CURRENT Group, LLC
Report of Measurements
CURRENT Bridge OH 6021

Table of Contents

1. General Information

Applicant: CURRENT Technologies, LLC

Applicant Address: 20420 Century Boulevard
Germantown, MD 20874
301-944-2700

Equipment: CURRENT Bridge OH 6021

Equipment Description: The CURRENT Bridge OH 6021 is part of a third generation Access BPL system. It operates on overhead electric utility power lines and utilizes both the low-voltage and medium-voltage utility wires.

The CURRENT Bridge OH 6021 is a pole-mounted BPL device that routes and controls data traffic flow between the low and medium voltage lines. The CURRENT Bridge serves as a gateway to all customers powered from the same distribution transformer as itself. It communicates over the medium voltage lines (via the CT Coupler® OH 5000) in the 31.4 to 47.9 MHz band and over the low voltage lines (via a standard 240V two-wire connection) in the 4.4 to 20.8 MHz band.

Test Operators: Ignacio Antonio Paulino and Robert Patrick

Dates of Testing: March 6, 2008 to May 6, 2008

Test Locations:
- CURRENT Technologies Rockville Test Area - (Macon Road and Old Drovers Lane in Rockville, Maryland)
- CURRENT Technologies Potomac Test Area – (Kentsdale Road and Tuckerman Lane in Potomac, MD)
- Washington Laboratories Open Area Test Site (Gaithersburg, Maryland)

Modes of Operation:
- LV Active: transmitting OFDM signals on the low-voltage power line (4.4 MHz to 20.8 MHz),
- MV Active: transmitting OFDM signals on the medium-voltage power line (31.4 MHz to 47.9 MHz)

Applicable EMC Specification:
- FCC Part 15, Subpart G

Class of Service:
- Class A

2. Applicable Documents

Testing of emissions was performed in accordance with FCC requirements.

- Federal Communication Commission (FCC), code of Federal Regulations 47, FCC docket 89-103, Part 15: Radio Frequency Devices, Subpart G, October 2005.
- Federal Communication Commission (FCC), code of Federal Regulations 47, FCC docket 89-103, Part 15: Radio Frequency Devices, Section 15.109(b) and 15.209, October 2001.
- FCC/OET, "FCC Procedure for Measuring Electromagnetic Emissions for Digital Devices", TP-5, March 1989.
- Federal Communication Commission (FCC), Report and Order, FCC-04-245, Appendix C, Measurement Guidelines for Broadband Over Power Line (BPL) Devices or Carrier Current Systems (CCS) and Certification Requirements for Access BPL Devices, October 2004.
- International Special committee on Radio Interference (CISPR) Publication 16, First Edition 1977, "CISPR Specification for Radio Interference Measuring, Apparatus and Measurement Methods".
- American National Standard, "Interim 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", ANSI C63.4, 2000.

3. Detailed Applicable EMC Requirements and Limits

The equipment was evaluated to Federal Communications Commission (FCC) requirements.

3.1 Conducted Limits

Conducted emissions limits do not apply to Access BPL equipment

3.2 Radiated Limits

The following radiated emissions limits apply:

Applicable Specification Reference	Frequency Range (MHz)	Class	Limit of Radiated Emissions		Measurement Distance (m)
			(µV/m)	(dBµV/m)	
FCC 15.107(c)(3), 15.109(c), 15.209	1.705 to 30	-	30	29.5	30
FCC 15.109	30 to 88	A	90	39.1	10
	88 to 216	A	150	43.5	10
	216 to 960	A	210	46.4	10
	960 and Above	A	300	49.5	10

Notes:

1. *The tighter limit shall apply at the edge between two frequency bands*
2. *Distance refers to the distance in meters from measuring instrument antenna to the closest point of any part of the equipment under test.*

4. Procedures for Measuring RF Emissions

The following test procedures were used to measure RF emissions from the CURRENT Bridge OH 6021.

4.1 AC Power Line Conducted Emissions Measurements

Conducted emissions limits do not apply to this Access BPL equipment.

4.2 Radiated Emissions Measurements

Measurements of radiated emissions were made using an EMC (spectrum) analyzer and calibrated broadband antennas. Tests were performed in the following frequency ranges: 1.705 MHz to 30 MHZ, 30 MHz to 50 MHz and 50 MHz to 1000 MHz. For the purposes of this testing, the CURRENT Bridge OH 6021 was operated in a test mode which forced uninterrupted transmissions on both bands at the maximum possible duty cycle and highest power output.

4.2.1 Radiated Emissions Measurement – 1.705 MHz to 30 MHz

In the frequency band 1.705 MHz to 30 MHz, the CURRENT Bridge OH 6021 functions as an Access BPL device as described in FCC Rules, Sections 15.3(ff). Radiated emissions were measured at three representative field installation sites as required under the rules. The measurement procedures as described in Appendix C of the FCC BPL *Report and Order* (dated October 14, 2004) were rigorously followed.

The CURRENT Bridge OH 6021 was installed in a residential neighborhood on a utility pole, approximately 7-9 meters above the ground. The CURRENT Bridge OH 6021 low-voltage wires were connected to the electric utility's low-voltage power lines. The CURRENT Bridge OH 6021 high band RF output was also routed to the electric utility's medium voltage lines via a CT Coupler OH 5000.

The CURRENT Bridge OH 6021 was operated under local control for this testing using a secure diagnostic interface provided on the low voltage side. A battery-powered portable test set communicated with the CURRENT Bridge on the pole via the utility ground wire and was removed once the appropriate test transmissions were started. At the conclusion of testing the portable unit was once again used to shut down transmissions from the CURRENT Bridge mounted on the pole.

The test (loop) antenna was placed at a fixed height of 1 meter above ground level at a lateral distance of approximately 10 meters measured horizontally from the CURRENT Bridge and its associated overhead power lines. If the antenna could not be placed at this distance due to interference from conductive objects within the test area (e.g. parked cars) it was moved further away from the power line. The antenna was moved to the left and right of the CURRENT Bridge location parallel to the low-voltage power line a distance of 36 meters in 6 meter increments. These distances correspond to 1.5 wavelengths and ¼ wavelength of the center frequency of the LV signal respectively.

The LV-signal radiated emissions were measured at frequencies between 4.4 MHz to 20.8 MHz using an efficient, two step procedure. At each measurement location, the test antenna was initially rotated to identify the orientation showing maximum emissions and that orientation was used for all subsequent measurements.

The first step of the procedure identifies all significant emissions by capturing the spectrum at all test locations in peak detection mode with a resolution bandwidth of 9 KHz. Prior to further processing, these spectra are individually examined for inadvertent captures of impulse noise and/or other in-band coherent signals unrelated to the BPL equipment under test. Verified valid data is then further processed to extract the emissions at each OFDM carrier center frequency and sorted in descending order to yield a table of (frequency, spatial location) pairs to be subsequently examined.

In the second step of the procedure, quasi-peak measurements are then made manually with the EMC analyzer in peak hold/zero span mode and resolution bandwidth of 9 KHz at the 10 highest emission points identified via the above procedure.

The height of the low-voltage (LV) power lines was measured. (Since the CURRENT Bridge must always be mounted above the LV power lines on the pole, only the slant range distance to the lines need be considered). The slant-range distance from the antenna to the nearest power line was calculated for each test location and the appropriate 40 dB/decade distance correction factor applied to the quasi-peak data for the 10 highest emission points. These final results were then compared to the limits given in Section 3.2 to yield the compliance margins shown in Appendix A.

4.2.2 Radiated Emissions Measurement – 30 MHz to 50 MHz

In the frequency band 30 MHz to 50 MHz, the CURRENT Bridge OH 6021 functions as an Access BPL device as described in FCC Rules, Sections 15.3(ff). Radiated emissions were measured at three representative field installation sites as required under the rules.

The CURRENT Bridge 6021A was installed, connected and operated in the same manner for this sequence of tests as discussed in Section 4.2.1 above. As above, the measurement procedures described in Appendix C of the FCC BPL *Report and Order* (dated October 14, 2004) were rigorously followed for this series with the addition of the 2-dimensional spatial probing for maximum emissions specified in Section 1, subparagraph 5.

The biconical test antenna was scanned over the 2-dimensional plane 7.6 meters to the left and right of the utility pole in 1.9 meter increments with antenna heights also varying from 1 to 4 meters. It was determined from an initial scan that the antenna orientation for maximum emissions was always horizontal and that orientation was used throughout this test.

The MV-signal radiated emissions were measured at frequencies between 31.4 MHz and 47.9 MHz using a similar two step procedure as discussed in Section 4.2.1 above.

The first step of the procedure identifies all significant emissions by capturing the spectrum at all test locations in peak detection mode with a resolution bandwidth of 120 KHz. Prior to further processing, these spectra are individually examined for inadvertent captures of impulse noise and/or other in-band coherent signals unrelated to the BPL equipment under test. Verified valid data is then further processed to extract the emissions at each OFDM carrier center frequency and sorted in descending order to yield a table of (frequency, spatial location) pairs to be subsequently examined.

In the second step of the procedure, quasi-peak measurements are then made manually with the EMC analyzer in peak hold/zero span mode and resolution bandwidth of 120 KHz at the 10 highest emission points identified via the above procedure.

The height of the CURRENT Bridge and associated medium voltage power lines were measured. Per the guidance provided by Andy Leimer in his presentation *Broadband over Power Line (BPL) Equipment Authorization – Detailed* (dated February 2006), the lesser of the slant range distance from the antenna to the nearest MV power line or the CURRENT Bridge itself was determined for

each test location and the appropriate 20 dB/decade distance correction factor applied to the quasi-peak data for the 10 highest emission points. These final results were then compared to the limits given in Section 3.2 to yield the compliance margins also shown in Appendix A.

4.2.3 Radiated Emissions Measurement – 50 MHz to 1000 MHz

The CURRENT Bridge OH 6021 was mounted on a wooden stand in the same orientation in which it would be mounted in an actual installation. The stand positioned the unit 0.8 meters above the ground plane. The power leads from the device were connected to the laboratory power source through an LISN. The device's medium voltage connections were terminated with standard coaxial cables, a 50-ohm attenuator and fed to another unit some distance away capable of terminating data traffic. Similarly, the low voltage signal set was extracted from the power line by the LISN and fed to another shielded modem capable of terminating data traffic.

The CT Bridge OH 6021 was then operated with both interfaces active, passing random traffic bi-directionally from one interface to the other at the maximum possible data rate. This configuration emphasizes the production of out-of-band emissions for the CURRENT Bridge as a digital device.

The CURRENT Bridge /stand were placed on a turntable at the Open Area Test Site. The test antenna was mounted horizontally polarized at a height of 1 meter and a distance of 3 meters. The radiated emissions were measured over a full rotation of the turntable by having the EMC analyzer record a "peak-hold" spectrum with a resolution bandwidth of 120 KHz.

Quasi-peak measurements were then made at each significant emission identified in the initial sweep. For the quasi-peak measurements, the EMC analyzer was set to quasi-peak detection and tuned to the recorded emission frequency using a large frequency span. The frequency span was then reduced while keeping the spectrum analyzer's center frequency tuned to the emission's peak. The CURRENT Bridge was then rotated 360 degrees to determine the direction of maximum emission. Further maximization of the measured emission was done by varying the antenna height from 1-4 meters.

The entire process was then repeated with the antenna vertically polarized and all significant emissions from both runs are reported in Appendix A of this report.

5. Description of the Test Signal

Normally the CURRENT Bridge OH 6021 is part of a large system in which access to the power line channel is shared fairly among many widely-separated network elements. This sharing is accomplished in the time domain by a CSMA-CA algorithm implemented in the MAC layer of the internal OFDM engine. The actual algorithm is complex but for the purposes of this report the only important elements are that each station with traffic to send must contend for the channel with the rest of its' peer group, with the outcome determined by random selection, and that any station in possession of the channel cannot hold onto it for more than a few milliseconds at a time. The same sharing mechanism operates simultaneously and asynchronously on the low voltage and medium voltage interfaces of the CT Bridge. In normal operation, any given network element is only allowed to transmit for a fairly low duty cycle which decreases as the number of elements in the network increases. The normal action of the system is to spread emissions out over both geographic area and time, thereby greatly minimizing any impact it might have on a stationary victim receiver.

Given the above, it is not possible to meet the requirements of Appendix C 1(2) of the *BPL Report and Order* within the bounds of normal operation of this system and therefore generation of test signal is necessary. The test signal for the CURRENT Bridge OH 6021 is commanded by an embedded firmware application which sends a continuous loop of special requests directly to the OFDM engine, thereby bypassing the normal MAC layer communications protocol. This "special request" is actually a low level command which forces the OFDM engine to broadcast a "how do you hear me?" message which would normally trigger responses from all other stations within range.

If the unit under test is operated in isolation, (with no peer elements within hearing range), then no responses are forthcoming. The embedded firmware then immediately forces the OFDM engine to issue the same request again in an infinite loop and this process produces the maximum transmit burst rate the OFDM engine is capable of generating (>10,000 bursts/sec). It should be underscored that this rate is the absolute maximum the hardware is capable of generating and is many hundreds of times faster than any single station in the system can generate in normal operation.

6. Description of the Test Sites

Radiated emissions testing was performed at six different locations. Not all testing was performed at each location. A description of each location is given below. A list of the testing performed at each location is included in the descriptive information for that location.

CURRENT Technologies Rockville Test Area – PLB1

Location:	4700 Macon Road Rockville, MD
Site Description:	System installation on a utility pole in a residential neighborhood. The pole is located next to a residential street and is equipped with a transformer, low-voltage wires and medium-voltage wires. Height of Bridge: 7.62m Distance to Pole: 9.00m LV-wire Height: 6.65m
Site Diagrams:	See Figure 1 below.
Site Photos:	See Photograph B-1 in Appendix B.
Tests Performed at this Location:	▪ Radiated Emissions, 1.705 MHz to 30 MHz, on April 18, 2008

Figure 1: Test Site Diagram – CURRENT Technologies Rockville Test Area – PLB1

CURRENT Technologies Rockville Test Area – PLB2

Location:	4806 Macon Dr. Rockville, MD
Site Description:	System installation on a utility pole in a residential neighborhood. The pole is located next to a residential street and is equipped with a transformer, low-voltage wires and medium-voltage wires. Height of Bridge: 7.62m Distance to Pole: 9.75m LV-wire Height: 7.01m
Site Diagrams:	See Figure 2 below.
Site Photos:	See Photographs B-2 and B-3 in Appendix B.
Tests Performed at this Location:	▪ Radiated Emissions, 1.705 MHz to 30 MHz, on May 5, 2008

Figure 2: Test Site Diagram – CURRENT Technologies Rockville Test Area – PLB2

CURRENT Technologies Rockville Test Area – PLB4

Location:	11818 Old Drover Way Rockville, MD
Site Description:	System installation on a utility pole in a residential neighborhood. The pole is located next to a residential street and is equipped with a transformer, low-voltage wires and medium-voltage wires. Height of Bridge: 7.77m Distance to Pole: 9.00m LV-wire Height: 7.22m
Site Diagrams:	See Figure 3 below.
Site Photos:	See Photographs B-4 and B-5 in Appendix B.
Tests Performed at this Location:	▪ Radiated Emissions, 1.705 MHz to 30 MHz, on March 6, 2008

Figure 3: Test Site Diagram – CURRENT Technologies Rockville Test Area – PLB4

CURRENT Technologies Potomac Test Area – 9417 Kentsdale

Location:	9417 Kentsdale Rockville, MD
Site Description:	System installation on a utility pole in a residential neighborhood. The pole is located next to a residential street and is equipped with a transformer, low-voltage wires and medium-voltage wires. Height of Bridge: 9.11m Distance to Pole: 12.80m MV-wire Height: 11.58m
Site Diagram:	See Figure 4 below.
Site Photos:	See Photographs B-6 and B-7 in Appendix B.
Tests Performed at this Location:	▪ Radiated Emissions, 30 MHz to 50 MHz, on May 2, 2008

Figure 4: Test Site Diagram – CURRENT Technologies Potomac Test Area – 9417 Kentsdale

CURRENT Technologies Potomac Test Area – 9705 Kentsdale

Location:	9705 Kentsdale Rockville, MD
Site Description:	System installation on a utility pole in a residential neighborhood. The pole is located next to a residential street and is equipped with low-voltage wires and medium-voltage wires. Height of Bridge: 8.99m Distance to Pole: 12.80m MV-wire Height: 12.80m
Site Diagram:	See Figure 5 below.
Site Photos:	See Photographs B-7 and B-8 in Appendix B.
Tests Performed at this Location:	▪ Radiated Emissions, 30 MHz to 50 MHz, on May 2, 2008

Figure 5: Test Site Diagram – CURRENT Technologies Potomac Test Area – 9705 Kentsdale

CURRENT Technologies Potomac Test Area – Tuckerman

Location:	Tuckerman Lane Rockville, MD
Site Description:	System installation on a utility pole in a BPL system test area. The pole is located is an open field and is equipped with low-voltage wires and medium-voltage wires. Height of Bridge: 10.21m Distance to Pole: 13.00m MV-wire Height: 12.50m
Site Diagram:	See Figure 6 below.
Site Photos:	See Photograph B-10 in Appendix B.
Tests Performed at this Location:	Radiated Emissions, 30 MHz to 50 MHz, on May 6, 2008

Figure 6: Test Site Diagram - CURRENT Technologies Potomac Test Area – Tuckerman

Washington Laboratories Open Area Test Site

Location:	Washington Laboratories 7560 Lindbergh Drive Gaithersburg, MD
Site Description:	Simulated system installation at an Open Area Test Site. The CURRENT Bridge OH 6021 was mounted on a wooden platform in approximately the same position in which they would be mounted in the field, at a height of approximately 0.8 meter above the floor. The medium-voltage connections were terminated with 4' coaxial cables and 50-ohm resistors. The cables were arranged in a way that was representative of the way they would be arranged in an actual installation.
Site Diagram:	See Figure 7 below.
Tests Performed at this Location:	▪ Radiated Emissions, 50 MHz to 1000 MHz, CURRENT Bridge OH 6021, on March 28, 2008

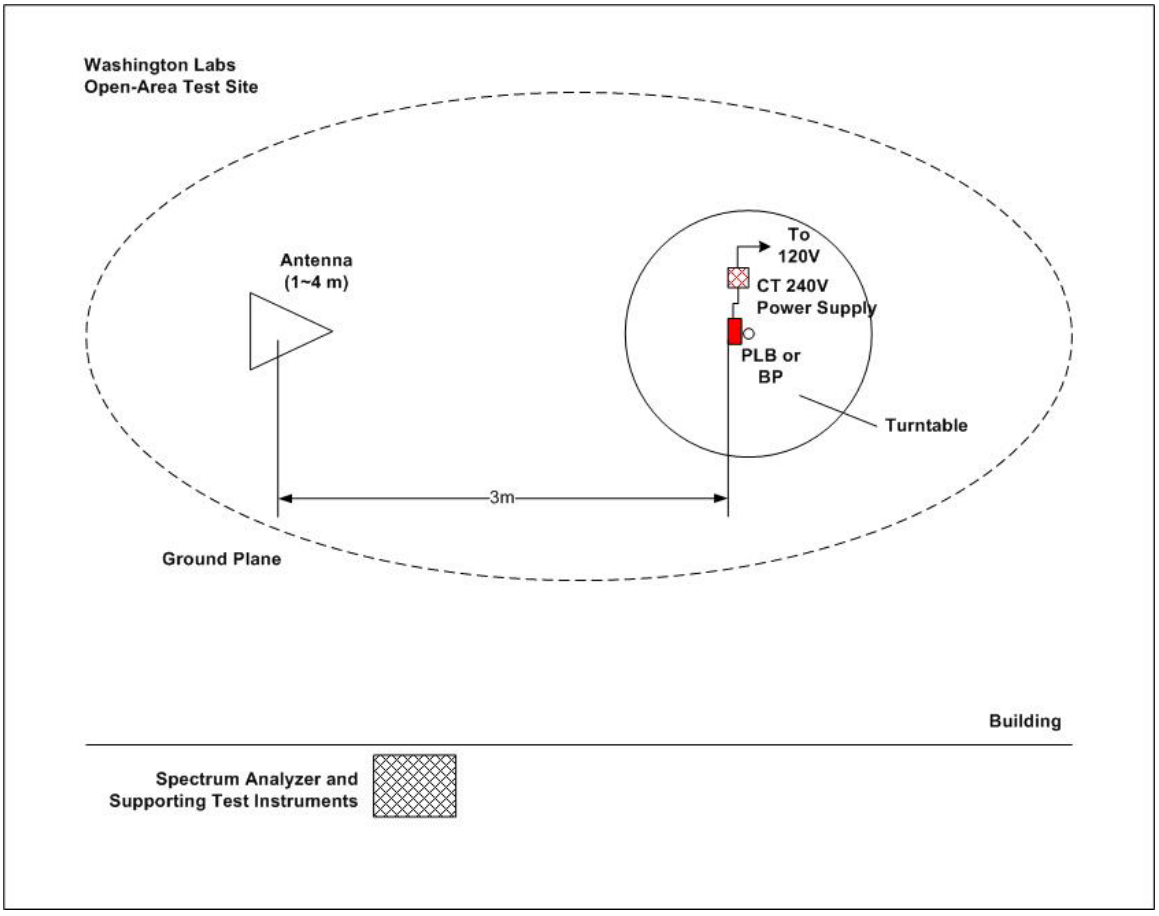

Figure 7: Test Site Diagram – Washington Laboratories Open Area Test Site

7. List of Test Equipment Used

The following is a list of test equipment used during testing.

Radiated Emissions Measurement – 1.705 MHz to 30 MHz

Description	Manufacturer and Model Number	Serial Number and Identification Number	Calibration Due Date
EMC Analyzer	Agilent E7405A	MY45115096	February 1, 2009
Antenna, Passive Loop	EMCO 6512	00069092	January 31, 2009
RF Cable, 125'	RG-58	CT #125	January 12, 2009

Radiated Emissions Measurement – 30 MHz to 50 MHz

Description	Manufacturer and Model Number	Serial Number and Identification Number	Calibration Due Date
EMC Analyzer	HP E7405A	MY45115096	February 1, 2009
Antenna, Biconical	A.H. Systems SAS-540	617	August 3, 2008
RF Cable, 125'	RG-58	CT #125	January 12, 2007

Radiated Emissions Measurement – 50 MHz to 1000 MHz

Description	Manufacturer and Model Number	Serial Number and Identification Number	Calibration Due Date
Spectrum Analyzer	HP 8568B	WL #00073	July 7, 2008
Quasi-Peak Adapter	HP 85650A	WL #00069	July 7, 2008
RF Preselector (w/ OPT 8ZE)	HP 85685A	WL #00071	July 7, 2008
Antenna, Biconlog	Sunol JB1	WL #00644	November 27, 2009

8. EMI Test Results

EMI test results for both conducted and radiated emissions measurements are summarized below.

8.1 Conducted Emission Data

Conducted emissions limits do not apply to this Access BPL equipment.

8.2 Radiated Emission Data

The final level of the radiated emission, in dBµV/m, is calculated by taking the reading from the spectrum analyzer (in dBµV) and adding the appropriate correction factors (antenna, cable loss, external pre-amplifier, filter, etc.). A distance correction factor is then added to compensate for the actual measurement distance being different from the specified measurement distance. The difference between this result and the FCC limit is calculated, giving the margin of compliance, as shown in Appendix A.

The field strength was calculated using the formula:

$$E(dB\mu V/m) = Vrec(dB\mu V) + AF(dB/m) + CL(dB)$$

Where Vrec is the voltage detected voltage by the spectrum analyzer, AF is the antenna factor at the specified frequency, and CL is the insertion loss on the RF cable which is connected between the antenna and the spectrum analyzer.

Conclusion: The CURRENT Bridge OH 6021 meets the FCC limits for radiated emissions from Access BPL devices in the frequency range 1.705 MHz to 30 MHz when actively transmitting LV signals (4.4 MHz to 20.8 MHz). In this operation mode and over this frequency range, the minimum passing margin was 1.3 dB.

The CURRENT Bridge OH 6021 meets the FCC limits for radiated emissions from Access BPL devices in the frequency range 30 MHz to 50 MHz when actively transmitting MV signals (31.4 MHz to 47.9 MHz). In this operation mode, and over this frequency range, the minimum passing margin was 0.3 dB.

The CURRENT Bridge OH 6021 meets the Part 15 Class A radiated emission requirements over the frequency range 50 MHz to 1000 MHz. Over this frequency range, the minimum passing margin was 11.0 dB.