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FCC/ISED Test Report

Prepared for: **Appareo Systems**

Address: **1810 NDSU Research Circle N.**
Fargo, ND 58102

Product: **Ag Tag**

Test Report No: **R20171229-20B**

Approved By:

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Technical Manager
iNARTE Certified EMC Engineer #EMC-003337-NE

DATE: **January 29, 2018**

Total Pages: **27**

ACCREDITED
TESTING LABORATORY
CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	8 January 2018	Original – NJohnson Prepared by KVepuri
A	25 January 2018	Includes NCEE Labs report R20171229-20 and its amendment in full
B	29 January 2018	Includes NCEE Labs report R20171229-20A and its amendment in full.

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1.0 SUMMARY OF TEST RESULTS

The EUT has been tested according to the following specifications:

APPLIED STANDARDS AND REGULATIONS		
Standard Section	**Test Type**	**Result**
FCC Part 15.35 RSS-Gen, Issue 4, Section 6.10	Duty Cycle Momemntary operation	Pass
FCC Part 15.231 RSS-210, Issue 9	Bandwidth	Pass
FCC Part 15.231(e) RSS Gen Issue 4, Section 7.1	Receiver Radiated Emissions	Pass
FCC Part 15.209 (restricted bands), 15.231(e) (unrestricted) RSS-210, Issue 9	Transmitter Radiated Emissions	Pass
FCC Part 15.209, 15.231(e) RSS-210, Issue 9	Band Edge Measurement	Pass

Test method: ANSI C63.10:2013

See Section 4 for details on the test methods used for each test.

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

EUT	Ag Tag
Description	The Equipment Under Test (EUT) was a wireless module used on agricultural products
EUT Received	2014 June 11
EUT Tested	2014 June 11 2018 Jan 05 (verified)*
Serial No.	CT10C
Operating Band	433.92 MHz
Device Type	Short range wireless
Power Supply	Internal non-rechargeable, non-replaceable battery

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

*Note: since the test data was over 2 years old, radiated emissions measurements were verified to be within 2 dB of the original data. The manufacturer has stated that the deisgn and manufacturing process has not changed since it was originally tested.

2.2 DESCRIPTION OF TEST MODES

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

Channel	Frequency
1	433.92 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.

The EUT only begins transmitting once a magnet is placed in the recess of the device mold. The recess is underneath the bottom sticker on the device. If the magnet is removed, AgTag will stop transmitting.

The EUT sends a periodic message only after 15 ± 1.5 sec seconds, and after it has been activated. AgTag is activated with a magnet is placed in the bottom recess, under the device sticker of the AgTag. Additionally, an internal clock and microprocessor in AgTag counts down to 15 seconds, to determine when to transmit. No other parameters are used to determine when the messages are transmitted. The baud rate of the messages is 28.0151 kBaud and the maximum message length is 15 bytes. Thus the messages are transmitted in less than 4.28 milliseconds (1/(kbaud * message length)). AgTag's firmware is programmed to be compliant with the requirements of FCC Part 15.231(e), of which any type of operation is allowed. The message ID is handed off to readers when received, which then do manipulation to determine approximate GPS coordinates, file information of maintenance and last movement. Movement of the AgTag.

The EUT did not need to be modified for testing purposes. Testing was performed on a production sample.

2.3 DESCRIPTION OF SUPPORT UNITS

None

3.0 LABORATORY DESCRIPTION

3.1 LABORATORY DETAILS

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	Karthik Vepuri	EMC Test Engineer	Testing,
3	Nic Johnson	Technical Manager	Review of Results

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

Testing and verification after 2018 JAN 05

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Rohde & Schwarz Test Receiver	ES126	100037	24 Jan 2017	24 Jan 2018
EMCO Biconilog Antenna	3142B	1647	02 Aug 2017	02 Aug 2018
EMCO Horn Antenna	3115	6416	25 Jan 2016	25 Jan 2018
EMCO Horn Antenna	3116	2576	26 Jan 2016	26 Jan 2018
Rohde & Schwarz Preamplifier	TS-PR18	3545700803	9 Feb 2017*	9 Feb 2018*
Trilithic High Pass Filter	6HC330	23042	9 Feb 2017*	9 Feb 2018*
Rohde & Schwarz LISN	ESH3-Z5	100023	23 Jan 2017	23 Jan 2018
RF Cable (preamplifier to antenna)	MFR-57500	01-07-002	09 Feb 2017*	09 Feb 2018*
RF Cable (antenna to 10m chamber bulkhead)	FSCM 64639	01E3872	09 Feb 2017*	09 Feb 2018*
RF Cable (10m chamber bulkhead to control room bulkhead)	FSCM 64639	01E3874	09 Feb 2017*	09 Feb 2018*
RF Cable (Control room bulkhead to RF switch)	FSCM 64639	01E3871	09 Feb 2017*	09 Feb 2018*
RF Cable (RF switch to test receiver)	FSCM 64639	01F1206	09 Feb 2017*	09 Feb 2018*
RF switch – Rohde and Schwarz	TS-RSP	1113.5503.14	09 Feb 2017*	09 Feb 2018*
N connector bulkhead (10m chamber)	PE9128	NCEEBH1	09 Feb 2017*	09 Feb 2018*
N connector bulkhead (control room)	PE9128	NCEEBH2	09 Feb 2017*	09 Feb 2018*

*Internal Characterization

Notes:
All equipment is owned by NCEE Labs and stored permanently at the laboratory. All calibrations are performed by A2LA or NVLAP accredited calibration laboratories.

Testing and verification from June 11 – 12, 2013

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Rohde & Schwarz Test Receiver	ES126	100037	21 JAN 2014	21 JAN 2015
EMCO Biconilog Antenna	3142B	1647	7 AUG 2013	7 AUG 2014
EMCO Horn Antenna	3115	6416	14 JAN 2013	14 JAN 2015

Notes:
All equipment is owned by NCEE Labs and stored permanently at the laboratory. All calibrations are performed by A2LA or NVLAP accredited calibration laboratories.

4.0 DETAILED RESULTS

4.1 DUTY CYCLE

Test Method: ANSI C63.10:2013, Section 7.5

Limits for duty cycle:

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.

(c) Unless otherwise specified, *e.g.,* §§15.255(b), and 15.256(l)(5), when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds. As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. The exact method of calculating the average field strength shall be submitted with any application for certification or shall be retained in the measurement data file for equipment subject to Supplier's Declaration of Conformity.

Test procedures:

Because the EUT did not have provisions for making conducted measurements, the duty cycle was measured in a 10m semi-anechoic chamber with the test receiver set to “Zero span” mode.

All field strength or power measurements shown in these plots are arbitrary and only the times and levels of the EUT relative to the remote are considered for compliance.

Deviations from test standard:

No deviation.

Test setup:

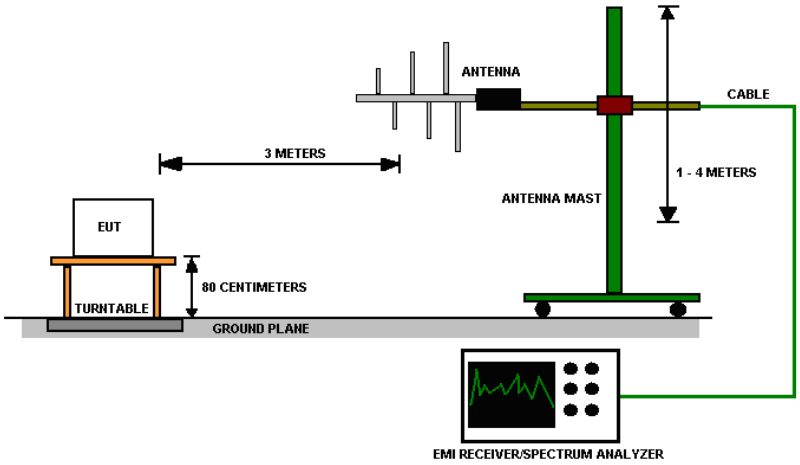

Figure 1 - Radiated Emissions Test Setup

EUT operating conditions:
The EUT was powered by 18 VDC unless specified. The duty cycle was only tested on the lowest channel as it will be identical for all channels.

The EUT will only transmit when triggered by a paired remote. In order to measure the maximum possible duty cycle in a user application, a button was held down on the remote.

Test results:

Duty cycle correction = 20 dB

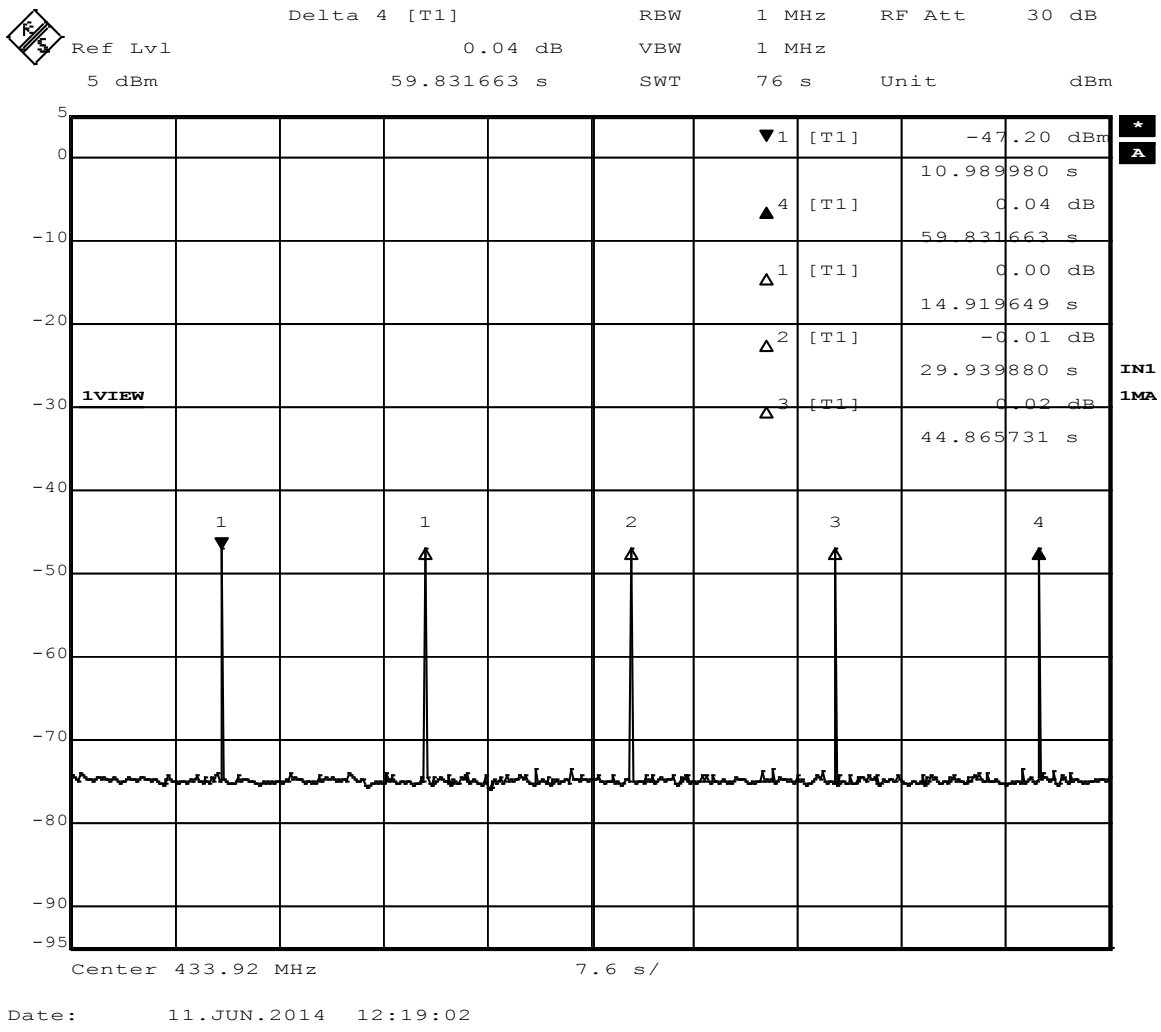

Figure 2 - Pulse period, 14.92s

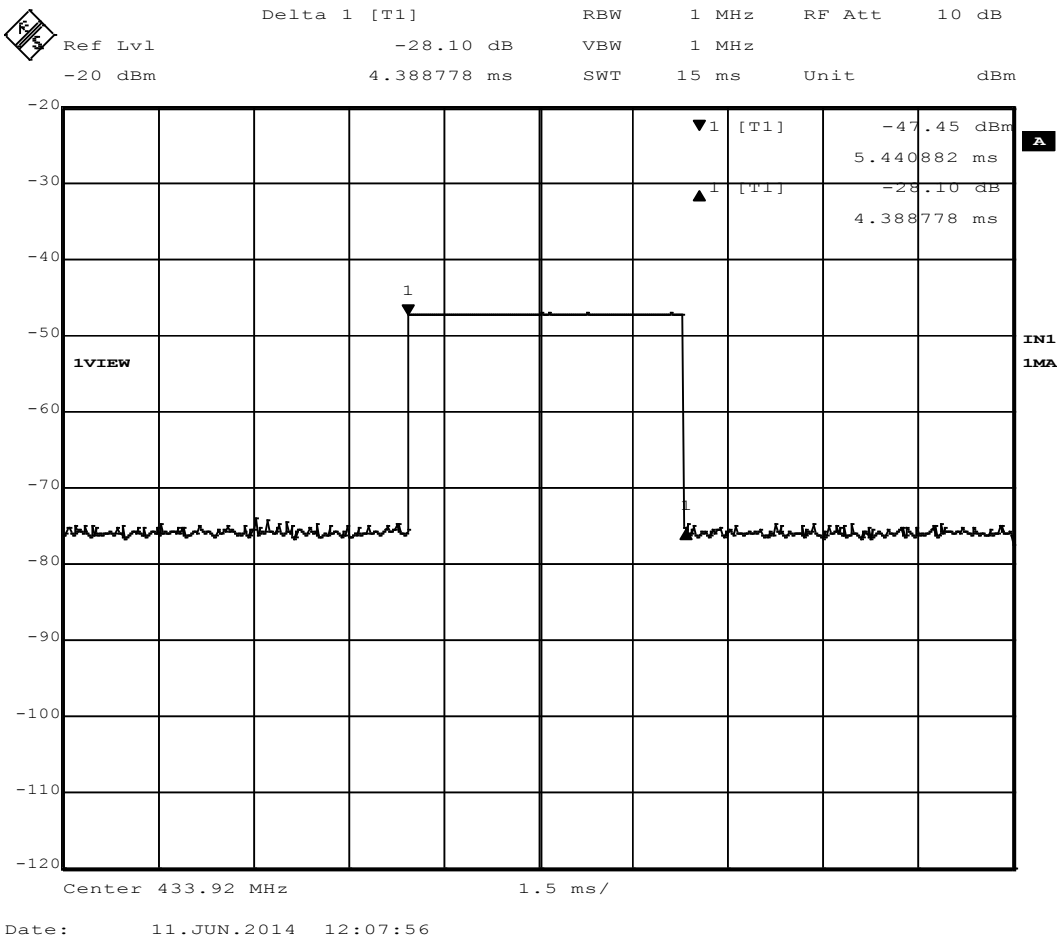

Figure 3 - Pulse Width, 4.39ms

Duty Cycle Correction Factor = 20*log(4.39 / 14.92) = -10.63 dB

Pulse width"

Measurement	Duration (ms)	Reference Figure
On Time	4.39***	2
Period*	100*	3

*Maximum 100ms

On time / Period =	Duty Cycle Factor = 20×log(duty cycle) spurious	Duty Cycle Factor = 20×log(duty cycle) For use with average power calculations
0.0044	-20**	-47.13

**Maximum -20 dB allowed for spurious emissions

***Measurement tolerance = ±5%

4.2 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.

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 form 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. Additional time was used during the pre-scan to account for the duty cycle of the transmitter.

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.

Test setup:

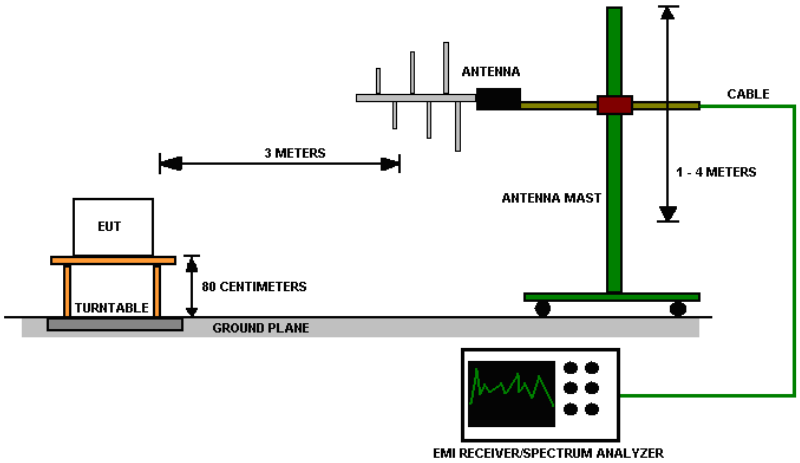

Figure 4 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by 18 VDC unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:

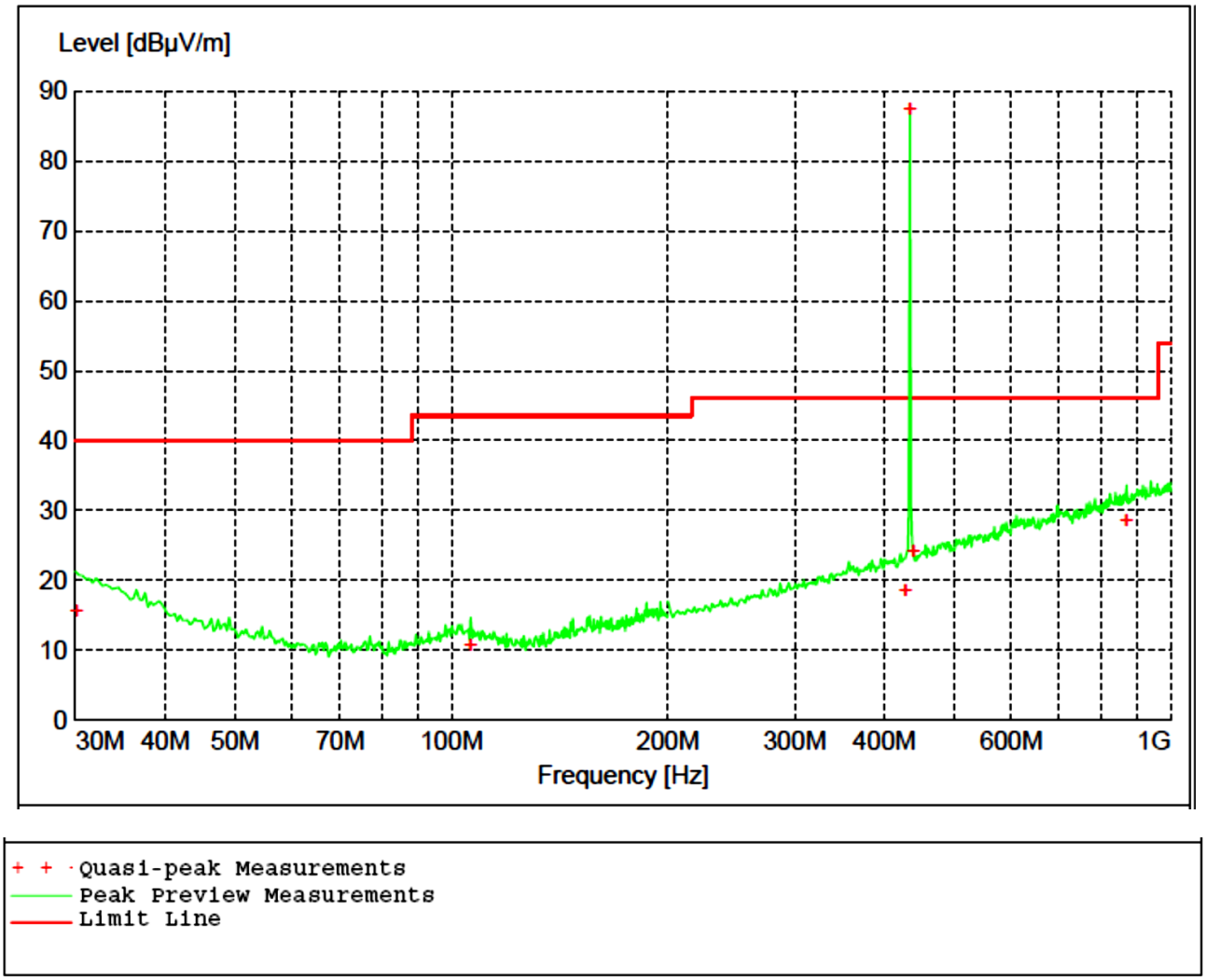

Figure 5 - Radiated Emissions Data Plot

Table 1 - Radiated Emissions , 30 MHz – 1GHz

Frequency	Level	Limit	Margin	Height	Angle	Polarity
MHz	dBµV/m	dBµV/m	dB	cm	deg	
30.120000	15.59	40.00	24.40	119	151	VERT
106.260000	10.60	43.50	32.90	165	52	VERT
428.160000	18.53	46.00	27.50	99	0	VERT
433.920000	87.44	NA	NA	123	52	VERT
438.780000	23.98	46.00	22.00	141	283	VERT
867.900000	28.60	46.00	17.40	250	300	VERT

Table 2 - Radiated Emissions Average Data, 30 MHz – 1GHz

Frequency	Level	Limit	Margin	Height	Angle	Polarity
MHz	dBµV/m	dBµV/m	dB	cm	deg	
433.920000	67.44*	72.90	5.46	123	52	VERT

***Includes average correction factor from Section 4.1.**

Table 3 - Radiated Emissions Average Measurements Data, 1-5 GHz

Frequency	Level	Limit	Margin	Height	Angle	Polarity
MHz	dBµV/m	dBµV/m	dB	cm	deg	
1302.000000	42.81	54.00	11.19	100	315	HORI
1736.000000	40.08	54.00	13.92	99	14	HORI
2169.500000	41.82	54.00	12.18	201	88	VERT
2604.000000	42.92	54.00	11.08	130	271	VERT
3037.800000	39.97	54.00	14.03	298	317	HORI
3472.000000	32.61	54.00	21.39	100	102	VERT
3905.400000	41.78	54.00	12.22	180	50	VERT
4339.200000	36.52	54.00	17.48	200	352	HORI

Average measurements are calculated based on the peak measurements in Table 5 with the correctionfactor from Figures 4 and 5 applied. Average Field Strength = Peak Field Strength – Averaging Factor

Table 4 - Radiated Emissions Peak Measurements Data, 1-5 GHz

Frequency	Level	Limit	Margin	Height	Angle	Polarity
MHz	dBµV/m	dBµV/m	dB	cm	deg	
1302.000000	53.44	74.00	20.56	100	315	HORI
1736.000000	50.71	74.00	23.29	99	14	HORI
2169.500000	52.45	74.00	21.55	201	88	VERT
2604.000000	53.55	74.00	20.45	130	271	VERT
3037.800000	50.60	74.00	23.40	298	317	HORI
3472.000000	43.24	74.00	30.76	100	102	VERT
3905.400000	52.41	74.00	21.59	180	50	VERT
4339.200000	47.15	74.00	26.85	200	352	HORI

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. The EUT was measured in all 3 orthagonal axis. It was found that the Y-axis produced the highest emissions, and this orientation was used for all testing. See the test setup photo exhibit for details on the orientations.
6. The axis shown in the last column of the data tables shows the axis where the emissions were found to be the highest.

4.4 BANDWIDTH

Test Method: ANSI C63.10, Section(s) 6.9

Limits of bandwidth measurements:
The 6dB bandwidth of the signal must be greater than 500 kHz.

Test procedures:
Bandwidth measurement was taken at a distance of 3m from the EUT. The bandwidth of the fundamental frequency was measured by spectrum analyzer with 100 kHz RBW and 300 kHz 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 1 MHz 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.

The 6 dB bandwidth is defined as the bandwidth of which is higher than peak power minus 6dB.

Deviations from test standard:
No deviation.

Test setup:

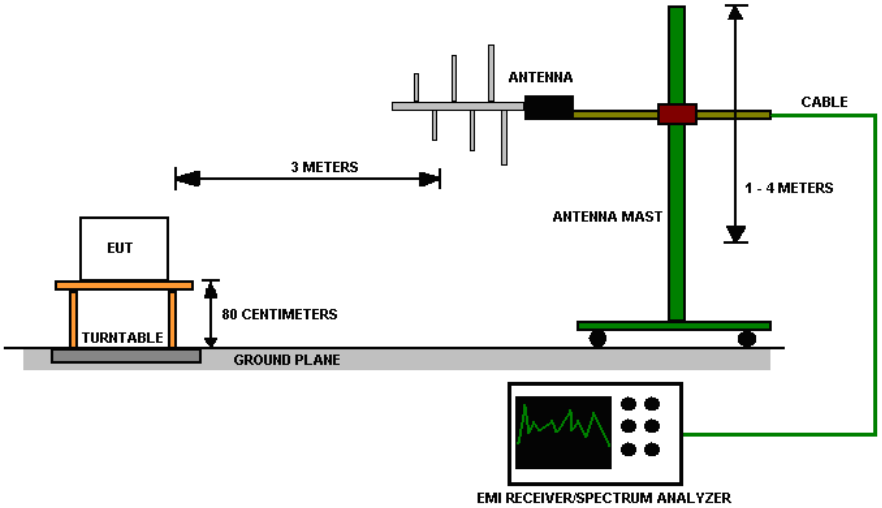

Figure 6 - Bandwidth Measurements Test Setup

EUT operating conditions:
The EUT was powered by 18 VDC unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:

Table 5 – 99% Occupied Bandwidth

CHANNEL	CHANNEL FREQUENCY (MHz)	99% Occupied BW LIMIT (kHz)	99% Occupied BW (kHz)	RESULT
1	433.92	1085	464.92	PASS

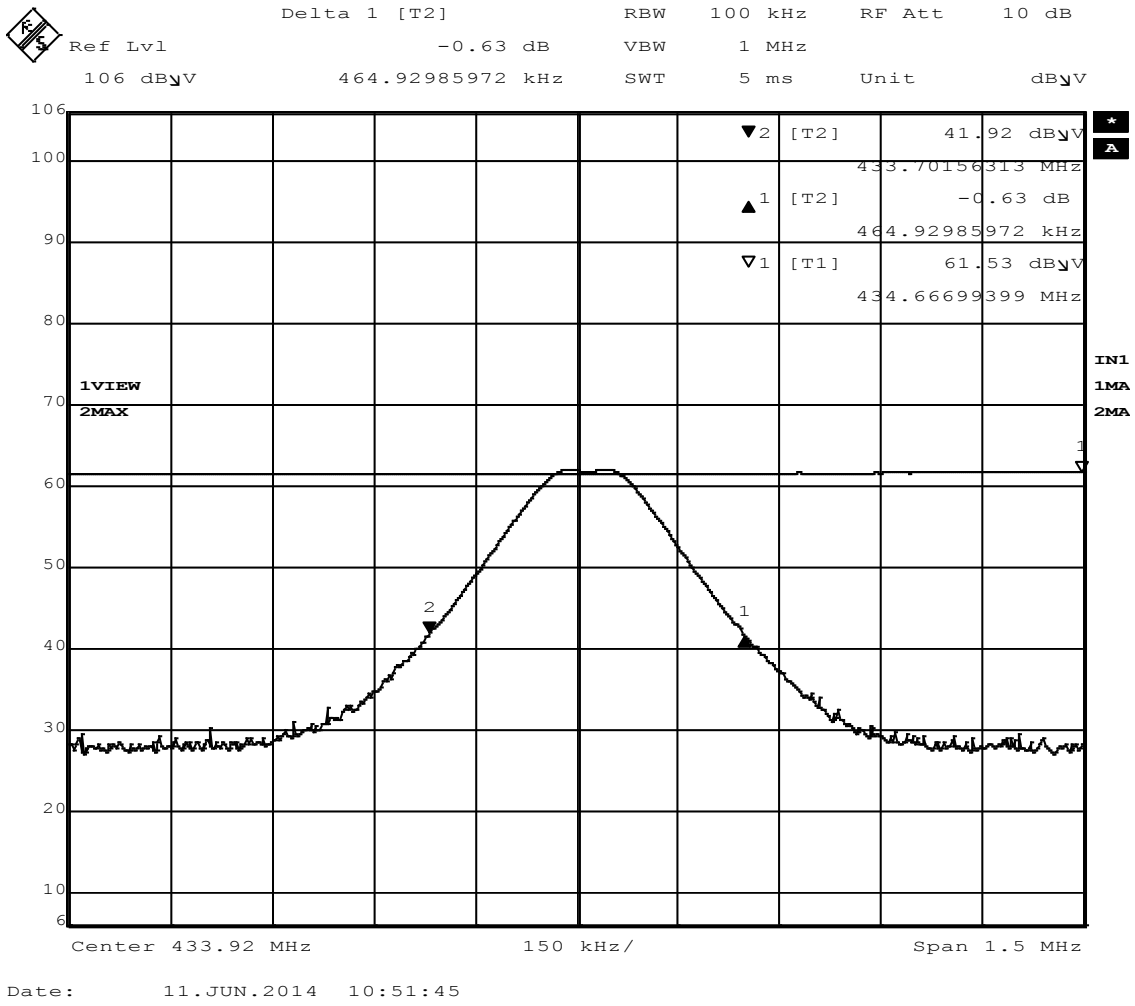

Figure 7 - 99% Occupied Bandwidth

Does not included correction factors

4.5 BANDEDGES

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

Limits of bandedge measurements:
For emissions outside of the allowed band of operation (260 - 470 MHz), 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 tested in the same method as described in section *4.3 - Bandwidth*. The EUT was oriented as to produce the maximum emission levels. The resolution bandwidth was set to 30kHz 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.

Deviations from test standard:
No deviation.

Test setup:
See Section 4.3

EUT operating conditions:
The EUT was powered by 18 VDC unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:

Highest Out of Band Emissions

CHANNEL	Band edge /Measurement Frequency (MHz)	Highest out of band level (peak) dBµV/m	Limit dBµV/m	Margin dB	Result
1	260.00	16.34	46.00 (restricted)	29.66	PASS
1	410.00	23.04	46.00 (restricted)	22.96	PASS
1	470.00	26.21	46.00 (restricted)	19.79	PASS
1	608.00	28.97	46.00 (restricted)	17.03	PASS

Notes:

1. Results taken from tabular data in Figure 5 on page 19
2. Peak meausrements were compared to quasi-peak limit
3. The nearest restricted band edge and band edge from 15.231 were tested.

*limit based on FCC Part 15.231(e) for spurious emissions in unrestricted bands for a transmitter operating at 433.92 MHz.

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