Broadband over Power Lines – FCC Emissions Compliance Guidelines

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BPL Emissions Compliance Guidelines - Introduction

What is BPL?

Access Broadband over Power Lines is a new type of carrier current technology

New medium for extending broadband access to more American homes & businesses

Enables marketing of VoIP, Video-On-Demand and other leading-edge Internet products

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BPL Emissions Compliance Guidelines - Introduction

Benefits to Society

The USA is #11 in the World in high-speed Broadband Internet access

Power lines extend into most American homes & businesses, delivering the "last mile"

Encourages competition with Cable TV, DSL, terrestrial microwave, satellite, etc.

BPL Emissions Compliance Guidelines - Introduction

Benefits to Power Providers

Automated outage detection & restoration confirmation

Remote monitoring & operation of switches, transformers, capacitor banks, etc.

More efficient demand-side management & power quality monitoring

Automated meter-reading and video surveillance of utility property

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BPL Emissions Compliance Guidelines - Background

Carrier Current Systems

Transmit RF energy by conduction over an electric power line to receivers on that line

Use power lines to carry communications by coupling low-power currents onto wiring

Operate on an un-licensed basis under 47CFR15

Part 15 devices may not cause "harmful interference" to licensed radio services

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BPL Emissions Compliance Guidelines - Background

Carrier Current Systems

How can we avoid interference?

"Noisy" modulation doesn't perturb voice

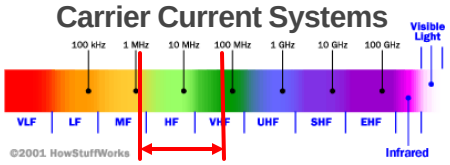
Multiple carriers can be amplitude controlled

Carriers can be selectively turned off ("notched")

Close spacing of BPL components keeps currents low and prevents interference

BPL Emissions Compliance Guidelines - Background

Carrier Current Systems



Access BPL systems operate between AM and FM radio (1.7 – 80 MHz)

Many licensed services share this spectrum

Amateur, short wave, Government, aeronautical

BPL Emissions Compliance Guidelines - Background

FCC Report & Order 04-245

Recognizes the concerns of licensed radio users to avoid the creation of "harmful interference"

Indicates that BPL systems can be configured & operated to minimize or eliminate interference

Develops a framework to encourage the rapid deployment of BPL systems

Removes regulatory uncertainties for BPL operators and manufacturers

BPL Emissions Compliance Guidelines - Background

FCC Report & Order 04-245

Develops rules for BPL deployment:

Operational requirements – to avoid and resolve harmful interference should they occur

Administrative requirements – to identify BPL installations and the frequencies they use

Measurement guidelines – to ensure repeatable Validation testing of BPL systems

BPL Emissions Compliance Guidelines – Network Equipment

System Architectures

Three basic types of equipment:

Injectors – bidirectional connections between Internet backhaul point and MV lines

Repeaters – extend distance beyond 2,000 ft.

Extractors – bidirectional connections between MV lines and in-house system (wired or wireless)

BPL Emissions Compliance Guidelines – Network Equipment

System Architectures

Table 1
BPL System Architectures

Modulation / Chipset	MV Access Signal	LV In-House Signal
OFDM (orthogonal FM)	VHF only (30-50MHz)	Home Plug (4-21MHz notched)
OFDM (DS2 chipset)	HF/VHF (notched)	DS2 / Home Plug / WiFi
DSSS (spread spectrum)	HF (notched)	HF (notched)
Microwave Surface Wave	2.4 & 5.8 GHz unlicensed bands	Home Plug / WiFi

OFDM modulates many narrow-band sub-carriers onto a single MV wire & uses Home Plug modems

DS2 uses separate frequencies for upstream and downstream traffic and several in-house systems

BPL Emissions Compliance Guidelines – Network Equipment

System Architectures

Table 1
BPL System Architectures

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DSSS modulates onto two MV wires and passes through transformers to in-house modems

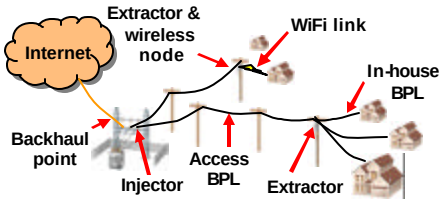
Experimental microwave surface wave system has shown 200Mbps on MV lines

BPL Emissions Compliance Guidelines – Network Equipment

System Deployments

BPL Emissions Compliance Guidelines – Types of BPL

Access BPL Overhead



BPL Emissions Compliance Guidelines – Types of BPL

In-House BPL

Such a power line modem is shown at left

Broadband signals are placed onto low-voltage wiring and decoded into Ethernet (CAT-5)

Facilitates networking of computers, set-top boxes, information appliances and consumer electronics to share access, printers, files, etc.

BPL Emissions Compliance Guidelines – Types of BPL

Access BPL Underground

Pad-mounted transformer

Same technology as used for overhead lines

Lines are run in conduit underground between transformer pads

Restricted access & shielding limit interference

Higher injected currents may be used

BPL Emissions Compliance Guidelines – Radio-frequency Emissions

Limits on Radiated Emissions

Overhead lines are not shielded and may radiate part of the RF energy they carry

Underground lines partly shield these emissions and transformers filter them

This signal leakage may become "harmful interference" without adequate safeguards

Part 15 rules impose Radiated Emissions limits below & above 30 MHz

BPL Emissions Compliance Guidelines – Mitigation

Mitigation of Interference

Access BPL systems employ "adaptive" interference mitigation

Remote control of carrier power and on-off status and shut-down features

Confirmation of any reported interference is possible with on-off checks

BPL Emissions Compliance Guidelines – Mitigation

Mitigation of Interference

Establishes "excluded frequency bands" to protect aeronautical and aircraft receivers

Mandates "exclusion zones" near sensitive Coast Guard or radio astronomy sites where BPL must avoid certain frequencies

Imposes "consultation requirements" with public safety, Government and aeronautical users

BPL Emissions Compliance Guidelines – Mitigation

Mitigation of Interference

Access database (www.uplc.com) must contain:

- Name of the Access BPL provider
- Frequencies of Access BPL operation
- Zip codes served by the system
- Mfg. & Type of equipment (FCC ID numbers)
- Phone number & e-mail of BPL contact
- Date of Access BPL turn-on

BPL Emissions Compliance Guidelines – Emissions Testing

Introduction to BPL Testing

FCC requires *in situ Certification* testing of all BPL types before being placed into service

Review of *Certification* tests is currently performed by the Commission, later by TCB's

Certification testing is the responsibility of the manufacturer of the BPL equipment

FCC & NTIA test methods are both valid, but the NTIA method is not workable

BPL Emissions Compliance Guidelines – Emissions Testing

Radiated Emissions Limits

Intentional radiator limits from 1.705 – 30 MHz are 30uV/m @ 30 meters distance (29.5dBuV/m)

No Conducted Emissions limits because BPL operates above the AM radio band

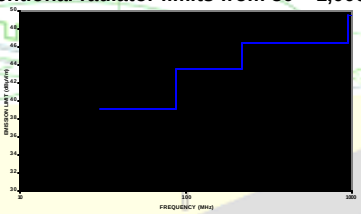
Unintentional radiator limits apply above 30 MHz

Access BPL devices operating on MV lines are considered Class A

BPL Emissions Compliance Guidelines – Emissions Testing

Radiated Emissions Limits

Unintentional radiator limits from 30 – 1,000 MHz



Testing may extend to higher frequencies

BPL Emissions Compliance Guidelines – Emissions Testing

Radiated Emissions Limits

Unintentional Radiators
Upper Frequency Range of Measurement

Highest frequency used in the device (MHz)	Upper Frequency of Measurement (MHz)
1.705-108MHz	1,000MHz
108-500MHz	2,000MHz
500-1,000MHz	5,000MHz
Above 1,000MHz	5th Harmonic <40GHz

Highest clock frequency determines the upper frequency of measurement

BPL Emissions Compliance Guidelines – Emissions Testing

How many tests?

Three major Access devices:

Injectors Repeaters Extractors

Three representative Overhead installations

Three representative Underground installations

Full power settings (reduced later for *Compliance*)

Three representative In-House installations

BPL Emissions Compliance Guidelines – Emissions Testing

Equipment Certification

Certification tests are run with maximum output power and duty cycle

This allows FCC to determine frequency-dependent radiation patterns from lines

Lower data rates and power settings necessary for *Compliance* are noted in Test Report

Operational power levels may be less than *Compliance* levels, but this is not mandated

BPL Emissions Compliance Guidelines – Emissions Testing

Test Setup

Tripod-mounted antenna 1 meter high

10 meters distance from the pole-line centerline

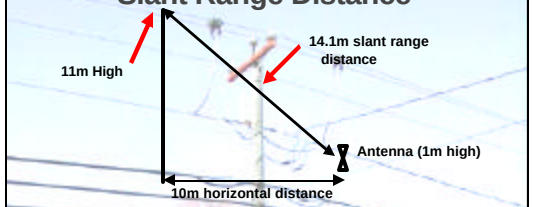
Ambients must be >6dB below the limit, or move to 3 meters distance from centerline

Apply slant-distance correction to readings

Add 5dB to the measured values above 30MHz

BPL Emissions Compliance Guidelines – Emissions Testing

Slant Range Distance

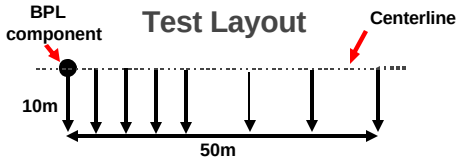


40dB/decade correction under 30MHz

20dB/decade correction above 30MHz

BPL Emissions Compliance Guidelines – Access Overhead Testing

Test Layout



Example: 3-27MHz injected onto MV mains

Mid-band frequency = 15MHz (20m wavelength)

¼ wavelength to 20m, ½ wavelength to 50m

Max distance = ½ wavelength of 3MHz (50m)

BPL Emissions Compliance Guidelines – Access Overhead Testing

Test Layout

CALCULATION OF MEASUREMENT POSITIONS			
FCC Example:		Actual Installation being tested:	
Frequency range of BPL component:	3-27 MHz	Frequency range of BPL component:	MHz
Midband frequency: = (24/ 2) + 3	15 MHz	Midband frequency: = ((H -L)/2) + L	MHz
Midband frequency wavelength: = v/f	20m	Midband frequency wavelength: = v/f	m
Lowest injected frequency	3 MHz	Lowest injected frequency	MHz
Lowest frequency wavelength: =v/f	100m	Lowest frequency wavelength: = v/f	m
Midband frequency exceed lowest by >2:1?	(yes)	Midband frequency exceed lowest by >2:1?	(yes no)
If yes, add positions at ½ midband wavelength intervals up to ½ wavelength of lowest frequency.		If yes, add positions at ½ midband wavelength intervals up to ½ wavelength of lowest frequency.	
(First five points) = (1/4 of midband wavelength)	0, 5, 10, 15, 20m	(First five points) = (1/4 of midband wavelength)	
Add ½ midbandwavelengths of 10 meters up to ½ of lowest frequency wavelength of 100 meters.	10m steps to 50m	Add ½ midbandwavelengths of X meters up to ½ of lowest frequency wavelength of 2X meters.	
(additional points) =	30, 40, 50	(additional points) =	

BPL Emissions Compliance Guidelines – Access Overhead Testing

Test Equipment

Frequency Range	Antenna
9kHz -30MHz	Loop (corrected to E-field by adding 51.2dB)
30-200MHz	Biconical (or other E-field antenna)
200-1,000MHz	Log-Periodic (or other E-field antenna)
Above 1,000MHz	Dual-ridge Horn (or other E-field antenna)

BPL Emissions Compliance Guidelines – Access Overhead Testing

Test Equipment

EMI Receiver

- Accurate but fixed-tuned
- Not subject to overload
- Best for Compliance work
- CISPR 16-1-1 compliant

Spectrum Analyzer & preamp

- Live display of spectra
- Subject to overload
- Best for signal tracing
- Not CISPR compliant

BPL Emissions Compliance Guidelines – Access Overhead Testing

Test Equipment

SUPPORTING EQUIPMENT DOCUMENTATION CHECKLIST		✓
Preamplifier gain VS frequency curve	Attached to test report	
BNC Cable insertion loss VS frequency curve	Attached to test report	
Type N Cable insertion loss VS frequency curve	Attached to test report	
Antenna factor VS frequency curves for all antennas used in this test	Attached to test report	
Calibration Certificates	Attached to test report	

BPL Emissions Compliance Guidelines – Access Overhead Testing

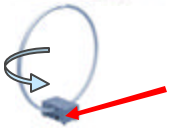
Setup Checklist

- EUT Power and burst rate set to Maximum for *Certification* testing
- Frequency steps of ½ bandwidth using Peak detection, QP on top 6
- 3 pixels inside IF pass-band using Peak detection, QP on top 6
- Above 1GHz top 6 signals identified using Peak and measured using AVG

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing below 30 MHz

- Orient the loop broadside to the pole-line, set bandwidth to 9 kHz
- Identify & AM demodulate top six signals to make sure they're BPL



- Rotate loop 180 degrees to assure signals are maximized
- Check that the overload indicator is not illuminated

Peak detection if data rate <20Hz, otherwise Quasi-Peak

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing below 30 MHz

Photograph the final setup and enter data in worksheet:

Field Strengths (location 1) 1.705 MHz (or lowest frequency generated) – 30 MHz						
Frequencies of six (6) highest readings: (MHz)						
Receiver voltages (dB? V) (indicate Peak or Q -P)						
Cable loss at the measurement frequency: (dB)						
Antenna Factor at the measurement frequency: (dB)						
E-Field conversion of magnetic loop readings	+51.2	+51.2	+51.2	+51.2	+51.2	+51.2
(Add voltage, cable loss, conversion & antenna factor) Uncorrected E-Field Strength (dB? V/m)						
Slant range distance to the wires (X meters)						
Slant range distance correction (40log 30/X) in dB						
(subtract distance correction from E-Field Strength) Corrected E-Field Strength (dB? V/m @ 30 meters)						
FCC Limit Field Strength (dB? V/m @ 30 meters)	**29.5**	**29.5**	**29.5**	**29.5**	**29.5**	**29.5**

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing below 30 MHz

Embed a representative spectral plot into the Test Report

Test the other locations in the same manner

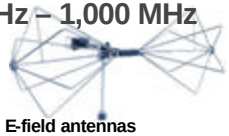
Acquire GPS locations of all measurement positions

Enter worst-case corrected field strengths into summary

Field Strengths (all locations) 1.705 MHz (or lowest frequency g enerated) – 30 MHz						
Frequencies of six (6) highest readings: (MHz)						
Worst Case Field Strength (dB? V/m @ 30 m) (P/QP)						
FCC Limit Field Strength (dB? V/m @ 30 meters)	29.5	29.5	29.5	29.5	29.5	29.5
Test Results: **PASS / FAIL**						

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing from 30 MHz – 1,000 MHz



Orient the E-field antennas vertically and horizontally, point towards wires, set BW to 120 kHz

Identify & FM demodulate top six signals to make sure they're BPL

Peak detection if data rate <20Hz, otherwise Quasi-Peak

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing from 30 MHz – 1,000 MHz

Enter data in Vertical & Horizontal worksheets:

Field Strengths (location 1) 30 MHz–1,000 MHz						
Frequencies of six highest Vertical readings: (MHz)						
Receiver voltages (dB? V) (indicate Peak or Q - P)						
Cable loss at the measurement frequency: (dB)						
Antenna Factor at the measurement frequency: (dB)						
Height conversion of E-Field readings (+5 dB)	+5.0	+5.0	+5.0	+5.0	+5.0	+5.0
(Add voltage, cable loss, conversion & antenna factor) Uncorrected Vertical E-Field Strength (dB? V/m)						
Slant range distance to the wires (X meters)						
Slant range distance correction (20log 10/X) in dB						
(subtract distance correction from E-Field Strength) Corrected Vertical Field (dB? V/m @ 10 meters)						

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing from 30 MHz – 1,000 MHz

Embed a representative spectral plot into the Test Report

Test the other locations calculated in the same manner

Enter worst-case corrected field strengths into summary

Field Strengths (all locations) 30 MHz – 1,000 MHz						
Frequencies of six (6) highest readings: (MHz)						
Worst case Field Strength (dB? V/m @ 10 m) (Peak / Quasi Peak)						
Test Results: **PASS / FAIL**						

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing above 1,000 MHz

Point the horn towards the wires

Set receiver to 1 MHz bandwidth and peak detection

Orient the horn vertically then horizontally for data acquisition

Identify & FM demodulate top six signals to make sure they're BPL

Use Average detection for final measurement of top six

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing above 1,000 MHz

Enter data in Vertical & Horizontal worksheets:

Field Strengths (location 1) 1,000 MHz– (upper frequency)						
Frequencies of six highest Vertical readings: (MHz)						
Receiver voltages (dB? V) (Average)						
Cable loss at the measurement frequency: (dB)						
Antenna Factor at the measurement frequency: (dB)						
Height conversion of E-Field readings (+5 dB)	+5.0	+5.0	+5.0	+5.0	+5.0	+5.0
(Add voltage, cable loss, conversion & antenna factor) Uncorrected Vertical E-Field Strength (dB? V/m)						
Slant range distance to the wires (X meters)						
Slant range distance correction (20log 10/X) in dB						
(subtract distance correction from E-Field Strength) Corrected Vertical Field (dB? V/m @ 10 meters)						

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing above 1,000 MHz

Embed a representative spectral plot into the Test Report

Test the other locations calculated in the same manner

Enter worst-case corrected field strengths into summary

Field Strengths (all locations) 1,000 MHz – (upper frequency)						
Frequencies of six (6) highest readings: (MHz)						
Worst case Field Strength (dB? V/m @ 10 m) (AVG)						
FCC Limit Field Strength (dB? V/m @ 10 meters)	49.5	49.5	49.5	49.5	49.5	49.5
Test Results: PASS / FAIL						

BPL Emissions Compliance Guidelines – Access Overhead Testing

Testing above 1,000 MHz

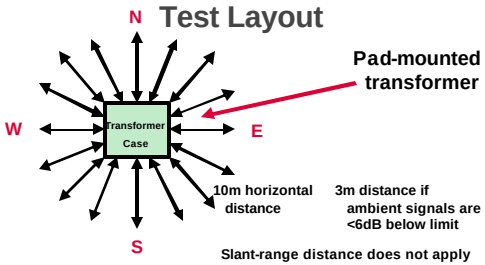
Ensure that the cumulative test results and the required signatures are entered in the Results summary

Cumulative Test Results:	PASS / FAIL
Name & Address of Testing Organization:	
Test Engineer's Signature:	
Date:	
Name & Address of Entity requesting this test:	

Embed the GPS map of locations tested into the report

BPL Emissions Compliance Guidelines – Access Underground Testing

Test Layout



BPL Emissions Compliance Guidelines – Access Underground Testing

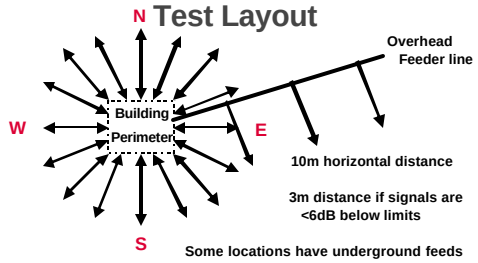
Test Layout

BPL Emissions Compliance Guidelines – Access Underground Testing

Test Layout

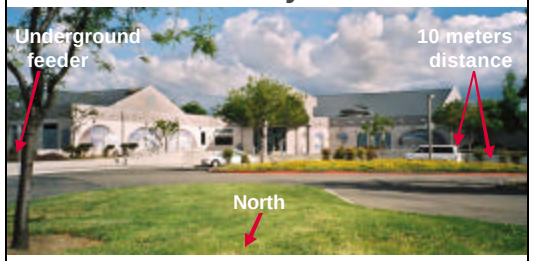
BPL Emissions Compliance Guidelines – In-House Testing

Test Layout



BPL Emissions Compliance Guidelines – In-House Testing

Test Layout



BPL Emissions Compliance Guidelines – In-House Testing

Test Layout

BPL Emissions Compliance Guidelines – ANSI C63.4 Test Reporting

Test Report Contents

- Applicable Standards used for the tests
- Equipment being tested, including product type, marketing designation, serial number, I/O's
- Test setup with equipment and cabling placement
- List of all test equipment used for the tests
- Radiated emissions reported in dBµV/m

BPL Emissions Compliance Guidelines – ANSI C63.4 Test Reporting

Test Report Contents

- Rationale for selection of each test site
- Test procedures (sequence of testing)
- Measurement results and limits (tabular or graph)
- Frequency & amplitude of six highest emissions
- Antenna polarization for each emission identified

BPL Emissions Compliance Guidelines – ANSI C63.4 Test Reporting

Test Report Contents

- Instrumentation, attenuator and bandwidth settings, detector function, EUT arrangement
- Summary of test results (pass / fail / margins)
- Required signatures
- Test report appendices (photos, maps etc.)
- Documentation of any changes made to EUT

BPL Emissions Compliance Guidelines – Legal Issues

Equipment Certification

- ***Certification*** **is an equipment authorization issued by FCC based on data submitted**
- **Mfg's *Declaration of Conformity* assures that the necessary measurements were made**
- **Laboratory must be accredited**
- **<u>Each device</u> type requires *in situ* testing**

BPL Emissions Compliance Guidelines – Legal Issues

System Validation

BPL operator should perform or technically witness any initial installation testing

If the system was Certified on the operator's network, initial tests not repeated

Compliance with Part 15 is required after installation but testing is not mandated

BPL Emissions Compliance Guidelines – Legal Issues

Maintaining Compliance

Utility operator verifies that each representative site complies with Part 15 following the installation

Periodic testing of the system should be performed to ensure that it complies with the emission limits

Select typical installation sites within the service area for testing purposes

BPL Emissions Compliance Guidelines – Conclusions

Conclusions

BPL *Certification* testing is performed by the manufacturer for each model number

Compliance power settings are determined during this type-testing

Operational power settings may be lower than Compliance settings to prevent interference

Prompt resolution of interference complaints is required (<24 hours for Government users)

BPL Emissions Compliance Guidelines – Conclusions

Conclusions

BPL offers a new source of revenue

BPL enhances power monitoring and control

Responsibility for conformity ultimately rests with the system operator

Validation of compliance should be performed after initial installation

Periodic maintenance testing is required to assure continued compliance

BPL Emissions Compliance Guidelines – Conclusions

Conclusions

Emissions vary widely (+20dB to -20dB of limits)

Independent study of system topologies needed

Compliance with Part 15 limits is mandatory

Testing of finished installations assures legality

"The record and our investigations indicate that BPL network systems can generally be configured and managed to minimize and/or eliminate... interference potential"

- FCC Report & Order 04-245

BPL Emissions Compliance Guidelines – Conclusions

References

Broadband over Power Line 2004: Technology and Prospects, EPRI

NARUC report from The BPL Task Force, February 2005

NTIA Report 04-413, Potential Interference from BPL Systems

FCC 04-245 Report and Order, guidelines for Access BPL Systems

American Radio Relay League

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