

BS ISO 21214:2015



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Intelligent transport systems — Communications access for land mobiles (CALM) — Infra- red systems

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National foreword

This British Standard is the UK implementation of ISO 21214:2015. It supersedes BS ISO 21214:2006 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/278, Intelligent transport systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Second edition
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Intelligent transport systems — Communications access for land mobiles (CALM) — Infra-red systems

*Systèmes intelligents de transport — Accès aux communications des
services mobiles terrestres (CALM) — Systèmes à infrarouges*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#).

The committee responsible for this document is ISO/TC 204, *Intelligent Transport Systems*.

This second edition cancels and replaces the first edition (ISO 21214:2006), which has been technically revised with the following changes:

- additional commands have been added in [Clause 10](#);
- a new informative [Annex F](#) has been added Compatibility mode for MR-IR protocol and MR-IR protocol specification;
- minor textual clarifications have been made throughout the document.

Introduction

This International Standard determines the air interface using infrared systems operating in the wavelength range at 850 nm.

This International Standard is part of a family of International Standards for communications access for land mobiles (CALM) which specify a common architecture, network protocols, and a set of air interface definitions for wireless communications using a number of mobile (i.e. with horizontal or vertical cell/cell handover) wireless media, including infrared communications, cellular second generation, cellular third generation, 5 GHz, millimetre, and mobile wireless broadband (MWB), over packet-based networks. It is anticipated that other air interfaces will be added in the future. Generally speaking, ISO 21217 is designed to include air interfaces that provide some subset of point-to-point, vehicle-to-vehicle, and vehicle-to-point communications over packet-based networks in the ITS Sector. In particular, this International Standard provides general specifications for air interfaces designed to provide mobile access to packet-based networks.

The requirements for transmission of information over comparatively large distances using wireless technology are functionally very different from the requirements for European 5,8 GHz DSRC. Large volumes of data are required for purposes such as safety, traffic information and management, video downloads to vehicles for tourist information and entertainment, and navigation system updates, etc. In order to support such services, mobile units need to be able to communicate over longer ranges with access points/base stations and the system has to be able to hand over sessions from one access point/base station to another (horizontal or vertical). CALM standards are explicitly designed to enable quasi-continuous data communications, as well as data communications of protracted duration between vehicles and service providers and between vehicles. It is important to note that the CALM architecture is specifically designed to support packet-based communications; support for circuit-switched communications is not included.

The fundamental advantage of the CALM concept over traditional systems is the ability to support media independent handover (MIH), also referred to as heterogeneous handover, between the various media that can be included in a CALM system. Selection policies are supported that include user preferences and media capabilities in making decisions as to which media to use for a particular session and when to handover between media or between service providers on the same medium. These handover mechanisms are defined within ISO 21217, ISO 21210, ISO 21218, and ISO 24102. Handovers between access points using the same technology and service provider use mechanisms that are defined within the particular medium-specific CALM International Standard.

ITS applications that can be enhanced or are enabled by the CALM architecture includes car-to-car and point-to-multipoint safety messaging, collision avoidance, update of roadside telemetry and messaging, probe data collection, general Internet access, image and video transfer, infotainment, multimedia multicast, traffic management, monitoring and enforcement in mobile situations, and route guidance, just to mention a few.

This first revision takes into account and accommodates related CALM International Standards approved since the publication of the original version of this International Standard. [Annex G](#) provides a summary of the changes from the first published edition of this International Standard.

Intelligent transport systems — Communications access for land mobiles (CALM) — Infra-red systems

1 Scope

This International Standard determines the air interface using infrared systems at 820 nm to 1 010 nm.

The International Standard provides protocols and parameters for medium range and medium to high speed wireless communications in the ITS sector using infrared systems.

Such links are required for quasi-continuous, prolonged, or short communications between the following:

- vehicles and the roadside;
- between vehicles;
- between mobile equipment and fixed infrastructure points;
- over medium and long ranges.

Vehicles may be moving or stationary.

Wherever practicable, this International Standard has been developed by reference to suitable extant International Standards, adopted by selection. Required regional variations are provided.

Due account is given to, and made use of, any relevant parts of appropriate communications systems such as Global Positioning Systems (GPS), Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), Radio Local Area Networks (RLANs), Digital Data Broadcasting (DDB), TETRA, FM subcarrier, Mobile Broadband Systems (MBS, W-ATM), Internet Protocols, and DSRC.

This International Standard

- supports data rates of 1 Mbit/s up to 128 Mbit/s (it may also support higher data rates),
- supports vehicle speeds to a minimum of 200 km/h (closing speeds could be double this value),
- defines or reference environmental parameters relevant to link operation,
- supports communication distances to 100 m (it may also support longer communication distances of 300 m to 1 000 m),
- supports latencies and communication delays in the order of milliseconds,
- is compliant to regional/national regulatory parameters, and
- may support other regional/national parameters, as applicable.

Application specific requirements are outside the scope of this International Standard. These requirements will be defined in the CALM management and upper layer standards and in application standards.

Application specific upper layers are not included in this International Standard but will be driven by application standards (which may not be technology specific).

2 Conformance

Systems claiming conformance with this International Standard shall meet the specifications herein.

3 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

For a list of related deliverables under concurrent development, see Bibliography.

ISO/IEC 8802-11:1999, *Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements — Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications*

IEC 60825-1, *Safety of laser products — Part 1: Equipment classification, requirements and user's guide*

4 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21217 and the following apply.

4.1 General terms and definitions

4.1.1

broadcast window

BcW

window ([4.1.27](#)) used to broadcast information to slaves, even to those who have not yet performed the “registration process”

4.1.2

chip

smallest information unit communicated over the link

Note 1 to entry: Depending on the chosen coding, one information bit may be represented by one or more consecutive chips.

4.1.3

communications profile

specific set of data rate, modulation, and flow control

4.1.4

communication zone

spatial zone in which two CALM-IR units are able to communicate with acceptable performance

4.1.5

compatibility window

CmpW

window ([4.1.27](#)) that enables non-CALM-IR systems that follow certain rules to co-exist with a CALM-IR system without harmful interference

4.1.6

default data rate

data rate used in the *default communications profile* ([4.1.7](#)) to determine the data rate if not otherwise specified

4.1.7

default communications profile

communications profile ([4.1.3](#)) used except where another communications profile is successfully negotiated

4.1.8

flush byte

8 bit sequence used to denote the end of the main body of the information to be transmitted using the HHH (1,13) coding procedure

4.1.9

forward direction

forward link

forward window

communication flow from master to slave

4.1.10

frame length indicator

FLen

code used to calculate the frame length from the last slot index

4.1.11

frame organisation table

FOT

table that carries all organisational data of the TDMA frame

4.1.12

free air time indicator

FATI

code used to signal that “free air time” follows the current frame

Note 1 to entry: This airtime may be used by units not being a slave of the current master to establish “secondary mastership”.

4.1.13

guard time

TG

time which precedes a ‘command alert’ CA in certain cases in order to allow the automatic gain control of the receivers to re-settle

4.1.14

HHH (1,13) code

special run length limited code with d=1 and k=13 used in the CALM-IR communications profiles 2 to 6

4.1.15

management window

first window in a CALM-IR frame and carries all organisational information for the current frame

4.1.16

master identifier

code which uniquely identifies a CALM-IR master

4.1.17

multicast window

McW

window ([4.1.27](#)) used for communication from master to multiple slaves, forward direction only

4.1.18

private window(s)

window(s) ([4.1.27](#)) that carry the information exchange between a master and a specific slave

4.1.19

registration phase

phase where a master identifies devices newly entering his communication zone

4.1.20

slave

device that is under the control of another device

4.1.21

spare window

SpW

window (4.1.27) not allocated to a slave and reserves airtime for slaves eventually registering during the current frame in order to enable the master to instantly allocate them a private window without the need for frame reorganisation

4.1.22

slot index (S)

index used to count the time slots

4.1.23

TDMA frame

time structure based on a train of consecutive time slots (at least one)

4.1.24

Time slot

subunit of a TDMA frame

4.1.25

temporary identifier

TempID

code used for addressing the slave device while it resides in the communication environment of the master

Note 1 to entry: Each time the slave registers in a communication zone, a new TempID is created.

4.1.26

wake-up window

WuW

special case of a broadcast window and is used to “wake-up” sleeping units entering the communication zone of an active master

4.1.27

window

smallest addressable time span of a CALM-IR frame and may consist of one or multiple time slots

4.2 Terms and definitions of the optical parameters

4.2.1

irradiance

E_e

(at a point of a surface) quotient of the radiant flux $d\Phi_e$ incident on an element of the surface containing the point, by the area dA of that element

Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the following expression

$$L_e \cdot \cos \theta \cdot d\Omega$$

where

L_e is the radiance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$;

θ is the angle between any of these beams and the normal to the surface at the given point

$$E_e = \frac{d\Phi_e}{dA} = \int_{2\pi \text{ sr}} L_e \cdot \cos\theta \cdot d\Omega$$

Note 1 to entry: It is expressed in W/m².

[SOURCE: IEC 60050 (845-01-37), modified]

4.2.2

luminous flux

Φ_v

quantity derived from radiant flux Φ_e by evaluating the radiation according to its action upon the CIE standard photometric observer. For photopic vision

$$\Phi_v = K_m \int_0^\infty \frac{d\Phi_e(\lambda)}{d\lambda} \cdot V(\lambda) \cdot d\lambda$$

where

$\frac{d\Phi_e(\lambda)}{d\lambda}$ is the spectral distribution of the radiant flux and $V(\lambda)$ is the spectral luminous efficiency.

Note 1 to entry: For the value K_m (photopic vision) and K'_m (scotopic vision), see IEC 60050 (845-01-56).

[SOURCE: IEC 60050 (845-01-35), modified]

4.2.3

luminous efficacy of radiation

K

quotient of the luminous flux Φ_v by the corresponding radiant flux $K = \frac{\Phi_v}{\Phi_e}$

Note 1 to entry: When applied to monochromatic radiation, the maximum value of $K(\lambda)$ is denoted by the symbol K_m . $K_m = 683 \text{ lm} \cdot \text{W}^{-1}$ for $\nu_m = 540 \times 10^{12} \text{ Hz}$ (λ_m approximately 555 nm) for photopic vision. $K'_m = 1\,700 \text{ lm} \cdot \text{W}^{-1}$ for λ'_m approximately 507 nm for scotopic vision.

For other wavelengths: $K(\lambda) = K_m V(\lambda)$ and $K'(\lambda) = K'_m V'(\lambda)$.

[SOURCE: IEC 60050 (845-01-55), modified]

4.2.4

radiance

L_e, L

(in given direction, at a given point of a real or imaginary surface) quantity defined by the following formula:

$$L_e = \frac{d\Phi_e}{dA \cdot \cos\theta \cdot d\Omega}$$

where

$d\Phi_e$ is the radiant flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction;

dA is the area of a section of that beam containing the given point;

θ is the angle between the normal to that section and the direction of the beam.

Note 1 to entry: It is expressed in W/sr·m².

[SOURCE: IEC 60050 (845-01-34), modified]

4.2.5 radiant exitance

M_e
quotient of the radiant flux $d\Phi_e$ leaving an element of the surface containing the point, by the area dA of that element

Equivalent definition. Integral, taken over the hemisphere visible from the given point of the following formula:

$$M_e = \frac{d\Phi_e}{dA} = \int_{2\pi sr} L_e \cdot \cos\theta \cdot d\Omega$$

where

$L_e \cdot \cos\theta \cdot d\Omega$ is the radiance at the given point in the various directions of the emitted elementary beams of solid angle $d\Omega$;

θ is the angle between any of these beams and the normal to the surface at the given point

Note 1 to entry: It is expressed in W/sr·m².

[SOURCE: IEC 60050 (845-01-47), modified]

4.2.6 radiant flux

alternative expression for radiant power

[SOURCE: IEC 60050 (845-01-24), modified]

4.2.7 radiant intensity

I_e
quotient of the radiant flux, $d\Phi_e$, leaving the source and propagated in the element of solid angle, $d\Omega$, containing the given direction, by the element of solid angle

$$I_e = \frac{d\Phi_e}{d\Omega}$$

Note 1 to entry: It is expressed in W/sr (Watt per steradian).

[SOURCE: IEC 60050 (845-01-30), modified]

4.2.8 radiant power

radiant power Φ_e is the power emitted, transmitted or received in the form of radiation

Note 1 to entry: It is expressed in W (Watt).

[SOURCE: IEC 60050 (845-01-24), modified]

4.2.9 steradian

sr
dimensionless SI unit of solid angle

Note 1 to entry: Solid angle that, having its vertex at the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere. (ISO, 31/1-2.1, 1978)

Note 2 to entry: Usually, the abbreviation "sr" is appended although this is mathematically incorrect.

EXAMPLE The unity solid angle, in terms of geometry, is the angle subtended at the centre of a sphere by an area on its surface numerically equal to the square of the radius (see [Figure 1](#)). Other than the figure might suggest, the shape of the area does not matter at all. Any shape on the surface of the sphere that holds the same area will define a solid angle of the same size.

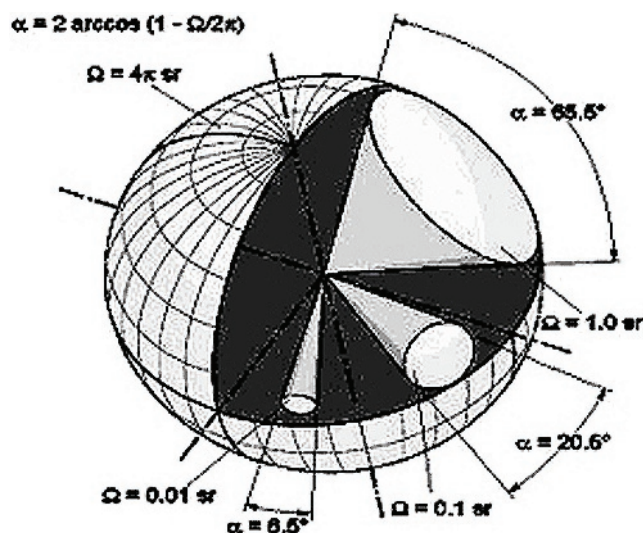


Figure 1 — Solid angle

Relation between distance r , irradiance E_e , and intensity I_e .

Using a single radiation point source, we get the following formula:

$$E_e = \frac{d\Phi_e}{dA} = \frac{I_e \cdot d\Omega}{dA} = \frac{I_e}{r^2} \left[\frac{W}{m^2} \right]$$

[SOURCE: IEC 60050 (845-01-24), modified]

5 Symbols (and abbreviated terms)

Symbols and abbreviated terms used in this International Standard are listed below. Reference should also be made to ISO 21217.

ϕ_e	radiant power, radiant flux
Φ_v	luminous power or luminous flux
BcW	broadcast window
BER	bit error ratio
CA	command alert
CALM	communications access for land mobiles
CCI	control channel indicator
CFA	CALM fast application
Cmd	command

ϕ_e	radiant power, radiant flux
CmpW	compatibility window
CRC	cyclic redundancy check
D	beam axis, “bore-sight direction”
DSRC	dedicated short range communication
E_e	irradiance
E_v	illuminance
FATI	free air time indicator
FB	flush byte
FCIR	fast CALM infrared packet format
FLen	frame length indicator
FOT	frame organization table
F-Sync	frame synchronisation pattern
HHH	Hirt, Hassner, Heise (inventors of the HHH(1,13) code)
I_e	radiant intensity
IR	infrared
IR-CAL	IR communication adaptation layer
IR-MAE	IR management adaptation entity
IR-ME	IR management entity
I_v	luminous intensity
K	luminous efficacy of radiation
L_e	radiance
L_v	luminance
MAC	medium access control. Sometimes used synonym to MAC layer.
McW	multicast window
M_e	radiant exitance
MID	master identifier
MnW	management window
Mv	luminous exitance
Nframe	number of time slots in a CALM-IR frame
Nmaxframe	maximum number of time slots in a CALM-IR frame

ϕ_e	radiant power, radiant flux
Nminframe	minimum number of timeslots in a CALM-IR frame
OBU	on board unit
PA	preamble
PL	payload
PP	preamble period
PrW	private window
RLL	run length limited code
RSU	road side unit
s	slot index
SAP	service access point
SpW	spare window
sr	steradian
STA	start flag
STO	stop flag
Tbit	bit time (duration of one bit)
Tchip	chip time (duration of one chip)
TCWAIT	waiting time of the slave for a reply to a proposed TempID
TDMA	time division multiple access
TDREG	registration time-out
TempID	temporary ID
TF-Sync	duration of the F-Sync signal
TG	guard time
TL	lead time - time from the rising edge of the last pulse of a synchronisation signal (F-Sync, W-Sync, CA) to the rising edge of the first pulse of the following command, etc
TPfall	optical pulse fall time
TPon	optical pulse on time
TPrise	optical pulse rise time
TREG	delay time before slave replies to an MC-RRQ or MC-REN
TRT	waiting time of the master for a reply to its MC-IDP
TRW	receiver window – time span around the allocated time slot when the receiver circuit shall be ready to detect a W-Sync signal

ϕ_e	radiant power, radiant flux
TRWAIT	waiting time of the master for a reply to an MC-RRQ or MC-REN
TTempID	tempID time-out
W-Sync	window synchronisation pattern
WuW	wake-up window
δ	elevation angle
θ_H	horizontal opening angle
θ_V	vertical opening angle
φ	azimuth angle
Φ_v	luminous flux ¹²⁵

6 Requirements: Transmitter and receiver parameters

6.1 Transmitter wavelengths and bandwidths

Table 1 — IR Transmitter parameter specification

Parameter name		Specification	
		Channel 870 (main channel)	Channel 970 (alternate channel)
TX1	Nominal transmitter wavelength	870 nm	970 nm
TX2	Transmitter pass band	820 nm to 910 nm	920 nm to 1 010 nm
TX3	Coherence length	<1 mm	
TX4	Total radiated power	dependent on transmitter class (see 6.2)	
TX5	Minimum receiver in-band (RX2) radiated power	80 % of TX4	
TX6a	Radiated power below pass band	not specified	<10 % of TX4
TX6b	Radiated power above pass band	<10 % of TX4	not specified

NOTE Re parameter TX3:

$$l_c = \frac{\lambda^2}{\Delta\lambda}$$

where

l_c is the coherence length;

λ is the wavelength;

$\Delta\lambda$ is the bandwidth.

EXAMPLE $\lambda = 900 \text{ nm}$, $\Delta\lambda = 40 \text{ nm}$

$$l_c = \frac{900 \text{ nm}^2}{40 \text{ nm}} \approx 20 \mu\text{m}$$

6.2 Radiated power

6.2.1 Radiated power limits

Table 2 — IR transmitter parameter limits

	Parameter name	Specification
TX7	Maximum radiated intensity	According to IEC 60825-1
TX8	Maximum transmitted power within the range of visible light	Not limited by this International Standard ^a

^a Certain automotive standards can have limitations on this parameter.

6.2.2 Transmitter classes

The transmitter class shall be declared in the associated product specification and shall be organized as follows.

Table 3 — Transmitter classes

TX class	T1	T2	T3	T4	T5	T6	T7	T8
TX4a - Minimum radiant intensity (W/sr) (pulse peak value)	0,36	0,75	1,5	3	6	12	25	50
	T9	T10	T11	T12	T13	T14	T15	T16
	100	200	400	800	1 600	3 200	6 400	12 800

6.3 Receiver wavelengths and bandwidths

Table 4 — IR receiver parameter specification

	Parameter name	Specification	
		Channel 870 (main channel) mandatory	Channel 970 (alternate channel) optional
RX1	Nominal receiver wavelength	870 nm	970 nm
RX2	Receiver pass band	835 nm to 905 nm ^a	935 nm to 1 005 nm
RX4a	Lower receiver stop band	≤805 nm	≤905 nm
RX4b	Upper receiver stop band	≥935 nm ^b	≥1 035 nm
RX5a	Receiver sensitivity in lower stop band	not specified	≥10 dB above RX6
RX5b	Receiver sensitivity in upper stop band	≥10 dB above RX6 ^c Not specified for receivers which shall be able to receive both channels	not specified

^a Receivers which shall be able to receive both channels employ an upper limit of 1 0005 nm

^b Receivers which shall be able to receive both channels employ an upper limit of 1 035 nm.

^c Not specified for receivers which shall be able to receive both channels.

The manufacturer shall declare whether he implemented in the equipment only the mandatory main channel or as well as the optional alternate channel.

6.4 Receiver class

The receiver class shall be declared in the associated product specification and shall be organized as follows.

Table 5 — Receiver classes

RX class	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
RX6 (mW/m ²) Receiver sensitivity in boresight at RX2, RX8, RX9 and RX11	better than 32	better than 16	better than 8	better than 4	better than 2	better than 1	better than 0,5	better than 0,25	better than 0,12	better than 0,06	better than 0,03
RX7 (mW/m ²) Saturation limit in boresight	12 800	6 400	3 200	1 600	800	400	200	100	48	24	≤12
RX8 Reference bit error ratio (B.E.R.)	10 ⁻⁶										
RX9 Immunity to interference caused by natural optical radiation	≥1 120 W/m ² (sunlight spectral distribution)										
RX10 (mW/m ²) Wake-up sensitivity in boresight at 500 kHz	better than 32	better than 16	better than 8	better than 4	better than 2	better than 1	better than 0,5	better than 0,25	better than 0,12	better than 0,08	better than 0,03
RX11 Reference communication profile	Default communication profile										

The manufacturer shall declare the guaranteed sensitivity for all communication profiles implemented in the equipment.

7 Modulation and coding

7.1 Wake-up modes

In systems where receivers which have a “sleeping mode” are to be expected, the master has to send a “wake-up signal” in order to eventually wake up “sleeping” slaves. The wake up signal is to be transmitted in a “wake up window”.

7.1.1 85 kHz coded WU

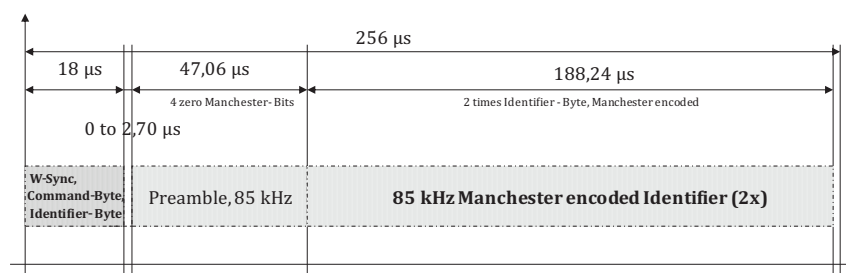


Figure 2 — Wake-up signal

Table 6 — Wake-up signal timing specification

	Parameter name	Specification
TX11	Wake-up signal	Burst frequency: 85 kHz $\pm$ 1 %, duty cycle: 45 % to 55 %
TX12a	max. allowed pulse rise time (optical):	1 000 ns
TX12b	max. allowed pulse fall time (optical):	1 000 ns

7.1.2 Transmitter generic modulation parameters

Table 7 — IR transmitter parameter TX10 specification

	Parameter name	Specification
TX10	Tolerance of bit clock	0,1 %

7.1.3 Receiver generic modulation parameters

Table 8 — IR receiver parameter RX12 specification

	Parameter name	Specification
RX12	Tolerance of bit clock	0,1 %
NOTE "Tracking" of the receiver clock or equivalent techniques are assumed in the sync modes.		

7.2 Communications profiles

CALM IR employs a whole set of data rates and coding schemes, which have to be selected depending on the application and on the actual link quality achieved.

Specific data rates and coding schemes constitute a "communications profile".

The following profiles apply.

NOTE Some of the parameters of profile 5 and profile 6 will be defined in future versions of this International Standard.

Table 9 — Communications profiles

	Profile 0 (base pro- file)	Profile 1 (default profile)	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6
Data rate	1 Mb/s	2 Mb/s	8 Mb/s	16 Mb/s	32 Mb/s	64 Mb/s	128 Mb/s
Modulation	3/16 OOK-RZ	6/16 OOK-RZ	CIR-8 HHH(1,13)	CIR-16 HHH(1,13)	CIR-32 HHH(1,13)	CIR-64 HHH(1,13)	CIR-128 HHH(1,13)
Bit time T_{bit}	1 000 ns + -1 %	500 ns + -1 %	n.a.				
Chip time T_{chip}	1 000 ns + -1 %	500 ns + -1 %	83,4 ns $\pm$ 6,6 ns	41,7 ns $\pm$ 3,3 ns	20,8 ns $\pm$ 1,6 ns	10,4 ns	5,2 ns
Equipment employing several communications profiles shall conform to the most stringent values, irrelevant of which profile is active at a given time							
NOTE 1 Further profiles may be added in future.							
^a For details, see Annex B .							

Table 9 (continued)

	Profile 0 (base profile)	Profile 1 (default profile)	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6
Optical pulse on time (T_{Pon})	190 ns ± 20 ns	190 ns ± 20 ns	83,4 ns ± 6,6 ns	41,7 ns ± 3,3 ns	20,8 ns ± 1,6 ns	10,4 ns	5,2 ns
Optical pulse rise time (T_{Prise}) (See Note below)	≤75	≤75	≤38 ns	≤19 ns	≤9 ns	to be added	to be added
Optical pulse fall time (T_{Pfall}) (See Note below)	≤75	≤75	≤38 ns	≤19 ns	≤9 ns	to be added	to be added
Format:	Sync						
MAC flow control:	By MAC commands ("Block start", "Block end", "Packet start", "Packet end", "Start of control-block")						
Forward error correction	Hamming L = 12, D = 3 ^a		none ^a				
Multiple error detection	Hamming L = 12, D = 3 ^a		CRC32				
Equipment employing several communications profiles shall conform to the most stringent values, irrelevant of which profile is active at a given time							
NOTE 1 Further profiles may be added in future.							
^a For details, see Annex B .							

7.3 Profile 0 (base profile) and profile 1 (default profile) modulation

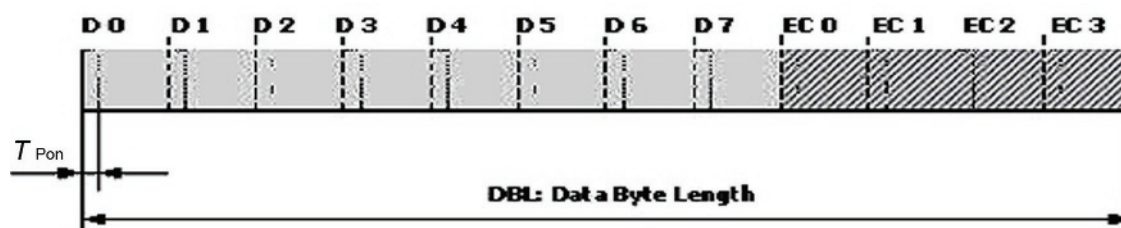


Figure 3 — Modulation of profile 0 and profile 1

The coding and decoding rules for the communications profile 0 and profile 1 are defined in [Annex A](#).

7.4 Profile 2 to profile 6

Profile 2 to profile 6 does not employ forward error correction.

NOTE Burst errors at these data-speeds are much more likely than single bit errors.

Burst errors are detected by the CRC.

The complete coding and decoding rules for the communications profile 2 to profile 6 (e.g. modulation types CIR-8 to CIR-128) are given in 0.

8 Directivity and communication zones

8.1 Directivity parameters

For a directional communication with CALM-IR devices, a three-dimensional coordinate system (x_{CALM} , y_{CALM} , and z_{CALM}) has to be constituted. The origin of the coordinate system corresponds to the source of the beam. The x-axis of the CALM-device corresponds with the forward direction of the vehicle.

[Figure 4](#) shows the azimuth angle, φ , and the elevation angle, δ , of the beam axis "D" ("bore-sight direction") in relation to the x-axis ("main direction").

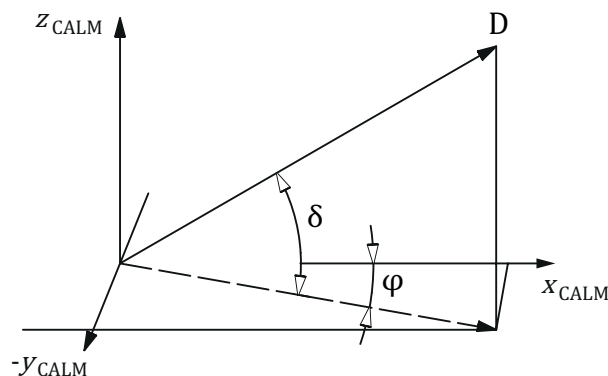


Figure 4 — Azimuth and elevation angle of the beam axis

Further parameters of directivity are the horizontal opening angle, Θ_H , and the vertical opening angle, Θ_V , as detailed in [Figure 5](#).

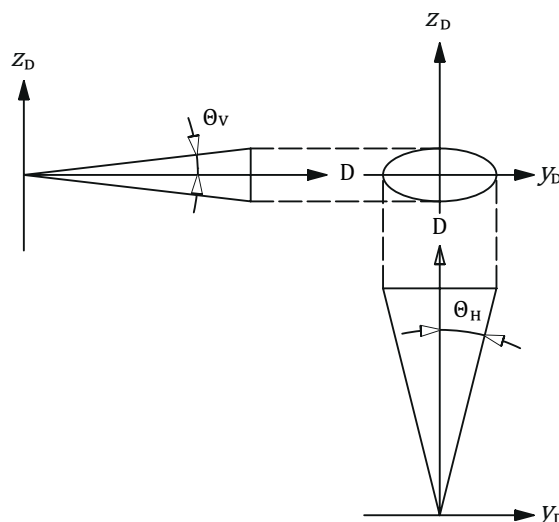


Figure 5 — Horizontal opening and vertical opening angles

Azimuth and elevation are measured according to [Figure 4](#).

Openings are symmetrical to the beam axis D.

Valid horizontal openings Θ_H encompass values from 0° to 360° .

Valid vertical openings Θ_V encompass values from 0° to 360° .

The resolution of these angles is Θ_{basic} ($\sim 1,5^\circ$).

8.2 Communication zones

8.2.1 Basic beam

A “basic beam” is defined to be a beam (in arbitrary direction) with the minimum possible horizontal and vertical opening angles equal to the resolution $\Theta_{\text{basic}} = 1,5^\circ$.

8.2.2 Communication zone construction

8.2.2.1 CALM-IR communication zones with any “footprint” on the sphere “illuminated” by the “antenna array” can be defined by assigning a number of “basic beams” being a member of it.

Alternatively, a CALM-IR communication zone with a regular (i.e. symmetrical) footprint can be defined by its associated directivity parameters azimuth φ , elevation δ , horizontal opening Θ_H , and vertical opening Θ_V .

8.2.2.2 Any communication zone may be assigned a specific transmitter or receiver class independently from each other. The assignment of transmitter and receiver classes to communication zones is dynamically controllable.

8.2.2.3 Inside the communication zone, the transmitter class and the receiver class parameters as defined in [Table 2](#), [Table 3](#), [Table 4](#), and [Table 5](#) shall apply.

NOTE 1 Any communication zone can be associated with the same “communication channel”, thus carrying identical communication streams.

NOTE 2 Alternatively, any communication zone can be associated with a different “communication channel”, thus carrying different communication streams which are independent from each other (dynamically controllable).

NOTE 3 Isolation between multiple communication zones is not defined by this International Standard.

8.2.3 Communication zones shortcuts

In order to speed up the direction control for pre-defined communication zones, the following shortcuts are defined.

Table 10 — Transmitter communication zones shortcuts

Dimensions are in degrees

Zone	φ	δ	Θ_H	Θ_V	Description
FG	0	30	90	90	Forward general
FS	0	0	7,5	7,5	Forward straight
FR	-18	0	9	7,5	Forward right
FL	18	0	9	7,5	Forward left
BG	180	30	90	90	Backward general
BS	180	0	7,5	7,5	Backward straight

Table 10 (continued)

Zone	φ	δ	ΘH	ΘV	Description
BR	-156	0	21	7,5	Backward right
BL	156	0	21	7,5	Backward left
GR	-90	30	90	90	General right
SR	-45	0	15	7,5	Side right
UR	-60	36	21	21	Up right
GL	90	30	90	90	General left
SL	45	0	15	7,5	Side left
UL	60	36	21	21	Up left
HS	0	90	210	210	Hemispheric
US	0	42	21	21	Up straight
DR	0	0	360	7,5	Disk-radiator

Table 11 — Receiver communication zones shortcuts

Dimensions are in degrees

Zone	φ	δ	ΘH	ΘV	Description
FG	0	30	90	90	Forward general
FS	0	0	7,5	7,5	Forward straight
FR	-18	0	9	7,5	Forward right
FL	18	0	9	7,5	Forward left
BG	180	30	90	90	Backward general
BS	180	0	7,5	7,5	Backward straight
BR	-156	0	21	7,5	Backward right
BL	156	0	21	7,5	Backward left
GR	-90	30	90	90	General right
SR	-45	0	15	7,5	Side right
UR	-60	36	21	21	Up right
GL	90	30	90	90	General left
SL	45	0	15	7,5	Side left
UL	60	36	21	21	Up left
HS	0	90	210	210	Hemispheric
US	0	42	21	21	Up straight
DR	0	0	360	7,5	Disk-radiator

NOTE For the RSU, no communication zone is defined because it depends strongly on the geographical location.

9 Frames and windows

9.1 General structure

This part of the International Standard describes the CALM-IR framing, the window structure, and window management.

The framing describes the CALM-IR TDMA scheme as media access method for simultaneous communication of multiple communication partners.

In a single communication environment with two or more communication partners, there shall exist exactly one master, which controls the organization of the TDMA sequence.

If no dedicated master exists, a procedure is provided to establish a new master.

Direct “slave-to-slave” communications requires that one of the slaves acts as a temporary master.

The CALM IR-frame consists of N_{frame} time slots and is defined and organized by the master.

The framing structure is defined by reserved signals which by definition never can occur in a data stream. This allows simple detection circuitry without the necessity to constantly supervise and analyse the data stream.

The following signals are used:

- F-Sync - frame synchronisation signal;
- W-Sync - window synchronisation signal;
- CA - command alert.

The patterns and the use of these signals are described and defined in the following subclauses.

9.2 Frame

9.2.1 Frame structure

A frame employs the following characteristics.

- The CALM-IR TDMA frame is generated by the master and starts with the F-Sync signal.
- The frame is either terminated by the F-Sync signal of the consecutive frame or, in the event that the option “free air time” is used, with a W-Sync signal and the MAC command “free air time” (MC-FAT).
- A frame is subdivided into timeslots T_s .
- The maximum length of the frame is N_{maxframe} time slots, the minimum length is N_{minframe} .
- A frame is organised in “windows” by means of window synchronisation signals W-Sync.
- The CALM-IR TDMA frame contains at least one window.
- The maximum number of windows within one frame is a dynamic parameter and depends on the size of the windows.
- The very first window of a frame is always the management window MnW .

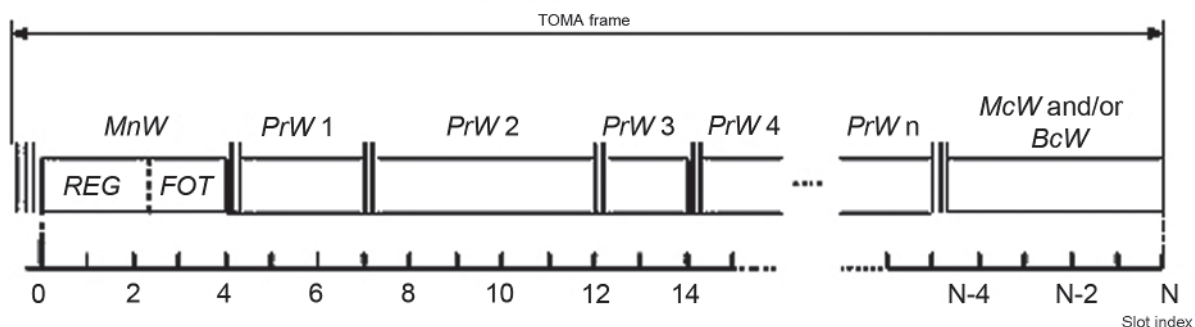


Figure 6 — CALM-IR frame structure, example

9.2.2 Frame synchronisation signal (F-Sync)

The frame synchronisation signal F-Sync is generated by the master at the beginning of a frame and has the following pattern as shown in Figure 7.

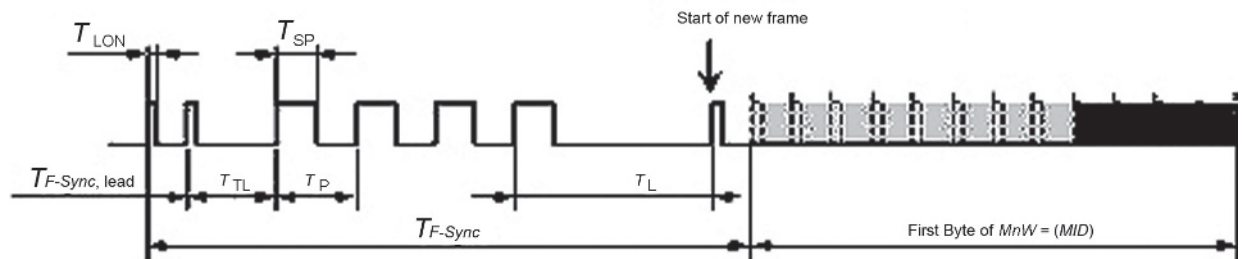


Figure 7 — F-Sync

All active slaves not being in a “transmit state” shall be ready to recognize an *F-Sync* at any time, since an *F-Sync* can also interrupt frames in progress, for example to prioritize emergency messages.

F-Sync never shall be sent directly after a “receive state” of the master. A guard interval of duration T_G (see 9.5) shall be inserted before the sending of *F-Sync* in order to allow the receiver circuitry of all slaves to re-settle.

9.3 Windows

9.3.1 Window structure and types

9.3.1.1 Frames are divided into windows by the window synchronisation signal *W-Sync* sent by the master.

9.3.1.2 Windows may carry forward information (master to slave), as well as return information (slave to master).

9.3.1.3 There exist the following types of window which are described in subsequent subclauses:

- management window (MnW);
- private window (PrW);
- multicast window (McW);
- broadcast window (BcW);
- compatibility window (CmpW);
- spare window (SpW);
- wake-up window (WuW).

9.3.1.4 The information flow within a window is controlled by MAC commands.

9.3.2 Window synchronisation (*W-Sync*)

9.3.2.1 The window synchronisation signal *W-Sync* is sent by the master at the beginning of all windows *PrW*, *BcW*, *McW*, and *WuW* except the first window of the *TDMA-frame* which is marked by the *F-Sync*.

9.3.2.2 Because of the propagation delay times, the receiver shall be protected by guard time T_G (see 9.5). Therefore, the *W-Sync* can be slightly asynchronous in respect to the time slot index.

9.3.2.3 In order to care for this effect on the receiver side, the receiver circuitry shall be ready to detect the *W-Sync* not just at the beginning of the time slot allocated by the FOT but from slightly before until slightly after the allocated time within the *W-Sync* receiver window $T_{W\text{Receive}}$.

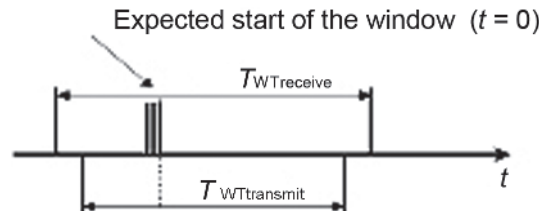


Figure 8 — W-Sync receiver and transmitter window

9.3.2.4 In the event that a system is configured with the feature “free air time”, the very last window (which may either be an MnW, a PrW, an McW, or a BcW) shall be followed by a *W-Sync* and the MAC command MC-FAT.

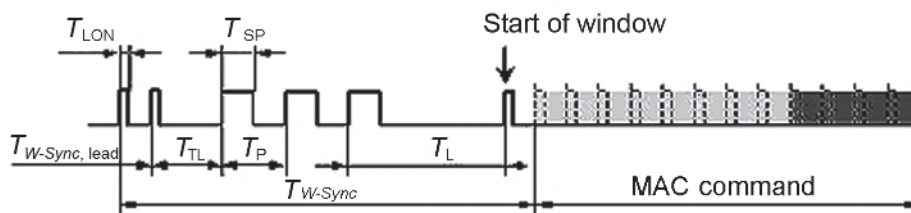


Figure 9 — W-Sync

9.3.2.5 A *W-Sync* shall never follow directly after a “receive state”. In such a case, a guard interval of duration T_G shall be inserted before the sending of *W-Sync* in order to allow the receiver circuitry of the communications partner to re-settle.

9.3.3 Management window

9.3.3.1 The management window is the first window in a CALM-IR frame and carries all organization information for the current frame as described below.

9.3.3.2 Within the management window (MnW)

- slaves newly entering the communication zone are registered and allocated appropriate window parameters,
- sufficient communication time is dynamically allocated to each slave,
- care is taken that timing requirements for time critical applications are met,
- care is taken that required command response/reaction times are met,
- if necessary, time slots are re-arranged, and
- short broadcast messages are sent.

In the management window, only the default communications profile shall be used.

9.3.3.3 The MnW follows immediately after the frame-Sync signal. It is subdivided into the generic frame information (i.e. MID, FLen, and FATI) and optional MAC commands for registration (MC-REG) and organization (MC-FOT, MC-FOTU, MC-FOTS, MC-SUS, and MC-SUA) (see [Clause 12](#)). The generic frame information is defined as follows.

9.3.3.4 The master identifier “MID” is the unique identifier of any CALM IR communications master. It consists of a three byte integer which comprises two parts as follows.

9.3.3.4.1 The one byte class identity gives information about the master (e.g. fixed roadside beacon, vehicle onboard unit, mobile enforcement, PDA or laptop, point-to-point link).

MSB	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	LSB
M	F1	F0	S	K3	K2	K1	K0
1	Function of the master		Sub - master	Kind of master			

Figure 10 — Structure of the class identity code

Table 12 — Class identity codes

Bit position	Value	Meaning	Description
M	1	Master identifier	Used in MAC address to distinguish slaves and masters
F1, F0	1, 1	Broadcaster	Indicates that the sender of the MID is a “broadcaster” only (e.g. a “Talking traffic sign”). The “broadcaster” supports no registration of slaves.
	1, 0	Master	Indicates a normal master to which slaves may register.
	0, 1	Pre master	Indicates a (normally mobile) unit which can become a slave or master.
	0, 0	Internet access point	Indicates that the Internet is accessible through the master.
S	1	Flag: active as sub-master	Indicates that the unit currently performs the following two functions at the same time: — it works as a slave versus a master (usually positioned in the infrastructure); — it works as secondary master, usually of a moving cluster.
	0	Flag: active as master	— Indicates that the unit currently works as the master of a usually moving cluster. — In case this cluster comes into the communications zone of a master, the unit assumes the function of a slave versus the master and as a secondary master versus the cluster and sets the flag to 1.
K3, K2, K1, K0		Reserved for future use	If not used, set to 0.

9.3.3.4.2 16 bit binary number.

In the event of a stationary master, this shall be a fixed number identifying the master and is assigned during installation time.

In the event of a temporary master, this shall be a random number created by the device which wants to take the master function.

9.3.3.5 The frame length indicator (FLen) gives the total length of the current frame in terms of available time slots as a one byte integer.

9.3.3.6 The free air time indicator (FATI) gives the air time following the last window of the current frame which is not used by the current master in order to allow other masters to build up a communications frame between two frames of the current master. The free air time is given in terms of the number of time slots unused by the current master between two consecutive frames as a single byte integer.

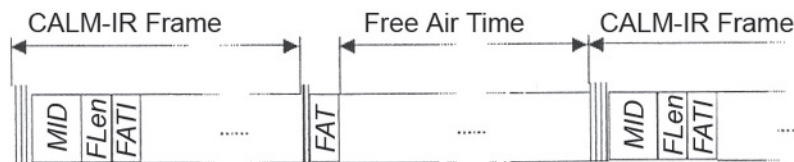


Figure 11 — Example of free air time

9.3.3.7 The coding and modulation during the management window is always according the default profile.

9.3.4 Private window

9.3.4.1 Private windows carry the information exchange between a master and a specific slave. Private windows are allocated to a master-slave relation by using a temporary MAC address, which is called “temporary identifier” (TempID), which is created during the registration process and “published” in the FOT during the management window.

9.3.4.2 One slave may use more than one private window. To do this, he should register again and a new TempID will be created and allocated to him.

9.3.4.3 Communications in a private window starts by using the default communications profile. Upon negotiation with the master, any communications profile which both master and slave support and which gives sufficient link quality may be used for subsequent information exchange.

9.3.4.4 A private window (PrW) employs at least one information transfer phase in “forward direction” and zero or more information transfer phases in “return direction”.

9.3.4.5 Each private window (PrW) starts immediately after the window synchronisation signal *W-Sync* emitted by the master.

9.3.4.6 The window phase now starting transfers information from the master to the slave (“forward direction”).

9.3.4.6.1 Immediately after the synchronisation signal *W-Sync*, the master sends an appropriate MAC command

- in the event that a new message shall be transmitted, the MAC command “Block Start” *MC-BLS* shall be used,
- in the event that the information to be transferred is the remainder of an earlier message which did not fit in the slave’s last private window, the MAC command “Packet Start” (*MC-PAS*) shall reinitiate the transfer of the whole packet, and
- in the event of “nothing to send”, the MAC command “Token” (*MC-TKN*) shall be sent.

9.3.4.6.2 The length of the information stream is signalled

- either inherently by the MAC command itself, or
- if the end is not inherently given by the MAC command,
- in the event that all the information which is to be transmitted fits in the current window, by the MAC command “block end” (MC-BLE) after the data, and
- in the event that all the information which is to be transmitted does not fit in the current window and will be continued in a further private window of the slave, by the MAC command “packet end” (MC-PAE) after the data.

NOTE All MAC commands which do not start immediately after a W-Sync have to be preceded by a command alert signal CA.

9.3.4.7 Now that the (first) transfer in forward direction (master to slave) is finished, the (first) transfer from slave to master (return direction) starts.

9.3.4.7.1 After the recognition of the end of reception (described above), the slave has to wait a “guard time” T_G before starting sending (this guard time allows the receiver on the other end of the link to re-establish correct thresholds).

9.3.4.7.2 The slave then sends an appropriate MAC command (preceded by a command alert CA).

9.3.4.7.3 The slave then transfers information towards the master (in “return direction”) in exactly the same manner as described above for the “forward direction”.

9.3.4.8 Where the pre-assigned window size allows, the slave switches to its “receive state” and the master may again send information to the slave.

9.3.4.8.1 In such cases, the master starts the second transfer in “forward direction” by waiting the “guard time” T_G and issuing an appropriate MAC command.

9.3.4.8.2 The further sequence is identical to that described above, until the window time expires or until none of the partners wants to exchange any more information.

9.3.5 Broadcast window

9.3.5.1 Broadcast windows (BcW) are used to broadcast information to all stations within the communication zone of the “broadcaster”, even to those which did not yet perform the “registration process”.

NOTE Unregistered slaves can also receive and decode the FOT and thus, decode the frame and receive the broadcast window.

A frame shall contain zero or one broadcast window.

The broadcast window is addressed by a reserved tempID (see [11.2](#)) in the frame organization table FOT.

The broadcast window can have any position in the frame.

The broadcast window (BcW) employs only one information transfer direction, namely “forward direction”.

In the BcW, the default profile shall be used.

The broadcast window (BcW) starts immediately after the window synchronisation signal W-Sync emitted by the master.

The broadcast now commences.

9.3.5.2 Immediately after the synchronisation signal, W-Sync the master/broadcaster sends either of the following:

- MAC command “block start” (MC-BLS) in case a new broadcast message is to be broadcasted;
- MAC command “packet start” (MC-PAS) if the following information is the continuation of an earlier broadcast message which did not fit in a single window.

9.3.5.3 The end of the information stream is signalled by either of the following:

- by the subsequent MAC command “block end” (MC BLE) in the event that all the information which is to be broadcasted fitted in the current window;
- by the subsequent MAC command “packet end” (MC-PAE) in the event that all the information which is to be broadcasted does not fit in the current window and will be continued in a further broadcast window.

NOTE All MAC commands which do not start immediately after a W-Sync have to be preceded by a command alert signal CA.

9.3.5.4 As the stations shall not respond in a BcW, the information transfer phase is now finished.

9.3.6 Multicast window

9.3.6.1 Multicast windows are used to transfer information to a certain group of registered stations (within the communication zone of the “multicast”) which had been included in that group.

NOTE Procedures on how slaves are assigned to “multicast groups” are not defined in this International Standard.

9.3.6.2 Multicast windows are addressed by one of the reserved TempIDs allocated to multicasting (see [11.2](#)) in the frame organization table FOT.

9.3.6.3 A multicast window (McW) employs only information transfer phases in “forward direction”.

9.3.6.4 In an McW, the communications profile which is set with the first MAC command of the multicast window shall be used (see below).

9.3.6.5 The multicast window McW starts immediately after the window synchronisation signal W-Sync emitted by the master.

9.3.6.6 The window phase now starting transfers information from the master to the slave(s) (“forward direction”).

9.3.6.6.1 Immediately after the synchronisation signal W-Sync, the master shall send in each McW the MAC command “set multicast profile” (MC-SMP) in order to signal to the slaves with which communications profile the information will be sent.

9.3.6.6.2 Subsequently, either the MAC command “block start” (MC-BLS) in case a new multicast message is to be sent, or the MAC command “packet start” (PAS), if the following information is the continuation of an earlier multicast message which did not fit in a single window.

NOTE All MAC commands which do not start immediately after a W-Sync have to be preceded by a command alert signal CA.

9.3.6.6.3 The end of the information stream is signalled either

- by the subsequent MAC command “block end” (MC-BLE) in the event that all the information which is to be multicasted fitted in the current window, or
- by the subsequent MAC command “packet end” (MC-PAE) in case the information which is to be multicasted does not fit in the current window and will be continued in a further multicast window.

NOTE All MAC commands which do not start immediately after a W-Sync have to be preceded by a command alert signal CA.

9.3.6.7 As stations shall not respond in an McW, the information transfer phase is now finished.

9.3.7 Spare window

9.3.7.1 Spare windows (SpW) are used to reserve airtime for slaves eventually registering during the current frame in order to enable the master to instantly allocate them a private window without the need for frame reorganization.

9.3.7.2 Spare windows start with a W-Sync addressed by a reserved TempID (see [11.2](#)).

9.3.7.3 The maximum number of spare windows in a frame is set in the master by the system administration.

9.3.8 Compatibility window

9.3.8.1 A compatibility window (CmpW) may be inserted into a frame in order to enable non-CALM-IR systems which observe certain rules to co-exist without harmful interference with a CALM-IR system.

9.3.8.2 The CmpW starts with a W-Sync addressed by a reserved TempID.

NOTE This allows CALM-IR units to recognize the compatibility window in a frame and thus, does not use it themselves for any reason.

9.3.8.3 No CALM-IR unit shall use the CmpW for information transfers, etc.

9.3.8.4 The CmpW may consist of one or multiple time slots. The number of time slots depends on the properties of the non-CALM-IR system to be considered and is set in the master by the system administration.

9.3.8.5 The proper use of a CmpW is explained in [Annex E](#).

9.3.9 Wake-up window

9.3.9.1 A wake-up window (WuW) is used to broadcast the wake-up signal pattern (see [7.1.1](#)) in order to activate “sleeping” slaves in the communication area of the master.

9.3.9.2 The WuW starts with a W-Sync addressed by a reserved TempID.

9.3.9.3 The wake-up signal follows directly after the W-Sync and the MAC Command MC-WU.

9.3.9.4 The wake-up window may consist of one or multiple time slots. The number of time slots of the wake-up window depends on the properties of the OBU population of the system and is set in the master by the system administration.

9.3.9.5 The wake-up window is terminated by the next F-Sync or W-Sync.

9.4 Command alert (CA)

9.4.1 Command alerts provide the possibility to interrupt current communications for immediate signalling of high prioritised messages (e.g. emergency situation).

9.4.2 Command alerts can be initiated from both master, as well as slave, devices.

9.4.2.1 A CA within an MnW can be sent only by the master and is dedicated to all slaves, even to the unregistered ones.

9.4.2.2 A CA within an McW is sent only by the master and is dedicated only to the active slaves.

9.4.2.3 A CA within a PrW may be sent by either the master or by the slave that “owns” the window and is dedicated only to the communications partner.

9.4.2.4 A CA shall only be sent, with one exception defined below, if the originating communications partner has the right to send.

9.4.2.5 The exception is if in the “receiving state”, the signal is lost. In such a case, it is allowed to enforce the sending of CA.

9.4.2.6 In the event that the intended sending of CA is preceded by a “receive state”, the CA shall be preceded by a guard interval of duration T_G .

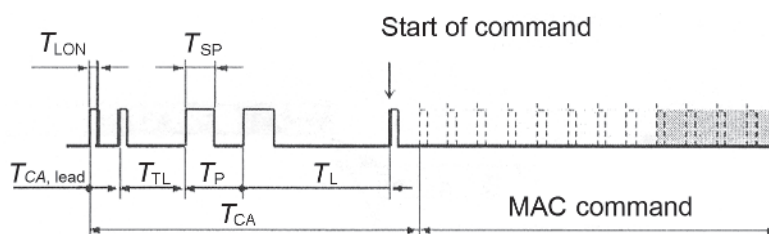


Figure 12 — Command alert (CA)

9.5 Frame and window parameters, summary

Table 13 — Frame and window parameters

Parameter name	Description	Value	Remark
Frame parameters			
$N_{framemax}$	Maximum time slots per frame	256	Refer to 9.2.1 .
T_{Ts}	Length of one time slot	256 μ s	
T_G	Guard time when changing from receive state to send state	15 000 ns	This guard time shall always be obeyed when a device changes from the receive state to the send state.
Frame synchronisation			

Table 13 (continued)

Parameter name	Description	Value	Remark
F-Sync	Frame synchronisation signal pattern		Refer to 9.2.2.
T _{F-Sync}	Total length of F-Sync	7 500 ns	
N _{F-Synclead}	Number of leader pulses in F-Sync	2	Refer to 9.2.2.
N _{F-Synctrail}	Number of trailer pulses in F-Sync	1	Refer to 9.2.2.
T _{LON}	On time of leader and trailer pulses	190 ns	
T _{F-Synclead}	Time between F-Sync leader pulses	500 ns	From rising edge of first pulse to rising edge of second pulse.
N _{F-Sync}	Number of synchronisation pulses	4	
T _{TL}	Time from last leader pulse to first synchronisation pulse	1 000 ns	From rising edge of last leader pulse to rising edge of first synchronisation pulse.
T _L	Time from last synchronisation pulse to trailer pulse	2 500 ns	From rising edge of last synchronisation pulse to rising edge of trailer pulse.
T _{SP}	On time of synchronisation pulse	500 ns	
T _p	Time between two synchronisation pulses	1 000 ns	From rising edge to rising edge.
	Window parameters		
N _{Windowmax}	Maximum time slots per window	256	
	Window synchronisation		
W-Sync	Window synchronisation signal pattern		Refer to 9.3.2.
T _{WTtransmit}	W-Sync detect tolerance, sender	-8 µs .. +20 µs	The master shall start to send the W-Sync signal not earlier or not later than this time with reference to the window's start time allocated in the management window.
T _{WTreceive}	W-Sync detect tolerance, receiver (µs)	-16 µs .. +32 µs	The slave shall be ready to detect the W-Sync signal within this time window with reference to the window's start time allocated in the management window.
T _{W-Sync}	Total length of W-Sync	6 500 ns	
N _{Wsynclead}	Number of leader pulses in W-Sync	2	Refer to 9.3.2.
N _{F-Wynctrail}	Number of trailer pulses in W-Sync	1	Refer to 9.3.2.
T _{LON}	On time of leader and trailer pulses	190 ns	
T _{Wsynclead}	Time between W-Sync leader pulses	500 ns	From rising edge of first pulse to rising edge of second pulse.
N _{W-Sync}	Number of synchronisation pulses	3	
T _L	Time from last synchronisation pulse to trailer pulse	2 500 ns	From rising edge of last synchronisation pulse to rising edge of trailer pulse.

Table 13 (continued)

Parameter name	Description	Value	Remark
T _{SP}	On time of synchronisation pulse	500 ns	
T _P	Time between two synchronisation pulses	1 000 ns	From rising edge to rising edge.
	Command alert		
CA	Command alert pattern		Refer to 9.4.
T _{CA}	Total length of CA	5 500 ns	
N _{CAlead}	Number of leader pulses in CA	2	Refer to 9.4.
N _{CAtrail}	Number of trailer pulses in CA	1	Refer to 9.4.
T _{LON}	On time of leader pulses	190 ns	
T _{CAlead}	Time between CA leader pulses	500 ns	From rising edge of first pulse to rising edge of second pulse.
N _{CA}	Number of CA pulses	2	
T _L	Time from last CA pulse to trailer pulse	2 500 ns	From rising edge of last synchronisation pulse to rising edge of trailer pulse.
T _{TL}	Time from last leader pulse to first CA pulse	1 000 ns	From rising edge of last leader pulse to rising edge of first CA pulse.
T _{SP}	On time of CA pulse	500 ns	
	Time-out		
T _{TempID}	TempID time-out	255	Measured in number of consecutive frames in which the slave did not respond although not being suspended.
T _{DREG}	Registration time-out	60 s	Measured in seconds since the last frame in which communications took place.

10 MAC commands

10.1 General

10.1.1 MAC commands are a special signalling mechanism between peer entities of the MAC layer of CALM-IR.

10.1.2 MAC commands may be initiated

- on request of the IR communication adaptation layer IR-CAL (see 14.2),
- on request of the IR management adaptation entity IR-MAE (see 14.3), or
- on request of the IR management entity IR-ME (see Clause 13).

10.1.3 A MAC command is always preceded either by

- command alert (CA), or

— window sync (W-Sync).

10.1.4 Any MAC command which is sent directly following the “receive state” shall be preceded by a guard interval of duration, T_G , before starting sending. This guard interval allows the receiver on the other end of the link to re-establish correct threshold levels.

10.1.5 A MAC command has a minimum length of one byte and may be followed by an optional attribute, the length of the attribute depends on the MAC command.

Optional payload data shall follow directly the attribute of the relevant MAC command or, if there is no attribute, directly the MAC command.

10.1.6 MAC commands and their attributes always use the data rate, modulation, and coding of the default communications profile.

10.1.7 For payload data, the valid communications profile is used (i.e. either the default communications profile or a negotiated and agreed communications profile).

10.2 MAC commands related to the frame and window organization

10.2.1 Frame organization table (*MC-FOT*)

10.2.1.1 Function

The command *MC-FOT* indicates that the table following the command contains the frame organization table *FOT*.

It shall be used in the *MnW* only.

10.2.1.2 Semantics of the service primitive

MC-FOT {*FOT* length}

Attribute	Description
<i>FOT</i> length	2 bytes provide the total length of the <i>FOT</i> in number of bytes

MC-FOT is immediately followed by the table containing the *FOT*.

Table 14 — Structure of the frame organization table *FOT*

Length	Meaning	Description
2 byte	TempID_1	Entry of slave 1
1 byte	Start slot index of window	
2 byte	TempID_2	Entry of slave 2
1 byte	Start slot index of window	(indicates at the same time the end of window 1)
2 byte	TempID_3	Entry of slave 3
1 byte	Start slot index of window	(indicates at the same time the end of window 2)
The last entry of the <i>FOT</i> does not relate to any of the slaves in the communication zone of the master but is used only to have a placeholder to signal the length of the last window in the list. The value of the <i>Dummy-ID</i> is a “Reserved <i>TempID</i> ” which shall not be able to be generated during the registration process by any slave.		

Table 14 (continued)

Length	Meaning	Description
		Entries of further slaves
2 byte	TempID_n	Entry of last slave
1 byte	Start slot index of window	(indicates at the same time the end of the last but one window)
2 byte	DummyID (see note)	Reserved TempID (see 11.2)
1 byte	Slot index of last time slot	(Indicates the end of the last window)
The last entry of the <i>FOT</i> does not relate to any of the slaves in the communication zone of the master but is used only to have a placeholder to signal the length of the last window in the list. The value of the <i>Dummy-ID</i> is a "Reserved <i>TempID</i> " which shall not be able to be generated during the registration process by any slave.		

10.2.2 When generated

10.2.2.1 This command is generated by the MAC after the end of the registration phase in case slaves changed from "registered" to "not registered" or vice versa, and the number of these changes exceeds a limit, or the window timing needs to be re-arranged.

10.2.2.2 In the event that fewer slaves have changed the status, the command *MC-FOTU* shall be used in order to save frame time.

10.2.2.3 The limit between the use of *MC-FOT* and *MC-FOTU* is at the discretion of system administration.

10.2.3 Effect on receipt

10.2.3.1 Upon receipt of this command, the slave uses the window with a start and stop time slot as indicated in the *FOT* for subsequent communication.

10.2.3.2 The receiving MAC shall enable the detection of a windows synchronisation signal, *W-Sync*, in the appropriate time interval defined in the *FOT* and shall interpret the allocated window as his private window, broadcast window, or multicast window, respectively.

10.2.4 Frame organization table update (*MC-FOTU*)

10.2.4.1 Function

The frame organization table update *FOTU* announces changes of the timing information that have occurred since the last reception of an *MC-FOT* or *MC-FOTU*.

It shall be used in the *MnW* only.

10.2.4.2 Semantics of the service primitive

MC-FOTU {*FOTU length*}

Attribute	Description
<i>FOTU length</i>	1 byte provides the total length of the <i>FOTU</i> in number of bytes

MC-FOTU is immediately followed by the table containing the *FOTU*.

Table 15 — Structure of the FOTU

Length	Meaning	Description
2 byte	TempID_I	Entry for slave “i” which shall change its window position
1 byte	Start slot index of window	
1 byte	Stop slot index of window	
2 byte	TempID_k	Entry for slave “k” which shall change its window position
1 byte	Start slot index of window	
1 byte	Stop slot index of window	

10.2.4.3 When generated

10.2.4.3.1 This command is generated by the MAC after the end of the registration phase in case slaves changed from “registered” to “not registered” or vice versa, and the number of these changes does not exceed a limit, or the window timing needs to be re-arranged.

10.2.4.3.2 In case more slaves have changed the status, the command *MC-FOT* shall be used in order to save frame time.

10.2.4.3.3 The limit between the use of *MC-FOT* and *MC-FOTU* is at the discretion of system administration.

10.2.4.4 Effect on receipt

10.2.4.4.1 Upon receipt of this command, the slave whose start and/or stop index have changed uses a new window with a new start and stop time slot as indicated in the *FOTU* for subsequent communication.

10.2.4.4.2 The receiving MAC shall enable the detection of a windows synchronisation signal *W-Sync* in the appropriate time interval defined in the *FOTU* and shall interpret the following window as his private window, broadcast window, or multicast window, respectively.

10.2.5 Frame organization table steady (*MC-FOTS*)

10.2.5.1 Function

The command “frame organization table steady” is sent if the registration status of the slaves has not changed since the last frame and the timing of windows is maintained.

It shall be used in the *MnW* only.

10.2.5.2 Semantics of the service primitive

MC-FOTS { }

10.2.5.3 When generated

This command is generated by the MAC in the event that no slaves have changed from “registered” to “not registered” or vice versa since the last frame.

10.2.5.4 Effect on receipt

The MAC receiving this command does not alter its window timing.

10.2.6 Submaster organization table (*MC-SOT*)

10.2.6.1 Function

The command *MC-SOT* indicates that the table following the command contains the submaster organization table *SOT*.

It shall be used in the *MnW* only.

10.2.6.2 Semantics of the service primitive

MC-SOT {*SOT*_length}

Attribute	Description
<i>SOT</i> _length	2 bytes provide the total length of the <i>SOT</i> in number of bytes

MC-SOT is immediately followed by the table containing the *SOT*.

Table 16 — Structure of the ‘Submaster organization table’ (*SOT*)

Length	Meaning	Description
3 byte	MID_1	Entry of submaster 1
1 byte	Start slot index of window	
3 byte	MID_2	Entry of submaster 2
1 byte	Start slot index of window	Indicates at the same time the end of window 1
3 byte	MID_3	Entry of submaster 3
1 byte	Start slot index of window	Indicates at the same time the end of window 2
		Entries of further submasters
3 byte	MID_n	Entry of last submaster
1 byte	Start slot index of window	Indicates at the same time the end of the last but one window
3 byte	Dummy_MID (see note)	Reserved MID
1 byte	Slot index of last time slot	Indicates the end of the last window
The last entry of the <i>SOT</i> does not relate to any of the submasters in the communication zone of the master but is used only to have a placeholder to signal the length of the last window in the list. The value of the Dummy-MID is a “reserved <i>MID</i> ” which shall be 0h.		

10.2.6.3 When generated

This command is generated by the *MAC* after the indication of a slave in its *PrW* to use the free air of the master for submaster purposes.

10.2.6.4 Effect on receipt

On receipt of this command, the submaster may use the “free air time” with a start and stop time slot as indicated in the *SOT* for subsequent communication with its own slaves. After the TDMA frame, the first timeslot of the free air time shall be indicated by the command *MC-FAT* (free air time).

10.2.7 Get submaster area (*MC-GSA*)

10.2.7.1 Function

With this command, a submaster requests time to communicate with its registered slaves within the free air time of the master.

It shall be used in a *PrW* only.

10.2.7.2 Semantics of the service primitive

MC-REST {ownMID, Slave_count, Timeslots}

Attribute	Length	Description
ownMID	3 byte	MID of the submaster
Slave_count	1 byte	Number of registered Slaves at ownMID
Timeslots	1 byte	Number of required timeslots

10.2.7.3 When generated

This command is generated by the *IR-ME* of the slave (submaster).

10.2.7.4 Effect on receipt

In the event that the master can accept the required submaster area, the *IR-ME* informs the CALM management about change of address. The master responds with the command “Submaster Area Confirmed” (*MC-SAC*).

In case the master cannot accept the required submaster area, the master responds with the command “Submaster Area Denied” (*MC-SAD*).

10.2.8 Submaster status (*MC-SST*)

10.2.8.1 Function

With this command, the submaster informs the master about a changed status of its slaves.

It shall be used in a *PrW* only.

10.2.8.2 Semantics of the service primitive

MC-SST {Slave_count, Timeslots}

Attribute	Length	Description
Slave_count	1 byte	Number of registered slaves at the submaster
Timeslots	1 byte	Number of required timeslots

10.2.8.3 When generated

This command is generated by the *IR-ME* of the slave (submaster).

10.2.8.4 Effect on receipt

10.2.8.4.1 In the event that the master can accept the changed status, the *IR-ME* informs the CALM management. The master responds with the command “Submaster Area Confirmed” (*MC-SAC*).

10.2.8.4.2 In the case the master cannot accept the changed status, the master responds with the command “Submaster Area Denied” (*MC-SAD*).

10.2.9 Submaster area confirmed (*MC-SAC*)

10.2.9.1 Function

With this command, the master confirms the requested submaster area within its free air time.

It shall be used in a *PrW* only.

10.2.9.2 Semantics of the service primitive

MC-SAC {}

10.2.9.3 When generated

This command is generated by the MAC of the master to confirm the submaster area.

10.2.9.4 Effect on receipt

IR-ME informs the CALM management about the confirmed communication area.

10.2.10 Submaster area denied (*MC-RESD*)

10.2.10.1 Function

With this command, the master denies the requested submaster area to the slave.

It shall occur in the *PrW* only.

10.2.10.2 Semantics of the service primitive

MC-SAD {}

10.2.10.3 When generated

This command is generated by the MAC of the master to deny the requested submaster area in the event that the free air time is not available.

10.2.10.4 Effect on receipt

IR-ME informs the CALM management about the rejection of the requested submaster area within the free air time of the master.

10.2.11 Broadcast (*MC-BRC*)

10.2.11.1 Function

This command indicates that the following data stream is a broadcast message.

Broadcast messages sent in the management window shall not be continued in another frame. They shall fit in the current management window.

It shall be used in the *MnW* only.

10.2.11.2 Semantics of the service primitive*MC-BRC {broadcast length}*

Attribute	Description
Broadcast length	One byte length of broadcast message in terms of transmitted 12 bit units (8 bit info plus 4 bit Hamming)

10.2.11.3 When generated

This command is generated by the MAC on request of the *IR-CAL*.

This command shall be followed immediately by the data to be broadcast.

10.2.11.4 Effect on receipt

The broadcast data are forwarded by the receiving MAC to the *IR-CAL*, together with address information.

10.2.12 Re-establish session (MC-REST)**10.2.12.1 Function**

With this command, a slave which lost and re-established the link and thus, now has a new *TempID*, may ask the master to re-establish all sessions related to his “old” *TempID*.

It shall be used in a *PrW* only.

10.2.12.2 Semantics of the service primitive*MC-REST {MID, TempID}***Table 17 — Session re-establishment**

Attribute	Length	Description
MID	3 byte	MID of last master the slave has communicated with
TempID	2 byte	Last valid TempID

10.2.12.3 When generated

This command is generated by the *IR-ME* of the slave in the event that the communication link was lost for more than two times the maximum frame duration and new registration was successful at the same master.

10.2.12.4 Effect on receipt

10.2.12.4.1 In the event that the master can accept the command, the *IR-ME* informs the CALM management about change of address. The master responds with the command “session re-establishment confirmed” (*MC-RESC*).

10.2.12.4.2 In case the master cannot accept the command, he responds with the command “session re-establishment denied” (*MC-RESD*).