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Telecommunications and information exchange between systems — Unmanned aircraft area network (UAAN) —

Part 3:
Physical and data link protocols for control communication

Télécommunications et échange d'information entre systèmes — Réseau de zone de drones (Unmanned aircraft area network - UAAN) —

Partie 3: Protocoles de liaison de données et physiques pour la communication de contrôle

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Foreword

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A list of all parts in the ISO/IEC 4005 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

Unmanned aircrafts (UAs) operating at low altitudes will provide a variety of commercial services in the near future. UAs that provide these services are distributed in the airspace. In low uncontrolled airspace, many people operate their own UAs without the assignment of communication channels from a central control centre.

This document describes control communication, which is a wireless distributed communication. Control communication allows control pairs of UA and controller distributed over the airspace to communicate with each other without serious interference. The channel used for control communication has a multi-channel structure, which enables UAs and controllers to independently use the communication link occupied by each other. A wireless distributed communication described by this document is intended to be used in licensed frequency bands.

The ISO/IEC 4005 series consists of the following four parts:

ISO/IEC 4005-1:	To support various services for UAs, it describes a wireless distributed communication model and the requirements that this model shall satisfy.
ISO/IEC 4005-2:	It describes communication in which all units involved in UA operation can broadcast or exchange information by sharing communication resources with each other.
ISO/IEC 4005-3	(this document): It describes the control communication for the controller to control the UA.
ISO/IEC 4005-4:	It describes video communication for UAs to send video to a controller.

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Telecommunications and information exchange between systems — Unmanned aircraft area network (UAAN) —

Part 3:
Physical and data link protocols for control communication

1 Scope

This document specifies communication protocols for the physical and data link layer for control communication, which is wireless distributed communication network for units related with unmanned aircrafts (UAs) in level II.

This document describes control communication, which is one-to-one communication between a UA and a controller.

2 Normative references

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

ISO/IEC 4005-1, *Telecommunications and information exchange between systems — Unmanned aircraft area network (UAAN) — Part 1: Communication model and requirements*

ISO/IEC 4005-2:2023, *Telecommunications and information exchange between systems — Unmanned aircraft area network (UAAN) — Part 2: Physical and data link protocols for shared communication*

ISO/IEC 4005-4, *Telecommunications and information exchange between systems — Unmanned aircraft area network (UAAN) — Part 4: Physical and data link protocols for video communication*

ISO 21384-4, *Unmanned aircraft systems — Part 4: Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions defined in ISO/IEC 4005-1, ISO/IEC 4005-2, ISO 21384-4 and the following apply.

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

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org/

3.1
subchannel map
2-bit string indicating whether subchannels are available

Note 1 to entry: In wireless distributed communication, the subchannel map of each unit is generally different.

4 Abbreviated terms

CC	Control Communication

CRC	Cyclic Redundancy Check
CSCH	Control Subchannel
DLL	Data Link Layer
DS	Dedicated Slot
FN	Frame Number
IWR	Initial Work Resource
LFSR	Linear Feedback Shift Register
PB	Parsing Block
PKH	Packet Header
PN	Pseudo Noise
SA	Source Address
SC	Shared Communication
TSB	Tone Slot Block
TX	Transmission
UTC	Coordinated Universal Time
VC	Video Communication
VSCH	Video Subchannel

5 Physical layer

5.1 Channel and frame structure for data channel

5.1.1 Number of data channels and bandwidth

The number of data channels is *N* as shown in Figure 1. *N* is greater than or equal to one. The bandwidth of one data channel is 1,25 MHz. The *N* is determined in the upper layer.

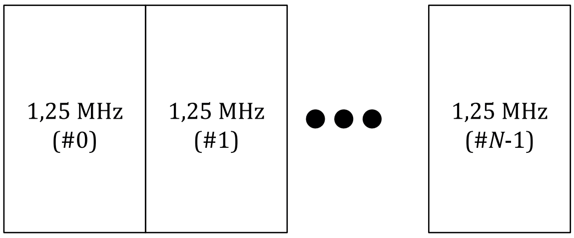
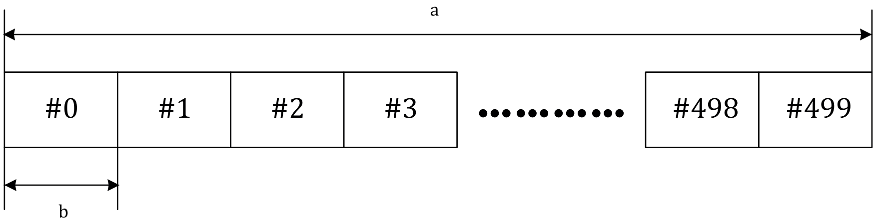


Figure 1 — Data channels in frequency region

5.1.2 Frame structure

The frame length of the data channel is 1 sec and consists of 500 slots and one slot time T_S is 2 ms as shown in Figure 2. *FN* is a frame number that varies from 0 to 59 and has the same value as the second of the current time.



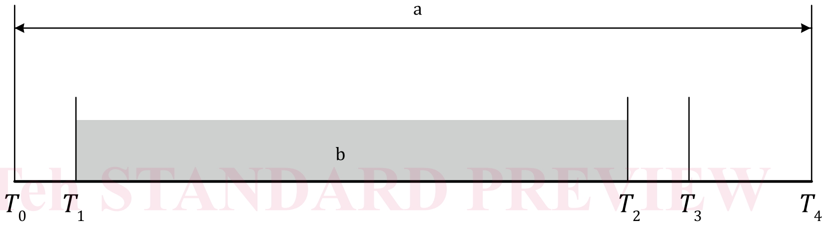
ᵃ 1 frame, T_f = 1 sec = 500 $T_{s.}$

ᵇ 1 slot, T_s = 2 ms.

Figure 2 — Frame structure of the control channel

5.1.3 Slot transmit time mask

The transmission time mask of a slot is shown in Figure 3.



ᵃ 2 ms.

ᵇ Modulated signal.

Figure 3 — The transmission time mask of a slot

T_1, T_2, T_3, T_4 are symbol offsets from T_0 and symbol time is 1/672000 sec. Each value is as follows: T_1 is 2, T_2 is 1297, T_3 is 1299, T_4 is 1344.

T_0 is 0 µs as the start time of the slot and the power amplifier is gated on and unmodulated fine signals begin to be transmitted. T_1 is an offset at which modulation signal transmission starts. T_2 is an offset at which the transmission of the modulated signal ends. T_3 is an offset at which the power amplifier is gated off, and transmission of unmodulated fine signals is stopped. The transmit power of T_0 to T_1, T_2 to T_3 shall be at least 50 dB less than the modulation signal transmit power.

5.1.4 Subchannels

5.1.4.1 General

One data channel consists of 20 subchannels as shown in Figure 4. Subchannel *y* of control channel *x* is composed of the following slot set.

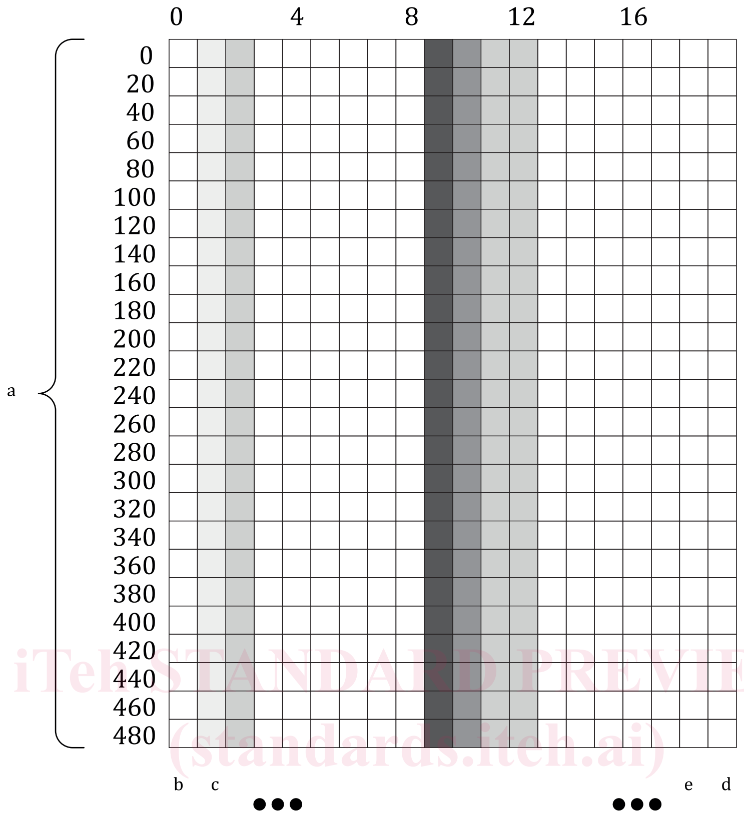
$$CCH_{x,y} = S_{x,z}, S_{x,z+20}, S_{x,z+40}, \ldots, S_{x,z+480}$$

$$z = \begin{matrix} y, & evenframe \\ y + 2 - \lfloor (y \bmod 4)/2 \rfloor \times 4, & oddframe \end{matrix} \qquad (1)$$

where

y is subchannel number, y=0, 1, ..., 19;

$S_{x,z}$ is slot z of control channel x.



a CCH_x

b $CCH_{x,0}$

c $CCH_{x,1}$

d $CCH_{x,18}$

e $CCH_{x,19}$

Figure 4 — Subchannel structure of control communication in even frame

A subchannel consists of 25 slots, the *i*-th slot resource of the subchannel y of the channel x is indicated by $SR_{x,y,\mathrm{i}}$ and the subchannel y of frequency channel x is indicated by $CCH_{x,y}$. Therefore, $CCH_{x,y}$ *is* as follows.

$$CCH_{x,y} = SR_{x,y,0}, SR_{x,y,1}, \ldots, SR_{x,y,24} \tag{2}$$

where $SR_{x,y,i}$ is i-th slot resource of subchannel y of channel x, i=0, ..., 24.

5.1.4.2 Up and down link decision of slot resources

For $SR_{x,y,i}$, 5 slots satisfying (i *mod* 5) =(FN *mod* 5) are downlink and remain 20 slots are uplink, where *mod* means modulo operation.

5.1.5 Initial work resources (IWR) and channel

The upper layer can set the initial work resource (IWR) as follows, and the use of the IWR is determined by the upper layer.

Four subchannels of frequency channel N_IWR, $CCH_{\mathrm{N\_IWR},16}$, $CCH_{\mathrm{N\_IWR},17}$, $CCH_{\mathrm{N\_IWR},18}$, $CCH_{\mathrm{N\_IWR},19}$ are designated as initial work channels. They are newly named $IWRCH_0$, $IWRCH_1$, $IWRCH_2$, $IWRCH_3$ respectively. These four initial work channels are not used for control, but are initially used to allocate control subchannels (CSCHs) between the UA and the controller, where N_IWR is received from the upper layer with UPtoDL.InfoIWRSlot.

The 25 slots of $IWRCH_y$ are divided into five IWRs in order.

$$IR_{y,i} = ISR_{x,5i}, ISR_{x,5i+1}, ISR_{x,5i+2}, ISR_{x,5i+3}, ISR_{x,5i+4} \tag{3}$$

where

y	is an *IWRCH* number and has the value from 0 to 3;
$ISR_{x,y,i}$	is *i*-th slot resource of $IWRCH_y$.

5.1.6 Dedicated slots and dedicated subchannels

The upper layer can pre-determine one or more subchannels as dedicated subchannels. In this case, the tone subslot sets mapped with the dedicated subchannel is not used as a competition tone and can be used for other purposes. Slots in the dedicated subchannel are used as dedicated slots (DSs). One or several dedicated slots can be assigned to UAs and controllers in advance. UAs and controllers use the dedicated slots without competition.

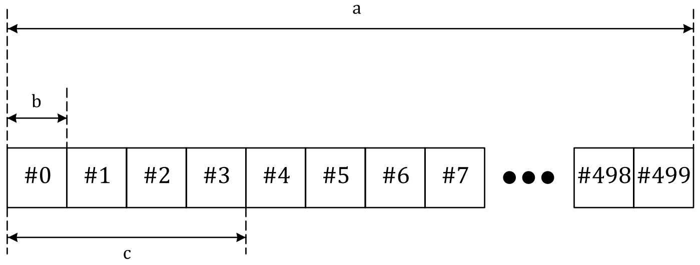
It is recommended to set the dedicated subchannel in frequency channel N_IWR.

Dedicated subchannel information and dedicated slot information are received from an upper layer through UPtoDL.InfoDedicatedChannel and UPtoDL.InfoDedicatedSlot.

5.2 Channel and frame structure for tone channel

5.2.1 Frame structure and bandwidth

The tone channel of the control communication indicates a competitive tone channel. The frame length of tone channel is 1 sec and the number of slots per frame is 500. Four tone slots constitute one tone slock block (TSB). Thus, there are 125 TSBs in one second frame as shown in Figure 5.



a 1 frame, T_f = 1 second = 500 T_s.

b 1 slot, T_s = 2 ms.

c 1 slot block, T_{sb} = 8 ms.

Figure 5 — Frame structure of tone channel in control communication

The bandwidth of the tone channel is 250 kHz. *FN* is a frame number that varies from 0 to 59 and has the same value as the second of the current time.

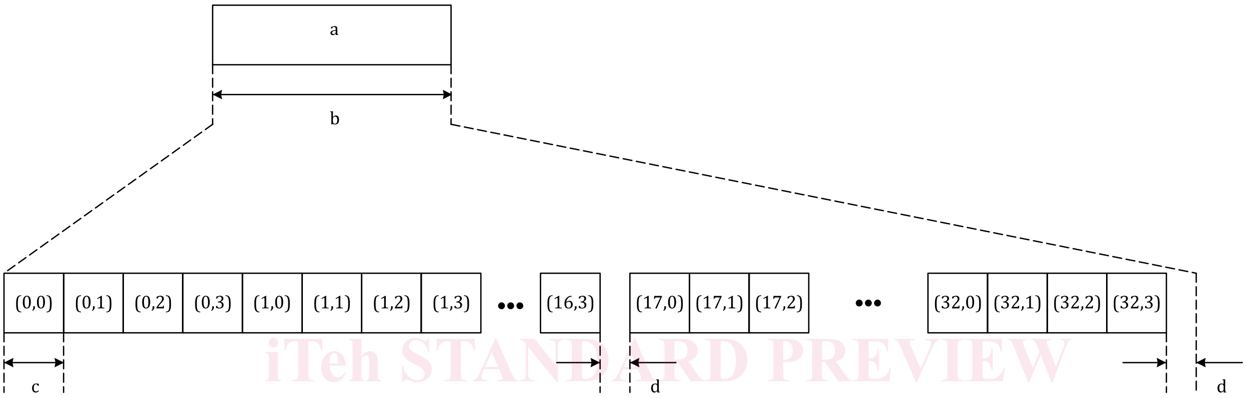
5.2.2 Slot transmit power

The maximum slot transmission power of the tone channel, PmaxTCH, is received as UPtoDL. InfoPowerParamCCH from the upper layer. The transmission power of the tone subslot signal is determined by adding the PTX_CCHTCH_differ value to the transmission power of the mapped CSCH.

5.2.3 Slot block structure

There are three types of slot blots. TSBtype0, TSBtype1, TSBtype2 are these. The type of each slot blot of the TCH is received from the upper layer as UPtoDL.InfoTSBTypeMap.

There are 132 subslots in one slot block of TSBtype0. The length T_{ss} of the subslot is 60 µs. The 132 subslots are divided into four parts, as shown in Figure 6, according to each slot numbers.



a	Type 0.
b	1 slot block, T_{sb} = 8 ms.
c	T_{ss} = 60 µs.
d	40 µs.

Figure 6 — Type 0 TSB structure

In case of TSBtype0, n-th slot block is composed as follows.

— $(0, 4n), (0, (4n + 1)), (0, (4n + 2)), (0, (4n + 3)), (1, 4n), (1, (4n + 1)), (1, (4n + 2)), (1, (4n + 3)),\ldots, (32, 4n), (32, (4n + 1)), (32, (4n + 2)), (32, (4n + 3))$

where (x, y) is the x-th subslot of the y-th subslot set. The 132 subslots are divided into four subslot sets.

— $\{S_{4n}\} = \{(0, 4n), (1, 4n), \ldots, (32, 4n)\}$

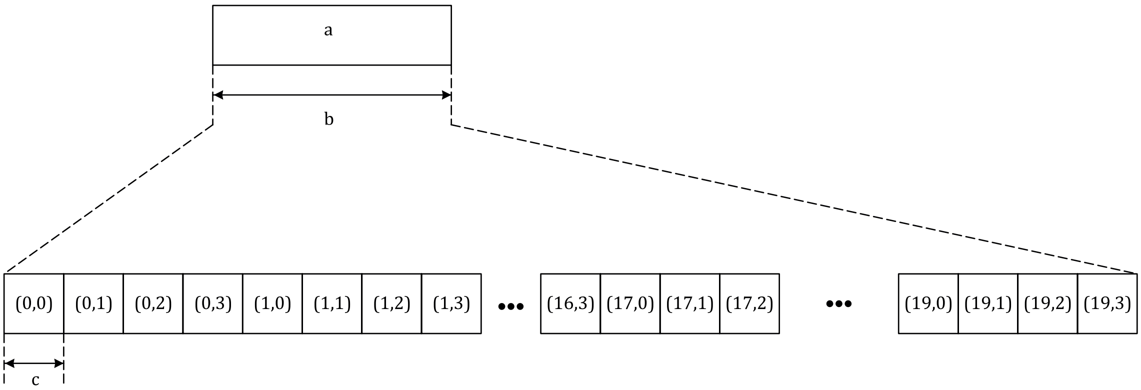
— $\{S_{4n+1}\} = \{(0, (4n + 1)), (1, (4n + 1)), \ldots, (32, (4n + 1))\}$

— $\{S_{4n+2}\} = \{(0, (4n + 2)), (1, (4n + 2)), \ldots, (32, (4n + 2))\}$

— $\{S_{4n+3}\} = \{(0, (4n + 3)), (1, (4n + 3)), \ldots, (32, (4n + 3))\}$

where $\{S_x\}$ is the x-th subslot set.

There are a total of 80 subslots in TSBtype1. The length T_{ss} of the subslot is 100 µs. The 80 subslots are divided into four parts, as shown in Figure 7, according to each slot number.



[a] Type1.

[b] 1 slot block, T_{sb} = 8 ms.

[c] T_{ss} = 100 µs.

Figure 7 — Type 1 TSB structure

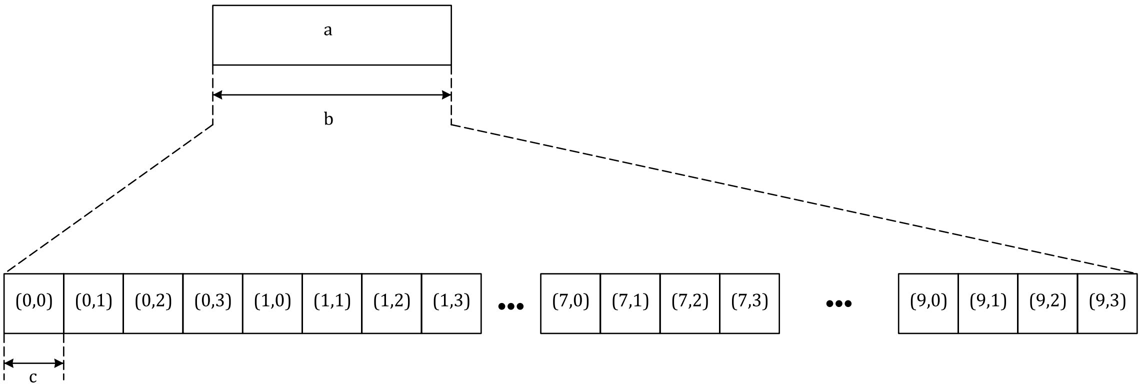
The *n*-th slot block that belongs to TSBtype1 is composed of the following subslot combinations.

- $(0, 4n), (0, (4n + 1)), (0, (4n + 2)), (0, (4n + 3)), (1, 4n), (1, (4n + 1)), (1, (4n + 2)), (1, (4n + 3)),\ldots , (19, 4n), (19, (4n + 1)), (19, (4n + 2)), (19, (4n + 3))$

The 80 subslots make up four subslot sets.

- $\{S_{4n}\} = \{(0, 4n), (1, 4n), \ldots, (19, 4n)\}$
- $\{S_{4n+1}\} = \{(0, (4n + 1)), (1, (4n + 1)), \ldots, (19, (4n + 1))\}$
- $\{S_{4n+2}\} = \{(0, (4n + 2)), (1, (4n + 2)), \ldots, (19, (4n + 2))\}$
- $\{S_{4n+3}\} = \{(0, (4n + 3)), (1, (4n + 3)), \ldots, (19, (4n + 3))\}$

There are a total of 40 subslots in TSBtype2. The length T_{ss} of the subslot is 200 µs. The 40 subslots are divided into four parts, as shown in Figure 8, according to each slot numbers.



[a] Type2.

[b] 1 slot block, T_{sb} = 8 ms.

[c] T_{ss} = 200 µs.

Figure 8 — Type 2 TSB structure

The *n*-th slot block that belongs to TSBtype2 is composed of the following subslot combinations.

— $(0, 4n)$, $(0, (4n + 1))$, $(0, (4n + 2))$, $(0, (4n + 3))$, $(1, 4n)$, $(1, (4n + 1)~)$, $(1, (4n + 2))$, $(1, (4n + 3))$,... , $(9, 4n)$, $(9, (4n + 1))$, $(9, (4n + 2))$, $(9, (4n + 3))$

The 40 subslots make up four subslot sets.

— $\{S_{4n}\} = \{(0, 4n), (1, 4n), ..., (9, 4n)\}$

— $\{S_{4n+1}\} = \{(0, (4n + 1)), (1, (4n + 1)), ..., (9, (4n + 1))\}$

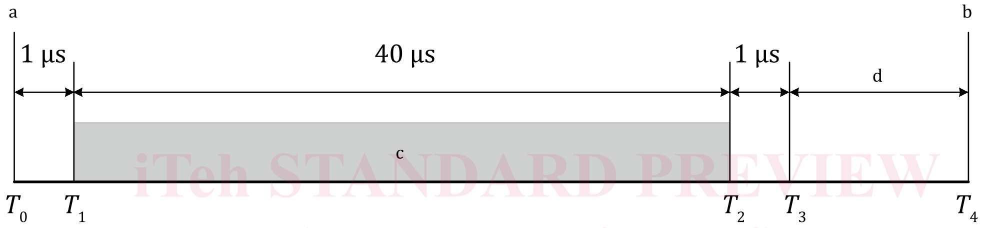
— $\{S_{4n+2}\} = \{(0, (4n + 2)), (1, (4n + 2)), ..., (9, (4n + 2))\}$

— $\{S_{4n+3}\} = \{(0, (4n + 3)), (1, (4n + 3)), ..., (9, (4n + 3))\}$

Regardless of the type of TSB, there are a total of 500 subslot sets in one frame.

5.2.4 Subslot transmission time mask

Subslot transmission time mask is shown in Figure 9.



Key

T_0	0 µs
T_1, T_2, T_3, T_4	time offsets from T_0
a	Subslot start.
b	Subslot end.
c	Tone signal.
d	Guard time.

Figure 9 — Subslot transmission time mask

T_1, T_2, T_3, and T_4 are time offsets from T_0. T_1 is 1 µs, T_2 is 41 µs, and T_3 is 42 µs.

In TSBtype0, T_4 is 60 µs, guard time is 18 µs.

In TSBtype1, T_4 is 100 µs, guard time is 58 µs.

In TSBtype2, T_4 is 200 µs, guard time is 158 µs.

T_0 is the time when the power amplifier is gated on, and unmodulated fine signals begin to be transmitted. T_1 is the time at which transmission of the modulated signal begins. T_2 is the time at which transmission of the modulated signal is terminated. T_3 is the time when the power amplifier is gated off and the transmission of unmodulated fine signals is stopped. The transmission power of the time region from T_0 to T_1 and the transmission power of the time region from T_2 to T_3 shall be 50dB or more less than the modulated signal transmission power.

5.2.5 Subslot signal waveform

The subslot signal waveform is the same as that of shared communication. See ISO/IEC 4005-2:2023, 5.1.2.3.

The modulation scheme of subslot signal is on-off keying. The subslot signal is started at T_1 and transmitted during the 40 µs interval. The waveform of the subslot transmission signal uses a raised cosine function. The subslot signal is generated by the following formula.

$$g(t;\alpha)=\frac{\cos(\pi\alpha(t-2T))}{1-(2\alpha(t-2T)/T)^2}\operatorname{sin}c\left(\frac{(t-2T)}{T}\right),\qquad 0\leq t\leq 4T \tag{4}$$

where

α is 0,75 as a roll-off factor;

T is 10 µs as a raised cosine period.

5.3 Encoding procedure

The encoding procedure is identical with that of shared communication. See ISO/IEC 4005-2:2023, 5.2.

The final encoded signal is located between T_1 and T_2 in Figure 3, i.e. in the modulated signal part.

5.4 Physical layer procedure

5.4.1 Synchronization

All messages shall be transmitted based on UTC absolute time. All times are measured on UTC.

The synchronization mode of the unit includes 'A sync', 'B sync' and 'C sync'.

- A sync is synchronization obtained from UTC.
- B sync is secondary synchronization acquired from the synchronization signal of the A sync unit.
- C sync is sync status within 20 sec after sudden loss of sync in A or B sync mode.

A sync unit shall know the date, hour, minute, second, slot number.

The time error of A sync shall be within ±0,4 µs. The time error of B sync shall be within ±4 µs. The time error of C sync shall be within ±5 µs.

The frequency error of A sync shall be within ±0,1 ppm. The frequency error of the B sync shall be within ±0,2 ppm. The frequency error of the C sync shall be within ±0,3 ppm.

5.4.2 Subchannel power

The maximum power of the CSCH, PmaxCCH, is received as UPtoDL.InfoPowerParamCCH from the upper layer. The maximum transmission power and minimum transmission power of each CSCH are received from the upper layer as UPtoDL.InfoPowerParamCCHsub. The power control of each CSCH is described in the resource allocation procedure.

5.4.3 Measurements

The physical layer shall have the ability to measure the following parameters. The received signal power of a tone subslot, the received signal power of a data slot, and propagation delay time of the received data signal shall be measured. The receiving power determination point shall be the receiving antenna connector.

5.4.4 Coexistence operation

If the hardware of shared communication described in ISO/IEC 4005-2 and the hardware of control communication described in this document and the hardware of video communication described in