

ISO/IEC 15444-2:2021-11 (E)

Information technology - JPEG 2000 image coding system - Part 2: Extensions

CONTENTS		<i>Page</i>
1	Scope	1
2	Normative references.....	1
2.1	Identical Recommendations International Standards.....	1
2.2	Paired Recommendations International Standards	1
2.3	Additional references.....	2
3	Definitions.....	2
4	Abbreviations	4
5	Conventions	4
6	General description.....	4
6.1	Extensions specified by this Recommendation International Standard	5
6.2	Relation between extensions	6
Annex A	Compressed data syntax, extension.....	8
A.1	Extended capabilities	8
A.2	Extensions to Rec. ITU-T T.800 ISO/IEC 15444-1 marker segment parameters.....	8
A.3	Extended marker segments	14
Annex B	Variable DC offset, extension	34
B.1	Variable DC offset flow	34
B.2	Inverse DC offset.....	34
B.3	Forward DC offset (informative)	34
Annex C	Variable scalar quantization, extension	36
C.1	Variable scalar quantization	36
C.2	Variable scalar dequantization for irreversible filters	36
C.3	Variable scalar quantization for irreversible filters (informative).....	36
Annex D	Trellis coded quantization extensions.....	38
D.1	Introduction to TCQ	38
D.2	Sequence definition	39
D.3	Forward TCQ quantization (informative).....	40
D.4	Inverse quantization (normative).....	41
D.5	Lagrangian rate allocation (informative)	44
Annex E	Visual masking, extensions	49
E.1	Introduction to visual masking (informative)	49
E.2	Point-wise extended non-linearity (informative)	49
E.3	Decoding with visual masking	51
E.4	Encoding with visual masking (informative).....	52
E.5	Setting parameters (informative).....	52
E.6	Compatibility with other technologies (informative)	52
Annex F	Arbitrary decomposition of tile-components, extensions.....	53
F.1	Wavelet sub-bands.....	53
F.2	Equation, text and decomposition updates.....	54
F.3	Inverse discrete wavelet transformation for general decompositions	63
F.4	Forward discrete wavelet transformation for general decompositions (informative)	70
Annex G	Whole-sample symmetric transformation of images, extensions.....	77
G.1	Wavelet transformation parameters, definitions and normalizations	77
G.2	Whole-sample symmetric (WS) wavelet transformations reconstruction	77
G.3	Whole-sample symmetric (WS) wavelet transformation decomposition (informative)	80
G.4	Examples of WS wavelet transformations (informative)	82
Annex H	Transformation of images using arbitrary wavelet transformations	85
H.1	Wavelet transformation parameters and normalizations	85
H.2	Arbitrary (ARB) wavelet transformation reconstruction procedures	86
H.3	Arbitrary (ARB) wavelet transformation decomposition procedures (informative).....	91
H.4	Examples of ARB wavelet transformations (informative)	94

	<i>Page</i>
Annex I – Single sample overlap discrete wavelet transform, extensions	98
I.1 Introduction to single sample overlapping.....	98
I.2 The code-block anchor points (CBAP) extension.....	98
I.3 The SSO extension	101
I.4 The TSSO extension.....	109
I.5 Combining the SSO and TSSO extensions (informative)	111
Annex J – Multiple component transformations, extension	112
J.1 Introduction to multiple component transformation concepts	112
J.2 Overview of inverse processing	112
J.3 Transformations.....	118
Annex K – Non-linear transformation.....	128
K.1 Signalling the use of the non-linear transformations.....	128
K.2 Non-linear transformation specifications.....	129
Annex L – Region of interest coding and extraction, extensions	133
L.1 Decoding of ROI	133
L.2 Description of the Scaling based method.....	133
L.3 Region of interest mask generation	134
L.4 Remarks on region of interest coding.....	138
Annex M – JPX extended file format syntax.....	139
M.1 File format scope	139
M.2 Introduction to JPX.....	139
M.3 Greyscale/Colour/Palette/multi-component specification architecture	142
M.4 Fragmenting the codestream between one or more files	143
M.5 Combining multiple codestreams.....	145
M.6 Using reader requirements masks to determine how a file can be used	149
M.7 Extensions to the JPX file format.....	156
M.8 Differences from the JP2 binary definition.....	157
M.9 Conformance	157
M.10 Key to graphical descriptions (informative)	161
M.11 Defined boxes.....	161
M.12 Dealing with unknown boxes.....	210
M.13 Using the JPX file format in conjunction with other multi-media standards (informative).....	211
M.14 Decomposing an XML document into multiple boxes.....	211
Annex N – JPX file format extended metadata definition and syntax	213
N.1 Introduction to extended metadata	213
N.2 Additional references for extended metadata.....	213
N.3 Scope of metadata definitions	213
N.4 Metadata syntax.....	214
N.5 Defined boxes.....	215
N.6 Metadata definitions	217
N.7 Fundamental type and element definitions	246
N.8 JPX extended metadata document type definition	264
N.9 JPX extended metadata XML Schema	275
Annex O – Examples and guidelines, extensions	293
O.1 Arbitrary decomposition examples.....	293
O.2 Odd Tile Low Pass First (OTLPPF) convention.....	314
O.3 Multiple component collection example.....	315
O.4 Background to enhancement of quantization.....	325
O.5 Wrapping JPEG XR (Rec. ITU-T T.832 ISO/IEC 29199-2) Codestreams by the JPX file format ...	326
O.6 Representing floating point numbers within JPEG 2000.....	328
O.7 Working with ROI Description boxes	329

	<i>Page</i>
Annex P – Block coder extensions.....	331
P.1 Selective arithmetic coding bypass (lazy mode).....	331
P.2 Enhancement of selective arithmetic coding bypass (fast mode).....	331
Bibliography	333

List of Tables

Table A.1 – Syntax support for extensions.....	8
Table A.2 – Capability Rsiz parameter, extended.....	9
Table A.3 – Start of tile-part parameter values, extended.....	9
Table A.4 – Number of tile-parts, TNsot, parameter value, extended.....	9
Table A.5 – Coding style parameter values for the Scod parameter.....	10
Table A.6 – Coding style parameter values of the SGcod parameter.....	10
Table A.7 – Coding style parameter values of the SPcod and SPcoc parameters, extended.....	11
Table A.8 – Multiple component transformation for the SGcod parameters.....	11
Table A.9 – Decomposition for the SPcod and SPcoc parameters, extended.....	11
Table A.10 – Transformation for the SPcod and SPcoc parameters, extended.....	11
Table A.11 – SSO parameters, extended.....	12
Table A.11bis – SXcod parameter.....	12
Table A.12 – Quantization default values for the Sqcd, Sqcc, Sqpd, and Sqpc parameters, extended.....	13
Table A.13 – Quantization values (irreversible transformation only), extended.....	13
Table A.14 – SPqcd, SPqcc, SPqpd, and SPqpc parameters (irreversible transformation only), extended.....	13
Table A.15 – SPqcd, SPqcc, SPqpd, and SPqpc parameters (irreversible transformation only), extended.....	14
Table A.16 – Region-of-interest parameter values for the Srgn parameter.....	14
Table A.17 – Component index parameter value for the Crgn parameter.....	14
Table A.18 – Region-of-interest values from SPRgn parameter (Srgn = 1 or Srgn = 2).....	14
Table A.19 – List of markers and marker segments.....	15
Table A.20 – Variable DC offset parameter values.....	16
Table A.21 – Variable DC offset parameter values for the Sdco parameter.....	16
Table A.22 – Visual masking parameter values.....	17
Table A.23 – Component parameter value for the Cvms parameter.....	17
Table A.24 – Visual masking for the Svms parameters.....	17
Table A.25 – Downsampling factor styles parameter values.....	18
Table A.26 – Arbitrary decomposition styles parameter values.....	19
Table A.27 – Arbitrary transformation parameter values.....	20
Table A.28 – Arbitrary transformation values for the Satk parameter.....	21
Table A.29 – Component bit depth definition parameter values.....	22
Table A.30 – Component bit depth definition values for the Ncbd parameter.....	22
Table A.31 – Component bit depth definition values for the BDcbd ⁱ parameter.....	22
Table A.32 – Multiple component transformation definition parameter values.....	23
Table A.33 – Multiple component transformation definition values for the Imct parameter.....	23
Table A.34 – Multiple component collection parameter values.....	25
Table A.35 – Multiple component collection values for the Xmcc ⁱ parameter.....	25
Table A.36 – Multiple component collection values for the Nmcc ⁱ parameter.....	25
Table A.37 – Multiple component collection values for the Mmcc ⁱ parameter.....	25

Table A.38 – Multiple component collection values for the $Tmcc^i$ parameter (array-based).....	26
Table A.39 – Multiple component collection values for the $Tmcc^i$ parameter (wavelet-based).....	26
Table A.40 – Multiple component intermediate collection parameter values.....	27
Table A.41 – Non-linearity transformation parameter values.....	28
Table A.42 – Non-linearity transformation parameter values for the $Cnlt$ parameter.....	28
Table A.43 – Decoded image component bit depth parameter values for the $BDnlt$ parameter.....	28
Table A.44 – Non-linearity transformation parameter values of the $Tnlt$ parameter.....	28
Table A.45 – Non-linearity transformation parameter values of the $STnlt$ parameter ($Tnlt = 1$).....	29
Table A.46 – Non-linearity transformation parameter values of the $STnlt$ parameter ($Tnlt = 2$).....	29
Table A.47 – Quantization default, precinct parameter values.....	30
Table A.48 – Quantization precinct component parameter values.....	32
Table A.49 – $Ccap^2$ syntax and semantics.....	32
Table A.50 – Precinct length, tile-part header parameter values.....	33
Table A.51 – $Srlt$ values and semantics.....	33
Table A.52 – Semantics of $Jrlt^i$ values when $Srlt$ is in the range $[0, 2^{31} - 1]$	33
Table D.1 – Parent LUTs for $k > 0$ in the trellis of Figure D.3.....	41
Table D.2 – Description of functional blocks in Figure D.4.....	41
Table D.3 – Description of functional blocks in Figure D.5.....	42
Table D.4 – Look-up table for $A(s)$	43
Table D.5 – Look-up table for $S(s, qk)$	43
Table D.6 – Description of functional blocks for Figure D.6.....	44
Table D.7 – Sub-band statistics required for LRA.....	45
Table D.8 – ρ_b parameters for TCQ.....	45
Table D.9 – Δ_b parameters for TCQ.....	45
Table D.10 – ρ_b parameters for SQ.....	46
Table D.11 – Δ_b parameters for SQ.....	46
Table D.12 – Description of functional blocks in Figure D.7.....	48
Table F.1 – Updates to contexts for significance propagation and cleanup coding passes.....	55
Table F.2 – Quantities for sub-band info calculation.....	59
Table F.3 – $S(a_b)$ and $J(a_b)$ as a function of $d_S(i)$	63
Table F.4 – $S(a_b)$ and $J(a_b)$ as a function of $d_R(i)$	63
Table F.5 – Characteristics for sample wavelet decomposition in Figure F.14.....	64
Table G.1 – Parameters for wavelet transformations.....	77
Table G.2 – Parameters of the 5-3 reversible wavelet transformation.....	82
Table G.3 – Parameters of the 13-7 reversible wavelet transformation.....	83
Table G.4 – Parameters of the 5-3 irreversible wavelet transformation.....	83
Table G.5 – Parameters of the irreversible 7-5 wavelet transformation.....	84
Table G.6 – Parameters of the irreversible 9-7 wavelet transformation.....	84
Table H.1 – Additional parameters for arbitrary wavelet transformations.....	85
Table H.2 – Minimum left extension length.....	89
Table H.3 – Minimum right extension length.....	89
Table H.4 – Parameters of the reversible Haar 2-2 wavelet transformation.....	95
Table H.5 – Parameters of the reversible 2-6 wavelet transformation.....	95

Table H.6 – Parameters of the reversible 2-10 wavelet transformation	95
Table H.7 – Parameters of the irreversible 6-10 wavelet transformation.....	96
Table H.8 – Parameters of the irreversible 10-18 wavelet transformation.....	96
Table M.1 – Example expression	151
Table M.2 – Expanded expression	151
Table M.3 – Example factored expression	151
Table M.4 – Example of a Reader Requirements expressions for Equations M-6 and M-7	153
Table M.5 – Example of a Reader Requirements box for Equations M-6 and M-7	153
Table M.6 – Reader Requirements table for Equations M-10 and M-11	154
Table M.7 – Reader Requirements box data for Equations M-10 and M-11	154
Table M.8 – Reader Requirements box data for Equations M-16 and M-17	155
Table M.9 – Example Reader Requirements box to test	155
Table M.11 – Items which can be extended through Recommendations International Standards	156
Table M.12 – Items which can be extended by registration	157
Table M.13 – Boxes defined within this Recommendation International Standard	163
Table M.14 – Legal values of the SF ⁱ field	165
Table M.15 – Format of the contents of the Reader Requirements box.....	167
Table M.16 – Format of the contents of the Data Reference box	168
Table M.17 – Format of the contents of the Fragment List box	169
Table M.18 – Format of the contents of the Cross-Reference box	170
Table M.19 – Legal C values	171
Table M.20 – BPC and BPC ⁱ parameters	172
Table M.21 – Format of the contents of the Image Header box	172
Table M.22 – Legal METH values.....	176
Table M.23 – Legal APPROX values	177
Table M.24 – Format of the contents of the Colour Specification box.....	177
Table M.24bis – Nominal maximum sample values.....	177
Table M.25 – Additional legal EnumCS values	178
Table M.26 – Format of the contents of the METHDAT field for the Enumerated method.....	179
Table M.27 – Format of the contents of the METHDAT field for the Any ICC method	180
Table M.28 – Format of the contents of the METHDAT field for the Vendor Colour method.....	180
Table M.28bis – Format of the METHDAT field for the Parameterized method	181
Table M.29 – Standard illuminant values for CIELab	182
Table M.30 – Format of the contents of the EP field for CIELab (EnumCS = 14).....	183
Table M.30bis – Default Offset Values and Encoding of Offsets for the CIEJab Colourspace.....	184
Table M.31 – Format of the contents of the EP field for CIEJab (EnumCS = 19).....	184
Table M.32 – Colours indicated by the Assoc ⁱ field	185
Table M.33 – Otyp field values	186
Table M.34 – Format of the contents of the Opacity box.....	186
Table M.35 – Format of the contents of the Codestream Registration box.....	188
Table M.35bis	189
Table M.35ter – Common floating point formats (informative).....	189
Table M.36 – Format of the contents of the Composition box.....	190
Table M.37 – Format of the contents of the Composition Options box.....	191
Table M.38 – Ityp field values	191

Table M.39 – Format of the contents of the Instruction Set box	192
Table M.40 – Format of the contents of the INST ⁱ parameter in the Instruction Set box.....	194
Table M.41 – Format of the contents of the Association box.....	196
Table M.42 – AN ⁱ field values.....	196
Table M.43 – Format of the contents of the Number List box	196
Table M.44 – Legal Filter types.....	197
Table M.45 – Format of the contents of the Binary Filter box	198
Table M.46 – Format of the contents of the Graphics Technology Standard Output box	199
Table M.47 – Legal R ⁱ values.....	199
Table M.48 – Allowed Rtyp ⁱ values.....	200
Table M.49 – Format of the contents of the ROI Description box	200
Table M.49bis – Interpreting the 2 bit D field of Rtyp ⁱ for quadrilateral refinements.....	201
Table M.50 – Legal Styp values	202
Table M.51 – Legal Ptyp values	203
Table M.52 – Format of the contents of the Digital Signature box	203
Table N.1 – Format of the contents of the Image Creation box.....	215
Table N.2 – Format of the contents of the Content Description box	216
Table N.3 – Format of the contents of the History box.....	216
Table N.4 – Format of the contents of the Intellectual Property Rights box.....	217
Table N.5 – Format of the contents of the Image Identifier box	217
Table N.6 – Image Source values.....	218
Table N.7 – Scene type values	218
Table N.8 – Sensor technology values	220
Table N.9 – Exposure program values	224
Table N.10 – Metering mode values	225
Table N.11 – Scene illuminant values.....	225
Table N.12 – Back light values.....	225
Table N.13 – Auto focus values.....	226
Table N.14 – Name description values.....	241
Table N.15 – Date description values.....	242
Table N.16 – Additional name description values	245
Table N.17 – Address component type values.....	249
Table N.18 – Address type values.....	250
Table N.19 – Phone number type values.....	250
Table N.20 – Name component type values	253
Table N.21 – Latitude reference values.....	258
Table N.22 – Latitude values	258
Table N.23 – Longitude reference values.....	258
Table N.24 – Longitude values	258
Table N.25 – GPS Status values	259
Table N.26 – GPS Measure mode values	259
Table N.27 – GPS Speed reference unit values	259
Table N.28 – Direction reference values	259
Table N.29 – GPS Destination distance reference unit values	260

	<i>Page</i>
Table O.1 – Sub-band labels for Figure O.15.....	298
Table O.2 – Mapping between ROT and SPATIAL_XFRM_SUBORDINATE.....	328
Table P.1 – Selective arithmetic coding bypass (default); (the same as Table D.9 of ITU-T T.800 ISO/IEC 15444-1).....	331
Table P.2 – Example of two bit planes (fast mode).....	332

List of Figures

Figure 6-1 – Decoder block diagram.....	7
Figure A.1bis – Coding style default syntax.....	10
Figure A.1 – Variable DC offset syntax.....	15
Figure A.2 – Visual masking syntax.....	16
Figure A.3 – Downsampling factor styles syntax.....	17
Figure A.4 – Arbitrary decomposition styles syntax.....	18
Figure A.5 – Arbitrary transformation default syntax.....	19
Figure A.6 – Component bit depth definition syntax.....	21
Figure A.7 – Multiple component transformation definition syntax.....	22
Figure A.8 – Multiple component collection syntax.....	24
Figure A.9 – Multiple component transform ordering syntax.....	26
Figure A.10 – Non-linearity point transformation syntax.....	27
Figure A.11 – Quantization default, precinct syntax.....	29
Figure A.12 – Quantization precinct component syntax.....	31
Figure A.13 – Precinct length, tile-part header syntax.....	32
Figure B.1 – Placement of the DC offset with multiple component transformation.....	34
Figure B.2 – Placement of the DC offset without multiple component transformation.....	34
Figure D.1 – Scalar quantizers used for TCQ.....	38
Figure D.2 – Union quantizers for TCQ.....	39
Figure D.3 – Trellis showing node indices.....	39
Figure D.4 – Forward TCQ processing.....	40
Figure D.5 – Full inverse processing for TCQ indices.....	42
Figure D.6 – Approximate dequantization of TCQ indices.....	44
Figure D.7 – Lagrangian rate allocation.....	47
Figure E.1 – System diagram for point-wise extended masking extension.....	49
Figure E.2 – Non-uniform quantization for self-contrast masking.....	50
Figure E.3 – Causal neighbourhood.....	51
Figure F.1 – Possible splits of sub-bands.....	54
Figure F.2 – Parameters for the GET_HOR_DEPTH and GET_VER_DEPTH procedures.....	55
Figure F.3 – The GET_HOR_DEPTH and GET_VER_DEPTH procedures.....	56
Figure F.4 – Parameters for the SET_SUBBAND_INFO procedure.....	57
Figure F.5 – The SET_SUBBAND_INFO procedure.....	57
Figure F.6 – Parameters for the RECUR_INFO procedure.....	58
Figure F.7 – The RECUR_INFO procedure.....	58
Figure F.8 – Parameters for the INIT_0 procedure.....	59
Figure F.9 – Procedure for setting maximum number of sub-levels, $\theta(lev)$	60
Figure F.10 – Parameters for the INIT_S_R procedure.....	60
Figure F.11 – Upper level procedure for defining $S(ab)$ and $R(lev)$	61

Figure F.12 – Parameters for the LEV_S procedure.....	62
Figure F.13 – Procedure for defining $S(a_b)$	62
Figure F.14 – Sample wavelet decomposition with labelled sub-bands	63
Figure F.15 – Parameters for the MOD_IDWT procedure.....	64
Figure F.16 – The MOD_IDWT procedure.....	65
Figure F.17 – Parameters for the MOD_2D_SR procedure	65
Figure F.18 – The MOD_2D_SR procedure	66
Figure F.19 – Parameters for the MOD_2D_INTERLEAVE procedure	66
Figure F.20 – The MOD_2D_INTERLEAVE procedure	67
Figure F.21 – Parameters for the 2D_HV_INTERLEAVE procedure	67
Figure F.22 – The 2D_HV_INTERLEAVE procedure.....	68
Figure F.23 – Parameters for the 2D_H_INTERLEAVE procedure	69
Figure F.24 – The 2D_H_INTERLEAVE procedure	69
Figure F.25 – Parameters for the 2D_V_INTERLEAVE procedure	70
Figure F.26 – The 2D_V_INTERLEAVE procedure	70
Figure F.27 – Parameters for the MOD_FDWT procedure.....	70
Figure F.28 – The MOD_FDWT procedure.....	71
Figure F.29 – Parameters for the MOD_2D_SD procedure	71
Figure F.30 – The MOD_2D_SD procedure	72
Figure F.31 – Parameters for the MOD_2D_DEINTERLEAVE procedure.....	72
Figure F.32 – The MOD_2D_DEINTERLEAVE procedure	73
Figure F.33 – Parameters for the 2D_HV_DEINTERLEAVE procedure	73
Figure F.34 – The 2D_HV_DEINTERLEAVE procedure.....	74
Figure F.35 – Parameters for the 2D_H_DEINTERLEAVE procedure	75
Figure F.36 – The 2D_H_DEINTERLEAVE procedure	75
Figure F.37 – Parameters for the 2D_V_DEINTERLEAVE procedure	75
Figure F.38 – The 2D_V_DEINTERLEAVE procedure	76
Figure G.1 – Parameters of the 1D_SR_WS procedures.....	78
Figure G.2 – The 1D_SR_WS procedure.....	79
Figure G.3 – Parameters of the 1D_FILTR_WS procedure	79
Figure G.4 – Parameters of the 1D_FILTR_WS procedure	80
Figure G.5 – Parameters of the 1D_SD_WS procedure.....	80
Figure G.6 – The 1D_SD_WS procedure.....	81
Figure G.7 – Parameters of the 1D_FILTD_WS procedure.....	81
Figure G.8 – Parameters of the 1D_FILTD_WS procedure.....	82
Figure H.1 – Parameters of the extended 1D_SR_ARB procedure	86
Figure H.2 – Extended procedure 1D_SR_ARB	87
Figure H.3 – Parameters of the 1D_SCALER procedure.....	87
Figure H.4 – Parameters of the 1D_STEPR procedure.....	88
Figure H.5 – Procedure 1D_STEPR.....	88
Figure H.6 – Parameters of the 1D_EXT_WS procedure	89
Figure H.7 – Parameters of the 1D_EXT_CON procedure	89
Figure H.8 – Parameters of the 1D_UPDATER_REV procedure	90
Figure H.9 – Parameters of the 1D_UPDATER_IRR procedure	90
Figure H.10 – Parameters of the extended 1D_SD_ARB procedure.....	91

Figure H.11 – Extended procedure 1D_SD_ARB	92
Figure H.12 – Parameters of the 1D_STEPD procedure.....	92
Figure H.13 – Procedure 1D_STEPD	93
Figure H.14 – Parameters of the 1D_UPDATED_REV procedure.....	93
Figure H.15 – Parameters of the 1D_UPDATED_IRR procedure	94
Figure H.16 – Parameters of the 1D_SCALED procedure.....	94
Figure H.17 – Lifting implementation for forward half-sample symmetric wavelet transformations.....	97
Figure I.1 – Precincts of one reduced resolution (modified Figure B.8 of Rec. ITU-T T.800 (2019/06) ISO/IEC 15444-1:2019).....	98
Figure I.2 – Codeblocks and precincts in sub-band b from four different tiles.....	100
Figure I.3 – The IDWT_SSO Procedure	102
Figure I.4 – The 2D_SR_SSO procedure	103
Figure I.5 – Parameters of the 1D_FILTR_SSO procedure	103
Figure I.6 – The FDWT_SSO procedure.....	105
Figure I.7 – The 2D_SD_SSO procedure.....	106
Figure I.8 – Parameters of the 1D_FILTD_SSO procedure	107
Figure I.9 – Position of SSO blocks.....	108
Figure I.10 – Tiling of the reference grid diagram.....	110
Figure J.1 – Inverse multiple component transformation processing	113
Figure J.2 – Procedure MCO_TRANSFORM.....	114
Figure J.3 – A single multiple component collection transformation (MCC_TRANS) stage.....	115
Figure J.4 – Procedure MCC_TRANS	116
Figure J.5 – A single component collection transformation (CC_TRANS) stage.....	117
Figure J.6 – Procedure CC_TRANS	117
Figure J.7 – SERM implementation of reversible decorrelation transformation.....	121
Figure J.8 – SERM implementation of forward reversible decorrelation transformation.....	122
Figure J.9 – Irreversible dependency transformation.....	123
Figure J.10 – Forward irreversible dependency transformation	124
Figure J.11 – Reversible dependency transformation	125
Figure J.12 – Forward reversible dependency transformation.....	126
Figure K.1 – Non-linear transformation application during decoding.....	128
Figure K.2 – Example gamma-type forward non-linear transformation.....	130
Figure L.1 – Rectangular mask on the reference grid	135
Figure L.2 – Elliptic mask on the reference grid	135
Figure M.1 – Example fragmented JPX file where all fragments are in the same file	144
Figure M.2 – Example fragmented JPX file where some fragments are stored in other files or resources	145
Figure M.3 – Example combination of two codestreams into a single compositing layer	146
Figure M.4 – Example of the box description figures.....	161
Figure M.5 – Example of the superbox description figures	161
Figure M.6 – Boxes defined within a JPX file.....	162
Figure M.7 – Organization of the contents of the Reader Requirements box	165
Figure M.8 – Organization of the contents of a Data Reference box.....	168
Figure M.9 – Organization of the contents of a Fragment Table box.....	168
Figure M.10 – Organization of the contents of a Fragment List box.....	169
Figure M.11 – Organization of the contents of a Fragment table box	170

Figure M.12 – Organization of the contents of an Image Header box	171
Figure M.13 – Organization of the contents of a Codestream Header box	173
Figure M.14 – Organization of the contents of a Compositing Layer Header box	174
Figure M.15 – Organization of the contents of a Colour Group box	175
Figure M.16 – Organization of the contents of a Colour Specification box	176
Figure M.17 – Organization of the contents of the METHDAT field for the Enumerated method	178
Figure M.18 – Organization of the contents of the METHDAT field for the Any ICC method	180
Figure M.19 – Organization of the contents of the METHDAT field for the Vendor Colour method	180
Figure M.19bis – Organization of the METHDAT field for the Parameterized method	181
Figure M.20 – Organization of the contents of the EP field for the CIELab (EnumCS = 14)	181
Figure M.21 – Organization of the contents of the EP field for the CIEJab (EnumCS = 19)	183
Figure M.22 – Organization of the contents of an Opacity box	185
Figure M.23 – Organization of the contents of a Codestream Registration box	187
Figure M.23bis – Layout of the Pixel Format Box	188
Figure M.24 – Organization of the contents of a Composition box	190
Figure M.25 – Organization of the contents of a Composition Options box	191
Figure M.26 – Organization of the contents of an Instruction Set box	191
Figure M.27 – Organization of the contents of an INST field within an Instruction Set box	192
Figure M.28 – Example of ROI specific metadata associated with one or more images	195
Figure M.29 – Example of Multiple XML documents associated with one or more images	195
Figure M.30 – Example of a Labelled XML document	195
Figure M.31 – Example of a labelled image	195
Figure M.32 – Organization of the contents of an Association box	196
Figure M.33 – Organization of the contents of a Number List box	196
Figure M.34 – Organization of the contents of a Label box	197
Figure M.35 – Organization of the contents of a Binary Filter box	197
Figure M.36 – Organization of the contents of the Desired Reproductions box	198
Figure M.37 – Organization of the contents of the Graphics Technology Standard Output box	198
Figure M.38 – Organization of the contents of the ROI Description box	199
Figure M.39 – Organization of the contents of a Digital Signature box	202
Figure M.40 – Organization of the contents of a MPEG-7 Binary box	204
Figure N.1 – Organization of the contents of Image Creation box	215
Figure N.2 – Organization of the contents of Content Description box	216
Figure N.3 – Organization of the contents of History box	216
Figure N.4 – Organization of the contents of Intellectual Property Rights box	216
Figure N.5 – Organization of the contents of Image Identifier box	217
Figure N.6 – Schema of the Image Creation metadata	217
Figure N.7 – Schema of the General Creation Information metadata	218
Figure N.8 – Schema of the Camera Capture metadata	219
Figure N.9 – Schema of the Device Characterization metadata	220
Figure N.10 – Schema of the Spatial Frequency Response metadata	221
Figure N.11 – Schema of the Colour Filter Array Pattern metadata	222
Figure N.12 – Schema of the Opto-electronic Conversion Function metadata	222
Figure N.13 – Schema of the Camera Capture Settings metadata	223
Figure N.14 – Schema of the Scanner Capture metadata	226

	<i>Page</i>
Figure N.15 – Schema of the Scanner Settings metadata	227
Figure N.16 – Schema of the Software Creation metadata	227
Figure N.17 – Schema of the Captured Item metadata	227
Figure N.18 – Schema of the Reflection Print metadata	228
Figure N.19 – Schema of the Film metadata	229
Figure N.20 – Schema of the Content Description metadata	229
Figure N.21 – Schema of the Person Description metadata	230
Figure N.22 – Schema of the Thing Description metadata	231
Figure N.23 – Schema of the Organization Description metadata.....	231
Figure N.24 – Schema of the Event Description metadata.....	232
Figure N.25 – Schema of the Participant metadata.....	233
Figure N.26 – Schema of the Event Relationship metadata	233
Figure N.27 – Schema of the Audio metadata	234
Figure N.28 – Schema of the Property metadata	234
Figure N.29 – Schema of the Dictionary Definition metadata	235
Figure N.30 – Schema of the History metadata.....	235
Figure N.31 – Schema of the Processing Summary metadata.....	236
Figure N.32 – Schema of the Image Processing Hints metadata.....	237
Figure N.33 – Schema of the Previous metadata.....	238
Figure N.34 – Schema of the Image Reference metadata	238
Figure N.35 – Schema of the Intellectual Property Rights metadata	239
Figure N.36 – Schema of the IPR Names metadata.....	240
Figure N.37 – Schema of the IPR Description metadata.....	241
Figure N.38 – Schema of the IPR Dates metadata.....	242
Figure N.39 – Schema of the IPR Exploitation metadata.....	243
Figure N.40 – Schema of the IPR Management Systems metadata.....	243
Figure N.41 – Schema of the IPR Identification metadata.....	244
Figure N.42 – Schema of the IPR Identifier metadata	244
Figure N.43 – Schema of the License Plate metadata	244
Figure N.44 – Schema of the IPR Contact Point metadata.....	245
Figure N.45 – Schema of the Image Identifier metadata.....	246
Figure N.46 – Schema of the non-negative double type	246
Figure N.47 – Schema of the rational type.....	246
Figure N.48 – Schema of the string including language attribute type.....	246
Figure N.49 – Schema of the degree type.....	247
Figure N.50 – Schema of the half degree type.....	247
Figure N.51 – Schema of the double size type	247
Figure N.52 – Schema of the integer size type	247
Figure N.53 – Schema of the DateTime type	248
Figure N.54 – Schema of the Address type	249
Figure N.55 – Schema of the Phone number type	250
Figure N.56 – Schema of the Email address type	251
Figure N.57 – Schema of the Web address type	251
Figure N.58 – Schema of the Person type	252
Figure N.59 – Schema of the Organization type.....	253

Figure N.60 – Schema of the Location type	254
Figure N.61 – Schema of the Coordinate location element.....	255
Figure N.62 – Schema of the Raw GPS Information element.....	256
Figure N.63 – Schema of the Raw GPS Information element (<i>continued</i>)	257
Figure N.64 – Schema of the Raw GPS Information element (<i>concluded</i>).....	258
Figure N.65 – Schema of the Direction type	260
Figure N.66 – Schema of the Position type	261
Figure N.67 – Schema of the Point type.....	262
Figure N.68 – Schema of the Rect type.....	262
Figure N.69 – Schema of the Region type.....	263
Figure N.70 – Schema of the Product Details type	263
Figure N.71 – Schema of the Language attribute	264
Figure N.72 – Schema of the Timestamp attribute	264
Figure N.73 – Schema of the Comment element	264
Figure O.1 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	293
Figure O.2 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	293
Figure O.3 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	294
Figure O.4 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	294
Figure O.5 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	294
Figure O.6 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	294
Figure O.7 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	295
Figure O.8 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	295
Figure O.9 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	295
Figure O.10 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	295
Figure O.11 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	296
Figure O.12 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	296
Figure O.13 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	296
Figure O.14 – Sample wavelet decomposition: $N_L = 3; I_R = 3; d_R() = 123; I_\theta = 2, d_\theta() = 31; I_S = 9,$ $d_S() = 320300203$	297
Figure O.15 – FBI decomposition: $N_L = 5; I_R = 0; d_R() = 0$ (since $I_R = 0, I_R$ and $d_R()$ get reset in Figure F.11 to $I_R = 5$ and $d_R() = 11111$); $I_\theta = 4, d_\theta() = 2321; I_S = 17, d_S() = 1110111111111111$	297

Figure O.16 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	299
Figure O.17 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	300
Figure O.18 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	301
Figure O.19 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	302
Figure O.20 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	303
Figure O.21 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	304
Figure O.22 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	305
Figure O.23 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	306
Figure O.24 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	307
Figure O.25 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	308
Figure O.26 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	309
Figure O.27 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	310
Figure O.28 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	311
Figure O.29 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	312
Figure O.30 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 1110111111111111$	313
Figure O.31 – SPACL decomposition: $N_L = 4$; $I_\theta = 2$, $d_\theta() = 21$; $I_R = 0$, $I_S = 0$	314
Figure O.32 – Component collection example	316
Figure O.33 – Original image components.....	316
Figure O.34 – Encoder multiple component transform decisions.....	317
Figure O.35 – Decorrelation transformation array (MCC ₀ component collection 0 parameters).....	318
Figure O.36 – Dependency transformation (MCC ₀ component collection 1 parameters).....	318
Figure O.37 – Passing through intermediate components (MCC ₀ component collection 2 parameters).....	318
Figure O.38 – Component collections in MCC ₀ , transformation processing stage 0.....	319
Figure O.39 – Decorrelation transformation array (MCC ₁ component collection 0 parameters).....	319
Figure O.40 – MCC ₁ component collection 1 (7 components passed through).....	320
Figure O.41 – Component collections in MCC ₁ , transformation processing stage 1.....	320
Figure O.42 – MCO marker segment for inverse multiple component transformation	320