ESA PSS-46 (TTC.A.02) Issue No. 1
April 1978

PCM telemetry standard

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VALIDITY

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E R R A T U M

PSS-46 (TTC-A-02)

Issue No. 1 (April 1978)

"PCM TELEMETRY STANDARD"

1. Page 11, subsection 3.4.5. The third sentence should read :

   (... is defined in subsections 4.4.9 and 4.4.10)....
   (instead of (... in subsection 4.3.9)...)

2. Page 18. Subsection 4.4.6, "Frame Synchronisation". The binary value of the 24. bit code is not correct : there should be one more "zero" at the end of the 3rd 8-bit word (octal 040 is correct).

   The same code is given correctly in Appendix B, subsection B5-2 (page 37).

3. This ERRATUM follows a previous ERRATUM made in September 1979 and provided as a sticker in the copies of PSS-46 which were distributed in October 1979.

   This sticker is reproduced here below :

ESA PSS-46 (TTC.A.02) Issue 1
PCM TELEMETRY STANDARD

ERRATUM

In Subsection 4.2.1 'Range', the second line should read:

...from 5 bit/s to **500** kilobits/s...

(instead of ... to 50 kilobits/s ...).

ESTEC - September 1979

D. Rouat (THA)

Technical Secretary of the
Standards Approval Board
(STAB)

ESTEC, July 1980.

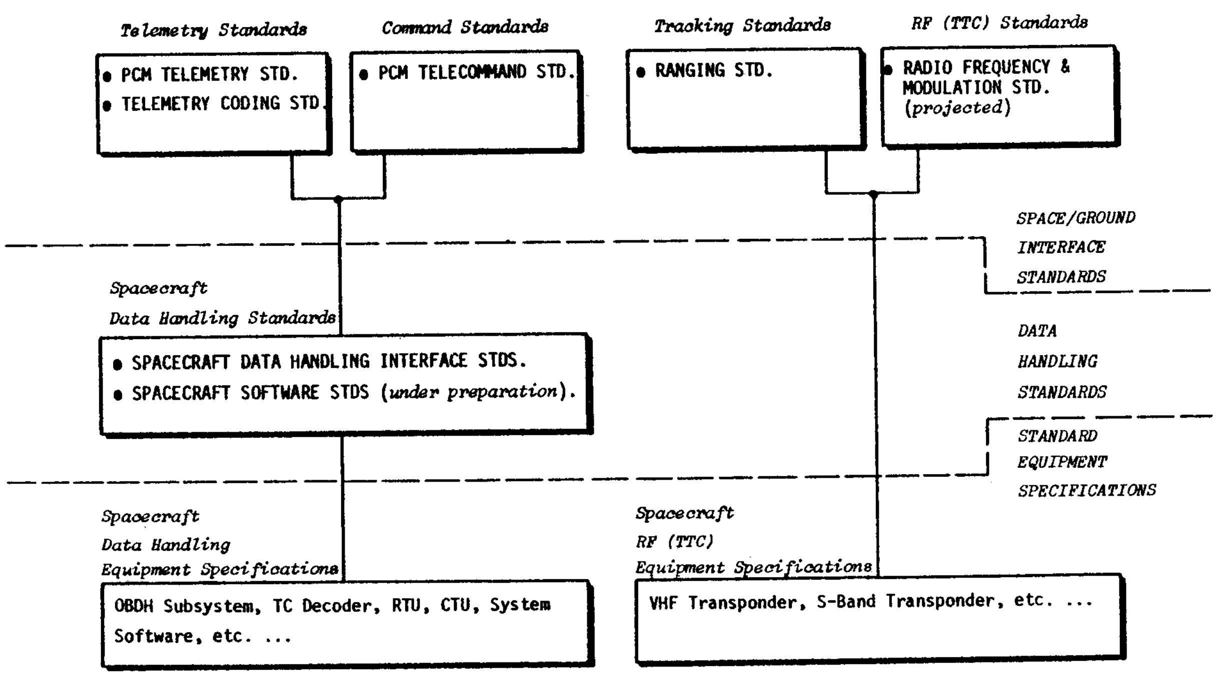
ABSTRACT

This standard is a section of the Telemetry, Tracking, Command and Data-handling Standards of the European Space Agency. It represents one of the documents defining the space/ground interfaces. As such, it establishes and specifies a set of uniform techniques that will permit reliable and efficient transmission of analogue and/or digital data from ESA spacecraft. As a consequence, it is possible to guarantee optimum performance during data-recovery operations in the ESA ground stations. The level of compatibility with the equivalent NASA-GSFC Telemetry Standards is also indicated.

ORGANISATIONAL STRUCTURE

(April 1978)

This standard is a section of the Telemetry, Tracking, Command and Data-handling Standards of ESA (ESA TTC & DH STDS), the organisational structure of which is shown diagrammatically below. It can be seen that, within this structure, the PCM Telemetry Standard (PCM TM STD) represents one of the documents defining the space/ground interfaces.



PCM TELEMETRY STANDARD

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PCM TELEMETRY STANDARD

1. PURPOSE

The purpose of this Standard is to:

- ensure compatibility of ESA spacecraft PCM telemetry encoding systems, ESTRACK station PCM telemetry decoding systems and Ground Data Handling and Processing systems;
- ensure compatibility of ESA spacecraft PCM telemetry encoding systems and NASA - GSFC Networks;
- establish a minimum acceptable level of end-to-end performance for PCM telemetry systems conforming to this Standard;
- unify data interfaces and data handling operations in ground systems.

2. APPLICABILITY

This Standard applies:

- to all space and ground systems sponsored or managed by ESA or its affiliated agencies and using the ESA infrastructure;
- to all space systems sponsored or managed by ESA and using the NASA - GSFC Networks (see chapter concerning NASA compatibility).

The capabilities provided within the constraints of this Standard will accommodate the requirements of a great variety of applications for PCM telemetry systems, thus providing a universal basis for cost-effective and technically compatible development of PCM telemetry equipment in different projects.
In exceptional cases, owing to mission-specific requirements, some deviations from this Standard may be warranted. Waivers to any requirements set forth in this Standard may be obtained only after:

- the technical and/or operational advantages of such deviant actions have been demonstrated, and
- it has been shown that the intended change is compatible with existing systems.

Requests for waivers, as well as requests for the allocation of each spacecraft telemetry characteristic (frequencies, synchronisation codes, etc. .....) should be addressed by the Project Manager to the Head of the Payload Technology Group (code: TX) of the Department of Development and Technology of ESTEC. Such requests should be submitted as early as possible, preferably during the study phase of the project.

3. CONCEPT AND DEFINITIONS

3.1 System Concept

A spacecraft/ground PCM Telemetry Data System is illustrated in Figure 3.1. In principle, the PCM telemetry encoding function is that of parallel-to-serial conversion, where the multiple parallel inputs are the telemetry (TM) channel inputs and the single serial output is the PCM telemetry message which is transmitted to the ground.

3.1.1 *The PCM telemetry encoding function*

The PCM telemetry encoding is performed by the on-board data-handling subsystem. PCM telemetry encoding consists of:

- sampling sequentially (time division multiplex) all TM data sources connected to its inputs;
- encoding the TM data inputs with a specified accuracy and according to a given format;
- providing the serial output TM message for transmission through the radio frequency (RF) link to the ground;
- providing encoded TM data to other points in the spacecraft as required;
- coding of the PCM telemetry message for error control. (This part of the PCM telemetry encoding function is covered separately in another section of the ESA Telemetry Standards.)

3.1.2 *The telemetry channels*

By time division multiplexing, the down link is subdivided into telemetry channels. A TM channel is associated with only one input to the TM encoder. One TM channel input can consist of one or several lines, depending on the type of TM channel. The standard TM encoder provides inputs for the following types of channels:

- analogue channels, for the acquisition of single-ended or double-ended analogue data;
- digital channels, for the acquisition of digital data (serial or parallel high speed);
- bi-level channels, for the acquisition of single-bit status data to be subsequently transmitted in groups of 8-bit words;
- datation channels, for the acquisition of event occurrence time (spacecraft time).

The interface characteristics of the corresponding TM encoder inputs are defined in the "Spacecraft Data Handling Interface Standards" (ESA PSS-47 (TCC.B.01) Issue 1 (April 1978)).

3.1.3 *The PCM telemetry message*

The PCM telemetry message is arranged in serial blocks:

- the TM word, consisisting of 8 consecutive bits;
- the TM frame, consisting of an integral number of TM words;
- the TM format, consisting of an integral number of TM frames.

In the TM format, a TM word can represent:

- one data sample, as in the case of analogue channels or 8-bit serial digital channels;
- one part of one data sample, as in the case of 16-bit serial digital channels or parallel digital channels (64 bits);
- eight data samples, as in the case of the bi-level channels.

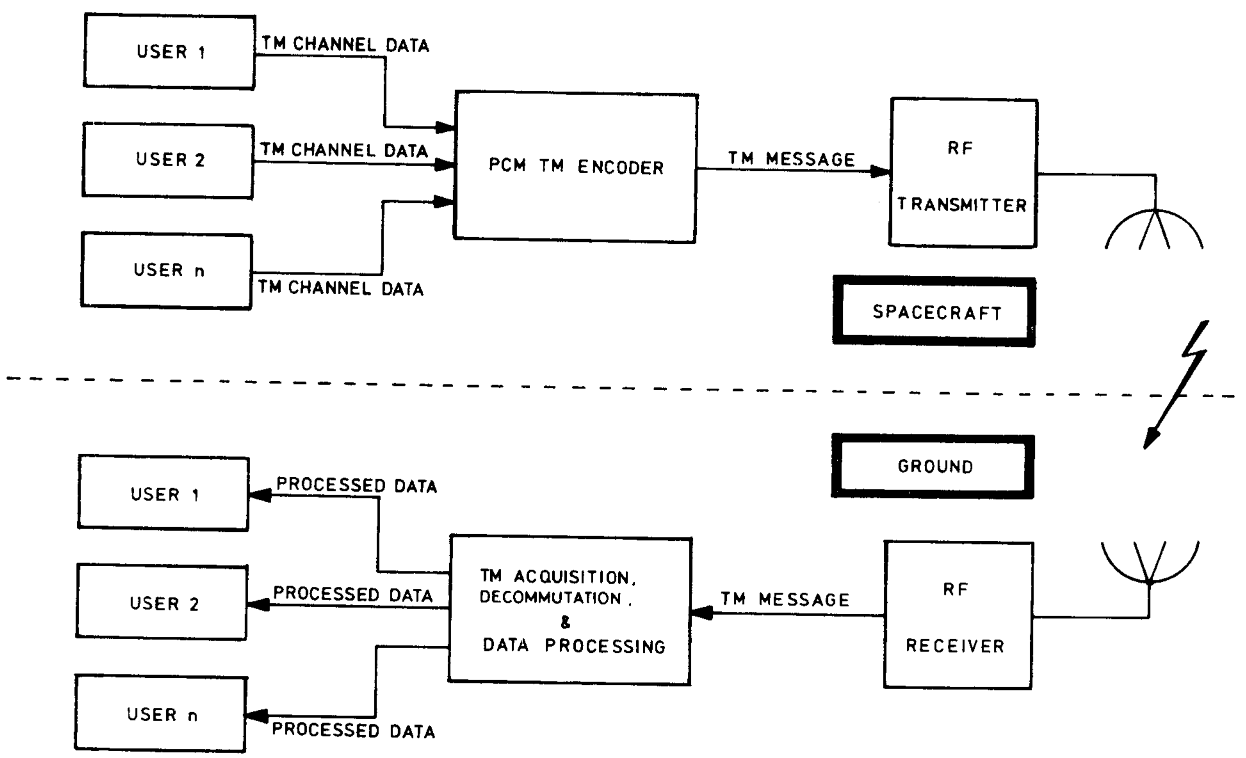


Figure 3.1 - Spacecraft/Ground PCM Telemetry Data System

3.1.4 *Ground data acquisition and processing*

The decommutation station acquires the serial bit stream of the telemetry message and retrieves the 8 bit TM words, including word identification (address of word in format).
"Quick-look" facilities available at the station are capable of displaying TM words in binary, octal, decimal or analogue form on a real-time basis. Further processing by computer provides data outputs to users in an engineering/scientific form.

While the largest proportion of telemetry-channel data samples have a resolution of 8 bits (hence the 8-bit basis for the TM word), many other data samples have a resolution of 16 bits. For this reason, and in order to make the most efficient use of the 16-bit word based Ground Data Handling and Processing facilities currently provided by ESA, standard telemetry formatting rules have been established, which are defined in Chapter 4: "Telemetry Format Standards".

3.2 Number System

The number systems used for PCM telemetry shall be the conventional decimal or octal system shown in Table 3.1. In all cases, the least significant bit (LSB) of any quantity generated within the PCM telemetry encoder shall be transmitted as the last bit of a TM word (encoding of analogue data, format counter etc.).
The users shall transmit their digital data to the TM encoder most significant bit (MSB) first, and the encoder shall transmit this data in the same order as received.

Binary (8 bits)	Decimal	Octal
0	0	0
1	1	1
10	2	2
---	---	---
111	7	7
1000	8	10
1001	9	11
----	---	---
1111	15	17
10000	16	20
-----	---	---
11111110	254	376
11111111	255	377

Table 3.1 - Number System Conventions

3.3 The PCM Telemetry Message

The PCM telemetry message is a serial pulse-code-modulated data stream. The elements composing the PCM telemetry message are in order of importance:

BIT, WORD, FRAME and FORMAT

3.3.1 *The bit*

The bit is a binary digit, "one" or "zero", occupying a unit bit interval in the PCM telemetry message. The bit frequency or bit rate is ultimately determined by the amount of information to be transmitted.

3.3.2 *The word*

The TM word consists of 8 consecutive bits and forms the basic information block for transmitting data through a TM channel. The allocation of TM channels is made in terms of position of a TM word (or TM words) with respect to the beginning of a specific TM frame (or a specific group of TM frames) of the TM format.
By convention, the last bit issued of the TM word shall be the least significant bit (LSB).
The first bit of the TM word issued is called bit "zero" (B 0) and the last bit of the TM word issued is called bit "seven" (B 7).

CAUTION Because of the above convention, bit 0 (MSB) corresponds to the binary weight 2^7 and bit 7 (LSB) corresponds to the binary weight 2^0.

3.3.3 *The frame*

The TM frame is a group of words transmitted consecutively in time. The number of words in a frame is fixed for a given TM format. The first word of the frame is referred to as word "zero" (W 0). A frame always begins with a frame synchronisation code, which is used to recognise the beginning of the frame.

3.3.4 *The format*

The TM format is a group of frames transmitted consecutively in time. The number of frames in a format is fixed for a given telemetry transmission. The first frame of the TM format is referred to as frame "zero" (F 0). The various frames of a format are identified by a frame counter word transmitted through an "Identification" channel (ID channel). (See Subsection 4.3.7.)

3.3.5 *Supercommutation and subcommutation*

Data commutation at sampling rates which are multiples or sub-multiples of the TM frame rate is permissible. A channel is said to be:

- frame commutated, if its input is sampled once per frame.
- supercommutated, if its input is sampled more than once per frame.
- subcommutated, if its input is sampled less than once per frame and at least once per format.

3.4 The Telemetry Channels

3.4.1 *Analogue channels*

The information is presented in the form of a voltage varying between two defined boundaries. This voltage is sampled regularly, analogue-to-digital converted and issued as an 8-bit TM word of the output message, LSB transmitted last. The input of an analogue channel can be:

- single ended (s.e.), reference terminal connected to the ground reference, input terminal positive with respect to the reference terminal.
- double ended (d.e.), reference terminal floating with respect to the ground reference, input terminal positive with respect to the reference terminal.

3.4.2 *Serial digital channels*

The information is required on one line in the form of a series 8 or 16 binary digits in NRZ-L. These data are sampled and acquired with the aid of:

- digital sampling signals, one for each serial digital channel input. A digital sampling signal is a gate pulse which is used by the user to control the transfer of data to the TM encoder. The duration of the digital sampling signal is such as to gate 8 or 16 acquisition clock pulses;
- one acquisition clock signal which is common to all channels and provided continuously.

The serial digital information is transmitted as one (8 bits) or two adjacent (16 bits) TM words.

3.4.3 *Parallel digital channels (High Speed)*

For each parallel digital channel input, the information is acquired on 8 lines in the form of 8 "bytes" of 8 parallel bits (64 bits). These 8 bytes are sampled and acquired with the aid of:

- one digital sampling signal, which is used to gate 8 acquisition clock pulses, each pulse being used to acquire one byte of 8 bits;
- one acquisition clock signal which is common to all channels and provided continuously (see Subsection 3.4.2).

3.4.4 *Digital bi-level channels*

The digital bi-level channels are used to transmit discrete status bits, each channel corresponding to one bit of the PCM telemetry message.

The digital bi-level information is presented in the form of a voltage that can assume only two distinct values, an on level ("ONE" level) and an off level ("ZERO" level), with respect to the ground reference.

The digital bi-level channels are transmitted in TM words which are especially allocated to these channels.

3.4.5 *Datation channels*

The datation channels are a special class of telemetry channels. The information to be "datated" is presented on one line in the form of a single event pulse representing the occurrence in time of an event. This event pulse is used to sample and store the contents of a 32 bit (maximum) timing counter in a datation register (the timing counter is defined in Subsection 4.3.9). The datation register is then read out at regular intervals by a serial digital channel especially allocated to this datation channel.

3.4.6 *Telemetry channel operating language*

For operational use it is necessary to specify the telemetry channel type and number. Appendix A, "Telemetry Channel Nomenclature", indicates the symbols and numbers to be used when referring to each type of TM channel.

4. TELEMETRY FORMAT STANDARDS

This chapter is concerned with the specification of the PCM telemetry message.

4.1 Binary State Representation

This Standard allows the use of the following PCM conventions for representing binary state "one" and binary state "zero":

- NRZ - level.
- NRZ - mark.
- split phase - level.
- split phase - mark.

(Refer to Figure 4.1: "PCM waveforms".)

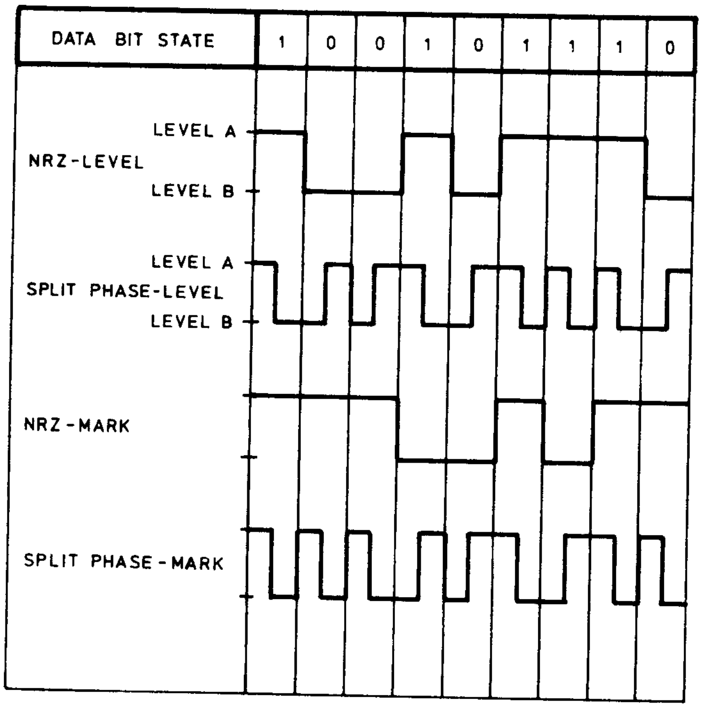
When any of the above codes are used, the following facts are to be observed:

a) a minimum of <u>one transition every 64 bits</u> is required when any NRZ type of code is used;

b) when a "mark" type of code is used, a single wrong decision on the input bit stream will provoke a <u>double bit error</u> at the output;

c) the conventions used in Figure 4.1, "PCM waveforms", are to be deemed part of the Standard;

d) waveform symmetry measured at the output of the encoder shall be such as to guarantee a mark-to-space ratio between 0.998 and 1.002.



NRZ-LEVEL:

- a level A signifies bit state "ONE"
- a level B signifies bit state "ZERO"

SPLIT PHASE-LEVEL:

- a level A during the first half-bit followed by a level B during the second half-bit signifies bit state "ONE"
- a level B during the first half-bit followed by a level A during the second half-bit signifies bit state "ZERO"

NRZ-MARK:

- a single change in level signifies bit state "ONE"
- no change in level signifies bit state "ZERO"

SPLIT PHASE-MARK:

- a single change in phase signifies bit state "ONE"
- no change in phase signifies bit state "ZERO"

Figure 4.1 - PCM Waveforms

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. . . from 5 bit/s to **500** kilobits/s . . .
(instead of . . . to 50 kilobits/s . . .).

ESTEC - September 1979

4.2 Bit Rate

4.2.1 *Range*

The permissible range of PCM telemetry bit rates is from 10 bits/s to 1 megabit/s for NRZ codes and from 5 bits/s to 50 kilobits/s for split-phase codes.

4.2.2 *Stability*

4.2.2.1 *Encoders*

Long-term stability (one year), short-term stability (5 minutes) and instantaneous stability (bit jitter) depend on:

- the spacecraft radio-frequency and modulation requirements;
- the spacecraft timing requirements, i.e. spacecraft clock accuracy and stability.

However, the minimum stability requirements shall always be better than:

- long-term stability : $\pm 1 \times 10^{-4}$ of bit rate;
- short-term stability : $\pm 1 \times 10^{-5}$ of bit rate;
- instantaneous stability: $\pm 1 \times 10^{-6}$ of bit rate.

4.2.2.2 *Tape recorders*

(To be defined on a case-by-case basis.)

4.2.3 *Data rate change*

Changes in bit rates during transmission are permissible only by command from a ground station. For a given TM format, the changes in bit rates shall always effectively occur at a time corresponding to the first bit of the first word of the first frame (B0 W0 F0) of the output message.

The TM data shall contain a positive indication of the bit rate in use.

4.3 Interface with the RF Subsystem

4.3.1 *Telemetry video signal*

The input signal to the RF transmitter is the telemetry video signal This video signal must be compatible with the ESA "Radio Frequency and Modulation Standard"†) and with the specifications of the RF transmitter.

The telemetry video signal to the RF transmitter can be either the PCM waveform direct (as specified in Sections 4.1 and 4.2) or a PCM modulated PSK subcarrier (as specified hereafter).

4.3.2 *PSK subcarrier*

Figure 4.2, "PSK Subcarrier", shows an example of PSK video signal.

Waveform: square wave, unless otherwise specified.

Frequency: the PSK subcarrier is directly related in phase and frequency to the PCM message clock. The subcarrier frequency is an integral multiple of the bit rate, in the range from 100 Hz to 1 MHz. The frequency stability is that of the encoder bit rate (see Paragraph 4.2.2.1).

Phase: The phase transitions (PSK switching) will commence within 10 degrees of the zero crossings of the subcarrier. The phase of the switched signal will be within 5 degrees that of a perfectly switched signal.

Modulating signal: PCM signal, as defined in Section 4.1.

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†TTC.A.05, in preparation.

4.4 The Standard Telemetry Format

4.4.1 *Scope and performance*

The performance of the Standard Telemetry Format is guaranteed for bit error rates of one bit in error for 10^5 bits or better.

4.4.2 *Word length*

The word length shall be 8 bits at all times.

4.4.3 *Frame length*

The maximum frame length shall be 1024 words. A frame shall always consist of an even number of TM words. Use of frames longer than 128 words shall be subject to ESA approval, following appropriate justification.

4.4.4 *Format length*

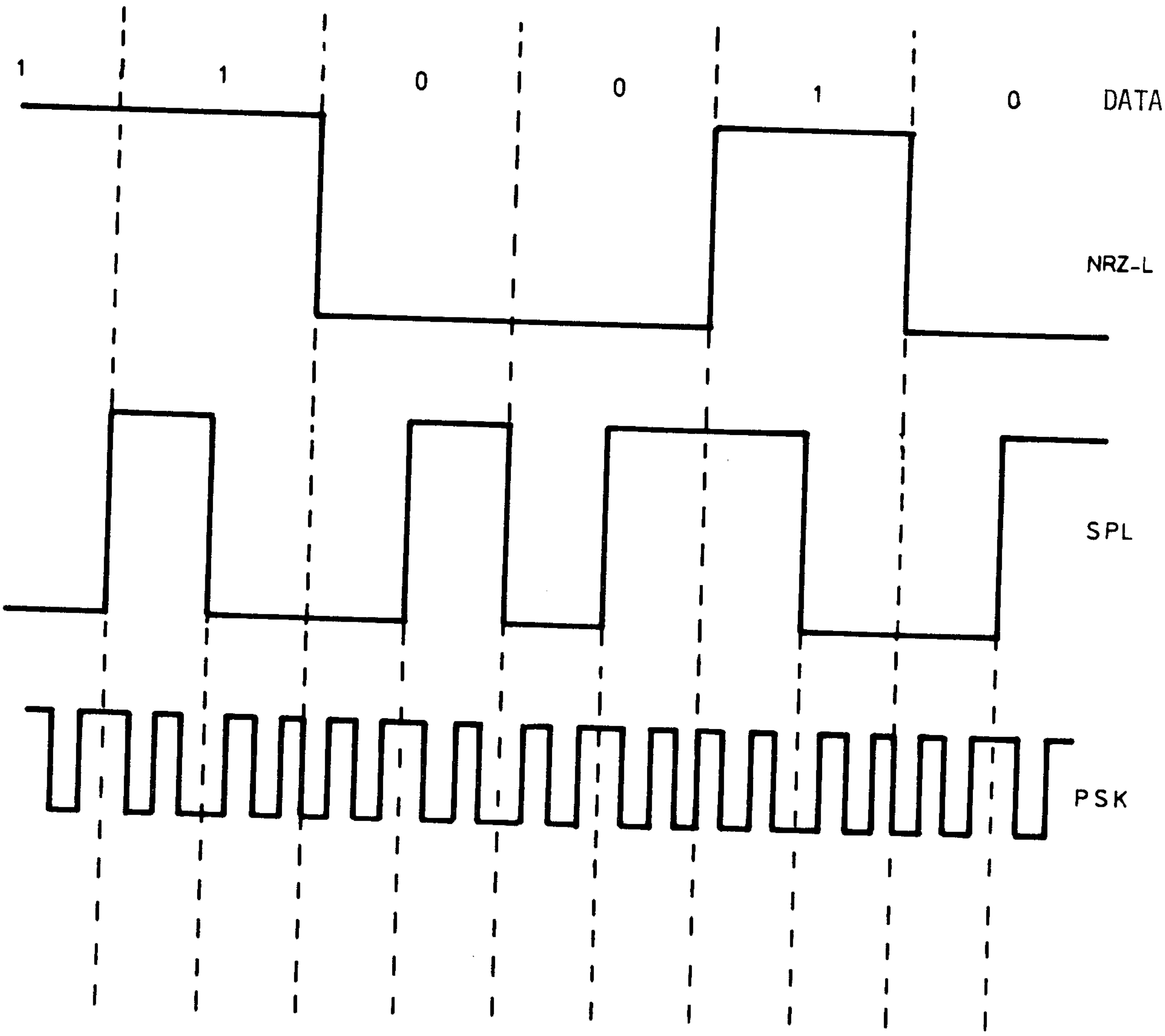
The maximum format length shall be 256 frames and 2^{15} TM words (32768 TM words).

4.4.5 *Bit synchronisation*

Bit synchronisation at the ground station shall be guaranteed by sufficient changes of state (bit transitions) in the PCM message generated on board the spacecraft. The maximum number of data bits between transitions must not exceed 64 when using NRZ codes.

4.4.6 *Frame synchronisation*

Frame synchronisation on the ground shall be achieved by using a synchronisation pattern of 16, 24 or 32 bits, repeated at the



This example shows an SPL-modulated PSK subcarrier, where the subcarrier frequency/bit-rate ratio equals 2.

Figure 4.2 - PSK Subcarrier

beginning of every frame. The standard frame synchronisation codes are as follows:

<u>16-BIT CODE</u>

11101011	10010000
octal 353	octal 220

<u>24-BIT CODE</u>

11111010	11110011	0010000
octal 372	octal 363	octal 040

<u>32-BIT CODE</u>

11111010	11110011	00110100	00000000
octal 372	octal 363	octal 064	octal 000

- For frame lengths up to 128 words, the 16-bit synchronisation code shall be used.
- For frame lengths from 129 words to 1024 words, the choice of the synchronisation code shall be subject to ESA approval following appropriate justification.

4.4.7 *Format synchronisation*

Format synchronisation shall be achieved by using a frame identification channel (ID channel). The ID channel is a frame-commutated 8-bit channel used to transmit the contents of a frame counter. The channel value "zero" shall correspond to the first frame (F 0). The frame counter shall be a binary counter.

The LSB of the ID channel shall be transmitted last, and when the number of frames is below 128, the bit(s) not used shall be transmitted as "zero(s)".

4.4.8 *Format change*

Changes in TM format structures during transmission are permissible only by command from a ground station. The changes in format shall always effectively occur at a time corresponding to the first bit of the first word of the first frame (BOWOFO) of the output message. The TM data shall contain a positive indication of the format in use.

4.4.9 *Format-counter channel*

The format-counter channel is a channel used to transmit the contents of a format counter. The format-counter channel shall be an 8-, 16-, 24- or 32-bit channel as required for the mission. The format counter shall be a binary counter. The LSB shall be transmitted last and the bits not used shall be transmitted as "zeros". In the case of simple mission timing requirements, the format-counter channel can also perform the function of a spacecraft timing channel.

4.4.10 *Spacecraft timing channels*

The spacecraft reference clock is the clock source which drives the TM encoder. All spacecraft timing functions are referenced to this clock and in particular the spacecraft timing counters associated with the spacecraft timing channels.
A spacecraft timing channel is used to transmit the contents of a spacecraft timing counter. The timing channel shall be an 8-, 16-, 24- or 32-bit channel, as required for the mission. The LSB of the timing counter shall be transmitted last.

4.4.11 *Telemetry channels formatting*

Data handling and processing requirements both on board the spacecraft and on the ground (see Subsection 3.1.4) make it necessary to follow some precise rules when establishing a TM format.

Rule 1: The TM format must always be established on the basis of successive pairs of TM words, i.e. on a 16-bit word basis. This complies with Subsection 4.4.3, which states that a frame must always consist of an even number of TM words.

Rule 2: All 16-bit based channel information shall be transmitted as a pair of TM words, as defined above, i.e. the first 8 bits being transmitted in an even TM word.

This rule applies, for example, to the 16-bit serial digital channel data, the parallel digital data (4 x 16 = 64), the contents of counters (timing, datation format) when they are longer than 8 bits.

4.5 The Floating Format

4.5.1 *Concept*

The standard TM format concept permits the transmission to ground of data which are sampled and encoded in a regular cyclic manner.

However, it is sometimes required to transmit to ground PCM data that are of an irregular nature in the sense that they may vary in length, time of occurrence, or both

To achieve this, it is necessary to ensure:

- correct ground acquisition performance, which is best done by using a rigid transmission procedure;
- data transmission efficiency which, for data of this type, requires a flexible transmission procedure.

To achieve this, a special data channel is constructed from all available words of the standard TM format. This data channel is used to transmit a PCM message which is formatted and buffered outside of the TM encoder. This message is called the floating format message, because it is not synchronous with the standard TM format.

With this procedure, acquisition at the ground station shall be made in two steps.

- The first step is the acquisition of the standard PCM telemetry message, the decommutation of all the channel data and, in particular, the floating-format-channel data.
- The second step is to process the floating format data by means of identification techniques specified in the following sections.

4.5.2 *Floating-format channel*

The data channel used to transmit the floating-format message is called the floating-format channel. Figure 4.3 shows an example of a standard TM format containing a floating-format channel. As can be seen, once all other telemetry functions have been allotted their location in the TM format ("normal" TM channels, ID channels etc.), the rest of the format can be used to transmit the floating-format information. The example in Figure 4.3 shows that the floating-format channel (normally a serial digital channel) can be an exception to the standards established in Subsection 3.3 5 (supercommutation and subcommutation), since this TM channel is not necessarily sampled at regular intervals. In the case of irregular sampling, the hardware "quick-look" facilities of the Ground Telemetry Equipment cannot display the contents of the floating-

format channel on a single display unit, as is normally done for any other TM channel, supercommutated or not.
The formatting rules defined in Subsection 4.4.11 apply to the floating-format channel: the floating-format channel shall consist of a succession of 16-bit words (integral pairs of TM words).

4.5.3 *Floating-format structures*

4.5.3.1 *Floating-format message*

In principle, the floating-format message can contain two sorts of message "fields":

- the Data Fields, which contain the floating data proper;
- the No-data Field, which is the period when no data are available.

There can be more than one specific data field in the same floating format. All fields must be clearly identified in the floating-format message in order to permit efficient data processing on the ground. For this purpose, standard field-identification techniques shall be employed where necessary (see Paragraph 4.5.3.2).
The basic length of the field word shall always be an integral multiple of 16 bits. Field words shall be TM-word synchronous, i.e. the first bit of a field word shall always coincide with the first bit of a TM word.

CAUTION Since transmission of the floating-format channel is performed on a 16-bit basis, a field word shall always begin with an even TM word.

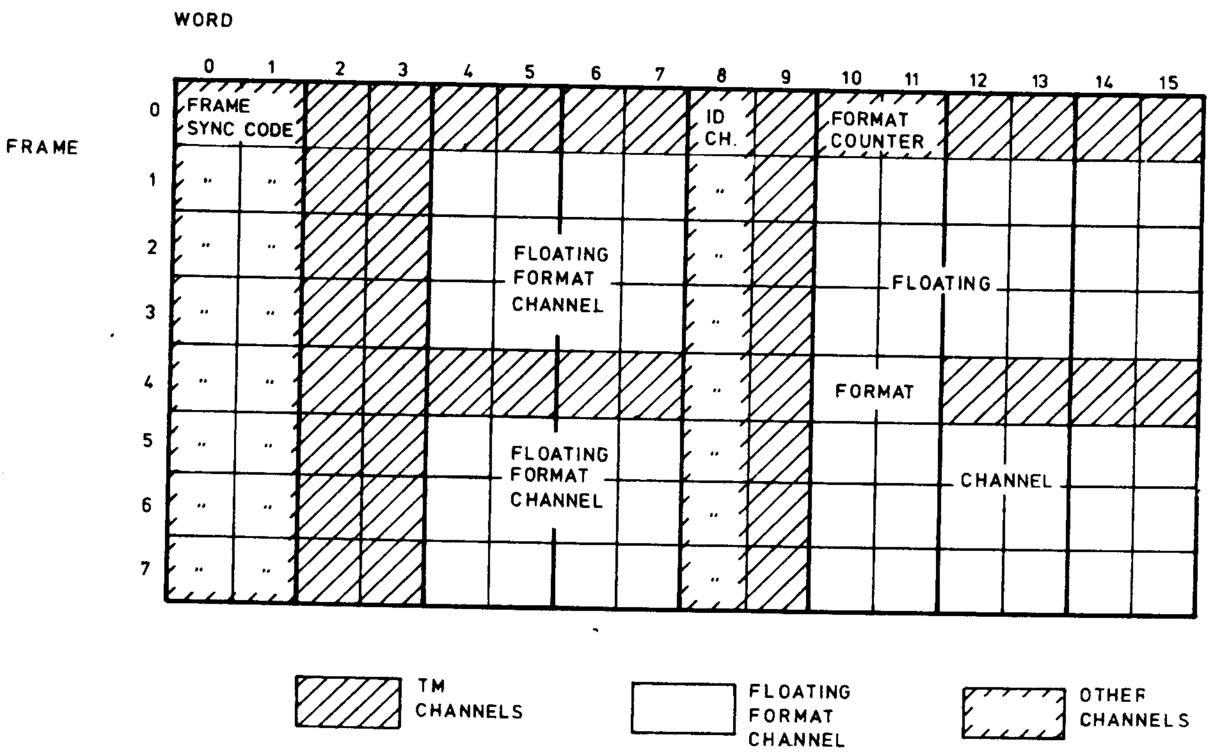


Figure 4.3 - Standard TM Format with Floating Format Channel

4.5.3.2 *Field identification techniques*

No-Data Field Pattern

Those periods during which no data are available shall be filled with a no-data field pattern. This pattern shall be determined for each mission, taking into account its specific data-handling and telemetry down-link transmission requirements.

Start Label Pattern

Each specific data field shall begin with a start label pattern which shall be the same for all data fields of a given mission. This pattern shall be 16 bits long.
The standard start label pattern to be used is:

00001110	11101101
octal 016	octal 355

Use of other patterns and of other pattern lengths shall be subject to ESA approval, following appropriate justification. The first 8 bits of the start label pattern shall always be transmitted in an even TM word.

Data Field Identification and Length

Each data field start label pattern shall be followed by one or two 16-bit word(s) exclusively dedicated to the data field identification and to its length.

a) one 16-bit word : first 8 bits for identification
last 8 bits for length

b) two 16-bit words: first 16 bits for identification
last 16 bits for length

The length of a data field shall not exceed 256 field words of 16 bits, with the inclusion of the start label pattern. Use of longer data fields shall be subject to ESA approval, following appropriate justification.

Data Field Flag Bit

In order to simplify the data processing at the ground station, it is recommended that one TM bi-level channel be used for transmitting one status bit in each TM frame. This status bit shall indicate the presence (digital "one") of a data field in the corresponding TM frame. When in the digital "zero" state, this status bit shall indicate that there is no data field in the TM frame.

4.5.3.3 *Protection of telemetry message acquisition*

The characteristics of the floating format message shall be such that the telemetry message acquisiton and data processing on the ground are not disturbed. In particular, the bit synchronisation and the TM frame acquisition and synchronisation shall be guaranteed.

5. COMPATIBILITY WITH NASA STANDARDS

The PCM telemetry message, as defined by the ESA PCM Telemetry Standard, is compatible with that of the PCM Telemetry Standard of the NASA - GSFC Aerospace Data Systems Standards, July 1, 1971, for all telemetry bit rates from 5 bits/s to 200 000 bits/s.

APPENDICES

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APPENDIX A

TELEMETRY CHANNEL NOMENCLATURE

A1. PURPOSE

For operational use, it is necessary to specify the TM channel number and type. The following nomenclature shall be used when referring to any TM channel.

A2. CHANNEL NUMBER

The channel number shall be a decimal number from 0 to 99999. The logic and the number system used to number each channel will depend on the particular telemetry hardware chosen for the mission as well as the particular data-handling requirements. However, for any given mission, the channel number alone should be sufficient to identify a TM channel input without any ambiguity, all over the spacecraft.

A3. CHANNEL TYPE

As an aid to channel identification, the channel number shall be followed by a two-letter code:

- The first letter of the code shall determine whether the channel is of the analogue or the digital type:

  A for Analogue
  D for Digital.

- The second letter shall specify the sort of analogue or digital channel.
  The following paragraphs give the corresponding conventions.

A3.1 Analogue - Single Ended

The full letter code is AS.
(S for Single)
Example: *Channel 2 AS.*

A3.2 Analogue - Double Ended

The full letter code is AD.
(D for Double)
Example: *Channel 2436 AD.*

A3.3 Digital Serial - 8 bits

The full letter code DS.
(S for Single)
Example: *Channel 2425 DS.*

A3.4 Digital Serial - 16 bits

The full letter code is DD.
(D for Double)
Example: *Channel 5001 DD.*

A3.5 Digital Parallel - High Speed

The full letter code is DH.
(H for High Speed)
Example: *Channel 1 DH.*

A3.6 Digital Bi-Level

The full letter code is DB
(B for Bi-Level)
Example: *201 DB.*

A3.7 Datation channels

In a TM format, a datation channel is best identified by the serial digital channel(s) used to acquire the datation information.

APPENDIX B.

PERFORMANCE OF THE FRAME SYNCHRONISATION CODES

B1. INTRODUCTION

In PCM telemetry systems, frame synchronisation performance is mainly determined by:

- the modes of operation of the frame synchroniser;
- the choice of the synchronisation code;
- the length of the synchronisation code relative to the frame length.

The synchronisation codes of the ESA PCM Telemetry Standard have been chosen in order to guarantee a given performance with the current PCM telemetry ground systems managed by the Agency.

B2. PRINCIPLE OF OPERATION OF A FRAME SYNCHRONISER

A frame synchroniser works in three modes:

- the SEARCH mode;
- the CHECK mode;
- the LOCK mode.

In the SEARCH mode, the system makes a bit-by-bit search for the selected synchronisation code. When a candidate code is found "good" according to a given criterion, the system goes into CHECK mode.

In the CHECK mode, the system verifies that the position found in the SEARCH mode is the correct synchronisation code location. If the CHECK test finds the position correct, the system goes to the LOCK mode. If the CHECK test finds the position false, the system returns to the SEARCH mode and continues searching.

In the LOCK mode, the system continues to check the synchronisation code position to make sure that frame synchronisation is effectively maintained.

B3. FRAME SYNCHRONISATION CODES

In order to guarantee an effective and performant frame synchronisation, a list of optimum frame synchronisation codes has been standardised by NASA's Goddard Space Flight Center. Three of these codes have been chosen for the ESA PCM Telemetry Standard: the 16-, 24- and 30-bit codes, the last-named forming a 32-bit code with the addition of two final "zeros" (see Subsection 4.4.6 of the PCM TM STD). These codes are chosen to have an optimum immunity to false sync recognition when the frame synchroniser is in the SEARCH mode.

B4. LENGTH OF THE SYNCHRONISATION CODE

The length of the synchronisation code should be chosen such that the mean time to achieve synchronisation is in the range from 0.5 to 1 frame.

Synchronisation is said to be achieved when the CHECK mode is entered from the SEARCH mode.

The number ρ of synchronisation bits needed to synchronise a frame of M bits is given by:

$$\rho \simeq (1 + C) \log_2 M$$

where C is a quality factor depending on how long a mean time to sync is desired. C normally varies from 0 to 0.5, which corresponds to a mean time to sync of between 1 and 0.5 of a frame. Increasing C (and hence ρ) does not improve the performance and, at high bit error rates, increasing C can actually degrade the mean time to sync.

B5. RECOMMENDATIONS

In order to guarantee a correct mean time for frame synchronisation when PCM telemetry is used, the following recommendations are made:

B5.1 For any bit error rate better than or equal to 10^{-2} and for frame lengths up to 128 TM words (1024 bits), the recommended code is the 16-bit code of the Standard, namely:

11101011	10010000
octal 353	octal 220

B5.2 For bit error rates better than or equal to 10^{-2} and for frame lengths from 128 TM words to 1024 TM words (8192 bits), the recommended code is the 24-bit code of the Standard, namely:

11111010	11110011	00100000
octal 372	octal 363	octal 040

B5.3 For conditions identical to those of Section B5.2, the 32-bit code of the Standard should be used instead of the 24-bit code when system considerations other than the mean time to sync make this choice advantageous. The 32-bit code is:

11111010	11110011	00110100	00000000
octal 372	octal 363	octal 064	octal 000

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This standard is a section of the Telemetry, Tracking, Command and Data-handling Standards of the European Space Agency. It represents one of the documents defining the space/ground interfaces. As such, it establishes and specifies a set of uniform techniques that will permit reliable and efficient transmission of analogue and/or digital data from ESA spacecraft. As a consequence, it is possible to guarantee optimum performance during data-recovery operations in the ESA ground stations. The level of compatibility with the equivalent NASA-GSFC Telemetry Standards is also indicated.

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