INTERNATIONAL STANDARD

ISO 21214

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Intelligent transport systems — Continuous air interface, long and medium range (CALM) — Infra-red systems

Systèmes intelligents de transport — Interface d'air continue, gamme longue et moyenne (CALM) — Systèmes à infrarouges

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Dedication

Exceptionally this International Standard is dedicated to the late Dipl. Ing. Helmut Strasser in grateful recognition of his leadership as the editor and project leader of ISO 21214, and for his commitment and services over more than a decade to meet the challenges of international standardization in the rapidly changing arena of ITS technology.

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 21214 was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Introduction

This International Standard is part of a family of International Standards for CALM (continuous air interface, long and medium range) which determine a common architecture, network protocols and air-interface definitions for wireless communications using cellular second generation, cellular third generation, 5 GHz, millimetre, and infra-red communications. Other air interfaces may be added at a later date. These air interfaces are designed to provide parameters and protocols for broadcast, point/point, vehicle/vehicle, and vehicle/point communications in the ITS sector.

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

The fast movement of information across the longer distances using wireless technology is functionally very different from the requirements definition for dedicated short range communication (DSRC). High volumes of data are required for purposes such as traffic information and management, video downloads to vehicles for tourist information and entertainment and navigation system updates, etc.

In order to support such services, transmitters need to be able to operate over long or medium range, and to be able to hand over a session from one transmitter to another.

These International Standards are designed to enable quasi-continuous communications, or communications of protracted duration, between vehicles and service providers, or between vehicles. As such they are complementary to dedicated short range, single point, technologies standardised in various regions of the world.

The CALM concept supports multiple bearer types (such as cellular, microwave, infra-red), where an option is proposed to offer user selection of preferred media, and to enable resumption of session interruptions (whether to change bearer media, service provider, or because of signal interruption or interference).

Some applications will have the requirement that communication sessions set up in a first communication zone may be continued in following communication zones; therefore “handover mechanisms” are included. Handover mechanisms need to be defined at two levels:

— Firstly, handover mechanisms within the same technology and service provider. These handover mechanisms are defined within the frequency-specific CALM International Standards.

— Secondly, handover mechanisms at the application level, for use where either the technology or the service provider changes. These handover mechanisms will be defined within the CALM architecture International Standard (ISO 21217), within the CALM networking protocols International Standard (ISO 21210) and within the CALM lower layer SAP International Standard (ISO 21218).

Applications include the update of roadside telemetry and messaging, internet, image and video transfer, infotainment, traffic management, monitoring and enforcement in mobile situations, route guidance, car-to-car safety messaging, maintenance management, and “yellow page” services. For medium- and long-range high-speed roadside/vehicle transactions such as on-board web access, broadcast and subscription services, entertainment, yellow page and booking transactions, etc., the functional characteristics of such systems require contact over significantly longer distance than is feasible or desirable for DSRC, and often for significantly longer connection periods – in some circumstances, continuous communication.

Intelligent transport systems — Continuous air interface, long and medium range (CALM) — Infra-red systems

1 Scope

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

It provides protocols and parameters for medium-range, medium- to high-speed wireless communications in the ITS sector using infra-red systems.

Such links are required for quasi-continuous, prolonged or short communications

- between vehicles and the roadside,
- between vehicles, and
- 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 use made 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 dedicated short range communication (DSRC).

The International Standard:

- supports data rates of 1 Mbit/s up to 128 Mbit/s (it may support higher data rates);
- supports vehicle speeds up to a minimum of 200 km/h (closing speeds could be double this value);
- defines or references environmental parameters relevant to link operation;
- supports communication distances up to 100 m (it may 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;
- 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 8802-11, *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 60050-845, *International Electrotechnical Vocabulary. Lighting*

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 following terms and definitions apply.

4.1 General

4.1.1
broadcast window
BcW
window used to broadcast information to slaves, even to those which have not yet performed the "registration process"

4.1.2
chip
smallest information unit communicated over the link

NOTE Depending on the chosen coding, one information bit may be represented by one or more consecutive chips.

4.1.3
communication 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
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
default communications profile
communications profile used unless 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
communication flow from master to slave

EXAMPLES forward link, forward window

4.1.10
frame length indicator
Flen
indicator is used to calculate the frame length from the last “slot index”

4.1.11
frame organisation table
FOT
table which carries all organisation data of the TDMA frame

4.1.12
free airtime indicator
FATI
indicator which signals that “free airtime” follows the current frame

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

4.1.13
guard time
T_G
time period preceding a “command alert” (*CA*) in certain cases in order to allow the automatic gain control of the receivers to resettle

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, which carries all organisation information for the current frame

4.1.16
master identifier
MID
code which uniquely identifies a CALM-IR master

4.1.17
multicast window
McW
window used for communication from master to multiple slaves, forward direction only

4.1.18
private window
window which carries the information exchange between a master and a specific slave

4.1.19
registration phase
phase during which a master identifies devices newly entering its communication zone

4.1.20
slave
device that is under the control of another device

4.1.21
spare window
SpW
window, not allocated to a slave, which reserves airtime for any slaves 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
index used to count time slots

4.1.23
TDMA frame
time (division multiple access) 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
identifier used for addressing the slave device while it resides in the communication environment of the master

NOTE 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 which 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 which may consist of one or multiple time slots

4.2 Optical parmeters

4.2.1
radiant power
radiant flux
Φ_e
power emitted, transmitted or received in the form of radiation

NOTE 1 The unit is the watt (W).

NOTE 2 Adapted from IEC 60050 (845-01-24).

4.2.2
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 Unit: W/sr (watts per steradian).

NOTE 2 Adapted from IEC 60050 (845-01-30).

4.2.3
irradiance
E_e
quotient of the radiant flux $d\Phi_e$ incident on an element of a surface containing a given point divided by the area dA of that element

NOTE 1 Unit: W/m^2.

NOTE 2 Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the 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 $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point.

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

NOTE 3 Adapted from IEC 60050 (845-01-37).

4.2.4
radiant exitance
M_e
quotient of the radiant flux $d\Phi_e$ leaving an element of a surface containing a given point divided by the area dA of that element

NOTE 1 Unit: W/m^2.

NOTE 2 Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the expression, 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 $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point.

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

NOTE 3 Adapted from IEC 60050 (845-01-47).

4.2.5
radiance
L_e
quantity (in a given direction, at a given point of a real or imaginary surface) (L_e; L) defined by the 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 Unit: W/sr.m^2.

NOTE 2 Adapted from IEC 60050 (845-01-34).

4.2.6
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 divided by the element of solid angle

NOTE Adapted from IEC 60050 (845-01-30).

4.2.7
steradian
sr
dimensionless SI unit of solid angle

NOTE 1 The steradian is the solid angle of a cone which, having its vertex in the centre of a sphere, cuts off on the surface of the sphere an area equal to that of a square with sides of length equal to the radius of the sphere. [ISO 31-1:1992, 1-2.a]

NOTE 2 Usually the abbreviation “sr” is appended, although mathematically this is 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.

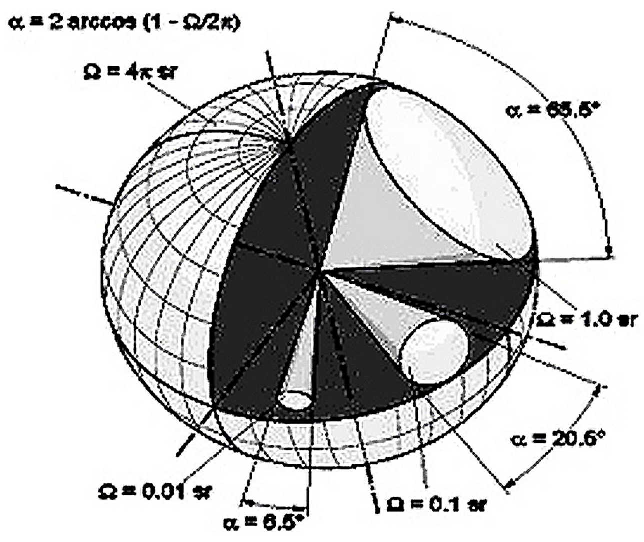

Figure 1 — Solid angle

Relation between distance r, irradiance E_e and intensity I_e

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

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

NOTE 3 Adapted from IEC 60050 (845-01-20).

4.2.8
luminous flux
Φ_v
quantity derived from radiant flux Φ_e by evaluating the radiation according to its action upon the CIE standard photometric observer, for photopic vision

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

where

$$\frac{d\Phi_e(\lambda)}{d\lambda}$$

is the spectral distribution of the radiant flux and $V(\lambda)$ is the spectral luminous efficiency

NOTE 1 For the values K_m (photopic vision) and K'_m (scotopic vision), see IEC 60050 (845-01-56).

NOTE 2 Adapted from IEC 60050 (845-01-25).

4.2.9
luminous efficacy of radiation
K
quotient of the luminous flux Φ_v divided by the corresponding radiant flux Φ_e

$$K = \frac{\Phi_v}{\Phi_e}$$

NOTE 1 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 $\nu_m = 540 \times 10^{12}$ Hz ($\lambda_m \approx 555$ nm) for photopic vision.

K'_m = 1700 lm.W^{-1} for $\lambda'_m \approx 507$ nm for scotopic vision.

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

NOTE 2 Adapted from IEC 60050 (845-01-55).

5 Symbols and abbreviated terms

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

BcW	broadcast window
CALM	continuous air interface, long and medium range
CFA	CALM-fast application
CME	CALM management entity
CmpW	compatibility window
CRC	cyclic redundancy check
D	beam axis, “bore-sight direction”
DAB	digital audio broadcasting
DDB	digital data broadcasting
DVB	digital video broadcasting
DSRC	dedicated short range communication
E_{e}	irradiance
E_{v}	illuminance
FATI	free airtime indicator
FB	flush byte
FCIR	fast-CALM infra-red packet format
FM	frequency modulation
IPv6	internet protocol version 6
MID	frame length indicator
FOT	frame organisation table
F-Sync	frame synchronisation signal
HHH	Hirt, Hassner, Heise (inventors of the *HHH(1,13)* code)
I_{e}	radiant intensity
IR-CAL	infra-red communication adaptation layer
IR-MAE	infra-red management adaptation entity
IR-ME	infra-red management entity
K	luminous efficacy of radiation
L_{e}	radiance
LLC	logical link control
MAC	medium access control (sometimes used as a synonym for MAC layer)
McW	multicast window
M_{e}	radiant exitance
MID	master identifier
MnW	management window
N_{frame}	number of time slots in a CALM-IR frame
$N_{\mathrm{frame,max}}$	maximum number of time slots in a CALM-IR frame
$N_{\mathrm{frame,min}}$	minimum number of timeslots in a CALM-IR frame
OBU	on-board unit

PA	preamble
PL	payload
PP	preamble period
PDU	protocol data unit
PrW	private window
RLL	run length limited code
RSU	roadside unit
SAP	service access point
SpW	spare window
sr	steradian
STA	start flag
STO	stop flag
T_{bit}	bit time (duration of one bit)
T_{chip}	chip time (duration of one chip)
T_{CWAIT}	waiting time of the slave for a reply to a proposed *TempID*
TDMA	time division multiple access
T_{DREG}	registration time-out
TempID	temporary ID
TETRA	trans-European trunked radio access (an ETSI standard for trunked radio networks)
$T_{F\text{-}Sync}$	duration of the *F-Sync* signal
T_{G}	guard time
T_{L}	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.
T_{Pfall}	optical pulse fall time
T_{Pon}	optical pulse on time
T_{Prise}	optical pulse rise time
T_{REG}	delay time before slave replies to a *MC-RRQ* or *MC-REN*
T_{RT}	waiting time of the master for a reply to its *MC-IDP*
T_{RW}	receiver window – time span around the allocated time slot when the receiver circuit shall be ready to detect a *W-Sync* signal
T_{RWAIT}	waiting time of the master for a reply to a *MC-RRQ* or *MC-REN*
T_{TempID}	*TempID* time-out.
W-ATM	wireless asynchronous transfer mode
W-Sync	window synchronisation pattern
WuW	wake-up window
Δ	elevation angle
Θ_{H}	horizontal opening angle
Θ_{V}	vertical opening angle
φ	azimuth angle
Φ_{e}	radiant power, radiant flux
Φ_{v}	luminous power or luminous flux

6 Requirements: transmitter and receiver parameters

6.1 Transmitter wavelengths and bandwidths

Table 1 — Infra-red 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 Regarding 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 — Infra-red 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 may have limitations on this parameter.

6.2.2 Transmitter classes

The transmitter class shall be declared in the associated product specification and shall be organised as shown in Table 3.

Table 3 — Transmitter classes

Parameter	TX class															
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16
TX4a - Minimum radiant intensity [W/sr] (pulse peak value)	0,36	0,75	1,5	3	6	12	25	50	100	200	400	800	1600	3200	6400	12800

6.3 Receiver wavelengths and bandwidths

Table 4 — IR receiver parameter specification

Parameter name		Specification	
		Channel 870 (main channel) mandatory	Channel 970 (alternate channel) optional
RX1	Nominal receiver wavelength	870 nm	970 nm
RX2	Receiver pass band	835 nm to 905 nm[a]	935 nm to 1 005 nm
RX4a	Lower receiver stop band	⩽ 805 nm	905 nm
RX4b	Upper receiver stop band	⩾ 935 nm[b]	⩾ 1 035 nm
RX5a	Receiver sensitivity in lower stop band	not specified	⩾ 10 dB above *RX6*
RX5b	Receiver sensitivity in upper stop band	⩾ 10 dB above *RX6*[c]	not specified

a Receivers which are able to receive both channels employ an upper limit of 1 005 nm.

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

c Not specified for receivers which are able to receive both channels.

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

6.4 Receiver class

The receiver class shall be declared in the associated product specification and shall be organised as follows:

Table 5 — Receiver classes

Parameter	**RX class**										
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
RX6 [mW/m^2] Receiver sensitivity in boresight @ *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	$\leqslant$ 12
RX8 Reference bit error ratio (B.E.R.)	10^{-6}										
RX9 Immunity to interference caused by natural optical radiation	$\geqslant$ 1 120 W/m^2 (sunlight spectral distribution)										
RX10 [mW/m^2] Wake-up sensitivity in boresight @ 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 Generic modulation parameters

7.1.1 Wake-up signal

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 wake-up any “sleeping” slaves. The wake-up signal is to be transmitted in a “wake-up window”.

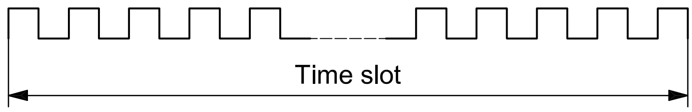

Figure 2 — Wake-up signal

Table 6 — Wake-up signal timing specification

Parameter name		Specification
TX11	Wake-up signal	Burst frequency: 500 kHz ± 1 %, duty cycle: 45 % to 55 %
TX12a	Max. allowed pulse rise time (optical)	200 ns
TX12b	Max. allowed pulse fall time (optical)	200 ns

7.1.2 Transmitter generic modulation parameters

Table 7 — Infra-red transmitter parameter TX10 specification

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

7.1.3 Receiver generic modulation parameters

Table 8 — Infra-red 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 in dependence of the application and of the actual link quality.

Specific data rates and coding schemes constitute a “communications profile”.

The profiles given in Table 9 apply.

Table 9 — Communications profiles

Parameter	Profile						
	0 (base profile)	1 (default profile)	2	3	4	5	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
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[a], T_{Prise}	⩽ 75	⩽ 75	⩽ 38 ns	⩽ 19 ns	⩽ 9 ns	to be added	to be added
Optical pulse fall time[a], T_{Pfall}	⩽ 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 $L = 12$, $D = 3$ [b]		none [b]				
Multiple error detection	Hamming $L = 12$, $D = 3$ [b]		CRC32				
NOTE Some of the parameters of profile 5 and profile 6 will be defined in future versions of this International Standard.							
[a] Equipment employing several communications profiles shall conform with the most stringent values, irrelevant which profile is active at a given time. [b] For details see Annex B.							

Further profiles may be added in the future.

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

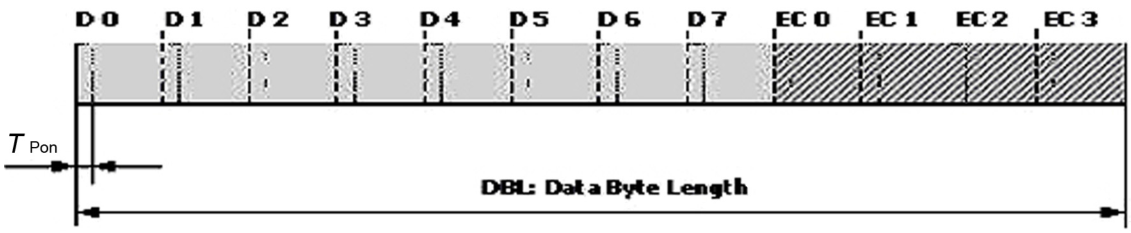

Figure 3 — Modulation of profiles 0 and 1

The coding and decoding rules for the communications profiles 0 and 1 are defined in Annex A.

7.4 Profiles 2 to 6

Profiles 2 to 6 do not employ forward error correction.

NOTE Burst errors at these dataspeeds are much more likely than single bit errors.

Burst errors are detected by the CRC.

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

8 Directivity and communication zones

8.1 Directivity parameters

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

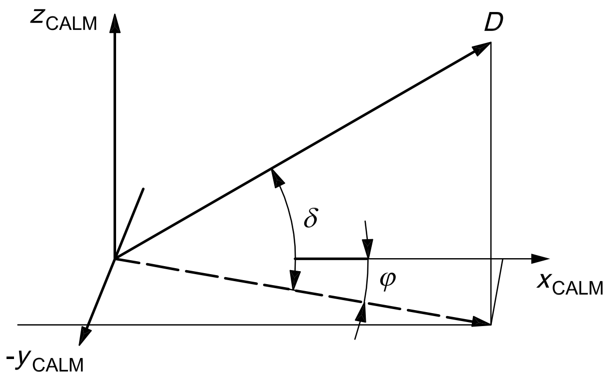

Figure 4 — Azimuth and elevation angle of the beam axis

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

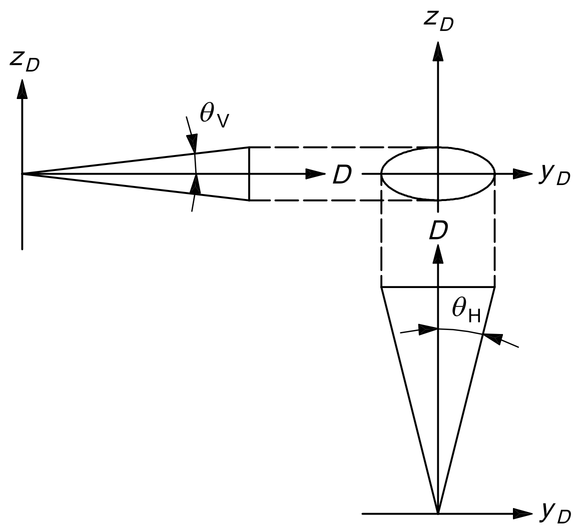

Figure 5 — Horizontal opening and vertical opening angles

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 degrees to 360 degrees.

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 as a beam (in arbitrary direction) with the minimum possible horizontal and vertical opening angles equal to the resolution Θ_{basic} = 1,5°.

8.2.2 Communication zone construction

8.2.2.1 A CALM-IR communication zone with any “footprint” on the sphere “illuminated” by the “antenna array” may 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 may 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 any 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 Tables 2, 3, 4 and 5 apply.

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

NOTE 2 Alternatively any communication zone may be associated with a different “communications channel”, thus carrying different communications streams, independent of each other (dynamically controllable).

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

8.2.3 Communication zone shortcuts

Shortcuts to speed up the direction control for predefined communication zones are defined in Tables 10 and 11.

Table 10 — Transmitter communication zones shortcuts

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

Table 11 — Receiver communication zones shortcuts

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

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

9 Frames and windows

9.1 General structure

Clause 9 defines the CALM-IR framing, the window structure and window management.

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

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

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

Direct “slave to slave” communications require that one of the slaves act as a temporary master.

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

The framing structure is defined by reserved signals which by definition can never 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 sub-clauses.

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 airtime” is used, with a *W-Sync* signal and the MAC command “free airtime” (*MC-FAT*).

— A frame is subdivided into time slots of duration T_{S}.

— The maximum length of the frame is $N_{\text{frame,max}}$ time slots, the minimum length is $N_{\text{frame,min}}$.

— 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*.

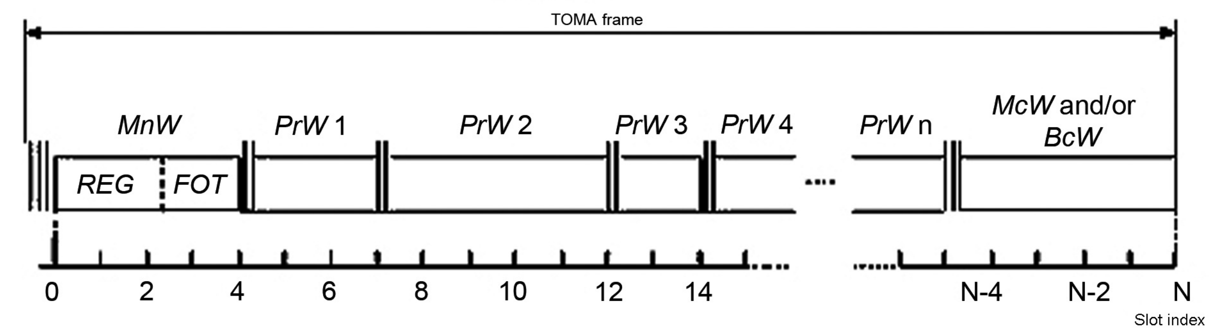

Figure 6 — An example CALM-IR frame structure

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 pattern shown in Figure 6.

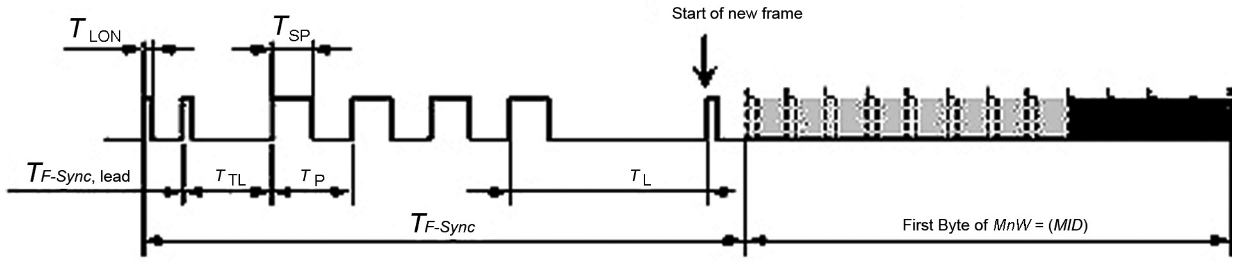

Figure 7 — Frame synchronisation signal (*F-Sync*)

All active slaves not in a "transmit state" shall be ready to recognise an *F-Sync* at all times as an *F-Sync* can also interrupt frames in progress, for example to prioritise emergency messages.

An *F-Sync* shall never be sent directly after a "receive state" of the master. In such a case, a guard interval of duration T_G shall be inserted before the sending of *F-Sync* in order to allow the receiver circuitry of all slaves to resettle.

9.3 Windows

9.3.1 Window structure and types

9.3.1.1 Frames are subdivided into communication 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 defined in subsequent sub-clauses:

— 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 and can also be interrupted, in case of high priority events, by the communications partner employing the "right to send" (Token) using the signal command alert (*CA*) followed by a MAC command.

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 sometimes significant propagation delay times of the signal arriving from the slaves, it may happen that the master transmits the *W-Sync* even whilst still in the receive state. This is not allowed. Therefore the *W-Sync* may be transmitted slightly asynchronously with respect to the time slot index.

9.3.2.3 In order to account 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, $T_{\mathrm{WTreceive}}$.

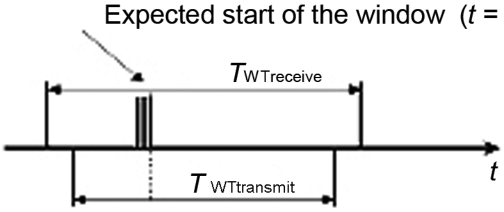

Figure 8 — Window synchronisation (*W-Sync*) receiver and transmitter window

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

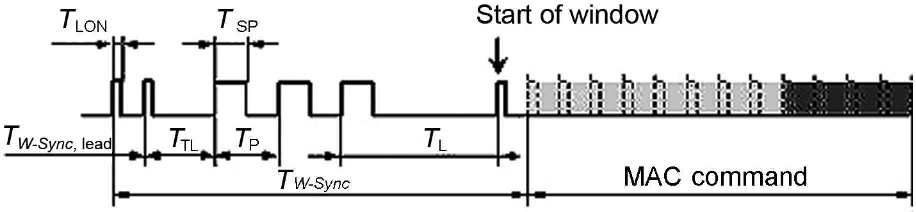

Figure 9 — Window synchronisation (*W-Sync*)

9.3.2.5 A *W-Sync* never shall follow directly after a "receive state". In such 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 resettle.

9.3.3 Management window

9.3.3.1 The management window (*MnW*) is the first window in a CALM-IR frame and carries all organisation information for the current frame as described below.

9.3.3.2 The following occur within the management window.

— 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.

— 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 *F-Sync* signal. It is subdivided into the generic frame information, i.e. *MID*, *MID* and *FATI*, and optional MAC commands for registration (*MC-REG*) and organisation (*MC-FOT*, *MC-FOT U*, *MC-FOT S*, *MC-SUS*, *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 is composed of two parts.

9.3.3.4.1 The first part, the one byte class identity, gives information about the master: fixed roadside beacon, vehicle onboard unit, mobile enforcement, PDA or laptop, point-to-point link, etc.

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 (for example 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, besides being a slave to a master, can also assume the function of a master (usually of a moving cluster).
	0, 0	Internet access point	Indicates that the internet is accessible via the master
S	1	Flag: Active as secondary master	Indicates that the unit currently performs 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 The second part is a 16 bit binary number which,

- in the event of a stationary master, shall be a fixed number identifying the master and is assigned during installation time;
- in the event of a temporary master, shall be a random number created by the device which wants to take the master function.

9.3.3.5 The frame length indicator *MID* 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 airtime indicator *FATI* gives the airtime 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 airtime is given in terms of the number of time slots unused by the current master between two consecutive frames as a single byte integer.

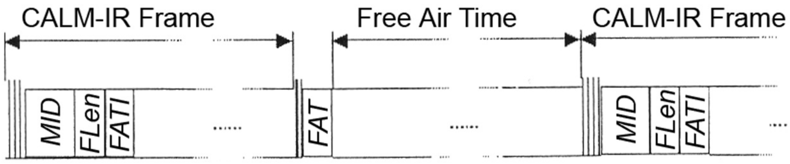

Figure 11 — Example of free airtime

9.3.3.7 The coding and modulation during the management window is always according to 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 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 (*PrW*). To do this it must register again and a new *TempID* will be created and allocated to it.

9.3.4.3 Communications in a *PrW* 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 *PrW* employs at least one information transfer phase in the "forward direction" and zero or more information transfer phases in the "return direction".

9.3.4.5 Each *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,

- in the event that a new message is to be transmitted, an appropriate MAC command;
- 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 *PrW*, the MAC command "packet start" (*MC-PAS*).

9.3.4.6.2 The length of the information stream is signalled

— either inherently by the MAC command itself, or

— if the length 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;

  — 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 *PrW* 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 the 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 it starts 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 the "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 a case, the master starts the second transfer in the "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 slaves within the communication zone of the "broadcaster", even to those which have not yet performed the "registration process".

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

9.3.5.1.1 A frame shall contain zero or one broadcast window.

9.3.5.1.2 The broadcast window is addressed by a reserved *TempID* (see 11.2) in the frame organisation table *FOT*.

9.3.5.1.3 The broadcast window can have any position in the frame.

9.3.5.1.4 The broadcast window *BcW* employs only one information transfer phase, namely in "forward direction".

9.3.5.1.5 In the *BcW* the default profile shall be used.

9.3.5.1.6 The *BcW* starts immediately after the window synchronisation signal *W-Sync* emitted by the master.

9.3.5.1.7 The window phase now starting transfers information from the master to the slave(s) ("forward direction").

9.3.5.2 Immediately after the synchronisation signal *W-Sync* the master sends either

— the MAC command "block start" (*MC-BLS*) in case a new broadcast message is to be broadcasted, or

— the 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 length 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 broadcasted fitted in the current window, or

— 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 slaves 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 slaves (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 *TempID*s allocated to multicasting (see 11.2) in the frame organisation table *FOT*.

9.3.6.3 A multicast window *McW* employs only information transfer phases in the "forward direction".

9.3.6.4 In a *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, the master sends 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 length 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*) if the information which is to be multicasted does not fit in the current window and will be continued in a further multicast window.

9.3.6.7 As slaves shall not respond in a *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 any slaves registering during the current frame in order to enable the master to instantly allocate them a private window without the need for frame reorganisation.

9.3.7.2 *SpW* start with a *W-Sync* addressed by a reserved *TempID* (see 11.2).

9.3.7.3 The maximum number of *SpW* 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 recognise the compatibility window in a frame and thus do 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*.

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 and 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, with one exception defined in 9.4.2.5, be sent only if the originating communications partner has the right to send.

9.4.2.5 If in the "receiving state" the signal is lost, the sending of a *CA* may be enforced.

9.4.2.6 In the event that the intended sending of a *CA* is preceded by a "receive state", the *CA* shall be preceded by a guard time T_G.

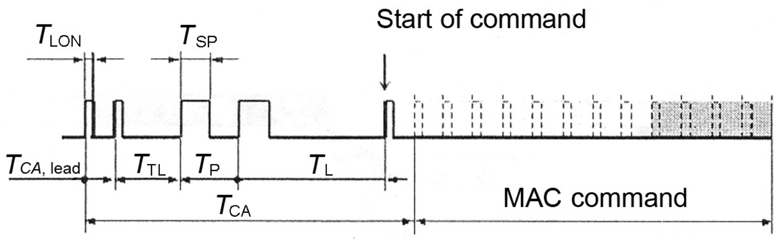

Figure 12 — Command alert (*CA*)

9.5 Summary

Table 13 summarises the frame and window parameters.

Table 13 — Frame and window parameters

Parameter name	Description	Value	Remark
Frame parameters			
$N_{\text{frame,max}}$	Maximum number of time slots per frame	256	Refer to 9.2.2
T_{S}	Length of one time slot	256 µs	
T_{G}	Guard time when changing from receive state to send state	5 000 ns	This guard time shall always be obeyed when a device changes from the receive state to the send state
Frame synchronisation			
F-Sync	Frame synchronisation signal pattern		Refer to 9.2.2
$T_{F\text{-}Sync}$	Total length of *F-Sync*	7 500 ns	
$N_{F\text{-}Sync\text{,lead}}$	Number of leader pulses in *F-Sync*	2	Refer to 9.2.2
$N_{F\text{-}Sync\text{,trail}}$	Number of trailer pulses in *F-Sync*	1	Refer to 9.2.2
T_{LON}	On time of leader and trailer pulses	190 ns	
$T_{F\text{-}Sync\text{,lead}}$	Time between *F-Sync* leader pulses	500 ns	From rising edge of 1st 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			
$N_{\text{window,max}}$	Maximum number of time slots per window	256	
Window synchronisation			
W-Sync	Window synchronisation signal pattern		Refer to 9.3.2
$T_{\text{WTtransmit}}$	*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
$T_{\text{WTreceive}}$	*W-Sync* detect tolerance, receiver	-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	
$N_{W\text{-}Sync\text{,lead}}$	Number of leader pulses in *W-Sync*	2	Refer to 9.3.2

Table 13 (*continued*)

Parameter name	Description	Value	Remark
$N_{W\text{-}Sync,\mathrm{trail}}$	Number of trailer pulses in *W-Sync*	1	Refer to 9.3.2
T_{LON}	On time of leader and trailer pulses	190 ns	
$T_{W\text{-}Sync,\mathrm{lead}}$	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
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	
$N_{CA,\mathrm{lead}}$	Number of leader pulses in *CA*	2	Refer to 9.4
$N_{CA,\mathrm{trail}}$	Number of trailer pulses in *CA*	1	Refer to 9.4
T_{LON}	On time of leader pulses	190 ns	
$T_{CA,\mathrm{lead}}$	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 infra-red communication adaptation layer *IR-CAL*, see 14.2

— on request of the infra-red management adaptation entity *IR-MAE*, see 14.3, or

— on request of the infra-red management entity *IR-ME*, see Clause 13.

10.1.3 A MAC command is always preceded

— by a command alert (*CA*), or

— by a 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 which depends on the MAC command.

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

10.2.1 frame organisation table (*MC-FOT*)

10.2.1.1 Function

The command *MC-FOT* indicates that the table following the command contains the frame organisation 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 organisation 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)
		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	*Dummy-ID* [a]	Reserved *TempID* (see 11.2)
1 byte	Slot index of last time slot	(indicates the end of the last window)
NOTE 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.		
[a] 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 the event that slaves have 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 If fewer slaves have changed status, the command *MC-FOT U* shall be used in order to save frame time.

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

10.2.3 Effect on receipt

10.2.3.1 On 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 window synchronisation signal *W-Sync* in the appropriate time interval defined in the *FOT* and shall interpret the allocated window as its private window, broadcast window or multicast window.

10.2.4 frame organisation table update (*MC-FOT U*)

10.2.4.1 Function

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

It shall be used in the *MnW* only.

10.2.4.2 Semantics of the service primitive

MC-FOT U {*FOT*U length}

Attribute	Description
*FOT*U length	1 byte provides the total length of the *FOT*U in number of bytes.

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

Table 15 — Structure of the *FOT*U

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 the event that slaves have 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 If more slaves have changed 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-FOT U* is at the discretion of system administration.

10.2.4.4 Effect on receipt

10.2.4.4.1 On 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 *FOT*U for subsequent communication.

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

10.2.5 frame organisation table steady (*MC-FOT S*)

10.2.5.1 Function

This command 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-FOT S

10.2.5.3 When generated

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

10.2.5.4 Effect on receipt

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

10.2.6 Broadcast (*MC-BRC*)

10.2.6.1 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.

10.2.6.2 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).

10.2.6.3 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.

10.2.6.4 Effect on receipt

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

10.2.7 Re-establish session (*MC-REST*)

10.2.7.1 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 its “old” *TempID*.

It shall be used in a *PrW* only.

10.2.7.2 Semantics of the service primitive

MC-REST {*MID*, *TempID*}

Table 16 — Session re-establishment

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

10.2.7.3 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.

10.2.7.4 Effect on receipt

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*).

If the master cannot accept the command, it responds with the command “session re-establishment denied” (*MC-RESD*).

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

10.2.8.1 Function

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

It shall be used in a *PrW* only.

10.2.8.2 Semantics of the service primitive

MC-RESC

10.2.8.3 When generated

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

10.2.8.4 Effect on receipt

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

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

10.2.9.1 Function

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

It shall occur in the *PrW* only.

10.2.9.2 Semantics of the service primitive

MC-RESD

10.2.9.3 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.

10.2.9.4 Effect on receipt

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

10.2.10 Kill all (*MC-KIA*)

10.2.10.1 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-FOT U*

10.2.10.2 Semantics of the service primitive

MC-KIA

10.2.10.3 When generated

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

10.2.10.4 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,

— invalidate the *TempID*.

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

10.2.11 Kill slave (*MC-KIS*)

10.2.11.1 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-FOT U*.

10.2.11.2 Semantics of the service primitive

MC-KIS {*TempID*}

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

10.2.11.3 When generated

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

10.2.11.4 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,

— invalidate the *TempID*.

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

10.2.12 De-register (*MC-DREG*)

10.2.12.1 Function

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

It shall be used in the *PrW* only.

10.2.12.2 Semantics of the service primitive

MC-DREG { }

10.2.12.3 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}.

10.2.12.4 Effect on receipt

10.2.12.4.1 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,
- delete all pending frames.

10.2.12.4.2 On receipt of this command by the slave, the MAC shall

- inform the *IR-ME* about loss of communication,
- delete the *TempID*,
- delete all pending frames.

10.2.12.4.3 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}.

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

10.2.13 Suspend all (*MC-SUA*)

10.2.13.1 Function

10.2.13.1.1 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-FOT U* is sent.

10.2.13.1.2 In the event that a following *MC-FOT*, *MC-FOT U* or *MC-FOT S* command again allocates a *PrW* for this *TempID*, this *MC-FOT*, *MC-FOT U* or *MC-FOT S* 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, assuming they are synchronised appropriately with the “CALM master”. See Annex E.

10.2.13.2 Semantics of the service primitive

MC-SUA

10.2.13.3 When generated

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

10.2.13.4 Effect on receipt

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.

In the event that a following *MC-FOT*, *MC-FOT U* or *MC-FOT S* command again allocates a slave a *TempID*, this *MC-FOT*, *MC-FOT U* or *MC-FOT S* command overrides the suspend command.

10.2.14 Suspend slave (*MC-SUS*)

10.2.14.1 Function

10.2.14.1.1 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 a *MnW*, it shall occur before the *MC-FOT* or *MC-FOT U* command is sent.

10.2.14.1.2 In the event that a following *MC-FOT*, *MC-FOT U* or *MC-FOT S* command again allocates a *PrW* for this *TempID*, this *MC-FOT*, *MC-FOT U* or *MC-FOT S* command overrides the suspend command.

NOTE 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 a complete frame reorganisation is necessary. However, the slave is informed that its registration attempt was successful.

10.2.14.2 Semantics of the service primitive

MC-SUS {*TempID*}

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

10.2.14.3 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 a complete frame reorganisation is necessary.

10.2.14.4 Effect on receipt

10.2.14.4.1 On receipt of this command, the MAC

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

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

10.2.14.4.2 In the event that a following *MC-FOT*, *MC-FOT U* or *MC-FOT S* command again allocates a slave a *TempID*, this *MC-FOT*, *MC-FOT U* or *MC-FOT S* command overrides the suspend command.

10.2.15 Free airtime (*MC-FAT*)

10.2.15.1 Function

This command is used by the master to indicate the start of the free airtime in the event that “free airtime” is allocated before the start of the next frame.

10.2.15.2 Semantics of the service primitive

MC-FAT

10.2.15.3 When generated

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

10.2.15.4 Effect on receipt

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

10.3 MAC commands related to flow control

10.3.1 Command not supported (*MC-CNS*)

10.3.1.1 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.

10.3.1.2 Semantics of the service primitive

MC-CNS {*CNS*}

Attribute	Description
CNS	1 byte code of the command which is not supported.

10.3.1.3 When generated

The MAC sends this command at the earliest possible point in time after receipt of the unsupported command.

10.3.1.4 Effect on receipt

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

10.3.2 Token (*MC-TKN*)

10.3.2.1 Function

10.3.2.1.1 With this command, the sending device hands over the token to its 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.

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

10.3.2.2 Semantics of the service primitive

MC-TKN

10.3.2.3 When generated

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

10.3.2.4 Effect on receipt

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

- in the event that the receiving MAC has data pending to be sent, the MAC sends this data; or
- in the event that the receiving MAC has nothing to send, the MAC replies with *MC-TKN*.

10.3.3 Block start (*MC-BLS*)

10.3.3.1 Function

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

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

10.3.3.2 Semantics of the service primitive

MC-BLS {block number}

Attribute	Description
Block number	One byte number of new block

10.3.3.3 When generated

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

10.3.3.4 Effect on receipt

Open a new receive buffer for CALM-fast applications.

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

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

10.3.4.1 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.

10.3.4.2 Semantics of the service primitive

MC-CCBS {block number}

Attribute	Description
Block number	One byte number of new block

10.3.4.3 When generated

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

10.3.4.4 Effect on receipt

Open a new receive buffer for the CALM control channel.

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

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

10.3.5.1 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.

10.3.5.2 Semantics of the service primitive

MC-FBS {block number}

Attribute	Description
Block number	One byte number of new block

10.3.5.3 When generated

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

10.3.5.4 Effect on receipt

Open a new receive buffer for IEEE 802 compliant mode.

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

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

10.3.6.1 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.

10.3.6.2 Semantics of the service primitive

MC-SMC {block number}

Attribute	Description
Block number	One byte number of new block

10.3.6.3 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.

10.3.6.4 Effect on receipt

Open a new receive buffer for MAC control block.

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

10.3.7 Packet start (*MC-PAS*)

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

10.3.7.2 Semantics of the service primitive

MC-PAS {block number, packet number}

Attribute	Description
Block number, packet number	Number of block to which the packet belongs, number of actual packet

10.3.7.3 When generated

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

10.3.7.4 Effect on receipt

Add received data to the corresponding receive buffer.

10.3.8 Packet end (*MC-PAE*)

10.3.8.1 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 may 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-PAE

10.3.8.3 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.

10.3.8.4 Effect on receipt

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

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

10.3.9 Block end (*MC-BLE*)

10.3.9.1 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.

10.3.9.2 Semantics of the service primitive

MC-BLE {block number}

Attribute	Description
Block number	Number of block of which the last packet was sent at least once

10.3.9.3 When generated

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

10.3.9.4 Effect on receipt

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

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

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, retransmission of these packets is requested with the MAC command *MC-RTQ*.

10.3.10 Transmission acknowledged (*MC-TAck*)

10.3.10.1 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.

10.3.10.2 Semantics of the service primitive

MC-TAck

10.3.10.3 When generated

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

10.3.10.4 Effect on receipt

The last transmitted packet will be erased from the buffer.

The communication token is recognised.

10.3.11 Transmission acknowledged & (*MC-TAck&*)

10.3.11.1 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.

10.3.11.2 Semantics of the service primitive

MC-TAck&

10.3.11.3 When generated

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

10.3.11.4 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&*.

10.3.12 Transmission not acknowledged (*MC-TNAck*)

10.3.12.1 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.

10.3.12.2 Semantics of the service primitive

MC-TNAck

10.3.12.3 When generated

In the event of a transmission received with uncorrectable errors.

10.3.12.4 Effect on receipt

The receiving device retransmits the last packet.

10.3.13 Transmission not acknowledged & (*MC-TNAck&*)

10.3.13.1 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.

10.3.13.2 Semantics of the service primitive

MC-TNAck&

10.3.13.3 When generated

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

10.3.13.4 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 in time.

10.3.14 Retransmission request (*MC-RTQ*)

10.3.14.1 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.

10.3.14.2 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.

10.3.14.3 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.

10.3.14.4 Effect on receipt

The receiving MAC repeats the requested packet.

10.3.15 Block acknowledge (*MC-BAck*)

10.3.15.1 Function

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

The command shall be used in a private window only.

10.3.15.2 Semantics of the service primitive

MC-BAck {block number}

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

10.3.15.3 When generated

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

10.3.15.4 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 a *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 See also Table 17.

Table 17 — *MC-REN* group selector

Selector bit number	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 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 a *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 17.

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 a *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

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.

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

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 be used in a *MnW* only.

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

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

In the event that *TempID* is not recognised 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 a *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 physical 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 that 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 that 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 18.

Table 18 — 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 18).

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

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

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

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

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

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

— shall 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 18).

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 its 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 18).

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 Status request 1 (*MC-SRQ1*)

10.6.1.1 Function

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

The command shall be used in a private window only.

10.6.1.2 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 19).

Table 19 — 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 retransmitted information packets
5	Block counter	Total number of received information blocks
6	Block retransmission	Number of received retransmitted information blocks
7	reserved for future use	

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

10.6.1.3 When generated

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

10.6.1.4 Effect on receipt

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*.

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

10.6.2 Status request 2 (*MC-SRQ2*)

10.6.2.1 Function

This command requests the radiation parameters from the communication partner.

The command shall be used in a private window only.

10.6.2.2 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 20)

Table 20 — 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.

10.6.2.3 When generated

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

10.6.2.4 Effect on receipt

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*.

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

10.6.3 Status request 3 (*MC-SRQ3*)

10.6.3.1 Function

This command requests the environmental parameters from the communication partner.

The command shall be used in a private window only.

10.6.3.2 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 21)

Table 21 — 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	
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

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*.

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

10.6.4 Status request 4 (*MC-SRQ4*)

10.6.4.1 Function

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

The command shall be used in a private window only.

10.6.4.2 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 22).

Table 22 — Manufacturer and certification parameters

Bit position	Status parameter
0 (LSB)	Manufacturer ID
1	Serial number
2	Certification1
3	Certification2
4	Certification3
5	Certification4
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

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*.

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

10.6.5 Status response 1 (*MC-SR1*)

10.6.5.1 Function

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

The command shall be used in a private window only.

10.6.5.2 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 19).

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 23 — 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 led nor trailed by any block or packet command.

10.6.5.3 When generated

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

10.6.5.4 Effect on receipt

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*.

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

10.6.6 Status response 2 (*MC-SR2*)

10.6.6.1 Function

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

The command shall be used in a private window only.

10.6.6.2 Semantics of the service primitive

MC-SR2 {field parameters indicator}

Attribute	Description
Field parameters indicator	One byte indicating the available parameter (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 — Field 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 led nor trailed by any block or packet command.

10.6.6.3 When generated

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

10.6.6.4 Effect on receipt

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*.

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

10.6.7 Status response 3 (*MC-SR3*)

10.6.7.1 Function

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

The command shall be used in a private window only.

10.6.7.2 Semantics of the service primitive

MC-SR3 {environmental parameters indicator}

Attribute	Description
Environmental parameters indicator	One byte indicating the available parameters (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 — 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 led 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

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*.

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

10.6.8 Status response 4 (*MC-SR4*)

10.6.8.1 Function

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

The command shall be used in a private window only.

10.6.8.2 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 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 — 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 led 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

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*.

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

10.6.9 Echo alert (*MC-EA*)

10.6.9.1 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 or distance between the two communication partners by 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.

10.6.9.2 Semantics of the service primitive

MC-EA { }

10.6.9.3 When generated

This command is generated on request of the service application via the *IR-ME*.

10.6.9.4 Effect on receipt

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.

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

10.6.10 Echo request (*MC-ERQ*)

10.6.10.1 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 to enable the requestor to calculate the signal travelling time or distance between the two communication partners.

The command shall be used in a private window only.

10.6.10.2 Semantics of the service primitive

MC-ERQ { }

10.6.10.3 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.

10.6.10.4 Effect on receipt

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

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

10.6.11 Echo (*MC-ECH*)

10.6.11.1 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.

10.6.11.2 Semantics of the service primitive

MC-ECH {echo delay time}

Attribute	Description
Echo delay time	2 byte giving the implementation-dependent, device internal delay time in nanoseconds between the reception of the first bit of the received command *MC-ERQ* and the first bit of the command *MC-ECH*.

10.6.11.3 When generated

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

10.6.11.4 Effect on receipt

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.

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

10.7 MAC command set overview

Table 27 — 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 organisation					
82h	frame organisation table	*MC-FOT* {*FOT* length}	2	*MnW*	MAC
83h	frame organisation table update	MC*FOT U* {*FOT*U length}	2	*MnW*	MAC
04h	frame organisation table-steady	*MC-FOT S* { }	none	*MnW*	MAC
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 confirmed	*MC-RESC* { }	none	*PrW*	*IR-ME*
0Dh	Session re-establishment denied	*MC-RESD* { }	none	*PrW*	*IR-ME*
06h	Kill all	*MC-KIA* { }	none	*MnW*	*IR-ME*
86h	Kill slave	*MC-KIS* {*TempID*}	2	*MnW*	*IR-ME*
01h	Deregister	*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 airtime	*MC-FAT* { }	none	*MnW*	*IR-ME*

Table 27 (*continued*)

Command code	MAC command	Mnemonic	Length of attribute (bytes)	Used in window types	Initiated by
Commands related to flow control					
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
11h	Transmission acknowledged	*MC-TAck { }*	none	*PrW*	MAC
12h	Transmission acknowledged &	*MC-TAck& { }*	none	*PrW*	MAC
13h	Transmission not acknowledged	*MC-TNAck { }*	none	*PrW*	MAC
14h	Transmission not acknowledged &	*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 confirmation	*MC-REC* { }	none	*MnW*	MAC
Commands related to the physical layer parameters					
0Ah	Profiles request	*MC-PRQ* { }	none	*PrW*	*IR-ME*
88h	Profiles response	*MC-PRP* {profile indicator}	2	*PrW*	*IR-ME*
49h	Request new profile	*MC-RNP* {profile selector}	1	*PrW*	*IR-ME*
8Ch	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

Table 27 (*continued*)

Command code	MAC command	Mnemonic	Length of attribute (bytes)	Used in window types	Initiated by
Commands related to test and services					
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

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*, *MID* 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 its priority creates a *TempID* with which it enters the registration process.

11.2 Normal registration procedure

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

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

11.2.3 A confirmed *TempID* is valid as long as the *TempID* time-out has not been exceeded.

11.2.4 When producing a *TempID* proposal, the slave shall fulfil the requirements given in 11.2.4.1 to 11.2.4.5.

11.2.4.1 The *TempID* shall be a 2 byte random number.

11.2.4.2 The slave shall not use one of the predefined reserved *TempID*s (see Table 28).

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

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

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

11.2.5 *TempID* codes are provided in Table 28.

Table 28 — *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…EFFFh	*Temp-ID*	Range of valid temporary identifiers
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 an answer for a period of time 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 any already 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 already 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* (via the master) not originated by themselves stay inactive until the next registration command.

11.3.8 The slave recognising 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 *FOT*U.

11.3.9 If the size of the management window allows it, the master may now broadcast a new registration command.

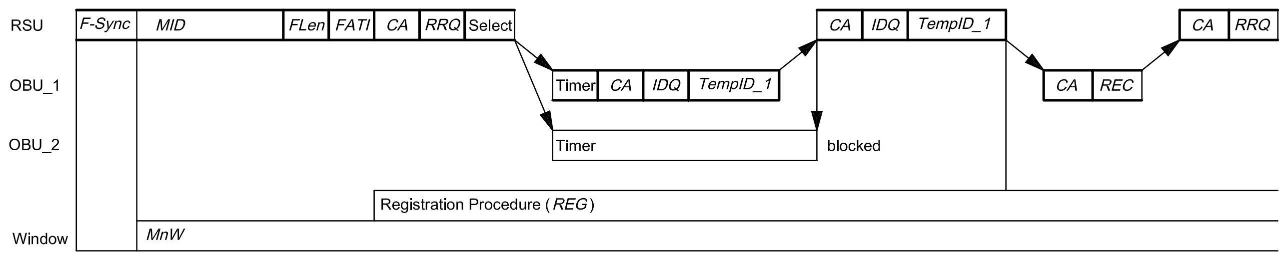

Figure 13 — Registration procedure without collision

11.4 Sequence of the registration procedure with collision

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

There are three possible scenarios.

11.4.1 Both signals appear with equal signal strength

Two slaves reply simultaneously or overlapping with different *TempID*s 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 neither of the slaves receives its correct *TempID*, neither of them is addressed and thus neither of them confirms and no *TempID* becomes valid.

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

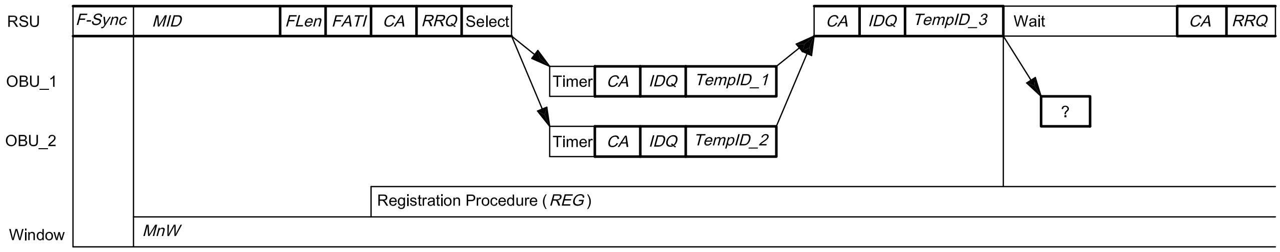

Figure 14 — Registration procedure with collision

11.4.2 Both signals appear with different signal strength

Two slaves reply simultaneously with different proposed *TempID*s, 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, the other slave recognises that it is not addressed.

11.4.3 Identical *TempID*s

Two slaves reply simultaneously with identical *TempID*s. This is the only complicated situation, but this case happens very seldom. 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 to 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 for 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 is that that the slave(s) will enter a new registration process.

11.5 Handover and re-registration

If a slave fails to respond in its private window in two consecutive frames, 11.5.1 and 11.5.2 apply.

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 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 it "lost" in its 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 29.

Table 29 — 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 $T_{\mathrm{REG,min}}$ = 5 µs $T_{\mathrm{REG,max}}$ = 91 µs
T_{CWAIT}	Waiting time of the slave for a reply to a proposed *TempID*	$T_{\mathrm{CWAIT,max}}$ = 32 µs
T_{RT}	Waiting time of the master for a reply to its *MC-IDP*	$T_{\mathrm{RT,max}}$ = 25 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;

— re-arrange the time slot allocation (if necessary).

12.2 Window allocation by frame organisation 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 organisation is transmitted to the slaves by the master during the management window using either of the MAC commands "frame organisation table" (*MC-FOT*) or "frame organisation table update" (*MC-FOT U*) that are defined 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 organises the slaves without the need for "continuous window counting". Instead of many interrupts, one timer is set in the slave, unblocking the interrupt 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 of 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 organisation 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*.

The new slave thus has a private window for his disposition even in the frame he used for registering. A complete frame reorganisation (deleting or adding windows) then can 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 shall

— be as equidistant as possible;

— 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 because of time slots not allocated to any active slave, those gaps shall be filled with “spare windows” as described in 12.3.

13 Infra-red management entity

13.1 General

The infra-red management entity *IR-ME* is in charge of controlling 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 may lead to a not supported command. Thus reception of the MAC command *MC-CNS* shall enforce retransmission 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 via 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-SRQ*i and *MC-SR*i, i = 1, …, 4, (see 10.6). These parameters shall be retrievable by the CALM management via the *IR-MAE*.

13.5 Testing

The *IR-ME* shall support tests as described in 10.6 on request of a service application via 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.

<table>
<tr><td>LS-Byte</td><td>Byte 1</td><td>Byte 2</td><td>Byte 3</td><td>Byte 4</td><td>MS-Byte</td></tr>
<tr><td colspan="3">Vendor value, manufacturer identifier</td><td colspan="3">User value, serial number</td></tr>
<tr><td colspan="3">Individual, local</td><td>Qualifier</td><td colspan="2">Identifier</td></tr>
</table>

Figure 15 — Unique MAC address

A MAC address consists of six bytes, divided into two groups:

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

— user value (being a serial number).

If the “vendor” value indicates an individual local MAC address, the “user” value shall be the concatenation of a qualifier and an identifier.

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

<table>
<tr><th>Comment</th><th>LSB</th><th>Bit 1</th><th>Bit 2</th><th>Bit 3</th><th>Bit 4</th><th>Bit 5</th><th>Bit 6</th><th>MSB</th></tr>
<tr><td>Unique MAC address for stationary equipment</td><td>1</td><td>1</td><td colspan="6">Extension of identifier, i.e. the identifier consists of 22 bits.</td></tr>
<tr><td>Unique MAC address for mobile equipment</td><td>0</td><td>1</td><td colspan="6">Extension of identifier, i.e. the identifier consists of 22 bits.</td></tr>
<tr><td>Temporary MAC address for master</td><td>1</td><td>0</td><td>CCI [a]</td><td>F1 [b]</td><td>F0 [b]</td><td>S [b]</td><td>Res. [c]</td><td>Res.</td></tr>
<tr><td>Temporary MAC address for slave</td><td>0</td><td>0</td><td>CCI</td><td>Res.</td><td colspan="4">Instance number [d]</td></tr>
</table>

[a] CCI is the control channel indicator. If set to “1”, the logical unit constitutes a control channel.

[b] F0, F1, and S are elements of the class identity code, see Table 12.

[c] Res. indicates a reserved bit which shall be set to “1”.

[d] The instance number indicates the 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 via 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*, *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 from using airtime in a single specific frame without losing its association with the master by using the MAC commands *MC-SUA*, *MC-SUS* {*TempID*}.

13.8 Communication

13.8.1 Organisation of IR communication

IR communication is organised in sequences of packets to be transmitted. Several packets may 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 00h to FFh. There shall be only 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 shall be 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 use 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 retransmitted 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 airtime. 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.

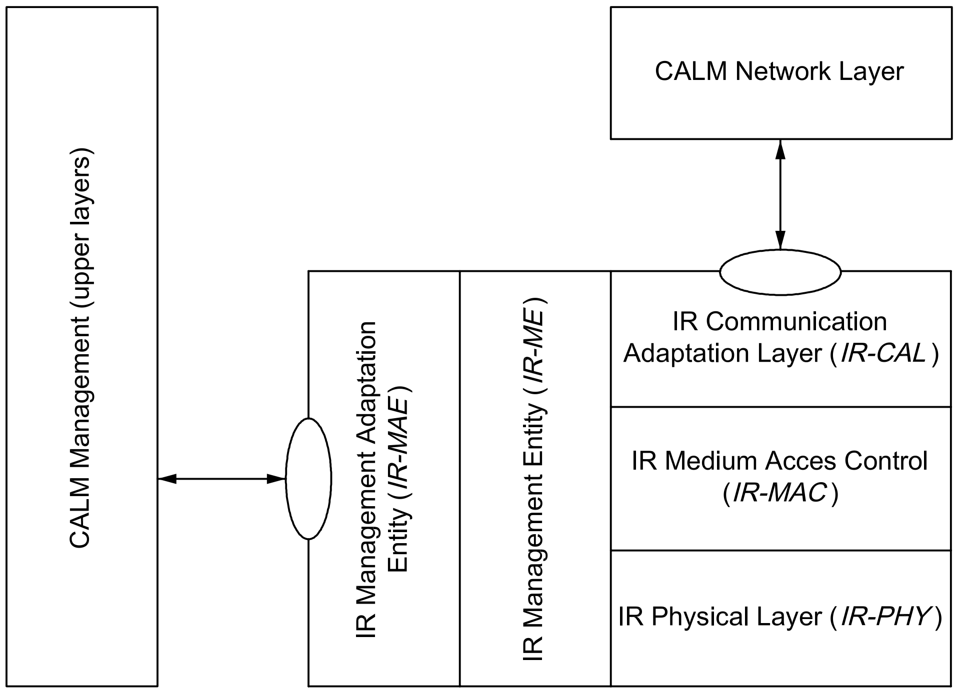

Figure 17 — Medium adaptation

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 service access points (SAPs) to the CALM management entity following the same principles as outlined in ISO/IEC 8802-11 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 will be defined in a future International Standard (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 will be defined in a future International Standard (ISO 21218).

14.2.1.5 Data

The data parameter carries the *N-PDU*.

14.2.1.6 Priority

To be harmonised with other CALM media.

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 compatible services

These services are optional.

For WLAN communication compliant with ISO/IEC 8802-11, 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 the future International Standard 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 the future International Standard ISO 21217).

14.2.3 WLAN functionality

14.2.3.1 Basics

In order to support the ISO/IEC 8802-11 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 via the IR link.

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

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 frame is relevant information. Only those ISO/IEC 8802-11 MAC frames for management and data described in Table 30 are supported by CALM-IR.

Table 30 — 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, are relevant information.

The frame control is reduced to one octet size, as described in Table 31.

Table 31 — 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 frames are not relevant to IR.

14.2.3.2.3 Addresses

The addresses 1–4 of an ISO/IEC 8802-11 frame shall be sent as described in ISO/IEC 8802-11 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 32.

Table 32 — 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[a]	SA[b]	BSSID[c]	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 destined for the distribution system.
Data	1	0	BSSID	SA	DA	n.a.	Data frame exiting the distribution system.
Data	1	1	RA[c]	TA[e]	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	Use of addresses as defined in ISO/IEC 8802-11						

[a] DA is the Final Destination Address.

[b] SA is the Source Address.

[c] BSSID is the BasicServiceSet ID.

[d] RA is the Receiver Address.

[e] TA is the Transmitter Address.

14.2.3.3 WLAN block

The relevant information to support ISO/IEC 8802-11 is transmitted in an IR specific frame header as described in Table 33. The frame body carries the *N-PDU* and shall directly follow this header.

Table 33 — 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 (first fragment)	*MC-BLE* or *MC-PAE*
Size in octets	1	2	1	6	6	6	6	0 … (max. packet size – overhead[a])	1
Contains	IR command	IR command attribute	IR data						IR command
[a] The overhead equals the size of the elements other than frame body fragments actually used.									

Table 34 — In the event of fragmentation used for 2nd up to last frame

Description	*MC-PAS*	*MC-PAS* attributes	frame body (subsequent 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, a MAC address consists of six bytes, divided into two groups: the vendor value or manufacturer ID and the user value or station ID. Each consists of three bytes. The first bit (LSB) of the LS-Byte of the MAC address is the I/G-Bit, which describes whether the MAC address is an individual (=0) or a group (=1) address. The second bit is the U/L-Bit, which 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.

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.

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.

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 dependent on the actual implementation.

14.3 *IR-MAE*

The service access point towards the CALM management will be defined in two future International Standards (ISO 21217 and ISO 21218).

15 Adoption of other standards and internationally adopted 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 relevant ITU regulations and International Standards.

NOTE Adoption of other standards and internationally adopted practices will be presented in a future International Standard (ISO 21217).

16 Marking and labelling

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

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

All transmitting equipment shall 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) may have to be used by a person or organisation complying with an ISO International Standard.

Table 35 — Table of patents

	Name of patent Holder:	Jurisdiction, patent number and title
1	Inventors: Martin Aureliano Hassner, Mountain View, CA (US) Nyles Heise, San Jose, CA (US) Walter Hirt, Wettswil (CH) Barry Marshall Trager, Yorktown Heights, NY (US) Assignee: International Business Machines Corporation, Armonk, NY (US)	United States Patent, 6,195,025, Hassner, et al., February 27, 2001 Methods and means for invertibly mapping binary sequences into rate 2/3 (1,k) run – length – limited coded sequences with maximum transition density constraints
	Address:	International Business Machines Corporation Intellectual Property & Licensing North Castle Drive Armonk, New York 10504
	Telephone:	FAX: (914) 765-4420
	Contact:	Director Intellectual Property & Licensing North Castle Drive Armonk, New York 10504 FAX - Attention: Director of Intellectual Property & Licensing

	Name of patent Holder:	Jurisdiction, patent number and title
2	Inventors: Hassner; Martin (Mountain View, CA); Heise; Nyles (San Jose, CA); 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
	Address:	International Business Machines Corporation Intellectual Property & Licensing North Castle Drive Armonk, New York 10504
	Telephone:	FAX: (914) 765-4420
	Contact:	Director Intellectual Property & Licensing North Castle Drive Armonk, New York 10504 FAX - Attention: Director of Intellectual Property & Licensing

Name of patent Holder:	Jurisdiction, patent number and title
3 Inventors:	
	PCT/EP03/05425 – "IR-Framing"
Raimund Pammer Grieskai 54 8020 Graz Austria	23.05.2003
Wolgang Boh Dürrgrabenweg 12 8045 Graz Austria Andreas Schalk Mantschawaldweg 48 8054 Graz Austria Helmut Rieder Südtirolerplatz 10 8020 Graz Austria	The invention relates to a method and device for optical data transmission, in particular a method for transmission of data by means of digitised infra-red 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
Assignee: EFKON AG	
Address:	EFKON AG Andritzer Reichsstrasse 66 8045 Graz Austria
Telephone:	+43 316 695675-0 FAX:
Contact:	Legal Department Andritzer Reichsstrasse 66 8045 Graz Austria

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 an advance 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 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 the following formula:

$$\overline{EC}0 = D_0 \oplus D_1 \oplus D_2 \oplus D_3 \oplus D_4$$
$$\overline{EC}1 = D_0 \oplus D_2 \oplus D_4 \oplus D_5 \oplus D_6$$
$$\overline{EC}2 = D_1 \oplus D_2 \oplus D_5 \oplus D_7$$
$$\overline{EC}3 = D_3 \oplus D_4 \oplus D_6 \oplus D_7$$

A.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}. The defect bits are shown in Table A.1.

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

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	R_0 defect
0	1	0	1	R_1 defect
0	0	0	1	R_2 defect
0	1	1	0	R_3 defect
0	0	1	0	R_4 defect
1	0	0	1	R_5 defect
1	0	1	0	R_6 defect
1	1	0	0	R_7 defect
0	1	1	1	R_8 defect
1	0	1	1	R_9 defect
1	1	0	1	R_{10} defect
1	1	1	0	R_{11} defect
any other combination				multiple bit errors

Annex B
(normative)

Coding and modulation of profiles 2 to 6

B.1 General

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

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

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

Table B.1 — *HHH(1,13)* properties

Property	Value
Code rate	2/3
Maximal duty cycle	1/3 (~ 33 %)
Average duty cycle	~ 26 %
Minimal duty cycle	1/12 (~ 8.3 %)
Run length constraints	(d,k) = (1,13)
Longest run of '10's	yyy'000'101'010'101'000'yyy
Chip rate	12 Mchips/s at 8 Mbit/s 24 Mchips/s at 16 Mbit/s 48 Mchips/s at 32 Mbit/s 96 Mchips/s at 64 Mbit/s 192 Mchips/s at 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 ten 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 Cyclic redundancy check

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

For reference, the CRC32 polynomial is defined as follows:

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

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

$$x^8 \oplus x^4 \oplus x^3 \oplus x^2 \oplus 1,$$

where $\oplus$ indicates a modulo-2 addition or, equivalently, a logic exclusive OR (XOR) operation, shall be used for implementing these functions.

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/descrambler initialisation

a) Transmit mode:

The scrambler’s shift register shall be initialised with the all-1 state, that is

$$(x_8, x_7, x_6, x_5, x_4, x_3, x_2, x_1) = (1, 1, 1, 1, 1, 1, 1, 1).$$

b) 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 requires 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) with 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 $B^1 = (b_1, b_2) \equiv (\alpha, \beta)$.

Table B.2 — *HHH(1,13)* 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 don't care.

B.2.9.2 *HHH(1,13)* encoding equations

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

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

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

NOTE First data input to be encoded: $D \equiv (\alpha, \beta)$.

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

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

Internal data: $B^1 = (B^1{}_1, B^1{}_2) = (b_1, b_2)$
$B^2 = (B^2{}_1, B^2{}_2) = (b_3, b_4)$
$B^3 = (B^3{}_1, B^3{}_2) = (b_5, b_6)$

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

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

Initial conditions (start up): $S = (s_1, s_2, s_3) = (1, 0, 0)$ when $B^1 = (b_1, b_2) \equiv D = (\alpha, \beta)$

With the boolean operator notation,

$$\overline{m} = INVERSE(m)\ ,$$

$$m + n = m\ OR\ n,$$

$$mn = m\ AND\ n,$$

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:

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

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

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

$$c_1 = s_1 s_2\ ,$$

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

$$c_3 = \overline{s_1} s_3 (\overline{b_1} + \overline{b}_2) + (\overline{s_1}\,\overline{s_3} b_1 b_2 \overline{b_3} b_4)\ .$$

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 equations:

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

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

Internal codewords:

$$Y^4 = (y_{10}, y_{11,} y_{12})$$
$$Y^3 = (y_7, y_{8,} y_9)$$
$$Y^2 = (y_4, y_{5,} y_6)$$
$$Y^1 = (y_1, y_{2,} y_3)$$

Internal variables:

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

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

Initial conditions (start up): *None*

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

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

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

Figure B.2 shows the complete CALM-fast IR packet (*FCIR-packet*) construction process.

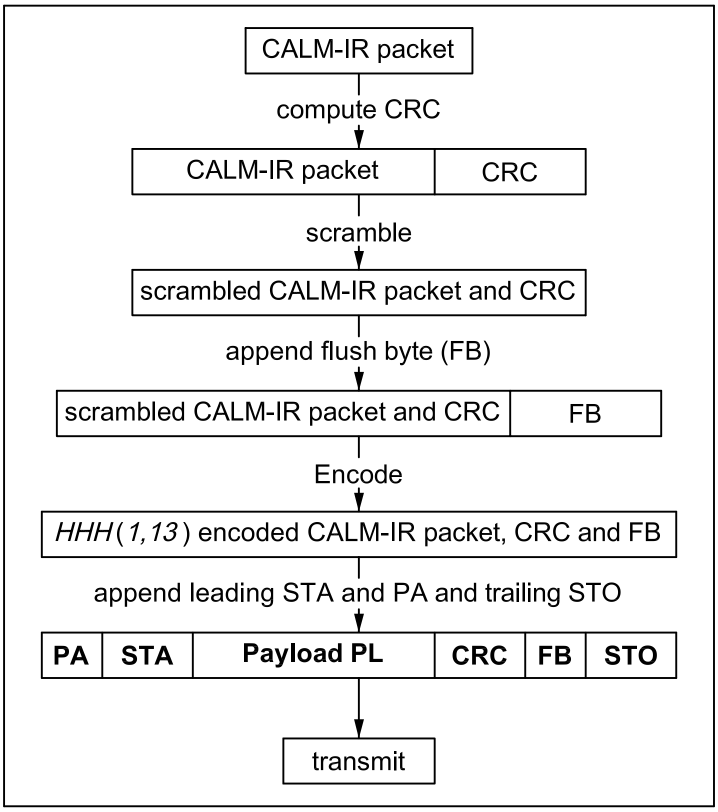

Figure B.1 — CALM-fast IR packet processing

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 economical and technical reasons to have non-symmetrical links. In general, on-board units (OBUs) should be economically priced, as normally many more OBUs are used than roadside units (RSUs). That means that 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 metres.

C.2.2 Transmission losses

All losses (L) are expressed in decibels: $L\ [\text{dB}] = 10 \cdot \log\left(\frac{P_{\text{in}}}{P_{\text{out}}}\right)$.

Transmission losses (L_{TR}) consist of path loss and additional losses: $L_{\text{TR}} = L_{\text{P}} + L_{\text{AD}}$

C.2.3 Path loss

The path loss (L_{P}) is the distance-related loss, without any lossy media between transmitter and receiver:

$$L_{\text{P}} = 10 \cdot \log D^2,$$

where

$$D = d/1$$

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

Path loss	Link distance, d m						
	10	20	50	100	200	500	1 000
L_{P} [dB]	20	26	34	40	46	54	60

C.2.4 Additional losses

C.2.4.1 Additional losses are calculated as follows:

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

where

L_W are losses due to windscreen and sun protection (coating or foil);

L_{WC} are losses due to weather conditions (rain, snow and fog);

L_{SUN} are losses due to sunlight.

C.2.4.2 IR loss measurements on all kinds of windscreens have been investigated from many independent institutions. All the windscreens measured so far were evaluated to be below 7 dB (most in the range 1,5 dB to 5,5 dB).

C.2.4.3 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

Weather condition	**Infra-red loss at various link distances** dB						
	10 m	20 m	50 m	100 m	200 m	500 m	1 000 m
Clear weather	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Light rain	< 1	< 1	< 1	< 1	< 1	1	2
Heavy rain	< 1	< 1	< 1	1,5	3	7,5	15
Fog	< 1	< 1	4	8	16	40	80
Dense fog	< 1	1,6	8	16	32	80	160

C.2.4.4 Sunlight-induced losses can, by proper receiver design, be kept below 2 dB, even against full sunlight.

C.2.4.5 The additional losses (especially the weather conditions) shall be considered in view of several realistic scenarios.

— Heavy rain and fog do not occur simultaneously.

— Full sun does not occur with bad weather.

— Sun-protected windscreens (“coated windscreens”) reduce also the sun-induced losses.

C.2.5 Symmetrical and non-symmetrical links

The physical layer of an infra-red CALM link may be either “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 or a class of applications, the relevant transmitter and receiver parameters are organised 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 — Achievable distance for different combinations of RX and TX classes

TX class	Achievable distance for a given RX class m										
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
T1	1,25	1,75	2,5	3,5	5	7	10	14	20	28	40
T2	1,75	2,5	3,5	5	7	10	14	20	28	40	56
T3	2,5	3,5	5	7	10	14	20	28	40	56	80
T4	3,5	5	7	10	14	20	28	40	56	80	110
T5	5	7	10	14	20	28	40	56	80	110	160
T6	7	10	14	20	28	40	56	80	110	160	250
T7	10	14	20	28	40	56	80	110	160	250	350
T8	14	20	28	40	56	80	110	160	250	350	500
T9	20	28	40	56	80	110	160	250	350	500	700
T10	28	40	56	80	110	160	250	350	500	700	1 000
T11	40	56	80	110	160	250	350	500	700	1 000	>1 000
T12	56	80	110	160	250	350	500	700	1 000	>1 000	>1 000
T13	80	110	160	250	350	500	700	1 000	>1 000	>1 000	>1 000
T14	110	160	250	350	500	700	1000	>1 000	>1 000	>1 000	>1 000
T15	160	250	350	500	700	1 000	>1 000	>1 000	>1 000	>1 000	>1 000
T16	250	350	500	700	1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000

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 decibels.

C.2.8 Receiver dynamic range

The receiver dynamic range R_{D} is the maximum irradiance profile the receiver shall be able to handle in relation to the minimum irradiance, calculated by

$$R_{\mathrm{D}} = 10 \cdot \log \frac{E_{R,\max}}{E_{R,\min}} \text{ [dB]},$$

where

$E_{R,\max}$ is the maximum irradiance,

$E_{R,\min}$ is the minimum irradiance.

C.2.9 Link power budget calculation examples

C.2.9.1 Example 1

We assume a given OBU with the following characteristics:

OBU receiver irradiance minimum sensitivity:	$E_{R,\min\_OBU} =$ 8 mW/m^2
OBU transmitter radiant minimum intensity:	$I_{e,\min\_OBU} =$ 6 W/sr

We want to calculate the minimum RSU parameters “transmitter radiant minimum intensity” and “receiver irradiance minimum sensitivity”.

Other given values are:

Link distance:	$d =$ 20 m
Additional losses	
Windshield with sun protection coating:	$L_W =$ 7 dB (max.)
Weather condition (rain, snow and fog):	$L_{WC} =$ 4 dB (max.)
Sunlight-induced noise:	$L_{SUN} =$ 2 dB

Calculated loss values: (from above)

Path loss:	$L_P =$ 26 dB
Additional losses:	$L_{AD} =$ 13 dB
Total transmission losses:	$L_{TR} =$ 39 dB

Calculation of the minimum irradiance profile at the RSU receiver ($E_{R,\min}$):

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

Calculation of the radiant minimum intensity of the RSU transmitter ($E_{R,\min}$):

It’s the way back:

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

C.2.9.2 Example 2

Now, as 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 is calculated as follows.

1. Direction OBU → RSU

   OBU radiant intensity: 6 W/sr
   RSU receiver sensitivity: 0,5 mW/m^2

$$r_1 = \sqrt{\frac{I_e}{E_e}} = \sqrt{\frac{6}{0{,}5 \cdot 10^{-3}}} = 109{,}54 \text{ m}$$

2. Direction RSU → OBU

   RSU radiant intensity: 100 W/sr
   OBU receiver sensitivity: 8 mW/m^2

$$r_2 = \sqrt{\frac{I_e}{E_e}} = \sqrt{\frac{100}{8 \cdot 10^{-3}}} = 111{,}8 \text{ m}$$

→ $d = \min.\ (r_1, r_2) = \underline{109{,}54 \text{ m}}$

C.2.10 Link power budget scheme

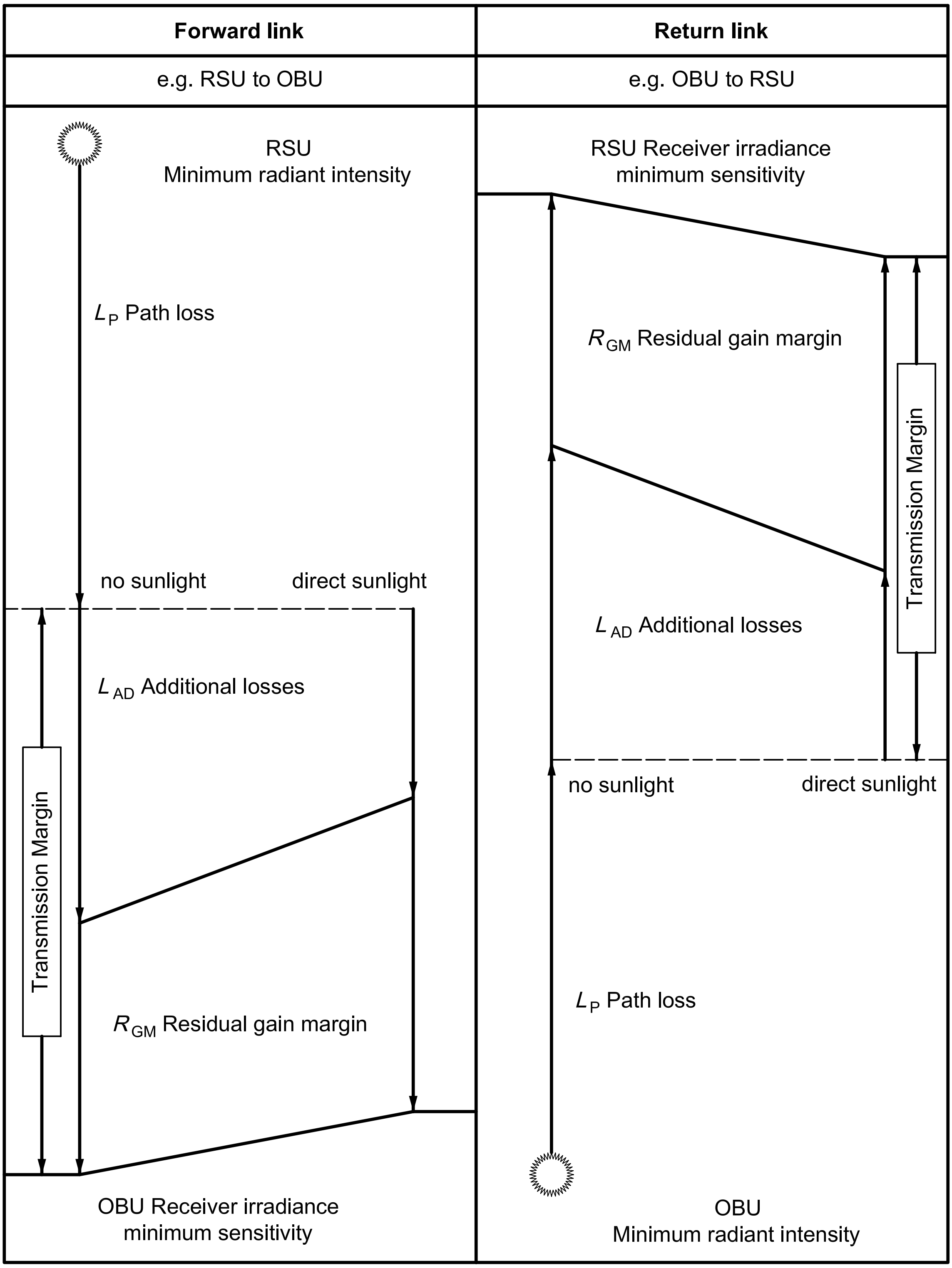

Figure C.1 — Link power budget scheme

Annex D
(informative)

Link directivity considerations

D.1 General

For a directional communication with CALM devices, a three-dimensional co-ordinate system (x_{CALM}, y_{CALM}, z_{CALM}) has to be constituted. The origin of the co-ordinate system corresponds to the source of the beam. The x-axis of the CALM device is defined as the main direction.

Figure 4 shows the azimuth angle φ and the elevation angle δ of the beam axis D (bore-sight direction) in relation to 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 to the beam axis D, see Figure 5.

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:

$D_1 = (\varphi_1, \delta_1, \Theta_{H,1}, \Theta_{V,1})$

$D_2 = (\varphi_2, \delta_2, \Theta_{H,2}, \Theta_{V,2})$

$D_3 = (\varphi_3, \delta_3, \Theta_{H,3}, \Theta_{V,3})$

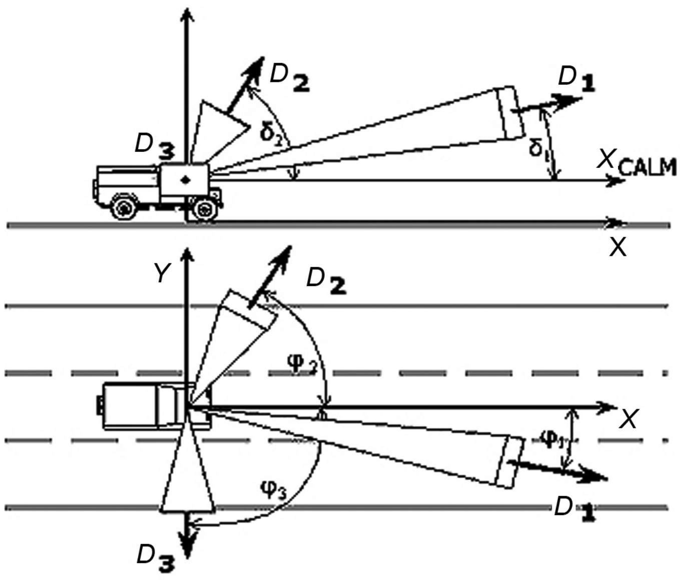

Figure D.1 — Multi-beam antenna

D.3 Communication zones shortcut illustration

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

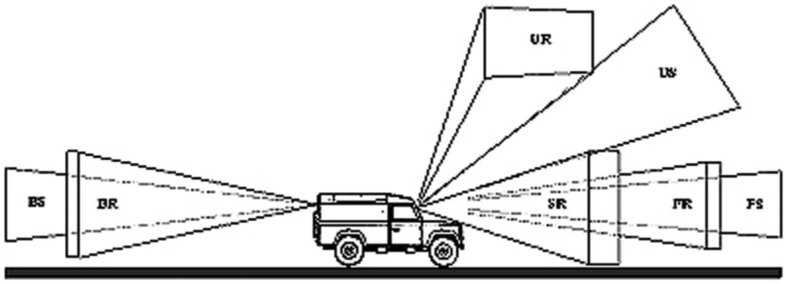

Figure D.2 — Side view of communication zones

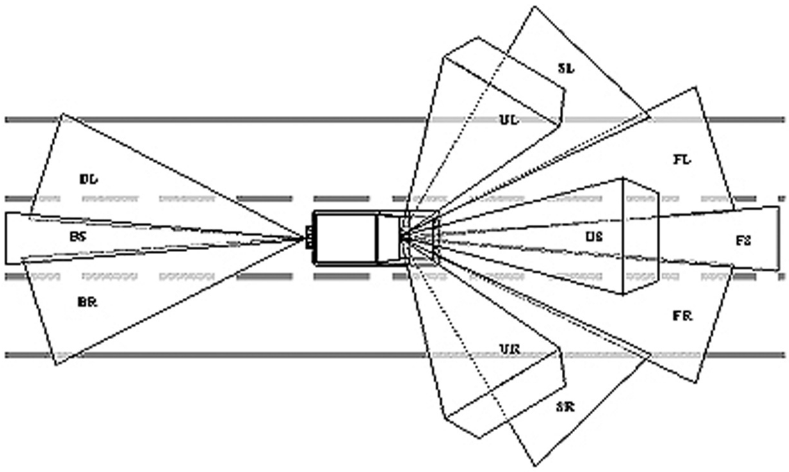

Figure D.3 — Ground view of communication zones

Annex E
(informative)

Compatibility of CALM and non-CALM infra-red 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, some completely proprietary.

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

When defining this International Standard, it was one of the essential requirements that the above systems be able at least 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 be 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 this airtime to be used 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 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

There are two key issues when synchronisation between CALM-IR and non-CALM-IR systems is required.

— The non-CALM-IR system must 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 colocated) 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 must be able to recognise 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

  — either by the master of the “non-CALM” system (in case step 1 had been performed “by wire”).

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

E.2.2.2 Creation of sufficient airtime for non-CALM-IR systems

It is evident that the compatibility window uses airtime of the frame.

If even the longest allowed frame is occupied by too many private windows so not sufficient airtime 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 need 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, four non-CALM infra-red systems which may coreside 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:

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 E.2.2.4, 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 coresiding CALM-IR and non-CALM-IR systems, the following conditions shall be fulfilled.

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

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

c) The 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) The 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 recognise 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, they shall be installed so that their beacon communications areas may not overlap one another, regardless of a) to e).

Bibliography

[1] IEC 60825-12, *Safety of laser products — Part 12: Safety of free space optical communication systems used for transmission of information*

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