The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

FLEXIBLE ADVANCED CODING AND MODULATION SCHEME FOR HIGH RATE TELEMETRY APPLICATIONS

RECOMMENDED STANDARD

CCSDS 131.2-B-2

BLUE BOOK

February 2023

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STATEMENT OF INTENT

The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of its members. The Committee meets periodically to address data systems problems that are common to all participants, and to formulate sound technical solutions to these problems. Inasmuch as participation in the CCSDS is completely voluntary, the results of Committee actions are termed **Recommended Standards** and are not considered binding on any Agency.

This **Recommended Standard** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommendation** is entirely voluntary. Endorsement, however, indicates the following understandings:

- o Whenever a member establishes a CCSDS-related **standard**, this **standard** will be in accord with the relevant **Recommended Standard**. Establishing such a **standard** does not preclude other provisions which a member may develop.
- o Whenever a member establishes a CCSDS-related **standard**, that member will provide other CCSDS members with the following information:
  - -- The **standard** itself.
  - -- The anticipated date of initial operational capability.
  - -- The anticipated duration of operational service.
- o Specific service arrangements shall be made via memoranda of agreement. Neither this **Recommended Standard** nor any ensuing **standard** is a substitute for a memorandum of agreement.

No later than five years from its date of issuance, this **Recommended Standard** will be reviewed by the CCSDS to determine whether it should: (1) remain in effect without change; (2) be changed to reflect the impact of new technologies, new requirements, or new directions; or (3) be retired or canceled.

In those instances when a new version of a **Recommended Standard** is issued, existing CCSDS-related member standards and implementations are not negated or deemed to be non-CCSDS compatible. It is the responsibility of each member to determine when such standards or implementations are to be modified. Each member is, however, strongly encouraged to direct planning for its new standards and implementations towards the later version of the Recommended Standard.

FOREWORD

This document describes a Serially Concatenated Convolutional turbo Coding (SCCC) scheme for telemetry applications. The flexibility, performance, and proper architecture of the proposed coding scheme together with a new frame structure make the scheme suitable for achieving a significantly high spectral and power efficiency while maintaining compatibility with the existing data layer protocols.

The proposed coding scheme and its associated frame structure are specifically designed to support reconfiguration of the downlink channel (variable or adaptive coding and modulation) and to provide means for reliable synchronization at the Physical Layer and the Data Link Layer.

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-4). Current versions of CCSDS documents are maintained at the CCSDS Web site:

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Questions relating to the contents or status of this document should be sent to the CCSDS Secretariat at the email address indicated on page i.

At time of publication, the active Member and Observer Agencies of the CCSDS were:

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 131.2-B-1	Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications, Recommended Standard, Issue 1	March 2012	Original issue, superseded
CCSDS 131.2-B-2	Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications, Recommended Standard, Issue 2	February 2023	Current issue – adds support for the Unified Space Data Link Protocol; – replaces the term Channel Access Data Unit (CADU) with Synch-Marked Transfer Frame (SMTF).

NOTE – Changes from the original issue are marked with change bars in the inside margin.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommended Standard is to define an efficient and comprehensive coding and modulation solution able to support a wide range of spectral efficiency values and data rates. The main target is given by high data rate telemetry applications (as suggested by the title of this Recommended Standard), i.e., Earth Exploration Satellite Service (EESS) telemetry payload, where the increase of the system throughput by means of advanced adaptive techniques is deemed essential in order to fulfil the requirements imposed by future missions. However, this Recommended Standard may be also adopted for other high-data-rate applications (either space-to-ground, ground-to-space, or space-to-space) and services (e.g., the Space Research service), as long as compliance to CCSDS recommendations for Radio Frequency modulations in reference [4] is ensured.

1.2 SCOPE

The current specification presents a turbo-like coding/modulation scheme based on one possible realization of a Serial Concatenated Convolutional Code (SCCC). This scheme makes use of a set of a large variety of modulation techniques (including QPSK, 8PSK, 16APSK, 32APSK, and 64APSK—see reference [4]) and a wide range of coding rates. The number of different modulation schemes available, combined with a properly selected coding rate, allows the overall system to make efficient use of the available bandwidth, adapting itself to the variable conditions of the link. The proposed scheme can implement Variable Coding and Modulation (VCM) mode, which varies the transmission scheme to the channel conditions following a predetermined schedule (for example, as a function of the elevation angle). When a channel[1] is available to provide feedback (e.g., via Telecommand), the transmission scheme can be dynamically adjusted using the Adaptive Coding and Modulation (ACM) mode. The proposed coding scheme is easily adapted to any of the available modulation formats thanks to the pragmatic approach adopted: the outputs of the binary encoders are mapped to the considered modulation scheme, after being interleaved. In other words, a bit-interleaved coded modulation scheme is proposed (reference [F1]).

The use of SCCC is intended mainly for high data rate applications. The Forward Error Correction (FEC) scheme is based on the concatenation of two simple four-state encoder structures. The SCCC scheme implies a Physical Layer frame of constant length, with pilots inserted in fixed positions. This architecture simplifies the synchronization procedure, thus further allowing fast and efficient acquisition at very high rates for the receiver.

This document describes a technique incorporating multiple modulation formats paired with a flexible coding and synchronization method in a tightly integrated fashion. In particular, the document provides a series of recommended formats where each format pairs a modulation technique with a tailored implementation of the coding and synchronization

[1] Such a channel is often referenced as a ‘return channel’; however, in CCSDS the ‘return link’ is associated with space-to-ground transmission of telemetry data.

method. However, where these modulations and/or codes are recommended in other CCSDS documents, this document does not limit the choice of modulations and/or codes consistent with those recommendations.

1.3 APPLICABILITY

This Recommended Standard applies to the creation of Agency standards and to 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, it is mandatory to implement them 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 DOCUMENT STRUCTURE

This document is divided into nine numbered sections and six 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 the system architecture;

c) section 3 specifies the mode adaptation;

d) section 4 specifies the SCCC encoding;

e) section 5 specifies the Physical Layer framing;

f) section 6 specifies baseband filtering;

g) section 7 specifies frame synchronization;

h) section 8 specifies the Pseudo-Randomizer;

i) section 9 specifies managed parameters;

j) annex A provides the service definition;

k) annex B provides the description of the interleaver;

l) annex C specifies the Physical Layer pseudo-randomization;

m) annex D discusses security, SANA, and patent considerations;

n) annex E lists acronyms and terms used within this document;

o) annex F provides a list of informative references.

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 NOMENCLATURE

The following conventions apply for the normative specifications in this Recommended Standard:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

NOTE – These conventions do not imply constraints on diction in text that is clearly informative in nature.

1.5.2 INFORMATIVE TEXT

In the normative sections of this document (sections 3 through 9 and annexes A through C), informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

– Overview;

– Background;

– Rationale;

– Discussion.

1.5.3 CONVENTIONS

In this document, the following convention is used to identify each bit in an *N*-bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be ‘Bit 0’, the following bit is defined to be ‘Bit 1’, and so on up to ‘Bit *N*-1’. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., ‘Bit 0’ (see figure 1-1).

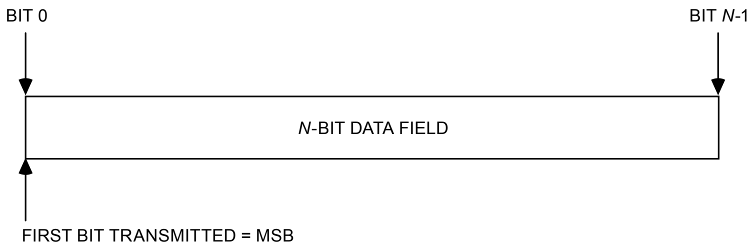

Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into 8-bit ‘words’ which conform to the above convention. Throughout this Recommended Standard, such an 8-bit word is called an ‘octet’.

The numbering for octets within a data structure starts with ‘0’.

1.6 PATENTED TECHNOLOGIES

The CCSDS draws attention to the fact that it is claimed that compliance with this document may involve the use of patents.

The CCSDS takes no position concerning the evidence, validity, and scope of these patent rights.

The holders of these patent rights have assured the CCSDS that they are willing to negotiate licenses under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statements of the holders of these patent rights are registered with CCSDS. Notwithstanding the statement provided to CCSDS, the holder of U.S. Patent No. 6,023,783 patent rights will negotiate licenses under reasonable and non-discriminatory terms and conditions, provided:

a) the CCSDS Recommended Standard CCSDS 131.2-B-2 is incorporated in its entirety into each applicant’s technology, including the intended limitations on scope and applicability set forth in the CCSDS Recommended Standard;

b) the incorporation of the CCSDS Recommended Standard CCSDS 131.2-B-2 into applicant’s technology is mandatory for the operability of applicant’s technology;

c) the applicant seeks a license only for extraterrestrial spaceflight (commercial and/or non-commercial) missions and spacecraft; and

d) applicant’s license will exclude land-based communications except those land-based communications supporting extraterrestrial spaceflight missions.

Information can be obtained from the CCSDS Secretariat at the address indicated on page i. Contact information for the holders of these patent rights is provided in annex D.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. The CCSDS shall not be held responsible for identifying any or all such patent rights.

1.7 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommended Standard. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommended Standard are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommended Standards.

[1] *TM Synchronization and Channel Coding*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.0-B-4. Washington, D.C.: CCSDS, April 2022.

[2] *TM Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 132.0-B-3. Washington, D.C.: CCSDS, October 2021.

[3] *AOS Space Data Link Protocol*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.0-B-4. Washington, D.C.: CCSDS, October 2021.

[4] *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft*. Issue 32. Recommendations for Space Data System Standards (Blue Book), CCSDS 401.0-B-32. Washington, D.C.: CCSDS, October 2021.

[5] *Unified Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.1-B-2. Washington, D.C.: CCSDS, October 2021.

NOTE – Informative references are listed in annex F.

2 OVERVIEW

2.1 ARCHITECTURE

Figure 2-1 illustrates the relationship of this Recommended Standard to the Open Systems Interconnection reference model (reference [F2]). Two sublayers of the Data Link Layer are defined for CCSDS space link protocols. The TM and AOS Space Data Link Protocols specified in references [2] and [3], respectively, and the Unified Space Data Link Protocol (USLP) specified in reference [5], 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 methods of synchronization and channel coding for transferring Transfer Frames over a space link while the Physical Layer provides the RF and modulation methods for transferring a stream of bits over a space link in a single direction.

This Recommended Standard covers the functions of both the Synchronization and Channel Coding Sublayer and the Physical Layer, the latter as relates to modulation schemes. CCSDS 401.0-B (reference [4]) covers additional features of the Physical Layer, such as frequency bands, polarizations, etc., that are not described or referenced here.

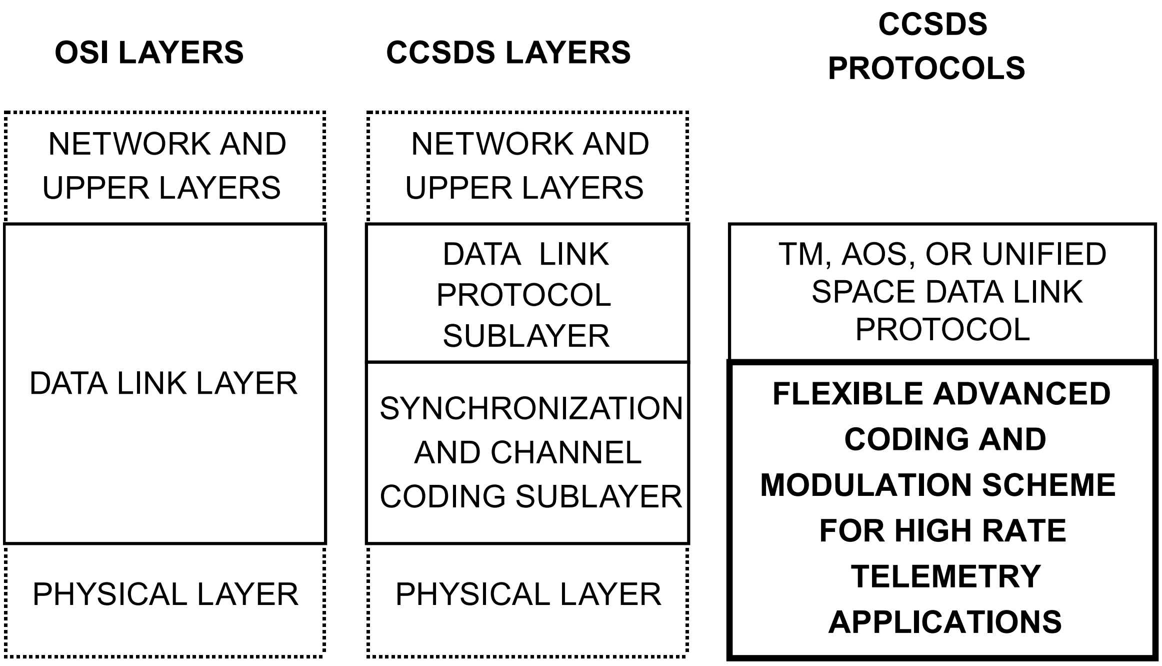

Figure 2-1: Relationship with OSI Layers

2.2 SUMMARY OF FUNCTIONS

2.2.1 GENERAL

This Recommended Standard provides the following functions for transferring Transfer Frames via a stream of bits over a space link:

a) error-control coding (based on serially concatenated convolutional coding), including frame validation;

b) Transfer Frame synchronization and pseudo-randomization; and

c) Physical Layer framing, bit synchronization, and pseudo-randomization.

2.2.2 ERROR-CONTROL CODING

This Recommended Standard specifies a turbo-like coding/modulation scheme based on Serial Concatenated Convolutional Code (SCCC) that makes use of a set of a large variety of modulation techniques and a wide range of coding rates.

NOTE – In this Recommended Standard, the characteristics of the codes are specified only to the extent necessary to ensure interoperability and cross-support. The specification does not attempt to quantify the relative coding gain or the merits of each approach discussed, nor does it specify the design requirements for encoders or decoders.

2.2.3 FRAME VALIDATION

After decoding is performed, the upper layers at the receiving end also need to know whether or not each decoded Transfer Frame can be used as a valid data unit; i.e., an indication of the quality of the received frame is needed. This function is called Frame Validation.

The SCCC code ensures a very low error probability and there is an extremely low probability of additional undetected errors that may escape this scrutiny. However, these errors may affect the system in unpredictable ways and the Frame Error Control Field is used to enforce the detection of residual errors; i.e., the Frame Error Control Field defined in references [2], [3], and [5] is used for Frame Validation.

2.2.4 SYNCHRONIZATION

This Recommended Standard specifies a method for synchronizing Transfer Frames using an Attached Sync Marker (ASM) (see section 7).

2.2.5 PSEUDO-RANDOMIZING

This Recommended Standard specifies a pseudo-randomizer to improve several aspects of the communication link that aid receiver acquisition, bit synchronization, and code synchronization.

2.3 INTERNAL ORGANIZATION

2.3.1 SENDING END

A general view of the functional blocks of the architecture for the sending end is presented in figure 2-2. This figure identifies functions performed by the system and shows logical relationships among these functions. The figure is not intended to imply any hardware or software configuration in a real system.

At the sending end, the system accepts Transfer Frames of fixed length from the Data Link Protocol Sublayer, performs functions selected for the mission, and transmits a continuous and contiguous stream of physical channel symbols.

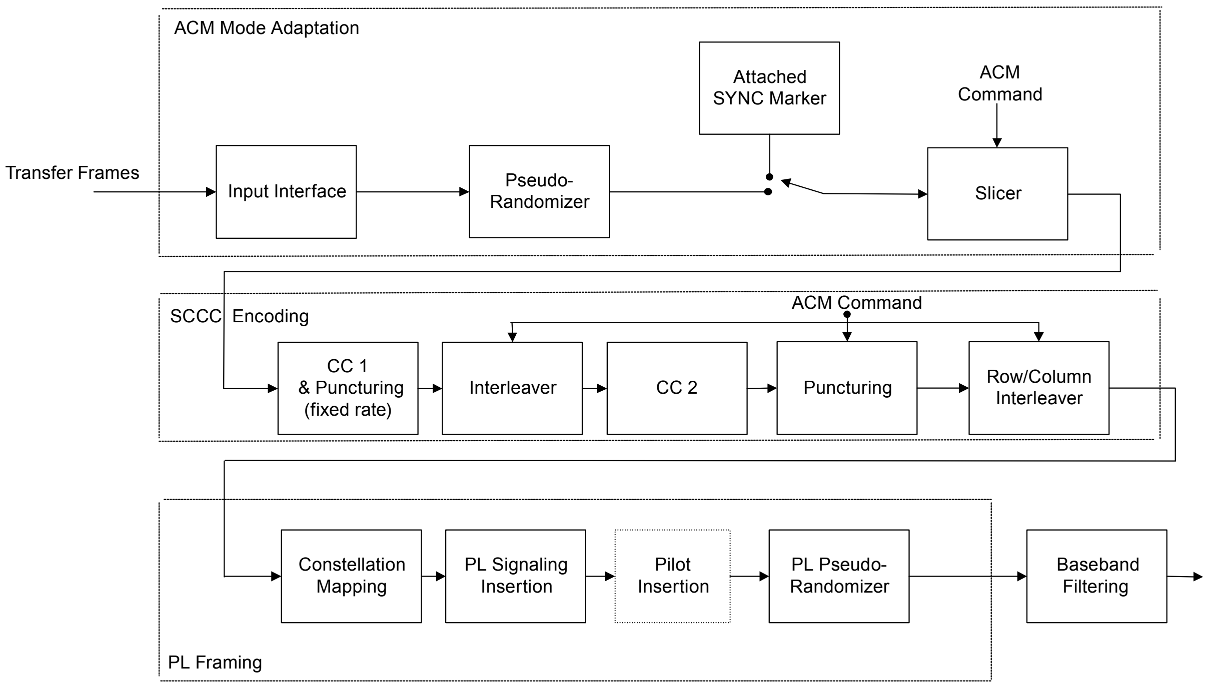

Figure 2-2: Functional Diagrams at Sending End

Figure 2-3 illustrates the frame structures and stream formats at different stages of processing. The input stream of Transfer Frames is compliant with the data link protocols in TM (reference [2]), AOS (reference [3]), and USLP (reference [5]).

Attached SYNC Markers (ASMs) are inserted between Transfer Frames prior to encoding. The information blocks at the input of the encoder are formed by slicing the input data stream (after ASM insertion) into blocks of length *K*. The information block size varies depending on the selected modulation and coding scheme (see table 4-3). A similar coding and modulation scheme is applied to every 16 consecutive blocks that form a Physical Layer (PL) frame. The length of encoded blocks (*N* bits) is determined according to the modulation scheme (independent of the coding rate as shown in table 4-3). The length of encoded symbol blocks after encoding and mapping to modulation symbols is constant (8100 symbols), independent of the modulation and coding scheme. Maintaining a constant symbol block size facilitates frame synchronization at the PL.

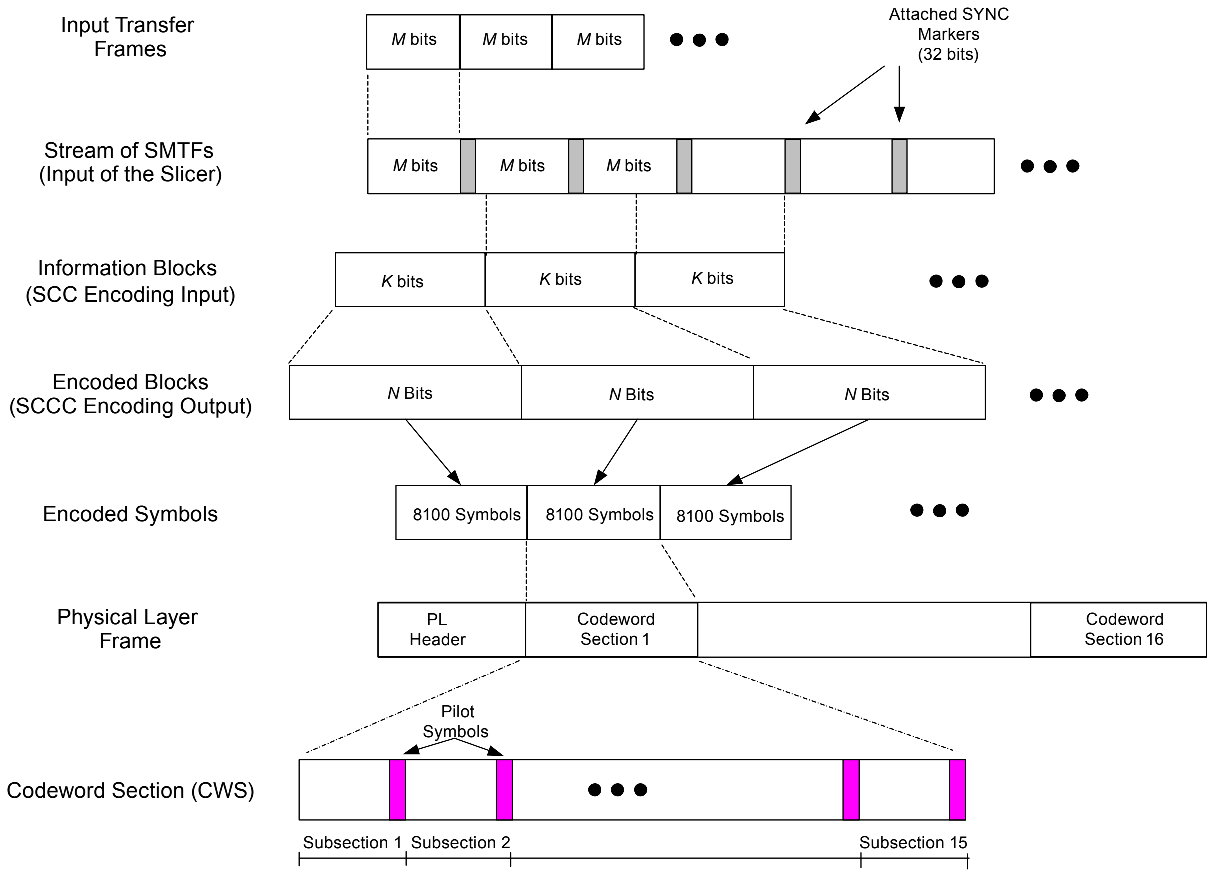

Figure 2-3: Stream Format at Different Stages of Processing

2.3.2 RECEIVING END

At the receiving end, the Synchronization and Channel Coding Sublayer accepts a continuous and contiguous stream of physical channel symbols, performs functions selected for the mission, and delivers Transfer Frames to the Data Link Protocol Sublayer.

3 MODE ADAPTATION

3.1 OVERVIEW

The mode adaptation unit provides the interface to the incoming stream units. The input interface of the mode adaptation unit maps the input electrical format into a stream of logical bit format.

3.2 SCCC SYSTEM INPUT AND INITIAL OPERATIONS

3.2.1 The SCCC system shall accept TM, AOS, or USLP Transfer Frames from the Data Link Protocol sublayer.

3.2.2 The SCCC system shall accept only fixed-length USLP Transfer Frames.

NOTE – USLP Transfer Frames can be variable or fixed in length (see reference [5]).

3.2.3 The Transfer Frame length shall vary between the following minimum and maximum values: 223 octets and 65536 octets (i.e., 524288 bits).

NOTE – The Transfer Frame length is denoted as *M* in figure 2-3. Neither the TM Space Data Link Protocol (reference [2]) nor AOS Space Data Link protocol (reference [3]) specifies the Transfer Frame length. When backward compatibility with legacy data link subsystems is important, the following values are preferable:

a) 1784 bits (=223 × 1 octets);

b) 3568 bits (=223 × 2 octets);

c) 7136 bits (=223 × 4 octets);

d) 8920 bits (=223 × 5 octets).

3.2.4 The SCCC system shall randomize each frame with the randomizer described in reference [1].

3.2.5 For each (randomized) Transfer Frame, the SCCC system shall construct a Synch-Marked Transfer Frame (SMTF) containing the ASM and the Transfer Frame.

NOTE – The SMTF is defined in reference [1] as the data unit that consists of the ASM and the Transfer Frame.

3.2.6 The SCCC system shall build a stream of SMTFs and provide it to the Slicer.

3.2.7 The Slicer shall split the SMTF stream into a sequence of information blocks of length *K*, corresponding to the information block size of the selected ACM format.

NOTE – No particular alignment between the Transfer Frame and the information blocks is considered.

3.2.8 The value of the information block size *K* shall be one of those specified in table 3-1.

NOTE – Changes of the value of the information block size *K* are done by a system to adjust the modulation and coding schemes. This is achieved through, e.g., one of the following approaches: the ground receiver provides the signal quality estimation (or prediction) through a feedback channel (e.g., via telecommand) or the change of modulation and coding schemes is pre-scheduled for each satellite pass based on geometrical information (elevation angle).

3.2.9 The value of *K* shall be set/modified via the 'ACM Command' according to the parameter 'ACM Format' as shown in table 3-1.

NOTE – The 'ACM Command' adjusts at the same time interleaving, puncturing, and bit-to-symbol mapping to ensure synchronized operations.

Table 3-1: Information Block Sizes for Different ACM Formats

ACM Format	Information Block Size (bits)	ACM Format	Information Block Size (bits)
1	5758	15	23518
2	6958	16	25918
3	8398	17	28318
4	9838	18	25918
5	11278	19	28318
6	13198	20	30958
7	11278	21	33358
8	13198	22	35998
9	14878	23	33358
10	17038	24	35998
11	19198	25	38638
12	21358	26	41038
13	19198	27	43678
14	21358		

3.2.10 When the value of *K* is modified via the 'ACM Command', the Slicer shall apply the change without losing Transfer Frames.

3.2.11 The mode adaptation unit shall provide each information block to the SCCC Encoder.

4 SCCC ENCODING

4.1 GENERAL

4.1.1 GENERAL STRUCTURE

4.1.1.1 The input to the encoder shall be information blocks of size K bits.

NOTES

1 The structure of the SCCC encoder is illustrated in figure 4-1.

2 The information block size is specified as described in 3.2.8, according to the applicable ACM format, with the objective of maintaining a constant length of the encoded blocks (N bits) at SCCC encoding output such that the number of modulation symbols generated by each information block will be constant and equal to 8100 symbols.

4.1.1.2 Each information block of size K shall be encoded by the outer convolutional encoder and then punctured to a rate 2/3, maintaining all the systematic bits while decimating the parity bits by half as shown in figure 4-3.

NOTE – The resulting outer encoder punctured output consists of [3/2 ($K+2$)] bits because of trellis termination. The overall coding rate adjustment is carried out by puncturing the output bits of the inner convolutional encoder. A detailed description of that puncturing scheme is provided in 4.4.

4.1.1.3 The punctured output of the outer convolutional encoder shall be interleaved according to the ad hoc permutation law defined in annex B.

4.1.1.4 The interleaver parameters shall be taken from tables B-1 and B-2.

4.1.1.5 The output of the interleaver shall be encoded by the inner convolutional encoder.

4.1.1.6 The output of the inner convolutional encoder shall be processed as defined in 4.4 and 4.5 to produce an encoded block.

NOTE – The puncturing rule determines the actual SCCC code rate. The length of the encoded block is N bits, with $N = 8100 \times m$, where m is the modulation order.

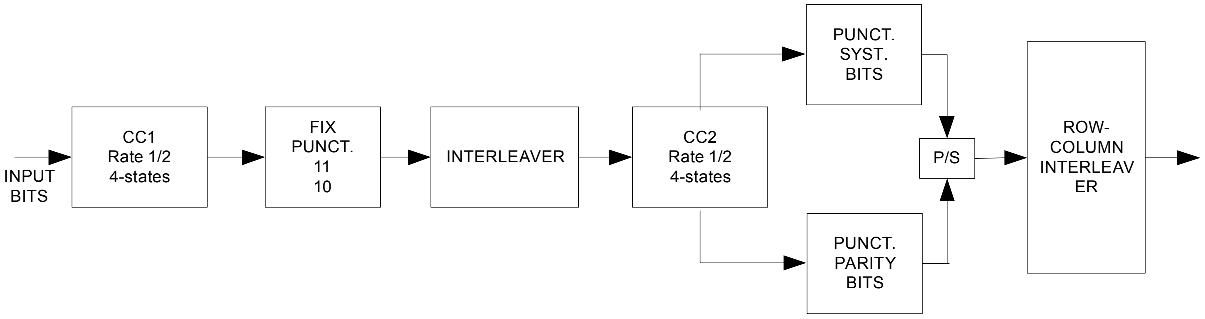

Figure 4-1: Block Diagram of the SCC Turbo Coding Scheme

4.2 CONVOLUTIONAL ENCODING

The outer (CC1) and inner (CC2) convolutional encoders shall use the code structure as detailed in figure 4-2 with the following rules.

a) The encoder initialized with ‘0’s in all registers.

b) Defining ‘u’, the size of the input stream, the encoder runs for a total of u+2 bit times, producing an output of [2 (u+2)] encoded bits.

NOTE – The outputs on the outer and inner convolutional encoders are eventually subject to puncturing.

c) For the first u bit times, the input switch is in the upper position (as indicated in figure 4-2) to receive input data.

d) For the final two bit times, the switch moves to the lower position to receive feedback from the shift registers.

NOTE – This feedback cancels the same feedback sent (unswitched) to the leftmost adder (i.e., Exclusive OR) and causes all two registers to become filled with zeros after the final two bit times. Filling the registers with zeros is called terminating the trellis.

e) During trellis termination the encoder continues to output encoded bits.

f) In particular, the ‘systematic uncoded’ output (line ‘C_1’ in the figure) includes an extra two bits from the feedback line in addition to the u input bits.

NOTE – These encoders are based on the same 4-state, rate 1/2 recursive, systematic encoder.

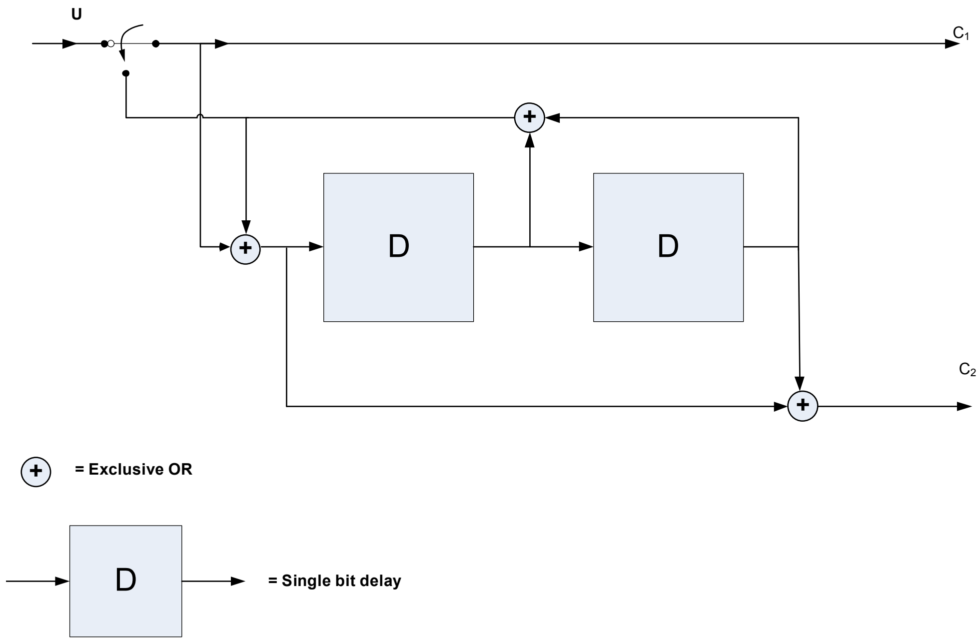

Figure 4-2: The Convolutional Encoder Block Diagram for CC1 and CC2

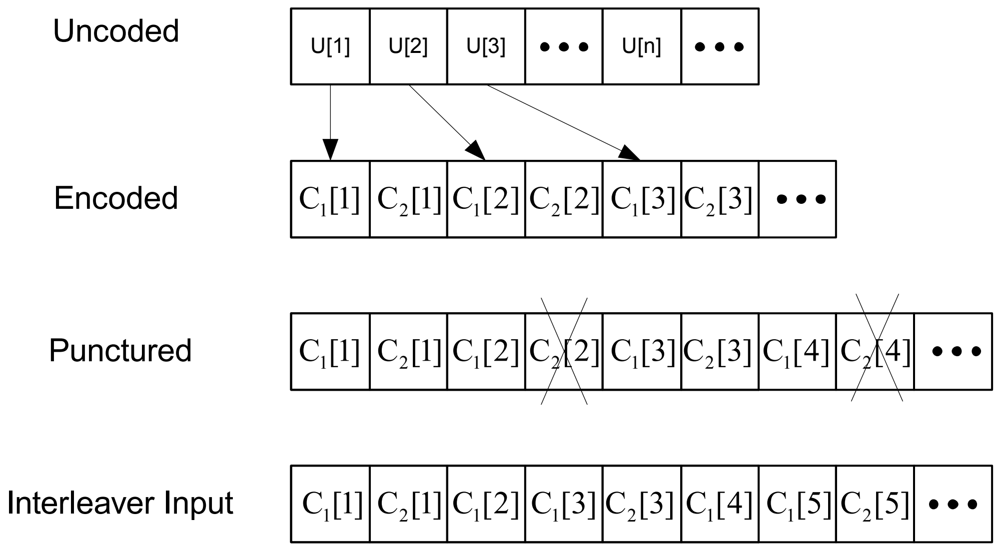

Figure 4-3: Outer Code Puncturing Scheme

4.3 INTERLEAVER

4.3.1 The interleaver length *I* and the corresponding permutation law shall be selected according to the parameter 'ACM Format' of the 'ACM Command'.

NOTES

1 This is done to keep the length of the SCCC Encoder output to a constant 8100 modulated symbols.

2 The interleaver is described by the ad hoc permutation law specified in annex B.

4.3.2 The Interleaver Length shall be according to table 4-1.

NOTE – It is worth noting that for the 27 selected ACM formats there are 19 different interleaver sizes.

Table 4-1: Interleaver Sizes for Different ACM Formats

ACM Format	Interleaver Length (bits)	ACM Format	Interleaver Length (bits)
1	8640	15	35280
2	10440	16	38880
3	12600	17	42480
4	14760	18	38880
5	16920	19	42480
6	19800	20	46440
7	16920	21	50040
8	19800	22	54000
9	22320	23	50040
10	25560	24	54000
11	28800	25	57960
12	32040	26	61560
13	28800	27	65520
14	32040		

4.4 CODING RATE ADJUSTMENT

4.4.1 OVERVIEW

Puncturing is performed at the output of the inner convolutional encoder to obtain the desired coding rate. Two different puncturing algorithms are used to puncture the systematic output C_1 and the parity output C_2 of the inner convolutional encoder.

4.4.2 GENERAL

4.4.2.1 The upper register at the output of the inner convolutional encoder (as specified in figure 4-1) shall contain the inner systematic bits, which coincide with the interleaved outer codeword, as well as two additional bits terminating the inner trellis.

4.4.2.2 The lower register shall contain the I+2 parity-check bits generated by the inner convolutional encoder.

4.4.2.3 The systematic output C_1 of the inner convolutional encoder shall be punctured excluding the two inner code-terminating bits (that are always transmitted) according to the periodic puncturing pattern described in 4.4.3.

4.4.2.4 The last two terminating bits of the inner convolutional encoder shall be always transmitted.

4.4.3 PUNCTURING SYSTEMATIC C_1 BITS

4.4.3.1 The puncturing of the systematic bits C_1 at the output of the inner convolutional encoder shall operate according to the parameters of table 4-2, where S_{sur} denotes the number of surviving bits in each 300-bit segment of the upper register after puncturing and is selected from table 4-3 based on the ACM format.

NOTE – Since in table 4-3 S_{sur} for ACM Format 1 and 2 has value 300, no puncturing of the systematic bits C_1 is performed in those cases.

4.4.3.2 Given the parameter S_{sur}, the puncturing of the systematic bits shall be performed according to the following algorithm:

a) After selecting the applicable S_{sur} in table 4-3 according to the current ACM format, a puncturing pattern of 300 elements (from 0 to 299) is obtained, inserting zeros at all the positions indicated by the column 'puncturing positions' of table 4-2 till (and including) the row for the applicable S_{sur} value, and ones elsewhere (e.g., for ACM Format 7, being S_{sur} = 292, the puncturing pattern will contains zeros in the positions 76, 1, 145, 214, 256, 37, 109, 181).

b) For each position i of the upper register containing the systematic bits, from i=0 to i=I-1 (i.e., excluding the two terminating bits, always transmitted), an index j is computed as

$$j = \pi(i) \bmod 300$$

where the π() is the function described in annex B and $\pi(i)$ is the interleaved position corresponding to i.

c) The position i in the upper register is punctured if the puncturing pattern of point a) contains a 0 at position j.

Table 4-2: Best Incremental Puncturing Positions

Index	S_{sur}	Rate	Punct. Pos.	Index	S_{sur}	Rate	Punct. Pos.
1	299	0.6689	**76**	51	249	0.8032	**72**
2	298	0.6711	**1**	52	248	0.8065	**15**
3	297	0.6734	**145**	53	247	0.8097	**297**
4	296	0.6757	**214**	54	246	0.8130	**211**
5	295	0.6780	**256**	55	245	0.8163	**138**
6	294	0.6803	**37**	56	244	0.8197	**102**
7	293	0.6826	**109**	57	243	0.8230	**174**
8	292	0.6849	**181**	58	242	0.8264	**39**
9	291	0.6873	**277**	59	241	0.8299	**250**
10	290	0.6897	**235**	60	240	0.8333	**57**
11	289	0.6920	**55**	61	239	0.8368	**120**
12	288	0.6944	**127**	62	238	0.8403	**156**
13	287	0.6969	**163**	63	237	0.8439	**84**
14	286	0.6993	**19**	64	236	0.8475	**229**
15	285	0.7018	**199**	65	235	0.8511	**193**
16	284	0.7042	**91**	66	234	0.8547	**283**
17	283	0.7067	**289**	67	233	0.8584	**262**
18	282	0.7092	**244**	68	232	0.8621	**25**
19	281	0.7117	**64**	69	231	0.8658	**238**
20	280	0.7143	**268**	70	230	0.8696	**60**
21	279	0.7168	**223**	71	229	0.8734	**201**
22	278	0.7194	**136**	72	228	0.8772	**294**
23	277	0.7220	**172**	73	227	0.8811	**132**
24	276	0.7246	**28**	74	226	0.8850	**96**
25	275	0.7273	**100**	75	225	0.8889	**159**
26	274	0.7299	**190**	76	224	0.8929	**34**
27	273	0.7326	**10**	77	223	0.8969	**265**
28	272	0.7353	**46**	78	222	0.9009	**114**
29	271	0.7380	**118**	79	221	0.9050	**177**
30	270	0.7407	**154**	80	220	0.9091	**225**
31	269	0.7435	**81**	81	219	0.9132	**79**
32	268	0.7463	**207**	82	218	0.9174	**12**
33	267	0.7491	**259**	83	217	0.9217	**151**
34	266	0.7519	**292**	84	216	0.9259	**51**
35	265	0.7547	**232**	85	215	0.9302	**274**
36	264	0.7576	**67**	86	214	0.9346	**204**
37	263	0.7605	**280**	87	213	0.9390	**105**
38	262	0.7634	**247**	88	212	0.9434	**4**
39	261	0.7663	**147**	89	211	0.9479	**241**
40	260	0.7692	**30**	90	210	0.9524	**169**
41	259	0.7722	**111**	91	209	0.9569	**69**
42	258	0.7752	**183**	92	208	0.9615	**124**
43	257	0.7782	**6**	93	207	0.9662	**22**
44	256	0.7813	**48**	94	206	0.9709	**216**
45	255	0.7843	**93**	95	205	0.9756	**285**
46	254	0.7874	**165**	96	204	0.9804	**141**
47	253	0.7905	**129**	97	203	0.9852	**252**
48	252	0.7937	**219**	98	202	0.9901	**187**
49	251	0.7968	**195**	99	201	0.9950	**206**
50	250	0.8000	**270**	100	200	1.0000	**36**

4.4.4 PUNCTURING PARITY C_2 BITS

4.4.4.1 General

4.4.4.1.1 The I+2 parity-check bits C_2 generated by the inner convolutional encoder shall be punctured using the rate-matching algorithm specified in 4.4.4.2.

NOTE – The puncturing of parity bits results in deleting a set of equally spaced bits.

4.4.4.1.2 The number of deleted parity bits shall be determined based on the rate matching parameter Δ/I, representing the ratio between the number of deleted parity bits Δ and the overall number of parity bits I before puncturing:

$$\Delta = I - (P - 2) \tag{1}$$

where $P=N–S$ is the total number of transmitted parity check bits.

NOTE – The last two terminating parity check bits are always transmitted.

4.4.4.2 Rate Matching Algorithm

4.4.4.2.1 Given the two parameters Δ (number of bits to be deleted) and I (total number of bits), the rate-matching algorithm shall use the following procedure:

a) Set the variable e=1.

b) For all possible positions i from 0 to I–1:

   1) if e>0 transmit the i^{th} bit; else set e=e+I;

   2) set e=e–Δ.

c) Continue.

NOTE – The last two terminating bits are always transmitted.

4.4.4.2.2 For each SCCC overall coding rate the parameter S_{sur} and the positions of the upper register punctured bits shall be determined in accordance with table 4-2.

NOTES

1 This is to optimize the coding scheme.

2 In each case, the value of S_{sur} determines the overall number of transmitted systematic bits S and, subsequently, the number of transmitted parity check bits P and the parameter Δ used by the rate-matching algorithm.

4.4.4.2.3 The parameter describing the encoder structure in each of the 27 ACM formats shall be taken from table 4-3.

Table 4-3: Main Encoder Parameters for 27 Selected ACM Formats

ACM format	m	S_{sur}	K	I	S	P	N	Δ
1	2	300	5758	8640	8642	7558	16200	1084
2	2	300	6958	10440	10442	5758	16200	4684
3	2	274	8398	12600	11510	4690	16200	7912
4	2	251	9838	14760	12351	3849	16200	10913
5	2	234	11278	16920	13200	3000	16200	13922
6	2	218	13198	19800	14390	1810	16200	17992
7	3	292	11278	16920	16470	7830	24300	9092
8	3	240	13198	19800	15842	8458	24300	11344
9	3	250	14878	22320	18602	5698	24300	16624
10	3	234	17038	25560	19939	4361	24300	21201
11	3	221	19198	28800	21218	3082	24300	25720
12	3	214	21358	32040	22857	1443	24300	30599
13	4	255	19198	28800	24482	7918	32400	20884
14	4	241	21358	32040	25741	6659	32400	25383
15	4	230	23518	35280	27051	5349	32400	29933
16	4	220	25918	38880	28515	3885	32400	34997
17	4	211	28318	42480	29880	2520	32400	39962
18	5	245	25918	38880	31755	8745	40500	30137
19	5	234	28318	42480	33137	7363	40500	35119
20	5	224	30958	46440	34677	5823	40500	40619
21	5	217	33358	50040	36197	4303	40500	45739
22	5	210	35998	54000	37802	2698	40500	51304
23	6	236	33358	50040	39366	9234	48600	40808
24	6	228	35998	54000	41042	7558	48600	46444
25	6	220	38638	57960	42507	6093	48600	51869
26	6	214	41038	61560	43915	4685	48600	56877
27	6	208	43678	65520	45429	3171	48600	62351

4.5 ROW-COLUMN INTERLEAVER

4.5.1 The input to the row-column interleaver shall be built with punctured systematic bits C_1 followed by punctured parity bits C_2.

4.5.2 Prior to the bit-to-symbol mapping at the transmitter, a row-column interleaver shall be used to pseudo-randomize the selection of bits that are assigned to one modulation symbol.

NOTE – This is to ensure that the correlation between bits assigned to one symbol does not adversely affect the decoding process. To implement the pragmatic code permutation, the output of the inner encoder, after puncturing, is bit interleaved. This technique is known as Bit Interleaved Coded Modulation (BICM) as introduced in reference [F1].

4.5.3 The bit-interleaving scheme shall follow figure 4-4, such that the interleaver depth (number of rows) is equal to the size of one codeword section (i.e., 8100 symbols) and the number of columns is equal to *m,* where *m* is the modulation order.

NOTES

1 The bit interleaving structure has 8,100 rows, independent of the ACM format, and *m* columns, where *m* is the modulation order. The first symbol carries the bits positioned at index 0, 8100, 16200, 24300, 32400, 40500, for 64 APSK for instance. The second symbol carries bits at position 1, 8101, 16201, 24301, 32401, 40501, and so on up to the last symbol (carrying bits 8099, 16199, 24299, 32399, 40499, 48599).

2 The maximum memory size to implement the bit-interleaver is $m \times 8100 = 6 \times 8100 = 48600$ locations, each containing one bit, for the 64 APSK modulation scheme. The memory can be seen as a matrix composed of *m* columns and 8100 rows. The number of rows is independent of the code rate and modulation scheme.

3 The modulation order *m* can be mapped to the selected modulation as follows: 2=QPSK, 3=8PSK, 4=16APSK, 5=32APSK and 6=64APSK.

4.5.4 The input data shall be serially written into the interleaving column-wise and serially read out row-wise (the most significant bit shall be read out first).

4.5.5 Punctured Systematic bits C_1 (corresponding to the upper branch of the inner convolutional encoder) shall be first written sequentially in the register followed by the punctured parity check bits C_2 (corresponding to the lower branch of the convolutional encoder).

NOTE – The SCCC encoding unit provides each encoded block to the PL Framing.

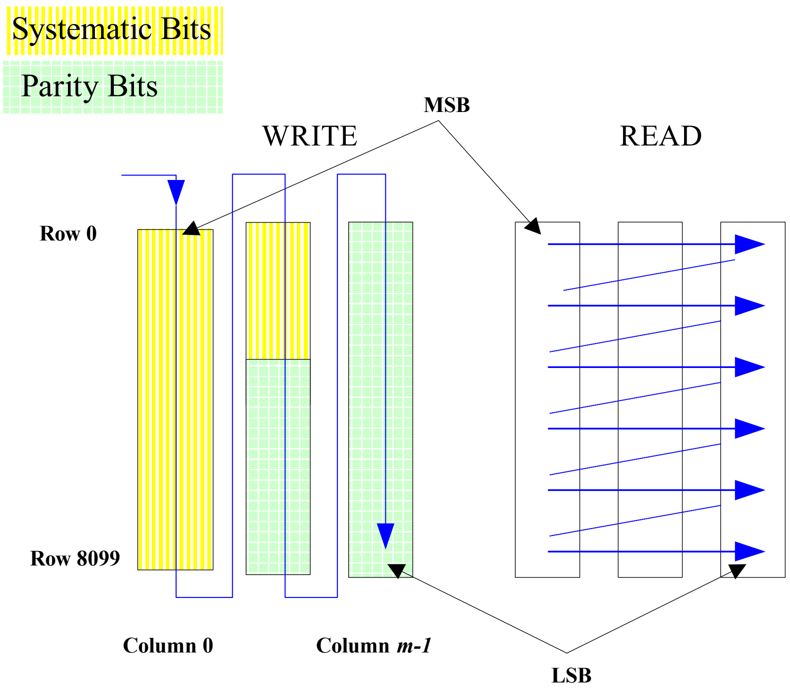

Figure 4-4: Row-Column Bit-Interleaving Scheme

5 PHYSICAL LAYER FRAMING

5.1 GENERAL

5.1.1 The SCCC encoding unit shall provide the PL Framing with encoded blocks of N=8100 × m bits, where m is the modulation order, that are used to generate PL Frames.

NOTE – In this section, when used alone, the term frame always refers to a PL Frame.

5.1.2 Each encoded block shall be mapped to 8100 modulation symbols as defined in 5.2.

5.2 CONSTELLATION MAPPING

5.2.1 GENERAL

5.2.1.1 One of the following constellation mappings shall be used:

a) PSK modulations

   1) QPSK modulation, as specified in subsection 2.4.10 of reference [4] (and illustrated in 5.2.2.1).

   2) 8PSK modulation, as specified in 5.2.2.2.

b) APSK modulations

   1) 16APSK modulation, as specified in 5.2.3.1.

   2) 32APSK modulation, as specified in 5.2.3.2.

   3) 64APSK modulation, as specified in 5.2.3.3.

5.2.1.2 For all the constellation mappings the Bit Numbering Convention shall be applied (see 1.5.3).

NOTE – Figure 5-1 shows the selected modulation constellations along with the associated bits-to-symbols mapping laws.

5.2.2 PSK MODULATIONS

5.2.2.1 QPSK

If used, a QPSK modulation scheme shall be the conventional Gray-Coded QPSK modulation with absolute mapping (no differential coding), following the specification in subsection 2.4.10 of reference [4].

NOTES

1 The normalized average energy per symbol is equal to 1 (Radius=1).

2 The normalization for QPSK and the modulations hereafter sets the level of the pilot symbols (5.3.4.3) relative to modulated data symbols.

5.2.2.2 8PSK

If used, an 8PSK modulation scheme shall be a conventional Gray-Coded 8PSK modulation with absolute mapping (no differential coding).

NOTE – The normalized average energy per symbol is equal to 1 (Radius=1).

5.2.3 APSK MODULATIONS

5.2.3.1 16APSK

5.2.3.1.1 If a 16APSK scheme is used, the constellation shall be composed of 2 concentric circumferences, whose number of points shall be set to $N_1 = 4$ and $N_2 = 12$.

5.2.3.1.2 If a 16APSK scheme is used, the values of $\gamma_1 = R_2/R_1$ (with R_2 and R_1 being the radius of the outer and inner ring of the constellation, respectively) for 16APSK modulation schemes and linear channels shall be those shown in table 5-1.

5.2.3.1.3 If a 16APSK scheme is used, the average signal energy shall be set to one; i.e.,

$$[R_1]^2 + 3\,[R_2]^2 = 4.$$

5.2.3.2 32APSK

5.2.3.2.1 If a 32APSK scheme is used, the constellation shall be composed of 3 concentric circumferences whose number of points shall be set to $N_1 = 4$, $N_2 = 12$, and $N_3 = 16$.

5.2.3.2.2 If a 32APSK scheme is used, the values of $\gamma_1 = R_2/R_1$ and $\gamma_2 = R_3/R_1$ (with R_2 and R_1 being the radius of the outer and inner ring of the constellation, respectively) for 32APSK modulation schemes shall be those shown in table 5-1.

5.2.3.2.3 If a 32APSK scheme is used, the average signal energy shall be set to one; i.e.,

$$[R_1]^2 + 3\,[R_2]^2 + 4\,[R_3]^2 = 8.$$

5.2.3.3 64APSK

5.2.3.3.1 If a 64APSK scheme is used, the constellation shall be composed of 4 concentric circumferences, whose number of points shall be set to $N_1 = 4$, $N_2 = 12$, $N_3 = 20$, and $N_4 = 28$.

5.2.3.3.2 If a 64APSK scheme is used, the following set of parameters shall be used to maximize the minimum Euclidean distance:

a) $\gamma_1 = R_2/R_1 = 2.73$;

b) $\gamma_2 = R_3/R_1 = 4.52$; and

c) $\gamma_3 = R_4/R_1 = 6.31$;

where R_4, R_3, R_2, and R_1 are the radii from the outer to the inner ring, respectively.

5.2.3.3.3 If a 64APSK scheme is used, the average signal energy shall be set to one; i.e.,

$$[R_1]^2 + 3\,[R_2]^2 + 5\,[R_3]^2 + 7\,[R_4]^2 = 16.$$

Table 5-1: Constellation Radius Ratios for 16APSK and 32APSK

ACM Format	Modulation	Coding Rate	γ_1	γ_2
13	16-APSK	0.5925	3.15	N/A
14	16-APSK	0.6592	3.15	N/A
15	16-APSK	0.7259	2.85	N/A
16	16-APSK	0.7999	2.75	N/A
17	16-APSK	0.8740	2.60	N/A
18	32-APSK	0.6400	2.84	5.27
19	32-APSK	0.6992	2.84	5.27
20	32-APSK	0.7644	2.84	5.27
21	32-APSK	0.8237	2.72	4.87
22	32-APSK	0.8888	2.54	4.33

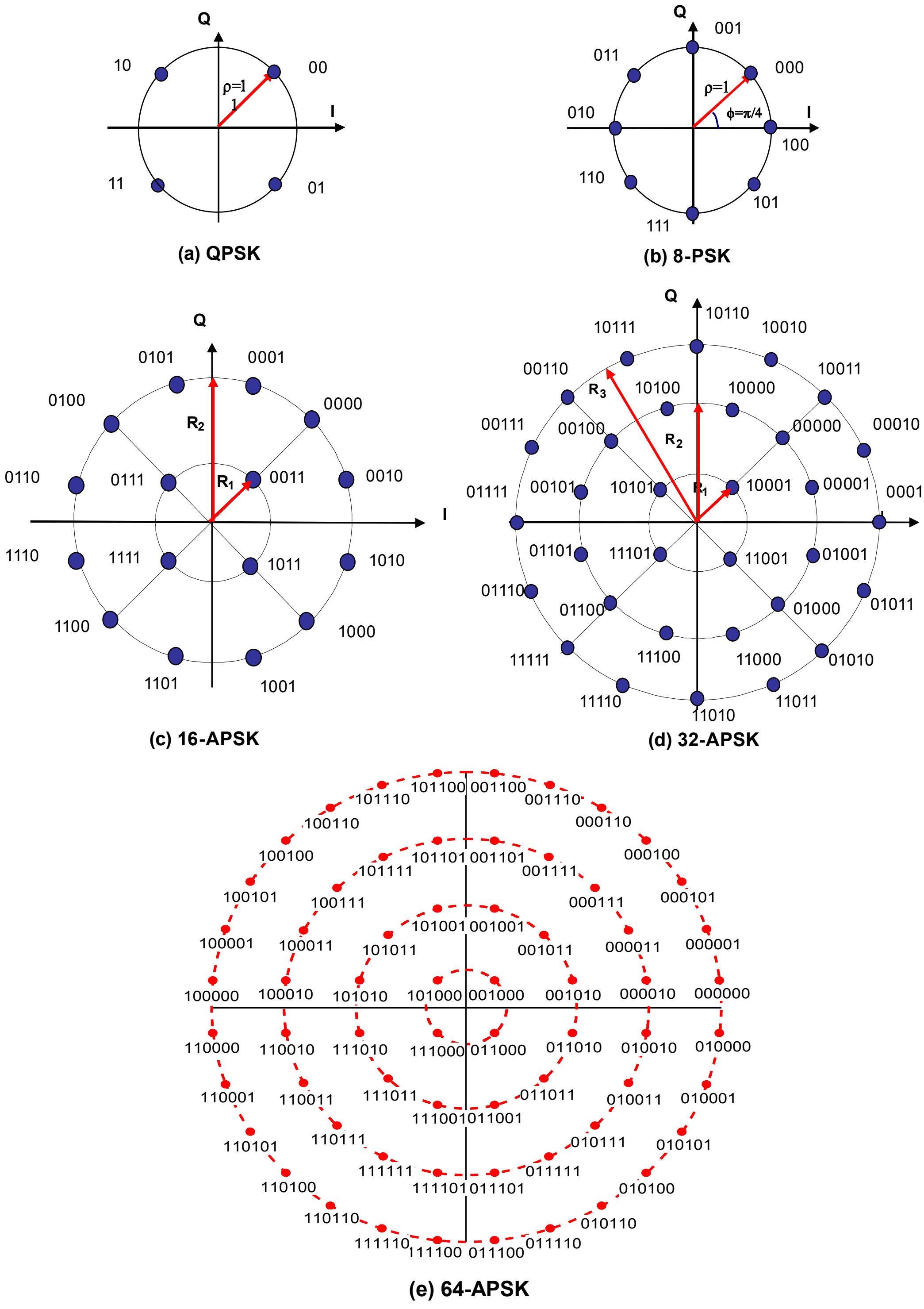

Figure 5-1: Bit Mapping into Constellations

5.2.4 SUPPORTED SET OF ACM FORMATS

The coding and modulation schemes (ACM formats) shall use the parameters specified in table 5-2.

NOTE – The two highest spectral efficiencies for each modulation scheme have also been included with the modulation scheme with higher cardinality. This overlap is necessary since the coded-modulator performance can be different depending on the channel impairments. In summary, a total of 27 ACM formats are supported, providing about 20 dB range in the required E_s/N_o for the link budget.

Table 5-2: ACM Formats of the SCCC Encoder

	ACM Format	***K*** **Information block size**	***I*** **Interleaver length**	***N*** **Number of encoded bits**	**Code rate Overall rate of the code (*K*/*N*)**
QPSK	1	5758	8640	16200	0.36
	2	6958	10440	16200	0.43
	3	8398	12600	16200	0.52
	4	9838	14760	16200	0.61
	5	11278	16920	16200	0.7
	6	13198	19800	16200	0.81
8PSK	7	11278	16920	24300	0.46
	8	13198	19800	24300	0.54
	9	14878	22320	24300	0.61
	10	17038	25560	24300	0.7
	11	19198	28800	24300	0.79
	12	21358	32040	24300	0.88
16APSK	13	19198	28800	32400	0.59
	14	21358	32040	32400	0.66
	15	23518	35280	32400	0.73
	16	25918	38880	32400	0.8
	17	28318	42480	32400	0.87
32APSK	18	25918	38880	40500	0.64
	19	28318	42480	40500	0.7
	20	30958	46440	40500	0.76
	21	33358	50040	40500	0.82
	22	35998	54000	40500	0.89
64APSK	23	33358	50040	48600	0.69
	24	35998	54000	48600	0.74
	25	38638	57960	48600	0.80
	26	41038	61560	48600	0.84
	27	43678	65520	48600	0.9

5.3 PL SIGNALLING INSERTION

5.3.1 GENERAL

The PL frame structure shall consist of the following segments:

a) frame header segment, which consists of two fields:

   1) Frame Marker (FM), as specified in 5.3.2;

   NOTE – Frame Marker consists of 256 known symbols used for start-of-frame detection and synchronization.

   2) Frame Descriptor (FD), as specified 5.3.3;

   NOTE – Frame Descriptor consists of 64 symbols to identify the ACM format used per each physical frame as well as the presence or absence of pilot symbols.

b) codeword segment, which consists of 16 codeword sections of modulation symbols (with additional optional pilot symbols, as specified in 5.3.4).

NOTE – The PL frame structure is illustrated in figure 5-2.

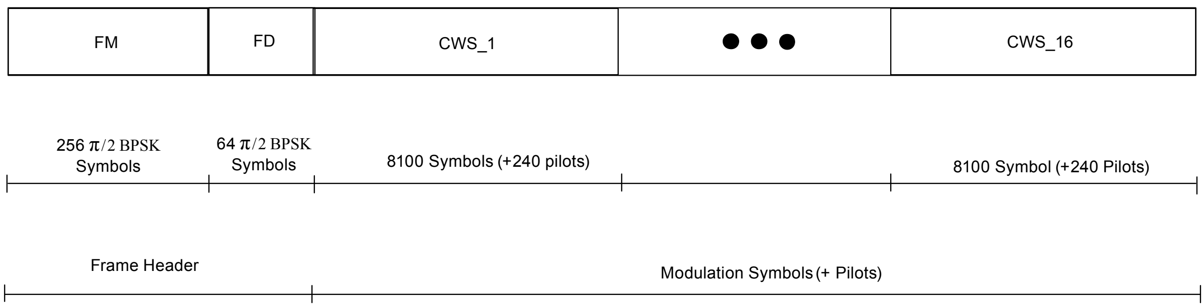

Figure 5-2: Physical Layer Frame Structure

5.3.2 FRAME MARKER

5.3.2.1 Overview

As explained in 5.4.1, the Frame Marker will consist of a 256-bit sequence mapped to 256 π/2-BPSK modulated symbols. The Frame Marker is used to detect the start of the PL frame as well as initial timing and coarse carrier synchronization. The length and the modulating bit sequence of the Frame Marker is selected such that the start of frame can be detected with a low probability of detection error (misdetection as well as false alarm) in the presence of severe channel impairments.

5.3.2.2 Frame Marker Generation

5.3.2.2.1 The Frame Marker shall be generated using the Gold sequence using the following polynomials for the feedback loop:

$$g_1(x) = x^8 + x^6 + x^5 + x^4 + 1$$
$$g_2(x) = x^8 + x^6 + x^5 + x^4 + x^3 + x + 1 \quad (2)$$

NOTE – Figure 5-3 shows the logical block diagram of the sequence generator using shift registers and exclusive-OR operators.

5.3.2.2.2 The upper and the lower shift registers of the Frame Marker Sequence Generator shall be initialized as shown in figure 5-3.

NOTE – The first 40 bits of the Frame Marker sequence for the generator are shown below. The left-most bit corresponds to the first modulating bit of the Frame Marker:

```
1111 1011 0100 0100 0001 1111 0001 1101 1011 1101 …
```

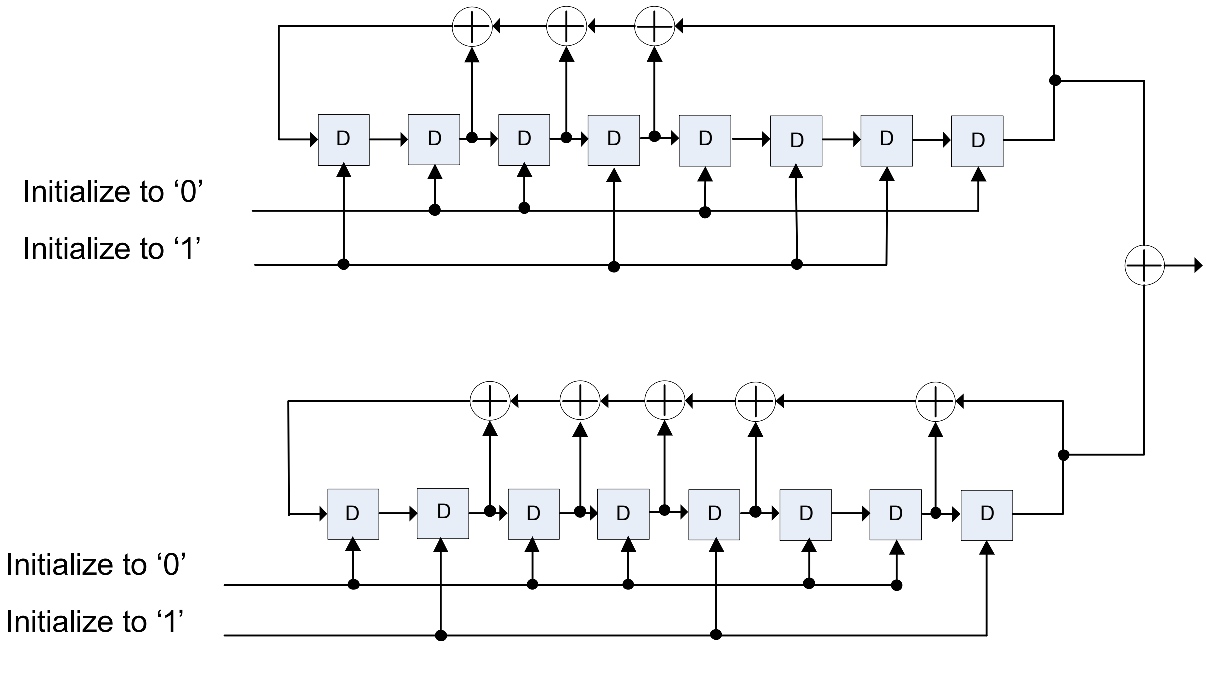

Figure 5-3: Frame Marker Sequence Generator

5.3.3 FRAME DESCRIPTOR STRUCTURE

5.3.3.1 Overview

The Frame Descriptor is generated by encoding 7 input bits with the non-systematic binary code of length 64 and dimension 7 with minimum distance d_{min}=32 shown in figure 5-3. The 7 input bits identify the ACM format of codeword sections within a PL frame (5 bits) as well as the absence or presence of distributed pilots. The code is similar to that used in reference [F3] for PL Signalling.

5.3.3.2 Frame Descriptor Content and Construction

5.3.3.2.1 The content of the seven input bits shall be as shown in table 5-3.

Table 5-3: Frame Descriptor Input Bits Content

Bit Number	Content
b_1-b_5	ACM Formats (Decimal values 1 to 27 are used with bit b_1 being the most significant bit)
b_6	Distributed Pilot On (=1) / Off (=0)
b_7	Reserved (set to 0)

5.3.3.2.2 The Frame Descriptor shall be constructed using the bi-orthogonal (32,6) code shown in figure 5-4, as follows:

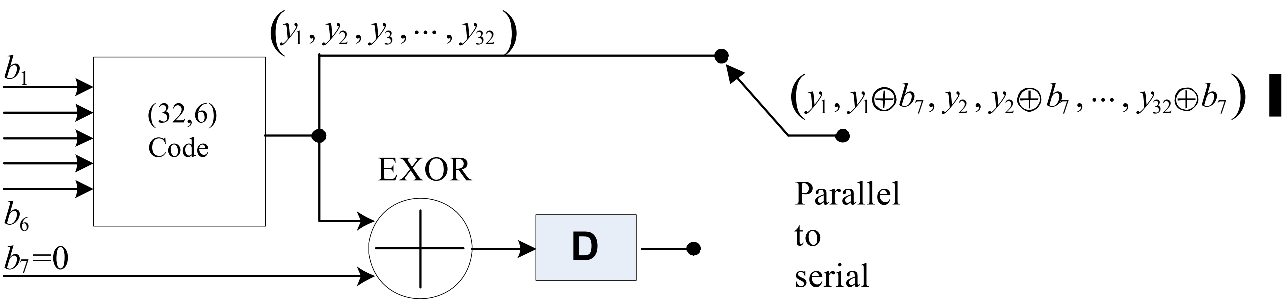

Figure 5-4: Frame Descriptor Code Structure

a) The first 6 bits, b_1-b_6, shall be encoded using a linear block code of length 32 with the generator matrix in figure 5-5.

$$
G = \begin{bmatrix}
01010101010101010101010101010101 \\
00110011001100110011001100110011 \\
00001111000011110000111100001111 \\
00000000111111110000000011111111 \\
00000000000000001111111111111111 \\
11111111111111111111111111111111
\end{bmatrix}
$$

Figure 5-5: Generator Matrix for (32,6) Code

b) The most significant bit b_1 shall be multiplied with the first row of the matrix, the following bit with the second row, and so on till bit b_6 to generate 32 coded bits denoted (y_1, y_2, …, y_{32}).

c) The least significant bit b_7 of the Frame Descriptor shall be set to 0 and the final output is therefore the 64-bit output code (y_1, y_1, y_2, y_2,…, y_{32}, y_{32}) where each symbol is present twice.

d) The 64-bit output code shall be further scrambled (i.e., EXORed) by the following binary sequence:

0111000110011101100000011110010010101001101000010001011011111010.

5.3.4 CODEWORD SEGMENT GENERATION AND PILOT INSERTION

5.3.4.1 Each encoded block mapped to 8100 modulation symbols shall be used to generate a codeword section optionally containing pilot symbols.

NOTE – A codeword section includes either 8100 or 8340 modulation symbols in case pilot symbols are used.

5.3.4.2 If insertion of distributed pilots is performed, it shall follow the format specified in figure 5-6.

NOTES

1 Each codeword section is composed of 15 subsections and each subsection is composed of 540 data symbols optionally followed by 16 pilot symbols. The use of distributed pilot symbols in codeword sections is an option to facilitate carrier and phase synchronization.

2 The presence or absence of pilot symbols can be changed using one bit (b_6) of the 7 input bits (see table 5-3).

5.3.4.3 Each pilot shall be an un-modulated symbol, with equal In-phase and Quadrature components: I=(1√2), Q=(1√2).

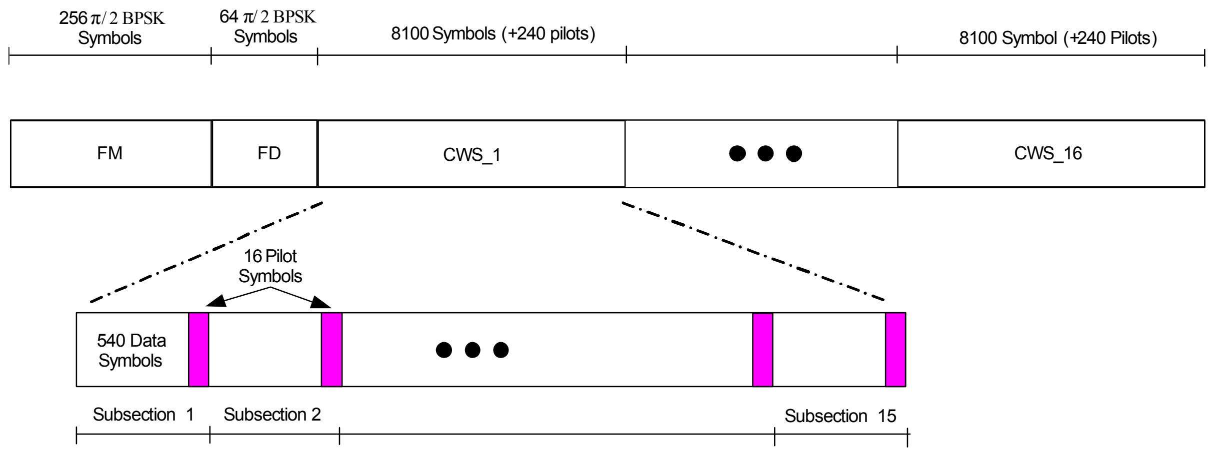

Figure 5-6: Distributed Pilot Pattern

5.3.4.4 The parameters to specify the pilot distribution pattern within each PL frame shall be those presented in table 5-4.

NOTE – The total overhead due to pilot insertion is around three per cent.

Table 5-4: Frame Parameters Related to Pilot Distribution

Parameter	Value
Codeword section length without pilot symbols	8100 symbols
Number of codeword sections per frame	16 sections
Number of subsections per codeword section	15 subsections
Number of data symbols per subsection	540 symbols
Number of pilots per subsection	16 symbols
Total number of pilots per section	240 Symbols
Total section length including pilot symbols	8340 symbols

5.4 FRAME HEADER MODULATION

5.4.1 The frame header shall be modulated into 320 π/2-BPSK symbols.

NOTE – As specified in 5.3, the frame header consists of the Frame Marker (256 bits) and Frame Descriptor (64 bits).

5.4.2 The frame header shall be modulated using the following mapping:

Assuming that the Frame Header binary sequence is denoted as (x_1, x_2, …, x_{320}), the In-phase (*I*) and Quadrature (*Q*) components of 320 π/2-BPSK modulated symbols are determined according the following rule:

$$\begin{aligned} I_{2i-1} &= Q_{2i-1} = \frac{1}{\sqrt{2}}(1-2x_{2i-1}) \\ I_{2i} &= -Q_{2i} = \frac{-1}{\sqrt{2}}(1-2x_{2i}) \end{aligned} \quad \text{for } i = 1,2,\ldots,160 \tag{3}$$

5.5 PHYSICAL LAYER *I*/*Q* PSEUDO-RANDOMIZATION

5.5.1 PL randomization shall be applied to all 16 codeword sections of a PL frame, including the data symbols as well as the pilots.

NOTE – This is done to disperse the signal energy in order to avoid any spectral spur due to repetitive data or pilot patterns. PL randomization is fixed for all Transfer Frames on a Physical Channel during a given Mission Phase (see section 9).

5.5.2 PL randomization shall use the PL pseudo-randomizer specified in annex C.

6 BASEBAND FILTERING

6.1.1 The baseband pulse shaping filter applied to In-phase and Quadrature signals shall be a square-root raised cosine filter using the following:

$$H(f)=\begin{cases}1 & |f|<f_N(1-\alpha)\\ \left\{\dfrac{1}{2}+\dfrac{1}{2}\sin\dfrac{\pi}{2f_N}\left(\dfrac{f_N-|f|}{\alpha}\right)\right\}^{1/2} & f_N(1-\alpha)<|f|<f_N(1+\alpha)\\ 0 & |f|>f_N(1+\alpha)\end{cases} \tag{4}$$

Where $f_N=\dfrac{1}{2T_s}=\dfrac{R_s}{2}$ is the Nyquist frequency and α is the roll-off factor.

6.1.2 The roll-off factor shall have one of the following values: α=0.2, 0.25, 0.30 or 0.35.

7 FRAME SYNCHRONIZATION

7.1 OVERVIEW

7.1.1 SYNCHRONIZATION

Frame synchronization is necessary for subsequent processing of the Transfer Frames. Furthermore, it is necessary for synchronization of the pseudo-random generator (see section 8).

7.1.2 SYNCH MARKED TRANSFER FRAME

The data unit that consists of the ASM and the Transfer Frame, consistent with reference [1], is the SMTF. The Transfer Frame in the SMTF is randomized.

7.2 THE ATTACHED SYNC MARKER

7.2.1.1 Transfer Frames shall be synchronized by using a stream of fixed-length Transfer Frames with an Attached Sync Marker (ASM) between them.

NOTE – Synchronization is acquired on the receiving end by recognizing the specific bit pattern of the ASM in the data stream; synchronization is then verified by making further checks.

7.2.1.2 The ASM shall be SCCC encoded.

7.3 ASM BIT PATTERNS

The ASM shall consist of a 32-bit (4-octet) marker with a pattern shown in table 7-1.

Table 7-1: ASM Bit Patterns

ASM length	32 bits
ASM sequence (Hex)	1ACFFC1D

7.4 LOCATION OF ASM

7.4.1 The ASM shall be attached to (i.e., shall immediately precede) the Transfer Frame.

7.4.2 The ASM shall immediately follow the end of the preceding Transfer Frame; i.e., there shall be no intervening bits (data or fill) preceding the ASM.

7.5 ASM FOR EMBEDDED DATA STREAM

NOTE – A different ASM pattern (see figure 7-1) may be required where another data stream (e.g., a stream of Transfer Frames played back from a tape recorder in the forward direction) is inserted into the data field of the Transfer Frame of the main stream appearing on the communications channel.

The ASM for the embedded data stream, to differentiate it from the main stream marker, shall consist of a 32-bit (4-octet) marker with a pattern as follows:

```
FIRST TRANSMITTED BIT
(Bit 0)
↓
0011  0101  0010  1110  1111  1000  0101  0011
                                           ↑
                       LAST TRANSMITTED BIT
                                    (Bit 31)
```

Figure 7-1: Embedded ASM Bit Pattern

NOTE – This pattern is represented in hexadecimal notation as:

352EF853

8 PSEUDO-RANDOMIZER

8.1 OVERVIEW

In order for the receiver system to work properly, every data capture system at the receiving end requires that the incoming signal have sufficient bit transition density (see recommendation 2.4.9 in reference [4]), and allow proper synchronization of the decoder.

In order to ensure proper receiver operation, the data stream must be sufficiently random. The Pseudo-Randomizer defined in this section is the preferred method to ensure sufficient randomness for all combinations of CCSDS-recommended modulation and coding schemes. The Pseudo-Randomizer defined in reference [1] is always required by SCCC.

8.2 PSEUDO-RANDOMIZER DESCRIPTION

8.2.1 The pseudo-randomizer shall be applied to the Transfer Frame before SCCC encoding.

8.2.2 On the receiving end, it shall be applied to de-randomize the data after SCCC decoding and Transfer Frame synchronization.

NOTES

1 The method for ensuring sufficient transitions is to exclusive-OR each bit of the codeblock, codeword, or Transfer Frame with a standard pseudo-random sequence.

2 The configuration at the sending end is shown in figure 8-1.

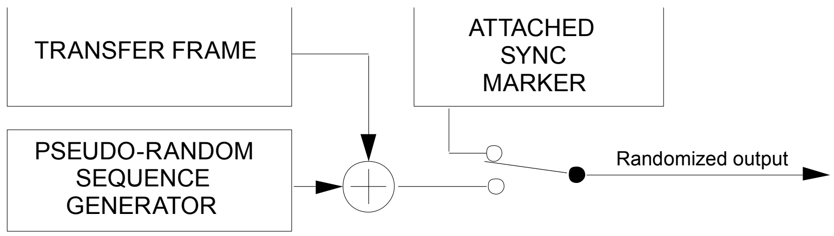

Figure 8-1: Pseudo-Randomizer Configuration

8.3 SYNCHRONIZATION AND APPLICATION OF PSEUDO-RANDOMIZER

8.3.1 The ASM shall be used for synchronizing the pseudo-randomizer.

NOTE – The ASM is already optimally configured for synchronization purposes.

8.3.2 The pseudo-random sequence shall be applied starting with the first bit of the Transfer Frame.

8.3.3 On the sending end, the Transfer Frame shall be randomized by exclusive-ORing the first bit of the Transfer Frame with the first bit of the pseudo-random sequence, followed by the second bit of the Transfer Frame with the second bit of the pseudo-random sequence, and so on.

8.3.4 On the receiving end, the original Transfer Frame shall be reconstructed (i.e., derandomized) using the same pseudo-random sequence.

8.3.5 After locating the ASM in the received data stream, the data immediately following the ASM shall be derandomized.

NOTES

1 The ASM was not randomized and is not derandomized.

2 Derandomization can be accomplished by performing exclusive-OR with hard bits or inversion with soft bits.

8.4 SEQUENCE SPECIFICATION

8.4.1 The pseudo-random sequence shall be generated using the following polynomial:

$$h(x) = x^8 + x^7 + x^5 + x^3 + 1$$

8.4.2 This sequence shall begin at the first bit of the Transfer Frame and shall repeat after 255 bits, continuing repeatedly until the end of the Transfer Frame. The sequence generator shall be initialized to the all-ones state at the start of each Transfer Frame.

NOTE – The first 40 bits of the pseudo-random sequence from the generator are shown below. The leftmost bit is the first bit of the sequence to be exclusive-ORed with the first bit of the Transfer Frame; the second bit of the sequence is exclusive-ORed with the second bit of the Transfer Frame, and so on.

1111 1111 0100 1000 0000 1110 1100 0000 1001 1010 . . . .

8.5 LOGIC DIAGRAM

NOTE – Figure 8-2 represents a possible generator for the specified sequence.

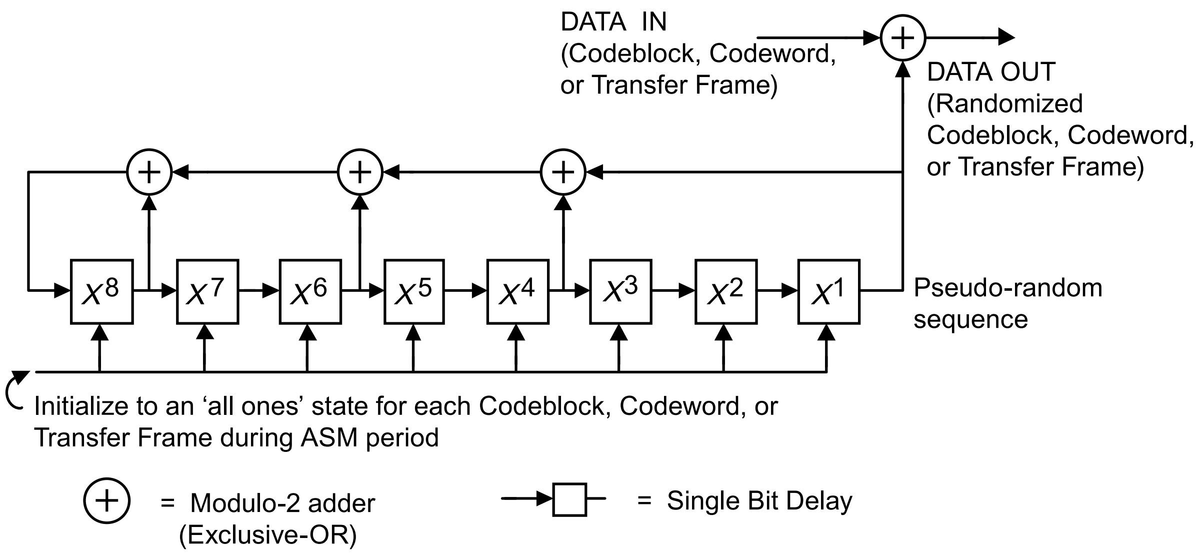

Figure 8-2: Pseudo-Randomizer Logic Diagram

9 MANAGED PARAMETERS

9.1 OVERVIEW

In order to conserve bandwidth on the space link, some parameters associated with modulation, synchronization, and channel coding are handled by management rather than by inline communications protocol. The managed parameters are generally those which tend to be static for long periods of time, and whose change generally signifies a major reconfiguration of the modulation, synchronization, and channel coding systems associated with a particular mission, i.e., parameters that are fixed within a mission phase. However, as mentioned in annex A, the coding and modulation scheme defined in this book also supports parameters that can be changed from one time interval to the next, within a sequence of time intervals in a mission phase. These two types will be referenced in this section respectively as Permanent Managed Parameters and Variable Managed Parameters.

Through the use of a management system, management conveys the required information to the modulation, synchronization, and channel coding systems.

In this section, the managed parameters used by systems applying this recommended standard are listed. These parameters are defined in an abstract sense and are not intended to imply any particular implementation of a management system.

9.2 PERMANENT MANAGED PARAMETERS

9.2.1 GENERAL

9.2.1.1 All the managed parameters specified in this section shall be fixed for all Transfer Frames on a Physical Channel during a given Mission Phase.

9.2.1.2 The Frame Error Control Field defined in reference [2], [3], or [5] shall be present.

NOTE – The Frame Error Control Field is used for Frame Validation as mentioned in 2.2.3.

9.2.2 MANAGED PARAMETERS FOR FRAME SYNCHRONIZATION

The managed parameters for frame synchronization shall be those specified in table 9-1.

Table 9-1: Managed Parameters for Frame Synchronization

Managed Parameter	Allowed Values
Transfer Frame Length (octets)	Integer: 223 to 65536 octets

9.2.3 MANAGED PARAMETERS FOR CODING AND MODULATION

The managed parameters for coding and modulation shall be those specified in table 9-2.

Table 9-2: Managed Parameters for Coding and Modulation

Managed Parameter	Allowed Values
Baseband pulse shaping roll-off factor	0.2, 0.25, 0.3, 0.35
Pilot symbols insertion	ON, OFF
Scrambling code number *n*	INTEGER from 0 to 2^{18}–2

9.2.4 MANAGED PARAMETERS FOR SUPPORTED ACM FORMATS

The managed parameters for supported ACM Formats shall be those specified in table 9-3.

Table 9-3: Managed Parameters for Supported ACM Formats

Managed Parameter	Allowed Values
Number of ACM Formats supported during a given Mission Phase	Integer: 1 to 27
List of ACM Formats supported during a given Mission Phase	List of Integers (dimension = 'Number of ACM Formats supported during a given Mission Phase'). Each integer is in the range 1 to 27 as per 9.3.2 below.

9.3 VARIABLE MANAGED PARAMETERS

9.3.1 GENERAL

All the managed parameters specified in this section shall be fixed for all Transfer Frames on a Physical Channel within one interval of a given Mission Phase.

NOTE – Variable managed parameters apply to reconfiguration of the modulation, synchronization, and channel coding systems during a mission phase.

9.3.2 CURRENT ACM FORMAT

The managed parameters for ACM Format shall be those specified in table 9-4.

NOTE – ACM Format can range from 1 to 27. As a consequence of this parameter several systems parameters shall be changed consistently. The complete set of parameters with their corresponding values is shown in table 9-5.

Table 9-4: Managed Parameters for ACM Format

Managed Parameter	Allowed Values
Current ACM Format	Integer: 1 to 27

Table 9-5: Variable Managed Parameters for 27 Selected ACM Formats

ACM format	m	S_{sur}	K	I	S	P	N	Δ
1	2 = QPSK	300	5758	8640	8642	7558	16200	1084
2	2 = QPSK	300	6958	10440	10442	5758	16200	4684
3	2 = QPSK	274	8398	12600	11510	4690	16200	7912
4	2 = QPSK	251	9838	14760	12351	3849	16200	10913
5	2 = QPSK	234	11278	16920	13200	3000	16200	13922
6	2 = QPSK	218	13198	19800	14390	1810	16200	17992
7	3 = 8PSK	292	11278	16920	16470	7830	24300	9092
8	3 = 8PSK	240	13198	19800	15842	8458	24300	11344
9	3 = 8PSK	250	14878	22320	18602	5698	24300	16624
10	3 = 8PSK	234	17038	25560	19939	4361	24300	21201
11	3 = 8PSK	221	19198	28800	21218	3082	24300	25720
12	3 = 8PSK	214	21358	32040	22857	1443	24300	30599
13	4 = 16APSK	255	19198	28800	24482	7918	32400	20884
14	4 = 16APSK	241	21358	32040	25741	6659	32400	25383
15	4 = 16APSK	230	23518	35280	27051	5349	32400	29933
16	4 = 16APSK	220	25918	38880	28515	3885	32400	34997
17	4 = 16APSK	211	28318	42480	29880	2520	32400	39962
18	5 = 32APSK	245	25918	38880	31755	8745	40500	30137
19	5 = 32APSK	234	28318	42480	33137	7363	40500	35119
20	5 = 32APSK	224	30958	46440	34677	5823	40500	40619
21	5 = 32APSK	217	33358	50040	36197	4303	40500	45739
22	5 = 32APSK	210	35998	54000	37802	2698	40500	51304
23	6 = 64APSK	236	33358	50040	39366	9234	48600	40808
24	6 = 64APSK	228	35998	54000	41042	7558	48600	46444
25	6 = 64APSK	220	38638	57960	42507	6093	48600	51869
26	6 = 64APSK	214	41038	61560	43915	4685	48600	56877
27	6 = 64APSK	208	43678	65520	45429	3171	48600	62351

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 Flexible Advanced Coding and Modulation scheme for High Rate Telemetry Applications provides unidirectional (one way) transfer of a sequence of fixed-length TM, AOS, or USLP Transfer Frames at constant frame rate over a Physical Channel across a space link, with optional error detection/correction.

The value of the constant frame rate can be changed from one time interval to the next, within a sequence of time intervals in a mission phase. There can be multiple time intervals within a mission phase. This annex does not specify the method for synchronizing the data exchange between the service user and the service provider when there is a change of frame rate: the synchronization is considered to be part of system management and is out of the scope of this annex.

Only one user can use this service on a Physical Channel, and Transfer Frames from different users are not multiplexed together within one Physical Channel.

A3 SERVICE PARAMETERS

A3.1 FRAME

A3.1.1 The Frame parameter is the service data unit of this service and shall be either a TM Transfer Frame defined in reference [2], an AOS Transfer Frame defined in reference [3], or a fixed-length USLP Transfer Frame defined in reference [5].

A3.1.2 The length of any Transfer Frame transferred on a Physical Channel must be the same, and is established by management.

A3.2 QUALITY INDICATOR

The Quality Indicator parameter shall be used to notify the user at the receiving end of the service that there is an uncorrectable error in the received Transfer Frame.

A3.3 SEQUENCE INDICATOR

The Sequence Indicator parameter shall be used to notify the user at the receiving end of the service that one or more Transfer Frames of the Physical Channel have been lost as the result of a loss of frame synchronization.

A4 SERVICE PRIMITIVES

A4.1 GENERAL

A4.1.1 The service primitives associated with this service are:

a) ChannelAccess.request;

b) ChannelAccess.indication.

A4.1.2 The ChannelAccess.request primitive shall be passed from the service user at the sending end to the service provider to request that a Frame be transferred through the Physical Channel to the user at the receiving end.

A4.1.3 The ChannelAccess.indication shall be passed from the service provider to the service user at the receiving end to deliver a Frame.

A4.2 ChannelAccess.request

A4.2.1 Function

The ChannelAccess.request primitive is the service request primitive for this service.

A4.2.2 Semantics

The ChannelAccess.request primitive shall provide a parameter as follows:

ChannelAccess.request (Frame)

A4.2.3 When Generated

The ChannelAccess.request primitive is passed to the service provider to request it to process and send the Frame.

A4.2.4 Effect On Receipt

Receipt of the ChannelAccess.request primitive causes the service provider to perform the functions described in 2.3.1 and to transfer the resulting channel symbols.

A4.3 ChannelAccess.indication

A4.3.1 Function

The ChannelAccess.indication primitive is the service indication primitive for this service.

A4.3.2 Semantics

The ChannelAccess.indication primitive shall provide parameters as follows:

ChannelAccess.indication (Frame,
Quality Indicator,
Sequence Indicator)

A4.3.3 When Generated

The ChannelAccess.indication primitive is passed from the service provider to the service user at the receiving end to deliver a Frame.

A4.3.4 Effect On Receipt

The effect of receipt of the ChannelAccess.indication primitive by the service user is undefined.

ANNEX B

PARALLELIZED INTERLEAVER

(NORMATIVE)

B1 OVERVIEW

In order to support 27 distinct ACM formats, it is necessary to designate only 19 permutations that allow a parallel implementation of the decoder with a degree of parallelism of 120. Thus the sizes of all 19 interleavers are integer multiples of 120.

As defined in 4.1.1.3, the punctured output of the outer convolutional encoder is interleaved according to the ad hoc permutation law defined here. In the SCCC encoding functional block, the outer convolutional encoder writes the output data in natural order and those data are eventually punctured to a code rate 2/3. This data, before being submitted in input to the inner convolutional encoder are permuted according to the Parallelized Interleaver algorithm described here.

B2 SPECIFICATIONS

B2.1 The interleaver shall process the punctured output of the outer encoder that will write its I bits data (numbered from 0 to I-1) in the memory in natural order.

NOTE – The allowed values of I are defined in table 4-1.

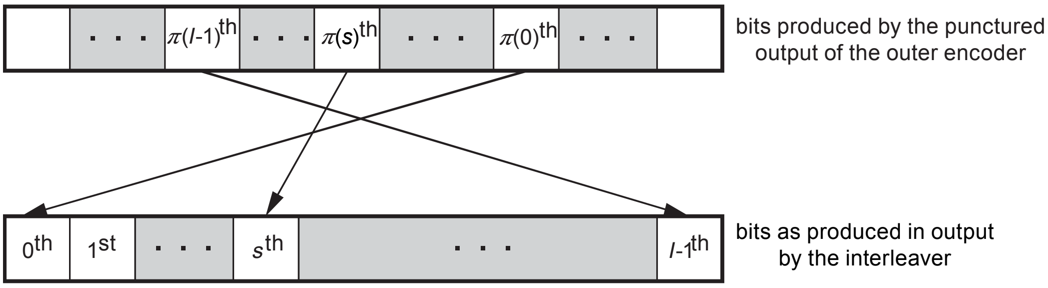

Figure B-1: Interpretation of Interleaver Algorithm

B2.2 The interleaver algorithm shall produce an output of I bits (numbered from 0 to I-1) according to the following relationship, which gives the reading address at time i:

$$\pi(i) = W \times [(\lfloor i/W \rfloor + \beta(i_W)) \bmod 120] + \alpha(i_W) \quad i = 0,\ldots,I-1 \tag{5}$$

where α and β are two vectors of length equal to $W=I/120$, and

$$i_W \equiv i \bmod W \tag{6}$$

where the elements of α (addresses of macrodata) range in [0,W-1] and the elements of β (cyclic shifts of macrodata) range in [0,119].

NOTES

1 In the equation above, $\lfloor x \rfloor$ denotes the largest integer less than or equal to x.

2 The interleaver can be thought of as a 120 x W memory block that is written to row by row, left to right, starting with bit 0 in column 0 of row 0, and ending with bit I-1 in column W-1 of row 119. Within each column c, bits are cyclically shifted by beta(c); then, each column c is assigned a new column position according to alpha(c). Finally, bits are read out row by row, left to right. In this way, the ith bit written is identified by its row r = $\lfloor i/W \rfloor$ and column c = i mod W, with i = rW + c, and the ith bit read from the memory block is pi(i) = r′W + c′, where r′ = (r + beta(c)) mod 120 and c′ = alpha(c).

B2.3 The interleaver parameters shall be obtained from tables B-1 and B-2.

Table B-1: Interleaver Parameters (1-10)

	1		2		3		4		5		6		7		8		9		10	
	I=8640 W=72		I=10440 W=87		I=12600 W=105		I=14760 W=123		I=16920 W=141		I=19800 W=165		I=22320 W=186		I=25560 W=213		I=28800 W=240		I=32040 W=267	
	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
0	63	116	70	82	85	97	106	1	60	14	116	87	18	114	50	32	109	98	63	93
1	33	69	53	27	91	27	82	89	107	55	42	34	95	1	134	71	179	66	238	10
2	64	103	63	101	1	47	115	49	4	31	66	36	68	116	200	47	129	13	92	78
3	56	92	67	106	0	69	17	43	102	68	77	47	108	72	68	89	214	109	189	72
4	59	77	10	59	35	104	58	20	87	53	13	38	11	119	74	15	186	45	73	25
5	5	73	29	22	3	90	81	24	89	76	99	25	104	61	1	18	128	72	172	68
6	58	58	47	105	77	66	113	41	117	42	84	69	118	108	32	40	60	8	94	96
7	52	46	52	49	98	57	28	3	68	19	123	8	172	20	102	69	112	91	49	14
8	61	107	82	33	51	50	12	78	67	113	1	80	181	84	33	79	8	93	228	6
9	47	1	58	15	13	29	2	111	96	58	102	60	19	95	154	119	183	117	219	5
10	57	52	65	111	63	60	76	107	15	110	73	101	121	92	21	29	170	64	197	46
11	35	90	72	7	97	86	10	67	140	105	109	82	106	93	22	111	225	114	173	47
12	29	32	2	74	78	35	40	10	114	44	21	77	75	88	103	61	35	15	232	111
13	60	119	40	86	49	37	108	117	112	17	48	89	73	60	162	108	97	77	195	108
14	36	3	4	70	68	25	9	38	22	28	6	30	109	16	130	54	87	35	144	42
15	24	68	31	71	7	84	74	51	9	109	47	57	142	101	83	16	88	85	21	80
16	10	60	36	100	103	117	64	74	34	16	142	52	69	32	38	99	188	6	134	102
17	20	30	7	31	96	53	92	40	21	34	124	93	117	100	190	105	47	99	161	104
18	66	83	23	13	57	72	31	87	116	11	150	73	103	80	180	55	165	107	135	19
19	17	63	77	62	75	115	35	94	62	24	104	112	116	70	61	116	156	88	102	67
20	31	41	45	39	67	59	101	14	28	79	72	19	113	62	104	75	52	55	259	31
21	16	50	17	1	58	106	26	63	105	95	4	118	83	87	167	114	233	15	101	97
22	67	6	79	80	25	7	27	44	79	35	119	10	78	118	168	21	151	95	200	43
23	28	24	35	104	59	52	69	64	121	20	135	78	138	0	100	101	0	20	3	72
24	18	22	56	56	65	119	70	104	5	47	43	50	147	58	191	81	17	17	7	53
25	9	101	33	48	60	23	68	8	6	29	10	1	85	102	26	19	235	115	115	50
26	6	62	78	19	14	65	34	16	125	39	3	65	59	91	142	67	157	71	114	49
27	62	57	38	64	74	32	112	54	50	70	156	38	97	98	10	43	70	22	31	65
28	2	18	37	38	22	13	1	119	41	54	118	17	91	66	178	91	191	67	9	89
29	27	66	60	35	42	40	55	53	78	93	138	110	46	56	140	33	44	94	255	65
30	71	9	39	25	87	14	105	106	77	89	163	31	145	52	87	63	50	11	2	76
31	34	37	30	45	95	102	20	59	53	84	2	84	136	77	158	13	83	48	22	57
32	14	81	19	37	29	91	18	21	54	63	31	67	22	55	45	90	223	28	89	37
33	39	114	8	69	10	79	41	97	33	105	159	41	169	57	145	95	155	87	90	60
34	68	115	6	24	104	18	61	70	106	117	88	26	111	27	207	46	216	111	240	87
35	51	82	21	58	24	39	91	65	82	43	68	43	105	85	64	3	192	79	50	70
36	21	26	80	94	31	11	36	90	31	103	63	35	158	22	184	24	30	28	74	12
37	13	29	9	99	30	43	84	22	132	10	117	4	2	52	4	66	160	49	20	36

	1		2		3		4		5		6		7		8		9		10	
	I=8640 W=72		I=10440 W=87		I=12600 W=105		I=14760 W=123		I=16920 W=141		I=19800 W=165		I=22320 W=186		I=25560 W=213		I=28800 W=240		I=32040 W=267	
	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
38	37	94	57	6	76	95	14	26	80	37	103	28	53	26	56	4	54	57	236	89
39	23	39	1	98	52	88	109	60	11	22	97	107	119	4	173	52	146	32	98	17
40	40	48	55	53	61	110	48	27	63	25	155	84	41	43	101	50	69	41	239	90
41	41	98	83	40	99	0	83	35	38	73	8	49	16	112	8	112	26	6	1	99
42	30	76	15	90	66	77	23	72	26	87	113	33	153	75	85	5	136	102	251	103
43	44	5	62	92	5	117	25	49	108	118	129	3	152	78	201	58	126	60	155	28
44	25	112	51	88	4	83	57	45	27	88	143	9	149	119	29	17	195	100	160	94
45	65	35	20	29	83	63	73	76	39	91	80	75	173	106	41	105	41	23	150	27
46	48	71	14	79	17	22	111	114	8	42	128	77	144	44	42	100	182	74	153	15
47	69	20	25	91	88	30	77	82	90	13	96	18	139	69	170	34	49	84	80	35
48	26	96	66	117	48	94	7	14	18	99	162	90	4	100	43	62	190	18	108	101
49	43	85	28	113	2	81	95	112	131	80	151	16	185	2	115	74	27	34	86	58
50	55	110	86	77	86	16	62	46	119	57	141	2	157	35	138	76	10	47	165	92
51	0	52	0	66	38	100	86	36	32	51	115	58	29	13	199	1	33	62	167	113
52	45	19	12	33	102	2	80	17	135	5	76	13	180	48	108	86	237	113	196	45
53	50	102	11	111	82	31	5	12	17	114	148	106	34	117	88	117	217	59	67	110
54	70	55	26	61	72	41	8	95	100	40	25	37	127	95	105	39	100	4	262	38
55	7	14	27	51	21	10	4	33	71	97	27	99	115	31	90	30	4	37	29	40
56	32	44	5	18	37	75	54	62	51	2	110	68	129	71	179	92	80	46	104	21
57	12	9	68	52	6	5	29	56	137	75	30	44	79	53	76	22	196	34	48	61
58	42	15	75	11	11	62	97	88	76	69	78	11	86	8	204	82	187	11	43	1
59	11	80	84	55	23	46	56	99	99	47	38	6	25	108	121	51	75	83	65	41
60	46	89	69	3	47	93	67	23	37	10	11	20	32	11	106	23	145	82	61	38
61	1	106	74	26	36	108	38	105	111	94	95	39	3	44	30	38	43	25	166	77
62	8	119	59	103	93	81	100	69	133	59	71	81	58	65	54	60	102	92	143	107
63	15	100	85	46	81	113	93	102	13	8	149	15	93	38	17	54	68	10	202	20
64	53	45	71	109	69	101	72	101	57	18	106	65	88	37	70	11	22	30	19	69
65	3	17	43	73	100	24	32	108	61	4	60	116	168	29	37	97	103	1	129	11
66	19	43	49	114	90	48	43	81	74	86	87	30	33	20	165	41	116	97	33	29
67	4	87	41	42	45	6	37	0	84	111	51	96	43	25	176	6	117	53	188	84
68	22	88	48	21	18	21	22	80	120	82	86	95	38	9	156	0	154	105	132	56
69	49	34	32	96	56	27	0	30	72	67	70	63	36	12	98	9	193	47	53	100
70	54	11	44	10	20	35	102	109	35	38	85	71	87	17	125	80	99	31	229	4
71	38	107	61	84	79	70	51	117	66	85	112	55	150	68	92	107	236	20	258	118
72			50	43	39	56	75	93	127	65	5	62	14	35	120	35	73	81	209	59
73			73	116	46	86	122	91	98	74	0	41	27	7	133	20	161	96	263	119
74			34	68	53	84	118	39	95	78	23	97	167	13	65	87	42	67	201	74
75			46	5	54	112	47	15	29	115	90	103	133	82	122	110	105	70	51	82
76			64	108	32	97	39	66	55	101	69	52	0	87	110	7	141	63	23	118
77			13	94	19	116	114	84	92	81	37	86	100	64	151	78	231	39	32	24
78			18	15	15	76	19	86	86	107	18	60	184	108	149	83	140	2	235	97
79			54	82	28	9	65	73	93	31	14	8	7	103	71	114	162	94	124	54
80			76	85	73	109	98	4	139	32	154	100	12	57	212	36	177	12	193	44
81			42	0	33	96	6	54	123	15	49	83	28	22	117	73	72	101	91	106
82			24	77	16	115	121	74	113	16	130	54	57	18	3	55	57	79	46	64
83			16	55	12	18	45	77	85	106	26	15	82	42	19	98	32	58	88	30
84			22	119	44	42	46	83	2	52	35	46	128	45	6	88	206	75	106	114
85			3	3	9	106	94	34	1	27	121	67	84	111	114	27	29	45	24	51
86			81	75	55	68	42	19	14	71	59	78	60	75	75	81	3	61	181	93
87					62	74	107	47	16	3	160	105	176	23	52	95	222	118	242	1
88					80	22	50	96	124	19	144	49	51	5	113	43	204	7	146	10
89					8	95	99	7	136	55	7	25	8	4	11	15	58	42	118	89
90					41	102	79	31	45	9	32	29	166	79	188	77	202	104	170	70
91					101	59	53	78	103	91	57	93	10	105	53	103	137	54	127	105
92					71	57	60	116	104	112	114	50	124	84	57	70	45	52	257	8
93					92	46	33	13	25	68	61	79	74	54	109	42	135	93	156	3
94					89	44	16	1	10	65	75	104	24	10	128	118	15	88	205	110
95					94	66	117	86	118	33	67	111	131	49	157	116	31	39	55	16
96					40	4	88	58	75	110	158	57	17	88	127	85	2	103	47	52
97					43	19	119	28	91	102	92	64	80	114	195	11	11	65	151	62
98					27	50	85	68	49	116	33	14	6	47	152	12	48	98	221	101
99					64	39	30	20	128	83	134	72	177	96	96	104	62	118	119	57
100					84	99	87	33	81	23	41	53	21	68	160	3	178	116	16	115
101					50	34	13	114	7	50	40	98	130	113	47	53	1	5	26	18
102					70	11	90	6	36	93	54	94	90	50	51	96	94	68	95	6
103					26	64	3	47	59	75	132	66	71	63	58	68	23	96	82	47
104					34	17	71	110	110	66	126	23	120	116	196	4	198	30	249	66
105							15	36	0	5	105	99	56	72	171	100	111	115	122	108
106							103	98	40	14	146	37	154	110	209	68	166	103	241	55
107							120	62	138	71	55	77	107	30	60	106	215	42	111	7
108							59	89	101	103	53	47	65	77	46	8	91	17	176	33

	1		2		3		4		5		6		7		8		9		10	
	I=8640 W=72		I=10440 W=87		I=12600 W=105		I=14760 W=123		I=16920 W=141		I=19800 W=165		I=22320 W=186		I=25560 W=213		I=28800 W=240		I=32040 W=267	
	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
109							21	37	23	90	131	69	102	115	182	29	127	0	208	25
110							78	57	122	63	19	5	182	15	169	61	158	110	260	22
111							116	100	3	69	45	105	52	48	63	113	171	27	213	21
112							89	27	70	22	153	119	170	89	135	64	229	81	190	32
113							24	113	48	108	93	73	171	25	194	70	159	23	131	13
114							49	10	52	119	34	82	89	39	192	32	221	1	72	48
115							66	32	109	35	20	19	55	46	118	58	67	49	149	80
116							44	103	88	88	12	36	114	97	69	77	85	109	18	84
117							63	5	44	28	74	114	81	21	111	10	194	73	35	4
118							11	97	69	117	111	41	26	28	7	116	77	72	252	82
119							104	81	24	0	157	75	92	14	147	59	65	38	10	55
120							52	59	46	82	36	110	183	105	153	40	150	21	139	39
121							96	56	126	1	62	45	1	29	136	45	153	119	141	53
122							110	99	19	21	17	109	49	74	2	3	142	33	110	65
123									115	113	120	86	35	110	187	30	9	59	158	75
124									47	53	98	117	63	34	25	52	149	45	100	103
125									20	86	140	0	163	40	210	90	181	61	168	87
126									42	7	91	84	9	99	163	28	180	56	223	100
127									65	73	15	28	179	90	23	115	19	66	217	26
128									83	46	58	112	143	66	80	49	173	40	198	71
129									64	95	122	31	50	93	12	16	56	7	222	64
130									56	47	56	80	137	19	112	1	20	73	99	81
131									134	93	83	91	125	20	91	119	95	47	17	112
132									130	39	94	6	135	118	131	82	40	89	133	79
133									73	100	127	21	20	82	84	111	234	86	145	96
134									129	86	152	22	62	76	155	60	197	50	59	104
135									58	105	145	12	40	23	185	62	218	3	112	5
136									30	79	161	25	31	83	132	44	81	69	116	90
137									94	2	89	118	72	107	97	79	219	85	44	45
138									43	61	137	98	174	31	20	39	139	19	246	42
139									12	98	65	24	148	10	144	71	205	91	37	25
140									97	99	64	56	175	77	16	56	106	113	70	19
141											24	65	98	55	77	109	213	13	187	12
142											108	8	162	65	86	26	118	24	45	113
143											164	68	47	95	175	9	133	6	120	63
144											82	89	156	91	119	99	209	32	140	29
145											79	42	64	1	0	9	119	90	206	36
146											100	97	110	12	148	105	189	52	138	14
147											101	2	30	52	55	0	55	29	66	59
148											29	103	101	26	164	107	13	110	137	8
149											22	59	132	43	39	34	59	107	211	99
150											133	82	48	15	139	108	207	22	233	91
151											107	46	178	37	49	66	64	37	41	34
152											136	115	5	17	67	57	122	84	256	104
153											52	107	77	36	31	47	152	15	162	51
154											81	106	141	7	211	74	28	93	216	30
155											147	95	155	42	161	23	132	64	38	86
156											39	55	122	6	28	25	174	111	56	74
157											139	33	37	112	78	32	210	9	34	107
158											50	17	23	51	197	50	92	44	36	85
159											44	71	13	116	14	102	232	0	185	116
160											16	72	42	49	198	104	208	14	182	9
161											125	60	44	98	141	112	224	70	234	78
162											9	64	70	79	206	42	96	95	212	2
163											28	74	126	108	40	28	61	80	93	119
164											46	101	96	106	66	83	79	114	175	67
165													151	54	193	69	125	25	54	42
166													39	40	15	27	114	48	107	76
167													140	8	35	94	101	112	226	31
168													76	90	183	95	76	62	220	95
169													165	38	82	97	86	3	87	44
170													61	35	166	91	203	78	64	17
171													45	64	73	29	108	16	97	109
172													123	13	205	5	238	53	142	55
173													54	31	202	21	84	63	79	49
174													164	47	48	50	147	8	245	37
175													94	80	189	113	134	57	25	35
176													67	24	79	15	25	102	121	115
177													134	74	174	37	63	22	125	83
178													99	11	24	35	14	75	148	58
179													146	57	34	59	37	0	126	118

	1		2		3		4		5		6		7		8		9		10	
	I=8640 W=72		I=10440 W=87		I=12600 W=105		I=14760 W=123		I=16920 W=141		I=19800 W=165		I=22320 W=186		I=25560 W=213		I=28800 W=240		I=32040 W=267	
	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
180													112	60	36	42	201	38	244	98
181													66	69	181	63	124	106	207	0
182													160	9	159	103	239	89	230	68
183													15	85	59	14	212	105	40	78
184													159	18	13	40	74	13	0	28
185													161	75	186	73	16	20	8	57
186															129	89	228	18	250	20
187															123	38	36	91	210	35
188															94	93	167	66	11	61
189															124	65	143	34	62	22
190															203	86	89	26	83	77
191															99	2	5	50	224	18
192															9	21	121	11	194	52
193															126	67	184	69	237	93
194															89	13	138	100	27	116
195															95	54	211	97	58	80
196															93	116	164	77	5	47
197															172	31	144	58	171	106
198															208	85	110	79	179	117
199															107	46	104	104	261	49
200															27	85	226	98	57	0
201															18	81	24	6	77	73
202															72	7	131	43	6	82
203															5	11	38	76	113	112
204															150	98	168	71	105	84
205															81	84	34	60	183	89
206															116	3	230	45	85	101
207															177	119	51	74	96	95
208															143	114	71	28	227	45
209															146	110	18	32	84	27
210															62	58	113	117	253	15
211															137	27	123	59	204	10
212															44	45	200	44	218	113
213																	21	55	109	110
214																	227	83	254	59
215																	53	81	117	4
216																	148	4	248	28
217																	172	51	152	72
218																	199	113	71	91
219																	107	40	69	3
220																	115	41	68	32
221																	82	97	78	75
222																	185	10	215	94
223																	93	1	12	103
224																	130	17	184	17
225																	120	31	178	24
226																	46	64	225	40
227																	12	27	180	41
228																	163	30	266	71
229																	176	102	186	61
230																	169	107	264	13
231																	98	39	199	65
232																	7	25	265	86
233																	39	77	164	107
234																	66	105	174	54
235																	175	87	76	23
236																	90	52	13	5
237																	6	57	14	102
238																	78	15	28	9
239																	220	64	243	108
240																			191	19
241																			136	60
242																			231	33
243																			30	63
244																			130	92
245																			128	30
246																			60	56
247																			39	106
248																			103	45
249																			214	63
250																			81	6

	1		2		3		4		5		6		7		8		9		10	
	I=8640 W=72		I=10440 W=87		I=12600 W=105		I=14760 W=123		I=16920 W=141		I=19800 W=165		I=22320 W=186		I=25560 W=213		I=28800 W=240		I=32040 W=267	
	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
251																			123	64
252																			15	117
253																			154	1
254																			75	11
255																			192	74
256																			159	25
257																			163	119
258																			247	3
259																			52	88
260																			147	37
261																			203	42
262																			169	70
263																			157	82
264																			177	100
265																			42	118
266																			4	31

Table B-2: Interleaver Parameters (11 to 19)

	11		12		13		14		15		16		17		18		19	
	I=35280 W=294		I=38880 W=324		I=42480 W=354		I=46440 W=387		I=50040 W=417		I=54000 W=450		I=57960 W=483		I=61560 W=513		I=65520 W=546	
	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
0	30	28	193	72	238	48	374	11	147	48	211	24	153	110	380	92	282	83
1	165	81	208	10	260	88	269	31	76	100	353	68	307	101	415	60	437	63
2	156	103	3	107	253	11	21	35	22	84	430	37	274	42	81	60	397	89
3	235	46	254	13	208	43	84	46	64	92	56	55	291	45	327	41	471	115
4	15	75	165	59	130	102	6	45	53	64	242	50	158	50	60	21	218	29
5	126	82	81	50	190	79	91	85	50	39	440	76	141	75	289	28	62	79
6	203	34	154	42	193	2	81	33	219	63	111	67	241	112	341	16	65	0
7	270	112	38	77	122	73	227	115	134	16	354	11	80	62	162	31	396	88
8	189	71	104	83	118	47	324	49	406	0	123	96	310	1	409	104	172	93
9	103	85	216	52	317	95	367	36	315	118	109	89	83	66	95	116	182	49
10	145	1	63	68	177	42	225	64	416	62	80	23	110	82	159	29	84	88
11	186	92	68	109	224	111	294	108	187	79	126	63	433	105	330	105	116	48
12	264	7	116	4	143	89	159	28	307	1	396	51	17	47	262	57	120	98
13	218	109	292	44	181	100	277	110	252	85	51	106	386	18	157	9	224	39
14	52	57	31	13	178	86	265	27	373	106	34	2	298	38	223	115	0	41
15	265	55	167	57	29	30	87	34	146	104	302	73	89	59	170	63	174	107
16	141	24	322	114	64	40	193	53	115	87	386	25	478	54	34	118	424	0
17	181	106	94	65	173	81	258	15	293	29	161	94	40	105	137	44	362	105
18	208	108	122	67	315	50	8	56	291	10	292	79	279	63	411	25	247	52
19	9	51	21	19	198	3	141	48	33	97	30	16	361	60	269	13	511	82
20	88	76	201	90	46	7	210	61	257	75	267	8	130	41	174	110	343	95
21	196	100	86	0	258	0	89	4	399	90	163	21	230	99	197	103	245	59
22	32	19	23	24	108	98	205	23	213	94	337	6	425	12	4	64	15	105
23	78	40	270	15	106	69	195	67	4	46	202	5	35	22	202	37	262	96
24	130	17	236	78	7	50	279	33	207	43	147	54	19	95	110	49	300	60
25	162	29	7	36	167	101	338	118	233	70	232	49	280	102	437	58	207	11
26	269	83	227	43	308	51	82	98	266	6	420	2	166	37	180	7	26	31
27	42	118	307	87	139	105	151	59	39	25	426	14	49	76	375	94	130	35
28	99	26	316	63	68	85	202	10	249	116	221	110	248	25	368	3	539	46
29	22	74	44	78	262	96	40	40	405	51	28	83	119	17	337	55	230	45
30	192	31	27	21	125	19	63	69	226	66	437	115	71	38	475	42	136	85
31	147	80	297	32	246	91	90	78	341	17	262	77	170	13	303	81	305	33
32	221	3	285	85	129	114	358	94	203	98	324	40	466	76	176	23	281	36
33	16	38	279	21	295	30	10	80	73	73	20	43	387	95	320	79	285	64
34	182	77	175	119	87	119	121	94	110	34	307	69	123	6	397	36	485	108
35	188	107	192	70	72	17	85	5	62	26	1	85	327	36	169	62	209	28
36	73	11	37	103	332	9	158	79	89	10	37	111	200	51	447	73	145	110
37	159	10	293	92	226	1	318	76	359	15	77	105	4	34	372	77	500	27
38	256	48	239	80	232	113	16	73	204	81	359	38	333	16	291	84	67	34
39	21	2	32	96	94	13	167	50	58	15	3	32	464	13	134	38	2	53
40	10	63	162	118	307	22	322	88	124	93	264	112	103	46	84	66	436	15
41	72	102	30	114	67	109	68	1	358	18	412	94	142	39	443	96	491	56
42	61	59	310	38	329	24	168	24	247	102	410	52	470	112	154	34	512	48
43	169	52	218	30	98	6	119	114	104	50	435	108	108	71	385	26	277	61
44	232	41	209	49	282	94	303	1	250	88	185	88	67	70	190	111	232	4
45	283	54	146	94	303	70	263	37	116	76	261	7	93	24	51	81	259	23
46	271	85	315	68	142	67	28	31	323	119	79	99	253	111	423	102	355	67
47	6	66	2	82	55	32	350	20	152	65	220	27	315	52	500	47	310	118
48	171	86	206	12	1	79	172	2	170	19	206	70	451	83	165	19	384	98
49	29	12	265	62	250	90	382	19	362	50	175	117	105	56	501	0	261	10
50	279	12	281	110	10	86	174	18	156	71	168	20	269	84	357	29	265	40
51	115	61	191	31	318	80	293	47	237	11	186	48	442	42	469	71	367	69
52	199	8	184	54	274	23	114	118	121	30	263	111	175	97	226	70	513	94
53	285	93	282	6	306	99	30	27	238	27	394	66	155	68	377	65	475	80
54	231	67	305	99	233	52	234	91	285	23	280	72	51	73	151	22	228	94
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57	129	27	214	48	255	110	247	51	65	9	289	96	271	64	206	39	44	73
58	210	98	158	60	289	69	215	14	95	21	407	45	2	45	12	86	398	50

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	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
59	19	89	109	85	163	18	189	72	175	53	365	19	357	90	294	15	258	111
60	253	115	278	103	6	58	380	8	316	41	245	107	448	77	192	71	221	1
61	163	64	289	8	343	107	252	45	348	99	447	119	101	9	381	9	446	24
62	263	69	42	12	144	118	297	70	374	78	23	37	403	82	346	113	141	114
63	255	113	126	40	124	27	307	92	44	6	223	51	432	79	8	2	444	1
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65	275	45	74	58	221	87	117	101	60	116	290	46	356	47	243	12	216	31
66	282	87	274	22	188	46	102	25	300	47	443	93	203	23	379	23	39	20
67	175	96	242	29	111	38	154	107	334	22	296	99	339	22	394	112	45	15
68	83	117	13	42	323	20	250	5	310	44	224	9	249	21	344	98	492	2
69	227	47	58	117	172	107	136	54	88	60	266	10	435	10	237	4	203	19
70	288	19	129	26	214	65	238	17	162	108	73	114	106	3	486	86	168	18
71	164	53	143	84	169	84	330	32	212	28	201	17	380	7	251	72	227	47
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74	82	25	34	41	297	62	363	52	28	49	284	22	346	29	326	80	64	27
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80	20	39	77	37	325	115	126	44	10	55	136	56	94	86	124	91	179	51
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96	154	19	28	91	107	25	22	115	389	116	422	59	447	98	97	14	92	63
97	56	77	180	87	61	59	315	93	206	17	371	0	190	35	58	24	423	73
98	27	110	121	72	160	48	345	28	67	112	279	34	154	42	234	60	271	34
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101	75	3	64	71	78	31	184	104	378	86	117	80	399	117	392	110	304	44
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107	250	97	269	1	340	105	4	76	281	52	392	74	136	31	454	39	484	23
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110	143	44	52	108	84	64	49	75	267	115	151	58	343	65	178	58	103	62
111	240	116	210	101	174	63	353	53	368	91	311	75	208	95	85	98	100	92
112	204	74	19	50	299	8	372	71	355	36	29	51	233	116	458	115	541	68
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115	274	101	57	92	37	102	240	90	361	38	446	27	318	44	32	102	153	89
116	70	82	0	87	202	119	370	3	222	34	181	15	402	100	184	108	386	26
117	36	22	222	112	320	75	343	113	196	106	165	90	250	33	264	75	339	35
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119	38	31	257	83	152	116	37	52	241	48	256	105	31	79	23	45	519	64
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123	233	94	235	28	313	59	111	43	42	95	131	32	211	76	474	119	390	104
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	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
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126	247	70	299	5	301	67	213	109	105	61	116	52	68	108	426	89	410	11
127	139	15	61	30	123	115	268	100	302	117	198	68	82	93	102	92	447	6
128	193	39	173	68	281	13	288	4	23	101	68	78	270	75	50	3	480	96
129	44	34	131	16	259	97	311	29	371	103	406	8	276	104	203	67	29	76
130	220	55	1	14	175	20	103	56	133	46	411	63	24	18	150	77	77	58
131	216	103	155	41	133	75	108	81	191	107	413	53	138	0	80	25	76	39
132	60	116	56	115	183	57	59	28	31	83	423	69	302	62	464	18	375	19
133	183	85	88	77	33	91	57	32	388	26	137	45	457	93	370	64	442	47
134	80	32	108	62	235	66	226	105	364	13	121	81	354	8	44	73	106	68
135	180	40	6	38	3	99	149	33	260	111	351	54	413	74	212	8	246	24
136	239	77	217	96	135	104	187	38	142	102	281	86	234	88	45	11	237	21
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139	14	79	150	10	348	1	352	54	218	77	350	95	267	105	82	47	150	14
140	120	18	317	30	314	11	373	117	186	45	300	71	220	28	319	50	349	53
141	205	65	286	117	213	35	204	16	154	118	180	28	20	116	442	82	427	59
142	131	87	90	81	292	42	337	35	12	80	378	82	437	53	108	61	461	106
143	117	105	207	76	88	4	203	78	120	69	13	119	151	101	354	2	445	62
144	190	33	304	77	12	52	101	0	25	48	219	91	353	114	191	81	331	90
145	93	71	65	107	83	21	179	30	393	85	269	94	14	98	349	34	118	3
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169	161	101	144	9	74	5	384	15	395	43	282	88	202	40	90	79	146	33
170	48	104	133	66	126	29	29	93	299	25	16	21	449	14	230	109	361	71
171	79	111	243	94	77	61	239	50	131	40	187	77	81	64	220	20	253	22
172	71	92	248	23	27	13	14	12	243	16	369	17	73	7	140	48	125	40
173	25	5	219	104	13	8	78	42	8	103	36	6	63	106	46	94	86	36
174	121	75	71	86	149	43	274	114	74	90	99	27	406	54	227	28	489	54
175	217	95	127	44	54	90	115	9	391	107	363	85	275	37	453	43	336	117
176	24	112	256	2	245	99	328	73	357	96	133	73	296	69	87	1	38	44
177	167	35	29	60	43	81	80	79	68	51	142	13	344	11	164	118	99	28
178	135	97	250	63	326	37	15	88	34	20	255	43	436	46	121	86	391	38
179	207	23	47	100	19	42	35	84	91	38	47	26	308	50	483	5	34	75
180	54	26	263	55	304	76	378	17	16	0	178	96	18	87	396	27	240	78
181	238	83	320	87	311	110	336	33	37	28	251	67	377	41	283	90	206	0
182	257	64	141	19	8	45	344	111	318	92	403	80	143	16	275	117	70	30
183	46	19	202	3	331	23	254	13	141	3	67	11	163	82	187	16	387	39
184	223	96	262	57	36	65	211	32	69	52	14	7	111	11	309	32	154	61
185	173	48	309	51	120	71	340	102	232	113	408	105	421	103	37	69	161	73
186	266	107	273	79	116	55	20	77	407	33	149	22	184	57	221	102	169	97
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188	31	38	70	46	283	21	349	82	97	64	154	39	76	13	422	116	23	91
189	236	20	67	59	11	69	5	106	169	22	424	68	177	12	248	24	299	99
190	241	1	76	93	333	29	129	70	176	13	172	60	43	1	361	96	28	119

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	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
191	98	37	174	108	23	94	42	3	127	49	401	34	265	55	284	11	408	100
192	67	4	66	94	240	84	150	27	402	64	343	14	132	22	314	62	403	91
193	23	56	130	117	156	88	19	97	220	95	50	88	78	91	6	42	537	41
194	224	68	271	113	254	9	71	2	61	111	26	89	236	81	256	69	223	49
195	90	119	259	84	49	116	316	108	261	61	145	74	331	59	62	23	185	95
196	292	50	20	112	252	94	332	38	280	90	303	101	272	79	366	38	205	27
197	214	26	15	40	50	46	56	41	87	75	18	47	195	74	38	18	117	38
198	142	41	183	106	209	83	191	75	198	110	48	82	334	51	238	93	27	78
199	104	30	253	70	319	74	27	67	242	71	8	103	222	34	261	41	544	115
200	211	10	87	12	207	28	220	94	246	19	308	15	176	111	389	63	198	52
201	246	16	223	32	277	0	34	113	303	17	429	79	116	44	508	67	178	46
202	96	100	296	61	158	93	73	114	130	98	5	101	194	20	198	97	202	48
203	267	71	284	68	62	20	173	35	335	70	310	51	32	53	17	53	22	72
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208	252	60	40	26	171	12	249	63	49	45	333	36	396	45	304	42	503	12
209	148	57	318	98	138	100	319	31	210	33	321	37	405	109	213	40	346	42
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211	273	5	125	31	18	23	361	22	367	54	421	44	423	116	436	66	378	9
212	50	47	25	68	75	103	283	25	287	67	416	97	465	85	274	114	394	79
213	87	107	308	20	176	68	79	116	324	73	271	56	337	9	280	44	4	21
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216	280	90	170	1	206	47	228	101	338	78	82	94	345	31	329	10	272	107
217	151	84	171	37	56	57	112	117	19	10	203	84	351	73	296	45	364	5
218	215	118	272	82	321	49	292	23	36	37	295	89	395	68	115	2	156	66
219	191	27	93	85	223	1	156	96	151	101	444	7	332	84	66	110	315	1
220	37	118	78	2	263	63	383	42	81	63	83	34	147	41	129	115	521	4
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224	245	62	203	8	300	77	242	72	269	50	405	31	127	75	143	84	66	104
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238	248	73	95	36	170	73	86	54	273	116	305	116	408	28	68	88	357	108
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241	198	19	275	105	24	85	67	64	253	15	9	76	61	21	323	76	307	67
242	200	92	258	66	70	40	169	34	86	23	434	45	227	112	31	46	392	14
243	157	103	83	118	112	84	105	87	158	56	427	16	54	32	300	101	456	57
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245	86	1	196	77	192	26	75	31	292	62	93	54	246	60	302	77	252	32
246	95	64	85	58	168	58	157	8	413	71	228	42	160	72	503	19	448	35
247	4	46	149	75	15	59	200	91	330	75	184	69	480	3	93	78	289	86
248	237	59	312	44	97	117	127	17	234	9	322	23	27	31	41	63	302	83
249	97	55	198	33	349	43	214	76	320	37	414	26	381	102	245	9	486	37
250	81	61	294	102	229	108	371	69	136	32	146	92	36	66	363	25	242	59
251	262	52	41	64	128	107	313	88	122	36	366	72	64	115	287	57	222	39
252	113	68	75	35	211	90	118	22	52	77	250	87	434	110	232	13	400	69
253	118	31	277	21	350	15	351	9	351	39	268	19	164	61	473	102	162	63
254	84	89	84	73	145	8	137	85	217	103	209	26	455	69	83	32	50	109
255	63	36	199	99	196	14	3	5	379	81	314	112	261	23	478	34	457	51
256	138	24	53	41	150	109	47	104	343	72	69	48	38	14	459	73	517	98

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	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
257	136	39	73	3	151	42	36	14	327	41	395	76	329	64	374	94	269	104
258	7	66	139	80	65	63	334	98	354	35	246	0	336	19	35	93	248	93
259	137	51	298	110	131	96	171	12	308	46	319	3	439	43	163	38	24	25
260	287	112	136	70	115	3	181	102	248	64	182	62	324	21	391	97	143	112
261	122	5	226	89	25	48	131	20	173	109	10	96	348	7	429	70	465	2
262	229	40	232	48	215	6	72	101	145	7	225	95	481	22	376	39	110	23
263	242	41	118	34	161	67	217	55	344	89	153	50	28	51	148	113	301	103
264	197	44	319	27	195	10	289	78	255	79	402	77	185	90	308	87	148	101
265	49	33	177	109	101	31	272	36	372	117	104	117	427	89	425	23	509	117
266	277	87	62	91	48	17	270	60	43	58	94	102	409	107	362	83	251	96
267	66	59	233	64	17	27	285	106	79	91	404	99	443	25	450	108	30	84
268	144	46	266	114	51	54	177	52	7	21	134	24	426	67	210	31	20	1
269	160	71	195	15	316	78	39	66	349	118	373	114	289	70	301	3	370	105
270	59	21	230	85	186	65	48	65	231	38	387	90	444	60	107	17	372	64
271	57	17	280	95	219	64	106	21	205	74	64	23	125	76	445	81	8	16
272	212	76	185	20	71	1	276	118	59	22	139	104	42	96	265	7	510	21
273	105	38	100	17	280	106	163	57	360	5	358	38	92	10	342	71	363	81
274	234	0	24	71	165	36	369	34	245	6	442	54	350	52	120	76	126	31
275	5	30	128	22	184	76	317	62	309	24	316	25	379	72	254	49	296	40
276	166	91	163	94	189	15	302	7	294	45	150	86	173	107	410	60	514	107
277	177	50	225	72	327	28	69	92	301	58	388	24	218	39	355	28	347	0
278	254	97	105	114	132	62	43	105	150	34	12	42	311	82	440	98	12	73
279	153	70	96	87	294	32	183	45	138	54	362	96	256	93	36	118	469	110
280	185	88	119	57	85	77	348	74	268	105	158	79	235	45	364	16	467	26
281	132	111	92	6	105	2	2	19	275	8	156	6	133	80	413	69	55	51
282	133	10	134	115	269	20	209	112	297	102	86	38	342	26	7	21	516	63
283	268	23	22	102	38	68	208	108	148	114	61	43	140	49	324	18	93	9
284	11	106	10	113	127	118	212	43	295	1	70	15	420	6	217	79	220	72
285	91	63	244	59	22	95	327	116	272	93	173	8	397	90	161	27	19	56
286	187	69	200	46	275	50	230	107	363	113	57	87	168	48	505	12	102	12
287	111	7	172	93	288	54	120	69	412	18	144	78	335	12	402	61	268	61
288	244	14	306	28	204	95	139	97	322	22	170	61	16	78	490	4	238	47
289	124	90	231	41	81	53	341	40	103	0	376	2	392	80	340	105	508	53
290	281	21	283	92	28	64	304	30	411	40	160	66	328	40	315	103	309	115
291	77	6	268	34	279	93	287	35	329	3	294	93	305	29	365	0	147	92
292	222	61	197	10	2	10	41	26	180	108	229	100	199	94	71	83	542	113
293	39	44	45	24	117	30	60	24	199	53	74	85	58	54	438	9	274	6
294			261	1	134	11	231	117	194	17	299	27	419	81	225	50	526	34
295			161	47	218	72	58	100	153	42	391	35	22	119	189	74	166	34
296			314	116	344	109	190	33	92	59	244	48	293	100	418	68	57	88
297			234	96	26	39	164	18	94	110	132	33	285	35	306	118	498	101
298			249	67	44	98	1	42	6	115	143	21	207	65	335	37	502	10
299			79	49	267	66	95	44	414	15	390	94	475	113	152	39	254	109
300			5	75	53	47	377	55	192	73	179	12	360	56	472	72	422	8
301			220	42	148	61	99	74	46	86	59	40	25	22	463	53	108	8
302			264	52	237	86	176	67	352	60	298	110	284	8	136	109	85	17
303			49	30	79	69	18	72	63	25	315	63	74	28	186	47	81	0
304			80	39	82	13	25	78	401	11	207	46	290	114	70	80	226	44
305			245	103	337	114	284	21	321	13	409	67	66	20	130	60	35	26
306			11	107	309	33	342	114	370	95	197	83	252	96	101	6	160	106
307			287	17	244	29	365	16	189	94	431	70	69	47	404	78	80	10
308			50	7	45	104	339	47	111	71	357	102	48	104	104	51	194	18
309			18	81	225	39	271	53	80	39	54	52	15	42	53	4	385	85
310			106	23	110	116	94	68	168	21	248	49	340	44	285	91	381	68
311			295	75	157	79	219	103	304	26	215	34	34	71	10	16	105	5
312			291	8	31	25	325	90	381	53	89	32	243	53	317	20	351	23
313			186	38	220	113	12	29	279	80	335	28	369	86	235	98	7	14
314			35	62	234	55	299	84	135	18	60	51	215	2	360	6	215	13
315			16	27	41	5	326	97	114	26	113	116	467	59	241	1	452	99
316			178	104	351	102	300	39	55	3	342	47	355	1	282	34	317	20
317			205	12	268	17	362	83	202	2	334	107	401	55	430	8	9	67
318			300	55	0	12	0	55	314	111	417	55	390	17	79	19	234	16
319			46	61	203	16	282	80	223	106	356	61	178	68	331	52	192	21
320			311	56	95	89	124	13	178	78	84	114	424	49	73	101	138	78
321			251	118	212	5	221	58	1	74	24	5	197	103	64	30	295	36
322			211	40	222	105	142	98	160	81	287	119	117	43	231	5	214	3

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	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
323			164	97	199	35	132	4	289	59	252	44	347	34	288	73	395	60
324					137	9	140	59	182	104	418	30	376	15	138	117	43	82
325					194	41	166	2	404	6	260	4	306	116	131	68	83	93
326					336	82	291	49	54	97	33	81	39	24	491	40	515	93
327					276	107	66	15	90	95	112	41	186	5	307	95	157	65
328					147	91	197	79	386	48	159	80	373	33	77	71	350	118
329					266	68	144	106	403	27	205	7	60	118	502	101	380	76
330					58	4	375	0	113	62	226	68	239	75	128	106	481	42
331					57	75	301	100	132	85	393	64	65	6	22	107	51	29
332					310	115	62	39	71	30	341	6	171	108	146	108	321	91
333					200	38	17	76	126	119	128	113	385	87	9	31	235	73
334					63	81	55	37	384	12	247	59	316	62	271	33	342	98
335					228	110	246	26	342	109	19	9	323	58	439	46	249	80
336					261	37	385	61	278	4	317	20	44	117	122	99	311	62
337					353	117	309	101	96	24	231	101	77	36	240	36	345	7
338					100	50	107	0	256	31	243	40	118	77	310	59	348	55
339					103	93	38	33	3	117	157	112	26	65	118	81	256	45
340					287	59	323	44	398	0	286	54	257	119	395	115	328	52
341					59	42	178	64	83	68	339	62	21	94	509	35	96	113
342					166	57	170	93	24	46	348	18	98	92	216	53	267	97
343					159	40	308	17	390	83	78	93	213	11	444	75	18	45
344					60	21	146	110	229	75	239	82	359	99	19	45	91	74
345					20	58	145	30	339	43	400	1	231	0	13	77	111	99
346					42	36	11	58	157	70	127	77	309	85	452	84	499	19
347					114	66	233	9	144	45	382	115	99	46	424	74	463	59
348					256	42	222	96	259	20	254	22	47	69	250	89	451	30
349					32	15	153	77	101	29	55	111	242	101	272	65	140	108
350					102	56	237	22	167	92	293	106	299	36	446	114	313	116
351					243	13	248	66	350	17	152	105	161	84	325	85	536	106
352					153	32	182	71	228	118	11	28	212	16	290	72	523	91
353					5	102	100	94	337	87	0	61	12	112	111	64	59	37
354							92	91	346	74	189	29	37	33	42	3	525	22
355							354	87	140	47	419	71	286	47	5	27	429	56
356							165	114	244	10	253	118	358	14	332	15	73	62
357							364	105	35	52	445	82	407	24	427	1	308	54
358							243	14	380	68	96	60	461	8	47	87	79	98
359							320	102	38	90	329	111	75	93	259	2	477	65
360							175	82	340	104	141	19	468	97	476	99	532	79
361							356	59	305	36	164	47	70	79	421	109	82	69
362							44	9	230	40	2	26	283	22	114	44	40	70
363							261	85	331	47	372	42	214	18	3	15	360	74
364							321	91	165	41	25	12	100	97	431	17	69	28
365							355	6	263	35	171	67	3	30	208	70	466	18
366							196	27	40	103	340	16	262	78	495	47	132	77
367							31	118	128	60	235	43	219	95	494	77	409	24
368							241	31	77	43	432	91	87	8	246	86	287	117
369							305	13	84	15	91	91	301	105	67	40	243	100
370							188	40	51	116	217	98	41	3	369	82	412	33
371							314	76	216	48	380	9	1	41	211	42	487	95
372							113	83	328	25	92	45	363	76	109	14	113	42
373							104	112	166	61	58	35	445	63	403	50	290	11
374							9	89	251	77	138	94	462	4	457	7	493	45
375							262	115	17	66	22	73	126	81	59	66	37	117
376							33	52	75	14	81	18	201	59	125	90	286	87
377							192	72	15	111	188	103	319	115	153	67	109	59
378							360	68	32	79	258	76	416	9	367	117	388	49
379							13	87	149	84	285	90	238	74	113	62	115	33
380							138	42	56	32	174	65	411	65	382	100	134	104
381							52	111	271	115	98	16	375	117	347	24	340	78
382							125	107	369	94	345	58	418	108	168	55	354	114
383							194	90	409	80	31	108	55	44	57	7	49	85
384							162	63	139	38	370	21	268	98	54	92	495	46
385							155	101	195	58	6	34	430	100	141	26	459	83
386							109	43	181	8	249	72	321	110	233	43	231	10
387									117	50	190	96	313	107	135	49	127	103
388									225	22	199	109	477	57	498	22	199	53

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	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
389									118	55	318	117	320	104	468	37	244	2
390									112	107	236	32	349	54	456	113	430	47
391									336	62	398	87	297	38	295	111	212	57
392									375	66	71	89	258	27	65	105	14	13
393									284	101	304	13	223	37	311	66	490	14
394									288	21	44	46	209	32	467	27	171	75
395									236	96	381	104	417	39	11	43	472	119
396									296	57	90	37	180	17	255	112	533	29
397									82	102	352	89	5	72	297	63	151	110
398									224	65	43	104	53	70	182	29	167	32
399									276	9	52	69	114	34	386	116	319	35
400									11	89	222	36	255	63	263	84	266	38
401									345	112	374	48	458	42	126	12	124	25
402									270	69	192	38	62	99	393	3	324	39
403									30	34	240	84	264	13	286	68	31	44
404									47	6	355	66	281	66	479	71	418	111
405									376	61	110	99	144	82	215	16	440	36
406									306	32	367	5	247	28	465	5	494	80
407									365	38	76	50	314	20	497	56	101	41
408									214	19	336	105	120	26	461	92	200	115
409									155	25	288	30	205	33	252	78	25	58
410									185	87	330	81	191	25	253	113	371	31
411									235	91	449	79	122	89	27	96	298	4
412									408	105	265	92	429	16	492	49	164	95
413									20	57	436	78	152	29	484	67	283	50
414									164	112	233	33	453	52	334	45	316	72
415									85	33	415	112	97	86	477	51	476	71
416									326	85	63	30	139	21	312	79	142	79
417											166	31	174	41	407	119	483	73
418											227	116	79	116	236	115	71	27
419											448	118	365	50	194	11	177	48
420											122	63	282	57	96	1	255	119
421											399	10	414	114	106	46	497	52
422											257	102	217	31	139	91	275	0
423											325	24	372	45	405	96	518	76
424											42	58	277	55	242	25	365	67
425											309	0	182	118	75	54	524	48
426											208	17	7	1	398	13	333	29
427											162	20	102	12	390	107	32	97
428											65	59	273	6	299	9	173	26
429											272	75	9	68	25	59	89	101
430											216	15	260	10	371	31	11	40
431											39	74	46	49	412	62	204	51
432											433	14	232	92	480	57	312	5
433											140	48	162	54	496	69	543	114
434											274	85	450	75	219	118	428	102
435											368	40	367	5	33	17	56	38
436											66	66	45	45	247	22	373	32
437											213	86	198	61	507	110	175	102
438											148	1	295	69	239	83	88	22
439											323	34	288	4	30	84	239	23
440											328	45	378	18	144	97	280	64
441											360	93	124	2	356	90	535	108
442											291	57	112	19	204	94	54	52
443											107	7	228	73	249	114	225	1
444											17	103	57	50	345	48	181	68
445											283	99	394	88	353	102	90	100
446											278	94	188	91	485	33	270	92
447											15	14	474	36	160	31	520	89
448											124	5	85	103	56	13	344	40
449											347	49	204	35	373	55	119	46
450													438	79	172	21	368	43
451													23	55	88	79	273	81
452													13	102	48	89	197	62
453													196	109	273	110	213	98
454													412	27	20	33	341	110

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	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
455													476	60	183	119	293	17
456													59	90	414	11	257	58
457													341	94	448	38	441	6
458													366	82	433	28	189	9
459													322	70	378	104	401	27
460													312	97	401	76	488	38
461													362	25	155	98	188	105
462													454	51	228	3	61	66
463													146	20	419	73	6	71
464													86	95	171	69	356	45
465													96	16	15	99	47	114
466													165	88	199	4	288	101
467													172	62	499	111	379	28
468													479	26	116	95	10	5
469													115	65	55	53	36	111
470													251	87	117	9	506	60
471													459	10	276	87	534	54
472													473	31	132	56	264	86
473													128	101	133	102	352	12
474													226	1	441	20	128	82
475													131	0	451	34	16	51
476													156	30	466	70	416	77
477													352	119	333	75	425	104
478													210	8	293	23	468	58
479													317	86	177	41	433	112
480													326	7	336	53	129	15
481													52	31	173	6	529	55
482													145	53	510	117	217	85
483															383	2	279	47
484															298	7	58	34
485															258	103	155	93
486															99	18	297	69
487															279	67	318	109
488															123	107	501	87
489															489	82	411	23
490															316	46	470	66
491															112	0	144	3
492															0	101	13	91
493															149	76	74	112
494															281	60	474	118
495															43	81	530	75
496															260	57	545	101
497															512	79	531	94
498															432	36	107	31
499															435	35	137	7
500															321	39	165	70
501															244	62	60	43
502															76	42	208	76
503															305	19	359	79
504															167	74	98	107
505															179	105	78	2
506															185	27	121	45
507															506	18	187	116
508															91	100	482	86
509															420	15	358	3
510															470	91	426	85
511															328	12	72	81
512															511	50	210	54
513																	46	19
514																	250	118
515																	507	92
516																	454	117
517																	438	98
518																	540	11
519																	376	26
520																	325	115

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521																	183	73
522																	158	96
523																	294	83
524																	402	107
525																	377	42
526																	383	22
527																	460	44
528																	449	13
529																	176	21
530																	334	59
531																	63	83
532																	241	56
533																	170	87
534																	327	111
535																	276	63
536																	149	72
537																	163	71
538																	413	8
539																	260	67
540																	419	72
541																	420	14
542																	114	8
543																	434	39
544																	306	103
545																	432	21

ANNEX C

PHYSICAL LAYER PSEUDO-RANDOMIZATION

(NORMATIVE)

C1 OVERVIEW

As specified in 5.5, PL pseudo-randomization is applied to all 16 codeword sections of a PL frame, including the data symbols as well as the pilots. Randomization is not applied to the PL frame header (i.e., to the Frame Marker and the Frame Descriptor).

C2 SPECIFICATIONS

C2.1 The PL pseudo-randomization shall be obtained by multiplying the In-phase and Quadrature samples by the complex randomization sequence ($C_I + j\, C_Q$) defined in C2.3; i.e.:

$$I_{\_\text{randomized}} = \{\, I \cdot C_I - Q \cdot C_Q \,\} \qquad Q_{\_\text{randomized}} = \{\, Q \cdot C_I + I \cdot C_Q \,\}$$

C2.2 The randomization sequence shall be reinitialized for each PL frame, i.e., at the end of the frame header (FM+FD) that is not randomized.

C2.3 The complex randomization sequence shall be constructed by combining two real *m*-sequences *x* and *y* (generated by means of two generator polynomials of degree 18) into a complex sequence (thus resulting in segments of Gold sequences), as follows:

a) The *x* sequence is constructed using the primitive polynomial $h(x)=1+x^7+x^{18}$.

b) The *y* sequence is constructed using the polynomial $g(y)=1+ y^5+ y^7+ y^{10}+ y^{18}$.

c) If the sequence depending on the chosen scrambling code number *n* is denoted z_n in the sequel, and $x(i)$, $y(i)$ and $z_n(i)$ denote the i^{th} symbol of the sequence *x*, *y*, and z_n, respectively, the *m*-sequences *x* and *y* are constructed as:

   1) Initial conditions:

      x is constructed with $x(0) = 1, x(1) = x(2) = ... = x(16) = x(17) = 0$.

      $y(0) = y(1) = \ldots = y(16) = y(17) = 1$.

   2) Recursive definition of subsequent symbols:

      $x(i+18) = x(i+7) + x(i) \bmod 2,\ i = 0, \ldots , 2^{18} - 20;$

      $y(i+18) = y(i+10) + y(i+7) + y(i+5) + y(i) \bmod 2,\ i = 0, \ldots, 2^{18} - 20.$

   3) The n^{th} Gold code sequence z_n, $n = 0,1,2,\ldots,2^{18}-2$, is then defined as:

      $$z_n(i) = [x((i+n) \bmod (2^{18}-1)) + y(i)] \bmod 2,\ i = 0,\ldots, 2^{18}-2.$$

d) These binary sequences are converted to integer valued sequences R_n (R_n assuming values 0, 1, 2, 3) by the following transformation:

$$R_n(i) = 2\, z_n\, ((i + 131\,072) \bmod (2^{18}\text{-}1)) + z_n\,(i), \qquad i = 0, 1, \ldots, 133440.$$

e) Finally, the n^{th} complex scrambling code sequence $C_I(i) + jC_Q(i)$ is defined as:

$$C_I(i) + jC_Q(i) = \exp^{(j\, Rn\,(i)\, \pi/2)}$$

Table C-1: Scrambling Sequences

R_n	$\exp^{(j\,Rn\,\pi/2)}$	I_randomized	Q_randomized
0	1	I	Q
1	j	$-Q$	I
2	-1	$-I$	$-Q$
3	$-j$	Q	$-I$

NOTE – Figure C-1 shows a possible block diagram for pseudo-randomization sequence generation for $n = 0$.

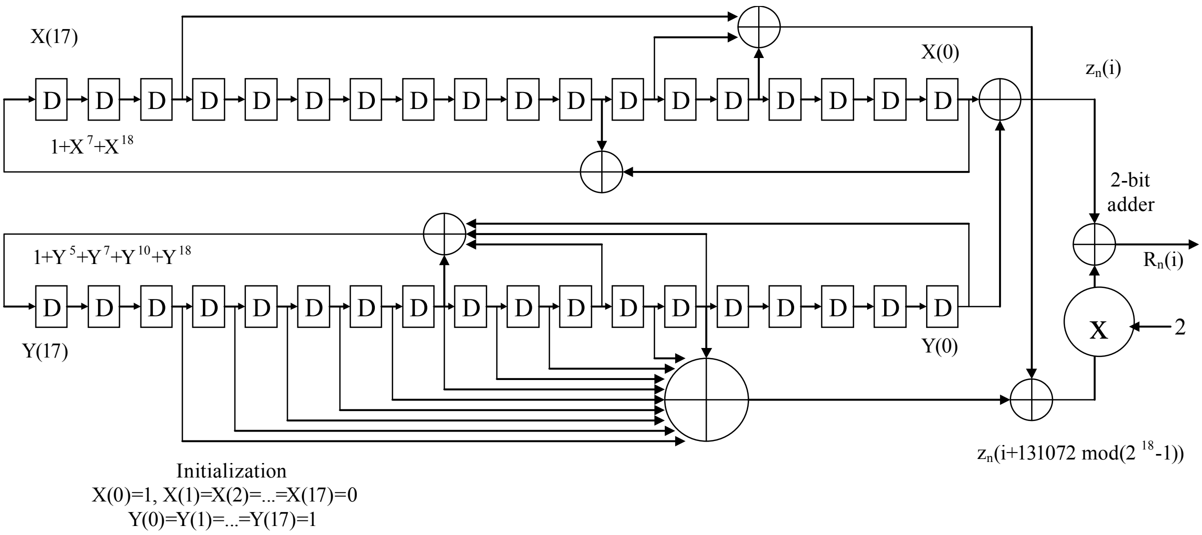

Figure C-1: Possible Block Diagram for Pseudo-Randomization Sequence Generation

ANNEX D

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

D1 SECURITY CONSIDERATIONS

D1.1 SECURITY BACKGROUND

It is assumed that security is provided by encryption, authentication methods, and access control to be performed at higher layers (Application and/or Transport Layers). Mission and service providers are expected to select from recommended security methods, suitable to the specific application profile. Specification of these security methods and other security provisions is outside the scope of this Recommended Standard. The coding layer has the objective of delivering data with the minimum possible amount of residual errors. The Serially Concatenated Convolutional Codes ensure a very low error probability and the Frame Error Control Field is used to insure that residual errors are detected and the frame flagged. There is an extremely low probability of additional undetected errors that may escape this scrutiny. These errors may affect the encryption process in unpredictable ways, possibly affecting the decryption stage and producing data loss, but will not compromise the security of the data.

D1.2 SECURITY CONCERNS

Security concerns in the areas of data privacy, authentication, access control, availability of resources, and auditing are to be addressed in higher layers and are not related to this Recommended Standard. The coding layer does not affect the proper functioning of methods used to achieve such protection at higher layers, except for undetected errors, as explained above.

The physical integrity of data bits is protected from channel errors by the coding systems specified in this Recommended Standard. In case of congestion or disruption of the link, the coding layer provides methods for frame re-synchronization.

D1.3 POTENTIAL THREATS AND ATTACK SCENARIOS

An eavesdropper can receive and decode the codewords, but will not be able to get to the user data if proper encryption is performed at a higher layer. An interferer could affect the performance of the decoder by congesting it with unwanted data, but such data would be rejected by the authentication process. Such interference or jamming must be dealt with at the Physical Layer and through proper spectrum regulatory entities.

D1.4 CONSEQUENCES OF NOT APPLYING SECURITY

There are no specific security measures prescribed for the coding layer. Therefore consequences of not applying security are only imputable to the lack of proper security measures in other layers. Residual undetected errors may produce additional data loss when the link carries encrypted data.

D2 SANA CONSIDERATIONS

The recommendations of this document do not require any action from SANA.

D3 PATENT CONSIDERATIONS

D3.1 HYBRID CONCATENATES CODES

Implementers should be aware that ‘Hybrid concatenated codes and iterative decoding’ are covered by U.S. Patent 6023783. Potential user agencies should direct their requests for licenses to the U.S. Patent 6023783 patent rights holder, whose contact information is:

Cellular Elements LLC
2215-B Renaissance Drive
Las Vegas NV 89119
Attn: Managing Director

D3.2 APSK MODULATIONS

Implementers should be aware that the APSK modulations are covered by U.S. Patents 7123663 and 7239668. Potential user agencies should direct their requests for licenses to:

Mr Luz Becker
Legal Department
European Space Agency
8-10 Rue Mario Nikis
75738 Paris Cedex 15
Tel: +33 1 536 97152
E-mail: lux.becker@esa.int

ANNEX E

ACRONYMS AND TERMS

(INFORMATIVE)

ACM	adaptive coding and modulation
APSK	amplitude phase-shift keying
ASM	attached sync marker
AOS	Advanced Orbiting Systems
AWGN	additive white Gaussian noise
BER	bit error ratio
CCSDS	Consultative Committee For Space Data Systems
FD	frame descriptor
FER	frame error ratio
FM	frame marker
PL	Physical Layer
PSK	phase-shift keying
TC	telecommand
TM	telemetry
SANA	Space Assigned Numbers Authority
SCCC	Serially Concatenated Convolutional (Turbo) Code
SMTF	synch-marked Transfer Frame
VCM	variable coding and modulation
USLP	Unified Space Data Link Protocol

ANNEX F

INFORMATIVE REFERENCES

(INFORMATIVE)

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