IEEE STANDARDS ASSOCIATION

IEEE Standard for Low-Frequency (less than 500 kHz) Narrowband Power Line Communications for Smart Grid Applications

IEEE Communications Society

Sponsored by the
Power Line Communications Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1901.2™-2013

IEEE Standard for Low-Frequency (less than 500 kHz) Narrowband Power Line Communications for Smart Grid Applications

Sponsor

Power Line Communications Standards Committee
of the
IEEE Communications Society

Approved 31 October 2013

IEEE-SA Standards Board

Abstract: A worldwide standard for narrowband power line communications (PLC) via alternating current, direct current, and nonenergized electric power lines using frequencies below 500 kHz. Data rates of up to 500 kb/s are supported. The field of use includes Smart Grid applications. Coexistence mechanisms that can be used by other PLC technologies operating below 500 kHz are also included. These coexistence mechanisms may be used separately from the rest of the standard.

Keywords: coexistence, G3-PLC, IEEE 1901.2™, IFFT OFDM, MAC, medium access control, narrowband, PHY, physical layer, PLC, power line communications, PRIME

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

PDF: ISBN 978-0-7381-8793-8 STD98470
Print: ISBN 978-0-7381-8794-5 STDPD98470

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Standards Documents."

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE-SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied "AS IS" and "WITH ALL FAULTS."

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

Photocopies

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at http://ieeexplore.ieee.org/xpl/standards.jsp or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at http://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: http://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at http://standards.ieee.org/about/sasb/patcom/patents.html. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was submitted to the IEEE-SA Standards Board for approval, the Low Frequency Narrow Band Power Line Communications Working Group had the following membership:

James LeClare, *Chair*
Oleg Logvinov, *Vice Chair*
Oleg Logvinov, *PHY/MAC up to 500 kHz Chair*
Vijay Dhingra, *Coexistence Subgroup Chair*
Michael Koch, *EMC Subgroup Chair*
Tom McLaughlin, *End-user Technical Requirements Subgroup Chair*
Gordon Gregg, *Channel Model Chair*
J. P. Vasseur, *Service Access Point (SAP) Definition Subgroup Chair*
James D. Allen, *Editor*
Sherman Gavette, *Technical Editor*

The Working Group gratefully acknowledges the contributions of many individual and entities. Without their assistance and dedication, this standard would not have been completed. The following individuals submitted technical contributions or commented on the standard at various stages of the project development:

Tommy Aizawa
Danie Algera
Keith Bargroff
James Bates
Anuj Batra
Yoav Ben-Yehezkel
Inigo Berganza
Ulrich Berold
Paul Bertrand
Paola Bisaglia
Simone Bois
Vladimir Borisov
Paul Bromley
Roberto Cappelletti
Henri Chabrier
Philippe Chiummiento
Joseph Choghi
Joseph Chou
Thomas Clausen
Zeev Collins
Nicola Crespi
Jean Marc Darchy
Andrew David
Gabriele Dell'amico
Karl Dietrich
Dacfey Dzung
Ed Eckert
Jean-Philippe Faure
Ullrich Feuchtinger
Fabrizio Francesconi
Ajai Gambhir
Alex Gelman
Andrea Giorgi
Angad Gill
Bill Godwin
Nathan Goldstick
Lorenzo Guerrieri
Eleonora Guerrini
Paul Heitman
Ulrich Herberg
Michael Himmels
Jeremy Hirsch
Jin-Meng Ho
Stephan Horvath
Jean-Philippe Huet
Amir Kamalizad
Il Han Kim
Joon Bae Kim
Neal King
Sravana Krishna
Sharad Kumar
Albert Kuo
Lutz Lampe
Pierre Lanau
Alessandro Lasciandare
Ken Laudel
Angus Lee
Bill Lichtensteiger
Fenghua Liu
Weilin Liu
Oleg Logvinov
Xiaolin Lu
Eddie Luaces
Thierry Lys
Patrick Melet
Anil Mengi
Ross Mitchell
Olivier Monnier
Alessandro Moscatelli
Andrés Muñoz
Michael Navid
Vladimir Oksman
Verne Olson
Jamshid Ourmazdi
Prasad Panchangam
Mallet Patrice
Sandrine Perino
Nicolas Pigeon
Shmulik Pisanty
Qi Qu
Purva Rajkotia
Rob Ranck
Sathya Rao
Matt Rhodes
David Ribner
Markus Rindchen
Beiyu Rong
Roger Samy
Alfredo Sanz
Thomas Schaub
Maik Seewald
Manu Sharma
Donald Shaver
Afshin Shaybani
Shakti Shenoy
Joel Silverman
Kiwi Smit
Daniel Smolinski
Nedo Speroni
Gary Stuebing
David Su
Phil Sutterlin
Keith Tilley
Kevin Traylor
Paolo Treffiletti
Badri Varadarajan
Thierry Vernet
Nanci Vogtli
Khurram Waheed
C. Scott Willy
Michael Wilson
Janez Zavasnik
Bo Zhang
Jin Zhang

The Working Group Chair gratefully acknowledges the following individuals for their significant technical contributions to this standard:

Anand Dabak
Ronen Gazit
Cédric Lavenu
Victor Loginov
Afshin Niktash
Tarkesh Pande
Daniel Popa
Kaveh Razazian
Shimon Solodkin
Mihai Stanciv
Maher Umari
Ramanuja Vedantham
Kumaran Vijayasankar
Jiang Yue

The following industry entities participated in the development of this standard:

ABB Ltd.
Accent S.p.A.
Accenture
Aclara/Esco Technologies
ACN Advanced Communications Networks
ADD Semiconductor
Alliander N.V.
Analog Devices
Applied Micro
Arkados
Atheros Communications
Atmel
Cisco Systems, Inc.
Current Technologies
Cypress Semiconductor
devolo AG
Duke Energy
Echelon Corporation
Ecole Polytechnique
ECOtality
EDF/ERDF
Encryptor
Enphse Energy
EnVerv
EPRI
Freescale Semiconductor, Inc.
Gigle Networks
HomePlug Alliance
iAd GmbH
Iberdrola
Iskraemeco
Itron, Inc.
K-micro (Kawasaki Microelectronics)
Landis+Gyr
Lantiq
Marvell
Maxim Integrated Products
Megachips
Mobix
MStar Semiconductor, Inc.
NXP
Panasonic
Power Plus Communications AG
Princeton Technology Corporation
Qualcomm
Realtek Semiconductor
Renesas Electronics Corporation
Sagemcom SAS
Semitech Semiconductor
Siemens Corporation
SPiDCOM Technologies
STMicroelectronics
Texas Instruments Incorporated
TOSHIBA Corporation
Watteco
Yitran Communications Ltd.

The following members of the entity balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

ABB Ltd.
ACN Advanced Communications Networks
Alliander N.V.
Atmel Corporation
Broadcom Corporation
China Datang Corporation
Cisco Systems, Inc.
Echelon Corporation
EDF/ERDF
ESCO Technologies Inc,
Freescale Semiconductor, Inc.
HomePlug Powerline Alliance
iAd GmbH
Iskraemeco
Itron, Inc.
K-micro (Kawasaki Microelectronics)
Maxim Integrated Products
Mstar Semiconductor, Inc.
Power Plus Communications AG
Princeton Technology Corporation
Renesas Electronics Corporation
Sagemcom SAS
Siemens Corporation
STMicroelectronics
Texas Instruments Incorporated
TOSHIBA Corporation
Yitran Communications Ltd.

When the IEEE-SA Standards Board approved this standard on 31 October 2013, it had the following membership:

John Kulick, *Chair*
David J. Law, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi
Peter Balma
Farooq Bari
Ted Burse
Wael William Diab
Stephen Dukes
Jean-Philippe Faure
Alexander Gelman
Mark Halpin
Gary Hoffman
Paul Houzé
Jim Hughes
Michael Janezic
Joseph L. Koepfinger*
Oleg Logvinov
Ron Petersen
Gary Robinson
Jon Walter Rosdahl
Adrian Stephens
Peter Sutherland
Yatin Trivedi
Phil Winston
Yu Yuan

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Don Messina
IEEE Standards Program Manager, Document Development

Brenda Mancuso
IEEE Client Services Manager, Professional Services

Introduction

This introduction is not part of IEEE Std 1901.2-2013, IEEE Standard for Low-Frequency (less than 500 kHz) Narrowband Power Line Communications for Smart Grid Applications.

This standard is designed to enable low-frequency (<500 kHz) narrowband power line communications (PLC) over indoor and outdoor electrical wiring. The standard supports data rates of up to 500 kb/s and was developed as the result of a collaborative effort undertaken by a large cross section of the PLC industry's technical experts and stakeholders.

It also contains a coexistence mechanism that was developed based on the requirements provided by the industry and with the input from the Smart Grid Interoperability Panel (SGIP) Priority Action Plan 15 (PAP15). This coexistence mechanism may be used by any PLC technology in this band without implementing the rest of the standard and will be maintained through the IEEE-SA.

The project was authorized 25 March 2010. The first draft was available in early January 2011. The first letter ballot was started in January 2012 and received final working group approval on 29 May 2013. Sponsor ballot was completed on 7 September 2013. The document was approved by the IEEE-SA Standards Board on 31 October 2013.

Contents

List of Figures

List of Tables

IEEE Standard for Low-Frequency (less than 500 kHz) Narrowband Power Line Communications for Smart Grid Applications

1. Overview

1.1 Scope

This standard specifies communications for low-frequency (less than 500 kHz) narrowband power line devices via alternating current and direct current electric power lines. This standard supports indoor and outdoor communications over low-voltage (less than 1000 V) (LV) and medium-voltage (1000 V to 72 kV) (MV) power lines and through associated transformers in both urban and long-distance rural applications. The standard uses transmission frequencies less than 500 kHz. Data rates will be scalable to 500 kb/s depending on the application requirements and network conditions. This standard addresses grid to utility meter, grid automation, electric vehicle to charging station, and within home area networking communications scenarios. Lighting and solar panel power line communications (PLC) are also potential uses of this communications standard. This standard focuses on the balanced and efficient use of the PLC channel by all classes of low-frequency narrowband devices, defining detailed mechanisms for coexistence between different low-frequency narrowband standards developing organization (SDO) technologies, assuring that desired bandwidth may be delivered. This standard assures coexistence with broadband power line devices by minimizing out-of-band emissions in frequencies greater than 500 kHz. The standard addresses the necessary security requirements that assure communication privacy and allow use for security-sensitive services. This standard defines the physical layer (PHY) and the medium access control (MAC) sublayer of the data link layer, as defined by the International Organization for Standardization (ISO) open systems interconnection (OSI) basic reference model as shown in 4.3.