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 DXX Test Report

Prepared for: **Garmin International Inc.**

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

Product: **A03525**

Test Report No: **R20181130-20-01**

Approved by:

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

DATE: **28 March 2019**

Total Pages: **56**

ilac-MRA A2LA ACCREDITED
TESTING LABORATORY
CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	29 January 2019	Original – NJohnson Prepared by KVepuri/CFarrington
A	28 March 2019	Added average detector measurements to spurious emissions results. Removed info on EUT antennas. This is provided in a separate document. Includes NCEE Labs test report R20181130-20-01 and its amendment in full -NJ

CONTENTS

TABLES OF FIGURES

Figure Number **Page**

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	PCB Antenna
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	No provisions for connection to AC mains

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

Summary

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

EUT	A03525
EUT Received	20 December 2018
EUT Tested	20 December 2018- 4 February 2019
Serial No.	NCEETEST1 (assigned, radiated) NCEETEST2 (assigned, conducted)
Operating Band	2400 – 2483.5 MHz
Device Type	GMSK, GFSK
Power Supply	Internal Battery/ Charger: Garmin (Phi Hong) MN: PSAI10R-050Q

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

2.2 DESCRIPTION OF TEST MODES

The EUT operates on, and was tested at the frequencies below:

Channel	Frequency
Low	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 on both battery and external USB.

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 2019
EMCO Biconilog Antenna	3142B	1647	02 Aug 2017	02 Aug 2019
EMCO Horn Antenna	3115	6416	26 Jan 2018	26 Jan 2020
EMCO Horn Antenna	3116	2576	31 Jan 2018	31 Jan 2020
Rohde & Schwarz Preamplifier	TS-PR18	3545700803	09 Mar 2018*	09 Mar 2019*
Trilithic High Pass Filter	6HC330	23042	09 Mar 2018*	09 Mar 2019*
Rohde & Schwarz LISN	ESH3-Z5	836679/010	26 Jul 2018	26 Jul 2019
RF Cable (preamplifier to antenna)	MFR-57500	01-07-002	09 Mar 2018*	09 Mar 2019*
RF Cable (antenna to 10m chamber bulkhead)	FSCM 64639	01E3872	09 Mar 2018*	09 Mar 2019*
RF Cable (10m chamber bulkhead to control room bulkhead)	FSCM 64639	01E3874	09 Mar 2018*	09 Mar 2019*
RF Cable (Control room bulkhead to RF switch)	FSCM 64639	01E3871	09 Mar 2018*	09 Mar 2019*
RF Cable (RF switch to test receiver)	FSCM 64639	01F1206	09 Mar 2018*	09 Mar 2019*
RF switch – Rohde and Schwarz	TS-RSP	1113.5503.14	09 Mar 2018*	09 Mar 2019*
N connector bulkhead (10m chamber)	PE9128	NCEEBH1	09 Mar 2018*	09 Mar 2019*
N connector bulkhead (control room)	PE9128	NCEEBH2	09 Mar 2018*	09 Mar 2019*

*Internal Characterization

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

GFSK:

Maximum duty cycle declared by the manufacturer = 13 ms per 100ms time period

Duty cycle correction factor = 20*log((13)/100) = -17.72 dB

GMSK:

Maximum duty cycle declared by the manufacturer = 100%

No duty cycle correction factor is applicable.

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 (MHz)	PEAK OUTPUT POWER (dBm)	PEAK OUTPUT POWER (mW)	Method	Transmsitter
1	2402	1.91	1.58	Conducted	GMSK
2	2440	0.42	1.19	Conducted	GMSK
3	2480	-0.43	0.91	Conducted	GMSK
1	2402	1.98	1.55	Conducted	GFSK
2	2440	0.74	1.10	Conducted	GFSK
3	2480	-0.43	0.91	Conducted	GFSK

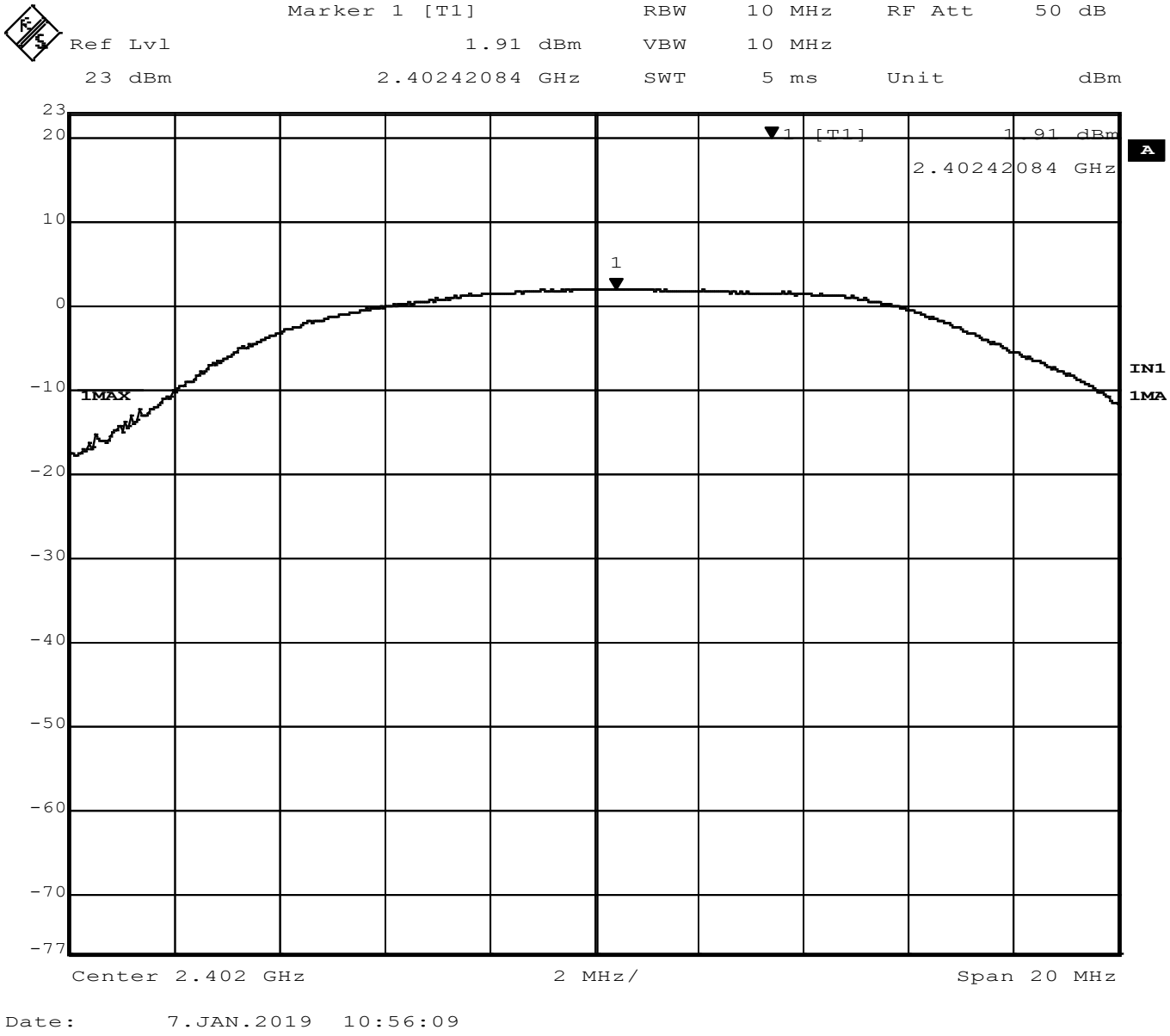

Figure 1 – Output Power, Low Channel, GMSK

Output power 1.91 dBm

Cable loss was less than 0.1 dB and not included

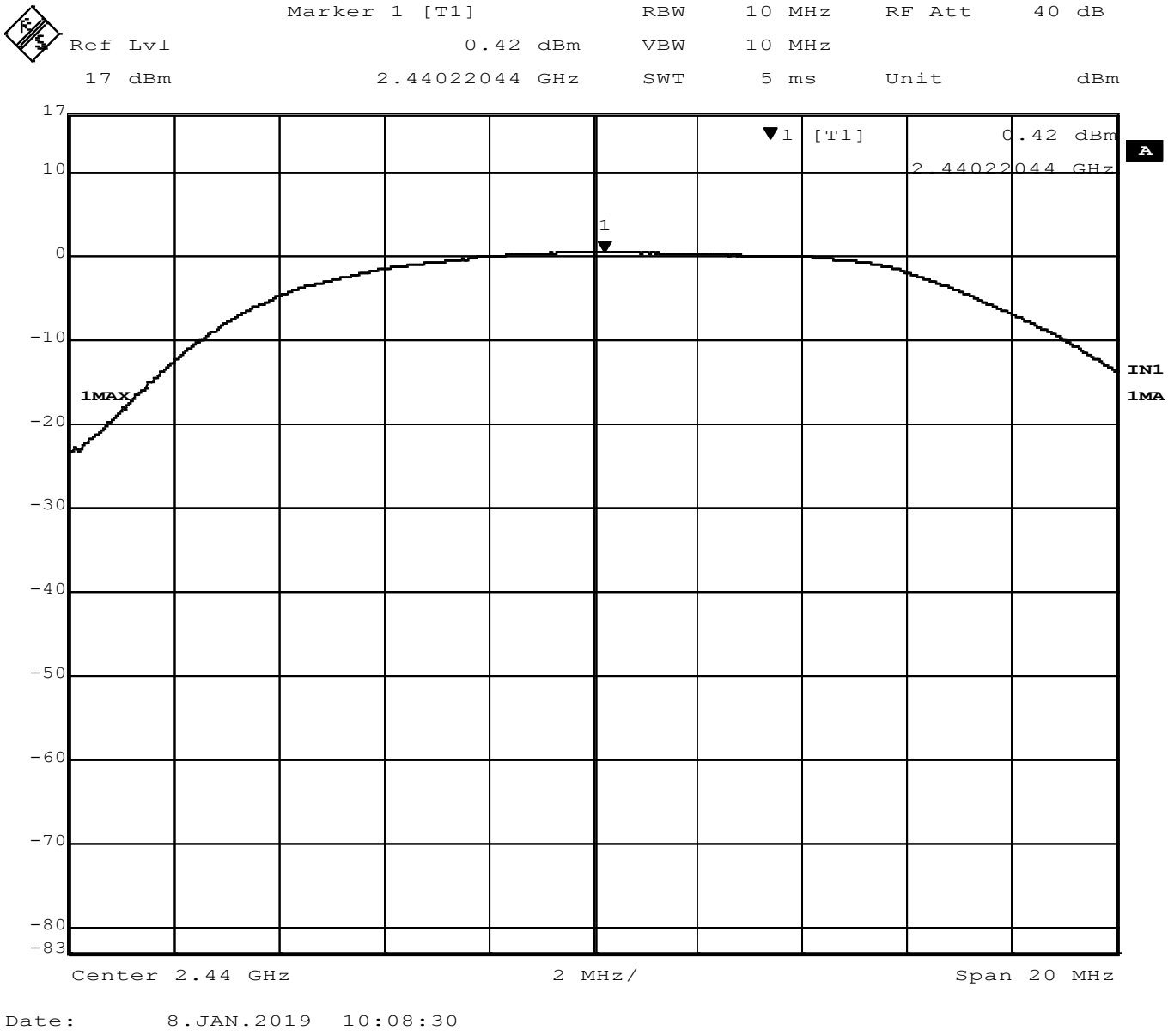

Figure 2 – Output Power, Mid Channel, GMSK

Output power = 0.42 dBm

Cable loss was less than 0.1 dB and not included

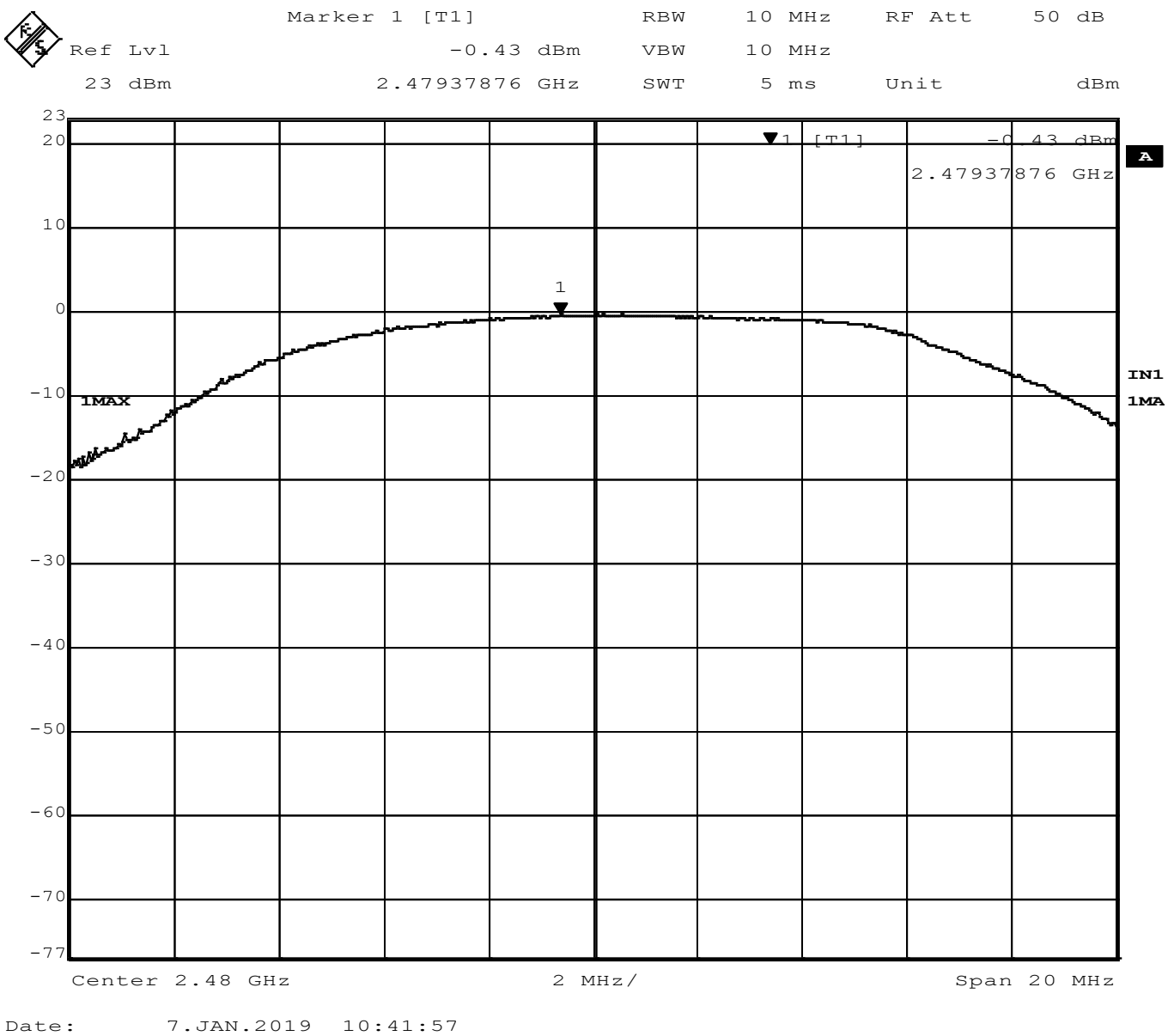

Figure 3 – Output Power, High Channel, GMSK

Output power = -0.43 dBm

Cable loss was less than 0.1 dB and not included

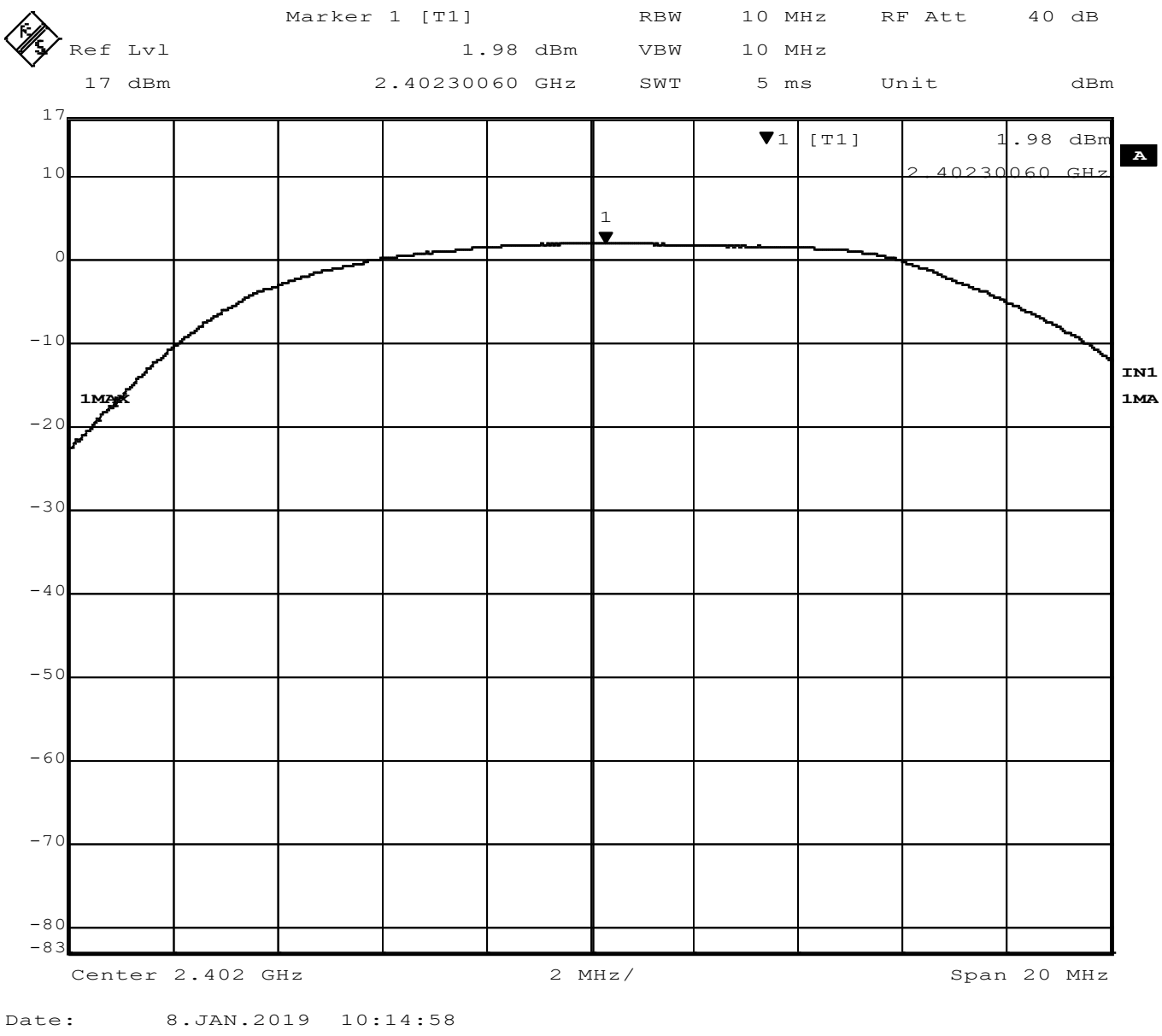

Figure 4 - Output Power, Low Channel, GFSK

Output power = 1.98 dBm

Cable loss was less than 0.1 dB and not included

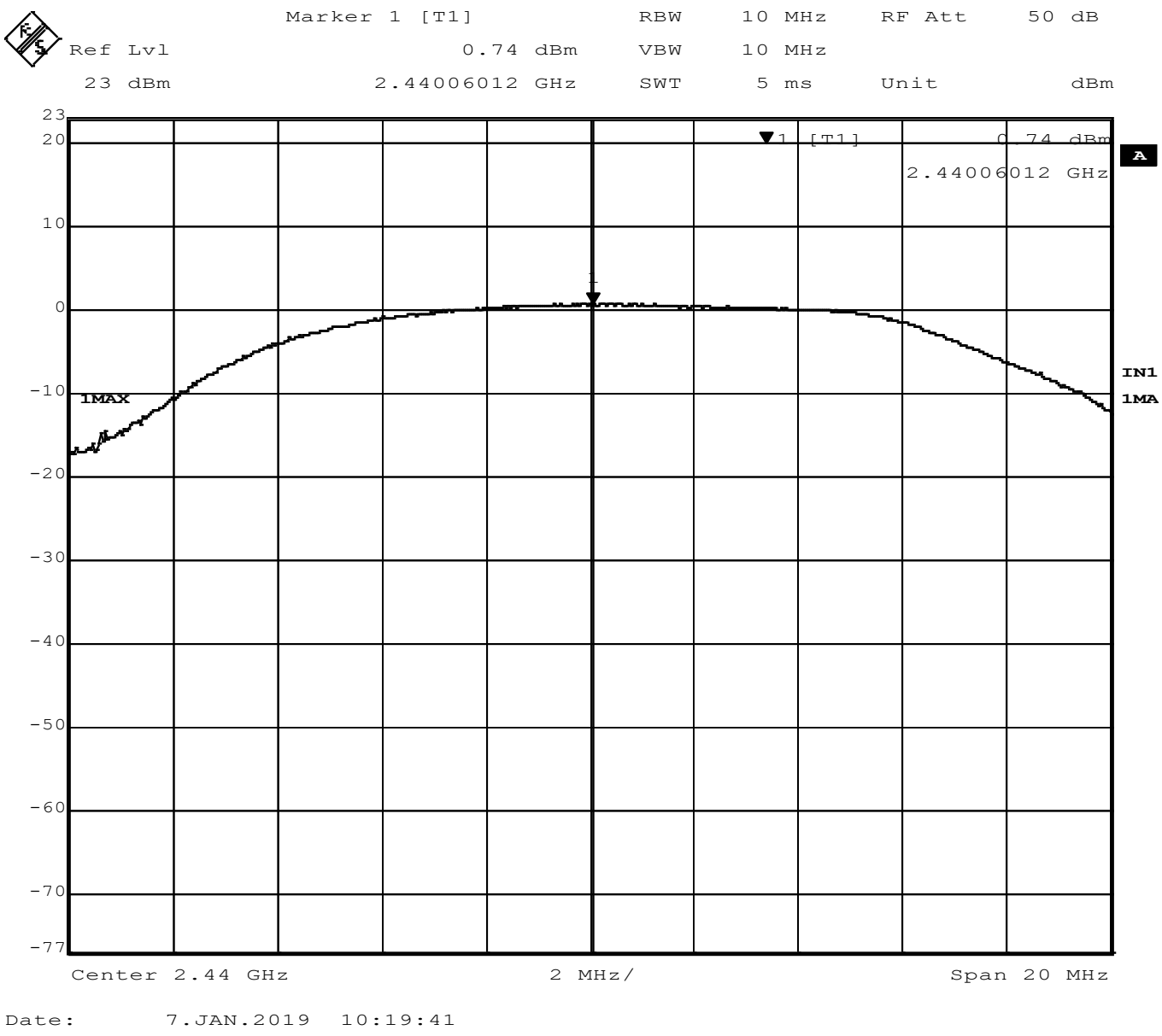

Figure 5 - Output Power, Mid Channel, GFSK

Output power = 0.74 dBm

Cable loss was less than 0.1 dB and not included

Figure 6 - Output Power, High Channel, GFSK

Output power = -0.43 dBm

Cable loss was less than 0.1 dB and not included

4.3 BANDWIDTH

Test Method: ANSI C63.10-2013, 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 is defined as the bandwidth of which is higher than peak power minus 20dB.

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 (KHz)	RESULT
Low	GMSK	2402	1.05	PASS
Mid	GMSK	2440	0.98	PASS
High	GMSK	2480	0.98	PASS
Low	GFSK	2402	1.34	PASS
Mid	GFSK	2440	1.18	PASS
High	GFSK	2480	1.18	PASS

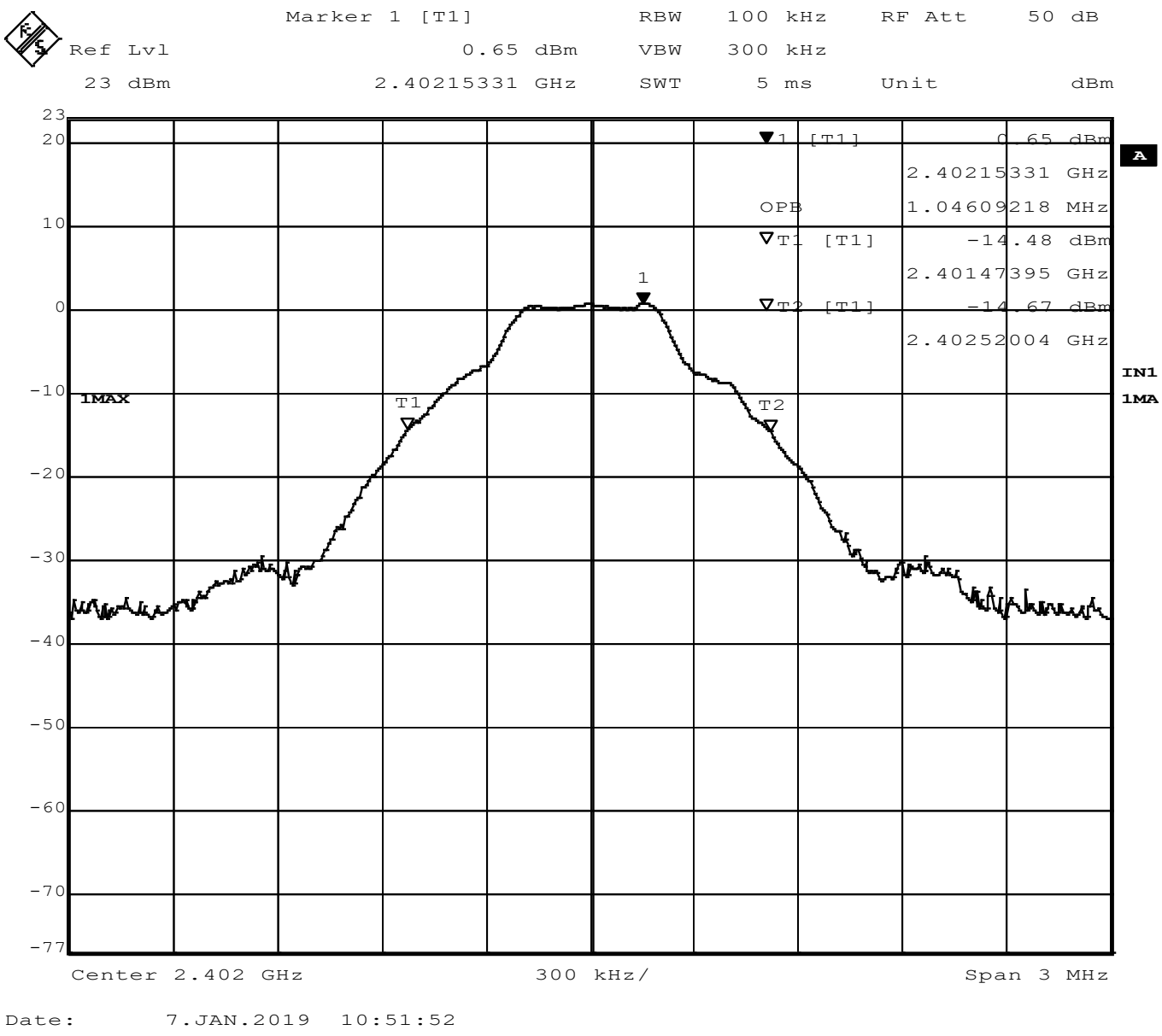

Figure 8 – Occupied Bandwidth, Low Channel, GMSK

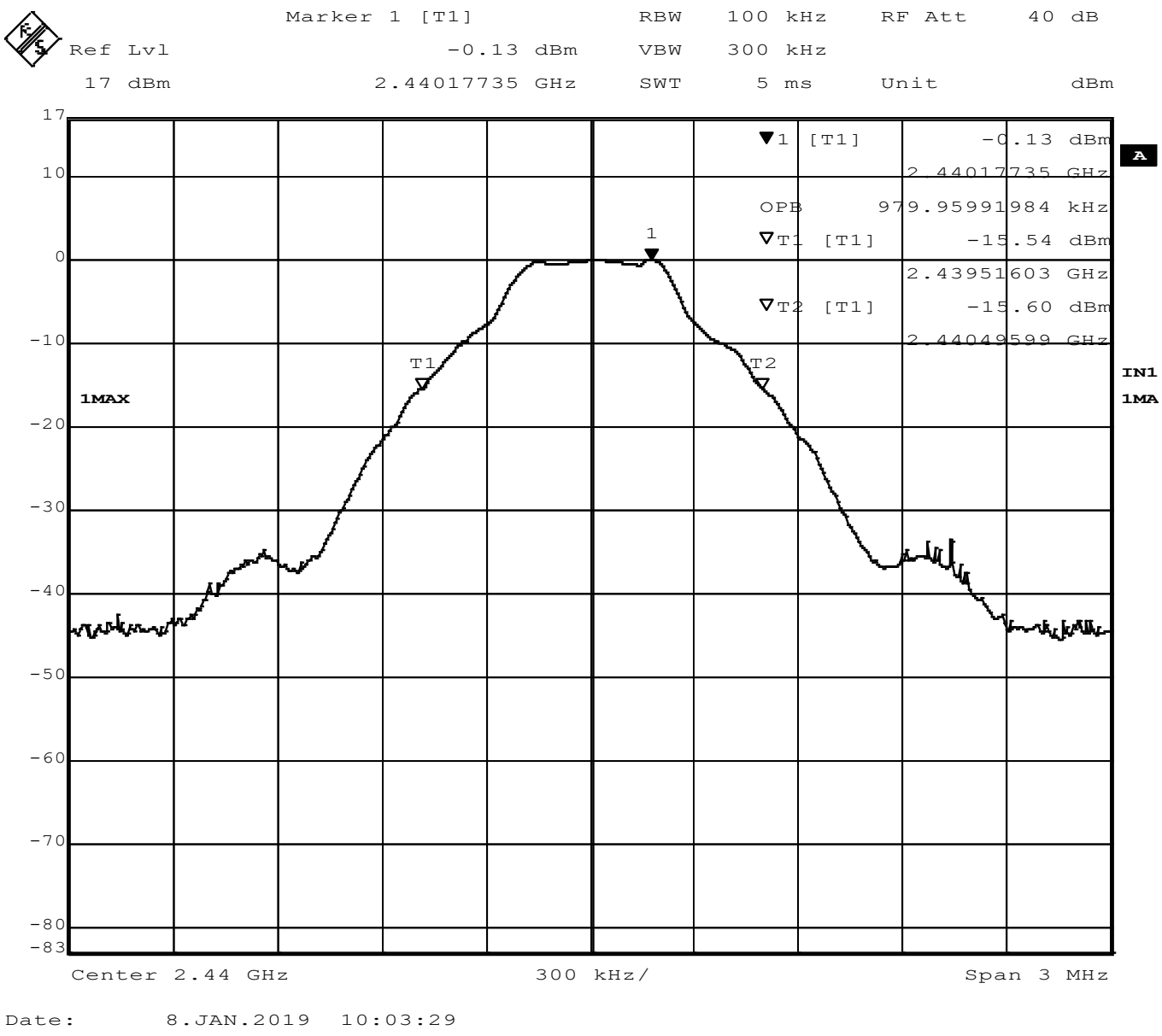

Figure 9 - Occupied Bandwidth, Mid Channel, GMSK

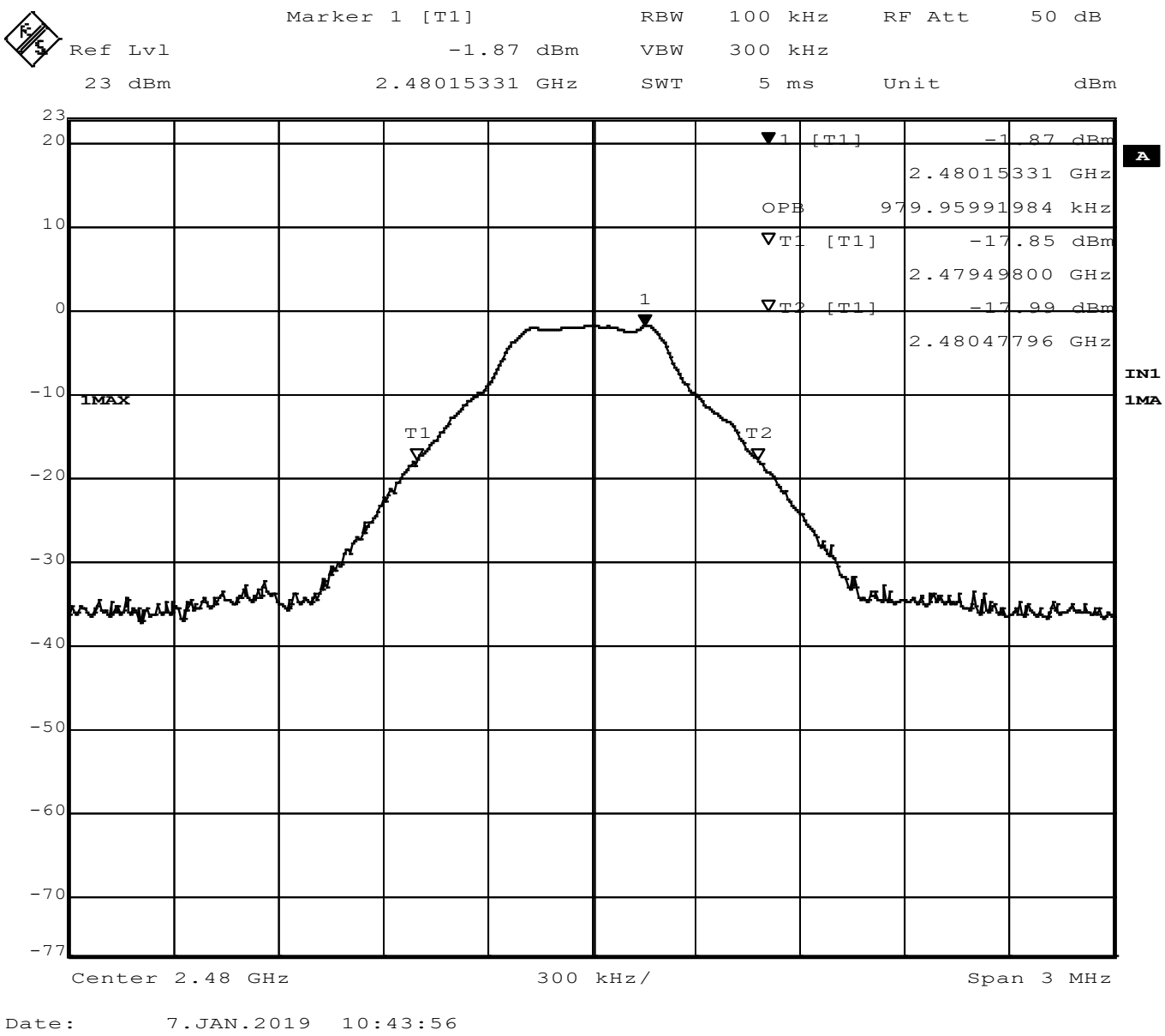

Figure 10 - Occupied Bandwidth, High Channel, GMSK

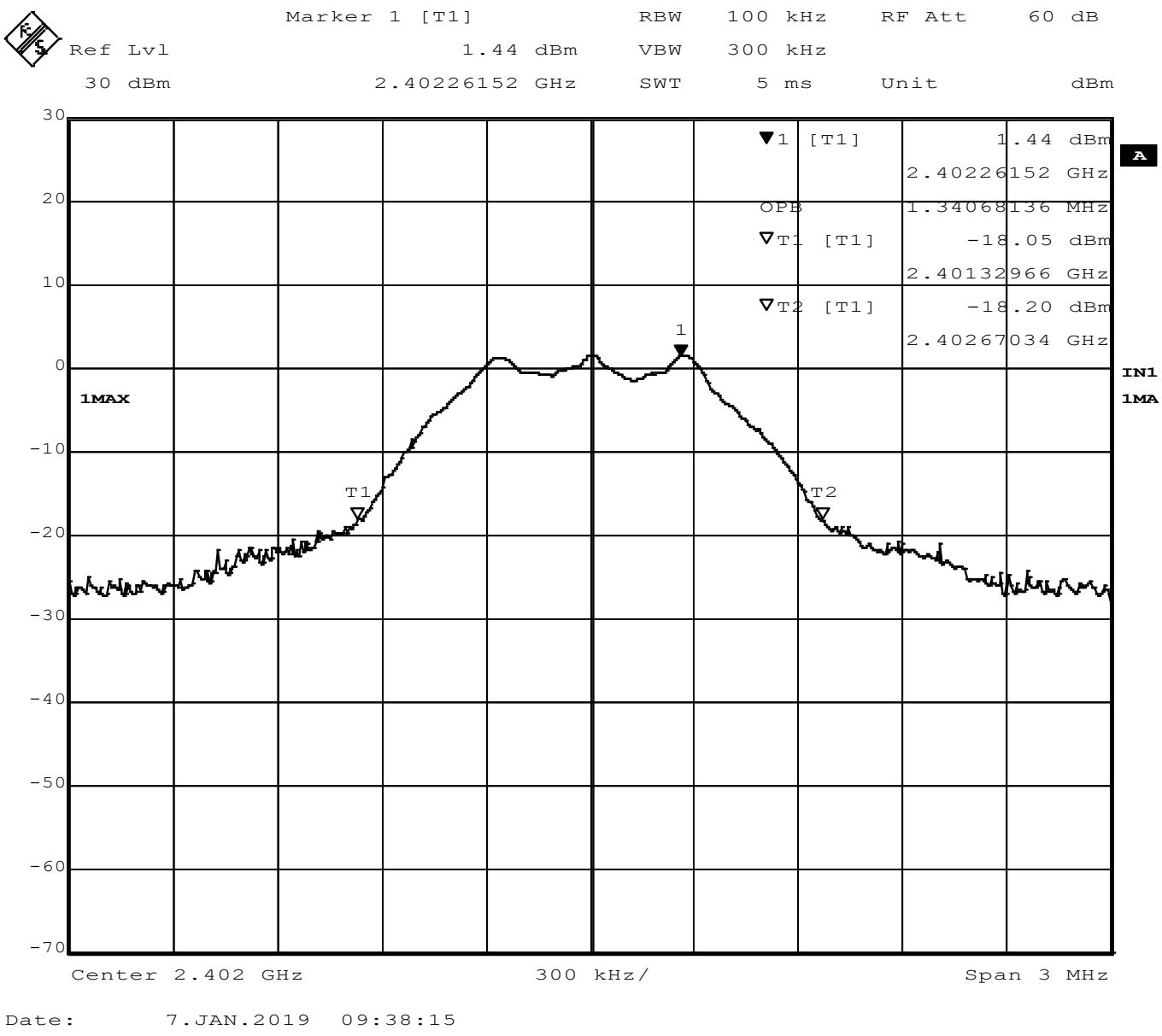

Figure 11 – Occupied Bandwidth, Low Channel, GFSK

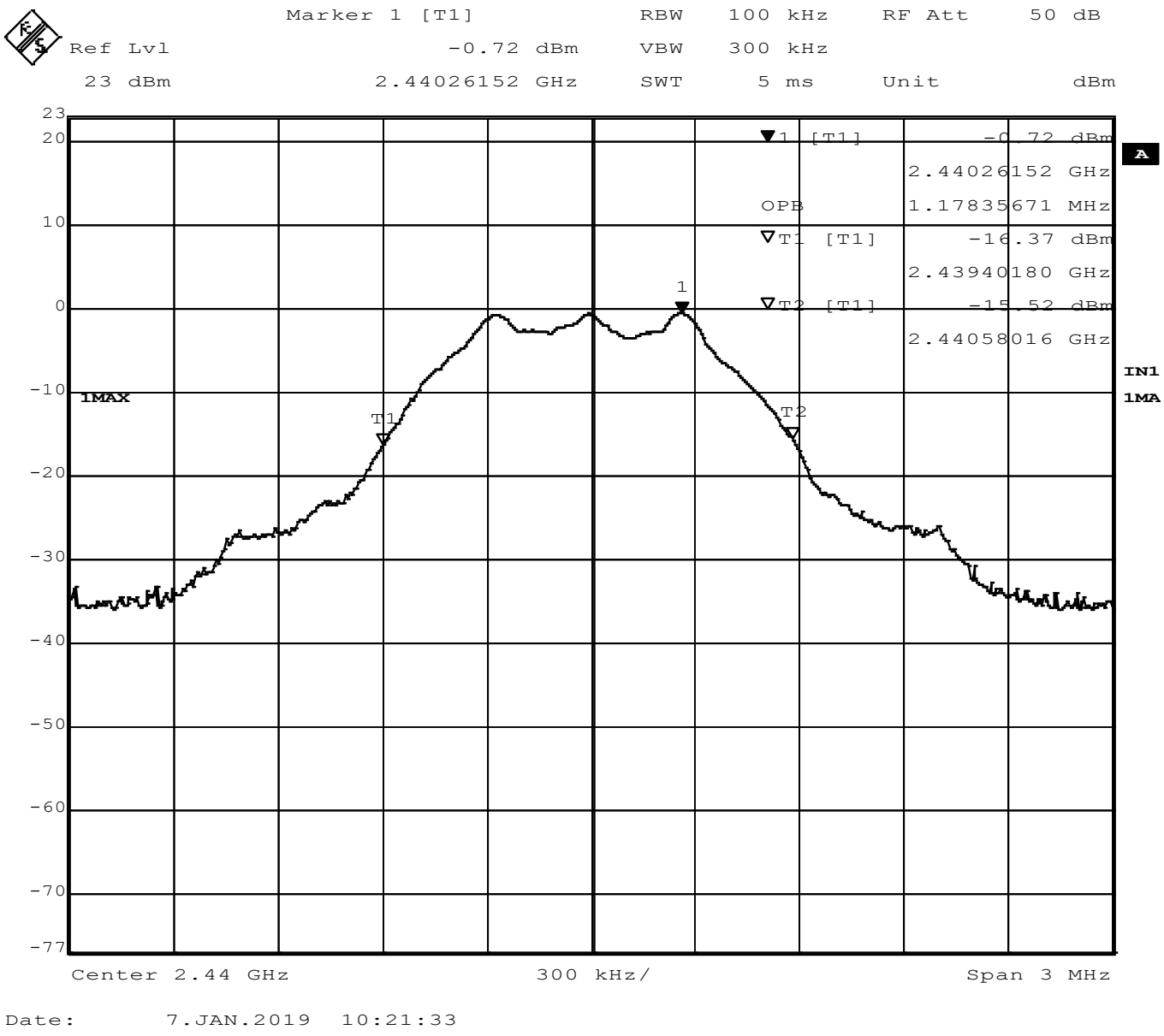

Figure 12 - Occupied Bandwidth, Mid Channel, GFSK

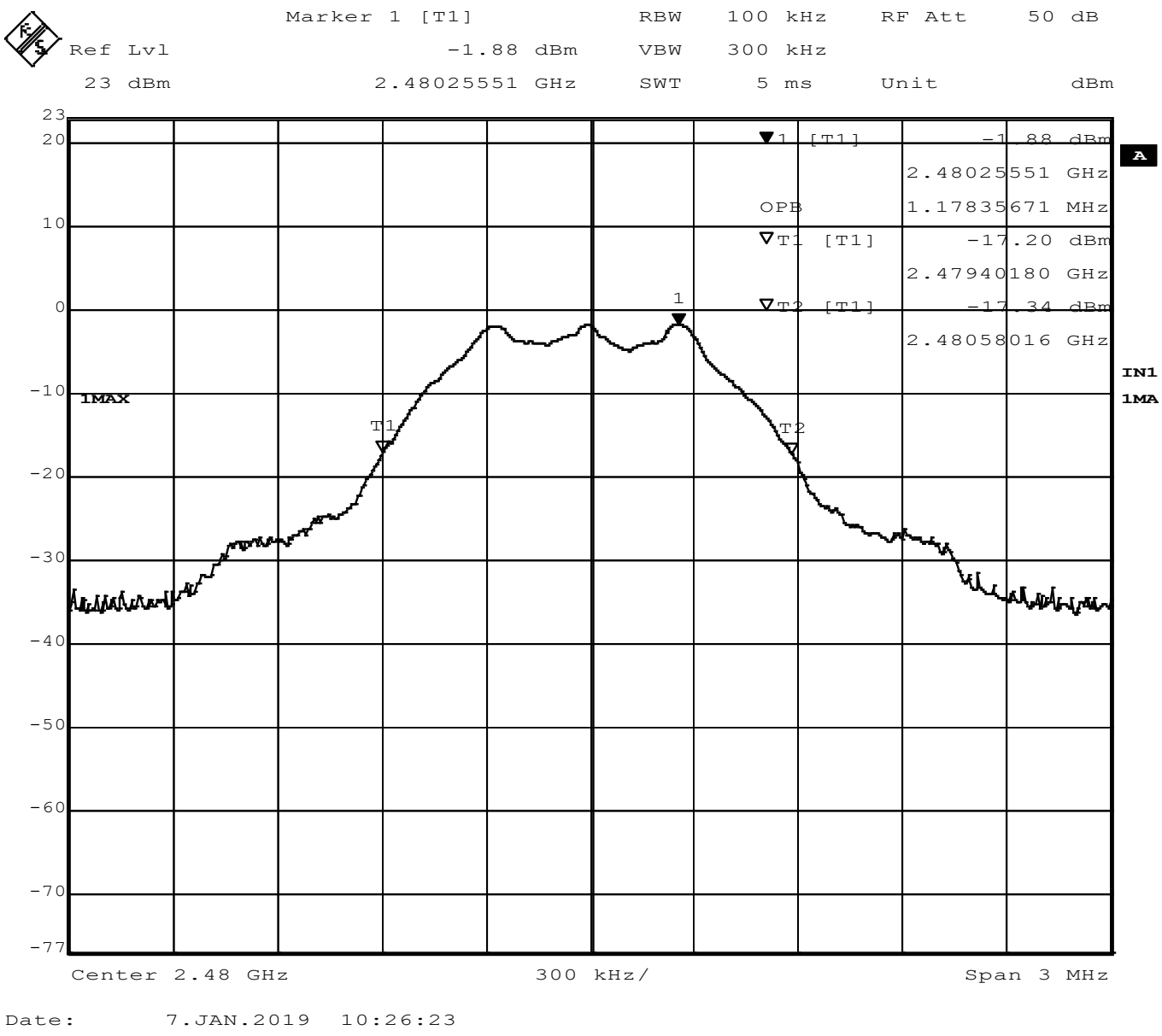

Figure 13 - Occupied Bandwidth, High Channel, GFSK

4.4 RADIATED EMISSIONS

Test Method: ANSI C63.10-2013, 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 (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:
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.
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.

h. The EUT was tested on both battery and external USB. The worse-case orientation was found during the preview scan, and it was with the USB, so that was used for the remainder of testing

Test setup:

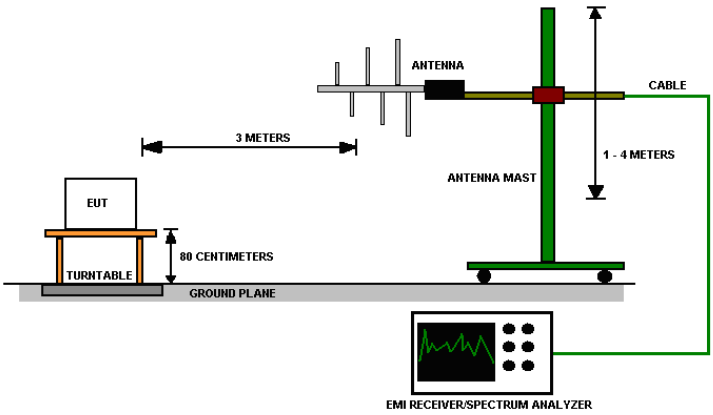

Figure 14 - Radiated Emissions Test Setup

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:

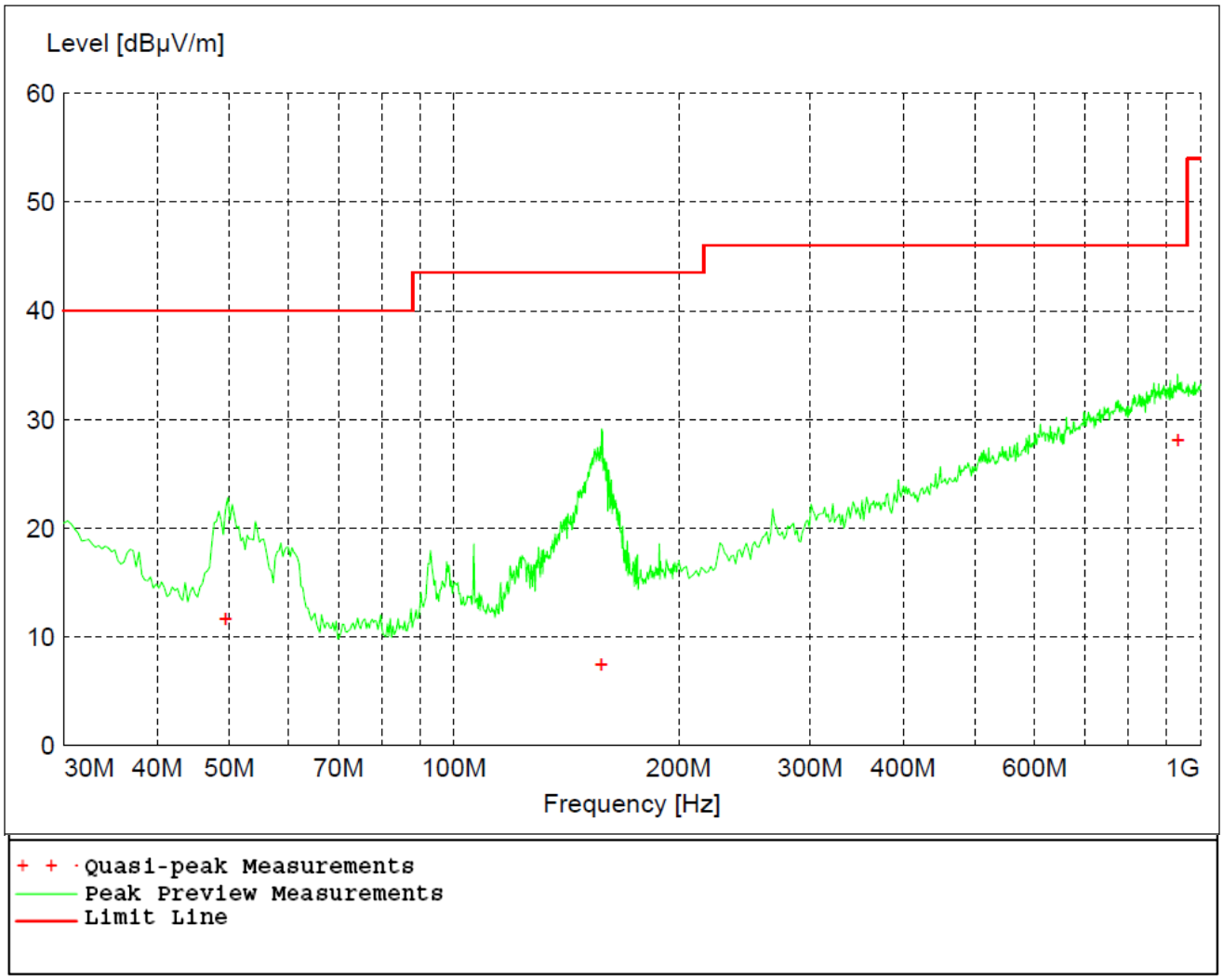

Figure 15 - Radiated Emissions Plot, Receive, GFSK

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

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

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
49.440000	11.75	40.00	28.30	384	80	VERT
157.560000	7.50	43.50	36.00	357	0	HORI
934.020000	28.09	46.00	17.90	384	11	HORI

Table 2 - Radiated Emissions Peak Measurement, Receive, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
1863.800000	35.26	54.00	18.70	278	329	VERT
2426.400000	44.14	54.00	9.90	160	327	VERT
2454.600000	47.87	54.00	6.10	115	260	VERT
14244.400000	51.74	54.00	2.30	99	351	VERT

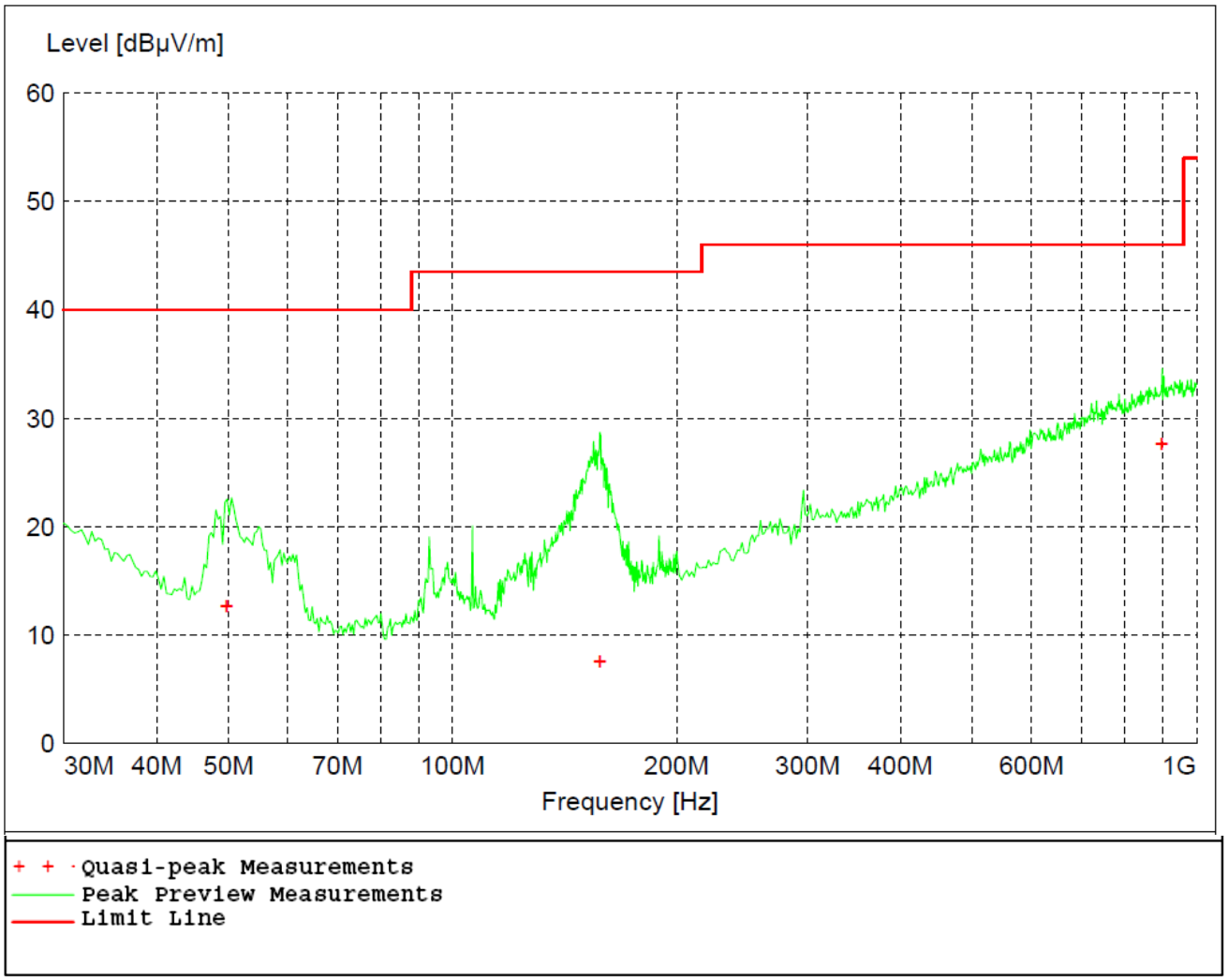

Figure 16 - Radiated Emissions Plot, Receive, GMSK

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

Table 3 - Radiated Emissions Quasi-peak Measurements, Receive, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
49.680000	12.68	40.00	27.30	385	108	VERT
157.920000	7.58	43.50	35.90	370	349	HORI
898.020000	27.73	46.00	18.30	398	0	VERT

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

Table 4 - Radiated Emissions Average Measurement, Receive, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2480.000000	27.59	54.00	26.41	123	10	VERT
6930.400000	28.54	54.00	25.46	99	133	HORI

Table 5 - Radiated Emissions Peak Measurement, Receive, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2480.000000	45.31	74.00	28.69	123	10	VERT
6930.400000	46.26	74.00	27.74	99	133	HORI

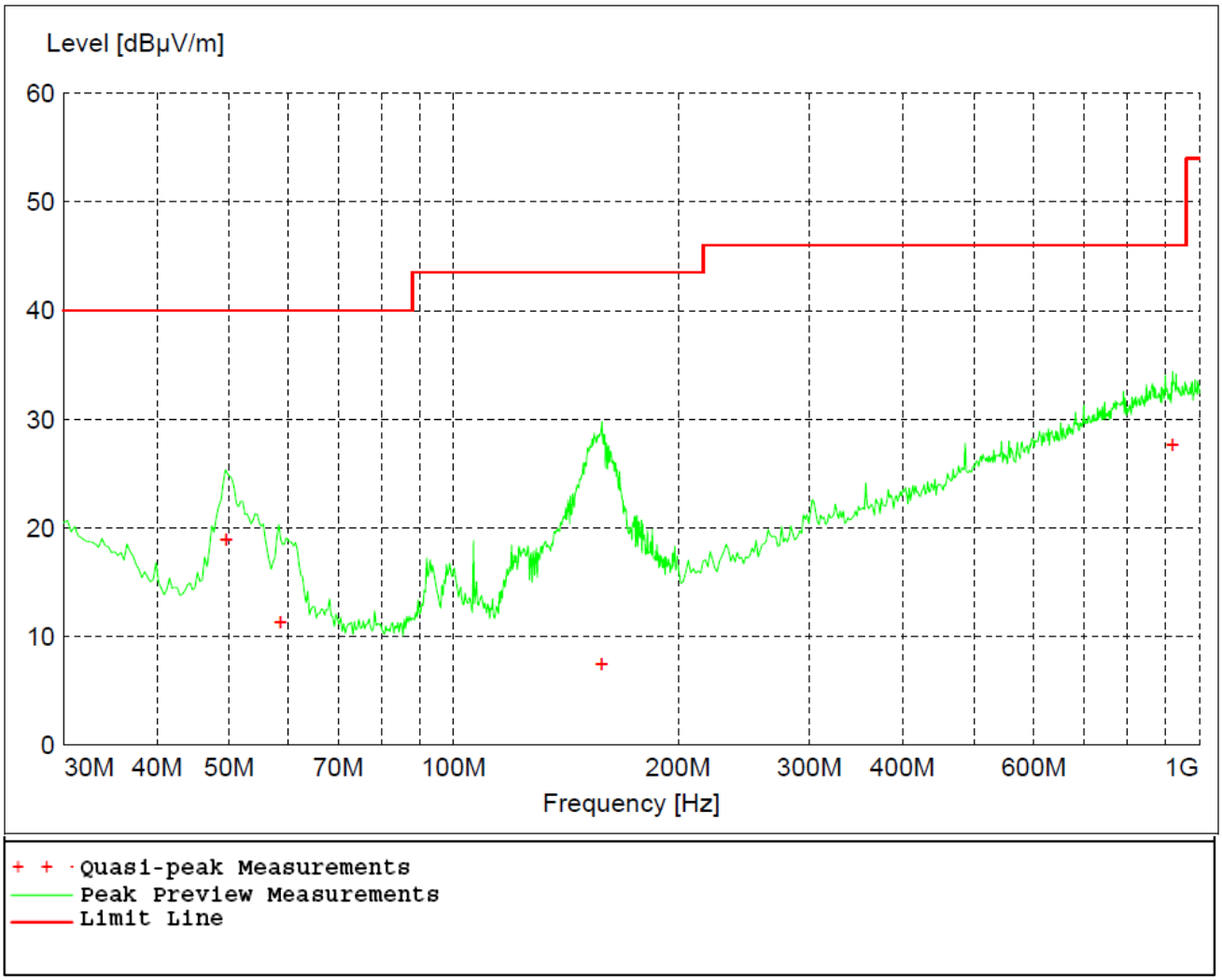

Figure 17 - Radiated Emissions Plot, Low Channel, GFSK

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

Table 6 - Radiated Emissions Quasi-peak Measurements, Low Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
49.560000	18.97	40.00	21.00	99	197	VERT
58.620000	11.31	40.00	28.70	329	21	VERT
158.100000	7.51	43.50	36.00	99	192	HORI
921.120000	27.71	46.00	18.30	267	128	HORI

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

Table 7 - Radiated Emissions Average Measurements, Low Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2402.000000	74.19	93.98	19.79	101	0	HORI
4804.400000	39.76	54.00	14.24	180	208	VERT
7205.000000	27.31	54.00	26.69	127	197	VERT
9597.600000	28.49	54.00	25.51	285	340	HORI

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is 17.72 dB.

Table 8 - Radiated Emissions Peak Measurements, Low Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2402.000000	91.91	113.98	22.07	101	0	HORI
4804.400000	57.48	74.00	16.50	180	208	VERT
7205.000000	45.03	74.00	29.00	127	197	VERT
9597.600000	46.21	74.00	27.80	285	340	HORI

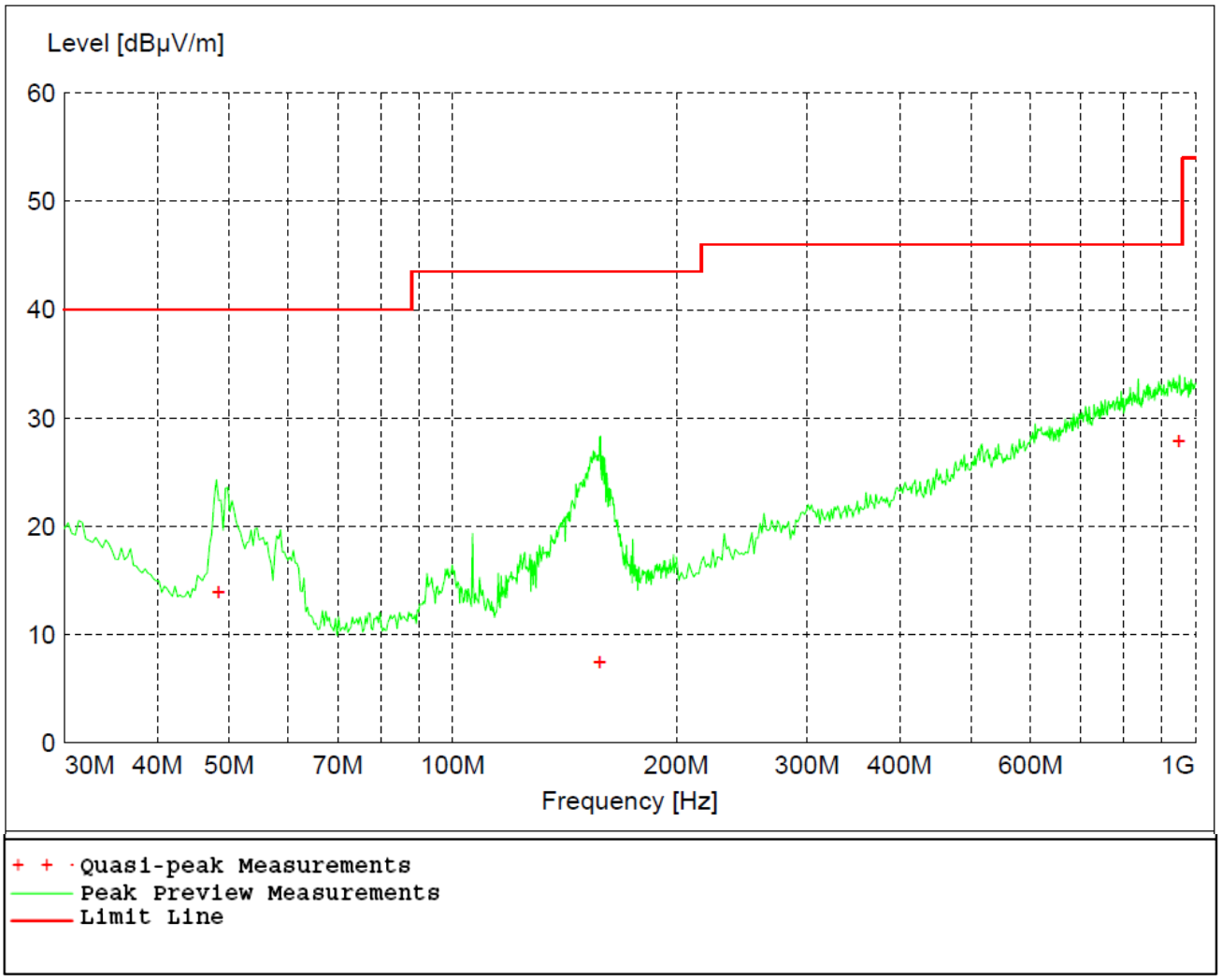

Figure 18 - Radiated Emissions Plot, Mid Channel, GFSK

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

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

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
48.420000	13.98	40.00	26.00	331	313	VERT
157.740000	7.50	43.50	36.00	294	4	HORI
951.600000	27.90	46.00	18.10	400	186	HORI

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

Table 10 - Radiated Emissions Average Measurements, Mid Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2440.000000	75.63	93.98	18.35	100	182	HORI
4880.600000	27.80	54.00	26.20	99	209	VERT
7309.400000	26.00	54.00	28.00	212	119	VERT

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is 17.72 dB.

Table 11 - Radiated Emissions Peak Measurements, Mid Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2440.000000	93.35	113.98	20.63	100	182	HORI
4880.600000	45.52	74.00	28.50	99	209	VERT
7309.400000	43.72	74.00	30.30	212	119	VERT

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

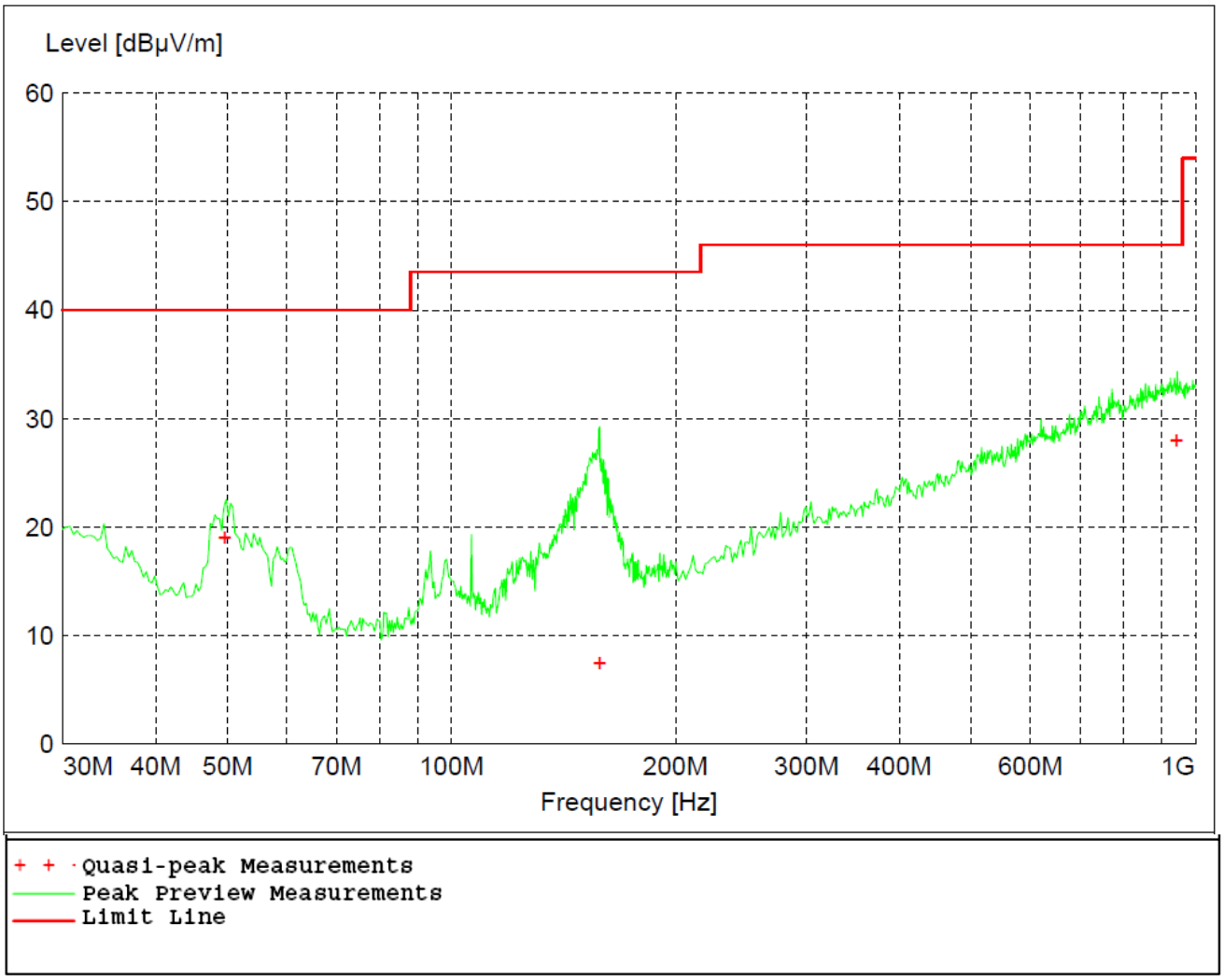

Figure 19 - Radiated Emissions Plot, High Channel, GFSK

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.

Table 12 - Radiated Emissions Quasi-peak Measurements, High Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
49.560000	19.04	40.00	21.00	98	166	VERT
158.220000	7.51	43.50	36.00	115	1	HORI
943.860000	28.00	46.00	18.00	204	80	HORI

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

Table 13 - Radiated Emissions Average Measurements, High Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2480.000000	72.78	93.98	21.20	100	175	HORI
4960.400000	38.09	54.00	15.91	100	155	VERT

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is 17.72 dB.

Table 14 - Radiated Emissions Peak Measurements, High Channel, GFSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2480.000000	90.50	113.98	23.48	100	175	HORI
4960.400000	55.81	74.00	29.00	100	155	VERT

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

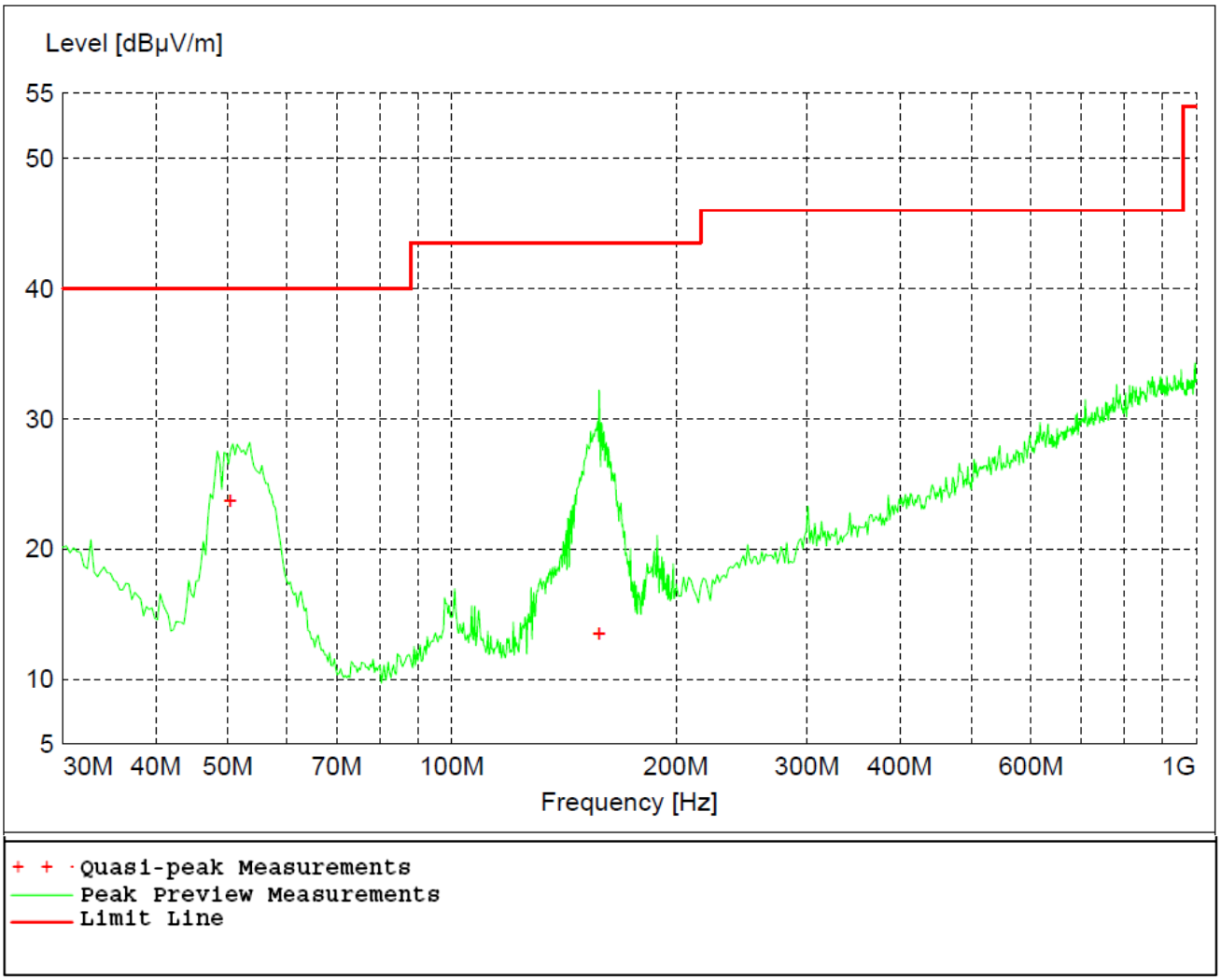

Figure 20 - Radiated Emissions Plot, Low Channel, GMSK

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

Table 15 - Radiated Emissions Quasi-peak Measurements, Low Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
50.400000	23.69	40.00	16.30	99	0	VERT
157.920000	13.50	43.50	30.00	314	87	HORI

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

Table 16 - Radiated Emissions Average Measurements, Low Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2402.000000	75.34	93.98	18.64	128	164	HORI
4803.600000	51.10	74.00	2.90	100	145	VERT

Table 17 - Radiated Emissions Peak Measurements, Low Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2402.000000	93.06	113.98	20.92	128	164	HORI
4803.600000	39.78	54.00	14.22	100	145	VERT

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

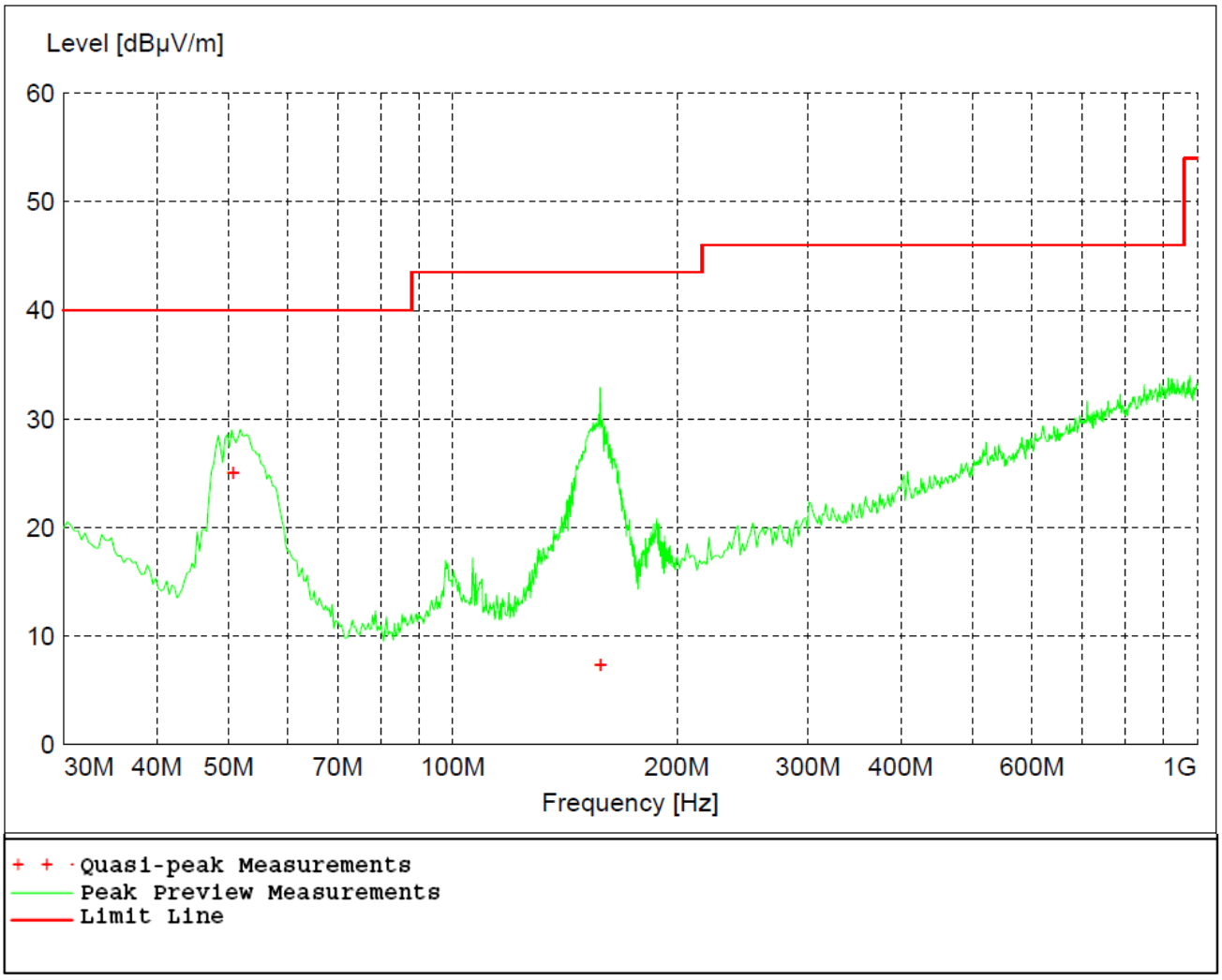

Figure 21 - Radiated Emissions Plot, Mid Channel, GMSK

REMARKS:
1. Emission level (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 18 - Radiated Emissions Quasi-peak Measurements, Mid Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
50.700000	25.08	40.00	14.90	100	114	VERT
158.040000	7.43	43.50	36.10	257	99	HORI

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

Table 19 - Radiated Emissions Average Measurements, Mid Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2440.000000	67.90	93.98	26.08	163	175	HORI
2446.000000	46.97	54.00	7.03	99	312	VERT
4880.400000	51.73	54.00	2.27	258	0	VERT

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is 17.72 dB.

Table 20 - Radiated Emissions Peak Measurements, Mid Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2440.000000	85.62	113.98	28.36	163	175	HORI
2446.000000	64.69	74.00	9.31	99	312	VERT
4880.400000	56.33	74.00	17.67	258	0	VERT

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

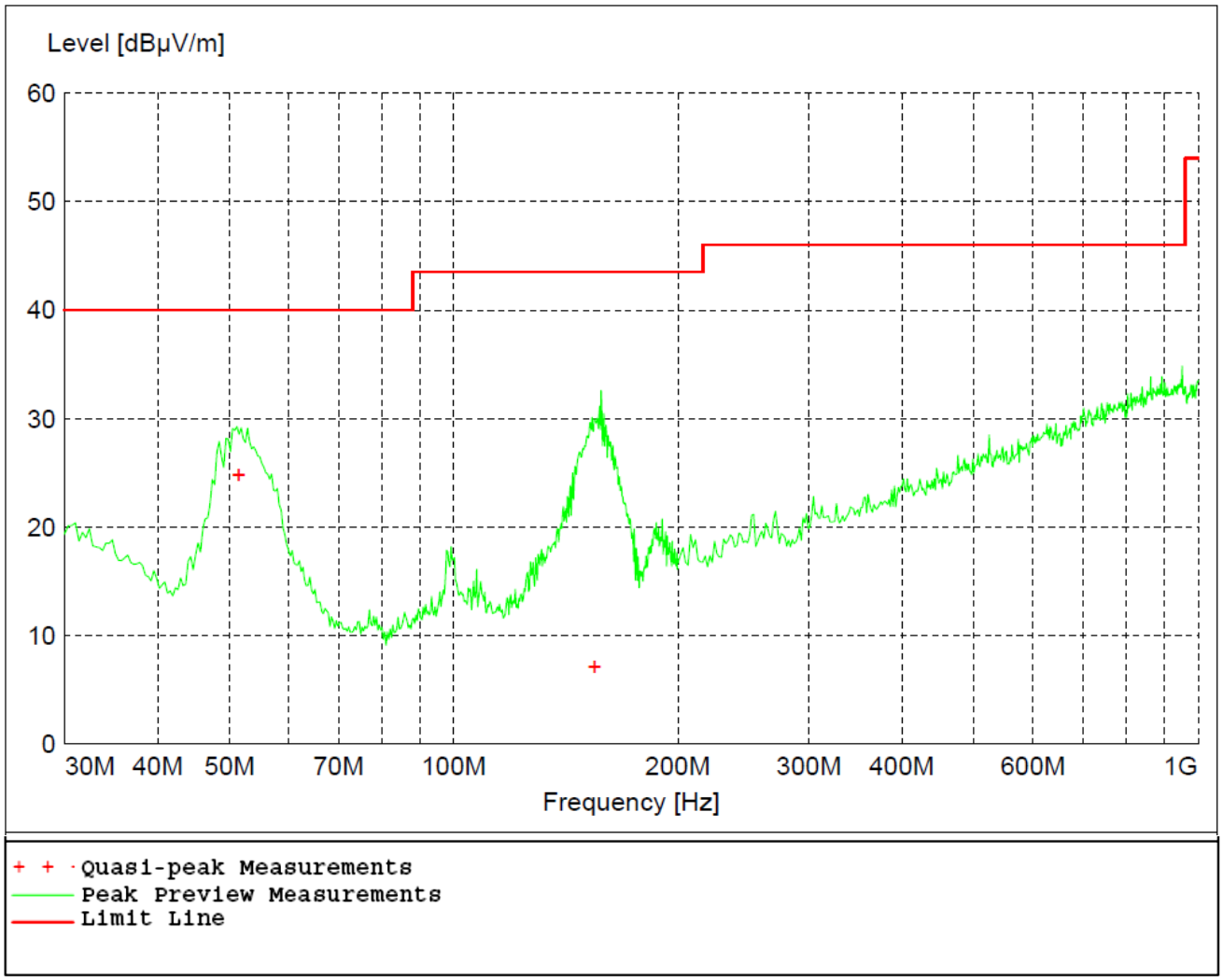

Figure 22 - Radiated Emissions Plot, High Channel, GMSK

REMARKS:
1. Emission level (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 21 - Radiated Emissions Quasi-peak Measurements, High Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
51.420000	24.80	40.00	15.20	100	16	VERT
154.680000	7.22	43.50	36.30	143	36	HORI

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

Table 22 - Radiated Emissions Average Measurements, High Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2480.000000	74.95	93.98	19.03	163	181	HORI
4959.600000	51.10	54.00	2.90	220	317	VERT

The EUT was maximized in all 3 orthogonal axis. The worst-case is shown in the table above.
Note: Average Level = Peak Level – Duty Cycle Correction Factor
Duty Cycle Correction Factor is 17.72 dB.

Table 23 - Radiated Emissions Peak Measurements, High Channel, GMSK

Frequency	Level	Limit	Margin	Height	Angle	Pol
MHz	dBµV/m	dBµV/m	dB	cm.	deg.	
2480.000000	92.67	113.98	21.31	163	181	HORI
4959.600000	56.60	74.00	17.40	220	317	VERT

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 C63.10-2013, 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.

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	-33.30	0.59	33.89	21.34	PASS
Low, Continuous	GFSK	2400	-24.15	1.40	25.55	20.95	PASS
High, Continuous	GMSK	2483.5	-35.38	-1.88	33.50	20.19	PASS
High, Continuous	GFSK	2483.5	-35.06	-1.88	33.18	18.78	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 GMSK = 75.34 dBµV/m
Fundamental peak field strength at High Channel GMSK = 74.95 dBµV/m
Fundamental peak field strength at Low Channel GFSK = 74.19 dBµV/m
Fundamental peak field strength at High Channel GFSK = 72.78 dBµV/m

Low Channel minimum delta GMSK = 75.34 – 54.0 dBµV/m = 21.34 dBc
High Channel minimum delta GMSK = 74.95 – 54.0 dBµV/m = 20.95 dBc
Low Channel minimum delta GFSK = 74.19 – 54.0 dBµV/m = 20.19 dBc
High Channel minimum delta GFSK = 72.78 – 54.0 dBµV/m = 18.78 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.

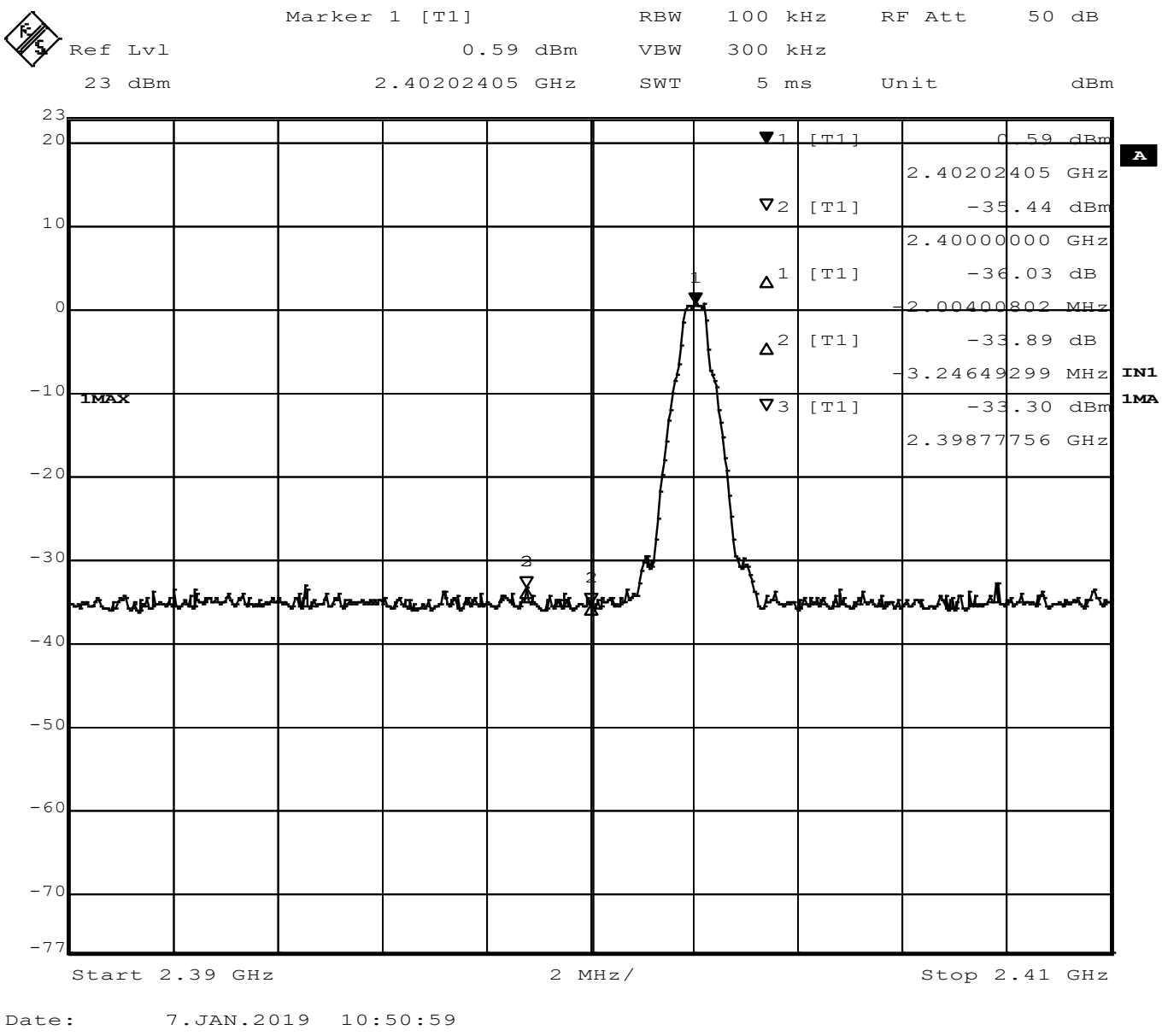

Figure 23 - Band Edge, Low Channel, GMSK

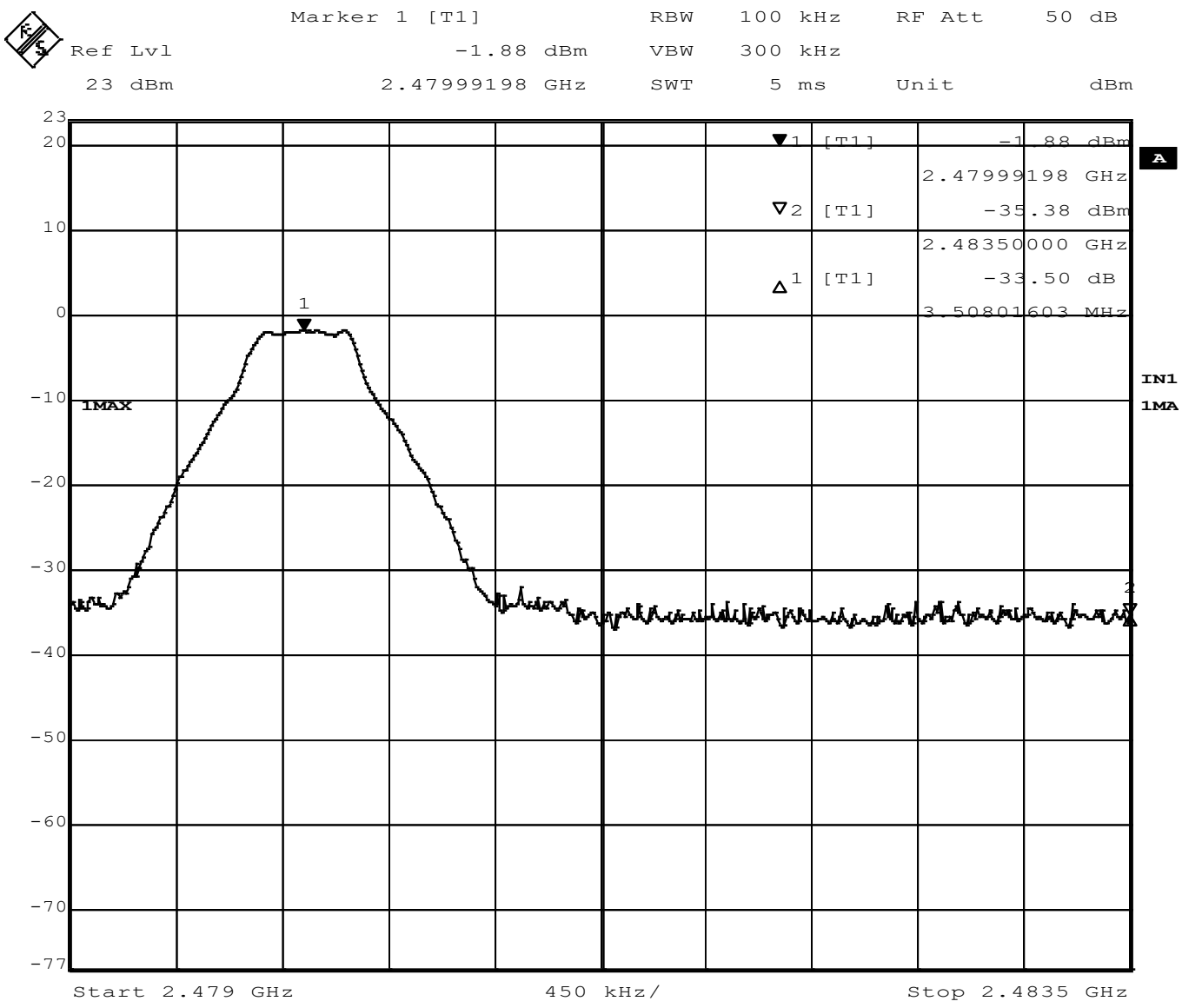

Figure 24 –Band Edge Measurement, High Channel, GMSK

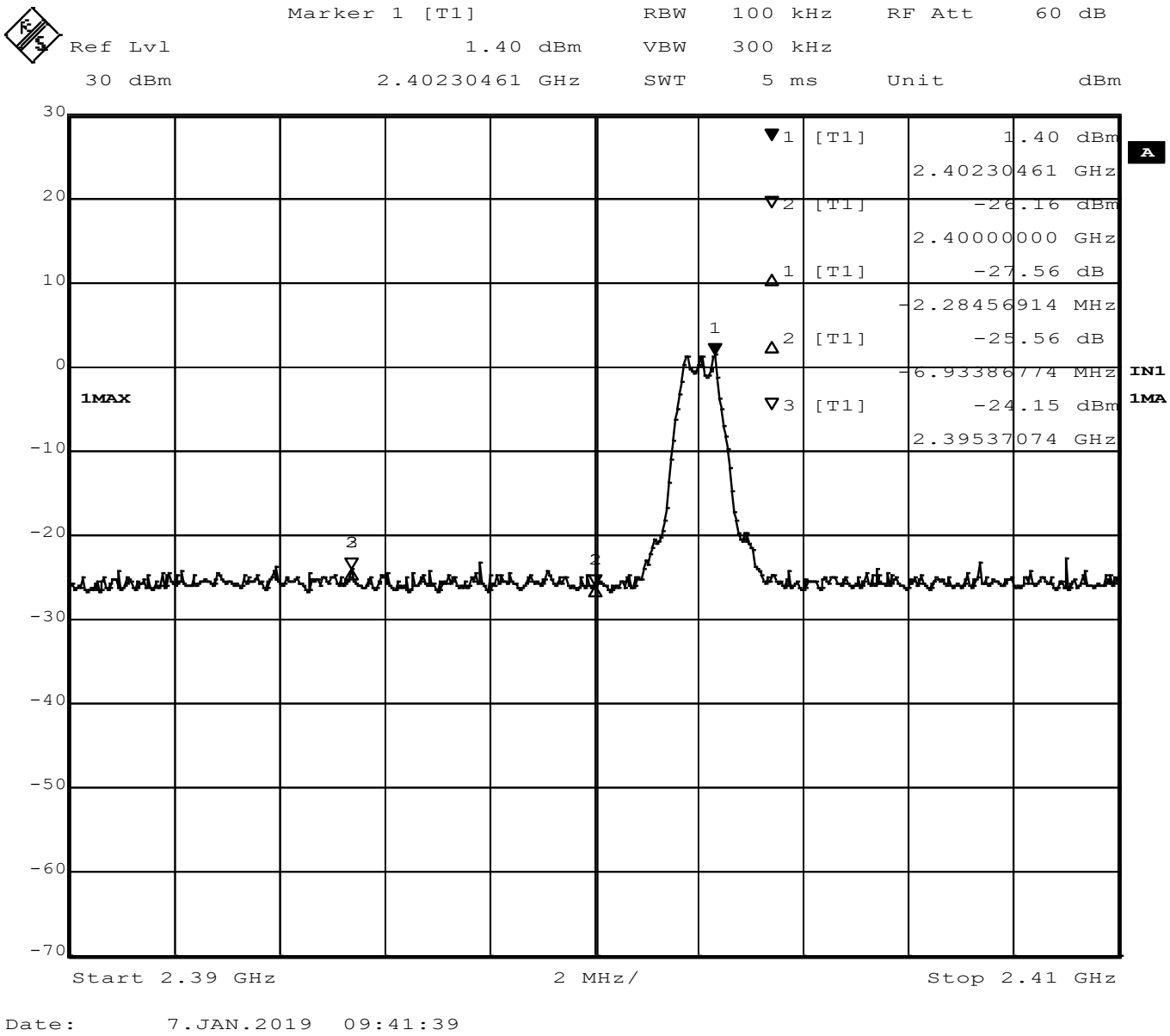

Figure 25 –Band Edge, Low Channel, GFSK

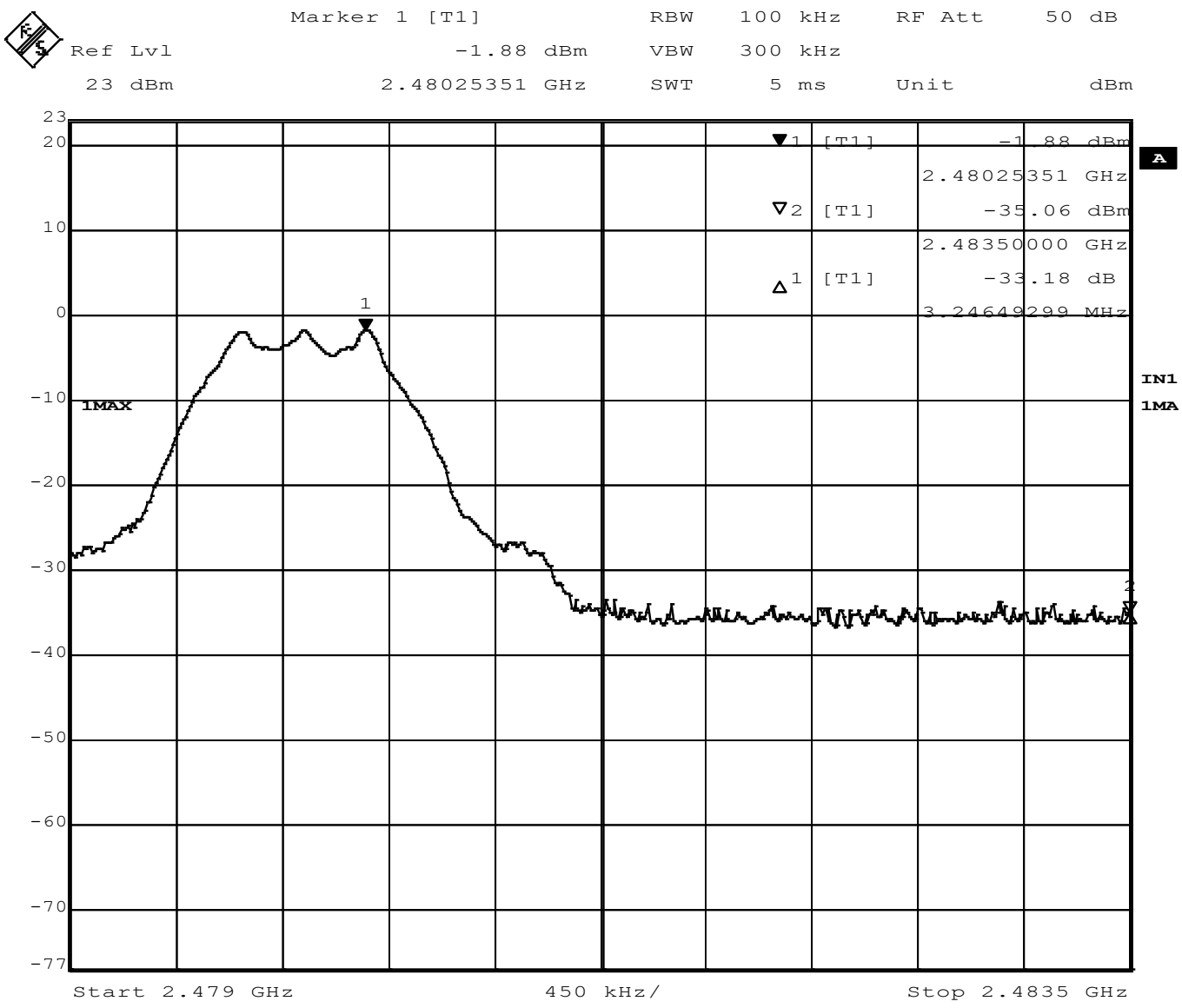

Figure 26 – Band Edge Measurement, High Channel, GFSK

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:

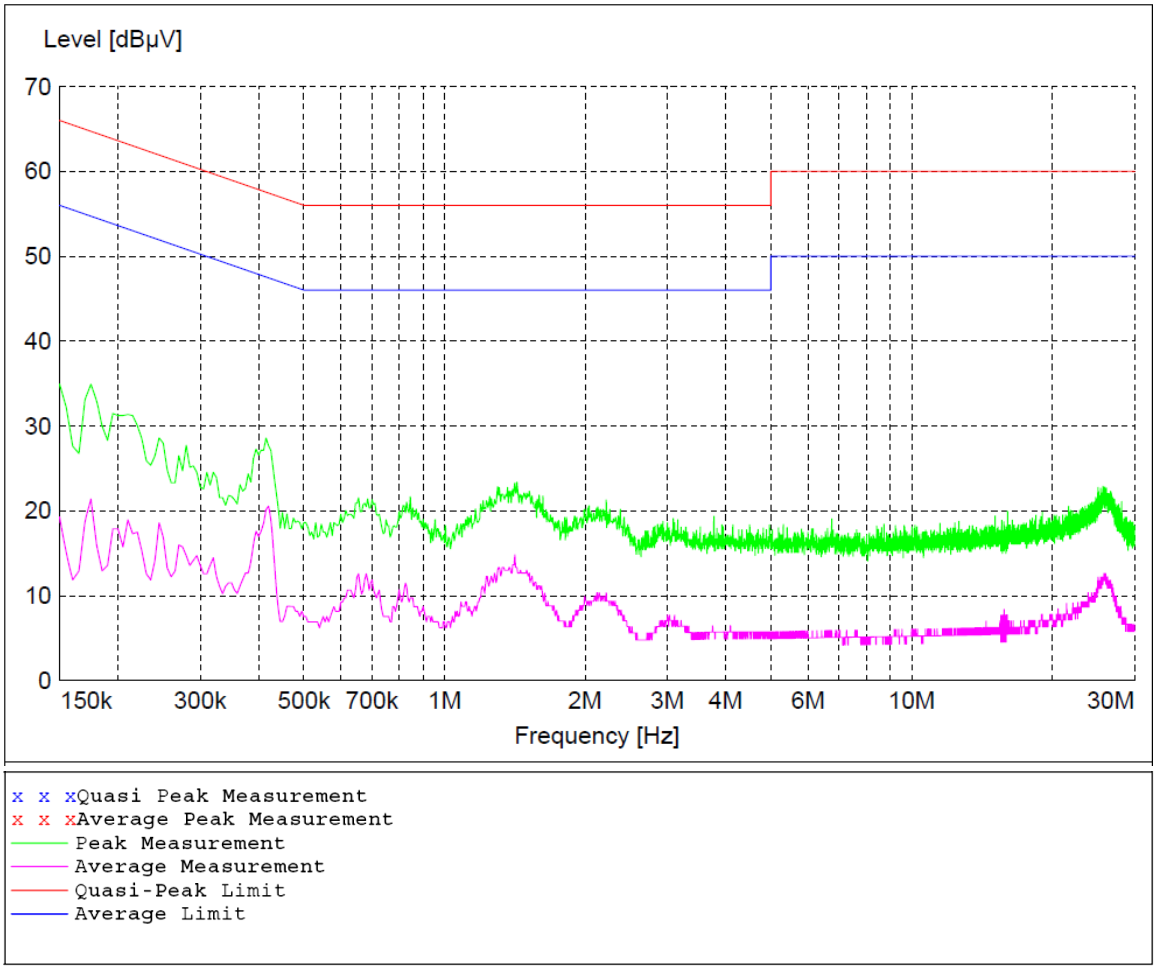

Figure 27 - Conducted Emissions Plot

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

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

APPENDIX A: SAMPLE CALCULATION

Field Strength Calculation

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

where FS = Field Strength

RA = Receiver Amplitude

AF = Antenna Factor

CF = Cable Attenuation Factor

AG = Amplifier Gain

AV = Averaging Factor (if applicable)

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

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

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

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

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

EIRP Calculations

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

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

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

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

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

Gain = 1 (numeric gain for isotropic radiator)

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

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

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

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

APPENDIX B – MEASUREMENT UNCERTAINTY

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

Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	3.82
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