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The Consultative Committee for Space Data Systems

**Draft Recommendation for
Space Data System Standards**

TM SYNCHRONIZATION AND CHANNEL CODING

DRAFT RECOMMENDED STANDARD

CCSDS 131.0-P-3.1

PINK SHEETS

August 2021

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DOCUMENT CONTROL

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CCSDS 131.0-P-3.1	TM Synchronization and Channel Coding, Draft Recommended Standard, Issue 3.1	August 2021	Current draft: – adds support for the Unified Space Data Link Protocol; – adds support for ground-to-space communications links.

NOTE – Only pages containing substantive changes from the current issue are included in this set of Pink Sheets.

PREFACE

This document is a draft CCSDS Recommended Standard. Its 'Pink Sheet' status indicates that the CCSDS believes the document to be technically mature and has released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process.

Implementers are cautioned **not** to fabricate any final equipment in accordance with this document's technical content.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommended Standard is to specify synchronization and channel coding schemes used with the TM Space Data Link Protocol (reference [1]), or the AOS Space Data Link Protocol (reference [2]), or the Unified Space Data Link Protocol (USLP) (reference [6]). These schemes are to be used over space-to-ground or, space-to-space, or ground-to-space communications links by space missions.

1.2 SCOPE

This Recommended Standard defines synchronization and channel coding schemes in terms of:

a) the services provided to the users of this specification;

b) data formats; and

c) the procedures performed to generate and process the data formats.

It does not specify:

a) individual implementations or products;

b) the methods or technologies required to perform the procedures; or

c) the management activities required to configure and control the system.

1.3 APPLICABILITY

This Recommended Standard applies to the creation of Agency standards and to the future data communications over space links between CCSDS Agencies in cross-support situations. This Recommended Standard includes comprehensive specification of the data formats and procedures for inter-Agency cross support. It is neither a specification of, nor a design for, real systems that may be implemented for existing or future missions.

The Recommended Standard specified in this document is to be invoked through the normal standards programs of each CCSDS Agency, and is applicable to those missions for which cross support based on capabilities described in this Recommended Standard is anticipated. Where mandatory capabilities are clearly indicated in sections of this Recommended Standard, they must be implemented when this document is used as a basis for cross support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross support agreements between the Agencies involved.

1.4   RATIONALE

The CCSDS believes it is important to document the rationale underlying the recommendations chosen, so that future evaluations of proposed changes or improvements will not lose sight of previous decisions.

1.5   DOCUMENT STRUCTURE

This document is divided into thirteen numbered sections and seven annexes:

a) section 1 presents the purpose, scope, applicability and rationale of this Recommended Standard and lists the conventions, definitions, and references used throughout the document;

b) section 2 provides an overview of synchronization and channel coding;

c) section 3 specifies convolutional coding;

d) section 4 specifies Reed-Solomon coding;

e) section 5 concatenated coding;

f) section 6 specifies Turbo coding;

g) section 7 specifies low-density parity-check coding of a Transfer Frame;

h) section 8 specifies low-density parity-check coding of a stream of Sync-Marked Transfer Frames (SMTFs);

i) section 9 specifies the frame synchronization scheme;

j) section 10 specifies the Pseudo-Randomizer;

k) section 11 specifies the allowed lengths of Transfer Frames;

l) section 12 lists the managed parameters associated with synchronization and channel coding;

m) section 13 specifies use of these codes for ground-to-space links;

n) annex A defines the service provided to the users;

o) annex B discusses security issues related to TM Channel Coding;

p) annex C provides the generator matrix circulant table applicable to rate-223/255 LDPC coding (see 7.3);

q) annex D lists acronyms and terms used within this document;

r) annex E provides a list of informative references;

documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommended Standards.

[1]   *TM Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 132.0-B-2. Washington, D.C.: CCSDS, September 2015.

[2]   *AOS Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.0-B-3. Washington, D.C.: CCSDS, September 2015.

[3]   *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[4]   *Information Technology—Open Systems Interconnection—Basic Reference Model—Conventions for the Definition of OSI Services*. International Standard, ISO/IEC 10731:1994. Geneva: ISO, 1994.

[5]   *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft*. Issue 31. Recommendations for Space Data System Standards (Blue Book), CCSDS 401.0-B-31. Washington, D.C.: CCSDS, February 2021.

[6]   *Unified Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.1-B-2. Washington, D.C.: CCSDS, forthcoming.

NOTE – Informative references are listed in annex E.

2   OVERVIEW

2.1   ARCHITECTURE

Figure 2-1 illustrates the relationship of this Recommended Standard to the Open Systems Interconnection reference model (reference [3]). Two sublayers of the Data Link Layer are defined for CCSDS space link protocols. The TM and AOS Space Data Link Protocols and USLP specified in references [1] and, [2], and [6], respectively, correspond to the Data Link Protocol Sublayer, and provide functions for transferring data using the protocol data unit called the Transfer Frame. The Synchronization and Channel Coding Sublayer provides additional functions necessary for transferring Transfer Frames over a space link. These functions are error-control coding/decoding, Transfer Frame delimiting/synchronizing, and bit transition generation/removal.
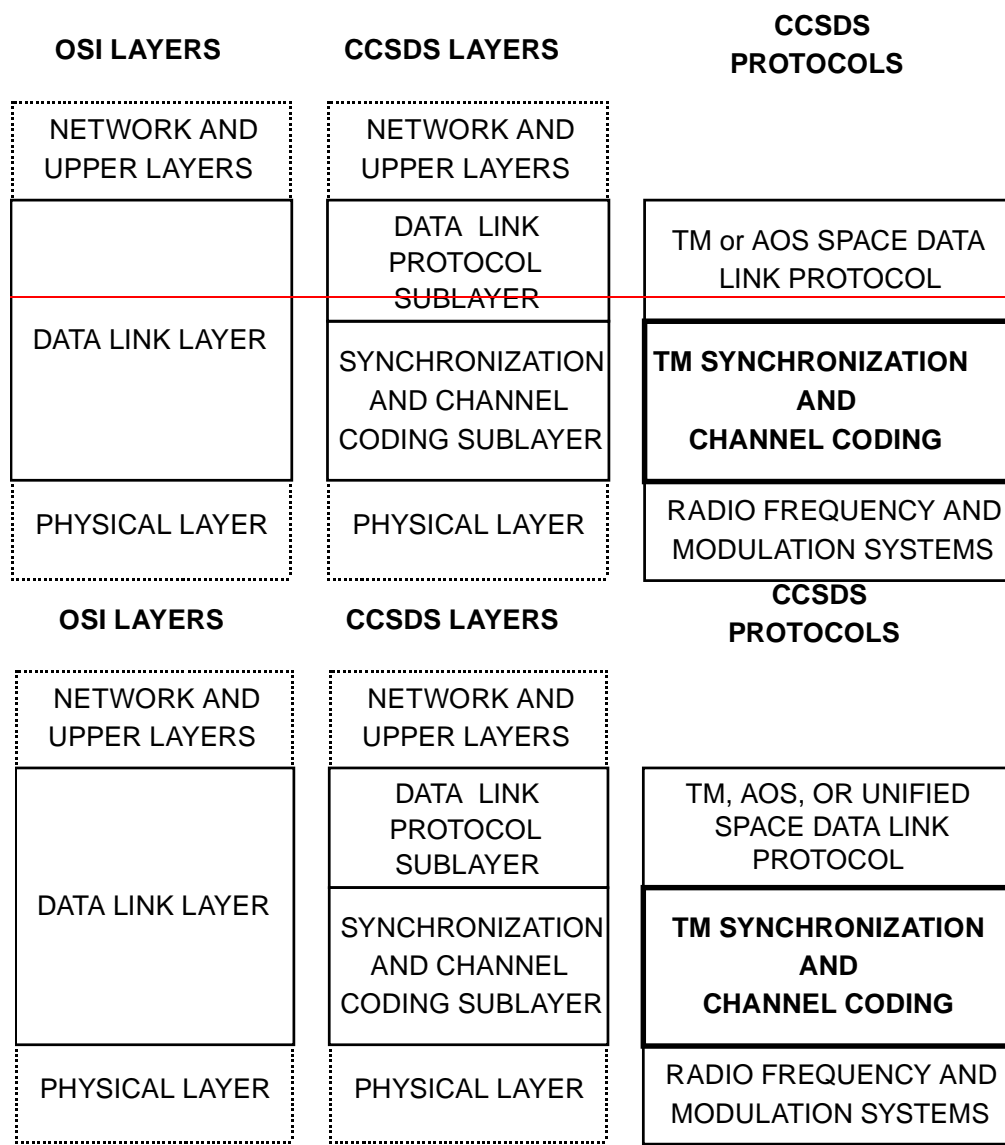

Figure 2-1: Relationship with OSI Layers

2.2 SUMMARY OF FUNCTIONS

2.2.1 GENERAL

The Synchronization and Channel Coding Sublayer provides the following three functions for transferring Transfer Frames over a space link:

a) error-control coding, including frame validation;

b) synchronization; and

c) pseudo-randomizing.

2.2.2 ERROR-CONTROL CODING

This Recommended Standard specifies the following four types of error-control coding:

a) convolutional coding (section 3);

b) Reed-Solomon coding (section 4);

c) Turbo coding (section 5);

d) Low-Density Parity-Check (LDPC) coding (sections 7 and 8).

One of the convolutional codes described in section 3 alone may be satisfactory depending on performance requirements.

For Physical Channels, which are bandwidth-constrained and cannot tolerate the increase in bandwidth required by the basic convolutional code specified in 3.3, the punctured convolutional codes specified in 3.4 have the advantage of smaller bandwidth expansion.

Alternatively, the Reed-Solomon codes and the high rate LDPC code specified in sections 4, 7, and 8 also have the advantage of smaller bandwidth expansion and have the capability to indicate the presence of uncorrectable errors. Where a greater coding gain is needed than can be provided by a convolutional code or Reed-Solomon code alone, a concatenation of a convolutional code as the inner code with a Reed-Solomon code as the outer code may be used for improved performance.

The Turbo codes specified in section 5 or the LDPC codes specified in sections 7 and 8 may be used to obtain even greater coding gain where the environment permits.

AOS and USLP are symmetrical and may be used over space-to-ground, ground-to-space, or space-to-space (in both directions).

NOTES

1   In this Recommended Standard, the characteristics of the codes are specified only to the extent necessary to ensure interoperability and cross-support. The specification

3   CONVOLUTIONAL CODING

3.1   OVERVIEW

The basic convolutional code is a rate (r) 1/2, constraint-length (K) 7 transparent code which is well suited for channels with predominantly Gaussian noise. This code is defined in 3.3. When this code is punctured according to 3.4, higher code rates may be achieved although with lower error correcting performance.

Puncturing allows a single code rate of either 2/3, 3/4, 5/6 or 7/8 to be selected. The four different puncturing schemes allow selection of the most appropriate level of error correction and symbol rate for a given service or data rate.

3.2   GENERAL

3.2.1   ATTACHED SYNC MARKER

The Attached Sync Marker used with convolutional code shall be the 32-bit pattern specified in 9.2, and it shall always be inserted before performing convolutional encoding.

3.2.2   DATA RANDOMIZATION

The pseudo-randomizer defined in section 10 shall be used unless the system designer verifies that the concerns identified in the note below are resolved by other means.

NOTE   –   An inverter is specified with the basic convolutional code to assure sufficient bit transitions to keep receiver symbol synchronizers in lock, when used with Binary Phase Shift Keying (BPSK) modulation. Sufficient bit transitions cannot be guaranteed by the inverter alone if some multiplexing schemes are used, e.g., with Quadrature Phase Shift Keying (QPSK) modulation, or if a punctured convolutional code is used. There are also data patterns for which convolutional code synchronization cannot be determined. The pseudo-randomizer is also used to aid signal acquisition and to mitigate spectral lines in the transmitted signal.

3.2.3   FRAME VALIDATION

When TM or, AOS, or USLP Transfer Frames are used, the Frame Error Control Field (FECF) specified in references [1] and, [2], or [6] shall be used to validate the Transfer Frame, unless the convolutional code is concatenated with an outer Reed-Solomon code (see section 4).

NOTE   –   If the decoder's correction capability is exceeded, undetected bursts of errors may appear in the output.

4   REED-SOLOMON CODING

4.1   OVERVIEW

The Reed-Solomon (R-S) codes defined in this section are powerful burst error correcting codes. One of two different error-correcting options may be chosen. For maximum performance (at the expense of accompanying overhead) the E=16 option can correct 16 R-S symbols in error per codeword. For lower overhead (with reduced performance) the E=8 option can correct 8 R-S symbols per codeword. The Reed-Solomon code may be used alone, and as such it provides an excellent forward error correction capability in a burst-noise channel. However, should the Reed-Solomon code alone not provide sufficient coding gain, it may be concatenated with the convolutional code defined in section 3. Used this way, the Reed-Solomon code is the *outer code*, while the convolutional code is the *inner code*.

4.2   GENERAL

4.2.1   DATA RANDOMIZATION

The pseudo-randomizer defined in section 10 shall be used unless the system designer verifies that the concerns identified in the note below are resolved by other means.

NOTE –   The recommended Reed-Solomon codes, by themselves, cannot guarantee sufficient bit transitions to keep receiver symbol synchronizers in lock. Because of the quasi-cyclic nature of these codes, undetected decoding errors may result from incorrect codeblock synchronization. The pseudo-randomizer is also used to aid signal acquisition and to mitigate spectral lines in the transmitted signal.

4.2.2   FRAME VALIDATION

The FECF specified in references [1] ~~and~~, [2], and [6] is optional. The system designer may choose to use it for additional codeblock validation, particularly with the E=8 code.

NOTE –   The Reed-Solomon code with E=16 has an extremely low undetected error rate, and that with E=8 has an undetected error rate low enough for some applications. Therefore the R-S decoder may be used alone to validate the codeblock, and consequently the contained TM Transfer Frame (reference [1]) ~~or~~, AOS Transfer Frame (reference [2]), or USLP Transfer Frame (reference [6]).

4.3   SPECIFICATION

4.3.1   PARAMETERS

The parameters of the selected Reed-Solomon (R-S) code are as follows:

   a)   *J* shall be 8 bits per R-S symbol.

NOTE – Shortening the transmitted codeblock length in this way changes the overall performance to a degree dependent on the amount of virtual fill used. Since it incorporates no virtual fill, the maximum codeblock length allows full performance. In addition, as virtual fill in a codeblock is increased (at a specific bit rate), the number of codeblocks per unit time that the decoder must handle increases. Therefore, care should be taken so that the maximum operating speed of the decoder (codeblocks per unit time) is not exceeded.

4.3.8   REED-SOLOMON CODEBLOCK PARTITIONING AND VIRTUAL FILL

4.3.8.1   Parts of the partitioned Reed-Solomon codeblock (see figure 4-1) are defined as follows:

a) The **Reed-Solomon Check Symbols** shall consist of the trailing $2EI$ symbols ($2EIJ$ bits) of the codeblock.

NOTES

1   As an example, when $E = 16$ and $k = 223$, for $I=5$ this is always 1280 bits.

2   The **Transfer Frame** is defined by the TM Space Data Link Protocol (reference [1]) or, the AOS Space Data Link Protocol (reference [2]), or the Unified Space Data Link Protocol (reference [6]). For constraints on the length of the Transfer Frame, see section 11.

b) The **Attached Sync Marker** used with R-S code

   1) shall be the 32-bit pattern specified in section 9;

   2) shall precede the transmitted codeblock.

NOTE – Frame synchronizers should therefore be set to expect a marker at every transmitted codeblock + 32 bits.

c) The **transmitted codeblock** shall consist of the Transfer Frame (without the 32-bit sync marker) and R-S check symbols.

NOTES

1   The transmitted codeblock is the received data entity physically fed into the R-S decoder. (As an example, when $E = 16$ and $k = 223$, using $I=5$ and no virtual fill, the length of the transmitted codeblock will be 10,200 bits; if virtual fill is used, it will be incrementally shorter, depending on the amount used.)

2   The **logical codeblock** is the logical data entity operated upon by the R-S decoder. It can have a different length than the transmitted codeblock because it accounts for the amount of virtual fill that was introduced. (As an example, when

6   TURBO CODING

6.1   OVERVIEW

Turbo codes are binary block codes with large codewords (hundreds or thousands of bits). Turbo codes may be used to obtain even greater coding gains than those provided by concatenated coding systems. They are systematic and inherently non-transparent.

6.2   GENERAL

6.2.1   DATA RANDOMIZATION

The pseudo-randomizer defined in section 10 shall be used unless the system designer verifies that the concerns identified in the note below are resolved by other means.

NOTE   –   The recommended Turbo codes, by themselves, cannot guarantee sufficient bit transitions to keep receiver symbol synchronizers in lock. The pseudo-randomizer is also used to aid signal acquisition and to mitigate spectral lines in the transmitted signal.

6.2.2   FRAME VALIDATION

When Turbo codes are used with TM or, AOS, or USLP Transfer Frames, the FECF specified in references [1] or, [2], or [6], respectively, shall be used to validate the Transfer Frame.

NOTE   –   While providing outstanding coding gain, Turbo codes may still leave some undetected errors in the decoded output.

6.3   SPECIFICATION

NOTE   –   A Turbo encoder is a combination of two simple encoders. The input is a frame of k information bits. The two component encoders generate parity symbols from two simple recursive convolutional codes, each with a small number of states. The information bits are also sent uncoded. A key feature of Turbo codes is an interleaver, which permutes bit-wise the original k information bits before input to the second encoder.

The recommended Turbo code is a systematic code that shall conform to the following specifications:

   a) Code type shall be systematic parallel concatenated Turbo code.

   b) Number of component codes shall be two (plus an uncoded component to make the code systematic).

   c) Type of component codes shall be recursive convolutional codes.

7.2.2   DATA RANDOMIZATION

The pseudo-randomizer defined in section 10 shall be used unless the system designer verifies that the concerns identified in the note below are resolved by other means.

NOTE – The recommended LDPC codes, by themselves, cannot guarantee sufficient bit transitions to keep receiver symbol synchronizers in lock. Because of the quasi-cyclic nature of these codes, undetected decoding errors may result from incorrect codeword synchronization. The pseudo-randomizer is also used to aid signal acquisition and to mitigate spectral lines in the transmitted signal.

7.2.3   FRAME VALIDATION

7.2.3.1   The LDPC decoder may be used alone to validate the codeword, and consequently the contained TM Transfer Frame (reference [1])~~or~~, AOS Transfer Frame (reference [2]), or USLP Transfer Frame (reference [6]).

7.2.3.2   The FECF specified in references [1]~~and~~, [2], and [6] is optional, and the system designer may choose to use it for additional frame validation.

NOTE – The undetected frame and bit error rates of these LDPC codes lie several orders of magnitude below the corresponding detected error rates for any given operating signal-to-noise ratio.

7.3   LOW-DENSITY PARITY-CHECK CODE WITH RATE 223/255

7.3.1   OVERVIEW

The (8160,7136) recommended code is an expurgated, shortened, and extended version of a basic (8176,7156) LDPC code.

The recommended code has rate 223/255, and matches the length and dimension of the (255,223) *I*=4 Reed-Solomon code.

The basic code is transparent, although the modified version of this code is not, because of the sense of the fill bits.

Construction of the initial code is described in 7.3.2, expurgation and encoding are described in 7.3.4, and the shortening and extension that yield the recommended code are described in 7.3.5.

7.3.2   BASIC (8176,7156) LDPC CODE USED IN CONSTRUCTION

7.3.2.1   The parity check matrix for the (8176,7156) LDPC code shall be formed by using a 2×16 array of 511×511 square circulants.

8.2.3   FRAME VALIDATION

The LDPC decoder may be used alone to validate the codeword, and consequently the contained TM Transfer Frame(s) (reference [1]) or, AOS Transfer Frame(s) (reference [2]), or USLP Transfer Frame(s) (reference [6]). Whenever an LDPC codeword fails decoding, the Quality Indicator (see annex A) of all the Transfer Frames affected by that decoding shall be set to show that there is an uncorrectable error in received Transfer Frame(s).

NOTE – The FECF specified in references [1] and, [2], and [6] is optional, and the system designer may choose to use it for additional checks.

8.2.4   ENCODING PROCESS AT SENDING END

8.2.4.1   The encoding process at the sending end shall add an ASM to each of the Transfer Frames creating a stream of SMTFs.

8.2.4.2   The encoding process at the sending end shall extract an information-block-size portion (slice) of k bits from the stream.

8.2.4.3   The encoding process at the sending end shall encode each slice of k bits into an LDPC codeword of n bits.

8.2.4.4   The encoding process shall form an LDPC codeblock by aggregating 'm' LDPC codewords.

8.2.4.5   The encoding process shall randomize each codeblock using the process articulated in section 10 and elaborated in 8.3 below.

8.2.4.6   The encoding process shall prepend a CSM to each (randomized) codeblock.

8.2.4.7   The CSM shall immediately follow the end of the preceding codeblock; i.e., there shall be no intervening bits (data, code, or fill) preceding the CSM.

NOTES

1   The encoding process at the sending end is shown in figure 8-2 a).

2   The CSM immediately precedes the LDPC codeblock.

3   The CSM is not presented to the input of the LDPC encoder (or decoder).

8.2.5   DECODING PROCESS AT THE RECEIVING END

On the receiving end, the reverse process is followed as shown in figure 8-2 b).

11 TRANSFER FRAME LENGTHS

11.1 OVERVIEW

Neither the TM Space Data Link Protocol (reference [1]) nor the AOS Space Data Link Protocol (reference [2]) specifies the length of Transfer Frames because there are constraints on the Transfer Frame length depending on the selected coding options.

The Unified Space Data Link Protocol (reference [6]) contains a frame length field that is specified by the sender for both fixed- or variable-length transfer frames. However, that field is not used by the procedures defined in this Recommended Standard.

The constraints on Transfer Frame lengths specified in this section apply to ~~both~~ TM Transfer Frames ~~and the~~, AOS Transfer Frames, and fixed-length USLP Transfer Frames..

11.2 GENERAL

11.2.1 Once selected, the Transfer Frame length shall be fixed for a Mission Phase on a particular Physical Channel.

NOTE – The Transfer Frame lengths shown here do not include the length of the Attached Sync Marker (ASM) specified in section 9.

11.3 CASE 1: UNCODED

The length of the Transfer Frames shall be any integer number of octets, as required by the using project, with a maximum of 2048 octets.

11.4 CASE 2: CONVOLUTIONAL ONLY

The length of the Transfer Frames shall be any integer number of octets, as required by the using project, with a maximum of 2048 octets.

11.5 CASE 3: REED-SOLOMON ONLY

NOTES

1   With the Reed-Solomon Codes specified in section 4, only certain specific lengths of Transfer Frames may be contained within the codeblock's data space. In some cases these lengths can be shortened at a small sacrifice in coding gain.

2   Since these R-S codes have a symbol length of 8 bits, the length of the codeblock (in octets) is a multiple of the interleaving depth, which provides 'octet compatibility'.

13 USE OF TELECOMMUNICATIONS CHANNEL CODES FOR GROUND-TO-SPACE LINKS

13.1 OVERVIEW

The error control codes specified in this document are designed for use with fixed-length Transfer Frames as defined in the TM Space Data Link Protocol (reference [1]), AOS Space Data Link Protocol (reference [2]), or Unified Space Data Link Protocol (reference [6]). The AOS and USLP protocols are defined for Telemetry (downlink) use, as is TM, but AOS and USLP are also designed for use for ground-to-space and space-to-space communications. This bidirectional use will typically be adopted for high-rate missions, missions for which the space-to-ground and ground-to-space links are symmetric, or for missions that are adopting upper-layer networking protocols like DTN or IP.

13.2 GROUND-TO-SPACE LINK TURBO CODES

13.2.1 DISCUSSION

Turbo codes are best suited to power-constrained links, for which the Signal-to-Noise Ratio (SNR), E_b/N_0, is a dominant concern. Their code rates of $r \leq 1/2$ provide greater coding gain than LDPC codes, at a cost of greater bandwidth expansion. They are best suited to links beyond low-Earth orbit.

13.2.2 SPECIFICATION

For AOS or USLP ground-to-space links, any of the turbo codes in section 6 shall be selected.

NOTES

1. The turbo codes in section 6 offer code rates of $r =1/2$, 1/3, 1/4, and 1/6, and block lengths of 1784, 3568, 7136, and 8920 information bits.

2. When a low-rate turbo code (particularly 1/4 or 1/6) is used near its decoding threshold, the symbol SNR may be below −5 dB. The radio receiver's symbol tracking loop may require an uncommonly narrow loop bandwidth, as well as an external means for Doppler compensation.

13.3 GROUND-TO-SPACE LINK LOW-DENSITY PARITY-CHECK CODES

13.3.1 DISCUSSION

LDPC codes are best suited to high-data-rate links because of their code rates of $r \geq 1/2$ and the potentially parallel implementation architecture for the decoder. They are best suited to links on which bandwidth is limited, onboard computational resources are available to support an iterative decoder, and a Physical Layer modulation that supports at least two code symbols per modulation symbol is available (e.g., QPSK/OQPSK and above—see reference [5]).

13.3.2 SPECIFICATION

For AOS or USLP ground-to-space links, any of the LDPC codes in section 7 shall be selected.

NOTE – The LDPC codes in section 7 offer code rates of $r=1/2$, 2/3, 4/5, and approximately 7/8. Block lengths of 1024, 4096, and 16384 information bits are available with the first three code rates, and 7136 information bits in the last case.

13.4 GROUND-TO-SPACE LINK CODING OF A STREAM OF SMTFS

13.4.1 DISCUSSION

In some cases, it is most practical to use a Transfer Frame length that need not match the information block length of the error correcting code. To support this application, synchronization markers may be prepended to the Transfer Frames, the resulting SMTFs concatenated into a stream and then 'sliced' according to the information block length of the code.

13.4.2 SPECIFICATION

When a stream of SMTFs is chosen for an AOS or USLP ground-to-space link, the encoding procedure defined in section 8 shall be selected.

ANNEX A

SERVICE

(NORMATIVE)

A1   OVERVIEW

A1.1   BACKGROUND

This annex provides service definition in the form of primitives, which present an abstract model of the logical exchange of data and control information between the service provider and the service user.   The definitions of primitives are independent of specific implementation approaches.

The parameters of the primitives are specified in an abstract sense and specify the information to be made available to the user of the primitives. The way in which a specific implementation makes this information available is not constrained by this specification. In addition to the parameters specified in this annex, an implementation can provide other parameters to the service user (e.g., parameters for controlling the service, monitoring performance, facilitating diagnosis, and so on).

A2   OVERVIEW OF THE SERVICE

The TM Synchronization and Channel Coding provides unidirectional (one way) transfer of a sequence of fixed-length TM, AOS, or USLP Transfer Frames at a constant frame rate over a Physical Channel across a space link, with optional error detection/correction.

Only one user can use this service on a Physical Channel.

A3   SERVICE PARAMETERS

A3.1   FRAME

The Frame parameter is the service data unit of this service and shall be either a TM Transfer Frame defined in reference [1], an AOS Transfer Frame defined in reference [2], or a fixed-length USLP Transfer Frame defined in reference [6].

A3.1.1   The length of any Transfer Frame transferred on a Physical Channel must be the same, and is established by management.

ANNEX D

ABBREVIATIONS AND ACRONYMS AND TERMS

(INFORMATIVE)

D1   INTRODUCTION

This annex lists key abbreviations and acronyms and terms that are used throughout this Recommended Standard to describe synchronization and channel coding.

D2   ACRONYMS

AOS	Advanced Orbiting Systems
ASM	Attached Sync Marker
CADU	Channel Access Data Unit
CCSDS	Consultative Committee For Space Data Systems
CSM	Code Sync Marker
FECF	Frame Error Control Field
GF	Galois Field
LDPC	Low-Density Parity-Check
MSB	Most Significant Bit
NRZ-L	Non-Return-to-Zero-Level
NRZ-M	Non-Return-to-Zero-Mark
OQPSK	Offset Quadrature Phase Shift Keying
OSI	Open Systems Interconnection
QPSK	Quadrature Phase Shift Keying
R-S	Reed-Solomon
SANA	Space Assigned Numbers Authority
SMTF	Sync-Marked Transfer Frame
TC	Telecommand
TCM	Trellis Coded Modulation
TM	Telemetry
USLP	Unified Space Link Protocol
VCDU	Virtual Channel Data Unit