The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

TC SYNCHRONIZATION AND CHANNEL CODING

ECSS MODIFIED VERSION

RECOMMENDED STANDARD

CCSDS 231.0-B-3

b) synchronization;

c) pseudo-randomizing (optional); and

d) repeated transmissions (optional).

2.2.2 ERROR-CONTROL CODING

This Recommended Standard specifies two error-control coding methods. One uses a modified BCH code as described in section 3; the other uses LDPC codes as described in section 4.

The modified BCH code specified in this Recommended Standard may be decoded either in an error-detecting mode or in an error-correcting mode, depending on mission requirements. The LDPC codes are typically decoded from soft symbols and operate at a lower Signal to Noise Ratio (SNR). The Frame Error Control Field (FECF) defined in reference [1] ~~may be~~is used to reduce the probability of undetected errors~~, particularly when the modified BCH code is chosen, and it is decoded in an error-correcting mode~~.

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 the design requirements for encoders or decoders.

2.2.3 SYNCHRONIZATION

This Recommended Standard specifies a method for synchronizing codewords using a data unit called the Communications Link Transmission Unit (CLTU), which consists of a Start Sequence, BCH or LDPC codewords, and a Tail Sequence (optional for LDPC). This is described in section 4.

The Start Sequence of the CLTU may also be used for resolution of data ambiguity (sense of '1' and '0') if data ambiguity is not resolved by the modulation method used in the Physical Layer.

This Recommended Standard also specifies a procedure called the Physical Layer Operations Procedure (PLOP) for activating and deactivating the physical communications channel so that the Physical Layer of the receiving end can achieve and maintain bit synchronization.

NOTE – Although PLOP belongs to the Physical Layer, it is included in this Recommended Standard because it must be used to transmit CLTUs specified in this document. The other specifications of the Physical Layer are contained in reference [4].

3.5 DECODING PROCEDURE

Codewords that have been encoded using the modified BCH code described in 3.3 ~~may~~ shall be decoded ~~either in an error-detecting mode (Triple Error Detection, or TED) or~~ in an error-correcting mode (Single Error Correction, or SEC)~~, depending on mission requirements. When the error-detecting mode is chosen, one, two or three bits in error will be detected within the codeword (not counting the appended Filler Bit); when the error-correcting mode is chosen, one bit in error will be corrected and two bits in error will be detected~~. In error-correcting mode, the code can correct one bit in error and can detect two bits in error.

NOTE – The decoding procedure described in 3.5 assumes the use of a hard-limiting detector before decoding, but the use of a soft-limiting detector is not intended to be precluded.

Table 5-1: CLTU Reception States (Receiving End)

State Number	State Name	State Definition
S1	INACTIVE	The communications channel is INACTIVE (i.e., 'no bit lock is achieved', or, alternatively, 'no bit modulation is detected').
S2	SEARCH	The incoming bit stream is searched, bit by bit, for the Start Sequence pattern.
S3	DECODE	1) Codewords, which are either free of error or which can be corrected, are received, decoded, and derandomized ~~(if necessary)~~, and their contents are transferred to the sublayer above. 2) Optional: Following each codeword, the incoming bit stream is compared to the Tail Sequence pattern.

Table 5-2: CLTU Reception Events (Receiving End)

Event Number	Event Name	Event Definition
E1	CHANNEL ACTIVATION	Carrier modulation is detected and bit lock is achieved: channel symbol stream is present.
E2	CHANNEL DEACTIVATION	Bit lock is lost or communications signal is lost: channel symbol stream is NOT present.
E3	START SEQUENCE FOUND	The Start Sequence pattern has been detected, signaling the beginning of the first codeword of the CLTU.
E4	CODEWORD REJECTION	The decoder has indicated uncorrected errors. No data from this decoding attempt are transferred to the sublayer above. When no tail sequence is used, the search for the start sequence must resume at the beginning of the uncorrected codeword. When a tail sequence is used, the search may resume at the end of the uncorrected codeword.
E5	TAIL SEQUENCE FOUND	Optional for (128, 64) LDPC: The tail sequence has been detected, signaling the end of a CLTU. The search for the start sequence resumes at the end of the tail sequence.

NOTES

1 When BCH code is used, ~~In~~ the search for the Start Sequence in State 2~~, no error in the Start Sequence is allowed if the modified BCH code is decoded in the error-detecting mode; one error in the Start Sequence is allowed if the modified BCH code is decoded in the error-correcting mode~~ accepts a Start Sequence containing one error.

2 When LDPC codes are used, a tail sequence is optional for the (128, 64) code at the end of each CLTU. If a tail sequence is transmitted, one may wish to check for its presence, e.g., with a correlator, rather than relying on the decoder to fail at the end of the CLTU. If so, one must allow for data ambiguity (sense of '1' and '0'). When BCH codes are used, it is standard practice to rely on codeword rejection when the decoder encounters the tail sequence.

6 RANDOMIZER

6.1 INTRODUCTION

6.1.1 In order to maintain bit (or symbol) synchronization with the received communications signal, every data capture system at the receiving end requires that the incoming signal must have a minimum bit transition density (see subsection 2.2.3 in reference [4]).

6.1.2 ~~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 this section shall be used~~is required unless the system designer verifies proper operation of the system if this Randomizer is not used~~.

~~**6.1.2**~~ NOTE – By using the Pseudo-Randomizer, the data stream is sufficiently random to ensure proper receiver operation.

6.1.3 The randomization shall be applied when BCH coding is used~~presence or absence of randomization is fixed for a Physical Channel and is managed for BCH (i.e., its presence or absence is not signaled but must be known a priori by the receiver)~~.

6.1.4 The randomization shall be applied when LDPC coding is used

6.1.5 A random sequence is exclusively ORed with the **Transfer Frame(s)** to increase the frequency of bit transitions. On the receiving end, the same random sequence is exclusively ORed with the decoded data, restoring the original data form. The random sequence is generated by the Bit Transition Generator (BTG).

6.2 RANDOMIZER DESCRIPTION

The random sequence shall be generated using the following polynomial:

$$h(x) = x^8 + x^6 + x^4 + x^3 + x^2 + x + 1$$

This sequence repeats after 255 bits, continuing as needed. The first 40 bits of the sequence are

1111 1111 0011 1001 1001 1110 0101 1010 0110 1000

Increasing Time---------->

NOTE – Figure 6-1 depicts a basic logic diagram of the BTG.

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7 PHYSICAL LAYER OPERATIONS PROCEDURES

7.1 INTRODUCTION

7.1.1 Operations within the Physical Layer begin with the activation of the physical communications channel by invoking the radio frequency carrier and modulation techniques. These techniques include provision of any required subcarrier(s) and data modulation in order to establish the physical connection from the transmitter to the receiver. During a communications session, a series of CLTUs is transmitted to the receiver. The session ends with the removal of the carrier.

7.1.2 The Physical Layer Operations Procedures (PLOPs) specify the sequence of operations performed during a communications session. Two procedures, PLOP-1 and PLOP-2, are currently defined. The selection of PLOPs is mission-specific.

7.1.3 PLOP-2 shall be used for missions whose planning begins after September 2010.

7.1.4 PLOP-1 may still be used in ground equipment for the support of legacy missions.

7.2 DATA FORMATS

7.2.1 GENERAL

The data formats used by the PLOPs are:

a) the Acquisition Sequence;

b) CLTU; and

c) the Idle Sequence.

They are used to provide synchronization of the symbol stream, and are described in 7.2.2 through 7.2.4.

7.2.2 ACQUISITION SEQUENCE

The Acquisition Sequence is a data structure forming a preamble which provides for initial symbol synchronization within the incoming stream of detected symbols. The length of the Acquisition Sequence shall be selected according to the communications link performance requirements of the mission~~, but the~~. The ~~preferred~~ minimum length ~~is~~ shall be 16 octets. The length is not required to be an integral multiple of octets. The pattern of the Acquisition Sequence shall be alternating 'ones' and 'zeros', starting with either a 'one' or a 'zero'.

7.2.3 CLTU

The CLTU is the data structure (symbol sequence) furnished from the Synchronization and Channel Coding Sublayer, and defined in 5.2. It contains the data symbols that are to be transmitted to the receiving end.

When BCH coding is used, each codeword within the CLTU, having the format specified in 3.2, shall provide at least 2 data transitions per codeword. If the receiver symbol synchronization design necessitates more frequent transitions, either the CLTU as delivered to the Physical Layer must have been randomized as described in section 6, or the Physical Layer must invoke a technique (modulation type, phase-coherent data and subcarrier, or other) to guarantee sufficiently frequent transitions for adequate symbol synchronization.

When LDPC coding is used, the randomizer described in section 6 is required. With high probability, this assures a large number of data transitions.

7.2.4 IDLE SEQUENCE

The Idle Sequence is the data structure which provides for maintenance of symbol synchronization in the absence of CLTUs. The bit pattern is a sequence of alternating 'ones' and 'zeros'. The length of the Idle Sequence shall be at least 8 bits. The maximum length of the Idle Sequence is an unconstrained number of bits.

NOTE – In the first issue of reference [D2], the Idle Sequence was constrained to begin with a 'zero' to be continuous with the CLTU Tail Sequence. Because of the improved performance of the Tail Sequence introduced later and specified in this Recommended Standard, the constraint is no longer necessary.

7.3 CARRIER MODULATION MODES

7.3.1 A PLOP consists of a sequential application of the various Carrier Modulation Modes (CMMs) in order to activate and deactivate the physical communications channel.

7.3.2 CMMs consist of different states of data modulation upon the RF carrier which creates the physical communications channel. The physical methods of modulating the carrier are described in reference [4]. The Carrier Modulation Modes are shown in table 7-1.

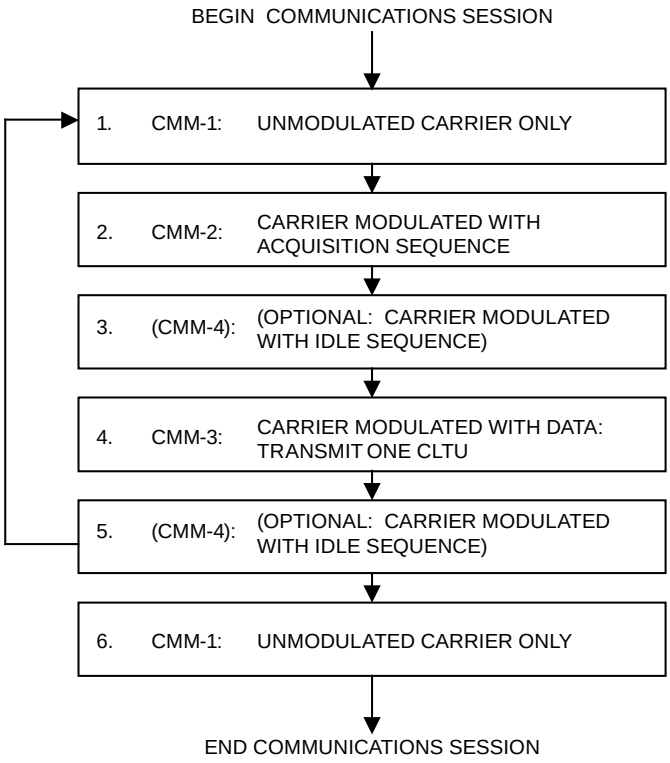

Figure 7-1: Sequence of CMMs Composing PLOP-1

7.5 PLOP-2

7.5.1 PLOP-2 is a procedure whereby the physical communications channel is not deactivated after each transmitted CLTU. The termination of an individual CLTU shall be provided only through the data path, using the CLTU Tail Sequence and, optionally, Idle Sequence. This places the receiver in the SEARCH state (S2) (see 5.3) after each CLTU. The receiver is forced into the INACTIVE state (S1) by deactivating the physical communications channel only at the end of transmission of a series of CLTUs, which may or may not be followed by an Idle Sequence.

7.5.2 ~~It should be noted that when~~When operating with PLOP-2,~~ it is recommended that~~ a minimum Idle Sequence of one octet shall be systematically inserted between each CLTU to eliminate the small but finite possibility of synchronization lockout. Such a lockout may occur if the start pattern of one CLTU is not detected (leaving the receiver in SEARCH state) and a start sequence exists over the last bits of the last codeword of that CLTU and the first bits of its Tail Sequence. This creates an erroneous but temporary CLTU start (DECODE

8 MANAGED PARAMETERS

8.1 OVERVIEW OF MANAGED PARAMETERS

In order to conserve bandwidth on the space link, some parameters associated with synchronization and channel coding are handled by management rather than by inline communications protocol. The managed parameters are those which tend to be static for long periods of time, and whose change generally signifies a major reconfiguration of the synchronization and channel coding systems associated with a particular mission. Through the use of a management system, management conveys the required information to the synchronization and channel coding systems.

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

8.2 MANAGED PARAMETERS FOR BCH AND LDPC CODING

Table 8-1 lists the managed parameters common to both BCH and LDPC coding. Table 8-2 lists additional managed parameters specific to BCH coding. Table 8-3 lists additional managed parameters specific to LDPC coding.

Table 8-1: Managed Parameters for Both BCH and LDPC Codes

Managed Parameter	Allowed Values
Error Correcting Code Type	BCH, LDPC
Maximum CLTU Length (octets)	Integer
Maximum value for the Repetitions parameter NOTE – If the maximum value is 1, then the repeated transmissions option is not	Integer
Physical Layer Operations Procedure	PLOP-1, PLOP-2

Table 8-2: Additional Managed Parameters when the BCH Code Is Used

Managed Parameter	Allowed Values
Decoding Mode	~~Error-Detecting,~~ Error-Correcting
Allowed Number of Errors in Start Sequence	~~0,~~1
Randomizer	Used~~, Not used~~

ANNEX A

SERVICE DEFINITION

(NORMATIVE)

A1 GENERAL

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 may 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 TC Synchronization and Channel Coding provides unidirectional (one way) transfer of a sequence of variable-length TC Transfer Frames over a Physical Channel across a space link, with optional error detection/correction.

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

The parameter Frames is the service data unit of this service and, at the sending end, shall consist of one ~~or more~~ TC Transfer ~~Frames~~ Frame defined in reference [1]. At the receiving end, however, the parameter Frames may contain an incomplete Frame or additional fill data, which are discarded by the TC Space Data Link Protocol (reference [1]).

If the optional Repetitions parameter is supported, then the parameter shall contain a positive integer value, greater than or equal to 1. If the value of the Repetitions parameter is greater than 1, then the Frames parameter should not contain any Type-BD frames defined in reference [1].