



IEEE Standard for the Performance Assessment of Industrial Wireless Systems

IEEE Instrumentation and Measurement Society

Developed by the

Technical Committee on Sensor Technology

IEEE Industrial Electronics Society

Developed by the

Industrial Electronics Society Standards Committee

STANDARDS

IEEE Std 3388™-2025

IEEE Standard for the Performance Assessment of Industrial Wireless Systems

Developed by the

Technical Committee on Sensor Technology
of the
IEEE Instrumentation and Measurement Society and the

Industrial Electronics Society Standards Committee
of the
IEEE Industrial Electronics Society

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IEEE SA Standards Board

Abstract: This standard establishes a radio-frequency (RF) reference environment model, test methodology, and evaluation process for the performance testing of industrial wireless networks. The standard is protocol agnostic as it applies to all wireless protocols intended for use in industrial and mission-critical industrial settings in which reliability concerns are essential to the functioning of the overlying operational systems, i.e., the industrial sensing and automation system. Industrial wireless systems are used for carrying vital sensor, actuator, command, and control information that is used for the operation of sensing, optimization, control, and safety applications. This standard includes a functional model of radio impairments (aggressors) that represents the RF environment. A reference test architecture and process of evaluation and reporting are provided. Key performance metrics are described and indicated for the evaluation of the test apparatus, the aggressors, and the industrial wireless system under evaluation. Finally, a framework for the specification of standardized test profiles is described.

Keywords: IEEE 3388™, industrial automation, industrial wireless, industrial wireless networks, system integration and test, wireless performance evaluation

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Introduction

This introduction is not part of IEEE Std 3388-2025, IEEE Standard for the Performance Assessment of Industrial Wireless Systems.

This standard establishes a radio-frequency (RF) reference environment model, test methodology, and evaluation process for the performance testing of industrial wireless networks. The standard is protocol agnostic as it applies to all wireless protocols intended for use in industrial and mission-critical industrial settings in which reliability concerns are essential to the functioning of the overlying operational systems (i.e., the industrial sensing and automation system). Industrial wireless systems are used for carrying vital sensor, actuator, command, and control information that is used for the operation of sensing, optimization, control, and safety applications. This standard includes a functional model of radio impairments (aggressors) that represents the RF environment. A reference test architecture and process of evaluation and reporting are provided. Key performance metrics are described and indicated for the evaluation of the test apparatus, the aggressors, and the industrial wireless system under evaluation. Finally, a framework for the specification of standardized test profiles is described.

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IEEE Standard for the Performance Assessment of Industrial Wireless Systems

1. Overview

1.1 Scope

Industrial wireless systems are used for carrying sensor, actuator, and control information for operational usage. This standard establishes a functional model for radio-frequency (RF) industrial wireless performance degradation factors (i.e., aggressors); a reference test architecture for the performance evaluation of industrial wireless systems; a transparent performance assessment process for test planning, evaluation, and reporting; and instructions for establishing profiles to tailor the process for specific industries, applications, and scenarios. The standard applies to all wireless networks for use in industrial settings in which reliability and latency concerns are important to the functioning of the underlying operational systems. Performance degradation factors considered include physical and electromagnetic (EM) forms of wireless signal degradation. The standard does not cover the specifics of hardware implementations, the underlying algorithms used to produce RF aggressors, or how the industrial wireless networks (IWNs) being evaluated operate within the specified test environments.

1.2 Purpose

The purpose of this standard is to establish a functional model for RF industrial wireless performance aggressors; to provide a reference test architecture for the performance evaluation of industrial wireless systems; to provide a transparent performance assessment process for test planning, evaluation, and reporting; and to provide procedures for establishing profiles to tailor the process for specific industries, applications, and scenarios. Use of this standard enhances the performance of industrial wireless systems for various scenarios and advances the adoption of wireless technology as a reliable mode of communications for industrial and other operational environments.

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*).^{6,7}

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

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*).

1.4 Organization

This standard provides a comprehensive technological overview and process for the evaluation of industrial wireless system, which will be used as a primary mode of communications for mission-critical and time-sensitive applications. This standard is used by those persons deploying a new wireless solution, upgrading an existing wireless solution, troubleshooting an existing wireless deployment, or evaluating wireless solution options for use in their enterprise. The standard is intended to provide knowledge of industrial wireless systems testing and a transparent process for industrial wireless technology users to better anticipate the expected performance of their deployed wireless networks. This document is organized as follows:

[Clause 1](#), [Clause 2](#), and [Clause 3](#) provide the scope and purpose of the document, as well as definitions, acronyms, and abbreviations. The reader should refer to the lists of definitions, acronyms, and abbreviations in these clauses for clarifications when terminology is not made explicitly clear in the main body text.

[Clause 4](#) introduces both industrial automation systems and industrial wireless systems followed by a discussion of the importance of wireless networking within those systems.

[Clause 5](#) provides the functional model that includes a theoretical overview of automation systems and a theoretical overview of communications systems within the context of the industrial environment. Following that, the clause provides a taxonomy and description of various factors, which degrade industrial wireless system performance in terms of reliability and latency. These factors are referred to as “aggressors,” which is an apt term for conditions affecting industrial wireless systems.

[Clause 6](#) provides a reference architecture for testing industrial wireless performance. The reference test architecture is a functional model of the test apparatus that would be used to evaluate a wireless system under test. The clause then expands upon the reference test architecture providing a standard set of recommended test approaches (i.e., methods ranging from an anechoic chamber method to on-site over-the-air testing *in-situ* method) to be used for the evaluation of an industrial wireless system. These methods are to be used when following this standard.

[Clause 7](#) provides the key performance metrics to be considered when evaluating an industrial wireless system’s performance. These metrics are divided into test apparatus characterization performance metrics and informational performance metrics of the wireless network being evaluated.

[Clause 8](#) through [Clause 13](#) provide the actual process by which an industrial wireless system is evaluated, given the information provided in the previous clauses. The users of this standard will employ this process to identify the properties of the network being evaluated, to identify the expected aggressors, to execute performance testing by utilizing the reference test architecture, and to identify the desired performance indicators to be recorded. Stakeholders will then utilize the results to make informed decisions on whether and how to deploy the wireless system given the performance indicated by the measured results.

[Clause 14](#) describes profiles. Profiles are preplanned strategies for the performance evaluation of a specific wireless system or a class of wireless systems for a specific set of conditions or scenario that is of interest to a group of end users or an industry. The process for specifying a profile is described. Standardized profiles

are defined individually within this standard as sub-numbered documents using the traditional IEEE dot convention, such as IEEE 3388.N, where N is designated as a number or letter.

Annexes are included to provide supplemental information for the reader.

2. Normative references

There are no normative references for this standard.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁸

adjacent channel interference (ACI): Radio-frequency (RF) energy that is adjacent to the channel containing a desired signal.

adjacent channel rejection (ACR): The ability of the receiver to suppress adjacent channel interference.

aggressor: Any physical manifestation that degrades communications performance.

antenna: A device that converts electrical energy into propagating electromagnetic waves or the reverse.

bandwidth: The amount of spectrum occupied by a signal defined by the difference between the uppermost and lowermost frequencies in a continuous band of frequencies.

bit rate: The number of transmitted or received bits that were observed during a measurement period. The average or peak amount of data transmitted during an interval of time. This is represented as bits per second (bps).

carrier: A single frequency sinusoidal signal represented by a vertical line or spike in frequency.

channel: A term used to identify a wireless communications link and includes the characteristics of the entire path of information flow from transmitter to receiver. A channel is defined by electrical and electromagnetic characteristics of the transmission medium, such as bandwidth and distortions.

clutter: Objects in the surrounding environment that affect radio wave propagation by the effects of blockage, reflection, and diffraction.

duty cycle: The rate at which a wireless channel is active, usually represented as a percentage of time.

dynamic range: The difference between the maximum and minimum received signal power. A large dynamic range is particularly helpful in accommodating strong adjacent channel interference that leaks past radio-frequency filtering.

error rate: The proportion of failed requests or operations (such as received bits, symbols, or frames) relative to the total number of requests or operations over a given period

⁸*IEEE Standards Dictionary Online* is available at: <https://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

frequency hopping (FH): A process by which the carrier frequency changes during or between transmissions according to a predefined synchronized method.

interference: Radio-frequency (RF) energy, typically in the RF band of interest, that disrupts communications by inhibiting the ability of a receiver to decode a desired transmission. Sources of interference could include anything that radiates electromagnetic energy, such as machinery and undesirable radio devices.

jammer: A source of interference used to intentionally degrade or prohibit communications.

jitter: Variation in latency.

latency: Time delay between the start of transmission and the end of reception measured in units of time.

link budget: Calculations that predict the probability that a transmission will be successfully detected and decoded by the receiver. A link budget will account for transmission power, signal formatting, noise, signal distortions, interference, receiver characteristics, and link reliability requirements.

link margin: The difference in decibels (dB) between the ability of a receiver to successfully receive a transmission and the expected minimum received power. A link margin of 10 dB indicates that a signal could be attenuated by an additional factor of 10 before it can no longer be received. A link margin should accommodate reasonable unexpected attenuations, distortions, and interference not directly addressed by the link budget.

machine noise: An unintentional generation and propagation of electromagnetic energy from operational equipment.

mean: The mean is the arithmetic average of the data values and provides an indication of the central tendency of the data.

median: The median is the middle value of the data when the values are arranged in order and provides an alternative measure of the central tendency that is less affected by extreme values.

mode: The mode is the value that occurs most frequently in the data and provides an indication of the most common value or category.

modulation: The method by which information is used to modify the behavior of a radio-frequency carrier. Different modulations exist, such as amplitude modulation, frequency modulation, and phase modulation. Digital modulations are discrete versions of the above modulations. Common modulations used in industrial communications include binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), and quadrature amplitude modulation (QAM), among others.

NOTE—As an example, IEEE 802.11 uses a combination of BPSK, QPSK, and QAM depending on channel quality.⁹

outliers: A statistical outlier is a data point or observation that differs significantly from other data points in a dataset. It is an observation that falls outside the typical range of values for the data.

payload: The information being transmitted. The size of the payload factors into transmission duration. All communication systems have a limit to the size of a payload before fragmentation is required. Not all communication systems support fragmentation. At the lowest layers of a communication system, the payload includes all data encoding and framing.

⁹Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

polarization: The orientation of the directionality of electromagnetic waves produced by an antenna. Common polarization schemes are vertical, horizontal, and circular.

power in decibels: A logarithmic representation of a power relative to a reference. The common notations, dBW and dBm, represent power levels relative to 1 W and 1 mW, respectively. The notation, dB, denotes a ratio of two numbers of the same units and should not be used to represent units of power or amplitude since they are not ratios.

quartiles: The statistical quartiles of a data set are values that divide the data into four equal parts and provide an indication of the spread of the data across different percentile ranges.

radio-frequency interference (RFI): Electromagnetic interference found in the radio bands utilized by communications equipment.

range (radio): The maximum distance of separation between transmitter and receiver at which an acceptable quality of service of communications is possible.

range (statistics): The range is defined as the difference between the maximum and minimum values in the data and provides an indication of the total spread of the data.

receiver: The device responsible for decoding incoming transmissions in accordance with an established protocol.

selectivity: The ability of a device to decode a transmission on one frequency without interference from transmissions on other frequencies.

sensitivity: The lowest power level required to enable an acceptable quality of service of communications. Sensitivity is usually measured or specified in units of power, such as milliwatts, power spectral density, or milliwatts per hertz.

signal-to-noise ratio (SNR): The ratio of signal power to naturally occurring emissions such as thermal noise and cosmic background radiation. Maximizing SNR is the primary goal of wireless communications.

signal-to-noise-and-interference ratio (SNIR): Ratio of signal power to the sum of naturally occurring noise power and power from interference. Minimizing the contribution of interference to SNIR is an important goal of a wireless communications system.

standard deviation: The standard deviation is defined as the square root of the variance and provides an indication of the typical amount of variation in the data.

transmit power: The average amount of radio-frequency energy per unit of time emitted by the transmit antenna. This is typically specified linearly in watts, or logarithmically in dBW or dBm.

transmitter: The device responsible for transmitting information wirelessly.

variance: The variance of a data set is a measure of the spread or variability of the data around the mean and is calculated as the average of the squared differences between each data value and the mean.

3.2 Acronyms and abbreviations

AA	acquiring authority
AC	aggressor capture
ACR	adjacent channel rejection
AGV	automated guided vehicle
AM	amplitude modulation
AOA	angle of arrival
AP	access point
BER	bit-error rate
BPSK	binary phase shift keying
CDF	cumulative density function
CIR	channel impulse response
DCS	distributed control systems
EM	electromagnetic
ERP	effective radiated power
FA	factory automation
FH	frequency hopping
FM	frequency modulation
FSPL	free space path loss
HVAC	heating, ventilation, and air conditioning
HMI	human-machine interface
ICS	industrial control system
IO	input-output
ISM	industrial, scientific, and medical
IWN	industrial wireless network
IWS	industrial wireless system
LOS	line of sight
LSB	large sectorized blockage
MCSI	modulation and coding scheme index
MIG	metal inert gas
NC	network capture
NTP	network time protocol
OTA	over the air
PA	process automation
PAPR	peak-to-average power ratio
PDP	power delay profile
PER	packet error rate
PL	path loss
PLC	programmable logic controllers
PLR	packet loss rate

PM	performance metric
PTP	precision time protocol
PWM	pulse wave modulated
PWN	protected wireless network
QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
QoS	quality of service
RCE	radio communications equipment
RF	radio frequency
RFC	reference clock source
RFEC	radio-frequency environment control
RFI	radio-frequency interference
RSQI	received signal quality indicator
RSSI	received signal strength indicator
RTA	reference test architecture
RTT	round trip time
RVC	reverberation chamber
SCADA	supervisory control and data acquisition
SDR	software-defined radio
SI	system integrator
SIR	signal to interference ratio
SJR	signal-to-jamming ratio
SNIR	signal-to-noise-and-interference ratio
SNR	signal-to-noise ratio
SSA	statistical summary analysis
SSB	small sectorized blockage
SUT	system under test
TC	test case
TCONF	test configuration
TG	traffic generation
TIG	Tungsten inert gas
TM	test methodology
TO	test orchestration
TP	test plan
TR	test report
TS	time stamping
VFD	variable frequency drive
VSD	variable speed drive
VSG	vector signal generator
WLAN	wireless local area network
WPAN	wireless personal area network