

BPL: EMC Issues

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ARRL

- **ARRL is the National Association for Amateur Radio**
- **Represents the interests of Amateur Radio in the US**
- **150,000 members**
- **650,000 licensed Amateur Radio Operators**
- **ARRL's interest in BPL is related only to its EMC aspects**
- **Other than EMC issues, BPL should be allowed to succeed or fail on its own merits**

About your presenter

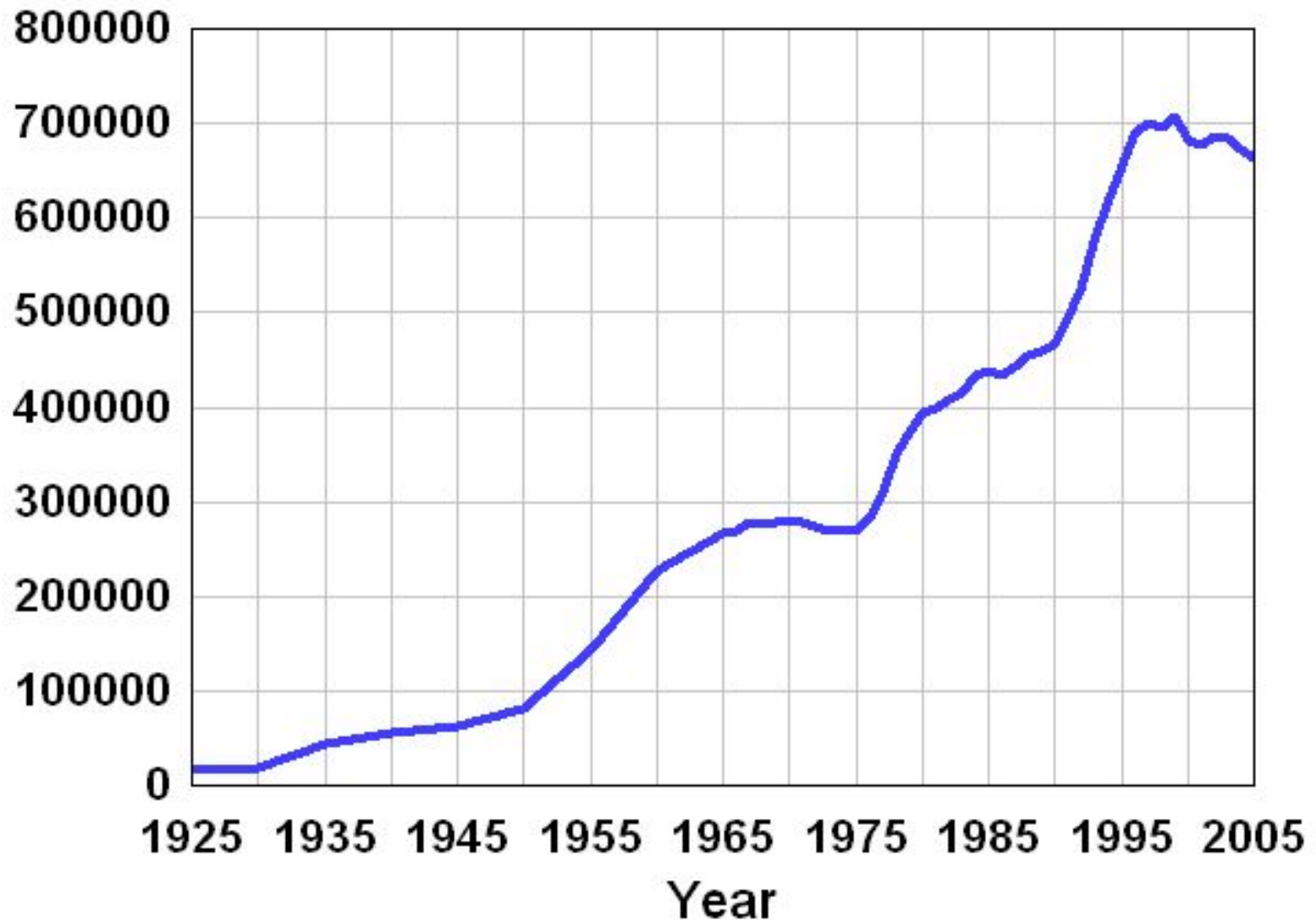
- **Ed Hare, W1RFI, has worked for ARRL since 1986**
- **He manages the ARRL Lab**
- **He has been ARRL's RFI "guru" for most of his career at ARRL HQ**
- **He is the author/editor of "The ARRL RFI Book" and "RF Exposure and You"**
- **He serves on a number of industry committees, including the IEEE EMC Society BPL Study Project, which he chairs**

Rules of W1RFI's Presentations

- It is okay to get up and leave!
- Everybody has to laugh at my jokes!
- I am the only one allowed to tell any jokes!
- Ask questions any time.
- Falling asleep. . .

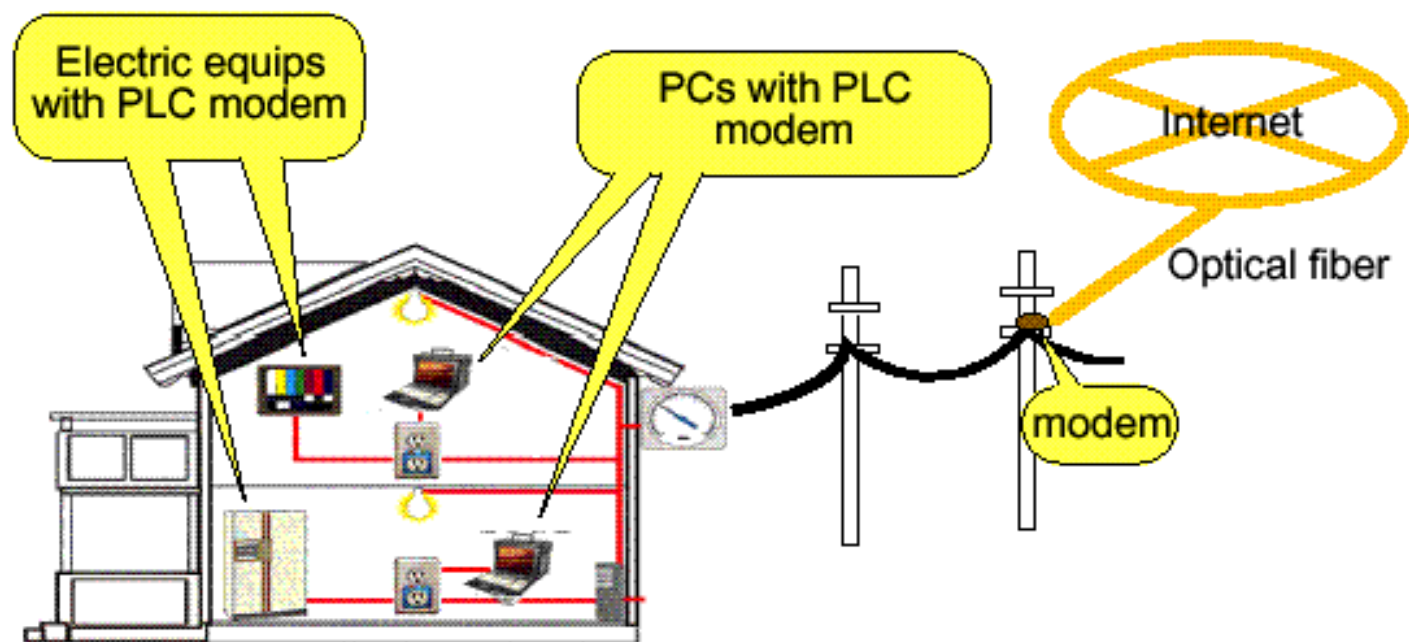
Myth #1: Amateur Radio is dying

Number of Licensed US Amateur Licensees



What is HF PLC? (1)

Broadband Network Realization using Existing Power Line



Why BPL?

- **Manufacturers not here, so I will represent them**
- **Broadband at every outlet**
- **Electrical wiring not as good as coax and Cat 7 wiring**
- **Broadband to rural areas**
- **NARUC report notes that latency and costs may make that impractical, although rural communities can be networked**
- **Utility applications – Most valuable use of BPL**
- **In-premise, multi-dwelling unit**
- **Meter reading; voltage monitoring; equipment control; video monitoring**
- **ARRL helping BPL being successful**

What Are the Rules?

- **Absolute-maximum limits defined in Part 15**
- **Carrier-current must meet limits for intentional emitters**
- **Part 15 also is clear that unlicensed devices such as BPL must not cause any harmful interference and they must accept any interference caused to them**
- **Manufacturer responsible for FCC authorization and maximum limits**
- **Operator responsible for harmful interference**
- **Both components to the rules are necessary for Part 15 to work**

What is New?

- **Interference Database – Zip code and contact information**
- **Mandate to have ability to control frequency, power level and shut off**
- **Certification instead of Verification**
- **List of forbidden frequencies**
- **FCC said interference would be “very rare” but carved out 13 blocks of government spectrum that access BPL using overhead MV lines couldn’t use**
- **Operate under “transition” rules for next 18 months**
- **Devil in details – will define what constitutes interference?**

Interference Database

Found Active Companies

We found **1** company listed as operating within zip code *30549*

Jackson EMC

Contact Name: [REDACTED]

Phone: [REDACTED]

Email: [REDACTED]

Street Address: [REDACTED]
Jefferson, GA 30549

Details:

Frequency	Manufacturer	Model
2-34MHz	[REDACTED]	Generation 2 (see notes)

Notes: B00001 Rack, MV, Indoor; B00005 Rack, Panel, Blank; B00015 Car Coupler, Capacitive, MV; B00059 Enclosure, Metal; B00060 Enclosure Connector, T Adapter; B00009 Card, MV, DSS9002, B Filter; B0001 SIP Notching the following frequencies: 3.5-4, 7-7.3, 10.1-10.15, 14

Date of operation: 2006-02-23

Interference Database

Error

Your search limit has been exceeded, though you may try again later.

If you feel you have reached this message in error, please email admin@utc.org with a description of the problem.

This service is provided by the United Power Line Council and the United Telecom Council, but all content is provided by, warranted to be accurate by, and the responsibility of the BPL Service Providers listed.

Probability

- **If a tree falls in the forest...**
- **BPL interference is local**
- **If it operates on spectrum not in use nearby, there will be no interference**
- **Low probability of interference?**
- **Most of the time, BPL won't cause interference because radio use is sporadic**
- **For individual user, high probability of interference**

**Even if interference is rare, it must
be corrected when it occurs**

Intentional Emitter Radiated Emissions Limits - HF

- **Sec 15.209**
- **1.705-30.0 MHz -- 30 $\mu\text{V}/\text{m}$ at 30 meters**
- **These limits should protect users of the spectrum against interference, yes?**

No!

- **If the absolute emissions limits were set to offer unconditional protection to all radio services, the permitted levels would be unworkably low**
- **Amateur Radio Service, by design, uses sensitive equipment and weak signals**
- **The “legal limit” will result in a strong signal to nearby amateur HF installations**
- **On 3.5 MHz, a half-wave dipole placed in a $30 \mu\text{V}/\text{m}$ field will receive a -86.4 dBW signal ($338 \mu\text{V}$ across 50 ohms)**
- **To amateurs, this is S9+16 dB – clearly harmful interference to typical amateur communications!**
- **Amateur operators have reported hearing BPL signals for over a mile from their source**

Meeting the FCC emission limits is not enough to protect against causing harmful interference.

Interference to radiocommunications can occur from emissions that are 50 dB lower than the permitted levels.

To avoid interference, must avoid locally used spectrum

- **Fixed and mobile commercial and military**
- **Fixed and mobile VHF public service**
- **In residential areas:**
 - **Amateur**
 - **CB**
 - **International shortwave broadcast**
 - **Fixed licensed stations relatively easy**
 - **International shortwave broadcast receivers at unknown locations**
 - **Mobile stations of all sorts impossible to predict**

Amateur HF and VHF stations

- **Bands at 1.8, 3.5, 5.1, 7.0, 10.1, 14.0, 18.1, 21.0, 24.8, 28.0, 50 and 144 MHz**
- **Receiver sensitivity -165 dBW (0.04 uV)**
- **Ambient noise levels -155 dBW (0.1 uV)**
- **Antenna gain 2.14 dBi (F.S) on 3.5 Mhz**
- **Antenna gain 7.5 dBi (F.S) on 14-30 MHz**
- **EIRP >20 kW**

Effectiveness of present rules

- **They work – to a degree – to control interference from most unlicensed devices**
- **Most devices do not emit on wide range of frequencies**
- **Most do not emit all the time**
- **Most do not emit over large geographical area**
- **Examples: Computer birdies and outside lights**

How BPL is Different from other unlicensed devices

- **Broadband**
- **Emit most of the time**
- **Emit over large area**
- **As built out, could be as big as an entire state?**
- **Significantly different interference potential**
- **Maintenance issues**

This is NOT a BPL problem!



The Bottom Line

- The legal emissions limits result in strong signals to nearby receivers**
- Nearby receivers that will receive interference if they are trying to receive signals on the same spectrum as analog signals**
- In residential neighborhoods, the risk is typically to Amateur Radio, Citizens Band and international shortwave broadcast**
- Meeting the FCC emissions limits is not going to completely prevent harmful interference and complaints**

Myth #2: Interference is a problem only for Amateur Radio

- **Emergency management**
- **National Guard**
- **US Coast Guard**
- **U.S. Military**
- **Fire Departments**
- **Law Enforcement**
- **CAP**
- **FAA**
- **FEMA**
- **NASA**
- **Voice of America**
- **TV stations**
- **Amateur and CB radio**

Federal Emergency Management Agency:

“This interference will severely impair FEMA’s mission-essential HF radio operations... The benefits if BPL... do not appear to outweigh the benefit... of radio capability as presently used by government, broadcasting and public-safety users.”

Disaster Emergency Response Association:

“DERA concludes that serious interference and disruption of critical emergency communications systems... would almost certainly result from BPL implementation as currently proposed.”

Myth #3: BPL users will outnumber Amateur Radio operators so BPL will be given priority

- **Under the FCC rules, licensed users are protected from unlicensed interference**
- **Cable TV users, telephone users, computer user and even electric-utility customers outnumber Amateur Radio**
- **The FCC has not taken any opportunity to change the rules governing the above users**
- **In the recent BPL Report and Order, the FCC did not change the rules that unlicensed operation must not interfere**
- **Giving unlicensed operation priority over licensed users would be a major paradigm shift**
- **If any in the industry are counting on such a rules change, that is a risky proposition**

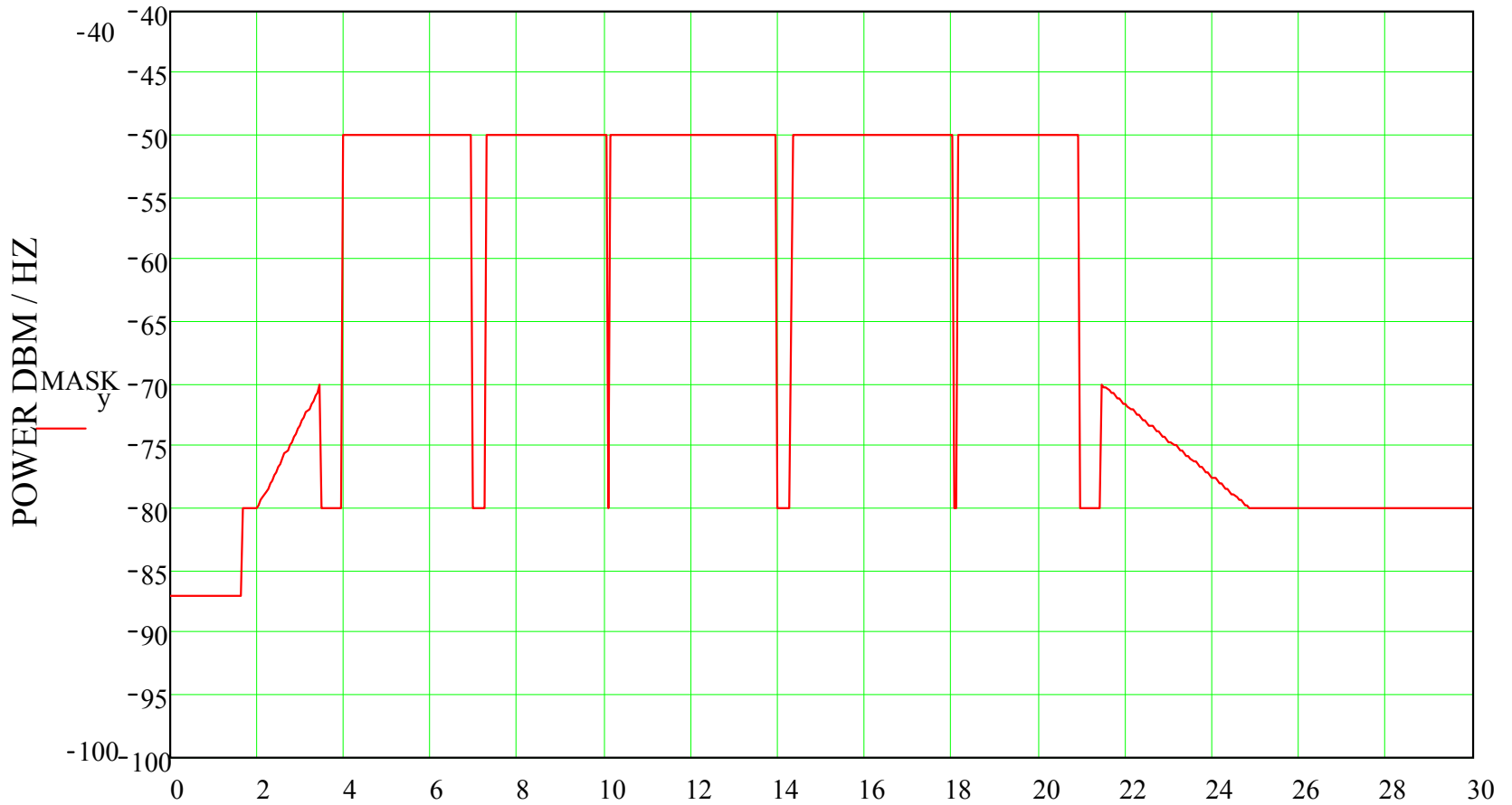
What is ARRL doing?

- **Here's the short list...**
- **Working with local BPL teams**
- **Filing supporting interference complaints**
- **Funding measurements in BPL areas where appropriate**
- **Petition for Reconsideration planned**
- **Federal Court of Appeals if necessary**
- **Maintaining contacts and presence in standards area**
- **Ed Hare is chair of IEEE SDCOM and ANSI C63 ad hoc BPL working group**
- **Funding staff and outside filings**
- **IEEE meeting next week**
- **Making other affected users aware of BPL interference issues and explaining how to file complaints**
- **Articles in QST and on ARRL web pages**
- **Petition for Reconsideration**

Cooperation

- **ARRL has a track record of working cooperatively with industry**
- **Over years, it has worked with the cable industry; VDSL; Home Phone Networking Alliance**
- **It has worked with HomePlug on their Version 1 standard and expects to work with them on the upcoming AV standard**
- **Within BPL industry, ARRL has worked effectively with many, but not all, of the BPL manufacturers**
- **It has also worked directly with electric utilities**
- **In other cases, manufacturers and utilities have chosen a more adversarial approach**
- **The door is still wide open for sincere cooperation**
- **ARRL and BPL industry will have differences, but there is common ground**

HomePlug – Final Specification



What about me?

- **Notching and other mitigation aimed toward Amateur Radio**
- **Knowledgeable users, well organized**
- **Other users potentially affected**
- **Most BPL systems, for example, use 30-50 MHz**
- **They need to do what ARRL is doing and ensure that their interests are protected**

What Are Our Differences?

- Interference is very rare vs interference will be everywhere
- BPL signals are very weak vs BPL signals are very strong
- BPL signals will be strong along miles of power line vs BPL signals are point sources that will be audible for only a short distance near the BPL device
- Mobile stations can just drive away from BPL interference vs mobile stations will experience BPL over large areas
- BPL is no different than other noises vs BPL is the worst noise we have ever heard
- Where do these differences come from?

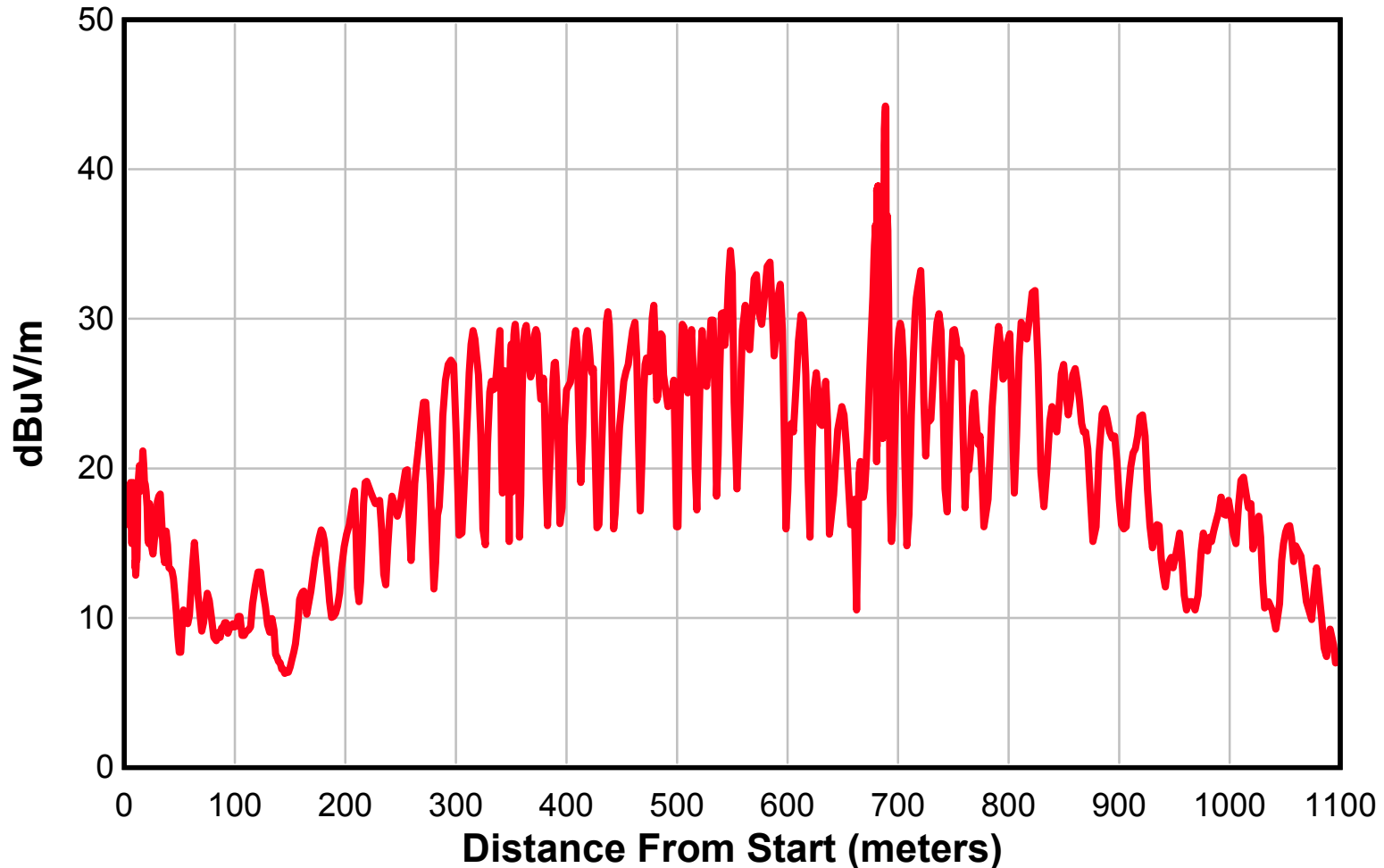
Possible Explanations

- The other side is lying to protect its own interests and can't be trusted!
- I don't believe it for a minute!
- However, all of our beliefs are shaped by our interests
- BPL manufacturers want an environment where they can manufacture and sell product
- Radio operators want an environment where their radio systems will not be degraded by external factors
- Utility engineers just want the stuff to work and not get fired for making the wrong decision!
- Everyone's perceptions are shaped by their viewpoint, experiences and what methods they use to investigate their environment

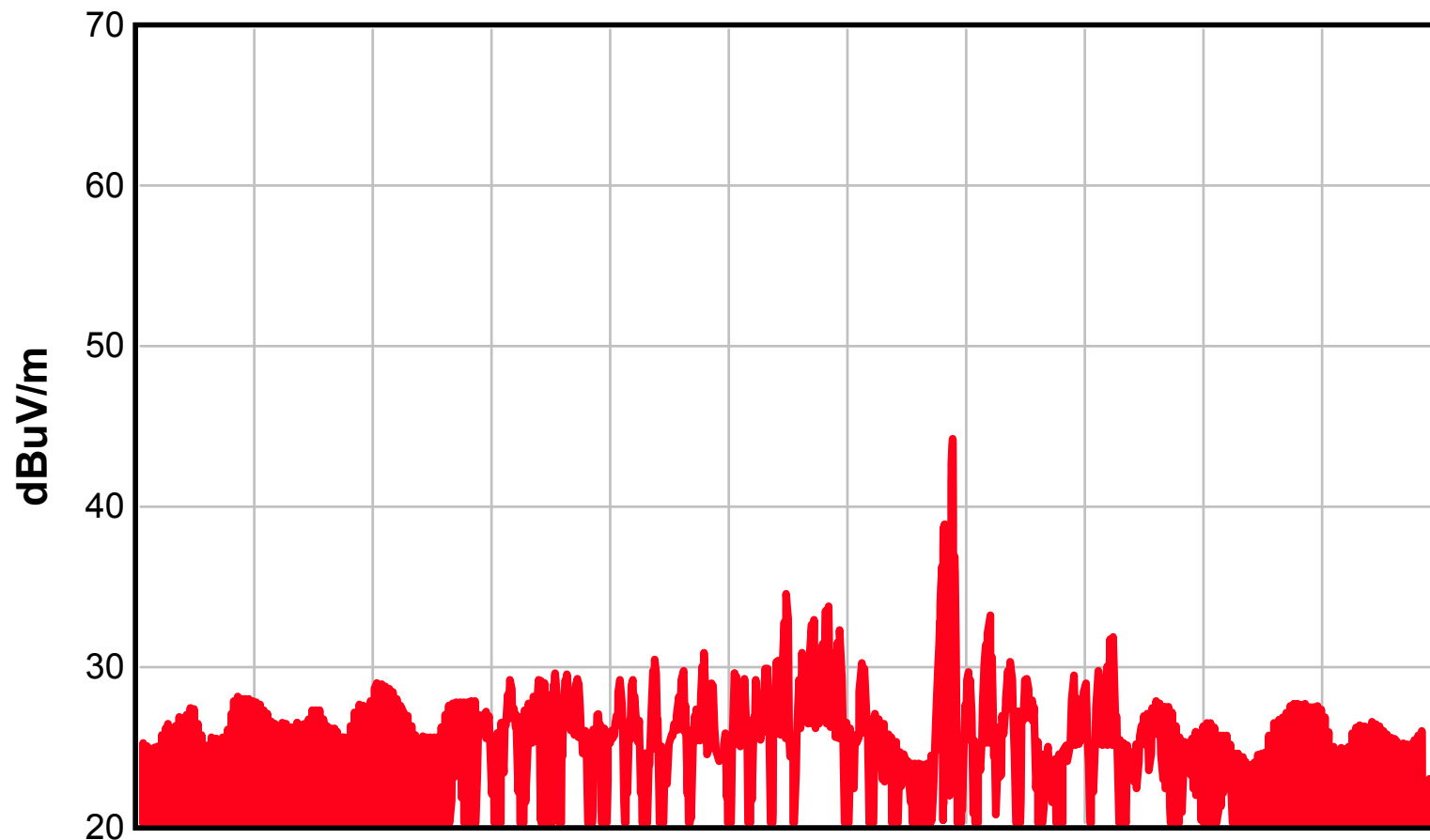
Receivers and spectrum analyzers see the world differently

- **Sensitivity**
- **Antenna gain**
- **Overload**
- **Those who use test equipment to analyze the EMC aspects of BPL will see the results differently than radiocommunications users**

14 MHz along a length of Road as seen by receiver



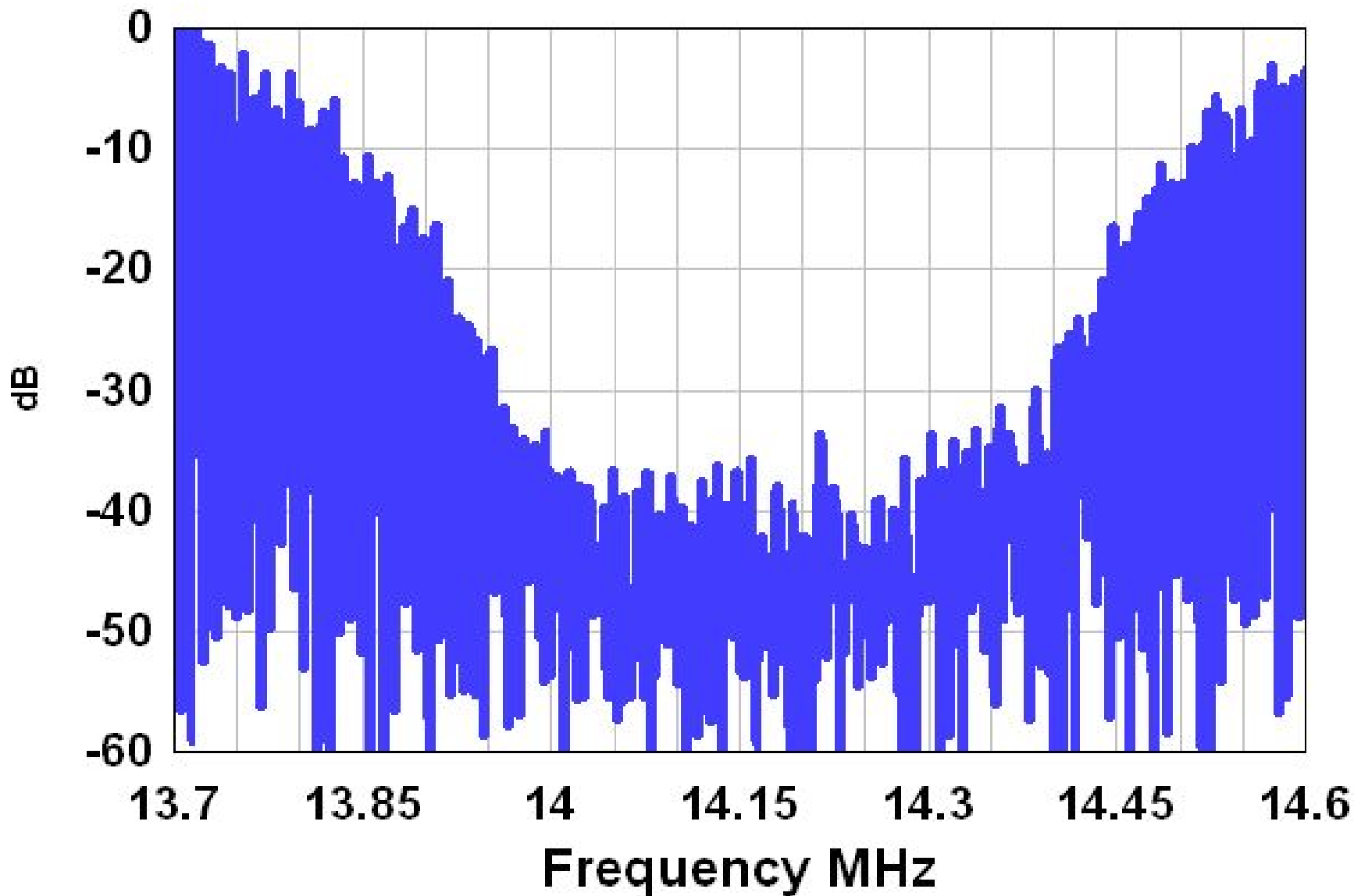
Same Data: Simulated Spectrum Analyzer



Some BPL Manufacturers are Actively Working with ARRL and Radio Users to Achieve Compatibility

- **At least for the Amateur bands...**
- **At least four BPL manufacturers have designed their systems to completely avoid the use of Amateur Radio spectrum in their systems**
- **One manufacturer has taken this one step farther, with hardware filtering to improve notches**
- **One of the chipset manufacturers 200 Mb/s technology has improved “notching” to -40 dB. This is an important improvement over existing technology**
- **Other major technology manufacturers have made the same claim**
- **The cable and DSL industries have effectively addressed EMC and if BPL is to compete, more BPL companies must follow the lead of the more progressive designs**

ARRL Lab 3/6/2006



BPL systems compared:

- **Vendor #1: wireless backbone, HomePlug modems on premise wiring, with additional filters.**
- **Vendor #2:– Primary distribution backbone, 802.11 wireless to premises**
- **Vendor #3, #4: 32-48 MHz on primary distribution, HomePlug modems on premise wiring.**
- **Vendor #5, #6, #7: Operate on 4 to 50 MHz range on primary distribution and premise wiring**
- **Vendor #8: Microwave surface wave on primary distribution wiring – still very developmental**

EMC – Why Do Utilities Care?

- **Electromagnetic Compatibility**
- **The FCC rules require compliance with emissions limits**
- **FCC rules also require that unlicensed operators not cause harmful interference**
- **Often an area of strong disagreement**
- **Win, lose or draw, interference complaints cost utilities money**
- **Licensed operators have been persistent with interference complaints**
- **Win, lose or draw – interference complaints cost utility companies money**
- **Harmful interference not clearly defined**
- **Make sure your phone doesn't ring**

Myth #5: Nobody cares about
Amateur Radio any more

Value of Amateur Radio

Rep. Steve Israel

NY-02 

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Israel Reintroduces Emergency Legislation Alongside Ham Radio Operators Who Have Served Huge Role In Rescue After Katrina

When Disaster Strikes, Ham Networks Spring Into Action; Event Features Demonstration of Amateur Radio Emergency Communication



West Babylon, NY (09/19/05)- On Monday, Rep. Israel announced the reintroduction of the "Amateur Radio Emergency Communications Consistency Act" that will help to protect the vital function of amateur radio as an emergency communications and public safety resource. Amateur radio operators have always filled in the gap when other communications systems failed. Hurricane Katrina was no exception. In the storm's aftermath, operators of amateur, or "ham," radios have been instrumental in helping residents in the hardest hit areas, including saving stranded flood victims in Louisiana and Mississippi. State and local governments, as well as disaster relief agencies, could not possibly afford to replace the services that radio amateurs dependably provide for free. However, the hundreds of thousands of amateur radio licensees face burdensome regulations that make it extremely difficult to provide their public services.

Value of Amateur Radio

“Amateur radio provides a vital public safety communications service to the public at no cost to taxpayers,” said Israel. “So-called ‘hams’ provide emergency communications when regular channels are disrupted or disabled. State and local governments, as well as disaster relief agencies, could not possibly afford to replace the services that radio amateurs dependably provide for free.”

Chapter 6

Other Radio Services

Amateur and Amateur-Satellite Services

The amateur service is defined internationally as "A Radiocommunications service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest." [EN574] Radio amateurs are trained and experienced in electronics, propagation theory, and communications techniques. [EN575] Amateurs also respond swiftly and effectively to calls for communications assistance when normal channels are lost. The amateur service has significantly contributed to the development of radio technology. Amateur operators continue to fulfill certain public service radiocommunications requirements, and increase their skills relating to emergency communications. During natural disasters such as hurricanes, floods, and other events, amateur radio communications have been particularly effective, and in many cases have been the sole means of communicating from the scene of a disaster.

The amateur-satellite service was formally created as a result of the 1971 World Administrative Radio Conference for Space Services. At that Conference and the 1979 WARC, both primary and secondary frequency allocations were granted to the service. Many of the secondary allocations are provided as a result of international Radio Regulation 664.

Amateur, or "ham" radio operators, have provided a unique service to the public while enjoying a popular, technical hobby. Many innovative uses of radio systems have been developed by amateurs for use in the amateur bands, such as packet-switched systems and amateur television. It is estimated that there are in excess of 632,000 amateur radio operators in the United States, and over 2.4 million worldwide. [EN576]

Electric Utility Interests

- **Anyone from local utility industry here?**
- **Relationship not adversarial**
- **Electric utilities want to make money**
- **RF and digital signals are a far cry from 60 Hz**
- **PPL technology**
- **Interference and other issues can undercut profitability**
- **ARRL has 300 power-line cases**
- **ARRL/FCC cooperative program**
- **50 cases referred to FCC**
- **Cases have dragged on for years**
- **“Conventional” power-line noise has solutions**
- **What are the solutions for interference from BPL?**
- **Profitable?**

Questions Utilities Should Ask

- **How does your technology deal with interference issues?**
- **What solutions do you have if notching doesn't work?**
- **What do you consider to be legitimate interference?**
- **Is your product Certified under the new FCC rules?**
- **Is G2 technology available right now?**
- **Does the implementation notch all of the NTIA bands and frequencies that may be in use locally?**
- **If the answer doesn't include Amateur Radio, expect interference complaints if it is deployed where fixed or local Amateur operation is likely**
- **Ask them what they think of Ed. 😊**

Interference to BPL

- **Initial tests show that BPL can be susceptible to ingress from nearby transmitters**
- **Amateur radio may use EIRPs of 20 kW or more**
- **Field strength at power lines may be 100 V/m (160 dBuV/m)**
- **Tests show as little as 2 watts can take it down**
- **More testing is needed, but industry reluctant to do so**
- **Utilities starting to work with ARRL, including the Electric Power Research Institute**

Scope of ARRL testing

- **ARRL staff have done testing in 16 cities where BPL is located**
- **Other radio Amateurs have done testing in several other areas**
- **ARRL testing done for EMC assessment, not for compliance purposes**

Types of ARRL testing

- **Computational, mainly using NEC-4**
- **Interference assessment**
- **Site survey, spectrum assessment**
- **Measurement of noise floor**
- **Measurement of ambient signal levels**
- **Relative measurements of noise-floor degradation**
- **Field-strength measurements**

Results of ARRL testing

- **247 pages of graphs and charts follow**
- **Findings have ranged from systems that exceed FCC emissions limits by 25 dB or more to systems operating 10 dB below the limits**
- **Findings have ranged from strong interference to systems that deployed without major interference problems**
- **Some systems in the middle, with interference problems that were corrected**

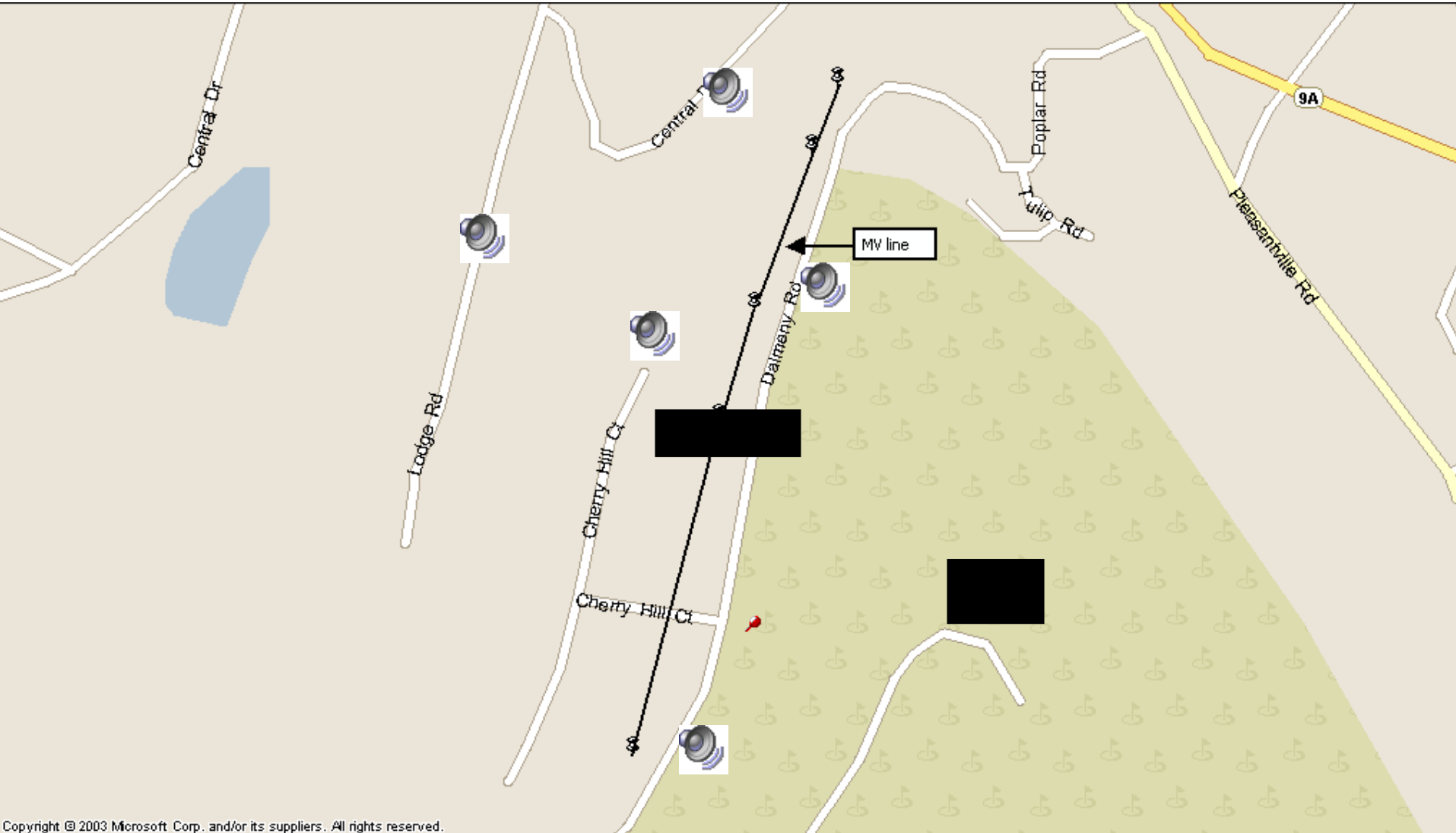
Measurement of noise floor

- **Ambient levels of man-made noise can range down to -20 dBuV/m at HF-station antennas**
- **It is not possible to measure this level with spectrum analyzer and typical EMC antenna**
- **Such measurements, even with active loops, are really measuring the noise floor of the test equipment**
- **Communications receivers and real-world antennas are much more sensitive than EMC test equipment**
- **To measure ambient levels, as a minimum, an EMC receiver and 8-foot monopole antenna, tuned to resonance with inductive loading, would be needed.**

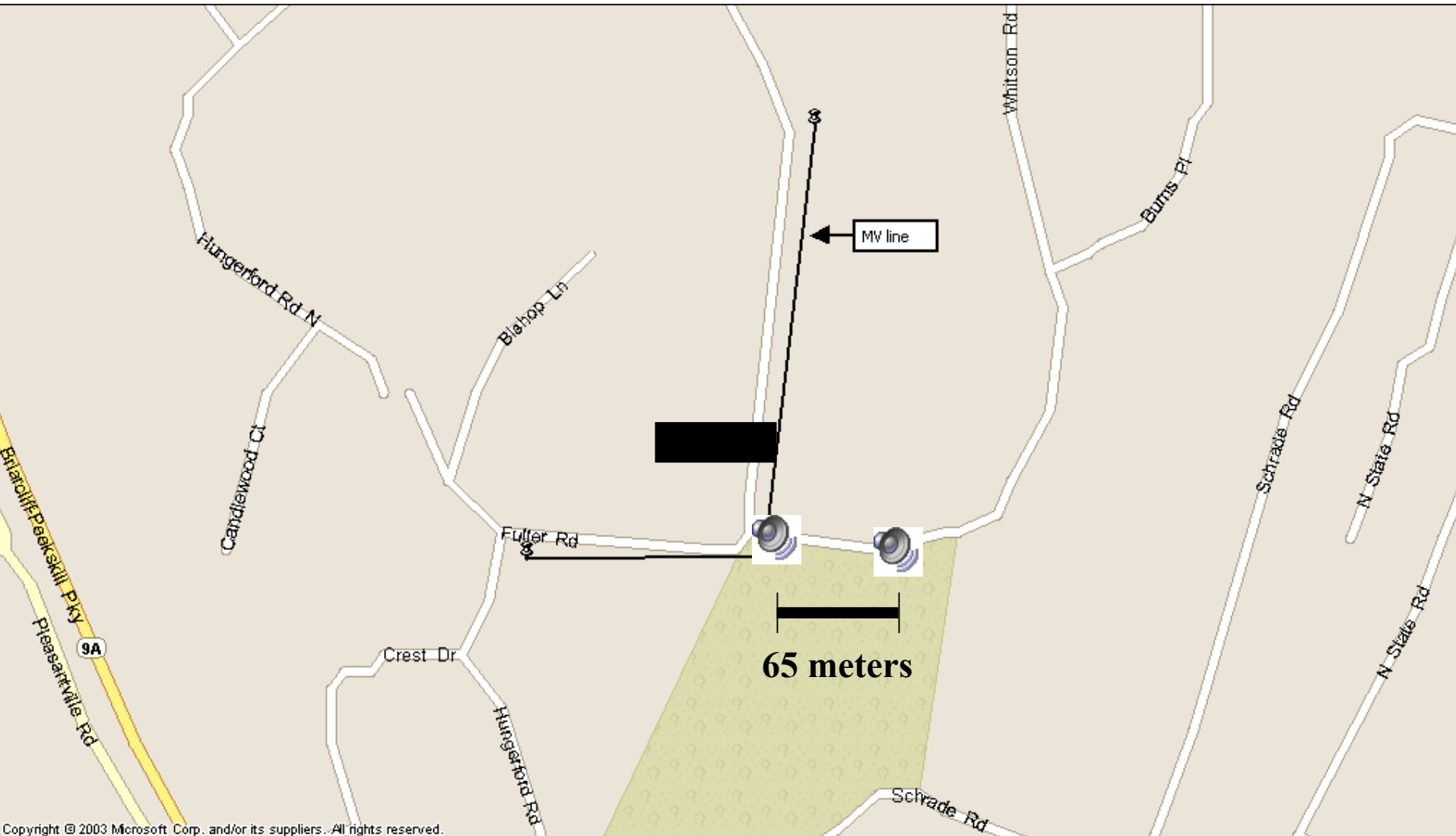
Distances From BPL Power Lines Within Which Interference Is Likely

Desired Signal Level		LOW – MODERATE	MODERATE - HIGH
Service			
Land Mobile Station		125 m	55 m
Fixed or Base Station (for Mobile)		770 m	450 m
Maritime Shipborne Station		135 m	85 m
Aircraft alt:	6 km	33 km	12 km
in Flight alt.	12 km	> 50 km	-

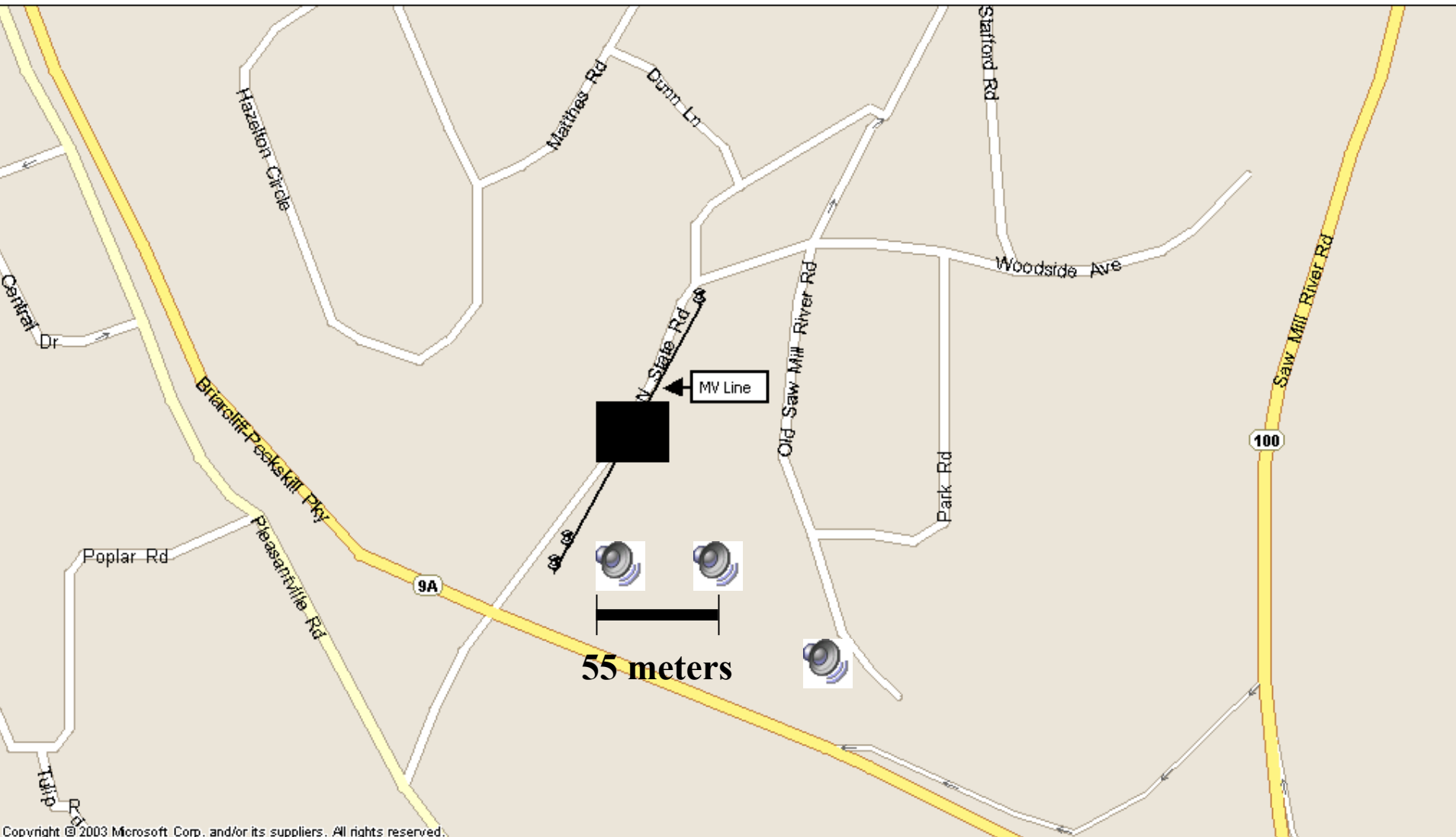
BPL at various locations in a BPL area. Injector is near point labeled “MV line”



The left speaker was recorded 10 meters from the BPL injector. The right speaker was recorded 75 meters from the injector. The power line does NOT run down the street where the recording was made.



This was recorded in a parking lot, with no power lines in the lot. The left speaker was 15 meters from the power line. The middle speaker was 70 meters from the power line and the right speaker 125 meters from the power line.



Video

<http://www.arrl.org/news/stories/2004/06/18/8/BPL-and-HF-web.mpg>

Calculations

- **Done with a variety of tools**
- **Simple calculators**
- **Show example**
- **Antenna modeling**

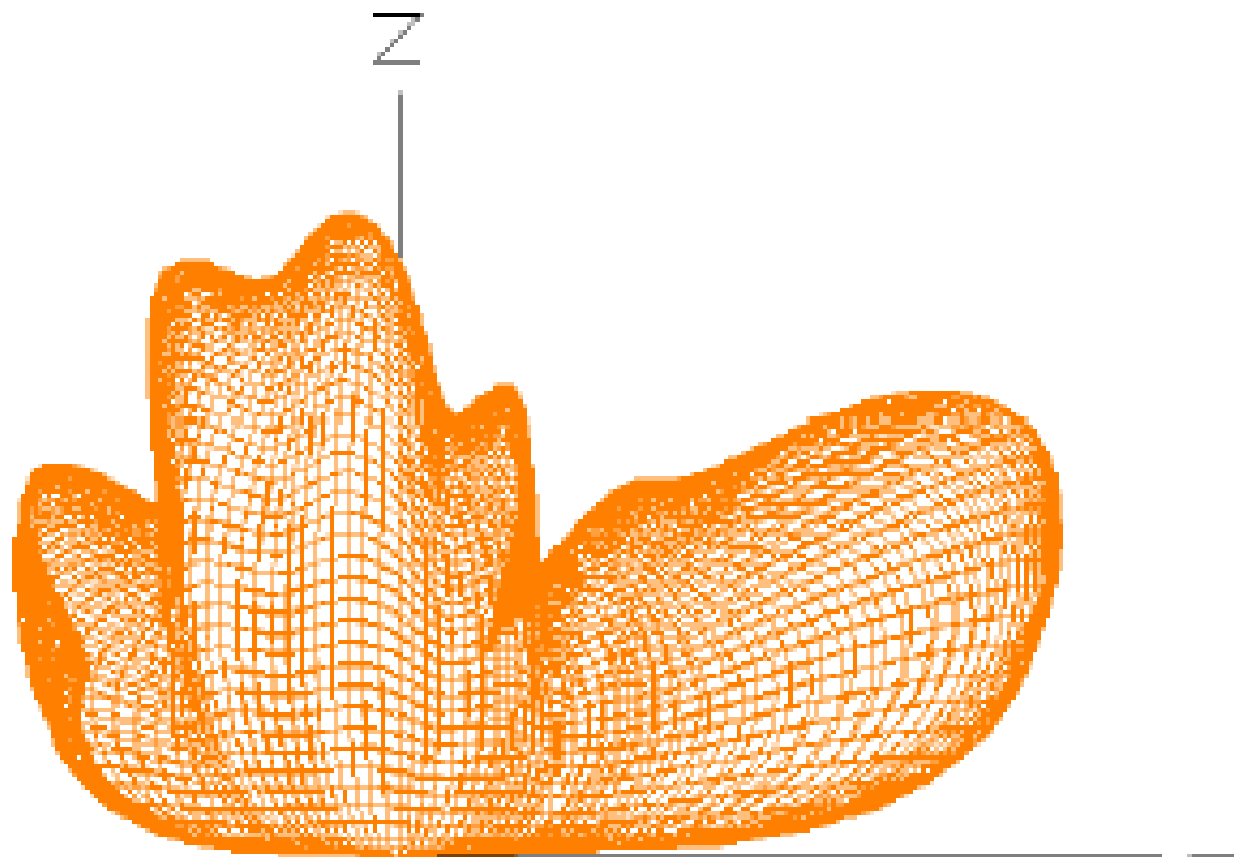


Figure 5:

At 5 MHz, the power-line model is showing considerable gain and directivity. At +1.3 dBi, this is no longer just a transmission line; it has become an effective antenna. Its gain generally increases with frequency. (DIP5.EZ)

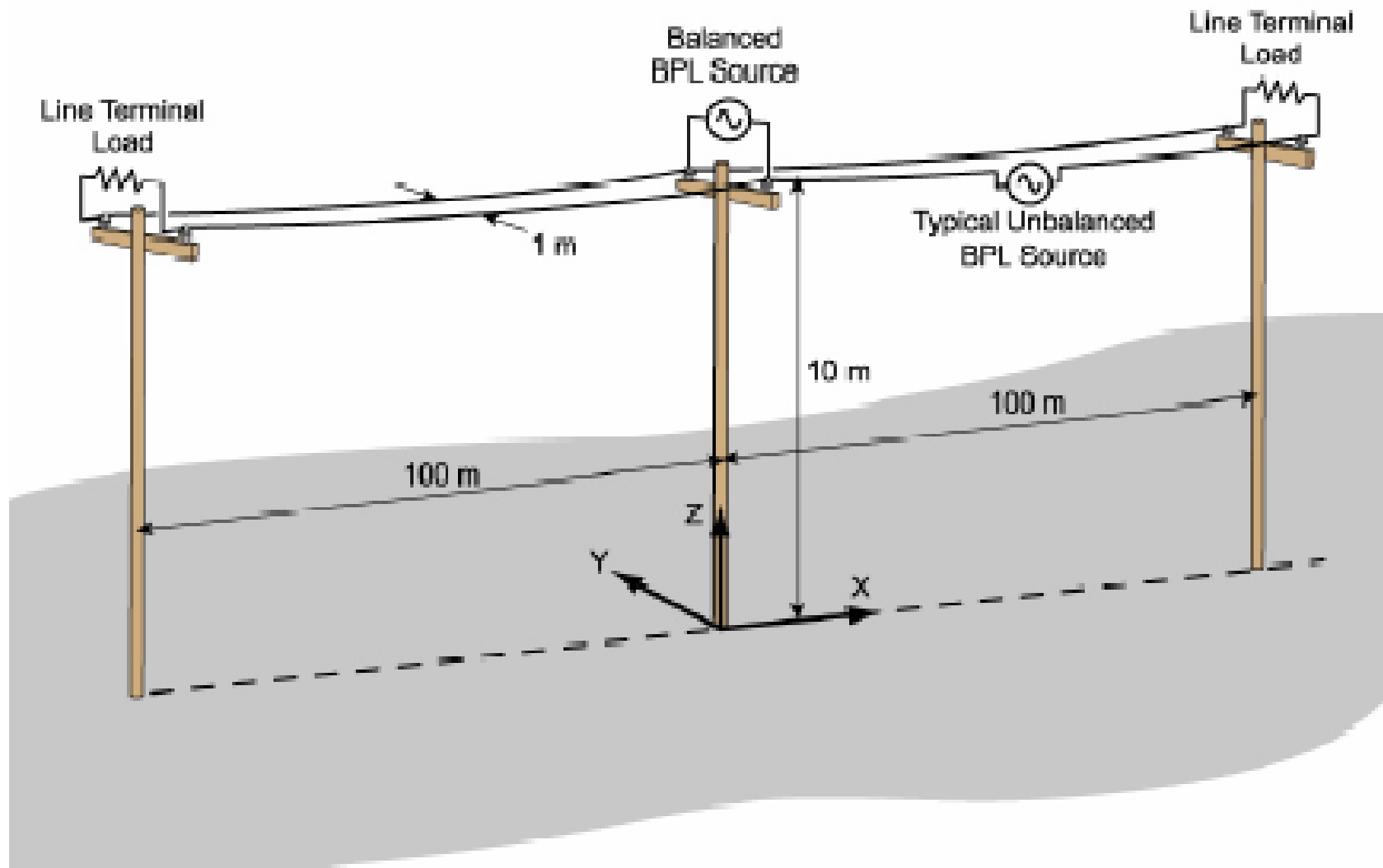
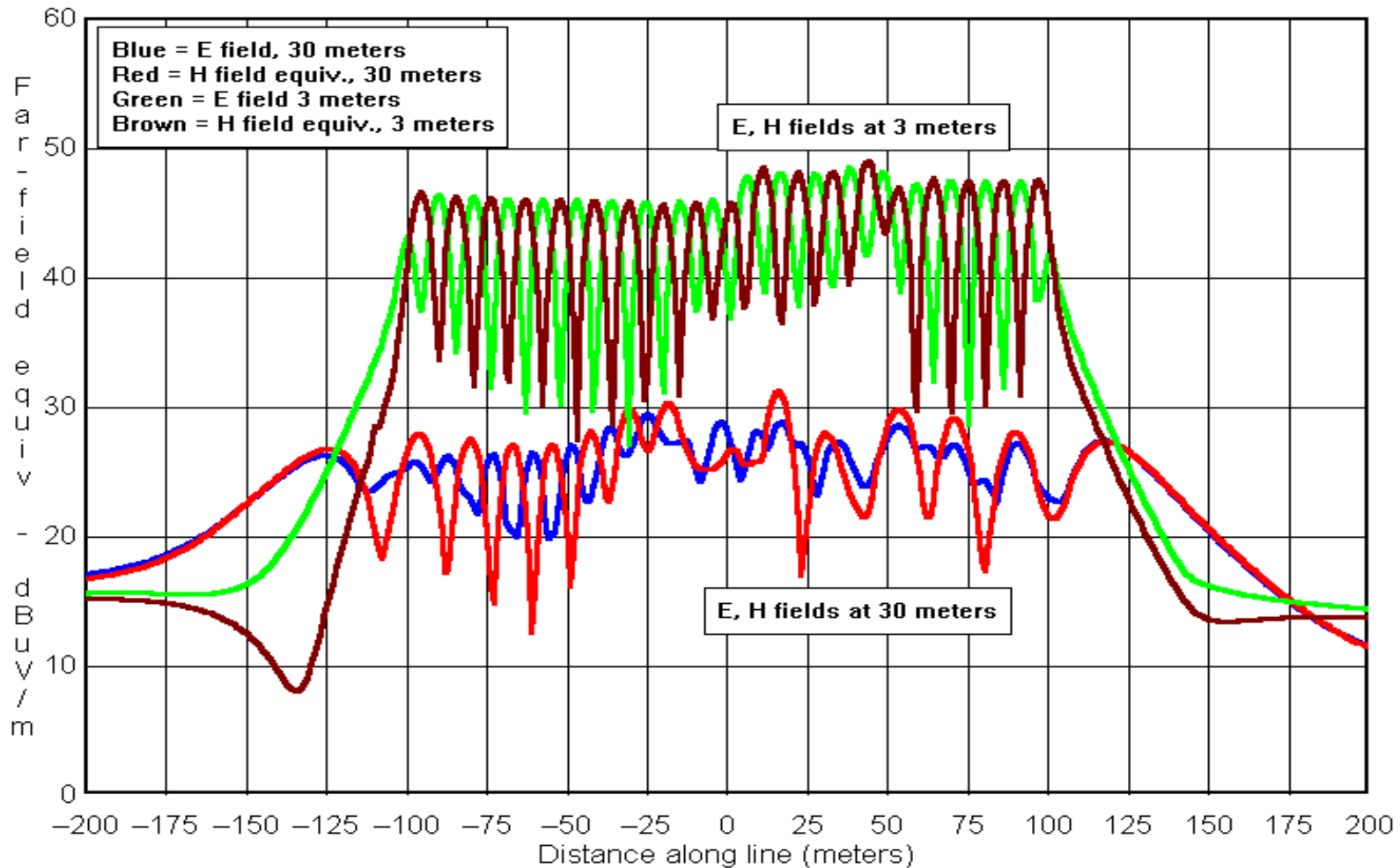


Figure A.1. ARRL used the dimensions of the model AEC described in its NPRM filing to model both the ideal balanced feed modeled by AEC and the typical unbalanced feed seen in present BPL systems.

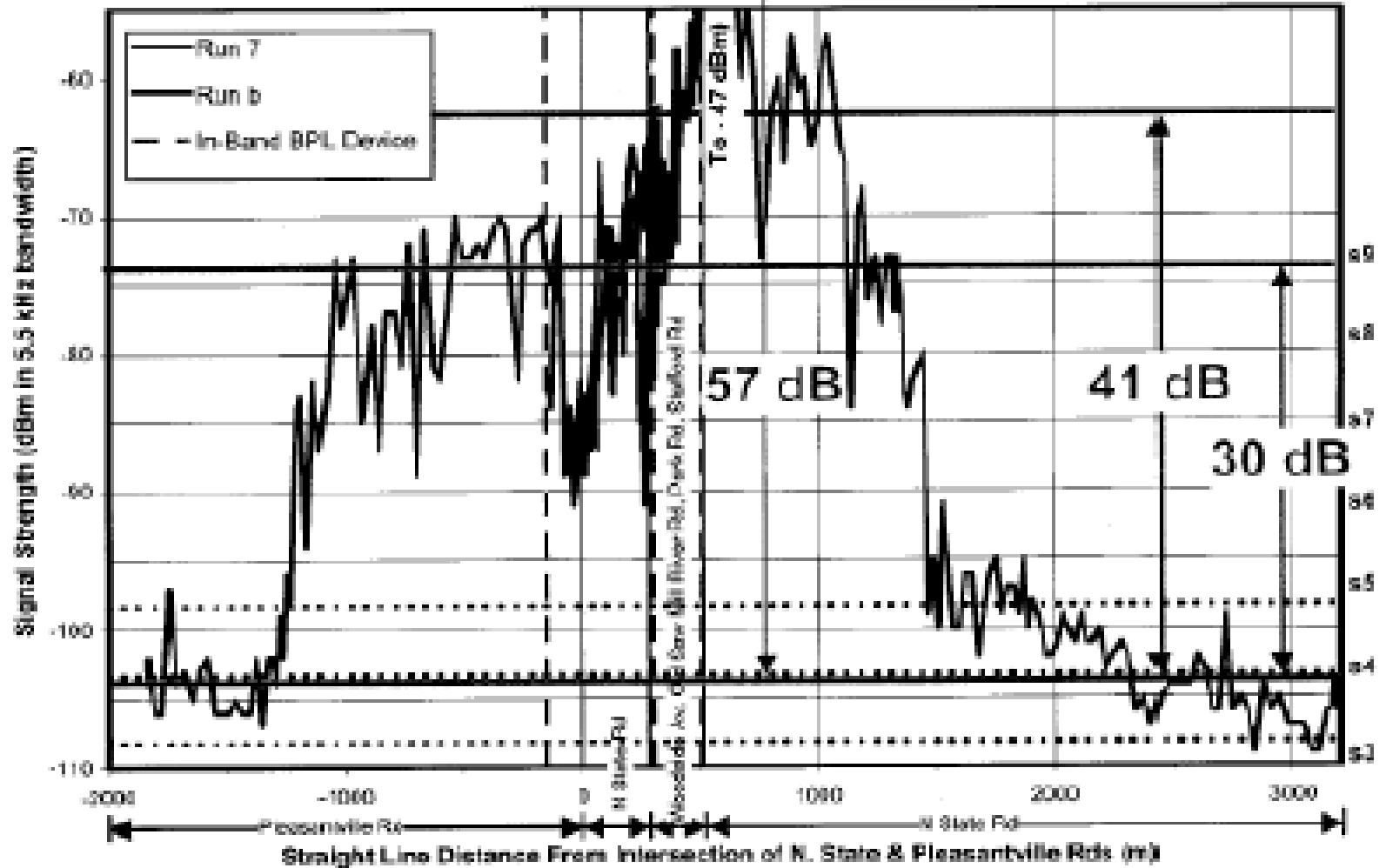
Fields Near Large Radiators – 14 MHz

30 meter/3 meter ratio 16 dB



(Unnotched Amateur Band)

FCC Laboratory



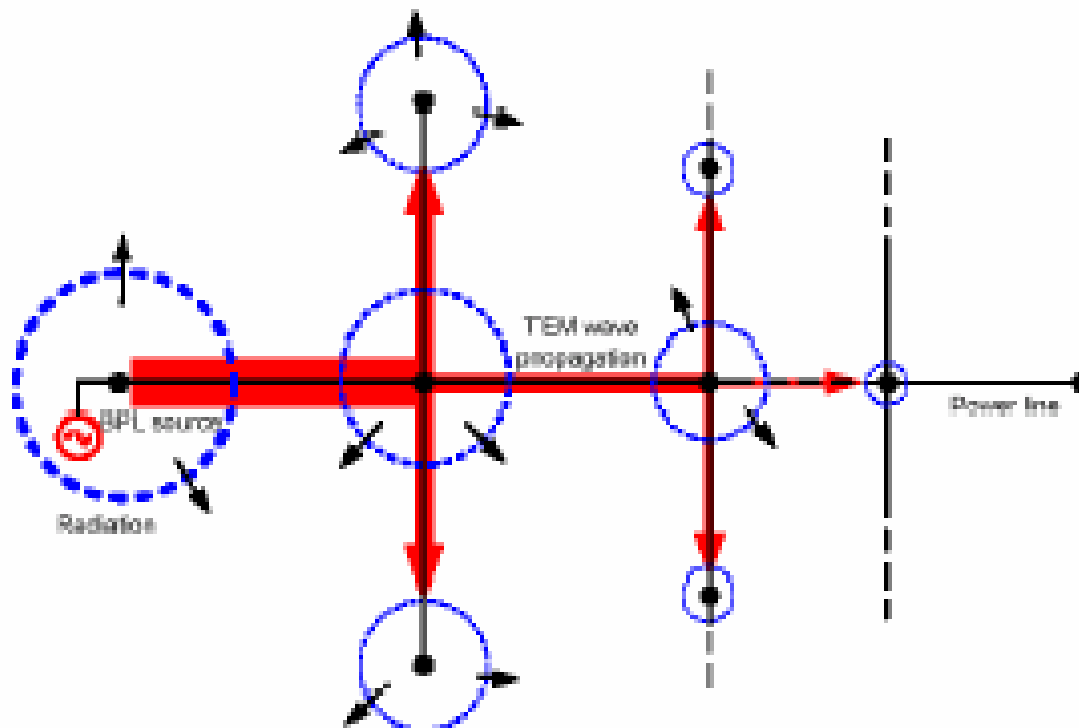


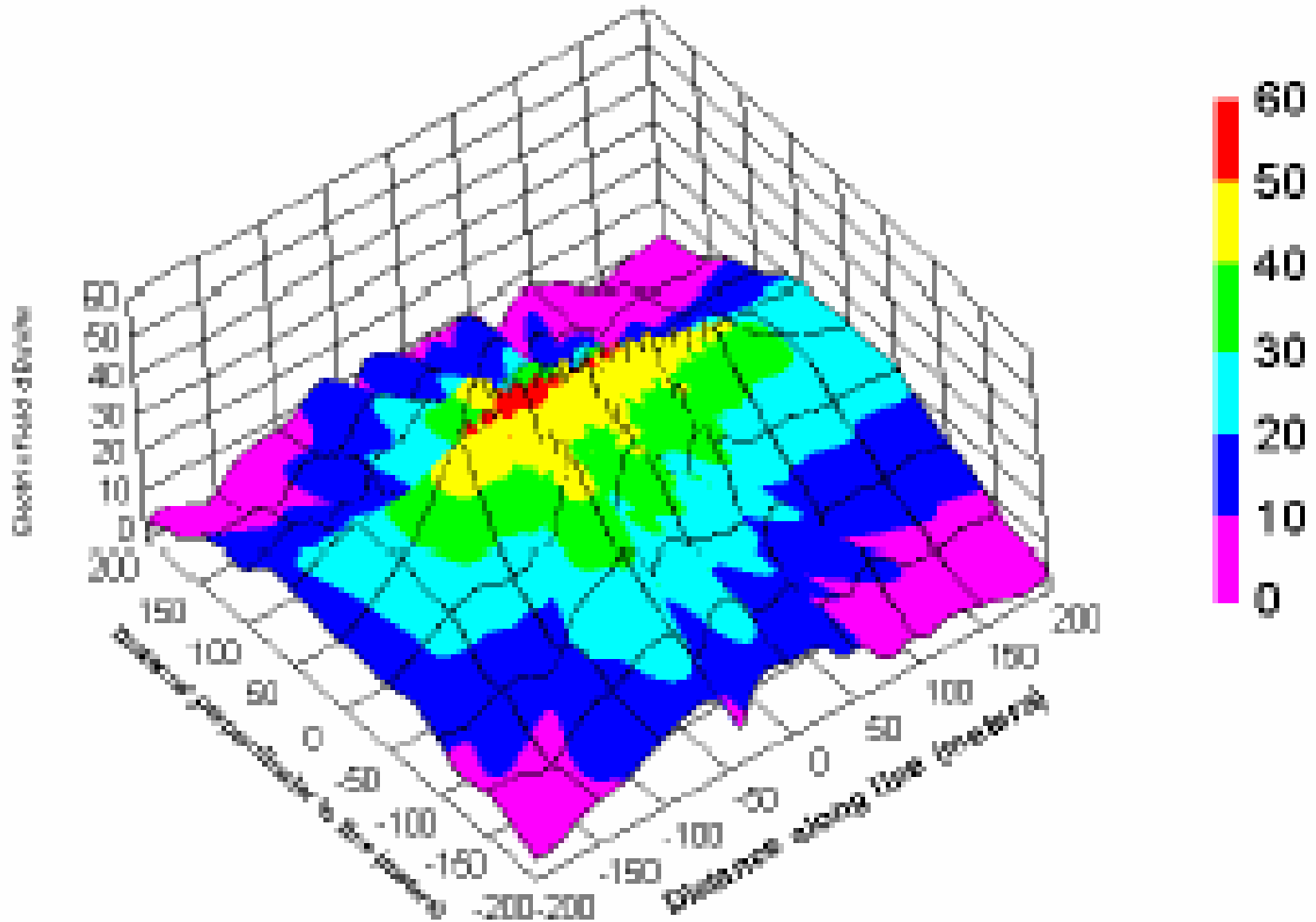
Fig. 3. Conceptual representation of the radiation from a single source BPL. Red line indicates the TEM wave path. Circles indicate the location and strength of radiation points.

Figure A.8. This line drawing was used by [REDACTED] to state that power lines radiate only as point sources.

Fields Near Power Line Antenna

Electric field at a height of 2 m

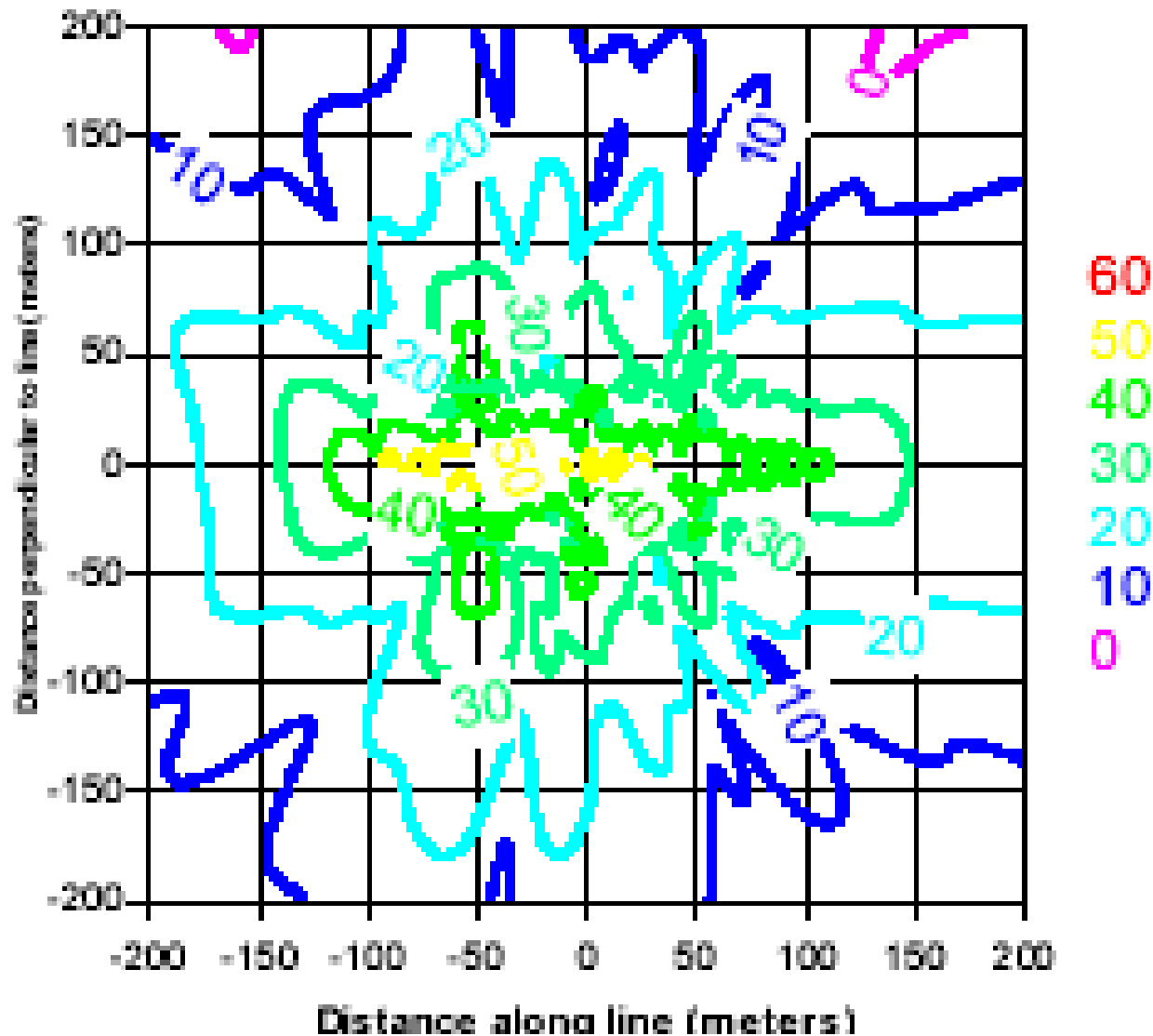
Normalized to 30 $\mu\text{V}/\text{m}$ at 30 m



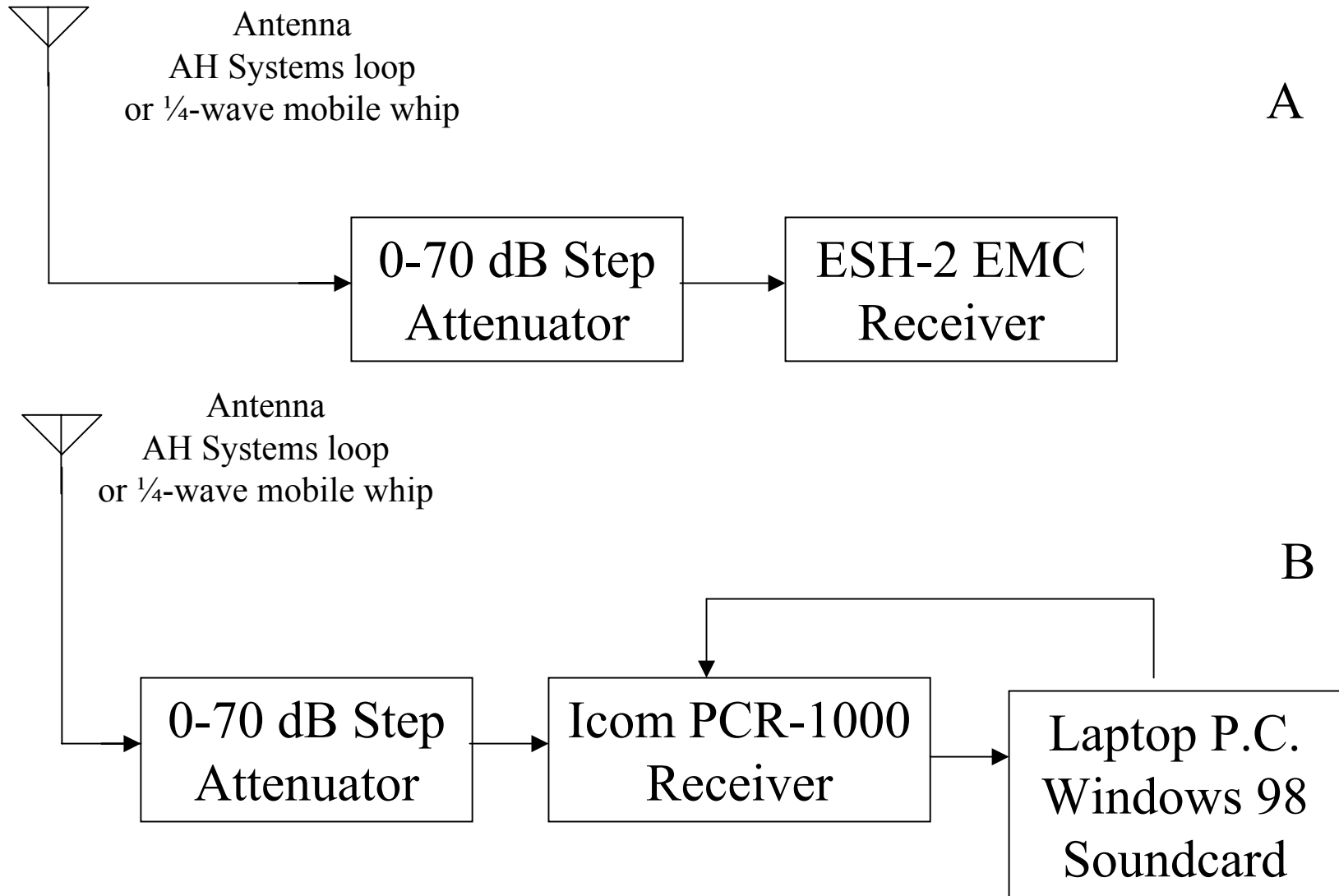
Fields Near Power Line Antenna

Electric field at a height of 2 m

Normalized to 30 uV/m at 30 m



Field testing – typical test fixture



Signals Measured in Amateur Radio Service Spectrum 14 - 14.35 MHz, October 1, 2004, 2220 UTC, Burlington, CT ESH-2 and Inductively Loaded Vertical Whip Antenna

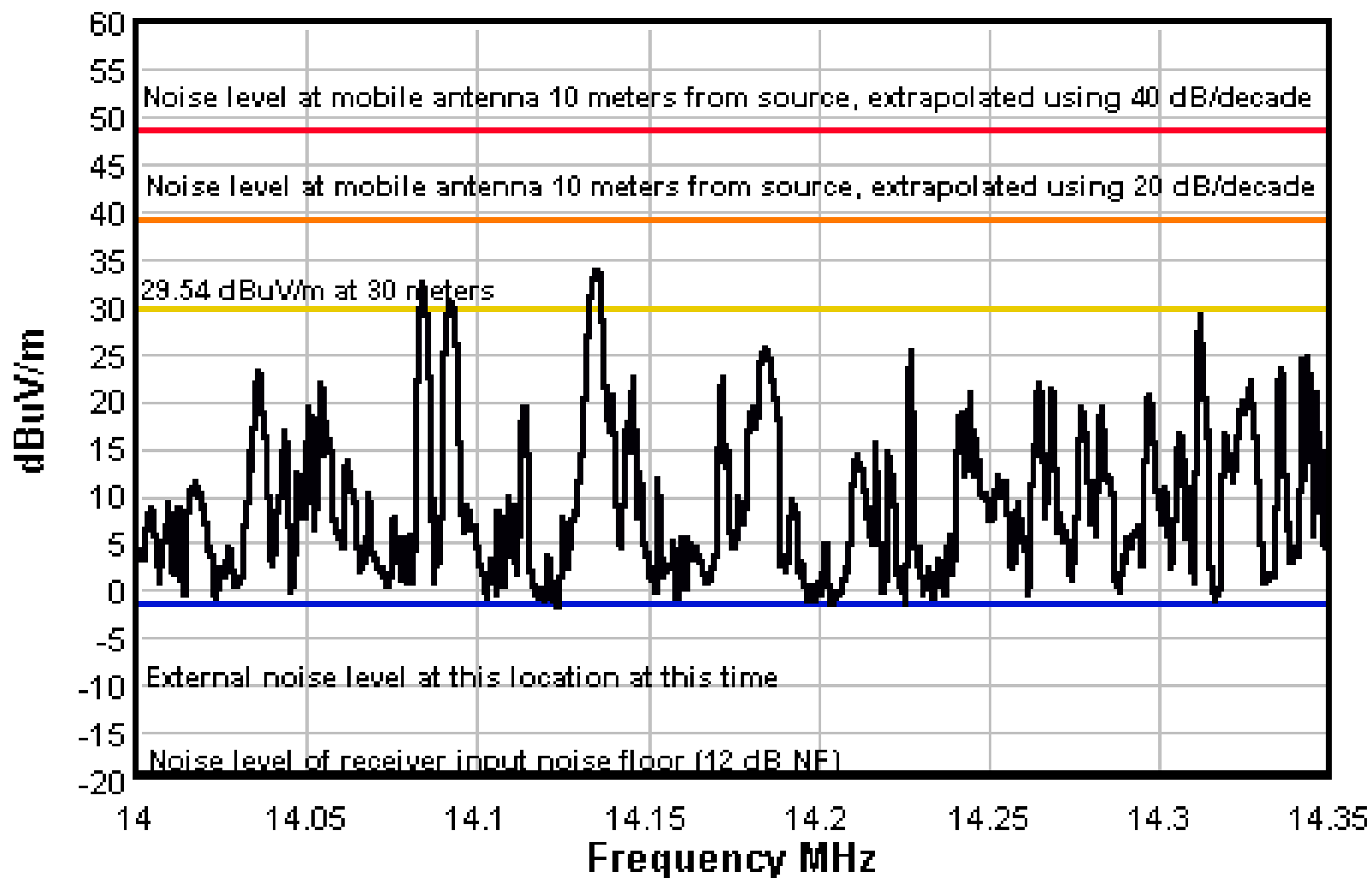
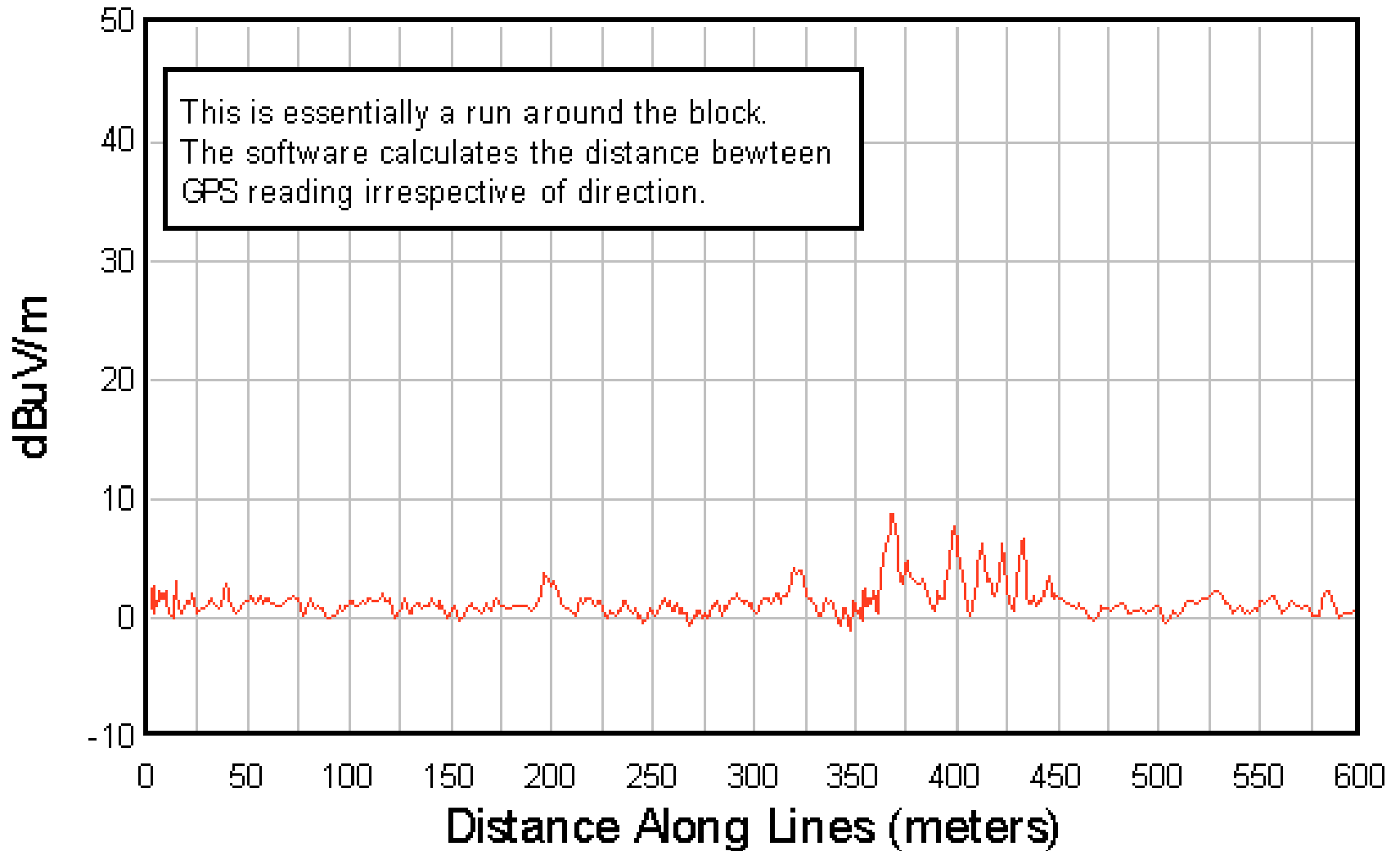


Figure 4 – These are the signals that were present on the 14-14.35 MHz Amateur band on October 1, 2004 at 2220 UTC. The lower line shows the sensitivity that would result from the use of a typical communications receiver with a 12 dB noise figure.

September 19, 2004 1700 UTC



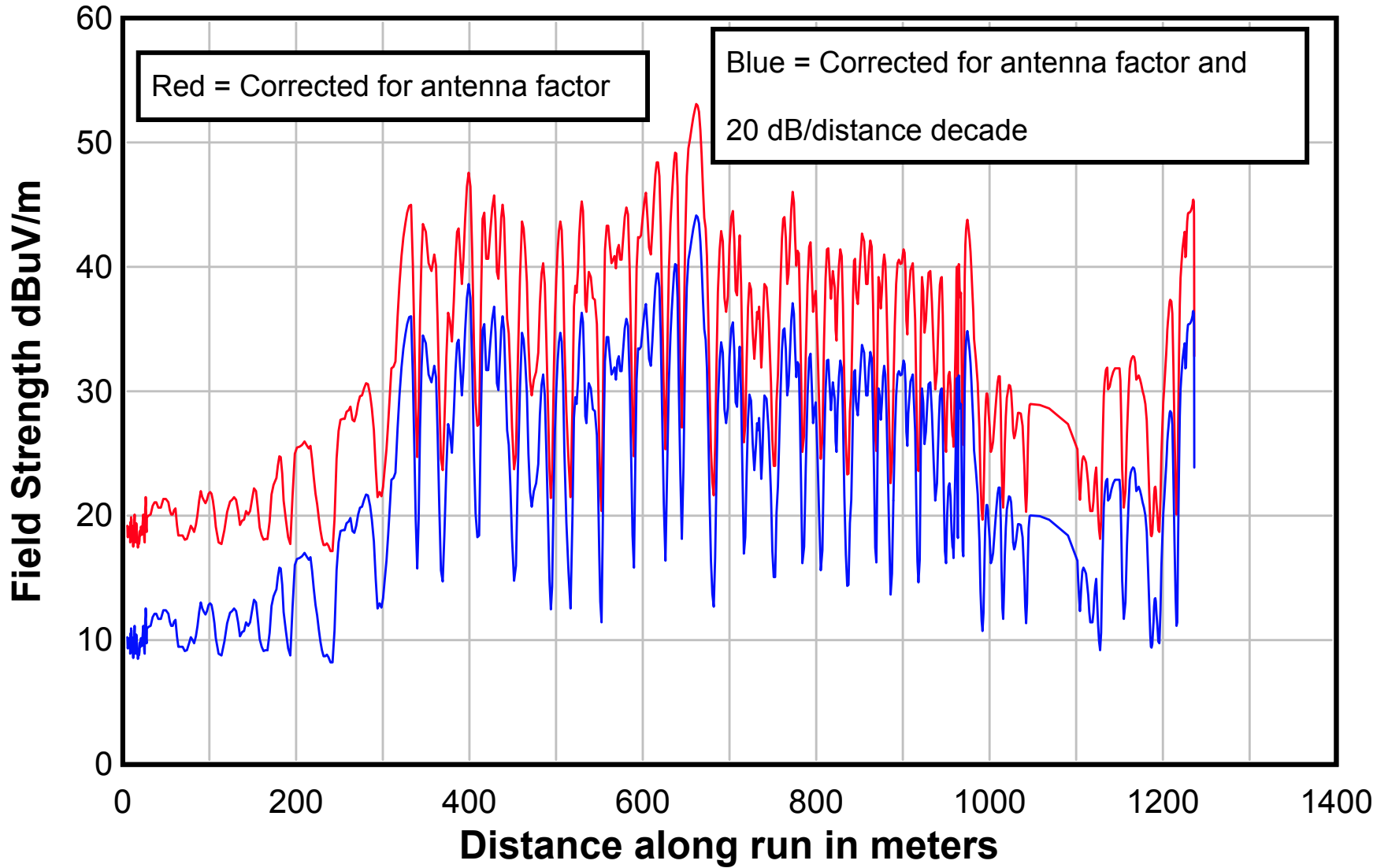
**Measurements of field
strength in areas where
BPL is deployed**

(vendor and city location not included)

FCC Measurement Method

- **CISPR Q.P. 9 kHz<30 MHz; 120 kHz>30 MHz**
- **Measure 10 meters horizontal distance from line**
- **Measure 1 meter off ground**
- **Use magnetic loop**
- **30 uV/m 30 meters from source**
- **Extrapolate at $1/D^2$ <30 MHz to slant-range distance to power line**
- **What's wrong with this picture?**

September 21, 2004 1600 UTC



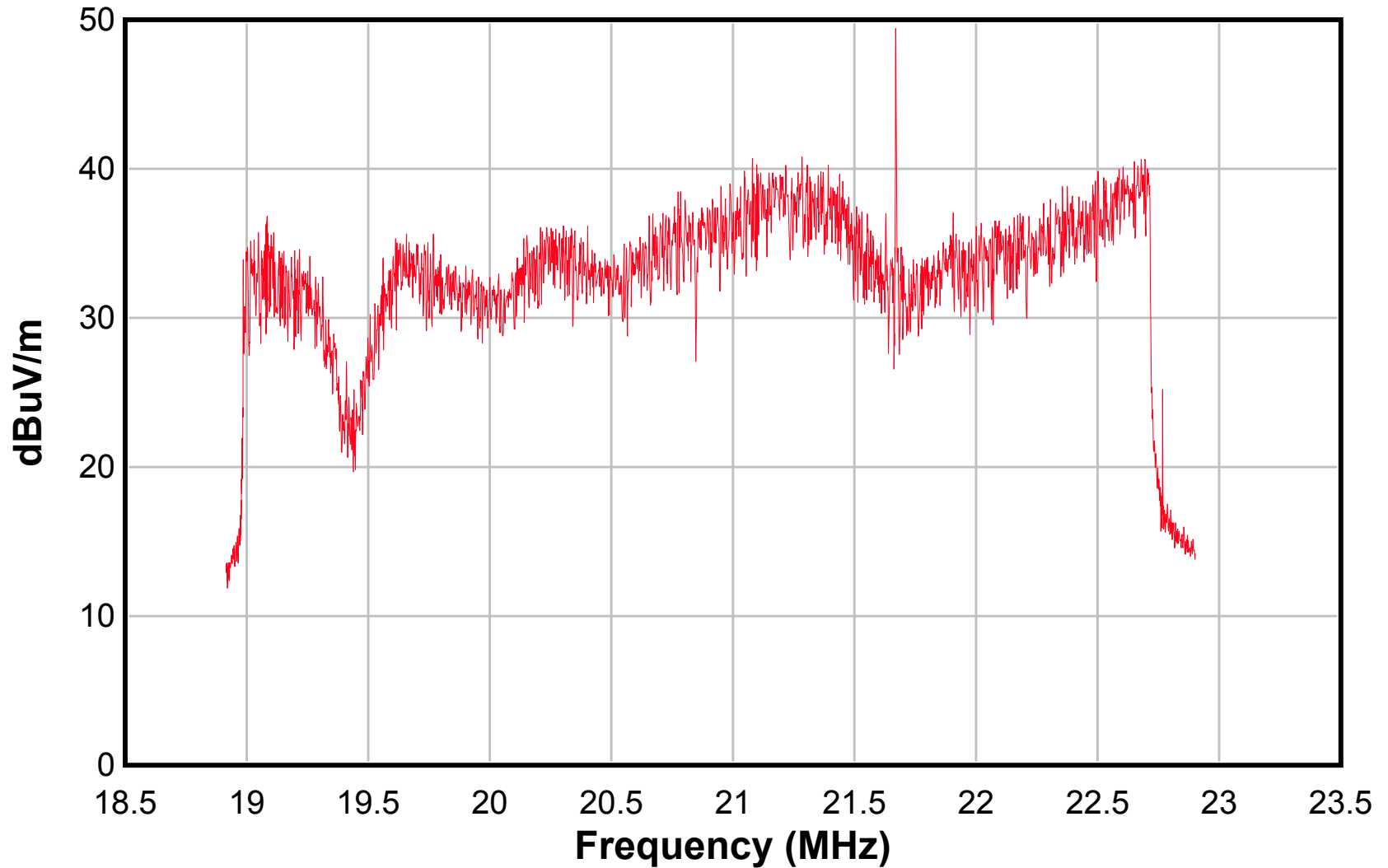
In addition to the mobile test run, tests were made at several fixed locations. The following show the actual measured signal levels at these points:

Test point	GPS coordinates	Frequency	Measured Field Strength
170 Dalmeny Road	41.14862° 73.83585°	14.588 MHz	36.9 dBuV/m at 30 m Extrapolated at 20 dB/decade
170 Dalmeny Road	41.14862° 73.83585°	14.345 MHz BPL on	22 dBuV/m Measured at mobile whip antenna
170 Dalmeny Road	41.14862° 73.83585°	14.345 MHz BPL off	8 dBuV/m ⁴ Measured at mobile whip antenna
Near corner of Dalmeny and Poplar	41.15156° 73.83231°	28.5 MHz	37.1 dBuV/m Measured at mobile whip antenna ⁵
67 Woodside Ave	41.15295° 73.82747°	3.85 MHz	37.5 dBuV/m at 30 m Extrapolated at 20 dB/decade
Park Road Behind police station	41.15201° 73.82778°	3.85 MHz	71.9 dBuV/m at 30 m Extrapolated at 20 dB/decade ⁶

These test data demonstrate significant, strong degradation of spectrum allocated to the Amateur Radio Service. In some cases, they show that the emissions are significantly greater than what is permitted by FCC Part 15 regulations. At the time these measurements were made, this system was not operating in compliance with Part 15.

Frequency sweep 18.9-22.9 MHz

October 3, 2004



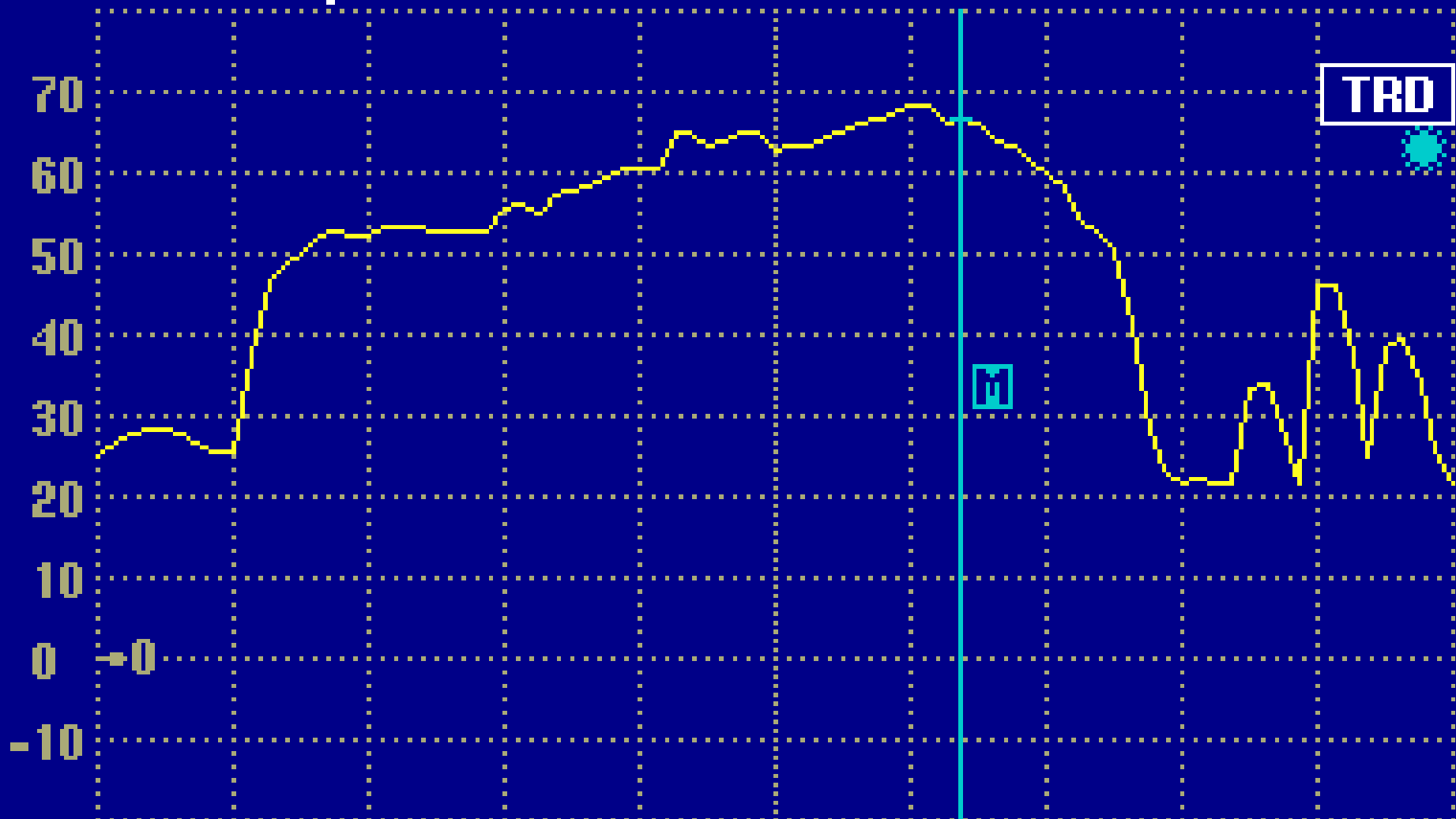
M : 16.55 MHz

66.4 dB μ V/m

RBW: 9 kHz

● Ref: 80 dB μ V/m

MT: 500 ms



Start: 14 MHz

□ Stop: 18 MHz

bcm.006

EXIT

ACTIVATE

SCREEN- \rightarrow
PRINTER

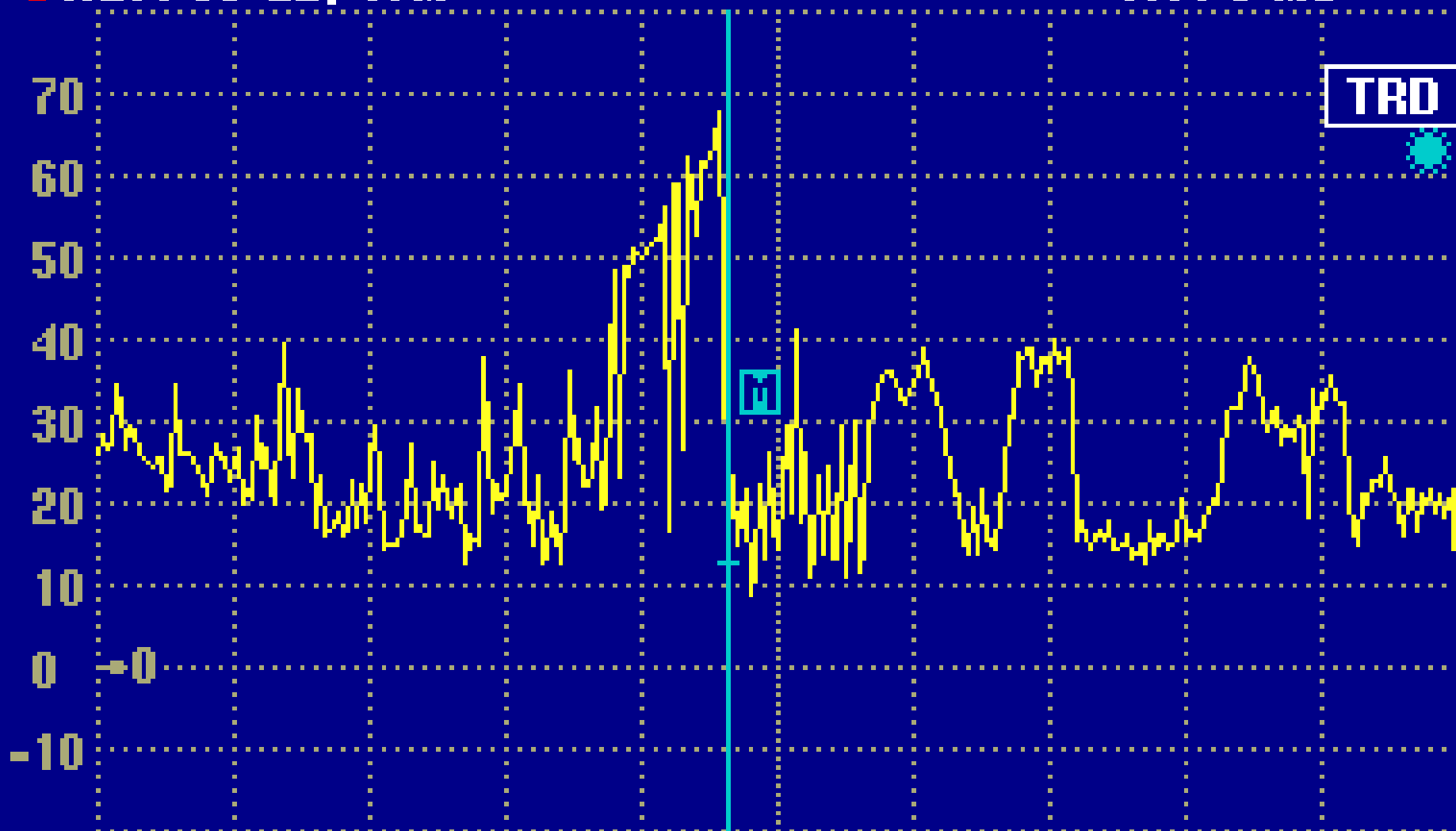
M : 16.6 MHz

12.7 dB μ V/m

RBW: 3 kHz

● Ref: 80 dB μ V/m

MT: 5 ms



Start: 5 MHz



Stop: 30 MHz

bcm.008

EXIT

ACTIVATE

SCREEN- \rightarrow
PRINTER

FCC Limits were apparently exceeded by at least 22 dB in this system:

The test fixture and measurement software made the following measurements, estimated as quasi peak field strength in a 9 kHz measurement bandwidth. These data are not extrapolated to distance.

3.52 MHz:

69.2 dBuV/m

68.7 dBuV/m

69.1 dBuV/m

69.0 dBuV/m

70.9 dBuV/m

Average: 69.4 dBuV/m

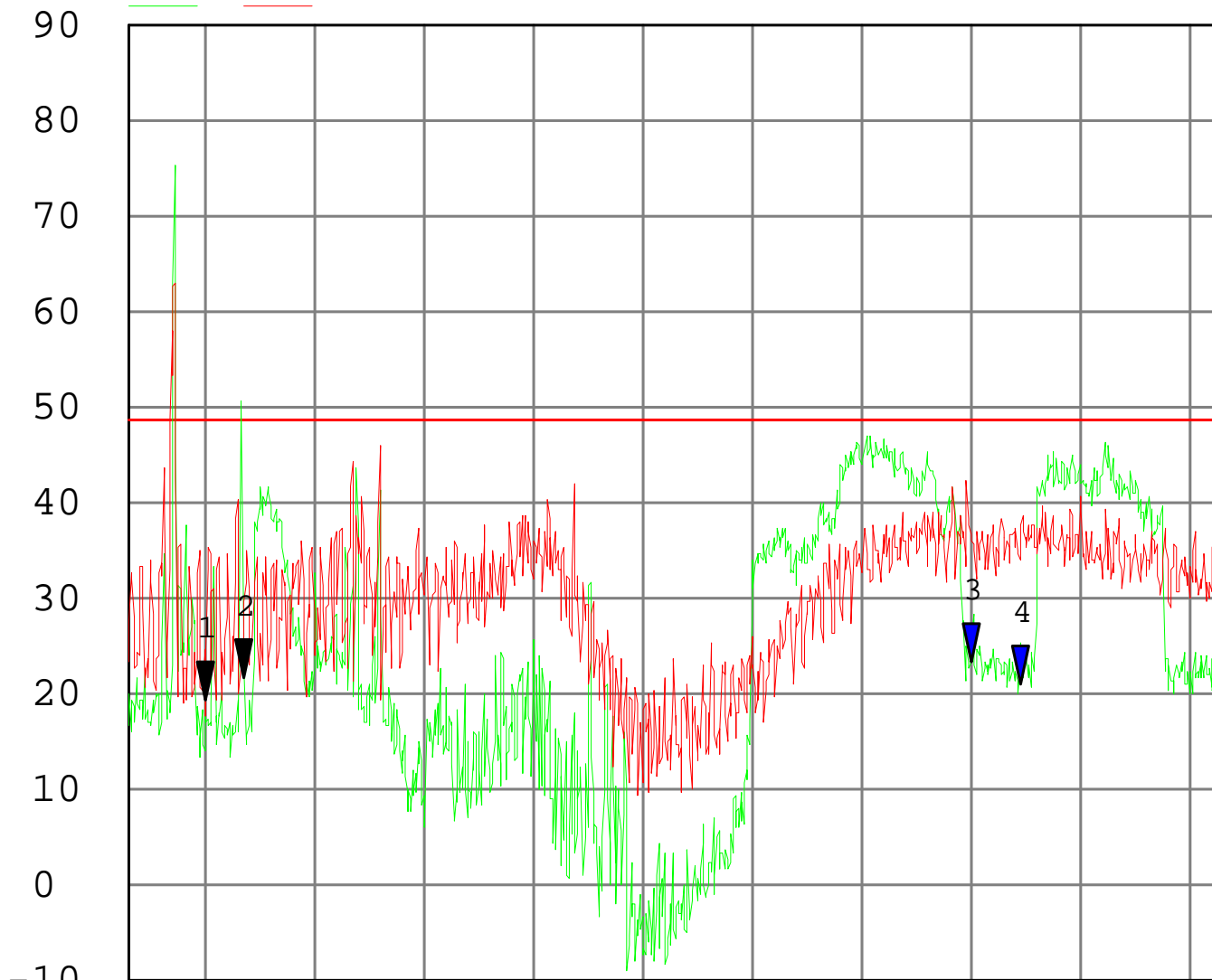
Bring the mountain to Mohammed

A number of BPL manufacturers have taken out experimental licenses. One of the conditions of their license is that they file 6-month reports with the FCC, showing the measurements they make to determine compliance with the emissions limits. The following are from some of their reports, or represent an ARRL analysis of same.

Sawmill Second Pole Mount

dBuV

PEAK OFF



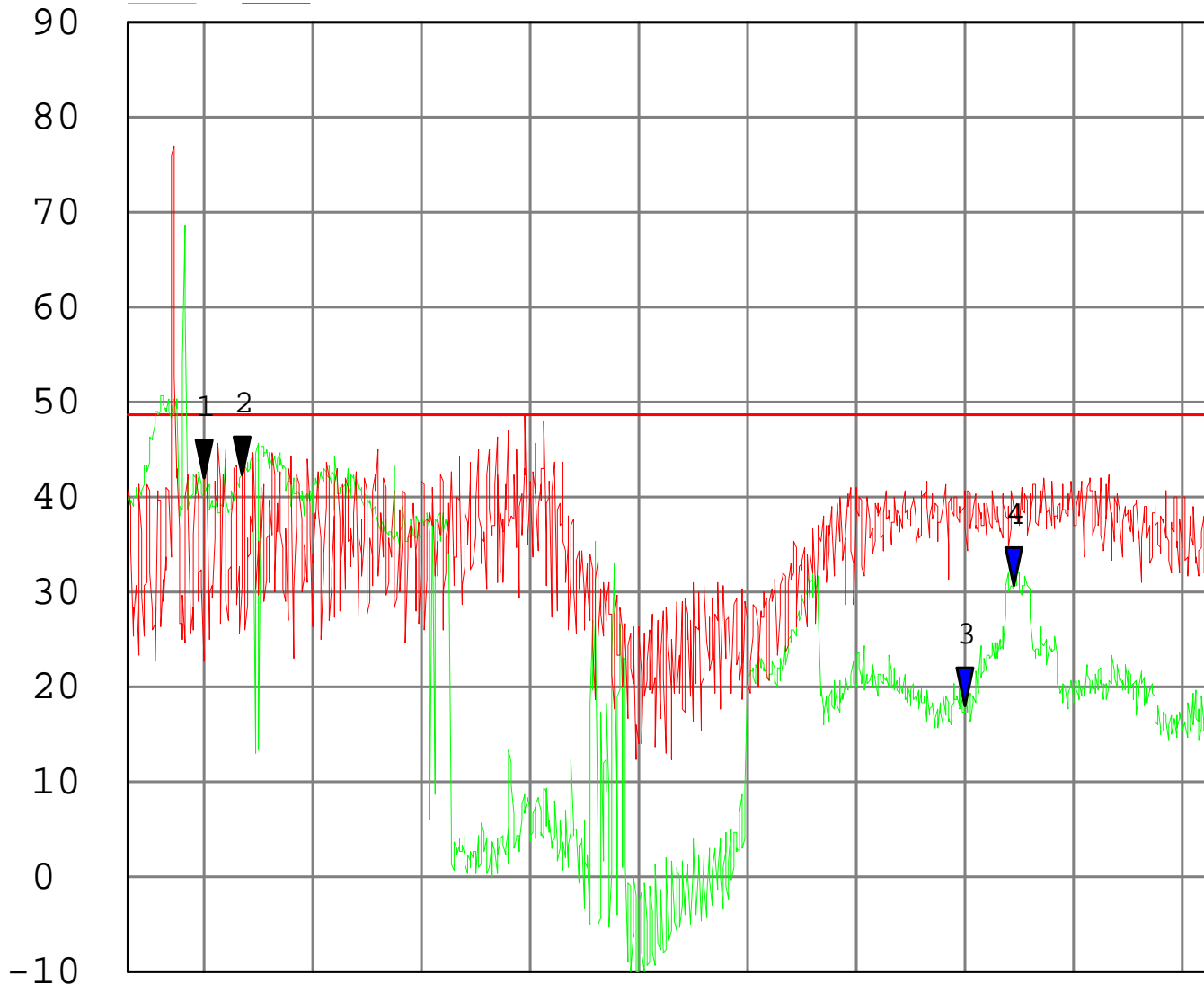
- 1 PEAK
▼ 14.000 MHz
19.45 dBuV
- 2 PEAK
▼ 14.350 MHz
21.71 dBuV
- 3 PEAK
▼ 21.000 MHz
23.19 dBuV
- 4 PEAK
▼ 21.450 MHz
21.15 dBuV

Start: 13.300 MHz Stop: 23.300 MHz
Res BW: 9 kHz Vid BW: 3 kHz Sweep: 1.20 s
9/8/2004 7:10:26 AM to 23.3.spt R3132

Sawmill First Pole Mount

dBuV

PEAK OFF



- 1 PEAK
▼ 14.000 MHz
41.90 dBuV
- 2 PEAK
▼ 14.350 MHz
42.17 dBuV
- 3 PEAK
▼ 21.000 MHz
17.99 dBuV
- 4 PEAK
▼ 21.450 MHz
30.70 dBuV

Start: 13.300 MHz

Stop: 23.300 MHz

Res BW: 9 kHz Vid BW: 1 kHz Sweep: 3.40 s

9/8/2004 6:42:01 AM 13 to 23_3.spt

R3132

To be done

- **More measurements of roll off vs distance**
- **Levels vs height**
- **Extrapolation (a distance vs height issue)**
- **Ingress**

Q&A

a.k.a. Stump the Speaker



MORE INFORMATION

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