

Amended  
**FCC/ISED Test Report**

**Prepared for:** Garmin International Inc.

**Address:** 1200 E. 151<sup>st</sup> Street  
Olathe, Kansas, 66062, USA

**Product:** AA3644

**Test Report No:** R20181212-20-01B

**Approved by:**



**Nic S. Johnson, NCE**

Technical Manager

iNARTE Certified EMC Engineer #EMC-003337-NE

**DATE:** 11 April 2019

**Total Pages:** 56

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## REVISION PAGE

Rev. No.	Date	Description
0	27 February 2019	Original – NJohnson Prepared by KVepuri/CFarrington
A	13 March 2019	Updated antenna description – NJohnson  Includes NCEE Labs report R20181212-20-01 and its amendment in full. -NJ
B	11 April 2019	Section 4.1 was updated to show duty cycle for each modulation type. Section 4.4 was modified to show peak measurement are compliant with average limit for measurements aboe 1 GHz with 100% duty cycle.  Includes NCEE Labs report R20181212-20-01A and its amendment in full. -NJ



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## 1.0 SUMMARY OF TEST RESULTS

The EUT has been tested according to the following specifications:

- (1) US Code of Federal Regulations, Title 47, Part 15
- (2) ISED RSS-Gen, Issue 5
- (3) ISED RSS-210, Issue 9

SUMMARY			
Requirement	Test Type and Limit	Result	Remark
FCC 15.203	Unique Antenna Requirement	Pass	Sheet metal mounted directly to PCB
FCC 15.35 RSS-Gen, 6.10	Duty cycle of pulsed emissions	N/A	Not required
NA	Maximum Peak Output Power	N/A	Informational Purpose Only
NA	Minimum Bandwidth	N/A	Informational Purpose Only
FCC 15.209 RSS-Gen, 7.1	Receiver Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.209 RSS-Gen, 8.9 RSS-210 A1.2 FCC 15.249(a)	Transmitter Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.209, 15.205, 15.249(d) RSS-Gen, 8.9 RSS-210, 5.5	Band Edge Measurement	Pass	Meets the requirement of the limit.
FCC 15.207 RSS-Gen. 8.8	Conducted AC Emissions	Pass	Meets the requirement of the limit.



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## 2.0 EUT DESCRIPTION

### 2.1 EQUIPMENT UNDER TEST

#### Summary

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

EUT	AA3544
EUT Received	4 February 2019
EUT Tested	4 February 2019- 5 February 2019
Serial No.	3986890358 (radiated) 3986890317 (conducted)
Operating Band	2400 – 2483.5 MHz
Device Type	GMSK, GFSK
Power Supply	Internal Battery/ Charger: Garmin (Phi Hong) MN: PSAI105R-050QL6

NOTE: For more detailed features description, please refer to the manufacturer's specifications or user's manual.



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## 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  $35 \pm 4\%$   
 Temperature of  $22 \pm 3^\circ$  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 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*
Rohde and Schwarz Software Version 1.60	ESK-1	2575	N/A	N/A

\*Internal Characterization

**Notes:**

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



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## 4.0 DETAILED RESULTS

### 4.1 DUTY CYCLE

**Test Method:** NA

GFSK Modulation

Maximum duty cycle declared by the manufacturer = 13 ms in 100ms window

Duty cycle correction factor =  $20 \cdot \log((13)/100) = -17.72$  dB

GMSK Modulation:

Up to 100%

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## 4.2 PEAK OUTPUT POWER

**Test Method:** N/A

For Informational Purposes only

**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 10 MHz and the video bandwidth was set to 10 MHz to capture the signal. The analyzer used a peak detector in max hold mode.

**Deviations from test standard:**

No deviation.

**Test setup:**

The field strength was measured by connecting the EUT directly to the spectrum analyzer. See Section 4.2.

**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 GFSK and GMSK.

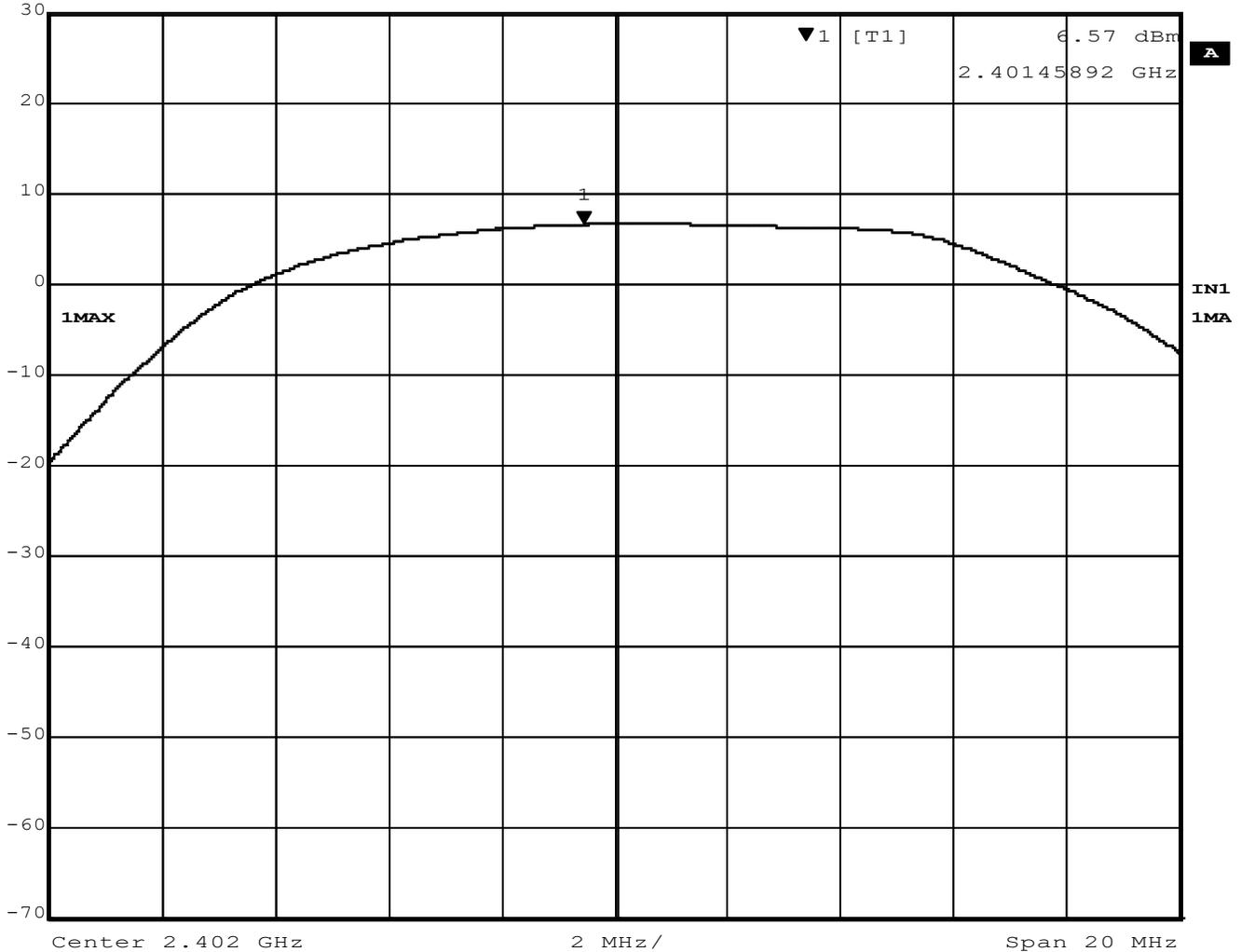
**Test results:**

**Peak Output Power**

CHANNEL	CHANNEL FREQUENCY (GHz)	PEAK OUTPUT POWER (dBm)	PEAK OUTPUT POWER (mW)	Method	Transmitter
1	2402	6.57	4.53	Conducted	GMSK
2	2440	5.92	3.91	Conducted	GMSK
3	2480	5.16	3.28	Conducted	GMSK
1	2402	2.72	1.87	Conducted	GFSK
2	2440	1.90	1.55	Conducted	GFSK
3	2480	0.96	1.25	Conducted	GFSK



Marker 1 [T1]      RBW    10 MHz    RF Att    40 dB  
 Ref Lvl                    6.57 dBm    VBW    10 MHz  
 30 dBm                    2.40145892 GHz    SWT    5 ms    Unit            dBm



**Figure 1 – Output Power, Low Channel, GMSK**

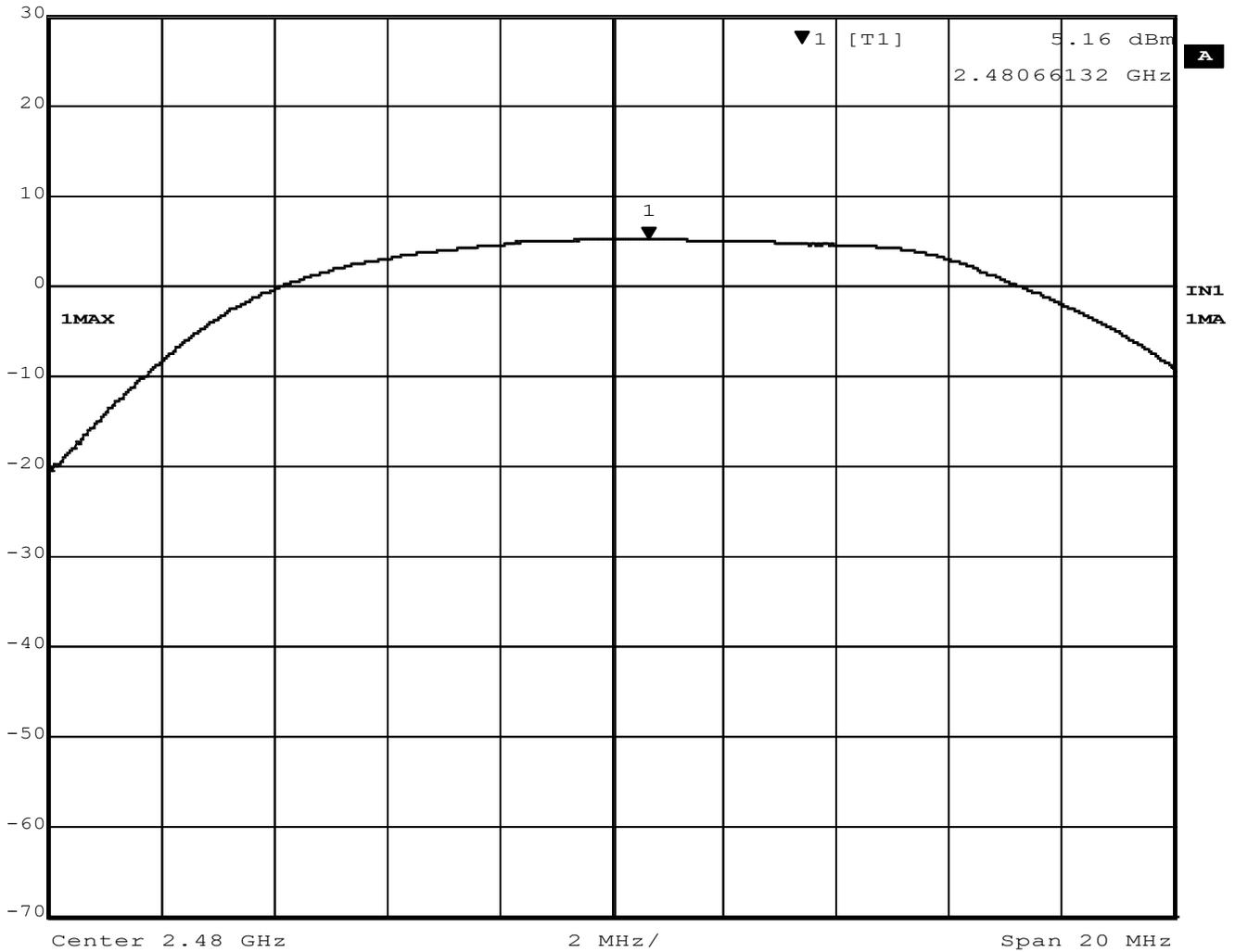
Output power: 6.57 dBm

Cable loss was less than 0.1 dB and not included





Marker 1 [T1]	RBW	10 MHz	RF Att	40 dB
Ref Lvl	5.16 dBm	VBW	10 MHz	
30 dBm	2.48066132 GHz	SWT	5 ms	Unit dBm



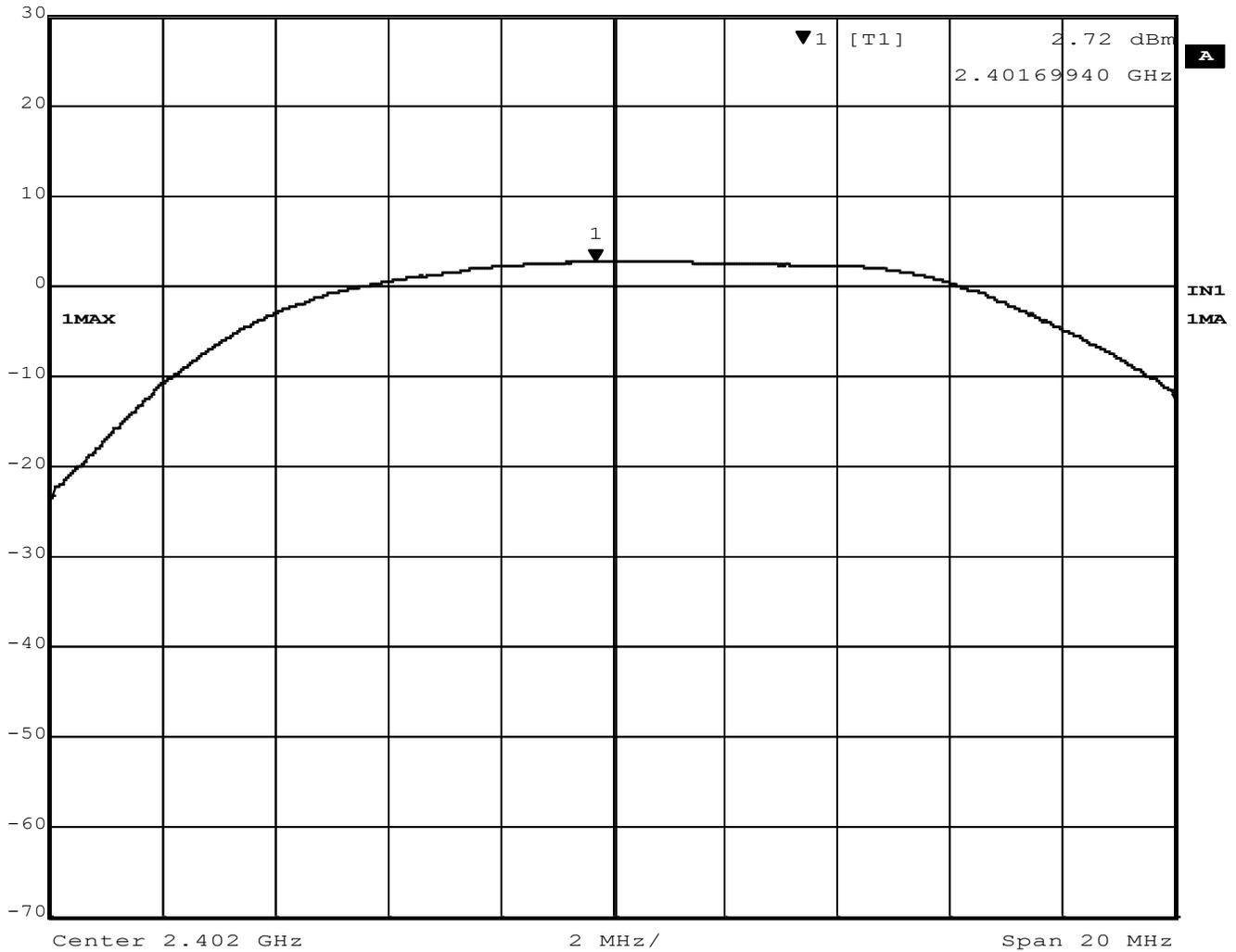
**Figure 3 – Output Power, High Channel, GMSK**

Output power = 5.16 dBm

Cable loss was less than 0.1 dB and not included



Marker 1 [T1]	RBW	10 MHz	RF Att	40 dB
Ref Lvl	2.72 dBm	VBW	10 MHz	
30 dBm	2.40169940 GHz	SWT	5 ms	Unit dBm



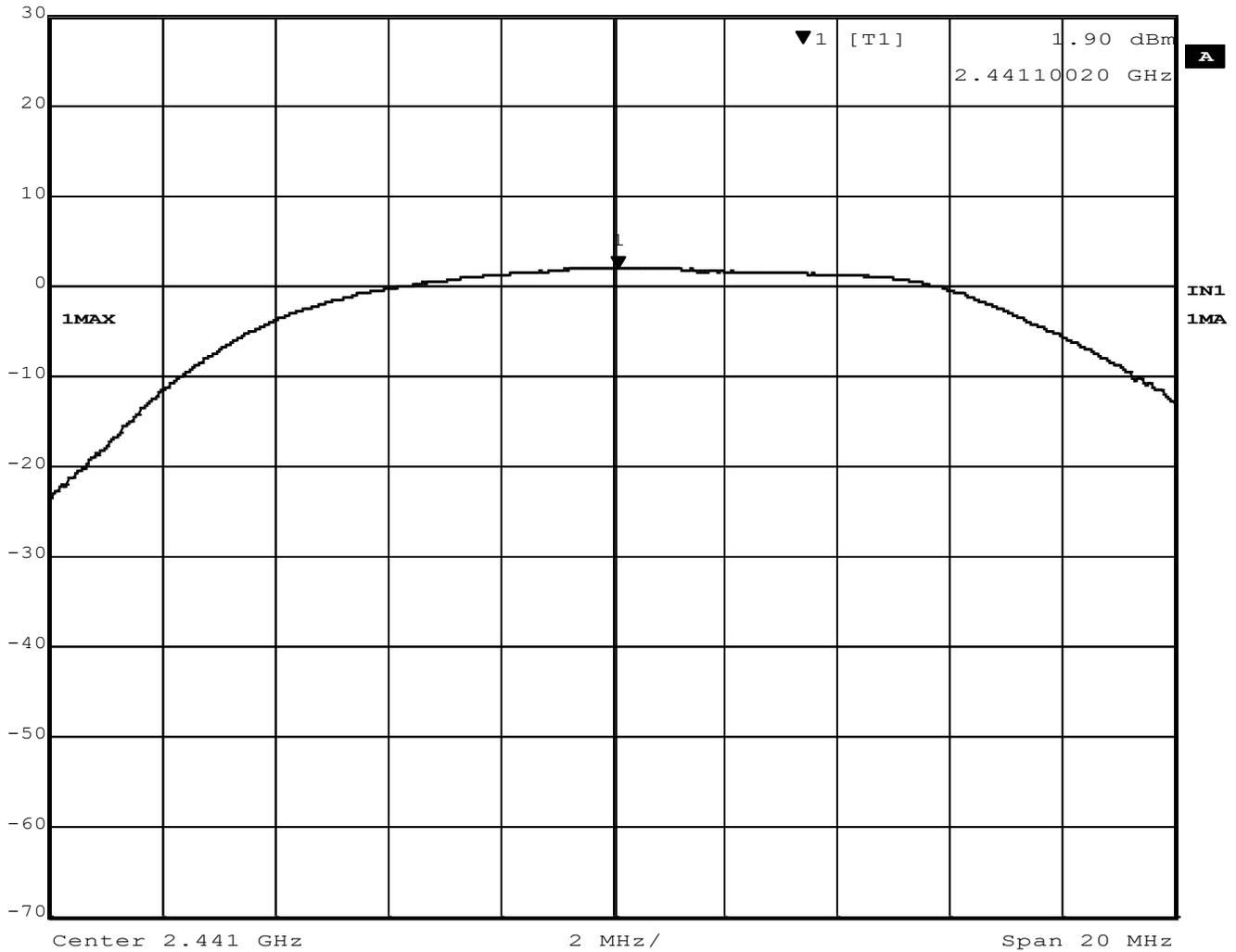
**Figure 4 - Output Power, Low Channel, GFSK**

Output power = 2.72 dBm

Cable loss was less than 0.1 dB and not included



Marker 1 [T1]	RBW	10 MHz	RF Att	40 dB
Ref Lvl	1.90 dBm	VBW	10 MHz	
30 dBm	2.44110020 GHz	SWT	5 ms	Unit dBm



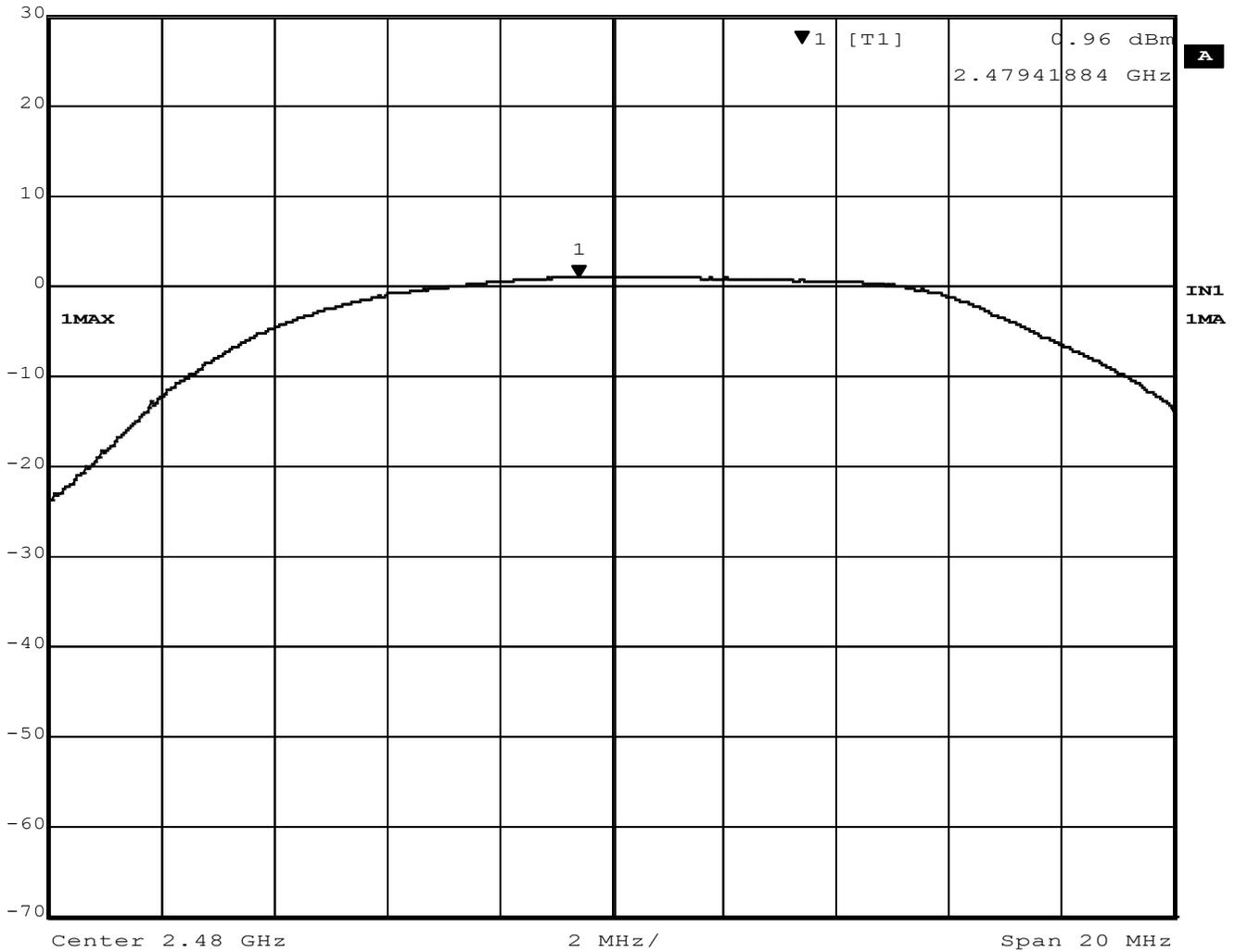
**Figure 5 - Output Power, Mid Channel, GFSK**

Output power = 1.90 dBm

Cable loss was less than 0.1 dB and not included



Marker 1 [T1]	RBW	10 MHz	RF Att	40 dB
Ref Lvl	0.96 dBm	VBW	10 MHz	
30 dBm	2.47941884 GHz	SWT	5 ms	Unit dBm



**Figure 6 - Output Power, High Channel, GFSK**

Output power = 0.96 dBm

Cable loss was less than 0.1 dB and not included



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### 4.3 BANDWIDTH

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

**Limits of bandwidth measurements:**

For Informational Purposes only

**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 100 kHz and the video bandwidth was set to 300 kHz to capture the signal. The analyzer used a peak detector in max hold mode.
3. The Occupied Bandwidth function of the spectrum analyzer was used to measure the value

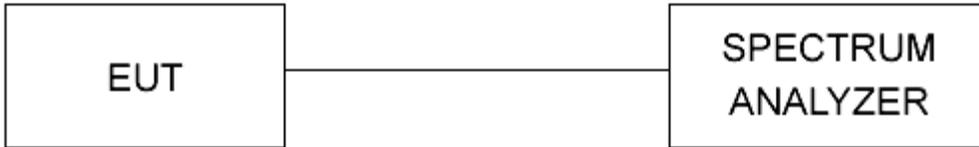
**Test setup:**

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

**Deviations from test standard:**

No deviation.

**Test setup:**



**Figure 7 - Bandwidth 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 GFSK and GMSK.

**Test results:**

Occupied Bandwidth			
CHANNEL	Mode	CHANNEL FREQUENCY (MHz)	OBW (MHz)
Low	GMSK	2402	1.09
Mid	GMSK	2440	1.09
High	GMSK	2480	1.10
Low	GFSK	2402	1.03
Mid	GFSK	2440	1.03
High	GFSK	2480	1.03



Marker 1 [T1] RBW 100 kHz RF Att 40 dB  
 Ref Lvl 6.58 dBm VBW 300 kHz  
 30 dBm 2.40175651 GHz SWT 5 ms Unit dBm

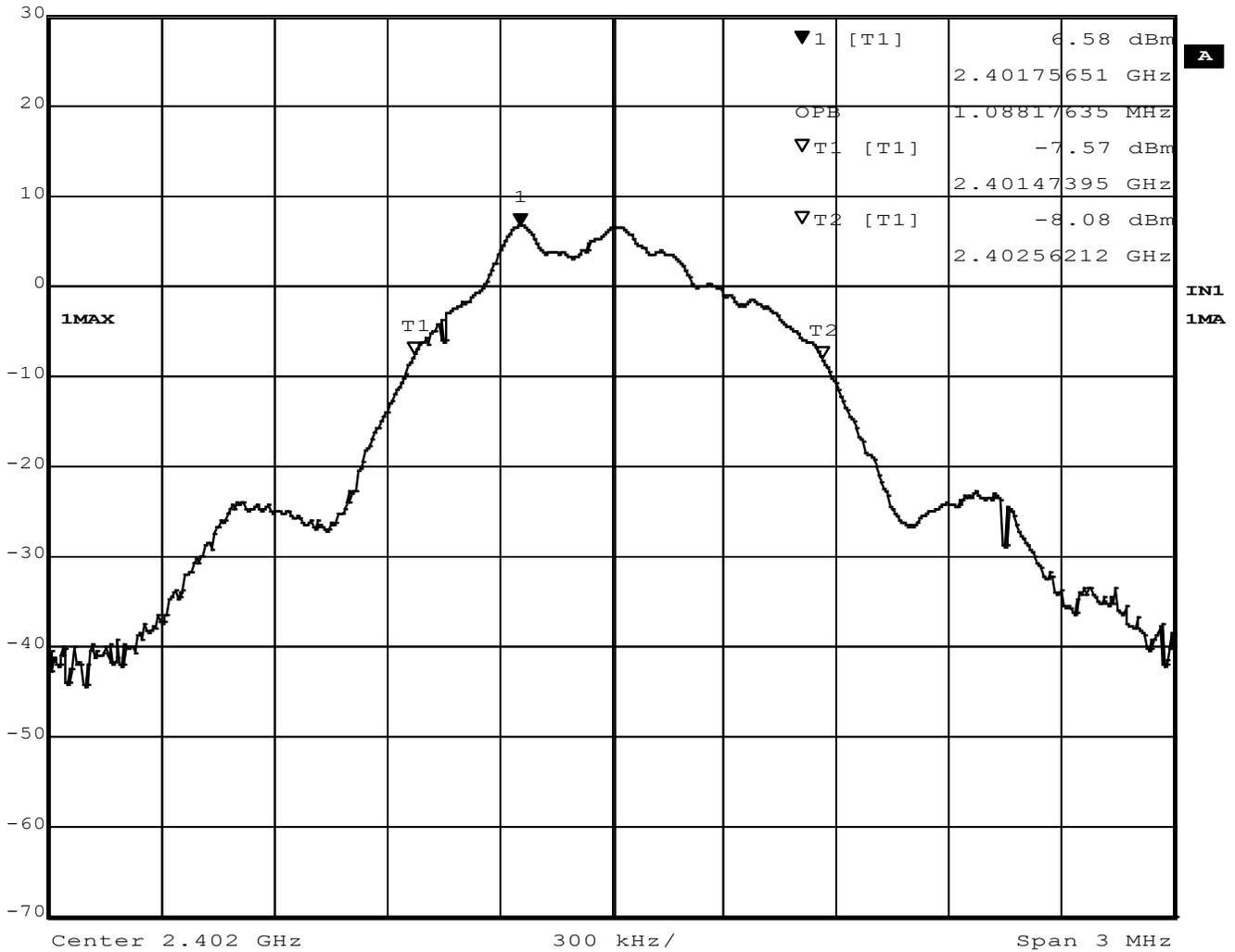


Figure 8 – Occupied Bandwidth, Low Channel, GMSK



Marker 1 [T1] RBW 100 kHz RF Att 40 dB  
 Ref Lvl 5.86 dBm VBW 300 kHz  
 30 dBm 2.43975651 GHz SWT 5 ms Unit dBm

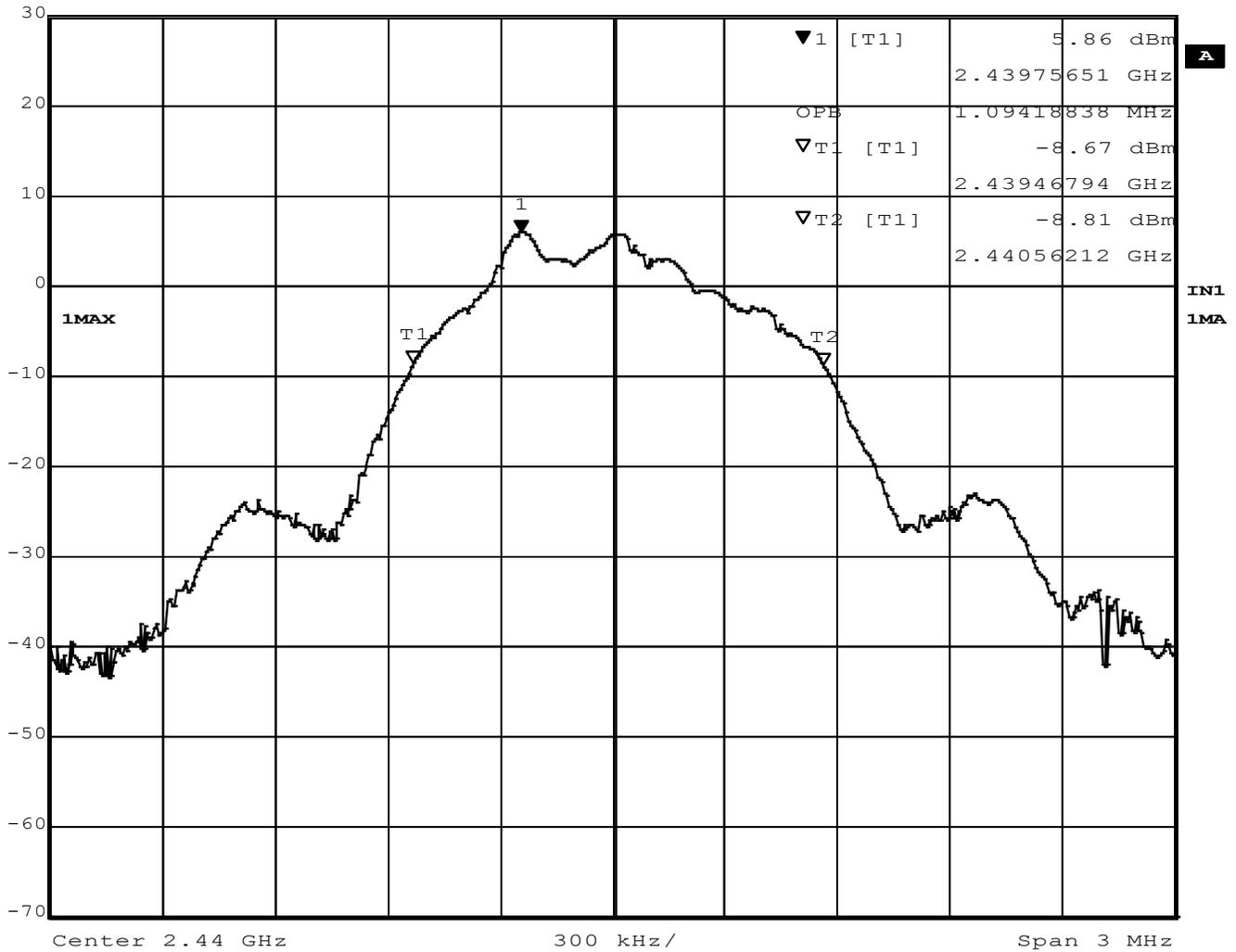
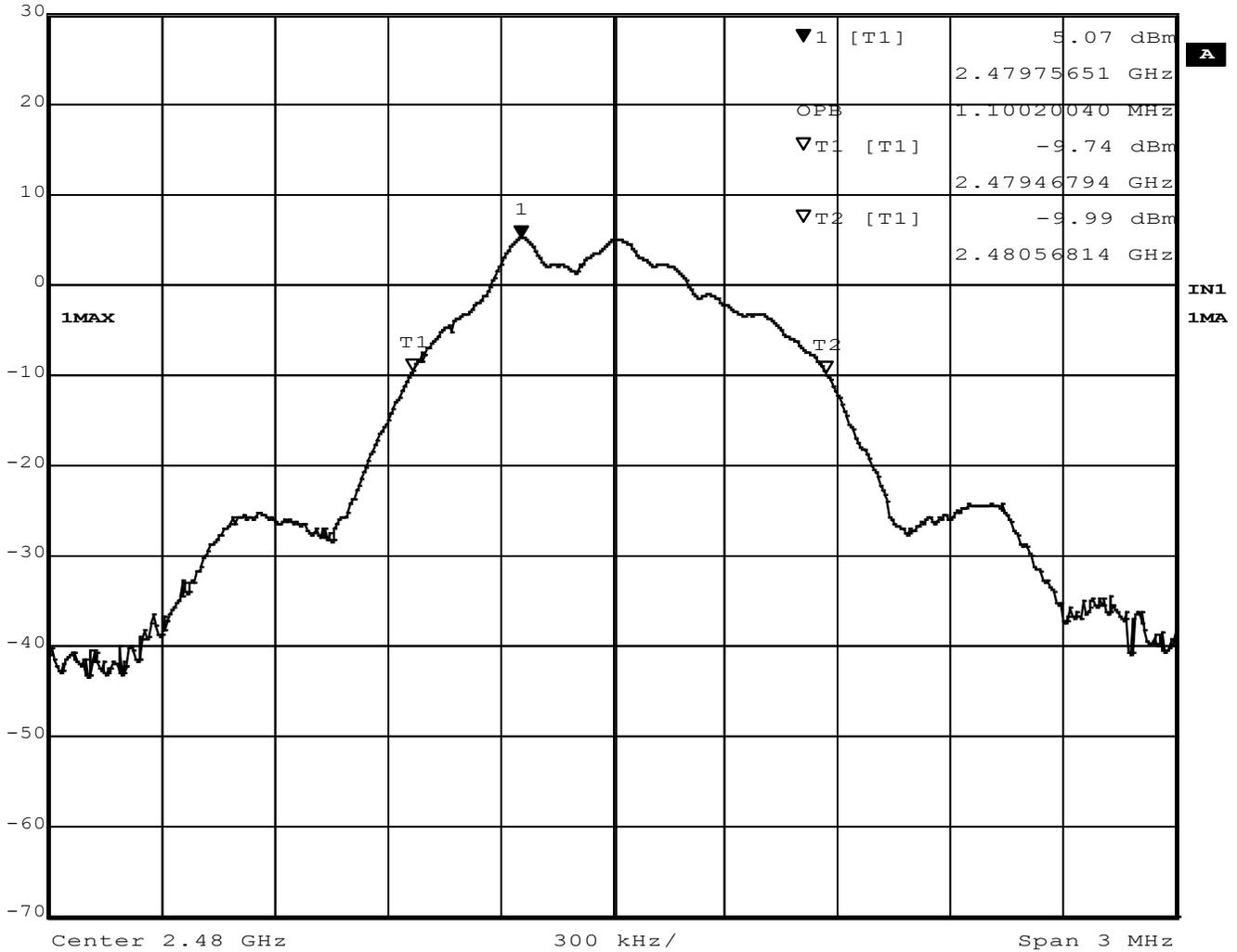


Figure 9 - Occupied Bandwidth, Mid Channel, GMSK



Marker 1 [T1] RBW 100 kHz RF Att 40 dB  
 Ref Lvl 5.07 dBm VBW 300 kHz  
 30 dBm 2.47975651 GHz SWT 5 ms Unit dBm



**Figure 10 - Occupied Bandwidth, High Channel, GMSK**



Marker 1 [T1] RBW 100 kHz RF Att 40 dB

Ref Lvl 2.61 dBm VBW 300 kHz  
 30 dBm 2.40184669 GHz SWT 5 ms Unit dBm

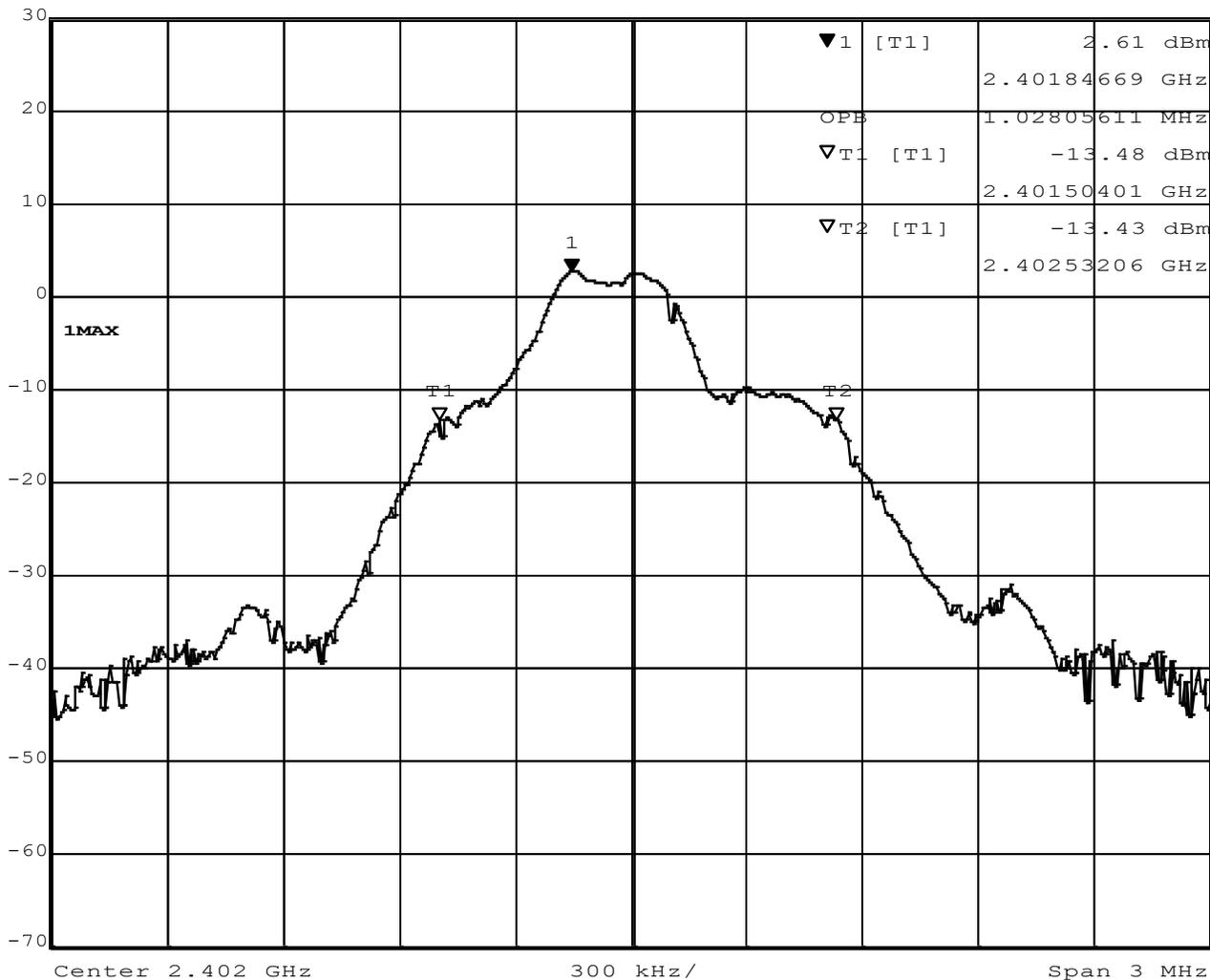


Figure 11 – Occupied Bandwidth, Low Channel, GFSK



Marker 1 [T1] RBW 100 kHz RF Att 40 dB

Ref Lvl 1.84 dBm VBW 300 kHz  
 30 dBm 2.44084669 GHz SWT 5 ms Unit dBm

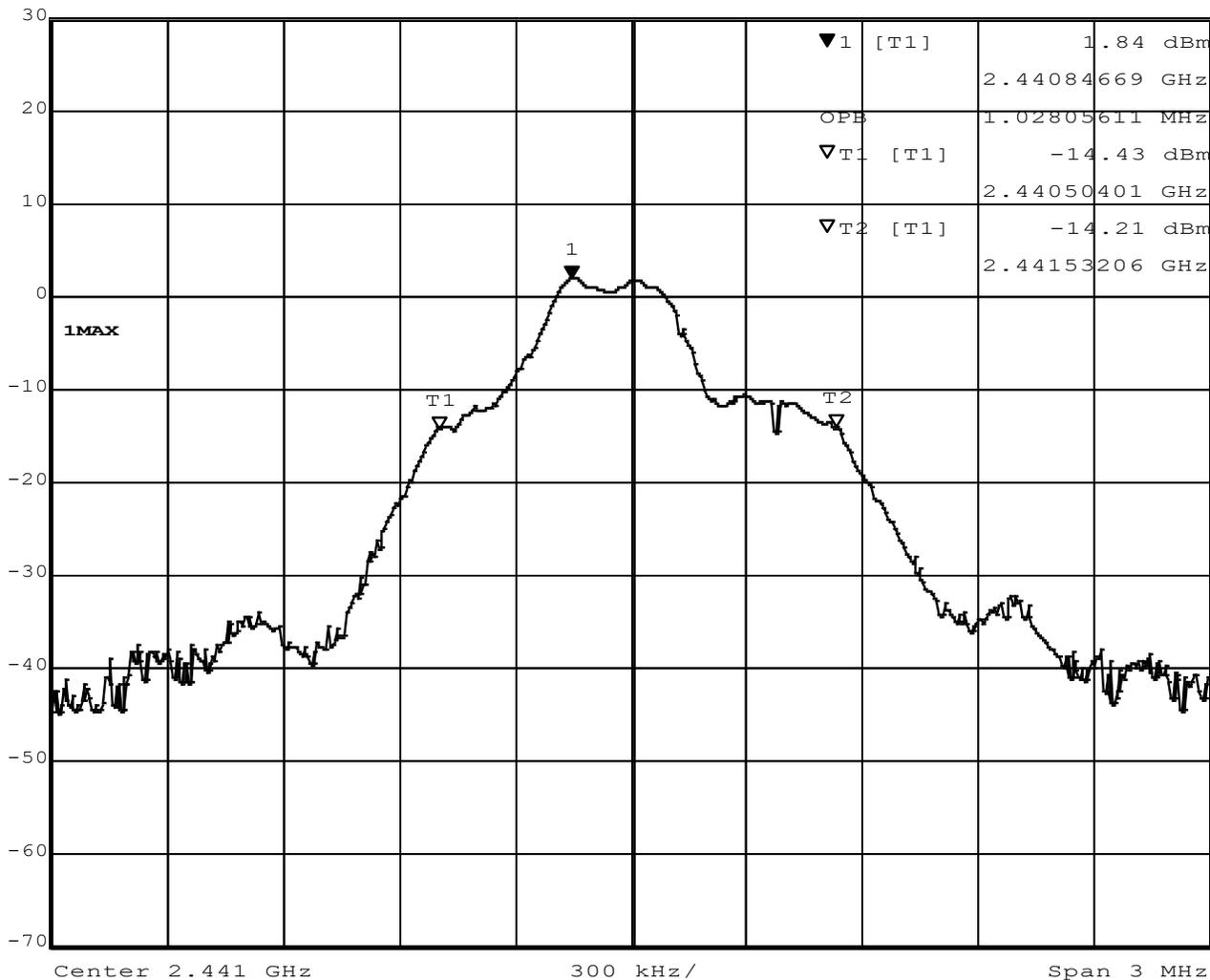


Figure 12 - Occupied Bandwidth, Mid Channel, GFSK



Marker 1 [T1]      RBW 100 kHz      RF Att 40 dB  
 Ref Lvl      0.93 dBm      VBW 300 kHz  
 30 dBm      2.47984669 GHz      SWT 5 ms      Unit dBm

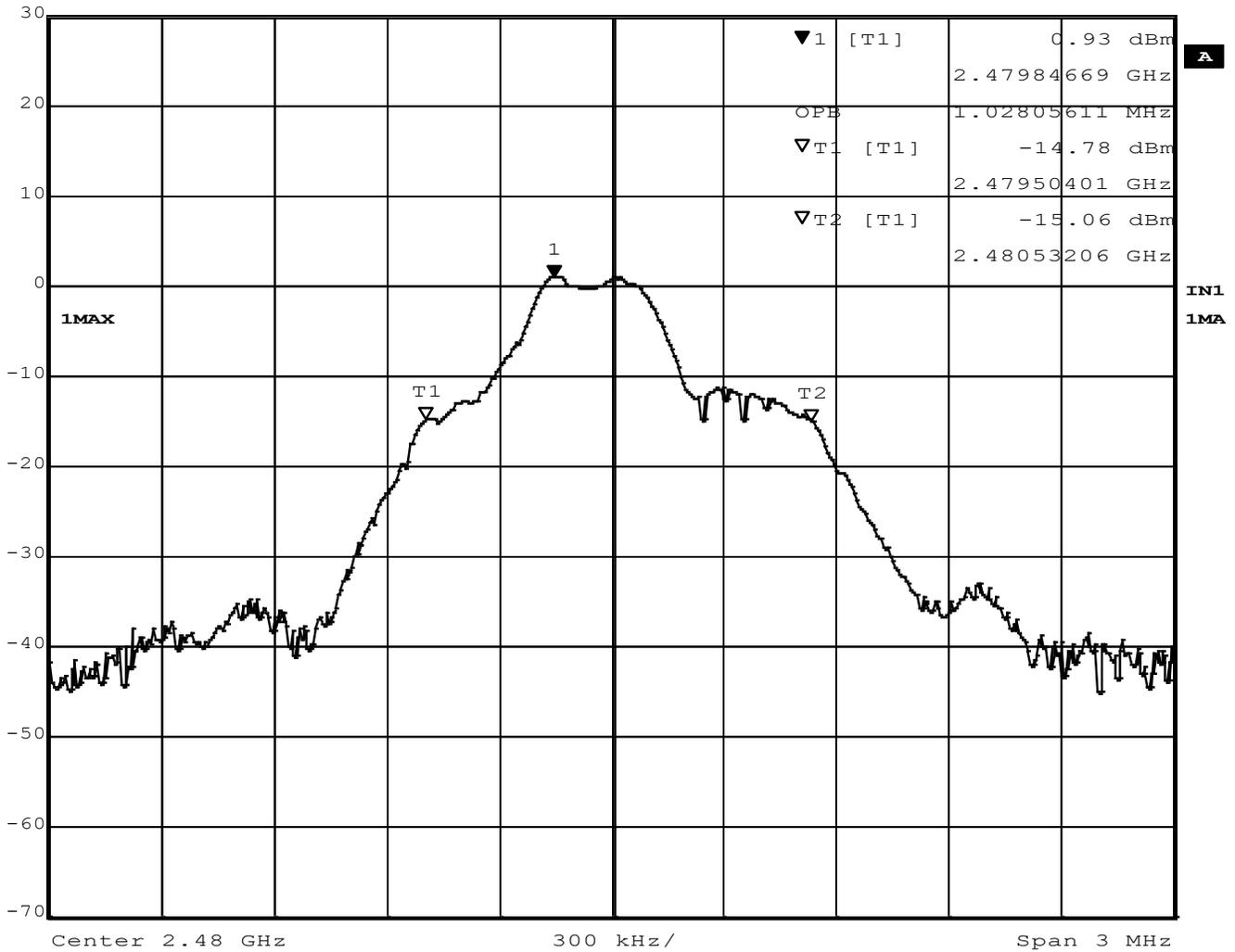


Figure 13 - Occupied Bandwidth, High Channel, GFSK

#### 4.4 RADIATED EMISSIONS

**Test Method:** ANSI C63.10, Section 6.5, 6.6

**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 ( $\mu\text{V/m}$ )	MEASUREMENT DISTANCE (m)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	3
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

**NOTE:**

1. The lower limit shall apply at the transition frequencies.
2. Emission level (dBuV/m) =  $20 * \log * \text{Emission level } (\mu\text{V/m})$ .
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.
4. The EUT was tested for spurious emissions while running off of battery power and external USB power. The worse-case emissions were produced while running off of USB power, so results from this mode are presented.

### 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 from 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.

### Test setup:

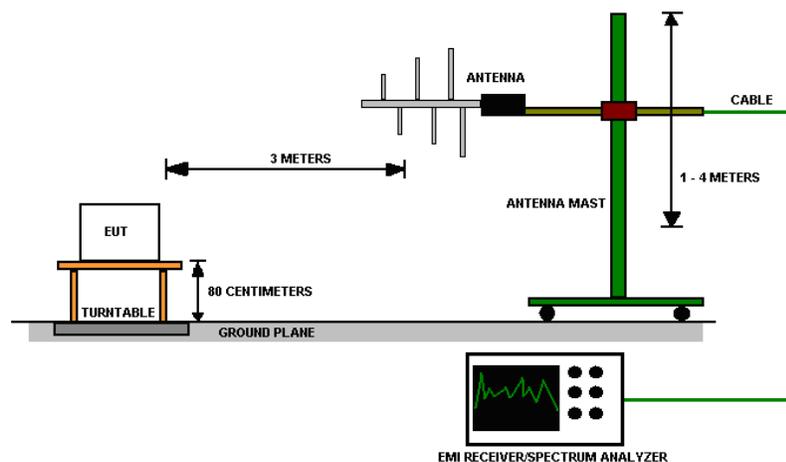


Figure 14 - Radiated Emissions Test Setup



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**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.

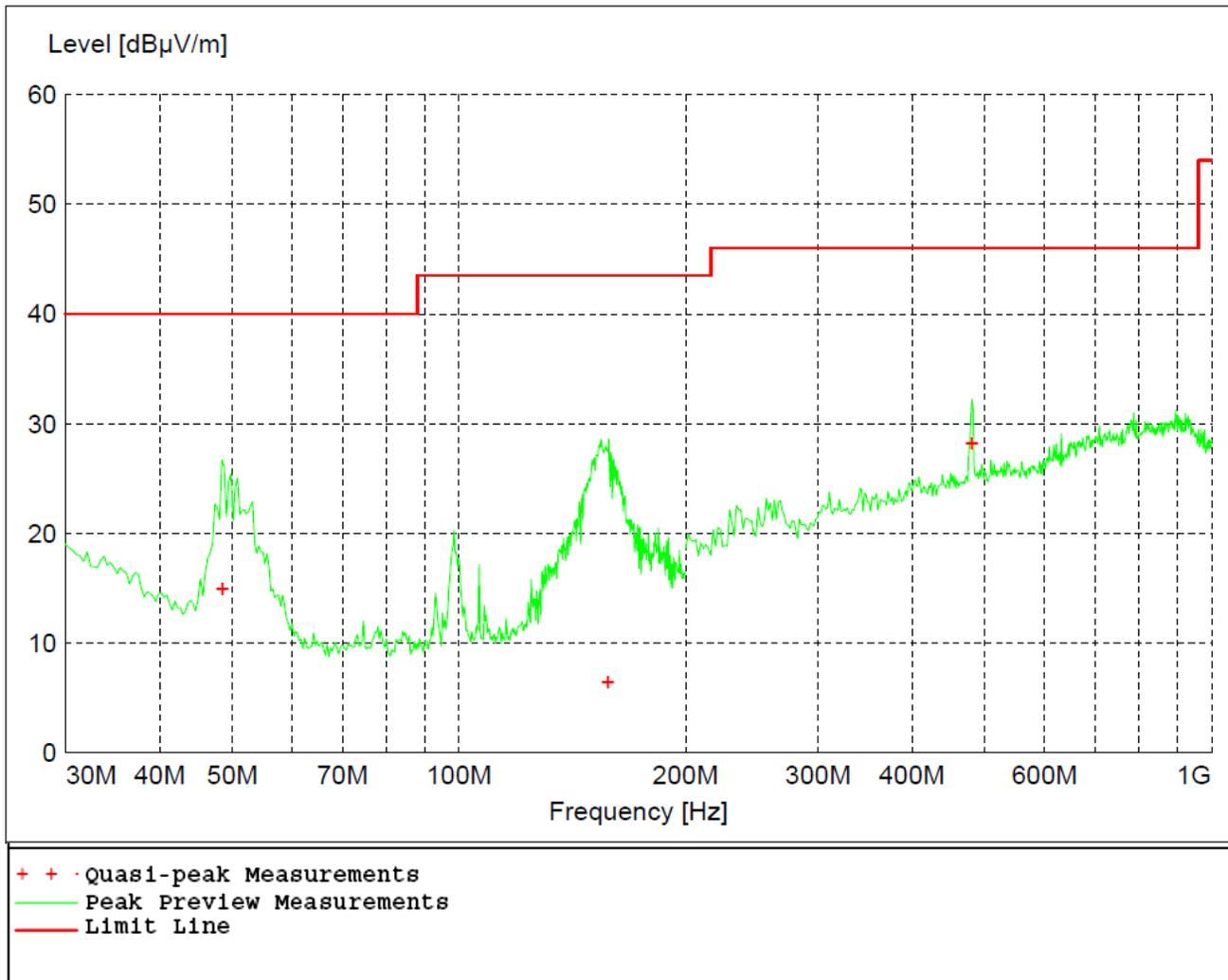
**Deviations from test standard:**

No deviation.

**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 GFSK and GMSK.

**Test results:**



**Figure 15 - Radiated Emissions Plot, Receive, GFSK**

**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



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**Table 1 - Radiated Emissions Quasi-peak Measurements, Receive, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
48.540000	14.98	40.00	25.00	100	252	VERT
157.920000	6.47	43.50	37.00	145	0	HORI
480.420000	28.23	46.00	17.80	400	6	HORI

**Table 2 - Radiated Emissions Average Measurement, Receive, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2467.600000	29.83	54.00	24.17	120	267	VERT
5224.800000	24.12	54.00	29.88	99	87	VERT

**Table 3 - Radiated Emissions Peak Measurement, Receive, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2467.600000	47.55	74.00	26.45	120	267	VERT
5224.800000	41.84	74.00	32.16	99	87	VERT

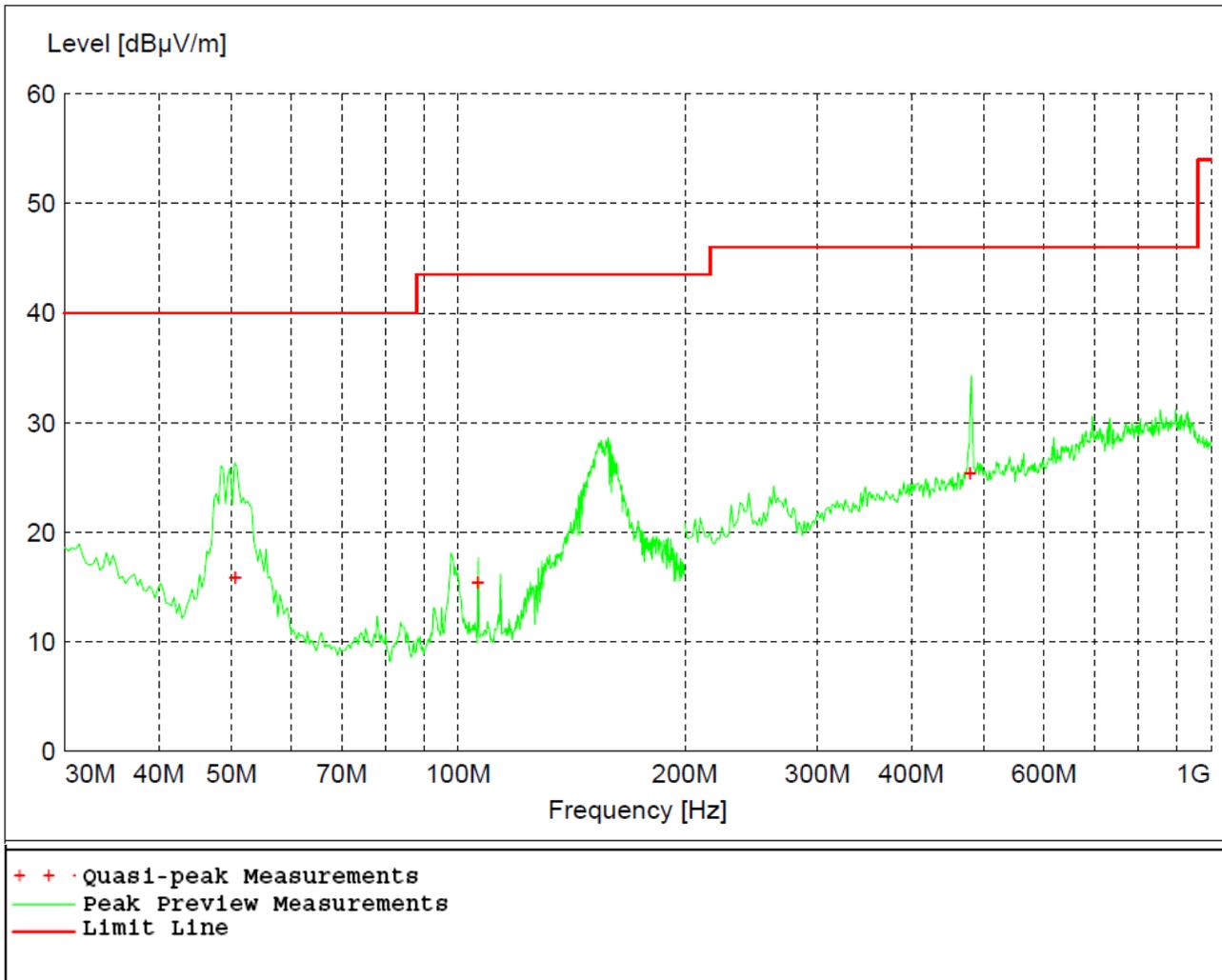


Figure 16 - Radiated Emissions Plot, Receive, GMSK

**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

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**Table 4 - Radiated Emissions Quasi-peak Measurements, Receive, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
50.580000	15.89	40.00	24.10	100	151	VERT
106.260000	15.42	43.50	28.10	180	150	HORI
479.160000	25.36	46.00	20.60	244	177	VERT

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

**Table 5 - Radiated Emissions Average Measurement, Receive, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2465.400000	30.77	54.00	23.23	184	0	VERT
4795.400000	24.73	54.00	29.27	320	5	VERT

**Table 6 - Radiated Emissions Peak Measurement, Receive, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2465.400000	48.49	74.00	25.51	184	0	VERT
4795.400000	42.45	74.00	31.55	320	5	VERT

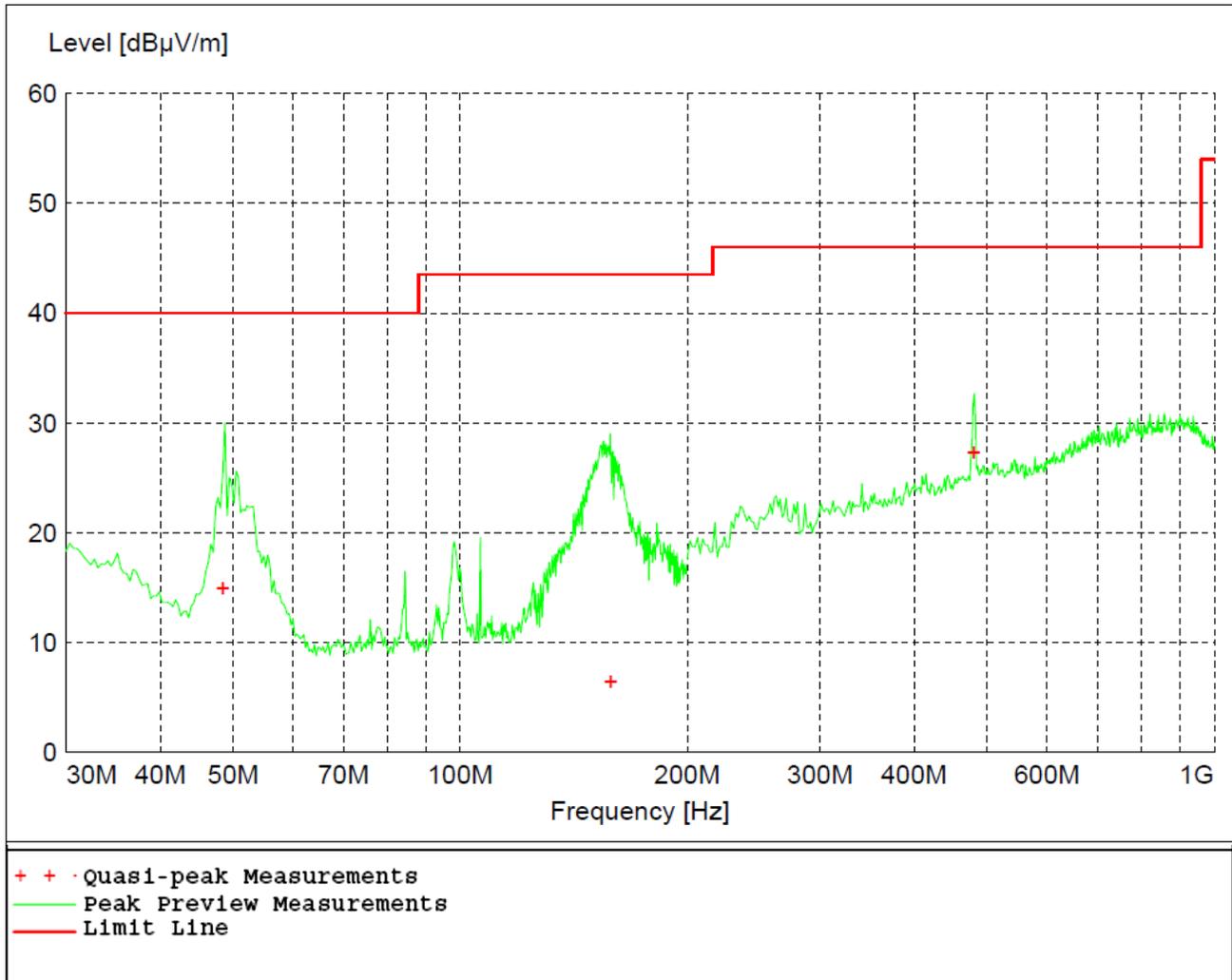


Figure 17 - Radiated Emissions Plot, Low Channel, GFSK

**REMARKS:**

1. Emission level (dBµV/m) = Raw Value (dBµV) + 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



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**Table 7 - Radiated Emissions Quasi-peak Measurements, Low Channel, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
48.480000	15.02	40.00	25.00	100	214	VERT
158.400000	6.48	43.50	37.00	400	51	HORI
480.000000	27.37	46.00	18.60	337	88	HORI

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

**Table 8 - Radiated Emissions Peak Measurements vs. Average Limits, Low Channel, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2402.000000	88.40	94.00	5.60	190	62	VERT
4793.800000	42.43	54.00	11.57	305	292	HORI
7197.400000	46.87	54.00	7.13	215	153	VERT

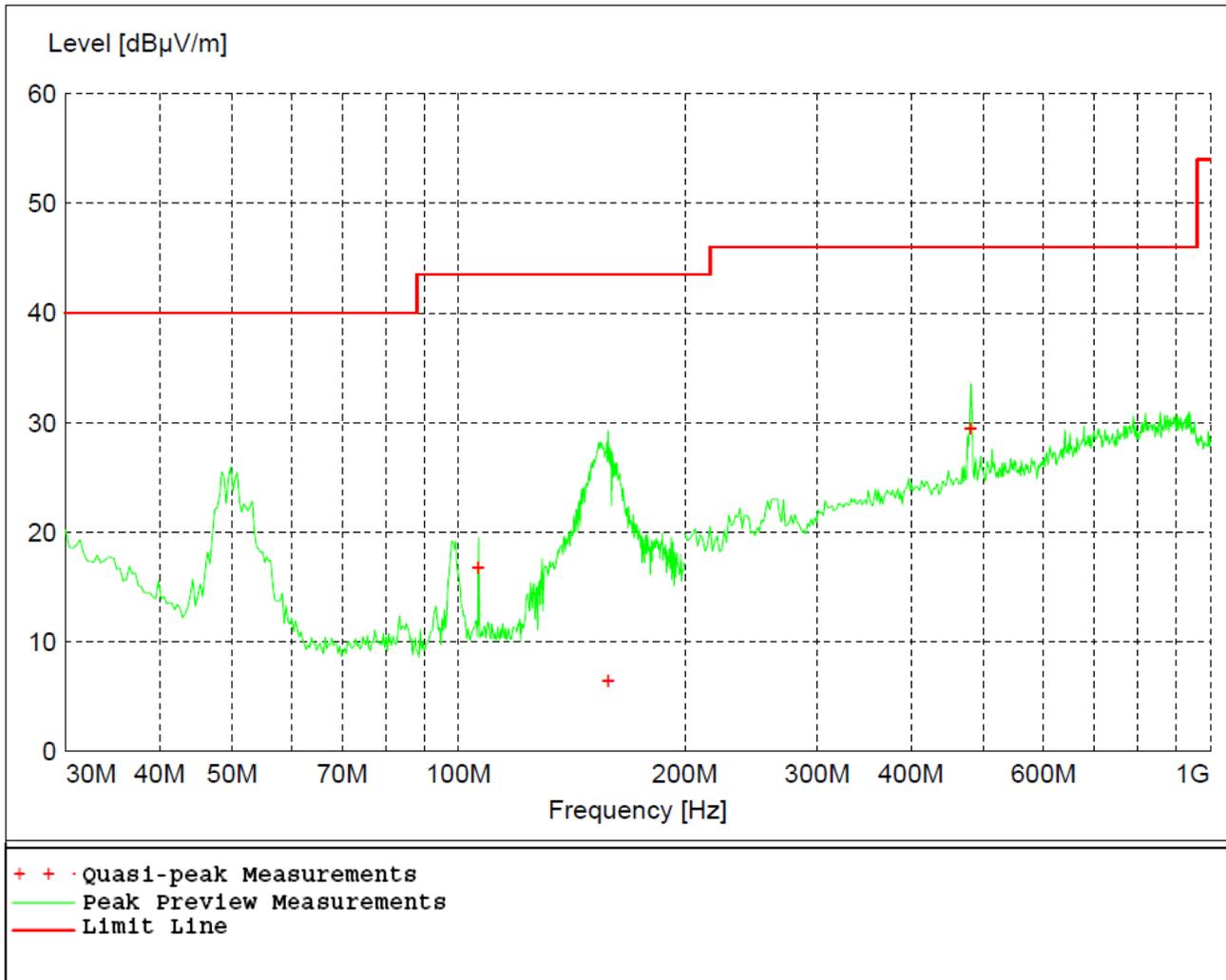


Figure 18 - Radiated Emissions Plot, Mid Channel, GFSK

**REMARKS:**

1. Emission level (dBµV/m) = Raw Value (dBµV) + 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



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**Table 9 - Radiated Emissions Quasi-peak Measurements, Mid Channel, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
106.320000	16.81	43.50	26.70	183	216	HORI
158.220000	6.47	43.50	37.00	349	282	HORI
480.240000	29.48	46.00	16.50	100	360	VERT

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

**Table 10 - Radiated Emissions Peak Measurements vs. Average limit, Mid Channel, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2441.000000	91.95	94.00	2.05	187	184	HORI
4883.200000	44.72	54.00	9.28	356	133	HORI

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

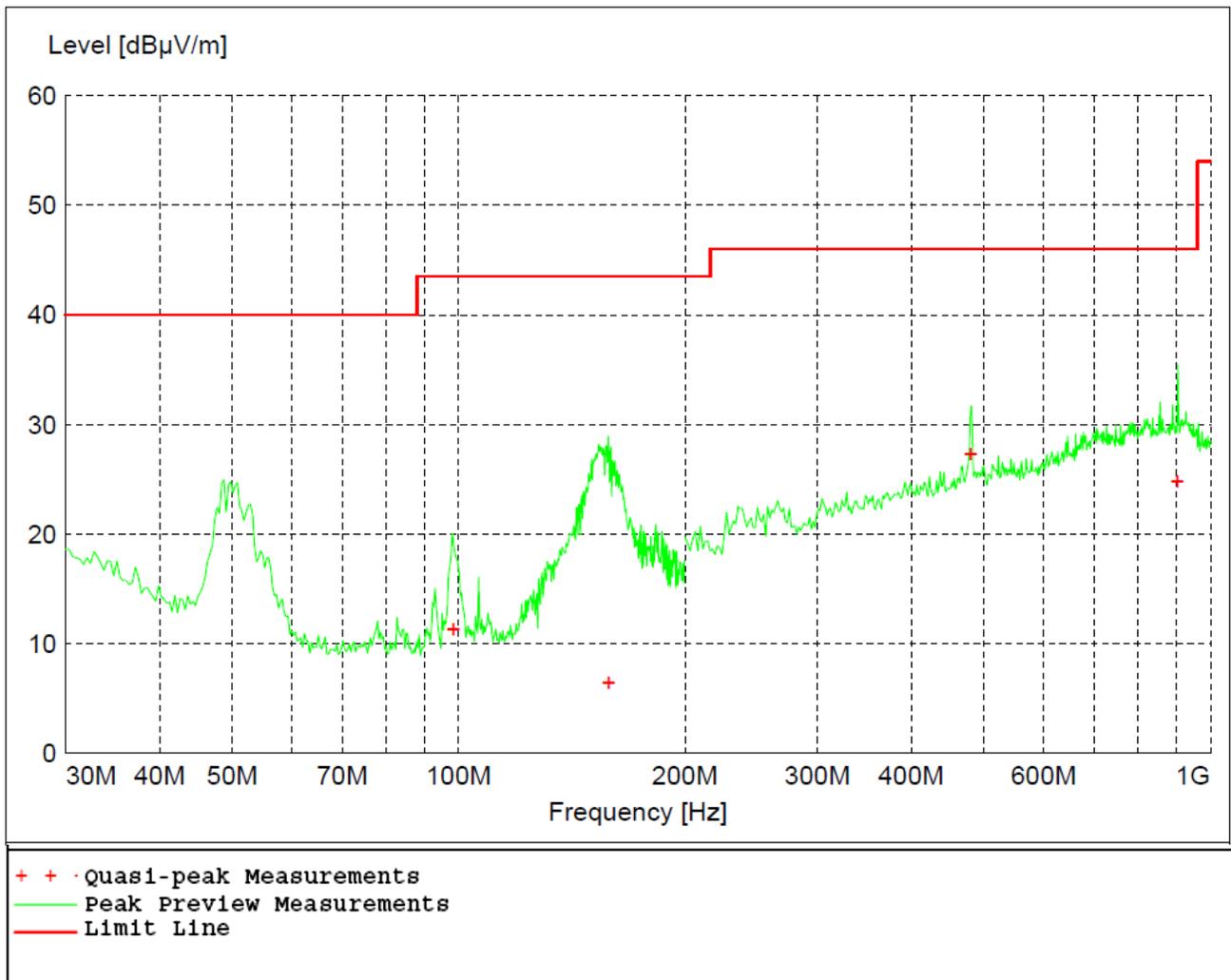


Figure 19 - Radiated Emissions Plot, High Channel, GFSK

**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.



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**Table 11 - Radiated Emissions Quasi-peak Measurements, High Channel, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
98.400000	11.37	43.50	32.20	298	144	VERT
158.400000	6.48	43.50	37.00	109	172	HORI
480.060000	27.40	46.00	18.60	315	92	HORI
903.840000	24.90	46.00	21.10	107	360	HORI

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

**Table 12 - Radiated Emissions Peak Measurements vs. Average Limits, High Channel, GFSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2480.000000	90.53	94.00	3.47	211	71	VERT
4959.600000	42.10	54.00	11.90	277	351	HORI

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

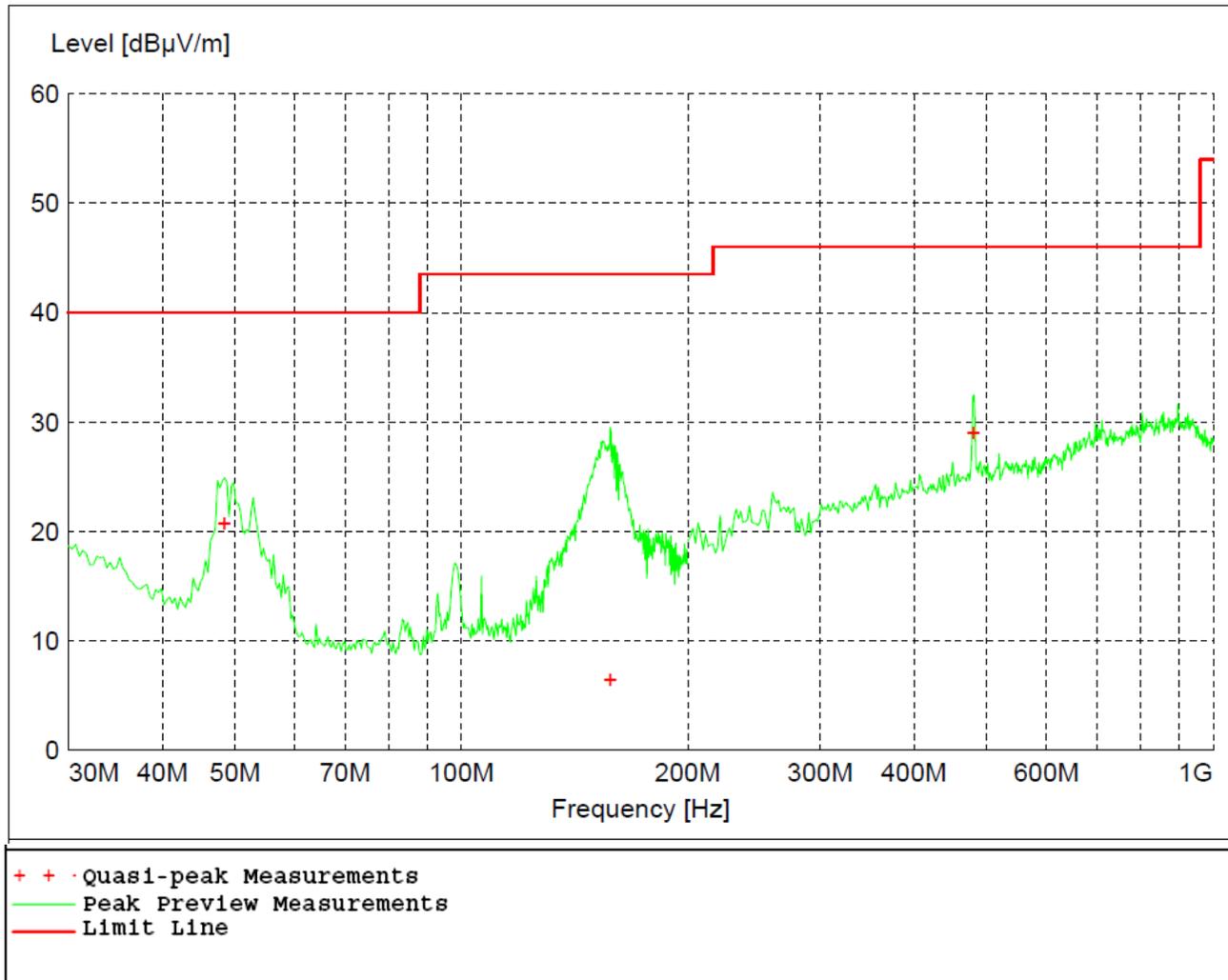


Figure 20 - Radiated Emissions Plot, Low Channel, GMSK

**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

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**Table 13 - Radiated Emissions Quasi-peak Measurements, Low Channel, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
48.420000	20.73	40.00	19.30	100	329	VERT
157.920000	6.47	43.50	37.00	399	175	HORI
480.120000	29.06	46.00	16.90	257	282	VERT

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

**Table 14 - Radiated Emissions Peak Measurements vs. Average limit, Low Channel, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2402.000000	91.68	94.00	N/A	164	287	VERT
4808.600000	42.97	54.00	11.03	153	121	HORI
7177.600000	46.98	54.00	7.02	238	360	HORI

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

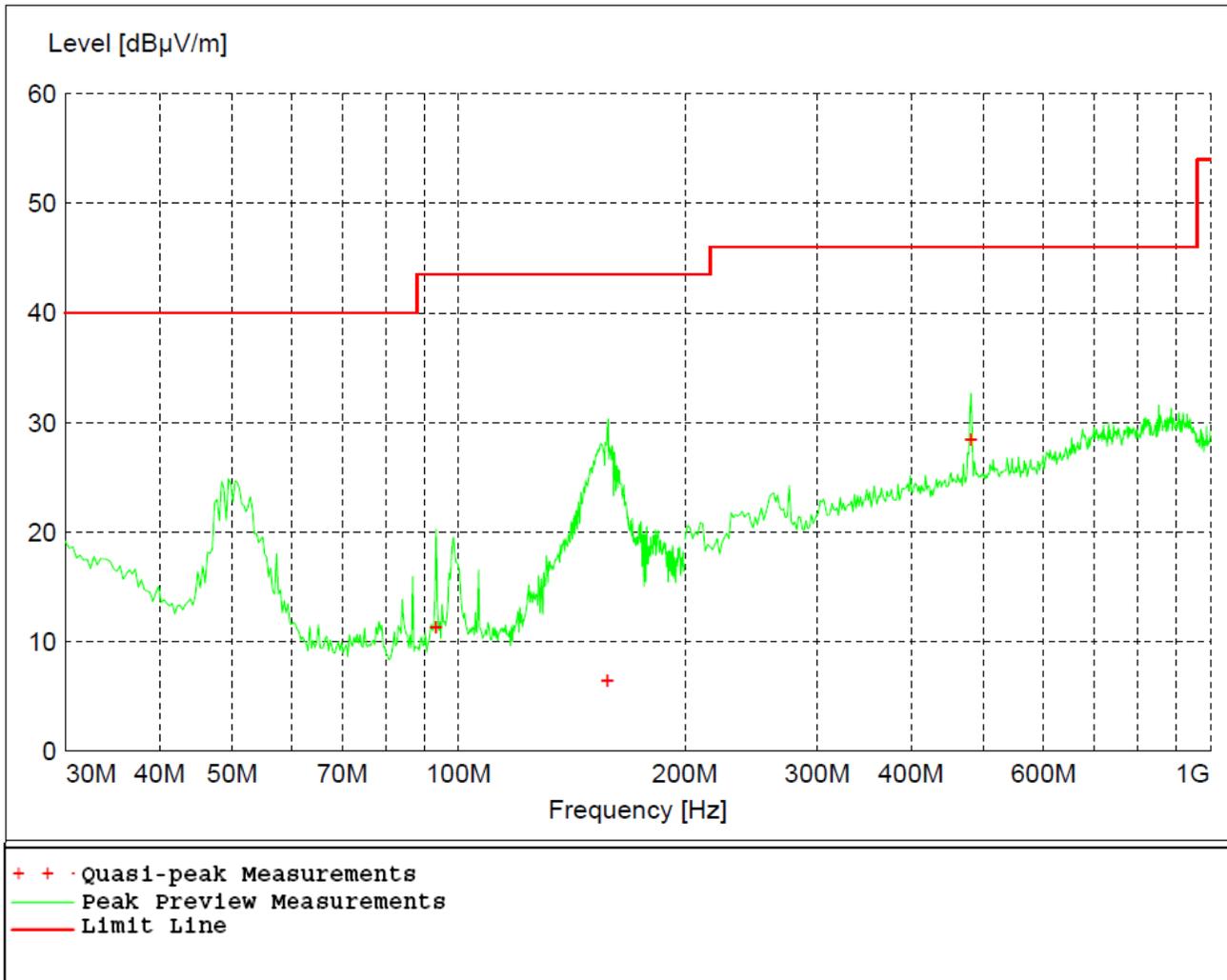


Figure 21 - Radiated Emissions Plot, Mid Channel, GMSK

**REMARKS:**

1. Emission level (dBµV/m) = Raw Value (dBµV) + 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



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**Table 15 - Radiated Emissions Quasi-peak Measurements, Mid Channel, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
93.420000	11.30	43.50	32.20	126	155	VERT
157.800000	6.47	43.50	37.10	277	254	HORI
480.360000	28.53	46.00	17.50	383	1	HORI

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

**Table 16 - Radiated Emissions Peak Measurements vs. Average Limit, Mid Channel, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2440.000000	89.00	94.00	5.00	153	298	VERT
7323.200000	45.83	54.00	8.17	333	177	VERT

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

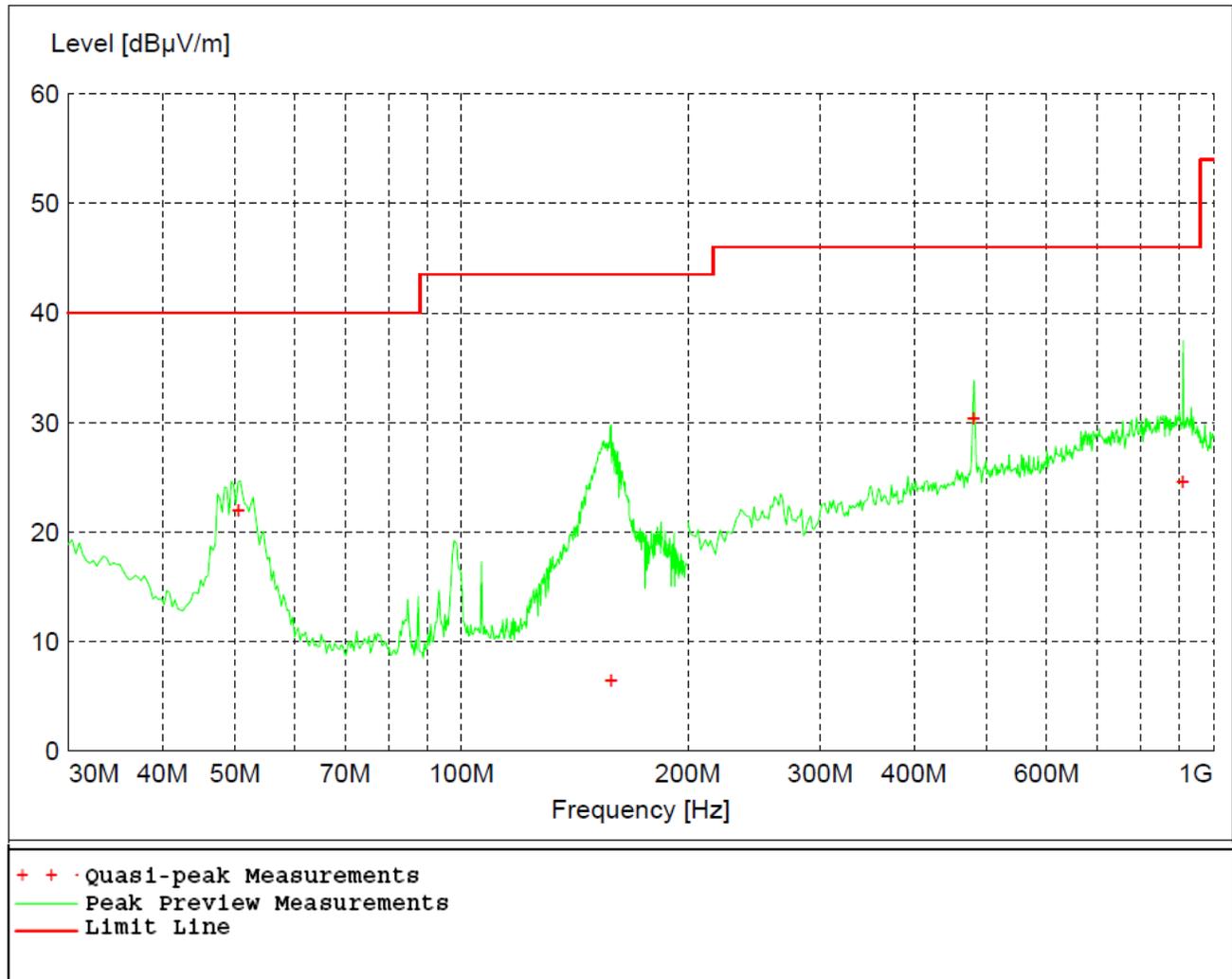


Figure 22 - Radiated Emissions Plot, High Channel, GMSK

**REMARKS:**

1. Emission level (dBµV/m) = Raw Value (dBµV) + 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



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**Table 17 - Radiated Emissions Quasi-peak Measurements, High Channel, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
50.520000	22.06	40.00	17.90	100	170	VERT
158.160000	6.47	43.50	37.00	284	121	HORI
480.180000	30.41	46.00	15.60	111	360	VERT
910.500000	24.67	46.00	21.30	163	182	HORI

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

**Table 18 - Radiated Emissions Peak Measurements vs. Average Limit, High Channel, GMSK**

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm.	deg.	
2480.000000	93.57	94.00	0.43	211	287	VERT
7417.800000	45.23	54.00	8.77	394	202	VERT

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



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#### 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. EUT was set to transmit in GFSK and GMSK.



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**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	GMSK	2400	-42.35	6.44	48.79	37.68	PASS
Low, Continuous	GFSK	2400	-42.71	2.48	45.19	34.40	PASS
High, Continuous	GMSK	2483.5	-45.64	5.02	50.66	39.57	PASS
High, Continuous	GFSK	2483.5	-44.04	0.86	44.9	36.53	PASS

\*Minimum delta = [highest fundamental peak field strength from Section 4.4 ] – [ Part 15.209 radiated emissions limit. ]

From Section 4.2

Fundamental peak field strength at Low Channel GMSK = 91.68 dBμV/m  
 Fundamental peak field strength at High Channel GMSK = 93.57 dBμV/m  
 Fundamental peak field strength at Low Channel GFSK = 88.40 dBμV/m  
 Fundamental peak field strength at High Channel GFSK = 90.53 dBμV/m

Low Channel minimum delta GMSK = 91.68 – 54.0 dBμV/m = 37.68 dBc  
 High Channel minimum delta GMSK = 93.57 – 54.0 dBμV/m = 39.57 dBc  
 Low Channel minimum delta GFSK = 88.40 – 54.0 dBμV/m = 34.40 dBc  
 High Channel minimum delta GFSK = 90.53 – 54.0 dBμV/m = 36.53 dBc

FCC Part 15.249 requires the attenuation of all emissions outside of the specified band to be at least 50 dB or below the 15.209 limits, whichever is the lesser. In this case, the 15.209 limits were the lesser and used to show compliance.



Marker 1 [T1] RBW 100 kHz RF Att 40 dB  
 Ref Lvl 6.44 dBm VBW 300 kHz  
 30 dBm 2.40178357 GHz SWT 5 ms Unit dBm

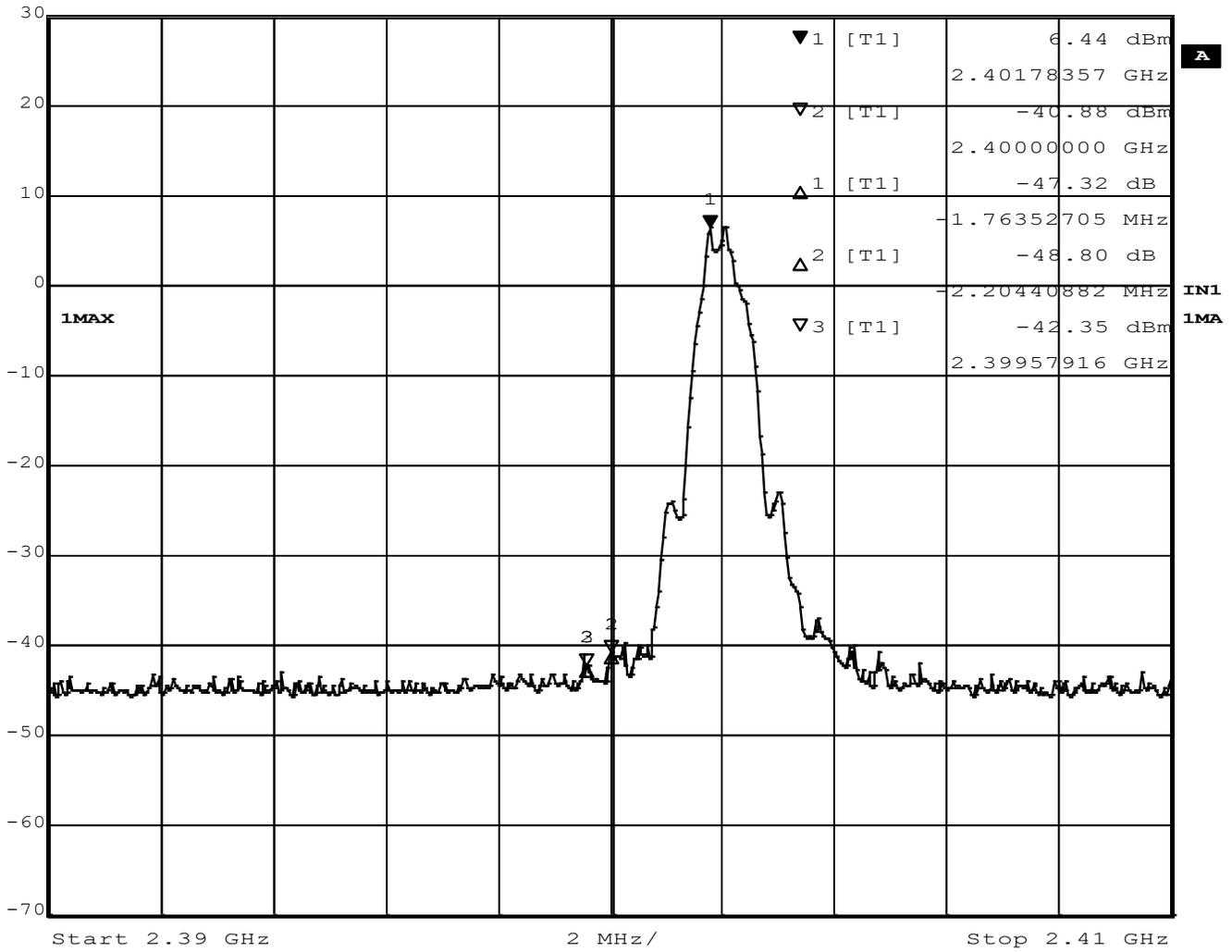


Figure 23 - Band Edge, Low Channel, GMSK



Delta 1 [T1] RBW 100 kHz RF Att 40 dB  
 Ref Lvl 0.00 dB VBW 300 kHz  
 30 dBm 0.00000000 Hz SWT 5 ms Unit dBm

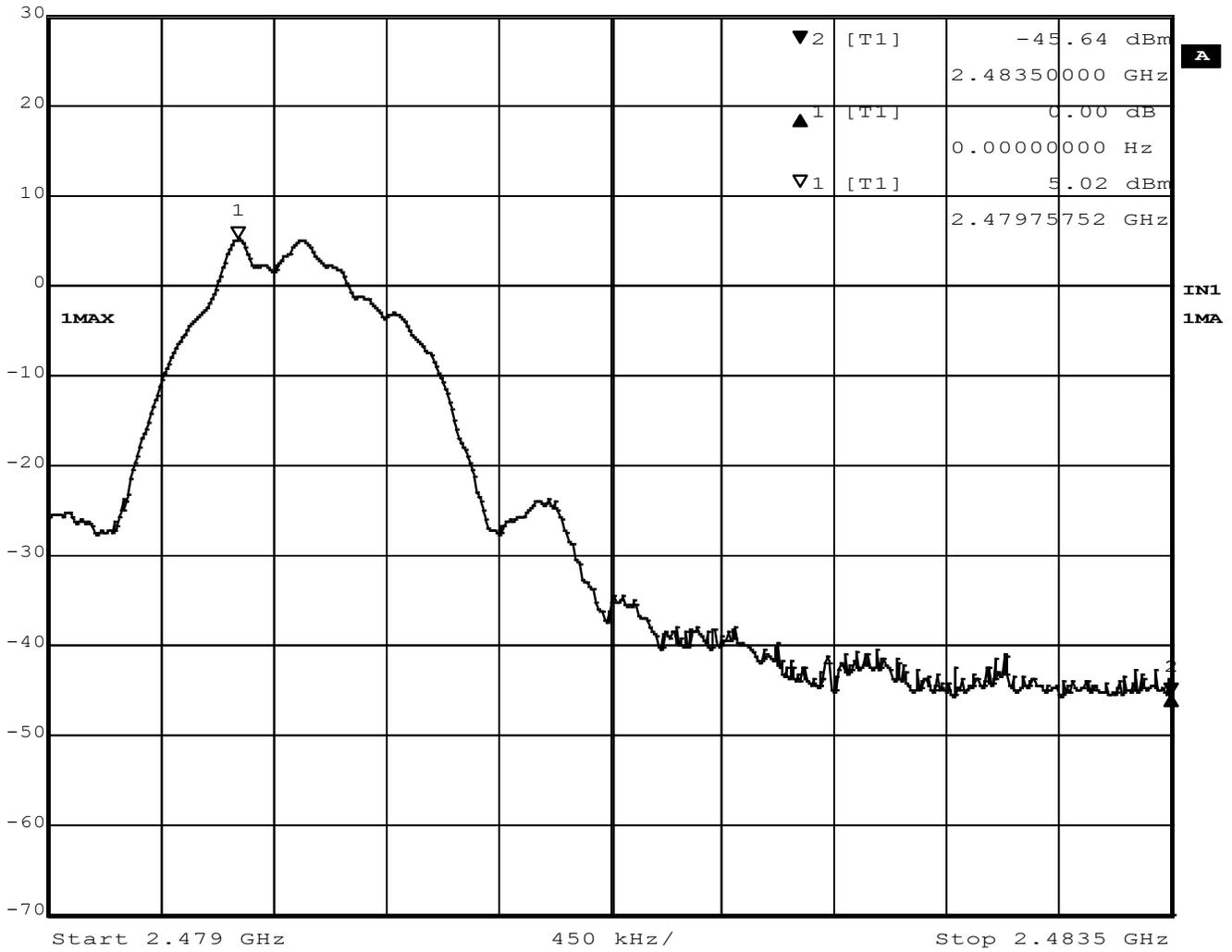


Figure 24 –Band Edge Measurement, High Channel, GMSK



Marker 1 [T1] RBW 100 kHz RF Att 40 dB  
 Ref Lvl 2.48 dBm VBW 300 kHz  
 30 dBm 2.40190381 GHz SWT 5 ms Unit dBm

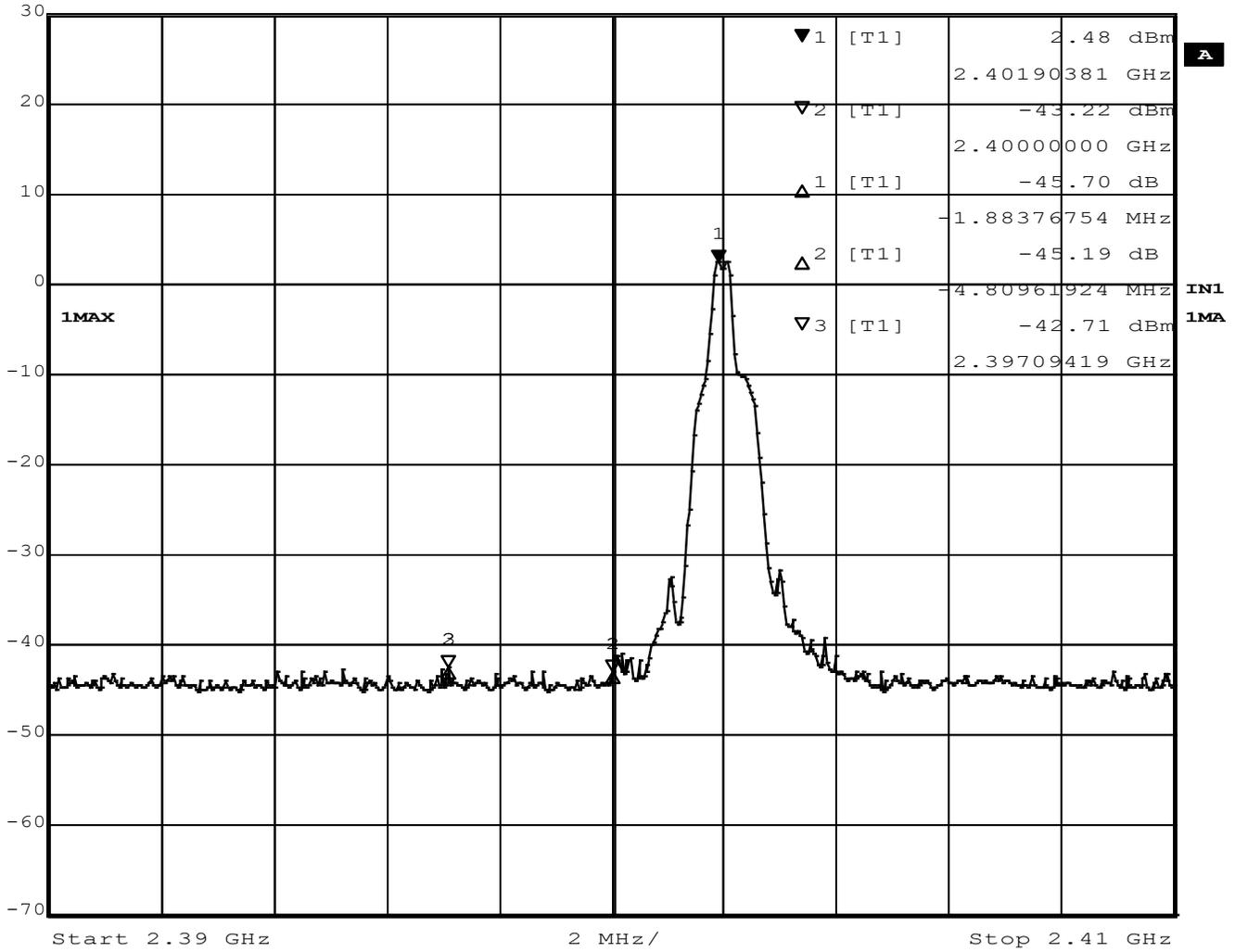


Figure 25 –Band Edge, Low Channel, GFSK



Marker 1 [T1]      RBW 100 kHz      RF Att 40 dB  
 Ref Lvl 0.86 dBm      VBW 300 kHz  
 30 dBm      2.47984770 GHz      SWT 5 ms      Unit dBm

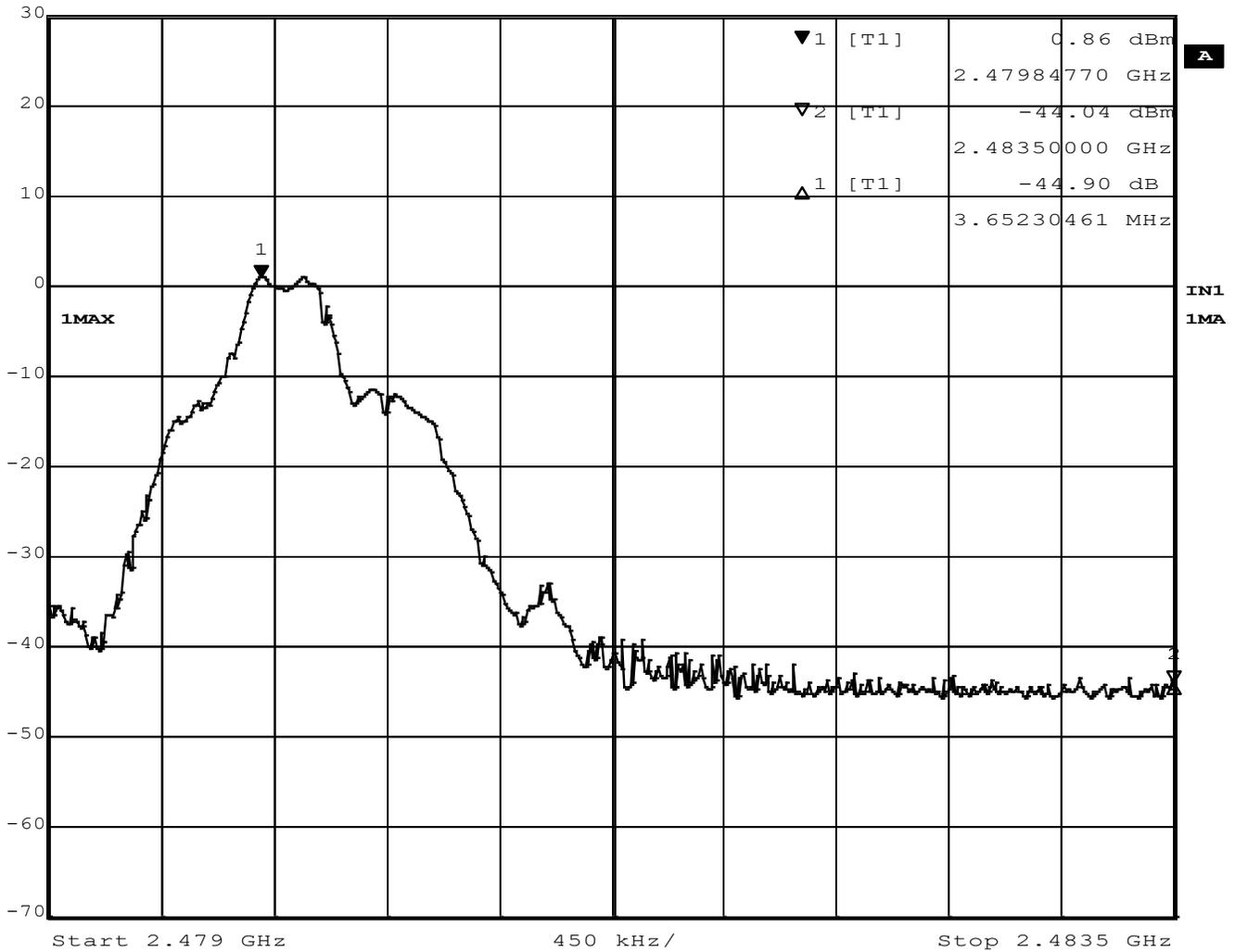


Figure 26 – Band Edge Measurement, High Channel, GFSK

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#### 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 (dB $\mu$ V)	
	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

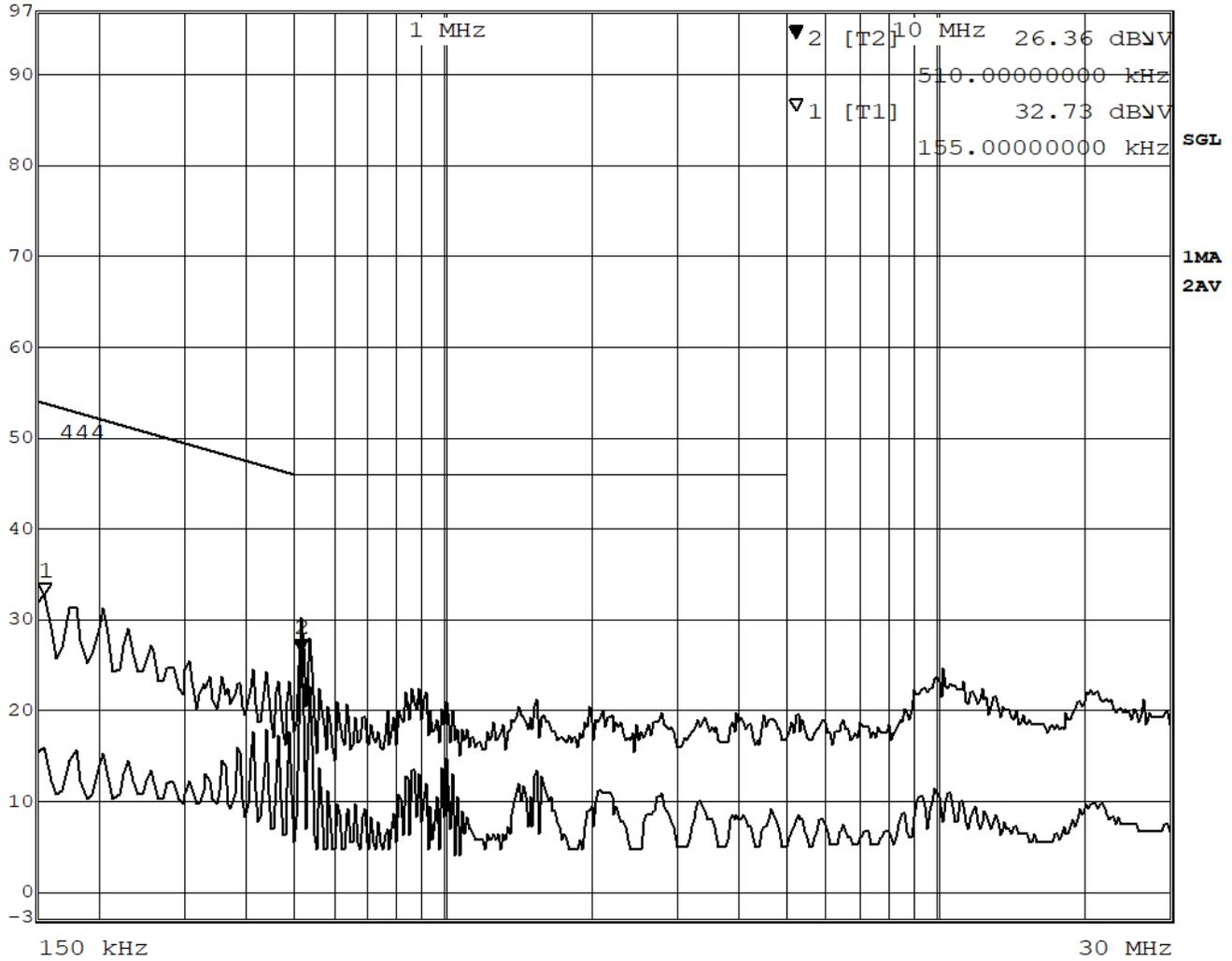
**EUT operating conditions:**

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

**Test Results:**



Att 10 dB AUTO	Marker 2 [T2]	Det	AV Trd	ES-K1
INPUT 2	26.36 dBV	ResBW	9 kHz	
	510.0000000 kHz	Meas T	100 ms Unit	dBV



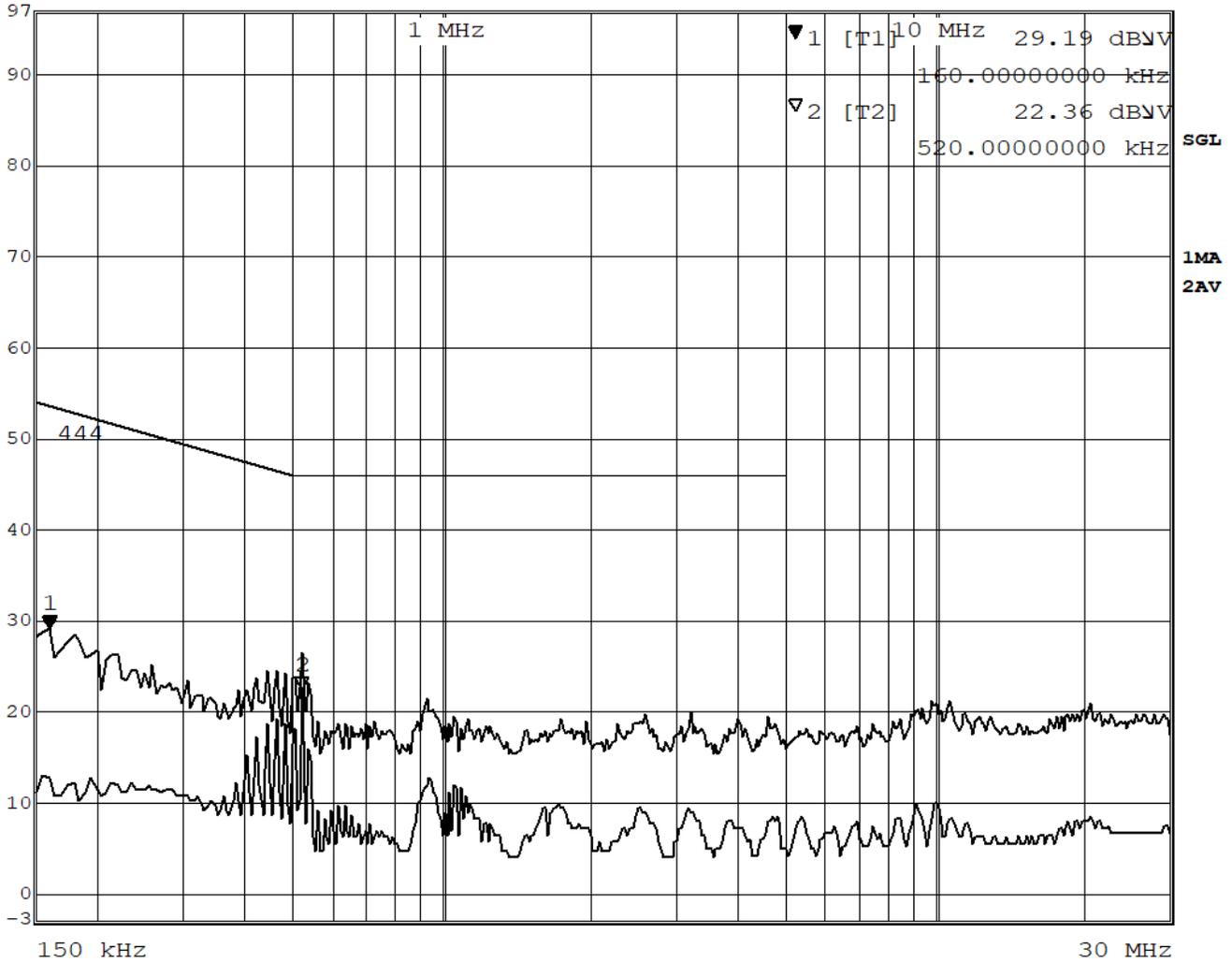
Date: 27.FEB.2019 09:55:57

**Figure 27 - Conducted Emissions Plot, L-F**

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



Marker 1 [T1]      Det      AV Trd      ES-K1  
 Att 10 dB AUTO      29.19 dBV      ResBW      9 kHz  
 INPUT 2      160.0000000 kHz      Meas T      100 ms Unit      dBV



Date: 27.FEB.2019 10:04:07

**Figure 28 - Conducted Emissions Plot, N-F**

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



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## 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 dB $\mu$ V 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 dB $\mu$ V/m.

$$FS = 55 + 12 - (-1.1 + 20) + 0 = 48.1 \text{ dB}\mu\text{V/m}$$

The 48.1 dB $\mu$ V/m value can be mathematically converted to its corresponding level in  $\mu$ V/m.

$$\text{Level in } \mu\text{V/m} = \text{Common Antilogarithm} [(48.1 \text{ dB}\mu\text{V/m})/20] = 254.1 \mu\text{V/m}$$

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

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### 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;

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

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

$$Voltage (dB\mu V) = Power (dBm) + 107 \text{ (for } 50\Omega \text{ measurement systems)}$$

$$Field Strength (V/m) = 10^{[Field Strength (dB\mu V/m) / 20]} / 10^6$$

$$Gain = 1 \text{ (numeric gain for isotropic radiator)}$$

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

$$EIRP = [FS(V/m) \times d^2]/30 = FS [0.3] \quad \text{for } d = 3$$

$$EIRP(dBm) = FS(dB\mu V/m) - 10(\log 10^9) + 10\log[0.3] = FS(dB\mu V/m) - 95.23$$

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



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## 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%.



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REPORT END