

IEEE Standard for Power Line Communication Equipment— Electromagnetic Compatibility (EMC) Requirements—Testing and Measurement Methods

Sponsored by the

Power System Communications Committee
of the
IEEE Power & Energy Society

and the

Standards Committee
of the
IEEE Communications Society

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Abstract: Electromagnetic compatibility (EMC) criteria and consensus test and measurements procedures for broadband over power line (BPL) communication equipment and installations are presented. Existing national and international standards for BPL equipment and installations are referenced. This standard does not include the specific emission limits, which are subject to national regulations.

Keywords: BPL, BPL emissions, BPL immunity, broadband over power line communication, electromagnetic compatibility, EMC, emissions measurements, IEEE 1775, measurement methods, PLC, power line communication, power line communication equipment, smart grid, testing methods

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Introduction

This introduction is not part of IEEE Std 1775-2010, IEEE Standard for Power Line Communication Equipment—Electromagnetic Compatibility (EMC) Requirements—Testing and Measurement Methods.

Power line communication (PLC) technology has developed over a long period of time.

As early as 1838 Edward Davy proposed remote electricity supply metering for the purpose of checking the voltage levels of the batteries at unmanned sites in the London-Liverpool telegraph system. The first carrier-current system for mains signaling was established in 1893 by the Swiss Electricity Board. The carrier frequency transmission of voice over power lines began in the 1920s. Due to low attenuation and low noise in the transmission lines at the carrier frequencies (15 KHz to 500 KHz), a distance of 900 km between transmitter and receiver could be attained with a power of 10 W. In 1930 Ripple Carrier Signaling was implemented in Germany over medium- and low-voltage distribution power lines. Such systems typically operated in the frequency band 125 Hz to 3000 Hz, so a carrier signal propagated with low losses.

Advances in communication technology in the late 1990's led to new research and development activities related to data communication through the power grid. Known widely as *power line communications* (PLC), this technology is also named *broadband over power line* (BPL), *power line telecommunication* (PLT), and *power line technology* (PLT). PLC created a mix of high expectations and concerns mainly due to perceived EMC problems and absence of regulatory and standardization framework to address them.

In 2000 several European countries independently proposed EMC regulations for PLC. Later, the Joint Working Group of CENELEC and ETSI started developing a standard covering the EMC aspects of wire-line telecommunications networks including their in-home extension. The standard scope is focusing on the limits and in situ measurements procedures for EMI measurements. Currently the standard is under development.

In 2004 the regulatory uncertainty in the U.S. ended when the FCC approved the Report and Order “Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems” (ET Docket No. 04-37). The Amendment: (a) defines the Access and In-House BPL system; (b) contains the emission limits for them; and (c) describes in detail the measurement procedure for emissions measurements from BPL equipment verification and certification. However, immunity requirements and testing were not covered under this document. In the U.S., narrowband carrier-current systems are regulated by the Federal Communication Commission (FCC) under CFR 47 Part 15 Rules for unintentional radiators. Therefore, for such systems the methods provided by ANSI C63.4 are fully applicable for emissions measurements.^a

In 2004 the IEEE published IEEE Std 643™-2004 [B31] for low-frequency power line communications covering 50 kHz to 450 kHz band operations.^b

In 2005 CENELEC published EN 50412-2-1, which is the first immunity standard for PLC equipment.

In 2007 the Japanese Ministry of Interior and Communication (MIC) published “Japanese (radio) Regulations for the Broadband PLC (or PLT or BPL),” which is part of Japanese Radio Law and Ordinance regulating radio equipment.

In 2008 CISPR sent out for circulation the Draft Amendment to CISPR 22, which will describe the limits and method of measurement of broadband telecommunication equipment over power lines.

Both the Japanese and CISPR documents are applicable for In-premises BPL devices.

^a Information on references can be found in Clause 2.

^b The numbers in brackets correspond to those of the bibliography in Annex G.

The growing concerns from PLC manufacturers and utility operators about the absence of an internationally recognized EMC measurement and testing methodology for PLC equipment and installations was addressed when in 2004 IEEE Standards Association established the PLC EMC Working Group [P1775] to develop this standard. The Working Group is co-sponsored by the Power & Energy Society and Communication Society. The standard is solely focused on EMC measurement techniques and does not attempt to establish regulatory limits for PLC devices or systems.

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1. Overview

1.1 Scope

The scope of this standard is electromagnetic compatibility (EMC) criteria and consensus test and measurements procedures for broadband over power line (BPL) communication equipment and installations. The standard references existing national and international standards for BPL equipment and installations. It does not include the specific emission limits, which are subject to national regulations.¹

1.2 Purpose

This standard is a part of a planned IEEE series of BPL standards that will cover major aspects of BPL communication technology: safety, EMC, media, coexistence, interoperability, and education. By providing test and measurement guidance as well as EMC criteria, this EMC standard will serve as a bridge between

¹ And local regulations, should they exist.

national spectrum regulations, power utility practice, and other interested party concerns. It is also will clearly identify the basic definitions of the applicable EMC parameters for BPL equipment and installations as well as measurements conditions and settings.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C63.4, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.²

CISPR 11, Industrial, scientific and medical (ISM) radio-frequency equipment—Electromagnetic disturbance characteristics—Limits and methods of measurement.³

CISPR 16-1-4, Specification for radio disturbance and immunity measuring apparatus and methods—Part 1-4: Radio disturbance and immunity measuring apparatus—Antennas and test sites for radiated disturbance measurements.

CISPR 16-2-1, Specification for radio disturbance and immunity measuring apparatus and methods—Part 2-1: Methods of measurement of disturbances and immunity—Conducted disturbance measurements.

CISPR 16-2-3, Specification for radio disturbance and immunity measuring apparatus and methods—Part 2-3: Methods of measurement of disturbances and immunity—Radiated disturbance measurements.

CISPR 18-1-2010, Radio interference characteristics of overhead power lines and high-voltage equipment—Part 1: Description of phenomena.

CISPR 18-2, Radio interference characteristics of overhead power lines and high-voltage equipment—Part 2: Methods of measurement and procedure for determining limits.

CISPR 22, Information technology equipment—Radio disturbance characteristics—Limits and methods of measurement.

CISPR 24, Information technology equipment—Immunity characteristics—Limits and methods of measurement.

EN 50412-2-1, Power line communication apparatus and systems used in low-voltage installations in the frequency range 1.6 MHz to 30 MHz—Part 2-1: Residential, commercial and industrial environment. Immunity requirements.⁴

² ANSI publications are available from the Customer Service Department, American National Standards Institute, 25 W. 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ CISPR documents are available from the Central Office of the International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211, Geneva 20, Switzerland (<http://www.iec.ch/>). They are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁴ EN publications are available from the European Committee for Standardization (CEN), 36, rue de Stassart, B-1050 Brussels, Belgium (<http://www.cenorm.be>).

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IEC 61000-3-2, Electromagnetic compatibility (EMC)—Part 3-2: Limits—Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).⁵

IEC 61000-3-3, Electromagnetic compatibility (EMC)—Part 3-3: Limits of voltage changes, voltage fluctuations and flicker in public low voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection.

IEC 61000-3-8, Electromagnetic compatibility (EMC)—Part 3: Limits—Section 8: Signalling on low-voltage electrical installations—Emission levels, frequency bands and electromagnetic disturbance levels.

IEC 61000-4-2, Electromagnetic compatibility (EMC)—Part 4-2: Testing and measurement techniques—Electrostatic discharge immunity test.

IEC 61000-4-3, Electromagnetic compatibility (EMC)—Part 4-3: Testing and measurement techniques—Radiated, radio-frequency, electromagnetic field immunity test.

IEC 61000-4-4, Electromagnetic compatibility (EMC)—Part 4-4: Testing and measurement techniques—Electrical fast transient/burst immunity test.

IEC 61000-4-5, Electromagnetic compatibility (EMC)—Part 4-5: Testing and measurement techniques—Surge immunity test.

IEC 61000-4-6, Electromagnetic compatibility (EMC)—Part 4-6: Testing and measurement techniques—Immunity to conducted disturbances, induced by radio-frequency field.

IEC 61000-4-8, Electromagnetic compatibility (EMC)—Part 4-8: Testing and measurement techniques—Power frequency magnetic field immunity test.

IEC 61000-4-11, Electromagnetic compatibility (EMC)—Part 4-11: Testing and measurement techniques—Voltage dips, short interruptions and voltage variations immunity tests.

U.S. Code of Federal Regulations Title 47 Part 15 (47CFR15), Subpart G, Appendix C, Guidelines: Measurement Guidelines for Broadband over Power Line (BPL) and Certification Requirements for Access BPL Systems.⁶

3. Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* should be consulted for terms not defined in this clause.⁷

⁵ IEC publications are available from the Central Office of the International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211, Geneva 20, Switzerland (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁶ CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA.

⁷ *The IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

3.1 Definitions

Access broadband over power line (BPL) equipment: Part of a carrier-current system installed and operated on an electricity utility service over medium- or low-voltage lines. Devices that enable Access BPL and together comprise an Access BPL system: BPL bridges, backhaul-interfaces, couplers, BPL repeaters. BPL equipment does not include accessories, e.g., connecting cables attached to BPL equipment but not essential for the provision of BPL.

ac power port: Connection point to the ac low-voltage electric distribution network for means of providing a power supply to the broadband over power line (BPL) equipment.

ac power port flicker: Short-term and long-term voltage changes at the interface between the equipment under test (EUT) and the electric supply system, produced by the EUT.

ac power port harmonics: Harmonic components of the input current injected into the electric supply system, produced by the equipment under test (EUT).

back-filter: The decoupling section of a coupling/decoupling network (CDN) designed to prevent interference from effecting auxiliary equipment (AE) during an immunity test.

backhaul-interface: The primary data interconnect point that connects the broadband over power line (BPL) system to the *telecommunications network point of presence*, aggregating and managing the data traffic to/from its downstream BPL bridges.

broadband over power line (BPL): A carrier-current system carrying high-speed digital communication on frequencies between 1.7 MHz and 100 MHz over medium-voltage and/or low-voltage power lines. Also known as *power line communication* (PLC).

broadband over power line (BPL) bridge: A device that provides a data interconnect between two or more segments of the power grid providing data interconnection from one medium to another.

broadband over power line (BPL) equipment: Devices that enable broadband over power lines (BPL), including Access BPL and In-premises BPL.

broadband over power line (BPL) repeater: A device that retransmits the signal on the power line without changing protocol.

capacitive coupler: A device that couples data signals bi-directionally onto a power line and includes a capacitive element connected to the power line.

coupler port: The terminal(s) on the broadband over power line (BPL) communications device that connect to the coupler.

coupling/decoupling network (CDN): A device for introducing a disturbance at ports that are to be tested and having provisions for isolating disturbances from the auxiliary equipment (AE).

demarcation point: The point of changeover from Access to In-premises broadband over power lines (BPL).

distance correction factor: A scaling factor that enables a radiated emissions measurement made at a distance different from the reference distance at which emissions limits are specified to be extrapolated to the value that would be present at the reference distance.

electrical fast transients (EFT): A conducted transient disturbance created by switching power currents via electrical contacts.

electromagnetic compatibility (EMC) criteria: The means by which EMC characteristics of electronic devices, systems, and installations are determined to meet national regulations and/or national and international standards to limit harmful interference between different devices, systems, and installations. Electronic devices, systems, and installations that can function and meet all of these criteria are electromagnetically compatible.

electrostatic discharge (ESD): A transfer of electric charge between bodies of different electrostatic potential in proximity or through direct contact.

immunity: Ability of a device, equipment, or system to perform without degradation of performance in the presence of electromagnetic disturbance.

inductive coupler: A device intended to couple data signals bi-directionally onto a power line, including an inductive element electrically in series with the power line.

In-premises broadband over power line (BPL) equipment: Equipment required in a *carrier-current system* providing high-speed digital communications capabilities by coupling radio-frequency (RF) signals onto the power lines (those not owned or operated by an electric service provider) within a premise

NOTE—Access BPL systems may physically have components within the premises. The separation of Access BPL and In-premises BPL is not necessarily the physical boundary of the building.⁸

In-premises broadband over power line (BPL) modem: A device that converts data between a broadband over power line (BPL) signal and another data communications format, e.g., Ethernet, in order to connect *customer premise equipment*.

low voltage (LV): A class of nominal system voltages 1000 V or less.

NOTE—In electric power delivery this refers to the voltage level delivered to premises on the secondary side of the last step-down transformer. Sometimes referred to as *distribution secondary voltage*. Typically between 100 V and 1000 V ac rms.

measurement distance: Distance between the equipment under test (EUT) and the receiving element (antenna) of the measurement device.

medium voltage (MV). A class of nominal system voltages greater than 1000 V and less than 100 000 V.

NOTE—In electric power delivery this can refer to the voltage level in the power distribution system on the primary side of the last step-down transformer (nearest the customer). Sometimes referred to as *distribution primary voltage*. Worldwide this can be from 1000 V to 100 000 V ac rms, but in North America this is typically between 4000 V and 35 000 V ac rms.

notch: A band of spectrum reduced in power relative to adjacent frequencies, to minimize interference.

performance criterion: Levels of equipment under test (EUT) functionality to be evaluated during or after immunity testing.

power port: The physical connection point to a device where energy may be supplied or withdrawn.

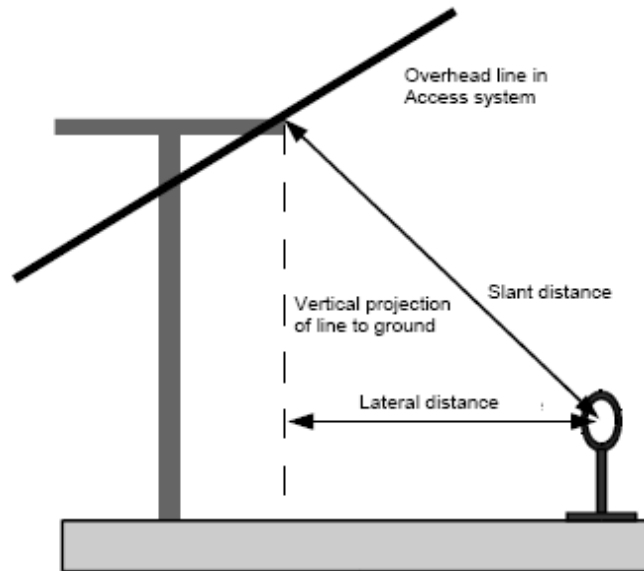
repeater: *See: BPL repeater.*

signal port: The physical connection point to a device where a carrier of data or telecommunications signals is provided.

⁸ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

slant distance: Diagonal distance measured from the center of the measurement antenna perpendicular to the overhead line carrying the broadband over power line (BPL) signal being measured. This distance will be used for extrapolation to the specified distance in case of overhead lines.

NOTE—Refer to the following figure.



Slant distance illustration

3.2 Acronyms

Some acronyms are defined for the convenience of the reader, who may not have ready access to the IEEE dictionary.

ac	alternating current
ANSI	American National Standards Institute
AE	auxiliary equipment
AMN	artificial mains network
BPL	broadband over power line
CDN	coupling/decoupling network
CENELEC	Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standardisation)
CISPR	International Special Committee on Radio Interference (Comité Internationale Spécial des Perturbations radioélectriques)
CPE	customer premises equipment
EFT	electrical fast transient

EMC	electromagnetic compatibility
EMI	electromagnetic interference
ESD	electrostatic discharge
ETSI	European Telecommunications Standards Institute
EUT	equipment under test
FCC	Federal Communications Commission
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISM	industrial, scientific, and medical
ISO	International Standards Organization
ITE	information technology equipment
ITU-T	International Telecommunication Union—Telecommunication Standardization Sector
LISN	line impedance stabilization network
OATS	open area test site
PLC	power line communication
PLT	power line telecommunications or power line technology
RF	radio frequency
RMS	root mean square
SPD	surge protective device
UPA	Universal Powerline Association

4. BPL networks typical installations

4.1 Topologies

The topologies of the electric distribution power supply networks are mainly described as the following:

- a) Loop (ring)
- b) Radial (tree and branch)
- c) Mesh or network

4.1.1 Loop or ring topology

There are two power paths from the source to any load. Ring topology is used mainly in Europe.

4.1.2 Radial topology

There is a single power path from the source to any load. Radial topology is used mainly in North America and Asia.

4.1.3 Mesh or network topology

Mesh or network topology provides many power paths from the source to the load. This topology is often used in large cities in the U.S.

4.2 Physical differences

EMC characteristics of power line communication (PLC) systems may be influenced by the construction, types, and locations of the power cabling and wire.

Common types of cables are as follows:

- a) Insulated cable with concentric neutral
- b) Insulated cable without concentric neutral
- c) Twisted cables
- d) Bare wires

Power lines are described by location as follows:

- 1) *Underground*: There are two kinds of underground lines: insulated cables with and without concentric neutrals. The characteristic impedance of underground cable with concentric neutral is low, usually $20\ \Omega$ to $40\ \Omega$.
- 2) *Overhead*: Overhead lines may be bare wire, unrated insulated (tree wire), and insulated. Insulated wires may be twisted or straight. The characteristic impedance of overhead bare wire, $200\ \Omega$ to $500\ \Omega$, is higher than that of underground insulated cables.

Annex E contains guidance on the selection of test sites according to physical characteristics.

4.3 Electrical non-BPL equipment

Power equipment on the power lines can cause BPL signal degradation due primarily to impedance mismatch. As a result of impedance mismatch, reflections and standing waves can be developed. Standing waves are one of the major contributors to increased emissions from the power line. Examples of such power equipment are the following:

- Transformers
- Meters (electronic and mechanical)
- Switchgear
- Fuses
- Bus bars