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IEEE Standard for Computation of Energy Efficiency Upper Bound for Apparatus Processing Communication Signal Waveforms

IEEE Communications Society

Developed by the
Green ICT Standards Committee

IEEE Std 1923.1™-2021

IEEE STANDARDS

IEEE Standard for Computation of Energy Efficiency Upper Bound for Apparatus Processing Communication Signal Waveforms

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Green ICT Standards Committee
of the
IEEE Communications Society

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Abstract: A method for computation of an energy efficiency upper bound for an apparatus (wireless or wired) processing a particular communication signal waveform is specified in this standard. This method utilizes the signal envelope probability density function in combination with apparatus' power dissipation characteristics to calculate the energy efficiency upper bound. The purpose of this standard is to provide a consistent tool to other Working Groups and other practitioners who need to evaluate any communication signal waveforms potential for energy efficiency when implemented in hardware.

Keywords: energy efficiency, IEEE 1923.1™, modulation, power amplifier, signal waveforms

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Introduction

This introduction is not part of IEEE Std 1923.1-2021, IEEE Standard for Computation of Energy Efficiency Upper Bound for Apparatus Processing Communication Signal Waveforms.

IEEE Std 1923.1™ provides a methodology to calculate the intrinsic energy efficiency of waveforms used in wireless communication transmitters [standardized in 2G, 3G, 4G, and 5G NR (New Radio), as well as WLAN (Wireless Local Area Network)], for specific device implementation. IEEE Std 1923.1 deals with analog circuits.

This standard provides a generic upper-bound methodology called Modulation-Available Energy Efficiency(MAEE) to quantify the energy efficiency of linear transmitters as a primary performance metric when using any given communication signal waveform. The impact of the semiconductor device technology is taken into account in MAEE as a determining factor together with the waveform transmitted. Non-linear transmitters will be treated in future revisions. Examples of application of MAEE to 2G through 5G and non-cellular are presented.

The MAEE is provided in terms of both a detailed algorithm and example MATLAB code.

Acknowledgements

The Working Group especially acknowledges the contributions of its Chair, Earl McCune, who passed away shortly before the publication of this standard. Earl was an IEEE Fellow and an emeritus MTT Distinguished Microwave Lecturer. He was a member of multiple IEEE conference committees and served as the Chair of the Energy Efficient Communications Hardware Standards Working Group.

Earl received his BSEE/CS from UC Berkeley, CA, USA MSEE from Stanford, and Ph.D. from UC Davis, CA, USA. His research interests included RF circuits and systems including modulation design, with an emphasis on jointly maximizing throughput and energy efficiency while also minimizing implementation cost. He was a Silicon Valley serial entrepreneur, and had 91 issued US patents.

This standard is dedicated to his memory.

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IEEE Standard for Computation of Energy Efficiency Upper Bound for Apparatus Processing Communication Signal Waveforms

1. Overview

1.1 Scope

This standard specifies a method for computation of an energy efficiency upper bound for an apparatus processing a particular communication signal waveform. This method utilizes the signal envelope probability density function in combination with apparatus' power dissipation characteristics.

1.2 Purpose

The purpose of this standard is to evaluate communication signal waveforms potential for energy efficiency.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals is *required to*).[1,2]

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

[1]The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.
[2]The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.