NTIA Report 04-413

POTENTIAL INTERFERENCE FROM BROADBAND OVER POWER LINE (BPL) SYSTEMS TO FEDERAL GOVERNMENT RADIOCOMMUNICATIONS AT 1.7 - 80 MHz

Phase 1 Study

VOLUME II

technical report

U.S. DEPARTMENT OF COMMERCE ● National Telecommunications and Information Administration

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Phase 1 Study

VOLUME II

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GLOSSARY

AC	Alternating Current
ACA	Australian Communications Authority
AERO-SAR	Aeronautical Search and Rescue
ALE	Automatic Link Establishment
AM	Amplitude Modulation
ANSI	American National Standards Institute
APD	Amplitude Probability Distribution
ARRL	Amateur Radio Relay League
AWG	American Wire Gauge
BBC	British Broadcasting Corporation
BBG	Broadcasting Board of Governors
BPL	Broadband over Power Line(s)
BW	Bandwidth
CA	Collision Avoidance
CB	Citizens Band
CCS	Carrier Current System
CD	Collision Detection
CEPT	European Conference of Postal and Telecommunications Administrations
CISPR	International Special Committee on Radio Interference
CONUS	Continental United States
COTHEN	Customs Over The Horizon Enforcement Network
CSMA	Carrier Sense Multiple Access
CW	Carrier Wave
dB	Decibel
dBi	Decibel referenced to an isotropic radiator
dBm	Decibel referenced to 1 milliWatt
dBW	Decibels above 1 Watt
DHS	Department of Homeland Security
DOA	Department of Agriculture
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOJ	Department of Justice
DRM	Digital Radio Mondiale
DSC	Digital Selective Calling
DSL	Digital Subscriber Line
DSSS	Direct Sequence Spread Spectrum
DUT	Device Under Test
E	Electric
EBU	European Broadcasting Union
ECC	Electronics Communications Committee
EFIE	Electric Field Integral Equation

EM	Electromagnetic
EMC	Electromagnetic Compatibility
EN	European Norm (Standard)
EUT	Equipment Under Test
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FICORA	Finnish Communications Regulatory Authority
FM	Frequency Modulation
FNRCS	FEMA National Radio Communication System
ft	Feet
GHz	Gigahertz
GMDSS	Global Maritime Distress and Safety System
GMF	Government Master File
GPS	Global Positioning System
GRWAVE	Ground Wave Propagation Program
H	Magnetic
HF	High Frequency
HPA	HomePlug Powerline Alliance
Hz	Hertz
I	Interference Power
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
ILS	Instrumentation Landing System
IMO	International Maritime Organization
IRAC	Interdepartment Radio Advisory Committee
ITS	Institute for Telecommunication Sciences
ITU	International Telecommunications Union
ITU-R	International Telecommunication Union Radiocommunication Sector
ITU-T	International Telecommunication Union Telecommunication Standardization Sector
JARL	Japan Amateur Radio League
kHz	Kilohertz
km	Kilometer
LAN	Local Area Network
LF	Low Frequency
LORAN	Long Range Aid to Navigation
LV	Low Voltage
m	Meter
MARS	Military Affiliate Radio System
Mbps	Megabits per second
MF	Medium Frequency
MFIE	Magnetic Field Integral Equation
MHz	Megahertz
MPHPT	Ministry of Public Management Home Affaires, Post and Telecommunications of Japan

MPT	Ministry of Posts and Telecommunications
mS	Siemens/meter
ms	Millisecond
MSI-HF	Marine Safety Information – High Frequency
MV	Medium Voltage
MWARA	Major World Air Route Areas
N	Noise Power
NATO	North Atlantic Treaty Organization
NB30	Usage Provision 30
NBDP-COM	Narrow-Band Direct Printing - Communications
NEC	Numerical Electromagnetics Code
NIST	National Institute of Standards and Technology
NOI	Notice of Inquiry
NPRM	Notice of Proposed Rulemaking
NRCS	National Radio Communication System
NSEP	National Security Emergency Preparedness
NTIA	National Telecommunications and Information Administration
OATS	Open Air Test Site
OFCOM	Swiss Federal Office of Communications
OFDM	Orthogonal Frequency Division Multiplexing
OR	Off-Route
OTH	Over the Horizon
PLC	Power Line Communications
PLT	Power Line Telecommunications
PSD	Power Spectral Density
QAM	Quadrature Amplitude Modulation
R	Route
RA	Radio Communications Agency of UK
RAM	Random Access Memory
RBW	Resolution Bandwidth
RDARA	Regional and Domestic Air Route Areas
RF	Radio Frequency
rms	Root Mean Square
RR	Radio Regulations
RSGB	Radio Society of Great Britain
RSMS	Radio Spectrum Measurement System
RTP-COM	Radio Telephony - Communications
S/N	Signal-to-Noise Ratio
SF&TS	Standard Frequency and Time Signal
SHARES	Shared Resources network
SINAD	Signal to Interference and Noise Ratio
SINCGARS	Single-Channel Ground and Airborne Radio System
SNR	Signal-to-Noise Ratio
SOLAS	Safety of Life at Sea
SSB	Single Sideband
TEM	Transverse Electromagnetic Mode

TV	Television
TVA	Tennessee Valley Authority
UHF	Ultra High Frequency
UK	United Kingdom
US&P	United States and Possessions
USCG	United States Coast Guard
USGS	United States Geological Survey
UTC	Coordinated Universal Time
VDSL	Very high-speed Digital Subscriber Line
VHF	Very High Frequency
VOA	Voice of America
VOACAP	Voice of America Coverage Analysis Program
VOLMET	Meteorological Information for Aircraft in Flight
WiFi	Wireless Fidelity
xDSL	Various types of Digital Subscriber Lines
μA	Microampere
μV	Microvolt

APPENDIX A
RELEVANT PART 15 PROVISIONS

Part 15 provisions regarding field strength limits and compliance measurements are quoted or paraphrased below. Observations relevant to the application of these provisions to BPL systems are presented in footnotes.

A.1 PROVISIONS REGARDING FIELD STRENGTH LIMITS

§15.15(c) "*Parties responsible for equipment compliance should note that the limits specified in this part will not prevent harmful interference under all circumstances.*"

§15.109(a) "*...the field strength of radiated emission from unintentional radiators at a distance of 3 meters shall not exceed the following values...*" [1]

§15.109(e) "*Carrier current systems used as unintentional radiators...shall comply with the radiated emission limits for intentional radiators provided in* §15.209 for the frequency range 9 kHz to 30 MHz."

§15.109(g) "*As an alternative to the radiated emission limits shown in paragraphs (a) and (b) of this section, digital devices may be shown to comply with the standards contained in the Third Edition of International Electrotechnical Commission ("IEC"), International Special Committee on Radio Interference ("CISPR") Pub. 22 (1997)...*"

§15.113(b) "*The operating parameters of a power line carrier system (particularly the frequency) shall be selected to achieve the highest practical degree of compatibility with authorized or licensed users of the radio spectrum.*" [2]

§15.113(c) "*Power line carrier system apparatus shall be operated with the minimum power possible to accomplish the desired purpose.*"

§15.205(a) "*...only spurious emissions are permitted in any of the frequency bands listed below:..*" [3]

§15.209(a) *"...emissions...shall not exceed the field strength levels specified in the following table...*" [4]

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[1] NTIA recommends a uniform ten (10) meter measurement distance. *See* Section 7.5.

[2] In Section 7, NTIA has identified potential means for enhancing compatibility of BPL systems with radio systems.

[3] NTIA recommends consideration of excluding BPL use of certain narrow frequency bands, but further study is needed to determine whether these exclusions can be specified on a geographical basis. Generally, BPL systems should not operate in certain frequency bands in order to protect distress, alarm, urgency or safety communications in accordance with ITU Radio Regulations (*see* RR No. 4.22).

[4] NTIA recommends a uniform ten (10) meter measurement distance. *See* Section 7.5.

A.2 PROVISIONS SPECIFYING COMPLIANCE MEASUREMENTS

§15.31(a) "*The following measurement procedures are used by the Commission to determine compliance with the technical requirements of this part.*"

§15.31(a)(6) Digital devices are to be measured using procedures specified in American National Standards Institute (ANSI) C63.4-1992 to determine compliance with the technical requirements of Part 15.

§15.31(b) "*All parties making compliance measurements on equipment subject to the requirements of this part are urged to use these procedures.*"

§15.31(d) Measurements are to be made at a calibrated test site to the extent possible. CCS are cited as a case where measurements can be made only at an installation site. Measurements "*...shall be performed at a minimum of three installations that can be demonstrated to be representative of typical installation sites.*" [5]

§15.31(f) "*To the extent practical, the device under test shall be measured at the distance specified in the appropriate rule section.*" The measurement distance is applied horizontally with respect to a boundary around the device and any interconnection cables.[6]

§15.31(f)(1) "*At frequencies at or above 30 MHz,...measurements are not made in the near field except where it can be shown that near field measurements are appropriate due to the characteristics of the device; and it can be demonstrated that the signal levels needed to be measured at the distance employed can be detected by the measurement equipment.*"[7] "*When performing measurements at a distance other than that specified, the results shall be extrapolated to the specified distance using an extrapolation factor of ...*" [8]

§15.31(f)(2) "*At frequencies below 30 MHz, measurements may be performed at a distance closer than that specified in the regulations; however, an attempt should be made to avoid making measurements in the near field.*" "*...when performing measurements at a closer distance than specified, the results shall be extrapolated to the specified distance....*"

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[5] *See* Section 7.9.

[6] None of the three proprietary access-BPL measurement reports reviewed by NTIA applied §15.31(f). Instead, these measurements were performed on radials at distances measured from the "telephone" pole on which the BPL device was mounted.

[7] NTIA's Phase 1 Study indicates that BPL emissions must be measured in the near-field because of its large expanse.

[8] NTIA's Phase 1 Study shows that BPL radiation characteristics may not be consistent with the extrapolation factors specified in §15.31(f). Further study is needed.

§15.31(f)(4) "*When measurements of 30 meters or less are specified in the regulations, the Commission will test the equipment at the distance specified unless measurement at that distance results in measurements being performed in the near field*."

§15.31(f)(5) "*The maximum field strength at the frequency being measured shall be reported in an application for certification*." [9]

§15.31(g) "*Equipment under test shall be adjusted, using those controls that are readily accessible to or are intended to be accessible to the consumer, in such a manner as to maximize the level of emissions. For those devices to which wire leads may be attached by the consumer, tests shall be performed with wire leads attached. The wire leads shall be of the length to be used with the equipment if that length is known. Otherwise, wire leads one meter in length shall be attached to the equipment.*" [10]

§15.31(h) "*For a composite system that incorporates devices contained either in a single enclosure or in separate enclosures connected by a wire or cable, testing for compliance with the standards in this part shall be performed with all of the devices in the system functioning.*" [11]

§15.31(i): "*The emission tests shall be performed with the device and accessories configured in a manner that tends to produce maximized emissions within the range of variations that can be expected under normal operating conditions.*"

§15.31(j): "*If the equipment under test consists of a central control unit and external or internal accessory(ies) (peripheral) and the party ...applying for a grant of equipment authorization manufactures or assembles the central control unit and at least one of the accessory devices that can be used with the control unit, testing of the control unit and/or the accessory(ies) must be performed using the devices manufactured or assembled by that party, in addition to any other needed devices which the party does not manufacture or assemble.*"

§15.31(k): "*If the individual devices in a composite system are subject to different technical standards, each such device must comply with its specific standards. In no*

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[9] Regardless of whether certification ultimately is required for BPL authorizations, under NTIA's recommended measurement provisions (Section 7) the maximum field strength at a given measurement frequency is determined from measurements made while operating the BPL system at each frequency at which it is capable of operating.

[10] The "consumer" for outdoor BPL devices normally will be the BPL system operator, whereas the consumer for indoor BPL devices normally will be the BPL subscriber. The length of outdoor "wire leads" used with access and in-house BPL devices vary substantially among the potential BPL installation sites and, as recommended by NTIA (Section 7.9), the representative power lines selected for BPL testing should encompass various features that significantly affect peak field strength levels. In no case can a one-meter or other short length of power line be used for BPL compliance measurements because standing waves associated with peak field strength will not be manifest.

[11] NTIA interprets §§15.31(h), (i), (j) and (k) to mean that at any frequency, during measurement and operational use, a network of BPL devices may not generate an aggregate field strength that exceeds the field strength limit for BPL systems. See Section 7.3.

event may the measured emissions of the composite system exceed the highest level permitted for an individual component."

§15.33(b)(1) "*...the spectrum shall be investigated from the lowest radio frequency signal generated or used in the device, without going below the lowest frequency for which a radiated emission limit is specified, up to the frequency shown in the following table*..."

§15.35(a): The limits are based on measurement using a CISPR quasi-peak detector and related bandwidths. [12]

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[12] *See* Publication 16 of the International Special Committee on Radio Interference (CISPR) of the International Electrotechnical Commission. Measurement bandwidths of 9 kHz and 120 kHz are to be used with a quasi-peak detector at frequencies below and above 30 MHz, respectively.

APPENDIX B
SUMMARY OF FOREIGN TECHNICAL REPORTS

B.1 INTRODUCTION

This appendix summarizes foreign technical reports related to BPL implementation. NTIA reviewed these reports in the course of designing and refining its technical approach. Citation and summarization of a report herein does not, in itself, signify NTIA concurrence with any aspect of the report and inclusion or exclusion of a report has no significance. In this appendix, the acronyms BPL (for Broadband on Power Line), PLC (for Power Line Communications), and PLT (for Power Line Telecommunications or Technologies) are synonymous and will be used in accordance with each original report.

B.2 IMPLEMENTATION REPORTS

Several telecom equipment manufacturers have teamed up with utility companies to build BPL systems in order to test the technical and economical feasibility of BPL. Results of some of these implementation efforts are presented in Table B-1.

Table B-1: BPL Implementation Results

Company / Nation	Result	Source of Information
SIEMENS / Germany	SIEMENS decided in March 2001to leave the PLC business. Power companies which were due to use SIEMENS equipments are now supplied by ASCOM.	http://www.darc.de/referate/emv/plc/PLC-in-Germany-3-2001-Press-release.pdf
NUON / Netherlands	NUON stops offering digital services through the power lines in the beginning of July, 2003.	http://www.webwereld.nl/nieuws/14920.phtml (in Dutch)
ASCOM / Switzerland	According to DARC, ASCOM has declared that it was unable to supply all PLC main outlets with sufficient low failure rate because it can not be supported by the NB30 requirement.	http://www.darc.de/referate/emv/plc/c3.4-rev1-PLC5RPRT.pdf
ASCOM: Swiss PLC equipment supplier NUON: Dutch energy company SIEMENS: German PLC equipment supplier		

B.3 MEASUREMENT REPORTS

Many EMC measurements conducted by government agencies and private groups have been reported. Some of these reports are presented in Table B-2.

Table B-2: Measurement Reports

Country or Agency	Report or Result	Source of Information
OVSV / Austria	Video Showing Effect of PLC in Tirol, Austria	http://www.darc.de/referate/emv/plc/plc_video_tirol.rm
OVSV / Austria	Video Showing Effect of PLC in Linz, Austria	http://www.darc.de/referate/emv/plc/plc_video_linz.rm
Austria	During an emergency exercise of the Austrian Red Cross in May 2003, communication was massively disturbed by PLC, with interference levels exceeding the limits by a factor 10,000.	http://futurezone.orf.at/futurezone.orf?read=detail&id=205693&tmp=4659
Finland	In October 2001, FICORA measured disturbance levels in the PLC test network in a residential area. The measurements revealed that data transmission caused a significant rise in disturbance levels inside buildings, and outside near buildings and underground cables. The measured levels were significantly higher than NB30.	http://www.ficora.fi/2001/VV_vsk2001.pdf
Germany	"PLT, DSL, cable communications (including cable TV), LANs and other effect on radio services"	ECC Report 24, Section 8.1.2
Germany	"PLT, DSL, cable communications (including cable TV), LANs and other effect on radio services"	ECC Report 24, Section 8.1.3
Germany	"PLT, DSL, cable communications (including cable TV), LANs and other effect on radio services"	ECC Report 24, Section 8.1.4
JARL / Japan	"On Radio Interference Assessments of Access PLC System"	http://www.qsl.net/jh5esm/PLC/isplc2003/isplc2003a2-3.pdf
JARL / Japan	"On Radio Interference Assessments of Access PLC System – Presentation Material"	http://www.qsl.net/jh5esm/PLC/isplc2003/isplc2003a2-3presentation.pdf

Japan	"Interference measurements in HF and UHF bands caused by extension of power line communication bandwidth for astronomical purpose"	http://www.qsl.net/jh5esm/PLC/isplc2003/isplc2003a7-1.pdf
VERON / Netherlands	"The Radio Amateur and the Effects of the Use of the 230-Volt Power Line for Broadband Data Communications"	http://www.darc.de/referate/emv/plc/VERON_PLC_Report.pdf
VERON / Netherlands	"HF radio reception compatibility test of an in-house PLC system using two brands of modems"	http://www.arrl.org/tis/info/HTML/plc/files/ModemRPRTVeron11-04-03.pdf
Netherlands	"Current Situation on the Field Trials and Other Tests Performed in the Netherlands" (in Dutch)	http://www.agentschap-telecom.nl/informatie/plc/Position_NL_PLC_C..pdf (special access required)
Netherlands	"Information on radiating properties of mains networks" (in Dutch)	http://www.agentschap-telecom.nl/informatie/plc/NL_versie 6_final.pdf (special access required)
Norway	"PLT, DSL, cable communications (including cable TV), LANs and other effect on radio services"	ECC Report 24, Section 8.1.1
Switzerland	"Power Line Communication at Fribourg" (study report in French only)	http://www.bakom.ch/en/funk/elektromagnetisch/plc_freiburg/index.html
BBC/U.K.	In October 2002, the Technical Working Group completed final report on the "Compatibility of VDSL and PLT with radio services in the range 1.6 MHz to 30 MHz", in which Appendix M contains emission limit proposed by BBC.	http://www.radio.gov.uk/topics/interference/documents/dslplt.htm
RA / U.K.	RA Technical Working Group Final Report "Compatibility of VDSL and PLT with radio services in the range 1.6 MHz to 30 MHz" (Sections 7.2 & 7.3, Appendices P, Q)	http://www.radio.gov.uk/topics/interference/documents/dslplt.htm
RSGB / U.K.	"Notes on RSGB Observations of HF Ambient Noise Floor"	http://www.qsl.net/rsgb_emc/RSGBMeasurements_1b.pdf
RSGB / U.K.	"A paper on the difficulty of measuring broadband interference emissions from cables and the problem of assessing the results with respect to interference to radio reception. Tests and experiences from an installed PLT system"	http://www.qsl.net/rsgb_emc/PLTREP.pdf
RSGB / U.K.	"Background noise on HF bands"	http://www.qsl.net/rsgb_emc/emcslides.html

RSGB / U.K.	"Notes on the RSGB investigation of PLT systems in Crieff"	http://www.qsl.net/rsgb_emc/CRIEFF%20Notes%20Version_1.html
White Box Solutions / U.K.	"Some Practical Measurements of Far Field Radiated Emissions from a PLT Cell and an Estimation of the Cumulative Ground-Wave Effects of PLT Deployment on a Sensitive HF Surveillance Site protected by a Non-Deployment Area of Radius 1500m", Appendix X of the RA Technical Working Group Final Report "Compatibility of VDSL and PLT with radio services in the range 1.6 MHz to 30 MHz"	http://www.radio.gov.uk/topics/interference/documents/dslplt.htm
ARRL / U.S.	"Home Phone Networking Alliance Testing"	http://www.arrl.org/tis/info/HTML/plc/files/hpnatests.html
ARRL / U.S.	"HomePlug and ARRL Joint Test Report", January 24, 2001	http://www.arrl.org/tis/info/HTML/plc/files/HomePlug_ARRL_Dec_2000.pdf
ECC: Electronic Communications Committer (within CEPT) JARL: Japan Amateur Radio League, Inc. OVSV: Austrian Amateur Radio Society RSGB: Radio Society of Great Britain VERON: Vereniging voor Experimenteel Radio Onderzoek Nederland		

Abstracts of some of the reports are presented as follows.

"Measurement results from PLT field trials – Germany, System A," ECC Report 24, Section 8.1.2. The section presented the measurement result of the radiated noise level from a PLT system. System A is designed for outdoor and indoor communication in several frequency bands. The outdoor portion begins at a transformer station and ends in the cellar of several houses, mostly in front of the power meter. At the same location the indoor portion begins using another frequency range and ends at the plugs in the rooms. The characteristics of a PLT signal is determined by switching off the PLT system, then comparing the scans made with the system on and off. The measurement results showed that the PLT signal in the field trial exceeded the NB 30 limit with an injected power level of +10 dBm. It was noted that the field trial was based on two examples of cabling and using PLT equipment which is still under development, and it covered only one injection point (outdoor master) and only less than three households, hence the result was not representative.

"Measurement results from PLT field trials – Germany, System B," ECC Report 24, Section 8.1.3. The section presented the measurement result of the radiated noise level from a PLT system. System B is designed for outdoor and indoor communication in the same frequency bands. The outdoor portion begins at a transformer station and ends in the cellar of several houses, mostly in front of the power meter. The indoor portion begins at the same location using the same frequency range and ends at the plugs in the rooms. A filter is inserted between outdoor slave and indoor master devices to suppress influence. The characteristics of a PLT signal were determined by switching off the PLT system, and comparing the scans made with the system on and off. The measurement results showed the PLT signal in the field trial exceeded the NB 30 limit with an injected power level of +17 dBm. It was noted that the trial was based on one example of cabling and using PLT equipment which was still under development, and covered only one injection point and only three households, hence the result was not representative.

"Measurement results from PLT field trials – Germany, System C," ECC Report 24, Section 8.1.4. The section presented the measurement result of the radiated noise level from a PLT system. System C was developed under the assumption that there would be no EMC problems if the system used low enough signal level such that the radiated noise met the threshold values specified in NB 30. The field strengths generated by the PLT signals, both inside and outside of buildings, were measured using the method in Measurement Specification 322MV05. The results showed that the radiated field strength at a distance of 3 meters from the injection point was close to the threshold values in NB 30, while the field strength at the "transformer station" exceeded the threshold.

"On Radio Interference Assessments of Access PLC System," JARL/Japan. Measurements were conducted to evaluate the impact of overhead access PLC to the amateur radio service and broadcasting service. Three cases were examined. First, the S/N of an AM signal and SINAD of a CW carrier were measured, and the results showed unacceptable degradation of HF broadcasting services from PLC interference. Second, observation using a spectrum analyzer showed that the HF broadcasting signal was completely jammed by the BPL modem operation. Third, measurement of the far-field component showed that short wave radio was jammed by the PLC signal at 156 meters away, and the PLC signal became undetectable at a distance of 200 to 400 meters. The experiment concluded that access PLC systems jam HF broadcasting and other radio communication services.

"Interference measurements in HF and UHF bands caused by extension of power line communication bandwidth for astronomical purpose," Japan. Two sets of modems, spread spectrum and OFDM, of the access PLC system were tested for the interference effect to radio astronomical observation. It was found that in the HF band, the PLC noise exceeds the level of the galactic noise by more than 30 dB when the two systems were 180 meters apart. In the UHF band, spurious emission near 327 MHz was observed at a 55 meter distance. In both cases, the interference noise exceeds the limit in ITU-R Rec. RA 769-1 for protection of radio astronomical observation. Safety separations to meet RA 769-1 limit are estimated to be 219 km and 12 km at 9.2 MHz and 327 MHz, respectively. The report concluded that PLC is harmful to radio astronomical observation in both the HF and UHF bands.

“The Radio Amateur and the Effects of the Use of the 230-Volt Power Line for Broadband Data Communications,” VERON/Netherlands. Measurement was conducted to evaluate the risks of interference from PLC to an amateur station. Both in-house and outside field strength measurements were taken and compared with the CEPT proposed radiation limits (NB 30, Norwegian Limit and BBC limit). The coupling between the mains wiring and the antennas of the amateur station was also determined. In the audio test, the level of interference in the HF amateur bands was evaluated using amateur antennas and receiver. The results showed that adequate protection can be provided against mains injected interference signals only in the BBC limit which was the strictest. Additional measurements were performed to find the “normal” interference levels on the mains wiring. The results showed that (1) it was apparent that the present interference levels in a quiet rural area are far below the CISPR 22 limits, and (2) injection of interference signals with a level equal to the CISPR 22 limit level causes harmful interference to the reception of signals in the amateur bands.

“HF radio reception compatibility test of an in-house PLC system using two brands of modems,” VERON/Netherlands. Tests were performed on the emissions of two types of in-house PLC modems developed to the HomePlug® standard. The measurements were done in a laboratory set-up, and in a residential house. The laboratory set-up, with many PCs running, was used to measure the mains disturbance voltage, field strength, and background noise; the residential house was used to measure the interference on an amateur radio receiving antenna, background signals, and noise on mains. The results show that one modem seems just to meet the mains disturbance limit in EN55022 for residential environment, and the other modem shows a level approximately 20 dB higher. Also, the following general observations were made: (1) interference from the modems is probably not a threat to the radio amateur service for a reasonably well constructed outdoor receive antenna, (2) interference may be harmful to the broadcasting services outside the spectrum notches, and (3) the background mains disturbance level is 30 dB or more below the EN55022 B limit in both the laboratory and residential environments.

“Measurement results from PLT field trials – Norway,” ECC Report 24, Section 8.1.1. The Norwegian Post and Telecommunications Authority conducted measurement tests on all experimental PLT systems in Norway in order to obtain information on unwanted radiation to other spectrally collocated radio systems in the HF band. The EMC requirement of PLT equipment for the mains port in wood buildings, a worst-case scenario, is 20 dBμV/m quasi-peak measured at a distance of 3 meters from the cable structure. The measured data are combined with a coupling factor to give the extent of field emission from equipment for the mains port. The measurement results show EM field levels 20–40 dB higher than 20 dBμV/m. This clearly indicates the need for a significant reduction in the spectral power density of the PLT signal to achieve compliance with existing EMC standards. Moreover, the report asserts that the field emission requirements for PLT should be somewhat more restrictive than the 20 dBμV/m limit because the PLT signal might be an ”always on” signal, and the geographical concentration of PLT units within a certain area might be fairly high.

"Power Line Communication at Fribourg," Switzerland. A PLC network had been installed at the Swiss city of Fribourg. The Swiss Federal Office of Communication (OFCOM) accomplished extensive interference measurements on site with the goal to find out if and to what extent radio services in the short wave range would be disturbed. The already existent man-made noise at urban and rural areas has been analyzed and accounted for as well. The statistical interpretation of measurement data shows that PLC interference below 10 MHz is of little impact at urban areas because of already existent interference from other sources. However, at frequencies above 10MHz, PLC emissions are clearly the predominant cause for interference. Furthermore it has been shown that the limit of the German standard NB30 is exceeded at all frequencies of interest between 2.4 MHz and 25.4 MHz at urban areas. This report is available only in French.

"Compatibility of VDSL and PLT with radio services in the range 1.6 MHz to 30 MHz," RA Technical Working Group Final Report, RA/U.K., Sections 7.2 & 7.3. Measurements of radiated emission from access and in-house PLC systems were conducted and data were presented. There was no discussion on the interference effect.

"Notes on the RSGB investigation of PLT systems in Crieff", RSGB/U.K. Two PLT systems, ACOM and MAINNET, were tested. The primary objective was to obtain information on levels of interference noise generated by PLT systems and how this will affect radio amateurs and short wave listeners. Interference noise was observed, but no quantitative data were reported. No analysis or conclusion was presented.

"Some Practical Measurements of Far Field Radiated Emissions from a PLT Cell and an Estimation of the Cumulative Ground-Wave Effects of PLT Deployment on a Sensitive HF Surveillance Site protected by a Non-Deployment Area of Radius 1500m," White Box Solutions/U.K. Field strength measurements were undertaken in a suburban/rural area. The results of these measurements were applied to the scenario of a sensitive HF radio surveillance site. It was concluded that for a non-deployment zone of radius 1500m, the dominant source of noise remains atmospheric noise (including man-made) and that the cumulative contribution from the surrounding PLT interferers would, in a worst case scenario, have less than 0.1 dB impact on the noise floor.

"HomePlug and ARRL Joint Test Report," ARRL/U.S. The experiment examined the interference effect from the BPL waveform and power spectral density (PSD) limits proposed by HomePlug to the amateur radio services. Tests showed in general that with moderate separation of the antenna from the structure containing the HomePlug signal that interference was barely perceptible. The cases of objectionable interference were noted for an antenna located close to the power lines, a configuration chosen to mimic the situation in which the HomePlug equipment was in one house and the amateur radio in another.

B.4 MODELING AND ANALYSIS REPORTS

Several studies have developed models to analyze the potential BPL EMC problems. Some of the reports are listed in Table B-3.

Table B-3: Modeling and Analysis Reports

Country or Agency	Report	Source of Information
CEPT	"Determination of limiting values for emissions from PLT to protect DRM"	ECC PT SE35
Japan	"Sharing studies between the radio astronomy telescopes and the power line communication systems in the HF region"	http://www.qsl.net/jh5esm/PLC/isplc2003/isplc2003a7-4.pdf
BBC / U.K.	"Cumulative Effects of Distributed Interferers", Appendix R of the RA Technical Working Group Final Report "Compatibility of VDSL and PLT with radio services in the range 1.6 MHz to 30 MHz"	http://www.radio.gov.uk/topics/interference/documents/dslplt.htm
White Box Solutions / U.K.	"Application of Power Control and Other Correction Factors to PLT Systems and their Subsequent Impact on the Cumulative Effects, via Space Wave Propagation, on Aircraft HF Receivers", Appendix Y of the RA Technical Working Group Final Report "Compatibility of VDSL and PLT with radio services in the range 1.6 MHz to 30 MHz"	http://www.radio.gov.uk/topics/interference/documents/dslplt.htm
ARRL / U.S.	"Calculated Impact of PLC on Stations Operating in the Amateur Radio Service" (p.9-13)	http://www.arrl.org/tis/info/HTML/plc/files/C63NovPLC.pdf

Abstracts of these reports are presented as follows.

"Determination of limiting values for emissions from PLT to protect DRM," CEPT/ECC PT SE35. This report presents measurement result for determining PLT emission limits to protect DRM transmission. The DRM system uses either 9 or 10 kHz channels or multiples thereof, QAM/OFDM modulation with channel coding, time interleaving, and FEC. The PLT system has neither defined bandwidth nor standardized modulation. The measurements were conducted in the HF band. The DRM reference field strength is 40 dBμV/m, which is the minimum sensitivity of an average AM receiver; this level is about 10 to 20 dB above the minimum usable field strength of DRM receivers. The PLT signal was transmitted with a mains power supply cable connecting two PLT modems. It was observed that the PLT signal in file transfer mode affects noticeably the DRM receiver sensitivity threshold by 7 to 15 dB. Moreover, the DRM receiver threshold is affected even when the PLT was switched on but not transferring files. It was also observed that when the PLT signal level reaches the NB30 limit (32 dBµV/m), the DRM receiver sensitivity threshold is 3 dB higher than the protected minimum field strength in mode 1 (43 dBµV/m instead of 40 dBµV/m), and 9 dB higher in mode 2. Therefore, the limiting value for emissions from a radiating PLT source to protect DRM receiver at less than 3-meter distance shall be equal to or less than 16 dBµV/m in the HF band. This value is 16 dB more stringent than the NB30 limit defined at 3-meter distance. The results clearly show that the NB30 limits are not sufficient to protect DRM receivers in presence of a PLT signal.

"Sharing studies between the radio astronomy telescopes and the power line communication systems in the HF region," Japan. The report develops a methodology to calculate the necessary distance between a radio astronomy antenna site and a metropolitan PLC system by using two equations in ITU-R P.525. First, it uses an equation for point-to-area links to calculate the radiation field strength at 30 meters. Then, it uses an equation for point-to-point links to calculate free space loss of the radiated field. Considering that 30-meter distance is likely in the near-field range for a BPL system, and that the BPL emission source may not be a point source, the accuracy of this model may be subject to examination.

"Cumulative Effects of Distributed Interferers," BBC/U.K. This model develops methodologies to estimate the aggregate interference power from a distribution of PLC sources. The receiver can be in either an aircraft or a ground-based system. This is a far-field model, and curvature of the Earth surface is being considered. The analysis indicates that the interference received by an aircraft is nearly independent of aircraft height when the entire visible earth is populated with the PLT systems. Limiting the area of distributed interferers from the visible earth to a smaller area representative of a major conurbation does not decrease the interference very greatly, unless the aircraft is very high. For ground receivers, the analysis indicates that sky-wave interference from widespread PLT systems to ground-based receivers may not always be negligible, even though it is less than that shown to be suffered by aircraft.

"Application of Power Control and Other Correction Factors to PLT Systems and their Subsequent Impact on the Cumulative Effects, via Space Wave Propagation, on Aircraft HF Receivers," White Box Solutions/U.K. This study utilizes the model in the report "Cumulative Effects of Distributed Interferers" to examine the possibility of using power control and other correction factors for the PLT systems to alleviate the impact from the distributed BPL systems to aircraft HF receivers. Its result indicates that practical PLT systems employing power control and power density less than -60dBm/Hz would not appear to raise the HF noise floor at an aircraft at any reasonable operational altitude.

"Calculated Impact of PLC on Stations Operating in the Amateur Radio Service," ARRL/U.S. ARRL uses EZNEC 3.1 with the NEC-4 engine to model a power line of 300 feet as an antenna. Its result shows that the emitted PLC signal at 30-meter distance is 275µV/m/9kHz, which exceeds the FCC limits by about 15 dB. ARRL claims that the data is supported by actual measurements made in Japan. Another message from this paper is that, by using a line source instead of a point source, the signal strength vs. distance relationship should be 20dB/decade instead of 40dB/decade.

APPENDIX C
CHARACTERIZATION OF FEDERAL GOVERNMENT SPECTRUM USAGE AND OPERATIONS, REPRESENTATIVE SYSTEMS AND TYPICAL PARAMETERS

C.1 INTRODUCTION

As summarized in Section 4, the 1.7-80 MHz frequency range hosts a number of radio services and supports well over one-hundred-thousand Federal Government RF systems. Frequencies in this range are intensively used on the bases of time-and geographic-sharing by several radio systems. This appendix provides a more detailed discussion on federal spectrum usage and operations under each radio service. In addition, this appendix provides a general characterization of Federal Government RF systems that includes presentation of representative federal systems and typical system parameters.

The main data sources used in the description of the Federal Government RF systems, spectrum usage and, in some cases, the radio services are the Government Master File (GMF), federal agencies' inputs, and an earlier NTIA study.[1] Section C.2 discusses the nature of relevant radio services and their allocations in the 1.7-80 MHz band. Special systems are described in Section C.3, and special operating considerations are summarized in Section C.4.

C.2 SERVICES AND EXAMPLE SYSTEMS

C.2.1 Fixed Service (1.7-29.7 MHz)

The use of radio frequencies below 30 MHz for domestic fixed service by the Federal Government is delineated in Section 8.2.11 of the NTIA Manual. An excerpt from the NTIA Manual regarding the use of fixed service below 30 MHz by the Federal Government is presented in Section C.4. The frequency bands allocated to the fixed service in the 1.7-30 MHz band are shown in Table C-1.

In general, the Federal Government fixed service applications include voice and data transmissions over intermediate and long-range distances (25 km to over 2,000 km). Many fixed stations are located in the vicinity of power lines which could eventually be used by BPL systems (*e.g.*, *see* Figure C-1). The DOD, for example, uses HF radios on military installations, both for ground and skywave modes of operations, on or near major urban environments. The DOJ and DHS employ fixed systems throughout the United States, including urban and suburban areas, in support of law enforcement activities.

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[1] Grant, W.B., et al., *Spectrum Resource Assessment of Government Use of the HF (3-30 MHz) Band*, NTIA Technical Memorandum 89-141, June 1989. Relevant information from this study is included in this Appendix.

Table C-1: Frequency Bands Allocated to the Fixed Service in the 1.7-30 MHz Band

Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)
1705-1800	95	5730-5900	170	13410-13570	160	19029-19680	651
2000-2065	65	5900-5950	50	13570-13600	30	19800-19990	190
2107-2170	63	6765-7000	235	13800-13870	70	20010-21000	990
2194-2495	301	7300-7350	50	13870-14000	130	21850-21924	74
2505-2850	345	7350-8100	750	14350-14990	640	22855-23000	145
3155-3230	75	9040-9500	460	15600-15800	200	23000-23200	200
3230-3400	170	9900-9995	95	15800-16360	560	23350-24890	1540
4438-4650	212	10150-11175	1025	17410-17480	70	25330-25550	220
4750-4850	100	11400-11600	200	17480-17550	70	26480-26950	470
4850-4995	145	11600-11650	50	18030-18068	38	27540-28000	460
5005-5060	55	12050-12100	50	18168-18780	612	---	
5060-5450	390	12100-12230	130	18900-19020	120	---	
Total Bandwidth = 12,030 kHz							

Both the DOJ and DHS HF systems that support law enforcement activities in many cases use encryption in both ground and skywave modes of operations.[2] Some of these systems support crisis response teams, including the Federal Government's SHARES network program that is described below. The vast majority of fixed systems in this portion of the spectrum operate in the simplex mode. Table C-2 shows the representative technical characteristics of fixed systems in the 1.7-30 MHz band.

Many foreign governments operate HF fixed stations at their embassy and mission facilities that typically are located in major cities throughout the United States. While many of these operations may backup or supplement other means of communications, these HF systems become critical sole means of communications in certain times of crises.

SHARES. The mission of the shared resources (SHARES) network is to provide backup or supplemental communications for exchange of critical information among federal entities during certain crisis situations. Normally, frequency assignments that support the SHARES network are nationwide or assigned under the United States and Possessions (US&P) category. The HF portion of the spectrum is most suitable for the operation of the SHARES network because it offers a medium in which a reliable, geographically expansive network can be established, without satellites, using easy to implement equipment operating over a range of frequencies (Federal Government satellite facilities are used for other purposes in certain times of crises). A summary of the emergency use of Federal Government HF frequencies for the SHARES program is provided in Section C.4.2.

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[2] Interference to encrypted radio channels can be particularly harmful insofar as considerable time is needed to reestablish communications in an encrypted mode of operation.

Figure C-1: An Example of a Federal Government Radio Antenna near Power Lines.

Table C-2: Typical Technical Characteristics of Fixed Systems (1.7-30 MHz Band)

System	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (ft)	Ant. Type/ Polarization	Modulations
Typical Fx	2.8	0-2	30-140	Dipole/ V& H	Analog, single channel, suppressed carrier, telephony

C.2.2 Fixed Service (29.7-80 MHz)

There are twelve fixed service bands, as shown in Table C-3, allocated to the Federal Government to support federal fixed service requirements in the 29.7-80 MHz band. The fixed systems operated by the federal non-military agencies in this frequency range normally compliment the mobile or land mobile service. They provide relay connectivity (repeater stations) to hand held and vehicular mobile phones used by the federal agencies for: management, protection, and preservation of the natural resources; search and rescue operations; and law enforcement activities. These fixed systems are also used for: exchange of meteorological data; detection of unauthorized vehicular traffic, such as on or near shuttle landing areas; and for fire alarm supervisory systems at various facilities.

Table C-3: Frequency Bands Allocated to the Federal Government for Fixed Service in the 29.7-80 MHz Band

Frequency (MHz)	BW (MHz)	Frequency (MHz)	BW (MHz)	Frequency (MHz)	BW (MHz)	Frequency (MHz)	BW (MHz)
29.89-29.91	0.02	34-35	1.0	38.25-39	0.75	49.6-50	0.4
30-30.56	0.56	36-37	1.0	40-42	2.0	74.6-74.8	0.2
32-33	1.0	38-38.25	0.25	46.6-47	0.4	75.2-75.4	0.2
Total Bandwidth = 7.78 MHz							

The DOD also employs their fixed systems as repeaters for: land and air networks; tactical and training purposes; and support of military bases operations. These include tactical communications exercises for base defense missions; command and control; law enforcement; remote control of multiple cameras on test ranges; airfield lighting; and acoustic range traffic lights. In addition, these fixed systems support research, development, test and evaluation of DOD systems.

Federal Agencies' Repeaters (Relay Stations). The vast majority of fixed systems used by the federal agencies in the 29.7-80 MHz band compliments or provides relay connectivity for land mobile systems. The majority of the federal fixed assignments that support relay operations are under the US&P category. Some of these assignments are required for short term intermittent use at unspecified locations and used for notification of planned regular operations. Typical technical characteristics of these systems are provided in Table C-4.

Table C-4: Typical Technical Characteristics of Fixed System (29.7-80 MHz Band)

Fixed Systems	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (Ft)	Ant. Type/ Polarization	Modulations
Non-DoD	16	0-3	16-250	Whip, yagi, collinear & dipole/V&H	Analog and digital, frequency modulated, single channel, data and telephony.
DoD	16-40	0-2	10-400	Whip, dipole, collinear, & coaxial/V&H	Analog and digital, frequency modulated, single channel, data and telephony.

C.2.3 Mobile Service

A total of 42 bands are allocated to the Federal Government for mobile service in the 1.7-80 MHz band. Of these, 13 bands provide secondary allocation to the mobile service and 17 bands exclude the use of aeronautical mobile service as indicated in Table C-5. Typical systems parameters are described below.

Table C-5: Frequency Bands Allocated to the Mobile Service in the 1.7-80 MHz Band

Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)
1705-1800	95	5060-5450*	390**	14350-14990*	640**	34000-35000	1000
2000-2065	65	5730-5900	170**	18168-18780*	612	36000-37000	1000
2107-2170	63	5900-5950	50**	20010-21000*	990	38000-38250	250
2173.5-2190.5	17	6765-7000*	235	23000-23200*	200**	38250-39000	750
2194-2495	301	7300-7350*	50	23350-24890	1540**	40000-42000	2000
2505-2850	345	7350-8100*	750	25330-25550	220**	46600-47000	400
3155-3230	75**	10150-11175*	1025**	26480-26950	470**	49600-50000	400
3230-3400	170**	13410-13570*	160**	27540-28000	460	74600-74800	200
4438-4650	212**	13570-13600*	30**	29890-29910	20	75200-75400	200
4750-4850	100**	13800-13870*	70**	30000-30560	560	—	--
4850-4995	145	13870-14000*	130**	32000-33000	1000	---	--

* Mobile service is secondary in this band

** The use of aeronautical mobile is prohibited in this band.

Total Bandwidth = 17,560 kHz

For the most part, federal mobile service requirements in this portion of the spectrum include voice and data, which also encompass intermediate and long-range operations. The military, for example, uses HF mobile radios in ground wave modes (*e.g.*, hundreds of kilometers) and skywave modes (thousands of kilometers) the same way they use the their fixed systems. The vast majority of military mobile radios operations are for tactical training, including tactical communications to ground units, ships and aircraft, base operations, and as back-ups or supplements to satellite communications. Normal training occurs in military bases which may be in the vicinity of power lines. Example systems used by the DOD for training and tactical communications are described below (AN/VRC-100 and SINCGARS).

The Coast Guard uses the HF and MF portions of the spectrum extensively for sea and air operations that include monitoring distress calls, both international and domestic digital selective calling including for distress calls, and search and rescue operations along the coastal areas of the United States. A total of about 160 base stations sites, including command and control sites, in the United States are used for these purposes. In addition, there are approximately 100 HF/MF-equipped buoy tenders and other vessels that operate on inland waters, up rivers and inshore along the coasts. These vessels/boats are frequently near power lines.

The DOJ and the DHS substantially use mobile radios in the HF band. The vast majority of these radios are dedicated for law enforcement or used in support of emergency and crises responses; as such, these systems are authorized to operate anywhere in the United States. Mobile radios employed by both agencies use encryption technology and some use ALE. An example system is the U.S. Customs Over the Horizon Enforcement Network (COTHEN). A brief description of the COTHEN system is presented below.

Single-Channel Ground and Airborne Radio System (SINCGARS). The SINCGARS is a family of VHF-FM combat net radios which provide the primary means of command and control for infantry, armor, and artillery units in the Army. It is capable of short range or long range operation for voice or digital data communications. The system's configurations include man-pack, vehicular, and airborne units. These units can be used for single channel operation or in a jam-resistant, frequency hopping mode which can be changed as needed. When configured for use of low VHF frequencies, the system operates on any of the 2320 channels between 30-88 MHz in 25 kHz increments and is designed to survive a nuclear environment. The SINCGARS Program is continuously evolving to provide the latest in improvements and capabilities to the soldier and to meet the Army's objectives for widespread digitization.

The SINCGARS system, which was once a conventional voice-only radio used for communications up and down the chain of command, has evolved into a software-defined, open architecture system with extensive networking capabilities. It offers clear or secure voice and data communications capabilities that provide situational awareness and transmit command and control information across entire theaters of battle or control.[3] A handheld unit, an airborne unit (AN/ARC-210D), a man-pack (AN/PRC-119F(V)), and various vehicular components (AN/VRC-90F(V), AN/VRC-87F(V), AN/VRC-87F(V), AN/VRC-89F(V), AN/VRC-91F(V) and VRC-92F(V)) are under production.[4] The SINCGARS program office has fielded more than 136,000 radios to training base and Army units worldwide.[5]

COTHEN. This network became widely operational in 1985. Previously, only Custom's marine vessels were equipped with the COTHEN radios; however, because of the success of this initial deployment, the network now provides communications support for more than 235 aircraft, numerous maritime interdiction vessels, several command offices, and numerous allied agencies including the Coast Guard, Drug Enforcement Administration, Border Patrol, Army, Navy, and Joint Interagency Task Forces.

The network integrates radio, computer, and a tactical voice privacy unit in a extremely reliable, state-of-the-art communications network that meets the demanding requirements of Customs' tactical interdiction aircraft and boats in their fight against smuggling activities. High powered fixed station transmitters located across the United States are connected to Customs' air, marine, and Special Agent In Charge (SAIC) locations via dedicated telephone lines. Tactical interdiction platforms equipped with COTHEN radio can place a call to any other platform or

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[3] http:/www.acd.itt.com/sincgars.htm.

[4] *Id.*

[5] http:/www.globalsecurity.org/military/systems/ground/sincgars.htm.

office in the network thousands of miles away typically using an ALE protocol. Units on the COTHEN network use encryption for most of the voice communications. The COTHEN network uses frequencies throughout the HF band in order to obtain both the needed capacity and frequency diversity (*see* Section C.4.1).

AN/VRC-100 (V). The Army's AN/VRC-100 (V) system works in conjunction with the AN/ARC-220 (V) to provide air-to-ground, ground-to-air, ground-to-ground, and air-to-air non-line of sight communications with aircraft at low altitude (30 meters to ground level in the HF band). These radios will support normal voice and encrypted voice communications, as well as message data. The AN/VRC-100 (V) uses multiple modulations and coding techniques and it uses an ALE tone (8-ary frequency shift keying). Table C-6 shows typical technical characteristics of mobile systems.

C.2.4 Land Mobile Service

For so many decades, the federal agencies land mobile requirements have been fulfilled in the mobile bands listed in Table C-5. The vast majority of federal agencies usage of the land mobile service are for: national defense (DOD); law enforcement (*e.g.*, DHS and DOJ); management and preservation of national resources; search and rescue; and emergency and safety communications operations in national seashores, lakes, forests, water resources, and wildlife refuge, including Tribal Lands and reservations (*e.g.*, DOI and DOA). Frequency assignments that support land mobile radios for law enforcement are under the US&P category. The areas of operation for these radios include the urban, suburban, and rural areas, both off-shore and in-land. Operation of these land mobile radios typically occurs near power lines that may be used for BPL systems.

Table C-6: Typical Technical Characteristics of Mobile Service in the 1.7-80 MHz Band

Mobile Systems	Freq. Range (MHz)	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (Ft))	Ant. Type/ Polarization	Modulations
Fx Station	1.7-30	2.8	0	30-100	Whip/V& H	Analog, single channel. Suppressed carrier, telephony
Mobile unit	1.7-30	2.8-3.0	0-2	6-32	Whip/V & H	Analog, single channel. Suppressed carrier, telephony
Fx Station	29.7-80	16	0-3	30-400	Whip, Dipole/V&H	Analog or digital, single channel, Frequency modulated, telephony and data.
Mobile unit	29.7-80	16	0	6-32	Whip/V	Analog or digital, single or multiple channels. Frequency Modulated, telephony and data

In some cases, especially in areas lacking adequate commercial telephone facilities, alternative communications that involve the use of non-government stations (*e.g.*, citizens radio service (CB)) are provided by the federal agencies. Such uses are in accordance with Part 95 of the FCC Rules and Regulations. In a practical sense, these systems typically may not be in areas where power lines are deployed.

The DOE's most prominent use of the HF spectrum is for secure communications. The DOE's HF system provides a nationwide communications capability to facilitate shipments in support of national defense. The system supplements existing physical security measures by providing normal and emergency communications between vehicles and the DOE's operations office control center.[6] The DOE also relies upon HF to provide essential communications during periods of critical emergencies around various DOE facilities throughout the United States. Typical technical characteristics of land mobile systems in the 1.7-80 MHz band are shown in Table C-7.

Table C-7: Typical Technical Characteristics of Land Mobile Services in the 1.7-80 MHz Band

Land Mobile Systems	Freq. Range (MHz)	Bandwidth (kHz)	Antenna Gain (dBi)	Antenna Height (Ft))	Antenna Type/ Polarization	Modulations
Base Station	1.7-30	2.8	0	30-100	Collinear, whip, dipole/V&H	Analog or digital, single channel., suppressed carrier, telephony and telegraphy
Mobile Unit	1.7-30	2.8-3.0	0-2	6-32	Whip/V&H	Analog or digital, single channel, suppressed carrier, telephony and telegraphy
Base Station	29.7-80	16-25	0-3	30-400	Collinear, whip, dipole/V&H	Analog or digital, single channel, suppressed carrier, telephony and telegraphy
Mobile Unit	29.7-80	16-25	0	6-32	Whip/V	Analog or digital, single channel, suppressed carrier, telephony and telegraphy

C.2.5 Maritime Mobile Service[7]

The maritime mobile bands in the 1.7-80 MHz frequency range allocated to the Federal Government are shown in Table C-8. The Federal Government's main users of the maritime mobile bands are the Coast Guard, Navy, DOI, and the Department of Commerce (DOC).

The Coast Guard operates HF systems for communications between shore stations and ships, and from ship-to-ship. These systems support command and control communications with cutters, aircraft, and shore facilities for various purposes including: off shore search and rescue; drug interdiction; enforcement of laws and treaties; and Arctic and Antarctic operations. Because of the Coast Guard's important role in the drug interdiction, a significant increase in the use of HF systems for air/ground and ship-to-shore communications has taken place over the last

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[6] *Supra* note 1 at 66.

[7] *Id.* at 69.

few decades. The Coast Guard also relies on the HF band for services such as distress and safety communications, broadcast of maritime safety information, emergency medical assistance communications, broadcast of weather observation reports, and receipt of vessel position reports for safety purposes.

Table C-8: Frequency Bands Allocated to the Federal Government for Maritime Mobile Service in the 1.7-80 MHz Band

Frequency Band (kHz)	BW (kHz)	Frequency Band (kHz)	BW (kHz)	Frequency Band (kHz)	BW (kHz)
2065-2107	42	6200-6525	325	18780-18900	120
2170-2173.5	3.5	8100-8195	95	19680-19800	120
2190.5-2194	3.5	8195-8815	620	22000-22855	855
4000-4063	63	12230-13200	970	25070-25210	140
4063-4438	375	16360-17410	1050	26100-26175	75
Total Bandwidth (BW) = 4,857 kHz					

In addition, the Coast Guard has an HF network that ties its major bases together, including bases in Alaska, throughout CONUS, Hawaii, Puerto Rico, the U.S. Virgin Islands, and the trust territories of the Pacific Ocean. The Coast Guard also has communication networks in the HF band to support the Long Range Aid to Navigation-C (LORAN-C). Although, the LORAN-C was earmarked for replacement by the Global Positioning System (GPS), the existing LORAN-C chains will be maintained and upgraded, at least till the year 2008, in the transition period to satellite-based navigation.[8]

The Coast Guard carefully monitors several protected HF channels 24 hours a day from several locations in the U.S. and its possessions for distress and maritime safety information communications. Some of these frequencies are used by the Global Maritime Distress and Safety System (GMDSS). Table C-9 shows the specific frequencies monitored by the Coast Guard for distress calling. Consistently over the last few decades, the Coast Guard annually responded to about 2000 search and rescue cases from boats and ships in trouble, where alerting is via frequencies listed in Table C-9.

The Navy also has communication systems between shore stations and ships, as well as ship-to-ship in the HF maritime mobile bands. Navy uses include: communications support to hydrographic surveys; tanker operations; weapon system testing; secure voice communications, and the naval telecommunications system that provides command, control, and communications for the Navy and Marine Corps operating forces. For the Navy, the HF band provides major back-up and supplemental capabilities for long distance emergency and war time communications and will continue to be very important asset to the Navy for fleet-wide communication needs.

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[8] http://webhome.idirect.com/~jproc/hyperbolic/loran_c_future.html.

Table C-9: Frequencies Monitored by Coast Guard for Distress and Safety Communications in the HF Band[9]

Freq. (kHz)	Usage	Freq. (kHz)	Usage	Freq. (kHz)	Usage
2174.5*	NBDP-COM	6215*	RTP-COM	12577*	DSC
2182*	RTP-COM	6268*	NBDP-COM	12579*	MSI
2187.5*	DSC	6312*	DSC	16420*	RTP-COM
3023	Aero-SAR	6314	MSI	16695*	NBDP-COM
4125*	RTP-COM	8291*	RTP-COM	16804.5*	DSC
4177.5*	NBDP-COM	8376.5*	NBDP-COM	16806.5	MSI
4207.5*	DSC	8414.5*	DSC	19680.5	MSI
4209.5	MSI	8416.5	MSI	22376	MSI
4210	MSI	12290*	RTP-COM	26100.5	MSI
5680	Aero-SAR	12520*	NBDP-COM	—	--

* Except provided in the ITU Radio Regulations, any emission capable of causing harmful interference to distress, alarm, urgency or safety communications on these frequencies is prohibited.

Legend:
NBDP = Narrow band direct printing
COM = Communication
RTP= Radio Telephony
DSC = Digital Selective Calling
Aero-SAR = Aeronautical Search and Rescue
MSI = Marine Safety Information

The DOI uses the HF maritime mobile bands for its U.S. Geological Survey organization (USGS) in support of marine geology exploration and mapping tasks. The DOI also has systems in the HF maritime mobile bands to support communications for the Pacific trust territories of the United States. This includes communications between the islands and ships, the outer island dispensary communications system in the marshal Islands, between islands in the Marianas group, and between islands in the American-Samoan group.

The DOC uses HF maritime mobile systems to support ships and boats used by the National Marine Fisheries Service and for communication links between major fishery centers and research vessels of the National Oceanic and Atmospheric Administration (NOAA) Corps Fleet. The National Ocean Service has radio communication facilities in the HF band to support ships and mobile field teams engaged in oceanographic and marine, and geodetic survey activities.

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[9] *Frequencies for Distress and Safety Communications for the Global Maritime Distress and Safety System*, ITU Radio Regulations, Appendix S15, Geneva 1998.

GMDSS. The GMDSS is a distress alerting and safety communications system that relies on satellite and terrestrial communications links, and has changed international communications networking from being primarily ship-to-ship to ship-to-shore (Rescue Coordination Center). In addition, the system provides for location determination in cases where a radio operator does not have time to send a complete SOS or MAYDAY call. Ships are required to receive broadcast of maritime safety information via the GMDSS. In 1988, the International Maritime Organization (IMO) amended the Safety of Life at Sea (SOLAS) Convention, requiring most ships to be retrofitted with GMDSS equipment. In the absence of interference, the GMDSS is able to reliably perform the following functions: alerting, including position determination of the unit in distress; search and rescue coordination; locating (homing); maritime information broadcasts; general communications; and bridge-to-bridge communications.

Section 5.4 of the NTIA Manual states that, "stations in the maritime and other radio services employing frequencies and techniques used in the GMDSS shall comply with the relevant ITU-R recommendations with respect to the technical characteristics of, among others, digital selective calling (DSC) distress call formats and . . . other broadcasts of maritime safety information using narrow band direct-printing (NBDP) in the bands 4-27.5 MHz." Additionally, such stations when using DSC shall conform to the calling, acknowledgment, and operating procedures for DSC contained in the ITU Radio Regulations (Article 32) and the relevant ITU-R recommendations. Table C-10 provides typical technical characteristics of maritime mobile systems in the HF band.

Table C-10: Typical Technical Characteristics of Maritime Mobile Systems (1.7-30 MHz Band)

System	Freq. Band (MHz)	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (Ft)	Ant. Type/ Polarization	Modulations
Distress/ SAR *	2-30	2.8	0-2	unknown	Whip, Cone/V	Single sideband-suppressed carrier, single channel, analog, telephony

* SAR = Search and Rescue.

C.2.6 Broadcasting Service

In the Federal Government, HF broadcasting from the U.S. is conducted by the Broadcasting Board of Governors (BBG). The BBG has the mission to promote understanding abroad of the United States, its policies, its people, and its culture. HF radio is a very practical means of communicating directly with the people of other nations because of the extensive availability of inexpensive broadcast receivers. The BBG's global radio network, the Voice of America (VOA), consists primarily of two powerful HF transmitter sites (located in California and Virginia).

The power levels for equipment at VOA installation can be as high as 500 kW. The modulation designator typically is 10K00A3E. This accommodates a 10 kHz bandwidth signal, amplitude modulation, and audio communication. A multi-band, curtain-array antenna is a representative type of antenna for VOA broadcast installation.

While the intended receivers of the VOA's transmissions generally are abroad there are numerous broadcasting receivers owned and operated by foreign citizens and government personnel in the United States that could be susceptible to BPL interference because of proximity to power lines. Protecting other administrations' broadcasting is critical because of reciprocity. The current ITU-R B-03, Seasonal Broadcasting Schedule, shows multiple administrations broadcasting to the United States for every timeframe within a 24- hour period.[10]

The 18 bands allocated to the Federal Government for broadcasting service in the HF portion of the spectrum are listed in Table C-11. Because of frequency reuse capabilities inherent in HF broadcasting, one should expect that broadcast receivers located in the United States are tuned within these bands.

Table C-11: Frequency Bands Allocated to the Federal Government for Broadcasting Service in the 1.7-80 MHz Band

Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)	Frequency (kHz)	BW (kHz)
5900-5950	50	11650-12050	400	15600-15800	200
5950-6200	250	12050-12100	50	17480-17550	70
7300-7350	50	13570-13600	30	17550-17900	350
9400-9500	100	13600-13800	200	18900-19020	120
9500-9900	400	13800-13870	70	21450-21850	400
11600-11650	50	15100-15600	500	25670-26100	430
Total Bandwidth (BW) = 3,720 kHz					

C.2.7 Aeronautical Mobile Service

The aeronautical mobile service is subdivided into two distinct radio services; namely, aeronautical mobile route (R) and aeronautical mobile off-route (OR) services. By definition, the aeronautical mobile (R) service is reserved for communications relating to safety and regularity of flight, primarily along national or international civil air routes; while, the aeronautical mobile (OR) service is intended for other communications, including those relating to flight coordination, primarily outside national or international civil air routes.[11] In the 1.7-80 MHz band, a total of 21 bands are allocated to these services with a total of 2176 kHz of spectrum. Out of the 2176 kHz of spectrum, 1331 kHz is dedicated for the aeronautical mobile (R) service and 845 kHz is assigned to aeronautical mobile (OR) service. In general, the Federal Government frequency assignments in the bands allocated to the aeronautical mobile service in this portion of the spectrum are used for controlling aircraft traffic. Other uses in the United

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[10] Broadcasting Board of Governors Response to NTIA Memo, *Questionnaire Regarding Equipment and Operations in the 1.7-80 MHz Frequency Range*, November 7, 2003.

[11] NTIA, *Manual of Regulations and Procedures for Federal Radio Frequency Managers,* U.S. Department of Commerce, National Telecommunications and Information Administration, Washington, D.C., January 2004 Revision.

States may include Airline Operational Control (AOC) communications of foreign air carriers, including for scheduled traffic.

C.2.7.1 Aeronautical Mobile (R) Service

Frequency assignments to stations in the aeronautical mobile (R) service, in the HF band, must be assigned in conformity with the provisions and the allotment plan of Appendix 27 of the ITU Radio Regulation (RR). Such assignments conform to the plan for the allotment of frequencies to: (a) Major World Air Route Areas (MWARAs); (b) Regional and Domestic Air Route Areas (RDARAs); (c) VOLMET Allotment Areas; and (d) Worldwide Allotment Areas contained in Appendix 27 (RR) or, to meet operational requirements not otherwise met by the Allotment Plan, must comply with the provisions of Appendix 27 for the adaptation of allotment procedures. Assignments in support of International Air Routes (MWARA and VOLMET allotments) are also within the purview of applicable International Civil Aviation Organization (ICAO) frequency assignment plans that have been agreed internationally and are recognized in the ITU RR.

As a matter of general policy, HF is not normally used for aeronautical mobile (R) communications in the domestic services within the conterminous United States, the need for such frequencies having been generally eliminated through successful use of the VHF communications.[12] However, Appendix 27 (RR) Part II, Section I, Article 2 provides for the allotment of frequencies to the RDARAs, which include the conterminous United States, and also Alaska, Hawaii, Puerto Rico, and the Virgin Islands. This then enables special aeronautical communication requirements, not conforming fully to the definition of the aeronautical mobile (R) service, to be satisfied by use of frequencies from these allotments within the limitations of the national criteria established jointly with the FCC.[13] Section C.4.4 provides these national criteria.

Certain frequencies in the HF band are available to all government agencies for operational control and safety of civil government aircraft in certain specified areas. These frequencies, as listed in Table C-12, are intended for support of operations not exclusively en route in nature. These frequencies were chosen so as to avoid those channels in which operation might result in harmful interference to aeronautical stations dedicated to the safety and regularity of flight.

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[12] *Id.* at 8-13.

[13] *Id.*

Table C-12: Frequencies Designated for Operational Control of Civil Government Aircraft

Assigned Freq. (kHz)	Carrier Freq. (kHz)	Areas of Operation
2897.4	2896	AK, HI, CONUS
2948.4	2947	AK, HI, CONUS
3002.4	3001	AK, HI, CONUS
6539.4	6538	CONUS
8886.4	8885	CONUS
8910.4	8909	AK, HI, CONUS
10055.4	10054	HI
11307.4	11306	CONUS
17950.4	7949	AK, HI, CONUS
21926.4	21925	AK, HI, CONUS
21929.4	21928	AK, HI, CONUS
21935.4	21934	AK, HI, CONUS

The Federal Government aeronautical stations that operate in the aeronautical mobile (R) service within the US&P are normally authorized only for the Federal Aviation Administration (FAA), mainly for its HF system called the National Radio Communications System (NRCS). As such, Federal Government spectrum use of the aeronautical mobile (R) service in the HF band is limited to few federal agencies. For example, the DOI use of the aeronautical mobile (R) service is mainly outside of the contiguous United States. Specifically, their use is mostly in Alaska, Hawaii, and the trust territories of the Mariana and Marshall Islands in the Pacific Ocean. Operations in the trust territories include inter-island communications. In Alaska, Hawaii, and CONUS, the DOI assignments are required for en route communications and flight following of aircraft in support of national resource programs.

Frequency assignments belonging to the Department of Treasury are used for aircraft in support of law enforcement responsibilities. Table C-13 specifies the particular bands used for aeronautical mobile (R) and respective bandwidths.

Table C-13: Frequency Bands Allocated to the Aeronautical Mobile Service (R) (1.7-30 MHz Band)

Frequency (kHz)	Bandwidth (kHz)	Frequency (kHz)/Service	Bandwidth (kHz)
2850-3025	175	10005-10100	95
3400-3500	100	11275-11400	125
4650-4700	50	13260-13360	100
5450-5680	230	17900-17970	70
6525-6685	160	21924-22000	76
8815-8965	150	—	---
Total Bandwidth = 1331 kHz			

Table C-14 shows typical technical characteristics of Federal Government systems in the aeronautical mobile (R) service.

Table C-14: Typical Technical Characteristics of Aeronautical Mobile (R) Systems (1.7-30 MHz Band)

System	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (Ft)	Ant. Type/ Polarization	Modulations
Airborne	2.8	0	18000-40000	Conformal/V	Analog, single channel, suppressed carrier, telephony.
Ground	2.8	0-3	unknown	Various /V	Analog, single channel, suppressed carrier, telephony.

C.2.7.2 Aeronautical Mobile (OR) Service

Frequencies in bands allocated exclusively to the (OR) service are internationally alloted to countries by Appendix 26 of the ITU RR, which also establishes frequency sharing criteria, protection ratios, and other technical and operational principles. These principles recognize the possible necessity for the adaptation of the allotment plan to meet valid requirements of the various administrations, provided these adaptations do not decrease the protection to frequencies assigned in strict adherence to the plan.[14]

Frequencies in the bands allocated exclusively to the (OR) service are nationally used primarily for the satisfaction of military aeronautical requirements. Assignments of frequencies in these bands are subject to coordination with the Military Departments through the Interdepartment Radio Advisory Committee (IRAC) mechanism.

Nationally, the use of the aeronautical mobile (OR) service bands is mainly for military operations that include controlling traffic routes and special military needs. The Navy and Air Force are the major users of the aeronautical mobile (OR) bands. The vast majority of their assignments are dedicated for air-ground-air communications provided by the AN/ARC family of radios. The AN/ARC-190 is a typical radio used by the Air Force in the HF band and is described below. Other uses of the aeronautical mobile (OR) service bands by the Air force are: global command and control stations required for air and ground communications; flight testing; ground tactical communications; communications for the Strategic Air Command (SAC) forces; data coordination; and de-orbiting satellite recovery operations.

Table C-15 shows the frequency bands allocated to the aeronautical mobile service (OR) in the 1.7-30 MHz band and Table C-16 shows a typical technical characteristics of aeronautical mobile service (OR) system in the HF band.

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[14] *Id.* at 8-14.

Table C-15: Frequency Bands Allocated to the Aeronautical Mobile (OR) Service (1.7-30 MHz Band)

Frequency (kHz)	Bandwidth (kHz)	Frequency (kHz)	Bandwidth (kHz)
3025-3155	130	11175-11275	100
4700-4750	50	13200-13260	60
5680-5730	50	15010-15100	90
6685-6765	80	17970-18030	60
8965-9040	75	23200-23350	150
Total Bandwidth = 845 kHz			

AN/ARC-190. The AN/ARC-190 works in conjunction with the AN/TRC-181 to provide short-, medium-, and long-range voice and data communications employing an automatic communications processor for auto link and anti-jam capabilities. These systems employ multiple modulations and coding techniques, including sideband suppressed carrier, single sideband reduced or variable level carrier, continuous wave employing frequency hopping and pseudo random pre-selection technique.

Table C-16: Typical Technical Characteristics of Aeronautical Mobile (OR) Systems (1.7-30 MHz Band)

System	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (ft)	Ant. Type/ Polarization	Modulations
AN/ARC (airborne)	3.5	0.0	30,000	Blade/V	Analog and digital, single channel, reduced or suppressed carrier, telephony and data.
AN/TRC (ground)	3.5	0.0	6-32	Whip/V	Analog and digital, single channel, reduced or suppressed carrier, telephony and data.

C.2.8 Standard Frequency and Time Signal[15]

The Federal Government, via the National Institute of Standards and Technology (NIST), has provided standard time and frequency services since 1923 in the HF band. These services are important to a community of technical users in support of basic activities such as navigation, power generations, and communications. However, many of these HF capabilities are being supplemented by the GPS. The services provided include: time announcements; standard time intervals; standard frequencies; geophysical alerts; marine storm warnings; Omega Navigation System status report; Coordinated Universal Time (UTC) corrections; and digital time code.

NIST provides time and frequency services at 2.5 MHz, 5 MHz, 10 MHz, 15 MHz, and 20 MHz. The services are broadcast from stations WWV, in Fort Collins, CO, and from WWVH, in Kauai, HI. Table C-17 shows the radiated power for the transmissions at each location. The antennas at WWV are omnidirectional, half-wave dipoles. At WWVH, the

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[15] *Supra* note 1 at 72.

antennas are phased vertical half-wave dipole arrays with maximum gain in a westerly direction. Double sideband amplitude modulation is employed at both stations. Four modulation levels (25, 50, 75, and 100 percent) are used depending on the particular information transmitted.

Table C-17: Radiated Power for Transmissions at Stations WWV and WWVH

Frequency (MHz)[a]	Radiated Power at WWV (kW)	Radiated Power at WWVH (kW)
2.5	10	10
10	10	10
15	10	10
20	2.5	--

[a] The 25 MHz is currently not in use.

As the GPS and other communications systems become more widely assimilated, HF time broadcasts service may become obsolete. Currently, the main users of the HF standard frequency and time signal services are hobbyists, amateurs, and signal propagation researchers.

In the 1.7- 30 MHz frequency range, 13 bands are allocated to the standard frequency and time signal radio service on a primary basis. Table C-18 shows these bands and their respective bandwidths.

Table C-18: Frequency Bands Allocated to the Standard Frequency and Time Signal Service in the 1.7-30 MHz Band

Frequency (kHz)	Bandwidth (kHz)		Frequency (kHz)	Bandwidth (kHz)
2495-2505	10		14990-15010	20
4995-5005	10		19990-20010	20
9995-10005	10		24990-25010	20
Total Bandwidth = 90 kHz				

C.2.9 Aeronautical Radionavigation

In the 1.7-80 MHz frequency range, the 74.8-75.2 MHz band is allocated to the aeronautical radionavigation service. The federal agencies that operate on this band are the Air Force, Army and the FAA. Basically, use of this band is for marker beacons that provide navigational aids, including the Instrumentation Landing System (ILS). Marker beacons provide the pilot a reliable altitude indicator as it approaches the runway (barometric altimeters are not accurate at low altitudes). Most ILS and localizer landing approaches incorporate at least one marker and as many as three. The first marker (Outer Marker) is anywhere from four to 10 miles from the end of a runway and, normally, supports navigation for the initial approach. The marker beacon transmit in the ground-to-air direction at 75 MHz and is modulated with a 400 Hz intermit tone. The second marker (Middle Marker) is normally used about 3,000 feet off the end of the landing runway. The Middle Marker is normally used about 200 feet above ground level. This marker is transmitted at 75 MHz with a 1,300 Hz tone modulation. The third marker (Inner

Marker) is normally installed around 1,000 feet from the end of the runway. Again, the transmit frequency is 75 MHz but the tone is at 3,000 Hz.[16]

ITU RR No. 5.180 states that,

> "The frequency 75 MHz is assigned to marker beacons. Administrations shall refrain from assigning frequencies close to the limits of the guardband to stations of other services which, because of their power or geographical position, might cause harmful interference or otherwise place a constraint on marker beacons. Every effort should be made to improve further the characteristics of airborne receivers and to limit the power of transmitting stations close to the limits 74.8-75.2 MHz."

About 98 percent of the federal assignments that support marker beacons operation belong to the FAA. Because many major airports are within the vicinity of metropolitan or urban areas, BPL operations generally should not be considered in the 74.8-75.2 MHz band. Typical technical characteristics of aeronautical radionavigation systems operating in the 7.4-75.2 MHz band are shown in Table C-19.

Table C-19: Typical Technical Characteristics of Radionavigation Systems in the 74.8-75.2 MHz Band

System	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (Ft)	Ant. Type/ Polarization	Modulations
Marker Beacon	0.8-6	-2.5-2.0	0-3000	Blade/H	Amplitude modulation, double sideband, single channel, digital and telegraphy

C.2.10 Radiolocation Service

The radiolocation service is a radiodetermination service used for detection and positional location of distant objects (targets).[17] There are three bands allocated to the radiolocation service in the 1.7-80 MHz range, as shown in Table C-20.

Table C-20: Frequency Bands Allocated to the Radiolocation Service (1.7-80 MHz Band)

Frequency Band (kHz)	Bandwidth (kHz)	Allocation
1705-1800	95	Primary
1900-2000	100	Primary
3230-3400	170	Secondary

In these bands, three federal entities (Navy, Army, and Tennessee Valley Authority (TVA)) are currently employing radiolocation systems. The Navy uses these bands in support of fleet operations and for surveillance. Specifically, the Navy's radiolocation systems provide position fixing in support of mine countermeasure operations and long range surveillance. For

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[16] http:/www.avionicswest.com/marker beacon receiver.htm.

[17] *Id.* at 6-11.

surveillance, the Navy employs a long range, re-locatable over the horizon radar system (AN/TPS-71). This system is described further in Section C.4. The Army has multiple radiolocation requirements in these bands, namely, for test range and off-shore operations, including such as; target scoring; hydrographic surveys; and for determining location of missile payloads during recovery operations. The TVA has two radiolocation assignments for establishing boat positions while conducting water quality surveys in the vicinity of thermal-electric generation plants in TVA service areas. Typical technical characteristics of a radiolocation system in the 1.7-80 MHz band are presented in Table C-21.

Table C-21: Representative Technical Characteristics of Radiolocation Systems in the 1.7-80 MHz Band

System Station	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (ft)	Ant. Type/ Polarization	Modulations
Land & Ship	0.001-0.600	0-3	unknown	unknown/V	Amplitude modulation, double sideband, single channel, digital and telegraphy

C.2.11 Amateur and Amateur-Satellite Services

The amateur service is a radiocommunication service for the purpose of self-training, inter-communication and technical investigation that is used by duly authorized persons interested in radio techniques solely with a personal aim and without pecuniary interest.[18] Amateur radio operators' licenses are granted by the FCC and uses must adhere to technical standards as given in the FCC Rules and Regulations, Part 97 — Amateur Radio Service. The Amateur-satellite service is a radiocommunication service using space stations on earth satellites for the same purposes as those of the amateur service.[19]

Amateur radio operators extensively assist the law enforcement community and other public service organizations during all kinds of emergencies including: hurricanes, earthquakes, tornadoes and floods, motorist accidents, fires and chemical spills, and search and rescue operations.[20]

There are 13 bands allocated to the amateur and amateur-satellite services (1.7-80 MHz band). The majority of these bands is in the lower portion of the HF band and is presented in Table C-22.

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[18] 47 C.F.R. §2.1(c).

[19] *Id.*

[20] http://www.arrl.org/hamradio.html.

Table C-22: Frequency Bands Allocated to the Amateur and Amateur-Satellite Services in the 1.7-80 MHz Band

Frequency Band (kHz)	Radio Service	Bandwidth (kHz)	Total Bandwidth (kHz)
1800-1900	Amateur	100	Amateur = 7650 Amateur-Satellite = 2700
3500-4000	Amateur	500	
7000-7100	Amateur/Amateur-Satellite	100	
7100-7300	Amateur	200	
10100-10150	Amateur	50	
14000-14250	Amateur/Amateur-Satellite	250	
14250-14350	Amateur	100	
18068-18168	Amateur/Amateur-Satellite	100	
21000-21450	Amateur/Amateur-Satellite	450	
24890-24990	Amateur/Amateur-Satellite	100	
28000-29700	Amateur/Amateur-Satellite	1700	
50000-54000	Amateur	4000	

The DOD administers the Military Affiliate Radio System (MARS). The MARS is managed and operated by the Army, Navy and the Air Force. The MARS program consists of civilian and military licensed amateur radio operators who are interested in supporting military communications. The MARS volunteer force includes more than 5,000 dedicated and skilled amateur radio operators.[21] They contribute to the MARS mission providing auxiliary or emergency communications on a local, national, and international basis as an adjunct to normal communications.[22] The radios used in the MARS program are the same or equivalent systems used by the amateur radio operators.

The MARS system continues to play an important role in the military for: (1) helping to maintain morale through assistance in the maintenance of contacts with spouses or friends even when the distance separation is great, and (2) when needed, it can augment emergency communication services within the military. The morale of servicemen and women is always an important area of concern for military commanders, particularly for personnel stationed in remote areas away from family and friends. Another area of concern for the military is to maintain an independent system that can be used in time of war, emergencies or other national disasters in ready-to-use condition. The MARS HF network is constantly being tested by calls made by the military personnel. Another benefit of this active system is as a training tool for reservists and active duty servicemen on a system they may be called upon to operate in an emergency situation.[23] Typical technical characteristics of a MARS radio are presented in Table C-23. Note, however, that the antennas used vary widely.

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[21] http:/www.asc.army.mil/mars/mars/.

[22] http:/www.//afmars.tripod.com/mars1.html.

[23] *Supra* note 1 at 83-84.

Table C-23: Representative Technical Characteristics of MARS System (1.7-30 MHz Band)

System	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (Ft)	Ant. Type/ Polarization	Modulations
MARS	2.7	0-10	0-80	Dipole, yagi, log periodic/ H & V	Amplitude modulated, Analog and digital, single or multiple channels, suppressed carrier, telephony and telegraphy.

C.3 FEDERAL GOVERNMENT SPECIAL OPERATIONS

C.3.1 Automatic Link Establishment (ALE) Systems

The Federal Government employs ALE subsystems in the medium to high frequency (MF-HF) range of the radio spectrum to eliminate the need for extensive training needed for manual establishment of HF and MF radio channels that use ionospheric (skywave) signal propagation. An ALE system is characterized by periodic polling of several frequencies (typically seven or more) that are assigned to a station to determine if ionospheric circuits are available at these frequencies. An ALE equipped radio automatically selects the best channel for communications by maintaining in real time a data base of link performance (*e.g.*, received signal-to-noise power ratio) versus frequency for each addressee in the users net and using that data to choose frequencies on which to initiate a link. A network of stations is assigned a number of frequencies over which to communicate, and each station is assigned a unique address (*e.g.,* alpha-numeric).

For example, station A, attempting to establish a link with station B will repetitively broadcast the address code for station B over one of the assigned network frequencies. This transmission will last long enough for station B to automatically scan its assigned frequencies. If station B receives and recognized its address code, it stops on that frequency. The equipment at both ends of the link will then automatically handshake and alert the operators that the link has been or can be established, and the desired traffic can be transmitted (*e.g.*, voice, secure voice, and data). If communications fail, the ALE equipment tries another frequency in the preset list until a link is established or the operator is informed of communications failure. Failures will occur, for example, if interference prevents communications on frequency assignments that an ALE system would otherwise determine to be the best available channels, in which the user will not realize that interference is the cause.

C.3.2 Sounders

In general, sounders are used to gain an in-depth real-time knowledge of the ionosphere conditions important to communication applications. In a stable ionospheric condition, sounder data need only to be taken every 15 minutes, and a complete record can be obtained in a fraction of a minute. Sounders data typically are used in support of non-ALE applications.

There are three main types of sounding systems; namely, backscatter, oblique and vertical incidence sounders. Backscatter sounders typically receive weak signals originating from a signal transmitted to the ionosphere, scattered back to the Earth's surface, back to the ionosphere, and scattered back to the original transmitter site and its associated receiver system. This technique is well suited for obtaining the propagation conditions as they relate to range, azimuth bearing, and frequency of operation. Oblique sounding uses an intermittent beacon located at a known distance from the receiver site. Since the range variable is removed, the resulting signal will be due to the ray-path distance associated with the various layers in the ionosphere. With good synchronization between the beacon and the receiver system, detailed information can be readily obtained. With this method, it is possible to determine the ionospheric virtual height. However, for this method to be applicable, the beacon must be placed in the area under the portion of the ionosphere that is of interest. Vertical incidence sounding provide information regarding the portion of the ionosphere that is directly overhead. The advantage of this type of sounding is that the transmitter and the receiver are co-located and this greatly simplifies the synchronization problem between the transmitter and the receiver. Operationally, however, the vertical incidence sounders are the least desirable type of sounder for determining appropriate communication system parameters. Table C-24 provides a summary of the Federal Government agencies sounding systems and relevant technical characteristics.

C.3.3   Over the Horizon (OTH) Radars[24]

Over the horizon radar systems are employed by the DOD. The OTH radars use skywave propagation to detect targets at long ranges from the radar transmitter site. The target return is a result of the backscatter signal traversing the path to the ionosphere and back to the original transmitter site (primary radar) or an alternative site (secondary site). OTH radar systems generally utilize more bandwidth than is typically used for communications. These systems place increased demands on the amount of spectrum used and performance is greatly affected by the characteristics of the ionospheric channel. OTH-HF radars are capable of detecting targets at distances beyond the horizon and therefore, targets located well beyond the range of the conventional microwave radar. This increased range is possible due to the ability of the HF signals to propagate well beyond the line-of-sight either by ground wave diffraction around the curvature of the Earth or by skywave. An example OTH radar system operating in the HF portion of the spectrum is the AN/TPS-71. A brief description of this system is provided below.

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[24] *Supra* note 1 at 74.

Table C-24: Federal Government Sounding Systems and Technical Characteristics

Federal Agency	Receiver Type	No. of Assignments[25]	Operating Frequency (kHz)	Emission Bandwidth	Antenna Type	Gain/ Polarization	Function(s)
AF	DIGISONDE 128	2	415-20012.5	20KM0N	--	15/T	-Provides ionosphere data to AF Global Weather Center
	DPS-4	2	1000-40000	30KV7D	--	10/T	-Ionospheric research. -Propagation research
	DIGITAL IONOSONDE	1	2220.5-2465	60KM1N	---	1	-Regional ionospheric forecast and specification
	AN/FMQ-12	20	1012.5-30000	2H5N0N 75KM0N 75KP0N 600HF9W	Broad-band dipole	0-16/ T/H	-Weather forecasting. -Ionospheric research -Provides ionospheric data to AF Global Weather Center
AR	AN/TRQ-35	2	2000-30000	2H5N0N	Double Delta		-Support Army's fixed communications
N	R-2368/URR AN/TPS-71 AN/ARC-191	15	2000-30000	2H5N0N 100HN0N 600HF1B 4K2F3N 4K2Q1N 100KQ1N 100KF3N	Phased array/ Whip/ Log periodic	0-36/ V&H	-Wide area surveillance. -Detection, location, tracking of aircraft and ships. -Air Defense warning.
C	---	1	1000-20000	40KP0N	--		-Propagation research studies
DOE	STQIONOSONDE	5	2505-14990	100HNON	Inverted-V	2	-Doppler shift measurement to support DOE earthquake monitoring system.

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[25] In the Government Master File, an assignment may represent multiple radio equipments.

AN/TPS-71. The Navy's AN/TPS-71 is transportable OTH radar, with an operating frequency range of 5-28 MHz that can provide wide area active surveillance in support of tactical forces. Uses include detection, location, and tracking of aircraft and ship targets at a range of up to 1600 nautical miles in high interest marine areas. Transportable, in this sense, refers to having the capability to redeploy the system to another location over a period of time, as opposed to tactical mobility. This provides the Navy flexibility to be responsive to changing threat patterns and capabilities. This is a frequency agile system. There are a few OTH radar sites in the United States (AK, TX, and, two in VA), and few more overseas. The basic technical characteristics of the AN/TPS-71 receiver are shown in Table C-25.

Table C-25: Technical Characteristics of the AN/TPS-71 System (1.7-30 MHz Band)

System	Bandwidth (kHz)	Ant. Gain (dBi)	Ant. Height (Ft)	Ant. Type/ Polarization	Modulations
AN/TPS-71	4.2-100	9-36*	Not available	Phased Array/ Vertical	FM/CW or Angle-modulated, single channel, with analog or digital signals.

* The 9 dBi and 36 dBi antenna gains are measured at the 5 MHz to 28 MHz, respectively.

C.4 SPECIAL OPERATIONAL CONSIDERATIONS

C.4.1 Operational Requirements for Access to Several Frequency Assignments within an Allocation

Ionospheric (skywave) signal propagation is frequency selective and frequencies usable for communications between any two points changes over time throughout the day. This is why several different segments of the 1.7-30 MHz frequency range are allocated to each radio service (*i.e.*, so that the service has full-time access to frequencies that are usable throughout the day). This is an important factor in assessing the operational impact of broadband interfering signals that typically overlap an entire HF allocation for one or more services. In the event local harmful interference occurs across an HF allocation, the associated service will not be able to operate in that locale for several hours during the day.

Even if only a portion of a given allocation is subjected to local harmful interference, the local communications reliability is greatly diminished for services that utilize multiple frequency assignments within a band. This is because the choice among multiple assignments allows the local radio operator (or ALE system) to avoid channels that are laden with relatively high local noise power levels or are in use by other radio systems.

C.4.2 Federal Government use of Radio Frequencies Below 30 MHz for Domestic Fixed Service

Section 8.2.11 of the NTIA Manual provides restrictions on fixed service use of frequencies below 30 MHz. To insure that, insofar as practicable, sufficient high frequencies will be available for the operation of radio circuits essential to the national security and defense and to conserve frequencies below 30 MHz for services which cannot operate adequately without them, only in following circumstances shall departments and agencies of the Executive Branch of the Government use frequencies below 30 MHz for domestic fixed service within the conterminous United States:

a) When it is indispensable to do so, and on the condition that the characteristics of the stations continue to conform to those in the GMF, a land station may communicate, on a secondary basis, with fixed stations or other land stations in same category, using its assigned frequencies;

b) Where technical and operational requirements dictate, fixed stations may transmit to other fixed stations for the domestic haul or overseas traffic in transit, or destined for the United Sates. Such domestic radio haul shall be a segment of the overall overseas radio system;

c) When there is a need to provide instantaneous transmission of vital emergency, operational command and alerting traffic of such importance as to affect the immediate survival and defense of the nation;

d) When required for use in an emergency jeopardizing life, public safety, or important property under conditions calling for immediate communication where other means of communication do not exist or are temporarily disrupted or inadequate;

e) When there is a need to provide for a communications system manned by fully qualified operators who are military reservists or affiliates (e.g., MARS). Except in emergencies, frequency assignments in this category shall not be used as a means for passing traffic that in the absence of such assignments would require delivery by other means;

f) When other telecommunication facilities do not exists, are inadequate, or are impracticable of installation, and when the use of frequencies above 30 MHz is not practicable; and

g) In an emergency where it has not been feasible to make prior arrangements for alternate means of communications, it is permissible to operate temporarily on regularly assigned frequencies in a manner other than that specified in the terms of an existing assignment or on other appropriate frequencies under special circumstances such as an emergency must actually exist or imminently threaten emergency operations shall be discontinued as soon as substantially normal communications facilities are restored.

Also, Section 8.2.11 (2) and (3) of the Manual supplements or clarifies the above mentioned restrictions with respect to the requests for the authorization of frequencies below 30 MHz for new systems or in circumstances where congestion in the radio spectrum would be increased materially, and establishing adequate radio backup of wireline facilities in advance for use during an emergency.

C.4.3 Summary of the Emergency use of Federal Government HF Frequencies for the SHARES Program

The National Communications System (NCS) SHARES HF Radio Program is a key element in the national telecommunications infrastructure using presently authorized HF radio networks and cooperating federal agencies. SHARES is a collection of existing federal agency controlled HF stations that will interoperate to exchange national security emergency preparedness (NSEP) traffic for any federal entity during a crisis or emergency. Participating agencies agree to accept SHARES actual or simulated emergency traffic, assuming responsibilities for delivery or relay to the extent it does not interfere with their own agency mission. The SHARES HF Program supports Executive Order 12472, 12656, and NSDD-97.

Agencies providing frequencies for the NCS SHARES program must have a US&P assignment in the GMF. Operations under these assignments are limited to SHARES operation and tests. Participating agencies in the NCS SHARES HF Radio Program are authorized to test the operating system periodically provided the respective agency Frequency Assignment Subcommittee Representatives are notified at least 30 days in advance.

C.4.4 National Criteria Established Jointly by NTIA and FCC on the use of Frequencies from Appendix 27 Allotment Plan

In the HF band, there are special and certain related aeronautical mobile requirements not fully conforming to the definition of the aeronautical mobile (R) service that have to be satisfied by the frequencies from ITU RR Appendix 27 allotment plan. However, the use of these frequencies will abide within the limitations of the following national criteria established jointly by the NTIA and FCC:

1) Communications related to safety and regularity of flight between an aircraft and those aeronautical stations primarily concerned with flight along national or international civil air routes shall have absolute priority over all other uses;

2) Use of (R) band high frequencies shall be limited to single sideband air/ground and incidental air/air communications beyond the range of VHF/UHF facilities;

3) Users shall share frequencies to the maximum extent possible;

4) Requirements shall be handled on a case-by-case basis;

5) A showing must be made that the accommodation of the requirements in the bands other than aeronautical mobile (R), *e.g.*, fixed bands, is not satisfactory for technical, operational, or economic reasons;

6) Only those requirements will be considered where the primary need for communications is for the safety of the aircraft and its passengers or for operational control communications, *i.e.*, "communications required or exercising authority over initiation, continuation, diversion, or termination of a flight in accordance with the provisions of Annex 6" (ICAO);

7) Use of aeronautical mobile (R) high frequencies in accordance with the foregoing normally shall be limited to non-military; and

8) If the aforementioned criteria are met, the stipulation that (R) bands are to be used only for flights along national and international civil air routes need not be met.

APPENDIX D
BROADBAND OVER POWER LINE
EMISSION MEASUREMENTS

D.1 INTRODUCTION

This appendix presents measurements performed by NTIA's Institute for Telecommunications Sciences (ITS) that quantified several aspects of BPL signals. The measurements were conducted in three areas where BPL systems are currently deployed for testing and are serving customers. Access BPL was implemented on MV wires in all three areas and in-house BPL was implemented on LV wires in two areas. Some access BPL was on overhead wires and some is on underground wires, whereas, all of the in-house BPL was above ground except where, in some cases, there were buried LV wires leading up to the houses. The objectives for the measurements were to:

1. Measure the received BPL signal power at points along power lines;
2. Measure the received BPL signal power at various distances from power lines;
3. Measure the received BPL signal peak, average and quasi-peak levels for comparison;
4. Measure the received BPL signal power at different antenna heights; and
5. Measure the amplitude probability distributions (APDs) of the BPL signal.

The measurement system used for this testing is described in Section D.2. Figures and tables of measured data are provided in Section D.3. In section D.4 of this report, background information about APDs is covered, and in Section D.5, gain and noise figure calibration is described.

D.2 THE MEASUREMENT SYSTEM

The measurement system block diagram is shown in Figure D-1. An antenna, positioned 10 meters above the ground atop a telescopic mast on the ITS "RSMS-4" measurement vehicle (Figure D-2) and 2 meters above the ground on a tripod, was used to measure the received power. Four different types of antennas were used. A small discone antenna over a small ground plane was used to measure the electric fields above 30 MHz. Below 30 MHz, two shielded loops were used to measure the magnetic fields and for the electric fields, a rod antenna over a small ground plane was used. To measure the received power that is expected to be seen by a typical land mobile radio, a 2.13 meter base-loaded whip antenna was mounted on the roof of a vehicle at an approximate height of 1.5 meters. The whips were narrow-band, so several of them were used to cover the measurement frequencies. The signal from the antenna was split into two measurement systems so that simultaneous measurements could occur and to minimize switching instrument setups. A preselector was used on each system in order to prevent an overload condition from occurring and improve the sensitivity. Computers were used to control the measurement instruments and store the data.

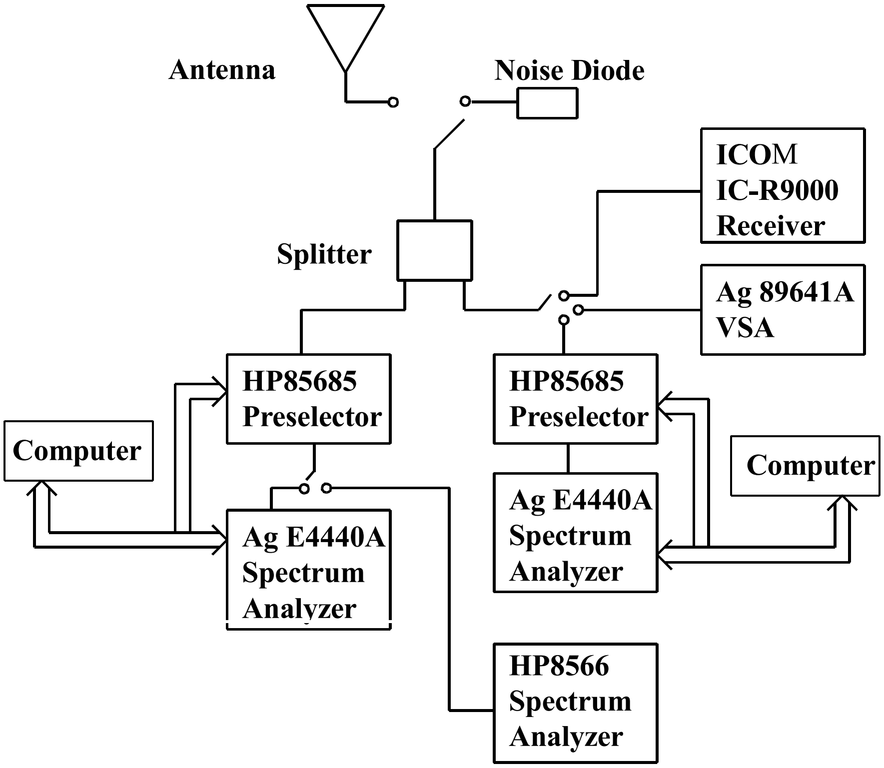

Figure D-1: BPL measurement system block diagram.

Figure D-2: Radio Spectrum Measurement System - 4 (RSMS-4)

The output of one of the preselectors was variously connected to a HP 8566 spectrum analyzer with a quasi-peak detector, a vector signal analyzer or a multi-mode communications receiver. The receiver was used to listen to the BPL signal in several demodulation modes and to assist with distinguishing between BPL and other signals. The vector signal analyzer was used to record the time-waveform for future analysis.

D.3 BPL MEASUREMENTS

D.3.1 Background on BPL Emissions Measurements

This sub-section provides general information on the BPL emissions from the three types of systems under test. These data are provided as an aid to understanding the measurements presented in Sections D.3.2 – D.3.6.

The BPL signal shown in Figure D-3 is representative of the weakest (lowest power density) BPL signals for which data were recorded. That is, nominal interference-to-noise ratio (I/N) levels had to exceed about 5 dB; otherwise no BPL signal level (I) was recorded[1]. Thus, even though much weaker BPL signal levels were measurable when turning the BPL system on and off (i.e., I/N of -6 dB), measurements with I/N ≥ 5 dB ensured that measured signals were unquestionably due to BPL emissions.

System #1

This system used different frequency bands for signals on the MV and LV wiring. Signal strength measurements were performed by acquiring multiple traces from a spectrum analyzer centered on specific frequencies with a zero span and a sampling detection mode. Trace data were downloaded to a computer and later analyzed statistically using Amplitude Probability Distributions (APDs). From these distributions, the temporal statistics of the BPL signal were identified and the power was determined as described in Section D.5. The signal power determined from these distributions is expressed as “100%-duty-cycle” power and represents the maximum power if the packet data were present 100% of the time (i.e. signal pulses occurring back-to-back), as further explained in Section D.4.0.

System #2

The BPL signal used OFDM modulation with a carrier spacing of approximately 1.1 kHz. BPL is transmitted only on the MV lines. The downstream (towards the customer) bandwidth was 3.75 MHz while the upstream (away from the customer) bandwidth was 2.5 MHz. An example portion of the spectrum is show in Figure D-3. The BPL signal displayed a repeating pattern of three carriers, then one carrier missing, and so on. The BPL signal duty cycle was 100% for the downstream signal and between 30% - 100% for the upstream. The envelope of an upstream signal is shown in Figure D-4 and it shows a duty cycle that is in the upper end of the range.

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[1] If a measurement is attempted and the BPL signal has an interference to background noise level (I/N) < 5 dB, the results reported in Subsections D.3.2 – D.3.6 will be referred to as “Not measurable.” If a particular measurement isn’t attempted, it will be reported as “*Not measured*.” The 100% duty-cycle power levels presented in this report were analyzed statistically from APD measurements and therefore did not need to satisfy the requirement of I/N ≥ 5 dB.

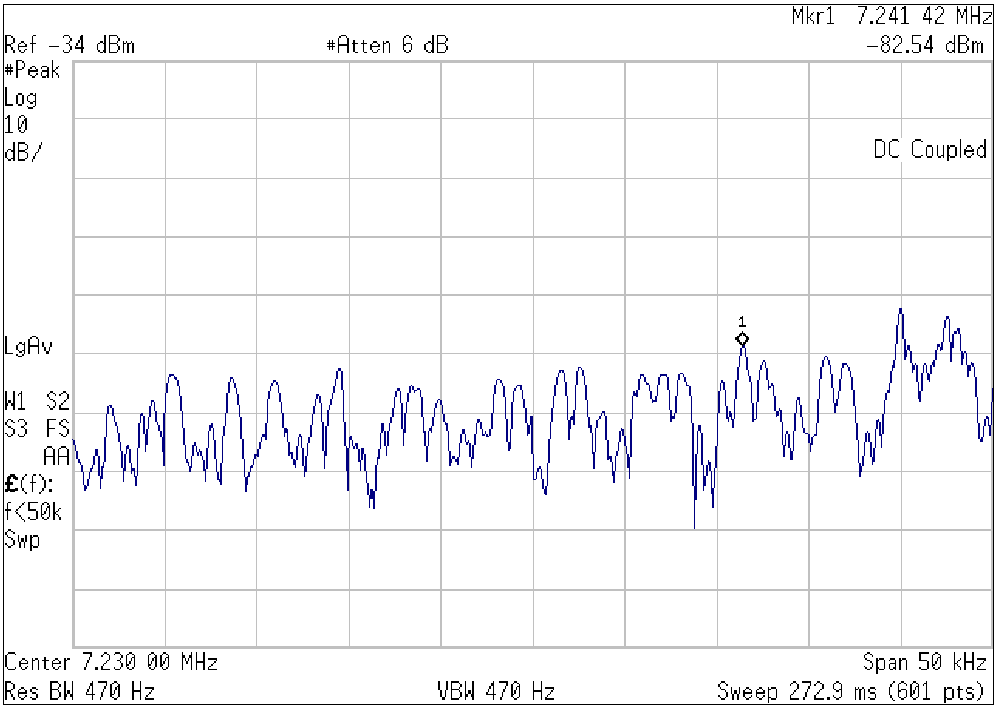

Figure D-3: A portion of the System #2 BPL spectrum.

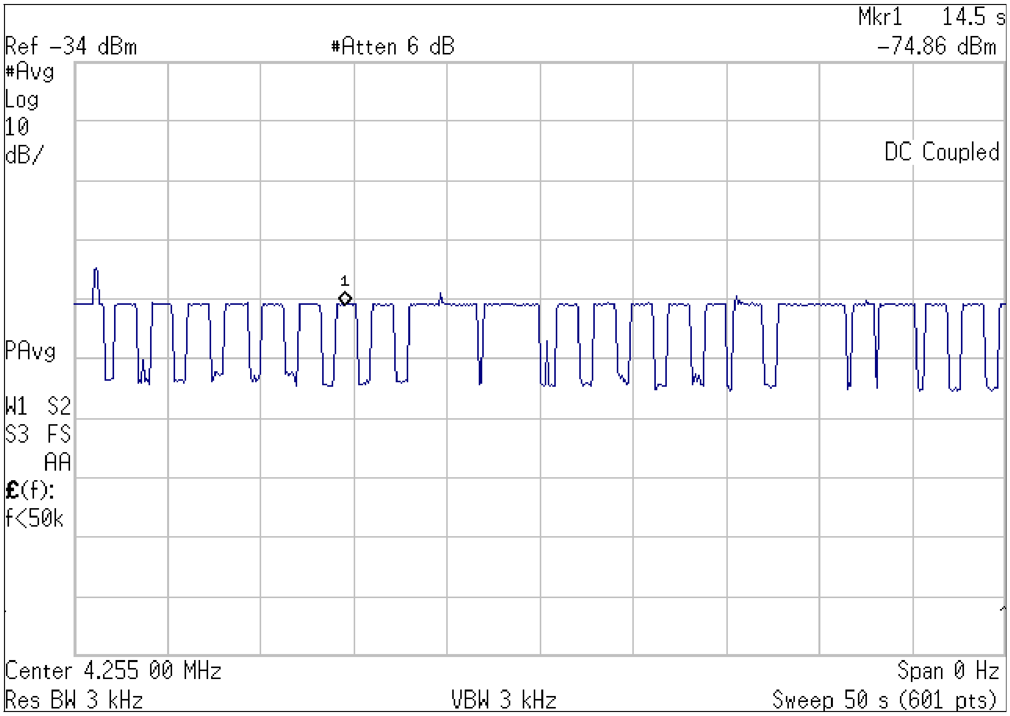

Figure D-4: The envelope of an upstream System #2 signal.

To measure System #2 emissions, the procedure involved examining the spectrum of the BPL transmission (see Figure D-3) and identifying a group of 3 adjacent carriers (since the measurement bandwidth was 3 kHz) that were among the strongest and were clear of background signals. If the signal was too weak (<5 dB above the background noise) to clearly see the spectrum or if background signals contaminated the BPL spectrum at certain frequencies, a measurement was not attempted at those frequencies. The marker in Figure D-3 shows the chosen measurement frequency. The resolution bandwidth was then set to 3 kHz and the marker (see Figure D-5) indicated the measured value using a peak detector. This value was later used to calculate the Received Power at the antenna terminals.

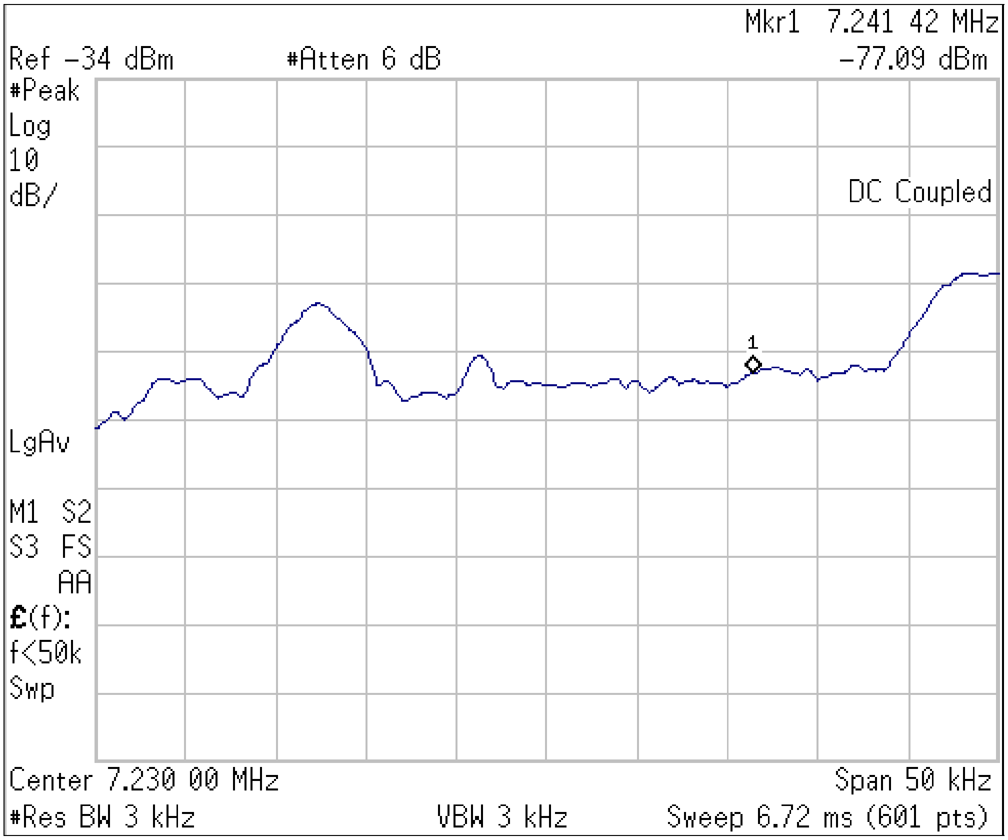

Figure D-5: The System #2 BPL spectrum in a 3 kHz bandwidth.

A measurement was performed to see how the received power varied as the receiver bandwidth was changed. This is shown in Figure D-6 for a frequency of 22.957 MHz. The narrow dips in signal level are due to the signal having a duty cycle of less than 100%. The upward spikes are due to noise sources.

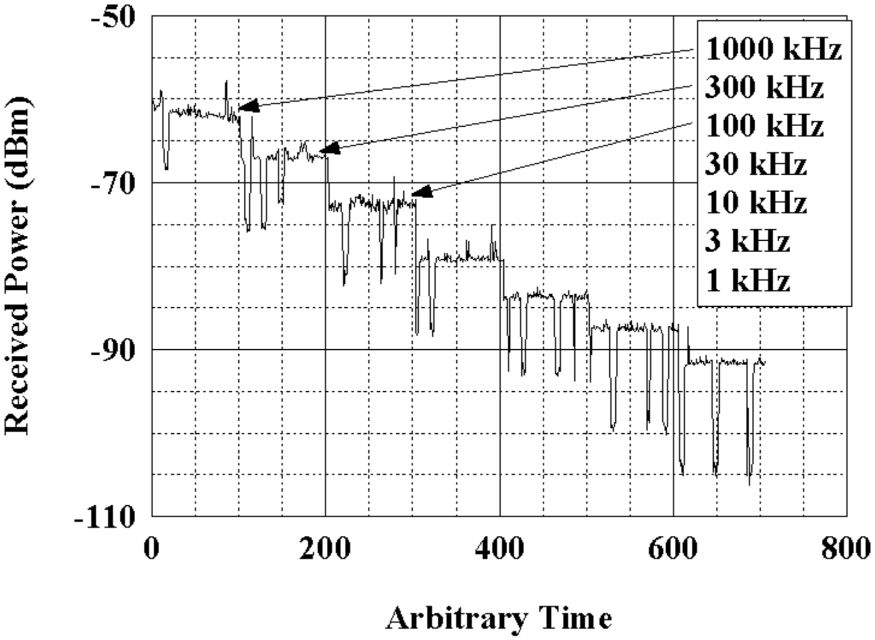

Figure D-6: Bandwidth progression at 22.957 MHz.

System #3

This BPL signal used DSSS modulation over the frequency range of about 1.8 to 21 MHz. BPL signals were transmitted on the MV and LV lines. The BPL signal duty cycle can be up to 90% when transmissions are occurring in both directions and about 87% for one direction. The envelope of the BPL signal is shown in Figure D-7. Four different amplitudes from four different transmitters are being received.

Figure D-7: Four different BPL transmitters.

In System #3, two co-frequency BPL sources were observed transmitting at the same time, as shown in the third graticule in Figure D-8. Noise sources can be present at levels stronger than the BPL signal as shown in the eight and ninth graticules in Figure D-9.

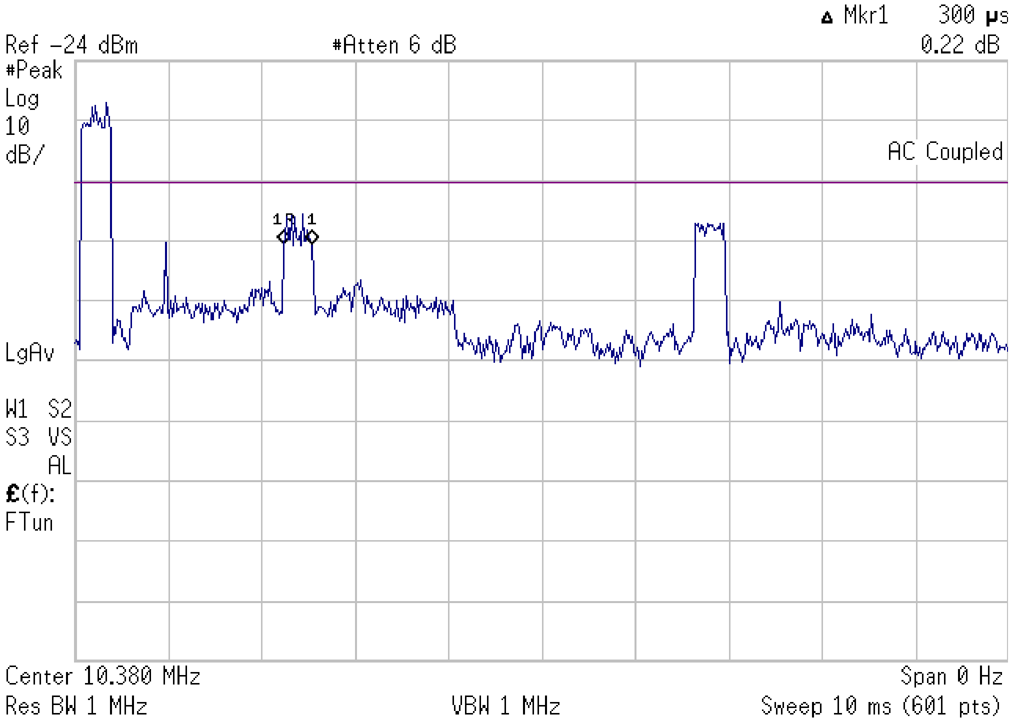

Figure D-8: Two simultaneous BPL transmissions.

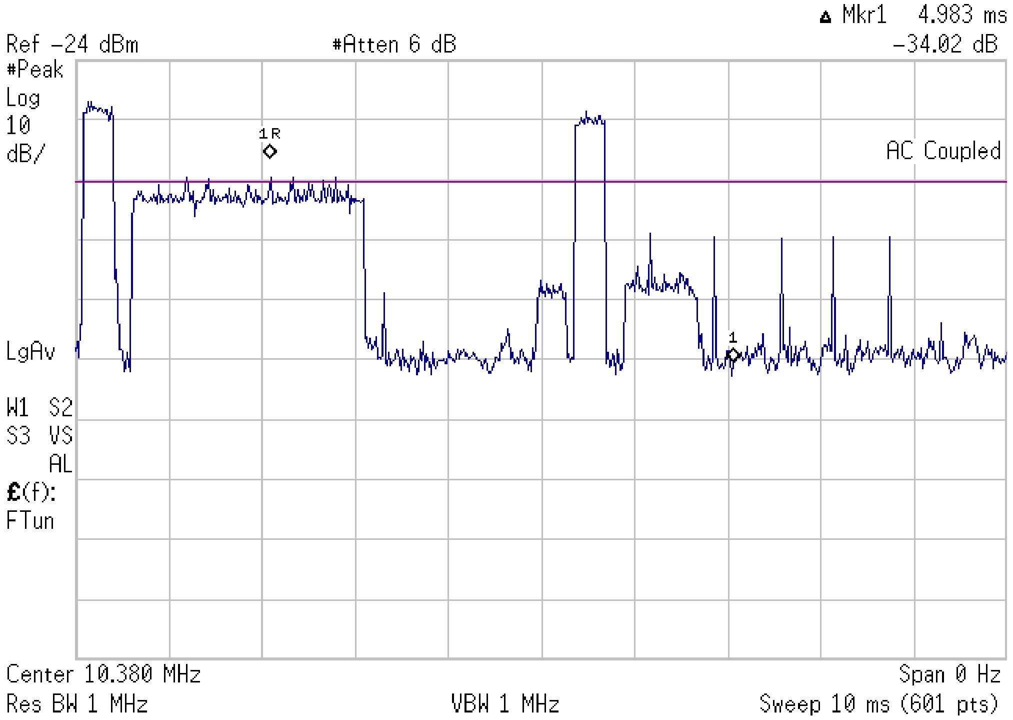

Figure D-9: Three BPL transmitters plus noise.

The measurement procedure for System #3 involved examining the spectrum of a BPL device's transmission and identifying a pair of frequencies that were the strongest and were clear of background signals. For each frequency, the signal envelope was observed for transmission bursts that were of the correct duration and pattern. Initially, the envelope was studied at a location where the BPL signals were received well. The durations of many bursts were measured to determine the typical range. This observation also yielded clearly identifiable transmission patterns that would repeat occasionally. The results of these observations were used to qualify the presence of BPL signals for future measurements. For each measurement location, the strongest BPL transmission was identified and its peak value was measured. The resolution bandwidth was then set to 30 kHz to allow for positive identification since at 3 kHz, the shorter BPL bursts would look like impulsive noise. The measured value was later used to calculate the received power at the antenna terminals.

D.3.2 Measurements of BPL Along the Energized Power Line

Measurements of BPL emissions along the energized power line (Site A, Figure D-10) were made using a variety of antennas. The first measurements were taken along a fairly straight segment of power line having both a repeater and an extractor.

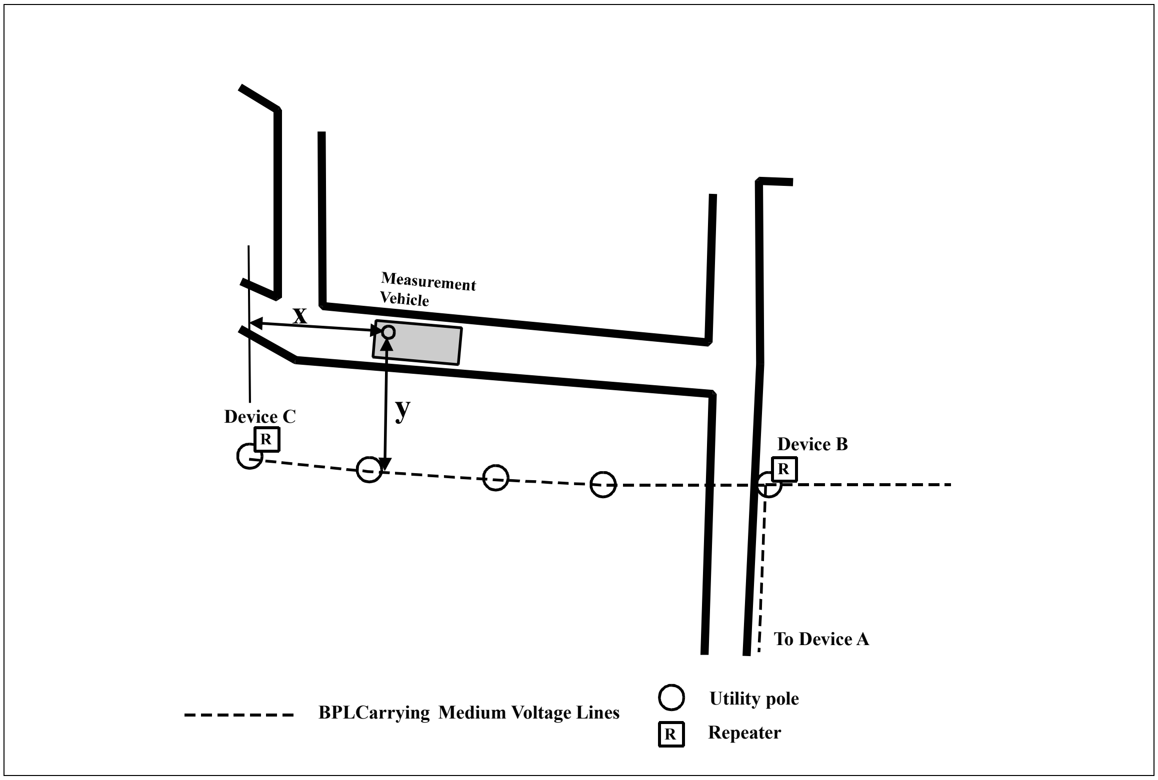

Figure D-10: Measurement Site A for measurements along the BPL energized power line.

Four measurement frequencies were chosen to represent the frequency bands used by this system (downstream injector-to-repeater, upstream repeater-to-injector, downstream repeater-to-extractor, and upstream extractor-to-repeater). Three mutually orthogonal components of the field were measured and plotted as three separate curves per graph for the frequencies 4.303, 8.125, 22.957 and 28.298 MHz, as shown in Figures D-11 through D-14 respectively. The measured peak power levels due to the orthogonal components of the electric field were plotted as a function of x, where x is the distance along the power line from the Device C. Note that in these and all other figures depicting BPL signal power vs. distance, lines connecting data points are connected to show possible trends but should not be interpreted to provide expected, interpolated values.

Measurement Conditions
Measurement Location: Site A
Antenna Type: Rod
Antenna Height: 2 meters
Antenna Polarization: (X) Horizontal Parallel, (Y) Horizontal Perpendicular, and (Z) Vertical
Measured Characteristic: Peak received power due to electric field
Measurement Variable: Distance along power line (x)
Comments: Measurements were made at 14 positions (x-distances). At some points, the BPL signal was too weak (I/N < 5 dB), hence, some curves have fewer data points.

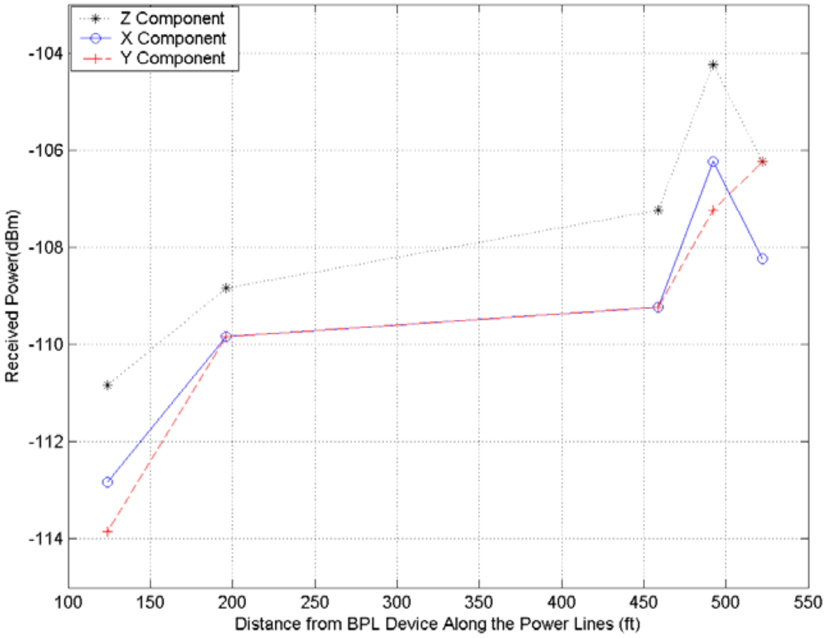

Figure D-11: Measured power levels along the power line – Site A, 4.303 MHz, rod antenna*

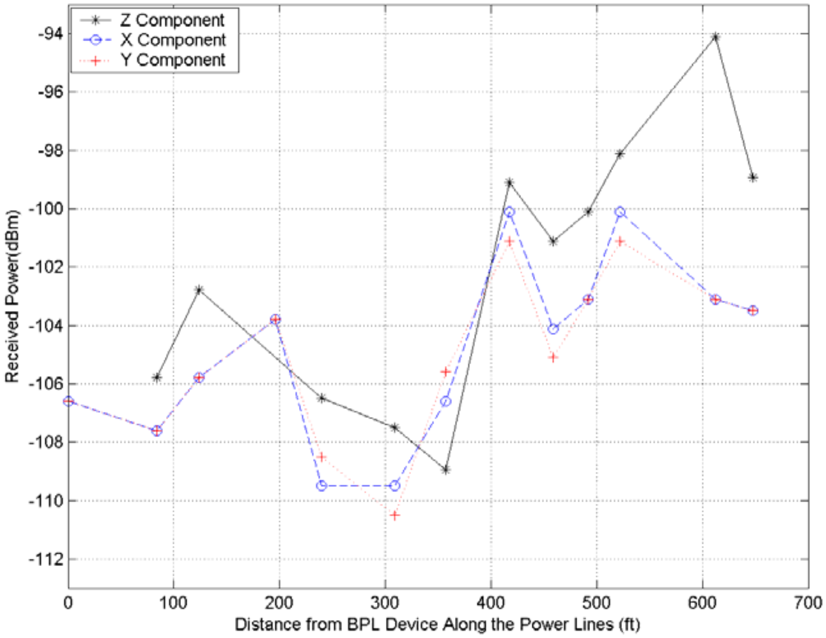

Figure D-12: Measured power levels along the power line – Site A, 8.125 MHz, rod antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

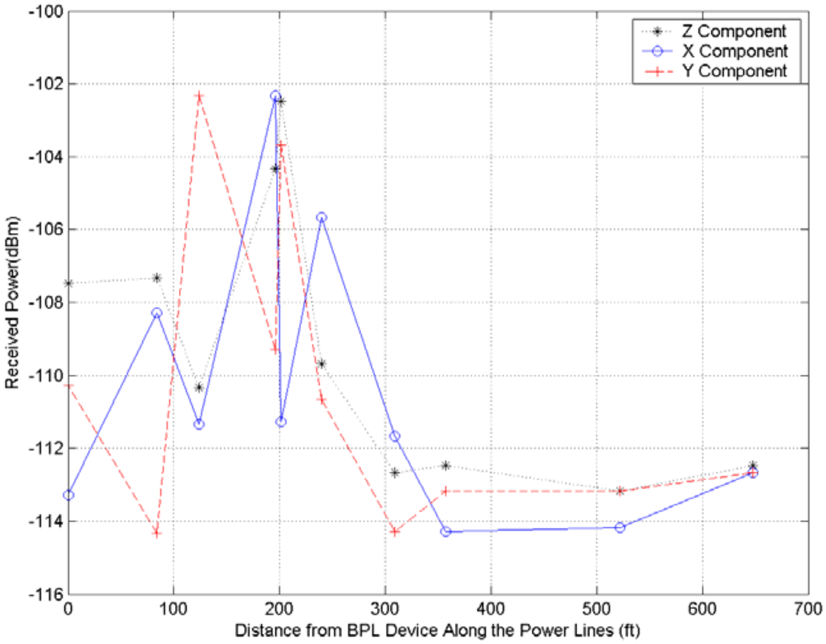

Figure D-13: Measured power levels along the power line – Site A, 22.957 MHz, rod antenna*

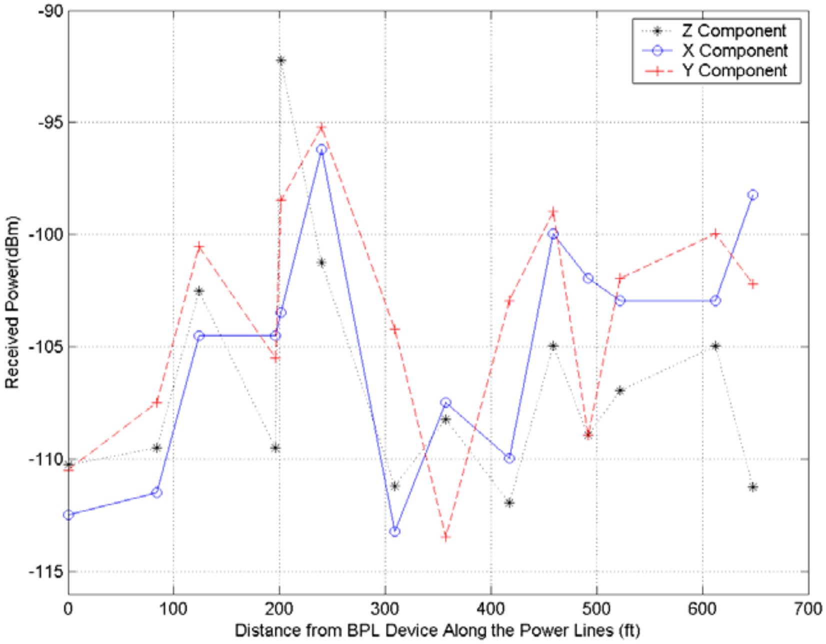

Figure D-14: Measured power levels along the power line – Site A, 28.298 MHz, rod antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

These curves indicate that the BPL electric field (relative to noise) along and near the line does not measurably decay with distance from the device (Device C) and is possibly impacted by the presence of Device B. It is interesting to note that even though the Device C is an injector that transmitted at 8.8 MHz, the electric field actually increased with increasing distance from the device. This is thought to be due to BPL signal reflection by one or more impedance discontinuities (perhaps the coupler of BPL Device B). Device B is a BPL repeater that transmitted at 28.8 MHz and 4.3 MHz. The electric field at 28.298 MHz is high closer to Device B, but is at comparable levels at other distances away from Device B as well.

An attempt was made to characterize the received power from the magnetic field at this same location (Site A, repeated here as Figure D-15). The results are illustrated in Tables D-1 thru D-4. These Tables indicate that the magnetic field using a loop antenna at 2 meters was not measurable along the power line at most locations.

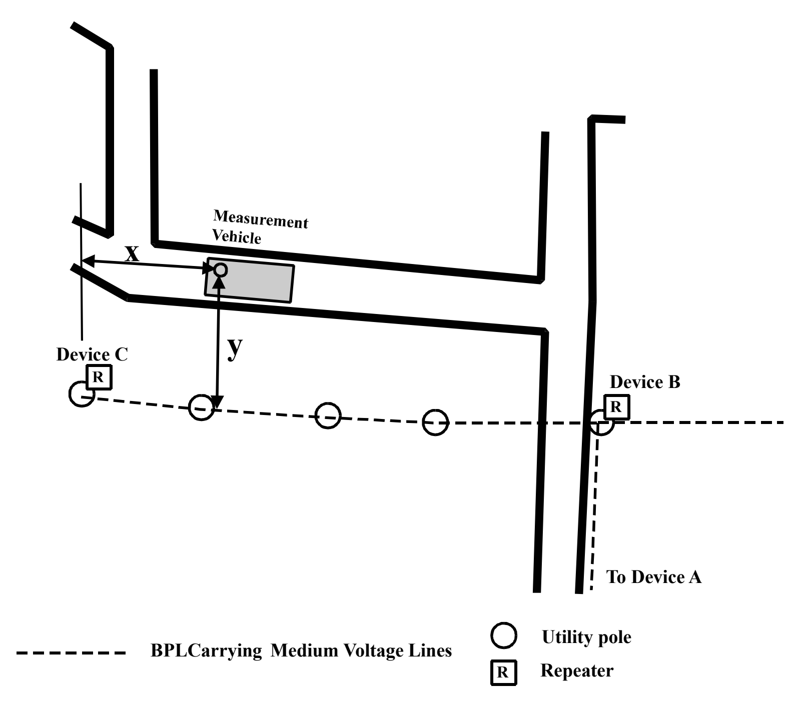

Figure D-15: Measurement Site A for measurements along the BPL energized power line.

<u>Measurement Conditions</u>

Measurement Location:	Site A
Antenna Type:	Shielded Loop
Antenna Height:	2 meters
Antenna Polarization:	(X) Horizontal Parallel, (Y) Horizontal Perpendicular, and (Z) Vertical
Measured Characteristic:	Peak received power due to magnetic field

Measurement Variable:	Distance along power line (x)
Comments:	This effort was abandoned after no signal was received for many measurements.

Table D-1: Measurements along the power line – Site A, 4.303 MHz, loop antenna

X Distance (feet)	Y Distance (feet)	Received Power Z Component(dBm)	Received Power Y Component(dBm)	Received Power X Component(dBm)
648	107	Not measurable	Not measurable	Not measurable
612	126	*Not measured*	*Not measured*	*Not measured*
522	96	*Not measured*	*Not measured*	*Not measured*
492	93	Not measurable	Not measurable	Not measurable
459	87	*Not measured*	*Not measured*	*Not measured*
417	123	*Not measured*	*Not measured*	*Not measured*
357	120	Not measurable	Not measurable	Not measurable
309	120	*Not measured*	*Not measured*	*Not measured*
240	120	*Not measured*	*Not measured*	*Not measured*
201	120	Not measurable	Not measurable	Not measurable
196	120	Not measurable	Not measurable	Not measurable
124	120	Not measurable	Not measurable	Not measurable
84	135	Not measurable	Not measurable	Not measurable
0	120	Not measurable	Not measurable	Not measurable

Table D-2: Measurements along the power line – Site A, 8.125 MHz, loop antenna

X Distance (feet)	Y Distance (feet)	Received Power Z Component(dBm)	Received Power Y Component(dBm)	Received Power X Component(dBm)
648	107	-114.94	Not measurable	-114.94
612	126	*Not measured*	*Not measured*	*Not measured*
522	96	*Not measured*	*Not measured*	*Not measured*
492	93	Not measurable	Not measurable	Not measurable
459	87	*Not measured*	*Not measured*	*Not measured*
417	123	*Not measured*	*Not measured*	*Not measured*
357	120	Not measurable	Not measurable	Not measurable
309	120	*Not measured*	*Not measured*	*Not measured*
240	120	*Not measured*	*Not measured*	*Not measured*
201	120	Not measurable	Not measurable	Not measurable
196	120	Not measurable	Not measurable	Not measurable
124	120	Not measurable	Not measurable	Not measurable
84	135	Not measurable	Not measurable	Not measurable
0	120	-107.94	Not measurable	Not measurable

Table D-3: Measurements along the power line – Site A, 22.957 MHz, loop antenna

X Distance (feet)	Y Distance (feet)	Received Power Z Component(dBm)	Received Power Y Component(dBm)	Received Power X Component(dBm)
648	107	Not measurable	Not measurable	Not measurable
612	126	*Not measured*	*Not measured*	*Not measured*
522	96	*Not measured*	*Not measured*	*Not measured*
492	93	Not measurable	Not measurable	Not measurable
459	87	*Not measured*	*Not measured*	*Not measured*
417	123	*Not measured*	*Not measured*	*Not measured*
357	120	Not measurable	Not measurable	Not measurable
309	120	*Not measured*	*Not measured*	*Not measured*
240	120	*Not measured*	*Not measured*	*Not measured*
201	120	Not measurable	Not measurable	Not measurable
196	120	Not measurable	Not measurable	-114.33
124	120	Not measurable	Not measurable	Not measurable
84	135	Not measurable	Not measurable	Not measurable
0	120	-112.48	Not measurable	-114.48

Table D-4: Measurements along the power line – Site A, 28.298 MHz, loop antenna

X Distance (feet)	Y Distance (feet)	Received Power Z Component(dBm)	Received Power Y Component(dBm)	Received Power X Component(dBm)
648	107	-107.23	-110.23	-110.23
612	126	*Not measured*	*Not measured*	*Not measured*
522	96	*Not measured*	*Not measured*	*Not measured*
492	93	Not measurable	Not measurable	-112.06
459	87	*Not measured*	*Not measured*	*Not measured*
417	123	*Not measured*	*Not measured*	*Not measured*
357	120	Not measurable	-112.23	Not measurable
309	120	*Not measured*	*Not measured*	*Not measured*
240	120	*Not measured*	*Not measured*	*Not measured*
201	120	-104.23	-105.23	-105.23
196	120	-111.50	Not measurable	-111.50
124	120	Not measurable	-112.50	-113.50
84	135	Not measurable	Not measurable	Not measurable
0	120	Not measurable	Not measurable	Not measurable

The peak received power due to the electric field was measured with the whip antenna along the power line (Site A, repeated here as Figure D-16). The measured received power levels are plotted in Figure D-17 (“x” referenced to Device C) and Figure D-18 (“x” referenced to Device B). The results are similar to those obtained from the electric field measurements previously accomplished using the rod antenna.

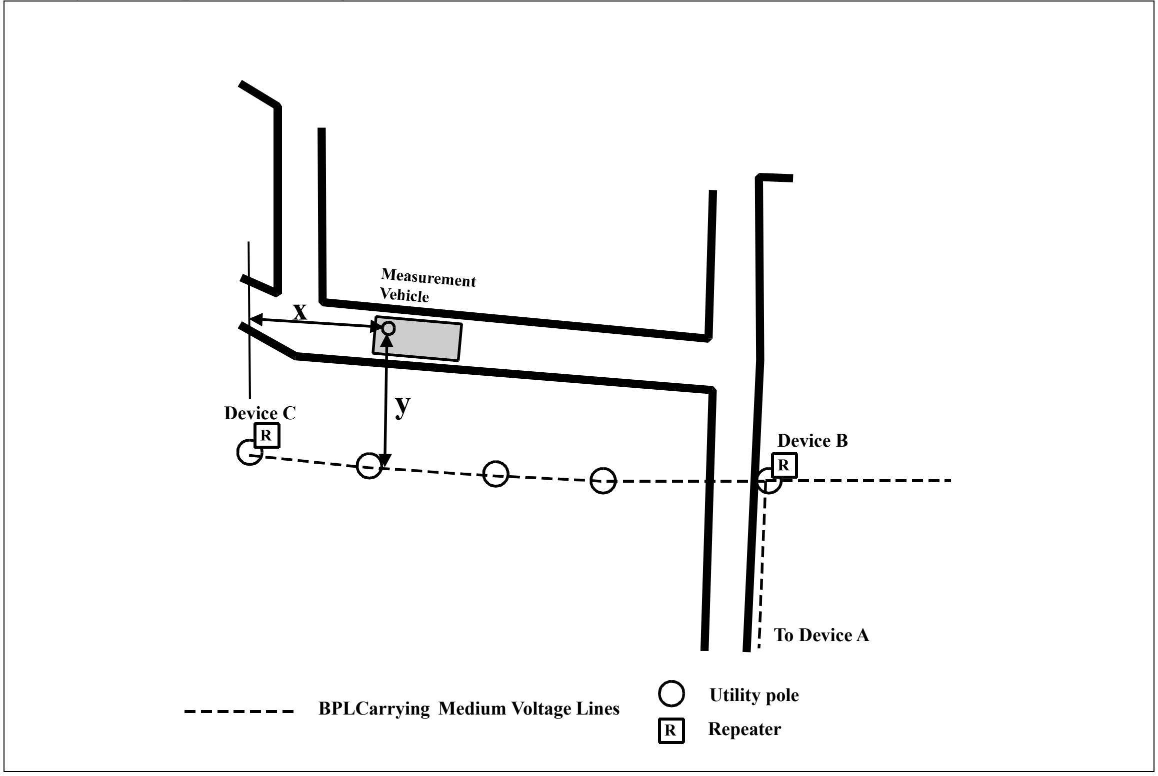

Figure D-16: Measurement Site A for measurements along the BPL energized power line.

<u>Measurement Conditions</u>

Measurement Location:	Site A
Antenna Type:	Whip
Antenna Height:	1.5 meters
Antenna Polarization:	Vertical
Measured Characteristic:	Peak received power due to electric field
Measurement Variable:	Distance along power line (x) referenced to (1) Device C, or (2) Device B
Comments:	Note that though the measurements were initially made at a frequency of 7.241 MHz, the frequency was changed to 7.25 MHz due to background signals covering up the BPL signal.

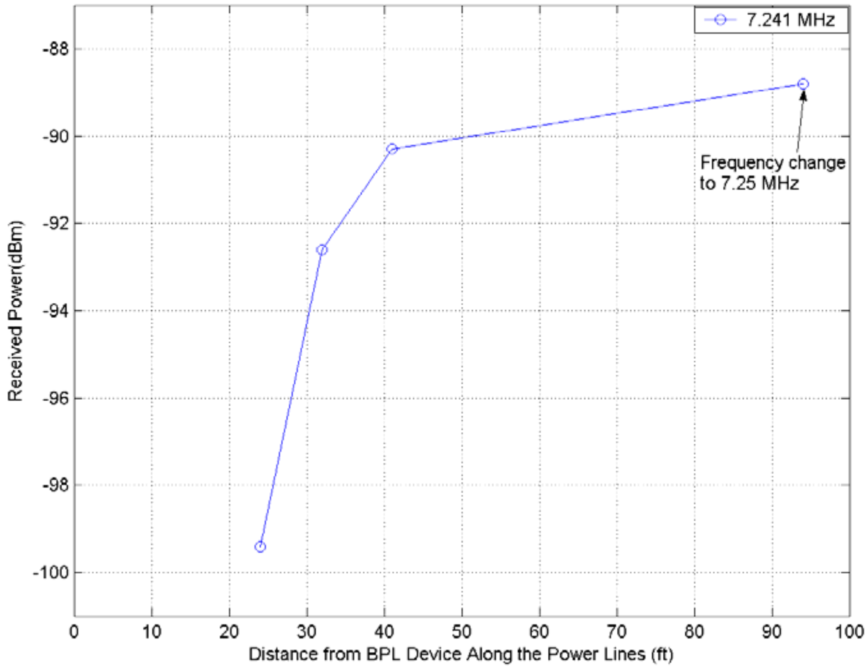

Figure D-17: Measured power levels along power line – Site A, “x” referenced to Device C, whip antenna*

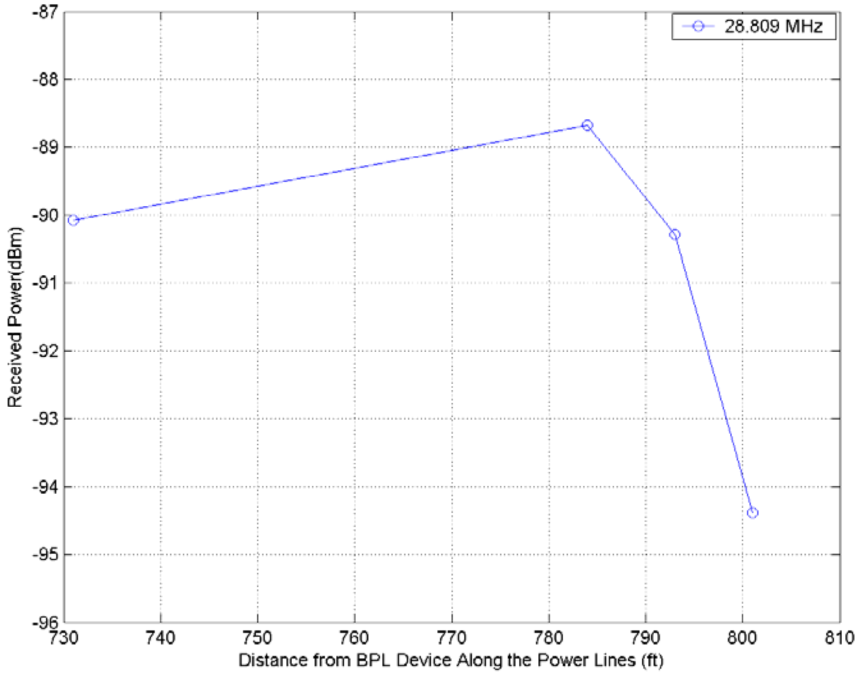

Figure D-18: Measured power levels along power line – Site A, “x” referenced to Device B, whip antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

Measurements were taken along the BPL energized power line (Site B, Figure D-19) using a discone antenna. Figure D-20 shows a picture of the utility lines located at the intersection as viewed from the approximate location of the measurement vehicle at point C. Results are shown in Table D-5 through D-8.

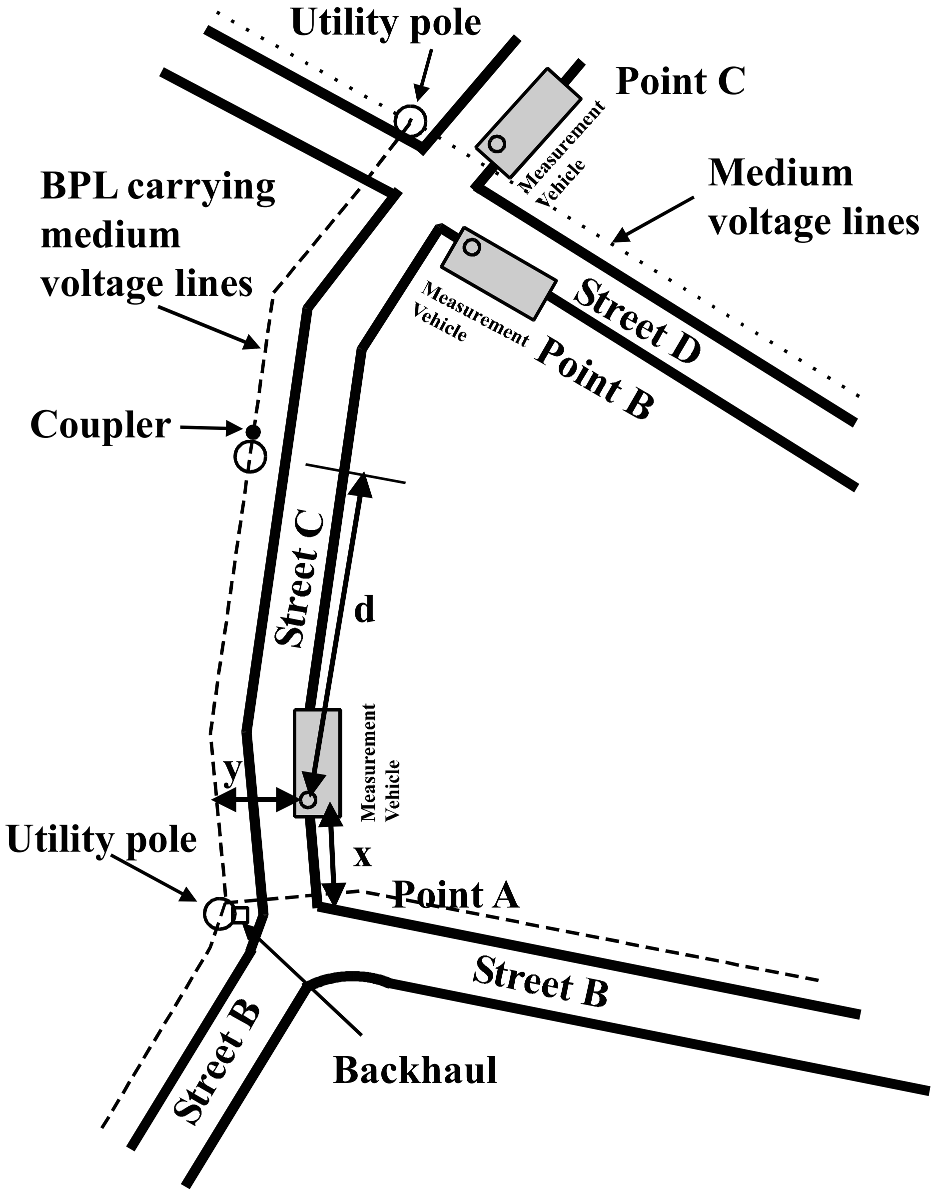

Figure D-19: Measurement Site B for BPL measurements along the power line using the discone antenna.

Figure D-20: Site B power lines as viewed from the measurement vehicle located at Point C

Measurement Conditions

Measurement Location:	Site B
Antenna Type:	Discone (Model SAS-210/C)
Antenna Height:	2 and 10 meters
Antenna Polarization:	Vertical
Measured Characteristic:	100% duty cycle power (from APDs) and pulse power due to electric field
Measurement Variable:	Distance along power line (x) referenced to Point A, (y = 7.9 m)
Comments:	Measurement frequencies – 32.699 MHz and 42.465 MHz Resolution bandwidths – 30 kHz and 10 kHz Pulse power measurements – zero span, peak power detection, 2 ms sweep time (601 pts per sweep) Power lines approximately 8.5 meters above the ground

Table D-5: Measured 100%-duty-cycle power and pulse power, x = 4.9 meters (16 ft)

	Ant. Ht.	Frequency	RBW	100%-duty-cycle Power	Pulse Power
Case 1	10 m	32.699 MHz	30 kHz	-96.3 dBm	-97.6 dBm
Case 2	10 m	42.465 MHz	30 kHz	*Not measured*	-104.4 dBm
Case 3	2 m	32.699 MHz	30 kHz	-101.1 dBm	-111.4 dBm
Case 4	2 m	42.465 MHz	30 kHz	*Not measured*	-116.1 dBm
Case 5	10 m	32.699 MHz	10 kHz	-100.7 dBm	-102.4 dBm
Case 6	10 m	42.465 MHz	10 kHz	*Not measured*	-112.0 dBm
Case 7	2 m	32.699 MHz	10 kHz	-111.4 dBm	-117.5 dBm
Case 8	2 m	42.465 MHz	10 kHz	*Not measured*	-120.2 dBm

Table D-6: Measured 100%-duty-cycle power and pulse power, x = 18.3 meters (60 ft)

	Ant. Ht.	Frequency	RBW	100%-duty-cycle Power	Pulse Power
Case 1	10 m	32.699 MHz	30 kHz	*Not measured*	-112.4 dBm
Case 2	10 m	42.465 MHz	30 kHz	*Not measured*	Not measurable
Case 5	10 m	32.699 MHz	10 kHz	-110.1 dBm	-115.2 dBm
Case 6	10 m	42.465 MHz	10 kHz	*Not measured*	Not measurable

Table D-7: Measured 100%-duty-cycle power and pulse power, x = 23.2 meters (76 ft)

	Ant. Ht.	Frequency	RBW	100%-duty-cycle Power	Pulse Power
Case 1	10 m	32.699 MHz	30 kHz	-110.5 dBm	-108.6 dBm
Case 2	10 m	42.465 MHz	30 kHz	*Not measured*	-107.7 dBm
Case 3	2 m	32.699 MHz	30 kHz	Not measurable	Not measurable
Case 4	2 m	42.465 MHz	30 kHz	Not measurable	Not measurable
Case 5	10 m	32.699 MHz	10 kHz	-110.5 dBm	-114.9 dBm
Case 6	10 m	42.465 MHz	10 kHz	*Not measured*	-119.3 dBm
Case 7	2 m	32.699 MHz	10 kHz	Not measurable	Not measurable
Case 8	2 m	42.465 MHz	10 kHz	Not measurable	Not measurable

Table D-8: Measured 100%-duty-cycle power and pulse power, x = 103.6 meters (340 ft)

	Ant. Ht.	Frequency	RBW	100%-duty-cycle Power	Pulse Power
Case 1	10 m	32.699 MHz	30 kHz	*Not measured*	-110.1 dBm
Case 2	10 m	42.465 MHz	30 kHz	-106.9 dBm	-105.4 dBm
Case 3	2 m	32.699 MHz	30 kHz	Not measurable	Not measurable
Case 4	2 m	42.465 MHz	30 kHz	Not measurable	Not measurable
Case 5	10 m	32.699 MHz	10 kHz	*Not measured*	-114.4 dBm
Case 6	10 m	42.465 MHz	10 kHz	-111.0 dBm	-110.9 dBm
Case 7	2 m	32.699 MHz	10 kHz	Not measurable	Not measurable
Case 8	2 m	42.465 MHz	10 kHz	Not measurable	Not measurable

Figure D-21 summarizes the measured received power along the power lines using data from Table D-5 through Table D-8 for a frequency of 32.699 MHz and for a vertically polarized Discone antenna at a height of 10 meters. This figure indicates that after an initial decrease of received power, the power remains at about the same level along the power line away from a Backhaul point.

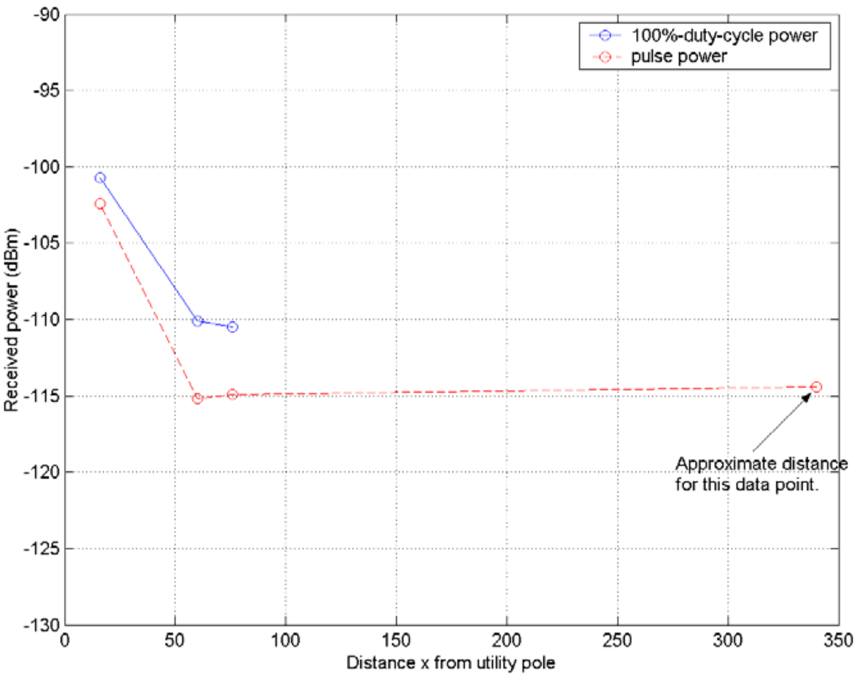

Figure D-21: Measured power levels along power line – Site B, discone antenna, antenna height = 10 m, frequency = 32.699 MHz, data from Table D.3.2-5 through Table D.3.2-8*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

D.3.3 Measurements of BPL Away From the Energized Power Line

A number of measurements of BPL emissions were made with varying distance away from the power line. In general, the measurements started out close to a pole mounted BPL device and moved away until the signal level was too low to make a confident measurement. For the first measurements away from the power line, Site C's physical layout of power lines and BPL devices is illustrated in Figure D-22 and the measured power away from the power lines is plotted in Figure D-23. With a loop antenna directly under the power line at a height of 2 meters, a small signal power was measured on all four frequencies (4.419 MHz, 8.777 MHz, 23.836 MHz and 28.777 MHz). At a distance of 148 feet from the power line, the signal was received only at 28.777 MHz as shown in Figure D-23.

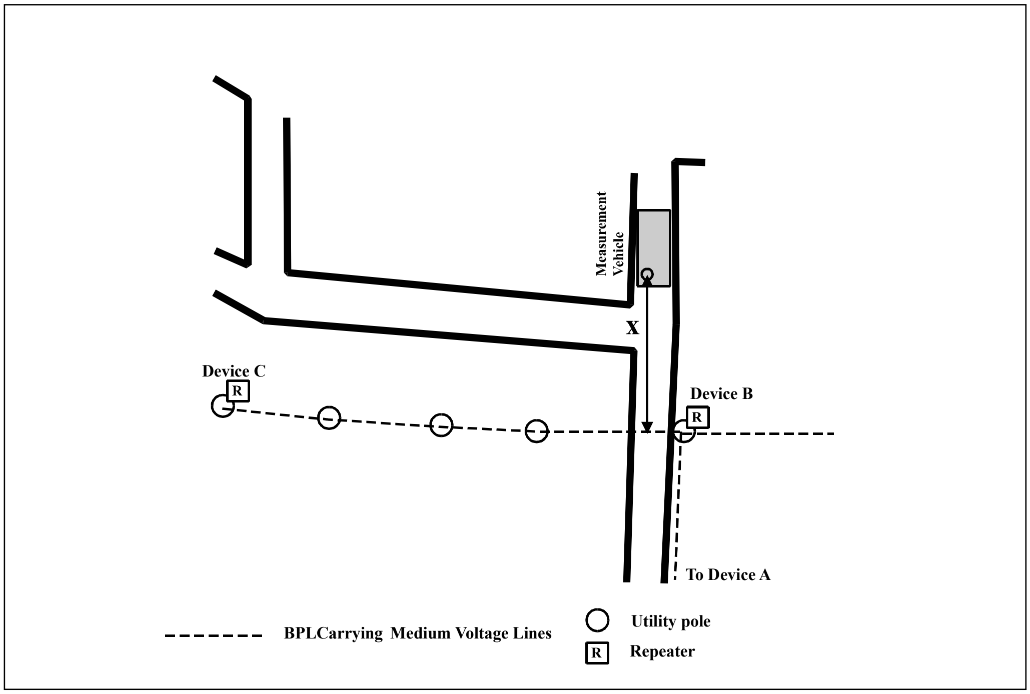

Figure D-22: Measurement Site C for BPL measurements away from the power line at Device B

<u>Measurement Conditions</u>

Measurement Location: Site C
Antenna Type: Shielded Loop
Antenna Height: 2 meters
Antenna Polarization: Horizontal Parallel
Measured Characteristic: Peak received power due to magnetic field
Measurement Variable: Distance away from power line (x)
Comments: Device A is an Extractor transmitting an upstream signal at 23.8 MHz. Device B is a repeater transmitting on 28.8 MHz downstream and 4.4 MHz upstream. Device C is an injector transmitting on 8.8 MHz downstream. When the antenna was moved 45.1 meters (148 ft) away from the power line the signal was not received on 3 of the 4 frequencies.

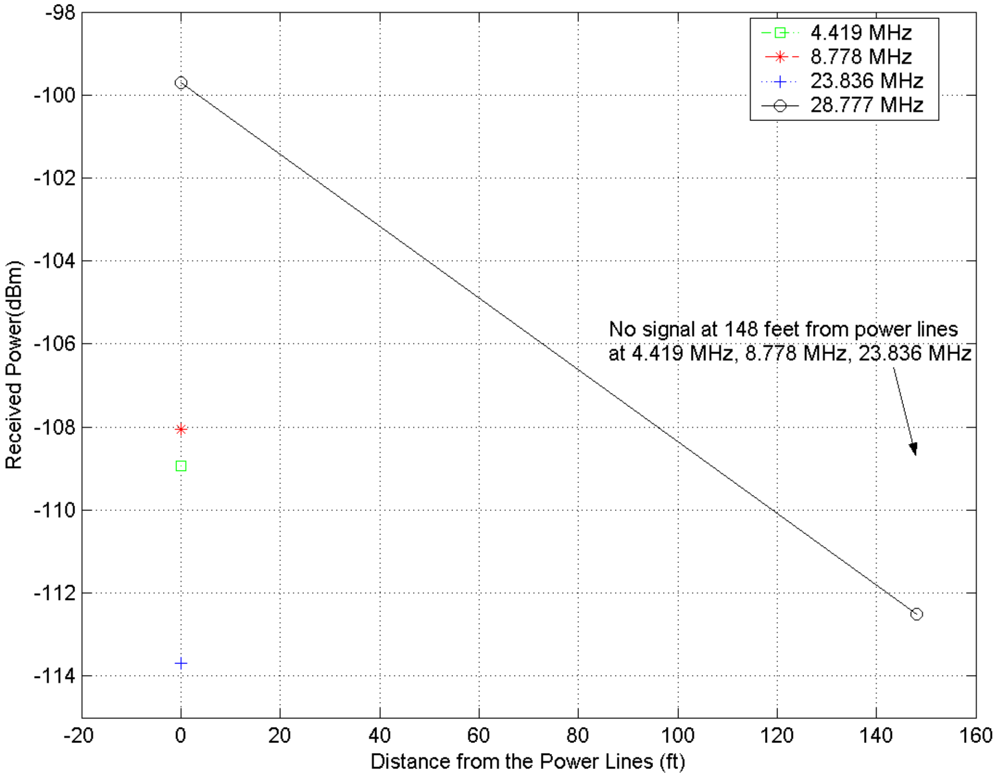

Figure D-23: Measured power levels away from the power line, Site C, loop antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

The peak received power due to the electric field was measured with the whip antenna away from the power line (Site C, repeated here as Figure D-24) at 4.255 MHz, 7.304 MHz and 28.777 MHz with the results shown in Figure D-25. The results indicate that there was a decrease in received power with increase in distance from the BPL device and power line, but the decrease was not monotonic at 28.777 MHz. The received power and the manner in which it decreased with increasing distance varied substantially at different frequencies.

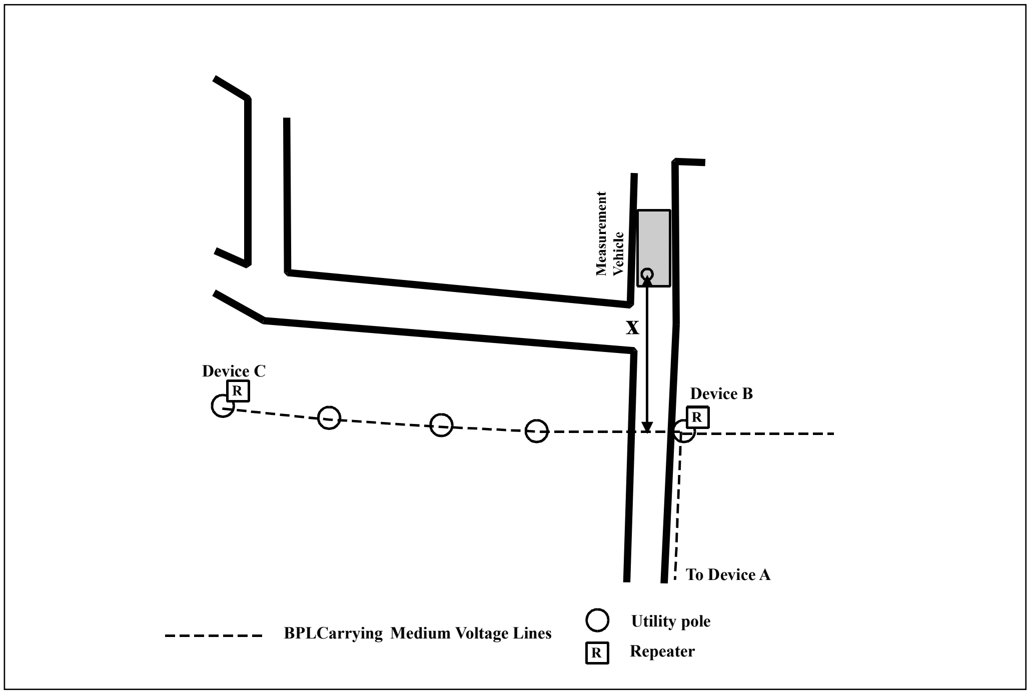

Figure D-24: Measurement Site C for BPL measurements away from the power line at Device B

<u>Measurement Conditions</u>
Measurement Location: Site C
Antenna Type: Whip
Antenna Height: 1.5 meters
Antenna Polarization: Vertical
Measured Characteristic: Peak received power due to electric field
Measurement Variable: Distance away from power line (x)
Comments: At 7.304 MHz, the measurement was terminated when background signals appeared and covered up the BPL signal. The frequency change to 4.241 MHz was due to background signals covering up the BPL signal.

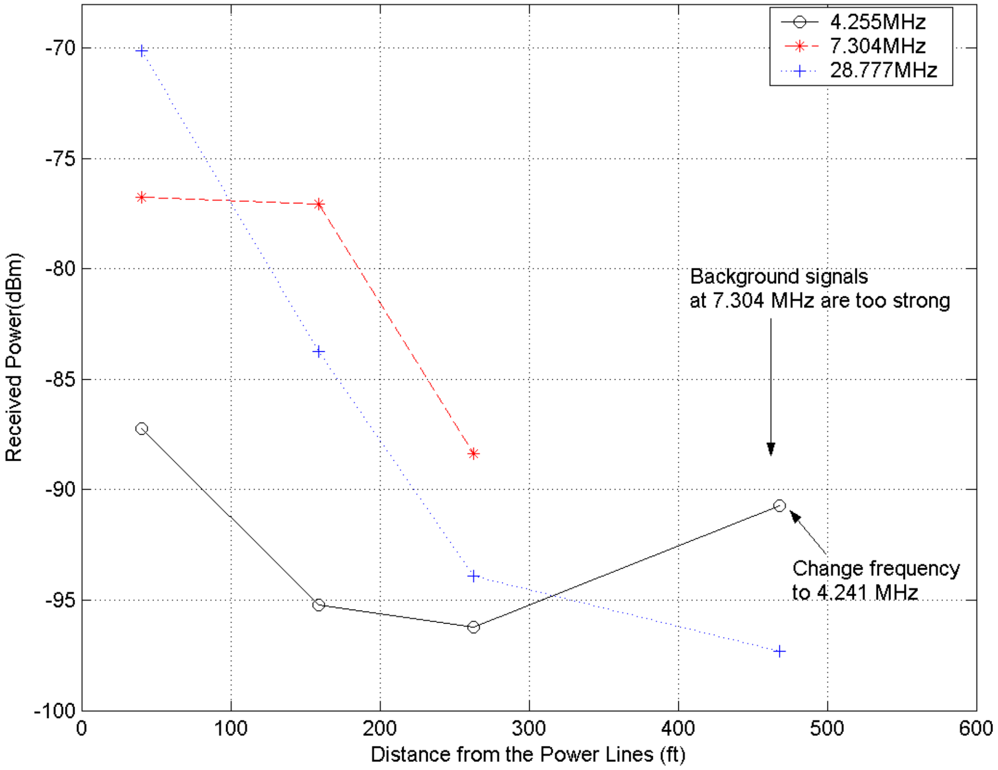

Figure D-25: Measured power levels away from power line at Device B – Site C, whip antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

The peak received power due to the electric field was measured with the whip antenna on a different path (measurement trend line) as a function of distance from the power line as shown in Figure D-26. The results, plotted in Figure D-27, show that even though the received power generally decreased with distance from Device C, the peak power level at 28.809 MHz exhibited significant oscillations as a function of increasing distance.

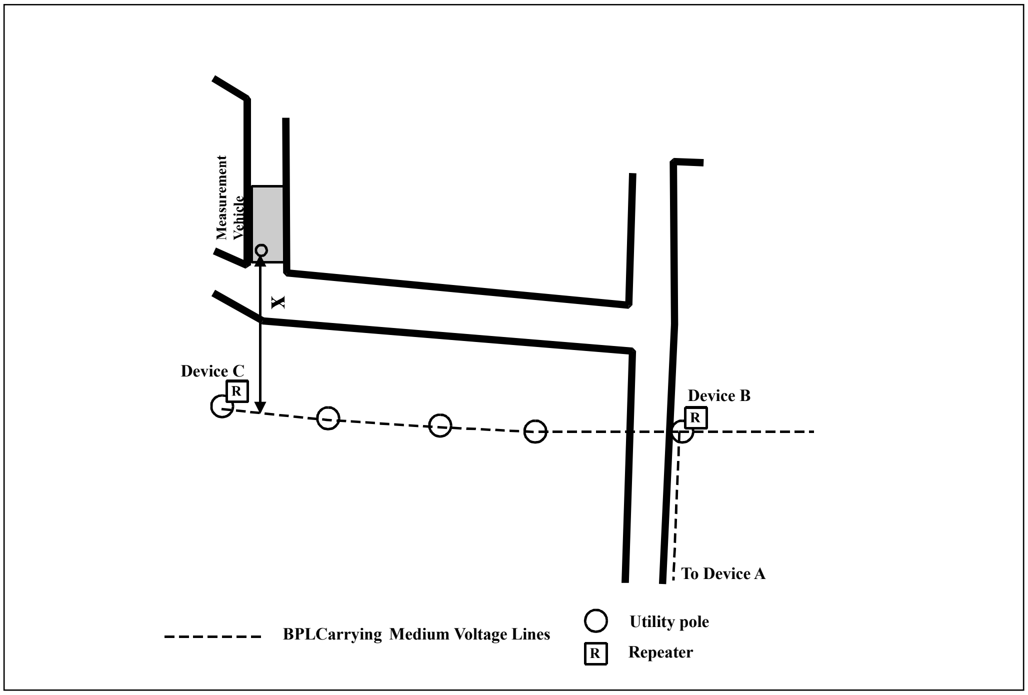

Figure D-26: Measurement Site C for BPL measurements away from the power line at Device C

<u>Measurement Conditions</u>

Measurement Location:	Site C
Antenna Type:	Whip
Antenna Height:	1.5 meters
Antenna Polarization:	Vertical
Measured Characteristic:	Peak received power due to electric field
Measurement Variable:	Distance away from power line (x)
Comments:	At 7.241 MHz, the measurement was terminated when background signals appeared and covered up the BPL signal.

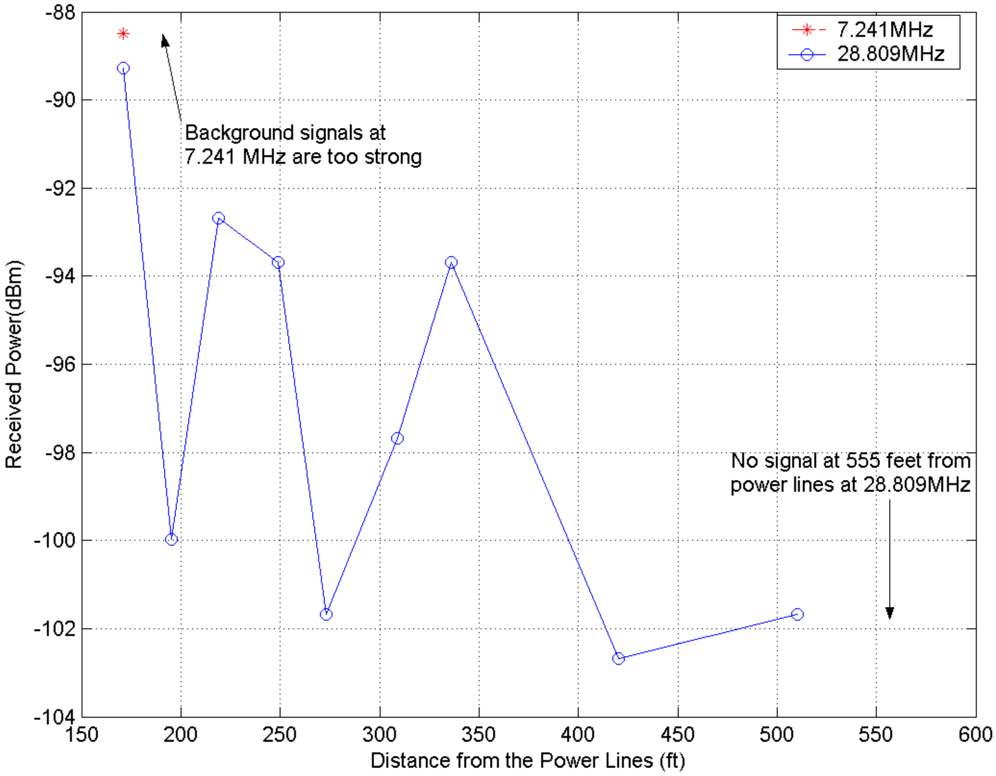

Figure D-27: Measured power levels away from power line at Device B – Site C, whip antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

Another set of measurements were made of the peak received power due to vertical electric field while moving the whip antenna away from the power line as shown in Figure D-28 (Site D). The received power has been plotted versus distance from the power lines in Figure D-29. In Figure D-29, the signal decreases to an immeasurable level within 600 ft.

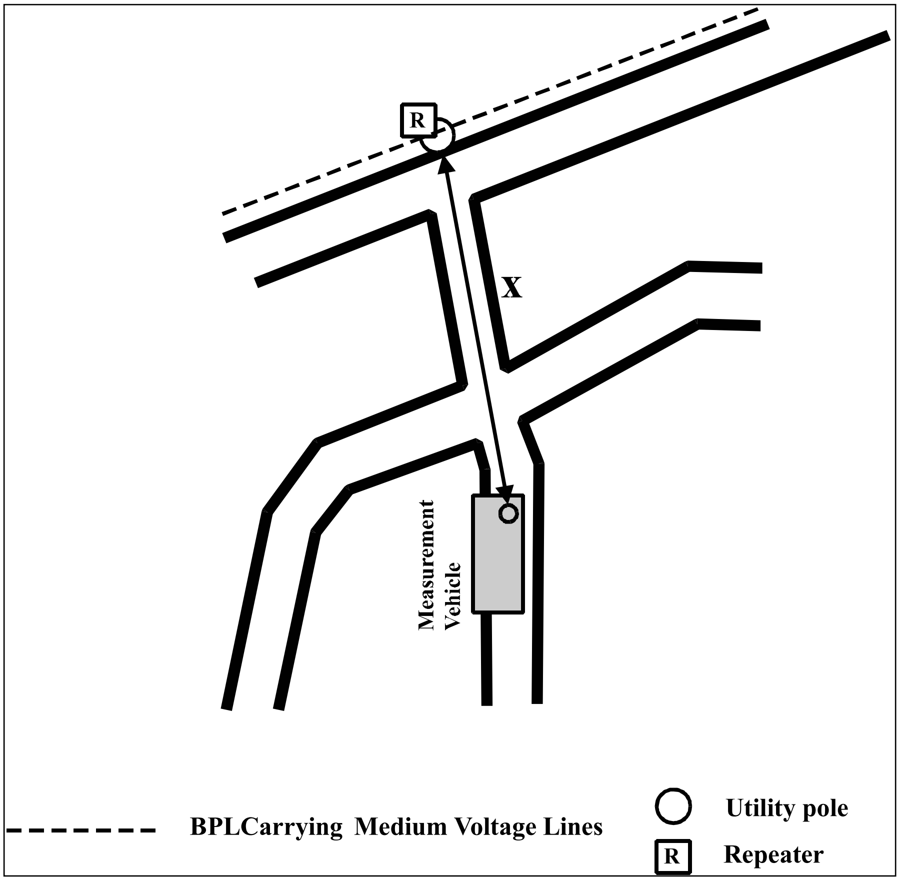

Figure D-28: Measurement Site D for BPL measurements away from power line at a pole mounted repeater

Measurement Conditions
Measurement Location: Site D
Antenna Type: Whip
Antenna Height: 1.5 meters
Antenna Polarization: Vertical
Measured Characteristic: Peak received power due to electric field
Measurement Variable: Distance away from power line (x)
Comments: None

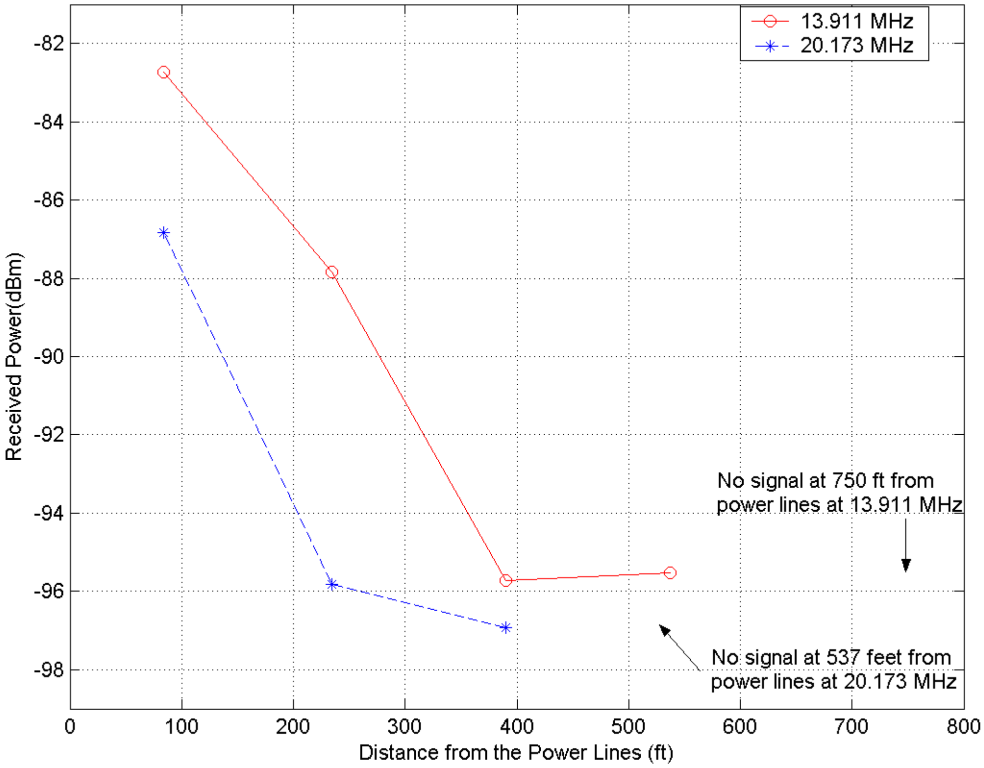

Figure D-29: Measured power levels away from power line – Site D, whip antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

The next measurements were made away from the power lines at Site E. The physical layout (Figure D-30) shows several repeaters and one concentrator (injector) and a network of MV lines all transmitting at various times over the same frequency range. In Figure D-31, the received power at 8.1 MHz and 14.8 MHz are plotted versus distance from the power lines, out to a distance exceeding 1500 ft, where the BPL signal diminished to within 5 dB of the noise floor.

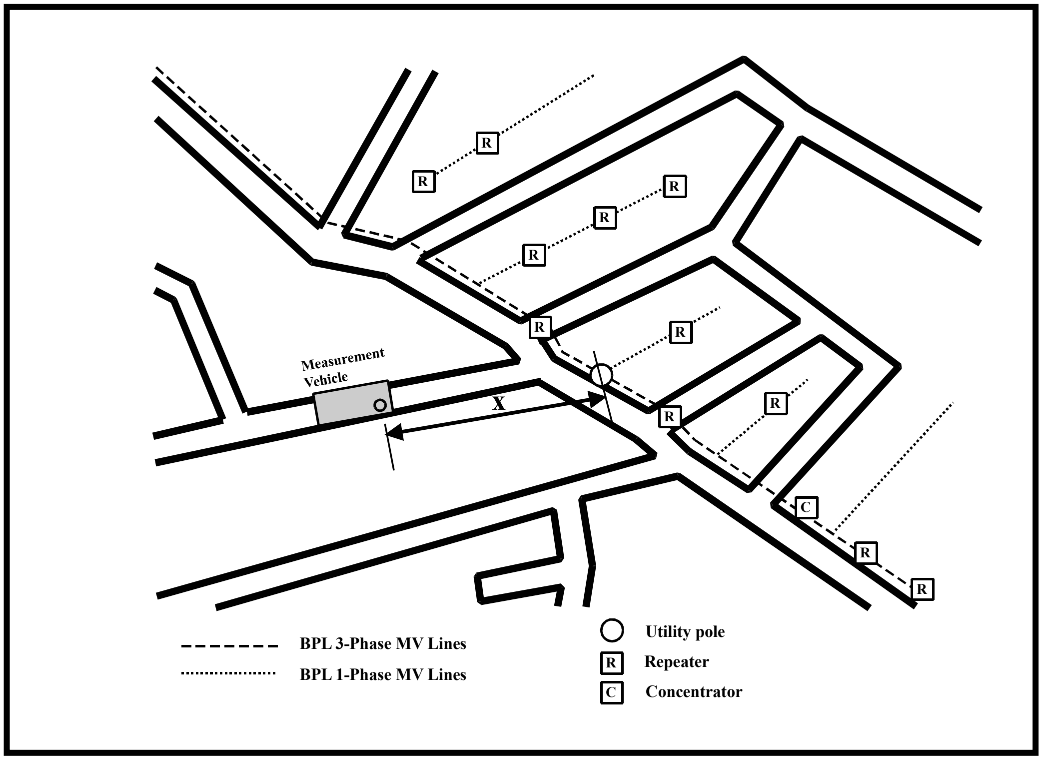

Figure D-30: Measurement Site E for BPL measurements away from power line at a repeater

Measurement Conditions
Measurement Location: Site E
Antenna Type: Whip
Antenna Height: 1.5 meters
Antenna Polarization: Vertical
Measured Characteristic: Peak received power due to electric field
Measurement Variable: Distance away from power line (x)
Comments: None

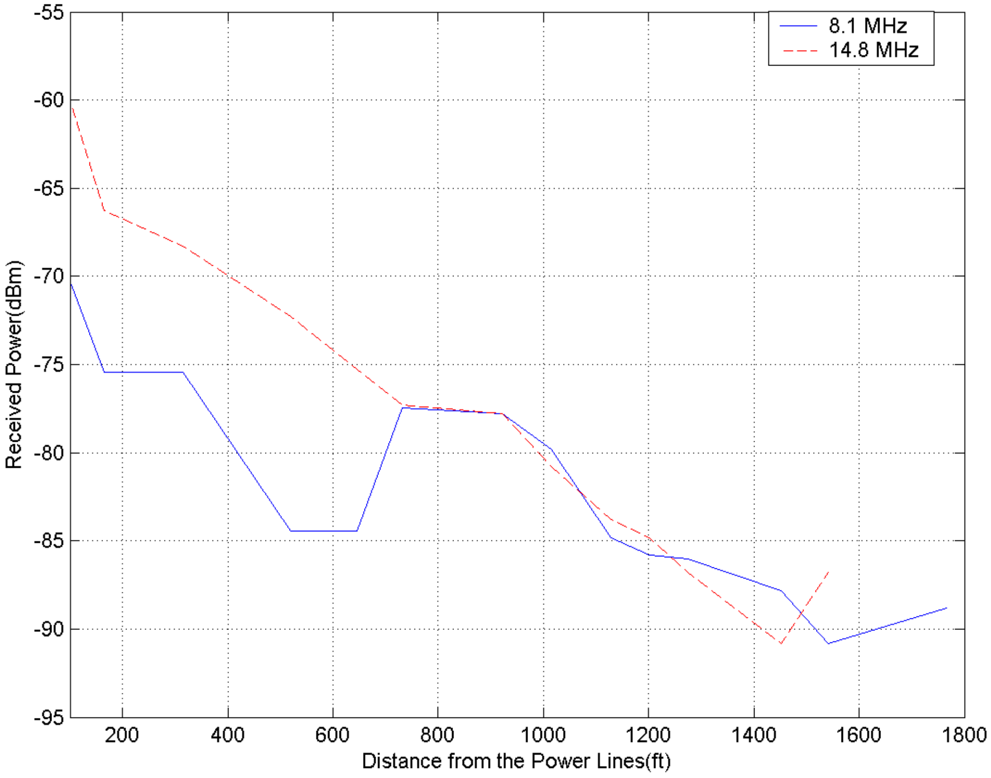

Figure D-31: Measured power levels away from power line – Site E, whip antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

The peak received power was measured using both whip and loop antennas at heights of 1.5 and 2 meters, respectively, near a transformer with underground power lines (Site F) carrying BPL signals. The measurements show that at 6.4 meters (21 ft) from the transformer, the BPL signal power was measurable at one of the three BPL frequencies as shown in Table D-9. At 29.3 meters (96 ft) from the transformer, no signal could be detected.

Measurement Conditions

Measurement Location:	Site F
Antenna Type:	Whip, Shielded Loop
Antenna Height:	1.5 meters (whip) and 2 meters (loop)
Antenna Polarization:	Whip - Vertical, Loop - Vertical Parallel, Vertical Perpendicular and Horizontal
Measured Characteristic:	Peak received power due to electric and magnetic fields
Measurement Variable:	Distance away from power line (x)
Comments:	None

Table D-9: Measure power levels away from power line – Site F, whip & loop antennas

Measurement Distance	Frequency (MHz)	Whip (Vertical)	Loop (Vertical, parallel to the power line)	Loop (Vertical, perpendicular to the power line)	Loop (Horizontal)
6.4 m (21 ft)	3.99	Not measurable	Not measurable	Not measurable	Not measurable
6.4 m (21 ft)	7.502	Not measurable	Not measurable	Not measurable	Not measurable
6.4 m (21 ft)	15.285	-80 dBm	-114 dBm	Not measurable	-114 dBm
29.3 m (96 ft)	3.99	Not measurable	Not measurable	Not measurable	Not measurable
29.3 m (96 ft)	7.502	Not measurable	Not measurable	Not measurable	Not measurable
29.3 m (96 ft)	15.285	Not measurable	Not measurable	Not measurable	Not measurable

Measurements were performed using a discone antenna with the power line configuration as shown in Figure D-32 for Site G. Manual pulse power measurements are plotted for three frequencies, 35.04992 MHz, 39.92954 MHz and 45.40195 MHz, as shown in Figure D-33. Also included are theoretical plots for loss proportional to $1/R$, $1/R^2$, and $1/R^4$, where *"R"* is distance from the power line (*i.e.*, "R" is depicted as the parameter "*x*" in Figure D-32). The results indicate that the received power decreases as distance from the power line increases at a rate lower than would be predicted by $1/R^2$ (space wave loss).

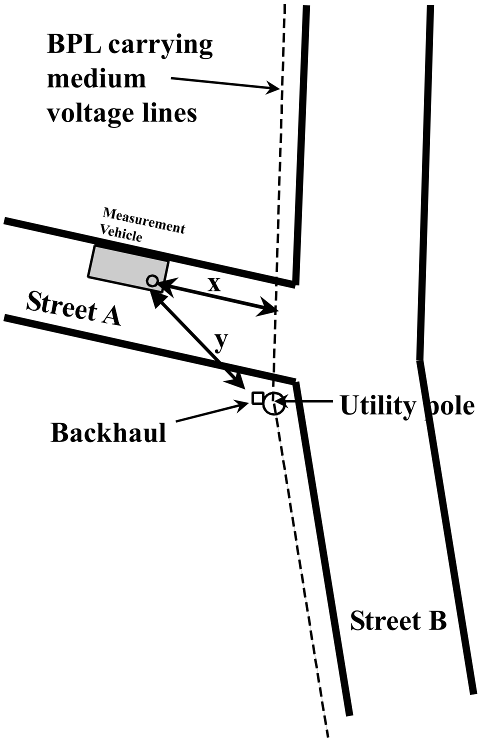

Figure D-32: Measurement Site G for BPL measurements away from power line using the discone antenna

Measurement Conditions

Measurement Location: Site G

Antenna Type: Discone (Model SAS-210/C)

Antenna Height: 3.4 meters (11.2 ft)

Antenna Polarization: Vertical

Measured Characteristic: Peak received power due to electric field

Measurement Variable: Distance away from power line (x)

Comments: Measurement frequencies – 35.04492 MHz, 39.92954 MHz, and 45.40195 MHz
Resolution bandwidths – 200 kHz
Pulse power measurements – zero span, peak power detection, 2 ms sweep time (601 pts per sweep)
Power lines approximately 8.5 meters above the ground

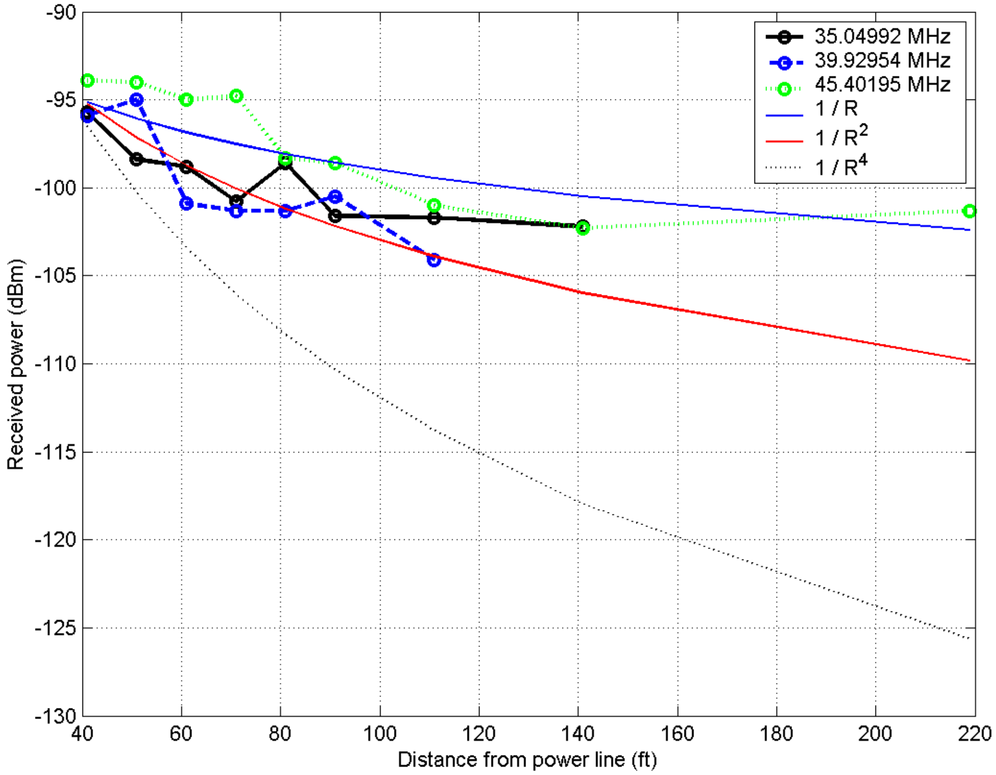

Figure D-33: Received pulse power measured away from power line – Site G, discone antenna*

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* Lines connecting data points illustrate potential trends but not expected interpolated values.

Manual pulse power levels were measured at 32.699 MHz and 42.465 MHz with the same discone antenna at points B and C as shown in Figure D-34. Both points B and C are at about the same distance from the power line; however, the measured pulse power at point C is consistently higher than at point B as shown in Tables D-10 and D-11.

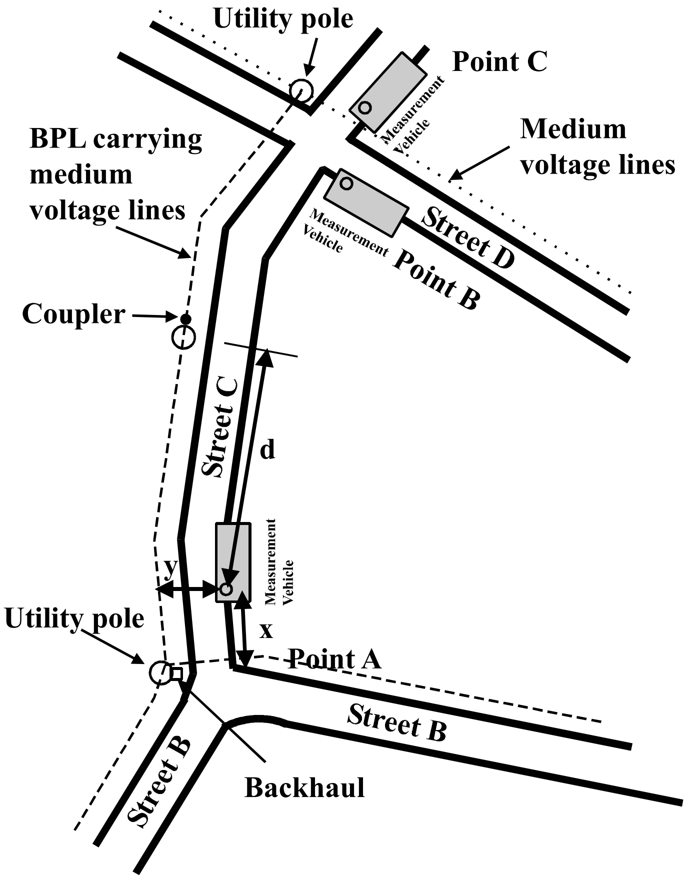

Figure D-34: Measurement Site B for BPL measurements away from power line

<u>Measurement Conditions</u>

Measurement Location:	Site B
Antenna Type:	Discone (Model SAS-210/C)
Antenna Height:	10 meters
Antenna Polarization:	Vertical
Measured Characteristic:	Pulse power measurements at two different radials; 100% duty cycle power determined from APDs measured at one of the radials
Measurement Variable:	Point B and Point C, radials away from the utility pole at the end of a BPL carrying segment of MV power line.
Comments:	Measurement frequencies – 32.699 MHz and 42.465 MHz Resolution bandwidths – 10 kHz and 30 kHz Pulse power measurements – zero span, peak power detection, 2 ms sweep time (601 pts per sweep)

Table D-10: Measured pulse power – Site B, Point B, discone antenna, radial 20.7 meters from utility pole.

	Frequency	RBW	Pulse Power
Case 1	32.699 MHz	30 kHz	Not measurable
Case 2	42.465 MHz	30 kHz	-112.2 dBm
Case 3	32.699 MHz	10 kHz	Not measurable
Case 4	42.465 MHz	10 kHz	Not measurable

Table D-11: Measured 100%-duty-cycle power and pulse power – Site B, Point C, discone antenna, radial 20.4 meters from utility pole.

	Frequency	RBW	100%-duty-cycle Power	Pulse Power
Case 1	32.699 MHz	30 kHz	-104.1 dBm	-106.4 dBm
Case 2	42.465 MHz	30 kHz	*Not measured*	-110.2 dBm
Case 3	32.699 MHz	10 kHz	-109.7 dBm	-109.7 dBm
Case 4	42.465 MHz	10 kHz	*Not measured*	Not measurable

D.3.4 Measurements of BPL Using Various Detectors

Measurements were made using three different spectrum analyzer detectors (peak, average and quasi-peak.) at Site A, as shown in Figure D-35. Table D-12 and D-13 show the detector levels for the two measurement frequencies. The data shown in these tables indicate that the measured quasi-peak power levels for this BPL signal are 0 to 5 dB greater than the average power levels.

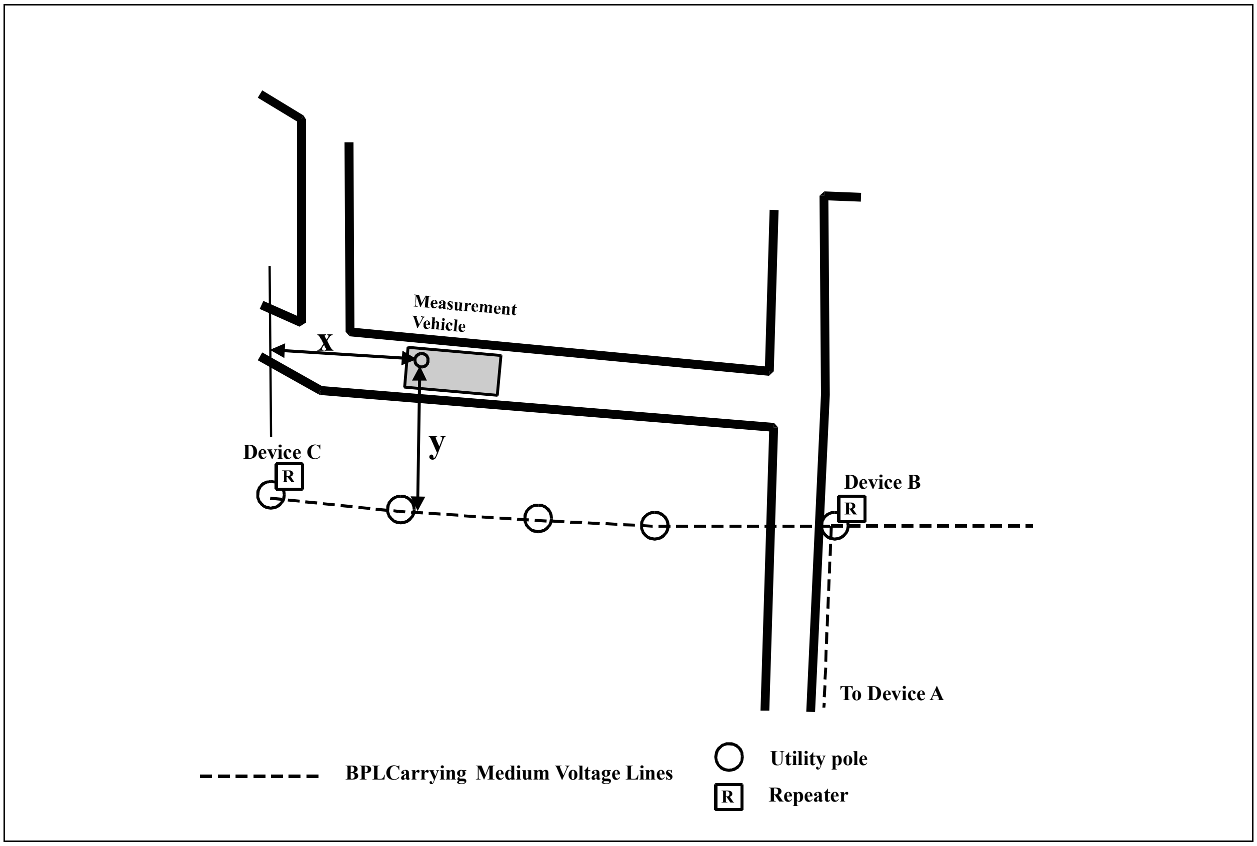

Figure D-35: Measurement Site A for BPL measurements using various detectors

Measurement Conditions

Measurement Location:	Site A
Antenna Type:	Whip
Antenna Height:	1.5 meters
Antenna Polarization:	Vertical
Measured Characteristic:	Peak, average, and quasi-peak power due to electric field
Measurement Variable:	Distance away from power line (x, y)
Comments:	Resolution bandwidths – 9.1 kHz (peak & average), 9 kHz quasi-peak Signal-to-noise ratio (SNR) at 22.957 MHz was 8 dB SNR at 28.298 MHz was 38 dB.

Table D-12: Measured peak, average and quasi-peak levels, x = 150 m, y = 28.3 m

Detector	Peak	Average	Quasi-Peak
Value at f = 22.957 MHz	-74 dBm	-81 dBm	-76 dBm

Table D-13: Measured peak, average and quasi-peak levels, x = 58.2 m, y = 39.3 m

Detector	Peak	Average	Quasi-Peak
Value at f = 28.298 MHz	-60 dBm	-65 dBm	-65 dBm

The measurements using the various detectors were made in a residential neighborhood environment. There were noise sources present, some of them appear impulsive on a spectrum analyzer and some appear bursty. Figure D-36 shows both kinds of noise sources at levels higher than the BPL signal. While it is possible to read the BPL level in between these noise sources with a peak and average (due to the 100% BPL duty cycle and if the symbol period is short enough) detector, the quasi-peak detector, with its longer time constant, will include the noise power in its measurement. When the BPL signal has a duty cycle less than 100% with a period greater than the period of the noise sources, the average detector will include the noise power in its measurement. An example of this signal is shown in Figure D-37. The period of the noise sources is much shorter than the period of the BPL signal. The off periods are large enough to cause the quasi-peak detector level to decay, Figure D-38, so to obtain a single value the operator chose a value when the BPL signal was on and ignored the noise induced spike near the center of the trace.

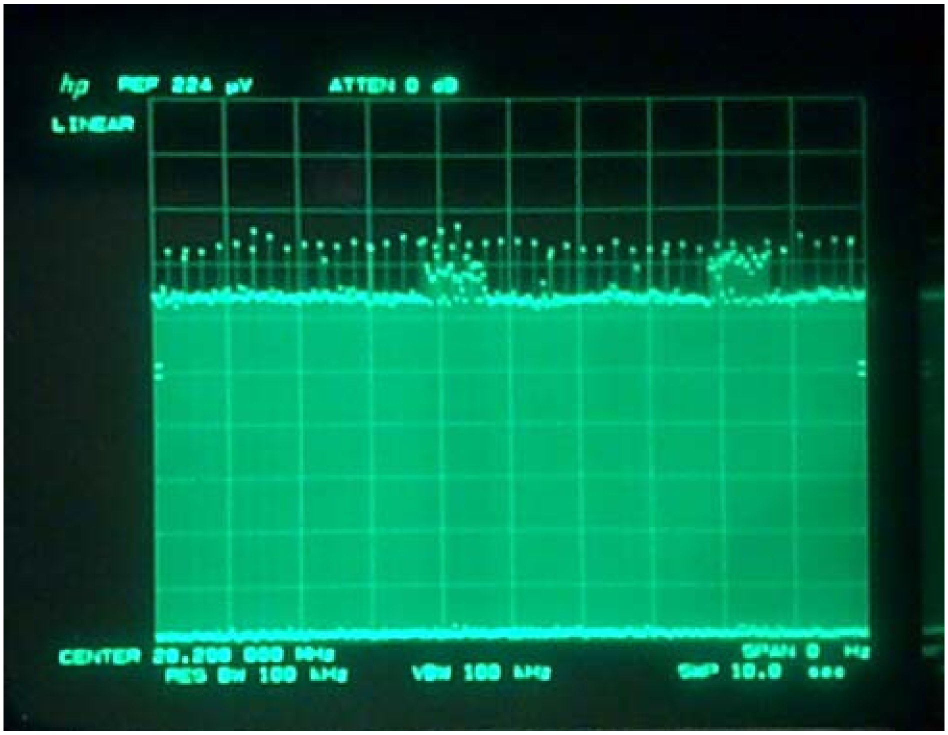

Figure D-36: BPL signal at 28.298 MHz.

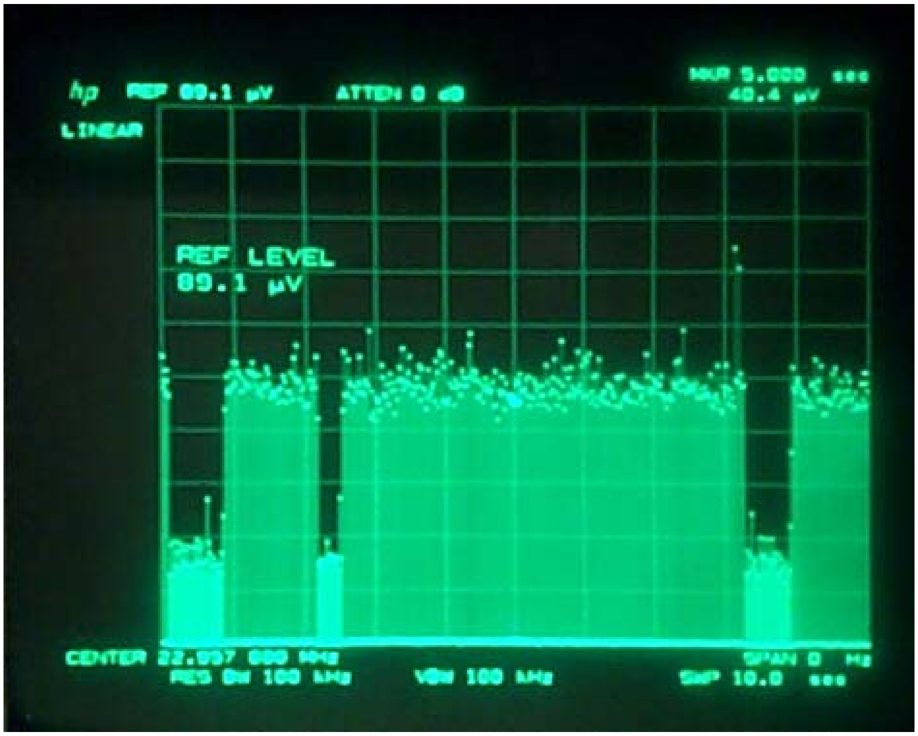

Figure D-37: BPL signal at 22.957 MHz.

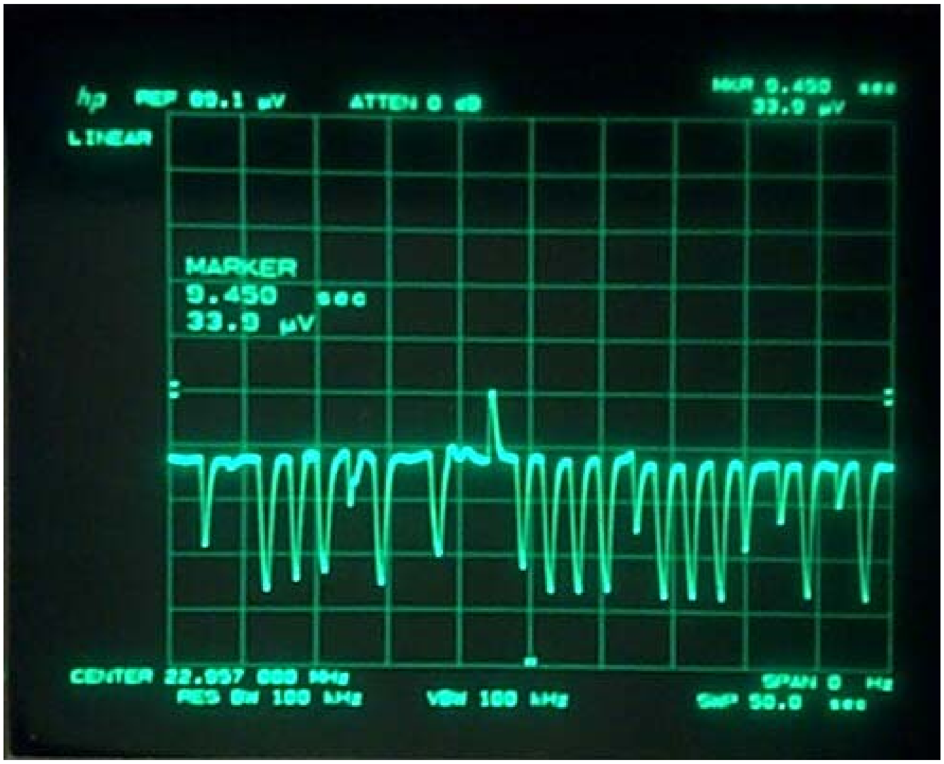

Figure D-38: BPL signal at 22.957 MHz.

Another measurement was made to compare detectors at a different location at Site A and on a different day. The results are in Table D-14.

Measurement Conditions	
Measurement Location:	Site A
Antenna Type:	Whip
Antenna Height:	1.5 meters
Antenna Polarization:	Vertical
Measured Characteristic:	Peak, average, and quasi-peak power due to electric field
Measurement Variable:	Distance away from power line (x, y)
Comments:	Resolution bandwidths – 3 kHz , corresponding to a typical land-mobile signal bandwidth in the HF spectrum

Table D-14: Measured detector levels, x – directly in front of Device B, y = 12.2 m

	Frequency		
Detector	4.255 MHz	7.304 MHz	28.777 MHz
Peak	-72 dBm	-60.4 dBm	-54.8 dBm
Average	-74.8 dBm	-63.5 dBm	-56.6 dBm
Quasi-Peak	-71.3 dBm	-59.3 dBm	-55.3 dBm

D.3.5 Measurements of BPL Varying Antenna Height

Measurements were performed using two different antenna heights at Site B, Figure D-39. Results are shown in Table D-15. The results show that in general, the measured power levels were higher at the greater antenna height. For example, the 100% duty cycle power measured at a frequency of 32.699 MHz and at a 10 meter antenna height was 4.8 to 10.7 dB greater than at 2 meters. The pulse power at a 10 meter antenna height for this same frequency was 8.2 to 15.1 dB higher than at 2 meters.

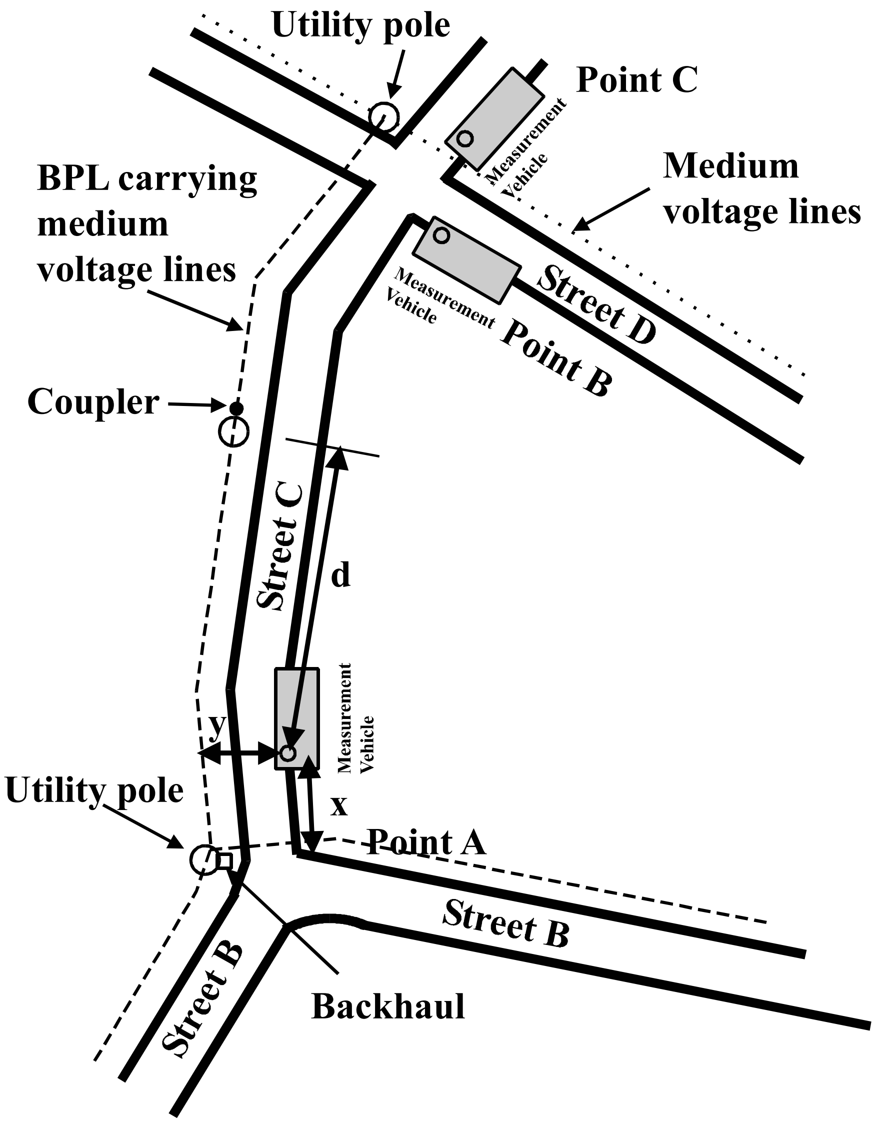

Figure D-39: Measurement Site B for BPL measurements with varying antenna height

Measurement Conditions

Measurement Location:	Site B
Antenna Type:	Discone (Model SAS-210/C)
Antenna Height:	2 and 10 meters
Antenna Polarization:	Vertical
Measured Characteristic:	100% duty cycle power (from APDs) and pulse power due to electric field
Measurement Variable:	Distance along power line (x = 4.9 m) referenced to Point A, (y = 7.9 m)
Comments:	Measurement frequencies – 32.699 MHz and 42.465 MHz

Resolution bandwidths – 30 kHz and 10 kHz
Pulse power measurements – zero span, peak power detection,
2 ms sweep time (601 pts per sweep)
Power lines approximately 8.5 meters above the ground

Table D-15: Measured 100%-duty-cycle power and pulse power – Site B, discone antenna, two antenna heights

	Ant. Ht.	Frequency	RBW	100%-duty-cycle Power	Pulse Power
Case 1	10 m	32.699 MHz	30 kHz	-96.3 dBm	-97.6 dBm
Case 2	10 m	42.465 MHz	30 kHz	*Not measured*	-104.4 dBm
Case 3	2 m	32.699 MHz	30 kHz	-101.1 dBm	-111.4 dBm
Case 4	2 m	42.465 MHz	30 kHz	*Not measured*	-116.1 dBm
Case 5	10 m	32.699 MHz	10 kHz	-100.7 dBm	-102.4 dBm
Case 6	10 m	42.465 MHz	10 kHz	*Not measured*	-112.0 dBm
Case 7	2 m	32.699 MHz	10 kHz	-111.4 dBm	-117.5 dBm
Case 8	2 m	42.465 MHz	10 kHz	*Not measured*	-120.2 dBm

Measurements were conducted at Site H as shown in Figure D-40. Figure D-41 shows a picture of the utility lines located immediately in front of the house as viewed from across the street parallel to the approximate location of the measurement vehicle.

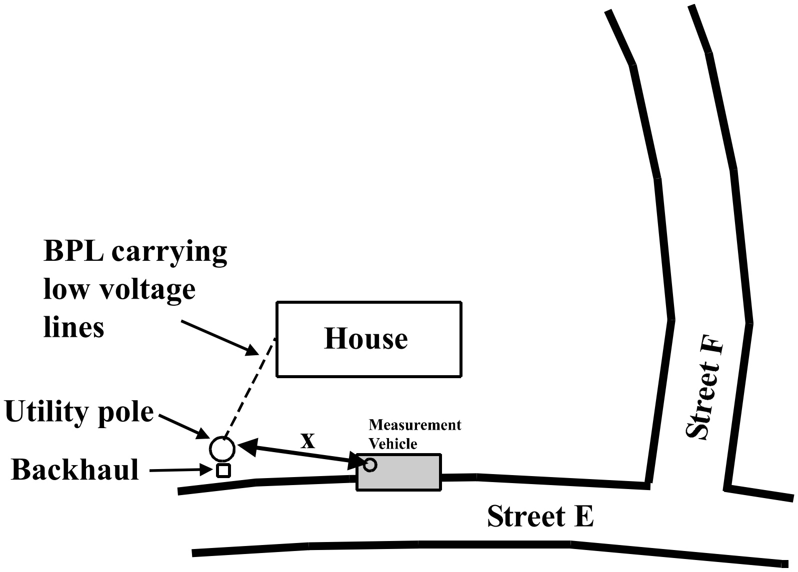

Figure D-40: Measurement Site H for BPL measurements with varying antenna height

Measurement Conditions

Measurement Location:	Site H
Antenna Type:	Shielded Loop
Antenna Height:	2 meters and 10 meters
Antenna Polarization:	Vertical, plane of antenna perpendicular to power line
Measured Characteristic:	Pulse power measurements and 100% duty cycle power (from APDs) of the magnetic field
Measurement Variable:	Distance away from low voltage power line (x = 8.7 meters)
Comments:	Measurement frequencies – 5.00 MHz, 6.43 MHz, 10.74 MHz and 18.38 MHz Resolution bandwidths – 3 kHz and 10 kHz Pulse power measurements – zero span, peak power detection, 5 ms sweep time (601 pts per sweep) Power line height ranging approximately 3 – 4.3 meters

The pulse-power and the 100%-duty-cycle power (both referenced to the antenna output) are shown for each case in Table D-16. The results shown indicate that measured power at a 10 meter height was always larger than the power measured at 2 meter height (by 3-10 dBm).

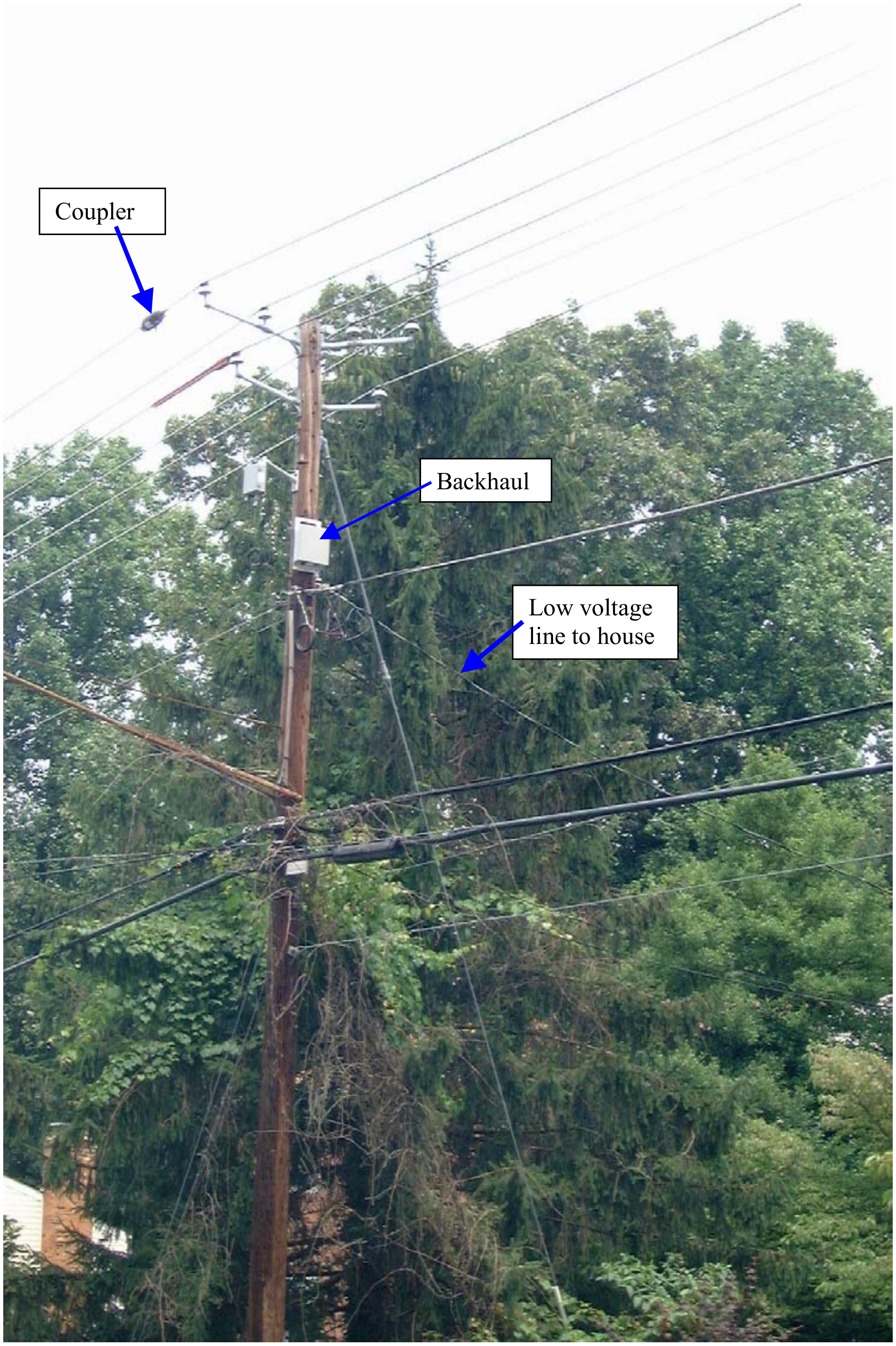

Figure D-41: Measurement Site H utility lines located immediately in front of house as viewed from across the street parallel to the approximate location of the measurement vehicle.

Table D-16: Measured 100%-duty-cycle power and pulse power – Site H, loop antenna, two antenna heights

	Ant. Ht.	Frequency	RBW	100%-duty-cycle Power	Pulse Power
Case 1	10 m	5.00 MHz	10 kHz	Not measurable	Not measurable
Case 2	10 m	5.00 MHz	3 kHz	Not measurable	Not measurable
Case 3	10 m	6.43 MHz	10 kHz	-106.4 dBm	-112.3 dBm
Case 4	10 m	6.43 MHz	3 kHz	-108.7 dBm	-114.0 dBm
Case 5	10 m	10.74 MHz	10 kHz	*Not measured*	-110.3 dBm
Case 6	10 m	10.74 MHz	3 kHz	-114.8 dBm	Not measurable
Case 7	10 m	18.38 MHz	10 kHz	*Not measured*	-101.4 dBm
Case 8	10 m	18.38 MHz	3 kHz	-106.6 dBm	-110.8 dBm
Case 9	2 m	5.00 MHz	10 kHz	Not measurable	Not measurable
Case 10	2 m	5.00 MHz	3 kHz	Not measurable	Not measurable
Case 11	2 m	6.43 MHz	10 kHz	-109.1 dBm	Not measurable
Case 12	2 m	6.43 MHz	3 kHz	-113.3 dBm	-112.6 dBm
Case 13	2 m	10.74 MHz	10 kHz	Not measurable	Not measurable
Case 14	2 m	10.74 MHz	3 kHz	Not measurable	Not measurable
Case 15	2 m	18.38 MHz	10 kHz	-111.2 dBm	-113.3 dBm
Case 16	2 m	18.38 MHz	3 kHz	-115.3 dBm	-117.3 dBm

D.3.6 Measurements of BPL APDs

APD measurements of the BPL signal were taken at Site I, as shown in Figure D-42. Results of these measurements, shown as 100% duty cycle power and / or pulse power levels are shown in Table D-17. This table shows that 100% duty cycle power is higher for higher resolution bandwidth at a given frequency and the power levels are proportional to bandwidth (confirming that 100% equivalent power was accurately estimated from APDs).

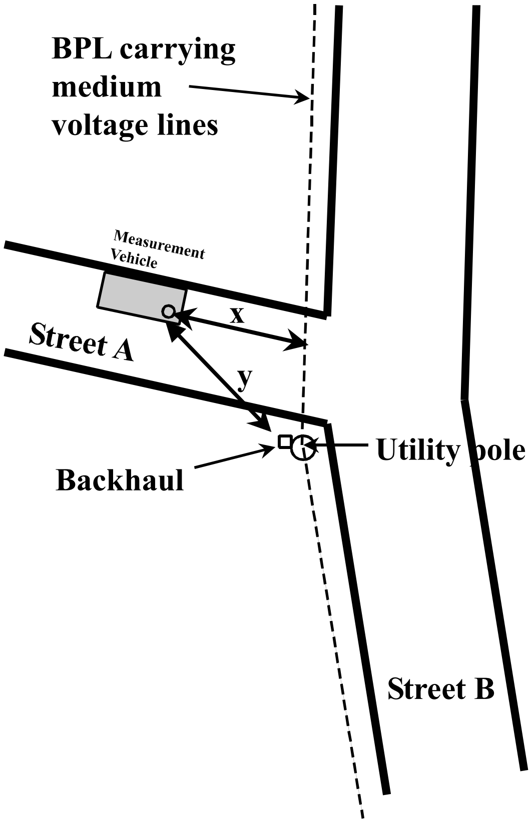

Figure D-42: Measurement Site I for BPL APD measurements

<u>Measurement Conditions</u>

Measurement Location:	Site I
Antenna Type:	Discone (Model SAS-210/C)
Antenna Height:	10 meters
Antenna Polarization:	Vertical
Measured Characteristic:	100% duty cycle power (from APDs) of the electric field
Measurement Variable:	Distance away from low voltage power line (x = 11.6 meters)
Comments:	Measurement frequencies – 32.699 MHz and 42.465 MHz Resolution bandwidths – 10 kHz, 30 kHz and 200 kHz

Table D-17: Measured 100%-duty-cycle power from APDs – Site I, discone antenna, x = 11.6 meters.

	Frequency	RBW	100%-duty-cycle Power
Case 1	32.699 MHz	200 kHz	-93.6 dBm
Case 2	32.699 MHz	30 kHz	-98.9 dBm
Case 3	32.699 MHz	10 kHz	-103.5 dBm
Case 4	42.465 MHz	200 kHz	-95.3 dBm
Case 5	42.465 MHz	30 kHz	-101.8 dBm
Case 6	42.465 MHz	10 kHz	-107.4 dBm

Another set of pulse-power measurements and APDs were performed at Site I at 32.699 MHz with two different resolution bandwidths (30 kHz, and 10 kHz) and three different antenna orientations. These results are shown in Table D-18. Figure D-43 shows APD plots for cases 7, 8, and 9 as described in the Table D-18. Both Table D-18 and Figure D-43 indicate that the measured power for all four cases is at similar levels for the same location.

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<u>Measurement Conditions</u>

Measurement Location:	Site I
Antenna Type:	Discone (Model SAS-210/C)
Antenna Height:	2 meters
Antenna Polarization:	Varies, see Table D.3.6-2
Measured Characteristic:	Pulse power measurements and 100% duty cycle power (from APDs) of the electric field
Measurement Variable:	Distance away from low voltage power line (x) and backhaul pt (y)
Comments:	Measurement frequency – 32.699 MHz Resolution bandwidths – 10 kHz and 30 kHz Pulse power measurements – zero span, peak power detection, 2 ms sweep time (601 pts per sweep)

Table D-18: Measured 100%-duty-cycle power from APDs and Pulse Power – Site I, discone antenna, various x-y distances

	Direct Distances	Antenna orientation	RBW	100%-duty-cycle Power	Pulse power
Case 1	x = 11.7 m	Vert. Polarization	30 kHz	-107.5 dBm	-114.6 dBm
	y = 15.2 m		10 kHz	-112.6 dBm	-115.6 dBm
Case 2	x = 17.1 m	Vert. Polarization	30 kHz	-107.4 dBm	-112.3 dBm
	y = 19.5 m		10 kHz	-112.2 dBm	-117.2 dBm
Case 3	x = 23.0 m	Vert. Polarization	30 kHz	Not measurable	Not measurable
	y = 25.0 m		10 kHz	Not measurable	Not measurable
Case 4	x = 23.0 m	Horz. Polarization	30 kHz	Not measurable	Not measurable
	y = 25.0 m	parallel to lines	10 kHz	Not measurable	Not measurable
Case 5	x = 17.1 m	Horz. Polarization	30 kHz	Not measurable	Not measurable
	y = 19.5 m	parallel to lines	10 kHz	Not measurable	Not measurable
Case 6	x = 17.1 m	Horz. Polarization	30 kHz	Not measurable	Not measurable

	y = 19.5 m	perpendicular to lines	10 kHz	Not measurable	Not measurable
Case 7	x = 11.7 m y = 15.2 m	Horz. Polarization perpendicular to lines	30 kHz	-107.9 dBm	-110.1 dBm
			10 kHz	-113.1 dBm	-115.8 dBm
Case 8	x = 11.7 m y = 15.2 m	Horz. Polarization parallel to lines	30 kHz	-106.2 dBm	-110.3 dBm
			10 kHz	-113.3 dBm	-118.1 dBm
Case 9	x = 11.7 m y = 15.2 m	Horz. Polarization pointed to pole	30 kHz	-107.8 dBm	-111.1 dBm
			10 kHz	-109.0 dBm	-116.8 dBm

The 100% duty-cycle power and manual pulse power levels were observed to be nearly the same for measurements performed at the same location with the antenna pointed in different directions (Case 7 – Case 9).

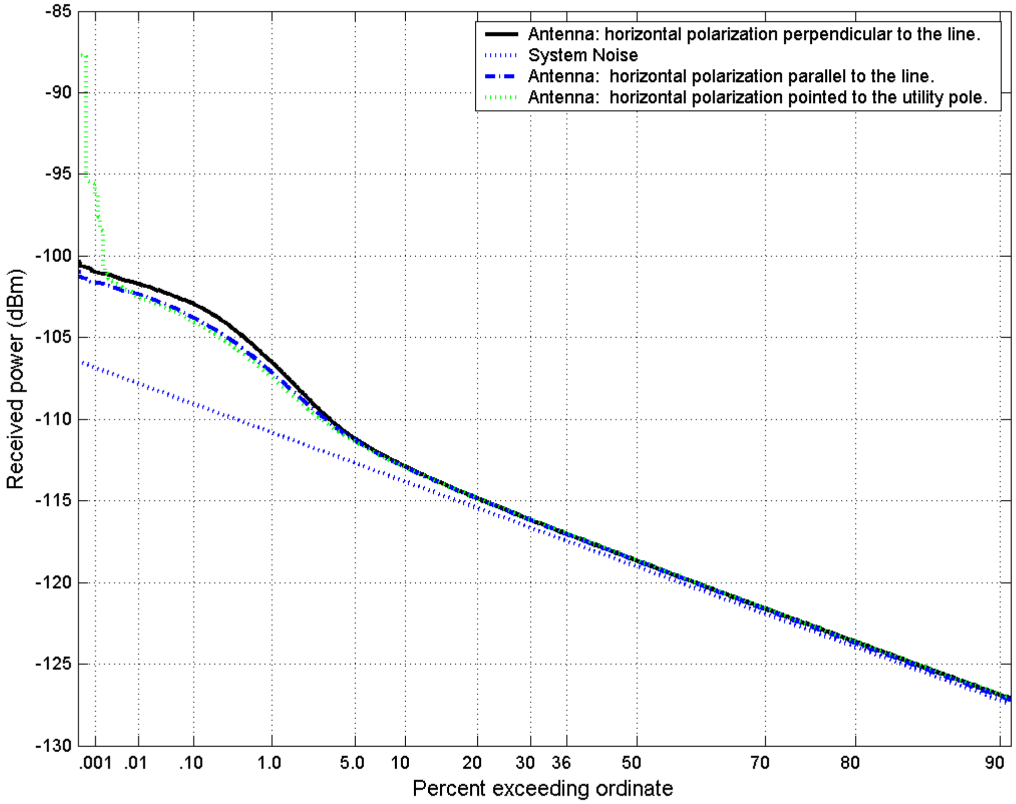

Figure D-43: APD measurements in a 30 kHz RBW for three different antenna orientations – Site I, located with a 11.7 m direct distance from power lines

D.4 BACKGROUND ON AMPLITUDE PROBABILITY DISTRIBUTIONS

Because of the random nature of the system noise, background noise, and the BPL signal itself, signal power data were, at times, collected and analyzed statistically using amplitude probability distributions (APDs).[2]

The reason for using APDs was to differentiate the BPL signal from the background (and system) noise and to extract mean power. While the APD can be used to characterize the background noise, doing so requires a sufficiently large ensemble and adequate sensitivity. It was not the original intention to use these measurements for the purpose of characterizing the background noise; therefore, the extent of sampling and the system configuration limit the use of these APDs for that purpose.

Data for these measurements were acquired by repeatedly collecting power traces from a spectrum analyzer and placing the power values in corresponding 0.1-dB bins of a histogram (later to be used for creating APDs). The spectrum analyzer was set in sample detection mode with a zero span and centered on specified frequencies of interest. So as to assure uncorrelated sampling, the trace sweep-time was set so that adjacent data points were no closer in time than 2/RBW, where RBW is the resolution bandwidth. To provide sufficient probability resolution, a minimum of 500,000 samples were collected for each APD - enough to give a probability of a single occurrence equal to 0.0002% .

By repeatedly collecting power data when the transmission lines are loaded with BPL and when the BPL is turned off, it is possible to identify the power contribution by BPL, assuming that the background noise does not change significantly. For example, Figure D-44 shows the APDs for the two scenarios - BPL on and BPL off. The “system noise” plot is emulated by calculating the curve from the system noise figure. Though the data from the two scenarios were not collected simultaneously, the characteristics of the noise environment, in this case, were changed only by inclusion or exclusion of the BPL signal. The features noted between points B and D are due predominantly to the BPL signal, whereas the features between points A and B for the “BPL-loaded” case and points A and C for the “BPL-off” case are due predominantly to extraneous environmental impulsive noise. The linear regions of the curves are due to system noise.

By taking multiple APDs of these two scenarios, it is possible to identify APD features that are characteristic of the BPL signal. For instance, after examining multiple APDs, it was possible to conclude that, for this example data, the BPL signal is present approximately 10% of the time when loaded. Figure D-45 shows data collected in a slightly different location within the site. However, in this example, changes in the noise environment between “loaded” and “off” cases are due not only to the BPL being turned off, but also due to some additional impulsive noise as noted in the region between points B and D of the “BPL-off” plot. Despite

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[2] “Measurements to determine potential interference to GPS receivers from ultrawideband transmission systems,” J.R. Hoffman, M.G. Cotton, R.J. Achatz, R.N. Statz, and R.A. Dalke, NTIA Report 01-384, Feb. 2001.

this added complexity, it is still possible to identify the power contribution by BPL because the region between points C and E on the “BPL-loaded” plot has the characteristic feature of 10% presence, and this feature of the curve is absent for the “BPL-off” case.

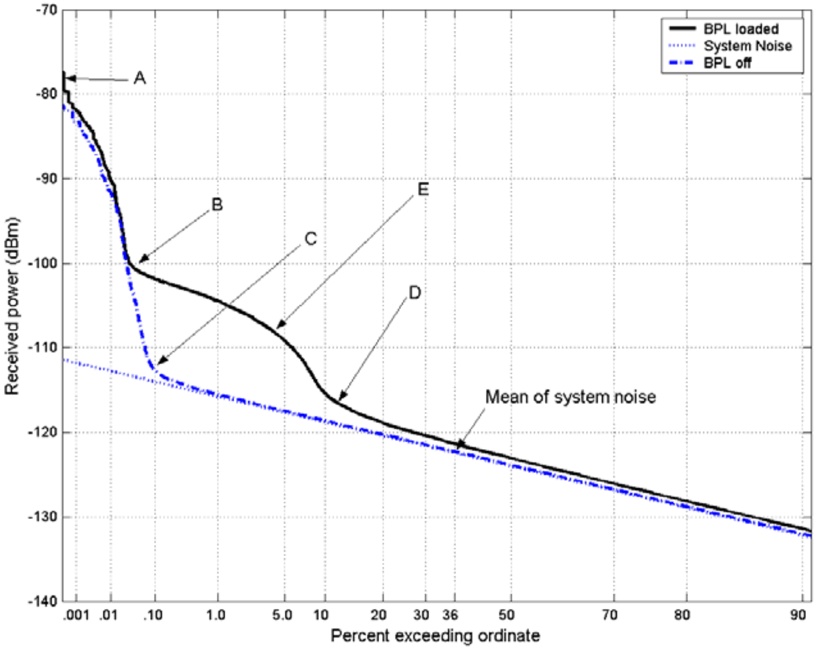

Figure D-44: Example APD plots for two different measurement scenarios - BPL loaded and BPL off.

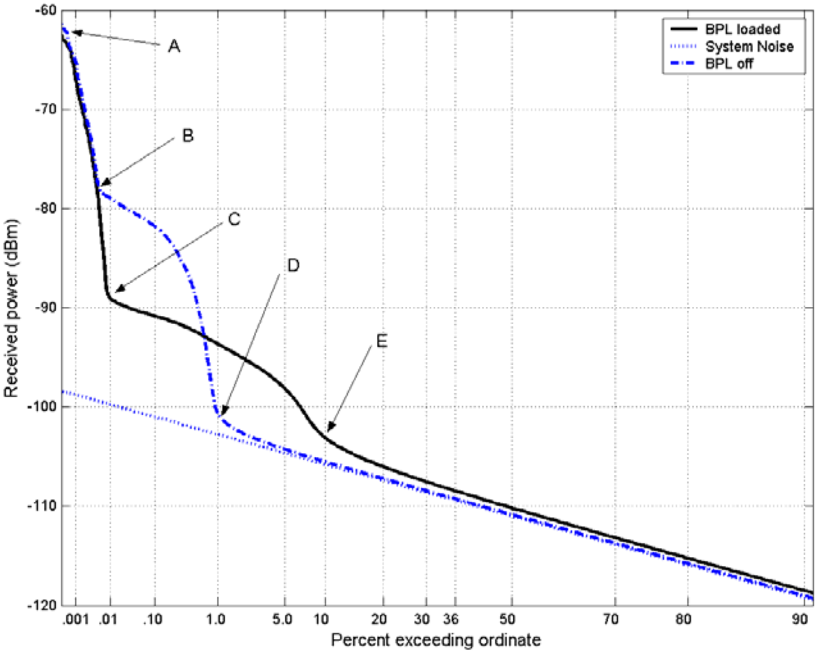

Figure D-45: Example APD plots for two different measurement scenarios - BPL loaded and BPL off.

For each of the APD plots, the powers on the ordinate are referenced to the output of the antenna terminals. Mean powers are calculated from the associated histograms by:

$$\sum_i x_i \frac{n_i}{N} ,$$

where x_i is power in the ith bin, n_i is the number of samples in the ith bin, and N is the total number of samples. In cases where the system noise or environmental noise may contribute significantly to the overall signal power, the mean signal power of the BPL is determined by subtracting the mean system noise power and/or environmental noise from the overall mean signal power. In some cases, the background noise is low enough in power or infrequent enough (for impulsive noise) that their contribution to the overall power can be disregarded.

For data shown in Figure D.46, the BPL signal is pulse-like in nature, and between the pulses, the signal power is dominated by the system (and environmental) noise. The calculated mean 100%-duty-cycle power (*i.e.*, the power when the pulses are present 100% of the time) is determined from the measured percentage of time the BPL pulses are present using the following equation:

$$M_p = M_s - 10 \log_{10}\frac{P}{100} ,$$

where M_p is the mean 100%-duty-cycle power in decibels, M_s is the mean measured signal power in decibels, and P is the percentage of time the measured BPL pulses are present. M_s is determined by subtracting mean power of the system noise from the mean power for the BPL-on data. Though there appears to be some impulsive environmental noise (far left side of the plot) contributing to the mean power of the BPL-on case, the probability (in combination with the magnitude) of this impulsive environmental noise is low enough that it contributes little to the overall mean power. To estimate P, it is assumed that the point at which the curve deviates from the system noise curve by 1.8 dB represents the point at which BPL pulses are starting to significantly contribute additional power above that of the system noise, and therefore, this represents the percent of the time for which the BPL pulses are present.3 For Figure D-46, this point occurs at 11%, and therefore, because the mean signal power is calculated to be -111.7 dBm, the mean pulse power is -103.3 dBm. It should be emphasized, however, that P and M_s are estimates and dependent upon an understanding of the background noise. Because the system noise power is Rayleigh distributed, the mean power occurs at the 37th percentile (true for any Rayleigh distributed power that is predominantly system noise); therefore for Figure D-46, the BPL pulse power is 18 dB above the mean system noise.

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[3] 1.8 dB was felt to be the first consistently perceptible deviation from the system noise curve.

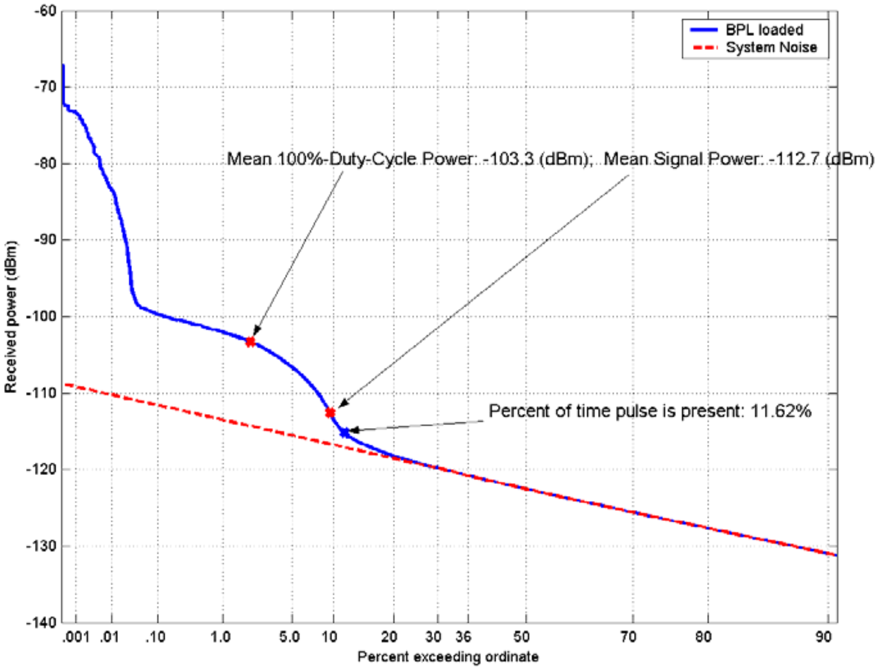

Figure D-46: Mean power for pulse-like BPL signal, dominated by system noise between pulses.

This measurement technique was verified by simulating a pulsed signal of known power and performing the same measurement and processing procedure. The simulated signal was centered at 30 MHz with a 10% duty cycle. Figures D-47 and D-48 shows the signal as measured on a spectrum analyzer with a span of zero. Figure D-47 shows the signal with a peak pulse power well above the system noise. Figure D-48 shows the signal with a peak pulse power approximately 6 dB above the system noise (–105 dBm at the input to the preselector). Because the peak pulse power could not be readily measured for the case where the power is less than 10 dB above the system noise, the peak pulse power was measured when it was well above the system noise and then attenuated prior to the preselector. APDs were performed for two different peak pulse power at the input to the preselector: -83 dBm and –105 dBm. The data were acquired and processed for mean signal power, mean 100%-duty-cycle power, and the measured duty cycle. Results are shown in Figures D-49 and D-50. In both cases, the mean 100%-duty-cycle power coincides well with the actual measured peak pulse power.

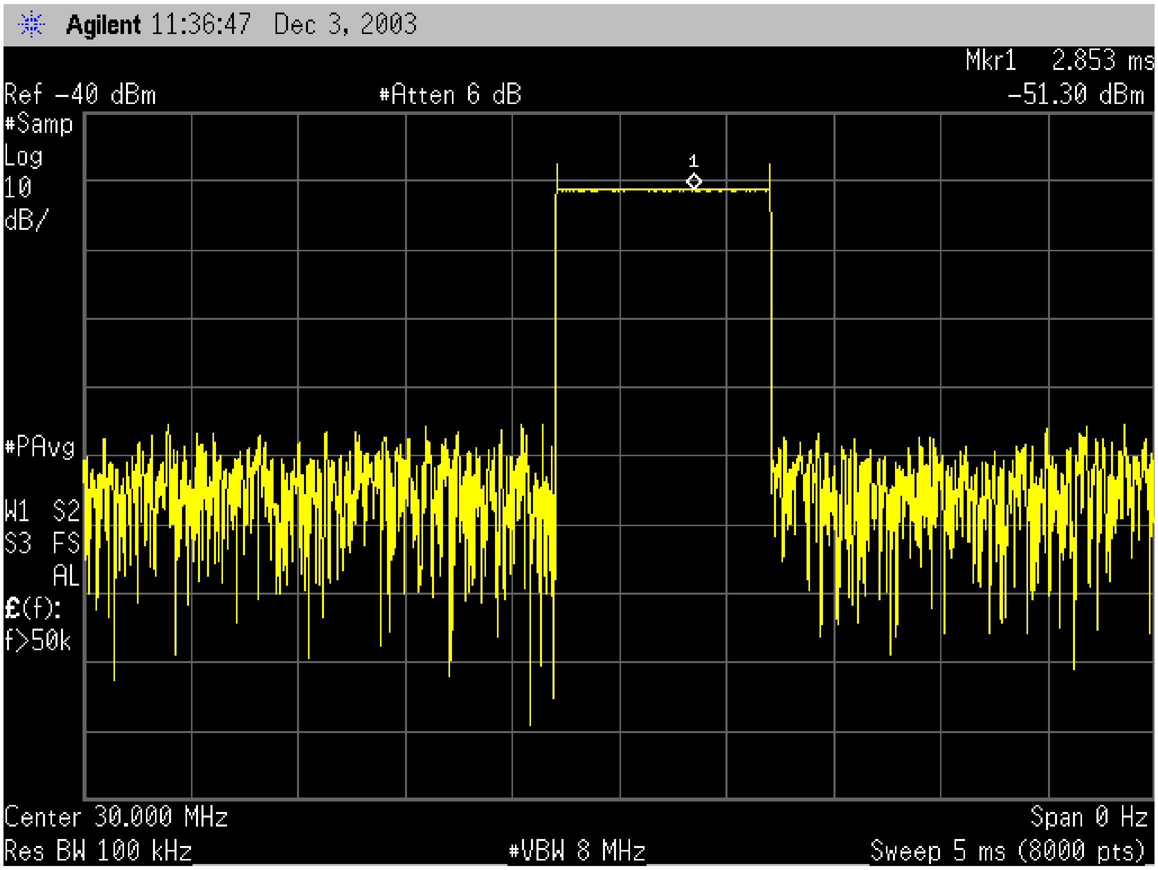

Figure D-47: Simulated signal with a peak pulse power well above the system noise.

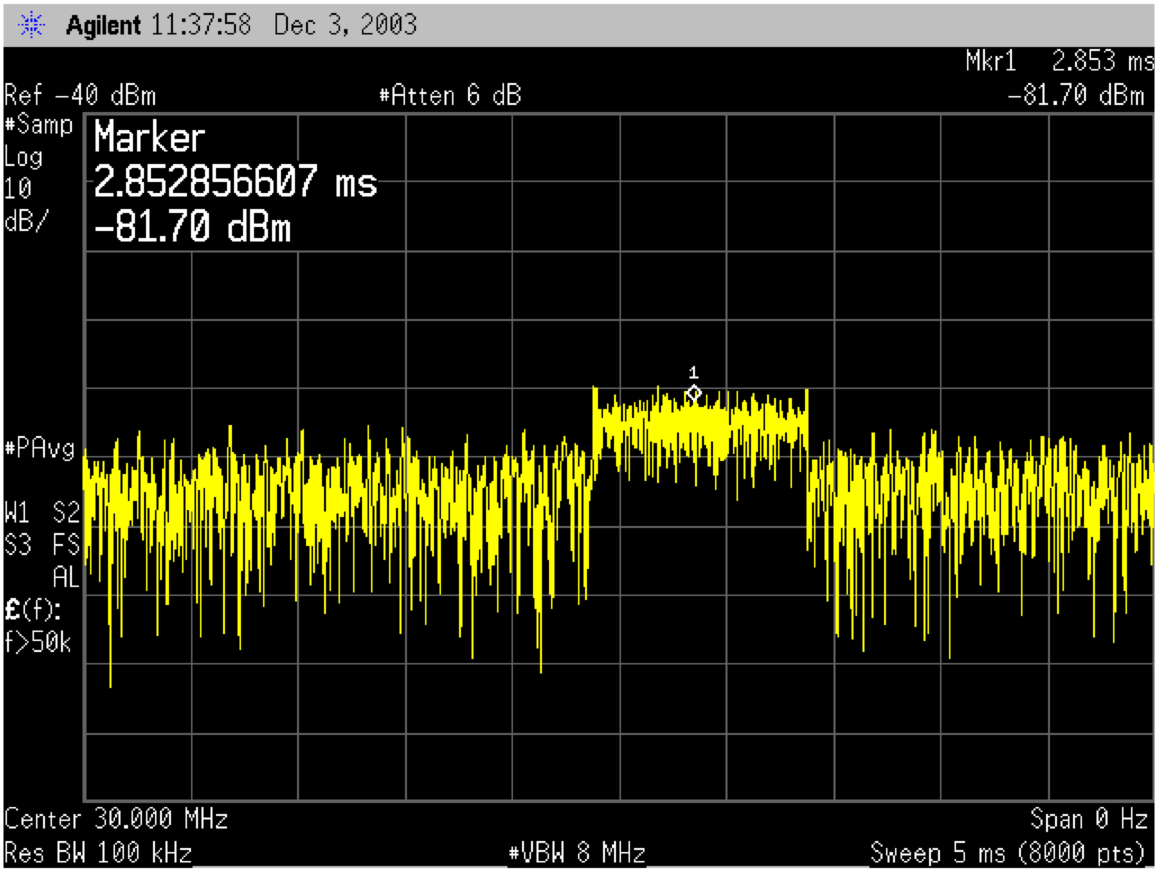

Figure D-48: Simulated signal with a peak pulse power 6 dB above the system noise.

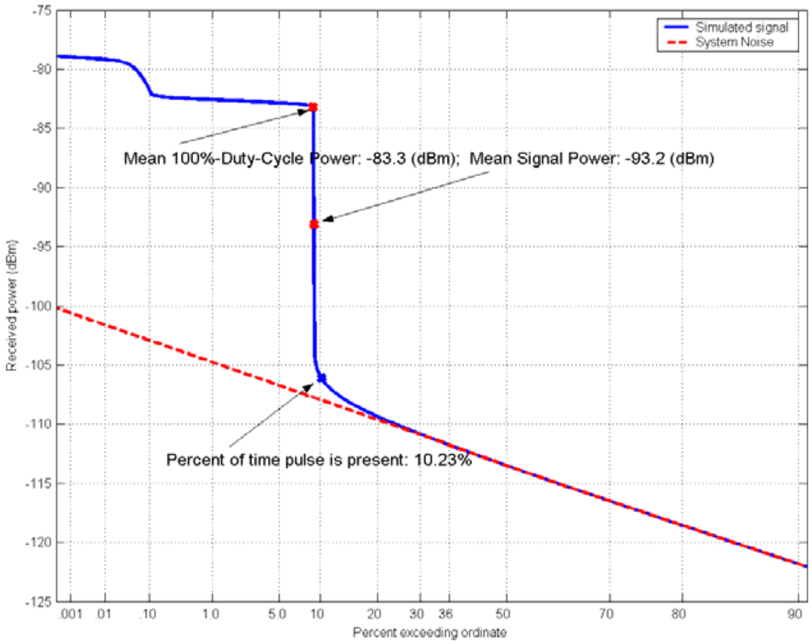

Figure D-49: APD of simulated signal with a peak pulse power of -83 dBm at the input to the preselector.

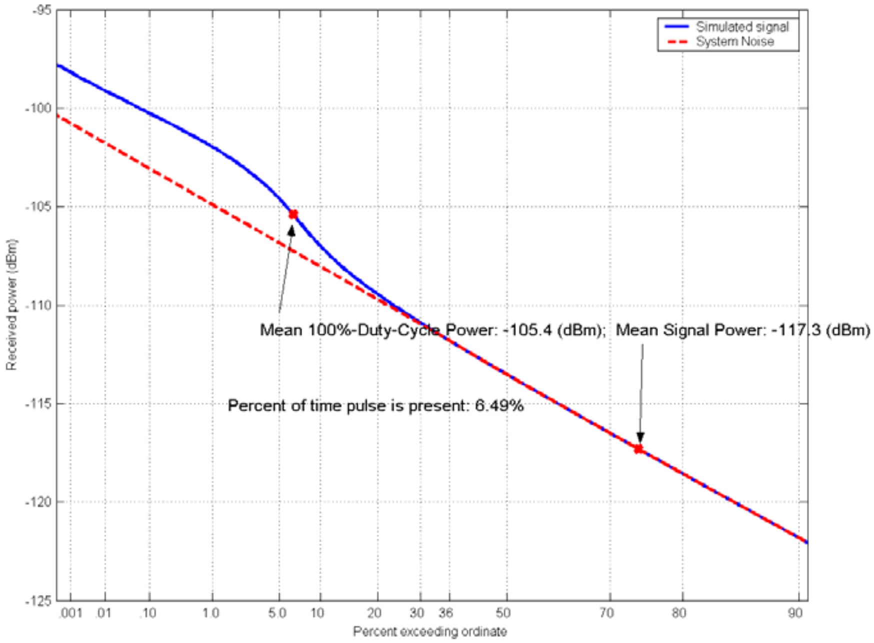

Figure D-50: APD of simulated signal with a peak pulse power of -105 dBm at the input to the preselector.

Figure D-51 shows APDs for data acquired for two conditions: when the BPL was loaded and when the BPL was turned off. In this case, there appears to be some impulsive noise that is present during both acquisitions. And though the contribution to the mean power by this impulsive noise is probably insignificant, it is possible to remove the effects of both environmental impulsive noise and the system noise by finding the difference in mean powers between the two data sets. Therefore, the mean measured signal power (M_S), in this case, is determined by subtracting the mean power for the BPL-off case from the mean power for the BPL-on case. The 100%-duty-cycle power is determined as described in the preceding paragraph.

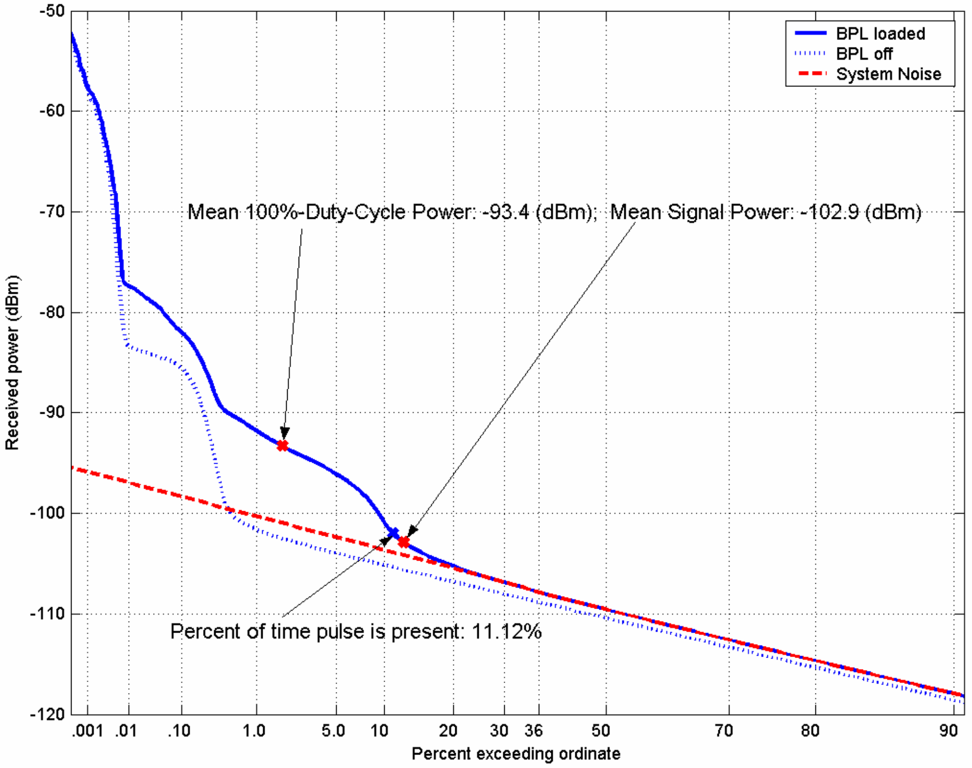

Figure D-51: Mean power for pulse-like BPL signal, dominated by system noise and impulsive noise between pulses.

Figure D-52 shows a BPL signal that (the mean power being less than 5 dB above mean system noise power) appears Gaussian noise-like and is present at least 90% of the time. Since the system noise may contribute significantly to the measured power, the mean measured signal power (M_S) is determined by subtracting the mean system noise power from the mean power for the BPL-on data.

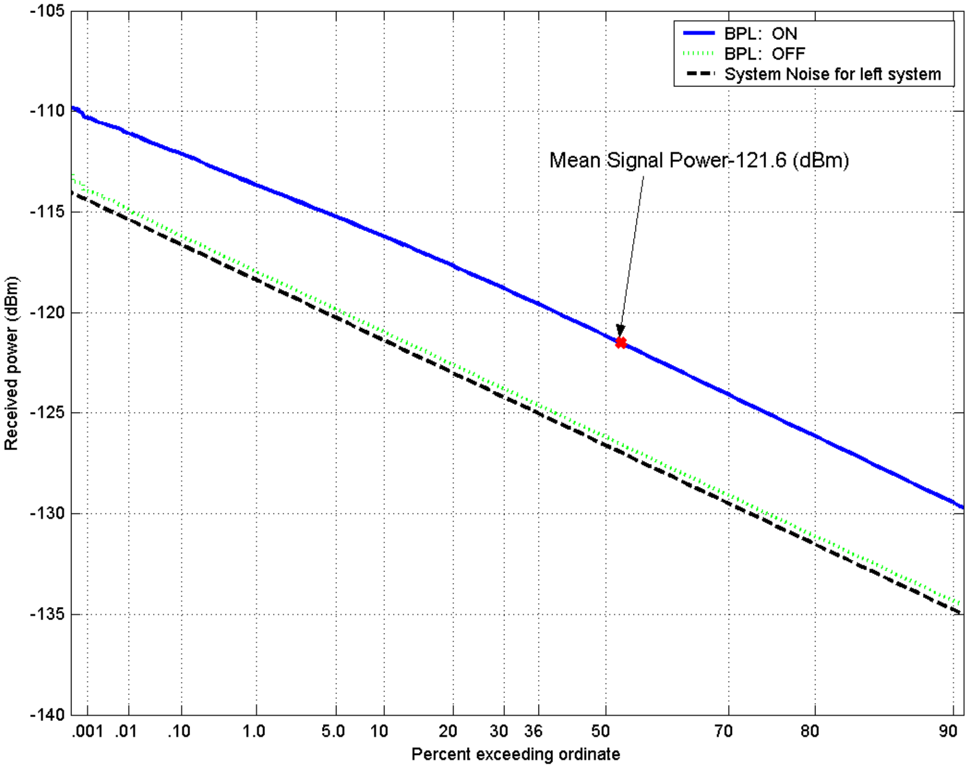

Figure D-52: Gaussian noise-like BPL signal data, the mean of which is less than 5 dB above the mean system noise.

Figure D-53 shows a BPL signal where the power appears randomly distributed with a variance less than system noise. Because the mean power of the signal is greater than 10 db above the mean system noise power, the system noise contributes little to the measured power, and therefore, the mean measured signal power (M_s) is determined only from the measured powers of the BPL-on case.

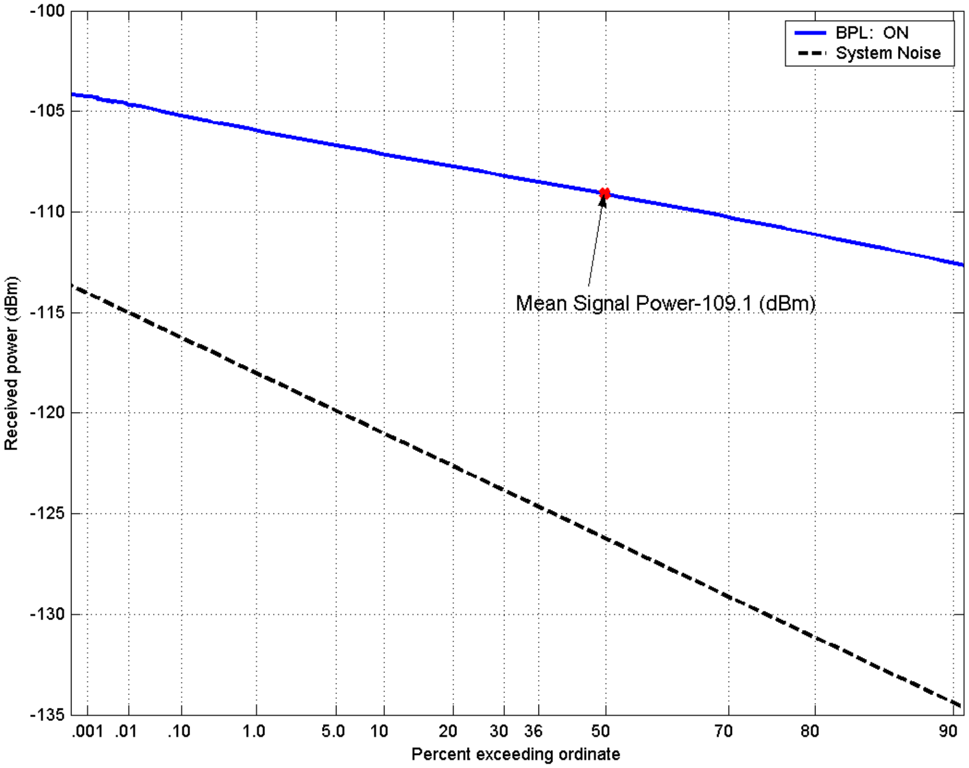

Figure D-53: Randomly distributed BPL signal power, the mean of which is greater than 10 dB above the mean system noise.

D.5 GAIN AND NOISE FIGURE CALIBRATION USING A NOISE DIODE

The RF paths to the E4440 Spectrum analyzers (see Figure D-1) were calibrated by injecting noise with a known excess noise ratio at the antenna input, collecting power data across the frequency range of interest, then terminating the input with a 50Ω terminator, and collecting the power data once again across the same frequency range. Power data were collected by putting the spectrum analyzer in zero span with average power detection and a sweep time long enough to produce a flat trace. Using an automated stepped frequency measurement routine, power levels were measured at approximately 200 kHz intervals across the band of interest. Using the Y-Factor method of calculation (as described below), both the gain through the system and noise figure at the input were determined. All power levels were referenced back to the antenna input by subtracting the gain.

Measurement system calibration should be performed prior to acquisitions where absolute values are required. As measurements are performed, gain corrections may be added automatically to every data point. For measurement system noise figures of 20 dB or less, noise diode Y-factor calibration may be used. The theory and procedure for such calibration are described herein.

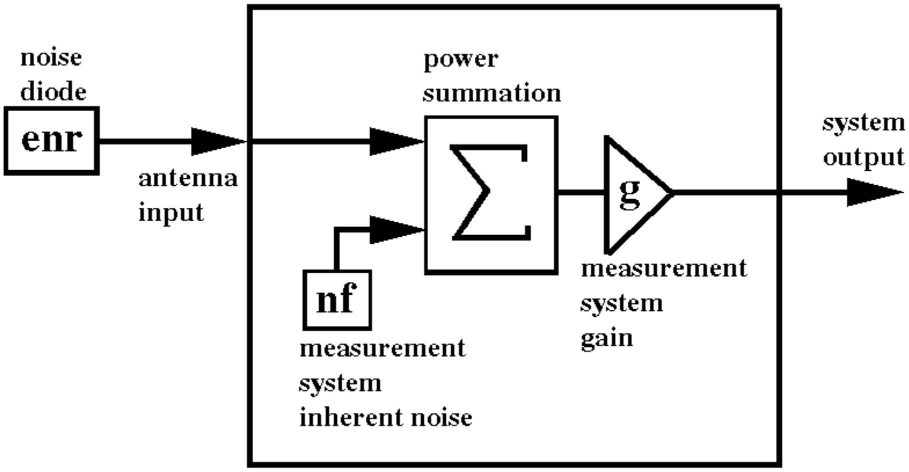

Figure D-54: Lumped component diagram of noise diode calibration

The noise diode calibration of a receiver tuned to a particular frequency may be represented in lumped-component terms as shown in Figure D-54. In this diagram, the symbol "Σ" represents a power-summing function that linearly adds any power at the measurement system input to the inherent noise power of the system. The symbol "g" represents the total gain of the measurement system. The measurement system noise factor is denoted by "nf," and the noise diode has an excess noise ratio denoted as "enr." (All algebraic quantities denoted by lower-case letters, such as "g," represent linear units. All algebraic quantities denoted by upper case letters, such as "G," represent decibel units).

Noise factor is the ratio of noise power from a device, n_{device}(W), and thermal noise,

$$\frac{n_{device}}{kTB}$$

where k is Boltzmann's constant ($1.38 \cdot 10^{-23}$J/K), T is system temperature in Kelvin, and B is bandwidth in hertz. The excess noise ratio is equal to the noise factor minus one, making it the fraction of power in excess of kTB. The noise figure of a system is defined as 10 log (noise factor). As many noise sources are specified in terms of excess noise ratio, that quantity may be used.

In noise diode calibration, the primary concern is the difference in output signal when the noise diode is switched on and off. For the noise diode = on condition, the power, P_{on}(W), is given by:

$$p_{on} = (nf_s + enr_d) \times gkTB$$

where nf_s is system noise factor and enr_d is the noise diode enr.

When the noise diode is off, the power, P_{off}(W), is given by:

$$p_{off} = (nf_s) \times gkTB$$

The ratio between P_{on} and P_{off} is the Y factor:

$$y = \left(\frac{p_{on}}{p_{off}}\right) = \frac{(nf_s + enr_d)}{nf_s}$$

$$Y = 10\log(y) = 10\log\left(\frac{p_{on}}{p_{off}}\right) = P_{on} - P_{off}$$

Hence the measurement system noise factor can be solved as:

$$nf_s = \frac{enr_d}{y-1}$$

The measurement system noise figure is:

$$NF_s = 10\log\left(\frac{enr_d}{y-1}\right) = ENR_d - 10\log(y-1) = ENR_d - 10\log\left(10^{Y/10} - 1\right)$$

Hence:

$$g = \frac{p_{on} - p_{off}}{enr_d \times kTB}$$

$$G = 10\log(p_{on} - p_{off}) - 10\log(enr_d \times kTB)$$

or

$$G = 10\log\left(10^{P_{on}/10} - 10^{P_{off}/10}\right) - ENR_d - 10\log(kTB)$$

In noise diode calibrations, the preceding equation is used to calculate measurement system gain from measured noise diode values.

Although the equation for NF_s may be used to calculate the measurement system noise figure, software may implement an equivalent equation:

$$nf_s = \frac{p_{off}}{gkTB}$$

$$NF_s = 10\log(p_{off}) - 10\log(gkTB) = P_{off} - G - 10\log(kTB)$$

Substituting the expression for gain into the preceding equation yields:

$$NF_s = P_{off} + ENR_d - 10\log\left(10^{P_{on}/10} - 10^{P_{off}/10}\right)$$

The gain and noise figure values determined with these equations may be stored in look-up tables. The gain values are used to correct the measured data points on a frequency-by-frequency basis.

Excluding the receive antenna, the entire signal path is calibrated with a noise diode source prior to a BPL measurement. A noise diode is connected to the input of the first RF line in place of the receiving antenna. The connection may be accomplished manually or via an automated relay, depending upon the measurement scenario. The noise level in the system is measured at a series of points across the frequency range of the system with the noise diode turned on. The noise diode is then turned off and the system noise is measured as before, at the same frequencies. The measurement system computer thus collects a set of P_{on} and P_{off} values at a series of frequencies across the band to be measured. The values of P_{on} and P_{off} are used to solve for the gain and noise figure of the measurement system in the equations above.

APPENDIX E
BPL MODELING OUTPUT

E.1 INTRODUCTION

Extensive work was done at NTIA's Institute for Telecommunication Sciences (ITS) on a typical arrangement of medium voltage power lines. The modeled power lines consist of three horizontal parallel copper wires 8.5 meters (27.9 feet) above average ground. Each wire has a diameter of 0.01 meter and the wires are separated in the horizontal plane by 0.60 meter. The feed is at the center of one of the wires which runs along the x axis ($y = 0$). The equivalent of a coupler in series with the center segment of the wire is used with a voltage source of 1 volt. The other two wires run parallel to the x axis at $y = 0.6$ and $y = 1.2$ meters.

All three components of electric and magnetic fields E_x, E_y, E_z, H_x, H_y and H_z in dBμV/m were plotted in a plane 2 meters above the ground at frequencies 2, 5, 10, 20 and 40 MHz. Three different line lengths of 100m, 200m and 340m were used with four different impedance conditions for the source and loads. The near field data have been plotted for four different scales of x and y coordinates *i.e.*, 0 to 20 m (65.6 ft), 200 m (656 ft), 1,000 m (3,280 ft) and 1,800 m (59,040 ft). The far field radiation patterns were also plotted at several azimuth angles. The complete dataset of the radiation patterns and near-field plots are available at NTIA. A few representative radiation patterns and near field plots are given in this Appendix.

The trends observed from the near field plots of the three components of the electric fields are summarized in Tables E-1, E-2 and E-3 for E_z, E_x and E_y respectively.

E.2 TABLES AND NEC PLOTS

Table E-1 summarizes the characteristics of the vertical electric field E_z at various ranges of x and y and at $z = 2$m as deduced from the near field plots. Similarly Table E-2 and E-3 summarize the characteristics of the horizontal electric field parallel to the wire E_x and horizontal electric field perpendicular to the wire E_y respectively.

Figures E-1 thru E-12 show elevation power patterns for azimuth (Φ) = 0° and 90° for source impedance of 150 Ω, load impedance of 575 Ω and several combinations of line lengths 100m, 200m and 340 m and frequencies 2 MHz, 5 MHz, 10 MHz, 20 MHz and 40 MHz. Figures E-13 thru E-30 show near field plots for E_x, E_y and E_z for a line length of 200 m, source impedance of 150 Ω, load impedance of 575 Ω, frequencies 40 MHz, 10 MHz and 2 MHz, $z = 2$ m for two different scales of x and y, 0 to 20 m (65.6 ft) and 200 m (656 ft). Figures E-31 thru E-34 illustrate the effect a neutral wire has on the radiation pattern.

Table E-1: Summary of Electric Fields Seen by an Antenna Having Vertical Polarization

Source & Load	BPL Frequency	Length of Line	Peak Field	Number of Peaks[1]	Minimum Distance Between Peak Field and BPL Device
Impedance (Ω)	(MHz)	(m)	(dBµV/m)		(feet)
150 & 575	2	100	83-85	2	59-85
575 & 50	2	100	83-85	2	90
150 & 50	2	100	86	2	58-120
575 & 575	2	100	81	2	100
150 & 575	10	100	75-79	4	33
575 & 50	10	100	74-77	4	38
150 & 50	10	100	74-79	3	33
575 & 575	10	100	71-75	3	36
150 & 50	40	100	69-76	8	7
575 & 50	40	100	69-73	8	7
575 & 575	40	100	70-75	7	6
150 & 575	40	100	72-77	6	7
150 & 50	2	200	84-86	2	58-120
575 & 50	2	200	82-85	2	95
575 & 575	2	200	79-81	2	100
150 & 575	2	200	85	1	58-100
150 & 50	10	200	75-80	4	33
575 & 50	10	200	75-78	4	32
150 & 575	10	200	74-79	4	32
575 & 575	10	200	71-75	4	35
150 & 50	40	200	71-74	8	7
575 & 575	40	200	68-74	7	6
575 & 50	40	200	72-74	6	6
150 & 575	40	200	71-76	5	7
150 & 50	2	340	80-83	3	80
575 & 575	2	340	76-79	3	95
150 & 575	2	340	82	3	85
575 & 50	2	340	81	3	70
575 & 575	10	340	68-74	8	21
575 & 50	10	340	73-77	7	20
150 & 50	10	340	76-79	6	50
150 & 575	10	340	72-78	2	21
150 & 575	40	340	71-77	10	13
575 & 575	40	340	67-73	10	16
575 & 50	40	340	70-76	9	15
150 & 50	40	340	73	2	53

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[1] All peak levels of vertically polarized electric field strength occurred near and under the power lines, and all local peaks had approximately the same level. The statistics are presented for one-half the overall length of the power line, which is center fed. Thus, the numbers of peaks for the entire power line are twice the values shown in the table.

Table E-2: Summary of Electric Fields Seen by an Antenna Having Horizontal-Parallel Polarization

Source & Load Impedance (Ω)	BPL Frequency (MHz)	Length of Line (m)	Field at Source[2] (dBμV/m)	Number of Secondary Peaks[3]
150 & 50	2	100	68	2
150 & 575	2	100	67	2
575 & 50	2	100	67	2
575 & 575	2	100	63	2
150 & 50	2	200	68	2
150 & 575	2	200	67	2
575 & 50	2	200	67	2
575 & 575	2	200	63	2
150 & 50	2	340	69	3
150 & 575	2	340	68	3
575 & 50	2	340	67	3
575 & 575	2	340	65	3
150 & 50	10	100	76	5
150 & 575	10	100	75	3
575 & 50	10	100	74	3
575 & 575	10	100	72	0
150 & 50	10	200	77	5
150 & 575	10	200	76	3
575 & 50	10	200	75	3
575 & 575	10	200	72	3
150 & 50	10	340	75	5
150 & 575	10	340	74	5
575 & 50	10	340	74	5
575 & 575	10	340	70	5
150 & 50	40	100	82	1
150 & 575	40	100	81	1
575 & 50	40	100	79	0
575 & 575	40	100	78	0
150 & 50	40	200	82	1
150 & 575	40	200	81	1
575 & 50	40	200	78	0
575 & 575	40	200	78	1
150 & 50	40	340	76	1
150 & 575	40	340	81	1
575 & 50	40	340	80	1
575 & 575	40	340	76	0

---

[2] Peak horizontal-parallel electric field strength always occurred near the BPL device.

[3] Secondary peaks levels were recorded if they were within 5 dB of the overall peak level near the BPL device. The statistics are presented for one-half the overall length of the power line, which is center fed. Thus, the numbers of peaks for the entire power line are twice the values shown in the table.

Table E-3: Summary of Electric Fields Seen by an Antenna Having Horizontal-Perpendicular Polarization

Source & Load Impedance (Ω)	BPL Frequency (MHz)	Length of Line (m)	Peak Field (dBμV/m)	Distance of Peak from the Line (ft)	Number of Peaks[4]	Minimum Distance From BPL Device (feet)
150 & 50	2	100	70	+/-10-20	1	60-100
150 & 575	2	100	64-69	+/-15-21	2	60-90
575 & 50	2	100	69	+/-10-20	1	65-100
575 & 575	2	100	58-65	+/-13-25	2	90
150 & 50	2	200	70	10-20	1	58-110
150 & 575	2	200	64-69	+/-15-25	2	90
575 & 50	2	200	69	+/-17	2	65-120
575 & 575	2	200	58-65	+/-15-25	2	95
150 & 50	2	340	60-67	0	4	50
150 & 575	2	340	61-66	+/-10-22	3	42-80
575 & 50	2	340	60-65	+/-10-22	2	90
575 & 575	2	340	57-63	+/-15-20	3	85
150 & 50	10	100	60-67	+/-10-25	2	32
150 & 575	10	100	63-67	+/-18	2	32
575 & 50	10	100	58-65	+/-12-23	2	32
575 & 575	10	100	57-63	+/-13-23	3	50
150 & 50	10	200	62-67	+/-10-25	3	32
150 & 575	10	200	61-67	+/-17-21	3	31
575 & 50	10	200	60-65	+/-10-25	3	17
575 & 575	10	200	57-63	+/-15-26	3	31
150 & 50	10	340	62-65	+/-10-25	12	50
150 & 575	10	340	60-65	16-21	2	21
575 & 50	10	340	60-63	+/-10-22	6	21
575 & 575	10	340	52-61	+/-12-23	7	22
150 & 50	40	100	71-73	+/-10-25	4	20
150 & 575	40	100	65-73	+/-15-38	4	32
575 & 50	40	100	69-71	+/-18-30	5	20
575 & 575	40	100	63-69	+/-15-35	6	19
150 & 50	40	200	68-73	+/-10-33	5	18
150 & 575	40	200	66-73	+/-10-30	5	33
575 & 50	40	200	62-72	+/-12-34	5	20
575 & 575	40	200	69	+/-18-30	5	19
150 & 50	40	340	64	+/-10-30	4	23
150 & 575	40	340	69-72	+/-18-23	6	10
575 & 50	40	340	64-70	+/-10-30	6	10
575 & 575	40	340	64-66	+/-17-23	5	10

---

[4] The statistics are presented for one-half the overall length of the power line, which is center fed. Thus, the numbers of peaks for the entire power line are twice the values shown in the table.

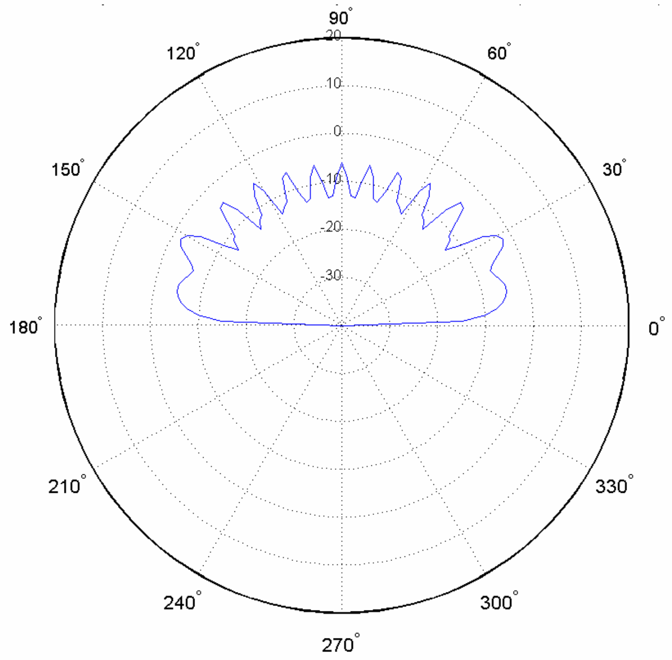

Figure E-1: Elevation pattern at azimuth (phi) = 0, line length = 340 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flc0.png]

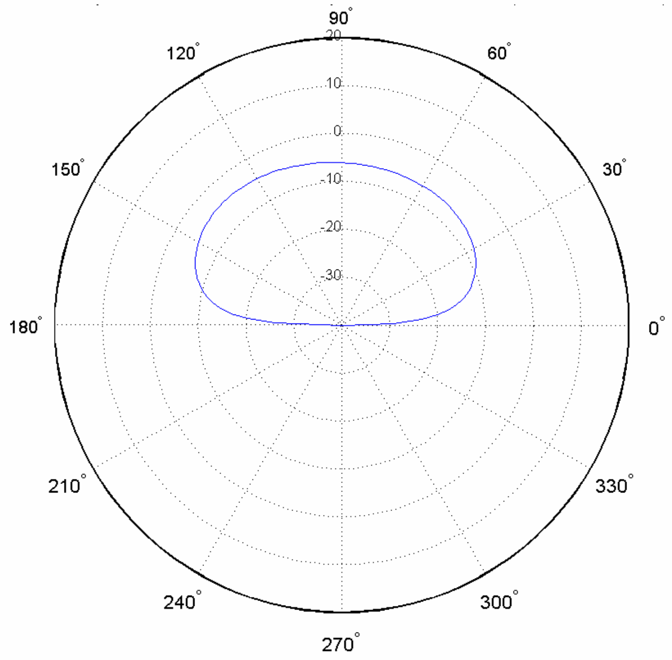

Figure E-2: Elevation pattern at azimuth (phi) = 90, line length = 340 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flc90.png]

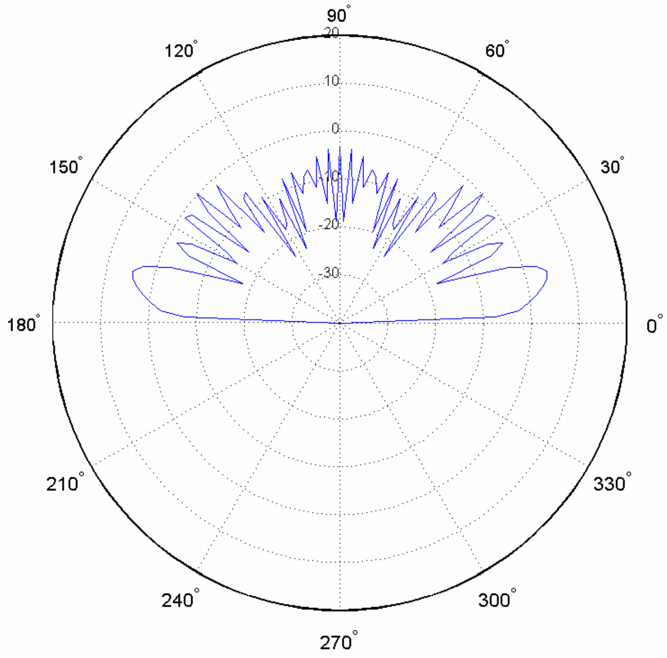

Figure E-3: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flf0.png]

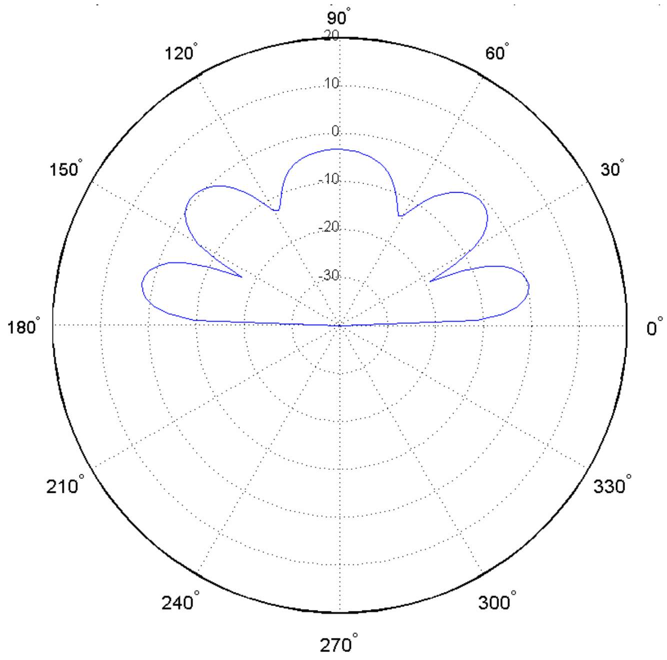

Figure E-4: Elevation pattern at azimuth (phi) =90, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flf90.png]

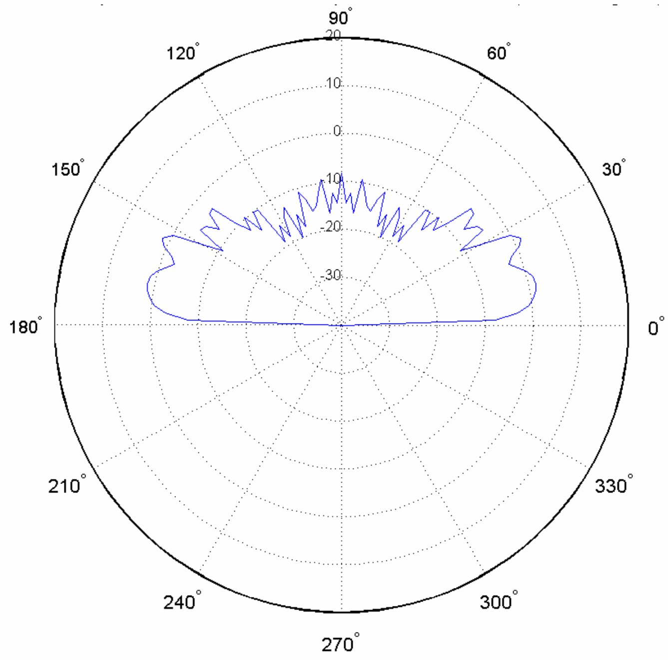

Figure E-5: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 20 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flg0.png]

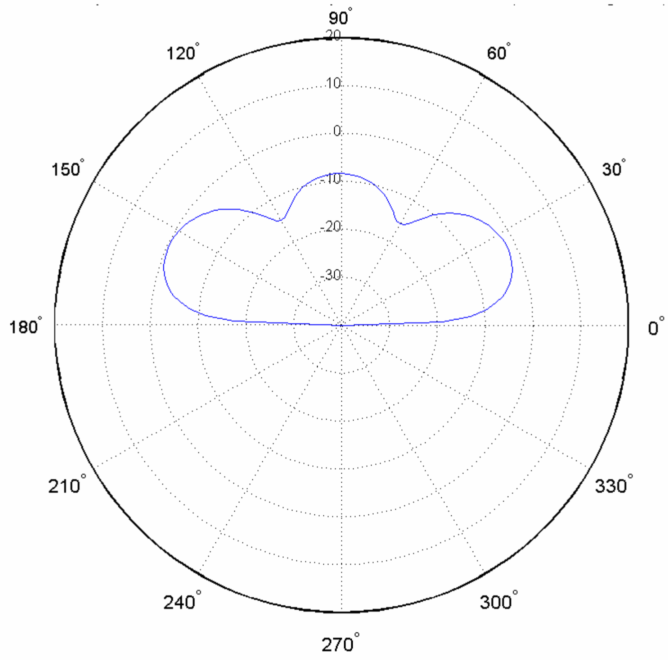

Figure E-6: Elevation pattern at azimuth (phi) = 90, line length = 200 m, frequency = 20 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flg90.png]

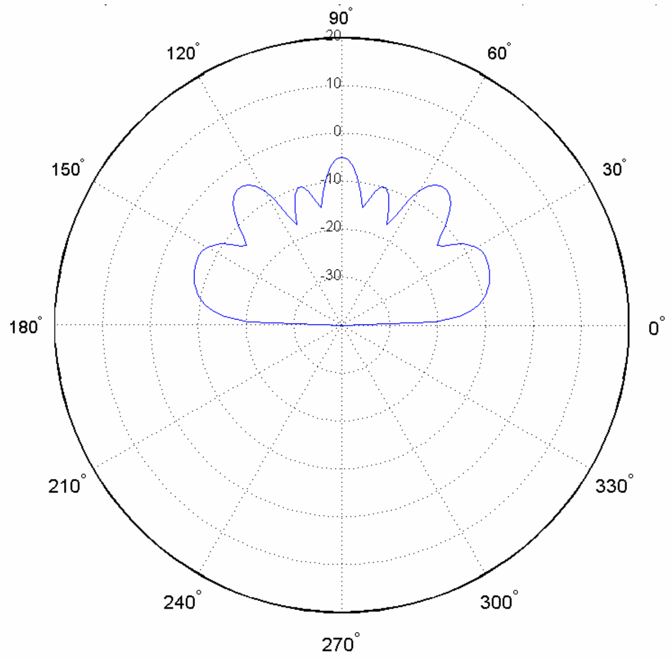

Figure E-7: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 5 MHz, source impedance = 150 Ω, load impedance = 575 Ω [fli0.png]

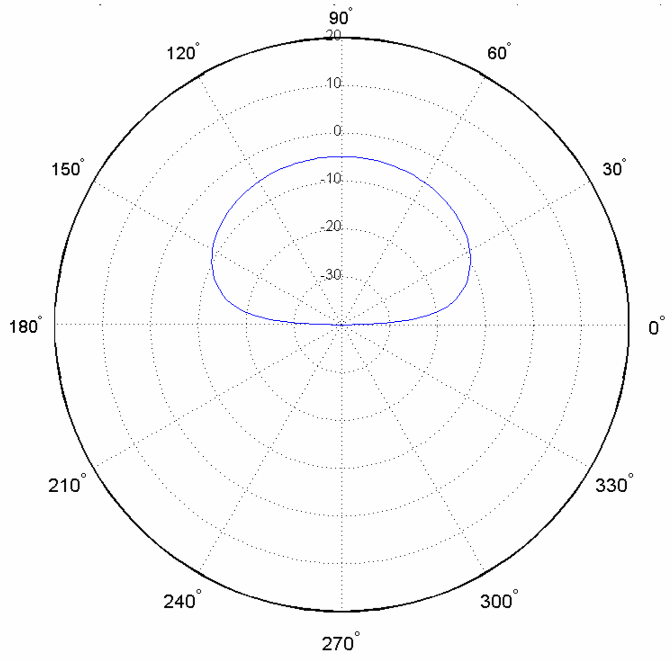

Figure E-8: Elevation pattern at azimuth (phi) =90, line length = 200 m, frequency = 5 MHz, source impedance = 150 Ω, load impedance = 575 Ω [fli90.png]

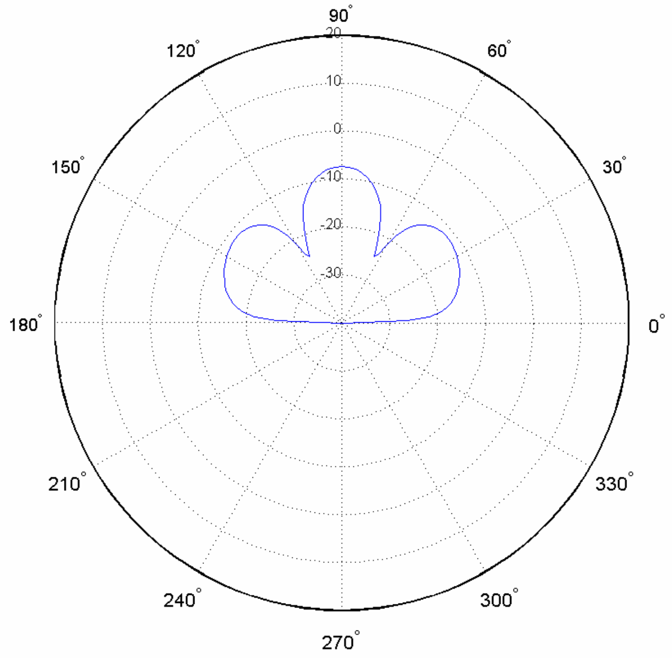

Figure E-9: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flj0.png]

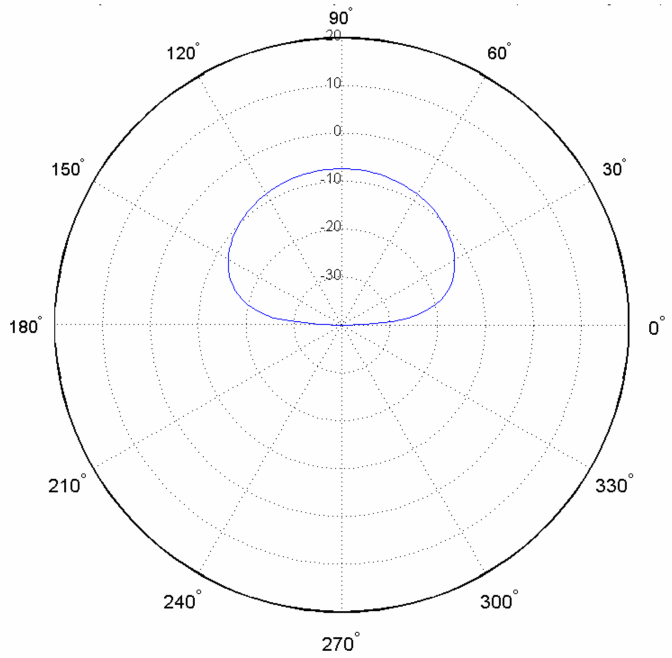

Figure E-10: Elevation pattern at azimuth (phi) = 90, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flj90.png]

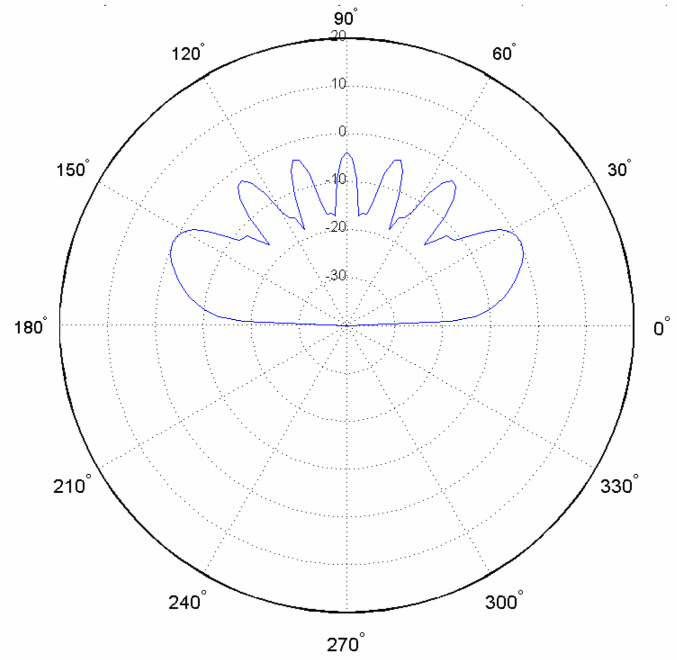

Figure E-11: Elevation pattern at azimuth (phi) = 0, line length = 100 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flm0.png]

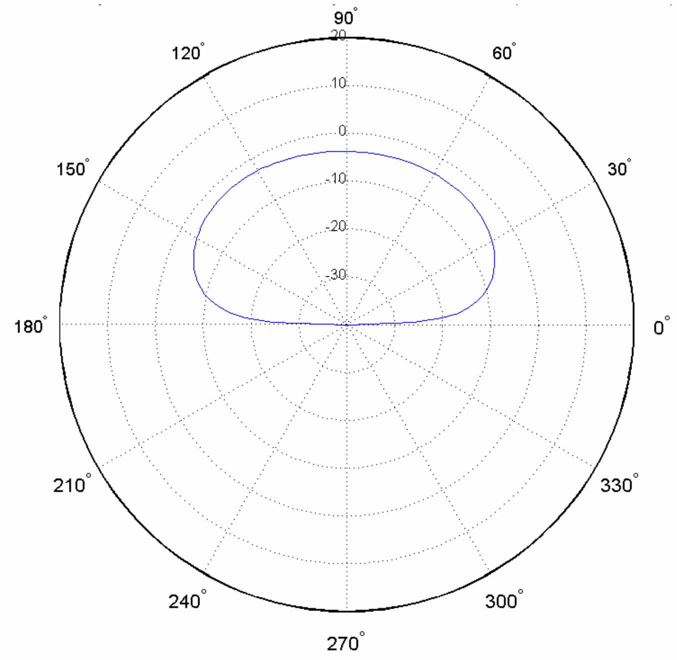

Figure E-12: Elevation pattern at azimuth (phi) =90, line length = 100 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flm90.png]

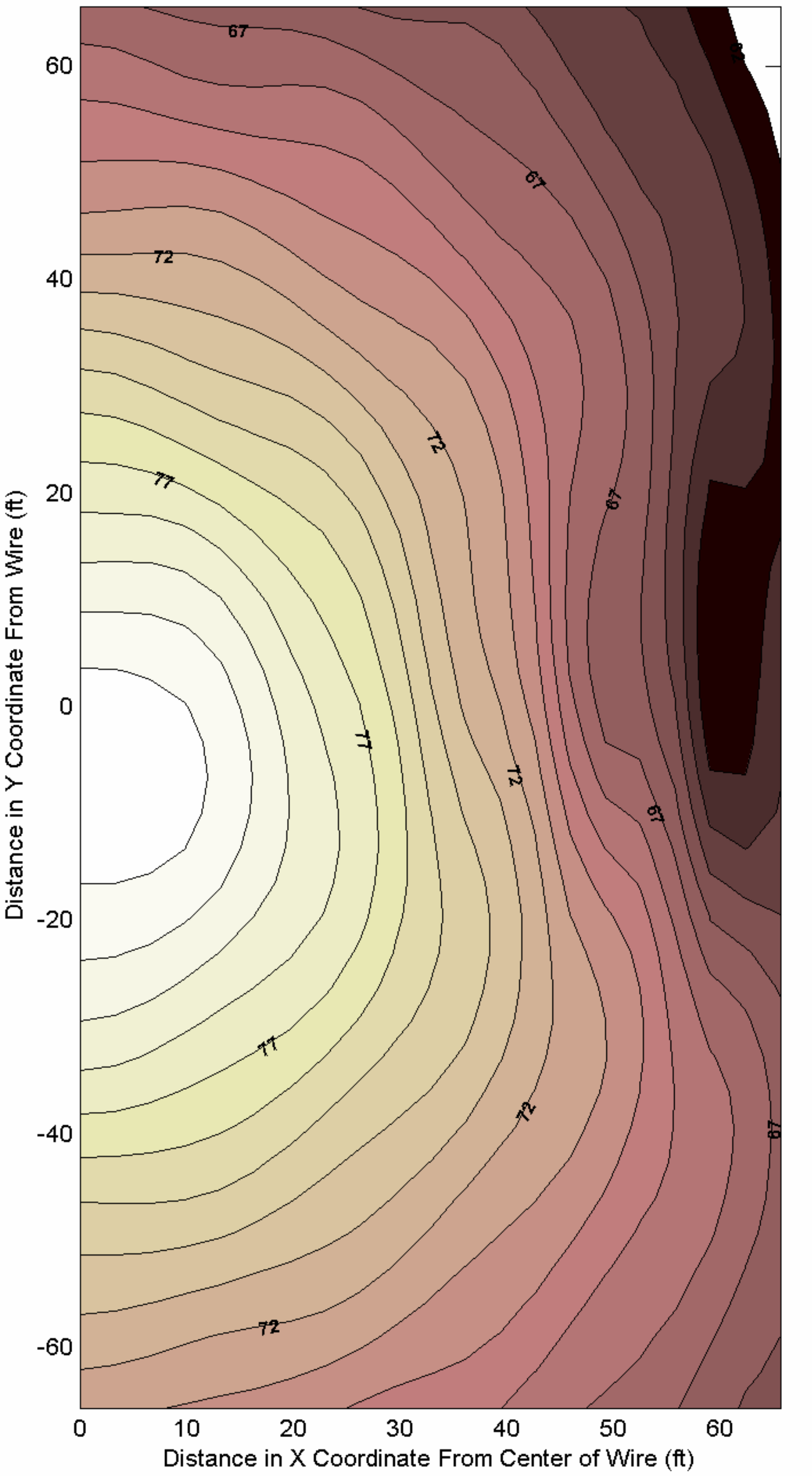

Figure E-13: Electric field strength (E_x) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfex1.png]

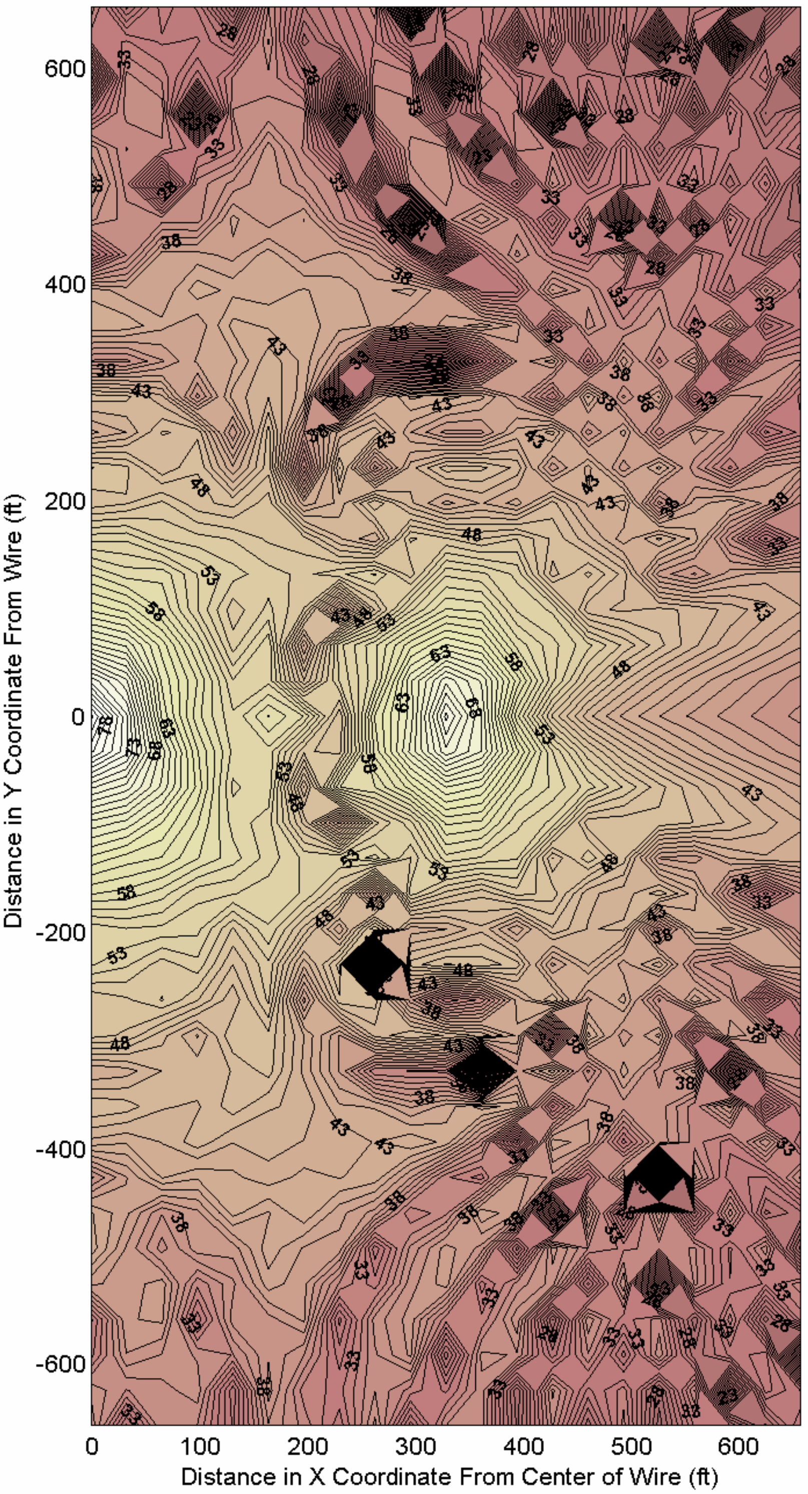

Figure E-14: Electric field strength (E_x) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfex2.png]

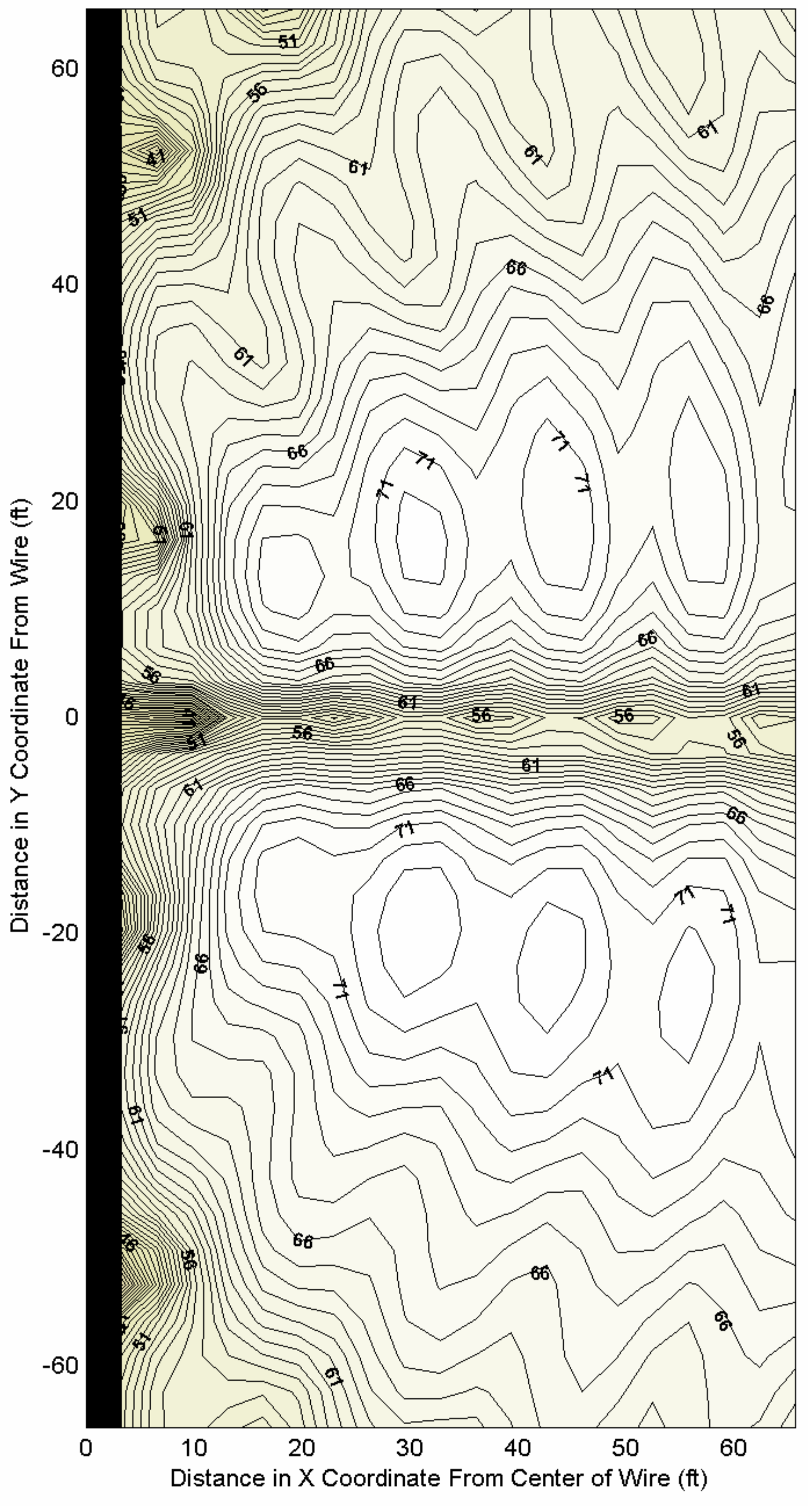

Figure E-15: Electric field strength (E_y) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfey1.png]

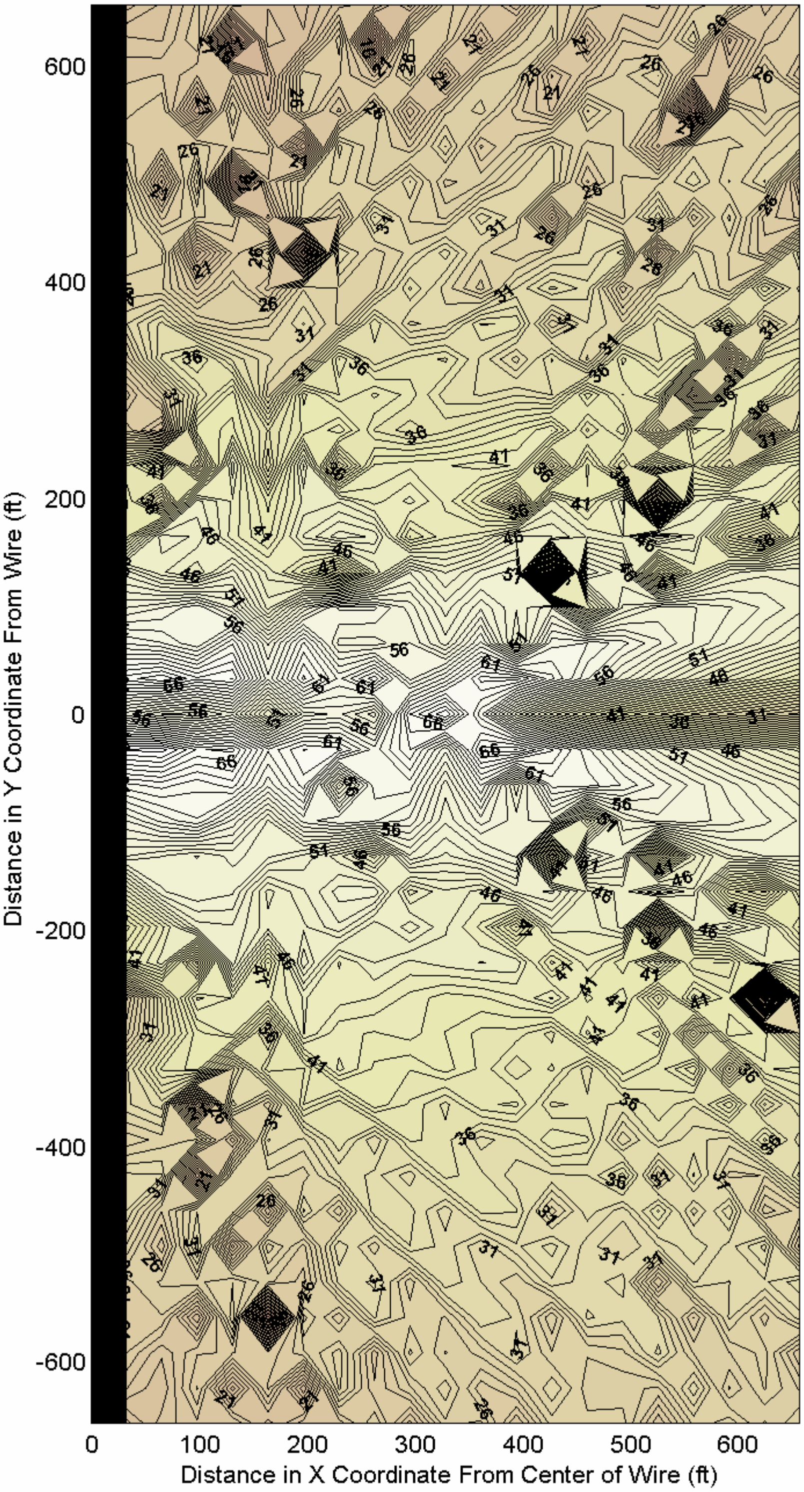

Figure E-16: Electric field strength (E_y) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfey2.png]

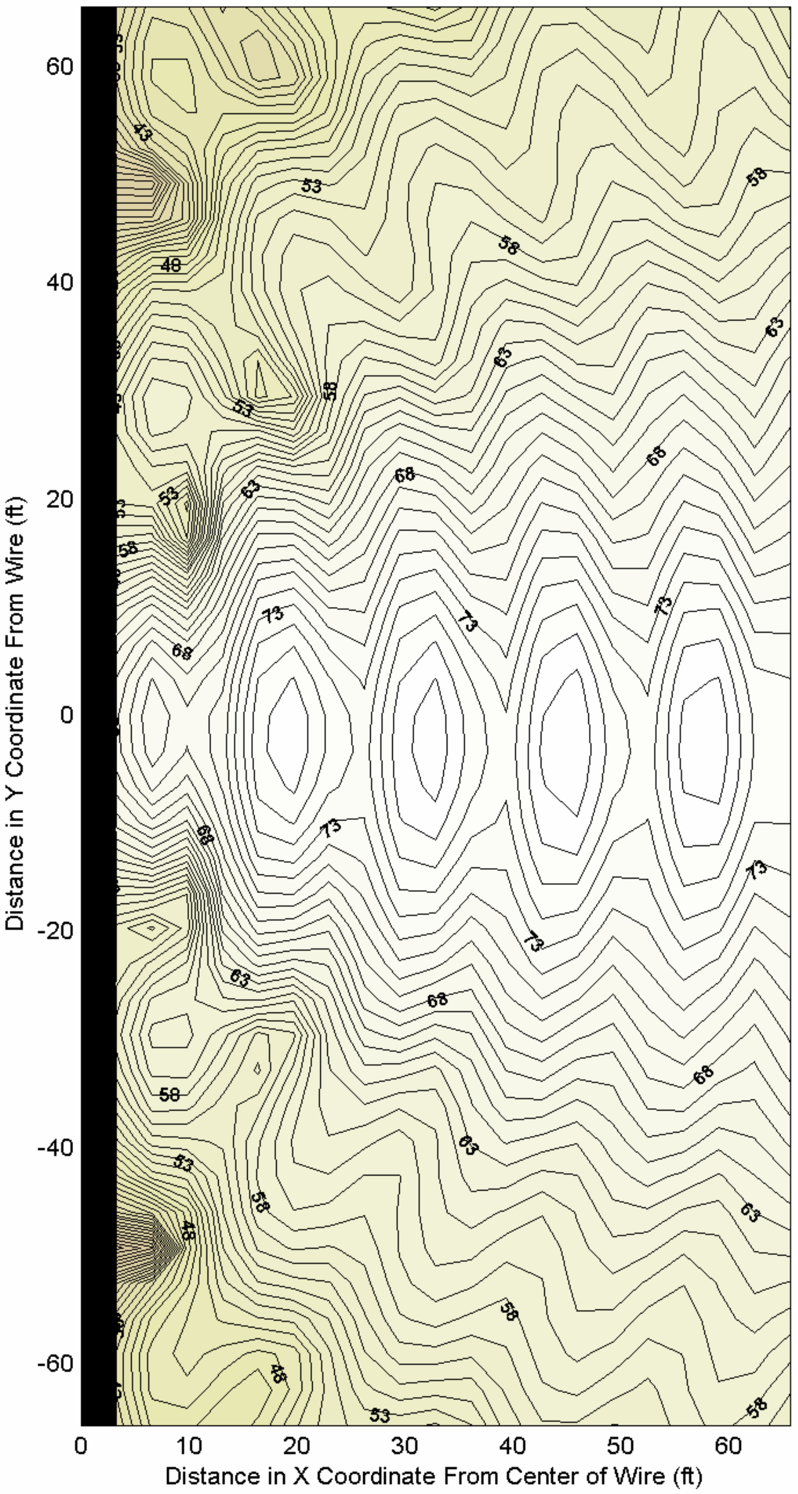

Figure E-17: Electric field strength (E_z) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfez1.png]

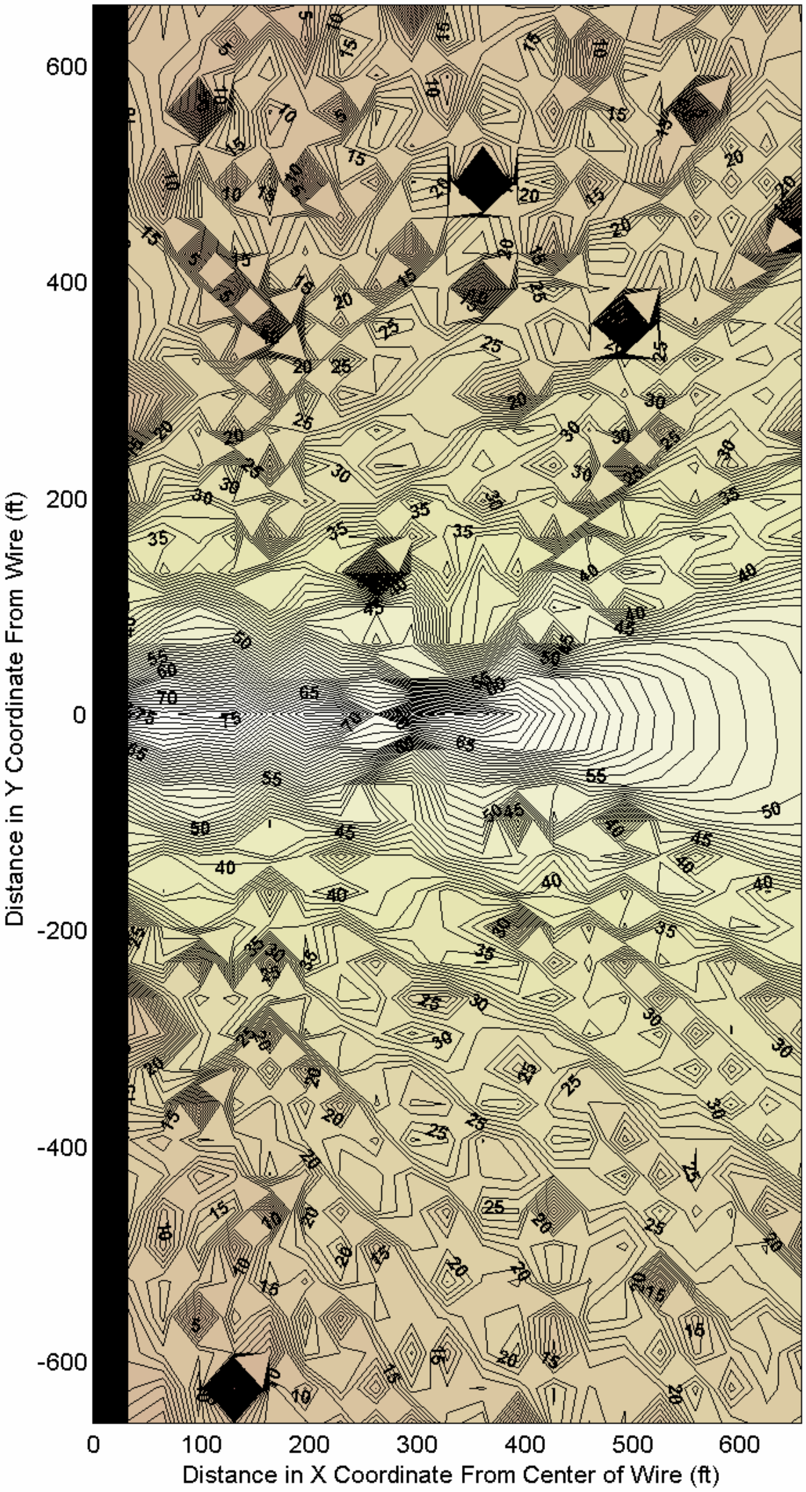

Figure E-18: Electric field strength (E_z) in dBµV/m from 65.6 to 656 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfez2.png]

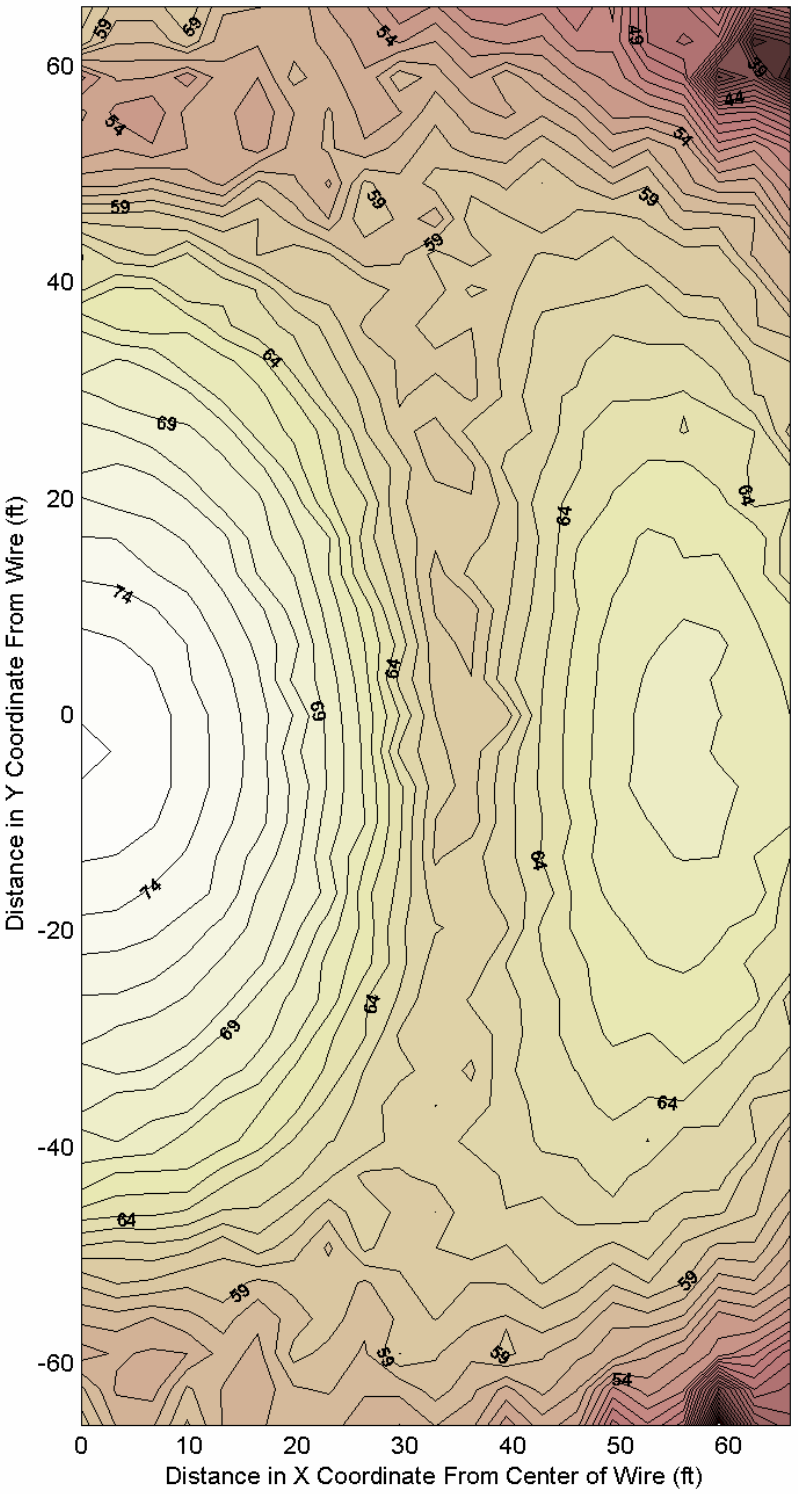

Figure E-19: Electric field strength (E_x) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhex1.png]

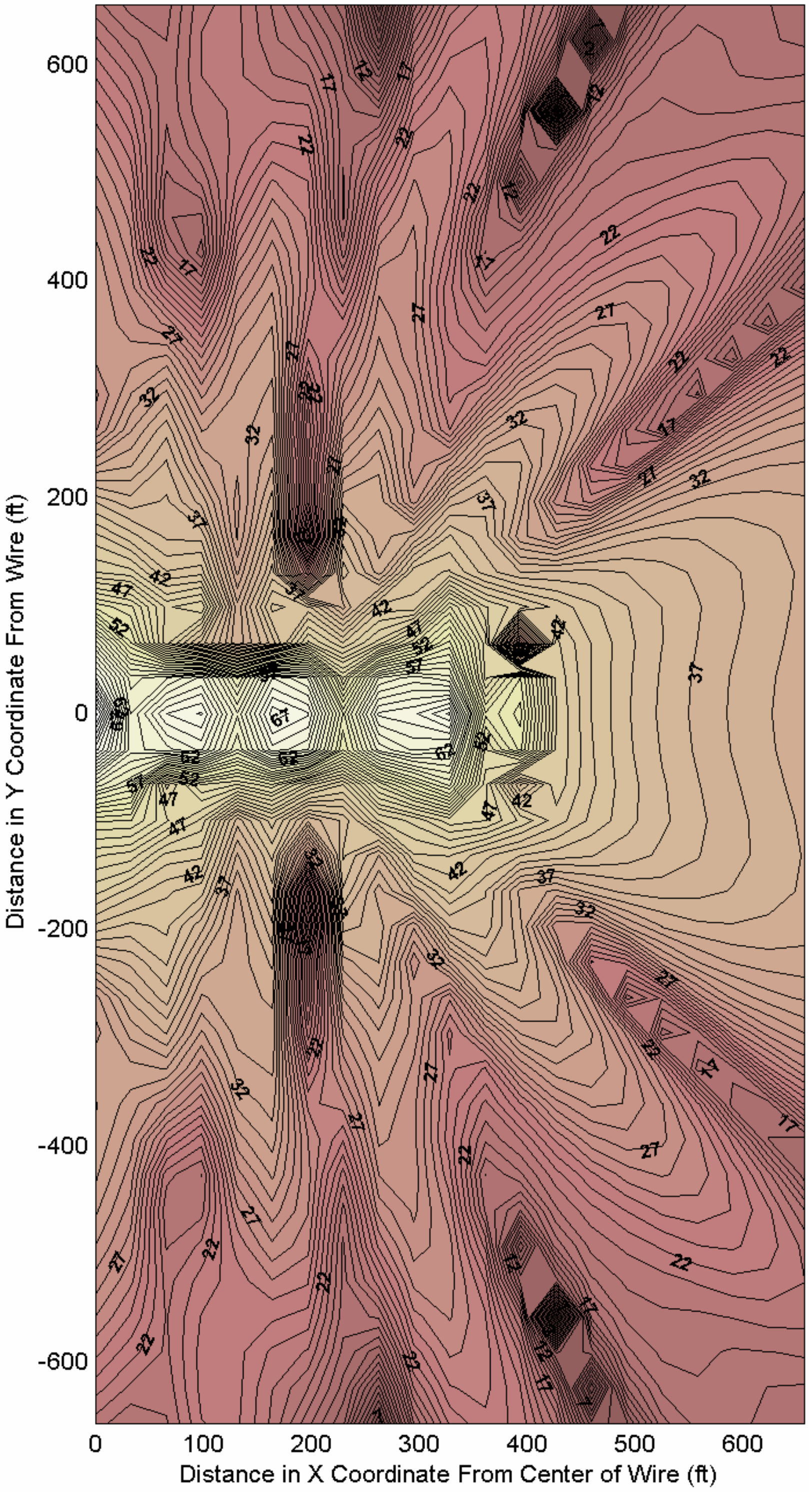

Figure E-20: Electric field strength (E_x) in dBµV/m from 65.6 to 656 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhex2.png]

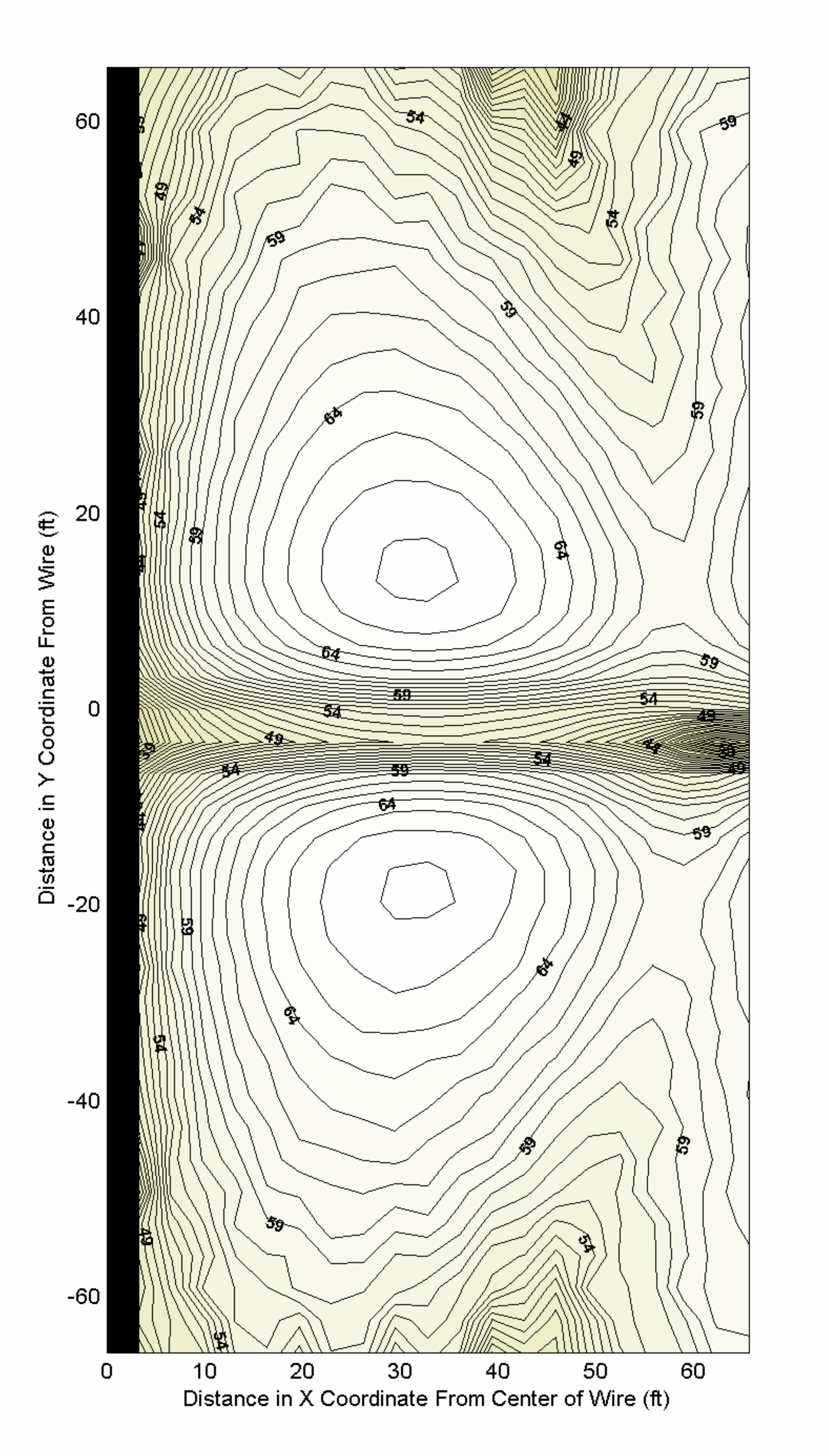

Figure E-21: Electric field strength (E_y) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhey1.png]

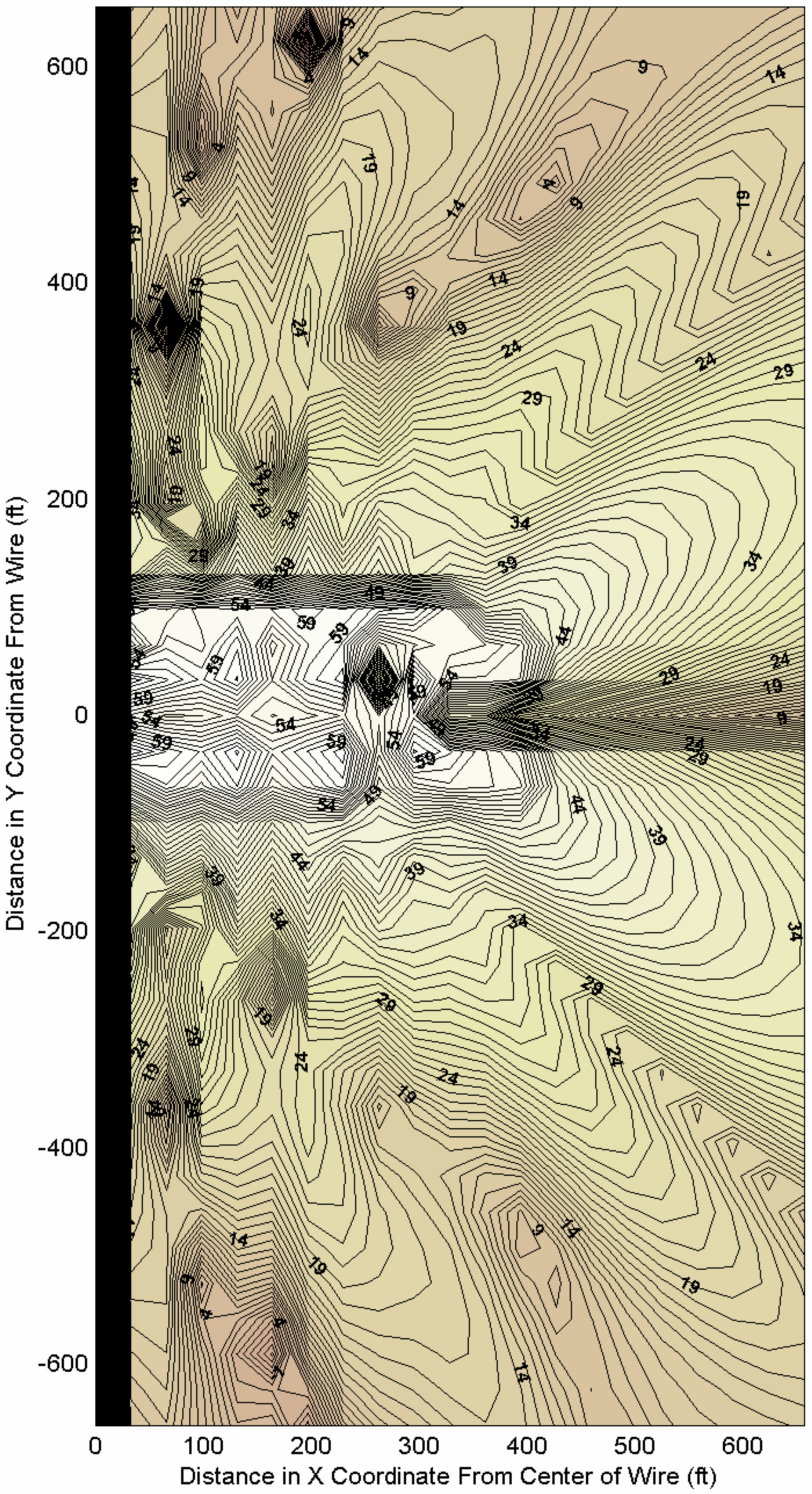

Figure E-22: Electric field strength (E_y) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhey2.png]

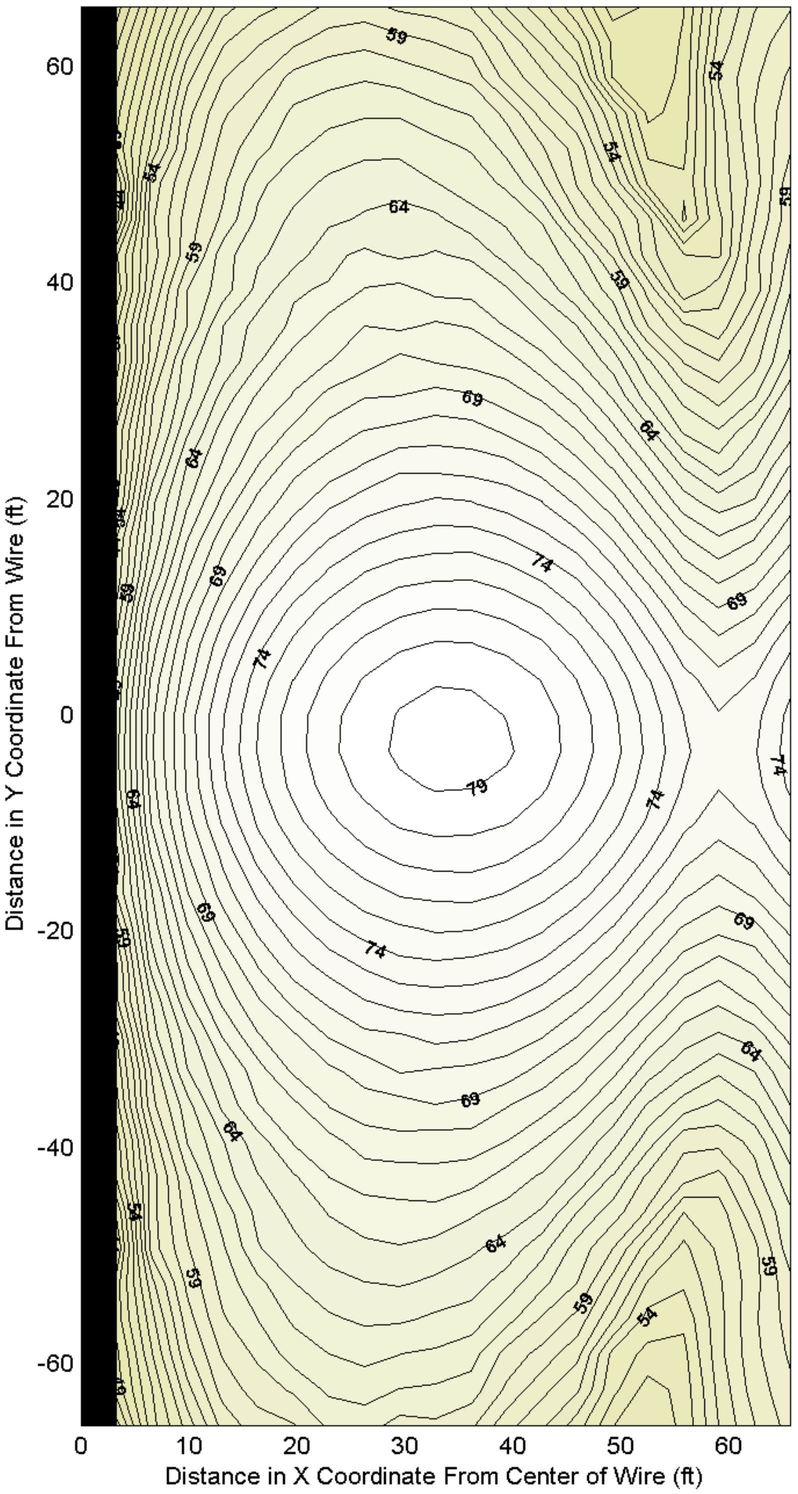

Figure E-23: Electric field strength (E_z) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhez1.png]

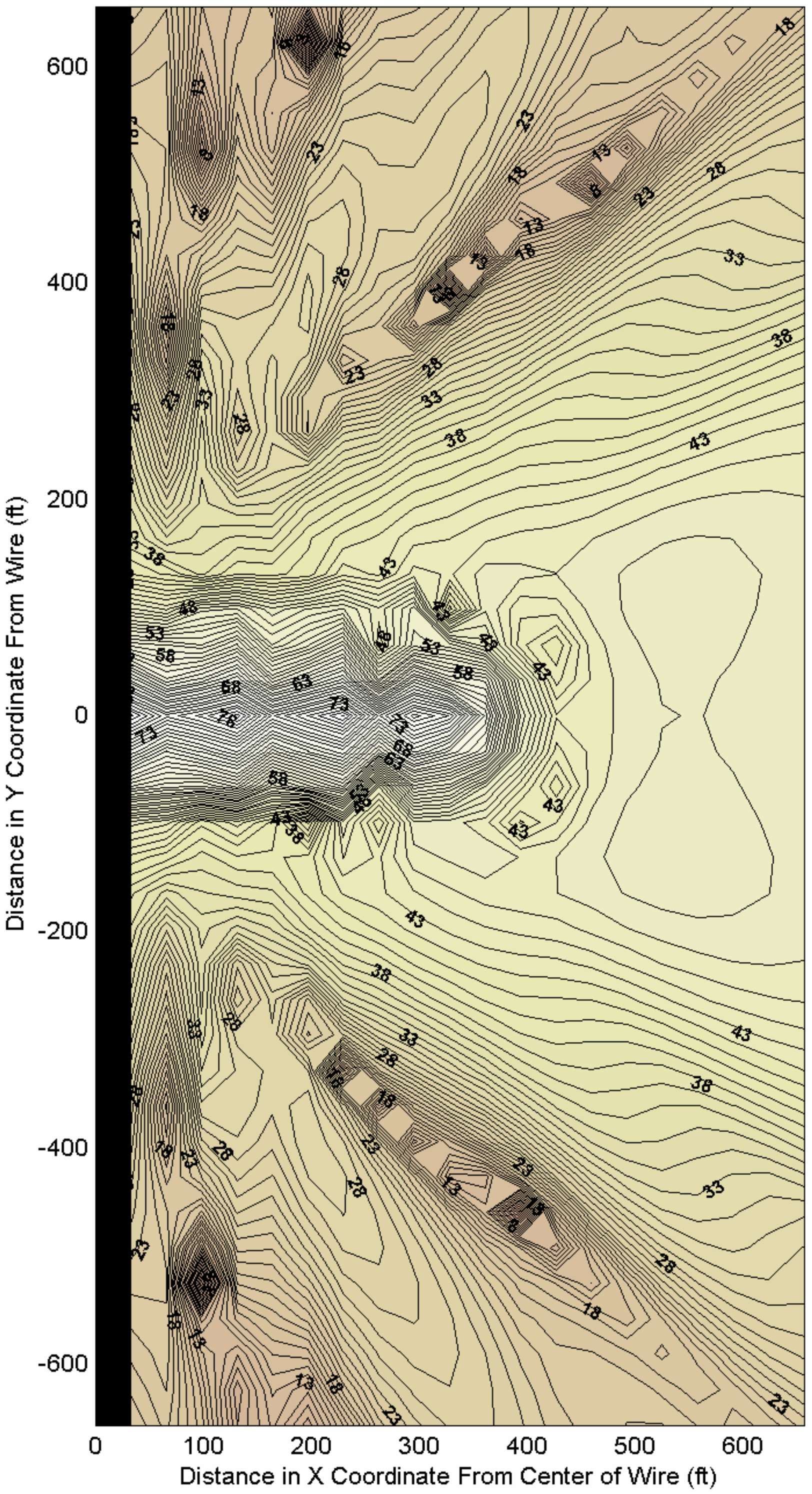

Figure E-24: Electric field strength (E_z) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhez2.png]

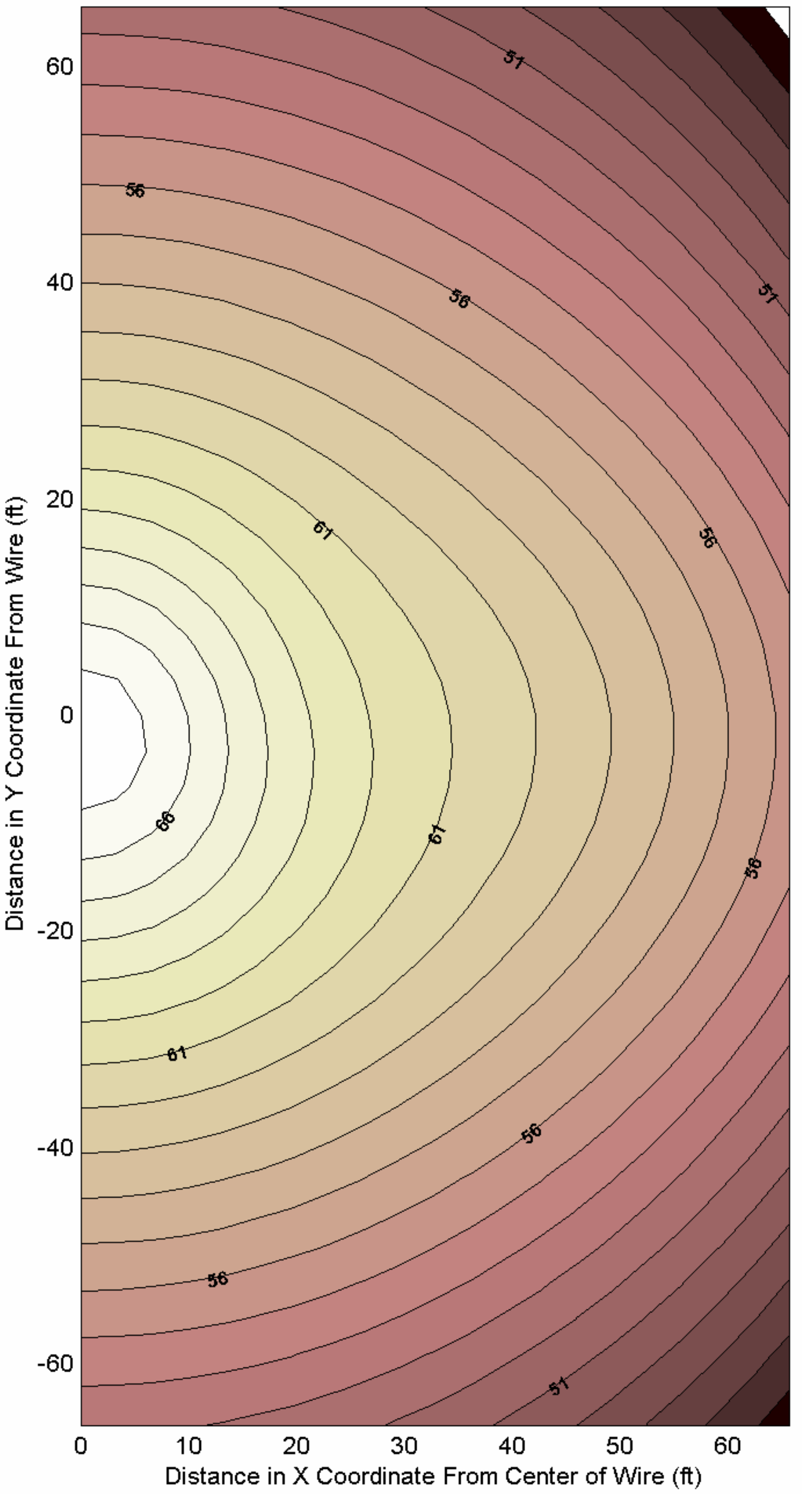

Figure E-25: Electric field strength (E_x) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljex1.png]

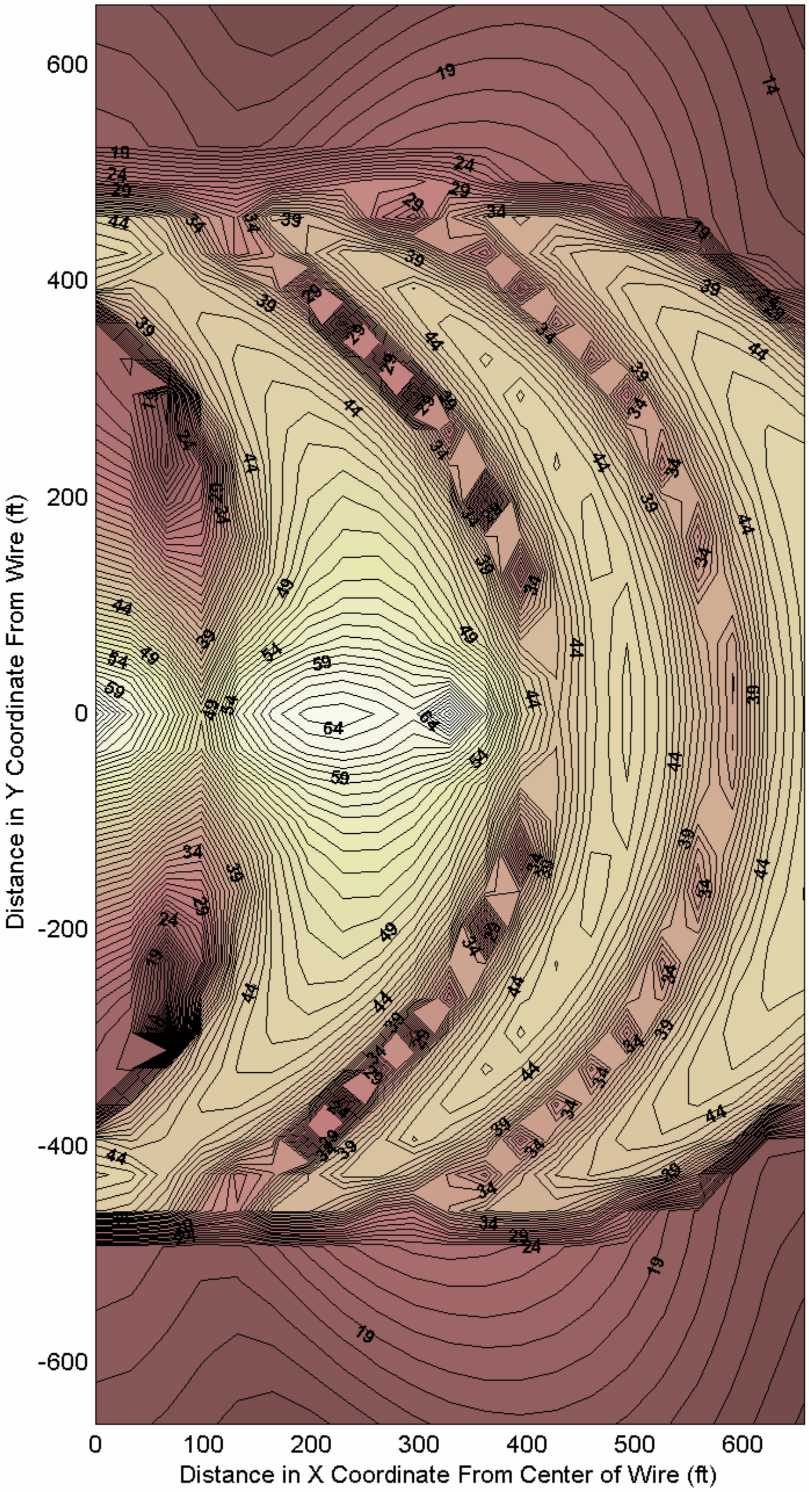

Figure E-26: Electric field strength (E_x) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljex2.png]

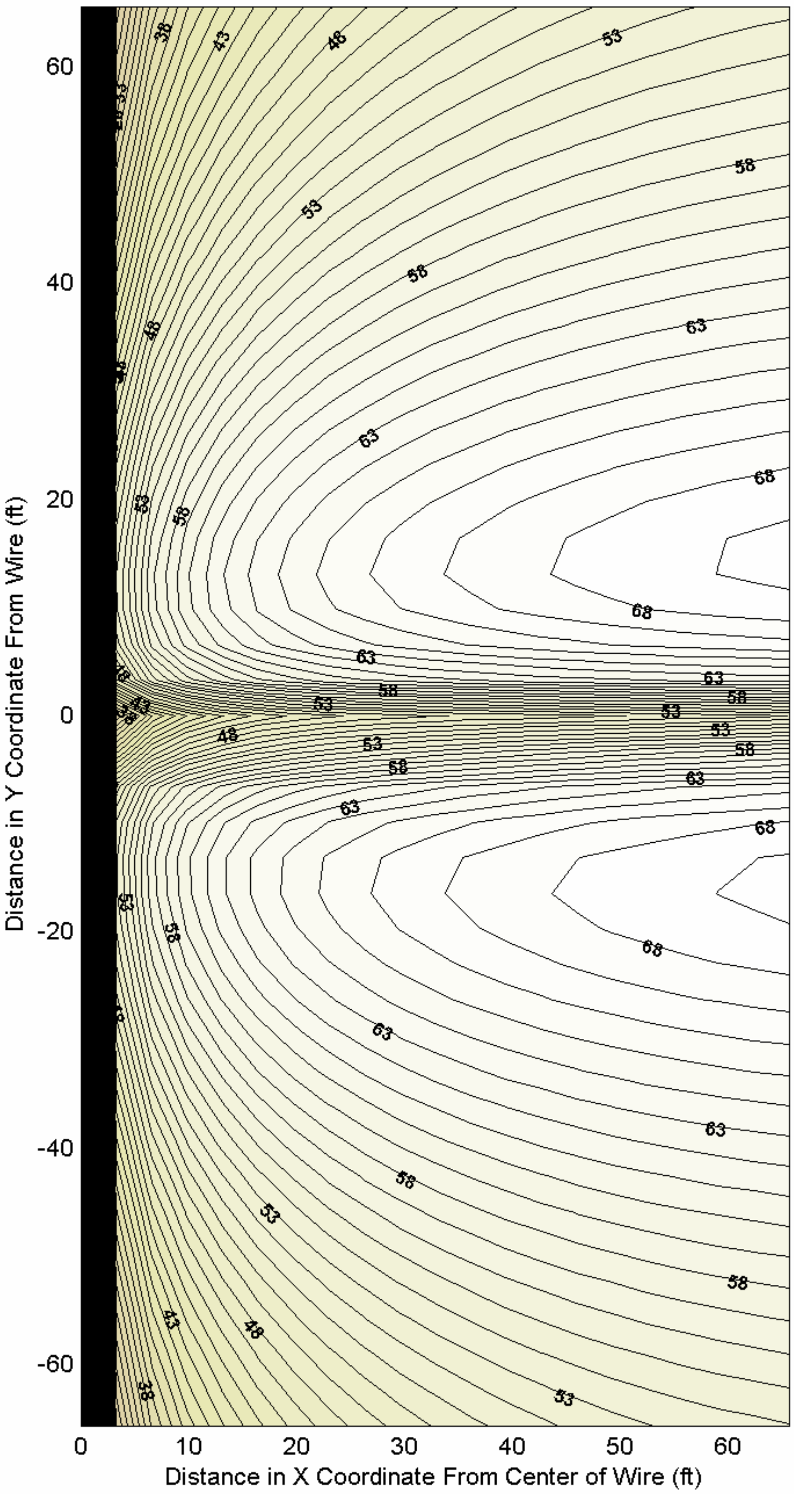

Figure E-27: Electric field strength (E_y) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljey1.png]

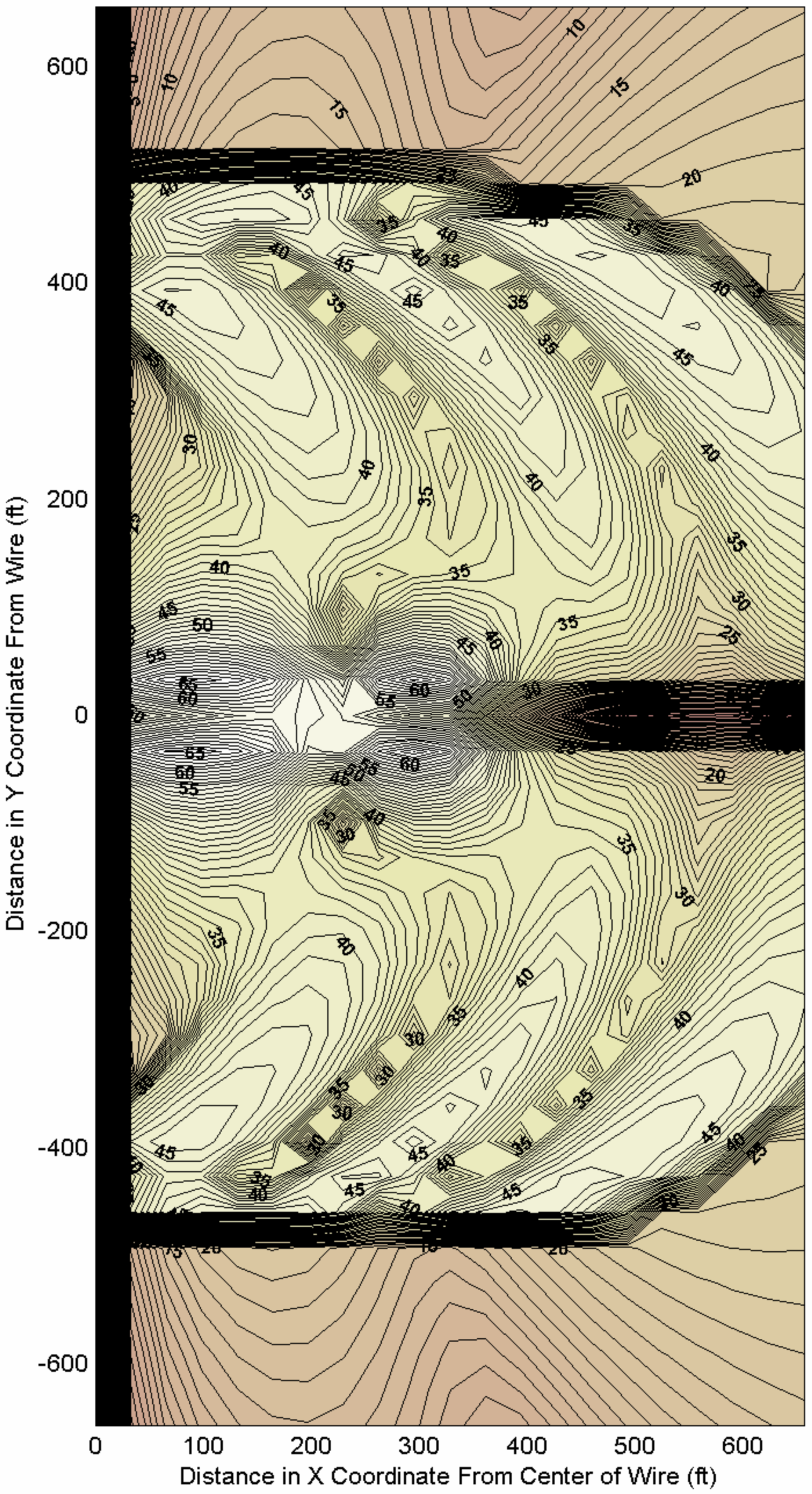

Figure E-28: Electric field strength (E_y) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljey2.png]

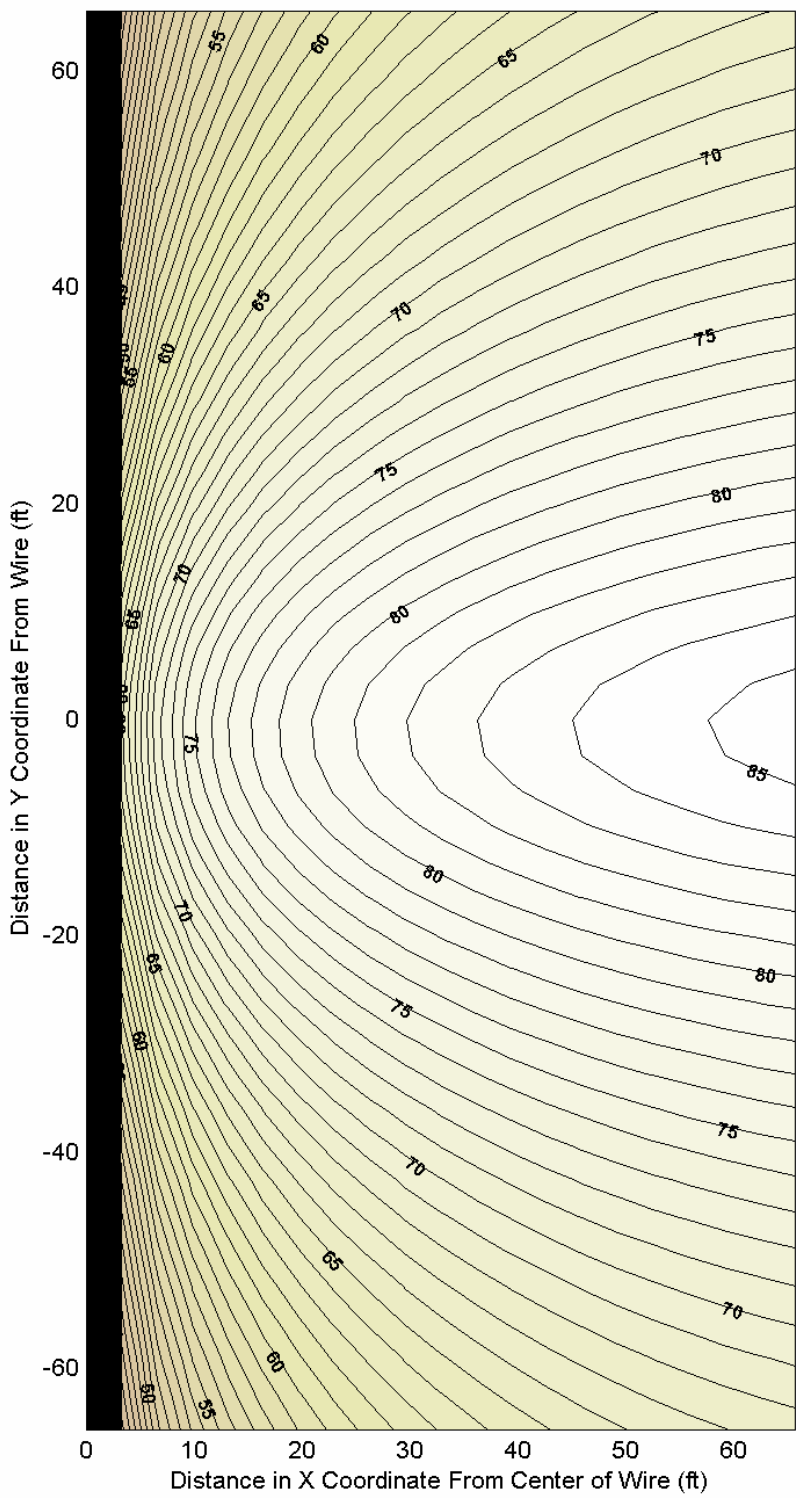

Figure E-29: Electric field strength (E_z) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljez1.png]

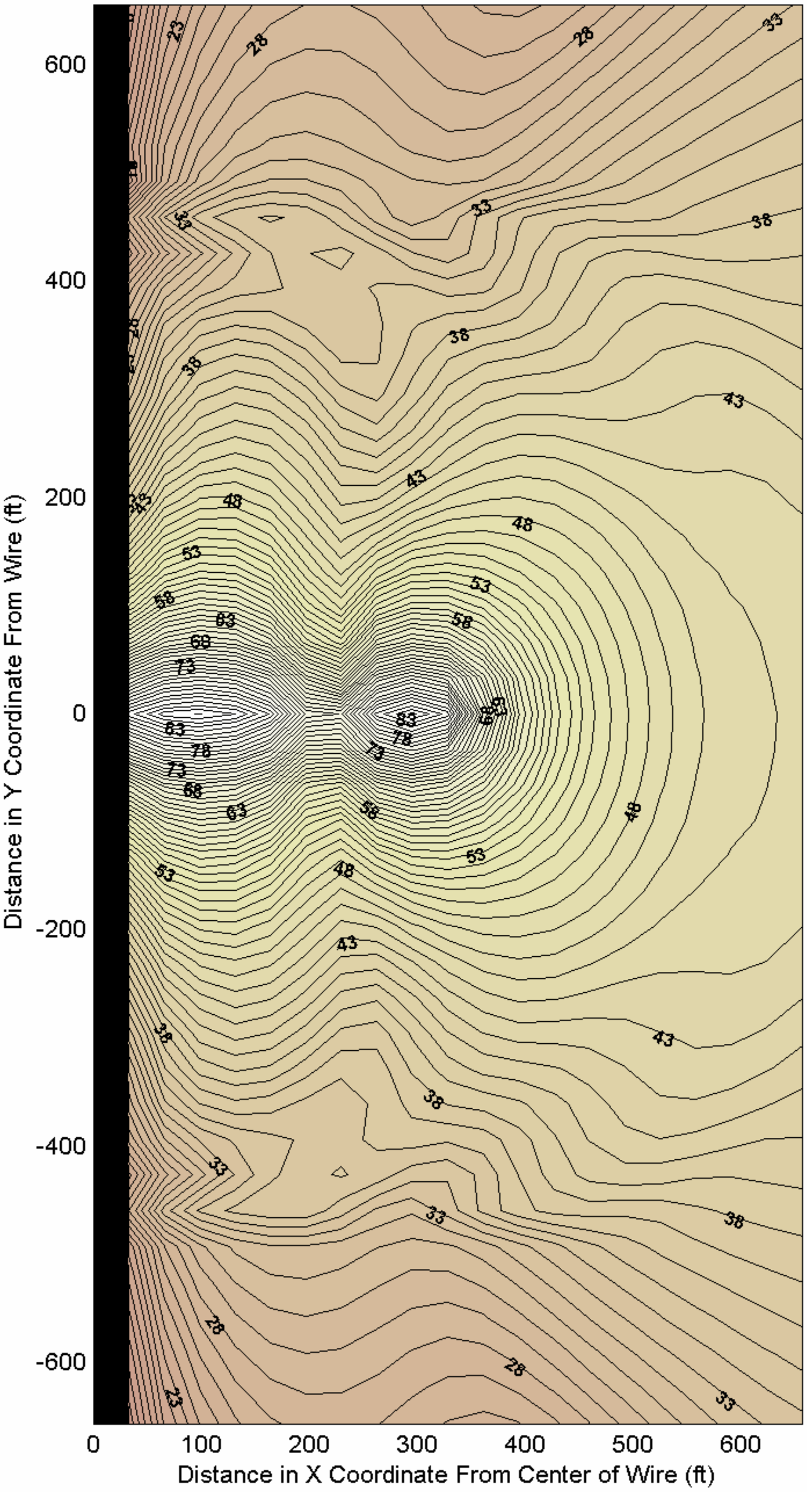

Figure E-30: Electric field strength (E_z) in dBµV/m from 65.6 to 656 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljez2.png]

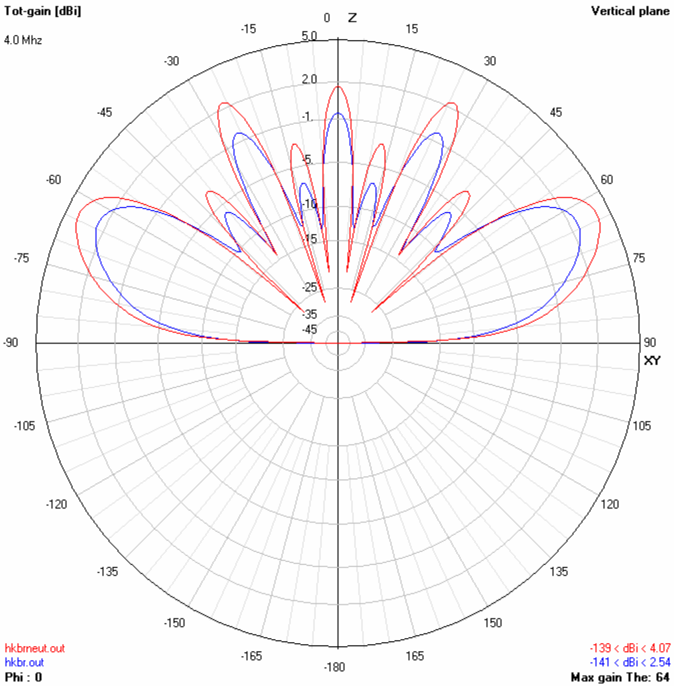

Figure E-31: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (4 MHz).

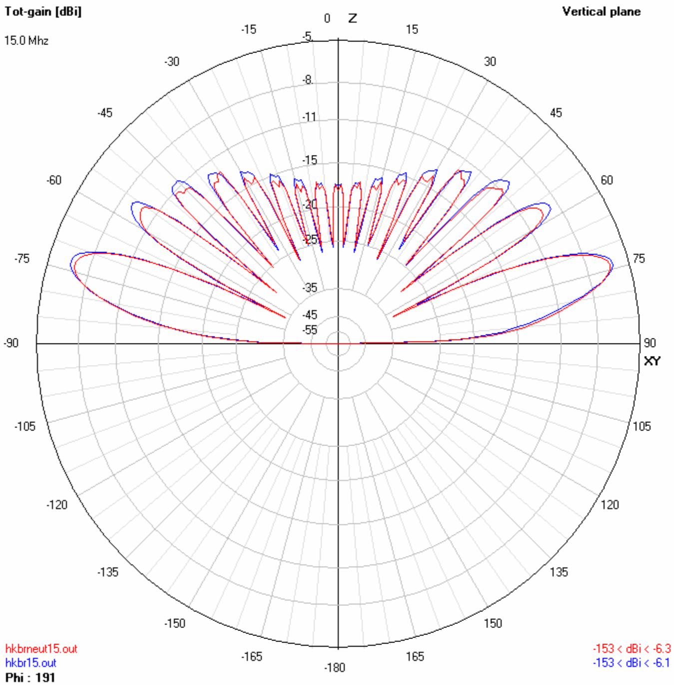

Figure E-32: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (15 MHz).

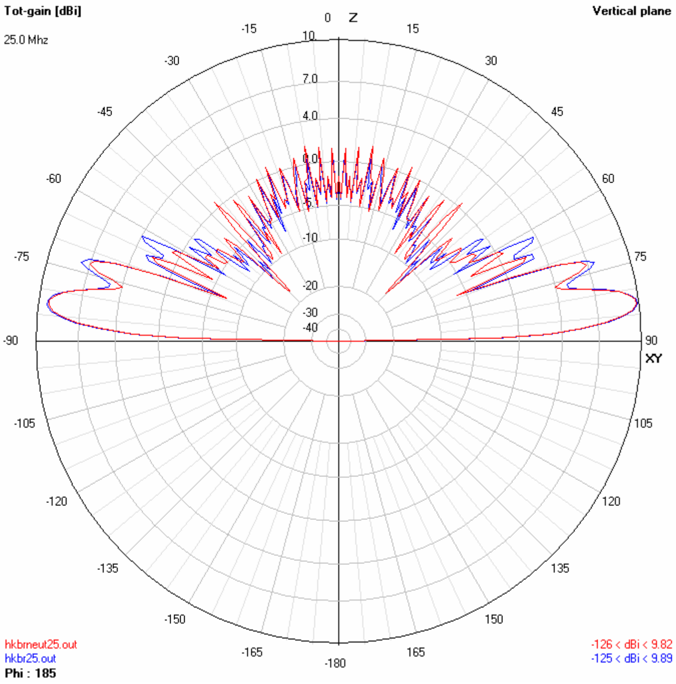

Figure E-33: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (25 MHz).

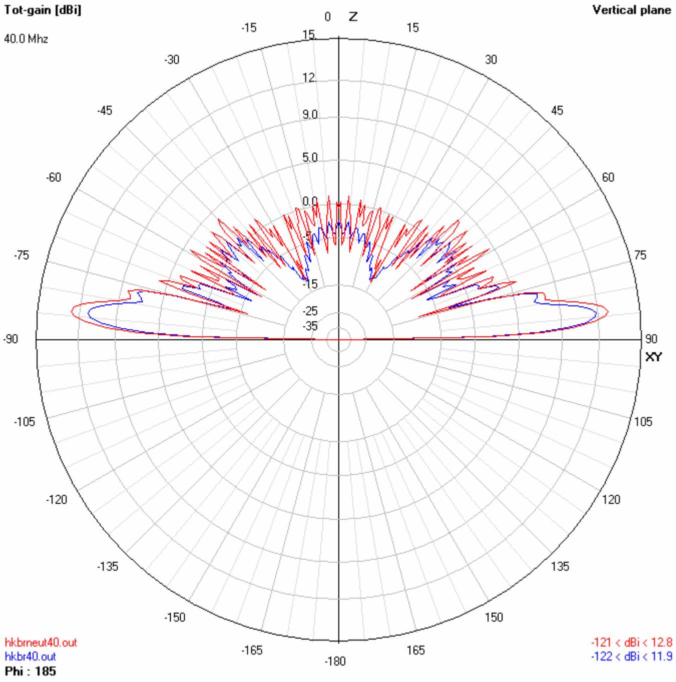

Figure E-34: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (40 MHz).

APPENDIX F
NTIA PHASE 2 STUDY BPL DEPLOYMENT MODELS

F.1 INTRODUCTION

The potential interference from mature large-scale deployments of BPL networks due to signal aggregation and propagation will be addressed in NTIA's Phase 2 study. NTIA's BPL deployment models[1] encompass three scenarios where the effects of aggregated BPL emissions are of interest. Differing mainly in geographic size and the potential interference impact to licensed radio service receivers, these three deployment models are:

- the neighborhood deployment model, in which the radio receiver antennas are at heights lower than the power lines (*e.g.*, a land mobile vehicle antenna);
- the antenna coverage area deployment model where radio receiver antennas are located above power lines (*e.g.*, atop buildings and masts and on aircraft) having a view of one or more neighborhoods; and
- the more expansive regional deployment model, from which BPL signals could arrive at a receiver via ionospheric ("skywave") propagation.

The objective for NTIA's family of BPL deployment models is to define potential physical layouts of BPL systems having various architectures that, when coupled with realistic cross-sections of radiation, propagation and signal aggregation, will aid in predicting the total levels of co-frequency BPL signals at various radio receiver antenna locations. Each model is parametric (*i.e.*, several factors will be varied), recognizing that many factors are variables that may greatly influence the predictions. For example, the geographic densities of emitting elements within the successively larger neighborhood, coverage area and regional geographic domains are expected to be highly influential, and the degree of influence will be determined in sensitivity analyses. At one extreme, we have the present limited deployment of experimental systems. Once BPL services are commercially available, there could be a rapid ramp up in deployment densities in all three geographic domains. In the long term, but at different times in the neighborhood, coverage area and regional domains, the deployment densities will converge on maximum levels. The interference risks in each geographic domain will concurrently increase over time. Variants of the BPL deployment parameters will be based on information filed in response to the BPL NOI as well as NTIA's research.

F.2 NEIGHBORHOOD DEPLOYMENT MODEL

The neighborhood deployment model addresses the case of a land mobile radio operating inside a BPL service area. The land mobile radio may be within 10 meters of the nearest active BPL device and one block away from another simultaneously active,

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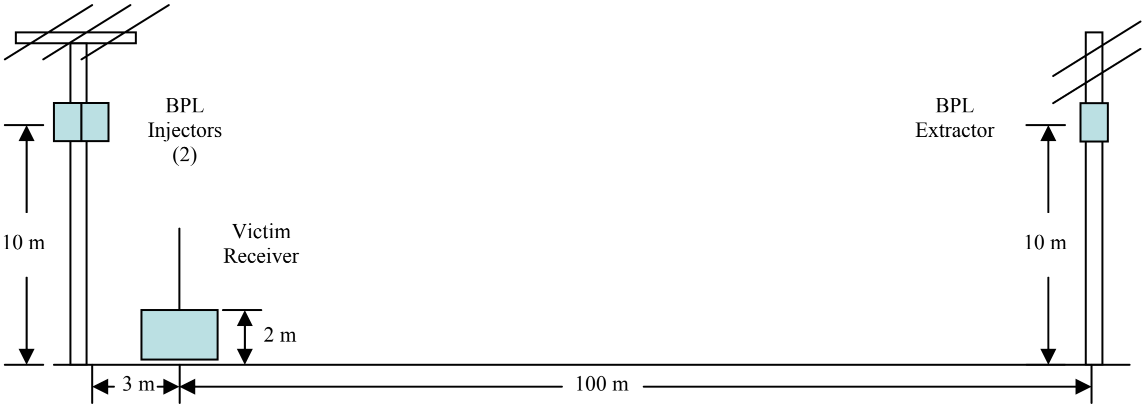
[1] The deployment models presented herein are preliminary. Comments from BPL proponents and opponents will be considered as the models are finalized and applied in NTIA's Phase 2 study.

co-channel BPL device.[2] An initial analysis is presented in Section 6, assuming the case of a single co-channel BPL device operating under existing Part 15 rules. The worst case which will be considered for the neighborhood deployment model would consist of a land mobile receiver operating in the presence of three co-channel BPL systems, two operating over power lines in close proximity to the receiver and one operating on a power line located one block away from the receiver. Considering the manner in which separate MV power lines are deployed and the coupling between adjacent power lines, it is unlikely that co-channel emissions from more than 3 BPL devices will aggregate significantly at any given land mobile receiver location.

The characteristics for this model are depicted in Figure F.1 and are as follows:

- Victim HF receiver with whip antenna located 2 meters above the ground;
- Two BPL injectors mounted on the same power pole, located no closer than 3 meters lateral to the victim receiver and 10 meters above the ground (location of receiver will be varied);
- A co-channel BPL extractor at 10 meters above the ground, located 100 meters away from the above injectors at a 45° angle. This is consistent with a power line feeding an adjacent street.



(a) Horizontal View

Figure F-1: Assumed Aggregate Neighborhood Deployment Scenario

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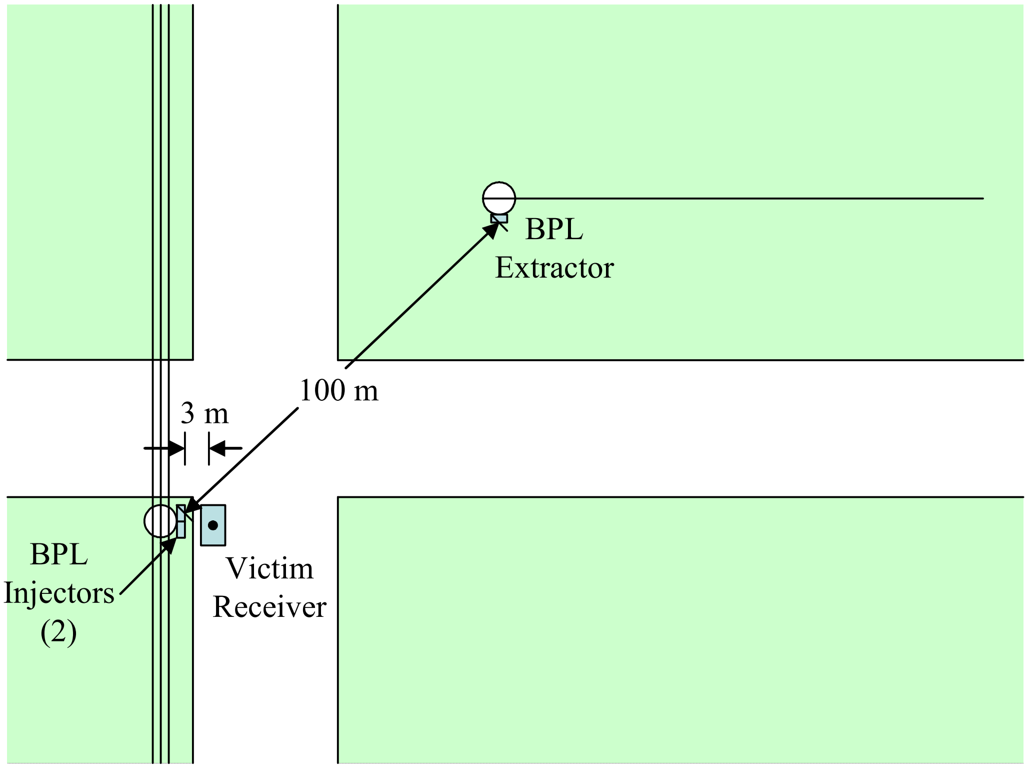
[2] NTIA personnel have observed and measured signals from two DSSS BPL injectors co-located on a single power pole, isolated by using two different phases of the same run of three phase power lines. Located one block away was a DSSS BPL repeater (extractor) on the third phase line. Even though all three of these devices may be coupled to different, adjacent phase lines of the same MV distribution network serving a community, they would be operating co-channel and may be transmitting at the same time. Later NTIA measured two independent co-channel signals for this case and the composite emission had about twice the power of the individual emissions.



(b) Overhead View

Figure F-1 continued: Assumed Aggregate Neighborhood Deployment Scenario

The transmit duty cycle for the two BPL injectors, T_i, and for the extractor, T_e, are parameters for the model.

The output of the neighborhood deployment model is a probability that three co-channel BPL devices, having the assumed physical orientation relative to the victim receiver as noted above, will be transmitting simultaneously. Using this result along with an emissions model for BPL devices attached to power lines, an analysis will be performed to estimate the percentage of local land mobile vehicle locations where harmful, co-channel interference may occur.

F.3 ANTENNA COVERAGE AREA DEPLOYMENT MODEL

Another case of interest is the mobile-service, aircraft or fixed-service base station receiver operating in close proximity to a fully deployed BPL service area. Receiving antennas for these stations typically can have unobstructed or lightly obstructed views of many more co-channel BPL devices that might affect a land mobile receiver in the neighborhood environment. HF base stations are frequently located in rural areas where the level of man-made noise is expected to be low; however, power lines are present in this environment. Over the years, a number of these remote locations have seen residential areas develop nearby, potentially resulting in an increase in the noise floor seen by the receiver. In some cases, HF stations are located in or near residential communities.[3] Aircraft and fixed stations generally are variously located anywhere.

The coverage area deployment model assumes that the radio station is located within or adjacent to a BPL service area and that the radio antenna has variously obstructed and unobstructed views of the BPL service area. The characteristics of the BPL deployment are described in the following section on the regional deployment model, the main difference being the size of the BPL deployment area being considered. A single county with a predominately suburban population density will be used to arrive at the density of BPL devices in the coverage area deployment model. In addition, the coverage area model assumes that the entire county is covered by the BPL service. This is a reasonable assumption since the housing density will be sufficiently high to provide good incentive for the electrical utility to make this service widely available to all its electricity customers.

The output of the coverage area deployment model will be a density of BPL devices and their locations relative to the radio station. As will be further described in the regional deployment model, the BPL service area will be composed of cells operating on the same or different frequency bands with variable frequency reuse patterns. This will be used to develop a model of aggregated emissions from the BPL service area as seen by the radio receiver.

F.4 REGIONAL DEPLOYMENT MODEL

In order to assess the aggregated electrical field strength arising from future, wide-scale deployments of BPL systems, a regional deployment model for BPL networks is proposed herein. The model characterizes the number and distribution of active BPL devices across the entire United States. Among other things, the results of this model will be used to characterize the effect BPL systems have on distant federal communication systems due to any increase in background noise level as a result of ionospheric propagation of unintentional BPL radiated emissions. This will also help address concerns that other countries may have with deployment of BPL systems in the United States.

The approach taken in developing the regional BPL deployment model is to:

- characterize the number and distribution of households served by the nation’s electrical power distribution network based on U.S. Census Bureau data;
- estimate the number of BPL devices based on the density of households and the BPL device capacities and range, as provided by the BPL proponents in their NOI comments and reply comments;
- factor in the characteristics of the various BPL signals such as frequency ranges used, bandwidths, network access mechanisms, and frequency reuse; and

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[3] Comments of the Federal Emergency Management Agency on Broadband Over Power Line Implementation, BPL Inquiry, December 4, 2003 at ¶10.

- estimate the percentage of these households that will end up being served by BPL service providers (i.e., market penetration), based on subscriber growth rates of competing technologies, such as cable and DSL.

F.4.1 Regional Deployment Model Description

As of 2000, there were 105.5 million occupied households in the United States,[4] and over the past 10 years, the number of households has been growing at an annual rate of approximately 1.4%.[5] The U.S. Census data provides the number of households (H_{cty}) and the area (A_{cty}) for each of the 3,142 counties and independent cities in the United States, with a breakdown by urban and rural classifications. The housing density within individual counties may vary widely, with a mix of urban, suburban, and rural areas. An individual county may also have large, unpopulated areas where no MV lines are present.

In Phase 1 of the NTIA study, development of the regional deployment model focuses initially on urban area deployment of BPL. Here, the housing densities are sufficient to support a large number of MV power lines in a given area, and access to the Internet backbone is widely available. Closely spaced BPL network cells, and cells sharing the same geographic location but separated by power line phase, will be considered in estimating the extent of frequency reuse in urban areas. The regional deployment model will be expanded in NTIA's Phase 2 studies to include the rural BPL environment, where the wide variability of rural housing density, MV power line density, and the availability of access to the Internet backbone will be considered.

The regional deployment model makes some simplifying assumptions to reduce data base and computational complexities and a number of the model's characteristics have been parameterized to enable sensitivity analysis of those characteristics.

F.4.2 Density and Distribution of Households

The average housing density (ρH) for each county is then given by

$$\rho H_{cty,u} = H_{cty,u} / A_{cty,u} \qquad \text{urban households / sq. km.} \qquad (F.1)$$

To account for the growth in the number of households over "y" years, the urban housing densities will be scaled by a factor of $(1+\text{rate})^{y}$.

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[4] County and City Data Book: 2000, U.S. Census Bureau, Table B-3.

[5] Meyers Group Report on Household Growth, by Bryan Glasshagel, http://www.meyersgroup.com/analysisobjects/householdgrowth.asp?ProductCategory=NHMR.

F.4.3 Density and Distribution of BPL Devices

The regional deployment model estimates the number of BPL devices for the urban areas of each county.

F.4.3.1 Injectors

Within urban areas, where there are a substantial number of power line branches and distribution transformers, the range of BPL injectors without requiring repeaters, "r_u", is expected to be up to ½ to 1 kilometer (¼ to ½ mi).[6] Thus, the number of injectors is given by

$$I_{cty,u} = A_{cty,u} / r_u^2 \qquad \text{urban injectors} \qquad (F.2)$$

F.4.3.2 Repeaters

The transmission ranges of BPL repeaters are expected to be the same as those for injectors. Like injectors in adjacent BPL cells, repeaters are generally expected to transmit using different frequencies to minimize the levels of co-channel interference. In addition, repeaters have two BPL transmitters, whereas injectors have only one BPL transmitter. BPL service providers may vary the size of each cell to account for the availability of fiber or T1 access to the Internet backbone.

From the standpoint of maximizing the utilization of the available bandwidth, it is more advantageous for BPL service providers to deploy injectors instead of repeaters wherever possible. In urban areas where there is ready access to the Internet backbone, the number of repeaters in a given area is assumed to be negligible as compared to the injector quantity for the area under consideration.

F.4.3.3 Extractors

BPL extractors (also referred to as repeaters in System #3) are typically located at each LV transformer. The parameter "x" defines the number of households per distribution transformer and ranges from 3 – 8 households per LV distribution transformer.[7] The resulting quantity of extractors is

$$EX_{cty,u} = H_{cty,u} / x \qquad \text{urban extractors} \qquad (F.3)$$

For System #2, a WiFi™ (or other non-BPL) interface to the subscribers' homes is used instead of the wired BPL interface implemented in the other system architectures.

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[6] Reply Comments of PowerComm Systems, Inc., BPL Inquiry, August 20, 2003, ("PowerComm Reply Comments") at 16; Comments of Ambient Corporation, BPL Inquiry, July 7, 2003 at 5.

[7] Comments of Current Technologies, LLC, BPL Inquiry, July 7, 2003, ("Current Technologies Comments") at 4, 6.

Therefore, the extractors for System #2 have only one BPL transmitter associated with them.

F.4.4 Other Factors

F.4.4.1 Frequency Range

In comments responding to the NOI, the BPL vendors and service providers stated widely varied frequency ranges that they propose using for BPL service.[8] The frequency range assumed for the regional deployment model is 1.7 – 80 MHz, although BPL devices will not be uniformly distributed in frequency (another variable in the models).

F.4.4.2 Frequency Reuse

In order to minimize signal degradation associated with co-channel interference, System #2 uses different frequency bands for upstream and downstream communications, and for adjacent BPL devices. Communication with the subscribers' homes is not accomplished using BPL. System #1 uses one frequency band for all access BPL devices and in-house BPL devices use another band. System #3 uses the same frequency band for all devices. Assuming that an injector serves one BPL cell, the number of frequency bands used in a cell is shown in Table F.1.

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[8] Comments of Ameren Energy Communications, Inc., BPL Inquiry, July 7, 2003 at 12; Comments of Amperion, Inc., BPL Inquiry, July 7, 2003 at 4; Current Technologies Comments at 17; Comments of Electric Broadband, BPL Inquiry, July 7, 2003 at 4; Comments of Main.net Communications, Ltd., BPL Inquiry, July 7, 2003 at 4; PowerComm Reply Comments at 4; Comments of PowerWAN, Inc., BPL Inquiry, July 3, 2003 at 1; Comments of Progress Energy, Inc., BPL Inquiry, July 7, 2003 at 2.

Table F-1: BPL Frequency Bands per Cell

Architecture	Number of Bands
System #1	2 (1 Access + 1 In-House)
System #2	2 (Access)
System #3	1 (Access & In-House)

In the regional deployment model, System #1 is assumed to reuse the same two frequency bands for each injector and its associated extractors. The model will scale the number of simultaneously active System #1 BPL devices in an area by a factor of ½.

In an urban environment, System #2 is expected to utilize separate frequencies for the injectors in adjacent cells. A minimum of 3 cells is required to implement frequency reuse in a cellular transmission architecture.[9] Assuming that the frequency range used for BPL services is 1.7 – 80 MHz, an urban deployment of System #2 devices (2 simultaneous Access transmissions per cell) would result in a maximum duplex bandwidth of approximately 26 MHz per cell (i.e., 78 MHz ÷ 3 cells). The regional deployment model will scale the number of simultaneously active System #2 BPL devices by a factor of 1/(2*3) = 1/6.

System #3 is assumed to reuse the same frequency band for every cell; therefore, the regional deployment model will assume simultaneously active System #3 BPL devices with no scaling.

A final point about frequency reuse is that with 3-phase MV power lines, three co-channel cells could share the same geographic location, assuming they can tolerate any coupling that occurs between the conductors of each phase.

F.4.4.3 Media Access

Based on BPL vendor comments, the media access protocols for their systems permit transmission by only one device at a time per cell in a given frequency band.[10] For System #1, one access BPL device and one in-house BPL device are active at a time. For System #2, one BPL injector and one BPL extractor may be transmitting at a time within a cell, with each transmission using separate frequency bands. For System #3, one BPL device (injector or extractor) will normally be transmitting at a time; however, it

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[9] Mobile Cellular Communication Systems, William C. Y. Lee, McGraw-Hill Book Company, 1989 at 52 – 53.

[10] Reply Comments of Ameren Energy Communications Inc., BPL Inquiry, Aug 20, 2003 at 13; Current Technologies Comments at 15; Reply Comments of Current Technologies, LLC, BPL Inquiry, Aug 20, 2003 at 12; Reply Comments of Main.net Communications LTD., BPL Inquiry, August 20, 2003 at 3.

appears that the media access mechanism is CSMA-CD and there is potential for multiple simultaneous co-channel transmissions in the same cell, especially during peak use periods.

F.4.4.4 BPL Market Penetration

There are currently almost 20 million households in the United States with a broadband connection to the Internet. Of these, approximately 6.5 million are xDSL customers and 12 million are cable customers. The growth rate for these services this past year is approximately 2.5 million customers per year for xDSL and 4 million customers per year for cable.[11]

The regional deployment model assumes an insignificant number of BPL customers in 2003, and an initially linear growth rate parameter that has a range of 2 to 4 million households per year. In addition to the growth of the overall BPL market, the model assumes an equal market share for each of the three types of BPL systems described above. The percentage of market share for each type of BPL system will be used to scale the number of BPL devices (injectors, repeaters, extractors) simultaneously using individual frequency bands throughout the United States.

F.4.5 Regional Model Output

The output of the regional deployment model is the expected number and distribution of BPL transmission sources, and the number of simultaneous frequencies in use, based on the expected overall BPL market share over a specified number of years. In NTIA’s Phase 2 studies, these results will be used in conjunction with a HF skywave propagation model to determine the increase in noise floor resulting from wide-scale deployment of BPL systems.

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[11] FCC News, *Federal Communications Commission Releases Data On High-Speed Services For Internet Access*, June 10, 2003, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-235274A1.doc.