dBi Corporation

FCC/IC Verification Test Report
Two Dimensional Instruments TVRFL4 Base Station, and WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors

FCC/IC Certification Test Report
Two Dimensional Instruments WS4TX Transmitter Module

Report Number 10dBi030a
November 4, 2010

This test report replaces test report 10dBi030, dated October 12, 2010, in its entirety.

ACCREDITED
Test Laboratory
Certificate Number 1985.01

ADMINISTRATIVE INFORMATION

Historical record:
Because dBi Corporation is a testing entity, and not a manufacturer, this original test report of the TVRFL4 Base Station, the WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors, and the WS4TX Transmitter Module, is being transmitted to the manufacturer, Two Dimensional Instruments. dBi will keep a copy for its historical records and to satisfy A2LA-Audit requirements. We strongly recommend archiving the units that we tested, to help answer any future inquiries about the products.

Retention of records:
The FCC requires the records for a Class A or Class B product to be retained by the responsible party for at least two years after the manufacture of said product has been permanently discontinued. These records should include the original certification or verification product report, quality audit data, and the test procedures used.

The European Union requires the Declaration of Conformity (DoC) and all supporting data for a product bearing the CE Marking to be retained, and available for inspection by enforcement authorities, for 10 years after last placing the product on the market.

Australia and New Zealand require the Declaration of Conformity, test reports, a description of the product, documentation that clearly identifies the product, and paperwork showing the product's brand name, model number, etc. to be kept for at least five years after the product ceases to be supplied to Australia or New Zealand.

Measurement uncertainties:
The Lexmark Electromagnetic Compatibility Laboratory (EMC Lab) has a documented calculation of the measurement uncertainties associated with tests performed at the Lexmark site.

Ongoing compliance:
This report applies only to the samples tested. Two Dimensional Instruments has full responsibility for ensuring that the modifications made to these samples are included in all production models of the TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, WS4HITMIHM, and WS4TX, so that they comply with the FCC/IC requirements, and continue to comply throughout their manufacturing life. Two Dimensional Instruments should check any changes to the products that could change their interference profiles.

A2LA approval:
dBi Corporation has been accredited by the American Association for Laboratory Accreditation (A2LA) for Radiated Emissions and Conducted Emissions, Electromagnetic Interference, and Electrostatic Discharge testing. Copies of our Accreditation Certificate and Scope of Accreditation follow.

The Federal Communications Commission (FCC) recognized the Lexmark site as meeting section 2.948 of the FCC Rules in letters dated October 30, 2007 (Registration No. 949691) and January 14, 2010 (Registration No. 991141). Industry Canada recognizes the Lexmark site in letters dated November 16, 2009 (number 2376A-1) and March 2, 2009 (number 2376A-3).

Please note: This report may be copied as needed, as long as it is copied in its entirety.

The American Association for Laboratory Accreditation

World Class Accreditation

Accredited Laboratory

A2LA has accredited

DBI CORPORATION

Lexington, KY

for technical competence in the field of

Electrical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General Requirements for the Competence of Testing and Calibration Laboratories*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009*).

Presented this 8th day of September 2010.

President & CEO
For the Accreditation Council
Certificate Number 1985.01
Valid to September 30, 2012

For the tests or types of tests to which this accreditation applies, please refer to the laboratory's Electrical Scope of Accreditation.

The American Association for Laboratory Accreditation

"World Class Accreditation"

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005

dBi CORPORATION
216 Hillsboro Avenue[1]
Lexington, KY 40511-2105
John R. Barnes Phone: 859 253 1178

ELECTRICAL (EMC)

Valid To: September 30, 2012 Certificate Number: 1985.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following tests:

Test Technology	**Test Method(s)**
Radiated Emissions (Up to 18 GHz)	FCC 47 CFR Part 15, Subpart A, B and C (Using C63.4: 2003, 2009 and C63.10: 2009); ICES-003:2004 (using CAN/CSA-CEI/IEC CISPR 22:2002); CISPR 22 (1997, 2003, 2005, 2008); EN 55022 (1994, 1998, 2006); AS/NZS CISPR 22 (2006, 2009); VCCI V-3 (2009, 2010); IEC 61000-6-3: 2006; EN 61000-6-3: 2007; AS/NZS 61000-6-3: 2007; AS/NZS 61000-6-4: 2007; IEC 61000-6-4: 2006; EN 61000-6-4: 2007; EN 55013: 2001(Up to 1 GHz); AS/NZS CISPR 13: 2004 (Up to 1 GHz); CISPR 13: 2001(Up to 1 GHz); IEC 61326-1: 2005; EN 61326-1: 2006; IEC 61326-2-3: 2006; EN 61326-2-3: 2006

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5301 Buckeystown Pike, Suite 350 | Frederick, Maryland 21704-8373 | Phone: 301 644 3248 | Fax: 301 662 2974 | www.A2LA.org

Test Technology	Test Method(s)
Conducted Emissions	FCC 47 CFR Part 15 (using C63.4-2003, 2009, C63.10-2009); ICES-003 (2004 using CAN/CSA-CEI/IEC CISPR 22:2002); CISPR 22 (1997, 2003, 2005, 2008); EN 55022 (1994, 1998, 2006); AS/NZS CISPR 22 (2006, 2009); VCCI V-3 (2009, 2010); IEC 61000-6-3: 2006; EN 61000-6-3: 2007; AS/NZS 61000-6-3: 2007; AS/NZS 61000-6-4: 2007; IEC 61000-6-4: 2006; EN 61000-6-4: 2007; EN 55013: 2001; AS/NZS CISPR 13: 2004; IEC 61326-1: 2005; EN 61326-1: 2006; IEC 61326-2-3: 2006; EN 61326-2-3: 2006
Disturbance Power	EN 55013: 2001; AS/NZS CISPR 13: 2004; CISPR 13: 2001
Harmonics	IEC 61000-3-2: 2005; EN 61000-3-2: 2006; AS/NZS 61000-3-2: 2007
Flicker	IEC 61000-3-3 (1994, 2002, 2008); EN 61000-3-3 (1995, 2008); AS/NZS 61000-3-3: 2006
Electrostatic Discharge	IEC 61000-4-2 (1995, 2008); EN 61000-4-2 (1995, 2009); AS/NZS 61000-4-2: 2002)
Radiated Immunity (80 MHz to 150MHz, 6V/m; 150 MHz to 1 GHz, 10V/m; 1GHz to 2GHz, 3V/m; 2GHz to 3GHz, 1V/m)	IEC 61000-4-3 (1995, 2002, 2006); EN 61000-4-3 (1996, 2006); AS/NZS 61000-4-3: 2006
Electrical Fast Transient/Burst	IEC 61000-4-4 (1995, 2004); EN 61000-4-4 (1995, 2004); AS/NZS 61000-4-4: 2006

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Test Technology	Test Method(s)
Surge Immunity	IEC 61000-4-5 (1995, 2005); EN 61000-4-5 (1995, 2006); AS/NZS 61000-4-5: 2006
Conducted Immunity	IEC 61000-4-6 (1996, 2003, 2008); EN 61000-4-6 (1996, 2009); AS/NZS 61000-4-6: 2006
Magnetic Field Immunity	IEC 61000-4-8 (1993, 2001); EN 61000-4-8: 1993; AS/NZS 61000-4-8: 2002
Voltage Dip Immunity	IEC 61000-4-11 (1994, 2001, 2004); EN 61000-4-11 (1994, 2004); AS/NZS 61000-4-11: 2005
ITE Product Family	CISPR 24: 1997; EN 55024: 1998; CISPR 22:1997, 2003, 2005, 2008; EN 55022:1994, 1998, 2006; AS/NZS CISPR 22:2006, 2009; AS/NZS CISPR 24:2002; VCCI V-3 2009, 2010
Generic Devices for Residential, Commercial, and Light Industrial Use	IEC 61000-6-1: 2005; EN 61000-6-1: 2007; IEC 61000-6-3: 2006; EN 61000-6-3: 2007; AS/NZS 61000-6-1: 2006; AS/NZS 61000-6-3: 2007
Generic Devices for Industrial Use	IEC 61000-6-2: 2005; EN 61000-6-2: 2005; IEC 61000-6-4: 2006; EN 61000-6-4: 2007; AS/NZS 61000-6-2: 2006; AS/NZS 61000-6-4: 2007
Electrical Equipment for Measurement, Control and Laboratory Use	IEC 61326-1: 2005; EN 61326-1: 2006; IEC 61326-2-6: 2006; IEC 61326-2-6: 2006
Sound and Television Broadcast Receivers and Associated Equipment	EN 55013: 2001; AS/NZS CISPR 13: 2004; CISPR 13: 2001

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Types of products, materials, and/or industry that the laboratory tests:
-Information Technology Equipment (ITE) – Computers, Printers, Peripheral Devices;
-Generic Devices for Residential, Commercial, and Light Industrial Use;
-Generic Devices for Industrial Use;
-Electrical Equipment for Measurement, Control, and Laboratory Use;
-Sound and Television Broadcast Receivers and Associated Equipment

[1]Note: Testing is performed using the equipment and facility at:
Lexmark International EMC Laboratory
740 New Circle Road NW
Lexington, KY 40550-1876
(A2LA Accreditaiton Certificate 0872.01)

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ADMINISTRATIVE DATA

Manufacturer:

Two Dimensional Instruments
6901 Briarhill Rd
Crestwood, KY 40014

Appliance/Product: Base Station and four Wireless Sensors
Model/Type Number: TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM
Rating: 9VDC

Power Line Filters and RF Suppression Components: see attached sheets.

Measurements According to, and Sample Units Comply with:

FCC 47 CFR Part 15-2008 Class B for the US, using ANSI C63.4:2003, with 30 dBuV/m - 26,58 dBuV/m = 3.42dB margin for Radiated Emissions.

Industry Canada (IC) ICES-003:2004 Class B for Canada, using CAN/CSA-CEI/IEC CISPR 22:02, with with 30 dBuV/m - 26,58 dBuV/m = 3.42dB margin for Radiated Emissions.

Appliance/Product: Transmitter Module
Model/Type Number: WS4TX
FCC ID: YVGWS4TX
Rating: 9VDC

Power Line Filters and RF Suppression Components: see attached sheets.

Measurements According to, and Sample Unit Complies with:

FCC 47 CFR Part 15-2008 for the US, using ANSI C63.4-2003, with 72.87 dBuV/m – 69.20 dBuV/m = 3.67dB margin for Radiated Emissions.

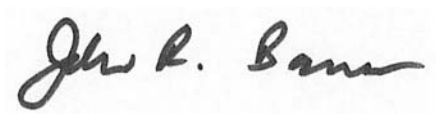
RSS-210 Issue 7 (June 2007) for Canada, using RSS-Gen Issue 2 (June 2007), with 72.87 dBuV/m – 69.20 dBuV/m = 3.67dB margin for Radiated Emissions

Measurement Equipment used: see attached sheets.

Report Prepared By: John R. Barnes KS4GL, PE, NCE, NCT, ESDC Eng, ESDC Tech, PSE, SM IEEE

Testing Performed by:
dBi Corporation
216 Hillsboro Avenue
Lexington, KY 40511-2105, USA
on September 4-October 10, 2010
at: Lexmark International, Inc.
Development Lab.
Lexington, KY 40550, USA

Reviewed and Approved by: John R. Barnes, KS4GL, PE, NCE, NCT, ESDC Eng, ESDC Tech, PSE, SM IEEE



SIGNED________________________________ Date: __ November 4,. 2010**__**
John R. Barnes, PRESIDENT dBi Corp.

November 4, 2010

To whom it may concern:

We, **Two Dimensional Instruments**, declare under our sole responsibility that the **TVRFL4 Base Station, and the WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors**, to which this declaration relates, conform with the protection requirements of FCC Part 15 for the US, and Industry Canada (IC) ICES-003 for Canada, for unintentional radiators.

This FCC/IC Declaration of Conformity (DoC) is based on the **TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM** complying with:

- FCC 47 CFR Part 15-2008, *Radio Frequency Devices.*
- IC ICES-003:2004, *Digital Apparatus.*

The tests that verified that the **TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM** conform to these standards were performed by:

dBi Corporation
216 Hillsboro Avenue
Lexington, KY 40511-2105, USA

including:

- ANSI C63.4-2003, *American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz,* for Radiated and Conducted Emissions.
- CAN\CSA-CEI/IEC CISPR 22:02, *Information technology equipment – Radio disturbance characteristics - Limits and methods of measurements,* for Radiated and Conducted Emissions.

The units that were tested are representative of those that will be manufactured for sale by **Two Dimensional Instruments.**

Signed:___________________________________ **Date:** __ November 4, 2010__

Two Dimensional Instruments
6901 Briarhill Rd
Crestwood, KY 40014

INFORMATION RELATING TO PRODUCT RF INTERFERENCE

Appliance/Product: Base Station and five Wireless Sensors
Model/Type Number: TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM
Rating: 9VDC

Power Line Filters: none.

RF Suppression Components: None.

Internal Frequencies:
Base Station 8MHz, 26.45125MHz
Wireless Sensors 300kHz, 8MHz

External Cables:
Data Cable, 0.15m unshielded with Steward 28A0640-0A2 ferrite between TVRFL4 Base
Station and ThermaViewer RF
2 Thermistor Cables, 1.7m unshielded between WS4HETMETM Wireless Sensor and thermistors
Thermocouple Cable, 1.2m unshielded between WS4HETC Wireless Sensor and thermocouple

Electronic Printed Circuit Boards:

Dual External Thermistor Base	Part #: WS4HETMETM
External Thermocouple Base	Part #: WS4HETC
Pressure Base	Part #: WS4IPR
Humidity Base	Part #: WS4ITMIHM
Humidity Base	Part #: WS4HITMIHM
Base Station RF Receiver	Part #: TVRFL4
433.920MHz Transmitter Module	Part #: WS4TX (one per Wireless Sensor, certified as a Modular Transmitter under FCC 47 CFR Part 15-2008 section 15.212 and RSS-Gen Issue 2 (June 2007) section 7.1.1)

Size of Product:
Base Station 95mm long x 60mm wide x 25mm high
Wireless Sensors 95mm long x 60mm wide x 25mm high
Weight of Product:
Base Station 0.1 kg
Wireless Sensors 0.1 kg
Operating Environment: Indoors

Modifications to the Equipment Under Test: None (Steward 28A0640-0A2 snap-on ferrite on the ThermaViewer RF's Data Cable used with the TVRFL4).

Appliance/Product: Transmitter Module
Model/Type Number: WS4TX
FCC ID: YVGWS4TX
Rating: 9VDC

Power Line Filters: none.

RF Suppression Components:
Resistor, 39 kohms, 1, R14

Internal Frequencies:
4MHz, 13.56MHz, 433.92MHz

External Cables: None

Electronic Printed Circuit Boards:
433.920MHz Transmitter Module Part #: WS4TX

Size of Product: 42mm long x 46mm wide x 6mm high
Weight of Product: 0.05 kg

Operating Environment: Indoors

Modifications to the Equipment Under Test:
R14 = 39 kohms, C1 = 0.1uF, and C19 = 330pF

Test Samples Received: Test samples were brought by the client for each test session

Overall Test Plan:
These units shall be tested as tabletop equipment. Equipment that normally is stacked, may be stacked in any convenient order. Tests may be performed in any order, except that that the last two tests shall be (if required):

1. Electrostatic Discharge (ESD).
2. Surge Immunity.

Composition of Equipment-Under-Test (EUT): Standard

Assembly of EUT (Options): Standard

Input/Output Ports:
Base Station: Data Port

WS4HETMETM Wireless Sensor: 2 Thermistor Ports

WS4HETC Wireless Sensor: Thermocouple Port

WS4IPR Wireless Sensor: None

WS4ITMIHM Wireless Sensor: None

WS4HITMIHM Wireless Sensor: None

WS4TX Transmitter Module: Power/Data Port

Auxiliary Equipment (AE):

ThermaViewer RF (DoC) for TVRFL4 Base Station

Cabling and grounding:

Data Cable plugged into the Data Port on the TVRFL4 Base Station and and any Data Port on the ThermaViewer RF
Thermistor Cable plugged into any Thermistor Port
Thermocouple Cable plugged into any Thermocouple Port

No grounding required.

Test Configuration:

TVRFL4 Base Station connected to ThermaViewer RF, with WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors nearby.

Operating Mode:

WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors measuring temperature, humidity, and pressure, and transmitting data to TVRFL4 Base Station for display on the ThermaViewer RF..

Symptoms of Malfunction for Immunity Tests:

Lose wireless link.
Data corrupted.

Performance Criteria for Immunity Tests:

1 or A = normal performance within the specification limits.
2 or B = temporary degradation, or temporary loss of function or performance during the test, which is self-recoverable.
3 or C = temporary degradation, or temporary loss of function or performance during the test, which requires operator intervention.
4 or D = loss of data, degradation, or loss of function or performance during the test, which is not recoverable due to damage to the hardware or software of the EUT.

Radiated Emissions/Radiated Disturbances 30-4,339.2MHz

Radiated Emission Standards:

FCC 47 CFR Part 15-2008 Class B, using ANSI C63.4-2003
ICES-003:2004 Class B, using CAN/CSA-CEI/IEC CISPR 22:02
RSS-210 Issue 7 (June 2007), using RSS-Gen Issue 2 (June 2007)

Appliance/Product: Base Station and five Wireless Sensors
Model/Type Number: TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM
Rating: 9VDC
Serial Number: 10, 5, 1, 7, 6, and 8

Appliance/Product: Transmitter Module
Model/Type Number: WS4TX
FCC ID: YVGWS4TX
Rating: 9VDC
Serial Number: 11

Host and Other Peripherals:

ThermaViewer RF (DoC) for TVRFL4 Base Station

Name of Test: Radiated Interference
Test Procedure: ANSI C63.4-2003 and EN 55022:2006+A1:2007
Test Location: 10m and 5m Semianechoic chambers at Lexmark test facility, located in Lexington, Kentucky
Test Distance: 10m distance for TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM in 10m Chamber

3m distance for WS4TX in 5m Chamber

Test Instrumentation: See attached sheets

Notes: Tests performed at 20.4°C, 40.9% relative humidity, and 98.29kPa atmospheric pressure in 10m chamber. Tests performed at 23.1°C, 45.6% relative humidity, and 98.15kPa atmospheric pressure in 5m chamber. Before starting any approval tests, we do Total Cals on all of the eceivers, then do a Radiated Checkout of the 10m Chamber (antenna, cables, and preamp) if one has not been performed within the last week The expanded uncertainty (k=2 for 95% probability) is +/-3.40dB for electric and magnetic fields below 30MHz; +/-3.26dB for electric fields from 30MHz to 1000MHz; and +/-3.84dB for electric fields from 1GHz to 18GHz.

The equipment-under-test (EUT) and auxiliary equipment (AE) are set up in the chamber according to the test plan and the test procedures. In general, we prefer to put the AE on the table with the EUT. Noisy AE, such as a Class A host computer or Class A router being used to test a Class B product, may be installed in the pit under the turntable or in the control room, cabled to the EUT through the hole in the middle of the turntable. In this case we put ferrites on the cable(s) underneath the turntable, to keep AE-induced and ambient noise from entering the chamber. Long input/output cables are serpentined to keep them >40cm from the floor.

If standard cables are available for an EUT's input/output port(s), we prefer to use them. If cables are custom-made for each installation of an EUT, we use cables that are at least 1m long. At least one port of each type on the EUT is connected to AE with a cable— except that we do not put cables on ports that are used only for manufacturing or servicing. If the EUT has multiple ports of a certain type, we add cables (that may go to AE, terminate in dummy loads, or be left unterminated) until adding a cable makes less than a 2dB increase in the emissions. The additional cables needed may be determined by testing this EUT, or by prior experience with these same input/output ports on previous products. If an EUT has several ports with identical functions that are mutually-exclusive— only one of them *can* be used in a particular installation of the EUT— we try to run the test with all of the cables attached, but only the noisiest port providing data to the EUT. If this configuration puts us over the limits, we experiment with one port at a time cabled to AE and providing data, with the other ports left unconnected. Then we make the official measurements using the noisiest port that will typically be used by users.

We set up the EUT, AE, input/output cables, and line cords/power cables in the configuration and typical operating mode that we think will maximize emissions. This may require some experimenting to determine for sure, but is usually the configuration/ operating mode that has as many subsystems of the EUT active simultaneously as possible, at their highest resolution, and operating at maximum speed.

We run an initial scan with the antenna in vertical polarization at heights of 1m, 2.5m, and 4m. We measure the 3-5 frequencies whose Radiated Emissions appear to be highest with respect to the test limits. Then we run an initial scan with the antenna in horizontal polarization the same way. For a small intentional radiator, we will perform three sets of initial scans (6 total), with the EUT sitting on its bottom or top, back or front, and left-side or right-side, to determine which orientation of the EUT maximizes emissions.

At any time during the approval testing, if a measurement is above or close to a limit, we try to determine the cause of the problem, and fix it. The first check is usually to turn off the EUT to see if there is a significant drop in the signal. Fixes to the EUT will be documented in the test notes and test report. If a piece of AE is the source of the noise, we may try a replacement (such as another hub/router, or using a crossover cable in place of a hub), or move the AE outside of the chamber. If AE is the source of the noise, and we can't resolve the problem any other way, we will measure these frequencies with the AE turned on and again with it turned off. We then note in the test notes, test plots, and test report that the excessive emissions are due to __________ piece of AE.

We examine the initial plots to see which frequency at which antenna orientation has the minimum margin versus the test limits. If the minimum margin is >6dB, we treat the cables as already being maximized, and immediately perform the official tests. Otherwise (the usual case), we return to the antenna orientation, frequency, azimuth, and antenna height with the minimum margin. We turn on the video projector in the chamber, or turn on the audio feedback, and take a baseline reading while we are in the chamber, before we touch anything. Then we move cables and line cords, trying to increase the emissions at this frequency, until any further changes have no effect, or reduce the emissions. This becomes our maximized cable configuration for the official tests, which will be photographed and included in the test report. For tests above 1GHz, we use the same cable configuration as maximized the emissions below 1GHz.

We now perform the official Radiated Emissions measurements. For each polarization of the antenna (vertical and horizontal), we spin the turntable at least one full turn each with the antenna at 1m. 2.5m. and 4m height. We choose at least 10 frequencies at each polarization that look “interesting”. At each of these frequencies we do a narrowband scan to find the frequency with the least margin against the test limits. We quasipeak (peak and average above 1GHz) this specific frequency, turning the turntable 360° with the antenna at the height that we think will maximize the emissions (usually 1m antenna height for vertical polarization, and 4m for horizontal polarization). After this full turn, we turn the turntable back to the azimuth (angle) with the highest emissions so far, and sit there long enough for the EUT to go through a full cycle. Then we vary the antenna height from 1m to 4m, to see if another antenna height gives us higher emissions. If so, we return to that antenna height, and turn the turntable again to find the maximum emissions. This becomes our official measurement. We repeat this process for all of the frequencies of interest in both antenna polarizations, at all AC input voltages/frequencies of concern, and for all frequency bands specified by the test standards.

For intentional radiators to be approved to EU and AUS/NZ standards, the fundamental and harmonics in the 30-1000MHz range should also be quasipeak measured with the EUT at 1.0m and 1.5m heights, at 10m distance.

For Radiated Emission Measurements below 30MHz we use a calibrated EMI receiver connected to a shielded-loop receiving antenna. We maximize power and modulation, move cables, and rotate both the EUT and the receiving antenna to maximize emissions. We set the receiver to:

- 200 Hz bandwidth for 9kHz to 150kHz measurements.
- 9kHz bandwidth for 150kHz to 30MHz measurements
- 120kHz bandwidth for 30MHz to 1GHz measurements.

Otherwise, there is very little agreement between nations, between overlapping standards/ regulations within a nation, between versions of a standard, or even *inside one standard*, for:

- Electric field strength, magnetic field strength, RF carrier current, effective radiated power (ERP), or equivalent isotropic radiated power (EIRP).
- 15dB, 20dB, or 33dB bandwidth.
- Of the fundamental, harmonics, out-of –band emissions, or spurious emissions,
- Measured with peak, quasipeak, or average detectors.
- Expressed in uV/m, dBuV/m, dBuA/m, or Watts
- Measured over a ground plane or not,
- At 300m, 30m, 10m, or 3m distance,
- Under 30MHz, extrapolated to other distances by using the square of the ratio of the distances (40dB/decade distance), by measurements at two distances on one radial from the EUT, or by using a frequency-dependent conversion factor,
- With tabletop EUT's on an 0.8m, 1.0m, or 1.5m high support,
- With floor-standing EUT's on a <= 12mm-thick insulator.
- With the center, or the bottom, of the loop antenna at 1m height,
- Over 0°C to 35°C, 0°C to 40°C, 0°C to 55°C, -10°C to 55°C, –20°C to 50°C, or -20°C to +55°C temperature range,
- Over nominal supply voltage +/-10%, nominal–10% to nominal+30%, nominal +/-15%, with a freshly-charged battery, or with a new battery.
- At temperature extremes, over a temperature range, or at temperature *and* supply voltage extremes.
- At 0 minutes, 1 minute, 2 minutes, 5 minutes, 10 minutes, 15 minutes, or 30 minutes after startup at a specific temperature/voltage.

Therefore, when running Radiated Emission tests on intentional radiators operating under 30MHz, we record the temperature, humidity, and atmospheric pressure at the test site as a baseline value for temperature/supply voltage measurements. If the EUT is AC powered, we test it at nominal, low, and high input voltage for each distance/EUT height/loop-antenna height/mode. We check emissions at the fundamental frequency, and for any harmonics (up through the 10^{th} harmonic) that fall into the frequency range being tested (i.e 9kHz to 30MHz, 30MHz to 1000MHz). For each test point (frequency, distance, EUT height, loop antenna height) we record the peak, quasipeak, and average values in whatever units the EMI receiver provides. With the EMI receiver set to a 1-second measurement time (so we have long enough to note the full reading), we observe the signal level for at least 10 seconds (>= 10 samples) with each detector, and record the highest level seen during this interval.

For the test report we translate these values into dBuV/m, dBuA/m, uV/m, and uA/m using the equations (or their inverses):

- Electric field strengh in uV/m = 377 ohms * magnetic field strength in uA/m.
- Electric field strength in dBuV/m = 20 * log (electric field strength in uV/m).
- Magnetic field strength in dBuA/m = 20 * log (magnetic field strngth in uA/m)

Extrapolation to other measurement distances, or conversion to power in Watts, is done using the formulas in the specific standards, The loop antenna is mounted on a tripod stand that lets us set its height, and turn the loop for the maximum signal pickup. This is typically with the plane of the loop perpendicular to the line-of-sight to the EUT. For an EUT with the antenna mounted on its front/back/ left/right, the maximum signal pickup will usually be with the EUT's antenna pointed at the loop antenna..

To estimate emissions at temperatures other than those at which the Chamber/OATS test were run, we put the EUT in a thermal chamber. We attach a magnetic field (H-field) probe to the antenna of the EUT using rubber bands, tape, or some other means to keep it in a fixed position with respect to the EUT. A coaxial cable, running through a port in the side/back of the thermal chamber, connects the H-field probe to an EMI receiver outside the chamber. We do a TOTAL CAL of the EMI receiver before starting testing. We put the EUT in the same mode, with the same supply voltage, and at the same temperature, at which the reference Chamber/OATS tests were run. After letting the temperature of the EUT stabilize, we measure the EUT's output as our baseline measurement. Then we vary the temperature, supply voltage, time from power-up, etc., as needed to get the variations due to temperature, supply voltage, and whatever else is specified by the standard(s).

The US and Canada permit these measurements to be made with a groundplane (in the 10m or 5m Chamber) or without a groundplane (next to the open air test site (OATS)). A tabletop EUT sits on an 0.8m high table, with the center of the loop antenna 1.0m high and 3m or 10m from the EUT. We use inverse square of the ratio of distances (-40dB/decade distance) to correct for electric and magnetic fields at other distances.(FCC 47 CFR Part 15-2008 15.31(f)(1)) For 9-90kHz and 110-490kHz we use average and peak measurements, with the peak limit 20dB above the average limit (FCC 47 CFR Part 15-2008 15.35(b)), otherwise we use quasipeak measurements. The loop antenna is the most sensitive when the coil is perpendicular to the line-of-sight. Record the temperature, humidity, and atmospheric pressure, as the baseline for temperature-chamber tests. Measure the fundamental and all of the harmonics (up through the 10^{th}) that fall into the frequency range 9kHz-30MHz..

For Europe, Australia, and New Zealand, these measurements must be made without a groundplane, at the open air test site (OATS). A tabletop EUT will be on a 1.0m or 1.5m high support (use the mag field table, and add boxes or reams of paper to get the desired height). Set the bottom of the loop antenna 1.0m high, 10m away.from the EUT. Make quasipeak measurements. The loop antenna is the most sensitive when the coil is perpendicular to the line-of-sight. Record the temperature, humidity, and atmospheric pressure, as the baseline for temperature-chamber tests. . Measure the fundamental and all of the harmonics (up through the 10^{th}) that fall into the frequency range 9kHz-30MHz..

Noise Floor measurements in the 10m Chamber are made with the door from the 10m Chamber to the control room open, and all other doors to the 10m Chamber, control room, and 5m Chamber closed. Everything is connected and placed for official measurements, but the EUT is powered off.

Noise Floor measurements at the OATS are made with everything connected and placed for official measurements, but with the EUT powered off (unplugged from AC power, or batteries removed).

For <= 30MHz Intentional Radiators:we consider each of the following tests, that one or more standards require

Test Name	**Applies to EUT**	**Status**
Power-line conducted emissions	no	----
Radiated emissions	no	----
Transmitter spectrum mask	no	----
Antenna port conducted signals	no	----
Carrier frequency stability	no	----
Occupied bandwidth	no	----
Output power	no	----
Power spectral density	no	----
In-situ radiated emissions	no	----
Cordless phone security code	no	----
Cordless phone frequency pairing	no	----
Input power	no	----
Periodic operation	no	----
Average value of pulsed emissions	no	----
Compliance with periodic emissions	no	----
Frequency hopping	no	----
Millimeter wave device	no	----
Transmitter etiquette	no	----
UWB device	no	----
Duty cycle	no	----
Operating frequency	no	----
Modulation bandwidth	no	----
Out-of-band transmissions	no	----
Spurious transmissions	no	----
Receiver adjacent channel sensitivity	no	----
Receiver blocking/desensitization	no	----
Receiver spurious emissions	no	----

In the tables below, “Cable Correction Factor dB” covers everything in the standard signal chain between the antenna and the EMI receiver(s). For Radiated Emission measurements with a:

- Loop antenna, below 30MHz, the standard signal chain consists of just the signal cable between the antenna and the EMI receiver. The EMI receiver gets the antenna identifier via the control cable, which also identifies the signal cable and its length, and thus the default antenna factors and cable losses.

- Bilog antenna, for 30 to 1000MHz, the standard signal chain consists of a coaxial cable with ferrites, a preamplifier under the chamber floor, coaxial cable(s) to the control station, a signal splitter, and short coaxial cables to two EMI receivers.
- Horn antenna, above 1GHz, the standard signal chain consists of a preamplifier next to the antenna, a coaxial cable to another preamplifier under the chamber floor, and a second coaxial cable to the EMI receiver.

For Radiated Emission measurements above 30MHz we use a low-noise preamplifier mounted as close as possible to the antenna to:

1. Lower the noise floor.
2. Boost the signal level.

   AND THUS

3. Increase the signal-to-noise ratio (SNR).

When calibrating the chamber, we use a vector network analyzer (VNA) to measure the total power loss/gain from the connector going to the antenna to the connector(s) going to the EMI receiver(s). This power loss/gain is our Cable Correction Factor.

Putting two EMI receivers in parallel for 30-1000MHz measurements has a number of benefits:

1. For wideband scans, one EMI receiver monitors 30-500MHz while the second EMI receiver monitors 500-1000MHz, giving us < 1MHz-wide.frequency bins over the entire 970MHz span.
2. While making quasipeak/average/peak measurements with one EMI receiver, we can simultaneously watch the (5MHz) span around this frequency to see just what the equipment-under-test (EUT) and auxiliary equipment (AE) are doing. This can be extremely useful when the noise level suddenly jumps up, to see if a clock/ strobe turns on, a switching regulator turns on or changes mode, data transfers start/stop, or whatever else might be causing the noise change.
3. We can simultaneously monitor two different frequency bands-- in close detail-- to see if noise on them has the same/different cause(s).
4. We can (manually) put one EMI Receiver into Spectrum Analyzer mode with 0-Hz span. This effectively turns it into a oscilloscope for one frequency, letting us see the waveform(s) that are causing a problem, while we observe the noise level/noise envelope with the second receiver.
5. Any other crazy experiments that we may come up with while chasing down noise problems, where seeing two different types of time/frequency-domain data simultaneously can help us identify the noise source(s) and antenna(s).

When testing intentional radiators, we may need to add attenuators or filters between the antenna and the preamplifier—that are not part of the standard signal chain. Strong signals can overload a preamplifier, causing signal compression or making it generate spurious harmonics. Or a strong signal at one frequency can desensitize the preamplifier to noise signals at other frequencies. These attenuators/filters must be calibrated, and we include their losses in our calculations when we crunch the Radiated Emissions data.

Due to software limitations, we must measure peak (PK+), quasipeak (QP), and average (AV) emissions of intentional radiators at least partly in manual mode. For a given waveform (shape, modulation, duty cycle) the true PK+, QP, and AV values are all be proportional to one another and to the magnitude of the signal.. *Measured* PK+, QP, and AV values may be higher than the true PK+, QP, and AV values, because the receiving antenna picks up noise from the Auxilary Equipment (AE) in addition to the desired signal from the equipment-under- test (EUT), and the EMI Receiver also sees thermal (and other) noise from the antenna, cables, preamplifier(s), and itself. These unwanted noise sources set a noise floor (minimum noise level) that depends on the frequency, detector, bandwidth, and any filters that we are using. But if we find an antenna polarization, azimuth (turntable angle), and antenna height that maximizes the measured value with one of the detectors, it will maximize the measured values for all detectors.

Thus we use a four-step process to measure the Radiated Emissions of intentional radiators:
1. Put the EUT into its noisiest operating mode
2. Identify the noise frequencies coming from the EUT.
3. Center the receive antenna in the strongest lobe of the noise coming from the EUT.
4. Measure PK+, QP, and AV.

For small intentional radiators that operate between 30 and 1000MHz, we measure PK+, QP, and AVE for the fundamental and any harmonics within this range as follows:
1. With the equipment-under-test (EUT) upright, measure the frequencies of interest in QP mode with the bi-con antenna vertical and horizontal (Lexmark's EMC software records the azimuth and antenna elevation for the highest QP emissions). If the receiver shows an overload, increase input attenuation by 10dB, then redo the measurement (as many times as needed).
2. Repeat step 1 with the EUT on its back or front.
3. Repeat step 1 with the EUT on its right or left side.
4. Study the plots to determine which orientation of the EUT had the highest emissions in QP mode.
5. Return the EUT to this position. With the bi-con antenna vertical, go back to the azimuth and antenna elevation that maximized the QP emissions at a given frequency.
6. Using a 1 second sampling time, measure PK+ and QP, taking the maximum values seen on the receiver over 10-20 seconds. If the receiver showed an overload, or we still suspected signal compression, we increased the input attenuation by 10dB. If the measurement stayed the same, we used the previous reading. If the value increased, we continued increasing the attenuation in 10dB steps until the measurement stayed the same, then reduced the attenuation 10dB for the official measurement.
7. Using a 100 millisecond sampling time, measure AVE, taking taking the maximum value seen on the receiver over 10-20 seconds. (Since we could only catch the top 2 digits, we used 0.99dB as the fractional part to be conservative.)
8. In the calculations, add the attenuator's loss to the measured value to get the true field strength.

9. Repeat steps 5 to 8 with the bi-con antenna horizontal.

Many intentional radiators are intended to transmit infrequently, or only when some event triggers them. For Radiated Emissions testing, we frequently need a test mode—or even special test code—to make the EUT transmit continuously, or frequently enough (say, once every one or two seconds) that we can measure its transmissions.

We do our initial scans in Spectrum Analyzer mode, turning the turntable and the EUT 360° with the receiving antenna at 1m, 2.5m, and 4m heights. At 10m distance, these positions are approximately 9° apart vertically, as seen from the EUT, At 5m distance they are approximately 18° apart vertically. An antenna would need to have a very-narrow beamwidth, and be aimed just right, for us to completely miss it in these initial scans. For convenience, we let the Spectrum Analyzer continue to scan while we change the antenna height, which gives us some additional nondeterministic coverage at heights between 1m and 2.5m, and between 2.5m and 4m..

The standards require us to check the 6 frequencies that look like they have the least margin— but we always check at least 10 frequencies in each polarization for official measurements. And just on general principles (to keep Murphy's Law at bay), we will check the fundamental frequency and its 2nd through 10th harmonics even if the Spectrum Analyzer displays don't show anything. We operate on the basis that it is much easier to collect a little extra data while everything is set up—and ignore it if it isn't significant—than to have to retest the danged thing later because we missed something important!

For measurements from 30-1000MHz we use the standard Radiated Emissions software to measure in peak mode, then in quasipeak mode. For measurements above 1GHz we use the standard Radiated Emissions software to measure in peak and average mode. For measurements below 30MHz we put the EMI Receiver in Spectrum Analyzer mode, measuring in peak mode.

If an intentional radiator is small, and can operate it any position, we will do initial scans with it rightside up/upside down, on its left side/right side, and on its front/back. If the intentional radiator is designed to operate only in a certain position(s), we will do initial scans in that/those position(s).

For measurements below 30MHz we use a loop antenna which is not polarized, so we only take one set of measurements in the initial scans. For measurements from 30 to 1000MHz we use a bilog antenna, and take measurements in vertical and horizontal polarizations. For measurements above 1GHz we use a horn antenna and take measurements in vertical and horizontal polarizations.

We first do a peak wideband scan of 9kHz to 30MHz, 30MHz to 1000MHz, 1GHz to 18GHz, or 18GHz to 40GHz to find suspicious signals. Then we do peak narrowband scans of this initial list, with a span less than 1% of the wideband span, to find the worst noise frequencies with kilohertz precision. Now we switch to EMI Receiver mode, with an appropriate detector (peak, quasipeak, or average).. We spin the turntable 360°, with the antenna at the height that we think will maximize the signal:

- For the loop antenna, whatever height is specified by the standard(s).
- 1m height for the bilog antenna in vertical polarization.
- 4m height for the bilog antenna in horizontal polarization.
- The same height as the EUT for the horn antenna(s).

We turn the turntable to the azimuth (angle) that saw the maximum emissions during the first spin. If the signal is pulsing, we may jog the turntable clockwise and counter-clockwise a few degrees to make sure we have found the tip of the lobe. If the EMI receiver shows "overload", we increase its input attenuation in 10dB steps until it come out of this mode, and can make accurate measurements again. We now sit at this azimuth for a few seconds, to let the EUT go through a complete operating cycle.

For the loop antenna, we turn the loop antenna to maximize the received signal (typically with the loop antenna perpendicular to the line-of-sight to the EUT).. For the bilog and horn antennas, we scan the antenna to the other end of its 1m to 4m height range. If we see a higher reading than from our first spin, we go back to that height and spin the turntable again to see if we can get an even higher reading at a different azimuth. Now we record the frequency, antenna polarization, azimuth, antenna height, and the maximum noise reading that we saw from the EUT.

The last step, taking peak, quasipeak, and average measurements, is completely manual. If we have been using the Radiated Emissions software, we close the program to keep it from butting in. We now:

- Turn on the peak, quasipeak, and average detectors.
- Set the sampling time to 1 second.
- Select continuous scan mode.
- Set the receiver bandwidth, if it hasn't done so automatically.
- For each frequency on our list:
    1. Set the EMI receiver to the desired frequency.
    2. Set the antenna to the desired polarization.
    3. Turn the turntable to the azimuth we recorded earlier.
    4. Raise/lower the antenna to the height we recorded earlier.
    5. Watch the receiver for 10+ seconds per measurement, recording the highest values.

If the receiver shows "overload", we increase the input attenuation in 10dB steps until the measurements don't change (the receiver isn't compressing the signal), then decrease the input 10dB to take the measurements.

If we had to use an attenuator or a high-pass filter right after the antenna—that isn't part of the standard signal chain—we record its equipment number, so we can include its (frequency-dependent) attenuation in our calculations.

For measurements from:

- 9kHz to 150kHz we use a 200Hz 6dB resolution bandwidth (RBW).
- 150kHz to 30MHz we use a 9kHz 6dB RBW.
- 30MHz to 1000MHz (1GHz) we use a 120kHz 6dB RBW.
- Above 1GHz we use a 1MHz 6dB RBW.

All quasipeak/average/peak measurements are made in EMI Receiver mode. According to the receiver specifications, video bandwidth (VBW) doesn't apply, the bandwidth error is under 10% and the shape factor (B(60dB)/B(6dB)) is under 10.

We tested the TVRFL4 Base Station and the WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors as a system, with all of these units plus the ThermaViewer RF on an 0.8m high table on the 10m Chamber's turntable. All measurements were made at 10m distance. The five Wireless Sensors all had down-level WS4TX Transmitter Modules transmitting 109ms data bursts at 2 second intervals at 433.92MHz, to generate traffic for the TVRFL4 and the ThermaViewer RF. We did not have an attenuator between the receive antenna and the preamp— which the 433.92MHz transmissions severely overloaded— generating bogus harmonics at 867.84MHz, 1301.76MHz, 1735.68MHz, etc,.during each data burst. Thus, to see if the TVRFL4 and ThermaViewer RF generated any noise around 433MHz and 867MHz, we unplugged the batteries from the Wireless Sensors, then rechecked these two frequency ranges.

For FCC/IC Certification, we tested the WS4TX Transmitter Module with a WS4ITMIHM board without an enclosure on an 0.8m high table on the 5m Chamber's turntable. . All measurements were made at 3m distance. Based on our experiences testing previous FCC 47 CFR Part 15-2008 15.231(e) products, we put a calibrated 20dB attenuator right after the bi-con antenna to prevent signal compression in the preamp/ receiver chain. for measurements from 30-1000MHz. We added its loss (20.21dB at 433.92MHz, 20.15dB at 837.84MHz) to the field strengths measured by the receiver in this band. We used a different antenna and preamp for measurements above 1GHz. The FCC 47 CFR Part 15-2009 15.231(e) limits above 1GHz are lower than the Class A limits above 1GHz, thus any linearity concerns had already been addressed during equipment calibration.

Under Section 15.231(e), the average limit for the fundamental is calculated by linear interpolation with frequency from 1500uV/m at 260MHz to 5000uV/m at 470MHz when measured at 3m distance. Thus the average limit = ((5000uV/m-1500uV/m)*(433.92MHz-260MHz)/(470MHz-260MHz))+1500uV/m = 4399uV/m at 3m distance. To convert this to deciBels (dB), which is defined by the ratio of two powers, we use one of the equations:

- dB = 10*log(power/reference_power)
- dB = 20*log(electric_field/reference_electric_field)
- dB = 20*log(magnetic_field/reference_magnetic_field)

20*log(4399 uV/m / 1 uV/m) = 20*log(4399) = 72.87dBuV/m at 3m distance. Section 15.35(b) sets the peak limit for the fundamental to 20 dB above the average limit =

72.87dBuV/m +20dB = 92.87dBuV/m at 3m distance. For spurious emissions, section 15.231(e) sets the average limit to 20dB below the maximum permitted fundamental level, or 72.87dBuV/m – 20dB = 52.87dBuV/m at 3m distance, with the peak limit 20dB higher = 52.87dBuV/m +20dB = 72.87dBuV/m at 3m distance.

The WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors transmit a 109ms data burst. This is longer than the 0.1s sampling time for pulsed emissions called out in FCC 47 CFR Part 15-2008 section 15.35(c) and RSS-Gen Issue 2 (June 2007) section 4.5. Therefore we did not use the peak emissions— corrected by the duty cycle— to calculate average field strength. Instead we measured the field strength with an average detector set for 0.1s sampling time, watching the EMI receiver long enough to observe at least 10 data bursts. With the AVE reading changing 10 times/second, we could only catch the first two digits (integer part) when it jumped up. To be conservative, we recorded the highest value that we saw— with an assumed fractional part of 0.99— and compared this value against the FCC/IC limit. For PK+ and QP measurements we set the measurement time to 1s, so it was easy to catch all 4 digits of the highest reading..

The 20dB occupied bandwidth (OBW) for the WS4TX is to be <= 0.25% of the center frequency = 0.0025 * 433.92MHz = 1.0848MHz. We measured this using the standard Radiated Emissions test setup, with the:

- EMI Receiver in spectrum analyzer mode, max hold, 5MHz span, 100kHz resolution bandwidth (RBW), 300kHz video bandwidth (VBW), 6ms sweep time (i.e. our standard narrowband scan configuration below 1GHz).
- Turntable stopped.
- Receive antenna stopped
- Wait long enough to get the whole envelope of the emissions, then measure the peak frequency and value. Move the marker right of the peak (higher frequencies) until everything past it is more than 20dB below the peak. This frequency is fH. Move the marker left of the peak (lower frequencies) until everything past it is more than 20dB below the peak. This frequency is fL. The occupied bandwidth = fH-fL..

Modifications to the Equipment Under Test:

The Wireless Sensors passed without any changes.

To make the ThermaViewer RF and TVRFL4 Base Station comply with the Class B limits, we had to put a Steward 28A0640-0A2 snap-on ferrite on the ThermaViewer RF's Data Cable.

To make the WS4TX comply with the FCC 47 CFR Part 15-2008 section 15.231(e) and RSS-210 Issue 7 (June 2007) section A1.1.5 limits, we had to add:

- R14 = 39 kohms.
- C1 = 0.1uF.
- C19 = 330pF.

These modifications will be performed by the manufacturer, before shipping any units to original equipment manufacturers (OEM's) or end users. The firmware that controls transmit-signal modulation can not be modified by OEM's or end users. This firmware enforces at least a 10 second silent period between transmitting data bursts, to ensure compliance-by-design to FCC 47 CFR Part 15-2008 section 15.231(e) and RSS-210 Issue 7 (June 2007) section A1.1.1,.

Test Results:

With this modification to the ThermaViewer RF's Data Cable, Table 1 shows that the TVRFL4 Base Station, and the WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors, meet the radiated interference requirements of:

- FCC 47 CFR Part 15-2008 Class B (CISPR 22:2008 Table 6, 15.109(a)).
- IC ICES-003:2004 Class B (CAN/CSA-CEI/IEC CISPR 22:02 Table 6).

With these modifications to the WS4TX, Tables 2 through 4 show that the WS4TX Transmitter Module meets the radiated interference requirements of:

- FCC 47 CFR Part 15-2008 (15.209 and 15.231(e)).
- IC RS-210 Section A1.1.5 (Tables 2 and 5).

SIGNED________________________________**DATE** __ November 4, 2010__

John R. Barnes KS4GL, PE, NCE, NCT, ESDC Eng, ESDC Tech, PSE, SM IEEE

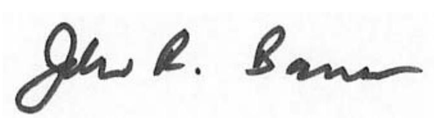
Radiated Emissions Data 30-1000MHz (9VDC)

Appliance/Product: Base Station and five Wireless Sensors
Model/Type Number: TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM
Rating: 9VDC
Serial Number: 10, 5, 1, 7, 6, and 8

TABLE 1: Quasipeak Emissions at 10m

Receiver Meas. Freq. MHz	Raw Reading Vert. dBuV	Raw Reading Horiz. dBuV	Cable Correction Factor dB	Antenna Factor dB/m	Radiated Interference Field Strength Vert. dBuV/m	Radiated Interference Field Strength Horiz. dBuV/m	CISPR 22 Class A Limit dBuV/m
73.298	33.847	------	-21.159	6.730	19.418	------	30
80.049	32.188	------	-19.876	7.407	19.719	------	30
146.673	27.969	33.576	-20.019	11.066	19.016	24.623	30
160.004	------	32.857	-19.271	10.200	------	23.786	30
166.674	29.917	------	-19.838	9.766	19.845	------	30
206.676	------	31.360	-19.709	8.900	------	20.551	30
213.368	30.485	32.869	-20.275	8.732	18.942	21.326	30
219.998	------	35.101	-21.049	9.000	------	23.052	30
226.679	31.191	36.432	-19.518	9.668	21.341	26.582	30
433.921	16.068	------	-19.695	16.896	13.269	------	37
435.135	------	15.240	-18.830	16.900	------	13.310	37
869.836	16.263	16.263	-17.904	22.216	20.575	20.575	37

Sample Calculation: Raw reading (dBuV) + cable correction factor (dB) + antenna factor (dB/m) = Radiated Interference Field Strength (dBuV/m).



SIGNED________________________________**DATE** __ November 4, 2010__
John R. Barnes KS4GL, PE, NCE, NCT, ESDC Eng, ESDC Tech, PSE, SM IEEE

Radiated Emissions Data 30-4,339.2MHz (9VDC)

Appliance/Product: Transmitter Module
Model/Type Number: WS4TX
FCC ID: YVGWS4TX
Rating: 9VDC
Serial Number: 11

TABLE 2: QUASIPEAK EMISSIONS AT 3m

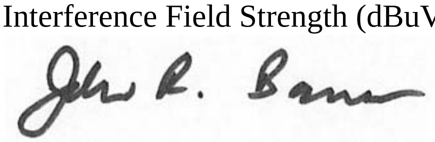
Receiver Meas. Freq. MHz	Raw Reading Vert. dBuV	Raw Reading Horiz. dBuV	Cable Corr. Factor dB	Anten. Factor dB/m	Receiver Reading Vert. dBuV/m	Receiver Reading Horiz. dBuV/m	Atten. dB	Rad. Inter. Field Strength Vert. dBuV/m	Rad. Inter. Field Strength Horiz. dBuV/m	15.231(e) QP Limit dBuV/m
433.912	53.120	41.337	-19.162	16.900	50.858	39.075	20.21	71.068	59.285	
867.840	24.960	24.724	-17.389	22.608	30.179	29.943	20.15	50.329	50.093	

Sample Calculation: Raw reading (dBuV) + cable correction factor (dB) + antenna factor (dB/m) = receiver reading (dBuV/m). Receiver reading (dBuV/m) + attentuation (dB) = Radiated Interference Field Strength (dBuV/m).

TABLE 3: PEAK EMISSIONS AT 3m

Receiver Meas. Freq. MHz	Raw Reading Vert. dBuV	Raw Reading Horiz. dBuV	Cable Corr. Factor dB	Anten. Factor dB/m	Receiver Reading Vert. dBuV/m	Receiver Reading Horiz. dBuV/m	Atten. dB	Rad. Inter. Field Strength Vert. dBuV/m	Rad. Inter. Field Strength Horiz. dBuV/m	15.231(e) Peak Limit dBuV/m
433.9	56.362		-19.162	16.900	54.100		20.21	74.310		92.87
867.8	31.331		-17.389	22.608	36.550		20.15	56.700		72.87
1301.8	46.982	45.034	-27.109	25.258	45.131	43.183	0.000	45.131	43.183	72.87
1735.7	42.493	37.396	-25.300	27.211	44.404	39.307	0.000	44.404	39.307	72.87
2169.7	38.074	31.778	-24.530	28.739	42.283	35.987	0.000	42.283	35.987	72.87
2603.5	36.936	40.088	-23.929	29.607	42.614	45.766	0.000	42.614	45.766	72.87
3037.4	28.858	28.044	-23.103	30.437	36.192	35.378	0.000	36.192	35.378	72.87
3471.4	27.793	27.793	-22.131	30.871	36.533	36.533	0.000	36.533	36.533	72.87
3905.3	26.297	27.035	-21.359	31.305	36.243	36.981	0.000	36.243	36.981	72.87
4339.2	25.380	25.380	-20.742	32.146	36.784	36.784	0.000	36.784	36.784	72.87

Sample Calculation: Raw reading (dBuV) + cable correction factor (dB) + antenna factor (dB/m) = receiver reading (dBuV/m). Receiver reading (dBuV/m) + attentuation (dB) = Radiated Interference Field Strength (dBuV/m).



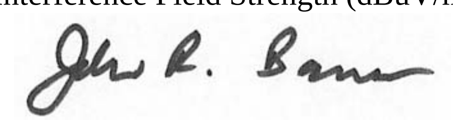
SIGNED________________________________**DATE** Oct. 12, 2010

John R. Barnes, PRESIDENT dBi Corp.

TABLE 4: MEASURED AVERAGE EMISSIONS AT 3m

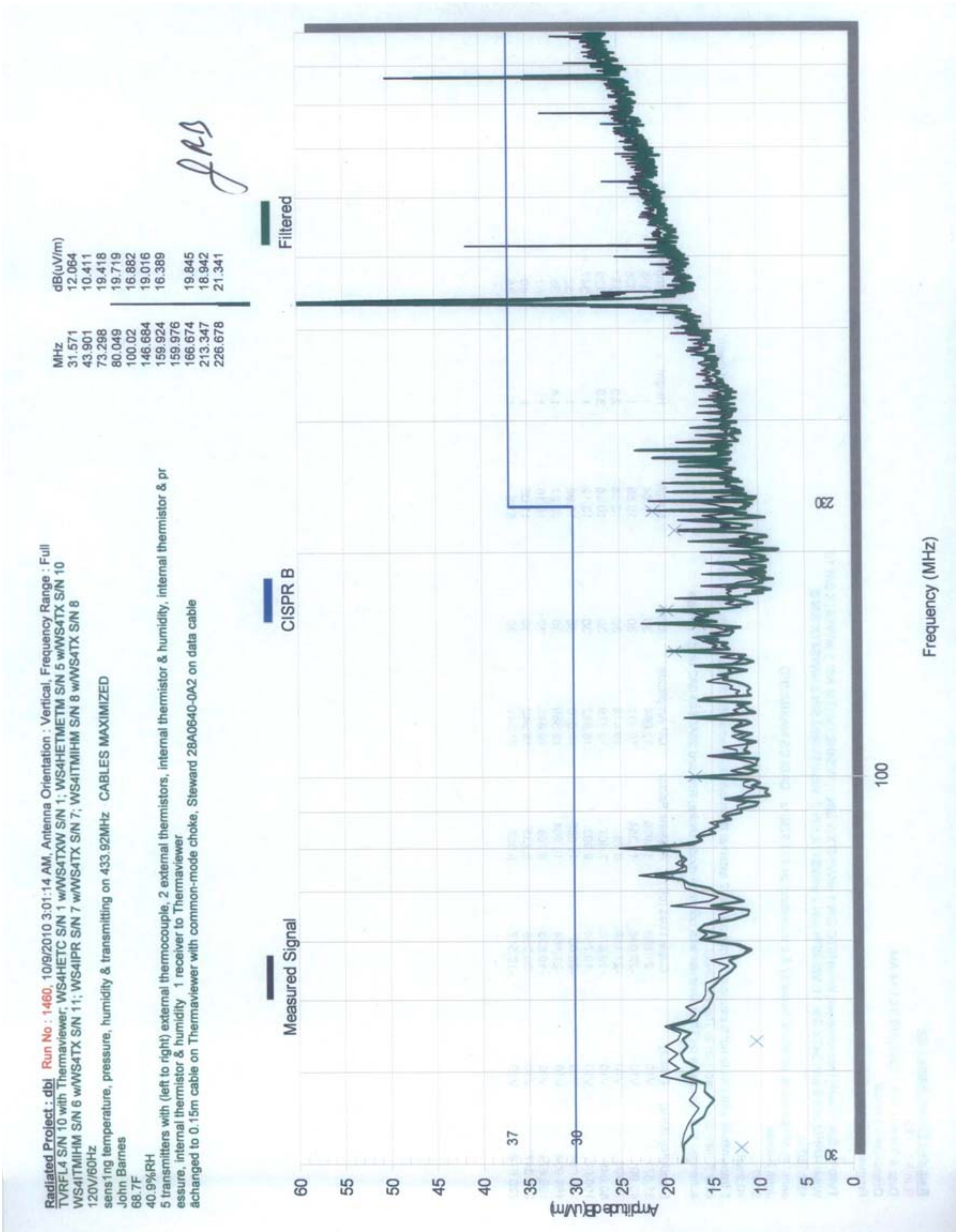
Receiver Meas. Freq. MHz	Raw Reading Vert. dBuV	Raw Reading Horiz. dBuV	Cable Corr. Factor dB	Anten. Factor dB/m	Receiver Reading Vert. dBuV/m	Receiver Reading Horiz. dBuV/m	Atten. dB	Rad. Inter. Field Strength Vert. dBuV/m	Rad. Inter. Field Strength Horiz. dBuV/m	15.231(e) Peak Limit dBuV/m
433.9	51.252		-19.162	16.900	48.990		20.21	69.200		72.87
867.8	18.771		-17.389	22.608	23.990		20.15	44.140		52.87
1301.8	39.246	36.922	-27.109	25.258	37.395	35.071	0.000	37.395	35.071	52.87
1735.7	35.182	28.276	-25.300	27.211	37.093	30.187	0.000	37.093	30.187	52.87
2169.7	29.461	20.529	-24.530	28.739	33.670	24.738	0.000	33.670	24.738	52.87
2603.5	28.777	31.180	-23.929	29.607	34.455	36.858	0.000	34.455	36.858	52.87
3037.4	15.919	14.896	-23.103	30.437	23.253	22.230	0.000	23.253	22.230	52.87
3471.4	13.947	14.144	-22.131	30.871	22.687	22.884	0.000	22.687	22.884	52.87
3905.3	12.530	12.643	-21.359	31.305	22.476	22.589	0.000	22.476	22.589	52.87
4339.2	12.061	12.063	-20.742	32.146	23.465	23.467	0.000	23.465	23.467	52.87

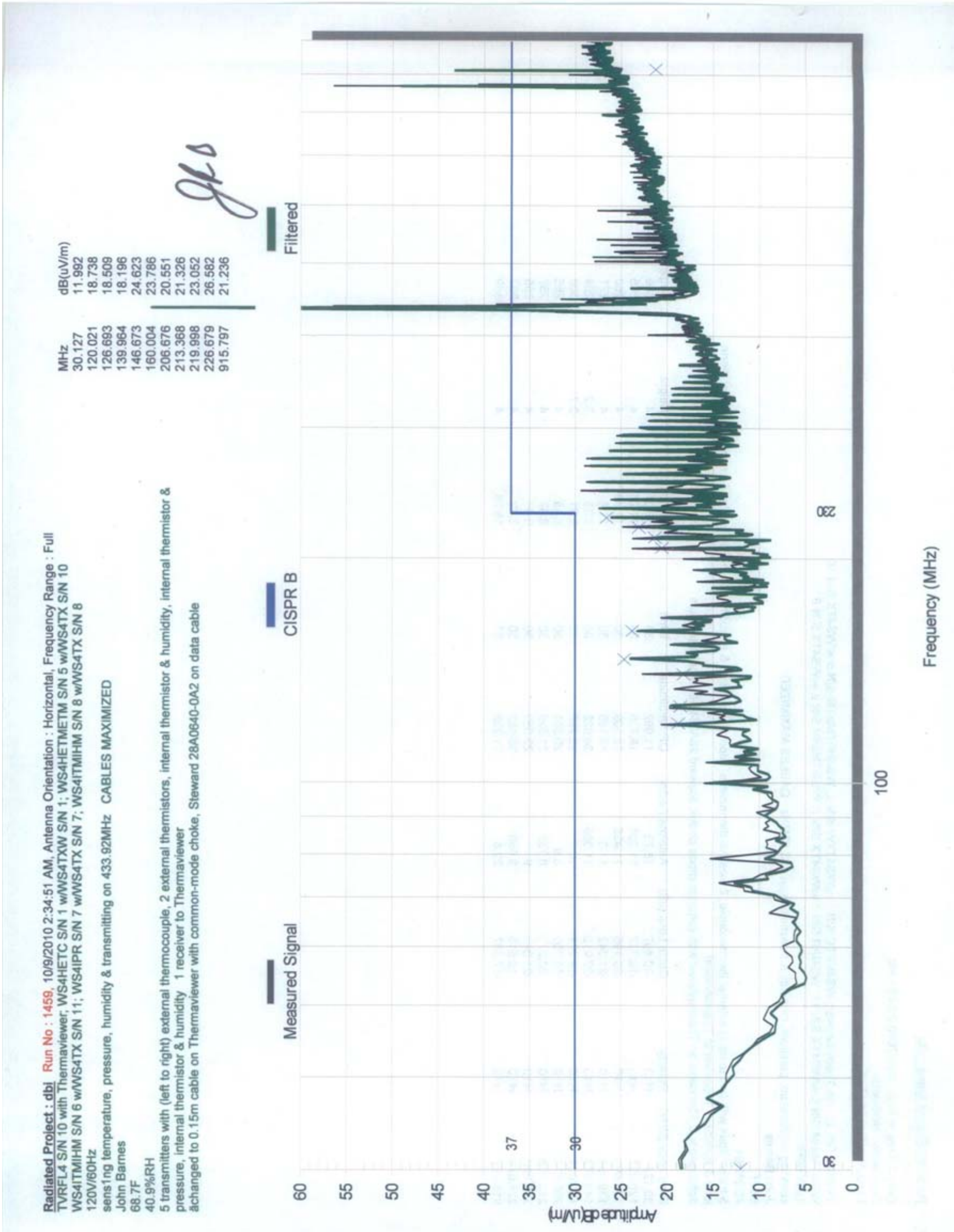
Sample Calculation: Raw reading (dBuV) + cable correction factor (dB) + antenna factor (dB/m) = receiver reading (dBuV/m). Receiver reading (dBuV/m) + attentuation (dB) = Radiated Interference Field Strength (dBuV/m).



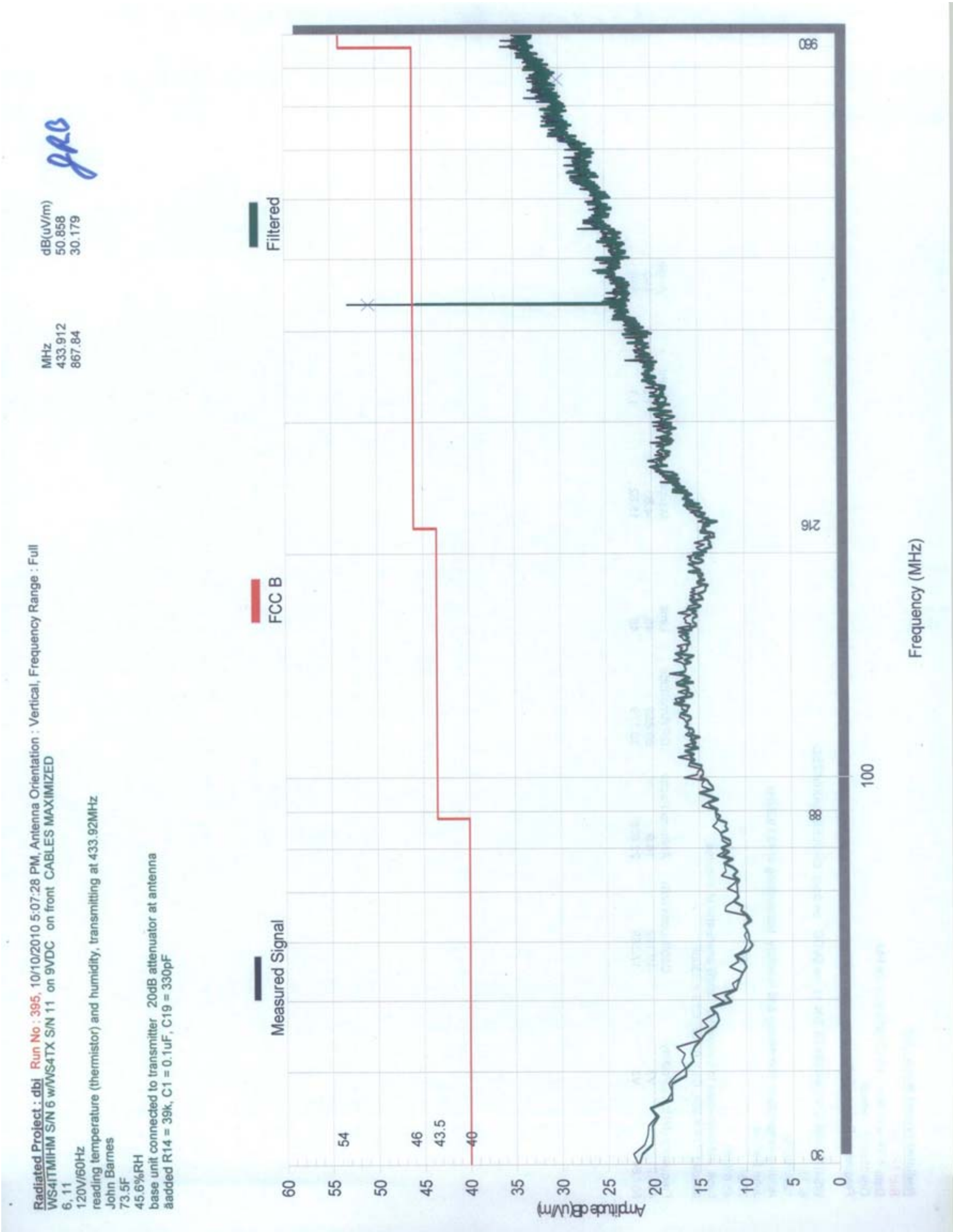
Signed______________________________________**Date** __April 30, 2010__

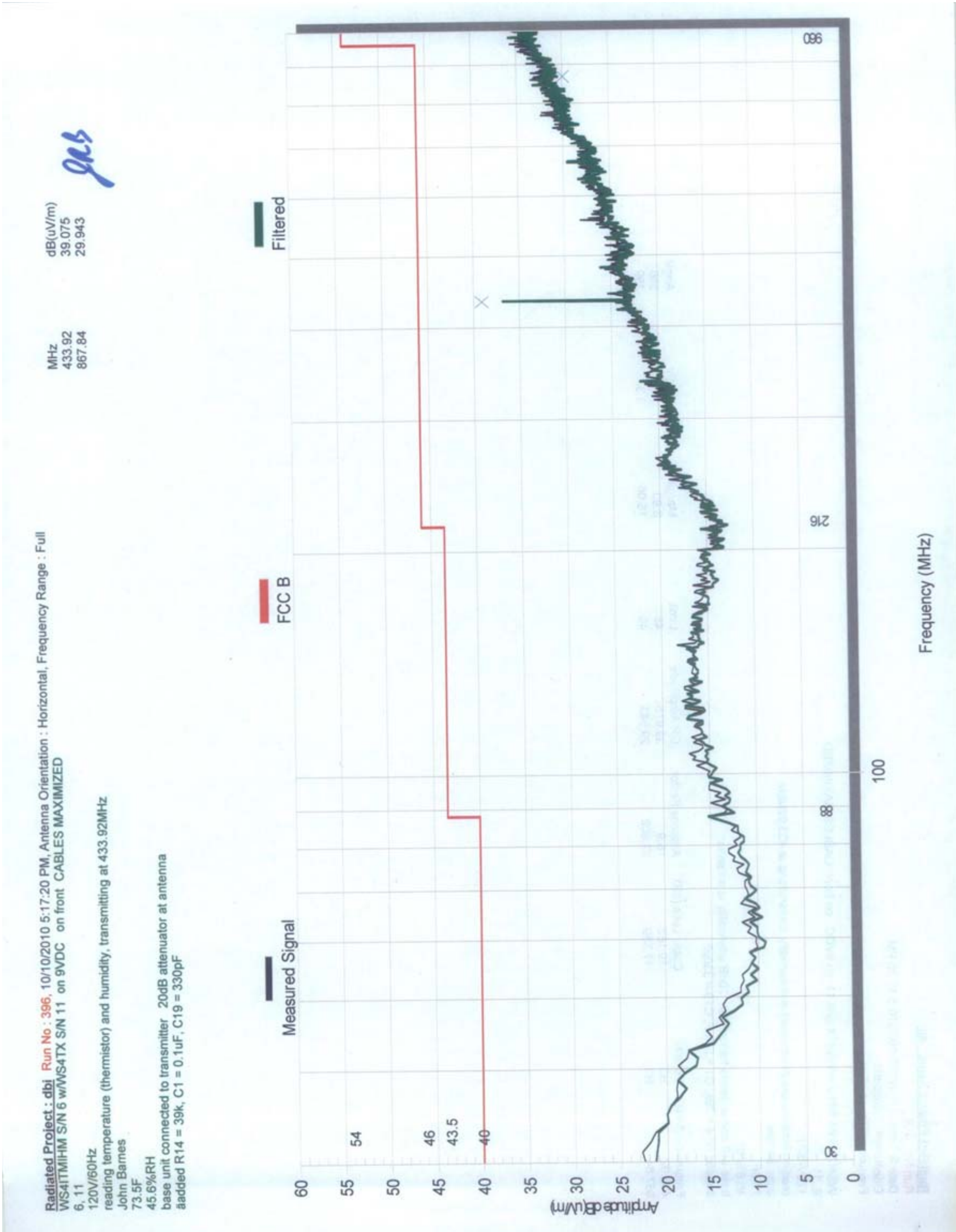
John R. Barnes, PRESIDENT dBi Corporation

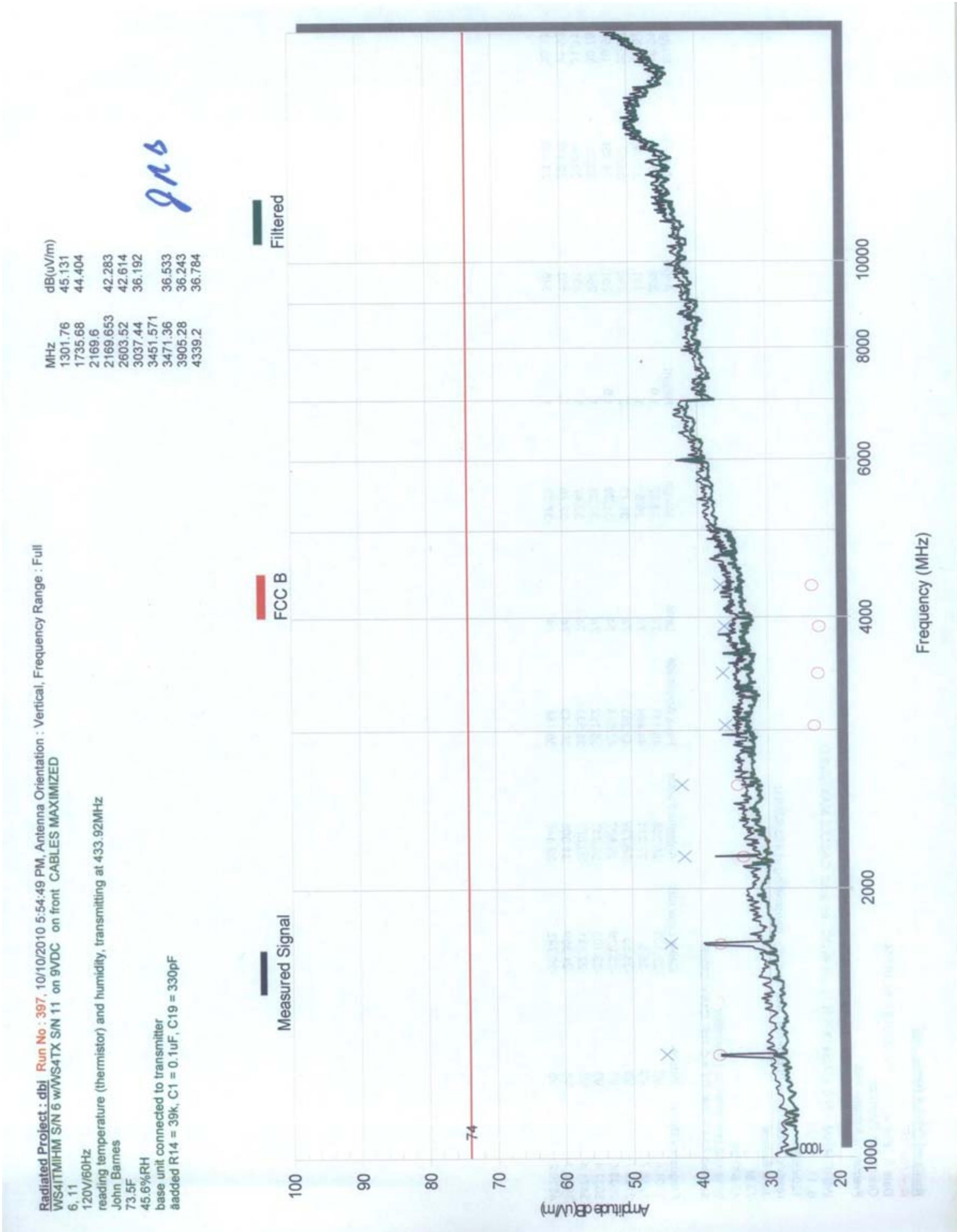

Radiated Project : dbi Run No : 1460, 10/9/2010 3:01:14 AM, Antenna Orientation : Vertical, Frequency Range : Full
TVRFL4 S/N 10 with Thermaviewer; WS4HETC S/N 1 w/WS4TXW S/N 1; WS4HETMETM S/N 5 w/WS4TX S/N 10
WS4ITMIHM S/N 6 w/WS4TX S/N 11; WS4IPR S/N 7 w/WS4TX S/N 7; WS4ITMIHM S/N 8 w/WS4TX S/N 8
120V/60Hz
sens1ng temperature, pressure, humidity & transmitting on 433.92MHz CABLES MAXIMIZED
John Barnes
68.7F
40.9%RH
5 transmitters with (left to right) external thermocouple, 2 external thermistors, internal thermistor & humidity, internal thermistor, internal thermistor & pr
essure, internal thermistor & humidity 1 receiver to Thermaviewer
achanged to 0.15m cable on Thermaviewer with common-mode choke, Steward 28A0640-0A2 on data cable
MHz dB(uV/m)
31.571 12.064
43.901 10.411
73.298 19.418
80.049 19.719
100.02 16.882
146.684 19.016
159.924 16.389
159.976
166.674 19.845
213.347 18.942
226.678 21.341
Measured Signal
CISPR B
Filtered
Amplitude dB(uV/m)
60
55
50
45
40
35
30
25
20
15
10
5
0
37
30
30
100
230
Frequency (MHz)

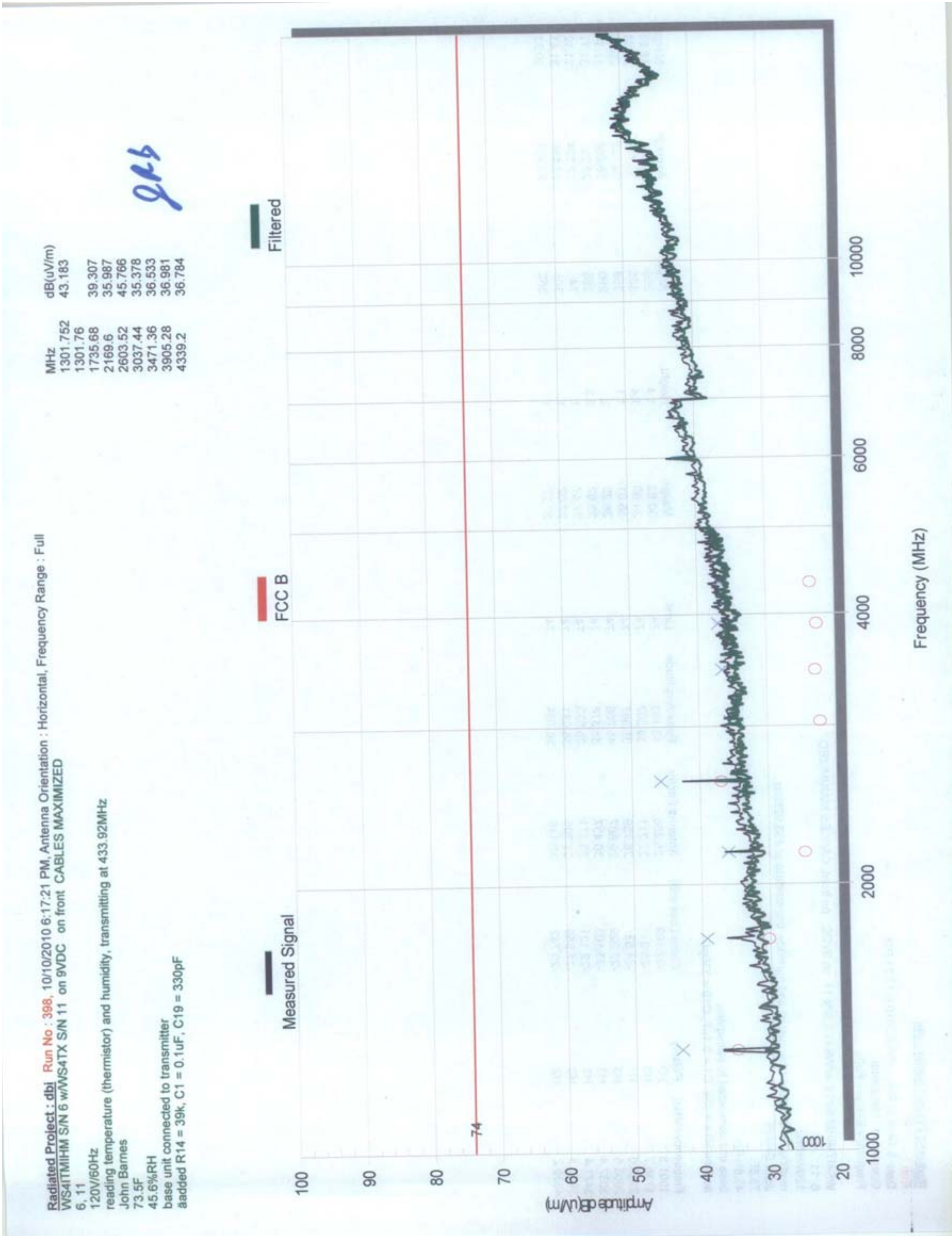


Radiated Project : dbi   Run No : 1459, 10/9/2010 2:34:51 AM, Antenna Orientation : Horizontal, Frequency Range : Full
TVRFL4 S/N 10 with Thermaviewer; WS4HETC S/N 1 w/WS4TXW S/N 1; WS4HETMETM S/N 5 w/WS4TX S/N 10
WS4ITMIHM S/N 6 w/WS4TX S/N 11; WS4IPR S/N 7 w/WS4TX S/N 7; WS4ITMIHM S/N 8 w/WS4TX S/N 8
120V/60Hz
sens1ng temperature, pressure, humidity & transmitting on 433.92MHz   CABLES MAXIMIZED
John Barnes
68.7F
40.9%RH
5 transmitters with (left to right) external thermocouple, 2 external thermistors, internal thermistor & humidity, internal thermistor & pressure, internal thermistor & humidity   1 receiver to Thermaviewer
áchanged to 0.15m cable on Thermaviewer with common-mode choke, Steward 28A0640-0A2 on data cable
MHz
30.127
120.021
126.693
139.964
146.673
160.004
206.676
213.368
219.998
226.679
915.797
dB(uV/m)
11.992
18.738
18.509
18.196
24.623
23.786
20.551
21.326
23.052
26.582
21.236
Measured Signal
CISPR B
Filtered
Amplitude dB(uV/m)
60
55
50
45
40
35
30
25
20
15
10
5
0
37
30
30
100
230
Frequency (MHz)


Radiated Project : dbi Run No : 395, 10/10/2010 5:07:28 PM, Antenna Orientation : Vertical, Frequency Range : Full
WS4ITMIHM S/N 6 w/WS4TX S/N 11 on 9VDC on front CABLES MAXIMIZED
6, 11
120V/60Hz
reading temperature (thermistor) and humidity, transmitting at 433.92MHz
John Barnes
73.5F
45.6%RH
base unit connected to transmitter 20dB attenuator at antenna
aadded R14 = 39k, C1 = 0.1uF, C19 = 330pF
MHz
433.912
867.84
dB(uV/m)
50.858
30.179
Measured Signal
FCC B
Filtered
Amplitude dB(uV/m)
Frequency (MHz)
54
46
43.5
40
30
88
100
216
960


Radiated Project : dbi Run No : 396, 10/10/2010 5:17:20 PM, Antenna Orientation : Horizontal, Frequency Range : Full
WS4ITMIHM S/N 6 w/WS4TX S/N 11 on 9VDC on front CABLES MAXIMIZED
6, 11
120V/60Hz
reading temperature (thermistor) and humidity, transmitting at 433.92MHz
John Barnes
73.5F
45.6%RH
base unit connected to transmitter 20dB attenuator at antenna
&added R14 = 39k, C1 = 0.1uF, C19 = 330pF
MHz
433.92
867.84
dB(uV/m)
39.075
29.943
Measured Signal
FCC B
Filtered
Amplitude dB(uV/m)
Frequency (MHz)
54
46
43.5
40
30
88
100
216
960


Radiated Project : dbi Run No : 397, 10/10/2010 5:54:49 PM, Antenna Orientation : Vertical, Frequency Range : Full
WS4ITMIHM S/N 6 w/WS4TX S/N 11 on 9VDC on front CABLES MAXIMIZED
6, 11
120V/60Hz
reading temperature (thermistor) and humidity, transmitting at 433.92MHz
John Barnes
73.5F
45.6%RH
base unit connected to transmitter
added R14 = 39k, C1 = 0.1uF, C19 = 330pF
MHz dB(uV/m)
1301.76 45.131
1735.68 44.404
2169.6
2169.653 42.283
2603.52 42.614
3037.44 36.192
3451.571
3471.36 36.533
3905.28 36.243
4339.2 36.784
Measured Signal
FCC B
Filtered
74
Amplitude dB(uV/m)
Frequency (MHz)
100
90
80
70
60
50
40
30
20
1000
2000
4000
6000
8000
10000

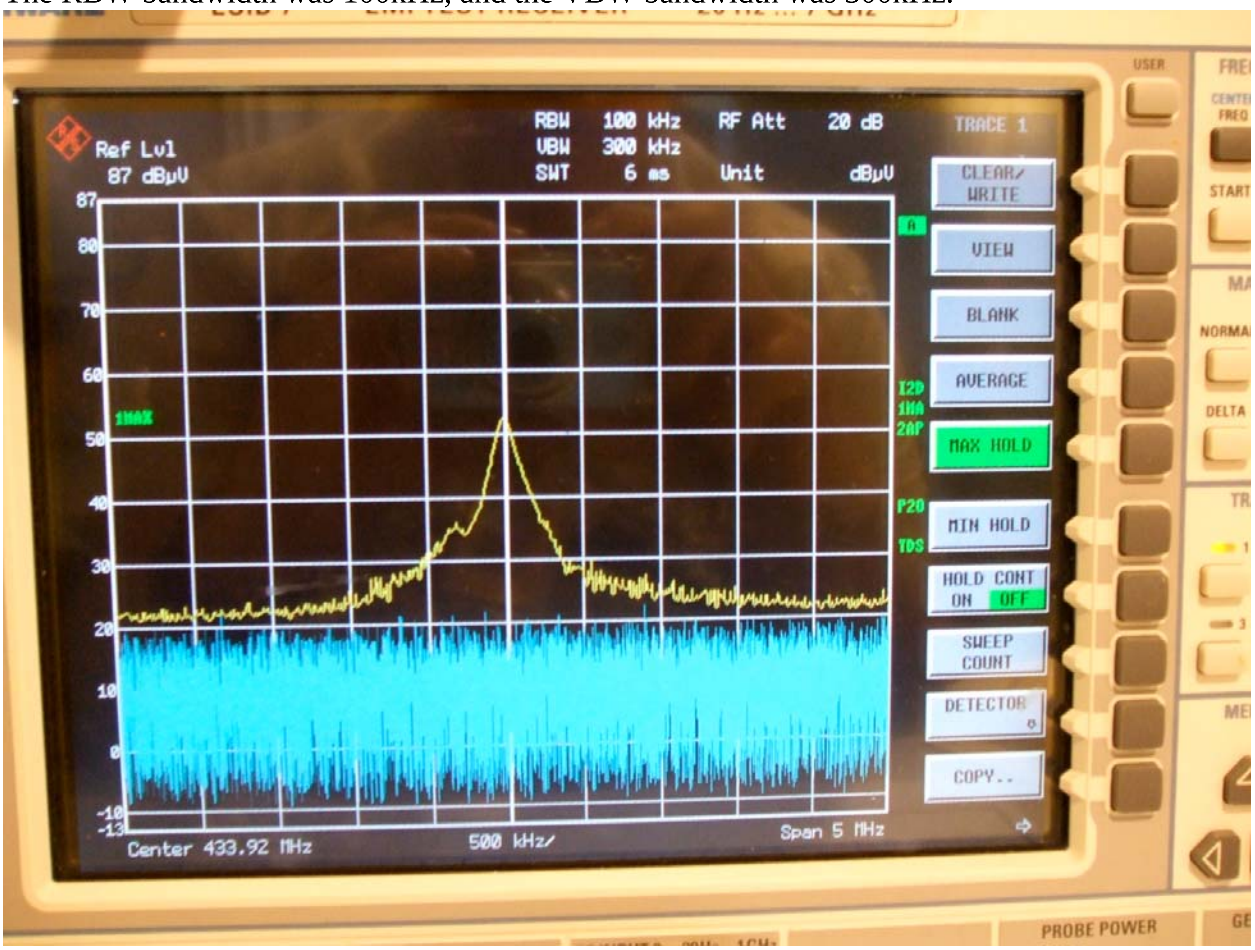


Radiated Project : dbi Run No : 398, 10/10/2010 6:17:21 PM, Antenna Orientation : Horizontal, Frequency Range : Full
WS4ITMIHM S/N 6 w/WS4TX S/N 11 on 9VDC on front CABLES MAXIMIZED
6, 11
120V/60Hz
reading temperature (thermistor) and humidity, transmitting at 433.92MHz
John Barnes
73.5F
45.6%RH
base unit connected to transmitter
aadded R14 = 39k, C1 = 0.1uF, C19 = 330pF
MHz dB(uV/m)
1301.752 43.183
1301.76
1735.68 39.307
2169.6 35.987
2603.52 45.766
3037.44 35.378
3471.36 36.533
3905.28 36.981
4339.2 36.784
Measured Signal
FCC B
Filtered
74
Amplitude dB(uV/m)
100
90
80
70
60
50
40
30
20
1000
2000
4000
6000
8000
10000
Frequency (MHz)

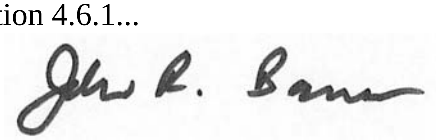
Transmitted Bandwidth Data (9VDC)

Appliance/Product: Transmitter Module
Model/Type Number: WS4TX
FCC ID: YVGWS4TX
Rating: 9VDC
Serial Number: 11

Test Results: The 20dB transmitted bandwidth of the WS4TX is fH – fL = 434.3258MHz - 433.4139MHz = 911.9kHz, within the 1085kHz (0.25% of 433.92MHz) maximum bandwidth permitted by FCC 47 CFR Part 15-2008 Section 15.231(c) and RSS-210 Issue 7 (June 2007) A1.1.3. In the photo, each horizontal division is 500kHz, and each vertical division is 10dB. The RBW bandwidth was 100kHz, and the VBW bandwidth was 300kHz.



PROCEDURE: Test Performed Per ANSI 63.4-2003 section 13.1.7 and RSS-Gen Issue 2 (June 2007) section 4.6.1...



Signed______________________________________**Date** __November 4, 2010__
John R. Barnes, PRESIDENT dBi Corporation

Conducted Emissions 150 kHz-30 MHz

Conducted Emission Standards:
FCC 47 CFR Part 15-2008 Class B, using ANSI C63.4-2003
ICES-003:2004 Class B, using CAN/CSA-CEI/IEC CISPR 22:02
RSS-210 Issue 7 (June 2007), using RSS-Gen Issue 2 (June 2007)

Appliance/Product: Base Station and five Wireless Sensors
Model/Type Number: TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM
Rating: 9VDC
Serial Number: 10, 5, 1, 7, 6, and 8

Appliance/Product: Transmitter Module
Model/Type Number: WS4TX
FCC ID: YVGWS4TX
Rating: 9VDC
Serial Number: 11

Host and Other Peripherals:
ThermaViewer RF (DoC) for TVRFL4 Base Station

Name of Test: Conducted Interference
Test Procedure: ANSI C63.4-2003, EN 55022:2006
Test Location: All welded 18 ft x 18 ft shielded enclosure, Lexmark test facility, located in Lexington, Kentucky
Test Instrumentation: See attached sheets

Notes: Tests performed at 15-30°C, 20-75% relative humidity, and any atmospheric pressure. Before starting any approval tests, we do a Total Cal of the receiver, then do a Conducted Checkout of the LISN, 150kHz highpass filter, 10dB attenuator, and cables. The expanded uncertainty (k=2 for 95% probability) is +/-2.76dB on AC power; and +/-2.85dB on input/output cables.

The equipment-under-test (EUT) and auxiliary equipment (AE) are set up in the shielded room according to the test plan and the test procedure(s). The EUT plugs into the main line-impedance stabilization network (LISN). AE plugs into multi-outlet strips attached to separate LISN's. Long input/output cables are serpentined to keep them >40cm from the floor.

If standard cables are available for an EUT's input/output port(s), we prefer to use them. If cables are custom-made for each installation of an EUT, we use cables that are at least 1m long. At least one port of each type on the EUT is connected to AE with a cable—except that we do not put cables on ports that are used only for manufacturing or servicing. If the EUT has multiple ports of a certain type, we add cables (that may go to AE, terminate in dummy loads, or be left unterminated) until adding a cable makes less than a 2dB increase in the emissions. The additional cables needed may be determined by testing this EUT, or by prior experience with these same input/output ports on previous products. If an EUT has several ports with identical functions that are mutually-exclusive— only one of them *can* be used in a particular installation of the EUT— we try to run the test with all of the cables attached, but only the noisiest port providing data to the EUT. If this configuration puts us over the limits, we experiment with one port at a time cabled to AE and providing data, with the other ports left unconnected. Then we make the official measurements with the noisiest port that will typically be used by users.

We set up the EUT, AE, input/output cables, and line cords/power cables in the configuration and typical operating mode that we think will maximize emissions. This may require some experimenting to determine for sure, but is usually the configuration/operating mode that has as many subsystems of the EUT active simultaneously as possible, at their highest resolution, and operating at maximum speed.

We run initial scans on phase and neutral. We quasipeak and average measure the 3-5 frequencies whose Conducted Emissions appear to be highest with respect to the test limits.

At any time during the approval testing, if a measurement is above or close to a limit, we try to determine the cause of the problem, and fix it. Fixes to the EUT will be documented in the test notes and test report. If a piece of AE is the source of the noise, we may try a replacement (such as another hub/router, or using a crossover cable in place of a hub), or move the AE outside of the chamber. If AE is the source of the noise, and we can't resolve the problem any other way, we will measure these frequencies with the AE turned on and again with it turned off. We then note in the test notes, test plots, and test report that the excessive emissions are due to __________ piece of AE.

We examine the initial plots to see which frequency on phase/neutral has the minimum margin versus the test limits. If the minimum margin is >6dB, we treate the cables as already being maximized, and perform the official tests. Otherwise we return to the AC line and frequency with the highest emissions. We take a baseline reading before we touch anything. Then we move cables and line cords, trying to increase the emissions at this frequency, until any further changes have no effect, or reduce the emissions. This becomes our maximized cable configuration for the official tests, which will be photographed and included in the test report.

We now perform the official Conducted Emissions measurements. For each AC line (phase, neutral) we choose at least 10 frequencies that look "interesting". At each of these frequencies we do a narrowband scan to find the frequency with the least margin against the test limits. We quasipeak and average measure these specific frequencies on phase and neutral. These become our official measurements. We repeat this process for all AC input voltages/frequencies of interest.

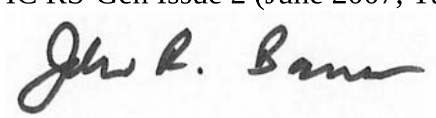
When the test standards require Conducted Emissions measurements on an input/output cable, such as a phone line or Ethernet port, we connect this cable to an impedance stabilization network (ISN) if one is available. If we don't have a suitable ISN, we run this cable through a current probe and a voltage probe, and maybe through a bunch of ferrite cores, before connecting it to the AE (see CISPR 22/EN 55022 Appendix C). The EUT still plugs into the main LISN. We make one set of measurements per cable, with all other cables in the configuration that maximized AC Conducted Emissions.

In the tables below, "Cable Factor dB" covers everything in the standard signal chain between the LISN/ISN/current probe and the EMI receiver(s). This includes a high-pass filter, a 10dB pad, and the cable.

Modifications to the Equipment Under Test: None.

Test Results: The TVRFL4 Base Station gets 9VDC power from the ThermaViewer RF. The WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM Wireless Sensors get power from internal 9V batteries. The WS4TX Transmitter Module gets 9VDC power from the sensor's base board. None of these products connect to AC power lines. Therefore, without testing, they all meet the conducted interference requirements of:

- FCC 47 CFR Part 15-2008 Class B (15.107(a) and 15.207)).
- IC ICES-003:2004 Class B (CAN/CSA-CEI/IEC CISPR 22:02 Table 2).
- IC RS-Gen Issue 2 (June 2007, Table 2).



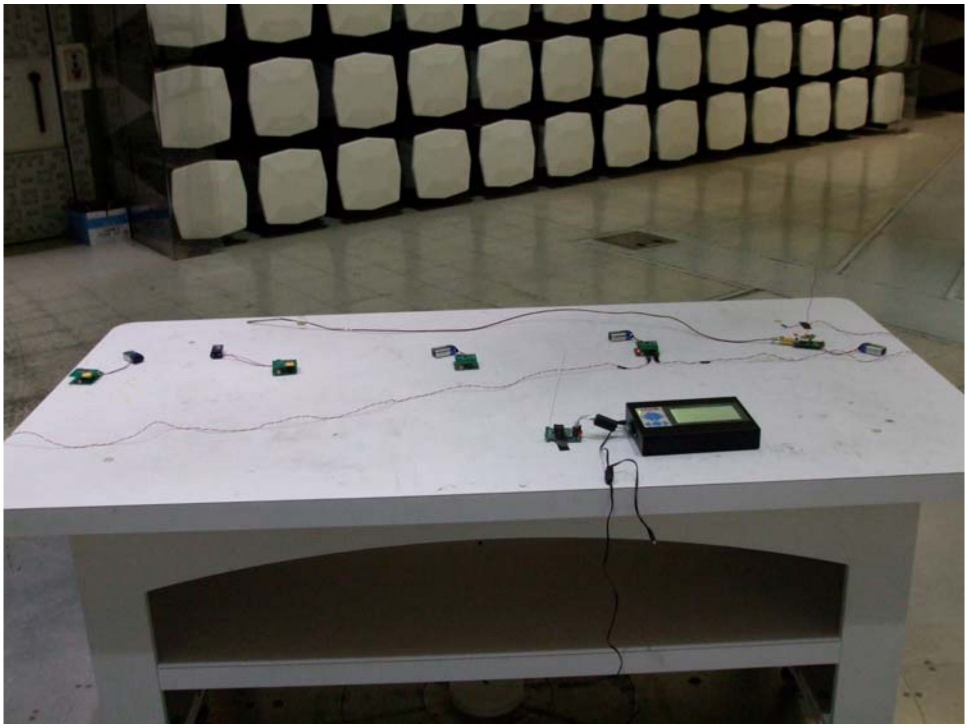
SIGNED________________________________DATE __ November 4, 2010**__**
John R. Barnes KS4GL, PE, NCE, NCT, ESDC Eng, ESDC Tech, PSE, SM IEEE

TESTING AND MEASURING EQUIPMENT USED AT LEXMARK

For Radiated Emissions Measurements:

ARA Horn Antenna, 1GHz to 18GHz #0388	DRG-118/A, S/N 1090 (Cal date: 10/15/09, Cal due date: 10/15/11)
Schaffner-Chase BI-Log Antenna 30 to 1000 MHz #0509	CBL6111C, S/N 2459 (Cal date: 5/12/10, Cal due date: 5/12/12)
Schaffner-Chase Bi-Log Antenna 30 to 1000 MHz #0517	CBL6111C, S/N 2580 (Cal date: 5/12/10, Cal due date: 5/12/12)
Rohde & Schwarz EMI Test Receiver #0543	ESI40, S/N 839283/008 (Cal date: 11/17/09, Cal due date: 11/17/11)
Rohde & Schwarz EMI Test Receiver #0549	ESI7, S/N 100009 (Cal date: 4/9/09, Cal due date: 4/9/11)
Rohde & Schwarz EMI Test Receiver #0632	ESIB7, S/N 100093 (Cal date: 10/13/09, Cal due date: 10/13/11)
Rohde & Schwarz EMI Test Receiver #0700	ESIB40, S/N 100148 (Cal date: 6/24/10, Cal due date: 6/24/12)

Calibration: The measuring equipment used at Lexmark is calibrated according to the instruction manual once a day. Once a week the accuracy of the test system is checked. This includes the test equipment, associated cables, and antennas. This is accomplished with a calibrated radiating source for the radiated measurements, and a synthesized signal generator for the conducted measurements.



RADIATED EMISSIONS TEST CONFIGURATION
TVRFL4, WS4HETMETM, WS4HETC, WS4IPR, WS4ITMIHM, and WS4HITMIHM
10m SEMIANECHOIC CHAMBER
LEXMARK INTERNATIONAL, LEXINGTON KY

RADIATED EMISSIONS TEST CONFIGURATION
WS4TX
5m SEMIANECHOIC CHAMBER
LEXMARK INTERNATIONAL, LEXINGTON KY