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Vesoljska tehnika - Vesoljske podatkovne povezave - Telemetrijska sinhronizacija in kodiranje kanalov

Space engineering - Space data links - Telemetry synchronization and channel coding

Raumfahrttechnik - Raumfahrt-Datenübertragung - Telemetriesynchronisation und -kanalkodierung

Ingénierie spatiale - Liaison de données spatiales - Synchronisation et codage canal de la télémesure

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Foreword

This document (EN 16603-50-01:2014) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN.

This standard (EN 16603-50-01:2014) originates from ECSS-E-ST-50-01C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2015, and conflicting national standards shall be withdrawn at the latest by March 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any EN covering the same scope but with a wider domain of applicability (e.g. : aerospace).

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This Standard establishes a common implementation of space telemetry channel coding systems.

Several space telemetry channel coding schemes are specified in this Standard. The specification does not attempt to quantify the relative coding gain or the merits of each scheme, nor the design requirements for encoders or decoders. However, some application profiles are discussed in Annex D. Performance data for the coding schemes specified in this Standard can be found in CCSDS 130.1-G-1. Annex G describes the related mission configuration parameters.

Further provisions and guidance on the application of this standard can be found in the following publications:

- ECSS-E-ST-50, Communications, which defines the principle characteristics of communication protocols and related services for all communication layers relevant for space communication (physical- to application-layer), and their basic relationship to each other.

- The handbook ECSS-E-HB-50, Communications guidelines, which provides information about specific implementation characteristics of these protocols in order to support the choice of a certain communications profile for the specific requirements of a space mission.

Users of this present standard are invited to consult these documents before taking decisions on the implementation of the present one.

This standard may be tailored for the specific characteristics and constraints of a space project in conformance with ECSS-S-ST-00.

2
Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revisions of any of these publications, do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system - Glossary of terms

3 Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 category A

category of spacecraft having an altitude above the Earth's surface less than 2×10^6 km

3.2.2 category B

category of spacecraft having an altitude above the Earth's surface equal to, or greater than 2×10^6 km

3.2.3 octet

group of eight bits

NOTE 1 The numbering for octets within a data structure starts with 0.

NOTE 2 Refer to clause 3.4 for the convention for the numbering of bits.

3.2.4 physical channel

stream of bits transferred over a space link in a single direction

3.3 Abbreviations

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01and the following apply:

Abbreviation	Meaning
8PSK	phase shift keying of eight states
AOS	advanced orbiting systems
APP	a posteriori probability
ASM	attached sync marker

AWGN	additive white Gaussian noise
BER	bit error rate
BPSK	binary phase shift keying
CADU	channel access data unit
CCSDS	Consultative Committee for Space Data Systems
CRC	cyclic redundancy check
FER	frame error rate
GF(n)	Galois field consisting of exactly n elements
GMSK	Gaussian minimum shift keying
MSB	most significant bit
MS/S	mega symbols per second
NRZ-L	non-return to zero level
NRZ-M	non-return to zero mark
QPSK	quadrature phase shift keying
R-S	Reed-Solomon
TCM	trellis-coded modulation

3.4 Conventions

3.4.1 bit 0, bit 1, bit N–1

To identify each bit in an N-bit field, the first bit in the field to be transferred (i.e. the most left justified in a graphical representation) is defined as bit 0; the following bit is defined as bit 1 and so on up to bit N–1.

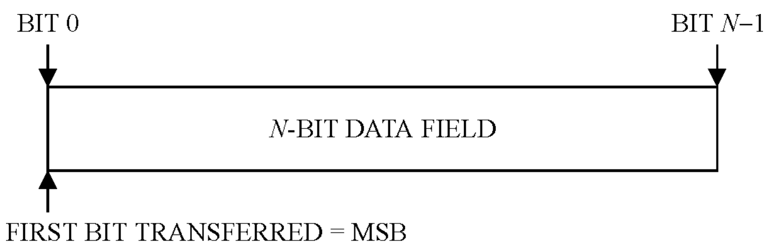

Figure 3-1: Bit numbering convention

3.4.2 most significant bit

When an N-bit field is used to express a binary value (such as a counter), the most significant bit is the first bit of the field, i.e. bit 0 (see Figure 3-1).

4
Overview

4.1 Introduction

Telemetry channel coding is a method of processing data that is sent from a source to a destination so that distinct messages are created that are easily distinguishable from one another and thus enable reconstruction of the data with low error probability, thus improve the performance of the channel.

4.2 Coding

4.2.1 Channel codes

A channel code is the set of rules that specify the transformation of elements of a source alphabet to elements of a code alphabet. The elements of the source alphabet and of the code alphabet are called symbols.

Depending on the code, the symbols can consist of one or more bits. The source symbols are also called information symbols. The code symbols are called channel symbols when they are the output of the last or only code applied during the encoding process.

Block encoding is a one-to-one transformation of sequences of length k source symbols to sequences of length n code symbols. The length of the encoded sequence is greater than the source sequence, so $n > k$.

The ratio k/n is the code rate, which can be defined more generally as the average ratio of the number of binary digits at the input of an encoder to the number of binary digits at its output.

A codeword of an (n,k) block code is one of the sequences of n code symbols in the range of the one-to-one transformation.

A codeblock of an (n,k) block code is a sequence of n channel symbols which are produced as a unit by encoding a sequence of k information symbols. The codeblock is decoded as a unit and, if successful, delivers a sequence of k information symbols.

A systematic code is one in which the input information sequence appears in unaltered form as part of the output codeword.

A transparent code has the property that complementing the input of the encoder or decoder results in complementing the output.

4.2.2 Connection vectors

Convolutional and turbo coding use connection vectors.

A forward connection vector is a vector which specifies one of the parity checks computed by the shift register(s) in the encoder. For a shift register with *s* stages, a connection vector is an *s*-bit binary number. A bit equal to "1" in position *i* (counted from the left) indicates that the output of the *i*th stage of the shift register is used in computing that parity check.

In turbo coding, a backward connection vector is a vector which specifies the feedback to the shift registers in the encoder. For a shift register with *s* stages, a backward connection vector is an *s*-bit binary number. A bit equal to "1" in position *i* (counted from the left) indicates that the output of the *i*th stage of the shift register is used in computing the feedback value, except for the leftmost bit which is ignored.

4.3 Convolutional codes

A convolutional code is a code in which a number of output symbols are produced for each input information bit. Each output symbol is a linear combination of the current input bit as well as some or all of the previous k–1 bits, where k is the constraint length of the code. The constraint length is the number of consecutive input bits that are used to determine the value of the output symbols at any time.

The rate 1/2 convolutional code is specified in clause 5. Depending on performance requirements, this code can be used alone.

For telecommunication channels that are constrained by bandwidth and cannot accommodate the increase in bandwidth caused by the basic convolutional code, clause 5 also specifies a punctured convolutional code which has the advantage of a smaller bandwidth expansion.

A punctured code is a code obtained by deleting some of the parity symbols generated by the convolutional encoder before transmission. There is an increase in the bandwidth efficiency due to puncturing compared to the original code, however the minimum weight (and therefore its error-correcting performance) is less than that of the original code.

4.4 Reed-Solomon codes

The Reed-Solomon (R-S) code specified in clause 6 is a powerful burst error correcting code. In addition, the code has the capability of indicating the presence of uncorrectable errors, with an extremely low undetected error rate.

The Reed-Solomon code has the advantage of smaller bandwidth expansion than the convolutional code.

The Reed-Solomon symbol is a set of J bits that represents an element in the Galois field GF(2^J), the code alphabet of a J-bit Reed-Solomon code. For the code specified in clause 6, J = 8 bits per R-S symbol.

4.5 Concatenated codes

Concatenation is the use of two or more codes to process data sequentially, with the output of one encoder used as the input to the next.

In a concatenated coding system, the first encoding algorithm that is applied to the data stream is called the outer code.

The last encoding algorithm that is applied to the data stream is called the inner code. The data stream that is input to the inner encoder consists of the codewords generated by the outer encoder.

To achieve a greater coding gain than the one that can be provided by the convolutional code or Reed-Solomon code alone, a concatenation of the convolutional code as the inner code with the Reed-Solomon code as the outer code can be used for improved performance.

This Standard also specifies the concatenation of the Reed-Solomon code with the 4-dimensional 8PSK trellis-coded modulation (4D-8PSK-TCM) defined in ECSS-E-ST-50-05. In this case, the Reed-Solomon code with E=8 is the outer code and the 4D-8PSK-TCM is the inner code.

4.6 Turbo codes

A turbo code is a block code formed by combining two component recursive convolutional codes. A turbo code takes as input a block of information bits. The input block is sent unchanged to the first component code and bit-wise interleaved to the second component code. The interleaving process, called the turbo code permutation, is a fixed bit-by-bit permutation of the entire input block.

The output is formed by the parity symbols contributed by each component code plus a replica of the information bits.

The turbo codes specified in clause 7 can be used to increase the coding gain in cases where the environment tolerates the bandwidth overhead.

4.7 Synchronization and pseudo-randomization

The methods for synchronization specified in clause 8 apply to all telemetry channels, coded or uncoded. An attached sync marker (ASM) is attached to the codeblock or transfer frame. The ASM can also be used for resolution of data ambiguity (sense of '1' and '0') if data ambiguity is not resolved by the modulation method used.

Successful bit synchronization at the receiving end depends on the incoming signal having a minimum bit transition density. Clause 9 specifies the method of pseudo-randomizing the data to improve bit transition density.

Figure 4-1 and Figure 4-2 provide an overview of how pseudo-randomization and synchronization are combined with the different coding options at the sending and receiving end.

At the sending end, the order of convolutional encoding and modulation is dependent on the implementation. At the receiving end, the order of