

CONTENTS

	<i>Page</i>
1 Scope.....	1
2 References.....	1
2.1 Identical Recommendations   International Standards .....	1
2.2 Additional references .....	1
3 Definitions.....	2
4 Abbreviations and symbols .....	6
4.1 Abbreviations .....	6
4.2 Symbols.....	7
5 General description.....	8
5.1 Purpose.....	8
5.2 Codestream.....	8
5.3 Coding principles .....	8
6 Encoder requirements.....	10
7 Decoder requirements.....	10
7.1 Codestream syntax requirements.....	10
7.2 Optional file format requirements .....	11
8 Implementation requirements .....	11
Annex A – Codestream syntax .....	12
A.1 Markers, marker segments, and headers .....	12
A.2 Information in the marker segments.....	14
A.3 Construction of the codestream.....	15
A.4 Delimiting markers and marker segments.....	19
A.5 Fixed information marker segment .....	20
A.6 Functional marker segments.....	22
A.7 Pointer marker segments .....	32
A.8 In-bit-stream marker and marker segments .....	38
A.9 Informational marker segments.....	39
A.10 Codestream restrictions conforming to this Recommendation   International Standard .....	40
Annex B – Image and compressed image data ordering.....	42
B.1 Introduction to image data structure concepts.....	42
B.2 Component mapping to the reference grid .....	42
B.3 Image area division into tiles and tile-components .....	44
B.4 Example of the mapping of components to the reference grid (informative).....	45
B.5 Transformed tile-component division into resolution levels and sub-bands .....	48
B.6 Division of resolution levels into precincts .....	49
B.7 Division of the sub-bands into code-blocks .....	50
B.8 Layers.....	51
B.9 Packets .....	52
B.10 Packet header information coding.....	54
B.11 Tile and tile-parts .....	59
B.12 Progression order .....	59
Annex C – Arithmetic entropy coding.....	64
C.1 Binary encoding (informative).....	64
C.2 Description of the arithmetic encoder (informative).....	65
C.3 Arithmetic decoding procedure.....	76

	<i>Page</i>
Annex D – Coefficient bit modeling.....	84
D.1 Code-block scan pattern within code-blocks.....	84
D.2 Coefficient bits and significance.....	84
D.3 Decoding passes over the bit-planes.....	85
D.4 Initializing and terminating.....	89
D.5 Error resilience segmentation symbol.....	90
D.6 Selective arithmetic coding bypass.....	90
D.7 Vertically causal context formation.....	92
D.8 Flow diagram of the code-block coding.....	92
Annex E – Quantization.....	95
E.1 Inverse quantization procedure.....	95
E.2 Scalar coefficient quantization (informative).....	97
Annex F – Discrete wavelet transformation of tile-components.....	98
F.1 Tile-component parameters.....	98
F.2 Discrete wavelet transformations.....	98
F.3 Inverse discrete wavelet transformation.....	98
F.4 Forward transformation (informative).....	110
Annex G – DC level shifting and multiple component transformations.....	120
G.1 DC level shifting of tile-components.....	120
G.2 Reversible multiple component transformation (RCT).....	121
G.3 Irreversible multiple component transformation (ICT).....	121
G.4 Chrominance component sub-sampling and the reference grid.....	122
Annex H – Coding of images with regions of interest.....	123
H.1 Decoding of ROI.....	123
H.2 Description of the Maxshift method.....	123
H.3 Remarks on region of interest coding (informative).....	124
Annex I – JP2 file format syntax.....	127
I.1 File format scope.....	127
I.2 Introduction to the JP2 file format.....	127
I.3 Greyscale/Colour/Palettized/multi-component specification architecture.....	129
I.4 Box definition.....	131
I.5 Defined boxes.....	133
I.6 Adding intellectual property rights information in JP2.....	148
I.7 Adding vendor-specific information to the JP2 file format.....	148
I.8 Dealing with unknown boxes.....	150
Annex J – Examples and guidelines.....	151
J.1 Software conventions adaptive entropy decoder.....	151
J.2 Selection of quantization step sizes for irreversible transformations.....	153
J.3 Filter impulse responses corresponding to lifting-based irreversible filtering procedures.....	153
J.4 Example of discrete wavelet transformation.....	154
J.5 Row-based wavelet transform.....	158
J.6 Scan-based coding.....	167
J.7 Error resilience.....	167
J.8 Compatibility requirement with JFIF/SPIFF files.....	168
J.9 Implementing the Restricted ICC method outside of a full ICC colour management engine.....	168
J.10 An example of the interpretation of multiple components.....	173
J.11 An example of decoding showing intermediate steps.....	173
J.12 Visual frequency weighting.....	177
J.13 Encoder sub-sampling of components.....	179
J.14 Rate control.....	180
J.15 Guidelines on handling YCC codestream.....	184

	<i>Page</i>
Annex K – Bibliography.....	186
K.1 General.....	186
K.2 Quantization and entropy coding.....	186
K.3 Wavelet transformation.....	186
K.4 Region of interest coding.....	187
K.5 Visual frequency weighting.....	187
K.6 Error resilience.....	187
K.7 Scan-based coding.....	188
K.8 Colour.....	188
Annex L – Patent statement.....	189
Index.....	190

## LIST OF FIGURES

	<i>Page</i>
Figure 5-1 – Specification block diagram.....	9
Figure A.1 – Example of the marker segment description figures.....	13
Figure A.2 – Construction of the codestream .....	16
Figure A.3 – Construction of the main header.....	17
Figure A.4 – Construction of the first tile-part header of a given tile.....	18
Figure A.5 – Construction of a non-first tile-part header.....	18
Figure A.6 – Start of tile-part syntax .....	19
Figure A.7 – Image and tile size syntax.....	21
Figure A.8 – Coding style default syntax .....	23
Figure A.9 – Coding style parameter diagram of the SGcod and SPcod parameters.....	24
Figure A.10 – Coding style component syntax.....	26
Figure A.11 – Coding style parameter diagram of the SPcoc parameters .....	27
Figure A.12 – Region-of-interest syntax .....	27
Figure A.13 – Quantization default syntax .....	28
Figure A.14 – Quantization component syntax .....	30
Figure A.15 – Progression order change tile syntax .....	31
Figure A.16 – Tile-part lengths.....	32
Figure A.17 – Tile part length syntax .....	33
Figure A.18 – Packets length, main header syntax .....	34
Figure A.19 – Packet length, tile-part header syntax.....	35
Figure A.20 – Packed packet headers, main header syntax .....	36
Figure A.21 – Packed packed headers, tile-part header syntax.....	37
Figure A.22 – Start of packet syntax .....	38
Figure A.23 – Component registration syntax .....	39
Figure A.24 – Comment syntax.....	40
Figure B.1 – Reference grid diagram.....	43
Figure B.2 – Component sample locations on the reference grid for different XRsiz and YRsiz values .....	43
Figure B.3 – Example of upper left component sample locations .....	44
Figure B.4 – Tiling of the reference grid diagram .....	44
Figure B.5 – Reference grid example .....	46
Figure B.6 – Example tile sizes and locations for component 0.....	47
Figure B.7 – Example tile sizes and locations for component 1 .....	48
Figure B.8 – Precincts of one reduced resolution .....	49

	<i>Page</i>
Figure B.9 – Code-blocks and precincts in sub-band $b$ from four different tiles.....	51
Figure B.10 – Diagram of precincts of one resolution level of one component .....	52
Figure B.11 – Diagram of code-blocks within precincts at one resolution level .....	53
Figure B.12 – Example of a tag tree representation.....	54
Figure B.13 – Example of the information known to the encoder.....	57
Figure B.14 – Example of progression order volume in two dimensions.....	62
Figure B.15 – Example of the placement of POC marker segments.....	63
Figure C.1 – Arithmetic encoder inputs and outputs .....	64
Figure C.2 – Encoder for the MQ-coder.....	66
Figure C.3 – ENCODE procedure .....	67
Figure C.4 – CODE1 procedure .....	67
Figure C.5 – CODE0 procedure .....	68
Figure C.6 – CODELPS procedure with conditional MPS/LPS exchange.....	69
Figure C.7 – CODEMPS procedure with conditional MPS/LPS exchange.....	71
Figure C.8 – Encoder renormalization procedure.....	72
Figure C.9 – BYTEOUT procedure for encoder.....	73
Figure C.10 – Initialization of the encoder .....	74
Figure C.11 – FLUSH procedure.....	75
Figure C.12 – Setting the final bits in the C register.....	76
Figure C.13 – Arithmetic decoder inputs and outputs .....	76
Figure C.14 – Decoder for the MQ-coder.....	77
Figure C.15 – Decoding an MPS or an LPS .....	78
Figure C.16 – Decoder MPS path conditional exchange procedure .....	79
Figure C.17 – Decoder LPS path conditional exchange procedure .....	80
Figure C.18 – Decoder renormalization procedure.....	81
Figure C.19 – BYTEIN procedure for decoder.....	82
Figure C.20 – Initialization of the decoder .....	83
Figure D.1 – Example scan pattern of a code-block bit-plane.....	84
Figure D.2 – Neighbors states used to form the context.....	85
Figure D.3 – Flow chart for all coding passes on a code-block bit-plane.....	93
Figure F.1 – Inputs and outputs of the IDWT procedure.....	98
Figure F.2 – The IDWT ( $N_L = 2$ ).....	99
Figure F.3 – The IDWT procedure .....	100
Figure F.4 – Inputs and outputs of the 2D_SR procedure.....	100
Figure F.5 – One level of reconstruction from four sub-bands (2D_SR procedure) into sub-bands .....	100
Figure F.6 – The 2D_SR procedure.....	101
Figure F.7 – Parameters of 2D_INTERLEAVE procedure .....	101
Figure F.8 – The 2D_INTERLEAVE procedure.....	102

	<i>Page</i>
Figure F.9 – Inputs and outputs of the HOR_SR procedure .....	103
Figure F.10 – The HOR_SR procedure .....	104
Figure F.11 – Inputs and outputs of the VER_SR procedure .....	105
Figure F.12 – The VER_SR procedure.....	105
Figure F.13 – Parameters of the 1D_SR procedure .....	106
Figure F.14 – The 1D_SR procedure.....	106
Figure F.15 – Periodic symmetric extension of signal.....	106
Figure F.16 – Parameters of the ID_FILTR procedure.....	107
Figure F.17 – Inputs and outputs of the FDWT procedure .....	110
Figure F.18 – The FDWT ( $N_L = 2$ ).....	110
Figure F.19 – The FDWT procedure .....	111
Figure F.20 – Inputs and outputs of the 2D_SD procedure .....	111
Figure F.21 – One-level decomposition into four sub-bands (2D_SD procedure) .....	112
Figure F.22 – The 2D_SD procedure.....	112
Figure F.23 – Inputs and outputs of the VER_SD procedure .....	112
Figure F.24 – The VER_SD procedure.....	113
Figure F.25 – Inputs and outputs of the HOR_SD procedure.....	114
Figure F.26 – The HOR_SD procedure .....	114
Figure F.27 – Parameters of 2D_DEINTERLEAVE procedure.....	115
Figure F.28 – The 2D_DEINTERLEAVE procedure.....	116
Figure F.29 – Parameters of the 1D_SD procedure.....	117
Figure F.30 – The 1D_SD procedure.....	117
Figure F.31 – Parameters of the 1D_FILTD procedure.....	118
Figure G.1 – Placement of the DC level shifting with component transformation.....	120
Figure G.2 – Placement of the DC level shifting without component transformation.....	120
Figure H.1 – The inverse wavelet transformation with the 5-3 reversible filter .....	125
Figure H.2 – The inverse wavelet transformation with the 9-7 irreversible filter.....	125
Figure I.1 – Conceptual structure of a JP2 file .....	128
Figure I.2 – Example of the box description figures.....	131
Figure I.3 – Example of the superbox description figures.....	131
Figure I.4 – Organization of a box.....	131
Figure I.5 – Illustration of box lengths .....	132
Figure I.6 – Organization of the contents of a File Type box .....	134
Figure I.7 – Organization of the contents of a JP2 Header box .....	135
Figure I.8 – Organization of the contents of an Image Header box .....	136
Figure I.9 – Organization of the contents of a Bits Per Component box .....	137
Figure I.10 – Organization of the contents of a Colour Specification box .....	138
Figure I.11 – Organization of the contents of the Palette box .....	140

	<i>Page</i>
Figure I.12 – Organization of the contents of a Component Mapping box.....	141
Figure I.13 – Organization of the contents of a Channel Definition box.....	142
Figure I.14 – Organization of the contents of the Resolution box.....	145
Figure I.15 – Organization of the contents of the Capture Resolution box.....	145
Figure I.16 – Organization of the contents of the Default Display Resolution box.....	146
Figure I.17 – Organization of the contents of the Contiguous Codestream box.....	147
Figure I.18 – Organization of the contents of the XML box.....	148
Figure I.19 – Organization of the contents of the UUID box.....	148
Figure I.20 – Organization of the contents of a UUID Info box.....	149
Figure I.21 – Organization of the contents of a UUID List box.....	149
Figure I.22 – Organization of the contents of a Data Entry URL box.....	150
Figure J.1 – Initialization of the software-conventions decoder.....	151
Figure J.2 – Decoding an MPS or an LPS in the software-conventions decoder.....	152
Figure J.3 – Inserting a new byte into the C register in the software-conventions decoder.....	152
Figure J.4 – The FDWT_ROW procedure.....	159
Figure J.5 – The GET_ROW procedure.....	160
Figure J.6 – The INIT procedure.....	161
Figure J.7 – The START_VERT procedure.....	162
Figure J.8 – The RB_VERT_1 procedure.....	163
Figure J.9 – The RB_VERT_2 procedure.....	164
Figure J.10 – The END_1 procedure.....	165
Figure J.11 – The END_2 procedure.....	166
Figure J.12 – Illustration of code-block contributions to bit-stream layers.....	181
Figure J.13 – 4:2:2 format (co-sited).....	184
Figure J.14 – 4:2:2 format (centered).....	184
Figure J.15 – 4:2:0 format (co-sited).....	185
Figure J.16 – 4:2:0 format (centered).....	185

## LIST OF TABLES

	<i>Page</i>
Table A.1 – Marker definitions.....	13
Table A.2 – List of markers and marker segments .....	14
Table A.3 – Information in the marker segments .....	15
Table A.4 – Start of codestream parameter values .....	19
Table A.5 – Start of tile-part parameter values .....	20
Table A.6 – Number of tile-parts, TNsot, parameter value .....	20
Table A.7 – Start of data parameter values .....	20
Table A.8 – End of codestream parameter values .....	20
Table A.9 – Image and tile size parameter values .....	22
Table A.10 – Capability Rsiz parameter.....	22
Table A.11 – Component Ssiz parameter .....	22
Table A.12 – Coding style default parameter values .....	23
Table A.13 – Coding style parameter values for the Scod parameter .....	24
Table A.14 – Coding style parameter values of the SGcod parameter .....	24
Table A.15 – Coding style parameter values of the SPcod and SPcoc parameters.....	24
Table A.16 – Progression order for the SGcod, SPcoc, and Ppoc parameters.....	25
Table A.17 – Multiple component transformation for the SGcod parameters.....	25
Table A.18 – Width or height exponent of the code-blocks for the SPcod and SPcoc parameters.....	25
Table A.19 – Code-block style for the SPcod and SPcoc parameters.....	25
Table A.20 – Transformation for the SPcod and SPcoc parameters.....	26
Table A.21 – Precinct width and height for the SPcod and SPcoc parameters.....	26
Table A.22 – Coding style component parameter values .....	27
Table A.23 – Coding style parameter values for the Scoc parameter .....	27
Table A.24 – Region-of-interest parameter values .....	28
Table A.25 – Region-of-interest parameter values for the Srgn parameter .....	28
Table A.26 – Region-of-interest values from SPRgn parameter (Srgn = 0) .....	28
Table A.27 – Quantization default parameter values.....	29
Table A.28 – Quantization default values for the Sqcd and Sqcc parameters .....	29
Table A.29 – Reversible step size values for the SPqcd and SPqcc parameters (reversible transform only) .....	29
Table A.30 – Quantization values for the SPqcd and SPqcc parameters (irreversible transformation only).....	30
Table A.31 – Quantization component parameter values .....	31
Table A.32 – Progression order change, tile parameter values.....	32
Table A.33 – Tile-part length parameter values .....	33

	<i>Page</i>
Table A.34 – Size parameters for Stlm.....	34
Table A.35 – Packets length, main header parameter values.....	35
Table A.36 – Iplm, Iplt list of packet lengths .....	35
Table A.37 – Packet length, tile-part headers parameter values .....	36
Table A.38 – Packed packet headers, main header parameter values.....	37
Table A.39 – Packet header, tile-part headers parameter values .....	37
Table A.40 – Start of packet parameter values .....	38
Table A.41 – End of packet header parameter values.....	39
Table A.42 – Component registration parameter values.....	39
Table A.43 – Comment parameter values.....	40
Table A.44 – Registration values for the Rcom parameter.....	40
Table A.45 – Codestream restrictions.....	41
Table B.1 – Quantities $(x_{o_b}, y_{o_b})$ for sub-band $b$ .....	49
Table B.2 – Example of layer formation (only one component shown).....	52
Table B.3 – Example of packet formation.....	53
Table B.4 – Codewords for the number of coding passes for each code-block.....	56
Table B.5 – Example packet header bit stream.....	58
Table C.1 – Encoder register structures.....	66
Table C.2 – $Q_e$ values and probability estimation.....	69
Table C.2 – $Q_e$ values and probability estimation ( <i>concluded</i> ).....	70
Table C.3 – Decoder register structures.....	77
Table D.1 – Contexts for the significance propagation and cleanup coding passes.....	86
Table D.2 – Contributions of the vertical (and the horizontal) neighbors to the sign context .....	86
Table D.3 – Sign contexts from the vertical and horizontal contributions .....	87
Table D.4 – Contexts for the magnitude refinement coding passes.....	87
Table D.5 – Run-length decoder for cleanup passes.....	88
Table D.6 – Example of sub-bit-plane coding order and significance propagation.....	88
Table D.7 – Initial states for all contexts .....	89
Table D.8 – Arithmetic coder termination patterns .....	89
Table D.9 – Selective arithmetic coding bypass .....	91
Table D.10 – Decisions in the context model flow chart.....	94
Table D.11 – Decoding in the context model flow chart.....	94
Table E.1 – Sub-band gains .....	96
Table F.1 – Decomposition level $n_b$ for sub-band $b$ .....	99
Table F.2 – Extension to the left.....	107
Table F.3 – Extension to the right.....	107
Table F.4 – Definition of lifting parameters for the 9-7 irreversible filter.....	109
Table F.5 – Definition of coefficients $g_n$ .....	109

Table F.6 – Intermediate expressions ( $r_0, r_1, s_0, t_0$ ).....	109
Table F.7 – Intermediate expressions .....	110
Table F.8 – Extension to the left.....	117
Table F.9 – Extension to the right.....	118
Table I.1 – Binary structure of a box .....	132
Table I.2 – Defined boxes.....	133
Table I.3 – Legal Brand values.....	134
Table I.4 – Format of the contents of the File Type box.....	135
Table I.5 – Format of the contents of the Image Header box .....	137
Table I.6 – BPC values .....	137
Table I.7 – Format of the contents of the Bits Per Component box.....	138
Table I.8 – BPC <sup>i</sup> values .....	138
Table I.9 – Legal METH values .....	139
Table I.10 – Legal EnumCS values .....	139
Table I.11 – Format of the contents of the Colour Specification box.....	140
Table I.12 – Format of the contents of the Palette box .....	141
Table I.13 – B <sup>i</sup> values .....	141
Table I.14 – MTYP <sup>i</sup> field values.....	142
Table I.15 – Format of the contents of the Component Mapping box .....	142
Table I.16 – Typ <sup>i</sup> field values .....	143
Table I.17 – Assoc <sup>i</sup> field values .....	143
Table I.18 – Colours indicated by the Assoc <sup>i</sup> field.....	144
Table I.19 – Format of the Channel Definition box.....	145
Table I.20 – Format of the contents of the Capture Resolution box .....	146
Table I.21 – Format of the contents of the Default Display Resolution box .....	147
Table I.22 – Format of the contents of the Contiguous Codestream box.....	147
Table I.23 – Format of the contents of a UUID box.....	149
Table I.24 – UUID List box contents data structure values.....	149
Table I.25 – Data Entry URL box contents data structure values.....	150
Table J.1 – Definition of impulse responses for the 9-7 irreversible analysis filter bank.....	153
Table J.2 – Definition of impulse responses for the 9-7 irreversible synthesis filter band .....	154
Table J.3 – Source tile component samples .....	154
Table J.4 – 2LL sub-band coefficients (9-7 irreversible wavelet transformation).....	155
Table J.5 – 2HL sub-band coefficients (9-7 irreversible wavelet transformation).....	155
Table J.6 – 2LH sub-band coefficients (9-7 irreversible wavelet transformation).....	155
Table J.7 – 2HH sub-band coefficients (9-7 irreversible wavelet transformation) .....	155
Table J.8 – 1HL sub-band coefficients (9-7 irreversible wavelet transformation).....	155
Table J.9 – 1LH sub-band coefficients (9-7 irreversible wavelet transformation).....	156

	<i>Page</i>
Table J.10 – 1HH sub-band coefficients (9-7 irreversible wavelet transformation) .....	156
Table J.11 – 2LL sub-band coefficients (5-3 reversible wavelet transformation) .....	156
Table J.12 – 2HL sub-band coefficients (5-3 reversible wavelet transformation) .....	156
Table J.13 – 2LH sub-band coefficient (5-3 reversible wavelet transformation) .....	157
Table J.14 – 2HH sub-band coefficients (5-3 reversible wavelet transformation) .....	157
Table J.15 – 1HL sub-band coefficients (5-3 reversible wavelet transformation) .....	157
Table J.16 – 1LH sub-band coefficients (5-3 reversible wavelet transformation) .....	157
Table J.17 – 1HH sub-band coefficients (5-3 reversible wavelet transformation) .....	158
Table J.18 – Error resilience tools .....	167
Table J.19 – Processing tags used by a Restricted ICC profile .....	169
Table J.20 – Decoding first packet header .....	175
Table J.21 – Decoding second packet header .....	175
Table J.22 – Arithmetic decode of first code-block .....	176
Table J.23 – Arithmetic decode of second code-block .....	177
Table J.24 – Recommended frequency weighting .....	179
Table J.25 – Recommended frequency weighting for multiple component (colour) images .....	179
Table J.26 – CRG (Component registration) values .....	185
Table L.1 – Received intellectual property rights statements .....	189