



Broadband over Power Line (BPL) Test Results and Considerations



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This presentation is part of an ongoing analysis.
The positions presented herein do not represent the positions of the FCC.

Two Types of BPL



ACCESS BPL

Broadband Internet Service on Through Outdoor Power Grids

(Medium Voltage & sometimes Low Voltage)

Benefits:

- Competitor to cable & DSL
- May reach customers not currently served, but typical ½ mile range may limit reach



IN-HOUSE BPL

Computer Networking On Mains Wiring within a House

Benefits:

- No new wiring--Competitor to wireless
- May operate when wall attenuation inhibits wireless networking

Risk: *Interference* to radio services may result from injecting RF signals on mains networks that were not designed to keep RF signals captive



OUTLINE/SUMMARY

- **Ambient Noise**
- **BPL Interference**
 - BPL interferes with nearby shortwave & amateur reception (including MARS)
 - Impact on Public Safety (VHF-LB) & ARINC not yet evaluated
 - Resolving interference complaints will be difficult/impractical
- **Part 15 Radiated Emission Limits**
 - Adequate for most Part 15 devices, but not for BPL
- **What is different about BPL?**
 - Broad Bandwidth—overlaps multiple services and channels
 - High emissions over a wide bandwidth
 - Exemption from conducted limits (except in AM broadcast band)—applies to devices < 30 MHz
 - Close proximity to neighboring residential antennas
 - No intervening walls to attenuate interference
 - Large spatial extent of radiators
- **What can we do?**
 - Additional protection for specific bands
- **Summary, Recommendations, Alternatives**

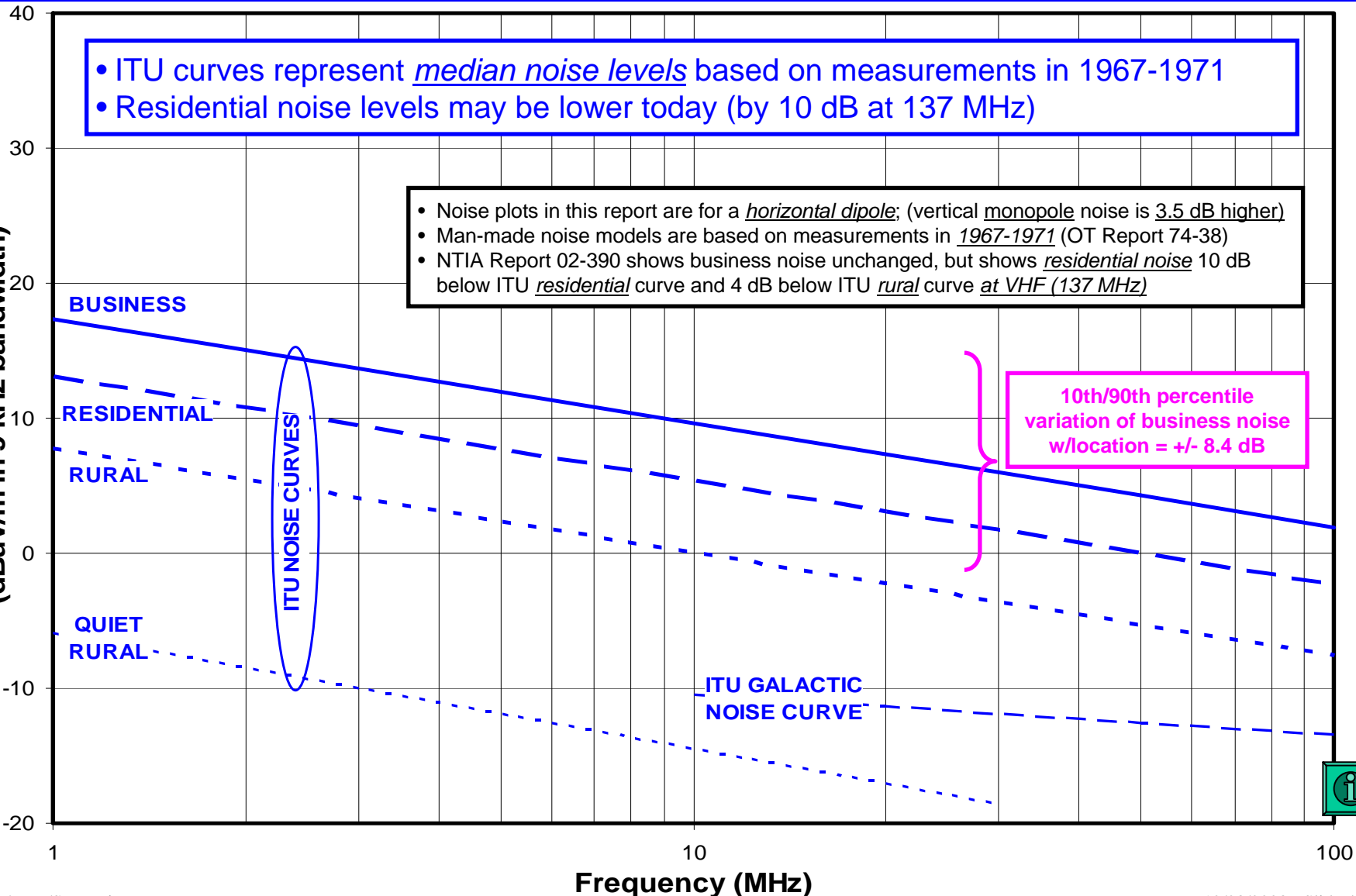


ITU-R P.372-8 Noise Model

- ITU curves represent *median noise levels* based on measurements in 1967-1971
- Residential noise levels may be lower today (by 10 dB at 137 MHz)

- Noise plots in this report are for a *horizontal dipole*; (vertical *monopole* noise is 3.5 dB higher)
- Man-made noise models are based on measurements in *1967-1971* (OT Report 74-38)
- NTIA Report 02-390 shows business noise unchanged, but shows *residential noise* 10 dB below ITU *residential* curve and 4 dB below ITU *rural* curve *at VHF (137 MHz)*

Average Field Strength Observed by Dipole
(dBuV/m in 9 kHz bandwidth)



Locations of Ambient Noise Measurements



Potomac, MD:

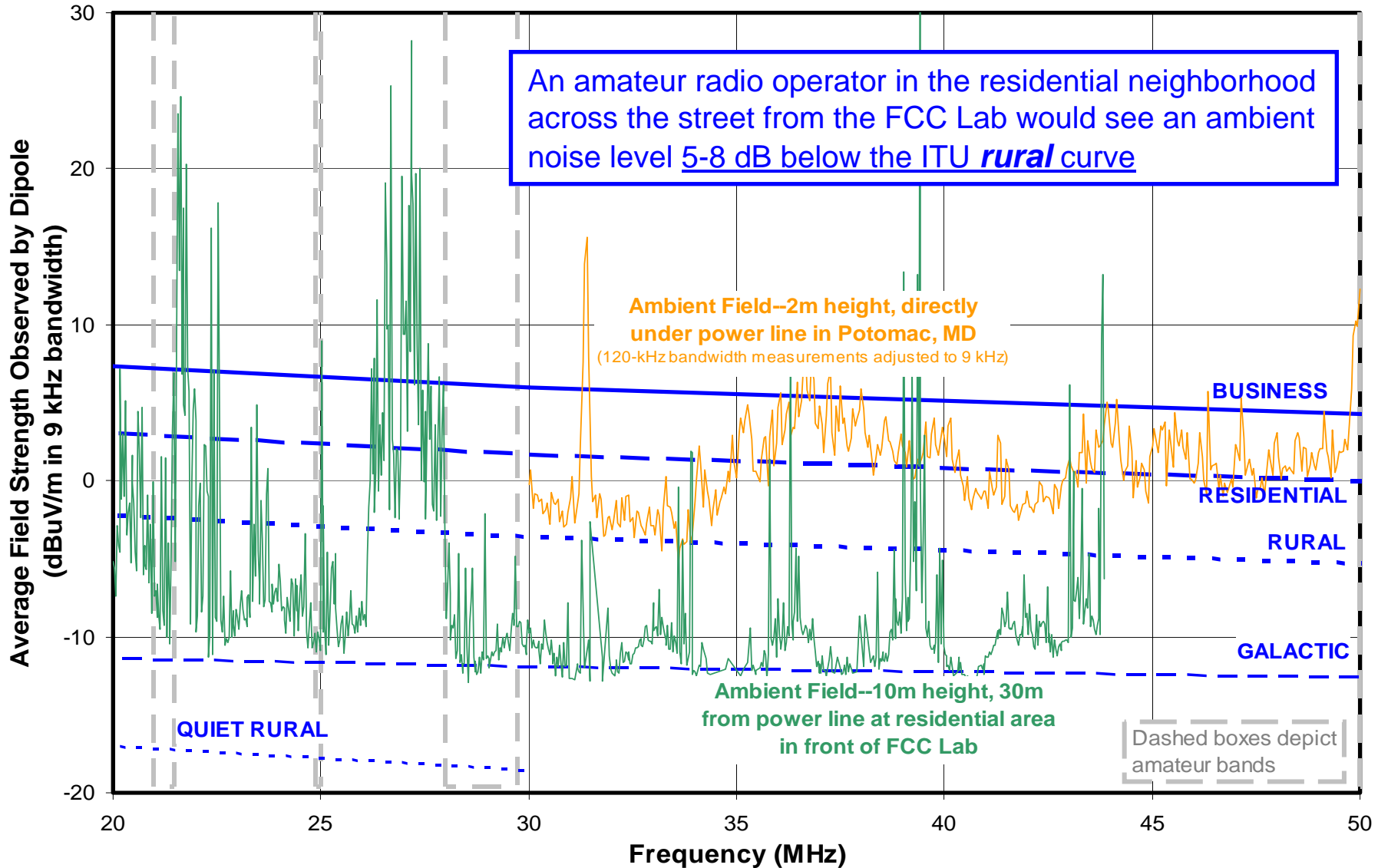
- 2-m antenna height
- **Directly under power line**
- **BPL disabled**



In front of FCC Laboratory:

- **Representative of amateur antenna location**
- 10-m antenna height
- 30-m from power lines w/no BPL

Today's Residential RF Noise Levels Near Power Lines





OUTLINE

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- **BPL Interference**
- Part 15 Radiated Emission Limits
- What is different about BPL?
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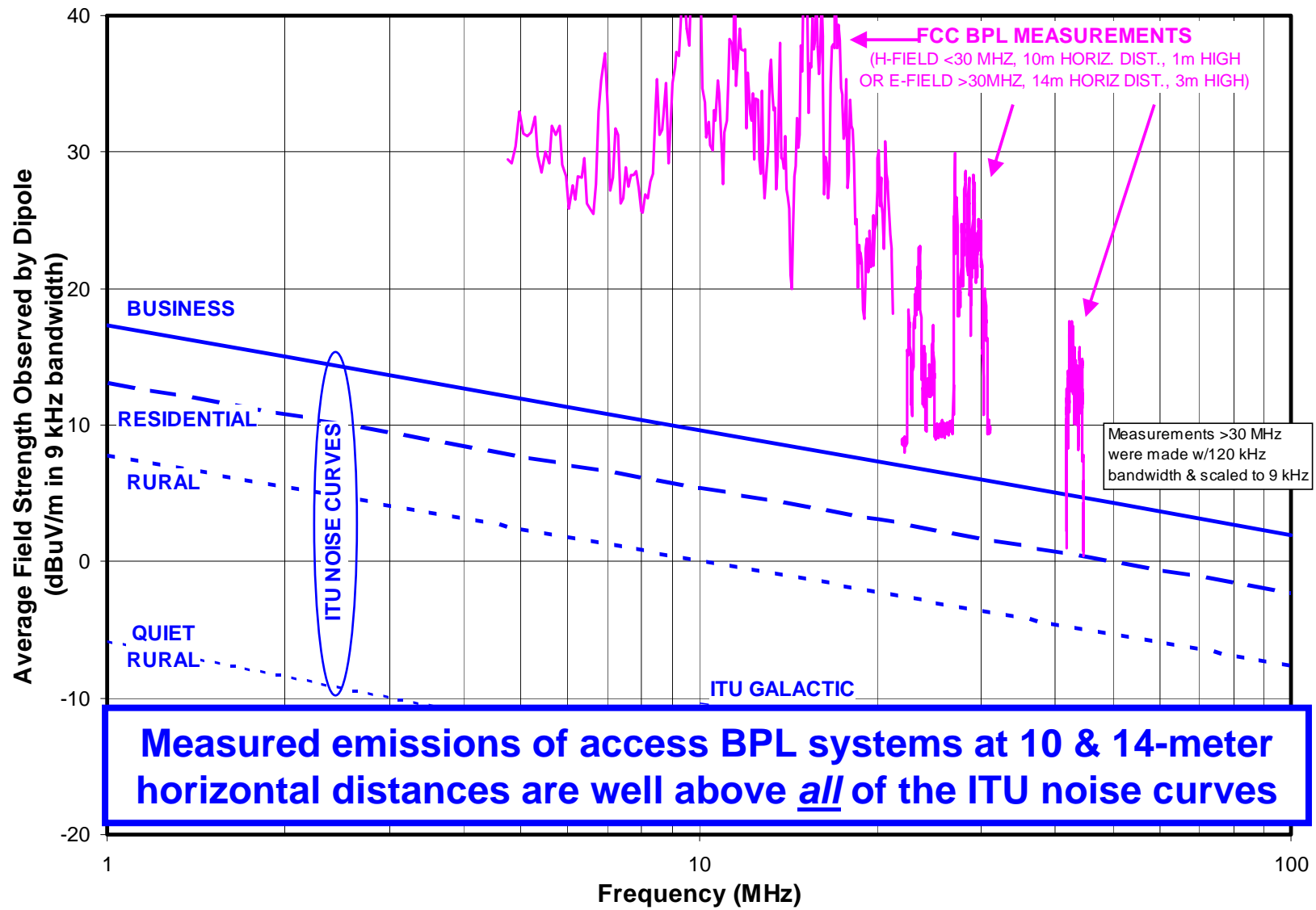
Observed Interference from Access BPL

- **FCC Lab observation during access system emission test**
 - Interference to shortwave radio reception was observed
- **ARRL Tests**
 - Interference observed on mobile radio in BPL test areas
 - “Tests ... by ARRL ... have shown that the system planned for Manassas causes harmful interference to the amateur radio”
(<http://www.elecdesign.com/Articles/Index.cfm?ArticleID=6850>)

The FCC Lab has not performed any controlled tests of interference from access BPL systems,
but we have measured emission levels...

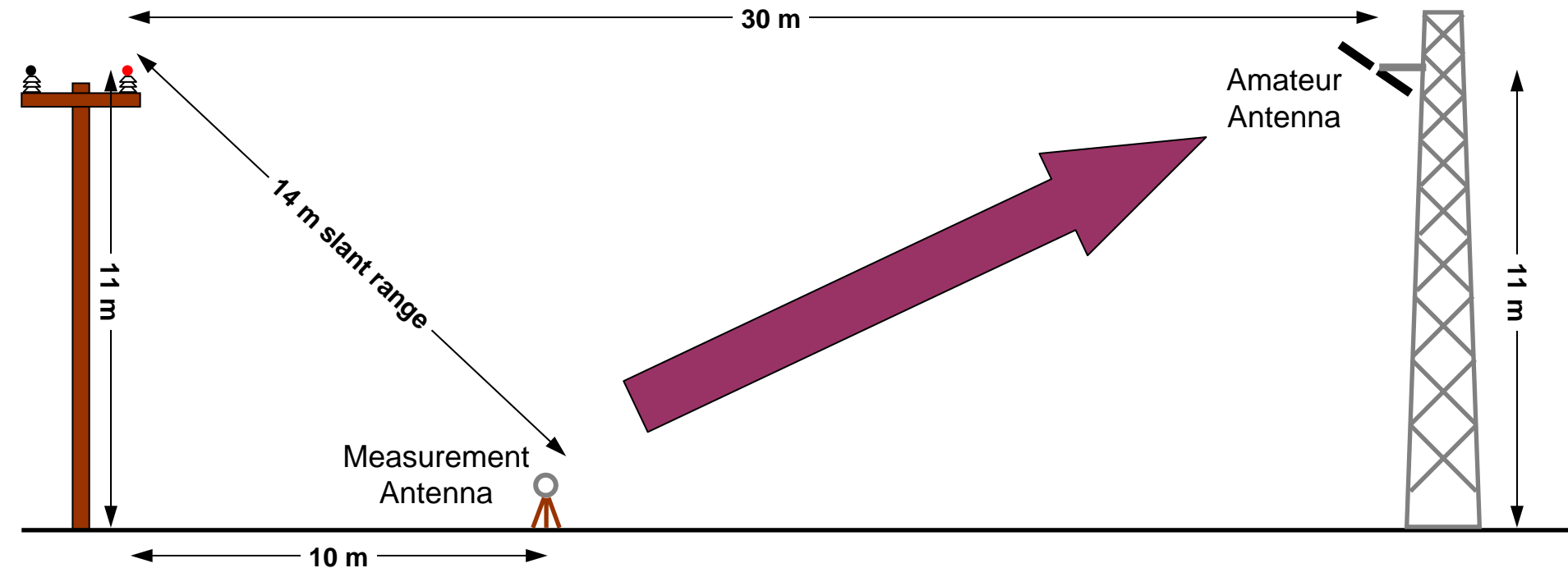


FCC Lab Measurements of Access BPL Emissions



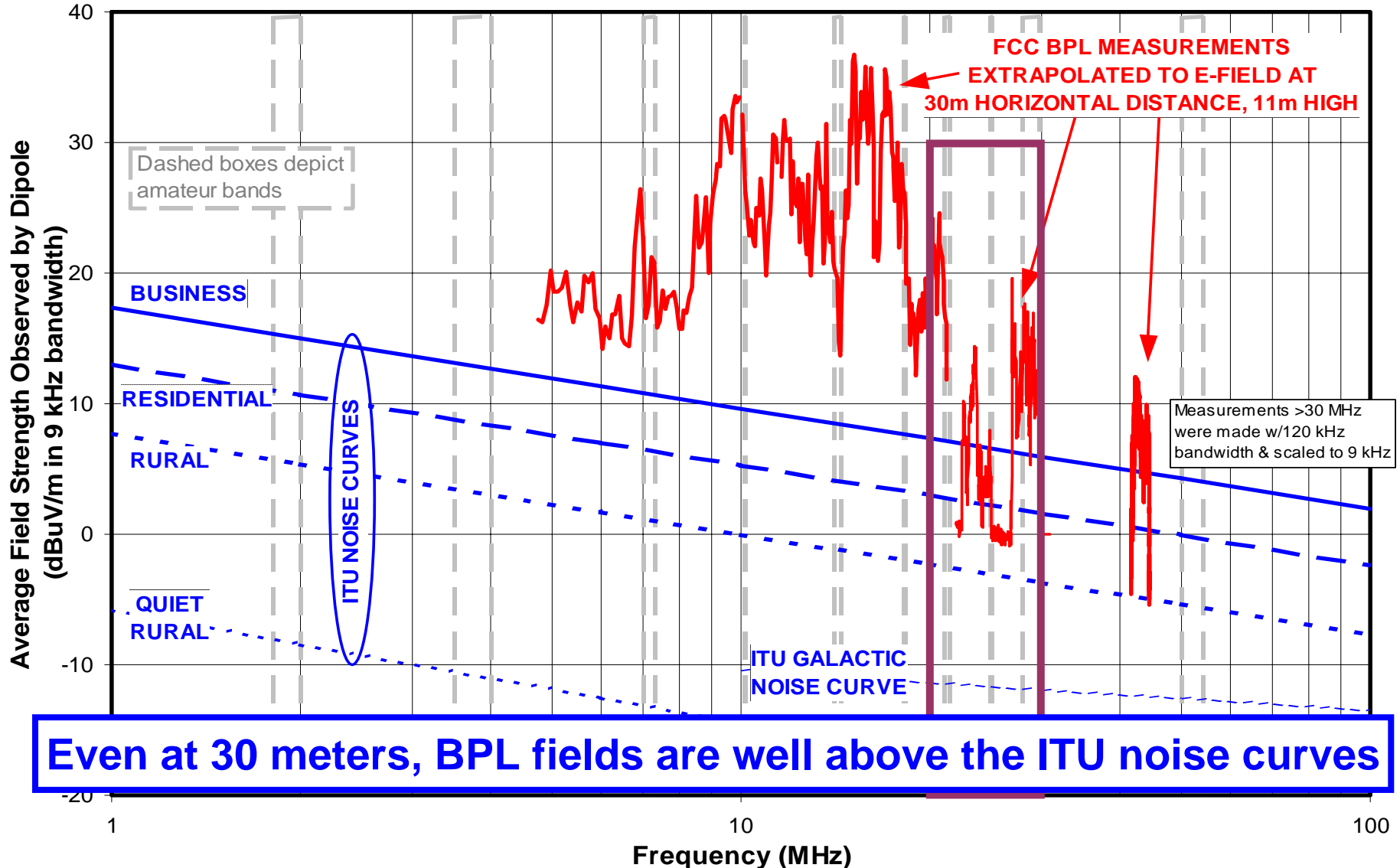
Measured emissions of access BPL systems at 10 & 14-meter horizontal distances are well above all of the ITU noise curves

Antenna Positions for Measurement and Analysis

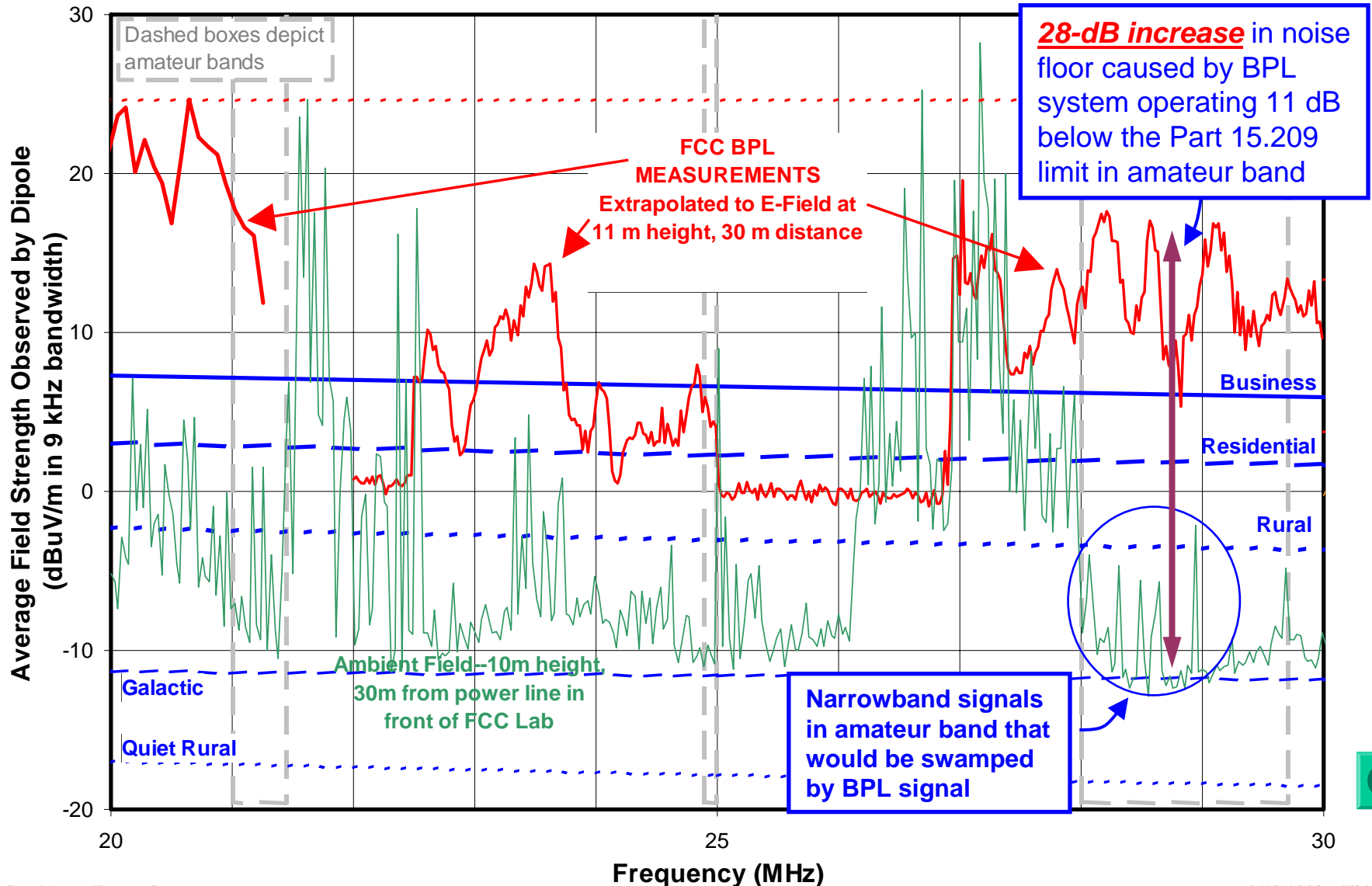


We can use Ron Chase's model to extrapolate field strengths from the measurement location to a representative amateur antenna location

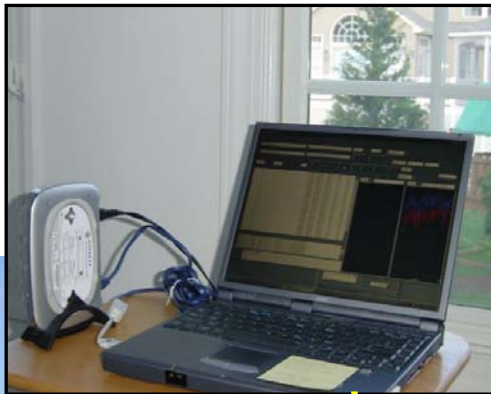
FCC Lab Access BPL Measurements Extrapolated to Representative Amateur Antenna Location



Extrapolated Access BPL Emissions Relative to Ambient Noise Fields at Representative Amateur Antenna Position



Test of Shortwave Radio Interference from HomePlug



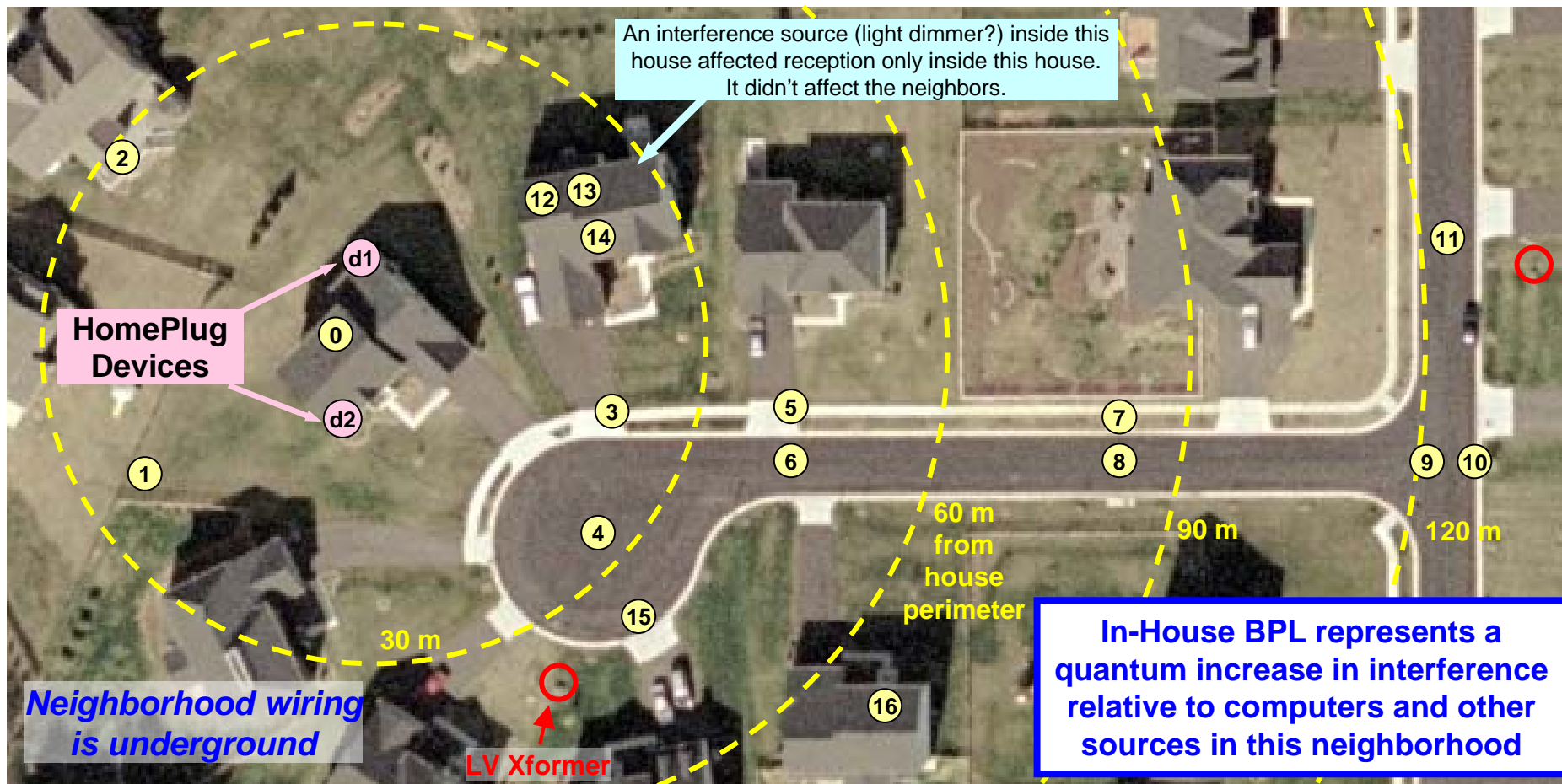
Two laptop computers and HomePlug modems on 1st floor (front left and right rear of house)



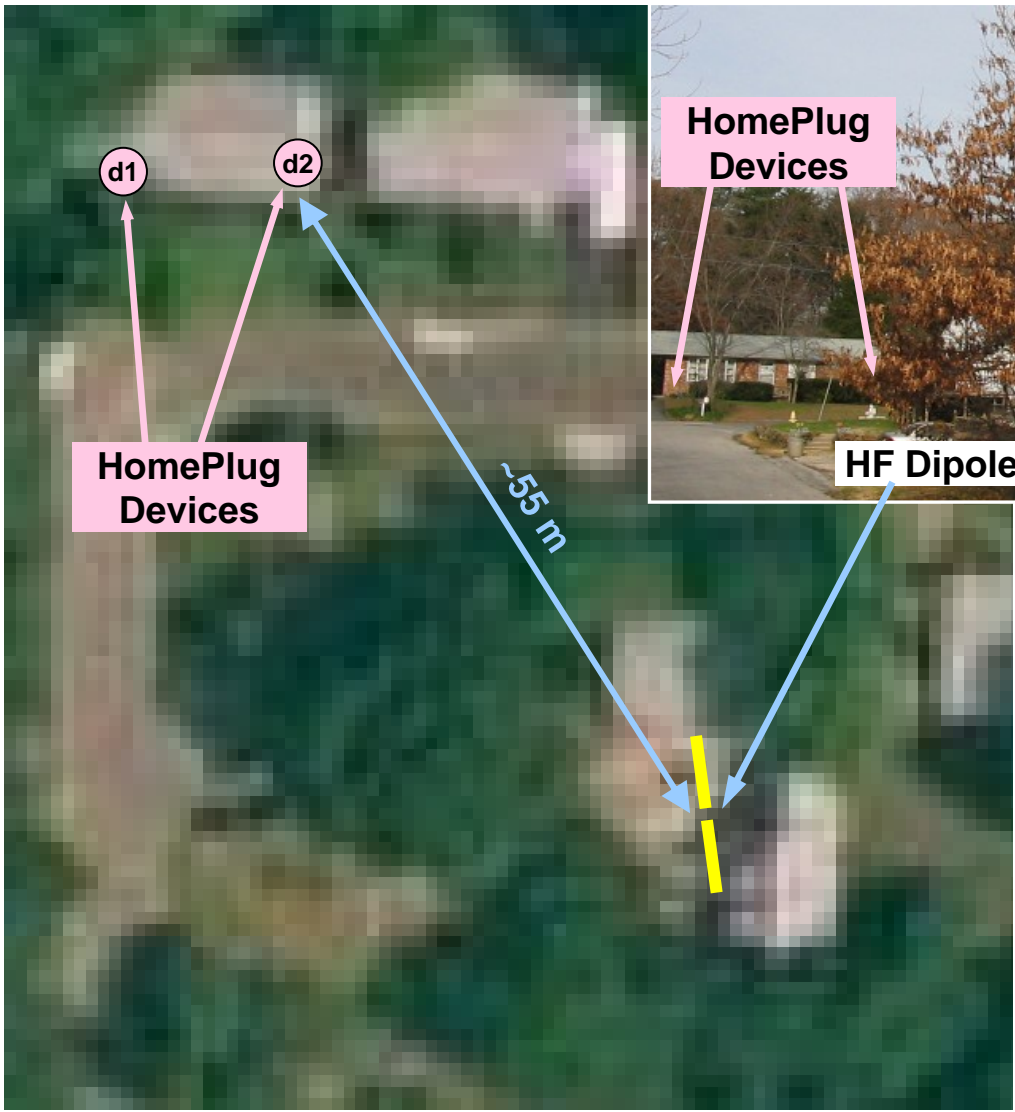
SHORTWAVE RADIO & PROFESSIONAL GRADE CASSETTE RECORDER
loaned by Andy Leimer

Shortwave Radio Interference from HomePlug

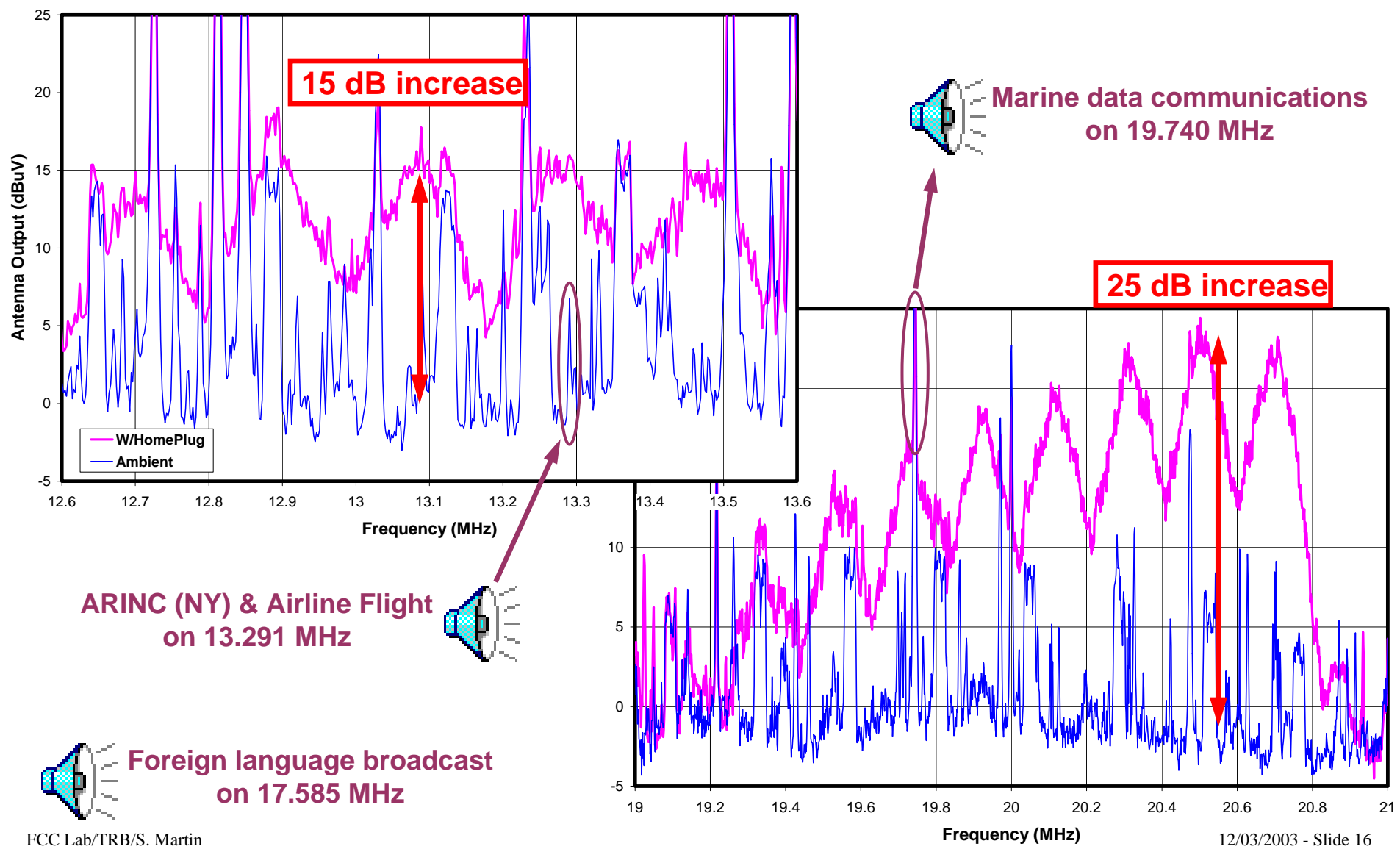
- **Click** a shortwave receiver site (n) to hear sound of WWV at 15 MHz before & during HomePlug coms (software repeatedly copied a 100 KB random file from d1 to d2 for ~1 second, then d2 to d1 for ~1 second, then repeat 4 more times)
- All indoor sites (d1, d2, 0, 12, 13, 14, & 16) are at 1st floor level; 2 is on a deck.
- **Click** here (0a) to hear effect of computers at site 0 [No computers, followed by 7 computers running in house: 3 laptop computers (scrolling H's) + 4 desktop computers (2 w/scrolling H's; one downloading a movie through 50' ethernet cable, access point, & cable modem)]



HomePlug Effect on Noise Floor



HomePlug Effect on Noise Floor





Phonex Narrowband Carrier Current Device

Carrier-current phone jack:

- 2 FM carriers (originally 3.52 & 8.27 MHz w/3.52 MHz always ON)
- Also **used with some cable TV boxes** for billing for pay-per-view

ARRL	ARINC (voice coms w/trans-oceanic flights)
<p><u>Interference</u></p> <ul style="list-style-type: none"> • S9+10 dB, 30 m from house (~15.209 limit) • Characteristics of the interferer facilitated its ID (Narrowband, analog voice, carrier always ON) 	<p><u>Interference</u> (per ARINC)</p> <ul style="list-style-type: none"> • 15 dB > noise floor • Believed to be Phonex devices at 1.5 mi • No positive ID due to multiple, intermittent sources • Observed Phonex at 5 mi in test • Facts disputed
<p><u>Complaint Resolution</u></p> <ul style="list-style-type: none"> • Phonex changed carrier frequency & set carriers OFF when not in use (recall & new production) 	<p><u>Complaint Resolution</u></p> <ul style="list-style-type: none"> • ARINC abandoned 3.013 MHz at Half Moon Bay

Interference caused by carrier-current device

No positive ID of interference source

Locating, identifying, & resolving interference from BPL will be difficult or impractical

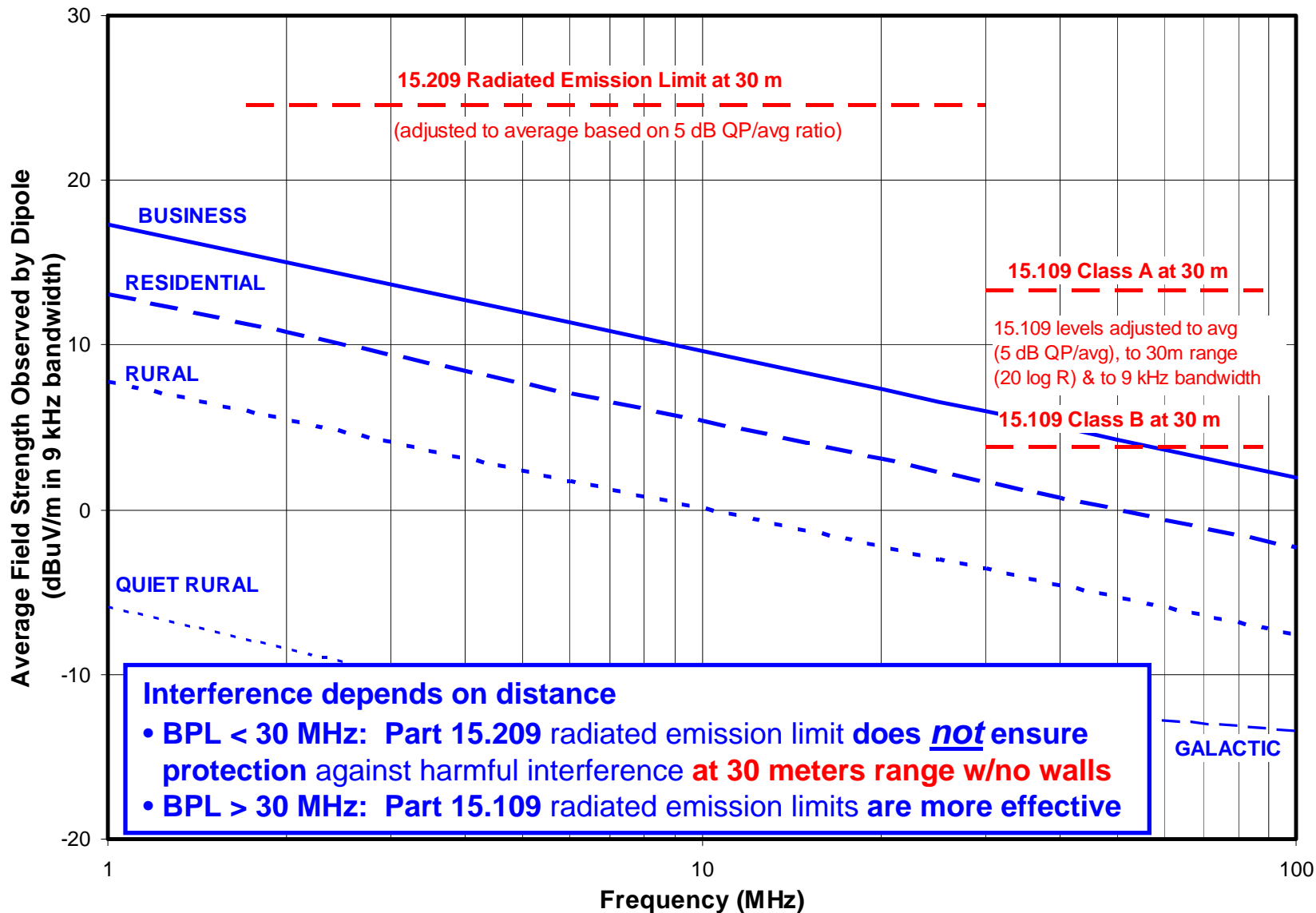
- Direction finding won't work with multiple, broadband, extended sources
- Temporary solutions such as abandoning a channel will not be available



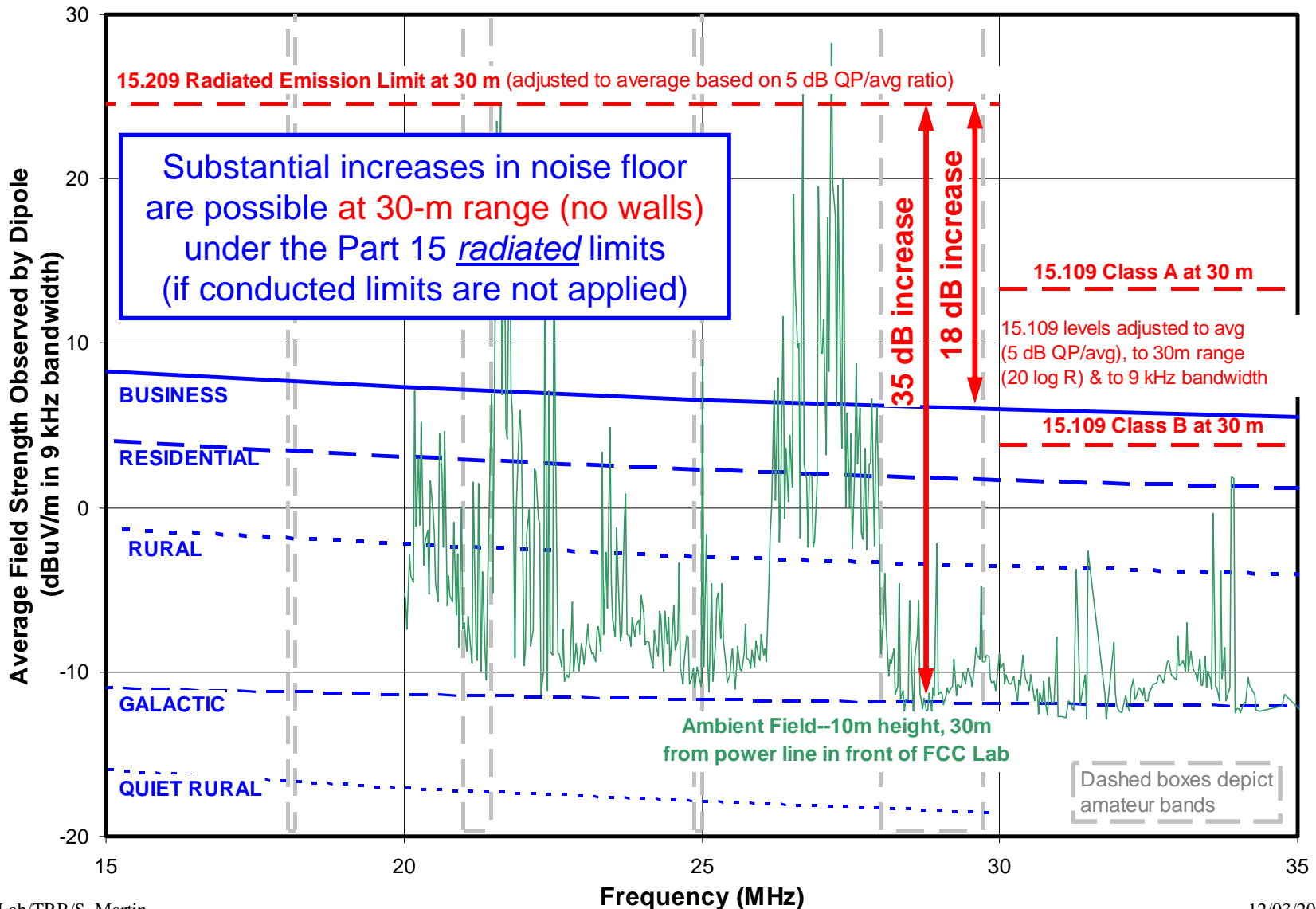
OUTLINE

- Ambient Noise
- BPL Interference
- **Part 15 Radiated Emission Limits**
- What is different about BPL?
- What can we do?
- Summary, Recommendations, Alternatives

Level of Protection Offered by Part 15 Radiated Emission Limits at 30 m



Level of Protection Offered by Part 15 Radiated Emission Limits at 30 m





Likelihood of Interference

The Part 15 limits are effective for most devices

“Harmful” interference may be possible, but is improbable because it depends on an unlikely combination of events:

- Interferer radiates a high level within the narrow bandwidth of the victim receiver

AND

- The emission occurs at a time when the victim receiver is in use

AND

- The interferer is close enough to cause interference (even through any intervening walls which may attenuate the signal)

AND

- The interferer is not under the victim’s control (i.e., not on the victim’s property)

AND, the problem is more severe if

- The victim is unable to avoid the interference by changing channels

The conditions necessary for harmful interference are unlikely for most Part 15 devices, but are likely to occur with BPL



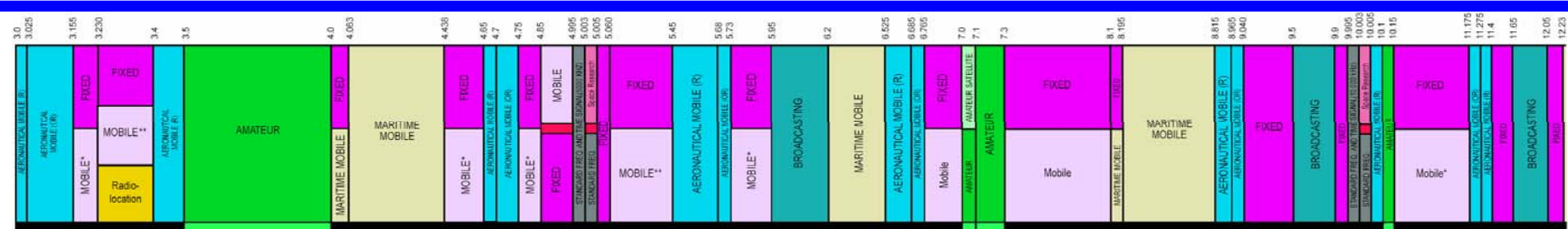
OUTLINE

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BPL: Broad Emission Bandwidths

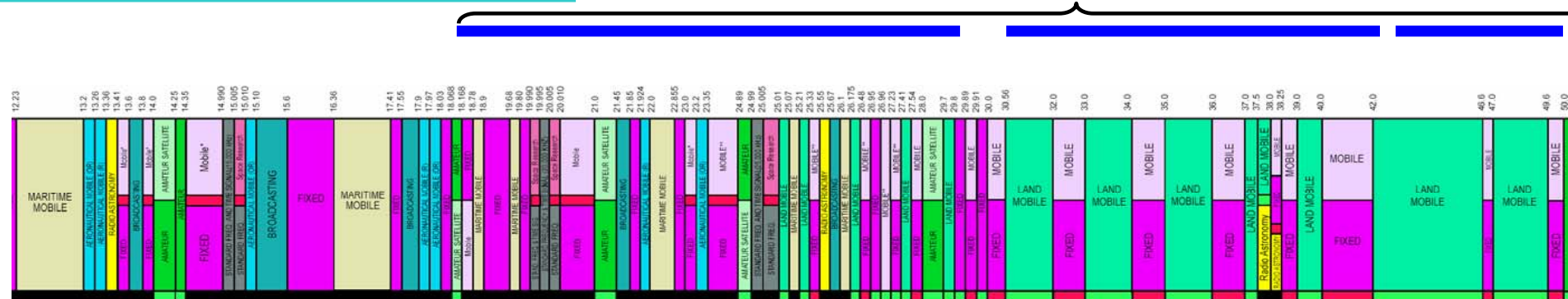
FCC Laboratory



ACCESS SYSTEM 1o & u

ACCESS SYSTEM 2u

HOMEPLUG



ACCESS SYSTEM 1o & u

ACCESS SYSTEM 2o

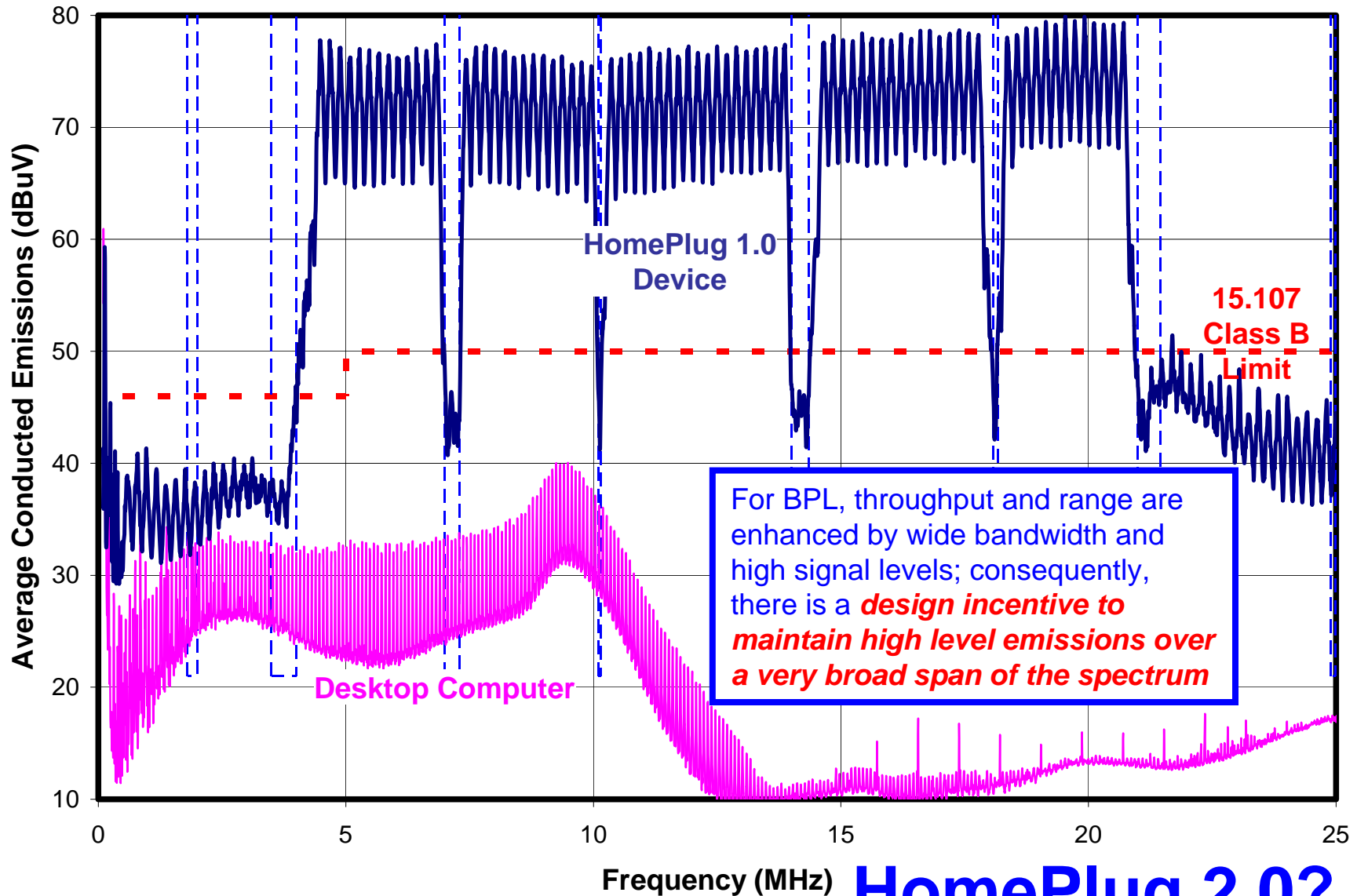
ACCESS SYSTEM 3o

HOMEPLUG

A single BPL device overlaps *many* services

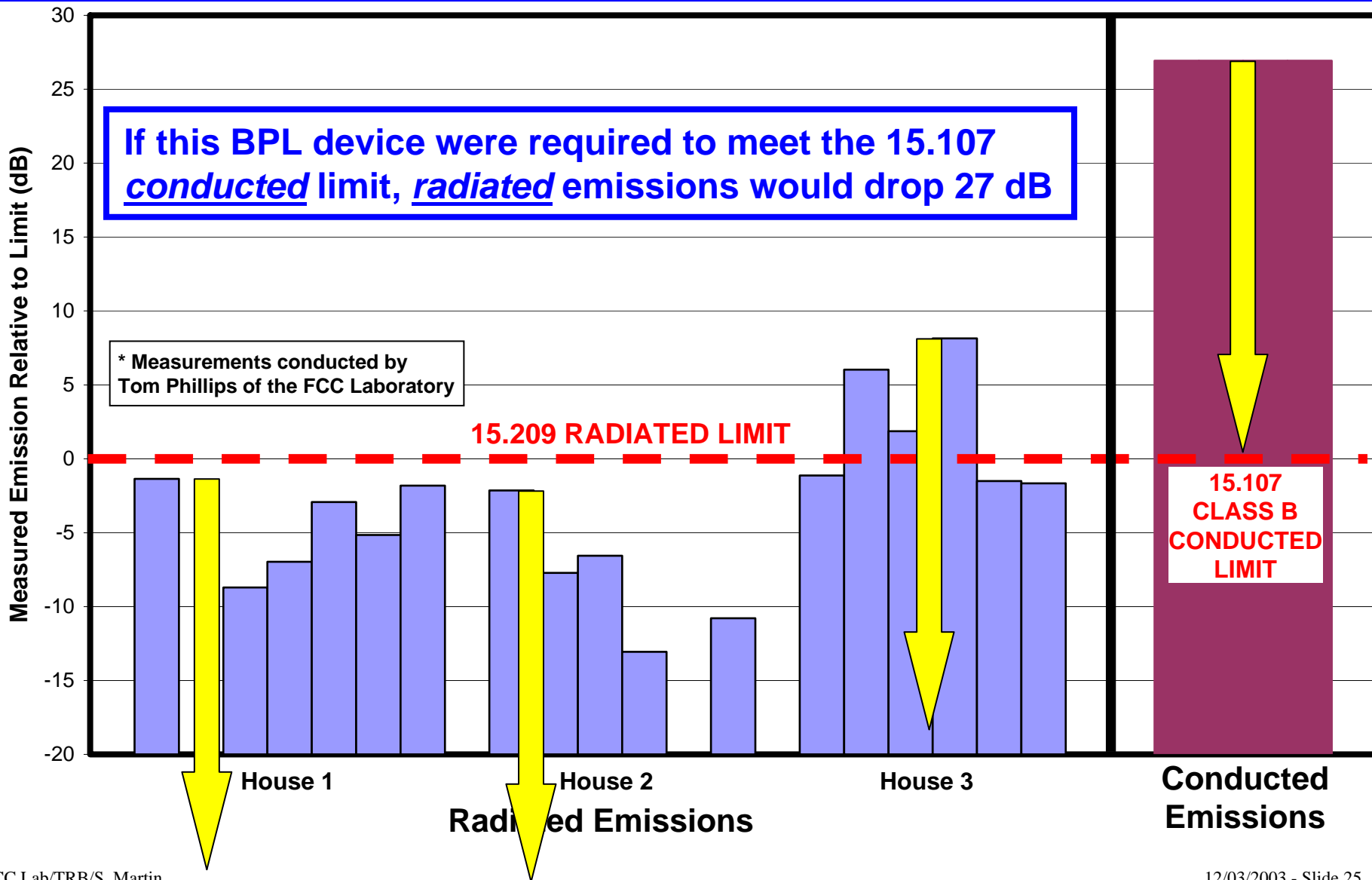
- Probability of overlapping victim's channel is high
- *If* interference occurs, "victim" probably can't avoid it by tuning to another channel
 - ARINC claims to have abandoned operations at one frequency (3.013 MHz) due to interference believed to be from a narrowband carrier current devices installed 1.5 mi from one of its receivers

BPL: High Emission Levels Across a Broad Band of Frequencies



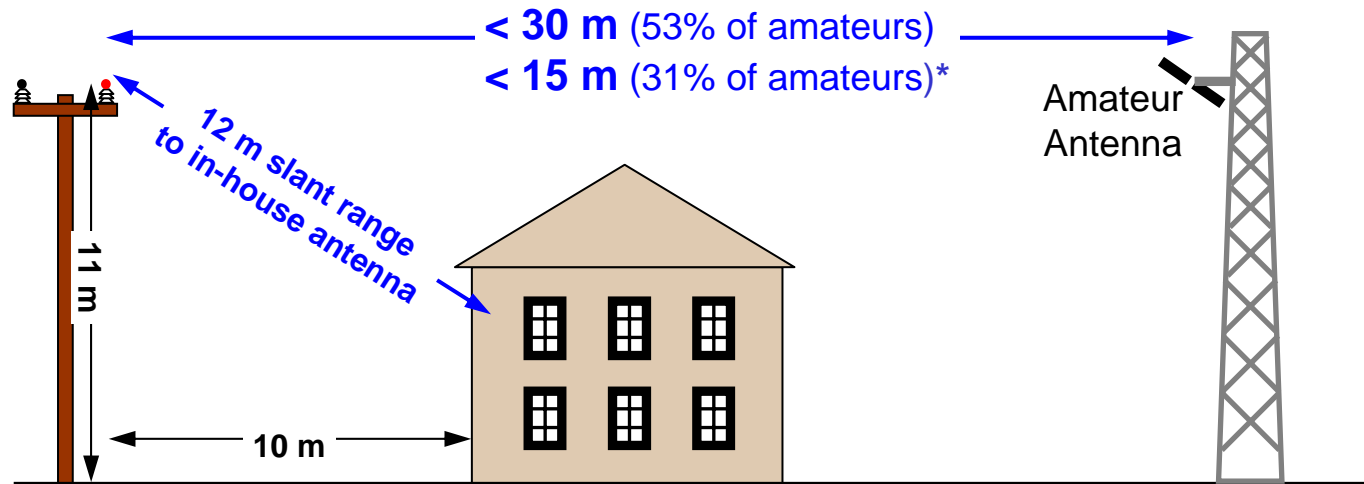
BPL Below 30 MHz: Exempt from Conducted Limits

(except in the AM broadcast band)



BPL Radiators: Close to Neighboring Residential Antennas

Access BPL Distance to Victim



* <http://www2.arrl.org/survey.php3?pollnr=195>

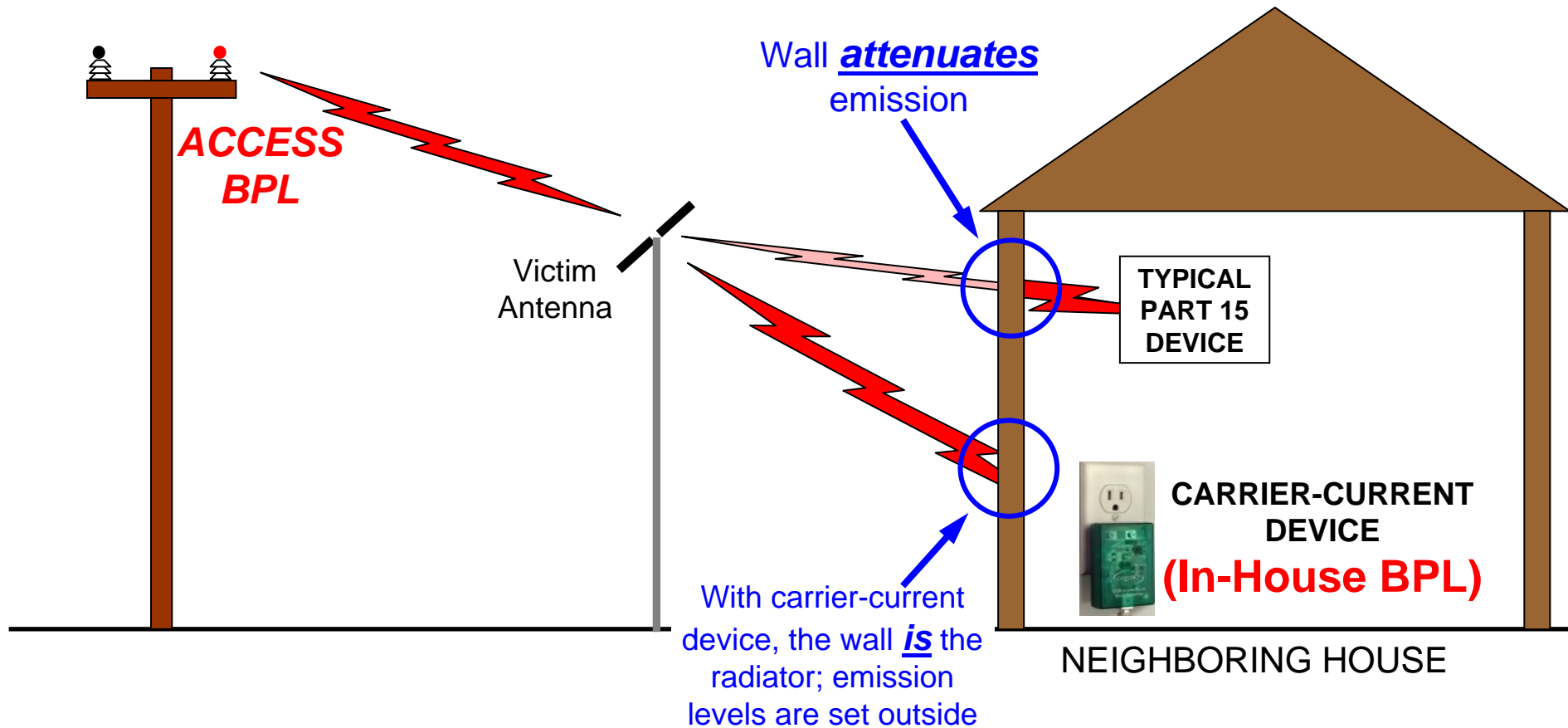


In-House BPL Distance to Victim



BPL radiators are about as close to a residential victim antenna as is possible without being on that victim's property (and under his/her control)

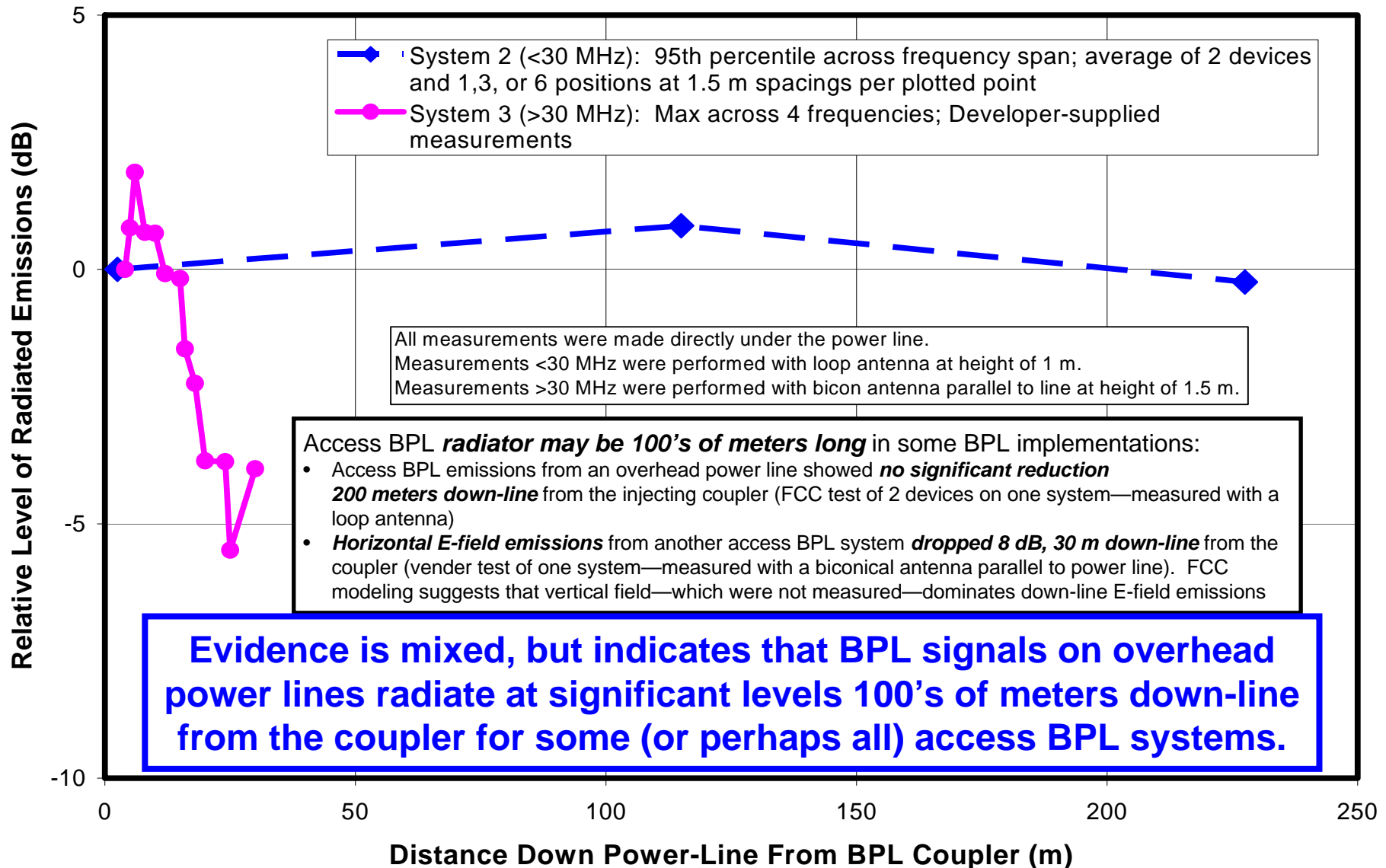
BPL: Radiation Without Walls



With carrier-current devices, (e.g., BPL) there is no wall around the interferer to attenuate the interference



BPL: Extended Radiators



◆ System 2 (<30 MHz): 95th percentile across frequency span; average of 2 devices and 1,3, or 6 positions at 1.5 m spacings per plotted point
● System 3 (>30 MHz): Max across 4 frequencies; Developer-supplied measurements

All measurements were made directly under the power line.
Measurements <30 MHz were performed with loop antenna at height of 1 m.
Measurements >30 MHz were performed with bicon antenna parallel to line at height of 1.5 m.

Access BPL *radiator may be 100's of meters long* in some BPL implementations:

- Access BPL emissions from an overhead power line showed **no significant reduction 200 meters down-line** from the injecting coupler (FCC test of 2 devices on one system—measured with a loop antenna)
- **Horizontal E-field emissions** from another access BPL system **dropped 8 dB, 30 m down-line** from the coupler (vender test of one system—measured with a biconical antenna parallel to power line). FCC modeling suggests that vertical field—which were not measured—dominates down-line E-field emissions

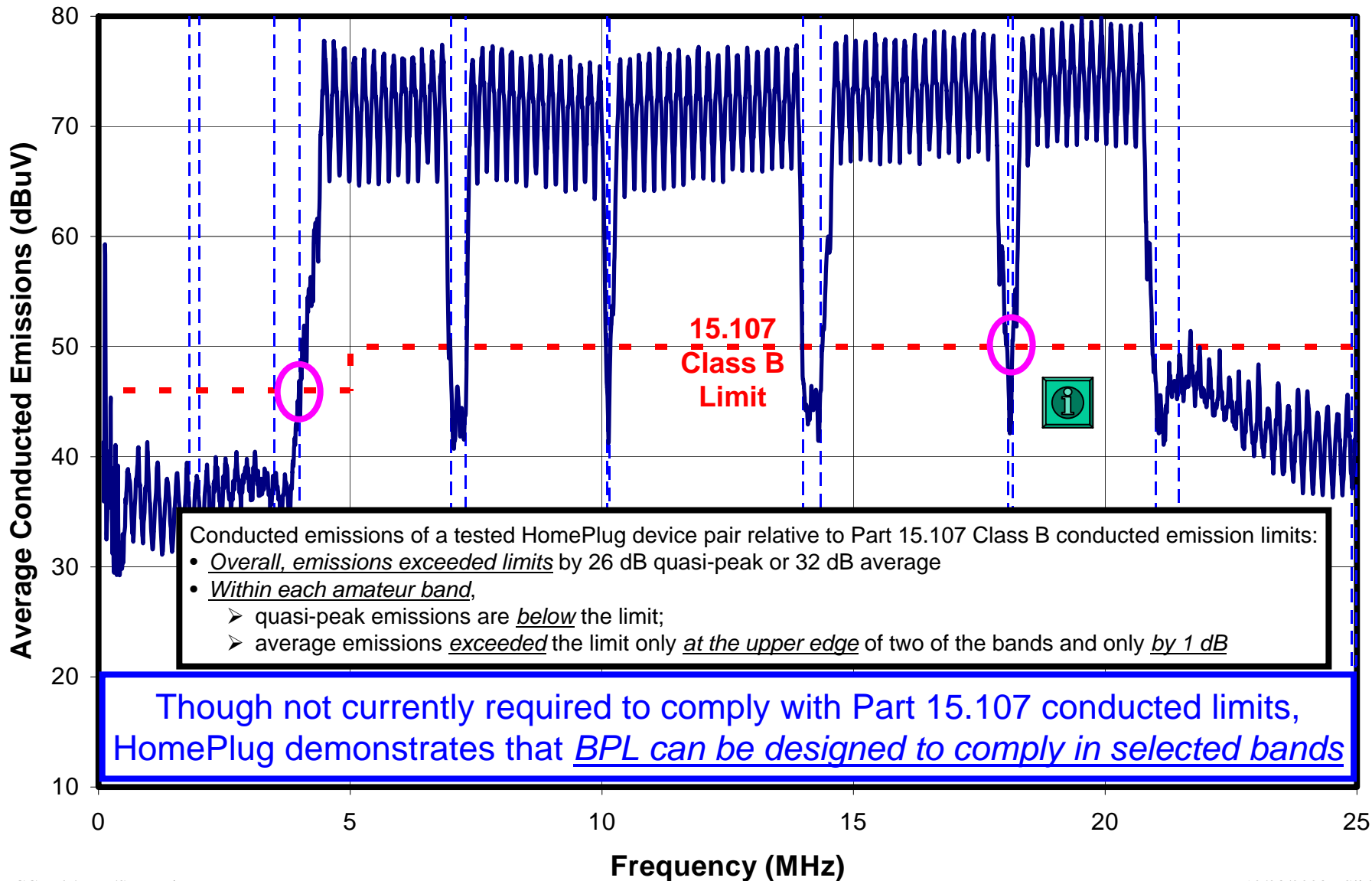
Evidence is mixed, but indicates that BPL signals on overhead power lines radiate at significant levels 100's of meters down-line from the coupler for some (or perhaps all) access BPL systems.



OUTLINE

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- Part 15 Radiated Emission Limits
- What is different about BPL?
- *What can we do?*
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HomePlug Was Voluntarily Designed to Protect Amateur Bands





OUTLINE

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- Part 15 Radiated Emission Limits
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- ***Summary, Recommendations, Alternatives***

Key Points

- **Radiated limits do not fully prevent interference at 30 m range/no intervening walls**
 - Services operating close to noise floor below 30 MHz are especially vulnerable
 - Conducted emissions for non-carrier-current devices offer good protection
 - The rules are adequate for most Part 15 devices
 - **BPL significantly increases the likelihood of interference**
 - Broad Bandwidth—overlaps multiple services and channels
 - High emissions over a wide bandwidth
 - Exemption from conducted limits (except in AM broadcast band)—applies to devices < 30 MHz
 - Close proximity to neighboring residential antennas
 - No intervening walls to attenuate interference
 - Large spatial extent of radiators
- Some other Part 15 devices have 1 or 2 of these characteristics. **BPL is the only one with all***
- **BPL interference**
 - BPL interferes with nearby shortwave & amateur reception (including Military Affiliate Radio Service)
 - Impact on Public Safety (VHF-LB) & ARINC not yet evaluated
 - Locating, identifying, & resolving interference will be difficult/impractical
 - Direction finding won't work (multiple, broadband, extended sources)
 - Can't avoid interference by channel abandonment
 - **Balance**
 - Can be designed to protect specific bands
 - Access BPL offers potential public benefit

Harmful?



Recommendations

Identify the source of interference to ARINC at Half Moon Bay ASAP. We must understand this before ruling on BPL.

Recommendations & Alternatives: In-House BPL

Provide Additional Protection for Some Bands

Justification: Necessary to reduce occurrence of harmful interference from devices that are marketed to consumers for consumer installation; change should be implemented before large-scale marketing of devices; some HomePlug devices may already satisfy Alternative MP3/B1

Downside: Rule change would impact the future of at least some existing products

- **Which bands to protect** [brackets indicate total bandwidth from 1.7 to 30 MHz]



- **Alternative B0:** No new protection
- **Alternative B1:** Amateur bands [3.75 MHz]
- **Alternative B2:** Band in B1 + some govt services (e.g., Std Freq & Time [0.1 MHz]), MARS, &, if necessary, ARINC)
- **Alternative B3:** Bands in B2 + shortwave broadcast [4.72 MHz]
- **Alternative B4:** Restrict operation to 30-50 MHz (North American Shortwave Association recommends 30-47 MHz)
- **Alternative B5:** Restrict operation to 30-50 MHz, but omit public safety bands [-7 MHz of the 30-50 MHz band]

- **How to specify additional protection**

- **Alternative IM0:** No new protection
- **Alternative IM1:** Specify “no intentional signal injection onto mains” in the bands requiring additional protection
 - **Justification:** Easy to implement
 - **Downside:** Difficult to verify; no limit on unintentional leakage into the bands that require additional protection
- **Alternative IM2:** Apply Class A conducted limits from 15.107 to bands requiring additional protection
 - **Justification:** Class A limits would be easier for manufacturers to achieve
 - **Downside:** Use of class A limits for residential consumer devices would be harder to justify.
- **Alternative IM3:** Apply Class B conducted limits from 15.107 to bands requiring additional protection [possible exemption near edges of the bands due to measurement equipment limitations]
 - **Justification:** Achieves adequate protection; extension of existing limit to BPL devices is easier to justify than development of a new limit; HomePlug device measurements demonstrate feasibility; HomePlug devices may already satisfy the new limit.
- **Alternative IM4:** Reduce the radiated emission limits in the bands requiring additional protection.
 - **Downside:** This alternative is not recommended below 30 MHz because of measurement limitations for in-situ radiated measurements.

Additional Recommendation: For any option except B4 & B5, continue measurements to determine conducted-to-radiated transfer functions of mains wiring in houses for use in developing conducted alternative to in-situ radiated emissions testing for in-house BPL devices.



Recommendations & Alternatives: Access BPL

Devices that inject signals on low-voltage lines (in-house or outdoors)

- **Recommendation:** Apply the same rules as for in-house BPL

Devices that inject signals on medium-voltage lines

- ***Which bands to protect***

- See in-house BPL list + provide protection near certain facilities (e.g., radio astronomy and ARINC)

- ***How to specify additional protection***

- **Alternative AP0:** No change in rules. Require that installers mitigate interference complaints

- **Justification:** Easy to implement

- **Downside:** Do we have teeth with power companies? Power companies may be misled into thinking FCC “blessing” means interference is not a problem

- <http://pennlive.com/news/expresstimes/pa/index.ssf?/base/news-7/1063271074318460.xml>

- “PPL officials said the shortwave operators shouldn't be affected. If there was the potential for a problem, the Federal Communications Commission, which regulates radio frequencies, wouldn't have given the company the green light on commercializing the service, they said.”*

- **Alternative AP1:** As above, but include caution statement regarding interference in rules

- “Because of the broadband nature of emissions from BPL devices and the proximity of the electrical wiring through which these devices radiate to various types of receivers and outdoor antennas, the likelihood of interference with licensed radio services is higher than for many other types of Part 15 devices. For access BPL devices that inject signals onto overhead power lines, the potential for interference may extend for hundreds of meters down the power line on which a BPL device is installed. Consequently, in designing, configuring, and installing a BPL system, care should be taken to avoid harmful interference to other services. For access BPL systems that are not user-installed, this may involve steps such as: notching the frequencies of amateur radio or radio astronomy bands for deployments in the vicinity of users of these services; avoiding overlap with public safety bands used in a given area; and avoiding overlap with VHF television bands.”

- **Alternative AP2:** Specify “no intentional signal injection onto mains” in the bands requiring additional protection

- **Alternative AP3:** Implement class A conducted limits from 15.107 in bands requiring additional protection

- **Alternative AP4:** Implement class B conducted limits from 15.107 in bands requiring additional protection

- **Downside:** Alternatives AP3 & AP4 will require development of new test techniques

- **Alternative AP5:** Reduce the radiated emission limits in the bands requiring additional protection

- **Downside:** This alternative is not recommended because of measurement limitations for in-situ radiated measurements



LINKED BACKUP

Noise Model Definitions

- **Business Area**

- Predominant usage throughout the area is for any type of business—including stores and offices, industrial parks, large shopping centers, main streets or highways lined with various business enterprises, etc.

- **Residential Area**

- Used predominantly for single or multiple family dwellings with a density of at least two single family units per acre and no large or busy highways. An occasional isolated business such as a drugstore or filling station can be included.

- **Rural Area**

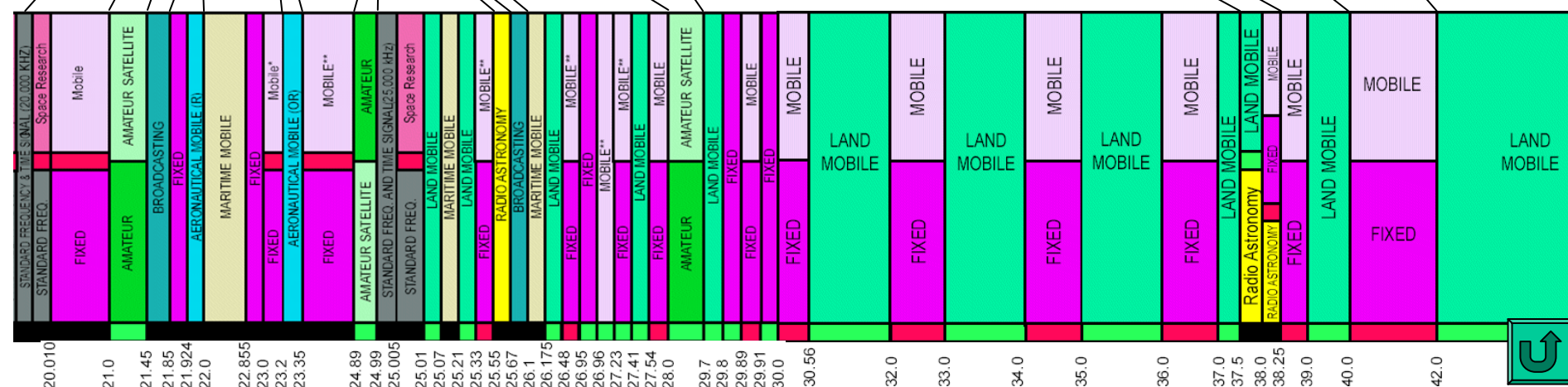
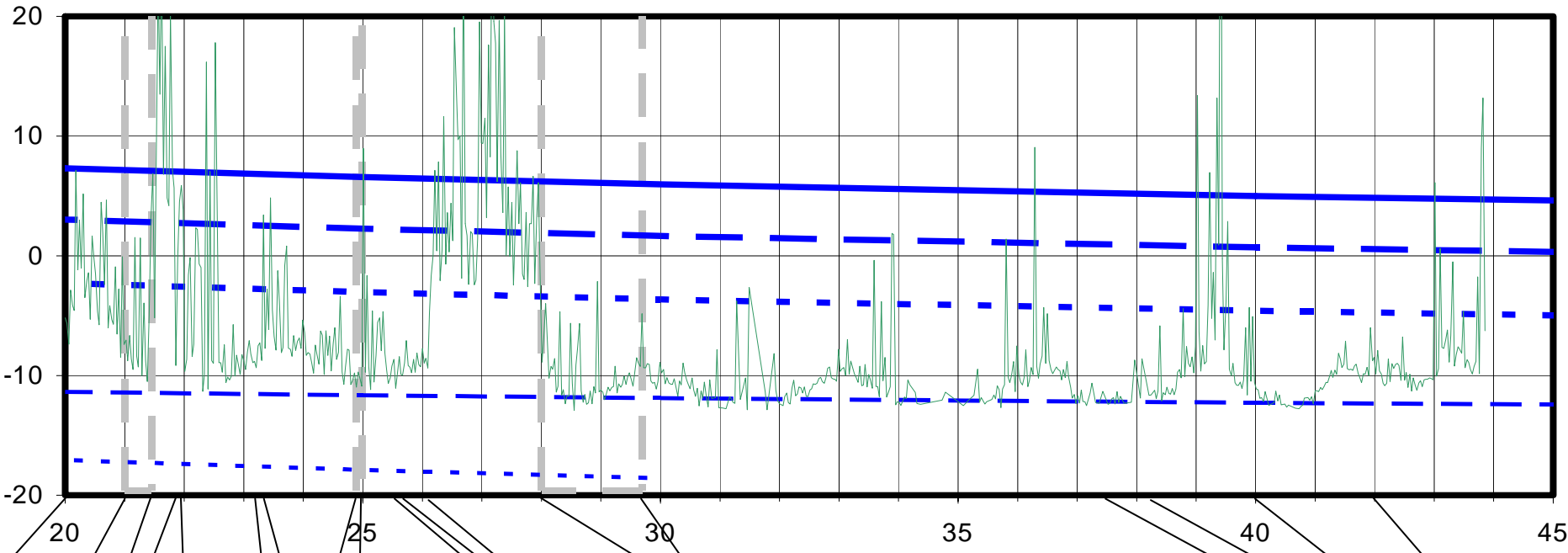
- Land usage is primarily for agricultural or similar pursuits; dwellings are no more than one every five acres.





Today's Residential RF Noise Levels w/Frequency Chart

FCC Laboratory



ARRL Web Survey Results

Poll date: July 18, 2003

How far is any part of your outside antenna from overhead power lines?

Less than 25 feet	=	11.7 % (347)
26 to 50 feet	=	19.4 % (576)
51 to 75 feet	=	12.5 % (370)
76 to 100 feet	=	9.7 % (288)
More than 100 feet	=	36.8 % (1091)
I have an indoor antenna	=	6.3 % (187)
I don't have an antenna	=	3.6 % (106)
Total votes: 2965		

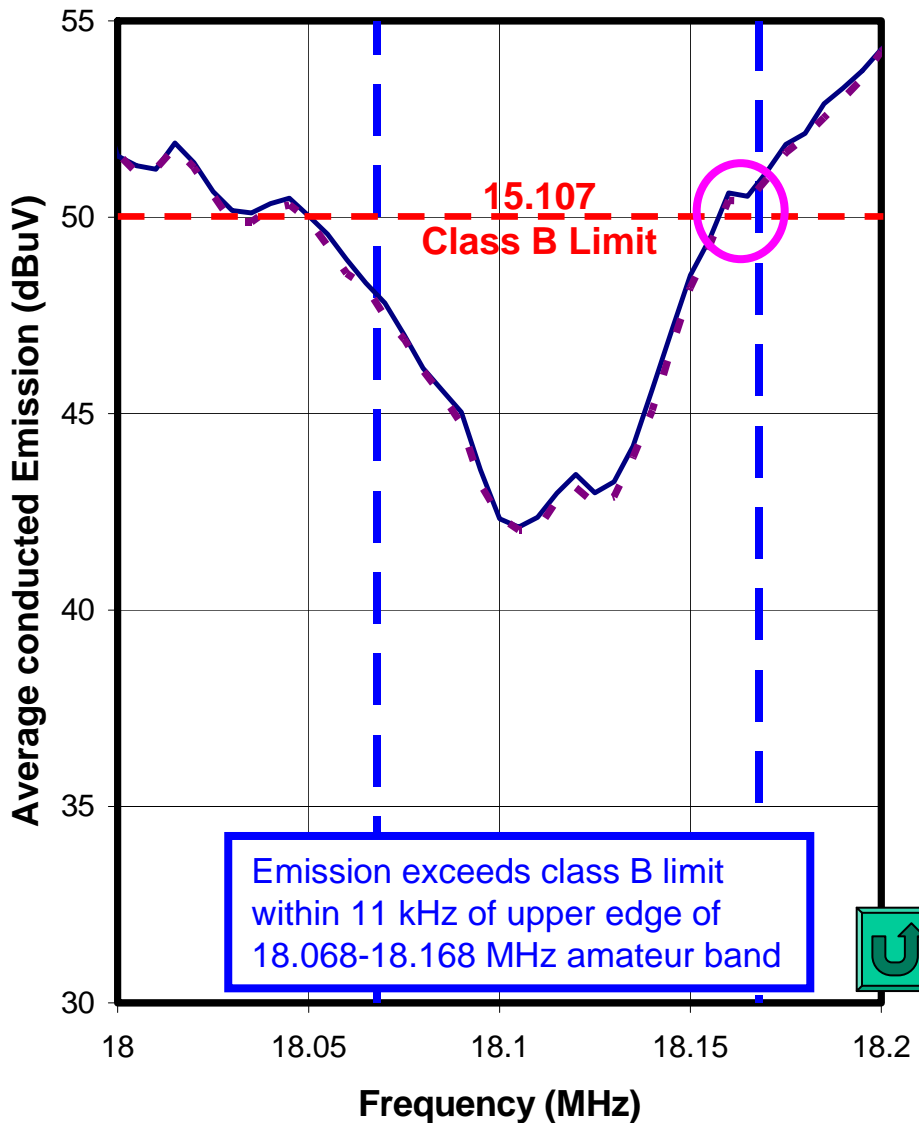
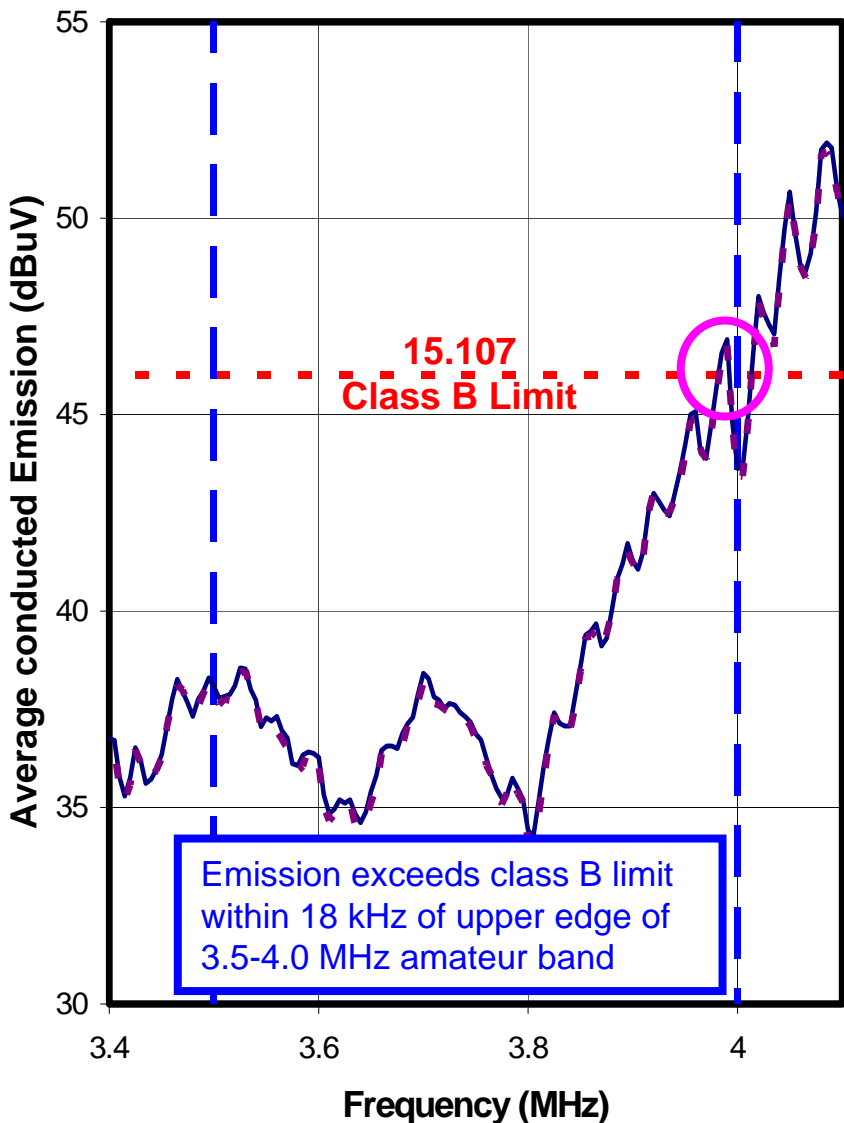
Source: <http://www2.arrl.org/survey.php3?pollnr=195>





Tested HomePlug Device Pair Complies with Class B Conducted Limits in Amateur Bands Except Near Band Edge

FCC Laboratory



What Bands Should We Protect in Residential Neighborhoods?

Band Occupancy of Potential Victims in Residential Neighborhoods

	AMATEUR RADIO	BROADCAST SHORTWAVE RADIO	PUBLIC SAFETY (VHF low band)
2 – 30 MHz Occupancy	<i>8 bands totaling 3.55 MHz</i>	<i>17 bands totaling 4.55 MHz</i> (broadcast + W W V)	None
30 - 50 MHz Occupancy	None	None	<i>~7-12 bands totaling 5.3 – 7.3 MHz</i>
Antenna Location	Usually outdoors	Indoors or outdoors	Vehicle-mounted on road or hand-held anywhere
Strongest BPL Interference Source	<ul style="list-style-type: none"> • Access: Overhead lines in front of house or conducted coupling to own mains if on same xformer as subscriber • In-House: Neighbor's wall or overhead drop line; conducted coupling to own mains 		<ul style="list-style-type: none"> • Vehicle-mounted: Overhead lines • Handheld: Is there a requirement to operate inside a home w/BPL?
Sensitivity to Interference	High (in quiet areas)	High (in quiet areas)	<ul style="list-style-type: none"> • Possibly less sensitive if designed to be reliable in higher noise environments??? • Antenna close to vehicle ignition • Tests by Current Technologies: Under power line, BPL raises signal level requirement by 1-2 dB (for 20-dB quieting)
Other factors			<ul style="list-style-type: none"> • High Priority! • Migration out of VHF low band???

In addition, Military Affiliate Radio Service (MARS) provided by amateurs has frequency allocations in HF and VHF

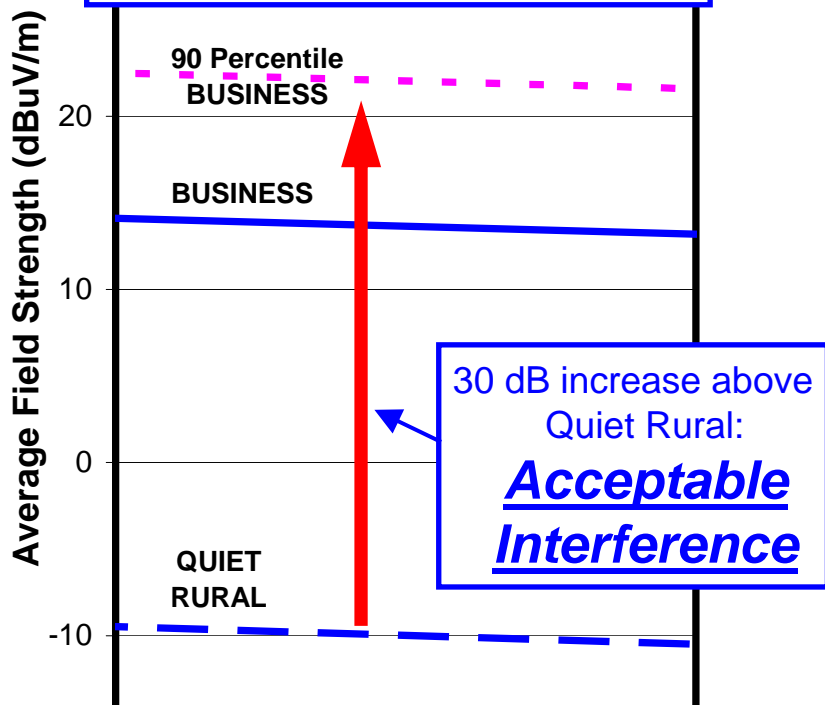




Harmful Interference

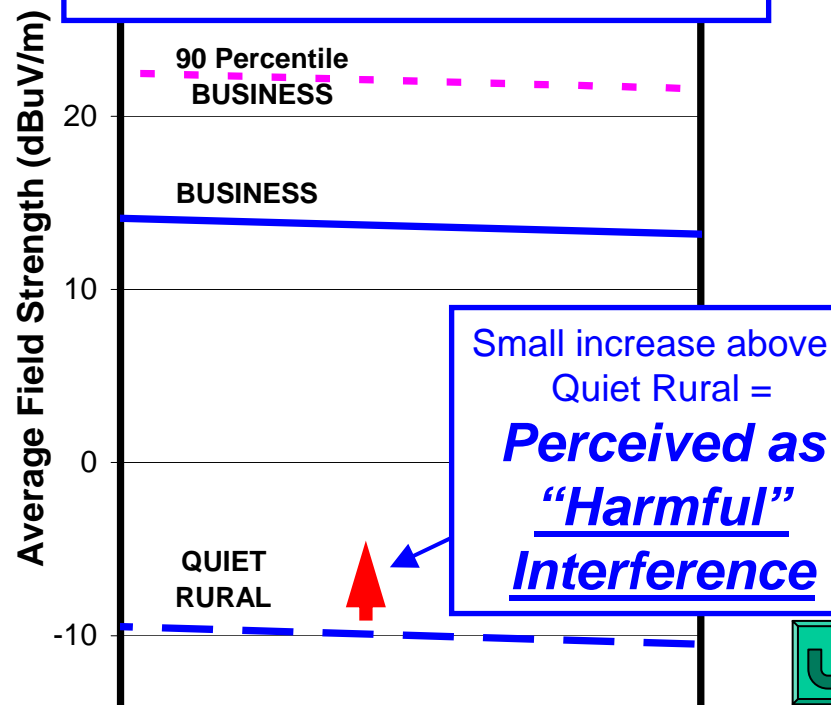
Victim 1 – Robust Coms

Designed for near-worst-case expected noise, e.g. 90th-percentile business noise



Victim 2 – Amateur or Shortwave DXer

Tries to detect the weakest signal that is detectable in the local environment



15.3(m) Harmful interference. Any emission, radiation or induction that **endangers** the functioning of a radio **navigation** service **or** of other **safety** services **or seriously degrades, obstructs or repeatedly interrupts** a radiocommunications service operating in accordance with this chapter.



BACKUP

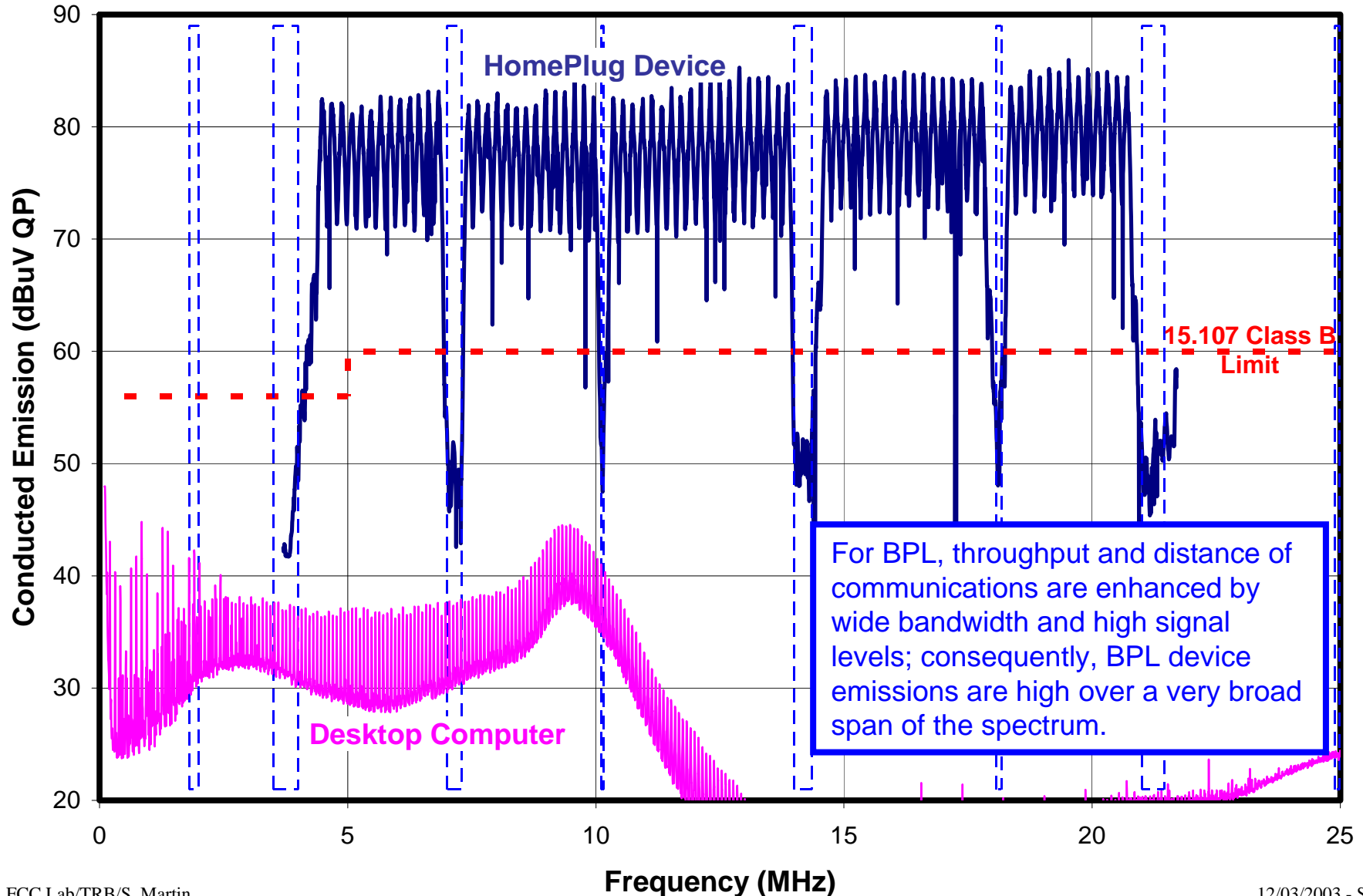
Summary of Freiburg Experiment

- **OFCOM (Federal Office of Communication), “Assessment of the interference capability of BPL installations in Freiburg”**
 - *No overhead lines in the test areas*
 - All measurements were made on public property to show interference potential of BPL on shortwave radio reception in areas accessible to the public
 - Maximum emissions occurred near the neighborhood transformers (17kV/230V)
 - Median emission levels ~ 41dBuV/m
 - Levels decrease quickly as measurements are taken further away from these places
 - Increase in ambient noise in urban environment (measured from van) Harmful?
 - Avg 1 dB increase below 10MHz, where BPL interference is probably masked by overhead lines of trolley buses (p.39)
 - Average 12 dB increase above 19 MHz (measurements at street)
 - BPL not detected outside the city ~ 500 meters from the closest installations

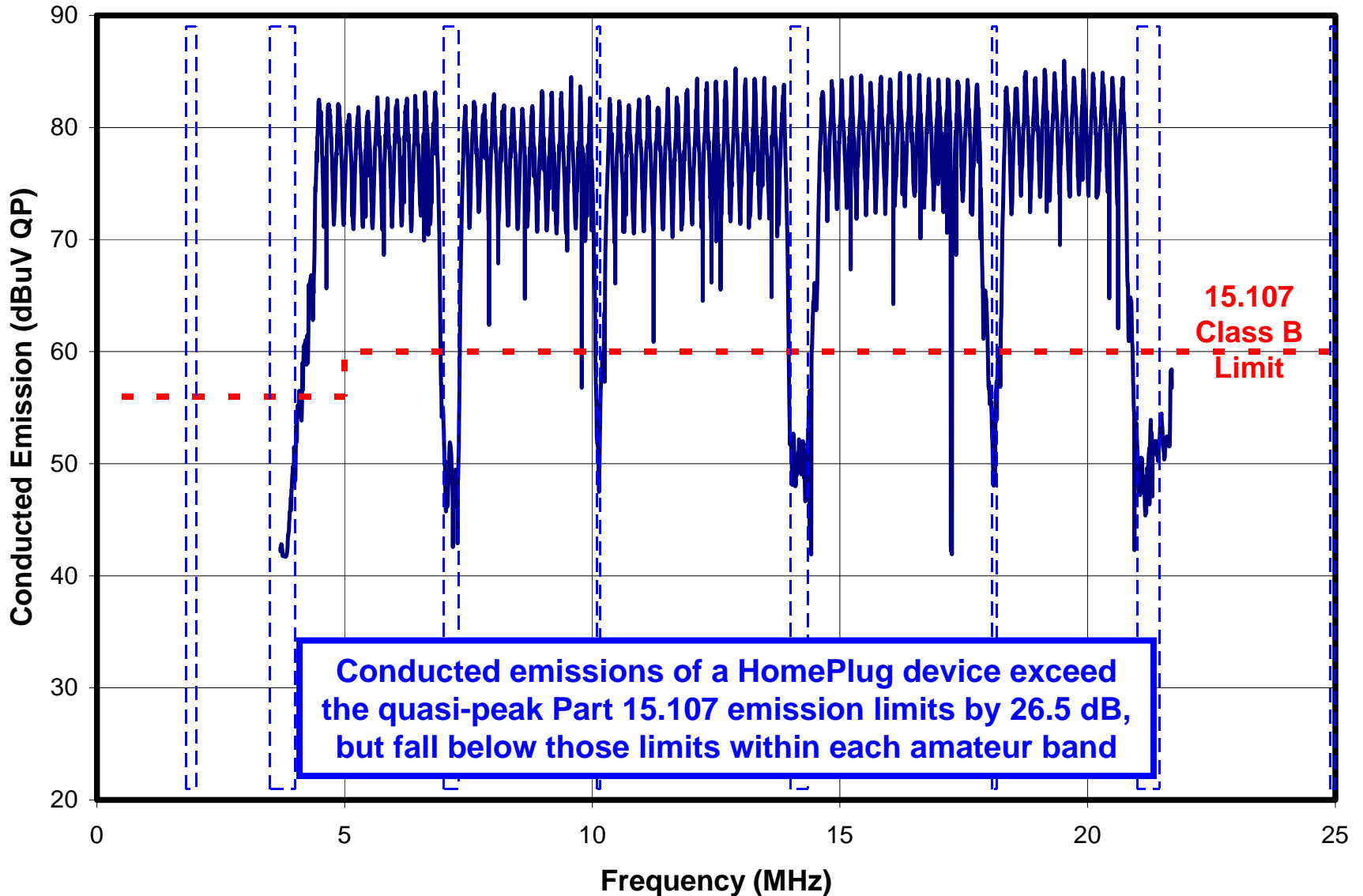


BPL Performance is Enhanced by Maintaining High Level Emissions Across a Broad Band of Frequencies

FCC Laboratory

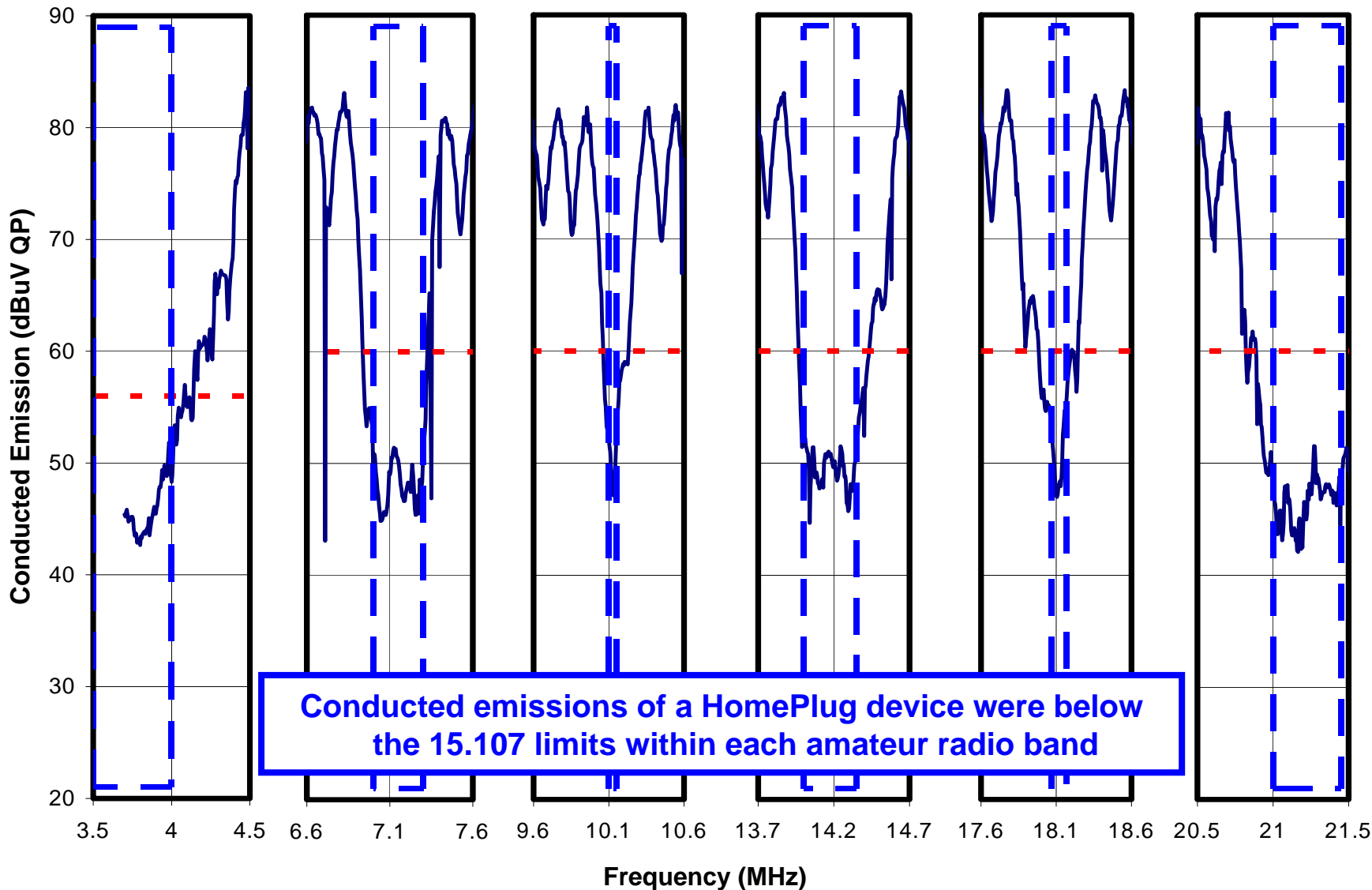


BPL Exceeds Conducted Limits, But Can Be Designed to Comply With Those Limits in Selected Bands



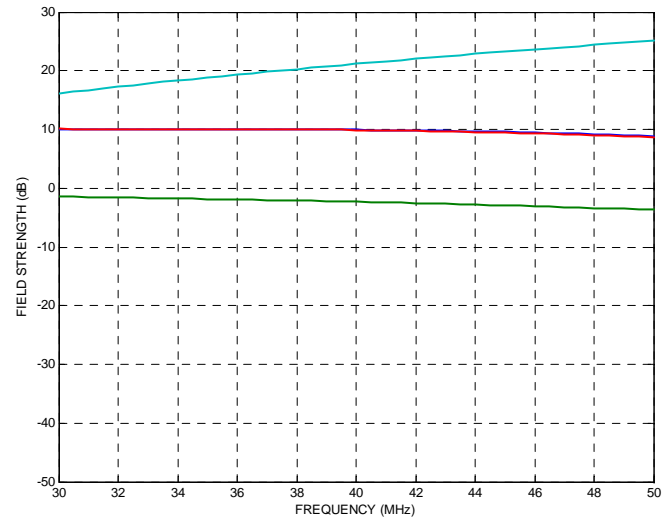
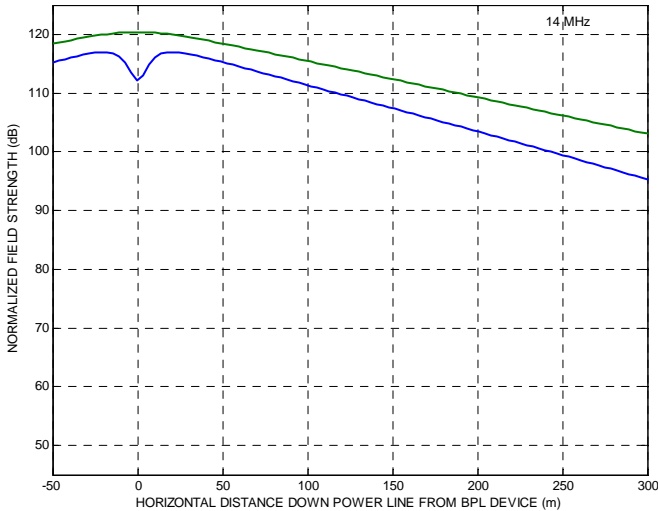
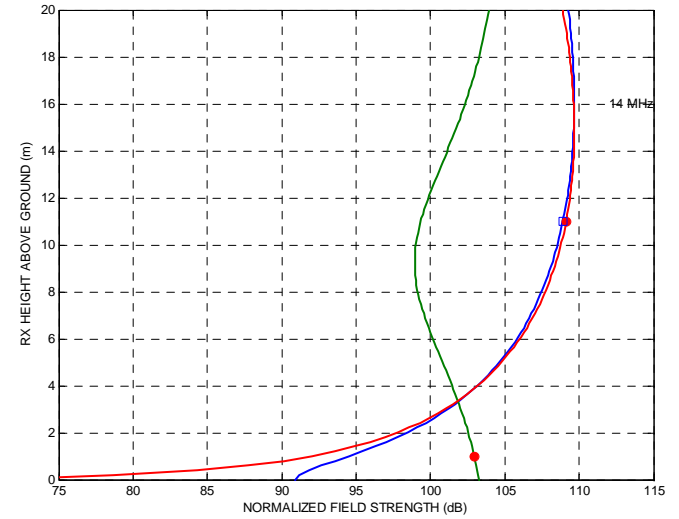
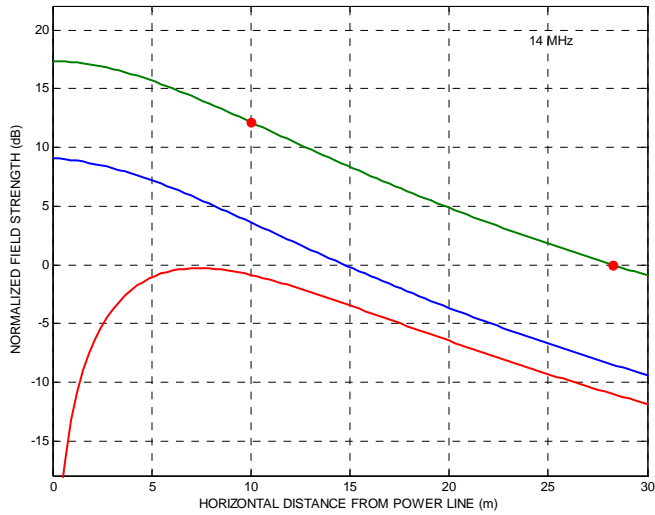


Conducted Emissions of a HomePlug Sample Within the Amateur Bands



Conducted emissions of a HomePlug device were below the 15.107 limits within each amateur radio band

Ron Chase's Model





Phonex Narrowband Carrier Current Device

Carrier-current phone jack: 2 FM carriers (originally at 3.52 & 8.27 MHz w/3.52 MHz always ON)

Also **used in some cable TV boxes** for billing for pay-per-view

ARRL	ARINC (voice coms w/trans-oceanic flights— <u>near noise floor</u>)
<ul style="list-style-type: none"> Observed S9+10 dB on antenna 30 m from a house [~3 dB > 15.209 limit, but within measurement error] Reports as high as S9+60 dB reported in mobile test 	<ul style="list-style-type: none"> Interference 15 dB > noise floor ARINC attributes to Phonex devices 1.5 miles from Rx & claims to have observed Phonex at 5 mi in a test No positive ID of source; some facts disputed
<p><u>Complaint Resolution</u></p> <ul style="list-style-type: none"> <u>Phonex responded rapidly</u>—changed production/recalled deployed units—new carrier frequency & carriers OFF when not in use 	<p><u>Complaint Resolution</u></p> <ul style="list-style-type: none"> Specific source not identified <u>ARINC abandoned 3.013 MHz</u> at Half Moon Bay
<p><u>Lessons</u></p> <p><i>Nature of interfering source facilitated its location & ID:</i></p> <ul style="list-style-type: none"> Narrowband (recognized as interference & frequency aids ID) Always ON; Analog voice modulation Local interference dominated by single nearby device 	<p><u>Lessons</u></p> <p>ARINC attributes lack of ID of the interferer to multiple interference sources (Phonex devices) that were ON for limited durations</p>

Interference caused by Phonex device

No positive ID of interference source

Locating, identifying, & resolving interference from BPL will be difficult or impractical:

- Traditional direction finding approaches won't work with multiple, broadband, extended sources
- Temporary solutions such as abandoning a channel will not be available for broadband interferers
- Permanent solutions will require notching rather than retuning

BPL Exemption from Conducted Limits

