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Information technology — JPEG 2000 image coding system: An entry level JPEG 2000 encoder

Technologies de l'information — Système de codage d'images JPEG 2000: Un encodeur JPEG 2000 de niveau d'entrée

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

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ISO/IEC 15444-13 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*, in collaboration with ITU-T. The identical text is published as ITU-T Rec. T.812.

ISO/IEC 15444 consists of the following parts, under the general title *Information technology — JPEG 2000 image coding system*:

— *Part 1: Core coding system*

— *Part 2: Extensions*

— *Part 3: Motion JPEG 2000*

— *Part 4: Conformance testing*

— *Part 5: Reference software*

— *Part 6: Compound image file format*

— *Part 8: Secure JPEG 2000*

— *Part 9: Interactivity tools, APIs and protocols*

— *Part 10: Extensions for three-dimensional data*

— *Part 11: Wireless*

— *Part 12: ISO base media file format*

— *Part 13: An entry level JPEG 2000 encoder*

INTERNATIONAL STANDARD
ITU-T RECOMMENDATION

Information technology – JPEG 2000 image coding system: An entry level JPEG 2000 encoder

1 Scope

This Recommendation | International Standard was developed by the Joint Photographic Experts Group (JPEG), the joint ISO/I–TU committee responsible for developing standards for continuous-tone still picture coding. It also refers to the Recommendations | International Standards produced by this committee: ITU-T Rec. T.81 | ISO/IEC 10918-1, ITU-T Rec. T.83 | ISO/IEC 10918-2, ITU-T Rec. T.84 | ISO/IEC 10918-3 and ITU-T Rec. T.87 | ISO/IEC 14495-1.

1.1 Context

This Recommendation | International Standard defines a set of lossless (bit-preserving) and lossy compression methods for coding bi-level, continuous-tone greyscale, palletized colour, or continuous-tone colour digital still images. This Recommendation | International Standard:

– specifies normative but optional encoding processes for converting source image data to JPEG 2000 compressed image data;
– specifies a complete encoding path to produce a conforming codestream as defined in Part 1 Annex A (ITU-T Rec. T.800 | ISO/IEC 15444-1);
– provides guidance on encoding processes for converting source image data to compressed image data;
– provides guidance on how to implement these processes in practice.

1.2 Requirements

This subclause contains a list of requirements for the definitions of an entry-level encoder.

An entry-level JPEG 2000 encoder implementation (this Recommendation | International Standard):

– shall be normative but optional; implementers shall be allowed to select necessary technologies/paths that would suite their application needs;
– shall define a JPEG 2000 Part 1 codestream encoder implementation; should define a JP2 file format encoder implementation;
– shall define a complete encoding path to produce a conforming codestream as defined in Annex A of ITU-T Rec. T.800 | ISO/IEC 15444-1:2004;
– shall consist of technology with clear IP status being royalty fee-free.

2 References

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

2.1 Identical Recommendations | International Standards

– ITU-T Recommendation T.81 (1992) | ISO/IEC 10918-1:1994, *Information technology – Digital compression and coding of continuous-tone still images: Requirements and guidelines*.
– ITU-T Recommendation T.84 (1996) | ISO/IEC 10918-3:1997, *Information technology – Digital compression and coding of continuous-tone still images: Extensions*.

- ITU-T Recommendation T.86 (1998) | ISO/IEC 10918-4:1999, *Information technology – Digital compression and coding of continuous-tone still images: Registration of JPEG profiles, SPIFF profiles, SPIFF tags, SPIFF colour spaces, APPn markers, SPIFF compression types and Registration Authorities (REGAUT)*.
- ITU-T Recommendation T.87 (1998) | ISO/IEC 14495-1:2000, *Information technology – Lossless and near-lossless compression of continuous-tone still images: Baseline*.
- ITU-T Recommendation T.88 (2000) | ISO/IEC 14492:2001, *Information technology – Lossy/lossless coding of bi-level images*.
- ITU-T Recommendation T.800 (2002) | ISO/IEC 15444-1:2004, *Information technology – JPEG 2000 image coding system: Core coding system*.
- ITU-T Recommendation T.801 (2002) | ISO/IEC 15444-2:2004, *Information technology – JPEG 2000 image coding system: Extensions*.
- ITU-T Recommendation T.803 (2002) | ISO/IEC 15444-4:2004, *Information technology – JPEG 2000 image coding system: Conformance testing*.
- ITU-T Recommendation T.804 (2002) | ISO/IEC 15444-5:2003, *Information technology – JPEG 2000 image coding system: Reference software*.

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply. The definitions defined in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004 clause 3 also apply to this Recommendation | International Standard.

3.1 5-3 reversible filter (5-3R): A particular filter pair used in the wavelet transformation. This reversible filter pair has 5 taps in the low-pass and 3 taps in the high-pass.

3.2 9-7 irreversible filter (9-7I): A particular filter pair used in the wavelet transformation. This irreversible filter pair has 9 taps in the low-pass and 7 taps in the high-pass.

3.3 arithmetic coder: An entropy coder that converts variable length strings to variable length codes (encoding) and visa versa (decoding).

3.4 bit-plane: A two-dimensional array of bits. In this Recommendation | International Standard, a bit-plane refers to all the bits of the same magnitude in all coefficients or samples. This could refer to a bit-plane in a component, tile-component, code-block, region of interest, or other.

3.5 bit stream: The actual sequence of bits resulting from the coding of a sequence of symbols. It does not include the markers or marker segments in the main and tile-part headers or the EOC marker. It does include any packet headers and in stream markers and marker segments not found within the main or tile-part headers.

3.6 channel: One logical component of the image. A channel may be a direct representation of one component from the codestream, or may be generated by the application of a palette to a component from the codestream.

3.7 cleanup pass: A coding pass performed on a single bit-plane of a code-block of coefficients. The first pass and only coding pass for the first significant bit-plane is a cleanup pass; the third and the last pass of every remaining bit-plane is a cleanup pass.

3.8 codestream: A collection of one or more bit streams and the main header, tile-part headers, and the EOC required for their decoding and expansion into image data. This is the image data in a compressed form with all of the signalling needed to decode.

3.9 code-block: A rectangular grouping of coefficients from the same sub-band of a tile-component.

3.10 coder: An embodiment of either an encoding or decoding process.

3.11 coding pass: A complete pass through a code-block where the appropriate coefficient values and context are applied. There are three types of coding passes: significance propagation pass, magnitude refinement pass and cleanup pass. The result of each pass (after arithmetic coding, if selective arithmetic coding bypass is not used) is a stream of compressed image data.

3.12 coefficient: The values that are the result of a transformation.

3.13 component: A two-dimensional array of samples. An image typically consists of several components, for instance representing red, green and blue.

3.14 context: Function of coefficients previously decoded and used to condition the decoding of the present coefficient.

3.15 decoder: An embodiment of a decoding process, and optionally a colour transformation process.

3.16 decoding process: A process which takes as its input all or part of a codestream and outputs all or part of a reconstructed image.

3.17 decomposition level: A collection of wavelet sub-bands where each coefficient has the same spatial impact or span with respect to the source component samples. These include the HL, LH, and HH sub-bands of the same two dimensional sub-band decomposition. For the last decomposition level, the LL sub-band is also included.

3.18 discrete wavelet transformation (DWT): A transformation that iteratively transforms one signal into two or more filtered and decimated signals corresponding to different frequency bands. This transformation operates on spatially discrete samples.

3.19 encoder: An embodiment of an encoding process.

3.20 encoding process: A process, that takes as its input all or part of a source image data and outputs a codestream.

3.21 file format: A codestream and additional support data and information not explicitly required for the decoding of codestream. Examples of such support data include text fields providing titling, security and historical information, data to support placement of multiple codestream within a given data file, and data to support exchange between platforms or conversion to other file formats.

3.22 guard bits: Additional most significant bits that have been added to sample data.

3.23 header: Either a part of the codestream that contains only markers and marker segments (main header and tile part header) or the signalling part of a packet (packet header).

3.24 image area: A rectangular part of the reference grid, registered by offsets from the origin and the extent of the reference grid.

3.25 image area offset: The number of reference grid points down and to the right of the reference grid origin where the origin of the image area can be found.

3.26 irreversible: A transformation, progression, system, quantization, or other process that, due to systemic or quantization error, disallows lossless recovery. An irreversible process can only lead to lossy compression.

3.27 JP2 file: The name of a file in the file format described in this Recommendation | International Standard. Structurally, a JP2 file is a contiguous sequence of boxes.

3.28 JPEG: Used to refer globally to the encoding and decoding process of the following Recommendations | International Standards:

– ITU-T Recommendation T.81 (1992) | ISO/IEC 10918-1:1994, *Information technology – Digital compression and coding of continuous-tone still images: Requirements and guidelines*.

– ITU-T Recommendation T.83 (1994) | ISO/IEC 10918-2:1995, *Information technology – Digital compression and coding of continuous-tone still images: Compliance testing*.

– ITU-T Recommendation T.84 (1996) | ISO/IEC 10918-3:1997, *Information technology – Digital compression and coding of continuous-tone still images: Extensions, plus Amendment 1 (1999), Provisions to allow registration of new compression types and versions in the SPIFF header*.

– ITU-T Recommendation T.86 (1998) | ISO/IEC 10918-4:1999, *Information technology – Digital compression and coding of continuous-tone still images: Registration of JPEG Profiles, SPIFF Profiles, SPIFF Tags, SPIFF Colour Spaces, APPn Markers, SPIFF Compression Types and Registration Authorities (REGAUT)*.

3.29 JPEG 2000: Used to refer globally to the encoding and decoding processes in this Recommendation | International Standard and their embodiment in applications.

3.30 JPX file: JPEG 2000 File Format defined in ITU-T Rec. T.801 | ISO/IEC 15444-2:2004; JPEG 2000 File Format Extended.

3.31 layer: A collection of compressed image data from coding passes of one, or more, code-blocks of a tile component. Layers have an order for encoding and decoding that must be preserved.

3.32 lossless: A descriptive term for the effect of the overall encoding and decoding processes in which the output of the decoding process is identical to the input to the encoding process. Distortion free restoration can be assured. All of the coding processes or steps used for encoding and decoding are reversible.

3.33 **lossy**: A descriptive term for the effect of the overall encoding and decoding processes in which the output of the decoding process is not identical to the input to the encoding process. There is distortion (measured mathematically). At least one of the coding processes or steps used for encoding and decoding is irreversible.

3.34 **magnitude refinement pass**: A type of coding pass.

3.35 **main header**: A group of markers and marker segments at the beginning of the codestream that describe the image parameters and coding parameters that can apply to every tile and tile-component.

3.36 **marker**: A two-byte code in which the first byte is hexadecimal FF (0xFF) and the second byte is a value between 1 (0x01) and hexadecimal FE (0xFE).

3.37 **marker segment**: A marker and associated (not empty) set of parameters.

3.38 **packet**: A part of the bit stream comprising a packet header and the compressed image data from one layer of one precinct of one resolution level of one tile-component.

3.39 **packet header**: Portion of the packet that contains signalling necessary for decoding that packet.

3.40 **precinct**: A one rectangular region of a transformed tile-component, within each resolution level, used for limiting the size of packets.

3.41 **precision**: Number of bits allocated to a particular sample, coefficient, or other binary numerical representation.

3.42 **progression**: The order of a codestream where the decoding of each successive bit contributes to a "better" reconstruction of the image. What metrics make the reconstruction "better" is a function of the application. Some examples of progression are increasing resolution or improved sample fidelity.

3.43 **quantization**: A method of reducing the precision of the individual coefficients to reduce the number of bits used to entropy-code them. This is equivalent to division while compressing and multiplying while decompressing. Quantization can be achieved by an explicit operation with a given quantization value or by dropping (truncating) coding passes from the codestream.

3.44 **reference grid**: A regular rectangular array of points used as a reference for other rectangular arrays of data. Examples include components and tiles.

3.45 **region of interest (ROI)**: A collections of coefficients that are considered of particular relevance by some user-defined measure.

3.46 **resolution level**: Equivalent to decomposition level with one exception: the LL sub-band is also a separate resolution level.

3.47 **reversible**: A transformation, progression, system, or other process that does not suffer systemic or quantization error and, therefore, allows lossless signal recovery.

3.48 **segmentation symbol**: A special symbol coded with a uniform context at the end of each coding pass for error resilience.

3.49 **selective arithmetic coding bypass**: A coding style where some of the code-block passes are not coded by the arithmetic coder. Instead the bits to be coded are appended directly to the bit stream without coding.

3.50 **significance propagation pass**: A coding pass performed on a single bit-plane of a code-block of coefficients.

3.51 **sub-band**: A group of transform coefficients resulting from the same sequence of low-pass and high-pass filtering operations, both vertically and horizontally.

3.52 **tile**: A rectangular array of points on the reference grid, registered with and offset from the reference grid origin and defined by a width and height. The tiles that overlap are used to define tile-components.

3.53 **tile-component**: All the samples of a given component in a tile.

3.54 **tile index**: The index of the current tile ranging from zero to the number of tiles minus one.

3.55 **tile-part**: A portion of the codestream with compressed image data for some, or all, of a tile. The tile-part includes at least one, and up to all, of the packets that make up the coded tile.

3.56 **tile-part header**: A group of markers and marker segments at the beginning of each tile-part in the codestream that describe the tile-part coding parameters.

3.57 **tile-part index**: The index of the current tile-part ranging from zero to the number of tile-parts minus one in a given tile.

3.58 **transformation**: A mathematical mapping from one signal space to another.

4 Abbreviations and symbols

4.1 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply. The abbreviations defined in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004 clause 4 also apply to this Recommendation | International Standard.

1D-DWT	One-dimensional Discrete Wavelet Transformation
FDWT	Forward Discrete Wavelet Transformation
ICC	International Colour Consortium
ICT	Irreversible Component Transformation
IDWT	Inverse Discrete Wavelet Transformation
JPEG	Joint Photographic Experts Group
JURA	JPEG Utilities Registration Authority
RCT	Reversible Component Transformation
ROI	Region of Interest

4.2 Symbols

For the purposes of this Recommendation | International Standard, the following symbols apply. The abbreviations defined in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004 clause 4 also apply to this Recommendation | International Standard.

0x----	Denotes a hexadecimal number
nnn	A three-digit number preceded by a backslash indicates the value of a single byte within a character string, where the three digits specify the octal value of that byte
ε_b	Exponent of the quantization value for a sub-band defined in QCD and QCC
μ_b	Mantissa of the quantization value for a sub-band defined in QCD and QCC
M_b	Maximum number of bit-planes coded in a given code-block
N_L	Number of decomposition levels as defined in COD and COC
R_b	Dynamic range of a component sample as defined in SIZ
COC	Coding style component marker
COD	Coding style default marker
COM	Comment marker
CRG	Component registration marker
EOC	End of codestream marker
EPH	End of packet header marker
PLM	Packet length, main header marker
PLT	Packet length, tile-part header marker
POC	Progression order change marker
PPM	Packed packet headers, main header marker
PPT	Packed packet headers, tile-part header marker
QCC	Quantization component marker
QCD	Quantization default marker
RGN	Region-of-interest marker
SIZ	Image and tile size marker

SOC	Start of codestream marker
SOD	Start of data marker
SOP	Start of packet marker
SOT	Start of tile-part marker
TLM	Tile-part lengths marker

5 General description

5.1 Codestream

The definition of codestream is the same as in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004.

5.2 Coding principles

The main procedures for this Recommendation | International Standard are shown in Figure 1. This shows the encoding order, a reverse ordering of the block diagram of Figure 5-1 in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004.

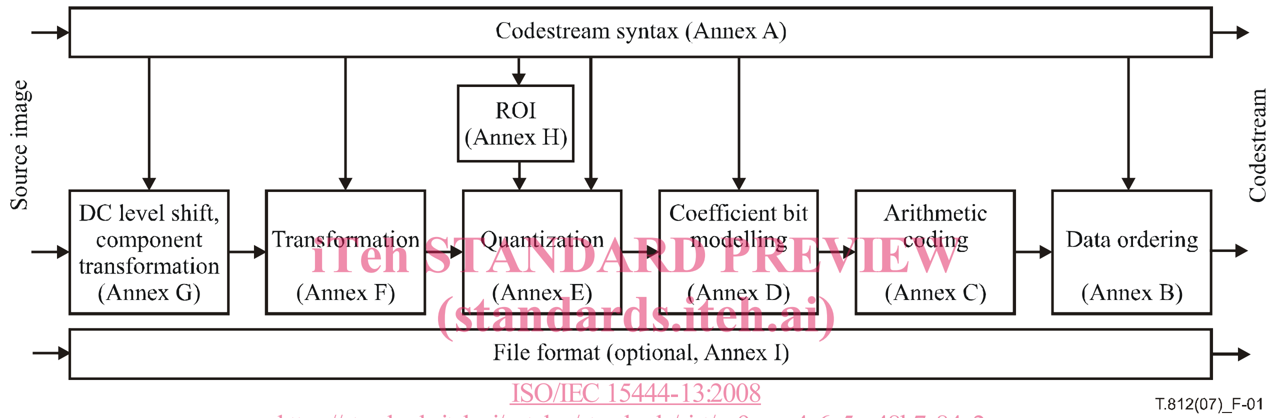

Figure 1 – Specification block diagram

Procedures are presented in the annexes. The category of the annexes is the same as in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004. Also the index of the annex is the same.

The coding process is summarized below.

Many images have multiple components. This Specification has a multiple component transformation to correlate three components. This is the only function in this Specification that relates components to each other. (See Annex G.)

The image components may be divided into tiles. These tile-components are rectangular arrays that relate to the same portion of each of the components that make up the image. Thus, tiling of the image actually creates tile-components that can be encoded independently of each other. This tile independence provides one of the methods for encoding a region of the image. (See Annex B.)

The tile-components are composed into different decomposition levels using a wavelet transformation. These decomposition levels contain a number of sub-bands populated with coefficients that describe the horizontal and vertical spatial frequency characteristics of the original tile-components. The coefficients provide frequency information about a local area, rather than across the entire image like the Fourier transformation. A decomposition level is related to the next decomposition level by a spatial factor of two. That is, each successive decomposition level of the sub-bands has approximately half the horizontal and half the vertical resolution of the previous. (See Annex F.)

Although there are as many coefficients as there are samples, the information content tends to be concentrated in just a few coefficients. Through quantization, the information content of a large number of small-magnitude coefficients is further reduced (Annex E). Additional processing by the entropy coder reduces the number of bits required to represent these quantized coefficients, sometimes significantly compared to the original image. (See Annexes C, D and B.)

The individual sub-bands of a tile-component are further divided into code-blocks. These rectangular arrays of coefficients can be extracted independently. The individual bit-planes of the coefficients in a code-block are coded with three coding passes. Each of these coding passes collects contextual information about the bit-plane compressed image data. (See Annex D.)

An arithmetic coder uses this contextual information, and its internal state, to encode coefficients. (See Annex C.) Different termination mechanisms allow different levels of independent extraction of this coding pass compressed image data.

The bit stream compressed image data created from these coding passes is grouped in layers. Layers are arbitrary groupings of coding passes from code-blocks. (See Annex B.)

NOTE – Although there is great flexibility in layering, the premise is that each successive layer contributes to a higher quality image.

Sub-band coefficients at each resolution level are partitioned into rectangular areas called precincts. (See Annex B.)

Packets are a fundamental unit of the compressed codestream. A packet contains compressed image data from one layer of a precinct of one resolution level of one tile-component. Packets provide another method for extracting a spatial region independently from the codestream. These packets are interleaved in the codestream using a few different methods. (See Annex B.)

A mechanism is provided that allows the compressed image data corresponding to regions of interest in the original tile components to be coded and placed earlier in the bit stream. (See Annex H.)

Several mechanisms are provided to allow the detection and concealment of bit errors that might occur over a noisy transmission channel. (See Annex D.)

The codestream relating to a tile, organized in packets, are arranged in one, or more, tile-parts. A tile-part header, comprised of a series of markers and marker segments, contains information about the various mechanisms and coding styles that are needed to locate, extract, decode, and reconstruct every tile-component. At the beginning of the entire codestream is a main header, comprised of markers and marker segments, that offers similar information as well as information about the original image. (See Annex A.)

The codestream is optionally wrapped in a file format that allows applications to interpret the meaning of, and other information about, the image. The file format may contain data besides the codestream. (See Annex I.)

To review, procedures that divide the original image are the following:

- The components of the image are divided into rectangular tiles. The tile-component is the basic unit of the original or reconstructed image.
- Performing the wavelet transformation on a tile-component creates decomposition levels.
- These decomposition levels are made up of sub-bands of coefficients that describe the frequency characteristics of local areas (rather than across the entire tile-component) of the tile-component.
- The sub-bands of coefficients are quantized and collected into rectangular arrays of code-blocks.
- Each bit-plane of the coefficients in a code-block is entropy coded in three types of coding passes.
- Some of the coefficients can be coded first to provide a region of interest.

At this point the image data is fully converted to compressed image data. The procedures that reassemble these bit stream units into the codestream are the following:

- The compressed image data from the coding passes are collected in layers.
- Packets are composed compressed image data from one precinct of a single layer of a single resolution level of a single tile-component. The packets are the basic unit of the compressed image data.
- All the packets from a tile are interleaved in one of several orders and placed in one, or more, tile-parts.
- The tile-parts have a descriptive tile-part header and can be interleaved in some orders.
- The codestream has a main header at the beginning that describes the original image and the various decomposition and coding styles.
- The optional file format describes the meaning of the image and its components in the context of the application.

6 Encoder requirements

6.1 General

An encoding process converts source image data to compressed image data. Annexes A, B, C, D, E, F, G and H describe the encoding process. All encoding processes are normative. An encoder is an embodiment of the encoding process. In order to conform to this Recommendation | International Standard, an encoder shall convert source image data to compressed image data, that conform to the codestream syntax specified in Annex A.

There is no required specific implementation for the encoder. In some cases, the descriptions use particular implementation techniques for illustrative purposes only.

The definition of an entry-level encoder is separated into three groups:

- encoder function;
- implementation;
- codestream description.

6.2 Encoder function definition

There are four encoding styles described in this Recommendation | International Standard:

- lossless based colour encoding;
- lossy based colour encoding;
- lossless based greyscale encoding;
- lossy based greyscale encoding.

The definition of image and compressed data ordering is applied commonly above four styles. Table 1 shows the definition of image and compressed data ordering. All reference of Table 1 is described in Annex B in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004.

Table 1 – Function definition of image and compressed data ordering

Item	Reference
Reference grid	B.2*
Tiling	B.3*
Sub-band	B.5*
Precinct	B.6*
Code-block (64x64 or 32x32)	B.7*
Layer	B.8*
Packet	B.9*
Packet header coding	B.10*
Tile-parts (plural)	B.11*
Part 1 progression order (one of 5 progression methods)	B.12.1*
Progression order change	B.12.2, B.12.3*
* Described in ITU-T Rec. T.800 | ISO/IEC 15444-1:2004.	

6.2.1 Lossless based colour encoding

Lossless based colour encoding process is shown in Figure 2. Because a basic concept of lossless based colour encoding is colour image exchange lossless, reversible component transformation (RCT) and reversible wavelet transformation (5-3R) shall be executed. Also scalar quantization shall not be executed. It may be used in truncated codestream to provide lossy compression.

Function definition of Lossless based colour encoding is shown in Table 2.

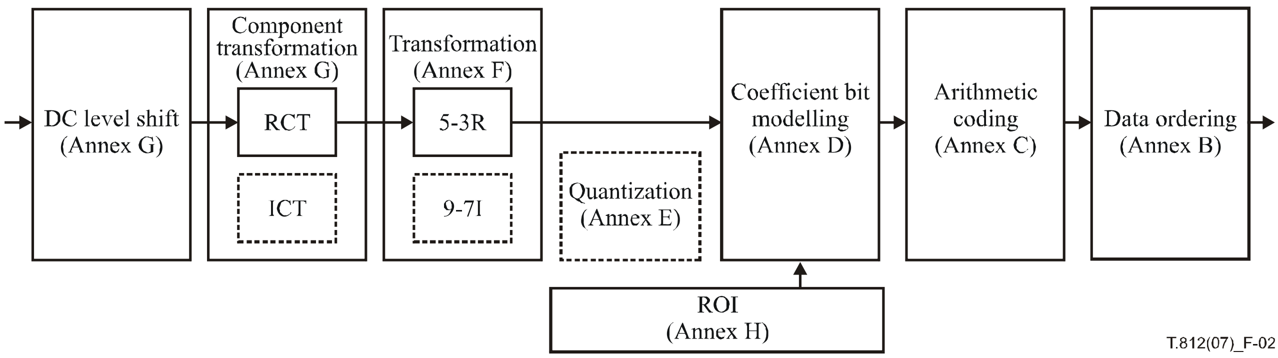

Figure 2 – Lossless based colour encoding block diagram

Table 2 – Function definition of lossless based colour encoding

Category	Item	Reference
DC level shifting and multiple component transformations	DC level shifting data	G.1
	RCT	G.2
Discrete wavelet transform	Wavelet transform (5-3R)	F.3
	Sub-sampling by discarding coefficients	F.4
	Visual frequency weighting	F.5
Coefficient bit modelling	3-coding pass, 4-coding mode (EBCOT)	D.3
	Predictable termination	D.4
	Reset context probabilities on coding pass boundaries	D.4
	Termination on each coding pass	D.4
	Segmentation symbols	D.5
	Selective AC bypass	D.6
	Vertically causal context	D.7
Arithmetic entropy coding	MQ-Coder Encoding	C.2
Region of Interest	Max-shift	H.1, H.2

6.2.2 Lossy based colour encoding

Lossy-based colour encoding process is shown in Figure 3. Lossy-based colour encoding has several purposes such as high compression performance or fixed codestream size. Irreversible component transformation (ICT) and irreversible wavelet transformation (9-7I) shall be executed. Scalar quantization may be executed.

Function definition of Lossy based colour encoding is shown in Table 3.

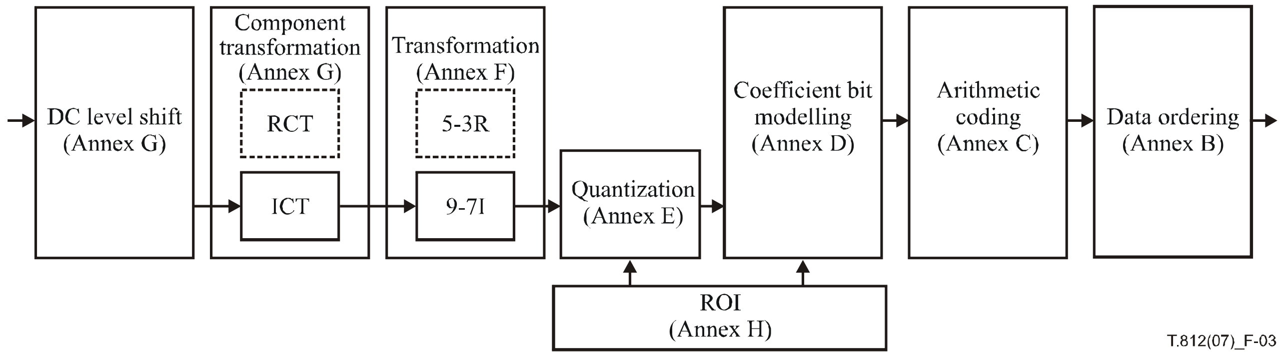

Figure 3 – Lossy based colour encoding block diagram

Table 3 – Function definition of lossy based colour encoding

Category	Item	Reference
DC level shifting and multiple component transformations	DC level shifting data	G.1
	ICT	G.3
Discrete wavelet transform	Wavelet transform (9-7I)	F.3
	Sub-sampling by discarding coefficients	F.4
	Visual frequency weighting	F.5
Quantization	Scalar quantization	E.2
Coefficient bit modelling	3-coding pass, 4-coding mode (EBCOT)	D.3
	Predictable termination	D.4
	Reset context probabilities on coding pass boundaries	D.4
	Termination on each coding pass	D.4
	Segmentation symbols	D.5
	Selective AC bypass	D.6
	Vertically causal context	D.7
Arithmetic entropy coding	MQ-Coder Encoding	C.2
Region of Interest	Max-shift	H.1, H.2

6.2.3 Lossless based greyscale encoding

Lossless based greyscale encoding process is shown in Figure 4. A basic concept of lossless based greyscale encoding is almost the same as lossless based colour encoding, but source image is changed colour to greyscale. Reversible wavelet transformation (5-3R) shall be executed. Component transformation and scalar quantization shall not be executed. It may be used in truncated codestream to provide lossy compression.

Function definition of lossless based greyscale encoding is shown in Table 4.

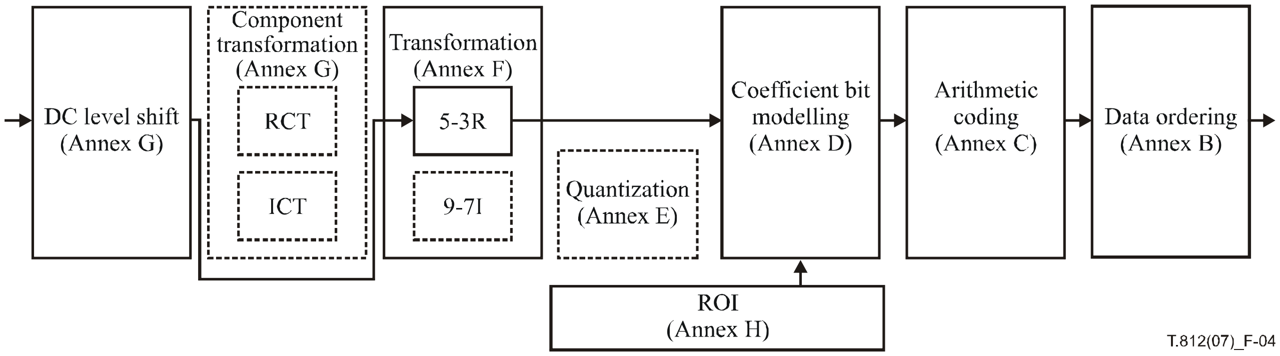

Figure 4 – Lossless based greyscale encoding block diagram

Table 4 – Function definition of lossless based greyscale encoding

Category	Item	Reference
DC level shifting and multiple component transformations	DC level shifting data	G.1
Discrete wavelet transform	Wavelet transform (5-3R)	F.3
	Visual frequency weighting	F.5
Coefficient bit modelling	3-coding pass, 4-coding mode (EBCOT)	D.3
	Predictable termination	D.4
	Reset context probabilities on coding pass boundaries	D.4
	Termination on each coding pass	D.4
	Segmentation symbols	D.5
	Selective AC bypass	D.6
	Vertically causal context	D.7
Arithmetic entropy coding	MQ-Coder Encoding	C.2
Region of Interest	Max-shift	H.1, H.2