IEEE SA
STANDARDS ASSOCIATION

STANDARDS

# IEEE Standard for Low-Rate Wireless Networks

# Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques

IEEE Computer Society

Developed by the
LAN/MAN Standards Committee

**IEEE Std 802.15.4z™-2020**
(Amendment to IEEE Std 802.15.4™-2020)

IEEE

**IEEE Std 802.15.4z™-2020**
(Amendment to IEEE Std 802.15.4™-2020)

# IEEE Standard for Low-Rate Wireless Networks

# Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques

Developed by the

**LAN/MAN Standards Committee**
of the
**IEEE Computer Society**

Approved 4 June 2020

**IEEE SA Standards Board**

**Abstract:** This amendment enhances the UWB PHYs with additional coding options and improvements to increase the integrity and accuracy of ranging measurements. It also enhances the MAC to support control of time-of-flight ranging procedures and exchange ranging related information between the participating ranging devices.

**Keywords:** amendment, double-sided two-way ranging, DS-TWR, enhanced ranging device, ERDEV, HRP UWB PHY, HRP-ERDEV, IEEE 802.15.4™, IEEE 802.15.4z™, low power, low-rate wireless networks, LRP UWB PHY, LRP-ERDEV, multi-node ranging, precision ranging, ranging device, RDEV, RF, RFID, real time location systems, RTLS, single-sided two-way ranging, SS-TWR, time of flight, TOF, TOF integrity, two-way ranging, TWR, ultra wideband, UWB, wireless specialty networks, WSN

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



PDF: ISBN 978-1-5044-6798-8 STD24237
Print: ISBN 978-1-5044-6799-5 STDPD24237

# 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 Notices and Disclaimers Concerning IEEE Standards Documents." They can also be obtained on request from IEEE or viewed at https://standards.ieee.org/ipr/disclaimers.html.

## 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. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups 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 Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

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. A current 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 https://ieeexplore.ieee.org 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 https://standards.ieee.org.

## Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE SA Website at the following URL: https://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 https://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 completed, the IEEE 802.15 Working Group had the following membership:

**Robert F. Heile,** *IEEE 802.15 Working Group Chair*
**Rick Alfvin,** *IEEE 802.15 Working Group Vice-Chair*
**Patrick W. Kinney,** *IEEE 802.15 Working Group Vice-Chair, IEEE 802.15 Working Group Secretary*
**James P. K. Gilb,** *IEEE 802.15 Working Group Technical Editor*
**Benjamin A. Rolfe,** *IEEE 802.15 Working Group Treasurer*

**Tim Harrington,** *IEEE 802.15.4z Task Group Chair*
**Benjamin A. Rolfe,** *IEEE 802.15.4z Task Group Vice-Chair and Secretary*
**Billy Verso,** *IEEE 802.15.4z Task Group Technical Editor*

Hendrik Ahlendorf
Koorosh Akhavan
Bernd Baer
David Barras
Tuncer Baykas
Philip Beecher
Friedbert Berens
Harry Bims
Lennert Bober
Monique Brown
Chris Calvert
Radhakrishna Canchi
Jaesang Cha
Soo-Young Chang
Matthew Chang
Clint Chaplin
Sangsung Choi
Nathan Clanney
Michael G. Cotton
Boris Danev
Luc Darmon
Hendricus De Ruijter
Brandon Dewberry
Anthony Fagan
Robert Finch
Michael Gagne
Matthew Gillmore
Tim Godfrey
Jianlin Guo
Joachim Hammerschmidt
Shinsuke Hara
Hiroshi Harada
Chris Hartman
Christopher Hett
Roger Hislop
Jay Holcomb
Oliver Holland
Iwao Hosako
Brima Ibrahim
Tetsushi Ikegami
Yeong Min Jang
Seongah Jeong
Seong-Soon Joo
Volker Jungnickel
Juha Juntunen
S. G. Karthik
Paul Kettle
Shoichi Kitazawa
Tero Kivinen
Daniel Knobloch
Ryuji Kohno
Fumihide Kojima
Ann Krieger
Thomas Kuerner
Jack Lee
Mingyu Lee
Frank Leong
Huan-Bang Li
Zheda Li
Sang-Kyu Lim
Thomas Lorbach
Masood Maqbool
Vinayagam Mariappan
Alejandro Marquez
Gianfranco Miele
Apurva Mody
Ayman Naguib
Kathleen Nelson
Jaroslaw Niewczas
Paul Nikolich
Philip Orlik
Aditya Padaki
Clark Palmer
Glenn Parsons
CharlesPerkins
Albert Petrick
Joe Polland
Clinton Powell
Demir Rakanovic
Ivan Reede
Joerg Robert
Alessandra Rocha
Ren Sakata
Ruben E. Salazar Cardozo
Ioannis Sarris
Peter Sauer
Nikola Serafimovski
Daoud Serang
Kunal Shah
Tushar Shah
Menashe Shahar
Stephen Shellhammer
Guy Simpson
William Smith
Frederick Smith
Gary Stuebing
Don Sturek
Craig Tedrow
Johannes Wechsler
Brian Weis
Peter Yee
Shaun Yu

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

Thomas Alexander
David Barras
Philip E. Beecher
Harry Bims
Nancy Bravin
Vern Brethour
Demetrio Bucaneg, Jr.
William Byrd
Paul Cardinal
Juan Carreon
Pin Chang
Clint Chaplin
Charles Cook
Boris Danev
Hendricus De Ruijter
Brandon Dewberry
Igor Dotlic
Edward Eckert
Anthony Fagan
Michael Fischer
Avraham Freedman
James P. K. Gilb
Matthew Gillmore
Robert Golshan
Randall Groves
Rainer Hach
Joachim Hammerschmidt
Timothy Harrington
Robert F. Heile
Jerome Henry
Marco Hernandez
Werner Hoelzl
Brima Ibrahim
Raj Jain
SangKwon Jeong
Srinivas Kandala
S. G. Karthik
Stuart Kerry
Yongbum Kim
Patrick W. Kinney
Tero Kivinen
Jarkko Kneckt
Daniel Knobloch
Jan Kruys
Yasushi Kudoh
Hyeong Ho Lee
Mingyu Lee
Wookbong Lee
Frank Leong
Zheda Li
Yong Liu
Thomas Lorbach
Michael Mc Laughlin
Michael McInnis
Ayman Naguib
Nick S. A. Nikjoo
Tetsu Nishimura
Bansi Patel
Dev Paul
Arumugam Paventhan
Clinton Powell
Maximilian Riegel
Robert Robinson
Benjamin A. Rolfe
Ruben E. Salazar Cardozo
Shigenobu Sasaki
Naotaka Sato
Peter Sauer
James Schuessler
Kunal Shah
Tushar Shah
Robert Stacey
Dorothy Stanley
Thomas Starai
Gary Stuebing
Don Sturek
Mark Sturza
Bo Sun
Mark-Rene Uchida
Aditya V. Padaki
Dmitri Varsanofiev
Billy Verso
George Vlantis
Lisa Ward
Karl Weber
Scott Willy
Andreas Wolf
Chi Xu
Shang-Te Yang
Kangjin Yoon
Yu Yuan
Oren Yuen
Sven Zeisberg

When the IEEE SA Standards Board approved this standard on 4 June 2020, it had the following membership:

**Gary Hoffman,** *Chair*
**Jon Walter Rosdahl,** *Vice Chair*
**John D. Kulick,** *Past Chair*
**Konstantinos Karachalios,** *Secretary*

Ted Burse
Doug Edwards
J. Travis Griffith
Grace Gu
Guido R. Hiertz
Joseph L. Koepfinger*
David J. Law
Howard Li
Dong Liu
Kevin Lu
Paul Nikolich
Damir Novosel
Dorothy Stanley
Mehmet Ulema
Lei Wang
Sha Wei
Philip B. Winston
Daidi Zhong
Jingyi Zhou

*Member Emeritus

# Introduction

This introduction is not part of IEEE Std 802.15.4z-2020, IEEE Standard for Low-Rate Wireless Networks—Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques.

This amendment of IEEE Std 802.15.4-2020 specifies enhancements and enhanced modes of operation for the HRP UWB PHY and the LRP UWB PHY and associated ranging techniques in the MAC. The PHY enhancements include facilities to improve the integrity and accuracy of the ranging measurements. The MAC enhancements include specification of information element definitions to facilitate ranging information exchange, and changes to support the PHY enhancements.

These enhancements meet the needs of a wider set of applications where the integrity and accuracy of distance measurement is important.

The standard is widely used in a variety of applications that employ the ranging capabilities enabled by the UWB PHYs specified by IEEE Std 802.15.4-2020. Current users and product manufacturers have identified the need for improved efficiency, integrity, and accuracy of the existing ranging measurement methods in order to expand the usefulness of the standard for applications such as RFID and automotive, in particular, automotive remote control, and similar personal devices. These enhancements are also expected to open up new areas of application.

# Contents

# IEEE Standard for Low-Rate Wireless Networks

# Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques

(This amendment is based on IEEE Std 802.15.4™-2020.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.[1]

[1] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.