ncee labs
Product Compliance Solutions

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 Test Report

Prepared for: **Garmin International Inc.**

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

Product: **A03558**

Test Report No: **R20181219-20-02B**

Approved by:

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

DATE: **31 July 2019**

Total Pages: **90**

REVISION PAGE

Rev. No.	Date	Description
0	21 May 2019	Original – NJohnson Prepared by KVepuri/CFarrington
A	15 July 2019	Includes NCEE Labs report R20181219-20-02 and its amendment in full -NJ
B	31 July 2019	Includes NCEE Labs report R20181219-20-02A 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

Summary

The Equipment Under Test (EUT) was a battery powered GMSK transceiver manufactured by GARMIN inc.

EUT	A03558
EUT Received	3 May 2019
EUT Tested	3 May 2019- 21 May 2019
Serial No.	3988450151 (conducted antenna port measurements); 3995696216 (radiated measurements)
Operating Band	2400 – 2483.5 MHz
Device Type	GMSK
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	2402 MHz
Mid	2440 MHz
High	2480 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

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
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 PEAK OUTPUT POWER

Test Method: ANSI C63.10:

1. Section(s) 11.9.1.1 “RBW ≥ DTS Bandwidth”

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.

Deviations from test standard:
No deviation.

Test setup:

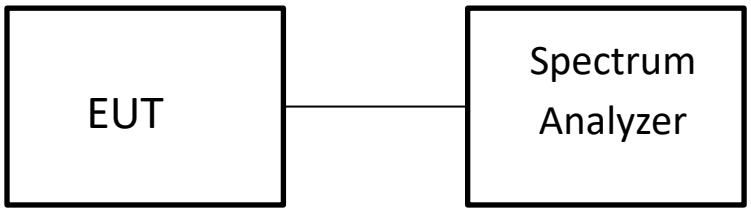

Figure 1 – Peak Output Power Measurements Test Setup

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. EUT was set to transmit in indicated modulation.

Test results:

Peak Output Power

CHANNEL	CHANNEL FREQUENCY (MHz)	PEAK OUTPUT POWER (dBm)	PEAK OUTPUT POWER (mW)	Method	RESULT	Transmitter
Low	2402	13.42	21.98	Conducted	PASS	BT BR (GFSK)
Mid	2440	12.62	18.28	Conducted	PASS	BT BR (GFSK)
High	2480	14.59	28.77	Conducted	PASS	BT BR (GFSK)
Low	2402	13.68	23.33	Conducted	PASS	BT EDR 2MB
Mid	2440	14.72	29.65	Conducted	PASS	BT EDR 2MB
High	2480	11.67	14.69	Conducted	PASS	BT EDR 2MB
Low	2402	13.82	24.10	Conducted	PASS	BT EDR 3MB
Mid	2440	13.02	20.04	Conducted	PASS	BT EDR 3MB
High	2480	11.67	14.69	Conducted	PASS	BT EDR 3MB

CHANNEL	CHANNEL FREQUENCY (MHz)	AVERAGE OUTPUT POWER (dBm)	AVERAGE OUTPUT POWER (mW)	Method	RESULT	Transmitter
Low	2402	11.70	14.79	Conducted	PASS	BT BR (GFSK)
Mid	2440	10.80	12.02	Conducted	PASS	BT BR (GFSK)
High	2480	9.41	8.73	Conducted	PASS	BT BR (GFSK)
Low	2402	8.74	7.48	Conducted	PASS	BT EDR 2MB
Mid	2440	8.57	7.19	Conducted	PASS	BT EDR 2MB
High	2480	7.43	5.53	Conducted	PASS	BT EDR 2MB
Low	2402	8.63	7.29	Conducted	PASS	BT EDR 3MB
Mid	2440	8.59	7.23	Conducted	PASS	BT EDR 3MB
High	2480	8.63	7.29	Conducted	PASS	BT EDR 3MB

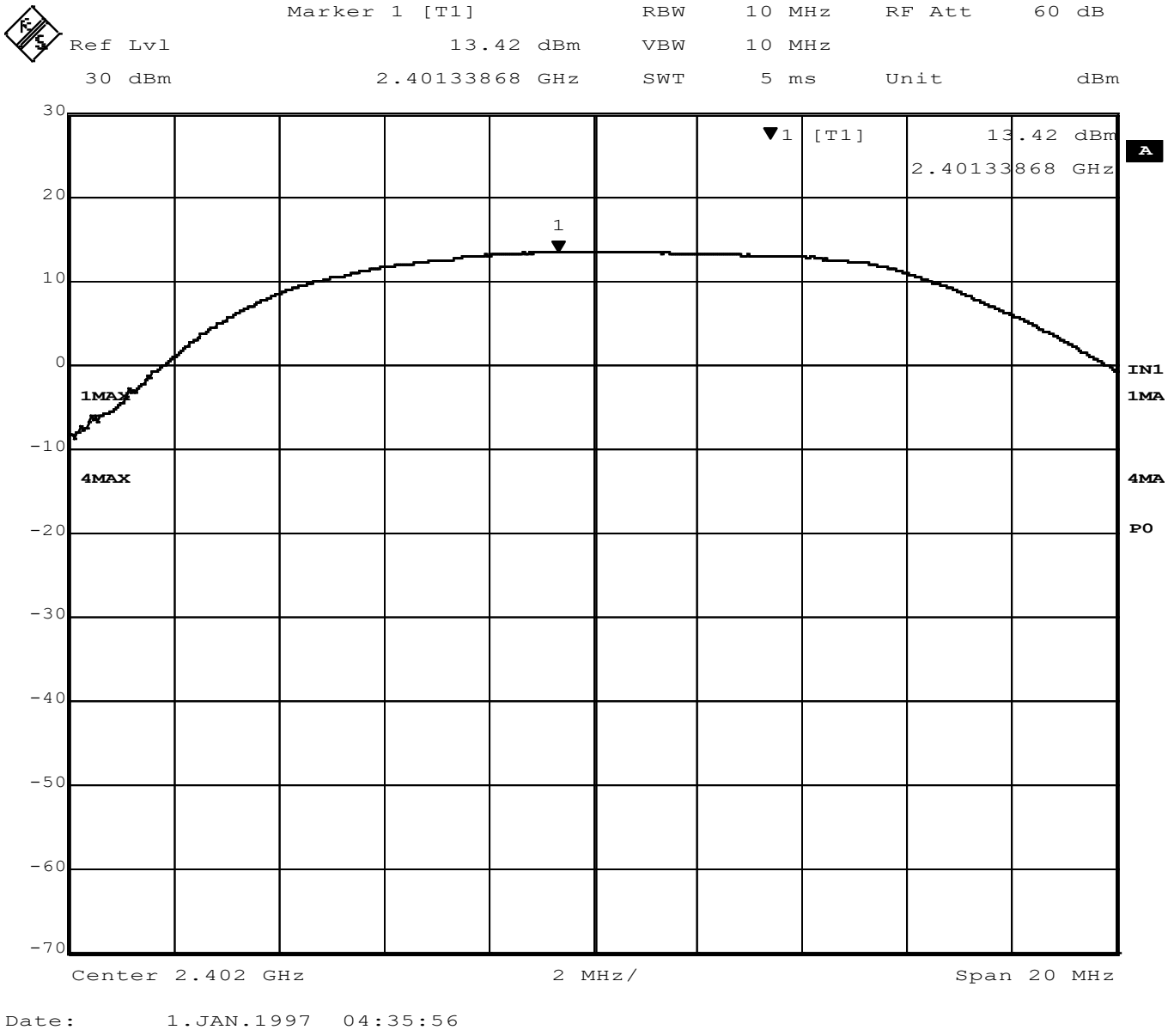

Figure 2 – Output Power, Low Channel, BT BR (GFSK)

Output power = 13.42 dBm

Cable loss was less than 0.1 dB and not included

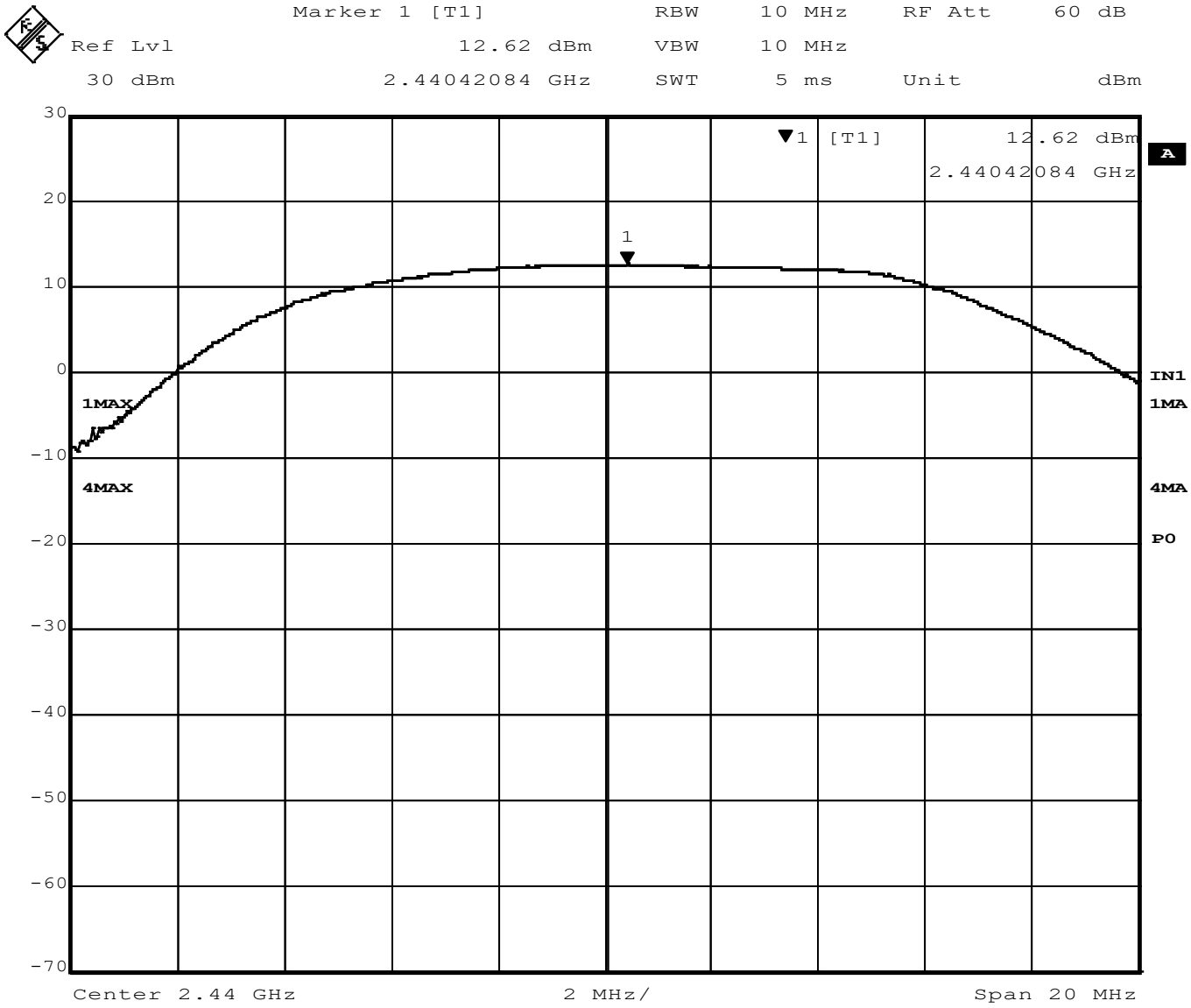

Figure 3 – Output Power, Mid Channel, BT BR (GFSK)

Output power = 12.62 dBm

Cable loss was less than 0.1 dB and not included

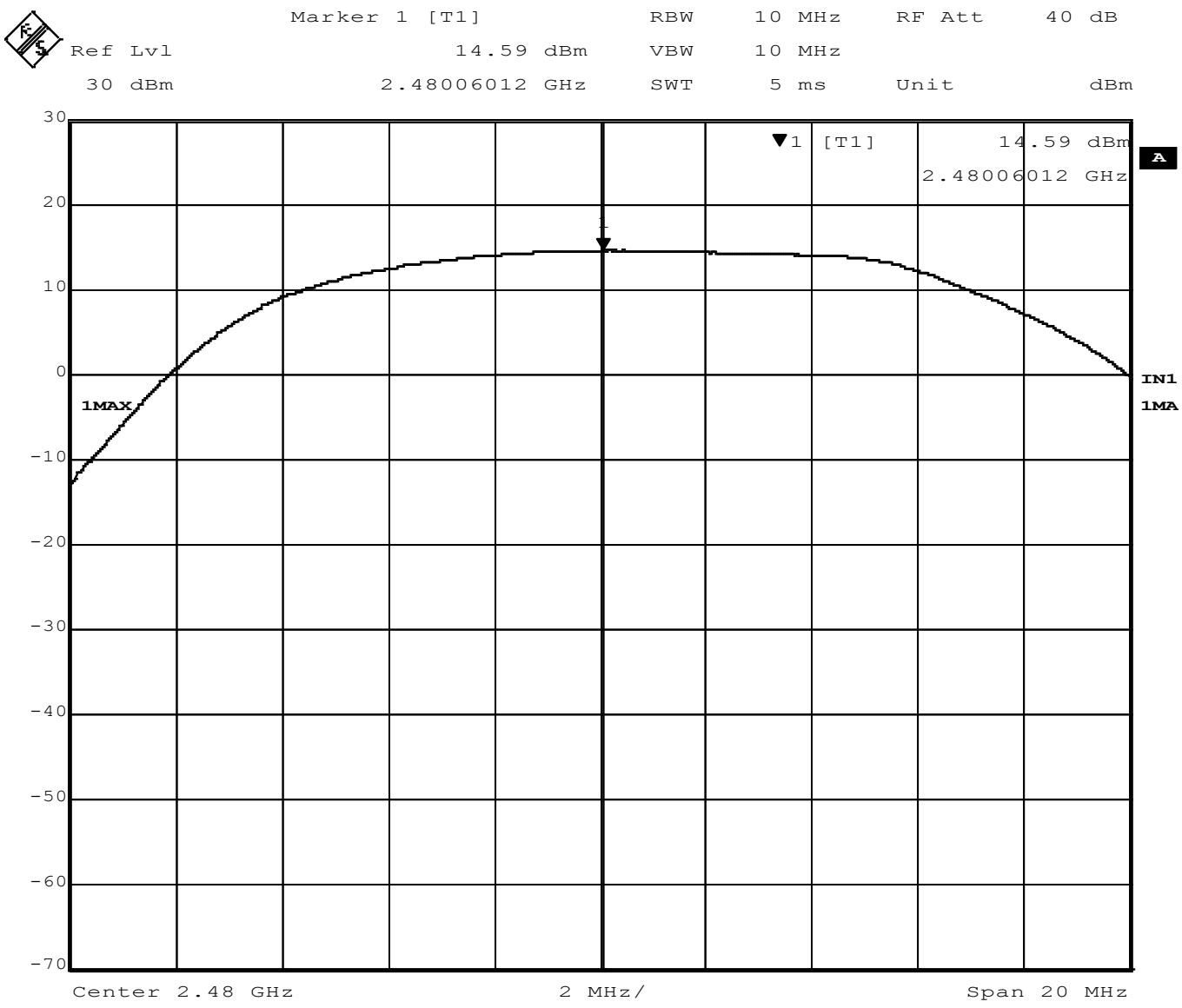

Figure 4 – Output Power, High Channel, BT BR (GFSK)

Output power = 14.59 dBm

Cable loss was less than 0.1 dB and not included

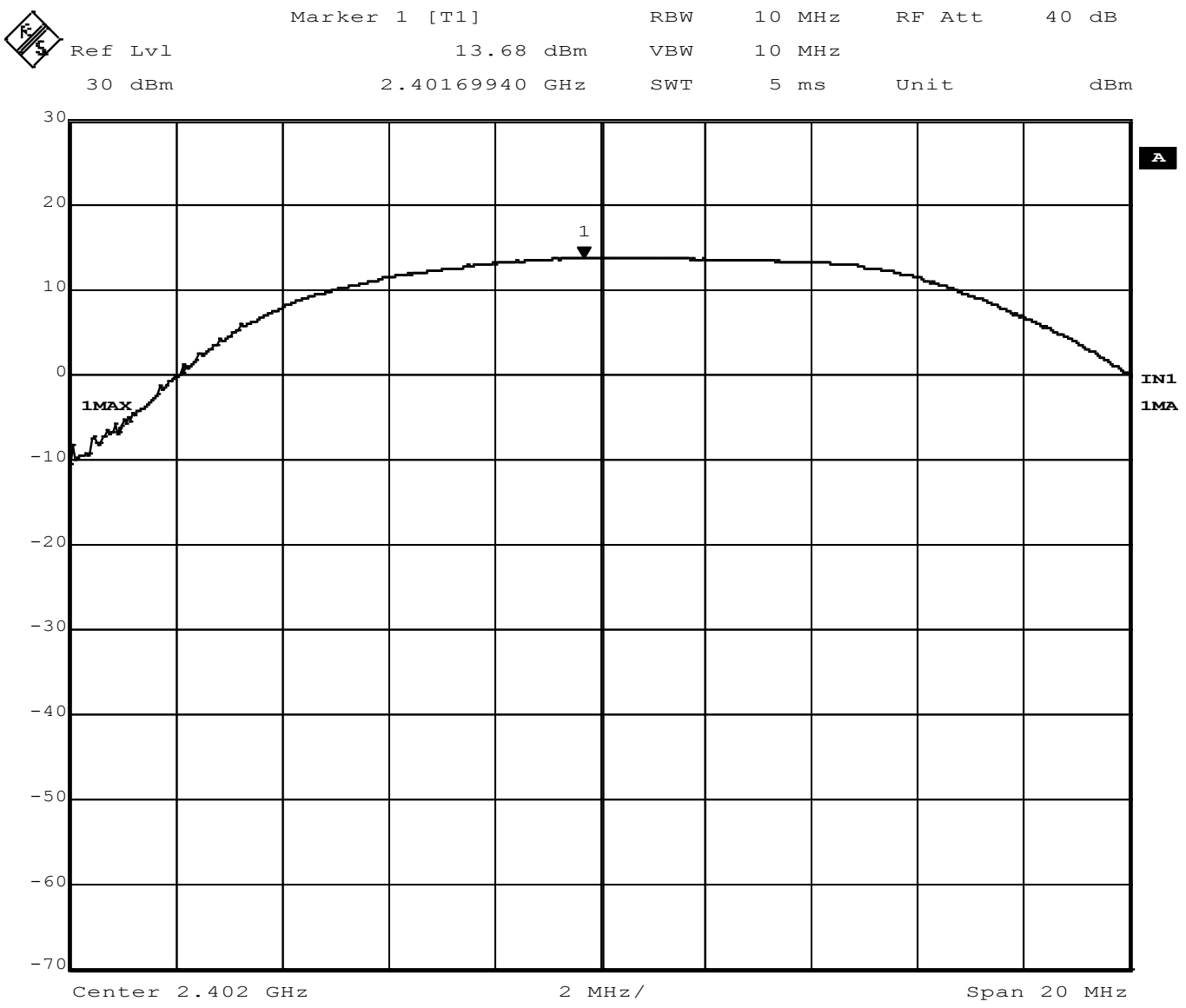

Figure 5 - Output Power, Low Channel, BT EDR 2MB

Output power = 13.68 dBm

Cable loss was less than 0.1 dB and not include.

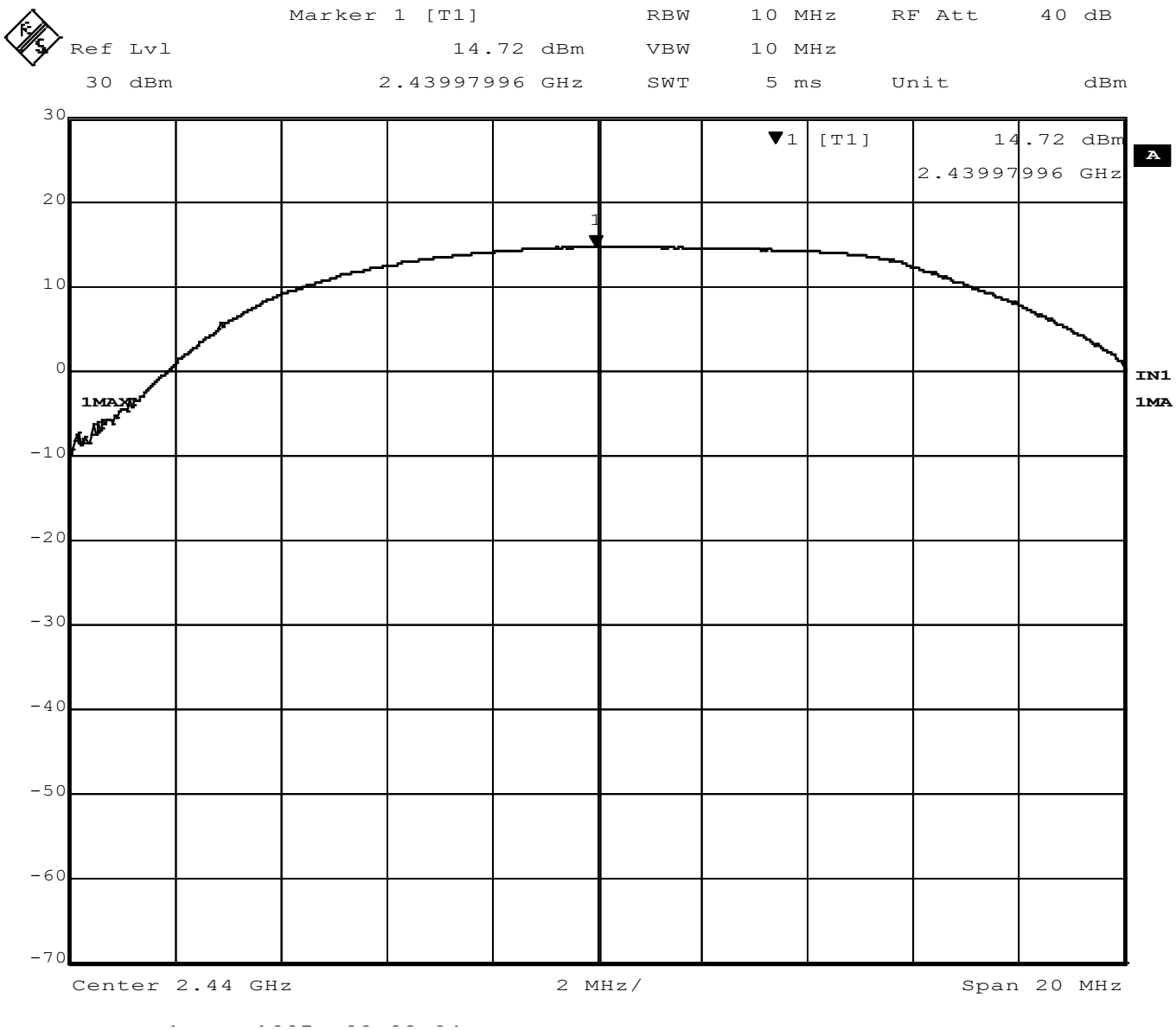

Figure 6 - Output Power, Mid Channel, BT EDR 2MB

Output power = 14.72 dBm

Cable loss was less than 0.1 dB and not included

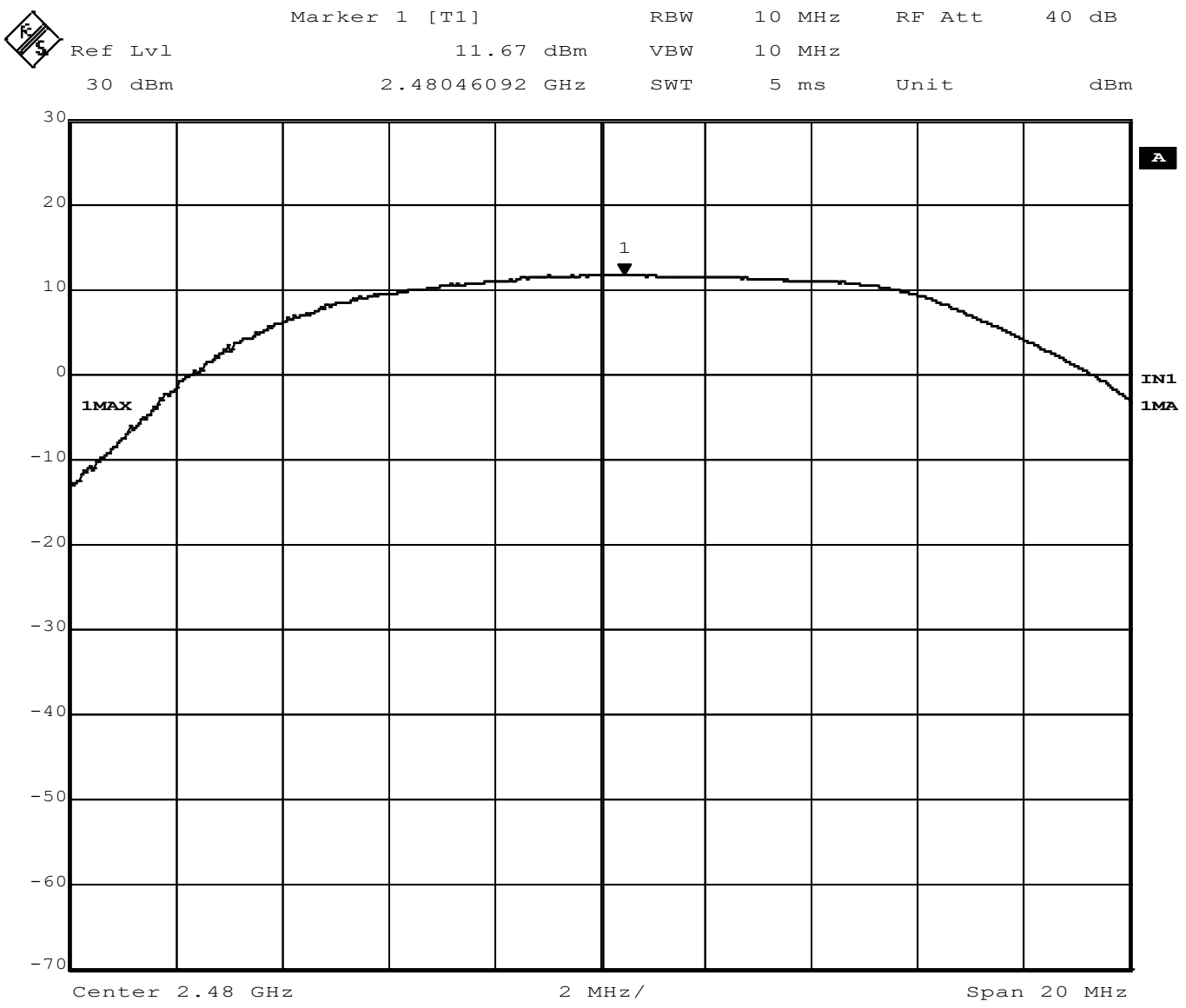

Figure 7 - Output Power, High Channel, BT EDR 2MB

Output power = 11.67 dBm

Cable loss was less than 0.1 dB and not included

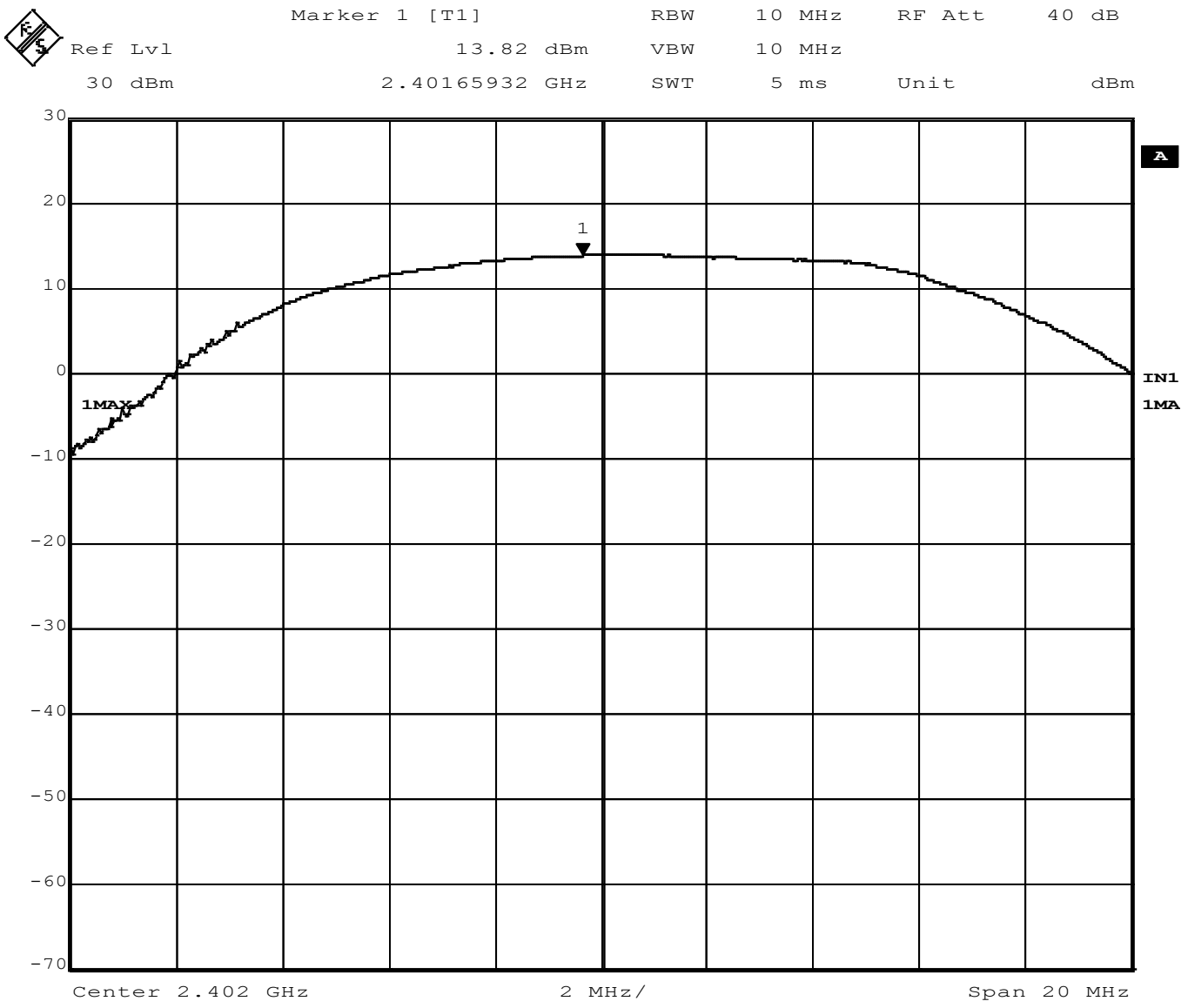

Figure 8 - Output Power, Low Channel, BT EDR 3MB

Output power = 13.82 dBm

Cable loss was less than 0.1 dB and not included

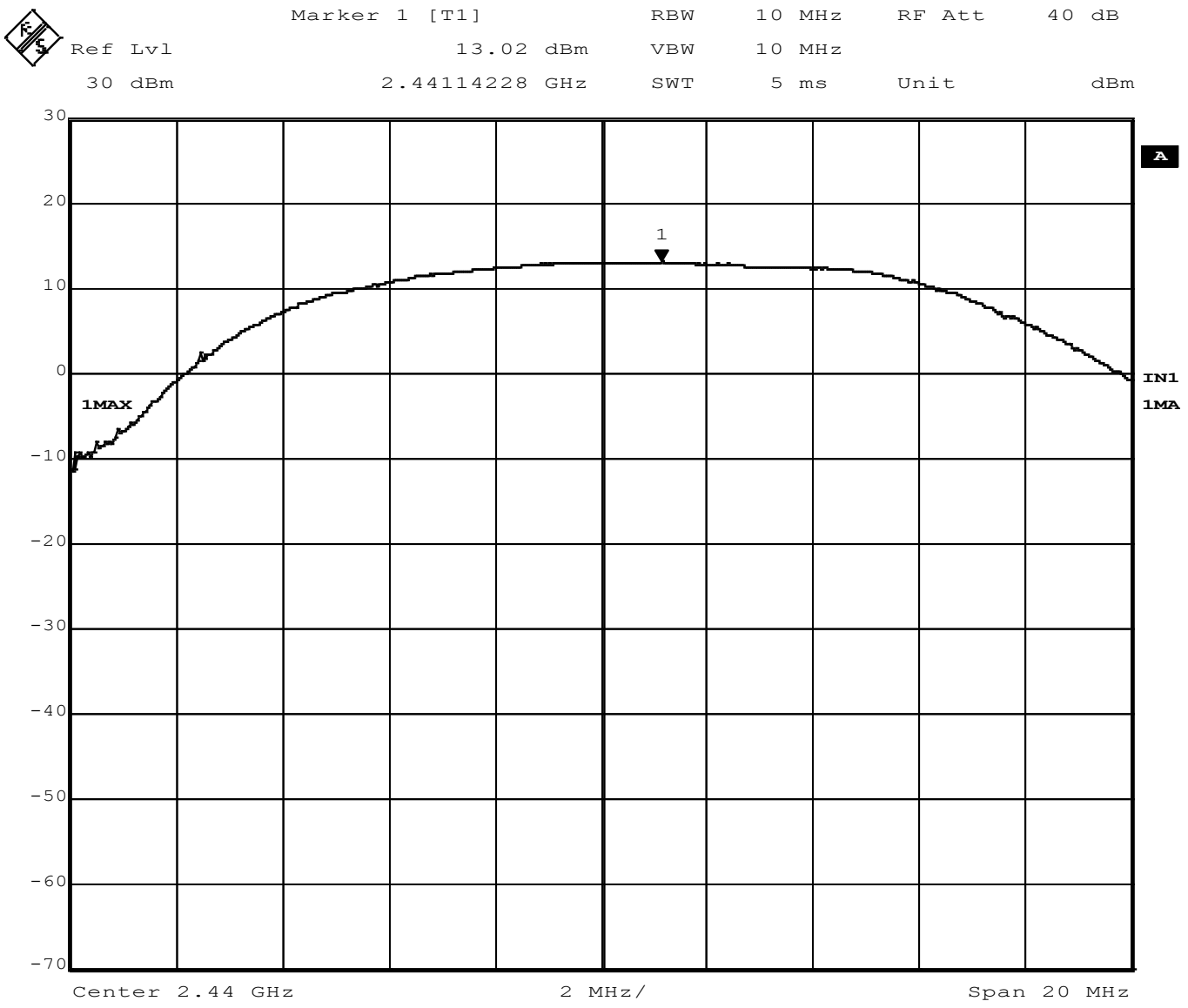

Figure 9 - Output Power, Mid Channel, BT EDR 3MB

Output power = 13.02 dBm

Cable loss was less than 0.1 dB and not included

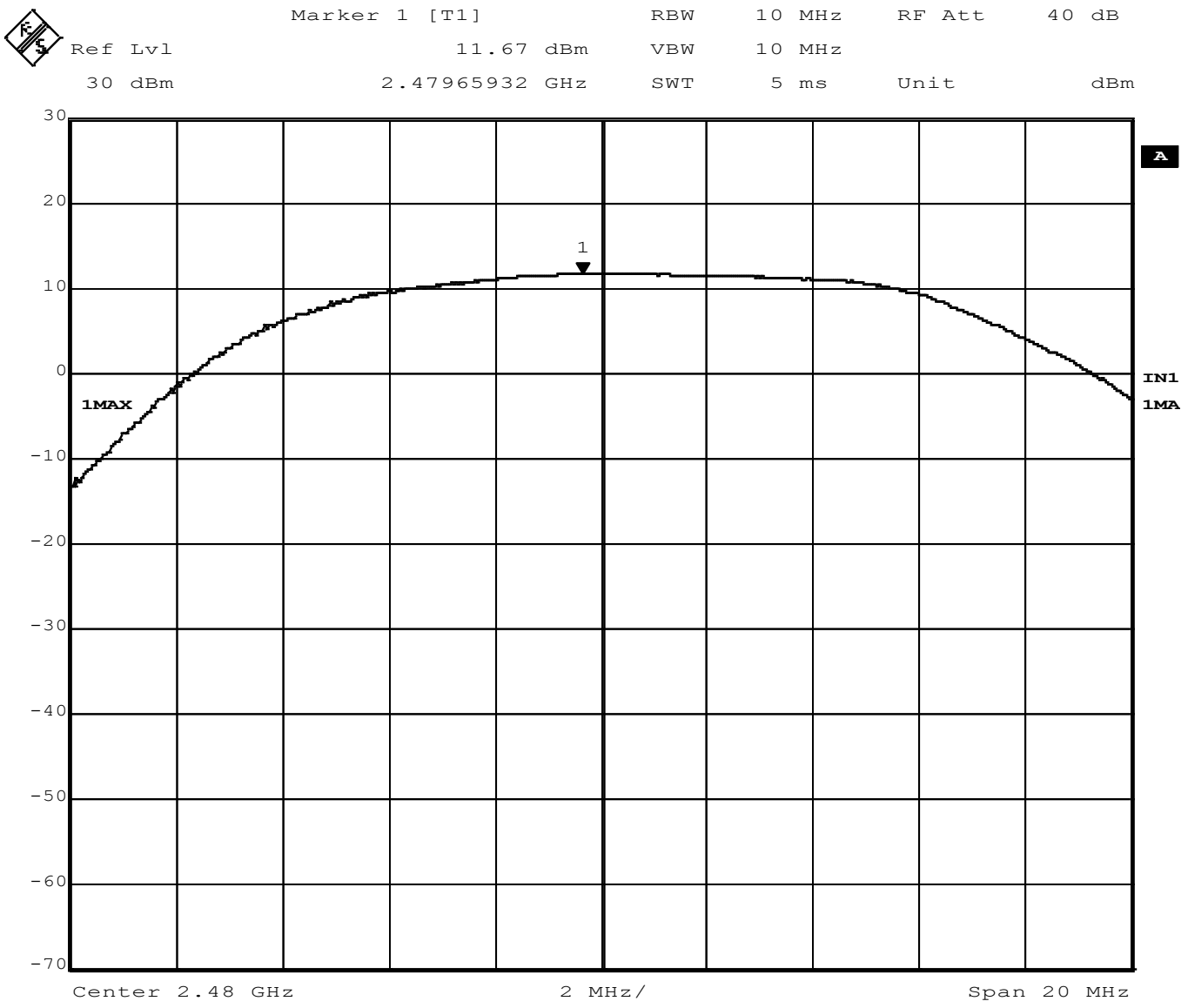

Figure 10 - Output Power, High Channel, BT EDR 3MB

Output power = 11.67 dBm

Cable loss was less than 0.1 dB and not included

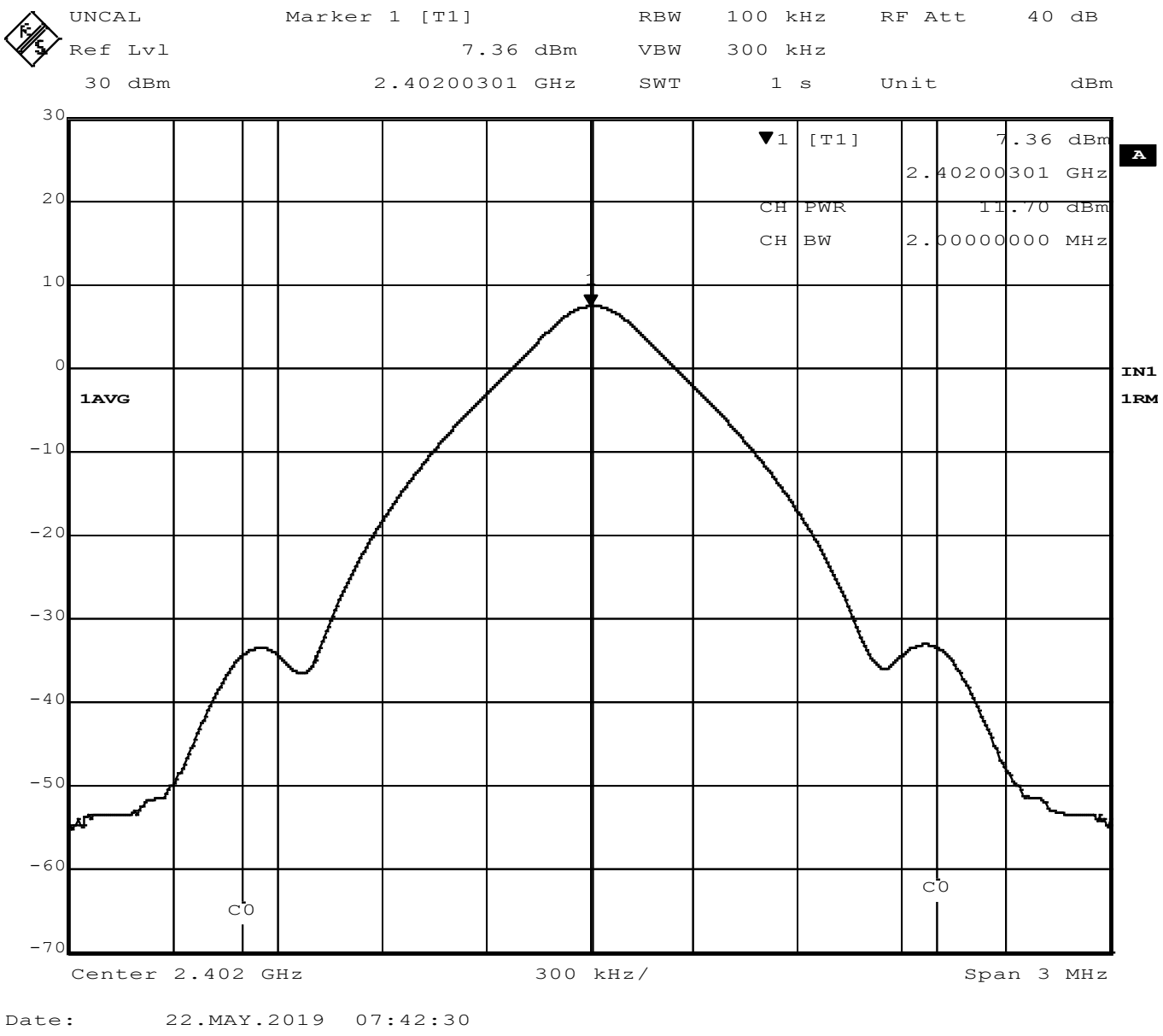

Figure 11 – Average Output Power, Low Channel, BT BR (GFSK)

Average Output power = 11.70 dBm

Cable loss was less than 0.1 dB and not included

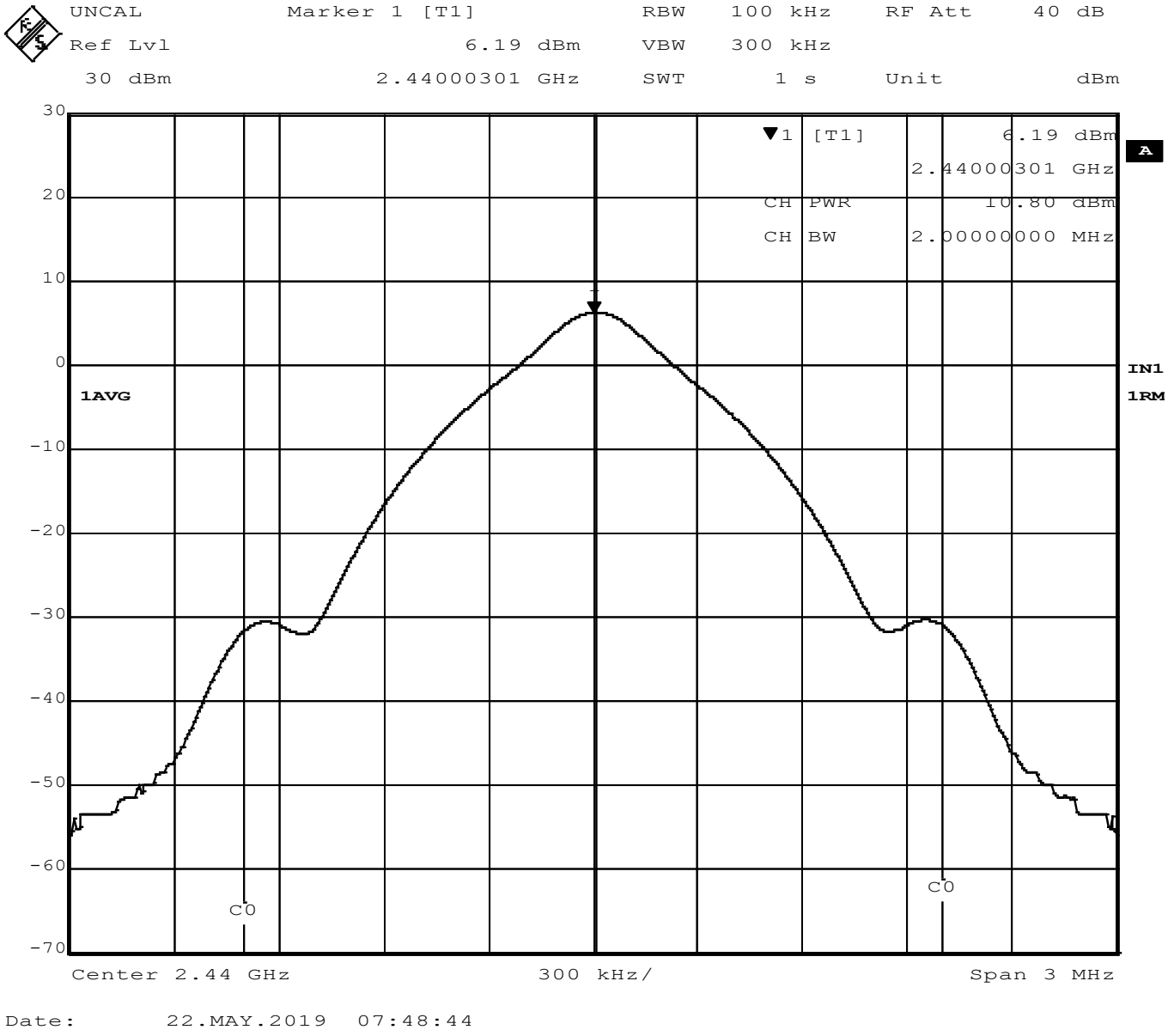

Figure 12 – Average Output Power, Mid Channel, BT BR (GFSK)

Average Output power = 10.80 dBm

Cable loss was less than 0.1 dB and not included

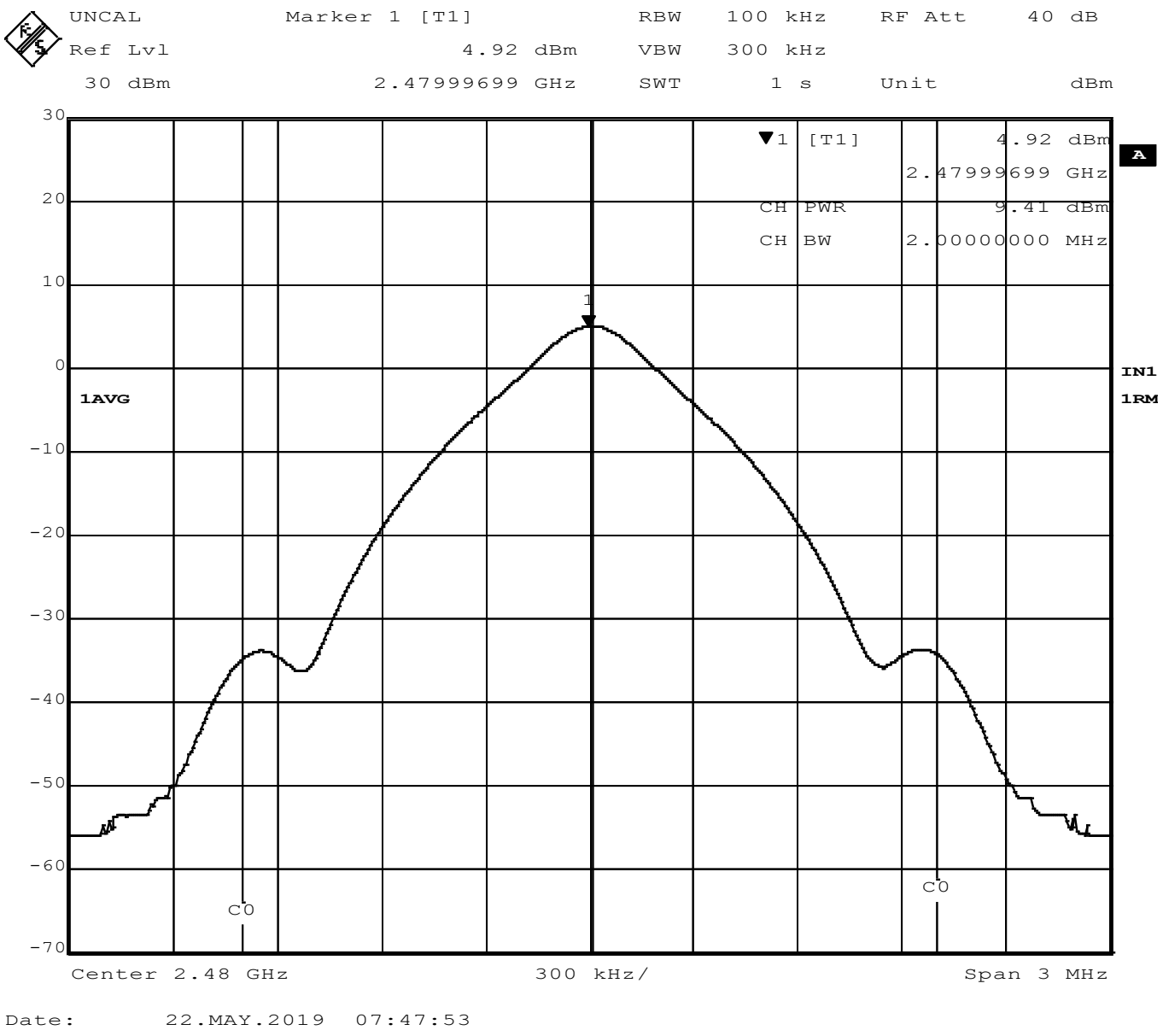

Figure 13 – Average Output Power, High Channel, BT BR (GFSK)

Average Output power = 9.41 dBm

Cable loss was less than 0.1 dB and not included

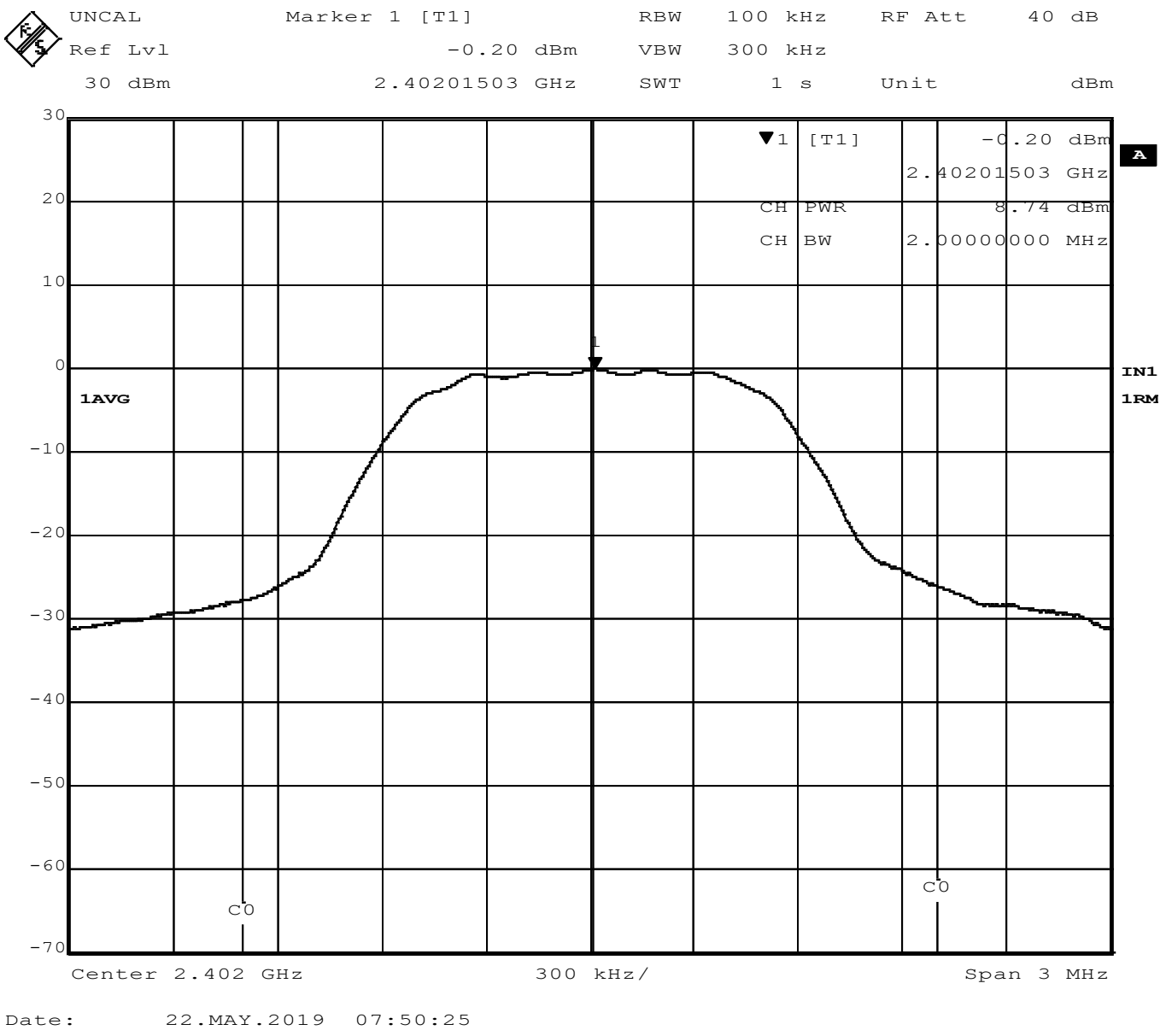

Figure 14 - Average Output Power, Low Channel, BT EDR 2MB

Average Output power = 8.74 dBm

Cable loss was less than 0.1 dB and not include.

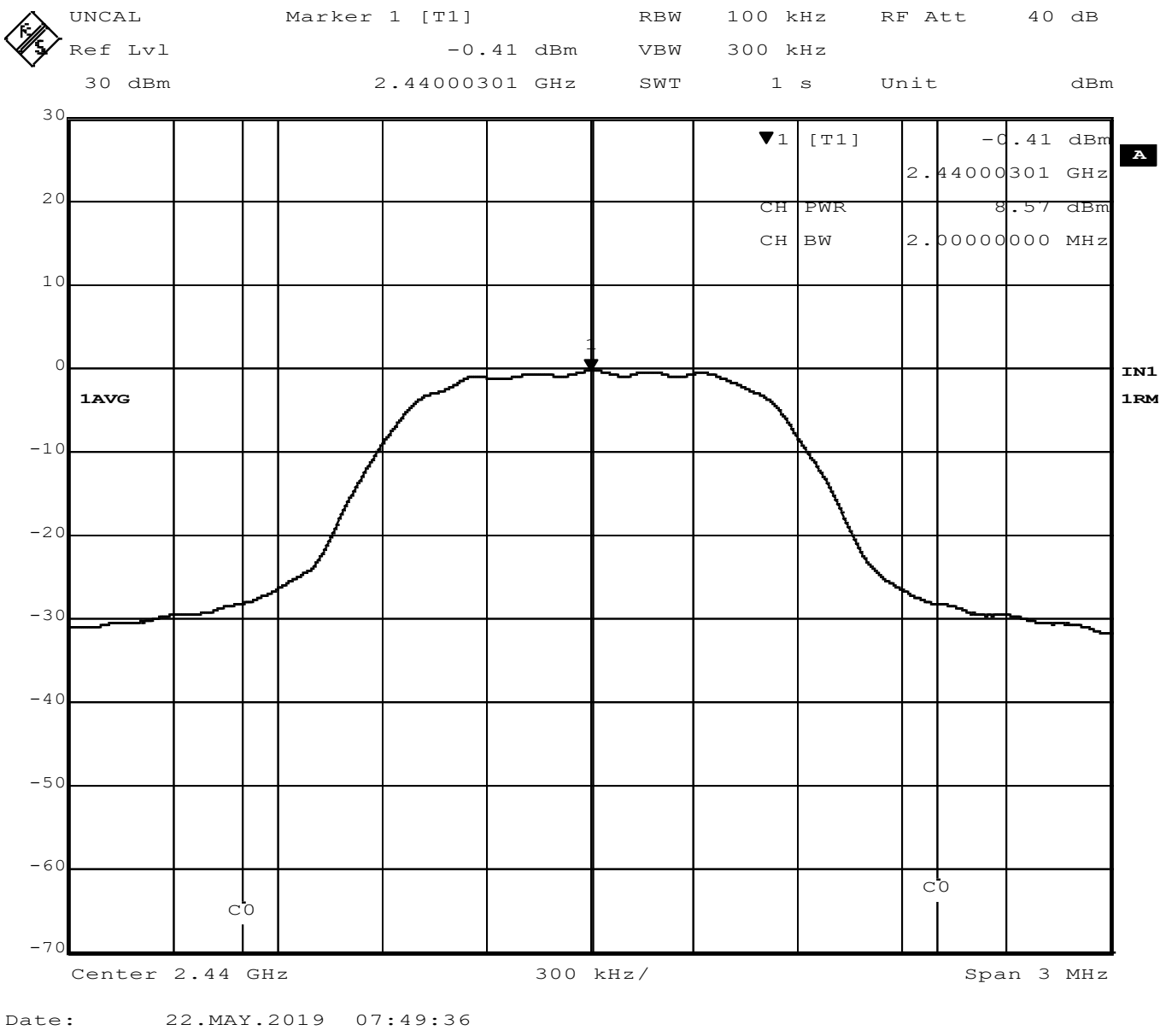

Figure 15 - Average Output Power, Mid Channel, BT EDR 2MB

Average Output power = 8.57 dBm

Cable loss was less than 0.1 dB and not included

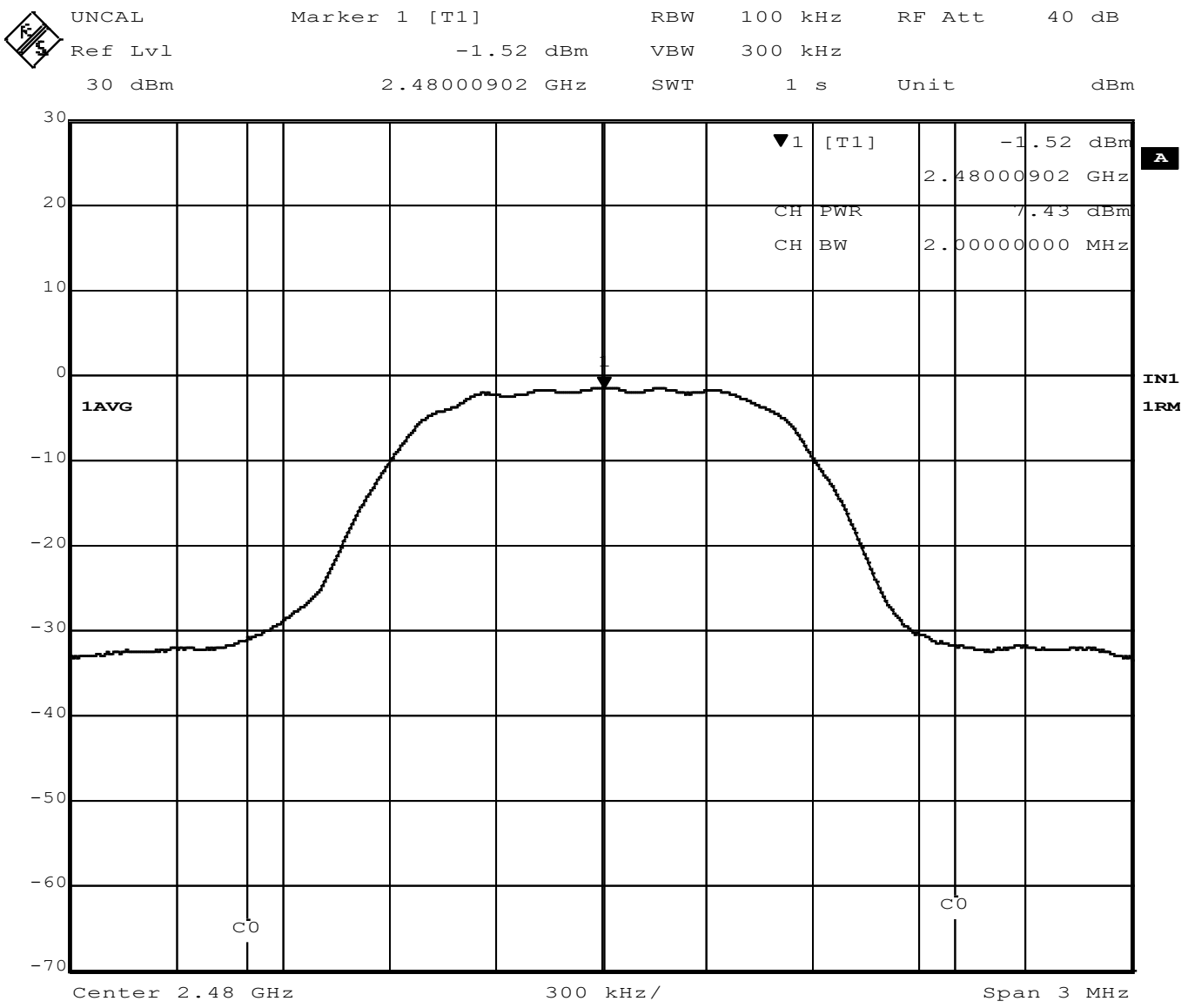

Figure 16 - Average Output Power, High Channel, BT EDR 2MB

Average Output power = 7.43 dBm

Cable loss was less than 0.1 dB and not included

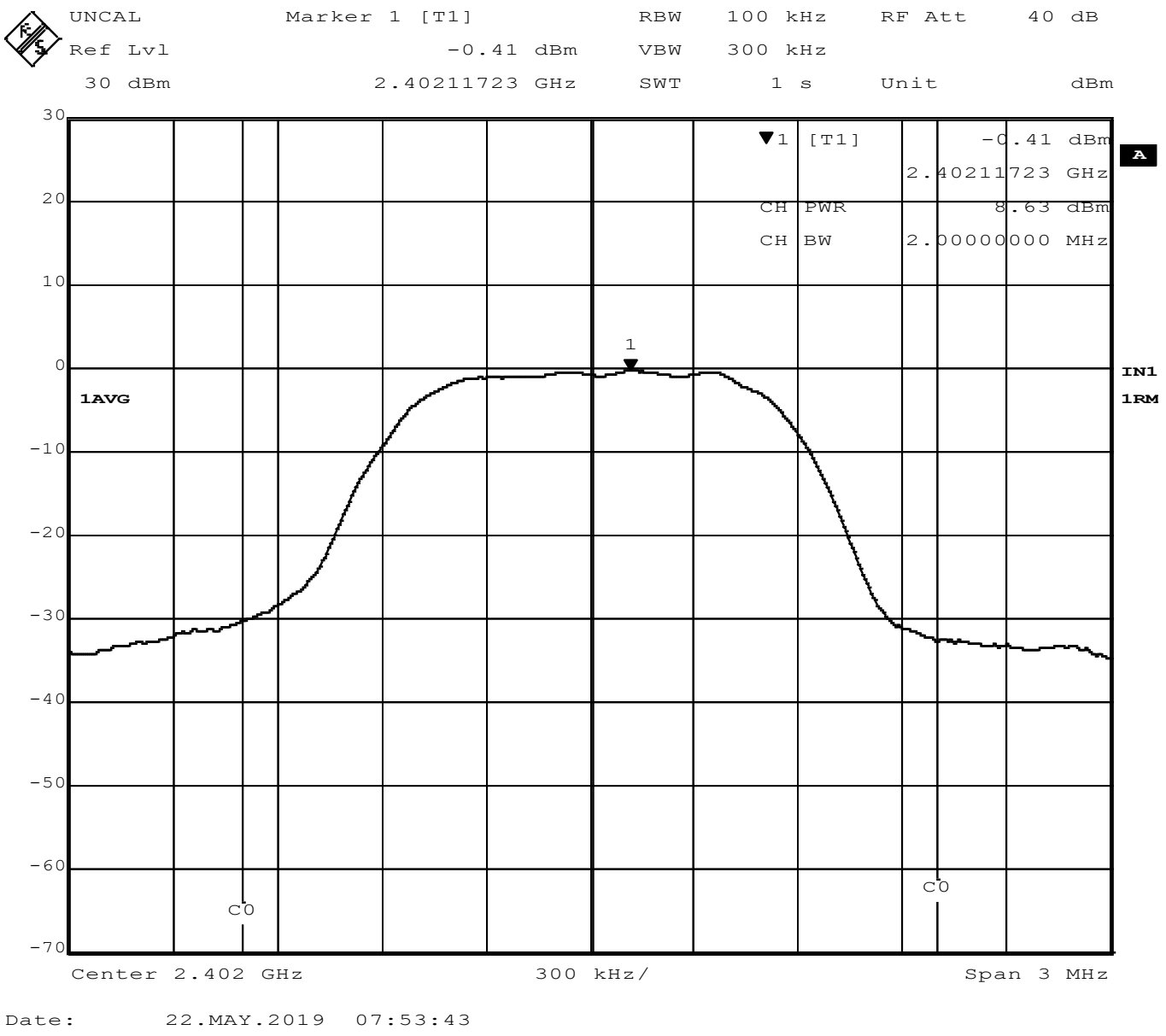

Figure 17 - Average Output Power, Low Channel, BT EDR 3MB

Average Output power = 8.63 dBm

Cable loss was less than 0.1 dB and not included

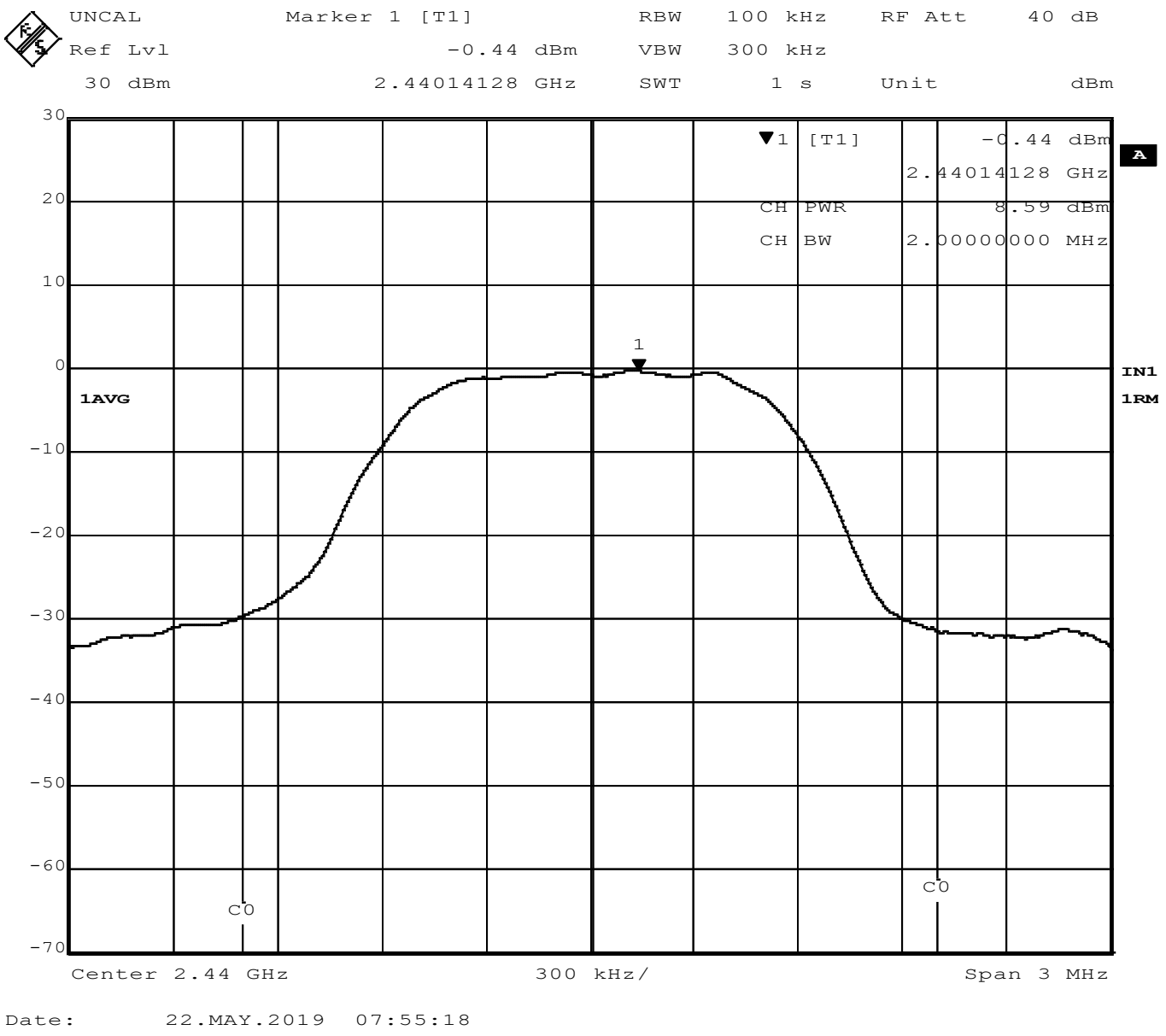

Figure 18 - Average Output Power, Mid Channel, BT EDR 3MB

Average Output power = 8.59 dBm

Cable loss was less than 0.1 dB and not included

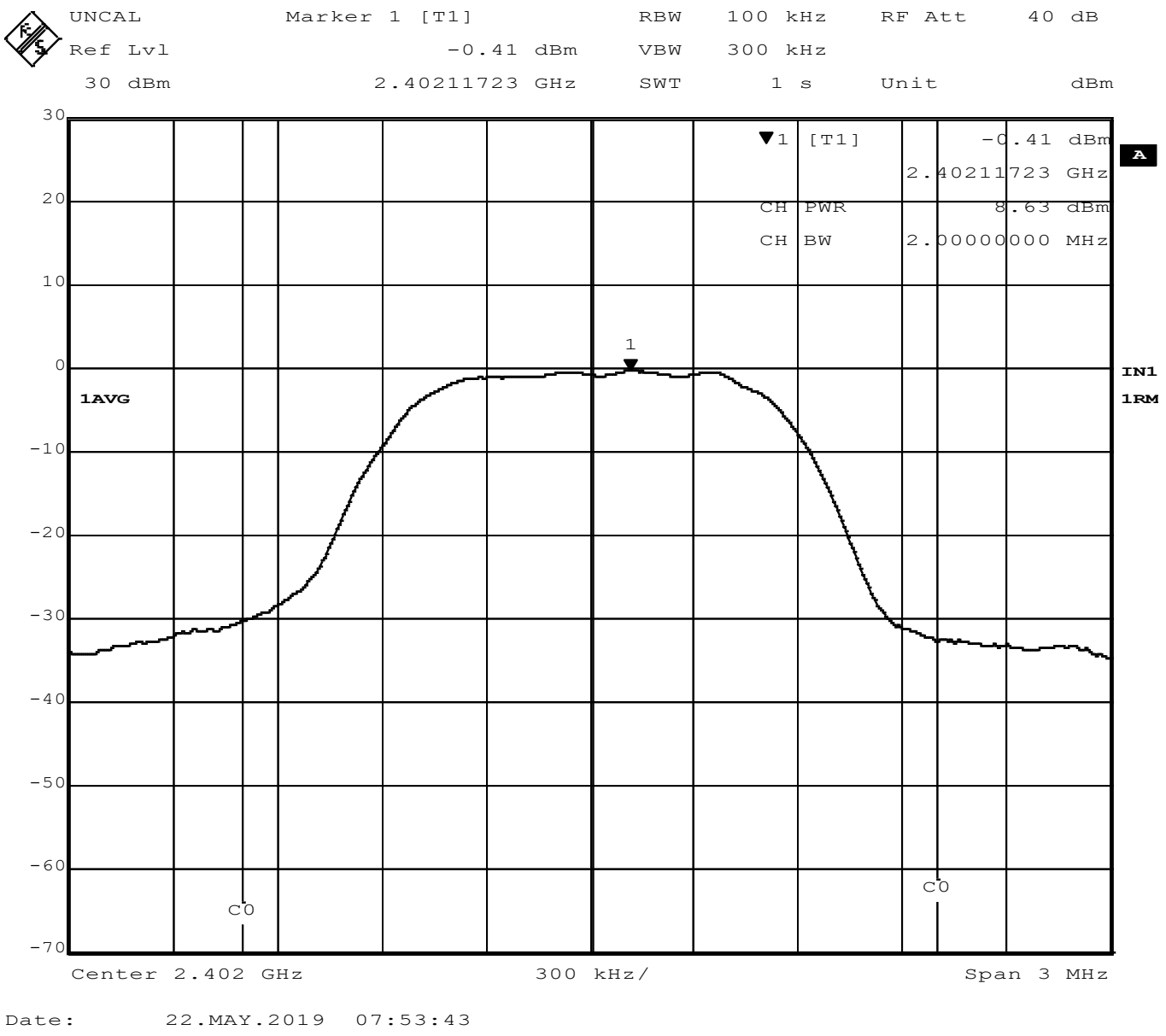

Figure 19 - Average Output Power, High Channel, BT EDR 3MB

Average Output power = 8.63 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:

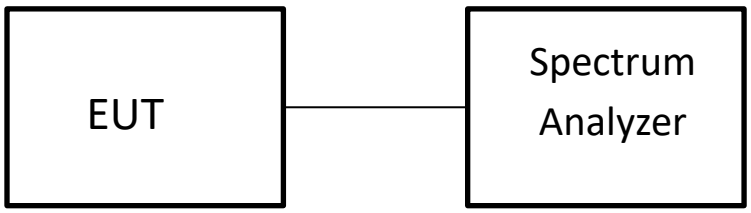

Figure 20 – Peak Output Power Measurements Test Setup

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. EUT was set to transmit in indicated modulation.

Test results:

Occupied Bandwidth

CHANNEL	Mode	CHANNEL FREQUENCY (MHz)	OBW (KHz)	RESULT
Low	BT BR (GFSK)	2402	1004.01	PASS
Mid	BT BR (GFSK)	2440	967.94	PASS
High	BT BR (GFSK)	2480	998.00	PASS
Low	BT EDR 2MB	2402	1304.61	PASS
Mid	BT EDR 2MB	2440	1328.66	PASS
High	BT EDR 2MB	2480	1304.61	PASS
Low	BT EDR 3MB	2402	1292.59	PASS
Mid	BT EDR 3MB	2440	1316.63	PASS
High	BT EDR 3MB	2480	1304.61	PASS

6dB Bandwidth

CHANNEL	Mode	CHANNEL FREQUENCY (MHz)	6dB Bandwidth (KHz)	RESULT
Low	BT BR (GFSK)	2402	535.07	PASS
Mid	BT BR (GFSK)	2440	535.07	PASS
High	BT BR (GFSK)	2480	535.07	PASS
Low	BT EDR 2MB	2402	1082.16	PASS
Mid	BT EDR 2MB	2440	1082.16	PASS
High	BT EDR 2MB	2480	1076.15	PASS
Low	BT EDR 3MB	2402	1106.21	PASS
Mid	BT EDR 3MB	2440	1106.09	PASS
High	BT EDR 3MB	2480	1106.21	PASS

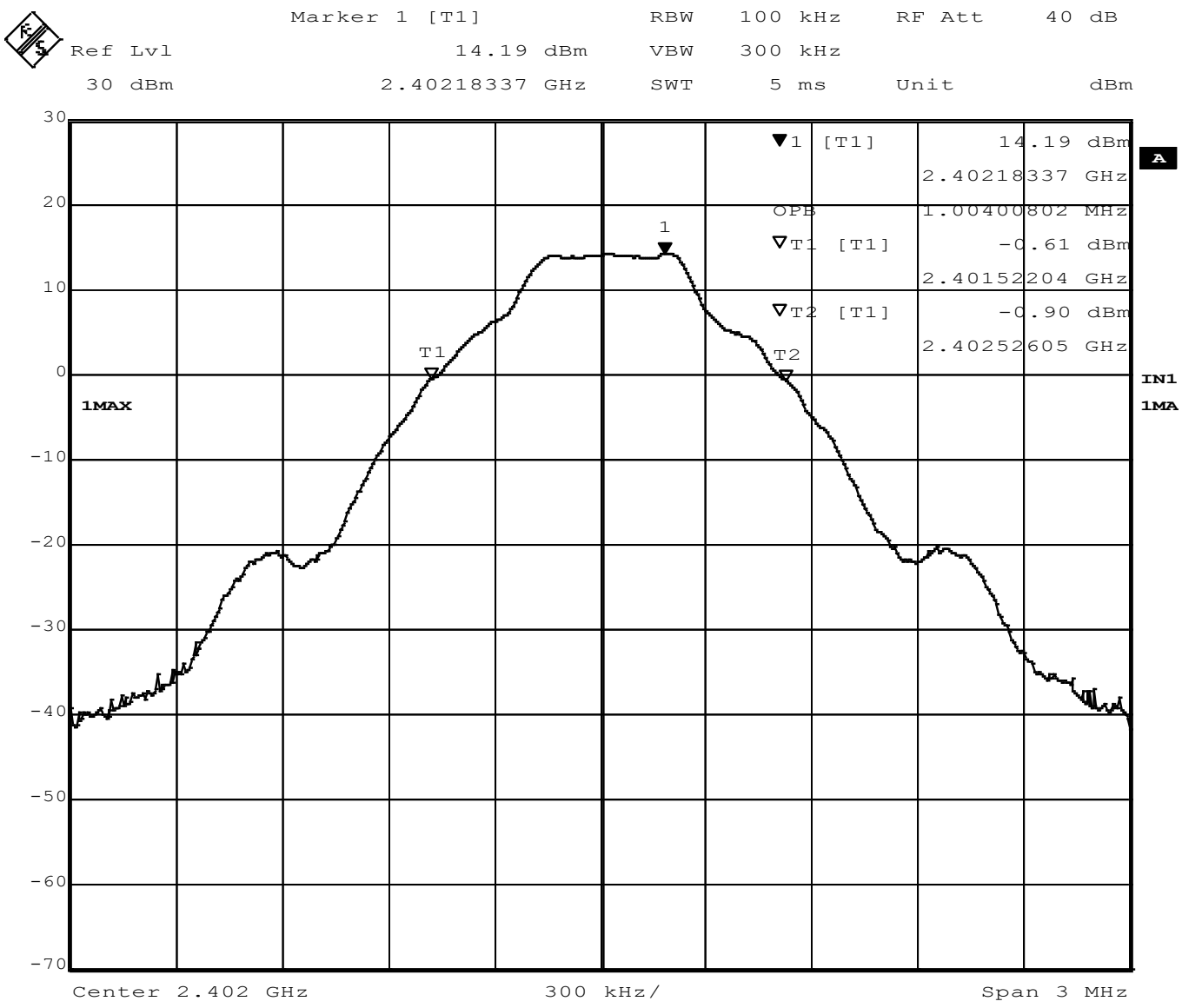

Figure 21 – Occupied Bandwidth, Low Channel, BT BR (GFSK)

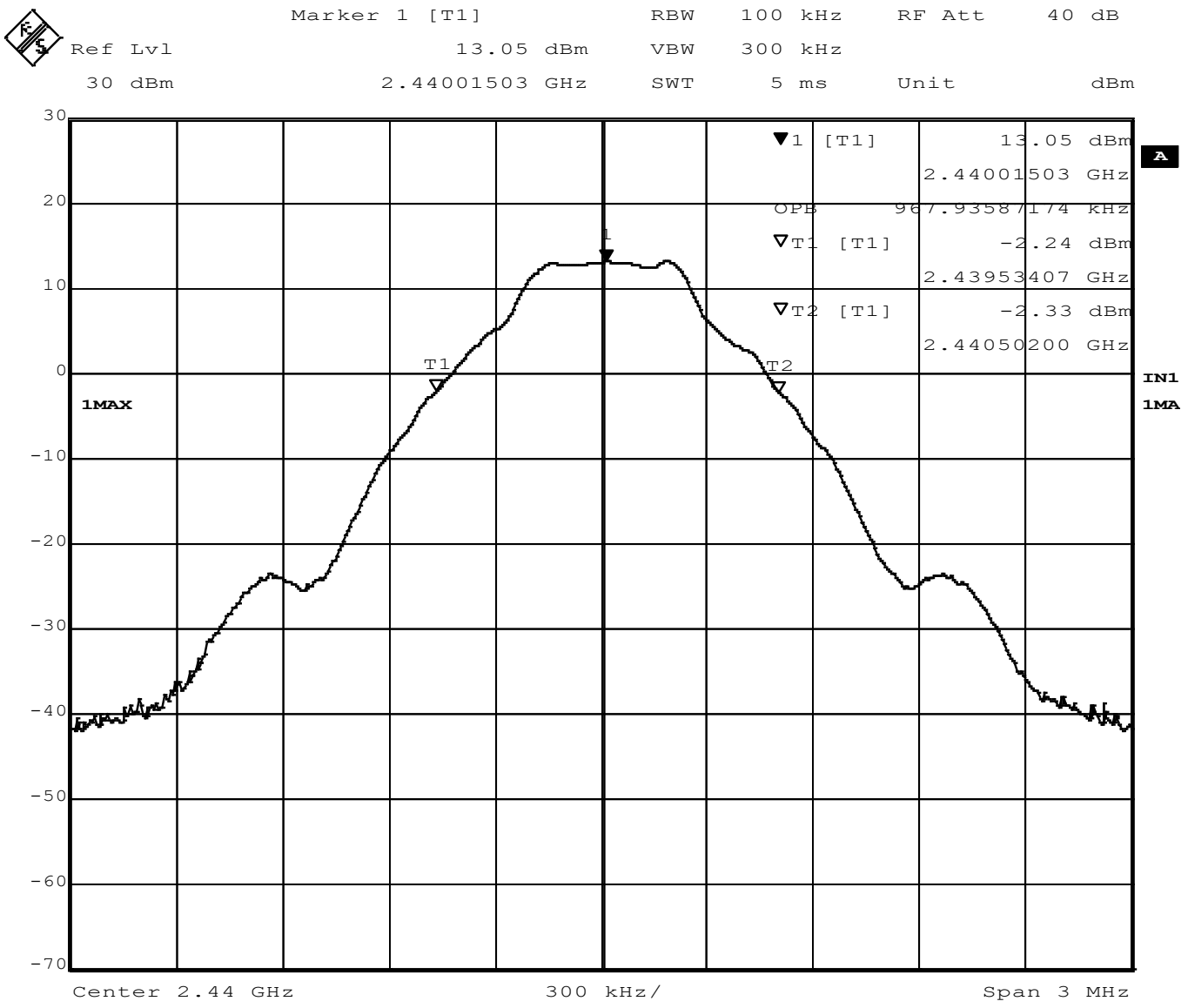

Figure 22 - Occupied Bandwidth, Mid Channel, BT BR (GFSK)

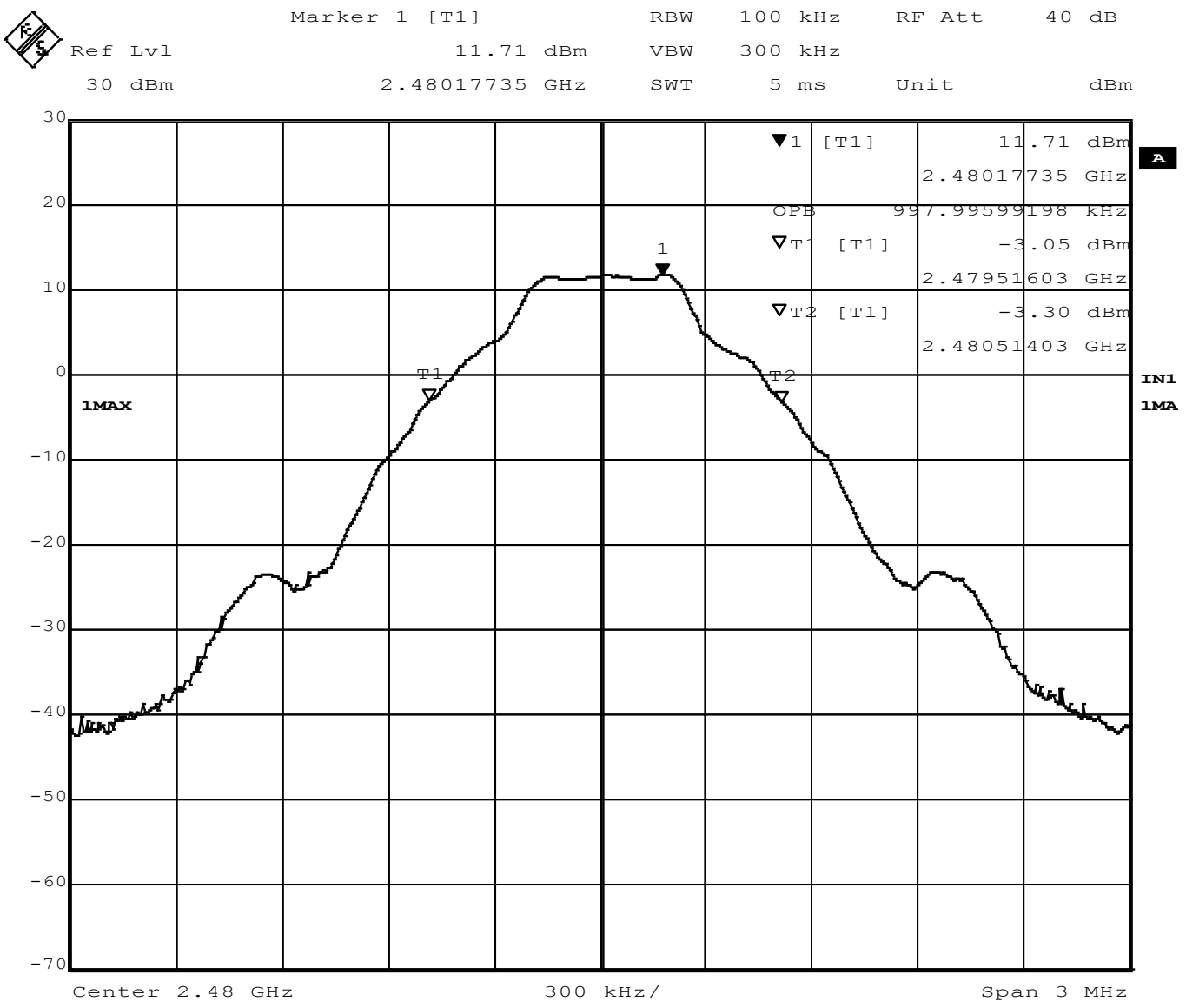

Figure 23 - Occupied Bandwidth, High Channel, BT BR (GFSK)

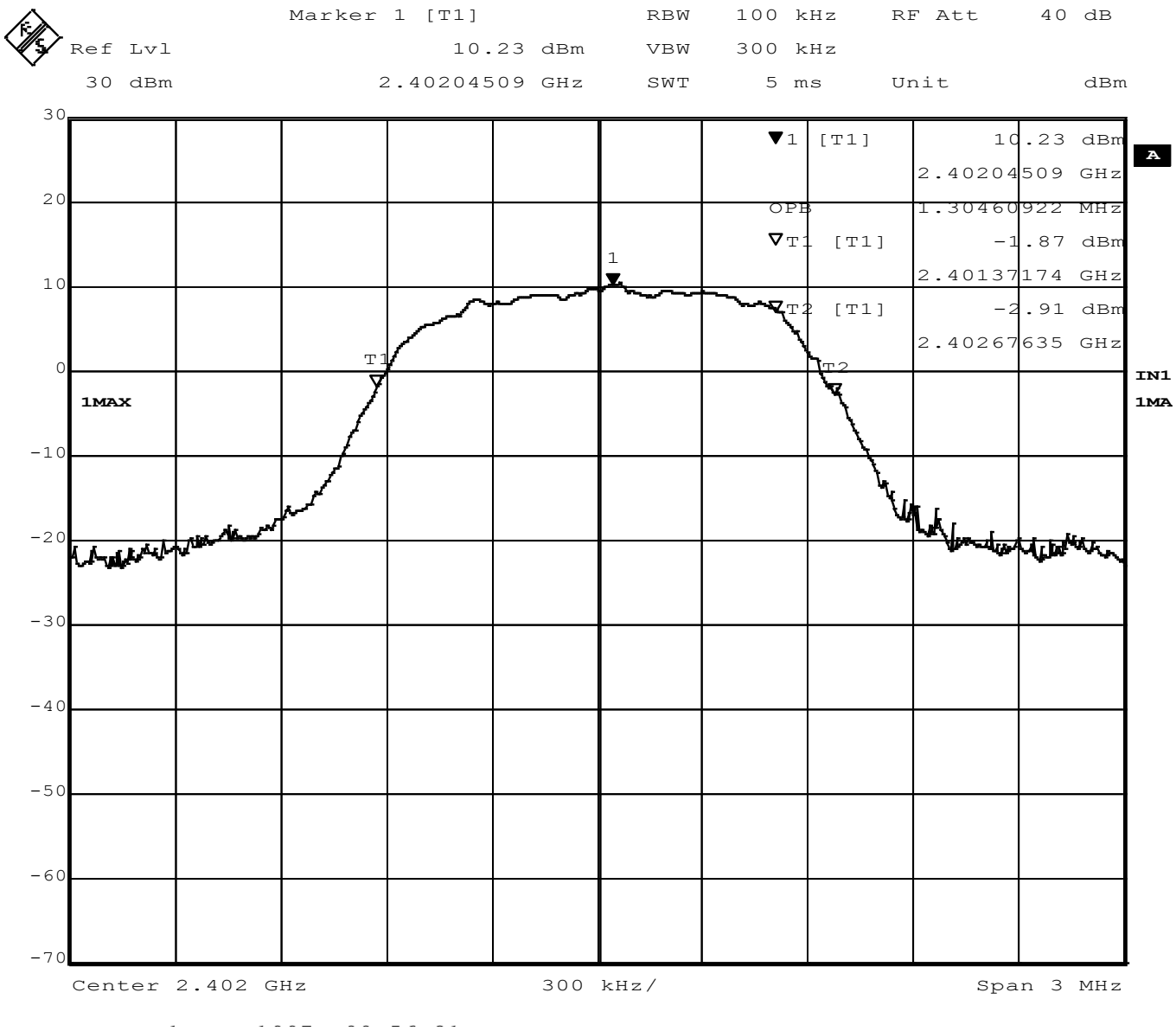

Figure 24 – Occupied Bandwidth, Low Channel, BT EDR 2MB

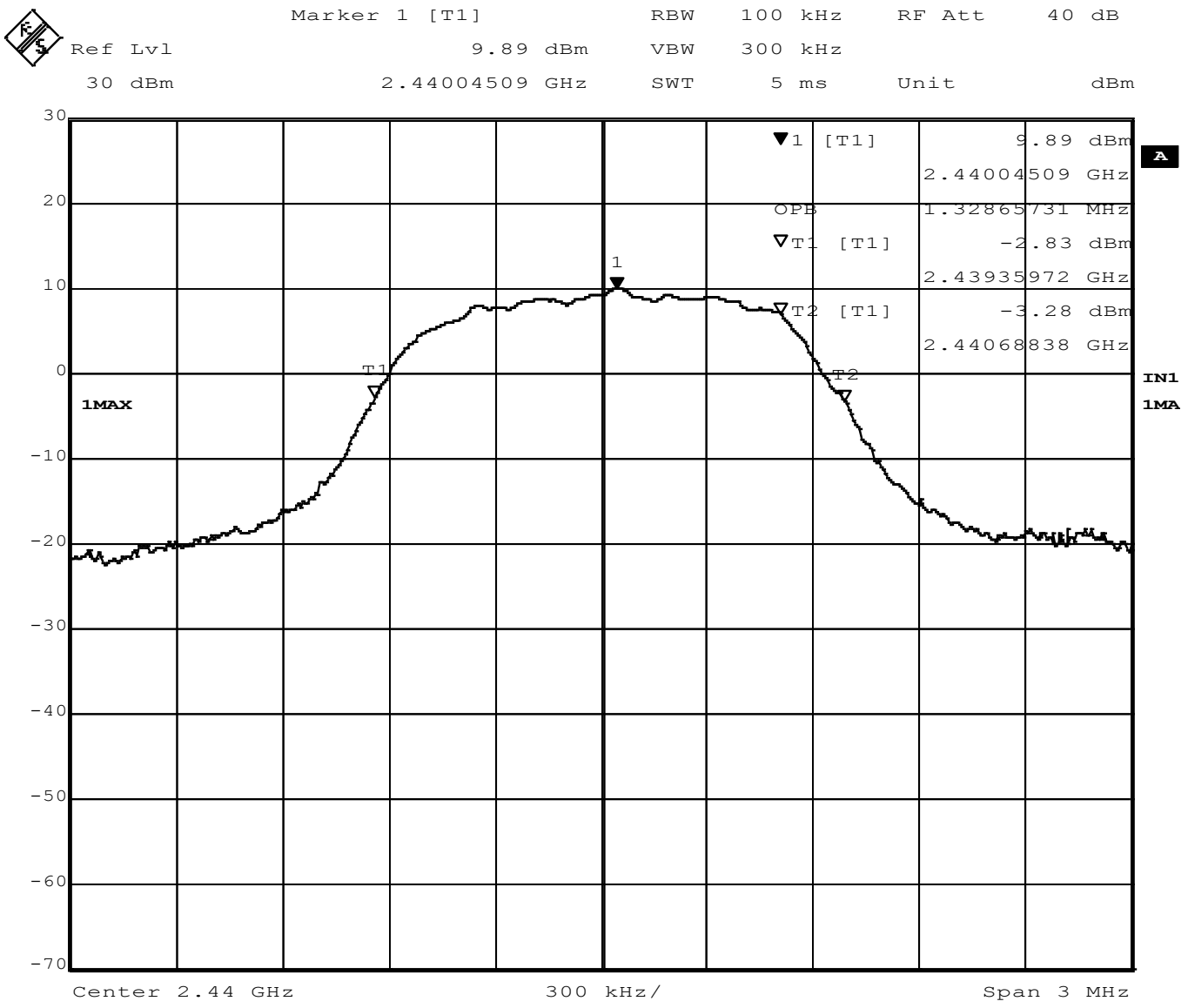

Figure 25 - Occupied Bandwidth, Mid Channel, BT EDR 2MB

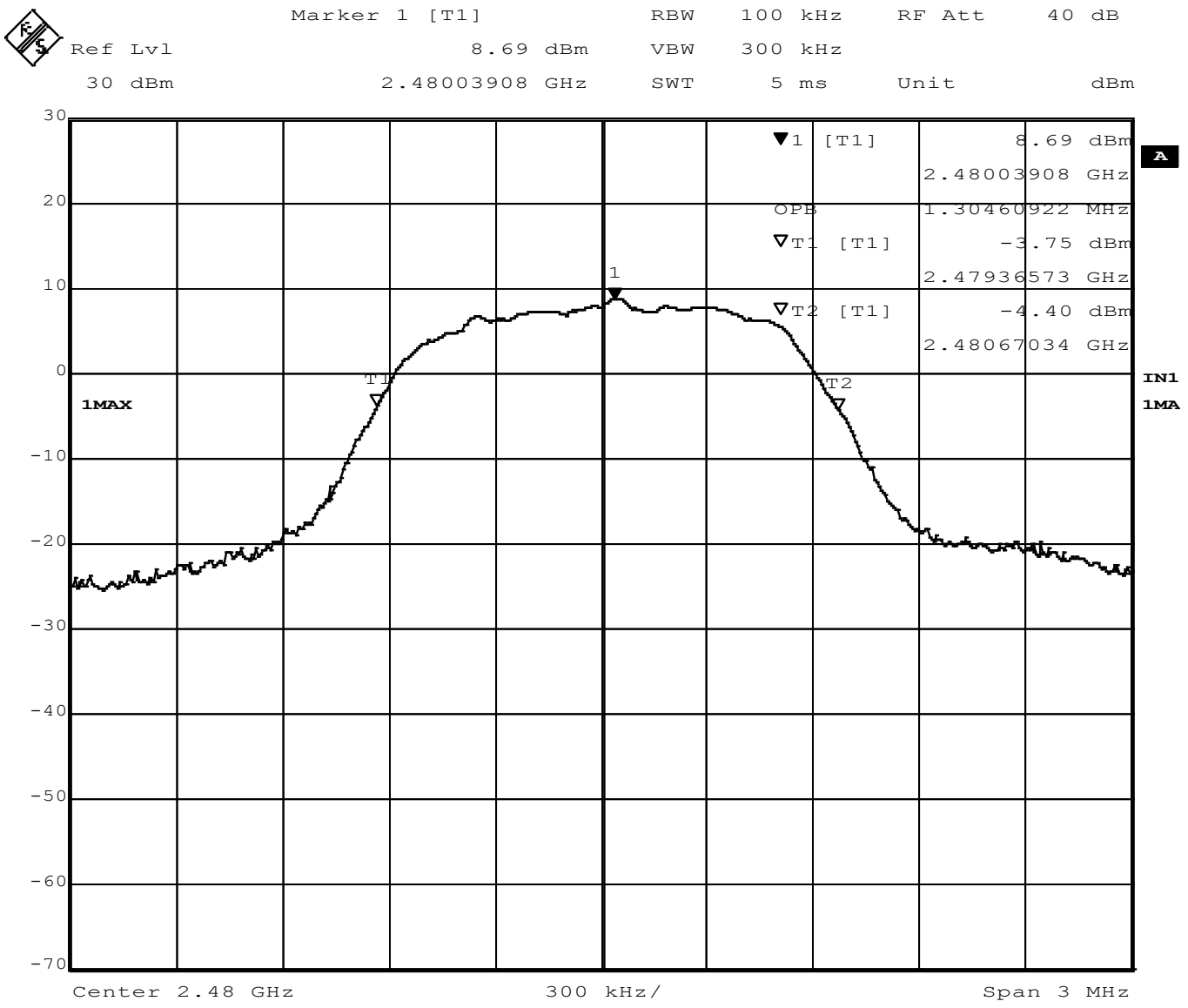

Figure 26 - Occupied Bandwidth, High Channel, BT EDR 2MB

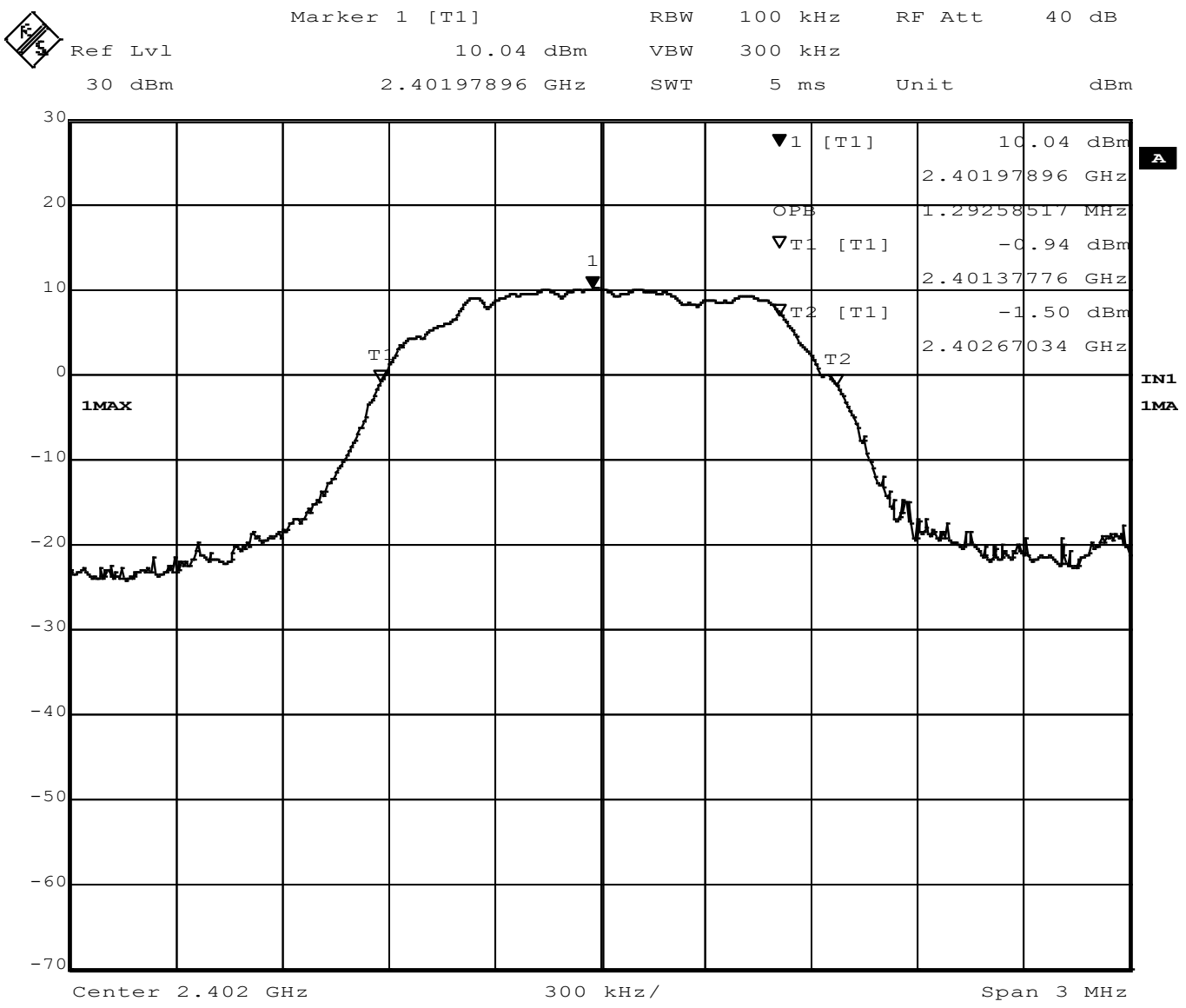

Figure 27 – Occupied Bandwidth, Low Channel, BT EDR 3MB

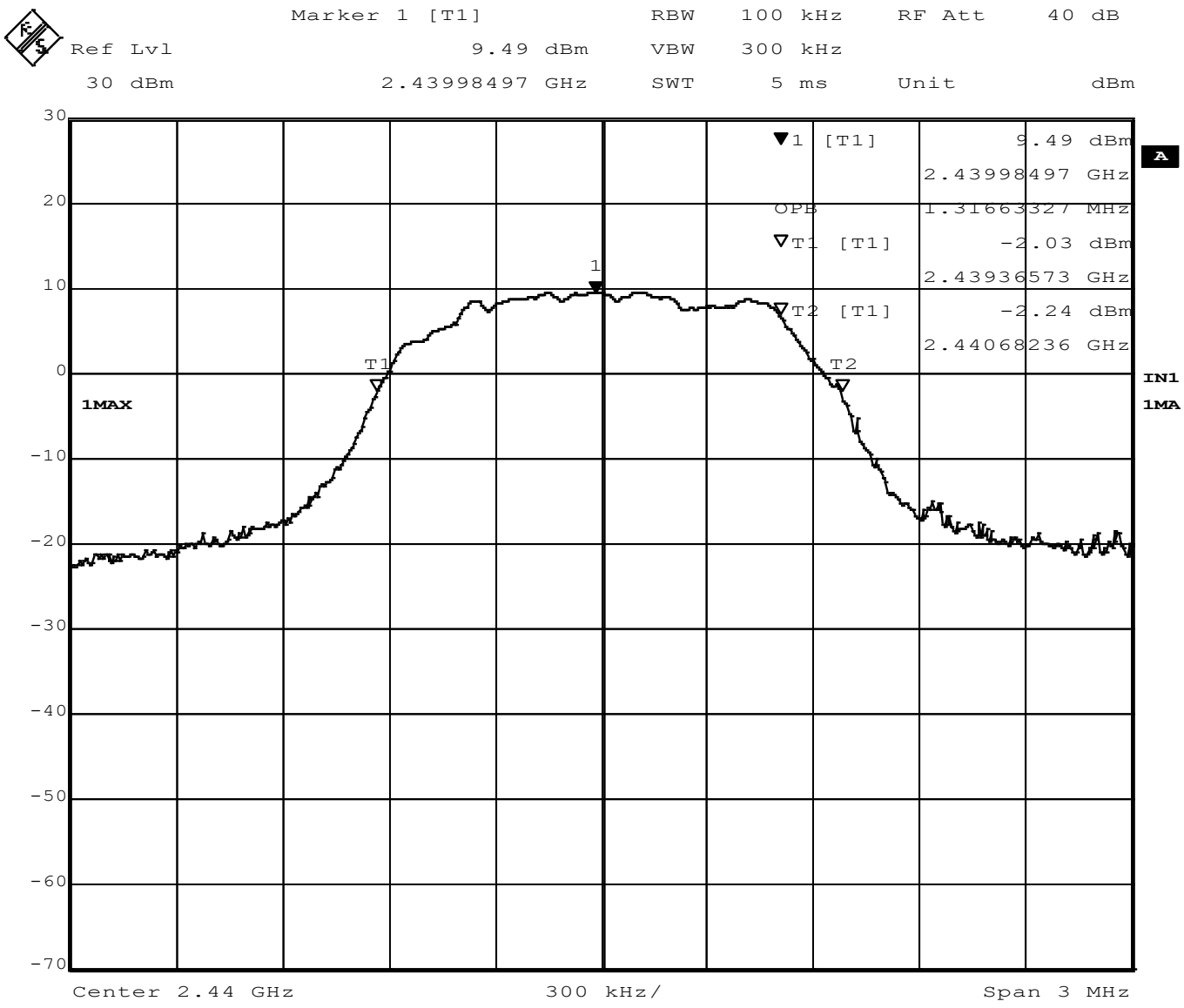

Figure 28 - Occupied Bandwidth, Mid Channel, BT EDR 3MB

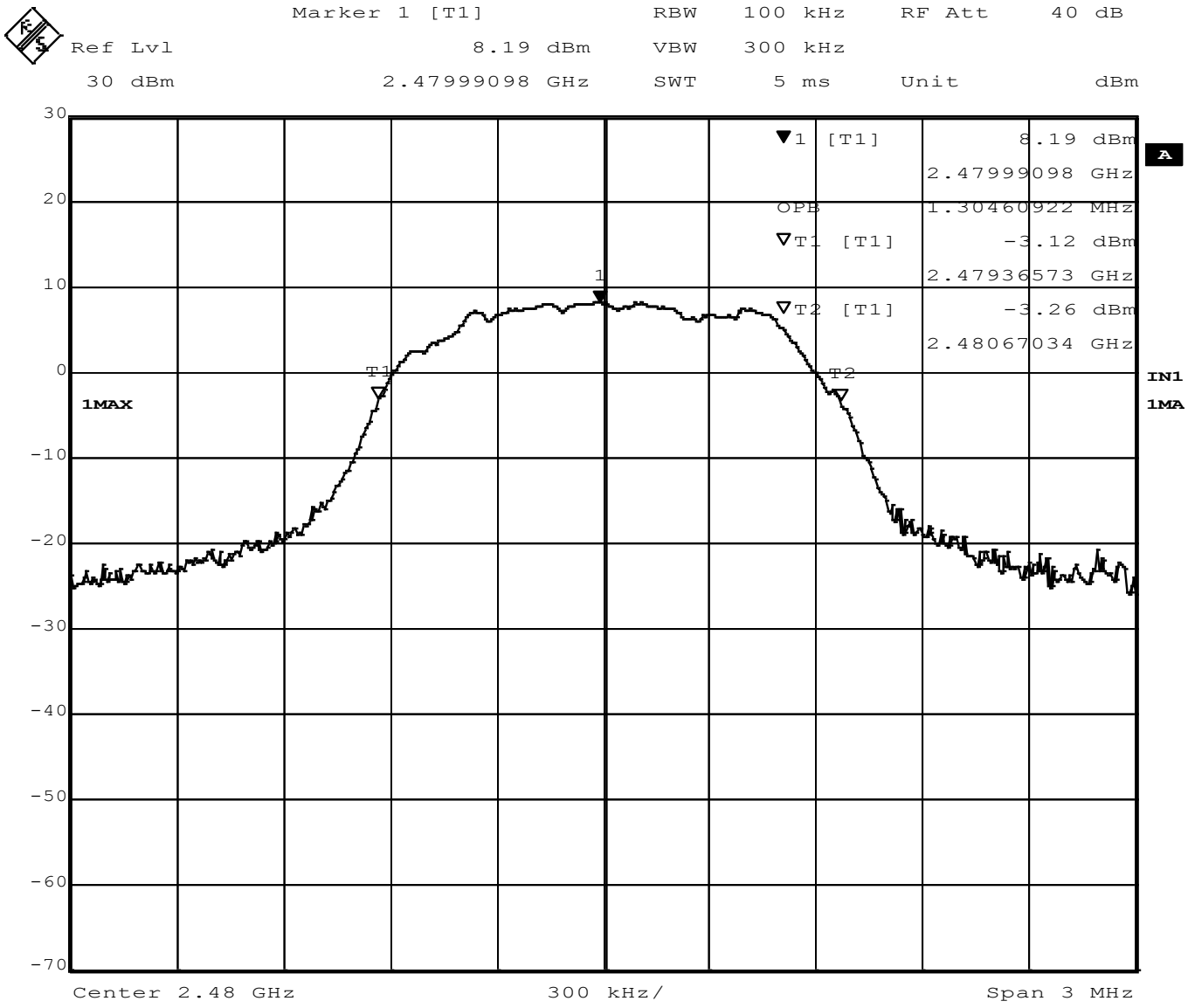

Figure 29 - Occupied Bandwidth, High Channel, BT EDR 3MB

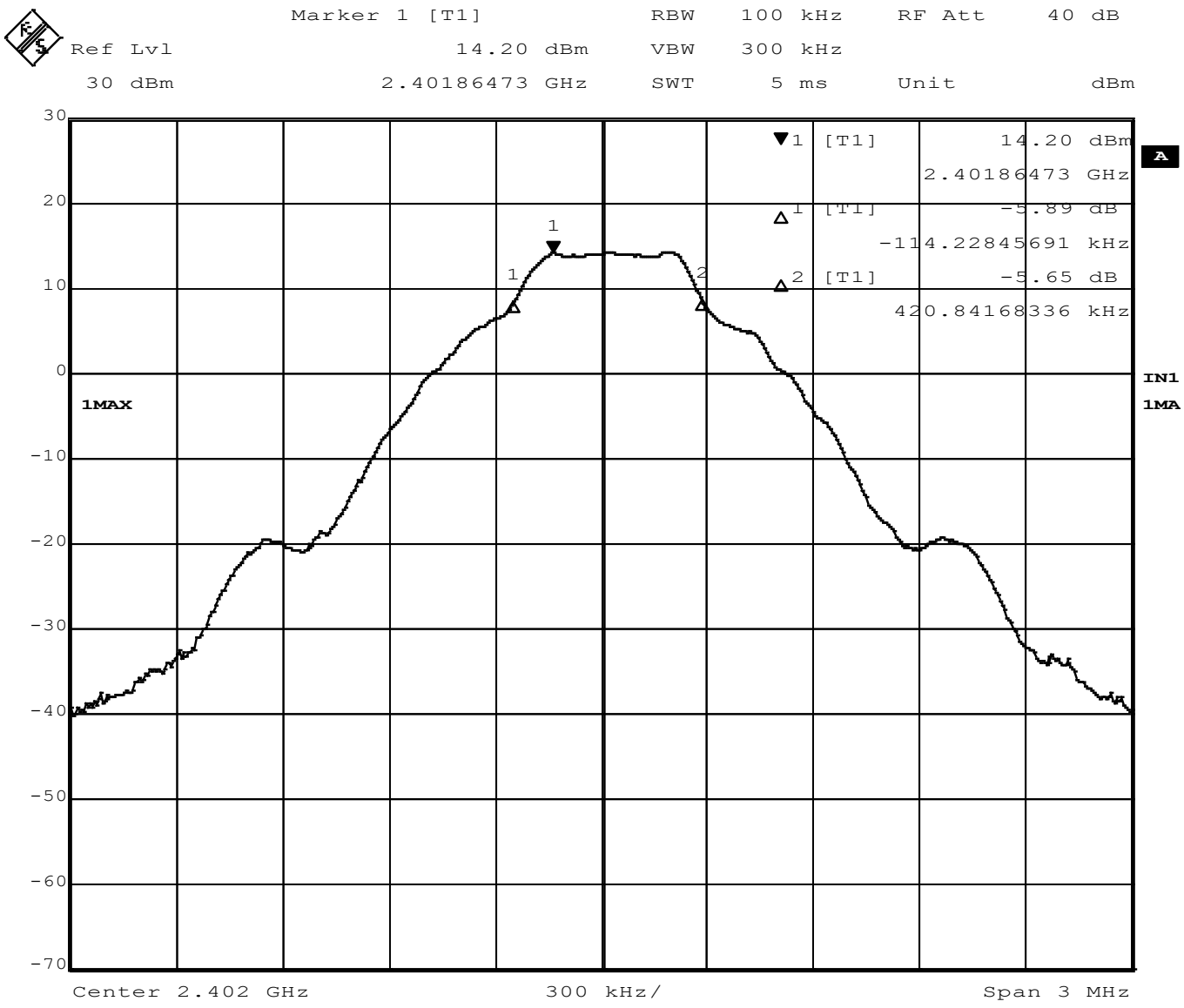

Figure 30 – 6dB Bandwidth, Low Channel, BT BR (GFSK)

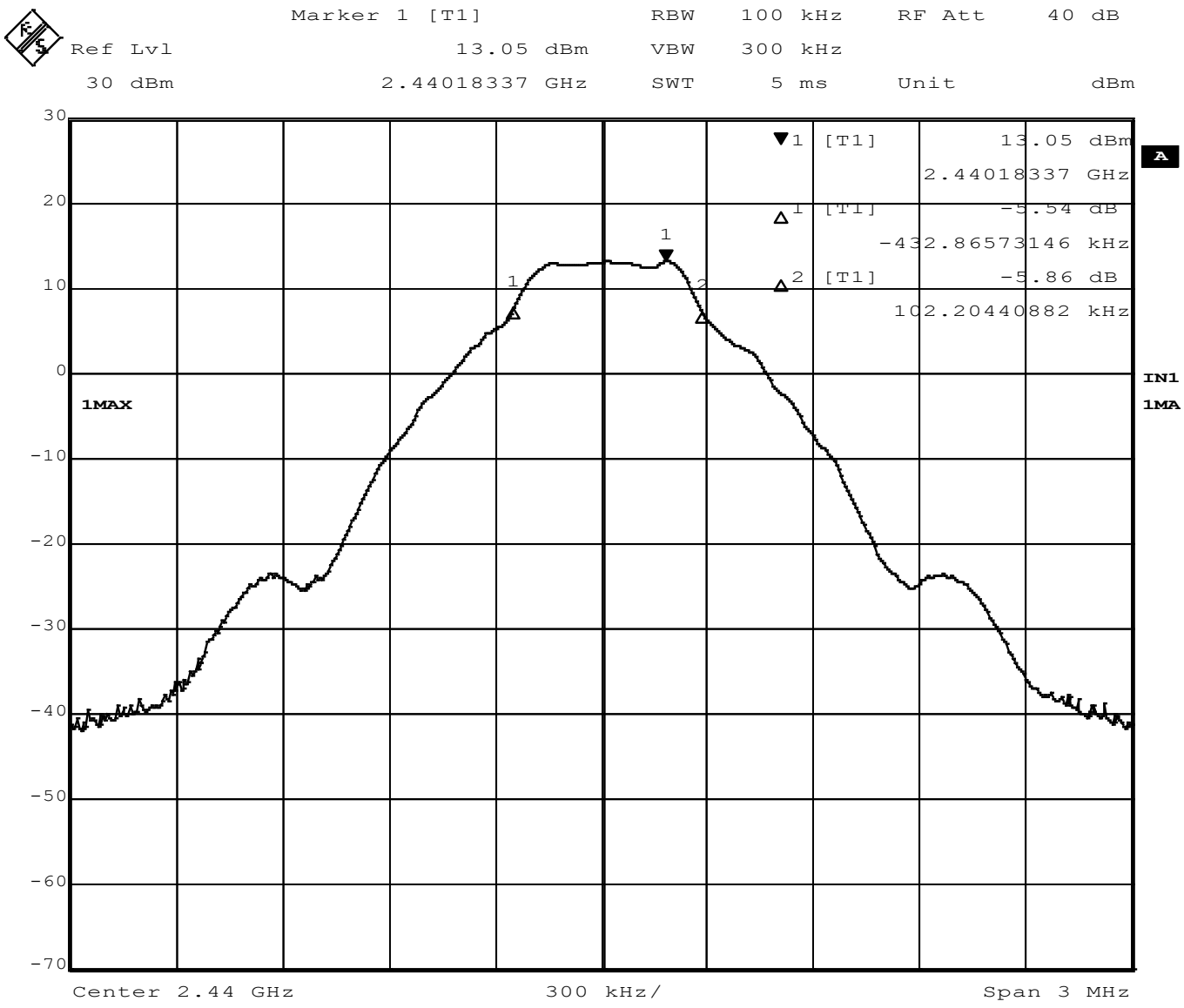

Figure 31 – 6dB Bandwidth, Mid Channel, BT BR (GFSK)

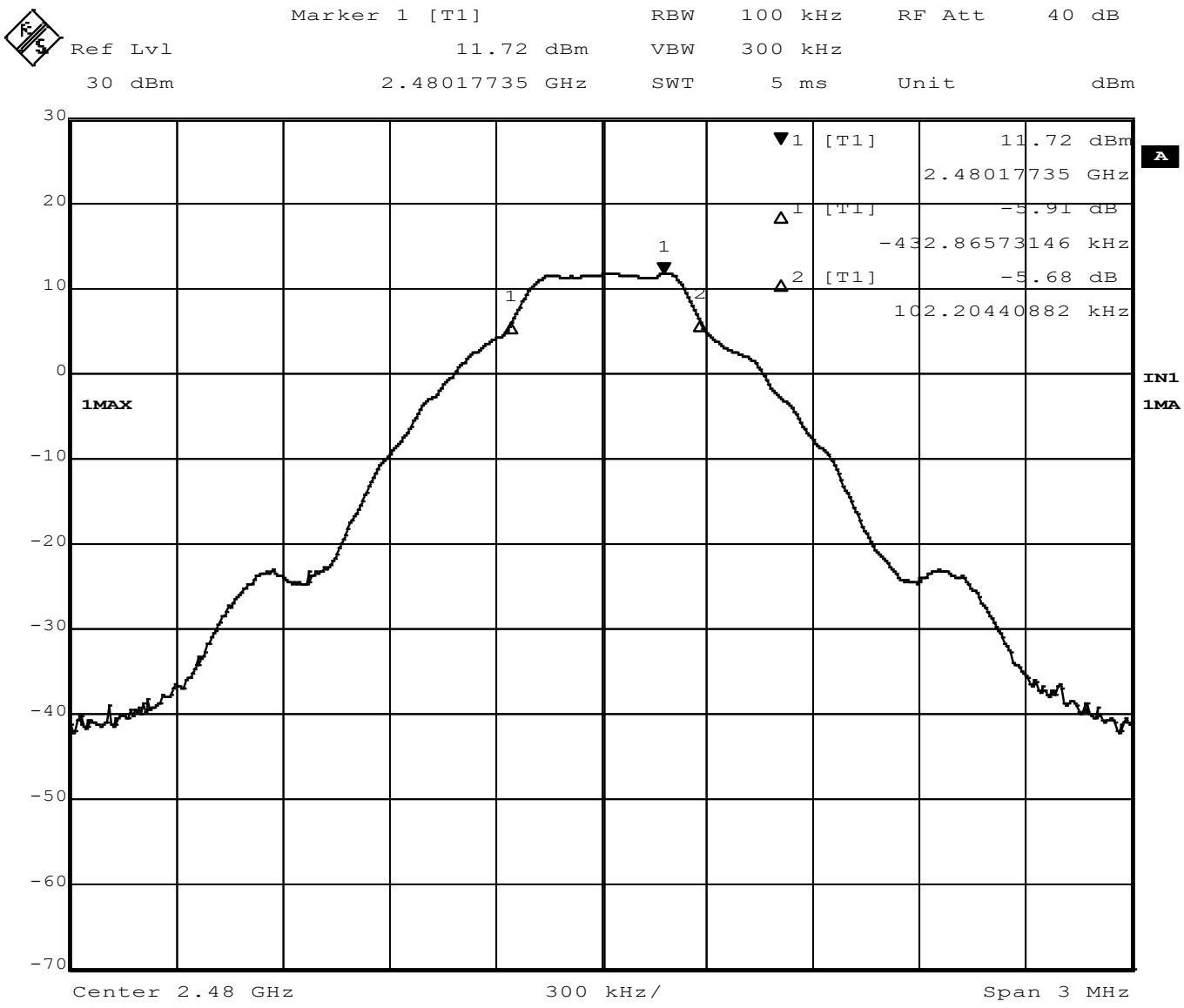

Figure 32 – 6dB Bandwidth, High Channel, BT BR (GFSK)

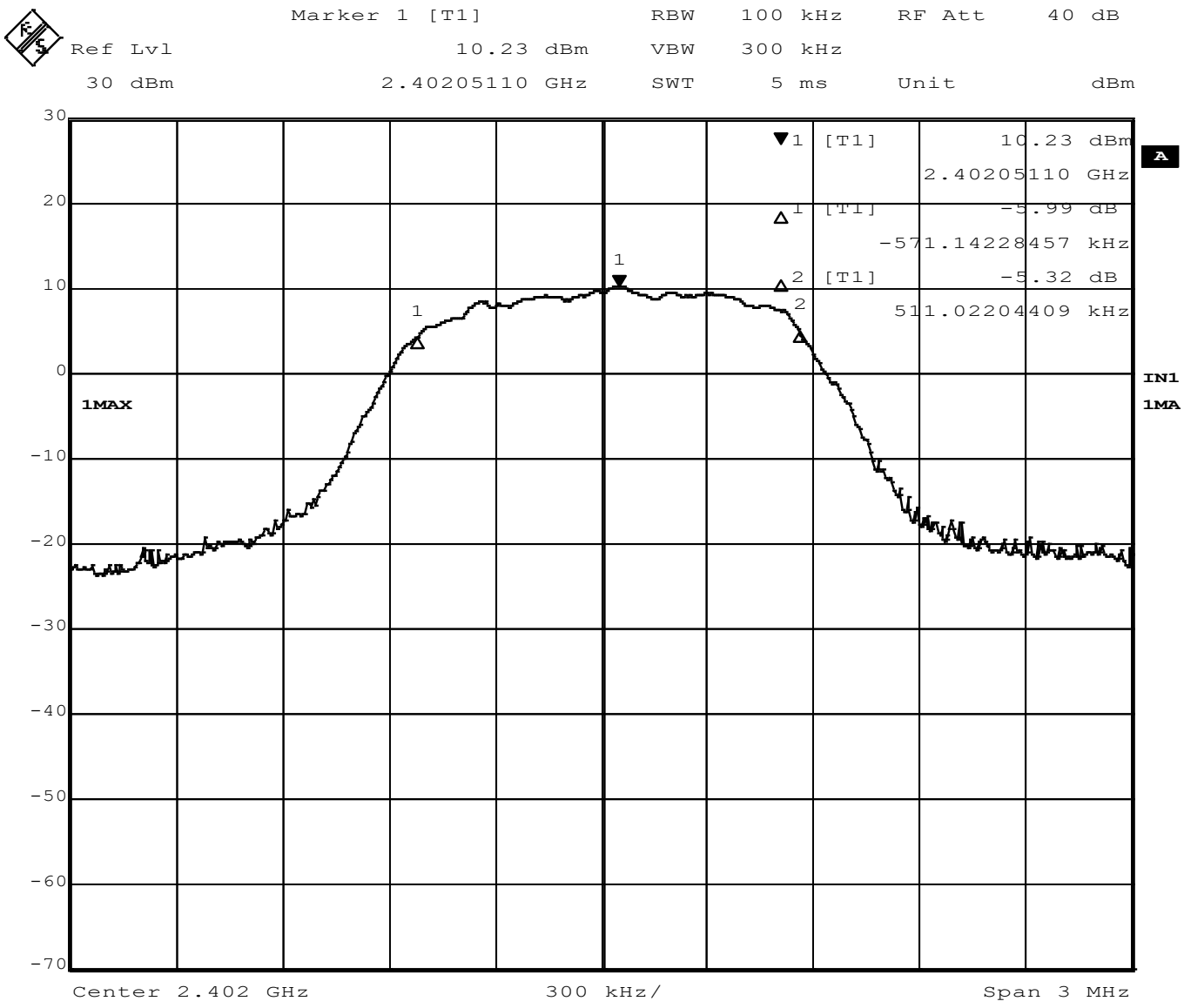

Figure 33 – 6dB Bandwidth, Low Channel, BT EDR 2MB

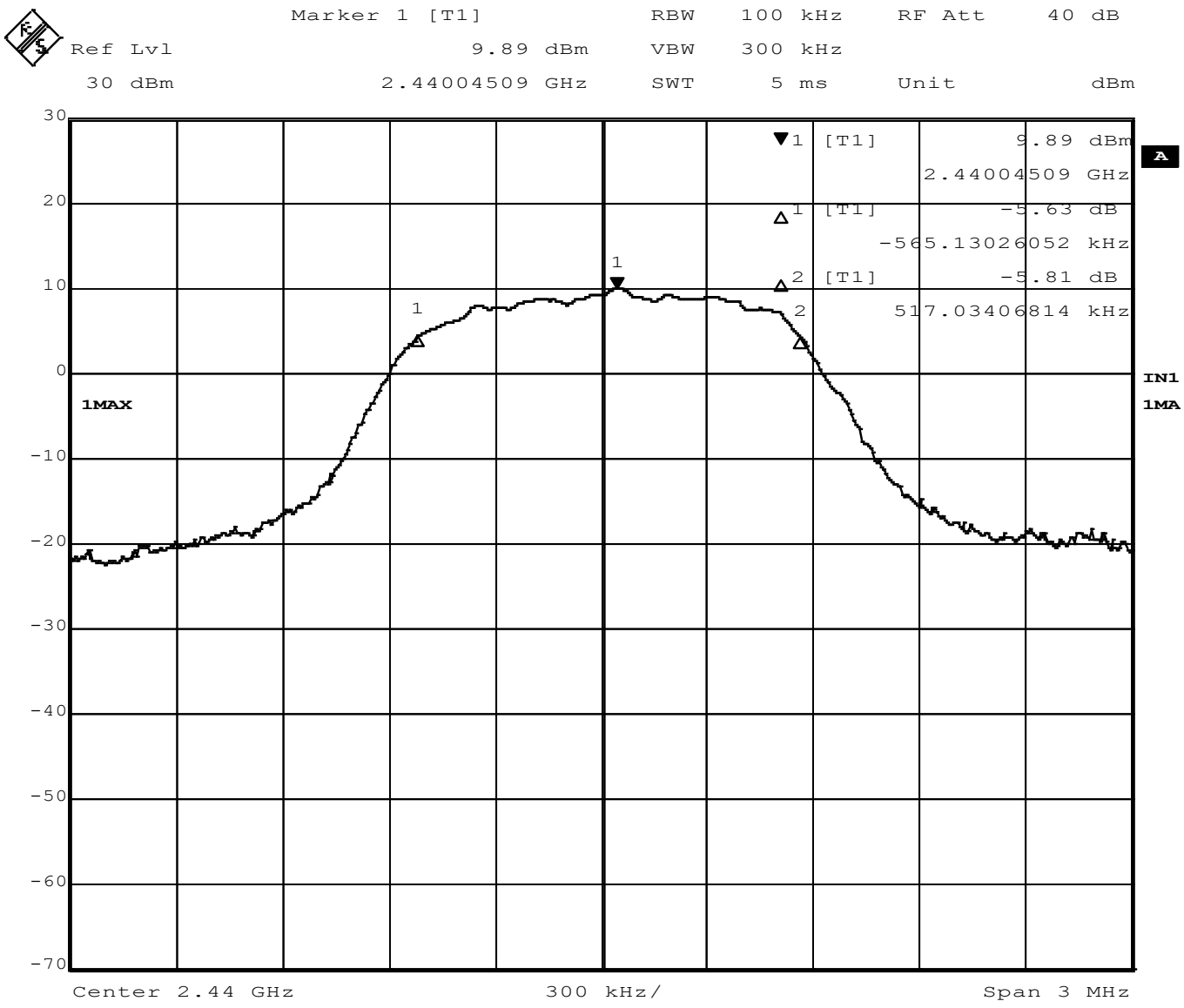

Figure 34 – 6dB Bandwidth, Mid Channel, BT EDR 2MB

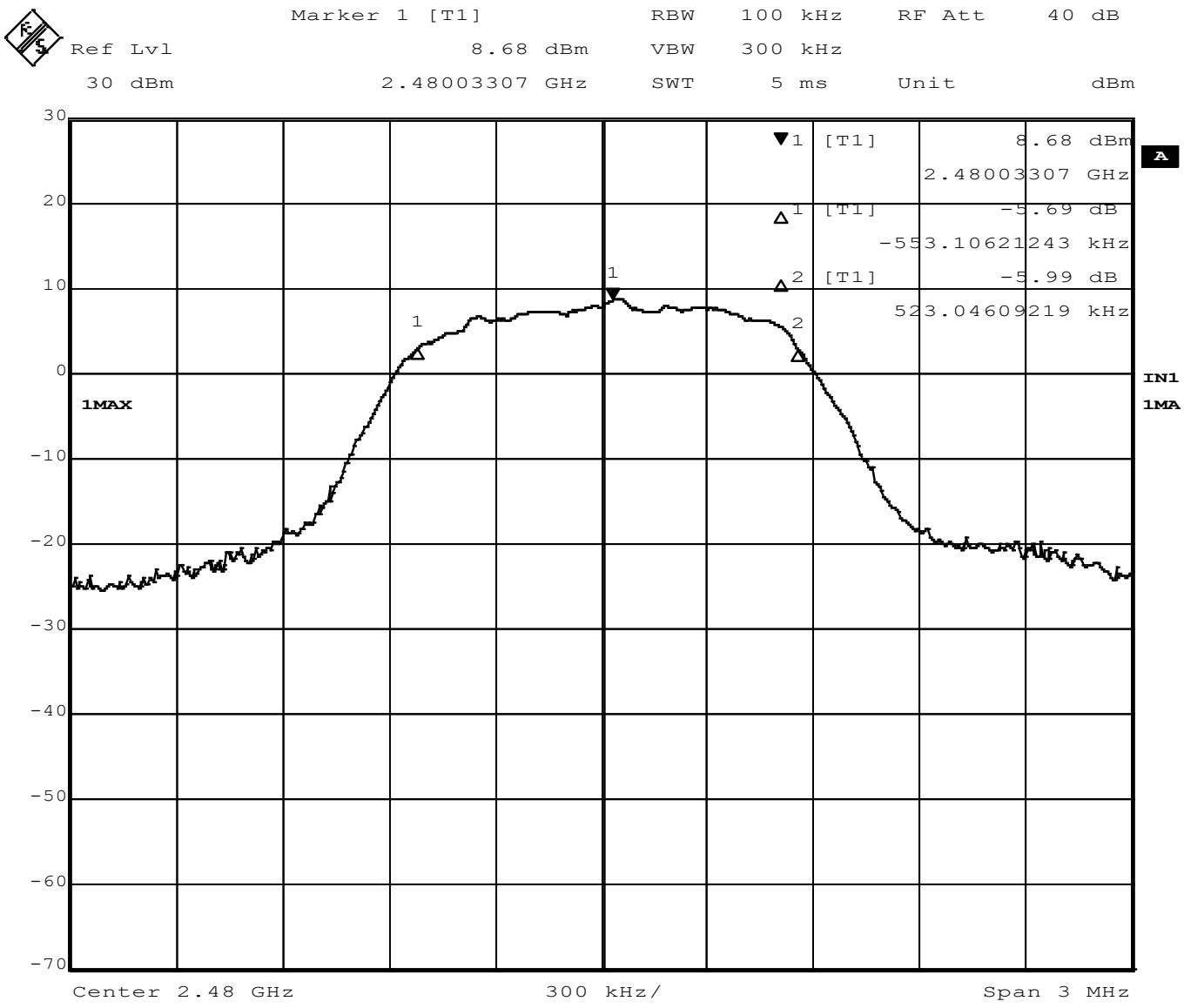

Figure 35 – 6dB Bandwidth, High Channel, BT EDR 2MB

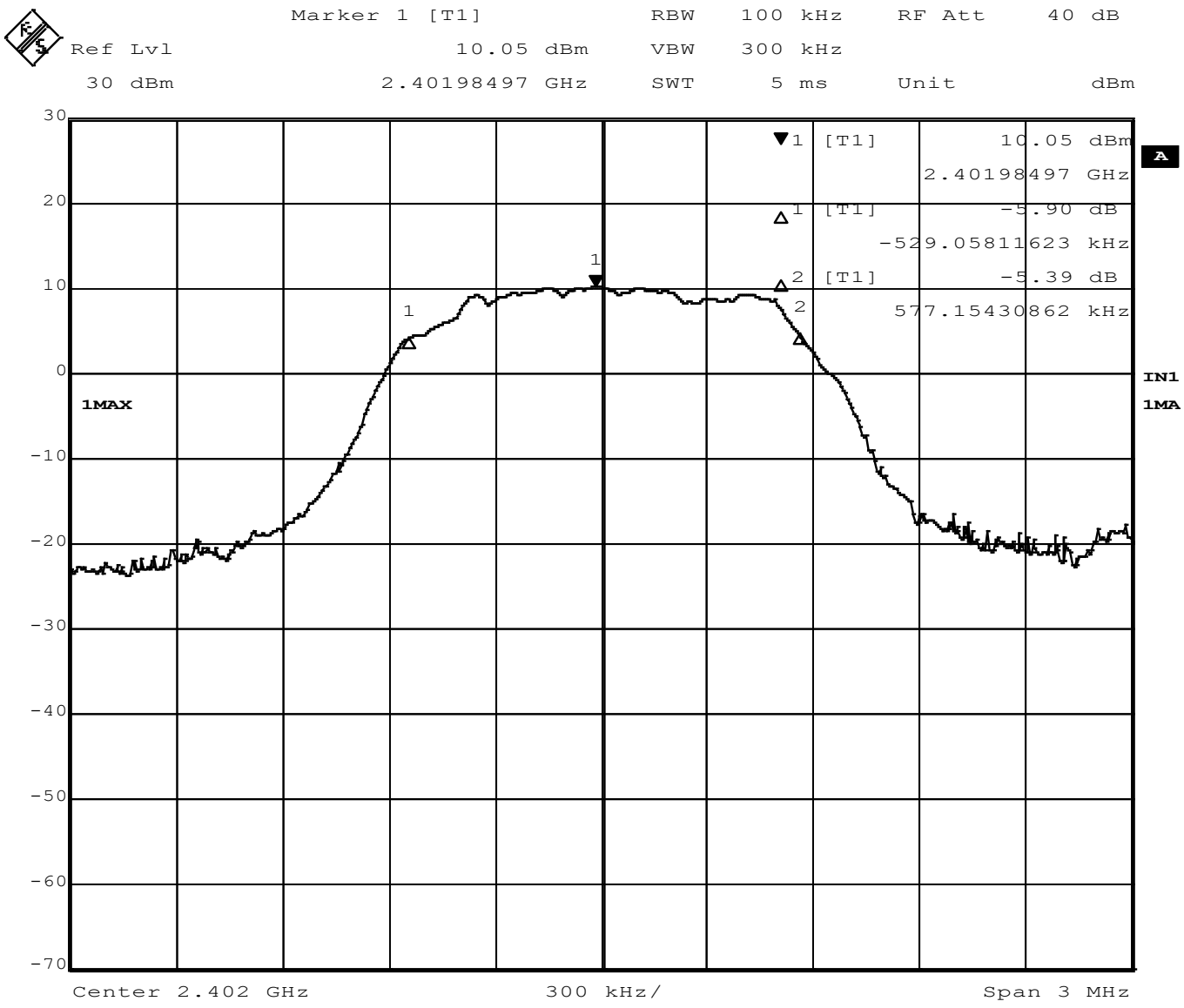

Figure 36 – 6dB Bandwidth, Low Channel, BT EDR 3MB

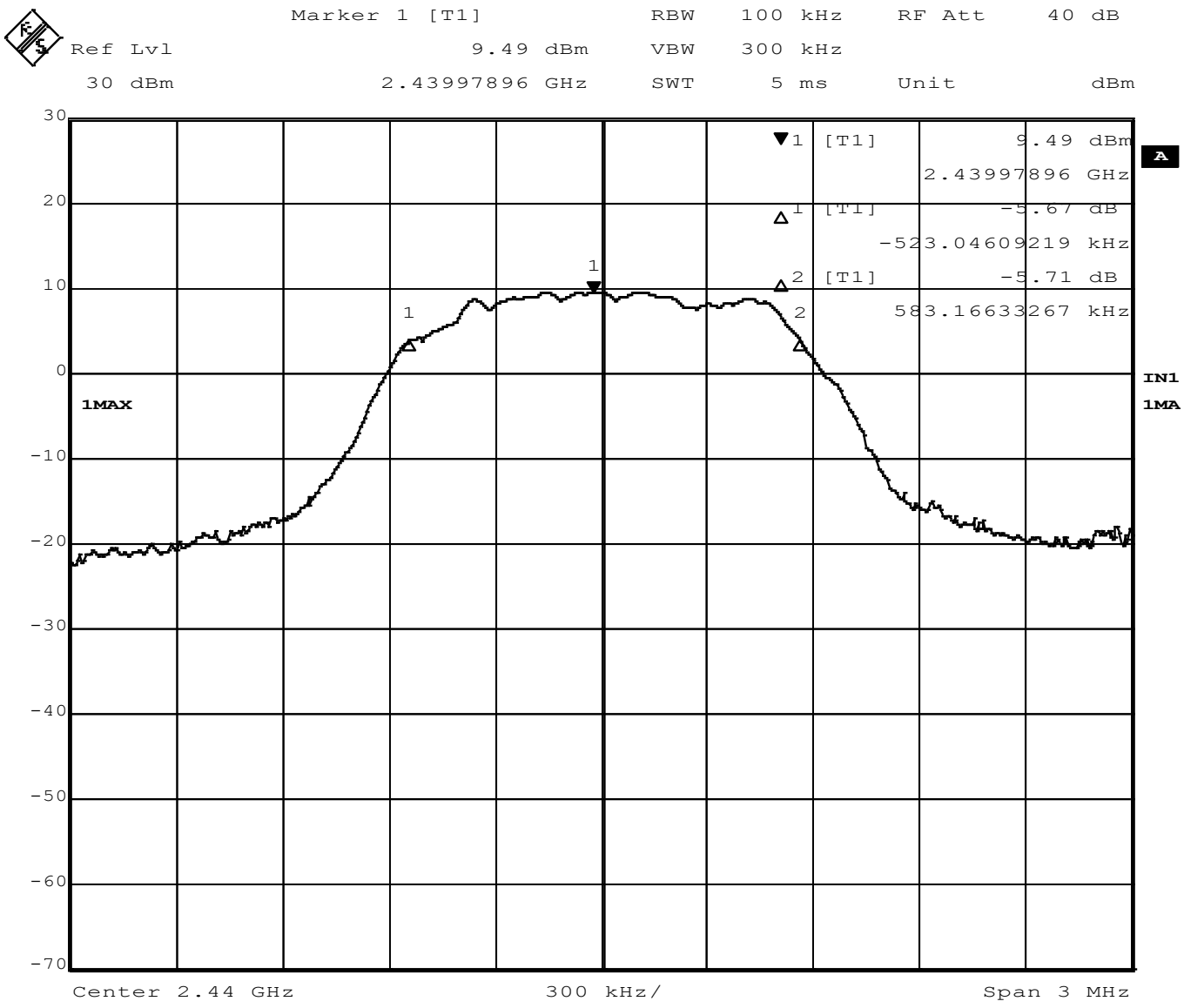

Figure 37 – 6dB Bandwidth, Mid Channel, BT EDR 3MB

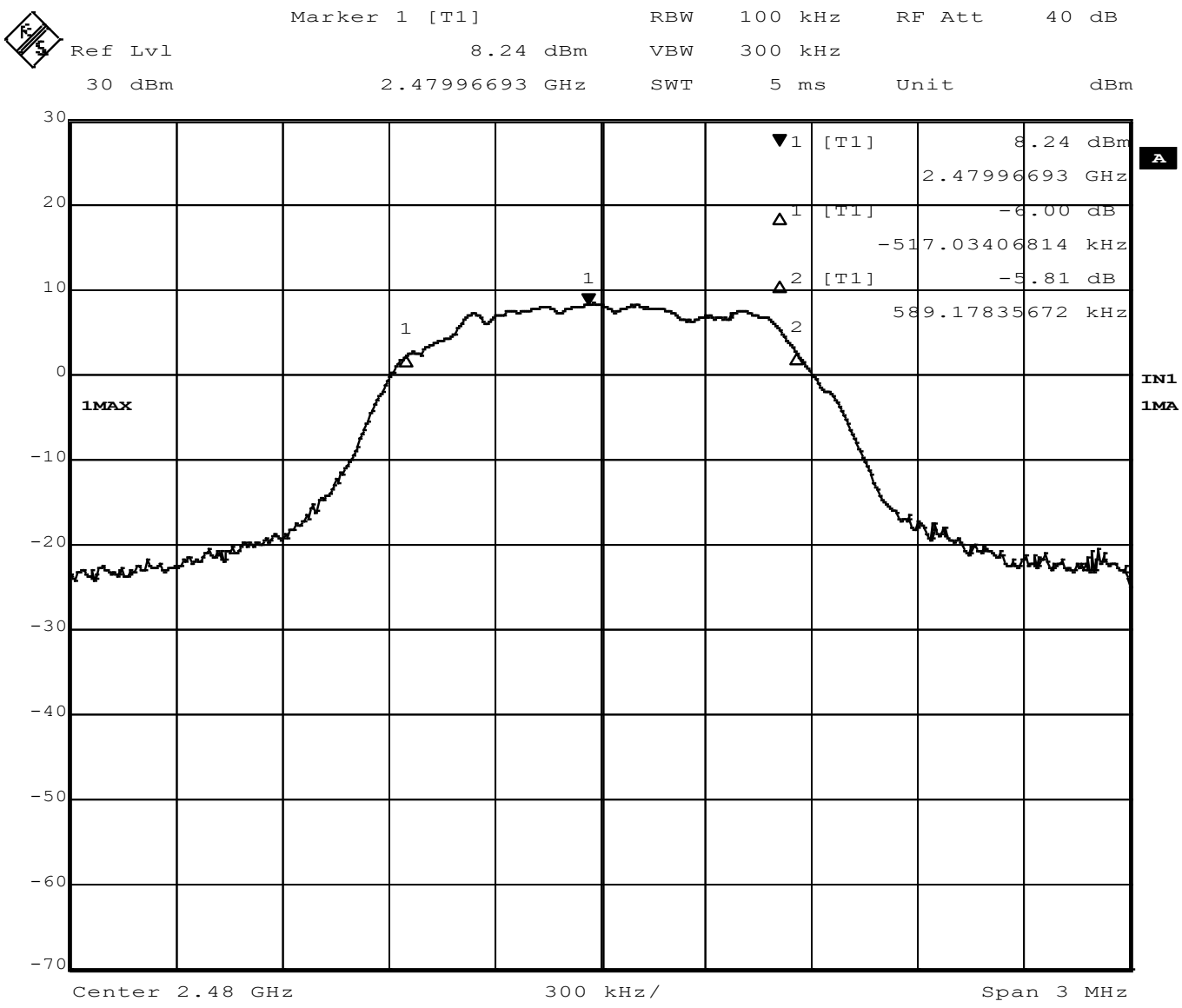

Figure 38 – 6dB Bandwidth, High Channel, BT EDR 3MB

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. The EUT was maximized in all 3 orthogonal positions. The results are presented for the axis that had the highest emissions.

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:

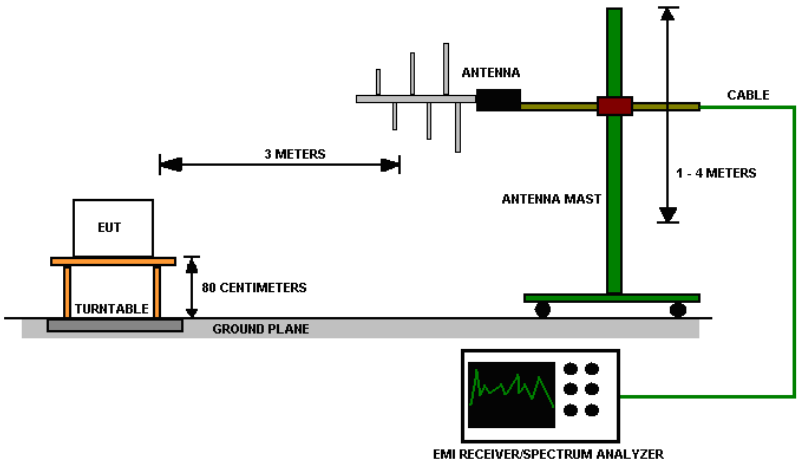

Figure 39 - Radiated Emissions Test Setup

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 indicated modulation.

Test results:

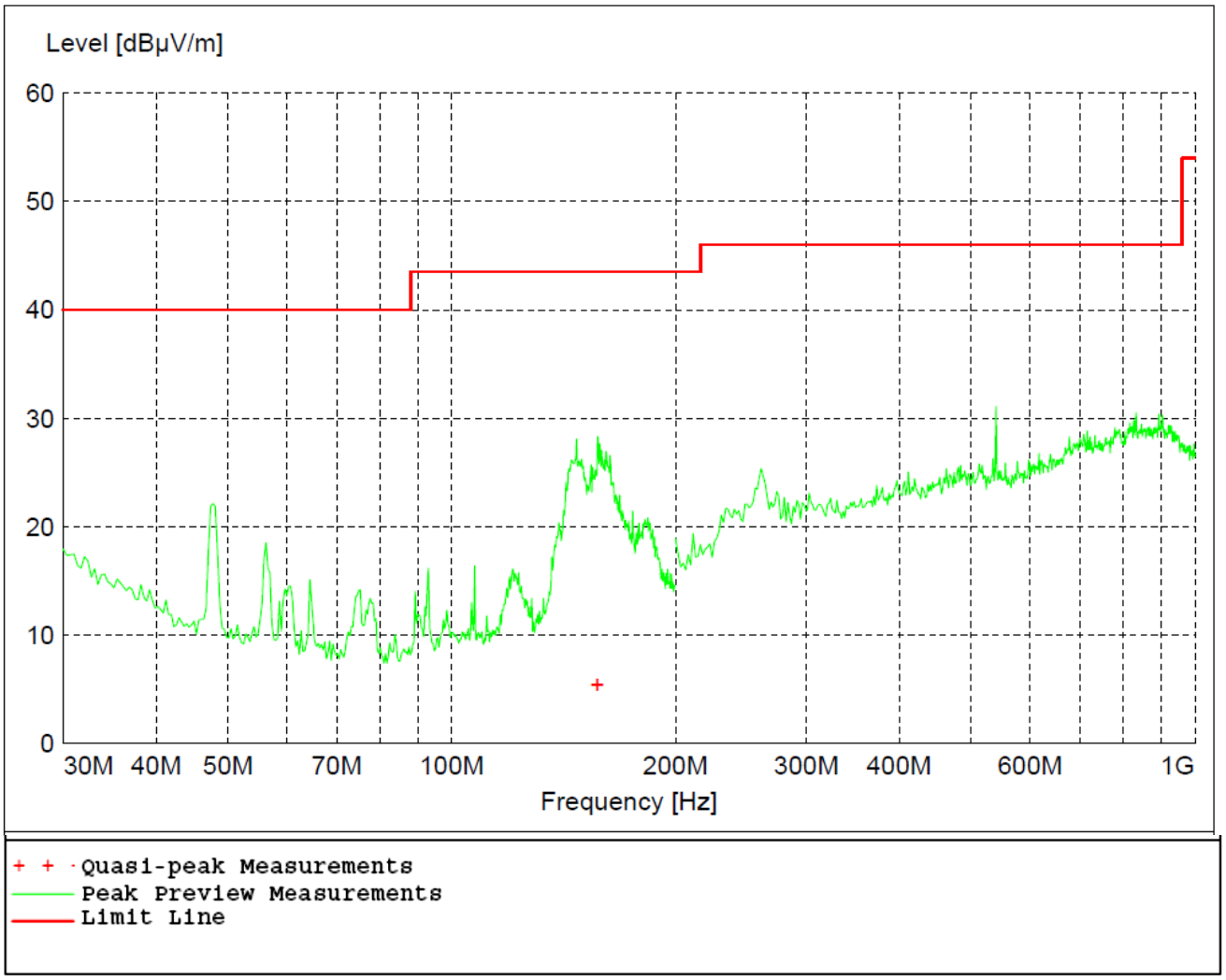

Figure 40 - Radiated Emissions Plot, Receive

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.	
157.140000	5.48	43.50	38.00	290	100	VERT

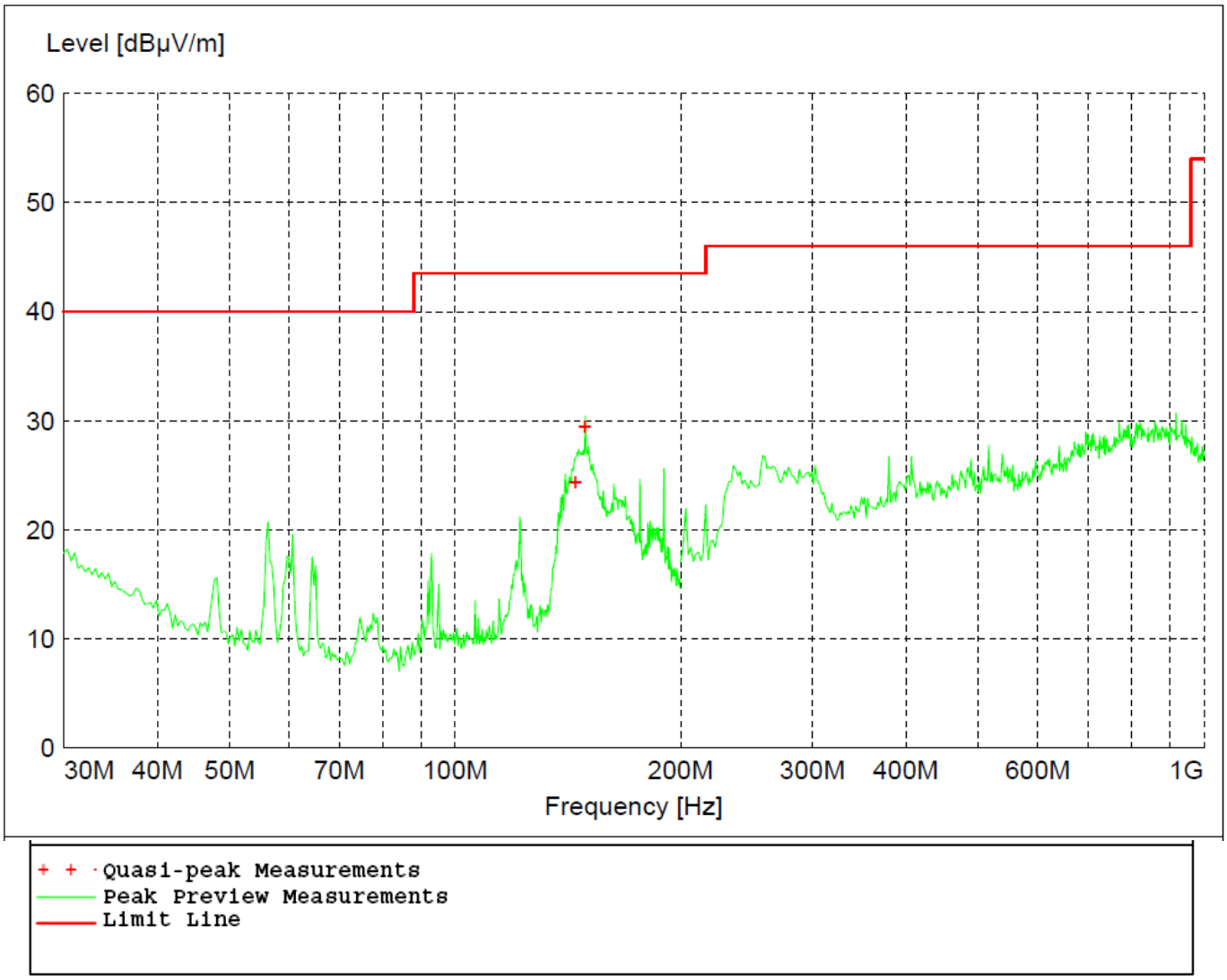

Figure 41 - Radiated Emissions Plot

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

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
144.720000	24.43	43.50	19.10	203	360	HORI
149.160000	29.53	43.50	14.00	223	21	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, BT BR (GFSK)

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	97.50	NA	NA	100	158	VERT	Low
2440.000000	96.85	NA	NA	100	158	VERT	Mid
2480.000000	95.52	NA	NA	100	158	VERT	High
4804.000000	29.27	54.00	24.73	200	209	HORI	Low
9608.000000	35.67	54.00	18.33	100	163	VERT	Low
4880.000000	28.52	54.00	25.48	200	209	HORI	Mid
9760.000000	45.77	54.00	8.23	100	163	VERT	Mid
4960.000000	28.58	54.00	25.42	200	209	HORI	Low
9920.000000	35.65	54.00	18.35	100	163	VERT	Low

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

Table 4 - Radiated Emissions Peak Measurements, BT BR (GFSK)

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	99.31	NA	NA	100	158	VERT	Low
2440.000000	97.81	NA	NA	100	158	VERT	Mid
2480.000000	97.59	NA	NA	100	158	VERT	High
4804.000000	42.48	74.00	31.52	200	209	HORI	Low
9608.000000	49.22	74.00	24.78	100	163	VERT	Low
4880.000000	42.54	74.00	31.46	200	209	HORI	Mid
9760.000000	54.81	74.00	19.19	100	163	VERT	Mid
4960.000000	42.21	74.00	31.79	200	209	HORI	Low
9920.000000	49.66	74.00	24.34	100	163	VERT	Low

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

Table 5 - Radiated Emissions Average Measurements, BT EDR 2MB

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	90.37	NA	NA	100	158	VERT	Low
2440.000000	90.27	NA	NA	100	158	VERT	Mid
2480.000000	89.48	NA	NA	100	158	VERT	High
4804.000000	36.56	54.00	17.44	100	238	VERT	Low
7206.000000	33.48	54.00	20.52	308	56	HORI	Low
4880.000000	28.58	54.00	25.42	100	238	VERT	High
4960.000000	28.72	54.00	25.28	100	238	VERT	High

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

Table 6 - Radiated Emissions Peak Measurements, BT EDR 2MB

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	95.38	NA	NA	100	158	VERT	Low
2440.000000	94.17	NA	NA	100	158	VERT	Mid
2480.000000	94.84	NA	NA	100	158	VERT	High
4804.000000	46.60	74.00	27.40	100	238	VERT	Low
7206.000000	46.69	74.00	27.31	308	56	HORI	Low
4880.000000	42.54	74.00	31.46	100	238	VERT	Mid
4960.000000	42.46	74.00	31.54	100	238	VERT	Mid

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

Table 7 - Radiated Emissions Average Measurements, BT EDR 3MB

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	90.52	NA	NA	100	158	VERT	Low
2440.000000	90.23	NA	NA	100	158	VERT	Mid
2480.000000	89.34	NA	NA	100	158	VERT	High
4804.000000	29.52	54.00	24.48	393	360	VERT	Low
4880.000000	28.74	54.00	25.26	393	360	VERT	Mid
4960.000000	29.59	54.00	24.41	393	360	VERT	High

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

Table 8 - Radiated Emissions Peak Measurements, BT EDR 3MB

Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2402.000000	94.74	NA	NA	100	158	VERT	Low
2440.000000	94.54	NA	NA	100	158	VERT	Mid
2480.000000	93.79	NA	NA	100	158	VERT	High
4804.000000	42.96	74.00	31.04	393	360	VERT	Low
4880.000000	42.29	74.00	31.71	393	360	VERT	Mid
4960.000000	43.09	74.00	30.91	393	360	VERT	High

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

4.5 BAND EDGES

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. EUT was set to transmit in indicated modulation.

Test results:

CHANNEL	Mode	Band edge /Measurement Frequency (MHz)	Relative Highest out of band level dBm	Relative Fundamental dBm	Delta (dB)	Min Delta (dB)	Result
Low, Continuous (restricted)	BT BR (GFSK)	2390	-91.45	14.53	105.98	25.31	PASS
High, Continuous (restricted)	BT BR (GFSK)	2483.5	-75.86	10.98	86.74	23.59	PASS
Low, Continuous (unrestricted)	BT BR (GFSK)	2400	-42.62	14.53	57.15	20.00	PASS
High, Continuous (unrestricted)	BT BR (GFSK)	2483.5	-52.21	10.98	63.20	20.00	PASS

*Minimum delta = [highest fundamental peak field strength from Section 4.2] – [Part 15.209 radiated emissions limit.]

From Section 4.2

Fundamental peak field strength at Low Channel BT BR (GFSK) = 99.31 dBµV/m
Fundamental peak field strength at High Channel BT BR (GFSK) = 97.59 dBµV/m

Low Channel minimum delta BT BR (GFSK) = 99.31 – 74.0 dBµV/m = 25.31 dBc
High Channel minimum delta BT BR (GFSK) = 97.59 – 74.0 dBµV/m = 23.59 dBc

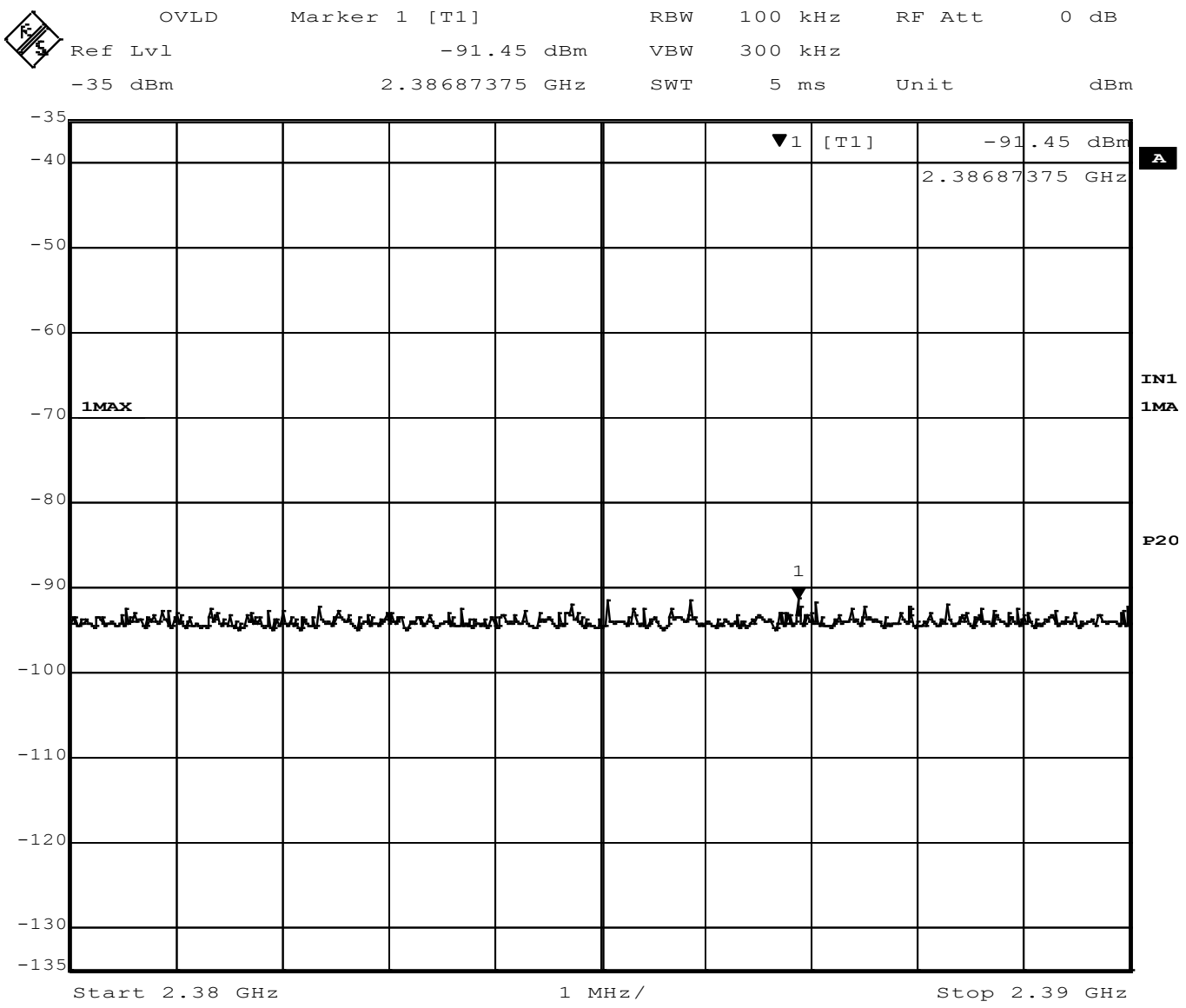

Figure 42 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

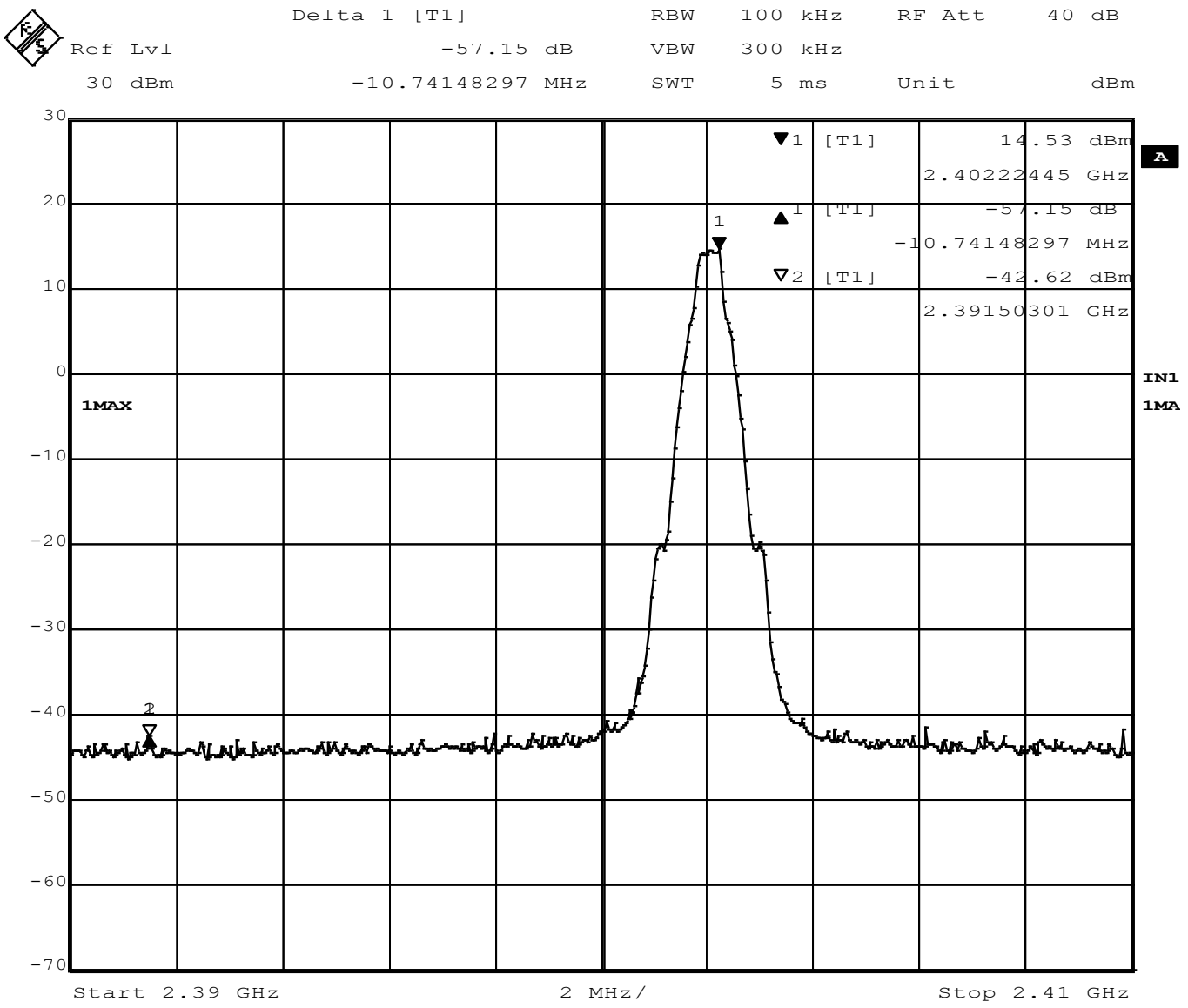

Figure 43 - Band-edge Measurement, Low Channel, Fundamental, Peak

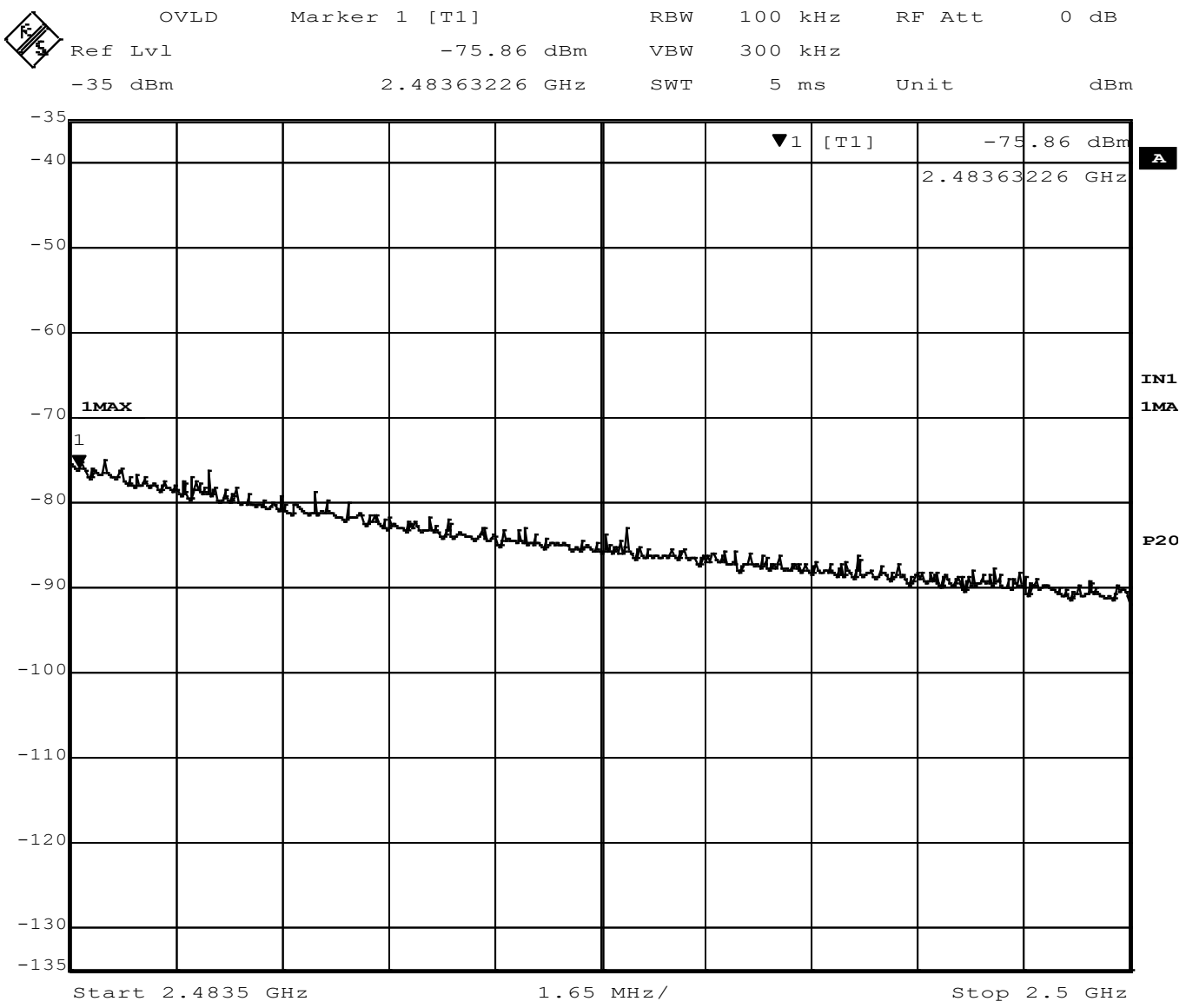

Figure 44 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

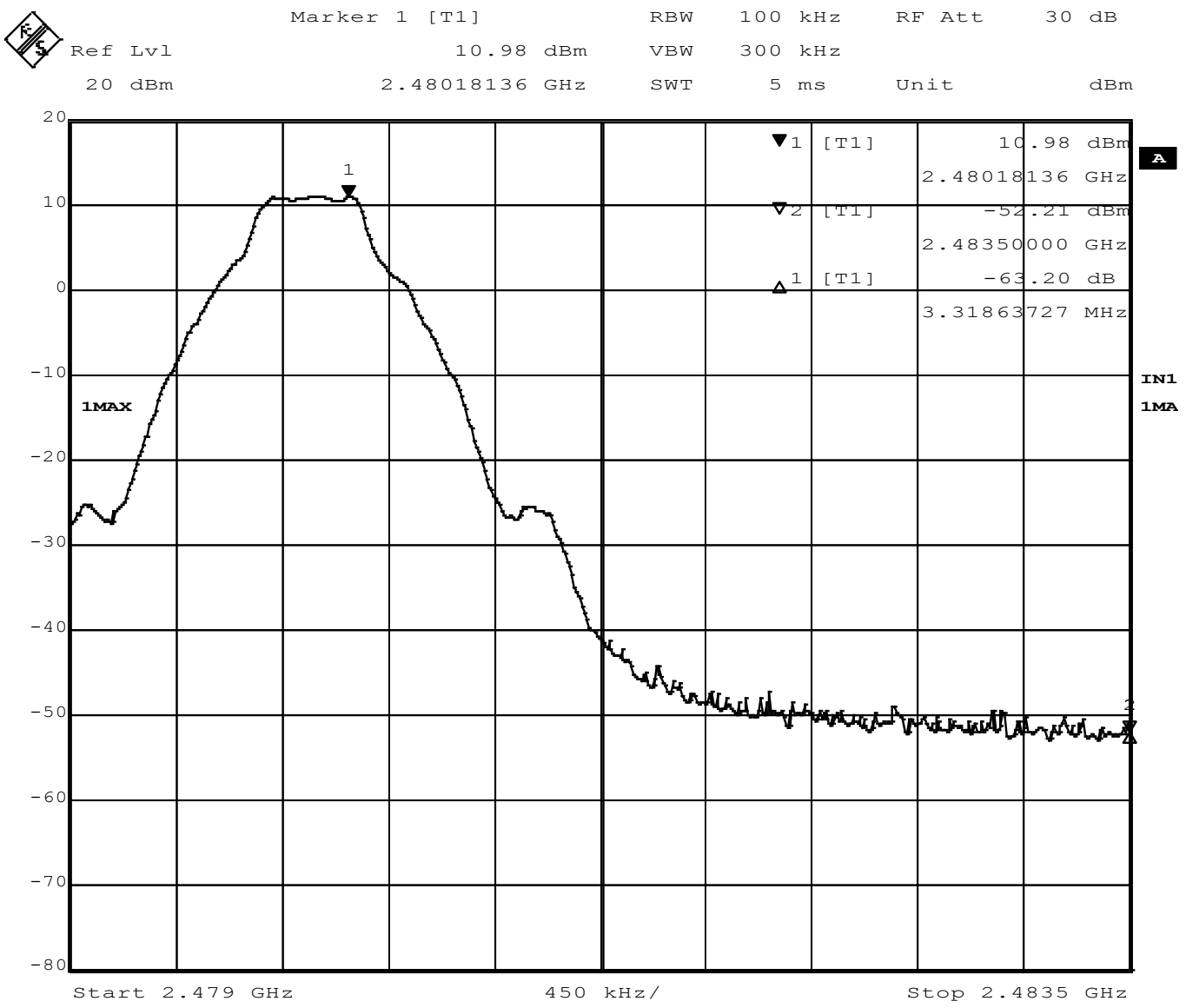

Figure 45 - Band-edge Measurement, High Channel, Fundamental, Peak

CHANNEL	Mode	Band edge /Measurement Frequency (MHz)	Relative Highest out of band level dBm	Relative Fundamental dBm	Delta (dB)	Min Delta (dB)	Result
Low, Continuous (restricted)	BT EDR 2MB	2390	-28.84	10.43	39.34	21.38	PASS
High, Continuous (restricted)	BT EDR 2MB	2483.5	-42.80	8.93	51.73	20.84	PASS
Low, Continuous (unrestricted)	BT EDR 2MB	2400	-81.33	10.43	91.76	20.00	PASS
High, Continuous (unrestricted)	BT EDR 2MB	2483.5	-48.52	8.93	57.45	20.00	PASS

*Minimum delta = [highest fundamental peak field strength from Section 4.2] – [Part 15.209 radiated emissions limit.]

From Section 4.2

Fundamental peak field strength at Low Channel BT EDR 2MB = 95.38 dBµV/m
Fundamental peak field strength at High Channel BT EDR 2MB = 94.84 dBµV/m

Low Channel minimum delta BT EDR 2MB = 95.38 – 74.0 dBµV/m = 21.38 dBc
High Channel minimum delta BT EDR 2MB = 94.84 – 74.0 dBµV/m = 20.84 dBc

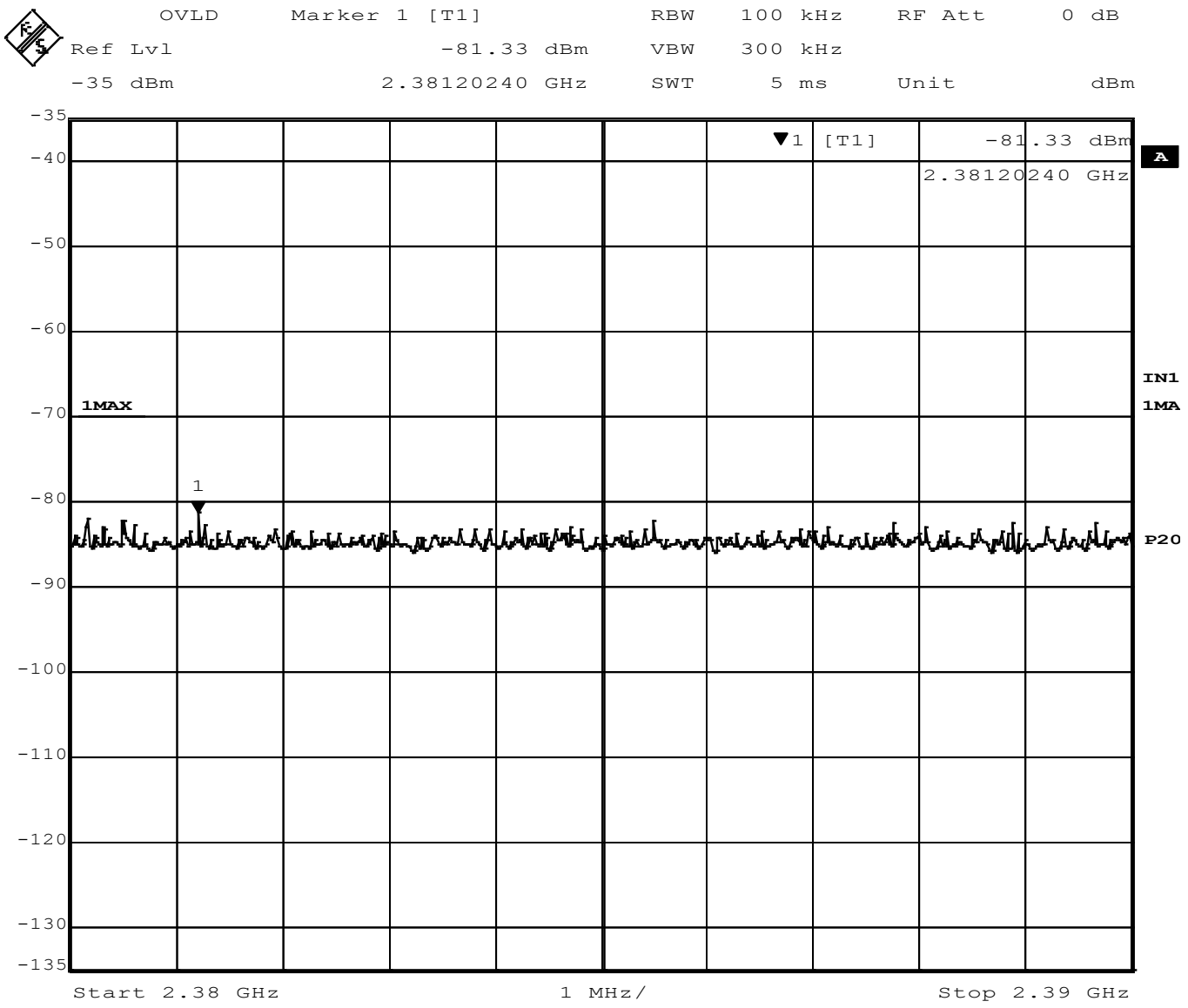

Figure 46 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

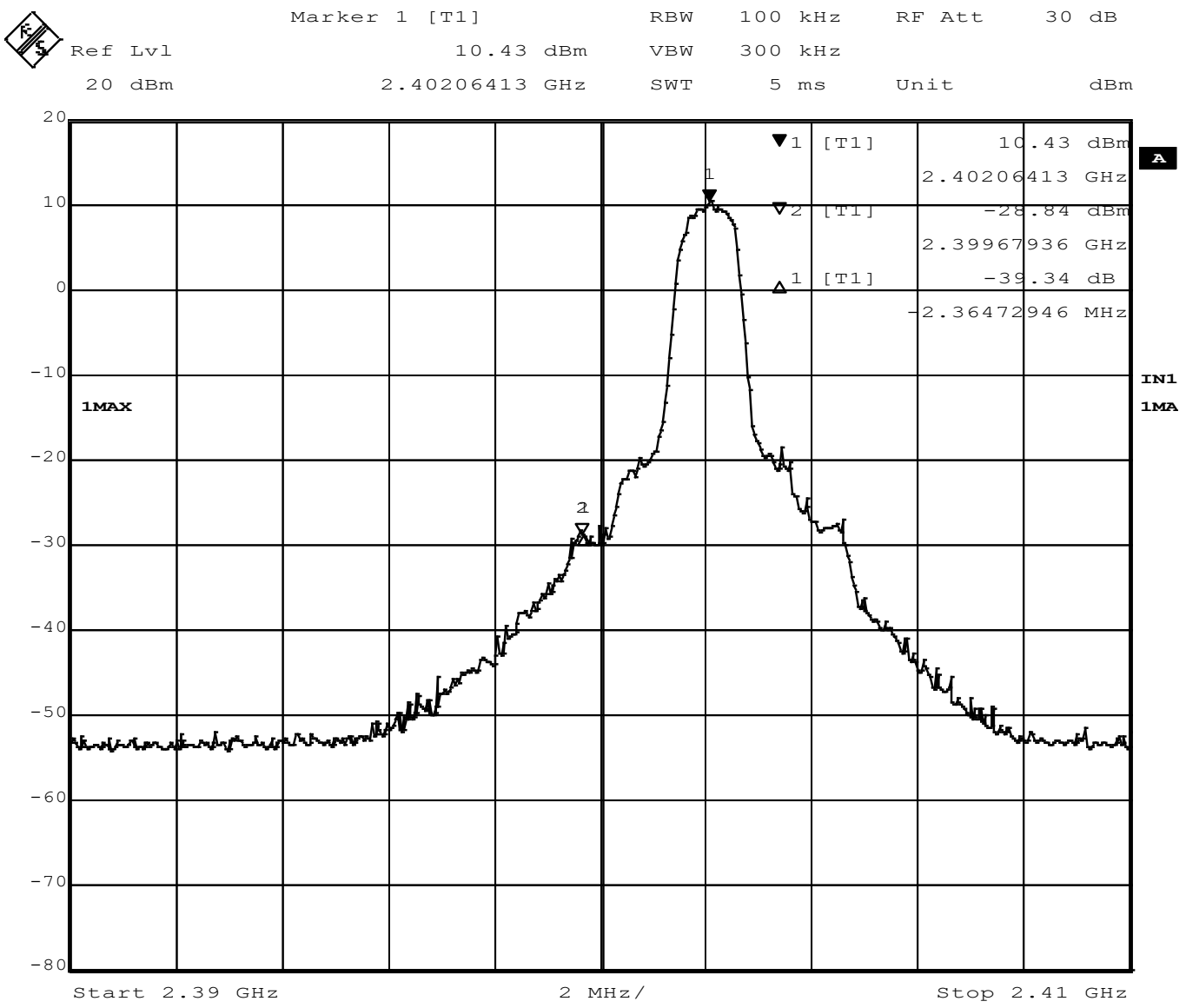

Figure 47 - Band-edge Measurement, Low Channel, Fundamental, Peak

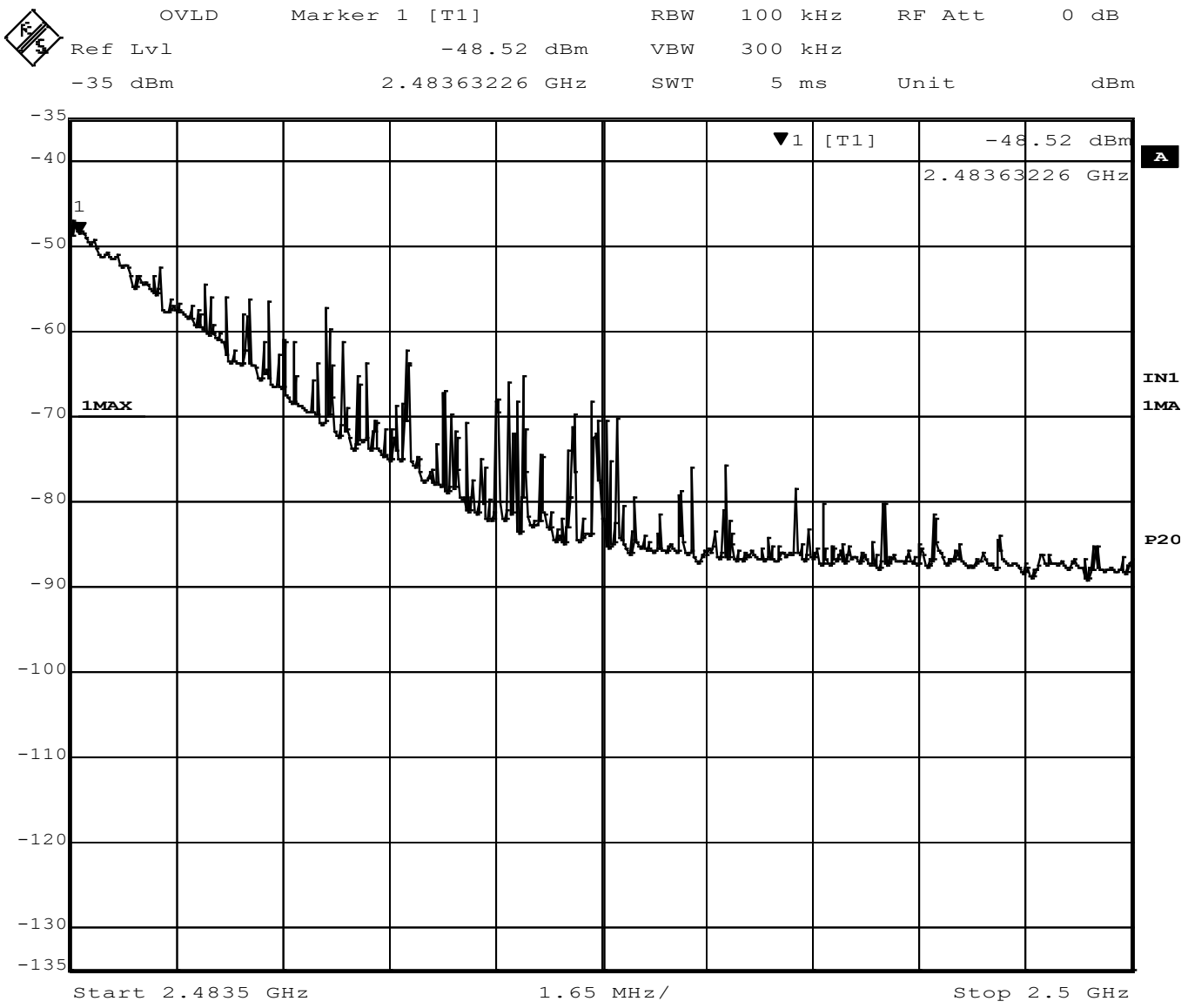

Figure 48 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

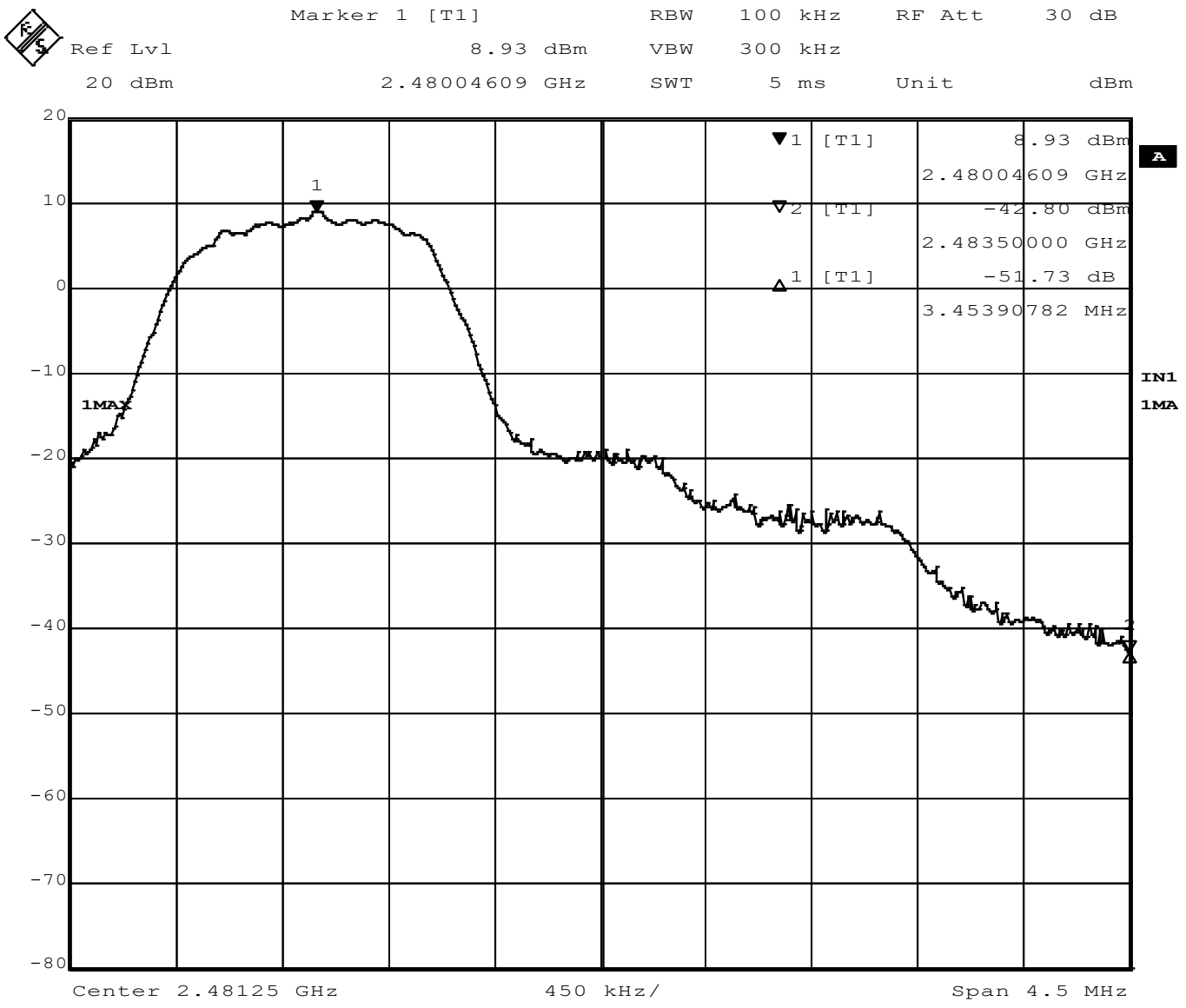

Figure 49 - Band-edge Measurement, High Channel, Fundamental, Peak

CHANNEL	Mode	Band edge /Measurement Frequency (MHz)	Relative Highest out of band level dBm	Relative Fundamental dBm	Delta (dB)	Min Delta (dB)	Result
Low, Continuous (restricted)	BT EDR 3MB	2390.0	-77.83	10.26	88.09	20.74	PASS
High, Continuous (restricted)	BT EDR 3MB	2483.5	-37.81	8.27	46.08	19.79	PASS
Low, Continuous (unrestricted)	BT EDR 3MB	2400.0	-25.08	10.26	35.33	20.00	PASS
High, Continuous (unrestricted)	BT EDR 3MB	2483.5	-42.30	8.27	50.57	20.00	PASS

*Minimum delta = [highest fundamental peak field strength from Section 4.2] – [Part 15.209 radiated emissions limit.]

From Section 4.2

Fundamental peak field strength at Low Channel BT BR (GFSK) = 94.74 dBµV/m
Fundamental peak field strength at High Channel BT BR (GFSK) = 93.79 dBµV/m

Low Channel minimum delta BT BR (GFSK) = 94.74 – 74.0 dBµV/m = 20.74 dBc
High Channel minimum delta BT BR (GFSK) = 93.79 – 74.0 dBµV/m = 19.79 dBc

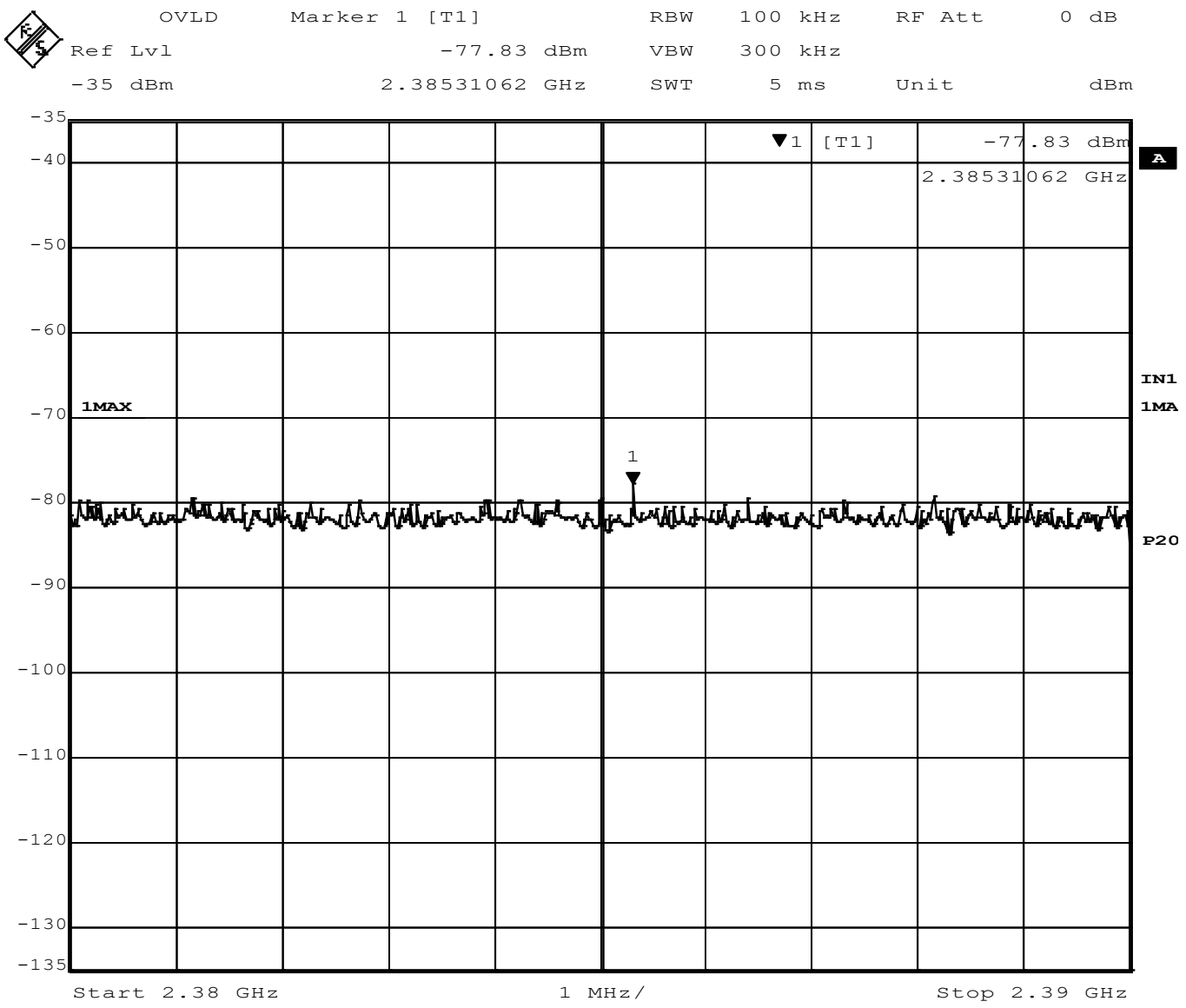

Figure 50 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

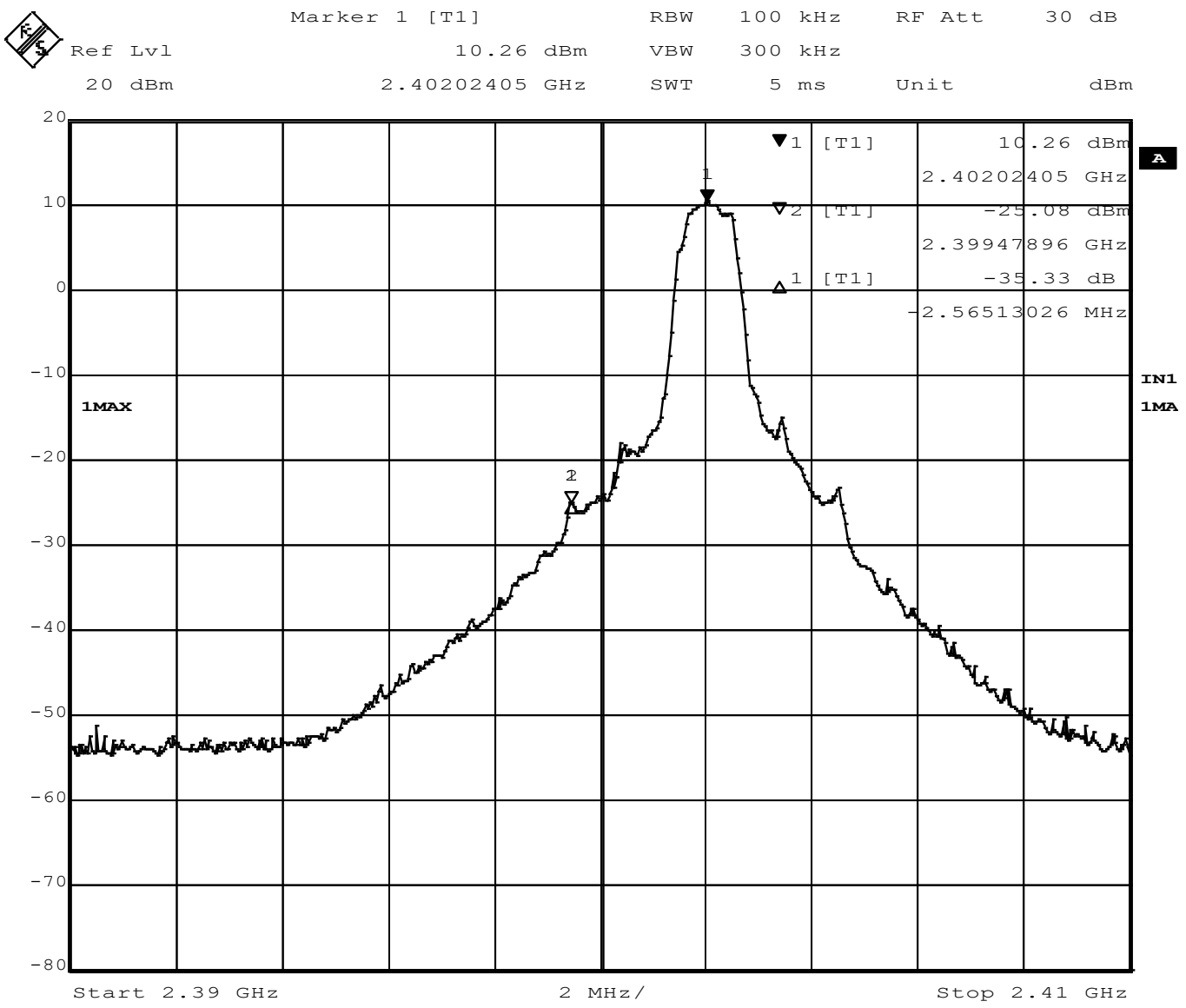

Figure 51 - Band-edge Measurement, Low Channel, Fundamental, Peak

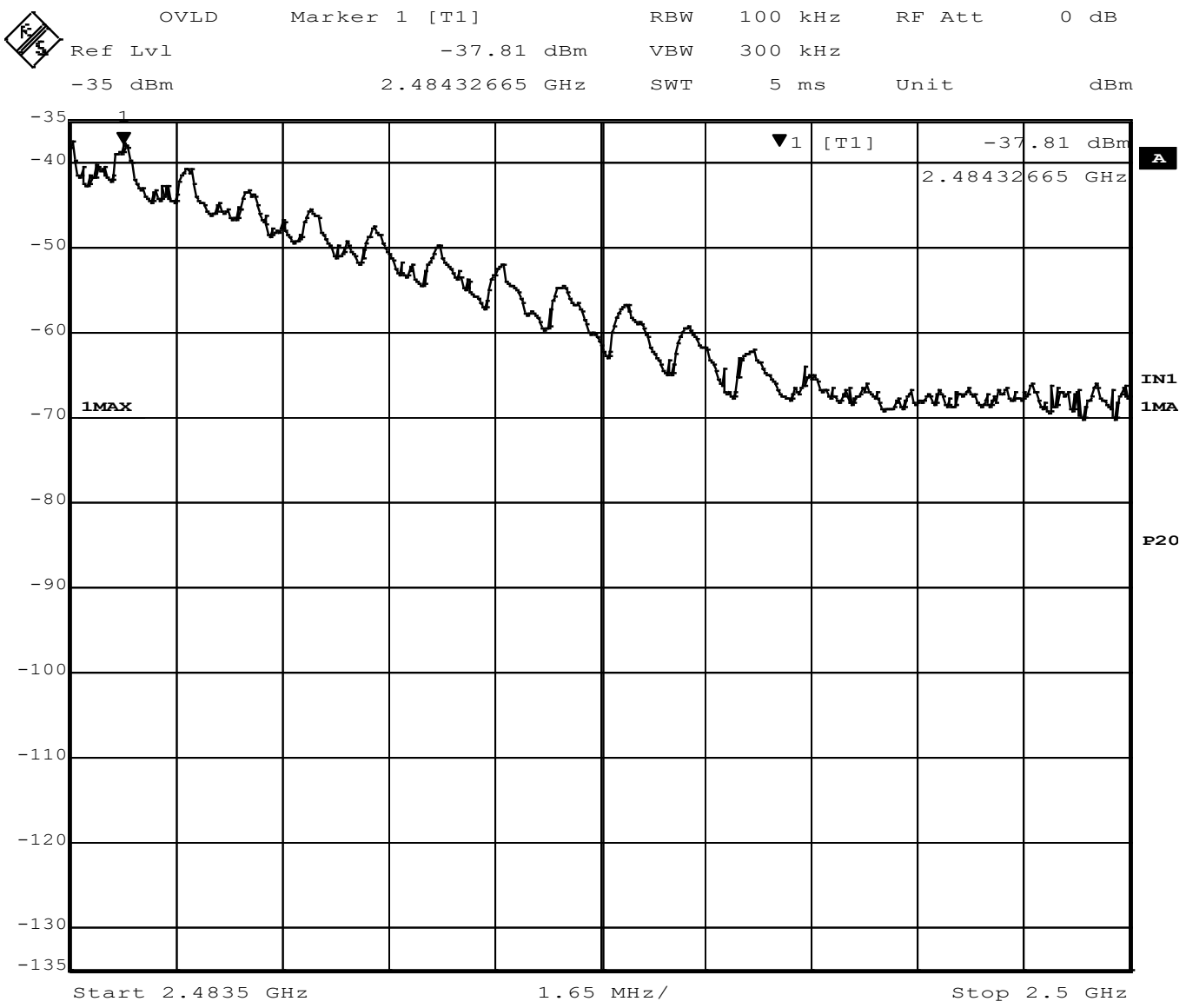

Figure 52 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

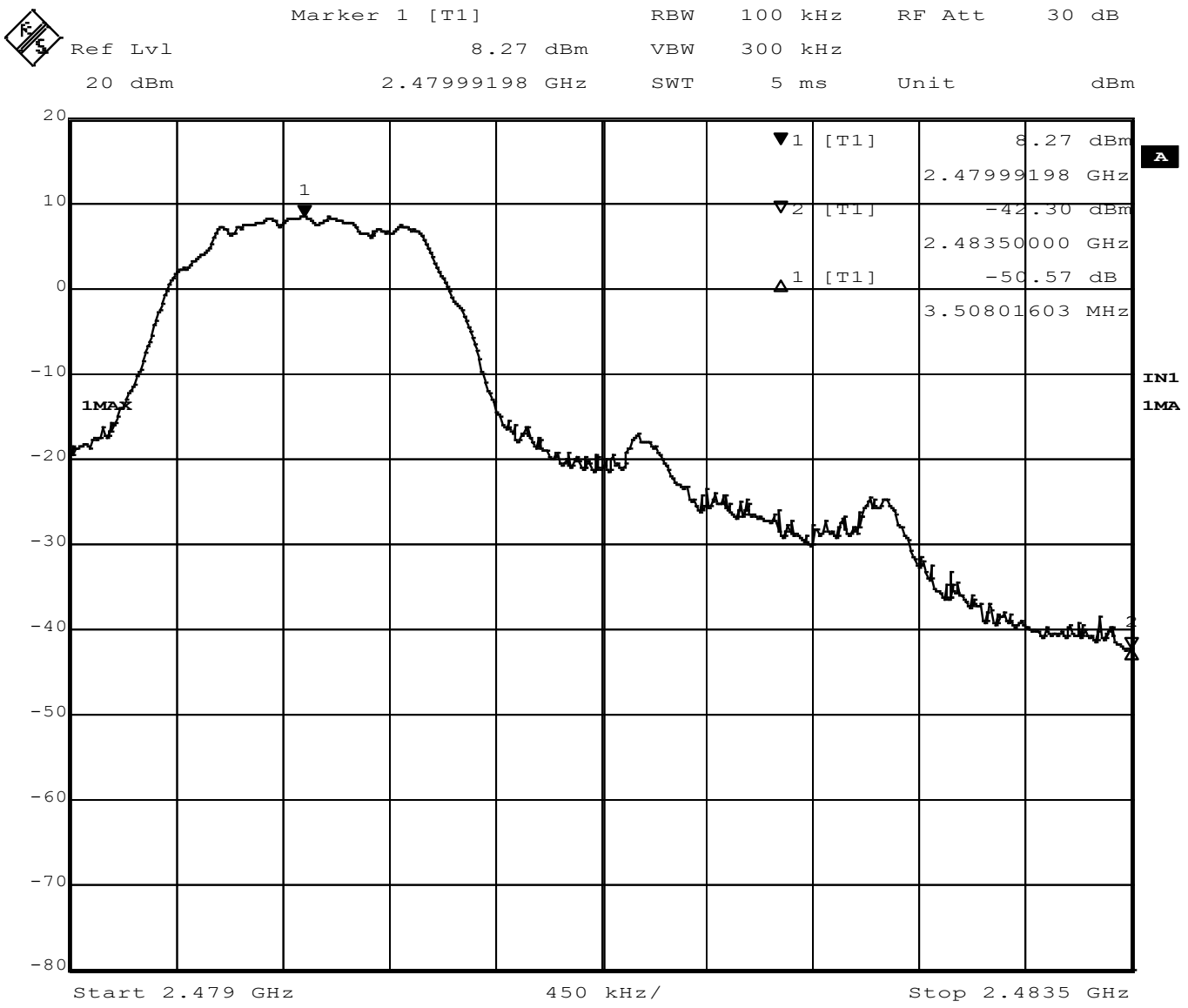

Figure 53 - Band-edge Measurement, High Channel, Fundamental, Peak

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. EUT was set to transmit in indicated modulation.

Test results:

Power Spectral Density

CHANNEL	MODE	CHANNEL FREQUENCY (MHz)	PEAK PSD(dBm)	Method	Limit (dBm)	RESULT
Low	BT BR (GFSK)	2402	0.80	Conducted	8.00	PASS
Middle	BT BR (GFSK)	2440	0.00	Conducted	8.00	PASS
High	BT BR (GFSK)	2480	0.05	Conducted	8.00	PASS
Low	BT EDR 2MB	2402	-5.91	Conducted	8.00	PASS
Middle	BT EDR 2MB	2440	-6.00	Conducted	8.00	PASS
High	BT EDR 2MB	2480	-7.06	Conducted	8.00	PASS
Low	BT EDR 3MB	2402	-6.40	Conducted	8.00	PASS
Middle	BT EDR 3MB	2440	-6.50	Conducted	8.00	PASS
High	BT EDR 3MB	2480	-7.89	Conducted	8.00	PASS

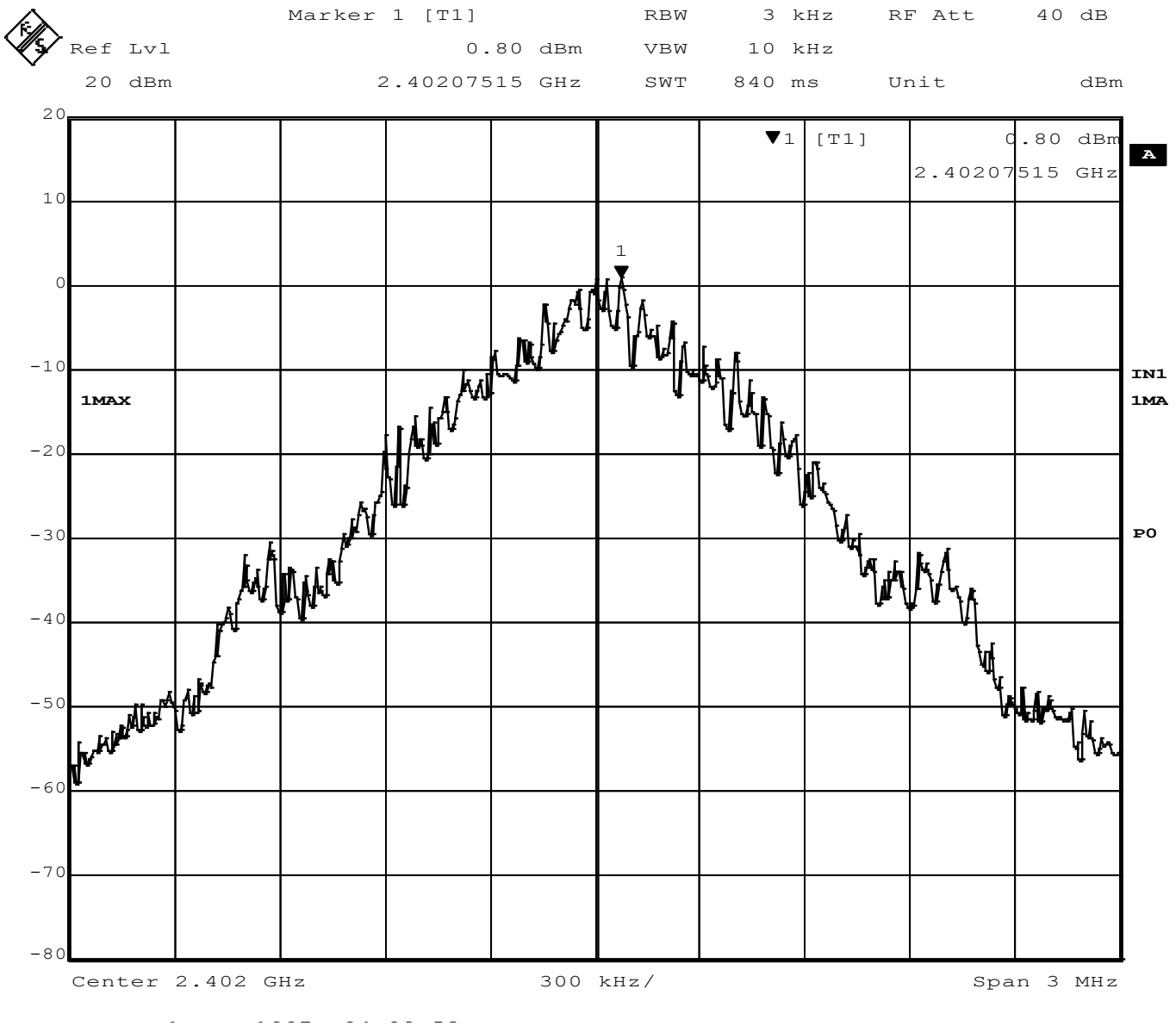

Figure 54 - Power Spectral Density, Low Channel, BT BR (GFSK)

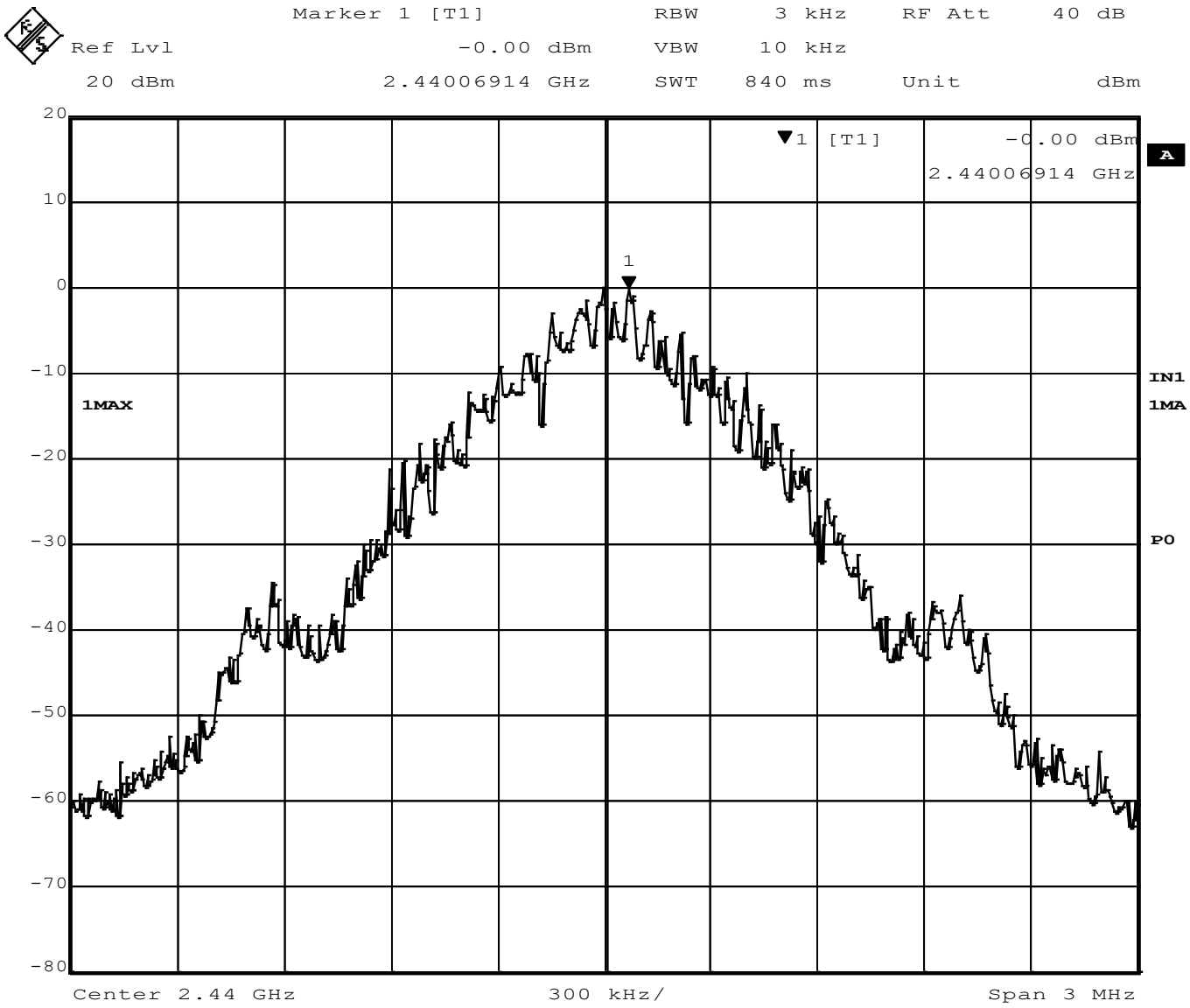

Figure 55 - Power Spectral Density, Mid Channel, BT BR (GFSK)

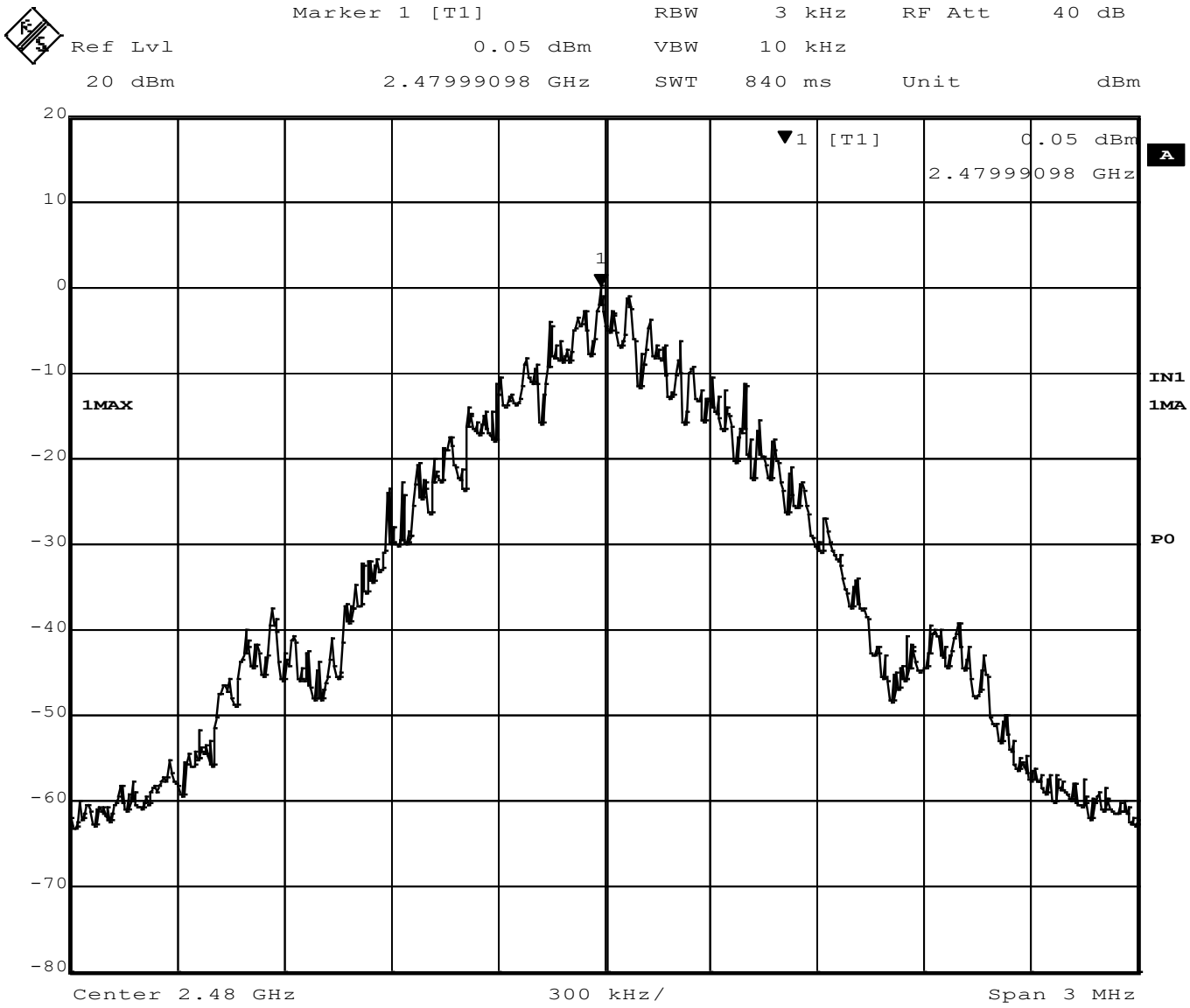

Figure 56 - Power Spectral Density, High Channel, BT BR (GFSK)

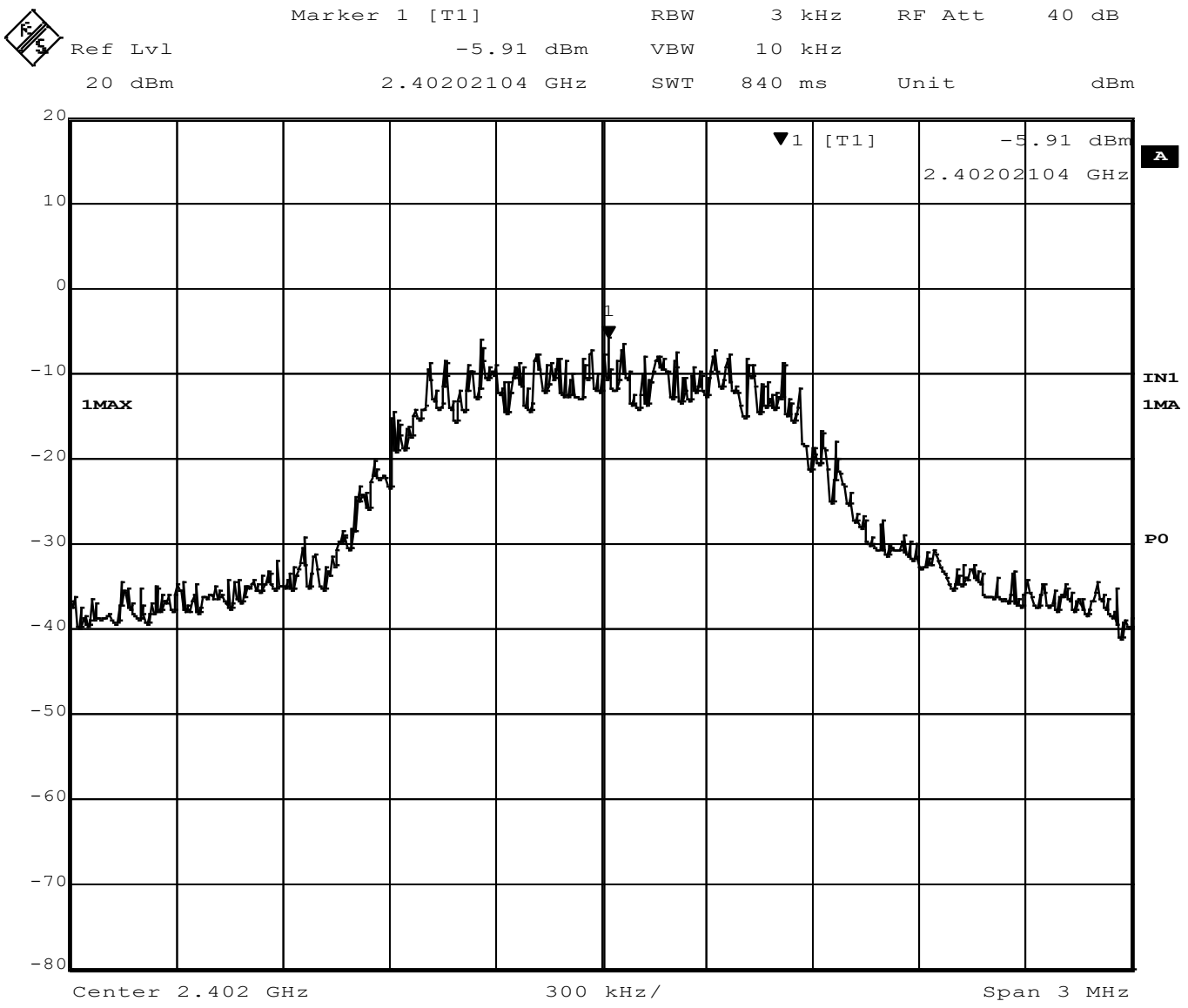

Figure 57 - Power Spectral Density, Low Channel, BT EDR 2MB

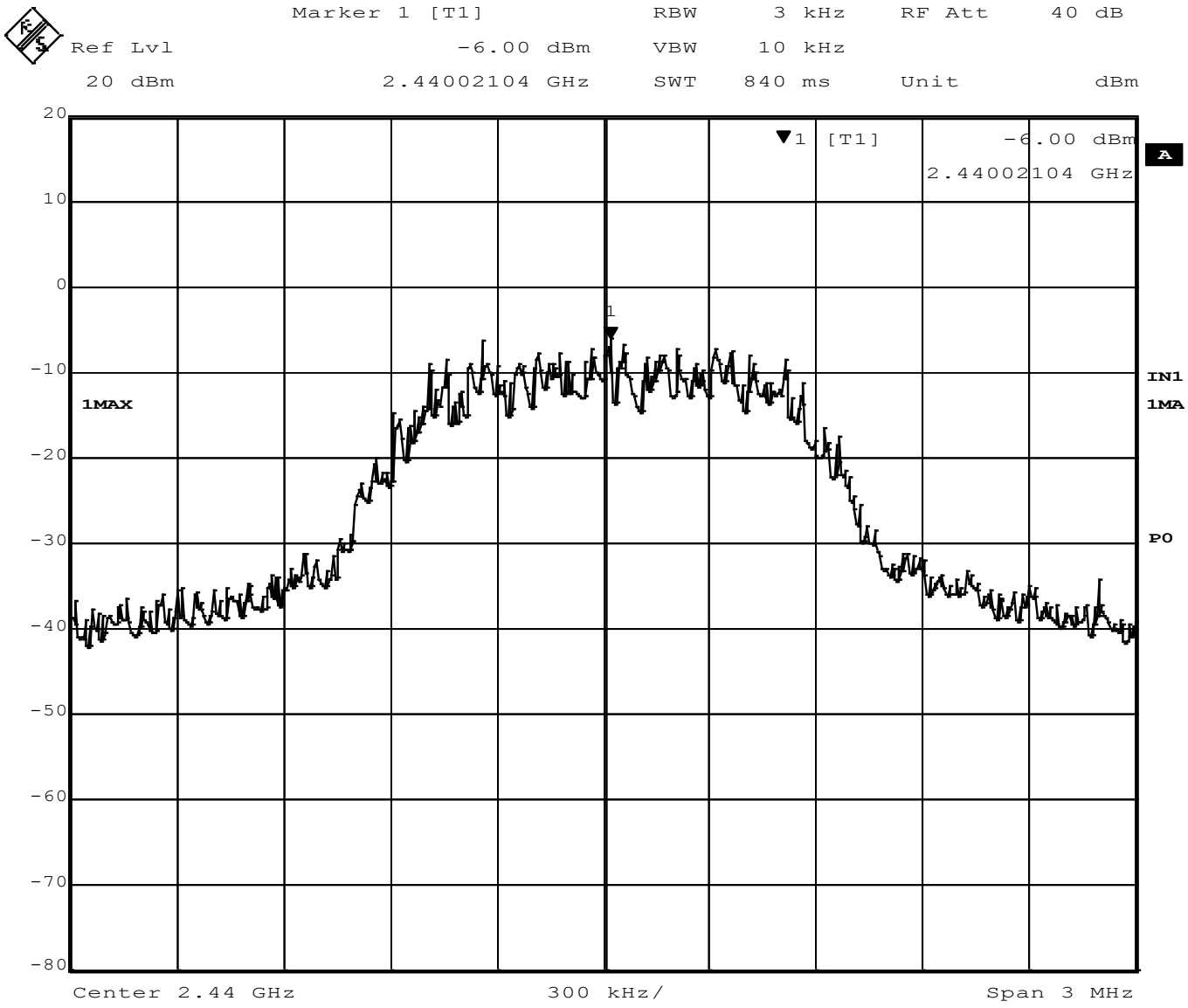

Figure 58 - Power Spectral Density, Mid Channel, BT EDR 2MB

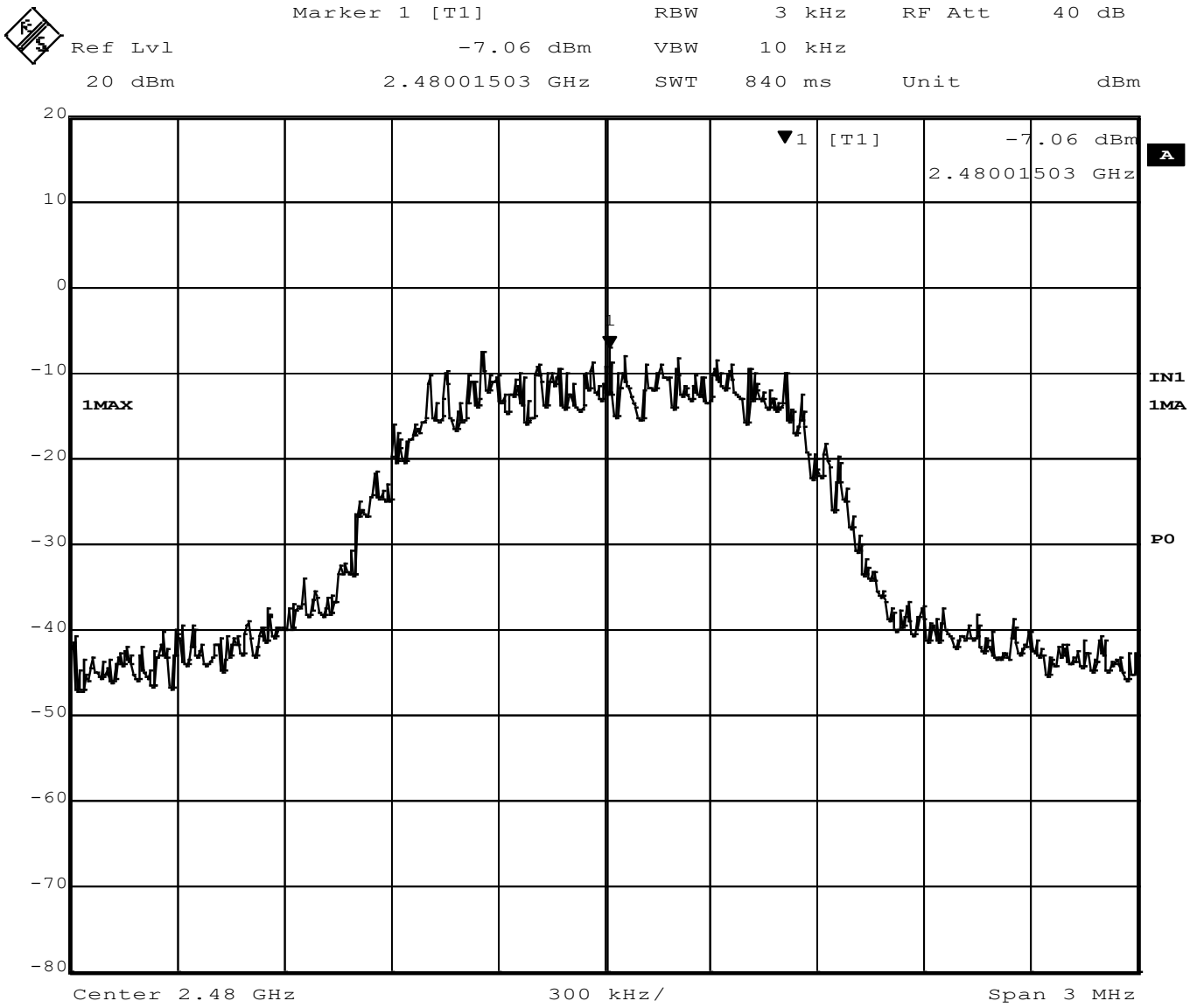

Figure 59 - Power Spectral Density, High Channel, BT EDR 2MB

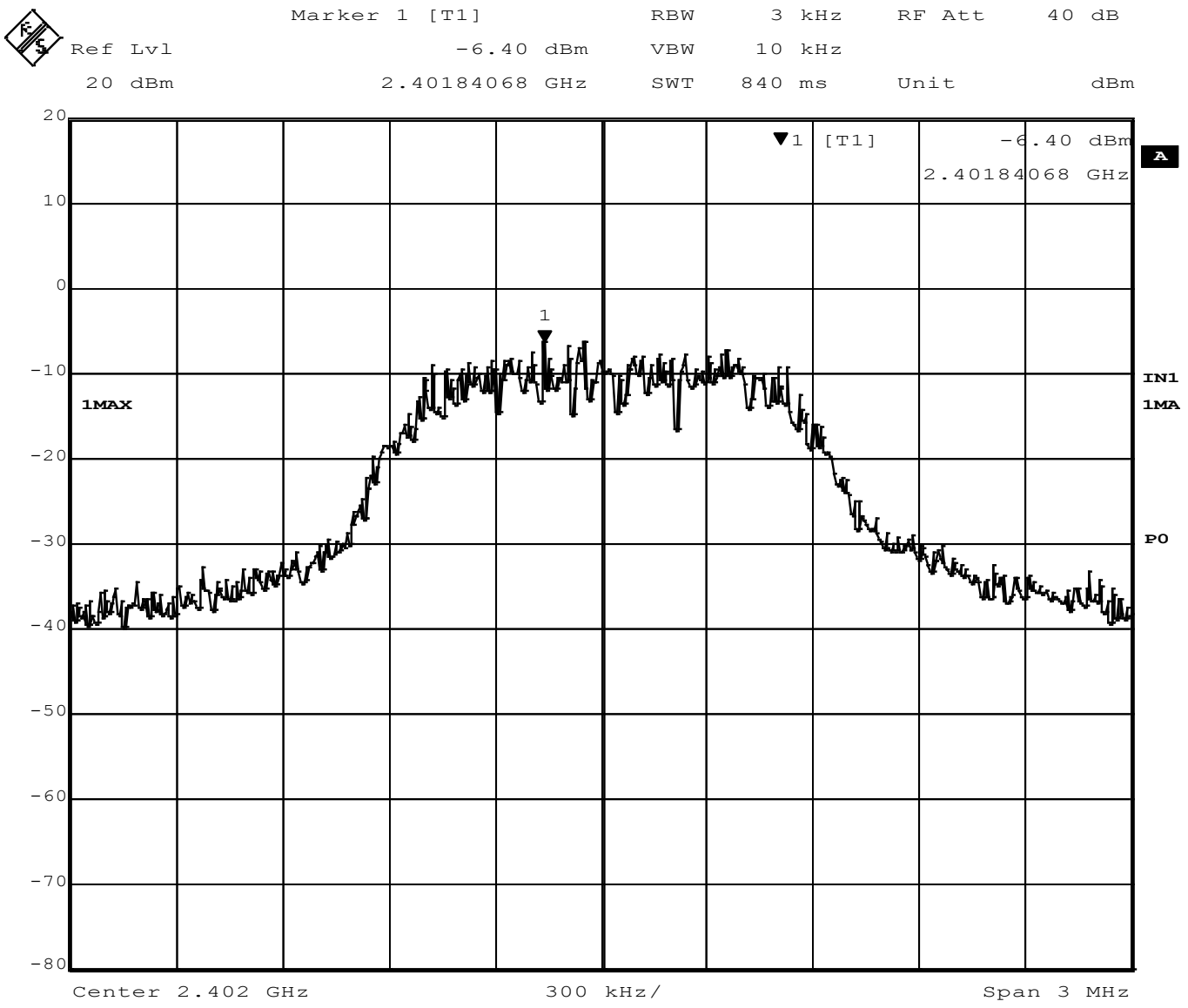

Figure 60 - Power Spectral Density, Low Channel, BT EDR 3MB

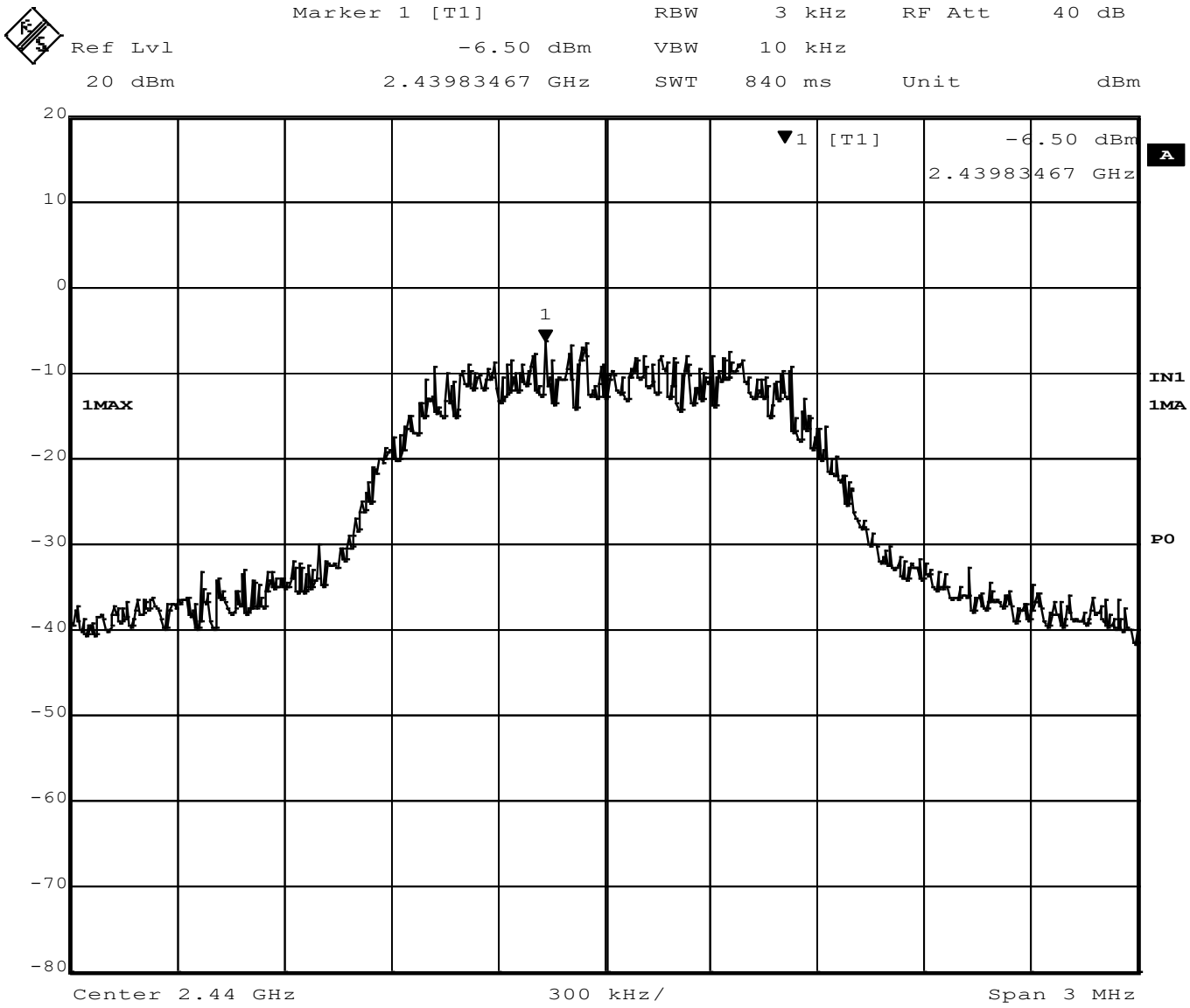

Figure 61 - Power Spectral Density, Mid Channel, BT EDR 3MB

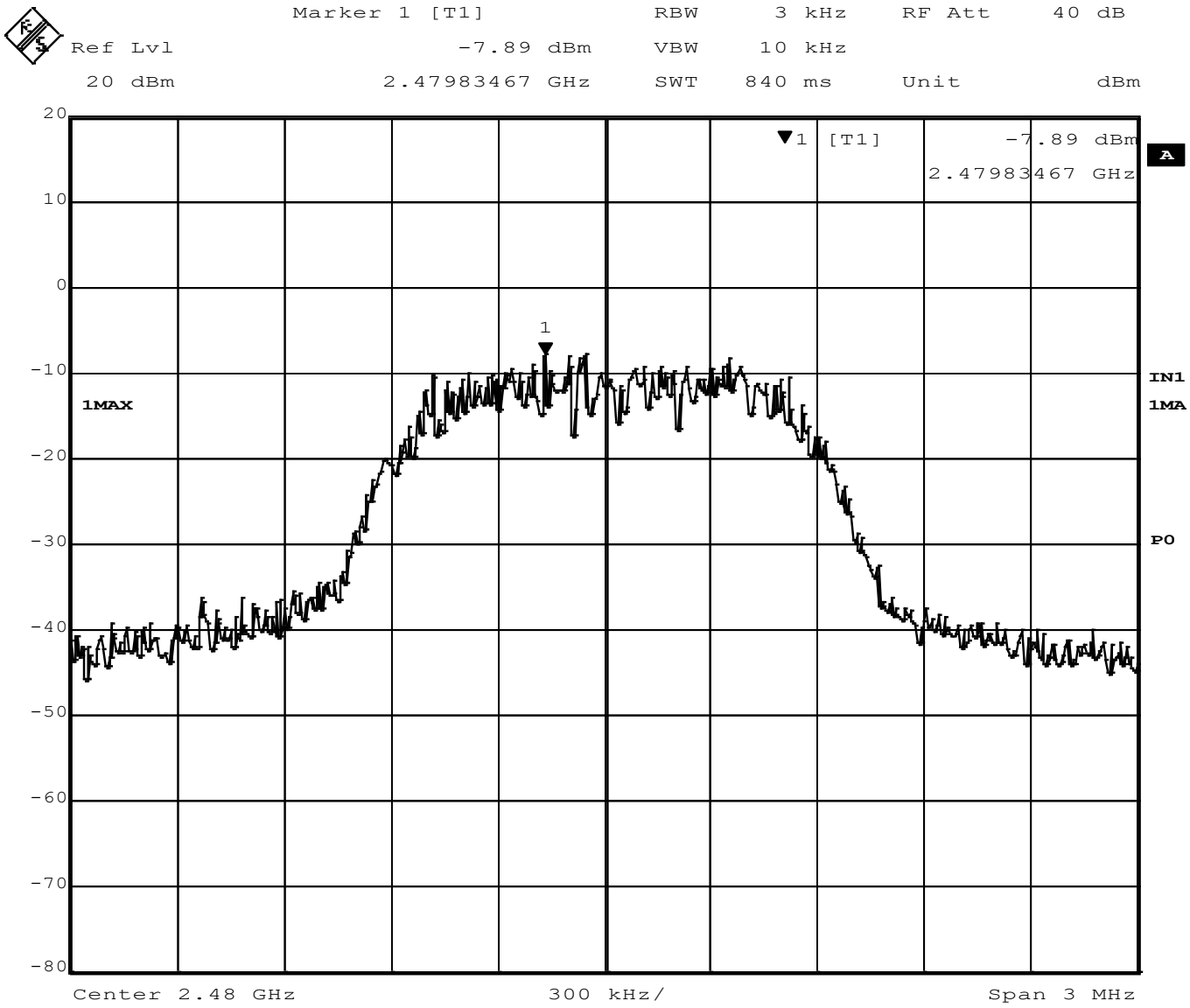

Figure 62 - Power Spectral Density, High Channel, BT EDR 3MB

4.6 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:

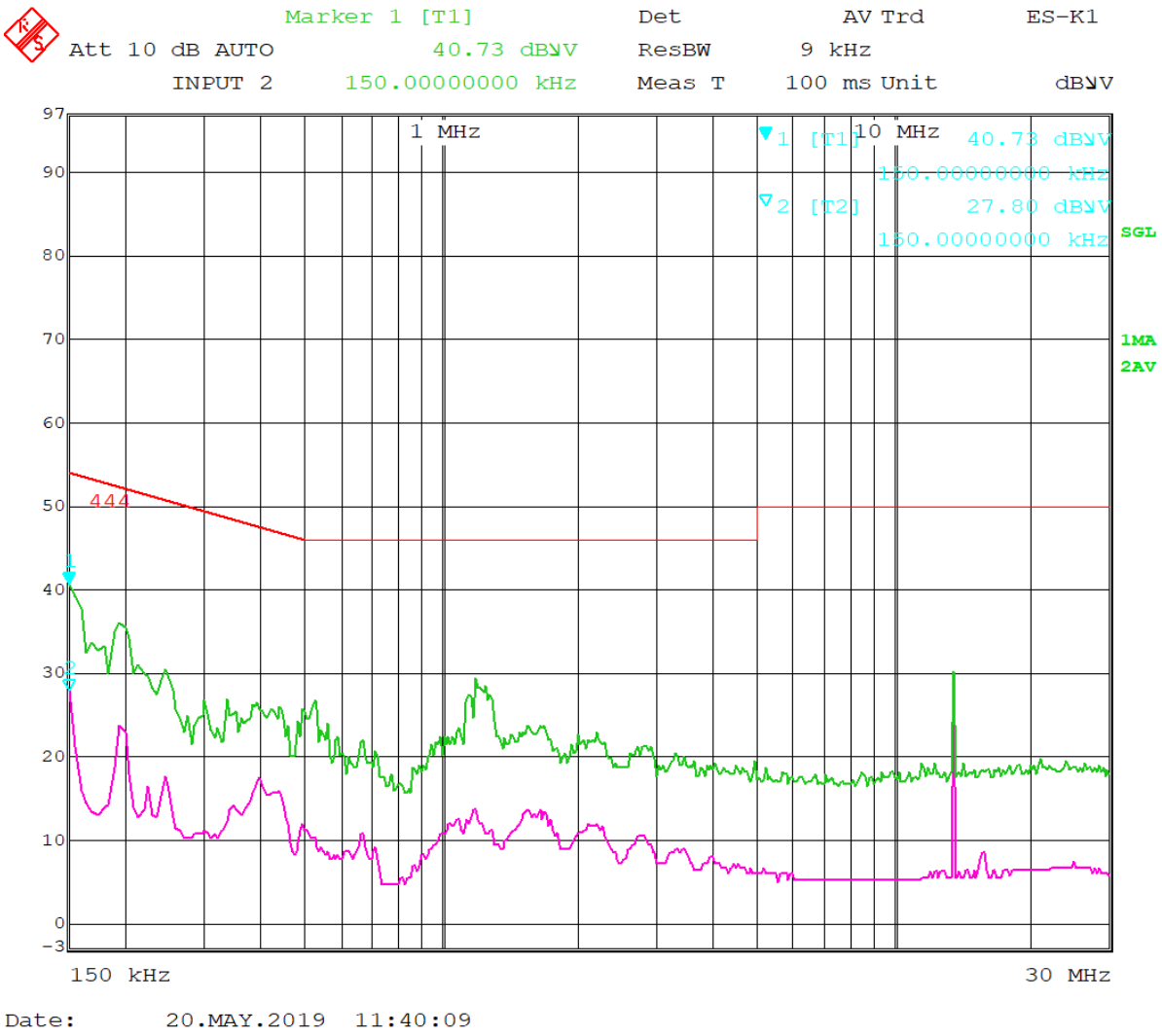

Figure 63 - Conducted Emissions, Line

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

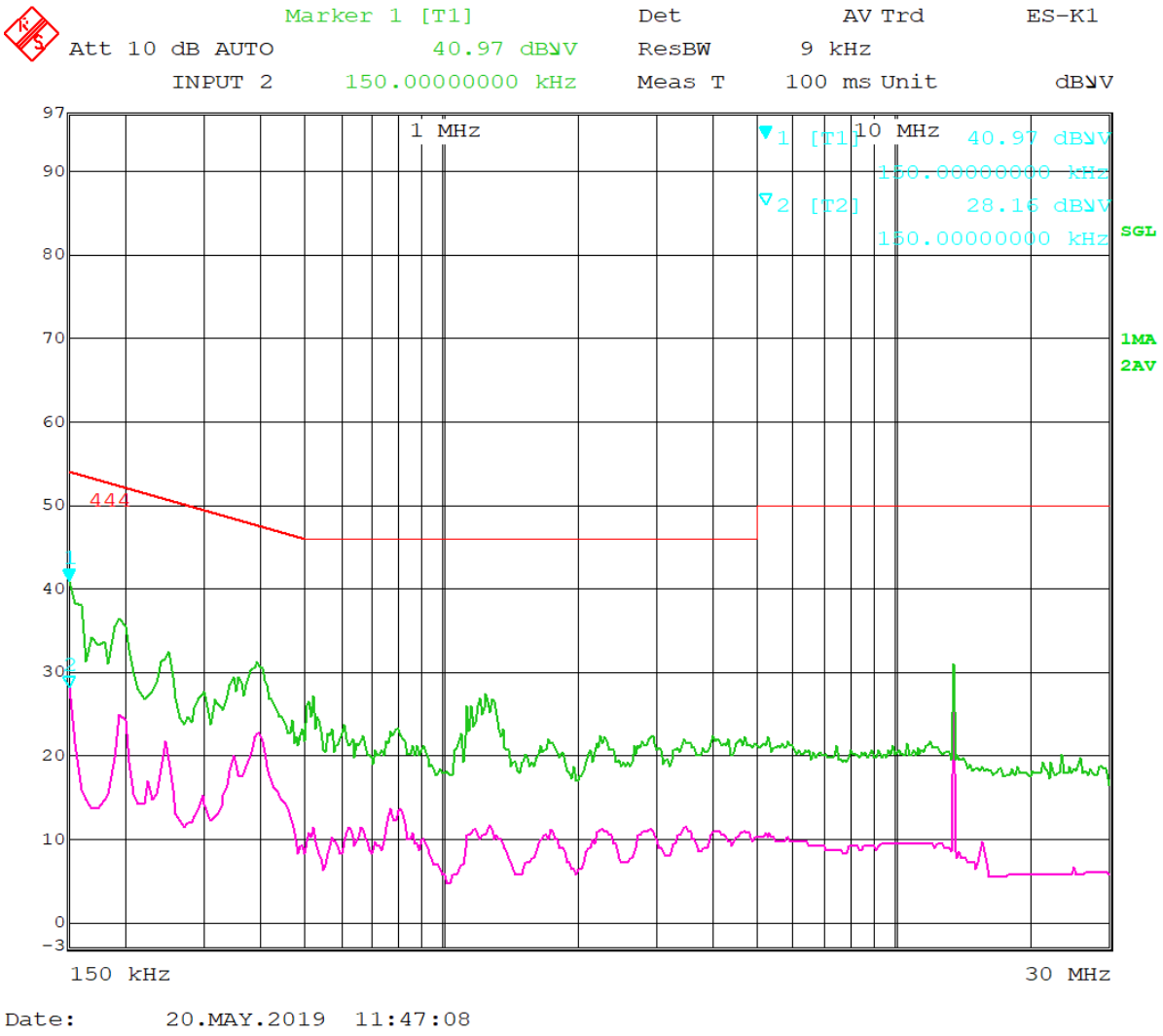

Figure 64 - Conducted Emissions, Neutral

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

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