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FCC/ISED Test Report

Prepared for: **Garmin International Inc.**

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

Product: **A03645**

Test Report No: **R20181219-20-12C**

Approved by:

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

DATE: **16 August 2019**

Total Pages: **70**

ilac-MRA A2LA ACCREDITED TESTING LABORATORY CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	18 June 2019	Original – NJohnson Prepared by KVepuri/CFarrington
A	15 July 2019	Includes NCEE Labs report R20181219-20-12 and its amendment in full. -NJ
B	13 August 2019	Includes NCEE Labs report R20181219-20-12A and its amendment in full. -NJ
C	16 August 2019	Includes NCEE Labs report R20181219-20-12B and its amendment in full. -NJ

CONTENTS

1.0 SUMMARY OF TEST RESULTS

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

APPLIED STANDARDS AND REGULATIONS		
Standard Section	**Test Type**	**Result**
FCC Part 15.35 RSS Gen, Issue 4, Section 6.10	Duty Cycle	Pass
FCC Part 15.247(a)(1) RSS-247 Issue 2 Section 5.2	Peak output power	Pass
FCC Part 15.247(a)(1) RSS-247 Issue 2 Section 5.2	Bandwidth	Pass
FCC Part 15.209 RSS-Gen Issue 4, Section 7.1	Receiver Radiated Emissions	Pass
FCC Part 15.209 (restricted bands), 15.247 (unrestricted) RSS-247 Issue 2 Section 5.5, RSS-Gen Issue 4, Section 8.9	Transmitter Radiated Emissions	Pass
FCC Part 15.247(a)(1) RSS-247 Issue 2 Section 5.2	Power Spectral Density	Pass
FCC Part 15.209, 15.247(d) RSS-247 Issue 2 Section 11.13	Band Edge Measurement	Pass
FCC Part 15.207 RSS-Gen Issue 4, Section 7.1	Conducted Emissions	Pass

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

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

Summary

The Equipment Under Test (EUT) was a battery powered BT EDR 2MB, BT EDR 3MB and BT BR (GFSK) transceiver manufactured by GARMIN inc.

EUT	A03645
EUT Received	16 April 2019
EUT Tested	16 April 2019- 20 May 2019 (GMSK measurements) 10 June 2019 (GFSK measurements) 20 June 2019 (EIRP output power measurements)
Serial No.	3991631270 (radiated unit); 3991631460 (conducted unit)
Operating Band	2400 – 2483.5 MHz
Device Type	BT BR, BT EDR 2MB, BT EDR 3MB
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
Keysight EXA Signal Analyzer	N9010A	MY56070862	14 Dec 2018	14 Dec 2020
Rohde & Schwarz Test Receiver	ES17	100007	31 Jul 2017	31 Jul 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 2020*
Trilithic High Pass Filter	6HC330	23042	09 Mar 2018*	09 Mar 2020*
Rohde & Schwarz LISN	ESH3-Z5	836679/010	26 Jul 2018	26 Jul 2019
Rohde & Schwarz Test Software	ES-K1	12575	NA	NA
RF Cable (preamplifier to antenna)	MFR-57500	01-07-002	09 Mar 2018*	09 Mar 2020*
RF Cable (antenna to 10m chamber bulkhead)	FSCM 64639	01E3872	09 Mar 2018*	09 Mar 2020*
RF Cable (10m chamber bulkhead to control room bulkhead)	FSCM 64639	01E3874	09 Mar 2018*	09 Mar 2020*
RF Cable (Control room bulkhead to RF switch)	FSCM 64639	01E3871	09 Mar 2018*	09 Mar 2020*
RF Cable (RF switch to test receiver)	FSCM 64639	01F1206	09 Mar 2018*	09 Mar 2020*
RF switch – Rohde and Schwarz	TS-RSP	1113.5503.14	09 Mar 2018*	09 Mar 2020*
N connector bulkhead (10m chamber)	PE9128	NCEEBH1	09 Mar 2018*	09 Mar 2020*
N connector bulkhead (control room)	PE9128	NCEEBH2	09 Mar 2018*	09 Mar 2020*

*Internal Characterization

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

4.0 DETAILED RESULTS

4.1 DUTY CYCLE

Test Method: NA

4.2 OUTPUT POWER

Test Method: ANSI C63.10:

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

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

Test procedures:
Except for BTBR mode (which was performed as an antenna port conducted measurement using a spectrum analyzer) all measurements were taken at a distance of 3m from the EUT. The EUT was maximized in all 3 orthogonal positions.10 MHz RBW and 10 MHz VBW was used.

Deviations from test standard:
No deviation.

Test setup:

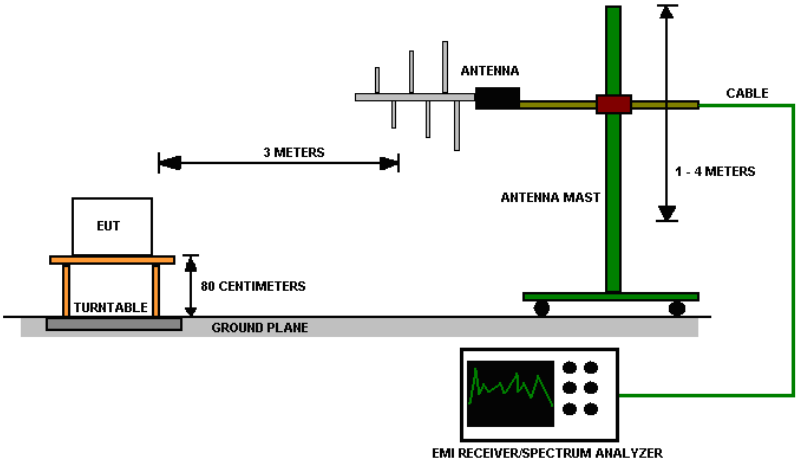

Figure 1 – Peak Output Power Measurements Test Setup

EUT operating conditions:
The EUT was set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Note: EIRP measurements were performed instead on conducted measurements because on uncertainties in the integrity of the conducted RF connector for this test.

Test results:

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

Test results:

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

Average Output Power

CHANNEL	CHANNEL FREQUENCY (MHz)	AVERAGE OUTPUT POWER (dBm)	AVERAGE OUTPUT POWER (mW)	Method	RESULT	Transmitter
Low	2402	13.42	21.98	Conducted	PASS	BT BR (GFSK)
Mid	2440	13.09	20.37	Conducted	PASS	BT BR (GFSK)
High	2480	13.08	20.32	Conducted	PASS	BT BR (GFSK)
Low	2402	6.26	4.2	Conducted	PASS	BT EDR 2MB
Mid	2440	6.08	4.1	Conducted	PASS	BT EDR 2MB
High	2480	5.11	3.2	Conducted	PASS	BT EDR 2MB
Low	2402	6.45	4.4	Conducted	PASS	BT EDR 3MB
Mid	2440	6.04	4.0	Conducted	PASS	BT EDR 3MB
High	2480	5.04	3.2	Conducted	PASS	BT EDR 3MB

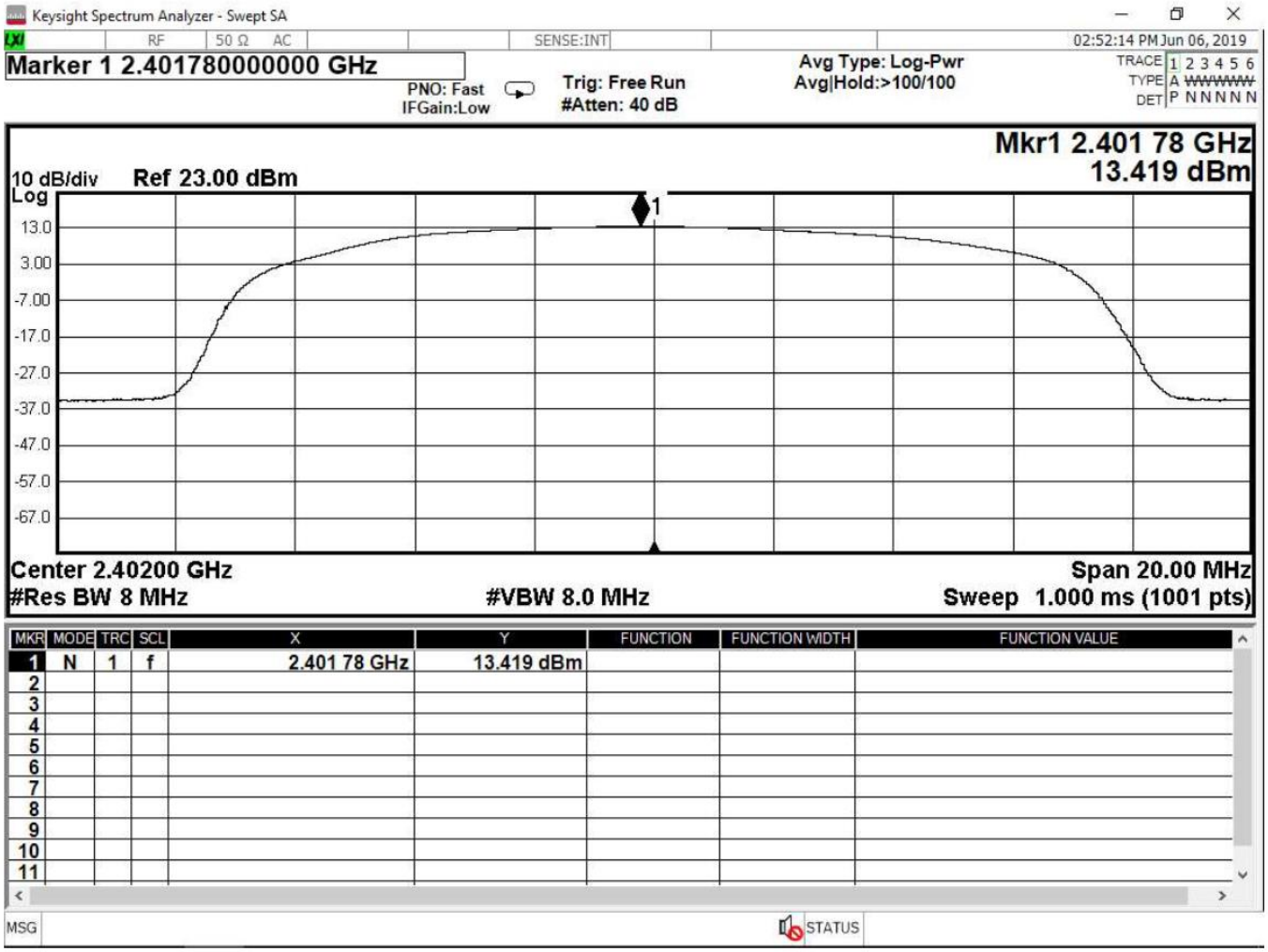

Figure 2 - Average Output Power, Low Channel, BT BR (highest power of 3 channels)

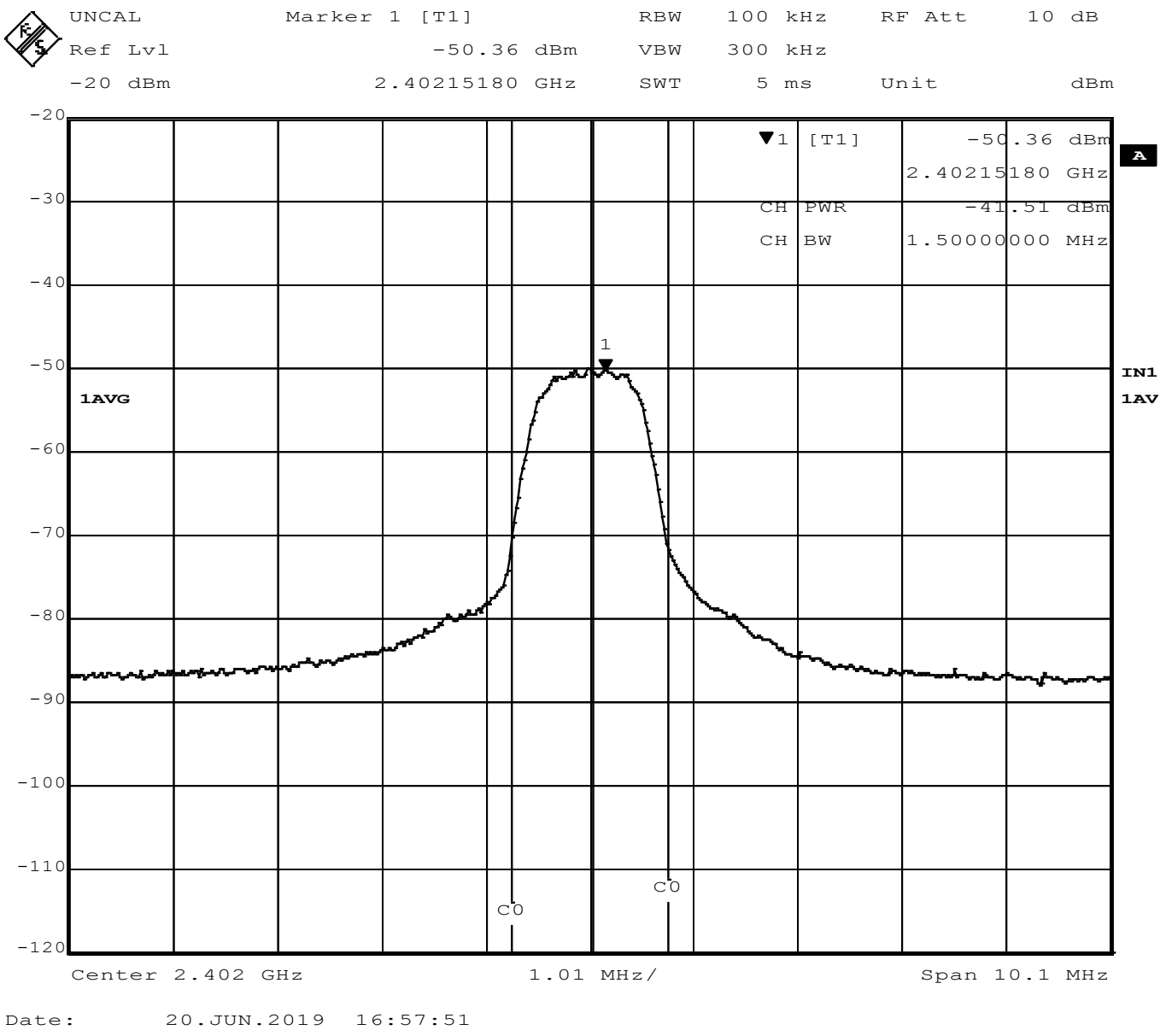

Figure 3 – Average Output Power, Low Channel, BT EDR 2MB

Maximum power = --41.51 + dBm + 107 + CL + AF - 95.23 = 6.26 dBm

CL = cable loss = 7.70 dB
AF = antenna factor = 28.30 dB
107 = conversion from dBm to dBµV on a 50Ω measurement system
-95.23 = Conversion from field strength (dBµV/m) to EIRP (dBm) at a 3m measurement distance

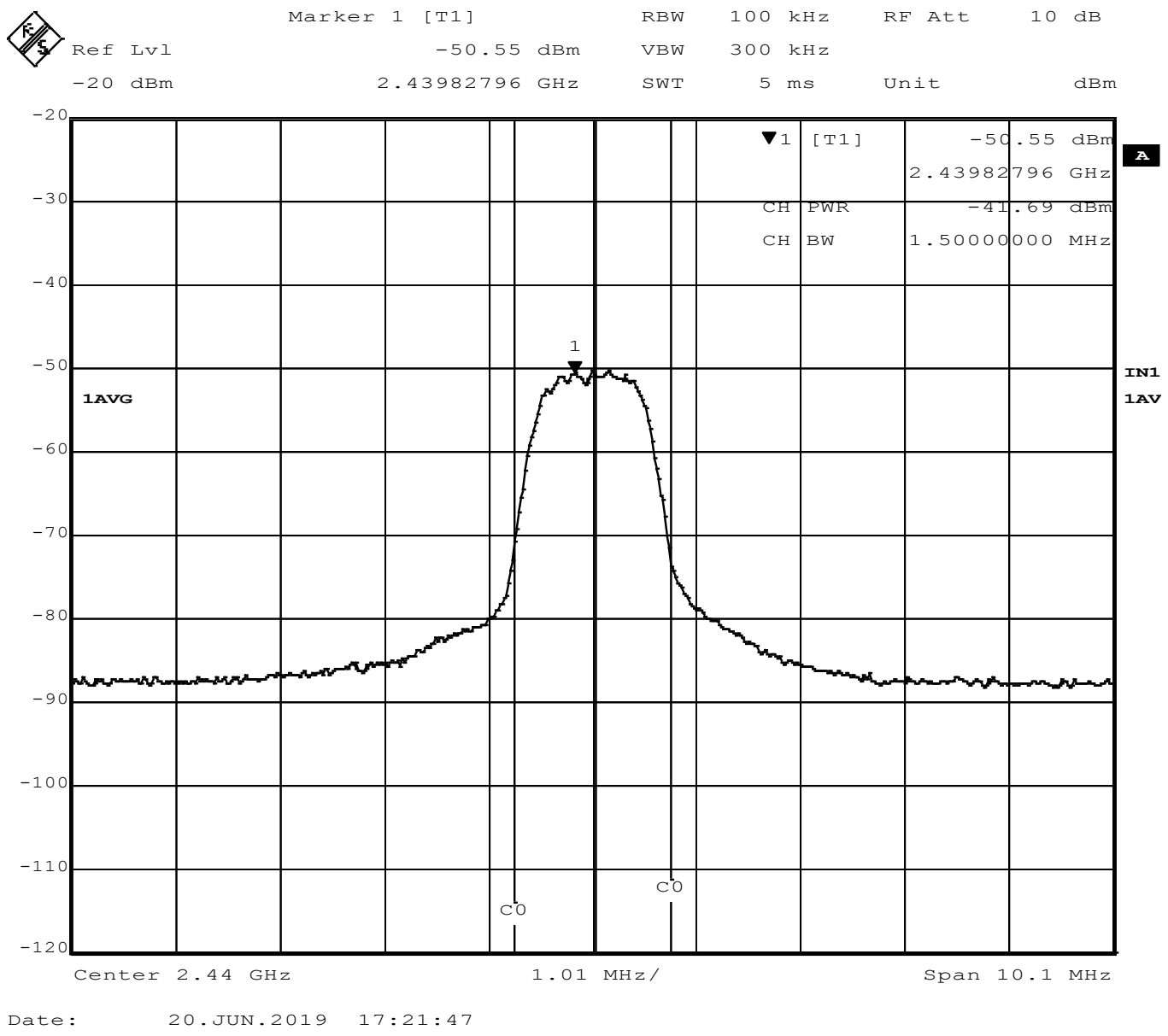

Figure 4 – Average Output Power, Mid Channel, BT EDR 2MB

Maximum power = --41.69 dBm + 107 + CL + AF - 95.23 = 6.08 dBm*

CL = cable loss = 7.70 dB
AF = antenna factor = 28.30 dB
107 = conversion from dBm to dBµV on a 50Ω measurement system
-95.23 = Conversion from field strength (dBµV/m) to EIRP (dBm) at a 3m measurement distance

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

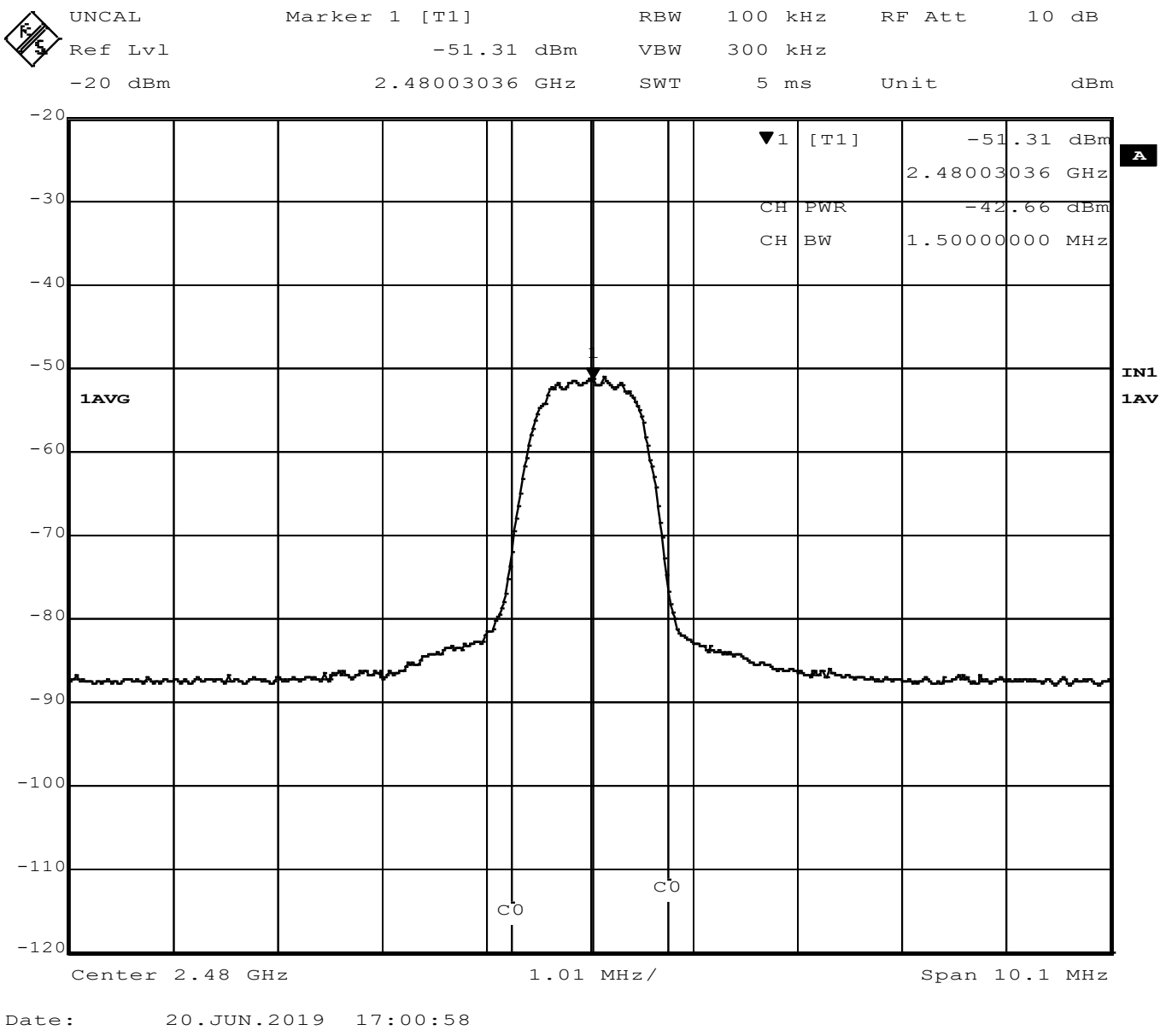

Figure 6 - Average Output Power, High Channel, BT EDR 2MB

Maximum power = -42.66 dBm + 107 + CL + AF - 95.23 = 5.11 dBm*

CL = cable loss = 7.70 dB
AF = antenna factor = 28.30 dB
107 = conversion from dBm to dBµV on a 50Ω measurement system
-95.23 = Conversion from field strength (dBµV/m) to EIRP (dBm) at a 3m measurement distance

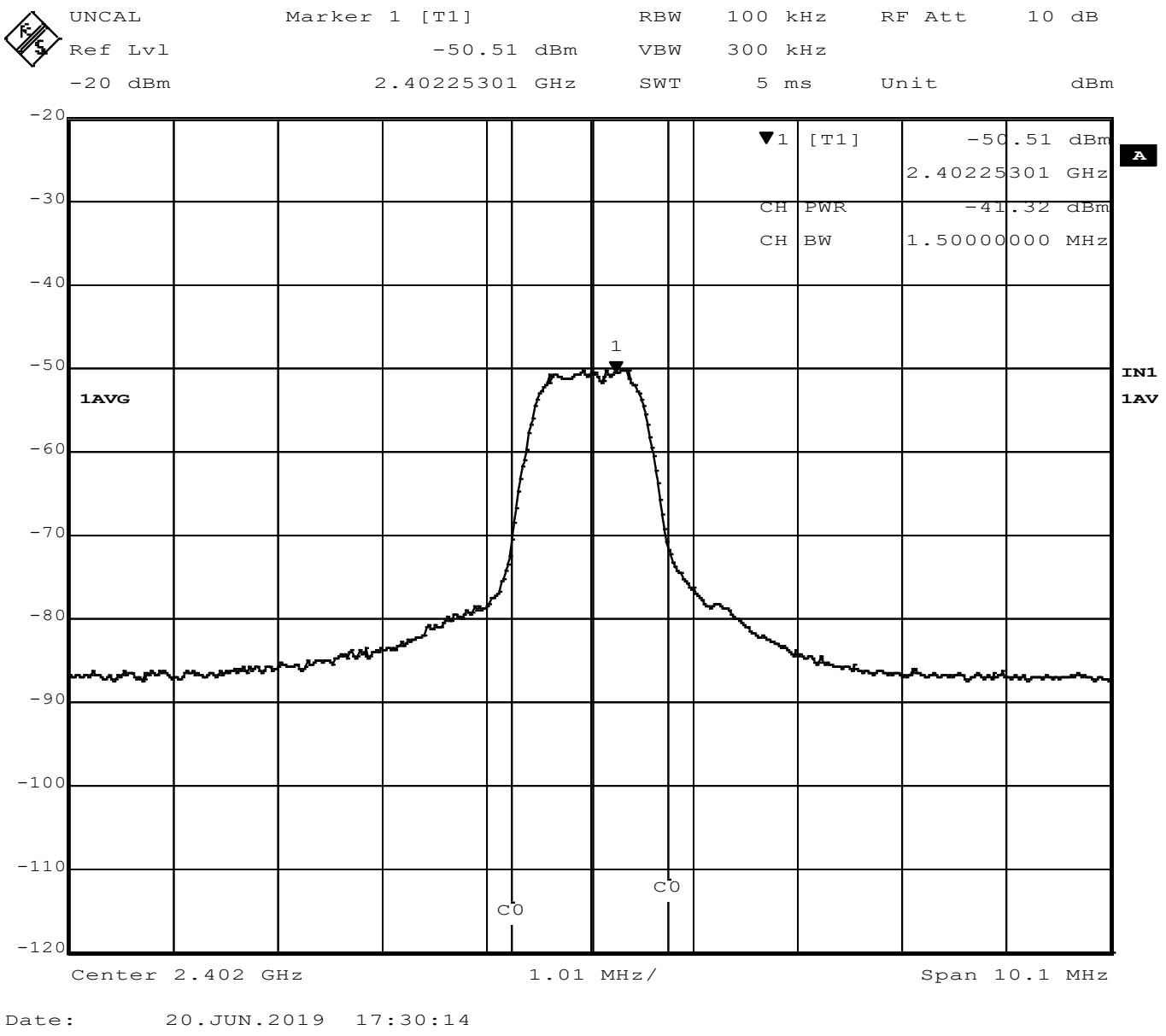

Figure 7 - Average Output Power, Low Channel, BT EDR 3MB

Maximum power = -41.32 dBm + 107 + CL + AF - 95.23 = 6.45 dBm

CL = cable loss = 7.70 dB
AF = antenna factor = 28.30 dB
107 = conversion from dBm to dBµV on a 50Ω measurement system
-95.23 = Conversion from field strength (dBµV/m) to EIRP (dBm) at a 3m measurement distance

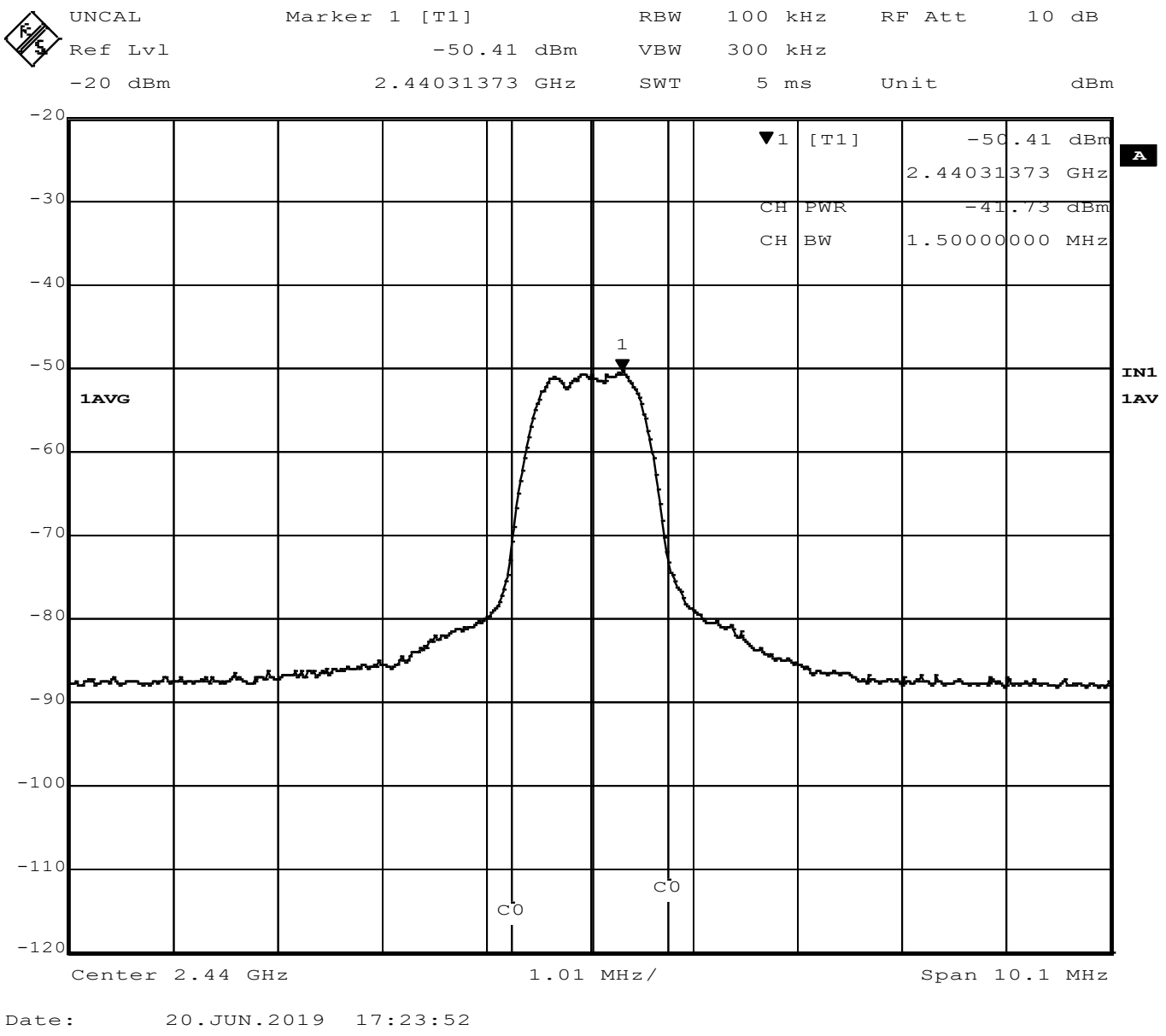

Figure 8 - Average Output Power, Mid Channel, BT EDR 3MB

Maximum power = -41.73 dBm + 107 + CL + AF - 95.23 = 6.04 dBm

CL = cable loss = 7.70 dB
AF = antenna factor = 28.30 dB
107 = conversion from dBm to dBµV on a 50Ω measurement system
-95.23 = Conversion from field strength (dBµV/m) to EIRP (dBm) at a 3m measurement distance

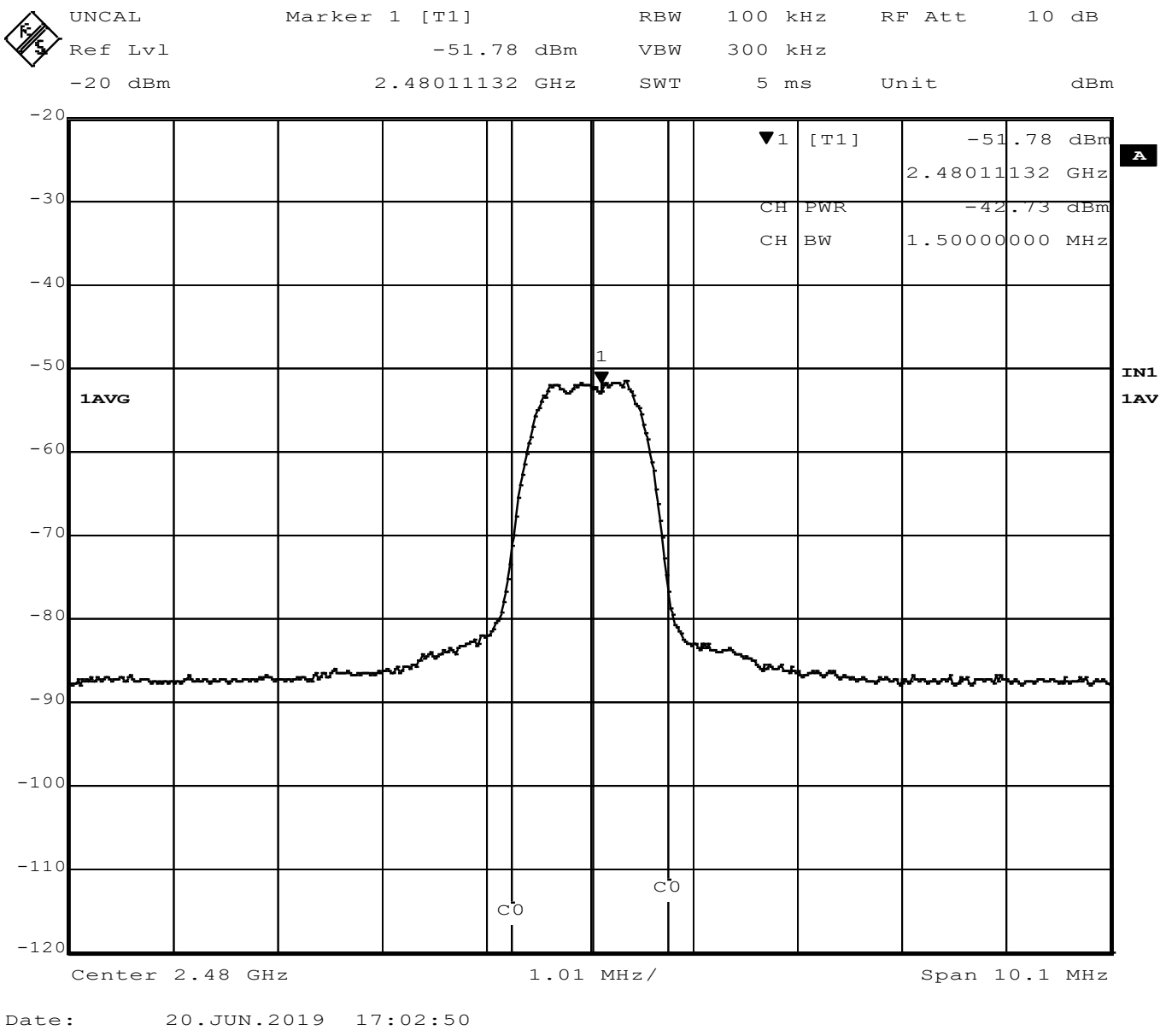

Figure 9 - Average Output Power, High Channel, BT EDR 3MB

Maximum power = -42.73 dBm + 107 + CL + AF - 95.23 = 5.04 dBm

CL = cable loss = 7.70 dB
AF = antenna factor = 28.30 dB
107 = conversion from dBm to dBµV on a 50Ω measurement system
-95.23 = Conversion from field strength (dBµV/m) to EIRP (dBm) at a 3m measurement distance

4.3 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:

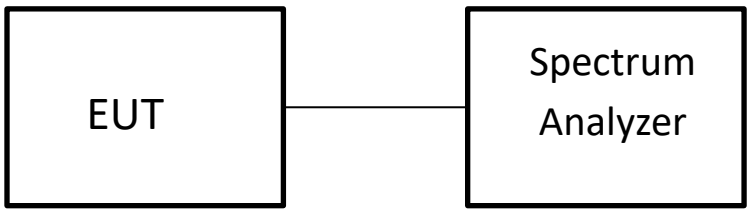

Figure 10 – Peak Output Power Measurements Test Setup

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

Test results:

Occupied Bandwidth

CHANNEL	Mode	CHANNEL FREQUENCY (MHz)	OBW (KHz)	RESULT
Low	BT BR (GFSK)	2402	1095.0	PASS
Mid	BT BR (GFSK)	2440	1068.0	PASS
High	BT BR (GFSK)	2480	1070.4	PASS
Low	BT EDR 2MB	2402	1309.1	PASS
Mid	BT EDR 2MB	2440	1278.7	PASS
High	BT EDR 2MB	2480	1263.6	PASS
Low	BT EDR 3MB	2402	1306.4	PASS
Mid	BT EDR 3MB	2440	1282.7	PASS
High	BT EDR 3MB	2480	1279.5	PASS

6dB Bandwidth

CHANNEL	Mode	CHANNEL FREQUENCY (MHz)	6dB (KHz)	RESULT
Low	BT BR (GFSK)	2402	649.8	PASS
Mid	BT BR (GFSK)	2440	565.0	PASS
High	BT BR (GFSK)	2480	573.6	PASS
Low	BT EDR 2MB	2402	1083	PASS
Mid	BT EDR 2MB	2440	1077	PASS
High	BT EDR 2MB	2480	1080	PASS
Low	BT EDR 3MB	2402	1092	PASS
Mid	BT EDR 3MB	2440	1091	PASS
High	BT EDR 3MB	2480	1105	PASS

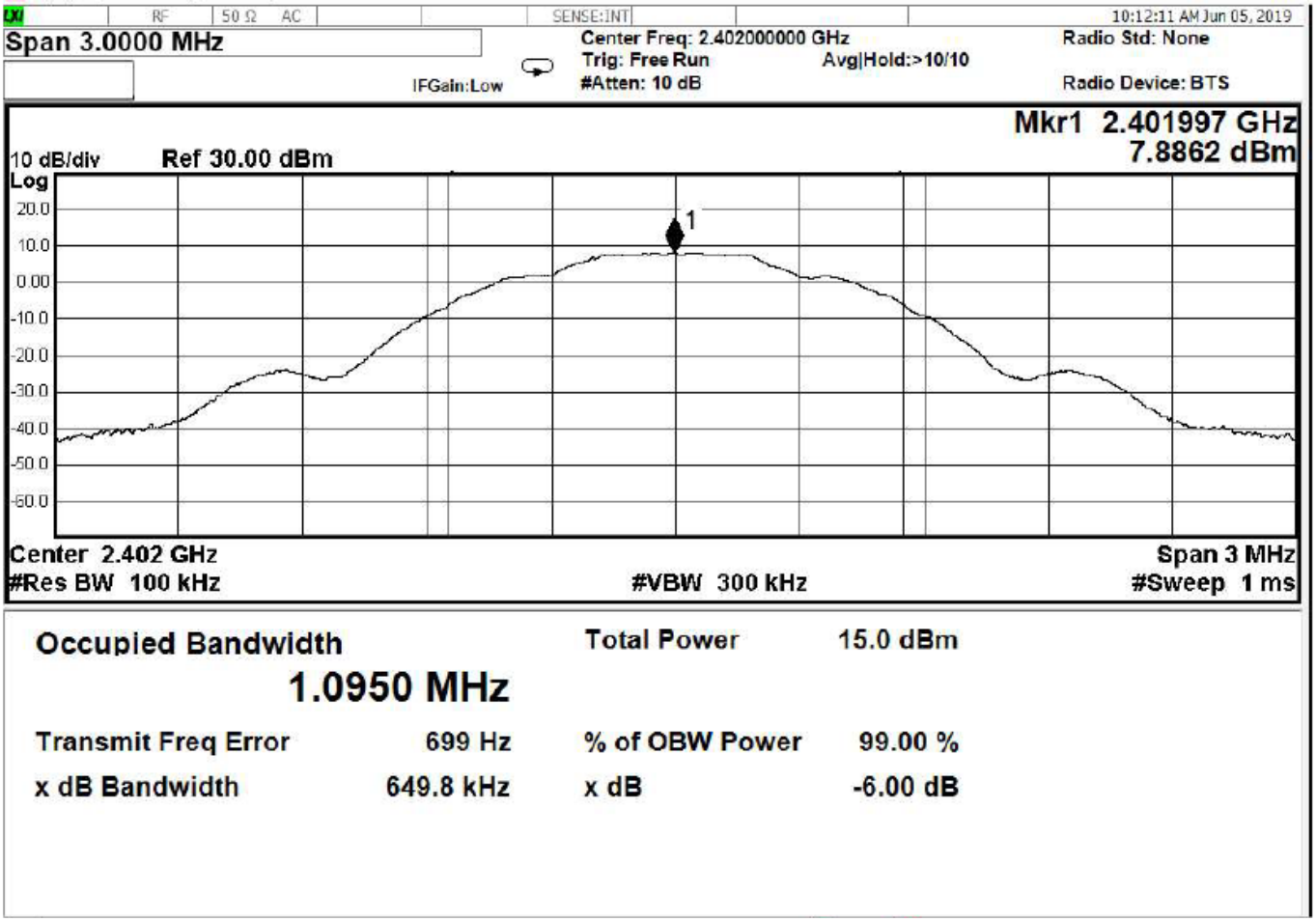

Figure 11 – Bandwidth, Low Channel, BT BR (GFSK)

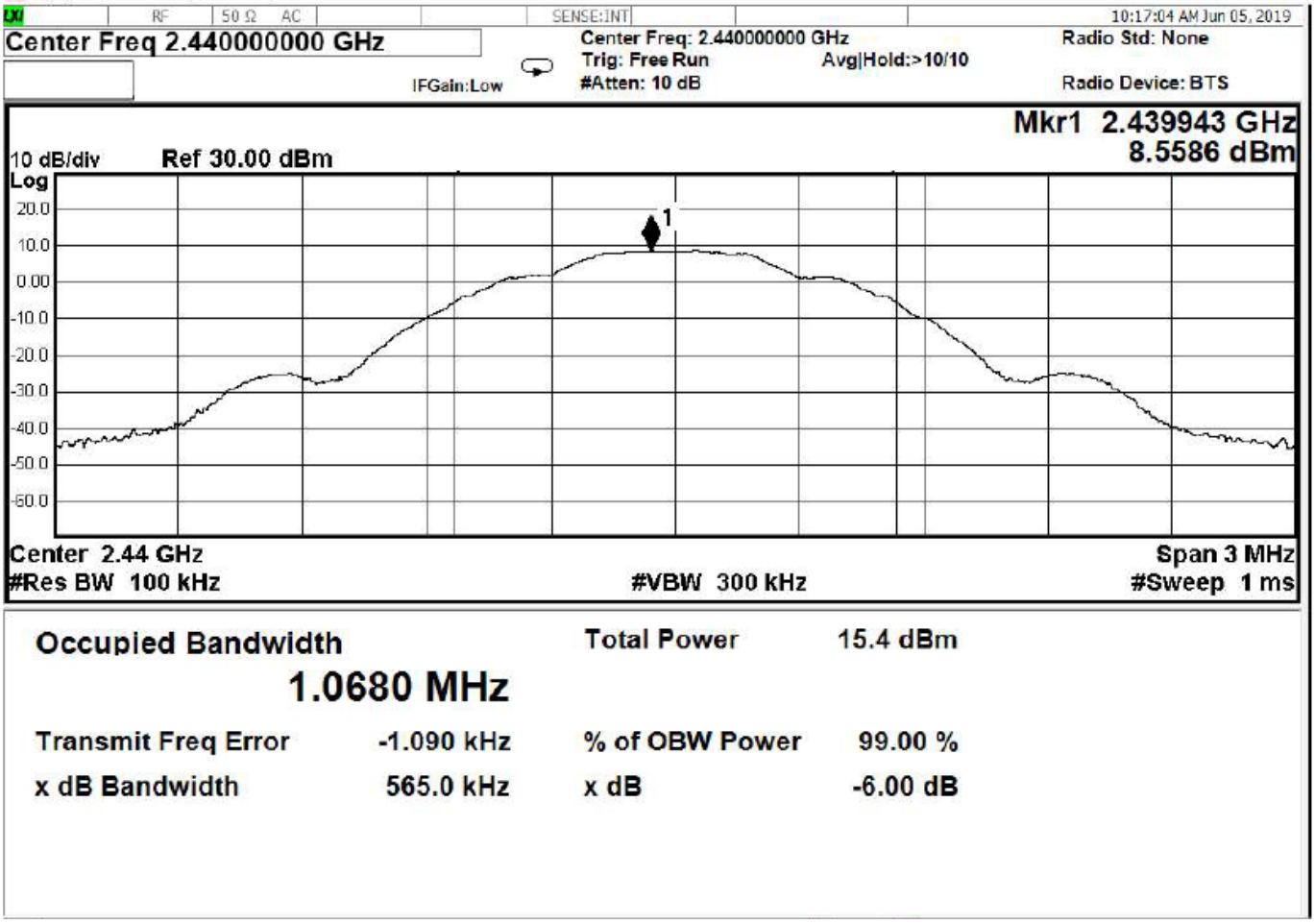

Figure 12 - Bandwidth, Mid Channel, BT BR (GFSK)

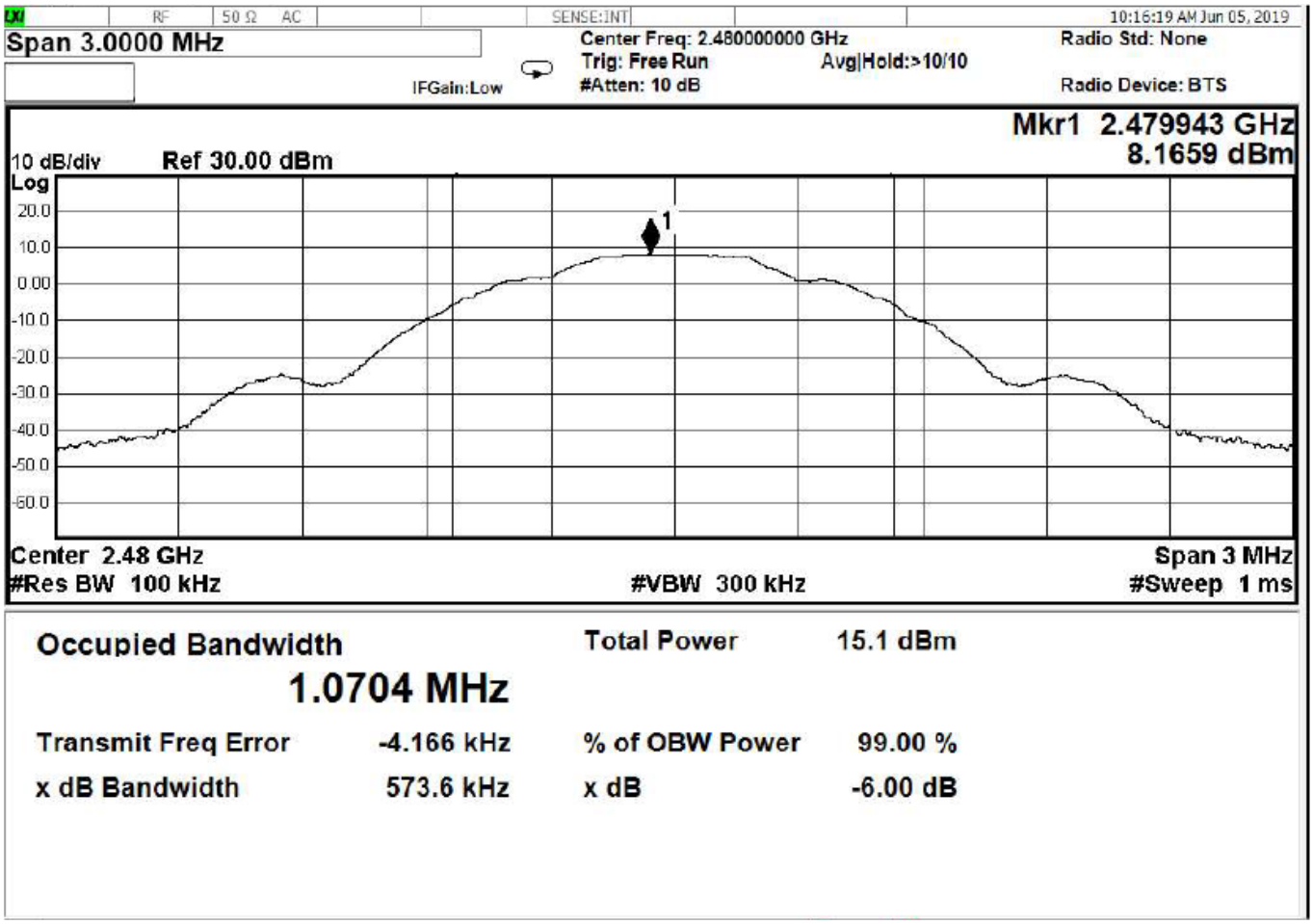

Figure 13 - Bandwidth, High Channel, BT BR (GFSK)

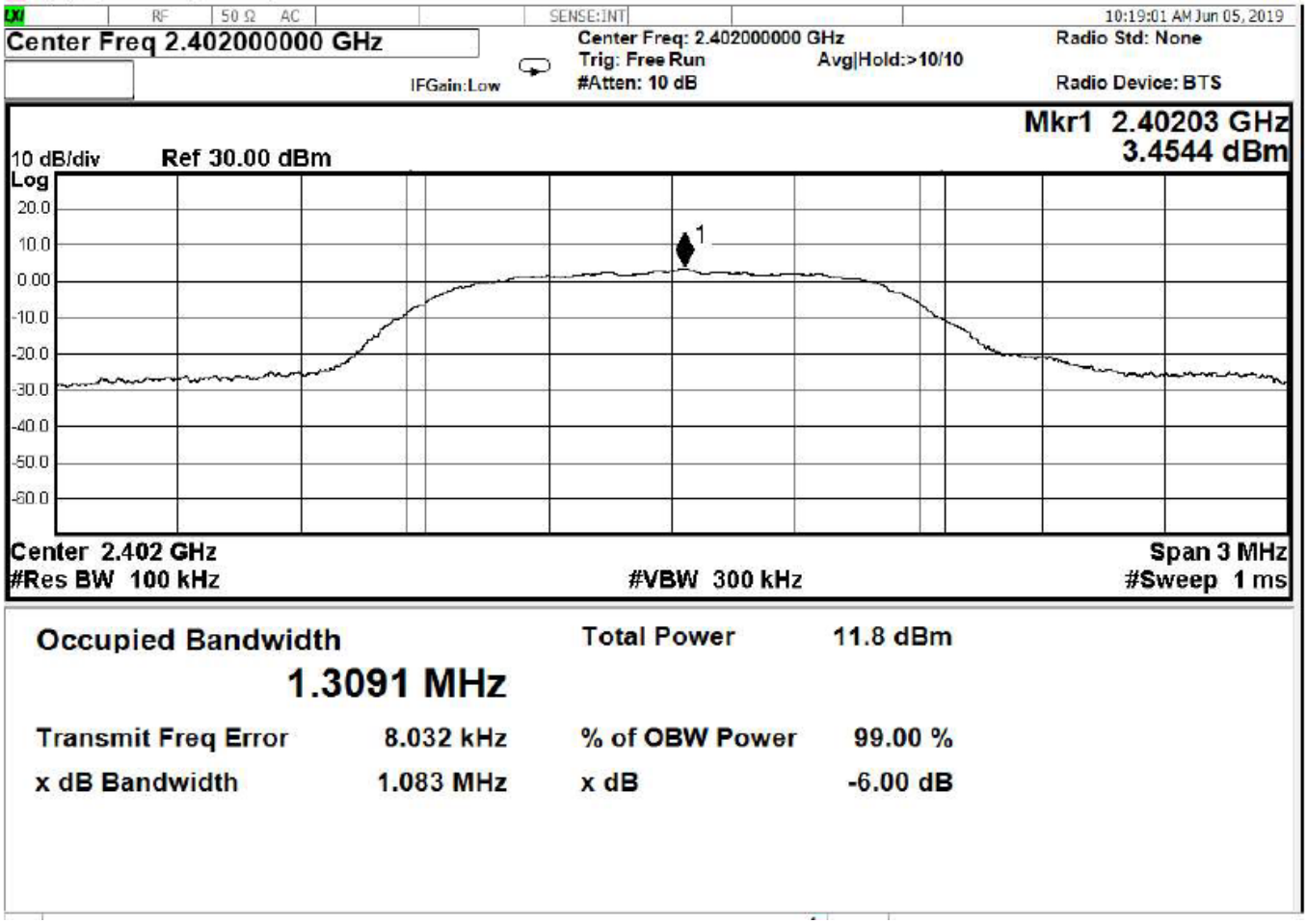

Figure 14 – Bandwidth, Low Channel, BT EDR 2MB

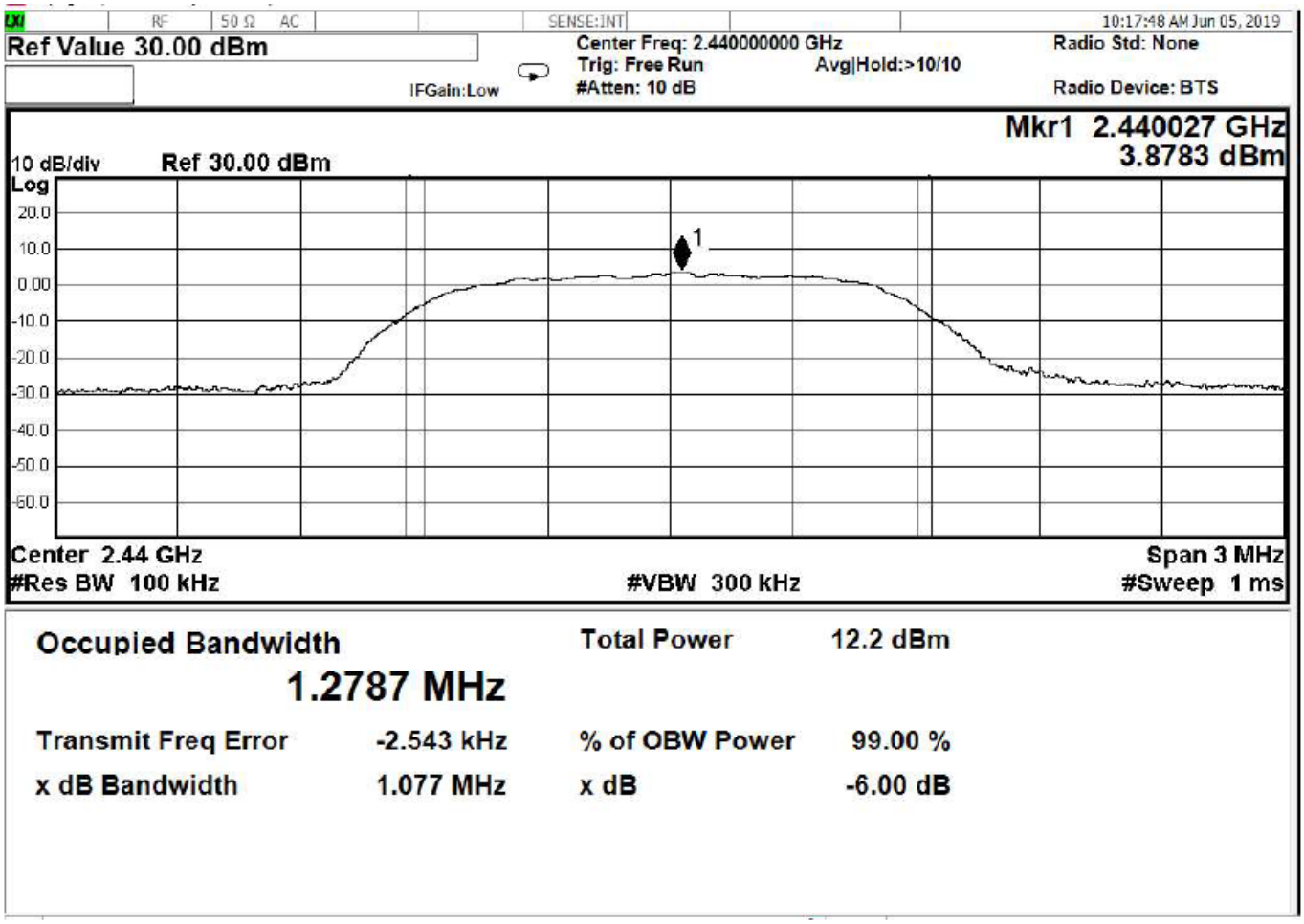

Figure 15 - Bandwidth, Mid Channel, BT EDR 2MB

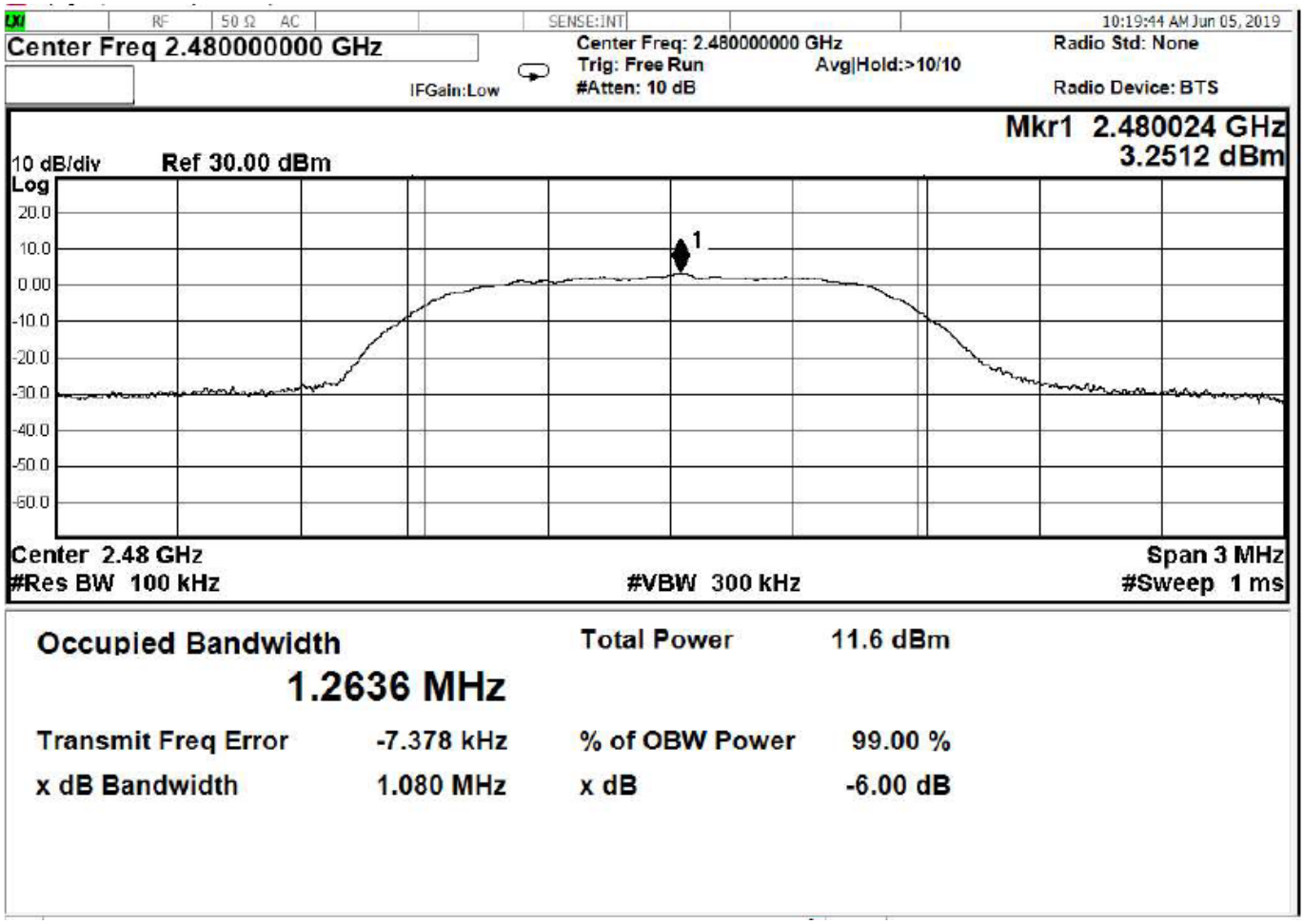

Figure 16 - Bandwidth, High Channel, BT EDR 2MB

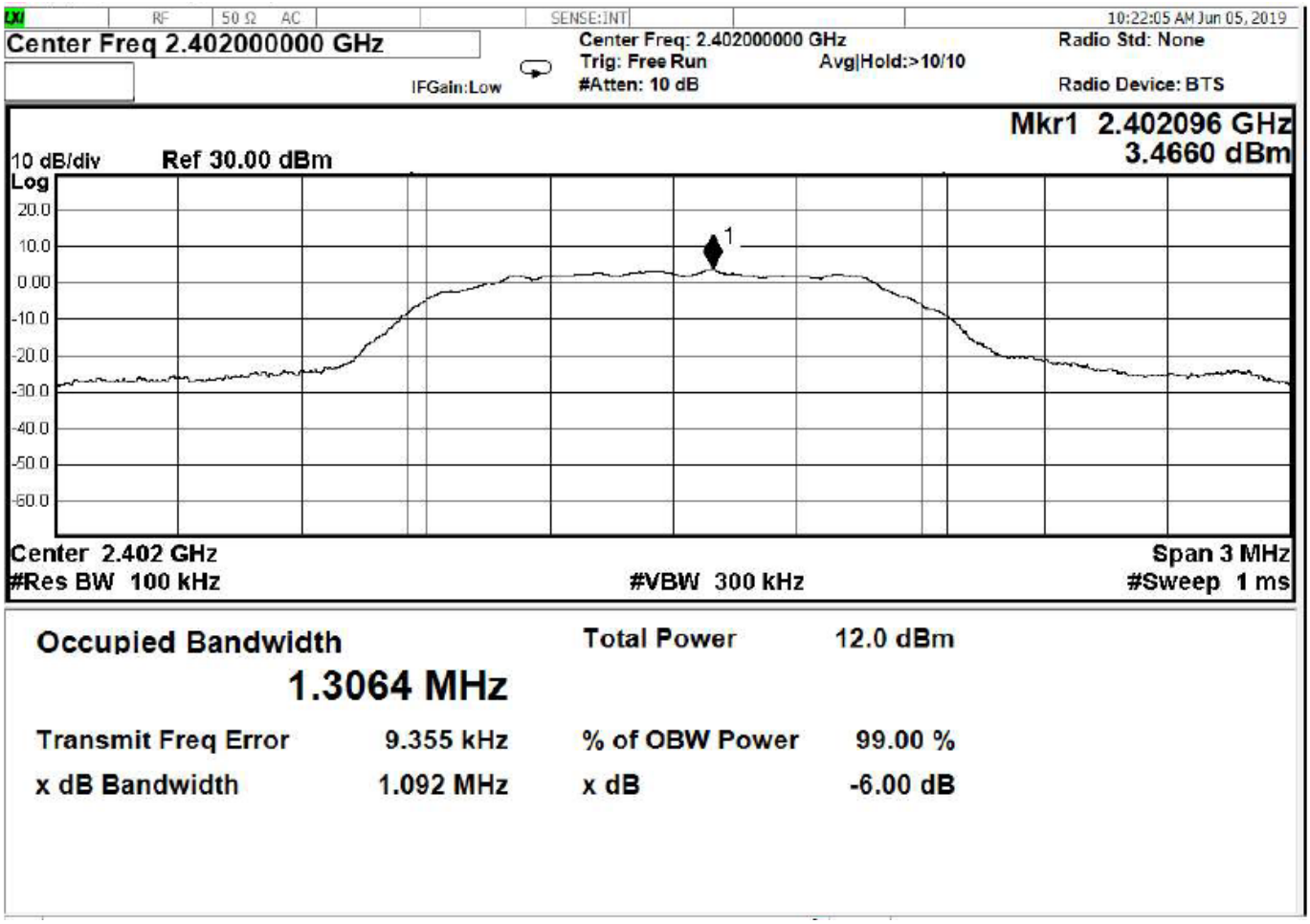

Figure 17 – Bandwidth, Low Channel, BT EDR 3MB

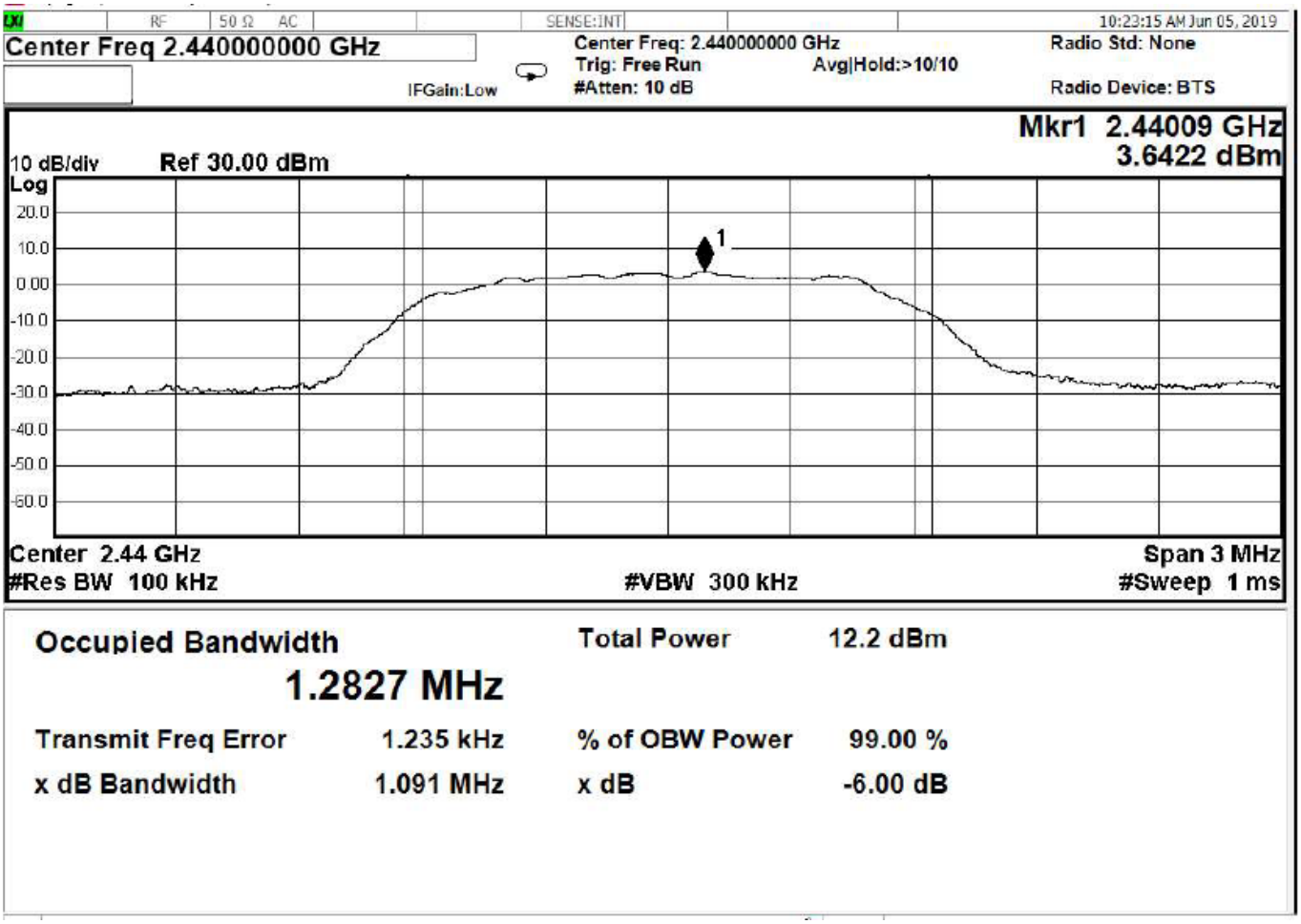

Figure 18 - Bandwidth, Mid Channel, BT EDR 3MB

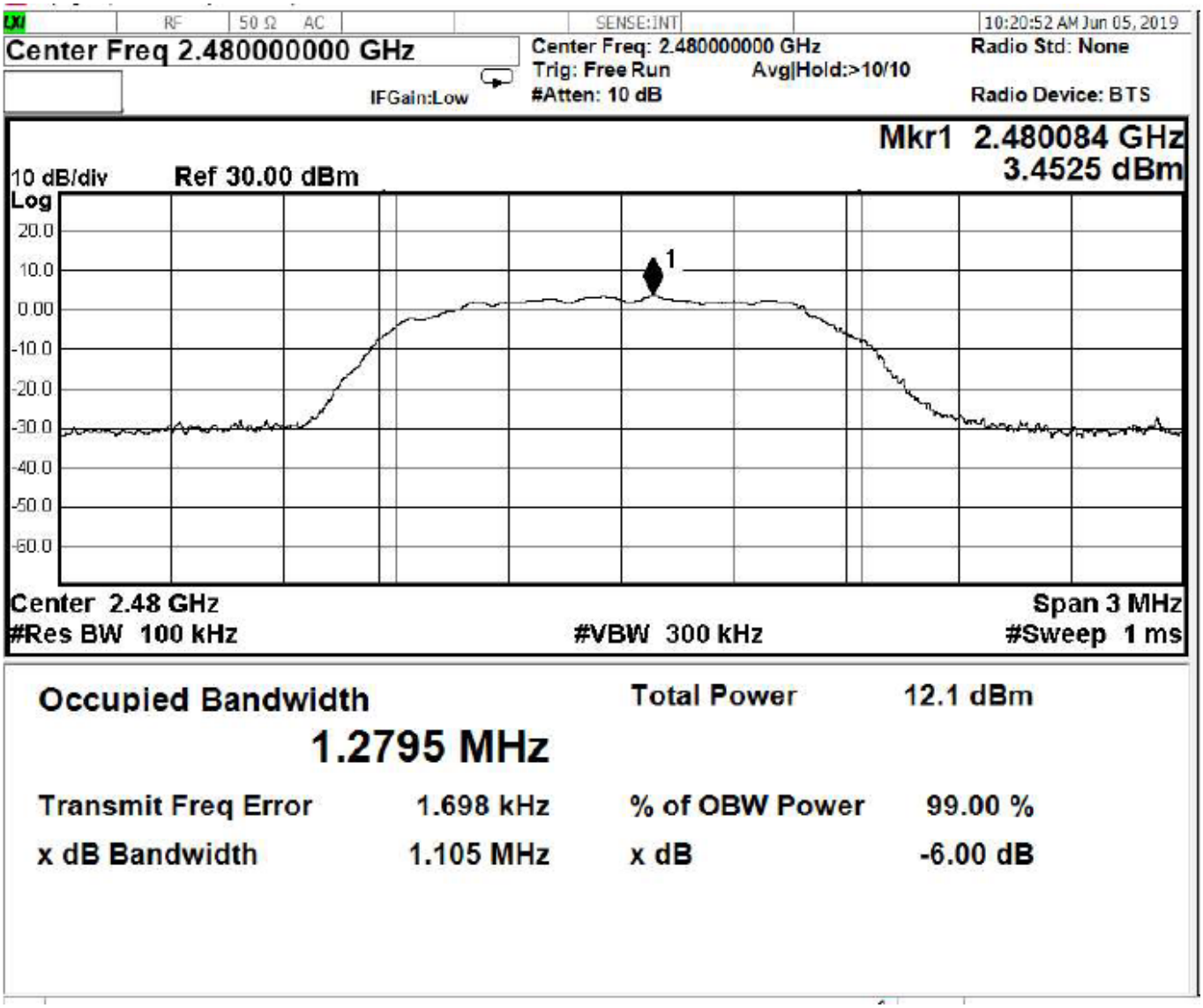

Figure 19 - Bandwidth, High Channel, BT EDR 3MB

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:

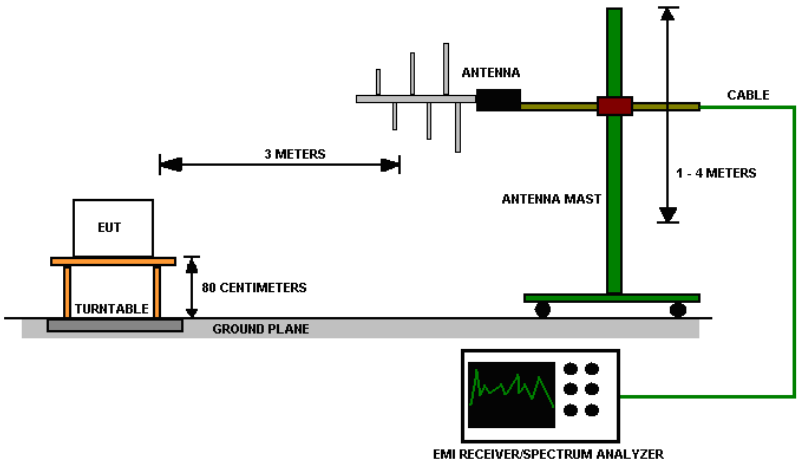

Figure 20 - Radiated Emissions Test Setup

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

Test results:

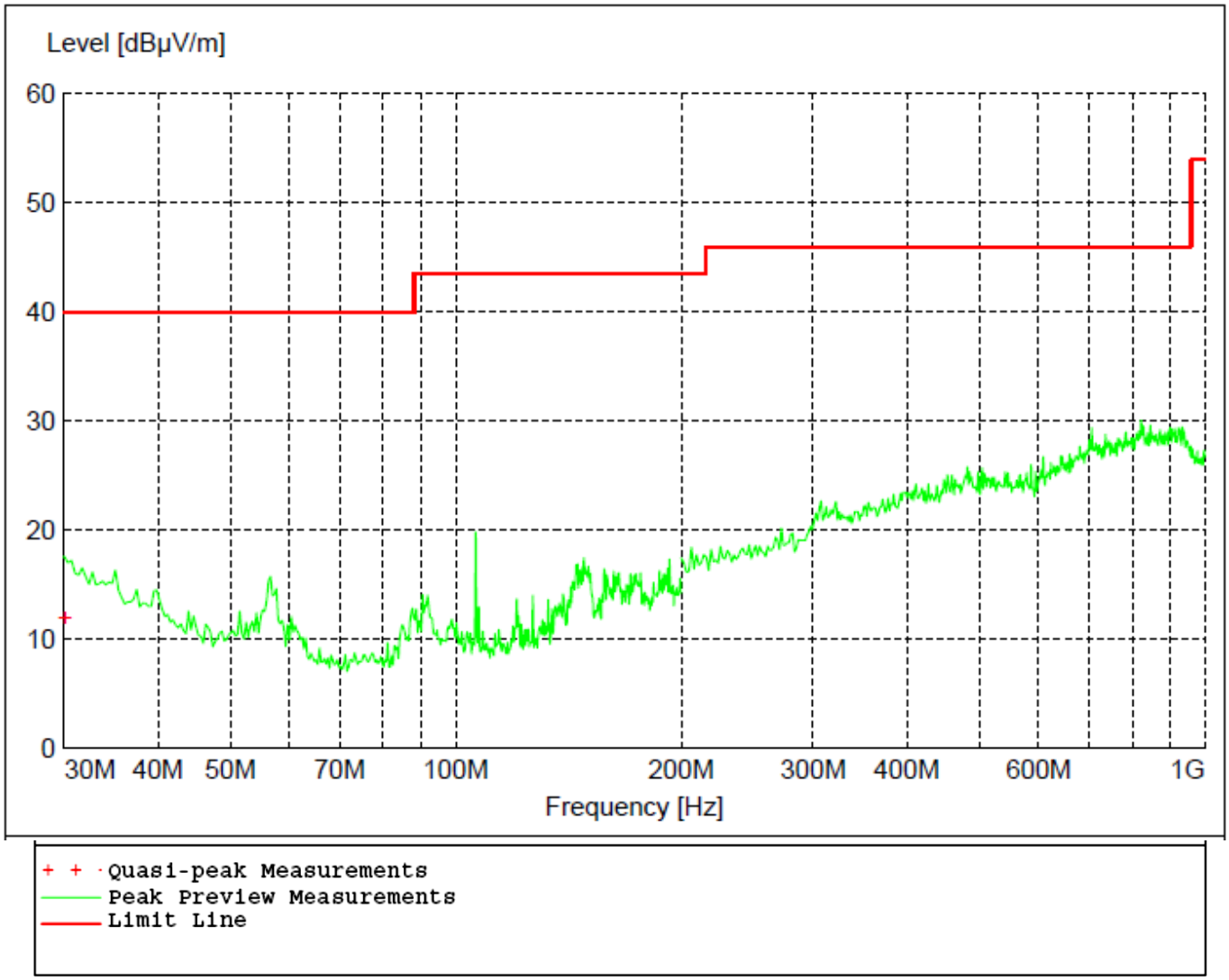

Figure 21 - Radiated Emissions Plot, Receive

REMARKS:
1. Emission level (dBuV/m) = Raw Value (dBuV) + Correction Factor (dB)
2. Correction Factor (dB/m) = Antenna Factor (dB/m) + Cable Factor (dB)
3. The other emission levels were very low against the limit.
4. Margin value = Emission level – Limit value

Table 1 - Radiated Emissions Quasi-peak Measurements, Receive

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

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

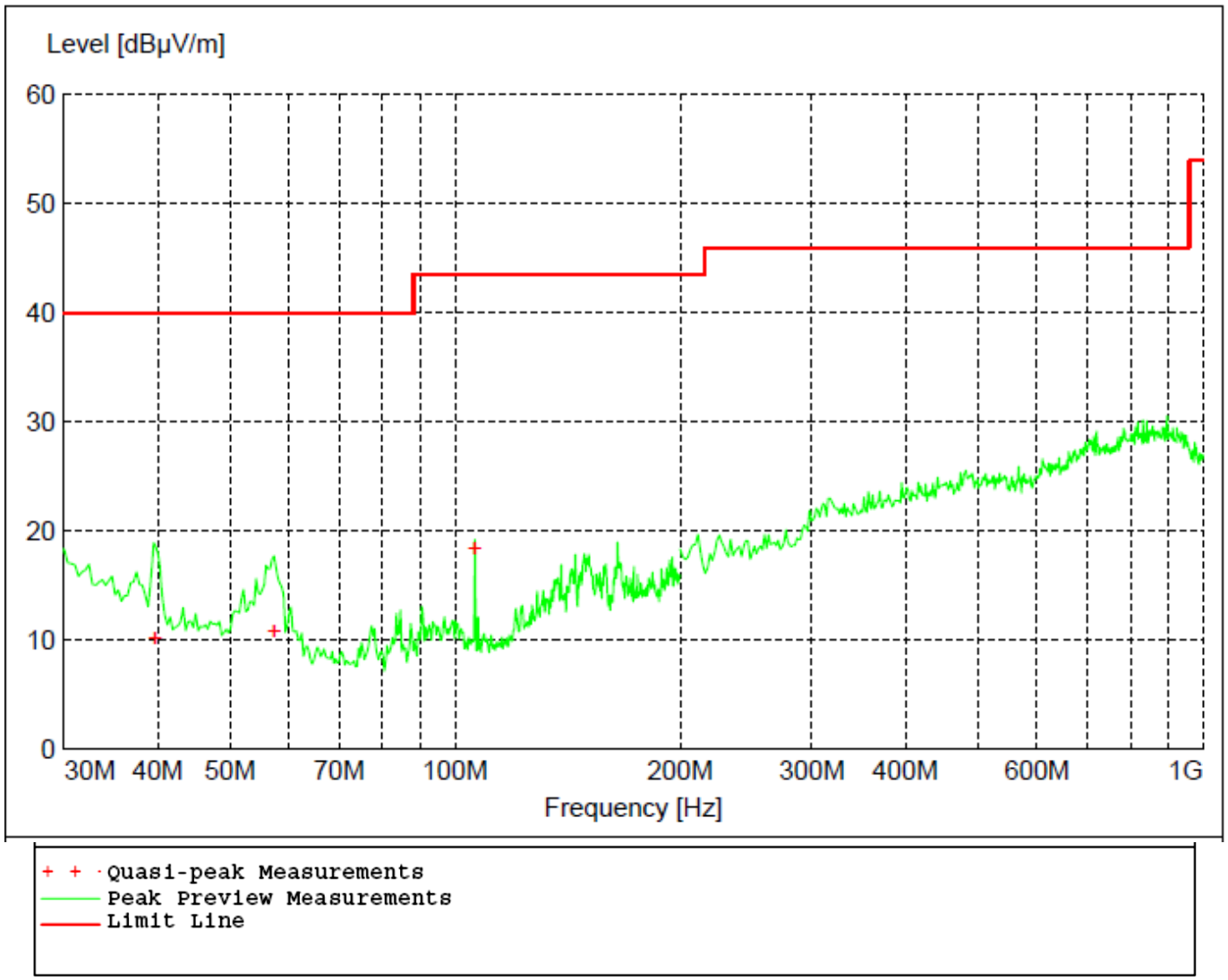

Figure 22 - Radiated Emissions Plot

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.	
39.720000	10.13	40.00	29.87	400.00	80.00	VERT
57.300000	10.79	40.00	29.21	100.00	123.00	VERT
106.260000	18.35	43.50	25.15	128.00	111.00	VERT

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	107.65	NA	NA	197.00	10.00	VERT	Low
2440.000000	106.58	NA	NA	197.00	10.00	VERT	Mid
2480.000000	104.55	NA	NA	197.00	10.00	VERT	High

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	108.41	NA	NA	197.00	10.00	VERT	Low
2440.000000	107.29	NA	NA	197.00	10.00	VERT	Mid
2480.000000	105.29	NA	NA	197.00	10.00	VERT	High

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	100.22	NA	NA	197.00	10.00	VERT	Low
2440.000000	100.33	NA	NA	197.00	10.00	VERT	Mid
2480.000000	99.15	NA	NA	197.00	10.00	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	103.89	NA	NA	197.00	10.00	VERT	Low
2440.000000	103.77	NA	NA	197.00	10.00	VERT	Mid
2480.000000	102.85	NA	NA	197.00	10.00	VERT	High

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	100.14	NA	NA	197.00	10.00	VERT	Low
2440.000000	100.20	NA	NA	197.00	10.00	VERT	Mid
2480.000000	99.31	NA	NA	197.00	10.00	VERT	High
4804.200000	29.01	54.00	24.99	338.00	23.00	VERT	Low

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	104.14	NA	NA	197.00	10.00	VERT	Low
2440.000000	104.15	NA	NA	197.00	10.00	VERT	Mid
2480.000000	103.1	NA	NA	197.00	10.00	VERT	High
4804.200000	43.43	74.00	30.57	338.00	23.00	VERT	Low

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

4.5 POWER SPECTRAL DENSITY

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

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

Test procedures:
1. The EUT was connected to the spectrum analyzer directly with a low-loss shielded coaxial cable.

2. The resolution bandwidth was set to 3 kHz and the video bandwidth was set to 10 kHz to capture the signal. The analyzer used a peak detector in max hold mode.

Test setup:
The EUT was connected to the spectrum analyzer directly with a low-loss shielded coaxial cable on a bench top.

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

Conducted measurements were performed because the direct RF connector was verified to have a good impedance match with low loss for this test.

Test results:

Power Spectral Density

CHANNEL	MODE	CHANNEL FREQUENCY (MHz)	PEAK PSD(dBm)	Method	Limit (dBm)	RESULT
Low	BT BR	2402	2.02	Conducted	8.00	PASS
Middle	BT BR	2440	1.38	Conducted	8.00	PASS
High	BT BR	2480	2.69	Conducted	8.00	PASS
Low	BT EDR 2MB	2402	-10.66	Conducted	8.00	PASS
Middle	BT EDR 2MB	2440	-10.54	Conducted	8.00	PASS
High	BT EDR 2MB	2480	-10.56	Conducted	8.00	PASS
Low	BT EDR 3MB	2402	-10.24	Conducted	8.00	PASS
Middle	BT EDR 3MB	2440	-10.30	Conducted	8.00	PASS
High	BT EDR 3MB	2480	-10.05	Conducted	8.00	PASS

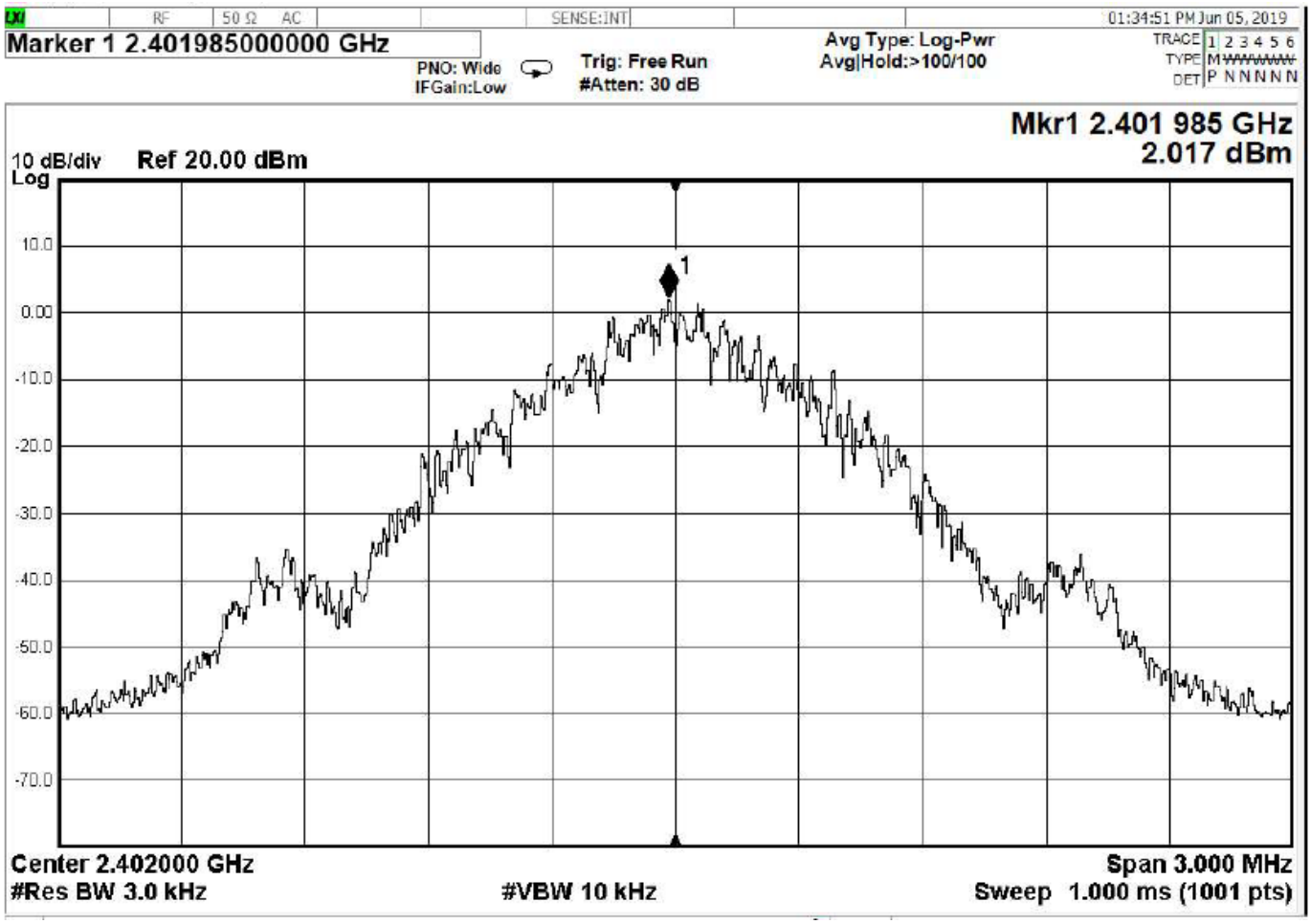

Figure 23 - Power Spectral Density, Low Channel, BT BR (GFSK)

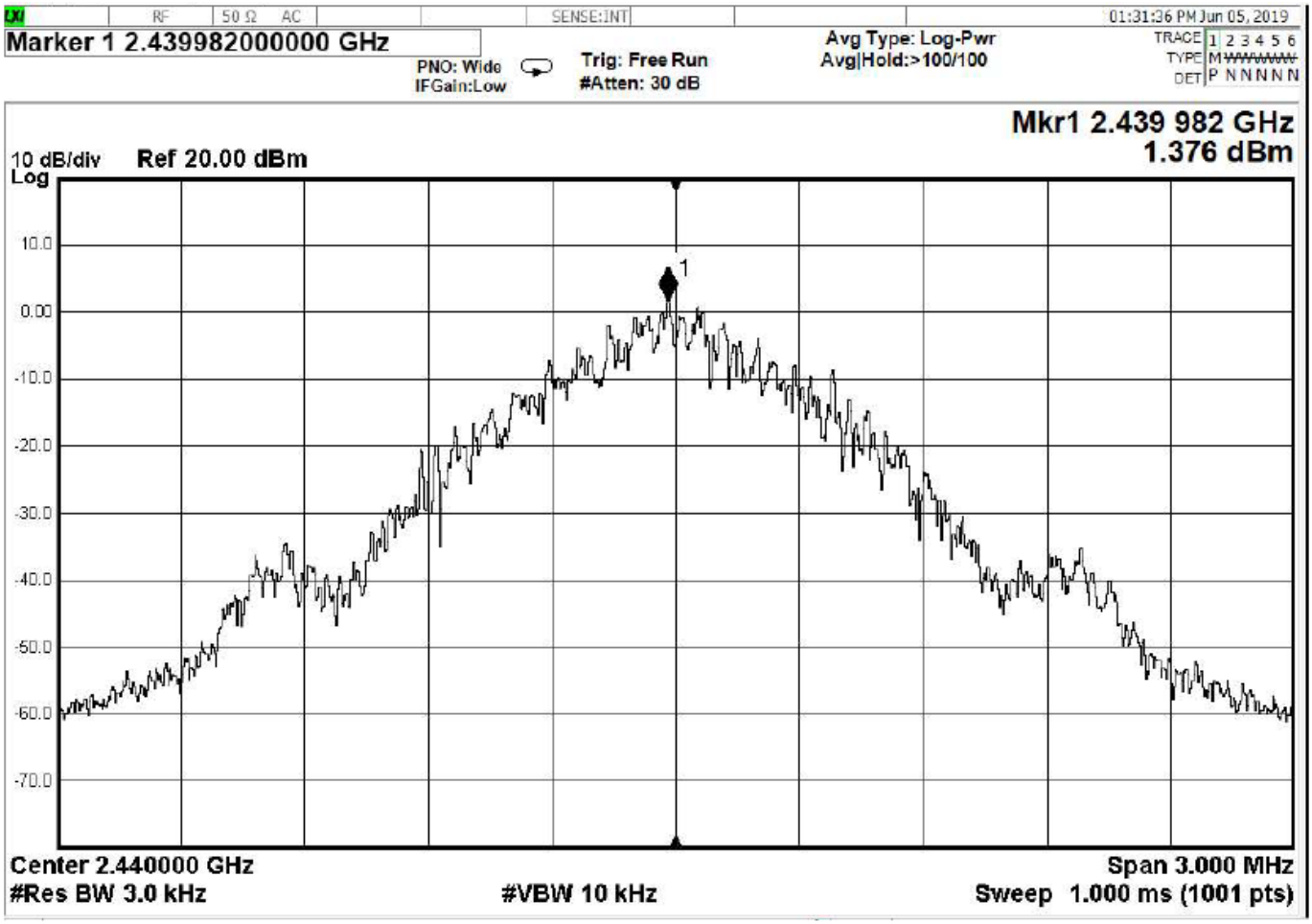

Figure 24 - Power Spectral Density, Mid Channel, BT BR (GFSK)

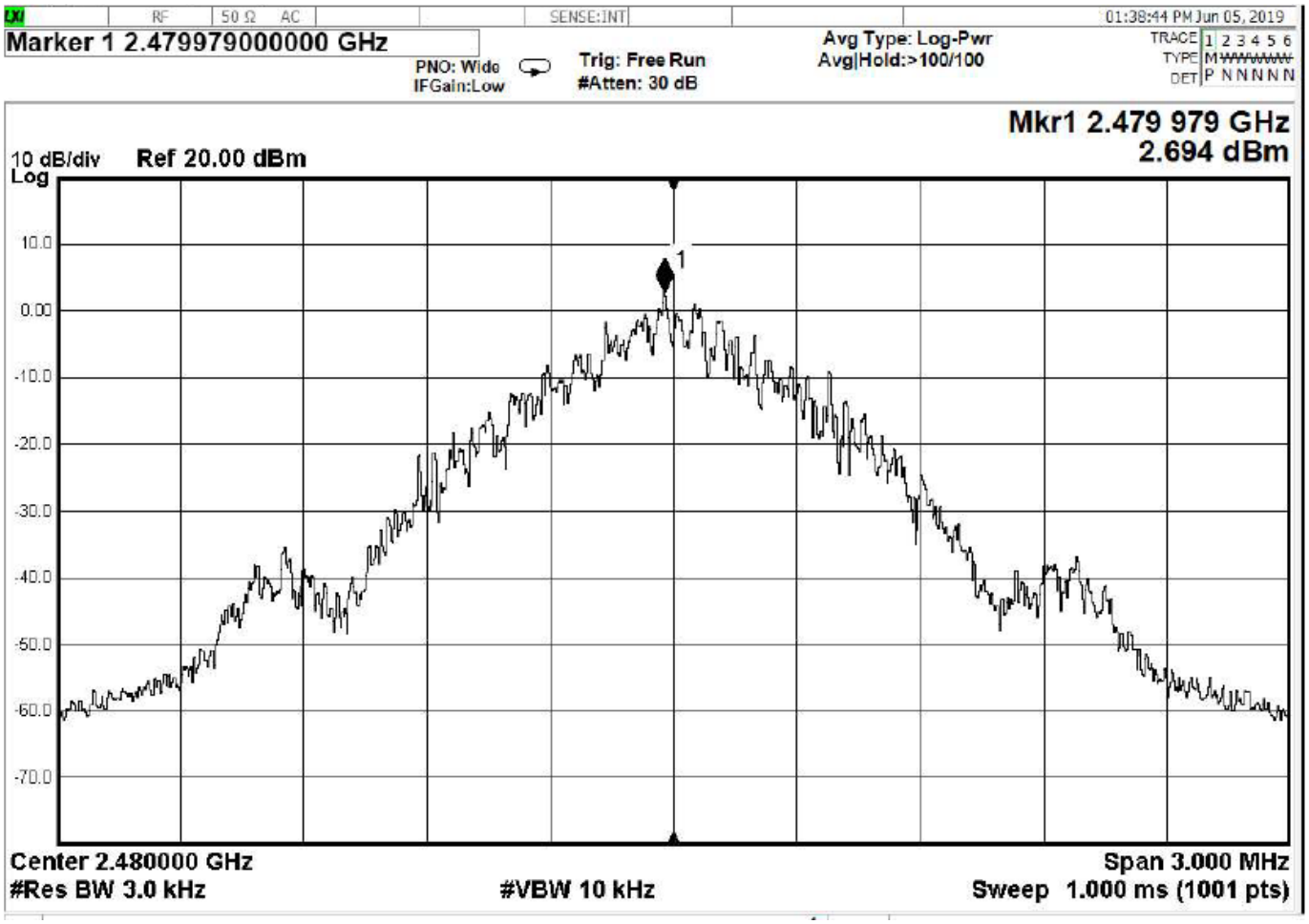

Figure 25 - Power Spectral Density, High Channel, BT BR (GFSK)

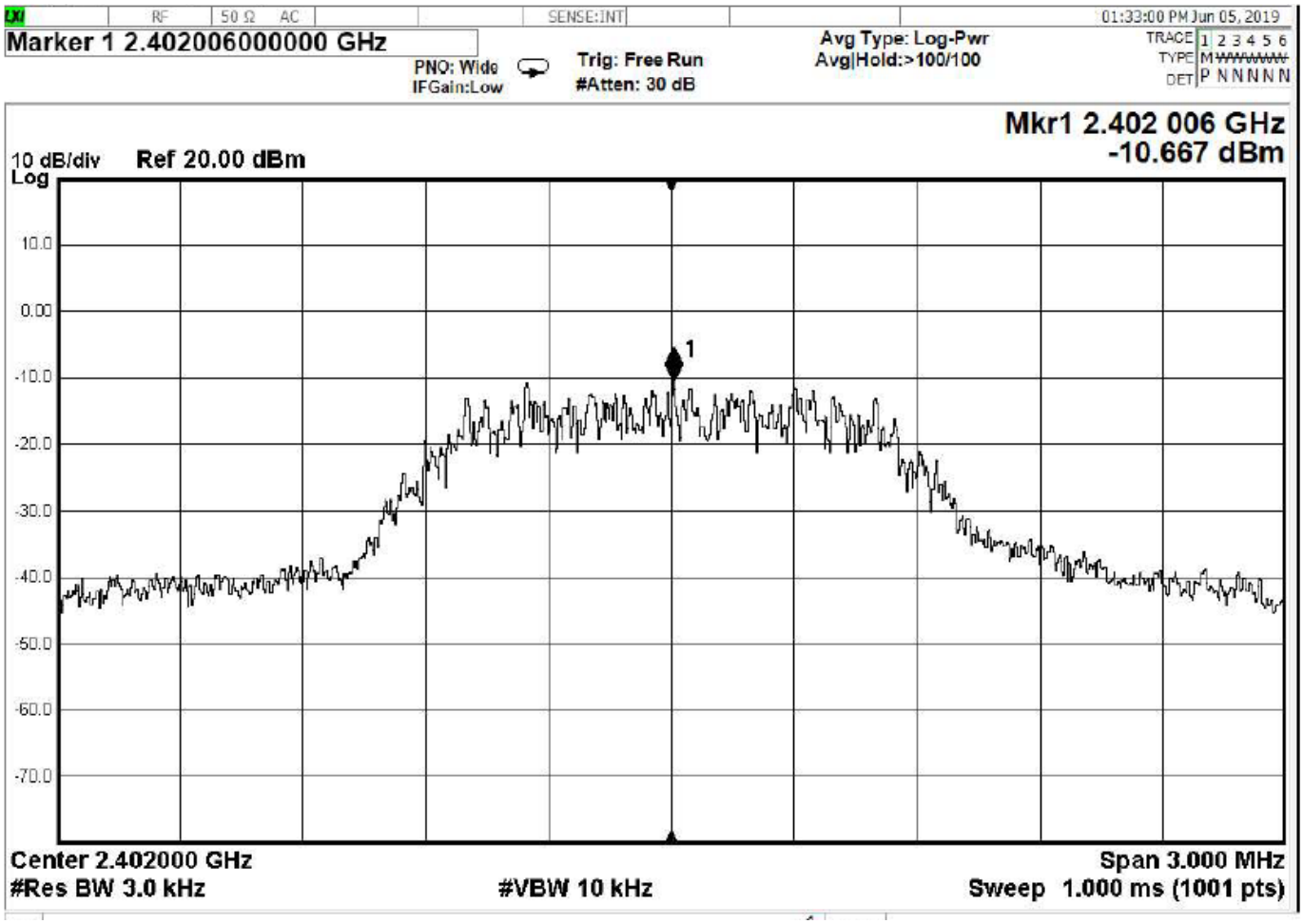

Figure 26 - Power Spectral Density, Low Channel, BT EDR 2MB

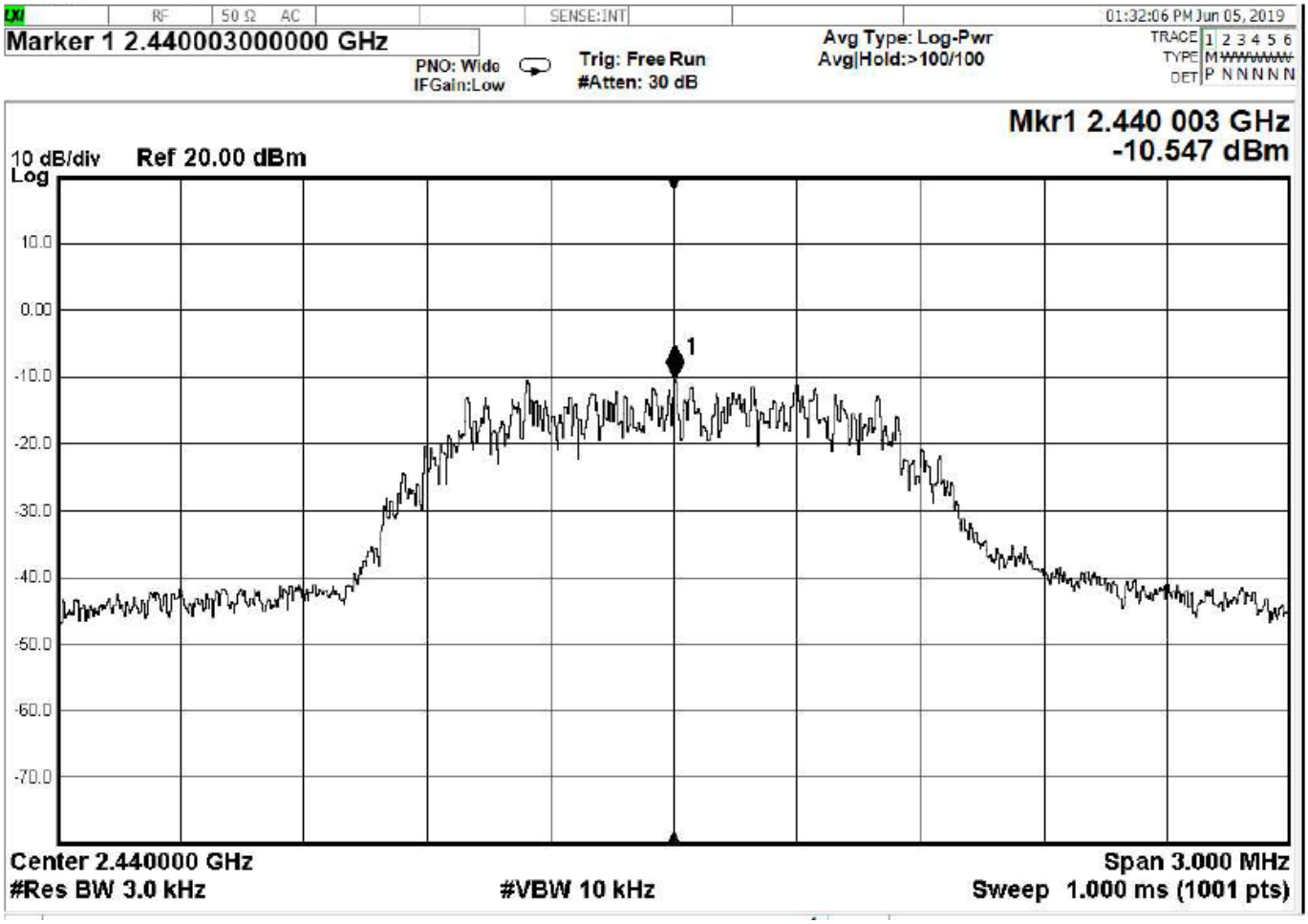

Figure 27 - Power Spectral Density, Mid Channel, BT EDR 2MB

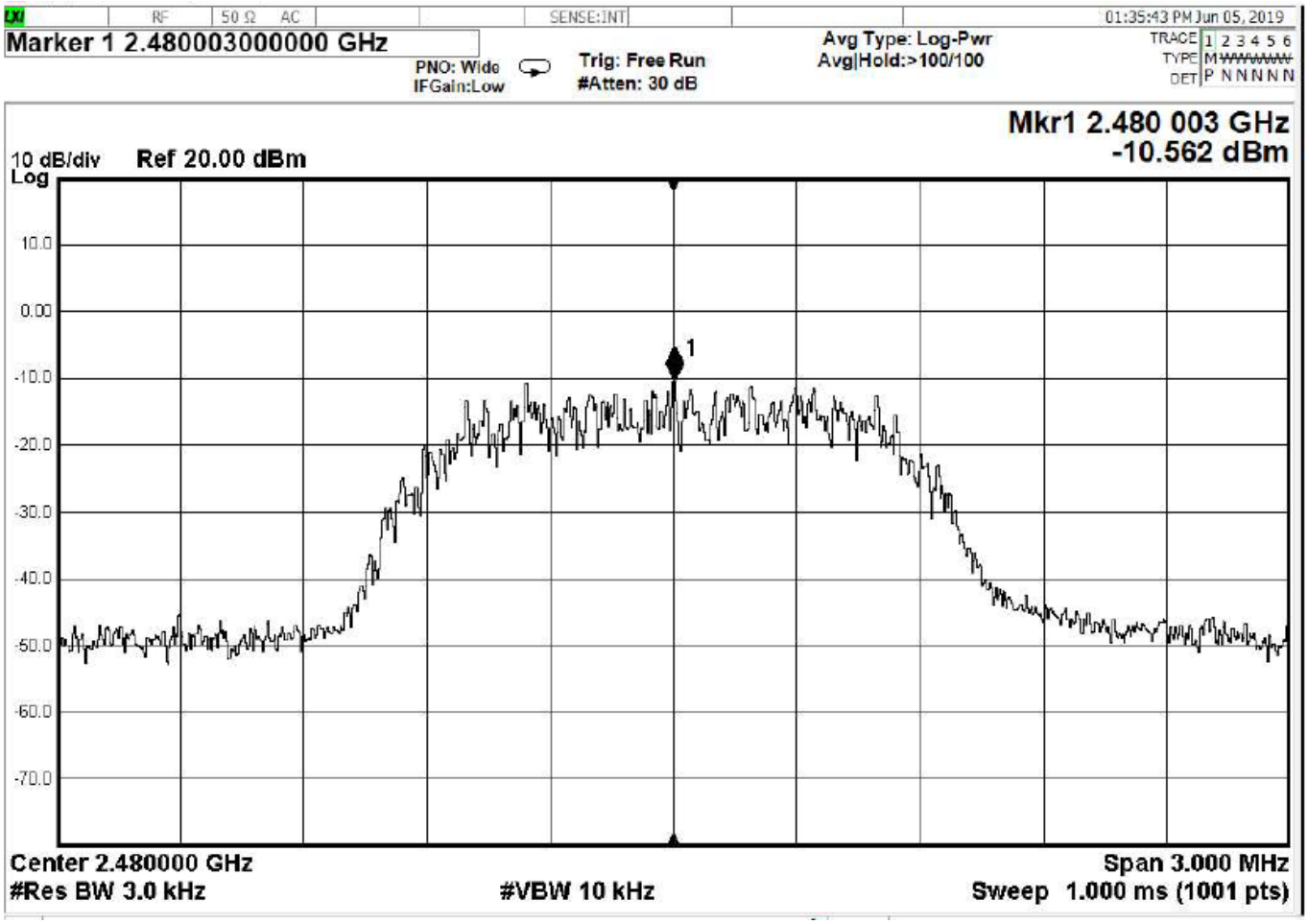

Figure 28 - Power Spectral Density, High Channel, BT EDR 2MB

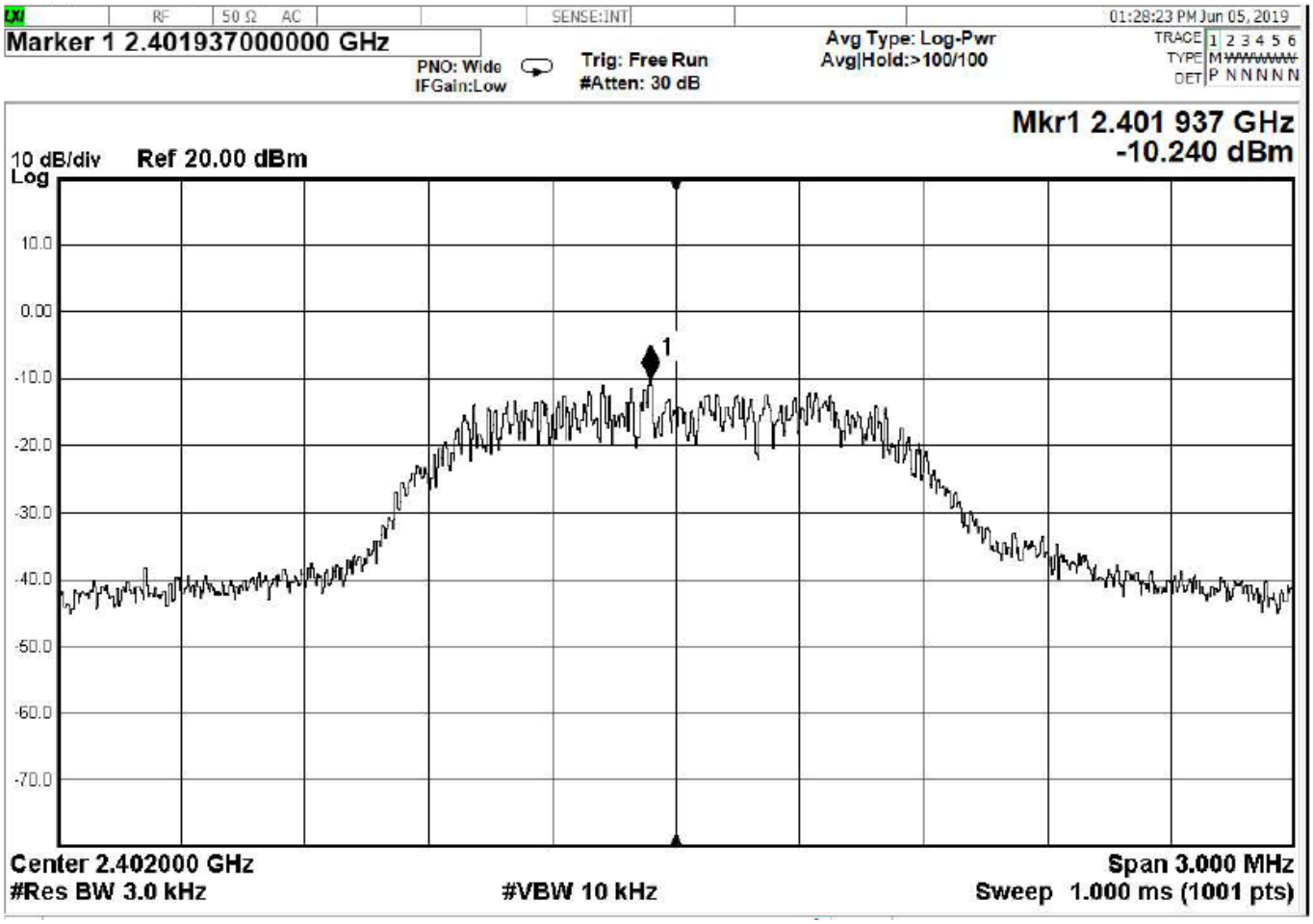

Figure 29 - Power Spectral Density, Low Channel, BT EDR 3MB

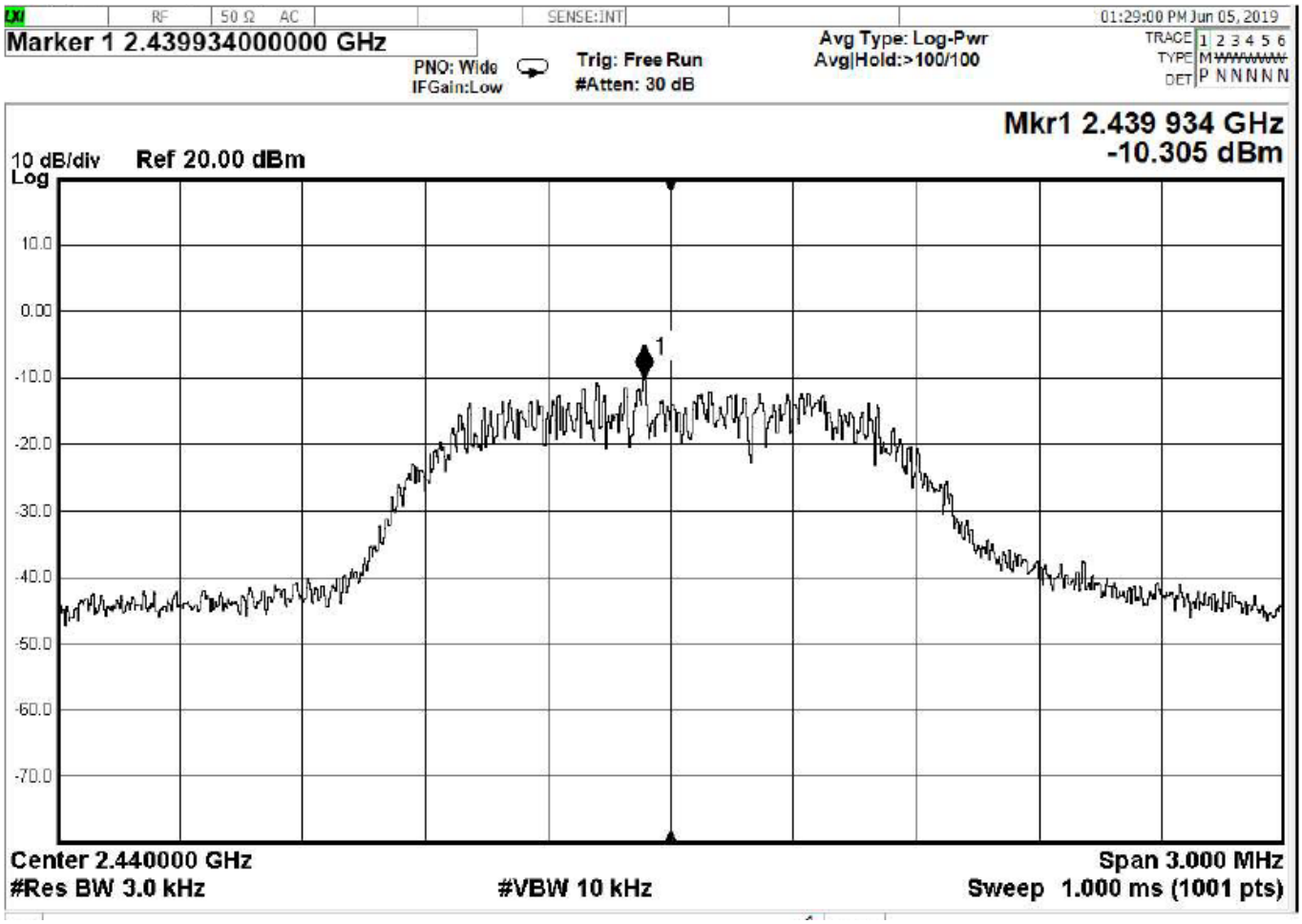

Figure 30 - Power Spectral Density, Mid Channel, BT EDR 3MB

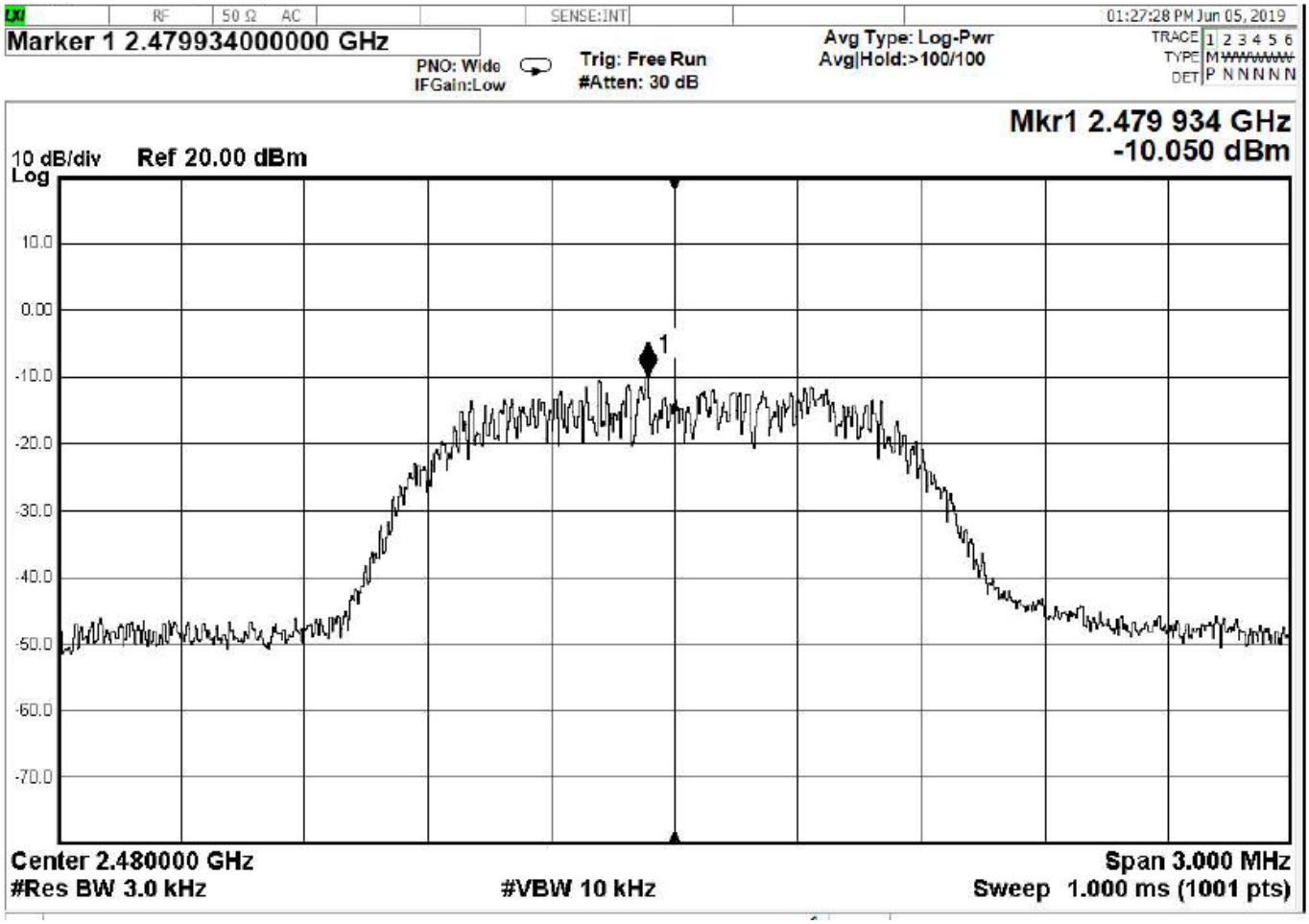

Figure 31 - Power Spectral Density, High Channel, BT EDR 3MB

4.5 BAND EDGES

Test Method: ANSI C63.10-2013, Section(s) 6.10.5

Limits of bandedge measurements:
For emissions outside of the allowed band of operation, 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:
Measurements were performed by connecting the output of the transmitter directly into a spectrum analyzer using an impedance matched cable and connector soldered to the EUT in place of the antenna. The resolution bandwidth was set to 100kHz and the EMI receiver was used to scan from the bandedge to the fundamental frequency with a 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.

To calculate the level at the bandedge frequencies, the difference between the peak and the band edge level was subtracted from the peak radiated value at the fundamental. This value was compared to the 15.209 radiated limits for compliance.

Deviations from test standard:
No deviation.

Test setup:
The field strength was measured by connecting the EUT directly to the spectrum analyzer.

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

Test results:

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	-56.97	13.13	70.10	54.41	PASS
High, Continuous (restricted)	BT BR (GFSK)	2483.5	-51.74	12.85	64.59	51.29	PASS
Low, Continuous (unrestricted)	BT BR (GFSK)	2400	-43.88	13.13	57.01	30.00	PASS
High, Continuous (unrestricted)	BT BR (GFSK)	2483.5	-52.52	12.85	65.37	30.00	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) = 108.41 dBµV/m
Fundamental peak field strength at High Channel BT BR (GFSK) = 105.29 dBµV/m

Low Channel minimum delta BT BR (GFSK) = 108.41 – 54.0 dBµV/m = 54.41 dBc
High Channel minimum delta BT BR (GFSK) = 105.29 – 54.0 dBµV/m = 51.29 dBc

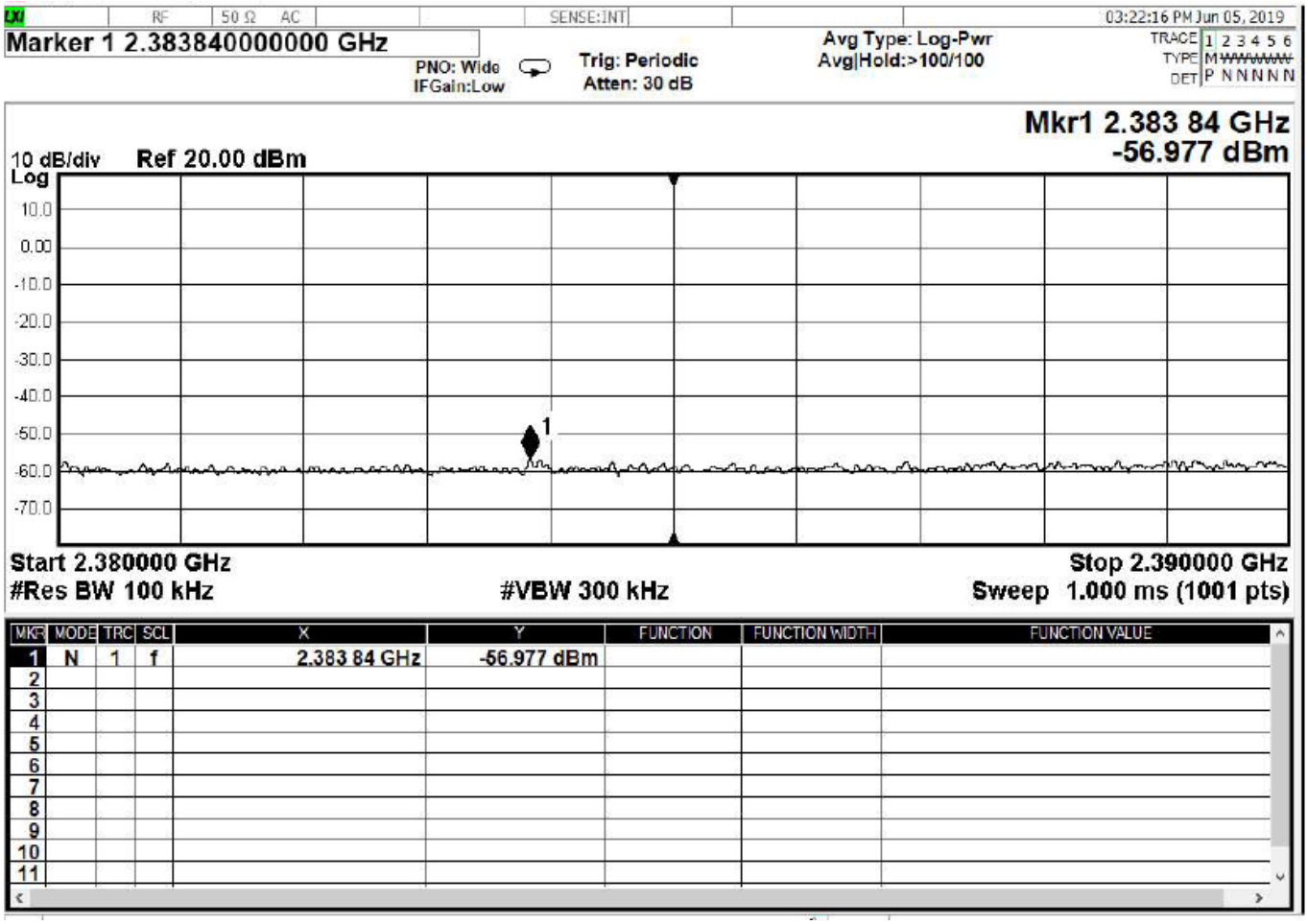

Figure 32 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

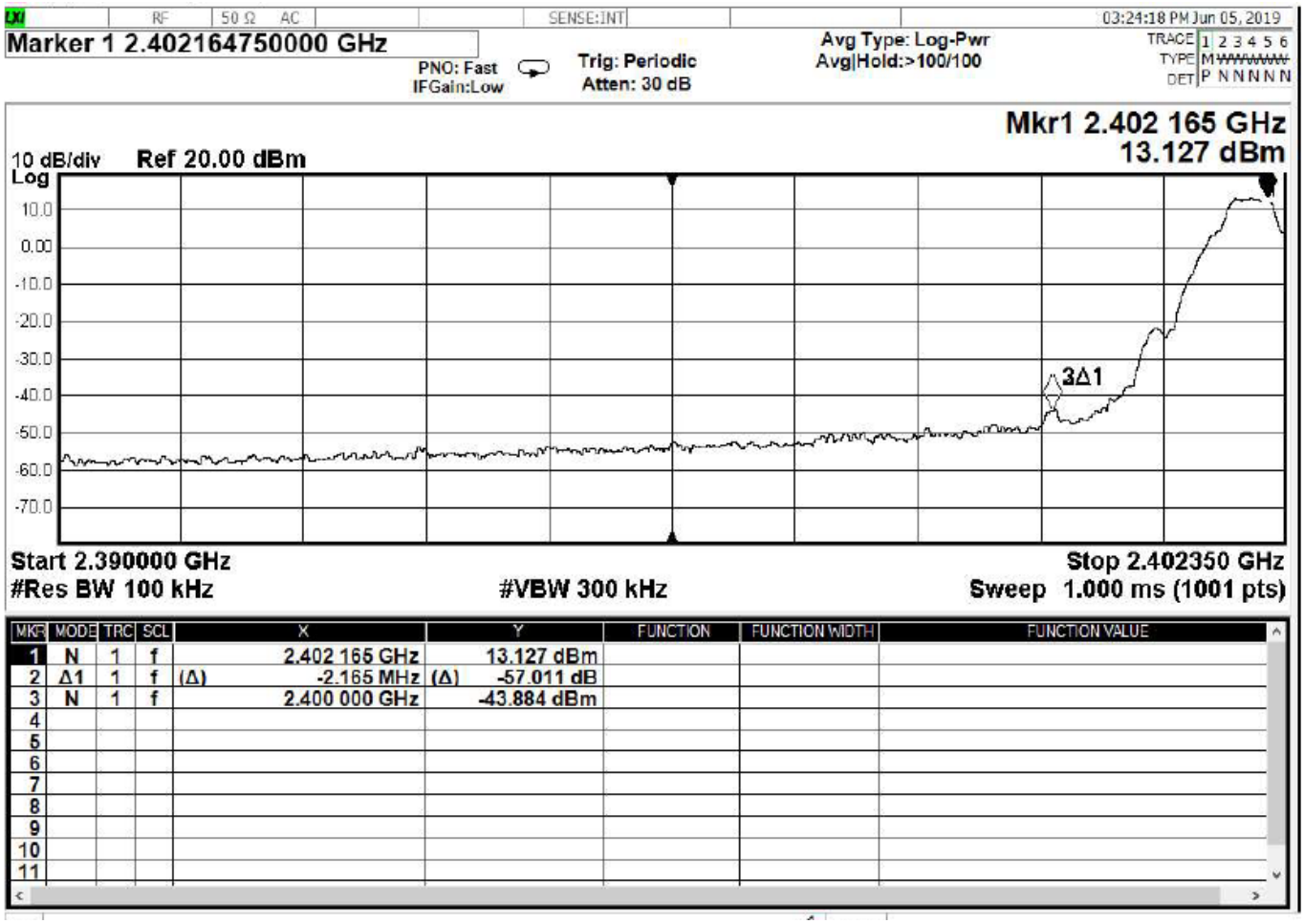

Figure 33 - Band-edge Measurement, Low Channel, Fundamental, Peak

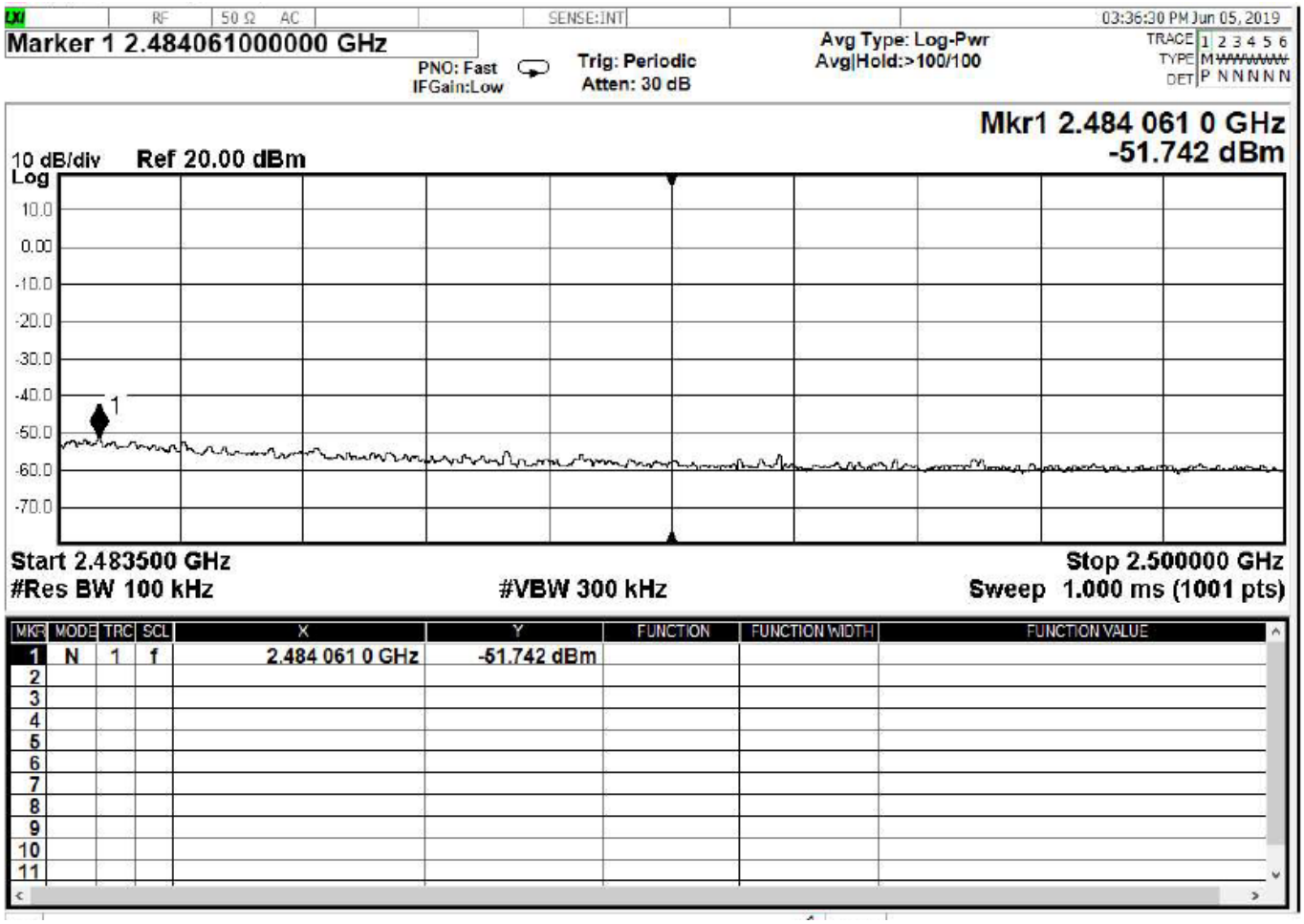

Figure 34 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

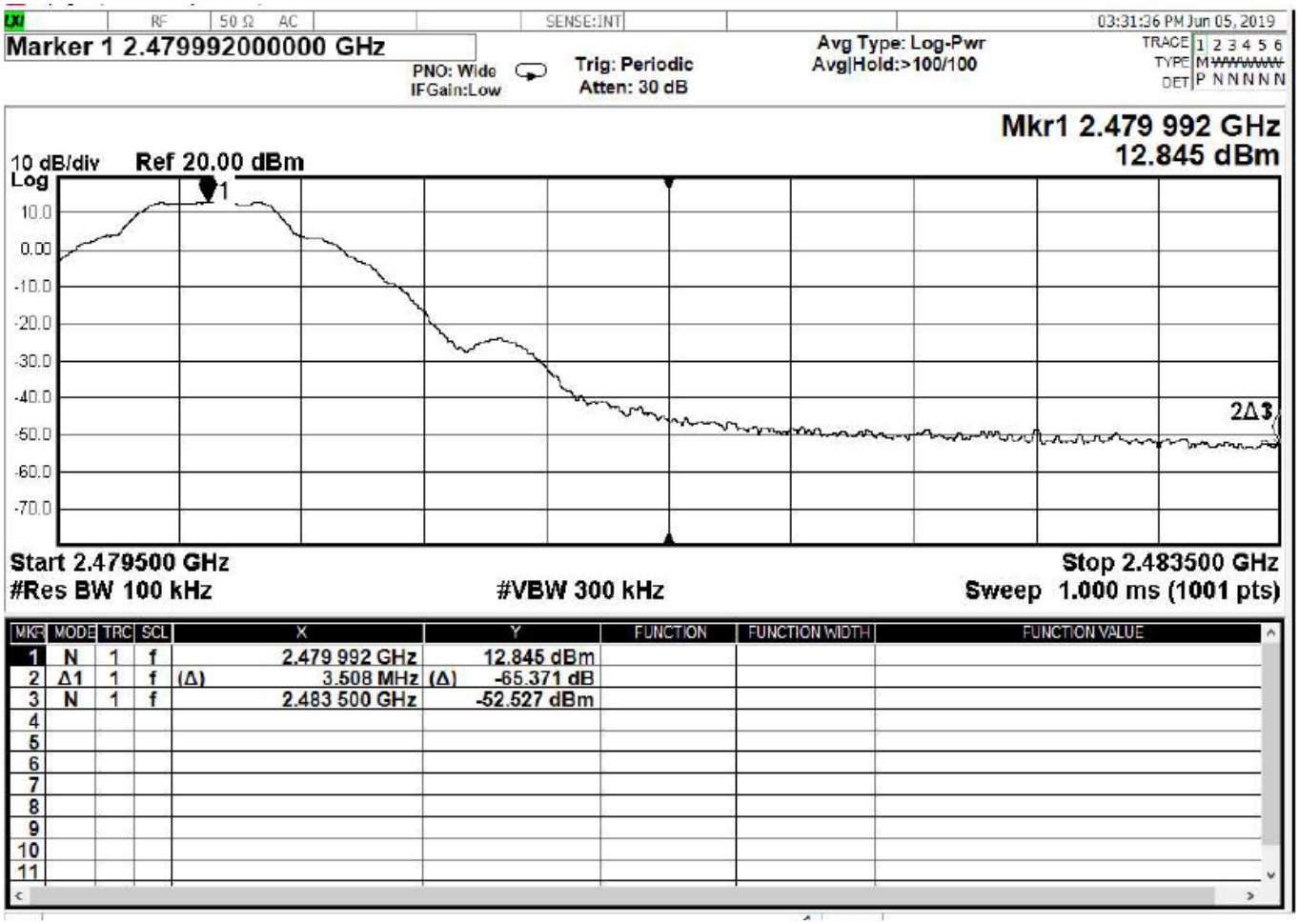

Figure 35 - Band-edge Measurement, High Channel, Fundamental, Peak

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	-57.43	3.31	60.74	49.89	PASS
High, Continuous (restricted)	BT EDR 2MB	2483.5	-50.75	3.33	54.08	48.85	PASS
Low, Continuous (unrestricted)	BT EDR 2MB	2400	-33.30	3.31	36.61	30.00	PASS
High, Continuous (unrestricted)	BT EDR 2MB	2483.5	-50.15	3.33	53.48	30.00	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 = 103.89 dBµV/m
Fundamental peak field strength at High Channel BT EDR 2MB = 102.85 dBµV/m

Low Channel minimum delta BT EDR 2MB = 103.89 – 54.0 dBµV/m = 49.89 dBc
High Channel minimum delta BT EDR 2MB = 102.85 – 74.0 dBµV/m = 48.85 dBc

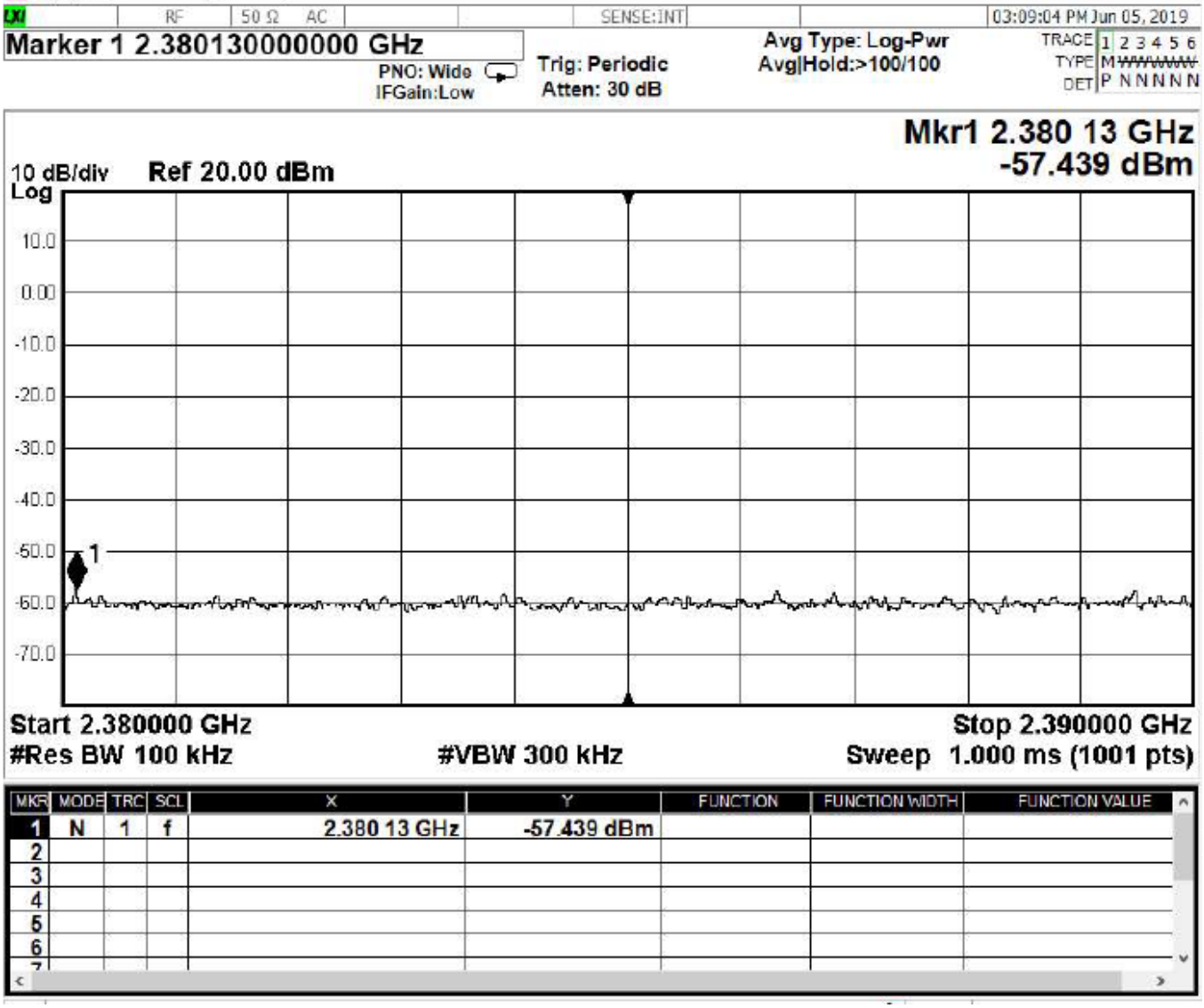

Figure 36 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

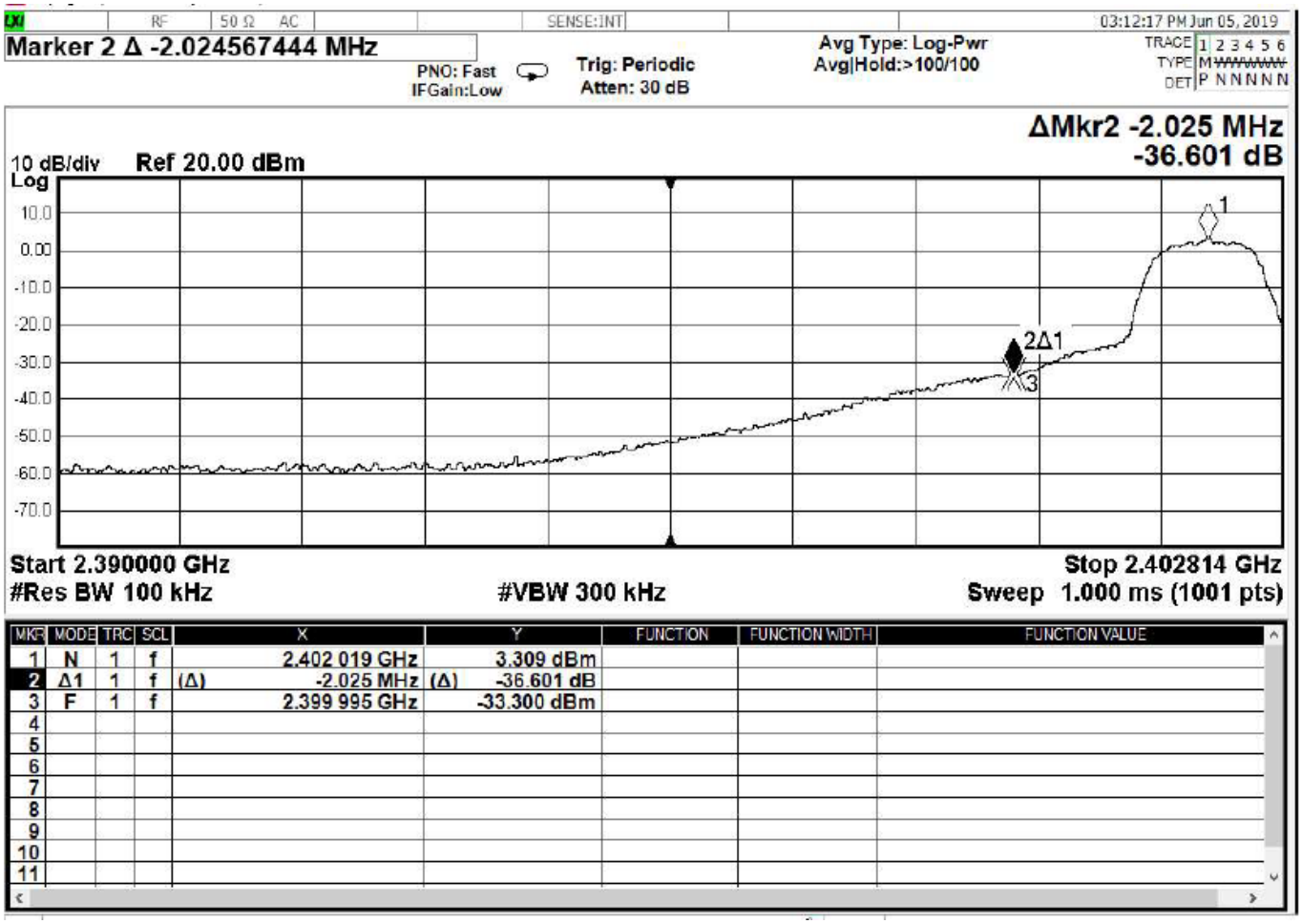

Figure 37 - Band-edge Measurement, Low Channel, Fundamental, Peak

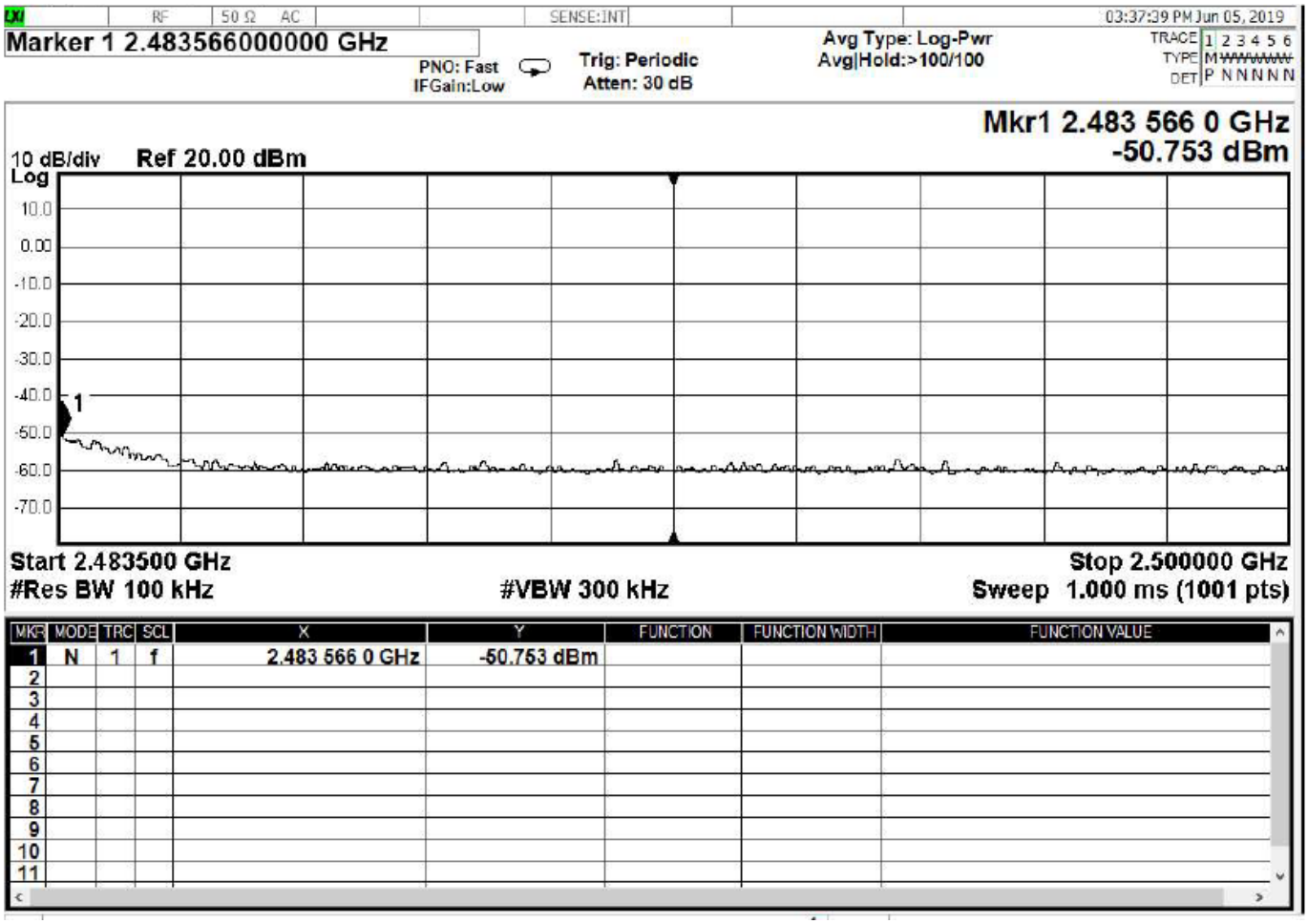

Figure 38 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

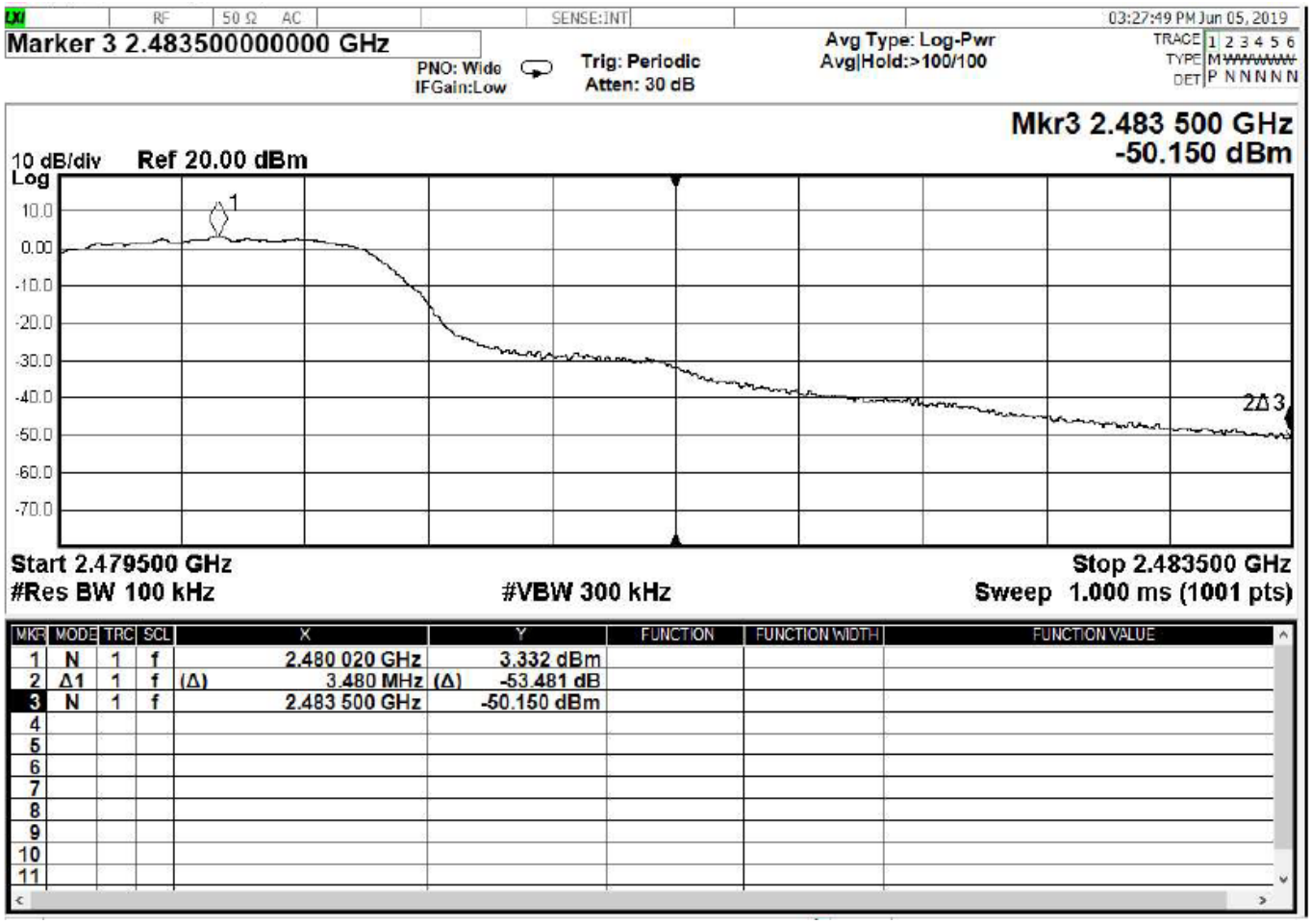

Figure 39 - Band-edge Measurement, High Channel, Fundamental, Peak

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	-57.30	3.40	60.70	50.14	PASS
High, Continuous (restricted)	BT EDR 3MB	2483.5	-50.06	3.18	53.24	49.10	PASS
Low, Continuous (unrestricted)	BT EDR 3MB	2400	-33.40	3.40	36.80	30.00	PASS
High, Continuous (unrestricted)	BT EDR 3MB	2483.5	-52.80	3.18	55.98	30.00	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 3MB = 104.14 dBµV/m
Fundamental peak field strength at High Channel BT EDR 3MB = 103.10 dBµV/m

Low Channel minimum delta BT EDR 3MB = 104.14 – 54.0 dBµV/m = 50.14 dBc
High Channel minimum delta BT EDR 3MB = 103.10 – 54.0 dBµV/m = 49.10 dBc

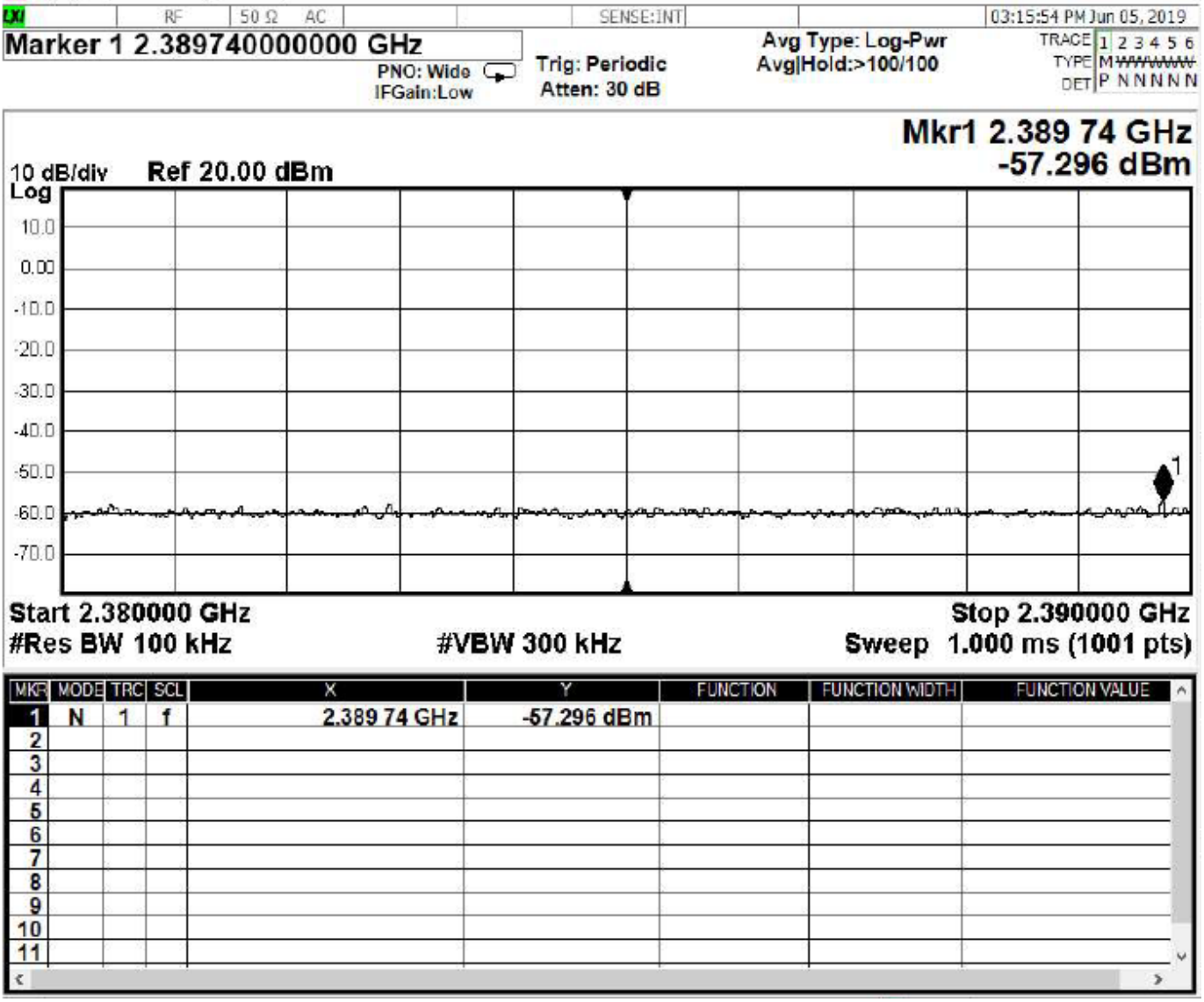

Figure 40 - Band-edge Measurement, Low Channel, Restricted Frequency, Peak

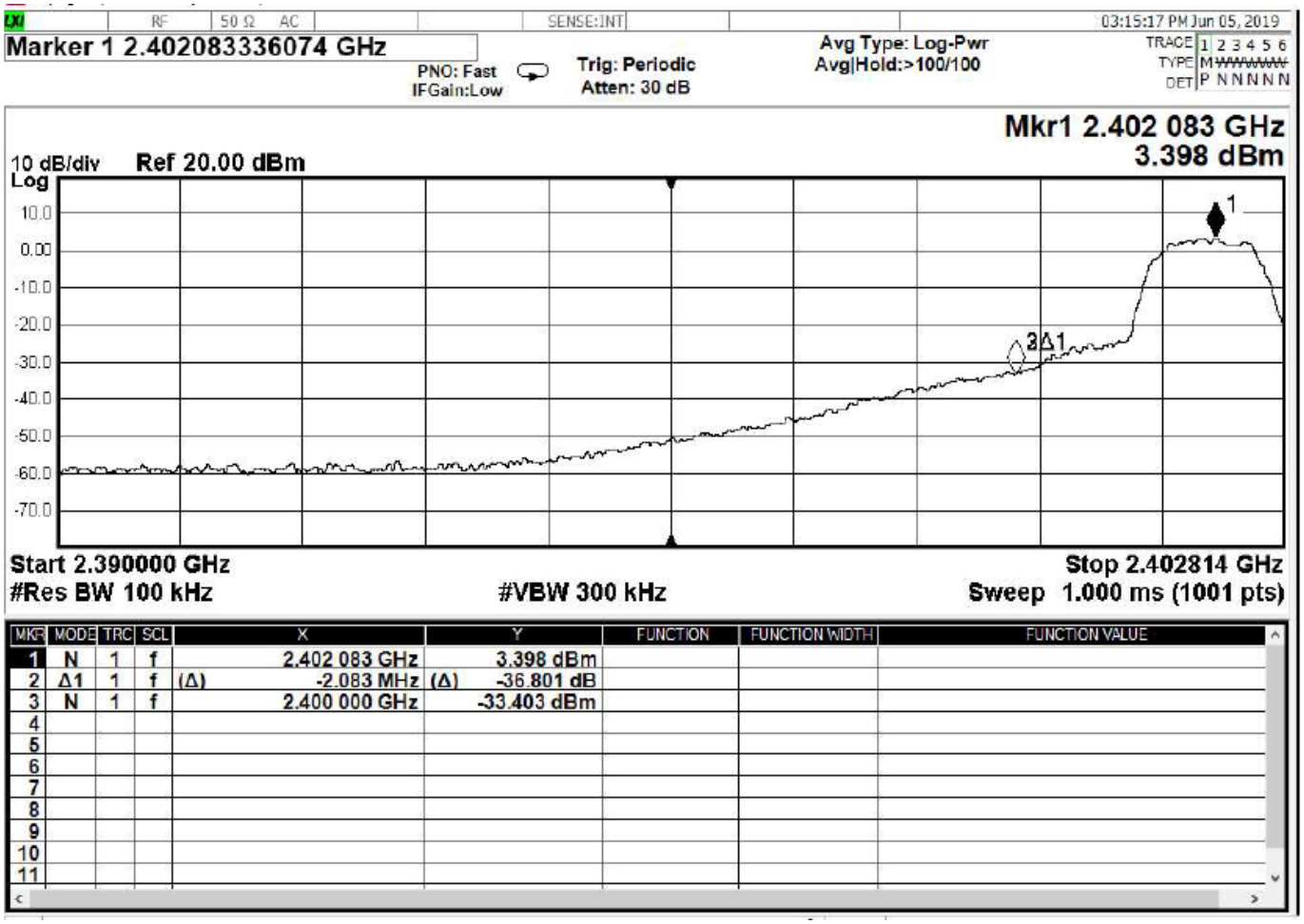

Figure 41 - Band-edge Measurement, Low Channel, Fundamental, Peak

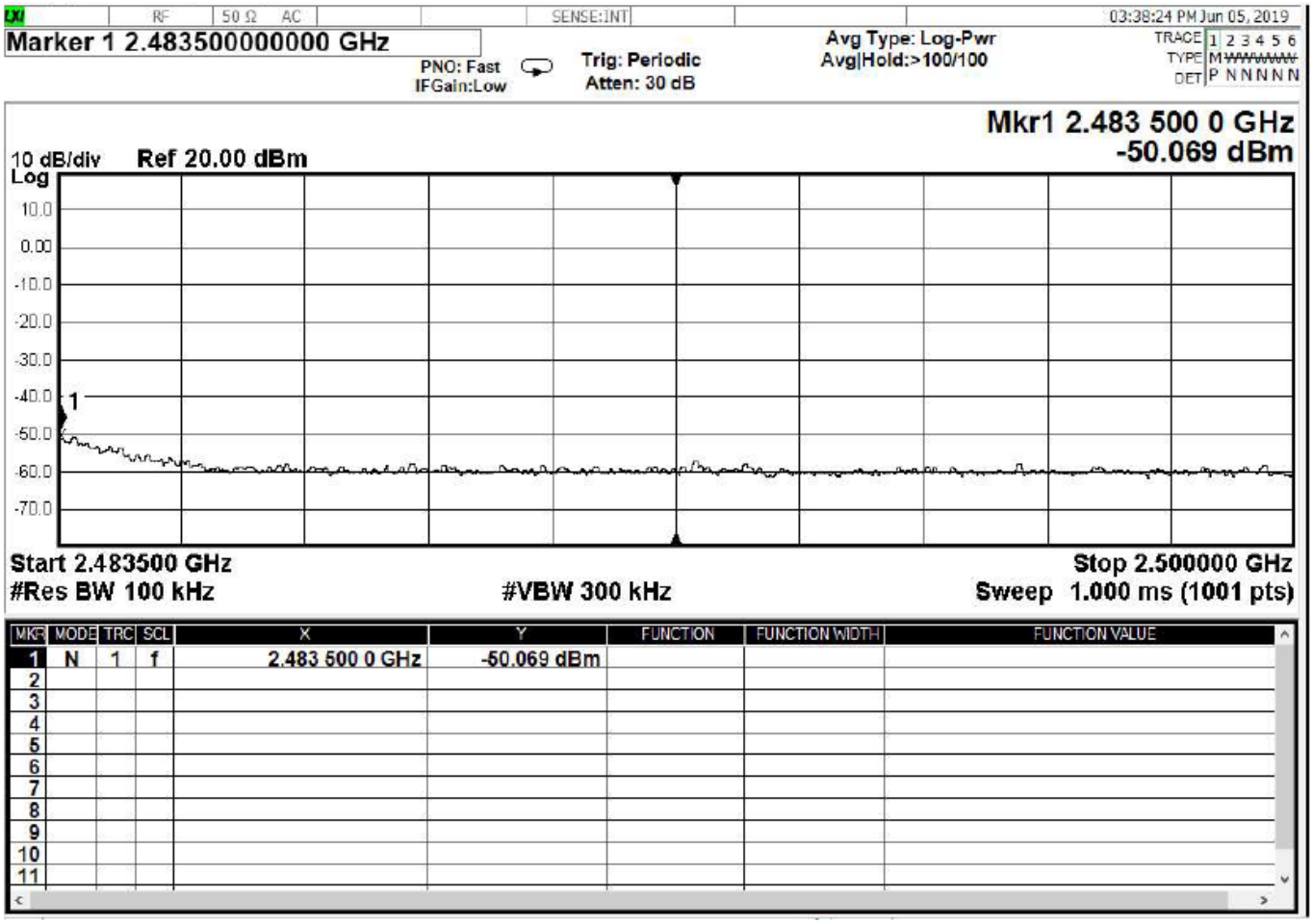

Figure 42 - Band-edge Measurement, High Channel, Restricted Frequency, Peak

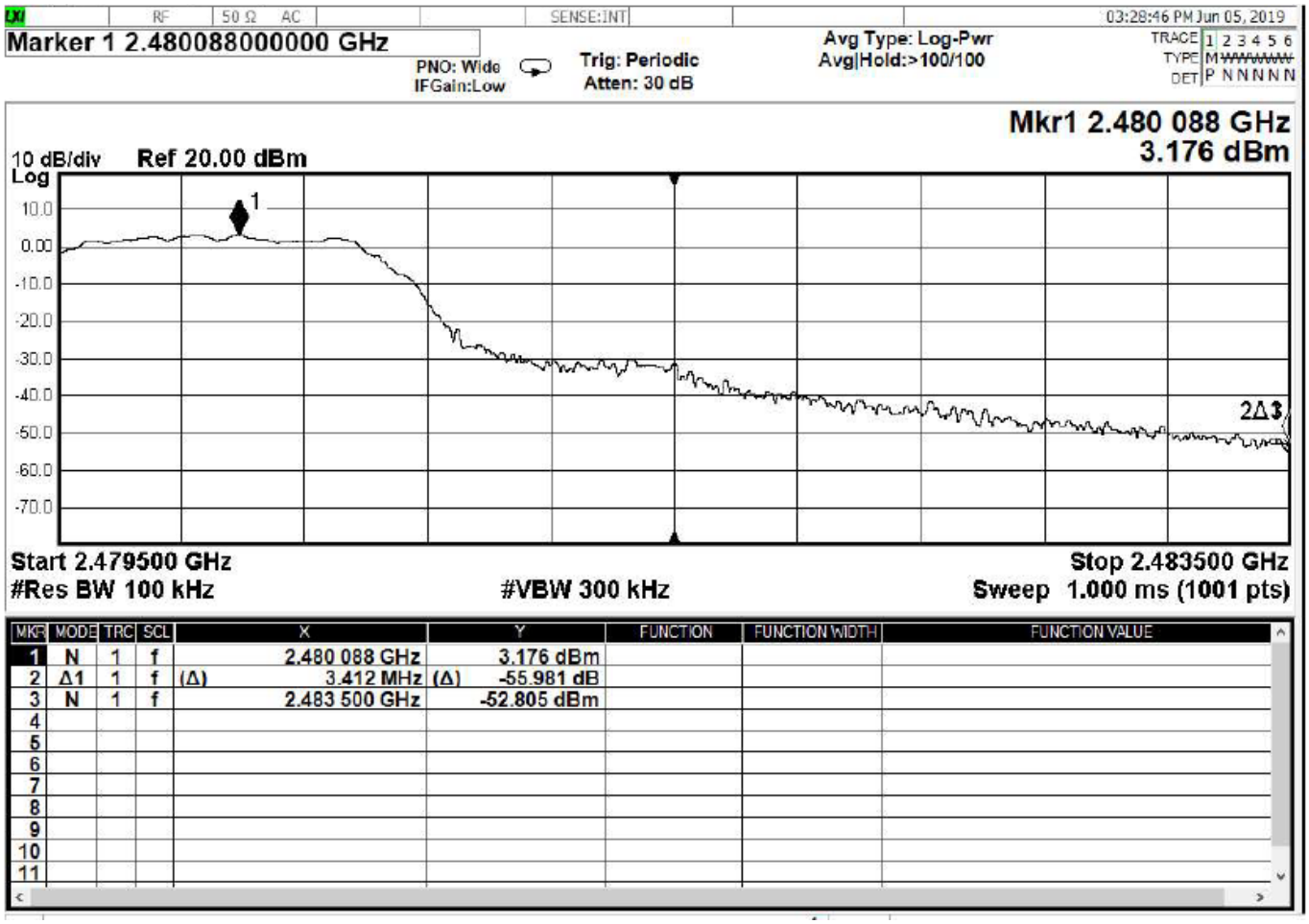

Figure 43 - Band-edge Measurement, High Channel, Fundamental, Peak

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. To produce the highest possible emissions, the WiFi mode that produced the highest output power was set to transmit simultaneously as well as the NFC radio.

Test Results:

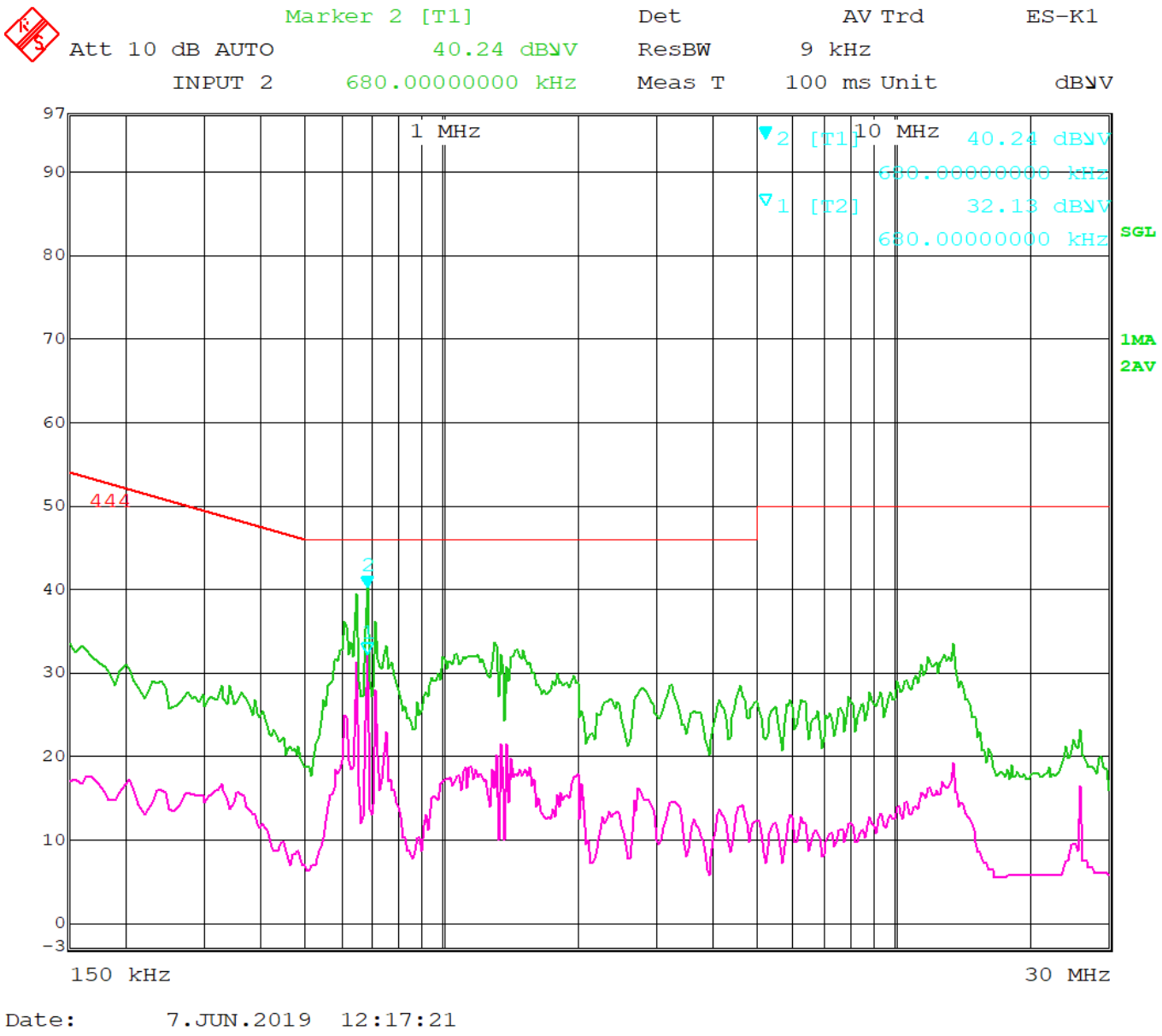

Figure 44 - Conducted Emissions Plot, Line

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

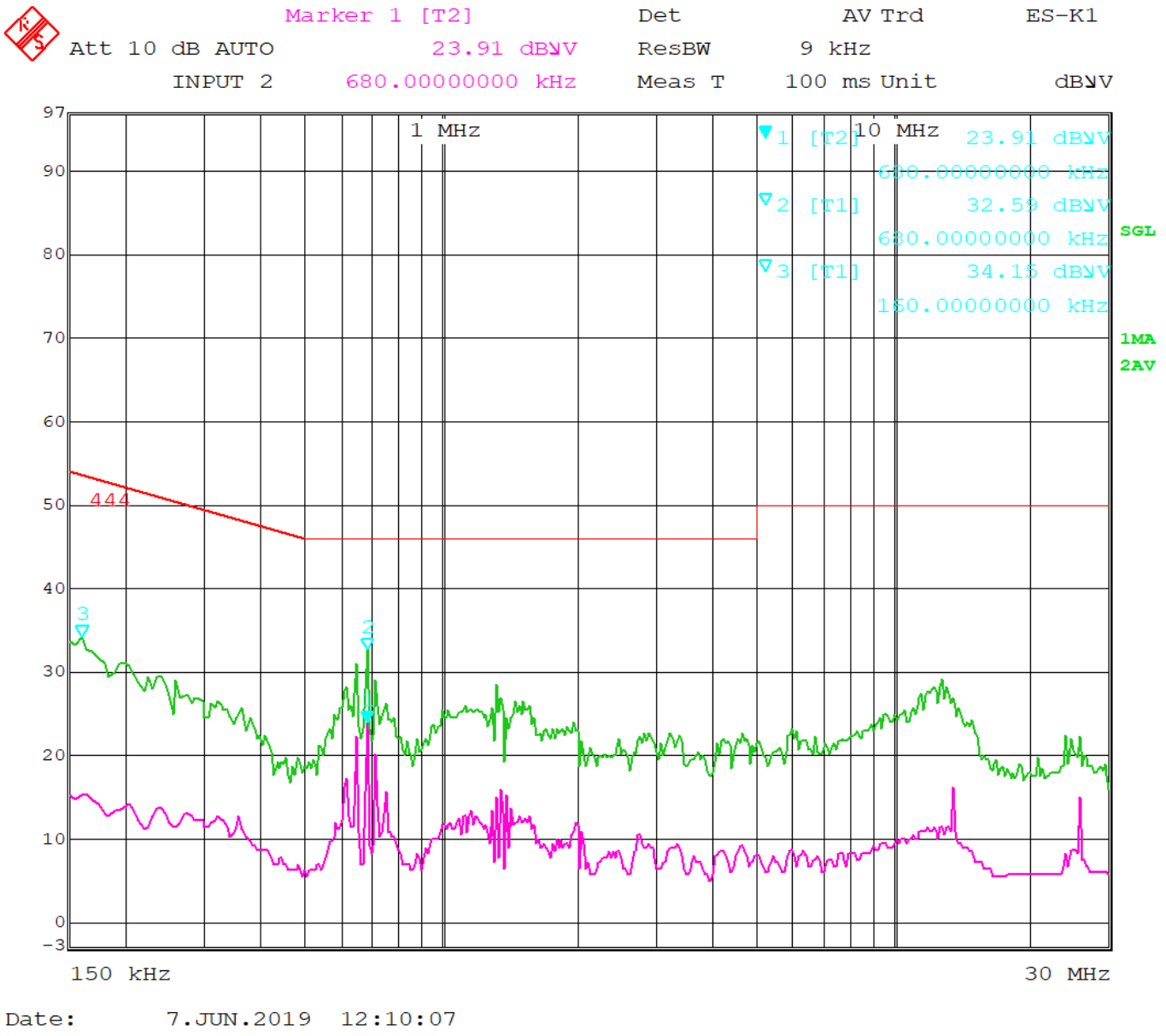

Figure 45 - Conducted Emissions Plot, Neutral

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

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

APPENDIX A: SAMPLE CALCULATION

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:
FS = RA + AF – (-CF + AG) + AV

where FS = Field Strength

RA = Receiver Amplitude

AF = Antenna Factor

CF = Cable Attenuation Factor

AG = Amplifier Gain

AV = Averaging Factor (if applicable)

Assume a receiver reading of 55 dBμV is obtained. The Antenna Factor of 12 and a Cable Factor of 1.1 is added. The Amplifier Gain of 20 dB is subtracted, giving a field strength of 48.1 dBμV/m.

FS = 55 + 12 – (-1.1 + 20) + 0 = 48.1 dBμV/m

The 48.1 dBμV/m value can be mathematically converted to its corresponding level in μV/m.

Level in μV/m = Common Antilogarithm [(48.1 dBμV/m)/20]= 254.1 μV/m

AV is calculated by the taking the 20*log(T_{on}/100) where T_{on} is the maximum transmission time in any 100ms window.

EIRP Calculations

In cases where direct antenna port measurement is not possible or would be inaccurate, output power is measured in EIRP. The maximum field strength is measured at a specified distance and the EIRP is calculated using the following equation;

EIRP (Watts) = [Field Strength (V/m) x antenna distance (m)]^2 / 30

Power (watts) = 10^[Power (dBm)/10] / 1000

Voltage (dBµV) = Power (dBm) + 107 (for 50Ω measurement systems)

Field Strength (V/m) = 10^[Field Strength (dBµV/m) / 20] / 10^6

Gain = 1 (numeric gain for isotropic radiator)

Conversion from 3m field strength to EIRP (d=3):

EIRP = [FS(V/m) x d^2]/30 = FS [0.3] for d = 3

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

10log(10^9) is the conversion from micro to milli

APPENDIX B – MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been for tests performed in this test report:

Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	3.82
Radiated Emissions, 3m	1GHz - 18GHz	4.44
Emissions limits, conducted	30MHz – 18GHz	±3.30 dB

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

REPORT END