INTERNATIONAL STANDARD

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21214

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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Contents

Page

Foreword

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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).

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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 handover 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

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

Note 1 to entry: It is expressed in W/m^2.

[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

$\dfrac{d\Phi_e(\lambda)}{d\lambda}$ is the spectral distribution of the radiant flux and V(λ) 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 $K = \dfrac{\Phi_v}{\Phi_e}$

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 lm. W^{-1} for v_m = 540 × 10^{12} Hz (λ_m approximately 555 nm) for photopic vision. K'_m = 1 700 lm. 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·m^2.

[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·m^2.

[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.
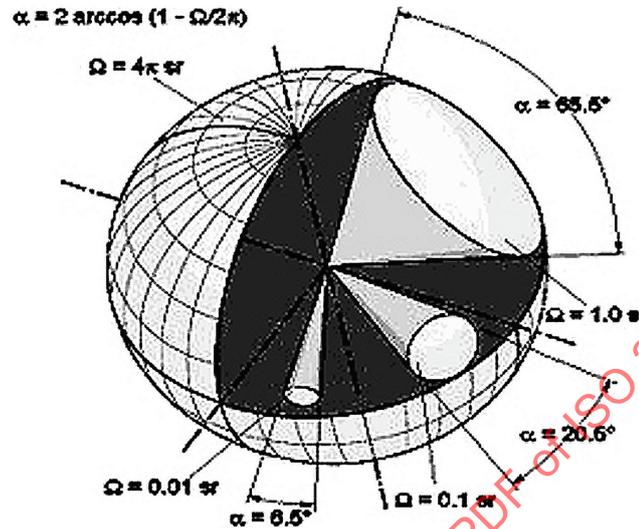
Figure 1 — Solid angle

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
ΘH	horizontal opening angle
ΘV	vertical opening angle
φ	azimuth angle
Φv	luminous flux125

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 $\lambda = 900$ nm, $\Delta\lambda = 40$ 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)	Channel 970 (alternate channel)
		mandatory	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
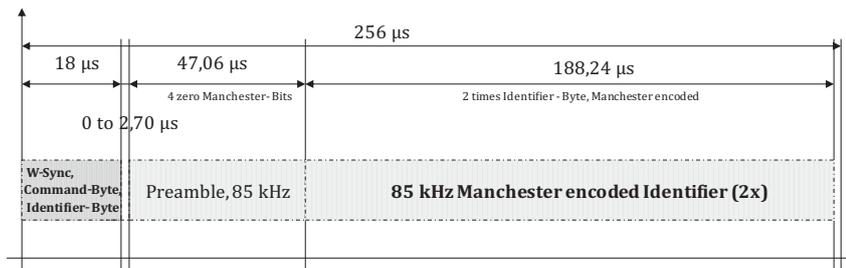
Figure 2 — Wake-up signal

Table 6 — Wake-up signal timing specification

	Parameter name	Specification
TX11	Wake-up signal	Burst frequency: 85 kHz ± 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 ± 6,6 ns	41,7 ns ± 3,3 ns	20,8 ns ± 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
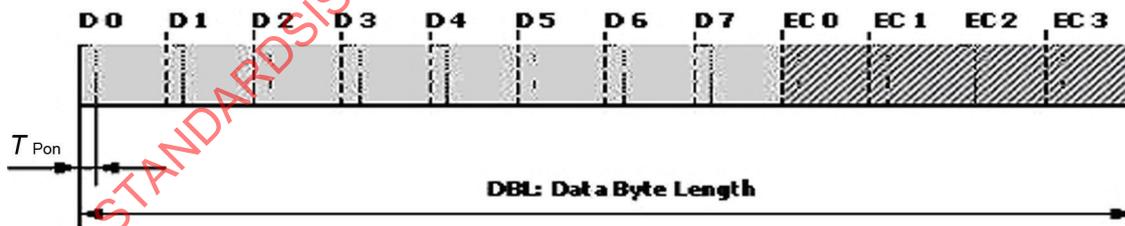
Figure 3 — Modulation of profile 0 and profile 1

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-dimenional 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").
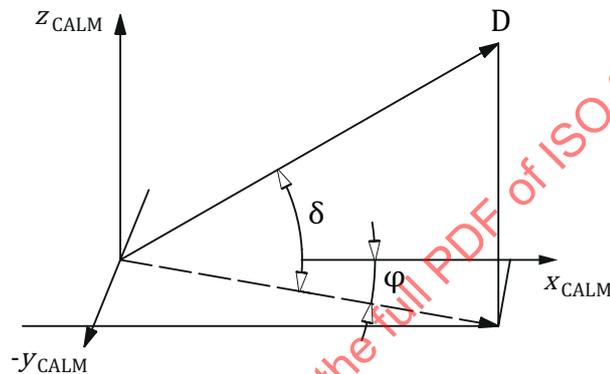
Figure 4 — Azimuth and elevation angle of the beam axis

Further parameters of directivity are the horizontal opening angle, Θ_H, and the vertical opening angle, Θ_V, as detailed in Figure 5.
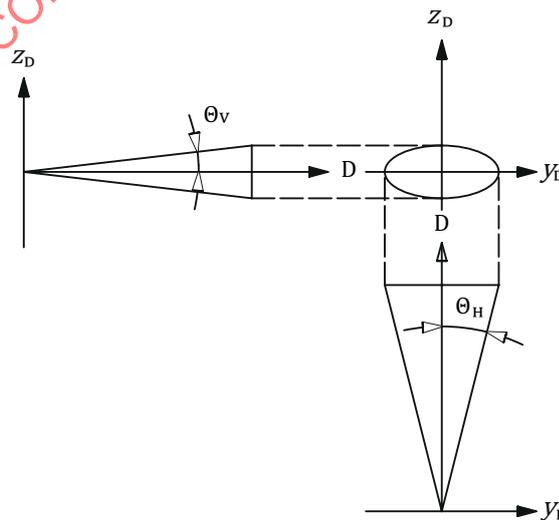
Figure 5 — Horizontal opening and vertical opening angles

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} (~ 1,5°).

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 $\Theta_{basic} = 1,5°$.

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	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

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 $Nmax_{frame}$ time slots, the minimum length is $Nmin_{frame}$.

— 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.
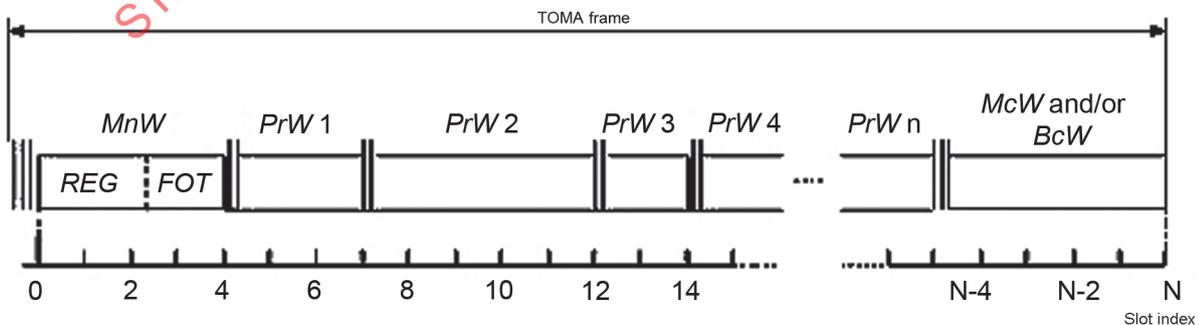
Figure 6 — CALM-IR frame structure, example

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.
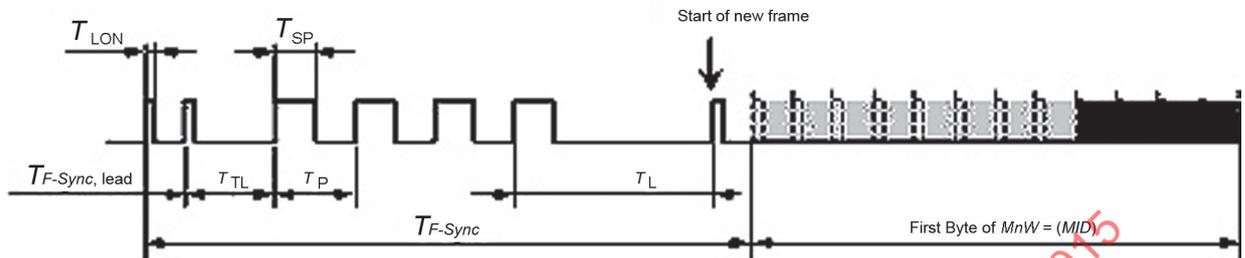
Figure 7 — F-Sync

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 $T_{WTreceive}$.
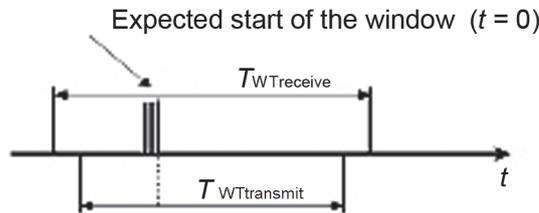
Figure 8 — W-Sync receiver and transmitter window

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.
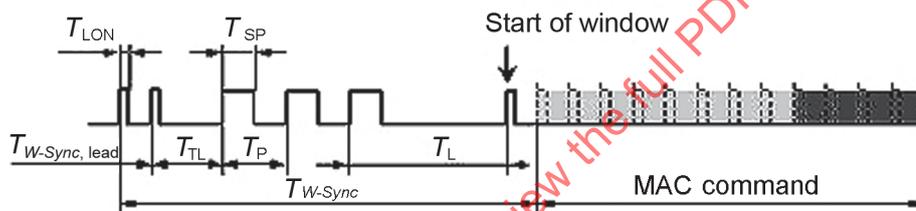
Figure 9 — W-Sync

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.
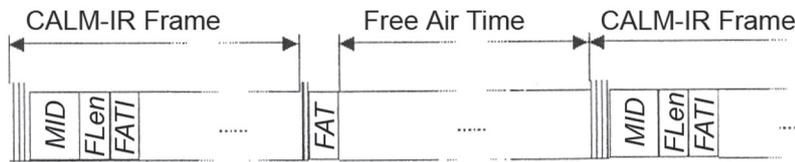
Figure 11 — Example of free air time

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.
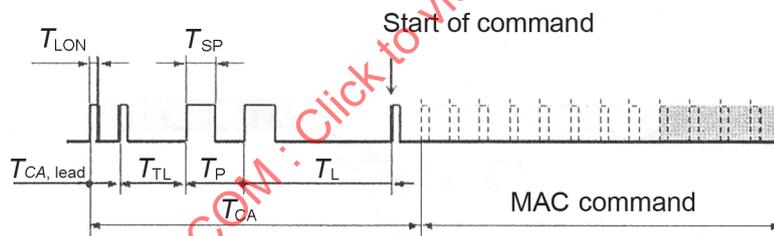
Figure 12 — Command alert (CA)

9.5   Frame and window parameters, summary

Table 13 — Frame and window parameters

Parameter name	Description	Value	Remark
	Frame parameters		
$N_{frame}max$	Maximum time slots per frame	256	Refer to 9.2.1.
T_{Ts}	Length of one time slot	256 µs	
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.
$T_{F\text{-}Sync}$	Total length of F-Sync	7 500 ns	
$N_{F\text{-}Synclead}$	Number of leader pulses in F-Sync	2	Refer to 9.2.2.
$N_{F\text{-}Synctrail}$	Number of trailer pulses in F-Sync	1	Refer to 9.2.2.
T_{LON}	On time of leader and trailer pulses	190 ns	
$T_{F\text{-}Synclead}$	Time between F-Sync leader pulses	500 ns	From rising edge of first pulse to rising edge of second pulse.
$N_{F\text{-}Sync}$	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		
$N_{Window}max$	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.
$T_{W\text{-}Sync}$	Total length of W-Sync	6 500 ns	
$N_{Wsynclead}$	Number of leader pulses in W-Sync	2	Refer to 9.3.2.
$N_{F\text{-}Wynctrail}$	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.
$N_{w\text{-}Sync}$	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
FOT length	2 bytes provide the total length of the *FOT* 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 *FOT* 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 *Dummy-ID* is a "Reserved *TempID*" 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 *FOT* 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 *Dummy-ID* is a "Reserved *TempID*" 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
FOTU length	1 byte provides the total length of the FOTU 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

10.2.4.1 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.

10.2.4.2 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
*SOT*_length	2 bytes provide the total length of the *SOT* 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 *SOT* 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 *MID*" 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 {own*MID*, 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*).

10.2.13 Session re-establishment confirmed (*MC-RESC*)

10.2.13.1 Function

With this command, the master confirms the requested session re-establishment to the slave.

It shall be used in a *PrW* only.

10.2.13.2 Semantics of the service primitive

MC-RESC { }

10.2.13.3 When generated

This command is generated by the MAC of the master to confirm the re-establishment of the session.

10.2.13.4 Effect on receipt

IR-ME informs the CALM management about change of address.

10.2.14 Session re-establishment denied (*MC-RESD*)

10.2.14.1 Function

With this command, the master denies the requested session re-establishment to the slave.

It shall occur in the *PrW* only.

10.2.14.2 Semantics of the service primitive

MC-RESD { }

10.2.14.3 When generated

This command is generated by the MAC of the master to deny the re-establishment of the sessions in the event that the session parameters are not available.

10.2.14.4 Effect on receipt

IR-ME informs the CALM management about loss of communication.

10.2.15 Change master identifier (*MC-CMI*)

10.2.15.1 Function

With this command, the master changes its *MID* to a new one.

It shall occur in the *MnW* only.

10.2.15.2 Semantics of the service primitive

MC-CMI {newMID}

Attribute	Length	Description
NewMID	3 byte	New *MID* of the master

10.2.15.3   When generated

This command is generated by the *IR-ME* of the master to change its *MID*.

10.2.15.4   Effect on receipt

IR-ME informs the CALM management about change of masters *MID*. The new *MID* is valid after the next F-Sync of the master.

10.2.16 Kill all (*MC-KIA*)

10.2.16.1   Function

This command orders all slaves in the communication zone of the master to terminate all registered communication with the master.

It shall be used in the *MnW* only.

If used, it shall occur before *MC-FOT* or *MC-FOTU*.

10.2.16.2   Semantics of the service primitive

MC-KIA { }

10.2.16.3   When generated

This command is generated by the MAC on request of the *IR-ME* to terminate communication.

10.2.16.4   Effect on receipt

On receipt of this command, the *MAC* shall

— inform the *IR-ME* about loss of communication,

— cancel the association with the master,

— delete pending frames, and

— invalidate the *TempID*.

The slave may enter a new registration process at any convenient time.

10.2.17 Kill slave (*MC-KIS*)

10.2.17.1   Function

This command orders a dedicated slave in the communication zone of the master to terminate communications related to the specific *TempID*, i.e. to invalidate this *TempID*.

It shall be used in the *MnW* only.

If used, it shall occur before *MC-FOT* or *MC-FOTU*.

10.2.17.2   Semantics of the service primitive

MC-KIS {TempID}

Attribute	Description
TempID	The identifier of the slave which has to be killed

10.2.17.3 When generated

This command is generated by the *MAC* on request of the *IR-ME* to terminate communication.

10.2.17.4 Effect on receipt

On receipt of this command, the *MAC* shall

— inform the *IR-ME* about loss of communication,

— cancel the association with the master,

— delete pending frames, and

— invalidate the *TempID.*

The slave may enter a new registration process at any convenient time.

10.2.18 De-register *(MC-DREG)*

10.2.18.1 Function

This command requires the peer entity to terminate the communication relation.

It shall be used in the *PrW* only.

10.2.18.2 Semantics of the service primitive

MC-DREG { }

10.2.18.3 When generated

This command is generated by the *MAC* on request of the *IR-ME* to terminate communication relation and to avoid new registration within a defined time of T_{DREG}.

10.2.18.4 Effect on receipt

10.2.18.4.1 On receipt of this command by the master, the *MAC* shall

— inform the *IR-ME* about loss of communication,

— delete the association with the slave, and

— delete all pending frames.

10.2.18.4.2 On receipt of this command by the slave, the *MAC* shall

— inform the *IR-ME* about loss of communication,

— delete the *TempID*, and

— delete all pending frames.

10.2.18.4.3 The slave may enter a new registration process at this master offered by the *MAC* command *MC-REN* only after a waiting time of T_{DREG}.

10.2.18.4.4 The slave shall immediately enter a new registration process at this master offered by the *MAC* command *MC-RRQ.*

10.2.19 Suspend all (*MC-SUA*)

10.2.19.1   Function

10.2.19.1.1   This command orders all registered slaves in the communication zone of the master to suspend communications in their private windows and the related time-outs during this frame.

It shall be used in the *MnW* only.

If used, it shall occur before the *MC-FOT* or *MC-FOTU* is sent.

10.2.19.1.2   In the event that a following *MC-FOT*, *MC-FOTU*, or *MC-FOTS* command again allocates a *PrW* for this *TempID*, this *MC-FOT*, *MC-FOTU*, or *MC-FOTS* command overrides the suspend command.

NOTE   This command is used to keep all slaves "alive" although not being addressed in the current frame. The now unused "airtime" of the current frame can now be used for example for a broadcast window or by "non-CALM" masters, assumed they are synchronised appropriately with the "CALM master". See Annex E.

10.2.19.2   Semantics of the service primitive

MC-SUA { }

10.2.19.3   When generated

This command is generated by the MAC *IR-ME* itself depending on the priority of pending transmission requests.

10.2.19.4   Effect on receipt

10.2.19.4.1   On receipt of this command, the MAC shall suspend any communications in private windows in the current frame and shall suspend related timer time-out in the current frame.

10.2.19.4.2   In the event that a following *MC-FOT*, *MC-FOTU*, or *MC-FOTS* command again allocates a slave a *TempID* this *MC-FOT*, *MC-FOTU*, or *MC-FOTS* command, respectively, overrides the suspend command.

10.2.20 Suspend slave (*MC-SUS*)

10.2.20.1   Function

10.2.20.1.1   This command orders a specific slave in the communication zone of the master to suspend its communication in the private window related to the concerned *TempID* and related time-outs during this frame.

It shall be used in the *MnW* and *PrW* only.

If used in an *MnW*, it shall occur before the *MC-FOT* or *MC-FOTU* command is sent.

10.2.20.1.2   In the event that a following *MC-FOT*, *MC-FOTU*, or *MC-FOTS* command again allocates a *PrW* for this *TempID*, this *MC-FOT*, *MC-FOTU*, or *MC-FOTS* command overrides the suspend command.

NOTE   This command is issued by the master to a newly registering slave in case in the current frame a window cannot be allocated instantly but complete frame reorganization is necessary. However, the slave is indicated that his registration attempt was successful.

10.2.20.2 Semantics of the service primitive

MC-SUS {TempID}

Attribute	Description
TempID	2 byte *TempID* identifies the slave to be suspended

10.2.20.3 When generated

This command is issued by the master to a newly registering slave in the event that in the current frame, a window cannot be allocated instantly and complete frame reorganization is necessary.

10.2.20.4 Effect on receipt

10.2.20.4.1 On receipt of this command, the MAC shall

— suspend any communications in private windows in the current frame, and

— suspend related timer time-out in the current frame.

10.2.20.4.2 In the event that a following *MC-FOT*, *MC-FOTU*, or *MC-FOTS* command again allocates a slave a *TempID*, this *MC-FOT, MC-FOTU*, or *MC-FOTS* command, respectively, overrides the suspend command.

10.2.21 Free air time (*MC-FAT*)

10.2.21.1 Function

This command is used by the master to indicate the start of the free air time in the event that "free air time" is allocated before the start of the next frame.

10.2.21.2 Semantics of the service primitive

MC-FAT { }

10.2.21.3 When generated

In the event that free air time shall be allocated, this command shall be sent after the last window (e.g. after the *W-Sync* indicating the end of the last window).

10.2.21.4 Effect on receipt

Slaves intending to become a sub-master use the free air time to set up a frame, etc.

10.2.22 Free air time (*MC-FAT*)

10.2.22.1 Function

This command is used by the master to indicate the start of the free air time in the event that "free air time" is allocated before the start of the next frame.

10.2.22.2 Semantics of the service primitive

MC-FAT { }

10.2.22.3 When generated

In the event that free air time shall be allocated, this command shall be sent after the last window (e.g. after the *W-Sync* indicating the end of the last window).

10.2.22.4 Effect on receipt

Slaves intending to become a sub-master use the free air time to set up a frame, etc.

10.2.23 Spare window (*MC-SPW*)

10.2.23.1 Function

This command is used by the master to indicate the start of a spare window.

The command shall be used in a spare window only.

10.2.23.2 Semantics of the service primitive

MC-SPW { }

10.2.23.3 When generated

In the event that a spare window shall be allocated, this command shall be sent after the *W-Sync* indicating of the spare window.

10.2.24 Wakeup (*MC-WU*)

10.2.24.1 Function

This command is used by the master to indicate the start of a wakeup window

The command shall be used in a wakeup window only.

10.2.24.2 Semantics of the service primitive

MC-WU {identifier}

Attribute	Description
identifier	One byte identifier

10.2.24.3 When generated

It is generated on request (or setup) by the IR-ME.

10.2.24.4 Effect on receipt

The command informs devices within the communication zone of the starting wakeup window.

10.3 MAC commands related to flow control

10.3.1 Busy (*MC-BSY*)

10.3.1.1 Function

This command indicates to the communication partner that he is busy and not able to communicate within the current window.

The command shall be used in a private window only.

10.3.1.2 Semantics of the service primitive

MC-BSY { }

10.3.1.3 When generated

The *MAC* sends this command in case no communication resource is available at this point of time.

10.3.1.4 Effect on receipt

The receiving MAC interrupts the communication to the communication partner until the next private window. The communication is not falling into the timeout condition.

10.3.2 Command not supported (*MC-CNS*)

10.3.2.1 Function

This command indicates that a command previously received in a *PrW* is not supported.

This command implies the transfer of a token.

The command shall be used in a private window only.

10.3.2.2 Semantics of the service primitive

MC-CNS {CNS}

Attribute	Description
CNS	One byte code of the command which is not supported

10.3.2.3 When generated

At the earliest possible point in time after receipt of the unsupported command.

10.3.2.4 Effect on receipt

The *IR-ME* is informed that the peer entity does not support the command indicated.

10.3.3   Token (*MC-TKN*)

10.3.3.1   Function

10.3.3.1.1   With this command, the sending device hands over the token to his communication partner in the event that there is nothing to be sent. The token indicates the right to transmit.

The command shall be used in a private window only.

10.3.3.1.2   An answer is expected within T_{TR}. In the event of a time-out, the token falls back.

10.3.3.2   Semantics of the service primitive

MC-TKN { }

10.3.3.3   When generated

The *MAC* sends this command in case no data or commands are to be transmitted at this point in time.

10.3.3.4   Effect on receipt

The receiving *MAC* changes the device state from the receive state to the transmit state in order to continue communications.

10.3.3.4.1   In the event that the receiving *MAC* has data pending to be sent, the *MAC* sends this data.

10.3.3.4.2   In the event that the receiving *MAC* has nothing to send, the *MAC* replies with *MC-TKN*.

10.3.4   Block start (*MC-BLS*)

10.3.4.1   Function

With this command, the sending *MAC* indicates the start of transmission of a data block for CALM-fast applications.

MC-BLS shall be used in all windows except in a wake-up window or a spare window.

10.3.4.2   Semantics of the service primitive

MC-BLS {block_number}

Attribute	Description
block_number	One byte number of block

10.3.4.3   When generated

This command is sent by the *MAC* at the start of a data block for CALM-fast applications to be transmitted.

10.3.4.4   Effect on receipt

Open a new receive buffer for CALM-fast applications.

NOTE   The first packet in a block always has packet number 00H.

10.3.5 Control channel block start (*MC-CCBS*)

10.3.5.1 Function

With this command, the sending *MAC* indicates the start of transmission of a control data block. This is equivalent to using the CALM control channel.

MC-CCBS may be used in all windows except in a wake-up window or a spare window.

10.3.5.2 Semantics of the service primitive

MC-CCBS {block_number}

Attribute	Description
Block_number	One byte number of the block

10.3.5.3 When generated

This command is sent by the MAC at the start of a data block in the control channel.

10.3.5.4 Effect on receipt

Open a new receive buffer for the CALM control channel.

NOTE   The first packet in a block always has packet number 00H.

10.3.6 IEEE frame block start (*MC-FBS*)

10.3.6.1 Function

With this command, the sending *MAC* indicates the start of transmission of a data block in the IEEE 802 compliant mode.

The command shall be used in a private window only.

10.3.6.2 Semantics of the service primitive

MC-FBS {block_number}

Attribute	Description
Block_number	One byte number of the block

10.3.6.3 When generated

This command is generated by the MAC in case an IEEE IPv6 frame has to be transmitted.

10.3.6.4 Effect on receipt

Open a new receive buffer for IEEE 802 compliant mode.

NOTE   The first packet in a block always has packet number 00H.

10.3.7 Start of MAC control block (*MC-SMC*)

10.3.7.1 Function

With this command, the sending *MAC* indicates the start of transmission of a command block to be forwarded to the *IR-ME* of the receiving CALM device.

The command shall be used in a private window only.

10.3.7.2 Semantics of the service primitive

MC-SMC {block_number}

Attribute	Description
Block_number	One byte number of the block

10.3.7.3 When generated

This command is generated by the *MAC* on request of the *IR-ME* in the event that a manufacturer-dependent service application wants to "tunnel" information into the receiving *MAC*.

10.3.7.4 Effect on receipt

Open a new receive buffer for *MAC* control block.

NOTE   The first packet in a block always has packet number 00H.

10.3.8 Packet start (*MC-PAS*)

10.3.8.1 Function

With this command, the sending *MAC* indicates the start of a data packet.

This data packet is the continuation of a transmission which did not completely fit in the previous packet.

MC-PAS shall be used in all windows except in a wake-up window or a spare window.

10.3.8.2 Semantics of the service primitive

MC-PAS {block_number, packet_number}

Attribute	Description
block_number	Number of block to which the packet belongs
packet_number	Number of actual packet

10.3.8.3 When generated

This command is sent by the *MAC* at the start of a data packet to be transmitted.

10.3.8.4 Effect on receipt

Add received data to the corresponding receive buffer.

10.3.9 Block start CRC16 (*MC-BLS16*)

10.3.9.1 Function

With this command, the sending MAC indicates the start of transmission of a data block encoded with CRC.

MC-BLS16 shall be used in all windows except in a wake-up window and a spare window.

10.3.9.2 Semantics of the service primitive

MC-BLS16 {block_number, CRC}

Attribute	Description
block_number	One byte number of block
CRC	CRC16 check sum according to CRC-CCITT (CRC-16)

10.3.9.3 When generated

This command is sent by the *MAC* at the start of a CRC encoded data block for CALM-fast applications.

10.3.9.4 Effect on receipt

— Open a new receive buffer for CALM-fast applications.

— Start CRC decoding.

NOTE   The first packet in a block always has packet number 00H.

10.3.10 Packet start CRC16 (*MC-PAS16*)

10.3.10.1 Function

With this command, the sending *MAC* indicates the start of a *CRC* encoded data packet.

This data packet is the continuation of a transmission which could not completely fit in the previous packet.

MC-PAS 16 shall be used in all windows except in a wake-up window or a spare window.

10.3.10.2 Semantics of the service primitive

MC-PAE {block_number, packet_number, CRC}

Attribute	Description
block_number	Number of block to which the packet belongs
packet_number	Number of actual packet
CRC	CRC16 check sum according to CRC-CCITT (CRC-16)

10.3.10.3 When generated

This command is sent by the *MAC* at the start of a CRC encoded data packet to be transmitted.

10.3.10.4 Effect on receipt

Start CRC decoding for current packet.

10.3.11 Packet end (*MC-PAE*)

10.3.11.1 Function

With this command, the sending device indicates that a packet of data has been transmitted. Except in a BcW or an McW, the transmit token is given to the receiving device.

The command implies that at least a further packet will follow.

MC-PAE shall be used in all windows except in a wake-up window or a spare window.

10.3.11.2 Semantics of the service primitive

MC-PAE { }

10.3.11.3 When generated

This command is sent by the MAC of the sending device at the end of a transmitted data packet if another packet of the same block is pending.

10.3.11.4 Effect on receipt

According to the communication profile used, the receiving *MAC* performs error correction.

10.3.11.4.1 In the event of no or correctable errors, the *MAC* replies with *MC-TAck* or *MC-TAck&* and adds the received data to the corresponding receive buffer.

10.3.11.4.2 In the event of non-correctable errors, the *MAC* replies with *MC-TNAck* or *MC-TNAck&* and discards the packet.

10.3.12 Block end (*MC-BLE*)

10.3.12.1 Function

With this command, the sending device indicates that a packet of data has been transmitted and indicates the end of the block. Except in a *BcW* or an *McW*, the transmit token is given to the receiving device.

MC-BLE may be used in all windows except in a wake-up window.

10.3.12.2 Semantics of the service primitive

MC-BLE {block_number}

Attribute	Description
block_number	Number of block of which the last packet was sent to at least once

10.3.12.3 When generated

This command is sent by the MAC of the sending device at the end of a transmitted information block.

10.3.12.4 Effect on receipt

According to the communication profile used, the receiving *MAC* performs error correction.

10.3.12.4.1 In the event of no or correctable errors, the *MAC* replies with *MC-TAck* or *MC-TAck&* and adds the received data to the corresponding receive buffer.

10.3.12.4.2   In the event of non-correctable errors, the *MAC* replies with *MC-TNAck* or *MC-TNAck&* and discards the packet.

10.3.12.4.3   In the event of error free reception of the packet, the completeness of the block is checked. If the block is complete, it is forwarded to the *IR-CAL* and successful reception of the block is acknowledged to the peer station with the *MAC* command *MC-BAck*. If packets are missing, then re-transmission of these packets is requested with the *MAC* command *MC-RTQ*.

10.3.13 Transmission acknowledged (*MC-TAck*)

10.3.13.1   Function

With this command, the *MAC* confirms the error-free receipt of a data packet.

The command shall be used in a private window only.

The communication token is given back.

10.3.13.2   Semantics of the service primitive

MC-Tack { }

10.3.13.3   When generated

In the event of a transmission received with no or corrected errors.

10.3.13.4   Effect on receipt

The last transmitted packet will be erased from the buffer.

The communication token is recognized.

10.3.14 Transmission acknowledged and *(MC-TAck&*)

10.3.14.1   Function

With this command, the *MAC* confirms the error-free receipt of a packet.

The communication token is not given back.

Additional information shall follow this command.

The command shall be used in a private window only.

10.3.14.2   Semantics of the service primitive

MC-TAck& { }

10.3.14.3   When generated

In the event of a transmission received with no or corrected errors and information pending for transmission.

10.3.14.4   Effect on receipt

The last transmitted packet will be erased from the buffer.

The receiving unit waits for the MAC command following the *MC-TAck&*.

10.3.15 Transmission NOT acknowledged (*MC-TNAck*)

10.3.15.1 Function

With this command, the *MAC* confirms the erroneous receipt of a data packet.

The communication token is given back.

The command shall be used in a private window only.

10.3.15.2 Semantics of the service primitive

MC-TNAck { }

10.3.15.3 When generated

In the event of a transmission received with uncorrectable errors.

10.3.15.4 Effect on receipt

The receiving device re-transmits the last packet.

10.3.16 Transmission NOT acknowledged and (*MC-TNAck&*)

10.3.16.1 Function

With this command, the *MAC* confirms the erroneous receipt of a data packet.

The communication token is not given back.

Additional information shall follow this command.

The command shall be used in a private window only.

10.3.16.2 Semantics of the service primitive

MC-TNAck& { }

10.3.16.3 When generated

In the event of a transmission received with uncorrectable errors and information pending for transmission.

10.3.16.4 Effect on receipt

The receiving unit waits for the MAC command following the *MC-TNAck&*.

The receiving device retransmits the last packet at the earliest possible point of time.

10.3.17 Retransmission request (*MC-RTQ*)

10.3.17.1 Function

If a non-correctable transmission error is detected by the *MAC*, this command requests the retransmission of the packet.

The command shall be used in a private window only.

10.3.17.2   Semantics of the service primitive

MC-RTQ {block_number, packet_number}

Attribute	Description
block_number	One byte number of block which contains the corrupted/missing packet
packet_number	One byte number of the corrupted/missing packet

10.3.17.3   When generated

This command is generated by the *MAC* if a non-correctable transmission error is detected or a block is not complete at time of successful reception of the last packet of this block.

10.3.17.4   Effect on receipt

The receiving MAC repeats the requested packet.

10.3.18 Block acknowledge (*MC-BAck*)

10.3.18.1   Function

This command acknowledges the successful, error-free reception of a complete block.

The command shall be used in a private window only.

10.3.18.2   Semantics of the service primitive

MC-BAck {block number}

Attribute	Description
Block number	One byte number of block which is to be acknowledged

10.3.18.3   When generated

Generated by the MAC after successful re-assembly of the received block.

10.3.18.4   Effect on receipt

— Erase transmit block buffer.

— Release block number.

10.4 MAC commands related to the registration process

10.4.1 Registration enable (*MC-REN*)

10.4.1.1 Function

This command indicates the start of a registration phase which enables all devices as selected by the attribute to participate.

It shall be used in the *MnW* only.

10.4.1.2 Semantics of the service primitive

MC-REN {selector}

Attribute	Description
Selector	One byte:
	Selector bit = 0: Registration of the related group is disabled
	Selector bit = 1: Registration of the related group is enabled

Table 18 — *MC*-REN group selector

Selector Bit Nr.	Related group
0 (LSB)	Group 0: Safety services (highest priority)
1	Group 1: Governmental services
2	Group 2: Standard CALM-fast applications
3	Group 3: Standard Internet services
4	Group 4: tbd
5	Group 5: tbd
6	Group 6: tbd
7 (MSB)	Group 7: tbd (lowest priority)

10.4.1.3 When generated

Generated by the MAC of the master in order to allow only devices of the indicated groups to enter the registration process.

10.4.1.4 Effect on receipt

Devices belonging to at least one of the enabled groups to enter the registration process.

10.4.2 Registration request (*MC-RRQ*)

10.4.2.1 Function

This command indicates the start of a registration phase which forces all devices as selected by the attribute to participate.

It shall be used in the *MnW* only.

10.4.2.2 Semantics of the service primitive

MC-RRQ {Selector}

Attribute	Description
Selector	One byte:
	Selector bit = 0: Registration of the related group is disabled
	Selector bit = 1: Registration of the related group is enforced
	See also Table 18

10.4.2.3 When generated

Generated by the MAC of the master in order to force devices of the indicated groups to enter the registration process.

10.4.2.4 Effect on receipt

Devices belonging to at least one of the indicated groups are forced to enter the registration process.

10.4.3 Identifier request (*MC-IDQ*)

10.4.3.1 Function

With this command, the slave proposes to the master a *TempID*.

The command shall be used in *MnW* only.

10.4.3.2 Semantics of the service primitive

MC-IDQ {TempID}

Attribute	Description
TempID	The TempID proposed by the slave

10.4.3.3 When generated

This command is generated by the *MAC* of the slave.

10.4.3.4 Effect on receipt

10.4.3.4.1 In the event that the proposed *TempID* is not yet used by one of the slaves in the master's communication zone, the master confirms to the slave that the proposed *TempID* can be used.

10.4.3.4.2 In the event that the proposed *TempID* is yet used by one of the slaves in the master's communication zone, the master gives no reply at all.

10.4.3.4.3 In the event that the proposed *TempID* is disturbed or faulty, the master gives no reply at all.

10.4.4 Identifier response (*MC-IDP*)

10.4.4.1 Function

With this command, the master confirms to the slave that the proposed *TempID* can be used.

The command shall only be used in *MnW*.

10.4.4.2 Semantics of the service primitive

MC-IDP {TempID}

Attribute	Description
TempID	The *TempID* proposed by the slave

10.4.4.3 When generated

In the event that the proposed *TempID* is not yet used in the communication zone of the master, this command is sent as confirmation that the use of the proposed *TempID* is granted.

10.4.4.4 Effect on receipt

10.4.4.4.1 In the event that the MAC recognizes the TempID proposed by him, he reconfirms with the command registration confirmation and the *IR-ME* is informed about establishment of a new association with a master.

10.4.4.4.2 In the event that *TempID* is not recognized as the one proposed, the slave enters the registration process again.

10.4.5 Registration confirmation (*MC-REC*)

10.4.5.1 Function

The command registration confirmation is sent by the *MAC* of the slave if the master sends back the proposed *TempID* of the slave.

The command shall be used in an *MnW* only.

10.4.5.2 Semantics of the service primitive

MC-REC { }

10.4.5.3 When generated

This command is generated by the *MAC* of the slave after receiving its proposed *TempID* from the master.

10.4.5.4 Effect on receipt

The proposed *TempID* of the slave is validated.

The *IR-ME* is informed about establishment of a new association with a master.

10.5 MAC commands related to the PHY layer parameters

10.5.1 Profiles request *(MC-PRQ)*

10.5.1.1 Function

This command requests the receiving device to submit the code of all communication profiles the device is able to handle.

The command shall be used in a private window only.

10.5.1.2 Semantics of the service primitive

MC-PRQ { }

10.5.1.3 When generated

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

10.5.1.4 Effect on receipt

The receiving *MAC* forwards the request to the *IR-ME*.

10.5.2 Profiles response (*MC-PRP*)

10.5.2.1 Function

This command replies to the command *MC-PRQ* with a table containing all the designators of the communication profiles the responding device is able to use.

The command shall be used in a private window only.

10.5.2.2 Semantics of the service primitive

MC-PRP {profile indicator}

Attribute	Description
Profile indicator	Two bytes. Meaning of bits as defined in Table 19

Table 19 — Profile indicators

Bit Position	Profile	profile selector
0 (LSB)	Profile 0	0
1	Profile 1	1
2	Profile 2	2
3	Profile 3	3
4	Profile 4	4
5	Profile 5	5
6	Profile 6	6
7	Profile 7 (reserved for future use)	7
8	Profile 8 (reserved for future use)	8
9	Profile 9 (reserved for future use)	9
10	Profile 10 (reserved for future use)	10
11	Profile 11 (reserved for future use)	11
12	Profile 12 (reserved for future use)	12
13	Profile 13 (reserved for future use)	13
14	Profile 14 (reserved for future use)	14
15 (MSB)	Extension indicator	Not applicable

If a bit position is set to "1", the related profile is indicated.

If the MSB (i.e. the extension indicator) is set to "1", further profiles exist. This functionality is reserved.

10.5.2.3 When generated

This command is generated by the *MAC* on request of the *IR-ME* as response to an *MC-PRQ*.

10.5.2.4 Effect on receipt

The receiving *MAC* forwards the profile designators to the *IR-ME*.

10.5.3 Request new profile (*MC-RNP*)

10.5.3.1 Function

With this command, a slave requests the master to assign a new communications profile to the private window.

The command shall be used in a private window only.

10.5.3.2 Semantics of the service primitive

MC-RNP {profile_selector}

Attribute	Description
profile selector	One byte indicating the requested profile (see Table 19)

10.5.3.3 When generated

This command is generated by the *MAC* on request of the *IR-ME*, when a change of profile is necessary.

10.5.3.4 Effect on receipt

10.5.3.4.1 The receiving *MAC* forwards the request to the *IR-ME*.

10.5.3.4.2 The receiving device suspends all "non-command" communications in the private window until a new communications profile is set.

10.5.3.4.3 The *IR-ME* decides on acceptance or non-acceptance of this request. The underlying rules are outside the scope of this International Standard.

10.5.3.4.4 In the event of acceptance, the *IR-ME* shall request the *MAC* to transmit MC-SPR with the requested profile designator as attribute.

10.5.3.4.5 In the event of non-acceptance of any of the requested profiles, the *IR-ME* shall

— request the *MAC* to transmit *MC-SPR* with the profile selector of the currently used profile as attribute in order to continue with the current profile, if the requested new profile implies higher data rate than the actual one, or

— request the *MAC* to transmit *MC-SPR* with the profile selector of the default profile in order to set the requestor to the default profile.

10.5.4 Set profile (*MC-SPR*)

10.5.4.1 Function

With this command, the master sets the appropriate profile to communicate with the slave in its private window (*PrW*).

The command shall be used in a private window only.

10.5.4.2 Semantics of the service primitive

MC-SPR {profile_selector}

Attribute	Description
profile selector	One byte indicating the requested profile (see Table 19)

10.5.4.3 When generated

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

10.5.4.4 Effect on receipt

The receiving *MAC* forwards the request to the *IR-ME* in order to adjust the own communications profile for this private window.

The slave gets the token.

The *MC-SPR* shall be confirmed with *MC-SPC*.

10.5.5 Set profile confirmation (*MC-SPC*)

10.5.5.1 Function

This command confirms the successful activation of the profile as indicated with the command *MC-SPR*.

10.5.5.2 Semantics

MC-SPC { }

10.5.5.3 When generated

This command is generated by the *MAC* after successful activation of the profile.

10.5.5.4 Effect on Receipt

The new profile becomes valid.

The master gets the token.

The *IR-ME* is informed about the new communication profile.

10.5.6 Set multicast profile *(MC-SMP*)

10.5.6.1 Function

This command sets the communications profile which is to be used in the current multicast window.

The command shall be used in a multicast window only.

10.5.6.2 Semantics

MC-SMP {profile_selector}

Attribute	Description
profile selector	One byte indicating the requested profile (see Table 19)

10.5.6.3 When generated

This command is generated by the *MAC* at the beginning of each multicast window.

10.5.6.4 Effect on Receipt

The new profile becomes valid.

10.6 MAC commands related to test and services

10.6.1 Ping (*MC-PING*)

10.6.1.1 Function

This command is used to request derive the field strength of the received signal of the communication partner.

10.6.1.2 Semantics of the service primitive

MC-PING { }

10.6.1.3 When generated

This command is generated by the *MAC* to enable field strength measurement.

10.6.1.4 Effect on receipt

In the event of reception *MC_PING*, the *MAC* responds immediately with the command *MC-PONG*.

10.6.2 Pong (*MC-PONG*)

10.6.2.1 Function

This command is used to support the measurement of the receiver field strength of the communication partner.

This command shall be used in the *PrW* only.

10.6.2.2 Semantics of the service primitive

MC-PONG { }

10.6.2.3 When generated

This command is generated by the *MAC* immediately after the reception of *MC-PING*.

10.6.2.4 Effect on receipt

In the event of reception, an RSSI measurement is triggered by the receiving *MAC*.

NOTE   RSSI means received signal strength indication.

10.6.3 Status request1 (*MC-SRQ1*)

10.6.3.1 Function

This command requests the transmission quality parameters of the communication partner.

The command shall be used in a private window only.

10.6.3.2 Semantics of the service primitive

MC-SRQ1 {transmission_quality_parameters_indicator}

Attribute	Description
transmission_quality_parameters_indicator	One byte indicating the requested parameters (see Table 20)

Table 20 — Transmission quality parameters

Bit Position	Status parameter	Description
0 (LSB)	Bit_counter	Total number of received information bits
1	Bit_uncorrected	Number of uncorrected information bits
2	Bit_corrected	Number of corrected information bits
3	Packet counter	Total number of received information packets
4	Packet retransmission	Number of received re-transmitted information packets
5	Block counter	Total number of received information blocks
6	Block retransmission	Number of received re-transmitted information blocks
7	reserved for future use	

If a bit-position is set to "1", the related status information is requested.

10.6.3.3 When generated

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

10.6.3.4 Effect on receipt

10.6.3.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the request to the *IR-ME*.

10.6.3.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.4 Status request2 (*MC-SRQ2*)

10.6.4.1 Function

This command requests the radiation parameters from the communication partner.

The command shall be used in a private window only.

10.6.4.2 Semantics of the service primitive

MC-SRQ2 {field_parameters_indicator}

Attribute	Description
field_parameters_indicator	One byte with all bits indicating the requested parameters set to one (see Table 21)

Table 21 — Field parameters

Bit Position	Status parameter	Description
0 (LSB)	Receiver class	Sensitivity class of receiver
1	Transmitter class	Power class of the transmitter
2	Field strength	Measured field strength at receiver input
3	Solar radiation	Measured solar brightness at receiver input
4	reserved for future use	
5	reserved for future use	
6	reserved for future use	
7	reserved for future use	

If a bit-position is set to "1", the related status information is requested.

10.6.4.3 When generated

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

10.6.4.4 Effect on receipt

10.6.4.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the request to the *IR-ME*.

10.6.4.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.5 Status request3 (*MC-SRQ3*)

10.6.5.1 Function

This command requests the environmental parameters from the communication partner.

The command shall be used in a private window only.

10.6.5.2 Semantics of the service primitive

MC-SRQ3 {environmental_parameters_indicator}

Attribute	Description
environmental_parameters_indicator	One byte with all bits indicating the requested parameters set to one (see Table 23)

Table 22 — Environmental parameters

Bit Position	Status parameter	Description
0 (LSB)	Temperature	Ambient temperature
1	Voltage	Battery voltage
2	Battery charge	remaining battery charge
3	reserved for future use	
4	reserved for future use	
5	reserved for future use	
6	reserved for future use	

Table 22 *(continued)*

Bit Position	Status parameter	Description
7	reserved for future use	

If a bit position is set to "1", the related status information is requested.

10.6.5.3 When generated

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

10.6.5.4 Effect on receipt

10.6.5.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the request to the *IR-ME*.

10.6.5.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.6 Status request4 (*MC-SRQ4*)

10.6.6.1 Function

This command requests the manufacturer and certification parameters from the communication partner.

The command shall be used in a private window only.

10.6.6.2 Semantics of the service primitive

MC-SRQ4 {manufacturer_and_certification_parameters_indicator}

Attribute	Description
manufacturer_and_certification_parameters_indicator	One byte with all bits indicating the requested parameters set to one (see Table 23)

Table 23 — Manufacturer and certification parameters

Bit Position	Status parameter
0 (LSB)	Manufacturer ID
1	Serial number
2	Certification 1
3	Certification 2
4	Certification 3
5	Certification 4
6	reserved for future use
7	reserved for future use

If a bit position is set to "1", the related status information is requested.

10.6.6.3 When generated

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

10.6.6.4 Effect on receipt

10.6.6.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the request to the *IR-ME*.

10.6.6.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.7 Status response1 *(MC-SR1)*

10.6.7.1 Function

This command responds the requested transmission quality parameters to the communication partner.

The command shall be used in a private window only.

10.6.7.2 Semantics of the service primitive

MC-SR1 {transmission_quality_parameters_indicator}

Attribute	Description
transmission_quality_ parameters_indicator	One byte indicating the available parameters (see Table 24)

The command shall be immediately followed by a table containing the requested status information. The status information is transmitted starting with the least significant entry.

Table 24 — Transmission quality parameters report

Parameter	Description	Format
Parameter1	Bit_counter	4 Byte Counter, LSB first
Parameter2	Bit_uncorrected	4 Byte Counter, LSB first
Parameter3	Bit_corrected	4 Byte Counter, LSB first
Parameter4	Packet counter	4 Byte Counter, LSB first
Parameter5	Packet retransmission	4 Byte Counter, LSB first
Parameter6	Block counter	4 Byte Counter, LSB first
Parameter7	Block retransmission	4 Byte Counter, LSB first
Parameter8	reserved for future use	4 Bytes

The table is sent using the negotiated communications profile of the private window. The table is neither lead nor trailed by any block or packet command.

10.6.7.3 When generated

This command is sent by the *MAC* on request of the *IR-ME*.

10.6.7.4 Effect on receipt

10.6.7.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the table to the *IR-ME*.

10.6.7.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.8 Status response2 (*MC-SR2*)

10.6.8.1 Function

This command responds the requested radiation parameters to the communication partner.

The command shall be used in a private window only.

10.6.8.2 Semantics of the service primitive

MC-SR2 {radiation_parameters_indicator}

Attribute	Description
radiation_parameters_indicator	One byte indicating the available parameter (see Table 25)

The command shall be immediately followed by a table containing the requested status information. The status information is transmitted starting with the least significant entry.

Table 25 — Radiation parameters report

Parameter	Description	Format
Parameter1	receiver class	one byte
Parameter2	transmitter class	one byte
Parameter3	field strength	two bytes
Parameter4	solar radiation	two bytes
Parameter5	reserved for future use	two bytes
Parameter6	reserved for future use	two bytes
Parameter7	reserved for future use	two bytes
Parameter8	reserved for future use	two bytes

The table is sent using the negotiated communications profile of the private window. The table is neither lead nor trailed by any block or packet command.

10.6.8.3 When generated

This command is sent by the *MAC* on request of the *IR-ME*.

10.6.8.4 Effect on receipt

10.6.8.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the table to the *IR-ME*.

10.6.8.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.9 Status response3 (*MC-SR3*)

10.6.9.1 Function

This command responds the requested environmental parameters to the communication partner.

The command shall be used in a private window only.

10.6.9.2 Semantics of the service primitive

MC-SR3 {environmental_parameters_indicator}

Attribute	Description
environmental_parameters_indicator	One byte indicating the available parameters (see Table 26)

The command shall be immediately followed by a table containing the requested status information. The status information is transmitted starting with the least significant entry.

Table 26 — Environmental parameters report

Parameter	Description	Format
Parameter1	Temperature	one byte
Parameter2	Voltage	one byte
Parameter3	Battery charge	one byte
Parameter4	reserved for future use	one byte
Parameter5	reserved for future use	two bytes
Parameter6	reserved for future use	two bytes
Parameter7	reserved for future use	two bytes
Parameter8	reserved for future use	two bytes

The table is sent using the negotiated communications profile of the private window. The table is neither lead nor trailed by any block or packet command.

10.6.9.3 When generated

This command is sent by the *MAC* on request of the *IR-ME*.

10.6.9.4 Effect on receipt

10.6.9.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the table to the *IR-ME*.

10.6.9.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.10 Status response4 (*MC-SR4*)

10.6.10.1 Function

This command responds the requested manufacturer and certification parameters to the communication partner.

The command shall be used in a private window only.

10.6.10.2 Semantics of the service primitive

MC-SR4 {manufacturer_and_certification_parameters_indicator}

Attribute	Description
manufacturer_and_certification_parameters_indicator	One byte indicating the available parameters (see Table 27)

The command shall be immediately followed by a table containing the requested status information. The status information is transmitted starting with the least significant entry.

Table 27 — Manufacturer and certification parameters report

Parameter	Description	Format
Parameter1	Manufacturer ID	4 bytes, LSB first
Parameter2	Serial number	4 bytes, LSB first
Parameter3	Certification1	4 bytes, LSB first
Parameter4	Certification2	4 bytes, LSB first
Parameter5	Certification3	4 bytes, LSB first
Parameter6	Certification4	4 bytes, LSB first
Parameter7	Reserved for future use	4 bytes, LSB first
Parameter8	Reserved for future use	4 bytes, LSB first

The table is sent using the negotiated communications profile of the private window. The table is neither lead nor trailed by any block or packet command.

10.6.10.3   When generated

This command is sent by the *MAC* on request of the *IR-ME*.

10.6.10.4   Effect on receipt

10.6.10.4.1   In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the table to the *IR-ME*.

10.6.10.4.2   In the event of reception with uncorrectable errors, the receiving MAC responds with MC-TNAck.

10.6.11 Echo alert (*MC-EA*)

10.6.11.1   Function

This command requests the *MAC* of the recipient to prepare for answering the echo request with a predefined delay time in order to enable the requestor to calculate the signal travelling time respectively distance between the two communication partners considering the delay time.

MC-EA shall be followed by no other command than *MC-ERQ*.

MC-EA is only valid for the current window.

The command shall be used in a private window only.

10.6.11.2   Semantics of the service primitive

MC-EA { }

10.6.11.3   When generated

On request of the service application through the *IR-ME*.

10.6.11.4 Effect on receipt

10.6.11.4.1 In the event of reception with none or correctable errors, the receiving *MAC* prepares for a response to an *MC-ERQ* with a defined delay time.

10.6.11.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck.*

10.6.12 Echo request (*MC-ERQ*)

10.6.12.1 Function

This command requests the *MAC* of the recipient to respond after the delay time T_{EC} with the command echo (*MC-ECH*) in order enable the requestor to calculate the signal travelling time respectively distance between the two communication partners.

The command shall be used in a private window only.

10.6.12.2 Semantics of the service primitive

MC-ERQ { }

10.6.12.3 When generated

This command is generated by the *MAC* on request of the *IR-ME* after sending the command *MC-EA.*

The command shall be preceded by the command *MC-EA* in the current window.

After sending the command, the sending *MAC* shall change to the receive state and wait for a reply.

10.6.12.4 Effect on receipt

10.6.12.4.1 In the event of reception with none or correctable errors, the receiving *MAC* changes immediately into the "send state" and responses with the command "echo" after the delay T_{ED} in the current window.

10.6.12.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck.*

10.6.13 Echo (*MC-ECH*)

10.6.13.1 Function

This command is sent by the *MAC* as reply to the command *MC-ERQ.*

The command shall be used in a private window only.

10.6.13.2 Semantics of the service primitive

MC-ECH {echo_delay_time}

Attribute	Description
echo_delay_time	Two byte giving the implementation dependent, device internal, delay time (ns) in between the reception of the first bit of the received command *MC-ERQ* and the first bit of the command *MC-ECH*

10.6.13.3 When generated

This command is generated by the *MAC* as reply to *MC-ERQ*.

Effect on receipt

10.6.13.4.1 In the event of reception with none or correctable errors, the receiving *MAC* forwards "echo delay time" to the *IR-ME* to be considered when calculating the signal travelling time or distance, respectively.

10.6.13.4.2 In the event of reception with uncorrectable errors, the receiving *MAC* responds with *MC-TNAck*.

10.6.14 Service table (*MC-ST*)

10.6.14.1 Function

The command indicates that the table following to the command contains the service table *ST*.

It shall be used in the *MnW* and *PrW*.

10.6.14.2 Semantics of the service primitive

MC-ST {ST_length}

Attribute	Description
ST_length	3 bytes provide the total number of service

MC-ST is immediately followed by the table containing the service table.

Table 28 — Structure of the service table *ST*

Length	Meaning
3 byte	Service 1
3 byte	Service 2
3 byte	Service n

Service is a number partitioned in three parts: category + subcategory + service_number.

Category shall be a one byte number.

Subcategory shall be a one byte number.

Service_number shall be a one byte number.

10.6.14.3 When generated

This command is generally generated by the *IR-ME* in the *MnW* or on request of a communication partner in a *PrW*.

10.6.14.4 Effect on receipt

In the event of reception, the registered slaves are informed about the availability of services provided by the master.

10.6.15 Service table request (*MC-STQ*)

10.6.15.1 Function

With this command, a slave requests the master to announce services provided by the master.

10.6.15.2 Semantics of the service primitive

MC-STQ {category, subcategory, service_number}

Attribute	Description
category	One byte defining the category
subcategory	One byte defining the subcategory
service_number	One byte defining the service

NOTE 1   In case category is 00h, the whole service table is requested (subcategory byte and service_number byte is ignored).

NOTE 2   In case subcategory is 00h, the whole services of a category are requested (the service_number byte is ignored).

NOTE 3   In case service_number is 00h, the whole services of a subcategory are requested.

10.6.15.3 When generated

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

10.6.15.4 Effect on receipt

The receiving *MAC* forwards the request to the *IR-ME*.

10.6.16 Service subscribe (*MC-SVS*)

10.6.16.1 Function

This command requests services or service categories of the communication partner.

The command shall be used in a private window only.

10.6.16.2 Semantics of the service primitive

MC-Service Subscribe {SVS_length}

Attribute	Description
SVS_length	3 bytes provide the number of services/service categories to subscribe

MC-SVS is immediately followed by the list containing the service numbers.

Table 29 — Structure of the service table *ST*

Length	Meaning
3 byte	Service 1 or service category 1
3 byte	Service 2 or service category 2
3 byte	service n or service category n

10.6.16.3 When generated

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

10.6.16.4 Effect on receipt

10.6.16.4.1 In the event of reception with none or correctable errors, the receiving *MAC* responds with *MC-TAck* and forwards the request to the *IR-ME*.

10.6.16.4.2 In the event of reception with uncorrectable errors, the receiving MAC responds with *MC-TNAck*.

10.6.17 Service (*MC-SVC*)

10.6.17.1 Function

With this command, the sending *MAC* indicates the start of a service requested by the communication partner.

The command shall be used in a private window only.

10.6.17.2 Semantics of the service primitive

MC-SVC {service}

Attribute	Description
service	3 bytes indicating the service

MC-SVC is immediately followed by the content of the service. The content shall be finalized by the command *MC-BLE*.

If it is not possible to transmit the whole content within the current window, the block shall be divided into packets.

10.6.17.3 When generated

This command is sent by the *MAC* at the start of the service to be transmitted.

10.6.17.4 Effect on receipt

Open a new receive buffer for the CALM infrared service channel.

NOTE   The first packet in a block always has packet number 00H.

10.6.18 Service unsubscribe (*MC-SVU*)

10.6.18.1 Function

This command terminates a subscribed service.

The command shall be used in a private window only.

10.6.18.2 Semantics of the service primitive

MC-Service Subscribe {service}

Attribute	Description
Service	3 bytes provide the number of services/service categories to subscribe to

10.6.18.3 When generated

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

10.6.18.4 Effect on receipt

In the event of reception, the receiving *MAC* terminates the specified service.

10.7 MAC command set overview

Table 30 — List of MAC commands

Command code	MAC command	Mnemonic	Length of attribute (bytes)	Used in window types	Initiated by
Commands related to the frame and window organization						
82h	Frame organization table	MC-FOT {FOT_length}	2	MnW	MAC
83h	Frame organization table update	MCFOTU {FOTU_length}	2	MnW	MAC
04h	Frame organization table-steady	MC-FOTS { }	none	MnW	MAC
C1h	Get submaster area	MC-GSA {ownMID, #Slaves, #Timeslots}	5	PrW	IR-ME
8Ch	Submaster status	MC-SST {#slaves, #Timeslots}	2	PrW	IR-ME
8Bh	Submaster organization table	MC-SOT {SOT_length}	2	MnW	IR-ME
17h	Submaster area con-firmed	MC-SAC { }	none	PrW	IR-ME
18h	Submaster area denied	MC-SAD { }	none	PrW	IR-ME
43h	Broadcast	MC-BRC {broadcast_length}	1	MnW	MAC
C0h	Re-establish session	MC-REST {MID, TempID}	5	PrW	IR-ME
0Ch	Session re-establishment confirmation	MC-RESC { }	none	PrW	IR-ME
0Dh	Session re-establishment denied	MC-RESD { }	none	PrW	IR-ME
C9h	Change master identifier	MC-CMI {newMID}	3	MnW	IR-ME
06h	Kill all	MC-KIA { }	none	MnW	IR-ME
86h	Kill slave	MC-KIS {TempID}	2	MnW	IR-ME
01h	De-register	MC-DREG { }	none	PrW	IR-ME
0Fh	Suspend all	MC-SUA { }	none	MnW	MAC
8Ah	Suspend slave	MC-SUS {TempID}	2	MnW	MAC
05h	Free air time	MC-FAT { }	none	MnW	IR-ME
15h	Spare window	MC-SPW { }	none	SpW	IR-ME

Table 30 *(continued)*

Command code	MAC command	Mnemonic	Length of attribute (bytes)	Used in window types	Initiated by
55h	Wakeup	*MC-WU {identifier}*	1	*WuW*	*IR-ME*
Commands related to flow control					
00h	Busy	*MC-BSY { }*	None	*PrW, McW, BcW*	*MAC*
44h	Command not supported	*MC-CNS {CNS}*	1	*PrW*	*MAC*
10h	Token	*MC-TKN { }*	none	*PrW*	*MAC*
42h	Block start	*MC-BLS {block_number}*	1	*PrW, McW BcW, MnW*	*IR-CAL*
45h	Control channel block Start	*MC-CCBS {block_number}*	1	*PrW, BcW, McW*	*IR-CAL*
46h	IEEE-Frame block Start	*MC-FBS {block_number}*	1	*PrW, BcW, McW*	*IR-CAL*
4Ch	Start of MAC control block	*MC-SMC {block_number}*	1	*PrW, McW, BcW, MnW*	*IR-ME*
87h	Packet start	*MC-PAS {block_number, packet_ number}*	2	*PrW, McW, BcW*	*MAC*
07h	Packet end	*MC-PAE { }*	none	*PrW, McW, BcW*	*MAC*
41h	Block end	*MC-BLE {block_number}*	1	*PrW, McW, BcW, MnW*	*MAC*
C2h	Packet start CRC16	*MC-PAE16 {block_number, packet_number, CRC}*	4	*All*	*MAC*
C3h	Block start CRC16	*MC-BLE16 {block_number, CRC}*	3	*All*	*MAC*
11h	Transmission acknowl- edge	*MC-TAck { }*	none	*PrW*	*MAC*
12h	Transmission acknowl- edge &	*MC-TAck& { }*	none	*PrW*	*MAC*
13h	Transmission not acknowledge	*MC-TNAck { }*	none	*PrW*	*MAC*
14h	Transmission not acknowledge &	*MC-TNAck& { }*	none	*PrW*	*MAC*
89h	Retransmission request	*MC-RTQ {block_number, packet_ number}*	2	*PrW*	*MAC*
40h	Block acknowledge	*MC-BAck {block_number}*	1	*PrW*	*MAC*
Commands related to the registration process					
47h	Registration enable	*MC-REN {selector}*	1	*MnW*	*MAC*
48h	Registration request	*MC-RRQ {selector}*	1	*MnW*	*MAC*
84h	Identifier request	*MC-IDQ {TempID}*	2	*MnW*	*MAC*
85h	Identifier response	*MC-IDP {TempID}*	2	*MnW*	*MAC*
0Bh	Registration confirma- tion	*MC-REC { }*	none	*MnW*	*MAC*
Commands related to the PHY layer parameters					
0Ah	Profiles request	*MC-PRQ { }*	none	*PrW*	*IR-ME*
88h	Profiles response	*MC-PRP {profile_indicator}*	2	*PrW*	*IR-ME*

Table 30 *(continued)*

Command code	MAC command	Mnemonic	Length of attribute (bytes)	Used in window types	Initiated by
49h	Request new profile	*MC-RNP {profile_selector}*	1	*PrW*	*IR-ME*
4Bh	Set profile	*MC-SPR {profile_selector}*	1	*PrW*	*IR-ME*
0Eh	Set profile confirmation	*MC-SPC { }*	none	*PrW*	*IR-ME*
4Ah	Set multicast profile	*MC-SMP {profile_selector}*	1	*McW*	*MAC*
Commands related to test and services					
08h	Ping	*MC-PING { }*	none	*PrW*	*MAC*
09h	Pong	*MC-PONG { }*	none	*PrW*	*MAC*
4Dh	Status request 1	*MC-SRQ1 {transmission quality parameters indicator}*	1	*PrW*	*IR-ME*
4Eh	Status request 2	*MC-SRQ2 {field parameters indicator}*	1	*PrW*	*IR-ME*
4Fh	Status request 3	*MC-SRQ3 {environmental parameters indicator}*	1	*PrW*	*IR-ME*
50h	Status request 4	*MC-SRQ4 {manufacturer and certification parameters indicator}*	1	*PrW*	*IR-ME*
51h	Status response 1	*MC-SR1 {transmission quality parameters indicator}*	1	*PrW*	*IR-ME*
52h	Status response 2	*MC-SR2 {field parameters indicator}*	1	*PrW*	*IR-ME*
53h	Status response 3	*MC-SR3 {environmental parameters indicator}*	1	*PrW*	*IR-ME*
54h	Status response 4	*MC-SR4 {manufacturer and certification parameters indicator}*	1	*PrW*	*IR-ME*
02h	Echo alert	*MC-EA { }*	none	*PrW*	*IR-ME*
03h	Echo request	*MC-ERQ { }*	none	*PrW*	*MAC*
81h	Echo	*MC-ECH {echo_delay_time}*	2	*PrW*	*MAC*
C4h	Service table	*MC-ST {category, subcategory, Service_number }*	3	*MnW, PrW*	*IR-ME*
C5h	Service table request	*MC-STQ {category, subcategory, Service_number }*	3	*PrW*	*IR-ME*
C6h	Service subscribe	*MC-SVS {SVS_length}*	3	*PrW*	*IR-ME*
C7h	Service	*MC-SVC {service}*	3	*PrW*	*IR-ME*
C8h	Service unsubscribe	*MC-SVU {service}*	3	*PrW*	*IR-ME*

11 Registration procedure

11.1 General

11.1.1 The registration procedure enables newly entered devices to be registered for communication. During this process, the slave is assigned a temporary identification (TempID) which is used for further addressing the slave device as long as it resides in the communication zone of the master.

11.1.2 The registration procedure takes place in the registration phase of the management window (e.g. after the generic frame Information MID, FLen, and FATI is sent).

11.1.3 During the registration procedure, a slave which has newly entered the communication zone of a master and which has detected the F-Sync Signal, the generic frame Information, and a MAC command registration Enable or registration request which fits his priority, creates a TempID with which he enters the registration process.

11.2 Normal registration procedure

11.2.1 Temporary identifier

11.2.1.1 The temporary identifier (TempID) is produced by the slave and proposed to the master to use it for further addressing of the slave.

11.2.1.2 The proposed TempID is checked by the master for uniqueness in his communication zone and confirmed to the slave in case of a successful registration.

11.2.1.3 A confirmed TempID is valid as long as the TempID time-out has not exceeded.

11.2.1.4 When producing a TempID proposal, the slave shall obey the following rules.

11.2.1.4.1 The TempID is a 2 byte random number.

11.2.1.4.2 The slave shall not use one of the predefined reserved TempIDs (see 11.2.2 and Table 31).

11.2.1.4.3 The slave device shall produce the TempID on a random basis such that all possible values are chosen with equal probability.

11.2.1.4.4 In the event that a "pseudo-random" process is used, the sequence of random numbers shall not be identical in all slave units.

11.2.1.4.5 The slave shall use a new random number for each registration process and for each registration attempt.

11.2.2 TempID codes

TempID codes are provided in Table 31.

Table 31 — TempID codes

ID number	Name	Description
0000h	Dummy-ID	Identifier of the last entry ("dummy entry") in the FOT
0001h	WuW-ID	Identifier for wake-up window
0002h 000Fh	SpW-ID	Identifiers for spare windows
0010h...00FFh	Future-ID	Reserved for future use
0100h...FEFFh	Temp-ID	Range of valid temporary identifier s
FF00...FFFEh	multicast ID	Range of valid multicast identifiers
FFFFh	Broadcast	Broadcast identifier

11.3 Sequence of the registration procedure without collision

11.3.1 The registration procedure is initiated with the command registration request (MC-RRQ) or registration enable (MC-REN).

11.3.2 After the sending of MC-RRQ or MC-REN, the master switches to the receive state and waits for answer during T_{RWAIT}.

11.3.3 An incoming device (slave) entering the communication zone receives the command.

11.3.4 After a random time delay T_{REG} which may depend on the priority of the device and the number of eventually yet failed registration attempts, the slave replies with the MAC command "identifier request" (MC-IDQ) whereby the attribute is the proposed TempID of the slave.

11.3.5 If no other slave uses this TempID, the master answers with the MAC command MC-IDP with the TempID proposed by the slave as attribute.

11.3.6 If the master detects that the TempID proposed by the slave is yet used by some other slave, the master rejects the current registration procedure by sending a new registration command (MC-REN or MC-RRQ).

11.3.7 Other slaves receiving the TempID (through the master) not originated by themselves stay inactive until the next registration command.

11.3.8 The slave recognizing its proposed TempID confirms immediately by sending the MAC command "registration confirmation" (MC-REC). The TempID becomes active and will be considered by the master when creating a new FOT or FOTU.

11.3.9 If the size of the management window allows it, the master may now broadcast a new registration command.
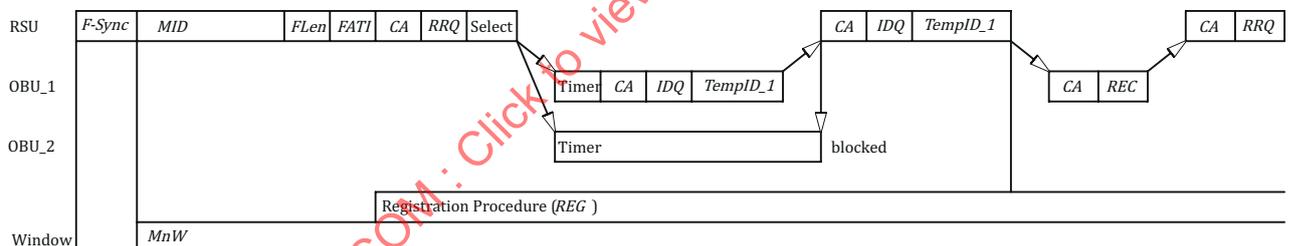
Figure 13 — Registration procedure without collision

11.4 Sequence of the registration procedure with collision

If two slaves reply, their proposed TempID simultaneously or overlapping a collision occurs.

The three possible scenarios are as follows.

11.4.1 Both signals appear with equal signal strength

Two slaves reply simultaneously or overlapping with different TempIDs and both signals appear with equal signal strength at the master (e.g. from the same distance to the master).

11.4.1.1 The master will receive a "wired OR" of both signals.

11.4.1.2 If the received signal conforms to an "allowed" TempID, the master replies with MC-IDP with this "mixture" as attribute. Otherwise, the master broadcasts another MC-RRQ or MC-REN.

11.4.1.3 As none of the slaves receives its correct TempID, none of the slave is addressed and thus, none of them confirms and no TempID becomes valid.

11.4.1.4 Thus, the master gets no confirmation and after a time-out period T_{RT}, the master broadcasts again a registration command.

RSU	F-Sync	MID		FLen	FATI	CA	RRQ	Select				CA	IDQ	TempID_3	Wait			CA	RRQ

(diagram:)

OBU_1: Timer | CA | IDQ | TempID_1 ; ?

OBU_2: Timer | CA | IDQ | TempID_2

Registration Procedure (*REG*)

Window: *MnW*
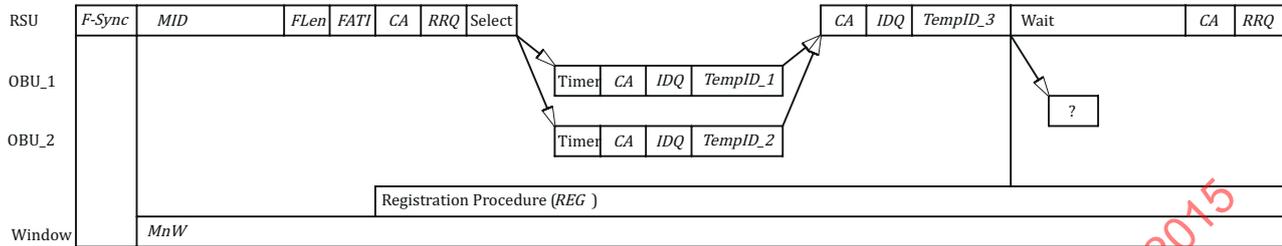
Figure 14 — Registration procedure with collision

11.4.2 Both signals appear with different signal strength

Two slaves reply simultaneously with different proposed TempIDs but both signals appear with different signal strength at the master (e.g. one slave is positioned nearby and the other far away from the master).

11.4.2.1 The master will receive the "stronger" TempID.

11.4.2.2 The master replies with MC-IDP with this TempID as attribute.

11.4.2.3 One slave receives its correct TempID and confirms while the other slave recognizes that it is not addressed.

11.4.3 Identical TempIDs

Two slaves reply simultaneously with identical TempIDs. This is the only possible scenario but it does not happen often. However, as described below, such a conflict will be detected so countermeasures can be initiated on the upper layers.

11.4.3.1 The master will receive a "correct" TempID.

11.4.3.2 The master replies this TempID.

11.4.3.3 Both slaves are addressed correctly and will be considered by the master as a single slave.

11.4.3.4 Both slaves will be assigned to the same private window.

11.4.3.5 This will cause collisions later on in the associated private window. As collisions can occur also by other reasons (e.g. cross-talking, interference), collisions in general shall be detected and solved by the layer 2 and above mechanism.

11.4.3.6 If a collision in the same window occurs more than once, the slave(s) shall be "killed" by a MAC command in the management window, the result being that that the slave(s) will enter a new registration process.

11.5 Handover and re-registration

If a slave misses to respond in his private window in two consecutive frames, the following actions should be taken.

11.5.1 Cancel TempID

The master shall cancel the TempID from the FOT but shall store, for a predefined time interval, the various session data related to this slave in order to enable a re-establishment of sessions, etc. in case the slave enters a new registration process, gets a new TempID, and has requested for session re-establishment using the MAC command "re-establish session" (MC-REST).

11.5.2 Advise adjacent masters

The master shall advise the adjacent masters about which slave he "lost" in his communication zone (TempID, session status) in order to enable the slave to re-establish the session when reaching the communication zone of the next master ("handover").

11.6 Registration process timers

Registration process timers are provided in .

Table 32 — Registration process timers

Timer	Description	Value
T_{RWAIT}	The master shall wait at least T_{RWAIT} for a reply to an MC-RRQ or MC-REN. The reception of a reply shall be processed by the master as soon as possible, depending on the implementation.	T_{RWAIT} = 125 μs
T_{REG}	Delay time before slave replies to an MC-RRQ or MC-REN.	Random T_{REG} min = 5 μs T_{REG} max = 91 μs
T_{CWAIT}	Waiting time of the slave for a reply to a proposed TempID.	T_{CWAIT} max = 42 μs
T_{RT}	Waiting time of the master for a reply to its MC-IDP.	T_{RT} max = 35 μs
T_{TempID}	TempID time-out.	255 Measured in number of consecutive frames. Frames, in which the related slave was suspended, are not counted.
T_{DREG}	Registration time-out.	60 s

12 Window management

12.1 General

A TDMA-frame includes, after the management window (MnW), a series of clustered time slots which form private and multicast windows (PrW, McW) enabling all the communication partners (master and slaves) to exchange information (e.g. application data and commands).

Those windows have to be managed by the master in order to

— allocate sufficient communication time to each slave device,

— meet time requirements for critical applications (e.g. real-time applications),

— maintain required command response/reaction time, and

— re-arrange the time slot allocation, if necessary.

12.2 Window allocation by frame organization tables

Windows are created by allocating them a start and a stop index defining their start and stop position in the time structure of a frame.

This organization is transmitted to the slaves by the master during the management window using either the MAC command frame organization table (MC-FOT) or frame organization table update (MC-FOT-U) that are described in 10.2.1 and 10.2.4.

Each window is addressed by a hexadecimal index of its time slot(s) from 00H to FFH. The start time slot (time slot 00H) is the very first time slot after the F-Sync.

If a slave is assigned to a window, this stays valid also for the next frame(s) until a new window is assigned or the communication ends.

As all devices in the communication zone receive this FOT-information, this organizes the slaves without the need of "continuous window counting". Instead of many interruptions, one timer is set in the slave, unblocking the interruption just before the start of the desired window.

NOTE   If no changes occur in the FOT, the command "frame organisation table steady" (MC-FOT-S) is sent instead the MC-FOT or MC-FOT-U.

The length of the window is the time difference from the start index to the start index of the subsequent window. The "Dummy-ID" is added to give the end information for the last window.

This frame organization method also avoids problems with "shadowing" which otherwise could lead to a temporal loss of sync information.

12.3 Spare windows

In order to enable the master during the registration process to instantly assign a private window to a newly registering slave, the master may maintain a "spare window" by allocating in the FOT a reserved TempID to an otherwise unused window.

If a slave newly registers, the master can assign the slave immediately this "spare window" by altering the "spare" TempID in the FOT before sending the FOT.

Thus, the new slave has a private window for his disposition even in the frame he used for registering. Complete frame reorganization (deleting or adding windows) can then be achieved before issuing a new frame.

12.4 Windows for isochronous services

If a service has stringent requirements concerning jitter and (minimum) bandwidth, the windows allocated to slaves requiring such services need to meet the following two criteria:

— they shall occur as equidistant as possible;

— they shall have a minimum length in terms of information bits (not necessarily in time as the necessary window time depends on the data rate of the communications profile used in the window).

Both criteria can be met by using a constant frame repetition rate (instead of using a constant inter-frame time) and placing the subject windows always in the same time slot.

In the event that "gaps" occur due to time slots not allocated to any active slave, those gaps shall be filled with "spare windows" as described in 12.3.

13 IR Management entity

13.1 General

The IR management entity IR-ME is in charge to control the IR MAC layer and IR physical layer (i.e. in all issues where an interaction with the upper layers of the CALM management is necessary).

13.2 MAC command not supported

Normally, proper implementations never generate MAC commands not supported at peer stations, except where these commands are optional commands.

Non-detectable transmission errors can lead to a not supported command. Thus, reception of the MAC command MC-CNS shall enforce re-transmission of the related MAC command. If this is not possible or if the command not supported was sent out, then the link shall be closed using the MAC commands MC-DREG and MC-KIS, as applicable.

13.3 Communication profiles

The management of communication profiles is detailed in 10.5. Available profiles shall be reported to the upper layers of the CALM management through the IR-MAE after power on and after every change of status.

13.4 Equipment status

The IR-ME shall maintain actual status information as described in the context of the MAC commands MC-SRQi and MC-SRi, i = 1 ... 4, (see 10.6). These parameters shall be retrievable by the CALM management through the IR-MAE.

13.5 Testing

The IR-ME shall support tests as described in 10.6 on request of a service application through the CALM management and the IR-MAE.

13.6 Registration

The registration procedure is specified in detail in Clause 11.

A physical IR identified by its MAC address which is unique in the CALM context shall be able to maintain logical instances of an IR unit, each identified by a temporary MAC address.

The unique MAC address is a six byte number as detailed in Figure 15.

LS -Byte	Byte 1	Byte 2	Byte 3	Byte 4	MS -Byte
Vendor value, manufacturer identifier			User value, serial number		
Individual, local			Qualifier	Identifier	

Figure 15 — Unique MAC address

NOTE   A MAC address consists of 6 bytes. These six bytes are divided into the following two groups:

— vendor value (also referred to as manufacturer identifier);

— user value (being a serial number).

In the event that the "Vendor" value indicates an individual local MAC address, the "User" value shall be the concatenation of a qualifier and identifier.

The MAC address qualifier shall be set as indicated in Figure 16.

Comment	LSB	Bit1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	MSB
Unique MAC address for stationary equipment	1	1	Extension of identifier, i.e. the identifier consists of 22 bits.					
Unique MAC address for mobile equipment	0	1	Extension of identifier, i.e. the identifier consists of 22 bits.					
Temporary MAC address for master	1	0	CCI	F1	F0	S	Res.	Res.
Temporary MAC address for slave	0	0	CCI	Res.	Instance number			

Key

CCI   control channel indicator (if set to "1", the logical unit constitutes a control channel)
F0, F1, S   elements of the class identity code (see Table 12)
Res.   reserved bit which shall be set to "1"
instance number logical instance of an IR communication entity

Figure 16 — MAC address qualifier

Any change of status for instances of IR communication units, i.e. any change in available MAC addresses, shall be reported to the CALM management through the IR-MAE together with the related unique and temporary MAC address.

13.7 Session management

13.7.1 The management of sessions is specified in detail in 10.2. See MAC commands MC-REST, MC-RESC, MC-RESD, MC-SUA, MC-SUS, MC-DREG, MC-KIS, and MC-KIA.

13.7.2 A session (i.e. the association between an IR master and an IR slave given by the pair of MID and TempID) can be closed by either the master or the slave.

13.7.2.1 The master may close the link by sending the MAC command MC-KIS {TempID}.

13.7.2.2 The slave may request to close the link by sending the MAC command MC-DREG.

13.7.2.3 In addition to this, the master can close all links by sending the MAC command MC-KIA.

13.7.3 A slave may be prohibited to use air time in a single specific frame without losing his association with the master by usage of the MAC commands MC-SUA, MC-SUS {TempID}.

13.8 Communication

13.8.1 Organization of IR communication

IR communication is organized in sequences of packets to be transmitted. Several packets can be associated with each other in an ordered sequence and build up a block, i.e. large blocks received from the IR-CAL need to be fragmented for transmission and defragmented after reception (see 14.2.5). For details on MAC commands, see 10.3.

13.8.2 Unique block number reference

13.8.2.1 Every block shall be referenced by a unique block number in the range of 00h to FFh. There shall only be a single block counter for all links of all logical instances of a single physical instance of an IR unit. A maximum of 256 blocks may be in use simultaneously.

13.8.2.2 The packets in a block are sequentially numbered starting with 00h.

13.8.2.3 The start of the first packet in a new block shall be indicated by one of the following block start commands:

— MC-BLS {block number}: CALM-fast application data transmission;

— MC-SCB {block number}: CALM-fast application control channel transmission;

— MC-BRC {block number}: single packet block for short broadcast messages in an MnW;

— MC-FBS {block number}: WLAN compliant data transmission.

13.8.2.4 The end of any one of these blocks shall be indicated by the MAC command MC-BLE.

13.8.2.5 The start of every packet in a block, except the first packet, shall be indicated by the command MC-PAS.

13.8.2.6 The end of every packet, except the last one of a block, shall be indicated by the command MC-PAE.

13.8.2.7 Blocks and the related block numbers shall be released for new usage as soon as error-free reception of a block is indicated by the MAC command MC-BAck.

13.8.2.8 Erroneous packets shall be re-transmitted on request of the recipient. A request for retransmission shall be indicated by the MAC commands MC-TNACK& or MC-TNACK or MC-RTQ, as applicable.

13.8.2.9 If a MAC command does not imply handover of the communication token (i.e. the right to send), this shall be done using the MAC command MC-TKN, if applicable. If a station has no packet or command to send, it shall send immediately the MAC command MC-TKN in order to dynamically share the channel capacity between master and slave.

13.9 Window management

An application service shall be able to command free air time. How this is achieved is outside the scope of this International Standard.

13.10 MAC Tunnel

An application service shall be able to request transmission of MAC internal and manufacturer specific commands and data to a peer station using the MAC command MC-SMC. How this is achieved is outside the scope of this International Standard.

14 Adaptation

14.1 Architecture

Medium adaptation is a means to adapt the IR specific lower layers to the common CALM network and CALM management entity CME. These lower layers include the physical layer and the data link layer, as well as an IR specific medium management entity IR-ME. The data link layer at least consists of the MAC sub-layer and the IR communication adaptation layer. The communication adaptation layer can be considered as an IR specific LLC.

The medium adaptation is outlined in Figure 17.
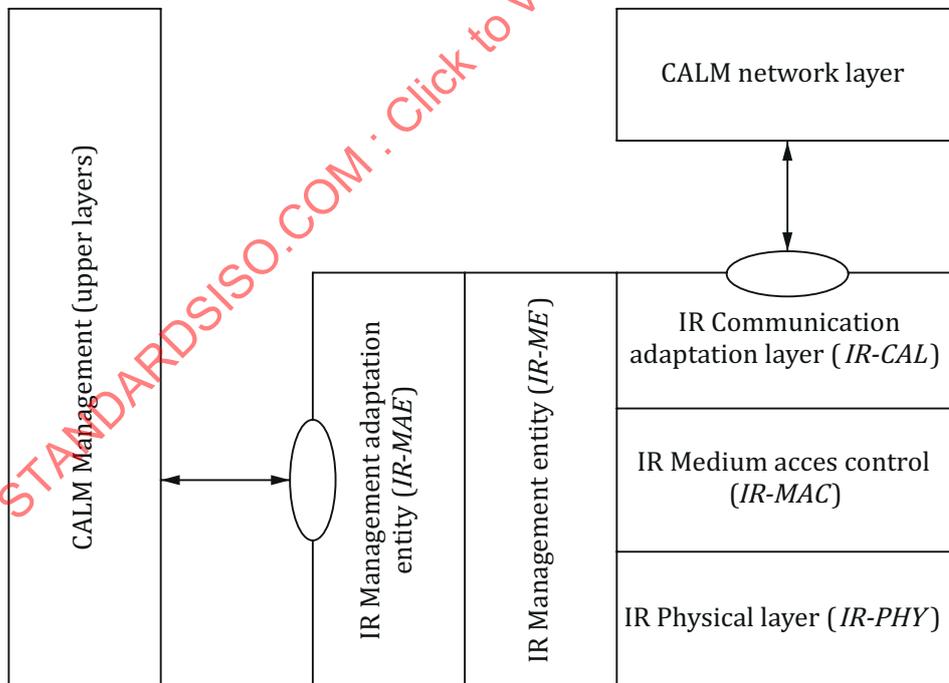
Figure 17 — Medium adaptation

IR-CAL provides a communication SAP to the CALM network layer following the same principles as outlined in ISO/IEC 8802-11:1999.

IR-MAE provides management SAPs to the CALM management entity following the same principles as outlined in ISO/IEC 8802-11:1999 with respect to the station management entity.

14.2 IR-CAL

14.2.1 Communication SAP

14.2.1.1 Reference

The service access point towards the CALM network layer is defined in ISO 21217. It provides the two service primitives CA-UNITDATA.request{} and CA-UNITDATA.indication{}, both with the parameters Source_Address, Destination_Address, data, and priority.

14.2.1.2 Source Address

The Source_Address parameter is the concatenation of source SAP address and source MAC address. The MAC address is defined in 14.2.4.

14.2.1.3 Destination Address

The Destination_Address parameter is the concatenation of destination SAP address and destination MAC address. The MAC address is defined in 14.2.4.

14.2.1.4 SAP Addresses

SAP Addresses are defined in ISO 21217, lower layer service access points.

14.2.1.5 Data

The data parameter carries the N-PDU.

14.2.1.6 Application priority

Application priorities shall apply in accordance with any defined priorities in ISO 21218 or ISO 24101 or where these International Standards do not define priority shall be at the discretion of the implementation of the communications system.

14.2.2 Communication types

14.2.2.1 CALM-fast applications

Default mandatory communication in CALM IR considers CALM-fast applications CFAs. Each packet received from the CALM network layer in the CA-UNITDATA.request service primitive shall be treated as one IR block.

Blocks may be associated with CALM data channels or with CALM control channels.

Upon error-free reception of a complete block, the IR-CAL shall forward it to the CALM network layer using the CA-UNITDATA.indication service primitive.

14.2.2.2 ISO/IEC 8802-11:1999 compatible services

These services are optional.

For WLAN communication compliant to ISO/IEC 8802-11:1999, a separate entity of the IR communication adapter shall be created with a new MAC address and be reserved for this type of communication. The CALM management shall be informed about such an entity via the IR-MAE. Each packet received from

the CALM network layer in the CA-UNITDATA.request service primitive (see ISO 21217) shall be treated as one IR block. The IR-CAL shall generate required WLAN MAC header information and insert it at the beginning of each block. The start of a block shall be indicated by the MAC command MC-FBS. The related procedures for generation and processing of header information for transmission and reception are defined in 14.2.3.

Upon error-free reception of a complete block, the IR-CAL shall evaluate the WLAN header information and then, shall forward the remaining body to the CALM network layer using the CA-UNITDATA. indication service primitive (see ISO 21217).

14.2.3 WLAN functionality

14.2.3.1 Basics

In order to support the ISO/IEC 8802-11:1999 mechanism for building and using BSSs with non-compliant media such as IR, the data normally generated and evaluated in the ISO/IEC 8802-11 MAC as part of the MAC procedures shall be treated as payload in the IR communication adapter.

As the IR communication adapter has its own mechanism to manage the data flow on the link, ISO/IEC 8802-11 flow control information shall not be transmitted through the IR link.

The IR communication adapter shall manage only data of the ISO/IEC 8802-11:1999 frames which are needed to provide the services supported by ISO/IEC 8802-11:1999.

All other information, such as data rate or others, is specific to the IR medium.

14.2.3.2 Relevant information

Relevant information (e.g. the BSSID of a BSS) shall be transmitted as payload following the MC-FBS-Command. Relevant information is explained in 14.2.3.2.1.

14.2.3.2.1 Type

The type of the ISO/IEC 8802-11:1999 frame is relevant information. Only ISO/IEC 8802-11:1999 MAC frames for management and data described in Table 33 are supported by CALM IR.

Table 33 — IR type field description

Type Description	IR type value	Subtype description
Management	0000	Association request
Management	0001	Association response
Management	0010	Reassociation request
Management	0011	Reassociation response
Management	0100	Scan request
Management	0101	Scan response
Management	0110	Join request
Management	0111	Join response
Management	1000–1001	Reserved
Management	1010	Disassociation
Management	1011	Authentication
Management	1100	Deauthentication
Reserved	1101–1110	Reserved
Data	1111	Data

14.2.3.2.2 Frame control

The two bits, to DS, and from DS, as described in ISO/IEC 8802-11:1999 are relevant information.

The frame control is reduced to one octet size as described in Table 34.

Table 34 — Frame control octet in IR

Bit	0	1	2	3	4	5	6	7
Description	0 (not used)	WEP	To Ds	From Ds	IR type value			

Other communication control fields from ISO/IEC 8802-11:1999 frames are not relevant to IR.

14.2.3.2.3 Addresses

The address 1 to address 4 of an ISO/IEC 8802-11:1999 frame shall be sent as described in ISO/IEC 8802-11:1999 without the sequence control field between address 3 and address 4.

The address fields Addr 2, Addr 3, and Addr 4 shall be transmitted only in cases as requested in Table 35.

Table 35 — Address types for IR

IR type	ToDs value	FromDs value	Addr 1 type	Addr 2 type	Addr 3 type	Addr 4 type	Description
Data	0	0	DA	SA	BSSID	n.a.	A data frame direct from one station to another station within the same Independent BSS, as well as all management and control type frames.
Data	0	1	DA	BSSID	SA	n.a.	Data frame destened for the distribution system.
Data	1	0	BSSID	SA	DA	n.a.	Data frame exiting the distribution system.
Data	1	1	RA	TA	DA	SA	Wireless distribution system frame being distributed from one access point to another access point.
SCAN request	n.a.	n.a.	SA	n.a.	n.a.	n.a.	
SCAN response	n.a.	n.a.	BSSID	DA	BSSID	n.a.	Addr 3 is used only in the event that the BSS provides an access point.
JOIN request	n.a.	n.a.	BSSID	n.a.	n.a.	n.a.	
JOIN response	n.a.	n.a.	BSSID / 0x000000	n.a.	n.a.	n.a.	Addr 1 equals 0x000000 in the event that the JOIN request is not accepted.
Association, re-association, dis-association, authentication, de-authentication	Usage of addresses as defined in ISO/IEC 8802-11:1999.						
NOTE DA: final destination address; RA: receiver address; SA: source address; TA: transmitter address; BSSID: BasicServiceSet ID.							

14.2.3.3 WLAN block

The relevant information to support ISO/IEC 8802-11:1999 is transmitted in an IR specific frame header as described in Table 36. The frame body carries the N-PDU and shall directly follow this header.

Table 36 — ISO/IEC 8802-11 compliance header for IR frames

Element	MC-FBS	MC-FBS attributes	frame control	Addr 1	Addr 2	Addr 3	Addr 4	frame Body (1. frag-ment)	MC-BLE or MC-PAE
Size in octets	1	2	1	6	6	6	6	0 … (Max packet size – overhead)	1
Contains	IR Cmd	IR Cmd attribute	IR data						IR Cmd
NOTE The overhead equals the size of the elements other than frame body fragments actually used.									

Table 37 — In the event of fragmentation used for second up to last frame

Description	MC-PAS	MC-PAS attributes	frame body (subse-quent fragment)	MC-BLE or MC-PAE	MC-BLE | MC-PAE
Size in octets	1	2	1 … (Max packet size – 4)	1	1 | 0
Contains	Command	Attribute	Data	Command	Attribute

14.2.4 MAC addresses

14.2.4.1 Basics

According to ISO/IEC 8802:1990, a MAC Address consists of 6 bytes. These 6 bytes are divided into two groups: vendor value or manufacturer ID and user value or station ID. Both consist of 3 bytes each. The first bit (LSB) of the LS Byte of the MAC Address is the I/G-Bit: It describes whether the MAC Address is an Individual (=0) or a Group Address (=1). The second bit is the U/L-Bit. It describes whether the MAC Address is a Universal Administered (=0) or a Local Address (=1). The individual, universal administered address is always the adapter MAC ID. It is not possible to change this physical address but it is possible to use a logical, individual, locally administered address.

14.2.4.2 MAC Addresses in CALM-IR

The real identity of a CALM medium adapter is the physical MAC address assigned to this adapter. In IR frames for CFAs, this unique MAC address is not used. Instead of the unique MAC address, only a two byte temporary ID applies in the link. The unique MAC address may be used only in WLAN compliant links.

In case of privacy on the medium, the private slave MAC address as used in the communication SAP is constructed as shown in Figure 18.

LS -Byte	Byte 1	Byte 2	Byte 3	Byte 4	MS -Byte
Vendor value			User value		
Individual, local			Slave qualifier	TempID	

Figure 18 — Slave MAC address

In case a vendor value is not known at the receiving station, it shall be set to 0x000002. The slave qualifier is detailed in Clause 13 (see Figure 16).

The private master MAC address as used in the communication SAP is constructed as shown in Figure 19.

LS -Byte	Byte 1	Byte 2	Byte 3	Byte 4	MS -Byte
Vendor value			User value = Master identifier MID		
Individual, local			Master qualifier	Identifier	

Figure 19 — Master MAC address

In case a vendor value is not known at the receiving station, it shall be set to 0x000002. The master qualifier is detailed in Clause 13 (see Figure 16).

The Broadcast MAC address as used in the communication SAP is constructed as shown in Figure 20.

LS -Byte	Byte 1	Byte 2	Byte 3	Byte 4	MS -Byte
Vendor value			User value		
0xFFFFFF			Master qualifier	TempID = 0xFFFF	

Figure 20 — Broadcast MAC address

In case a vendor value is not known at the receiving station, it shall be set to 0xFFFFFF. The master qualifier is detailed in Clause 13 (see Figure 16).

14.2.5 Fragmentation and defragmentation

CALM IR may use shorter frames than required for IPv6 (i.e. 1 280 byte). Thus, a fragmentation procedure performed at the MAC, which is invisible to the upper layers, shall be implemented. Independent of the actually used frame length, the IR-MAE shall report a frame length of at least 1 500 byte to the CALM management; larger values shall be allowed dependending on the actual implementation.

14.3 IR-MAE

The service access point towards the CALM management is defined in ISO 21217.

15 Adoption of other standards and internationally accepted practices

Within the various ITU regions, the family of CALM International Standards, including this International Standard, shall operate within local regulations and in the environment of, and to the parameters defined in, the ITU regulations and International Standards as presented in ISO 21217.

16 Marking and labelling

All transmitting equipment is to be clearly and permanently marked stating with which national regulations it complies.

All transmitting equipment is to be provided with clear instructions as to tuning and adjustment to meet the regulations of the country in which it is to be used.

All transmitting equipment is to be clearly and permanently marked to indicate which CALM interfaces it supports.

All transmitting equipment is to be clearly and permanently marked to instruct that it shall only be used when adjusted to meet national radio regulations pertaining to the frequencies at which it operates.

17 Declaration of patents and Intellectual Property

NOTE   This form is to be used to record the statement of a patent holder whose patented device or design (pending or approved) might have to be used by a person or organization complying with an International Standard.

Table 38 — Table of patents

Name of patent Holder:	Jurisdiction, patent number, and title
1. Inventors:	United States Patent
Martin Aureliano Hassner, Mountain View, CA (US)	6,195,025, Hassner, et al., February 27, 2001
Nyles Heise, San Jose, CA (US)	Methods and means for invertibly mapping binary sequences into rate 2/3 (1,k) run – length – limited coded sequences with maximum transition density constraints,
Walter Hirt, Wettswil (CH)	
Barry Marshall Trager, Yorktown Heights, NY (US)	
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Hirt; Walter (Wettswil, CH)

Assignee:

International Business Machines Corporation (Armonk, NY)

United States Patent

6,344,807, Hassner, et al., February 5, 2002

Packet frame generator for creating an encoded packet frame and method thereof

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EFKON AG

PCT/EP03/05425 – "IR-Framing"

23.05.2003

The invention relates to a method and device for optical data transmission, in particular a method for transmission of data by means of digitised infrared signals. Data sequences are transmitted using a time-division multiplex access protocol with communication frames comprising single sequential windows with a given minimal bit transmission rate. At least one control impulse sequence is provided in each communication frame. According to the invention, the control impulse sequence is transmitted at a bit transmission rate which is lower than the minimum bit transmission rate for the data sequence

87

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Annex A
(normative)

Coding and error correction of profiles 0 and 1 and of commands

A.1 General

All information bits are protected by error correction bits (EC_0, EC_1, EC_2, EC_3) using a modified Hamming code with the length L = 12 and the Hamming distance of min. D = 3. The modification is done in order to avoid an "all zero" pattern to for the benefit of the receiver.

During transmission, the data bits in the sequence D_0, D_1, D_2, D_3, D_4, D_5, D_6, D_7 are always transmitted first, followed by the error correction bits EC_0 to EC_3.

A.2 Coding

The coding of the correction bits is according to Formula (A.1):

$$\overline{EC_0} = D_0 \oplus D_1 \oplus D_2 \oplus D_3 \oplus D_4$$
$$\overline{EC_1} = D_0 \oplus D_2 \oplus D_4 \oplus D_5 \oplus D_6$$
$$\overline{EC_2} = D_1 \oplus D_2 \oplus D_5 \oplus D_7$$
$$\overline{EC_3} = D_3 \oplus D_4 \oplus D_6 \oplus D_7$$

(A.1)

A.3 Transmission

The coded bits are transmitted as follows (least significant bit first).

D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7	EC_0	EC_1	EC_2	EC_3

A.4 Reception and decoding

After reception, the following syndrome is calculated over the received bits R_0 to R_{11} as given in Formula (A.2). The defect bits are shown in Table A.1.

$$S_0 = R_0 \oplus R_1 \oplus R_2 \oplus R_3 \oplus R_4 \oplus R_8$$
$$S_1 = R_0 \oplus R_2 \oplus R_4 \oplus R_5 \oplus R_6 \oplus R_9$$
$$S_2 = R_1 \oplus R_2 \oplus R_5 \oplus R_7 \oplus R_{10}$$
$$S_3 = R_3 \oplus R_4 \oplus R_6 \oplus R_7 \oplus R_{11}$$

(A.2)

Table A.1 — Decoding table

S_0	S_1	S_2	S_3	Result
1	1	1	1	all bits correct
0	0	1	1	R0 defect
0	1	0	1	R1 defect
0	0	0	1	R2 defect
0	1	1	0	R3 defect
0	0	1	0	R4 defect

Table A.1 *(continued)*

S_0	S_1	S_2	S_3	Result
1	0	0	1	R5 defect
1	0	1	0	R6 defect
1	1	0	0	R7 defect
0	1	1	1	R8 defect
1	0	1	1	R9 defect
1	1	0	1	R10 defect
1	1	1	0	R11 defect
any other combination				multiple bit errors

Annex B
(normative)

Coding and modulation of profile 2 to profile 6

B.1   General

In the CALM IR communications profile 2 to profile 6, a special packet format based (CALM-fast IR packet format - FCIR) on the run length limited code (RLL) HHH(1,13) is used.

HHH(1,13) was especially developed for infrared transmission links in order to take care of the specific properties of the medium infrared and the components available for implementation.

HHH(1,13) has the following properties which make it especially useful for IR-links, as shown in Table B.1.

Table B.1 — HHH (1,13) Properties

Code rate:	2/3
Maximal duty cycle:	1/3 (approximately 33 %)
Average duty cycle	~26 %
Minimal duty cycle:	1/12 (~8,3 %)
Run length constraints:	(d,k) = (1,13)
Longest run of '10s:	yyy'000'101'010'101'000'yyy
Chip rate:	12 Mchips/s @ 8 Mbit/s;
	24 Mchips/s @ 16 Mbit/s;
	48 Mchips/s @ 32 Mbit/s;
	96 Mchips/s @ 64 Mbit/s;
	192 Mchips/s @ 128 Mbit/s.

B.2   FCIR packet

B.2.1   Packet format

The FCIR packet has the following format which ensures efficient and effective decoding, as well as proper synchronisation and error-detection.

Preamble (PA)	Start (STA)	Payload (PL)	CRC	Flush byte (FB)	Stop (STO)

B.2.2   Preamble

The preamble PA ensures proper bit synchronisation even if the FCIR packet follows a MAC command that ends with a zero.

It is constructed by concatenating 10 times the 24 chip preamble period (PP), where

PP = '100'010'010'001'001'001'000'100'

to form the 240 chip preamble

PA = 'PP'PP'PP'PP'PP'PP'PP'PP'PP'PP'

The left-most chip of PP and PA respectively shall be transmitted first.

B.2.3   Start flag

The start flag STA allows for packet synchronisation.

STA is the 48 chip sequence:

STA = '100'101'010'100'100'010'000'001'001'010'101'001'000'001'010'000'

The left most chip shall be transmitted first.

The start flag detector shall declare a flag as having been found when there is a perfect match. The flag contains a subsequence '1001010101001' that violates the HHH (1,13) code. This subsequence occurs twice in the start flag and never occurs within the main HHH code.

B.2.4   Payload

The payload PL is the CALM-IR packet which follows one of the MAC commands MC-BLS, Mc-CBS, MC-FBS, MC-SMC, MC-PAS, MC-TAck&, MC-TNAck&, MC-SR1, MC-SR2, MC-SR3, MC-SR4.

The CRC32 for the CALM-IR packet shall be calculated before the CALM-IR packet is scrambled.

B.2.5   CRC

The frame check sequence (FCS) field is a 32 bit field that contains a cyclic redundancy check (CRC) value according the IEEE 802 CRC32 algorithm.

For reference, the CRC32 polynomial is defined as given in Formula (B.1):

$$CRC_{(x)} = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1 \qquad (B.1)$$

The CRC is a calculated, payload data dependent field, calculated before HHH(1,13) encoding.

Payload data bytes are input to this calculation in LSB first format.

The 32 bit CRC register shall be preset to all "1's" prior to calculation of the CRC.

The CRC32 calculated result for each packet is treated as four data bytes and each byte is encoded in the same fashion as is payload data (e.g. it shall be appended to the CALM-IR packet before being scrambled and HHH(1,13) encoded).

B.2.6   Flush byte

The flush byte FB is required to enable complete decoding of the CRC field and denotes the end of the main body.

FB is the 8 bit sequence FB = '00'00'00'00'. It shall not be scrambled and shall be appended to the CRC before HHH(1,13) encoding.

B.2.7   Stop flag

The stop flag STO indicates the end of the FCIR packet.

STO is the 48 chip sequence:

STO = '001'001'010'101'001'000'100'000'100'101'010'100'100'000'100'000'

As does the start flag, the stop flag also contains a subsequence '1001010101001' that violates the HHH (1,13) code. This subsequence also occurs twice in the stop flag.

B.2.8 Scrambling and Descrambling

B.2.8.1 Effects and Limits

By enhancing the system with scrambling/descrambling functions during data transmission/reception, one achieves generally better duty cycle statistics in the HHH(1, 13) coded channel chip stream; the resulting duty cycle converges towards the average duty cycle of the code (≈26 %) for typical payload data. It is important to note that scrambling cannot entirely eliminate possible worst case duty cycle patterns in the transmitted signal stream that can result from certain specific input data sequences. However, scrambling can greatly reduce the probability of occurrence of such worst case patterns.

B.2.8.2 Scrambling and descrambling functions

The primitive polynomial given in Formula (B.2) shall be used for implementing these functions.

$$x^8 \oplus x^4 \oplus x^3 \oplus x^2 \oplus 1 \tag{B.2}$$

where

$\oplus$ indicates a modulo 2 addition or, equivalently, a logic exclusive OR (XOR) operation.

The operations of the scrambling and descrambling functions shall be performed according to the principles of frame synchronised scrambling/descrambling (FSS) mechanisms.

NOTE   FSS does not introduce memory into the signal path, i.e. FSS does not increase the encoding/decoding delay and it does not aggravate error propagation in the decoded data stream.

B.2.8.3 Scrambler/descramber initialisation

Transmit mode:

The scrambler's shift register shall be initialised with the all-1 state, that is $(x_8, x_7, x_6, x_5, x_4, x_3, x_2, x_1) = (1, 1, 1, 1, 1, 1, 1, 1)$.

Receive mode:

The descrambler's shift register shall be initialised with the all-1 state, that is $(x_8, x_7, x_6, x_5, x_4, x_3, x_2, x_1) = (1, 1, 1, 1, 1, 1, 1, 1)$.

B.2.9 HHH (1,13) encoding and decoding

B.2.9.1 State transition table

The encoding definition of the HHH (1,13) code is provided by a state transition table.

The state transition table would be typically implemented as a set of boolean logic equations and flip flops.

The particular HHH(1, 13) code construction require the following interpretation of the table entries with respect to the mapping of internal inputs and present state into next state and internal output, respectively:

— A specific data pair $D \equiv D^* = (\delta_1, \delta_2)$ arriving at the encoder input is first associated with a corresponding next state $N \equiv N^*$. This occurs as soon as the data D^* have advanced into the positions of the internal data bits $B^1 = (b_1, b_2)$ (i.e. when $(b_1, b_2, b_3, b_4, b_5, b_6) \equiv (\delta_1, \delta_2, x, x, x, x)$). In a second step, during the next encoding cycle, the state S takes on the value of N^*, i.e. $S \equiv S^* \leftarrow N^*$ so that S is now associated with (δ_1, δ_2). In the same cycle, the inner codeword $C \equiv C^*$ now carrying the information of D^* is computed. Thus, referring to Table B.2, a given internal input vector $(b_1, b_2, b_3, b_4, b_5, b_6)$ associates the bits (b_1, b_2) with the next state N and a given state S associates the data

pair ahead of (b_1, b_2) to the output C. In other words, the pair-wise values for N and C as listed in Table B.2 are not associated with the same input data pair.

— Encoder initialisation: The state S = (s_1, s_2, s_3) = (1, 0, 0) is also used as the initial state of the encoder, i.e. denoting with (α, β) the first pair of data bits to be encoded, the state S is forced to take on the value (1, 0, 0) when the bits (α, β) have advanced into the encoding circuits such that the internal inputs B^1 = (b_1, b_2) ≡ (α, β).

Table B.2 — HHH (1,3) encoding state transition table

Present state: S = (s_1, s_2, s_3)	Next state/internal output: N = (n_1, n_2, n_3)/C = (c_1, c_2, c_3)							
	Internal inputs: (b_1, b_2, b_3, b_4, b_5, b_6)							
	00xxxx	01xxxx	10xxxx	1100xx	1101xx	111011	1110(11)	1111xx
0 0 0	000/010	001/010	010/010	111/010	100/010	111/010	011/010	011/010
0 0 1	000/001	001/001	100/001	100/010	111/101	100/010	100/010	100/010
0 1 0	000/100	001/100	010/100	111/100	100/100	111/100	011/100	011/100
0 1 1	000/101	001/101	100/101	100/100	011/000	100/100	100/100	100/100
1 0 0	000/000	001/000	010/000	011/000	011/000	011/000	011/000	011/000
1 1 1	100/000	100/000	111/000	100/000	100/000	100/000	100/000	100/000

NOTE   The state (s_1, s_2, s_3) = (1, 0, 0) is the required initial state during the one encoding cycle where the internal input pair B^1 = (b_1, b_2) represents the first data pair to be encoded; 'x' signifies do not care.

B.2.9.2   HHH (1,13) encoding equations

The state transition table above can be implemented as a set of encoding formulae as below.

Define the following encoder signal vectors where increasing indexes mean increasing time in the equivalent serial signal streams:

Data input: $D = \left(d^1, d^2 \right)$

NOTE   First data input to be encoded: D ≡ (α, β)

Present state: S = (s_1, s_2, s_3)

Next state: N = (n_1, n_2, n_3)

Internal data: $B^1 = \left(B_1^1, B_2^1 \right) = \left(b_1, b_2 \right)$

$B^2 = \left(B_1^2, B_2^2 \right) = \left(b_3, b_4 \right)$

$B^3 = \left(B_1^3, B_2^3 \right) = \left(b_5, b_6 \right)$

Internal codeword: C = (c_1, c_2, c_3)

Encoder output: Y = (Y_1, Y_2, Y_3)

Initial conditions (startup): S = (s_1, s_2, s_3) = (1, 0, 0) when B^1 = (b_1, b_2) ≡ D = (α, β)

With the boolean operator notation,

$\overline{m} = \text{INVERSE}\left(m \right)$,

    M + n = m OR n,

mn = m AND n

the components of N and C are computed in terms of the components of S, B^1, B^2, and B^3 with the following boolean expressions:

$$n_1 = (s_3 s_3)(s_3 b_1)\left(\overline{s_1} b_1 b_2 \overline{b_3}\right)\left(\overline{s_1} b_1 b_2 \overline{b_4} b_5 b_6\right),$$

$$n_2 = \left(\overline{\overline{s_3} b_1}\right) + \left(s_1 s_2 b_1 \overline{b_2}\right),$$

$$n_3 = \left(\overline{\overline{s_3} b_2}\right) + \left(\overline{\overline{s_1} \overline{b_1}} b_2\right) + \left(s_1 s_2 b_1 \overline{b_2}\right),$$

$$c_1 = s_1 s_2,$$

$$c_2 = \overline{\overline{s_1}\,\overline{s_2}\,\overline{c_3}},$$

$$c_3 = \overline{\overline{s_1}} s_3 \left(\overline{b_1 b_2}\right) + \left(\overline{\overline{s_1}\,\overline{s_3}} b_1 b_2 \overline{b_3} b_4\right)$$

The vectors B^1, B^2, B^3, S, and Y are outputs of latches; in every encoding cycle, they are updated as follows:

$$B^1 \leftarrow B^2 \leftarrow B^3 \leftarrow D,$$

$$S \leftarrow N \text{ and } Y \leftarrow C$$

B.2.9.3   HHH (1,13) decoding equations

The decoding function of the HHH (1,13) is defined by the following formulae:

NOTE   Increasing indexes mean increasing time in the equivalent serial signal streams.

Received codeword: $R = (r^1, r^2, r^3)$

Internal codewords:

$$Y^4 = \left(y_{10}, y_{11}, y_{12} \right)$$
$$Y^3 = \left(y_7, y_8, y_9 \right)$$
$$Y^2 = \left(y_4, y_5, y_6 \right)$$
$$Y^1 = \left(y_1, y_2, y_3 \right)$$

Internal variables:

$$Z_B = \overline{y_4} + \overline{y_5} + \overline{y_6}$$
$$Z_C = \overline{y_7} + \overline{y_8} + \overline{y_9}$$
$$Z_D = \overline{y_{10}} + \overline{y_{11}} + \overline{y_{12}}$$
$$X^1 = \left(X_1^1, X_2^1 \right) = \left(x_1, x_2 \right)$$
$$X^2 = \left(X_1^2, X_2^2 \right) = \left(x_3, x_4 \right)$$
$$X^3 = \left(X_1^3, X_2^3 \right) = \left(x_5, x_6 \right)$$
$$W = \left(w_1, w_2 \right)$$
$$V = \left(v_1, v_2 \right)$$

Decoder output: $\qquad U = (u_1, u_2)$

Initial conditions (start-up): *None*

The components of X^1, X^2, and X^3 are computed with the following boolean expressions:

$$x_1 = v_1$$
$$x_2 = \left(y_6 \overline{Z_C} \right) + \left(\overline{Z_B} \, \overline{Z_C} \, \overline{Z_D} \right) + v_2$$
$$x_3 = \left(Z_B Z_C Z_D \right) + \left(\overline{Z_B} Z_C \right) + w_1 + w_2$$
$$x_4 = \left(Z_B Z_C \overline{Z_D} y_3 \right) \left[\overline{Z_B} Z_C \left(Z_D + y_6 \right) \right] + w_2$$
$$x_5 = y_{10}$$
$$x_6 = Z_B Z_C Z_D$$

The vectors Y^1, Y^2, Y^3, Y^4, U, V, and W are outputs of latches; in every decoding cycle, they are updated as follows:

$$Y^1 \leftarrow Y^2 \leftarrow Y^3 \leftarrow Y^4 \leftarrow R,$$

$$W \leftarrow X^3, V \leftarrow X^2, U \leftarrow X^1,$$

where U represents the decoded data bit pair.

NOTE   Both Z_B and Z_C can be directly obtained from delayed versions of Z_D: $Z_B \leftarrow Z_C \leftarrow Z_D$.

B.2.10 Fast packet processing summary

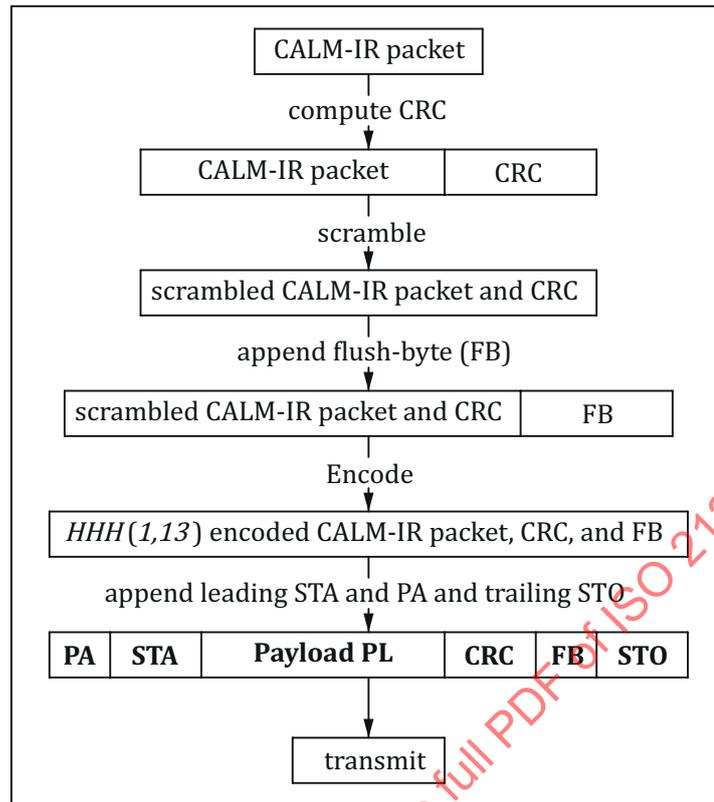The complete process how a Fast CALM-IR packet (FCIR-packet) is constructed is shown in <u>Figure B.1</u>.

```
                    ┌─────────────────────┐
                    │   CALM-IR packet    │
                    └─────────────────────┘
                              │ compute CRC
                              ▼
              ┌───────────────────────┬─────────┐
              │     CALM-IR packet    │   CRC   │
              └───────────────────────┴─────────┘
                              │ scramble
                              ▼
              ┌─────────────────────────────────┐
              │ scrambled CALM-IR packet and CRC │
              └─────────────────────────────────┘
                              │ append flush-byte (FB)
                              ▼
          ┌─────────────────────────────────┬────────┐
          │ scrambled CALM-IR packet and CRC │   FB   │
          └─────────────────────────────────┴────────┘
                              │ Encode
                              ▼
        ┌───────────────────────────────────────────────┐
        │ HHH(1,13) encoded CALM-IR packet, CRC, and FB  │
        └───────────────────────────────────────────────┘
                              │ append leading STA and PA and trailing STO
                              ▼
   ┌────┬─────┬──────────────┬──────┬────┬──────┐
   │ PA │ STA │  Payload PL  │ CRC  │ FB │ STO  │
   └────┴─────┴──────────────┴──────┴────┴──────┘
                              │
                              ▼
                    ┌─────────────────────┐
                    │      transmit       │
                    └─────────────────────┘
```

Figure B.1 — CALM-fast IR packet processing

Annex C
(informative)

Link power budget

C.1 General

The link power budget has to take into account both directions, master to slave and slave to master, considering a non-symmetrical link having transmitters with different power and receivers with different sensitivity at the ends of the link.

There are both economic and technical reasons to have non-symmetrical links. In general, OBUs should be economically priced as normally, many more OBUs are used than RSUs. That means, OBUs have transmitters with lower power than RSUs and, on the other hand, the receiver sensitivity of the RSUs shall be increased to achieve power balance in both directions.

In addition to this, OBUs are often battery powered and should therefore employ lower power transmitters.

C.2 Link power budget definitions

C.2.1 Link distance

The link distance "d" is the distance between the communication devices in m.

C.2.2 Transmission losses

All losses (L) are expressed in (dB): $L(dB) = 10\log\left(\dfrac{P_{in}}{P_{out}}\right)$.

Transmission losses (L_{TR}) consists of path loss and additional losses: $L_{TR} = L_P + L_{AD}$.

C.2.3 Path loss

The path loss (L_p) is the distance related loss, without any lossy media between transmitter and receiver: $L_p = 10 \cdot \log D^2$; D = d(m)/1(m)

Table C.1 — Path loss in relation to the distance

d (m)	10	20	50	100	200	500	1 000
L_P	100	400	2 500	10k	40k	250k	1M
L_P (dB)	20	26	34	40	46	54	60

C.2.4 Additional losses

$$L_{AD} = L_W + L_{WC} + L_{SUN}$$

Additional losses can be caused by the following.

— Windshield and sun protection (coating or foil) L_W

IR loss measurements on all kinds of windshields have been investigated from many independent institutions. All the so far measured windshields where evaluated to be below 7 dB (most in the range between 1,5…5,5 dB).

— Weather condition L_{WC} (rain, snow, and fog)

IR loss measurements under many weather conditions have been investigated from many independent institutions. The relevant results are given in Table C.2.

Table C.2 — IR loss under different weather conditions

	10 m	20 m	50 m	100 m	200 m	500 m	1 km
Clear weather	<1 dB	<1 dB	<1 dB	<1 dB	<1 dB	<1 dB	<1 dB
Light rain	<1 dB	<1 dB	<1 dB	<1 dB	<1 dB	1 dB	2 dB
Heavy rain	<1 dB	<1 dB	<1 dB	1,5 dB	3 dB	7,5 dB	15 dB
Fog	<1 dB	<1 dB	4 dB	8 dB	16 dB	40 dB	80 dB
Dense fog	<1 dB	1,6 dB	8 dB	16 dB	32 dB	80 dB	160 dB

— Sunlight inducted loss (L_{SUN})

Sunlight induced losses can, by proper receiver design, be kept below 2 dB, even against full sunlight.

The additional losses (especially the weather conditions) shall be considered in view to several realistic scenarios.

— Heavy rain and fog do not occur simultaneously.

— Full sun does not occur with bad weather.

— Sun protected windscreens ("coated windscreens") also reduce the sun induced losses.

C.2.5 Symmetrical and non-symmetrical links

The physical layer of an infrared CALM link may either be "symmetrical" or "non-symmetrical", the choice of which is chosen according the application requirements.

In a "symmetrical link", the transmitter power parameters, as well as the receiver sensitivity parameters of both communications partners, are equal, whereas in "non-symmetrical" links, those parameters differ.

In order to support a proper selection for a given application, respectively a class of applications the relevant transmitter, and receiver, parameters are organized in "transceiver classes".

C.2.6 Transmitter/receiver combinations

Table C.3 gives the achievable distances (without considering "additional losses") in free space.

Table C.3 — Combinations of RX and TX classes

RX class TX class	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
T1	1,25 m	1,75 m	2,5 m	3,5 m	5 m	7 m	10 m	14 m	20 m	28 m	40 m
T2	1,75 m	2,5 m	3,5 m	5 m	7 m	10 m	14 m	20 m	28 m	40 m	56 m
T3	2,5 m	3,5 m	5 m	7 m	10 m	14 m	20 m	28 m	40 m	56 m	80 m
T4	3,5 m	5 m	7 m	10 m	14 m	20 m	28 m	40 m	56 m	80 m	110 m
T5	5 m	7 m	10 m	14 m	20 m	28 m	40 m	56 m	80 m	110 m	160 m
T6	7 m	10 m	14 m	20 m	28 m	40 m	56 m	80 m	110 m	160 m	250 m
T7	10 m	14 m	20 m	28 m	40 m	56 m	80 m	110 m	160 m	250 m	350 m
T8	14 m	20 m	28 m	40 m	56 m	80 m	110 m	160 m	250 m	350 m	500 m
T9	20 m	28 m	40 m	56 m	80 m	110 m	160 m	250 m	350 m	500 m	700 m
T10	28 m	40 m	56 m	80 m	110 m	160 m	250 m	350 m	500 m	700 m	1 000 m
T11	40 m	56 m	80 m	110 m	160 m	250 m	350 m	500 m	700 m	1 000 m	1 km+
T12	56 m	80 m	110 m	160 m	250 m	350 m	500 m	700 m	1 000 m	1 km+	1 km+
T13	80 m	110 m	160 m	250 m	350 m	500 m	700 m	1 000 m	1 km+	1 km+	1 km+
T14	110 m	160 m	250 m	350 m	500 m	700 m	1 000 m	1 km+	1 km+	1 km+	1 km+
T15	160 m	250 m	350 m	500 m	700 m	1 000 m	1 km+	1 km+	1 km+	1 km+	1 km+
T16	250 m	350 m	500 m	700 m	1 000 m	1 km+	1 km+	1 km+	1 km+	1 km+	1 km+

NOTE   As the sensitivity is related to the noise floor and the noise floor depends on the square root of the receiver bandwidth, all tables are based on a specific data rate. Changing the data rate will influence the receiver sensitivity.

C.2.7   Transmission margin

The transmission margin is the margin for all additional losses L_{AD} in (dB).

C.2.8   Receiver dynamic range

The receiver dynamic range R_D is the maximum irradiance profile in relation to the minimum irradiance, calculated by $R_D = 10 \log \dfrac{E_{Rmax}}{E_{Rmin}} [dB]$, the receiver shall be able to handle (E_{R_max} = maximum irradiance, E_{R_min} = minimum irradiance).

C.2.9   Link power budget calculation examples

Example 1

We assume a given OBU with an

OBU receiver irradiance minimum sensitivity: $E_{R\_min\_OBU} =$ 8 mW/m²

OBU transmitter radiant minimum intensity: $I_{e\_min\_OBU} =$ 6 W/sr

and want to calculate the minimum RSU parameters "Transmitter radiant minimum intensity" and "receiver irradiance minimum sensitivity".

<u>Other given values are:</u>

Link distance $\qquad$ d = 20 m

Additional losses

Windshield with sun protection coating $\qquad$ L_W = 7 dB (max)
Weather condition (rain, snow and fog) $\qquad$ L_{WC} = 4 dB (max)
Sunlight inducted noise $\qquad$ L_{SUN} = 2 dB

<u>Calculated loss values:</u> (from above)

Path loss: $\qquad$ L_P = 26 dB

Additional losses: $\qquad$ L_{AD} = 13 dB

Total transmission losses: $\qquad$ L_{TR} = 39 dB

<u>Calculation of the minimum irradiance profile at the RSU receiver (E_{R_min}):</u>

$$E_{e\_RSU} = I_{e,\min\_OBU} \cdot 10^{\frac{L_{TR}}{10}} = \frac{6}{10^{\frac{39}{10}}} \rightarrow E_{e,\min\_RSU} = 0{,}75\,mW/m^2$$

<u>Calculation of the radiant minimum intensity of the RSU transmitter (E_{R_min}):</u>

It is the way back:

$$I_{e\_RSU} = E_{e,\min\_OBU} \cdot 10^{\frac{L_{TR}}{10}} = 0{,}008 \cdot 10^{\frac{39}{10}} \rightarrow I_{e,\min\_RSU} = 63{,}5\,mW/sr$$

Example 2

Now that we have selected all transmitter and receiver classes we want to calculate, the maximum distance the OBU-RSU pair can span.

This maximum distance is the lower value of the distance OBU → RSU and RSU → OBU and calculates as follows:

a) Direction OBU → RSU

OBU radiant intensity: 6 W/sr

RSU receiver sensitivity: 0,5 mW/m²

b) Direction RSU → OBU

RSU Radiant intensity: 100 W/sr

OBU receiver sensitivity: 8 mW/m²
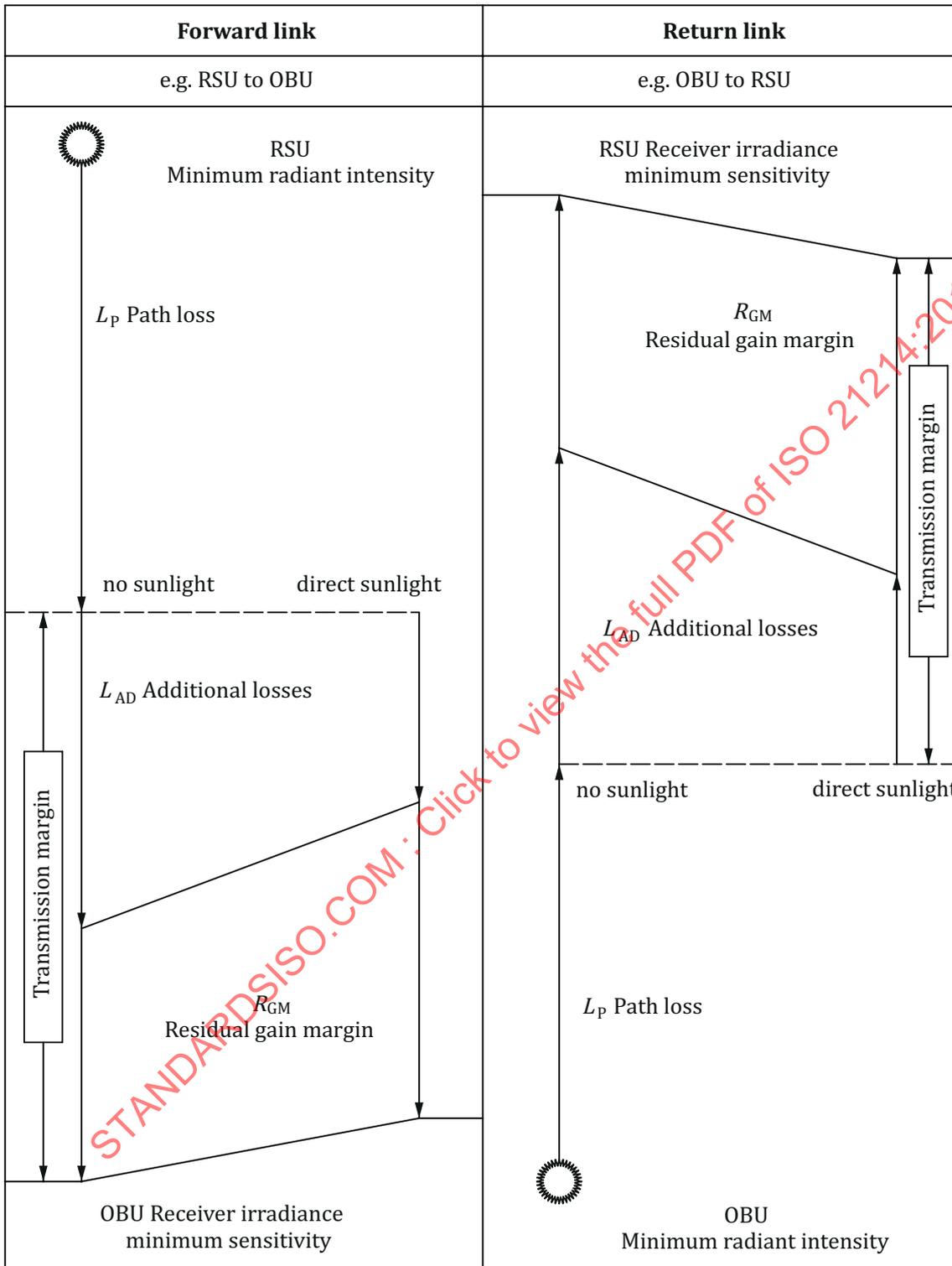
C.2.10 Link power budget scheme

Figure C.1 — Link power budget scheme

Annex D
(informative)

Link directivity considerations

D.1   General

For a directional communication with CALM devices, a three dimensional coordinate system (x_{CALM}, y_{CALM}, 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 is defined as main direction.

Figure D.1 show the azimuth angle "φ" and the elevation angle "δ" of the beam axis "D" (bore-sight direction) in relation of the main direction.

Further parameters of directivity are the horizontal opening angle, Θ_H, and the vertical opening angle, Θ_V, which are specified in relation of the beam axis "D" (see Figure D.1).

D.2   Multi beam antenna example

Figure D.1 shows an example of a multi beam antenna and the related control parameters.

The direction control parameters in this scenario are defined as follows.

— $D_1 = (\varphi_1, \delta_1, \Theta_{H1}, \Theta_{V1})$

— $D_2 = (\varphi_2, \delta_2, \Theta_{H2}, \Theta_{V3})$

— $D_3 = (\varphi_3, \delta_3, \Theta_{H3}, \Theta_{V3})$
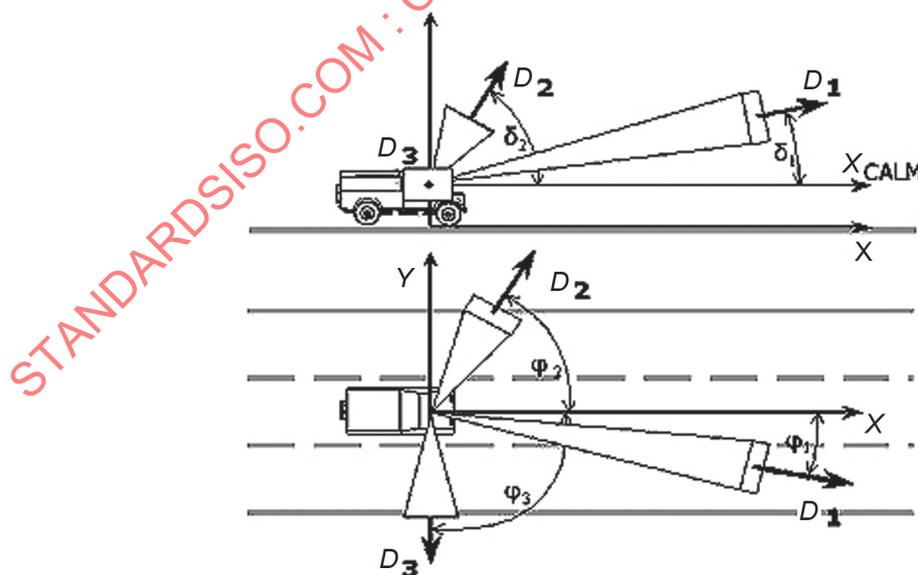

Figure D.1 — Example of multi beam antenna

D.3 Communication zones shortcut illustration

Figure D.2 and Figure D.3 show the communication zones in the side and ground view, respectively. The zone names used are the shortcuts as defined in Table 10 and Table 11.
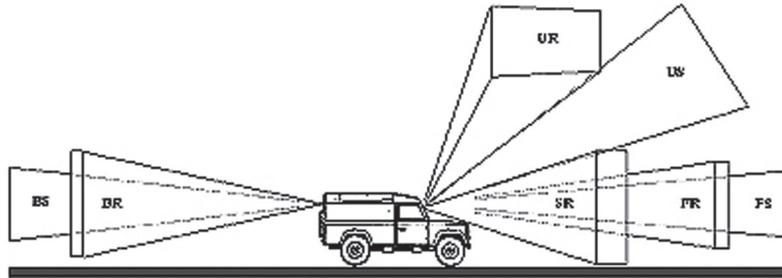

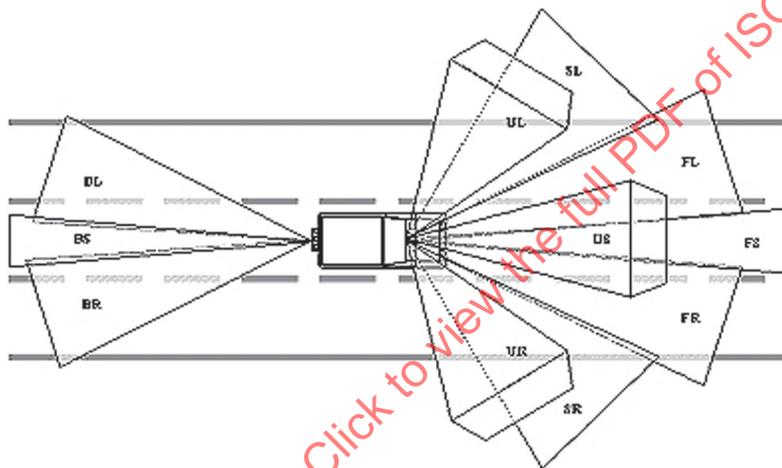**Figure D.2 — Example of side view of communication zones**

Figure D.3 — Example of ground view of communication zones

Annex E
(informative)

Compatibility of CALM and non-CALM infrared systems

E.1 General

There exist a number of non-CALM IR systems within the global ITS environments, some of them close to CALM IR while some are completely proprietary.

Examples are the IRVD in Japan, the Malaysian road tolling system, and the truck tolling system in Germany.

When defining the CALM IR International Standard, it was one of the essential requirements that those systems shall at least be able to co-exist with CALM IR without harmful mutual interference even if using the same optical band in overlapping communication zones and that, under certain conditions, a migration path from those systems towards a full CALM IR system is feasible.

E.2 Co-existence

E.2.1 Creating free airtime for non-CALM IR users

In order to enable adequate co-existence for non-CALM IR systems residing in the same or overlapping communication zone, any CALM IR master (either residing on the roadside or in a vehicle) grants free airtime to all non-CALM IR equipment coming along as follows.

— The CALM IR master does not use every CALM IR window for CALM IR communications but leaves a certain window "empty" in order to enable to use this airtime by other systems without any interference with CALM IR.

— In order to signal to the active CALM-IR slaves that a window shall not be used for CALM IR communications, the CALM IR master includes a "compatibility window" in the FOT.

— The compatibility window remains unused by CALM-IR units, the airtime may be used by non-CALM IR systems provided that there exists a synchronisation mechanism between CALM IR and non-CALM IR systems. Possible synchronisation methods are described in E.2.2.

— When the compatibility window has terminated (marked by the W-Sync issued by the CALM-IR master at its end), all control automatically falls back to the CALM IR master.

E.2.2 Synchronisation of CALM-IR and non-CALM IR systems

E.2.2.1 Synchronisation principle

The two key issues when synchronisation between CALM-IR and non-CALM IR systems shall be achieved are as follows.

— The non-CALM IR system shall be able to recognise that a CALM-IR master has created "free airtime" for "non-CALM" use.

This function can be performed either "by wire" (in case both masters are fixedly installed and co-located) or "via air", either by using a synchronisation signal to be emitted by the CALM-IR master or implicitly, if the non-CALM-master can interpret the CALM-IR frame.

— The specific non-CALM IR system should be able to recognize that the "free airtime" is dedicated to it.

This step can be performed by a specific synchronisation signal, reserved for the specific "non-CALM" system, emitted by either of the following:

— master of the "non-CALM" system (in case step 1 had been performed "by wire");

— master of the CALM IR system after the W-Sync marking the compatibility window.

E.2.2.2   Creation of Sufficient air time for non-CALM-IR systems

It is evident that the compatibility window uses air time of the frame.

If even the longest allowed frame is occupied by too many private windows so not sufficient air time can be granted to the non-CALM IR system, the CALM master may suspend some or all CALM IR slaves in order to be able to allocate a sufficiently long compatibility window.

Of course, this shall not be done in each consecutive frame (this would disable all CALM-IR communications) but with a repetition rate adequate to the overall system requirements.

To suspend the slaves, the MAC commands MC-SUS or MC-SUA may be used.

E.2.2.3   Reserved synchronisation pattern

At the time of developing this International Standard, the following four non-CALM infrared systems which may co-reside with CALM IR in the ITS domain are known:

— Japanese IRVD system;

— German truck tolling system;

— Malaysian road tolling system;

— IrDA interfaces.

The subsequent patterns have been selected after a careful study of the above listed systems, as shown in Table E.1.

Table E.1 — Reserved ID patterns for non-CALM IR systems

System	Frequency	Cycles
Japanese IRVD system	Not applicable as no overlapping of beacon communication zones (according to paragraph f)	
German truck tolling system	85 kHz	4
Malaysian road tolling system	85 kHz	4
IrDA interfaces	tbd	tbd

E.2.2.4   Limitations and restrictions

In order to avoid any harmful mutual interference between co-residing CALM IR and non-CALM IR systems, the following conditions shall be fulfilled:

a)   non-CALM system shall not use any signal or code which could be misinterpreted as CALM IR F-Sync or W-Sync;

b)   non-CALM system shall not respond to a CALM IR F-Sync or W-Sync;

c) frame of the non-CALM IR system shall not be longer than 64 ms in order to fit in the longest possible free airtime a CALM IR system can grant;

d) CALM-IR system shall grant, as a minimum, a free airtime long enough for the maximum frame of the non-CALM system as long as condition c) is met;

e) non-CALM IR masters installed in vehicles shall recognize the synchronisation pattern assigned to their system and shall consider the following airtime as assigned to the non-CALM system;

f) to allow IRVD and CALM-IR to exist together, it is absolutely necessary that they be installed so that their beacon communications areas might not overlap one another, regardless of a) to e).