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Amended

FDS
FCC/ISED Test Report

Client:	**Garmin International Inc.**
EUT:	**1200 E. 151st Street Olathe, Kansas, 66062, USA**
Product:	**A03491**
Test Report No.:	**R20181015-20-02C**
Approved By:	**Nic S. Johnson, NCE Technical Manager iNARTE Certified EMC Engineer #EMC-003337-NE**
Date:	**31 May 2019**
Total Pages:	**26**

ilac-MRA A2LA ACCREDITED TESTING LABORATORY CERTIFICATE NO. 1953.01

Revision Page

Rev. No.	Date	Description
Original	2/28/2019	Original – Njohnson Prepared by KVepuri/CFarrington
A	5/29/2019	Changed to 15.245. Repeated measurements at 24.176 GHz for the high channel. High band edge measurements were repeated. Includes NCEE Labs report R20181015-20-02 and its amendment in full -NJ
B	5/29/2019	Corrected Table 1 to show Part 15.245 Corrected limit for fundamental frequency on Page 7 Removed frequency tolerance data Includes NCEE Labs report R20181015-20-02A and its amendment in full -NJ
C	5/31/2019	Repeated low band edge measurements with 100 Hz RBW. Includes NCEE Labs report R20181015-20-02B and its amendment in full -NJ

Table of Contents

1 Summary of Test Results

1.1 Emissions 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-210, Issue 9

Testing was performance in accordance with the methods published in ANSI C63.10-2013

Table 1 - Emissions Test Results

Emissions Tests	Test Method and Limits	Result
Fundamental, Harmonic and frequency tolerance	FCC Part 15.245 RSS-210, Issue 9, Section F2	Complies

2 EUT Description

2.1 Equipment under Test (EUT)

Table 2 - Equipment under Test (EUT)

EUT	A03491
EUT Received	1/14/2019
EUT Tested	1/14/2019 - 2/19/2019 5/29/2019 (high bandegde measurements)
Serial No.	3492 398407923bw 00
Operating Band	24 GHz - 24.25 GHz
Device Type	Low-power transmitter
Power Supply	PHIHong MN: PSAF10R-050Q

2.2 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 32 ± 4%
Temperature of 22 ± 3° Celsius

2.3 EUT Setup

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

Channel	Frequency
	GHz
Low	24.0754
Mid	24.1610
High	24.1737

3 Test Results

3.1 Fundamental Emissions

Test: FCC Part 15.245; RSS-210, Issue 9, Section F.1

Test Result: Complies Date: 2/28/2019

3.1.1 Test Description

Emissions measurements were made using a 26 GHz spectrum analyzer with an external mixer and horn antenna. Measurements were taken at a distance of 1 meter. The analyzer was set to a resolution bandwidth of 10 MHz and a video bandwidth of 10 MHz for the fundamental measurement. The resolution bandwidth was set to 1 MHz and video bandwidth set to 1 MHz for the harmonic measurement. The results were compared against the limits published in FCC Part 15.245.

3.1.2 Test Results

No radiated emissions measurements were found in excess of the limits. Test result data can be seen below.

3.1.3 Test Environment

Testing was performed at the NCEE Labs Lincoln facility. Laboratory environmental conditions varied slightly throughout the test:

Relative humidity of 33 ± 5%
Temperature of 22 ±2^{o} C

3.1.4 Test Setup

For measurements from 24 – 100 GHz, RF absorber was not used. The antennas used we directional antennas and all measurements were performed line-of-sight. The measurements were performed at least 2 meters away from any other objects other than the non-conductive table and the test receiver. Reflections from the floor or any other surface were not a significant factor in the measurements. See Section 2.3 for further details.

3.1.5 Test Equipment Used

Serial No.	Manufacturer	Model	Description	Last Cal.	Calibration due
2576	ETS	3116	Horn Antenna	31 Jan 2018	31 Jan 2020
100037	Rhode & Schwarz	ESI26*	EMI Test Receiver	30 Jan 2018	30 Jan 2020
8077	Pasternack	PE13U1002	Mixer	28 Jan 2017	28 Jan 2019
32/2016	Pasternack	PE9881-24	Horn Antenna	CNR**	CNR**
1823	Pasternack	SMW22AC001-24F	Mixer	13 Aug 2018	13 Aug 2020
Ncee1	Pasternack	SH122-23	Horn Antenna	CNR**	CNR**
1618	Pasternack	PE-W15CA001	WR-19 to WR-28 adapter	28 Jan 2017	28 Jan 2019

*Note: spectrum analyzer included a firmware upgrade and internal local oscillator output upgrade for measurements above 26.5 GHz. Rohde and Schwarz F/W version 4.32.
**Calibration Not Required, internal verification
***Calibration not required, standard gain horn antenna.
All mixers and pre-amplimers were calibrated with associated cables.

3.1.6 Test Pictures and/or Figures

Table 3 - Fundamental and Harmonic Emissions Data
Measurements made at 1m. Limits extrapolated to 1 meter using 20dB/dec

Channel	Frequency (ƒ)	Level (E)	Fundamental Limit	Harmonic Limit	Margin
	GHz	dBmV/m	dBmV/m	dBmV/m	dB
Low	24.075	63.62	77.50		13.88
Mid	24.161	59.52	77.50		17.98
High	24.1747	63.01	77.50		14.49
Low	48.150	20.07		37.50	17.43
Mid	48.322	19.68		37.50	17.82
High	48.300	23.97		37.50	13.53
Low	72.225	34.99	-	37.50	2.51
Mid	72.483	35.48	-	37.50	2.02
High	72.600	34.70		37.50	2.8

All measurements were made with peak detector unless noted.

Sample measurements and antenna, cable factors used

Fundamental limit: 2500 mV/m at 3 meters = 67.96 dBmV/m = 77.50 dBmV/m at 1 meter.
Level Measurement: 17.61 dBmV/m + 46.01 dB corrections = 63.62 dBmV/m.

Cable	0.50 dB
Antenna	45.51 dB

Harmonic limit: 25 mV/m at 3 meters = 27.95 dBmV/m = 37.50 dBmV/m at 1 meter.
Harmonic Measurement: -21.19 dBmV/m + 41.26 dB corrections = 20.07 dBmV/m.

Mixer	0.40 dB
Antenna factor	40.86 dB/m (standard gain horn, gain = 23 dBi)

Harmonic limit: 25 mV/m at 3 meters = 27.95 dBmV/m = 37.50 dBmV/m at 1 meter.
Harmonic Measurement: -16.07 dBmV/m + 51.06 dB corrections = 34.99 dBmV/m.

Mixer	7.0 dB at 72.00 GHz
WR-19 to WR-28 waveguide transition	0.55 dB
Antenna factor	43.51 dB/m (standard gain horn, gain = 24 dBi)

*Measurement was in the system noise floor

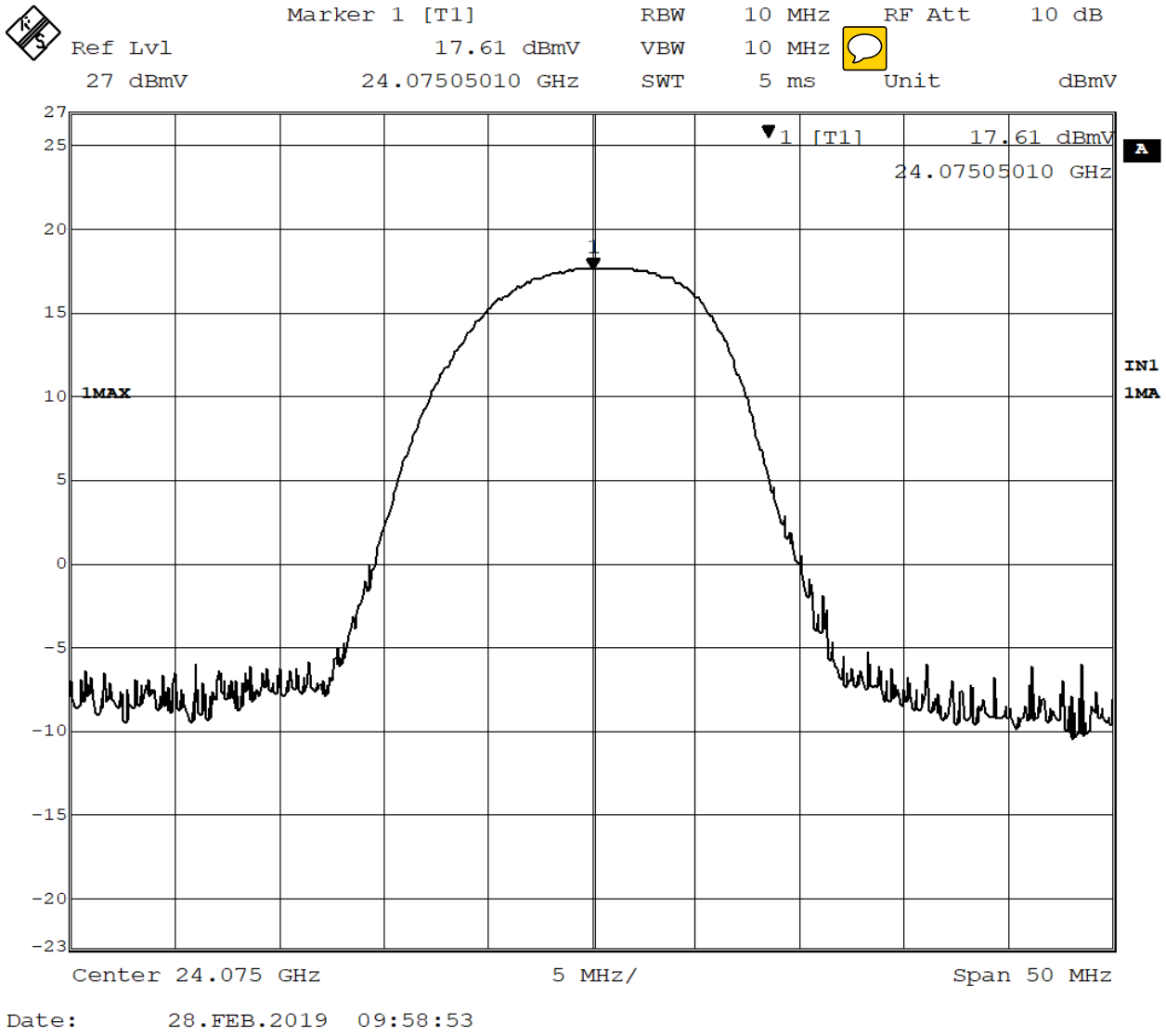


Figure 1 - Analyzer Measurement – Fundamental, Channel Low

Uncorrected measurement as recorded on spectrum analyzer

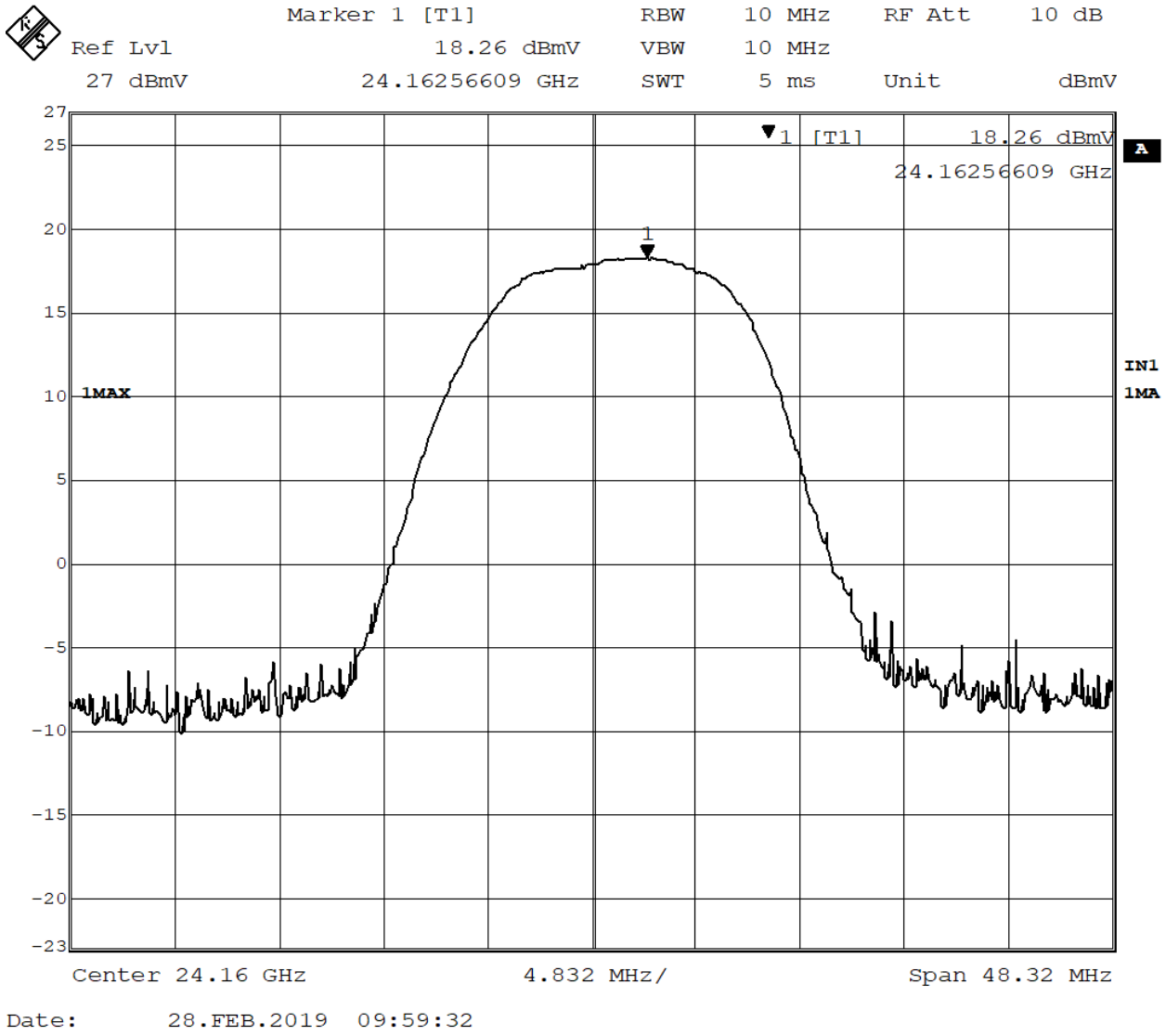


Figure 2 - Analyzer Measurement – Fundamental, Channel Mid

Uncorrected measurement as recorded on spectrum analyzer

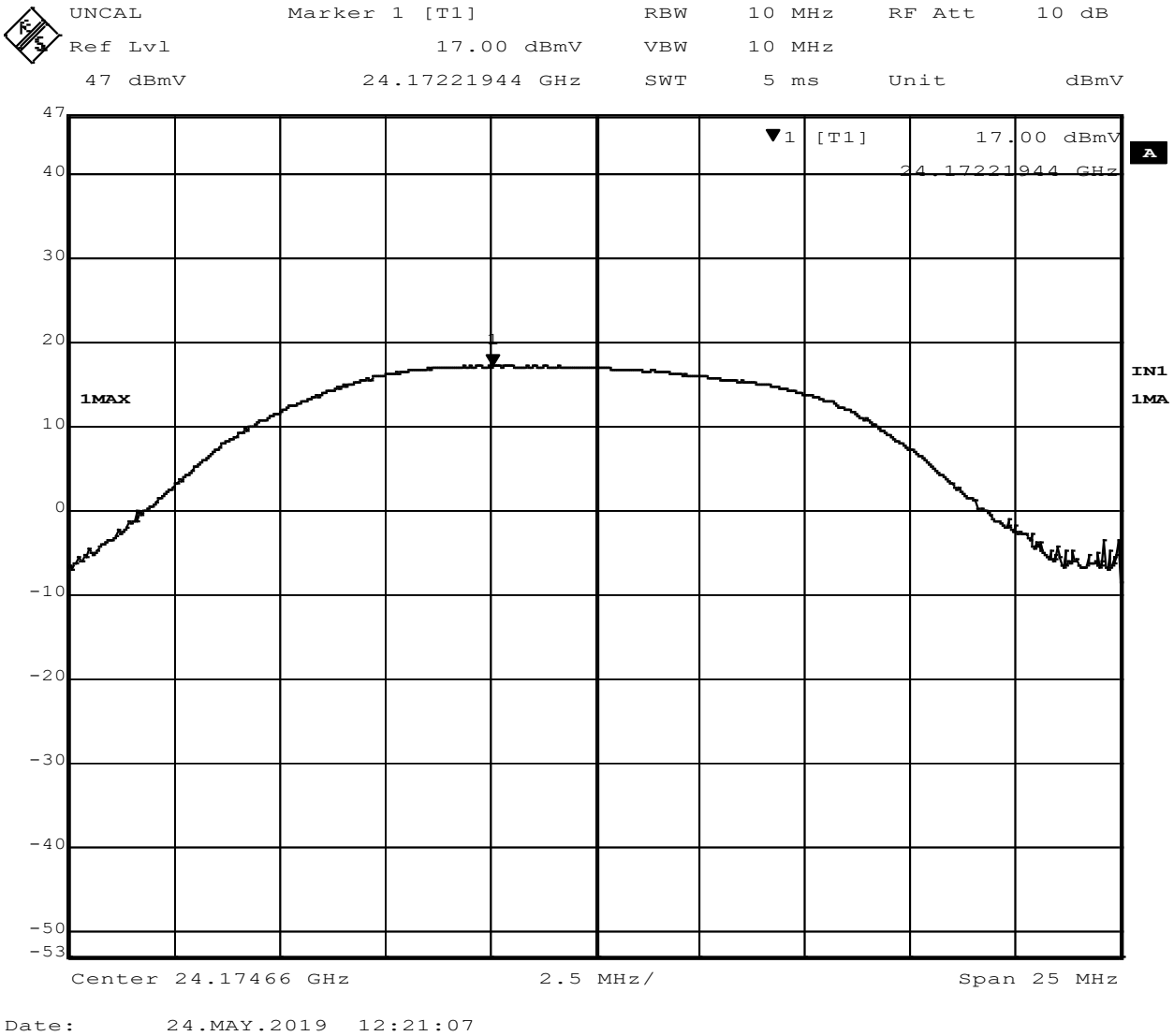


Figure 3 - Analyzer Measurement – Fundamental, Channel High

Uncorrected measurement as recorded on spectrum analyzer

Figure 4 - Analyzer Measurement – Band edge Channel High

Uncorrected measurement as recorded on spectrum analyzer

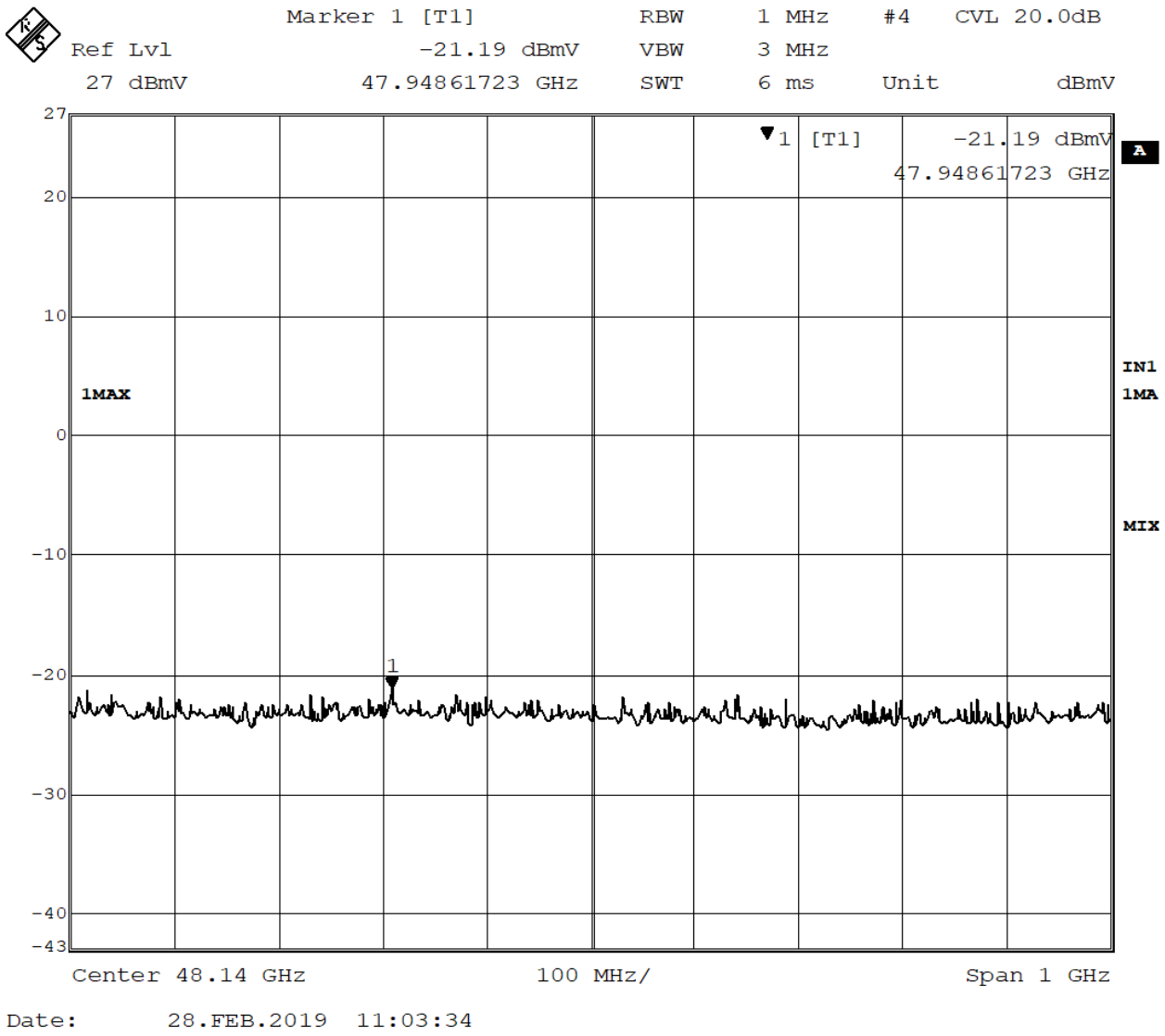


Figure 5 - Analyzer Measurement – 2nd Harmonic, Channel Low

Uncorrected measurement as recorded on spectrum analyzer

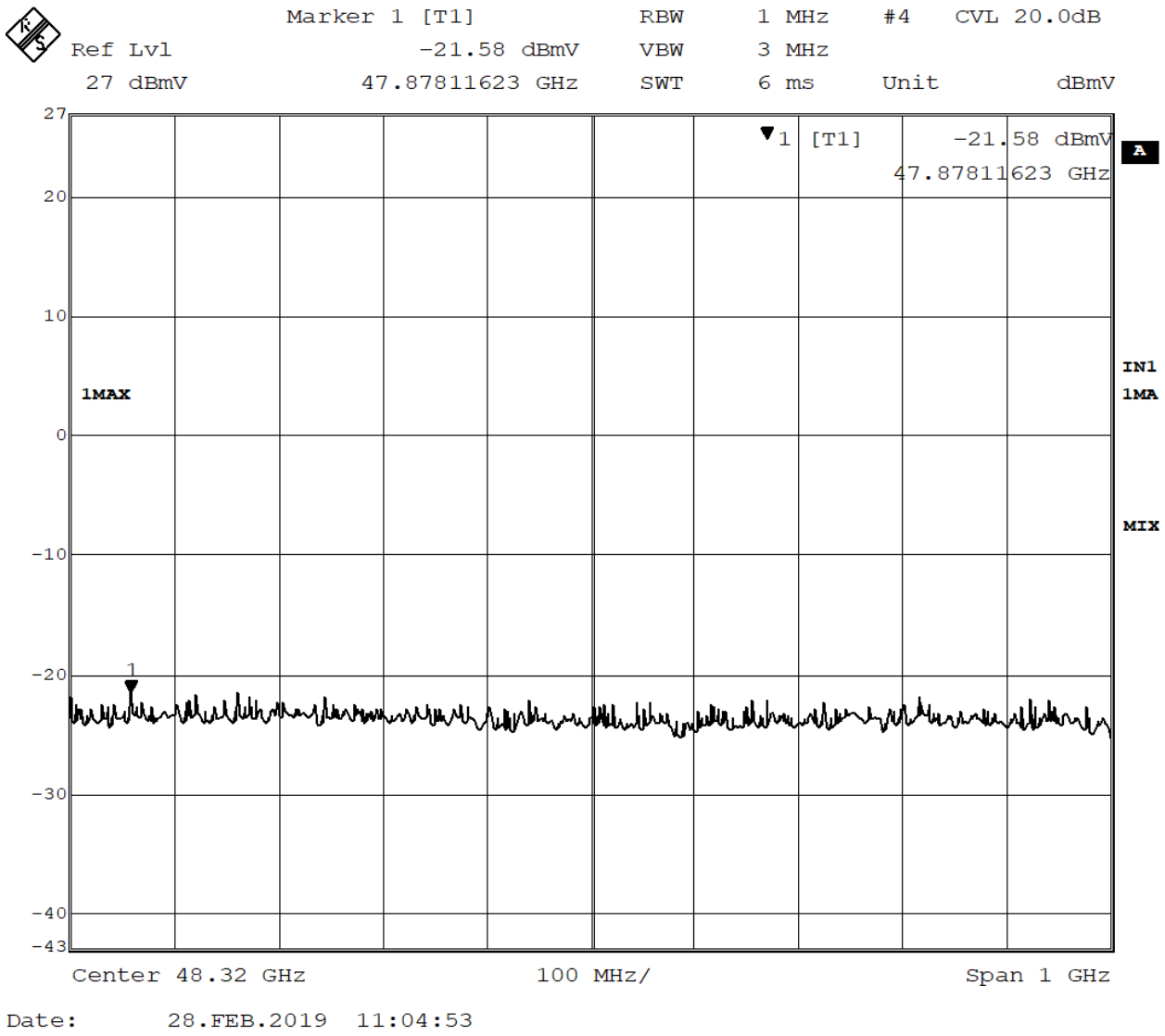


Figure 6 - Analyzer Measurement – 2nd Harmonic, Channel Mid

Uncorrected measurement as recorded on spectrum analyzer

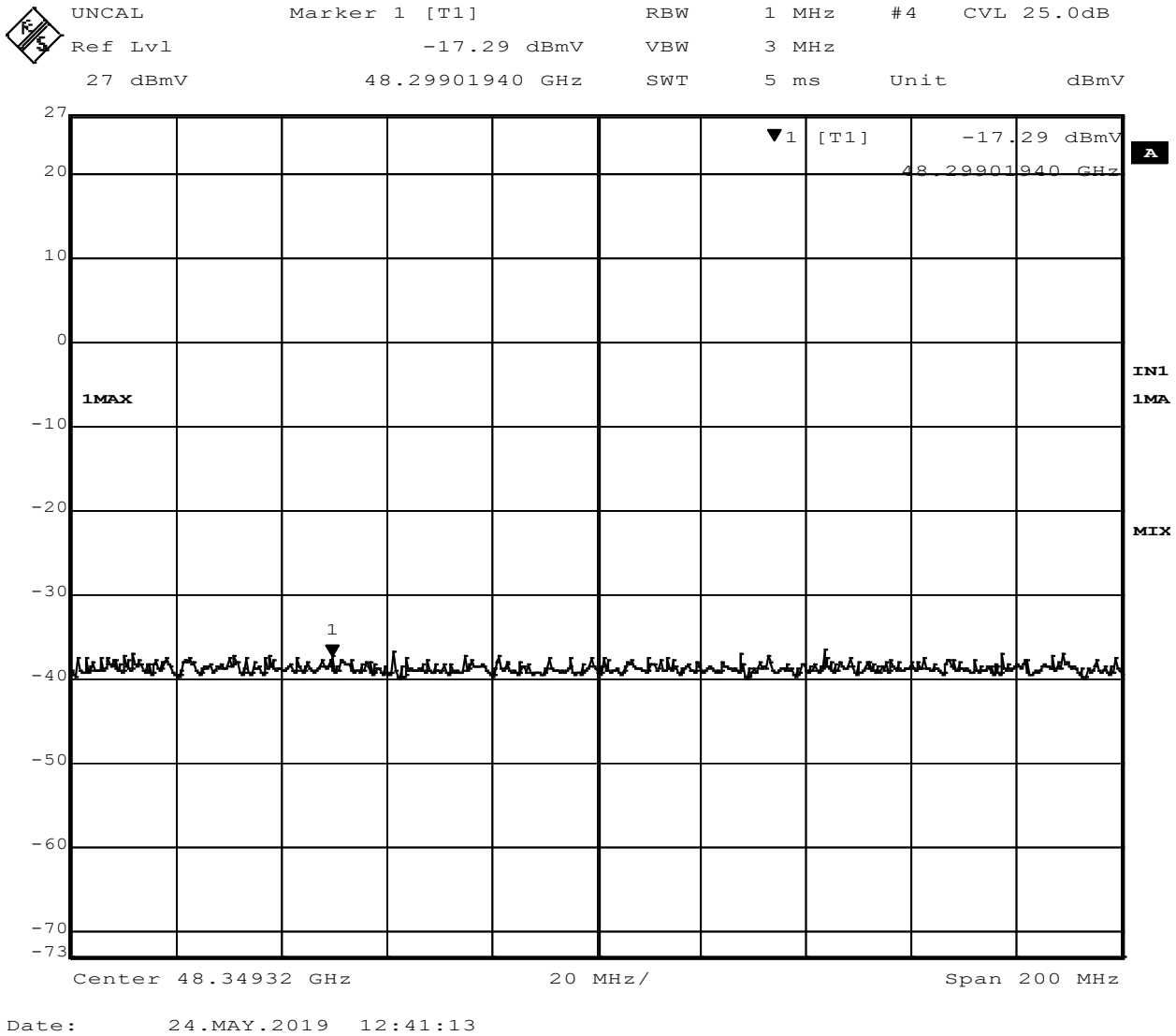


Figure 7 - Analyzer Measurement – 2nd Harmonic, Channel High

Uncorrected measurement as recorded on spectrum analyzer

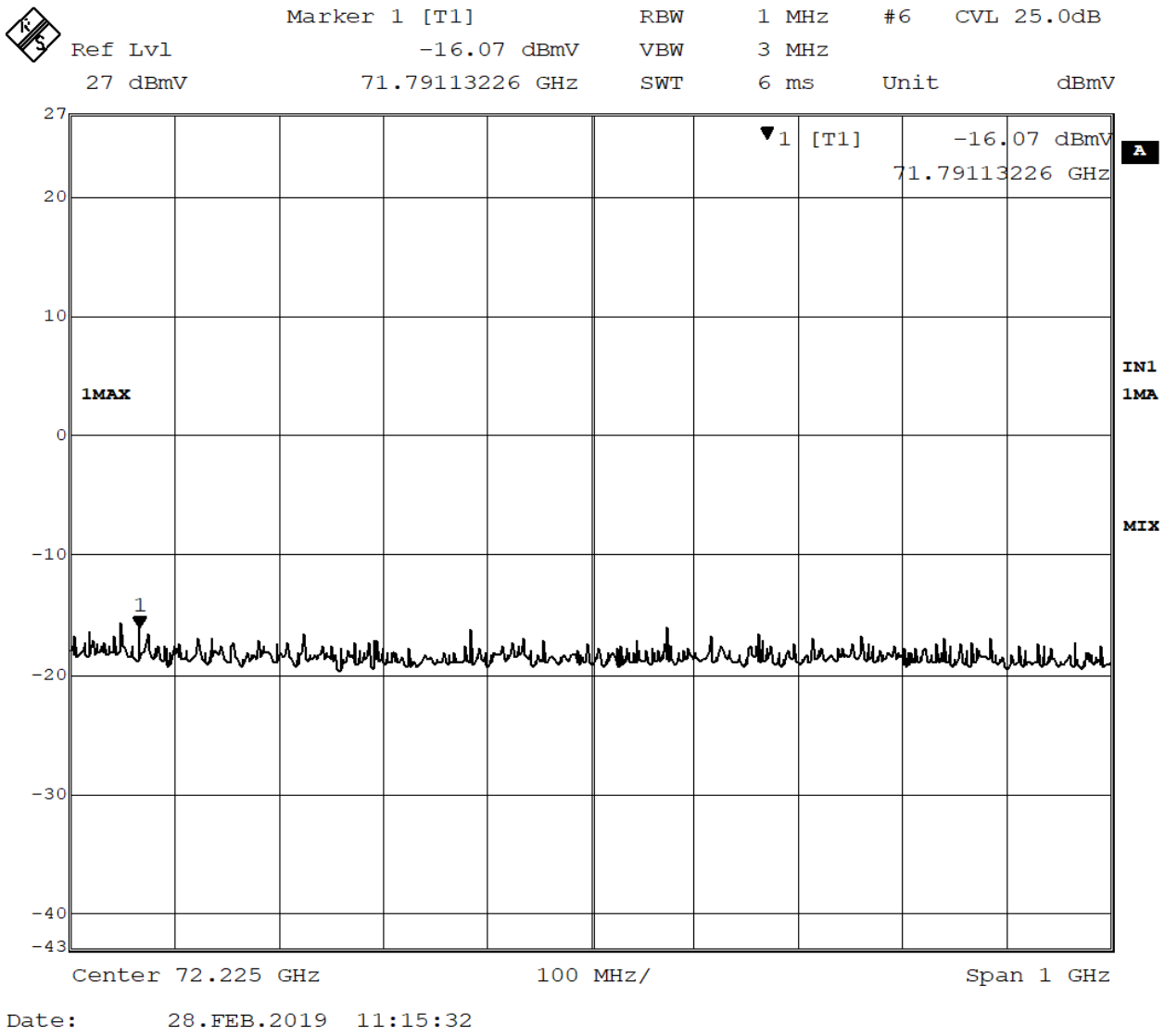


Figure 8 - Analyzer Measurement – 3rd Harmonic, Channel Low

Uncorrected measurement as recorded on spectrum analyzer

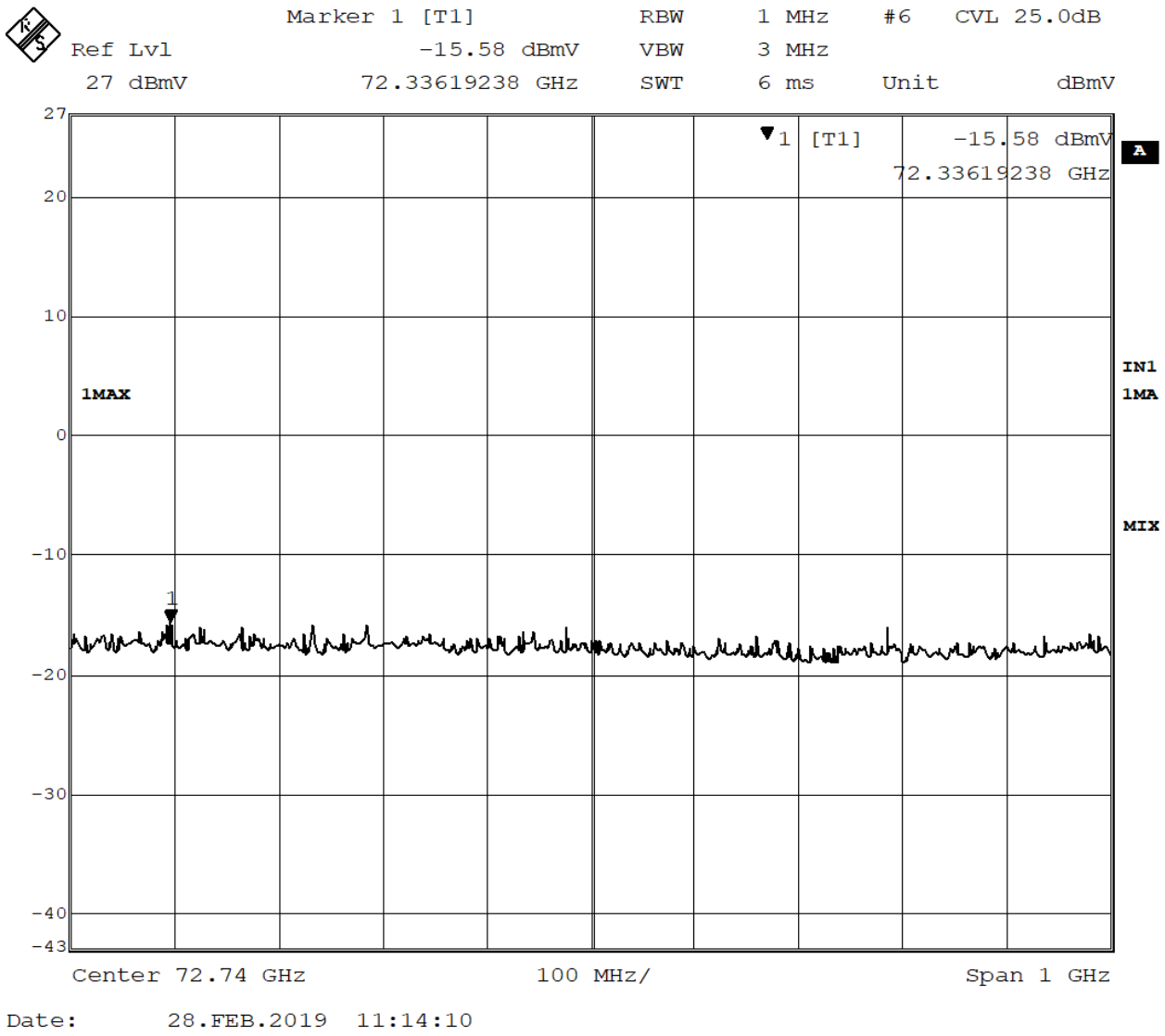


Figure 9 - Analyzer Measurement – 3rd Harmonic, Channel Mid

Uncorrected measurement as recorded on spectrum analyzer

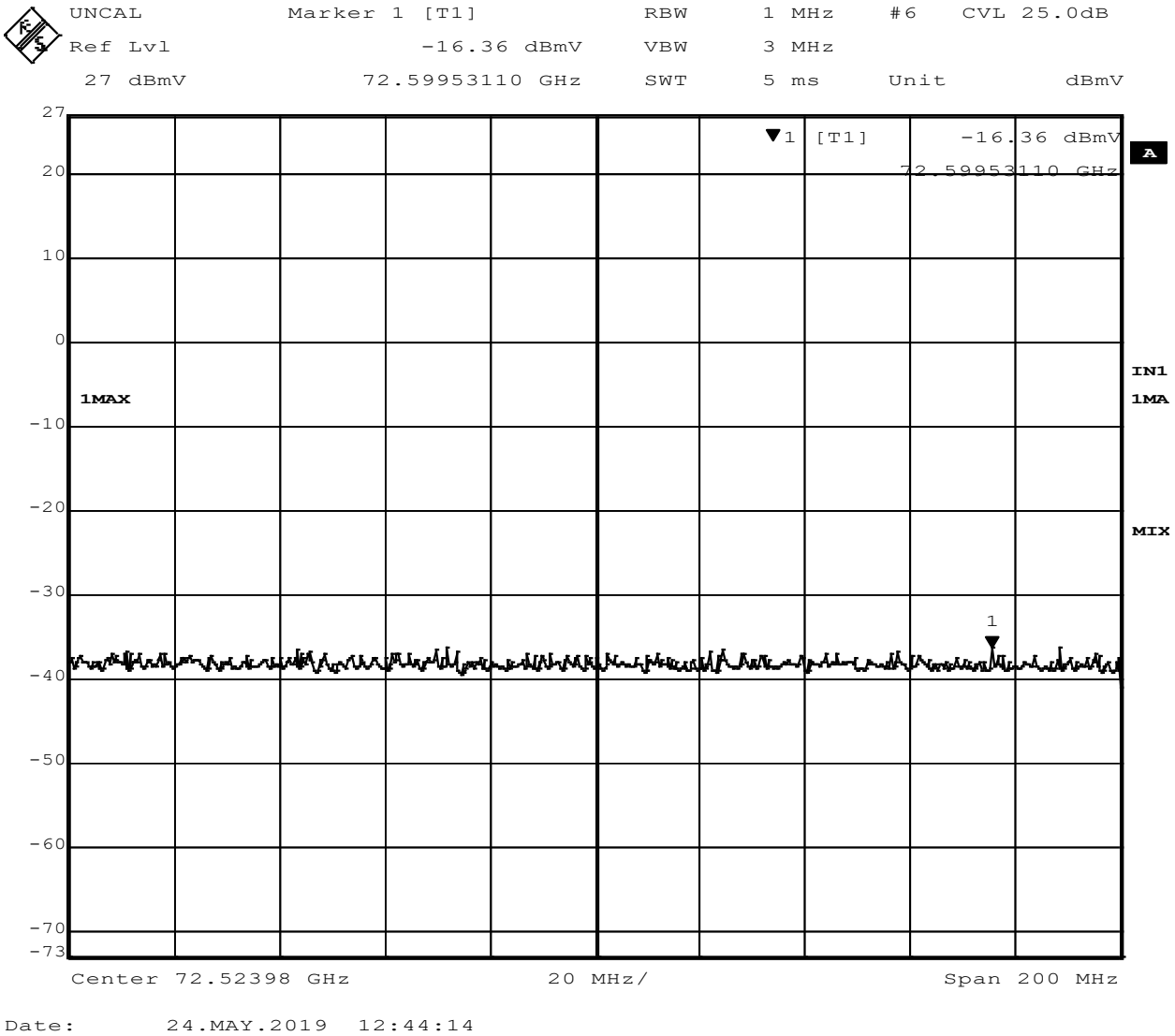


Figure 10 - Analyzer Measurement – 3rd Harmonic, Channel High

Uncorrected measurement as recorded on spectrum analyzer

3.2 Bandedges

Test Method: ANSI C63.10-2013, Section(s) 6.10.6

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:
The EUT was oriented as to produce the maximum emission levels. The resolution bandwidth was set to 100kHz and the EMI receiver was used to scan from the bandedge to the fundamental frequency with a quasi-peak detector. The highest emissions level beyond the bandedge was measured and recorded. All band edge measurements were evaluated to the general limits in Part 15.209.

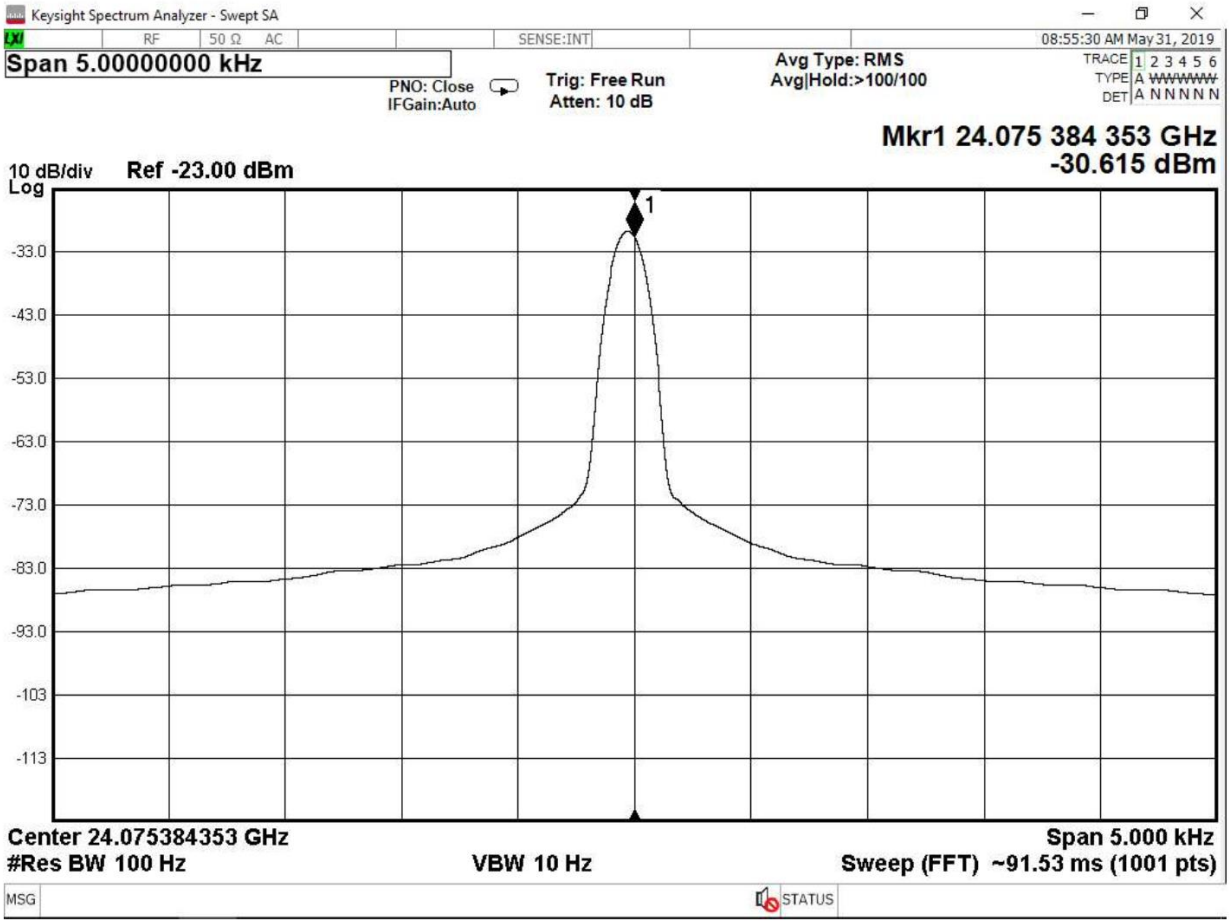
Measurements were performed as radiated measurements in the same manner as Section 3.1 of this report.

Deviations from test standard:
No deviation.

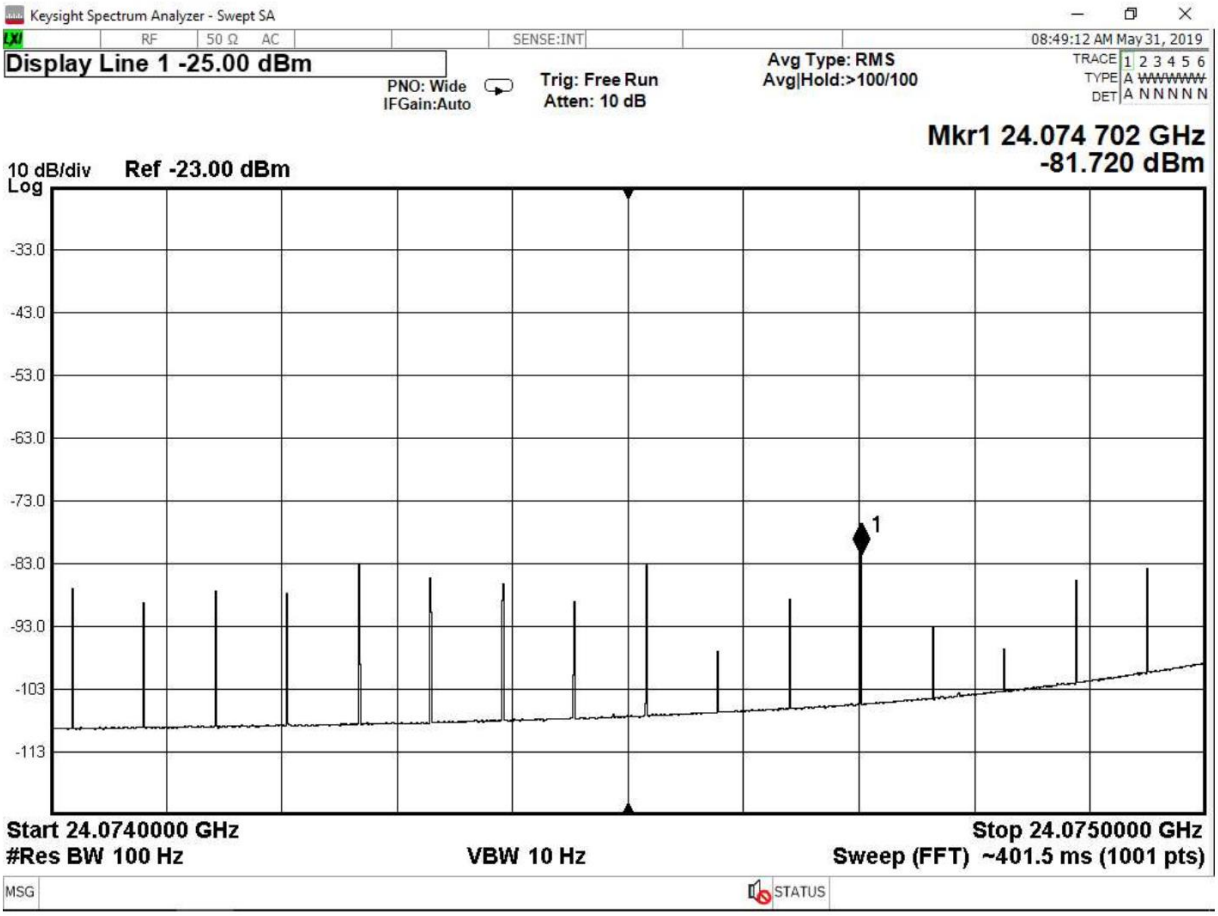
Test setup:
All the measurements were done at 3m test distance while an operator was trying to activate the hopping sequence manually.

EUT operating conditions:
The EUT was powered by 5 VDC unless specified and set to transmit continuously on the lowest frequency channel, and the highest frequency channel.

Test results:



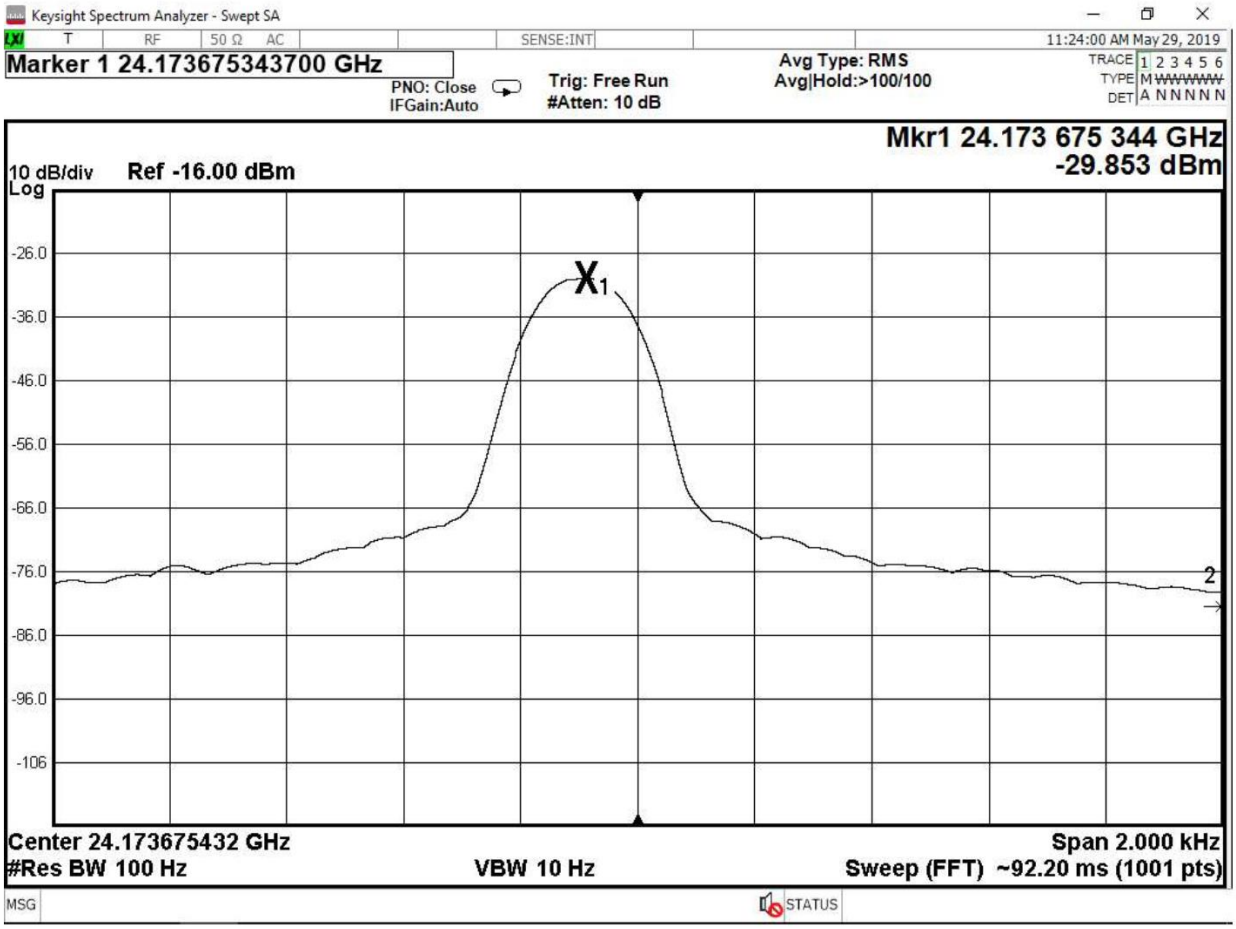
Fundamental value with 100 Hz RBW = -30.615 dBm



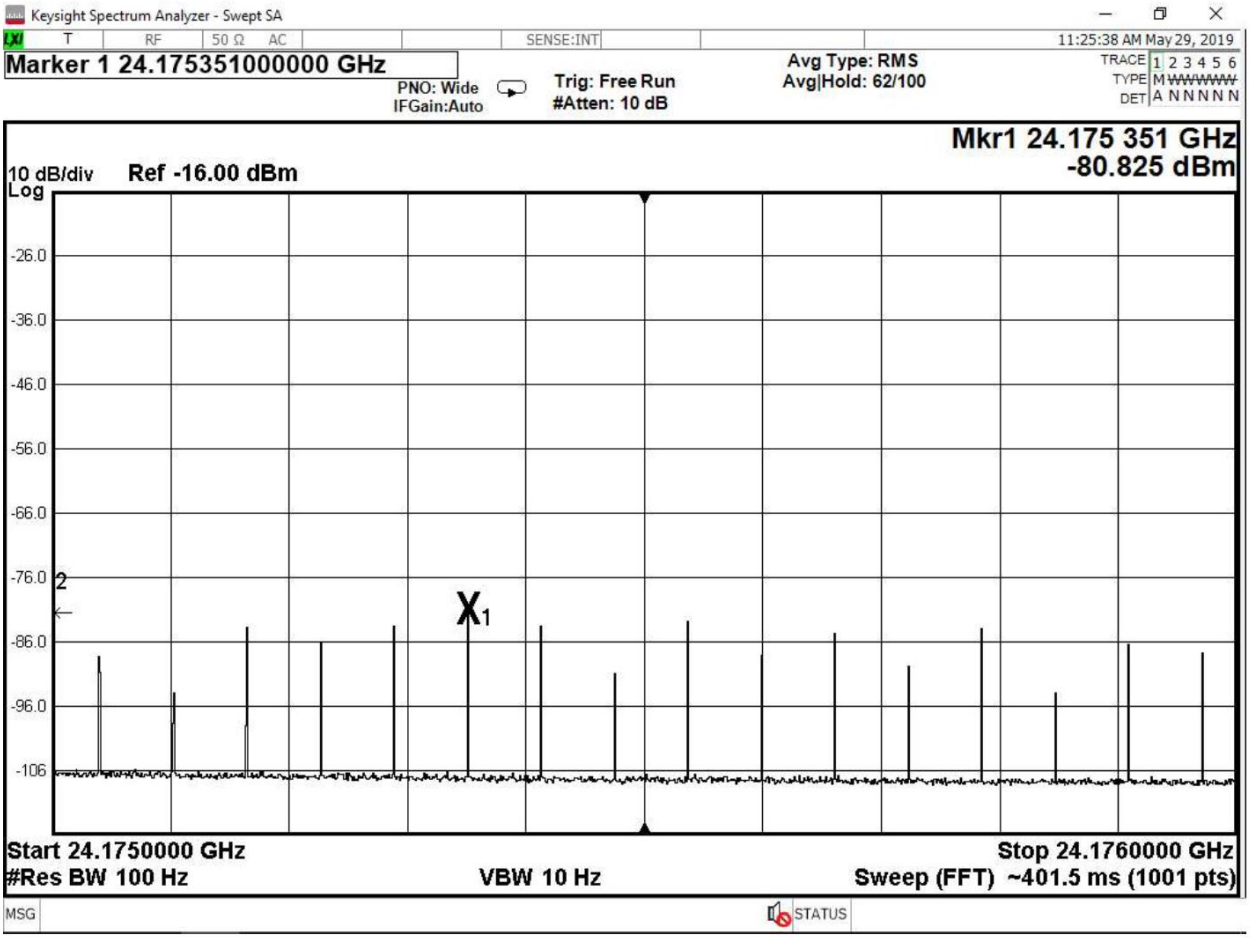
Band edge value with 100 Hz RBW = -81.720 dBm

Delta = -30.615 – (-81.720) = 51.105

FCC Part 15.245(b)(2) minimum delta = 50 dBm.



Fundamental value with 100 Hz RBW = -29.853 dBm



Band edge value with 100 Hz RBW = -80.825 dBm

Delta = -29.853 – (-80.825) = 50.972

FCC Part 15.245(b)(2) minimum delta = 50 dBm.

3.3 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 0.5-5 5-30	66 to 56 56 60	56 to 46 46 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:

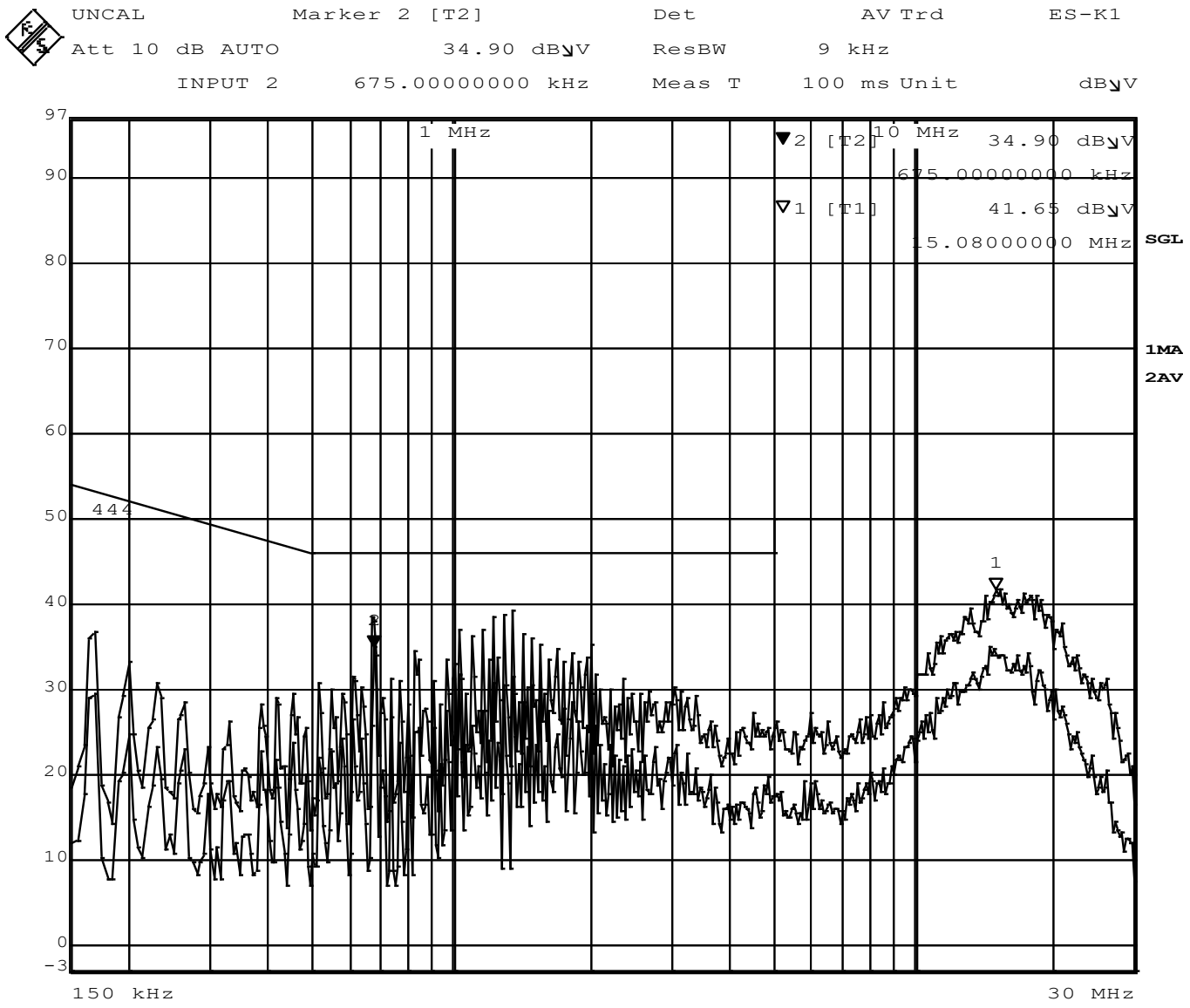


Figure 11 - Conducted Emissions Plot, L-F

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

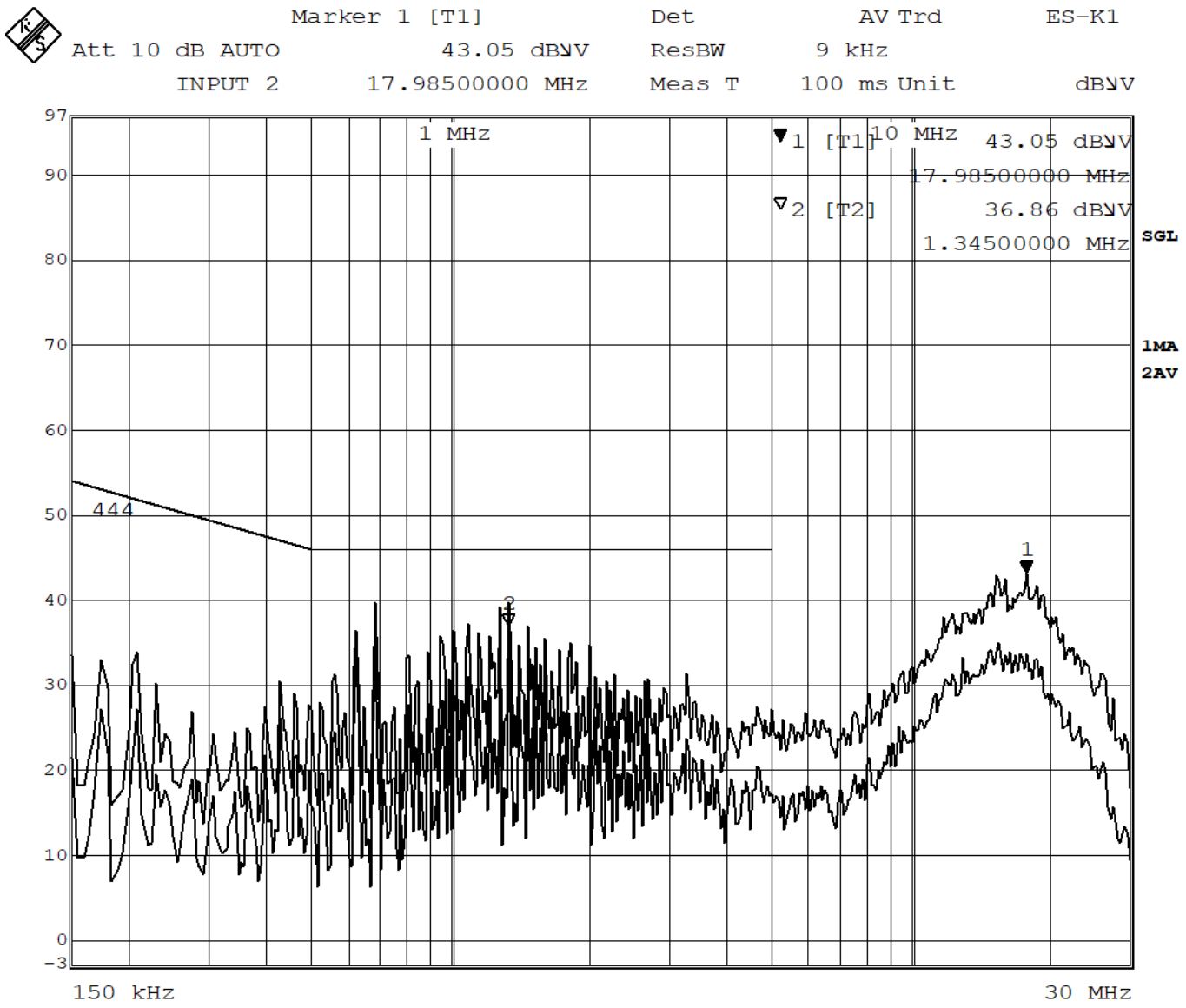


Figure 12 - Conducted Emissions Plot, N-F

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

Annex 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 x Gain (numeric)]

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

Field Strength (dBµV/m) = Field Strength (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 x d^2)/30 = FS [(d^2)/30] = FS [0.3}

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

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

Annex 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	150kHz – 18GHz	±3.30 dB

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

CISPR 16-4-2:2011 was used to calculate the above values.