Technical note

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Multiplex data bus systems

Material for a standard extension of MIL-STD-1553B, Notice 2 for space applications: a preliminary proposal

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It is subject to changes and does not represent any agreement between the author of the document, ESA or any standardization organization.

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Foreword

This document is contains material for standardization.

Requirements in this document are defined in terms of what must be accomplished, rather than in terms of how to organise and perform the necessary work. This allows existing organisational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the document.

The formulation of this document takes into account the existing ISO 9000 family of documents.

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1
Scope

This document establishes requirements for exchange of information over MIL-STD-1553 data bus in spacecraft.

The purpose of these requirements is to minimize the interfacing variations across spacecraft to interface equipment one with the other through MIL-STD-1553 data bus.

The goal is to achieve interface compatibility and reusability across projects.

The scope of this document is limited to interface definition. It does not contain all the detailed requirements for concrete implementation of protocols in products.

2
Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of any of these publications do not apply. However, parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

ECSS-P-001	Glossary of terms.
MIL-STD-1553B Notice 2	Interface Standard for Digital Time Division Command/Response Multiplex Data Bus (5.1 "Application of MIL-STD-1553B")
MIL-HDBK-1553A Section 100	RT Validation Test Plan (Annex A.2 "Terminal verification"; Annex A.3 "Equipment verification")
AS 4113	Validation Test Plan for the Aircraft Internal Time Division Command/ Response Multiplex Data Bus Controllers (Annex A.2 "Terminal verification"; Annex A.3 "Equipment verification")
AS4117	Test Plan for the digital time division command/Response Multiplex Data Bus Couplers, Terminators, and Data Bus Cables (Annex A.4 "Bus network verification")
AS 4115	Test Plan for the Digital Time Division Command/Response Multiplex Data Bus system (Annex A.4 "Bus network verification")
ESCC Detail Specification No. 3401/052	Connectors, Electrical, Circular, Triple-start, Self-locking Coupling, Scoop-proof, Removable Crimp Contacts, Based on MIL-C-38999 Series III (Annex B.2 "Main bus line extension connectors")

ESCC Detail Specification No. 3401/066	Contacts, Electrical, Triax, Crimp for 3401/056 Connectors (Annex B.2 “Main bus line extension connectors”)
ESCC Detail Specification No. 3401/001	Connectors, Electrical, Rectangular, Non-removable solder bucket, PCB and Wire-Wrap Contacts and Removable Coaxial and Power Contacts, Based on Type D*M (Annex B.1.3 “Connectors with RT address contacts only”)
ESCC Detail Specification No. 3401/008	Connectors, Miniature, Electrical, Circular, Push-Pull Coupling, Removable Crimp Contacts, Based on Type DBAS (Annex B.1.1 “Connectors with data bus and RT address contacts”; Annex B.1.2 “Connectors with data bus contacts only”)
ESCC Detail Specification No. 3901/002	Polyimide Insulated Wires and Cables, Low Frequency, 600V, -100 TO +200 °C (6.3 ”Cabling”)

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3
Terms, definitions and abbreviated terms

3.1 Terms and definitions

3.1.1 Terms defined in MIL-STD-1553B Notice 2

This document makes use of the following terms defined in MIL-STD-1553B Notice 2:

a) data bus;

b) bus controller;

c) bus monitor;

d) message;

e) mode code;

f) remote terminal;

g) subsystem;

h) terminal.

3.1.2 Terms defined in this document

The following terms and definitions are specific to this standard in the sense that they are complementary or additional to those contained in ECSS-P-001 and MIL-STD-1553B Notice 2.

3.1.1
ambiguity

the characteristic or property whereby more than one possible interpretation, or measurement, or value satisfies the conditions stated

NOTE Example – Time ambiguity: A clock which displays 3 hours 5 minutes could be indicating that time for either A.M. or P.M. or for any days.

3.1.2
asynchronous event (wrt a reference)

event that is not synchronous wrt the considered reference

NOTE The term “synchronous” is defined in 3.1.27.

3.1.3
BC equipment

equipment that acts or may act as bus controller for the considered bus

3.1.4
data block

payload of a MIL-STD-1553 message which consists of up to 32 contiguous 16-bit words

3.1.5
data bus system

set of hardware, firmware, and software pieces that forms an autonomous whole capable of performing transfer of information over a data bus

3.1.6
data bus terminator

shielded resistor used to terminate the bus in its characteristic impedance

NOTE Examples of data bus terminators are shown in Figure 1

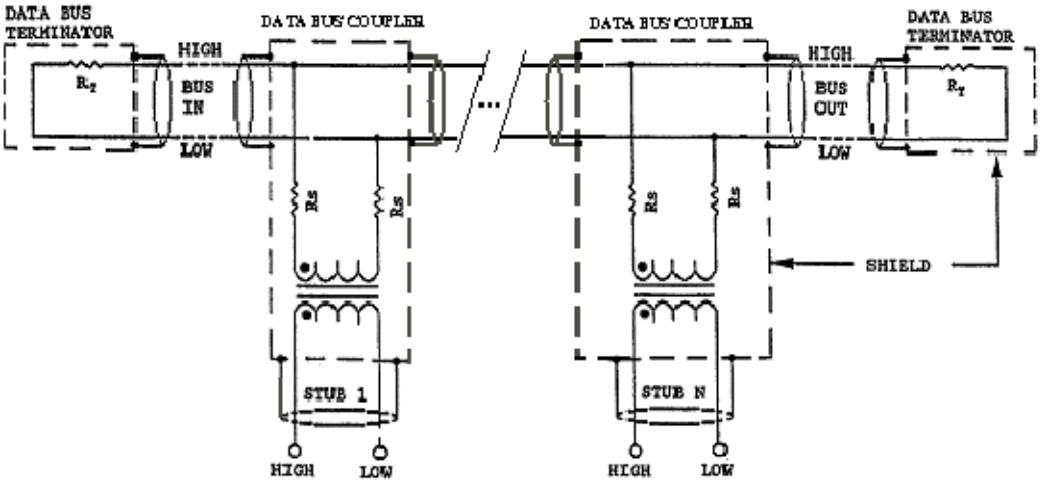


Figure 1: Transformer data bus couplers and data bus terminators

3.1.7
duplicated data block

data block received by subsystem on a logical channel that meets both of the following conditions:

a) the data block was not submitted two times consecutively by the sending subsystem on that logical channel;

b) the received data block is bitwise identical to the one that was previously received by the subsystem on that logical channel.

3.1.8
equipment

item designed and built to perform a specific function as a self-contained unit or to perform a function in conjunction with other units

NOTE An equipment encompasses terminal(s) and subsystem(s) parts as defined in MIL-STD-1553B Notice 2.

3.1.9
event

something that happens at a single point in time

3.1.10
function (in a layered system)

A part of the activity of entities within a given layer

NOTE Examples of functions are multiplexing, demultiplexing, segmentation, reassembly, sequence control, error control.

3.1.11
fractional frequency deviation

the difference between the actual frequency of a signal and a specified nominal frequency, divided by the nominal frequency.

NOTE Mathematically, the fractional frequency deviation y(t) can be expressed as $y(t) = \frac{f(t) - f_{nom}}{f_{nom}}$

3.1.12
frequency accuracy

the maximum magnitude of the fractional frequency deviation for a specified time period.

NOTE The frequency accuracy includes possible frequency offset from nominal frequency, ageing and environmental effects.

3.1.13
frame (in time division multiplexing)

set of consecutive time intervals in which the position of each time interval can be identified by reference to a frame alignment signal

NOTE An example of frame is shown in Figure 2

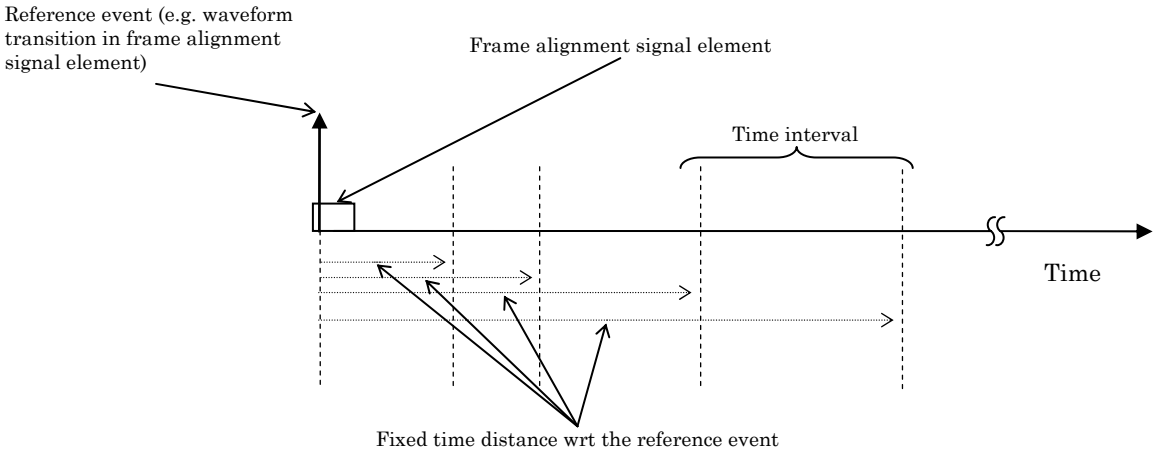


Figure 2: Example of frame

3.1.14
frame alignment signal

distinctive signal inserted in every frame or once in every *n* frames, always occupying the same relative position within the frame, and used to establish and maintain frame alignment

3.1.15
hamming distance

number of digit positions in which two binary numerals of the same length are different

NOTE For example the Hamming distance between 100101 and 101001 is two.

3.1.16
information transaction

coordinated sequence of user and communications system actions that cause information present at a source user to become present at a destination user

NOTE An information transaction over a MIL-STD-1553B data bus system may map with several MIL-STD-1553 transfers.

3.1.17
label

set of one or more bits within or attached to a set of data units, that contains information about the set, including its identification

3.1.18
labelled channel

temporally ordered collection of transmitted data units having a common label value

3.1.19
location in time

interval of arbitrary size in time at which an event can occur

3.1.20
logical channel (in MIL-STD-1553B data bus systems)

labelled channel associated to a MIL-STD-1553B data bus where (RT ADDRESS, T/R, SUBADRESS /MODE) is used as label

3.1.21
receive logical channel (in MIL-STD-1553B data bus systems)

logical channel associated to a MIL-STD-1553B data bus where T/R bit is equal to logic 0

3.1.22
removable data bus terminator

data bus terminator that can be disconnected and connected back with the data bus without damaging the data bus

3.1.23
recurring time interval

series of consecutive time intervals of the same duration or nominal duration

3.1.24
RT equipment

equipment that acts or may act as remote terminal on the considered bus

3.1.25
signal element

part of a signal and distinguished from the other parts constituting the signal by one or more characteristics such as nature, magnitude, duration or relative position

3.1.26
synchronization signal (of a data bus system)

nominally periodic signal, generated by a clock, used to control the timing of operations in a data bus system

NOTE Due to unavoidable disturbances, such as oscillator phase fluctuations, actual timing signals are pseudo-periodic ones, i.e. time intervals between successive equal phase instants show slight variations.

3.1.27
synchronous event (wrt a reference event)

event for which it exits a bounded time interval that is fixed wrt to the reference event and contains all potential instants of event occurrence.

NOTE 1 Figure 3 depicts an event B synchronous wrt a reference event A.

NOTE 2 The word synchronous describes the relationship between an event and a reference. It does not describe an independent characteristic of a single event.

NOTE 3 The synchronous relation is transitive:
If event B is synchronous wrt event A and event C is synchronous wrt event B then event C is synchronous wrt event A.
This property enables to consider sets of synchronous events (events that are synchronous one to the other).
This property enables also to qualify the relationship between a given event and a set of synchronous event (e.g. an event synchronous/asynchronous wrt a time scale).

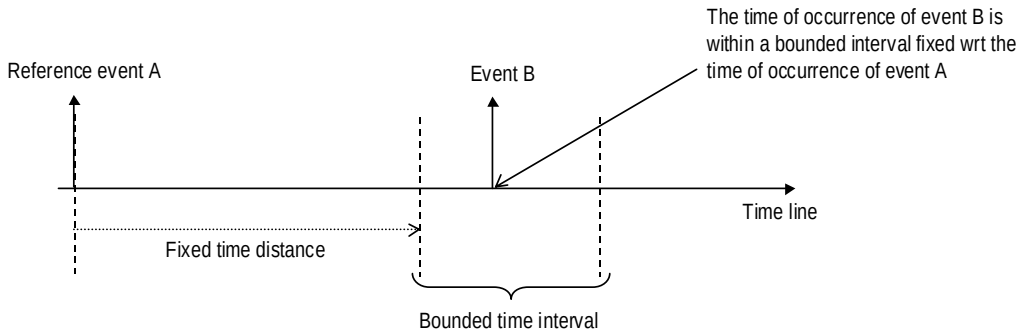


Figure 3: Synchronous events

3.1.28
time interval

The duration between two instants read on the same time scale

3.1.29
topology (of bus network)

interconnectivity of the data bus and their associated elements (terminals and controllers) to accomplish the desired data path required by the integration

3.1.30
transformer data bus coupler

circuit used to couple signals between the main bus cable and transformer coupled stub cables

NOTE 1 A single data bus coupler consists of a transformer, two isolation resistors, and a shielded enclosure.

NOTE 2 Examples of transformer data bus couplers are shown in Figure 1

3.1.31
transmit logical channel (of a MIL-STD-1553B data bus)

logical channel associated to a MIL-STD-1553B data bus where T/R bit is equal to logic 1

3.2 Abbreviated terms

The following abbreviations are defined and used within this standard.

BC	bus controller
BM	bus monitor
CW	command word
DW	data word
I/O	Input/Output
LSB	least significant bit
MA	MIL-STD-1533B adaptation
MSB	most significant bit
N/A	not applicable
N.C.	not connected
O	optional
PDU	protocol data unit
RT	remote terminal
SW	status word
SYNCH	data bus system synchronization signal

4
Overview

4.1 Context

MIL-STD-1553B Notice 2 :

a) does not define all the communication functions that are necessary for a MIL-STD-1553B data bus system to operate;

b) is not sufficient to get equipment input / output interfaces compatible across various MIL-STD-1553B data bus systems.

4.2 Motivation

This document provides with a common framework for the development and verification of MIL-STD-1553 data bus systems for space applications.

The main difference between this document and a data bus system specification is the provision of concepts and protocols capable of supporting a wide range of space missions.

The expected benefits are:

a) possibilities of independent development of MIL-STD-1553 data bus system elements;

b) reduction of costs through economies in production and reuse of equipment interfaces.

4.3 Relationship with MIL-STD-1553B Notice 2

MIL-STD-1553B data bus products are developed and qualified using MIL-STD-1553B Notice 2 as a reference.

This document does not repeat the requirements contained in MIL-STD-1553B Notice 2. The link between the requirements in this document and those in MIL-STD-1553B Notice 2 is made through cross references.

As a result this document is not a standalone document and shall be used together with MIL-STD-1553B Notice 2.

This document and MIL-STD-1553B are complementary and can be regarded as a single document (see Figure 4).

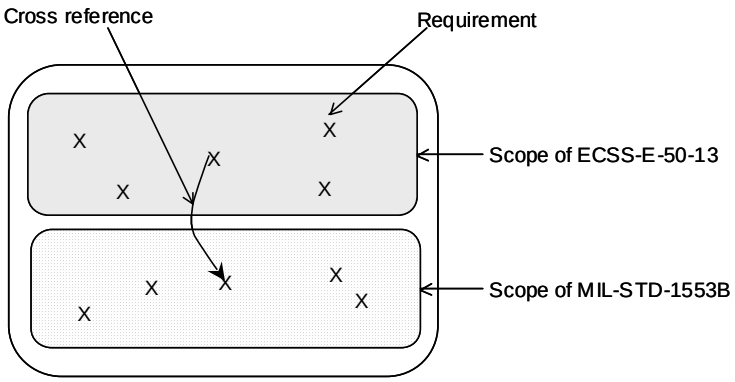


Figure 4: Relationship between this document and MIL-STD-1553B Notice 2

NOTE The benefits of not duplicating MIL-STD-1553B Notice 2 requirements are:

- reuse of existing terminals and data bus products whose conformity wrt MIL-STD-1553B Notice 2 is certified;
- reuse of existing MIL-STD-1553 documentation which contains cross references to MIL-STD-1553B Notice 2 (e.g. MIL-HDBK-1553A Section 100, AS 4113, AS4117, AS 4115).

4.4 Protocol reference model

MIL-STD-1553B Notice 2 does not explicitly define layers.

The protocol reference model used in this document is shown in Figure 5. It is composed of a Physical layer, a Data Link layer and an Adaptation layer.

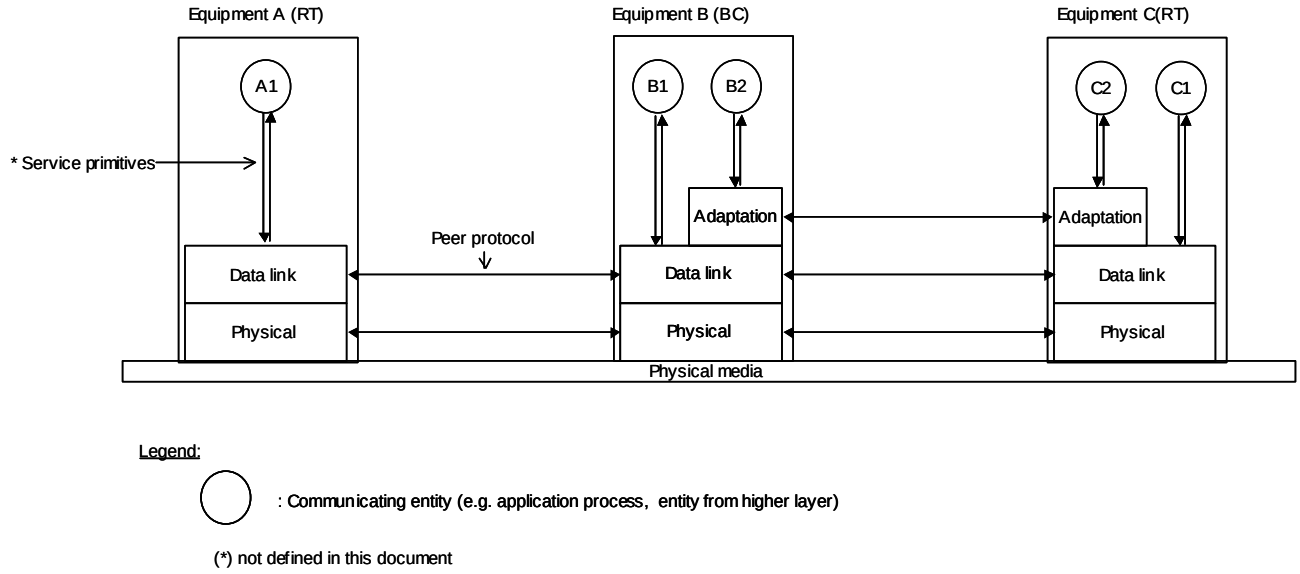


Figure 5: Protocol reference model used in this document

4.4.1 Physical layer

The Physical layer provides bit transmission capability including bit transfer and bit alignment.

4.4.2 Data Link layer

The Data Link Layer consists of two sublayers.

The Data Link Lower sublayer provides with the capability to transfer data units of up to 64 octets and mode codes over the data bus.

The Data Link Upper sublayer provides with the capability to share and control in time access to the transfer service offered by the Data Link Lower sublayer.
The Data Link Upper sublayer includes a synchronization and coordination function between control signals (e.g. synchronization signal) and user data transfers to support time-division multiplexing.

4.4.3 Adaptation layer

The Adaptation layer enhances the capabilities provided by underlying layers to meet needs peculiar to each data bus user. It supports multiple functions to fit individual user's needs, including segmentation and reassembly.

4.4.3.1 Flexibility

Individual data bus user's needs can be decomposed into elementary functions (e.g. delineation, multiplexing).

Adaptation layer provides with a reduced set of these functions as well as with the capability to combine them into compound functions and procedures.

All the functions in Adaptation layer are called adaptation functions.

When used in combination, the adaptation functions in this document are defined to cover a wide range of data bus user's needs.

Flexibility in adaptation layer enables equipment to implement only those communications functions that are needed for equipment operation. In a same data bus system an equipment may implement a subset of adaptation functions while an other equipment may not need any of them. If an equipment does not need any adaptation function then it does not need implement the Adaptation layer (see equipment A in Figure 5)

4.4.3.2 Unified data structure

Adaptation layer operates with a single protocol data unit that supports all possible combinations of adaptation functions.

An entity operating in a multipoint configuration (e.g. a flight computer exchanging information with several equipments) sees flows of protocol data units supporting various functions. The unified data structure provides with homogeneity in these flows. All protocol data units incoming to or outgoing from a given adaptation layer entity have a common structure and encoding.

4.4.3.3 Portability

The peer protocol for Adaptation layer in this document is defined to be portable across MIL-STD-1553 data bus systems. It is based on MIL-STD-1553B Notice 2 assumptions only. The techniques used in Adaptation layer are asynchronous so that they can operate in different MIL-STD-1553 data bus systems independently from the time-division multiplexing scheme used in those systems.

5
General

5.1 Application of MIL-STD-1553B

The data bus and the equipment connected to it shall meet the requirements contained in:

a. section 1 to 4 of MIL-STD-1553B Notice 2 with the exclusion of subclause 4.5.1.5.3, and;

NOTE Subclause 4.5.1.5.3 in MIL-STD-1553B Notice 2 requires the use of MIL-E-6051 "Electromagnetic Compatibility Requirements, Systems". Projects may use other document than MIL-E-6051 for electromagnetic compatibility.

b. the appendix of MIL-STD-1553B Notice 2, including section 30, irrespective whether or not dual standby redundancy is used, with the exclusion of subclauses 30.4.2., 30.6 and 30.8.

NOTE 1 Subclause 30.4.2 in MIL-STD-1553B Notice 2 implies the use of dual standby-redundant bus. Projects may use other redundancy schemes than dual-standby redundancy.

NOTE 2 Subclause 30.6 in MIL-STD-1553B Notice 2 precludes the use the broadcast message format for data transfer. Projects may use broadcast data transfers (e.g. for time distribution).

NOTE 3 Subclause 30.8 in MIL-STD-1553B Notice 2 requires RT to RT transfer formats to be implemented. Spacecraft project do usually not use RT to RT transfer formats. There are other methods for transferring the data from one RT to another.

5.2 Verification of conformance to MIL-STD-1553B

MIL-STD-1553B Notice 2 requirements shall be verified as specified in Annex A.

6
Physical layer

6.1 Object

Physical Layer provides mechanical and electrical capability for bit transmission over bus.

6.2 General

a. Electrical coupling scheme (bus harness)

Cable stubs shall be transformer coupled as specified in MIL-STD-1553B Notice 2, subclause 4.5.1.5.

b. Electrical coupling scheme (terminal characteristics)

Equipment I/O characteristics shall be transformer-coupled as specified in MIL-STD-1553B Notice 2, subclause 4.5.2.1.

c. Reference point for electrical interface

Equipment electrical I/O characteristics as defined in MIL-STD-1553B Notice 2 subclause 6.2 shall apply to equipment pieces when integrated (connector receptacle included) as depicted in Figure 6.

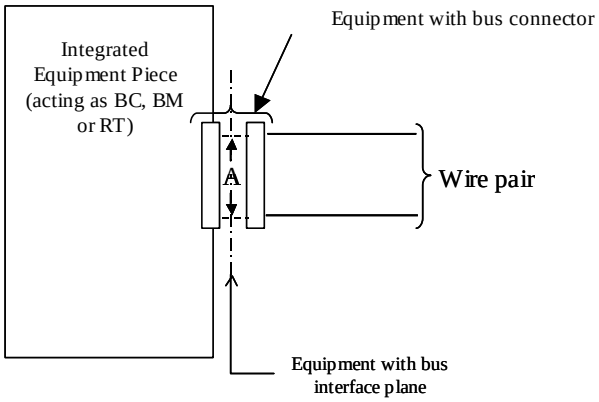


Figure 6: Equipment with bus interface -Reference point A

d. Bus with stub junctions

Each main bus with stub cable junction shall be supported by a separate single transformer data bus coupler as defined in 3.1.25.

6.3 Cabling

a. Robustness against disconnections

Bus network shall be designed so that the bus remains operational if a stub is open circuited between coupling and isolation transformers.

b. Robustness against short circuits on stubs

Bus network shall be designed so that the bus remains operational if a stub is short circuited between coupling and isolation transformers.

c. Cable for MIL-STD-1553 data bus on spacecraft

If the cable used for MIL-STD-1553 data bus on spacecraft implements:

1. polyimide insulated wires then it shall meet the requirements contained in ESCC Detail Specification No. 3901/002.
2. polytetrafluoroethylene (TEFLON, TFE) insulated wires then it shall meet the requirements contained in TBD.

NOTE Use of special connectors (e.g. triax as defined in ESCC Detail Specification No. 3401/066) may restrict the choice of cable.

Editorial note:
For writing this standard, the pros and cons of using Polytetrafluoroethylene (TFE) insulated with Fluorinated Ethylene Propylene (FEP) jacket cables instead of polyimide insulated cables as defined in ESCC 3901/002 shall be studied.

Cables with TFE insulated wires have been used for programs in cooperation with the International Space Station (ISS). The cable specification was the ISS Program document SSQ21655 "Cable, Electric, MIL-STD-1553 Data Bus, Space Quality, General Specification for". If cables with TFE insulated wires have a significant chance to be used for future programmes then they should be standardized in an ESCC specification.

6.4 Connecting

a. Connector Mounting

Connectors shall be arranged in such a way that the harness connectors can be mated and demated without special tools and without manipulating any neighbouring connectors.

b. Prevention against inadvertent disconnection

Male and female connectors shall be mechanically locked together to prevent inadvertent disconnection.

c. Prevention against plugging mistakes

Mechanical methods in conjunction with identification markings shall be employed to prevent incorrect mating of connectors.

d. Male-female allocation

Female connector receptacles shall be mounted on equipment structure.

e. Bus segregation

Separate connectors shall segregate redundant bus lines from nominal ones.

f. Polarity for the concentric connectors or inserts (if used at stub or equipment interface)

If concentric connectors or inserts are used then connector polarity shall conform to MIL-STD-1553B Notice 2, subclause 30.10.3.

g. Dedicated bus with equipment connectors

Bus with equipment connections shall be supported by dedicated connectors (i.e. connectors that support no other signals than bus line signals or RT address setting signals).

h. RT address error control

1. Any connector used for RT address configuration shall assign a parity bit in addition to the 5 RT address bits.
2. The parity bit specified in 6.4.h.1 shall implement odd parity (i.e. the combination of the 5 RT address bits and the parity bit shall comprise an odd parity sum in order to enable recognition of terminal address by RT equipment).

i. RT address assignment connection interface

1. The RT address assignment connection interface shall include five binary encoded address bit contacts, one address parity contact and one common address return contact.
2. Address bit and parity value shall be defined by wire bridges referenced to the address return contact according to the representation convention defined in 6.4.j.

j. Logic level representation for wire bridge connectors

By convention a wire bridge between connector contacts shall represent a logic zero, and no bridge a logic one.

NOTE An example of RT address connection interface is given in Figure 7.

Conventions are as defined in 6.4.j, that is:

— A pin connected to Address return represents logic 0;

— A pin not connected to Address return represents logic 1.

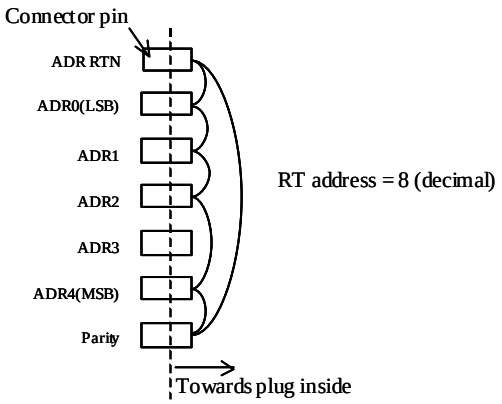


Figure 7: Example of RT address connection interface

k. Cross compatible equipment with bus connector interface

For new equipment developments, equipment with data bus and RT address assignment connections shall be implemented using the connector type, contact arrangement and signal assignment specified in Annex B.

l. Main bus line interconnections

Single triax contact connectors shall be used for main bus line interconnections.

m. Main bus line extension connector interface

Main bus line interconnections shall be implemented by the connector type, contact arrangement and signal assignment specified in Annex B.2.

7
Data Link layer

7.1 Object

Data Link layer provides with the capability to transfer data units of up to 64 octets and mode codes over the data bus and to interleave in time those transfers over a common data bus.

It consists of a Lower and an Upper sublayer as introduced in 4.4.

7.2 Lower sublayer

7.2.1 Object

The Data Link Lower sublayer provides with the capability to transfer data units of up to 64 octets and mode codes over the bus.

7.2.2 Message formats

7.2.2.1 BC to RTs broadcast transfers (RT or BM)

Any equipment acting as RT or BM shall implement broadcast option for BC to RT transfers as specified in MIL-STD-1553B Notice 2, subclause 4.3.3.6.7.1.

7.2.3 Command word

7.2.3.1 RT address

a. RT address setting up procedure

The RT address shall be established through an external connector as specified in 6.4.i.

b. Digital distance between RT addresses

On each bus, the RT addresses should be digitally spaced to maximize the hamming distance between the RT address values used on this bus.

NOTE This reduces the risk that an error introduced in a RT address during data handling changes this RT address value into the value of another RT equipment used on the same data bus.

7.2.3.2 Sub-address

a. Data wrap around

Receive and Transmit sub-addresses 30 (decimal) shall be used for data wrap around as defined in MIL-STD-1553B Notice 2, subclause 30.7.

7.2.3.3 Mode code

a. Mode code minimum capability (RT equipment)

Any RT equipment on-board spacecraft shall implement the following mode codes as a minimum:

i Transmit status word;

ii Transmit last command;

iii Reset remote terminal (non-broadcast);

iv Synchronize with data word (broadcast and non-broadcast).

7.2.4 Data word

7.2.4.1 Data/bit transmission order

From a data field, the first data to be transmitted shall be the most significant.

7.2.4.2 Information gathering in DW

The information susceptible to be transmitted over the data bus by an equipment shall be gathered by data blocks in order to reduce as low as reasonably achievable the number of messages per second to be exchanged with this equipment to operate it.

NOTE 1 Therefore:

— status bits, short or length register and other bi-level measurements are functionally grouped together into an integer multiple of octets.

— data are grouped by function and frequency into data blocks to reduce the number of sub-addresses used per equipment.

NOTE 2 The level of acceptance of the message rate constraints put by an equipment/subsystem to the data bus system is not specified in this document. It has to be defined jointly by data bus system designer, equipment/subsystem and software engineers.

7.2.4.3 Octet alignment

Any data coded on more than 4 bits and conveyed in data word (DW) shall have its least significant bit (LSB) positioned as depicted in Table 1.

Table 1: Octet alignment

Data Length (bit)	Data LSB position in DW (bit time number as depicted in MIL-STD-1553B Notice 2 figure 3)
8 <..	19
4< .. ≤ 8	19 or 11

7.2.5 Status word

7.2.5.1 Service Request bit

a. Capability to detect/ignore Service Request bit

BC equipment shall have the capability to detect or ignore whether Service Request bit has been set by an individual RT.

b. BC and RT interaction when Service Request bit is used

If Service Request bit is used then BC and RT shall interact according to the logic defined in 7.2.5.1.c, 7.2.5.1.d, 7.2.5.1.e.

c. Assignment of predefined actions to Service Request bit

When used, the Service Request bit in conjunction with an RT address value shall be attached a predefined requirement for BC to initiate actions.

d. Service Request bit logic (RT side)

1. RT shall inform BC of the presence of predefined requirement for actions as defined in 7.2.5.1.c by setting the service request bit in the status word from logic 0 to logic 1.
2. RT shall ensure that once service request bit is set to logic 1, all the conditions of readiness on RT side are fulfilled for the specified actions to be immediately initiated by BC.
3. Once service request bit in the status word is set 1, RT shall not alter service request bit value until the status word is transmitted on data bus.

e. Service Request bit logic (BC side)

Upon receipt of a SW with service request bit at logic 1:

1. BC shall examine if the previous SW received with the same value in RT address field had Service Request bit at logic 1;
2. if the condition in 1 is true then BC shall disregard Service Request bit;
3. if the condition in 1 is false then BC initiate predefined actions attached to the RT address contained SW in as defined in 7.2.5.1.c within a bounded time period after SW receipt.

7.2.5.2 Busy bit

a. Availability of the communication function in absence of failure

Unless failed, RT terminal and subsystem shall be able to move data to and from subsystem when commanded by the bus controller.

b. Use of Busy bit on spacecraft

Unless otherwise specified, Busy bit shall not be used on spacecraft.

c. Busy bit usage - Handling of waivers

If 7.2.5.2.a or 7.2.5.2.b is not met then:

1. analysis of the impact of the Busy bit usage on the availability of the function performed by RT equipment and on spacecraft safety shall be performed;
2. the conditions under which the Busy bit is set to logic 1 shall be identified;
3. the duration for which the Busy bit is set to logic 1 shall be bounded per busy condition;

NOTE This duration is further called busy time.

4. RT equipment shall not exceed the bounded busy time value associated to a busy condition when this busy condition occurs;
5. busy conditions and maximum busy time values shall be documented.

NOTE Equipment specification and equipment interface control document are suited documents to respectively contain required and achieved values.

7.2.5.3 Subsystem Flag bit

a. Use of Subsystem Flag bit on spacecraft

Subsystem Flag bit should be used on spacecraft.

b. Capability to detect/ignore Subsystem Flag bit

BC equipment shall have the capability to detect or ignore whether Subsystem Flag bit has been set by an individual RT.

c. BC and RT interaction when Subsystem Flag bit is used

If Subsystem Flag bit is used then BC and RT shall interact according to the logic defined in 7.2.5.3.d and 7.2.5.3.e.

d. Subsystem Flag bit logic (RT side)

If Subsystem flag bit is used by RT, then:

1. RT equipment shall set subsystem flag to logic one within a bounded time period after detection a fault in its subsystem part;
2. The maximum value of this bounded time period (see 7.2.5.3.d.1) shall be documented.

NOTE Equipment specification and equipment interface control document are suited documents to respectively contain required and achieved values.

3. Once RT has set Subsystem flag bit to logic one it shall maintained Subsystem Flag bit to this value until equipment is reset or powered-off.
4. Subsystem flag bit shall be set to zero value during equipment reset or power-up.
5. RT equipment shall logically OR its internal fault signal into the single Subsystem Flag bit

6. An exhaustive list of these internal fault signals in 7.2.5.3.d.5 shall be provided in equipment documentation.

7. RT equipment may display information in dedicated data words to report the cause of subsystem error as identified by the RT equipment itself (e.g. equipment health status, error codes).

e. Subsystem flag bit logic (BC side)

When BC equipment receives a SW with:

- Subsystem Flag bit at logic 1 ; and
- an RT address that corresponds to an equipment that use Subsystem Flag bit,

then BC shall:

i declare the RT equipment which corresponds to the RT address contained in status word as failed;

ii take actions (e.g. reconfiguration) to isolate the failed equipment and recover the function this failed equipment was required to perform within a bounded period after receipt of positive Subsystem Flag bit.

7.2.5.4 Terminal Flag bit

a. Capability to detect/ignore Terminal Flag bit

BC equipment shall have the capability to detect or ignore whether Subsystem Flag bit has been set by an individual RT.

b. Terminal Flag capability

If Terminal flag bit is used by RT, then:

1. RT equipment shall set Terminal flag to logic one within a bounded time period after detection of a fault in the terminal part of the equipment

2. Once RT has set Terminal flag bit to logic one it shall maintained Terminal Flag bit to this value as long as the fault persists.

3. When no fault affects the terminal, Terminal Flag bit shall be logic zero valued.

4. RT equipment shall logically OR its terminal fault signals into the single Terminal Flag bit.

5. An exhaustive list of these fault signals shall be provided in equipment documentation.

c. Terminal flag bit coverage

If used, Terminal Flag bit shall at least cover the failure cases when:

1. terminal fail safe time-out as defined in MIL-STD-1553B Notice 2, subclause 4.4.1.3 expires ;

2. any of the tests performed during loopback self test as defined in 7.2.6.a.3 fails.

d. Terminal flag bit coverage exclusion

Any fault that is not due to the terminal part of the equipment shall not alter the Terminal Flag bit.

7.2.6 FDIR support

a. Loopback self test

1. A loopback self test should be implemented in any equipment susceptible to generate words on data bus (i.e. BC or RT).
2. When implemented, loopback self test shall be performed by the receiver section of a terminal when transmitter section of the same terminal generates words on the data bus.
3. During loopback self test the receiver section shall at least check the following:
   i the words generated by the transmitter section of the same terminal meet the validation criteria defined in MIL-STD-1553B Notice 2, subclause 4.4.1.1, and
   ii the 16-bit information field in the words received by the receiver section are bit-wise identical to the 16-bit information field sent by the transmitter section of the same terminal.

b. Filtering out message content when message error occurs

Any message which meets the conditions leading Message Error bit to be set to logic one shall have its related DWs not propagated from terminal to subsystem.

c. Robustness against non expected messages

When RT equipment receives a message (including broadcast message) for which it is not designed, it shall:

1. not fail nor act faulty;
2. not handle nor execute further the information contained in this message.

d. Command illegalisation (RT side)

1. RT equipment should implement command illegalisation as defined in MIL-STD-1553B Notice 2, subclause 4.4.3.4.
2. If command illegalisation is implemented then the list of legal and illegal commands shall be provided in equipment documentation.

e. Prevention against illegal command generation

Any equipment acting as Bus Controller shall assume tight control of command word generation on data bus so that no illegal commands can be sent out to any equipment.

7.3 Upper sublayer

7.3.1 Object

The Data Link Upper sublayer provides the capability to share and control in time access to the transfer service provided by the Data Link Lower sublayer.

It provides with a synchronization and coordination function to support time-division multiplexing.

7.3.2 Time-division multiplexing

7.3.2.1 General

a. Frame alignment signal format

The format of a frame alignment signal on a MIL-STD-1553 bus shall be distinct from BC-to-RT, RT-to-BC, RT-to-RT, broadcast and non-broadcast transfer formats as defined in MIL-STD-1553B Notice 2 subclause 4.3.3.6.

NOTE Frame alignment signal is defined in 3.1.14

b. Identification of frame alignment signal elements

Each element of a frame alignment signal as defined in 3.1.14 shall be distinguished from the other elements of this signal by an identifier contained in this signal element.

c. Cross compatibility of frame alignment signals

1. To ensure compatibility across spacecraft, the data bus system synchronization signal defined in 7.3.3 shall be used as frame alignment signal.
2. When data bus system synchronization signal is used as frame alignment signal, the phase reference information as defined in 7.3.3.3 shall be used to identify frame alignment signal elements as specified in 7.3.2.1a.

7.3.2.2 Frame structure

NOTE No specific frame time division is specified in this document. Various frame time divisions may be used across data bus systems as long as they are compatible with the timing of the frame alignment signal specified in 7.3.2.1.c.

7.3.3 Data bus system synchronization signal

In general, synchronization can be provided by periodically inserting a signal into the transmitted data stream or by using a separate timing path (e.g. dedicated synchronization lines). In MIL-STD-1553 data bus systems the preferred method is insertion of a synchronization signal into the data stream.

7.3.3.1 Provision of a signal to control timing of operations in data bus system

BC shall broadcast towards RT equipments a signal used to control the timing of operations in the data bus system.

NOTE 1 This signal is further called broadcast synchronization signal (SYNCH).

NOTE 2 An element in the broadcast synchronization signal is further called broadcast synchronization message.

NOTE 3 Data bus system is defined in 3.1.5

Editorial note: The use of project specific data bus synchronization signals is one of the main sources of incompatibility between equipment I/O across MIL-STD-1553 data bus systems. This section defines requirements to render data bus system synchronization signal cross compatible. Like for any section in this document, this paragraph is open for discussions within the working group.

7.3.3.2 Synchronization signal transmission timing

a. Time of occurrence of a broadcast synchronization message

The time of occurrence of a broadcast synchronization message at equipment input or output shall be the time when the sync mid-zero crossing of the command word in the broadcast synchronization message occurs at reference point A of the equipment as shown in Figure 6.

NOTE See illustration in Figure 8.

b. Measuring output timing characteristics

The timing characteristics of the data bus system synchronization signal at output from BC equipment shall be measured with the equipment connected to a resistance RL as specified in MIL-STD-1553B Notice 2 para. 4.5.2.1.1.

c. Output fractional frequency deviation

The time distance between two consecutive occurrences of broadcast synchronization messages at output from BC equipment shall meet the following relationship:

$$\left| \frac{\frac{1}{T_{OUT}} - F_{NOM}}{F_{NOM}} \right| \leq A_{OUT}$$

where:

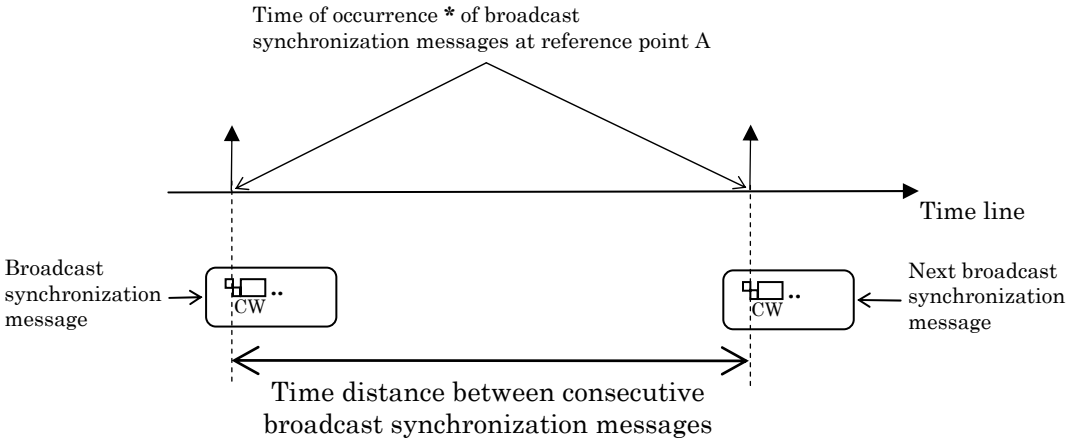
– T_{OUT} is the time distance between two consecutive broadcast synchronization messages at output from BC equipment as shown in Figure 8 and measured as specified in 7.3.3.2.b.

- F_{NOM} is the nominal frequency of the data bus system synchronization signal;
- A_{OUT} is the frequency accuracy of the data bus system synchronization signal at output from BC equipment as specified in 7.3.3.2.d.

d. Output frequency accuracy

The frequency accuracy of the data bus system synchronization signal at output from BC equipment (A_{OUT}) as defined in 7.3.3.2.c shall be equal to or lower than 10^{-4} (TBC) over the data bus system life time.

NOTE The frequency accuracy includes possible frequency offset from nominal frequency, ageing and environmental effects.



(*) Time when the sync mid-zero crossing of the command word in the broadcast synchronization message occurs at reference point A of equipment.

Figure 8: Time distance between consecutive broadcast synchronization messages

7.3.3.3 Identification of data bus system synchronization signal elements

a. Discriminating synchronization signal elements

1. Each broadcast synchronization message shall be attached an information piece that allows to:
   - i distinguish this broadcast synchronization message in the stream of broadcast synchronization messages transmitted on the data bus within the ambiguity period (T_{AMB}) specified in 7.3.3.3.b , and
   - ii determine the relative position of this synchronization message in the sequence of broadcast synchronization messages sent on the data bus.

NOTE 1 This piece of information is further called phase reference information.

NOTE 2 The bus controller (BC) is responsible for initiating all information transfers on the data bus. Depending on the equipment, a phasing between RT and BC I/O processes may be needed so that BC initiates RT→BC transfers when the expected data blocks are ready to be transferred on RT side. The phase reference information can be used to resolve phasing ambiguities between BC and RT I/O processes within the ambiguity period.

b. Relationship between nominal frequency and ambiguity period

The ambiguity period in the data bus system synchronization signal shall be an integral multiple of the inverse of the nominal frequency.

NOTE Mathematically, subclause 7.3.3.3.b can be expressed as : $T_{AMB} \times F_{NOM} = N$ with N an integral number different from zero.

c. Phase reference information

1. The phase reference information attached to the first broadcast synchronization message emitted after initialisation shall be set to zero.

2. The phase reference information attached to a broadcast synchronization message shall be set to :

$$INCR \times COUNT$$

where:

- COUNT is a sequential binary count of the occurrences of broadcast synchronization signal messages at output from BC equipment modulo ($T_{AMB} \times F_{NOM}$)
- T_{AMB} is the ambiguity period as defined in 7.3.3.3.a and 7.3.3.3.b;
- INCR is a integral number different from zero.

NOTE 1 The parameter INCR is further called counter increment unit.

NOTE 2 With mathematical notations:
COUNT= {number of transmitted broadcast SYNCH messages since initialization - 1} $[T_{AMB} \times F_{NOM}]$

NOTE 3 The phase reference information is an integral number.

d. Relationship between the counter increment unit and nominal frequency

The counter increment unit (INCR) in the phase reference information as defined in 7.3.3.3.c shall meet the following relationship:

$$INCR \times F_{NOM} = F_{MAX}$$

where:

- F_{NOM} is the nominal frequency of the data bus system synchronization signal as defined in 7.3.3.2.c
- F_{MAX} is the maximum value of the nominal frequency of the synchronization signal across data bus systems as specified in 7.3.3.3.e.

NOTE 1 The nominal frequency of the synchronization signal (F_{NOM}) is a submultiple of F_{MAX}.

NOTE 2 The value of the phase reference information is independent from the nominal frequency of the synchronization signal (see Figure 9).

NOTE 3 The phase reference information can be regarded as representing the time elapsed since counter initialization in the time scale defined by recurring time intervals between synchronization broadcast messages. This time is expressed in the time unit $T_U = 1/F_{MAX}$, has a resolution equal to T_{NOM} and an ambiguity period equal to T_{AMB}

e. Cross compatible data bus system synchronization signal

For the purpose of cross compatibility between data bus systems:

1. the ambiguity period (T_{AMB}) in the data bus system synchronization signal shall be fixed to 10 seconds;

NOTE If the value of the ambiguity period (T_{AMB}) is fixed, then the nominal frequency of the synchronization signal F_{NOM} is a multiple of $1/T_{AMB}$ (see 7.3.3.3.b)

2. the maximum value of the nominal frequency of the synchronization signal(F_{MAX}) as defined in 7.3.3.3.d shall be fixed to 10 Hz.

NOTE Examples of cross compatible data bus system synchronization signals are given in Figure 9. These signals are synchronous one with the other.

7.3.3.4 Synchronization signal format

a. Format of the broadcast synchronization messages

1. Broadcast synchronization messages as defined in 7.3.3.2 and 7.3.3.1 shall be transmitted on bus using the broadcast synchronize with data word mode command.
2. The data word that accompany the synchronize with data word mode shall contain the phase reference information attached to that synchronization message as defined in 7.3.3.3 b

b. Format of the phase reference information

The phase reference information as defined in 7.3.3.3 shall be formatted as a 16-bit unsigned integer.

7.3.3.5 Tolerances wrt synchronization signal

a. Input fractional frequency deviation

RT equipment shall be capable to receive and tolerate (i.e. operate without indication of improper operation or degradation of performance) an incoming broadcast synchronization signal that meets the following relationship:

$$\left| \frac{\frac{1}{T_{IN}} - F_{NOM}}{F_{NOM}} \right| \leq D_{IN}$$

where:

- T_{IN} is the time distance between two consecutive broadcast synchronization messages at input to RT equipment as shown in Figure 8;
- F_{NOM} is the nominal frequency of the data bus system synchronization signal as defined in 7.3.3.2.c;
- D_{IN} is the equipment tolerance to synchronisation signal input fractional frequency deviation as specified in 7.3.3.5.b.

b. Tolerance to input fractional frequency deviation

RT equipment tolerance to broadcast synchronization signal input fractional frequency deviation (D_{IN}) as defined in 7.3.3.5.a shall be equal to or greater than 10^{-3} (TBC).

NOTE This value takes into account the synchronization signal frequency accuracy at output from BC equipment as well as margin for possible signal distortion when propagating through the data bus.

c. Out-of-synchronization time

1. The time during which the incoming broadcast synchronization signal is lost at RT interface shall be measured as follows:

$T_{Out\text{-}Of\text{-}SYNCH} = N_{LOST} \times T_{NOM}$

Where:

— $T_{NOM} = 1/F_{NOM}$ as defined in 7.3.3.2 7.3.3.2.c ;

— N_{LOST} is the number of consecutive broadcast synchronization messages not received at reference point A as depicted in Figure 6.

2. RT equipment shall keep performing its specified function with specified performances when the incoming broadcast synchronization signal is lost at RT interface less than the ambiguity period (T_{AMB}) as defined in 7.3.3.3.a.

7.3.3.6 Interface with synchronization networks

This section is dedicated to those applications that require the data bus system synchronization signal to be traceable to an external reference.

It defines the interface between a data bus system and a synchronization network.

One typical application is the interconnection of several data bus systems to form a synchronous network of data buses (e.g. hierarchical networks).

a. Capability of external synchronization

BC equipment shall be capable of synchronizing the broadcast synchronization signal to a synchronization signal from an external source.

b. Control of frequency offset

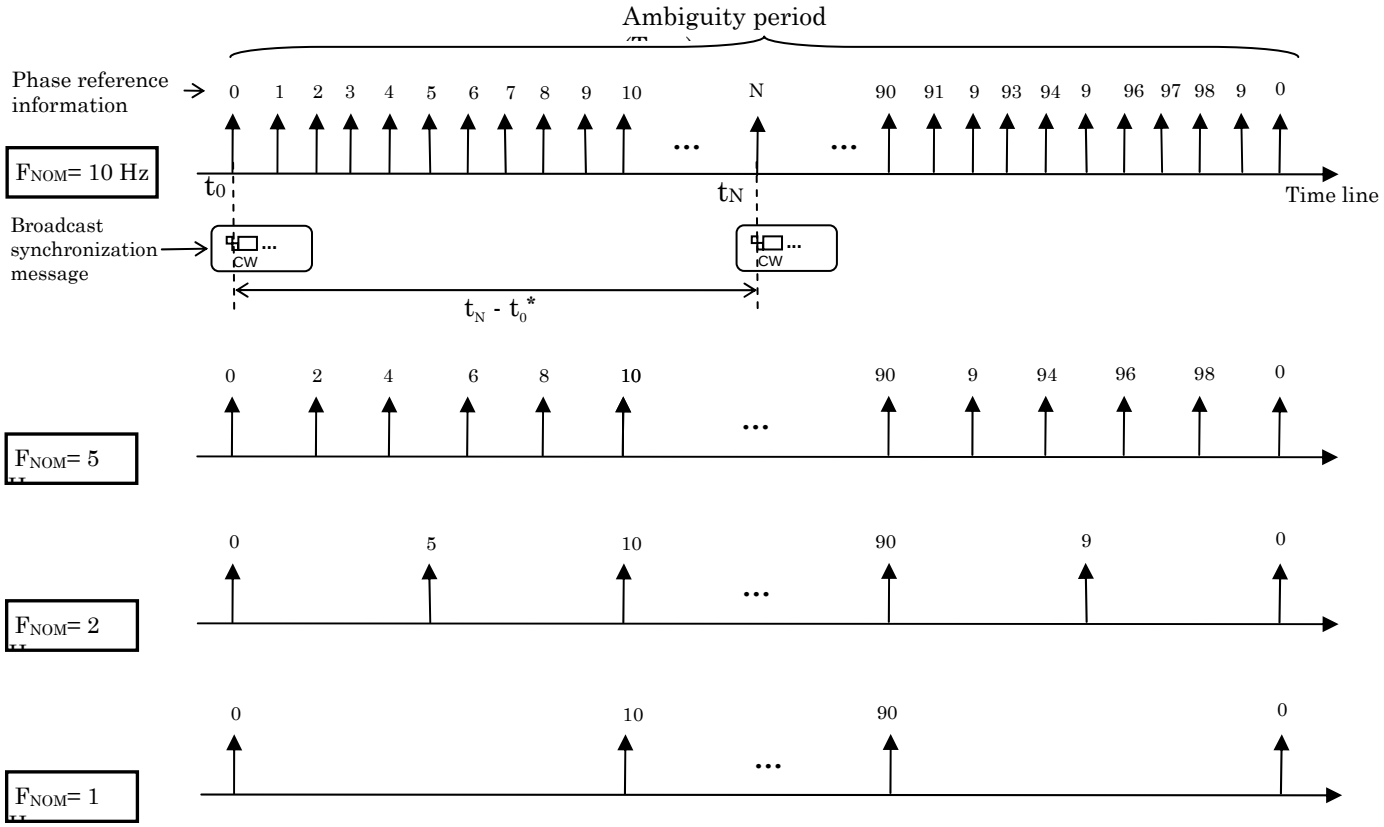
BC equipment shall have the capability to advance or retard emission of broadcast synchronization message on the bus within the output frequency accuracy specified in 7.3.3.2.c to control possible frequency offset between the local broadcast synchronization signal and an external frequency source.

c. Capability of free running mode

BC equipment shall have the ability to maintain the synchronization signal when all external synchronization references are lost.

NOTE The data bus system is protected from possible failure in external synchronization signal dissemination.

Editorial note:
This section is to be further developed.



(*) $t_N - t_0 = N \times T_U \times (1 \pm e)$

with

$|e| < A_{OUT}$ at output from BC equipment

$|e| < D_{IN}$ at input to RT equipment

$T_U = 1/F_{MAX}$; A_{OUT} ; D_{IN} as defined in 7.3.3.3, 7.3.3.2, 7.3.3.4

Figure 9: Examples of data bus system synchronization signals

8
Adaptation layer

8.1 Object

Adaptation layer enhances the capabilities provided by lower layers to be able to meet constraints (e.g. in size, symmetry) peculiar to each data bus user.

The adaptation layer to MIL-STD-1553B provides with the functions listed in Table 2.

The adaptation functions can be used separately or in combination depending on the need of each data bus user.

The use of Adaptation layer is not mandatory. Within the same data bus system an equipment may use a subset of adaptation functions while an other equipment may not need any adaptation function (see Figure 5).

Table 2: Functions in the Adaptation layer to MIL-STD-1553B

Function	Equipment (1)		Comment
	Sending	Receiving	
Segmentation	O [RT, BC]	N/A	Provides with the capability to transmit data units whose length exceeds the maximum data unit size that can be transferred in one MIL-STD-1553 message (e.g. 64 bytes).
Reassembly	N/A	O [RT, BC, BM]	
Sequence control	O [RT]	O [BC, BM]	Supports asynchronous RT→BC transactions.
Delineation	O [RT]	O [BC, BM]	Provides with the capability to indicate the boundaries of variable length data units in RT→BC transactions.
Multiplexing	O [RT]	N/A	Provides with the capability to : - separate data streams within a transmit logical channel; - control in which order data units are transmitted to BC.
Demultiplexing	N/A	O [BC, BM]	
O	Optional		
N/A	Not applicable		
[XX] (2)	Scope of application is limited to those equipments that act as XX on the data bus		

Notes in Table 2:

(1) The status in the "sending" column applies to the support of the given function for user data units sent by the equipment; similarly the status in the "receiving" column applies to the support of the given function for user data units received by the equipment.

(2) The implementation of functions in adaptation layer depends on the mapping of the communication functions in the protocol stack as well as between end systems (i.e. equipments). The functions that are already supported by entities in lower layers are not relevant to be implemented in Adaptation layer.

Example:
A delineation function is included in Data Link Layer.
The control of the delineation function in Data Link Layer is provided to those equipments that act as bus controller.
Those equipments that act as remote terminal have no control of delineation in Data Link layer.
When transmission of variable length data units (e.g. variable length network protocol data units) from RT to BC equipment is required, the use of a delineation function in adaptation layer is needed (with RT equipment as sending end and BC equipment as receiving end).

8.2 Adaptation protocol data unit

a. Application of Adaptation layer protocol

Transfer through one logical channel of data units:

- susceptible to vary in size, presentation or significance or
- exceeding 64-octets in length

shall be performed using a MIL-STD-1533B adaptation layer protocol data unit (MA-PDU) as defined in this section.

b. MA-PDU length

The length of an MA-PDU shall be an integral multiple of 2 octets, lower than or equal to 64 octets.

c. MA-PDU position in MIL-STD-1553 message

The first bit transmitted from MA-PDU shall coincide with bit time 4 of the first Data Word transmitted from MIL-STD-1553 message as shown in figure 3 of MIL-STD-1553B Notice 2.

d. MA-PDU composition

An MA-PDU shall comprise an MA-PDU Header field and Data Zone field as shown in Figure 10.

MA-PDU HEADER				**MA-PDU DATA ZONE**	
Fill Data Pointer	Sequence Count	Logical Channel Extension Number	Seq. Flags	User Data	Fill Data (optional)
← 6 bits →	← 2 bits →	← 6 bits →	← 2 bits →	← N octets →	← (2*L)-N octets →
← 2 octets →				← 2*L octets →	

Note: $0 \leq L \leq 31$; $0 \leq N \leq 2*L$

Figure 10: MA-PDU format

8.2.1 MA-PDU Header

8.2.1.1 MA-PDU Header

a. The first 2 octets in the MA-PDU shall be the MA-PDU Header field.

b. MA-PDU header field shall be comprised of a Fill Data Pointer field, a MA-PDU Sequence Count field, a Logical Channel Extension Number field and Sequence Flags field as depicted in Figure 10.

8.2.1.2 Fill Data Pointer

a. Location of Fill Data Pointer field

The first 6 bits transmitted from MA-PDU Header shall be the Fill Data Pointer field.

b. Purpose of Fill Data Pointer field

1. Fill Data Pointer field shall indicate the presence or absence of fill data in MA-PDU Data Zone.
2. In case of fill data presence, Fill Data Pointer shall indicate the off-set in octets from the most significant bit in Fill Data Pointer field till most significant bit in Fill Data field (i.e. the boundary between user data and fill data as shown in Figure 10).
3. If MA-PDU Data Zone contains fill data then Fill Data Pointer shall be set to value N+2 where N is the number of user data octets in MA-PDU Data Zone as defined in 8.2.2.d.
4. If MA-PDU Data Zone does not contain fill data then Fill Data Pointer shall be set to value “all ones”.
5. If MA-PDU Data Zone does not contain user data then Fill Data Pointer shall be set to value 2 (decimal).

8.2.1.3 Sequence Count

a. Location of MA-PDU Sequence Count field

The next 2 bits following Fill Data Pointer field in MA-PDU shall be the Sequence Count field.

b. Purpose of Sequence Count field

When used, MA-PDU Sequence Count shall provide MA-PDU recipient with the means to detect lost and duplicated data blocks in a stream of data blocks submitted for transmission over a logical channel.

NOTE Detection of duplicated data block enables to distinguish between duplicated data block as defined in 3.1.7 and consecutive submissions of bitwise identical data blocks on the same logical channel.

c. Content of MA-PDU Sequence Count field when not used

If not used, MA-PDU Sequence Count field shall be

1. set to value 00 (binary), and
2. ignored by MA-PDU recipient.

d. Content of MA-PDU Sequence Count field when used

If used, MA-PDU Sequence Count field shall contain a cyclic sequential count (modulo 4)

1. associated to the logical channel and Logical Channel Extension Number over which MA-PDU is transmitted, and
2. incremented by value “1” modulo “4“ each time an MA-PDU is submitted by subsystem for transmission over the logical channel and Logical Channel Extension Number associated to that Sequence Count.

8.2.1.4 Logical Channel Extension Number

a. Location of Logical Channel Extension Number field

1. The next 6 bits following Fill Data Pointer field shall be the Logical Channel Extension Number field.
2. The use or not of Logical Channel Extension Number field shall be defined per logical channel.

b. Content of Logical Channel Extension Number field when not used

If not used, Logical Channel Extension Number field shall be

1. set to value “all zeroes”, and
2. ignored by MA-PDU recipient.

c. Content of Logical Channel Extension Number field when used

If used, Logical Channel Extension Number field shall contain the information to distinguish between various streams of data blocks transferred over a particular logical channel.

d. Logical Channel Extension Number assignment

1. Separate Logical Channel Extension Number value shall be used to distinguish between the following types of information:
   - TYPE 1: information used to operate the data bus system (e.g. request for access or resource allocations/release, request for communication services);
   - TYPE2: information exchanged from data bus user to data bus user without incidence on the operating of the data bus system.

2. Logical Channel Extension Number value “all ones” shall be reserved for TYPE 1 information as defined in 8.2.1.4.d.1.

NOTE 1 This standard separates user information from control information channel. This separation provides with an architecture open to various signalisation protocols. Various signalisation techniques to operate the data bus system may take place in the signalisation channel (TYPE2).

NOTE 2 The definition of common signalisation techniques is for further study. The separation of signalling (or control information) from the user information channel will facilitate the specification of a flexible, common signalling protocol, capable of supporting multiple missions.

e. Relationship between Logical Channel Extension Number and logical channel

Logical Channel Extension Number shall be associated to the logical channel through which MA-PDU is transmitted.

8.2.1.5 Sequence (seq.) Flags

a. Location of sequence flags field

The next 2 bits following Fill Data Pointer field shall be the sequence flags field.

b. Content of sequence flags field

The content of sequence flags field shall indicate whether or not the data in MA-PDU user data field is a segment of a larger set of user data as shown in Table 3.

Table 3: MA-PDU - Sequence flags codes

SEQ FLAGS code (binary)	Meaning
00	data field contains a **continuation segment** of user data
01	data field contains the **first segment** of user data
10	data field contains the **last segment** of user data
11	data field contains **unsegmented** user data

c. Relationship between sequence flags, logical channel and Logical Channel Extension Number

Sequence flags shall be associated to

1. the logical channel through which MA-PDU is transmitted, and
2. the value contained in MA-PDU Logical Channel Extension Number field.

8.2.2 MA-PDU Data Zone

a. Location of MA-PDU Data Zone

The next field after MA-PDU Header field shall be the Data Zone field.

b. Length of MA-PDU Data Zone

1. The length of MA-PDU Data Zone shall be an even multiple of octets.
2. The length of MA-PDU Data Zone shall be fixed per logical channel

c. From an MA-PDU Data Zone field, user data shall be transmitted first.

d. Volume of user data in MA-PDU Data Zone

1. The volume of user data in MA-PDU Data Zone
   - i shall be an integral number of octets (shown as N on Figure 10):
   - ii may be equal to zero;
   - iii shall be lower or equal to the MA-PDU Data Zone length as defined in 8.2.2.b.
2. If the volume of user data in MA-PDU Data Zone is :
   - i lower than MA-PDU Data Zone length then MA-PDU Data Zone shall contain fill data.
   - ii equal to MA-PDU Data Zone length then MA-PDU Data Zone shall not contain fill data.

e. Volume of fill data when used

If MA-PDU Data Zone contains fill data then

1. from Data Zone, fill data shall be transmitted after user data.
2. the volume of fill data in MA-PDU Data Zone shall be complementary to the volume of user data as defined in 8.2.2.d so that both together fit with the length of MA-PDU Data Zone as defined in 8.2.2. b.

8.3 Adaptation procedures

8.3.1 Object

An adaptation procedure may consist in:

- partial fill,
- duplication/loss detection,
- labelled multiplexing/demultiplexing,
- segmentation/reassembly.

8.3.2 General

a. Conditions to pass data unit to Adaptation layer user

At receiving end, the user data unit contained in a MA-PDU shall be passed to the Adaptation layer user if and only if MA-PDU is accepted by all used adaptation procedures.

8.3.3 Partial fill

8.3.3.1 Object

Partial fill provides with the capability to insert variable length user data units into fixed length carrying structures.

In particular partial fill provides data bus users in RT equipment with the capability to change the length of user data units in RT→ BC transfers without prior notification of length change to the Bus Controller.

8.3.3.2 Actions at sending end

a. If the volume of user data to be sent over a logical channel is equal to the length of MA-PDU Data Zone then partial fill procedure on sending end shall:

   1. set Fill Data Pointer to indicate absence of fill data in Data Zone as specified in 8.2.1.2.4 ; and
   2. insert user data in Data Zone.

b. If the volume of user data to be sent over a logical channel is lower than the length of MA-PDU Data Zone then partial fill procedure on sending end shall:

   1. concatenate fill data to user data, with user data in leading position so that resulting user plus fill data fits with the length of MA-PDU Data Zone; and
   2. insert the concatenation result into Data Zone; and
   3. set Fill Data Pointer to indicate the boundary between user data and fill data as specified in 8.2.1.2.3.

8.3.3.3 Actions at receiving end

a. If the value contained in Fill Data Pointer field indicates presence of fill data in MA-PDU Data Zone then partial fill procedure on receiving end shall:

   1. determine the location the first octet of fill data in MA-PDU Data Zone using the value contained of Fill Data Pointer
   2. not pass to the Adaptation layer user the octets comprised from first octet of fill data in Data Zone till end of Data Zone.

b. If :

   - the value contained in Fill Data Pointer field indicates absence of fill data in MA-PDU Data Zone; and
   - MA-PDU is accepted by the other adaptation procedures used on the logical channel through which MA-PDU has been transmitted

   then whole MA-PDU Data Zone content shall be passed to the Adaptation layer user.

8.3.4 Labelled multiplexing/demultiplexing

8.3.4.1 Object

Labelled multiplexing/demultiplexing of logical channel provides with the capability to share one logical channel among several data streams.

In particular it provides data bus users in RT equipment with the capability to interleave data units over a transmit channel without prior notification of message content change to the Bus Controller.

The benefit of labelled multiplexing is a gain in latency times in asynchronous RT→BC transactions as well as share of data bus resources.

8.3.4.2 General

a. Labelled multiplexing/demultiplexing of a logical channel shall be conducted independently for each logical channel.

8.3.4.3 Actions at sending end

a. At sending end, MA-PDUs shall be submitted for transfer over a logical channel in an order defined by:

   1. the value contained in MA-PDU Logical Channel Extension Number field; and
   2. an algorithm to define which Logical Channel Extension Number among those used on that logical channel shall be transmitted on that logical channel at a given time.

   NOTE The algorithm for multiplexing a logical channel is not specified in this document. It shall be defined by project. Various algorithms may be used (e.g. priority-based, round-robin, schedule-based schemes).

b. No other field than MA-PDU Logical Channel Extension Number shall be used in the decision to select which Logical Channel Extension Number shall be transmitted on a logical channel at a given time.

8.3.4.4 Actions at receiving end

a. When an AP-PDU is received on a logical channel, the demultiplexing procedure shall examine the Logical Channel Extension Number field in MA-PDU header.

   1. If Logical Channel Extension Number field contains a value that is not used on that logical channel then MA-PDU shall be discarded.

   2. If Logical Channel Extension Number field contains a value that is used on that logical channel then MA-PDU shall be declared as accepted by demultiplexing procedure.

b. If MA-PDU is accepted by demultiplexing procedure then content of User Data field shall be passed to the Adaptation layer user associated to the logical channel and Channel Extension Number.

8.3.5 Duplication/loss detection

8.3.5.1 Object

Duplication/loss detection provides with the capability to detect lost or duplicated data blocks in a given stream of data blocks submitted for transmission over a given logical channel.

8.3.5.2 General

a. The use or not of duplication/loss detection procedure shall be defined per logical channel and Logical Channel Extension Number.

b. Duplication/loss detection shall be conducted independently for each logical channel and Logical Channel Extension Number where duplication/loss detection is used.

8.3.5.3 Actions at sending end

a. If duplication/loss detection is used, then

   1. the sending end shall associate a counter modulo “4” to each logical channel and Logical Channel Extension Number where duplication/loss detection is used;

   2. the initial value of this counter shall be value “0”;

   3. this counter shall be incremented by “1” modulo “4” each time an MA-PDU is submitted for transmission over the logical channel and Channel Extension Number associated to this counter;

8.3.5.4 Actions at receiving end

a. At receiving end, duplication/loss detection shall detect if an MA-PDU has been duplicated or lost.

   NOTE An example of duplication/loss detection algorithm is provided in 8.3.5.5. Projects may use other algorithms.

b. If an MA-PDU is detected as duplicated then it shall be discarded.

8.3.5.5 Example of duplication/loss detection algorithm

a. The description of this duplication/loss detection algorithm makes use of the following notations:

— MA-PDU(R): last MA-PDU received by duplication/loss detection algorithm

— MA-PDU(R-1): MA-PDU received previously to MA-PDU(R) on the same logical channel and with the same Logical Channel Extension Number value.

— SEQ(R): value contained in MA-PDU(R) Sequence Count field.

b. Upon receipt of MA-PDU(R), duplication/loss detection algorithm shall examine the value contained in Sequence Count field:

1. if SEQ(R) –SEQ(R-1) = 1 modulo 4 then MA-PDU(R) shall be accepted by duplication/loss detection algorithm;

NOTE This algorithm assumes that the probability for a multiple of four MA-PDUs to be lost between MA-PDU(R-1) and MA-PDU(R) receipt is negligible.

2. if SEQ(R) –SEQ(R-1)= 0 modulo 4 then MA-PDU(R) shall be declared as duplicated.

NOTE Same assumption as in NOTE in 8.3.5.5.b.1.

3. if SEQ(R) –SEQ(R-1) ≠ 0 or 1 modulo 4 then loss of data block(s) on logical channel and Channel Extension Number shall be declared.

8.3.6 Segmentation/reassembly

8.3.6.1 Object

Segmentation/reassembly provides with the capability to send data units whose length exceeds the maximum size of user information that can be transferred in one message over a particular logical channel.

8.3.6.2 General

a. The segmentation/reassembly procedure shall be conducted independently for each logical channel.

b. If multiplexing is used on a logical channel then segmentation/reassembly procedure shall be conducted independently for each Logical Channel Extension Number used on that logical channel.

8.3.6.3 Actions at sending end

a. If a user data unit to be sent over bus exceeds the length of MA-PDU Data Zone, then the segmentation procedure shall divide it into portions that do not exceed MA-PDU Data Zone length.

b. The length of each portion of user data shall be an integer number of octets.

c. The portions of user data shall be placed in order into a sequence of MA-PDUs.

d. The Sequence Flags of each MA-PDU in the sequence shall be set to indicate whether it contains a first, continuing or last segment of user data.

e. The first octet of user data shall be placed in the first octet of the Data Zone of the first segment MA-PDU.

f. The user data portions in the first and continuing segment MA-PDUs shall have a length equal to the maximum length of the MA-PDU Data Zone.

g. The last segment MA-PDU shall contain the remainder of the user data division.

h. If the last portion of user data has a length lower than MA-PDU Data Zone then the last portion of user data shall be delineated from the rest of MA-PDU Data Zone using partial fill procedure as specified in 8.3.3.

i. If the data unit to be sent over bus does not exceed the length of MA-PDU Data Zone, then the complete data unit shall be placed in a single MA-PDU.

NOTE In this case the Sequence Flags are set to indicate no segmentation.

8.3.6.4 Actions at receiving end

a. Reassembly procedure shall:

1. detect start and end of each sequence of segmented user data ; and
2. reassemble first, continuing and last segments in the detected sequence of segmented user data to recreate the original user data as it was before submission to segmentation/reassembly.

NOTE An example of reassembly algorithm is provided in 8.3.6.5. Projects may use other algorithms.

b. If segmentation/reassembly is performed on a logical channel where data blocks are susceptible to be duplicated or lost then the receiver shall control that no continuation segment has been lost or duplicated within a series of consecutive continuation segments.

NOTE This control may be done in Adaptation Layer by means of lost/duplicated detection procedure or at higher layers by means of an error detection function (e.g. using checksums, cyclic redundancy codes).

8.3.6.5 Example of reassembly algorithm

a. The description of this reassembly algorithm makes use of the following notation:

- INFO_buffer: temporarily storage of segmented user data not yet reassembled.

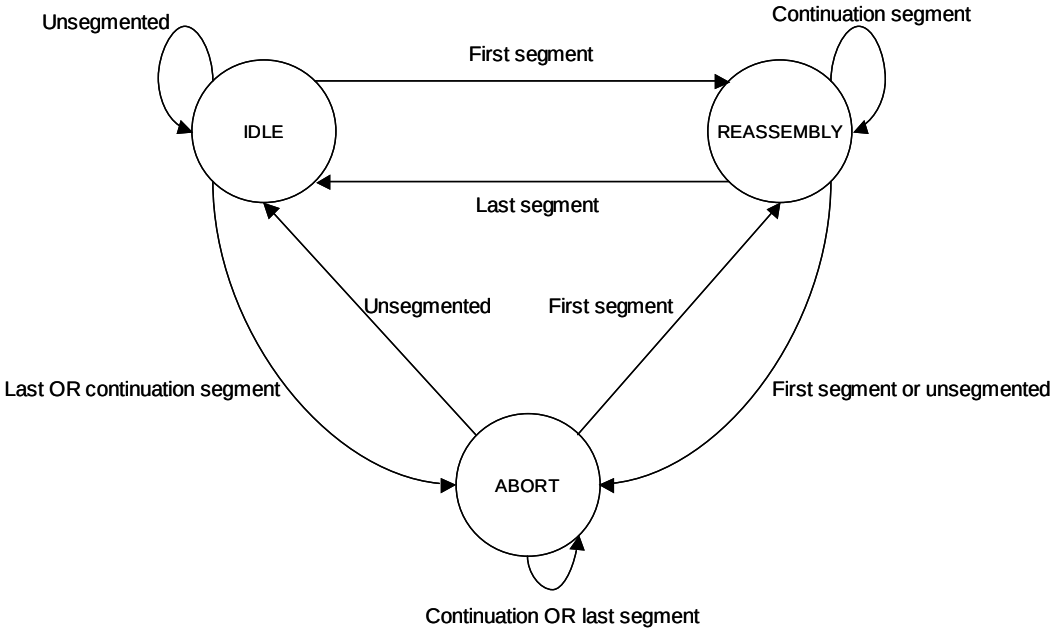


Figure 11: Example of reassembly algorithm – State diagram for the receiver

Table 4: Example of reassembly algorithm - State definition for the receiver

State	Definition
IDLE	Waiting to begin to reassemble a new MA-PDU
REASSEMBLY	Reassembling an MA-PDU
ABORT	Aborting an illegal MA-PDU sequence

b. At initialisation, the reassembly process shall enter ABORT state as depicted in Figure 11.

c. When the reassembly process enters ABORT state, INFO_buffer shall be emptied.

d. If reassembly process is in ABORT state, and a MA-PDU received with sequence flags indicating that MA-PDU contains:

1. a continuation segment or a last segment of user data then :
   - i MA-PDU shall be discarded; and
   - ii reassembly process shall stay in ABORT state as depicted in Figure 11.

2. unsegmented user data then :
   - i MA-PDU shall be declared as accepted by reassembly process; and
   - ii the content of MA-PDU User Data field shall be passed to the Adaptation layer user as specified in 8.3.2.a; and
   - iii reassembly process shall enter into IDLE state as depicted in Figure 11.

3. a first segment of user data then:
   - i the user data contained in MA-PDU shall be stored into INFO_buffer ; and
   - ii reassembly process shall enter into REASSEMBLY state as depicted in Figure 11.

e. If reassembly process is in IDLE state, and a MA-PDU received with sequence flags indicating that MA-PDU contains:

1. unsegmented user data then :
   - i the MA-PDU shall be declared as accepted by reassembly process; and
   - ii content of MA-PDU User Data field shall be passed to the Adaptation layer user as specified in 8.3.2.a; and
   - iii reassembly process shall stay in IDLE state as depicted in Figure 11.

2. a continuation segment or a last segment of user data then :
   - i MA-PDU shall be discarded; and
   - ii reassembly process shall enter into ABORT state as depicted in Figure 11.

3. a first segment of user data then:
   i the user data contained in MA-PDU shall be stored into INFO_buffer ; and
   ii reassembly process shall enter into REASSEMBLY state as depicted in Figure 11.

f. If reassembly process is in REASSEMBLY state, and a MA-PDU received with sequence flags indicating that MA-PDU contains:

1. a continuation segment then:
   i the user data contained in MA-PDU shall be appended to the current content of INFO_buffer ; and
   ii reassembly process shall stay in REASSEMBLY state as depicted in Figure 11.

2. a last segment then :
   i the user data contained in MA-PDU shall be extracted from MA-PDU, possibly using the partial fill procedure and appended with the current content of INFO_buffer ; and
   ii the content of INFO_buffer declared as accepted by reassembly process and passed to the Adaptation layer user
   iii reassembly process shall enter into IDLE state as depicted in Figure 11.

3. unsegmented or a first segment of user data then :
   i MA-PDU shall be discarded; and
   ii the content of INFO_buffer shall not be passed to the Adaptation layer user
   iii reassembly process shall enter into ABORT state as depicted in Figure 11.

Annex A (Normative)
Verification of conformance to MIL-STD-1553B

A.1 General

a. Tracing applicable MIL-STD-1553B Notice 2 requirements

Applicable requirements in MIL-STD-1553B Notice 2 shall be traced throughout the development of the data bus system.

NOTE See also 5.1.

b. Incremental verification

Verification of applicable requirements in MIL-STD-1553B Notice 2 shall be performed incrementally from terminal to complete data bus system.

NOTE This is to allow early detection of non-conformances or incompatibilities.

c. Verification documentation

1. Verification of applicable MIL-STD-1553B Notice 2 requirements shall be documented.
2. The verification documentation required in 1 shall at least cover the following points:
   - i verification logic;
   - ii verification methods;
   - iii test / simulation objectives, procedures, pass criteria;
   - iv verification results.

A.2 Terminal verification

a. Verifying remote terminal as a separate entity

Whenever possible, the remote terminal part of an equipment should be verified as a separate entity against MIL-HDBK-1553A Section 100 prior to assembly with the rest of equipment.

b. Verifying bus controller as a separate entity

Whenever possible, the bus controller part of an equipment should be verified as a separate entity against AS 4113 prior to assembly with the rest of equipment.

NOTE Verifying the terminal part of equipment as a separate entity allows detection of possible non-conformance to MIL-STD-1553B Notice 2 before equipment development is finished.

A.3 Equipment verification

a. Testing remote terminals when integrated in equipment

Remote terminal equipment shall be verified against MIL-HDBK-1553A Section 100 with point A as defined in Figure 6.

b. Testing remote terminals when integrated in equipment

Bus controller equipment shall be verified against AS 4113 with point A as defined in Figure 6.

A.4 Bus network verification

A.4.1 Verification of bus network design

a. Verifying bus network design prior to development

Bus network design (including topology) shall be verified prior to harness development.

A.4.2 Testing bus network components

a. Verification of transformers and resistors prior to assembly in bus network

Transformers and resistors in bus network shall be tested prior to assembly into bus network.

b. Testing data bus cable

Data bus cable shall be tested against AS4117, clause 3.3.

c. Testing removable data bus terminator

Removable data bus terminator shall be tested against AS4117, clause 3.2.

NOTE Removable data bus terminator is defined in 3.1.22

d. Testing data bus coupler

Data bus coupler shall be tested against AS4117, clause 3.1.

A.4.3 Testing bus network

a. Testing bus network as a separate entity

Bus network shall be tested as a separate entity prior to integration into data bus system.

b. Bus network test procedure

Bus network shall be tested using the test procedures and pass criteria specified in AS 4115, clause 5.1.

A.5 Data bus system verification

c. Objective of data bus system verification

Data bus system verification shall demonstrate that all the components of the data bus system (hardware and software) interact as specified in nominal and failure modes and that the data bus system meets its performance requirements.

NOTE The variety of system configurations precludes a definition of a generic data bus system test specification. Individual specification has to be written by project. AS 4115, clause 5.2 contains some guideline information for defining system integration tests.

Annex B (Normative)
Interface connectors and contact assignments

Editorial note: Like for any section in this document, this annex is open for discussions within the working group. Other connectors than those herein addressed may be proposed. At the end of the discussions a set of connectors should be selected as project cross compatible for future equipments. The objective is to limit the proliferation of various connection interfaces.

B.1 Equipment connectors

B.1.1 Connectors with data bus and RT address contacts

a. If an equipment connector supports data bus and RT address assignment signals then:

   1. this connector shall meet the form, fit, function, and interface requirements of type 01B, shell size 12, contact arrangement 12-0, DBAS connectors defined in ESCC Detail Specification No. 3401/008.

   2. the contact assignments shall be compatible with the contact assignments of Table B- 2.

Table B- 1: Equipment connectors with data bus and RT address contacts - contact assignments

Contact Ref#	Signal Name
1	n.c.
2	Address bit A0 (LSB)
3	Address bit A1
4	n.c.
5	Bus High (positive) Manchester bi-phase signal
6	Bus Low (negative) Manchester bi-phase signal
7	n.c.
8	Address bit A2
9	Address bit A3
10	Address bit A4 (MSB)
11	Address parity
12	Return

B.1.2 Connectors with data bus contacts only

a. If an equipment connector supports no other signals than data bus signals then:

1. this connectors shall meet the form, fit, function, and interface requirements of type 01B, shell size 3, contact arrangement 3-0, DBAS connectors defined in ESCC Detail Specification No. 3401/008.

2. the contact assignments shall be compatible with the contact assignments of Table B- 2.

NOTE This connector is suitable for bus repeaters.

Table B- 2: Equipment connectors with data bus contacts only - contact assignments

Contact Ref#	Signal Name
1	Bus High (positive) Manchester bi-phase signal
2	Bus Low (negative) Manchester bi-phase signal
3	Bus Shield

B.1.3 Connectors with RT address contacts only

a. If an equipment connector supports no other signals than RT address assignment signals then :

1. this connectors shall meet the form, fit, function, and interface requirements of type 01B, shell size E, contact arrangement 09, D*M connectors defined in ESCC Detail Specification No. 3401/001 (TBC);

2. the contact assignments for RT address connectors shall be compatible with the contact assignments of Table B- 3.

Table B- 3: Connectors with RT address contacts only - contact assignments

Contact Ref#	Signal Name
1	Address return
2	Address bit A0 (LSB)
3	Address bit A1
4	Address bit A2
5	Address bit A3
6	Address bit A4 (MSB)
7	Address parity
8	n.c.
9	n.c.

B.2 Main bus line extension connectors

B.2.1 Contact and mechanical specification

Main bus lines extension connectors shall:

a. meet the form, fit, function, and interface requirements of type 01B, shell size 09, contact arrangement 09-01, triax connectors defined in ESCC Detail Specification No. 3401/052;

b. conform to ESCC Detail Specification No. 3401/066.

B.2.2 Contact assignments

The contact assignments for main bus line extension connectors shall be compatible with the contact assignments of Table B- 4.

Table B- 4: Main bus line extension connectors - contact assignments

Contact Ref.	Signal Name
Inner	Bus High (positive) Manchester bi-phase signal
Intermediate	Bus Low (negative) Manchester bi-phase signal
Outer	Bus Shield

Bibliography

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