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Amended

Test Report

Client: **Appareo Systems**
1810 NDSU Research Circle N.
Fargo, ND 58102

EUT: **Intelligent Ag – 608065-000034**

Test Report No.: **R20180530-23D**

Approved By:

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

Date: **27 December 2018**

Total Pages: **43**

ACCREDITED
TESTING LABORATORY
CERTIFICATE NO. 1953.01

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1.0 Summary of test results

The EUT has been tested according to the following specifications:

APPLIED STANDARDS: FCC Part 15, Subpart C			
Standard Section	**Test Type and Limit**	**Result**	**Remark**
FCC Part 15.203	Unique Antenna Requirement	N/A	N/A
FCC Part 15.207 RSS-210 Sec 3 ANSI C63.10 Sec. 6.2	Conducted Emissions	N/A	N/A
FCC Part 15.209 RSS-210 Section 4 ANSI C63.10 Sec. 6.5 ANSI C63.10 Sec. 6.6	Radiated Emissions	Pass	Meets the requirement of the limit.
FCC Part 15.231 (a) RSS-210 Annex A ANSI C63.10 Sec. 6.9.2	Minimum Bandwidth, Limit: 108.5 MHz	Pass	Meets the requirement of the limit.
FCC Part 15.231 (a), (e) RSS-210 Annex A ANSI C63.10 Sec. 6.3.3	Transmitter Radiated Emissions, Limit: Table 15.209	Pass	Meets the requirement of the limit.

2.0 Description

2.1 Equipment under test

The Equipment Under Test (EUT) was IntelligentAg wireless computer from Appareo Systems, LLC. The device functions as a telematics device.

EUT Received Date: 29 November 2018
EUT Tested Date: 29 November 2018

PRODUCT	IntelligentAg
MODEL (HVIN)	153010-000069 (LTE) 153010-000070 (GMS)
POWER INPUT	12 VDC
MODULATION TYPE	FSK
FREQUENCY RANGE	433.92 MHz
NUMBER OF CHANNELS	1
ANTENNA TYPE	External Antenna
SERIAL NUMBER OF TEST UNIT	0411-000002(GSM unit – used to test 433.92 MHz Radio and GSM Intermodulation) 0410-000005 (LTE unit – used for LTE Intermodulation)
POWER SUPPLY	Battery powered.

NOTE:

1. For more detailed features description, please refer to the manufacturer's specifications or User's Manual.

2.2 Laboratory description

All testing was performed at the NCEE Lincoln facility, which is a FCC and IC registered lab. Laboratory environmental conditions varied slightly throughout the tests:

Relative humidity of 32 ± 4%
Temperature of 23 ± 3° Celsius

2.3 Description of test modes

Channel	Frequency
1	433.92 MHz

2.4 Applied standards

The EUT is a digital transmission device operating at 433.92 MHz. According to the specifications of the manufacturer, it must comply with the requirements of the following standards:

1. *FCC Part 15, Subpart c (15.231) using;*
   ANSI/IEEE C63.4:2014 and ANSI/IEEE C63.10:2013
2. *Industry Canada, RSS 210, Issue 9, Category I Equipment*

All test items have been performed and recorded as per the above standards.

2.5 Description of support units

None

2.6 Configuration of system under test

The EUT was powered by 12VDC for radiated emissions measurements. It was tested by itself. The EUT was programmed by the manufacturer to transmit continually for testing purposes only. The EUT contains:

HVIN 153010-000069 (LTE) contains modules:
Satellite Module - FCC ID: Q639603N, IC: 4629A-9603N
WiFi/BT Module - FCC ID: XF6-RS9113SB, IC: 8407A-RS9113SB
Cellular LTE Module - FCC ID: XPY1EIQN2NN, IC: 8595A-1EIQN2NN

HVIN 153010-000070 (GSM) contains modules:
Satellite Module - FCC ID: Q639603N, IC: 4629A-9603N
WiFi/BT Module - FCC ID: XF6-RS9113SB, IC: 8407A-RS9113SB
Cellular GSM Module - FCC ID: XPY1CGM5NNN, IC: 8595A-1CGM5NNN

3.0 Test equipment used

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 2018**
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
** Extended Cal

4.0 Detailed results

4.1 Unique antenna requirement

4.1.1 Standard applicable

For intentional device, according to FCC 47 CFR Section 15.203, an intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device.

4.1.2 Antenna description

The antenna is an external antenna that requires professional installation.

4.2 Radiated emissions

4.2.1 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 (uV/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.

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.
5. *Radiated limits according to 15.209 do not apply within the 902MHz to 928MHz band for transmitters.
6.**For frequencies not in a restricted band as specified in 15.205, spurious emissions shall be at least 20dB less than the field strength at the fundamental frequency.

4.2.2 Test procedures

a. The EUT was placed on the top of a rotating table 0.8 meters 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.

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. In order to test the EUT is all three axis, The EUT was tested in both a horizontal and vertical orientation and the turntable was rotated 360deg. The vertical orientation produces the highest emissions, so all measurements were made with the EUT in this orientation.

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 of test receiver/spectrum analyzer is 1 MHz for peak and average detectors at frequencies above 1GHz.

4.2.3 Deviations from test standard

No deviation.

4.2.4 Test setup

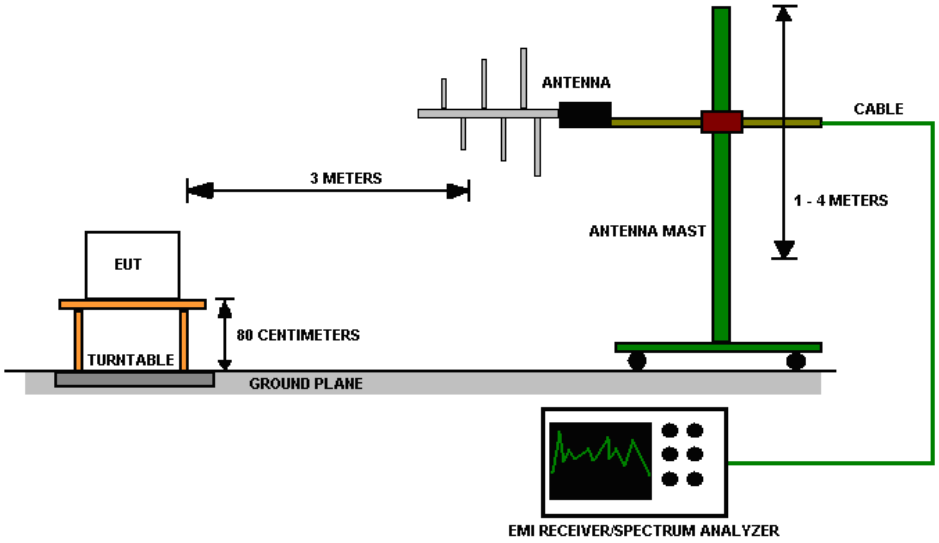


Figure 1 - Radiated Emissions Test Setup

4.2.5 EUT operating conditions

The 433MHz radio was set to continuously transmit as well as the other 3 radios present in the device. The field strength measurements from fundamental frequency or harmonics from the other radios are not presented in this report as the intention was to measure any intermodulation products. See section 2.6.

4.2.6 Test results

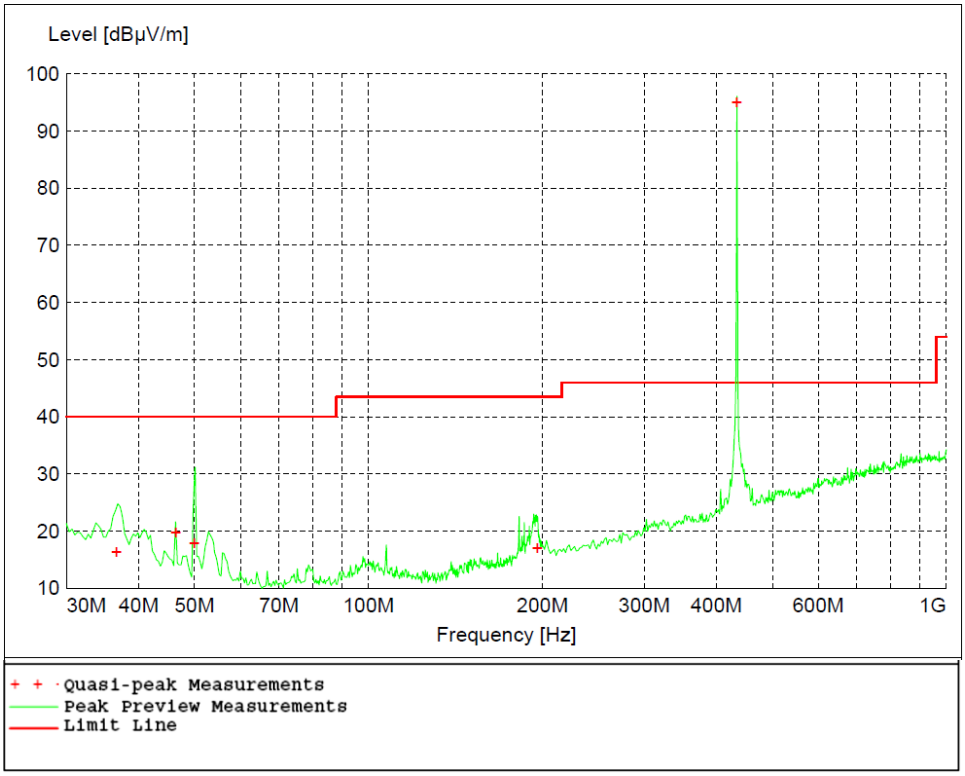


Figure 2 - Radiated Emissions Plot, HVIN 153010-000069

Emissions were measured from both models/HVINs and the 153010-000069 model was found to be worse-case and is presented here. Although, both models were very similar in emissions.

Fundamental frequency (MHz)	Field strength of fundamental (microvolts/meter)	Field strength of spurious emissions (microvolts/meter)
40.66-40.70	2,250	225
70-130	1,250	125
130-174	[1]1,250 to 3,750	[1]125 to 375
174-260	3,750	375
260-470	[1]3,750 to 12,500	[1]375 to 1,250
Above 470	12,500	1,250

Quasi-peak/Average Measurements

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
36.660000	16.31	40.00	23.70	397	254	VERT
46.440000	19.73	40.00	20.30	99	229	VERT
49.980000	17.91	40.00	22.10	100	98	VERT
196.140000	17.10	43.50	26.40	111	288	VERT
433.920000	95.08**	NA	NA	100	0	HORI
36.660000	16.31	40.00	23.70	397	254	VERT
46.440000	19.73	40.00	20.30	99	229	VERT
49.980000	17.91	40.00	22.10	100	98	VERT

**The EUT was running at 100% duty cycle in continuous power mode and unit will not be running in this mode in actual operation.

*Peak measurement

Peak Measurements

Frequency	Level	Limit	Margin	Height	Angle	Pol.
MHz	dBµV/m	dBµV/m	dB	cm	deg	
2169.600000	44.16	54.00	9.80	220	93	HORI
3037.400000	51.27	54.00	2.70	180	112	HORI
3905.200000	44.91	54.00	9.10	99	360	VERT

Peak measurements were compared to average limit and found to be compliant so average measurements were not performed

INTERMODULATION: The intention of this testing is to investigate potential intermodulation of and possible combination of 2 of the 4 radios collocated radio modules (Cell Module & WIFI Module) which operate in 434 MHz, 1621 MHz, 779 MHz and 2.4 GHz (LTE unit) band and 434 MHz, 1621 MHz, 825 MHz and 2.4 GHz (GSM unit) and Iridium satellite module at 1.6265 GHz. The intermodulation products were investigated and found to be at least 10 dB below the limits.

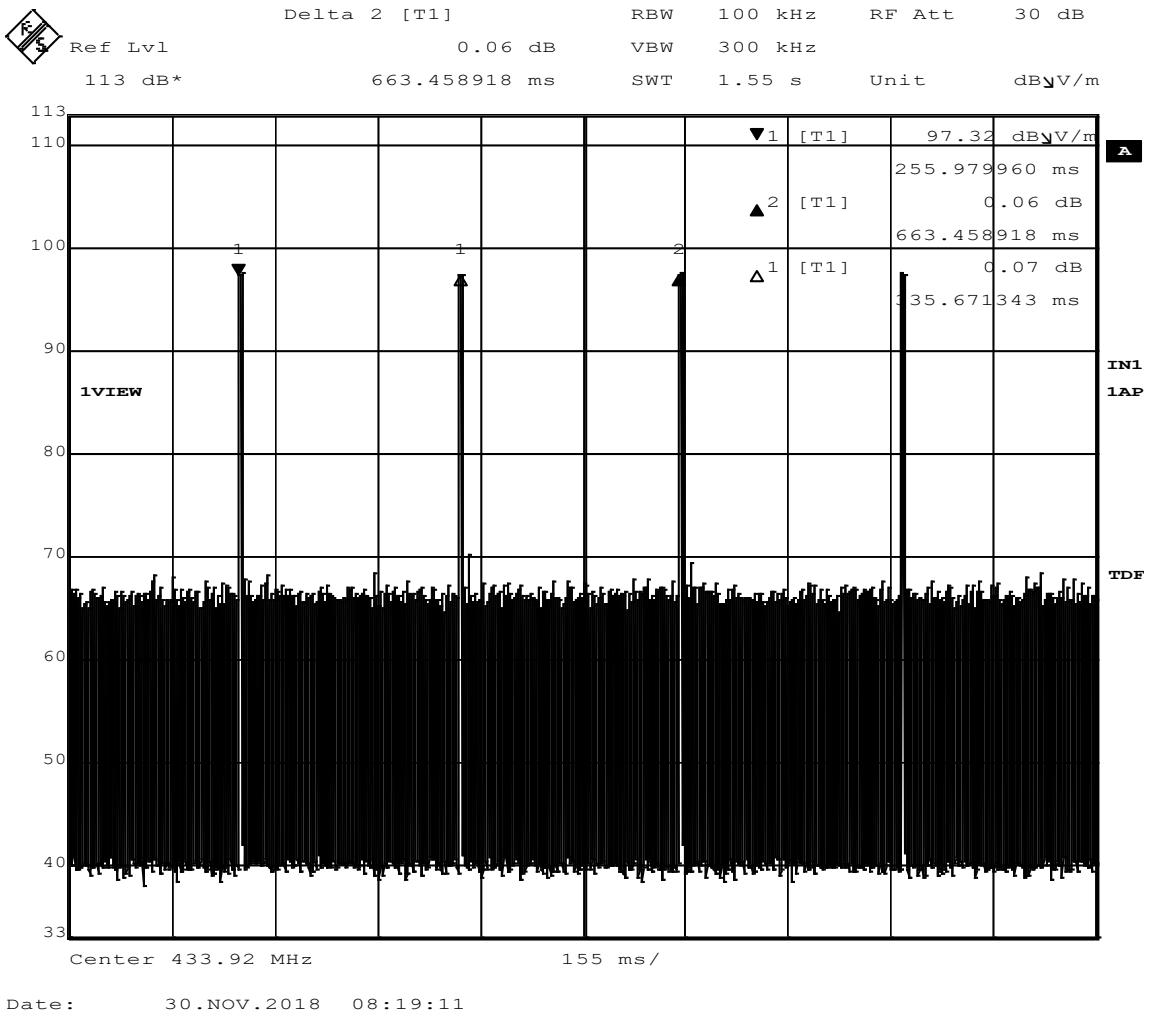


Figure 3 - Period = 335 ms >100 ms

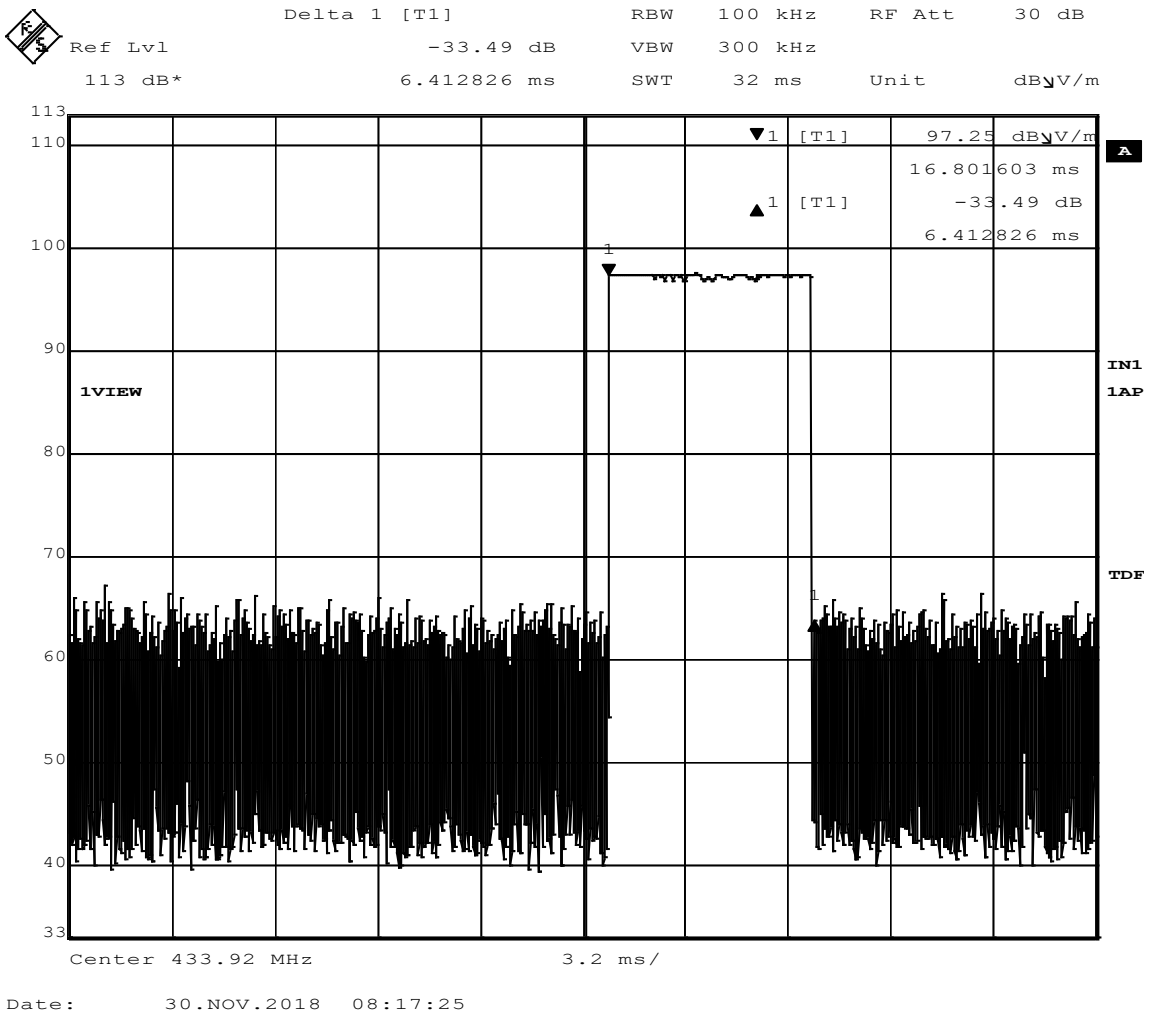


Figure 4 – Pulse Length Mode 1A – 6.5 ms, Non-Periodic Mode

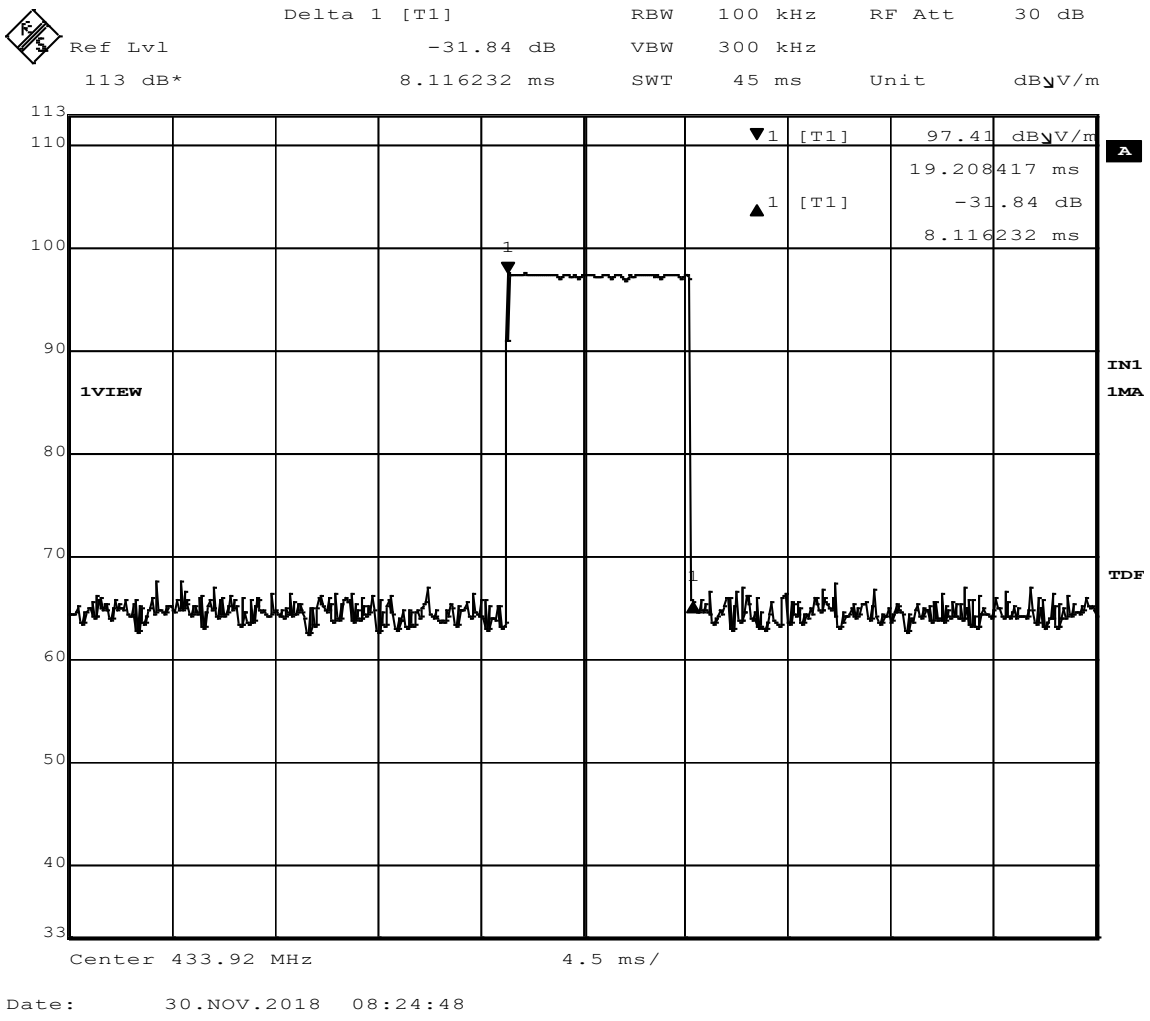


Figure 5 – Pulse Length Mode 1A – 8.3 ms, Non-Periodic Mode

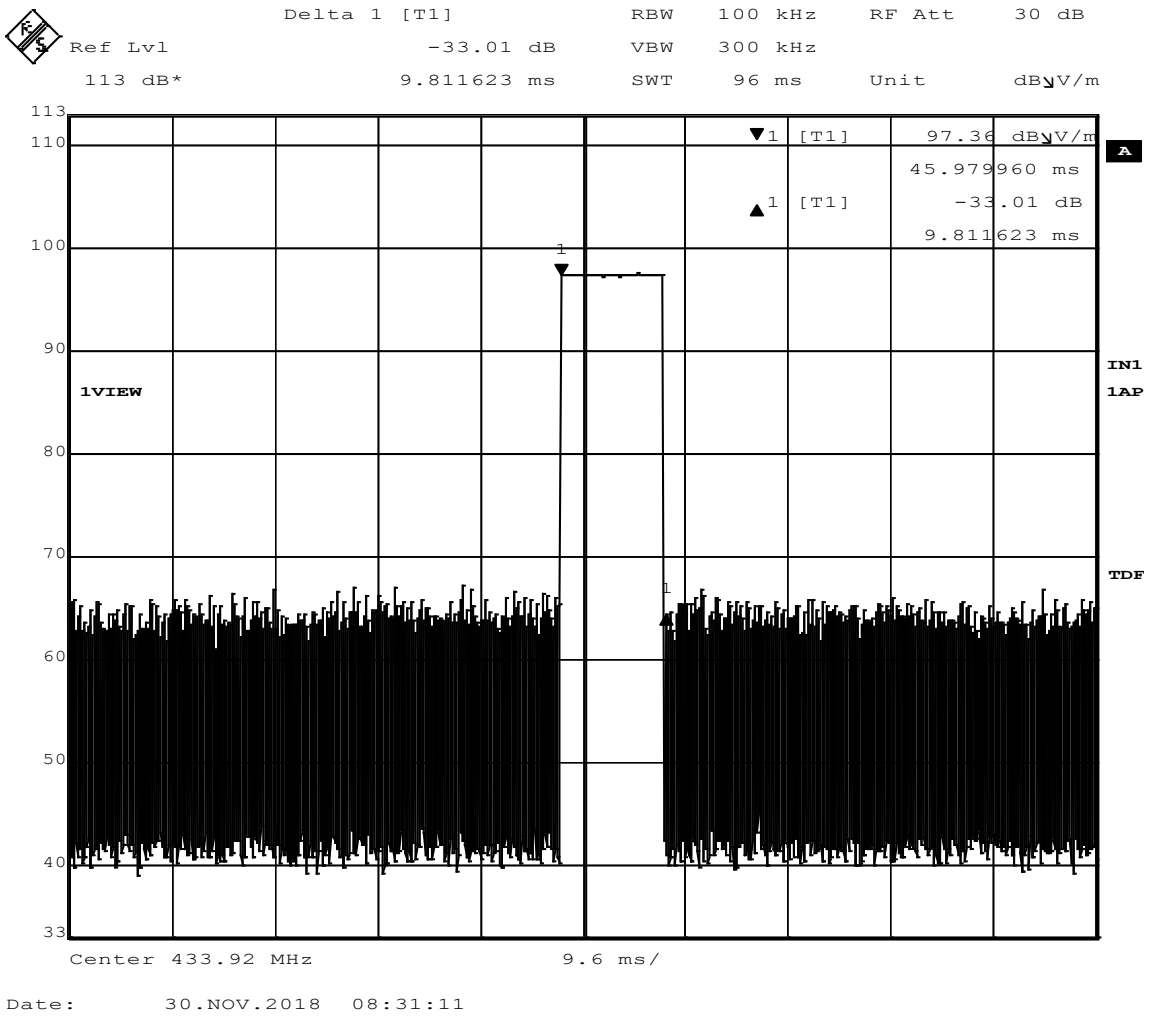


Figure 6 – Pulse Length Mode 1A – 9.7 ms, Non-Periodic Mode

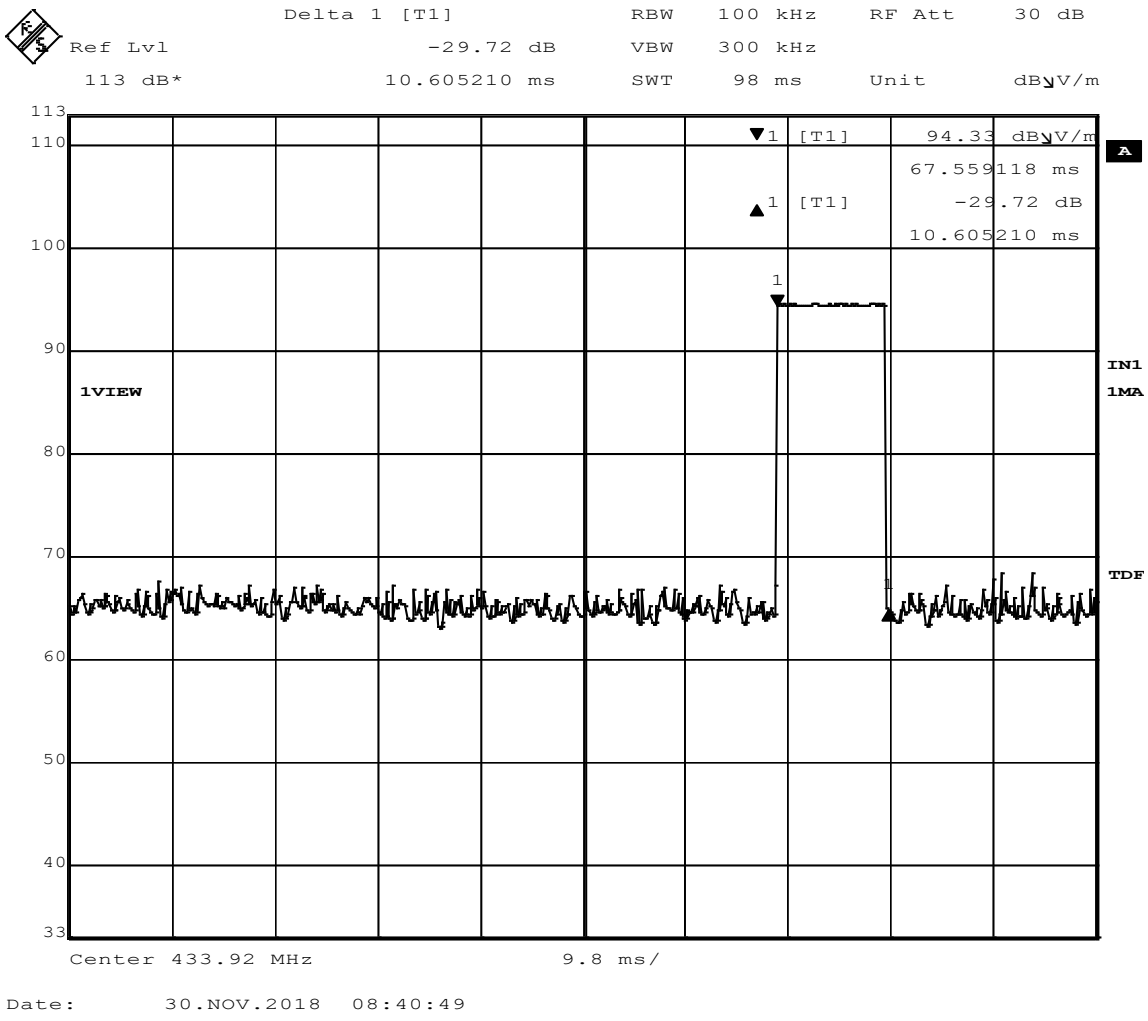


Figure 7 – Pulse Length Mode 2A – 10.5 ms, Non-Periodic Mode

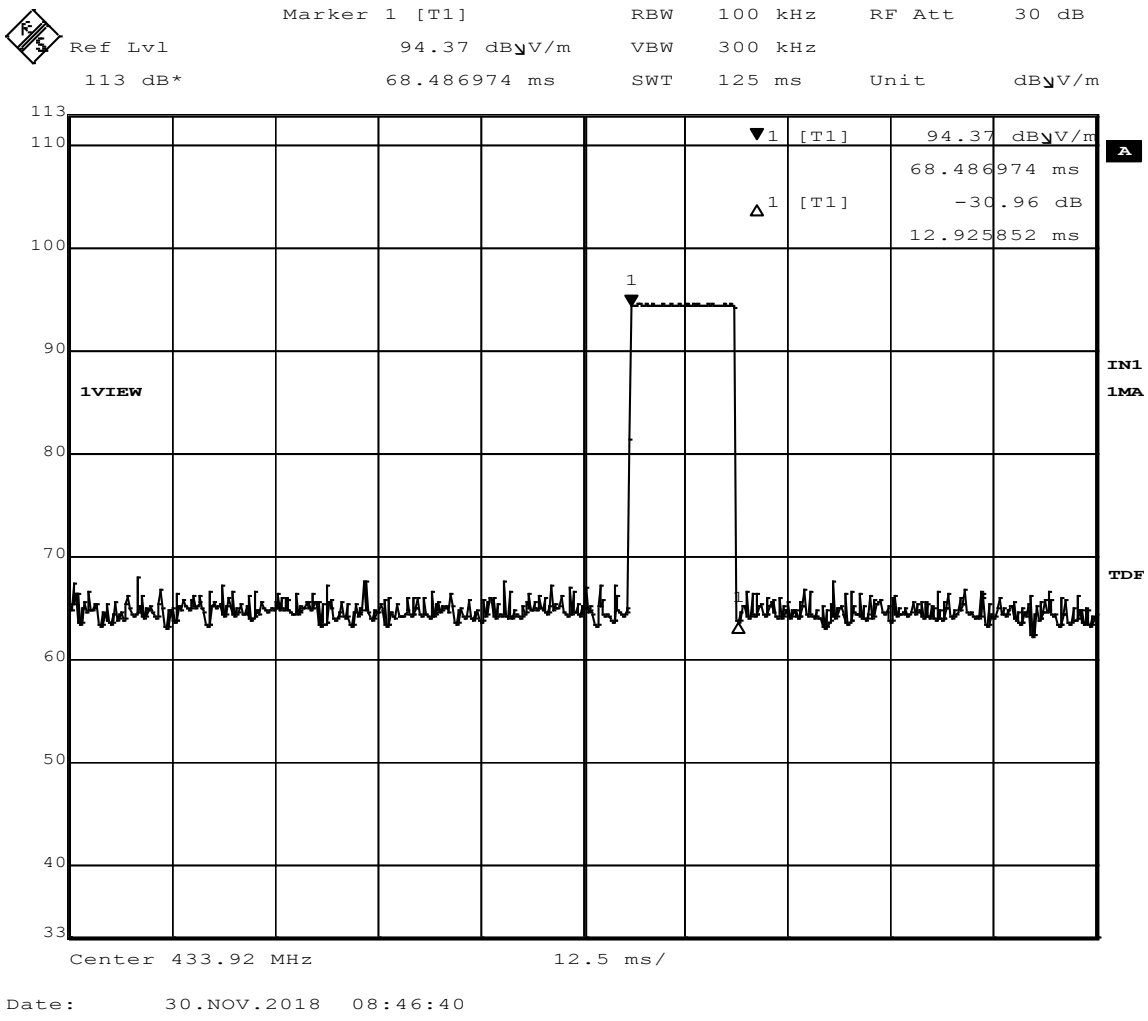


Figure 8 – Pulse Length Mode 2A – 13 ms, Non-Periodic Mode

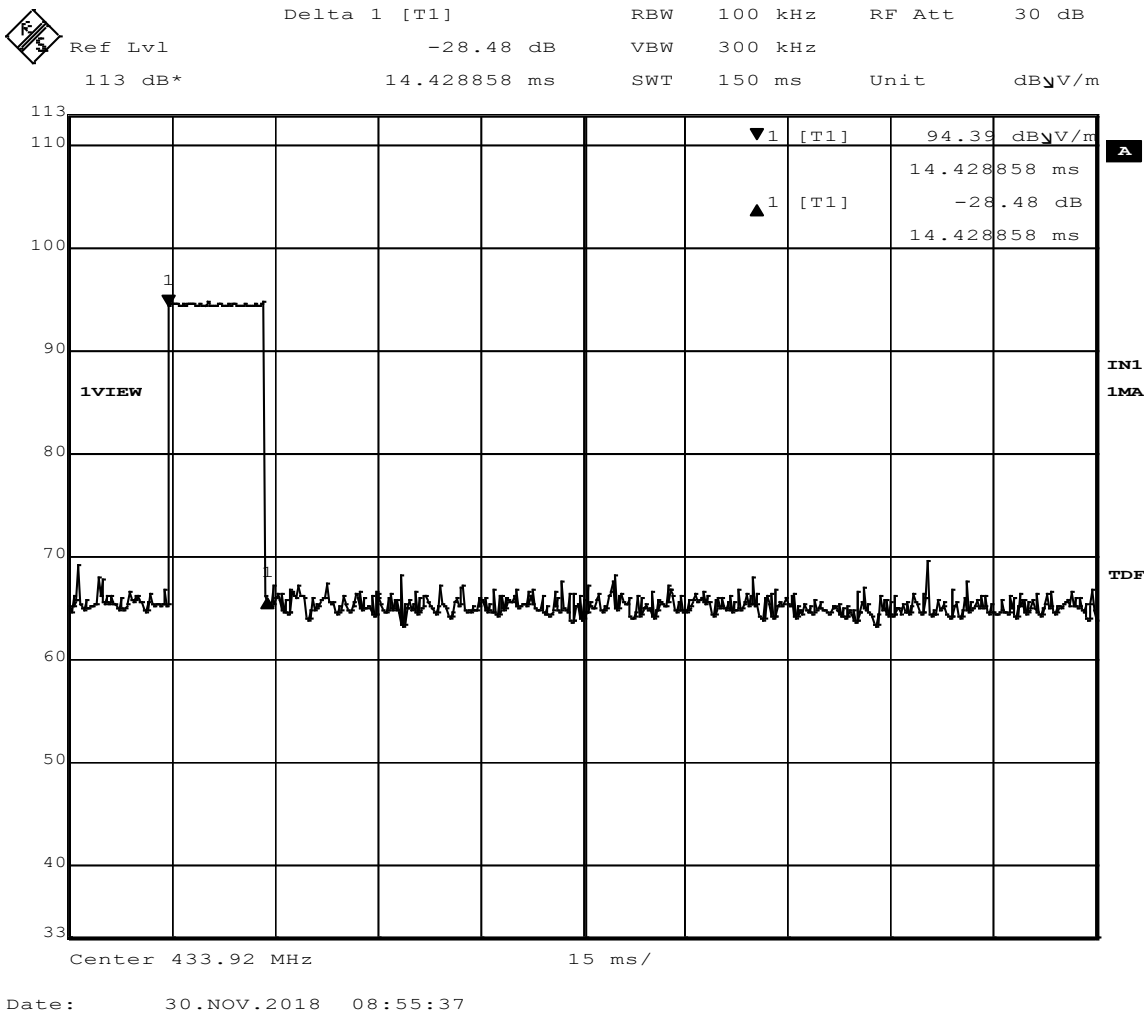


Figure 9 – Pulse Length Mode 2A – 14.7 ms, Non-Periodic Mode

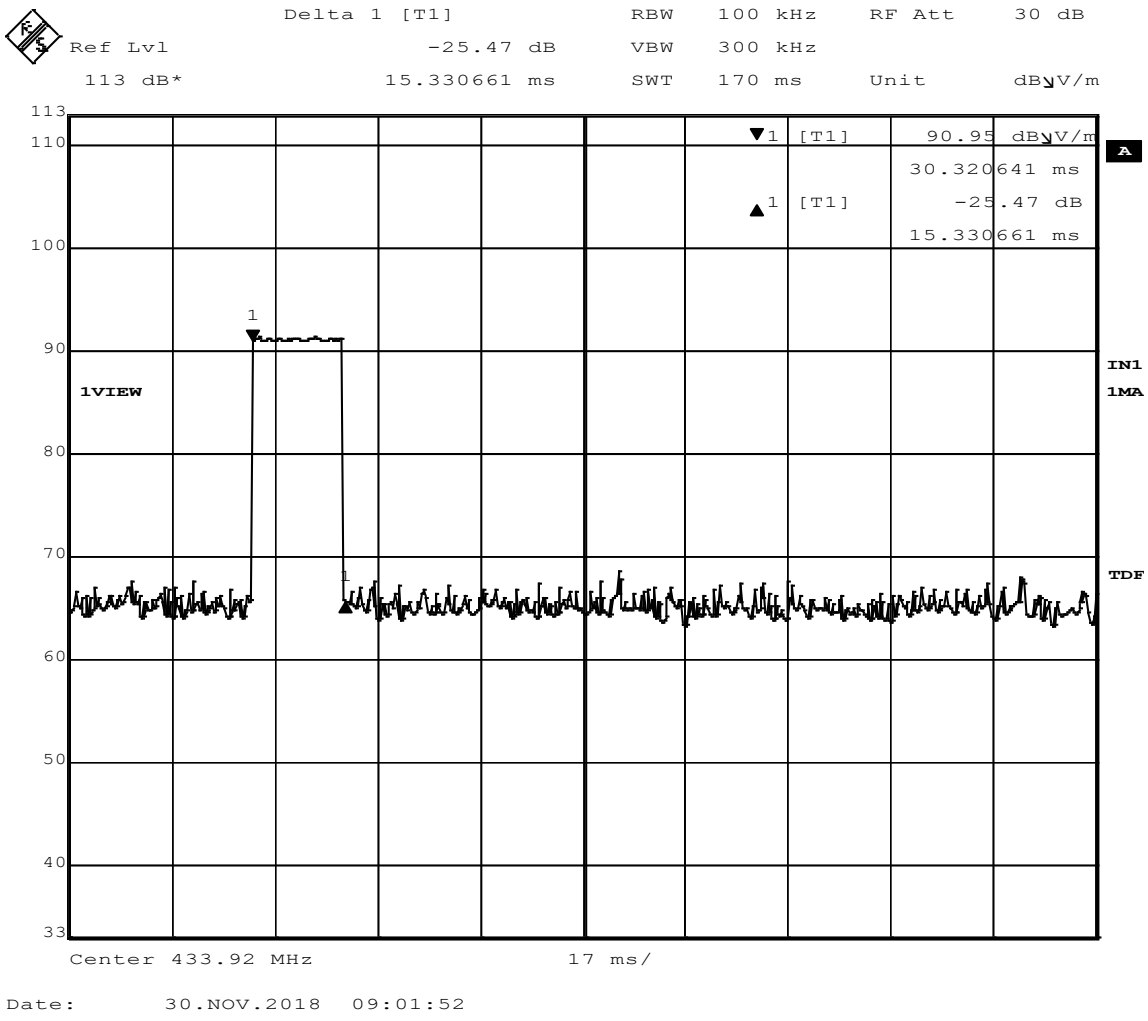


Figure 10 – Pulse Length Mode 3A – 15.4 ms, Non-Periodic Mode

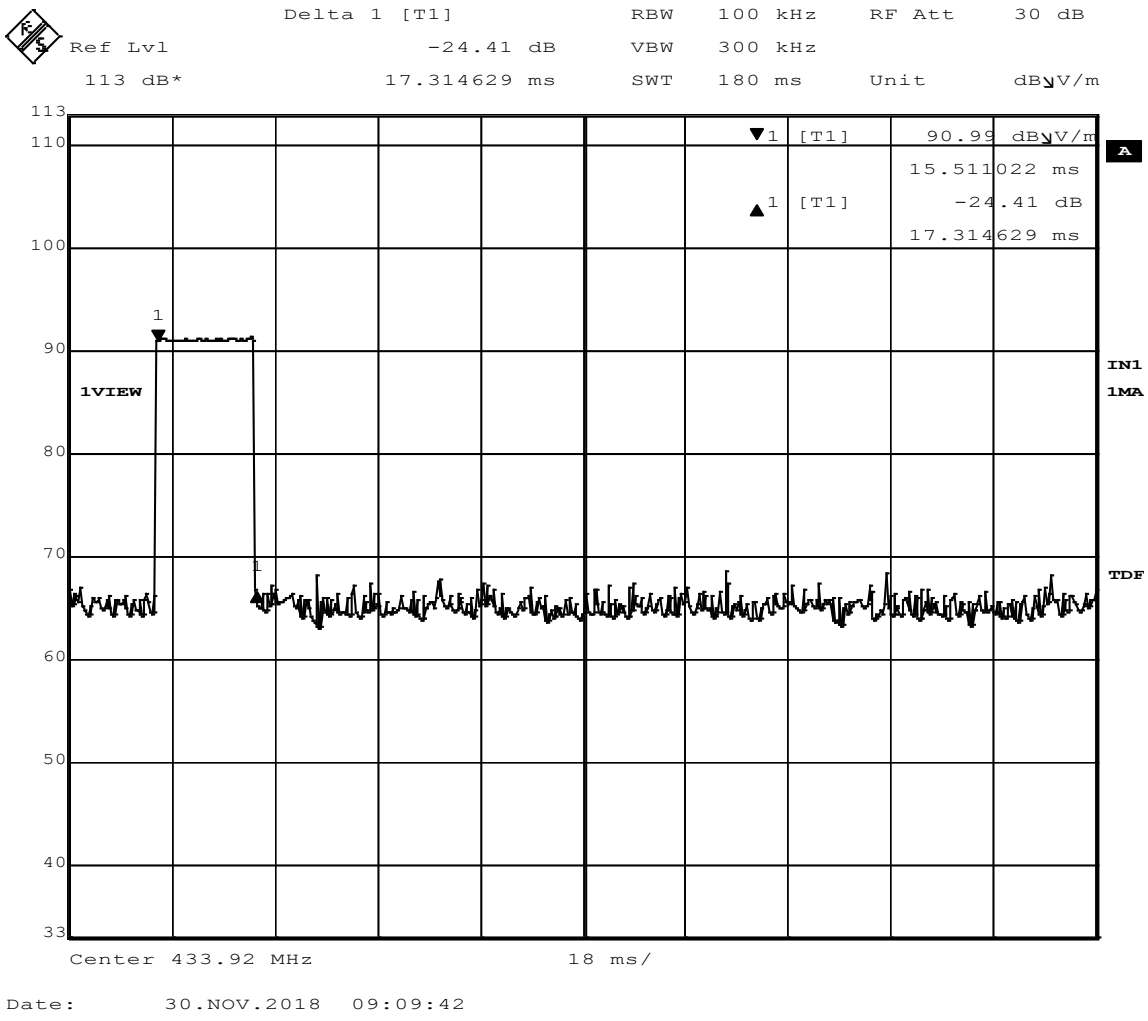


Figure 11 – Pulse Length Mode 3A – 17.4 ms, Non-Periodic Mode

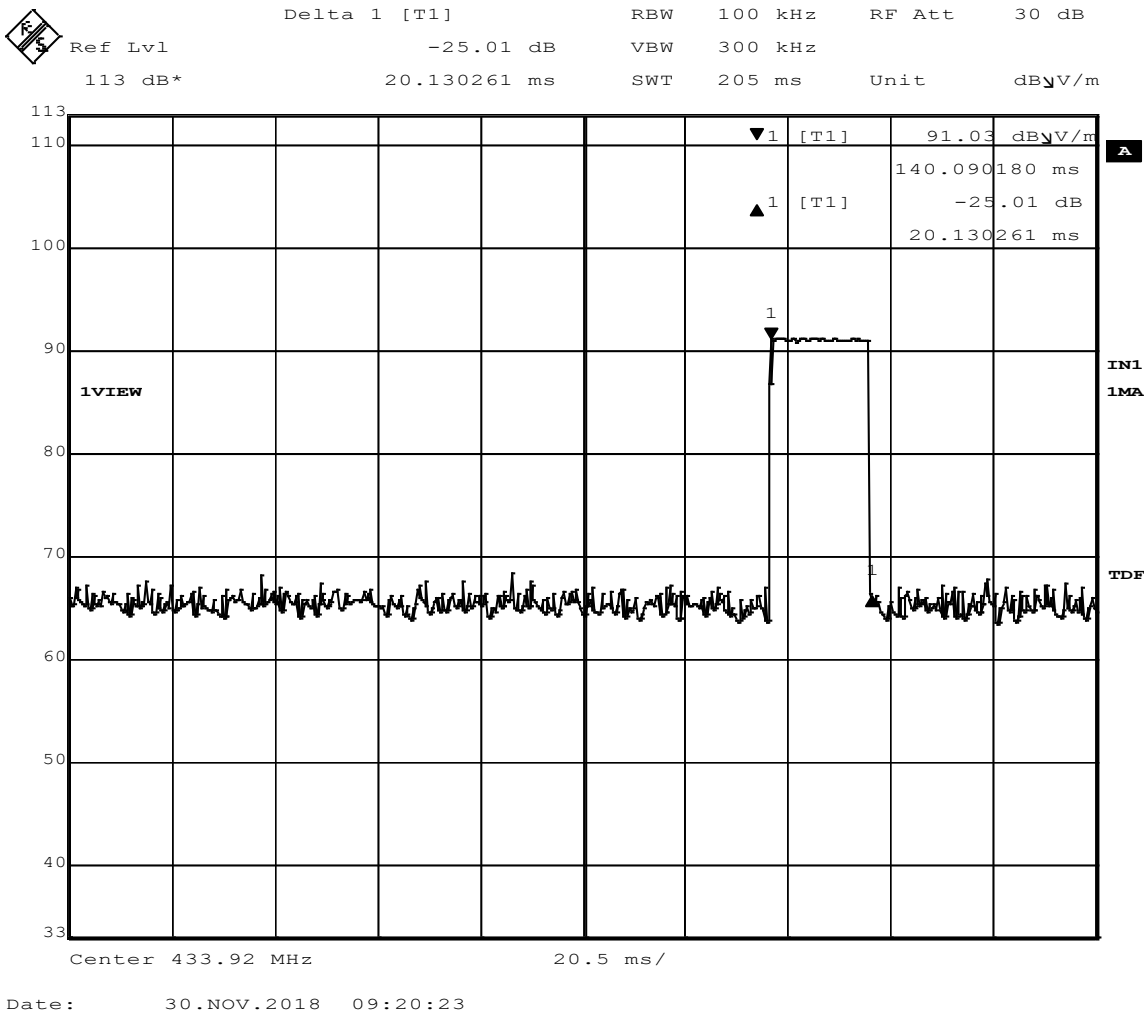


Figure 12 – Pulse Length Mode 3A – 19.7 ms, Non-Periodic Mode

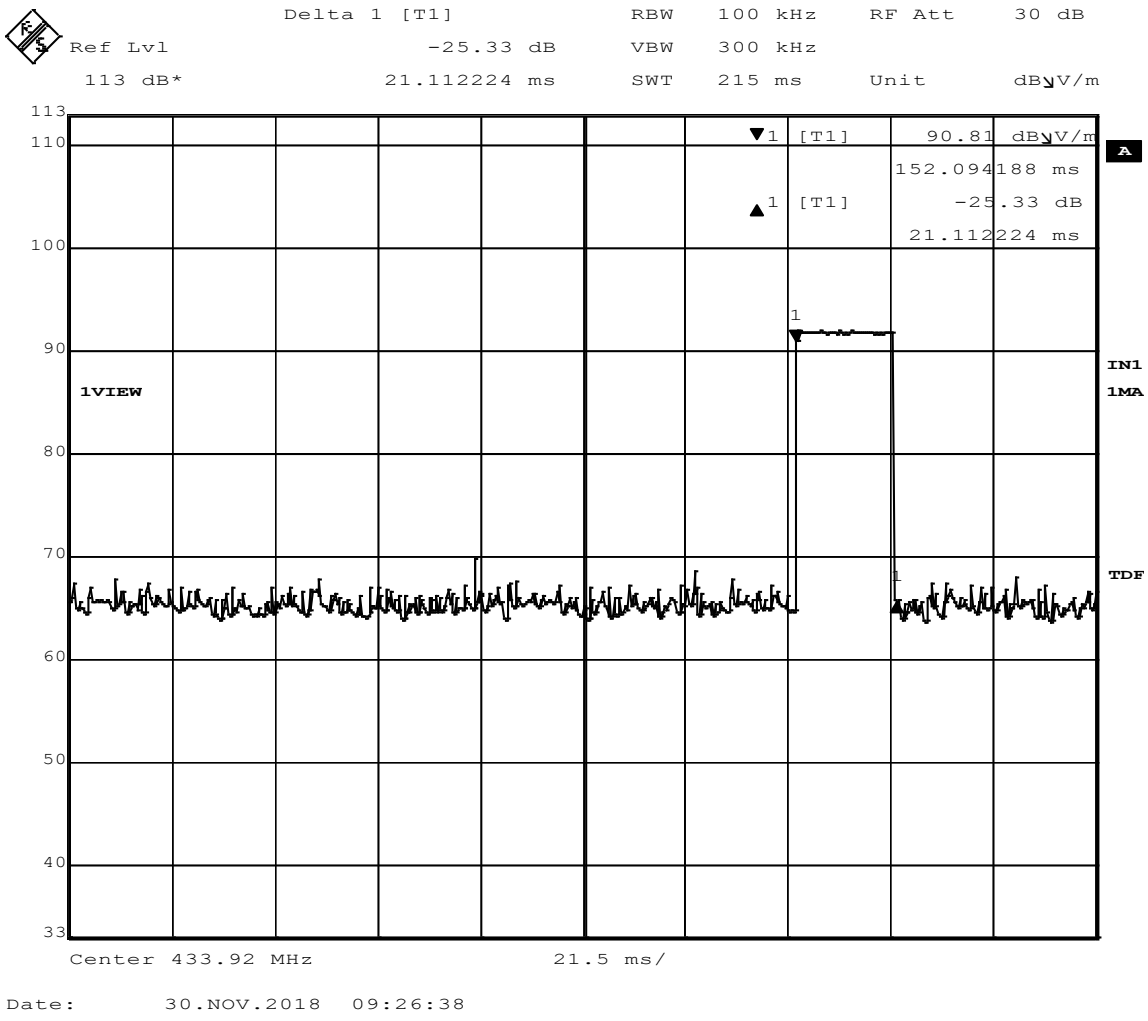


Figure 13 – Pulse Length Mode 4A – 20.2 ms, Non-Periodic Mode

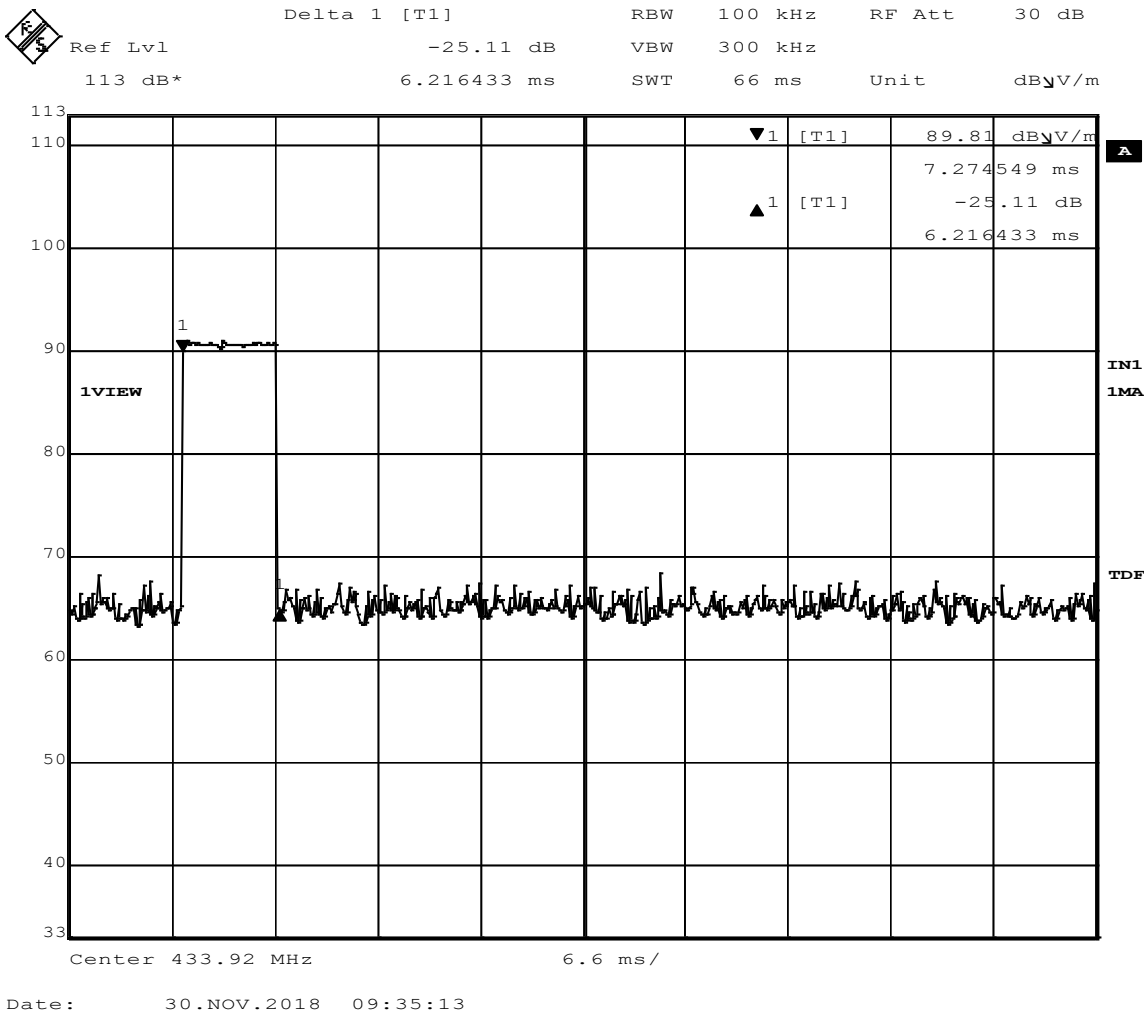


Figure 14 – Pulse Length Mode 1B – 6.5 ms, Periodic Mode

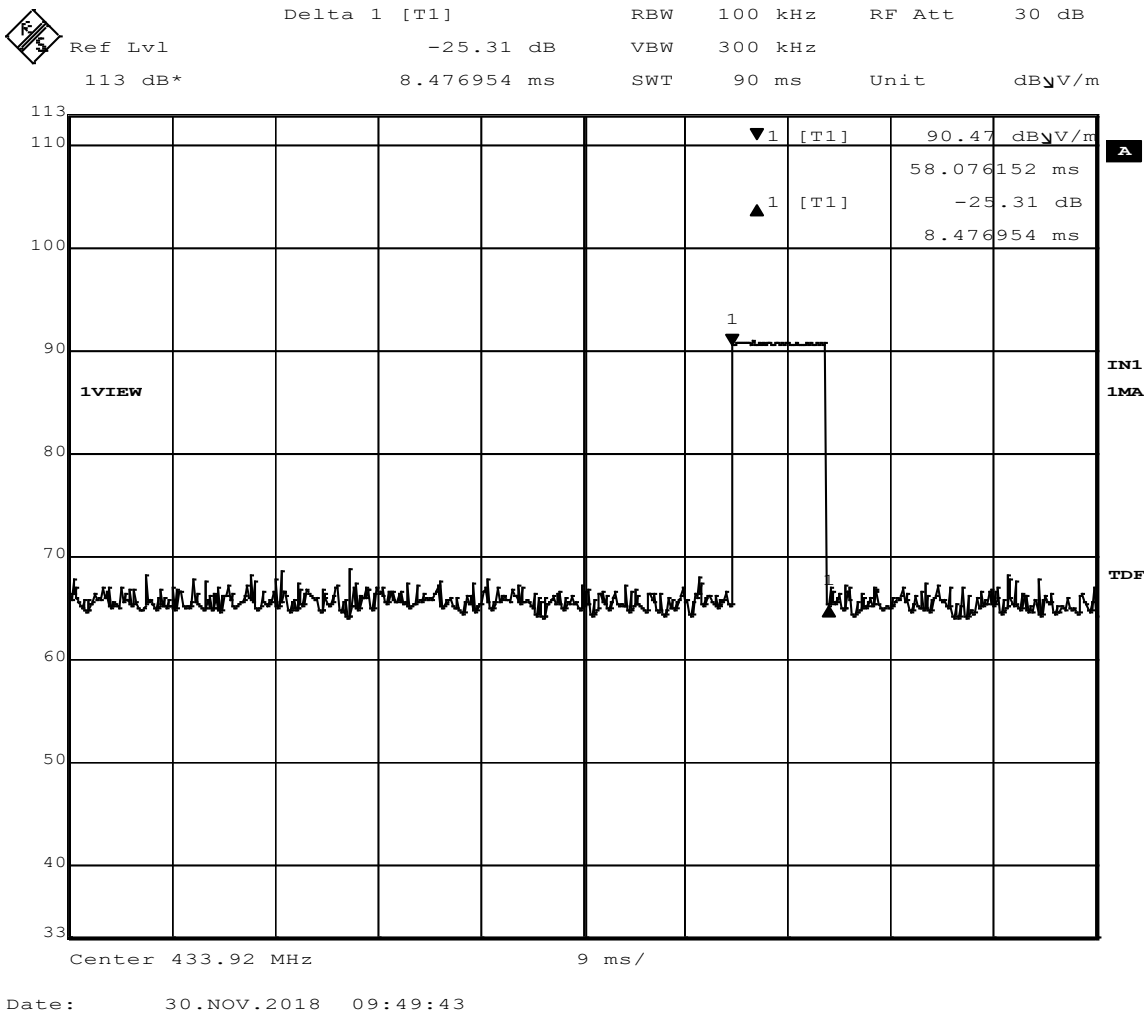


Figure 15 – Pulse Length Mode 1B – 8.3 ms, Periodic Mode

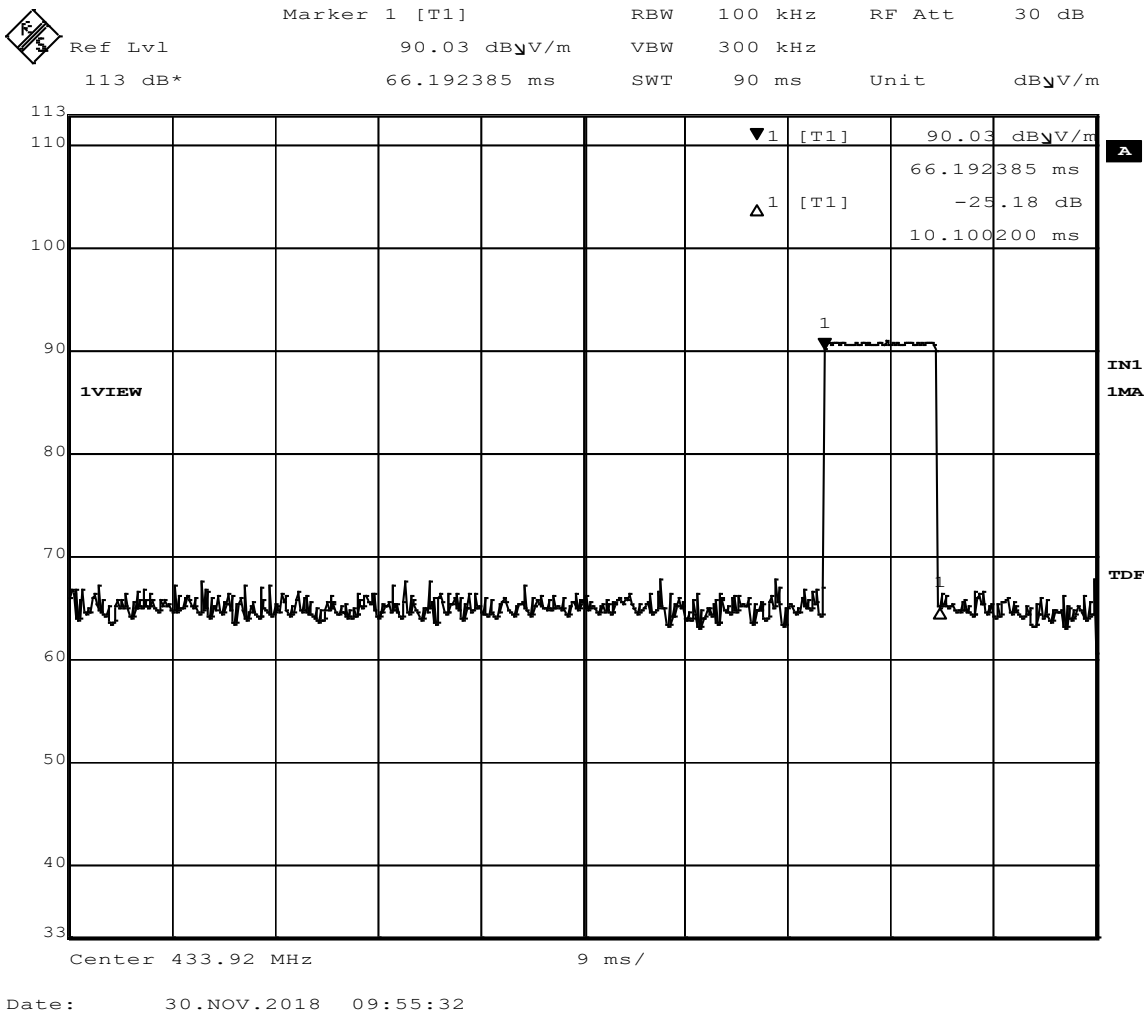


Figure 16 – Pulse Length Mode 1B – 9.7 ms, Periodic Mode

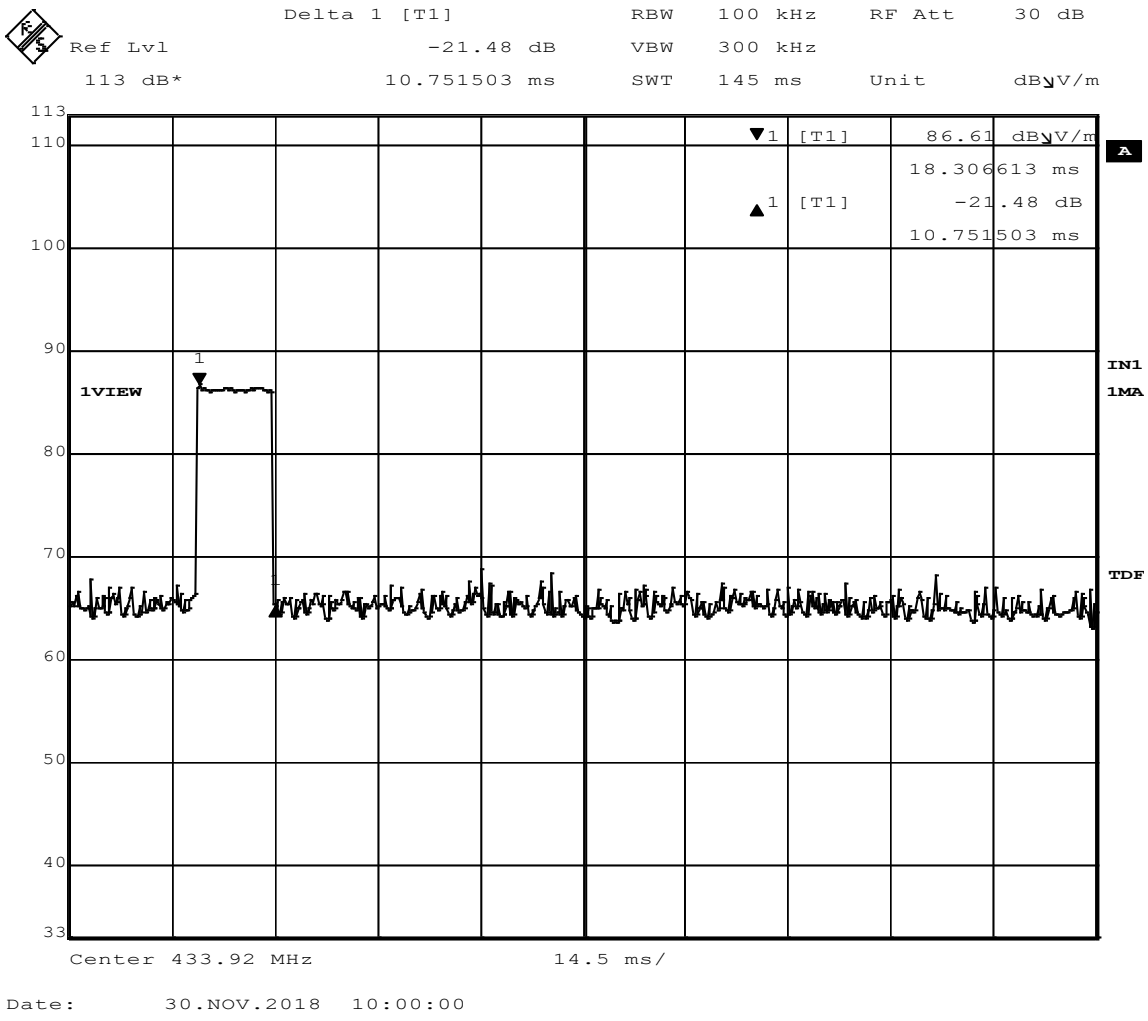


Figure 17 – Pulse Length Mode 1B – 10.5 ms, Periodic Mode

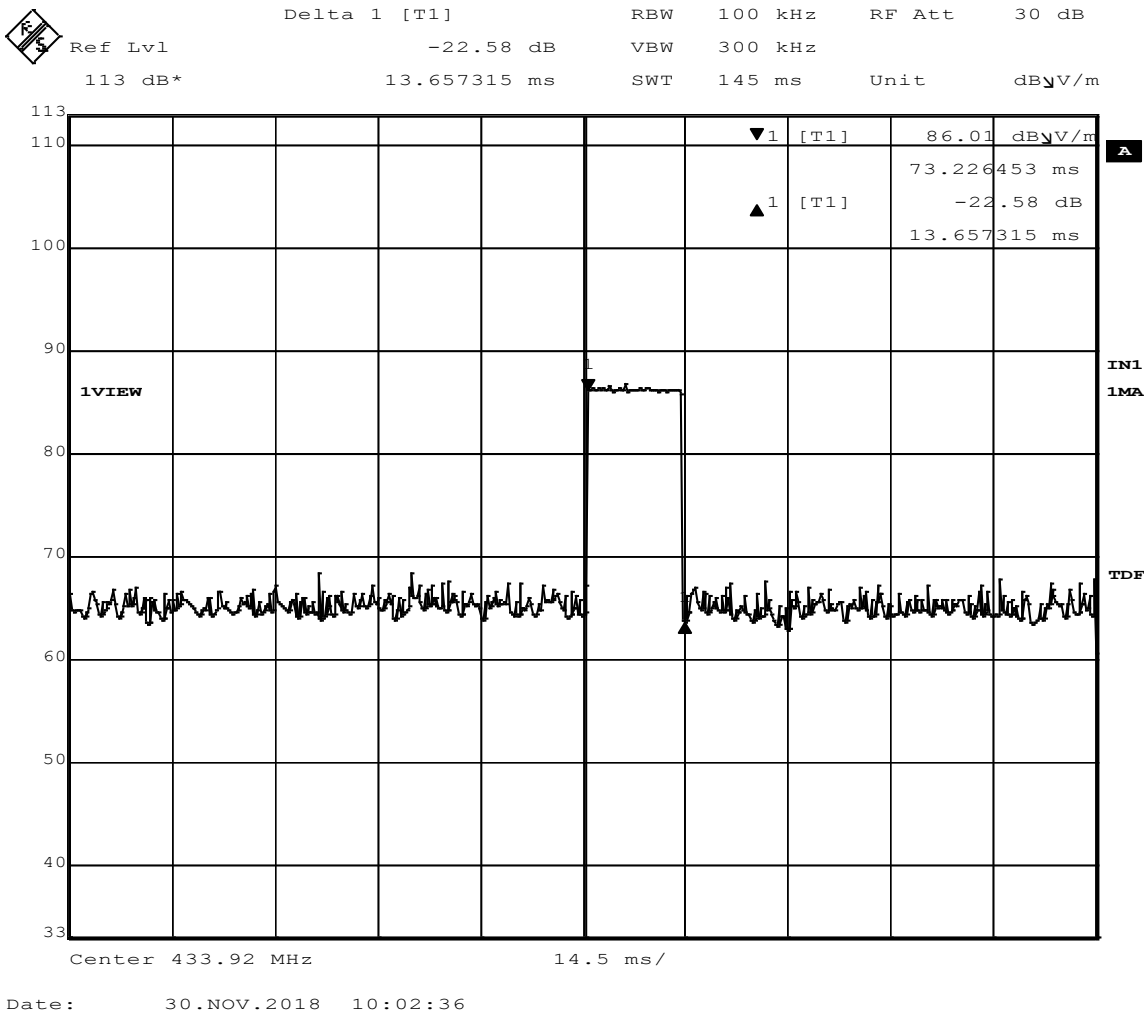


Figure 18 – Pulse Length Mode 2B – 13 ms, Periodic Mode

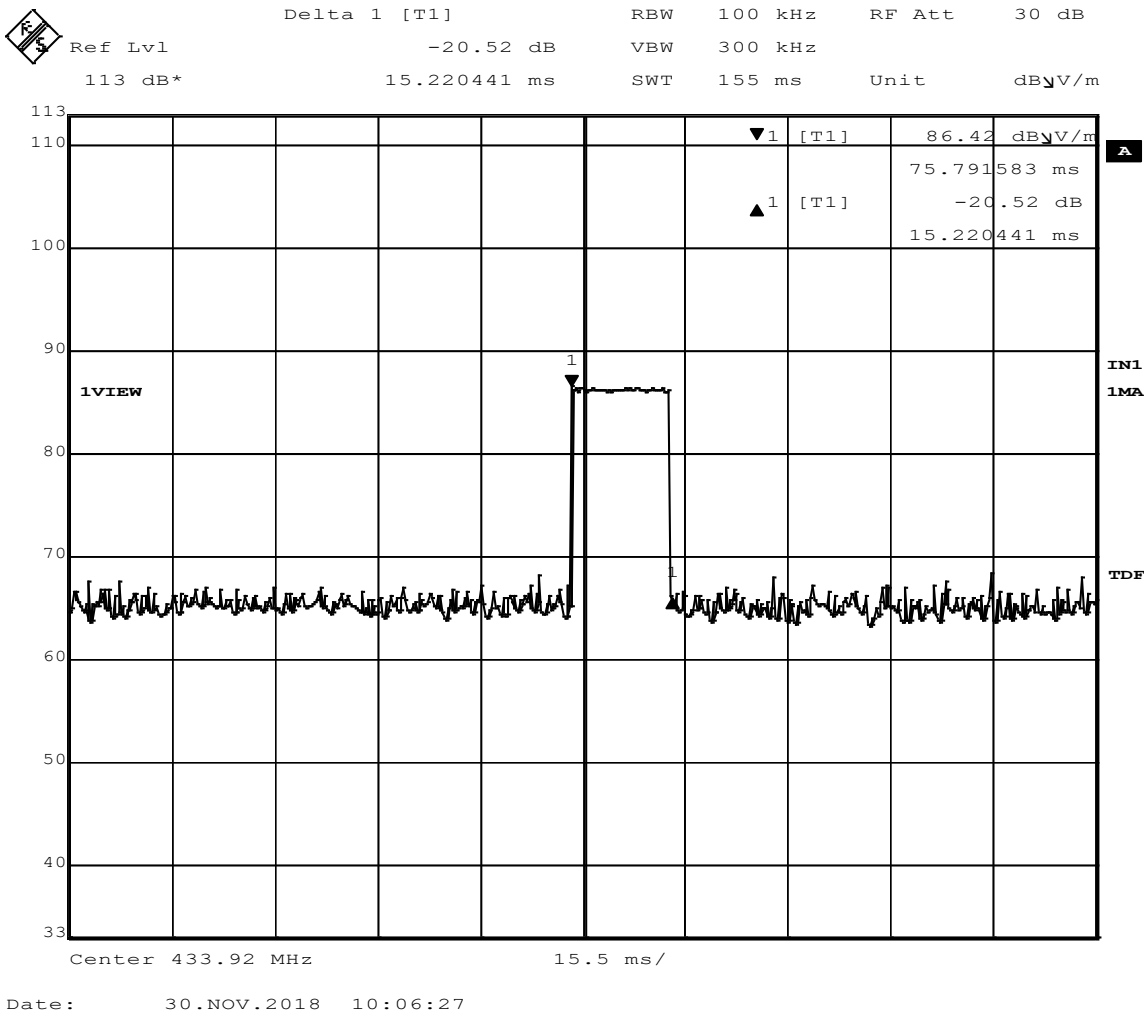


Figure 19 – Pulse Length Mode 2B – 14.7 ms, Periodic Mode

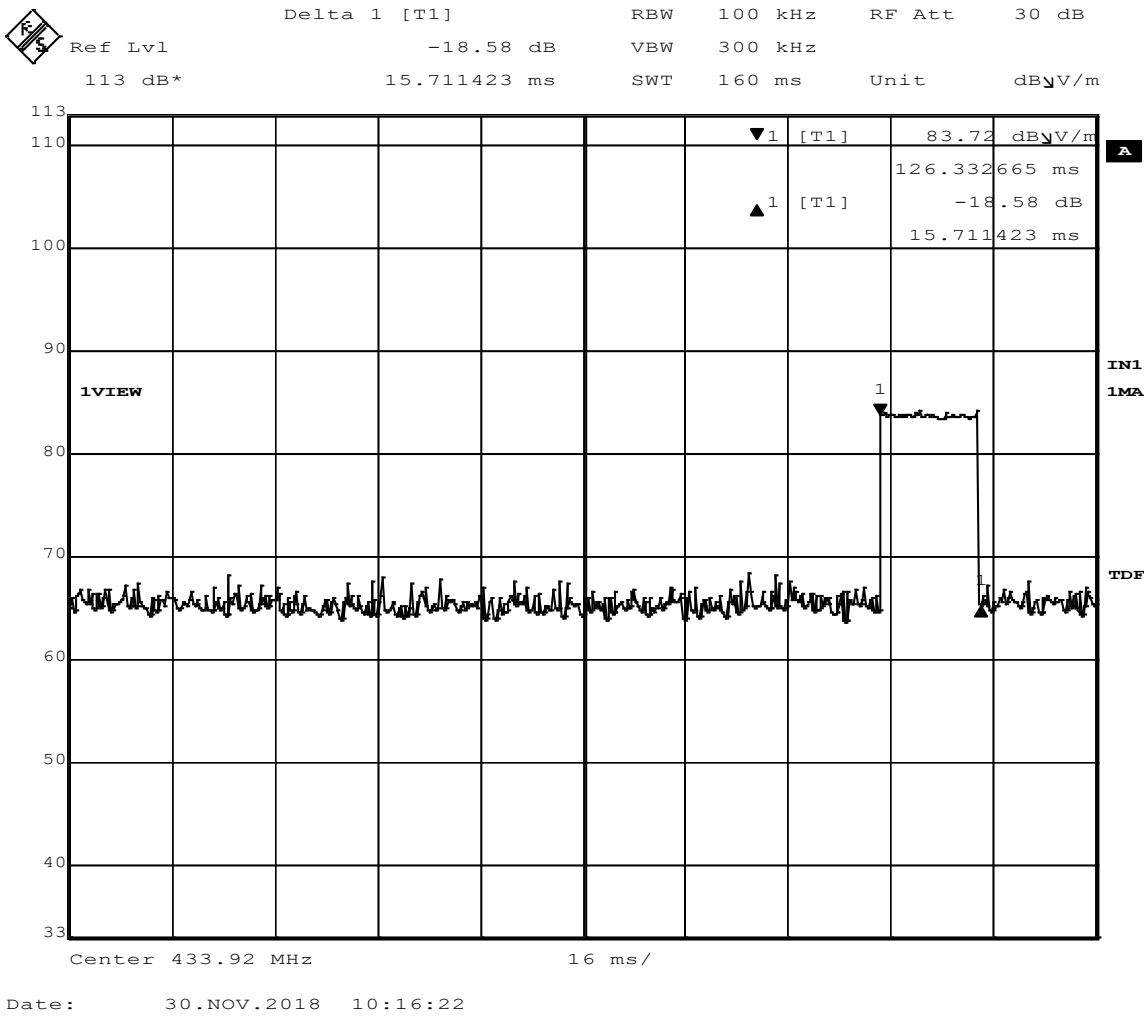


Figure 20 – Pulse Length Mode 2B – 15.4 ms, Periodic Mode

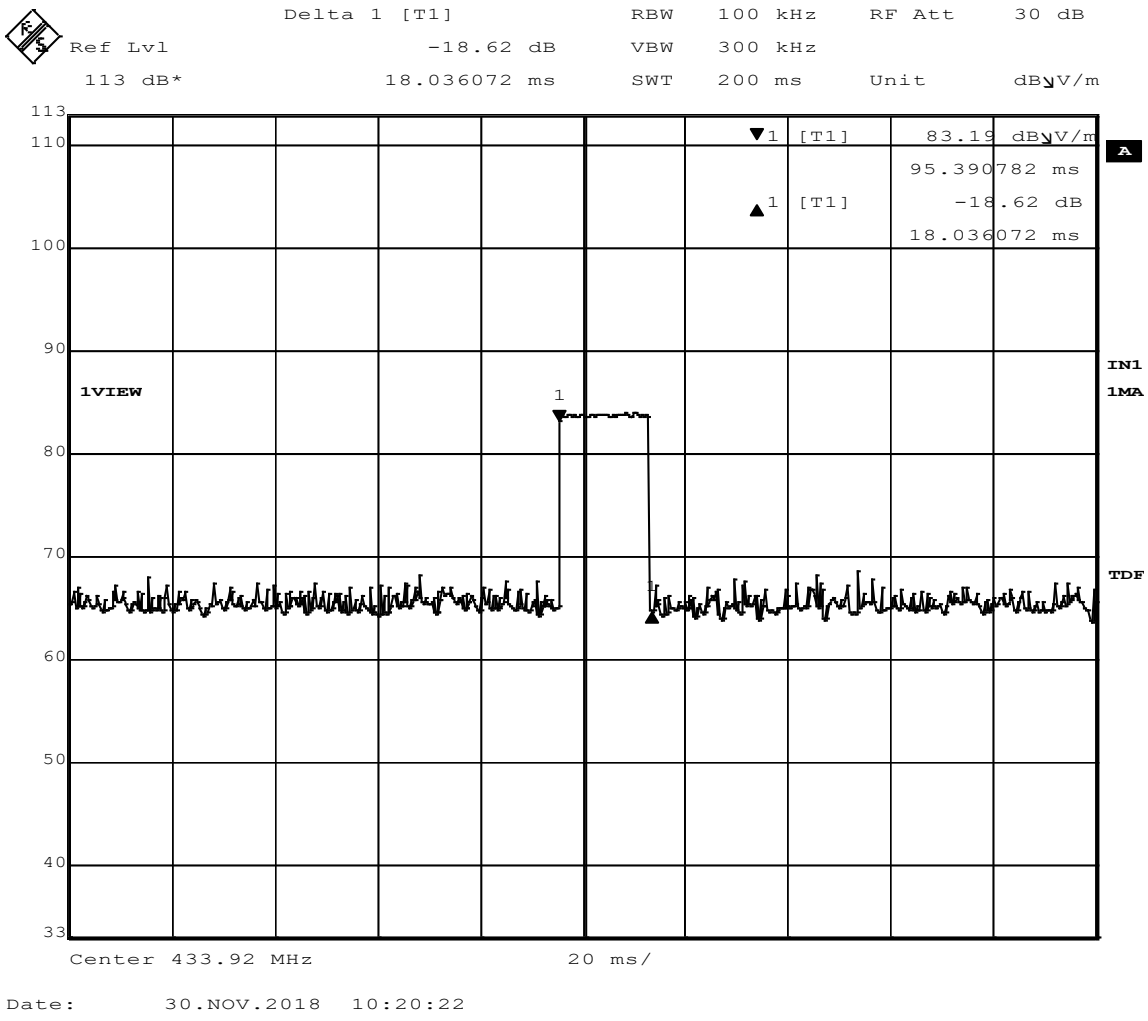


Figure 21 – Pulse Length Mode 3B – 17.4 ms, Periodic Mode

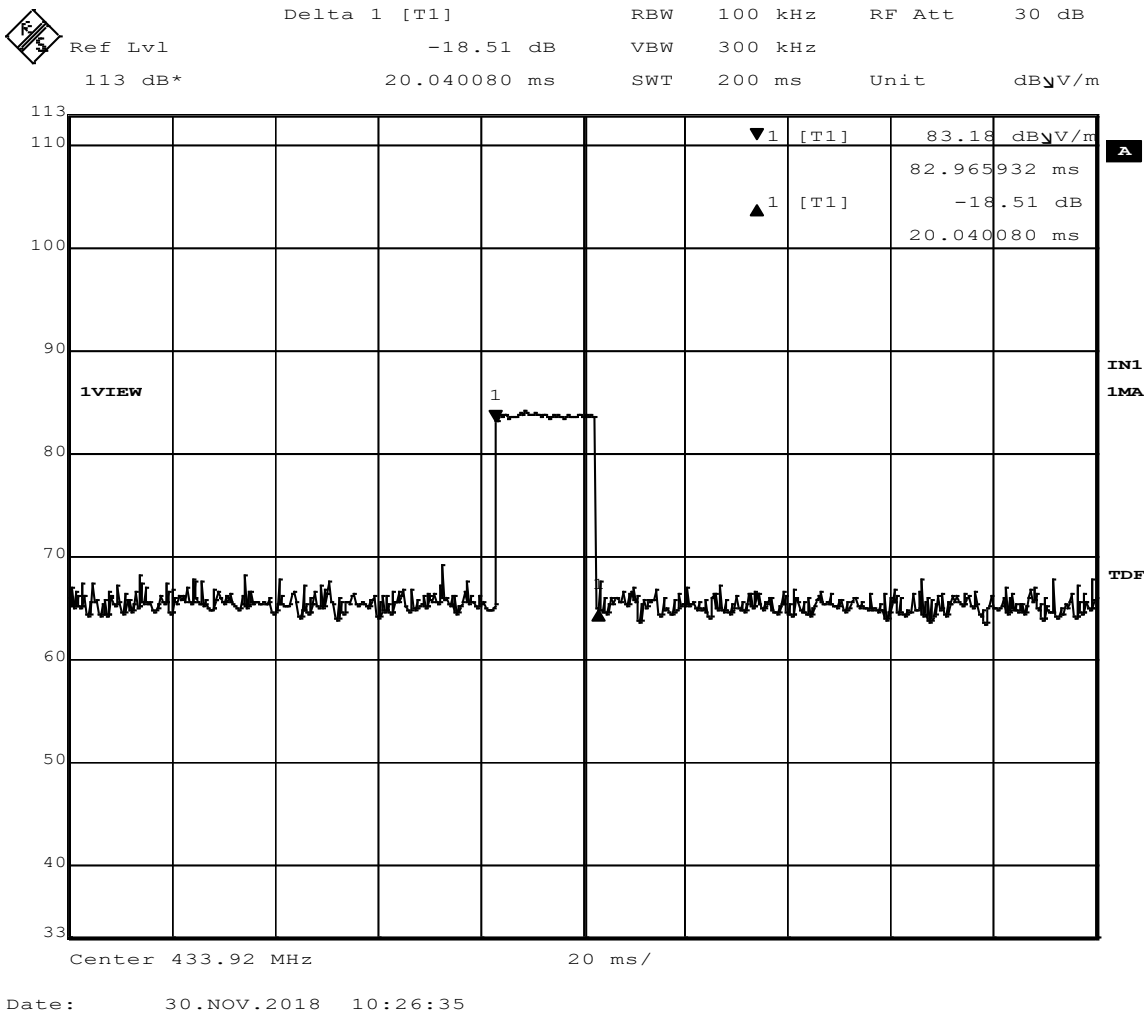


Figure 22 – Pulse Length Mode 3B – 19.7 ms, Periodic Mode

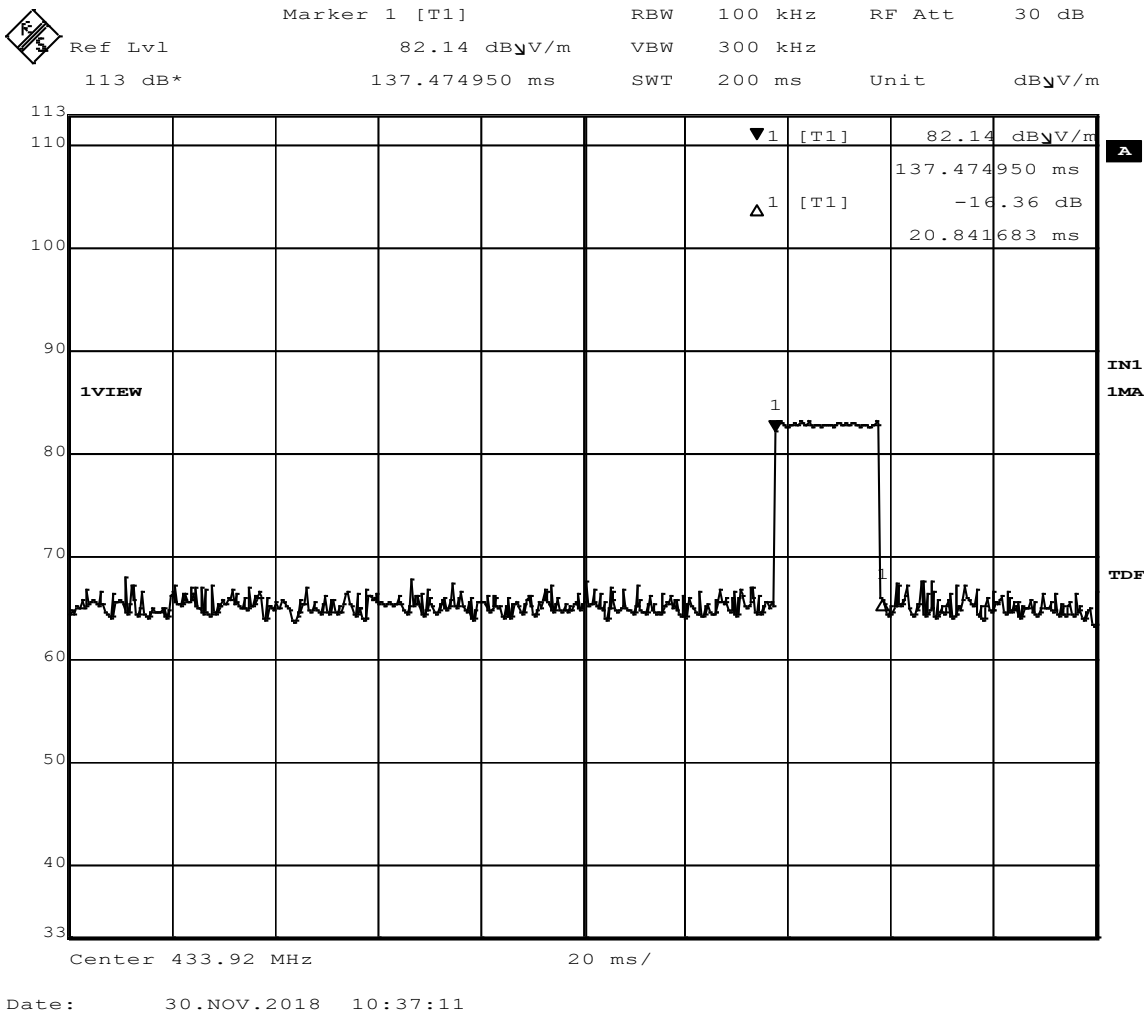


Figure 23 – Pulse Length Mode 4B – 20.2 ms, Periodic Mode

Non-periodic Mode, Duty cycle and power Measurements

Duty cycle			Message Length	Peak Level	Average Level	Average Limit	Margin
Mode	Actual	Intended	Bytes	dBµV/m	dBµV/m	dBµV/m	dB
1A	6.40	6.00	10	97.77	77.77	80.83	3.06
1A	8.10	8.30	18	97.76	77.76	80.83	3.07
1A	9.80	9.70	23	97.83	77.83	80.83	3.00
2A	10.60	10.50	26	94.99	75.50	80.83	5.33
2A	12.93	13.00	34	94.95	77.18	80.83	3.65
2A	14.42	14.70	41	94.88	78.06	80.83	2.77
2A	15.33	15.40	43	91.53	75.24	80.83	5.59
3A	17.31	17.40	50	91.53	76.30	80.83	4.53
3A	20.13	19.70	58	91.41	77.49	80.83	3.34
4A	21.11	20.20	60	92.19	78.68	80.83	2.15

Periodic Mode, Duty cycle and power Measurements

	Duty cycle		Message Length	Peak Level	Average Level	Average Limit	Margin
Mode	Actual	Intended	Bytes	dBµV/m	dBµV/m	dBµV/m	dB
1B	6.21	6.00	10	91.10	71.10	72.87	1.77
1B	8.47	8.30	18	91.19	71.19	72.87	1.68
1B	10.10	9.70	23	91.03	71.12	72.87	1.75
1B	10.75	10.50	26	86.51	67.14	72.87	5.73
2B	13.65	13.00	34	86.63	69.33	72.87	3.54
2B	15.22	14.70	41	86.58	70.23	72.87	2.64
2B	15.71	15.40	43	84.08	68.00	72.87	4.87
3B	18.03	17.40	50	84.20	69.32	72.87	3.55
3B	20.04	19.70	58	84.18	70.22	72.87	2.65
4B	20.84	20.20	60	83.51	69.89	72.87	2.98

Example of averaging factor calculation:
Duty cycle = 10 %; Period = Maximum usable = 100 ms
Averaging Factor = 20*log(10/100) = -20 dB

4.3 Bandwidth

4.3.1 Limits of bandwidth measurements and test method

The 20 dB Band width must be less than 0.25% of center frequency. Test method used: C63.10: 2013 – 6.9.2

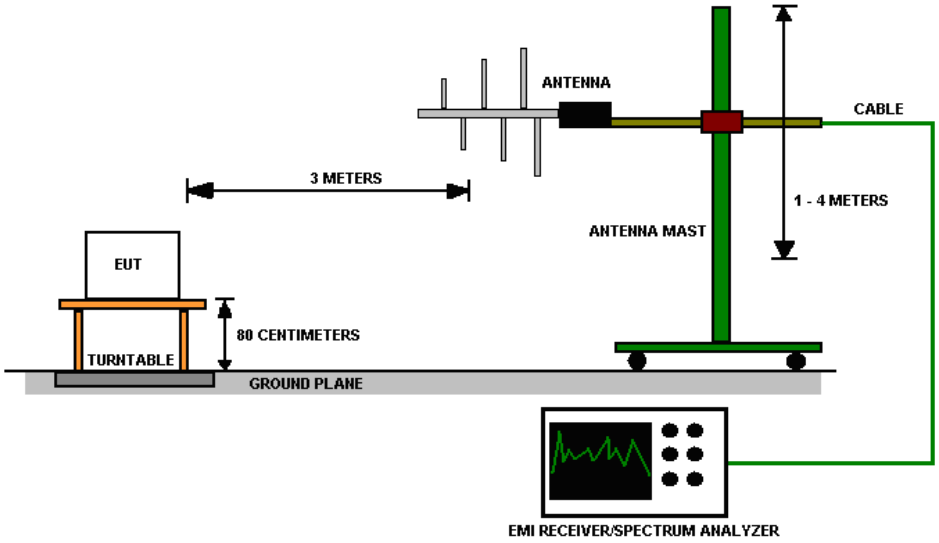
4.3.2 Test procedures

The bandwidth of the fundamental frequency was measured by spectrum analyzer with 10 kHz RBW and 30 kHz VBW (per C63.10: 2013 – 6.9.2). The 20 dB bandwidth is defined as the bandwidth corresponding to 20dB down from the maximum peak level. The frequencies where the measurements were 20 dB below the maximum peak were marked. The bandwidth between these frequencies was recorded as 20 dB bandwidth.

4.3.3 Deviations from test standard

No deviation.

4.3.4 Test setup



4.3.5 EUT operating conditions

See section 2.6.

4.3.6 Test results

CHANNEL	CHANNEL FREQUENCY (MHz)	20 dB BW / OBW LIMIT (kHz)	20 dB/ OBW BW (kHz)	RESULT	Mode
1	433.92	108500	105.21	PASS	Non-Periodic
1	433.92	108500	105.71	PASS	Periodic
1	433.92	108500	102.20	Pass	Occupied Bandwidth in Non-Periodic mode

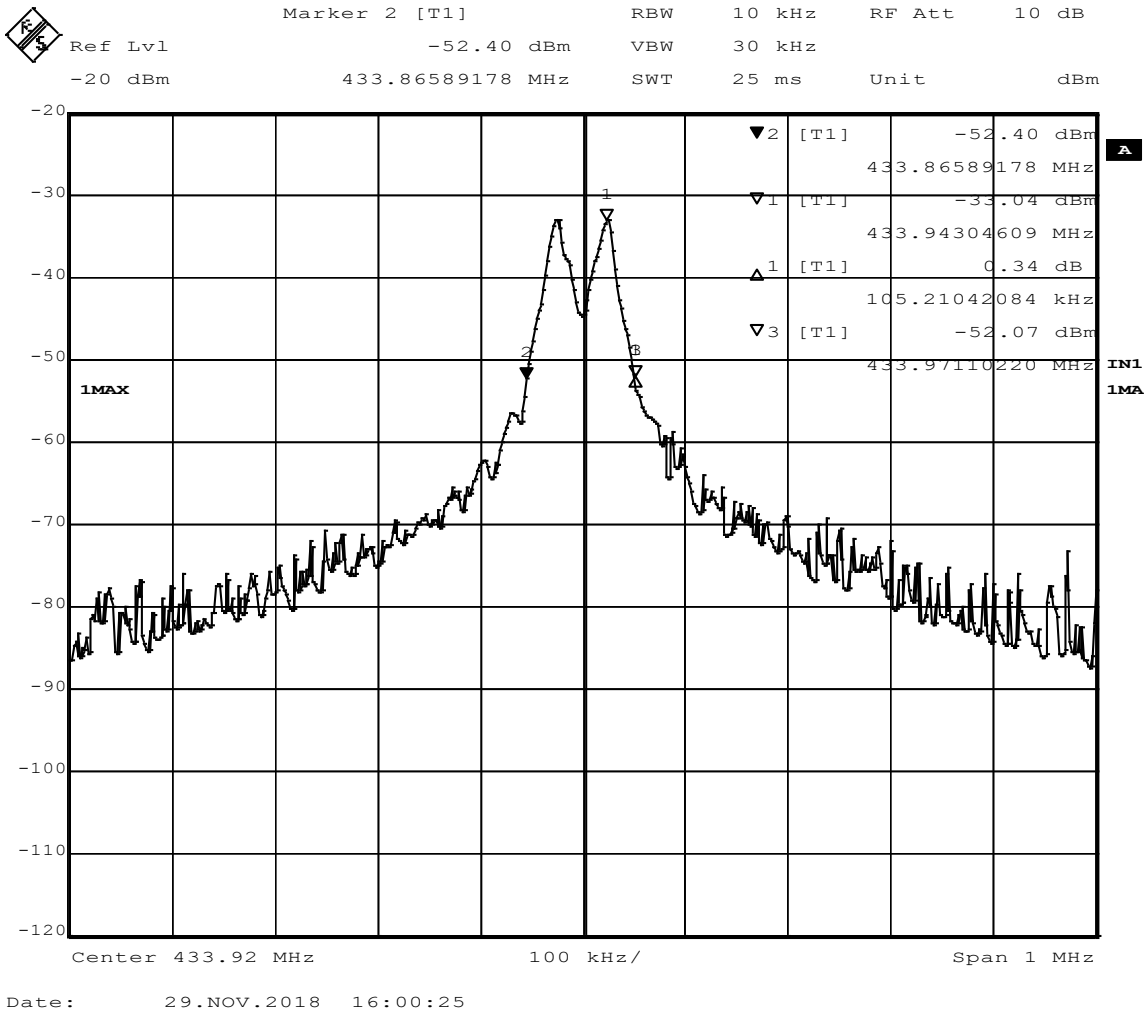


Figure 24 – 20 dB Bandwidth, Non-Periodic Mode

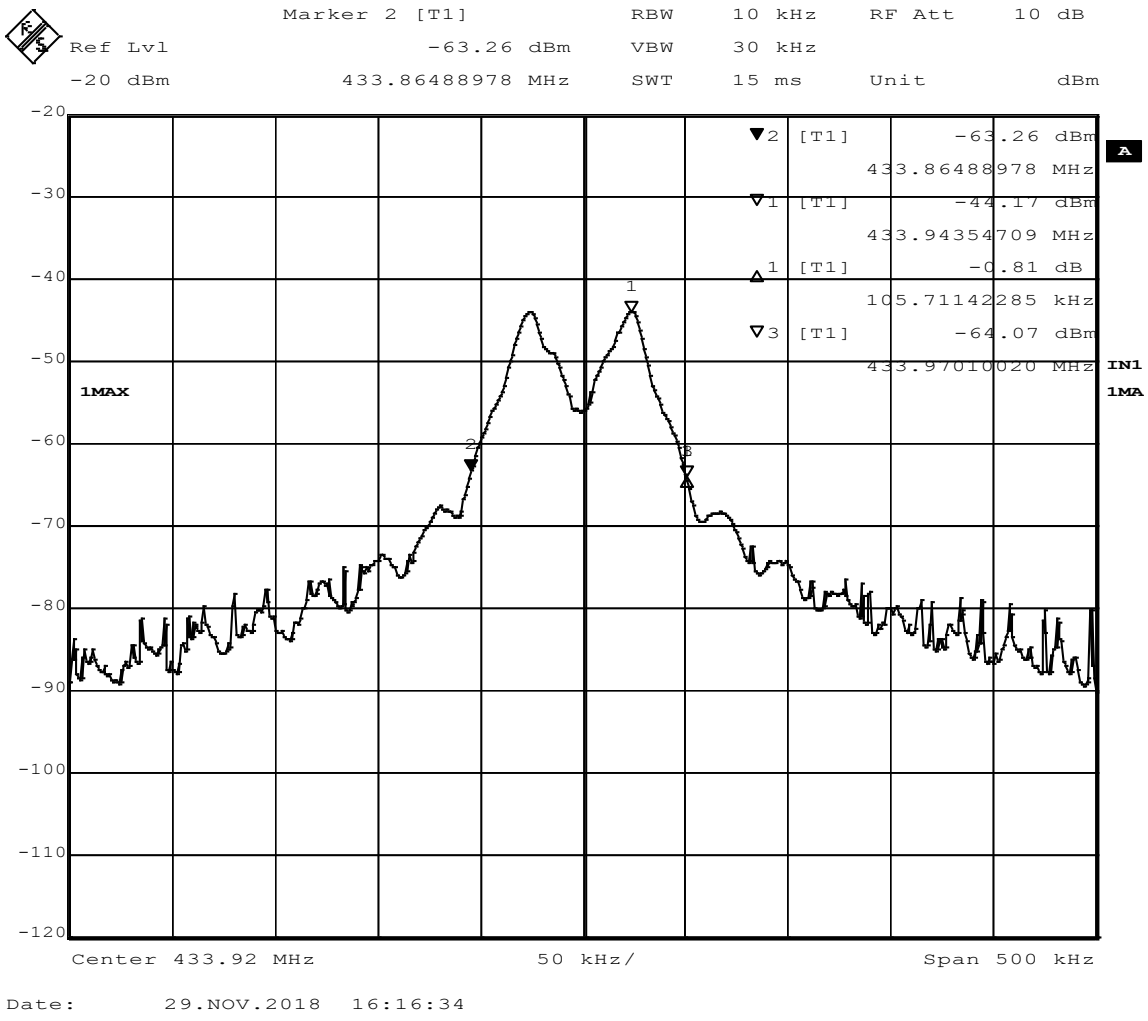


Figure 25 – 20 dB Bandwidth, Periodic Mode

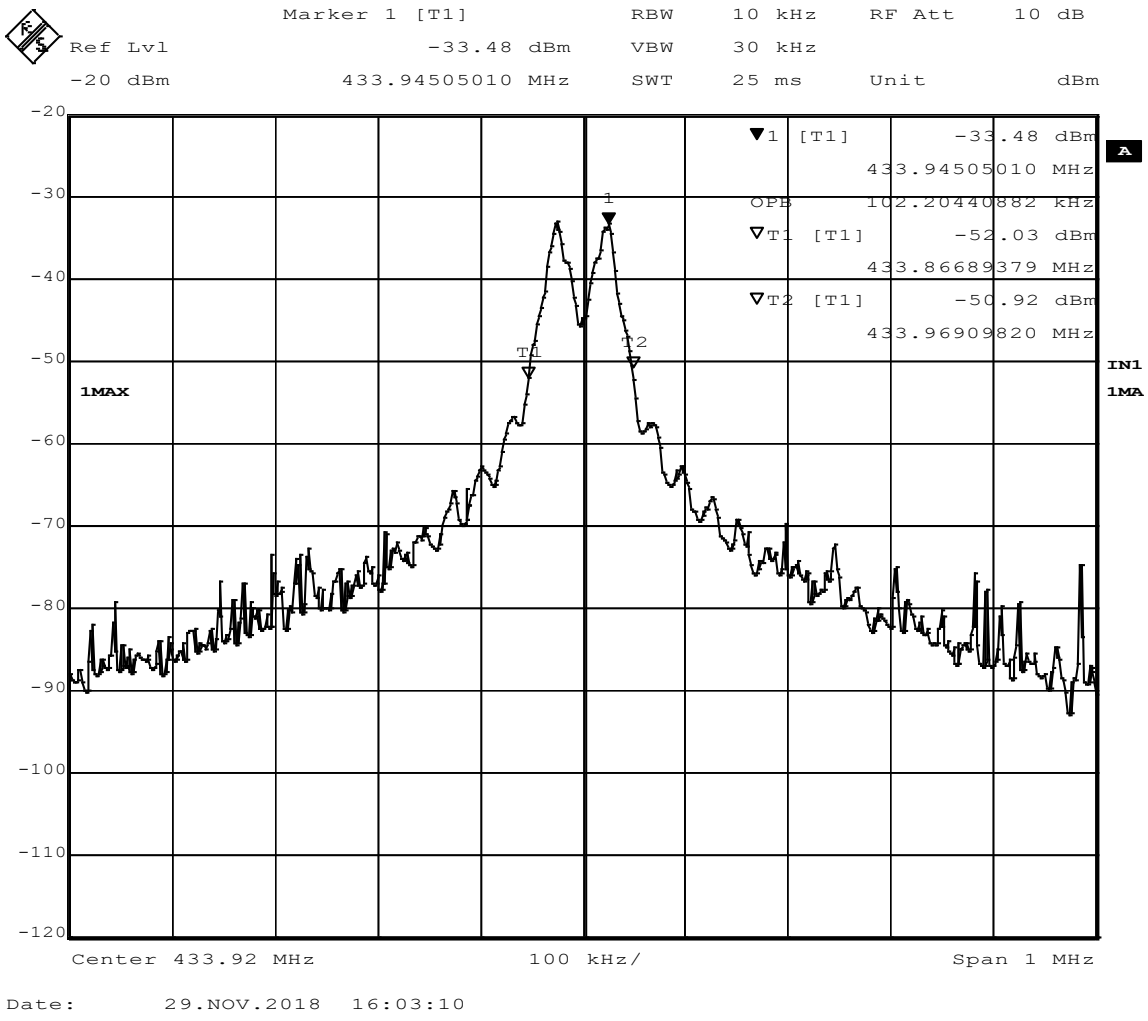


Figure 26 – Occupied Bandwidth, Non- Periodic Mode

4.4 Maximum peak output power

4.4.1 Limits of power measurements

N/A – peak limits are specified in field strength for Part 15.231, as found in Section 4.2. The data is presented for informational purposes only.

4.4.2 Test procedures

1. The EUT was placed in the maximum configuration as found in the measurements in section 4.2.

2. The resolution bandwidth was set to 1MHz and the video bandwidth was set to 3MHz to capture the maximum amount of signal. The analyzer used a peak detector in max hold mode. This represented the maximum output power in EIRP.

4.4.3 Deviations from test standard

No deviation.

4.4.4 Test setup

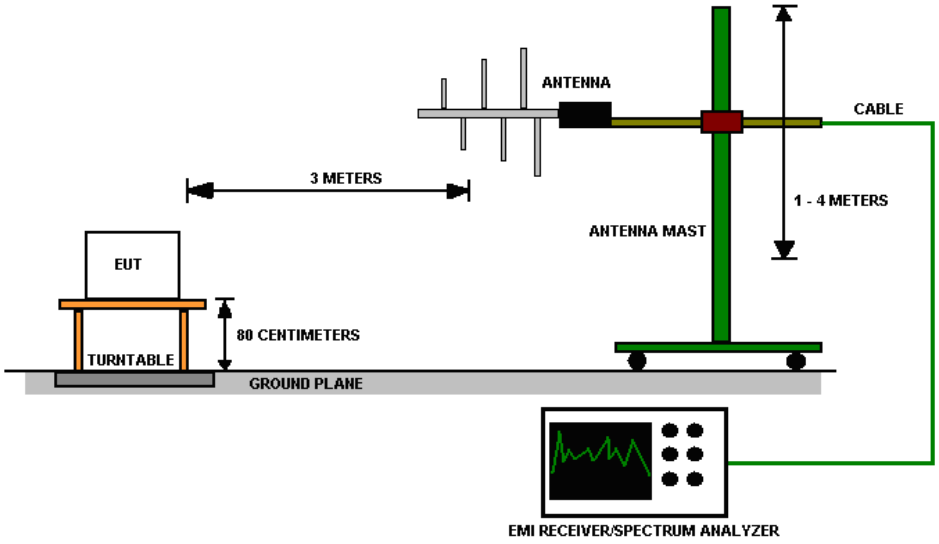


Figure 27 – Power Measurement Test Setup

4.4.5 EUT operating conditions

See Section 2.6

4.4.6 Test results

Maximum peak output power

CHANNEL	CHANNEL FREQUENCY (MHz)	EIRP PEAK POWER OUTPUT (dBm)	PEAK POWER LIMIT (dBm)	RESULT	Mode
1	433.92	-0.56	N/A*	PASS	Non-Periodic
1	433.92	-11.62	N/A*	PASS	Periodic

Antenna Factor = 17.00; Cable Factor = 3.30

Power measurement is included for informational purposes only and is not required in FCC Part 15.231 or RSS-210.

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

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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) 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

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
Emissions limits, radiated	30MHz - 1GHz	±3.82 dB
Emissions limits, radiated	1GHz - 18GHz	±4.44 dB
Emissions limits, conducted	30MHz – 18GHz	±3.30 dB
Power Limits	9kHz – 18GHz	±1.0 dB
Frequency Tolerance	9kHz – 18GHz	±5 Hz

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