4740 Discovery Drive | Lincoln, NE 68521
tel- 402.323.6233 | tel -888.657.6860 | fax - 402.323.6238
info@nceelabs.com | http://nceelabs.com

FCC/ISED DTS Test Report (802.11)

Prepared for: Garmin International Inc.

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

Product: A03525

Test Report No: R20181130-20-02A

Approved By:

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

DATE: 28 March 2019

Total Pages: 115

ACCREDITED
TESTING LABORATORY
CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	31 January 2019	Original – NJohnson Prepared by KVepuri/CFarrington
A	28 March 2019	Antenna gain was corrected to be -4 dBi. Bandedge measurements were updated accordingly. Includes NCEE Labs test report R20181130-20-02 and its amendment in full -NJ

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1.0 SUMMARY OF TEST RESULTS

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

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

The Equipment Under Test (EUT) was a portable transceiver from Garmin. It features 802.11b, 802.11g, 802.11n, GFSK and GMSK modules and has transmit and receives capabilities.

Model	A03525
EUT Received	20 December 2018
EUT Tested	20 December 2018 - 4 January 2019
Serial No.	NCEETEST1 (assigned, radiated testing) NCEETEST2 (assigned, conducted testing)
Operating Band	2400.0 - 2483.5 GHz
Device Type	802.11b, 802.11g, 802.11n
Power Supply	Internal Battery/ Charger: Garmin (Phi Hong) MN: PSAI10R-050Q

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 (Channel 1)	2412
Middle (Channel 6)	2437
High (Channel 11)	2462

As well as the following modes:

WIFI Mode
802.11b
802.11g
802.11n (HT20)

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

NA

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 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 2019*
Trilithic High Pass Filter	6HC330	23042	09 Mar 2018*	09 Mar 2019*
Rohde & Schwarz LISN	ESH3-Z5	836679/010	26 Jul 2018	26 Jul 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

4.0 DETAILED RESULTS

4.1 DUTY CYCLE

Duty Cycle measurements were not conducted as the EUT is capable of continuous transmission.

4.2 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.

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:

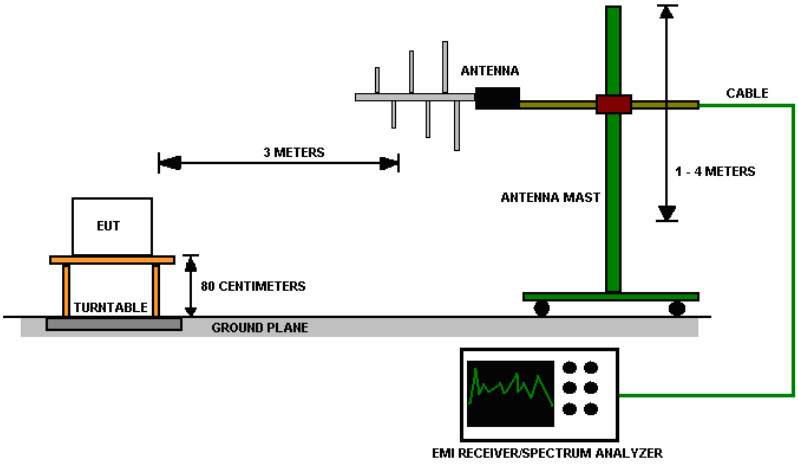

Figure 1 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by 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. EUT was set to transmit in 80211b, 80211g and 80211n.

Test results:

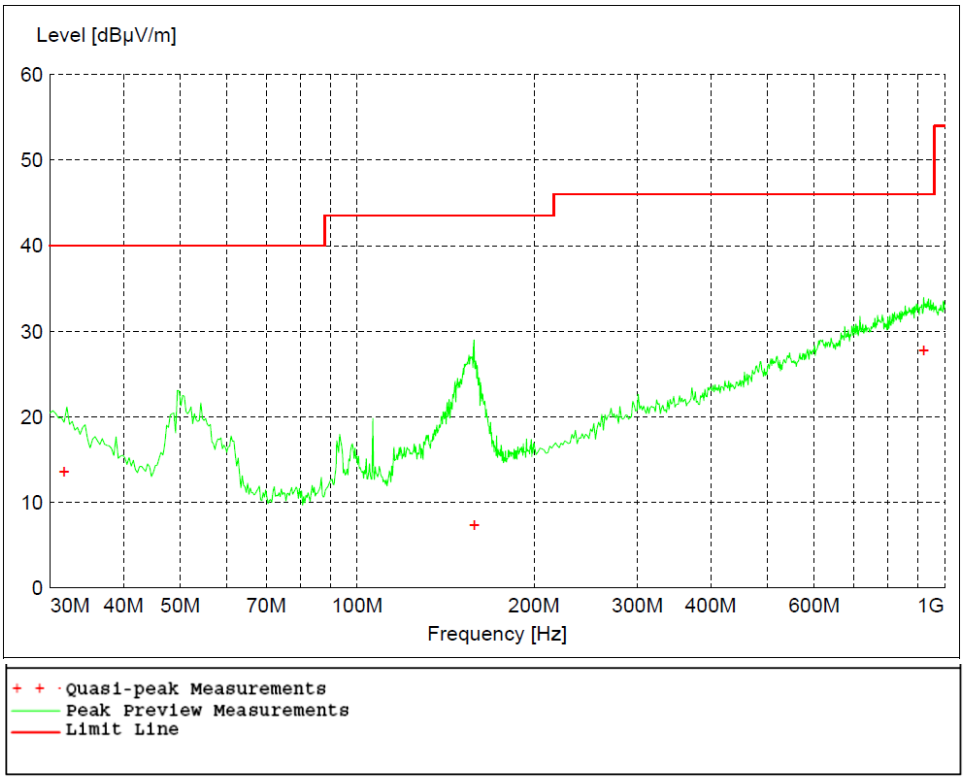

Figure 2 - Radiated Emissions Plot, Receive

Table 1 - Radiated Emissions Quasi-peak and Peak Measurements, Receive, 802.11b

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
31.740000	13.60	40.00	26.40	363	217	VERT
158.460000	7.36	43.50	36.20	243	1	HORI
922.680000	27.84	46.00	18.20	400	295	VERT

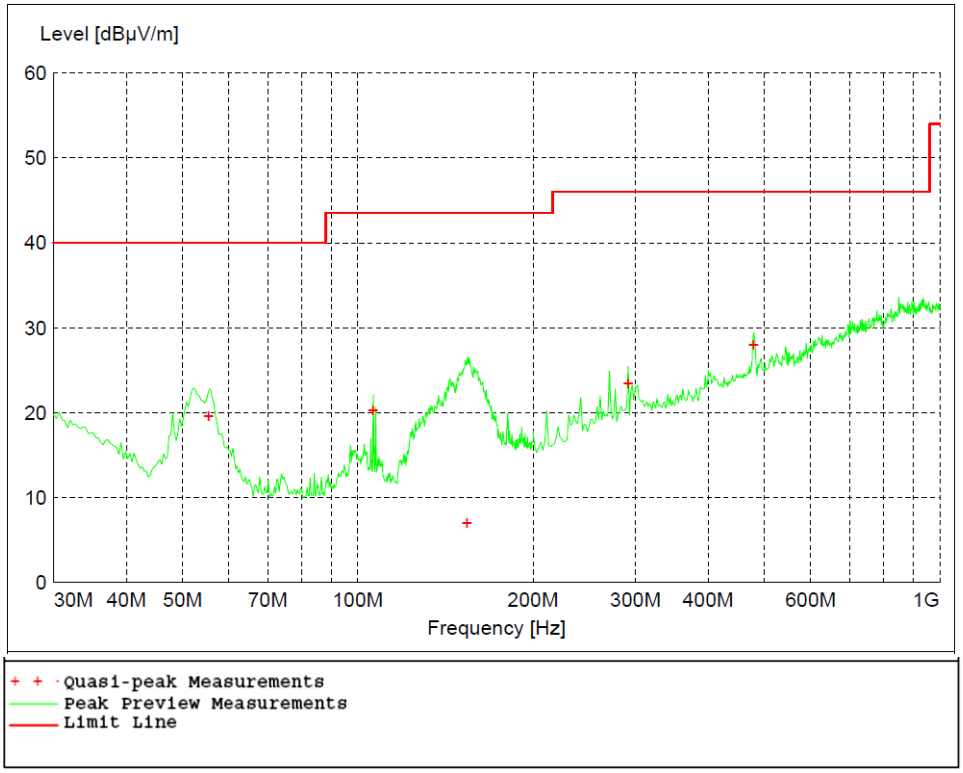

Figure 3 - Radiated Emissions Plot, Low Channel

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

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
55.440000	19.60	40.00	20.40	110	113	VERT
106.320000	20.34	43.50	23.20	322	310	HORI
154.020000	7.06	43.50	36.50	399	0	HORI
291.480000	23.43	46.00	22.60	123	300	HORI
478.560000	27.99	46.00	18.00	310	65	VERT

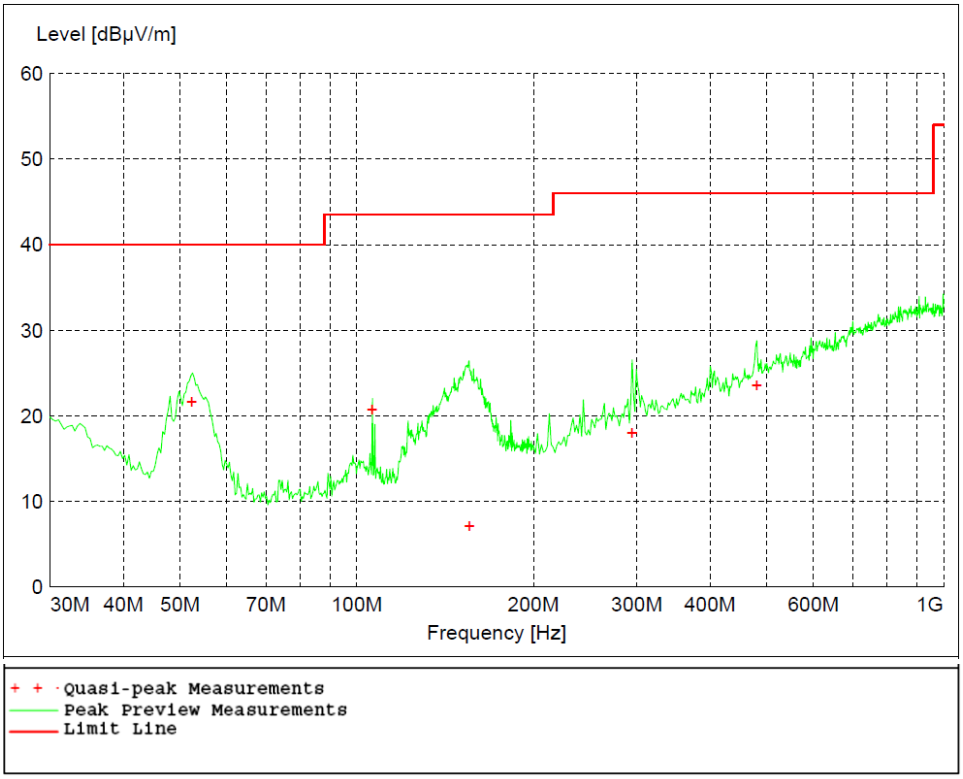

Figure 4 - Radiated Emissions Plot, Mid Channel

Table 3 - Radiated Emissions Quasi-peak Measurements, Mid Channel, 802.11b

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
52.380000	21.65	40.00	18.40	99	84	VERT
106.260000	20.72	43.50	22.80	332	318	HORI
155.580000	7.13	43.50	36.40	311	360	HORI
294.480000	18.07	46.00	27.90	100	126	HORI
480.420000	23.60	46.00	22.40	102	360	VERT

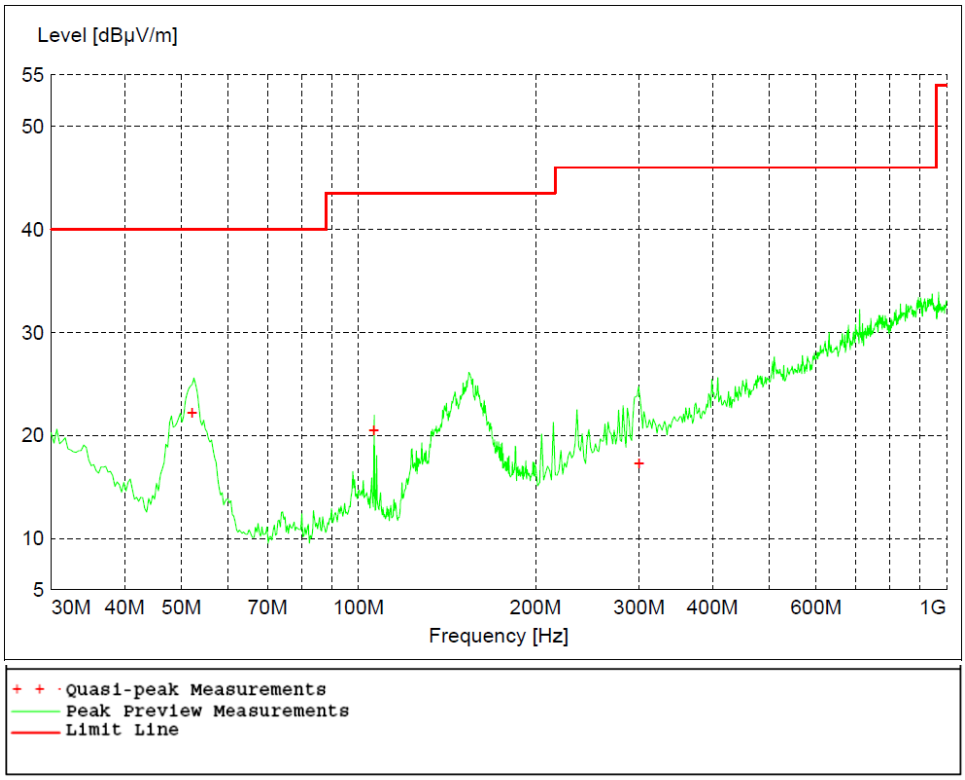

Figure 5 - Radiated Emissions Plot, High Channel

Table 4 - Radiated Emissions Quasi-peak Measurements, High Channel, 802.11b

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
52.140000	22.23	40.00	17.80	99	360	VERT
106.260000	20.53	43.50	23.00	336	179	HORI
300.240000	17.29	46.00	28.70	100	314	HORI

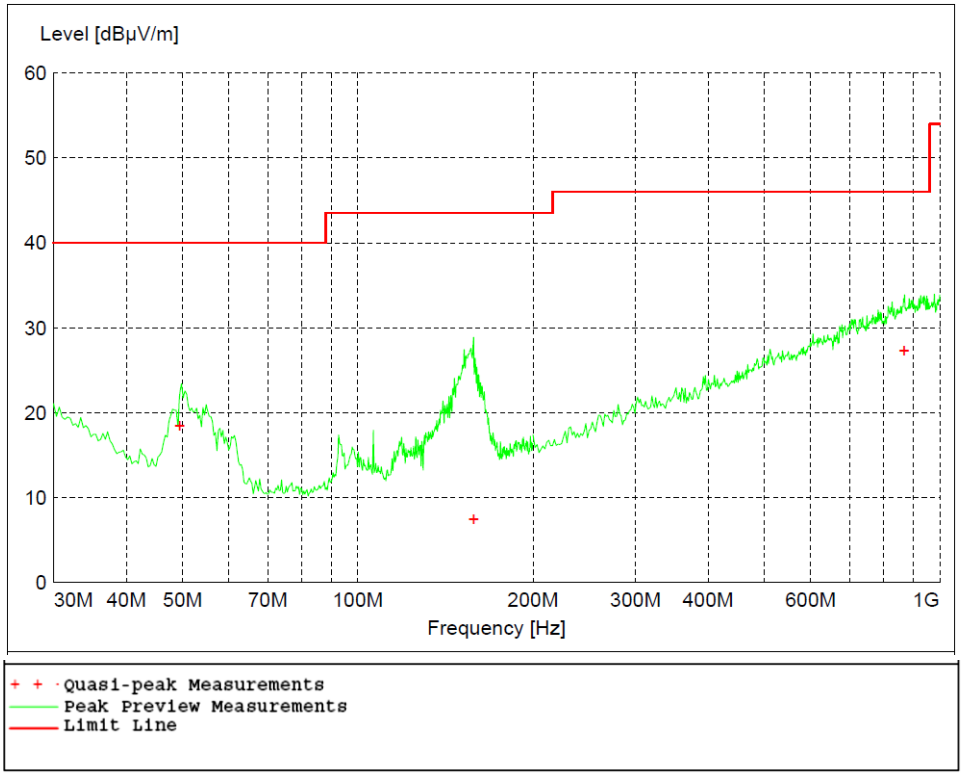

Figure 6 - Radiated Emissions Plot, Receive

Table 5 - Radiated Emissions Quasi-peak and Peak Measurements, Receive, 802.11g

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
49.440000	18.51	40.00	21.50	99	211	VERT
158.220000	7.51	43.50	36.00	283	74	HORI
869.220000	27.40	46.00	18.60	390	226	HORI

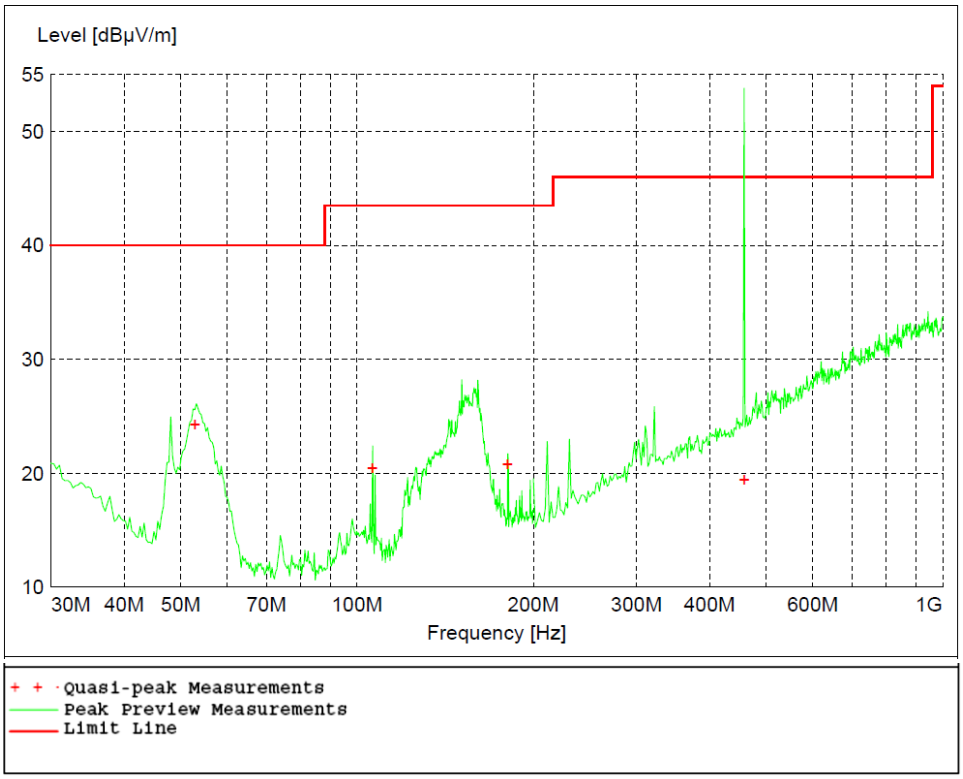

Figure 7 - Radiated Emissions Plot, Low Channel

Table 6 - Radiated Emissions Quasi-peak Measurements, Low Channel, 802.11g

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
52.920000	24.33	40.00	15.70	103	136	VERT
106.320000	20.49	43.50	23.00	288	175	HORI
180.900000	20.78	43.50	22.70	156	1	HORI
458.700000	19.44	46.00	26.60	169	77	VERT

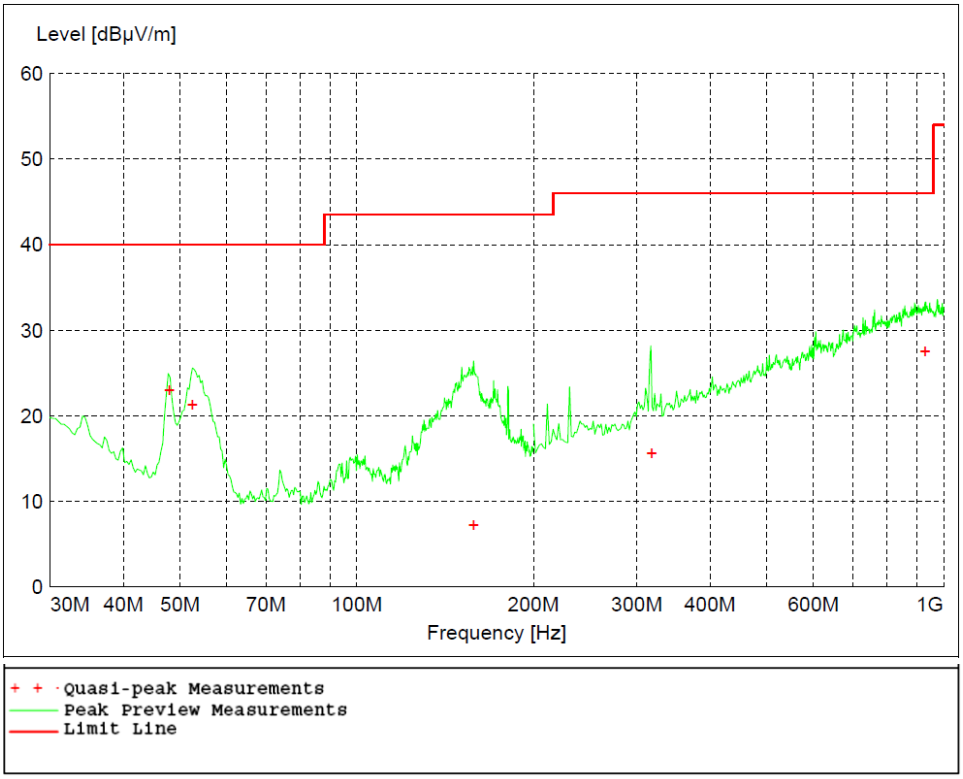

Figure 8 - Radiated Emissions Plot, Mid Channel

Table 7 - Radiated Emissions Quasi-peak Measurements, Mid Channel, 802.11g

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
48.000000	22.98	40.00	17.00	109	282	VERT
52.500000	21.36	40.00	18.60	100	360	VERT
158.280000	7.28	43.50	36.20	231	312	VERT
318.480000	15.66	46.00	30.30	244	265	VERT
931.260000	27.58	46.00	18.40	210	0	VERT

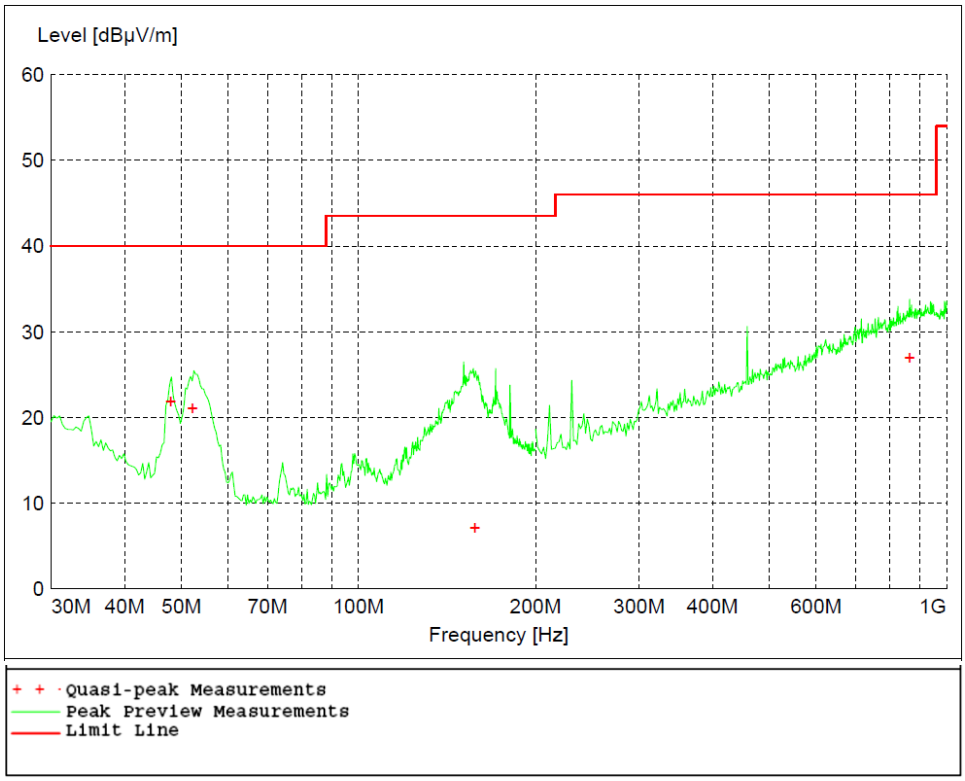

Figure 9 - Radiated Emissions Plot, High Channel

Table 8 - Radiated Emissions Quasi-peak Measurements, High Channel, 802.11g

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
48.000000	21.88	40.00	18.10	147	192	VERT
52.200000	21.12	40.00	18.90	99	1	VERT
157.800000	7.12	43.50	36.40	399	241	VERT
865.860000	26.98	46.00	19.00	99	194	HORI

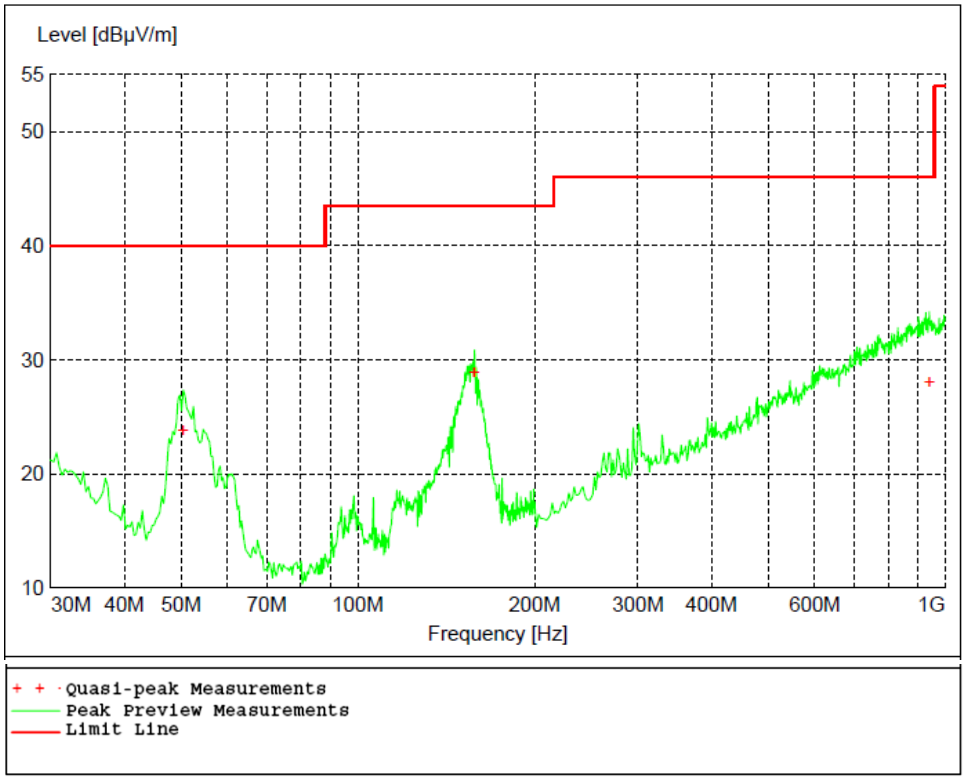

Figure 10 - Radiated Emissions Plot, Receive

Table 9 - Radiated Emissions Quasi-peak and Peak Measurements, Receive, 802.11n

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
50.400000	23.75	40.00	16.30	100	50	VERT
157.860000	28.88	43.50	14.60	213	172	HORI
941.100000	28.05	46.00	18.00	399	324	VERT

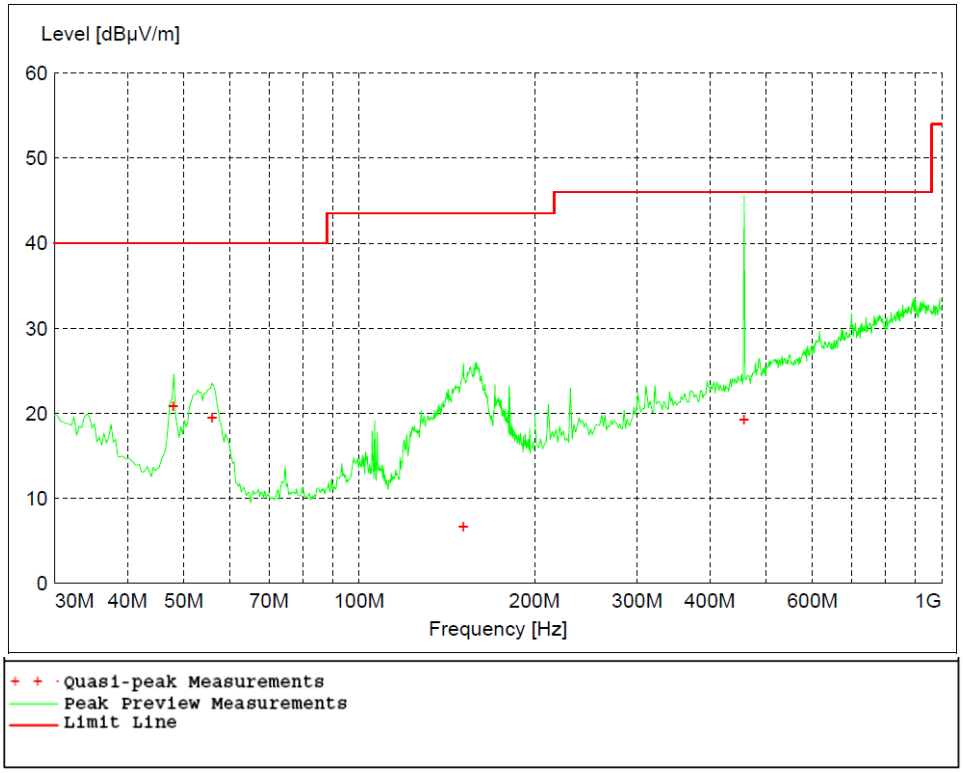

Figure 11 - Radiated Emissions Plot, Low Channel

Table 10 - Radiated Emissions Quasi-peak Measurements, Low Channel, 802.11n

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
48.000000	20.93	40.00	19.10	101	353	VERT
55.920000	19.55	40.00	20.40	99	190	VERT
151.080000	6.76	43.50	36.80	350	41	VERT
458.220000	19.34	46.00	26.70	156	6	VERT

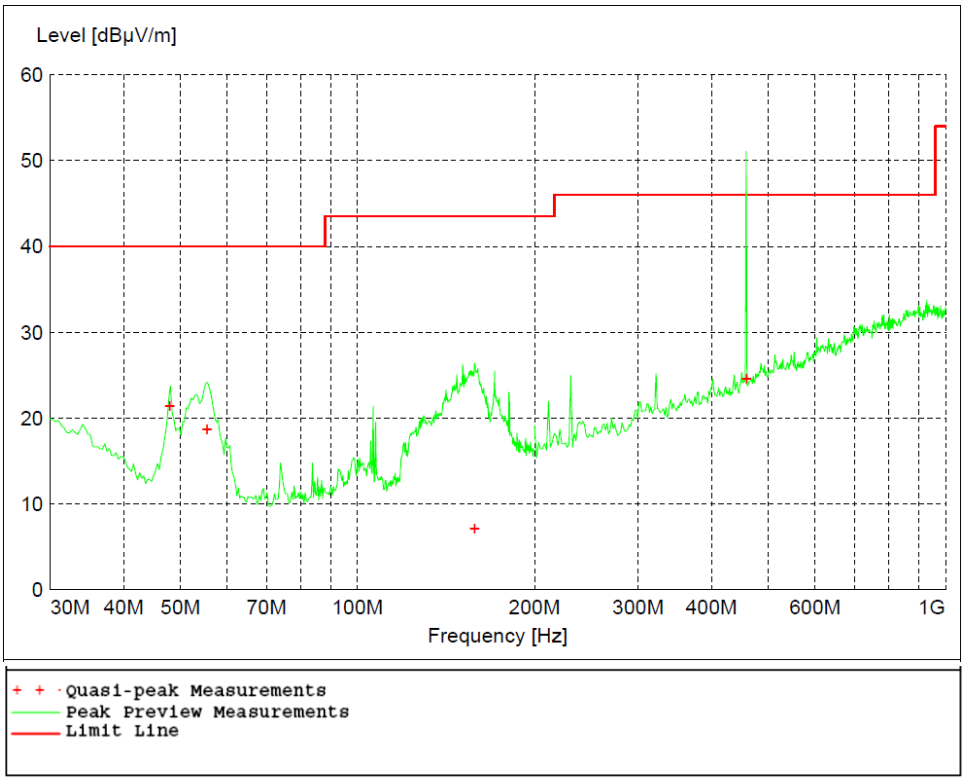

Figure 12 - Radiated Emissions Plot, Mid Channel

Table 11 - Radiated Emissions Quasi-peak Measurements, Mid Channel, 802.11n

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
48.000000	21.50	40.00	18.50	126	343	VERT
55.500000	18.77	40.00	21.20	193	307	VERT
158.160000	7.20	43.50	36.30	364	162	HORI
459.000000	24.57	46.00	21.40	189	200	HORI

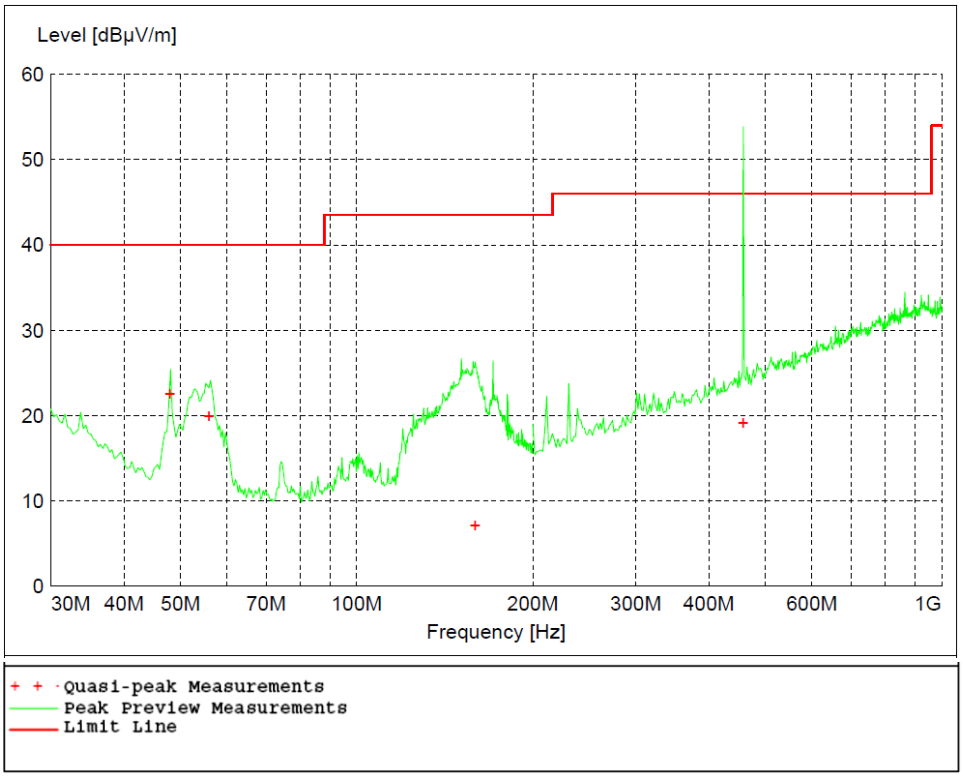

Figure 13 - Radiated Emissions Plot, High Channel

Table 12 - Radiated Emissions Quasi-peak Measurements, High Channel, 802.11n

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
48.000000	22.57	40.00	17.40	98	96	VERT
55.920000	19.98	40.00	20.00	101	268	VERT
159.480000	7.14	43.50	36.40	334	0	HORI
457.980000	19.15	46.00	26.90	152	121	HORI

Table 13 - Radiated Emissions Peak Detector Measurements, Low Channel, 1-26 GHz

Frequency	Level	Limit	Margin	Height	Angle	Pol	Mode
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		802.11
2412.000000	95.12	N/A	N/A	201	322	HORI	b
9648.000000	54.36	74.00	19.40	163	350	VERT	b
2412.000000	101.12	N/A	N/A	127	360	HORI	g
9648.000000	54.89	74.00	19.90	130	0	VERT	g
2412.000000	94.75	N/A	N/A	126	0	HORI	n
7309.200000	43.85	74.00	30.20	100	35	VERT	n
No signals detected above system sensitivity							

Table 14 - Radiated Emissions Average Detector Measurements, Low Channel, 1-26 GHz

Frequency	Level	Limit	Margin	Height	Angle	Pol	Mode
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		802.11
2412.000000	90.37	N/A	N/A	201	322	HORI	b
9648.000000	50.41	54.00	3.60	163	350	VERT	b
2412.000000	89.25	N/A	N/A	127	360	HORI	g
9648.000000	50.96	54.00	3.00	130	0	VERT	g
2412.000000	82.56	N/A	N/A	126	0	HORI	n
7309.200000	30.48	54.00	23.50	100	35	VERT	n
No signals detected above system sensitivity							

Table 15 - Radiated Emissions Peak Measurements, Middle Channel, 1-26 GHz

Frequency	Level	Limit	Margin	Height	Angle	Pol	Mode
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		802.11
2437.000000	94.77	N/A	N/A	105	348	HORI	b
9748.000000	55.37	74.00	18.40	121	357	VERT	b
2437.000000	100.58	N/A	N/A	105	355	VERT	g
9748.000000	54.84	74.00	19.80	288	223	VERT	g
2437.000000	99.49	N/A	N/A	130	0	HORI	n
9748.000000	54.71	74.00	19.70	115	8	VERT	n

Table 16 - Radiated Emissions Average Measurements, Middle Channel, 1-26 GHz

Frequency	Level	Limit	Margin	Height	Angle	Pol	Mode
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		802.11
2437.000000	90.16	N/A	N/A	105	348	HORI	b
9748.000000	51.65	54.00	2.40	121	357	VERT	b
2437.000000	89.34	N/A	N/A	105	355	VERT	g
9748.000000	49.87	54.00	4.10	288	223	VERT	g
2437.000000	87.54	N/A	N/A	130	0	HORI	n
9748.000000	50.71	54.00	3.30	115	8	VERT	n

Table 17 - Radiated Emissions Peak Measurements, High Channel, 1-26 GHz

Frequency	Level	Limit	Margin	Height	Angle	Pol	Mode
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		802.11
2462.000000	92.95	N/A	N/A	100	349	HORI	b
9868.000000	55.42	74.00	18.58	136	346	VERT	b
2462.000000	92.96	N/A	N/A	98	339	HORI	g
4926.800000	44.63	74.00	29.40	400	357	VERT	g
7410.000000	44.04	74.00	30.00	187	0	VERT	g
2462.000000	98.58	N/A	N/A	126	7	HORI	n
9936.000000	48.47	74.00	25.50	164	355	VERT	n
No signals detected above system sensitivity							

Table 18 - Radiated Emissions Average Measurements, High Channel, 1-26 GHz

Frequency	Level	Limit	Margin	Height	Angle	Pol	Mode
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		802.11
2462.000000	88.11	N/A	N/A	100	349	HORI	b
9868.000000	52.05	54.00	2.00	136	346	VERT	b
2462.000000	81.87	N/A	N/A	98	339	HORI	g
4926.800000	30.55	54.00	23.40	400	357	VERT	g
7410.000000	30.87	54.00	23.10	187	0	VERT	g
2462.000000	86.63	N/A	N/A	126	7	HORI	n
9936.000000	39.62	54.00	14.40	164	355	VERT	n
No signals detected above system sensitivity							

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. All 3 possible 802.11 modes were tested. The highest of each is presented in the tables.

4.3 PEAK OUTPUT POWER

Test Method: ANSI C63.10:
1. Section(s) 11.9.2.2.2

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

Test procedures:
The EUT was connected to ab RF power meter directly with a low-loss shielded coaxial cable with 10 MHz RBW and 10 MHz VBW. The intention was to verify that the measurement results were the same as the original filing for this device within the measurement uncertainty of the laboratory.

Deviations from test standard:
No deviation.

Test setup:

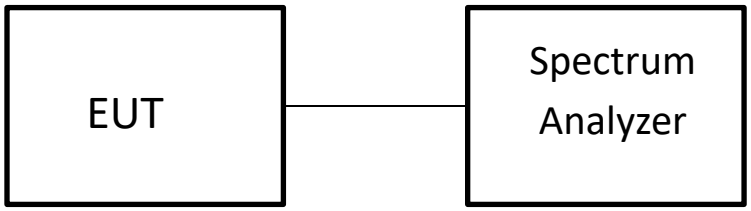

Figure 14 – Peak Output Power Measurements Test Setup

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.

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)	WIFI Type	PEAK OUTPUT POWER (dBm) MU = ±1.1 dB	Method	RESULT
Low	2412	802.11b	21.11	Conducted	PASS
Middle	2437	802.11b	19.50	Conducted	PASS
High	2462	802.11b	18.99	Conducted	PASS
Low	2412	802.11g	25.06	Conducted	PASS
Middle	2437	802.11g	24.51	Conducted	PASS
High	2462	802.11g	23.74	Conducted	PASS
Low	2412	802.11n	24.13	Conducted	PASS
Middle	2437	802.11n	24.17	Conducted	PASS
High	2462	802.11n	23.31	Conducted	PASS

Average Output Power

CHANNEL	CHANNEL FREQUENCY (MHz)	WIFI Type	Average OUTPUT POWER (dBm) MU = ±1.37	Method	RESULT
Low	2412	802.11b	15.33	Conducted	PASS
Middle	2437	802.11b	13.84	Conducted	PASS
High	2462	802.11b	13.35	Conducted	PASS
Low	2412	802.11g	16.85	Conducted	PASS
Middle	2437	802.11g	16.33	Conducted	PASS
High	2462	802.11g	15.48	Conducted	PASS
Low	2412	802.11n	16.50	Conducted	PASS
Middle	2437	802.11n	16.19	Conducted	PASS
High	2462	802.11n	15.39	Conducted	PASS

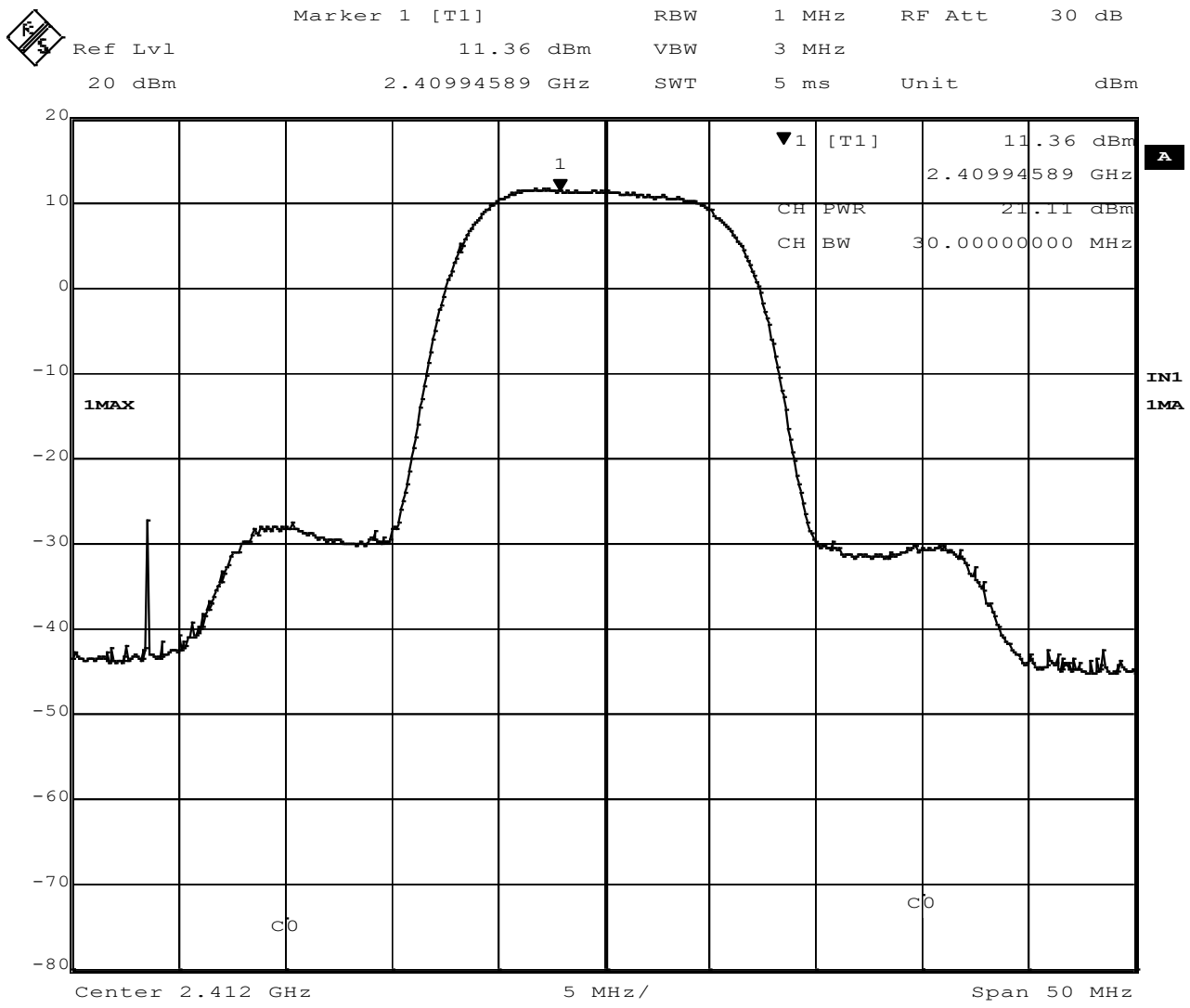

Figure 15 – Peak Power Measurement, Low Channel, 802.11b

Worst case was determined to be 11 Mbps for 802.11b

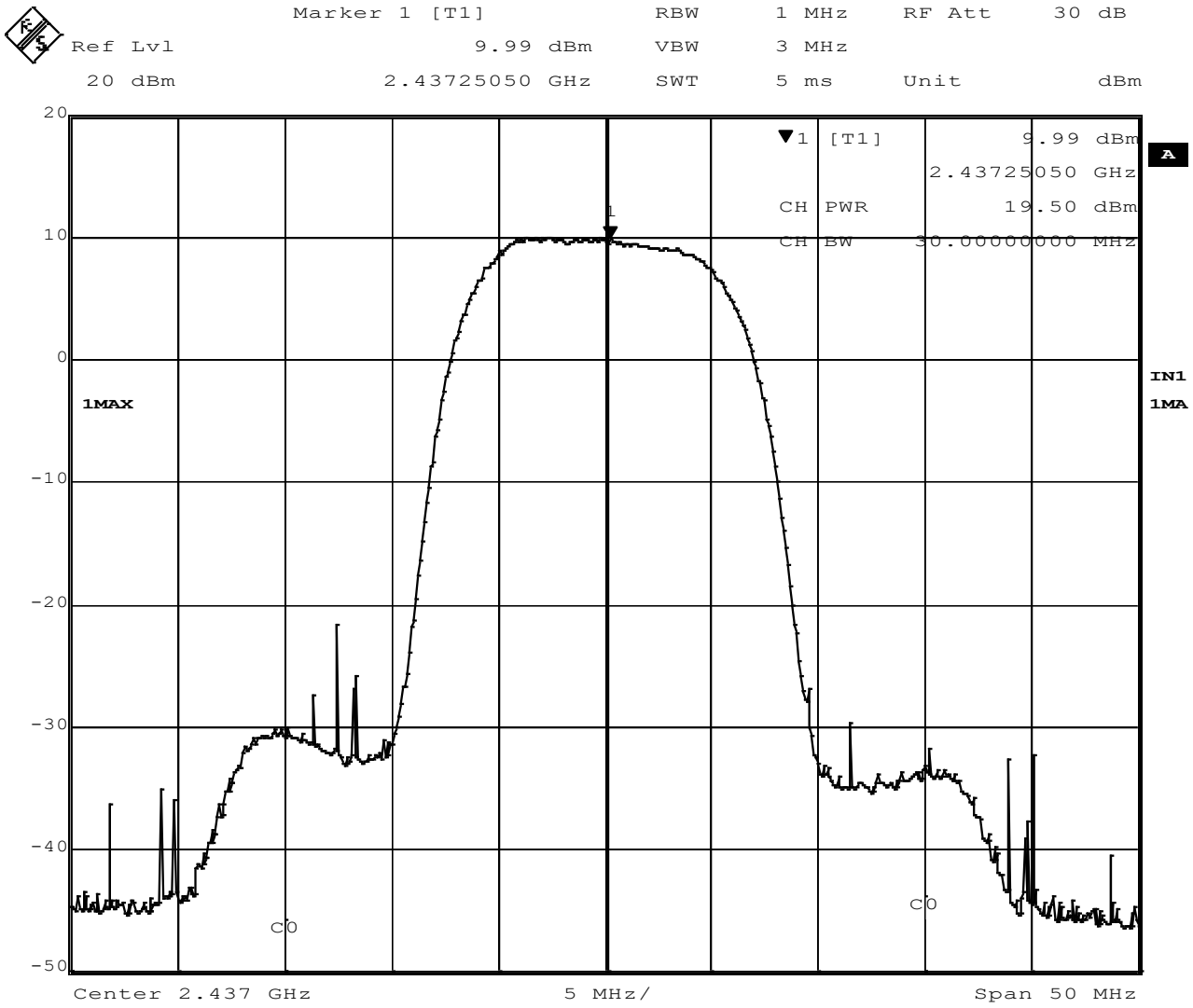

Figure 16 - Peak Power Measurement, Mid Channel, 802.11b

Worst case was determined to be 11 Mbps for 802.11b

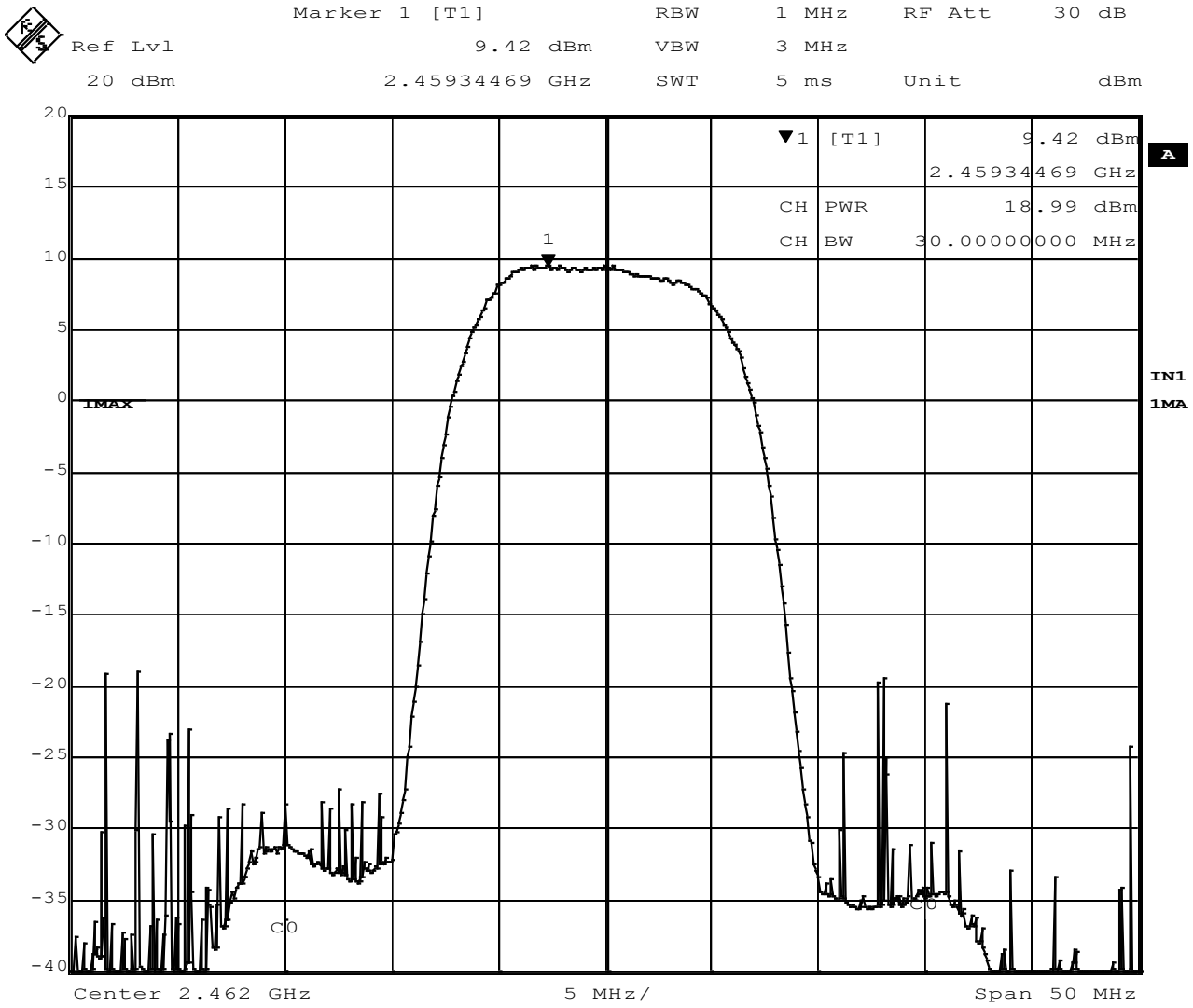

Figure 17 - Peak Power Measurement, High Channel, 802.11b

Worst case was determined to be 11 Mbps for 802.11b

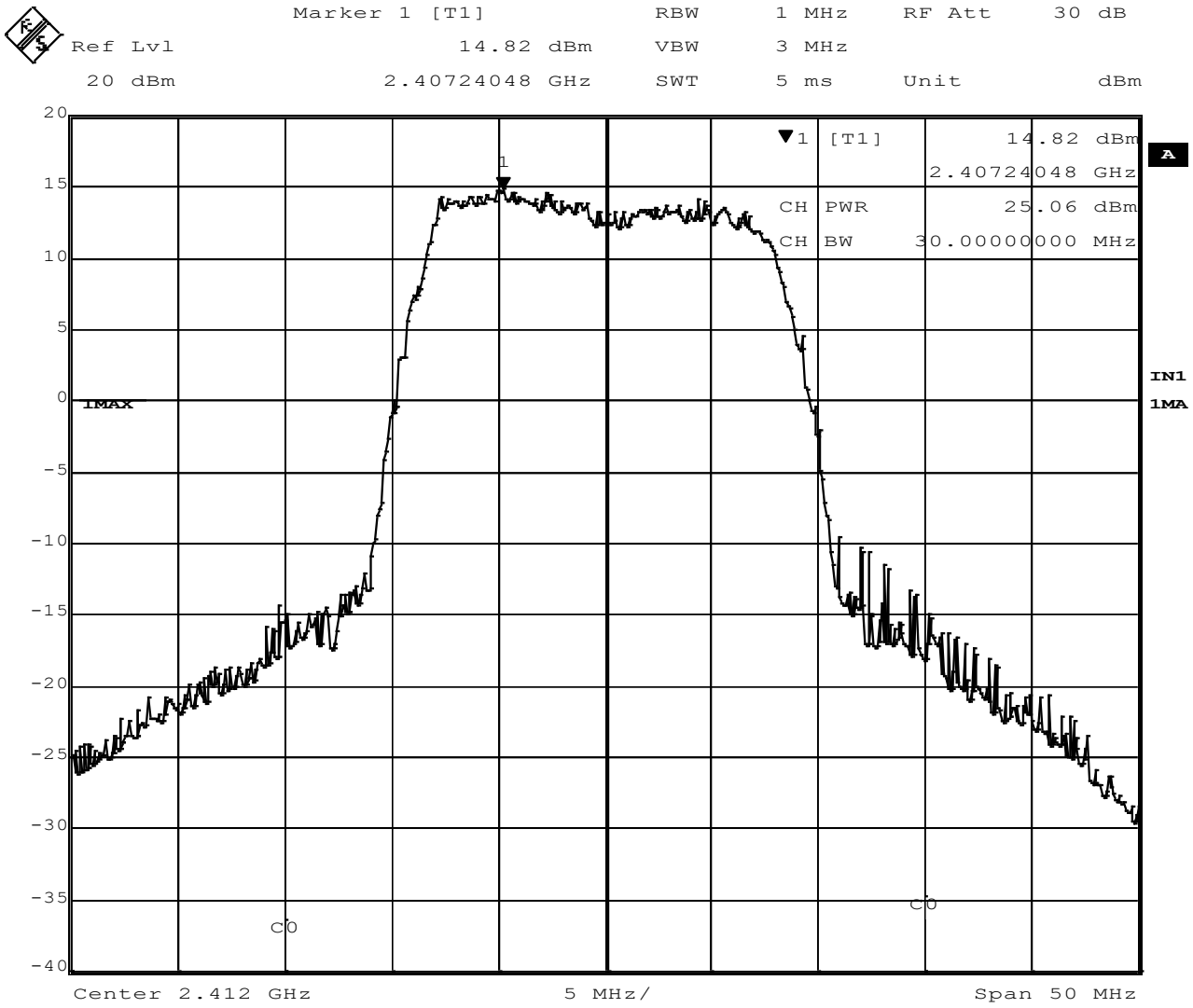

Figure 18 – Peak Power Measurement, Low Channel, 802.11g

Worst case was determined to be 54 Mbps for 802.11g

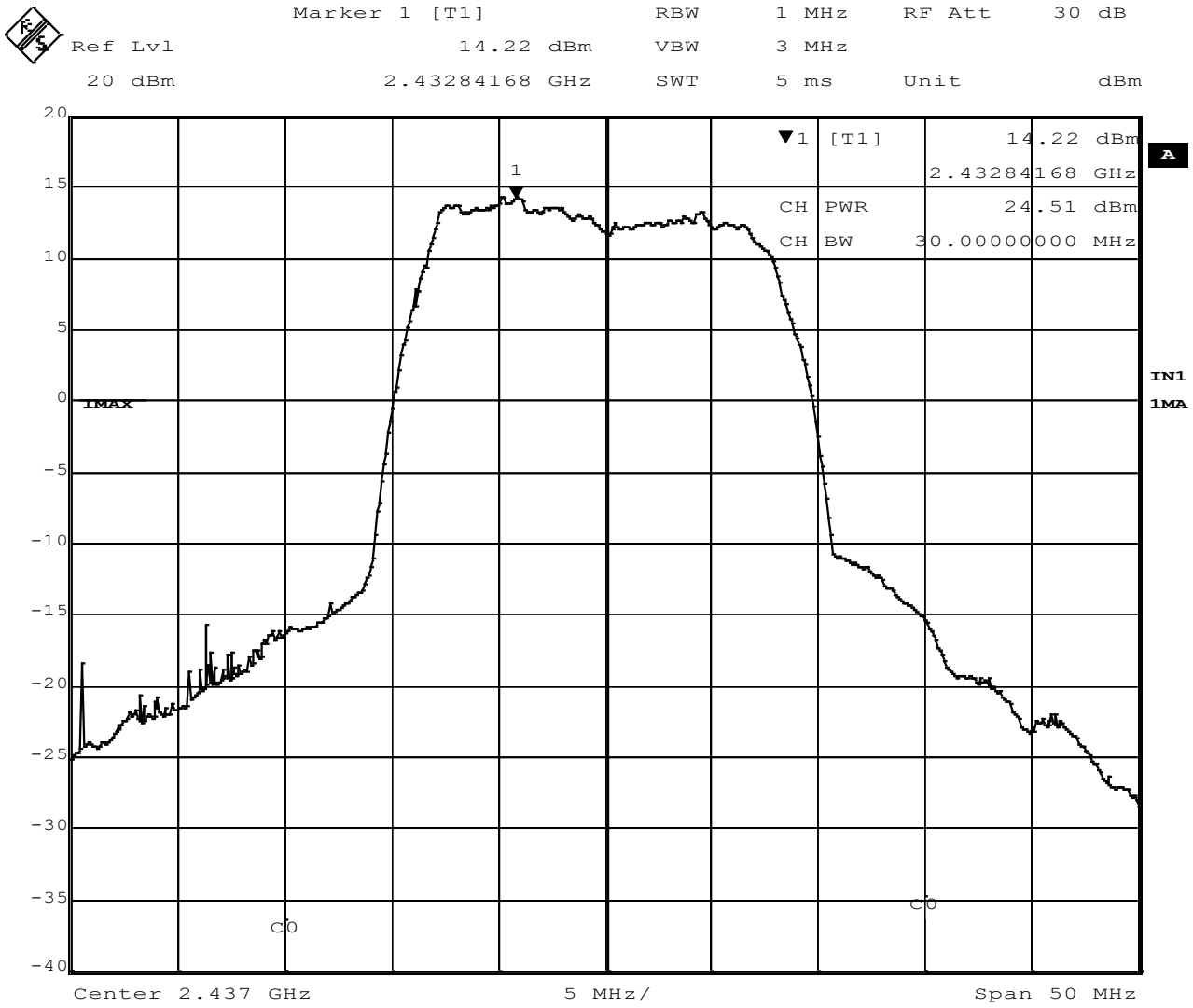

Figure 19 - Peak Power Measurement, Mid Channel, 802.1g

Worst case was determined to be 54 Mbps for 802.11g

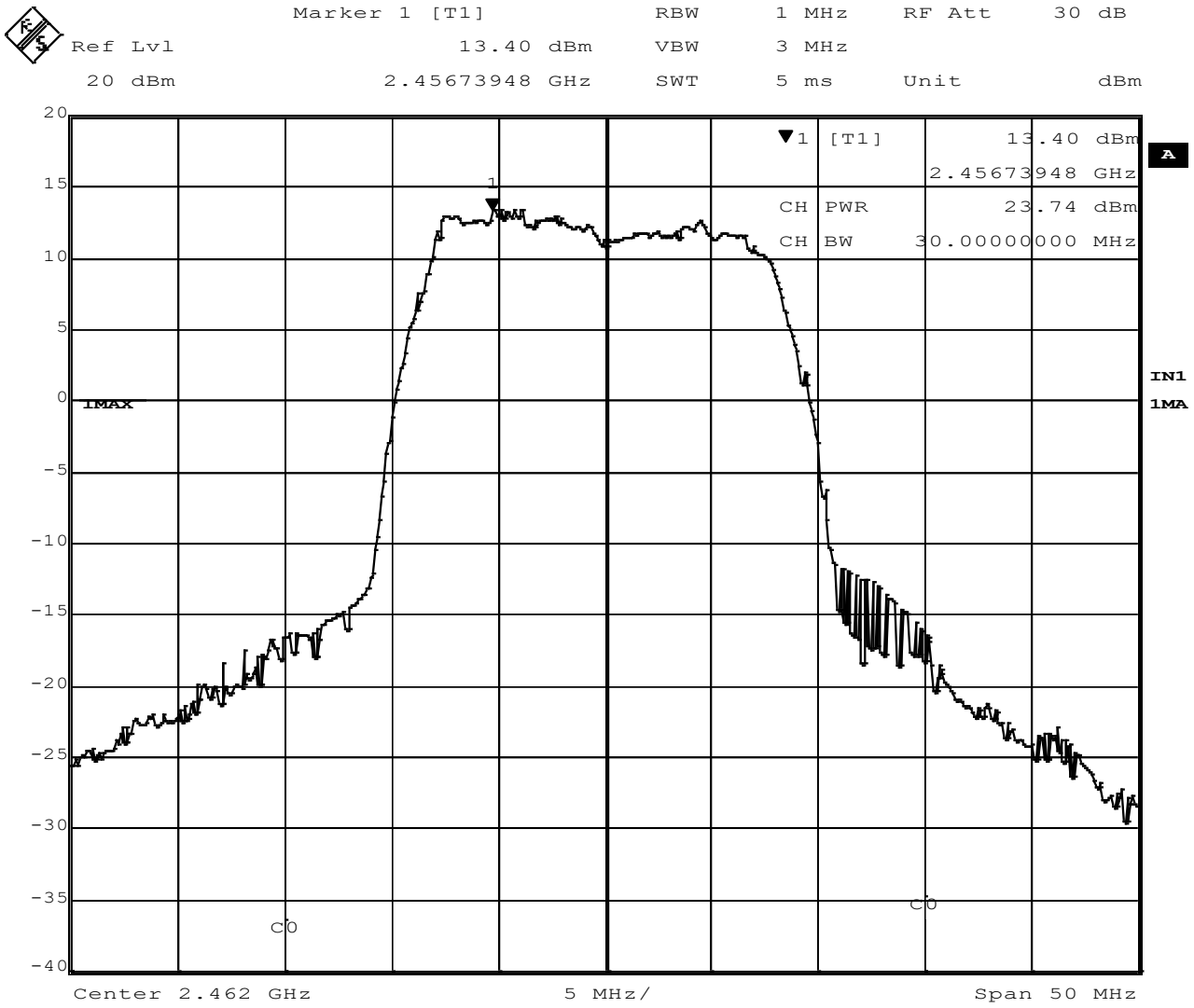

Figure 20 - Peak Power Measurement, High Channel, 802.11g

Worst case was determined to be 54 Mbps for 802.11g

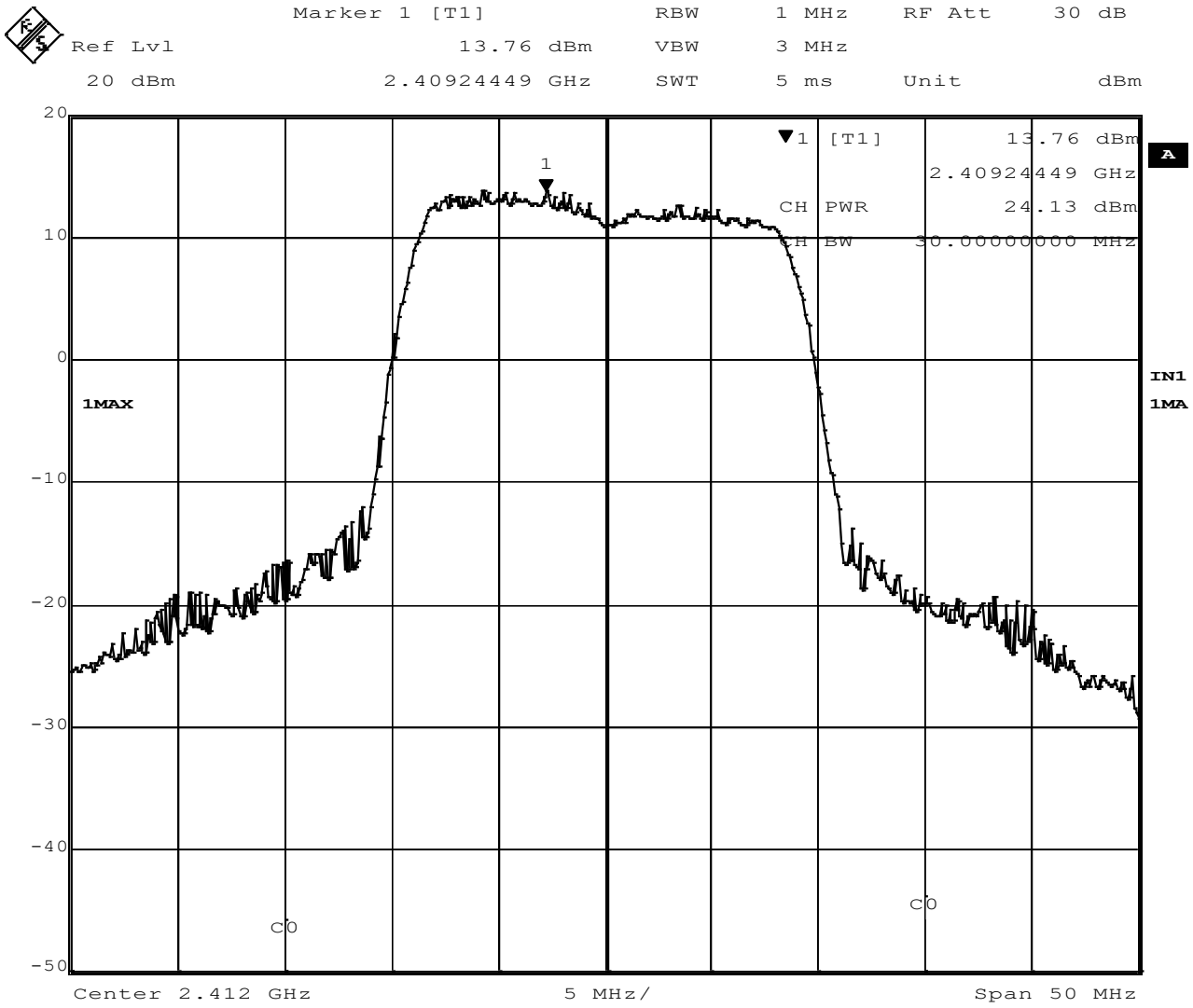

Figure 21 – Peak Power Measurement, Low Channel, 802.11n

Worst case was determined to be MSC7 for 802.11n

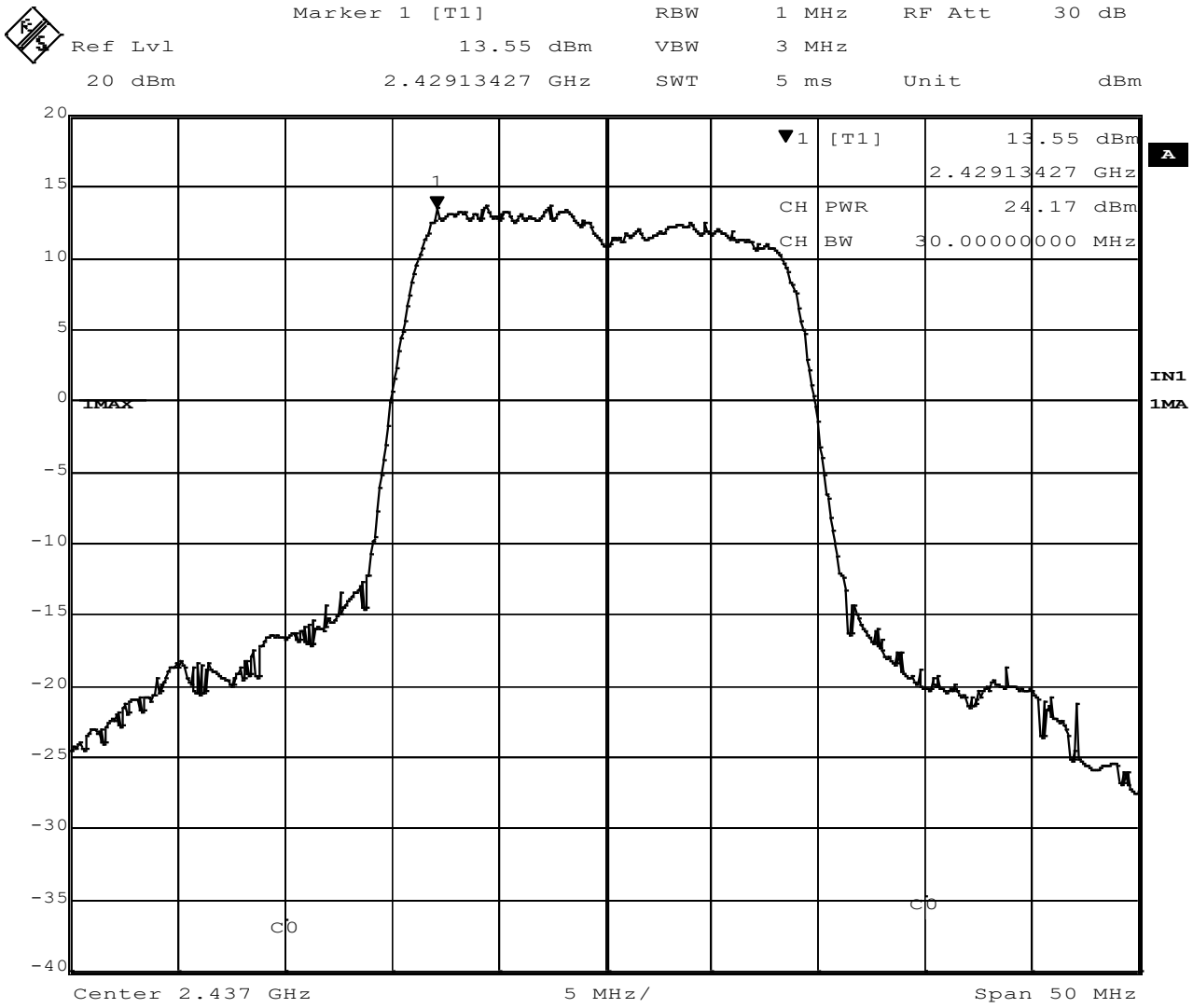

Figure 22 - Peak Power Measurement, Mid Channel, 802.1n

Worst case was determined to be MSC7 for 802.11n

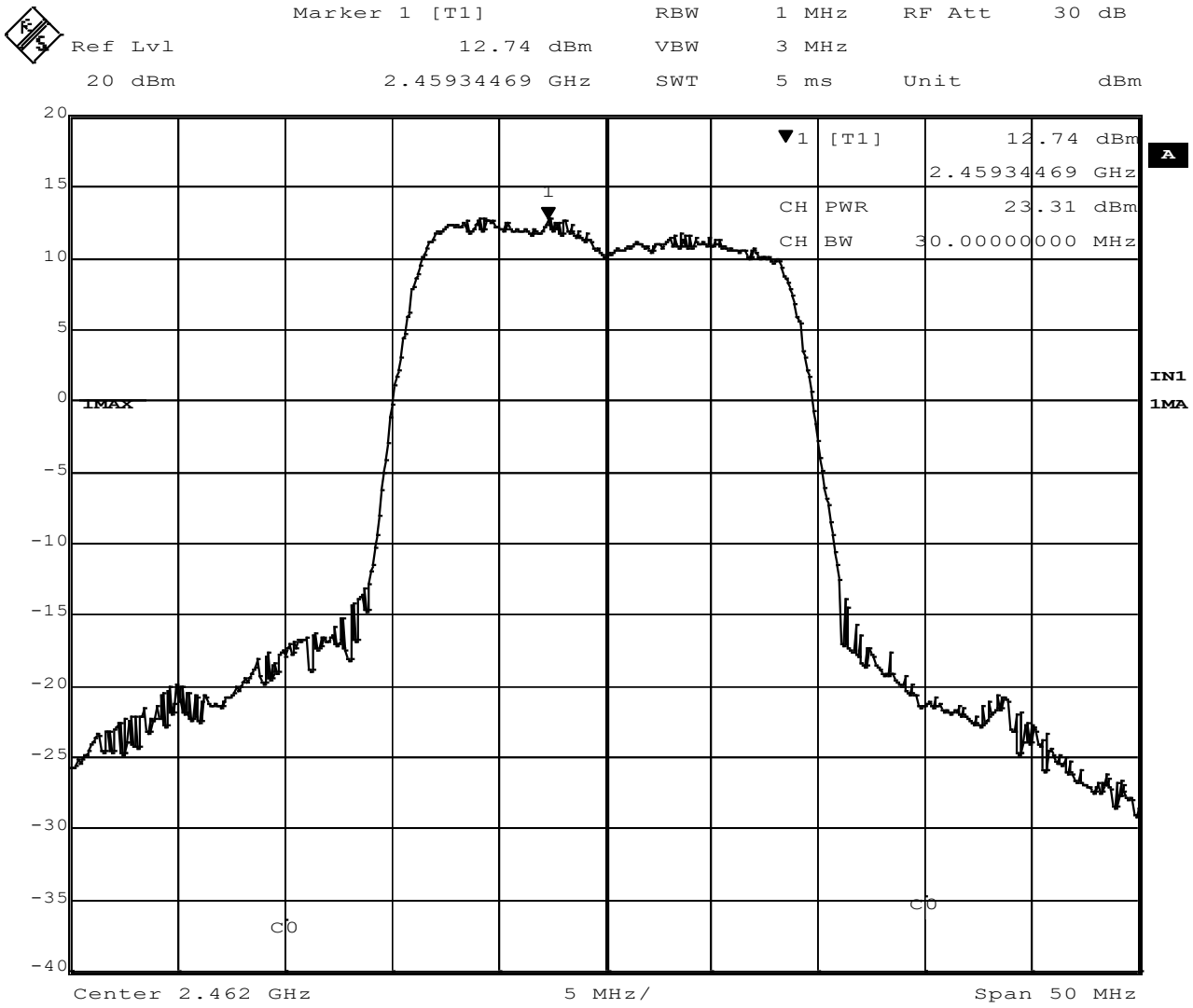

Figure 23 - Peak Power Measurement, High Channel, 802.11n

Worst case was determined to be MSC7 for 802.11n

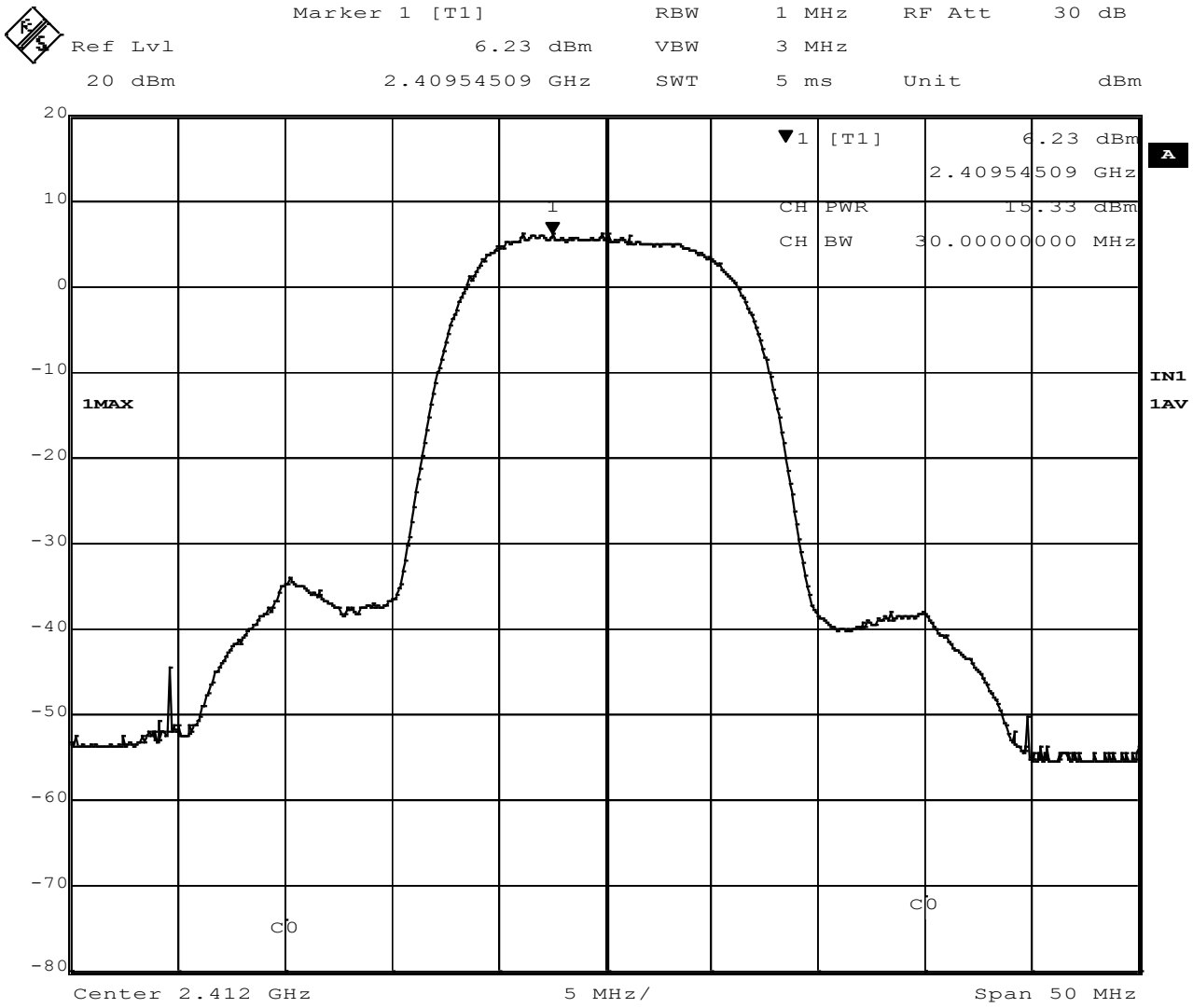

Figure 24 – Average Power Measurement, Low Channel, 802.11b

Worst case was determined to be 11 Mbps for 802.11b

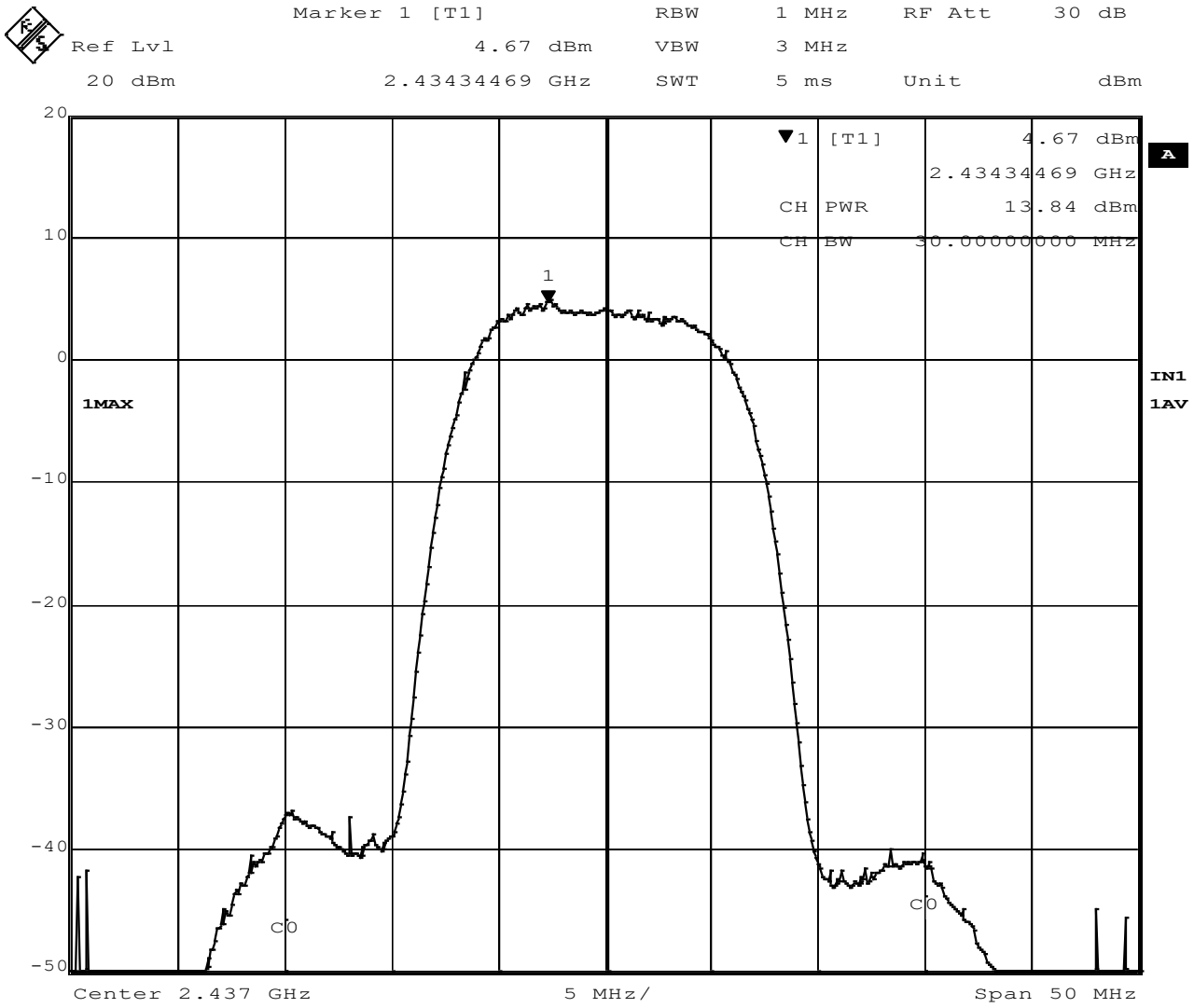

Figure 25 - Average Power Measurement, Mid Channel, 802.11b

Worst case was determined to be 11 Mbps for 802.11b

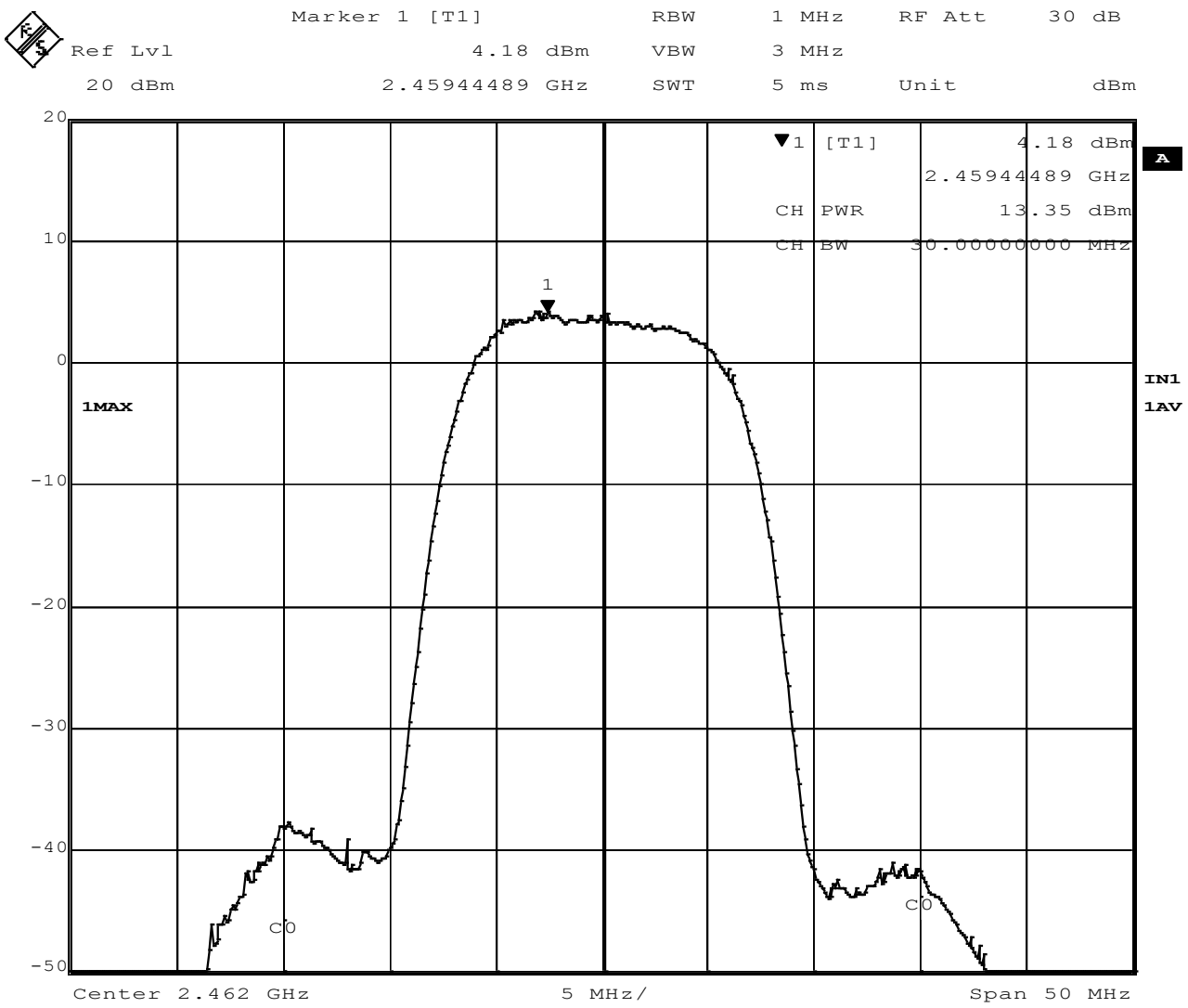

Figure 26 - Average Power Measurement, High Channel, 802.11b

Worst case was determined to be 11 Mbps for 802.11b

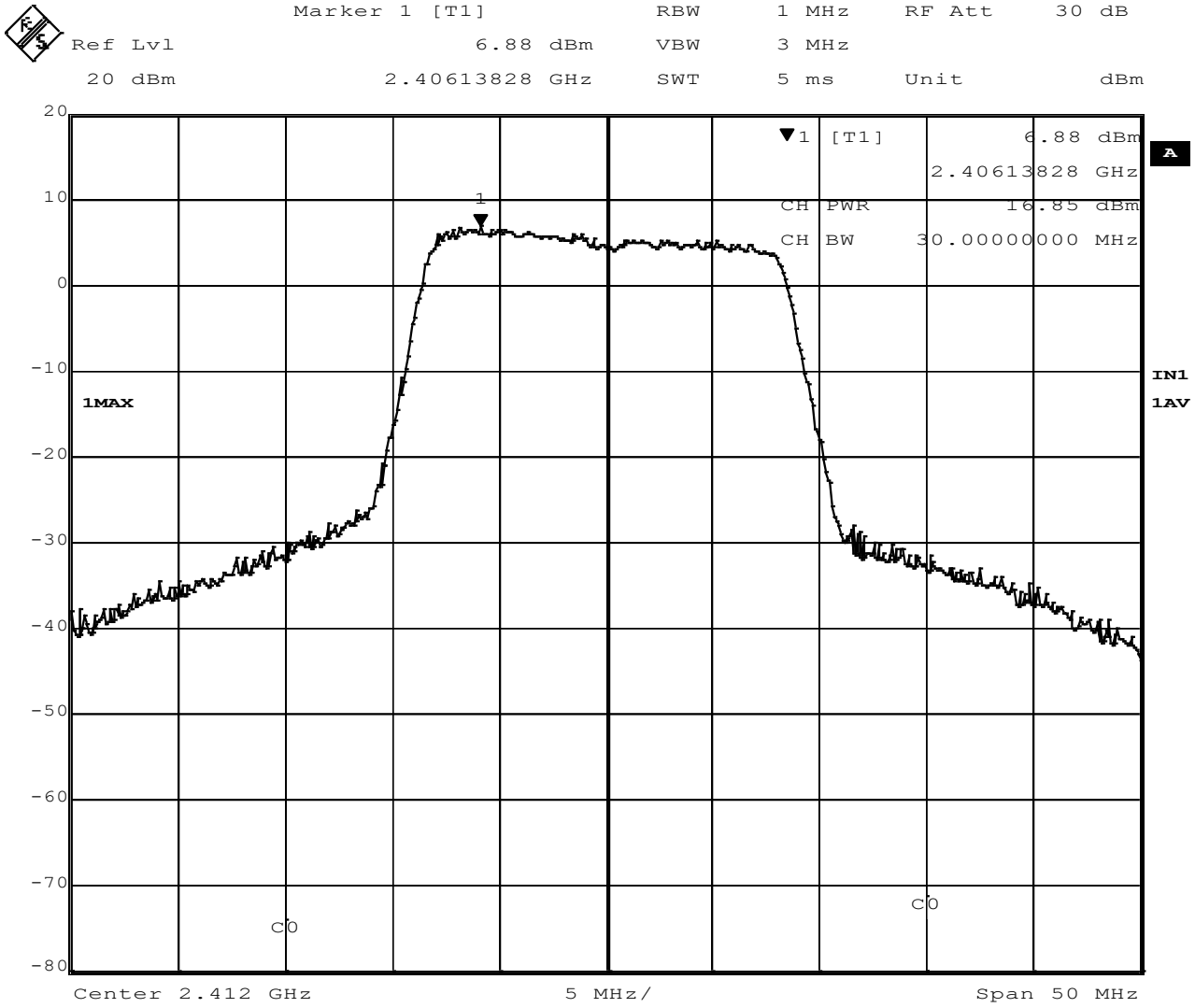

Figure 27 – Average Power Measurement, Low Channel, 802.11g

Worst case was determined to be 54 Mbps for 802.11g

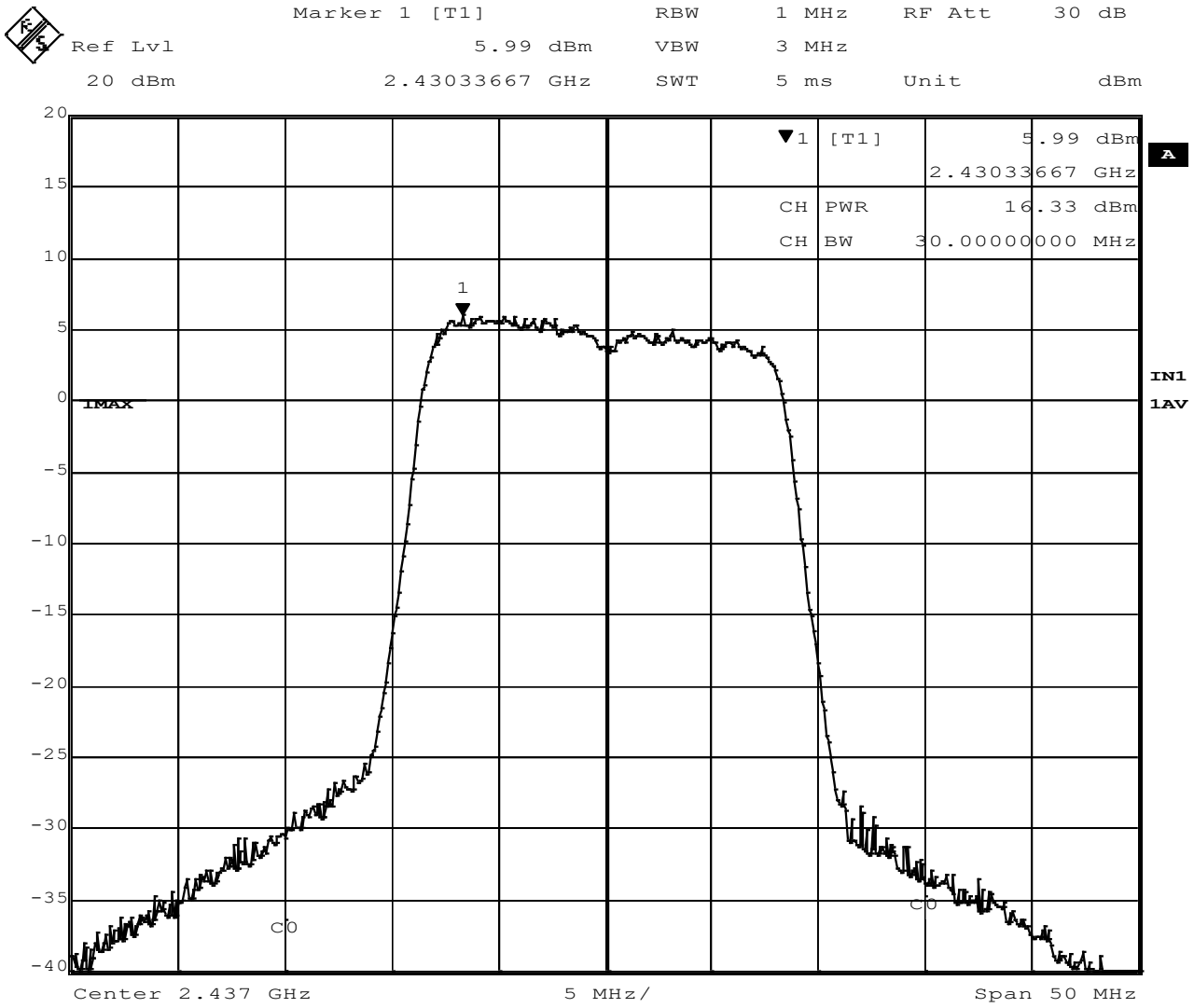

Figure 28 - Average Power Measurement, Mid Channel, 802.1g

Worst case was determined to be 54 Mbps for 802.11g

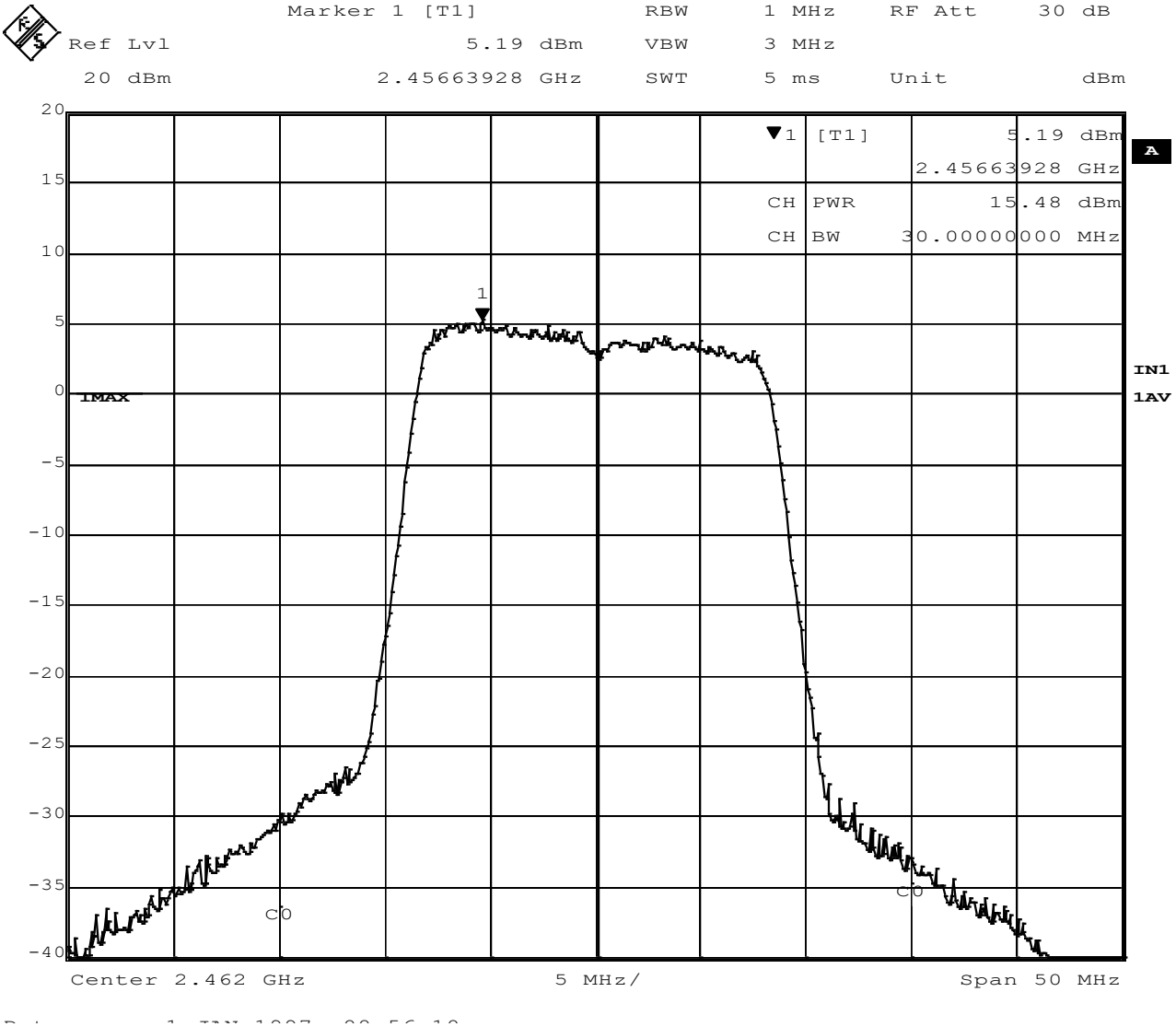

Figure 29 - Average Power Measurement, High Channel, 802.11g

Worst case was determined to be 54 Mbps for 802.11g

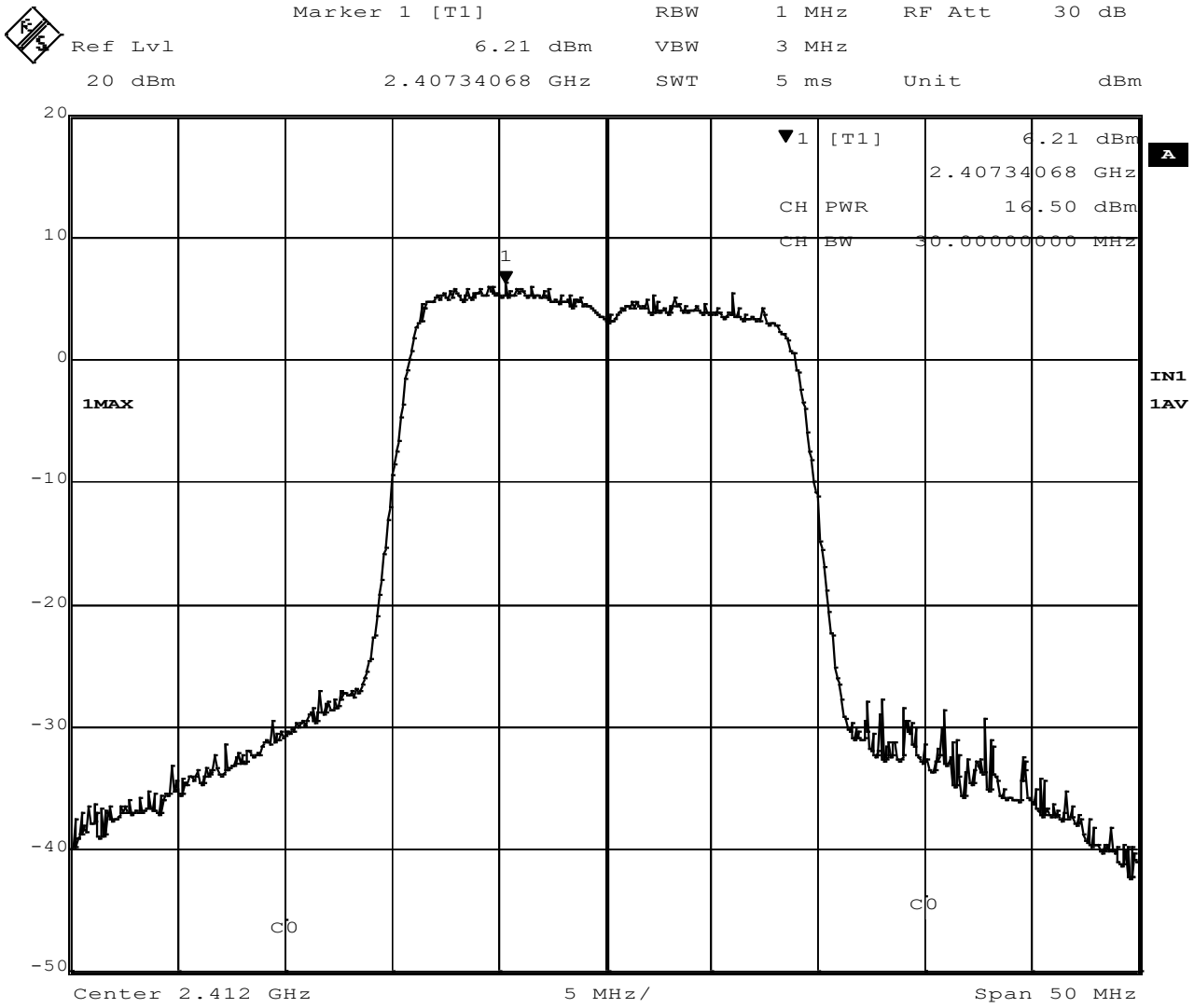

Figure 30 – Average Power Measurement, Low Channel, 802.11n

Worst case was determined to be MSC7 for 802.11n

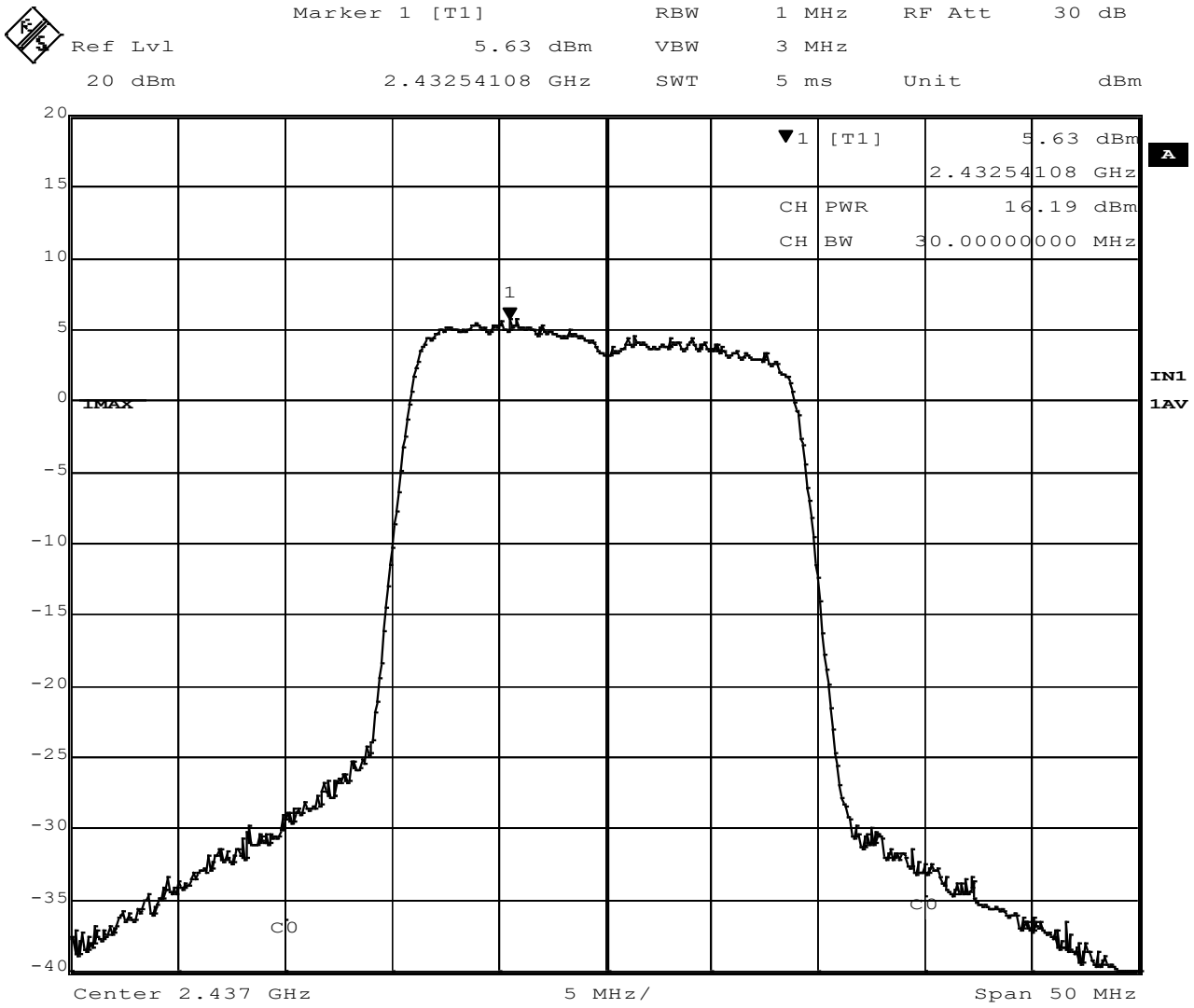

Figure 31 - Average Power Measurement, Mid Channel, 802.1n

Worst case was determined to be MSC7 for 802.11n

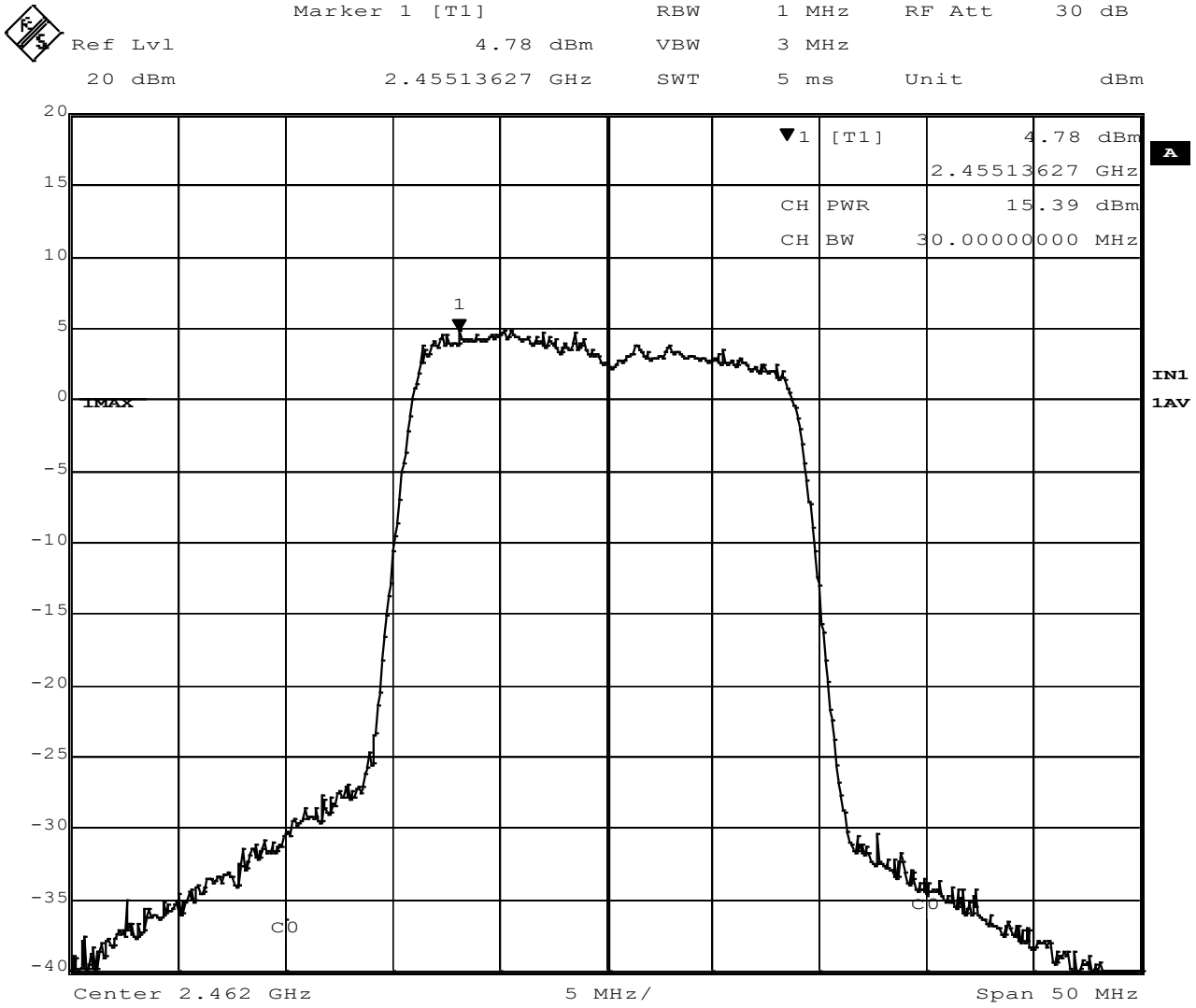

Figure 32 - Average Power Measurement, High Channel, 802.11n

Worst case was determined to be MSC7 for 802.11n

4.4 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:

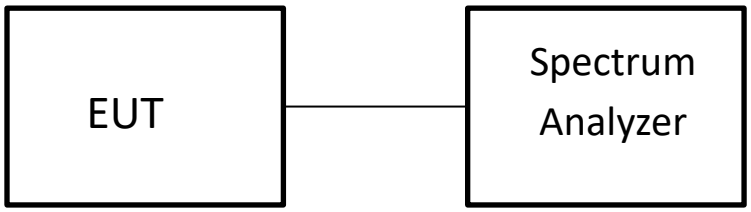

Figure 33 – Peak Output Power Measurements Test Setup

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.

Test results:

99% Occupied Bandwidth

CHANNEL	CHANNEL FREQUENCY (MHz)	WIFI Type	99% Occupied BW (MHz)
Low	2412	802.11b	14.08
Middle	2437	802.11b	14.03
High	2462	802.11b	14.93
Low	2412	802.11g	16.58
Middle	2437	802.11g	16.53
High	2462	802.11g	16.58
Low	2412	802.11n	17.69
Middle	2437	802.11n	17.74
High	2462	802.11n	17.74

6dB Bandwidth

CHANNEL	CHANNEL FREQUENCY (MHz)	WIFI Type	6 dB BW (MHz)
Low	2412	802.11b	11.70
Middle	2437	802.11b	11.94
High	2462	802.11b	11.42
Low	2412	802.11g	16.59
Middle	2437	802.11g	16.33
High	2462	802.11g	16.55
Low	2412	802.11n	17.84
Middle	2437	802.11n	17.80

High	2462	802.11n	17.80

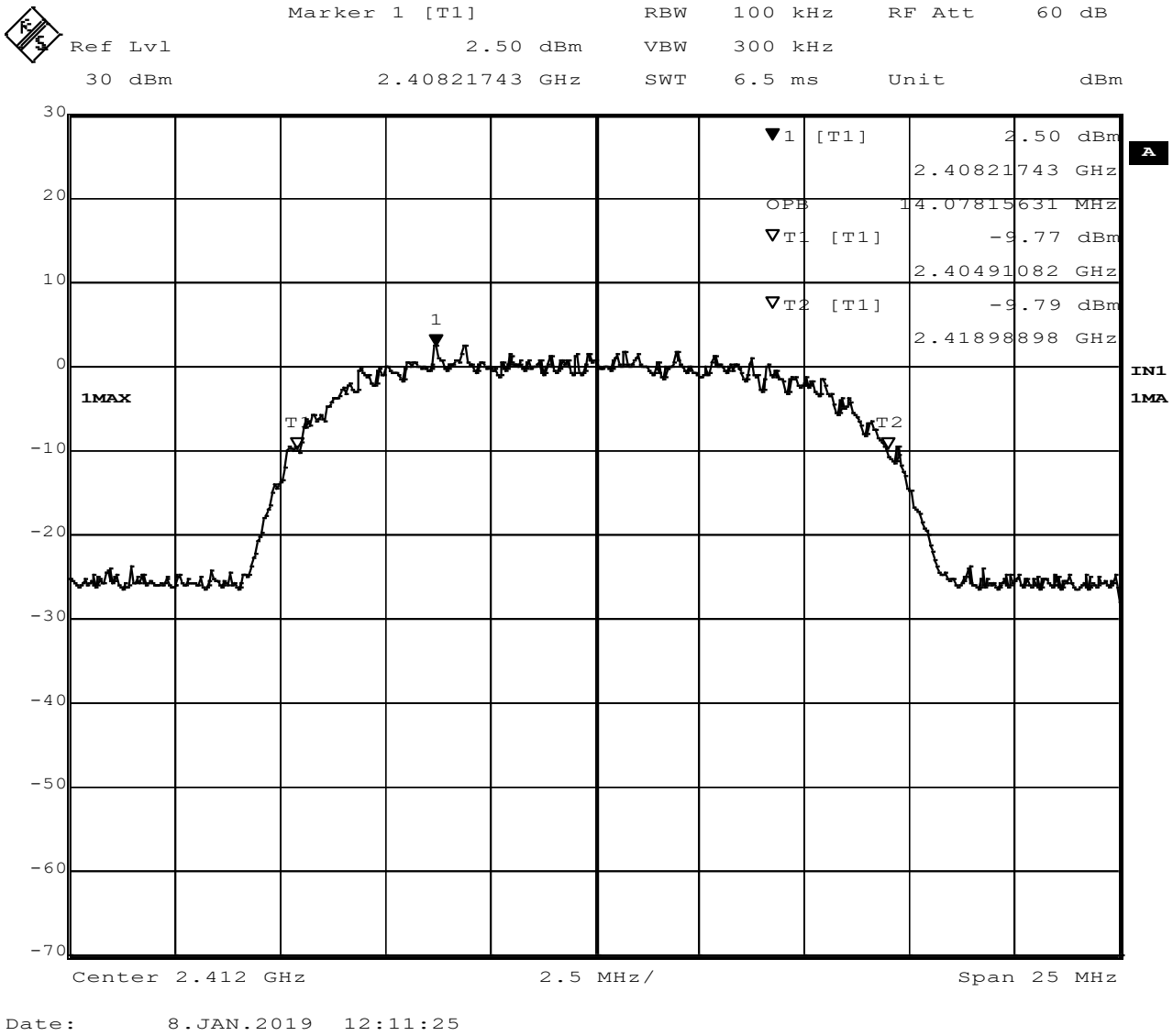

Figure 34 - 99% Occupied Bandwidth, Low Channel, 802.11b

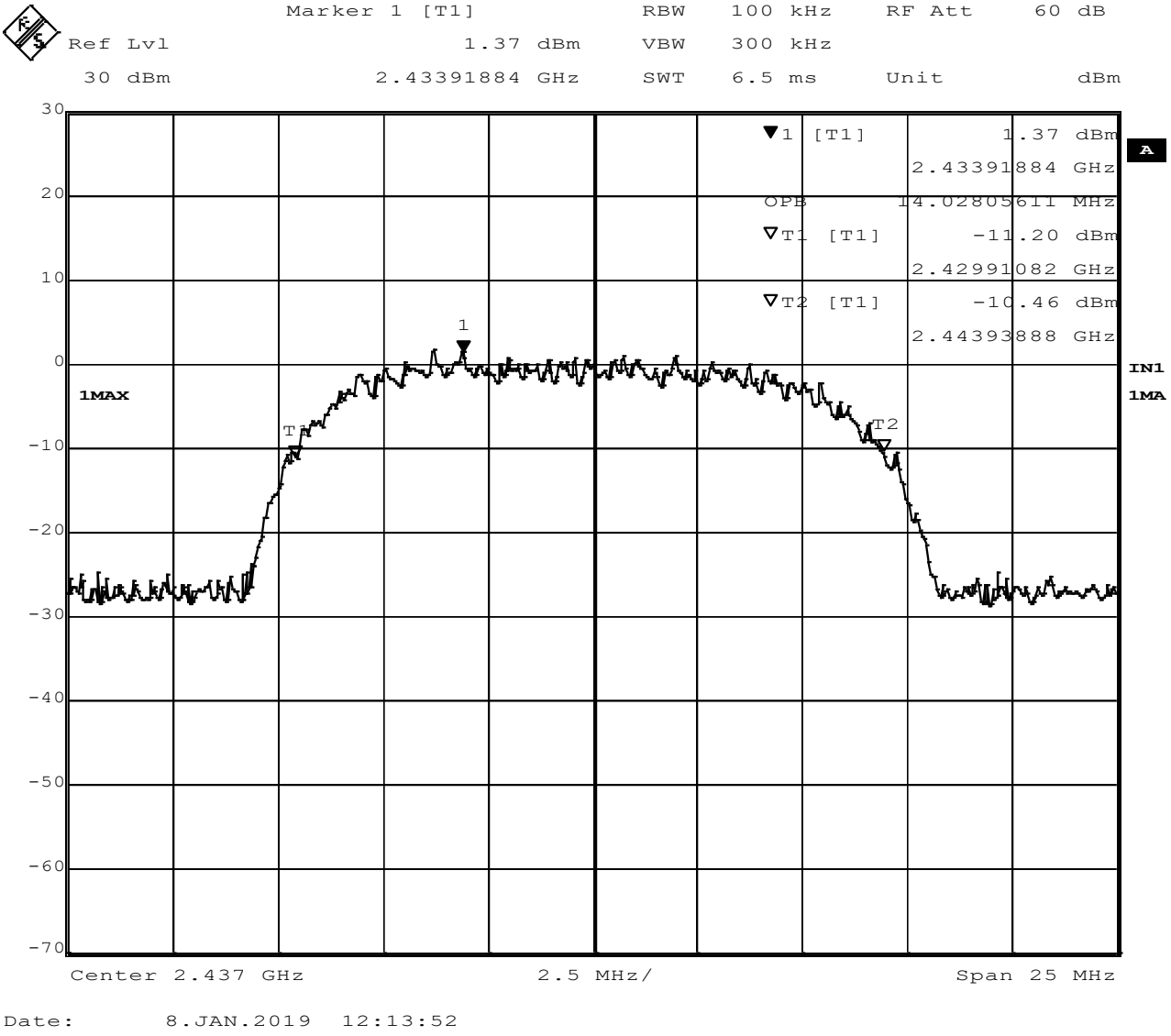

Figure 35 - 99% Occupied Bandwidth, Mid Channel, 802.11b

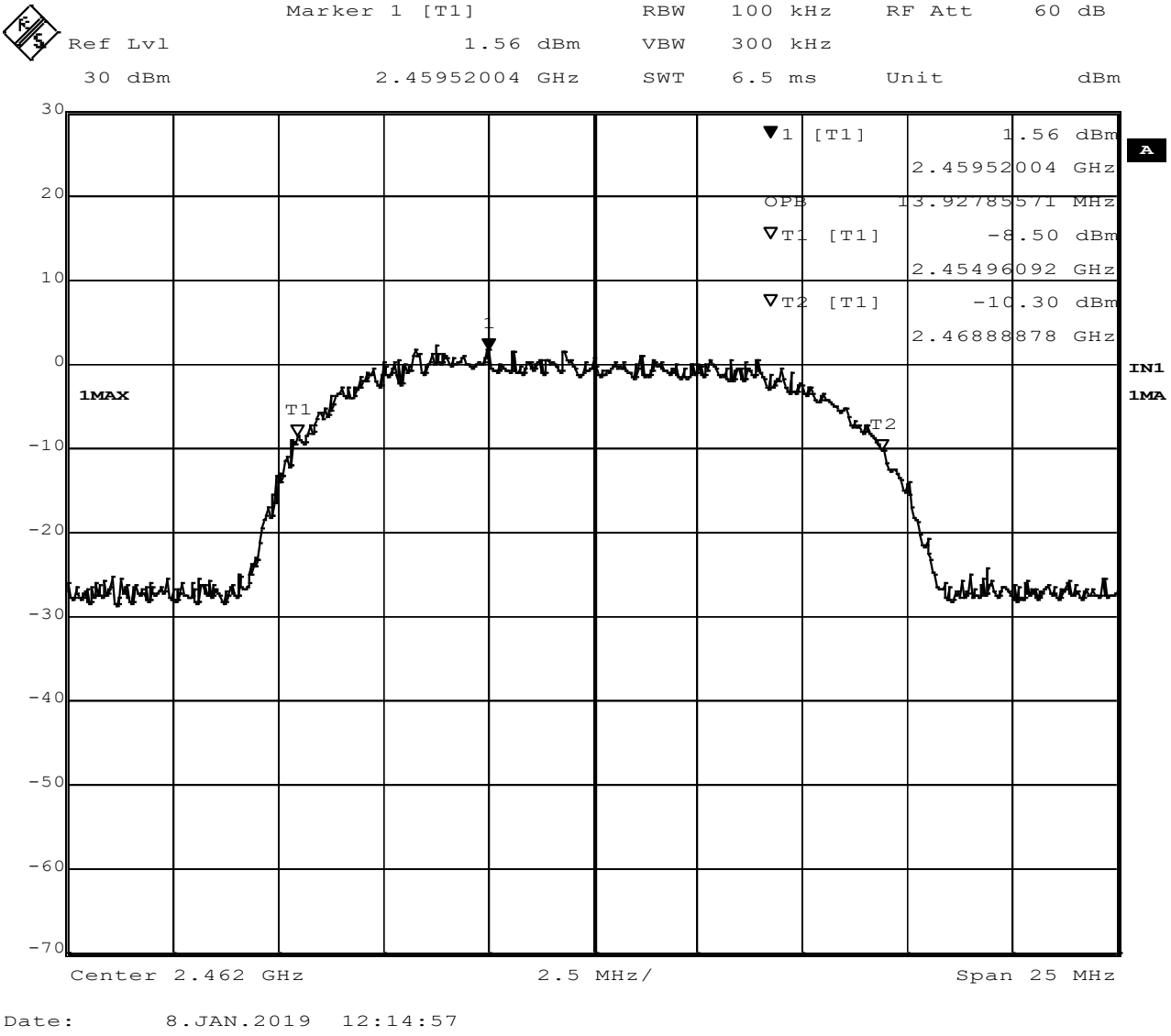

Figure 36 - 99% Occupied Bandwidth, High Channel, 802.11b

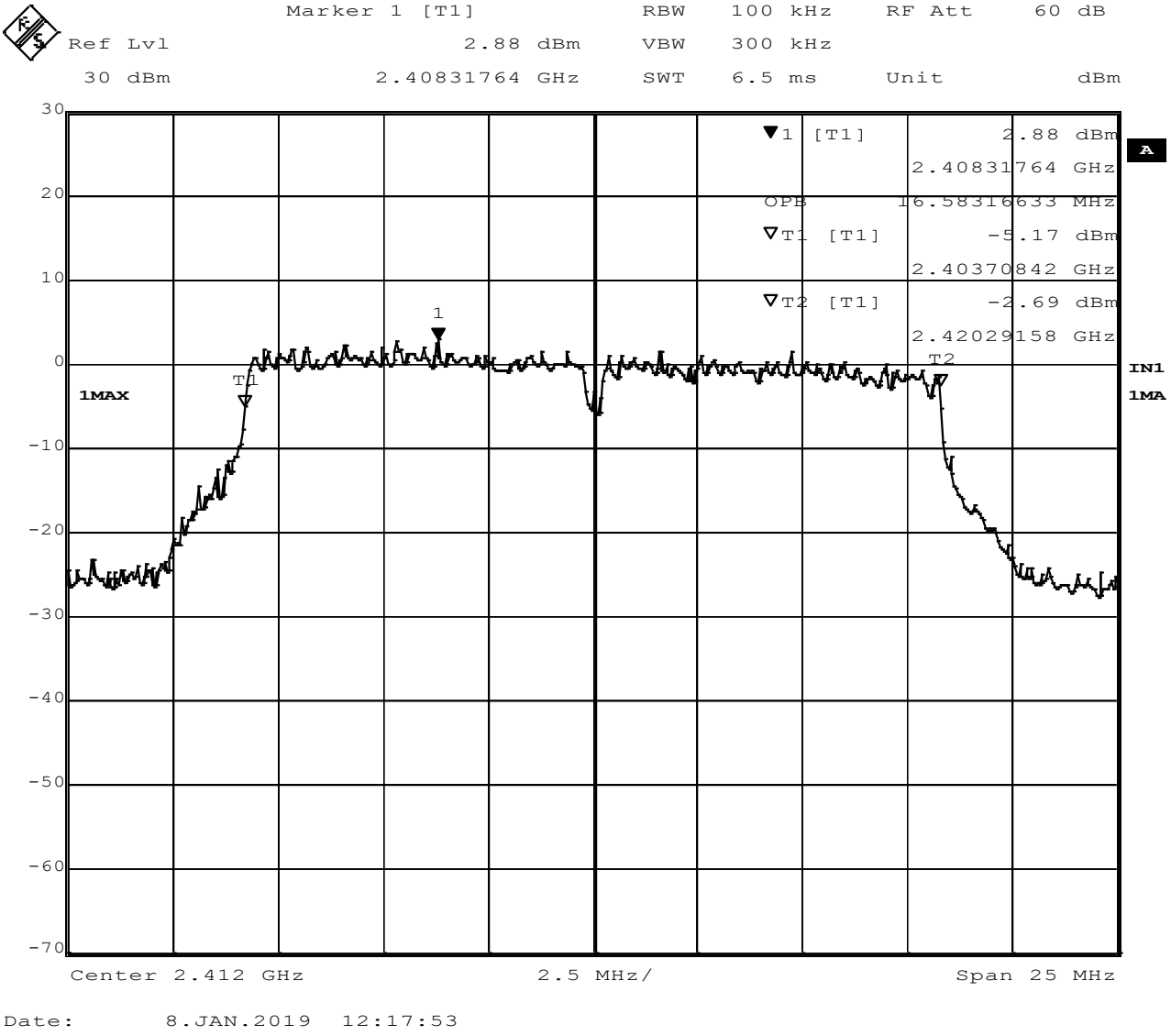

Figure 37 - 99% Occupied Bandwidth, Low Channel, 802.11g

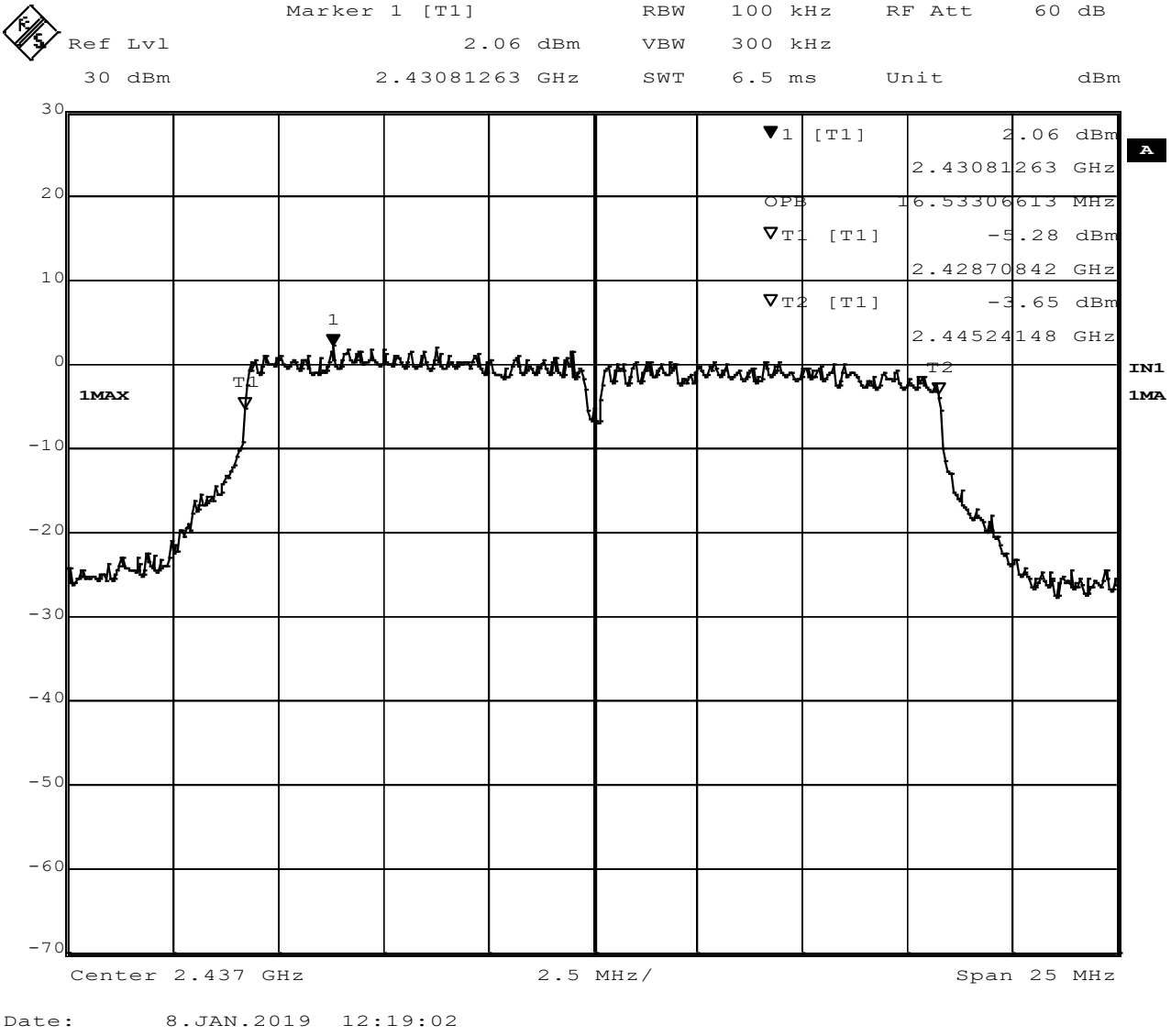

Figure 38 - 99% Occupied Bandwidth, Mid Channel, 802.11g

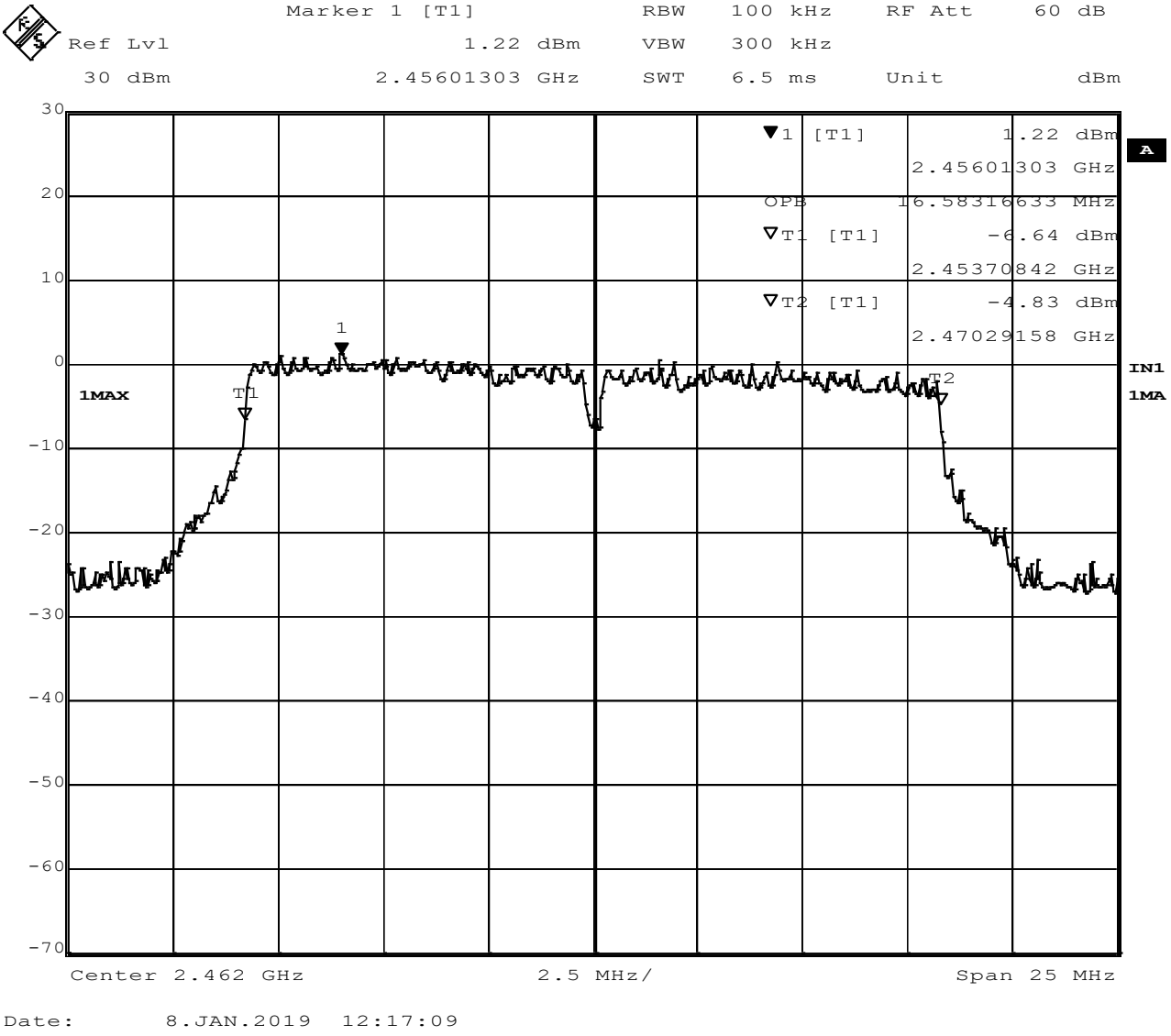

Figure 39 - 99% Occupied Bandwidth, High Channel, 802.11g

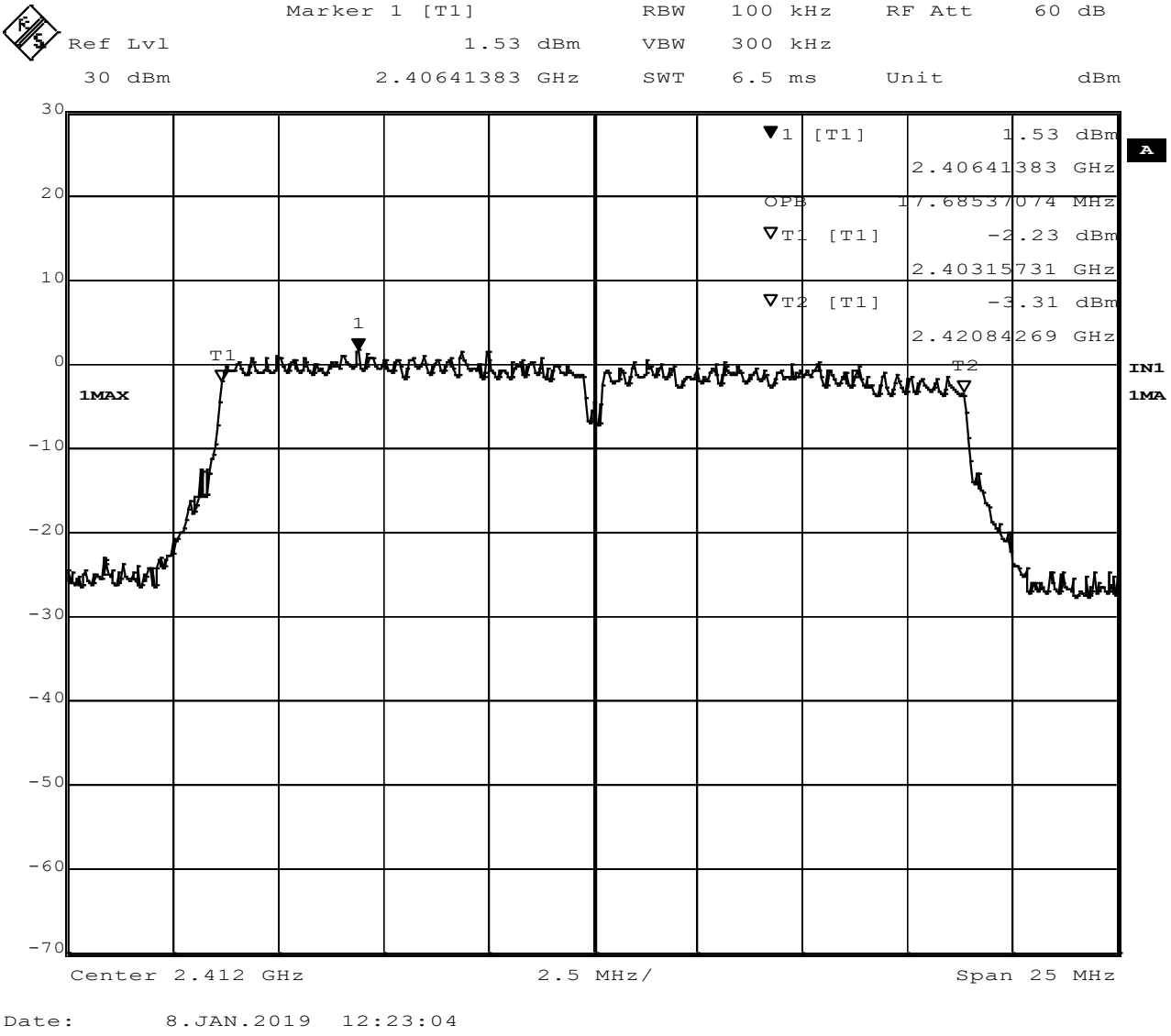

Figure 40 - 99% Occupied Bandwidth, Low Channel, 802.11n

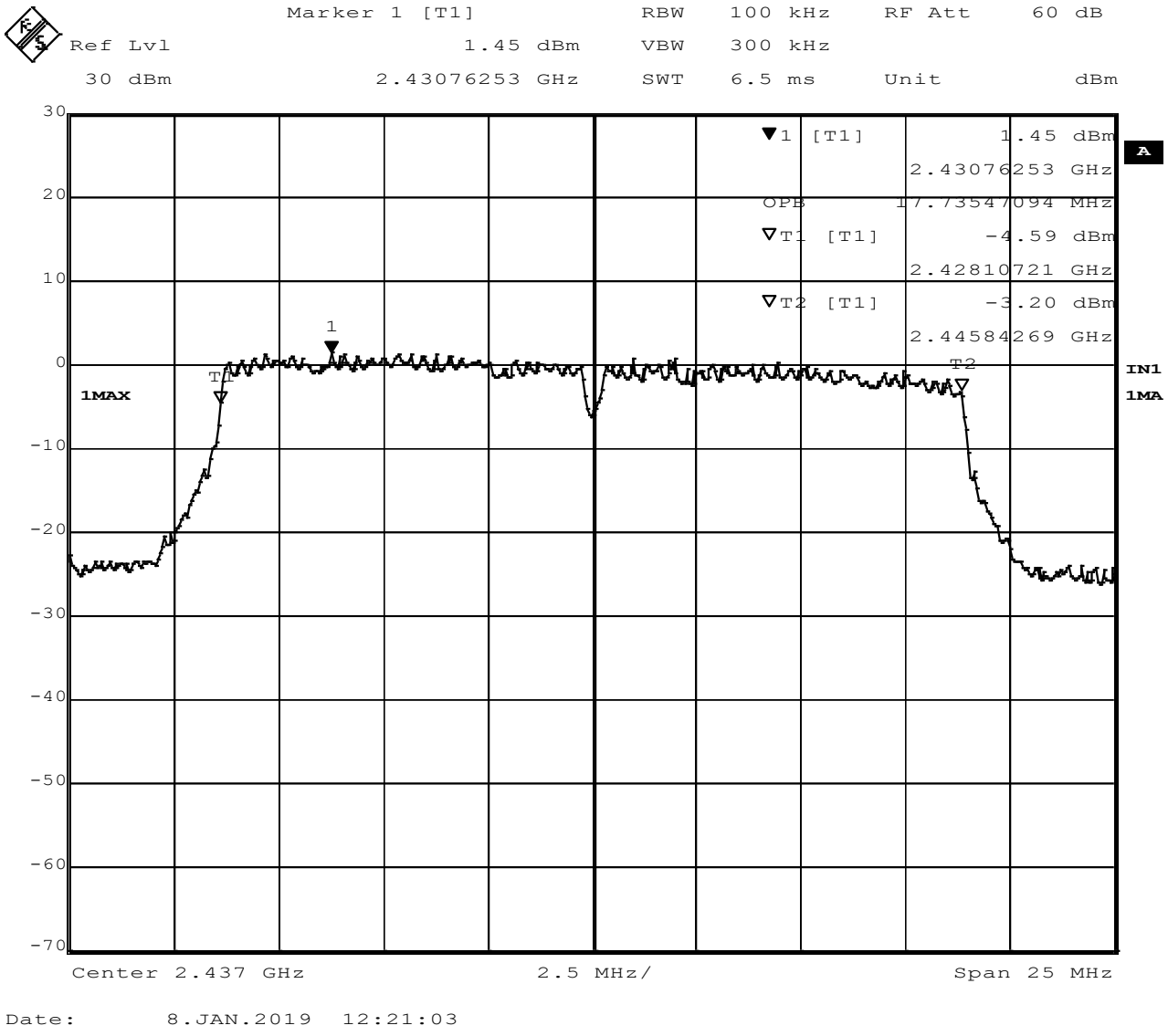

Figure 41 - 99% Occupied Bandwidth, Mid Channel, 802.11n

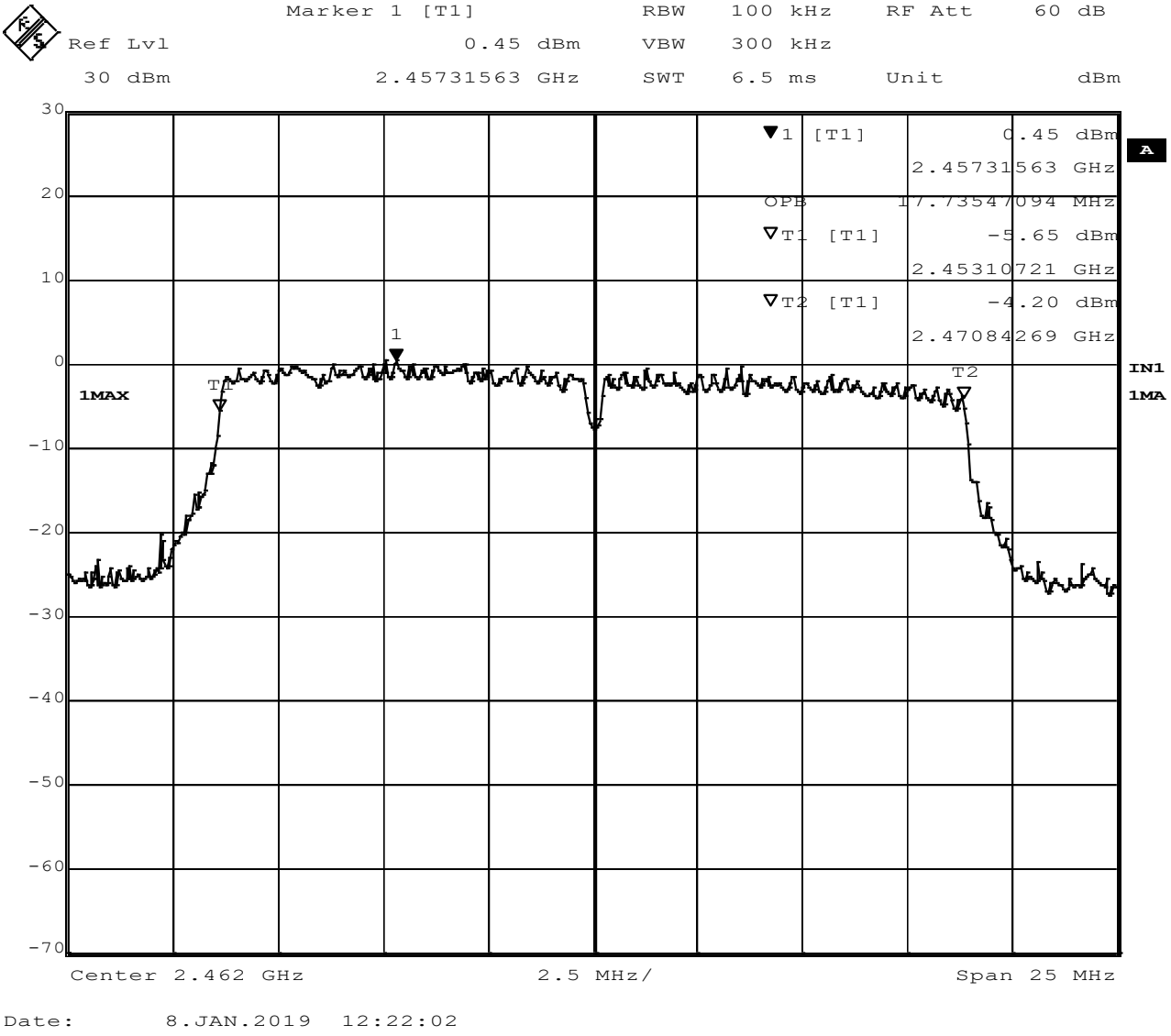

Figure 42 - 99% Occupied Bandwidth, High Channel, 802.11n

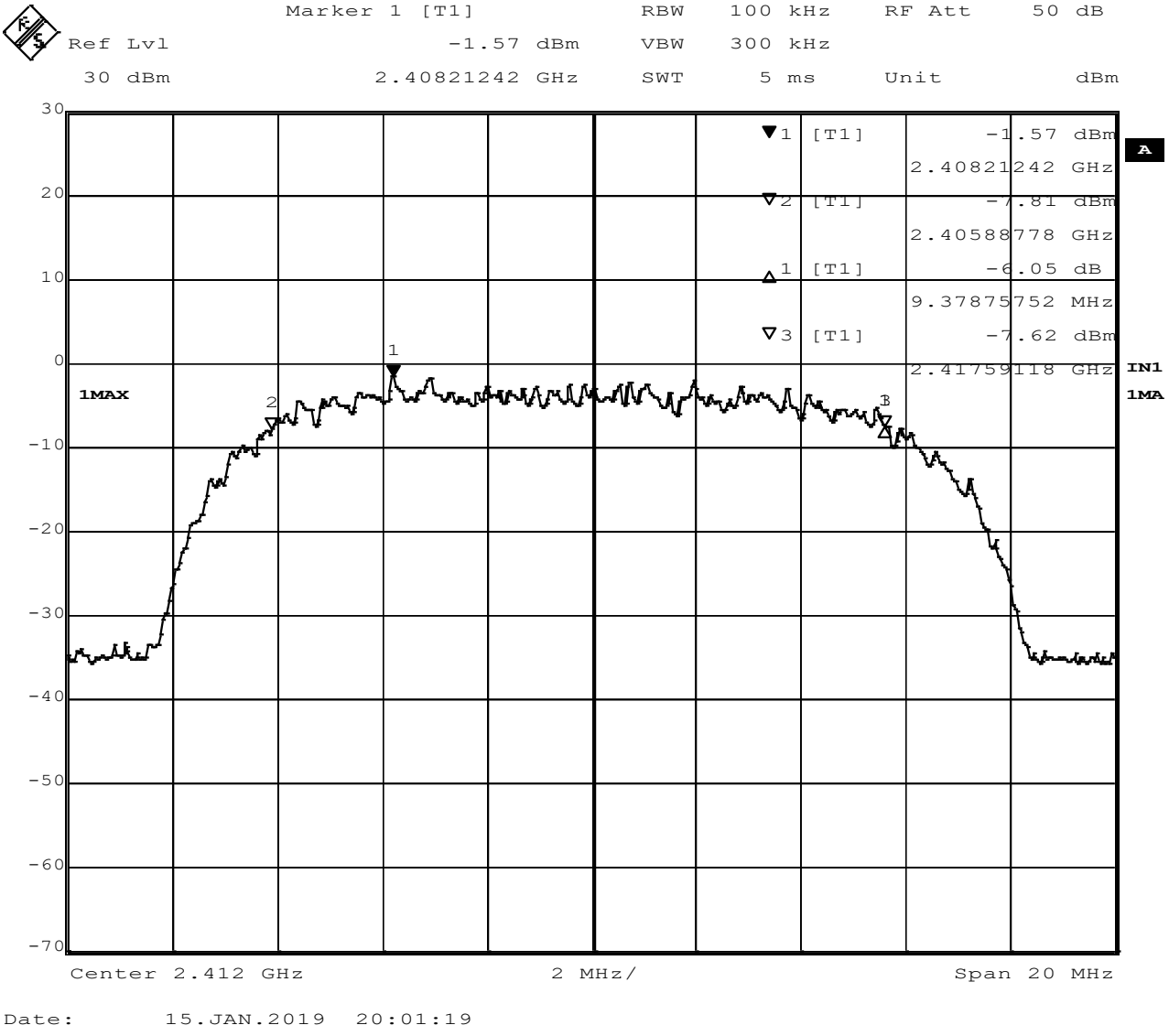

Figure 43 - 6dB Bandwidth, Low Channel, 802.11b

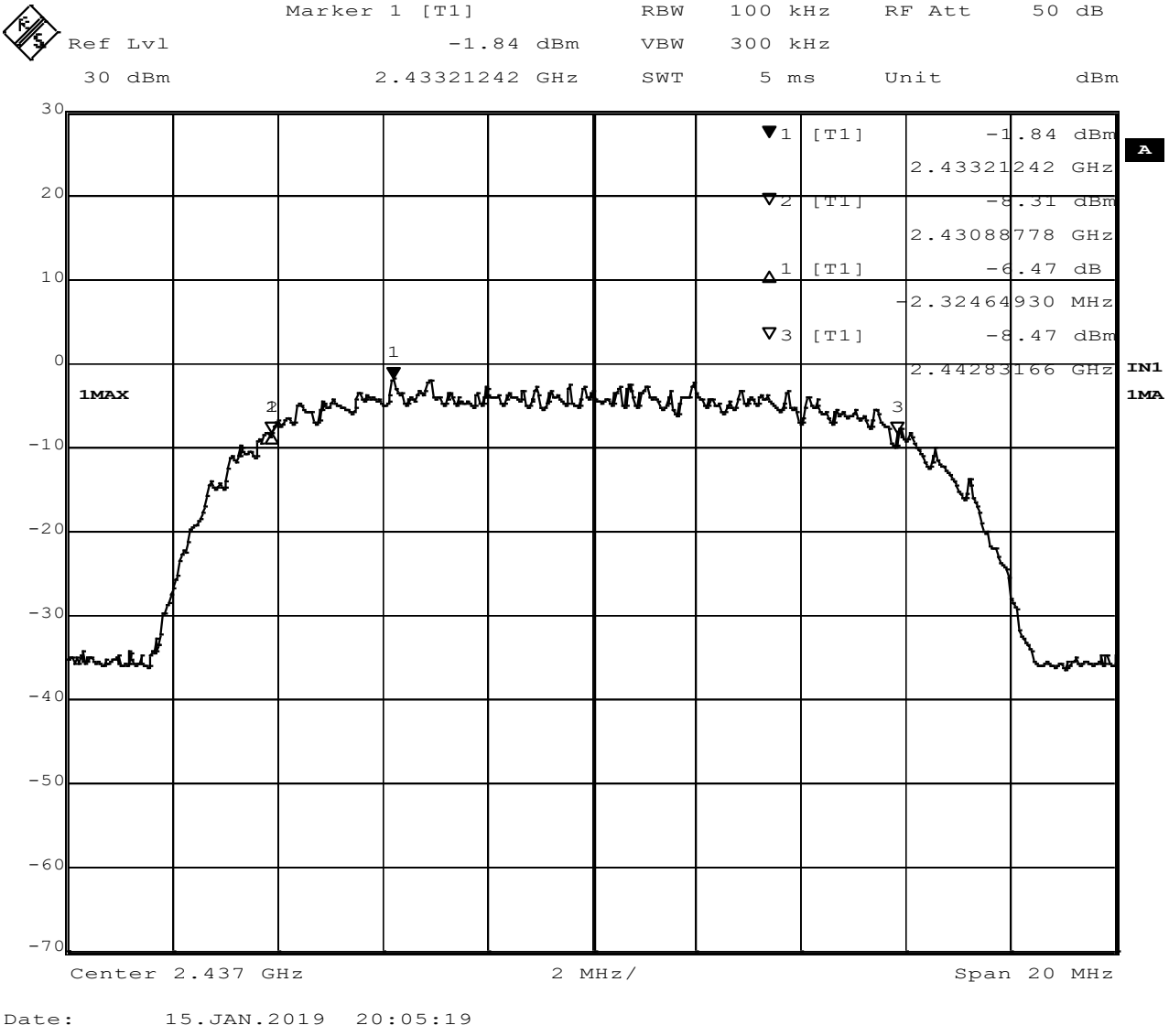

Figure 44 - 6dB Bandwidth, Mid Channel, 802.11b

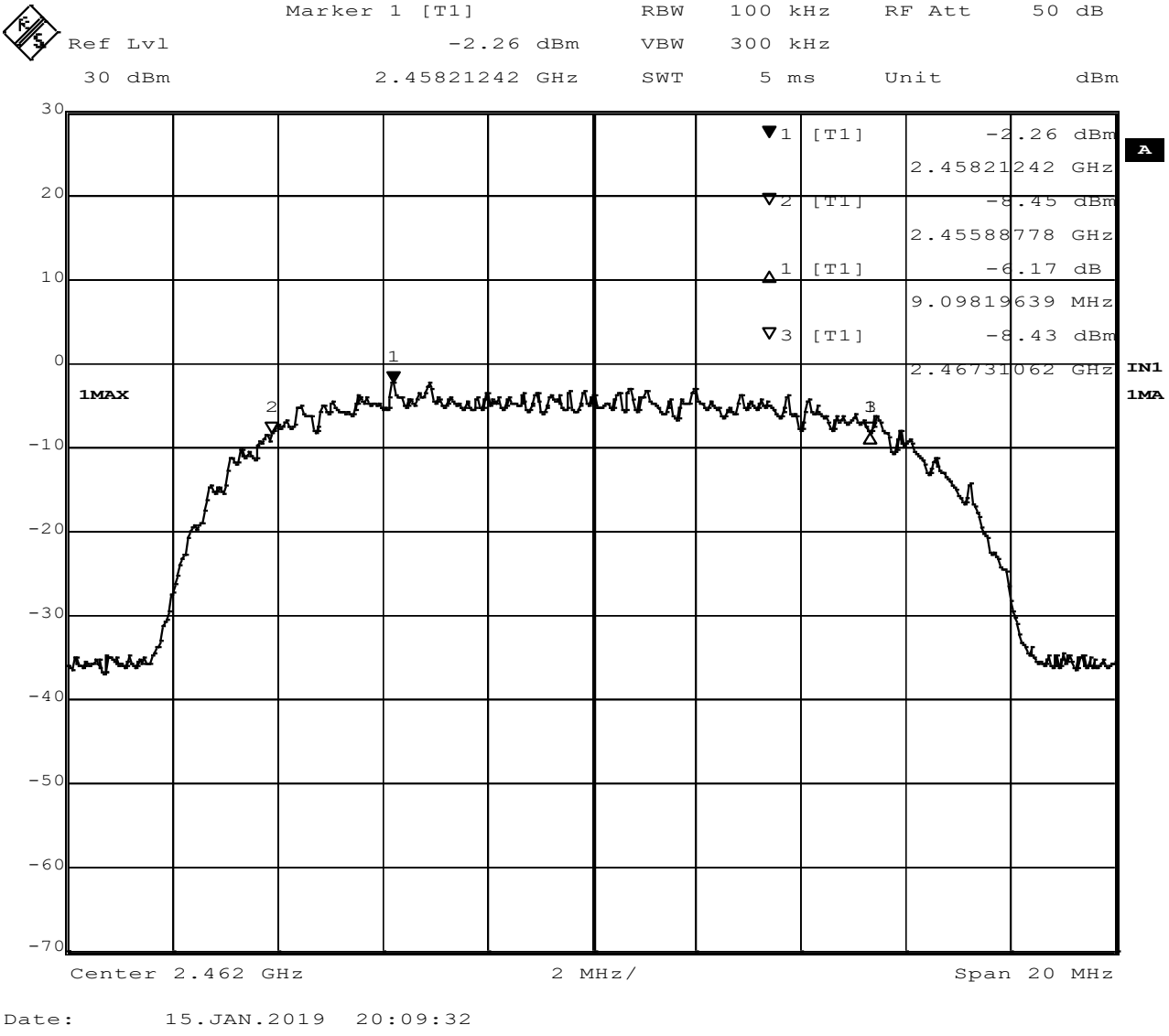

Figure 45 - 6dB Bandwidth, High Channel, 802.11b

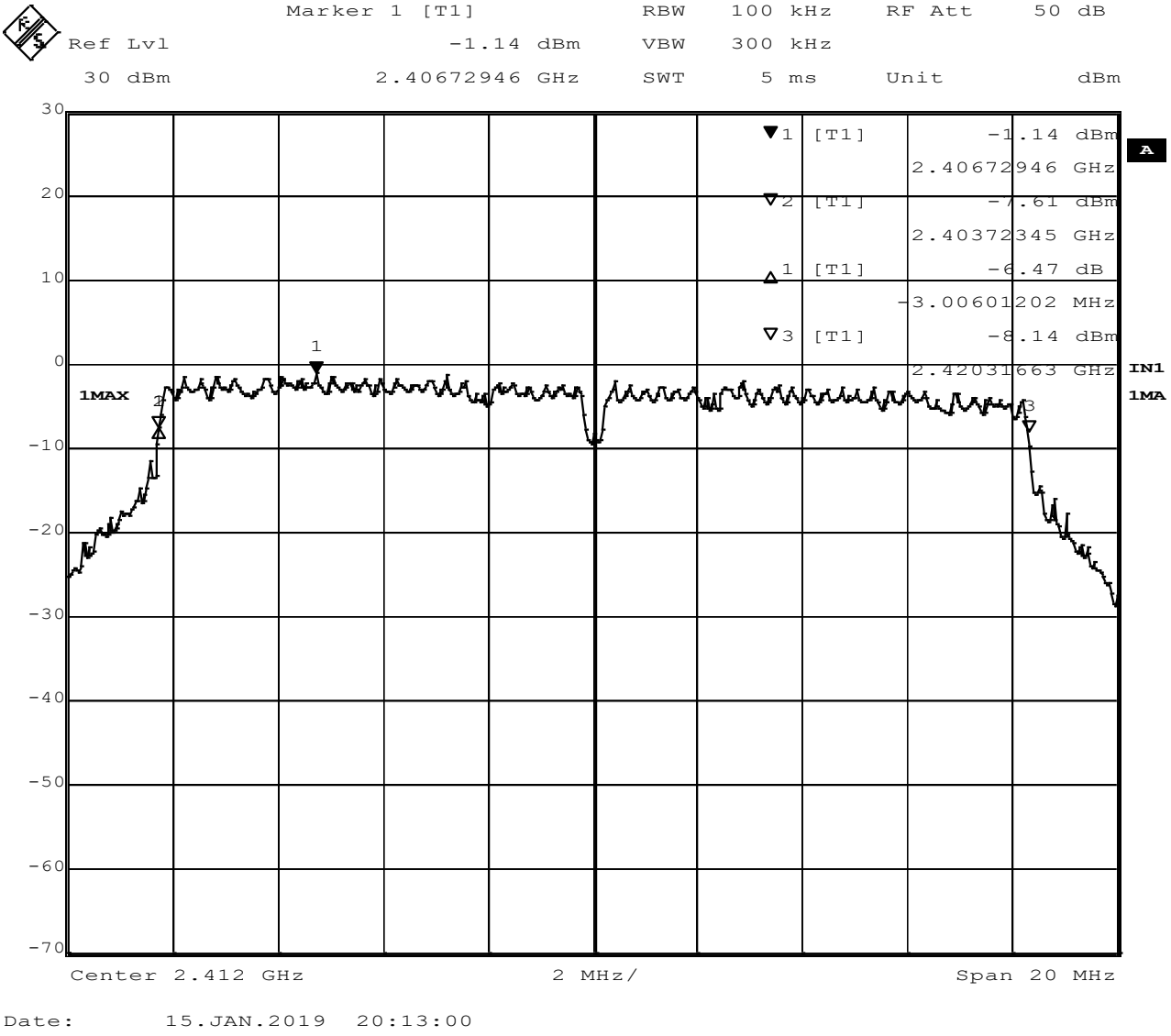

Figure 46 - 6dB Bandwidth, Low Channel, 802.11g

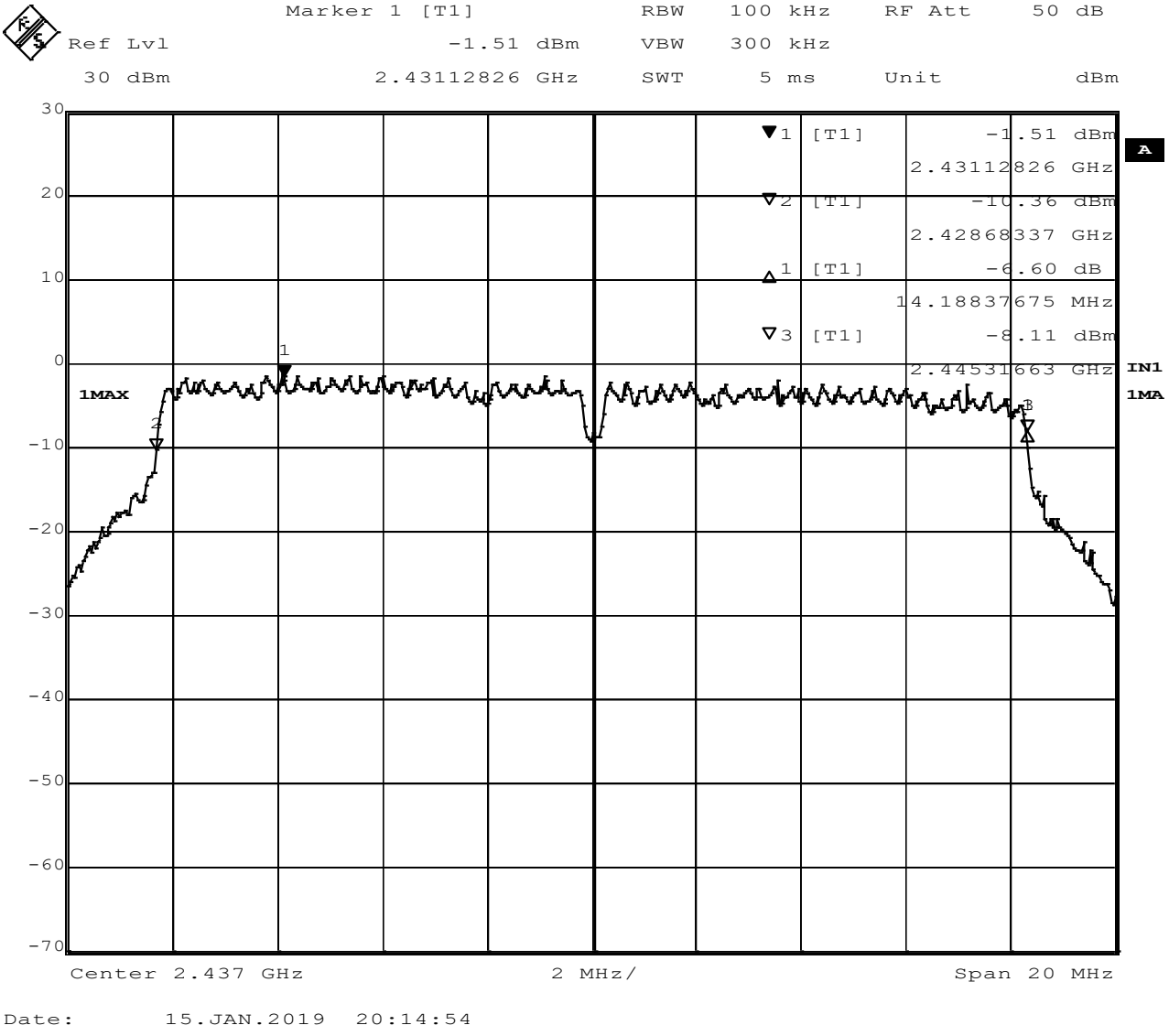

Figure 47 - 6dB Bandwidth, Mid Channel, 802.11g

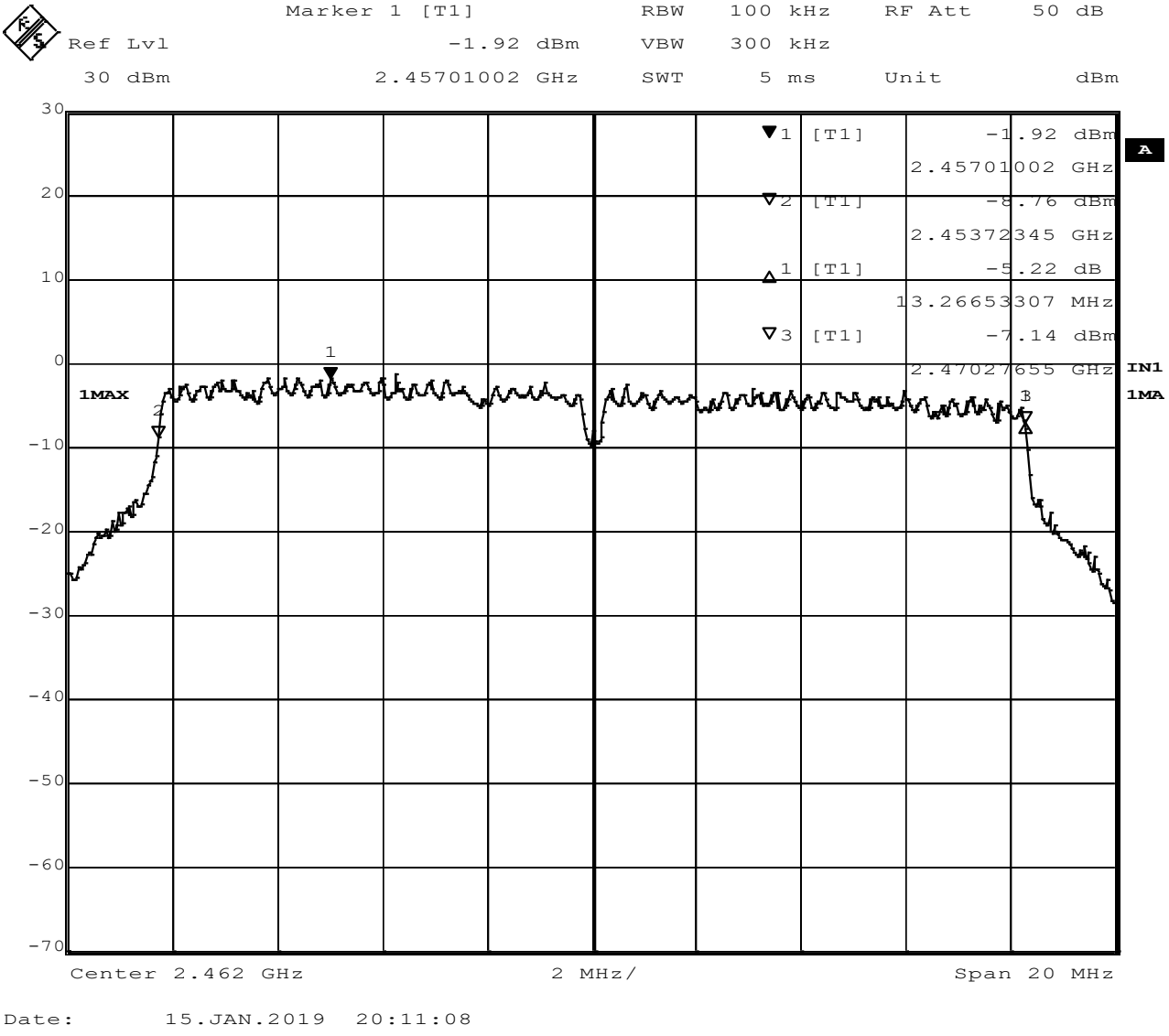

Figure 48 - 6dB Bandwidth, High Channel, 802.11g

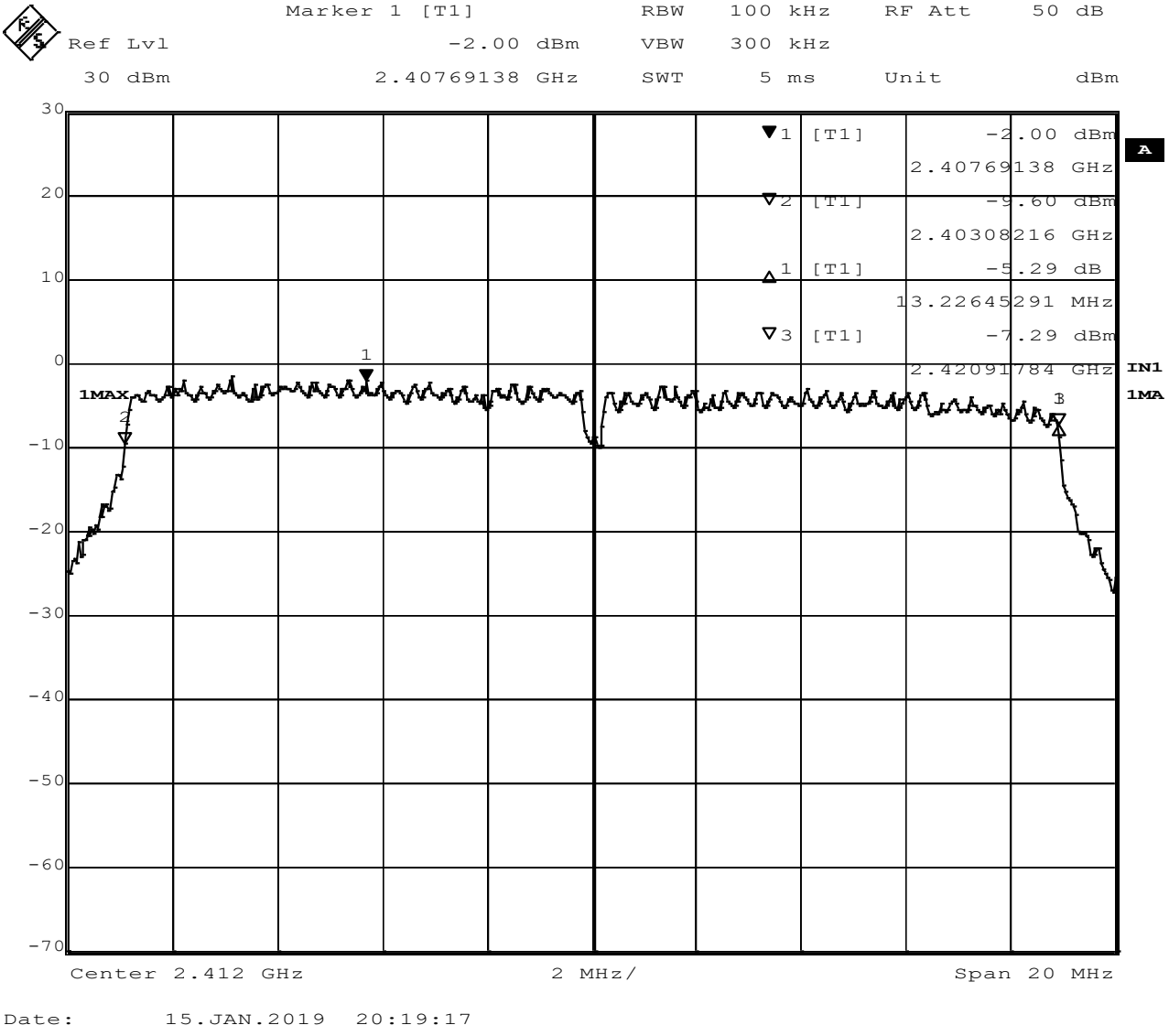

Figure 49 - 6dB Bandwidth, Low Channel, 802.11n

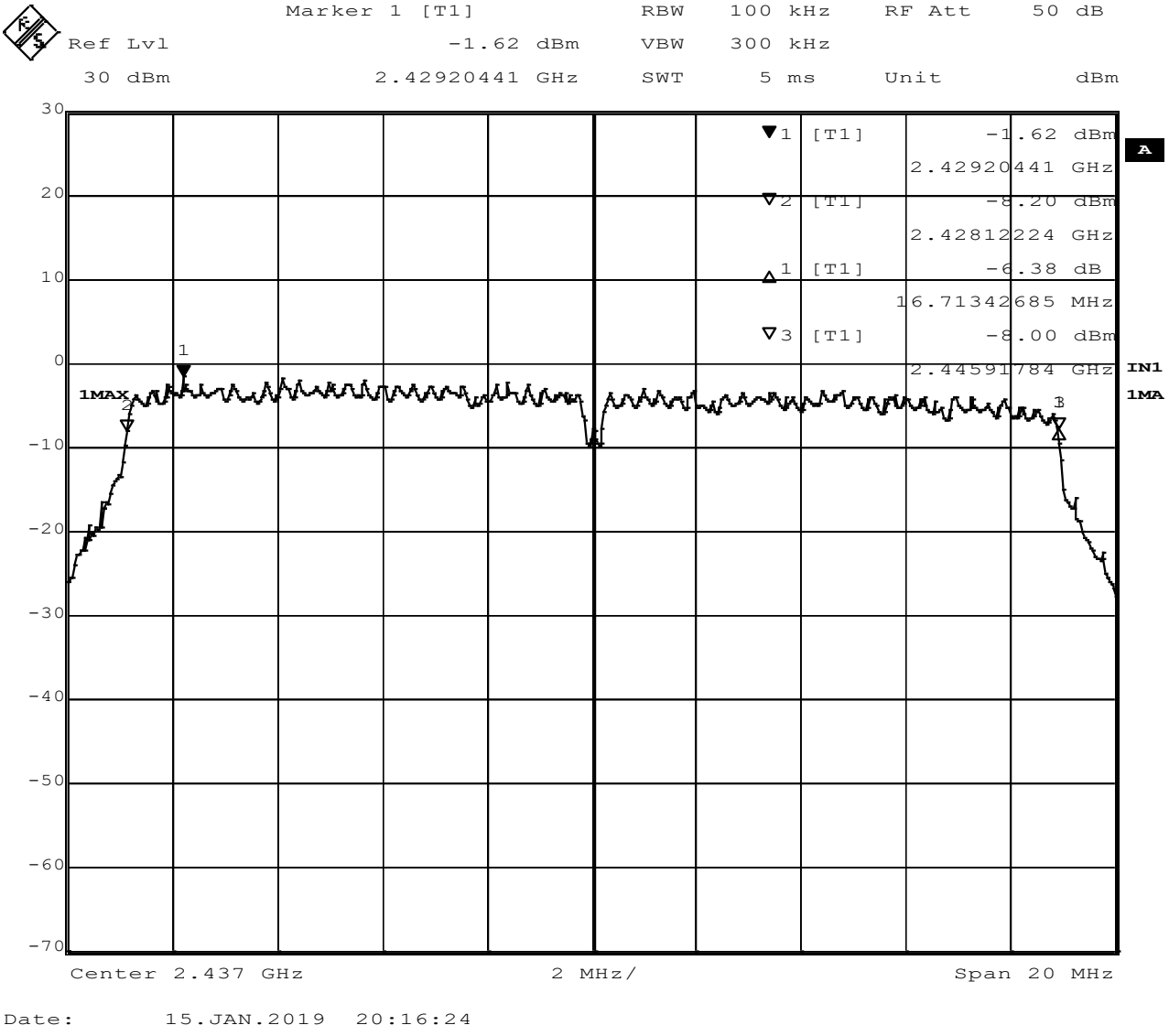

Figure 50 - 6dB Bandwidth, Mid Channel, 802.11n

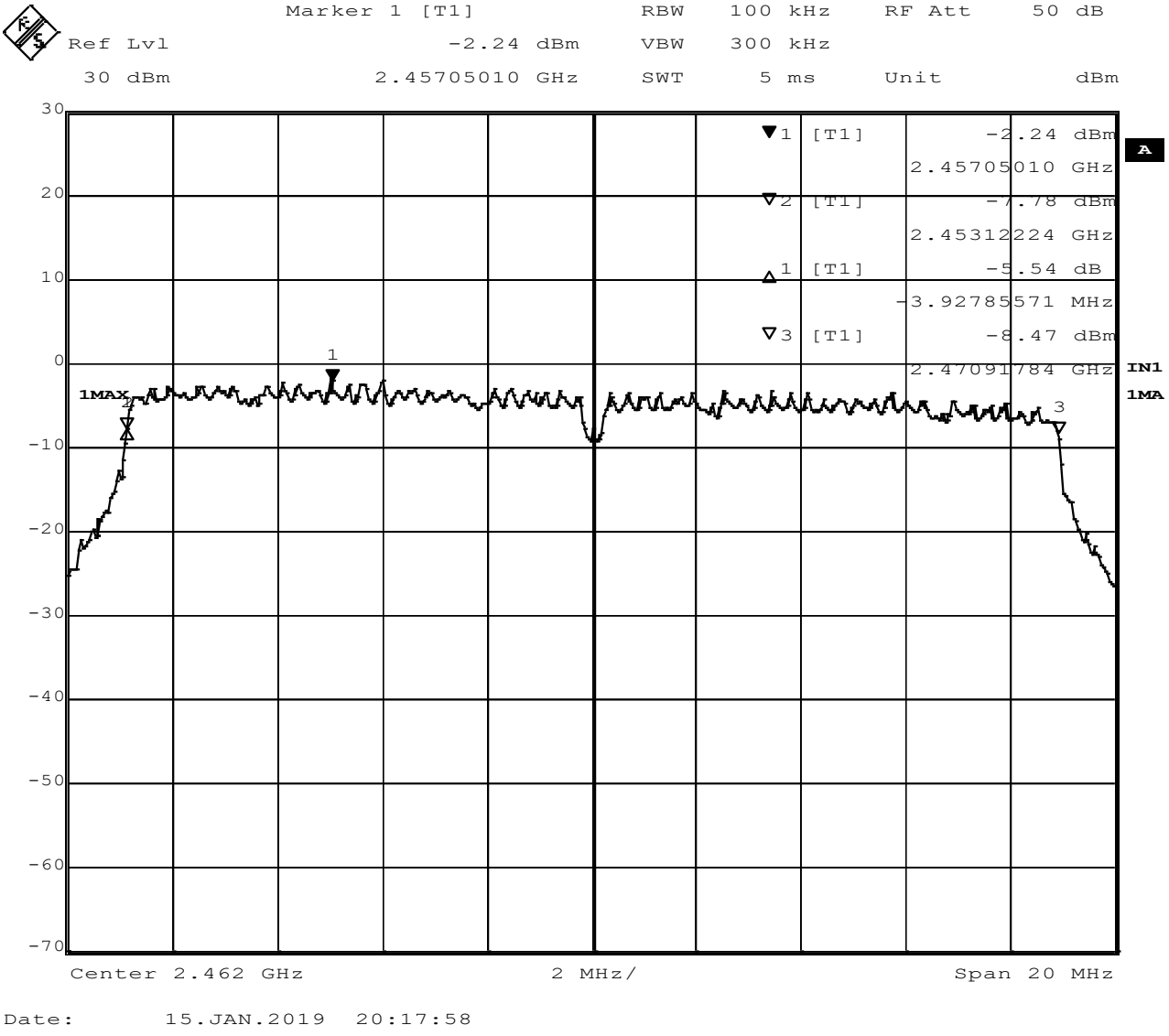

Figure 51 - 6dB Bandwidth, High Channel, 802.11n

4.5 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	2400.0 (Unrestricted, Peak)	-40.69	1.50	42.19	20	PASS
1	2400.0 (Unrestricted, Average)	-44.44	-2.59	41.85	20	PASS
11	2483.5 (Unrestricted, Peak)	-61.32	0.67	61.99	20	PASS
11	2483.5 (Unrestricted, Average)	-66.48	-2.99	63.49	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)	-67.12	-71.12	-21.23	-4.00	49.89	PASS
1	2340.0 (Restricted, Average)	-75.83	-79.83	-41.23	-4.00	38.60	PASS
11	2483.5 (Restricted, Peak)	-58.75	-62.75	-21.23	-4.00	41.52	PASS
11	2483.5 (Restricted, Average)	-62.70	-66.70	-41.23	-4.00	25.47	PASS

Corrected Emission level= Highest out of band conducted measurement + Gain
Margin= Limit-Corrected Emission Level
*Limits from Part 15.209 in dBm, converted from 3m limit to EIRP. 3m Limit – 95.23 = EIRP.
**Antenna gain declared by the manufacturer

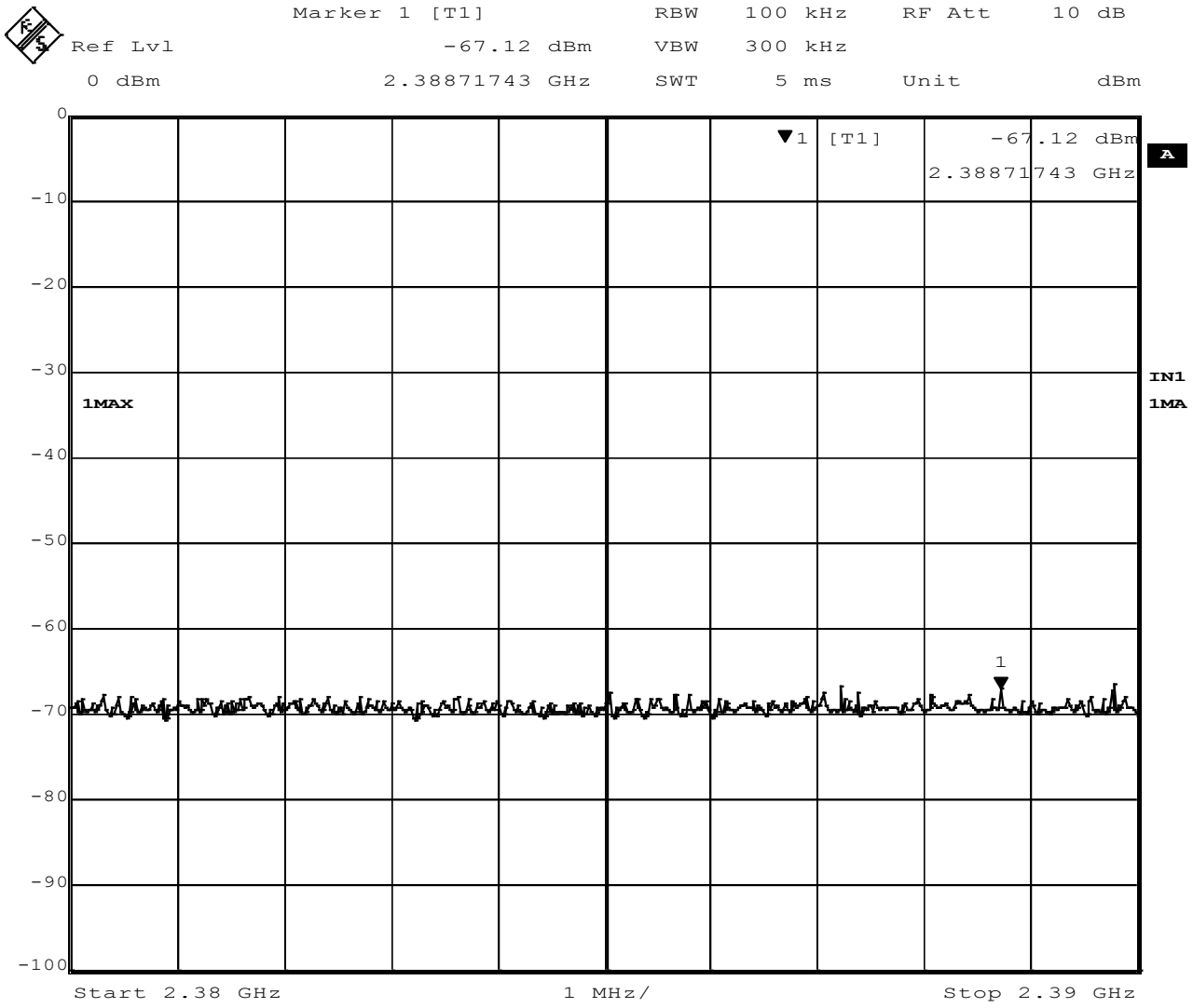

Figure 52 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

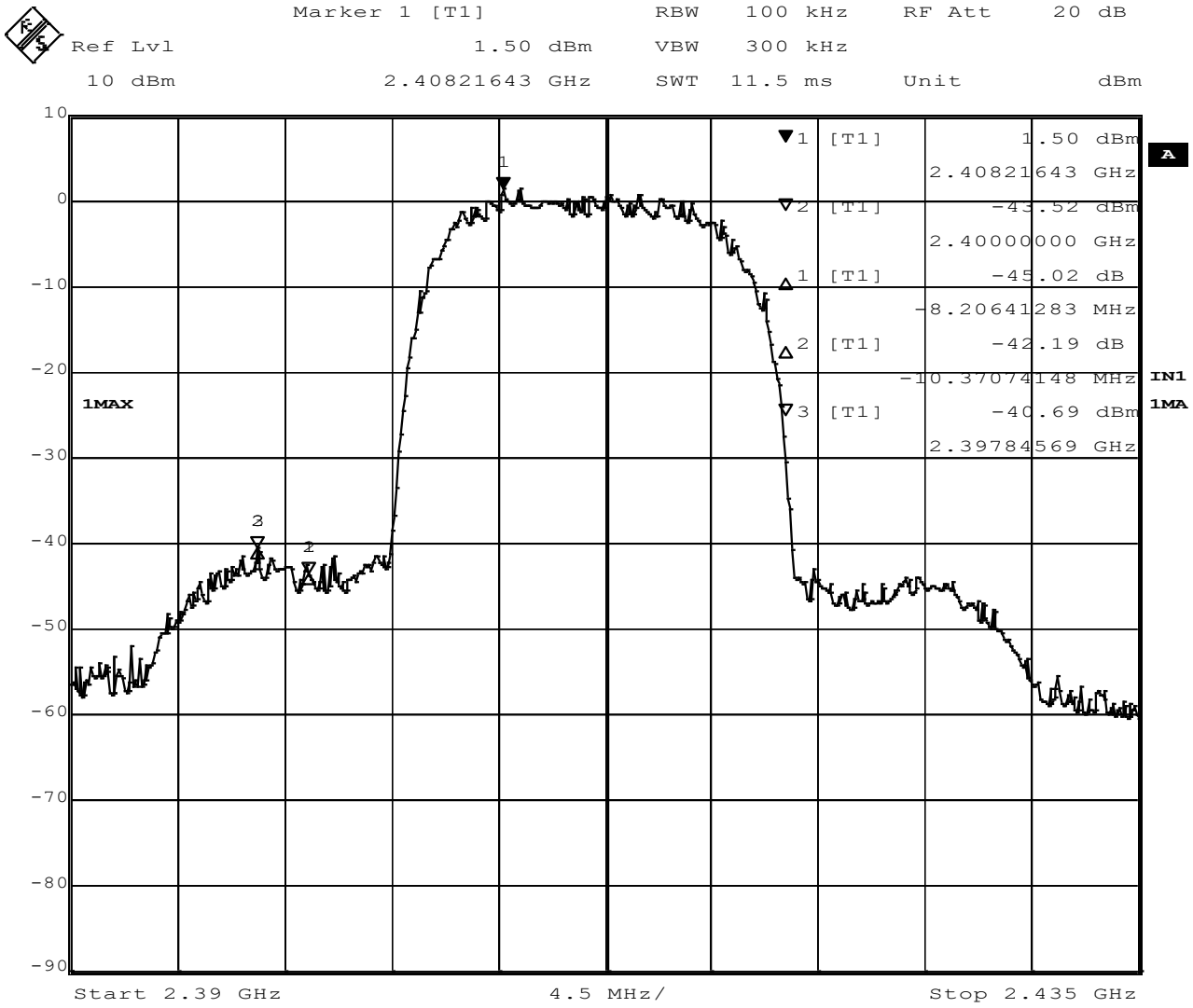

Figure 53 - Band-edge Measurement, Low Channel, Fundamental, Peak

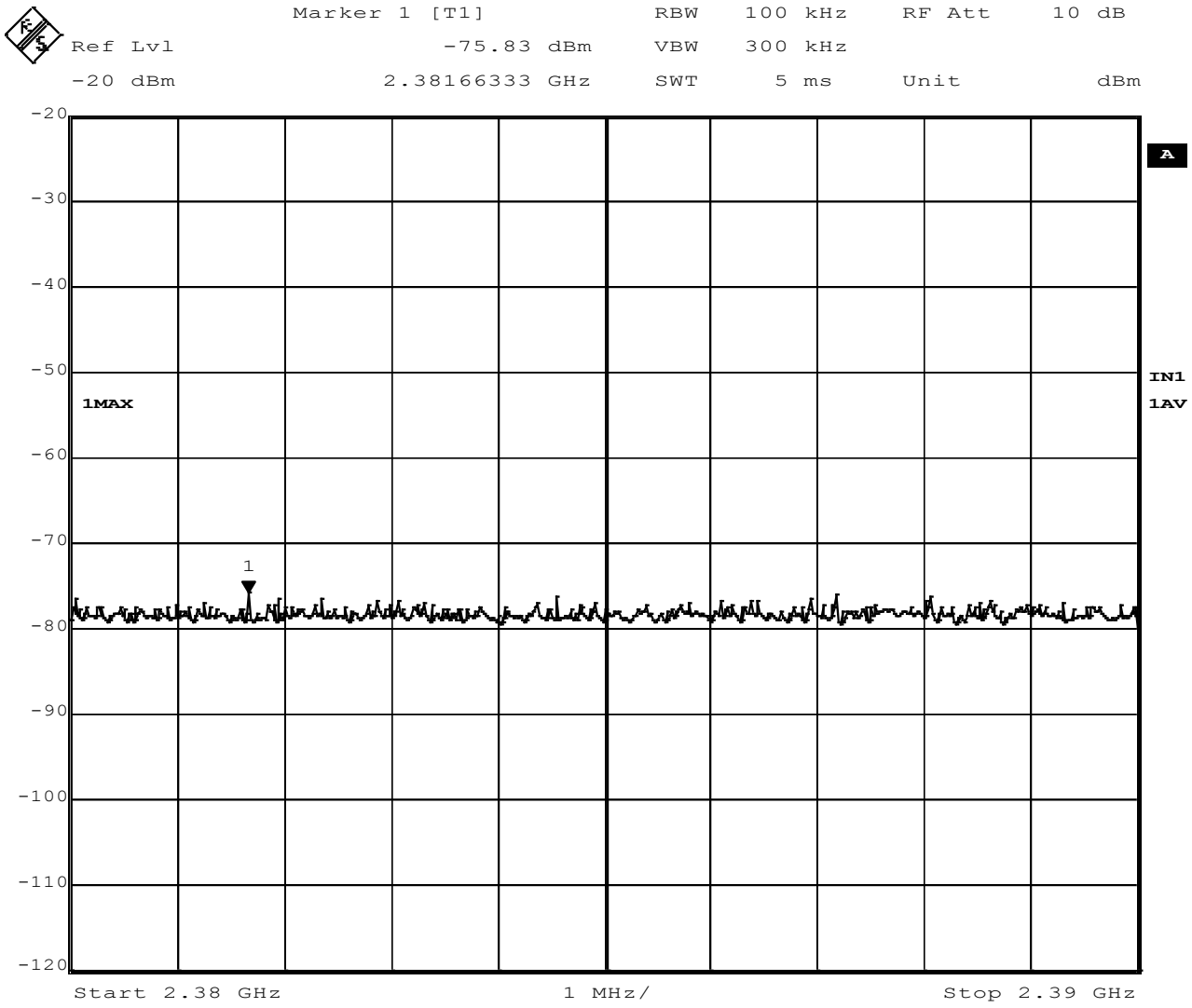

Figure 54 - Band-edge Measurement, Low Channel, Restricted Frequency, Average

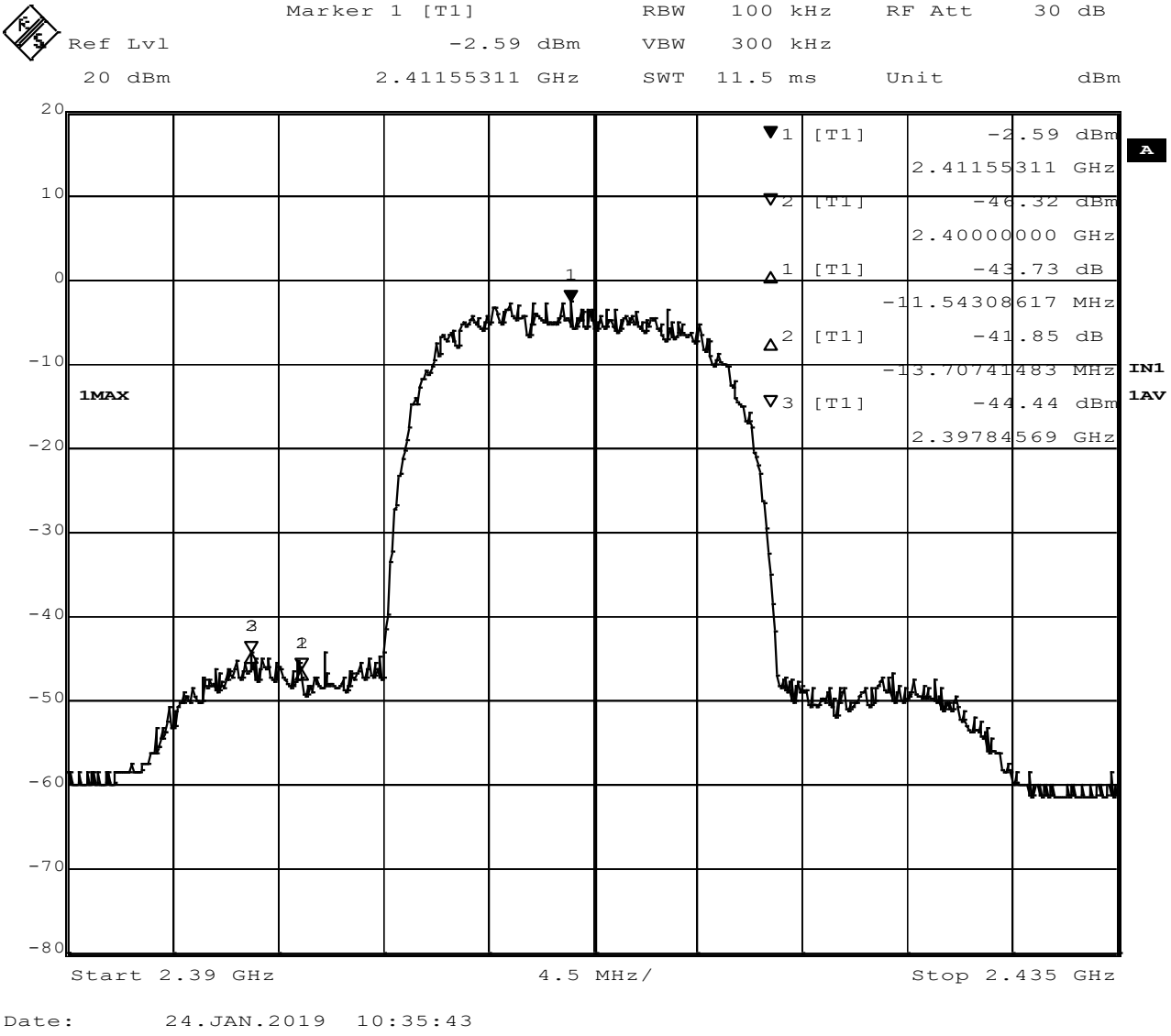

Figure 55 - Band-edge Measurement, Low Channel, Fundamental, Average

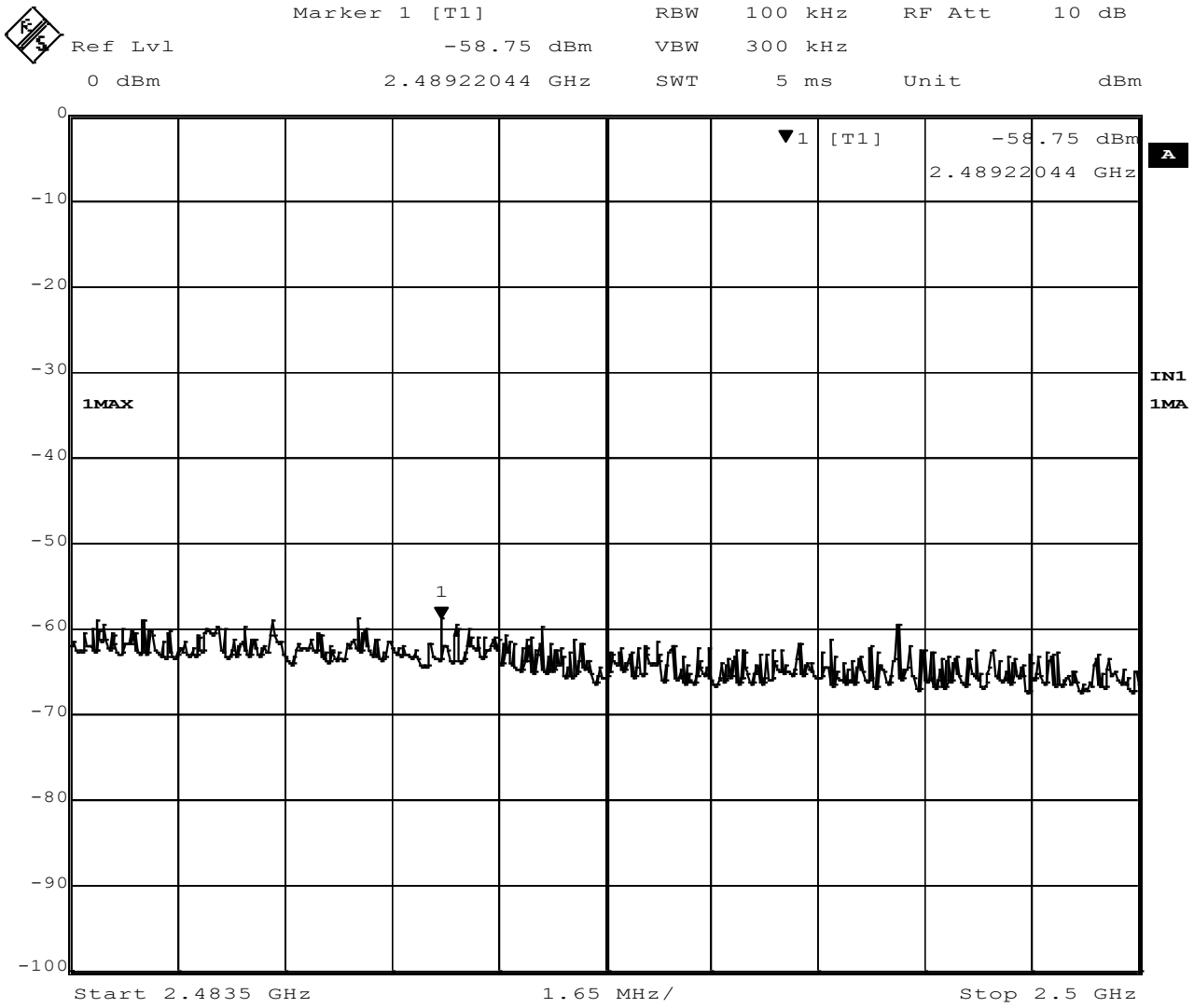

Figure 56 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

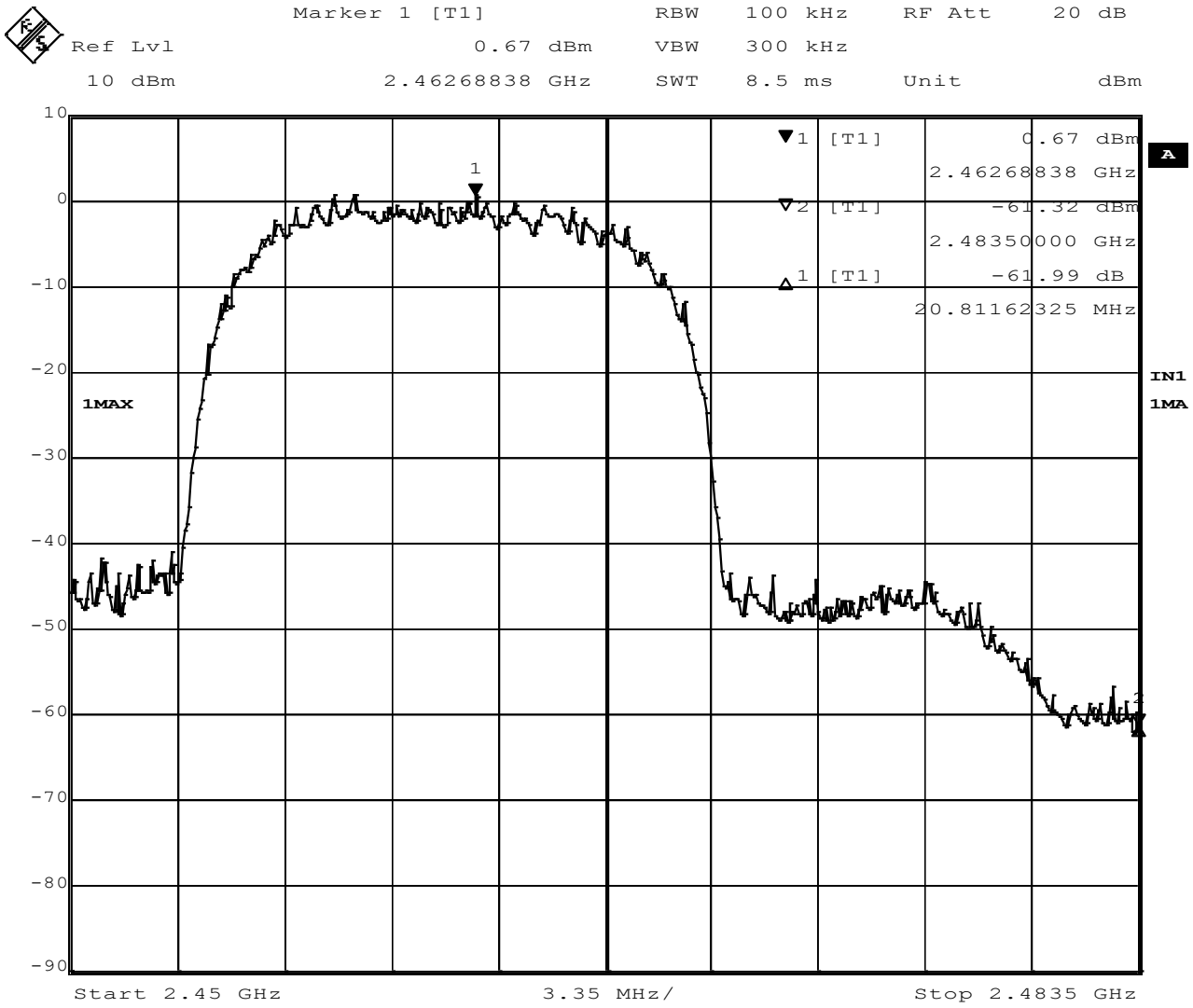

Figure 57 - Band-edge Measurement, High Channel, Fundamental, Peak

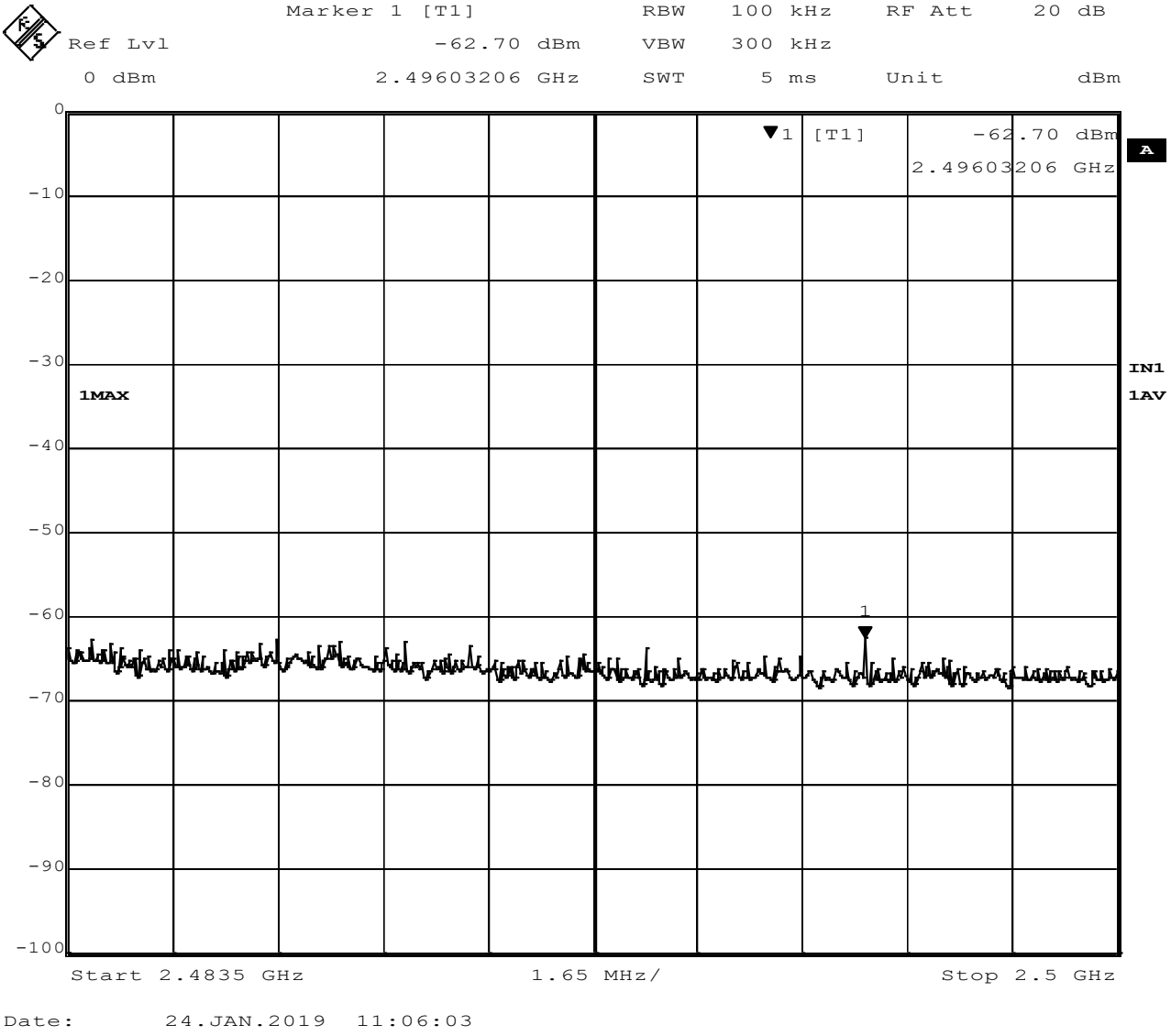

Figure 58 - Band-edge Measurement, High Channel, Restricted Frequency, Average

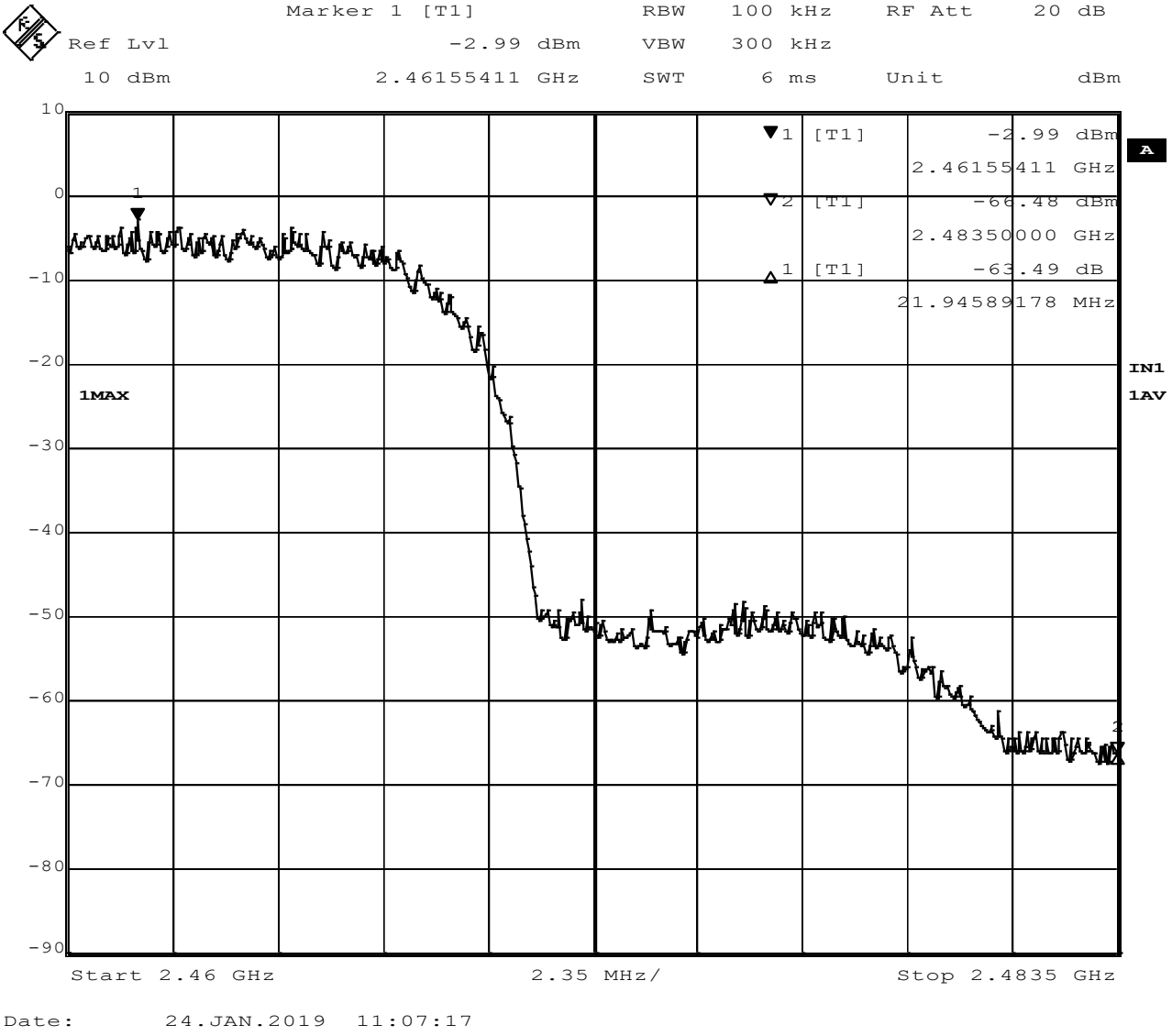

Figure 59 - Band-edge Measurement, High Channel, Fundamental, Average

Highest Out of Band Emissions, 802.11g

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level dBm	Fundamental Level (dBm)	Delta	Min (dBc)	Result
1	2400.0 (Unrestricted, Peak)	-27.89	2.13	30.02	20	PASS
1	2400.0 (Unrestricted, Average)	-33.56	-0.98	32.58	20	PASS
11	2483.5 (Unrestricted, Peak)	-43.17	0.92	44.09	20	PASS
11	2483.5 (Unrestricted, Average)	-49.17	-2.64	46.53	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)	-39.83	-43.83	-21.23	-4.00	22.60	PASS
1	2340.0 (Restricted, Average)	-42.31	-46.31	-41.23	-4.00	5.08	PASS
11	2483.5 (Restricted, Peak)	-41.29	-45.29	-21.23	-4.00	25.06	PASS
11	2483.5 (Restricted, Average)	-46.41	-50.41	-41.23	-4.00	9.18	PASS

Corrected Emission level= Highest out of band conducted measurement + Gain

Margin= Limit-Corrected Emission Level

*Limits from Part 15.209 in dBm, converted from 3m limit to EIRP. 3m Limit – 95.23 = EIRP.

**Antenna gain declared by the manufacturer

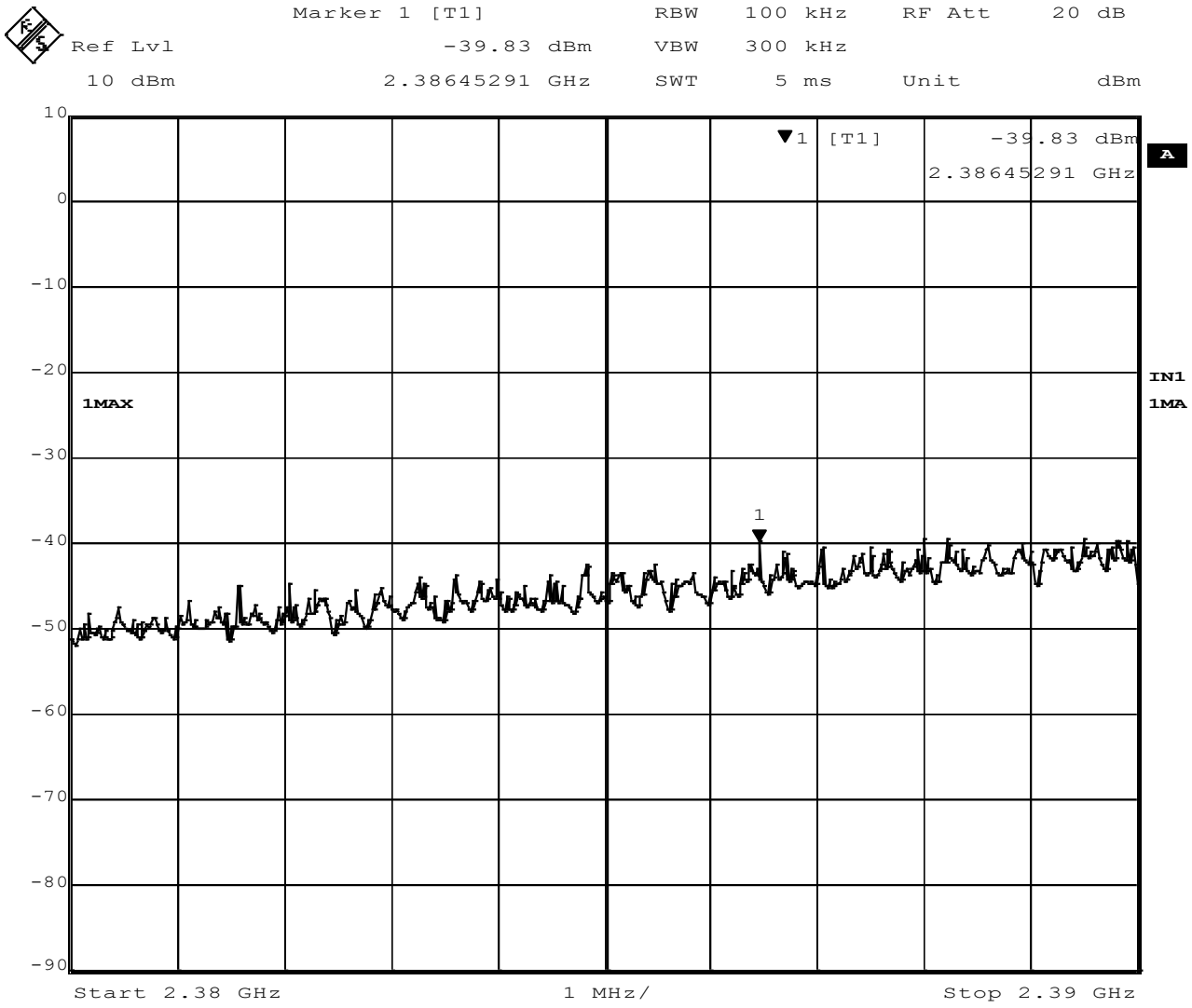

Figure 60 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

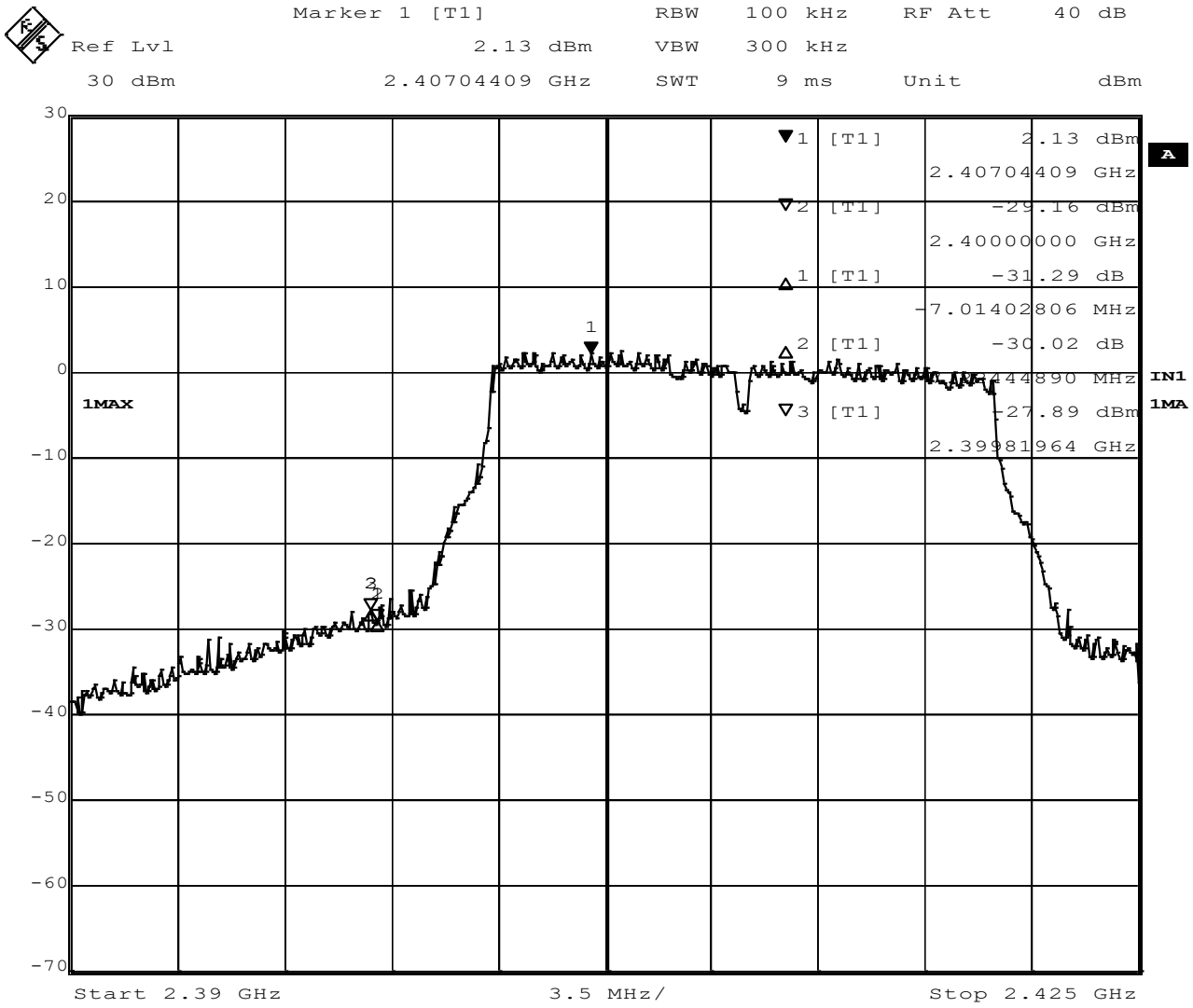

Figure 61 - Band-edge Measurement, Low Channel, Fundamental, Peak

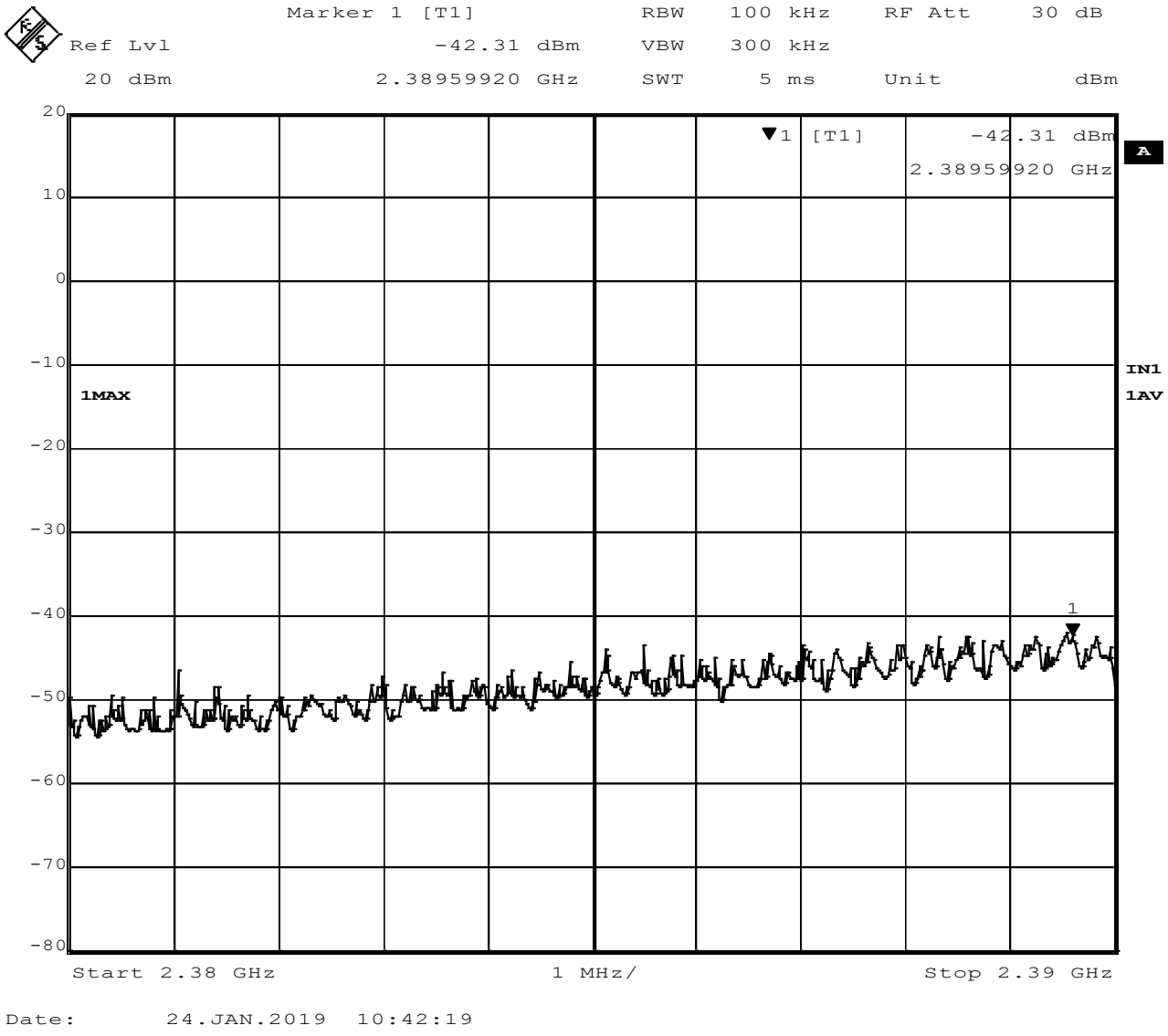

Figure 62 - Band-edge Measurement, Low Channel, Restricted Frequency, Average

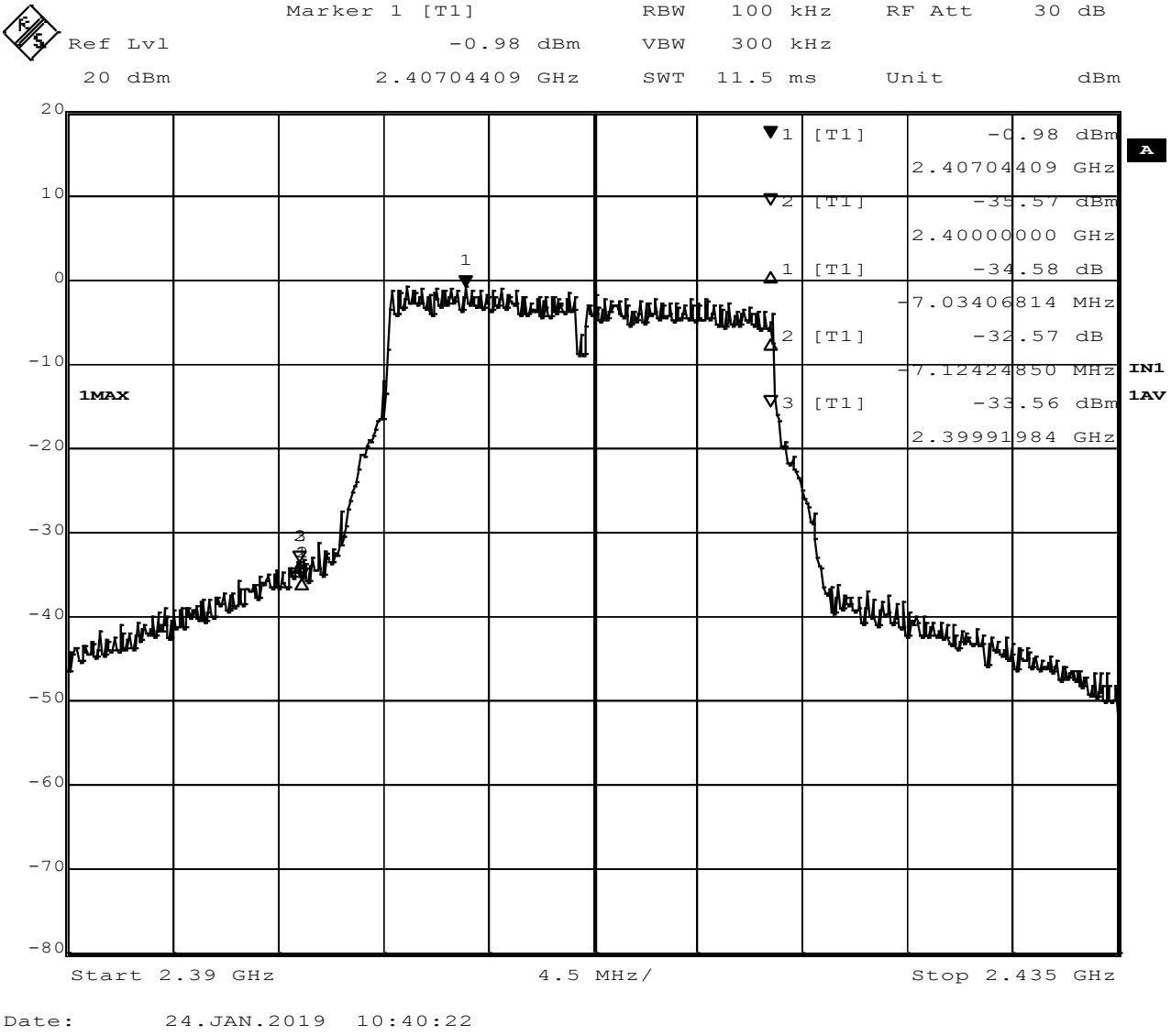

Figure 63 - Band-edge Measurement, Low Channel, Fundamental, Average

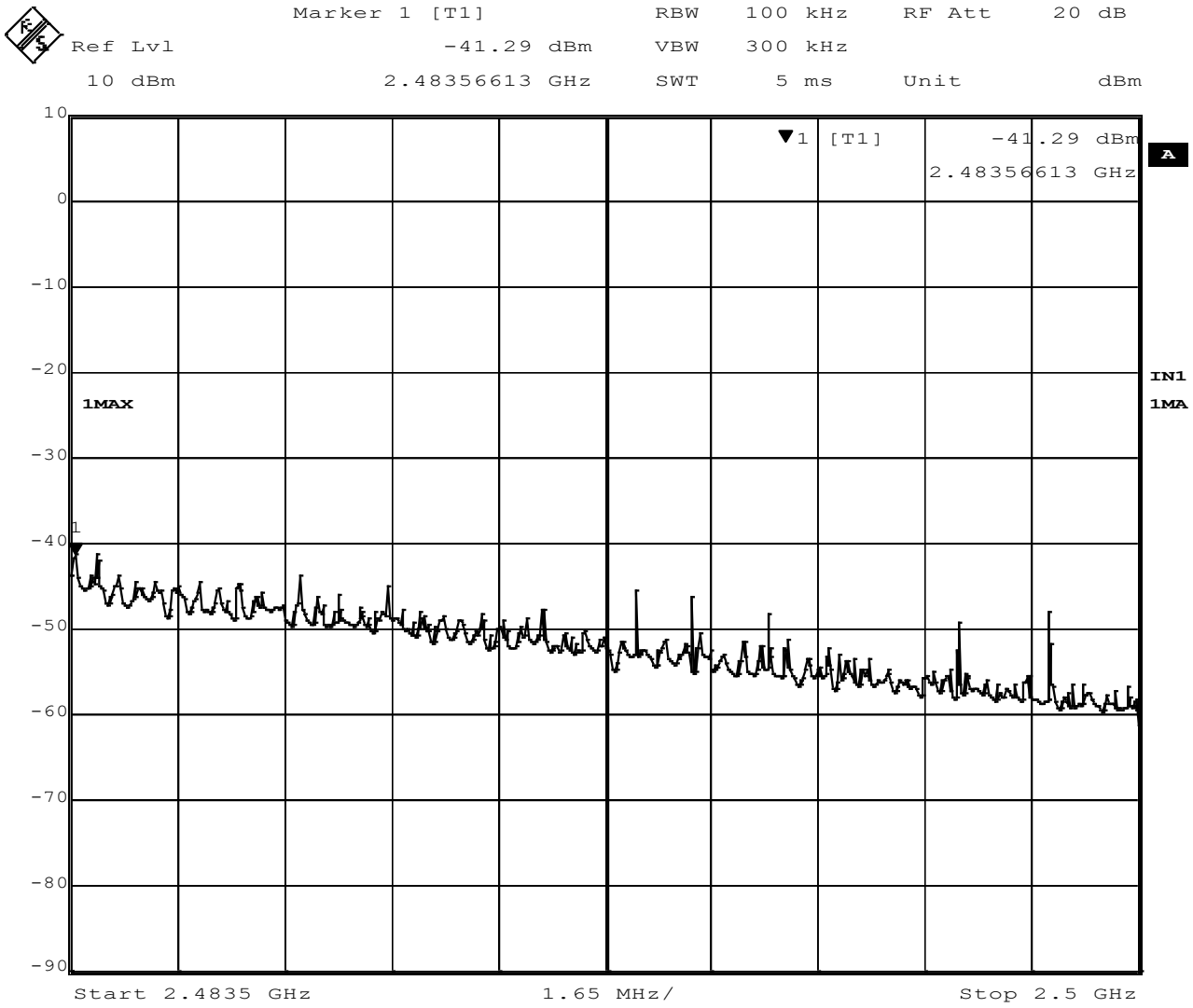

Figure 64 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

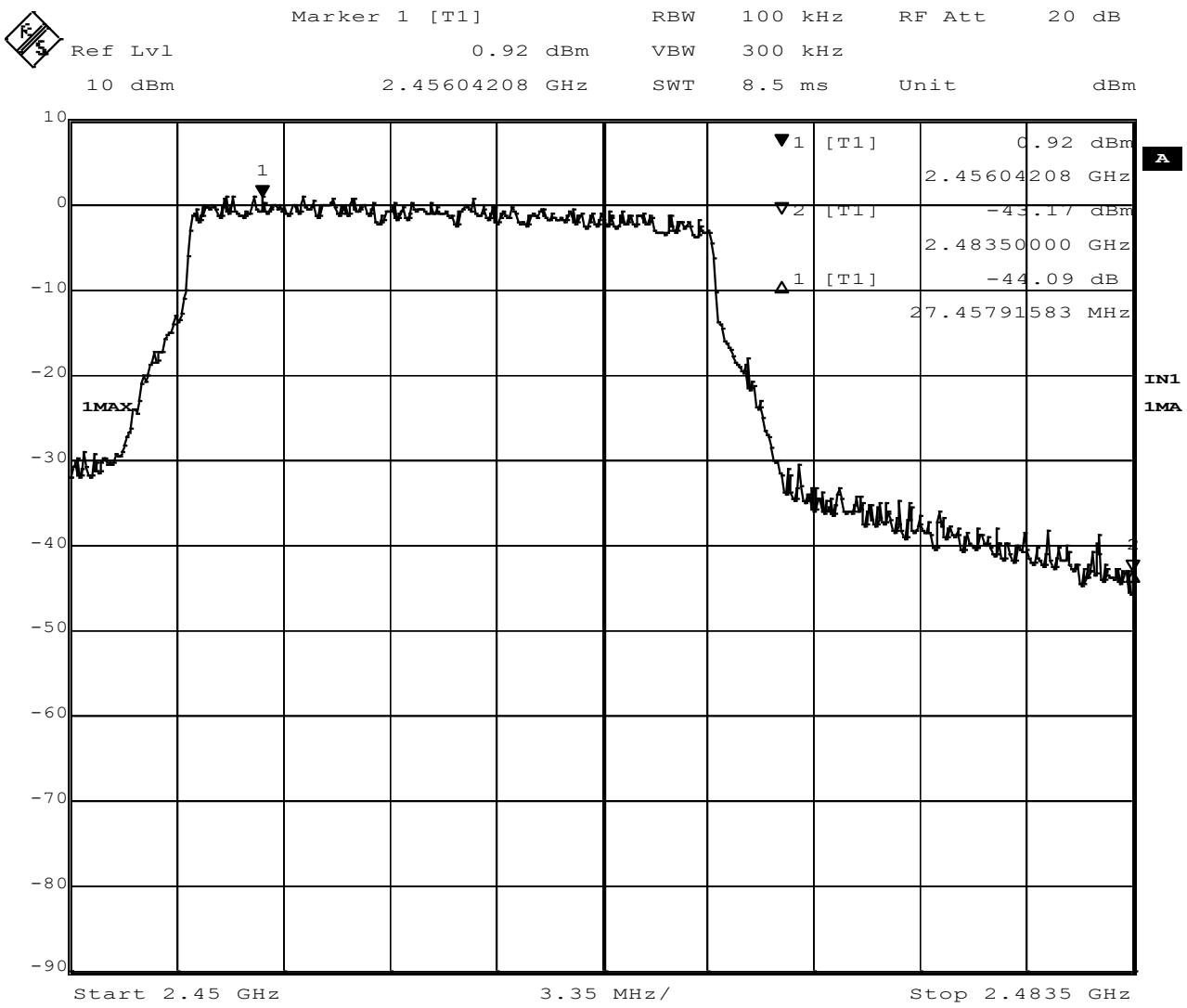

Figure 65 - Band-edge Measurement, High Channel, Fundamental, Peak

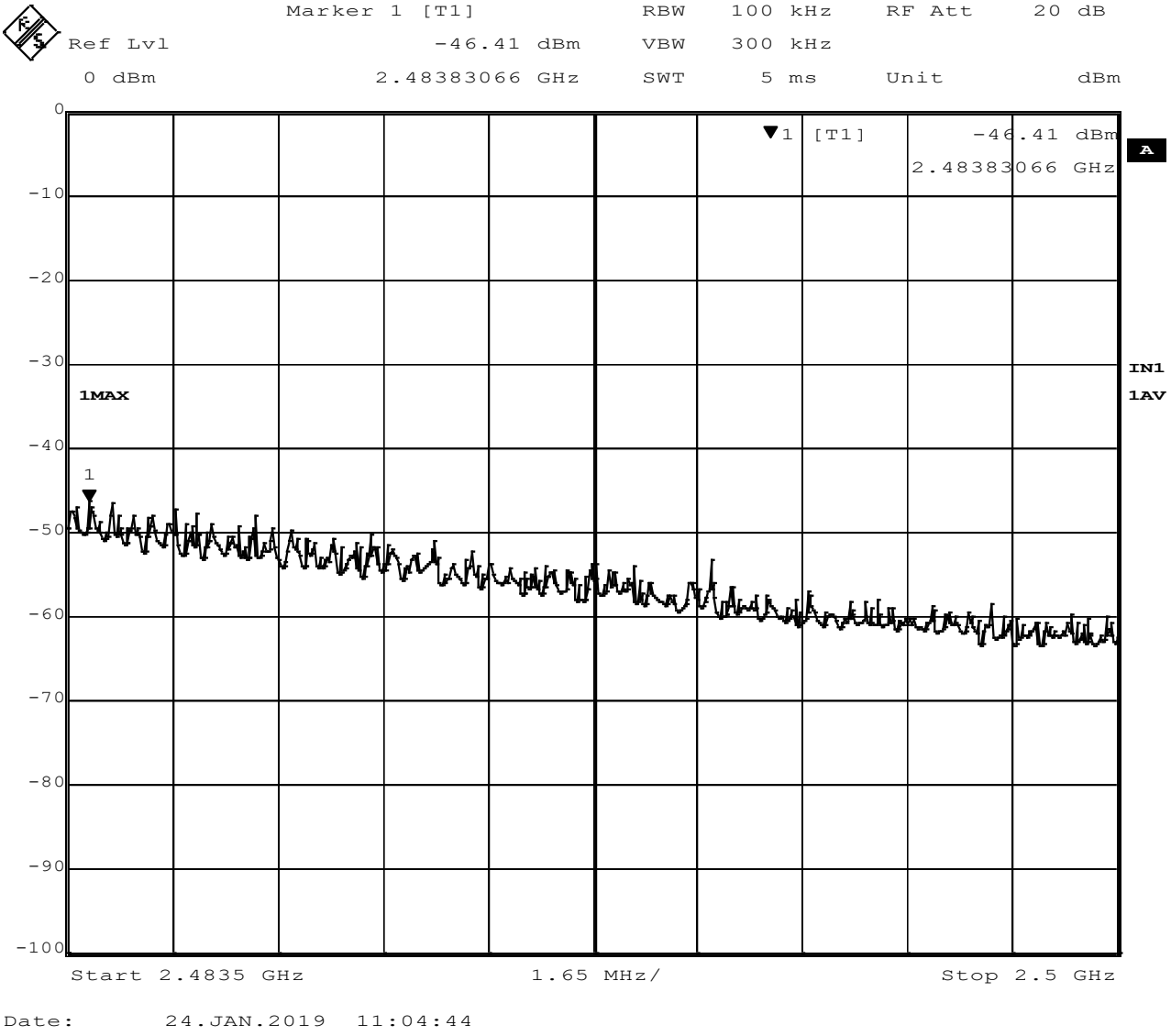

Figure 66 - Band-edge Measurement, High Channel, Restricted Frequency, Average

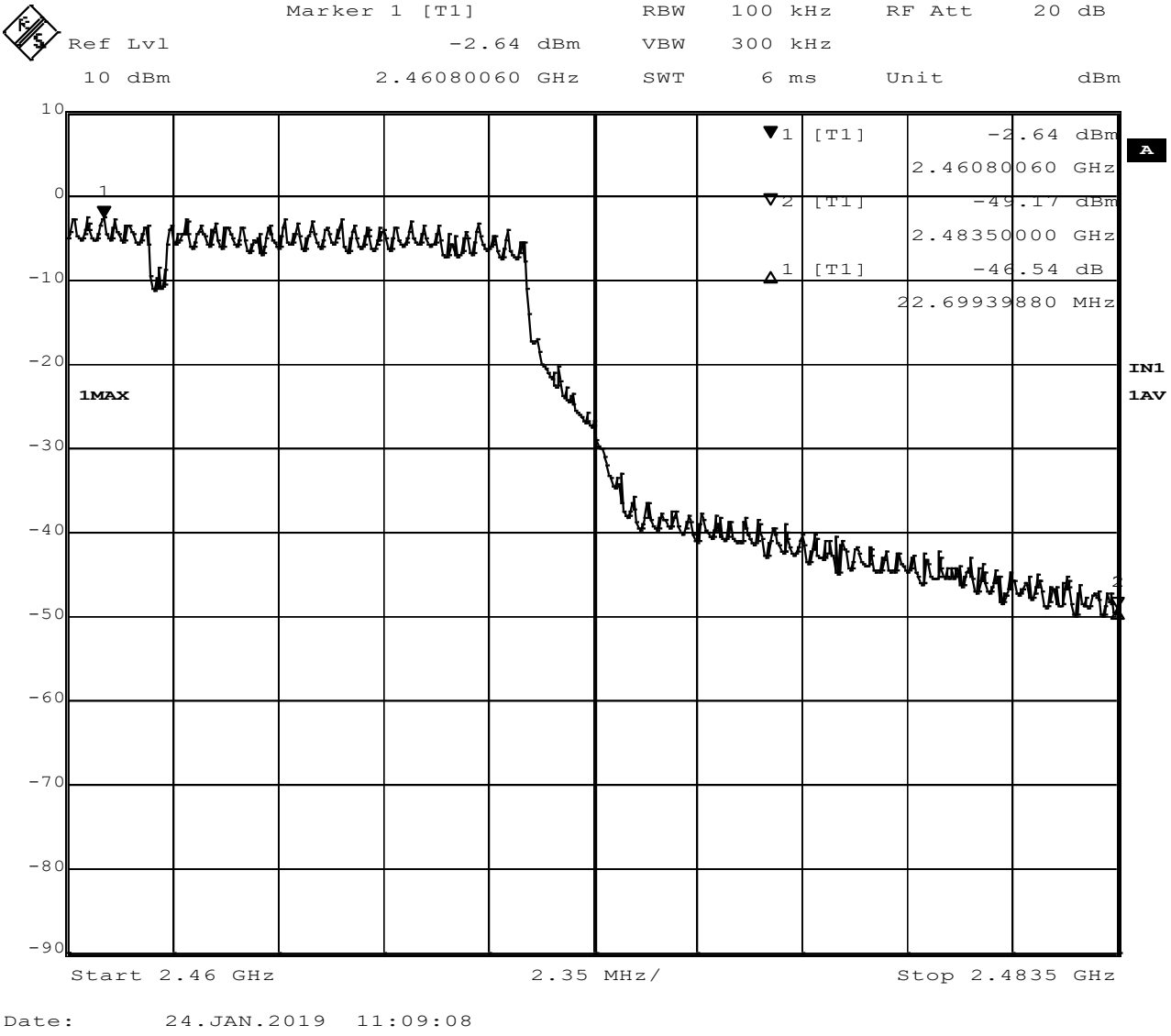

Figure 67 - Band-edge Measurement, High Channel, Fundamental, Average

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	2400.0 (Unrestricted, Peak)	-27.29	1.51	28.80	20	PASS
1	2400.0 (Unrestricted, Average)	-32.52	-1.68	30.84	20	PASS
11	2483.5 (Unrestricted, Peak)	-41.72	0.43	42.15	20	PASS
11	2483.5 (Unrestricted, Average)	-47.72	-2.96	44.76	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)	-36.20	-40.20	-21.23	-4.00	18.97	PASS
1	2340.0 (Restricted, Average)	-41.08	-45.08	-41.23	-4.00	3.85	PASS
11	2483.5 (Restricted, Peak)	-40.23	-44.23	-21.23	-4.00	23.00	PASS
11	2483.5 (Restricted, Average)	-44.66	-48.66	-41.23	-4.00	7.43	PASS

Corrected Emission level= Highest out of band conducted measurement + Gain

Margin= Limit-Corrected Emission Level

*Limits from Part 15.209 in dBm, converted from 3m limit to EIRP. 3m Limit – 95.23 = EIRP.

**Antenna gain declared by the manufacturer

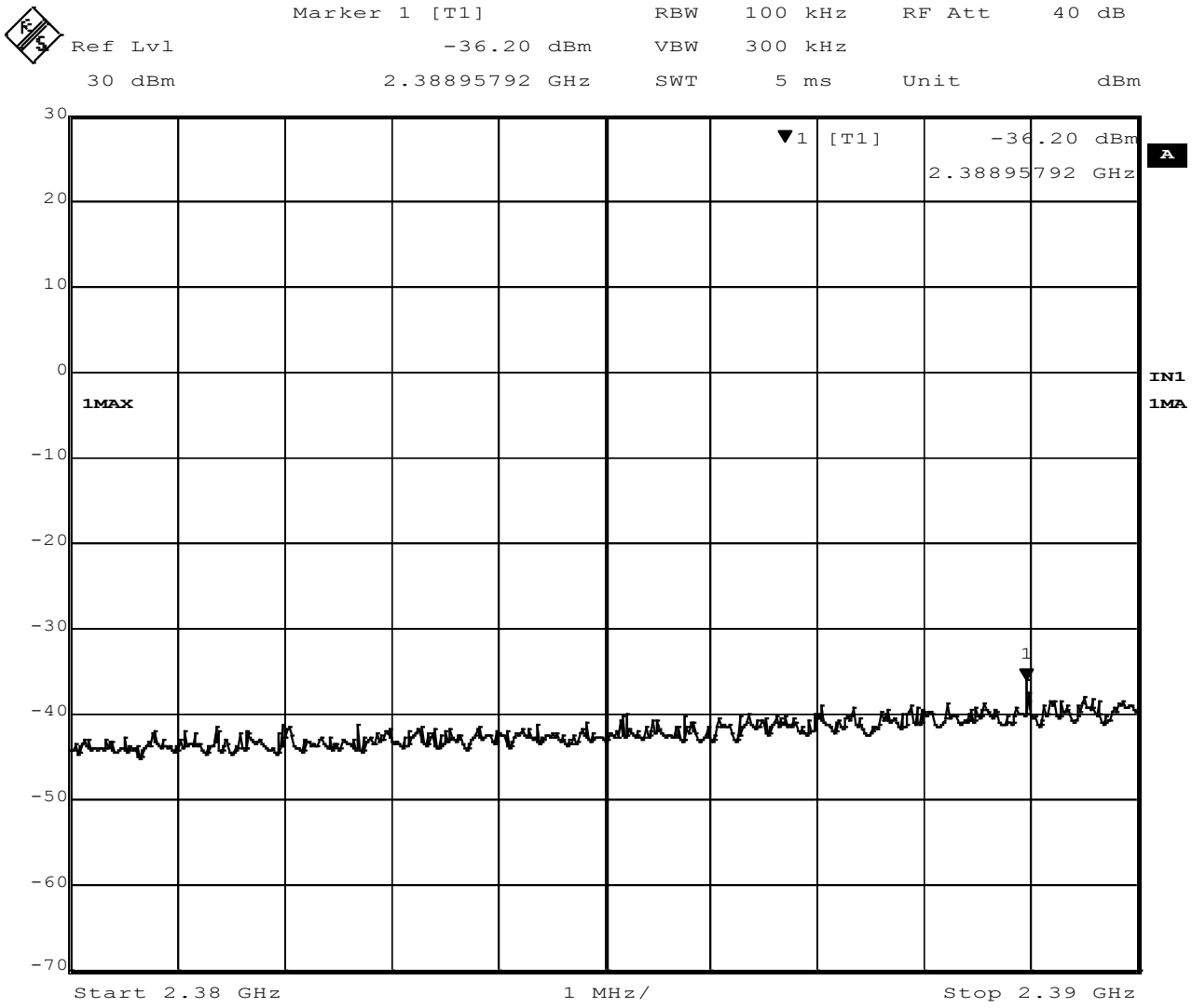

Figure 68 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

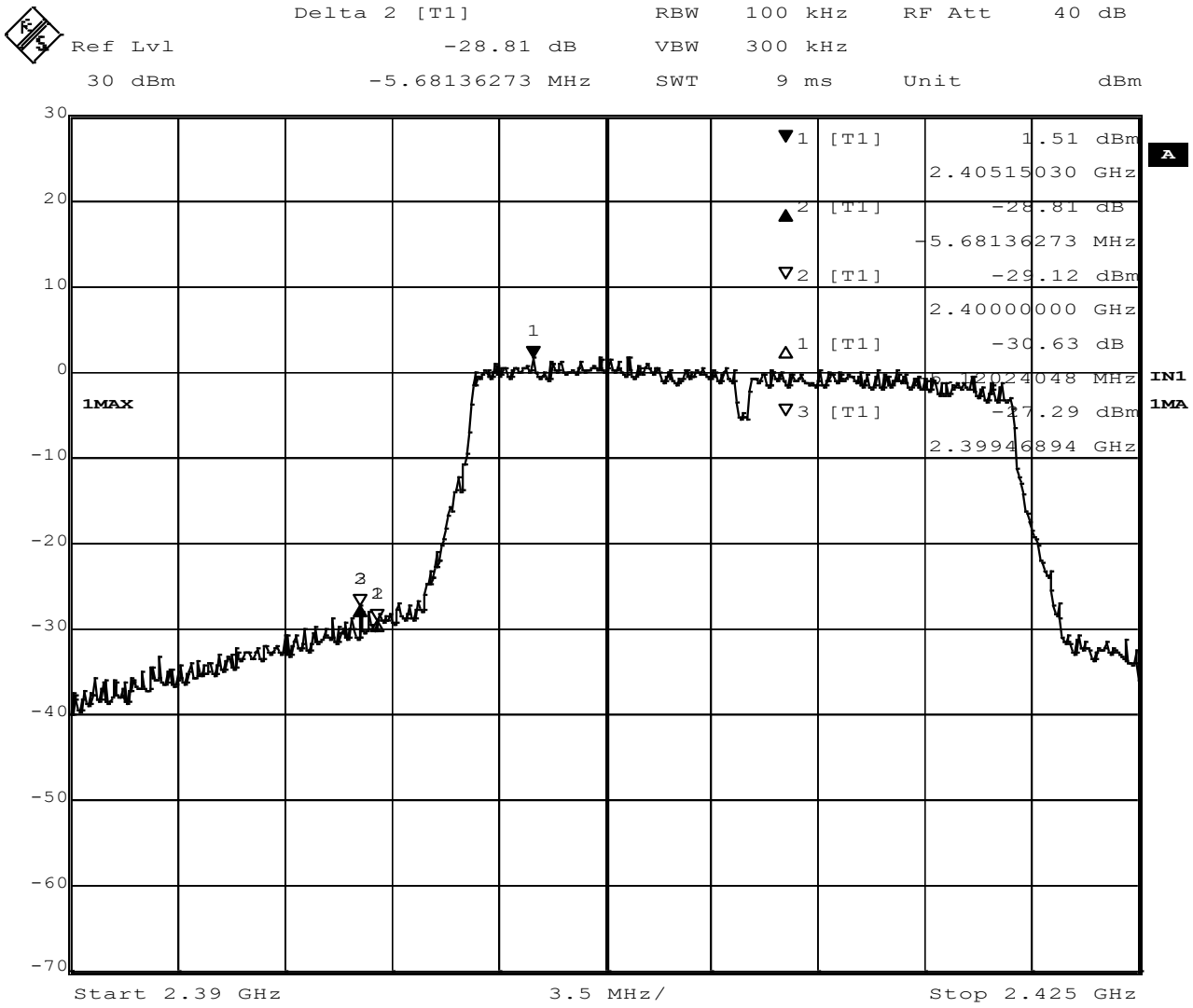

Figure 69 - Band-edge Measurement, Low Channel, Fundamental, Peak

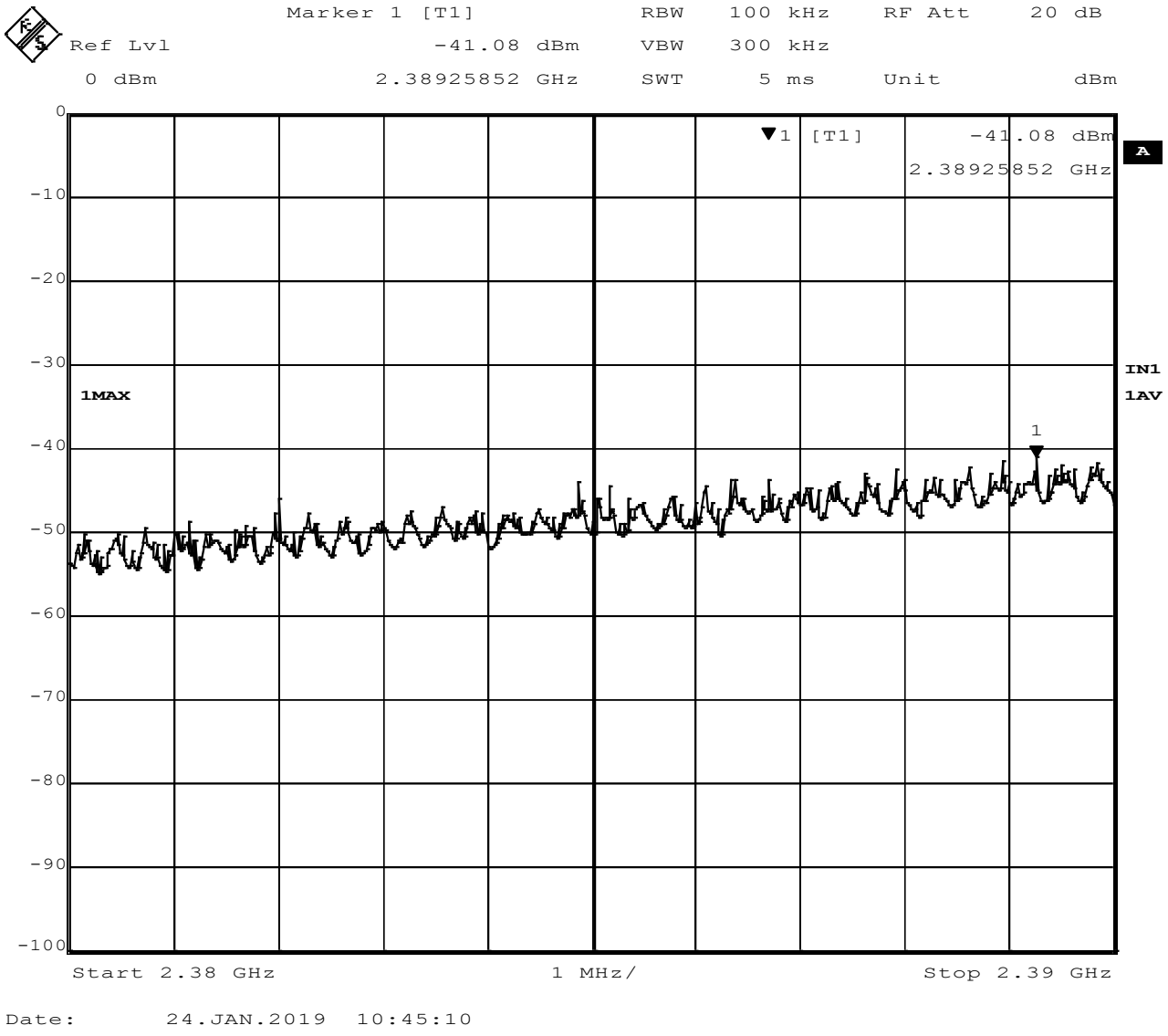

Figure 70 - Band-edge Measurement, Low Channel, Restricted Frequency, Average

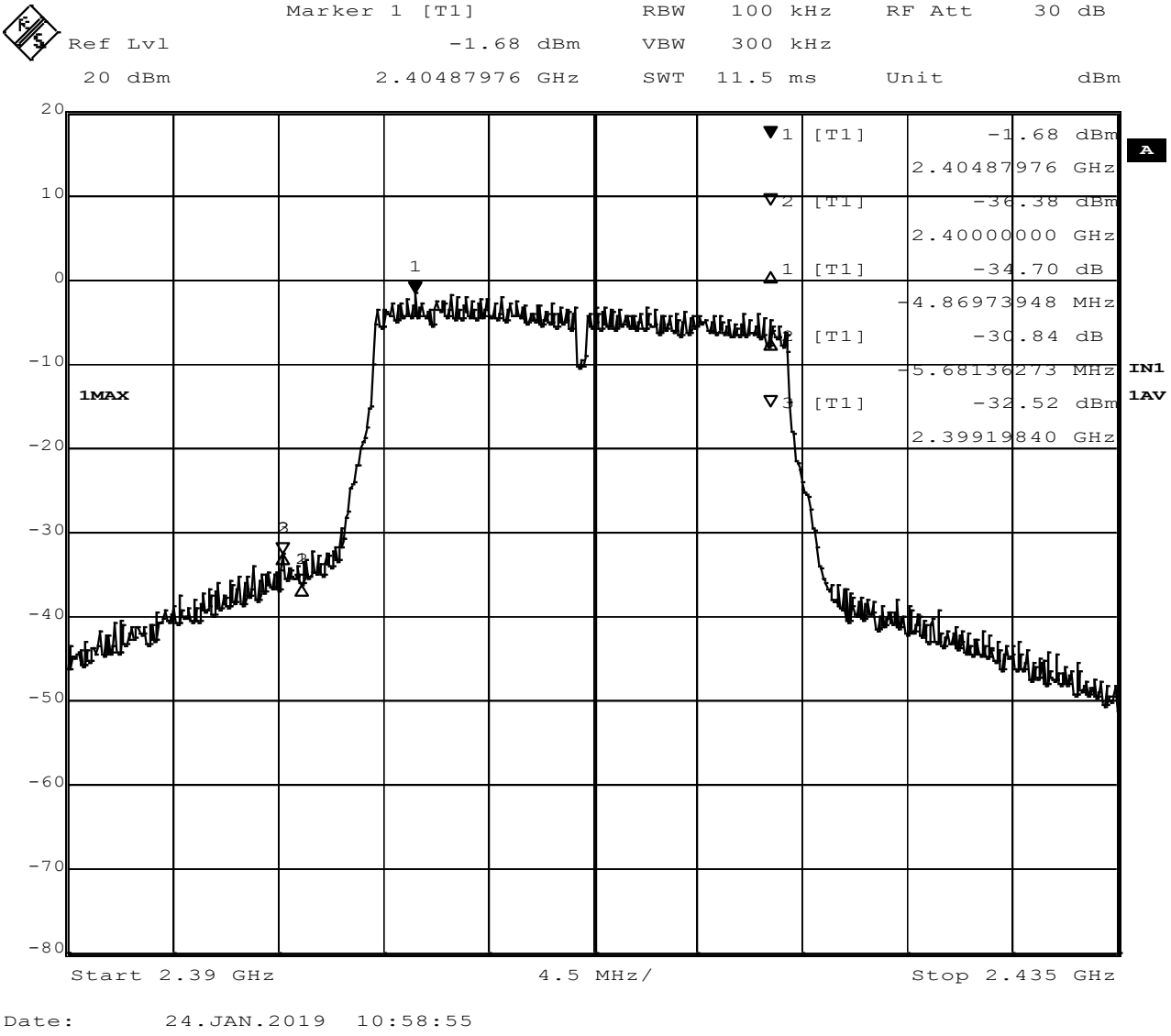

Figure 71 - Band-edge Measurement, Low Channel, Fundamental, Average

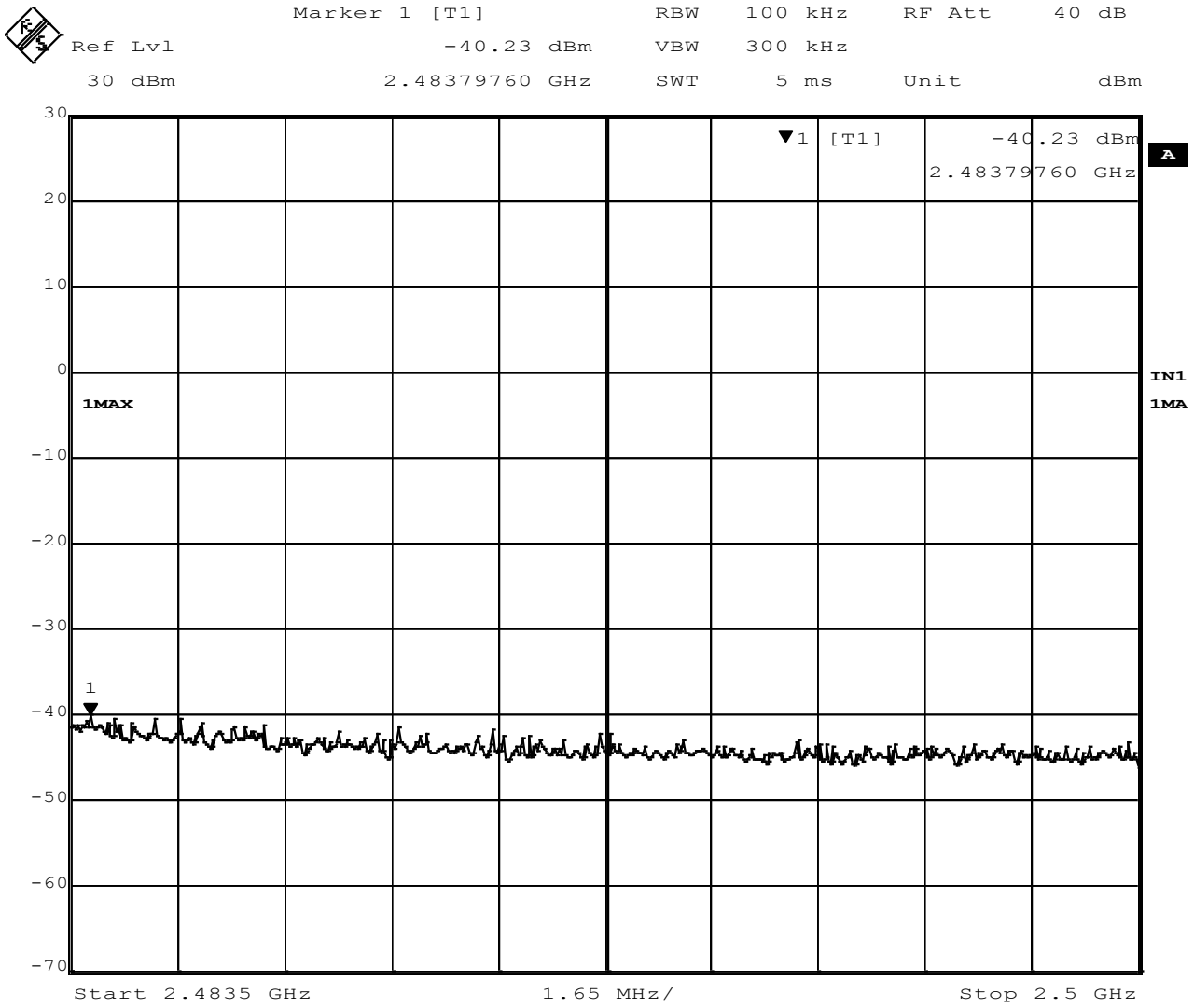

Figure 72 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

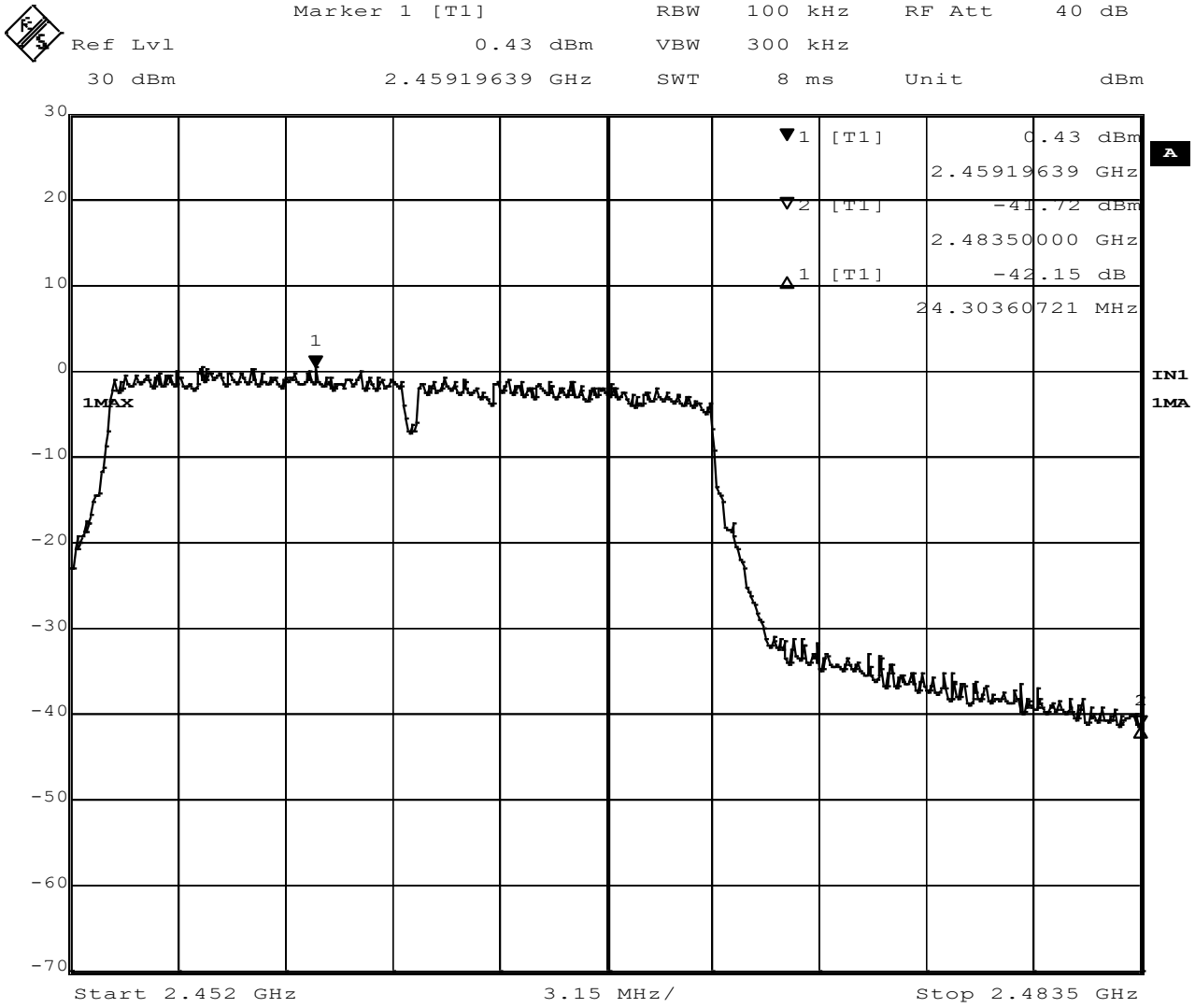

Figure 73 - Band-edge Measurement, High Channel, Fundamental, Peak

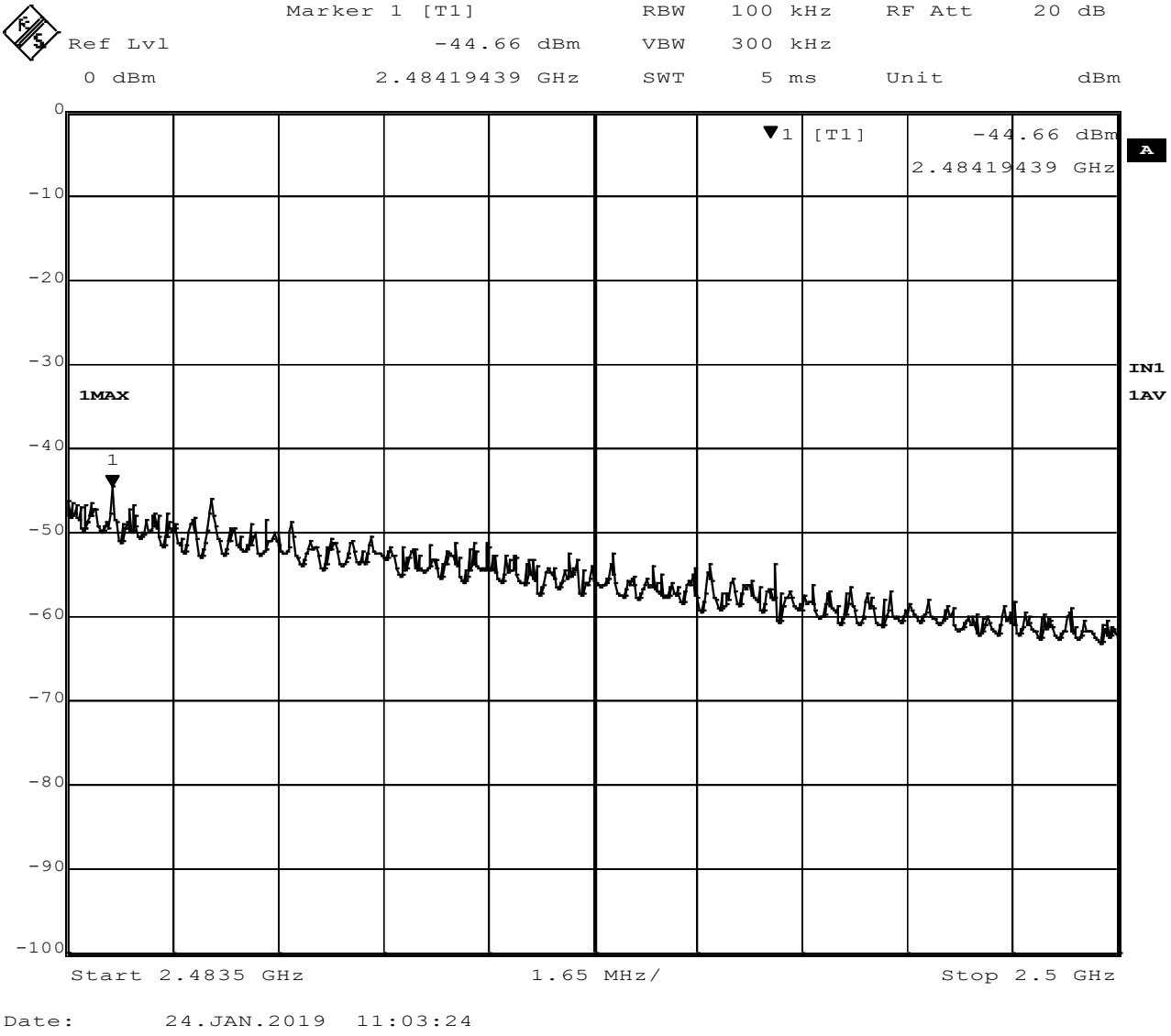

Figure 74 - Band-edge Measurement, High Channel, Restricted Frequency, Average

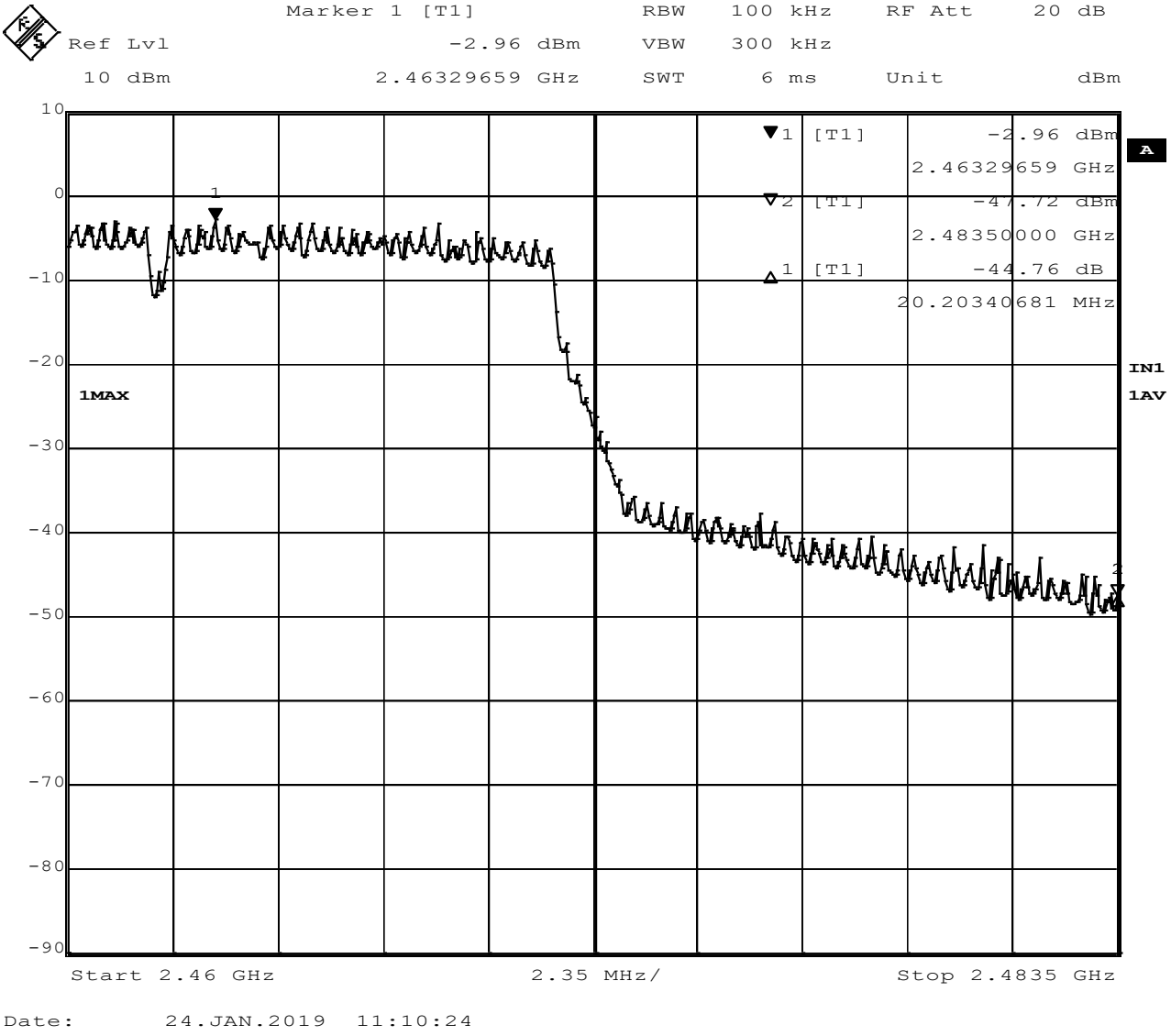

Figure 75 - Band-edge Measurement, High Channel, Fundamental, Average

4.6 POWER SPECTRAL DENSITY

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

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

Test procedures:
1. The EUT was 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.

Test results:

Power Spectral Density

CHANNEL	CHANNEL FREQUENCY (MHz)	WIFI Type	PEAK PSD(dBm)	Method	Limit (dBm)	RESULT
Low	2412	802.11b	-10.87	Conducted	8.00	PASS
Middle	2437	802.11b	-11.50	Conducted	8.00	PASS
High	2462	802.11b	-12.52	Conducted	8.00	PASS
Low	2412	802.11g	-10.38	Conducted	8.00	PASS
Middle	2437	802.11g	-11.50	Conducted	8.00	PASS
High	2462	802.11g	-11.89	Conducted	8.00	PASS
Low	2412	802.11n	-8.45	Conducted	8.00	PASS
Middle	2437	802.11n	-11.74	Conducted	8.00	PASS
High	2462	802.11n	-12.83	Conducted	8.00	PASS

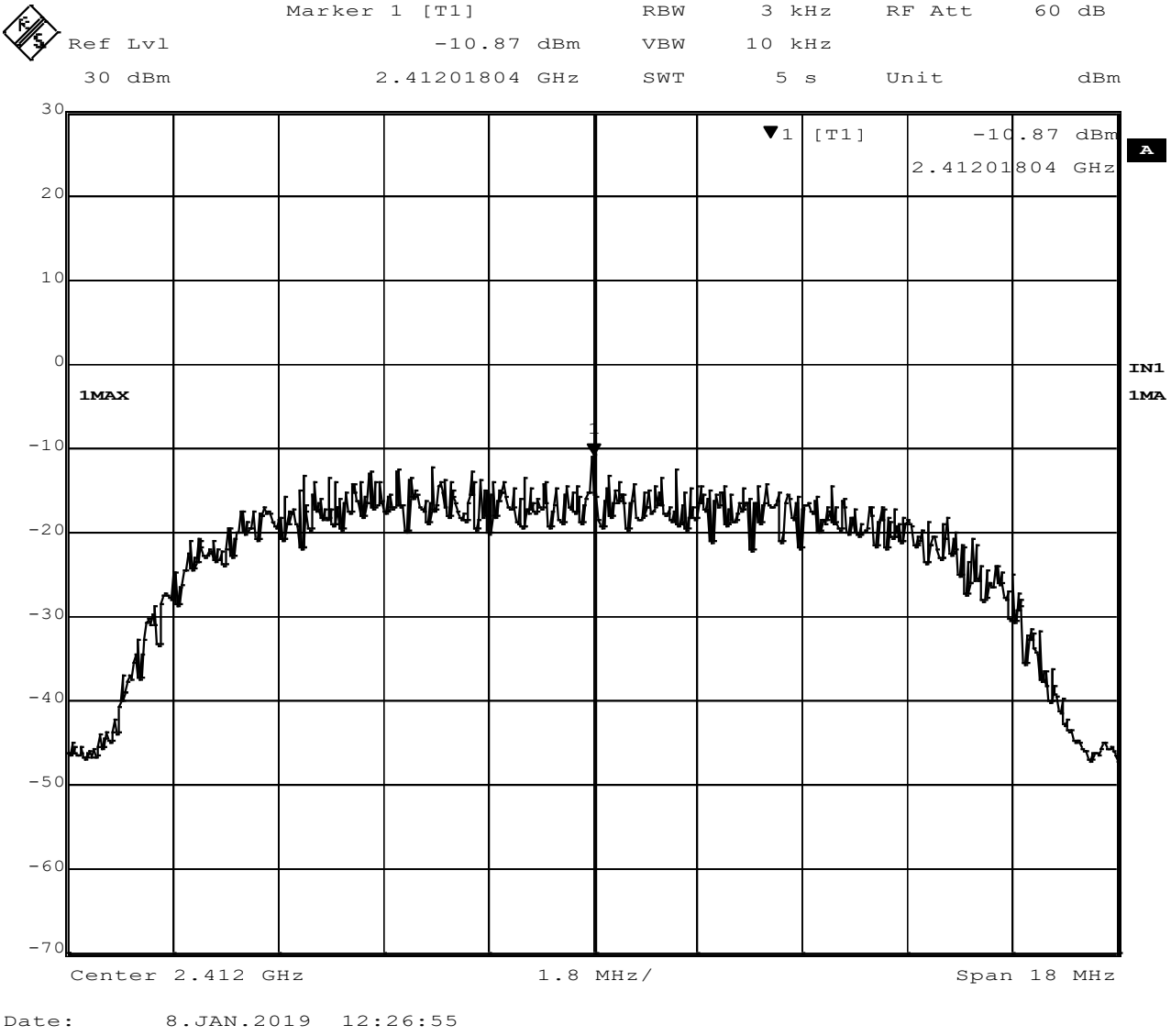

Figure 76 - Power Spectral Density, Low Channel, 802.11b

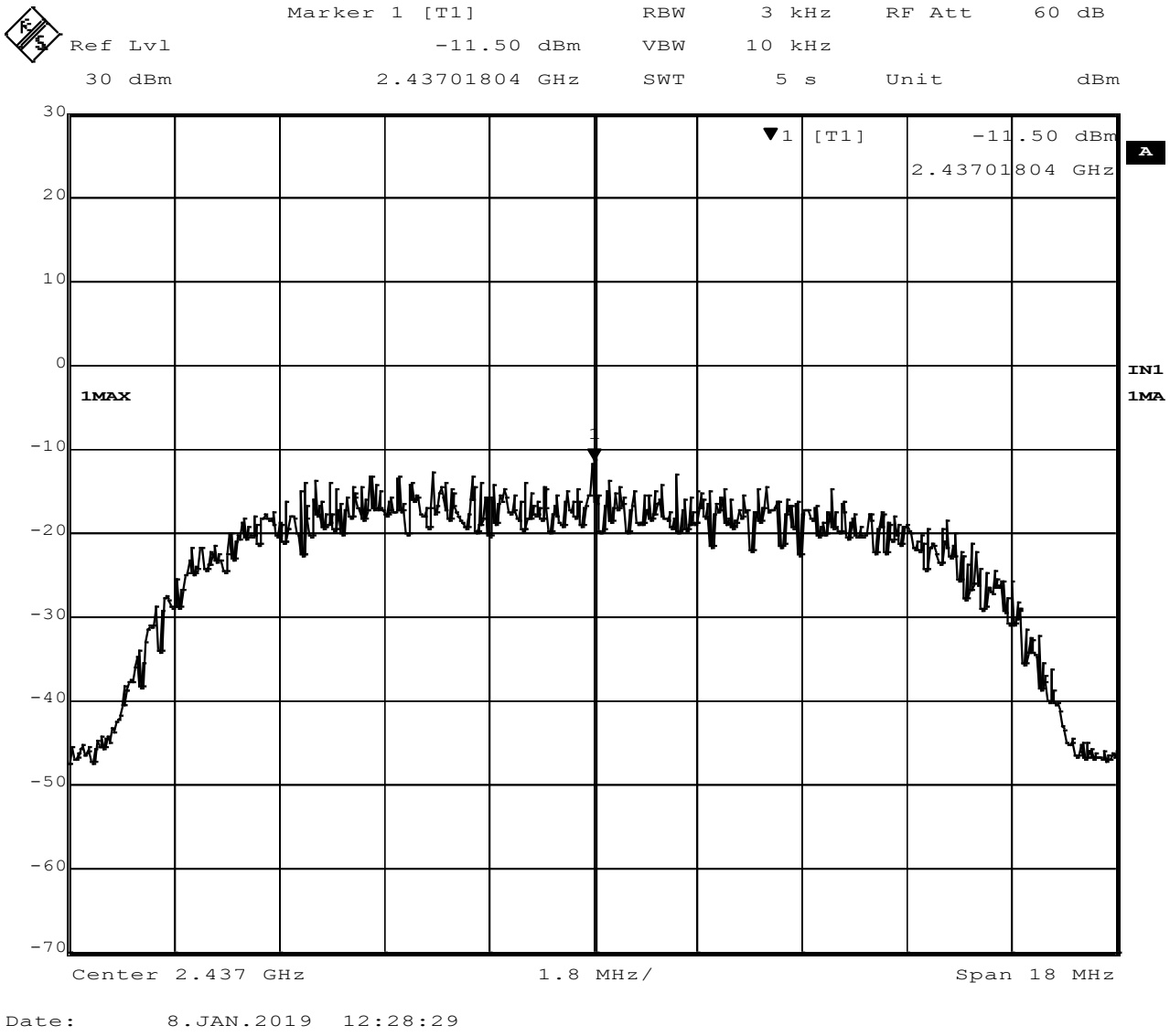

Figure 77 - Power Spectral Density, Mid Channel, 802.11b

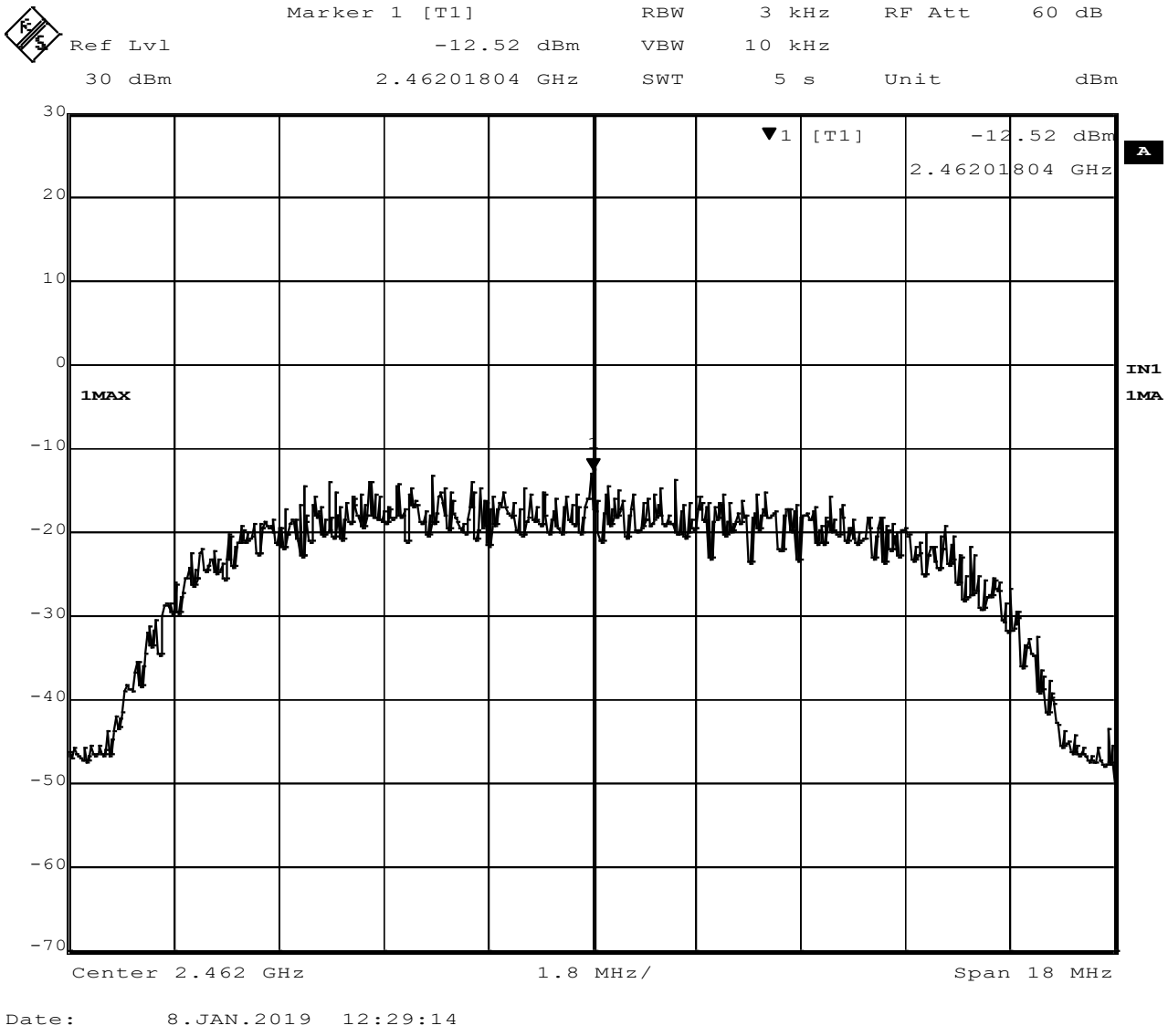

Figure 78 - Power Spectral Density, High Channel, 802.11b

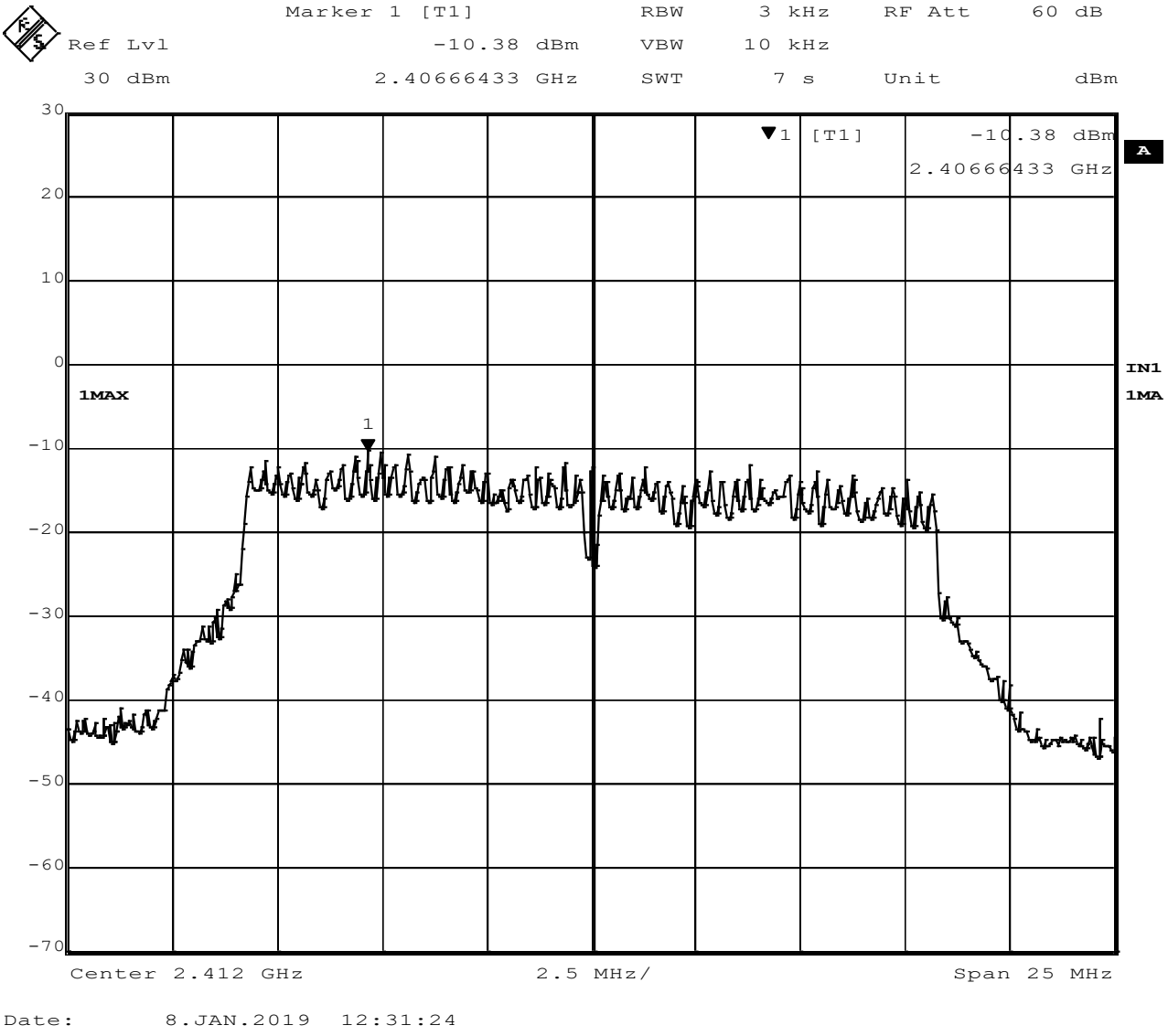

Figure 79 - Power Spectral Density, Low Channel, 802.11g

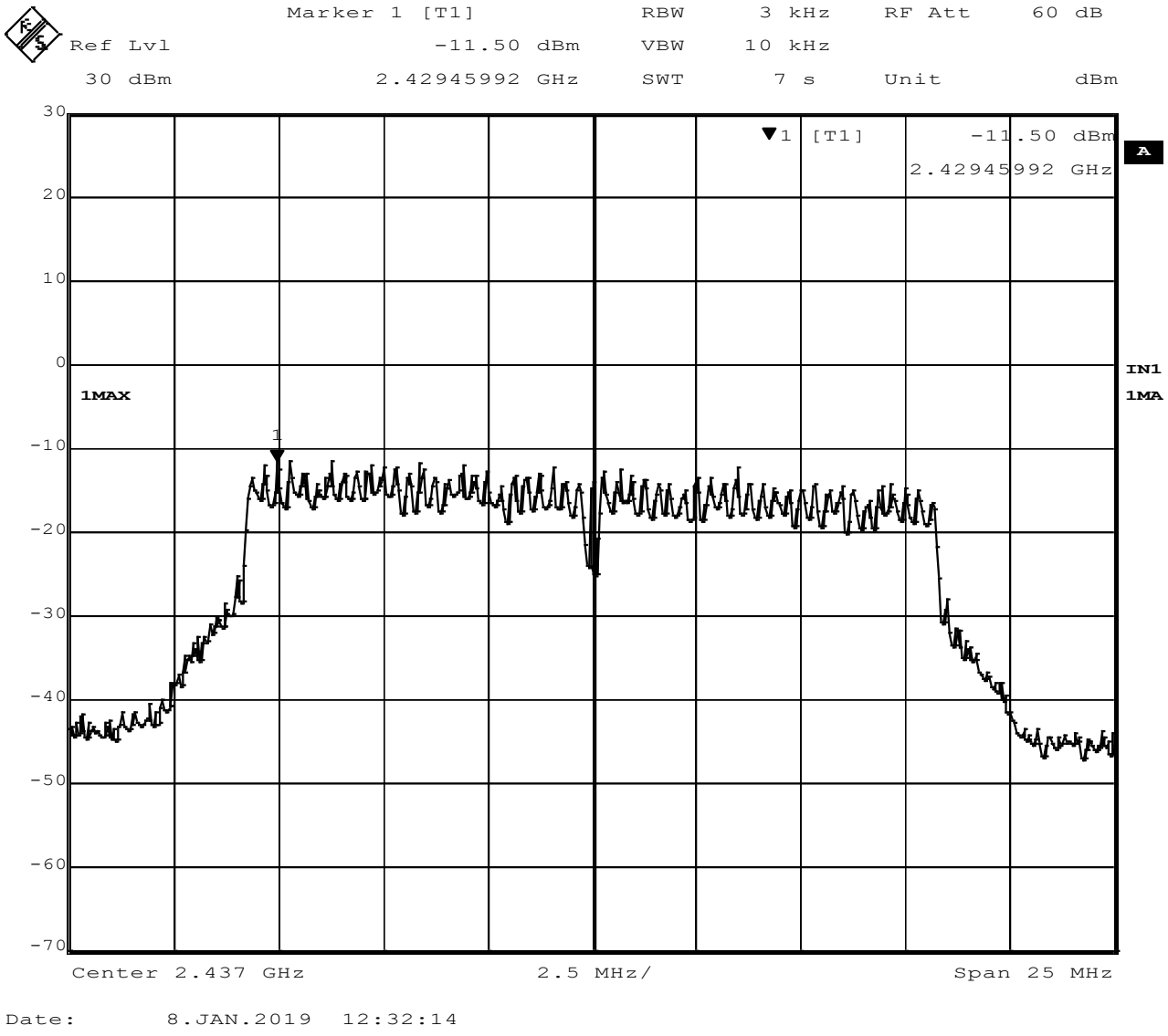

Figure 80 - Power Spectral Density, Mid Channel, 802.11g

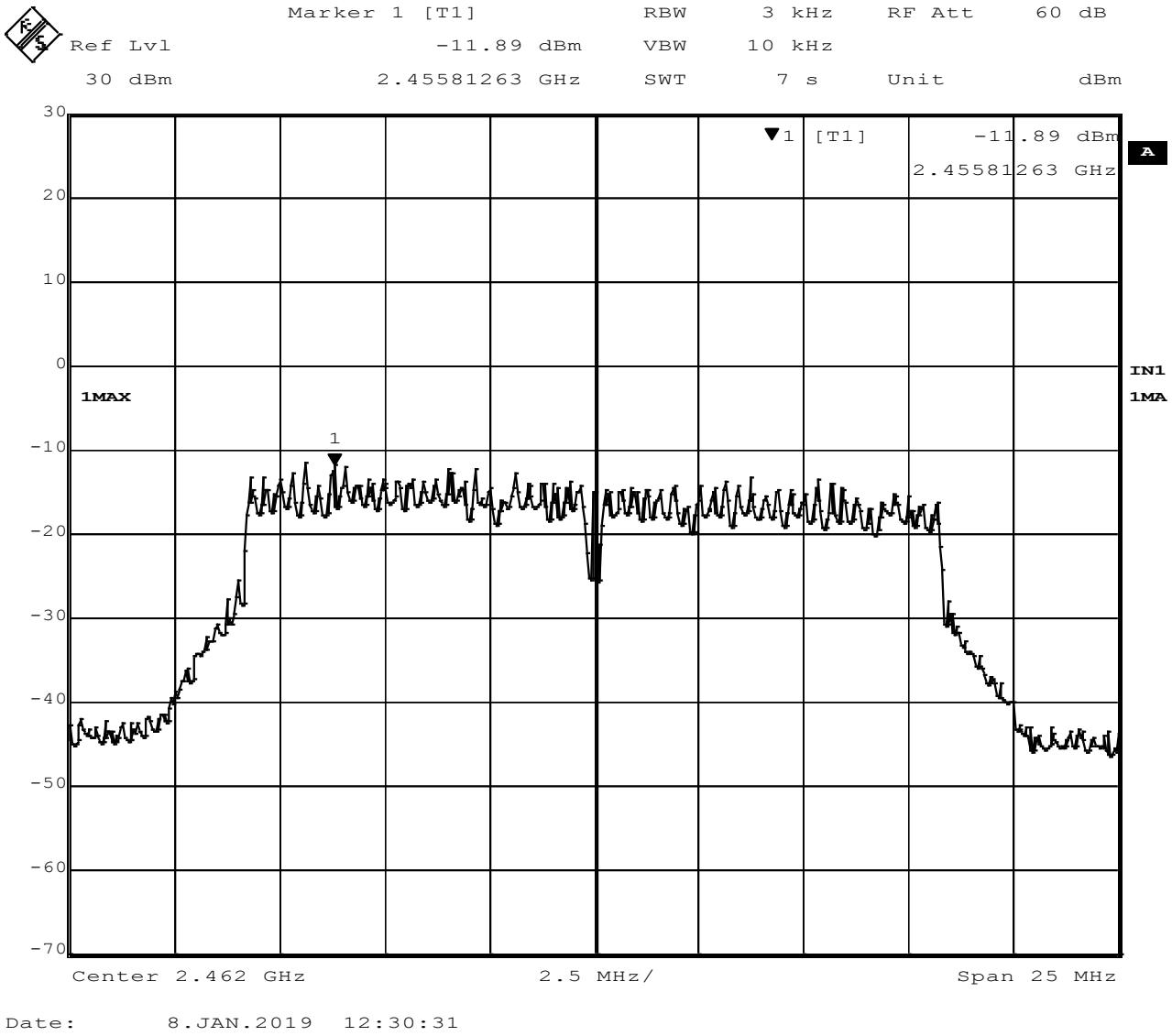

Figure 81 - Power Spectral Density, High Channel, 802.11g

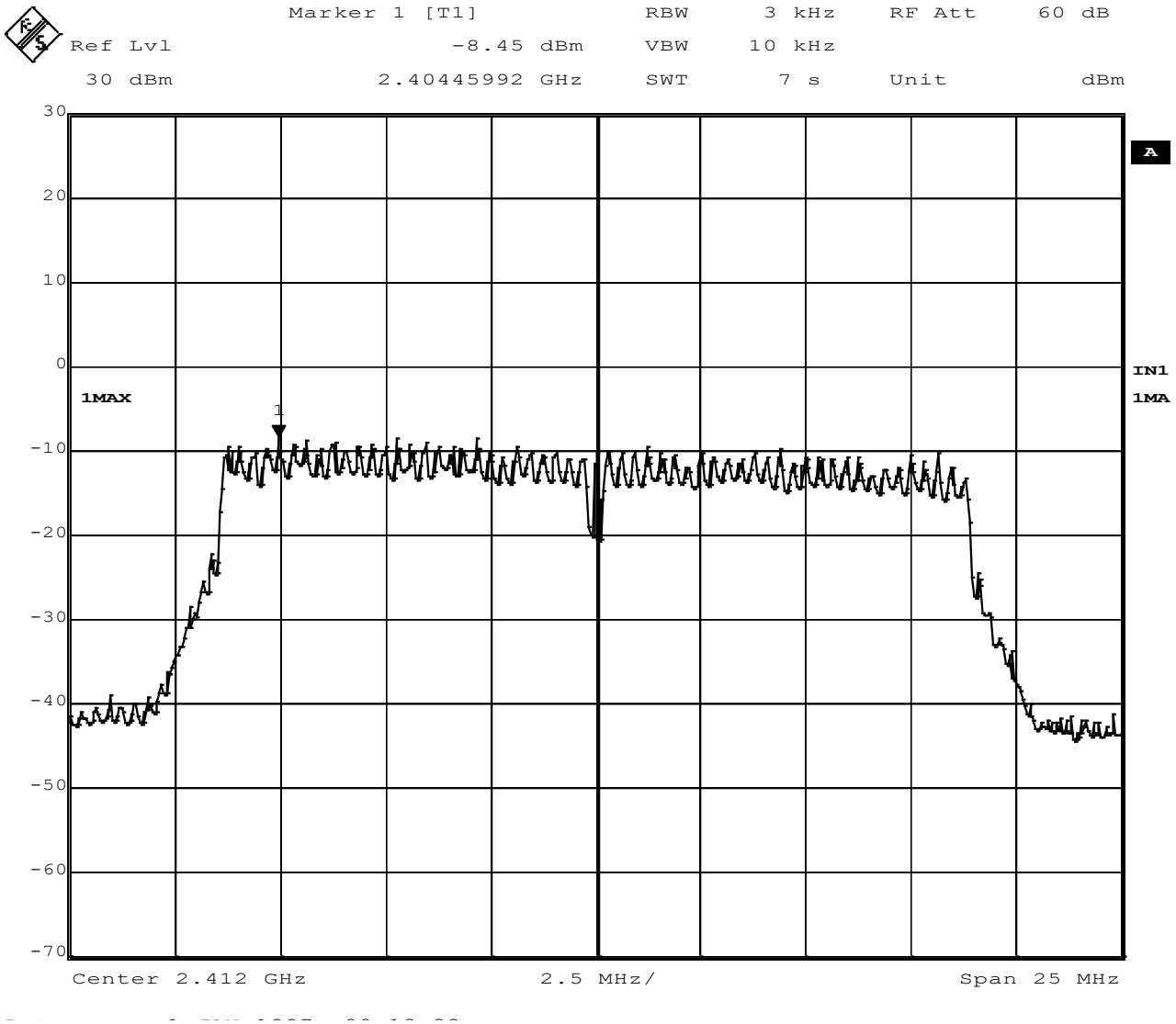

Figure 82 - Power Spectral Density, Low Channel, 802.11n

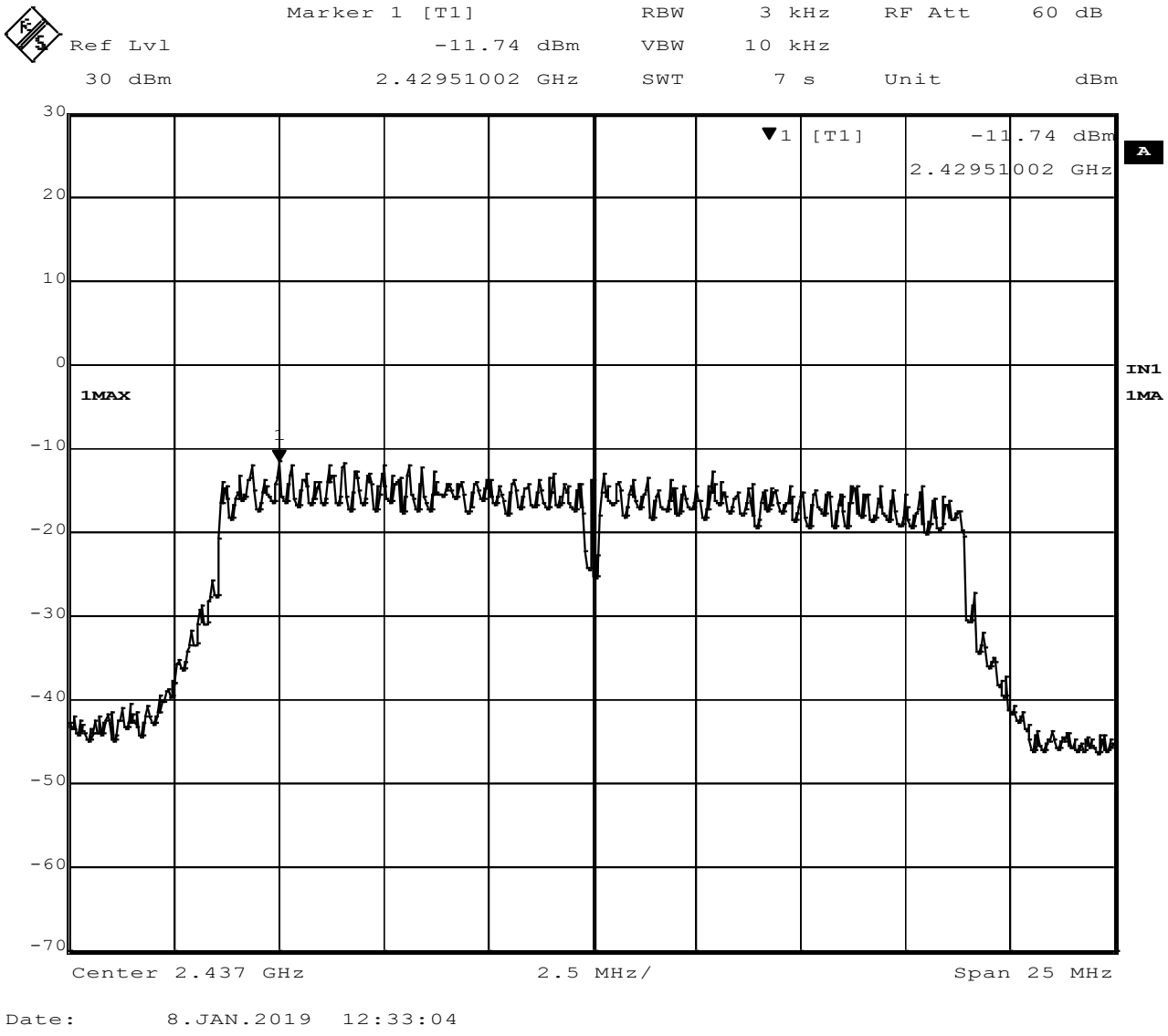

Figure 83 - Power Spectral Density, Mid Channel, 802.11n

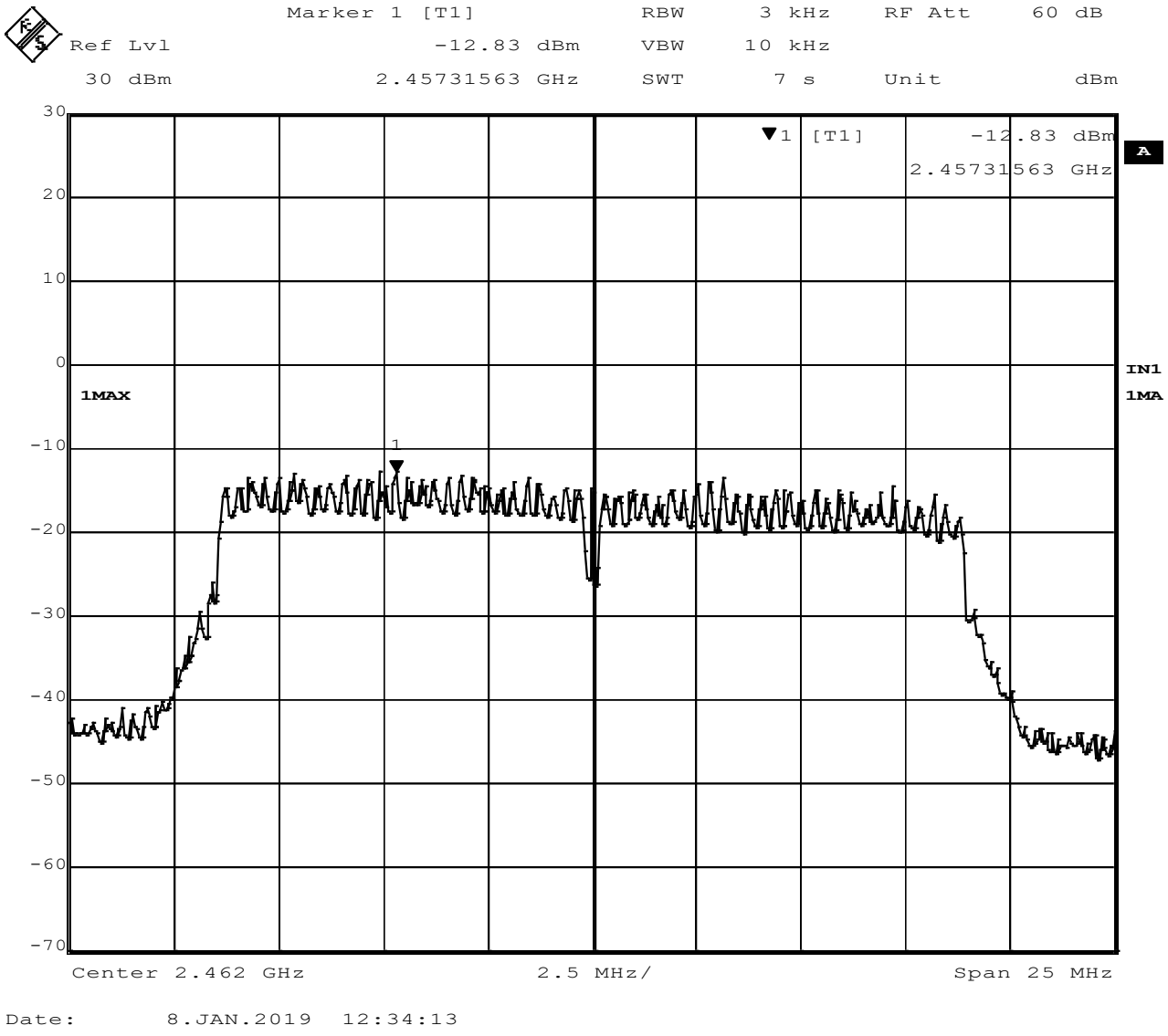

Figure 84 - Power Spectral Density, High Channel, 802.11n

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:

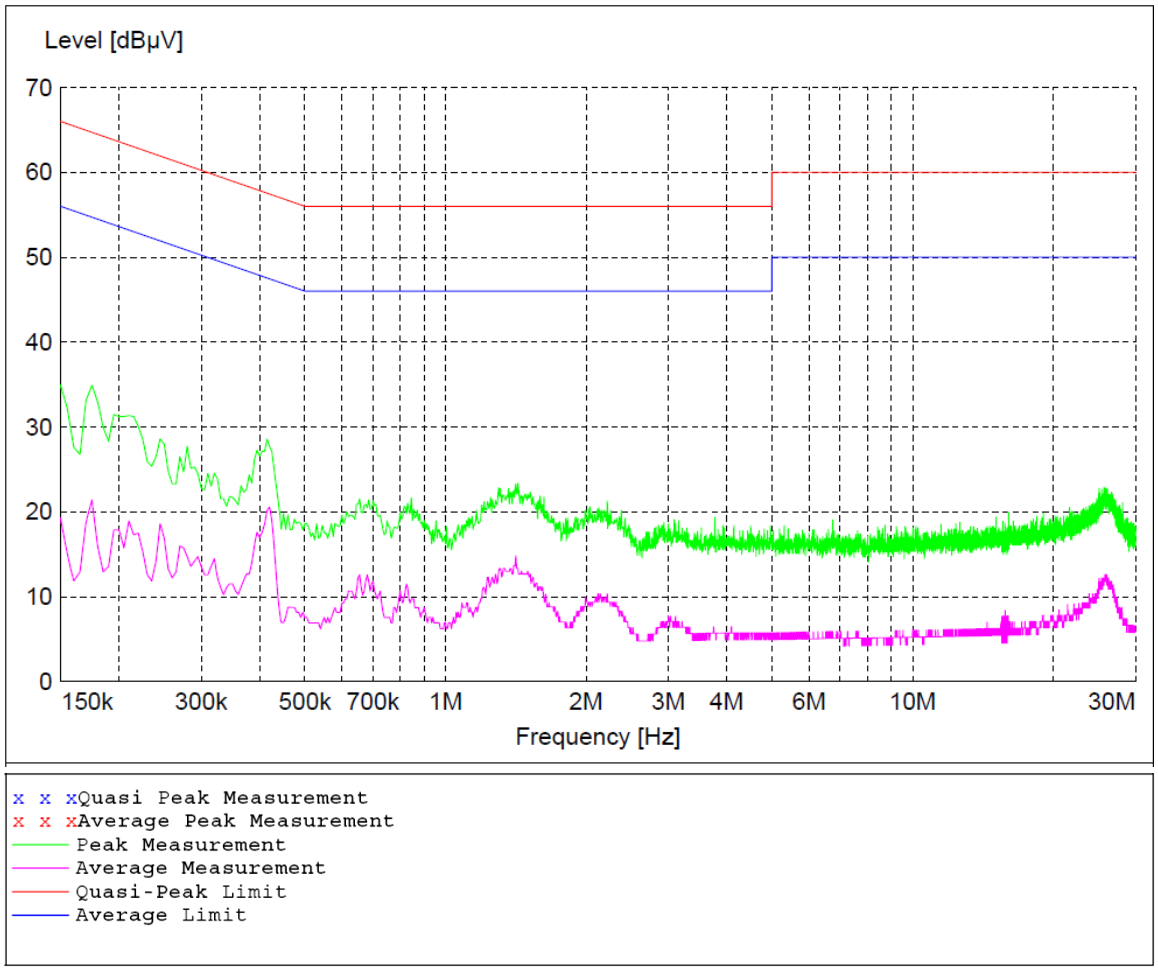

Figure 85 - Conducted Emissions Plot

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 dB
Radiated Emissions, 3m	1GHz - 18GHz	±4.44 dB
Emissions limits, conducted	30MHz – 18GHz	±3.30 dB
Antenna port conducted	9 kHz – 25 GHz	±0.50 dB

Values were calculated per CISPR 16-4-2:2011

Expanded uncertainty values are calculated to a confidence level of 95%.

REPORT END