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REDLINE VERSION

INTERNATIONAL STANDARD

Industrial networks – Coexistence of wireless systems – Part 2: Coexistence management

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IEC 62657-2:2025-02 RLV(en)

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INDUSTRIAL NETWORKS – COEXISTENCE OF WIRELESS SYSTEMS –

Part 2: Coexistence management

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62657-2:2022. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62657-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2022. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) alignment of some definitions and specifications of coexistence parameters in order to facilitate their future inclusion in the IEC Common Data Dictionary (IEC CDD) maintained by the IEC;

b) alignment of some definitions and specifications to be consistent with the new IEC 62657-3 and IEC 62657-4;

c) edition 3 of this document was published in June 2022. Some comments were made in the last development stages of this document asking for explanations on how the parts of the IEC 62657 series were structured and how they were related to each other. Resolution of these comments was deferred until a next edition, which means this edition.

The text of this International Standard is based on the following documents:

Draft	Report on voting
65C/1329/FDIS	65C/1337/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all the parts of the IEC 62657 series, under the general title *Industrial networks – Coexistence of wireless systems,* can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

The overall market for wireless communication solutions spans a range of diverse applications, with differing performance and functional requirements. Within this overall market, the industrial automation domain could include:

- process automation, covering for example the following industry branches:
  - oil and gas, refining,
  - chemical,
  - pharmaceutical,
  - mining,
  - pulp and paper,
  - water and wastewater,
  - steel,
- electric power such as:
  - power generation (for example wind turbine),
  - power transmission and distribution (grid),
- factory automation, covering for example the following industry branches:
  - food and beverage,
  - automotive,
  - machinery,
  - semiconductor.

Industrial automation requirements for wireless communication systems are different from those of, for example, the telecommunications, commercial and consumer markets. These industrial automation requirements are identified and provided in IEC 62657-1.

Industrial premises can contain a variety of wireless communication technologies and other sources of radio emissions.

This document is intended for designers and persons responsible for production and process plants, system integrators and mechanical engineers having to integrate and start up wireless systems in machines and plants, and producers of industrial wireless solutions. In particular, it is intended to motivate the exchange of information between automation and radio engineers.

Many wireless industrial automation applications are also located in physical environments over which the operator/owner can exert control, that is, within a physical facility where the presence and operation of all radio emitting devices are under the control of a single entity. This allows wireless management strategies to be employed which are not feasible for equipment installed in public or other unmanaged areas.

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In industrial automation, many different wireless communication systems can operate in the same premises. Examples of these communication systems are IEC 62591 [1][1] (WirelessHART®[2]), IEC 62601 [2] (WIA-PA) and IEC 62734 [3] (ISA100.11a). All these communication systems use IEEE 802.15.4 [4] for the process automation applications. Other examples of wireless communication systems are specified in the IEC 61784-1 series [5] and IEC 61784-2 series [6] CP that use IEEE 802.11 [7] and IEEE 802.15.1 [8] for factory automation applications. Different to wired fieldbuses, the wireless communication devices can interfere with others on the same premises or environment, disturbing each other. Other sources of radio energy in these bands, often at high energy levels, include radiated process heating, plastic welding, plasma lamps, and microwave irradiation devices.

Clearly, without a means to manage the coexistence of these varied emitters, it would be problematic to ensure that wireless systems meet the time-criticality and other performance requirements of industrial automation.

This document describes the management of independent radio sources that use the same transmission medium. The management within a wireless communication system is not the subject of this document. It is assumed that the standard of a wireless system regulates it, for example by a medium access control mechanism.

The IEC 62657 series has four parts:

- Part 1: Wireless communication requirements and spectrum considerations,
- Part 2: Coexistence management,
- Part 3: Formal description of the automated coexistence management and application guidance,
- Part 4: Coexistence management with central coordination of wireless applications.

IEC 62657-1 provides general requirements for industrial automation and spectrum considerations that are the basis for industrial communication solutions. This document specifies the coexistence management of wireless devices to ensure predicable performance. It is intended to facilitate harmonization of future adjustments to international, national, and local regulations.

This document provides the coexistence management concept and process. Based on the coexistence management process, a predictable assuredness of coexistence can be achieved for a given spectrum with certain application requirements. This document describes principles to manage the potential mutual interference that ~~might~~ could occur due to the operation of multiple wireless devices in a plant.

This document provides guidance to the users of wireless systems on selection and proper use of wireless systems. To provide suitable wireless devices to the market, it also serves vendors in describing the behaviours of wireless devices to build wireless systems matching the application requirements.

This document is based on analyses of a number of International Standards, which focus on specific technologies. The intention of this document is not to invent new parameters but to use already defined ones and to be technology independent.

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1 Numbers in square brackets refer to the Bibliography.

2 WirelessHART® is the registered trade name of the FieldComm Group, see www.fieldcommgroup.org. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

INDUSTRIAL NETWORKS – COEXISTENCE OF WIRELESS SYSTEMS –

Part 2: Coexistence management

1 Scope

This part of IEC 62657

- specifies the fundamental assumptions, concepts, parameters, and procedures for wireless communication coexistence;
- specifies coexistence parameters and how they are used in an application requiring wireless coexistence;
- provides guidelines, requirements, and best practices for wireless communication's availability and performance in an industrial automation plant; it covers the life-cycle of wireless communication coexistence;
- helps the work of all persons involved with the relevant responsibilities to cope with the critical aspects at each phase of life-cycle of the wireless communication coexistence management in an industrial automation plant. Life-cycle aspects include: planning, design, installation, implementation, operation, maintenance, administration and training;
- provides a common point of reference for wireless communication coexistence for industrial automation sites as a homogeneous guideline to help the users assess and gauge their plant efforts;
- deals with the operational aspects of wireless communication coexistence regarding both the static human/tool-organization and the dynamic network self-organization.

~~This document provides a major contribution to national and regional regulations. It does not exempt devices from conforming to all requirements of national and regional regulations.~~

This document provides a major contribution to national and regional regulations by supporting to fulfil the requirements using coexistence management.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62443 (all parts), ~~*Industrial communication networks – Network and system security*~~ *Security for industrial automation and control systems*

IEC 62657-1:2017, *Industrial communication networks – Wireless communication networks – Wireless communication requirements and spectrum considerations*

IEC 62657-3:2022, *Industrial networks – Coexistence of wireless systems – Part 3: Formal description of the automated coexistence management and application guidance*

IEC 62657-4:—, *Industrial networks – Coexistence of wireless systems – Part 4: Coexistence management with central coordination of wireless applications*[3]

3 Terms, definitions, abbreviated terms and conventions

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/ [9]
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
active environmental influence
influence on the signal propagation through interfering of the wireless communication application or wireless application

3.1.2
adjacent channel interference
interference that occurs from wireless devices using adjacent frequency channels

3.1.3
adjacent channel selectivity
ability of a radio receiver to respond to the desired signal and to reject signals in adjacent frequency channels

3.1.4
antenna gain
measure of the effectiveness of an antenna that expresses the ratio between the power required at the input of a reference antenna ~~to~~ and the power ~~supplied to~~ delivered at the input of the given antenna ~~to produce, in a given direction,~~ to achieve the same field strength at the same distance of a given direction

~~[SOURCE: Federal Standard 1037C:1996, modified – Deletion of "loss-free" before "reference antenna", deletion of the two notes and synonyms] [29]~~

3.1.5
antenna radiation pattern
variation of the field intensity of an antenna as an angular function with respect to the axis

3.1.6
antenna type
kind of part of a radio transmitting or receiving system which is designed to provide the required coupling between a transmitter or a receiver and the medium in which the radio wave propagates

Note 1 to entry: In practice, the terminals of the antenna or the points to be considered as the interface between the antenna and the transmitter or receiver should be specified.

Note 2 to entry: If a transmitter or receiver is connected to its antenna by a feed line, the antenna may be considered to be a transducer between the guided waves of the feed line and the radiated waves in space.

[3] Under preparation. Stage at the time of publication: IEC/FDIS 62657-4:2024.

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[SOURCE: IEC 60050-712:1992, 712-01-01, modified – "Addition of "type" after the term, addition of "kind of" at front.] [10]

3.1.7
application communication requirements
quantitative requirements specifying the required conditions and the required characteristics of wireless communication solutions at the communication interface that is met in order to achieve the purpose of the automation application

3.1.8
area of operation
distinguishing properties of the area where the wireless communication system is operated

3.1.9
automated collaborative coexistence management
tool supported collaborative coexistence management with defined interfaces between the tool and the wireless communication system

Note 1 to entry: The tool can be according to IEC 62657-4[4].

3.1.10
automation application
industrial automation application
application of measurement and automatic control in the industrial automation domain

3.1.11
automation application data length
user data length
number of octets that are exchanged at the reference interface

3.1.12
bit rate of the physical link
measure of the number of binary digits transferred per second

~~**3.1.13**~~
~~**blocking frequency**~~
~~ability of a device to avoid part of the available spectrum~~

~~[SOURCE: ETSI TR 102 889-2: 2011, modified – Changed "blacklisting frequencies" to "blocking frequency"] [22]~~

3.1.13
blocked frequency list
list of the blocked frequencies to avoid part of the available spectrum

~~[SOURCE: ETSI TR 102 889-2: 2011, modified – Exchanged "blacklisting frequencies" by "blocked frequency list" and added "to avoid part of the available spectrum"] [22]~~

3.1.14
cellular topology
cellular network topology
network topology where the geographical area is divided in cells

Note 1 to entry: A device can move from one cell to another cell. Devices that are in a cell communicate through a central hub. Hubs in different cells are interconnected.

~~[4] Under preparation. Stage at the time of publication: IEC FDIS 62657-4:2022.~~

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3.1.15
centre frequency
geometric mean of lower cut-off frequency and upper cut-off frequency of a frequency channel

3.1.16
channel number
unsigned integer number identifying a wireless communication channel in accordance with an authoritative document or rule

3.1.17
channel occupation
time interval in which the medium is busy

Note 1 to entry: Beyond the pure transfer of user data, this time includes all time slices necessary to process the transmission protocol, for example to transfer an acknowledgement.

3.1.18
coexistence
wireless communication coexistence
state in which all wireless communication solutions of a plant using shared medium fulfil all their application communication requirements

Note 1 to entry: In IEEE 802.15.2-2003 [11], coexistence is defined as a characteristic of a device.

3.1.19
coexistence management
process to establish and to maintain coexistence that includes technical and organizational measures

3.1.20
coexistence management information
parameters for the wireless coexistence management process

3.1.21
coexistence manager
role of a nominated person to manage coexistence

3.1.22
coexistence planning
process that describes the allocation of wireless communication resources (time, frequencies, coding, space) to each wireless communication system in order to achieve coexistence

3.1.23
collaborative coexistence management
coexistence management process in which data is exchanged between the wireless communication applications involved with the aim of influencing the wireless communication so that all applications meet the requirements

3.1.24
communication availability
<wireless communication> ratio of the time interval of error free transmission (uptime) to an observation time

3.1.25
communication availability
<performance> ability of an item to be in a state to perform as required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

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Note 1 to entry: This ability depends on the combined aspects of the reliability performance, the maintainability performance, and the maintenance support performance.

Note 2 to entry: Required external resources, other than maintenance resources, do not affect the availability performance of the item.

3.1.26
communication load
amount of user data to be transmitted from the automation application within a certain period of time

3.1.27
communication reliability
ability of a physical link and the related nodes to perform communication services under given conditions for a given time interval

3.1.28
cut-off frequency
frequency limit, nearest to the frequency where the spectral power density drops below a certain level, defining the frequency bandwidth

3.1.29
data throughput
ratio between the number of user data transferred to the application at the target reference interface and the observation time

3.1.30
device
piece of hardware that provides connectivity and functionality

Note 1 to entry: Does not exclude software using the hardware to perform functions or support connectivity.

3.1.31
device type
shared characteristics of a device as specified so that the used devices build instances of the shared characteristics

EXAMPLE The specification can be part of a catalogue from a manufacturer.

Note 1 to entry: These shared characteristics include: technology, design, area of application, parts or modules with respect to safety, EMC, performance, functionality, etc.

Note 2 to entry: The shared characteristics of a device type may be engineered, configured and parameterized in a device instance.

3.1.32
distance between wireless devices
geographical distance between devices within a three-dimensional space

3.1.33
distributed automation system
functions of the automation devices that are the spatial extent of a wireless industrial automation

3.1.34
duty cycle
ratio of the transmitter sequence referenced to a given observation time for the used frequency channel

3.1.35
dwell time
period spent at a particular frequency during any single hop of a frequency hopping system

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3.1.36
equivalent isotropic radiated power
product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain)

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.161, modified – Term modified from isotropically to isotropic and definition reformatted according to the ISO/IEC Directives Part 2] [12]

3.1.37
effective radiated power
product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.162, modified – Deleted "(in a given direction)" and definition reformatted according to the ISO/IEC Directives Part 2] [12]

3.1.38
electromagnetic interference
EMI
degradation of the performance of equipment or transmission channel or system caused by an electromagnetic disturbance

Note 1 to entry: In French, the terms "perturbation électromagnétique" and "brouillage électromagnétique" designate respectively the cause and the effect, and should not be used indiscriminately.

Note 2 to entry: In English, the terms "electromagnetic disturbance" and "electromagnetic interference" designate respectively the cause and the effect, and should not be used indiscriminately.

[SOURCE: IEC 60050-161:2018, 161-01-06] [13]

3.1.39
frequency band
range in the frequency spectrum that is assigned by regulatory organizations for use for specific applications or a group of applications

Note 1 to entry: The ITU as international regulatory organization assigns only radio communication services to a specific range in the frequency spectrum.

3.1.40
frequency bandwidth
bandwidth
difference between upper cut-off frequency and lower cut-off frequency

3.1.41
frequency channel
span of the frequency spectrum which is characterized by lower cut-off frequency and upper cut-off frequency or by centre frequency and frequency bandwidth

3.1.42
frequency hopping sequence
sequence of frequency channels used for transmission (hopping sequence) and dwell time

3.1.43
future expansion plan
possible installation of new wireless communication solutions and buildings that can affect coexistence

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3.1.44
general plant characteristics
parameters that characterize the plant in general with respect to all wireless communication applications

3.1.45
geographical dimension of the plant
length, width and height of the intended space of the wireless system

3.1.46
geolocation capability
capability of equipment to determine its geographical location

3.1.47
industrial, scientific and medical application
operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.15] [12]

3.1.48
industrial communication network
data communications sub-systems for industrial-process measurement and control as well as on instrumentation systems used for research, development or testing purposes

3.1.49
infrastructure device
device that is essential for building up a wireless communication system according to a technology or standard, but not having an interface to an automation application

EXAMPLE Router or base stations without interfaces to the wired industrial network or without automation application functions.

3.1.50
initiation of data transmission
method that specifies how the application initiates the data transfer

3.1.51
interference
radio frequency interference
effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a wireless communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.166, modified – Deleted leading "The" according to ISO/IEC Directives Part 2] [12]

3.1.52
interference type
kind of unwanted energy caused by a certain source or application

Note 1 to entry: Examples of interference types are: an EMI source, an ISM application, or a non-industrial wireless application.

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3.1.53
intermodulation sensitivity
levels of out-of-band interfering signals that, when mixed in the receiver front-end, produce an in-band third order non-linearity product

3.1.54
intervisibility
property of a logical link that describes a possible influence on radio signal propagation by obstruction, refraction or reflection

EXAMPLE Line of Sight (LOS), Non Line of Sight (NLOS) and Obstructed Line of Sight (OLOS) between those devices are possible parameters.

3.1.55
immunity
ability of an item to continue operating properly in the event of an interference, up to a certain level of interference, and to be resilient above this level

Note 1 to entry: Immunity of an item is achieved by adding to the robustness of the item the ability to be resilient to interference.

3.1.56
jitter
time variation of an expected occurrence

Note 1 to entry: Examples are variation of transmission time and update time.

3.1.57
length of user data per transfer interval
number of the octets sent out during a transfer interval, where the octets that are added because of the requirements of the wireless communication protocol are subtracted

Note 1 to entry: The application data length affects the communication load and might account for the temporal separation of the wireless communication systems.

3.1.58
life-cycle
length of time from the start of the development phase of a product type to the product abandonment

[SOURCE: IEC 62890:2020, 3.1.22] [14]

3.1.59
limitation from neighbours of the plant
description of the neighbours of the plant that are likely to cause limitations for wireless communication

EXAMPLE High power radio source(s).

3.1.60
linear topology
linear network topology
topology where the nodes are connected in series, with two nodes connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

Note 1 to entry: This topology corresponds to that of an open ring.

[SOURCE: IEC 61918:2018, 3.1.51, modified – Added an admitted term.] [15]

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3.1.61
line of sight
LOS
path of propagation of a radio frequency (RF) signal that is not obscured (partially or completely) by obstacles

3.1.62
logical link
application oriented communication relationship which enables the transmission of user data between one logical end point of the reference interface in a source device and one logical end point of the reference interface in a target device

3.1.63
lower cut-off frequency
frequency furthest below the frequency of maximum power where the power spectral density drops below a certain level

3.1.64
maximum number of retransmissions
upper limit of how many times the communication stack is allowed to retransmit user data automatically because of transmission errors

3.1.65
mechanism for adaptivity
measures to modify one or more of the systems operational parameters in order to improve the systems robustness against interferences and to minimize the medium utilization

3.1.66
medium access control mechanism
transmission technique for how to access the medium

Note 1 to entry: Examples are CSMA, TDMA, or combination of both.

3.1.67
medium utilization factor
measure to quantify the amount of resources (power and time) used by non-adaptive equipment

3.1.68
message
ordered series of octets intended to convey information

Note 1 to entry: During the transport of the conveyed information, the octets can be split in various packets.

[SOURCE: ISO/IEC 2382-16:1996, 16.02.01, modified – Replaced "sequence of characters" by "series of octets", Note to entry added.] [16]

3.1.69
message loss ratio
ratio of number of messages, transferred from the application at the reference interface within the producer, and the number of messages, transferred at the reference interface to the application within the consumer

3.1.70
mesh topology
mesh network topology
network topology in which redundant physically-diverse routing paths are available between each pair of network nodes

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Note 1 to entry: Wireless mesh topology is usable to extend coverage via multi-hop capability and/or to facilitate communication reliability by providing redundant paths between devices.

[SOURCE: IEC 62734:2014, 3.1.2.95, modified – Added an admitted term.] [3]

3.1.71
modulation
process of varying one or more properties of a periodic waveform with a modulating signal that contains information to be transmitted

3.1.72
natural environmental condition
condition that surrounds the wireless device and wireless system

Note 1 to entry: Examples are temperature, humidity, air pressure.

3.1.73
network
all of the media, connectors, repeaters, routers, gateways and associated node communication elements by which a given set of communicating devices are interconnected

[SOURCE: IEC 61158-2:~~2014~~2023, 3.1.30] [17]

3.1.74
network topology
topology of a network
pattern of the relative positions and interconnections of the individual elements of the network

[SOURCE: IEC 61918:2018, 3.1.81, modified – Deleted the "Note 1 to entry" and added an admitted term.] [15]

3.1.75
node
addressable logical or physical device attached to the network

[SOURCE: IEC 62591:2016, 3.2.75] [1]

3.1.76
non line of sight
NLOS
path of propagation of a radio frequency (RF) signal that is obscured (partially or completely) by obstacles, thus making it difficult for the radio signal to pass through

Note 1 to entry: Common obstacles between radio transmitters and radio receivers are tall buildings, trees, physical landscape and high-voltage power conductors. While some obstacles absorb and others reflect the radio signal, they all limit the transmission ability of signals.

3.1.77
number of consecutive lost messages
counted value of not correct received messages between two successfully received messages

3.1.78
obstructed line of sight
OLOS
~~obstacles that intrude into the first Fresnel zone but do not block the LOS path, it is the constructive or destructive interference from the reflected wavefront that is of concern~~

path of propagation of a radio frequency (RF) signal that is obscured (partially or completely) by obstacles, thus making it difficult for the radio signal to pass through

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Note 1 to entry: An intrusion into the inner most area of the first Fresnel zone will result in a decrease or fading of the received signal level. At the point where the obstruction becomes tangent to the LOS path, signal losses will be as much as 6 dB or more. Best practice is to maintain at least 60 % of the first Fresnel zone radius free of obstructions to avoid fading of the received signal.

3.1.79
operating time between failures
sum of the operating time periods between two successive failures on a logical link where the message is considered as a repairable item in the sense that a message can be repeated within the survival time

3.1.80
other frequency user
user which generates and uses radio energy without having the objective of telecommunication

Note 1 to entry: Examples are welding machine, electrical drive and frequency converter.

3.1.81
out-of-band emission
emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.144] [12]

3.1.82
object movement
specification of the trajectory of mobile assets that can significantly influence the radio propagation conditions

Note 1 to entry: Examples for mobile objects are vehicles, cranes or persons.

3.1.83
observation time
duration of the supervision of events

Note 1 to entry: Examples are the reception of user data or the use of a transmission medium by a wireless device. For them the observation time is the reference parameter to calculate the data rate and the duty cycle.

3.1.84
packet
formatted, aggregated bits that are transmitted together in time across the physical medium

[SOURCE: IEC 62591:2016, 3.2.77] [1]

3.1.85
passive environmental influence
influence on the signal propagation through the characteristic of the area of operation, the dimension of the space of operation, the intervisibility, mobile objects and natural environmental conditions

3.1.86
performance requirements
requirements describing the time and error behaviour necessary to achieve the purpose of the automation application

3.1.87
physical link
relation between radio transceivers (physical end points) of two wireless devices

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3.1.88
plant
managed facility, typically with a physically protected perimeter, hosting the physical process, operation, personnel, equipment

3.1.89
point-to-point topology
point-to-point network topology
topology where two nodes are directly connected to each other

3.1.90
position of wireless device
geographical position of the three-dimensional space in absolute or relative coordinates where the device is located

3.1.91
power spectral density
distribution as a function of frequency of the power per unit bandwidth of the spectral components of a signal or a noise having a continuous spectrum and a finite mean power

[SOURCE: IEC 60050-713:1998, 713-09-12 modified – Deleted the admitted term and the abbreviation.] [18]

3.1.92
purpose of the automation application
summary of the automation application supported by the wireless system to the extent needed to provide a useful overview of the requirements imposed on the wireless system

3.1.93
radio channel
~~model considers~~ radio propagation model that takes into account the characteristic of the frequency channel, the environmental conditions, the distance between the wireless devices, the antenna characteristic

3.1.94
radio environment
~~represents~~ surroundings for the ~~transmission medium~~ radio signal propagation with its passive environmental influences and active environmental influences

3.1.95
radio resource
means used by multiple wireless communication solutions for the purpose of radio signal transmission

3.1.96
radio robustness
attribute of wireless communication to fulfil the designated function despite the presence of other active wireless applications interfering in the sphere of influence

Note 1 to entry: This term has the same meaning as the definition of the term coexistence in IEEE 802.15.2:2003, 3.1.2 [11].

3.1.97
received signal strength indication
relative number for the field strength at the receiver of wireless devices, depending on the respective implementation of a radio technology

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3.1.98
receiver blocking
effect of a strong interfering signal on the receiver's ability to detect a low-level wanted signal

3.1.99
receiver maximum input level
maximum signal power that the system can tolerate without distortion of the signal

3.1.100
receiver sensitivity
minimal signal power to receive data with a defined bit error ratio

3.1.101
reference interface
exposed interface between an automation application and the wireless communication function

Note 1 to entry: There is no consistently defined interface for measurement and automation. The interface of the device might be a serial or a parallel hardware interface, a fieldbus interface, a software interface, or serial, parallel, discrete, and analog interface.

3.1.102
regional radio regulation
regulation of important coexistence parameters such as frequency band and output power related to the region where the wireless application is intended to be used

3.1.103
relative movement
position of a wireless device over time

3.1.104
requirements influencing the characteristic of wireless solutions
application communication requirements that influence the performance of wireless solutions and thus the coexistence state

3.1.105
response time
time interval between the instant delivery of the first user data bit, or octet, of a message to the reference interface of a transmitter, and the instant when the last bit, or octet, of the confirmation message is delivered at the reference interface of the same transmitter, which can be assigned to the request

3.1.106
ring topology
ring network topology
active network where each node is connected in series to two other nodes

[SOURCE: IEC 61918:2018, 3.1.71, modified – Changed "ring" to "ring topology" and added an admitted term.] [15]

3.1.107
robustness
ability of an item to continue operating properly in the event of an interference, up to a certain level of the interference

Note 1 to entry: The robustness of an item ~~may~~ can be increased with measures that modify one or more of its operational parameters.

3.1.108
security level
requirement category for cyber security

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3.1.109
spatial extent of the application
cuboid defined by the positions and/or the maximum movement radius of the automation devices of a distributed automation system

3.1.110
shared medium
resource of frequency band in particular area shared by several wireless applications

Note 1 to entry: In the industrial, scientific and medical (ISM)-bands, many wireless applications are used. Due to this joint use, the term shared medium is used in this document. The frequency bands are used by diverse ISM applications and wireless communication applications.

3.1.111
signal-to-interference and noise ratio
quotient of the strength of the wanted signal and the strength of the unwanted signals, consisting of noise and interference

3.1.112
spatial coverage of the wireless communication system
spatial coverage specified by length, width and height of a cuboid that encloses the wireless communication system

3.1.113
spurious emission
emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which ~~may~~ can be reduced without affecting the corresponding transmission of information, including harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.145] [12]

3.1.114
spurious response
receiver output due to unwanted signals

Note 1 to entry: That means having frequencies other than those of the tuned frequency channel.

3.1.115
star topology
star network topology
network of three or more devices topology where all devices are connected to a central device

[SOURCE: IEC 61918:2018, 3.1.77, modified – "topology" has been added, "point (which may be active or passive)" has been replaced by "device", and an admitted term has been added] [15]

3.1.116
survival time
time that an application, consuming a communication service, continues without receiving an anticipated message

3.1.117
telecommunication
any transmission, emission or reception of signs, signals, writings, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.3] [12]

3.1.118
total radiated power
spatial power density integrated across the surface of the sphere

3.1.119
transfer interval
time difference between two consecutive transfers of user data from the automation application via the reference interface to the wireless communication function

3.1.120
transmission gap
gap between two successive channel usages by a transmitter

3.1.121
~~**transmission**~~ **transmitter output power**
total radiated power reduced by losses between the transmitter output and the antenna

3.1.122
transmission time
interval from starting the delivery of the first application data octet of a message to the reference communication interface of a producer until the delivery of the last application data octet of the same message from the reference communication interface of a consumer

3.1.123
transmitter sequence
time that a transmitter uses a frequency channel without the possibility to be interrupted by a wireless device of the same system

3.1.124
transmitter spectral mask
envelope of maximum values of power spectral density over a frequency range

3.1.125
tree topology
tree network topology
network topology where all nodes are connected in a combination of a linear and a star topology

3.1.126
update time
interval from the delivery of the last user data octet of the message of a producer, from the reference interface of a consumer to the automation application, until the delivery of the last user data byte of the following message of the same producer

3.1.127
upper cut-off frequency
frequency furthest above the frequency of maximum power where the power spectral density drops below a certain level

3.1.128
wireless application
any use of electromagnetic waves with devices or equipment for the generation and use of radio energy using radio environment with active and passive environmental influences

Note 1 to entry: The definition includes wireless communication systems with wireless communication functions representing a set of spatially distributed automation functions, distributed automation system with local functions and physical system with physical system functions.

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Note 2 to entry: The definition includes radio determination equipment.

3.1.129
wireless communication
communication in which electromagnetic radiations are used to transfer information without the use of wires or optical fibers

3.1.130
wireless communication application
part of an industrial automation application that uses wireless communication

3.1.131
wireless communication solution
parameters of wireless communication solutions which are implementations of wireless communication systems and devices

3.1.132
wireless communication solution density
ratio of the number of wireless communication solutions and the spatial coverage of the plant

3.1.133
wireless communication system
set of wireless communication devices, infrastructure devices and physical links communicating using radio frequencies using various topologies

3.1.134
wireless device
wireless automation device
equipment of wireless communication applications that uses radio waves for wireless communication with other equipment of wireless communication applications

3.1.135
wireless device density
number of wireless devices within the spatial coverage of the wireless communication system

3.1.136
wireless device receiver parameters
wireless receiver parameters
specification of wireless receiver characteristics

3.1.137
wireless device solution
parameters related to individual nodes within a system implementing a wireless communication solution

3.1.138
wireless device transmitter parameters
wireless transmitter parameters
specification of wireless transmitter characteristics

3.1.139
wireless device type
specification of a device according to the catalogue data

3.1.140
wireless network
wireless communication network
network consisting of at least two wireless devices that established wireless communication

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3.1.141
wireless network solution
parameters related to a network as a whole used implementing a wireless communication solution

3.1.142
wireless solution
wireless communication solution
specific implementation or instance of a wireless communication system

Note 1 to entry: A wireless solution ~~may~~ can be composed of products of one or more producers.

3.1.143
wireless system
wireless communication system
set of interrelated elements providing wireless communication

Note 1 to entry: A wireless system is a high-level representation of a system, while a wireless solution is a practical instance of a system.

3.1.144
wireless system type
parameters describing the kind of wireless communication system

3.1.145
wireless system type and wireless device type
parameters that characterize the model of a wireless system or a wireless device by providing the parameters to specify a wireless system type and a wireless device type

3.1.146
wireless technology or standard
naming the wireless technology or standard

EXAMPLE Examples of standards specifying a wireless communication system are IEC 62591 [1], IEC 62601 [2] and IEC 62734 [3].

3.2 Abbreviated terms

AFH adaptive frequency hopping
BFWA broadband fixed wireless access
CEPT European conference of postal and telecommunications administrations
CP communication profile according to IEC 61784-2 series [6]
CSMA carrier sense multiple access
DAA detect and avoid
DAR detect and reduce
DAS detect and suppress
~~DECT Digital enhanced cordless telecommunications~~
ECO European communications office (the electronic communications committee of CEPT)
EIRP equivalent isotropic radiated power
EMC electromagnetic compatibility
EMI electromagnetic interference
ERP effective radiated power
~~GSM Global system for mobile communications~~
IF intermediate frequency

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IP Internet protocol
ISM industrial, scientific and medical
IT information technology
ITU International telecommunication union
LAN local area network
LOS line of sight
~~MAC Medium access control~~
MLR message loss ratio
NLOS non line of sight
N/A not applicable
OLOS obstructed line of sight
PCB printed circuit board
~~PHY Physical layer~~
PSD power spectral density
RF radio frequency
RFID radio frequency identification
RSRP reference signal received power
RSRQ reference signal received quality
RSSI received signal strength indication
SIR signal-to-interference ratio
TDMA time division multiple access
TRP total radiated power
~~UMTS Universal mobile telecommunications system~~
WD wireless device
WIA-PA wireless network for industrial automation – process automation
WLAN wireless local area network
ZVEI Zentralverband Elektrotechnik- und Elektronikindustrie e.V.; the german electrical and electronic manufacturers' association

3.3 Conventions

NOTE The graphical representations of flow charts in figures are based on ISO 5807 [19].

The following conventions for the coexistence management parameter templates in Clause 8 apply:

- The column "Parameter" uses indentations to cluster certain parameters. The parameters that are more to the right belong to the parameter above that is more left.
- The column "Usage" specifies whether the parameter is mandatory, optional, or selection, if one out of several parameters is selected.
- The item "Value" can contain a range or a list of values if the parameters allow multiple options. If a parameter does not have a unit, then the item "Unit" shall be marked with not applicable (N/A).

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4 Coexistence concept in industrial automation

4.1 Overview

Wireless communication allows industrial processes to be implemented more cost-efficiently, flexibly and reliably, as well as allowing the use of new automation concepts. Industrial automation applications usually place stricter requirements on reliability and real-time capability of wireless communication than applications in the domestic and office domain. Industrial automation applications can also reside in industrial facilities with higher ambient electromagnetic interference (EMI) levels than those in non-industrial domains.

Additional sources of radio emissions will also need to be taken into account during coexistence management.

NOTE In some industrial environments, other sources of radio emissions can be present within the same bands as used by the wireless communications systems. These emitters can include devices with unintentional emissions, such as high-power welding devices which generate wideband electromagnetic energy.

Because of those requirements, different wireless systems are used. It is quite likely that several wireless systems ~~may~~ can operate simultaneously in one place. Since these wireless systems share a common medium, interferences can be assumed throughout their life-cycles. This impacts system performance including reliability and its ability to meet real-time response requirements. This document is intended to help identify potential risks and to recommend measures to control these risks, depending on the requirements of the industrial automation application. This document also illustrates that most often the coexistence of several wireless systems and simultaneously the efficient handling of the frequency spectrum as a limited resource is feasible if an appropriate approach is chosen, taking into account the respective requirements. In order to achieve this, a process is needed in which all aspects of the coexistence of wireless systems during design, commissioning, and operation, as well as maintenance, are considered. This process, called coexistence management of wireless solutions, is the subject of this document. Associated actions and decisions serve to comply with the claimed limit values for the application over the whole life-cycle of the plant.

This process can be more or less complex, depending on the relevance of the requirements related to the wireless communication for the plant. This complexity depends, among other aspects, on the characteristics of the wireless communication application served by each wireless solution (for example control with strict real time requirements), the number and location of the wireless solutions that can potentially interfere with each other, and the presence of any other radio emitters in the same bands.

If no, or just modest, requirements are made on the wireless system, a lower effort for the coexistence of wireless solutions will be necessary than in the case of a wireless system that is part of a control application with strict real-time requirements. However, it is strongly recommended to consider that additional wireless systems ~~might~~ could be implemented later or that the requirements on the present wireless system might change in the future (for example due to additional applications). The plant design shall ensure that the applied coexistence measures match the requirements of the wireless system.

The state of coexistence is characterized by meeting the limit values of relevant parameters for all wireless communication applications in the considered area. This state of coexistence is accomplished with appropriate actions in planning and in operation. This clarifies that coexistence is not a static attribute of a wireless solution, but rather a state within the life-cycle of a plant. It is possible to leave this state temporarily or permanently due to certain events. The parameter limit values are determined by the automation application in which the wireless communication takes place. This also implies that the coexistence management shall be evaluated and established contextually and in full accordance with the automation application.

From a general point of view, coexistence of two or more wireless solutions can be achieved by making orthogonal the transmissions that come from different sources.

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There are three possibilities to manage coexistence, where a) means a higher amount of labor hours to establish and maintain the coexistence management and b) and c) means an increasing level of automation:

a) manual coexistence management (lowest level);

a) automated non-collaborative coexistence management;

b) automated collaborative coexistence management (highest level).

Automated techniques, and the algorithms on which they are based, are usually classified into two broad categories: collaborative and non-collaborative.

4.2 Objective

This document is focused on measures to provide coexistence of wireless systems for measurement and automation applications. These industrial automation applications can be classified in various ways. For example, in Table 1 they are classified according to the degree of the application criticality. Efforts for coexistence management can vary according to the classification described in Table 1.

Table 1 – Example of a classification of application communication requirements

Class	Application	Application communication requirements
Functional safety	Implementation of a safety-related system whose failure could have an impact on the safety of persons and/or the environment and/or the plant	The communication protocol should support functional safety communication and the coexistence management shall be established in order to fulfil all requirements of this document.
Control	Closed or open loop control	The communication protocol should support a higher availability, reliability, and time-criticality protocol than the one used for other application domains like consumer industry or telecommunication. The coexistence management shall be established in order to fulfil most of the requirements of this document.
Monitoring	Process visualization and alerting	No specific add-ons required for the communication protocol. Typically, monitoring application can be satisfied by a relaxed set of requirements. The coexistence management shall be established in order to fulfil these minimum requirements.
NOTE The relative terms "most" and "minimum" are based on the graphical description in Figure 3.		

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The classification of automation applications provided with Table 1 refers to the functional requirements of the process industry application to be satisfied. This classification can also be adapted in other application domains.

However, the determination of the criticality and the associated application communication requirements shall be determined on a case-by-case basis by the coexistence manager.

NOTE 1 Application communication requirements are described in IEC 62657-1.

Applications ranging from radio bar code readers to voice and video over IP applications can be classified likewise and can be dealt with according to this document.

The applicability of this document is not confined to a specific frequency band, for example the 2,4 GHz ISM band. Both concurrent communication systems and other approved wireless applications, such as microwave systems for drying or plastics welding, are considered as

interferences. Moreover, further interferences might occur due to powerful low frequency electromagnetic fields (for example transformers, powerful motors or other electromagnetic interferences (EMI), see Figure 1). The interference sources to be considered are detailed in 4.4.

NOTE 2 The analysis of EMI is outside of scope of this document but has been considered.

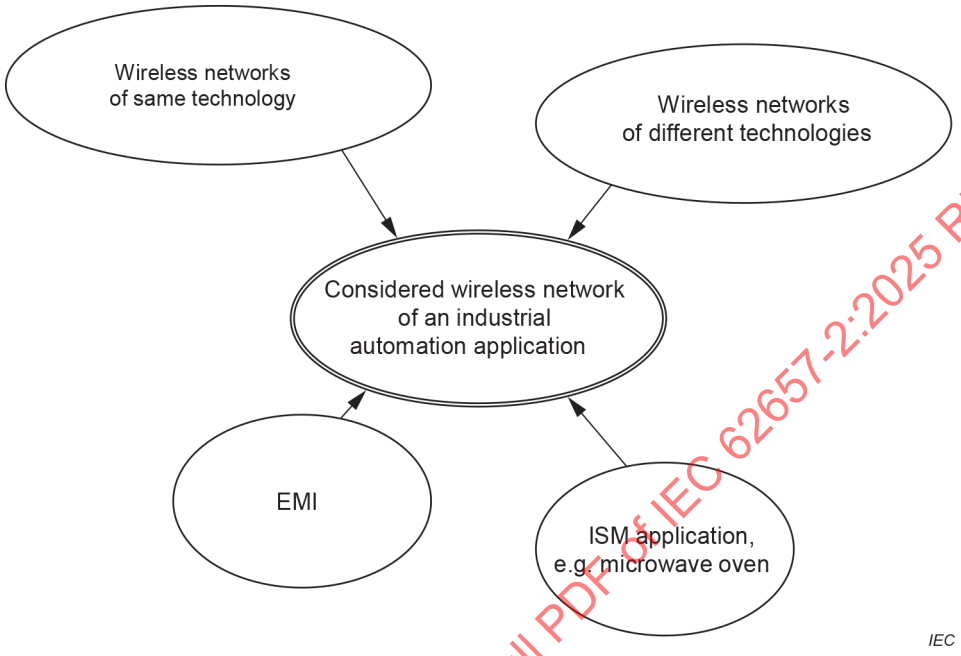

Figure 1 – Issues of consideration

In Figure 2, the relation between industrial automation application, wireless communication application, EMI, industrial, scientific and medical (ISM) application and non-industrial wireless application is depicted. Wireless application is used as generic term for wireless communication application, ISM application and non-industrial wireless communication (grey in Figure 2). Wireless communication applications are parts of an automation application. Other parts of automation applications may use ISM spectrum e.g. for welding processes. Furthermore, equipment of industrial automation applications can be source of electromagnetic interference (EMI). In addition, non-industrial wireless applications (e.g. smart phones or laptops) may use the spectrum in an industrial environment.

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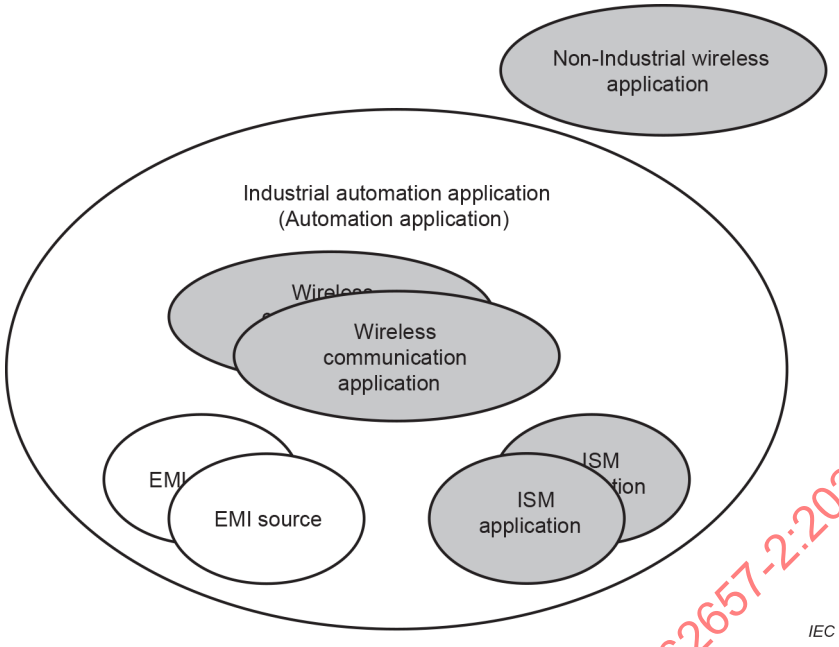

Figure 2 – Applications using frequency spectrum

This document is aimed at addressing coexistence management at the location of an enterprise; however, the manager shall take into consideration the fact that some interference could come from outside the location of the plant. The manager shall identify and characterize potential external radio energy sources and their distance from the enterprise. Controls should be in place to ensure that unauthorized or unaccounted mobile sources are not allowed in the enterprise area.

It is assumed that, in conditions without interference, a wireless communication system basically meets the requirements of the wireless automation application and that, in particular, the limit values for time and error behaviour are taken into account by planning the communication requirements.

The measures described here are to ensure the required performance even in the presence of other wireless applications.

4.3 Necessity to implement a coexistence management

The frequency spectrum is a valuable limited resource which will be rapidly exhausted in the case of unmanaged use.

The following list shows an example of wireless devices to be found in industrial environments:

- wireless sensors and actuators;
- WLAN access points and clients;
- mobile panels;
- RFID devices and RFID readers.

There are also devices which can emit radiated power in the same bands as the wireless devices:

- radio-frequency process heating;
- plastic welding;
- plasma lamps;

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- general welding; and
- other devices.

There is a high risk of interference whereby, under certain conditions, the assumed availability and performance requirements cannot be observed. In order to avoid this, or rather to reduce the risk of interference, a company-wide process for the administration of wireless applications for all parties involved is strongly recommended, and if adopted, shall be implemented according to this document. Coexistence management is an intra-company process which should be adjusted to the structure and the internal processes of the enterprise. In each individual company, the structure and the processes can be organized differently.

Moreover, the focus in defining the process or its sub-steps can vary according to the user groups concerned:

- wireless communication applications with a high data throughput, but relaxed real-time requirements: the coexistence management puts the focus on the provision of ~~adequate~~ frequency bandwidth meeting the application requirements;
- wireless communication applications without specific requirements for performance and real-time: the coexistence management aims at ensuring the spatial coverage;
- wireless communication applications with strict real-time requirements: the coexistence management safeguards against functional problems caused by the influence of other wireless applications (application classes Functional Safety or Control).

In addition, the following basic measures to implement coexistence management are recommended:

- nomination of a company-wide coexistence manager;
- nomination of a location-specific coexistence manager if the company has several facilities;
- establishment of a committee, consisting of contact persons of all company divisions using wireless applications (task of the committee should be the issues shown in Figure 1 and Figure 2);
- inventory of all installed and, if possible, all planned wireless applications including wireless communication;
- establishment of a policy to register new wireless applications or solutions and for the identification of existing ones;
- coordination and adoption of decisions regarding the approval and application of wireless systems within the committee;
- establishment of a policy and enforceable consequences for non-authorized introduction of new wireless applications or solutions.

Effective coexistence management is a concerted process with representation of all company divisions concerned (sub-divisions, departments, technologies). The divisions concerned are those involved in planning, procurement, installation, commissioning, operation and maintenance of wireless applications, for example process planning, IT, automation, plant operation (production), development, purchasing, facility management.

Coexistence management offers various benefits:

- reduction or elimination of interferences leading to unplanned downtimes;
- reduction or elimination of laborious, cost-intensive and time-consuming fault troubleshooting;
- reduction or elimination of disinvestments in wireless solutions that cannot be operated in the present radio environment of the enterprise.

NOTE The term 'wireless solution' is used here instead of the term 'wireless system' because it takes into account the distinct attributes of a product that are important for the coexistence management.

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4.4 Interference potential

For wireless communication applications, interference will occur at a point in space (corresponding to an antenna location, received energy, antenna characteristics and polarization) if the received signals:

- overlap in the frequency domain;
- overlap in the time domain; and
- overlap in coding.

NOTE 1 In the case of buildings and areas close to airports, harbors, transmitter masts and other places of powerful wireless systems, the interference potential is extremely high.

This leads to interferences between wireless solutions with the consequence of lost packets so that, for example, a transferred packet ~~has~~ needs to be repeated. The system reaction to the described interference depends on several factors, for example on the wireless standard, on the hardware and software implementation or on the application class (see Table 1) the wireless system uses for transfer.

The separation of non-overlapping frequency channels is a method to achieve coexistence. However, there might be interference between wireless systems using different channels in the same frequency band, for example because of adjacent channel interference. This is called cross-channel interference. In particular, analog wireless systems hold a high interference potential for digital wireless systems due to their high channel occupation.

Moreover, wireless systems using different frequency bands ~~may~~ can interfere with each other. Beneath the main signal, a wireless system also emits outer band signals that might penetrate the frequency channel of the endangered wireless system, thus affecting the wanted signal.

The received signal quality at a receiver as a function of interference by other wireless systems is typically measured by the signal-to-interference ratio (SIR), which is the ratio of the power of the wanted signal to the total residual power of the unwanted signals. The receiver can correctly interpret incoming data only if the SIR is above a given threshold.

The value of the threshold depends on the adopted modulation, while the actual SIR value depends on the superposition of interferers with respect to the intentional communication in the following two domains: time and frequency.

Different performances can be obtained if superposition (that means interference) in these domains is complete or only partial.

For the time domain, since the traffic of victim and interferer(s) wireless system(s) ~~may~~ can change each time, the SIR evaluation should be preceded by the definition of a time interval in which the interference is constant.

For the frequency domain, the SIR evaluation should consider at least the combined effect of interfering transmitter(s) and receiver victim spectral masks. In fact, the interfering transmitter(s) can have spurious emission even outside the adopted frequency channel. On the other hand, the receiver blocking mask can reject the interferer(s) signal(s), mitigating its effect.

In order to foresee/estimate the effect of interferers, it is possible to use analytical models, simulations and experimental test beds. These three approaches have different (increasing) complexity and hence different (increasing) accuracy.

In order to assess whether there is a risk of interference or not, an interference risk should always be assumed if wireless applications are operating in parallel in the same frequency band without proof of their radio robustness.

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NOTE 2 This term wireless application is more comprehensive than the term wireless system, because in wireless applications, the radiated power is not only used for information transfer.

NOTE 3 The use of the electromagnetic energy can be either intentional (as needed to serve the specific application) or unintentional/accidental.

However, an interference risk does not mean that parallel operation of competing wireless systems is unfeasible. They can co-exist if the requirements on the wireless solutions involved are met. This criterion should be taken as a basis for decisions regarding the application of wireless systems.

If possible, future changes in the requirements, implicating changes of the interference potential, should also be considered. In industrial automation, the life-cycle of a wireless solution typically lasts more than 5 years. During this time, new applications for the existing wireless system can be developed and deployed. Determination, coordination and control of these changes are part of coexistence management.

One more influence is radiated EMI. In particular, regional regulations can allow significant radiated power for specific wireless applications in unlicensed spectrum, potentially generating a high field strength in the proximity of a wireless system.

A wireless solution shows a certain interference resistance against those radiated interferences. This limit value can be exceeded by the signal of a powerful wireless application.

EXAMPLE RFID applications in Europe are allowed to use 4 W in the 2,4 GHz band whereas other short-range devices are limited to 100 mW.

Even though wireless solutions often hold a higher interference resistance than normatively claimed, and exceeding the limit value does not always result in harmful interference, the design of the wireless solutions shall be such that the noise level at the receiver does not exceed this limit value. Interferences from the same frequency band are much more likely than from other frequency bands. Nevertheless, the interference potentials from other frequency bands also shall be taken into account.

EMI caused by defective devices and exceeding the normal operating limits should not influence the coexistence management. The defective device should instead be repaired to return to normal operating conditions.

4.5 Ancillary conditions

For wireless communication, there are only limited communication resources available, thus thorough planning is required. The higher the requirements of the application class on the wireless system, as to time behaviour, availability, dimension and others, the higher is the technical and organizational effort required to guarantee coexistence. The costs rise disproportionately as shown in Figure 3. A certain span of expense results from the complexity of the wireless network solutions (for example, simple point-to-point link or linear-, ring-, star-, cellular-, tree-, mesh- topology ~~network~~) and from the number of influencing factors to be considered (for example medium load, transmitter power). The span between the two curves moves upwards the more efficiently the spectrum is used. This applies to both:

- the expenses for the coexistence management in the coexistence planning phase; and
- the costs of developing appropriate wireless solutions.

The bold arrow in Figure 3 shows that the curves will go higher as the coexistence management efforts increase to gain a higher efficient use of the spectrum.

The effort might be reduced by strategic regulations for coexistence management. A possible regulation is to confine the number of considered influencing factors, for example by exclusive assignment of frequencies to specific wireless applications. It is essential to take into account that strategic decisions in the coexistence planning phase have effects on the future expenditures and therewith on the life-cycle costs of the plant. The technical and organizational

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expenses for coexistence management in the operating phase can multiply the coexistence planning costs throughout the life-cycle of a plant.

It is therefore important to analyze whether the requirements of the planned application fit the intended application requirements. In relaxing the requirements, a more efficient use of the resource can be achieved. If the resource is exhausted, other solutions will need to be found.

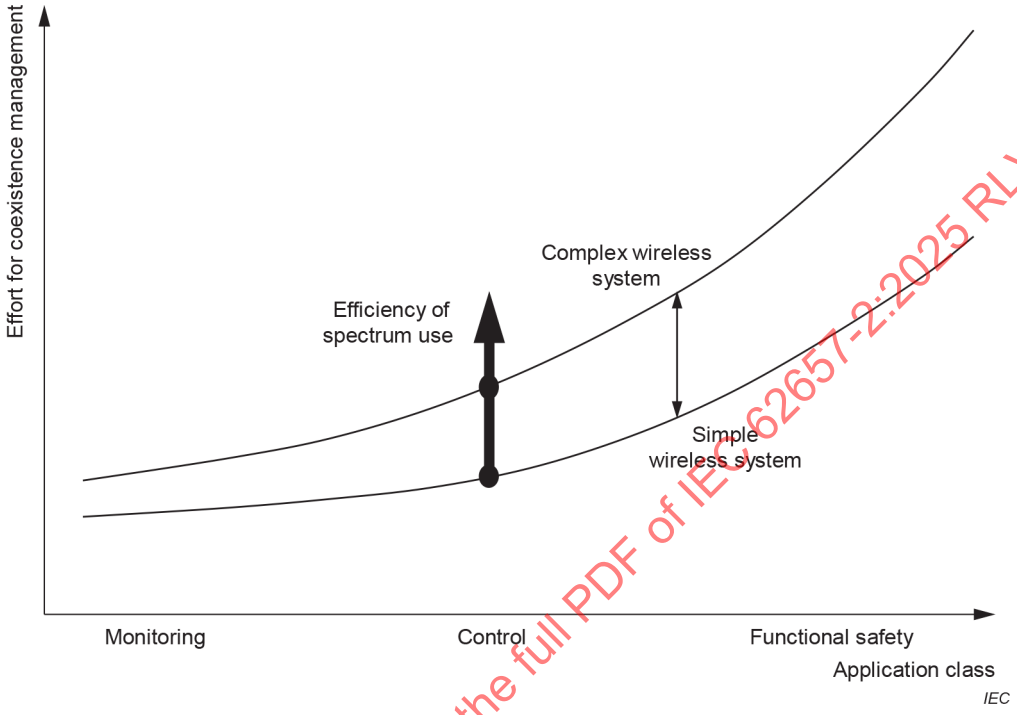

Figure 3 – Progression of expense to achieve coexistence corresponding to the application classes

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4.6 Requirements to wireless devices for support of coexistence management

Wireless devices shall be capable to vary parameters that are specified in Clause 5 to achieve the coexistence management by reducing the interference potential as specified in 4.4.

EXAMPLE The device is so constructed that certain frequencies can be blocked; power can be adjusted to be below the threshold of the incumbent services/applications.

4.7 Concepts

4.7.1 Manual coexistence management

In the case of manual coexistence management, the coexistence manager (see 7.2.1) shall define a fixed planning of the wireless solutions intended to prevent transmission overlaps. The manager shall implement manual measures to react to modifications that change the wireless coexistence state. This is the simplest management method, especially if multiple wireless solutions of different technologies and from several vendors are involved, or if several frequency bands ~~have~~ need to be managed.

This method can be used if there are non-manageable radio emitters in the same bands as used by wireless solutions.

However, the manual coexistence management capabilities are limited if some coexistence management parameters cannot be configured.

4.7.2 Automated non-collaborative coexistence management

In automated non-collaborative coexistence management, the different wireless solutions are not capable of exchanging information. They are fully independent and rely only on interference detection and estimation. In other words, each offended wireless solution classifies the behaviour of the offending ones and tries consequently to adapt its own behaviour to the new estimated situation. For this reason, non-collaborative techniques are more general but less efficient than the collaborative ones. As an example, non-collaborative algorithms dynamically modify the communication strategies (for example the frequency band, the timeslot/packet scheduling, and so on) as a result of an assessment of the wireless application requirements versus the wireless application solution capable of establishing the required communication performance.

Such methods are being proposed to address coexistence in uncontrolled public areas, however such methods would not be effective for the management of industrial automation wireless devices which ~~have~~ need to meet performance requirements.

NOTE Some metrics are described in IEEE Std.802.15.2 [11].

4.7.3 Automated collaborative coexistence management

4.7.3.1 General

In automated collaborative coexistence management, the different wireless solutions shall be able to exchange characteristic parameters.

The precondition for collaborative coexistence management for wireless systems using multiple technologies provided by multiple vendors is that a common standardized communication link is available amongst these solutions. This link can either be:

- a pilot channel between the collaborative coexistence manager and the coordinated devices using a common standardized communication protocol and service set, as for example specified in IEC 62657-4, to make the task of the collaborative coexistence manager easy;
- a wireless solution of the coordinated devices that is also understood by the collaborative coexistence manager, which means that the collaborative coexistence manager shall talk the language of all the coordinated devices that participate in the automated collaborative coexistence management;
- a wired link between the coordinated devices and the collaborative coexistence manager using a common standardized communication protocol and service set.

An automated collaborative coexistence management could result in some restrictions on the adopted hardware since, for instance, collaborative methods are usually implemented by means of a centralized arbiter/scheduler. The exchanged information allows each offended wireless solution to effectively adapt its own behaviour to the real new situation, taking into account the requirements of its own application and the applications of the other wireless systems. These dynamic modifications could influence the determinism or reliability of the communication and can therefore be inappropriate for various wireless communication applications.

An example of such an automated collaborative coexistence management is a central coordination point (CCP), see IEC 62657-1:2017, 4.3.4.3. National, regional and regulatory aspects are also described there.

IEC 62657-3 provides the formal description of the automated coexistence management and application guidance.

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Three different application use cases for automated collaborative coexistence manager exist:

a) for sharing the same frequencies with other incumbent services/applications (see 4.7.3.2, 4.7.3.3 and 4.7.3.4);

b) for intra-system coexistence in a controlled environment;

c) for intra-system coexistence in a public area.

A possible approach of an automated collaborative coexistence management for industrial automation is specified in IEC 62657-4.

4.7.3.2 Simple CCP

A collaborative coexistence manager is responsible for detecting the primary users and identifying the devices which are coordinated. The CCP shall then inform the underlying coordinated devices that they shall react to fulfil the requested mitigation techniques of the primary user. No reconfiguration of the assigned frequencies is requested. Examples of how the coordinated devices could react are to lower the transmit power or stop transmission.

4.7.3.3 Intra-system CCP

All or at least most radio equipment in space is known with their dynamic requirements. It is assumed that the installed devices are static. Nomadic devices are known and as such seen as static in configuration, for example if they have geolocation capability. The collaborative coexistence manager is responsible for detecting primary users and for informing the underlying coordinated devices (incumbent services/applications) if they could interfere with primary users. The collaborative coexistence manager can decide whether the coordinated devices shall react to fulfil the requested mitigation techniques of the primary user, or the coexistence manager can assign different spectrum to the coordinated devices. Some additional alternatives could be that the collaborative coexistence manager organizes time synchronization or influences other parameters specified in 4.4.

4.7.3.4 Public CCP

All behaviours described in 4.7.1 and 4.7.2 as well as 4.7.3.2 and 4.7.3.3 could be supported. In addition, unknown devices can ask the collaborative coexistence manager to also be managed.

The coordinated coexistence management increases the spectrum efficiency and the quality of service.

4.8 Best practices to achieve coexistence

The establishment of coexistence is a combination of technical and/or organizational measures to ensure the correct operation of wireless communication applications in their environments. The main criteria in the selection of appropriate actions to achieve coexistence are effectiveness, feasibility, economic efficiency and the loss of performance acceptable for the application if the wireless solution ~~has~~ needs to share the medium with other wireless systems. Future developments of the wireless communication application in the enterprise should be considered here as well.

Technically, signals of wireless communication at a point in space (corresponding to an antenna location, received energy, antenna characteristics and polarization) can be separated by:

- frequency;
- time;
- coding.

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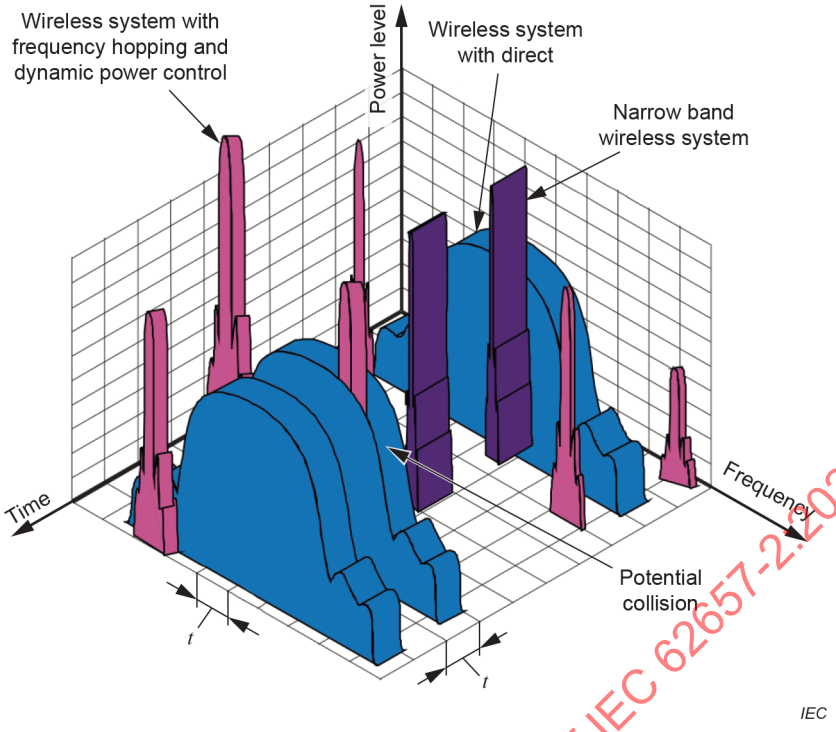

Figure 4 – Separation of wireless systems according to frequency and time

The separation in the frequency domain (see Figure 4) usually causes the least performance loss and initially the lowest expense. However, these measures occupy the medium to a great extent and should therefore be reserved for specific application classes used in the plant such as functional safety and control. A separation in time can be accomplished by configuring the communication request with respect to the application communication requirements.

For applications with a certain dynamic, the communication cycle should be set as long as possible and/or event driven communication should be used. Wireless technologies with automatic adaptive medium sharing mechanisms should also be used.

A spatial separation is rarely possible in the case of a wireless communication application. Radio propagation can only be restricted spatially with great efforts. Structural conditions (for example large steel reinforced concrete walls) and the reduction of the radiated power (by adjusting the output power of the radio transmitter and the choice of the antenna radiation pattern) can be used for spatial separation. For larger facilities, the control of power levels can be a viable approach. If the power is reduced, the power of all related wireless devices (for example base stations, repeaters, and end devices) should be adjusted accordingly.

If the transceivers have multiple antennas, then it would be possible to utilize spatial processing, such as interference rejection techniques, to separate simultaneous transmissions in space.

Separation via polarization involves the specific attribute of an antenna to subdue radio waves with an orthogonal polarization (cross polarization). For example, a horizontally polarized antenna of a signal receiver can attenuate a vertically polarized interference signal. However, inside buildings or in other highly reflective surroundings, the effects of a polarization separation are relatively small.

In addition, directional pillbox antennas or other emerging antenna concepts can be used to restrict the radio propagation within a certain area.

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The organizational measures apply to the operation of the wireless system and they have indirect implications for the uncoupling mechanism described in Figure 4. Hence the application of a wireless system can, for example, be restricted in space or time, or just services of a wireless solution meeting the coexistence requirements can be approved. The organizational measures (in particular those for wireless systems related to business process or safety) should evaluate in advance to what extent compliance with the specifications can be ensured and controlled.

Impact of the typically non-ideal radio propagation characteristics found in many industrial environments can impact the time and error behaviour of a wireless solution. Therefore, suitable allowances shall be made in the planning of wireless systems.

In the operation phase, investigation of mechanisms to enhance the agility of wireless communication applications against the appearance of unexpected interferences shall be considered, for example diversity techniques and cognitive radio medium access methods.

In order to define adequate measures and to evaluate their efficiency, the assistance of wireless experts is recommended.

4.9 Coexistence conceptual model

Figure 5 shows the coexistence conceptual model. ~~A wireless communication application (Automation application A) has application requirements to fulfil its intended tasks. Part of the wireless communication application A is the selected wireless system A. It has certain immunity against interference from other wireless communication systems and the utilization of its resources can interfere with other wireless communication systems.~~ In this example, three wireless communication applications (A, B and C) are assumed. According to the definition of wireless coexistence, all three wireless communication applications shall fulfill their application communication requirements. Each wireless communication system in a wireless communication application has certain immunity against interference from other wireless communication systems and the utilization of its resources can interfere with other wireless communication systems.

The conceptual model of coexistence can be seen as a closed loop control process. This process of coexistence management is not just one activity during the system planning; it is an iterative process throughout the entire life cycle of the system.

NOTE IEC 62890 provides more details about a life-cycle management.

An investigation of the requirements, the characteristics of the wireless communication systems and the medium utilization factor shall be reported in an inventory. According to the life cycle phase (see 7.4), the resulting coexistence planning or maintenance shall be carried out. This results in a current resource allocation plan, which shall be the basis for configuring or implementing the wireless communication applications.

The coexistence state is achieved if the robustness to interference in a wireless communication system is better than the interference produced by the resource, and if the wireless communication applications fulfill their application communication requirements.

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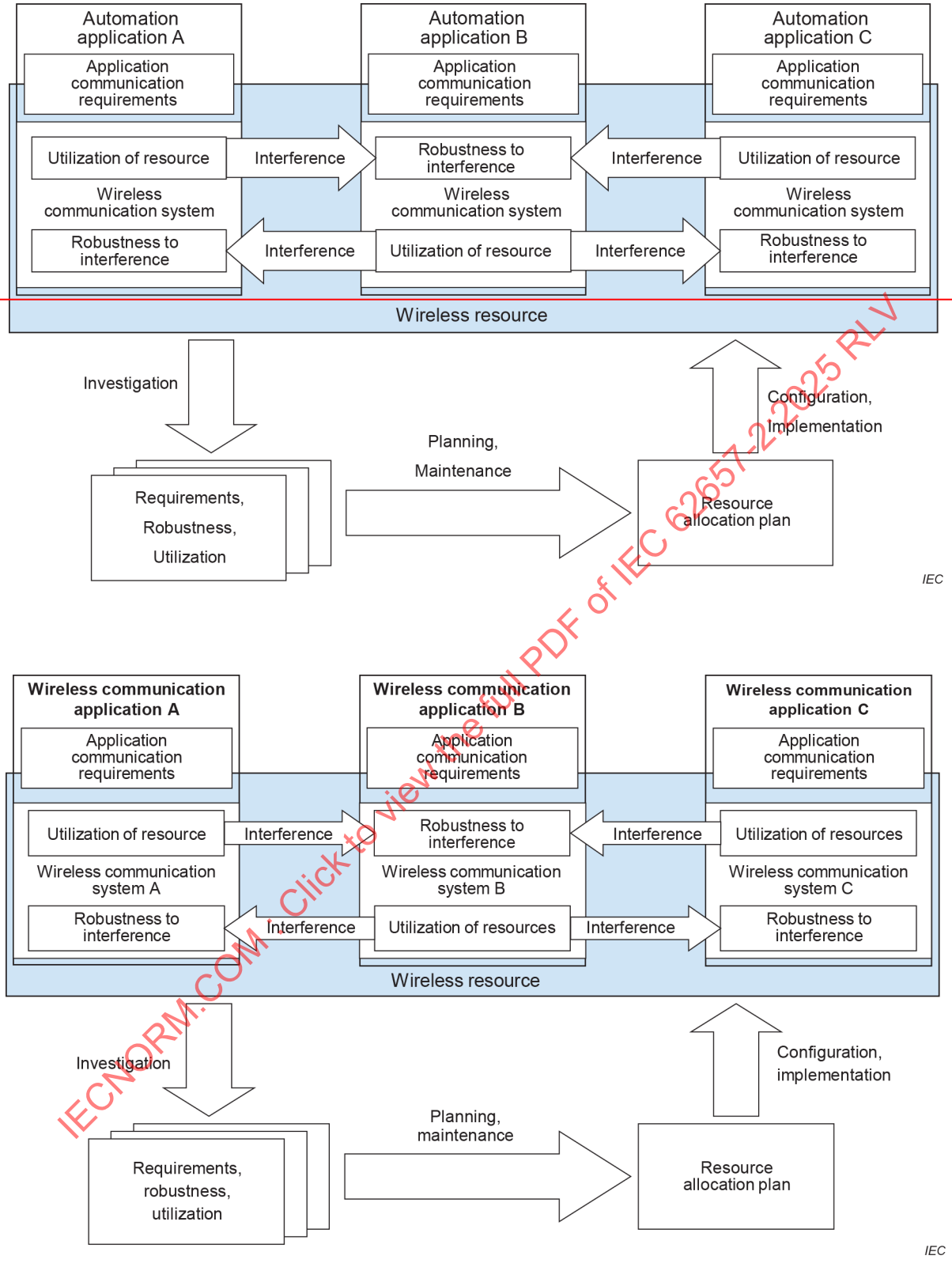

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Figure 5 – Coexistence conceptual model

Figure 6 shows some of the contents of Figure 5 as a flow chart to provide the relations to Figure 7, Figure 29 and Figure 30. The coexistence management system specification is shown in Figure 6 only at the start to keep the figure simple. The documentation shall be extended and updated at each phase. If the requirements of a certain phase are not fulfilled, then the process should restart from the beginning, see lines in Figure 6 going from the output of a phase to the return path. The documentation is specified in 7.1.2.

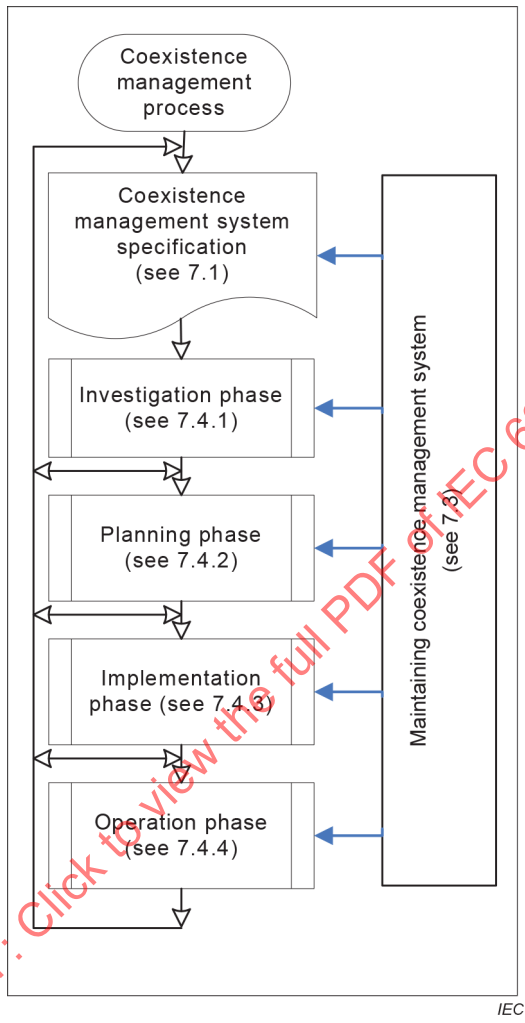

Figure 6 – Flow chart of the coexistence conceptual model

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4.10 Coexistence management and selection of a wireless solution

The starting point and precondition for the implementation phase is that the wireless solution is suitable for the requirements made on it. The investigation phase begins by reviewing the wireless system requirements and making a determination as to whether or not the system is able to fulfil application communication requirements. As part of this process, new wireless systems can be evaluated against application communication requirements. Figure 7 maps decisions and actions into the flowchart shown in Figure 6.

While investigating whether a wireless solution meets the requirements of an automation application, radio transmission shall be analyzed to see whether it is a reasonable approach when considering the efforts that are required to be taken to achieve coexistence. In this respect, the selection process of a wireless solution is already part of the coexistence management process.

The decision to install a wireless system shall be followed by the decision to implement a coexistence management process (see 6.8). The coexistence management process includes

coexistence planning, installation, operation and maintenance of wireless systems. The coexistence planning phase (see 7.4.2.2) begins with the inventory of all wireless applications, because they can be regarded as potential interferers (see 7.3).

In the coexistence planning phase, it might become apparent that a chosen wireless solution cannot be integrated into the existing plant. Another wireless solution might be chosen or the idea of a wireless system might be abandoned. If, in the coexisting planning phase, it is ensured that all wireless communication applications meet the respective requirements, the coexistence management process for the operating phase can be initiated (see 7.4.4).

NOTE 1 Processes in the planning phase and in the operating phase are specified in more detail later in this document.

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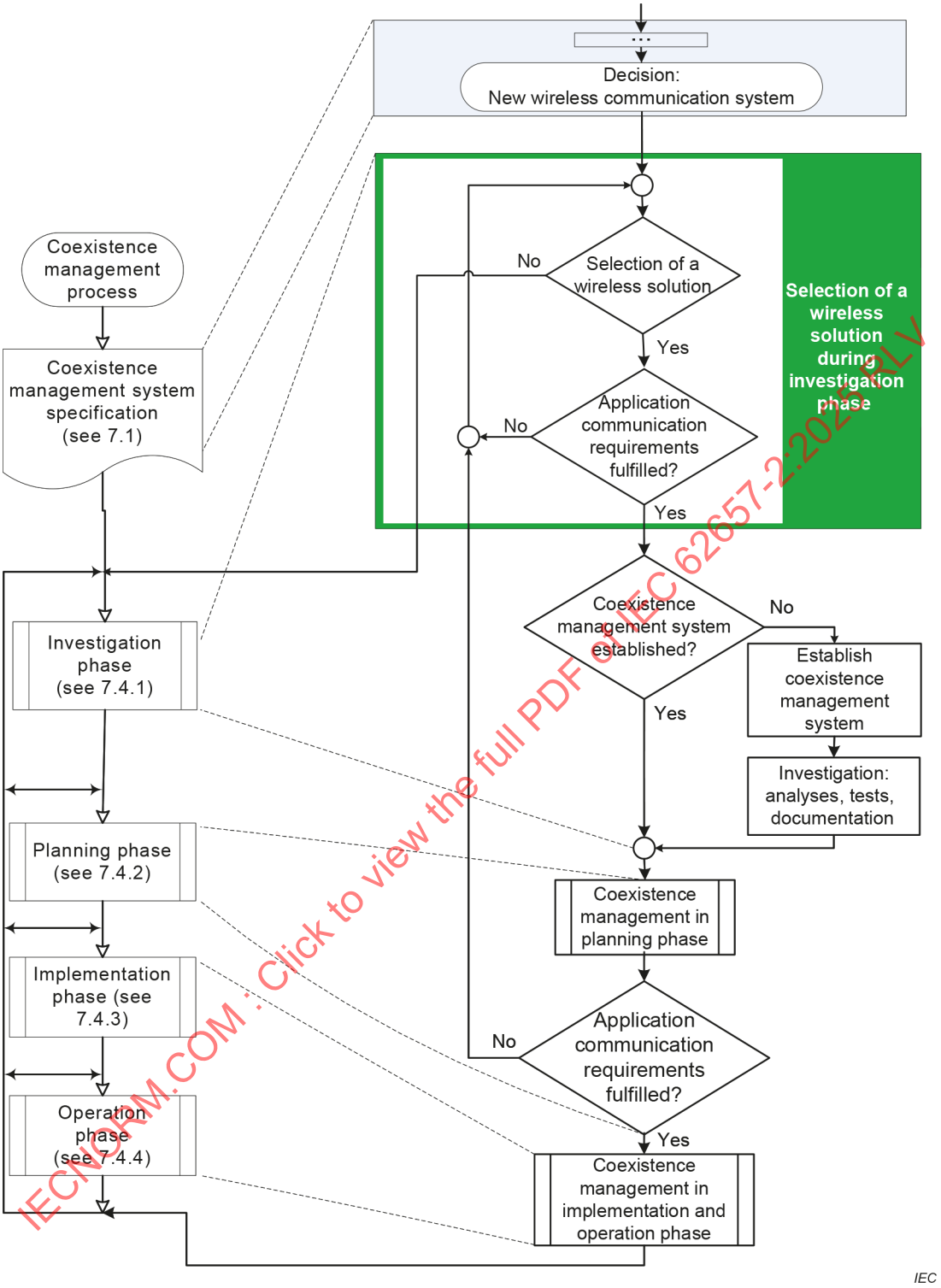

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Figure 7 – Selection of a wireless system in the coexistence management process

NOTE 2 Figure 7 does not show the box "Maintaining coexistence management system (see 7.3)" as it is shown in Figure 6, to avoid making Figure 7 too complicated.

4.11 Coexistence management system

The coexistence management system consists of an organizational structure and procedural documents. The execution of the coexistence management brings the system into a state of "coexistence management in operating phase". The coexistence management system specification shall include the following information:

- scope of the coexistence management;
- commitment of the organization to coexistence management;
- procedure for maintaining the coexistence management system specification;
- organizational issues including structure of the organization, roles of personnel, communication with external organizations and personnel education;
- procedures for coexistence management.

The coexistence management system specification shall be documented, see 7.1.2 and maintained, see 7.3.

5 Coexistence management parameters

5.1 General

5.1.1 Definition and usage of parameters

Clause 5 specifies the parameters of a coexistence management process. These parameters are relevant to the automation communication requirements and conditions within the area of operation and characterize wireless devices and systems.

Their usage is specified in Clause 6. Clause 8 contains the templates related to some of these parameters.

The parameters are listed in alphabetical order. All parameters also have a definition in 3.1. As there are more definitions than parameters, the numbering is different.

The data types of the parameters can be defined in the Common Data Dictionary (CDD) or other tools where the parameters are part of the electronic repository.

Annex A shows the parameter usage in the IEC 62657 series.

5.1.2 Physical link

The concept of physical link is used in the definition of several coexistence parameters.

A physical link is the relation between radio transceivers (physical end points) of two wireless devices. The set of physical links of a wireless system forms its physical topology. A physical link may use different frequency channels for transmissions. Wireless transmission conditions can be described with a radio channel model. Such a model considers the characteristic of the frequency channel, the environmental conditions, the distance between the wireless devices, the antenna characteristic, etc. Because the antenna systems of the wireless devices ~~may~~ can be different and the propagation conditions depend on the position of the wireless devices, the radio channel is normally different for both directions of a physical link.

Where wireless devices have redundant wireless modules, for example for different frequency channels, the related physical links shall be counted separately. It is not required that a wireless device has a physical link to all other wireless devices. There can be physical, technological or application related reasons. The communication load of a physical link is determined by the logical links which use this physical link. A logical link may use more than one physical link, in sequence (via repeater) or in parallel (for redundancy). More than one logical link may use one physical link (different communication services).

5.2 Adjacent channel selectivity

Adjacent channel selectivity is the lower value (of the upper and lower adjacent channels) of the ratios, in decibels, of the levels of the unwanted signal level, expressed as field strength to a specified wanted signal level expressed as field strength producing a data signal with a bit

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error ratio of 10^{-2}. Adjacent channel selectivity is suitable to estimate the immunity of the equipment against systems in adjacent channels.

NOTE This is in line with the specification of adjacent channel selectivity in ETSI TR 100 027 [20].

The unit of this parameter shall be the decibel (dB) over the intended frequency range.

5.3 Antenna gain

The antenna gain is a value that describes the focusing of a transmitted or received signal. The values are given in relation to a half-wave dipole or a theoretical isotropic radiator. Since the isotropic gain of a half-wave dipole is 2,15 dBi, the antenna gain of a half wave-dipole is 2,15 dBi lower than the antenna gain of an isotropic radiator.

The antenna gain together with transmit power values, the receiver sensitivity and taking into account the propagation conditions can be used to optimize the location and orientation of the wireless device or antenna.

The unit of this parameter shall be the decibel relative to isotropic (dBi).

5.4 Antenna radiation pattern

A radiation pattern illustrates the directional (angular) dependence of the strength of the radio waves of an antenna. It is usually represented graphically for the far-field conditions in either the horizontal or vertical plane. This information can be used to optimize the location and the orientation of the wireless device or antenna.

This parameter shall be represented as a figure or a table.

5.5 Antenna type

Wireless devices can use different kinds of antennas to collect or radiate electromagnetic waves. Examples include omni-directional antennas, directional antennas, antenna arrays, smart antennas and PCB antennas. The antennas can be integrated into the wireless device (internal) or antenna connectors are available to mount antennas externally. If a device has an antenna connector, special antenna systems such as radio coaxial radiating cables or slotted waveguide antennas can also be connected. In addition, the antenna can be mounted independently of the device in a position that is favorable for error-free transmission. If a wireless device can only be used with one certain antenna, it is called dedicated antenna. The information concerning the antenna type can be used to estimate the quality of the physical link and the sensitivity to interferences.

The parameter shall be an indexed list with the items omni-directional antennas, directional antennas, antenna arrays, smart antennas and PCB antennas extensible with entries of new antenna types.

5.6 Communication availability

Communication availability is a measure to quantify the dependability of wireless communication. Requirements for availability of wireless communication shall be specified.

Other wireless solutions could cause degradation of availability of target wireless communication application. Tolerable availability levels to achieve the target of the application should be clarified. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to a local application or wireless communication application. The communication availability is the ratio between the up time to the observation time. This can also be expressed by the ratio of successful transmitted messages and all messages.

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The unit of this parameter shall be the percent (%).

5.7 Communication reliability

The communication reliability of a physical link and the related nodes is a measure to quantify the dependability of wireless communication. Requirements for reliability of wireless communication shall be specified for a given time interval that the communication services under given conditions shall perform without an error.

The unit of this parameter shall be the second (s).

5.8 Bit rate of physical link

The bit rate of the physical link is a measure of the number of binary digits transferred per second. Since data is often combined by modulation or coding, the time utilization of a telegram cannot always be calculated by simply dividing the number of bits of the telegram by the bit rate. It has also to be mentioned that the bit rate of the physical link is normally not identical to the bit rate of the reference interface. A high bit rate of the physical link does not automatically mean a high quality of service.

The unit shall be the bit per second (bit/s).

5.9 Blocked frequency list

Avoiding the use of the same radio frequency ranges for different wireless communication systems is the first measure to prevent interference. For wireless communication systems that use Frequency Hopping Spread Spectrum (FHSS) technology, this means that frequency ranges in the hopping sequence that are used by other wireless communication systems are blocked and with that, not used. A list of frequency channels that shall not be used, called blocked frequency list, shall be specified for the wireless system.

~~Blocking frequencies~~ A blocked frequency list can also be used in non-FHSS systems with dynamic frequency allocation.

The parameter shall be a list of frequency channels according to 5.22.

5.10 Centre frequency

Some wireless standards define frequency channels using centre frequency and frequency bandwidth. Thus, the centre frequency indicates the position of a frequency channel within the frequency spectrum. The centre frequency shall be calculated based on the relevant cut-off frequencies. The centre frequency is the geometric mean of lower cut-off frequency and upper cut-off frequency.

The unit of this parameter shall be the hertz (Hz).

5.11 Area of operation

The following areas of operation shall be considered:

- indoor;
- outdoor;
- indoor and outdoor.

For indoor areas of operation, it is reasonable to define whether the communication is concentrated in a machine or manufacturing cell or if it operates all over the entire factory hall or plant.

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The content of this parameter shall be text expressed with a multiple octet string.

5.12 Communication load

The communication load describes the requirement of the automation application to transfer a certain amount of user data within a certain period of time as shown in Figure 8. The communication load is the ratio of ~~user~~ automation application data length and transfer interval. The communication load (L_c) is determined as follows:

$$L_c = \sum_i \frac{DL_{Ui}}{T_{Ii}}$$

where

DL_U is the number of user data transferred per device i;

T_I is the transfer interval per device i.

Depending on the granularity of coexistence management, the communication load and its parameters can refer to a logical link or, more generally, to an application.

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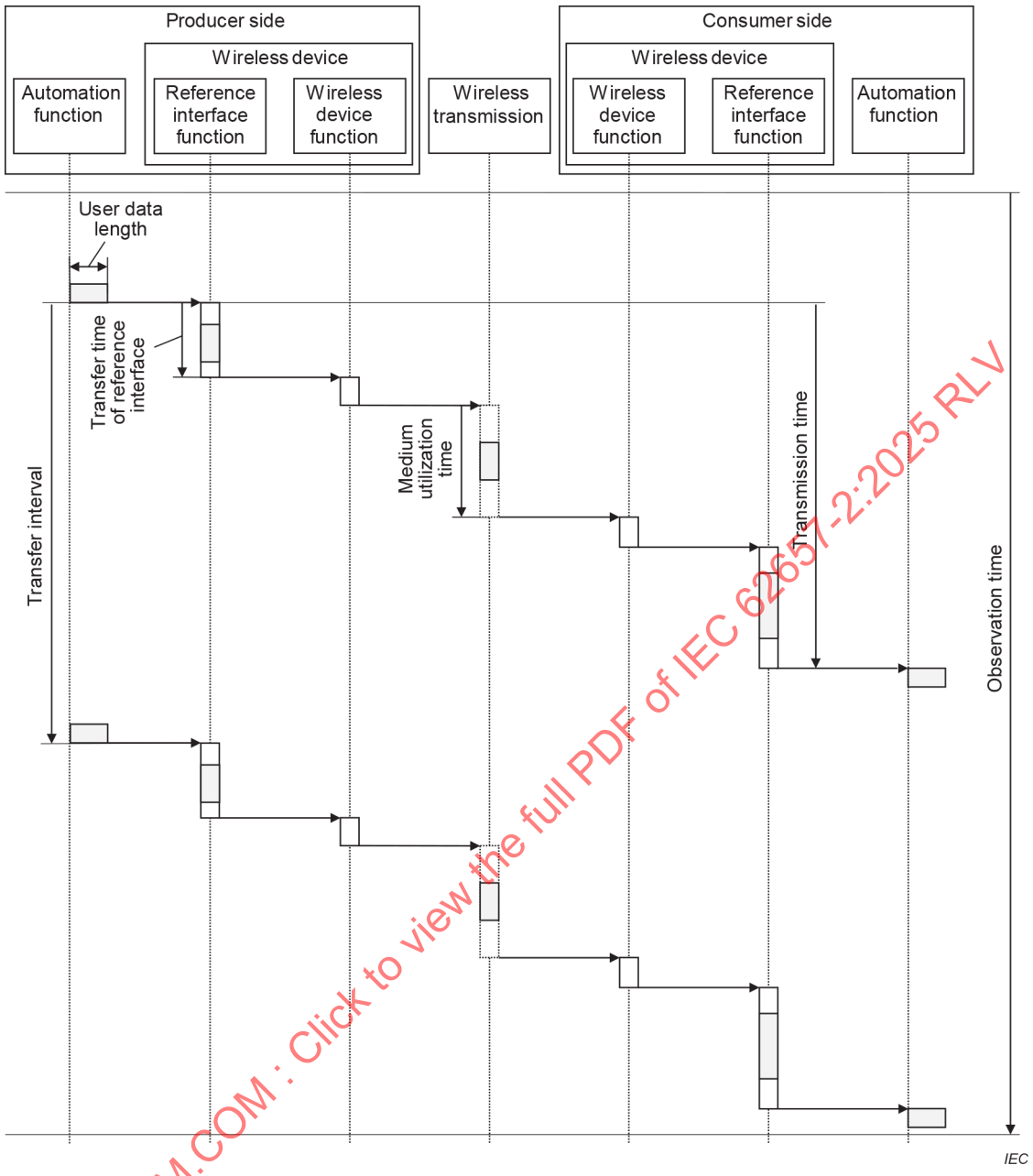

Figure 8 – Communication load in case of two wireless devices

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However, the actual medium utilization depends on the applied wireless solution. In the example in Figure 9, the communication load is indicated for more than two wireless devices.

The unit of this parameter shall be the bit per second (bit/s).

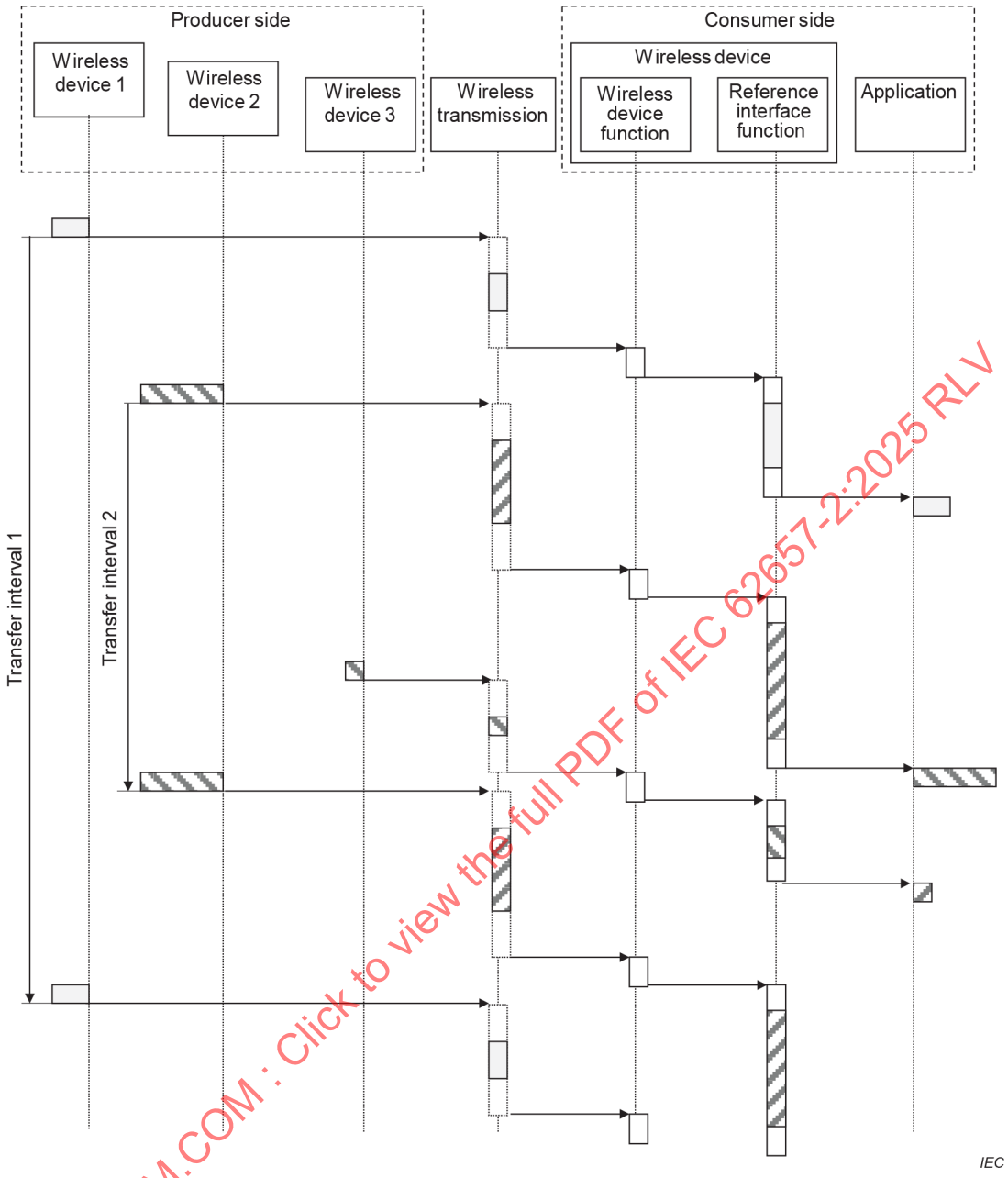

Figure 9 – Communication load in the case of several wireless devices

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5.13 Cut-off frequency

In principle, there are two cut-off frequencies. The upper cut-off frequency is the highest relevant frequency of the spectrum envelope. The lower cut-off frequency is the lowest relevant frequency of the spectrum envelope. However, it depends on the wireless technology or standard as to what relevant means.

There are two principal approaches:

- The first approach is shown in Figure 10 with the help of a wireless LAN system. The reference level is the maximum transmitted power spectral density. From this maximum level, a certain value is subtracted. An example of this value is 20 dB. The frequency furthest above the frequency, where the power spectral density drops below the resulting level, is called the lower cut-off frequency. Accordingly, the frequency furthest below the frequency, where the power spectral density drops below this level, is called the upper cut-off frequency.

- The second approach defines the cut-off frequencies with respect to a certain spurious emission level.

The cut-off frequencies determine the frequency bandwidth of a system and thus the medium utilization in the frequency domain. Furthermore, the cut-off frequencies can be used to calculate the centre frequency.

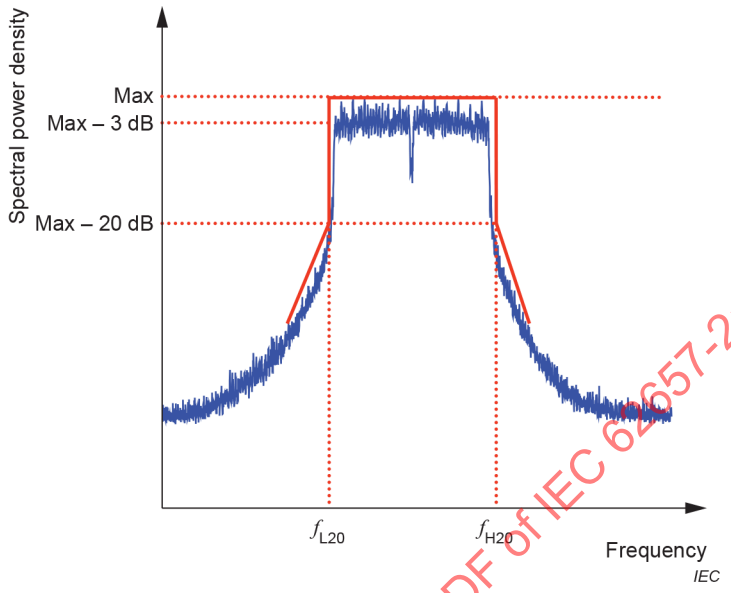

Figure 10 – Cut-off frequencies derived from maximum power level

The unit of this parameter shall be the hertz (Hz).

5.14 Data throughput

The data throughput is relevant to the transfer of large amounts of data (for example the transmission of huge parameter data sets to drives or the downloading of programs into complex field devices). Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

The data throughput is the number of user data bytes, or user data bits, transferred within a consumer from the reference interface to the application per time unit.

To evaluate the coexistence, the average value of a series of measurements can be used, compared with a value given by the automation application.

The unit of this parameter shall be the bit per second (bit/s).

5.15 Distance between wireless devices

The distance between wireless devices determines attenuation and fading, an important influence on the characteristic of the frequency channel. It depends on the positions of the wireless devices which are mainly determined by the automation application. Figure 11 shows the distances of wireless devices within a three-dimensional space. This distance can vary dynamically in the case of moving or mobile wireless devices.

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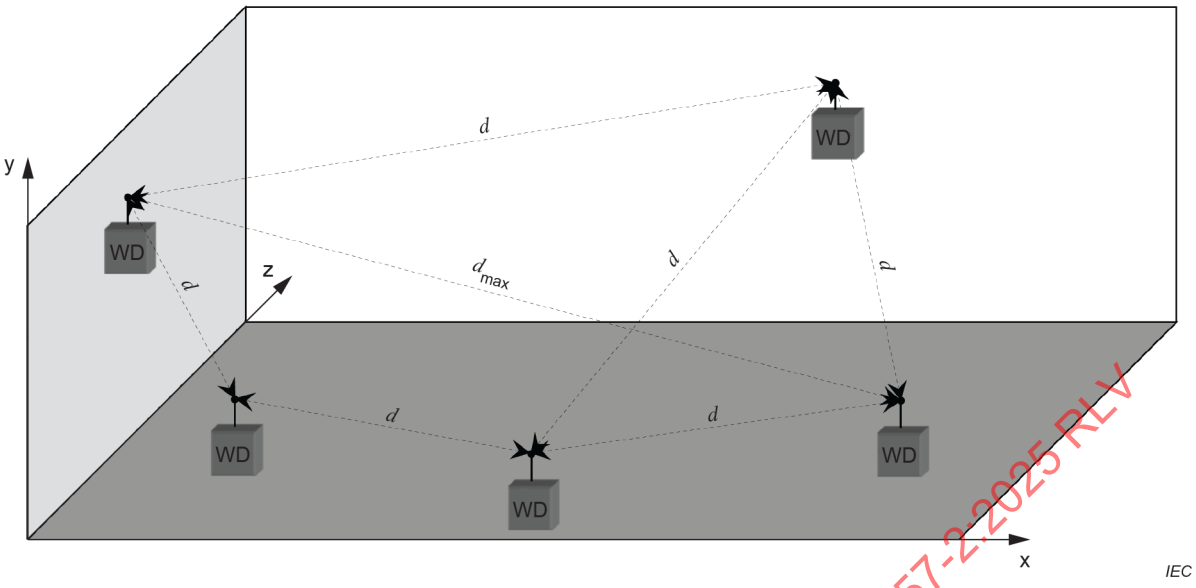

Key

d	distance (m)
WD	wireless device

Figure 11 – Distance of the wireless devices

If feasible, the distance between the wireless devices of a wireless system should be chosen in a way leading to optimal signal power levels; this improves the robustness of the wireless system. The distance to wireless devices of other wireless systems should be chosen in a way that results in interference signal power levels being as low as possible. This reduces the interference of the other wireless system.

At least the maximum distance within a wireless system should be provided.

The unit of this parameter shall be the meter (m).

5.16 Duty cycle

The duty cycle is the ratio of the transmitter sequence referenced to a given observation time for the used frequency channel. The way the observation time is chosen influences the duty cycle value. This is illustrated in Figure 12. For system 1 with observation time 1, the duty cycle is greater than for system 2. However, it is lower for system 1 with observation time 2.

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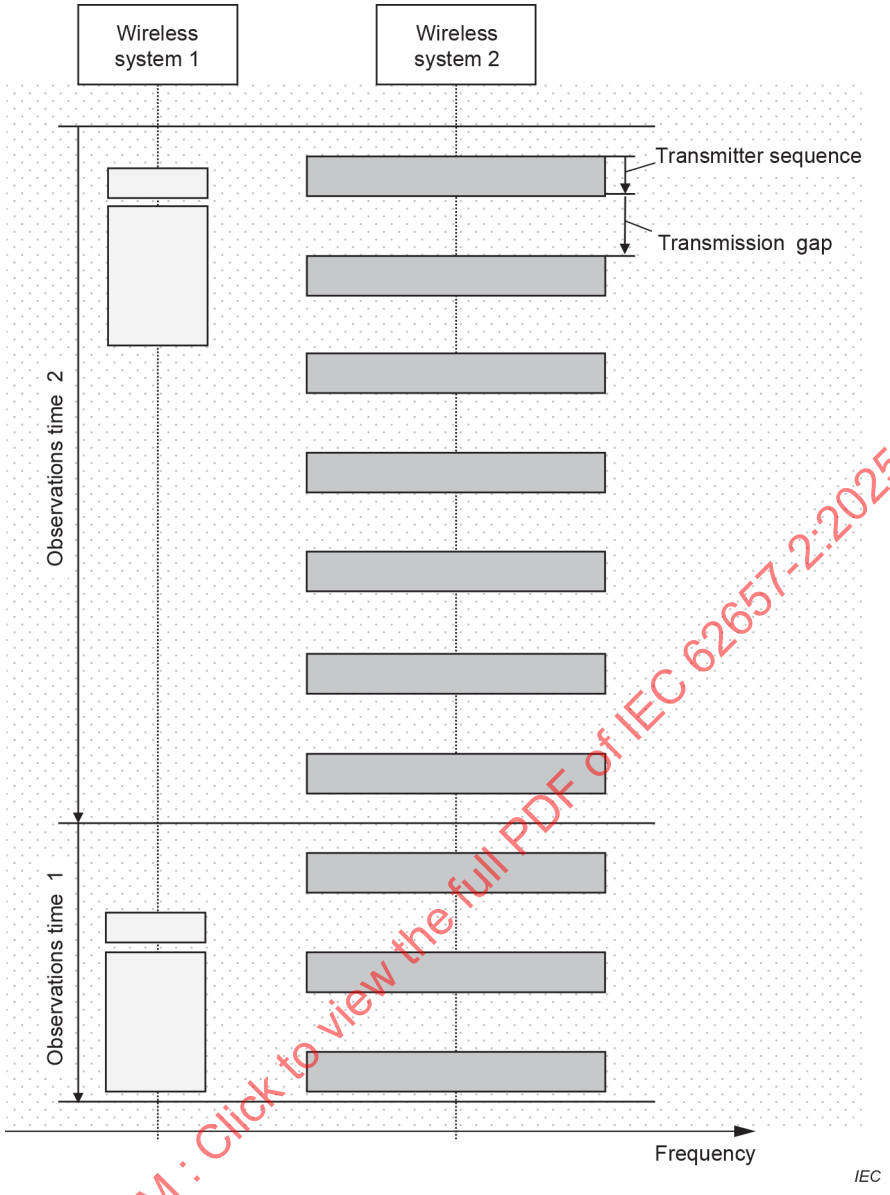

Key

Light grey transmission of wireless system 1

Dark grey transmission of wireless system 2

Figure 12 – Duty cycle

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It is reasonable to specify the observation time with respect to the application profiles. The observation time should be ten times the typical transfer interval of an application profile, as shown in Table 2. The transfer interval is herewith the time difference between two transfers of user data from the automation application. The observation time for duty cycle specifications is sometimes dictated by standards.

Table 2 – Application profile dependent observation time values

Application profile	Machine	Factory hall	Process plant
Transfer interval	100 ms	250 ms	4 s
Observation time	1 s	2,5 s	40 s

The duty cycle is the key parameter to assess the medium utilization in time. A small duty cycle results in small medium utilization and therewith a smaller influence on other frequency users.

The content of this parameter shall be expressed in %.

5.17 Dwell time

The dwell time specifies the agility of a frequency hopping system. The dwell time together with the number of frequency channels can be used to estimate how often the system appears in a certain channel. The number of frequency hopping channels is implicitly given with the parameter frequency hopping sequence, see 5.23.

The dwell time is the period of time a system is assigned to a certain channel. If the system requires an immediate response, this and the idle time shall be considered. It is suitable for frequency hopping systems only. In order to consider a worst-case scenario, the maximum dwell time shall be declared for a wireless device or a wireless system. The maximum dwell time is shown in Figure 13 with max t_{Dw}.

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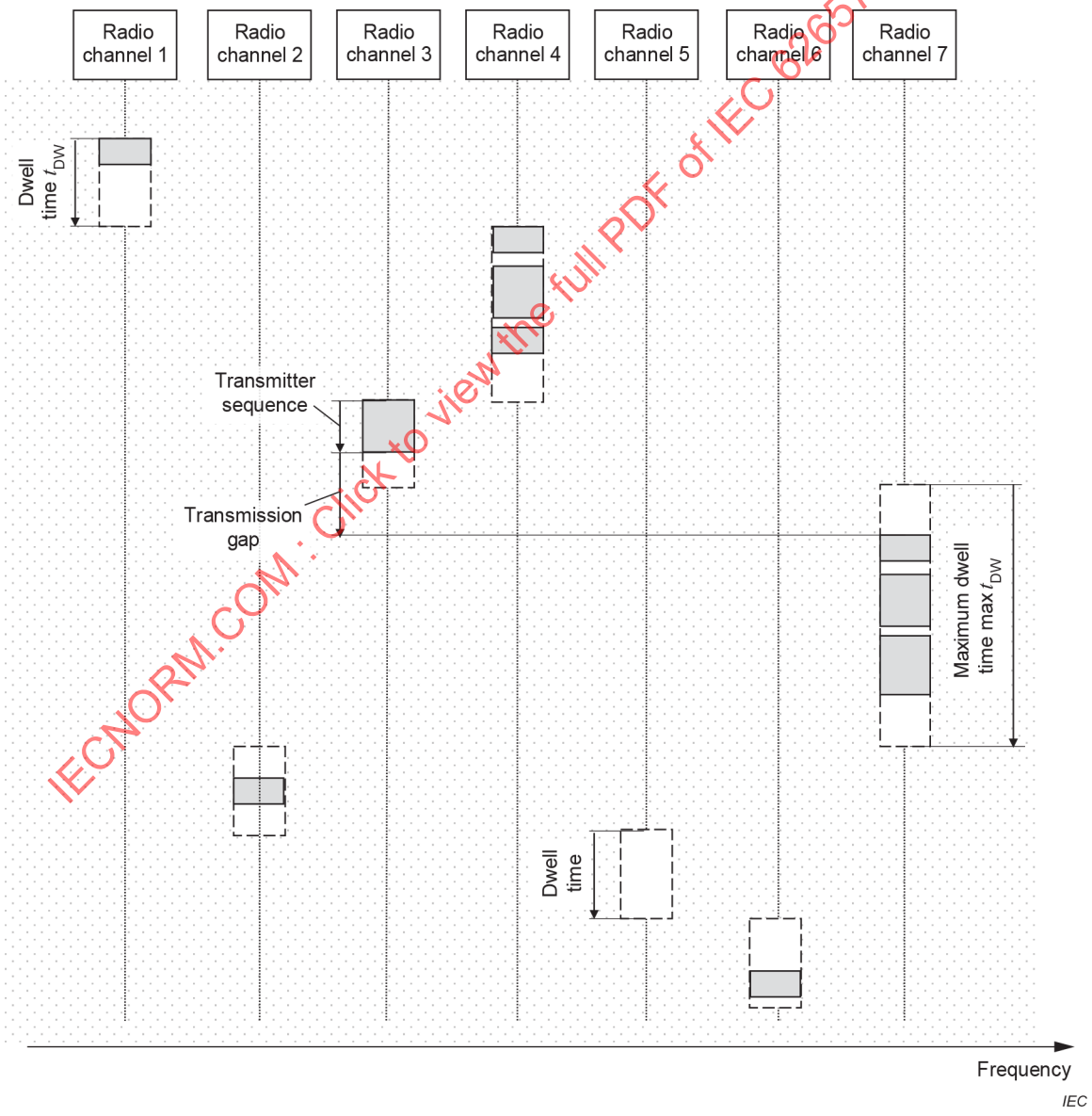

Figure 13 – Maximum dwell time

The unit of this parameter shall be the second (s).

5.18 Equivalent isotropic radiated power

The equivalent isotropic radiated power (EIRP) is the product of the power supplied to the antenna (total radiated power) and the antenna gain G_i in a given direction relative to an isotropic antenna (absolute or isotropic gain), see ITU-R BS.561-2 [21].

As the isotropic gain of a half wave dipole is 2,15 dBi, the EIRP values are 2,15 dB larger than the ERP values.

EIRP is one of the fundamental parameters in order to estimate the power level at a certain position.

EXAMPLE Assuming an antenna with an antenna gain of 3 dBi is used (see also 5.3), then to meet the requirement of ≤ 20 dBm EIRP, the total radiated power at the antenna input cannot exceed 17 dBm.

The unit of this parameter shall be the watt (W).

5.19 Equivalent radiated power

The equivalent radiated power (ERP) is the product of the power supplied to the antenna (total radiated power) and its gain relative to a half-wave dipole in a given direction, see also ITU-R BS.561-2 [21]. If the direction of an antenna is not specified, the direction of maximum gain is assumed. The ERP takes into account the losses of the transmission line and connectors.

The unit of this parameter shall be the watt (W).

5.20 Frequency band

A frequency band is a segment of the frequency spectrum that is assigned to one or more wireless applications by radio regulations. The regulations characterize the wireless application and describe conditions of utilization e.g. power or medium access. A given frequency band ~~may~~ can be divided into frequency channels. Wireless specifications or standards specify the number of channels in the frequency band, its frequency bandwidth, and the channel separation. Depending on the wireless technology and the implementation of a wireless device type, a frequency band and one or more frequency channels can be selected during configuration. Furthermore, there is the possibility to change a frequency band or a frequency channel during operation. So-called frequency hopping systems use more than one frequency channel per definition. The frequency band and the number of frequency channels that are selected, or that are actually used, are part of the essential parameters of coexistence management.

The unit of this parameter shall be the hertz (Hz).

5.21 Frequency bandwidth

The frequency bandwidth is the range of frequencies occupied by a modulated carrier signal. The frequency bandwidth value depends on the spectral power level referred to (see 5.46). The bit rate of a communication channel is proportional to the frequency bandwidth of the signal used for the communication. From the point of view of coexistence management, the frequency bandwidth indicates the utilization of the frequency spectrum by the wireless equipment. Systems can also unintentionally radiate outside the defined frequency bandwidth. This could lead to so-called adjacent channel interference (for the next) or even alternate channel interference (for the next but one).

The unit of this parameter shall be the hertz (Hz).

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5.22 Frequency channel

The (radio) frequency channel is a part of the frequency band and the physical part of a logical link. Thus, it is used to transmit a radio wave between two wireless communication modules. Within a wireless device, this parameter ~~may~~ can be used as:

- range of frequency channels: all possible;
- operational frequency channels: configured for current use;
- blocked frequency channels: configured not to be used.

The frequency channel shall be expressed as a number represented as an unsigned integer value without a unit according to a specification or standard. If no channel number is specified, combinations of centre frequency and frequency bandwidth or lower and upper cut-off frequency shall be given in hertz (Hz).

Table 3 shows the selection of units.

Table 3 – Parameter options for frequency channel

Option name	Parameter	Unit
ChannelNumber	ChannelNumber	—
CutoffFrequency	UpperCutOffFrequency	Hz
	LowerCutOffFrequency	Hz
CentreFrequency	CentreFrequency	Hz
	FrequencyBandwidth	Hz

The presentation in IEC CDD could

- have the structure frequency channel <ChannelNumber>, <UpperCutOffFrequency, LowerCutOffFrequency>, <CentreFrequency, FrequencyBandwidth>, where only one of the three options can be used and the remaining two options shall have the value 0, or
- be expressed with relations of parameters, or
- use polymorphism to describe the selection of the different optional description forms in Table 3.

5.23 Frequency hopping sequence

The description of the frequency hopping sequence shall include the sequence of frequency channels used for transmission (hopping sequence) and dwell time. The procedure can be described in accordance with the relevant wireless standard, for example by means of a parameter table or a mathematical rule. The description ~~may~~ can include adaptation mechanisms such as a list of frequency channels not to be used, named blocked frequency list.

The parameter can be expressed in different ways depending on the used wireless technology.

a) The frequency channels shall be according to 5.22 and the dwell time shall be according to 5.17. These two parameters could
   - be expressed in a value list of the two parameters: frequency channel and dwell time, or
   - be expressed with relations of parameters, or
   - use polymorphism to describe the selection of the two different optional description forms.

b) Formula, that includes frequency channels and dwell time.

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5.24 Future expansion plan

Future expansion plans should be taken into account. Installation of new wireless solutions and changes to the physical environment (e.g., buildings) can affect conditions for wireless communications. For example, reserving resources could avoid changes in the installed base when adding more wireless devices. The parameter shall be a multiple octet string with text.

The content of this parameter shall be text expressed with a multiple octet string.

5.25 Geographical dimension of the plant

For the purpose of the wireless communication coexistence, the geographical dimension of the plant shall be specified by the length, width and height of the space in which the wireless systems can be installed. The area of operation, for example the factory hall for a machine, should be considered.

Within this space, several wireless systems with different spatial coverage (see 5.55) may operate. The geographical dimension of the plant determines the passive influences on radio propagation, for example by reflections.

The content of this parameter shall be length, width and height; the unit shall be the meter (m).

5.26 Infrastructure device

Infrastructure devices are devices such as routers or base stations without interface to the automation application, for example via wired industrial networks. Infrastructure devices are necessary to build up the wireless system according to the wireless technology or standard. They ~~may~~ can improve the robustness of a network, however they can also interfere with other wireless systems. Thus, infrastructure devices are not part of the automation application but of the wireless system.

Router or base stations that have an interface to wired industrial networks or which implement automation application functions are not counted among infrastructure devices. They are part of the wireless automation application and with that counted among wireless automation devices.

The content of this parameter shall be text expressed with a multiple octet string.

5.27 Initiation of data transmission

This parameter specifies how the application initiates the data transfer for a logical link: periodically, aperiodically or stochastically. A periodic transfer might result in a higher communication load than an aperiodic transfer because the same values might be frequently transmitted. The initiation of data transmission influences the communication load and can contribute to a temporal separation of the wireless systems.

The parameter shall be a multiple octet string with text.

5.28 Interference type

This parameter describes spectrum users that emit energy due to emissions, radiation, induction, or combinations thereof, resulting in degradation, misinterpretation, or loss of information at the receiver of a wireless device that would not occur in the absence of such energy. According to Figure 2, these frequency users are electromagnetic interfering (EMI) sources, industrial, scientific, medical (ISM) applications or non-industrial wireless applications. The type of interference and its medium utilization factor shall be known.

The content of this parameter shall be text expressed with a multiple octet string.

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5.29 Intervisibility

This parameter describes the logical link between two implemented logical automation devices. The intervisibility considers Line of Sight (LOS), Non Line of Sight (NLOS) and Obstructed Line of Sight (OLOS) between those devices. The intervisibility influences the radio signal propagation. The specification of this parameter is important to specify the conditions for radio channel measurements and modelling.

The required value considers the logical topology of the automation application. The promised value can require specific measures of the wireless communication system. This can be differences in the positions of communication devices compared to the required positions of the automation devices linked by cables, different antenna positions, specific antenna types, or wireless devices with wireless communication functions (for example access points).

The content of this parameter shall be text expressed with an indexed list: LOS, NLOS, or OLOS.

5.30 ISM application

This parameter describes frequency users emitting radio waves without transmitting data such as welding machines, microwave oven operating in the same area. The type of the other frequency user and its medium utilization factor shall be known.

The content of this parameter shall be text expressed with a multiple octet string.

5.31 Length of user data per transfer interval

The ~~user~~ automation application data length is the number of octets that is carried in the payload of a wireless packet. Normally user data are transferred via the reference interface. However, there are cases where an event at the reference interface initiates the transmission of a certain number of user data. The user data length determines the medium utilization. However, there can be a complex or non-linear relation between user data length and medium utilization. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

The unit of this parameter shall be the bit (bit).

5.32 Limitation from neighbours of the plant

Neighbours of the plant might cause limitations for wireless communication. Examples are high power radio source(s) and sensitive equipment.

Documenting the possible interfering elements from neighbours will make the designer aware of potential constraints placed upon the wireless systems by the neighbours.

The content of this parameter shall be text, expressed with a multiple octet string.

5.33 Maximum number of retransmissions

This parameter describes how many times user data are retransmitted automatically by the communication stack because of transmission errors. It is possible that retransmissions are initiated by different protocol layers. Therefore, the maximum number of retransmissions shall be specified for each relevant layer. If possible, details of the mechanism, for example waiting times, should be explained. This parameter can have a significant influence on medium utilization.

Depending on the use case, the maximum number of retransmissions of the device (wireless device type) or the configured maximum number of retransmissions (wireless communication solution) shall be specified.

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The content of this parameter shall be expressed with an unsigned number.

5.34 Mechanism for adaptivity

One or more mechanisms for adaptivity can be used to modify one or more of a system's operational parameters in order to improve a system's robustness against interferences and to minimize medium utilization factor. Adaptive communication mechanisms ~~may~~ can use automatically feedback information obtained from a system itself or from the signals carried by a system to modify dynamically a system's operational parameters. It is also possible to plan the operational parameters in advance and configure the systems appropriately.

Mechanisms for adaptivity are as follows:

- detect and avoid (DAA): if the channel is occupied, change the channel (for example AFH);
- detect and suppress (DAS): if the channel is occupied, don't transmit (for example listen before talk);
- detect and reduce (DAR): if the channel is occupied, reduce the output power and/or channel usage.

Depending on how many systems are using mechanisms for adaptivity and which parameter they adapt, these measures can help improving coexistence or ~~may~~ can lead to unstable and unreliable system behaviour.

The content of this parameter shall be text expressed with a multiple octet string.

5.35 Medium access control mechanism

The medium access control ensures, for example, that a communication request is served as long as the medium is free (see CSMA for example in IEEE Std.802.3 [22]) or it allocates the request to well defined time slots (see TDMA for example in IEEE Std.802.15.4 [4]). Combinations of these two as well as other access mechanisms are possible. The purpose of these mechanisms is primarily to control the medium access within one wireless system. However, it also influences the immunity and the medium utilization characteristic of a system and shall be considered, therefore, in the coexistence management process.

The content of this parameter shall be text expressed with a multiple octet string.

5.36 Medium utilization factor

The Medium Utilization (MU) factor is a measure to quantify the amount of resources (Power and Time) used by non-adaptive equipment. The MU factor is defined by Formula (1).

$$MU = \left(P_{\text{out}} / 100\ \text{mW}\right) \times DC \quad (1)$$

where

MU is medium utilization factor in %;

P_{out} is the transmitter output power in mW;

DC is the duty cycle expressed in %.

The equipment may have a dynamic behaviour with regard to duty cycle and corresponding power level.

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For devices using frequency hopping spread spectrum that blocks one or more hopping frequencies, these blocked frequencies are considered as active transmitting for the calculation of the MU factor.

The parameter value shall be given in %.

5.37 Message

Based on the OSI layer model, a packet denotes the data unit that is used in the network layer. User data of the application should therefore not be called a packet. In addition to the term user data, the term message is therefore used, for example, for the parameter message loss ratio. Depending on the wireless technology and the length of the application's user data, messages can be transmitted in one packet, multiple messages can be combined into one packet, or messages can be split into multiple packets.

The content of this parameter shall be expressed by an array type with two elements of integer measure type; the first element is the number of octets of the message and the second element is the number of packets in that the message is divided. The number of packets shall be set to 0 if the message transport doesn't use packets. The number of packets shall be set to −1, if the packet length is variable.

5.38 Modulation

A signal gets its information content by changing amplitude, frequency or phase of a wave. This is done by modulating the wave. Both analog and digital modulations are used. Digital modulations can be combined with spreading schemes in order to improve the robustness of the physical signal.

The content of this parameter shall be text expressed with a multiple octet string.

5.39 Natural environmental condition

Natural environmental conditions such as temperature, humidity or air pressure can influence the propagation conditions.

The content of this parameter shall be text expressed with a multiple octet string.

5.40 Network topology

The topology describes the structure and composition of a wireless communication network in a wireless communication application.

NOTE See IEC 62657-1 for use cases of different topologies. Definitions of these topologies are given in IEC 61918 [15].

Applicable topologies are:

- point-to-point;
- linear;
- ring;
- star;
- tree;
- mesh;
- cellular.

Combinations of these topologies are possible. This information can be used to assess the intended coverage of a wireless solution.

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The content of this parameter shall be an indexed list with the topologies: point-to-point, linear, ring, star, tree, mesh, cellular, other.

5.41 Number of consecutive lost messages

This parameter specifies how many messages of a logical link delivered for transmission were not received correctly between the correct reception of two messages. This means that between two messages received successfully, one or a sequence of messages had their reception completely or partially failed.

The content of this parameter shall be expressed with an unsigned number.

5.42 Object movement

Mobile objects such as forklifts or loads on moving cranes can significantly influence the radio propagation conditions. Mobile objects cause temporal and frequency-selective fluctuations in radio signal power. This has consequences for the reception of the wanted signal and/or interference.

The movement shall be specified as a trajectory for a worst-case scenario with respect to the signal propagation. The specification of a trajectory is a list of pairs of target position and speed to the target position.

The unit for position is m for each dimension, the unit for speed is m/s.

5.43 Operating time between failures

The operating time between failures of a logical link is the sum of the operating time periods between two successive failures. The logical link is considered as a repairable item in the sense that a message can be repeated within the survival time. A measure to assess a logical link is the mean operating time between failures.

The unit shall be the second (s).

5.44 Message loss ratio

The message loss ratio (MLR) reveals how many of the messages, transferred from the application to the reference interface within the producer, are transmitted from the reference interface to the application within the consumer.

The MLR is determined as follows:

$$\mathrm{MLR} = \frac{N_t - N_r}{N_t}$$

where

N_t is the number of transmitted messages;

N_r is the number of regularly received messages.

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Assuming that an application expects a message by a time t_{DL} at the latest, all messages with a transmission time greater than t_{DL} shall be counted as lost and assigned to the number of not received messages ($N_t - N_r$). For the evaluation of coexistence, it shall be proved how many consecutive message losses are tolerated before a wireless communication application fails. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application. The accumulated downtime of wireless communication application per observation interval defines the communication availability which is the focal quality criterion of wireless communication.

The parameter value shall be given in %.

5.45 Position of wireless devices

The position of wireless devices (or their antennas) influences the frequency channel characteristic. Nearby obstacles, moving equipment or narrow corridors can worsen propagation conditions. This is valid for the absolute position of one wireless device or the position relative to other wireless devices. That means, the position of wireless devices shall be chosen in order to achieve optimal propagation conditions for wireless transmission. Therefore, it could be advantages to separate the implementation of automation functions from the implementation of the wireless communication functions and connect the devices via wired communication. Another option is to separate the antenna only, e.g. when the automation device is mounted in an electrical cabinet. For moving or mobile wireless devices, the trajectory of the movement is important.

The position of a wireless device is specified in a three-dimensional space.

The unit of each dimension of this parameter shall be the meter (m).

5.46 Power spectral density

The power spectral density (PSD) describes how the power of a signal is distributed with frequency. Colloquially, the area below the PSD curve is often called the spectrum of the signal. The measurement unit of the power spectral density is in watts per hertz. The PSD shall be provided for example as shown in Figure 14 for an IEEE Std.802.15.4 [4] system.

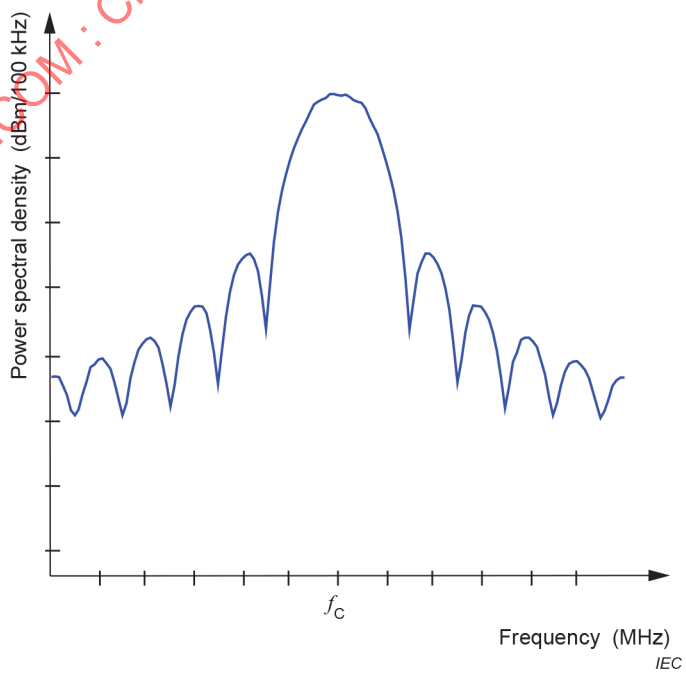

Figure 14 – Power spectral density of an IEEE Std.802.15.4 system

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The PSD as shown in Figure 14 provides a comprehensive picture of the signal power in the frequency spectrum for the coexistence management.

The unit of this parameter shall be the decibel-milliwatt per hertz (dBm/Hz) over the intended frequency range.

5.47 Purpose of the automation application

The description of the automation application supported by the wireless system shall be summarized to the extent needed to provide a useful overview of the requirements imposed on the wireless system.

The content of this parameter shall be text expressed with a multiple octet string.

5.48 Receiver blocking

The receiver blocking is an indicator of the correct receiver operation in the presence of out-of-channel signals.

Receiver blocking response (or performance level) is defined as the maximum interfering signal level expressed in dBm reducing the specified receiver sensitivity by a certain number of dB (usually 3 dB). Consequently, the receiver blocking response is normally evaluated at a wanted signal level, which is 3 dB above the receiver sensitivity and at frequencies differing from that of the wanted signal (see additional information in the ZVEI document [23]).

Receiver blocking considers effects like spurious response, intermodulation sensitivity and adjacent channel selectivity.

The unit of this parameter shall be the decibel-milliwatt (dBm).

5.49 Receiver maximum input level

Received signals with levels above the receiver maximum input level can disturb or disrupt the data reception. The receiver maximum input level shall be used to estimate or assess the minimum recommended distance to other wireless devices. For this purpose, the transmit power values of wireless devices and of interferers, as well as the propagation conditions shall be taken into account.

The unit of this parameter shall be the decibel-milliwatt (dBm).

5.50 Receiver sensitivity

Receiver sensitivity determines how well a receiver can accept wanted signals in the absence of interference (see also ETSI TR 100 027 [20]). It defines the minimum received signal power that the receiver requires to achieve a given bit error ratio according to the given implementation. Together with transmit power values of the system and of interferers, and considering the propagation conditions, the power margin of the system can be estimated and assessed.

The unit of this parameter shall be the decibel-milliwatt (dBm).

5.51 Regional radio regulations

Regional radio regulations specify important coexistence parameters such as frequency band and output power. These specifications ~~shall be~~ are taken into account within the coexistence management process.

NOTE This list of coexistence parameters can be shortened by listing the regional radio regulation standards with which the system/device is compliant, for example ETSI EN 300 328 [24].

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The content of this parameter shall be text expressed with a multiple octet string.

5.52 Relative movement

The trajectory of a wireless device`s movement changes the distance to other wireless devices and interferers. This can increase or decrease the wanted signal value or the interference. The movement itself and the relative speed between the communicating wireless devices can worsen the propagation conditions and thus increase the interference.

The movement of a wireless device shall be specified as a trajectory. The specification of a trajectory is a list of pairs of target position and speed to the target position.

The unit for position is m for each dimension, the unit for speed is m/s.

5.53 Response time

The response time is primarily important in confirmed services, for example in application-oriented transmission of process data or parameter data, and also real-time communications, also IEC 62657-1:2017, 5.3.1.

The response time is the time interval between the instant delivery of the first user data bit, or byte, of a message to the reference interface of a transmitter, and the instant when the last bit, or byte, of the confirmation message is delivered at the reference interface of the same transmitter, which can be assigned to the request.

This means that the response time is composed of at least one transmission time between transmitter and receiver and one transmission time between receiver and transmitter. The processing time within the receiver shall be added.

The communication between transmitter and receiver can be affected directly via infrastructure device (for example base station) or via further network nodes (for example sensor networks).

Interferences influence response time values. Coexistence exists as long as a limit value given by the automation application is met. Otherwise, the corresponding transmission shall be assessed as a message loss.

The response time is a random variable. This is important because response times depend more highly on external transmission conditions compared to wire-bound communication. Since the response time is essentially determined by the time values of two transmissions, the distribution of the random values corresponds to Figure 17.

The unit of this parameter shall be the second (s).

5.54 Security level

Requirements for cyber security could affect coexistence management. Some sensitive wireless solutions might need to be physically separated from some other kind of wireless systems, or might need to have clearance from the boundary of the site. The definition and the usage of security levels shall be according to the IEC 62443 series.

A system can require technical and organizational measures in order to ensure a certain security level. Technical measures can increase the processing time, introduce additional transmissions, and increase the packet length. Thus, the transmission time and the medium utilization time could be increased. The communication system could become more prone to interferences if the coexistence management does not take into account these measures.

The content of this parameter shall be expressed with an unsigned number.

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5.55 Spatial coverage of the wireless communication system

The spatial coverage of the wireless communication system depends on the application communication requirements. However, it is also decisive for the feasibility of spatial separation of wireless applications. In positioning the several wireless devices, the antenna mounting height shall be regarded. The spatial coverage is specified by length, width and height of a cuboid that encloses the wireless communication system.

The content of this parameter shall be the length, width and height; the unit shall be the meter (m).

5.56 Spatial extent of the application

The spatial extent of an application is determined by the automation devices that belong to a distributed automation system. Automation devices define with its positions a cuboid that is to be covered by a wireless communication solution. For mobile automation devices, the maximum movement radius is to be considered.

The content of this parameter shall be the length, width and height; the unit shall be the meter (m).

5.57 Spurious response

Spurious response is a receiver parameter that indicates the robustness against unwanted signals, which means having frequencies other than the tuned frequency channel. It is a response in the receiver intermediate frequency (IF) stage produced by an undesired emission in which the fundamental frequency (or harmonics above the fundamental frequency) of the undesired emission mixes with the fundamental or harmonic of the receiver local oscillator.

The unit of this parameter shall be the decibel (dB).

5.58 Survival time

The survival time provides a time that an application that consumes communication services can continue without receiving an anticipated message.

The unit of this parameter shall be the second (s).

5.59 Total radiated power

The total radiated power (TRP) is the power supplied to an antenna reduced by antenna losses. TRP is often specified in more recent standards. It can be measured with a three-dimensional turn table which allows integrating the spatial power density over 360°.

The unit of this parameter shall be the watt (W).

5.60 Transfer interval

The transfer interval has an effect on the communication load and can contribute to temporal separation. For aperiodic transfer, the minimum value is of interest as the worst case. For stochastic transfers, the parameters of the distribution function are relevant. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

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In Figure 15, the relations between machine cycle or plant cycle, transfer interval and communication cycle are depicted. Usually, the industrial automation applications follow cycles of the production process. During such a machine cycle or plant cycle, a number of events occur which shall be transmitted via a wireless communication medium. In the case of a periodic transmission, the communication cycle shall be faster than the transfer interval. If an aperiodic data transmission is involved, the transfer interval is the least possible time between two transfer requests.

The unit of this parameter shall be the second (s).

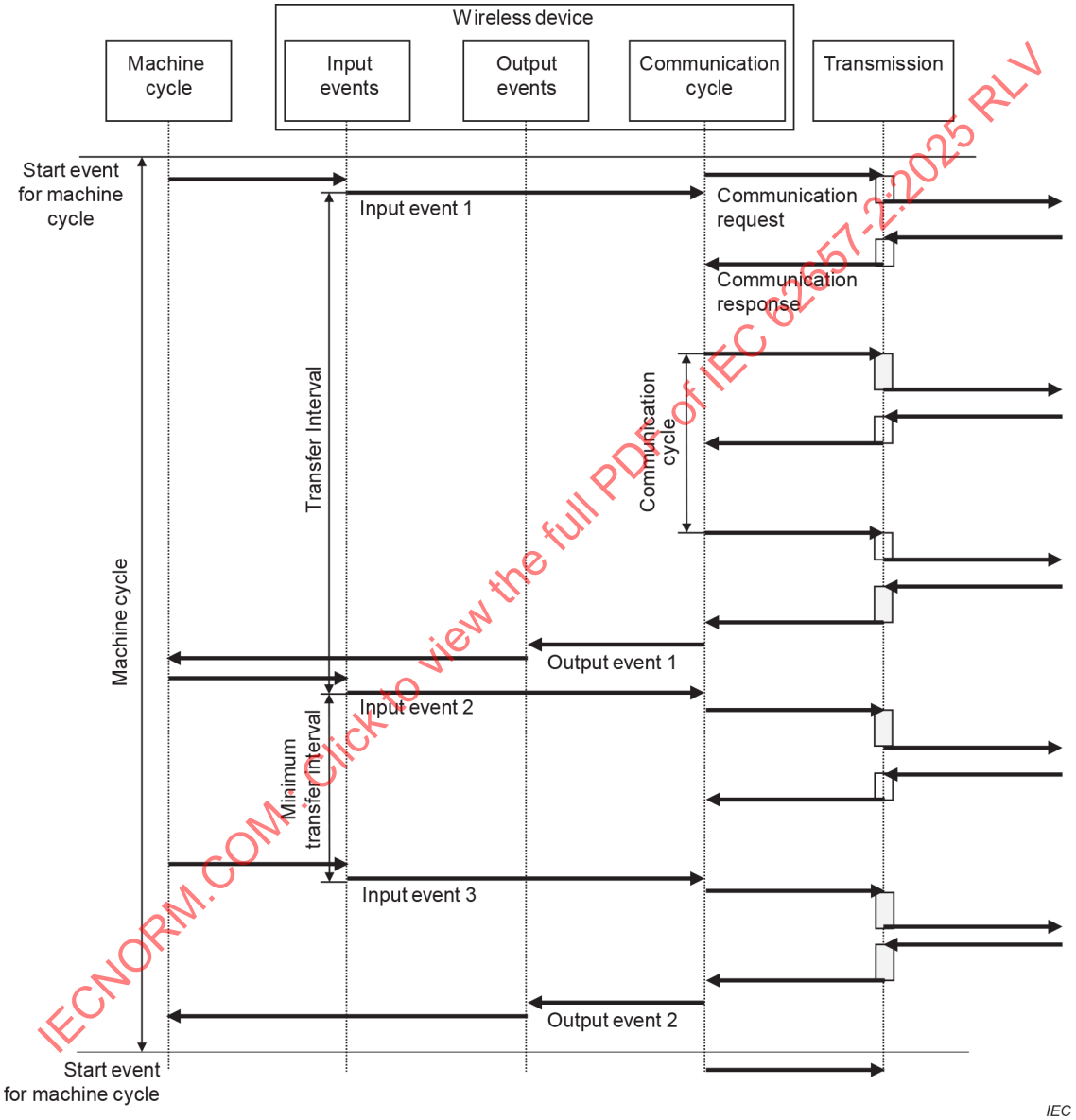

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Figure 15 – Communication cycle, application event interval and machine cycle

5.61 Transmission gap

The transmission gap is the time between two successive channel usages by a transmitter. If a request requires an immediate response, the idle time is not considered. In Figure 16, the transmission gap is depicted with t_{TG}.

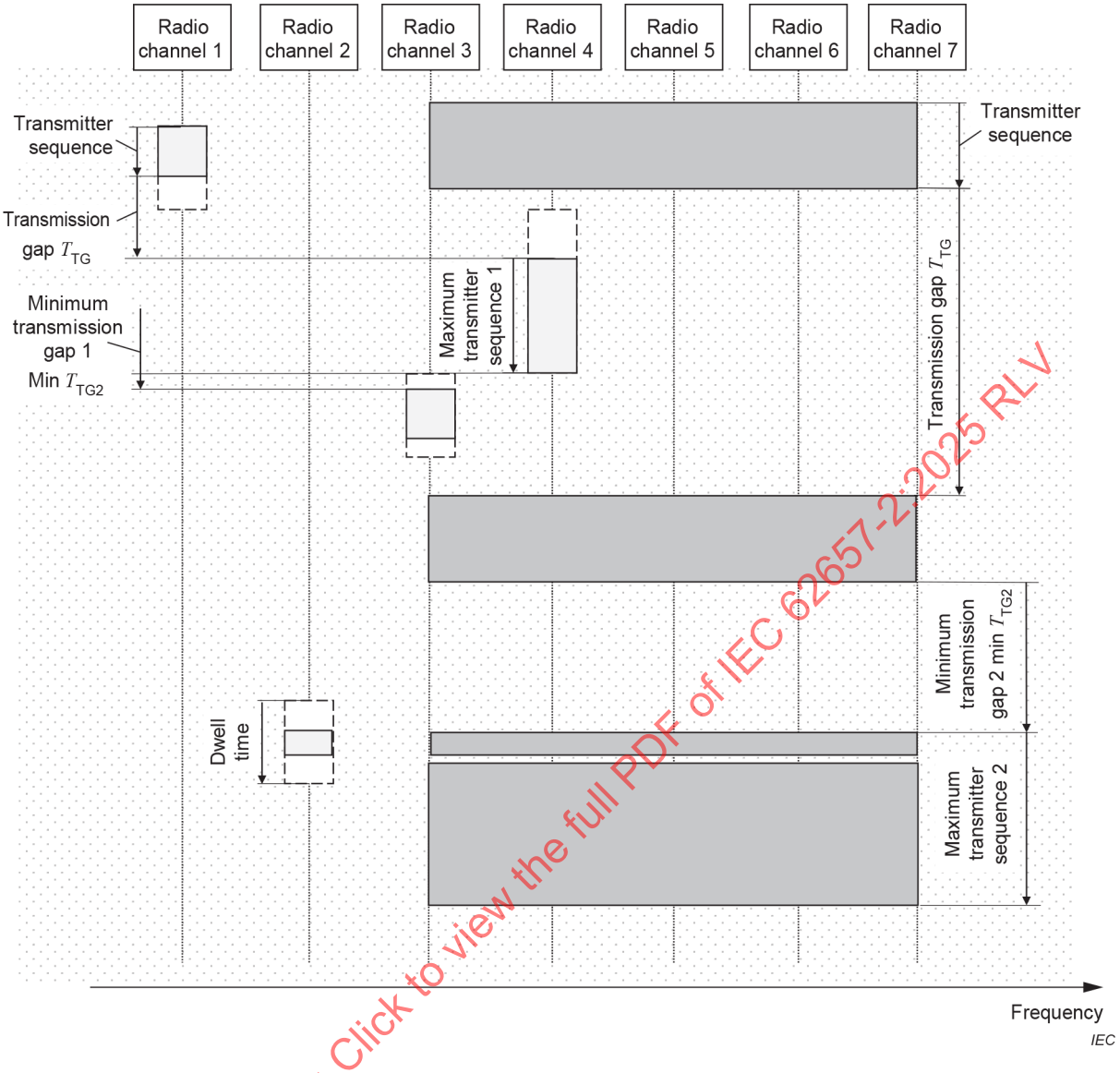

Figure 16 – Transmission gap

For frequency hopping systems, the transmission gap is related to one of the used channels and not between transmissions of different channels. The minimum transmission gap gives an impression of the minimum available time for other wireless devices to transmit. Real applications ~~may~~ can leave larger gaps. Therefore, additionally the duty cycle should be considered.

The unit of this parameter shall be the second (s).

5.62 Transmission time

The transmission time is an adequate instrument to evaluate the coexistence in terms of automation application with event-driven transfer. An example is the transmission of a state change in a proximity sensor and real-time applications, see IEC 62657-1:2017, 5.3.1.2.3.1.

The transmission time is the interval from starting the delivery of the first user data byte of a message to the reference interface of a producer until the delivery of the last user data byte of the same message from the reference interface of a consumer.

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The interferences described in 4.4 entail longer transmission time. Coexistence exists as long as the transmitted messages keep a limit value given by the automation application. Otherwise, the corresponding transmission shall be assessed as a message loss (see also 5.44).

The transmission time is a random variable. This is important because transmission times depend more highly on external transmission conditions compared to wire-bound communication.

Figure 17 exemplifies density functions of the transmission times of wireless solutions resulting from measurements with large samples. The density functions represent the number of messages needing a certain transmission time.

Usually, the number of messages with a greater transmission time, for example t_{TT2}, increases from N_2 to N'_2 if other wireless solutions interfere. On the other hand, the number of messages with a smaller transmission time, for example t_{TT1}, decreases from N_1 to N'_1 if other wireless solutions interfere. The causes might be, for example, waiting times for a free medium or retransmissions due to message losses.

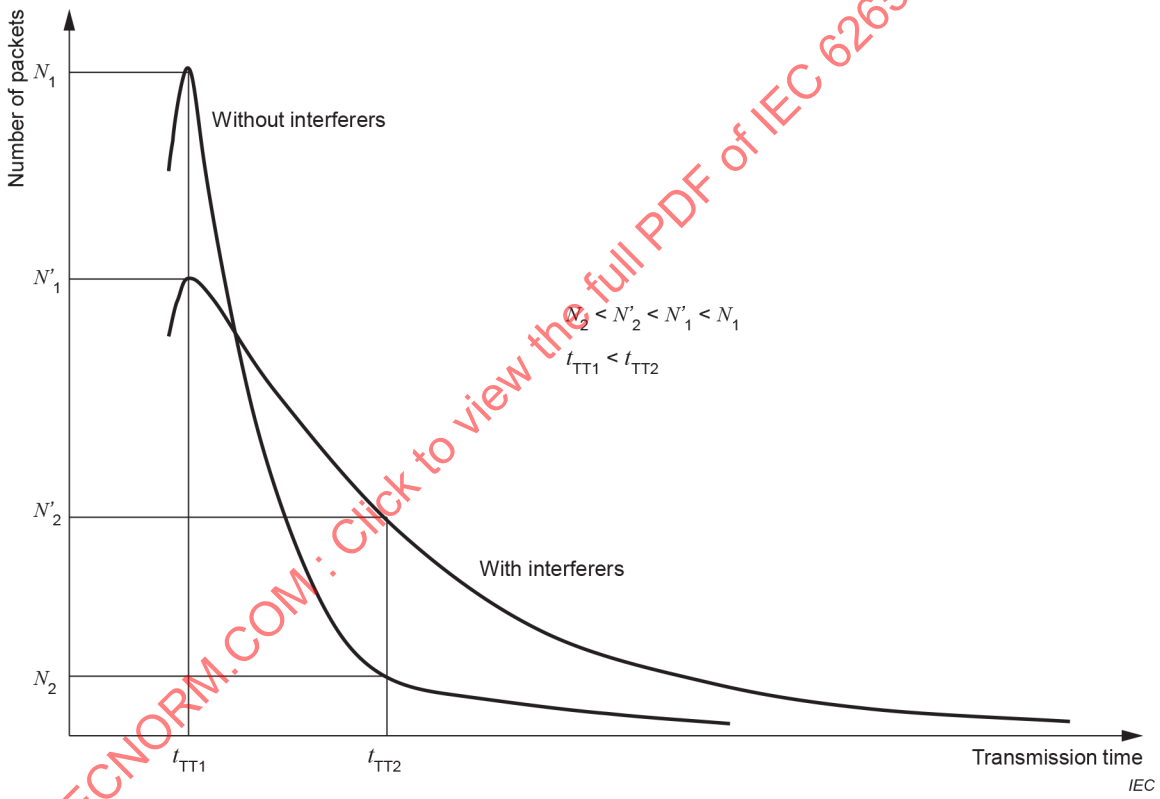

Figure 17 – Example of the density functions of transmission time

Figure 18 shows an example of the distribution functions of the transmission time. The two curves show the number of received messages that arrive within a certain transfer time.

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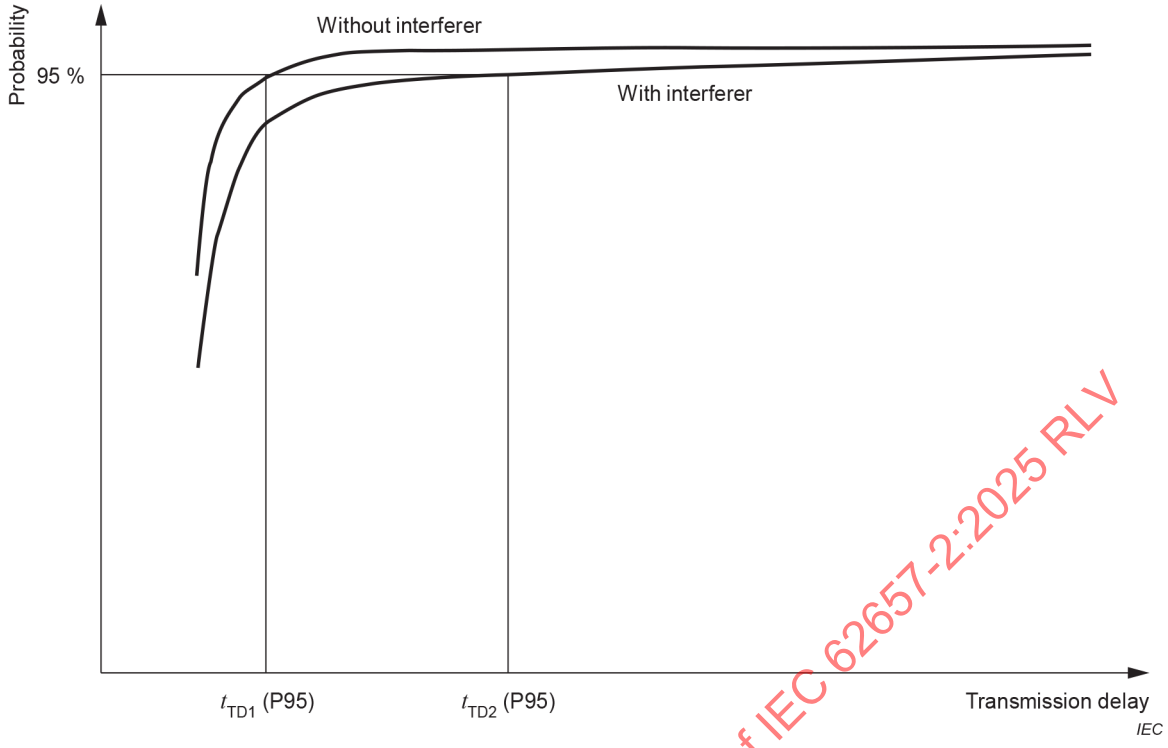

Figure 18 – Example of the distribution functions of transmission time

In a metrological ascertainment of transmission time values, the statistical parameter can be ascertained from the sample. Changes in statistical parameters, depending on the presence of other wireless applications, are a measure of the strength of influence on the wireless solution. For this relative evaluation, distribution parameters are adequate instruments, for example the percentile. The percentile P95 is a common value (see Figure 18). In 95 % of all transmissions, this value is not exceeded. Experience shows that the P95-value is a sensible compromise between the required sample size and significant information. Other statistical distribution parameters can, however, also be consulted. These distribution parameters (for example percentile P95) are not identical to the availability of the plant.

A maximum value of transmission time would be necessary in order to get an absolute result on coexistence by comparing this time value with a limit required by the application. However, the maximum value of a certain measurement is not equivalent to the absolute maximum transmission time. The measured maximum value has a certain probability that can be calculated if the functional equations of the curves in Figure 17 and Figure 18 are known. The reliability of the calculation depends on the sample size of the measurement on which the functional equations are based.

Besides this, the maximum value for the transmission time can in principle be estimated analytically by taking the maximum value for all time segments. This maximum value is not suitable to evaluate coexistence because, in this case, for the time segments influenced by other wireless applications, the maximum value shall be taken as well. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

Medium access delay should also be considered in the transmission time.

The unit of this parameter shall be the second (s).

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5.63 Transmitter output power

The parameter transmitter output power is an indicator for transmission range. It can be constant or configurable. The transmitter output power reduced by losses between the transmitter output and the antenna is the total radiated power.

The unit of this parameter shall be the watt (W).

5.64 Transmitter sequence

The transmitter sequence t_{TS} is the time that a transmitter uses a frequency channel without the possibility to be interrupted by a wireless device of the same wireless system. If a request requires an immediate response, and during the idle time the medium cannot be used by a device of the same wireless system, the entire time shall be considered (see $\max T_{TS2}$ in Figure 19). This is a reasonable simplification, even though devices of other systems could start a transmission. For coexistence management, the maximum value of the transmitter sequence of a wireless communication system is of interest. In the example shown in Figure 19, the relevant transmitter sequence of system 1 is $\max T_{TS1}$ and the relevant transmitter sequence of system 2 is $\max T_{TS2}$.

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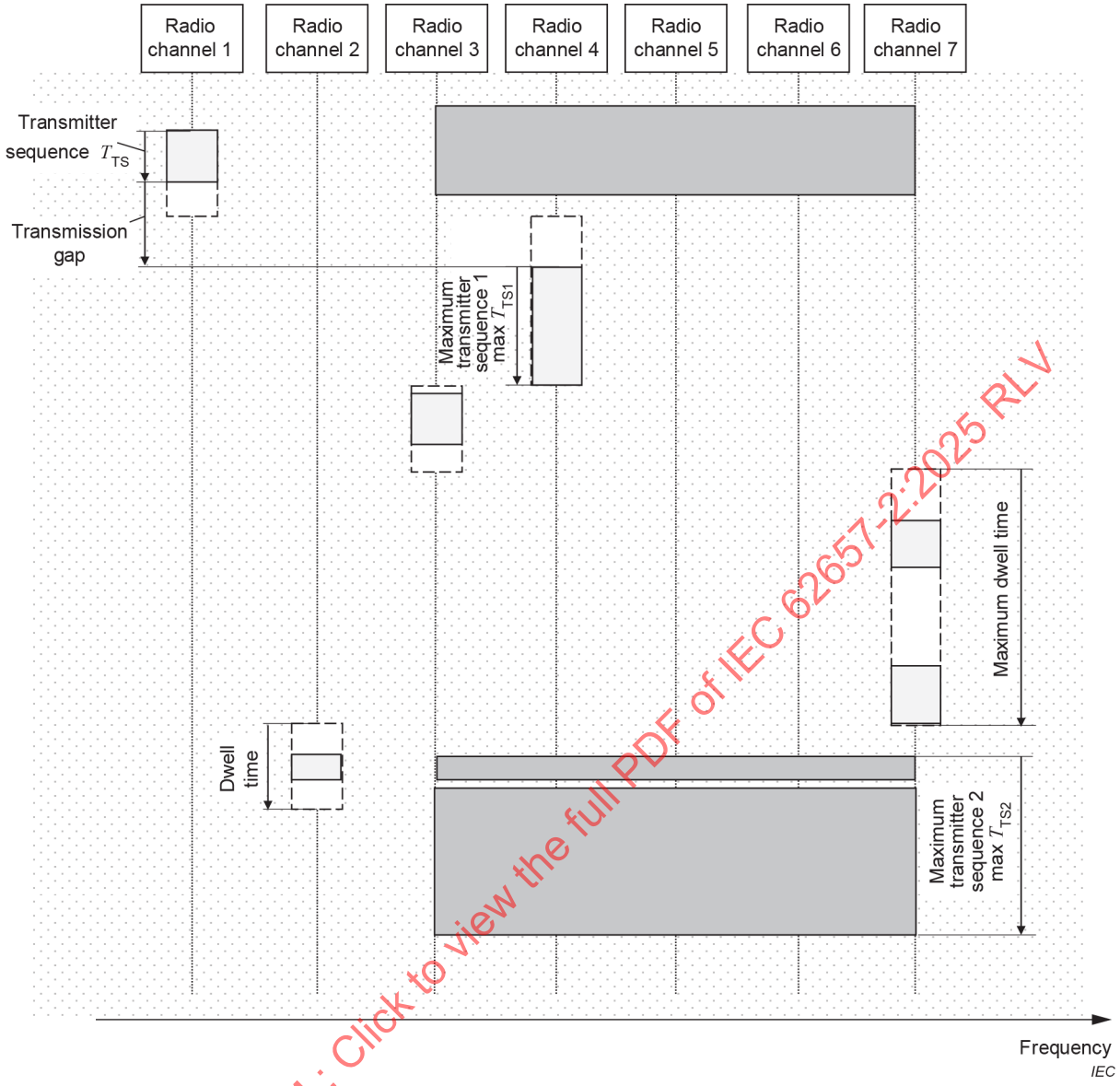

Key

Light grey transmission of wireless system 1

Dark grey transmission of wireless system 2

Figure 19 – Transmitter sequence

For frequency hopping systems, this time shall be considered for each used frequency channel. Depending on the use case, the maximum transmitter sequence of the device (wireless device type) or the maximum transmitter sequence of wireless communication solution (wireless communication solution) shall be specified. The maximum transmitter sequence gives an impression of the maximum occupied time. Real applications ~~may~~ can use a small portion only. Therefore, additionally the duty cycle should be considered.

The unit of this parameter shall be the second (s).

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5.65 Transmitter spectral mask

The power spectral density envelope can be characterized by a number of specific points creating the transmitter spectral mask as shown in Figure 20 for an IEEE Std.802.15.4 [4] system. This is a reasonable simplification for the coexistence management. Specific transmitter spectral masks are defined by a standard document. This document considers not only the power in the intended channel but also in the adjacent and alternate channels. The power spectral density shall be less than the limits specified through the transmitter spectral mask. The spectral profile of the transmitter radiated power can be used to emphasize the quality of equipment with respect to coexistence if the transmitter spectral mask is markedly smaller than required by the related standard.

There is no unit for this parameter. The parameter shall represent a figure.

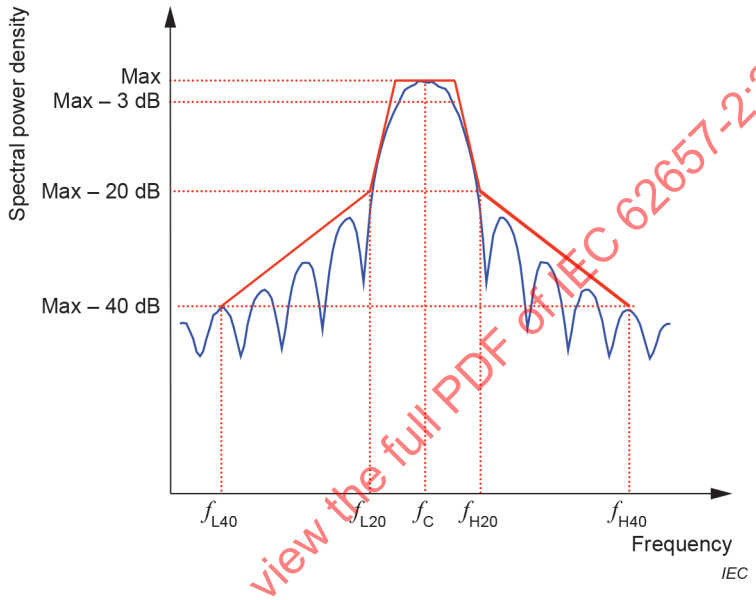

Figure 20 – Transmitter spectral mask of an IEEE Std.802.15.4 system

5.66 Update time

The update time can be used for evaluation in case of automation application with cyclic transfer and real-time applications, see IEC 62657-1:2017, 5.3.1.2.3.2. The cyclic transfer of a position detection system might serve as an example.

The update time is the interval from the delivery of the last user data byte of the message of a producer from the reference interface of a consumer to the automation application, until the delivery of the last user data byte of the following message of the same producer.

The interferences described in 4.4 result in distributions of the transmission time. Coexistence exists as long as the transmitted messages keep a limit value for the distribution of the update time given by the automation application.

The update time is a random variable. Figure 21 shows an example of distribution functions of the update time. For a relative assessment, which means whether a wireless application interferes more or less, the standard deviation can be consulted as a distribution parameter.

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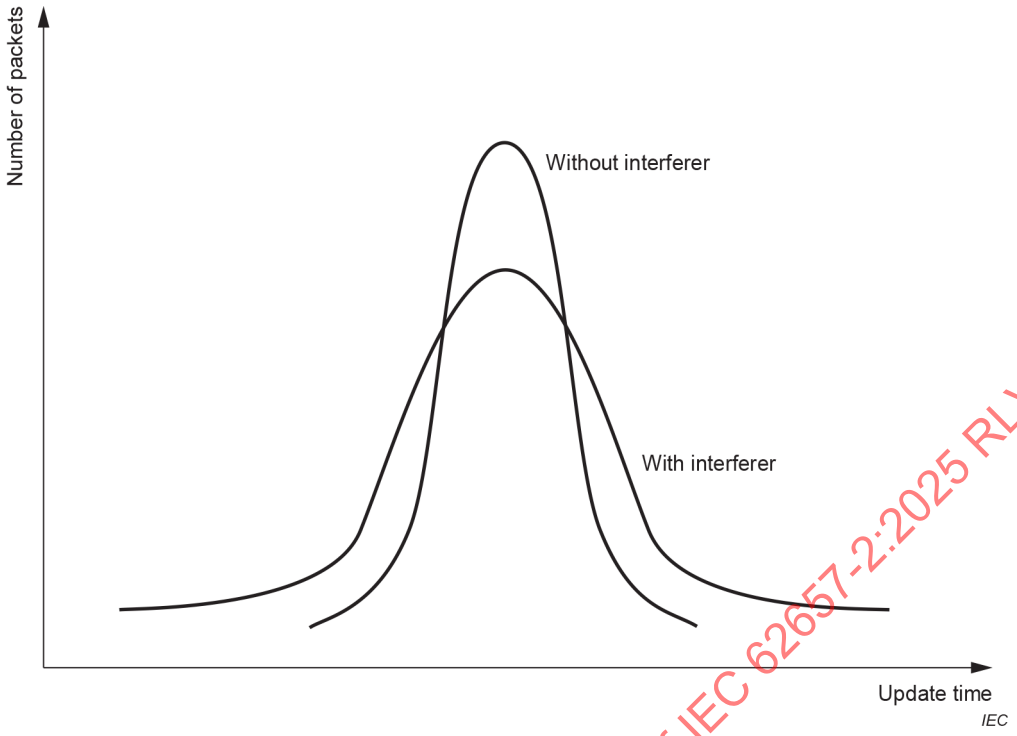

Figure 21 – Example of distribution functions of the update time

A maximum span of the update time, also called jitter, would be necessary in order to get an absolute result on coexistence by comparing this time value with a limit required by the application. However, the maximum span of a certain measurement is not equivalent to the absolute maximum span of update time. The maximum span has a certain probability that can be calculated if the functional equations of the curves in Figure 21 are known. The reliability of the calculation depends on the sample size of the measurement on which the functional equations are based. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

The unit of this parameter shall be the second (s).

5.67 Wireless device density

The number of wireless devices has an impact on communication load and medium utilization. The fewer wireless devices which are communicating within the wireless system, the lower is the probability of interferences.

Wireless device density is the number of wireless devices within the spatial coverage, see 5.55, of the wireless communication system. The wireless device density has an impact on medium utilization.

This parameter shall be expressed as a number represented as an unsigned integer value and the unit shall be the number of devices per m^2.

5.68 Wireless device type information

For each device, the typical device type information, such as model type, manufacturer, hardware version, shall be provided.

The content of this parameter shall be text expressed with a multiple octet string.

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5.69 Wireless communication solution density

This parameter describes wireless communication solutions operating in the same area. All wireless solutions shall be considered, independently of technology or used frequency band. The medium utilization factor of these wireless solutions shall be described.

Wireless communication solution density is the number of wireless communication solutions within the geographical dimension of the plant (see 5.25).

This parameter shall be expressed as a number represented as an unsigned integer value and the unit shall be the number of devices per m^3.

5.70 Wireless technology or standard

Most wireless equipment will use a standardized basic technology which sometimes already predefines some of the parameters listed in Clause 5. Therefore, the values or the domain for a number of parameters are implicitly defined by naming the wireless technology or standard.

The frequency band shall be provided explicitly since this allows a first general categorization of a wireless solution. Furthermore, the modulation scheme shall be specified. The kind of modulation, or the coding of the symbols before physical transmission, might help to avoid interferences of the wireless solutions. Moreover, the communication requests are transferred differently onto the communication medium, meaning that one and the same communication load can lead to different channel occupation ratios.

Implementations that use a basic technology might, for certain parameters, be much better than the basic standard. A wireless implementation may also only use a subset of a reference wireless standard and therefore not all parameters could be relevant. Moreover, there are wireless technologies that do not follow a certain standard.

Examples of standards specifying a wireless communication system are IEC 62591 [1], IEC 62601 [2] and IEC 62734 [3].

The content of this parameter shall be text expressed with a multiple octet string.

6 Coexistence management information structures

6.1 General

Clause 6 specifies the structuring of coexistence management parameters according to usage dimensions. The principle is depicted in Figure 22. The parameters explained in Clause 5 are selected and structured in Clause 6. Table 4 shows the hierarchy of the characteristics.

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Table 4 – Hierarchy of the characteristic parameters

Hierarchy	Explanation or references
Industrial communication network	Part of the automation application; super class of the class wireless industrial automation and wired industrial automation
Wireless industrial automation	Contains one or more physical system interface
Distributed automation system	Elements, relations, and interfaces that exchange data through physical links where the dependable communication availability of the data at the logical target endpoints of the reference interface determines the correct operation of the application
General plant characteristic	See 6.2 and Table 22
Application communication requirements	See 6.3 and Table 23
Requirements influencing the characteristic of wireless solutions	See 6.3.2 and Table 23
Performance requirements	See 6.3.3 and Table 23
Radio environment	Has one or more physical layer interfaces and the relevant elements are passive environmental influences and active environmental influences
Passive environmental influences	See 6.2.3
Active environmental influences	See 6.2.4
Interference type	See 5.28 and Table 30
Wireless communication system	See 6.4 and 6.5
Wireless system type and wireless device type	See 6.4
Wireless system type	See 6.4.2 and Table 24
Wireless device type	See 6.4.3 and Table 25
Wireless device transmitter parameters	See 6.4.3.2 and Table 25
Wireless device receiver parameters	See 6.4.3.3 and Table 25
Wireless solution	See 6.5
Wireless system solution	See 6.5.2 and Table 26
Wireless device solution	See 6.5.3 and Table 27
Wireless device solution general parameters	See 6.5.2 and Table 27
Wireless device solution transmitter parameters	See 6.5.3 and Table 27
Wireless device solution receiver parameters	See 6.5.3 and Table 27
Wired industrial automation	Out of the scope of this document but shown as a possibility

The structures provided in Clause 6 are used in the templates given in Clause 8. Parameters to describe the relevant information shall be provided and the parameter can be a value range or a list of values.

The templates given in Clause 8 shall be used to describe a specific object of the items relevant for the coexistence management by assigning values or value ranges to the parameters. Thus, the information can be deployed within the wireless coexistence management process.

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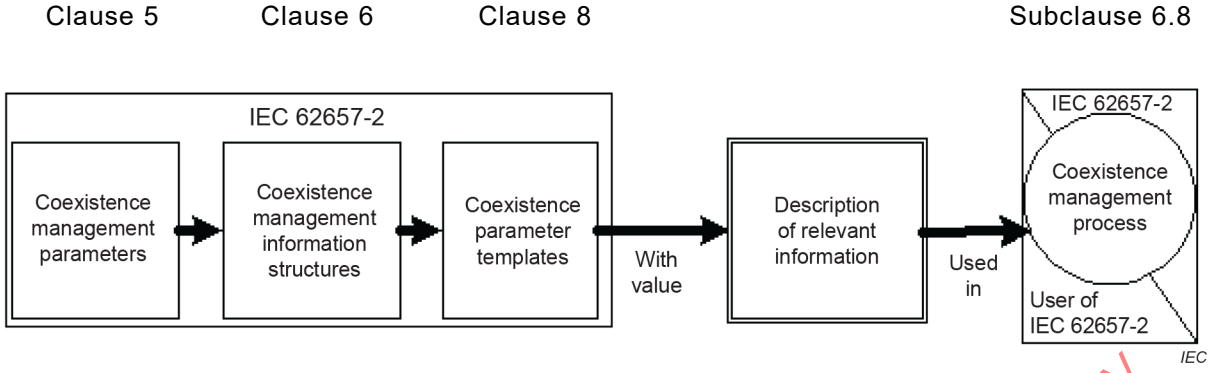

Figure 22 – Principle for use of coexistence parameters

Four sets of parameters are specified for the wireless coexistence management process. They are used to describe

- the general characteristics of plants common to all wireless communication systems (see 6.2),
- the application communication requirements of each automation application (see 6.3),
- the characteristics of each wireless system and device-type (see 6.4),
- the characteristics of each wireless solution (see 6.5).

6.2 General plant characteristic

6.2.1 General

Subclause 6.2 specifies the set of parameters that characterizes the plant in general with respect to all wireless communication applications. For the description of a plant characteristic, the templates given in Clause 8 shall be used. The definitions and specifications of the coexistence management parameters are according to the descriptions in Clause 5. The description of the plant characteristic shall be used in the coexistence management process, which is defined in 6.8. Figure 23 shows the relation between the definition and specification in this document and the use of them in a coexistence management system specification.

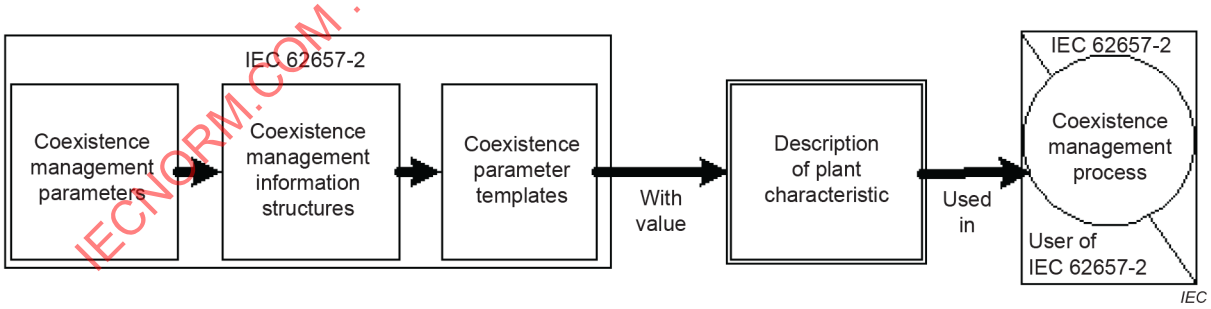

Figure 23 – Parameters to describe the general plant characteristic

6.2.2 General plant characteristic

The parameters in Table 5 shall be used to describe the propagation conditions and the interference potential within a plant to describe the general plant characteristic.

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Table 5 – List of parameters used to describe the general plant characteristic

Parameter name	Reference	Content
Regional radio regulations	5.51	List of relevant regional radio regulations
Future expansion plan	5.24	Informal specification of the potential possible future expansions of the plant

6.2.3 Passive environmental influences

The parameters in Table 6 shall be used to describe the propagation conditions and the interference potential within a plant for the passive environmental influences.

Table 6 – List of parameters used to describe the passive environmental influences

Parameter name	Reference	Content
Area of operation	5.11	Informal specification of the area of operation with respect to its influences on the passive environmental effects
Object movement	5.42	Specifies the mobility of assets (e.g. obstacles)
Geographical dimension of the plant	5.25	Specification of the geographical dimension of the plant using length, width and height
Natural environmental condition	5.39	Informal specification of expected natural environmental conditions with respect to its influences on the passive environmental effects
Intervisibility	5.29	Informal specification of the radio propagation conditions with respect to its influences onto the passive environmental effects or formal specification of the transition factor
Frequency band	5.20	The frequency band used by the planned wireless system has a significant influence on radio propagation

6.2.4 Active environmental influences

Examples of devices that can cause active environmental influence are welding machines, electrical drives or frequency converters.

Other sources of active environmental influences are wireless communication devices that use the same frequency range or the same or nearby frequency channels.

The parameters in Table 7 shall be used to describe the propagation conditions and the interference potential within a plant for the active environmental influences.

Table 7 – List of parameters used to describe the active environmental influences

Parameter name	Reference	Content
Wireless communication solution density	5.69	List of wireless solutions (including all relevant parameters according to 6.5.2) in the plant (active environmental influences)
Interference type	5.28	List of frequency users including detailed description with respect to its influences on the active environmental effects
Limitation from neighbours of the plant	5.32	Informal specification of limitations from neighbours of the plant with respect to their influences on the active environmental effects
Frequency band	5.20	To take interference into account, the frequency band used by the planned wireless system shall be known

Most of the parameter values can be provided by the plant owner. However, for some parameters, expertise of wireless experts is required. If such expertise is not available within the organization of the plant, it is strongly recommended to consult external expertise.

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Textual descriptions can be used for these parameters if it is not feasible to provide quantitative values. In these cases, the textual description should be as specific as possible. Graphics and pictures can support such descriptions.

Additional information ~~may~~ could be needed.

For example, a wireless system can be tagged by an identifier referring to such additional information.

Table 8 provides the list of parameters used to describe an interference type.

Table 8 – List of parameters used to describe the interference type

Parameter name	Reference	Content
Interference type	5.28	List of frequency users including detailed description with respect to its influences on the active environmental effects
Frequency band	5.20	To take interference into account, the frequency band used by the planned wireless system shall be known
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22).
Total radiated power	5.59	Possible total radiated power values
Power spectral density	5.46	Description of power spectral density
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Duty cycle	5.16	Declaration of maximum duty cycle value
Dwell time	5.17	Declaration of maximum dwell time value
Medium utilization factor	5.36	Declaration of the MU factor

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6.3 Application communication requirements

6.3.1 Overview

Application communication requirements are mostly quantitative requirements specifying the required conditions and the required characteristics of wireless solutions at the reference interface. These requirements shall be met in order to achieve the purpose of the automation application.

By definition, coexistence is the state in which all applications using wireless communication fulfil their requirements. These requirements are usually related to business goals and take into account, in addition, a number of conditions such as safety of persons, efficient use of resources or hazard conditions.

In order to fulfil these goals, the wireless solution shall meet the application communication requirements in terms of communication availability and real time capability, considering the industrial conditions and the characteristics of wireless systems that influence those requirements.

Figure 24 shows the relationship between the definition and specification of parameters in this document and its use to describe the application communication requirements in a coexistence management system specification.

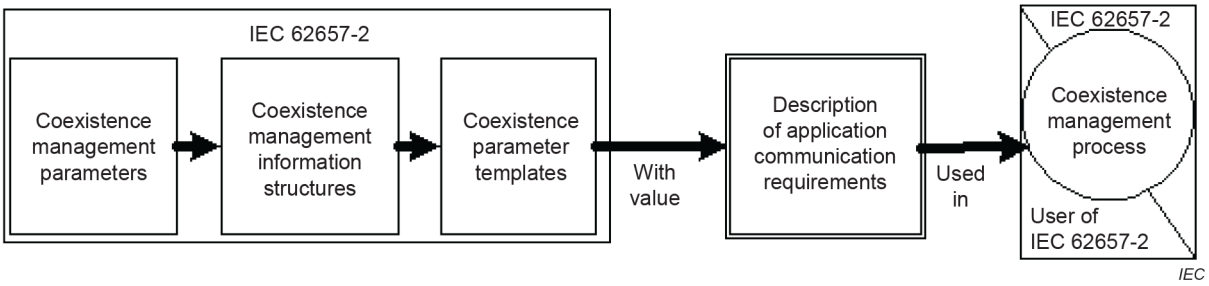

Figure 24 – Parameters to describe application communication requirements

Application communication requirements can be divided into requirements that influence the behaviour of a wireless device or system and performance requirements that shall be met by the wireless solution in order to ensure the purpose of the automation application.

6.3.2 Requirements influencing the characteristic of wireless solutions

The set of parameters in Table 9 are application communication requirements that influence the performance of wireless solutions and thus the coexistence state. The values of these parameters shall be collected.

Table 9 – List of parameters used to describe the requirements influencing the characteristic of wireless solutions

Parameter name	Reference	Content
Communication load	5.12	Specification of the required communication load at a reference interface using user data length and ~~transmission~~ transfer interval
Initiation of data transmission	5.27	Specification of the required initiation of data transmission at a reference interface
Length of user data per transfer interval	5.31	Specification of the required length of user data at a reference interface
Maximum number of retransmissions	5.33	Specifies how many times user data are acceptable to be retransmitted automatically by the communication stack because of transmission errors
Position of wireless devices	5.45	Specification of the required position of a wireless device using three dimensions according to the spatial coverage of the wireless communication system
Distance between wireless devices	5.15	Specification of the length of a physical link
Purpose of the automation application	5.47	Description of the purpose of the automation application
Relative movement	5.52	Specification of the trajectory of a device and its moving profile or the length of a physical link, the relative acceleration and speed
Security level	5.54	Specification of the required security level
Spatial coverage of the wireless communication	5.56	Specification of the required spatial coverage of the wireless communication system using length, width and height
Transfer interval	5.60	Specification of the required transfer interval at a reference interface
Wireless device density	5.67	Specification of the required wireless device density according to the spatial coverage of the wireless communication system

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6.3.3 Performance requirements

Performance requirements describe the time and error behaviour necessary to achieve the purpose of the automation application.

The set of parameters in Table 10 shall be used to describe the required performance including the acceptable maximum number of retransmissions and MLR.

Table 10 – List of characteristic parameters

Parameter name	Reference	Content
Data throughput	5.14	Specification of the required values for data throughput
Communication availability	5.6	Specification of the required values for communication availability
Transmission time	5.62	Specification of the required values for transmission time
Update time	5.66	Specification of the required values for update time
Response time	5.53	Specification of the required values for response time

NOTE The parameters given in Table 10 are random variables. These parameters are specified in terms of their mean value, percentile, standard deviation or span (jitter).

6.4 Wireless system type and wireless device type

6.4.1 Overview

Subclause 6.4 specifies sets of parameters that characterize the model of a wireless system or a wireless device by providing the parameters to specify a wireless system type and a wireless device type.

Depending on the life cycle, the content can change for example from

- what is required from the point of view of a planner;
- what is specified in a standard including options and recommendations?

NOTE These parameters are not those of a particular implementation of a wireless system or device; that is called a wireless solution.

Additional information could be useful. For example, the parameter in 5.68 can be listed.

Figure 25 shows the relationship between the definition and specification in this document and its use in a coexistence management system specification.

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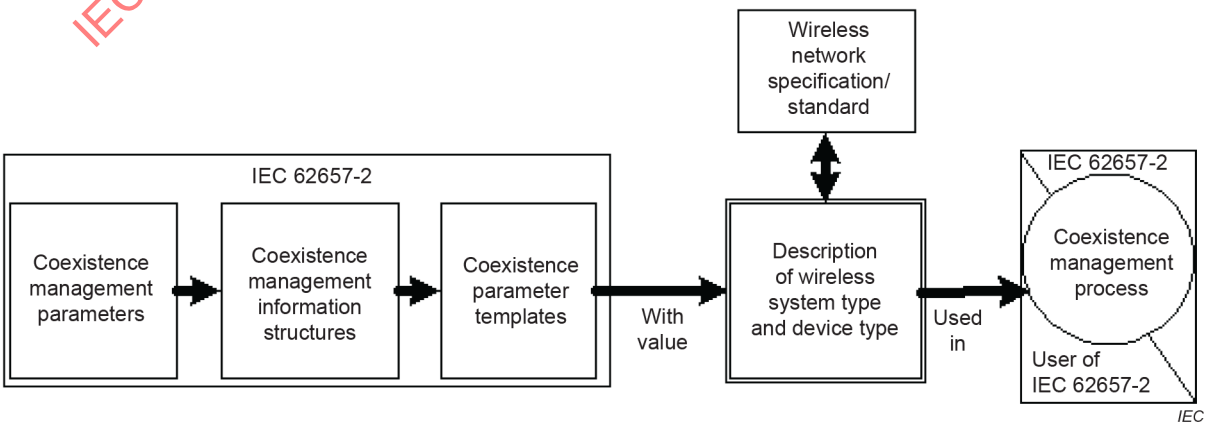

Figure 25 – Parameters to describe wireless system type and device type

Almost all parameters are specified in standards or specifications for wireless systems. However, a particular wireless communication system or device might have better or worse performance than specified. Furthermore, specifications sometimes allow value ranges for parameters. The values and value ranges of the parameters in Table 11, Table 12 and Table 13 shall be provided together with the wireless product. References can be used for parameters whose values or value ranges can be found in specifications or standards.

Subclause 6.4 differentiates between common wireless system parameters and specific device parameters.

6.4.2 Wireless system type

The type of a wireless system shall be characterized using the parameters given in Table 11.

Table 11 – List of parameters used to describe the wireless system type

Parameter name	Reference	Content
Wireless technology or standard	5.70	Reference to specifications or standards with which the wireless system is compliant
Regional radio regulations	5.51	List of regional radio regulations with which the wireless system is compliant
Network topology	5.40	Topologies of the wireless network
Wireless device density	5.67	Declaration of maximum possible number of active devices in the spatial coverage
Infrastructure device	5.26	Description of possible or required infrastructure devices
Frequency band	5.20	Description of possible frequency band
Lower cut-off frequency	5.13	Lower frequency limit of the frequency band
Upper cut-off frequency	5.13	Upper frequency limit of the frequency band
Frequency hopping sequence	5.23	Description of possible or required frequency hopping sequences
Modulation	5.38	Description of possible or required modulations
Communication reliability	5.7	Description of possible or required bit rate value of a physical link or a list from which can be selected
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Dwell time	5.17	Declaration of maximum dwell time value
Medium access control mechanism	5.35	Description of possible or required medium access control mechanisms
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35
Mechanism for adaptivity	5.34	Description of possible or required mechanisms for adaptivity
Security level	5.54	Description of functions for ensuring security levels

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6.4.3 Wireless device type

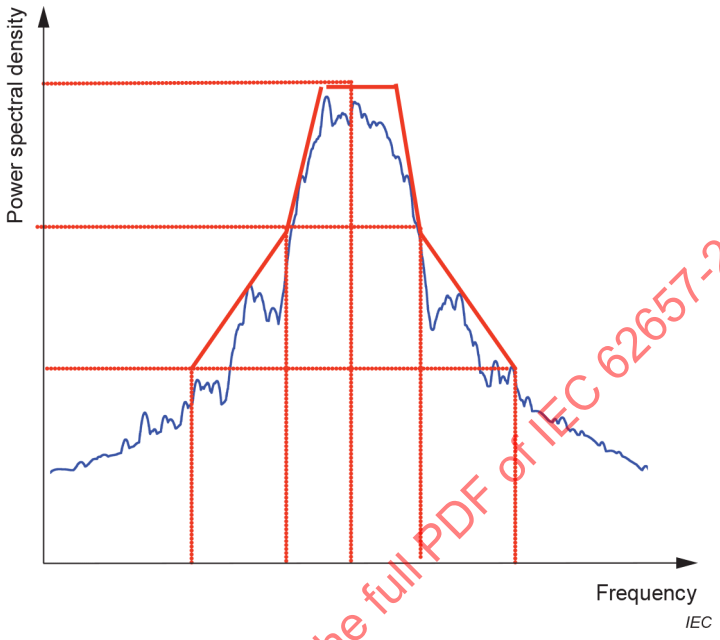
6.4.3.1 General

A wireless device type can be characterized by the specification of transmitter and receiver parameters. For a device implementing both transmitting and receiving functions, both sets of parameters shall be specified.

6.4.3.2 Wireless device transmitter parameters

The spectral energy radiated by a device can be measured with a spectrum analyzer. An example of a measurement is shown in Figure 26. The blue line illustrates the power spectral density of a transmitter. A simplified representation is the transmitter spectral mask, see 5.65, which is overlaid in Figure 26 (see red colored line).

NOTE Depending on the specific technology or standard, different parameters are used to describe the frequency spectrum and the power level.



Key

solid line (red) spectral mask

solid line (blue) the power spectral density

Figure 26 – Example of power spectral density and transmitter spectral mask

While frequency and power are originally determined by the wireless device or system, the utilization of the spectrum in time also depends on the communication requests of the application. In Figure 27, the principle of medium utilization in time and frequency is depicted. It can also be recorded using a spectrum analyzer. The yellow color in Figure 27 shows the area of the centre frequencies with the highest power level. Relevant parameters describe the time of a transmission and the time between two consecutive transmissions. In certain circumstances, it is of interest as to whether the time refers to one or several frequency channels.

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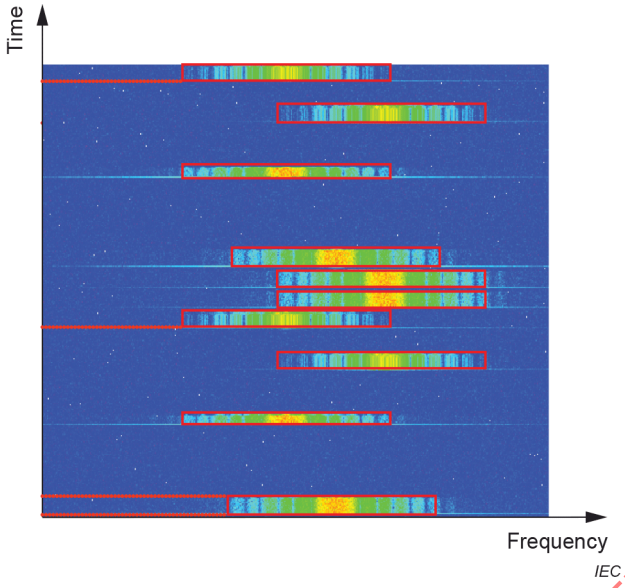

Figure 27 – Example of medium utilization in time and frequency

The values or value ranges of a wireless device type ~~may~~ can be better than the values specified for the wireless system type. Therefore, the transmitter parameters in Table 12 shall be used to characterize a wireless device type.

Table 12 – List of parameters used to describe the transmitter of a wireless device type

Parameter name	Reference	Content
Wireless device density	5.67	Declaration of maximum possible number of active devices in the spatial coverage
Antenna type	5.5	Description of antenna types that are used, or that can be selected
Antenna gain	5.3	Declaration of antenna gain
Antenna radiation pattern	5.4	Declaration of antenna radiation pattern
Equivalent radiated power	5.19	Declaration of maximum ERP value
Equivalent isotropic radiated power	5.18	Declaration of maximum EIRP value
Receiver maximum input level	5.49	Declaration of radiated power value or a list from which can be selected
Total radiated power	5.59	Possible total radiated power value
Transmitter output power	5.63	Description of transmitter output power in case the antenna is external or the ERP/EIRP ~~has~~ needs to be adjusted by the parameter transmitter output power
Transmitter spectral mask	5.65	Description of transmitter spectral mask
Power spectral density	5.46	Description of power spectral density
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22)
Communication reliability	5.7	Declaration of communication reliability
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Duty cycle	5.16	Declaration of maximum duty cycle value
Dwell time	5.17	Declaration of maximum dwell time value
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35

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6.4.3.3 Wireless device receiver parameters

The receiver parameters in Table 13 shall be used to characterize a wireless device type.

Table 13 – List of parameters used to describe the receiver of a wireless device type

Parameter name	Reference	Content
Adjacent channel selectivity	5.2	Description of adjacent channel selectivity value
Receiver sensitivity	5.50	Description of receiver sensitivity value
Receiver maximum input level	5.49	Description of maximum receiver input level value
Receiver blocking	5.48	Declaration of receiver blocking response value
Spurious response	5.57	Declaration of receiver spurious response value

6.5 Wireless solution

6.5.1 Overview

Subclause 6.5 describes the characterization of wireless solutions which are implementations of wireless systems and device types. In contrast to the description of wireless systems and device types, here the parameter values refer to a certain installation within a plant.

Figure 28 shows the relationship between the definition and specification of parameters in this document and their use. Based on a type description of a certain wireless system and its wireless devices (see 6.4), with respect to the coexistence management information structure, and the description of wireless solution given in 6.5, the wireless communication solution and its wireless device solutions can be described.

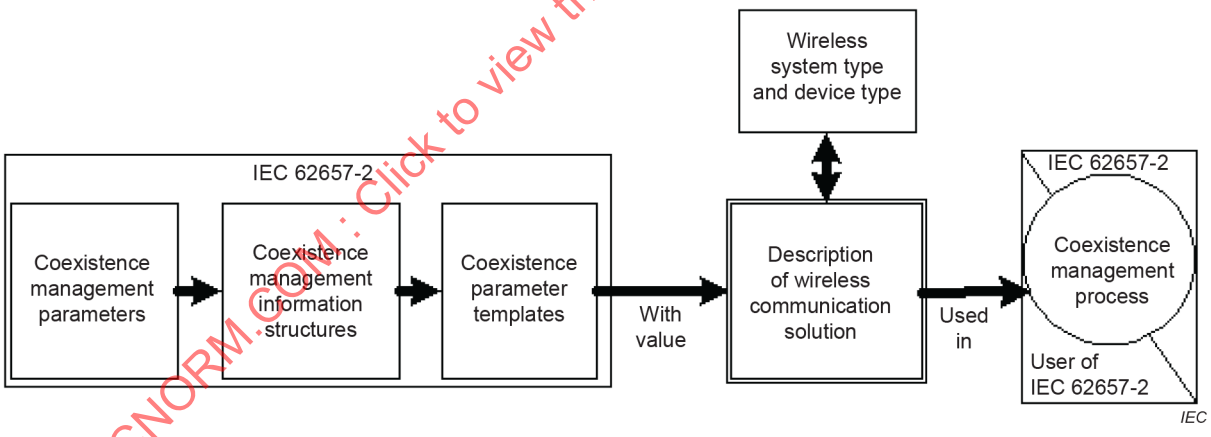

Figure 28 – Parameters to describe a wireless communication solution

6.5.2 Wireless system solution

The wireless system solution shall be characterized using the parameters in Table 14, in addition to the parameters of the wireless system type and wireless device type according to 6.4.

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Table 14 – List of parameters used to describe a wireless solution

Parameter name	Reference	Content
Wireless system type	6.4.2	Reference to a wireless system type described with parameters according to 6.4.2
Network topology	5.40	Description of network topologies
Wireless device density	5.67	Declaration of maximum possible number of active devices in the spatial coverage
Position of wireless devices	5.45	List of positions of wireless devices
Relative movement	5.52	List of descriptions of movement of wireless devices
Infrastructure device	5.26	List of positions of infrastructure devices
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22)
Frequency hopping	5.23	Configured frequency hopping sequences
Modulation	5.38	Configured modulations
Bit rate of physical link	5.8	Configured bit rates of physical link
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Dwell time	5.17	Declaration of maximum dwell time value
Medium access control mechanism	5.35	Description of configured medium access control mechanisms
Mechanism for adaptivity	5.34	Description of configured mechanisms for adaptivity
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35
Security level	5.54	Description of configured functions for ensuring security level

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6.5.3 Wireless device solution

The wireless device solution shall be characterized using the parameters in Table 15 and Table 16, in addition to the parameters of the wireless device type according to 6.4.3.

Table 15 – List of general parameters used to describe the wireless device solution

Parameter name	Reference	Content
Wireless system type	6.4.2	Reference to a wireless system type described with parameters according to 6.4.2
Wireless device type	6.4.3	Reference to a wireless device type described with parameters according to 6.4.3

Table 16 – List of parameters used to describe the transmitter of a wireless device solution

Parameter name	Reference	Content
Antenna type	5.5	Description of antenna types
Antenna gain	5.3	Declaration of antenna gain
Antenna radiation pattern	5.4	Declaration of antenna radiation pattern
Equivalent radiated power	5.19	Declaration of effective radiated power values
Equivalent isotropic radiated power	5.18	Declaration of EIRP value
Total radiated power	5.59	Declaration of total radiated power values
Transmitter output power	5.63	Description of transmitter output power in case the antenna is external or the ERP/EIRP ~~has~~ needs to be adjusted by the parameter transmitter output power
Power spectral density	5.46	Description of power spectral density
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22)
Bit rate of physical link	5.8	Declaration of minimum bit rate
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Duty cycle	5.16	Declaration of maximum duty cycle value
Dwell time	5.17	Declaration of maximum dwell time value
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35

The receiver parameters of a device are mostly specified by the wireless device type. Only the receiver sensitivity can be configured, see Table 17.

Table 17 – List of parameters used to describe the receiver of a wireless device solution

Parameter name	Reference	Content
Adjacent channel selectivity	5.2	Description of adjacent channel selectivity value
Receiver sensitivity	5.50	Configured values of receiver sensitivity
Receiver maximum input level	5.49	Description of maximum receiver input level value
Receiver blocking	5.48	Declaration of receiver blocking response value
Spurious response	5.57	Declaration of receiver spurious response value

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6.6 Application related characteristic parameters

Characteristic parameters allow a quantitative assessment of a wireless communication ~~systems~~ solution, see Table 18. A set of required values are part of application communication requirements. A set of promised values are part of the capability description of a wireless communication ~~system~~ solution. The characteristic parameters refer to the interfaces between the logical wireless communication devices and the assumed logical automation device, called reference interface.

Table 18 – List of relevant characteristic parameters of wireless solutions

Parameter name	Reference	Content
Transmission time	5.62	Specification of the required values for transmission time
Update time	5.66	Specification of the required values for update time
Response time	5.53	Specification of the required values for response time
Data throughput	5.14	Specification of the required values for data throughput
Communication availability	5.6	Specification of the required values for communication availability
Message loss ratio	5.44	Specifies the acceptable MLR
Communication reliability	5.7	Applied to the function of a wireless communication system, communication reliability is the ability of a logical link to transmit messages under stated conditions for a specified period of time. The communication reliability can be determined using the operating time between failures
Operating time between failures	5.43	The operating time between failures of a logical link is the sum of the operating time periods between two successive failures. The logical link is considered as a repairable item in the sense that a message can be repeated within the survival time. A measure to assess a logical link is the mean operating time between failures
Survival time	5.58	A time that an application, consuming a communication service, can continue without an anticipated message

Relevant statistical values of the characteristic parameters are listed in Table 19. There is the mention of minimum, mode, mean and percentile P95 values. The minimum, mode, mean, standard deviation, and percentile statistical values are the most relevant ways to express the characteristic parameters. For evaluation of message transmission, all proposed values from each parameter name are relevant.

Table 19 – List of relevant statistical values of characteristic parameters

Parameter name	Reference	Statistical values
Transmission time	5.62	Minimum, mode, percentile P95
Update time	5.66	Mean, standard deviation
Response time	5.53	Minimum, mode, percentile P95
Data throughput	5.14	Capacity of a communications channel
Communication availability	5.6	The ratio of the time interval of error free transmission (uptime, t_U) to an observation time t_O
Message loss ratio	5.44	The ratio, expressed as a percentage, of the number of messages not delivered divided by the total number of messages during a time interval T, where the number of messages not delivered is the difference between the number of messages arriving at the ingress flow point and the number of messages delivered at the egress flow point in a point-to-point connection
Survival time	5.58	A time that an application, consuming a communication service, can continue without an anticipated message

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6.7 Radio environment related performance parameters

Radio environment related performance parameters allow a quantitative assessment of passive and active environmental influences on radio signal propagation. The values of these parameters can be measured and/or calculated during the operation of wireless communication solutions by their wireless devices or by special devices for determining the use of the radio spectrum.

In general, radio environment related performance parameters are not part of the application communication requirements and are not part of the capability description of a wireless communication solution. Therefore, usually the required values are not of interest. Promised values could be specified in terms of reference values or thresholds for initiating coexistence measures. The current values of radio environment related performance parameters can be considered for calculating the coexistence state. In this way, problems due to shadowing or interference can be detected before the values of the application related characteristic parameters exceed relevant threshold values.

The radio environment related performance parameters refer to the interfaces between the logical wireless communication device and the radio environment, called physical layer interface.

There is no common standard for radio environment related performance parameters and their determination. They depend on the wireless technology, the various wireless communication standards and/or their implementations. Table 20 lists a non-exhaustive summary of possible parameters.

Table 20 – List of radio environment related performance parameters

Parameter name	Content
Duty cycle	Ratio of the transmitter sequence referenced to a given observation time for the used frequency channel
Link quality	Quality of a physical link between two Bluetooth devices with a value from 0 to 255
Power spectral density (PSD)	Power of a signal distributed over a frequency range
Receive signal level	Estimated receive signal level according to IEC 62591 [1]
Reference signal received power (RSRP)	Received power level, parameter is used in cellular mobile communications
Reference signal received quality (RSRQ)	Signal level and quality, parameter is used in cellular mobile communications considering RSRP, RSSI and used resource blocks
Received signal strength indication (RSSI)	Relative value that represents the power of a received radio signal, sometimes also called received signal strength indicator
Signal-to-interference ratio (SIR)	Power of a certain signal of interest divided by the sum of the interference power
Transmitter sequence	Time that a transmitter uses a frequency channel without the possibility to be interrupted by a wireless device of the same wireless communication system
Transmission gap	Time between two successive channel usages by a transmitter

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The type of value (mean value, instantaneous value) depends on the respective definitions of the parameters for the respective implementation. If possible, statistical values should be calculated based on these values for a well-defined and system-wide uniform observation time.

6.8 Wireless communication solution related performance parameters

Wireless communication solution related performance parameters allow a quantitative assessment of the wireless communication in a wireless communication solution. The values of these parameters can be measured and/or calculated during the operation of wireless communication solutions by their wireless devices.

In general, wireless communication solution related performance parameters are not part of the application communication requirements. Therefore, usually the required values are not of interest. These parameters can be part of the capability description of a wireless communication solution. Promised values could be specified in terms of reference values or thresholds for initiating coexistence measures. The current values of wireless communication solution related performance parameters can be considered for calculating the coexistence state. In this way, problems with the wireless communication solution can be detected before the values of the application related characteristic parameters exceed relevant threshold values.

The interface, the wireless communication solution related performance parameters refer to, depends on the implementation.

There is no common standard for wireless communication solution related performance parameters and their determination. They depend on the wireless technology, the various wireless communication standards and/or their implementations. Table 21 lists a non-exhaustive summary of possible parameters.

Table 21 – List of wireless communication solution related performance parameters

Parameter name	Content
Bit rate	Number of bits transmitted by a wireless device during a given observation time
Data rate	Number of bytes transmitted by a wireless device during a given observation time
Number of received octets	Number of octets successful received by a wireless device
Number of received packets	Number of packets successful received by a wireless device
Number of retry packets	Number of packets retransmitted by a wireless device because of transmission failures
Number of transmission failures	Number of non-successful transmissions by a wireless device
Number of transmitted octets	Number of octets transmitted by a wireless device
Number of transmitted packets	Number of packets transmitted by a wireless device

The type of value (mean value, instantaneous value) depends on the respective definitions of the parameters for the respective implementation. If possible, statistical values should be calculated based on these values for a well-defined and system-wide uniform observation time.

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7 Coexistence management process

7.1 General

7.1.1 Overview

A coexistence management process represents the activities of the coexistence management system.

The coexistence management process includes technical and organizational activities in order to establish and to maintain the coexistence state of all wireless solutions in a plant. The coexistence parameters specified in Clause 5, and organized as described in Clause 6, are used in different phases of the coexistence management process. The overall process starting from the decision to establish such a process is depicted in Figure 7. The coexistence management process consists of the following phases:

- investigation phase (see 7.4.1);
- planning phase (see 7.4.2);
- implementation phase (see 7.4.3);

- operation phase (see 7.4.4).

NOTE As all these phases belong to the coexistence management, in the following text the term 'coexistence management' is omitted in front of the phase names.

The investigation phase shall be initiated when changes are discovered or when a new wireless system or other radio emitter in the managed band(s) are planned to be installed.

In the planning phase, the resource allocation plan is developed or modified based on the coexistence parameter values.

In the implementation phase, new wireless solutions are installed, and the configuration of existing wireless solutions is modified in accordance with the resource allocation plan.

In the operation phase, the status of wireless communication applications is monitored to detect problems related to coexistence and to initiate maintenance procedures.

~~In all phases, the local and regional legal and regulatory issues shall be considered and shall be fulfilled.~~

7.1.2 Documentation

The coexistence management system shall be documented in a coexistence management system specification and maintained as part of the coexistence management process.

The scope of the documentation should correspond to the application class.

Some elements that should be part of the coexistence management system specification that are mentioned in this document are listed below:

- scope;
- commitment of the organization;
- procedure for maintaining;
- structure of the organization;
- roles of personnel;
- communication with external organizations;
- procedures for coexistence management;
- visualization of the interference risk;
- occupation of the frequency bands;
- location and positions of the wireless applications;
- inventory results;
- commissioning of external or internal service providers;
- information on the wireless applications;
- results of analyses and measurements;
- particulars of installation and approval;
- establishment of communication channels;
- establishment of a committee;
- establishment of an obligation to register wireless systems;
- release or rejection of newly registered wireless applications;
- document management and coordination of specifications;

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- training;
- procedure of the audit;
- audit results;
- results of analysis and metrological examination;
- action plan;
- general plant characteristic;
- automation communication requirements;
- wireless system type;
- wireless device type;
- wireless system solution;
- wireless device solution.

NOTE The order of the bullet list above is not mandatory. The organization of a document structure can be based on different points of view like life cycle, hierarchical structure, etc., referring to the same content. This is out of the scope of this document.

The following documents contain the elements listed above and shall be part of the coexistence management system specification:

- general plant characteristic (see 6.2, Table 22 and Table 30);
- application communication requirements (see 6.3 and Table 23)
  - requirements influencing the characteristic of wireless solutions (see 6.3.2);
  - performance requirements (see 6.3.3, Table 28 and Table 29);
- wireless communication system (see 6.4, 6.5)
  - wireless system type and wireless device type (see 6.4)
    - i) wireless system type (see 6.4.2 and Table 24);
    - ii) wireless device type (see 6.4.3 and Table 25)
      - a) wireless device transmitter parameters (see 6.4.3.2);
      - b) wireless device receiver parameters (see 6.4.3.3);
  - wireless solution (see 6.5) (this represents the resource allocation plan)
    - i) wireless system solution (see 6.5.2 and Table 26);
    - ii) wireless device solution (see 6.5.3 and Table 27);
- resource allocation plan (see 6.3, 6.4, and 6.5).

It is recommended to support the documentation by a suitable documentation method. The requirements on such a method are described in 7.1.3.

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7.1.3 Suitable documentation method

For an efficient processing of coexistence management, related to the complexity of the local situation, the application of a suitable documentation method is advisable. The documentation should at least include the following content:

- storage of information about numerous wireless systems and devices, including information about their spatial position and their radio parameters (for example in a data base);
- plausibility check of the recorded data;
- administration of information concerning the status of the known wireless applications;
- access to the documentation and their administration for all parties involved in the project (if necessary, even for those located in other countries) subject to access authorizations;

- visualization of the interference risk and the occupation of the frequency bands in an intuitive comprehensible form (for human beings);
- experiences of the company in handling the wireless applications;
- optionally, visualization of the positions of the wireless applications.

7.1.4 Application of tools

The essential steps to administer radio frequencies can be supported with suitable tools.

Software tools can be used to administer the documentation specified in 7.1.3.

Other tools can support the concepts specified in 4.7.

7.2 Establishment of a coexistence management system

7.2.1 Nomination of a coexistence manager

For effective control of the coexistence management process, a central responsibility is required at the appropriate level.

One or more central contact persons (coexistence managers) shall be assigned. The area of responsibility of the coexistence manager shall be determined individually for each enterprise. Thus, a coexistence manager ~~may~~ could be responsible for the whole company, for one or more locations, or for business divisions and departments, depending on the company organization. The crucial factor is to ensure the efficiency of the process.

Whatever the approach adopted by the specific company, it could be considered as belonging to one of two main options:

- based on the relevance of the problem;
- independent of the relevance of the problem.

In the first case, the coexistence manager is chosen from the divisions mostly affected by potential interferences. Often the IT and the automation divisions are the ones concerned.

In the second case, the neutrality of the responsible division is emphasized. Hence, for example, the coexistence manager could be chosen from the "facility management" division administrating the company resources, because the frequency spectrum is to be considered a limited and therefore a valuable resource.

Internal processes and the organization of a company are the decisive factors to choose either of the two strategies. In each individual case, the decision shall be made subject to the respective conditions. Here it is important to ensure the efficiency of the process. The coexistence manager shall have basic knowledge about automation applications and the characteristics of wireless systems. The coexistence manager shall have the authority to take the necessary measures to fulfil the defined tasks.

This document describes the coexistence manager as a person. However, this does not imply that some of the sub-functions of the coexistence manager could not be allocated to an automated process. Clearly, the final responsibility of the overall coexistence manager function shall remain with an individual.

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7.2.2 Responsibility of a coexistence manager

The coexistence manager shall be responsible for the following activities:

- establishment of communication channels within the company;
- establishment of a committee, consisting of contact persons of all company divisions using wireless systems;
- establishment of an obligation to register wireless systems in the location(s) of interest in the company;
- inventory of wireless applications and, if necessary, commissioning of external or internal service providers to accomplish the inventory;
- release or rejection of newly registered wireless applications and, where necessary, generation of requirements for the use of wireless applications based on the agreed decisions of the internal committee;
- development and coordination of specifications and regulations to implement and operate wireless applications;
- documentation of information about the operational wireless applications, of the decisions of the coexistence management committee and of the accomplished examinations (if necessary, commissioning external or internal service providers to get these documents);
- ensure the existence of a policy with enforcement for non-authorized introduction of new wireless applications or solutions.

7.2.3 Support by wireless experts

A coexistence manager shall have basic knowledge of wireless technologies, associated radio compatibilities and protocol expertise. Specialist knowledge is required to promote qualified decisions regarding the use of wireless applications which involve considerable risks. If a coexistence manager does not have the specialist knowledge, the coexistence manager shall be assisted by a wireless expert.

The following typical tasks are examples that require the assistance of a wireless expert:

- performing inventory;
- analysis of radio robustness;
- metrological testing of radio robustness;
- designing the architecture of the wireless solution;
- preparation of a draft decision memo for the use of wireless technologies;
- determination of strategies for the use of wireless technologies in the future;
- controlling the adherence to the agreed specifications;
- specifying the values of the parameters for the selected solutions.

7.2.4 Training

The coexistence manager and, if necessary, other members of the committee shall be trained at regular intervals. This training serves to update the knowledge of the persons concerned and to communicate the following information:

- requisite professional background (basics of radio robustness);
- basic knowledge about modern wireless technologies;
- impact of potential problems with practical examples;
- handling of the coexistence management process;
- available tools and monitoring technology.

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The training content should be adjusted to the actual situation in the company. Due to the extremely dynamic nature of technology development, it is advisable to organize these trainings at regular intervals (for example once a year or every two years).

7.3 Maintaining coexistence management system

The coexistence management system shall be appropriately maintained so that it can keep those wireless solutions within its scope in conditions of coexistence, even after requirements and/or environment change.

The coexistence manager within the organization, for example of a company or a hospital, shall be responsible for maintaining the coexistence management system.

Documents in the management system shall be modified appropriately in the following cases:

- when inconsistency of the coexistence management system is detected;
- if the organization is changed.

Audit of the coexistence management system should be conducted to check consistency of the coexistence management system. The procedure of the audit shall be documented.

7.4 Phases of a coexistence management process

7.4.1 Investigation phase

7.4.1.1 Overview

The investigation phase shall be initiated when one of the following events occurs:

- new wireless system needs to be installed or upgrades/modifications of existing solutions are going to be realized;
- environment of wireless system changes;
- problem related to coexistence occurs.

The investigation aims to

- ascertain the actual state in respect of operating wireless applications;
- identify free and occupied frequency resources.

The investigation provides a basis for the coexistence management and is an important step in its implementation. A crucial premise to implement coexistence management successfully is that the results of the investigation are complete and correct.

7.4.1.2 Practical tips to accomplish an investigation

7.4.1.2.1 General

Depending on the application, the investigation can be a complex task so that assistance by skilled and qualified wireless experts is recommended.

In order to accomplish an investigation efficiently, the interrogation of specialist departments (operators and planners of manufacturing plants and building equipment) and radio measurements is essential.

Tools (for example suitable questionnaires) for the investigation shall be provided, allowing the registration of operating wireless systems. It is important to define which responsible parties in the company are able to provide reliable and up-to-date information. Therefore, an agreement within the coexistence management committee is necessary.

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Subject to the application requirements (particularly in the application classes "safety" to "control", see Table 1), the investigation shall be supported by measurements. These measurements serve to verify the plausibility of the interrogation results and, in addition, to ascertain unknown and external wireless applications (for example from the vicinity or from outside sources). In order to reduce the measuring effort, the results of the interrogation can be used as input data to determine the measuring method. The operating procedures shall also collect information about the runtimes of the wireless systems. The measurements shall be carried out under the realistic conditions of an application.

Further information can be gathered with the aid of automatic monitoring systems. Several modern wireless systems (for example controller-based WLANs) allow the recording of information per wireless system. Moreover, radio monitoring systems are offered which automatically gather information concerning the occupation of the frequency spectrum. In the scope of a measurement, the information provided by these systems shall be analyzed, or rather shall be metrologically checked.

If this specific knowledge is not available in-house, the companies can use the external service providers.

7.4.1.2.2 Accomplishment of metrological investigations

Spectrum and protocol analyzers can be used for metrological examinations of the coexistence.

Protocol analyzers are based on an end device or on specialized hardware.

The end device-based protocol analyzer is a software solution, processing the data recorded by an end device (for example network adapter, specialized end device).

Protocol analyzers, based on specialized hardware, are specialized measurement or monitoring systems, particularly used by large systems for the development of hardware, control, and fault finding. Usually, these devices are faster than end-device-based solutions. They are able to record and analyze more parameters, but they are significantly more expensive and sometimes difficult to transport.

As an additional function, wireless solutions can continuously ascertain the actual values of the parameters and provide them to the automation application.

The choice of a tool to perform simulations, measurements or tests should consider its suitability for the planned application and its economic efficiency.

7.4.1.2.3 Evaluation of coexistence

7.4.1.2.3.1 Digital wireless systems

The wireless systems assumed here are systems with digital modulation and coding mechanisms.

Typically, industrial automation applications use digital wireless solutions. Coexistence exists if all wireless solutions involved fulfil the communication requirements of their applications. Therefore, the evaluation of coexistence requires application related characteristic parameters. The characteristic parameters related to the reference interfaces of the wireless solution shall be derived from values provided with the characteristic of the wireless solution according to 6.5.

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7.4.1.2.3.2 Analog wireless systems

Analog wireless systems are primarily used for the transmission of video and voice data.

A crucial factor for the orderly operation of analog systems is compliance with the required signal-to-interference ratio (SIR), or rather signal-to-(interference + noise) ratio (RSSI). The non-compliance with this ratio leads to a reduction in the received signal quality. Depending on the transmitted information, the following negative effects might result:

- reduction in speech quality in the case of voice transmission;
- reduction in image quality in the case of picture/video transmission.

NOTE The values of the signal-to-(interference + noise) ratio range from about 14 dB to 60 dB. They can be ascertained from the respective ITU or ECO/CEPT recommendations or from the device manual.

7.4.1.2.4 Analysis and measurement

During the implementation of a new wireless system, or in the inventory, the interference risk should be analyzed. The interference risk should be analyzed in two steps.

In the first step, analyze whether interference potentials as described in 4.4 do exist. If there is an interference risk between the wireless systems, in the second step a thorough analysis shall follow. The coexistence manager, if necessary, with assistance from a wireless specialist, can preliminarily analyze the interference risk.

The second step is an in-depth analysis, taking into account the particularities of the wireless systems, the radio surroundings and if needed of the automation application and the wireless devices. This analysis shall determine the influences to be expected, the degree of interference risk and the potential measures to be taken in order to ensure coexistence.

In many cases, this analysis will turn out to be very complex so that a metrological examination will be necessary. In this case, the analysis serves to systematically prepare the metrological examination.

The metrological examination shall determine to what extent the requirements on the wireless system are answered and what influences ~~have~~ need to be faced. The result of the metrological test is a draft decision memo for the application of the wireless system and shall be agreed upon by the coexistence management committee. According to this agreement, a wireless solution will be released (if needed with requirements) or rejected.

The results of analysis and metrological examination shall be documented and auditable. They can be further used in the scope of coexistence management, for example in the consideration of similar situations.

The metrological examination can take place either in the physical (application) world or under laboratory conditions. In this context, laboratory conditions mean an environment where several practice-relevant situations can be examined in a comprehensible and reproducible (and if possible standardized) way.

Normally an investigation in real surroundings is preferred, because transmitter-specific realities can be considered here. This cannot be achieved in laboratory studies. The measurement process to be determined should simulate typical, potential operational scenarios of the wireless system and of already existing wireless systems, taking into account the particularities of the automation application. The parameters to be ascertained should be chosen in such a way as to allow one to evaluate whether the requirements for the wireless system are met. Moreover, the examination shall not disturb operating wireless communication applications. If, for that reason, the parameters at the user interface listed in 7.4.1.2.3 are indeterminate in particular cases, the analysis can be accomplished by use of specific wireless protocol analyzers or by indicators (such as plant failure, bus error).

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Realistic investigations under laboratory conditions can provide repeatable and thus valuable information concerning the reaction of the wireless system to different interferences. This information might be useful to analyze coexistence and to prepare the approval. The investigation results might be provided to the contractor accompanied by the documentation of the wireless solution.

Examinations under laboratory conditions can also be useful to prepare the implementation of a wireless system, in cases where the target environment is not yet available (for example during the construction of a new production hall).

Measurements can also be used as examples to verify the analytical results, if the analysis is meant to allow authoritative statements for the coexistence of wireless systems. The metrological examination can also be used as a basis for further analyses, for example to predict interferences in the case of an increasing number of wireless devices.

7.4.2 Planning phase

7.4.2.1 Overview

In the planning phase, the resource allocation plan is developed or modified based on the updated inventory.

The resource allocation plan describes how to allocate radio resources to each wireless solution.

The resource allocation plan shall be documented appropriately. It shall be reviewed by the coexistence management committee and shall be authorized by the coexistence manager.

7.4.2.2 Coexistence management in the planning phase

Figure 29 shows a sub-process of Figure 6 and Figure 7. Figure 29 gives a review of the decisions and actions of the coexistence management process essential in the planning phase.

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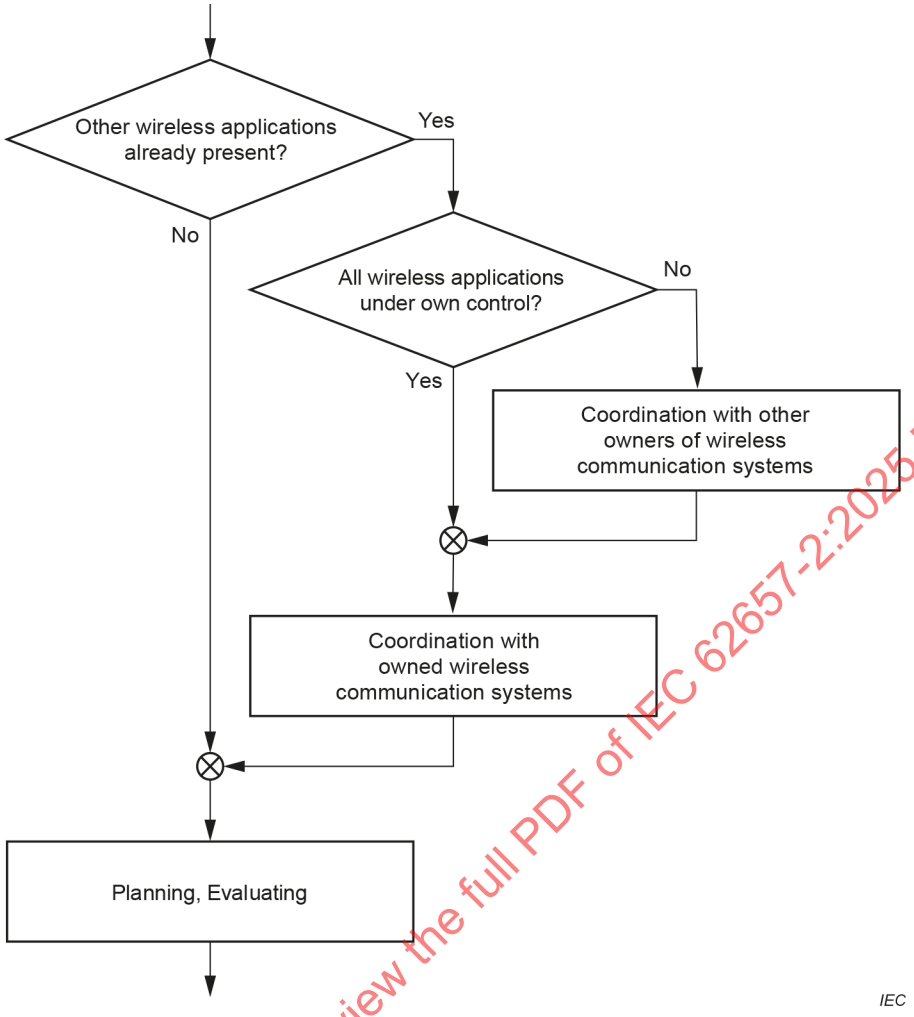

Figure 29 – Planning of a wireless system in the coexistence management process

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Even if there are no operating wireless applications, it should be considered that wireless applications can be introduced after the initial planning.

If there are working wireless applications already, it shall be ascertained whether they are all under the control of the coexistence manager. On the one hand, it might be that external systems irradiate; on the other hand, it might be that for example existing wireless solutions or wireless solutions of critical application classes (for example classes functional safety and control) are prioritized and cannot be modified. In these cases, the realities shall be accepted and the remaining degrees of freedom (for example frequency, time, space) can be used to achieve coexistence. It is easier if all wireless applications are under one's own control. It is also best if existing or concurrently planned wireless applications can be optimized to operate together with regard to radio robustness.

7.4.2.3 Radio field planning

It is recommended to use software tools to accomplish radio field planning. The following groups can be distinguished:

- system-specific software tools;
- system-independent software tools.

System-specific software (for example for IEEE Std.802.11 [7]) can factor in several features of the wireless standard and facilitates measurement with an end device.

System-independent software is usually a product that simulates radio wave propagation and hence can be used for nearly any system. However, only physical variables are simulated (for example signal level or signal propagation delay). The planner shall deduce site specific-related parameters from physical variables.

In the implementation of a wireless system, radio field planning should be performed assisted by the described software products.

Planning (at least for the application classes safety and control) should be accomplished by measurement and simulation. Simulation as a support for planning is advisable because exact measurements over a wide area are laborious and they often only represent a snapshot (for example for varying surroundings such as tall bay warehouses or production halls) and they rarely allow for optimization.

The simulations should, if possible, be specified with measurements. A pure simulation-based planning is only advisable for environments where measurements are not perceivable or not feasible (for example for not yet constructed or equipped buildings).

In radio field planning, other wireless applications should also be taken into account.

If there is no reliable information concerning the frequency occupation in the relevant range and in the immediate area, an environmental analysis should be accomplished in each planning. For that purpose, spectrum and protocol analyzers can be used. If spectrum analyzers are applied, antennas with known directional characteristics should be used to ascertain absolute level values.

7.4.2.4 Coexistence management measures

Coexistence measures shall be considered in the resource allocation plan.

7.4.3 Implementation phase

7.4.3.1 Overview

In the implementation phase, new wireless solutions are installed and configuration of existing wireless solutions is modified in accordance with the resource allocation plan.

The radio resource allocation is achieved by configuring options and parameters related to utilization of the radio resource to the wireless systems.

Implementation shall be validated in order to ensure that the resource allocation plan has been implemented appropriately.

NOTE The investigation phase, planning phase and implementation phase together are called development phase in IEC 62890.

7.4.3.2 Installation and approval

In order to meet the specifications of coexistence management, it is crucial to implement these specifications when the considered wireless system and other wireless applications are installed and commissioned. The internal or external service providers accomplishing the installations shall be informed about the requirements. It is advisable to implement the specifications of the coexistence management, for example intra-company regulations, at least for services related to the business process or to safety. If necessary, these requirements can be integrated into the work plan.

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The validation of installation shall ensure that it is in accordance with the resource allocation plan developed in the planning phase and the specifications of coexistence management. Aside from a function test and a visual inspection of the installation, the suitable acceptance controls should at least imply registration of the relevant performance parameters of the system and controlling the frequency bands.

7.4.4 Operation phase

7.4.4.1 Overview

In the operation phase, the condition of wireless solutions shall be monitored in order to detect problems related to coexistence and changes of environment.

Monitoring to check the condition of coexistence shall be conducted continuously or on a regular basis. Results shall be recorded appropriately.

Detailed specification of methods and tools used for monitoring is out of the scope of this document.

If events listed below are detected, then the investigation phase shall be initiated:

- problem related to coexistence occurs;
- new wireless system needs to be installed;
- environment of wireless system changes.

7.4.4.2 Coexistence management in the operating phase

Figure 30 presents the implementation and operation of a wireless system in the coexistence management process of the operating phase. After a wireless solution has been selected and coexistence established due to planning, installation and commissioning can be initiated. Subsequently, all information relevant to coexistence shall be documented.

A vital part of coexistence management during operation is to establish the obligation to register internal wireless applications. This applies to the report of interferences as well as for the information that further wireless applications are scheduled. If new wireless systems are to be installed, the selection process with add-on planning and evaluation shall be initiated. In the case of interferences, the reasons shall be understood via measurements and analyses and the required function shall be re-established.

Interferences in wireless communication become apparent when something in the plant fails or does not react as planned. These situations should be avoided. Therefore, it is advisable to control the compliance with the specifications of coexistence management regularly. For this purpose, an automatic system for the permanent monitoring of the frequency spectrum and the characteristic parameters (see 6.6), which might locate irregularities even if the plant operation is not yet affected, can be installed. In addition, control measurement should be performed periodically in order to identify variances in the propagation conditions and the existence of other frequency users.

These measures can also help identify an interferer outside the responsibility and control of the coexistence manager that shall not be disturbed. The coexistence manager can take immediate actions to incorporate the interferer outside of his/her control into the coexistence management plan.

EXAMPLE To achieve the compatibility of the industrial wireless communication solutions with the Broadband Fixed Wireless Access (BFWA) in the band of 5 725 MHz to 5 875 MHz in Europe (BFWA link can be affected within a radius around the industrial wireless communication solutions between 3 km and 10 km), an efficient way could be a sensing antenna to be installed on top of the industrial plant to detect the BFWA signal and react immediately to stop using this band beyond the normal energy. Such an antenna would have the advantage of a better propagation condition to the victim link and the possibility to choose a higher gain antenna for the sensing purpose.

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The coexistence manager shall create an action plan, enabling a quick response to events and initiation of the necessary actions without delay.

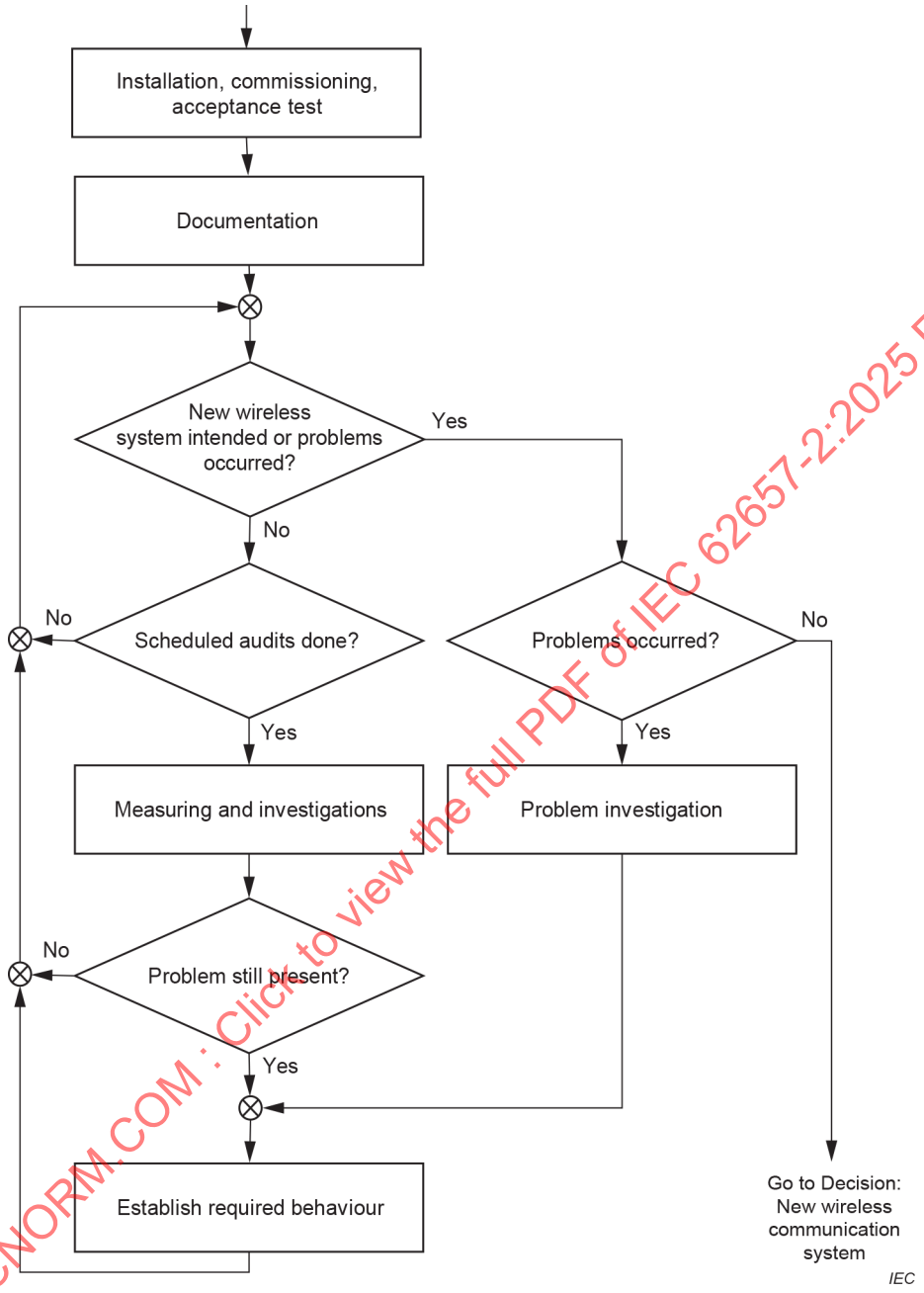

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Figure 30 – Implementation and operation of a wireless system in the coexistence management process

For this purpose, the coexistence manager shall work closely with the other company divisions to be informed about the acquisition of wireless applications. The coexistence manager shall approve them. For the acceptance of coexistence management, it is important to adopt and integrate the process into the internal regulations.

The operational phase includes a maintenance process to preserve the coexistence state. Wireless communication applications using coexistence management can be considered as a system with renewal possibilities. This means that if the probability of coexistence decreases, maintenance measures shall be initiated to retain the required probability of coexistence. Besides the identification of the coexistence problem, according to Figure 5 the medium resource allocation can be adjusted. This can be done by frequency channel separation, by reducing the data traffic volume or by local separation of the applications using for example beam forming. For details, see 4.7 and 4.8. Maintenance should consider temporarily installations of additional devices or changing the position of a devices.

8 Coexistence parameter templates

Clause 8 provides templates for coexistence parameters defined in Clause 5 and structured in Clause 6 from a coexistence management point of view. These templates shall be used in order to gather or provide the required information and thus support the coexistence management process.

Each parameter shall be represented by the following items: value, unit, usage and remark, by using the convention described in 3.3.

From these templates, an actual instance can be derived, for example using a printed table or an equivalent description in a formal language. The instantiation process is not described here since it is out of the scope of this document. The term template used in this document does not require any specific formatting. That means that the table form of the templates in this document can be transferred to any other form for example in paper form, electronically, and as a data base. The requirement of the template is that the listed parameter with the associated values or units or other information are present and linked together as given in the templates in this document to form the required structure.

The template in Table 22 shall be used to describe the characteristic of the plant. The content is specified in Table 5, Table 6 and Table 7.

If a parameter does not have a unit, then the corresponding cell shall be marked with not applicable (N/A). The column marked "Value" can contain a list of values.

NOTE 1 Templates given in Clause 8 with the corresponding definitions in 3.1 are intended for future inclusion in the IEC Common Data Dictionary (CDD, see IEC 61360 series [25]). The IEC CDD content can then be used in an electronic form.

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Table 22 – Template used to describe the general plant characteristic

Parameter name	Value	Unit	Usage	Remark
General plant characteristics				
Regional radio regulations				
Future expansion plan				
Passive environmental influences				
Area of operation				
Object movement				
Geographical dimension of the plant				
Natural environmental condition				
Intervisibility				
Frequency band				
Active environmental influences				
Wireless communication solution density				
Interference type				
Limitation from neighbours of the plant				
Frequency band				

The template in Table 23 shall be used to describe the application communication requirements for each wireless communication system. The content is specified in Table 9, Table 10 and Table 11.

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Table 23 – Template used to describe the application communication requirements

Parameter name	Value	Unit	Usage	Remark
Influencing parameters				
Communication load				
Initiation of data transmission				
Length of user data per transfer interval				
Maximum number of retransmissions				
Position of wireless devices				
Distance between wireless devices				
Purpose of the automation application				
Relative movement				
Security level				
Spatial extent of the application				
Length				
Width				
Height				
Transfer interval				
Wireless device density				
Characteristic parameters				
Data throughput				
Communication availability				
Transmission time				
Update time				
Response time				
Message loss ratio				

The templates in Table 24 and Table 25 shall be provided with a wireless solution. They describe the options of the wireless system or device. The content of Table 24 is specified in Table 11. The content of Table 25 is specified in Table 12 and in Table 13.

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Table 24 – Template used to describe the wireless system type

Parameter name	Value	Unit	Usage	Remark
Wireless technology or standard				
Regional radio regulations				
Network topology				
Wireless device density				
Infrastructure device				
Frequency band				
Lower cut-off frequency				
Upper cut-off frequency				
Frequency hopping				
Modulation				
Communication reliability				
Transfer interval				
Transmission gap				
Transmitter sequence				
Dwell time				
Medium access control mechanism				
Mechanism for adaptivity				
Security level				

Table 25 – Template used to describe a wireless device type

Parameter name	Value	Unit	Usage	Remark
Transmitter				
Regional radio regulations				
Antenna gain				
Antenna radiation pattern				
Equivalent radiated power				
Equivalent isotropic radiated power				
Total radiated power				
Transmitter output power				
Transmitter spectral mask				
Power spectral density				
Frequency channel				
Medium access control mechanism				
Communication reliability				
Transfer interval				
Transmission gap				
Transmitter sequence				
Duty cycle				
Dwell time				
Medium utilization factor				

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Parameter name	Value	Unit	Usage	Remark
Receiver				
Adjacent channel selectivity				
Receiver sensitivity				
Receiver maximum input level				
Receiver blocking				
Spurious response				

The templates in Table 26 and Table 27 shall be used to document the current configuration and operation of each implemented wireless solution. The content of Table 26 is specified in Table 14. The content of Table 27 is specified in Table 12 and in Table 13.

Table 26 – Template used to describe the wireless system solution

Parameter name	Value	Unit	Usage	Remark
Wireless system type				
Network topology				
Wireless device density				
Position of wireless devices				
Relative movement				
Infrastructure device				
Frequency channel				
Frequency hopping				
Modulation				
Bit rate of physical link				
Transfer interval				
Transmission gap				
Transmitter sequence				
Dwell time				
Medium access control mechanism				
Mechanism for adaptivity				
Security level				

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Table 27 – Template used to describe a wireless device solution

Parameter name	Value	Unit	Usage	Remark
General				
Wireless system type				
Wireless device type				
Transmitter				
Antenna type				
Antenna gain				
Antenna radiation pattern				
Equivalent radiated power				
Equivalent isotropic radiated power				
Total radiated power				
Transmitter output power				
Power spectral density				
Frequency channel				
Bit rate of physical link				
Transfer interval				
Transmission gap				
Transmitter sequence				
Duty cycle				
Dwell time				
Receiver				
Adjacent channel selectivity				
Receiver sensitivity				
Receiver maximum input level				
Receiver blocking				
Spurious response				

The templates in Table 28 and Table 29 shall be used to describe the relevant characteristic parameters for the coexistence management. The content is specified in Table 18 und Table 19.

Table 28 – Template used to describe the relevant characteristic parameters of wireless solutions

Parameter name	Value	Unit	Usage	Remark
Transmission time				
Update time				
Response time				
Data throughput				
Communication availability				
Message loss ratio				
Communication reliability				
Operating time between failures				
Survival time				

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Table 29 – Template used to describe the relevant statistical values of characteristic parameters

Parameter name	Value	Unit	Usage	Remark
Transmission time				
Update time				
Response time				
Data throughput				
Communication availability				
Message loss ratio				
Survival time				

The templates in Table 30 shall be provided to describe an interference type. The content is specified in Table 8.

Table 30 – Template used to describe an interference type

Parameter name	Value	Unit	Usage	Remark
Interference type				
Frequency band				
Frequency channel				
Total radiated power				
Power spectral density				
Transfer interval				
Transmission gap				
Transmitter sequence				
Duty cycle				
Dwell time				

NOTE 2 The content of the templates could be used as a property definition-set in IEC 61360 series.

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Annex A
(normative)

Parameter usage in the IEC 62657 series

A.1 General

Figure A.1 shows the use of the parameters in the IEC 62657 series. Wireless automation devices and systems implement many parameters that can be used to improve the dependability and the coexistence. This document defines relevant parameters for coexistence management that are used in various contexts in the other parts of the IEC 62657 series. This annex is intended to provide an overview of parameter usage among the IEC 62657 series for coexistence management.

A.2 Outline of the IEC 62657 series

IEC 62657-1 describes use cases and motivations for wireless industrial automation. The document provides general requirements for industrial automation in terms of spectrum considerations. Performance of wireless industrial automation can be evaluated with value of characteristic parameters of wireless communication via reference interface.

IEC 62657-2 (this document) specifies coexistence parameters and provides its descriptions. A set of characteristic parameters, influencing parameters and statistics parameters is defined to characterize the wireless industrial automation for coexistence management. The document provides coexistence management process utilizing a set of parameters.

IEC 62657-3 provides the formal description of coexistence system that helps to establish an automated coexistence management system. The document specifies the system elements, properties, interfaces and relationships between influencing parameters and characteristic parameters specified in IEC 62657-1 and IEC 62657-2.

IEC 62657-4 specifies a concept and methods for central coordination (CC) of automation applications using wireless communications to extend the coexistence management according to IEC 62657-2. It establishes system elements, interfaces, and relationships for a central coordination. Functions, data, and data exchange for assessing and maintaining the coexistence state are specified.

A.3 Parameter usage in coexistence management process in IEC 62657-2

The characteristic parameters and influencing parameters are derived from practical considerations of coexistence management. As illustrated in Figure A.1, the parameters play an important role in the conceptual model of the coexistence management defined in IEC 62657-2.

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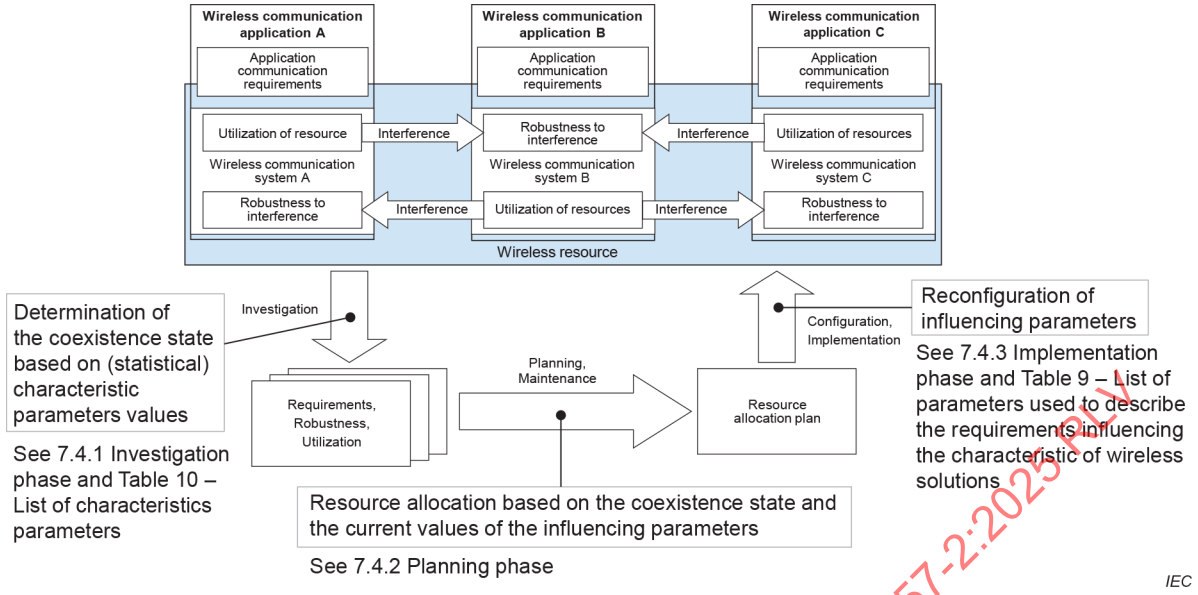

Figure A.1 – Usage of parameters in IEC 62657-2

Each parameter can be used for different purposes. In principle, a parameter can be used to make three different statements: to formulate a requirement, to make a promise or to describe a current state. Consequently, for each parameter, a distinction shall be made between the required value, the assured value and the current value at a certain point in time. Instead of a single value, a value range can be relevant. If a parameter is a random variable, it shall be specified which statistical parameter the given value corresponds to, for example the mean value or the maximum value.

Characteristic parameters and influencing parameters of wireless communication devices and systems, defined in IEC 62657-2, should be considered throughout the life cycle of these devices and systems.

Already in the design phase of a wireless automation device, target values or ranges of values for the device-specific influencing parameters according to 6.4.3 are specified and implemented for a specific device type. Sometimes not all parameter values of a wireless module are provided by its manufacturer. The manufacturers of the wireless automation device should request those parameter values.

The more options the wireless device provides for adjusting influencing parameters such as the transmission power, the frequency range, and/or the time of use of the radio resource, the more effective are the opportunities for coexistence management. Wherever possible, adjustments should also be made possible during the active operating phase of the wireless devices.

In addition to the influencing parameters, manufacturers should also provide values for characteristic parameters according to 6.3.3, to be determined by performance tests. For an automated coexistence management, the provision of characteristic parameter values according to 6.3.3 in the wireless devices is of decisive importance. There are various possibilities to provide the characteristic values, for example, per logical link or per device, individually or in pre-processed form.

For coexistence management, the manufacturer of a wireless automation device should provide the assured values of a device type for the characteristic parameters according to 6.3.3 and for the influencing parameters according to 6.4.3 in a suitable manner.

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The designer of a distributed automation system, interconnected with a wireless communication system, specifies required values for the system and its devices. The system is then designed according to 7.4.2 based on the assured values of the parameters provided for the distributed automation system, the radio environment and the wireless communication system and its devices. The assured values for the parameters of the radio environment should be determined according to 7.4.1.

Table A.1 shows an example of parameter usage in coexistence management process where a coexistence state below the margin during operation and then the maintenance process is initiated. Relevant parameters are used in each phase of the coexistence management process shown in Table A.1.

Table A.1 – Example for parameters usage in coexistence management process

Coexistence management process		Coexistence management parameters		
		Distributed automation system	Radio environment	Wireless communication system
1.Investigation phase	Investigate actual state in respect of operating wireless applications	– General plant characteristic parameters (see 6.2.2, and Table 22)		
	Identify free and occupied spectrum resources		– Active environmental influences parameters (see 6.2.4 , Table 22 and Table 30) – Passive environmental influences parameters (see 6.2.3, and Table 22)	
	Select wireless communication system and investigate capabilities against the requirements	– Application communication requirements parameters (see 6.3, and Table 23)		– Wireless system type and wireless device type parameters (see 6.4, Table 25 and Table 26)
2. Planning phase	Radio field planning and profile development	– Application communication requirements parameters (see 6.3 and Table 23)	– Active environmental influences parameters (see 6.2.4, Table 22 and Table 30) – Passive environmental influences parameters (see 6.2.3, and Table 22)	– Wireless communication system parameters (see 6.4, 6.5, Table 25, Table 26, Table 27 and Table 28)
	Planning of the radio resource allocation			
3. Implementation phase	Installing and commissioning wireless applications	– Application communication requirements parameters (see 6.3, and Table 23)		– Wireless communication system parameters (see 6.4, 6.5, Table 25, Table 26, Table 27 and Table 28)
	Approve radio resource allocation plan and implement spectrum resource allocation	– Application communication requirements parameters (see 6.3, and Table 23)		– Wireless communication system parameters (see 6.4, 6.5, Table 25, Table 26, Table 27 and Table 28)

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Coexistence management process		Coexistence management parameters		
		Distributed automation system	Radio environment	Wireless communication system
4. Operation phase	Monitoring radio environment		– Active environmental influences parameters (see 6.2.4, Table 22 and Table 30) – Passive environmental influences parameters (see 6.2.3, and Table 22)	
	Monitoring characteristic parameters	– Performance requirements parameters (see 6.3.3, and Table 23) – Statistical values of characteristic parameters (see 6.6 and Table 29)		
	Initiate maintenance process or go to investigation phase			– Wireless solution parameters (see 6.5, Table 27 and Table 28)

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A.4 Parameters usage among the IEC 62657 series

Figure A.2 illustrates the use of coexistence parameters defined in some of the parts and clauses of the IEC 62657 series.

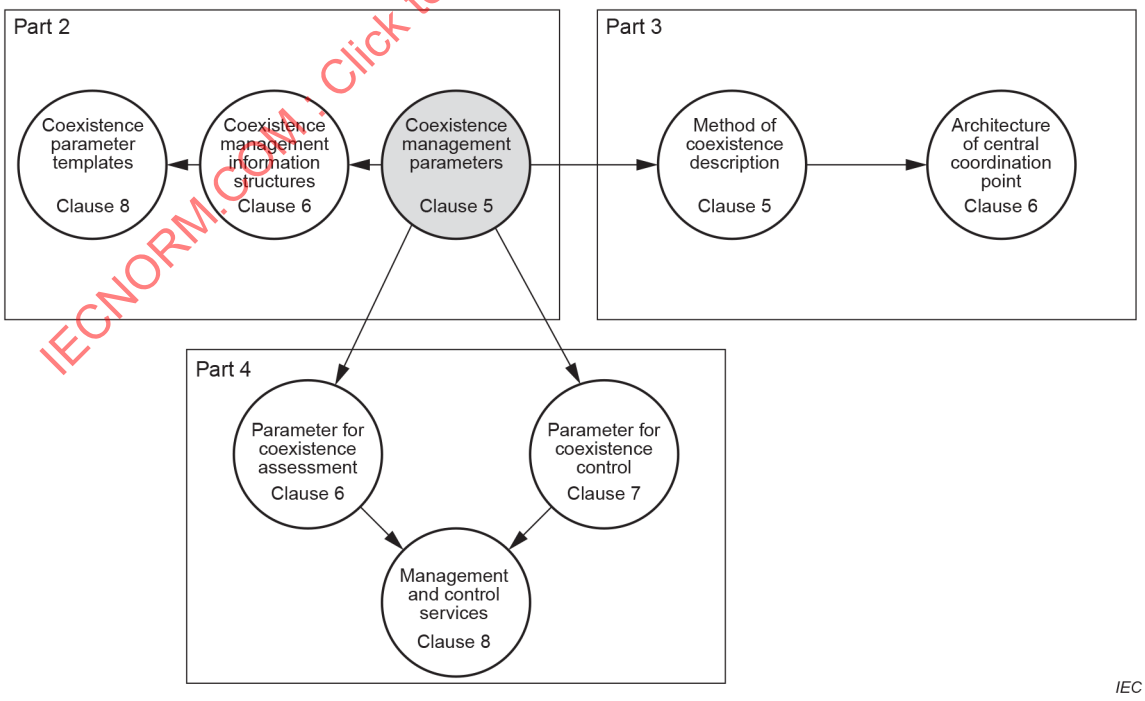

Figure A.2 – Parameter usage among the IEC 62657 series

In IEC 62657-2:2024:

- Clause 5 lists characteristic and influencing parameters relevant in a coexistence management process in alphabetic order and describes them in detail. These parameters are relevant to specify the automation communication requirements, to describe conditions within the area of operation and to characterize wireless devices and systems.
- Clause 6 specifies the structuring of coexistence management parameters according to usage dimensions. This describes which parameters are applied in which context.
- Clause 8 provides templates for coexistence parameters defined in Clause 5 and structured in Clause 6 from a coexistence management point of view. These templates can be used to describe a specific object of the items relevant for the coexistence management by assigning values or value ranges to the parameters.

In IEC 62657-3:2022:

- Clause 5 provides a class model for wireless coexistence management. The relevant classes of the model and their relationships are described. The parameters described in IEC 62657-2 are attributes of the classes.
- Clause 6 gives guidance on how to use the class model defined in Clause 5 for implementing an automated collaborative coexistence management with central coordination point as one possible implementation.

In IEC 62657-4:—:

- Clause 6 summarises the characteristic parameters to be used by an automated collaborative coexistence management system with central coordination point (CCP system) to assess the wireless coexistence state.
- Clause 7 summarises influencing parameters to be used by the CCP system to control the wireless coexistence state.
- Clause 8 defines management and control services for exchanging coexistence management data between the elements of a CCP system. The parameters described in IEC 62657-2 are attributes of the service primitives.

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IEC 62657-2

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Industrial networks – Coexistence of wireless systems – Part 2: Coexistence management

Réseaux industriels – Coexistence des systèmes sans fil – Partie 2: Gestion de coexistence

IEC 62657-2:2025-02(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INDUSTRIAL NETWORKS – COEXISTENCE OF WIRELESS SYSTEMS –

Part 2: Coexistence management

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62657-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2022. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) alignment of some definitions and specifications of coexistence parameters in order to facilitate their future inclusion in the IEC Common Data Dictionary (IEC CDD) maintained by the IEC;

b) alignment of some definitions and specifications to be consistent with the new IEC 62657-3 and IEC 62657-4;

c) edition 3 of this document was published in June 2022. Some comments were made in the last development stages of this document asking for explanations on how the parts of the IEC 62657 series were structured and how they were related to each other. Resolution of these comments was deferred until a next edition, which means this edition.

The text of this International Standard is based on the following documents:

Draft	Report on voting
65C/1329/FDIS	65C/1337/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all the parts of the IEC 62657 series, under the general title *Industrial networks – Coexistence of wireless systems,* can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

The overall market for wireless communication solutions spans a range of diverse applications, with differing performance and functional requirements. Within this overall market, the industrial automation domain could include:

- process automation, covering for example the following industry branches:
  - oil and gas, refining,
  - chemical,
  - pharmaceutical,
  - mining,
  - pulp and paper,
  - water and wastewater,
  - steel,
- electric power such as:
  - power generation (for example wind turbine),
  - power transmission and distribution (grid),
- factory automation, covering for example the following industry branches:
  - food and beverage,
  - automotive,
  - machinery,
  - semiconductor.

Industrial automation requirements for wireless communication systems are different from those of, for example, the telecommunications, commercial and consumer markets. These industrial automation requirements are identified and provided in IEC 62657-1.

Industrial premises can contain a variety of wireless communication technologies and other sources of radio emissions.

This document is intended for designers and persons responsible for production and process plants, system integrators and mechanical engineers having to integrate and start up wireless systems in machines and plants, and producers of industrial wireless solutions. In particular, it is intended to motivate the exchange of information between automation and radio engineers.

Many wireless industrial automation applications are also located in physical environments over which the operator/owner can exert control, that is, within a physical facility where the presence and operation of all radio emitting devices are under the control of a single entity. This allows wireless management strategies to be employed which are not feasible for equipment installed in public or other unmanaged areas.

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In industrial automation, many different wireless communication systems can operate in the same premises. Examples of these communication systems are IEC 62591 [1][1] (WirelessHART®[2]), IEC 62601 [2] (WIA-PA) and IEC 62734 [3] (ISA100.11a). All these communication systems use IEEE 802.15.4 [4] for the process automation applications. Other examples of wireless communication systems are specified in the IEC 61784-1 series [5] and IEC 61784-2 series [6] CP that use IEEE 802.11 [7] and IEEE 802.15.1 [8] for factory automation applications. Different to wired fieldbuses, the wireless communication devices can interfere with others on the same premises or environment, disturbing each other. Other sources of radio energy in these bands, often at high energy levels, include radiated process heating, plastic welding, plasma lamps, and microwave irradiation devices.

Clearly, without a means to manage the coexistence of these varied emitters, it would be problematic to ensure that wireless systems meet the time-criticality and other performance requirements of industrial automation.

This document describes the management of independent radio sources that use the same transmission medium. The management within a wireless communication system is not the subject of this document. It is assumed that the standard of a wireless system regulates it, for example by a medium access control mechanism.

The IEC 62657 series has four parts:

- Part 1: Wireless communication requirements and spectrum considerations,
- Part 2: Coexistence management,
- Part 3: Formal description of the automated coexistence management and application guidance,
- Part 4: Coexistence management with central coordination of wireless applications.

IEC 62657-1 provides general requirements for industrial automation and spectrum considerations that are the basis for industrial communication solutions. This document specifies the coexistence management of wireless devices to ensure predicable performance. It is intended to facilitate harmonization of future adjustments to international, national, and local regulations.

This document provides the coexistence management concept and process. Based on the coexistence management process, a predictable assuredness of coexistence can be achieved for a given spectrum with certain application requirements. This document describes principles to manage the potential mutual interference that could occur due to the operation of multiple wireless devices in a plant.

This document provides guidance to the users of wireless systems on selection and proper use of wireless systems. To provide suitable wireless devices to the market, it also serves vendors in describing the behaviours of wireless devices to build wireless systems matching the application requirements.

This document is based on analyses of a number of International Standards, which focus on specific technologies. The intention of this document is not to invent new parameters but to use already defined ones and to be technology independent.

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1 Numbers in square brackets refer to the Bibliography.

2 WirelessHART® is the registered trade name of the FieldComm Group, see www.fieldcommgroup.org. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

INDUSTRIAL NETWORKS – COEXISTENCE OF WIRELESS SYSTEMS –

Part 2: Coexistence management

1 Scope

This part of IEC 62657

- specifies the fundamental assumptions, concepts, parameters, and procedures for wireless communication coexistence;
- specifies coexistence parameters and how they are used in an application requiring wireless coexistence;
- provides guidelines, requirements, and best practices for wireless communication's availability and performance in an industrial automation plant; it covers the life-cycle of wireless communication coexistence;
- helps the work of all persons involved with the relevant responsibilities to cope with the critical aspects at each phase of life-cycle of the wireless communication coexistence management in an industrial automation plant. Life-cycle aspects include: planning, design, installation, implementation, operation, maintenance, administration and training;
- provides a common point of reference for wireless communication coexistence for industrial automation sites as a homogeneous guideline to help the users assess and gauge their plant efforts;
- deals with the operational aspects of wireless communication coexistence regarding both the static human/tool-organization and the dynamic network self-organization.

This document provides a major contribution to national and regional regulations by supporting to fulfil the requirements using coexistence management.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62443 (all parts), *Security for industrial automation and control systems*

IEC 62657-1:2017, *Industrial communication networks – Wireless communication networks – Wireless communication requirements and spectrum considerations*

IEC 62657-3:2022, *Industrial networks – Coexistence of wireless systems – Part 3: Formal description of the automated coexistence management and application guidance*

IEC 62657-4:—, *Industrial networks – Coexistence of wireless systems – Part 4: Coexistence management with central coordination of wireless applications*[3]

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[3] Under preparation. Stage at the time of publication: IEC/FDIS 62657-4:2024.

3 Terms, definitions, abbreviated terms and conventions

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/ [9]
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
active environmental influence
influence on the signal propagation through interfering of the wireless communication application or wireless application

3.1.2
adjacent channel interference
interference that occurs from wireless devices using adjacent frequency channels

3.1.3
adjacent channel selectivity
ability of a radio receiver to respond to the desired signal and to reject signals in adjacent frequency channels

3.1.4
antenna gain
measure of the effectiveness of an antenna that expresses the ratio between the power required at the input of a reference antenna and the power delivered at the input of the given antenna to achieve the same field strength at the same distance of a given direction

3.1.5
antenna radiation pattern
variation of the field intensity of an antenna as an angular function with respect to the axis

3.1.6
antenna type
kind of part of a radio transmitting or receiving system which is designed to provide the required coupling between a transmitter or a receiver and the medium in which the radio wave propagates

Note 1 to entry: In practice, the terminals of the antenna or the points to be considered as the interface between the antenna and the transmitter or receiver should be specified.

Note 2 to entry: If a transmitter or receiver is connected to its antenna by a feed line, the antenna may be considered to be a transducer between the guided waves of the feed line and the radiated waves in space.

[SOURCE: IEC 60050-712:1992, 712-01-01, modified – "Addition of "type" after the term, addition of "kind of" at front.] [10]

3.1.7
application communication requirements
quantitative requirements specifying the required conditions and the required characteristics of wireless communication solutions at the communication interface that is met in order to achieve the purpose of the automation application

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3.1.8
area of operation
distinguishing properties of the area where the wireless communication system is operated

3.1.9
automated collaborative coexistence management
tool supported collaborative coexistence management with defined interfaces between the tool and the wireless communication system

Note 1 to entry: The tool can be according to IEC 62657-4.

3.1.10
automation application
industrial automation application
application of measurement and automatic control in the industrial automation domain

3.1.11
automation application data length
user data length
number of octets that are exchanged at the reference interface

3.1.12
bit rate of the physical link
measure of the number of binary digits transferred per second

3.1.13
blocked frequency list
list of the blocked frequencies to avoid part of the available spectrum

3.1.14
cellular topology
cellular network topology
network topology where the geographical area is divided in cells

Note 1 to entry: A device can move from one cell to another cell. Devices that are in a cell communicate through a central hub. Hubs in different cells are interconnected.

3.1.15
centre frequency
geometric mean of lower cut-off frequency and upper cut-off frequency of a frequency channel

3.1.16
channel number
unsigned integer number identifying a wireless communication channel in accordance with an authoritative document or rule

3.1.17
channel occupation
time interval in which the medium is busy

Note 1 to entry: Beyond the pure transfer of user data, this time includes all time slices necessary to process the transmission protocol, for example to transfer an acknowledgement.

3.1.18
coexistence
wireless communication coexistence
state in which all wireless communication solutions of a plant using shared medium fulfil all their application communication requirements

Note 1 to entry: In IEEE 802.15.2-2003 [11], coexistence is defined as a characteristic of a device.

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3.1.19
coexistence management
process to establish and to maintain coexistence that includes technical and organizational measures

3.1.20
coexistence management information
parameters for the wireless coexistence management process

3.1.21
coexistence manager
role of a nominated person to manage coexistence

3.1.22
coexistence planning
process that describes the allocation of wireless communication resources (time, frequencies, coding, space) to each wireless communication system in order to achieve coexistence

3.1.23
collaborative coexistence management
coexistence management process in which data is exchanged between the wireless communication applications involved with the aim of influencing the wireless communication so that all applications meet the requirements

3.1.24
communication availability
<wireless communication> ratio of the time interval of error free transmission (uptime) to an observation time

3.1.25
communication availability
<performance> ability of an item to be in a state to perform as required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

Note 1 to entry: This ability depends on the combined aspects of the reliability performance, the maintainability performance, and the maintenance support performance.

Note 2 to entry: Required external resources, other than maintenance resources, do not affect the availability performance of the item.

3.1.26
communication load
amount of user data to be transmitted from the automation application within a certain period of time

3.1.27
communication reliability
ability of a physical link and the related nodes to perform communication services under given conditions for a given time interval

3.1.28
cut-off frequency
frequency limit, nearest to the frequency where the spectral power density drops below a certain level, defining the frequency bandwidth

3.1.29
data throughput
ratio between the number of user data transferred to the application at the target reference interface and the observation time

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3.1.30
device
piece of hardware that provides connectivity and functionality

Note 1 to entry: Does not exclude software using the hardware to perform functions or support connectivity.

3.1.31
device type
shared characteristics of a device as specified so that the used devices build instances of the shared characteristics

EXAMPLE The specification can be part of a catalogue from a manufacturer.

Note 1 to entry: These shared characteristics include: technology, design, area of application, parts or modules with respect to safety, EMC, performance, functionality, etc.

Note 2 to entry: The shared characteristics of a device type may be engineered, configured and parameterized in a device instance.

3.1.32
distance between wireless devices
geographical distance between devices within a three-dimensional space

3.1.33
distributed automation system
functions of the automation devices that are the spatial extent of a wireless industrial automation

3.1.34
duty cycle
ratio of the transmitter sequence referenced to a given observation time for the used frequency channel

3.1.35
dwell time
period spent at a particular frequency during any single hop of a frequency hopping system

3.1.36
equivalent isotropic radiated power
product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain)

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.161, modified – Term modified from isotropically to isotropic and definition reformatted according to the ISO/IEC Directives Part 2] [12]

3.1.37
effective radiated power
product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.162, modified – Deleted "(in a given direction)" and definition reformatted according to the ISO/IEC Directives Part 2] [12]

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3.1.38
electromagnetic interference
EMI
degradation of the performance of equipment or transmission channel or system caused by an electromagnetic disturbance

Note 1 to entry: In French, the terms "perturbation électromagnétique" and "brouillage électromagnétique" designate respectively the cause and the effect, and should not be used indiscriminately.

Note 2 to entry: In English, the terms "electromagnetic disturbance" and "electromagnetic interference" designate respectively the cause and the effect, and should not be used indiscriminately.

[SOURCE: IEC 60050-161:2018, 161-01-06] [13]

3.1.39
frequency band
range in the frequency spectrum that is assigned by regulatory organizations for use for specific applications or a group of applications

Note 1 to entry: The ITU as international regulatory organization assigns only radio communication services to a specific range in the frequency spectrum.

3.1.40
frequency bandwidth
bandwidth
difference between upper cut-off frequency and lower cut-off frequency

3.1.41
frequency channel
span of the frequency spectrum which is characterized by lower cut-off frequency and upper cut-off frequency or by centre frequency and frequency bandwidth

3.1.42
frequency hopping sequence
sequence of frequency channels used for transmission (hopping sequence) and dwell time

3.1.43
future expansion plan
possible installation of new wireless communication solutions and buildings that can affect coexistence

3.1.44
general plant characteristics
parameters that characterize the plant in general with respect to all wireless communication applications

3.1.45
geographical dimension of the plant
length, width and height of the intended space of the wireless system

3.1.46
geolocation capability
capability of equipment to determine its geographical location

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3.1.47
industrial, scientific and medical application
operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.15] [12]

3.1.48
industrial communication network
data communications sub-systems for industrial-process measurement and control as well as on instrumentation systems used for research, development or testing purposes

3.1.49
infrastructure device
device that is essential for building up a wireless communication system according to a technology or standard, but not having an interface to an automation application

EXAMPLE Router or base stations without interfaces to the wired industrial network or without automation application functions.

3.1.50
initiation of data transmission
method that specifies how the application initiates the data transfer

3.1.51
interference
radio frequency interference
effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a wireless communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.166, modified – Deleted leading "The" according to ISO/IEC Directives Part 2] [12]

3.1.52
interference type
kind of unwanted energy caused by a certain source or application

Note 1 to entry: Examples of interference types are: an EMI source, an ISM application, or a non-industrial wireless application.

3.1.53
intermodulation sensitivity
levels of out-of-band interfering signals that, when mixed in the receiver front-end, produce an in-band third order non-linearity product

3.1.54
intervisibility
property of a logical link that describes a possible influence on radio signal propagation by obstruction, refraction or reflection

EXAMPLE Line of Sight (LOS), Non Line of Sight (NLOS) and Obstructed Line of Sight (OLOS) between those devices are possible parameters.

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3.1.55
immunity
ability of an item to continue operating properly in the event of an interference, up to a certain level of interference, and to be resilient above this level

Note 1 to entry: Immunity of an item is achieved by adding to the robustness of the item the ability to be resilient to interference.

3.1.56
jitter
time variation of an expected occurrence

Note 1 to entry: Examples are variation of transmission time and update time.

3.1.57
length of user data per transfer interval
number of the octets sent out during a transfer interval, where the octets that are added because of the requirements of the wireless communication protocol are subtracted

Note 1 to entry: The application data length affects the communication load and might account for the temporal separation of the wireless communication systems.

3.1.58
life-cycle
length of time from the start of the development phase of a product type to the product abandonment

[SOURCE: IEC 62890:2020, 3.1.22] [14]

3.1.59
limitation from neighbours of the plant
description of the neighbours of the plant that are likely to cause limitations for wireless communication

EXAMPLE High power radio source(s).

3.1.60
linear topology
linear network topology
topology where the nodes are connected in series, with two nodes connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

Note 1 to entry: This topology corresponds to that of an open ring.

[SOURCE: IEC 61918:2018, 3.1.51, modified – Added an admitted term.] [15]

3.1.61
line of sight
LOS
path of propagation of a radio frequency (RF) signal that is not obscured (partially or completely) by obstacles

3.1.62
logical link
application oriented communication relationship which enables the transmission of user data between one logical end point of the reference interface in a source device and one logical end point of the reference interface in a target device

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3.1.63
lower cut-off frequency
frequency furthest below the frequency of maximum power where the power spectral density drops below a certain level

3.1.64
maximum number of retransmissions
upper limit of how many times the communication stack is allowed to retransmit user data automatically because of transmission errors

3.1.65
mechanism for adaptivity
measures to modify one or more of the systems operational parameters in order to improve the systems robustness against interferences and to minimize the medium utilization

3.1.66
medium access control mechanism
transmission technique for how to access the medium

Note 1 to entry: Examples are CSMA, TDMA, or combination of both.

3.1.67
medium utilization factor
measure to quantify the amount of resources (power and time) used by non-adaptive equipment

3.1.68
message
ordered series of octets intended to convey information

Note 1 to entry: During the transport of the conveyed information, the octets can be split in various packets.

[SOURCE: ISO/IEC 2382-16:1996, 16.02.01, modified – Replaced "sequence of characters" by "series of octets", Note to entry added.] [16]

3.1.69
message loss ratio
ratio of number of messages, transferred from the application at the reference interface within the producer, and the number of messages, transferred at the reference interface to the application within the consumer

3.1.70
mesh topology
mesh network topology
network topology in which redundant physically-diverse routing paths are available between each pair of network nodes

Note 1 to entry: Wireless mesh topology is usable to extend coverage via multi-hop capability and/or to facilitate communication reliability by providing redundant paths between devices.

[SOURCE: IEC 62734:2014, 3.1.2.95, modified – Added an admitted term.] [3]

3.1.71
modulation
process of varying one or more properties of a periodic waveform with a modulating signal that contains information to be transmitted

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3.1.72
natural environmental condition
condition that surrounds the wireless device and wireless system

Note 1 to entry: Examples are temperature, humidity, air pressure.

3.1.73
network
all of the media, connectors, repeaters, routers, gateways and associated node communication elements by which a given set of communicating devices are interconnected

[SOURCE: IEC 61158-2:2023, 3.1.30] [17]

3.1.74
network topology
topology of a network
pattern of the relative positions and interconnections of the individual elements of the network

[SOURCE: IEC 61918:2018, 3.1.81, modified – Deleted the "Note 1 to entry" and added an admitted term.] [15]

3.1.75
node
addressable logical or physical device attached to the network

[SOURCE: IEC 62591:2016, 3.2.75] [1]

3.1.76
non line of sight
NLOS
path of propagation of a radio frequency (RF) signal that is obscured (partially or completely) by obstacles, thus making it difficult for the radio signal to pass through

Note 1 to entry: Common obstacles between radio transmitters and radio receivers are tall buildings, trees, physical landscape and high-voltage power conductors. While some obstacles absorb and others reflect the radio signal, they all limit the transmission ability of signals.

3.1.77
number of consecutive lost messages
counted value of not correct received messages between two successfully received messages

3.1.78
obstructed line of sight
OLOS
path of propagation of a radio frequency (RF) signal that is obscured (partially or completely) by obstacles, thus making it difficult for the radio signal to pass through

Note 1 to entry: An intrusion into the inner most area of the first Fresnel zone will result in a decrease or fading of the received signal level. At the point where the obstruction becomes tangent to the LOS path, signal losses will be as much as 6 dB or more. Best practice is to maintain at least 60 % of the first Fresnel zone radius free of obstructions to avoid fading of the received signal.

3.1.79
operating time between failures
sum of the operating time periods between two successive failures on a logical link where the message is considered as a repairable item in the sense that a message can be repeated within the survival time

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3.1.80
other frequency user
user which generates and uses radio energy without having the objective of telecommunication

Note 1 to entry: Examples are welding machine, electrical drive and frequency converter.

3.1.81
out-of-band emission
emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions

Note 1 to entry: Reproduced with the permission of ITU.

[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.144] [12]

3.1.82
object movement
specification of the trajectory of mobile assets that can significantly influence the radio propagation conditions

Note 1 to entry: Examples for mobile objects are vehicles, cranes or persons.

3.1.83
observation time
duration of the supervision of events

Note 1 to entry: Examples are the reception of user data or the use of a transmission medium by a wireless device. For them the observation time is the reference parameter to calculate the data rate and the duty cycle.

3.1.84
packet
formatted, aggregated bits that are transmitted together in time across the physical medium

[SOURCE: IEC 62591:2016, 3.2.77] [1]

3.1.85
passive environmental influence
influence on the signal propagation through the characteristic of the area of operation, the dimension of the space of operation, the intervisibility, mobile objects and natural environmental conditions

3.1.86
performance requirements
requirements describing the time and error behaviour necessary to achieve the purpose of the automation application

3.1.87
physical link
relation between radio transceivers (physical end points) of two wireless devices

3.1.88
plant
managed facility, typically with a physically protected perimeter, hosting the physical process, operation, personnel, equipment

3.1.89
point-to-point topology
point-to-point network topology
topology where two nodes are directly connected to each other

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3.1.90
position of wireless device
geographical position of the three-dimensional space in absolute or relative coordinates where the device is located

3.1.91
power spectral density
distribution as a function of frequency of the power per unit bandwidth of the spectral components of a signal or a noise having a continuous spectrum and a finite mean power

[SOURCE: IEC 60050-713:1998, 713-09-12 modified – Deleted the admitted term and the abbreviation.] [18]

3.1.92
purpose of the automation application
summary of the automation application supported by the wireless system to the extent needed to provide a useful overview of the requirements imposed on the wireless system

3.1.93
radio channel
radio propagation model that takes into account the characteristic of the frequency channel, the environmental conditions, the distance between the wireless devices, the antenna characteristic

3.1.94
radio environment
surroundings for the radio signal propagation with its passive environmental influences and active environmental influences

3.1.95
radio resource
means used by multiple wireless communication solutions for the purpose of radio signal transmission

3.1.96
radio robustness
attribute of wireless communication to fulfil the designated function despite the presence of other active wireless applications interfering in the sphere of influence

Note 1 to entry: This term has the same meaning as the definition of the term coexistence in IEEE 802.15.2:2003, 3.1.2 [11].

3.1.97
received signal strength indication
relative number for the field strength at the receiver of wireless devices, depending on the respective implementation of a radio technology

3.1.98
receiver blocking
effect of a strong interfering signal on the receiver's ability to detect a low-level wanted signal

3.1.99
receiver maximum input level
maximum signal power that the system can tolerate without distortion of the signal

3.1.100
receiver sensitivity
minimal signal power to receive data with a defined bit error ratio

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3.1.101
reference interface
exposed interface between an automation application and the wireless communication function

Note 1 to entry: There is no consistently defined interface for measurement and automation. The interface of the device might be a serial or a parallel hardware interface, a fieldbus interface, a software interface, or serial, parallel, discrete, and analog interface.

3.1.102
regional radio regulation
regulation of important coexistence parameters such as frequency band and output power related to the region where the wireless application is intended to be used

3.1.103
relative movement
position of a wireless device over time

3.1.104
requirements influencing the characteristic of wireless solutions
application communication requirements that influence the performance of wireless solutions and thus the coexistence state

3.1.105
response time
time interval between the instant delivery of the first user data bit, or octet, of a message to the reference interface of a transmitter, and the instant when the last bit, or octet, of the confirmation message is delivered at the reference interface of the same transmitter, which can be assigned to the request

3.1.106
ring topology
ring network topology
active network where each node is connected in series to two other nodes

[SOURCE: IEC 61918:2018, 3.1.71, modified – Changed "ring" to "ring topology" and added an admitted term.] [15]

3.1.107
robustness
ability of an item to continue operating properly in the event of an interference, up to a certain level of the interference

Note 1 to entry: The robustness of an item can be increased with measures that modify one or more of its operational parameters.

3.1.108
security level
requirement category for cyber security

3.1.109
spatial extent of the application
cuboid defined by the positions and/or the maximum movement radius of the automation devices of a distributed automation system

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3.1.110
shared medium
resource of frequency band in particular area shared by several wireless applications

Note 1 to entry: In the industrial, scientific and medical (ISM)-bands, many wireless applications are used. Due to this joint use, the term shared medium is used in this document. The frequency bands are used by diverse ISM applications and wireless communication applications.

3.1.111
signal-to-interference and noise ratio
quotient of the strength of the wanted signal and the strength of the unwanted signals, consisting of noise and interference

3.1.112
spatial coverage of the wireless communication system
spatial coverage specified by length, width and height of a cuboid that encloses the wireless communication system

3.1.113
spurious emission
emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which can be reduced without affecting the corresponding transmission of information, including harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.145] [12]

3.1.114
spurious response
receiver output due to unwanted signals

Note 1 to entry: That means having frequencies other than those of the tuned frequency channel.

3.1.115
star topology
star network topology
network of three or more devices topology where all devices are connected to a central device

[SOURCE: IEC 61918:2018, 3.1.77, modified – "topology" has been added, "point (which may be active or passive)" has been replaced by "device", and an admitted term has been added] [15]

3.1.116
survival time
time that an application, consuming a communication service, continues without receiving an anticipated message

3.1.117
telecommunication
any transmission, emission or reception of signs, signals, writings, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems

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[SOURCE: ITU Radio Regulations, edition of 2020 – Art.1 §1.3] [12]

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3.1.118
total radiated power
spatial power density integrated across the surface of the sphere

3.1.119
transfer interval
time difference between two consecutive transfers of user data from the automation application via the reference interface to the wireless communication function

3.1.120
transmission gap
gap between two successive channel usages by a transmitter

3.1.121
transmitter output power
total radiated power reduced by losses between the transmitter output and the antenna

3.1.122
transmission time
interval from starting the delivery of the first application data octet of a message to the reference communication interface of a producer until the delivery of the last application data octet of the same message from the reference communication interface of a consumer

3.1.123
transmitter sequence
time that a transmitter uses a frequency channel without the possibility to be interrupted by a wireless device of the same system

3.1.124
transmitter spectral mask
envelope of maximum values of power spectral density over a frequency range

3.1.125
tree topology
tree network topology
network topology where all nodes are connected in a combination of a linear and a star topology

3.1.126
update time
interval from the delivery of the last user data octet of the message of a producer, from the reference interface of a consumer to the automation application, until the delivery of the last user data byte of the following message of the same producer

3.1.127
upper cut-off frequency
frequency furthest above the frequency of maximum power where the power spectral density drops below a certain level

3.1.128
wireless application
any use of electromagnetic waves with devices or equipment for the generation and use of radio energy using radio environment with active and passive environmental influences

Note 1 to entry: The definition includes wireless communication systems with wireless communication functions representing a set of spatially distributed automation functions, distributed automation system with local functions and physical system with physical system functions.

Note 2 to entry: The definition includes radio determination equipment.

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3.1.129
wireless communication
communication in which electromagnetic radiations are used to transfer information without the use of wires or optical fibers

3.1.130
wireless communication application
part of an industrial automation application that uses wireless communication

3.1.131
wireless communication solution
parameters of wireless communication solutions which are implementations of wireless communication systems and devices

3.1.132
wireless communication solution density
ratio of the number of wireless communication solutions and the spatial coverage of the plant

3.1.133
wireless communication system
set of wireless communication devices, infrastructure devices and physical links communicating using radio frequencies using various topologies

3.1.134
wireless device
wireless automation device
equipment of wireless communication applications that uses radio waves for wireless communication with other equipment of wireless communication applications

3.1.135
wireless device density
number of wireless devices within the spatial coverage of the wireless communication system

3.1.136
wireless device receiver parameters
wireless receiver parameters
specification of wireless receiver characteristics

3.1.137
wireless device solution
parameters related to individual nodes within a system implementing a wireless communication solution

3.1.138
wireless device transmitter parameters
wireless transmitter parameters
specification of wireless transmitter characteristics

3.1.139
wireless device type
specification of a device according to the catalogue data

3.1.140
wireless network
wireless communication network
network consisting of at least two wireless devices that established wireless communication

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3.1.141
wireless network solution
parameters related to a network as a whole used implementing a wireless communication solution

3.1.142
wireless solution
wireless communication solution
specific implementation or instance of a wireless communication system

Note 1 to entry: A wireless solution can be composed of products of one or more producers.

3.1.143
wireless system
wireless communication system
set of interrelated elements providing wireless communication

Note 1 to entry: A wireless system is a high-level representation of a system, while a wireless solution is a practical instance of a system.

3.1.144
wireless system type
parameters describing the kind of wireless communication system

3.1.145
wireless system type and wireless device type
parameters that characterize the model of a wireless system or a wireless device by providing the parameters to specify a wireless system type and a wireless device type

3.1.146
wireless technology or standard
naming the wireless technology or standard

EXAMPLE Examples of standards specifying a wireless communication system are IEC 62591 [1], IEC 62601 [2] and IEC 62734 [3].

3.2 Abbreviated terms

AFH	adaptive frequency hopping
BFWA	broadband fixed wireless access
CEPT	European conference of postal and telecommunications administrations
CP	communication profile according to IEC 61784-2 series [6]
CSMA	carrier sense multiple access
DAA	detect and avoid
DAR	detect and reduce
DAS	detect and suppress
ECO	European communications office (the electronic communications committee of CEPT)
EIRP	equivalent isotropic radiated power
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ERP	effective radiated power
IF	intermediate frequency
IP	Internet protocol
ISM	industrial, scientific and medical

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IT	information technology
ITU	International telecommunication union
LAN	local area network
LOS	line of sight
MLR	message loss ratio
NLOS	non line of sight
N/A	not applicable
OLOS	obstructed line of sight
PCB	printed circuit board
PSD	power spectral density
RF	radio frequency
RFID	radio frequency identification
RSRP	reference signal received power
RSRQ	reference signal received quality
RSSI	received signal strength indication
SIR	signal-to-interference ratio
TDMA	time division multiple access
TRP	total radiated power
WD	wireless device
WIA-PA	wireless network for industrial automation – process automation
WLAN	wireless local area network
ZVEI	Zentralverband Elektrotechnik- und Elektronikindustrie e.V.; the german electrical and electronic manufacturers' association

3.3 Conventions

NOTE The graphical representations of flow charts in figures are based on ISO 5807 [19].

The following conventions for the coexistence management parameter templates in Clause 8 apply:

- The column "Parameter" uses indentations to cluster certain parameters. The parameters that are more to the right belong to the parameter above that is more left.
- The column "Usage" specifies whether the parameter is mandatory, optional, or selection, if one out of several parameters is selected.
- The item "Value" can contain a range or a list of values if the parameters allow multiple options. If a parameter does not have a unit, then the item "Unit" shall be marked with not applicable (N/A).

4 Coexistence concept in industrial automation

4.1 Overview

Wireless communication allows industrial processes to be implemented more cost-efficiently, flexibly and reliably, as well as allowing the use of new automation concepts. Industrial automation applications usually place stricter requirements on reliability and real-time capability of wireless communication than applications in the domestic and office domain. Industrial automation applications can also reside in industrial facilities with higher ambient electromagnetic interference (EMI) levels than those in non-industrial domains.

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Additional sources of radio emissions will also need to be taken into account during coexistence management.

NOTE In some industrial environments, other sources of radio emissions can be present within the same bands as used by the wireless communications systems. These emitters can include devices with unintentional emissions, such as high-power welding devices which generate wideband electromagnetic energy.

Because of those requirements, different wireless systems are used. It is quite likely that several wireless systems can operate simultaneously in one place. Since these wireless systems share a common medium, interferences can be assumed throughout their life-cycles. This impacts system performance including reliability and its ability to meet real-time response requirements. This document is intended to help identify potential risks and to recommend measures to control these risks, depending on the requirements of the industrial automation application. This document also illustrates that most often the coexistence of several wireless systems and simultaneously the efficient handling of the frequency spectrum as a limited resource is feasible if an appropriate approach is chosen, taking into account the respective requirements. In order to achieve this, a process is needed in which all aspects of the coexistence of wireless systems during design, commissioning, and operation, as well as maintenance, are considered. This process, called coexistence management of wireless solutions, is the subject of this document. Associated actions and decisions serve to comply with the claimed limit values for the application over the whole life-cycle of the plant.

This process can be more or less complex, depending on the relevance of the requirements related to the wireless communication for the plant. This complexity depends, among other aspects, on the characteristics of the wireless communication application served by each wireless solution (for example control with strict real-time requirements), the number and location of the wireless solutions that can potentially interfere with each other, and the presence of any other radio emitters in the same bands.

If no, or just modest, requirements are made on the wireless system, a lower effort for the coexistence of wireless solutions will be necessary than in the case of a wireless system that is part of a control application with strict real-time requirements. However, it is strongly recommended to consider that additional wireless systems could be implemented later or that the requirements on the present wireless system might change in the future (for example due to additional applications). The plant design shall ensure that the applied coexistence measures match the requirements of the wireless system.

The state of coexistence is characterized by meeting the limit values of relevant parameters for all wireless communication applications in the considered area. This state of coexistence is accomplished with appropriate actions in planning and in operation. This clarifies that coexistence is not a static attribute of a wireless solution, but rather a state within the life-cycle of a plant. It is possible to leave this state temporarily or permanently due to certain events. The parameter limit values are determined by the automation application in which the wireless communication takes place. This also implies that the coexistence management shall be evaluated and established contextually and in full accordance with the automation application.

From a general point of view, coexistence of two or more wireless solutions can be achieved by making orthogonal the transmissions that come from different sources.

There are three possibilities to manage coexistence, where a) means a higher amount of labor hours to establish and maintain the coexistence management and b) and c) means an increasing level of automation:

a) manual coexistence management (lowest level);

b) automated non-collaborative coexistence management;

c) automated collaborative coexistence management (highest level).

Automated techniques, and the algorithms on which they are based, are usually classified into two broad categories: collaborative and non-collaborative.

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4.2 Objective

This document is focused on measures to provide coexistence of wireless systems for measurement and automation applications. These industrial automation applications can be classified in various ways. For example, in Table 1 they are classified according to the degree of the application criticality. Efforts for coexistence management can vary according to the classification described in Table 1.

Table 1 – Example of a classification of application communication requirements

Class	Application	Application communication requirements
Functional safety	Implementation of a safety-related system whose failure could have an impact on the safety of persons and/or the environment and/or the plant	The communication protocol should support functional safety communication and the coexistence management shall be established in order to fulfil all requirements of this document.
Control	Closed or open loop control	The communication protocol should support a higher availability, reliability, and time-criticality protocol than the one used for other application domains like consumer industry or telecommunication. The coexistence management shall be established in order to fulfil most of the requirements of this document.
Monitoring	Process visualization and alerting	No specific add-ons required for the communication protocol. Typically, monitoring application can be satisfied by a relaxed set of requirements. The coexistence management shall be established in order to fulfil these minimum requirements.
NOTE The relative terms "most" and "minimum" are based on the graphical description in Figure 3.		

The classification of automation applications provided with Table 1 refers to the functional requirements of the process industry application to be satisfied. This classification can also be adapted in other application domains.

However, the determination of the criticality and the associated application communication requirements shall be determined on a case-by-case basis by the coexistence manager.

NOTE 1 Application communication requirements are described in IEC 62657-1.

Applications ranging from radio bar code readers to voice and video over IP applications can be classified likewise and can be dealt with according to this document.

The applicability of this document is not confined to a specific frequency band, for example the 2,4 GHz ISM band. Both concurrent communication systems and other approved wireless applications, such as microwave systems for drying or plastics welding, are considered as interferences. Moreover, further interferences might occur due to powerful low frequency electromagnetic fields (for example transformers, powerful motors or other electromagnetic interferences (EMI), see Figure 1). The interference sources to be considered are detailed in 4.4.

NOTE 2 The analysis of EMI is outside of scope of this document but has been considered.

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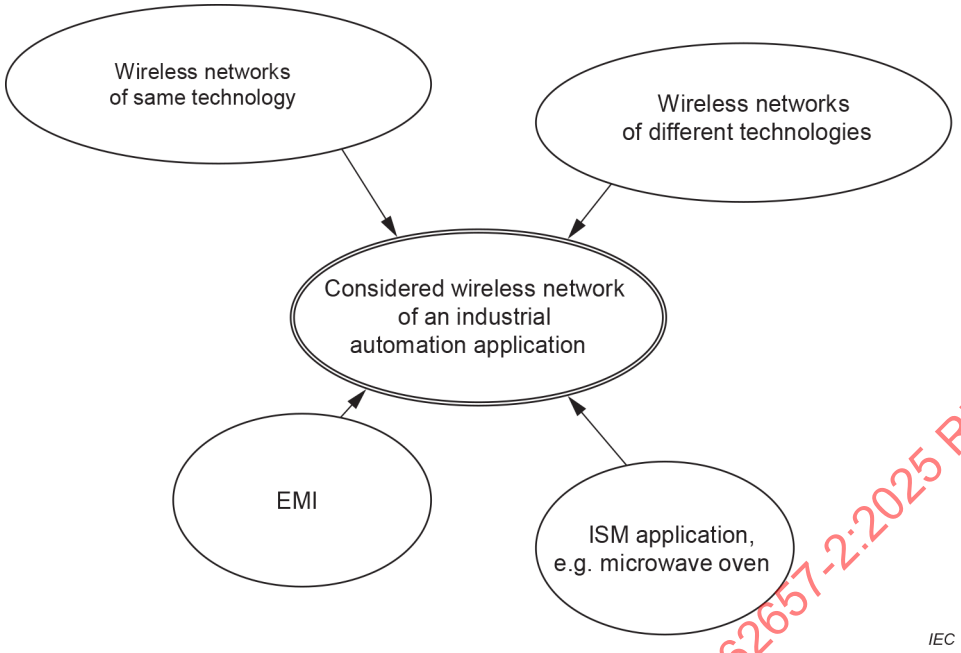

Figure 1 – Issues of consideration

In Figure 2, the relation between industrial automation application, wireless communication application, EMI, industrial, scientific and medical (ISM) application and non-industrial wireless application is depicted. Wireless application is used as generic term for wireless communication application, ISM application and non-industrial wireless communication (grey in Figure 2). Wireless communication applications are parts of an automation application. Other parts of automation applications may use ISM spectrum e.g. for welding processes. Furthermore, equipment of industrial automation applications can be source of electromagnetic interference (EMI). In addition, non-industrial wireless applications (e.g. smart phones or laptops) may use the spectrum in an industrial environment.

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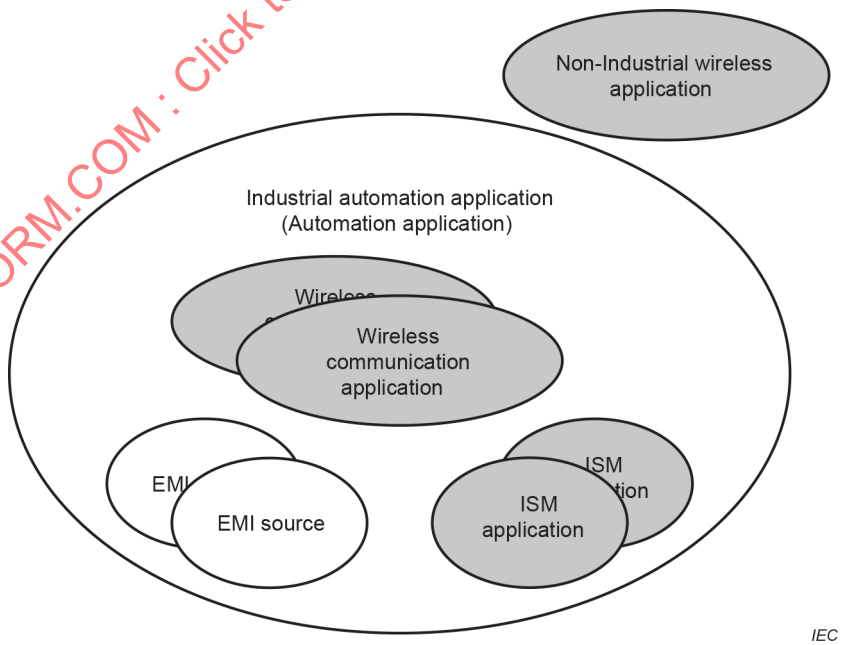

Figure 2 – Applications using frequency spectrum

This document is aimed at addressing coexistence management at the location of an enterprise; however, the manager shall take into consideration the fact that some interference could come from outside the location of the plant. The manager shall identify and characterize potential external radio energy sources and their distance from the enterprise. Controls should be in place to ensure that unauthorized or unaccounted mobile sources are not allowed in the enterprise area.

It is assumed that, in conditions without interference, a wireless communication system basically meets the requirements of the wireless automation application and that, in particular, the limit values for time and error behaviour are taken into account by planning the communication requirements.

The measures described here are to ensure the required performance even in the presence of other wireless applications.

4.3 Necessity to implement a coexistence management

The frequency spectrum is a valuable limited resource which will be rapidly exhausted in the case of unmanaged use.

The following list shows an example of wireless devices to be found in industrial environments:

- wireless sensors and actuators;
- WLAN access points and clients;
- mobile panels;
- RFID devices and RFID readers.

There are also devices which can emit radiated power in the same bands as the wireless devices:

- radio-frequency process heating;
- plastic welding;
- plasma lamps;
- general welding; and
- other devices.

There is a high risk of interference whereby, under certain conditions, the assumed availability and performance requirements cannot be observed. In order to avoid this, or rather to reduce the risk of interference, a company-wide process for the administration of wireless applications for all parties involved is strongly recommended, and if adopted, shall be implemented according to this document. Coexistence management is an intra-company process which should be adjusted to the structure and the internal processes of the enterprise. In each individual company, the structure and the processes can be organized differently.

Moreover, the focus in defining the process or its sub-steps can vary according to the user groups concerned:

- wireless communication applications with a high data throughput, but relaxed real-time requirements: the coexistence management puts the focus on the provision of frequency bandwidth meeting the application requirements;
- wireless communication applications without specific requirements for performance and real-time: the coexistence management aims at ensuring the spatial coverage;
- wireless communication applications with strict real-time requirements: the coexistence management safeguards against functional problems caused by the influence of other wireless applications (application classes Functional Safety or Control).

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In addition, the following basic measures to implement coexistence management are recommended:

- nomination of a company-wide coexistence manager;
- nomination of a location-specific coexistence manager if the company has several facilities;
- establishment of a committee, consisting of contact persons of all company divisions using wireless applications (task of the committee should be the issues shown in Figure 1 and Figure 2);
- inventory of all installed and, if possible, all planned wireless applications including wireless communication;
- establishment of a policy to register new wireless applications or solutions and for the identification of existing ones;
- coordination and adoption of decisions regarding the approval and application of wireless systems within the committee;
- establishment of a policy and enforceable consequences for non-authorized introduction of new wireless applications or solutions.

Effective coexistence management is a concerted process with representation of all company divisions concerned (sub-divisions, departments, technologies). The divisions concerned are those involved in planning, procurement, installation, commissioning, operation and maintenance of wireless applications, for example process planning, IT, automation, plant operation (production), development, purchasing, facility management.

Coexistence management offers various benefits:

- reduction or elimination of interferences leading to unplanned downtimes;
- reduction or elimination of laborious, cost-intensive and time-consuming fault troubleshooting;
- reduction or elimination of disinvestments in wireless solutions that cannot be operated in the present radio environment of the enterprise.

NOTE The term 'wireless solution' is used here instead of the term 'wireless system' because it takes into account the distinct attributes of a product that are important for the coexistence management.

4.4 Interference potential

For wireless communication applications, interference will occur at a point in space (corresponding to an antenna location, received energy, antenna characteristics and polarization) if the received signals:

- overlap in the frequency domain;
- overlap in the time domain; and
- overlap in coding.

NOTE 1 In the case of buildings and areas close to airports, harbors, transmitter masts and other places of powerful wireless systems, the interference potential is extremely high.

This leads to interferences between wireless solutions with the consequence of lost packets so that, for example, a transferred packet needs to be repeated. The system reaction to the described interference depends on several factors, for example on the wireless standard, on the hardware and software implementation or on the application class (see Table 1) the wireless system uses for transfer.

The separation of non-overlapping frequency channels is a method to achieve coexistence. However, there might be interference between wireless systems using different channels in the same frequency band, for example because of adjacent channel interference. This is called cross-channel interference. In particular, analog wireless systems hold a high interference potential for digital wireless systems due to their high channel occupation.

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Moreover, wireless systems using different frequency bands can interfere with each other. Beneath the main signal, a wireless system also emits outer band signals that might penetrate the frequency channel of the endangered wireless system, thus affecting the wanted signal.

The received signal quality at a receiver as a function of interference by other wireless systems is typically measured by the signal-to-interference ratio (SIR), which is the ratio of the power of the wanted signal to the total residual power of the unwanted signals. The receiver can correctly interpret incoming data only if the SIR is above a given threshold.

The value of the threshold depends on the adopted modulation, while the actual SIR value depends on the superposition of interferers with respect to the intentional communication in the following two domains: time and frequency.

Different performances can be obtained if superposition (that means interference) in these domains is complete or only partial.

For the time domain, since the traffic of victim and interferer(s) wireless system(s) can change each time, the SIR evaluation should be preceded by the definition of a time interval in which the interference is constant.

For the frequency domain, the SIR evaluation should consider at least the combined effect of interfering transmitter(s) and receiver victim spectral masks. In fact, the interfering transmitter(s) can have spurious emission even outside the adopted frequency channel. On the other hand, the receiver blocking mask can reject the interferer(s) signal(s), mitigating its effect.

In order to foresee/estimate the effect of interferers, it is possible to use analytical models, simulations and experimental test beds. These three approaches have different (increasing) complexity and hence different (increasing) accuracy.

In order to assess whether there is a risk of interference or not, an interference risk should always be assumed if wireless applications are operating in parallel in the same frequency band without proof of their radio robustness.

NOTE 2 This term wireless application is more comprehensive than the term wireless system, because in wireless applications, the radiated power is not only used for information transfer.

NOTE 3 The use of the electromagnetic energy can be either intentional (as needed to serve the specific application) or unintentional/accidental.

However, an interference risk does not mean that parallel operation of competing wireless systems is unfeasible. They can co-exist if the requirements on the wireless solutions involved are met. This criterion should be taken as a basis for decisions regarding the application of wireless systems.

If possible, future changes in the requirements, implicating changes of the interference potential, should also be considered. In industrial automation, the life-cycle of a wireless solution typically lasts more than 5 years. During this time, new applications for the existing wireless system can be developed and deployed. Determination, coordination and control of these changes are part of coexistence management.

One more influence is radiated EMI. In particular, regional regulations can allow significant radiated power for specific wireless applications in unlicensed spectrum, potentially generating a high field strength in the proximity of a wireless system.

A wireless solution shows a certain interference resistance against those radiated interferences. This limit value can be exceeded by the signal of a powerful wireless application.

EXAMPLE RFID applications in Europe are allowed to use 4 W in the 2,4 GHz band whereas other short-range devices are limited to 100 mW.

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Even though wireless solutions often hold a higher interference resistance than normatively claimed, and exceeding the limit value does not always result in harmful interference, the design of the wireless solutions shall be such that the noise level at the receiver does not exceed this limit value. Interferences from the same frequency band are much more likely than from other frequency bands. Nevertheless, the interference potentials from other frequency bands also shall be taken into account.

EMI caused by defective devices and exceeding the normal operating limits should not influence the coexistence management. The defective device should instead be repaired to return to normal operating conditions.

4.5 Ancillary conditions

For wireless communication, there are only limited communication resources available, thus thorough planning is required. The higher the requirements of the application class on the wireless system, as to time behaviour, availability, dimension and others, the higher is the technical and organizational effort required to guarantee coexistence. The costs rise disproportionately as shown in Figure 3. A certain span of expense results from the complexity of the wireless network solutions (for example, simple point-to-point link or linear-, ring-, star-, cellular-, tree-, mesh- topology) and from the number of influencing factors to be considered (for example medium load, transmitter power). The span between the two curves moves upwards the more efficiently the spectrum is used. This applies to both:

- the expenses for the coexistence management in the coexistence planning phase; and
- the costs of developing appropriate wireless solutions.

The bold arrow in Figure 3 shows that the curves will go higher as the coexistence management efforts increase to gain a higher efficient use of the spectrum.

The effort might be reduced by strategic regulations for coexistence management. A possible regulation is to confine the number of considered influencing factors, for example by exclusive assignment of frequencies to specific wireless applications. It is essential to take into account that strategic decisions in the coexistence planning phase have effects on the future expenditures and therewith on the life-cycle costs of the plant. The technical and organizational expenses for coexistence management in the operating phase can multiply the coexistence planning costs throughout the life-cycle of a plant.

It is therefore important to analyze whether the requirements of the planned application fit the intended application requirements. In relaxing the requirements, a more efficient use of the resource can be achieved. If the resource is exhausted, other solutions will need to be found.

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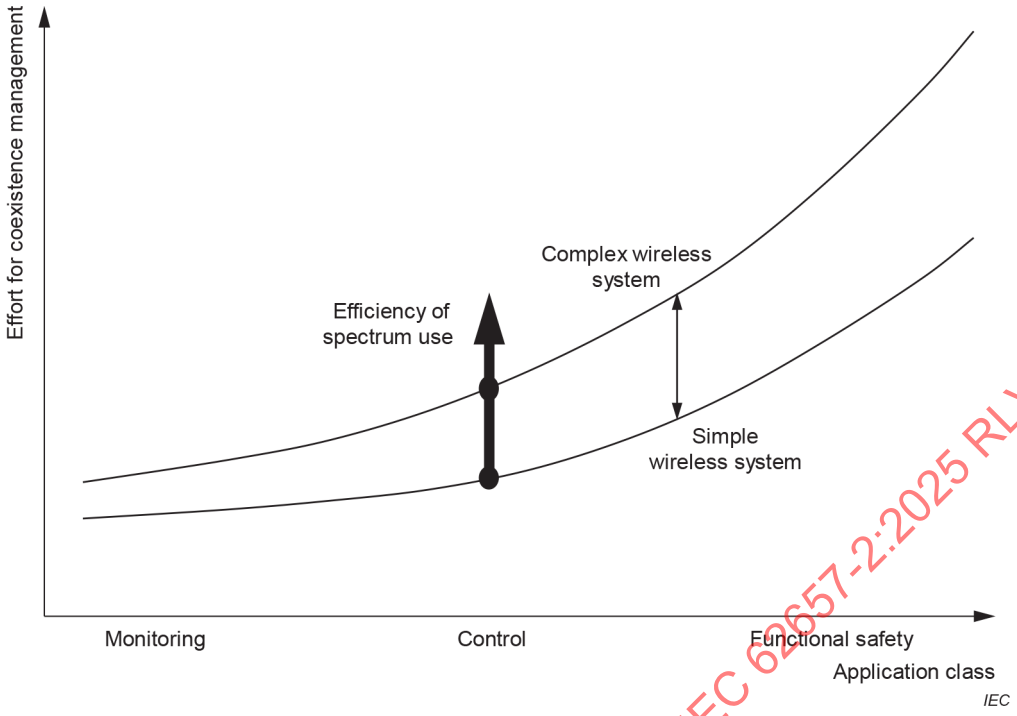

Figure 3 – Progression of expense to achieve coexistence corresponding to the application classes

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4.6 Requirements to wireless devices for support of coexistence management

Wireless devices shall be capable to vary parameters that are specified in Clause 5 to achieve the coexistence management by reducing the interference potential as specified in 4.4.

EXAMPLE The device is so constructed that certain frequencies can be blocked; power can be adjusted to be below the threshold of the incumbent services/applications.

4.7 Concepts

4.7.1 Manual coexistence management

In the case of manual coexistence management, the coexistence manager (see 7.2.1) shall define a fixed planning of the wireless solutions intended to prevent transmission overlaps. The manager shall implement manual measures to react to modifications that change the wireless coexistence state. This is the simplest management method, especially if multiple wireless solutions of different technologies and from several vendors are involved, or if several frequency bands need to be managed.

This method can be used if there are non-manageable radio emitters in the same bands as used by wireless solutions.

However, the manual coexistence management capabilities are limited if some coexistence management parameters cannot be configured.

4.7.2 Automated non-collaborative coexistence management

In automated non-collaborative coexistence management, the different wireless solutions are not capable of exchanging information. They are fully independent and rely only on interference detection and estimation. In other words, each offended wireless solution classifies the behaviour of the offending ones and tries consequently to adapt its own behaviour to the new estimated situation. For this reason, non-collaborative techniques are more general but less efficient than the collaborative ones. As an example, non-collaborative algorithms dynamically modify the communication strategies (for example the frequency band, the timeslot/packet scheduling, and so on) as a result of an assessment of the wireless application requirements versus the wireless application solution capable of establishing the required communication performance.

Such methods are being proposed to address coexistence in uncontrolled public areas, however such methods would not be effective for the management of industrial automation wireless devices which need to meet performance requirements.

NOTE Some metrics are described in IEEE Std.802.15.2 [11].

4.7.3 Automated collaborative coexistence management

4.7.3.1 General

In automated collaborative coexistence management, the different wireless solutions shall be able to exchange characteristic parameters.

The precondition for collaborative coexistence management for wireless systems using multiple technologies provided by multiple vendors is that a common standardized communication link is available amongst these solutions. This link can either be:

- a pilot channel between the collaborative coexistence manager and the coordinated devices using a common standardized communication protocol and service set, as for example specified in IEC 62657-4, to make the task of the collaborative coexistence manager easy;
- a wireless solution of the coordinated devices that is also understood by the collaborative coexistence manager, which means that the collaborative coexistence manager shall talk the language of all the coordinated devices that participate in the automated collaborative coexistence management;
- a wired link between the coordinated devices and the collaborative coexistence manager using a common standardized communication protocol and service set.

An automated collaborative coexistence management could result in some restrictions on the adopted hardware since, for instance, collaborative methods are usually implemented by means of a centralized arbiter/scheduler. The exchanged information allows each offended wireless solution to effectively adapt its own behaviour to the real new situation, taking into account the requirements of its own application and the applications of the other wireless systems. These dynamic modifications could influence the determinism or reliability of the communication and can therefore be inappropriate for various wireless communication applications.

An example of such an automated collaborative coexistence management is a central coordination point (CCP), see IEC 62657-1:2017, 4.3.4.3. National, regional and regulatory aspects are also described there.

IEC 62657-3 provides the formal description of the automated coexistence management and application guidance.

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Three different application use cases for automated collaborative coexistence manager exist:

a) for sharing the same frequencies with other incumbent services/applications (see 4.7.3.2, 4.7.3.3 and 4.7.3.4);

b) for intra-system coexistence in a controlled environment;

c) for intra-system coexistence in a public area.

A possible approach of an automated collaborative coexistence management for industrial automation is specified in IEC 62657-4.

4.7.3.2 Simple CCP

A collaborative coexistence manager is responsible for detecting the primary users and identifying the devices which are coordinated. The CCP shall then inform the underlying coordinated devices that they shall react to fulfil the requested mitigation techniques of the primary user. No reconfiguration of the assigned frequencies is requested. Examples of how the coordinated devices could react are to lower the transmit power or stop transmission.

4.7.3.3 Intra-system CCP

All or at least most radio equipment in space is known with their dynamic requirements. It is assumed that the installed devices are static. Nomadic devices are known and as such seen as static in configuration, for example if they have geolocation capability. The collaborative coexistence manager is responsible for detecting primary users and for informing the underlying coordinated devices (incumbent services/applications) if they could interfere with primary users. The collaborative coexistence manager can decide whether the coordinated devices shall react to fulfil the requested mitigation techniques of the primary user, or the coexistence manager can assign different spectrum to the coordinated devices. Some additional alternatives could be that the collaborative coexistence manager organizes time synchronization or influences other parameters specified in 4.4.

4.7.3.4 Public CCP

All behaviours described in 4.7.1 and 4.7.2 as well as 4.7.3.2 and 4.7.3.3 could be supported. In addition, unknown devices can ask the collaborative coexistence manager to also be managed.

The coordinated coexistence management increases the spectrum efficiency and the quality of service.

4.8 Best practices to achieve coexistence

The establishment of coexistence is a combination of technical and/or organizational measures to ensure the correct operation of wireless communication applications in their environments. The main criteria in the selection of appropriate actions to achieve coexistence are effectiveness, feasibility, economic efficiency and the loss of performance acceptable for the application if the wireless solution needs to share the medium with other wireless systems. Future developments of the wireless communication application in the enterprise should be considered here as well.

Technically, signals of wireless communication at a point in space (corresponding to an antenna location, received energy, antenna characteristics and polarization) can be separated by:

- frequency;
- time;
- coding.

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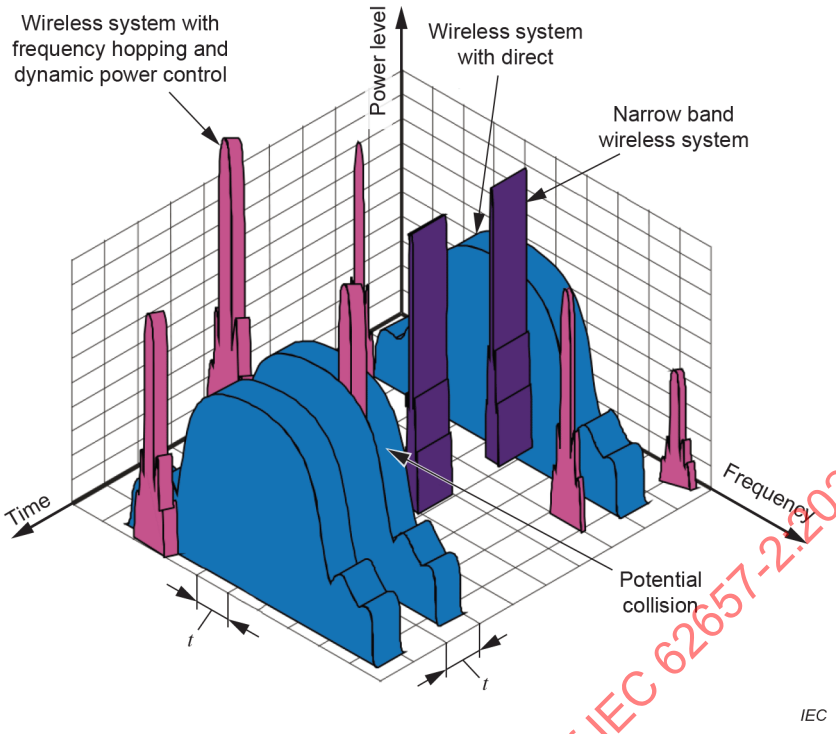

Figure 4 – Separation of wireless systems according to frequency and time

The separation in the frequency domain (see Figure 4) usually causes the least performance loss and initially the lowest expense. However, these measures occupy the medium to a great extent and should therefore be reserved for specific application classes used in the plant such as functional safety and control. A separation in time can be accomplished by configuring the communication request with respect to the application communication requirements.

For applications with a certain dynamic, the communication cycle should be set as long as possible and/or event driven communication should be used. Wireless technologies with automatic adaptive medium sharing mechanisms should also be used.

A spatial separation is rarely possible in the case of a wireless communication application. Radio propagation can only be restricted spatially with great efforts. Structural conditions (for example large steel reinforced concrete walls) and the reduction of the radiated power (by adjusting the output power of the radio transmitter and the choice of the antenna radiation pattern) can be used for spatial separation. For larger facilities, the control of power levels can be a viable approach. If the power is reduced, the power of all related wireless devices (for example base stations, repeaters, and end devices) should be adjusted accordingly.

If the transceivers have multiple antennas, then it would be possible to utilize spatial processing, such as interference rejection techniques, to separate simultaneous transmissions in space.

Separation via polarization involves the specific attribute of an antenna to subdue radio waves with an orthogonal polarization (cross polarization). For example, a horizontally polarized antenna of a signal receiver can attenuate a vertically polarized interference signal. However, inside buildings or in other highly reflective surroundings, the effects of a polarization separation are relatively small.

In addition, directional pillbox antennas or other emerging antenna concepts can be used to restrict the radio propagation within a certain area.

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The organizational measures apply to the operation of the wireless system and they have indirect implications for the uncoupling mechanism described in Figure 4. Hence the application of a wireless system can, for example, be restricted in space or time, or just services of a wireless solution meeting the coexistence requirements can be approved. The organizational measures (in particular those for wireless systems related to business process or safety) should evaluate in advance to what extent compliance with the specifications can be ensured and controlled.

Impact of the typically non-ideal radio propagation characteristics found in many industrial environments can impact the time and error behaviour of a wireless solution. Therefore, suitable allowances shall be made in the planning of wireless systems.

In the operation phase, investigation of mechanisms to enhance the agility of wireless communication applications against the appearance of unexpected interferences shall be considered, for example diversity techniques and cognitive radio medium access methods.

In order to define adequate measures and to evaluate their efficiency, the assistance of wireless experts is recommended.

4.9 Coexistence conceptual model

Figure 5 shows the coexistence conceptual model. In this example, three wireless communication applications (A, B and C) are assumed. According to the definition of wireless coexistence, all three wireless communication applications shall fulfill their application communication requirements. Each wireless communication system in a wireless communication application has certain immunity against interference from other wireless communication systems and the utilization of its resources can interfere with other wireless communication systems.

The conceptual model of coexistence can be seen as a closed loop control process. This process of coexistence management is not just one activity during the system planning; it is an iterative process throughout the entire life cycle of the system.

NOTE IEC 62890 provides more details about a life-cycle management.

An investigation of the requirements, the characteristics of the wireless communication systems and the medium utilization factor shall be reported in an inventory. According to the life cycle phase (see 7.4), the resulting coexistence planning or maintenance shall be carried out. This results in a current resource allocation plan, which shall be the basis for configuring or implementing the wireless communication applications.

The coexistence state is achieved if the robustness to interference in a wireless communication system is better than the interference produced by the resource, and if the wireless communication applications fulfill their application communication requirements.

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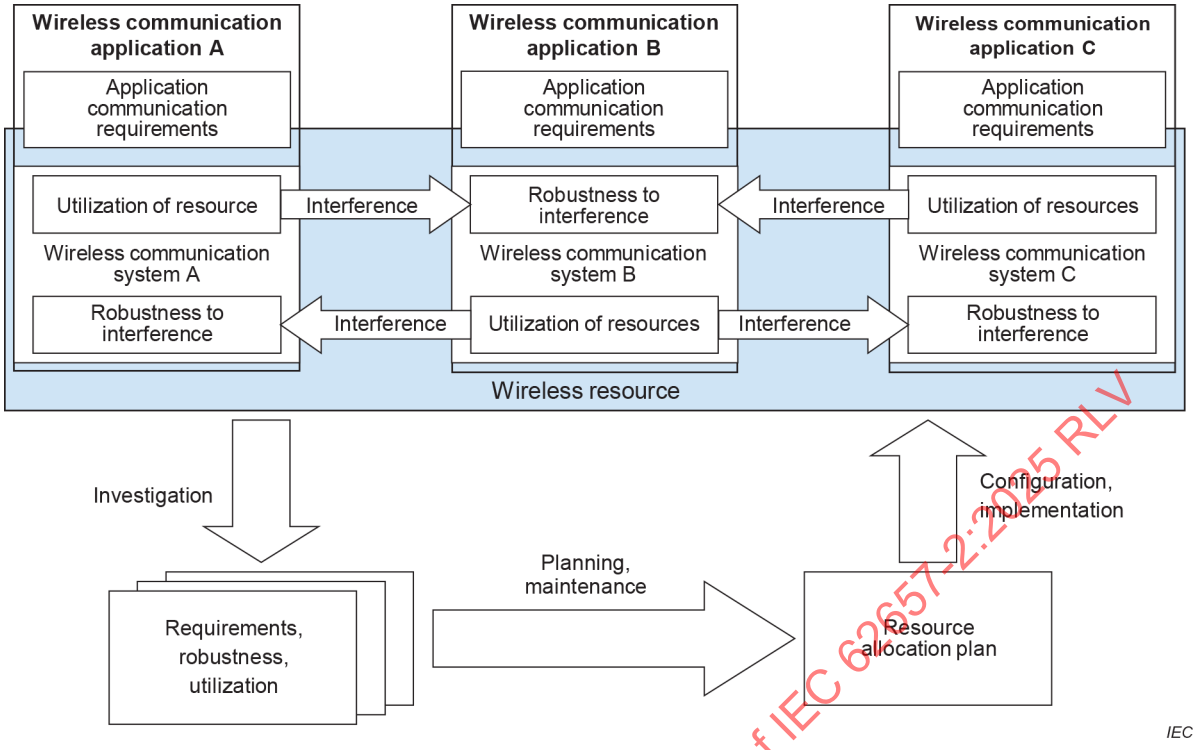

Figure 5 – Coexistence conceptual model

Figure 6 shows some of the contents of Figure 5 as a flow chart to provide the relations to Figure 7, Figure 29 and Figure 30. The coexistence management system specification is shown in Figure 6 only at the start to keep the figure simple. The documentation shall be extended and updated at each phase. If the requirements of a certain phase are not fulfilled, then the process should restart from the beginning, see lines in Figure 6 going from the output of a phase to the return path. The documentation is specified in 7.1.2.

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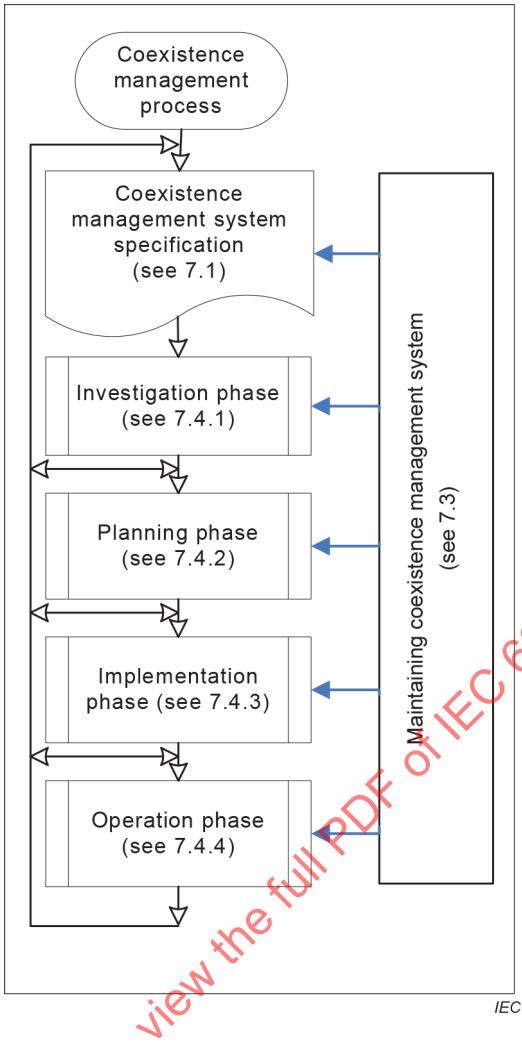

Figure 6 – Flow chart of the coexistence conceptual model

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4.10 Coexistence management and selection of a wireless solution

The starting point and precondition for the implementation phase is that the wireless solution is suitable for the requirements made on it. The investigation phase begins by reviewing the wireless system requirements and making a determination as to whether or not the system is able to fulfil application communication requirements. As part of this process, new wireless systems can be evaluated against application communication requirements. Figure 7 maps decisions and actions into the flowchart shown in Figure 6.

While investigating whether a wireless solution meets the requirements of an automation application, radio transmission shall be analyzed to see whether it is a reasonable approach when considering the efforts that are required to be taken to achieve coexistence. In this respect, the selection process of a wireless solution is already part of the coexistence management process.

The decision to install a wireless system shall be followed by the decision to implement a coexistence management process (see 6.8). The coexistence management process includes coexistence planning, installation, operation and maintenance of wireless systems. The coexistence planning phase (see 7.4.2.2) begins with the inventory of all wireless applications, because they can be regarded as potential interferers (see 7.3).

In the coexistence planning phase, it might become apparent that a chosen wireless solution cannot be integrated into the existing plant. Another wireless solution might be chosen or the idea of a wireless system might be abandoned. If, in the coexisting planning phase, it is ensured that all wireless communication applications meet the respective requirements, the coexistence management process for the operating phase can be initiated (see 7.4.4).

NOTE 1 Processes in the planning phase and in the operating phase are specified in more detail later in this document.

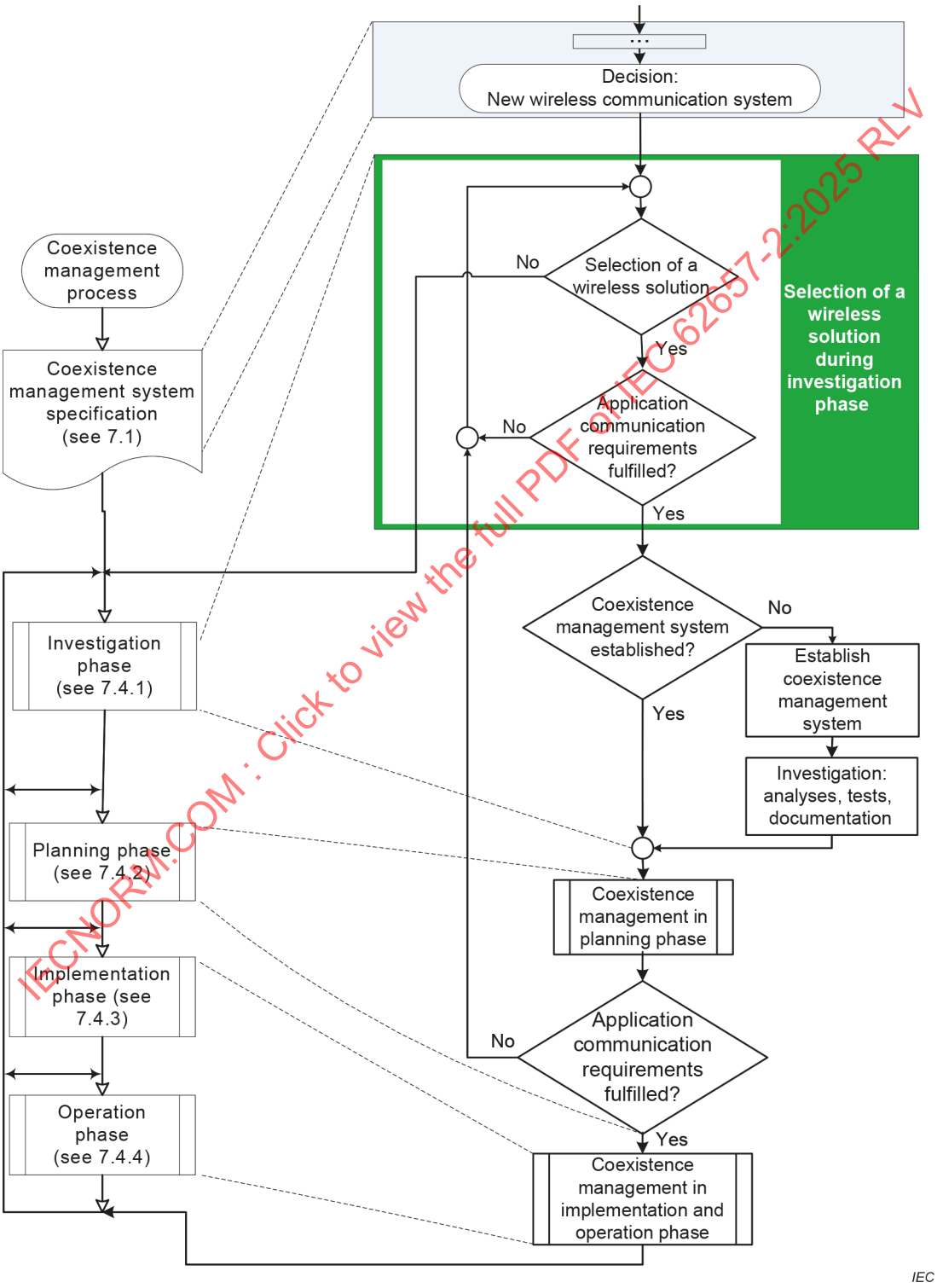

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Figure 7 – Selection of a wireless system in the coexistence management process

NOTE 2 Figure 7 does not show the box "Maintaining coexistence management system (see 7.3)" as it is shown in Figure 6, to avoid making Figure 7 too complicated.

4.11 Coexistence management system

The coexistence management system consists of an organizational structure and procedural documents. The execution of the coexistence management brings the system into a state of "coexistence management in operating phase". The coexistence management system specification shall include the following information:

- scope of the coexistence management;
- commitment of the organization to coexistence management;
- procedure for maintaining the coexistence management system specification;
- organizational issues including structure of the organization, roles of personnel, communication with external organizations and personnel education;
- procedures for coexistence management.

The coexistence management system specification shall be documented, see 7.1.2 and maintained, see 7.3.

5 Coexistence management parameters

5.1 General

5.1.1 Definition and usage of parameters

Clause 5 specifies the parameters of a coexistence management process. These parameters are relevant to the automation communication requirements and conditions within the area of operation and characterize wireless devices and systems.

Their usage is specified in Clause 6. Clause 8 contains the templates related to some of these parameters.

The parameters are listed in alphabetical order. All parameters also have a definition in 3.1. As there are more definitions than parameters, the numbering is different.

The data types of the parameters can be defined in the Common Data Dictionary (CDD) or other tools where the parameters are part of the electronic repository.

Annex A shows the parameter usage in the IEC 62657 series.

5.1.2 Physical link

The concept of physical link is used in the definition of several coexistence parameters.

A physical link is the relation between radio transceivers (physical end points) of two wireless devices. The set of physical links of a wireless system forms its physical topology. A physical link may use different frequency channels for transmissions. Wireless transmission conditions can be described with a radio channel model. Such a model considers the characteristic of the frequency channel, the environmental conditions, the distance between the wireless devices, the antenna characteristic, etc. Because the antenna systems of the wireless devices can be different and the propagation conditions depend on the position of the wireless devices, the radio channel is normally different for both directions of a physical link.

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Where wireless devices have redundant wireless modules, for example for different frequency channels, the related physical links shall be counted separately. It is not required that a wireless device has a physical link to all other wireless devices. There can be physical, technological or application related reasons. The communication load of a physical link is determined by the logical links which use this physical link. A logical link may use more than one physical link, in sequence (via repeater) or in parallel (for redundancy). More than one logical link may use one physical link (different communication services).

5.2 Adjacent channel selectivity

Adjacent channel selectivity is the lower value (of the upper and lower adjacent channels) of the ratios, in decibels, of the levels of the unwanted signal level, expressed as field strength to a specified wanted signal level expressed as field strength producing a data signal with a bit error ratio of 10^{-2}. Adjacent channel selectivity is suitable to estimate the immunity of the equipment against systems in adjacent channels.

NOTE This is in line with the specification of adjacent channel selectivity in ETSI TR 100 027 [20].

The unit of this parameter shall be the decibel (dB) over the intended frequency range.

5.3 Antenna gain

The antenna gain is a value that describes the focusing of a transmitted or received signal. The values are given in relation to a half-wave dipole or a theoretical isotropic radiator. Since the isotropic gain of a half-wave dipole is 2,15 dBi, the antenna gain of a half wave-dipole is 2,15 dBi lower than the antenna gain of an isotropic radiator.

The antenna gain together with transmit power values, the receiver sensitivity and taking into account the propagation conditions can be used to optimize the location and orientation of the wireless device or antenna.

The unit of this parameter shall be the decibel relative to isotropic (dBi).

5.4 Antenna radiation pattern

A radiation pattern illustrates the directional (angular) dependence of the strength of the radio waves of an antenna. It is usually represented graphically for the far-field conditions in either the horizontal or vertical plane. This information can be used to optimize the location and the orientation of the wireless device or antenna.

This parameter shall be represented as a figure or a table.

5.5 Antenna type

Wireless devices can use different kinds of antennas to collect or radiate electromagnetic waves. Examples include omni-directional antennas, directional antennas, antenna arrays, smart antennas and PCB antennas. The antennas can be integrated into the wireless device (internal) or antenna connectors are available to mount antennas externally. If a device has an antenna connector, special antenna systems such as radio coaxial radiating cables or slotted waveguide antennas can also be connected. In addition, the antenna can be mounted independently of the device in a position that is favorable for error-free transmission. If a wireless device can only be used with one certain antenna, it is called dedicated antenna. The information concerning the antenna type can be used to estimate the quality of the physical link and the sensitivity to interferences.

The parameter shall be an indexed list with the items omni-directional antennas, directional antennas, antenna arrays, smart antennas and PCB antennas extensible with entries of new antenna types.

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5.6 Communication availability

Communication availability is a measure to quantify the dependability of wireless communication. Requirements for availability of wireless communication shall be specified.

Other wireless solutions could cause degradation of availability of target wireless communication application. Tolerable availability levels to achieve the target of the application should be clarified. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to a local application or wireless communication application. The communication availability is the ratio between the up time to the observation time. This can also be expressed by the ratio of successful transmitted messages and all messages.

The unit of this parameter shall be the percent (%).

5.7 Communication reliability

The communication reliability of a physical link and the related nodes is a measure to quantify the dependability of wireless communication. Requirements for reliability of wireless communication shall be specified for a given time interval that the communication services under given conditions shall perform without an error.

The unit of this parameter shall be the second (s).

5.8 Bit rate of physical link

The bit rate of the physical link is a measure of the number of binary digits transferred per second. Since data is often combined by modulation or coding, the time utilization of a telegram cannot always be calculated by simply dividing the number of bits of the telegram by the bit rate. It has also to be mentioned that the bit rate of the physical link is normally not identical to the bit rate of the reference interface. A high bit rate of the physical link does not automatically mean a high quality of service.

The unit shall be the bit per second (bit/s).

5.9 Blocked frequency list

Avoiding the use of the same radio frequency ranges for different wireless communication systems is the first measure to prevent interference. For wireless communication systems that use Frequency Hopping Spread Spectrum (FHSS) technology, this means that frequency ranges in the hopping sequence that are used by other wireless communication systems are blocked and with that, not used. A list of frequency channels that shall not be used, called blocked frequency list, shall be specified for the wireless system.

A blocked frequency list can also be used in non-FHSS systems with dynamic frequency allocation.

The parameter shall be a list of frequency channels according to 5.22.

5.10 Centre frequency

Some wireless standards define frequency channels using centre frequency and frequency bandwidth. Thus, the centre frequency indicates the position of a frequency channel within the frequency spectrum. The centre frequency shall be calculated based on the relevant cut-off frequencies. The centre frequency is the geometric mean of lower cut-off frequency and upper cut-off frequency.

The unit of this parameter shall be the hertz (Hz).

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5.11 Area of operation

The following areas of operation shall be considered:

- indoor;
- outdoor;
- indoor and outdoor.

For indoor areas of operation, it is reasonable to define whether the communication is concentrated in a machine or manufacturing cell or if it operates all over the entire factory hall or plant.

The content of this parameter shall be text expressed with a multiple octet string.

5.12 Communication load

The communication load describes the requirement of the automation application to transfer a certain amount of user data within a certain period of time as shown in Figure 8. The communication load is the ratio of automation application data length and transfer interval. The communication load (L_c) is determined as follows:

$$L_c = \sum_i \frac{DL_{Ui}}{T_{Ii}}$$

where

DL_U is the number of user data transferred per device i;

T_I is the transfer interval per device i.

Depending on the granularity of coexistence management, the communication load and its parameters can refer to a logical link or, more generally, to an application.

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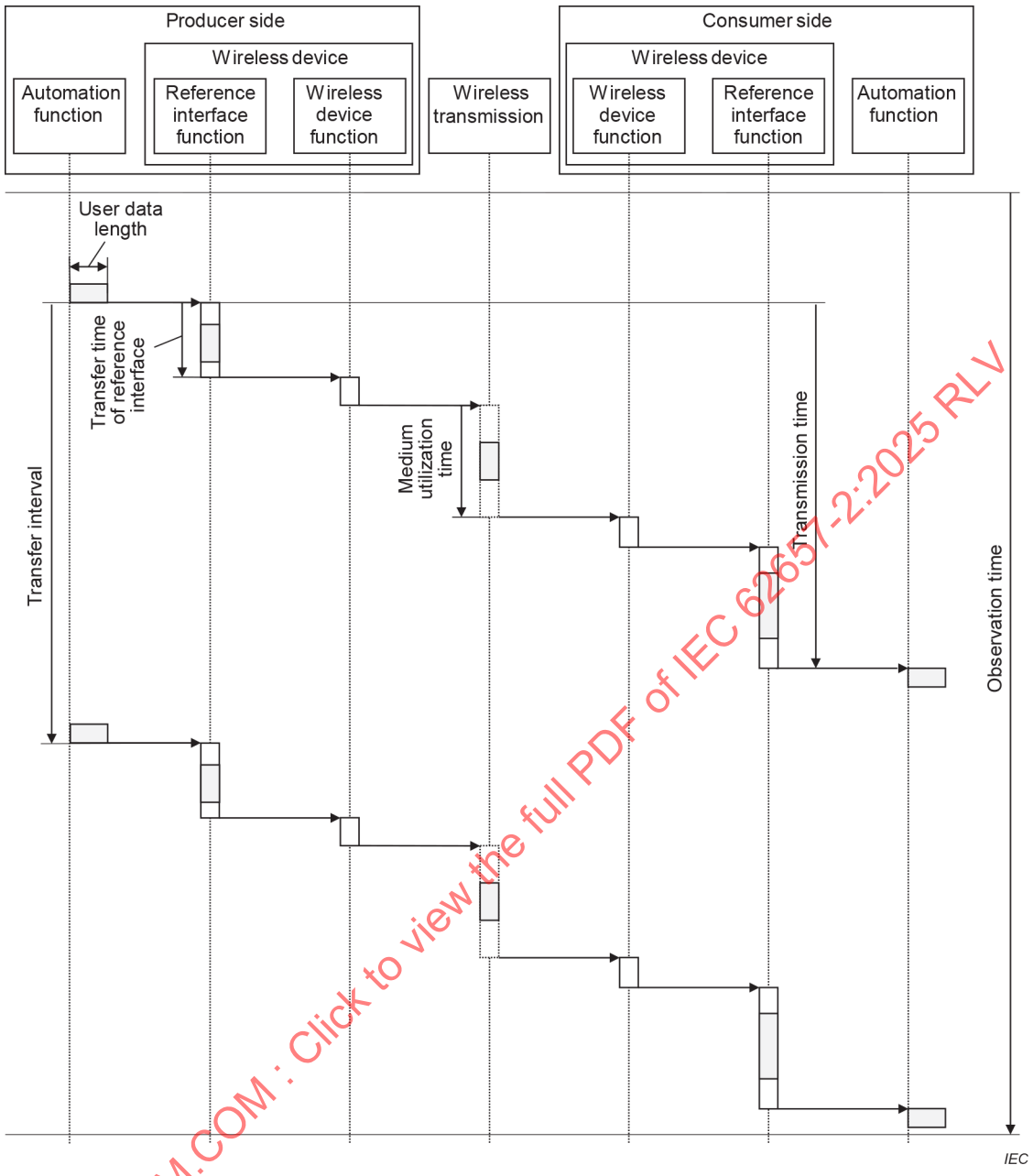

Figure 8 – Communication load in case of two wireless devices

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However, the actual medium utilization depends on the applied wireless solution. In the example in Figure 9, the communication load is indicated for more than two wireless devices.

The unit of this parameter shall be the bit per second (bit/s).

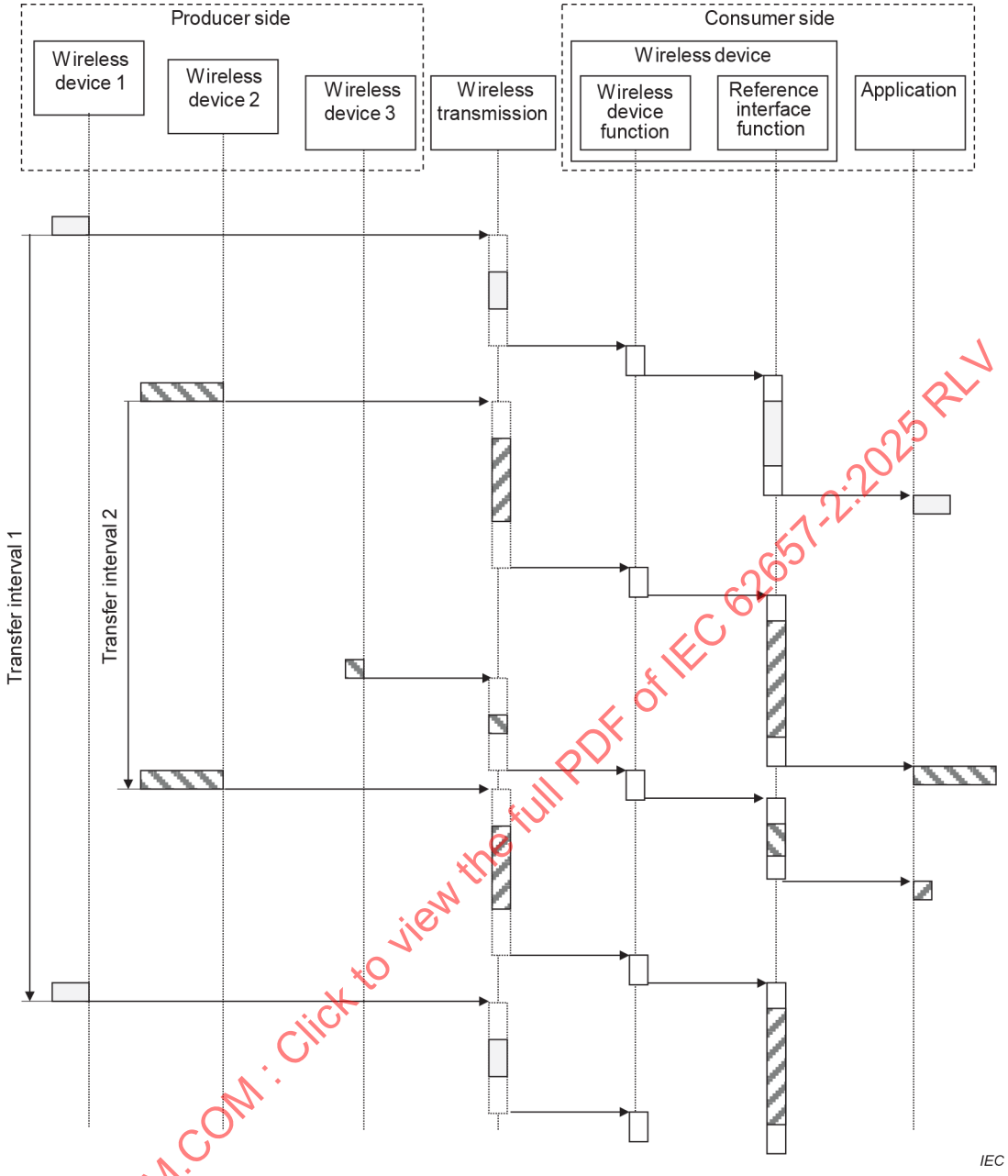

Figure 9 – Communication load in the case of several wireless devices

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5.13 Cut-off frequency

In principle, there are two cut-off frequencies. The upper cut-off frequency is the highest relevant frequency of the spectrum envelope. The lower cut-off frequency is the lowest relevant frequency of the spectrum envelope. However, it depends on the wireless technology or standard as to what relevant means.

There are two principal approaches:

- The first approach is shown in Figure 10 with the help of a wireless LAN system. The reference level is the maximum transmitted power spectral density. From this maximum level, a certain value is subtracted. An example of this value is 20 dB. The frequency furthest above the frequency, where the power spectral density drops below the resulting level, is called the lower cut-off frequency. Accordingly, the frequency furthest below the frequency, where the power spectral density drops below this level, is called the upper cut-off frequency.

- The second approach defines the cut-off frequencies with respect to a certain spurious emission level.

The cut-off frequencies determine the frequency bandwidth of a system and thus the medium utilization in the frequency domain. Furthermore, the cut-off frequencies can be used to calculate the centre frequency.

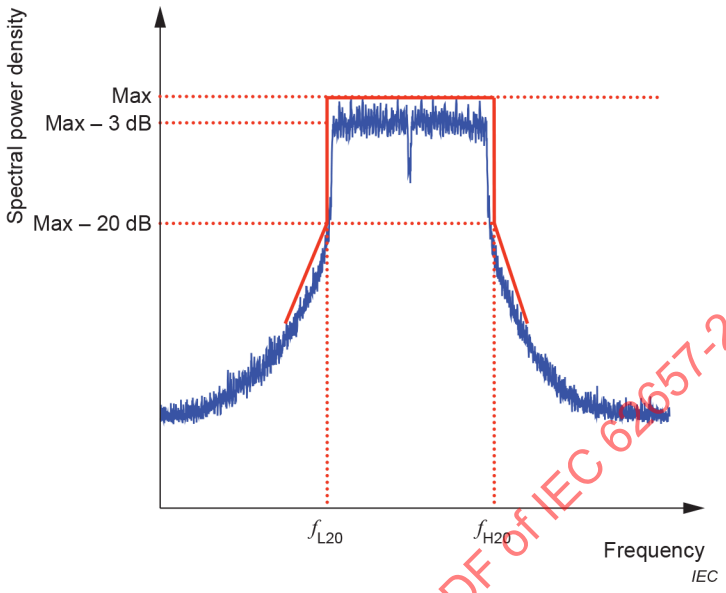

Figure 10 – Cut-off frequencies derived from maximum power level

The unit of this parameter shall be the hertz (Hz).

5.14 Data throughput

The data throughput is relevant to the transfer of large amounts of data (for example the transmission of huge parameter data sets to drives or the downloading of programs into complex field devices). Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

The data throughput is the number of user data bytes, or user data bits, transferred within a consumer from the reference interface to the application per time unit.

To evaluate the coexistence, the average value of a series of measurements can be used, compared with a value given by the automation application.

The unit of this parameter shall be the bit per second (bit/s).

5.15 Distance between wireless devices

The distance between wireless devices determines attenuation and fading, an important influence on the characteristic of the frequency channel. It depends on the positions of the wireless devices which are mainly determined by the automation application. Figure 11 shows the distances of wireless devices within a three-dimensional space. This distance can vary dynamically in the case of moving or mobile wireless devices.

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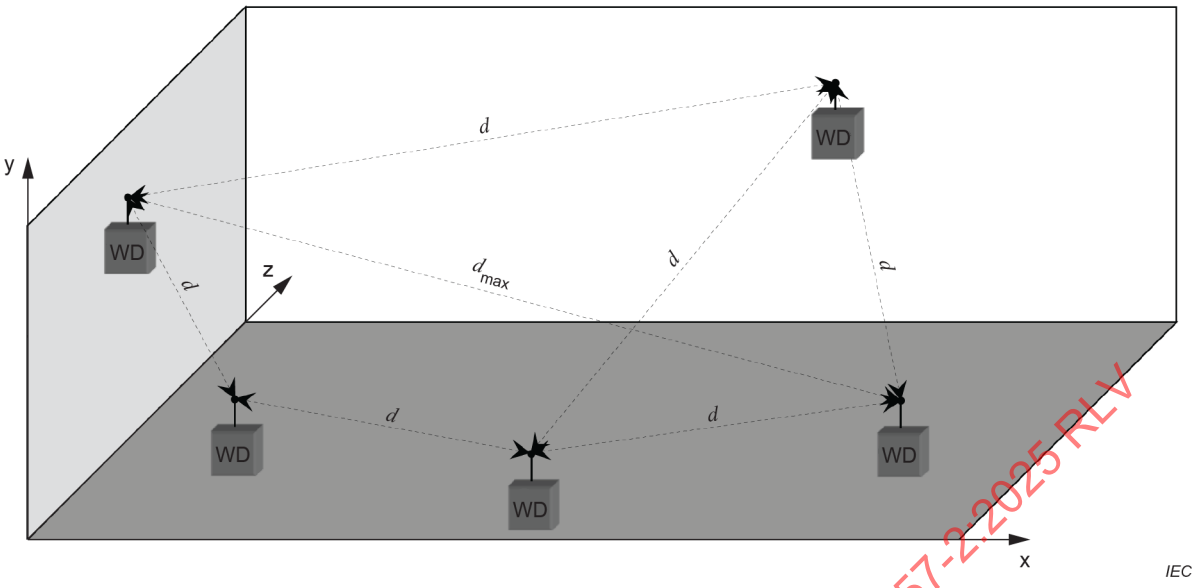

Key

d	distance (m)
WD	wireless device

Figure 11 – Distance of the wireless devices

If feasible, the distance between the wireless devices of a wireless system should be chosen in a way leading to optimal signal power levels; this improves the robustness of the wireless system. The distance to wireless devices of other wireless systems should be chosen in a way that results in interference signal power levels being as low as possible. This reduces the interference of the other wireless system.

At least the maximum distance within a wireless system should be provided.

The unit of this parameter shall be the meter (m).

5.16 Duty cycle

The duty cycle is the ratio of the transmitter sequence referenced to a given observation time for the used frequency channel. The way the observation time is chosen influences the duty cycle value. This is illustrated in Figure 12. For system 1 with observation time 1, the duty cycle is greater than for system 2. However, it is lower for system 1 with observation time 2.

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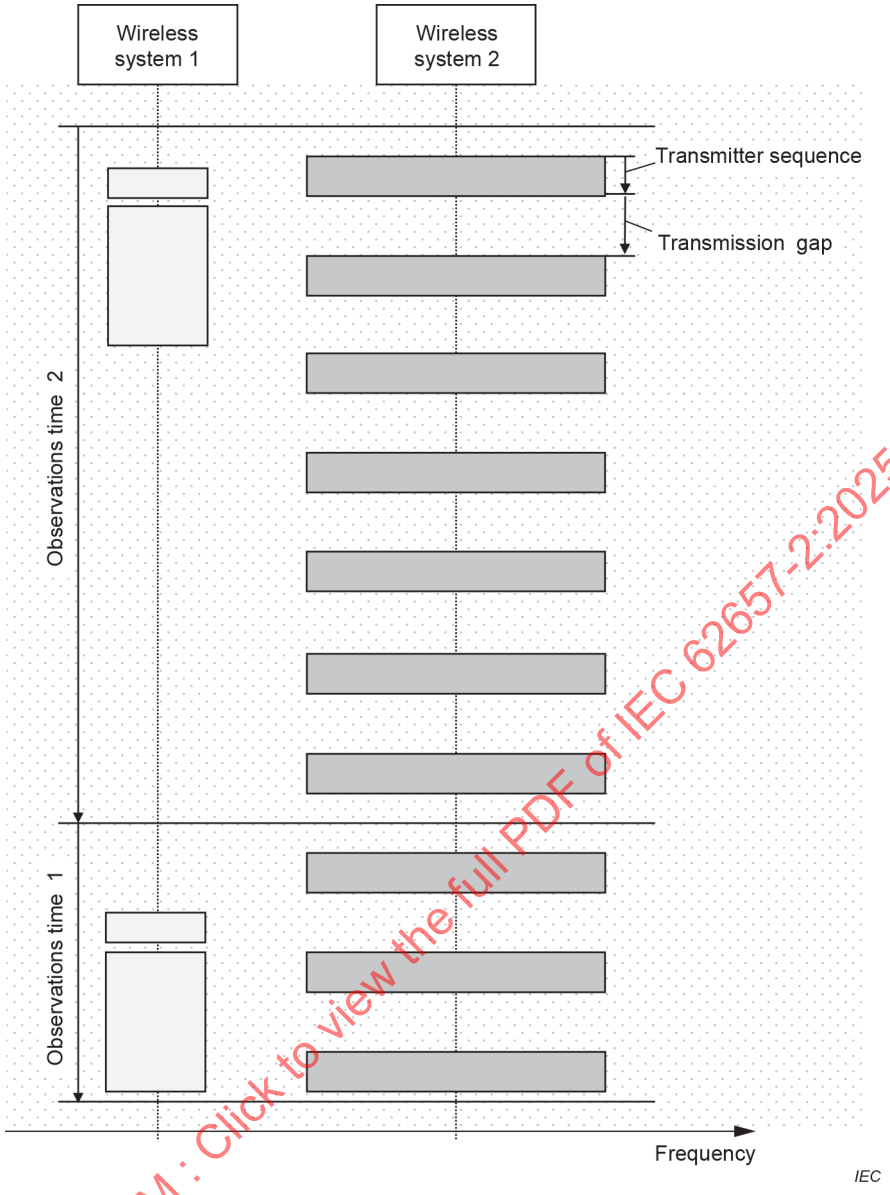

Key

Light grey transmission of wireless system 1

Dark grey transmission of wireless system 2

Figure 12 – Duty cycle

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It is reasonable to specify the observation time with respect to the application profiles. The observation time should be ten times the typical transfer interval of an application profile, as shown in Table 2. The transfer interval is herewith the time difference between two transfers of user data from the automation application. The observation time for duty cycle specifications is sometimes dictated by standards.

Table 2 – Application profile dependent observation time values

Application profile	Machine	Factory hall	Process plant
Transfer interval	100 ms	250 ms	4 s
Observation time	1 s	2,5 s	40 s

The duty cycle is the key parameter to assess the medium utilization in time. A small duty cycle results in small medium utilization and therewith a smaller influence on other frequency users.

The content of this parameter shall be expressed in %.

5.17 Dwell time

The dwell time specifies the agility of a frequency hopping system. The dwell time together with the number of frequency channels can be used to estimate how often the system appears in a certain channel. The number of frequency hopping channels is implicitly given with the parameter frequency hopping sequence, see 5.23.

The dwell time is the period of time a system is assigned to a certain channel. If the system requires an immediate response, this and the idle time shall be considered. It is suitable for frequency hopping systems only. In order to consider a worst-case scenario, the maximum dwell time shall be declared for a wireless device or a wireless system. The maximum dwell time is shown in Figure 13 with max t_{Dw}.

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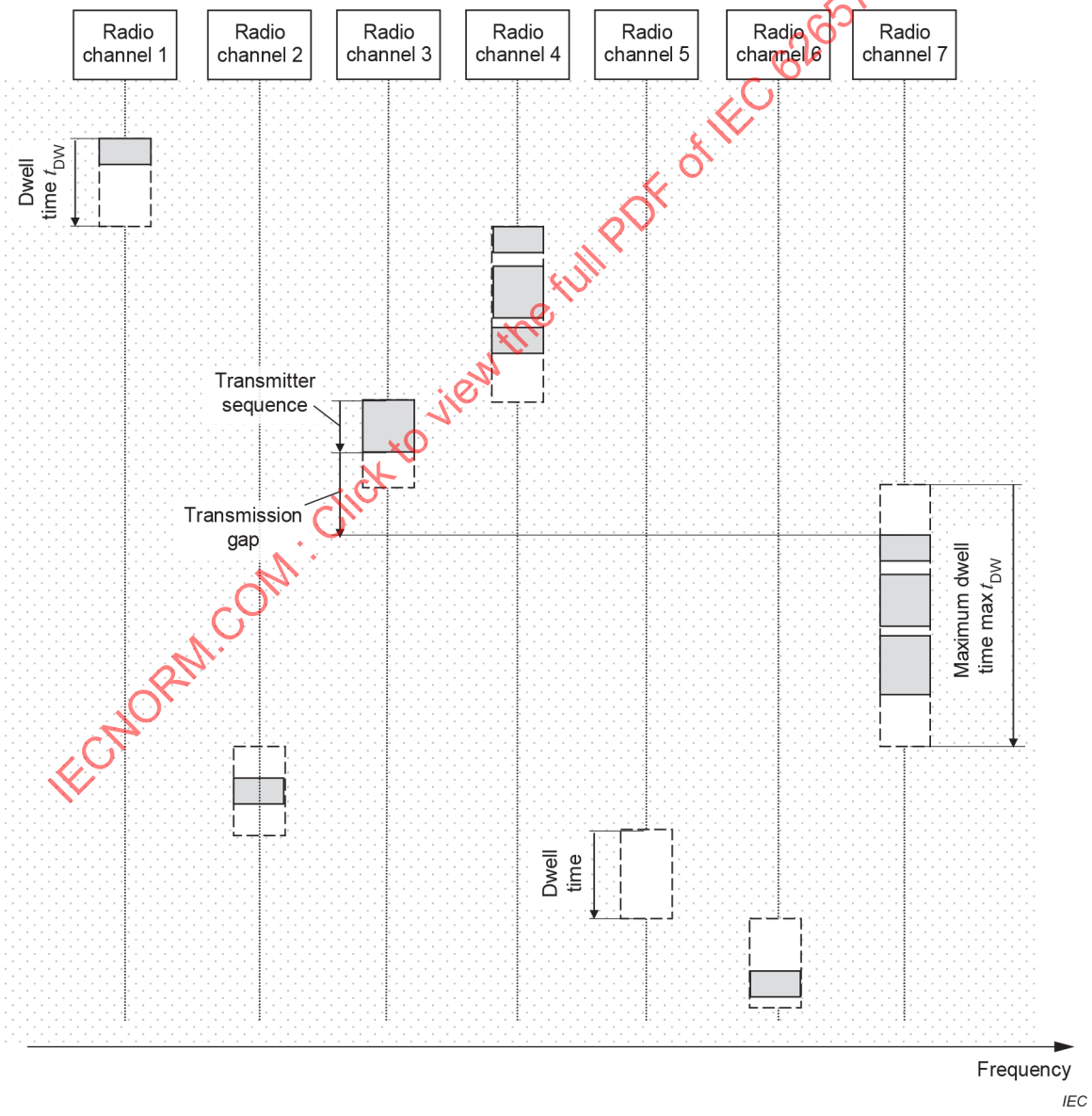

Figure 13 – Maximum dwell time

The unit of this parameter shall be the second (s).

5.18 Equivalent isotropic radiated power

The equivalent isotropic radiated power (EIRP) is the product of the power supplied to the antenna (total radiated power) and the antenna gain G_i in a given direction relative to an isotropic antenna (absolute or isotropic gain), see ITU-R BS.561-2 [21].

As the isotropic gain of a half wave dipole is 2,15 dBi, the EIRP values are 2,15 dB larger than the ERP values.

EIRP is one of the fundamental parameters in order to estimate the power level at a certain position.

EXAMPLE Assuming an antenna with an antenna gain of 3 dBi is used (see also 5.3), then to meet the requirement of ≤ 20 dBm EIRP, the total radiated power at the antenna input cannot exceed 17 dBm.

The unit of this parameter shall be the watt (W).

5.19 Equivalent radiated power

The equivalent radiated power (ERP) is the product of the power supplied to the antenna (total radiated power) and its gain relative to a half-wave dipole in a given direction, see also ITU-R BS.561-2 [21]. If the direction of an antenna is not specified, the direction of maximum gain is assumed. The ERP takes into account the losses of the transmission line and connectors.

The unit of this parameter shall be the watt (W).

5.20 Frequency band

A frequency band is a segment of the frequency spectrum that is assigned to one or more wireless applications by radio regulations. The regulations characterize the wireless application and describe conditions of utilization (e.g. power or medium access. A given frequency band can be divided into frequency channels. Wireless specifications or standards specify the number of channels in the frequency band, its frequency bandwidth, and the channel separation. Depending on the wireless technology and the implementation of a wireless device type, a frequency band and one or more frequency channels can be selected during configuration. Furthermore, there is the possibility to change a frequency band or a frequency channel during operation. So-called frequency hopping systems use more than one frequency channel per definition. The frequency band and the number of frequency channels that are selected, or that are actually used, are part of the essential parameters of coexistence management.

The unit of this parameter shall be the hertz (Hz).

5.21 Frequency bandwidth

The frequency bandwidth is the range of frequencies occupied by a modulated carrier signal. The frequency bandwidth value depends on the spectral power level referred to (see 5.46). The bit rate of a communication channel is proportional to the frequency bandwidth of the signal used for the communication. From the point of view of coexistence management, the frequency bandwidth indicates the utilization of the frequency spectrum by the wireless equipment. Systems can also unintentionally radiate outside the defined frequency bandwidth. This could lead to so-called adjacent channel interference (for the next) or even alternate channel interference (for the next but one).

The unit of this parameter shall be the hertz (Hz).

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5.22 Frequency channel

The (radio) frequency channel is a part of the frequency band and the physical part of a logical link. Thus, it is used to transmit a radio wave between two wireless communication modules. Within a wireless device, this parameter can be used as:

- range of frequency channels: all possible;
- operational frequency channels: configured for current use;
- blocked frequency channels: configured not to be used.

The frequency channel shall be expressed as a number represented as an unsigned integer value without a unit according to a specification or standard. If no channel number is specified, combinations of centre frequency and frequency bandwidth or lower and upper cut-off frequency shall be given in hertz (Hz).

Table 3 shows the selection of units.

Table 3 – Parameter options for frequency channel

Option name	Parameter	Unit
ChannelNumber	ChannelNumber	—
CutoffFrequency	UpperCutOffFrequency	Hz
	LowerCutOffFrequency	Hz
CentreFrequency	CentreFrequency	Hz
	FrequencyBandwidth	Hz

The presentation in IEC CDD could

- have the structure frequency channel <ChannelNumber>, <UpperCutOffFrequency, LowerCutOffFrequency>, <CentreFrequency, FrequencyBandwidth>, where only one of the three options can be used and the remaining two options shall have the value 0, or
- be expressed with relations of parameters, or
- use polymorphism to describe the selection of the different optional description forms in Table 3.

5.23 Frequency hopping sequence

The description of the frequency hopping sequence shall include the sequence of frequency channels used for transmission (hopping sequence) and dwell time. The procedure can be described in accordance with the relevant wireless standard, for example by means of a parameter table or a mathematical rule. The description can include adaptation mechanisms such as a list of frequency channels not to be used, named blocked frequency list.

The parameter can be expressed in different ways depending on the used wireless technology.

a) The frequency channels shall be according to 5.22 and the dwell time shall be according to 5.17. These two parameters could
   - be expressed in a value list of the two parameters: frequency channel and dwell time, or
   - be expressed with relations of parameters, or
   - use polymorphism to describe the selection of the two different optional description forms.

b) Formula, that includes frequency channels and dwell time.

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5.24 Future expansion plan

Future expansion plans should be taken into account. Installation of new wireless solutions and changes to the physical environment (e.g., buildings) can affect conditions for wireless communications. For example, reserving resources could avoid changes in the installed base when adding more wireless devices. The parameter shall be a multiple octet string with text.

The content of this parameter shall be text expressed with a multiple octet string.

5.25 Geographical dimension of the plant

For the purpose of the wireless communication coexistence, the geographical dimension of the plant shall be specified by the length, width and height of the space in which the wireless systems can be installed. The area of operation, for example the factory hall for a machine, should be considered.

Within this space, several wireless systems with different spatial coverage (see 5.55) may operate. The geographical dimension of the plant determines the passive influences on radio propagation, for example by reflections.

The content of this parameter shall be length, width and height; the unit shall be the meter (m).

5.26 Infrastructure device

Infrastructure devices are devices such as routers or base stations without interface to the automation application, for example via wired industrial networks. Infrastructure devices are necessary to build up the wireless system according to the wireless technology or standard. They can improve the robustness of a network, however they can also interfere with other wireless systems. Thus, infrastructure devices are not part of the automation application but of the wireless system.

Router or base stations that have an interface to wired industrial networks or which implement automation application functions are not counted among infrastructure devices. They are part of the wireless automation application and with that counted among wireless automation devices.

The content of this parameter shall be text expressed with a multiple octet string.

5.27 Initiation of data transmission

This parameter specifies how the application initiates the data transfer for a logical link: periodically, aperiodically or stochastically. A periodic transfer might result in a higher communication load than an aperiodic transfer because the same values might be frequently transmitted. The initiation of data transmission influences the communication load and can contribute to a temporal separation of the wireless systems.

The parameter shall be a multiple octet string with text.

5.28 Interference type

This parameter describes spectrum users that emit energy due to emissions, radiation, induction, or combinations thereof, resulting in degradation, misinterpretation, or loss of information at the receiver of a wireless device that would not occur in the absence of such energy. According to Figure 2, these frequency users are electromagnetic interfering (EMI) sources, industrial, scientific, medical (ISM) applications or non-industrial wireless applications. The type of interference and its medium utilization factor shall be known.

The content of this parameter shall be text expressed with a multiple octet string.

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5.29 Intervisibility

This parameter describes the logical link between two implemented logical automation devices. The intervisibility considers Line of Sight (LOS), Non Line of Sight (NLOS) and Obstructed Line of Sight (OLOS) between those devices. The intervisibility influences the radio signal propagation. The specification of this parameter is important to specify the conditions for radio channel measurements and modelling.

The required value considers the logical topology of the automation application. The promised value can require specific measures of the wireless communication system. This can be differences in the positions of communication devices compared to the required positions of the automation devices linked by cables, different antenna positions, specific antenna types, or wireless devices with wireless communication functions (for example access points).

The content of this parameter shall be text expressed with an indexed list: LOS, NLOS, or OLOS.

5.30 ISM application

This parameter describes frequency users emitting radio waves without transmitting data such as welding machines, microwave oven operating in the same area. The type of the other frequency user and its medium utilization factor shall be known.

The content of this parameter shall be text expressed with a multiple octet string.

5.31 Length of user data per transfer interval

The automation application data length is the number of octets that is carried in the payload of a wireless packet. Normally user data are transferred via the reference interface. However, there are cases where an event at the reference interface initiates the transmission of a certain number of user data. The user data length determines the medium utilization. However, there can be a complex or non-linear relation between user data length and medium utilization. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

The unit of this parameter shall be the bit (bit).

5.32 Limitation from neighbours of the plant

Neighbours of the plant might cause limitations for wireless communication. Examples are high power radio source(s) and sensitive equipment.

Documenting the possible interfering elements from neighbours will make the designer aware of potential constraints placed upon the wireless systems by the neighbours.

The content of this parameter shall be text, expressed with a multiple octet string.

5.33 Maximum number of retransmissions

This parameter describes how many times user data are retransmitted automatically by the communication stack because of transmission errors. It is possible that retransmissions are initiated by different protocol layers. Therefore, the maximum number of retransmissions shall be specified for each relevant layer. If possible, details of the mechanism, for example waiting times, should be explained. This parameter can have a significant influence on medium utilization.

Depending on the use case, the maximum number of retransmissions of the device (wireless device type) or the configured maximum number of retransmissions (wireless communication solution) shall be specified.

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The content of this parameter shall be expressed with an unsigned number.

5.34 Mechanism for adaptivity

One or more mechanisms for adaptivity can be used to modify one or more of a system's operational parameters in order to improve a system's robustness against interferences and to minimize medium utilization factor. Adaptive communication mechanisms can use automatically feedback information obtained from a system itself or from the signals carried by a system to modify dynamically a system's operational parameters. It is also possible to plan the operational parameters in advance and configure the systems appropriately.

Mechanisms for adaptivity are as follows:

- detect and avoid (DAA): if the channel is occupied, change the channel (for example AFH);
- detect and suppress (DAS): if the channel is occupied, don't transmit (for example listen before talk);
- detect and reduce (DAR): if the channel is occupied, reduce the output power and/or channel usage.

Depending on how many systems are using mechanisms for adaptivity and which parameter they adapt, these measures can help improving coexistence or can lead to unstable and unreliable system behaviour.

The content of this parameter shall be text expressed with a multiple octet string.

5.35 Medium access control mechanism

The medium access control ensures, for example, that a communication request is served as long as the medium is free (see CSMA for example in IEEE Std.802.3 [22]) or it allocates the request to well defined time slots (see TDMA for example in IEEE Std.802.15.4 [4]). Combinations of these two as well as other access mechanisms are possible. The purpose of these mechanisms is primarily to control the medium access within one wireless system. However, it also influences the immunity and the medium utilization characteristic of a system and shall be considered, therefore, in the coexistence management process.

The content of this parameter shall be text expressed with a multiple octet string.

5.36 Medium utilization factor

The Medium Utilization (MU) factor is a measure to quantify the amount of resources (Power and Time) used by non-adaptive equipment. The MU factor is defined by Formula (1).

$$MU = \left(P_{\text{out}} / 100\ \text{mW}\right) \times DC \tag{1}$$

where

MU is medium utilization factor in %;

P_{out} is the transmitter output power in mW;

DC is the duty cycle expressed in %.

The equipment may have a dynamic behaviour with regard to duty cycle and corresponding power level.

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For devices using frequency hopping spread spectrum that blocks one or more hopping frequencies, these blocked frequencies are considered as active transmitting for the calculation of the MU factor.

The parameter value shall be given in %.

5.37 Message

Based on the OSI layer model, a packet denotes the data unit that is used in the network layer. User data of the application should therefore not be called a packet. In addition to the term user data, the term message is therefore used, for example, for the parameter message loss ratio. Depending on the wireless technology and the length of the application's user data, messages can be transmitted in one packet, multiple messages can be combined into one packet, or messages can be split into multiple packets.

The content of this parameter shall be expressed by an array type with two elements of integer measure type; the first element is the number of octets of the message and the second element is the number of packets in that the message is divided. The number of packets shall be set to 0 if the message transport doesn't use packets. The number of packets shall be set to −1, if the packet length is variable.

5.38 Modulation

A signal gets its information content by changing amplitude, frequency or phase of a wave. This is done by modulating the wave. Both analog and digital modulations are used. Digital modulations can be combined with spreading schemes in order to improve the robustness of the physical signal.

The content of this parameter shall be text expressed with a multiple octet string.

5.39 Natural environmental condition

Natural environmental conditions such as temperature, humidity or air pressure can influence the propagation conditions.

The content of this parameter shall be text expressed with a multiple octet string.

5.40 Network topology

The topology describes the structure and composition of a wireless communication network in a wireless communication application.

NOTE See IEC 62657-1 for use cases of different topologies. Definitions of these topologies are given in IEC 61918 [15].

Applicable topologies are:

- point-to-point;
- linear;
- ring;
- star;
- tree;
- mesh;
- cellular.

Combinations of these topologies are possible. This information can be used to assess the intended coverage of a wireless solution.

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The content of this parameter shall be an indexed list with the topologies: point-to-point, linear, ring, star, tree, mesh, cellular, other.

5.41 Number of consecutive lost messages

This parameter specifies how many messages of a logical link delivered for transmission were not received correctly between the correct reception of two messages. This means that between two messages received successfully, one or a sequence of messages had their reception completely or partially failed.

The content of this parameter shall be expressed with an unsigned number.

5.42 Object movement

Mobile objects such as forklifts or loads on moving cranes can significantly influence the radio propagation conditions. Mobile objects cause temporal and frequency-selective fluctuations in radio signal power. This has consequences for the reception of the wanted signal and/or interference.

The movement shall be specified as a trajectory for a worst-case scenario with respect to the signal propagation. The specification of a trajectory is a list of pairs of target position and speed to the target position.

The unit for position is m for each dimension, the unit for speed is m/s.

5.43 Operating time between failures

The operating time between failures of a logical link is the sum of the operating time periods between two successive failures. The logical link is considered as a repairable item in the sense that a message can be repeated within the survival time. A measure to assess a logical link is the mean operating time between failures.

The unit shall be the second (s).

5.44 Message loss ratio

The message loss ratio (MLR) reveals how many of the messages, transferred from the application to the reference interface within the producer, are transmitted from the reference interface to the application within the consumer.

The MLR is determined as follows:

$$\mathrm{MLR} = \frac{N_\mathrm{t} - N_\mathrm{r}}{N_\mathrm{t}}$$

where

N_t is the number of transmitted messages;

N_r is the number of regularly received messages.

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Assuming that an application expects a message by a time t_{DL} at the latest, all messages with a transmission time greater than t_{DL} shall be counted as lost and assigned to the number of not received messages ($N_t - N_r$). For the evaluation of coexistence, it shall be proved how many consecutive message losses are tolerated before a wireless communication application fails. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application. The accumulated downtime of wireless communication application per observation interval defines the communication availability which is the focal quality criterion of wireless communication.

The parameter value shall be given in %.

5.45 Position of wireless devices

The position of wireless devices (or their antennas) influences the frequency channel characteristic. Nearby obstacles, moving equipment or narrow corridors can worsen propagation conditions. This is valid for the absolute position of one wireless device or the position relative to other wireless devices. That means, the position of wireless devices shall be chosen in order to achieve optimal propagation conditions for wireless transmission. Therefore, it could be advantages to separate the implementation of automation functions from the implementation of the wireless communication functions and connect the devices via wired communication. Another option is to separate the antenna only, e.g. when the automation device is mounted in an electrical cabinet. For moving or mobile wireless devices, the trajectory of the movement is important.

The position of a wireless device is specified in a three-dimensional space.

The unit of each dimension of this parameter shall be the meter (m).

5.46 Power spectral density

The power spectral density (PSD) describes how the power of a signal is distributed with frequency. Colloquially, the area below the PSD curve is often called the spectrum of the signal. The measurement unit of the power spectral density is in watts per hertz. The PSD shall be provided for example as shown in Figure 14 for an IEEE Std.802.15.4 [4] system.

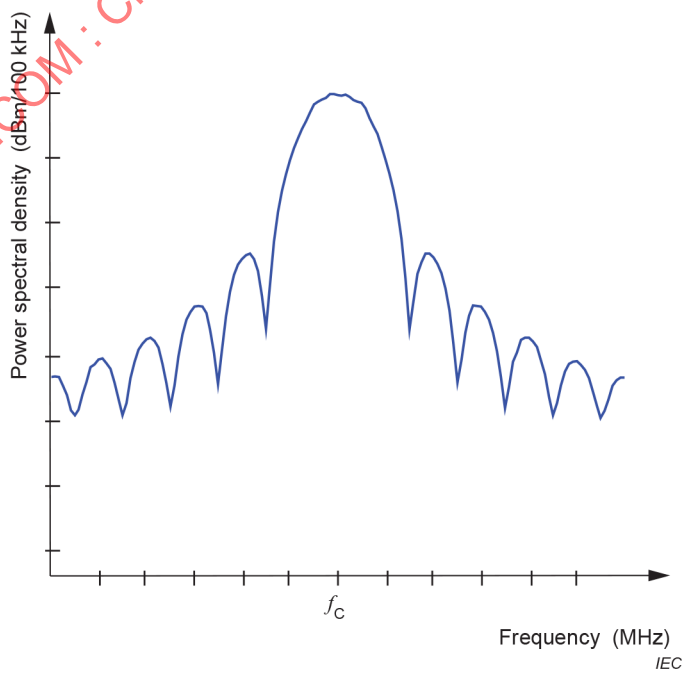

Figure 14 – Power spectral density of an IEEE Std.802.15.4 system

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The PSD as shown in Figure 14 provides a comprehensive picture of the signal power in the frequency spectrum for the coexistence management.

The unit of this parameter shall be the decibel-milliwatt per hertz (dBm/Hz) over the intended frequency range.

5.47 Purpose of the automation application

The description of the automation application supported by the wireless system shall be summarized to the extent needed to provide a useful overview of the requirements imposed on the wireless system.

The content of this parameter shall be text expressed with a multiple octet string.

5.48 Receiver blocking

The receiver blocking is an indicator of the correct receiver operation in the presence of out-of-channel signals.

Receiver blocking response (or performance level) is defined as the maximum interfering signal level expressed in dBm reducing the specified receiver sensitivity by a certain number of dB (usually 3 dB). Consequently, the receiver blocking response is normally evaluated at a wanted signal level, which is 3 dB above the receiver sensitivity and at frequencies differing from that of the wanted signal (see additional information in the ZVEI document [23]).

Receiver blocking considers effects like spurious response, intermodulation sensitivity and adjacent channel selectivity.

The unit of this parameter shall be the decibel-milliwatt (dBm).

5.49 Receiver maximum input level

Received signals with levels above the receiver maximum input level can disturb or disrupt the data reception. The receiver maximum input level shall be used to estimate or assess the minimum recommended distance to other wireless devices. For this purpose, the transmit power values of wireless devices and of interferers, as well as the propagation conditions shall be taken into account.

The unit of this parameter shall be the decibel-milliwatt (dBm).

5.50 Receiver sensitivity

Receiver sensitivity determines how well a receiver can accept wanted signals in the absence of interference (see also ETSI TR 100 027 [20]). It defines the minimum received signal power that the receiver requires to achieve a given bit error ratio according to the given implementation. Together with transmit power values of the system and of interferers, and considering the propagation conditions, the power margin of the system can be estimated and assessed.

The unit of this parameter shall be the decibel-milliwatt (dBm).

5.51 Regional radio regulations

Regional radio regulations specify important coexistence parameters such as frequency band and output power. These specifications are taken into account within the coexistence management process.

NOTE This list of coexistence parameters can be shortened by listing the regional radio regulation standards with which the system/device is compliant, for example ETSI EN 300 328 [24].

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The content of this parameter shall be text expressed with a multiple octet string.

5.52 Relative movement

The trajectory of a wireless device`s movement changes the distance to other wireless devices and interferers. This can increase or decrease the wanted signal value or the interference. The movement itself and the relative speed between the communicating wireless devices can worsen the propagation conditions and thus increase the interference.

The movement of a wireless device shall be specified as a trajectory. The specification of a trajectory is a list of pairs of target position and speed to the target position.

The unit for position is m for each dimension, the unit for speed is m/s.

5.53 Response time

The response time is primarily important in confirmed services, for example in application-oriented transmission of process data or parameter data, and also real-time communications, also IEC 62657-1:2017, 5.3.1.

The response time is the time interval between the instant delivery of the first user data bit, or byte, of a message to the reference interface of a transmitter, and the instant when the last bit, or byte, of the confirmation message is delivered at the reference interface of the same transmitter, which can be assigned to the request.

This means that the response time is composed of at least one transmission time between transmitter and receiver and one transmission time between receiver and transmitter. The processing time within the receiver shall be added.

The communication between transmitter and receiver can be affected directly via infrastructure device (for example base station) or via further network nodes (for example sensor networks).

Interferences influence response time values. Coexistence exists as long as a limit value given by the automation application is met. Otherwise, the corresponding transmission shall be assessed as a message loss.

The response time is a random variable. This is important because response times depend more highly on external transmission conditions compared to wire-bound communication. Since the response time is essentially determined by the time values of two transmissions, the distribution of the random values corresponds to Figure 17.

The unit of this parameter shall be the second (s).

5.54 Security level

Requirements for cyber security could affect coexistence management. Some sensitive wireless solutions might need to be physically separated from some other kind of wireless systems, or might need to have clearance from the boundary of the site. The definition and the usage of security levels shall be according to the IEC 62443 series.

A system can require technical and organizational measures in order to ensure a certain security level. Technical measures can increase the processing time, introduce additional transmissions, and increase the packet length. Thus, the transmission time and the medium utilization time could be increased. The communication system could become more prone to interferences if the coexistence management does not take into account these measures.

The content of this parameter shall be expressed with an unsigned number.

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5.55 Spatial coverage of the wireless communication system

The spatial coverage of the wireless communication system depends on the application communication requirements. However, it is also decisive for the feasibility of spatial separation of wireless applications. In positioning the several wireless devices, the antenna mounting height shall be regarded. The spatial coverage is specified by length, width and height of a cuboid that encloses the wireless communication system.

The content of this parameter shall be the length, width and height; the unit shall be the meter (m).

5.56 Spatial extent of the application

The spatial extent of an application is determined by the automation devices that belong to a distributed automation system. Automation devices define with its positions a cuboid that is to be covered by a wireless communication solution. For mobile automation devices, the maximum movement radius is to be considered.

The content of this parameter shall be the length, width and height; the unit shall be the meter (m).

5.57 Spurious response

Spurious response is a receiver parameter that indicates the robustness against unwanted signals, which means having frequencies other than the tuned frequency channel. It is a response in the receiver intermediate frequency (IF) stage produced by an undesired emission in which the fundamental frequency (or harmonics above the fundamental frequency) of the undesired emission mixes with the fundamental or harmonic of the receiver local oscillator.

The unit of this parameter shall be the decibel (dB).

5.58 Survival time

The survival time provides a time that an application that consumes communication services can continue without receiving an anticipated message.

The unit of this parameter shall be the second (s).

5.59 Total radiated power

The total radiated power (TRP) is the power supplied to an antenna reduced by antenna losses. TRP is often specified in more recent standards. It can be measured with a three-dimensional turn table which allows integrating the spatial power density over 360°.

The unit of this parameter shall be the watt (W).

5.60 Transfer interval

The transfer interval has an effect on the communication load and can contribute to temporal separation. For aperiodic transfer, the minimum value is of interest as the worst case. For stochastic transfers, the parameters of the distribution function are relevant. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

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In Figure 15, the relations between machine cycle or plant cycle, transfer interval and communication cycle are depicted. Usually, the industrial automation applications follow cycles of the production process. During such a machine cycle or plant cycle, a number of events occur which shall be transmitted via a wireless communication medium. In the case of a periodic transmission, the communication cycle shall be faster than the transfer interval. If an aperiodic data transmission is involved, the transfer interval is the least possible time between two transfer requests.

The unit of this parameter shall be the second (s).

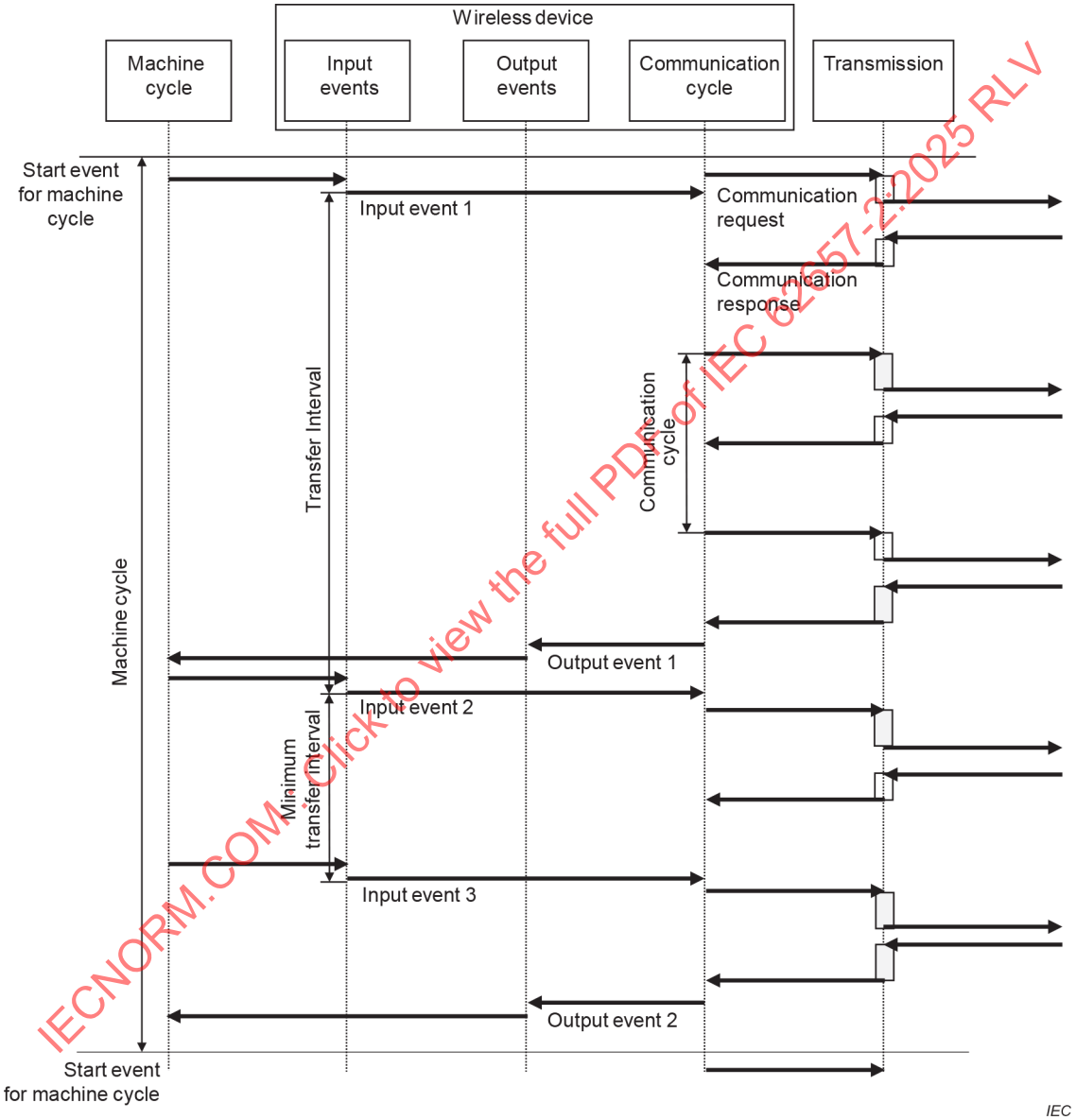

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Figure 15 – Communication cycle, application event interval and machine cycle

5.61 Transmission gap

The transmission gap is the time between two successive channel usages by a transmitter. If a request requires an immediate response, the idle time is not considered. In Figure 16, the transmission gap is depicted with t_{TG}.

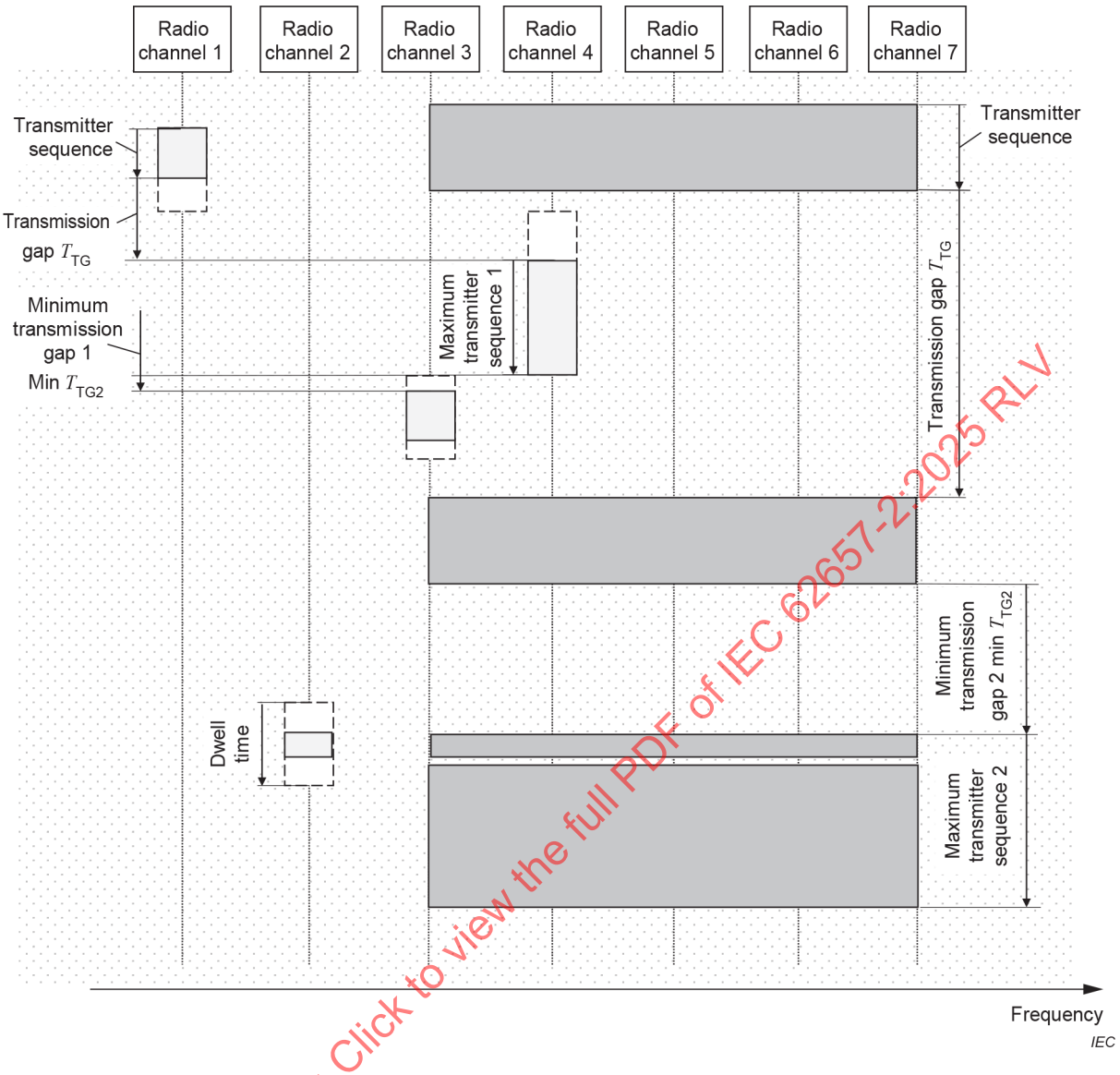

Figure 16 – Transmission gap

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For frequency hopping systems, the transmission gap is related to one of the used channels and not between transmissions of different channels. The minimum transmission gap gives an impression of the minimum available time for other wireless devices to transmit. Real applications can leave larger gaps. Therefore, additionally the duty cycle should be considered.

The unit of this parameter shall be the second (s).

5.62 Transmission time

The transmission time is an adequate instrument to evaluate the coexistence in terms of automation application with event-driven transfer. An example is the transmission of a state change in a proximity sensor and real-time applications, see IEC 62657-1:2017, 5.3.1.2.3.1.

The transmission time is the interval from starting the delivery of the first user data byte of a message to the reference interface of a producer until the delivery of the last user data byte of the same message from the reference interface of a consumer.

The interferences described in 4.4 entail longer transmission time. Coexistence exists as long as the transmitted messages keep a limit value given by the automation application. Otherwise, the corresponding transmission shall be assessed as a message loss (see also 5.44).

The transmission time is a random variable. This is important because transmission times depend more highly on external transmission conditions compared to wire-bound communication.

Figure 17 exemplifies density functions of the transmission times of wireless solutions resulting from measurements with large samples. The density functions represent the number of messages needing a certain transmission time.

Usually, the number of messages with a greater transmission time, for example t_{TT2}, increases from N_2 to N'_2 if other wireless solutions interfere. On the other hand, the number of messages with a smaller transmission time, for example t_{TT1}, decreases from N_1 to N'_1 if other wireless solutions interfere. The causes might be, for example, waiting times for a free medium or retransmissions due to message losses.

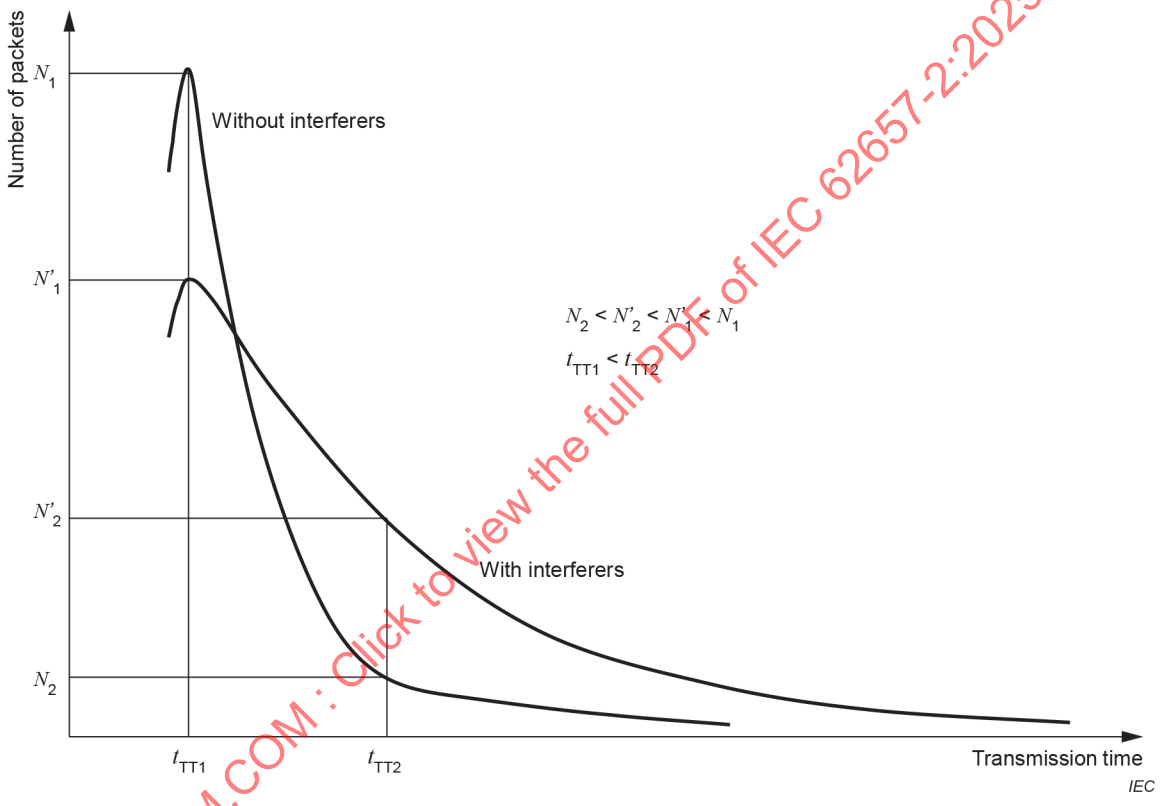

Figure 17 – Example of the density functions of transmission time

Figure 18 shows an example of the distribution functions of the transmission time. The two curves show the number of received messages that arrive within a certain transfer time.

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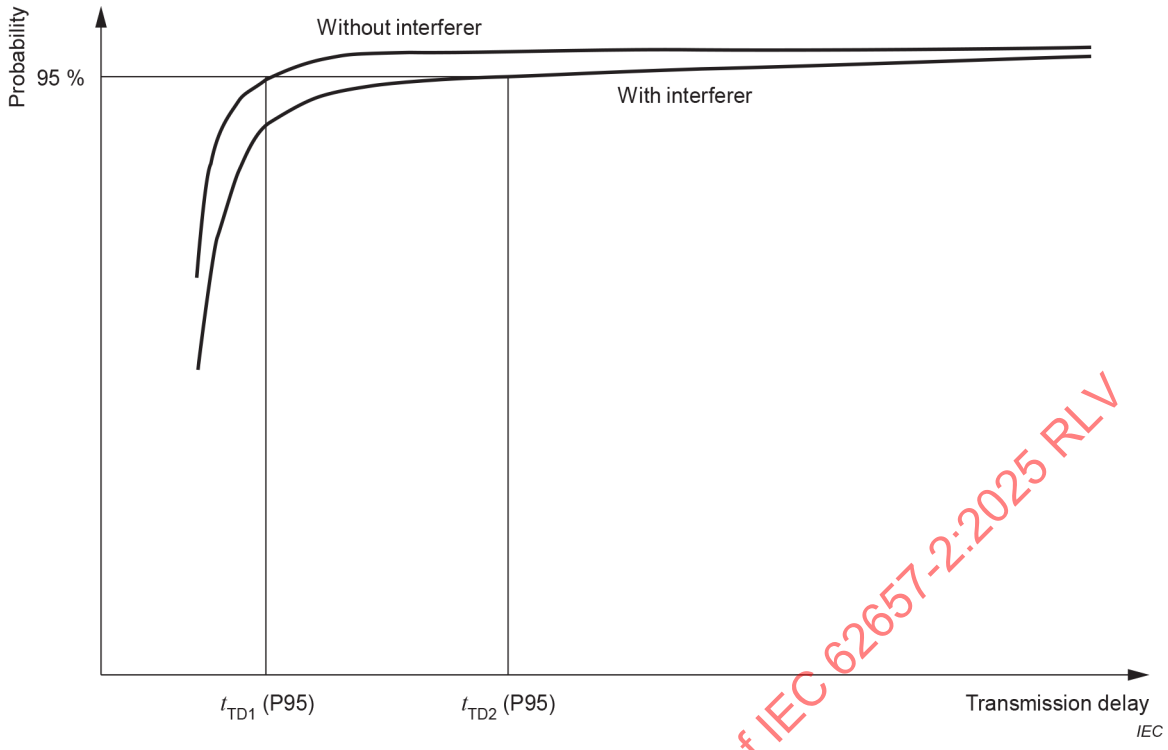

Figure 18 – Example of the distribution functions of transmission time

In a metrological ascertainment of transmission time values, the statistical parameter can be ascertained from the sample. Changes in statistical parameters, depending on the presence of other wireless applications, are a measure of the strength of influence on the wireless solution. For this relative evaluation, distribution parameters are adequate instruments, for example the percentile. The percentile P95 is a common value (see Figure 18). In 95 % of all transmissions, this value is not exceeded. Experience shows that the P95-value is a sensible compromise between the required sample size and significant information. Other statistical distribution parameters can, however, also be consulted. These distribution parameters (for example percentile P95) are not identical to the availability of the plant.

A maximum value of transmission time would be necessary in order to get an absolute result on coexistence by comparing this time value with a limit required by the application. However, the maximum value of a certain measurement is not equivalent to the absolute maximum transmission time. The measured maximum value has a certain probability that can be calculated if the functional equations of the curves in Figure 17 and Figure 18 are known. The reliability of the calculation depends on the sample size of the measurement on which the functional equations are based.

Besides this, the maximum value for the transmission time can in principle be estimated analytically by taking the maximum value for all time segments. This maximum value is not suitable to evaluate coexistence because, in this case, for the time segments influenced by other wireless applications, the maximum value shall be taken as well. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

Medium access delay should also be considered in the transmission time.

The unit of this parameter shall be the second (s).

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5.63 Transmitter output power

The parameter transmitter output power is an indicator for transmission range. It can be constant or configurable. The transmitter output power reduced by losses between the transmitter output and the antenna is the total radiated power.

The unit of this parameter shall be the watt (W).

5.64 Transmitter sequence

The transmitter sequence t_{TS} is the time that a transmitter uses a frequency channel without the possibility to be interrupted by a wireless device of the same wireless system. If a request requires an immediate response, and during the idle time the medium cannot be used by a device of the same wireless system, the entire time shall be considered (see $\max T_{TS2}$ in Figure 19). This is a reasonable simplification, even though devices of other systems could start a transmission. For coexistence management, the maximum value of the transmitter sequence of a wireless communication system is of interest. In the example shown in Figure 19, the relevant transmitter sequence of system 1 is $\max T_{TS1}$ and the relevant transmitter sequence of system 2 is $\max T_{TS2}$.

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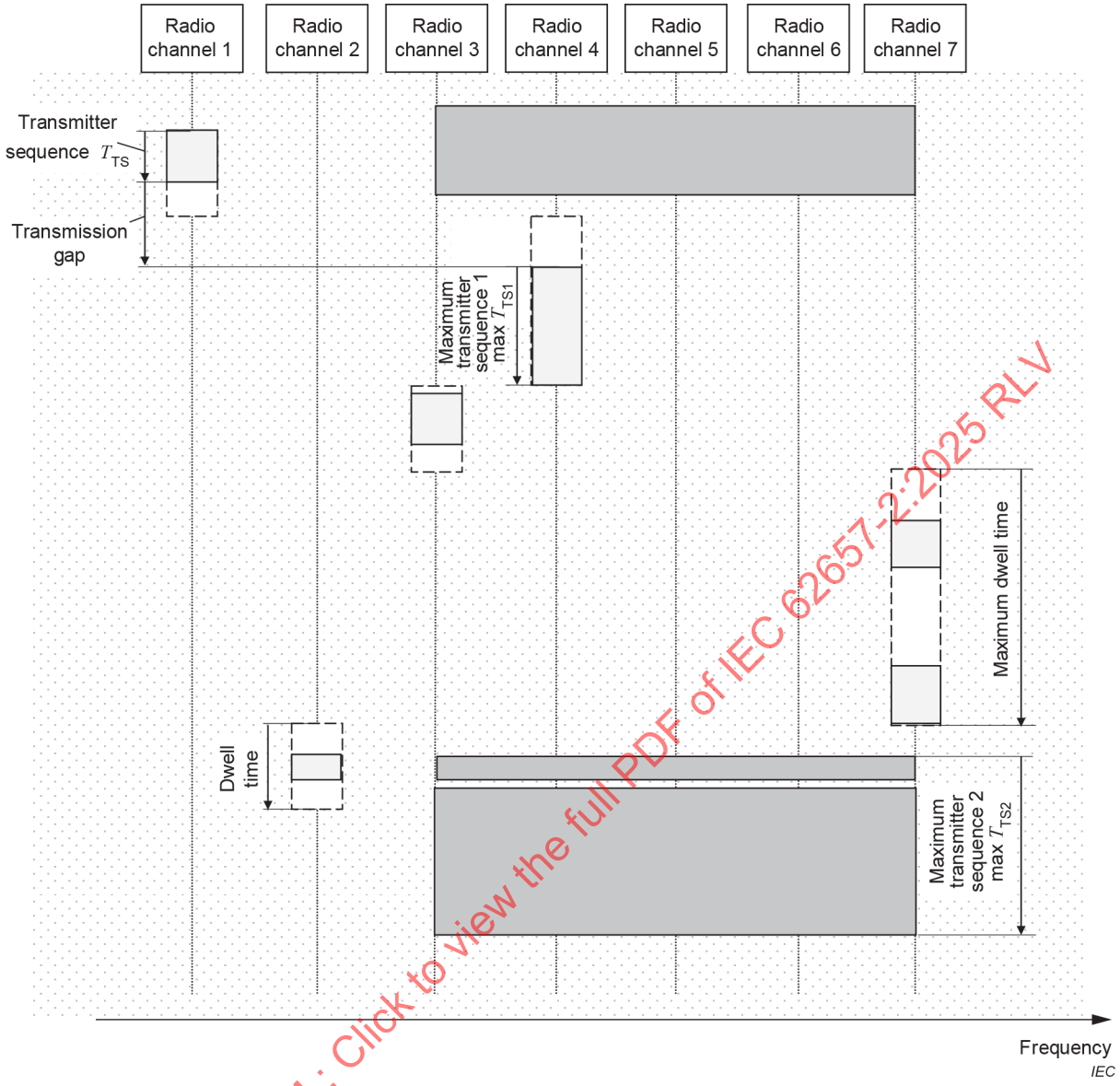

Key

Light grey transmission of wireless system 1

Dark grey transmission of wireless system 2

Figure 19 – Transmitter sequence

For frequency hopping systems, this time shall be considered for each used frequency channel. Depending on the use case, the maximum transmitter sequence of the device (wireless device type) or the maximum transmitter sequence of wireless communication solution (wireless communication solution) shall be specified. The maximum transmitter sequence gives an impression of the maximum occupied time. Real applications can use a small portion only. Therefore, additionally the duty cycle should be considered.

The unit of this parameter shall be the second (s).

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5.65 Transmitter spectral mask

The power spectral density envelope can be characterized by a number of specific points creating the transmitter spectral mask as shown in Figure 20 for an IEEE Std.802.15.4 [4] system. This is a reasonable simplification for the coexistence management. Specific transmitter spectral masks are defined by a standard document. This document considers not only the power in the intended channel but also in the adjacent and alternate channels. The power spectral density shall be less than the limits specified through the transmitter spectral mask. The spectral profile of the transmitter radiated power can be used to emphasize the quality of equipment with respect to coexistence if the transmitter spectral mask is markedly smaller than required by the related standard.

There is no unit for this parameter. The parameter shall represent a figure.

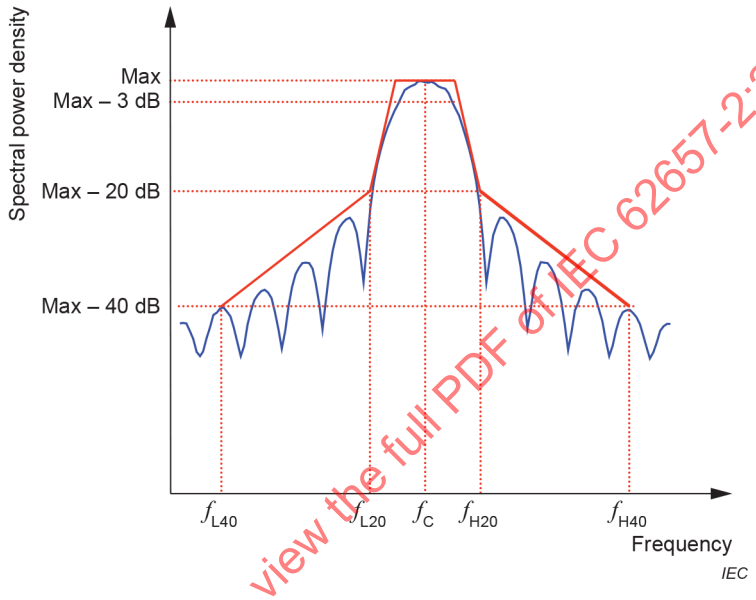

Figure 20 – Transmitter spectral mask of an IEEE Std.802.15.4 system

5.66 Update time

The update time can be used for evaluation in case of automation application with cyclic transfer and real-time applications, see IEC 62657-1:2017, 5.3.1.2.3.2. The cyclic transfer of a position detection system might serve as an example.

The update time is the interval from the delivery of the last user data byte of the message of a producer, from the reference interface of a consumer to the automation application, until the delivery of the last user data byte of the following message of the same producer.

The interferences described in 4.4 result in distributions of the transmission time. Coexistence exists as long as the transmitted messages keep a limit value for the distribution of the update time given by the automation application.

The update time is a random variable. Figure 21 shows an example of distribution functions of the update time. For a relative assessment, which means whether a wireless application interferes more or less, the standard deviation can be consulted as a distribution parameter.

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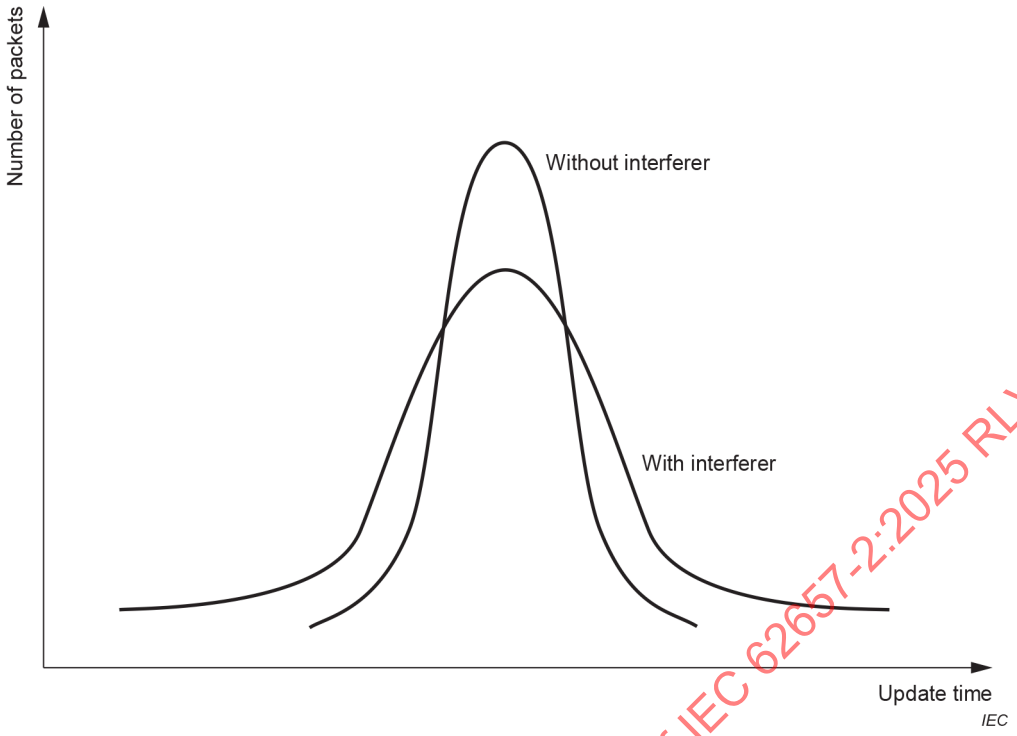

Figure 21 – Example of distribution functions of the update time

A maximum span of the update time, also called jitter, would be necessary in order to get an absolute result on coexistence by comparing this time value with a limit required by the application. However, the maximum span of a certain measurement is not equivalent to the absolute maximum span of update time. The maximum span has a certain probability that can be calculated if the functional equations of the curves in Figure 21 are known. The reliability of the calculation depends on the sample size of the measurement on which the functional equations are based. Depending on the granularity of coexistence management, the parameter can refer to a logical link or, more generally, to an application.

The unit of this parameter shall be the second (s).

5.67 Wireless device density

The number of wireless devices has an impact on communication load and medium utilization. The fewer wireless devices which are communicating within the wireless system, the lower is the probability of interferences.

Wireless device density is the number of wireless devices within the spatial coverage, see 5.55, of the wireless communication system. The wireless device density has an impact on medium utilization.

This parameter shall be expressed as a number represented as an unsigned integer value and the unit shall be the number of devices per m^2.

5.68 Wireless device type information

For each device, the typical device type information, such as model type, manufacturer, hardware version, shall be provided.

The content of this parameter shall be text expressed with a multiple octet string.

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5.69 Wireless communication solution density

This parameter describes wireless communication solutions operating in the same area. All wireless solutions shall be considered, independently of technology or used frequency band. The medium utilization factor of these wireless solutions shall be described.

Wireless communication solution density is the number of wireless communication solutions within the geographical dimension of the plant (see 5.25).

This parameter shall be expressed as a number represented as an unsigned integer value and the unit shall be the number of devices per m^3.

5.70 Wireless technology or standard

Most wireless equipment will use a standardized basic technology which sometimes already predefines some of the parameters listed in Clause 5. Therefore, the values or the domain for a number of parameters are implicitly defined by naming the wireless technology or standard.

The frequency band shall be provided explicitly since this allows a first general categorization of a wireless solution. Furthermore, the modulation scheme shall be specified. The kind of modulation, or the coding of the symbols before physical transmission, might help to avoid interferences of the wireless solutions. Moreover, the communication requests are transferred differently onto the communication medium, meaning that one and the same communication load can lead to different channel occupation ratios.

Implementations that use a basic technology might, for certain parameters, be much better than the basic standard. A wireless implementation may also only use a subset of a reference wireless standard and therefore not all parameters could be relevant. Moreover, there are wireless technologies that do not follow a certain standard.

Examples of standards specifying a wireless communication system are IEC 62591 [1], IEC 62601 [2] and IEC 62734 [3].

The content of this parameter shall be text expressed with a multiple octet string.

6 Coexistence management information structures

6.1 General

Clause 6 specifies the structuring of coexistence management parameters according to usage dimensions. The principle is depicted in Figure 22. The parameters explained in Clause 5 are selected and structured in Clause 6. Table 4 shows the hierarchy of the characteristics.

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Table 4 – Hierarchy of the characteristic parameters

Hierarchy	Explanation or references
Industrial communication network	Part of the automation application; super class of the class wireless industrial automation and wired industrial automation
Wireless industrial automation	Contains one or more physical system interface
Distributed automation system	Elements, relations, and interfaces that exchange data through physical links where the dependable communication availability of the data at the logical target endpoints of the reference interface determines the correct operation of the application
General plant characteristic	See 6.2 and Table 22
Application communication requirements	See 6.3 and Table 23
Requirements influencing the characteristic of wireless solutions	See 6.3.2 and Table 23
Performance requirements	See 6.3.3 and Table 23
Radio environment	Has one or more physical layer interfaces and the relevant elements are passive environmental influences and active environmental influences
Passive environmental influences	See 6.2.3
Active environmental influences	See 6.2.4
Interference type	See 5.28 and Table 30
Wireless communication system	See 6.4 and 6.5
Wireless system type and wireless device type	See 6.4
Wireless system type	See 6.4.2 and Table 24
Wireless device type	See 6.4.3 and Table 25
Wireless device transmitter parameters	See 6.4.3.2 and Table 25
Wireless device receiver parameters	See 6.4.3.3 and Table 25
Wireless solution	See 6.5
Wireless system solution	See 6.5.2 and Table 26
Wireless device solution	See 6.5.3 and Table 27
Wireless device solution general parameters	See 6.5.2 and Table 27
Wireless device solution transmitter parameters	See 6.5.3 and Table 27
Wireless device solution receiver parameters	See 6.5.3 and Table 27
Wired industrial automation	Out of the scope of this document but shown as a possibility

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The structures provided in Clause 6 are used in the templates given in Clause 8. Parameters to describe the relevant information shall be provided and the parameter can be a value range or a list of values.

The templates given in Clause 8 shall be used to describe a specific object of the items relevant for the coexistence management by assigning values or value ranges to the parameters. Thus, the information can be deployed within the wireless coexistence management process.

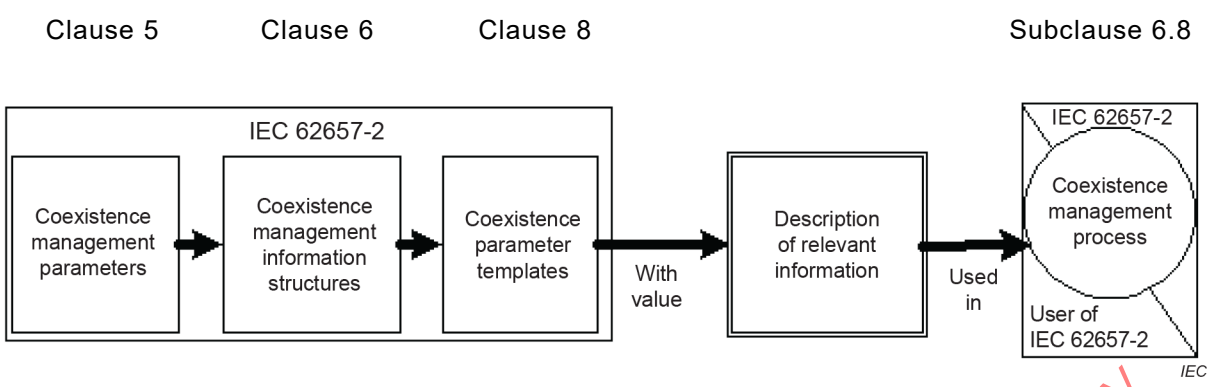

Figure 22 – Principle for use of coexistence parameters

Four sets of parameters are specified for the wireless coexistence management process. They are used to describe

- the general characteristics of plants common to all wireless communication systems (see 6.2),
- the application communication requirements of each automation application (see 6.3),
- the characteristics of each wireless system and device-type (see 6.4),
- the characteristics of each wireless solution (see 6.5).

6.2 General plant characteristic

6.2.1 General

Subclause 6.2 specifies the set of parameters that characterizes the plant in general with respect to all wireless communication applications. For the description of a plant characteristic, the templates given in Clause 8 shall be used. The definitions and specifications of the coexistence management parameters are according to the descriptions in Clause 5. The description of the plant characteristic shall be used in the coexistence management process, which is defined in 6.8. Figure 23 shows the relation between the definition and specification in this document and the use of them in a coexistence management system specification.

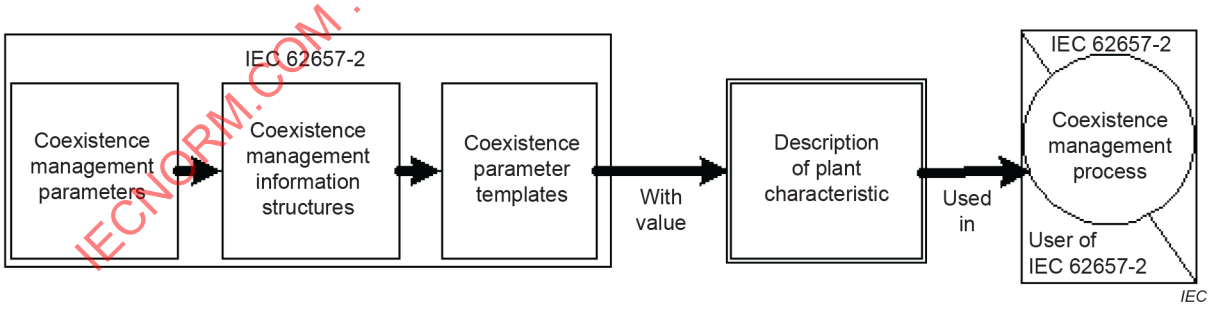

Figure 23 – Parameters to describe the general plant characteristic

6.2.2 General plant characteristic

The parameters in Table 5 shall be used to describe the propagation conditions and the interference potential within a plant to describe the general plant characteristic.

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Table 5 – List of parameters used to describe the general plant characteristic

Parameter name	Reference	Content
Regional radio regulations	5.51	List of relevant regional radio regulations
Future expansion plan	5.24	Informal specification of the potential possible future expansions of the plant

6.2.3 Passive environmental influences

The parameters in Table 6 shall be used to describe the propagation conditions and the interference potential within a plant for the passive environmental influences.

Table 6 – List of parameters used to describe the passive environmental influences

Parameter name	Reference	Content
Area of operation	5.11	Informal specification of the area of operation with respect to its influences on the passive environmental effects
Object movement	5.42	Specifies the mobility of assets (e.g. obstacles)
Geographical dimension of the plant	5.25	Specification of the geographical dimension of the plant using length, width and height
Natural environmental condition	5.39	Informal specification of expected natural environmental conditions with respect to its influences on the passive environmental effects
Intervisibility	5.29	Informal specification of the radio propagation conditions with respect to its influences onto the passive environmental effects or formal specification of the transition factor
Frequency band	5.20	The frequency band used by the planned wireless system has a significant influence on radio propagation

6.2.4 Active environmental influences

Examples of devices that can cause active environmental influence are welding machines, electrical drives or frequency converters.

Other sources of active environmental influences are wireless communication devices that use the same frequency range or the same or nearby frequency channels.

The parameters in Table 7 shall be used to describe the propagation conditions and the interference potential within a plant for the active environmental influences.

Table 7 – List of parameters used to describe the active environmental influences

Parameter name	Reference	Content
Wireless communication solution density	5.69	List of wireless solutions (including all relevant parameters according to 6.5.2) in the plant (active environmental influences)
Interference type	5.28	List of frequency users including detailed description with respect to its influences on the active environmental effects
Limitation from neighbours of the plant	5.32	Informal specification of limitations from neighbours of the plant with respect to their influences on the active environmental effects
Frequency band	5.20	To take interference into account, the frequency band used by the planned wireless system shall be known

Most of the parameter values can be provided by the plant owner. However, for some parameters, expertise of wireless experts is required. If such expertise is not available within the organization of the plant, it is strongly recommended to consult external expertise.

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Textual descriptions can be used for these parameters if it is not feasible to provide quantitative values. In these cases, the textual description should be as specific as possible. Graphics and pictures can support such descriptions.

Additional information could be needed.

For example, a wireless system can be tagged by an identifier referring to such additional information.

Table 8 provides the list of parameters used to describe an interference type.

Table 8 – List of parameters used to describe the interference type

Parameter name	Reference	Content
Interference type	5.28	List of frequency users including detailed description with respect to its influences on the active environmental effects
Frequency band	5.20	To take interference into account, the frequency band used by the planned wireless system shall be known
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22).
Total radiated power	5.59	Possible total radiated power values
Power spectral density	5.46	Description of power spectral density
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Duty cycle	5.16	Declaration of maximum duty cycle value
Dwell time	5.17	Declaration of maximum dwell time value
Medium utilization factor	5.36	Declaration of the MU factor

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6.3 Application communication requirements

6.3.1 Overview

Application communication requirements are mostly quantitative requirements specifying the required conditions and the required characteristics of wireless solutions at the reference interface. These requirements shall be met in order to achieve the purpose of the automation application.

By definition, coexistence is the state in which all applications using wireless communication fulfil their requirements. These requirements are usually related to business goals and take into account, in addition, a number of conditions such as safety of persons, efficient use of resources or hazard conditions.

In order to fulfil these goals, the wireless solution shall meet the application communication requirements in terms of communication availability and real time capability, considering the industrial conditions and the characteristics of wireless systems that influence those requirements.

Figure 24 shows the relationship between the definition and specification of parameters in this document and its use to describe the application communication requirements in a coexistence management system specification.

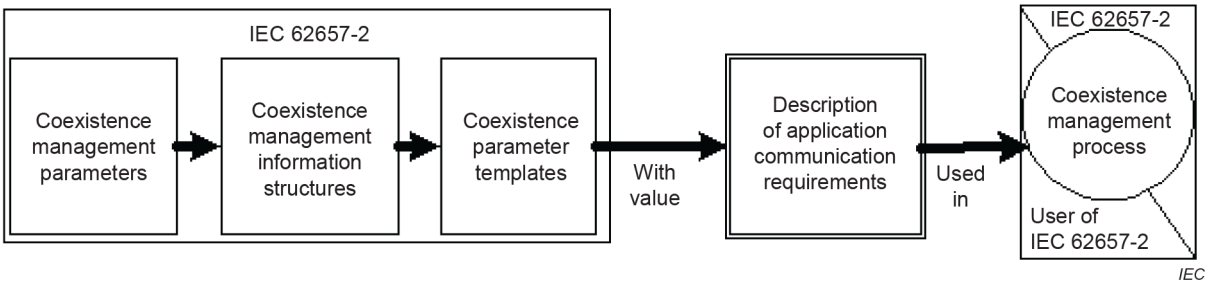

Figure 24 – Parameters to describe application communication requirements

Application communication requirements can be divided into requirements that influence the behaviour of a wireless device or system and performance requirements that shall be met by the wireless solution in order to ensure the purpose of the automation application.

6.3.2 Requirements influencing the characteristic of wireless solutions

The set of parameters in Table 9 are application communication requirements that influence the performance of wireless solutions and thus the coexistence state. The values of these parameters shall be collected.

Table 9 – List of parameters used to describe the requirements influencing the characteristic of wireless solutions

Parameter name	Reference	Content
Communication load	5.12	Specification of the required communication load at a reference interface using user data length and transfer interval
Initiation of data transmission	5.27	Specification of the required initiation of data transmission at a reference interface
Length of user data per transfer interval	5.31	Specification of the required length of user data at a reference interface
Maximum number of retransmissions	5.33	Specifies how many times user data are acceptable to be retransmitted automatically by the communication stack because of transmission errors
Position of wireless devices	5.45	Specification of the required position of a wireless device using three dimensions according to the spatial coverage of the wireless communication system
Distance between wireless devices	5.15	Specification of the length of a physical link
Purpose of the automation application	5.47	Description of the purpose of the automation application
Relative movement	5.52	Specification of the trajectory of a device and its moving profile or the length of a physical link, the relative acceleration and speed
Security level	5.54	Specification of the required security level
Spatial coverage of the wireless communication	5.56	Specification of the required spatial coverage of the wireless communication system using length, width and height
Transfer interval	5.60	Specification of the required transfer interval at a reference interface
Wireless device density	5.67	Specification of the required wireless device density according to the spatial coverage of the wireless communication system

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6.3.3 Performance requirements

Performance requirements describe the time and error behaviour necessary to achieve the purpose of the automation application.

The set of parameters in Table 10 shall be used to describe the required performance including the acceptable maximum number of retransmissions and MLR.

Table 10 – List of characteristic parameters

Parameter name	Reference	Content
Data throughput	5.14	Specification of the required values for data throughput
Communication availability	5.6	Specification of the required values for communication availability
Transmission time	5.62	Specification of the required values for transmission time
Update time	5.66	Specification of the required values for update time
Response time	5.53	Specification of the required values for response time

NOTE The parameters given in Table 10 are random variables. These parameters are specified in terms of their mean value, percentile, standard deviation or span (jitter).

6.4 Wireless system type and wireless device type

6.4.1 Overview

Subclause 6.4 specifies sets of parameters that characterize the model of a wireless system or a wireless device by providing the parameters to specify a wireless system type and a wireless device type.

Depending on the life cycle, the content can change for example from

- what is required from the point of view of a planner;
- what is specified in a standard including options and recommendations?

NOTE These parameters are not those of a particular implementation of a wireless system or device; that is called a wireless solution.

Additional information could be useful. For example, the parameter in 5.68 can be listed.

Figure 25 shows the relationship between the definition and specification in this document and its use in a coexistence management system specification.

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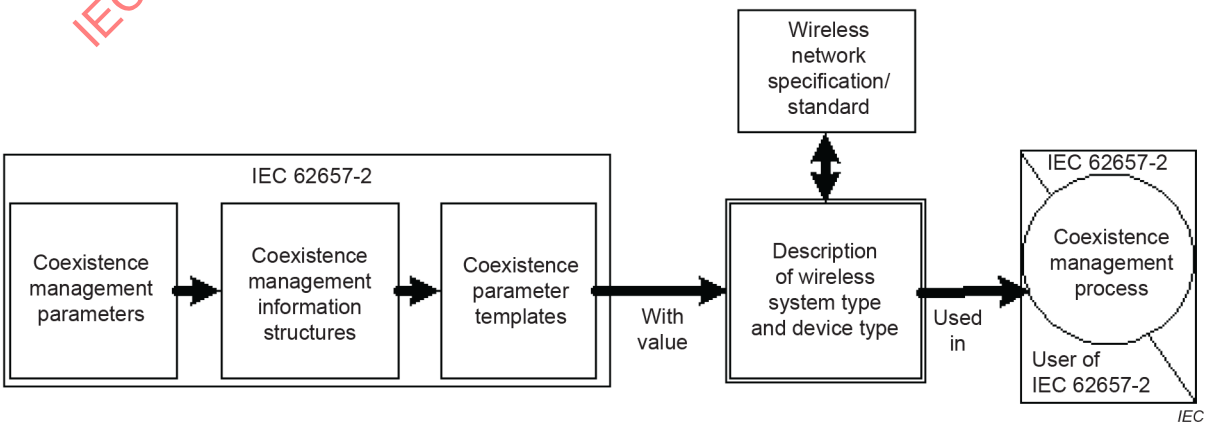

Figure 25 – Parameters to describe wireless system type and device type

Almost all parameters are specified in standards or specifications for wireless systems. However, a particular wireless communication system or device might have better or worse performance than specified. Furthermore, specifications sometimes allow value ranges for parameters. The values and value ranges of the parameters in Table 11, Table 12 and Table 13 shall be provided together with the wireless product. References can be used for parameters whose values or value ranges can be found in specifications or standards.

Subclause 6.4 differentiates between common wireless system parameters and specific device parameters.

6.4.2 Wireless system type

The type of a wireless system shall be characterized using the parameters given in Table 11.

Table 11 – List of parameters used to describe the wireless system type

Parameter name	Reference	Content
Wireless technology or standard	5.70	Reference to specifications or standards with which the wireless system is compliant
Regional radio regulations	5.51	List of regional radio regulations with which the wireless system is compliant
Network topology	5.40	Topologies of the wireless network
Wireless device density	5.67	Declaration of maximum possible number of active devices in the spatial coverage
Infrastructure device	5.26	Description of possible or required infrastructure devices
Frequency band	5.20	Description of possible frequency band
Lower cut-off frequency	5.13	Lower frequency limit of the frequency band
Upper cut-off frequency	5.13	Upper frequency limit of the frequency band
Frequency hopping sequence	5.23	Description of possible or required frequency hopping sequences
Modulation	5.38	Description of possible or required modulations
Communication reliability	5.7	Description of possible or required bit rate value of a physical link or a list from which can be selected
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Dwell time	5.17	Declaration of maximum dwell time value
Medium access control mechanism	5.35	Description of possible or required medium access control mechanisms
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35
Mechanism for adaptivity	5.34	Description of possible or required mechanisms for adaptivity
Security level	5.54	Description of functions for ensuring security levels

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6.4.3 Wireless device type

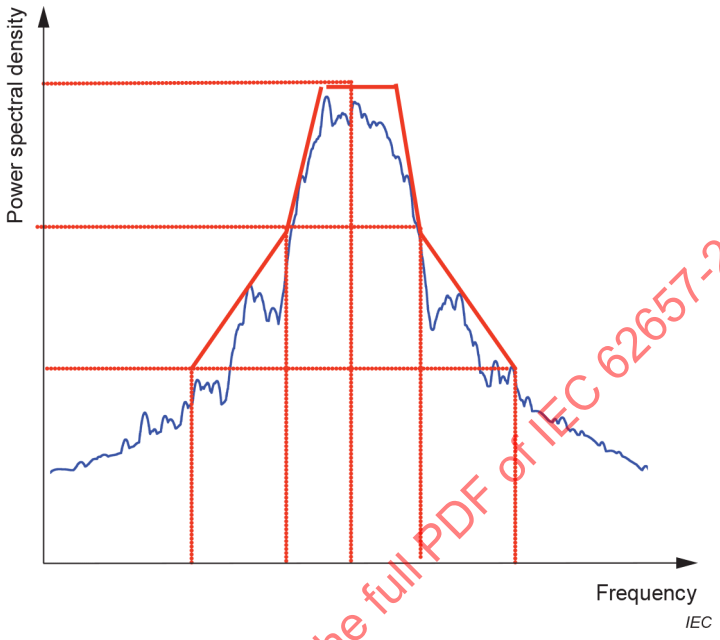
6.4.3.1 General

A wireless device type can be characterized by the specification of transmitter and receiver parameters. For a device implementing both transmitting and receiving functions, both sets of parameters shall be specified.

6.4.3.2 Wireless device transmitter parameters

The spectral energy radiated by a device can be measured with a spectrum analyzer. An example of a measurement is shown in Figure 26. The blue line illustrates the power spectral density of a transmitter. A simplified representation is the transmitter spectral mask, see 5.65, which is overlaid in Figure 26 (see red colored line).

NOTE Depending on the specific technology or standard, different parameters are used to describe the frequency spectrum and the power level.



Key

solid line (red) spectral mask

solid line (blue) the power spectral density

Figure 26 – Example of power spectral density and transmitter spectral mask

While frequency and power are originally determined by the wireless device or system, the utilization of the spectrum in time also depends on the communication requests of the application. In Figure 27, the principle of medium utilization in time and frequency is depicted. It can also be recorded using a spectrum analyzer. The yellow color in Figure 27 shows the area of the centre frequencies with the highest power level. Relevant parameters describe the time of a transmission and the time between two consecutive transmissions. In certain circumstances, it is of interest as to whether the time refers to one or several frequency channels.

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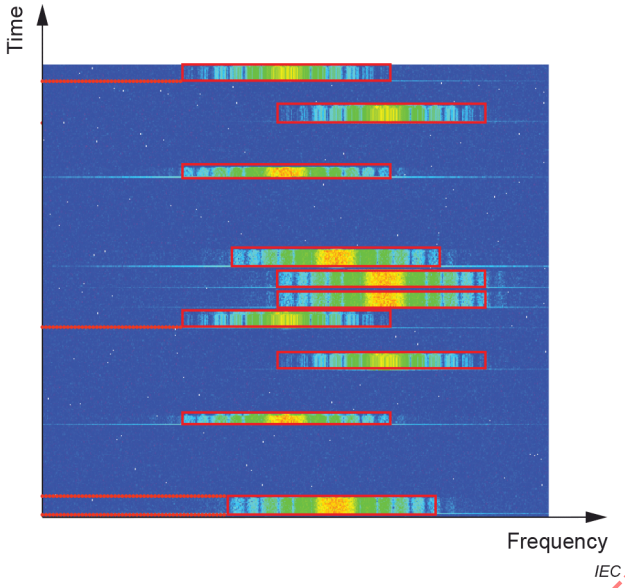

Figure 27 – Example of medium utilization in time and frequency

The values or value ranges of a wireless device type can be better than the values specified for the wireless system type. Therefore, the transmitter parameters in Table 12 shall be used to characterize a wireless device type.

Table 12 – List of parameters used to describe the transmitter of a wireless device type

Parameter name	Reference	Content
Wireless device density	5.67	Declaration of maximum possible number of active devices in the spatial coverage
Antenna type	5.5	Description of antenna types that are used, or that can be selected
Antenna gain	5.3	Declaration of antenna gain
Antenna radiation pattern	5.4	Declaration of antenna radiation pattern
Equivalent radiated power	5.19	Declaration of maximum ERP value
Equivalent isotropic radiated power	5.18	Declaration of maximum EIRP value
Receiver maximum input level	5.49	Declaration of radiated power value or a list from which can be selected
Total radiated power	5.59	Possible total radiated power value
Transmitter output power	5.63	Description of transmitter output power in case the antenna is external or the ERP/EIRP needs to be adjusted by the parameter transmitter output power
Transmitter spectral mask	5.65	Description of transmitter spectral mask
Power spectral density	5.46	Description of power spectral density
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22)
Communication reliability	5.7	Declaration of communication reliability
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Duty cycle	5.16	Declaration of maximum duty cycle value
Dwell time	5.17	Declaration of maximum dwell time value
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35

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6.4.3.3 Wireless device receiver parameters

The receiver parameters in Table 13 shall be used to characterize a wireless device type.

Table 13 – List of parameters used to describe the receiver of a wireless device type

Parameter name	Reference	Content
Adjacent channel selectivity	5.2	Description of adjacent channel selectivity value
Receiver sensitivity	5.50	Description of receiver sensitivity value
Receiver maximum input level	5.49	Description of maximum receiver input level value
Receiver blocking	5.48	Declaration of receiver blocking response value
Spurious response	5.57	Declaration of receiver spurious response value

6.5 Wireless solution

6.5.1 Overview

Subclause 6.5 describes the characterization of wireless solutions which are implementations of wireless systems and device types. In contrast to the description of wireless systems and device types, here the parameter values refer to a certain installation within a plant.

Figure 28 shows the relationship between the definition and specification of parameters in this document and their use. Based on a type description of a certain wireless system and its wireless devices (see 6.4), with respect to the coexistence management information structure, and the description of wireless solution given in 6.5, the wireless communication solution and its wireless device solutions can be described.

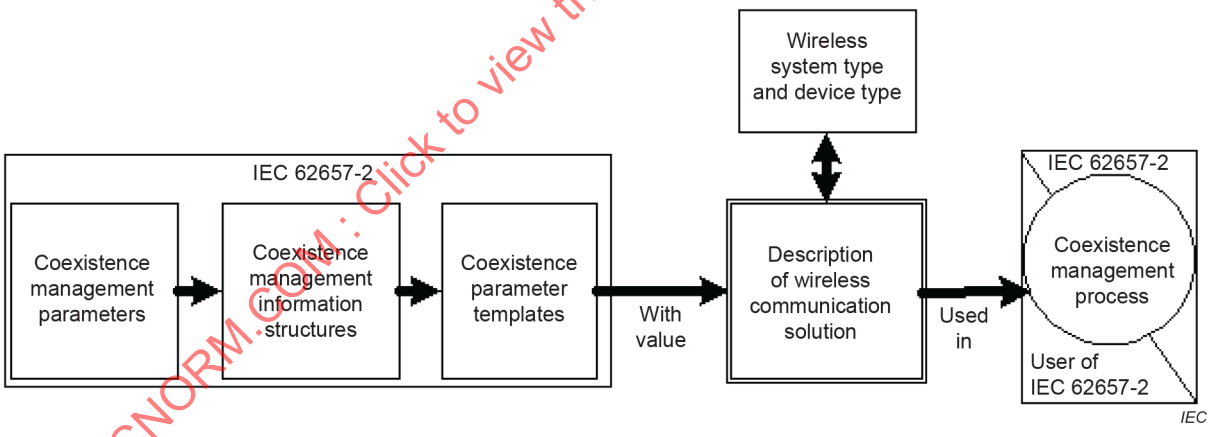

Figure 28 – Parameters to describe a wireless communication solution

6.5.2 Wireless system solution

The wireless system solution shall be characterized using the parameters in Table 14, in addition to the parameters of the wireless system type and wireless device type according to 6.4.

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Table 14 – List of parameters used to describe a wireless solution

Parameter name	Reference	Content
Wireless system type	6.4.2	Reference to a wireless system type described with parameters according to 6.4.2
Network topology	5.40	Description of network topologies
Wireless device density	5.67	Declaration of maximum possible number of active devices in the spatial coverage
Position of wireless devices	5.45	List of positions of wireless devices
Relative movement	5.52	List of descriptions of movement of wireless devices
Infrastructure device	5.26	List of positions of infrastructure devices
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22)
Frequency hopping	5.23	Configured frequency hopping sequences
Modulation	5.38	Configured modulations
Bit rate of physical link	5.8	Configured bit rates of physical link
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Dwell time	5.17	Declaration of maximum dwell time value
Medium access control mechanism	5.35	Description of configured medium access control mechanisms
Mechanism for adaptivity	5.34	Description of configured mechanisms for adaptivity
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35
Security level	5.54	Description of configured functions for ensuring security level

6.5.3 Wireless device solution

The wireless device solution shall be characterized using the parameters in Table 15 and Table 16, in addition to the parameters of the wireless device type according to 6.4.3.

Table 15 – List of general parameters used to describe the wireless device solution

Parameter name	Reference	Content
Wireless system type	6.4.2	Reference to a wireless system type described with parameters according to 6.4.2
Wireless device type	6.4.3	Reference to a wireless device type described with parameters according to 6.4.3

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Table 16 – List of parameters used to describe the transmitter of a wireless device solution

Parameter name	Reference	Content
Antenna type	5.5	Description of antenna types
Antenna gain	5.3	Declaration of antenna gain
Antenna radiation pattern	5.4	Declaration of antenna radiation pattern
Equivalent radiated power	5.19	Declaration of effective radiated power values
Equivalent isotropic radiated power	5.18	Declaration of EIRP value
Total radiated power	5.59	Declaration of total radiated power values
Transmitter output power	5.63	Description of transmitter output power in case the antenna is external or the ERP/EIRP needs to be adjusted by the parameter transmitter output power
Power spectral density	5.46	Description of power spectral density
Frequency channel	5.22	Declaration of frequency channel values that are used or that can be selected, specified by centre frequency and frequency bandwidth (see 5.10 and 5.21), cut-off frequencies (see 5.13), or numbers of frequency channels (see 5.22)
Bit rate of physical link	5.8	Declaration of minimum bit rate
Transfer interval	5.60	Declaration of minimum transfer interval value
Transmission gap	5.61	Declaration of minimum transmission gap value
Transmitter sequence	5.64	Declaration of maximum transmitter sequence value
Duty cycle	5.16	Declaration of maximum duty cycle value
Dwell time	5.17	Declaration of maximum dwell time value
Medium utilization factor	5.36	Declaration of the MU factor dependent of 5.35

The receiver parameters of a device are mostly specified by the wireless device type. Only the receiver sensitivity can be configured, see Table 17.

Table 17 – List of parameters used to describe the receiver of a wireless device solution

Parameter name	Reference	Content
Adjacent channel selectivity	5.2	Description of adjacent channel selectivity value
Receiver sensitivity	5.50	Configured values of receiver sensitivity
Receiver maximum input level	5.49	Description of maximum receiver input level value
Receiver blocking	5.48	Declaration of receiver blocking response value
Spurious response	5.57	Declaration of receiver spurious response value

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6.6 Application related characteristic parameters

Characteristic parameters allow a quantitative assessment of a wireless communication solution, see Table 18. A set of required values are part of application communication requirements. A set of promised values are part of the capability description of a wireless communication solution. The characteristic parameters refer to the interfaces between the logical wireless communication devices and the assumed logical automation device, called reference interface.

Table 18 – List of relevant characteristic parameters of wireless solutions

Parameter name	Reference	Content
Transmission time	5.62	Specification of the required values for transmission time
Update time	5.66	Specification of the required values for update time
Response time	5.53	Specification of the required values for response time
Data throughput	5.14	Specification of the required values for data throughput
Communication availability	5.6	Specification of the required values for communication availability
Message loss ratio	5.44	Specifies the acceptable MLR
Communication reliability	5.7	Applied to the function of a wireless communication system, communication reliability is the ability of a logical link to transmit messages under stated conditions for a specified period of time. The communication reliability can be determined using the operating time between failures
Operating time between failures	5.43	The operating time between failures of a logical link is the sum of the operating time periods between two successive failures. The logical link is considered as a repairable item in the sense that a message can be repeated within the survival time. A measure to assess a logical link is the mean operating time between failures
Survival time	5.58	A time that an application, consuming a communication service, can continue without an anticipated message

Relevant statistical values of the characteristic parameters are listed in Table 19. There is the mention of minimum, mode, mean and percentile P95 values. The minimum, mode, mean, standard deviation, and percentile statistical values are the most relevant ways to express the characteristic parameters. For evaluation of message transmission, all proposed values from each parameter name are relevant.

Table 19 – List of relevant statistical values of characteristic parameters

Parameter name	Reference	Statistical values
Transmission time	5.62	Minimum, mode, percentile P95
Update time	5.66	Mean, standard deviation
Response time	5.53	Minimum, mode, percentile P95
Data throughput	5.14	Capacity of a communications channel
Communication availability	5.6	The ratio of the time interval of error free transmission (uptime, t_U) to an observation time t_O
Message loss ratio	5.44	The ratio, expressed as a percentage, of the number of messages not delivered divided by the total number of messages during a time interval T, where the number of messages not delivered is the difference between the number of messages arriving at the ingress flow point and the number of messages delivered at the egress flow point in a point-to-point connection
Survival time	5.58	A time that an application, consuming a communication service, can continue without an anticipated message

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6.7 Radio environment related performance parameters

Radio environment related performance parameters allow a quantitative assessment of passive and active environmental influences on radio signal propagation. The values of these parameters can be measured and/or calculated during the operation of wireless communication solutions by their wireless devices or by special devices for determining the use of the radio spectrum.

In general, radio environment related performance parameters are not part of the application communication requirements and are not part of the capability description of a wireless communication solution. Therefore, usually the required values are not of interest. Promised values could be specified in terms of reference values or thresholds for initiating coexistence measures. The current values of radio environment related performance parameters can be considered for calculating the coexistence state. In this way, problems due to shadowing or interference can be detected before the values of the application related characteristic parameters exceed relevant threshold values.

The radio environment related performance parameters refer to the interfaces between the logical wireless communication device and the radio environment, called physical layer interface.

There is no common standard for radio environment related performance parameters and their determination. They depend on the wireless technology, the various wireless communication standards and/or their implementations. Table 20 lists a non-exhaustive summary of possible parameters.

Table 20 – List of radio environment related performance parameters

Parameter name	Content
Duty cycle	Ratio of the transmitter sequence referenced to a given observation time for the used frequency channel
Link quality	Quality of a physical link between two Bluetooth devices with a value from 0 to 255
Power spectral density (PSD)	Power of a signal distributed over a frequency range
Receive signal level	Estimated receive signal level according to IEC 62591 [1]
Reference signal received power (RSRP)	Received power level, parameter is used in cellular mobile communications
Reference signal received quality (RSRQ)	Signal level and quality, parameter is used in cellular mobile communications considering RSRP, RSSI and used resource blocks
Received signal strength indication (RSSI)	Relative value that represents the power of a received radio signal, sometimes also called received signal strength indicator
Signal-to-interference ratio (SIR)	Power of a certain signal of interest divided by the sum of the interference power
Transmitter sequence	Time that a transmitter uses a frequency channel without the possibility to be interrupted by a wireless device of the same wireless communication system
Transmission gap	Time between two successive channel usages by a transmitter

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The type of value (mean value, instantaneous value) depends on the respective definitions of the parameters for the respective implementation. If possible, statistical values should be calculated based on these values for a well-defined and system-wide uniform observation time.

6.8 Wireless communication solution related performance parameters

Wireless communication solution related performance parameters allow a quantitative assessment of the wireless communication in a wireless communication solution. The values of these parameters can be measured and/or calculated during the operation of wireless communication solutions by their wireless devices.

In general, wireless communication solution related performance parameters are not part of the application communication requirements. Therefore, usually the required values are not of interest. These parameters can be part of the capability description of a wireless communication solution. Promised values could be specified in terms of reference values or thresholds for initiating coexistence measures. The current values of wireless communication solution related performance parameters can be considered for calculating the coexistence state. In this way, problems with the wireless communication solution can be detected before the values of the application related characteristic parameters exceed relevant threshold values.

The interface, the wireless communication solution related performance parameters refer to, depends on the implementation.

There is no common standard for wireless communication solution related performance parameters and their determination. They depend on the wireless technology, the various wireless communication standards and/or their implementations. Table 21 lists a non-exhaustive summary of possible parameters.

Table 21 – List of wireless communication solution related performance parameters

Parameter name	Content
Bit rate	Number of bits transmitted by a wireless device during a given observation time
Data rate	Number of bytes transmitted by a wireless device during a given observation time
Number of received octets	Number of octets successful received by a wireless device
Number of received packets	Number of packets successful received by a wireless device
Number of retry packets	Number of packets retransmitted by a wireless device because of transmission failures
Number of transmission failures	Number of non-successful transmissions by a wireless device
Number of transmitted octets	Number of octets transmitted by a wireless device
Number of transmitted packets	Number of packets transmitted by a wireless device

The type of value (mean value, instantaneous value) depends on the respective definitions of the parameters for the respective implementation. If possible, statistical values should be calculated based on these values for a well-defined and system-wide uniform observation time.

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7 Coexistence management process

7.1 General

7.1.1 Overview

A coexistence management process represents the activities of the coexistence management system.

The coexistence management process includes technical and organizational activities in order to establish and to maintain the coexistence state of all wireless solutions in a plant. The coexistence parameters specified in Clause 5, and organized as described in Clause 6, are used in different phases of the coexistence management process. The overall process starting from the decision to establish such a process is depicted in Figure 7. The coexistence management process consists of the following phases:

- investigation phase (see 7.4.1);
- planning phase (see 7.4.2);
- implementation phase (see 7.4.3);

- operation phase (see 7.4.4).

NOTE As all these phases belong to the coexistence management, in the following text the term 'coexistence management' is omitted in front of the phase names.

The investigation phase shall be initiated when changes are discovered or when a new wireless system or other radio emitter in the managed band(s) are planned to be installed.

In the planning phase, the resource allocation plan is developed or modified based on the coexistence parameter values.

In the implementation phase, new wireless solutions are installed, and the configuration of existing wireless solutions is modified in accordance with the resource allocation plan.

In the operation phase, the status of wireless communication applications is monitored to detect problems related to coexistence and to initiate maintenance procedures.

7.1.2 Documentation

The coexistence management system shall be documented in a coexistence management system specification and maintained as part of the coexistence management process.

The scope of the documentation should correspond to the application class.

Some elements that should be part of the coexistence management system specification that are mentioned in this document are listed below:

- scope;
- commitment of the organization;
- procedure for maintaining;
- structure of the organization;
- roles of personnel;
- communication with external organizations;
- procedures for coexistence management;
- visualization of the interference risk;
- occupation of the frequency bands;
- location and positions of the wireless applications;
- inventory results;
- commissioning of external or internal service providers;
- information on the wireless applications;
- results of analyses and measurements;
- particulars of installation and approval;
- establishment of communication channels;
- establishment of a committee;
- establishment of an obligation to register wireless systems;
- release or rejection of newly registered wireless applications;
- document management and coordination of specifications;
- training;
- procedure of the audit;
- audit results;

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- results of analysis and metrological examination;
- action plan;
- general plant characteristic;
- automation communication requirements;
- wireless system type;
- wireless device type;
- wireless system solution;
- wireless device solution.

NOTE The order of the bullet list above is not mandatory. The organization of a document structure can be based on different points of view like life cycle, hierarchical structure, etc., referring to the same content. This is out of the scope of this document.

The following documents contain the elements listed above and shall be part of the coexistence management system specification:

- general plant characteristic (see 6.2, Table 22 and Table 30);
- application communication requirements (see 6.3 and Table 23)
  - requirements influencing the characteristic of wireless solutions (see 6.3.2);
  - performance requirements (see 6.3.3, Table 28 and Table 29);
- wireless communication system (see 6.4, 6.5)
  - wireless system type and wireless device type (see 6.4)
    - i) wireless system type (see 6.4.2 and Table 24);
    - ii) wireless device type (see 6.4.3 and Table 25)
      - a) wireless device transmitter parameters (see 6.4.3.2);
      - b) wireless device receiver parameters (see 6.4.3.3);
  - wireless solution (see 6.5) (this represents the resource allocation plan)
    - i) wireless system solution (see 6.5.2 and Table 26);
    - ii) wireless device solution (see 6.5.3 and Table 27);
- resource allocation plan (see 6.3, 6.4, and 6.5).

It is recommended to support the documentation by a suitable documentation method. The requirements on such a method are described in 7.1.3.

7.1.3 Suitable documentation method

For an efficient processing of coexistence management, related to the complexity of the local situation, the application of a suitable documentation method is advisable. The documentation should at least include the following content:

- storage of information about numerous wireless systems and devices, including information about their spatial position and their radio parameters (for example in a data base);
- plausibility check of the recorded data;
- administration of information concerning the status of the known wireless applications;
- access to the documentation and their administration for all parties involved in the project (if necessary, even for those located in other countries) subject to access authorizations;
- visualization of the interference risk and the occupation of the frequency bands in an intuitive comprehensible form (for human beings);
- experiences of the company in handling the wireless applications;
- optionally, visualization of the positions of the wireless applications.

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7.1.4 Application of tools

The essential steps to administer radio frequencies can be supported with suitable tools.

Software tools can be used to administer the documentation specified in 7.1.3.

Other tools can support the concepts specified in 4.7.

7.2 Establishment of a coexistence management system

7.2.1 Nomination of a coexistence manager

For effective control of the coexistence management process, a central responsibility is required at the appropriate level.

One or more central contact persons (coexistence managers) shall be assigned. The area of responsibility of the coexistence manager shall be determined individually for each enterprise. Thus, a coexistence manager could be responsible for the whole company, for one or more locations, or for business divisions and departments, depending on the company organization. The crucial factor is to ensure the efficiency of the process.

Whatever the approach adopted by the specific company, it could be considered as belonging to one of two main options:

- based on the relevance of the problem;
- independent of the relevance of the problem.

In the first case, the coexistence manager is chosen from the divisions mostly affected by potential interferences. Often the IT and the automation divisions are the ones concerned.

In the second case, the neutrality of the responsible division is emphasized. Hence, for example, the coexistence manager could be chosen from the "facility management" division administrating the company resources, because the frequency spectrum is to be considered a limited and therefore a valuable resource.

Internal processes and the organization of a company are the decisive factors to choose either of the two strategies. In each individual case, the decision shall be made subject to the respective conditions. Here it is important to ensure the efficiency of the process. The coexistence manager shall have basic knowledge about automation applications and the characteristics of wireless systems. The coexistence manager shall have the authority to take the necessary measures to fulfil the defined tasks.

This document describes the coexistence manager as a person. However, this does not imply that some of the sub-functions of the coexistence manager could not be allocated to an automated process. Clearly, the final responsibility of the overall coexistence manager function shall remain with an individual.

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7.2.2 Responsibility of a coexistence manager

The coexistence manager shall be responsible for the following activities:

- establishment of communication channels within the company;
- establishment of a committee, consisting of contact persons of all company divisions using wireless systems;
- establishment of an obligation to register wireless systems in the location(s) of interest in the company;
- inventory of wireless applications and, if necessary, commissioning of external or internal service providers to accomplish the inventory;
- release or rejection of newly registered wireless applications and, where necessary, generation of requirements for the use of wireless applications based on the agreed decisions of the internal committee;
- development and coordination of specifications and regulations to implement and operate wireless applications;
- documentation of information about the operational wireless applications, of the decisions of the coexistence management committee and of the accomplished examinations (if necessary, commissioning external or internal service providers to get these documents);
- ensure the existence of a policy with enforcement for non-authorized introduction of new wireless applications or solutions.

7.2.3 Support by wireless experts

A coexistence manager shall have basic knowledge of wireless technologies, associated radio compatibilities and protocol expertise. Specialist knowledge is required to promote qualified decisions regarding the use of wireless applications which involve considerable risks. If a coexistence manager does not have the specialist knowledge, the coexistence manager shall be assisted by a wireless expert.

The following typical tasks are examples that require the assistance of a wireless expert:

- performing inventory;
- analysis of radio robustness;
- metrological testing of radio robustness;
- designing the architecture of the wireless solution;
- preparation of a draft decision memo for the use of wireless technologies;
- determination of strategies for the use of wireless technologies in the future;
- controlling the adherence to the agreed specifications;
- specifying the values of the parameters for the selected solutions.

7.2.4 Training

The coexistence manager and, if necessary, other members of the committee shall be trained at regular intervals. This training serves to update the knowledge of the persons concerned and to communicate the following information:

- requisite professional background (basics of radio robustness);
- basic knowledge about modern wireless technologies;
- impact of potential problems with practical examples;
- handling of the coexistence management process;
- available tools and monitoring technology.

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The training content should be adjusted to the actual situation in the company. Due to the extremely dynamic nature of technology development, it is advisable to organize these trainings at regular intervals (for example once a year or every two years).

7.3 Maintaining coexistence management system

The coexistence management system shall be appropriately maintained so that it can keep those wireless solutions within its scope in conditions of coexistence, even after requirements and/or environment change.

The coexistence manager within the organization, for example of a company or a hospital, shall be responsible for maintaining the coexistence management system.

Documents in the management system shall be modified appropriately in the following cases:

- when inconsistency of the coexistence management system is detected;
- if the organization is changed.

Audit of the coexistence management system should be conducted to check consistency of the coexistence management system. The procedure of the audit shall be documented.

7.4 Phases of a coexistence management process

7.4.1 Investigation phase

7.4.1.1 Overview

The investigation phase shall be initiated when one of the following events occurs:

- new wireless system needs to be installed or upgrades/modifications of existing solutions are going to be realized;
- environment of wireless system changes;
- problem related to coexistence occurs.

The investigation aims to

- ascertain the actual state in respect of operating wireless applications;
- identify free and occupied frequency resources.

The investigation provides a basis for the coexistence management and is an important step in its implementation. A crucial premise to implement coexistence management successfully is that the results of the investigation are complete and correct.

7.4.1.2 Practical tips to accomplish an investigation

7.4.1.2.1 General

Depending on the application, the investigation can be a complex task so that assistance by skilled and qualified wireless experts is recommended.

In order to accomplish an investigation efficiently, the interrogation of specialist departments (operators and planners of manufacturing plants and building equipment) and radio measurements is essential.

Tools (for example suitable questionnaires) for the investigation shall be provided, allowing the registration of operating wireless systems. It is important to define which responsible parties in the company are able to provide reliable and up-to-date information. Therefore, an agreement within the coexistence management committee is necessary.

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Subject to the application requirements (particularly in the application classes "safety" to "control", see Table 1), the investigation shall be supported by measurements. These measurements serve to verify the plausibility of the interrogation results and, in addition, to ascertain unknown and external wireless applications (for example from the vicinity or from outside sources). In order to reduce the measuring effort, the results of the interrogation can be used as input data to determine the measuring method. The operating procedures shall also collect information about the runtimes of the wireless systems. The measurements shall be carried out under the realistic conditions of an application.

Further information can be gathered with the aid of automatic monitoring systems. Several modern wireless systems (for example controller-based WLANs) allow the recording of information per wireless system. Moreover, radio monitoring systems are offered which automatically gather information concerning the occupation of the frequency spectrum. In the scope of a measurement, the information provided by these systems shall be analyzed, or rather shall be metrologically checked.

If this specific knowledge is not available in-house, the companies can use the external service providers.

7.4.1.2.2 Accomplishment of metrological investigations

Spectrum and protocol analyzers can be used for metrological examinations of the coexistence.

Protocol analyzers are based on an end device or on specialized hardware.

The end device-based protocol analyzer is a software solution, processing the data recorded by an end device (for example network adapter, specialized end device).

Protocol analyzers, based on specialized hardware, are specialized measurement or monitoring systems, particularly used by large systems for the development of hardware, control, and fault finding. Usually, these devices are faster than end-device-based solutions. They are able to record and analyze more parameters, but they are significantly more expensive and sometimes difficult to transport.

As an additional function, wireless solutions can continuously ascertain the actual values of the parameters and provide them to the automation application.

The choice of a tool to perform simulations, measurements or tests should consider its suitability for the planned application and its economic efficiency.

7.4.1.2.3 Evaluation of coexistence

7.4.1.2.3.1 Digital wireless systems

The wireless systems assumed here are systems with digital modulation and coding mechanisms.

Typically, industrial automation applications use digital wireless solutions. Coexistence exists if all wireless solutions involved fulfil the communication requirements of their applications. Therefore, the evaluation of coexistence requires application related characteristic parameters. The characteristic parameters related to the reference interfaces of the wireless solution shall be derived from values provided with the characteristic of the wireless solution according to 6.5.

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7.4.1.2.3.2 Analog wireless systems

Analog wireless systems are primarily used for the transmission of video and voice data.

A crucial factor for the orderly operation of analog systems is compliance with the required signal-to-interference ratio (SIR), or rather signal-to-(interference + noise) ratio (RSSI). The non-compliance with this ratio leads to a reduction in the received signal quality. Depending on the transmitted information, the following negative effects might result:

- reduction in speech quality in the case of voice transmission;
- reduction in image quality in the case of picture/video transmission.

NOTE The values of the signal-to-(interference + noise) ratio range from about 14 dB to 60 dB. They can be ascertained from the respective ITU or ECO/CEPT recommendations or from the device manual.

7.4.1.2.4 Analysis and measurement

During the implementation of a new wireless system, or in the inventory, the interference risk should be analyzed. The interference risk should be analyzed in two steps.

In the first step, analyze whether interference potentials as described in 4.4 do exist. If there is an interference risk between the wireless systems, in the second step a thorough analysis shall follow. The coexistence manager, if necessary, with assistance from a wireless specialist, can preliminarily analyze the interference risk.

The second step is an in-depth analysis, taking into account the particularities of the wireless systems, the radio surroundings and if needed of the automation application and the wireless devices. This analysis shall determine the influences to be expected, the degree of interference risk and the potential measures to be taken in order to ensure coexistence.

In many cases, this analysis will turn out to be very complex so that a metrological examination will be necessary. In this case, the analysis serves to systematically prepare the metrological examination.

The metrological examination shall determine to what extent the requirements on the wireless system are answered and what influences need to be faced. The result of the metrological test is a draft decision memo for the application of the wireless system and shall be agreed upon by the coexistence management committee. According to this agreement, a wireless solution will be released (if needed with requirements) or rejected.

The results of analysis and metrological examination shall be documented and auditable. They can be further used in the scope of coexistence management, for example in the consideration of similar situations.

The metrological examination can take place either in the physical (application) world or under laboratory conditions. In this context, laboratory conditions mean an environment where several practice-relevant situations can be examined in a comprehensible and reproducible (and if possible standardized) way.

Normally an investigation in real surroundings is preferred, because transmitter-specific realities can be considered here. This cannot be achieved in laboratory studies. The measurement process to be determined should simulate typical, potential operational scenarios of the wireless system and of already existing wireless systems, taking into account the particularities of the automation application. The parameters to be ascertained should be chosen in such a way as to allow one to evaluate whether the requirements for the wireless system are met. Moreover, the examination shall not disturb operating wireless communication applications. If, for that reason, the parameters at the user interface listed in 7.4.1.2.3 are indeterminate in particular cases, the analysis can be accomplished by use of specific wireless protocol analyzers or by indicators (such as plant failure, bus error).

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Realistic investigations under laboratory conditions can provide repeatable and thus valuable information concerning the reaction of the wireless system to different interferences. This information might be useful to analyze coexistence and to prepare the approval. The investigation results might be provided to the contractor accompanied by the documentation of the wireless solution.

Examinations under laboratory conditions can also be useful to prepare the implementation of a wireless system, in cases where the target environment is not yet available (for example during the construction of a new production hall).

Measurements can also be used as examples to verify the analytical results, if the analysis is meant to allow authoritative statements for the coexistence of wireless systems. The metrological examination can also be used as a basis for further analyses, for example to predict interferences in the case of an increasing number of wireless devices.

7.4.2 Planning phase

7.4.2.1 Overview

In the planning phase, the resource allocation plan is developed or modified based on the updated inventory.

The resource allocation plan describes how to allocate radio resources to each wireless solution.

The resource allocation plan shall be documented appropriately. It shall be reviewed by the coexistence management committee and shall be authorized by the coexistence manager.

7.4.2.2 Coexistence management in the planning phase

Figure 29 shows a sub-process of Figure 6 and Figure 7. Figure 29 gives a review of the decisions and actions of the coexistence management process essential in the planning phase.

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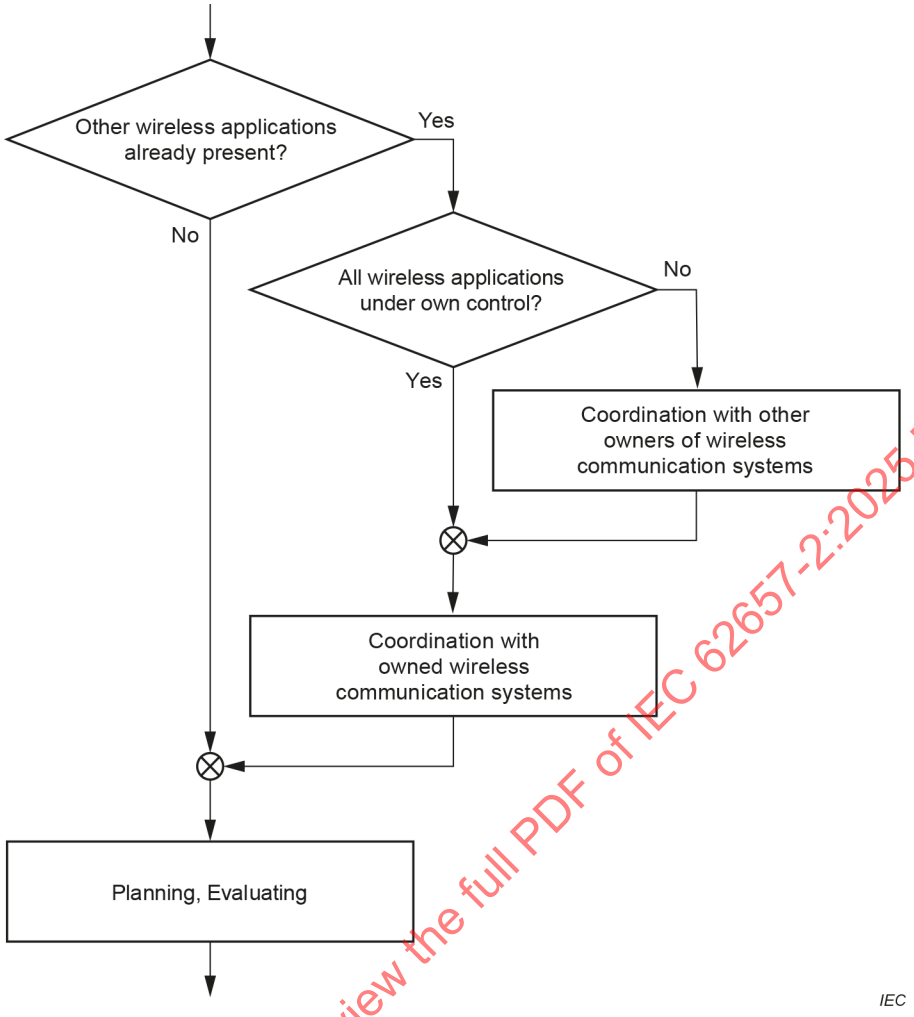

Figure 29 – Planning of a wireless system in the coexistence management process

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Even if there are no operating wireless applications, it should be considered that wireless applications can be introduced after the initial planning.

If there are working wireless applications already, it shall be ascertained whether they are all under the control of the coexistence manager. On the one hand, it might be that external systems irradiate; on the other hand, it might be that for example existing wireless solutions or wireless solutions of critical application classes (for example classes functional safety and control) are prioritized and cannot be modified. In these cases, the realities shall be accepted and the remaining degrees of freedom (for example frequency, time, space) can be used to achieve coexistence. It is easier if all wireless applications are under one's own control. It is also best if existing or concurrently planned wireless applications can be optimized to operate together with regard to radio robustness.

7.4.2.3 Radio field planning

It is recommended to use software tools to accomplish radio field planning. The following groups can be distinguished:

- system-specific software tools;
- system-independent software tools.

System-specific software (for example for IEEE Std.802.11 [7]) can factor in several features of the wireless standard and facilitates measurement with an end device.

System-independent software is usually a product that simulates radio wave propagation and hence can be used for nearly any system. However, only physical variables are simulated (for example signal level or signal propagation delay). The planner shall deduce site specific-related parameters from physical variables.

In the implementation of a wireless system, radio field planning should be performed assisted by the described software products.

Planning (at least for the application classes safety and control) should be accomplished by measurement and simulation. Simulation as a support for planning is advisable because exact measurements over a wide area are laborious and they often only represent a snapshot (for example for varying surroundings such as tall bay warehouses or production halls) and they rarely allow for optimization.

The simulations should, if possible, be specified with measurements. A pure simulation-based planning is only advisable for environments where measurements are not perceivable or not feasible (for example for not yet constructed or equipped buildings).

In radio field planning, other wireless applications should also be taken into account.

If there is no reliable information concerning the frequency occupation in the relevant range and in the immediate area, an environmental analysis should be accomplished in each planning. For that purpose, spectrum and protocol analyzers can be used. If spectrum analyzers are applied, antennas with known directional characteristics should be used to ascertain absolute level values.

7.4.2.4 Coexistence management measures

Coexistence measures shall be considered in the resource allocation plan.

7.4.3 Implementation phase

7.4.3.1 Overview

In the implementation phase, new wireless solutions are installed and configuration of existing wireless solutions is modified in accordance with the resource allocation plan.

The radio resource allocation is achieved by configuring options and parameters related to utilization of the radio resource to the wireless systems.

Implementation shall be validated in order to ensure that the resource allocation plan has been implemented appropriately.

NOTE The investigation phase, planning phase and implementation phase together are called development phase in IEC 62890.

7.4.3.2 Installation and approval

In order to meet the specifications of coexistence management, it is crucial to implement these specifications when the considered wireless system and other wireless applications are installed and commissioned. The internal or external service providers accomplishing the installations shall be informed about the requirements. It is advisable to implement the specifications of the coexistence management, for example intra-company regulations, at least for services related to the business process or to safety. If necessary, these requirements can be integrated into the work plan.

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The validation of installation shall ensure that it is in accordance with the resource allocation plan developed in the planning phase and the specifications of coexistence management. Aside from a function test and a visual inspection of the installation, the suitable acceptance controls should at least imply registration of the relevant performance parameters of the system and controlling the frequency bands.

7.4.4 Operation phase

7.4.4.1 Overview

In the operation phase, the condition of wireless solutions shall be monitored in order to detect problems related to coexistence and changes of environment.

Monitoring to check the condition of coexistence shall be conducted continuously or on a regular basis. Results shall be recorded appropriately.

Detailed specification of methods and tools used for monitoring is out of the scope of this document.

If events listed below are detected, then the investigation phase shall be initiated:

- problem related to coexistence occurs;
- new wireless system needs to be installed;
- environment of wireless system changes.

7.4.4.2 Coexistence management in the operating phase

Figure 30 presents the implementation and operation of a wireless system in the coexistence management process of the operating phase. After a wireless solution has been selected and coexistence established due to planning, installation and commissioning can be initiated. Subsequently, all information relevant to coexistence shall be documented.

A vital part of coexistence management during operation is to establish the obligation to register internal wireless applications. This applies to the report of interferences as well as for the information that further wireless applications are scheduled. If new wireless systems are to be installed, the selection process with add-on planning and evaluation shall be initiated. In the case of interferences, the reasons shall be understood via measurements and analyses and the required function shall be re-established.

Interferences in wireless communication become apparent when something in the plant fails or does not react as planned. These situations should be avoided. Therefore, it is advisable to control the compliance with the specifications of coexistence management regularly. For this purpose, an automatic system for the permanent monitoring of the frequency spectrum and the characteristic parameters (see 6.6), which might locate irregularities even if the plant operation is not yet affected, can be installed. In addition, control measurement should be performed periodically in order to identify variances in the propagation conditions and the existence of other frequency users.

These measures can also help identify an interferer outside the responsibility and control of the coexistence manager that shall not be disturbed. The coexistence manager can take immediate actions to incorporate the interferer outside of his/her control into the coexistence management plan.

EXAMPLE To achieve the compatibility of the industrial wireless communication solutions with the Broadband Fixed Wireless Access (BFWA) in the band of 5 725 MHz to 5 875 MHz in Europe (BFWA link can be affected within a radius around the industrial wireless communication solutions between 3 km and 10 km), an efficient way could be a sensing antenna to be installed on top of the industrial plant to detect the BFWA signal and react immediately to stop using this band beyond the normal energy. Such an antenna would have the advantage of a better propagation condition to the victim link and the possibility to choose a higher gain antenna for the sensing purpose.

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The coexistence manager shall create an action plan, enabling a quick response to events and initiation of the necessary actions without delay.

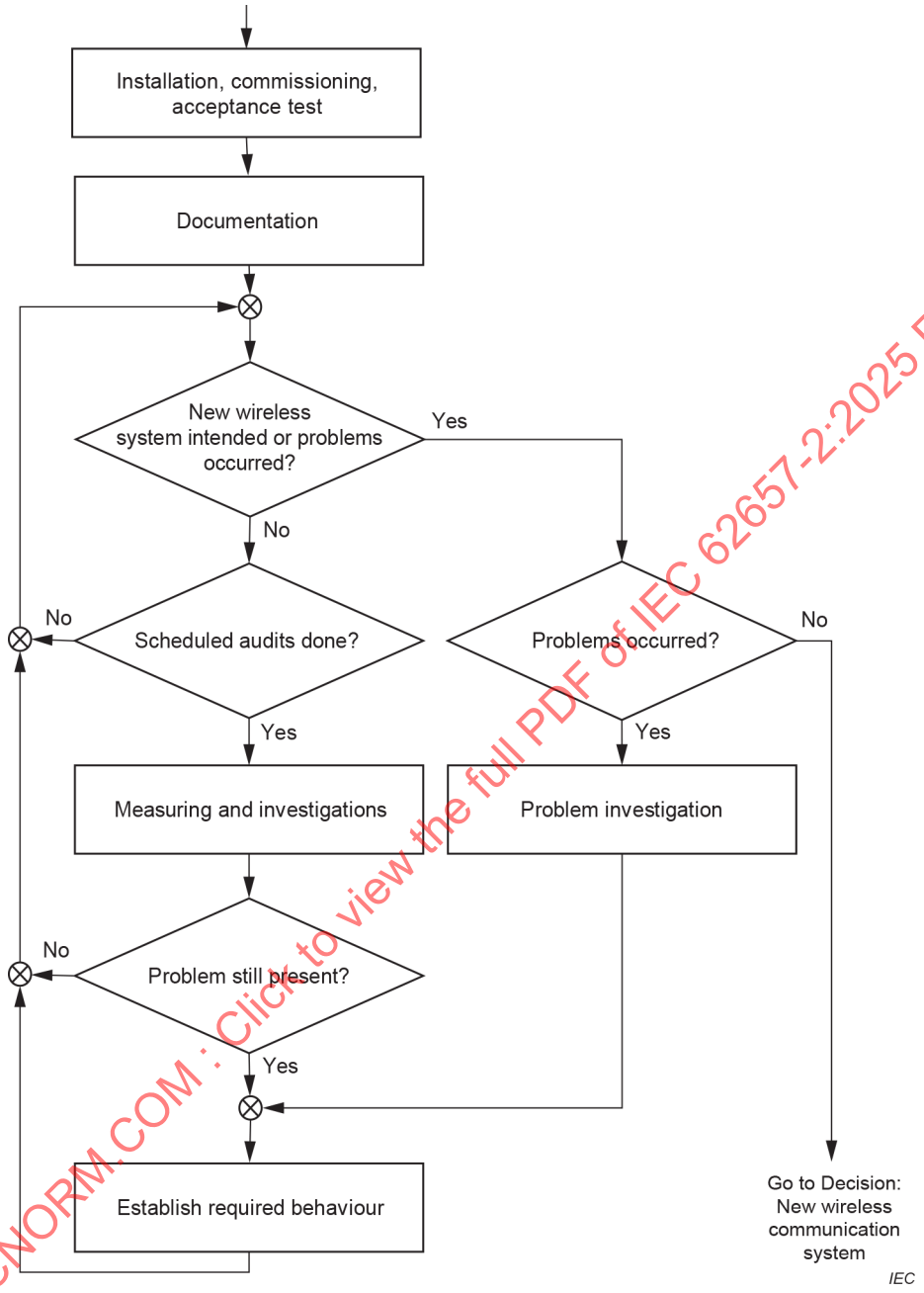

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Figure 30 – Implementation and operation of a wireless system in the coexistence management process

For this purpose, the coexistence manager shall work closely with the other company divisions to be informed about the acquisition of wireless applications. The coexistence manager shall approve them. For the acceptance of coexistence management, it is important to adopt and integrate the process into the internal regulations.

The operational phase includes a maintenance process to preserve the coexistence state. Wireless communication applications using coexistence management can be considered as a system with renewal possibilities. This means that if the probability of coexistence decreases, maintenance measures shall be initiated to retain the required probability of coexistence. Besides the identification of the coexistence problem, according to Figure 5 the medium resource allocation can be adjusted. This can be done by frequency channel separation, by reducing the data traffic volume or by local separation of the applications using for example beam forming. For details, see 4.7 and 4.8. Maintenance should consider temporarily installations of additional devices or changing the position of a devices.

8 Coexistence parameter templates

Clause 8 provides templates for coexistence parameters defined in Clause 5 and structured in Clause 6 from a coexistence management point of view. These templates shall be used in order to gather or provide the required information and thus support the coexistence management process.

Each parameter shall be represented by the following items: value, unit, usage and remark, by using the convention described in 3.3.

From these templates, an actual instance can be derived, for example using a printed table or an equivalent description in a formal language. The instantiation process is not described here since it is out of the scope of this document. The term template used in this document does not require any specific formatting. That means that the table form of the templates in this document can be transferred to any other form for example in paper form, electronically, and as a data base. The requirement of the template is that the listed parameter with the associated values or units or other information are present and linked together as given in the templates in this document to form the required structure.

The template in Table 22 shall be used to describe the characteristic of the plant. The content is specified in Table 5, Table 6 and Table 7.

If a parameter does not have a unit, then the corresponding cell shall be marked with not applicable (N/A). The column marked "Value" can contain a list of values.

NOTE 1 Templates given in Clause 8 with the corresponding definitions in 3.1 are intended for future inclusion in the IEC Common Data Dictionary (CDD, see IEC 61360 series [25]). The IEC CDD content can then be used in an electronic form.

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Table 22 – Template used to describe the general plant characteristic

Parameter name	Value	Unit	Usage	Remark
General plant characteristics				
Regional radio regulations				
Future expansion plan				
Passive environmental influences				
Area of operation				
Object movement				
Geographical dimension of the plant				
Natural environmental condition				
Intervisibility				
Frequency band				
Active environmental influences				
Wireless communication solution density				
Interference type				
Limitation from neighbours of the plant				
Frequency band				

The template in Table 23 shall be used to describe the application communication requirements for each wireless communication system. The content is specified in Table 9, Table 10 and Table 11.

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Table 23 – Template used to describe the application communication requirements

Parameter name	Value	Unit	Usage	Remark
Influencing parameters				
Communication load				
Initiation of data transmission				
Length of user data per transfer interval				
Maximum number of retransmissions				
Position of wireless devices				
Distance between wireless devices				
Purpose of the automation application				
Relative movement				
Security level				
Spatial extent of the application				
Length				
Width				
Height				
Transfer interval				
Wireless device density				
Characteristic parameters				
Data throughput				
Communication availability				
Transmission time				
Update time				
Response time				
Message loss ratio				

The templates in Table 24 and Table 25 shall be provided with a wireless solution. They describe the options of the wireless system or device. The content of Table 24 is specified in Table 11. The content of Table 25 is specified in Table 12 and in Table 13.

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Table 24 – Template used to describe the wireless system type

Parameter name	Value	Unit	Usage	Remark
Wireless technology or standard				
Regional radio regulations				
Network topology				
Wireless device density				
Infrastructure device				
Frequency band				
Lower cut-off frequency				
Upper cut-off frequency				
Frequency hopping				
Modulation				
Communication reliability				
Transfer interval				
Transmission gap				
Transmitter sequence				
Dwell time				
Medium access control mechanism				
Mechanism for adaptivity				
Security level				

Table 25 – Template used to describe a wireless device type

Parameter name	Value	Unit	Usage	Remark
Transmitter				
Regional radio regulations				
Antenna gain				
Antenna radiation pattern				
Equivalent radiated power				
Equivalent isotropic radiated power				
Total radiated power				
Transmitter output power				
Transmitter spectral mask				
Power spectral density				
Frequency channel				
Medium access control mechanism				
Communication reliability				
Transfer interval				
Transmission gap				
Transmitter sequence				
Duty cycle				
Dwell time				
Medium utilization factor				

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Parameter name	Value	Unit	Usage	Remark
Receiver				
Adjacent channel selectivity				
Receiver sensitivity				
Receiver maximum input level				
Receiver blocking				
Spurious response				

The templates in Table 26 and Table 27 shall be used to document the current configuration and operation of each implemented wireless solution. The content of Table 26 is specified in Table 14. The content of Table 27 is specified in Table 12 and in Table 13.

Table 26 – Template used to describe the wireless system solution

Parameter name	Value	Unit	Usage	Remark
Wireless system type				
Network topology				
Wireless device density				
Position of wireless devices				
Relative movement				
Infrastructure device				
Frequency channel				
Frequency hopping				
Modulation				
Bit rate of physical link				
Transfer interval				
Transmission gap				
Transmitter sequence				
Dwell time				
Medium access control mechanism				
Mechanism for adaptivity				
Security level				

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Table 27 – Template used to describe a wireless device solution

Parameter name	Value	Unit	Usage	Remark
General				
Wireless system type				
Wireless device type				
Transmitter				
Antenna type				
Antenna gain				
Antenna radiation pattern				
Equivalent radiated power				
Equivalent isotropic radiated power				
Total radiated power				
Transmitter output power				
Power spectral density				
Frequency channel				
Bit rate of physical link				
Transfer interval				
Transmission gap				
Transmitter sequence				
Duty cycle				
Dwell time				
Receiver				
Adjacent channel selectivity				
Receiver sensitivity				
Receiver maximum input level				
Receiver blocking				
Spurious response				

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The templates in Table 28 and Table 29 shall be used to describe the relevant characteristic parameters for the coexistence management. The content is specified in Table 18 und Table 19.

Table 28 – Template used to describe the relevant characteristic parameters of wireless solutions

Parameter name	Value	Unit	Usage	Remark
Transmission time				
Update time				
Response time				
Data throughput				
Communication availability				
Message loss ratio				
Communication reliability				
Operating time between failures				
Survival time				

Table 29 – Template used to describe the relevant statistical values of characteristic parameters

Parameter name	Value	Unit	Usage	Remark
Transmission time				
Update time				
Response time				
Data throughput				
Communication availability				
Message loss ratio				
Survival time				

The templates in Table 30 shall be provided to describe an interference type. The content is specified in Table 8.

Table 30 – Template used to describe an interference type

Parameter name	Value	Unit	Usage	Remark
Interference type				
Frequency band				
Frequency channel				
Total radiated power				
Power spectral density				
Transfer interval				
Transmission gap				
Transmitter sequence				
Duty cycle				
Dwell time				

NOTE 2 The content of the templates could be used as a property definition-set in IEC 61360 series.

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Annex A
(normative)

Parameter usage in the IEC 62657 series

A.1 General

Figure A.1 shows the use of the parameters in the IEC 62657 series. Wireless automation devices and systems implement many parameters that can be used to improve the dependability and the coexistence. This document defines relevant parameters for coexistence management that are used in various contexts in the other parts of the IEC 62657 series. This annex is intended to provide an overview of parameter usage among the IEC 62657 series for coexistence management.

A.2 Outline of the IEC 62657 series

IEC 62657-1 describes use cases and motivations for wireless industrial automation. The document provides general requirements for industrial automation in terms of spectrum considerations. Performance of wireless industrial automation can be evaluated with value of characteristic parameters of wireless communication via reference interface.

IEC 62657-2 (this document) specifies coexistence parameters and provides its descriptions. A set of characteristic parameters, influencing parameters and statistics parameters is defined to characterize the wireless industrial automation for coexistence management. The document provides coexistence management process utilizing a set of parameters.

IEC 62657-3 provides the formal description of coexistence system that helps to establish an automated coexistence management system. The document specifies the system elements, properties, interfaces and relationships between influencing parameters and characteristic parameters specified in IEC 62657-1 and IEC 62657-2.

IEC 62657-4 specifies a concept and methods for central coordination (CC) of automation applications using wireless communications to extend the coexistence management according to IEC 62657-2. It establishes system elements, interfaces, and relationships for a central coordination. Functions, data, and data exchange for assessing and maintaining the coexistence state are specified.

A.3 Parameter usage in coexistence management process in IEC 62657-2

The characteristic parameters and influencing parameters are derived from practical considerations of coexistence management. As illustrated in Figure A.1, the parameters play an important role in the conceptual model of the coexistence management defined in IEC 62657-2.

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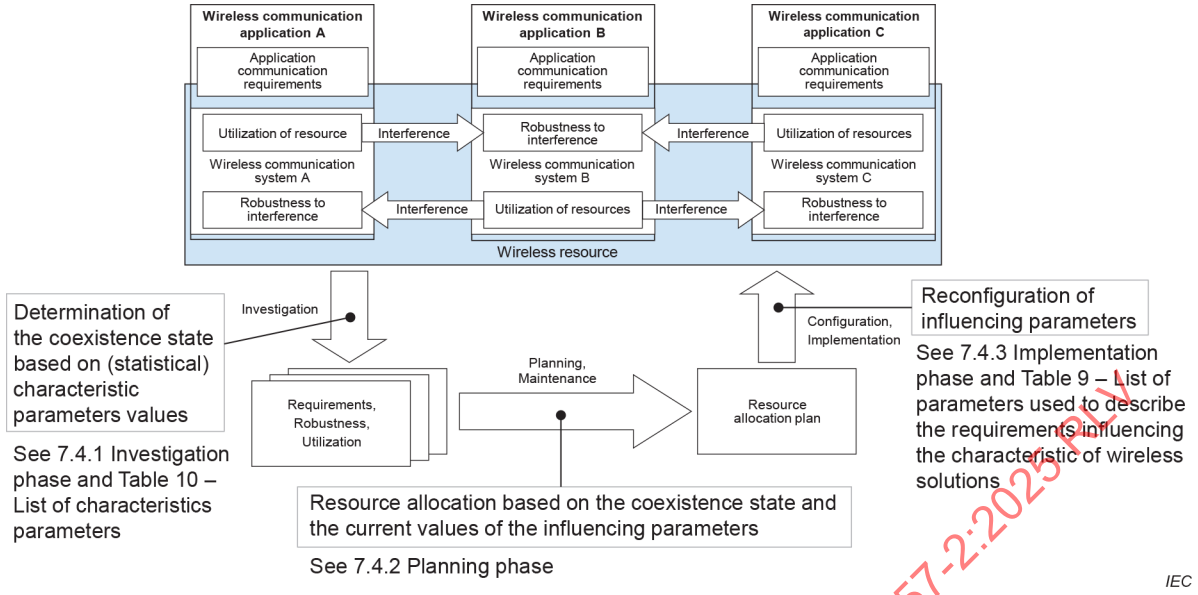

Figure A.1 – Usage of parameters in IEC 62657-2

Each parameter can be used for different purposes. In principle, a parameter can be used to make three different statements: to formulate a requirement, to make a promise or to describe a current state. Consequently, for each parameter, a distinction shall be made between the required value, the assured value and the current value at a certain point in time. Instead of a single value, a value range can be relevant. If a parameter is a random variable, it shall be specified which statistical parameter the given value corresponds to, for example the mean value or the maximum value.

Characteristic parameters and influencing parameters of wireless communication devices and systems, defined in IEC 62657-2, should be considered throughout the life cycle of these devices and systems.

Already in the design phase of a wireless automation device, target values or ranges of values for the device-specific influencing parameters according to 6.4.3 are specified and implemented for a specific device type. Sometimes not all parameter values of a wireless module are provided by its manufacturer. The manufacturers of the wireless automation device should request those parameter values.

The more options the wireless device provides for adjusting influencing parameters such as the transmission power, the frequency range, and/or the time of use of the radio resource, the more effective are the opportunities for coexistence management. Wherever possible, adjustments should also be made possible during the active operating phase of the wireless devices.

In addition to the influencing parameters, manufacturers should also provide values for characteristic parameters according to 6.3.3, to be determined by performance tests. For an automated coexistence management, the provision of characteristic parameter values according to 6.3.3 in the wireless devices is of decisive importance. There are various possibilities to provide the characteristic values, for example, per logical link or per device, individually or in pre-processed form.

For coexistence management, the manufacturer of a wireless automation device should provide the assured values of a device type for the characteristic parameters according to 6.3.3 and for the influencing parameters according to 6.4.3 in a suitable manner.

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The designer of a distributed automation system, interconnected with a wireless communication system, specifies required values for the system and its devices. The system is then designed according to 7.4.2 based on the assured values of the parameters provided for the distributed automation system, the radio environment and the wireless communication system and its devices. The assured values for the parameters of the radio environment should be determined according to 7.4.1.

Table A.1 shows an example of parameter usage in coexistence management process where a coexistence state below the margin during operation and then the maintenance process is initiated. Relevant parameters are used in each phase of the coexistence management process shown in Table A.1.

Table A.1 – Example for parameters usage in coexistence management process

Coexistence management process		Coexistence management parameters		
		Distributed automation system	Radio environment	Wireless communication system
1.Investigation phase	Investigate actual state in respect of operating wireless applications	– General plant characteristic parameters (see 6.2.2, and Table 22)		
	Identify free and occupied spectrum resources		– Active environmental influences parameters (see 6.2.4 , Table 22 and Table 30) – Passive environmental influences parameters (see 6.2.3, and Table 22)	
	Select wireless communication system and investigate capabilities against the requirements	– Application communication requirements parameters (see 6.3, and Table 23)		– Wireless system type and wireless device type parameters (see 6.4, Table 25 and Table 26)
2. Planning phase	Radio field planning and profile development	– Application communication requirements parameters (see 6.3 and Table 23)	– Active environmental influences parameters (see 6.2.4, Table 22 and Table 30) – Passive environmental influences parameters (see 6.2.3, and Table 22)	– Wireless communication system parameters (see 6.4, 6.5, Table 25, Table 26, Table 27 and Table 28)
	Planning of the radio resource allocation			
3. Implementation phase	Installing and commissioning wireless applications	– Application communication requirements parameters (see 6.3, and Table 23)		– Wireless communication system parameters (see 6.4, 6.5, Table 25, Table 26, Table 27 and Table 28)
	Approve radio resource allocation plan and implement spectrum resource allocation	– Application communication requirements parameters (see 6.3, and Table 23)		– Wireless communication system parameters (see 6.4, 6.5, Table 25, Table 26, Table 27 and Table 28)

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Coexistence management process		Coexistence management parameters		
		Distributed automation system	Radio environment	Wireless communication system
4. Operation phase	Monitoring radio environment		– Active environmental influences parameters (see 6.2.4, Table 22 and Table 30) – Passive environmental influences parameters (see 6.2.3, and Table 22)	
	Monitoring characteristic parameters	– Performance requirements parameters (see 6.3.3, and Table 23) – Statistical values of characteristic parameters (see 6.6 and Table 29)		
	Initiate maintenance process or go to investigation phase			– Wireless solution parameters (see 6.5, Table 27 and Table 28)

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A.4 Parameters usage among the IEC 62657 series

Figure A.2 illustrates the use of coexistence parameters defined in some of the parts and clauses of the IEC 62657 series.

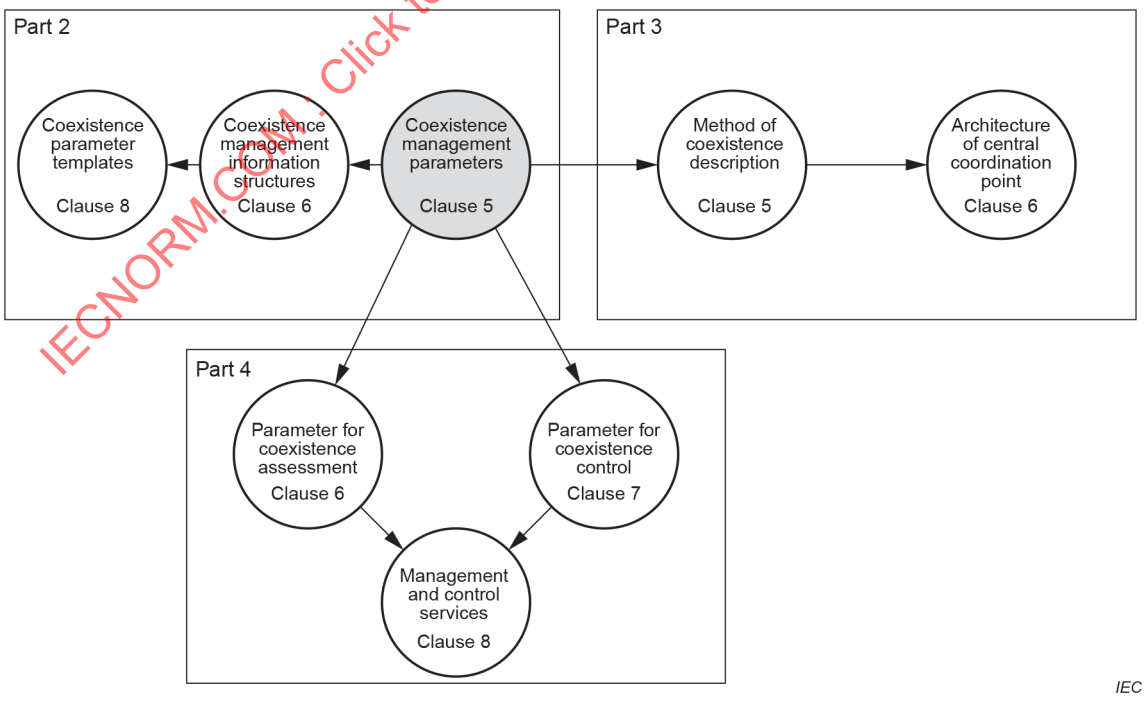

Figure A.2 – Parameter usage among the IEC 62657 series

In IEC 62657-2:2024:

- Clause 5 lists characteristic and influencing parameters relevant in a coexistence management process in alphabetic order and describes them in detail. These parameters are relevant to specify the automation communication requirements, to describe conditions within the area of operation and to characterize wireless devices and systems.
- Clause 6 specifies the structuring of coexistence management parameters according to usage dimensions. This describes which parameters are applied in which context.
- Clause 8 provides templates for coexistence parameters defined in Clause 5 and structured in Clause 6 from a coexistence management point of view. These templates can be used to describe a specific object of the items relevant for the coexistence management by assigning values or value ranges to the parameters.

In IEC 62657-3:2022:

- Clause 5 provides a class model for wireless coexistence management. The relevant classes of the model and their relationships are described. The parameters described in IEC 62657-2 are attributes of the classes.
- Clause 6 gives guidance on how to use the class model defined in Clause 5 for implementing an automated collaborative coexistence management with central coordination point as one possible implementation.

In IEC 62657-4:—:

- Clause 6 summarises the characteristic parameters to be used by an automated collaborative coexistence management system with central coordination point (CCP system) to assess the wireless coexistence state.
- Clause 7 summarises influencing parameters to be used by the CCP system to control the wireless coexistence state.
- Clause 8 defines management and control services for exchanging coexistence management data between the elements of a CCP system. The parameters described in IEC 62657-2 are attributes of the service primitives.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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RÉSEAUX INDUSTRIELS – COEXISTENCE DES SYSTÈMES SANS FIL –

Partie 2: Gestion de coexistence

AVANT-PROPOS

1) La Commission Électrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. À cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
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L'IEC 62657-2 a été établie par le sous-comité 65C: Réseaux industriels, du comité d'études 65 de l'IEC: Mesure, commande et automation dans les processus industriels. Il s'agit d'une Norme internationale.

Cette quatrième édition annule et remplace la troisième édition parue en 2022. Cette édition constitue une révision technique.

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Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) certaines définitions et spécifications des paramètres de coexistence ont été alignées afin de faciliter ultérieurement leur ajout dans le dictionnaire de données communes de l'IEC (CDD de l'IEC) géré par l'IEC;

b) certaines définitions et spécifications ont été alignées pour des raisons de cohérence sur les nouvelles IEC 62657-3 et IEC 62657-4;

c) l'édition 3 du présent document a été publiée en juin 2022. Des commentaires ont été formulés au cours des dernières étapes d'élaboration du présent document pour demander des explications concernant la structure des parties de la série IEC 62657 et les liens qui existent entre elles. Le traitement de ces commentaires a été reporté jusqu'à une prochaine édition, autrement dit la présente édition.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
65C/1329/FDIS	65C/1337/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 62657, publiées sous le titre général *Réseaux industriels – Coexistence des systèmes sans fil*, se trouve sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
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INTRODUCTION

L'ensemble du marché des solutions de communication sans fil représente une vaste gamme d'applications, dont les exigences de performances et de fonctionnement sont différentes. Au sein de ce marché global, le domaine d'automatisation industrielle peut inclure:

- le contrôle de procédés, par exemple dans les secteurs suivants de l'industrie:
  - hydrocarbures, raffinage;
  - chimie;
  - pharmacie;
  - extraction minière;
  - pâte et papier;
  - eaux et eaux usées;
  - acier;
- l'énergie électrique comme:
  - la production électrique (par exemple: éolienne);
  - la transmission et la distribution de puissance (réseau);
- l'automatisation d'usine, par exemple dans les secteurs industriels suivants:
  - alimentaire;
  - automobile;
  - machinerie;
  - semiconducteurs.

Les exigences d'automatisation industrielle pour les systèmes de communication sans fil sont différentes de celles, par exemple, des marchés des télécommunications, des marchés commerciaux et des marchés grand public. Ces exigences d'automatisation industrielle sont identifiées et fournies dans l'IEC 62657-1.

Les locaux industriels peuvent contenir une variété de technologies de communication sans fil et d'autres sources d'émission radioélectrique.

Le présent document s'adresse aux concepteurs et responsables d'usines de production et de transformation, aux intégrateurs systèmes et aux ingénieurs-mécaniciens qui doivent intégrer et démarrer des systèmes sans fil dans des machines et des installations, ainsi qu'aux fabricants de solutions sans fil pour l'industrie. Il vise en particulier à promouvoir l'échange d'informations entre les ingénieurs d'automatisation et les ingénieurs de radiocommunication.

De nombreuses applications d'automatisation industrielle sans fil se trouvent également dans des environnements physiques sur lesquels l'exploitant/le propriétaire peut avoir le contrôle, c'est-à-dire au sein d'une installation physique contenant des appareils d'émission radioélectrique dont le fonctionnement est contrôlé par une seule entité. Cela permet de développer des stratégies de gestion sans fil, ce qui s'avère impossible pour les équipements installés dans les espaces publics ou d'autres zones non gérées.

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En automatisation industrielle, de nombreux systèmes de communication sans fil peuvent fonctionner dans un même lieu. Des exemples de ces systèmes de communication sont spécifiés dans l'IEC 62591 [1][1] (WirelessHART®[2]), l'IEC 62601 [2] (WIA-PA) et l'IEC 62734 [3] (ISA100.11a). Tous ces systèmes de communication utilisent l'IEEE 802.15.4 [4] pour les applications de contrôle de procédés. D'autres exemples de systèmes de communication sans fil sont spécifiés dans les profils de communication de la série IEC 61784-1 [5] et de la série IEC 61784-2 [6] qui s'appuient sur l'IEEE 802.11 [7] et l'IEEE 802.15.1 [8] pour les applications d'automatisation d'usine. Contrairement aux bus de terrain filaires, les appareils de communication sans fil peuvent interférer avec d'autres dans les mêmes locaux ou le même environnement et se perturber mutuellement. D'autres sources d'énergie radioélectrique dans ces bandes, souvent à des niveaux d'énergie élevés, sont les appareils de production de chaleur industrielle rayonnée, les appareils de soudage du plastique, les lampes à plasma et les appareils de rayonnement par microondes.

De toute évidence, en l'absence de méthode de gestion de la coexistence de ces différents émetteurs, il serait difficile de s'assurer que ces systèmes sans fil satisfont aux exigences de criticité temporelle et de performances d'automatisation industrielle.

Le présent document décrit la gestion de radiosources indépendantes qui utilisent le même support de transmission. Il ne traite pas de la gestion dans un système de communication sans fil. Il est admis par hypothèse que celle-ci est réglementée par la norme d'un système sans fil, par exemple au moyen d'un mécanisme de contrôle d'accès au support.

La série IEC 62657 se compose de quatre parties:

- Partie 1: Exigences de communication sans fil et considérations relatives au spectre,
- Partie 2: Gestion de coexistence,
- Partie 3: Description formelle de la gestion automatisée de la coexistence et recommandations d'application,
- Partie 4: Gestion de coexistence avec coordination centralisée des applications sans fil.

L'IEC 62657-1 fournit les exigences générales en matière d'automatisation industrielle et les considérations relatives au spectre qui servent de fondement aux solutions de communication industrielles. Le présent document spécifie la gestion de coexistence des appareils sans fil afin d'assurer des performances prévisibles. Il est destiné à faciliter l'harmonisation de futures adaptations à des règlements internationaux, nationaux et locaux.

Le présent document stipule le concept et le processus de gestion de coexistence. À partir du processus de gestion de coexistence, une assurance prévisible de la coexistence peut être obtenue pour un spectre donné, avec certaines exigences d'application. Le présent document décrit des principes de gestion des brouillages mutuels potentiels qui pourraient se produire en raison du fonctionnement de plusieurs appareils sans fil dans une installation.

Le présent document fournit des recommandations aux utilisateurs de systèmes sans fil pour le choix et le bon usage de ces systèmes. Dans l'offre d'appareils sans fil sur le marché, elle aide également les fournisseurs en décrivant les comportements des appareils sans fil qui composent les systèmes sans fil conformes aux exigences de l'application.

Le présent document s'appuie sur des analyses de nombreuses Normes internationales consacrées à des technologies particulières. L'objet du présent document n'est pas d'inventer de nouveaux paramètres, mais d'utiliser ceux déjà définis et de s'affranchir de la technologie.

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1 Les chiffres entre crochets renvoient à la Bibliographie.

2 WirelessHART® est l'appellation commerciale d'un produit distribué par FieldComm Group (voir www.fieldcommgroup.org.). Cette information est donnée à l'intention des utilisateurs du présent document et ne signifie nullement que l'IEC approuve l'emploi du produit ainsi désigné. Des produits équivalents peuvent être utilisés s'il est démontré qu'ils aboutissent aux mêmes résultats.

RÉSEAUX INDUSTRIELS – COEXISTENCE DES SYSTÈMES SANS FIL –

Partie 2: Gestion de coexistence

1 Domaine d'application

La présente partie de l'IEC 62657:

- spécifie les hypothèses, concepts, paramètres et procédures de base qui permettent la coexistence de communications sans fil;
- spécifie les paramètres de coexistence et comment ils sont utilisés dans une application qui exige une coexistence sans fil;
- fournit les lignes directrices, exigences et meilleures pratiques en matière de disponibilité et de performance des communications sans fil dans une installation d'automatisation industrielle. Elle couvre le cycle de vie de la coexistence de communications sans fil;
- facilite la tâche des personnes appelées à faire face aux aspects fondamentaux à chaque phase du cycle de vie de la gestion de coexistence de communications sans fil dans une installation d'automatisation industrielle. Les aspects du cycle de vie incluent: la planification, la conception, l'installation, la mise en œuvre, le fonctionnement, la maintenance, l'administration et la formation;
- fournit une référence commune sur la coexistence de communications sans fil pour des sites d'automatisation industrielle sous la forme de ligne directrice homogène aidant les utilisateurs à évaluer et mesurer les efforts de leur installation;
- traite des aspects fonctionnels de la coexistence de communications sans fil concernant tant l'organisation statique homme-outil que l'autoorganisation dynamique du réseau.

Le présent document apporte une contribution majeure aux règlements nationaux et régionaux en fournissant un appui pour respecter les exigences en utilisant la gestion de coexistence.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 62443 (toutes les parties), *Sécurité des systèmes d'automatisation et de commande industriels*

IEC 62657-1:2017, *Réseaux de communication industriels – Réseaux de communication sans fil – Exigences de communication sans fil et considérations relatives au spectre*

IEC 62657-3:2022, *Réseaux industriels – Coexistence des systèmes sans fil – Partie 3: Description formelle de la gestion automatisée de la coexistence et recommandations d'application*

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IEC 62657-4:—, *Réseaux industriels – Coexistence des systèmes sans fil – Partie 4: Gestion de coexistence avec coordination centralisée des applications sans fil*[3]

3 Termes, définitions, abréviations et conventions

3.1 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/ [9]
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1.1
influence environnementale active
influence sur la propagation du signal par brouillage de l'application de communication sans fil ou de l'application sans fil

3.1.2
brouillage dans le canal adjacent
brouillage qui se produit lorsque des appareils sans fil utilisent des canaux de fréquences adjacents

3.1.3
sélectivité pour le canal adjacent
aptitude d'un récepteur radioélectrique à répondre au signal utile et à renvoyer des signaux dans des canaux de fréquences adjacents

3.1.4
gain d'antenne
mesure de l'efficacité d'une antenne qui exprime le rapport de la puissance exigée en entrée d'une antenne de référence sur la puissance fournie en entrée de l'antenne donnée pour atteindre la même intensité de champ à la même distance dans une direction donnée

3.1.5
caractéristique de rayonnement de l'antenne
variation de l'intensité de champ d'une antenne comme une fonction angulaire par rapport à l'axe

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[3] En cours d'élaboration. Stade au moment de la publication: IEC/FDIS 62657-4:2024.

3.1.6
type d'antenne
type de partie d'une installation d'émission ou de réception d'ondes radioélectriques destinée à assurer le couplage entre un émetteur ou un récepteur et le milieu où se propagent les ondes radioélectriques

Note 1 à l'article: Dans chaque cas particulier, il convient de spécifier le point considéré comme accès de l'antenne ou comme sa jonction avec l'émetteur ou le récepteur.

Note 2 à l'article: Si l'émetteur ou le récepteur est relié à l'antenne par une ligne d'alimentation, l'antenne peut être considérée comme un dispositif qui permet de passer d'un régime d'ondes guidées à un régime d'ondes libres et inversement.

[SOURCE: IEC 60050-712:1992, 712-01-01, modifié – Le terme "antenne" a été remplacé par "type d'antenne" et "partie d'une installation" a été remplacé par "type de partie d'une installation" au début de la définition.] [10]

3.1.7
exigences de communication de l'application
exigences quantitatives qui spécifient les conditions exigées et les caractéristiques de solution de communication sans fil exigées au niveau de l'interface de communication qui sont respectées afin d'atteindre l'objectif de l'application d'automatisation

3.1.8
zone de fonctionnement
propriétés distinctives de la zone dans laquelle le système de communication sans fil est en fonctionnement

3.1.9
gestion de coexistence collaborative automatisée
gestion de coexistence collaborative prise en charge par un outil avec des interfaces définies entre l'outil et le système de communication sans fil

Note 1 à l'article: L'outil peut être conforme à l'IEC 62657-4.

3.1.10
application d'automatisation
application d'automatisation industrielle
application de mesure et de commande automatique dans le domaine de l'automatisation industrielle

3.1.11
longueur des données d'application d'automatisation
longueur des données utilisateur
nombre d'octets échangés au niveau de l'interface de référence

3.1.12
débit binaire de la liaison physique
mesure du nombre d'éléments binaires transférés par seconde

3.1.13
liste de fréquences bloquées
liste des fréquences bloquées afin d'éviter une partie du spectre disponible

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3.1.14
topologie cellulaire
topologie de réseau cellulaire
topologie de réseau dans laquelle la zone géographique est divisée en cellules

Note 1 à l'article: Un appareil peut être déplacé d'une cellule à l'autre. Les appareils qui se trouvent dans une cellule communiquent par l'intermédiaire d'un concentrateur central. Les concentrateurs présents dans différentes cellules sont interconnectés.

3.1.15
fréquence centrale
moyenne géométrique des fréquences de coupure inférieure et supérieure d'un canal de fréquences

3.1.16
numéro de canal
nombre entier non signé qui identifie un canal de communication sans fil conformément à un document ou une loi officielle

3.1.17
occupation de canal
intervalle de temps pendant lequel le support est occupé

Note 1 à l'article: En plus du pur transfert de données utilisateur, cette durée comprend toutes les périodes nécessaires à l'exécution du protocole de transmission, par exemple pour transférer un accusé de réception.

3.1.18
coexistence
état de la coexistence de communications sans fil
dans lequel toutes les solutions de communication sans fil d'une installation qui utilisent un support commun satisfont à toutes les exigences de communication de leur application

Note 1 à l'article: Dans l'IEEE 802.15.2-2003 [11], la coexistence est définie comme une caractéristique d'un appareil.

3.1.19
gestion de coexistence
processus visant à établir et maintenir la coexistence qui comporte des mesures techniques et organisationnelles

3.1.20
informations de gestion de coexistence
paramètres du processus de gestion de coexistence sans fil

3.1.21
gestionnaire de coexistence
rôle d'une personne nommée afin de gérer la coexistence

3.1.22
planification de coexistence
processus qui décrit l'allocation de ressources de communication sans fil (périodes, fréquences, codage, espaces, etc.) pour chaque système de communication sans fil afin d'obtenir la coexistence

3.1.23
gestion de coexistence collaborative
processus de gestion de coexistence dans lequel des données sont échangées entre les applications de communication sans fil impliquées afin d'influencer la communication sans fil de sorte que toutes les applications respectent les exigences

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3.1.24
disponibilité de communication
<communication sans fil> rapport de l'intervalle de temps d'une transmission sans erreur (durée de fonctionnement) sur la période d'observation

3.1.25
disponibilité de communication
<performance> aptitude d'une entité à être en état d'accomplir une fonction exigée dans des conditions données, à un instant donné ou pendant un intervalle de temps donné, en admettant que les ressources externes exigées soient disponibles

Note 1 à l'article: La disponibilité dépend des aspects combinés de la fiabilité, de la maintenabilité et de la logistique de maintenance.

Note 2 à l'article: Les ressources externes exigées, autres que les ressources de maintenance, n'influencent pas la disponibilité de l'entité.

3.1.26
charge de communication
quantité de données utilisateur à transmettre depuis l'application d'automatisation en un certain laps de temps

3.1.27
fiabilité des communications
capacité d'une liaison physique et des nœuds correspondants à fournir des services de communications dans les conditions données pour un intervalle de temps donné

3.1.28
fréquence de coupure
limite de fréquence, la plus proche de la fréquence à laquelle la densité spectrale de puissance passe au-dessous d'un certain niveau, définissant la largeur de bande de fréquences

3.1.29
débit de données
rapport entre le nombre de données utilisateur transférées vers l'application sur l'interface de référence cible et la période d'observation

3.1.30
appareil
matériel qui fournit une connectivité et des fonctions

Note 1 à l'article: N'exclut pas les logiciels qui utilisent le matériel pour assurer des fonctions ou renforcer la connectivité.

3.1.31
type d'appareil
caractéristiques partagées d'un appareil, qui sont spécifiées de telle sorte que les appareils utilisés créent des instances de ces caractéristiques partagées

EXEMPLE Une spécification peut faire partie d'un catalogue d'un fabricant.

Note 1 à l'article: Ces caractéristiques partagées sont notamment les suivantes: technologie, conception, domaine d'application, parties ou modules relatifs à la sécurité, CEM, performances, fonctionnalité, etc.

Note 2 à l'article: Les caractéristiques partagées d'un type d'appareil peuvent être conçues, configurées et paramétrées dans une instance d'appareil.

3.1.32
distance entre des appareils sans fil
distance géographique entre les appareils dans un espace tridimensionnel

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3.1.33
système d'automatisation réparti
fonctions des appareils d'automatisation qui constituent l'étendue spatiale d'une automatisation industrielle sans fil

3.1.34
cycle de service
rapport de la séquence de l'émetteur référencée sur une période d'observation donnée pour le canal de fréquences utilisé

3.1.35
temps de tenue
temps passé à une fréquence lors d'un saut de fréquence simple d'un système à sauts de fréquence

3.1.36
puissance isotrope rayonnée équivalente
produit de la puissance fournie à l'antenne par son gain dans une direction donnée par rapport à une antenne isotrope (gain isotrope ou absolu)

Note 1 à l'article: Cette définition est reproduite avec l'autorisation de l'UIT.

[SOURCE: Règlement des radiocommunications de l'UIT, édition 2020 – Art.1 §1.161, modifié – La modification de la version anglaise pour cette définition ne concerne pas la version française.] [12]

3.1.37
puissance apparente rayonnée
produit de la puissance fournie à l'antenne par son gain par rapport à un doublet demi-onde dans une direction donnée

Note 1 à l'article: Cette définition est reproduite avec l'autorisation de l'UIT.

[SOURCE: Règlement des radiocommunications de l'UIT, édition 2020 – Art.1 §1.162, modifié – L'expression "(dans une direction donnée)" a été supprimée et la définition a été reformulée conformément aux Directives ISO/IEC Partie 2.] [12]

3.1.38
brouillage électromagnétique
EMI
détérioration du fonctionnement d'un appareil, d'une voie de transmission ou d'un système due à une perturbation électromagnétique

Note 1 à l'article: En français, les termes "perturbation électromagnétique" et "brouillage électromagnétique" désignent respectivement la cause et l'effet et il convient de ne pas les utiliser indistinctement.

Note 2 à l'article: En anglais, les termes "electromagnetic disturbance" et "electromagnetic interference" désignent respectivement la cause et l'effet et il convient de ne pas les utiliser indistinctement.

Note 3 à l'article: L'abréviation "EMI" est dérivée du terme anglais développé correspondant "electromagnetic interference".

[SOURCE: IEC 60050-161:2018, 161-01-06] [13]

3.1.39
bande de fréquences
plage du spectre de fréquences, affectée par les organisations de réglementation à des applications spécifiques ou à un groupe d'applications

Note 1 à l'article: L'UIT, en tant qu'organisation internationale de réglementation, attribue uniquement les services de radiocommunication à une plage spécifique dans le spectre de fréquences.

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3.1.40
largeur de bande de fréquences
largeur de bande
différence entre la fréquence de coupure supérieure et la fréquence de coupure inférieure

3.1.41
canal de fréquences
plage du spectre des fréquences, définie par une fréquence de coupure inférieure et une fréquence de coupure supérieure ou par une fréquence centrale et une largeur de bande de fréquences

3.1.42
séquence de saut de fréquence
séquence des canaux de fréquences utilisés pour la transmission (séquence de saut) et le temps de tenue

3.1.43
plan d'extension future
installation possible de nouvelles solutions de communication sans fil et construction de nouveaux bâtiments qui peuvent avoir une incidence sur la coexistence

3.1.44
caractéristiques générales de l'installation
paramètres qui caractérisent l'installation en général par rapport à toutes les applications de communication sans fil

3.1.45
dimensions géographiques de l'installation
longueur, largeur et hauteur de l'espace prévu du système sans fil

3.1.46
capacité de géolocalisation
capacité d'un équipement à déterminer sa position géographique

3.1.47
application industrielle, scientifique et médicale
fonctionnement d'un équipement ou d'appareils conçus pour générer et utiliser en local l'énergie radioélectrique pour les besoins industriels, scientifiques, médicaux, domestiques ou des besoins similaires, à l'exclusion des applications dans le domaine des télécommunications

Note 1 à l'article: Cette définition est reproduite avec l'autorisation de l'UIT.

[SOURCE: Règlement des radiocommunications de l'UIT, édition 2020 – Art.1 §1.15] [12]

3.1.48
réseau de communication industriel
sous-systèmes de communication de données utilisés pour le mesurage et la commande de processus industriel, ainsi que sur les systèmes d'instrumentation utilisés à des fins de recherche, développement ou essai

3.1.49
appareil d'infrastructure
appareil essentiel à la construction d'un système de communication sans fil conformément à une technologie ou à une norme, mais sans interface avec l'application d'automatisation

EXEMPLE Routeur ou stations de base sans interface avec des réseaux industriels filaires ni fonction d'application d'automatisation.

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3.1.50
initiation de la transmission de données
méthode qui spécifie de quelle manière l'application lance le transfert de données

3.1.51
brouillage
brouillage radioélectrique
effet, sur la réception dans un système de communication sans fil, d'une énergie non désirée due à une émission, à un rayonnement ou à une induction (ou à une combinaison de ces émissions, rayonnements ou inductions), se manifestant par une dégradation de la qualité de transmission, une déformation ou une perte de l'information que l'on aurait pu extraire en l'absence de cette énergie non désirée

Note 1 à l'article: Cette définition est reproduite avec l'autorisation de l'UIT.

[SOURCE: Règlement des radiocommunications de l'UIT, édition 2020 – Art.1 §1.166, modifié – La modification de la version anglaise pour cette définition ne concerne pas la version française.] [12]

3.1.52
type de brouillage
type d'énergie indésirable causé par une certaine source ou application

Note 1 à l'article: Une source EMI, une application industrielle, scientifique et médicale (ISM) ou une application sans fil non industrielle sont des exemples de types de brouillages.

3.1.53
sensibilité d'intermodulation
niveaux de signaux brouilleurs hors bande qui, mélangés dans l'extrémité frontale du récepteur, donnent un produit non linéaire de troisième ordre dans la bande

3.1.54
intervisibilité
propriété d'une liaison logique qui décrit une possible influence sur la propagation du signal radiofréquence par obstruction, réfraction ou réflexion

EXEMPLE La ligne visuelle (LOS), la ligne sans visibilité directe (NLOS) et la ligne visuelle obstruée (OLOS) entre les appareils sont des paramètres possibles.

3.1.55
immunité
capacité d'une entité à continuer à fonctionner correctement en cas de brouillage, jusqu'à un certain niveau de brouillage, et à résister lorsque ce niveau est dépassé

Note 1 à l'article: L'immunité d'une entité est obtenue en ajoutant à la robustesse de l'entité la capacité à résister aux brouillages.

3.1.56
gigue
variation temporelle d'une occurrence attendue

Note 1 à l'article: Les variations de la durée de transmission et du temps d'actualisation en sont des exemples.

3.1.57
longueur des données utilisateur par intervalle de transfert
nombre d'octets envoyés au cours d'un intervalle de transfert, les octets ajoutés compte tenu des exigences du protocole de communication sans fil étant soustraits

Note 1 à l'article: La longueur des données de l'application a une incidence sur la charge de communication et peut causer la séparation temporelle des systèmes de communication sans fil.

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3.1.58
cycle de vie
période entre le début de la phase de développement d'un type de produit et l'abandon du produit

[SOURCE: IEC 62890:2020, 3.1.22] [14]

3.1.59
restrictions imposées par les voisins de l'installation
description des voisins de l'installation susceptibles d'imposer des limites à la communication sans fil

EXEMPLE Une ou plusieurs radiosources à forte puissance.

3.1.60
topologie linéaire
topologie de réseau linéaire
topologie dans laquelle les nœuds sont connectés en série, deux nœuds étant connectés à un seul autre nœud et tous les autres étant connectés à deux autres nœuds (en d'autres termes, la connexion forme une ligne)

Note 1 à l'article: Cette topologie correspond à celle d'un anneau ouvert.

[SOURCE: IEC 61918:2018, 3.1.51, modifié – Un terme admis a été ajouté.] [15]

3.1.61
ligne visuelle
LOS
chemin de propagation d'un signal radiofréquence (RF) qui n'est pas masqué (partiellement ou totalement) par des obstacles

Note 1 à l'article: L'abréviation "LOS" est dérivée du terme anglais développé correspondant "line of sight".

3.1.62
liaison logique
relation de communication orientée application qui permet de transmettre des données utilisateur entre un point d'extrémité logique de l'interface de référence d'un appareil source et un point d'extrémité logique de l'interface de référence d'un appareil cible

3.1.63
fréquence de coupure inférieure
première fréquence sous la fréquence de puissance maximale à laquelle la densité spectrale de puissance chute sous un niveau donné

3.1.64
nombre maximal de retransmissions
nombre maximal de fois que la pile de communication peut retransmettre les données utilisateur automatiquement en raison d'erreurs de transmission

3.1.65
mécanismes d'adaptabilité
mesures visant à modifier un ou plusieurs des paramètres fonctionnels des systèmes afin d'améliorer leur insensibilité aux brouillages et de réduire le plus possible l'utilisation du support

3.1.66
mécanisme de contrôle d'accès au support
technique de transmission pour l'accès au support

Note 1 à l'article: Le CSMA et/ou le AMRT constituent des exemples d'un tel mécanisme.

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3.1.67
facteur d'utilisation moyen,
mesure visant à évaluer la quantité de ressources (puissance et temps) utilisées par des équipements non adaptatifs

3.1.68
message
suite ordonnée d'octets destinée à communiquer des informations

Note 1 à l'article: Lors du transport des informations communiquées, les octets peuvent être répartis dans plusieurs paquets.

[SOURCE: ISO/IEC 2382-16:1996, 16.02.01, modifié – L'expression "suite de caractères" a été remplacée par "suite d'octets", une Note à l'article a été ajoutée.] [16]

3.1.69
facteur de pertes de messages
rapport du nombre de messages, transférés de l'application vers l'interface de référence chez le producteur, et du nombre de messages transférés de l'interface de référence à l'application chez le client

3.1.70
topologie maillée
topologie de réseau maillée
topologie de réseau dans laquelle des chemins redondants d'acheminement physiquement différents sont disponibles entre chaque paire de nœuds du réseau

Note 1 à l'article: La topologie maillée sans fil est utilisable pour étendre la couverture par une fonctionnalité de sauts multiples et/ou pour faciliter la fiabilité des communications par la fourniture de chemins redondants entre les appareils.

[SOURCE: IEC 62734:2014, 3.1.2.95, modifié – Un terme admis a été ajouté.] [3]

3.1.71
modulation
processus de variation d'une ou de plusieurs propriétés d'une forme d'onde périodique avec un signal de modulation contenant les informations à transmettre

3.1.72
condition environnementale naturelle
condition d'environnement de l'appareil sans fil et du système sans fil

Note 1 à l'article: Il s'agit, par exemple, de la température, de l'humidité, de la pression atmosphérique.

3.1.73
réseau
tous les supports, connecteurs, répéteurs, routeurs, passerelles et éléments de communication du nœud associés permettant d'interconnecter un ensemble donné d'appareils de communication

[SOURCE: IEC 61158-2:2023, 3.1.30] [17]

3.1.74
topologie de réseau
topologie d'un réseau
configuration des positions relatives et des interconnexions des différents éléments du réseau

[SOURCE: IEC 61918:2018, 3.1.81, modifié – La "Note 1 à l'article" a été supprimée et un terme admis a été ajouté.] [15]

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3.1.75
nœud
appareil physique ou logique adressable attaché au réseau

[SOURCE: IEC 62591:2016, 3.2.75] [1]

3.1.76
sans visibilité directe
NLOS
chemin de propagation d'un signal radiofréquence (RF) qui est masqué (partiellement ou totalement) par des obstacles, ce qui rend le passage du signal radiofréquence difficile

Note 1 à l'article: Les obstacles courants entre les émetteurs radioélectriques et les récepteurs radioélectriques sont les grands bâtiments, les arbres, le paysage physique et les conducteurs électriques à haute tension. Alors que certains obstacles absorbent le signal radiofréquence, d'autres le reflètent, mais tous limitent la capacité de transmission des signaux.

Note 2 à l'article: L'abréviation "NLOS" est dérivée du terme anglais développé correspondant "non-line of sight".

3.1.77
nombre de messages perdus consécutifs
nombre de messages qui n'ont pas été reçus dans l'intervalle entre la réception de deux messages

3.1.78
ligne visuelle obstruée
OLOS
chemin de propagation d'un signal radiofréquence (RF) qui est masqué (partiellement ou totalement) par des obstacles, ce qui rend le passage du signal radiofréquence difficile

Note 1 à l'article: Une intrusion dans la zone la plus intérieure de la première zone Fresnel entraîne une diminution ou une atténuation du niveau du signal reçu. Au point où l'obstruction devient tangente au chemin de la ligne visuelle, les pertes de signal atteignent 6 dB ou plus. La meilleure pratique consiste à maintenir au moins 60 % du rayon de la première zone de Fresnel exempt d'obstructions afin d'éviter l'atténuation du signal reçu.

Note 2 à l'article: L'abréviation "OLOS" est dérivée du terme anglais développé correspondant "obstructed line of sight".

3.1.79
durée de fonctionnement entre défaillances
somme des durées de fonctionnement entre deux défaillances successives sur une liaison logique où le message est considéré comme un élément réparable dans le sens où il peut être répété dans la durée de survie

3.1.80
autre utilisateur de fréquence
utilisateur qui génère et utilise l'énergie radioélectrique sans aucun objectif de télécommunication

Note 1 à l'article: Il s'agit, par exemple, d'une soudeuse, d'un moteur électrique ou d'un convertisseur de fréquence.

3.1.81
émission hors bande
émission sur une ou des fréquences situées en dehors de la largeur de bande nécessaire, mais en son voisinage immédiat, due au processus de modulation, à l'exclusion des rayonnements non essentiels

Note 1 à l'article: Cette définition est reproduite avec l'autorisation de l'UIT.

[SOURCE: Règlement des radiocommunications de l'UIT, édition 2020 – Art.1 §1.144] [12]

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3.1.82
mouvement des objets
spécification de la trajectoire des biens mobiles qui peuvent avoir une influence significative sur les conditions de propagation radioélectrique

Note 1 à l'article: Des véhicules, des grues ou des personnes sont des exemples d'objets mobiles.

3.1.83
période d'observation
durée de la supervision des événements

Note 1 à l'article: La réception de données utilisateur ou l'utilisation d'un support de transmission par un appareil sans fil sont des exemples pour lesquels la période d'observation est le paramètre de référence utilisé pour calculer la vitesse de transfert de données et le cycle de service.

3.1.84
paquet
bits regroupés et formatés émis simultanément à travers le support physique

[SOURCE: IEC 62591:2016, 3.2.77] [1]

3.1.85
influence environnementale passive
influence des caractéristiques de la zone de fonctionnement, des dimensions de l'espace de fonctionnement, de l'intervisibilité, des objets mobiles et des conditions environnementales naturelles sur la propagation du signal

3.1.86
exigences de performances
exigences qui décrivent la réactivité et les défaillances nécessaires pour remplir l'objet de l'application d'automatisation

3.1.87
liaison physique
relation entre les émetteurs-récepteurs radioélectriques (points limites physiques) de deux appareils sans fil

3.1.88
installation
aménagement géré, qui comporte en général un périmètre de protection physique, hébergeant le procédé physique, le fonctionnement, le personnel et les équipements

3.1.89
topologie point à point
topologie de réseau point à point
topologie dans laquelle deux nœuds sont directement connectés l'un à l'autre

3.1.90
position de l'appareil sans fil
position géographique de l'espace tridimensionnel dans les coordonnées absolues ou relatives dans lesquelles se trouve l'appareil

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3.1.91
densité spectrale de puissance
répartition en fonction de la fréquence de la puissance par unité de largeur de bande des composantes spectrales d'un signal ou d'un bruit à spectre continu et de puissance moyenne finie

[SOURCE: IEC 60050-713:1998, 713-09-12, modifié – Le terme admis et l'abréviation ont été supprimés.] [18]

3.1.92
objet de l'application d'automatisation
récapitulatif de l'application d'automatisation prise en charge par le système sans fil dans la mesure nécessaire pour donner une vue d'ensemble utile des exigences imposées au système sans fil

3.1.93
canal radioélectrique
modèle de propagation radioélectrique qui tient compte des caractéristiques du canal de fréquences, des conditions environnementales, de la distance entre les appareils sans fil, des caractéristiques d'antenne

3.1.94
environnement radioélectrique
environnement de propagation du signal radiofréquence avec ses influences environnementales passives et ses influences environnementales actives

3.1.95
ressource radioélectrique
moyen utilisé par de nombreuses solutions de communication sans fil pour leur transmission de signal radiofréquence

3.1.96
robustesse radioélectrique
aptitude d'une communication sans fil à accomplir la fonction prévue malgré la présence du brouillage d'autres applications sans fil actives dans sa sphère d'influence

Note 1 à l'article: La signification de ce terme est identique à celle du terme "coexistence" défini dans l'IEEE 802.15.2:2003, 3.1.2 [11].

3.1.97
indication de puissance du signal reçu
valeur relative de l'intensité de champ au niveau du récepteur des appareils sans fil, qui dépend de la mise en œuvre correspondante d'une technologie de radiocommunication

3.1.98
blocage de récepteur
effet d'un fort signal brouilleur sur la capacité du récepteur à détecter un signal utile faible

3.1.99
niveau d'entrée maximal du récepteur
puissance de signal maximale que le système peut tolérer sans distorsion du signal

3.1.100
sensibilité de récepteur
puissance de signal minimale pour recevoir des données avec un taux d'erreur sur les bits donné

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3.1.101
interface de référence
interface visible entre une application d'automatisation et la fonction de communication sans fil

Note 1 à l'article: Il n'existe pas d'interface unanimement définie pour le mesurage et l'automatisation. L'interface de l'appareil est susceptible d'être une interface matérielle série ou parallèle, une interface de bus de terrain, une interface logicielle ou une interface série, parallèle, discrète et analogique.

3.1.102
règlement régional des radiocommunications
règlement relatif aux paramètres de coexistence importants, comme la bande de fréquences et la puissance de sortie, en fonction de la région dans laquelle il est prévu d'utiliser l'application sans fil

3.1.103
déplacement relatif
position d'un appareil sans fil dans le temps

3.1.104
exigences influençant les caractéristiques des solutions sans fil
exigences de communication de l'application qui ont une incidence sur les performances des solutions sans fil et, donc, sur l'état de la coexistence

3.1.105
temps de réponse
intervalle de temps entre l'instant où le premier bit ou octet de données utilisateur d'un message est transmis à l'interface de référence d'un émetteur et l'instant où le dernier bit ou octet du message de confirmation est transmis à l'interface de communication du même émetteur, qui peut être affecté à la demande

3.1.106
topologie en anneau
topologie de réseau en anneau
réseau actif dans lequel chaque nœud est connecté en série à deux autres nœuds

[SOURCE: IEC 61918:2018, 3.1.71, modifié – Le terme "anneau" a été remplacé par "topologie en anneau" et un terme admis a été ajouté.] [15]

3.1.107
robustesse
capacité d'une entité à continuer à fonctionner correctement en cas de brouillage, jusqu'à un certain niveau de brouillages

Note 1 à l'article: La robustesse d'une entité peut être accrue en modifiant un ou plusieurs de ses paramètres fonctionnels.

3.1.108
niveau de sécurité
catégorie d'exigences pour la cybersécurité

3.1.109
étendue spatiale de l'application
cuboïde défini par les positions et/ou le rayon de mouvement maximal des appareils d'automatisation d'un système d'automatisation réparti

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3.1.110
support partagé
ressource de bande de fréquences dans une zone particulière partagée par plusieurs applications sans fil

Note 1 à l'article: Dans les bandes industrielle, scientifique et médicale (ISM), de nombreuses applications sans fil sont utilisées. En raison de ces utilisations conjointes, le terme "support partagé" est employé dans le présent document. Les bandes de fréquences sont utilisées par différentes applications ISM et applications de communication sans fil.

3.1.111
rapport signal à l'interférence plus bruit
quotient de la puissance du signal utile et de la puissance des signaux non désirés, qui comporte le bruit et le brouillage

3.1.112
couverture spatiale du système de communication sans fil
couverture spatiale spécifiée par la longueur, la largeur et la hauteur d'un cuboïde qui englobe le système de communication sans fil

3.1.113
rayonnement non essentiel
rayonnement sur une ou des fréquences situées en dehors de la largeur de bande nécessaire et dont le niveau peut être réduit sans affecter la transmission de l'information correspondante, y compris les rayonnements harmoniques, les rayonnements parasites, les produits d'intermodulation et de conversion de fréquence, à l'exclusion des émissions hors bande

Note 1 à l'article: Cette définition est reproduite avec l'autorisation de l'UIT.

[SOURCE: Règlement des radiocommunications de l'UIT, édition 2020 – Art.1 §1.145] [12]

3.1.114
réponse parasite
sortie du récepteur en raison de signaux non désirés

Note 1 à l'article: Cela signifie que les fréquences sont en dehors du canal de fréquences réglé.

3.1.115
topologie en étoile
topologie de réseau en étoile
topologie de réseau composé d'au moins trois appareils, chacun étant connecté à un appareil central

[SOURCE: IEC 61918:2018, 3.1.77, modifié – Le terme "topologie" a été ajouté, "point central (qui peut être actif ou passif)" a été remplacé par "appareil central" et un terme admis a été ajouté.] [15]

3.1.116
durée de survie
durée pendant laquelle une application qui utilise un service de communication continue sans recevoir de message anticipé

3.1.117
télécommunication
toute transmission, émission ou réception de signes, de signaux, d'écrits, d'images, de sons ou de renseignements de toute nature, par fil, radioélectricité, optique ou autres systèmes électromagnétiques

Note 1 à l'article: Cette définition est reproduite avec l'autorisation de l'UIT.

[SOURCE: Règlement des radiocommunications de l'UIT, édition 2020 – Art.1 §1.3] [12]

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3.1.118
puissance totale rayonnée
densité de puissance spatiale intégrée sur la surface de la sphère

3.1.119
intervalle de transfert
différence temporelle entre deux transferts consécutifs de données utilisateur depuis l'application d'automatisation par le biais de l'interface de référence vers la fonction de communication sans fil

3.1.120
écart d'émission
écart entre deux utilisations successives de canal par un émetteur

3.1.121
puissance de sortie de l'émetteur
puissance totale rayonnée diminuée des pertes entre la sortie de l'émetteur et l'antenne

3.1.122
durée de transmission
intervalle de temps entre le début de la livraison du premier octet de données d'application d'un message à l'interface de communication de référence d'un producteur et la livraison du dernier octet de données d'application du même message depuis l'interface de communication de référence d'un client

3.1.123
séquence d'émetteur
durée pendant laquelle un émetteur utilise un canal de fréquences sans pouvoir être interrompu par un appareil sans fil du même système

3.1.124
gabarit spectral d'émetteur
enveloppe des valeurs maximales de la densité spectrale de puissance sur une plage de fréquences

3.1.125
topologie en arbre
topologie de réseau en arbre
topologie de réseau dans laquelle tous les nœuds sont connectés dans une combinaison de topologie linéaire et de topologie en étoile

3.1.126
temps d'actualisation
intervalle de temps entre la livraison du dernier octet de données utilisateur du message d'un producteur, depuis l'interface de référence d'un client vers l'application d'automatisation, et la livraison du dernier octet de données utilisateur du message suivant du même producteur

3.1.127
fréquence de coupure supérieure
première fréquence au-dessus de la fréquence de puissance maximale à laquelle la densité spectrale de puissance chute sous un niveau donné

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3.1.128
application sans fil
toute utilisation d'ondes électromagnétiques par des appareils ou des équipements pour générer et utiliser l'énergie radioélectrique dans un environnement radioélectrique avec des influences environnementales actives et passives

Note 1 à l'article: La définition inclut les systèmes de communication sans fil avec des fonctions de communication sans fil qui représentent un ensemble de fonctions d'automatisation réparties dans l'espace, les systèmes d'automatisation répartis avec des fonctions locales et les systèmes physiques avec des fonctions systèmes physiques.

Note 2 à l'article: La définition inclut les équipements de localisation radioélectrique.

3.1.129
communication sans fil
communication dans laquelle le transfert d'information se fait au moyen de rayonnement électromagnétique, sans utilisation de câbles ni de fibres optiques

3.1.130
application de communication sans fil
partie d'une application d'automatisation industrielle qui utilise une communication sans fil

3.1.131
solution de communication sans fil
paramètres des solutions de communication sans fil qui sont des mises en œuvre des systèmes et appareils de communication sans fil

3.1.132
densité de solutions de communication sans fil
rapport entre le nombre de solutions de communication sans fil et la couverture spatiale de l'installation

3.1.133
système de communication sans fil
ensemble d'appareils de communication sans fil, d'appareils d'infrastructure et de liaisons physiques qui communiquent par radiofréquences à l'aide de différentes topologies

3.1.134
appareil sans fil
appareil d'automatisation sans fil
équipement des applications de communication sans fil qui utilise les ondes radioélectriques pour la communication sans fil avec un autre équipement des applications de communication sans fil

3.1.135
densité d'appareils sans fil
nombre d'appareils sans fil dans la couverture spatiale du système de communication sans fil

3.1.136
paramètres de réception de l'appareil sans fil
paramètres de réception sans fil
spécification des caractéristiques du récepteur sans fil

3.1.137
solution à appareils sans fil
paramètres relatifs aux différents nœuds d'un système qui mettent en œuvre une solution de communication sans fil

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3.1.138
paramètres d'émission de l'appareil sans fil
paramètres d'émission sans fil
spécification des caractéristiques de l'émetteur sans fil

3.1.139
type d'appareil sans fil
spécification d'un appareil selon les données de catalogue

3.1.140
réseau sans fil
réseau de communication sans fil
réseau composé d'au moins deux appareils sans fil qui établissent une communication sans fil

3.1.141
solution réseau sans fil
paramètres relatifs à un réseau utilisé dans son ensemble exécutant une solution de communication sans fil

3.1.142
solution sans fil
solution de communication sans fil
mise en œuvre particulière ou exemple particulier d'un système de communication sans fil

Note 1 à l'article: Une solution sans fil peut se composer de produits issus d'un ou de plusieurs fabricants.

3.1.143
système sans fil
système de communication sans fil
ensemble d'éléments interdépendants qui permettent une communication sans fil

Note 1 à l'article: Un système sans fil est une représentation générique d'un système, tandis qu'une solution sans fil est une mise en œuvre pratique d'un système.

3.1.144
type de système sans fil
paramètres qui décrivent le type de système de communication sans fil

3.1.145
type de système sans fil et type d'appareil sans fil
paramètres qui caractérisent le modèle d'un système sans fil ou d'un appareil sans fil en fournissant les paramètres qui permettent de spécifier un type de système sans fil et un type d'appareil sans fil

3.1.146
norme ou technologie sans fil
dénomination de la norme ou de la technologie sans fil

EXEMPLE L'IEC 62591 [1], l'IEC 62601 [2] et l'IEC 62734 [3] sont des exemples de normes qui spécifient un système de communication sans fil.

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3.2 Abréviations

AFH (Adaptive Frequency Hopping)	saut de fréquence adaptatif
BFWA (Broadband Fixed Wireless Access)	accès sans fil fixe à large bande
CEPT	conférence européenne des administrations des postes et des télécommunications
CP (Communication Profile)	profil de communication conformément à la série IEC 61784-2 [6]
CSMA (Carrier Sense Multiple Access)	accès multiple avec détection de porteuse
DAA (Detect And Avoid)	détection et évitement
DAR (Detect And Reduce)	détection et réduction
DAS (Detect And Suppress)	détection et suppression
ECO (European Communications Office)	bureau européen des radiocommunications du comité des communications électroniques de la CEPT
PIRE	puissance isotrope rayonnée équivalente
CEM	compatibilité électromagnétique
EMI (Electromagnetic Interference)	brouillage électromagnétique
PAR	puissance apparente rayonnée
FI	fréquence intermédiaire
IP (Internet Protocol)	protocole Internet
ISM	industriel, scientifique et médical
TI	technologie de l'information
UIT	Union Internationale des Télécommunications
LAN (Local Area Network)	réseau local
LOS (Line Of Sight)	ligne visuelle
MLR (Message Loss Ratio)	facteur de pertes de messages
NLOS (Non-Line Of Sight)	sans visibilité directe
N/A	non applicable
OLOS (Obstructed Line Of Sight)	ligne visuelle obstruée
PCB (Printed Circuit Board)	carte de circuit imprimé
DSP	densité spectrale de puissance
RF	radiofréquence
RFID (Radio Frequency Identification)	identification par radiofréquence
RSRP (Reference Signal Received Power)	puissance de référence du signal reçu
RSRQ (Reference Signal Received Quality)	qualité de référence du signal reçu
RSSI (Received Signal Strength Indication)	indication de puissance du signal reçu
SIR (Signal-to-Interference Ratio)	rapport signal sur brouillage
AMRT	accès multiple par répartition temporelle
PTR	puissance totale rayonnée
WD	appareil sans fil
WIA-PA (Wireless Network for Industrial Automation – Process Automation)	réseau sans fil pour automatisation industrielle – contrôle de procédés

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WLAN (Wireless Local Area Network)	réseau local sans fil
ZVEI (Zentralverband Elektrotechnik- und Elektronikindustrie e.V.)	association des fabricants allemands de produits électriques et électroniques

3.3 Conventions

NOTE Les représentations graphiques des organigrammes dans les figures reposent sur l'ISO 5807 [19].

Les conventions suivantes pour les modèles de paramètres de gestion de coexistence de l'Article 8 s'appliquent:

- la colonne "Paramètre" utilise des indentations pour catégoriser certains paramètres. Les paramètres les plus à droite appartiennent au paramètre le plus à gauche immédiatement au-dessus;
- la colonne "Utilisation" spécifie si le paramètre est obligatoire, facultatif ou un choix, si un seul paramètre sur plusieurs est choisi;
- la colonne "Valeur" peut contenir une plage ou une liste de valeurs, si le paramètre permet plusieurs options. Si un paramètre n'a pas d'unité, la case de la colonne "Unité" doit alors indiquer "non applicable" (N/A).

4 Concept de coexistence en automatisation industrielle

4.1 Vue d'ensemble

La communication sans fil permet une mise en œuvre plus économique, souple et fiable de l'automatisation industrielle, tout en permettant l'utilisation de nouveaux concepts d'automatisation. Les exigences en matière de fiabilité et d'aptitude en temps réel des communications sans fil des applications d'automatisation industrielle sont généralement plus strictes que celles des applications domestiques ou bureautiques. Les applications d'automatisation industrielle peuvent également se trouver dans des installations industrielles qui présentent des niveaux de brouillages électromagnétiques (EMI) ambiants supérieurs à ceux des domaines non industriels.

Il est également nécessaire de prendre en compte les sources d'émission radioélectrique supplémentaires lors de la gestion de coexistence.

NOTE Dans certains environnements industriels, d'autres sources d'émission radioélectrique peuvent être présentes dans les mêmes bandes que celles utilisées par les systèmes de communication sans fil. Ces émetteurs peuvent inclure les appareils à émissions involontaires (les appareils à souder à puissance élevée, qui génèrent de l'énergie électromagnétique à large bande, par exemple).

Du fait de ces exigences, différents systèmes sans fil sont utilisés. Il est fort probable que plusieurs systèmes sans fil puissent fonctionner simultanément en un même lieu. Étant donné que ces systèmes sans fil partagent un support commun, il peut être admis par hypothèse que des brouillages se produisent tout au long de leur cycle de vie. Cela a une incidence sur les performances du système, y compris sa fiabilité et son aptitude à satisfaire aux exigences de réponse en temps réel. Le présent document a pour objet de faciliter l'identification des risques potentiels, et de recommander des mesures de maîtrise des risques en fonction des exigences de l'application d'automatisation. Le présent document montre également que, le plus souvent, la coexistence de plusieurs systèmes sans fil et parallèlement la gestion efficace du spectre des fréquences qui constitue une ressource limitée sont possibles sous réserve d'adopter une approche adaptée en tenant compte des exigences applicables. Pour cela, un processus qui tient compte de tous les aspects de la coexistence de systèmes sans fil, depuis la conception jusqu'à l'exploitation, en passant par la mise en service et la maintenance, est nécessaire. Ce processus, appelé "gestion de coexistence des solutions sans fil", fait l'objet du présent document. Des actions et décisions associées permettent de satisfaire aux valeurs limites revendiquées pour l'application sur l'ensemble du cycle de vie de l'installation.

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Ce processus peut être plus ou moins complexe, selon la pertinence des exigences de communication sans fil pour l'installation. Cette complexité dépend notamment des caractéristiques de l'application de communication sans fil desservie par chaque solution sans fil (commande accompagnée d'exigences strictes de réactivité en temps réel, par exemple), du nombre et de l'emplacement des solutions sans fil qui peuvent potentiellement interférer entre elles, et de la présence d'autres émetteurs radioélectriques dans les mêmes bandes.

S'il n'y a pas ou peu d'exigences relatives au système sans fil, la coexistence des solutions sans fil impose un effort plus modéré comparativement à celui nécessaire pour un système sans fil qui fait partie d'une application de commande accompagnée d'exigences strictes de réactivité en temps réel. Il est toutefois fortement recommandé d'envisager que d'autres systèmes sans fil soient susceptibles d'être ajoutés ultérieurement ou que les exigences relatives au système sans fil présent évoluent à l'avenir (en raison d'applications supplémentaires, par exemple). La conception de l'installation doit assurer que les mesures de coexistence appliquées correspondent aux exigences du système sans fil.

L'état de coexistence se caractérise par le respect, par toutes les applications de communication sans fil dans la zone étudiée, des valeurs limites de certains paramètres. Cet état de coexistence est obtenu par des actions appropriées en planification et exploitation. Il apparaît ainsi que la coexistence n'est pas une propriété immuable d'une solution sans fil, mais plutôt un état dans le cycle de vie d'une installation. À la suite de certains événements, cet état peut être quitté temporairement ou définitivement. Les valeurs limites des paramètres sont déterminées par l'application d'automatisation dans laquelle s'inscrit la communication sans fil. Une autre implication est que la gestion de coexistence doit être évaluée et établie en contexte et en plein accord avec l'application d'automatisation.

En règle générale, la coexistence de plusieurs solutions sans fil peut être obtenue en rendant orthogonales les transmissions qui proviennent de sources différentes.

Il existe trois possibilités de gestion de coexistence, a) impliquant une quantité d'heures de travail plus importante pour établir et maintenir la gestion de coexistence, et b) et c) impliquant un niveau plus élevé d'automatisation:

a) gestion de coexistence manuelle (niveau le plus bas);

b) gestion de coexistence automatisée non collaborative;

c) gestion de coexistence collaborative automatisée (niveau le plus élevé).

Les techniques automatisées, ainsi que les algorithmes sur lesquels elles s'appuient, sont généralement réparties en deux grandes catégories: les techniques collaboratives et les techniques non collaboratives.

4.2 Objectif

Le présent document porte sur les moyens qui permettent d'assurer la coexistence des systèmes sans fil pour des applications d'automatisation et de mesure. Ces applications d'automatisation industrielle peuvent être classées de différentes manières. Par exemple, dans le Tableau 1, elles sont classées selon le degré de criticité de l'application. Les efforts de gestion de coexistence peuvent varier en fonction de la classification décrite dans le Tableau 1.

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Tableau 1 – Exemple de classification des exigences de communication de l'application

Classe	Application	Exigences de communication de l'application
Sécurité fonctionnelle	Mise en œuvre d'un système lié à la sécurité dont la défaillance peut avoir des conséquences sur la sécurité des personnes et/ou de l'environnement et/ou des installations	Il convient que le protocole de communication prenne en charge la communication de sécurité fonctionnelle, et la gestion de coexistence doit être établie de manière à satisfaire à toutes les exigences du présent document.
Commande	Commande en boucle ouverte ou fermée	Il convient que le protocole de communication prenne en charge plus de disponibilité, fiabilité et criticité temporelle que dans d'autres secteurs comme celui des biens de consommation et des télécommunications. La gestion de coexistence doit être établie de manière à satisfaire à la plupart des exigences du présent document.
Surveillance	Visualisation de processus et alerte	Aucune extension particulière exigée pour le protocole de communication. En règle générale, l'application de surveillance peut reposer sur un ensemble d'exigences moins strictes. La gestion de coexistence doit être établie de manière à satisfaire à toutes ces exigences minimales.
NOTE Les termes relatifs "la plupart" et "minimales" reposent sur la description graphique donnée à la Figure 3.		

La classification des applications d'automatisation fournie avec le Tableau 1 s'appuie sur les exigences fonctionnelles de l'application de l'industrie de transformation à respecter. Cette classification peut également être adaptée dans d'autres domaines d'application.

Cependant, la criticité et les exigences de communication de l'application associées doivent être déterminées au cas par cas par le gestionnaire de coexistence.

NOTE 1 Les exigences de communication de l'application sont décrites dans l'IEC 62657-1.

Des applications, allant du lecteur radioélectrique de code à barres aux applications de voix et vidéo par IP, peuvent être classées de la même manière, et peuvent être traitées conformément au présent document.

L'applicabilité du présent document ne se limite pas à une bande de fréquences particulière (la bande ISM 2,4 GHz, par exemple). Les systèmes de communication concurrents et les autres applications sans fil approuvées, comme les faisceaux hertziens pour le séchage ou le soudage du plastique, sont considérés comme des brouillages. En outre, d'autres brouillages peuvent être générés par de puissants champs électromagnétiques basse fréquence (transformateurs, moteurs puissants ou autres brouillages électromagnétiques [EMI], par exemple; voir Figure 1). Les sources de brouillages à prendre en considération sont décrites en 4.4.

NOTE 2 L'analyse des brouillages électromagnétiques (EMI) est hors du domaine d'application du présent document, mais a néanmoins été prise en considération.

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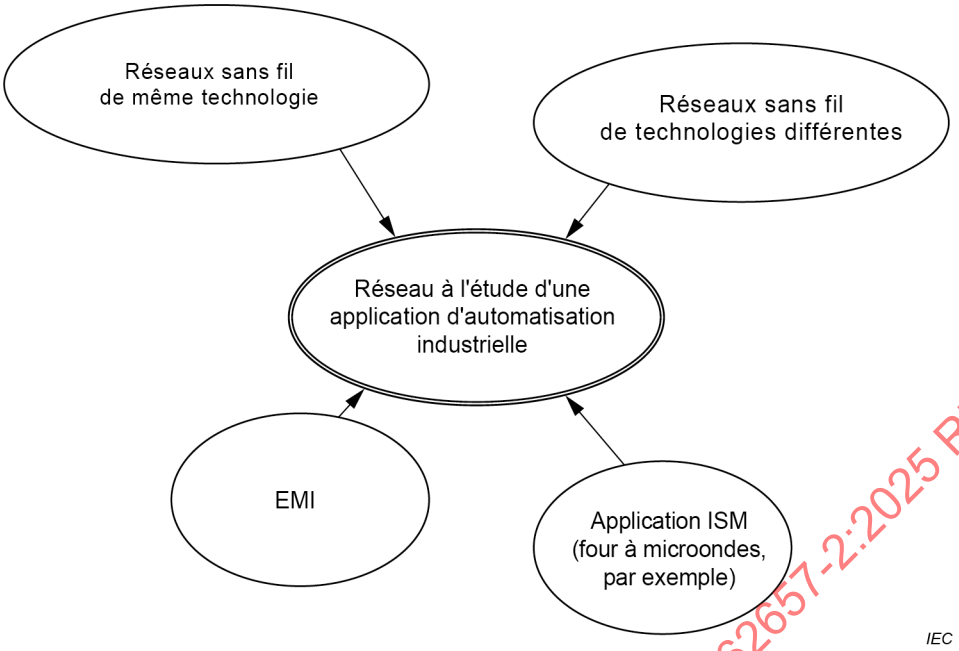

Figure 1 – Problèmes pris en compte

La Figure 2 décrit la relation entre l'application d'automatisation industrielle, l'application de communication sans fil, les brouillages électromagnétiques (EMI), l'application industrielle, scientifique et médicale (ISM) et l'application sans fil non industrielle. Le terme "application sans fil" est utilisé comme terme générique pour désigner l'application de communication sans fil, l'application ISM et la communication sans fil non industrielle (en gris sur la Figure 2). Les applications de communications sans fil font partie intégrante d'une application d'automatisation. Les autres parties des applications d'automatisation peuvent utiliser le spectre ISM (pour les processus de soudage, par exemple). De plus, les équipements des applications d'automatisation industrielle peuvent être une source de brouillages électromagnétiques (EMI). En outre, les applications sans fil non industrielles (les mobiles multifonctions ou les ordinateurs portables, par exemple) peuvent utiliser le spectre dans un environnement industriel.

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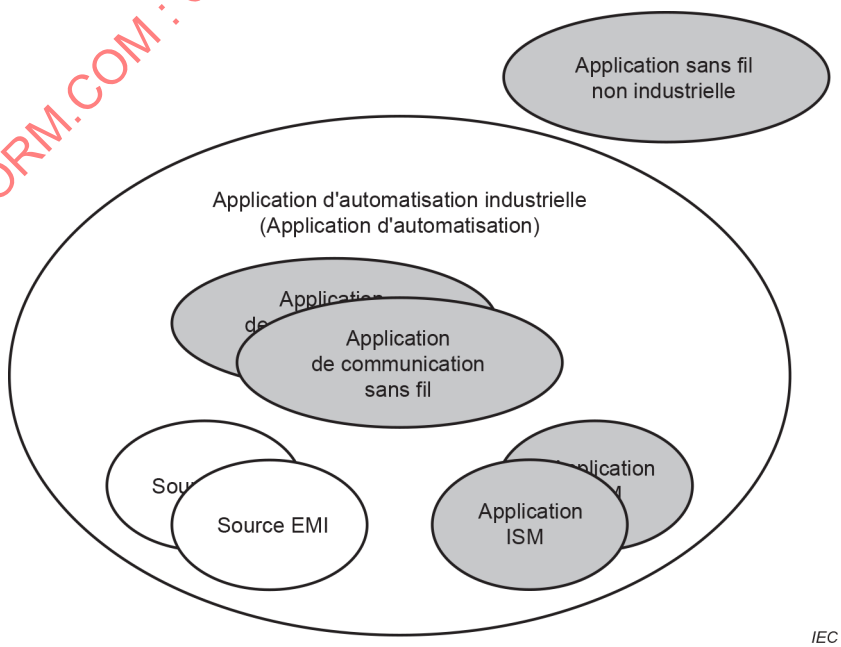

Figure 2 – Applications qui utilisent le spectre de fréquences

Le présent document traite de la gestion de coexistence à l'emplacement d'une entreprise. Toutefois, le gestionnaire doit tenir compte du fait qu'un brouillage peut provenir de l'extérieur de l'installation. Le gestionnaire doit identifier et caractériser les sources externes potentielles d'énergie radioélectrique et leur distance par rapport à l'entreprise. Il convient que des commandes soient en place pour assurer que des sources mobiles non autorisées ou non recensées ne sont pas admises dans la zone de l'entreprise.

Le postulat de départ est qu'en l'absence de brouillages, un système de communication sans fil satisfait aux exigences de l'application d'automatisation sans fil et que, en particulier, la réactivité et les défaillances sont prises en compte en planifiant les exigences de communication.

Les mesures ici décrites doivent assurer les performances exigées, même en présence d'autres applications sans fil.

4.3 Nécessité de mettre en œuvre une gestion de coexistence

Le spectre des fréquences est une ressource limitée précieuse qui s'épuise rapidement en cas d'utilisation non gérée.

La liste suivante présente un exemple d'appareils sans fil classique des environnements industriels:

- capteurs et actionneurs sans fil;
- points d'accès WLAN et clients;
- panneaux mobiles;
- appareils RFID et lecteurs RFID.

Des appareils peuvent également émettre de la puissance rayonnée dans les mêmes bandes que celles des appareils sans fil:

- appareils de production de chaleur industrielle par radiofréquence;
- appareils de soudage du plastique;
- lampes à plasma;
- appareils de soudage général; et
- autres appareils.

Il existe un risque important de brouillages où, dans certaines conditions, les exigences de disponibilité et de performances présumées ne peuvent pas être respectées. Pour prévenir ce cas de figure, ou plutôt pour réduire le risque de brouillage, un processus d'entreprise pour l'administration des applications sans fil de toutes les parties impliquées est vivement recommandé et, s'il est adopté, doit être mis en œuvre conformément au présent document. La gestion de coexistence est un processus intraentreprise qu'il convient d'adapter à la structure et aux processus internes de l'entreprise. D'une entreprise à l'autre, la structure et les processus peuvent être organisés différemment.

En outre, la définition du processus ou de ses phases peut varier en fonction des groupes d'utilisateurs concernés:

- applications de communication sans fil avec un débit de données élevé, mais avec des exigences de réactivité en temps réel moins strictes: la gestion de coexistence s'attache à la mise à disposition de la largeur de bande de fréquences conforme aux exigences de l'application;
- applications de communication sans fil sans exigence particulière de performance et de réactivité en temps réel: la gestion de coexistence vise à assurer la couverture spatiale;

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- applications de communication sans fil avec des exigences strictes de réactivité en temps réel: la gestion de coexistence protège des problèmes de fonctionnement générés par l'influence d'autres applications sans fil (classes d'applications "sécurité fonctionnelle" ou "commande").

En outre, les mesures élémentaires suivantes sont recommandées pour mettre en œuvre la gestion de coexistence:

- désignation d'un gestionnaire de coexistence pour l'ensemble de l'entreprise;
- désignation d'un gestionnaire de coexistence local si l'entreprise possède plusieurs sites;
- constitution d'un comité composé d'interlocuteurs pour chaque service de l'entreprise qui utilise une application sans fil (il convient que les activités du comité répondent aux problèmes de la Figure 1 et de la Figure 2);
- inventaire de toutes les applications sans fil installées et, le cas échéant, planifiées, y compris la communication sans fil;
- établissement d'une politique d'enregistrement des nouvelles applications ou solutions sans fil et d'identification des applications ou solutions sans fil existantes;
- coordination et adoption de décisions concernant l'approbation et la mise en œuvre de systèmes sans fil au sein du comité;
- établissement d'une politique et des conséquences applicables pour l'introduction non autorisée de nouvelles applications ou solutions sans fil.

La gestion efficace de coexistence est un processus concerté impliquant des représentants de toutes les parties de l'entreprise concernées (divisions, services, technologies). Ces parties concernées sont celles qui sont impliquées dans la planification, l'approvisionnement, l'installation, la mise en service, l'exploitation et la maintenance des applications sans fil. Par exemple: la planification de processus, les TI, l'automatisation, l'exploitation (production), le développement, les achats, la gestion des locaux.

La gestion de coexistence présente de nombreux avantages:

- réduction ou élimination des brouillages menant à des indisponibilités fortuites;
- réduction ou élimination des recherches de panne pénibles, coûteuses et chronophages;
- réduction ou élimination des désinvestissements dans les solutions sans fil qui ne peuvent pas être exploitées dans l'environnement radioélectrique actuel de l'entreprise.

NOTE Ici, le terme "solution sans fil" est utilisé à la place du terme "système sans fil" afin de tenir compte des différentes propriétés d'un produit qui sont importantes pour la gestion de coexistence.

4.4 Potentiel de brouillage

Pour les applications de communication sans fil, des brouillages se produisent en un point de l'espace (correspondant à un emplacement d'antenne, à de l'énergie reçue, à des caractéristiques et une polarisation d'antenne) si les signaux reçus:

- se chevauchent dans le domaine fréquentiel;
- se chevauchent dans le domaine temporel; et
- se chevauchent pour le codage.

NOTE 1 Dans le cas des bâtiments et zones proches d'aéroports, de ports, de pylônes émetteurs et d'autres lieux où sont installés des systèmes sans fil puissants, le potentiel de brouillage est très élevé.

Cela entraîne des brouillages entre les solutions sans fil ayant pour conséquence une perte de paquets, ce qui nécessite par exemple la répétition d'un paquet transféré. La réaction du système à de tels brouillages dépend de plusieurs facteurs, par exemple de la norme sans fil, de la mise en œuvre du matériel et des logiciels ou de la classe d'application que le système sans fil utilise pour le transfert (voir Tableau 1).

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La séparation des canaux de fréquences qui ne se chevauchent pas est une méthode qui permet d'assurer la coexistence. Des brouillages peuvent toutefois se produire entre des systèmes sans fil utilisant des canaux différents dans une même bande de fréquences, à cause d'un brouillage dans le canal adjacent, par exemple. Il s'agit d'un brouillage intercanal. En particulier, les systèmes sans fil analogiques présentent un fort potentiel de brouillage avec les systèmes sans fil numériques compte tenu de leur forte occupation de canal.

De plus, les systèmes sans fil utilisant des bandes de fréquences différentes peuvent interférer les uns avec les autres. Au-dessous du signal principal, un système sans fil émet aussi des signaux hors bande susceptibles de pénétrer dans le canal de fréquences du système sans fil menacé et de perturber ainsi le signal utile.

La qualité du signal reçu par un récepteur en fonction des brouillages d'autres systèmes sans fil est généralement mesurée par le rapport signal sur brouillage (SIR) qui correspond au rapport de la puissance du signal utile sur la puissance résiduelle totale des signaux non désirés. Le récepteur ne peut correctement interpréter les données entrantes que si le SIR dépasse un seuil défini.

La valeur de ce seuil dépend de la modulation adoptée, tandis que la valeur réelle du SIR dépend de la superposition des brouilleurs sur la communication désirée dans les deux domaines suivants: temporel et fréquentiel.

Les performances peuvent varier en fonction du degré de superposition complète ou partielle (c'est-à-dire des brouillages) dans ces deux domaines.

Pour le domaine temporel, étant donné que le trafic des systèmes sans fil victimes et brouilleurs peut varier très rapidement, il convient de définir un intervalle de temps sur lequel le brouillage est constant avant de déterminer le SIR.

Pour le domaine fréquentiel, il convient que la détermination du SIR prenne au moins en compte les effets combinés des gabarits spectraux des émetteurs brouilleurs et du récepteur victime. En effet, les émetteurs brouilleurs peuvent avoir des rayonnements non essentiels même en dehors du canal de fréquences adopté. Par ailleurs, le gabarit de blocage du récepteur peut rejeter les signaux brouilleurs, limitant ainsi les effets.

Pour prévoir/estimer les effets des brouilleurs, des modèles analytiques, des simulations et des bancs d'essai expérimentaux peuvent être utilisés. Ces trois approches présentent des complexités (croissantes) différentes et, donc, des niveaux d'exactitude différents (croissants).

Afin de déterminer s'il existe un risque de brouillage ou non, sans preuve de la robustesse radioélectrique des applications sans fil, il convient de toujours admettre par hypothèse un risque de brouillage si elles fonctionnent en parallèle dans la même bande de fréquences.

NOTE 2 Le terme "application sans fil" est plus exhaustif que le terme "système sans fil", car la puissance rayonnée ne sert pas uniquement au transfert d'informations dans les applications sans fil.

NOTE 3 L'utilisation de l'énergie électromagnétique peut être soit intentionnelle (pour alimenter l'application spécifique) soit involontaire/accidentelle.

Toutefois, un risque de brouillage ne signifie pas que le fonctionnement en parallèle de systèmes sans fil concurrents soit impossible. Ils peuvent coexister si les exigences relatives aux solutions sans fil impliquées sont respectées. Il convient de s'appuyer sur ce critère pour prendre des décisions concernant l'application des systèmes sans fil.

Si possible, il convient également d'envisager les modifications ultérieures des exigences qui induiront des variations du potentiel de brouillage. En automatisation industrielle, le cycle de vie d'une solution sans fil est généralement supérieur à 5 ans. Pendant cette période, de nouvelles applications pour le système sans fil existant peuvent être développées et diffusées. La détermination, la coordination et la maîtrise de ces changements font partie de la gestion de coexistence.

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Les brouillages électromagnétiques (EMI) rayonnés sont une autre influence à prendre en compte. Les règlements régionaux, en particulier, peuvent autoriser une puissance rayonnée significative pour les applications sans fil particulières dans le spectre sans licence, générant potentiellement de fortes intensités du champ à proximité d'un système sans fil.

Une solution sans fil présente une certaine résilience aux brouillages par rapport à ces brouillages rayonnés. Cependant, cette valeur limite peut être dépassée par le signal d'une application sans fil puissante.

EXEMPLE En Europe, les applications RFID sont autorisées à utiliser 4 W dans la bande de 2,4 GHz, tandis que les autres appareils de courte portée sont limités à 100 mW.

Même si les solutions sans fil possèdent souvent une résilience aux brouillages supérieure à celle revendiquée par les normes et qu'un dépassement de la valeur limite ne provoque pas toujours de brouillages dangereux, les solutions sans fil doivent être conçues de sorte que le niveau de bruit sur le récepteur ne dépasse pas cette valeur limite. Des brouillages provenant de la même bande de fréquences sont bien plus probables que ceux provenant d'autres bandes de fréquences. Néanmoins, les potentiels de brouillage d'autres bandes de fréquences doivent aussi être pris en compte.

Il convient que les brouillages électromagnétiques (EMI) causés par des appareils défectueux dépassant les limites de fonctionnement normal n'aient aucune incidence sur la gestion de coexistence. Il convient plutôt de réparer l'appareil défectueux pour revenir à des conditions de fonctionnement normal.

4.5 Conditions annexes

Pour la communication sans fil, les ressources de communication disponibles sont limitées, ce qui exige une planification soigneusement réfléchie. Plus les exigences (réactivité, disponibilité, dimensions, etc.) de la classe d'application du système sans fil sont élevées, plus les efforts techniques et organisationnels exigés pour assurer la coexistence sont importants. Les coûts augmentent de façon disproportionnée, comme cela est représenté à la Figure 3. Ils sont en partie imputables à la complexité des solutions réseau sans fil (une liaison simple de point à point ou bien une topologie linéaire, en anneau, en étoile, cellulaire, en arbre ou maillée, par exemple), ainsi qu'au nombre de facteurs d'influence à prendre en considération (la charge du support, la puissance de l'émetteur, par exemple). Plus le spectre est exploité efficacement, plus l'écart entre les deux courbes s'accroît. Cette règle est valable pour:

- les dépenses de gestion de coexistence lors de la phase de planification de coexistence; et
- les coûts de développement de solutions sans fil appropriées.

La flèche en gras de la Figure 3 montre que les courbes s'élèvent au fur et à mesure de l'augmentation des efforts de gestion de coexistence pour obtenir une exploitation plus efficace du spectre.

L'effort peut être réduit au moyen de régulations stratégiques pour la gestion de coexistence. L'une des régulations possibles consiste à limiter le nombre de facteurs d'influence pris en compte, par exemple par l'assignation exclusive de fréquences à des applications sans fil précises. Il est essentiel de tenir compte du fait que les décisions stratégiques dans la phase de planification de coexistence ont des conséquences sur les dépenses ultérieures et, par là même, sur les coûts du cycle de vie de l'installation. Les dépenses techniques et organisationnelles pour la gestion de coexistence lors de la phase d'exploitation peuvent multiplier les coûts de planification de la coexistence sur l'ensemble du cycle de vie d'une installation.

Il est par conséquent important d'analyser si les exigences de l'application planifiée correspondent à celles nécessaires pour l'application. En allégeant les exigences, un emploi plus efficace de la ressource peut être obtenu. Si la ressource est épuisée, il est nécessaire de trouver d'autres solutions.

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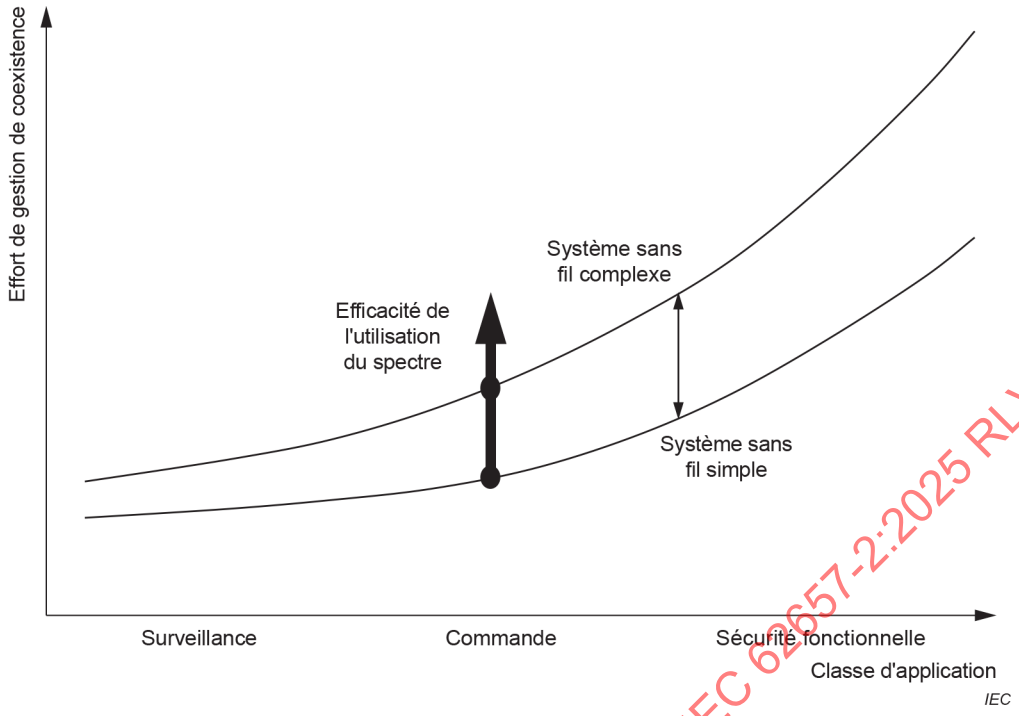

Figure 3 – Évolution des dépenses pour atteindre la coexistence en fonction des classes d'applications

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4.6 Exigences relatives aux appareils sans fil pour la prise en charge de la gestion de coexistence

Les appareils sans fil doivent être en mesure de varier les paramètres comme cela est spécifié à l'Article 5 afin d'assurer la gestion de coexistence en réduisant le potentiel de brouillage, comme cela est spécifié en 4.4.

EXEMPLE L'appareil est construit de sorte que certaines fréquences peuvent être bloquées ou que la puissance peut être réglée sous le seuil des services/applications titulaires.

4.7 Concepts

4.7.1 Gestion de coexistence manuelle

Dans le cas d'une gestion de coexistence manuelle, le gestionnaire de coexistence (voir 7.2.1) doit définir une planification fixe des solutions sans fil destinées à prévenir les recouvrements de transmissions. Le gestionnaire doit mettre en œuvre les mesures manuelles pour réagir aux modifications qui influencent l'état de coexistence sans fil. Il s'agit de la méthode de gestion la plus simple, en particulier si plusieurs solutions sans fil employant des technologies différentes et provenant de plusieurs fournisseurs entrent en jeu ou si plusieurs bandes de fréquences doivent être gérées.

Cette méthode peut être utilisée si des émetteurs radioélectriques ingérables sont utilisés dans les mêmes bandes que les solutions sans fil.

Cependant, les fonctionnalités de la gestion de coexistence manuelle sont limitées si certains paramètres de gestion de coexistence ne peuvent être configurés.

4.7.2 Gestion de coexistence automatisée non collaborative

Dans une gestion de coexistence automatisée non collaborative, les différentes solutions sans fil sont incapables d'échanger des informations. Elles sont totalement indépendantes et ne reposent que sur la détection et l'estimation des brouillages. En d'autres termes, chaque solution sans fil touchée classe le comportement des solutions qui ont une incidence et essaye en conséquence d'adapter son propre comportement à la nouvelle situation estimée. C'est la raison pour laquelle les techniques non collaboratives sont plus généralistes, mais moins efficaces que les collaboratives. Par exemple, les algorithmes non collaboratifs modifient de façon dynamique les stratégies de communication (la bande de fréquences, l'ordonnancement des durées par lot/paquet, etc.) à la suite d'une évaluation des exigences d'application sans fil par rapport à la solution d'application sans fil capable d'établir la performance de communication exigée.

Ces méthodes sont proposées pour traiter la coexistence dans des espaces publics non contrôlés. Toutefois, elles ne sont pas efficaces pour la gestion des appareils d'automatisation industrielle sans fil qui doivent satisfaire à des exigences de performances.

NOTE Certaines métriques sont décrites dans l'IEEE Std.802.15.2 [11].

4.7.3 Gestion de coexistence collaborative automatisée

4.7.3.1 Généralités

Dans une gestion de coexistence collaborative automatisée, les différentes solutions sans fil doivent être capables d'échanger des paramètres caractéristiques.

La condition préalable pour qu'une gestion de coexistence collaborative de systèmes sans fil utilisant différentes technologies proposées par des fournisseurs différents soit collaborative est que, parmi ces solutions, il existe une liaison de communication normalisée commune. Cette liaison peut être:

- un canal pilote établi entre le gestionnaire de coexistence collaborative et les appareils coordonnés à l'aide d'un protocole de communication et d'un ensemble de services normalisés communs, comme cela est par exemple spécifié dans l'IEC 62657-4, en vue de faciliter la tâche du gestionnaire de coexistence collaborative;
- une solution sans fil d'appareils coordonnés également comprise par le gestionnaire de coexistence collaborative, ce qui signifie que ce dernier doit parler le langage de tous les appareils coordonnés qui participent à la gestion de coexistence collaborative automatisée;
- une liaison filaire établie entre les appareils coordonnés et le gestionnaire de coexistence collaborative à l'aide d'un protocole de communication et d'un ensemble de services normalisés communs.

Une gestion de coexistence collaborative automatisée peut imposer un certain nombre de restrictions sur le matériel adopté; par exemple parce que les méthodes collaboratives sont généralement mises en œuvre au moyen d'un arbitre/ordonnanceur centralisé. Les informations échangées permettent à chaque solution sans fil touchée d'adapter efficacement son propre comportement à la nouvelle situation réelle, en tenant compte des exigences de sa propre application et des applications des autres systèmes sans fil. Ces modifications dynamiques peuvent influencer le déterminisme ou la fiabilité de la communication et peuvent donc être inadaptées aux différentes applications de communication sans fil.

Un point de coordination central (CCP, *Central Coordination Point*) est un exemple de ce type de gestion de coexistence collaborative automatisée (voir l'IEC 62657-1:2017, 4.3.4.3). Les aspects nationaux, régionaux et règlementaires sont également décrits.

L'IEC 62657-3 fournit la description formelle de la gestion automatisée de la coexistence et des recommandations d'application.

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Il existe trois cas d'utilisation d'application différents pour le gestionnaire de coexistence collaborative automatisée:

a) pour le partage des mêmes fréquences avec d'autres services/applications titulaires (voir 4.7.3.2, 4.7.3.3 et 4.7.3.4);

b) pour la coexistence interne au système dans un environnement commandé;

c) pour la coexistence interne au système dans un espace public.

Une approche possible de la gestion de coexistence collaborative automatisée pour l'automatisation industrielle est spécifiée dans l'IEC 62657-4.

4.7.3.2 Point de coordination central simple

Un gestionnaire de coexistence collaborative est chargé de détecter les utilisateurs principaux et d'identifier les appareils qui sont coordonnés. Le point de coordination central doit alors informer les appareils coordonnés sous-jacents qu'ils doivent réagir pour répondre aux techniques d'atténuation exigées de l'utilisateur principal. Aucune reconfiguration des fréquences assignées n'est exigée. Pour savoir comment les appareils coordonnés pourraient réagir, il suffit de diminuer la puissance transmise ou d'arrêter la transmission.

4.7.3.3 Point de coordination central interne au système

La totalité ou au moins la plupart des équipements radioélectriques dans l'espace sont connus avec leurs exigences dynamiques. Les appareils installés sont par hypothèse considérés comme étant statiques. Les appareils nomades sont connus et, en tant que tels, considérés comme étant statiques dans la configuration, par exemple s'ils possèdent une capacité de géolocalisation. Le gestionnaire de coexistence collaborative est chargé de détecter les utilisateurs principaux et d'indiquer aux appareils coordonnés sous-jacents (services/applications titulaires) s'ils sont susceptibles d'interférer avec eux. Le gestionnaire de coexistence collaborative peut décider si les appareils coordonnés doivent réagir pour répondre aux techniques d'atténuation exigées de l'utilisateur principal ou peut attribuer un spectre différent aux appareils coordonnés. Le gestionnaire de coexistence collaborative peut également organiser la synchronisation temporelle ou influencer d'autres paramètres spécifiés en 4.4.

4.7.3.4 Point de coordination central public

Tous les comportements décrits en 4.7.1 et en 4.7.2 ainsi qu'en 4.7.3.2 et en 4.7.3.3 peuvent être pris en charge. De plus, les appareils inconnus peuvent demander au gestionnaire de coexistence collaborative d'être également gérés.

La gestion de coexistence coordonnée augmente l'efficacité du spectre et la qualité de service.

4.8 Meilleures pratiques pour atteindre la coexistence

L'établissement de la coexistence est une combinaison de mesures techniques et/ou organisationnelles qui permet d'assurer un fonctionnement sans brouillages des applications de communication sans fil dans leurs environnements. Les principaux critères pris en compte lors du choix des mesures appropriées pour atteindre la coexistence sont l'efficacité, la faisabilité, l'efficacité économique et la perte de performance acceptable pour l'application si la solution de communication sans fil doit partager son support avec d'autres systèmes sans fil. Il convient également de prendre en considération les développements futurs d'applications de communication sans fil dans l'entreprise.

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D'un point de vue technique, les signaux de communication sans fil en un point de l'espace (correspondant à un emplacement d'antenne, à de l'énergie reçue, à des caractéristiques et une polarisation d'antenne) peuvent être séparés en fonction:

- de la fréquence;
- du temps;
- du codage.

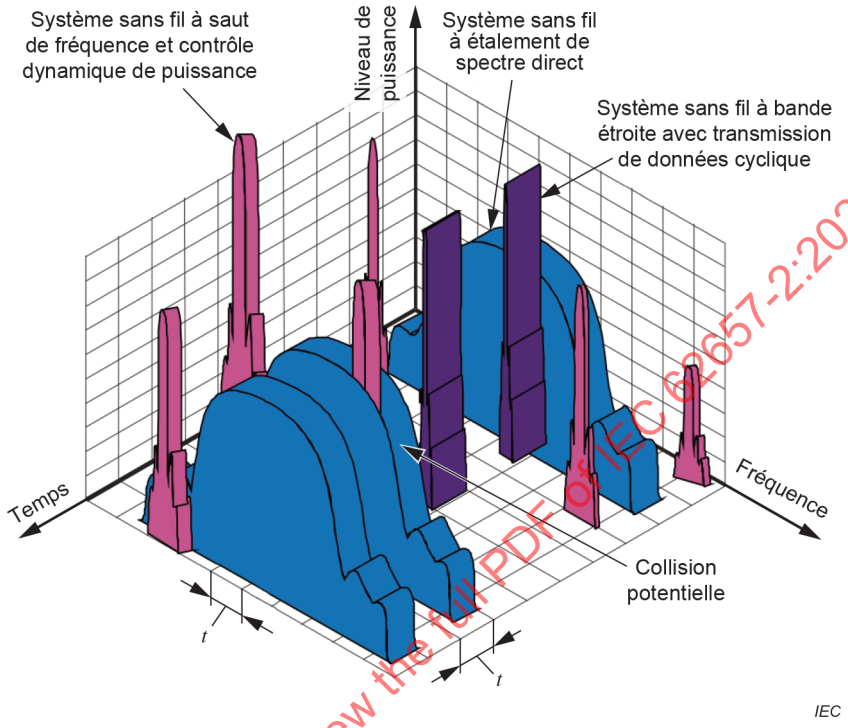

Figure 4 – Séparation des systèmes sans fil selon la fréquence et le temps

La séparation dans le domaine fréquentiel (voir Figure 4) cause généralement moins de pertes de performance et au départ moins de frais. Toutefois, ces mesures occupant fortement le support, il convient de les réserver à des classes d'applications spécifiques de l'installation (la sécurité fonctionnelle et la commande, par exemple). Une séparation dans le temps peut être réalisée en configurant la demande de communication selon les exigences de communication de l'application.

Pour les applications avec une certaine dynamique, il convient que le cycle de communication soit aussi long que possible et/ou qu'une communication événementielle soit utilisée. Il convient que des technologies sans fil avec des mécanismes automatiques adaptatifs de partage de support soient également utilisées.

Une séparation spatiale est rarement possible avec une application de communication sans fil. La propagation radioélectrique ne peut être limitée dans l'espace que difficilement. La séparation spatiale peut s'obtenir par des conditions structurelles (murs de béton armé de grandes dimensions, par exemple) et une réduction de la puissance rayonnée (en réglant la puissance de sortie de l'émetteur radioélectrique et en choisissant bien la caractéristique de rayonnement de l'antenne). Pour les installations plus importantes, la commande des niveaux de puissance peut être une approche viable. Si la puissance est réduite, il convient d'ajuster en conséquence la puissance de tous les appareils sans fil connexes (station de base, répéteurs, appareils terminaux, par exemple).

Si les émetteurs-récepteurs possèdent plusieurs antennes, il est alors possible d'utiliser un traitement spatial (des techniques de rejet des bruits, par exemple) pour séparer dans l'espace des transmissions simultanées.

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La séparation par polarisation met en jeu l'aptitude particulière d'une antenne à soumettre ses ondes radioélectriques à une polarisation orthogonale (transpolarisation). Par exemple, une antenne à polarisation horizontale d'un récepteur de signal peut affaiblir un signal brouilleur à polarisation verticale. Cependant, à l'intérieur des bâtiments ou dans d'autres environnements fortement réfléchissants, les effets d'une séparation de polarisation sont relativement limités.

En outre, des antennes pill-box ou d'autres nouveaux types d'antennes peuvent permettre de restreindre la propagation radioélectrique à une certaine zone.

Les mesures organisationnelles s'appliquent au fonctionnement du système sans fil et ont des conséquences indirectes sur le mécanisme de séparation décrit à la Figure 4. Il s'ensuit que l'application d'un système sans fil peut, par exemple, être limitée dans l'espace ou dans le temps ou que seuls les services d'une solution sans fil satisfaisant aux exigences de coexistence peuvent être approuvés. Il convient que les mesures organisationnelles (en particulier celles concernant les systèmes sans fil liés au processus métier ou à la sécurité) évaluent par avance dans quelle mesure la conformité aux spécifications peut être assurée et contrôlée.

L'incidence des caractéristiques de propagation radioélectrique non idéale classiques dans la plupart des environnements industriels peut avoir des conséquences sur la réactivité et les défaillances d'une solution sans fil. Cela doit être pris en compte lors de la planification de systèmes sans fil.

Pour la phase d'exploitation, les mécanismes d'amélioration de l'agilité des applications de communication sans fil en réponse à l'apparition de brouillages inattendus doivent être étudiés (au moyen de techniques de diversité et de méthodes cognitives d'accès au support radioélectrique, par exemple).

Afin de définir des mesures adéquates et d'évaluer leur efficacité, l'assistance d'experts de la communication sans fil est recommandée.

4.9 Modèle conceptuel de coexistence

La Figure 5 montre le modèle conceptuel de coexistence. Dans cet exemple, trois applications de communication sans fil (A, B et C) sont prises pour hypothèse. Conformément à la définition de la coexistence sans fil, les trois applications de communication sans fil doivent respecter leurs exigences de communication respectives. Chaque système de communication sans fil d'une application de communication sans fil présente une certaine immunité aux brouillages des autres systèmes de communication sans fil et l'utilisation de ses ressources peut interférer avec d'autres systèmes de communication sans fil.

Le modèle conceptuel de coexistence peut être considéré comme un processus de contrôle en boucle fermée. Ce processus de gestion de coexistence ne se limite pas à une activité réalisée lors de la planification du système; il s'agit d'un processus itératif tout au long du cycle de vie du système.

NOTE L'IEC 62890 donne des détails supplémentaires relatifs à la gestion du cycle de vie.

Une investigation des exigences, des caractéristiques des systèmes de communication sans fil et du facteur d'utilisation du support doit être consignée dans un inventaire. Selon la phase du cycle de vie (voir 7.4), la planification ou la maintenance de la coexistence qui en résulte doit être effectuée. En découle un plan d'allocation des ressources actuelles, ce qui doit constituer la base de la configuration ou de la mise en œuvre des applications de communication sans fil.

L'état de coexistence est atteint si la robustesse aux brouillages d'un système de communication sans fil est supérieure aux brouillages produits par la ressource, et si les applications de communication sans fil respectent leurs exigences de communication respectives.

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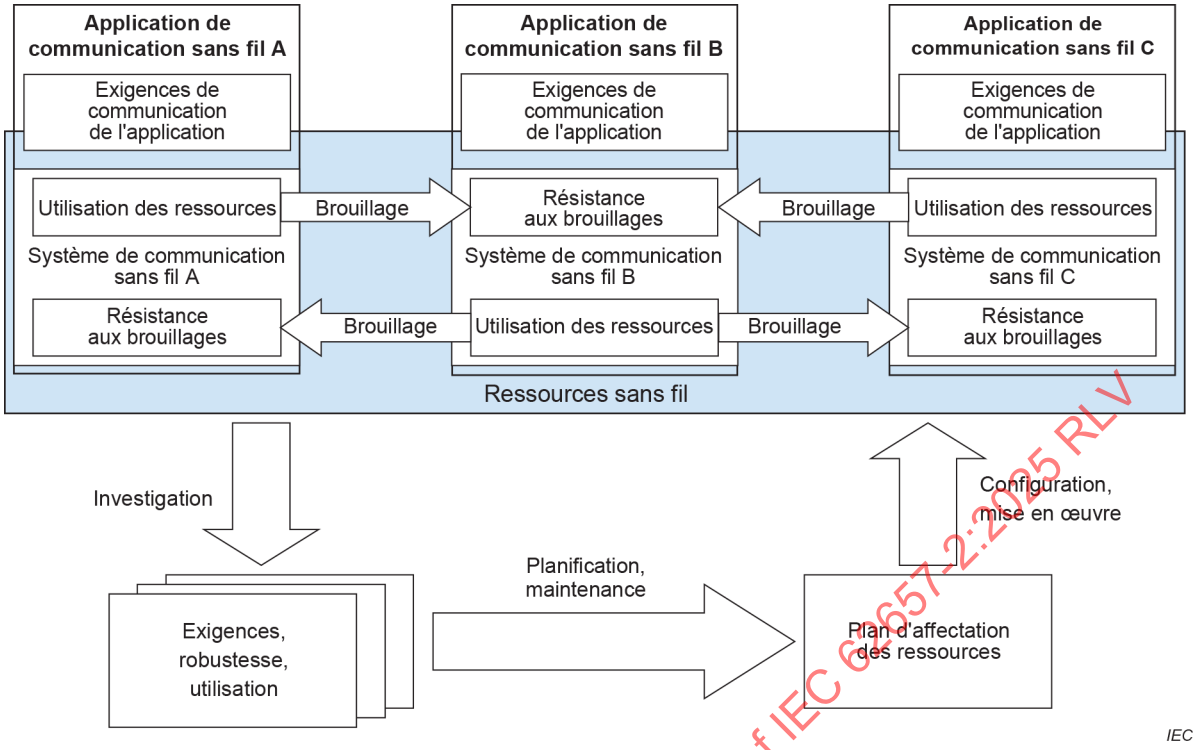

Figure 5 – Modèle conceptuel de coexistence

La Figure 6 représente une partie du contenu de la Figure 5 sous la forme d'un organigramme pour indiquer les relations à la Figure 7, à la Figure 29 et à la Figure 30. La spécification du système de gestion de coexistence n'est représentée à la Figure 6 qu'au début afin de ne pas surcharger la figure. À chaque phase, la documentation doit être complétée et mise à jour. Si les exigences d'une phase donnée ne sont pas respectées, il convient que le processus recommence depuis le départ (voir les traits de la Figure 6 qui vont de la sortie d'une phase au chemin de retour). La documentation est spécifiée en 7.1.2.

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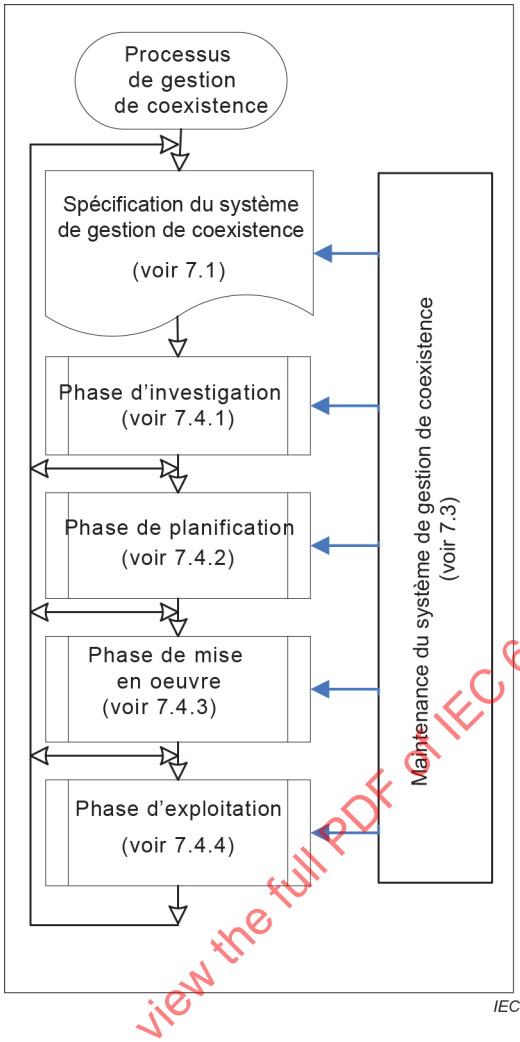

Figure 6 – Organigramme du modèle conceptuel de coexistence

4.10 Gestion de coexistence et choix d'une solution sans fil

La conformité de la solution sans fil aux exigences constitue le point de départ et la condition préalable pour la phase de mise en œuvre. La phase d'investigation commence par un examen des exigences du système sans fil et par une enquête afin de déterminer si le système est en mesure de satisfaire aux exigences de communication de l'application. Dans le cadre de ce processus, de nouveaux systèmes sans fil peuvent être évalués par rapport aux exigences de communication de l'application. La Figure 7 met en correspondance les décisions et les actions avec l'organigramme représenté à la Figure 6.

Tout en vérifiant si une solution sans fil satisfait aux exigences d'une application d'automatisation, la transmission radioélectrique doit être analysée pour voir s'il s'agit d'une approche raisonnable compte tenu des efforts exigés pour atteindre la coexistence. À cet égard, le processus de sélection d'une solution sans fil fait déjà partie du processus de gestion de coexistence.

La décision d'installer un système sans fil doit être suivie de la décision de mettre en œuvre un processus de gestion de coexistence (voir 6.8). Le processus de gestion de coexistence comprend la planification, l'installation, l'exploitation et la maintenance de la coexistence de systèmes sans fil. La phase de planification de coexistence (voir 7.4.2.2) commence avec l'inventaire de toutes les applications sans fil, car elles peuvent être considérées comme étant des brouilleurs potentiels (voir 7.3).

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Lors de la phase de planification de coexistence, il peut apparaître qu'une solution sans fil choisie ne peut pas être intégrée à l'installation existante. Une autre solution sans fil peut être choisie ou bien l'idée d'un système sans fil peut tout simplement être abandonnée. Si, lors de la phase de planification de coexistence, il est établi que toutes les applications de communication sans fil satisfont à leurs exigences respectives, le processus de gestion de coexistence de la phase d'exploitation peut être initié (voir 7.4.4).

NOTE 1 Les processus dans la phase de planification et dans la phase d'exploitation sont spécifiés plus en détail plus loin dans le présent document.

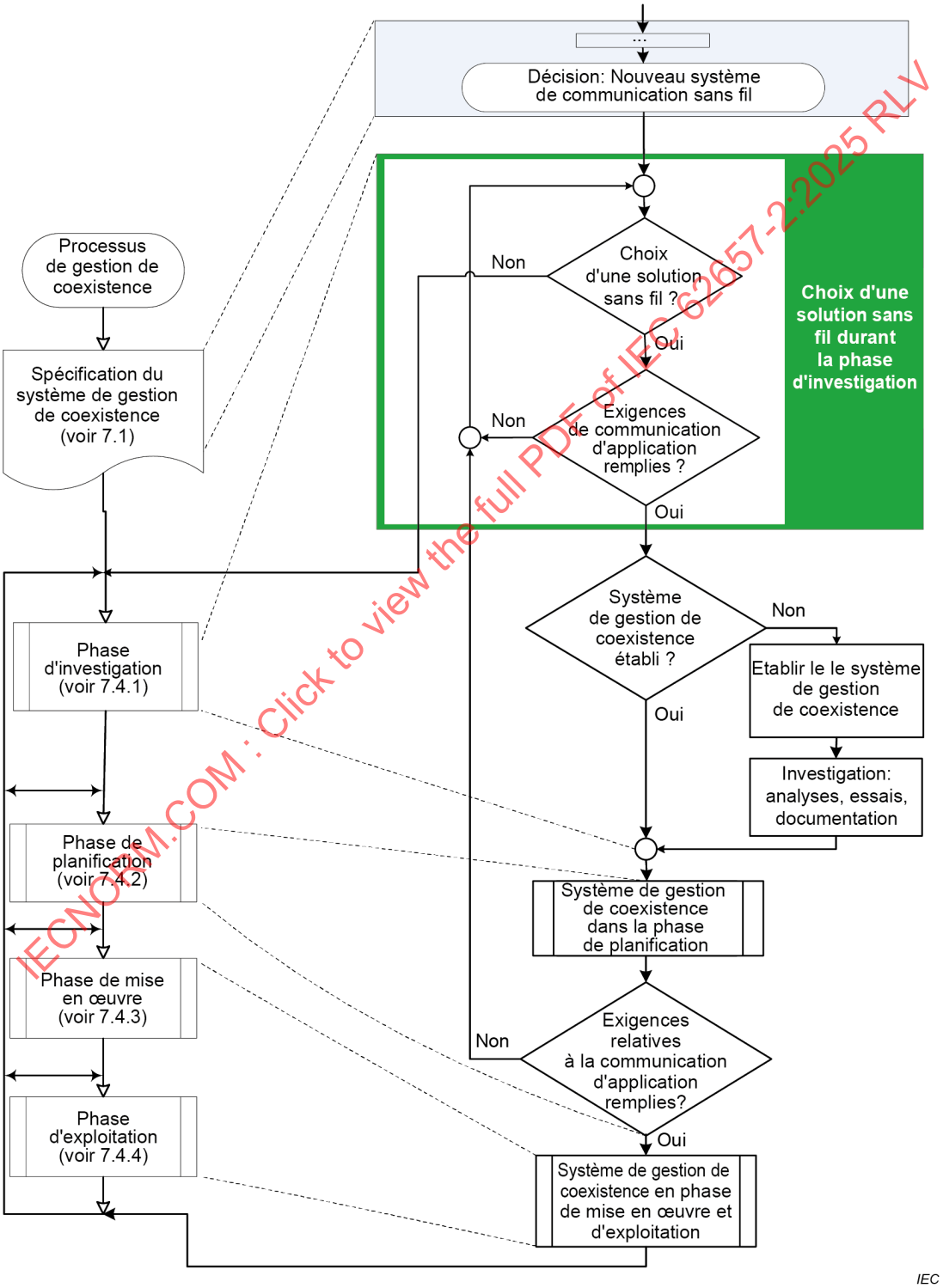

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Figure 7 – Choix d'un système sans fil dans le processus de gestion de coexistence

NOTE 2 La case "Maintenance d'un système de gestion de coexistence (voir 7.3)" représentée à la Figure 6 n'apparaît pas dans la Figure 7 afin de ne pas surcharger la figure.

4.11 Système de gestion de coexistence

Le système de gestion de coexistence consiste en une structure organisationnelle et en des documents procéduraux. L'exécution de la gestion de coexistence amène le système dans un état de "gestion de coexistence en phase d'exploitation". La spécification du système de gestion de coexistence doit inclure les informations suivantes:

- le périmètre de la gestion de coexistence;
- l'engagement de l'organisation en faveur de la gestion de coexistence;
- la procédure de maintenance des spécifications du système de gestion de coexistence;
- les questions organisationnelles, notamment la structure de l'organisation, les fonctions du personnel, la communication avec des organisations externes et la formation du personnel;
- les procédures de gestion de coexistence.

La spécification du système de gestion de coexistence doit être documentée (voir 7.1.2) et tenue à jour (voir 7.3).

5 Paramètres de gestion de coexistence

5.1 Généralités

5.1.1 Définition et utilisation des paramètres

L'Article 5 spécifie les paramètres d'un processus de gestion de coexistence. Ces paramètres ont rapport aux exigences de communication de l'automatisation et aux conditions existantes dans la zone de fonctionnement et caractérisent les appareils et systèmes sans fil.

Leur utilisation est spécifiée à l'Article 6. L'Article 8 contient, quant à lui, les modèles relatifs à certains de ces paramètres.

Les paramètres sont énumérés dans l'ordre alphabétique anglais. Tous les paramètres ont également une définition en 3.1. Étant donné qu'il y a plus de définitions que de paramètres, la numérotation est différente.

Les types de données des paramètres peuvent être définis dans le dictionnaire de données communes (CDD, *Common Data Dictionary*) ou dans d'autres outils, où les paramètres font partie du répertoire électronique.

L'Annexe A décrit l'utilisation des paramètres dans la série IEC 62657.

5.1.2 Liaison physique

Le concept de liaison physique est utilisé dans la définition de plusieurs paramètres de coexistence.

Une liaison physique est la relation entre les émetteurs-récepteurs radioélectriques (points limites physiques) de deux appareils sans fil. L'ensemble des liaisons physiques d'un système sans fil constitue sa topologie physique. Une liaison physique peut utiliser des canaux de fréquences différents pour assurer les transmissions. Les conditions de transmission sans fil peuvent être décrites avec un modèle de canal radioélectrique. Ce modèle tient compte des caractéristiques du canal de fréquences, des conditions environnementales, de la distance entre les appareils sans fil, des caractéristiques d'antenne, etc. Dans la mesure où les systèmes d'antenne des appareils sans fil peuvent être différents et où les conditions de propagation dépendent de la position des appareils sans fil, le canal radioélectrique est en principe différent pour les deux directions d'une liaison physique.

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Si les appareils sans fil disposent de modules sans fil redondants (pour des canaux de fréquences différents, par exemple), les liaisons physiques correspondantes doivent être comptées séparément. Il n'est pas exigé qu'un appareil sans fil dispose d'une liaison physique vers tous les autres appareils sans fil. Il peut y avoir des raisons physiques, technologiques ou liées à l'application pour cela. La charge de communication d'une liaison physique est déterminée par les liaisons logiques qui utilisent cette liaison physique. Une liaison logique peut utiliser plusieurs liaisons physiques, en séquence (par l'intermédiaire d'un répéteur) ou en parallèle (pour la redondance). Plusieurs liaisons logiques peuvent utiliser une seule liaison physique (services de communication différents).

5.2 Sélectivité pour le canal adjacent

La sélectivité pour le canal adjacent est la plus basse valeur (des canaux adjacents supérieur et inférieur) des rapports, en décibels, des niveaux du signal non désiré, exprimés sous la forme d'intensité du champ, sur un niveau de signal utile spécifié, exprimé aussi sous la forme d'intensité du champ, qui produit un signal de données avec un taux d'erreur sur les bits de 10^{-2}. La sélectivité pour le canal adjacent permet d'estimer l'immunité de l'équipement par rapport à des systèmes dans des canaux adjacents.

NOTE Cela concorde avec la spécification de la sélectivité pour le canal adjacent de l'ETSI TR 100 027 [20].

L'unité de ce paramètre doit être le décibel (dB) sur la plage de fréquences considérée.

5.3 Gain d'antenne

Le gain d'antenne est une valeur qui décrit la concentration d'un signal émis ou reçu. Les valeurs sont données par rapport à un doublet demi-onde ou une antenne isotrope théorique. Puisque le gain isotrope d'un doublet demi-onde est de 2,15 dBi, le gain d'antenne d'un doublet demi-onde est de 2,15 dBi inférieur au gain d'antenne d'une antenne isotrope.

Le gain d'antenne associé aux valeurs de puissance d'émission, la sensibilité du récepteur et la prise en compte des conditions de propagation peuvent servir à optimiser l'emplacement et l'orientation de l'appareil sans fil ou de l'antenne.

L'unité de ce paramètre doit être le décibel par rapport à une antenne isotrope (dBi).

5.4 Caractéristique de rayonnement de l'antenne

Une caractéristique de rayonnement représente la dépendance directionnelle (angulaire) de l'intensité des ondes radioélectriques d'une antenne. Elle est généralement représentée graphiquement pour les conditions de champ lointain, soit dans le plan horizontal, soit dans le plan vertical. Cette information peut servir à optimiser l'emplacement et l'orientation de l'appareil sans fil ou de l'antenne.

Ce paramètre doit être représenté sous la forme d'une figure ou d'un tableau.

5.5 Type d'antenne

Les appareils sans fil peuvent utiliser différents types d'antennes pour recueillir ou rayonner des ondes électromagnétiques. Il s'agit, par exemple, des antennes omnidirectionnelles, des antennes directionnelles, des batteries d'antennes, des antennes intelligentes et des antennes PCB. Les antennes peuvent être intégrées à l'appareil sans fil (internes) ou être montées de façon externe au moyen de connecteurs. Si l'appareil dispose d'un connecteur d'antenne, des systèmes d'antennes particuliers, comme des câbles radioélectriques rayonnants coaxiaux ou des antennes à guide d'ondes fendu, peuvent également être connectés. De plus, l'antenne peut être montée indépendamment de l'appareil dans une position favorable à une transmission sans erreur. Si un appareil sans fil peut uniquement être utilisé avec un seul type d'antenne, il s'agit alors d'une antenne dédiée. Les informations relatives au type d'antenne peuvent servir à estimer la qualité de la liaison physique et la sensibilité aux brouillages.

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Le paramètre doit être une liste indexée des éléments suivants: antennes omnidirectionnelles, antennes directionnelles, batteries d'antennes, antennes intelligentes et antennes PCB; la liste est extensible par des entrées de nouveaux types d'antennes.

5.6 Disponibilité de communication

La disponibilité de communication est une mesure qui permet de quantifier la sûreté de fonctionnement de la communication sans fil. Les exigences en matière de disponibilité de la communication sans fil doivent être spécifiées.

D'autres solutions sans fil peuvent dégrader la disponibilité de l'application de communication sans fil ciblée. Il convient donc de clarifier les niveaux de disponibilité tolérables pour l'application. Selon la granularité de la gestion de coexistence, le paramètre peut faire référence à une liaison logique ou, plus généralement, à une application locale ou à une application de communication sans fil. La disponibilité de communication est le rapport entre la durée de fonctionnement et la période d'observation. Elle peut également être exprimée par le rapport des messages transmis avec succès sur tous les messages.

L'unité de ce paramètre doit être le pourcentage (%).

5.7 Fiabilité des communications

La fiabilité des communications d'une liaison physique et des nœuds correspondants est une mesure qui permet de quantifier la sûreté de fonctionnement de la communication sans fil. Les exigences en matière de fiabilité de la communication sans fil doivent être spécifiées pour un intervalle de temps donné pendant lequel les services de communication doivent fonctionner sans erreur dans les conditions données.

L'unité de ce paramètre doit être la seconde (s).

5.8 Débit binaire de la liaison physique

Le débit binaire de la liaison physique est le nombre d'éléments binaires qu'elle transfère par seconde. Les données étant souvent combinées par modulation ou codage, l'utilisation temporelle d'un télégramme ne peut pas toujours être calculée en divisant le nombre de chiffres binaires (ou bits) du télégramme par le débit binaire. Il est aussi à préciser que le débit binaire de la liaison physique n'est en principe pas identique à celui de l'interface de référence. Un débit binaire élevé de la liaison physique n'implique pas nécessairement une qualité de service élevée.

L'unité doit être le bit par seconde (bits/s).

5.9 Liste de fréquences bloquées

La première mesure de prévention des brouillages consiste à éviter l'utilisation des mêmes plages de radiofréquences pour plusieurs systèmes de communication sans fil. Pour les systèmes de communication sans fil qui utilisent la technologie de modulation par étalement de spectre à saut de fréquence (FHSS), cela signifie que les plages de fréquences de la séquence de saut qui sont utilisées par d'autres systèmes de communication sans fil sont bloquées et ne sont donc pas utilisées. Une liste des canaux de fréquences qui ne doivent pas être utilisés, appelée liste de fréquences bloquées, doit être spécifiée pour le système sans fil.

Une liste de fréquences bloquées peut également être utilisée dans des systèmes sans FHSS avec l'allocation dynamique de fréquences.

Le paramètre doit être une liste de canaux de fréquences conformément au 5.22.

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5.10 Fréquence centrale

Certaines normes pour appareils sans fil définissent les canaux de fréquences au moyen de la fréquence centrale et de la largeur de bande de fréquences. Ainsi, la fréquence centrale indique la position d'un canal de fréquences dans le spectre des fréquences. Cette fréquence centrale doit être calculée à partir des fréquences de coupure correspondantes. Il s'agit de la moyenne géométrique de la fréquence de coupure inférieure et de la fréquence de coupure supérieure.

L'unité de ce paramètre doit être le hertz (Hz).

5.11 Zone de fonctionnement

Les zones de fonctionnement suivantes doivent être examinées:

- en intérieur;
- en extérieur;
- en intérieur et en extérieur.

Pour les zones de fonctionnement en intérieur, il est judicieux de définir si la communication est concentrée dans une machine ou cellule de production ou si elle se fait sur la totalité de l'atelier de production ou de l'usine de transformation.

Le contenu de ce paramètre doit être du texte exprimé par une chaîne à plusieurs octets.

5.12 Charge de communication

La charge de communication désigne l'exigence que l'application d'automatisation transfère une certaine quantité de données utilisateur sur une période donnée, comme cela est représenté à la Figure 8. Il s'agit du rapport de la longueur des données d'application d'automatisation sur l'intervalle de transfert. La charge de communication (L_c) est déterminée comme suit:

$$L_c = \sum_i \frac{DL_{Ui}}{T_{Ii}}$$

où

DL_U est le nombre de données utilisateur transférées par appareil i;

T_I est l'intervalle de transfert par appareil i.

Selon la granularité de la gestion de coexistence, la charge de communication et ses paramètres peuvent faire référence à une liaison logique ou, plus généralement, à une application.

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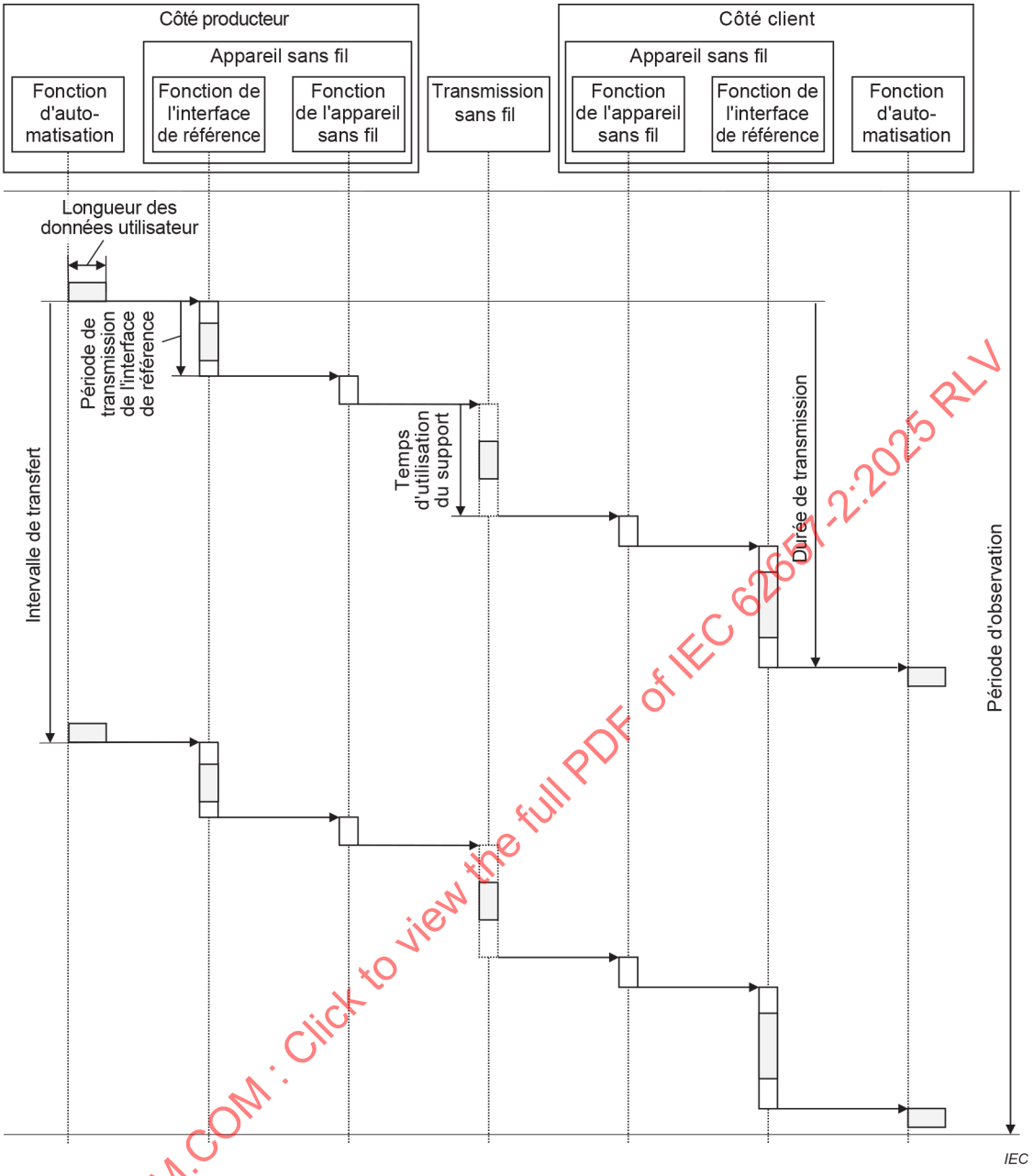

Figure 8 – Charge de communication avec deux appareils sans fil

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Toutefois, l'utilisation effective du support dépend de la solution sans fil employée. Dans l'exemple de la Figure 9, la charge de communication est représentée pour plus de deux appareils sans fil.

L'unité de ce paramètre doit être le bit par seconde (bits/s).

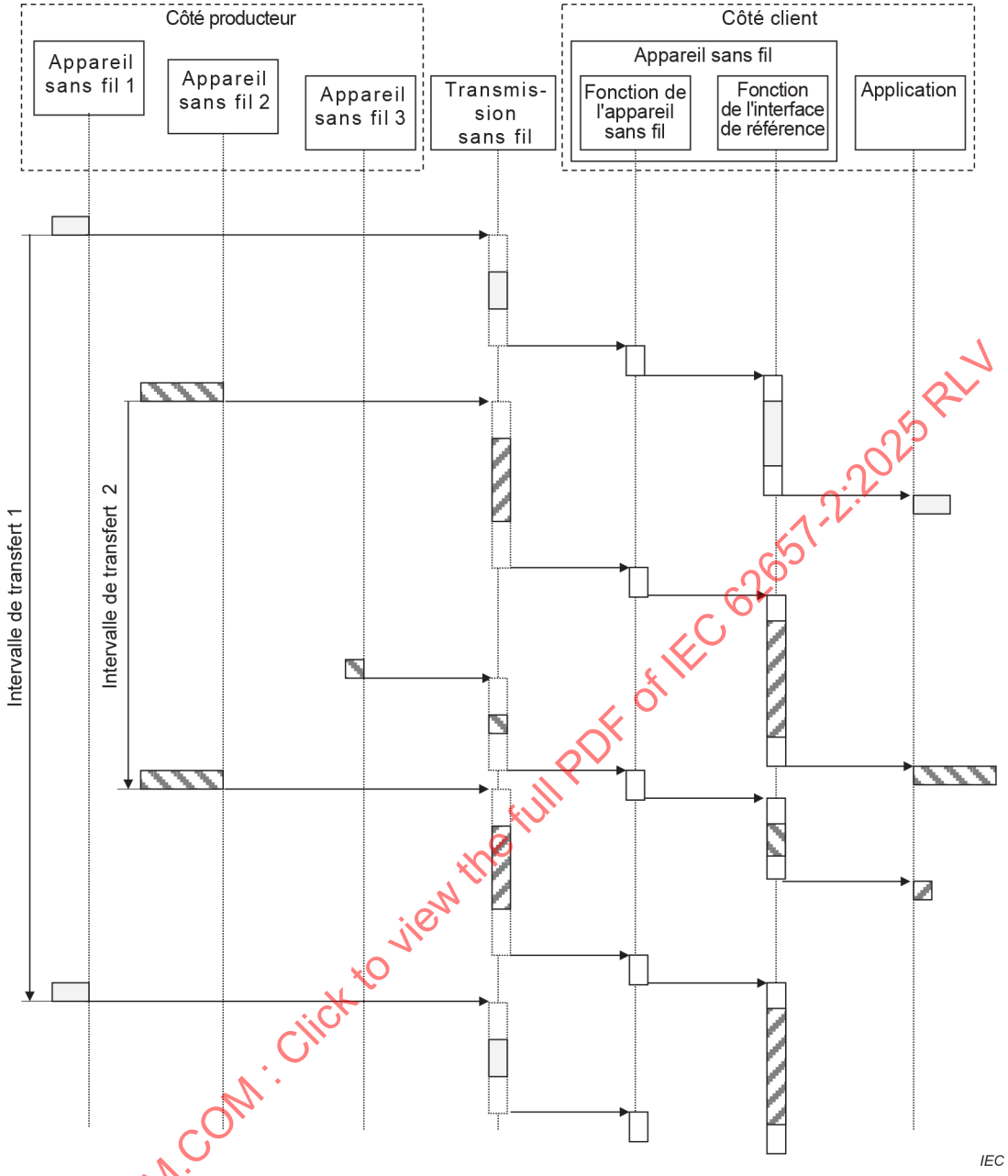

Figure 9 – Charge de communication avec plusieurs appareils sans fil

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5.13 Fréquence de coupure

En principe, il y a deux fréquences de coupure. La fréquence de coupure supérieure est la fréquence impliquée la plus élevée de la partie du spectre concernée. La fréquence de coupure inférieure est la fréquence impliquée la plus basse de la partie du spectre concernée. Toutefois, la signification du mot "impliquée" dépend de la norme ou de la technologie sans fil.

Il existe deux approches principales:

- la première approche est représentée à la Figure 10 à l'aide d'un système LAN sans fil. Le niveau de référence est la densité spectrale de puissance émise maximale. Une certaine valeur est retranchée de ce niveau maximal (20 dB, par exemple). La fréquence immédiatement au-dessus de la fréquence à laquelle la densité spectrale de puissance chute sous le niveau résultant est appelée "fréquence de coupure inférieure". De la même manière, la fréquence immédiatement au-dessous de la fréquence à laquelle la densité spectrale de puissance chute sous le niveau résultant est appelée "fréquence de coupure supérieure";
- la seconde approche définit les fréquences de coupure par rapport à un niveau donné de rayonnements non essentiels.

Les fréquences de coupure déterminent la largeur de bande de fréquences d'un système et ainsi l'utilisation du support dans le domaine fréquentiel. En outre, elles peuvent servir à calculer la fréquence centrale.

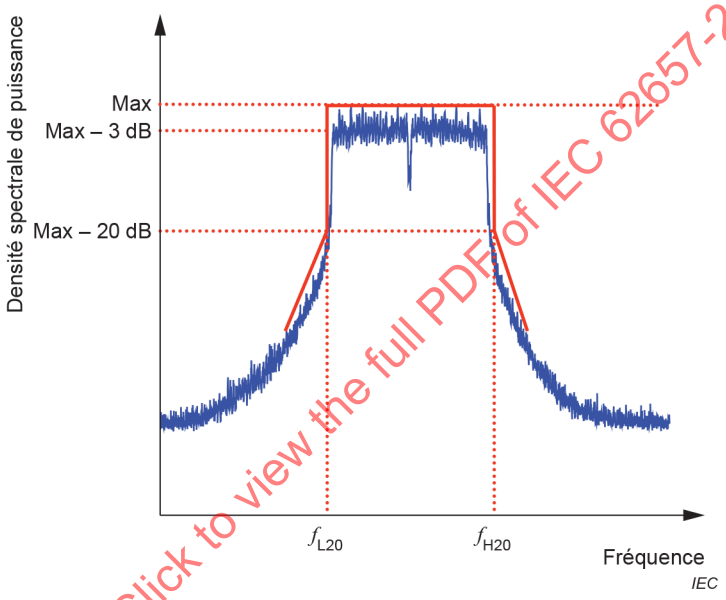

Figure 10 – Fréquences de coupure déduites du niveau de puissance maximal

L'unité de ce paramètre doit être le hertz (Hz).

5.14 Débit de données

Le débit de données est important pour le transfert de grandes quantités de données (la transmission de lourds ensembles de données de paramétrage à des variateurs ou le téléchargement de programmes dans des appareils de terrain complexes, par exemple). Selon la granularité de la gestion de coexistence, le paramètre peut faire référence à une liaison logique ou, plus généralement, à une application.

Le débit de données est le nombre d'octets ou de bits de données utilisateur transférés chez un client, de l'interface de référence vers l'application, par unité de temps.

La valeur moyenne d'une série de mesures peut être utilisée pour évaluer la coexistence, en la comparant à une valeur donnée par l'application d'automatisation.

L'unité de ce paramètre doit être le bit par seconde (bits/s).

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