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# *Electromagnetic Emissions Test Report and Application for Grant of Equipment Authorization pursuant to FCC Part 15, Subpart C (15.247) DTS Specifications and Industry Canada RSS 210 Issue 6 for an Intentional Radiator on the Moteiv Corporation Model: Tmote Sky*

| | |
|---|---|
| FCC ID: | TOQTMOTESKY |
| UPN: | 6142A-TMOTESKY |
| GRANTEE: | Moteiv Corporation<br>7224 View Ave.<br>El Cerrito, CA 94530 |
| TEST SITE: | Elliott Laboratories, Inc.<br>684 W. Maude Avenue<br>Sunnyvale, CA 94086 |
| REPORT DATE: | September 30, 2005 |
| FINAL TEST DATE: | September 22, 2005 |

AUTHORIZED SIGNATORY: _____

Juan Martinez
Senior EMC Engineer

ACCREDITED
2016-01

## *DECLARATIONS OF COMPLIANCE*

Equipment Name and Model:
Tmote Sky

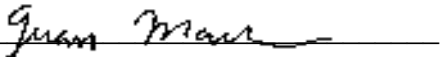
Manufacturer:
Moteiv Corporation
7224 View Ave.
El Cerrito, CA 94530

Tested to applicable standards:
RSS-210, Issue 6, September 2005 (Low Power License-Exempt Radiocommunication Devices)
FCC Part 15.247 (DTS)

Measurement Facility Description Filed With Department of Industry:

Departmental Acknowledgement Number: IC2845 SV2 Dated August 16, 2007

I declare that the testing was performed or supervised by me; that the test measurements were made in accordance with the above mentioned departmental standards (through the use of ANSI C63.4:2003 as detailed in section 5.3 of RSS-210, Issue 6); and that the equipment performed in accordance with the data submitted in this report.

| | |
|---|---|
| Signature |  |
| Name | Juan Martinez |
| Title | Senior EMC Engineer |
| Company | Elliott Laboratories Inc. |
| Address | 684 W. Maude Ave<br>Sunnyvale, CA 94086<br>USA |
| Date: | September 30, 2005 |

Maintenance of compliance with the above standards is the responsibility of the manufacturer. Any modification of the product which may result in increased emissions should be checked to ensure compliance has been maintained (i.e., printed circuit board layout changes, different line filter, different power supply, harnessing or I/O cable changes, etc.).

## *TABLE OF CONTENTS*

## *SCOPE*

An electromagnetic emissions test has been performed on the Moteiv Corporation model Tmote Sky pursuant to Subpart C of Part 15 of FCC Rules for intentional radiators and RSS-210 Issue 6 for licence-exempt low power devices. Conducted and radiated emissions data has been collected, reduced, and analyzed within this report in accordance with measurement guidelines set forth in ANSI C63.4:2003 as outlined in Elliott Laboratories test procedures.

The intentional radiator above has been tested in a simulated typical installation to demonstrate compliance with the relevant FCC performance and procedural standards.

Final system data was gathered in a mode that tended to maximize emissions by varying orientation of EUT, orientation of power and I/O cabling, antenna search height, and antenna polarization.

Every practical effort was made to perform an impartial test using appropriate test equipment of known calibration. All pertinent factors have been applied to reach the determination of compliance.

The test results recorded herein are based on a single type test of the Moteiv Corporation model Tmote Sky and therefore apply only to the tested sample. The sample was selected and prepared by Robert Szewcrzyk of Moteiv Corporation

## *OBJECTIVE*

The primary objective of the manufacturer is compliance with Subpart C of Part 15 of FCC Rules and RSS-210 Issue 6 for license-exempt low power devices for the radiated and conducted emissions of intentional radiators. Certification of these devices is required as a prerequisite to marketing as defined in Part 2 the FCC Rules.

Certification is a procedure where the manufacturer or a contracted laboratory makes measurements and submits the test data and technical information to the FCC. The FCC issues a grant of equipment authorization upon successful completion of their review of the submitted documents. Once the equipment authorization has been obtained, the label indicating compliance must be attached to all identical units which are subsequently manufactured.

## *SUMMARY OF RESULTS*

| FCC Part 15 Section | RSS 210 Section | Description | Measured Value | Comments | Result |
|---|---|---|---|---|---|
| 15.247(a) | 6.2.2(o)(b) | Digital Modulation | Systems uses DSSS techniques | System must utilize a digital transmission technology | Complies |
| 15.247 (a) (2) | 6.2.2(o)(b) | 6dB Bandwidth | 1.6 MHz | Minimum allowed is 500kHz | Complies |
| | RSP 100 | 99% Bandwidth | 16 MHz | For information only | Complies |
| 15.247 (b) (3) | 6.2.2(o)(b) | Output Power, 2400 - 2483.5 MHz | 3.39 dBm<br>EIRP = 0.0022 W | Multi-point applications: Maximum permitted is 1Watt, with EIRP limited to 4 Watts. | Complies |
| 15.247(d) | 6.2.2(o)(b) | Power Spectral Density | -40dBm / kHz | Maximum permitted is 8dBm/3kHz | Complies |
| 15.247(c) | 6.2.2(o)(e1) | Antenna Port Spurious Emissions – 30MHz – 26 GHz | All spurious emissions < -20dBc | Measurement was not made since antenna is permanently attached, so only radiated emissions was performed instead | Complies |
| 15.247(c) / 15.209 | | Radiated Spurious Emissions – 30MHz – 26 GHz | 53.9dBuV/m @ 2483.5 MHz<br>(-0.1 dB) | Emissions in restricted bands must meet the radiated emissions limits detailed in 15.207. All others must be < -20dBc | Complies |
| 15.207 | | AC Conducted Emissions | Battery Operated | N/A | N/A |
| | 6.6 | AC Conducted Emissions | Battery Operated | N/A | N/A |
| 15.247 (b) (5) | | RF Exposure Requirements | MPE calculation | | |
| 15.203 | | RF Connector | Antenna is permanently attached | | Complies |

EIRP calculated using antenna gain of dBi (-5) for the highest EIRP point-to-multipoint system.

***MEASUREMENT UNCERTAINTIES***

ISO Guide 17025 requires that an estimate of the measurement uncertainties associated with the emissions test results be included in the report. The measurement uncertainties given below are based on a 95% confidence level and were calculated in accordance with UKAS document LAB 34.

| Measurement Type | Frequency Range (MHz) | Calculated Uncertainty (dB) |
|---|---|---|
| Conducted Emissions | 0.15 to 30 | ± 2.4 |
| Radiated Emissions | 30 to 1000 | ± 3.6 |

## *EQUIPMENT UNDER TEST (EUT) DETAILS*

### *GENERAL*

The Moteiv Corporation model Tmote Sky is a wireless sensor node which is designed for low power, low bandwidth data collection and processing. The device is equipped with environmental sensors (temperature, humidity, photosynthetically active radiation). Additional sensors can be attached to the device through the expansion connector. The signals propagating through that connector may not exceed 2.5V in peak-to-peak amplitude and 100kHz in frequency and 1mA in current. The EUT is primarily powered from a battery (supply in the range 1.8 to 3.6V). The device can interface with personal computers over a USB port. Normally, the EUT would be placed on near a phenomenon to be sensed. The end user environment was approximated using a tabletop. The EUT cannot be powered from AC lines.

The sample was received on September 22, 2005 and tested on September 22, 2005. The EUT consisted of the following component(s):

| Manufacturer | Model | Description | Serial Number | FCC ID |
|---|---|---|---|---|
| Moteiv | Tmote Sky | Low power wireless sensing module | prototype | TOQTMOTESKY |

### *OTHER EUT DETAILS*

The supplied unit has been programmed to perform the following functions:
receive, send on low channel (2405 MHz), mid channel (2440 MHz), and high channel (2480 MHz). The transmission could be enabled in two different modes: the packet mode, exercising maximum transmission rate of the radio stack, and continuous modulated carrier mode.

When powered up with supplied AA batteries, unit will function in receive mode, and all LEDs should remain off. Pressing the USER button will cycle between the modes Receive -> low channel -> mid channel -> high channel -> receive

When a transmit mode is selected, the device will send packets on the selected channel. The packets are sent one after another; there is a channel contention period between the packets. Each packet sent will blink the LED corresponding to the currently selected channel:

. Red LED - low channel
. Green LED - mid channel
. Blue LED - high channel

The LED on selected channel blinks with a period of 1s; the continuous modulated carrier test mode cycles the LED between on and off; the packet mode cycles the LED between 75% and 25% duty cycle. The transmission power was set as follows:
Low channel: 0dBm
Mid channel: 0dBm
High channel: -3.5dBm

***ENCLOSURE***

The EUT RF shield is 0.008" tin-plated brass. The module measures 3.25"x1.25x3/16" without a default battery pack and 3.25"x1.25x.75" with the AA battery pack attached.

***MODIFICATIONS***

The EUT did not require modifications during testing in order to comply with the emission specifications.

***SUPPORT EQUIPMENT***

No equipment was used as support equipment for emissions testing.

***EUT INTERFACE PORTS***

The I/O cabling configuration during emissions testing was as follows:

| Port | Connected To | Cable(s) | | |
|---|---|---|---|---|
| | | Description | Shielded or Unshielded | Length(m) |
| None | | | | |

***EUT OPERATION DURING TESTING***

The supplied unit has been programmed to perform the following functions:
receive, send on low channel (2405 MHz), mid channel (2440 MHz), and high channel (2480 MHz). The transmission could be enabled in two different modes: the packet mode, exercising maximum transmission rate of the radio stack, and continuous modulated carrier mode.

***ANTENNA REQUIREMENTS***

Antenna is permanently attached. The internal antenna has the peak gain of -5dBi

## *TEST SITE*

### *GENERAL INFORMATION*

Final test measurements were taken on September 22, 2005at the Elliott Laboratories Open Area Test Site #2 located at 684 West Maude Avenue, Sunnyvale, California. The test site contains separate areas for radiated and conducted emissions testing. Pursuant to section 2.948 of the Rules, construction, calibration, and equipment data has been filed with the Federal Communications Commission. In accordance with Industry Canada rules detailed in RSS 210 Issue 6 and RSS-212, construction, calibration, and equipment data for the test sites have been filed with the Federal Communications Commission.

The FCC recommends that ambient noise at the test site be at least 6 dB below the allowable limits. Ambient levels are below this requirement with the exception of predictable local TV, radio, and mobile communications traffic. The test site contains separate areas for radiated and conducted emissions testing. Considerable engineering effort has been expended to ensure that the facilities conform to all pertinent FCC requirements.

### *CONDUCTED EMISSIONS CONSIDERATIONS*

Conducted emissions testing is performed in conformance with ANSI C63.4:2003. Measurements are made with the EUT connected to the public power network through a nominal, standardized RF impedance, which is provided by a line impedance stabilization network, known as a LISN. A LISN is inserted in series with each current-carrying conductor in the EUT power cord.

### *RADIATED EMISSIONS CONSIDERATIONS*

The FCC has determined that radiation measurements made in a shielded enclosure are not suitable for determining levels of radiated emissions. Radiated measurements are performed in an open field environment. The test site is maintained free of conductive objects within the CISPR defined elliptical area incorporated in ANSI C63.4:2003 guidelines.

## *MEASUREMENT INSTRUMENTATION*

### *RECEIVER SYSTEM*

An EMI receiver as specified in CISPR 16-1 is used for emissions measurements. The receivers used can measure over the frequency range of 9 kHz up to 2000 MHz. These receivers allow both ease of measurement and high accuracy to be achieved. The receivers have Peak, Average, and CISPR (Quasi-peak) detectors built into their design so no external adapters are necessary. The receiver automatically sets the required bandwidth for the CISPR detector used during measurements.

For measurements above the frequency range of the receivers, a spectrum analyzer is utilized because it provides visibility of the entire spectrum along with the precision and versatility required to support engineering analysis. Average measurements above 1000MHz are performed on the spectrum analyzer using the linear-average method with a resolution bandwidth of 1 MHz and a video bandwidth of 10 Hz.

### *INSTRUMENT CONTROL COMPUTER*

The receivers utilize either a Rohde and Schwarz EZM Spectrum Monitor/Controller or contain an internal Spectrum Monitor/Controller to view and convert the receiver measurements to the field strength at an antenna or voltage developed at the LISN measurement port, which is then compared directly with the appropriate specification limit. This provides faster, more accurate readings by performing the conversions described under Sample Calculations within the Test Procedures section of this report. Results are printed in a graphic and/or tabular format, as appropriate. A personal computer is used to record all measurements made with the receivers.

The Spectrum Monitor provides a visual display of the signal being measured. In addition, the controller or a personal computer run automated data collection programs which control the receivers. This provides added accuracy since all site correction factors, such as cable loss and antenna factors are added automatically.

### *LINE IMPEDANCE STABILIZATION NETWORK (LISN)*

Line conducted measurements utilize a fifty microhenry Line Impedance Stabilization Network as the monitoring point. The LISN used also contains a 250 uH CISPR adapter. This network provides for calibrated radio frequency noise measurements by the design of the internal low pass and high pass filters on the EUT and measurement ports, respectively.

***POWER METER***

A power meter and peak power sensor are used for all direct output power measurements from transmitters as they provide a broadband indication of the power output.

***FILTERS/ATTENUATORS***

External filters and precision attenuators are often connected between the receiving antenna or LISN and the receiver. This eliminates saturation effects and non-linear operation due to high amplitude transient events.

***ANTENNAS***

A biconical antenna is used to cover the range from 30 MHz to 300 MHz and a log periodic antenna is utilized from 300 MHz to 1000 MHz. Narrowband tuned dipole antennas are used over the entire 30 to 1000 MHz range for precision measurements of field strength. Above 1000 MHz, a horn antenna is used. The antenna calibration factors are included in site factors programmed into the test receivers.

***ANTENNA MAST AND EQUIPMENT TURNTABLE***

The antennas used to measure the radiated electric field strength are mounted on a non-conductive antenna mast equipped with a motor-drive to vary the antenna height.

ANSI C63.4:2003 specifies that the test height above ground for table mounted devices shall be 80 centimeters. Floor mounted equipment shall be placed on the ground plane if the device is normally used on a conductive floor or separated from the ground plane by insulating material from 3 to 12 mm if the device is normally used on a non-conductive floor. During radiated measurements, the EUT is positioned on a motorized turntable in conformance with this requirement.

***INSTRUMENT CALIBRATION***

All test equipment is regularly checked to ensure that performance is maintained in accordance with the manufacturer's specifications. All antennas are calibrated at regular intervals with respect to tuned half-wave dipoles. An exhibit of this report contains the list of test equipment used and calibration information.

## *TEST PROCEDURES*

### *EUT AND CABLE PLACEMENT*

The FCC requires that interconnecting cables be connected to the available ports of the unit and that the placement of the unit and the attached cables simulate the worst case orientation that can be expected from a typical installation, so far as practicable. To this end, the position of the unit and associated cabling is varied within the guidelines of ANSI C63.4:2003 , and the worst case orientation is used for final measurements.

### *CONDUCTED EMISSIONS*

Conducted emissions are measured at the plug end of the power cord supplied with the EUT. Excess power cord length is wrapped in a bundle between 30 and 40 centimeters in length near the center of the cord. Preliminary measurements are made to determine the highest amplitude emission relative to the specification limit for all the modes of operation. Placement of system components and varying of cable positions are performed in each mode. A final peak mode scan is then performed in the position and mode for which the highest emission was noted on all current carrying conductors of the power cord.

### *RADIATED EMISSIONS*

Radiated emissions measurements are performed in two phases as well. A preliminary scan of emissions is conducted in which all significant EUT frequencies are identified with the system in a nominal configuration. At least two scans are performed from 30 MHz up to the frequency required by the regulation specified on page 1. One or more of these is with the antenna polarized vertically while the one or more of these is with the antenna polarized horizontally. During the preliminary scans, the EUT is rotated through 360°, the antenna height is varied and cable positions are varied to determine the highest emission relative to the limit.

A speaker is provided in the receiver to aid in discriminating between EUT and ambient emissions. Other methods used during the preliminary scan for EUT emissions involve scanning with near field magnetic loops, monitoring I/O cables with RF current clamps, and cycling power to the EUT.

Final maximization is a phase in which the highest amplitude emissions identified in the spectral search are viewed while the EUT azimuth angle is varied from 0 to 360 degrees relative to the receiving antenna. The azimuth which results in the highest emission is then maintained while varying the antenna height from one to four meters. The result is the identification of the highest amplitude for each of the highest peaks. Each recorded level is corrected in the receiver using appropriate factors for cables, connectors, antennas, and preamplifier gain. Emissions which have values close to the specification limit may also be measured with a tuned dipole antenna to determine compliance.

***CONDUCTED EMISSIONS FROM ANTENNA PORT***

Direct measurements are performed with the antenna port of the EUT connected to either the power meter or spectrum analyzer via a suitable attenuator and/or filter. These are used to ensure that the front end of the measurement instrument is not overloaded by the fundamental transmission.

Measurement bandwidths (video and resolution) are set in accordance with FCC procedures for the type of radio being tested.

## *SPECIFICATION LIMITS AND SAMPLE CALCULATIONS*

The limits for conducted emissions from the AC power port are given in units of microvolts, the limits for radiated electric field emissions are given in units of microvolts per meter at a specified test distance and the output power limits are given in temrs of Watts, milliwatts or dBm. Data is measured in the logarithmic form of decibels relative to one microvolt, or dB microvolts (dBuV). For radiated emissions, the measured data is converted to the field strength at the antenna in dB microvolts per meter (dBuV/m). The results are then converted to the linear forms of uV and uV/m for comparison to published specifications.

Where the radiated electric field strength is expressed in terms of the equivalent isotropic radiated power (eirp) the following formula is used to determine the field strength limit in terms of microvolts per meter at a distance of 3m from the equipment under test:

$$E = \frac{1000000 \text{ v } 30\ P}{3} \quad \text{microvolts per meter}$$

where P is the eirp (Watts)

For reference, converting the voltage and electric field strength specification limits from linear to decibel form is accomplished by taking the base ten logarithm, then multiplying by 20. Conversion of power specification limits from linear units (in milliwatts) to decibel form (in dBm) is accomplished by taking the base ten logarithm, then multiplying by 10.

***FCC 15.407 (a)and RSS 210 (o) OUTPUT POWER LIMITS***

The table below shows the limits for output power and output power density. Where the signal bandwidth is less than 20 MHz the maximum output power is reduced to the power spectral density limit plus 10 times the log of the bandwidth (in MHz).

| Operating Frequency (MHz) | Output Power | Power Spectral Density |
|---|---|---|
| 902 – 928 | 1 Watts (30 dBm) | 8 dBm/3kHz |
| 2400 – 2483.5 | 1 Watts (30 dBm) | 8 dBm/3kHz |
| 5725 – 5850 | 1 Watts (30 dBm) | 8 dBm/3kHz |

The maximum permitted output power is reduced by 1dB for every dB the antenna gain exceeds 6dBi. Fixed point-to-point applications using the 5725 – 5850 MHz band are not subject to this restriction.

***RSS 210 (o) AND FCC 15.247 SPURIOUS RADIATED EMISSIONS LIMITS***

T limits for unwanted (spurious) emissions from the transmitter falling in the restricted bands detailed in Part 15.205 and for all spurious emissions from the receiver are:

| Frequency Range (MHz) | Limit (uV/m @ 3m) | Limit (dBuV/m @ 3m) |
|---|---|---|
| 30 to 88 | 100 | 40 |
| 88 to 216 | 150 | 43.5 |
| 216 to 960 | 200 | 46.0 |
| Above 960 | 500 | 54.0 |

All other unwanted (spurious) emissions shall be at least 20dB below the level of the highest in-band signal level.

***FCC 15.205 AC POWER PORT CONDUCTED EMISSIONS LIMITS***

The table below shows the limits for emissions on the AC power line as detailed in FCC Part 15.205.

| Frequency (MHz) | Average Limit (dBuV) | Quasi Peak Limit (dBuV) |
|---|---|---|
| 0.150 to 0.500 | Linear decrease on logarithmic frequency axis between 56.0 and 46.0 | Linear decrease on logarithmic frequency axis between 66.0 and 56.0 |
| 0.500 to 5.000 | 46.0 | 56.0 |
| 5.000 to 30.000 | 50.0 | 60.0 |

***RSS-210 SECTION 6.6 AC POWER PORT CONDUCTED EMISSIONS LIMITS***

The table below shows the limits for emissions on the AC power line as detailed in Industry Canada RSS-210 section 6.6.

| Frequency Range (MHz) | Limit (uV) | Limit (dBuV) |
|---|---|---|
| 0.450 to 30.000 | 250 | 48 |

***SAMPLE CALCULATIONS - CONDUCTED EMISSIONS***

Receiver readings are compared directly to the conducted emissions specification limit (decibel form) as follows:

$$R_r - B = C$$

and

$$C - S = M$$

where:

$R_r$ = Receiver Reading in dBuV

B = Broadband Correction Factor*

C = Corrected Reading in dBuV

S = Specification Limit in dBuV

M = Margin to Specification in +/- dB

* Broadband Level - Per ANSI C63.4:2003 , 13 dB may be subtracted from the quasi-peak level if it is determined that the emission is broadband in nature. If the signal level in the average mode is six dB or more below the signal level in the peak mode, the emission is classified as broadband.

***SAMPLE CALCULATIONS - RADIATED EMISSIONS***

Receiver readings are compared directly to the specification limit (decibel form). The receiver internally corrects for cable loss, preamplifier gain, and antenna factor. The calculations are in the reverse direction of the actual signal flow, thus cable loss is added and the amplifier gain is subtracted. The Antenna Factor converts the voltage at the antenna coaxial connector to the field strength at the antenna elements. A distance factor, when used for electric field measurements, is calculated by using the following formula:

$$F_d = 20*LOG_{10} (D_m/D_s)$$

where:

$F_d$ = Distance Factor in dB

$D_m$ = Measurement Distance in meters

$D_s$ = Specification Distance in meters

Measurement Distance is the distance at which the measurements were taken and Specification Distance is the distance at which the specification limits are based. The antenna factor converts the voltage at the antenna coaxial connector to the field strength at the antenna elements.

The margin of a given emission peak relative to the limit is calculated as follows:

$$R_c = R_r + F_d$$

and

$$M = R_c - L_s$$

where:

$R_r$ = Receiver Reading in dBuV/m

$F_d$ = Distance Factor in dB

$R_c$ = Corrected Reading in dBuV/m

$L_s$ = Specification Limit in dBuV/m

$M$ = Margin in dB Relative to Spec

# *EXHIBIT 1: Test Equipment Calibration Data*

1 Page

**Radiated Emissions, 30 - 26,500 MHz, 22-Sep-05**
**Engineer: Mehran Birgani**

| Manufacturer | Description | Model # | Asset # | Cal Due |
|---|---|---|---|---|
| EMCO | Horn antenna, D. Ridge 1-18GHz (SA40 system antenna)30Hz sunnyvale | 3115 | 1142 | 11-Jun-06 |
| Hewlett Packard | Microwave EMI test system (SA40, 30Hz - 40GHz), Sunnyvale | 84125C | 1149 | 09-Jun-06 |
| EMCO | Log Periodic Antenna, 0.2-2 GHz | 3148 | 1321 | 30-Mar-07 |
| Rohde & Schwarz | Test Receiver, 0.009-2750 MHz | ESN | 1332 | 23-May-06 |
| EMCO | Biconical Antenna, 30-300 MHz | 3110B | 1497 | 15-Jun-06 |

**Radiated Emissions, 30 - 12,500 MHz, 26-Sep-05**
**Engineer: Mehran Birgani**

| Manufacturer | Description | Model # | Asset # | Cal Due |
|---|---|---|---|---|
| EMCO | Horn Antenna, D. Ridge 1-18GHz | 3115 | 1242 | 19-Oct-06 |
| Hewlett Packard | EMC Spectrum Analyzer 9kHz - 40 GHz, Fremont (SA40) | 8564E (84125C) | 1393 | 26-Oct-05 |

# *EXHIBIT 2: Test Data Log Sheets*

***ELECTROMAGNETIC EMISSIONS***

***TEST LOG SHEETS***

***AND***

***MEASUREMENT DATA***

T 61218 14 Pages

Elliott

*EMC Test Data*

| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Emissions Spec: | FCC 15.247, RSS-210 / FCC | Class: | Radio / B |
| Immunity Spec: | | Environment: | |

# EMC Test Data

For The

## Moteiv Corporation

Model

**Tmote Sky**

Date of Last Test: 9/22/2005

| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Emissions Spec: | FCC 15.247, RSS-210 / FCC | Class: | Radio / B |
| Immunity Spec: | Enter immunity spec on cover | Environment: | |

# EUT INFORMATION

## General Description

The EUT is a wireless sensor node which is designed for low power, low bandwidth data collection and processing. The device is equipped with environmental sensors (temperature, humidity, photosynthetically active radiation). Additional sensors can be attached to the device through the expansion connector. The signals propagating through that connector may not exceed 2.5V in peak-to-peak amplitude and 100kHz in frequency and 1mA in current. The EUT is primarily powered from a battery (supply in the range 1.8 to 3.6V). The device can interface with personal computers over a USB port. Normally, the EUT would be placed on near a phenomenon to be sensed. The end user environment was approximated using a table-top. The EUT cannot be powered from AC lines.

## Equipment Under Test

| Manufacturer | Model | Description | Serial Number | FCC ID |
|---|---|---|---|---|
| Moteiv | Tmote Sky | Low power wireless | prototype | TOQTMOTESKY |

## Other EUT Details

Each package is 16 bits and 0.5 mS long. Time between packets is a minimum of 2.5ms. Measured about 12 packets in 50ms, total time of 0.8ms per packet = 9.6ms/50ms (19.25, ACF = 14.2dB)

## EUT Antenna

The antenna is integral to the device. The internal antenna has the peak gain of -5dBi

## EUT Enclosure

The EUT RF shield is 0.008" tin-plated brass. The module measures 3.25"x1.25x3/16" without a default battery pack and 3.25"x1.25x.75" with the AA battery pack attached.

## Modification History

| Mod. # | Test | Date | Modification |
|---|---|---|---|
| 1 | - | - | None |

Modifications applied are assumed to be used on subsequent tests unless otherwise stated as a further modification.

| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Emissions Spec: | FCC 15.247, RSS-210 / FCC | Class: | Radio / B |
| Immunity Spec: | Enter immunity spec on cover | Environment: | |

# Test Configuration #1

## Local Support Equipment

| Manufacturer | Model | Description | Serial Number | FCC ID |
|---|---|---|---|---|
| None | | | | |

## Remote Support Equipment

| Manufacturer | Model | Description | Serial Number | FCC ID |
|---|---|---|---|---|
| None | | | | |

## Interface Cabling and Ports

| Port | Connected To | Cable(s) | | |
|---|---|---|---|---|
| | | Description | Shielded or Unshielded | Length(m) |
| None | | | | |

## EUT Operation During Emissions Tests

The supplied unit has been programmed to perform the following functions:
receive, send on low channel (2405 MHz), mid channel (2440 MHz), and high channel (2480 MHz). The transmission could be enabled in two different modes: the packet mode, exercising maximum transmission rate of the radio stack, and continuous modulated carrier mode.
When powered up with supplied AA batteries, unit will function in receive mode, and all LEDs should remain off. Pressing the USER button will cycle between the modes Receive -> low channel -> mid channel -> high channel -> receive
When a transmit mode is selected, the device will send packets on the selected channel. The packets are sent one after another; there is a channel contention period between the packets. Each packet sent will blink the LED corresponding to the currently selected channel:

. Red LED - low channel
. Green LED - mid channel
. Blue LED - high channel

The LED on selected channel blinks with a period of 1s; the continuous modulated carrier test mode cycles the LED between on and off; the packet mode cycles the LED between 75% and 25% duty cycle. The transmission power was set as follows:
Low channel: 0dBm
Mid channel: 0dBm
High channel: -3.5dBm

| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

# FCC 15.247 DTS - Power, Bandwidth and Spurious Emissions

## Test Specifics

Objective: The objective of this test session is to perform final qualification testing of the EUT with respect to the specification listed above.

Date of Test: 9/22/2005
Test Engineer: Mehran Birgani
Test Location: SVOATS #2

Config. Used: 1
Config Change: None
EUT Voltage: Battery Mode

## General Test Configuration

The EUT was located on the turntable for radiated spurious emissions testing.

For radiated emissions testing the measurement antenna was located 3 meters from the EUT.

## Ambient Conditions:

Temperature: 20 °C
Rel. Humidity: 60 %

## Summary of Results

| Run # | Test Performed | Limit | Pass / Fail | Result / Margin |
|---|---|---|---|---|
| 1 | RE, 30 - 26500 MHz - Tx Spurious Emissions | FCC Part 15.209 / 15.247( c) | Pass | 53.9dBµV/m (495.5µV/m) @ 2483.6MHz (-0.1dB) |
| 1d | RE,30 - 12500 MHz - Rx Spurious Emissions | FCC Part 15.209 / 15.247( c) | Pass | Refer to run |
| 2 | 6dB Bandwidth | 15.247(a) | Pass | 1.6 MHz |
| 3 | Output Power | 15.247(b) | Pass | 3.39 dBm |
| 4 | Power Spectral Density (PSD) | 15.247(d) | Pass | -40 dBm |

## Modifications Made During Testing:

No modifications were made to the EUT during testing

## Deviations From The Standard

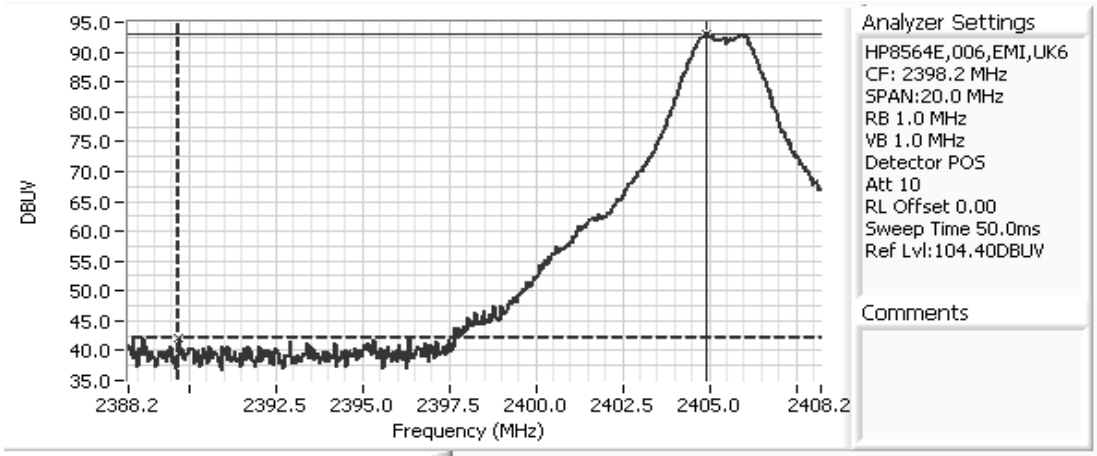
No deviations were made from the requirements of the standard.

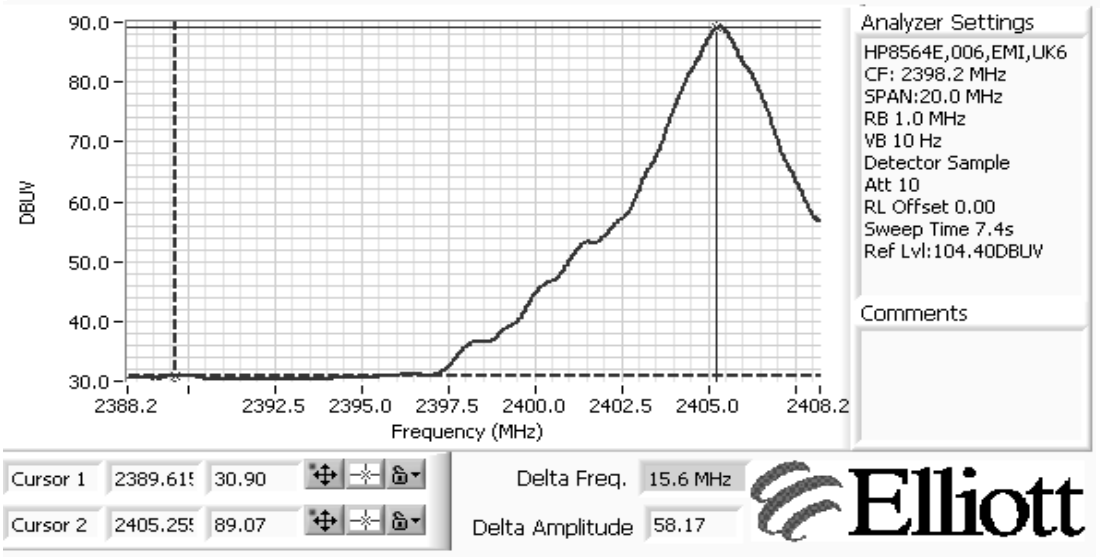
| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

**Run #1a: Radiated Spurious Emissions, 30 - 26500 MHz. Low Channel @ 2405 MHz**

**Fundamental Signal Field Strength:** Peak and average values measured in 1 MHz, and peak value measured in 100kHz

| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| 2405.058 | 89.2 | H | - | - | AVG | 74 | 2.4 | RB = 1MHz, VB = 10Hz |
| 2405.058 | 92.9 | H | - | - | PK | 74 | 2.4 | RB = VB = 1MHz |
| 2405.083 | 96.9 | V | - | - | AVG | 160 | 1.0 | RB = 1MHz, VB = 10Hz |
| 2405.083 | 100.7 | V | - | - | PK | 160 | 1.0 | RB = VB = 1MHz |



| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

| | | |
|---|---|---|
| Delta Marker - Peak | 50.7 dB | Delta between highest in-band and highest |
| Delta Marker - Average | 58.2 dB | |

**Band Edge Signal Field Strength**

| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| 2389.615 | 38.7 | V | 54.0 | -15.3 | AVG | 160 | 1.0 | |
| 2389.710 | 50.0 | V | 74.0 | -24.0 | PK | 160 | 1.0 | |

| | |
|---|---|
| Note 1: | Calculated by subtracting the marker delta values from the fundamental field strength measurements. |

**Other Spurious Emissions**

| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| 4809.189 | 46.8 | V | 54.0 | -7.2 | Avg | 166 | 1.0 | Note 2 |
| 4809.244 | 60.8 | V | 74.0 | -13.2 | PK | 166 | 1.0 | |
| 4809.283 | 52.8 | H | 54.0 | -1.2 | AVG | 183 | 2.0 | Note 2 |
| 4809.283 | 66.8 | H | 74.0 | -7.2 | PK | 183 | 2.0 | |
| 7213.610 | 53.3 | V | 74.0 | -20.8 | PK | 113 | 1.4 | |
| 7213.650 | 39.3 | V | 54.0 | -14.7 | Avg | 113 | 1.4 | Note 2 |
| 7213.655 | 41.3 | H | 54.0 | -12.7 | Avg | 117 | 1.4 | Note 2 |
| 7213.955 | 55.3 | H | 74.0 | -18.8 | PK | 117 | 1.4 | |

| | |
|---|---|
| Note 1: | For emissions in restricted bands, the limit of 15.209 was used. For all other emissions, the limit was set 20dB below the level of the fundamental. |
| Note 2: | Average value calculated from peak value with duty cycle of <20% in any 100ms period (14dB correction). |

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# EMC Test Data

| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

**Run #1b: Radiated Spurious Emissions, 30 - 26500 MHz. Center Channel @ 2440 MHz**

| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| 4879.135 | 60.2 | H | 74.0 | -13.9 | PK | 242 | 2.0 | |
| 4880.094 | 46.2 | H | 54.0 | -7.8 | AVG | 242 | 2.0 | Note 2 |
| 7318.664 | 52.2 | H | 74.0 | -21.8 | PK | 308 | 2.1 | |
| 7318.398 | 38.2 | H | 54.0 | -15.8 | AVG | 308 | 2.1 | Note 2 |
| 4879.105 | 60.6 | V | 74.0 | -13.4 | PK | 147 | 1.6 | |
| 4880.100 | 46.6 | V | 54.0 | -7.4 | AVG | 147 | 1.6 | Note 2 |

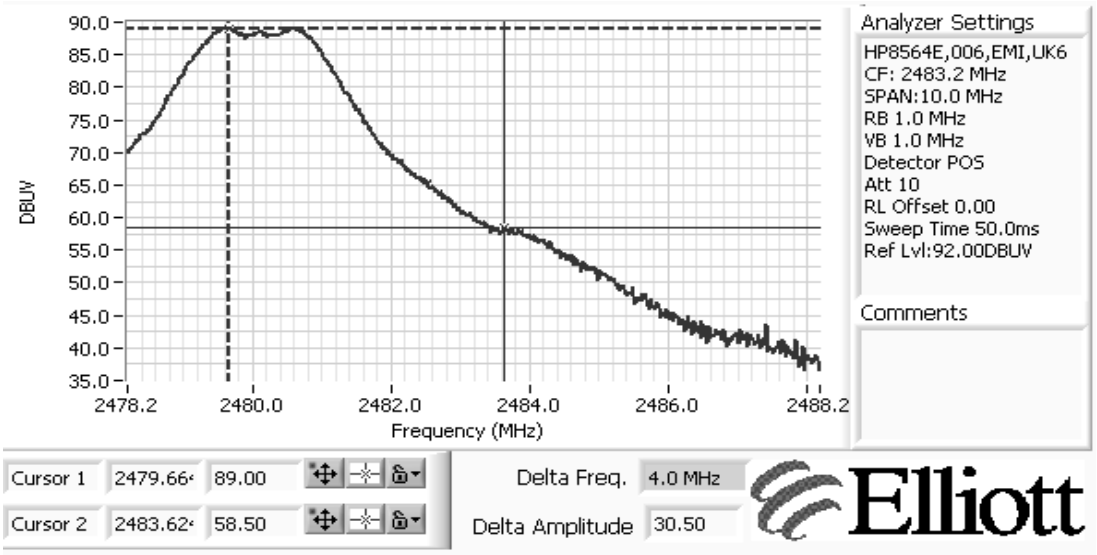
| | |
|---|---|
| Note 1: | For emissions in restricted bands, the limit of 15.209 was used. For all other emissions, the limit was set 20dB below the level of the fundamental. |
| Note 2: | Average value calculated from peak value with duty cycle of <20% in any 100ms period (14dB correction). |

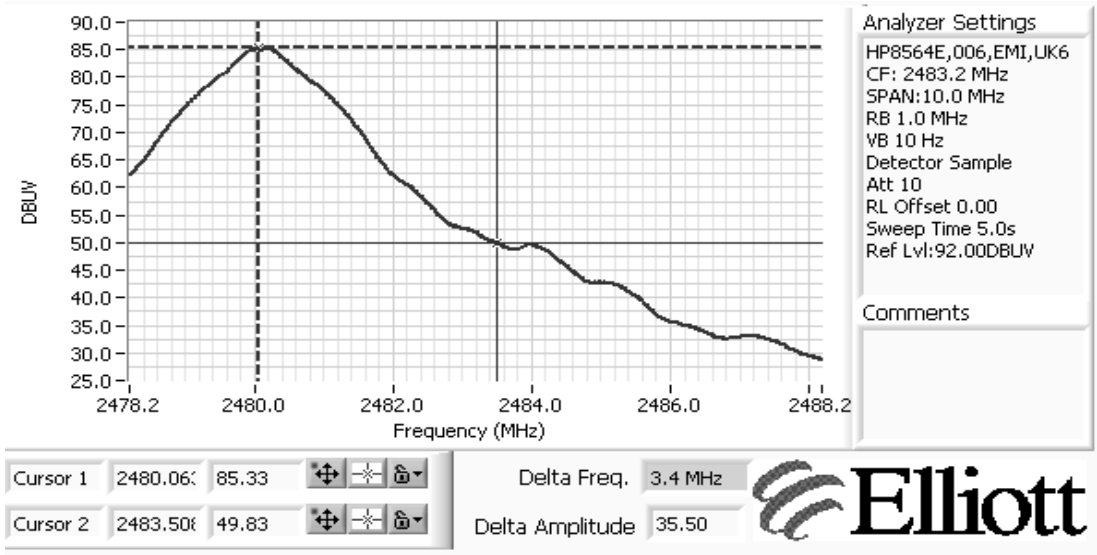
# EMC Test Data

| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

**Run #1c: Radiated Spurious Emissions, 30 - 26500 MHz. High Channel @ 2480 MHz**

| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| 2480.067 | 89.3 | V | - | - | AVG | 149 | 1.0 | RB = 1MHz, VB = 10Hz |
| 2480.067 | 93.2 | V | - | - | PK | 149 | 1.0 | RB = VB = 1MHz |
| 2480.050 | 89.4 | H | - | - | AVG | 137 | 1.8 | RB = 1MHz, VB = 10Hz |
| 2480.050 | 93.2 | H | - | - | PK | 137 | 1.8 | RB = VB = 1MHz |



| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

| | | |
|---|---|---|
| Delta Marker - Peak | 30.5 dB | Delta between highest in-band and highest |
| Delta Marker - Average | 35.5 dB | |

**Band Edge Signal Field Strength**

| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| 2483.550 | 53.9 | V | 54.0 | -0.1 | AVG | 164 | 1.0 | |
| 2483.620 | 62.7 | V | 74.0 | -11.3 | PK | 164 | 1.0 | |

Note 1: Calculated by subtracting the marker delta values from the fundamental field strength measurements.

**Other Spurious Emissions**

| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| 4960.120 | 55.7 | V | 74.0 | -18.3 | PK | 70 | 1.1 | |
| 4960.110 | 41.7 | V | 54.0 | -12.3 | AVG | 70 | 1.1 | Note 2 |
| 7439.355 | 49.7 | V | 74.0 | -24.3 | PK | 232 | 1.1 | Noise Floor |
| 7439.355 | 38.5 | V | 54.0 | -15.5 | AVG | 232 | 1.1 | Noise Floor |
| 4960.105 | 60.5 | H | 74.0 | -13.5 | PK | 245 | 2.0 | |
| 4960.135 | 46.5 | H | 54.0 | -7.5 | AVG | 244 | 2.0 | Note 2 |
| 7438.645 | 50.4 | H | 74.0 | -23.6 | PK | 245 | 2.0 | Noise Floor |
| 7438.645 | 38.8 | H | 54.0 | -15.2 | AVG | 245 | 2.0 | Noise Floor |

Note 1: For emissions in restricted bands, the limit of 15.209 was used. For all other emissions, the limit was set 20dB below the level of the fundamental.

Note 2: Average value calculated from peak value with duty cycle of <20% in any 100ms period (14dB correction).

**Run #1d: Radiated Spurious Emissions, 30 - 12500 MHz. Receive Mode**

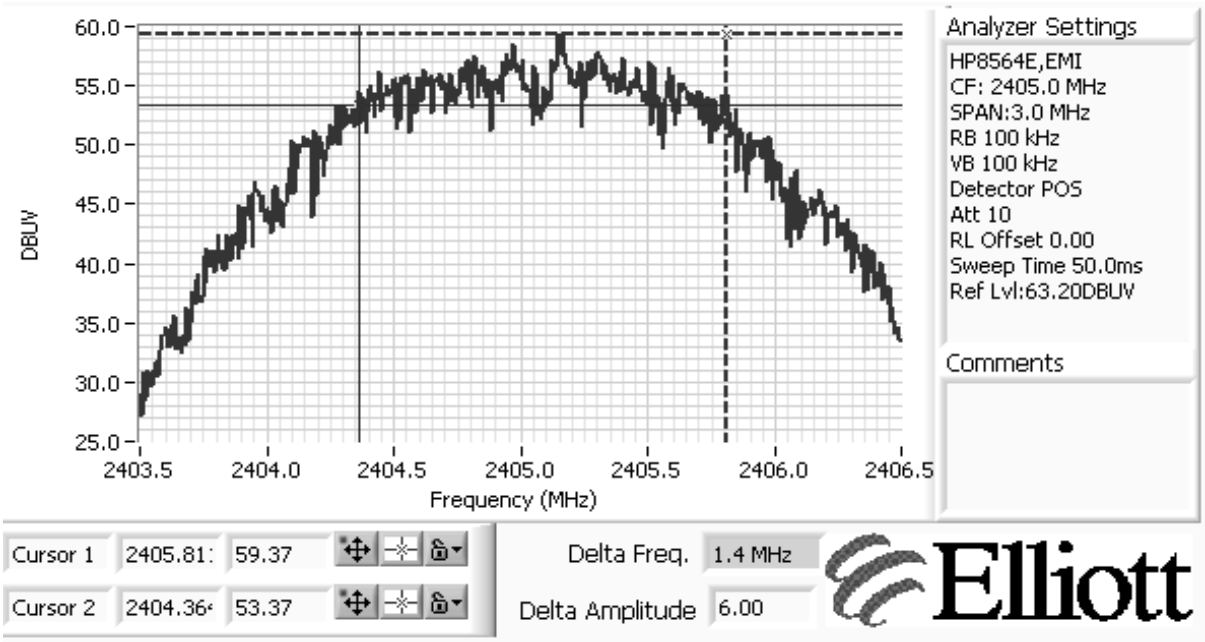
| Frequency | Level | Pol | 15.209 / 15.247 | | Detector | Azimuth | Height | Comments |
|---|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | V/H | Limit | Margin | Pk/QP/Avg | degrees | meters | |
| Note 1 | | | | | | | | |

Note 1: No signal was found within 15 dB of limit line.

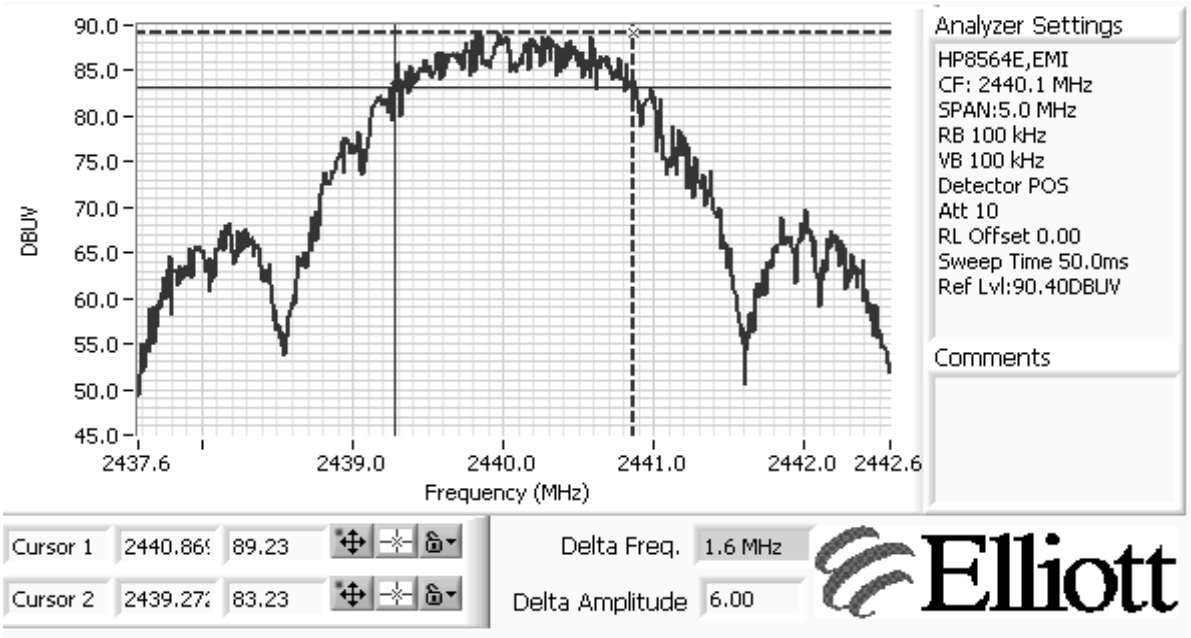
| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

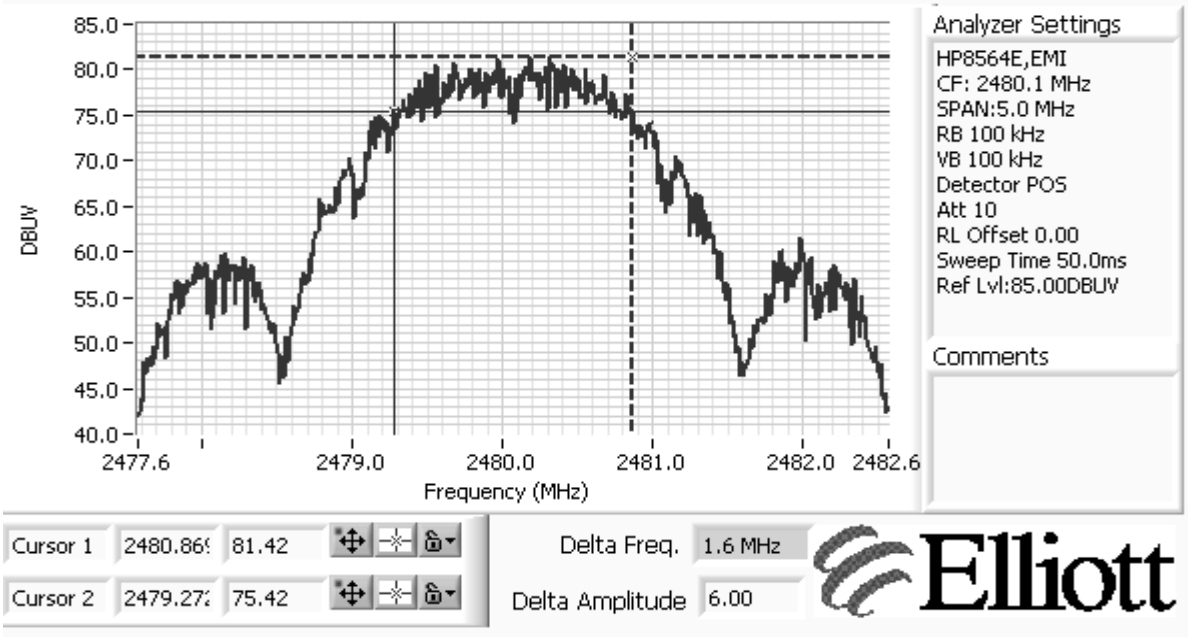
**Run #2: Signal Bandwidth**

| Power Setting | Frequency (MHz) | Resolution Bandwidth | 6dB Signal Bandwidth (MHz) | 99% Signal Bandwidth (MHz) |
|---|---|---|---|---|
| | 2405 | 100kHz | 1.4 | 4.5 |
| | 2440 | 100kHz | 1.6 | 4.5 |
| | 2480 | 100kHz | 1.6 | 4.5 |



| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |



| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

**Run #3: Output Power**

Maximum antenna gain: dBi

| Power Setting | Frequency (MHz) | Field Strength at 3m (dBuV/m) | Antenna Pol. (H/V) | Res BW (MHz) | Signal BW (MHz) | Bandwidth Correction | Power (dBm) | Power (Watts) |
|---|---|---|---|---|---|---|---|---|
| | 2405 | 95.70 | H | 2 | 1 | 0 | 0.4 | 0.00109648 |
| | 2440 | 95.03 | H | 2 | 1 | 0 | -0.27 | 0.00093972 |
| | 2480 | 92.62 | H | 2 | 1 | 0 | -2.68 | 0.00053951 |
| | 2405 | 98.11 | V | 2 | 1 | 0 | 2.81 | 0.00190985 |
| | 2440 | 98.69 | V | 2 | 1 | 0 | 3.39 | 0.00218273 |
| | 2480 | 94.95 | V | 2 | 1 | 0 | -0.35 | 0.00092257 |

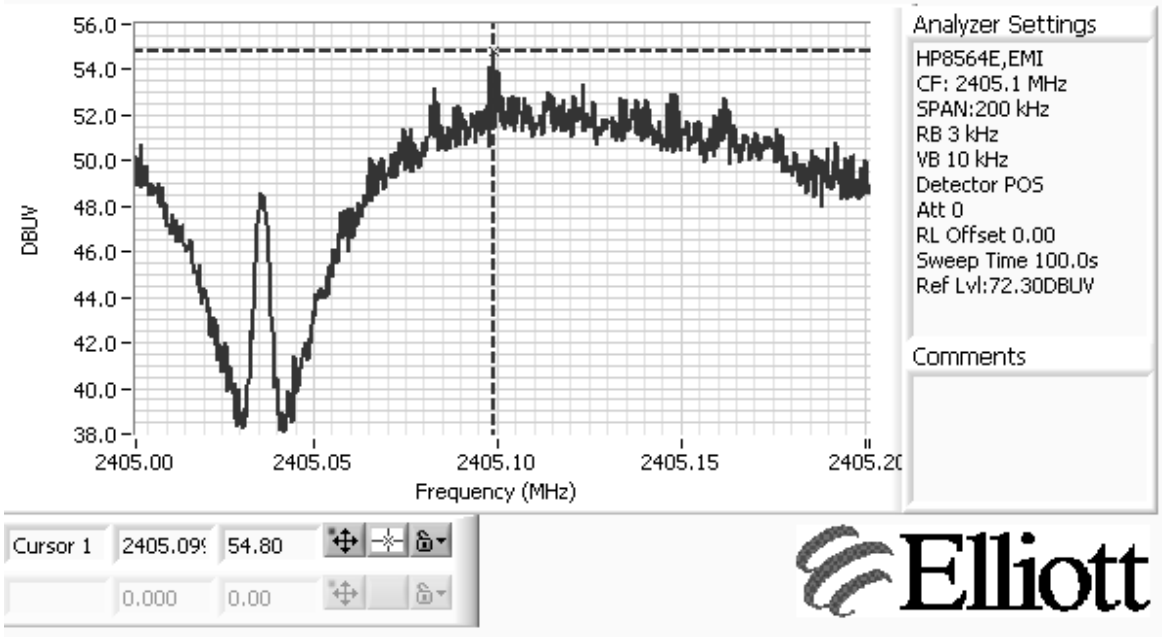
| | |
|---|---|
| Note 1: | Output power calculated from field strength at 3m based on free space path loss formula $E = \sqrt{(30PG)} / d$, where E is the field strength (V/m), PG is the effective isotropic radiated power (W) and d is the distance (3m). Additional correction to the calculated power is made to account for the difference between the measurement bandwidth and signal bandwidth. |

| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |

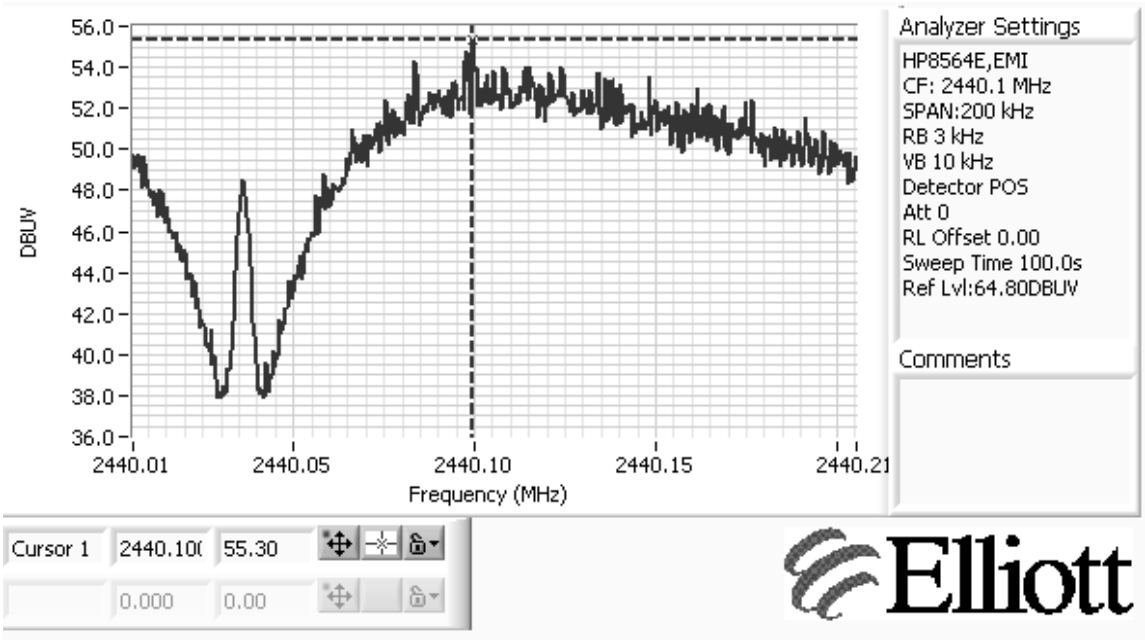
**Run #4: Power Spectral Density**

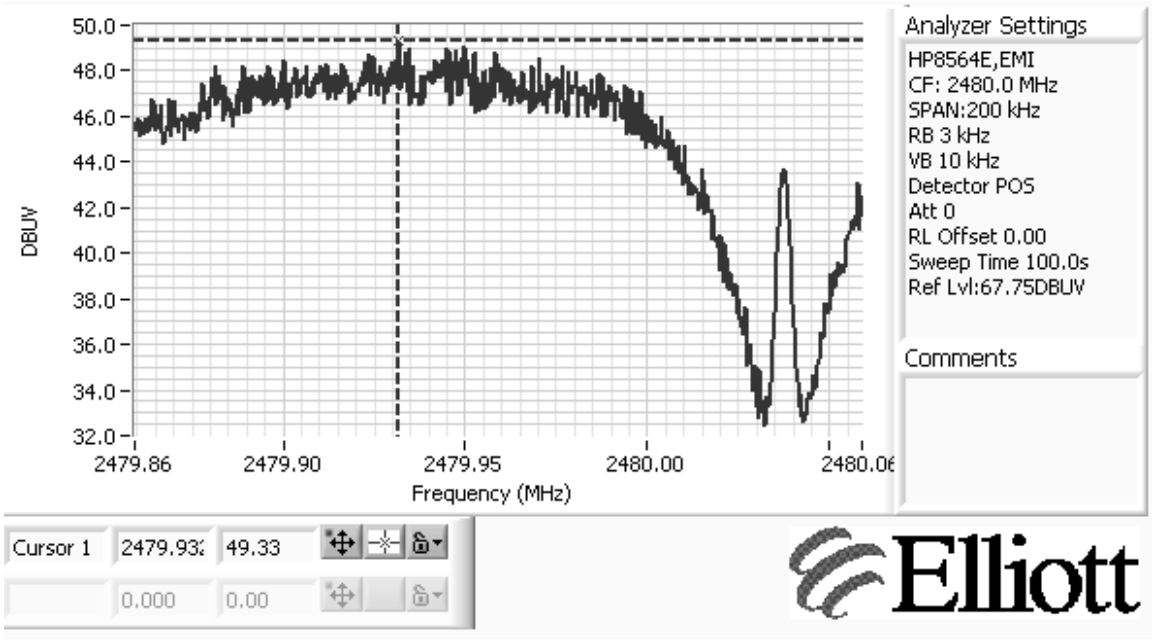
| Power Setting | Operating Frequency (MHz) | Freq. @ PPSD | Res BW | Field Strength (dBuV/m/3kHz) | Power Spectral Density (dBm / 3kHz ) Note 3 |
|---|---|---|---|---|---|
| | 2405 | 2405.09 | 3kHz | 54.80 | -40.5 |
| | 2440 | 2440.10 | 3kHz | 55.30 | -40.0 |
| | 2480 | 2479.93 | 3kHz | 49.33 | -46.0 |

| | |
|---|---|
| Note 1: | Freq. @ PPSD: Frequency of the Peak Power Spectral Density (PPSD) |
| Note 2: | Power spectral density measured using RB=3 kHz, VB=10kHz with a sweep time set to ensure a dwell time of at least 1 second per 3kHz. The measurement is made at the frequency of PPSD determined from preliminary scans using RB=3kHz using multiple sweeps at a faster rate over the 6dB bandwidth of the signal. |
| Note 3: | Power spectral density calculated from field strength at 3m based on free space path loss formula E = √(30PG) / d, where E is the field strength (V/m), PG is the effective isotropic radiated power (W) and d is the distance (3m). |



| | | | |
|---|---|---|---|
| Client: | Moteiv Corporation | Job Number: | J61193 |
| Model: | Tmote Sky | T-Log Number: | T61218 |
| | | Account Manager: | Esther Zhu |
| Contact: | Robert Szewczyk | | |
| Spec: | FCC 15.247, RSS-210 / FCC | Class: | N/A |



# *EXHIBIT 3: Test Configuration Photographs*

Uploaded as A Separate Attachment

# *EXHIBIT 4: Proposed FCC ID Label & Label Location*

Uploaded as A Separate Attachment

# *EXHIBIT 5: Detailed Photographs of Moteiv Corporation Model Tmote SkyConstruction*

Uploaded as A Separate Attachment

# *EXHIBIT 6: Operator's Manual for Moteiv Corporation Model Tmote Sky*

Uploaded as A Separate Attachment

# *EXHIBIT 7: Block Diagram of Moteiv Corporation Model Tmote Sky*

Uploaded as A Separate Attachment

# *EXHIBIT 8: Schematic Diagrams for Moteiv Corporation Model Tmote Sky*

Uploaded as A Separate Attachment

# *EXHIBIT 9: Theory of Operation for Moteiv Corporation Model Tmote Sky*

Uploaded as A Separate Attachment

# *EXHIBIT 10: Advertising Literature*

Uploaded as A Separate Attachment

# *EXHIBIT 11: RF Exposure Information*

Uploaded as A Separate Attachment