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Amended

Test Report

Includes NCEE Labs report R20141212-20-01A and its amendment in full

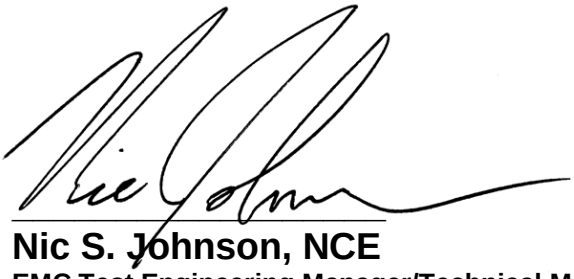
Client: **Appareo Systems**
1810 NDSU Research Circle N.
Fargo, ND 58102

EUT: **Gateway**

FCC ID: **2AETC-1535103**
IC: **12021A-1535103**

Test Report No.: **R20141212-20-01B**

Approved By:



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Date: **18 February 2016**

Total Pages: **32**

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 7.7.2 ANSI C63.10 Sec. 6.2	Conducted Emissions	N/A	N/A
FCC Part 15.209 RSS-210 Sec 2.6 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 I ANSI C63.10 Sec. 6.9	Minimum Bandwidth, Limit: 1085 MHz	Pass	Meets the requirement of the limit.
FCC Part 15.231 (a) RSS-210 Sec 2.6 ANSI C63.10 Sec. 6.3.3	Transmitter Radiated Emissions, Limit: Table 15.209	Pass	Meets the requirement of the limit.

1.1 Reason for Amendment

Section 2.4 was updated to clarify the use of the load box and to specify that all radios were operating.

Added timing plots for duty cycle measurements and calculations.

2.0 Description

2.1 Equipment under test

The Equipment Under Test (EUT) was the GW03 Gateway from Appareo Systems, LLC. The device functions as a wireless hub for Agricultural vehicles.

EUT Received Date: 20 October 2015
EUT Tested Date: 20 October 2015 - 19 November 2015

PRODUCT	GW03 Gateway
PART NUMBER	153510-000003
POWER INPUT	12 VDC/14 VDC
MODULATION TYPE	FSK
FREQUENCY RANGE	433.92 MHz
NUMBER OF CHANNELS	1
MAXIMUM OUTPUT POWER	2.54 dBm EIRP (continuous mode) -13.24 dBm EIRP (Periodic mode)
ANTENNA TYPE	External Antenna
SERIAL NUMBER OF TEST UNIT	B0009 (radiated emissions unit) B0001 (Duty cycle measurement unit)
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. This site has been fully described in previously submitted reports. Laboratory environmental conditions varied slightly throughout the tests:

Relative humidity of 22 ± 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 8, 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 tests under 1 GHz and 14 VDC for above 1 GHz measurements. It was tested by itself. The EUT was programmed by the manufacturer to transmit continually for testing purposes only.

Modifications to the unit: Manufacturer installed a copper plate on the back side of the unit after testing was completed. The fundamental did not deviate by 2 dB and harmonics were lower than original measured level. So the testing was not repeated and original test results were installed. Refer to Figure 1 to view the modification done on the unit.

The EUT was tested with antennas placed on a metal surface 10cm away from the EUT. The metal base was used because the antennas are required to be placed on a metal surface,

Antennas tested: HCEL-S2-016A-01 and HIRD-S2-0146A-01 from Hirschmann Car Communication, Inc.

A load box and laptop PC was placed on the floor of the turntable/ground plane. The load box was required to exercise the EUT. It was placed on the floor in an effort to minimize the effects from the load box as it would not be present in a typical installation. The cable required for the load box was not a standard type cable and could not easily be routed outside of the test chamber, so it was required to have the load box in the test field. The load box is intended to simulate the connections in an agricultural implement.

Figure 1 – Modifications done after testing (copper plate installed)

3.0 Test equipment used

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Rohde & Schwarz Test Receiver	ES126	100037	20 Jan 2015	20 Jan 2016
EMCO Biconilog Antenna	3142B	1654	26 Jan 2015	26 Jan 2016
EMCO Horn Antenna	3115	6416	14 Jan 2014	14 Jan 2016
Rohde & Schwarz Preamplifier	TS-PR18	3545700803	19 Nov 2014*	19 Nov 2015*
Trilithic High Pass Filter	6HC330	23042	19 Nov 2014*	19 Nov 2015*

*Internal characterization

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

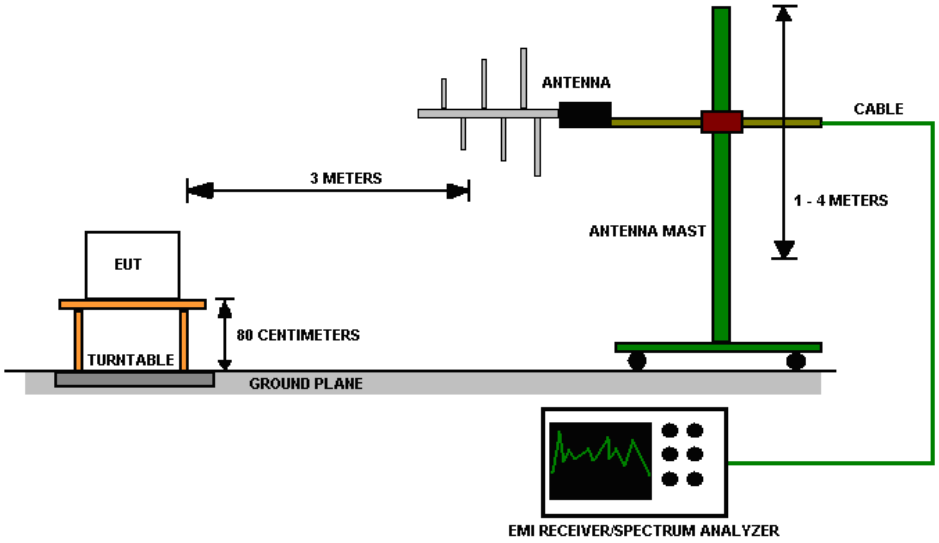


Figure 2 - Radiated Emissions Test Setup

For the actual test configuration, please refer to Appendix A for photographs of the test configuration.

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

EUT	Garrison Hub	Model	NCEETEST 1 (assigned)
MODE	Continuous Transmit	FREQUENCY RANGE	30 MHz – 5 GHz
INPUT POWER (SYSTEM)	12 VDC (30-1GHz)/ 14 VDC (1-5 GHz)	ORIENTATION	Horizontally Placed
ENVIRONMENTAL CONDITIONS	23 % ± 5% RH 25 ± 3ºC	TECHNICIAN	kvepuri

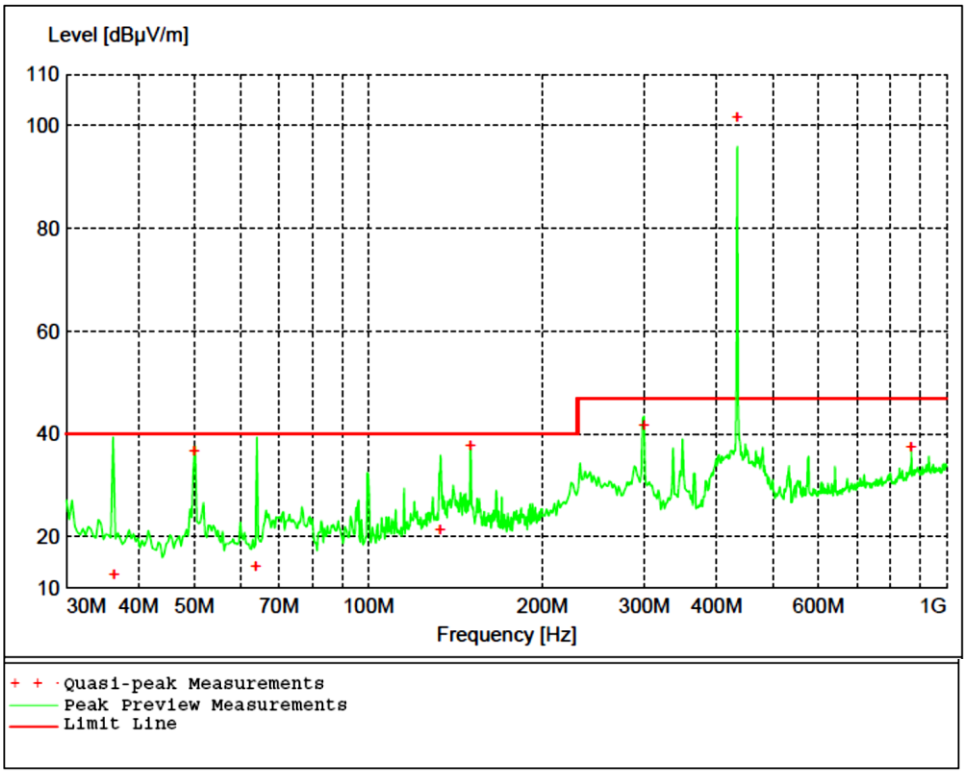


Figure 3 - Radiated Emissions Plot

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	
36.300000	12.73	40.00	27.30	324	206	HORI
49.980000	36.68	40.00	3.30	112	312	VERT
63.900000	14.12	40.00	25.90	280	89	VERT
133.020000	21.42	40.00	18.60	100	248	VERT
150.000000	37.71	40.00	2.30	100	243	VERT
299.760000	41.59	47.00	5.40	109	204	VERT
433.920000	101.59*	NA**	NA**	109	219	VERT
867.780000	37.42	47.00	9.60	173	278	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	
1297.200000	45.94	54.00	8.10	146	283	VERT
1742.200000	45.69	54.00	8.30	190	272	VERT
2169.400000	48.42	54.00	5.60	304	203	HORI
2603.400000	46.58	54.00	7.40	311	190	HORI
3037.600000	52.23	54.00	1.80	183	55	VERT
3471.400000	48.17	54.00	5.80	123	182	HORI
3905.400000	49.69	54.00	4.30	173	290	VERT
4339.200000	45.30	54.00	8.70	214	12	VERT

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

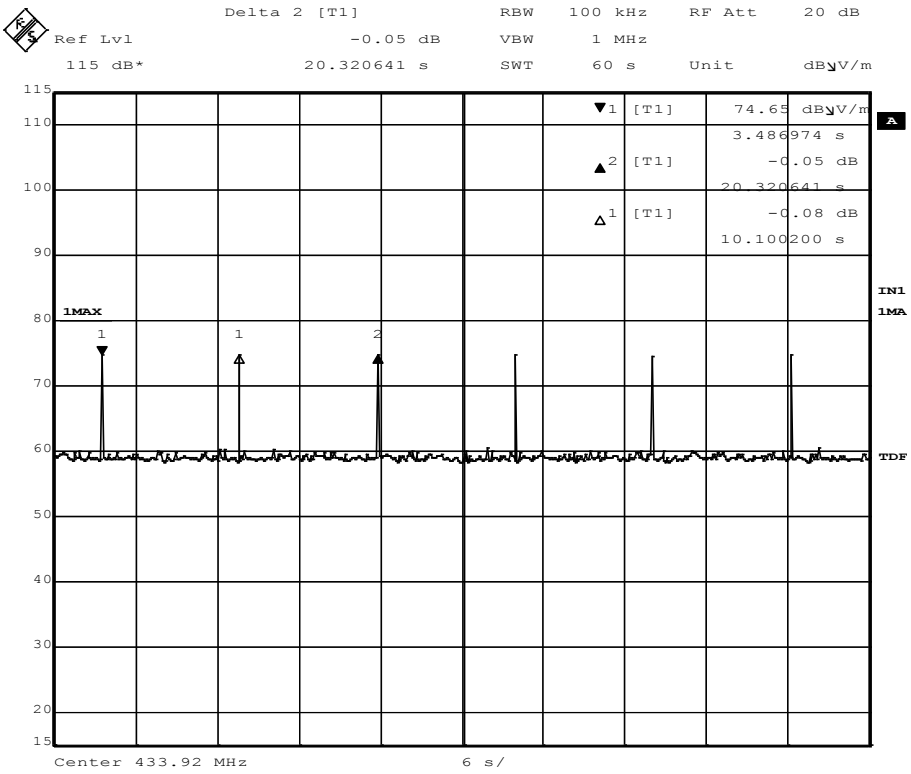


Figure 4 - Period = 10.1 s >100 ms

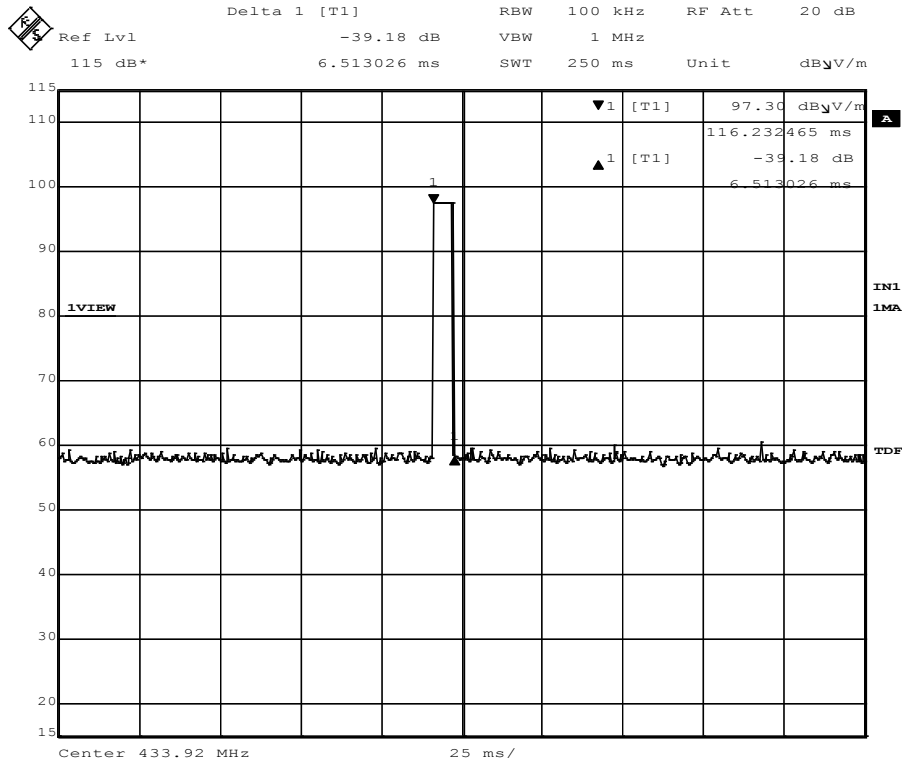


Figure 5 – Pulse Length Mode 1A – 6.5 ms, Non-Periodic Mode

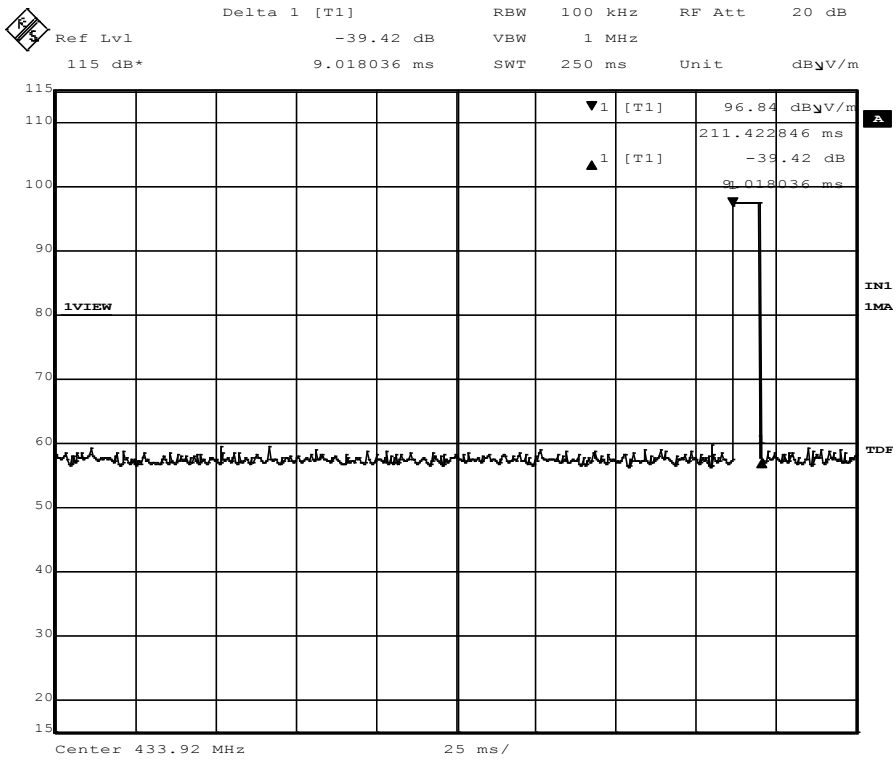


Figure 6 – Pulse Length Mode 1A – 8.3 ms, Non-Periodic Mode

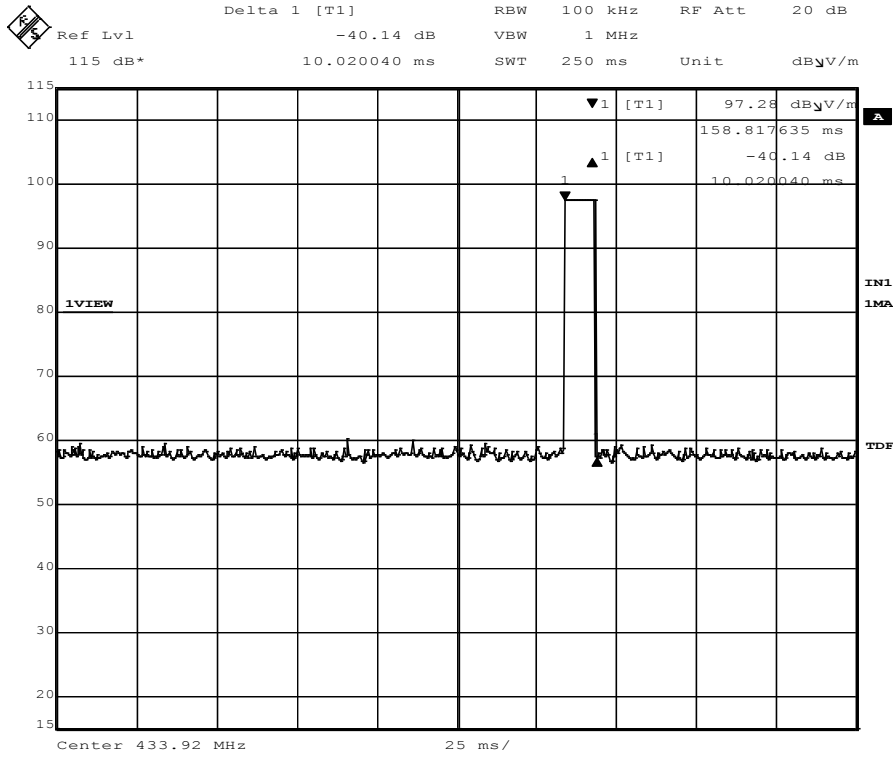


Figure 7 – Pulse Length Mode 1A – 9.7 ms, Non-Periodic Mode

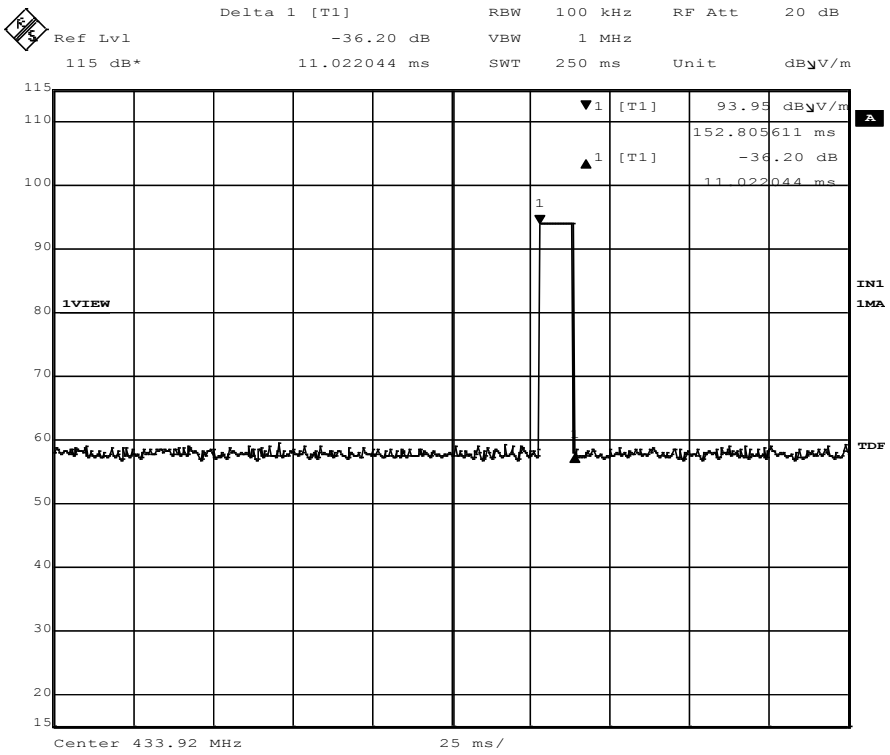


Figure 8 – Pulse Length Mode 1A – 10.5 ms, Non-Periodic Mode

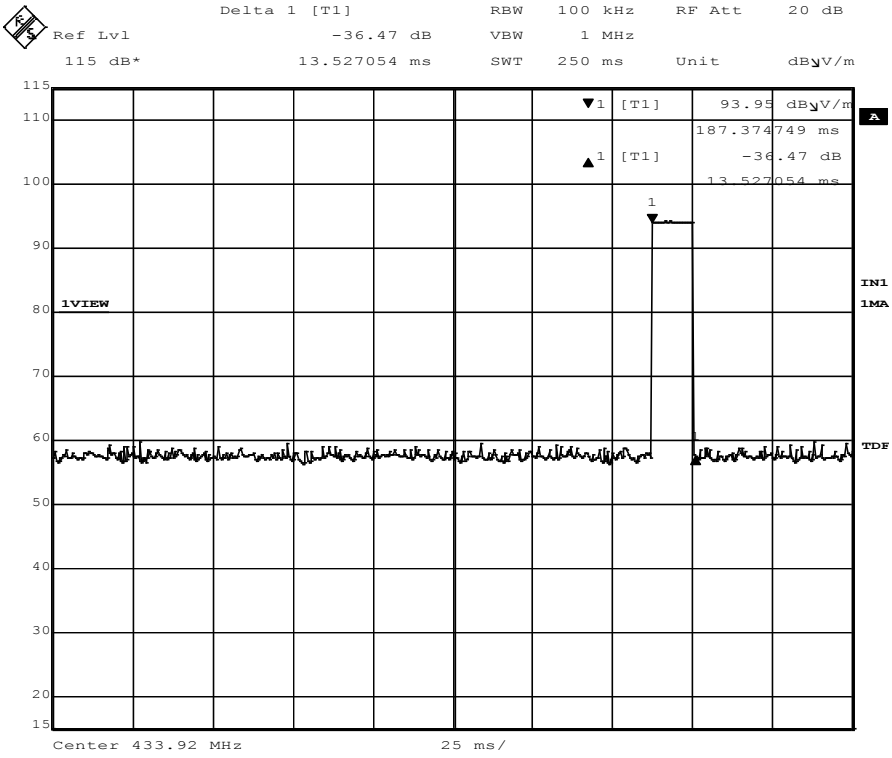


Figure 9 – Pulse Length Mode 2A – 13 ms, Non-Periodic Mode

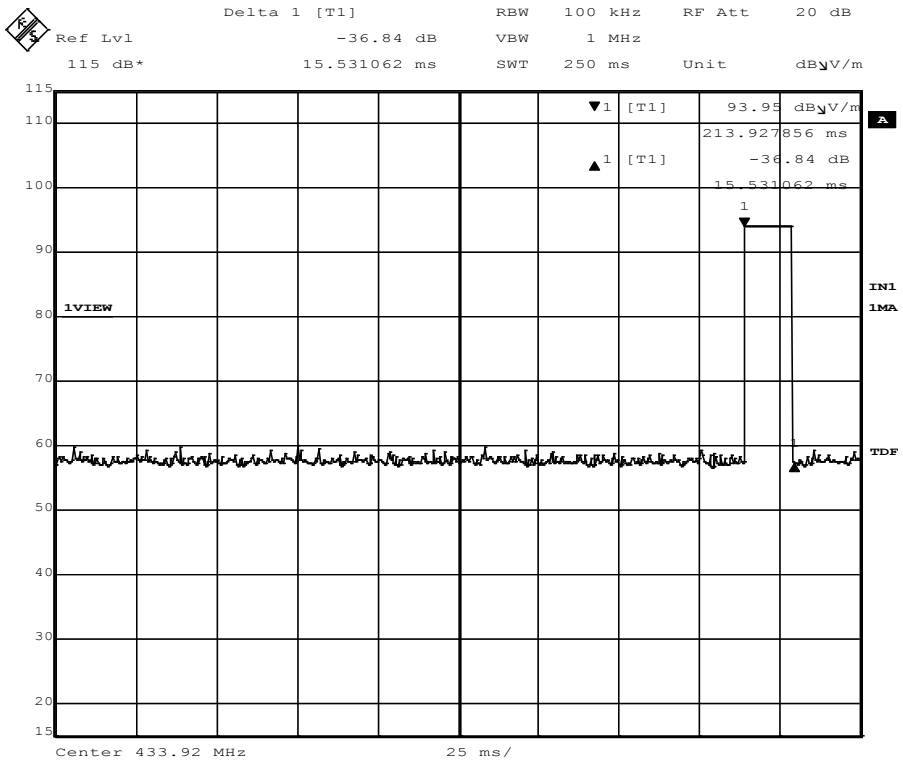


Figure 10 – Pulse Length Mode 2A – 14.7 ms, Non-Periodic Mode

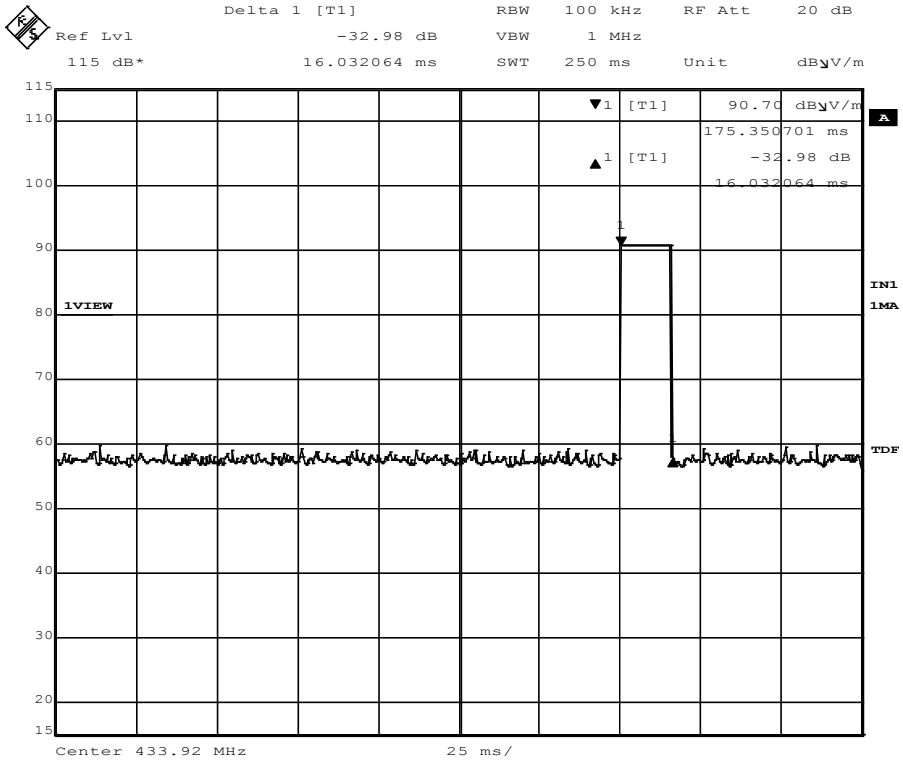


Figure 11 – Pulse Length Mode 2A – 15.4 ms, Non-Periodic Mode

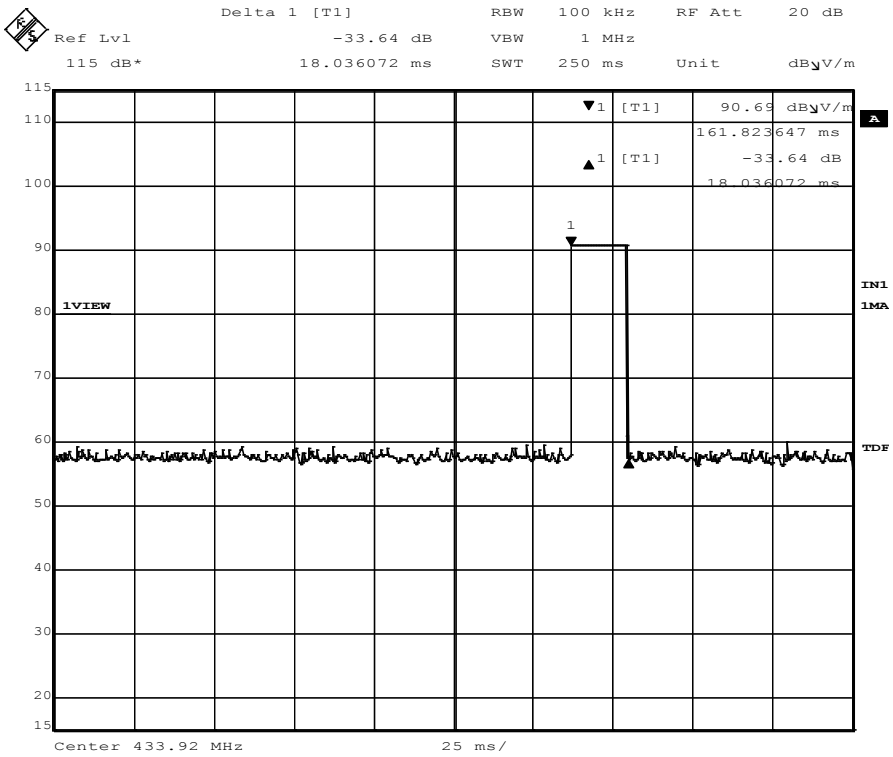


Figure 12 – Pulse Length Mode 3A – 17.4 ms, Non-Periodic Mode

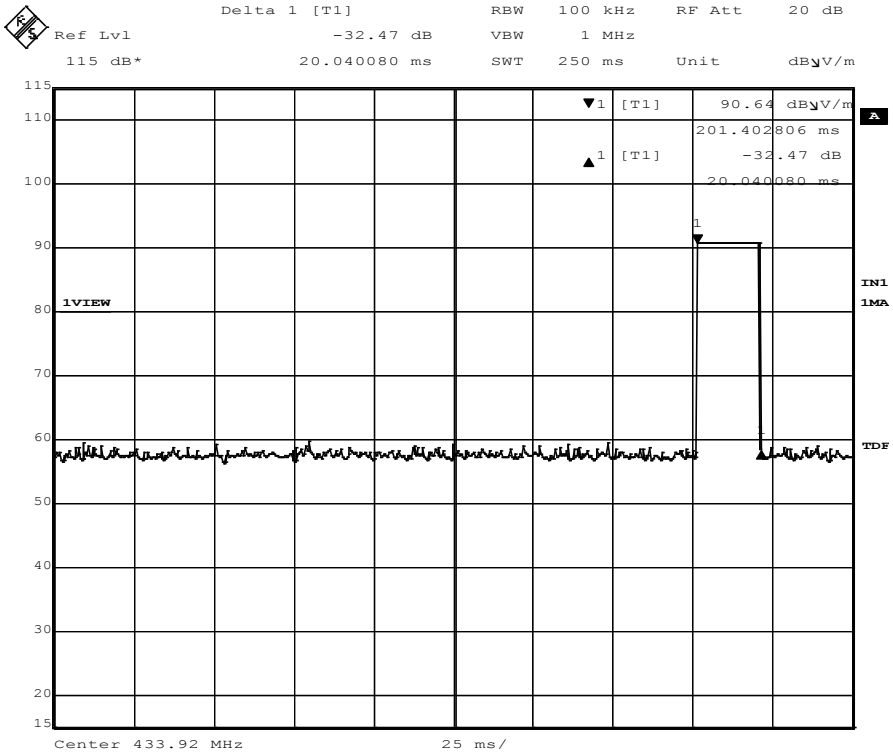


Figure 13 – Pulse Length Mode 3A – 19.7 ms, Non-Periodic Mode

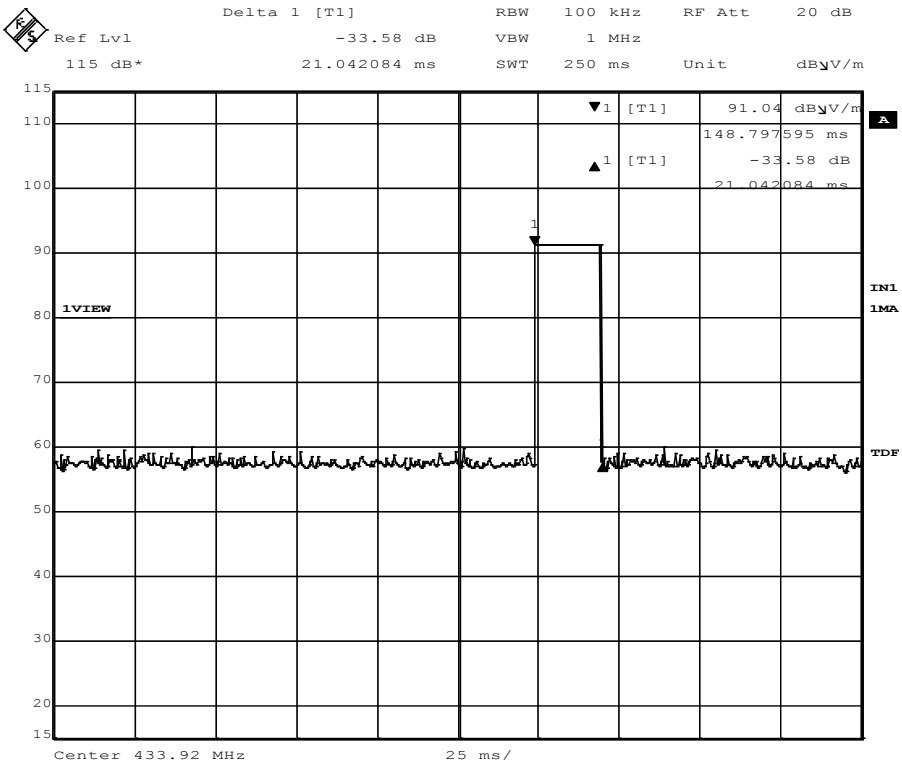


Figure 14 – Pulse Length Mode 3A – 20.2 ms, Non-Periodic Mode

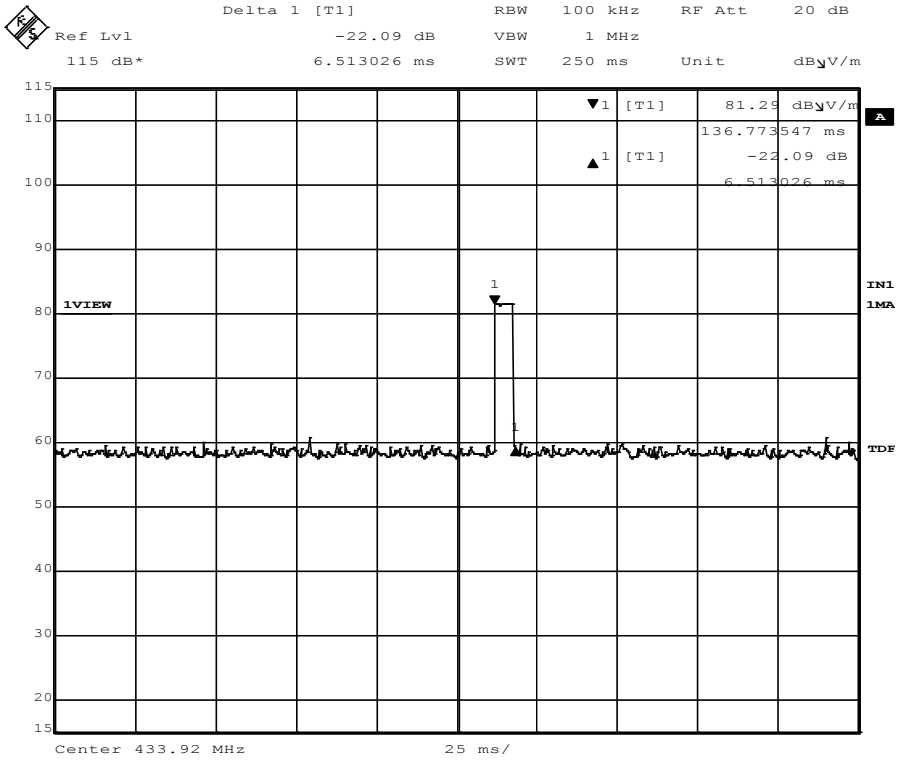


Figure 15 – Pulse Length Mode 1B – 6.5 ms, Periodic Mode

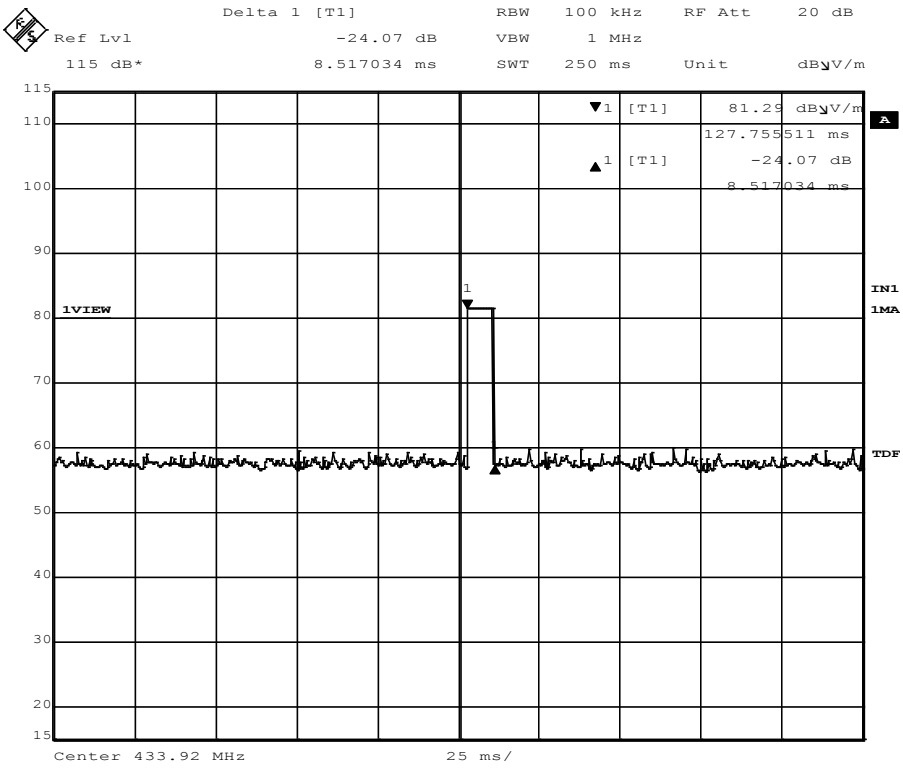


Figure 16 – Pulse Length Mode 1B – 8.3 ms, Periodic Mode

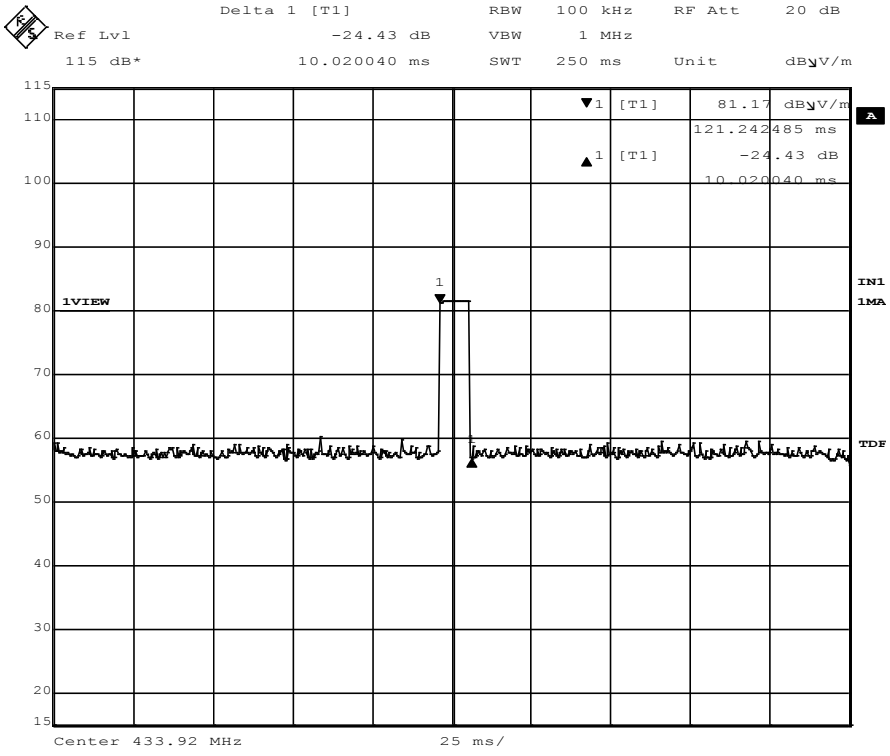


Figure 17 – Pulse Length Mode 1B – 9.7 ms, Periodic Mode

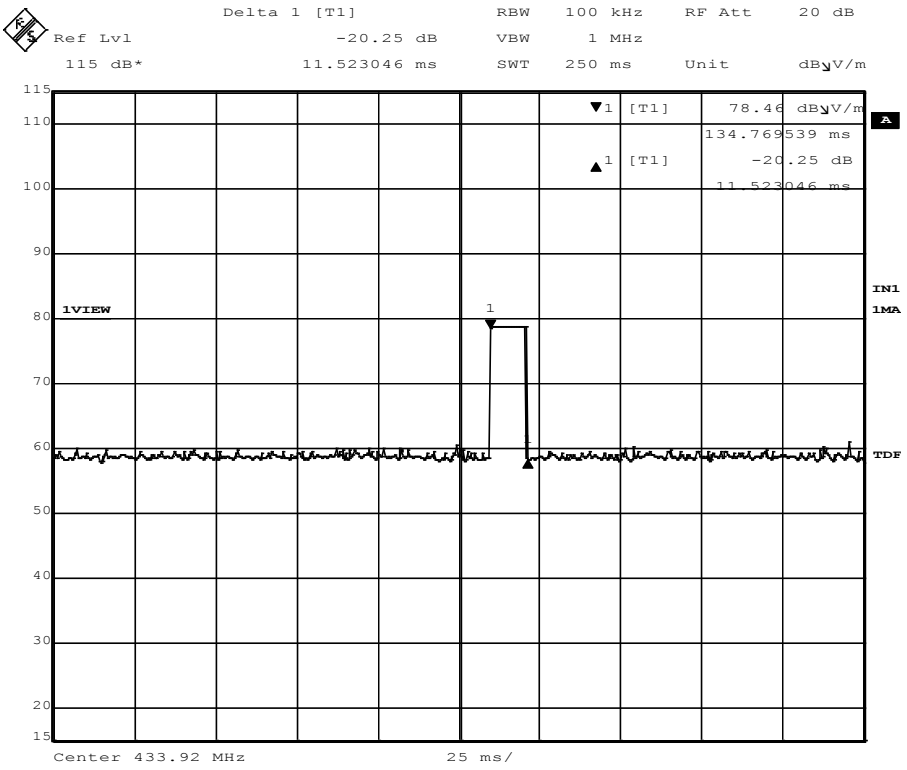


Figure 18 – Pulse Length Mode 1B – 10.5 ms, Periodic Mode

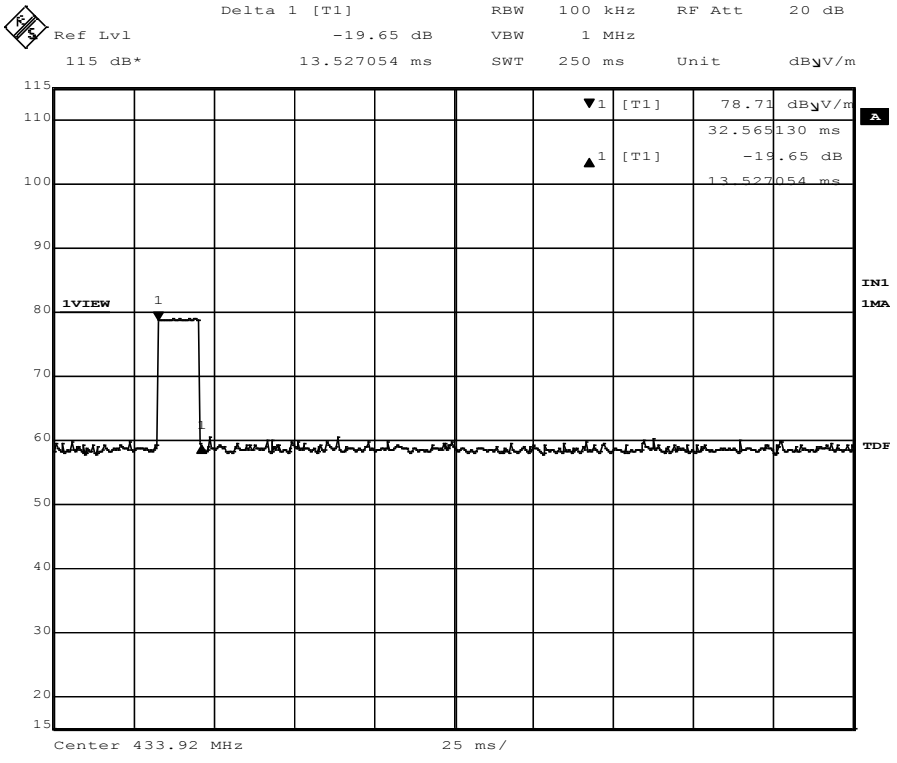


Figure 19 – Pulse Length Mode 2B – 13 ms, Periodic Mode

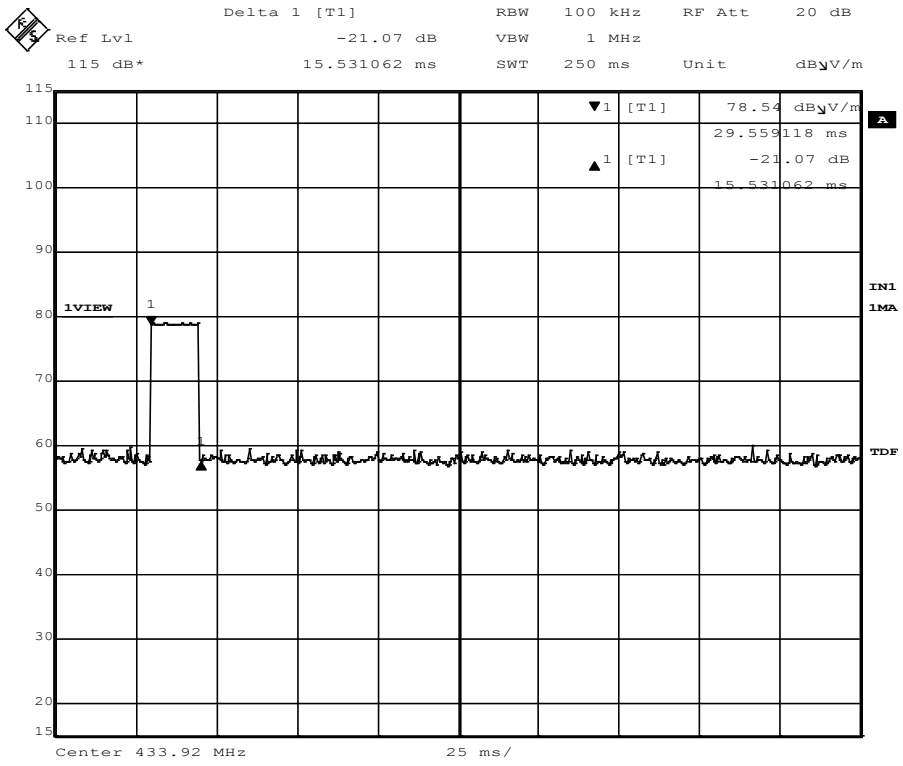


Figure 20 – Pulse Length Mode 2B – 14.7 ms, Periodic Mode

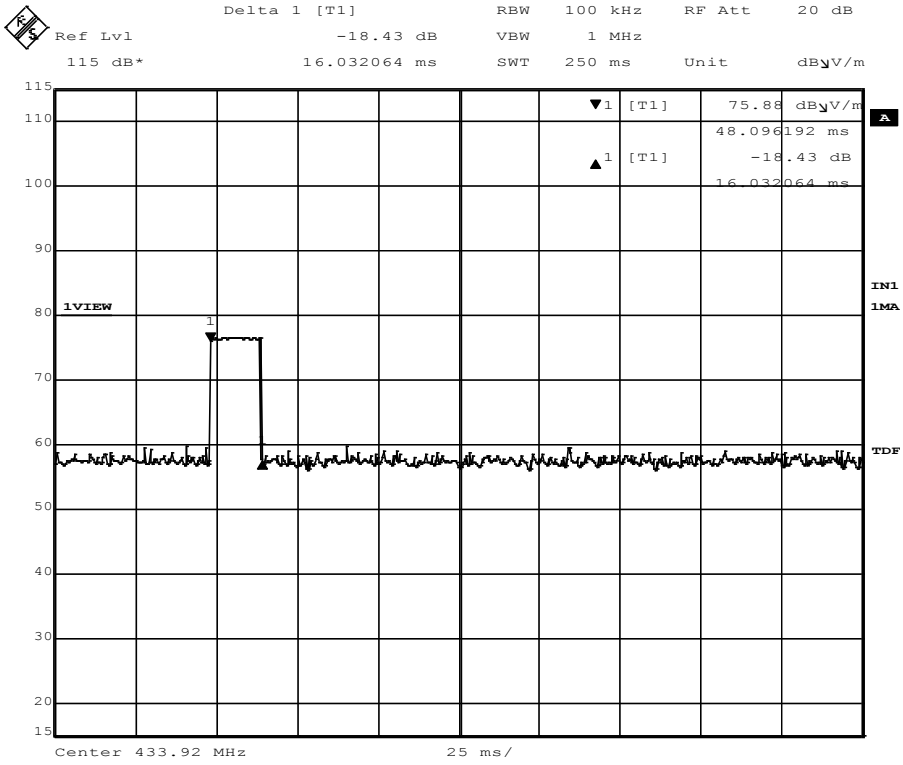


Figure 21 – Pulse Length Mode 2B – 15.4 ms, Periodic Mode

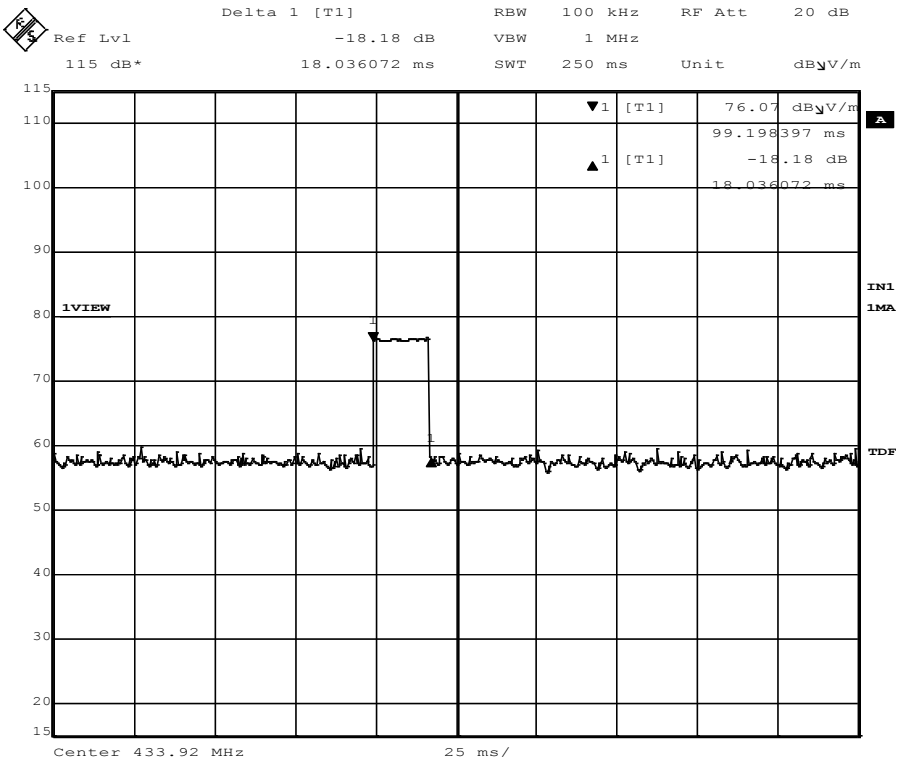


Figure 22 – Pulse Length Mode 3B – 17.4 ms, Periodic Mode

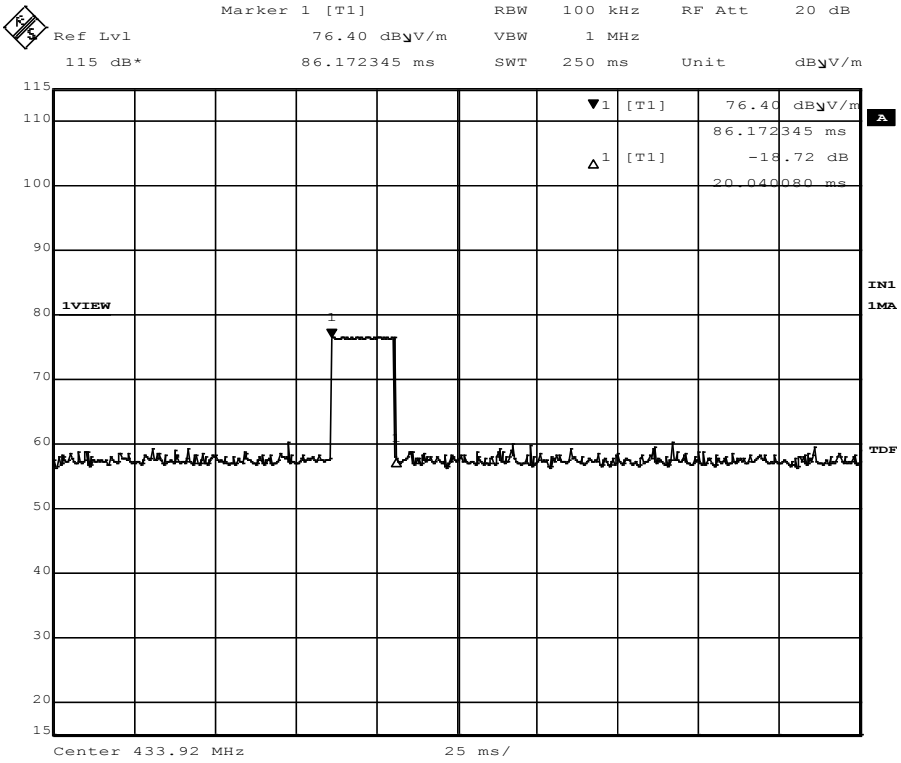


Figure 23 – Pulse Length Mode 3A – 19.7 ms, Non-Periodic Mode

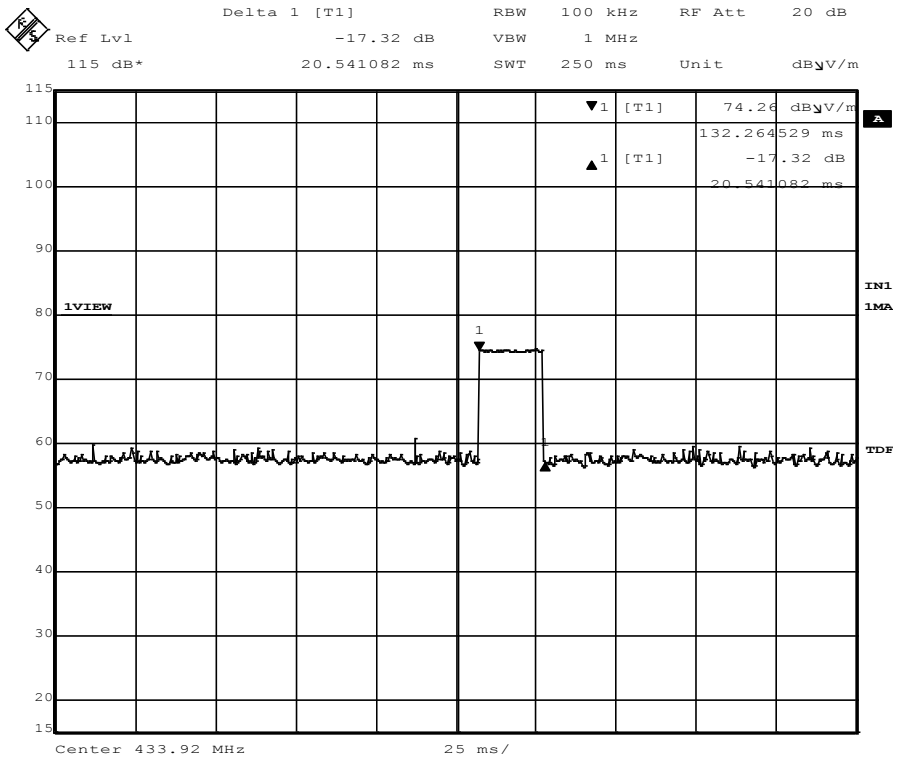


Figure 24 – Pulse Length Mode 3A – 20.2 ms, Non-Periodic Mode

Note: The EUT's output is controlled by software and output is controlled by duty cycle. In the following tables low, mid and highest of each possible output power are reported.

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	6.5	6	10	97.62	77.62	80.83	3.21
1A	9.01	8.3	18	97.61	77.61	80.83	3.22
1A	10.02	9.7	23	97.61	77.82	80.83	3.01
1A	11.02	10.5	26	94.28	75.00	80.83	5.83
2A	13.52	13	34	94.33	76.83	80.83	4.00
2A	15.53	14.7	41	94.35	77.99	80.83	2.84
2A	16.03	15.4	43	91.26	75.25	80.83	5.58
3A	18.03	17.4	50	91.28	76.23	80.83	4.60
3A	20.04	19.7	58	91.24	77.34	80.83	3.49
4A	21.04	20.2	60	91.82	78.05	80.83	2.78

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	6.51	6	10	81.67	61.67	72.87	11.20
1B	8.51	8.3	18	81.68	61.68	72.87	11.19
1B	10.02	9.7	23	81.65	61.86	72.87	11.01
1B	11.52	10.5	26	79.09	59.81	72.87	13.06
2B	13.52	13	34	79.04	61.34	72.87	11.53
2B	15.53	14.7	41	79.02	62.66	72.87	10.21
2B	16.03	15.4	43	76.76	60.61	72.87	12.26
3B	18.03	17.4	50	76.71	61.66	72.87	11.21
3B	20.04	19.7	58	76.71	62.67	72.87	10.20
4B	20.54	20.2	60	74.99	61.22	72.87	11.65

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

4.4 Bandwidth

4.4.1 Limits of bandwidth measurements

The 20 dB Band width must be less than 0.25% of center frequency.

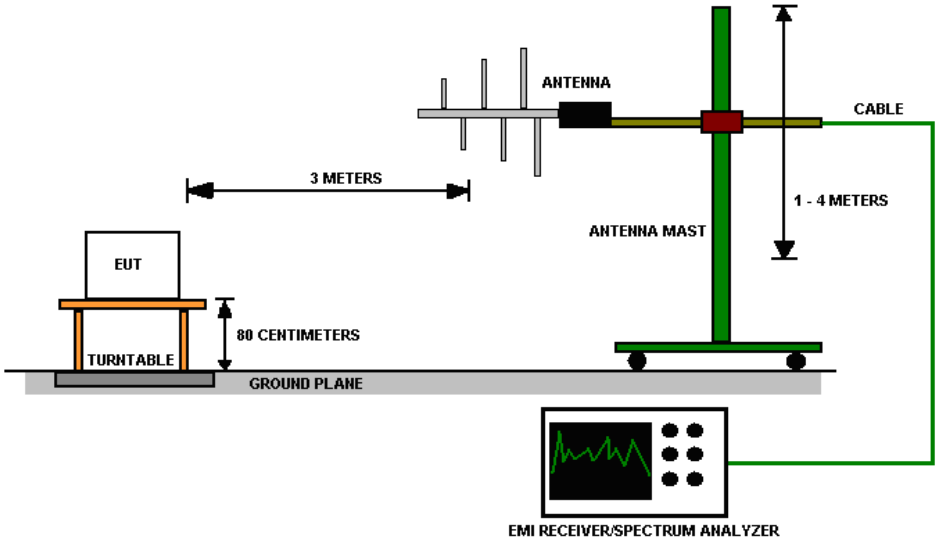
4.4.2 Test procedures

The transmitter output was connected to the spectrum analyzer through an attenuator. The bandwidth of the fundamental frequency was measured by spectrum analyzer with 100 kHz RBW and 1 MHz VBW. The 99% occupied is defined as the bandwidth at which 99% of the signal power is found. This corresponds to 20dB down from the maximum power level. The maximum power was measured with the largest resolution bandwidth possible (10MHz) and this value was recorded. The signal was then captured with a 100kHz resolution bandwidth and the frequencies where the measurements were 20dB below the maximum power were marked. The bandwidth between these frequencies was recorded as the 99% occupied bandwidth.

4.4.3 Deviations from test standard

No deviation.

4.4.4 Test setup



4.4.5 EUT operating conditions

See section 2.6.

4.4.6 Test results

EUT	Garrison Hub	Model	NCEETEST 1 (assigned)
MODE	Continuous Transmit	FREQUENCY RANGE	30 MHz – 5 GHz
INPUT POWER (SYSTEM)	14 VDC	ORIENTATION	Horizontally Placed
ENVIRONMENTAL CONDITIONS	30 % ± 5% RH 25 ± 3ºC	TECHNICIAN	KVepuri

CHANNEL	CHANNEL FREQUENCY (MHz)	99% Occupied BW LIMIT (kHz)	99% Occupied BW (kHz)	RESULT	Mode
1	433.92	1085	330.66	PASS	Continuous
1	433.92	1085	321.64	PASS	Periodic

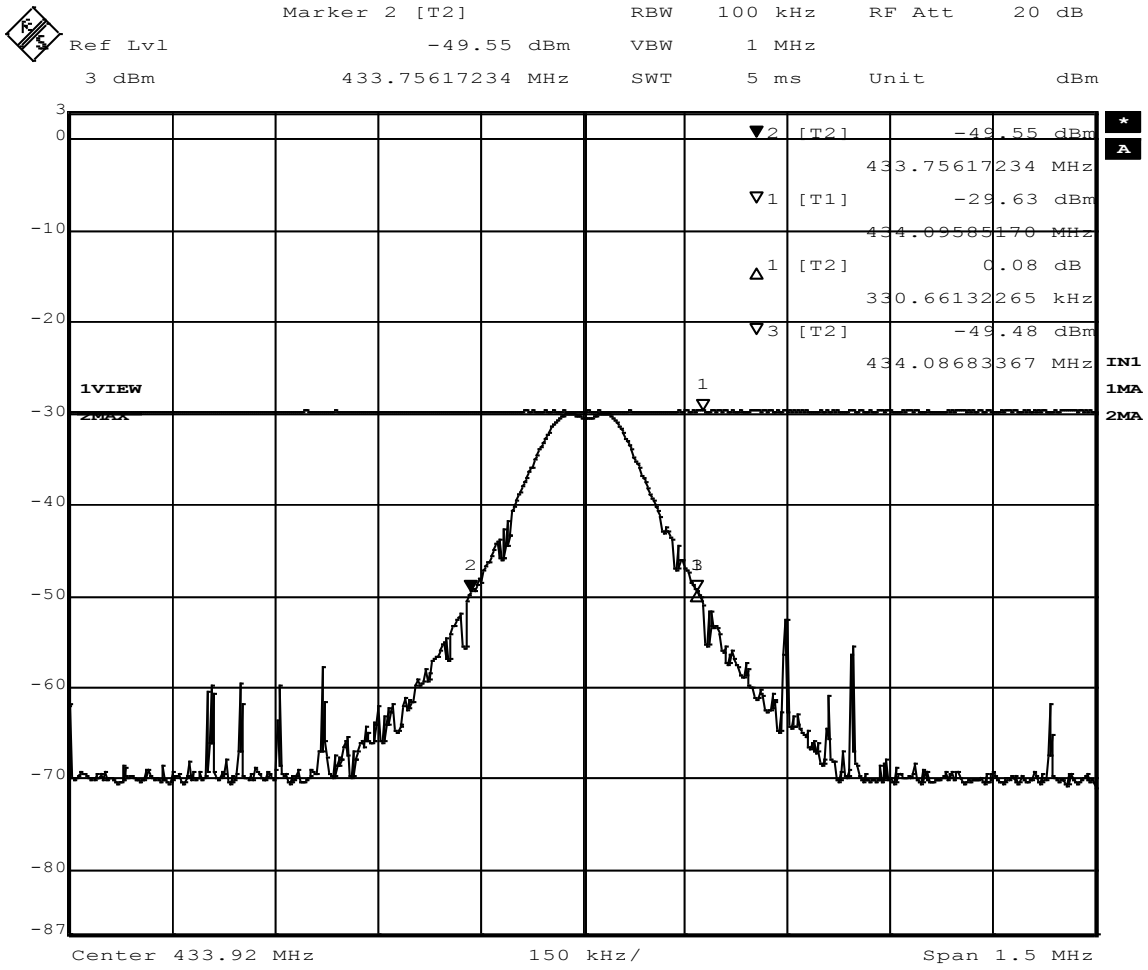


Figure 25 - 99% Occupied Bandwidth, Continuous Mode

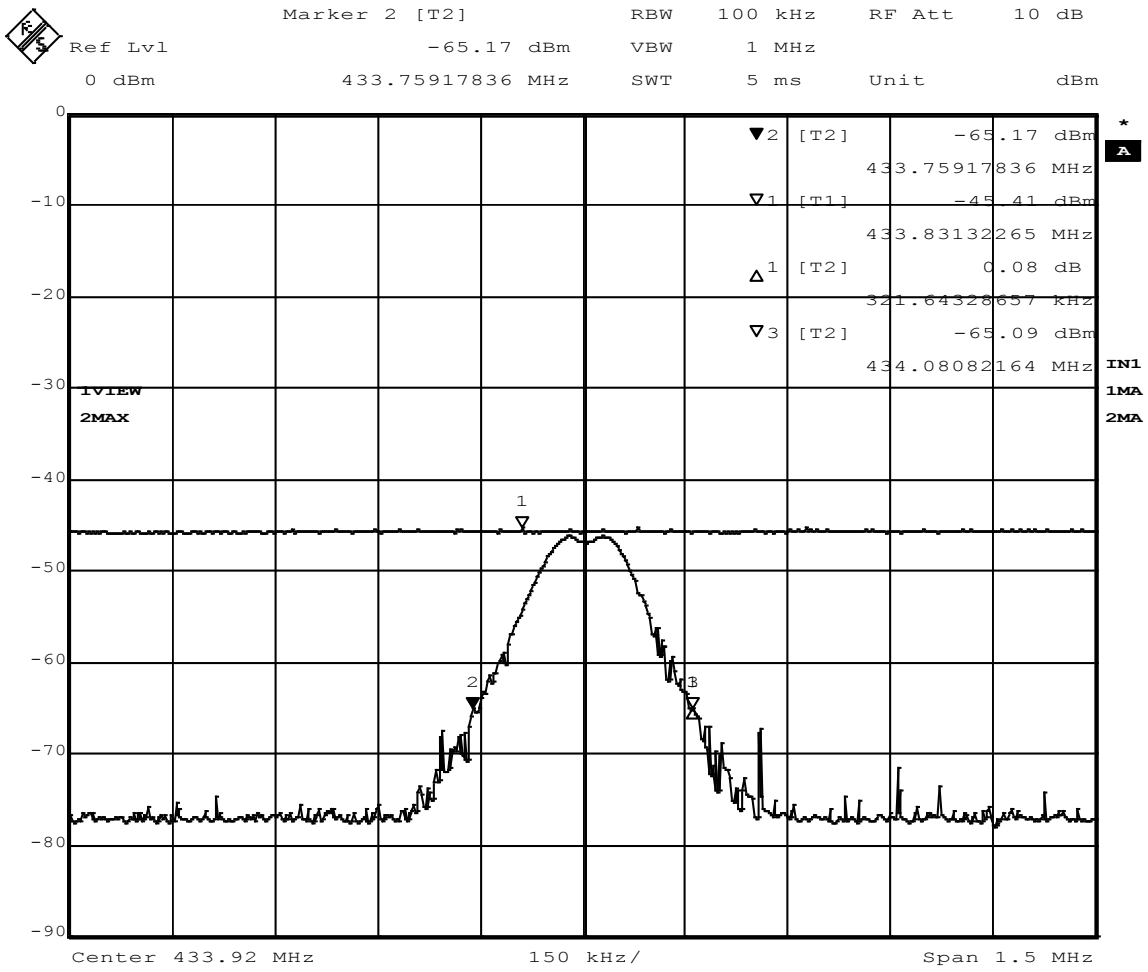


Figure 26 - 99% Occupied Bandwidth, Periodic Mode

4.5 Maximum peak output power

4.5.1 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.

4.5.2 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 10MHz and the video bandwidth was set to 10MHz 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.

4.5.3 Deviations from test standard

No deviation.

4.5.4 Test setup

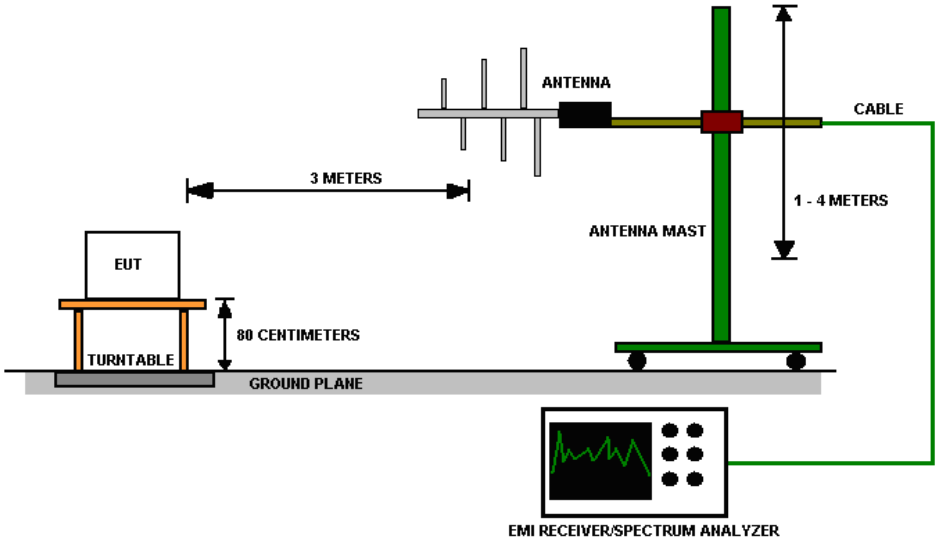


Figure 27 – Power Measurement Test Setup

4.5.5 EUT operating conditions

See Section 2.6

4.5.6 Test results

Maximum peak output power

EUT	Garrison Hub	Model	NCEETEST 1 (assigned)
MODE	Continuous Transmit	FREQUENCY RANGE	30 MHz – 5 GHz
INPUT POWER (SYSTEM)	14 VDC	ORIENTATION	Horizontally Placed
ENVIRONMENTAL CONDITIONS	30 % ± 5% RH 25 ± 3ºC	TECHNICIAN	KVepuri

CHANNEL	CHANNEL FREQUENCY (MHz)	EIRP PEAK POWER OUTPUT (dBm)	PEAK POWER LIMIT (dBm)	RESULT	Mode
1	433.92	2.34	N/A*	PASS	Continuous
1	433.92	-13.48	N/A*	PASS	Periodic

Antenna Factor = 17.10; 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%.