	100	166	VERT	Low
9748.000000*	58.20	65.13*	6.93	98	165	VERT	Mid
9848.000000*	58.10	63.30*	5.20	101	163	VERT	High

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
*Unrestricted Band

Table 10 - Radiated Emissions Peak Measurements, 802.11n

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2412.000000	99.46	NA	NA	197	10	VERT	Low
2437.000000	98.49	NA	NA	197	10	VERT	Mid
2462.000000	96.20	NA	NA	197	10	VERT	High
9648.000000*	60.07	79.46*	19.39	100	166	VERT	Low
9748.000000*	60.77	78.49*	17.72	98	165	VERT	Mid
9848.000000*	60.47	76.20*	15.73	101	163	VERT	High

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.

*Unrestricted Band

4.5 POWER SPECTRAL DENSITY

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

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

Test procedures:
1. The EUT was 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 internal battery power unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range on each indicated modulation.

Test results:

Power Spectral Density

CHANNEL	MODE	CHANNEL FREQUENCY (MHz)	PEAK PSD (dBm)	Method	Limit (dBm)	RESULT
Low	2412	802.11 b	-11.265	Conducted	8.00	PASS
Mid	2440	802.11 b	-12.690	Conducted	8.00	PASS
High	2460	802.11 b	-12.327	Conducted	8.00	PASS
Low	2412	802.11 g	-11.442	Conducted	8.00	PASS
Mid	2440	802.11 g	-11.832	Conducted	8.00	PASS
High	2460	802.11 g	-11.967	Conducted	8.00	PASS
Low	2412	802.11 n	-11.702	Conducted	8.00	PASS
Mid	2440	802.11 n	-12.737	Conducted	8.00	PASS
High	2460	802.11 n	-12.407	Conducted	8.00	PASS

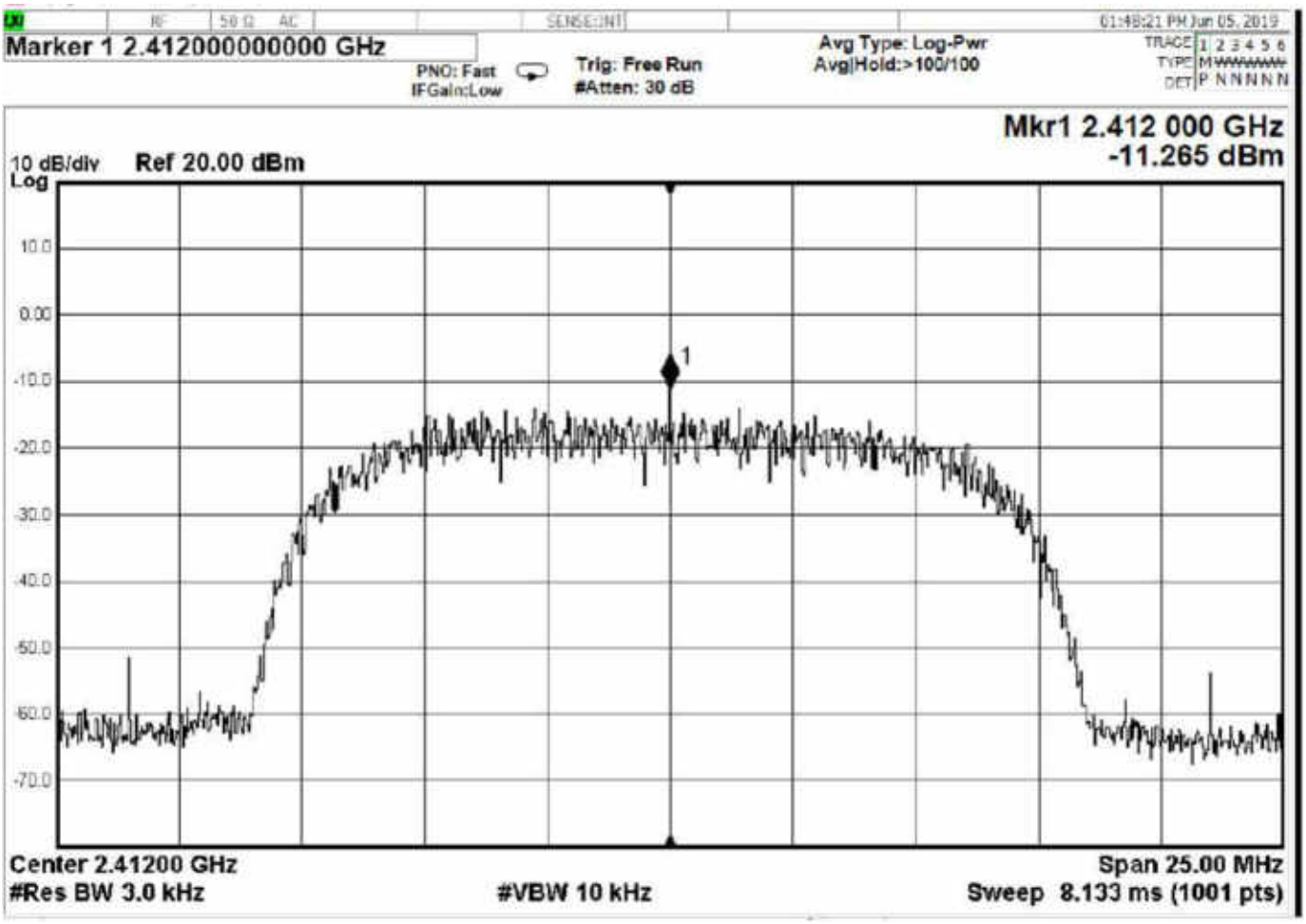

Figure 35 - Power Spectral Density, Low Channel, 802.11b

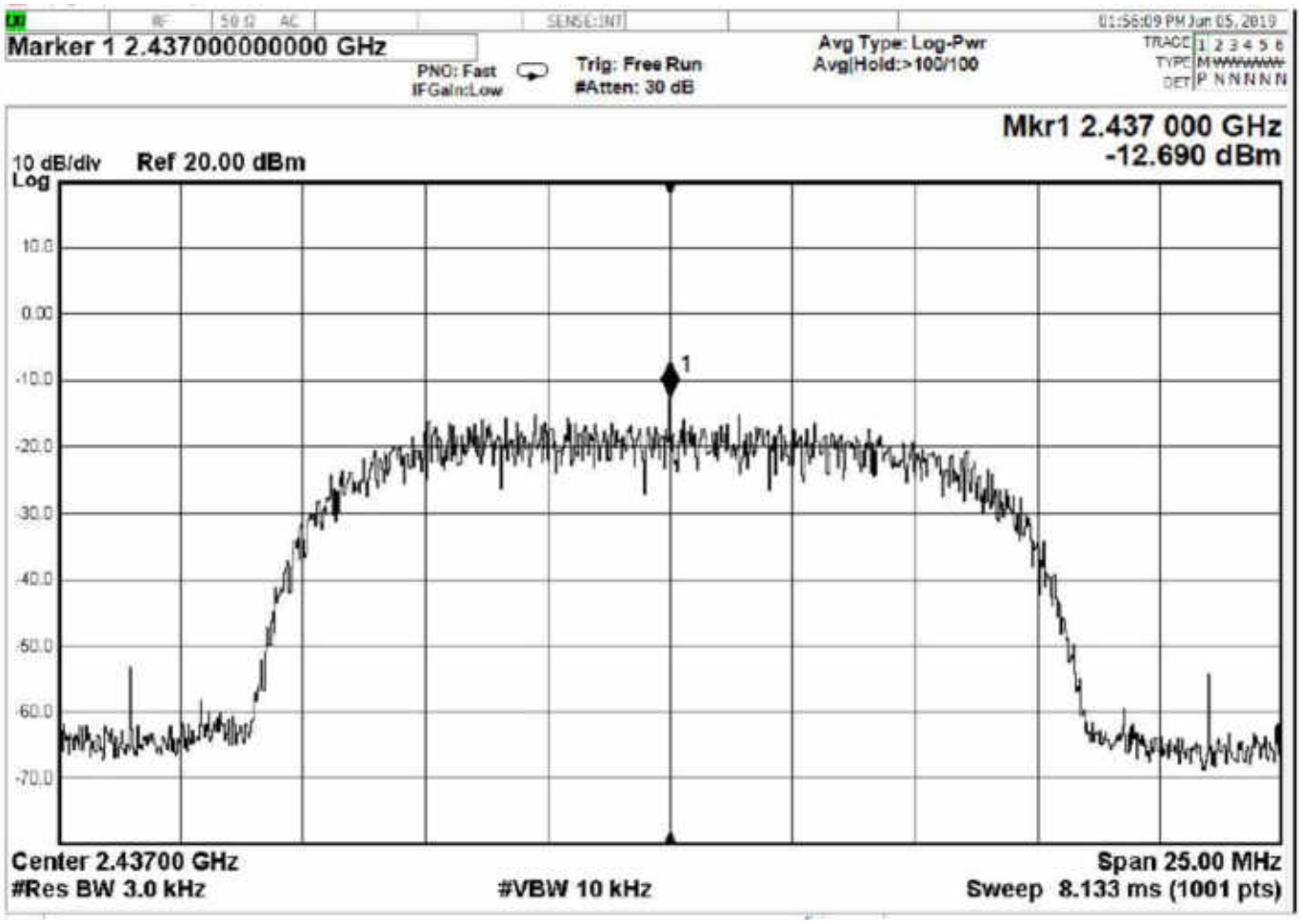

Figure 36 - Power Spectral Density, Mid Channel, 802.11b

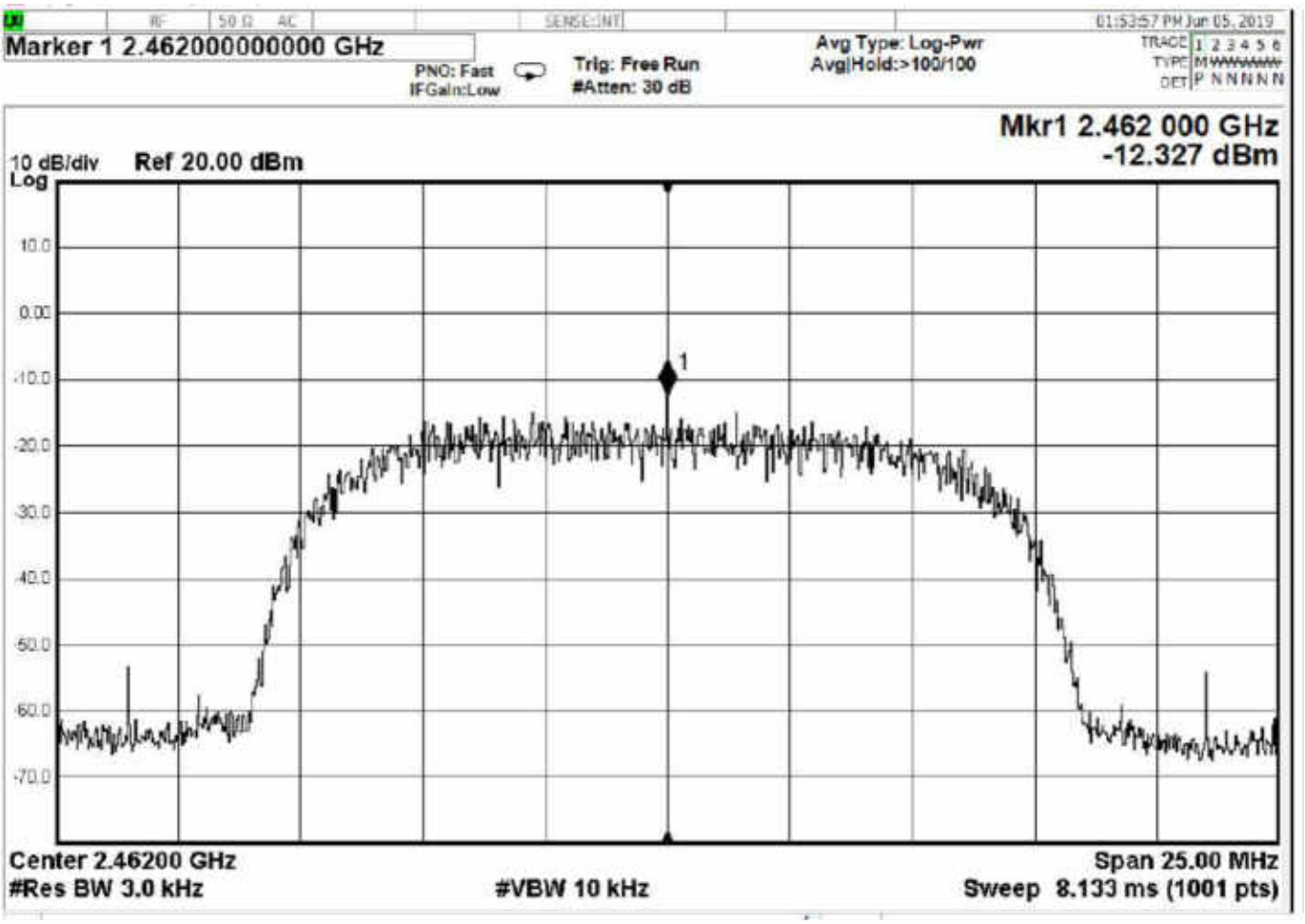

Figure 37 - Power Spectral Density, High Channel, 802.11b

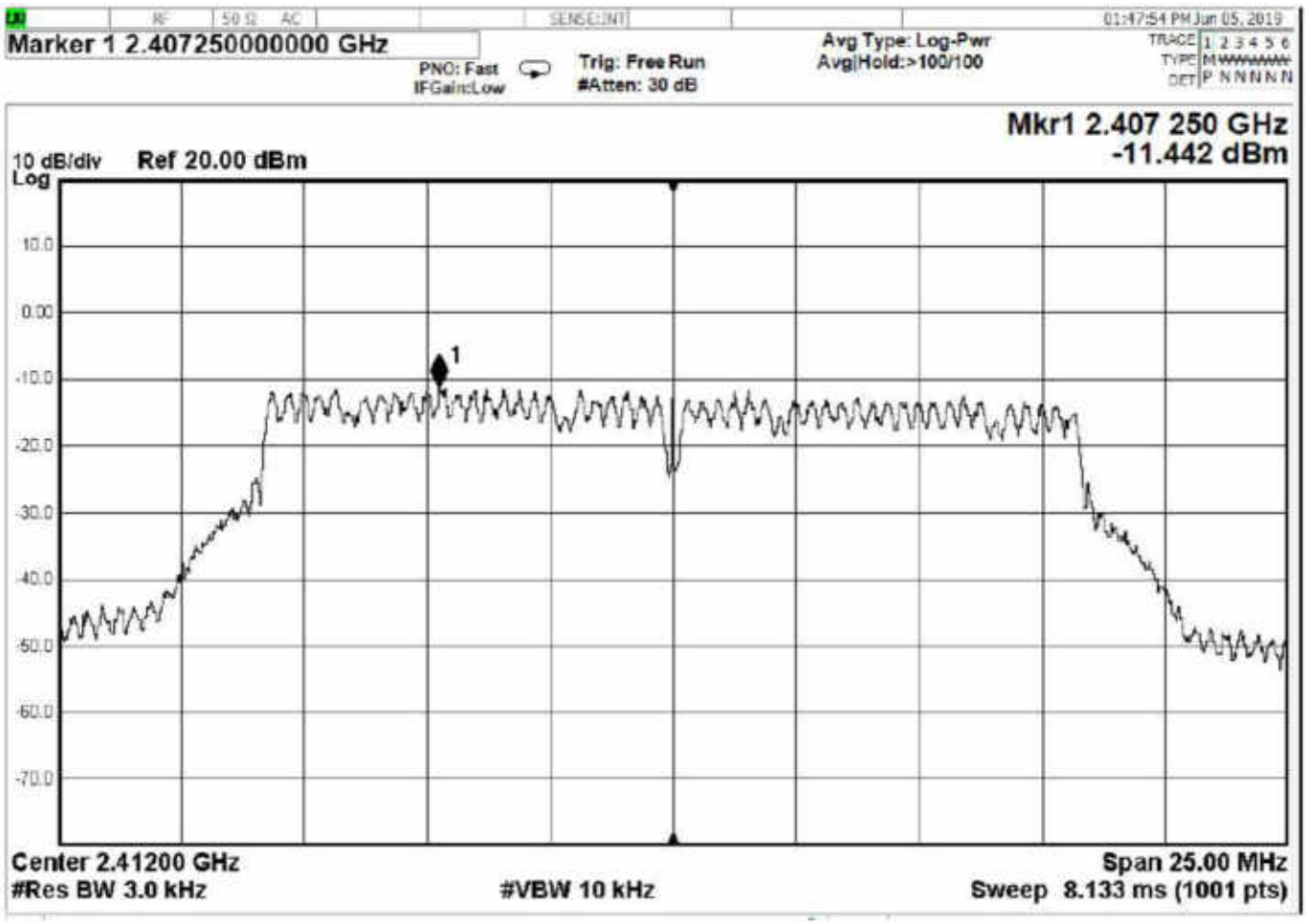

Figure 38 - Power Spectral Density, Low Channel, 802.11g

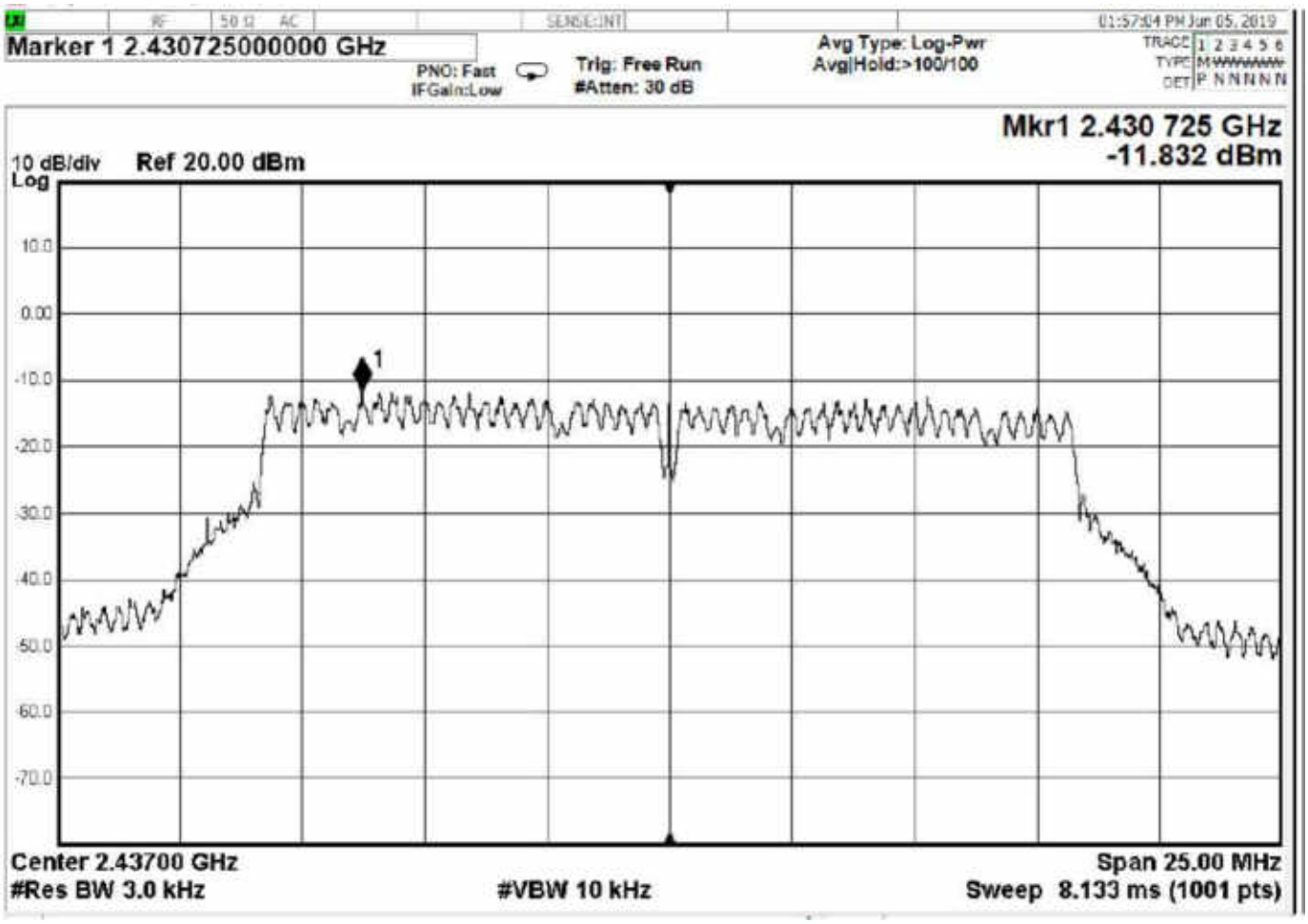

Figure 39 - Power Spectral Density, Mid Channel, 802.11g

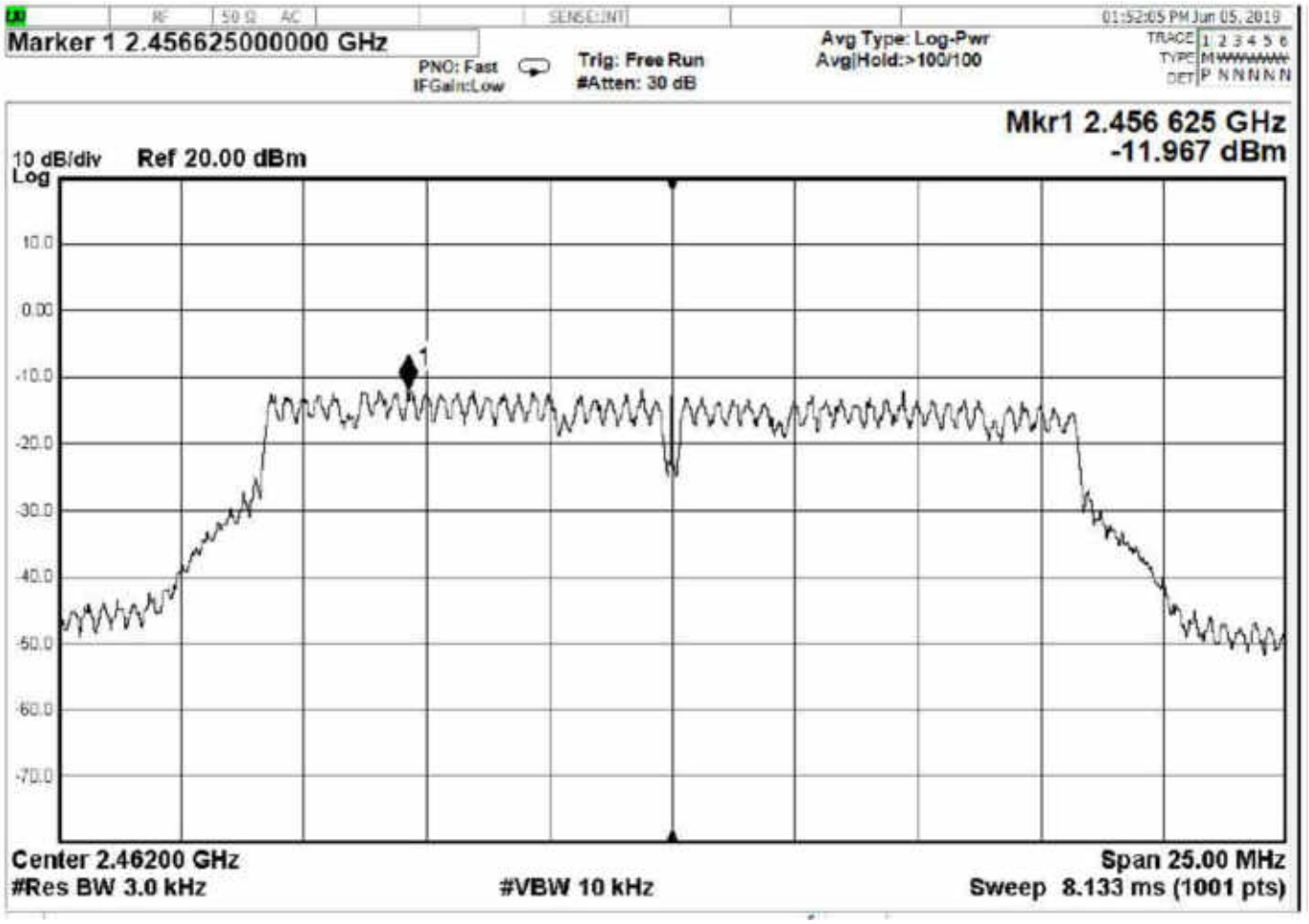

Figure 40 - Power Spectral Density, High Channel, 802.11g

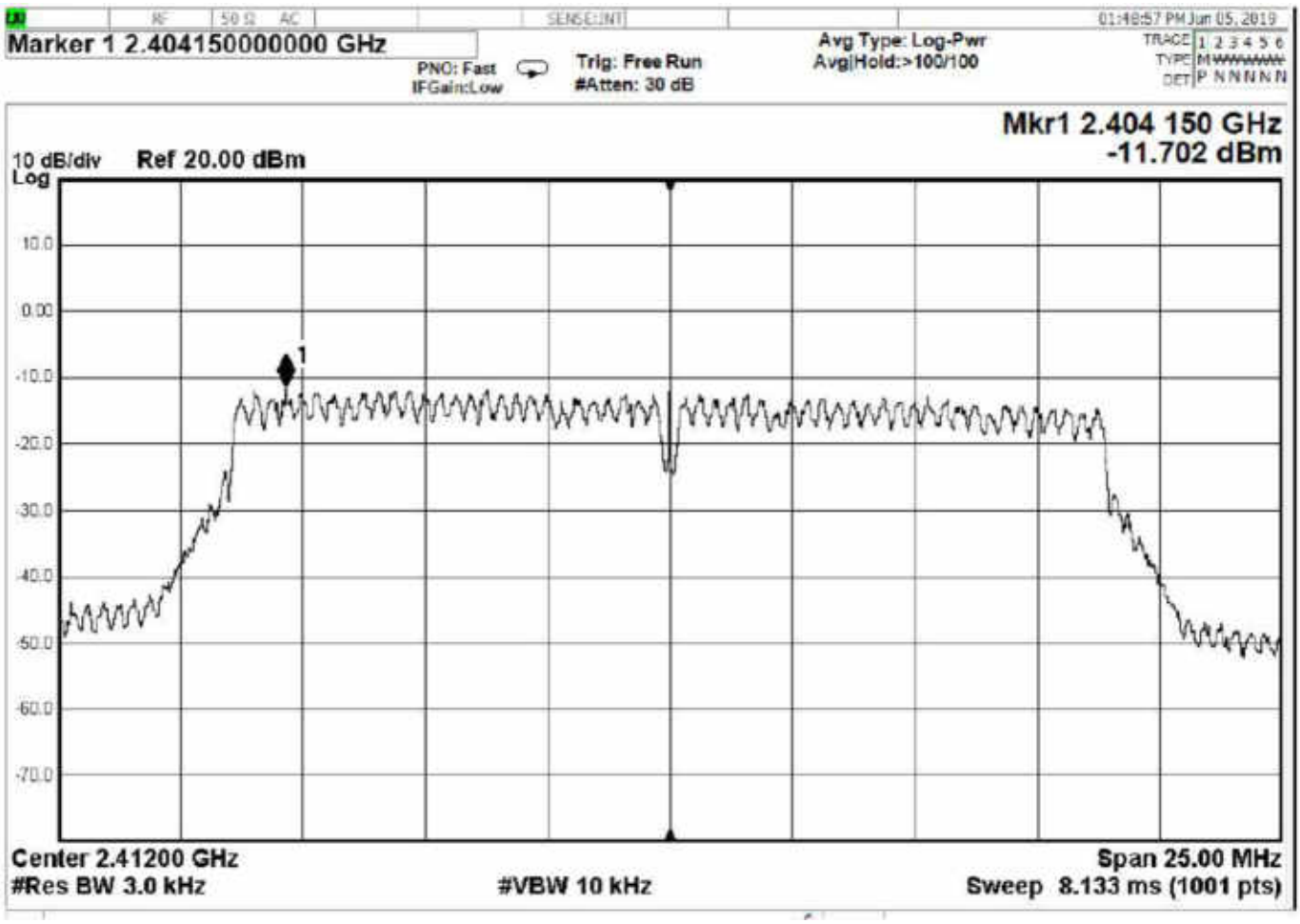

Figure 41 - Power Spectral Density, Low Channel, 802.11n

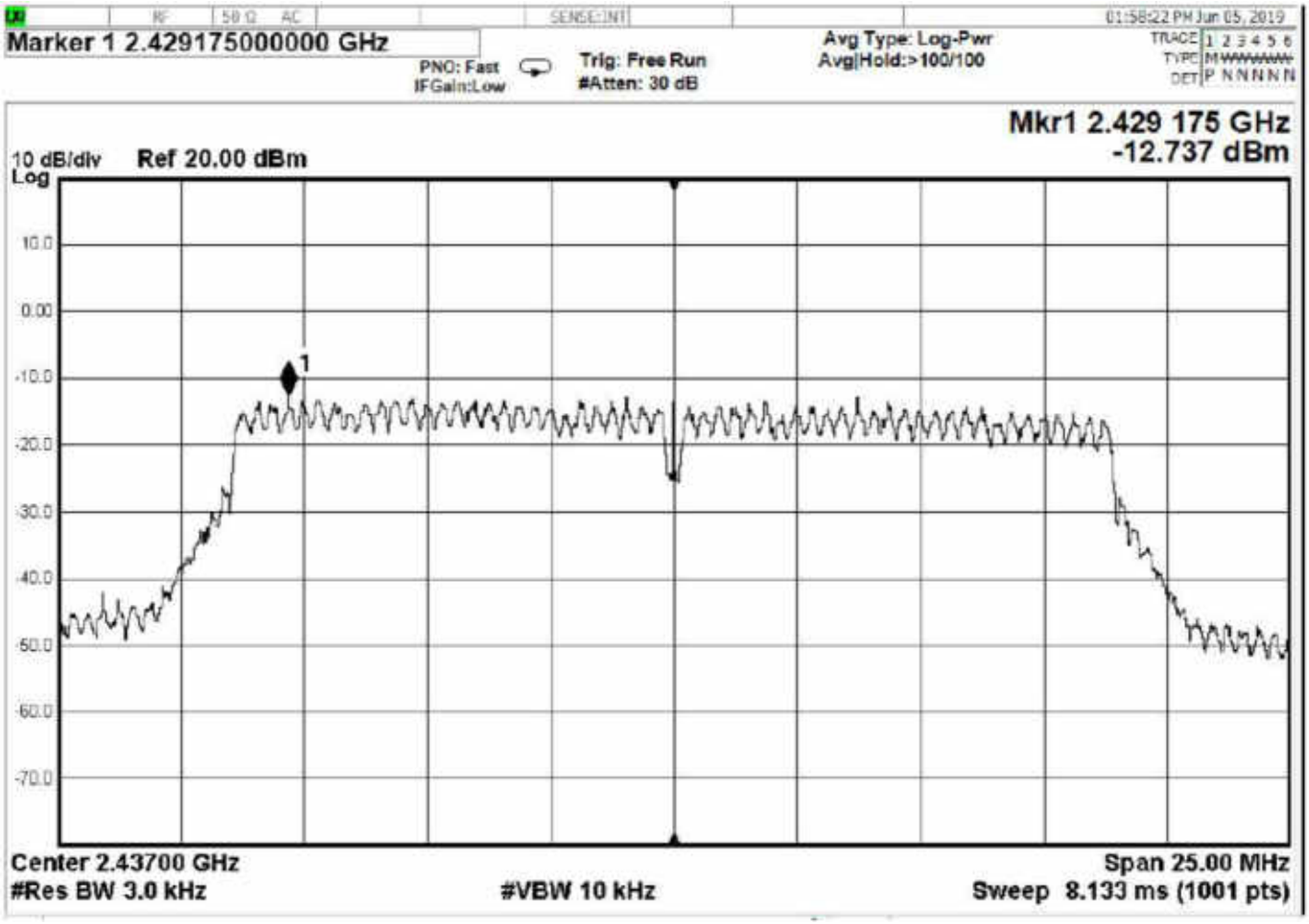

Figure 42 - Power Spectral Density, Mid Channel, 802.11n

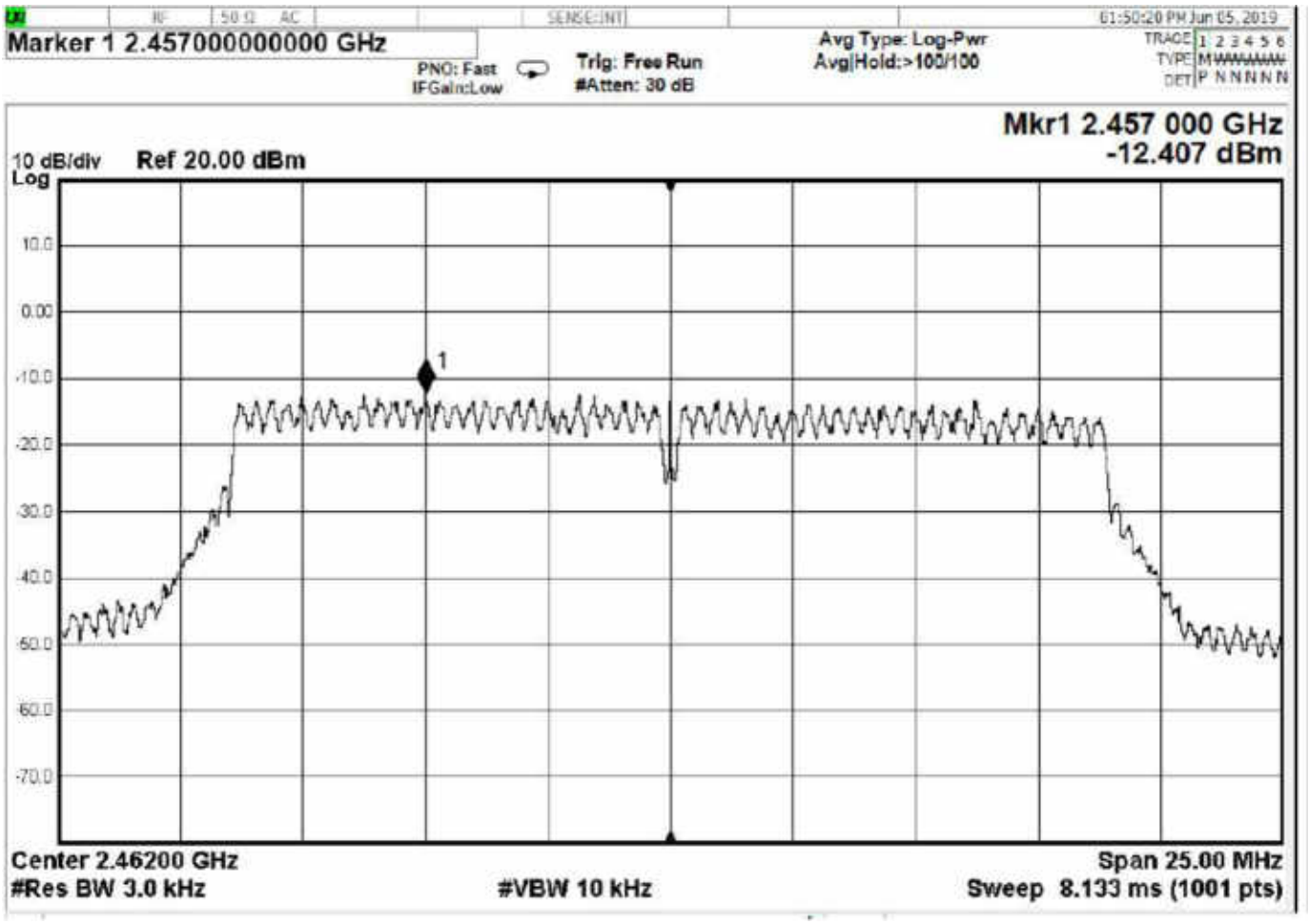

Figure 43 - Power Spectral Density, High Channel, 802.11n

4.6 BANDEDGES

Test Method: ANSI C63.10:

1. Section 6.10.5 (used for restricted bands)
2. Section 11.13.2 “Marker-delta method” (for unrestricted bands)
3. Section 11.11, “Measurement in unrestricted frequency bands”

Limits of bandedge measurements:
For emissions outside of the allowed band of operation (2400.0MHz – 2480.0MHz), the emission level needs to be 20dB under the maximum fundamental field strength. However, if the emissions fall within one of the restricted bands from 15.205 the field strength levels need to be under that of the limits in 15.209.

Test procedures:
The EUT was tested in the same method as described in section *4.4 - Bandwidth*. The resolution bandwidth was set to 100kHz and video bandwidth to 300 kHz 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:
See Section 4.3

EUT operating conditions:
The EUT was powered by internal battery power 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, 802.11b

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level dBm	Fundamental Level (dBm)	Delta	Min (dBc)	Result
1	2390.0 (Unrestricted, Peak)	-41.61	0.24	41.85	20	PASS
1	2390.0 (Unrestricted, Average)	-53.72	-10.45	43.27	20	PASS
11	2483.5 (Unrestricted, Peak)	-48.26	-1.81	46.45	20	PASS
11	2483.5 (Unrestricted, Average)	-61.14	-11.95	49.19	20	PASS

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level (dBm)	Corrected Emission Level (dBm)	Limit* (dBm)	Gain (dBi)	Margin	Result
1	2340.0 (Restricted, Peak)	-47.14	-47.14	-21.23	0	25.91	PASS
1	2340.0 (Restricted, Average)	-60.81	-60.81	-41.23	0	19.58	PASS
11	2483.5 (Restricted, Peak)	-46.85	-46.85	-21.23	0	25.62	PASS
11	2483.5 (Restricted, Average)	-62.02	-62.02	-41.23	0	20.79	PASS

Corrected Emission level= Highest out of band level +Gain
Margin= Limit-Corrected Emission Level
*Limits from Part 15.209 in dBm **Antenna gain declared by the manufacturer

Part 15.209 Peak Limit = 74.00 dBµV/m

Part 15.209 Average Limit = 54.00 dBµV/m

EIRP(dBm) = FS(dBµV/m) – 10(log 10^9)+ 10log[0.3] = FS_{3m}(dBµV/m) - 95.23

Peak Limit (delta) = 74.00 dBµV/m – 95.23 = -21.23dBm

Average Limit (delta) = 54.00 dBµV/m – 95.23 = -41.23dBm

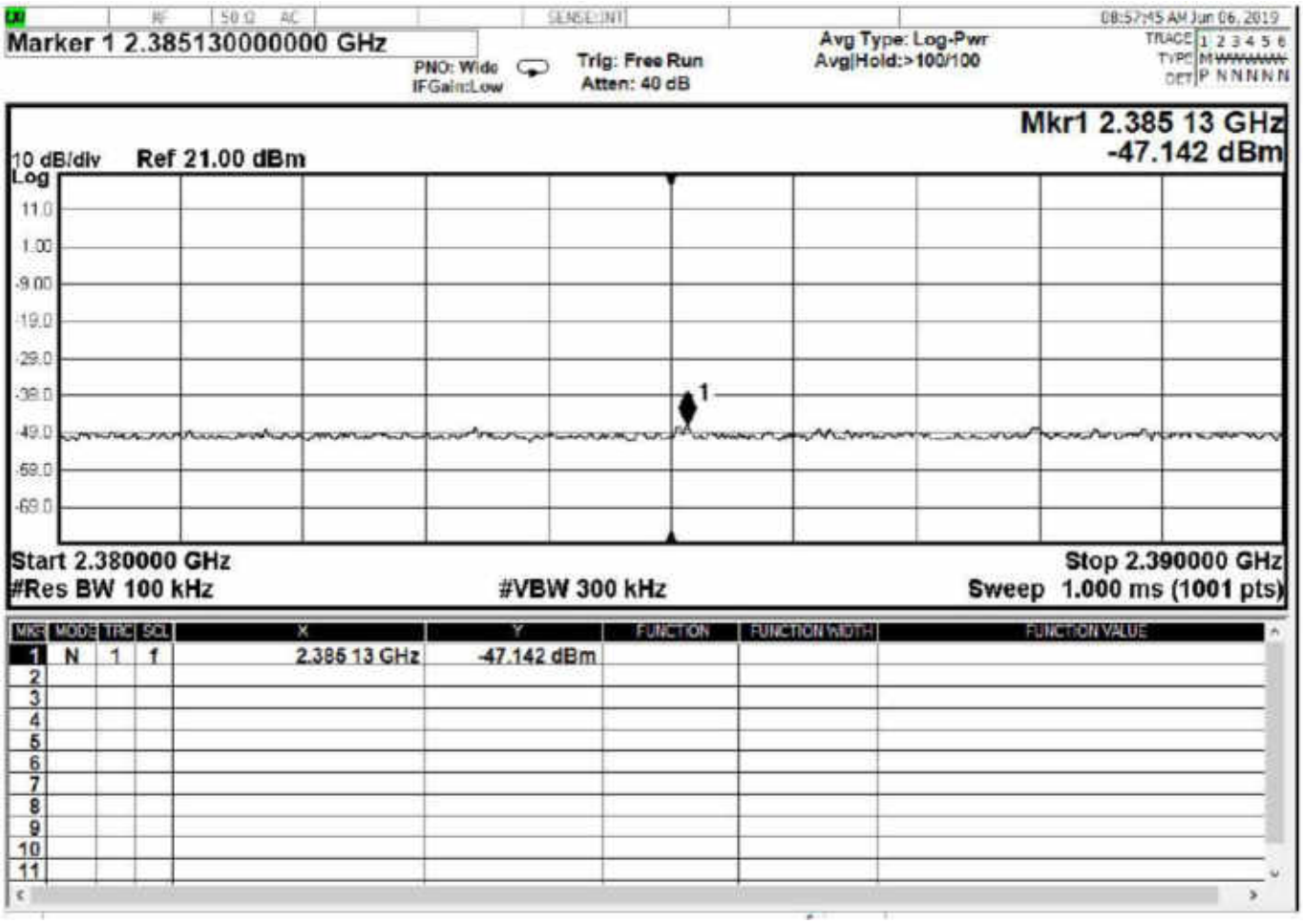

Figure 44 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

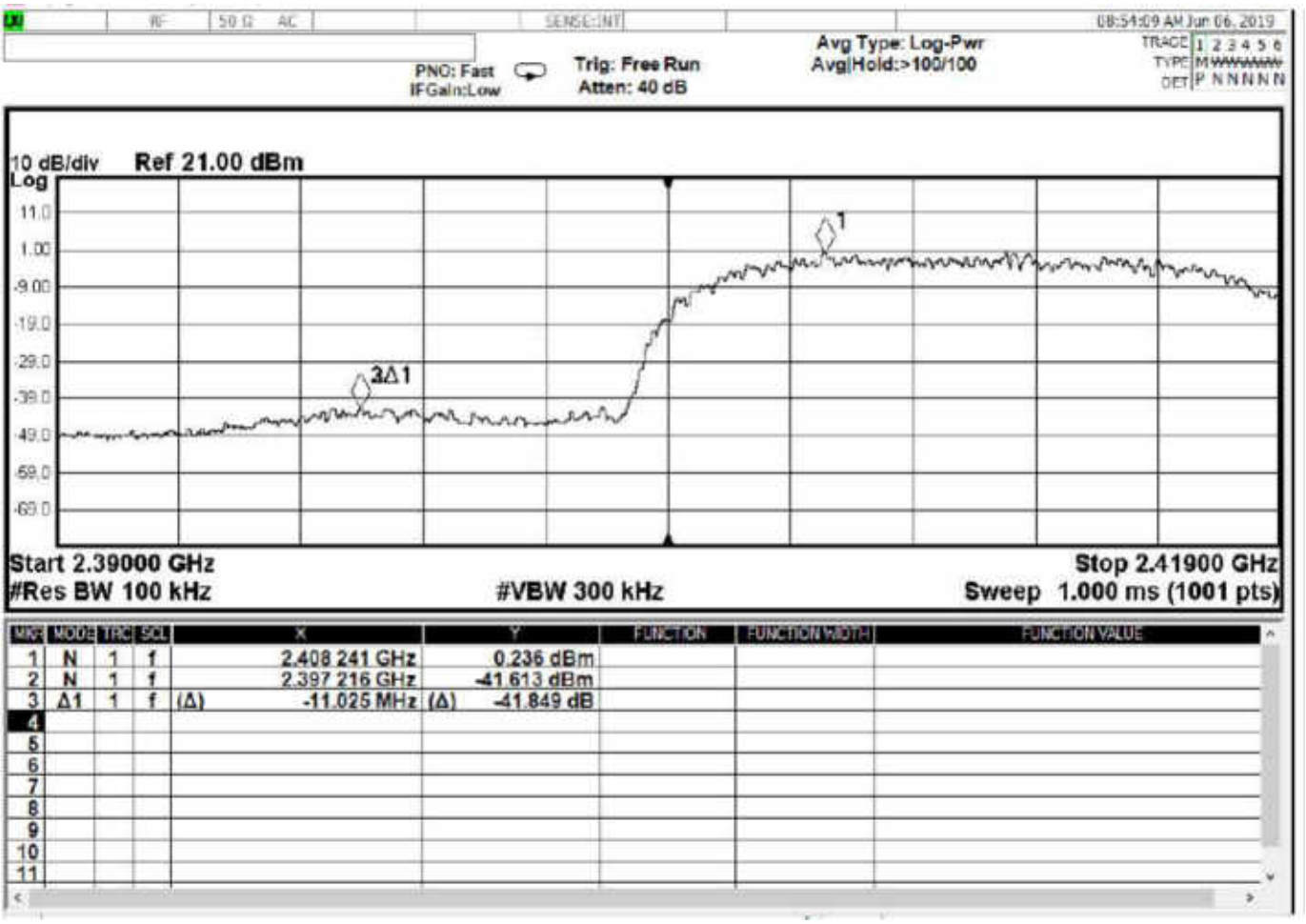

Figure 45 - Band-edge Measurement, Low Channel, Fundamental, Peak

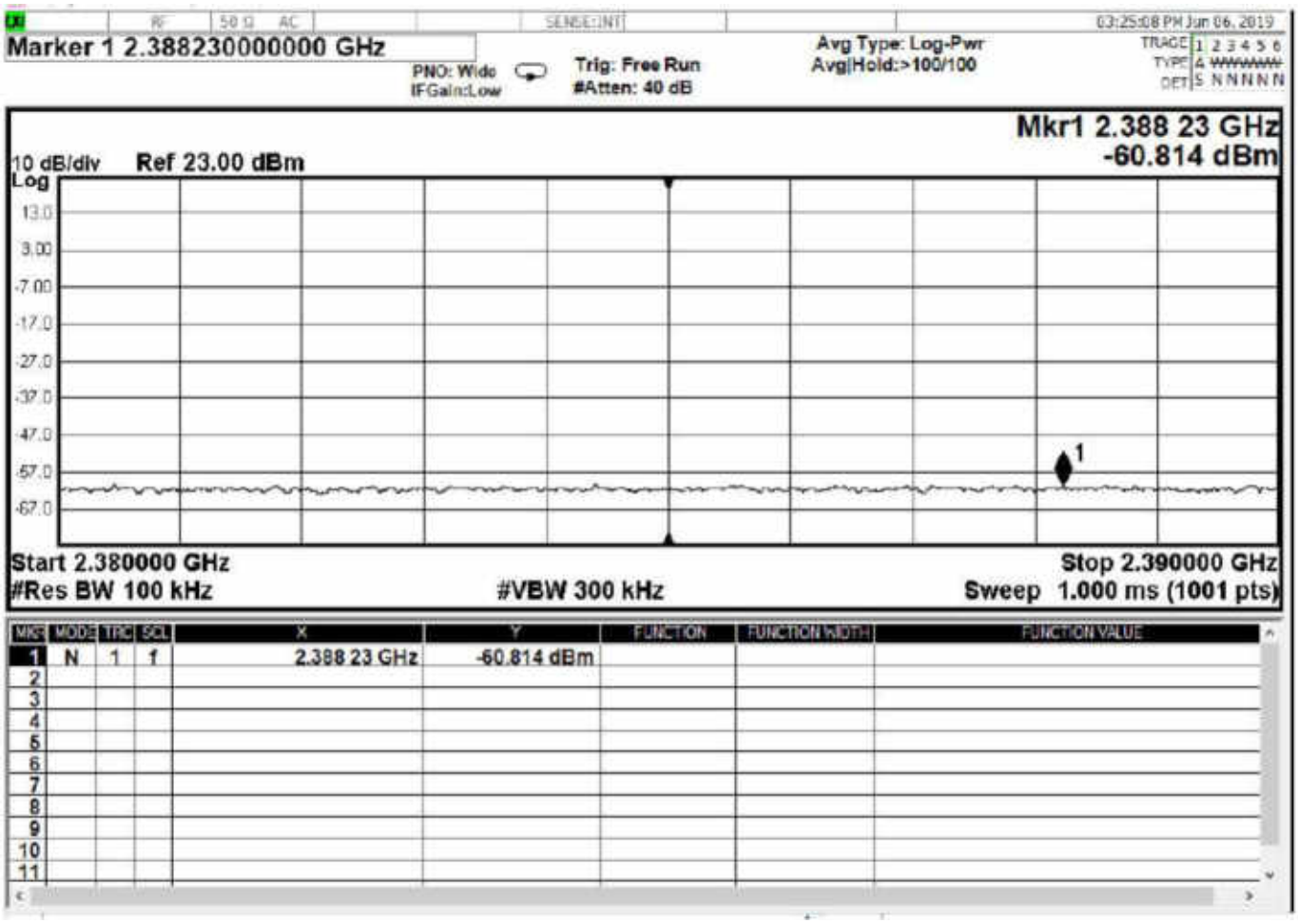

Figure 46 - Band-edge Measurement, Low Channel, Restricted Frequency, Average

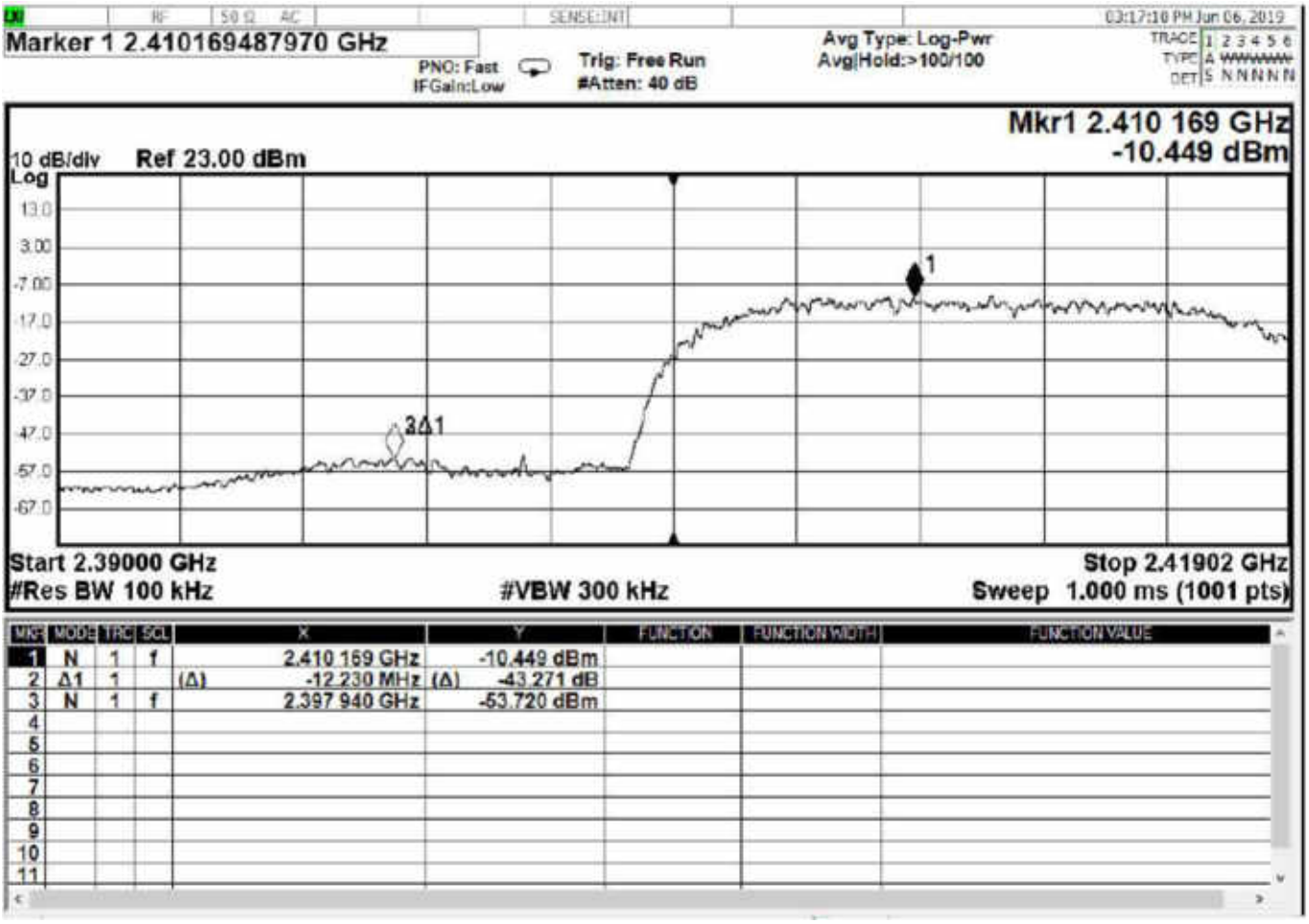

Figure 47 - Band-edge Measurement, Low Channel, Fundamental, Average

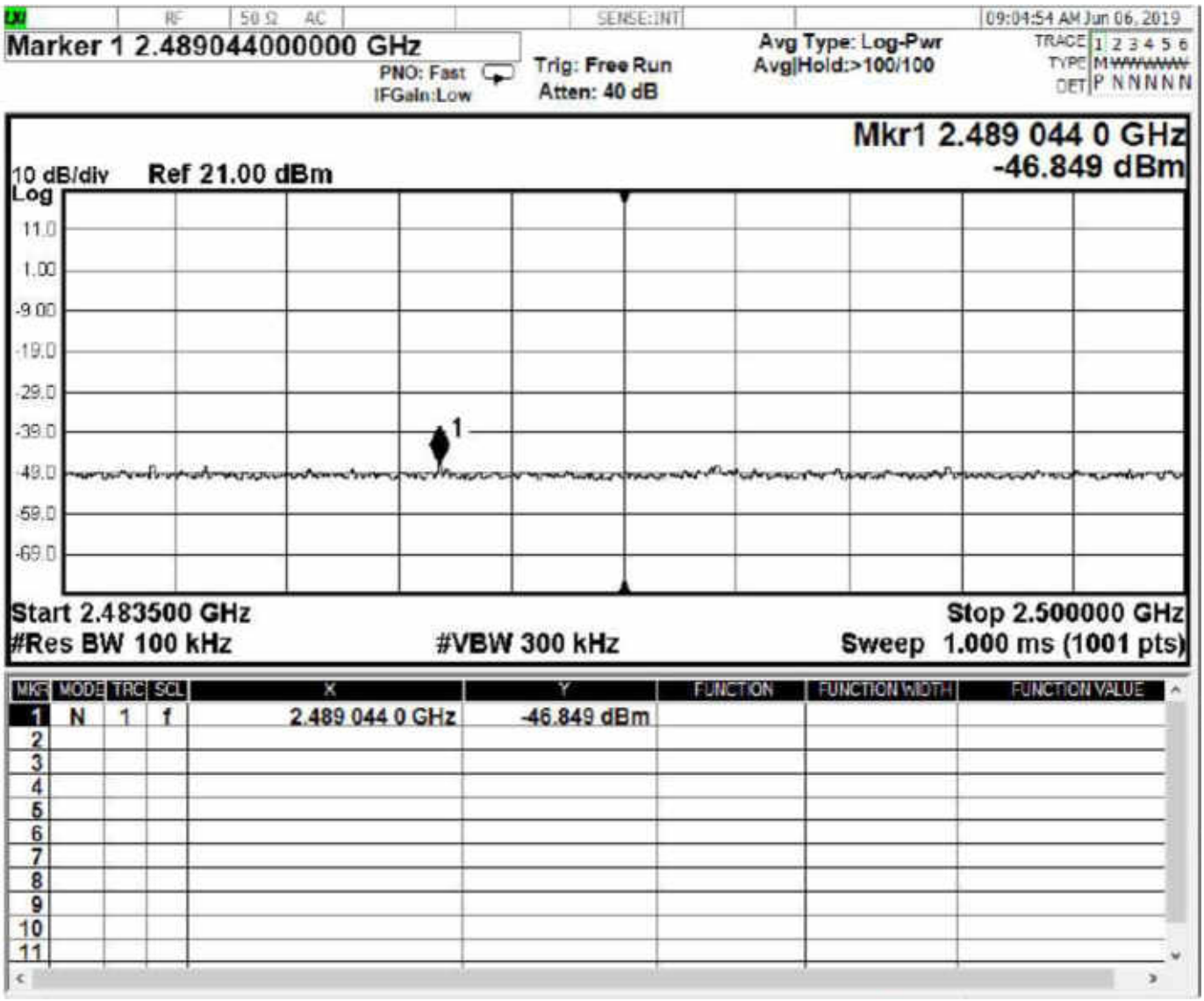

Figure 48 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

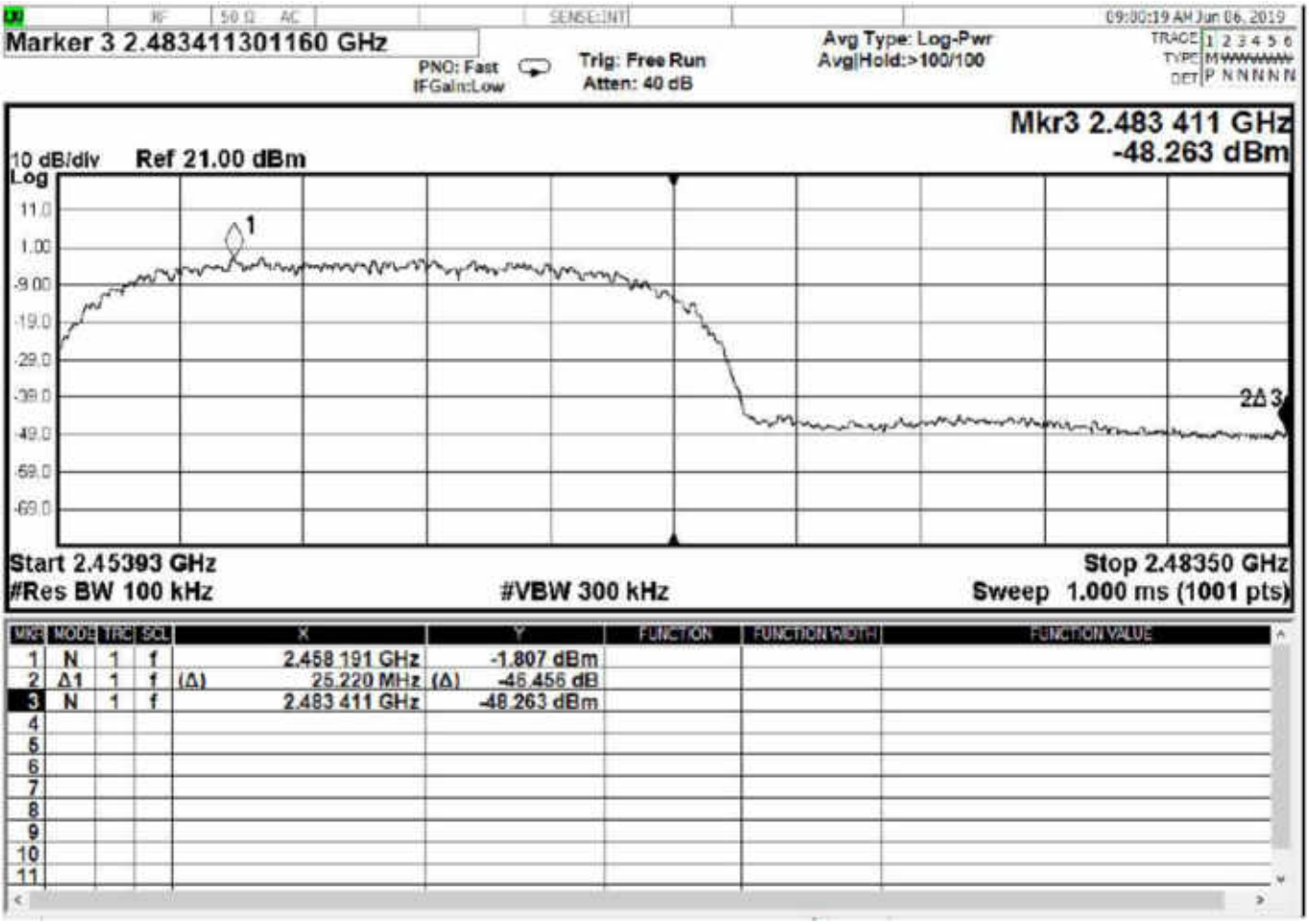

Figure 49 - Band-edge Measurement, High Channel, Fundamental, Peak

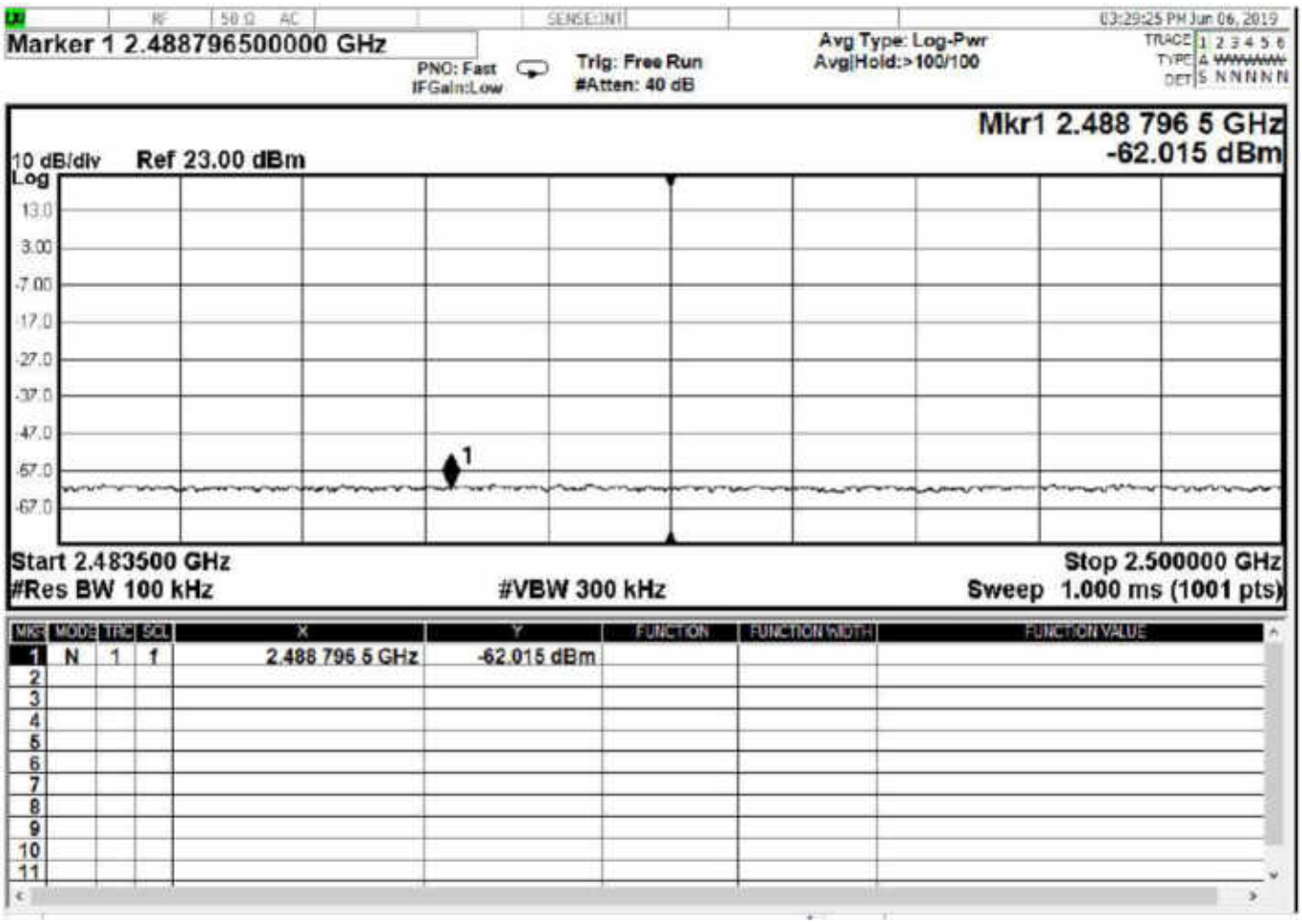

Figure 50 - Band-edge Measurement, High Channel, Restricted Frequency, Average

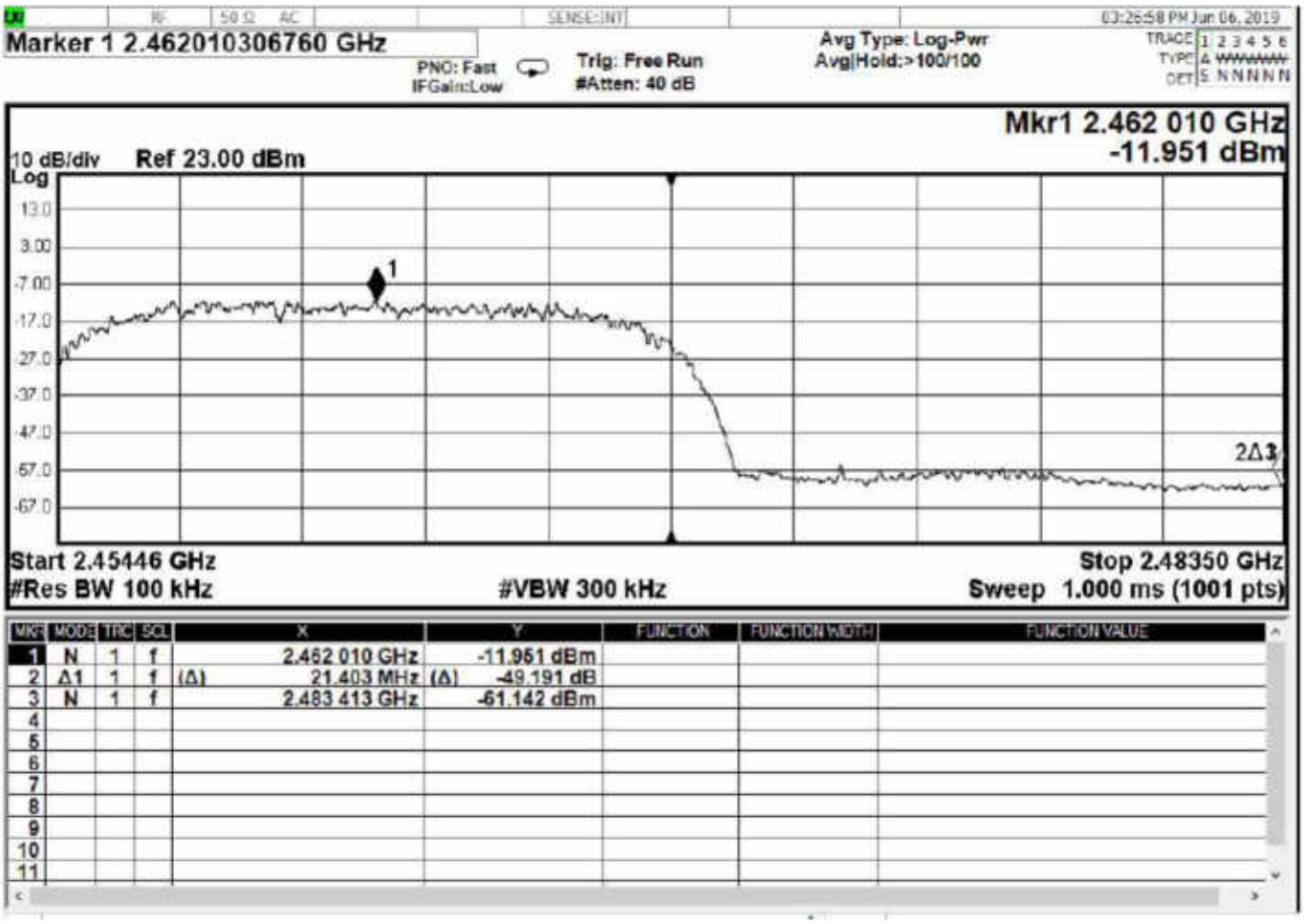

Figure 51 - Band-edge Measurement, High Channel, Fundamental, Average

Highest Out of Band Emissions, 802.11g

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level dBm	Fundamental Level (dBm)	Delta	Min (dBc)	Result
1	2390.0 (Unrestricted, Peak)	-31.35	0.55	31.90	20	PASS
1	2390.0 (Unrestricted, Average)	-48.53	-8.97	39.56	20	PASS
11	2483.5 (Unrestricted, Peak)	-44.70	-0.82	43.88	20	PASS
11	2483.5 (Unrestricted, Average)	-57.95	-10.11	47.84	20	PASS

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level (dBm)	Corrected Emission Level (dBm)	Limit* (dBm)	Gain (dBi)	Margin	Result
1	2340.0 (Restricted, Peak)	-39.50	-39.50	-21.23	0	18.265	PASS
1	2340.0 (Restricted, Average)	-54.66	-54.66	-41.23	0	13.43	PASS
11	2483.5 (Restricted, Peak)	-42.70	-42.70	-21.23	0	21.47	PASS
11	2483.5 (Restricted, Average)	-55.56	-55.56	-41.23	0	14.33	PASS

Corrected Emission level= Highest out of band level +Gain
Margin= Limit-Corrected Emission Level
*Limits from Part 15.209 in dBm **Antenna gain declared by the manufacturer

Part 15.209 Peak Limit = 74.00 dBµV/m

Part 15.209 Average Limit = 54.00 dBµV/m

EIRP(dBm) = FS(dBµV/m) – 10(log 10^9)+ 10log[0.3] = FS_{3m}(dBµV/m) - 95.23

Peak Limit (delta) = 74.00 dBµV/m – 95.23 = -21.23dBm

Average Limit (delta) = 54.00 dBµV/m – 95.23 = -41.23dBm

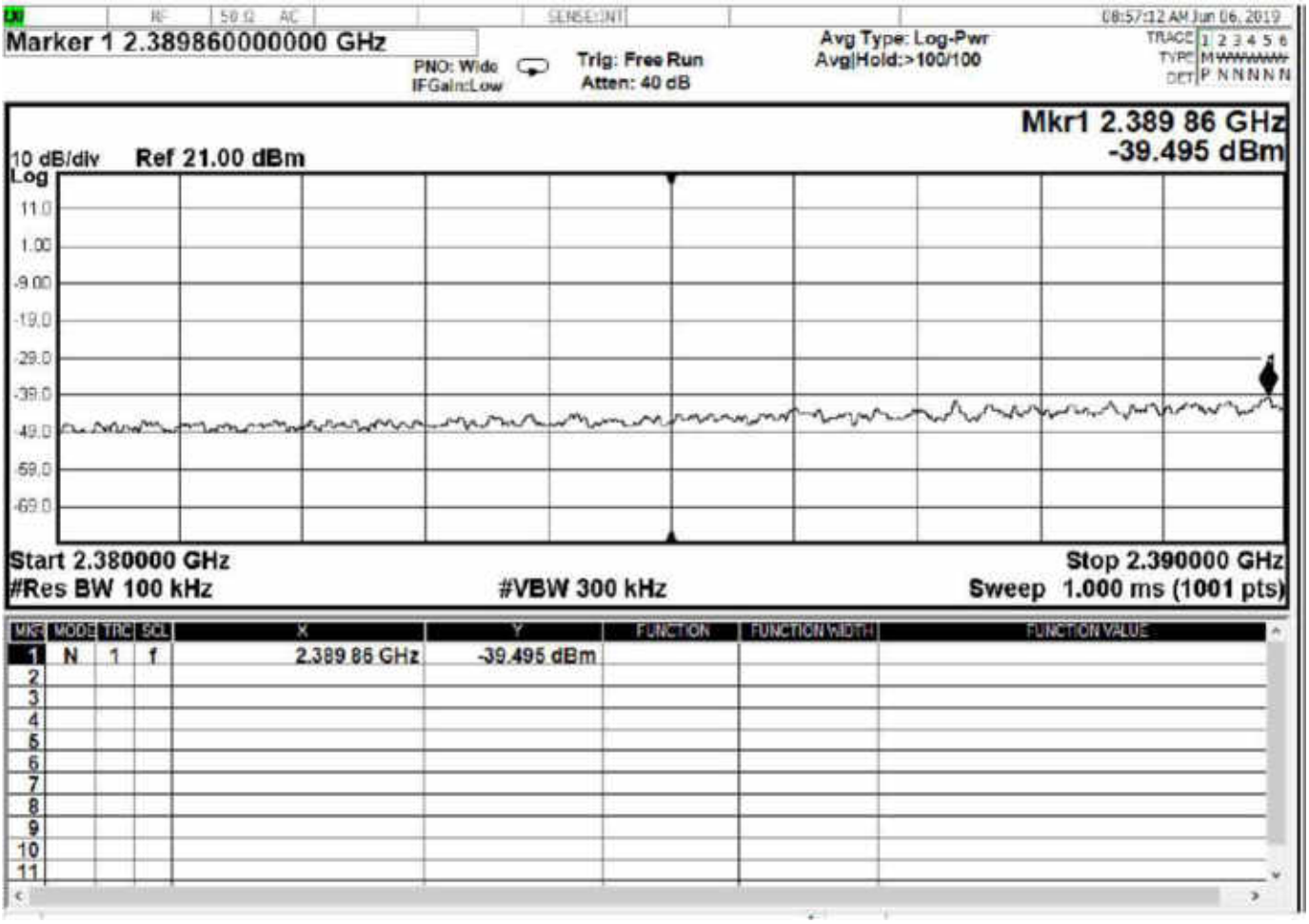

Figure 52 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

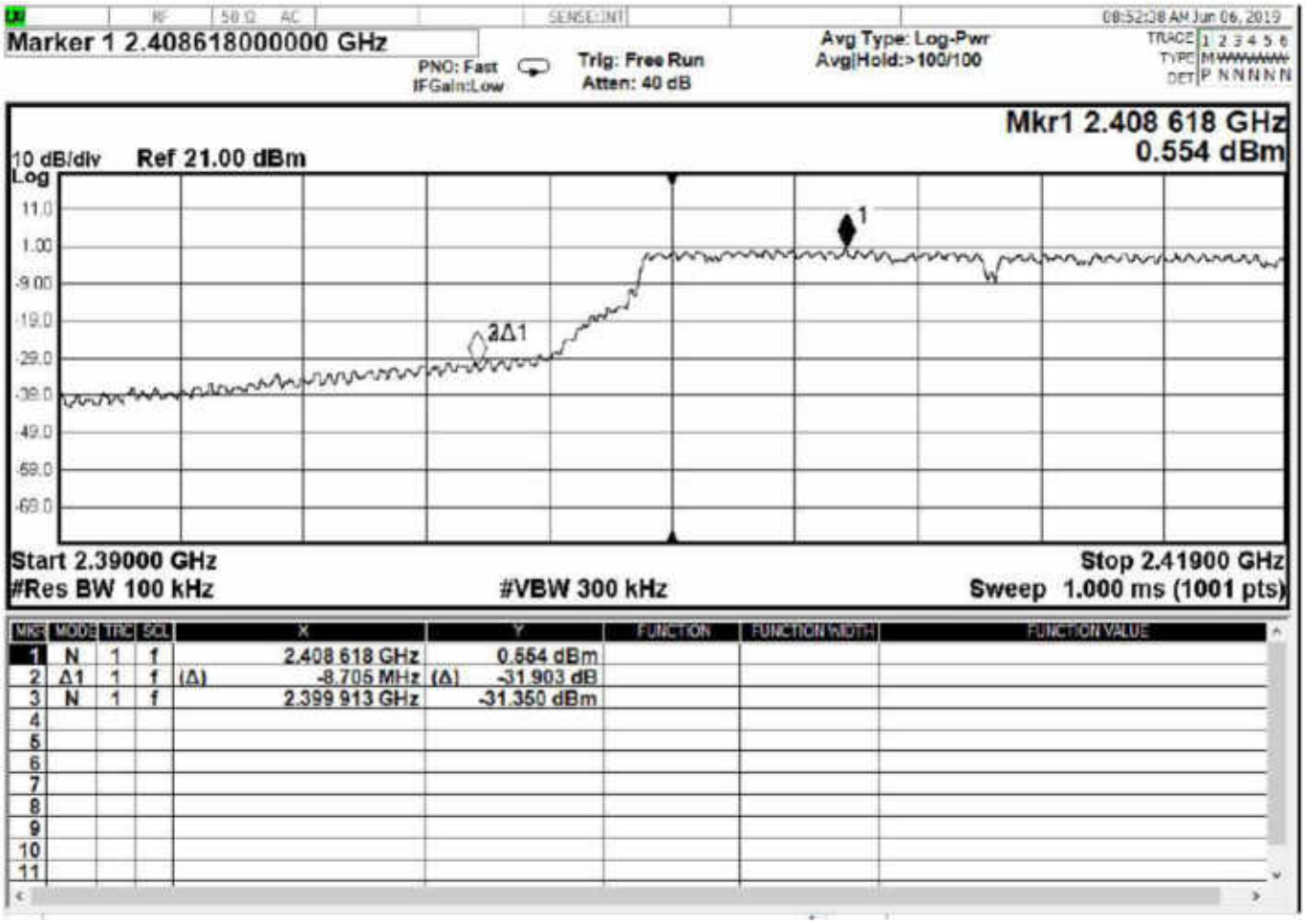

Figure 53 - Band-edge Measurement, Low Channel, Fundamental, Peak

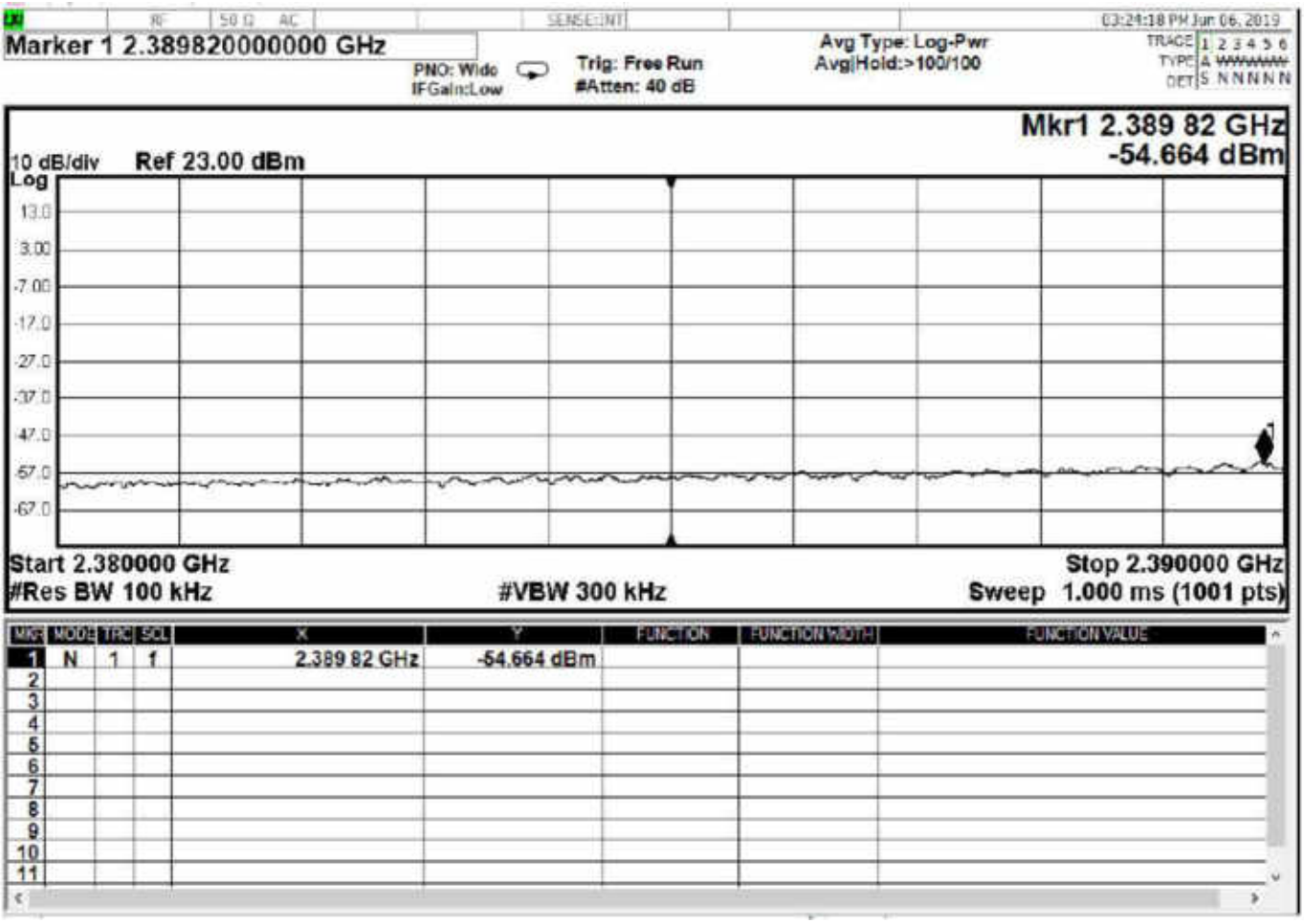

Figure 54 - Band-edge Measurement, Low Channel, Restricted Frequency, Average

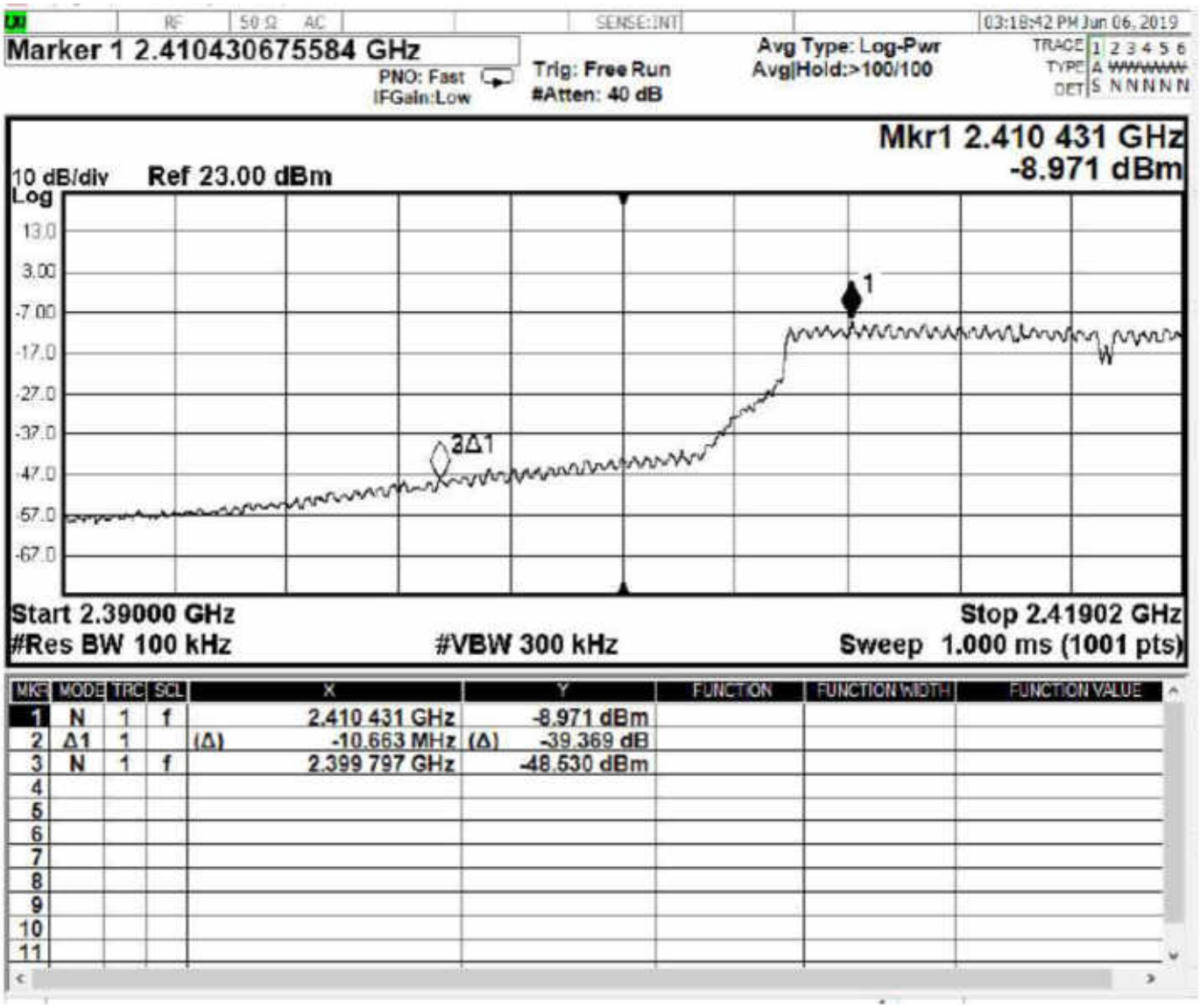

Figure 55 - Band-edge Measurement, Low Channel, Fundamental, Average

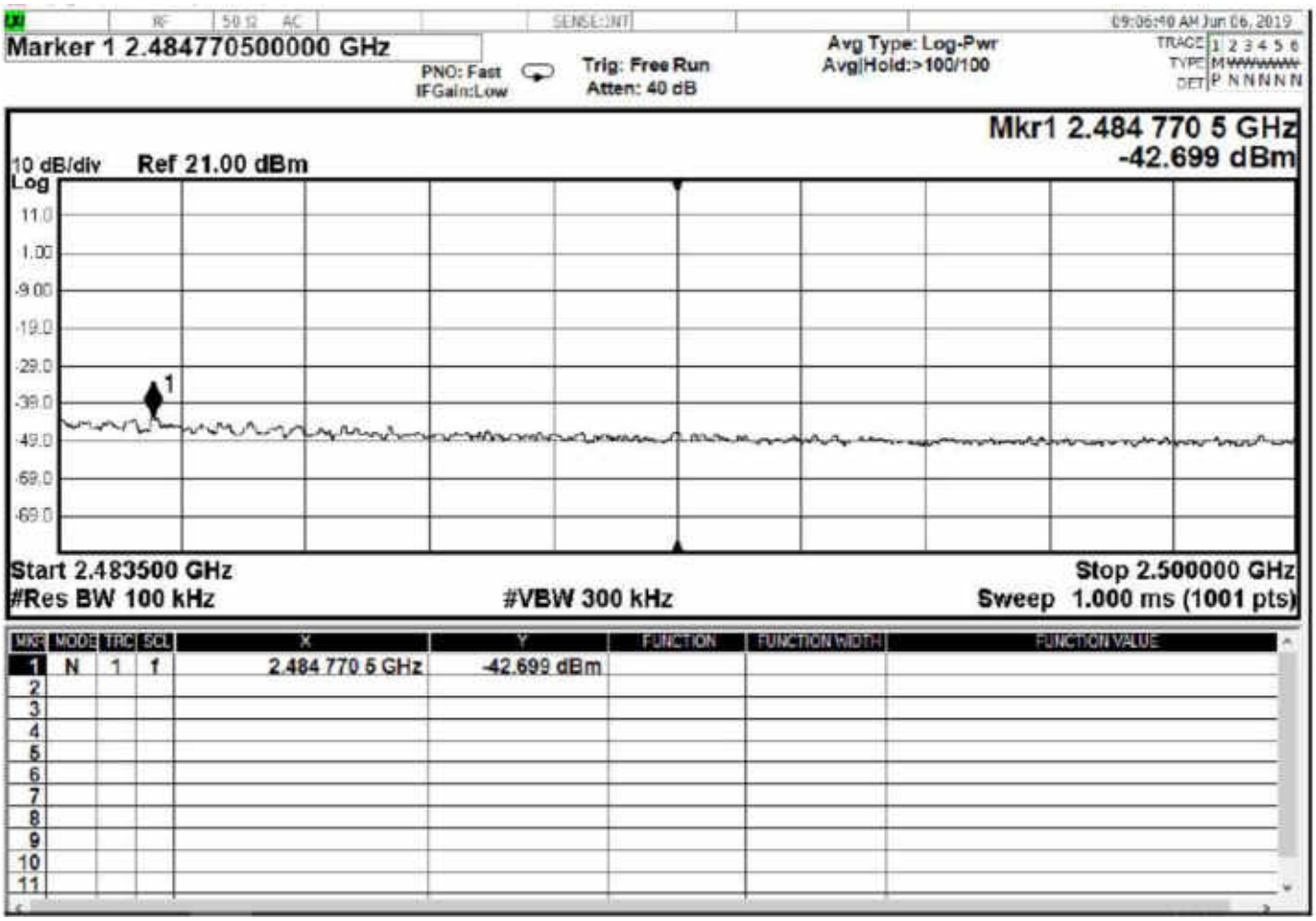

Figure 56 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

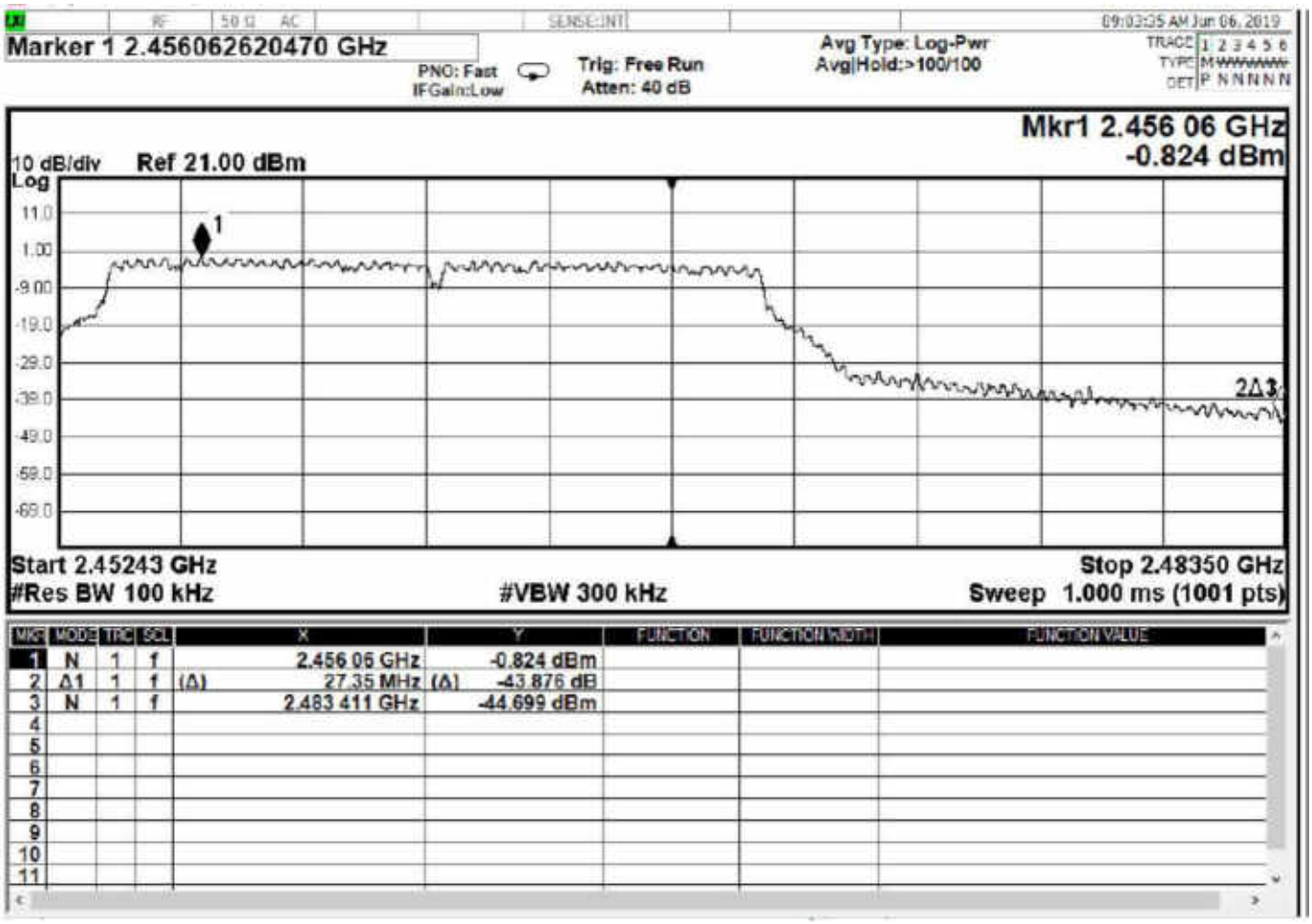

Figure 57 - Band-edge Measurement, High Channel, Fundamental, Peak

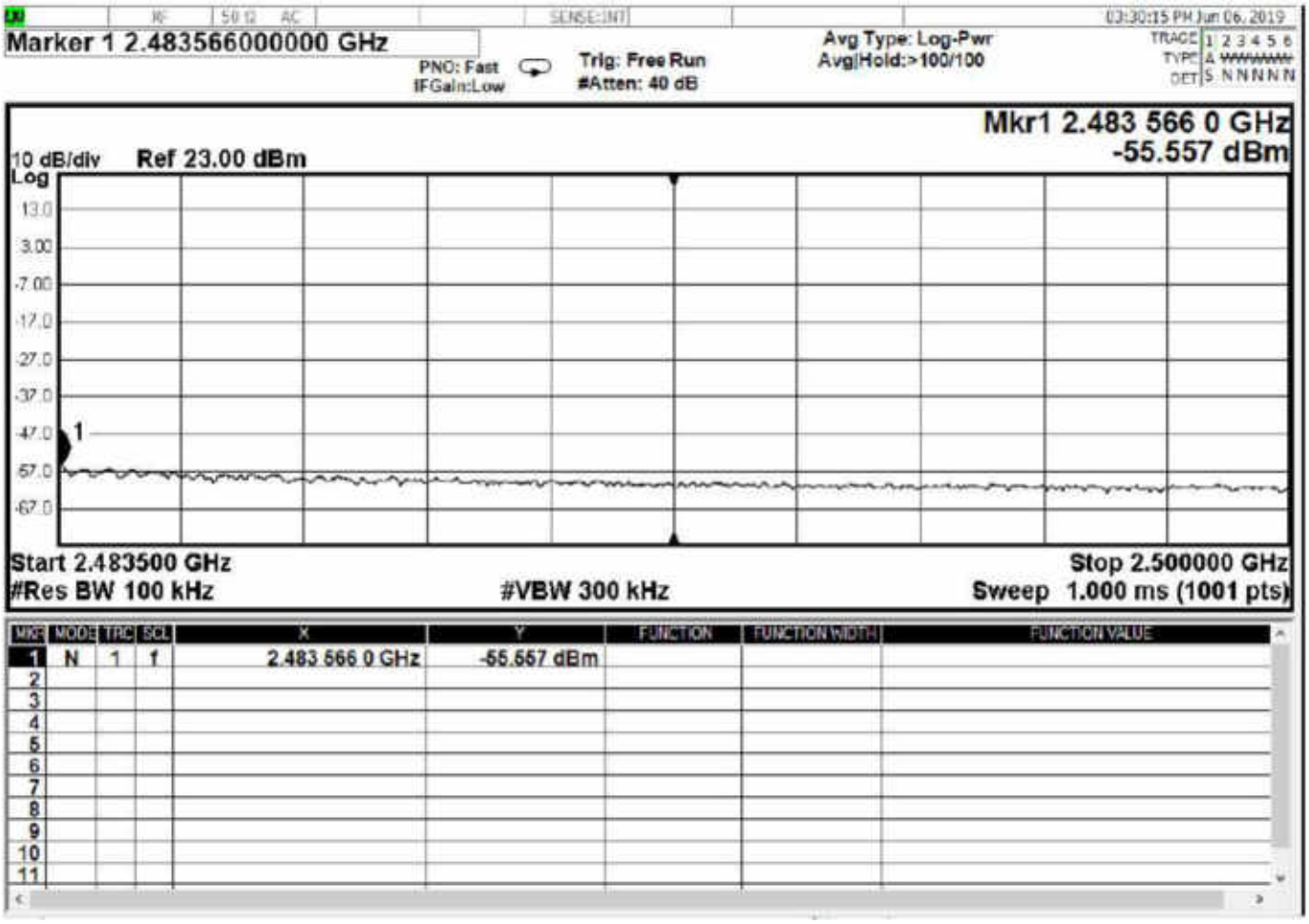

Figure 58 - Band-edge Measurement, High Channel, Restricted Frequency, Average

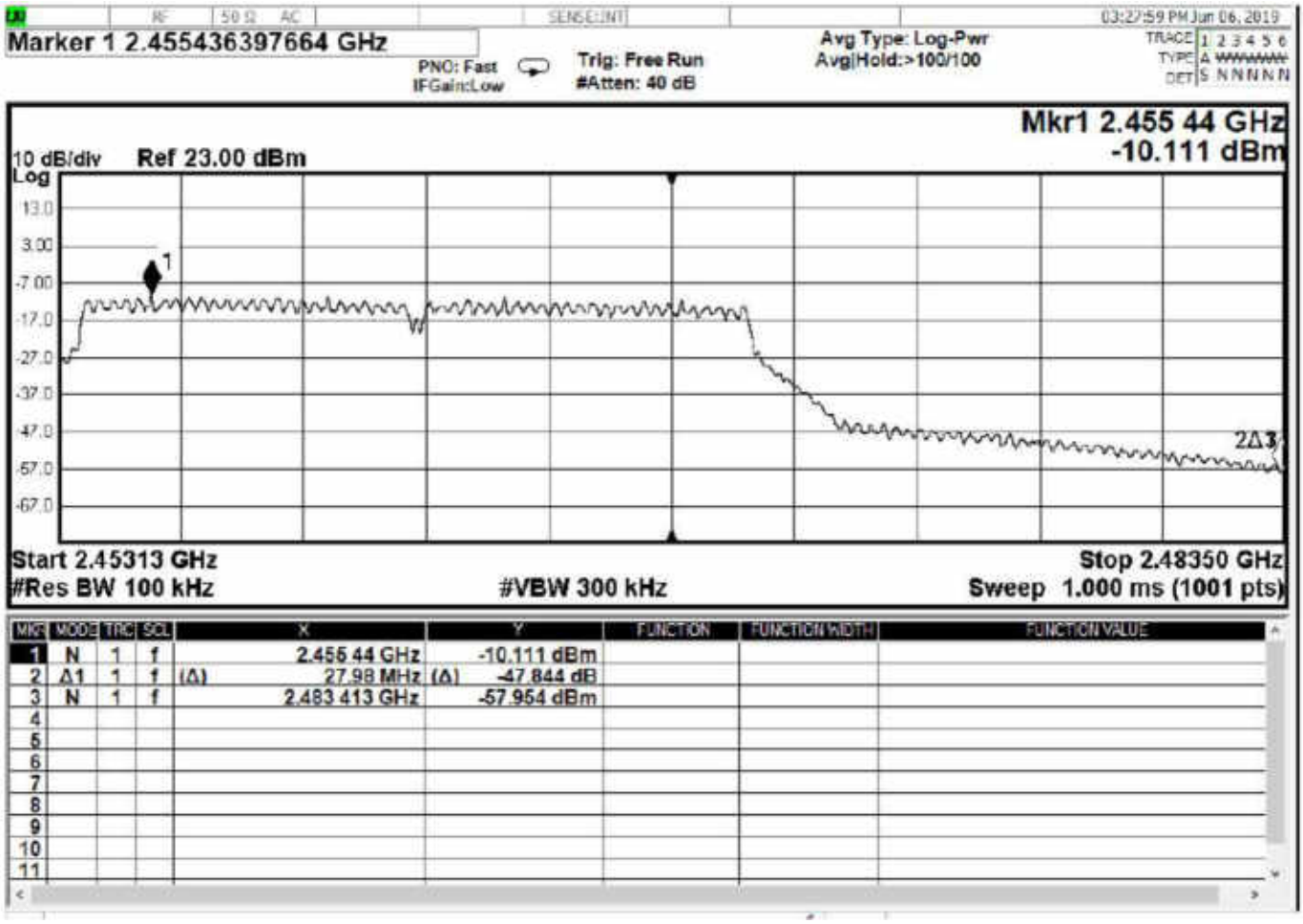

Figure 59 - Band-edge Measurement, High Channel, Fundamental, Average

Highest Out of Band Emissions, 802.11n

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level dBm	Fundamental Level (dBm)	Delta	Min (dBc)	Result
1	2390.0 (Unrestricted, Peak)	-30.35	-0.15	30.2	20	PASS
1	2390.0 (Unrestricted, Average)	-42.66	-9.68	32.98	20	PASS
11	2483.5 (Unrestricted, Peak)	-43.46	-1.32	42.14	20	PASS
11	2483.5 (Unrestricted, Average)	-57.00	-10.28	46.72	20	PASS

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level (dBm)	Corrected Emission Level (dBm)	Limit* (dBm)	Gain** (dBi)	Margin	Result
1	2340.0 (Restricted, Peak)	-39.20	-39.20	-21.23	0	17.97	PASS
1	2340.0 (Restricted, Average)	-53.45	-53.45	-41.23	0	12.22	PASS
11	2483.5 (Restricted, Peak)	-42.32	-42.32	-21.23	0	21.09	PASS
11	2483.5 (Restricted, Average)	-55.40	-55.40	-41.23	0	14.17	PASS

Corrected Emission level= Highest out of band level +Gain
Margin= Limit-Corrected Emission Level
*Limits from Part 15.209 in dBm **Antenna gain declared by the manufacturer

Part 15.209 Peak Limit = 74.00 dBµV/m

Part 15.209 Average Limit = 54.00 dBµV/m

EIRP(dBm) = FS(dBµV/m) – 10(log 10^9)+ 10log[0.3] = FS_{3m}(dBµV/m) - 95.23

Peak Limit (delta) = 74.00 dBµV/m – 95.23 = -21.23dBm

Average Limit (delta) = 54.00 dBµV/m – 95.23 = -41.23dBm

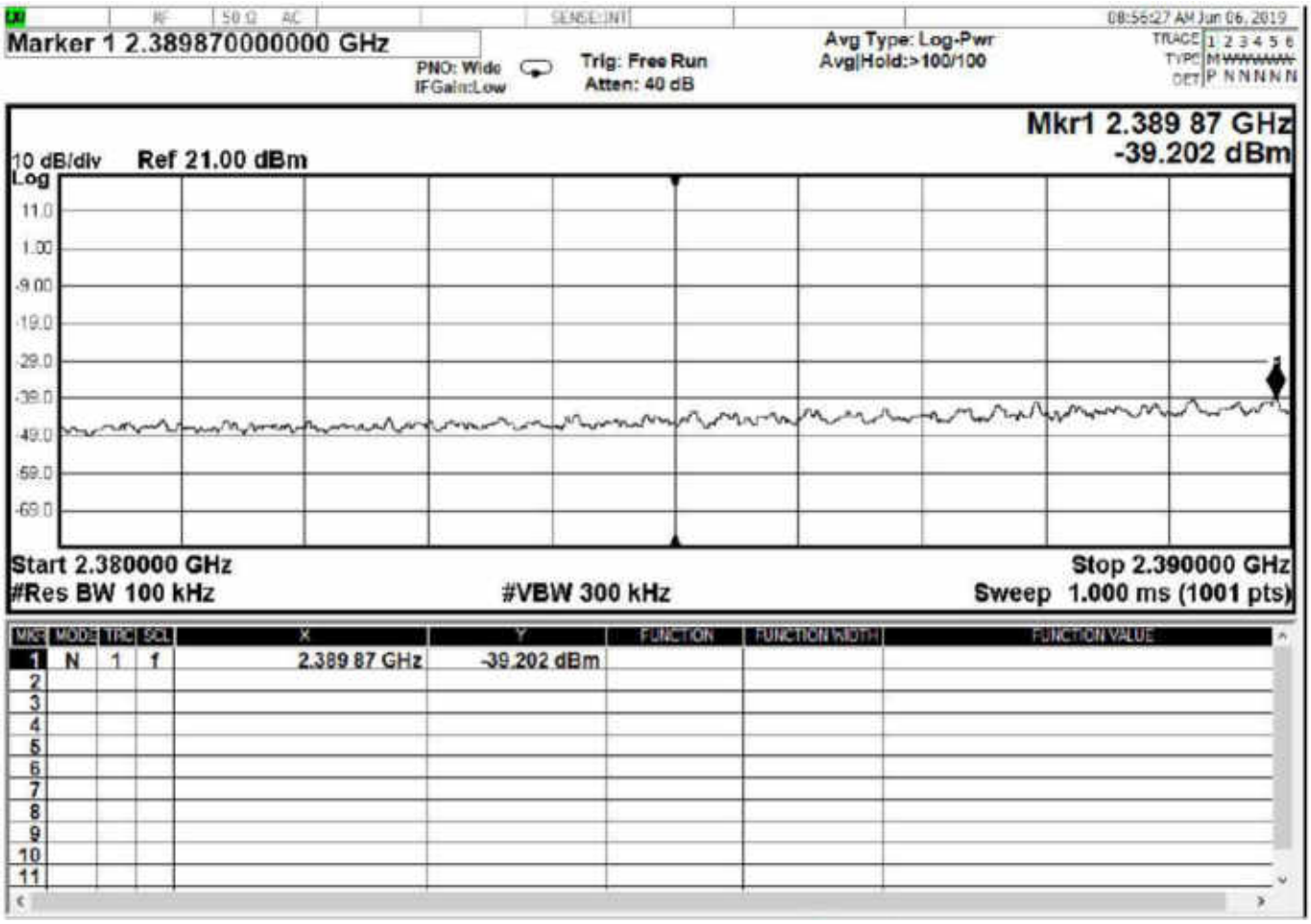

Figure 60 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

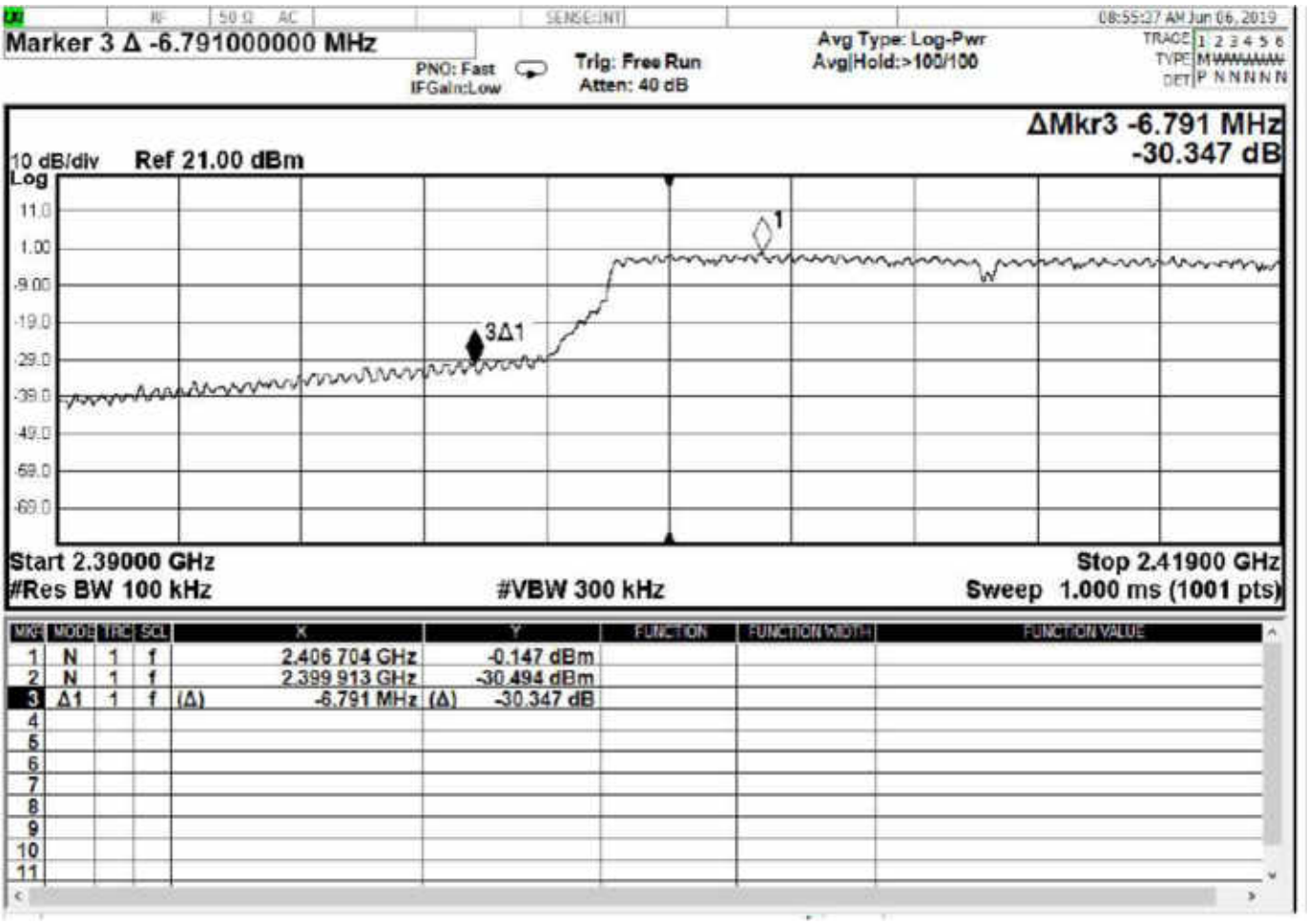

Figure 61 - Band-edge Measurement, Low Channel, Fundamental, Peak

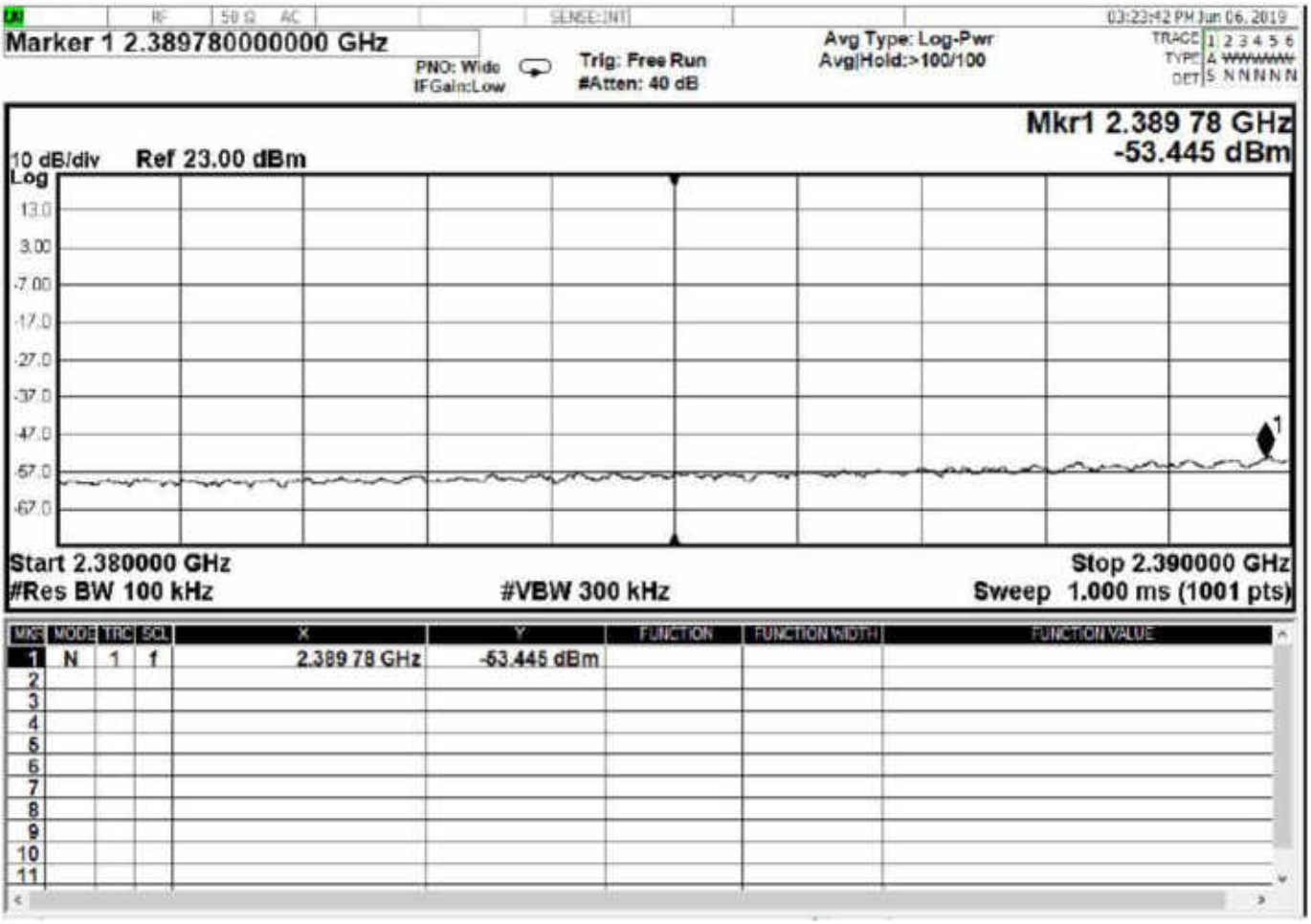

Figure 62 - Band-edge Measurement, Low Channel, Restricted Frequency, Average

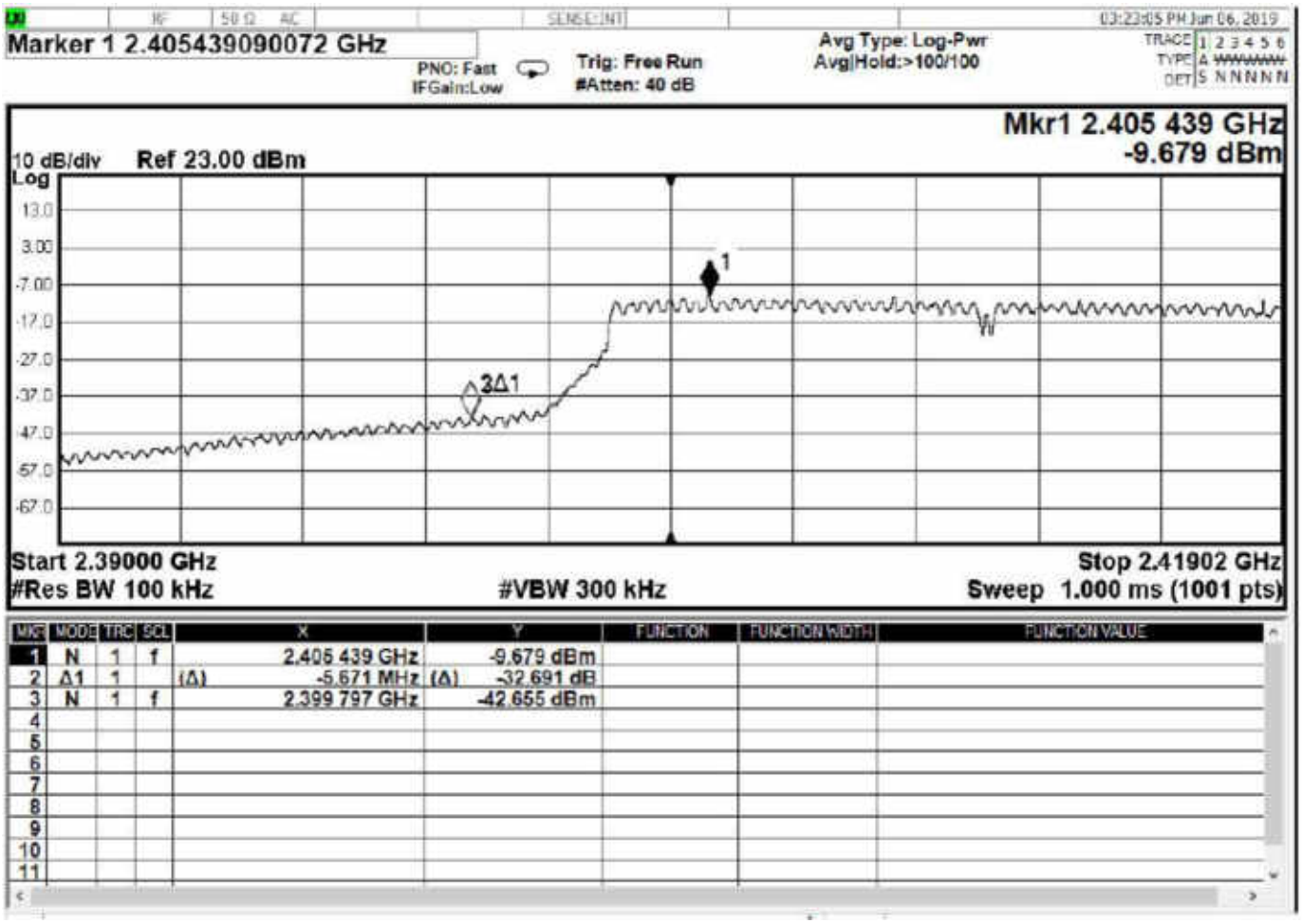

Figure 63 - Band-edge Measurement, Low Channel, Fundamental, Average

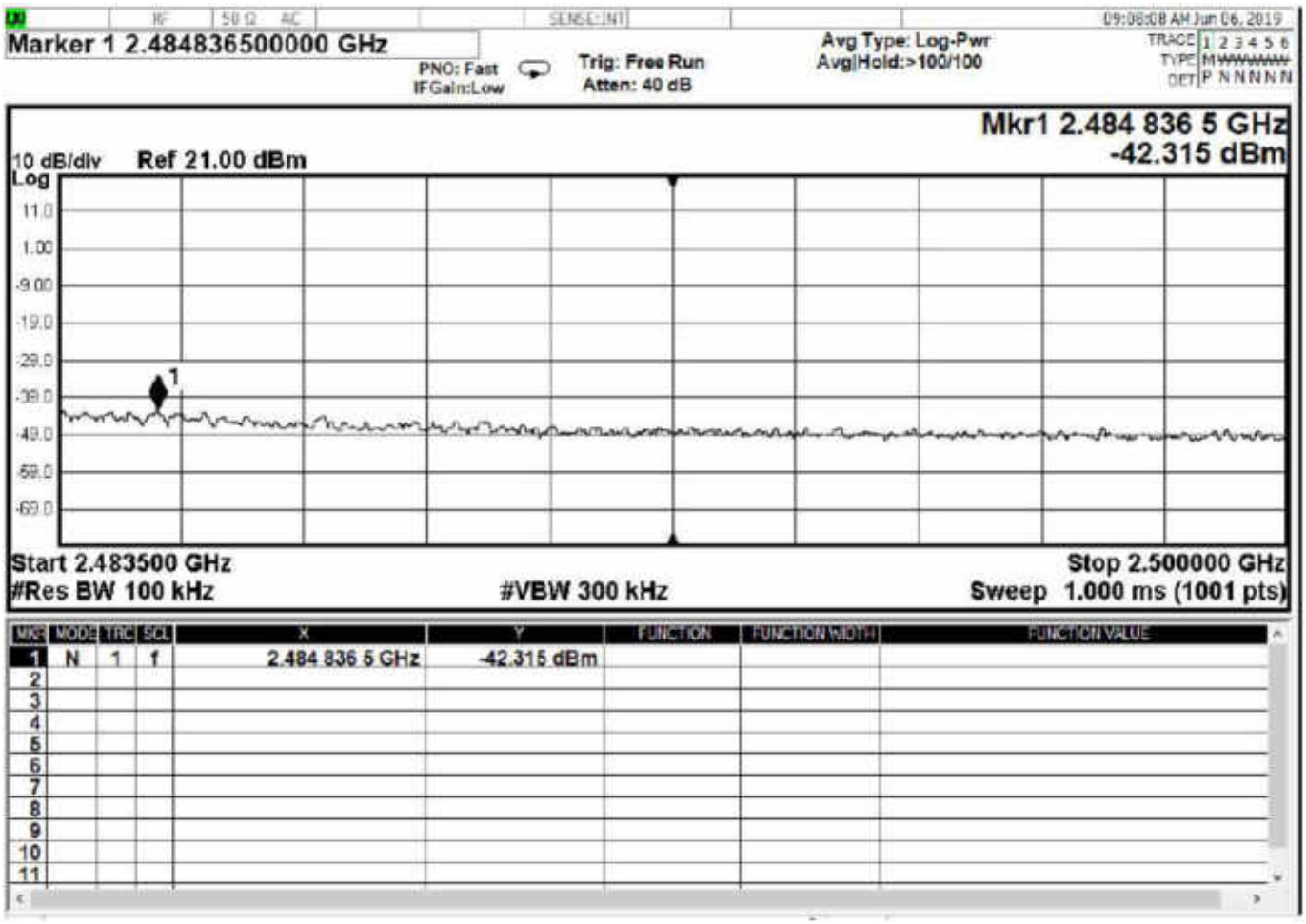

Figure 64 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

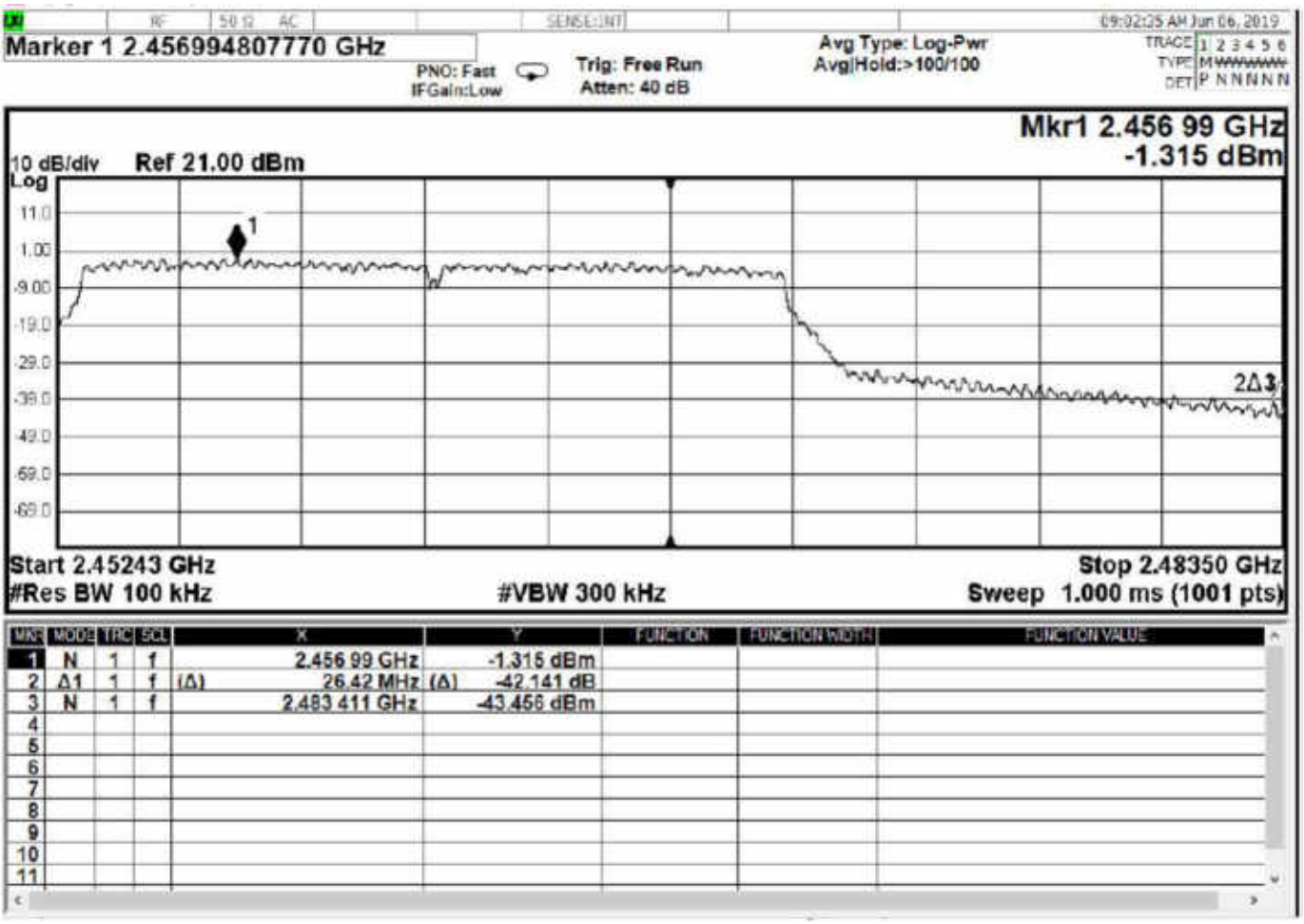

Figure 65 - Band-edge Measurement, High Channel, Fundamental, Peak

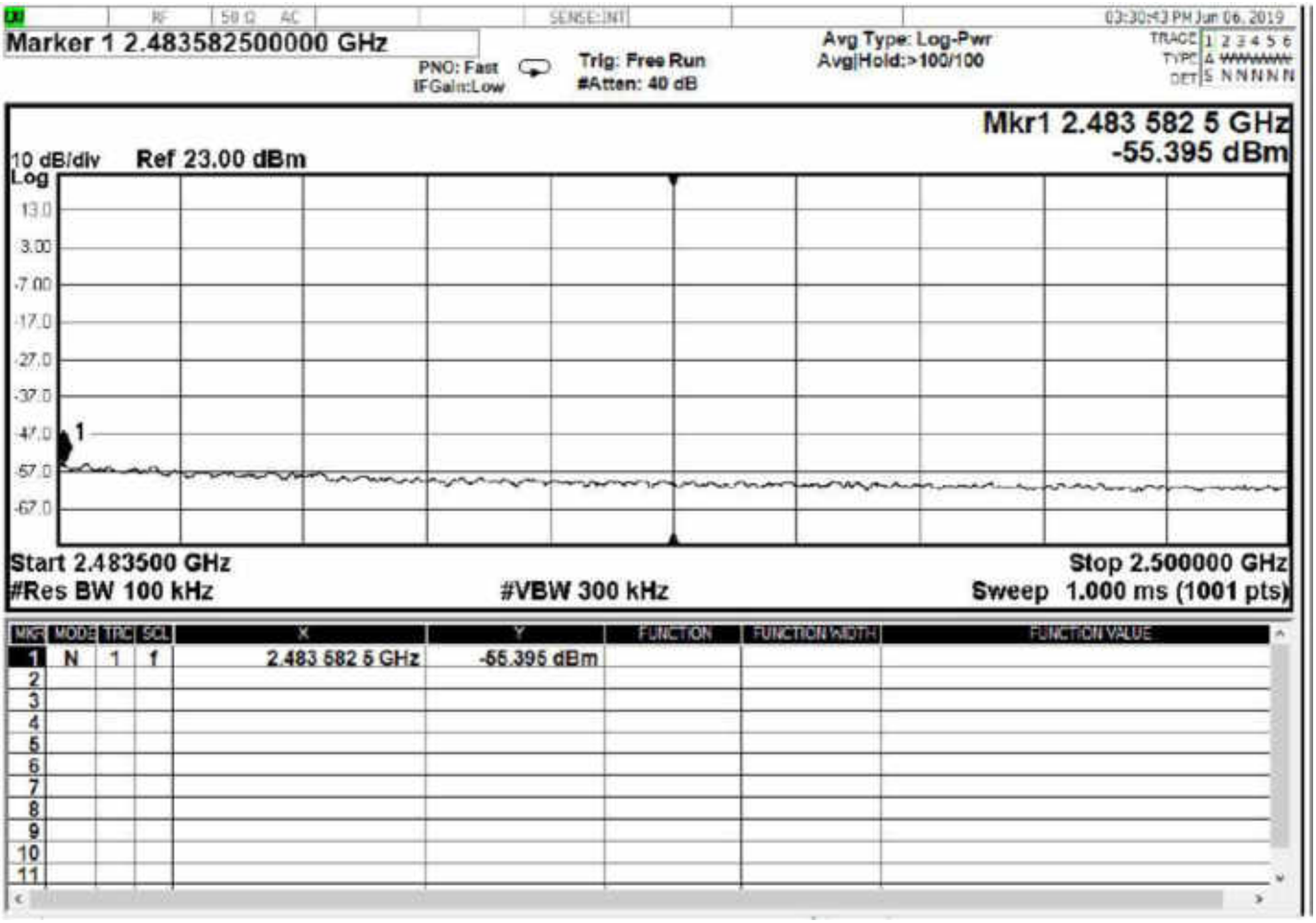

Figure 66 - Band-edge Measurement, High Channel, Restricted Frequency, Average

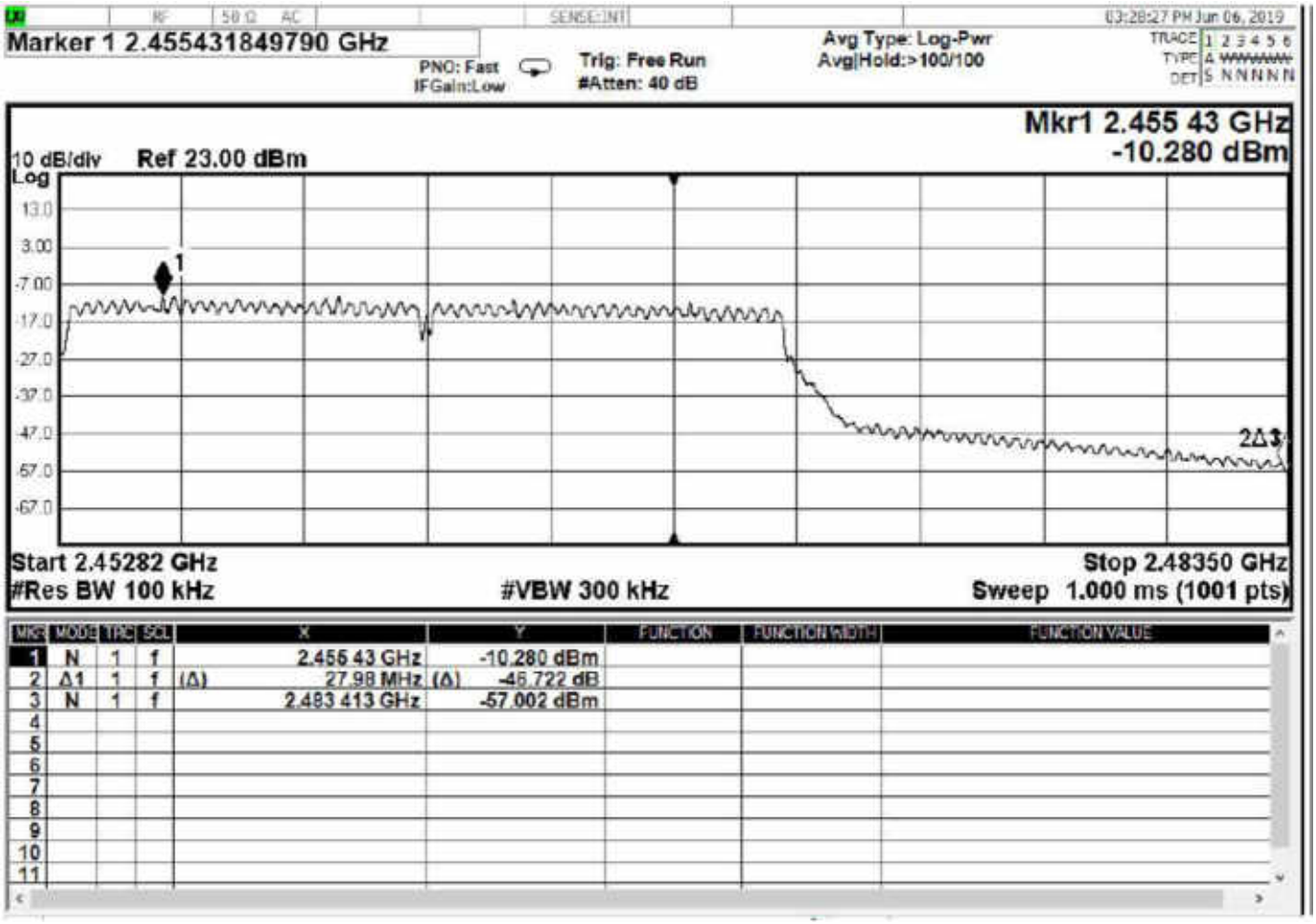

Figure 67 - Band-edge Measurement, High Channel, Fundamental, Average

4.7 CONDUCTED AC MAINS EMISSIONS

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

Limits for conducted emissions measurements:

FREQUENCY OF EMISSION (MHz)	CONDUCTED LIMIT (dBµV)	
	Quasi-peak	Average
0.15-0.5	66 to 56	56 to 46
0.5-5	56	46
5-30	60	50

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

Test Procedures:

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

Deviation from the test standard:
No deviation

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

Test Results:

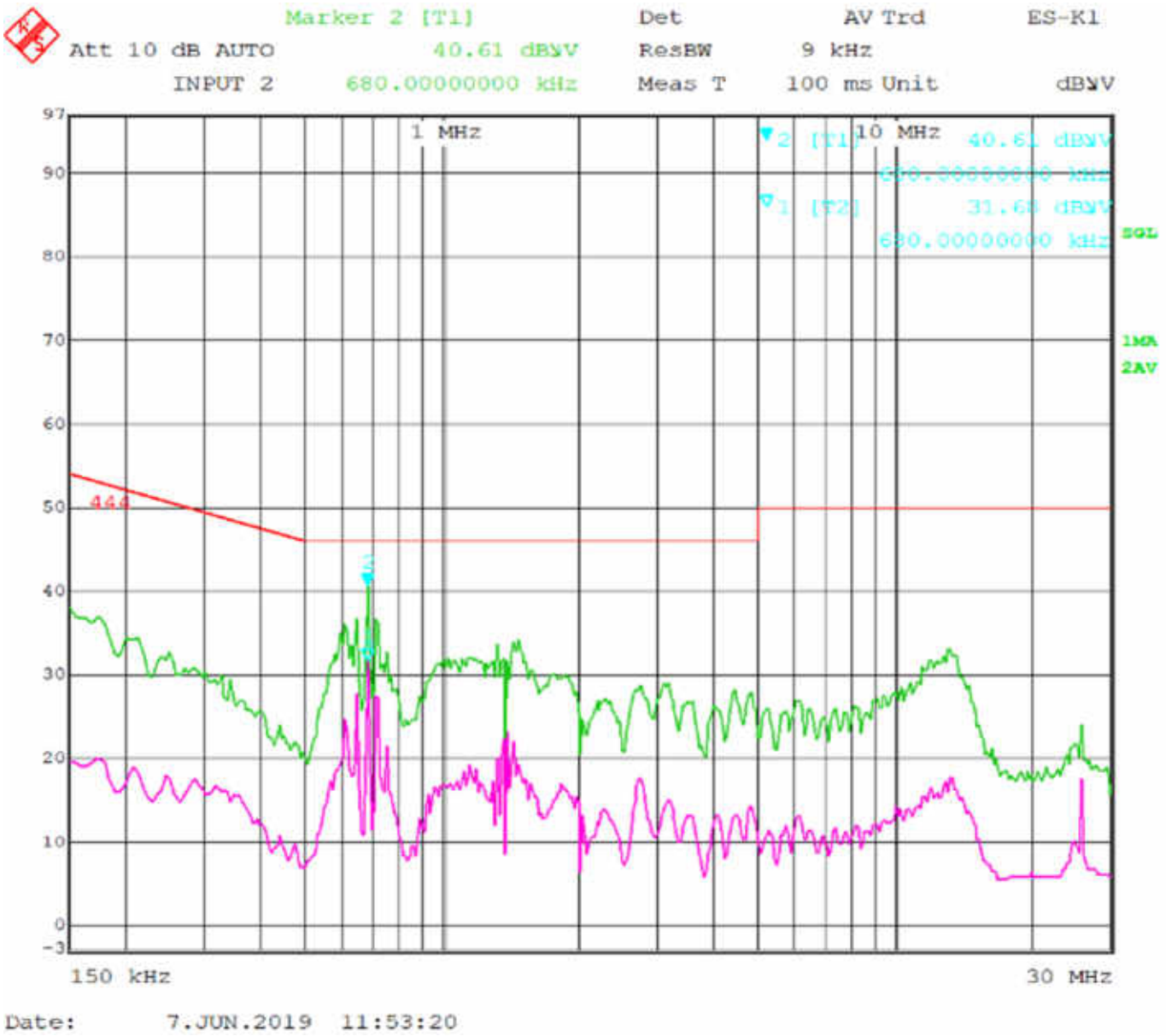

Figure 68 - Conducted Emissions Plot, Line

All Measurements were found to be at least 10 dB below the limits.

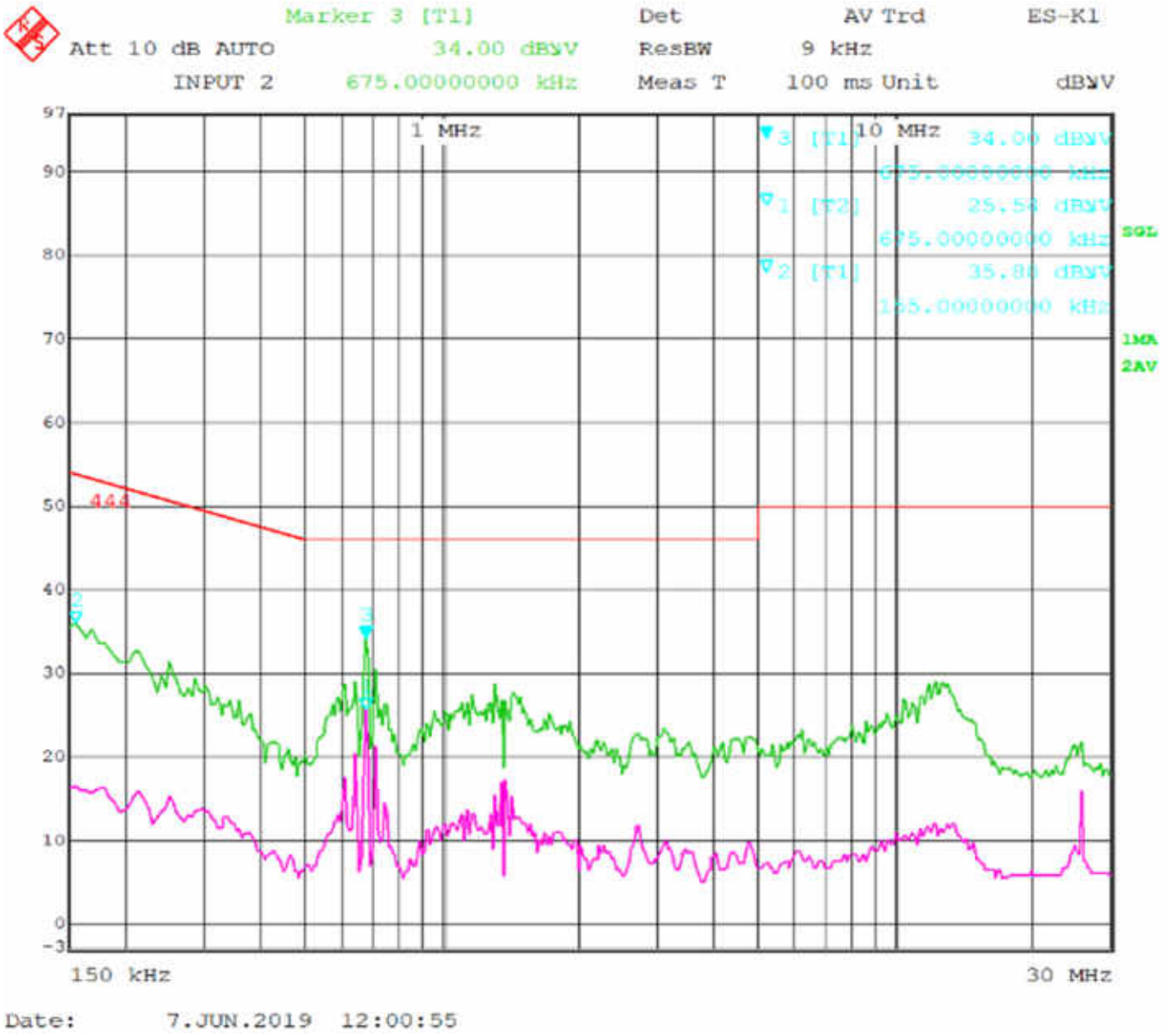

Figure 69 - Conducted Emissions Plot, Neutral

All Measurements were found to be at least 10 dB below the limits.

The plot shows the composite maximum value of both the line and neutral conductors. It shows the worse-case at each frequency.

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