INTERNATIONAL STANDARD

ISO/IEC 4005-2

First edition
2023-03

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

Part 2: Physical and data link protocols for shared communication

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

Partie 2: Protocoles de liaison de données et physiques pour la communication partagée

Reference number
ISO/IEC 4005-2:2023(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

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

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

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

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html. In the IEC, see www.iec.ch/understanding-standards.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*.

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 altitude will provide a variety of commercial services in the near future. UAs that provide these services are distributed in the airspace. In level II, many people operate their own UAs without the assignment of communication channels from a central control centre.

This document describes shared communication, which is a wireless distributed communication. Shared communication allows all units related with UAs to communicate with UAs when necessary. Shared communication can support communication between UAs, UAs and controllers, UAs and ground equipment, UAs and landing devices, and UAs and obstacle devices. 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 (this document): It describes communication in which all units involved in UA operations can broadcast or exchange information by sharing communication resources with each other.

— ISO/IEC 4005-3: 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.

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of patents.

ISO and IEC take no position concerning the evidence, validity and scope of these patent rights.

The holders of these patent rights have assured ISO and IEC that they are willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statements of the holders of these patent rights are registered with ISO and IEC. Information may be obtained from the patent database available at www.iso.org/patents.

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

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

Part 2: Physical and data link protocols for shared communication

1 Scope

This document describes communication protocols for the physical and data link layer of shared communication, which is a wireless distributed communication network for units related with UAs in level II.

Physical layer includes frame structure, encoding procedure, physical layer procedure and coexistence operations. Data link layer includes channel and slot, resource management, broadcast and exchange of data, synchronization, security, and interface with upper layer and other communication layers.

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 4005-3:2023, *Telecommunications and information exchange between systems — Unmanned aircraft area network (UAAN) — Part 3: Physical and data link protocols for control communication*

ISO/IEC 4005-4:2023, *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 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
broadcast slot
slot used to broadcast the information of a unit

3.2
data slot block
block in which multiple slots are grouped together for efficient resource allocation

3.3
linearization slot
slot used to maintain the linearity of the power amplifier

3.4
response clearing
transmission of a tone signal in subslot 0 of the subslot set corresponding to the same slot of this frame, in order to respond to a talk packet received in a slot of the previous frame

3.5
slot block
block in which four slots are grouped together to perform efficient competition

3.6
super frame slot
slot with a frame period greater than one second

3.7
talk slot
slot used to exchange information with a specific counterpart

3.8
tone slot block
block in which multiple slots are grouped together to perform efficient competition

4 Abbreviated terms

CC	Control Communication
CRC	Cyclic Redundancy Check
CSCH	Control Subchannel
DL	Data Link
DLL	Data Link Layer
DQPSK	Differential Quadrature Phase Shift Keying
GF	Galois Field
LFSR	Linear Feedback Shift Register
PCCC	Parallel Concatenated Convolutional Code
PB	Parsing Block
PF	Parsing Field
PN	Pseudo Noise
SA	Source Address
SC	Shared Communication
SRRC	Square Root Raised Cosine
TX	Transmission
UTC	Coordinated Universal Time

VC Video Communication

VSCH Video Subchannel

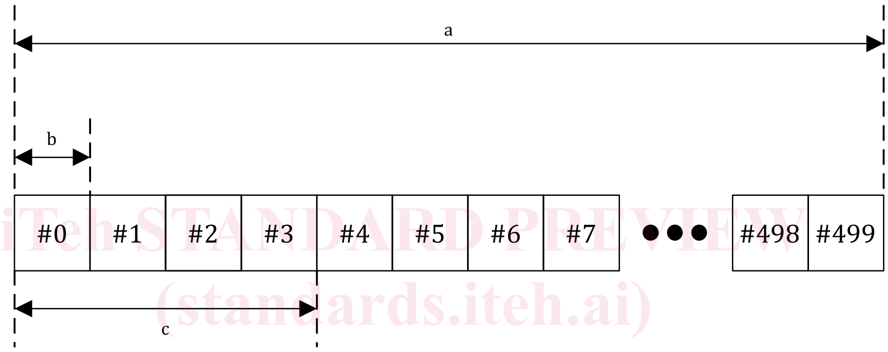
5 Physical layer

5.1 Physical layer frame structure

5.1.1 Data channel

5.1.1.1 Frame structure

The frame length of the data channel is 1 second and consists of 500 slots. The one slot time T_s is 2 ms. A data slot block has four slots. Therefore, there are 125 slot blocks in one frame, and the slot block is 8 ms in length as shown in Figure 1. The frame number changes from 0 to 59 in 1 min interval.



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

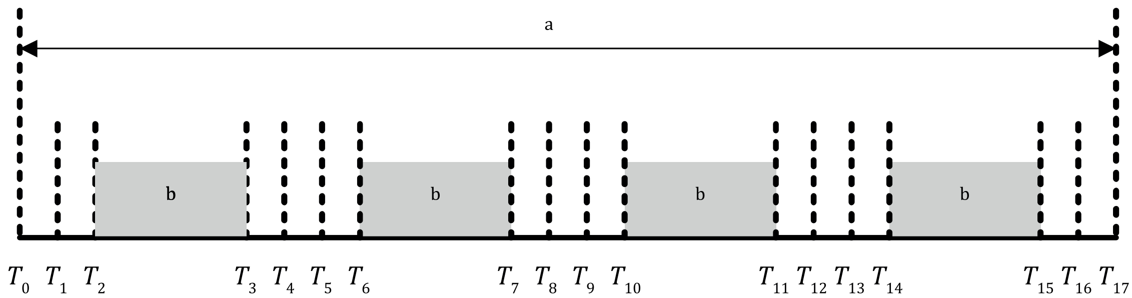
[b] 1 slot, T_s=2 ms.

[c] 1 slot block, T_{sb}=8 ms=4 T_s.

Figure 1 — Data channel frame structure

5.1.1.2 Slot block transmit time mask

The transmission time mask of a slot block is shown Figure 2.



Key

T_0	0 µs
T_1, T_2, ..., T_{17}	symbol time offsets from T_0
a	8 ms.
b	Modulated signal.

Figure 2 — Transmission time mask of a slot block

T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{17} are symbol offsets from T_0, and symbol time is 1/672000 second. Each value is as follows.

T_1 is 152, T_2 is 154, T_3 is 1449, T_4 is 1451, T_5 is 1456.5, T_6 is 1459.5, T_7 is 2754.5, T_8 is 2756.5, T_9 is 2763, T_{10} is 2765, T_{11} is 4060, T_{12} is 4062, T_{13} is 4068.0, T_{14} is 4070.5, T_{15} is 5365.5, T_{16} is 5366.5, T_{17} is 5376.

T_0 is 0 µs as the start time of the slot block. T_1, T_5, T_9 and T_{13} are offsets when the power amplifier is gated on, and unmodulated fine signals begin to be transmitted. T_2, T_6, T_{10}, and T_{14} are offsets at which modulation signal transmission starts. T_3, T_7, T_{11}, and T_{15} are offsets at which the transmission of the modulated signal ends. T_4, T_8, T_{12}, and T_{16} are offsets at which the power amplifier is gated off, and transmission of unmodulated fine signals is stopped. The transmit powers of T_1 to T_2, T_3 to T_4, T_5 to T_6, T_7 to T_8, T_9 to T_{10}, T_{11} to T_{12}, T_{13} toT_{14} and T_{15} to T_{16} shall be at least 50 dB less than the modulation signal transmit power.

5.1.2 Tone channel

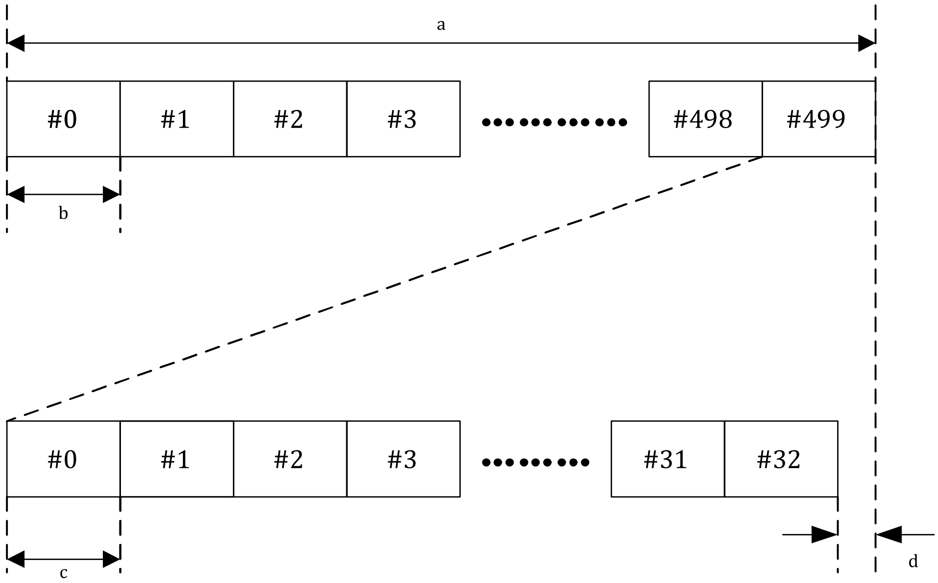
5.1.2.1 Frame structure

5.1.2.1.1 General

There are two types of tone channels. One is a competition tone channel and the other is an information tone channel. The competition tone channel is used for resource allocation, occupation, and management operations. Information tone channels are used to convey simple information. In this document, the frame structure for the information tone channel is described, but whether and how to use the information tone channel is determined by the upper layer.

5.1.2.1.2 Information tone channel frame structure

The frame length of information tone channel is 1 sec and the number of slots per frame is 500. One slot is divided into 33 subslots, and the length T_{ss} of a subslot is 60 µs as shown in Figure 3. The information given to each subslot is determined by the upper layer. SS_x means the x-th subslot (see Annex G).



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

[b] 1 slot, T_s = 2 ms.

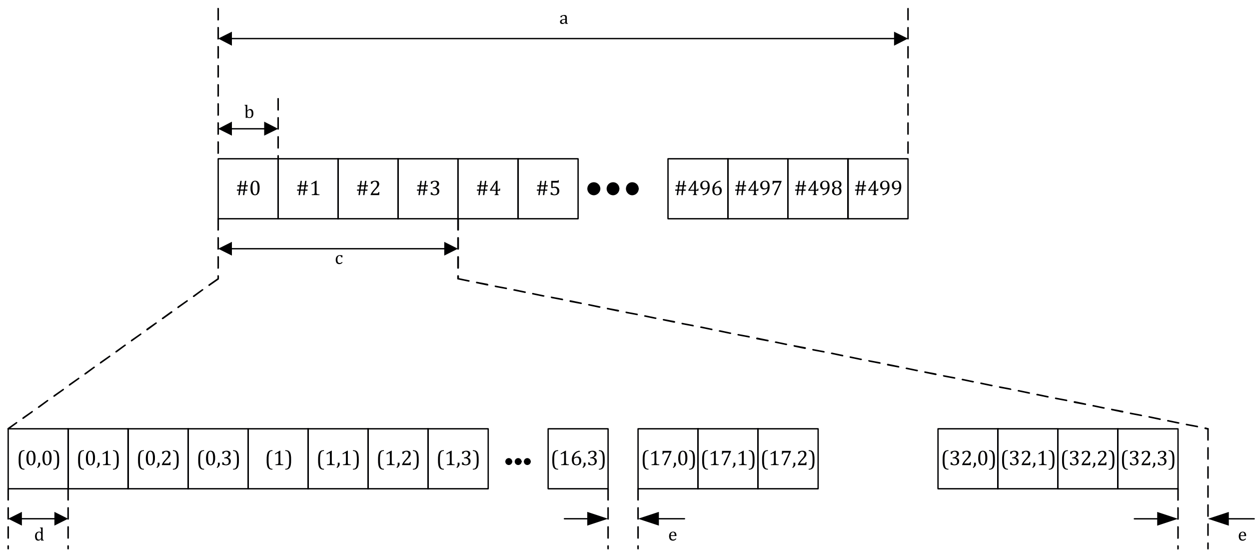
[c] T_{ss} = 60 µs.

[d] 20 µs.

Figure 3 — Frame structure of information tone channel

5.1.2.1.3 Competition tone channel frame structure

The frame length of competition tone channel is 1 sec and the number of slots per frame is 500. Four tone slots constitute one slock block. Thus, there are 125 slot blocks in one second frame. There are a total of 132 subslots in one slot block. The length T_{ss} of the subslot is 60 µs. The 132 subslots are divided into four parts, as shown in Figure 4, according to each slot numbers.



[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.

[d] T_{ss} = 60 µs.

[e] 40 µs.

Figure 4 — Frame structure of competition tone channel

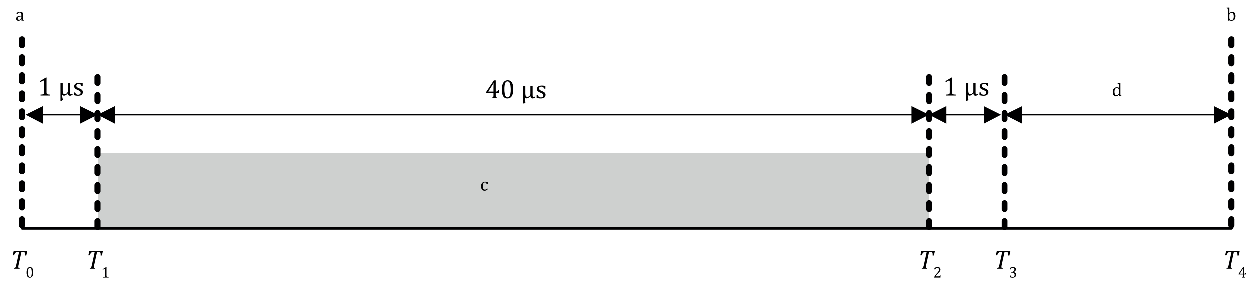
The *n*-th slot block is composed of the following subslots.

— (0, 4*n*), (0, (4*n* + 1)), (0, (4*n* + 2)), (0, (4*n* + 3)), (1, 4*n*), (1, (4*n* + 1)), (1, (4*n* + 2)), (1, (4*n* + 3)),... , (32, 4*n*), (32, (4*n* + 1)), (32, (4*n* + 2)), (32, (4*n* + 3))

where (*x*, *y*) is the *x*-th subslot of the *y*-th subslot set. The 132 subslots constitute 4 subslot sets.

5.1.2.2 Subslot transmit time mask

Subslot transmission time mask is shown in Figure 5.



Key

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

T_3 is 42 µs

T_4 is 60 µs

T_0 is the start time of the subslot, the power amplifier is gated on and the unmodulated fine signal starts 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

a Subslot start.

b Subslot end.

c Tone signal.

d Guard time.

Figure 5 — Subslot transmission time mask

The transmission power between T_0 and T_1 and between T_2 and T_3 shall be 50 dB less or less than the maximum transmission power of the modulated signal.

5.1.2.3 Subslot signal waveform

The modulation scheme of subslot signal is on-off keying. The subslot transmission signal is transmitted in the 40 µs interval from T_1 to T_2 in Figure 5. The waveform of the subslot transmission signal uses a raised cosine function. The subslot signal is generated by the following formula.

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

where

α is 0,75 as a roll-off factor;

T is 10 µs as a raised cosine period.

See Annex D.

5.2 Encoding procedure

The encoding follows the following procedure as shown in Figure 6. CRC encoding, turbo coding, rate matching, interleaving, modulation mapping, burst mapping, and pulse mapping are performed in this order.

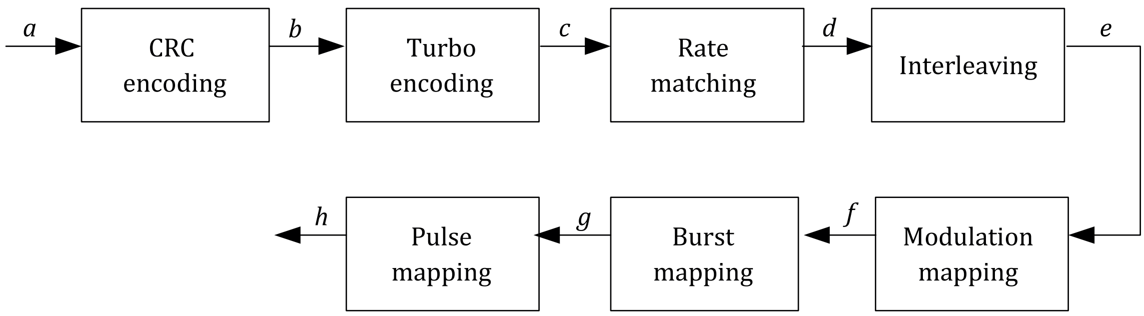


Figure 6 — Encoding procedure

The number of symbols according to each encoding stage is shown in Table 1.

Table 1 — Number of symbols at each encoding stage

Stage	Number of symbols
a	792 (binary)
b	816 (binary)
c	2460 (binary)
d	2432 (binary)
e	2432 (binary)
f	1216 (Complex)
g	1288 (Complex)
h	1295×OS (Complex)

5.2.1 CRC encoding

The input bits are defined as $a_0, a_1, a_2, a_3, ..., a_{A-1}$ and parity bits as $p_0, p_1, p_2, p_3, ..., p_{23}$ where, A represents the number of input sequences. Parity bits are generated through CRC generation polynomial as follows.

$$g_{CRC}(D) = D^{24} + D^{22} + D^6 + D^5 + D + 1 \quad (2)$$

The encoding performed through the cyclic generator polynomials has a systematic form as follows. The resulting polynomial has zero remainder when it is divided by $g_{CRC}(D)$ on GF(2).

$$a_0D^{A+23} + a_1D^{A+22} + ... + a_{A-1}D^{24} + p_0D^{23} + p_1D^{22} + ... + p_{22}D^1 + p_{23} \quad (3)$$

After CRC insertion, bits are represented by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ (where $B = A + 24$), and the relationship between a_k and b_k is as follows.

$$b_k = \begin{cases} a_k, & for\, k = 0,1,2,\cdots,A-1 \\ P_{k-A}, & for\, k = A, A+1, A+2,\cdots,A+23 \end{cases} \quad (4)$$

5.2.2 Turbo encoding

The turbo encoder consists of Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one turbo coded internal interleaver. The coding rate of the turbo encoder is 1/3. The structure of the turbo encoder is shown in Figure 7. The PCCC transfer function is as follows:

$$G(D) = [1, g_1(D)/g_0(D)] \quad (5)$$

where $g_0(D) = 1+D^2+D^3$, $g_1(D) = 1+D+D^3$.

When the input bits of the turbo encoder are encoded, the initial values of the shift registers of the 8-state constituent encoder shall all be zero.

For $k = 0, 1, 2, ..., K$-1, the output value of the turbo encoder is expressed as follows:

$$c_{3k} = x_k$$

$$c_{3k+1} = z_k$$

$$c_{3k+2} = z'_k \qquad (6)$$

Output bits of the first and second 8-state constituent encoders for turbo encoder input bits $b_0, b_1, b_2, b_3, ..., b_{B-1}$ are $z_0, z_1, z_2, z_3, ..., z_{B-1}$ and $z'_0, z'_1, z'_2, z'_3, ..., z'_{B-1}$, and the output bits through the turbo code internal interleaver that is described in Annex A are represented by $b'_0, b'_1, b'_2, b'_3, ..., b'_{B-1}$ and these output bits are used as inputs for the second 8-state constituent encoder. The turbo code internal interleaver shall use Table A.1 in Annex A.

Trellis termination is performed by taking tail bits from shift register feedback after all information bits have been encoded. The generated tail bits are added after encoding of the information bits.

The first three tail bits are used for the first constituent encoder termination and not the second constituent encoder. The remaining three tail bits are used for the termination of the second constituent encoder and not the first constituent encoder.

The bits transmitted for trellis termination are determined as follows:

$$c_{3B} = x_B,\ c_{3B+3} = z_{B+1},\ c_{3B+6} = x'_B,\ c_{3B+9} = z'_{B+1}$$

$$c_{3B+1} = z_B,\ c_{3B+4} = x_{B+2},\ c_{3B+7} = z'_B,\ c_{3B+10} = x'_{B+2}$$

$$c_{3B+2} = x_{B+1},\ c_{3B+5} = z_{B+2},\ c_{3B+8} = x'_{B+1},\ c_{3B+11} = z'_{B+2} \qquad (7)$$