



BSI Standards Publication

Space data and information transfer systems — Flexible advanced coding and modulation scheme for high rate telemetry applications

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National foreword

This British Standard is the UK implementation of ISO 17854:2013.

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INTERNATIONAL STANDARD

BS ISO 17854:2013

ISO
17854

First edition
2013-06-01

Space data and information transfer systems — Flexible advanced coding and modulation scheme for high rate telemetry applications

*Systèmes de transfert des informations et données spatiales —
Schéma de modulation et de codage flexible avancé pour applications
en télémesure à haut débit*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

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

ISO 17854 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 131.2-B-1, March 2012) and was adopted (without modifications except those stated in Clause 2 of this International Standard) by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 13, *Space data and information transfer systems*.

Space data and information transfer systems — Flexible advanced coding and modulation scheme for high rate telemetry applications

1 Scope

This International Standard defines 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, 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.

This International Standard 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) 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 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 International Standard describes a technique incorporating multiple modulation formats paired with a flexible coding and synchronization method in a tightly integrated fashion. In particular, this International Standard provides a series of recommended formats where each format pairs a modulation technique with a tailored implementation of the coding and synchronization method. However, where these modulations and/or codes are recommended in other CCSDS documents, this International Standard does not limit the choice of modulations and/or codes consistent with those recommendations.

The scope and field of application are furthermore detailed in subclause 1.3 of the enclosed CCSDS publication.

2 Requirements

Requirements are the technical recommendations made in the following publication (reproduced on the following pages), which is adopted as an International Standard:

CCSDS 131.2-B-1, March 2012, Flexible advanced coding and modulation scheme for high rate telemetry applications.

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 131.2-B-1.

Pages i to v

This part is information which is relevant to the CCSDS publication only.

Page 1-5

Add the following information to the reference indicated:

- [1] Document CCSDS 131.0-B-2, August 2011, is equivalent to ISO 22641:2012.
- [2] Document CCSDS 132.0-B-1, September 2003, is equivalent to ISO 22645:2005.
- [3] Document CCSDS 732.0-B-2, July 2006, is equivalent to ISO 22666:2007.

3 Revision of publication CCSDS 131.2-B-1

It has been agreed with the Consultative Committee for Space Data Systems that Subcommittee ISO/TC 20/SC 13 will be consulted in the event of any revision or amendment of publication CCSDS 131.2-B-1. To this end, NASA will act as a liaison body between CCSDS and ISO.

Recommendation for Space Data System Standards

FLEXIBLE ADVANCED CODING AND MODULATION SCHEME FOR HIGH RATE TELEMETRY APPLICATIONS

RECOMMENDED STANDARD

CCSDS 131.2-B-1

BLUE BOOK

March 2012

AUTHORITY

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Location:	Washington, DC, USA

This document has been approved for publication by the Management Council of the Consultative Committee for Space Data Systems (CCSDS) and represents the consensus technical agreement of the participating CCSDS Member Agencies. The procedure for review and authorization of CCSDS documents is detailed in *Organization and Processes for the Consultative Committee for Space Data Systems*, and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This document is published and maintained by:

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CCSDS RECOMMENDED STANDARD FOR FLEXIBLE ADVANCED CODING AND
MODULATION SCHEME FOR HIGH RATE TELEMETRY APPLICATIONS

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 three 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 the *Procedures Manual for the Consultative Committee for Space Data Systems*. Current versions of CCSDS documents are maintained at the CCSDS Web site:

<http://www.ccsds.org/>

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

CCSDS RECOMMENDED STANDARD FOR FLEXIBLE ADVANCED CODING AND MODULATION SCHEME FOR HIGH RATE TELEMETRY APPLICATIONS

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- National Aeronautics and Space Administration (NASA)/USA.
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- China Satellite Launch and Tracking Control General, Beijing Institute of Tracking and Telecommunications Technology (CLTC/BITTT)/China.
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- Swedish Space Corporation (SSC)/Sweden.
- United States Geological Survey (USGS)/USA.

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CCSDS RECOMMENDED STANDARD FOR FLEXIBLE ADVANCED CODING AND
MODULATION SCHEME FOR HIGH RATE TELEMETRY APPLICATIONS

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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, 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.

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) 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 channel¹ 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 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 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.

CCSDS RECOMMENDED STANDARD FOR FLEXIBLE ADVANCED CODING AND
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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).

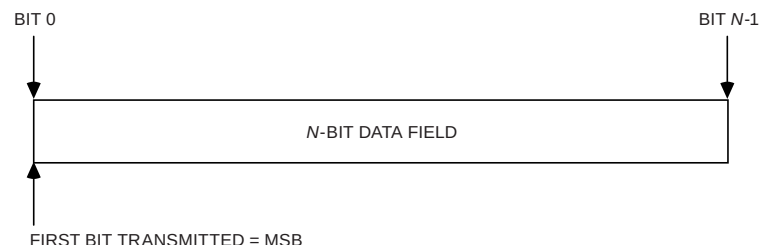


Figure 1-1: Bit Numbering Convention

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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-1 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-1 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*. Recommendation for Space Data System Standards, CCSDS 131.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, August 2011.
- [2] *TM Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 132.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.
- [3] *AOS Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 732.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, July 2006.
- [4] *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft*. Recommendation for Space Data System Standards, CCSDS 401.0-B-21. Blue Book. Issue 21. Washington, D.C.: CCSDS, July 2011.

NOTE — Informative references are listed in annex F.

CCSDS RECOMMENDED STANDARD FOR FLEXIBLE ADVANCED CODING AND MODULATION SCHEME FOR HIGH RATE TELEMETRY APPLICATIONS

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, 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.

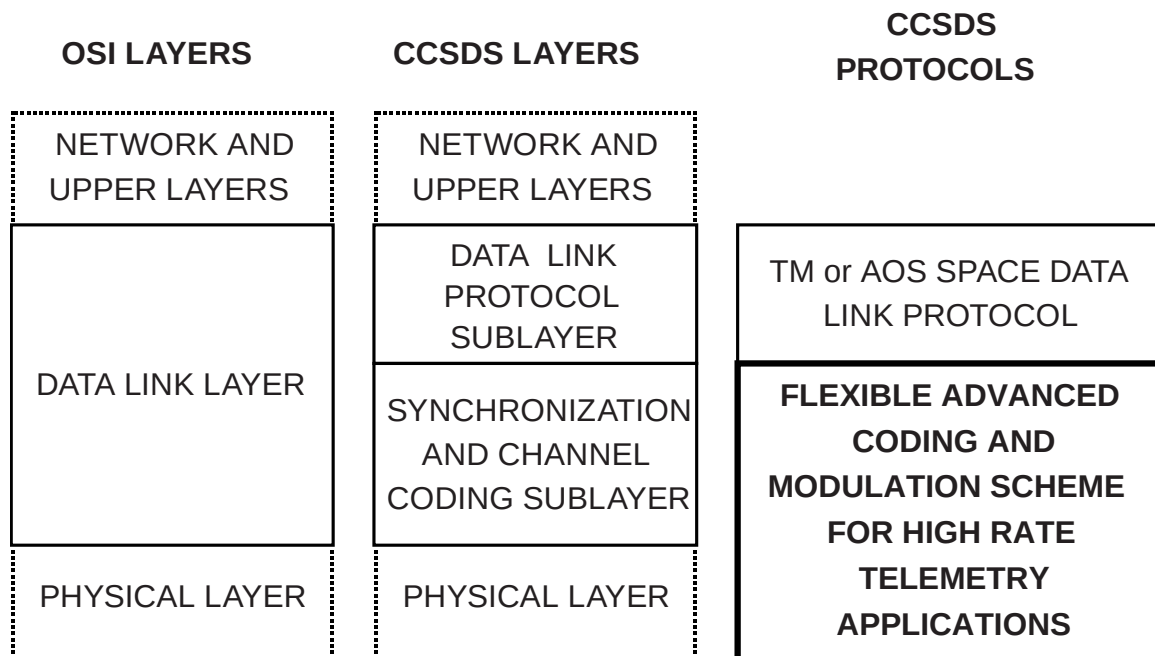


Figure 2-1: Relationship with OSI Layers

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] and [3] 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 telemetry 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.

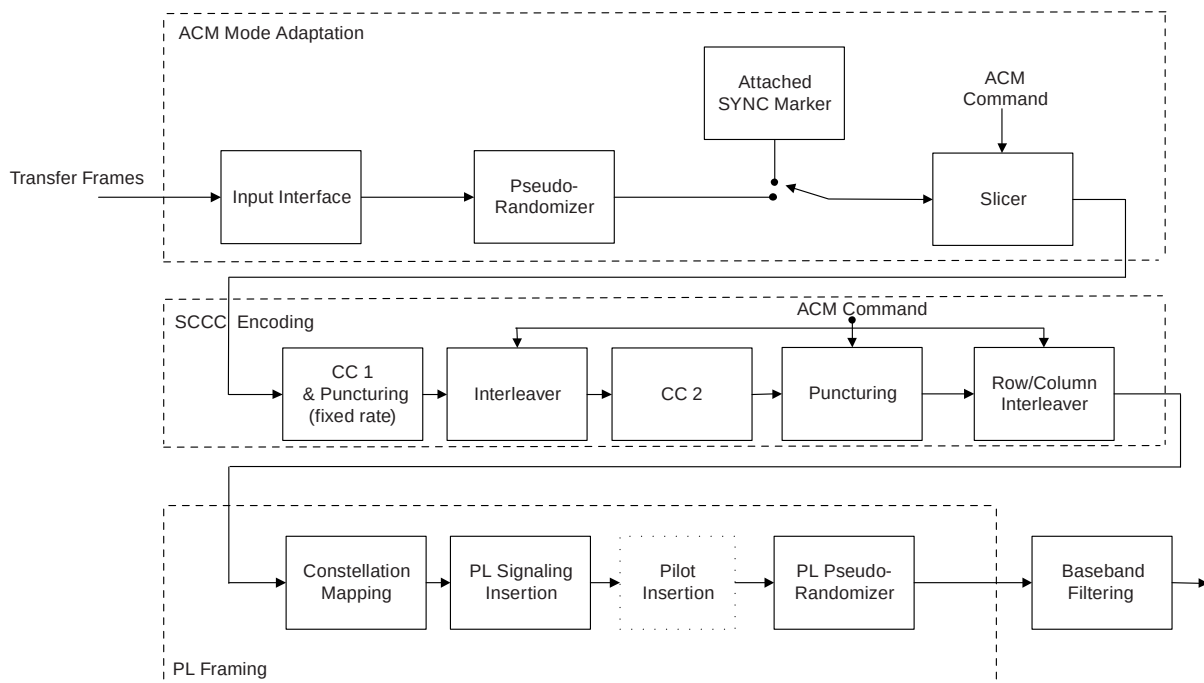


Figure 2-2: Functional Diagrams at Sending End

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]) and AOS (reference [3]).

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.

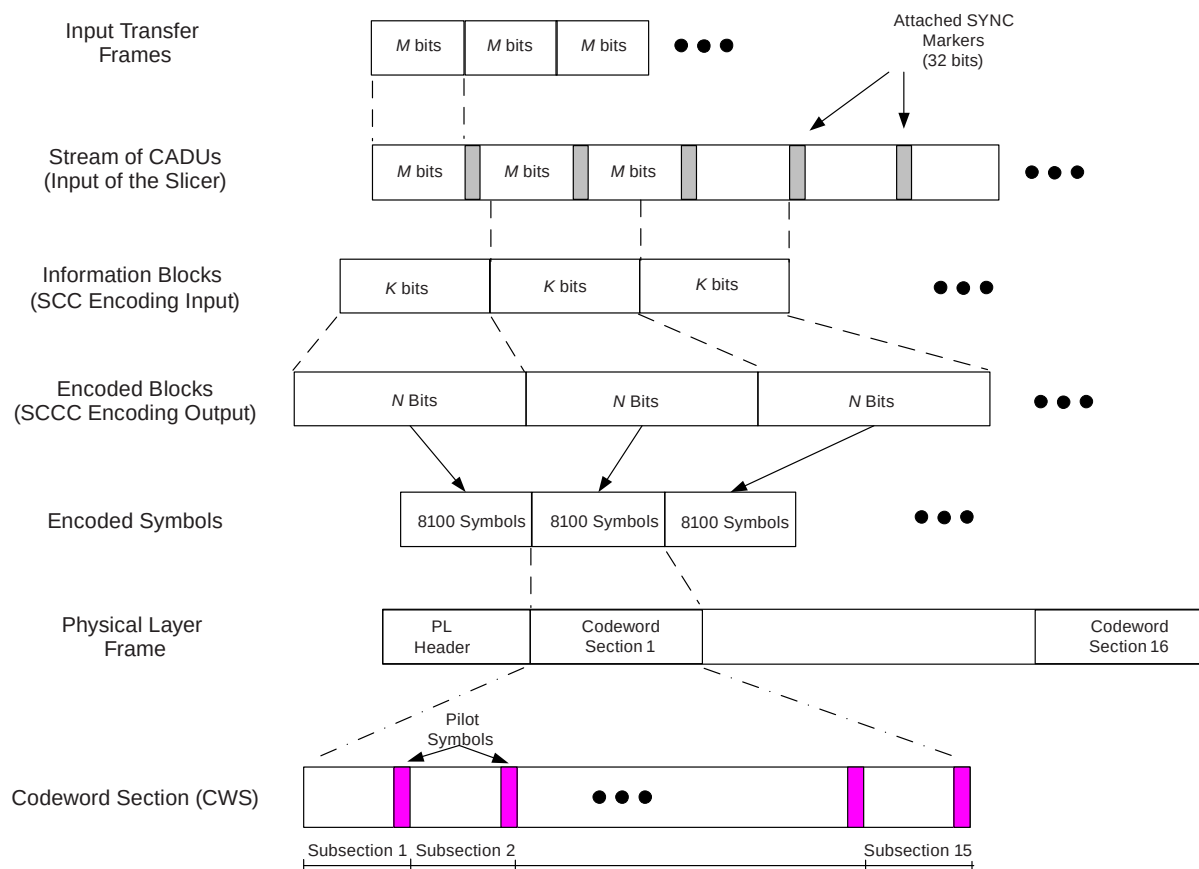


Figure 2-3: Stream Format at Different Stages of Processing

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.