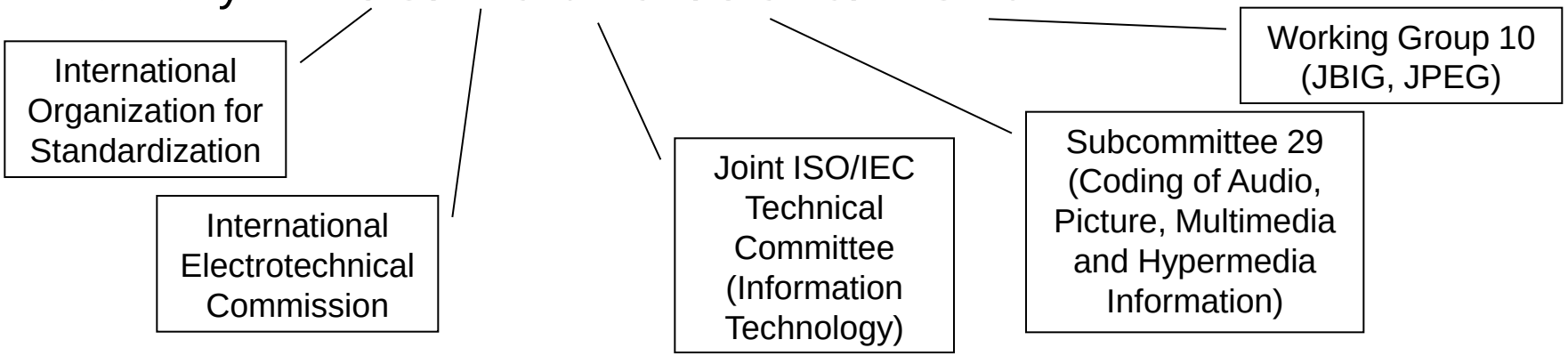
JPEG standard

- JPEG: “Joint Photographic Experts Group”
- Formally: ISO/IEC JTC1/SC29/WG10



- Joint effort with CCITT (International Telephone and Telegraph Consultative Committee, now ITU-T) Study Group VIII
- Work commenced in 1986
- International standard ISO/IEC 10918-1 and CCITT Rec. T.81 in 1992
- Widely used for image exchange, WWW, and digital photography
- Motion-JPEG is de facto standard for digital video editing

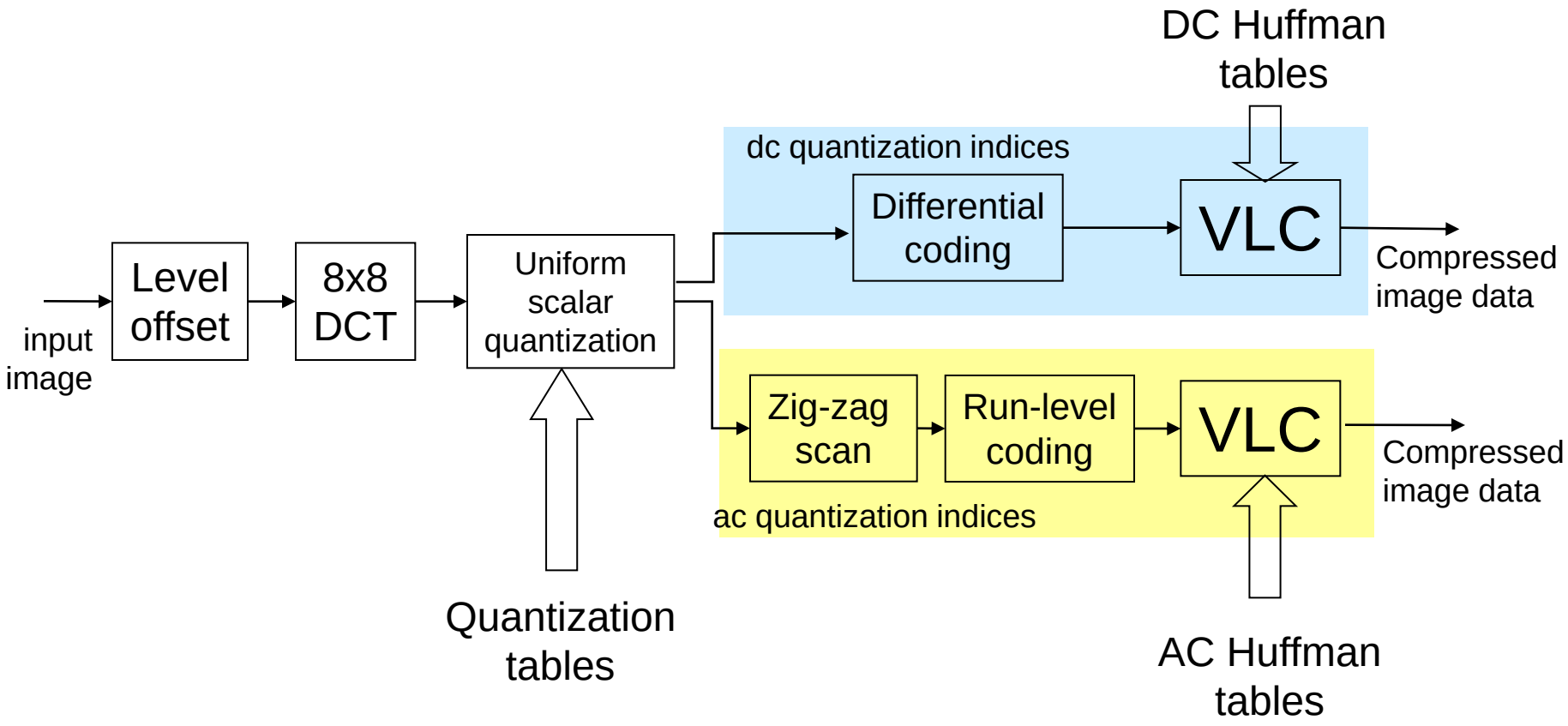
JPEG: image partition into 8x8 block

8x8 blocks

Padding of right boundary blocks

Padding of lower boundary blocks

Baseline JPEG coder



Recommended quantization tables

- Based on psychovisual threshold experiments
- Luminance

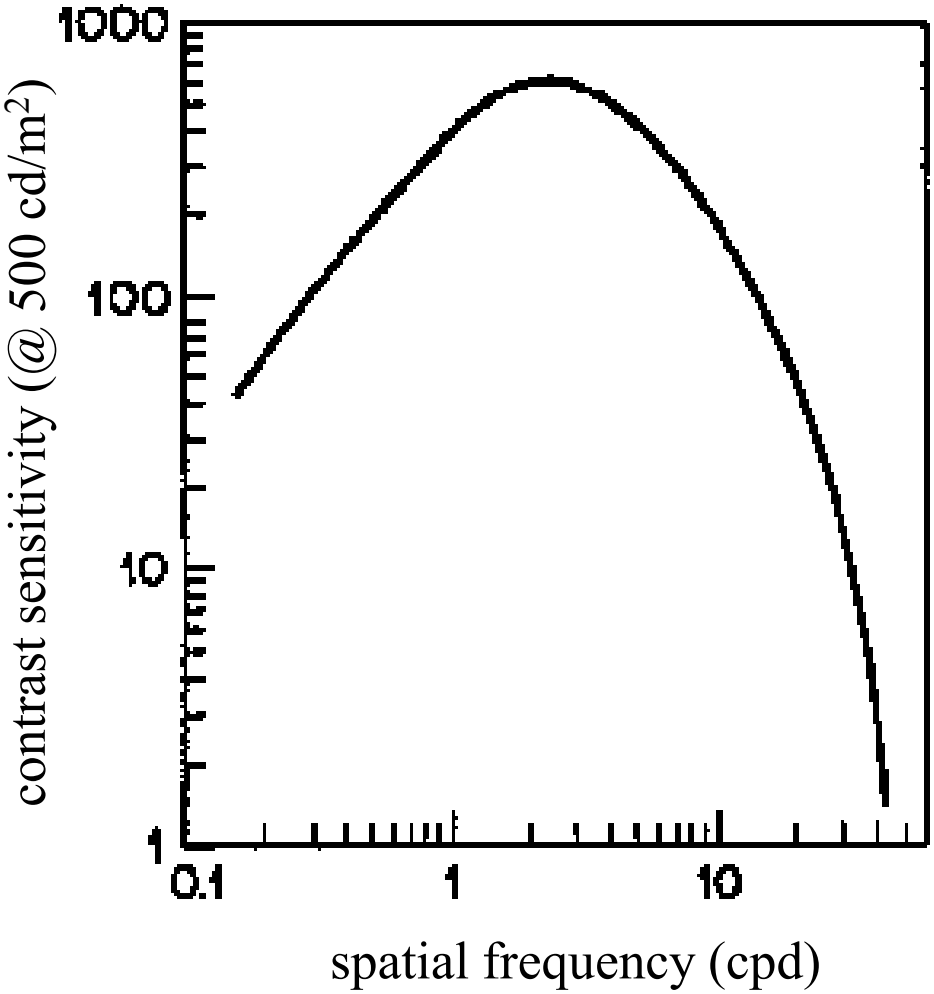
16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	36	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

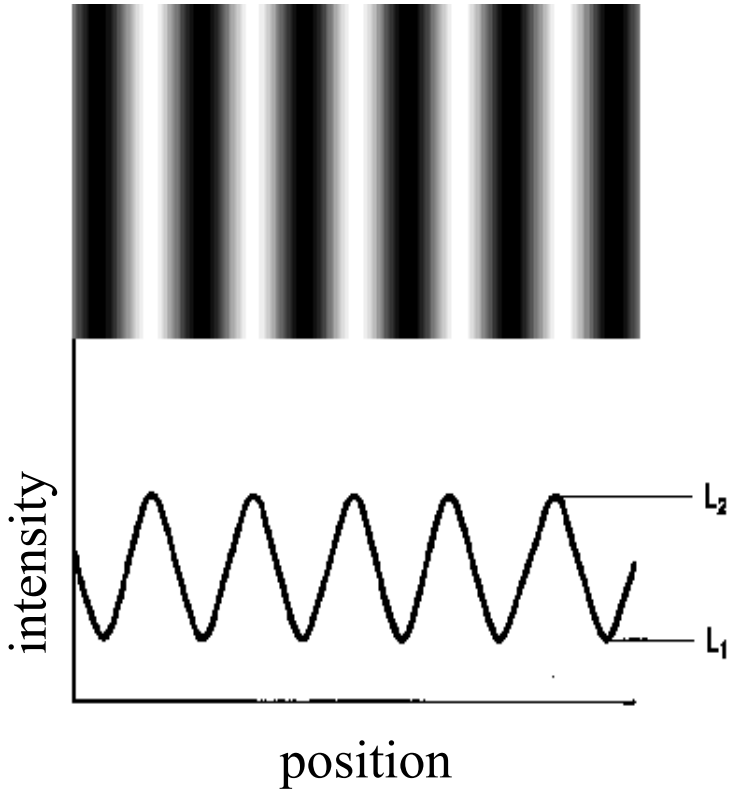
- Chrominance, subsampled 2:1

17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

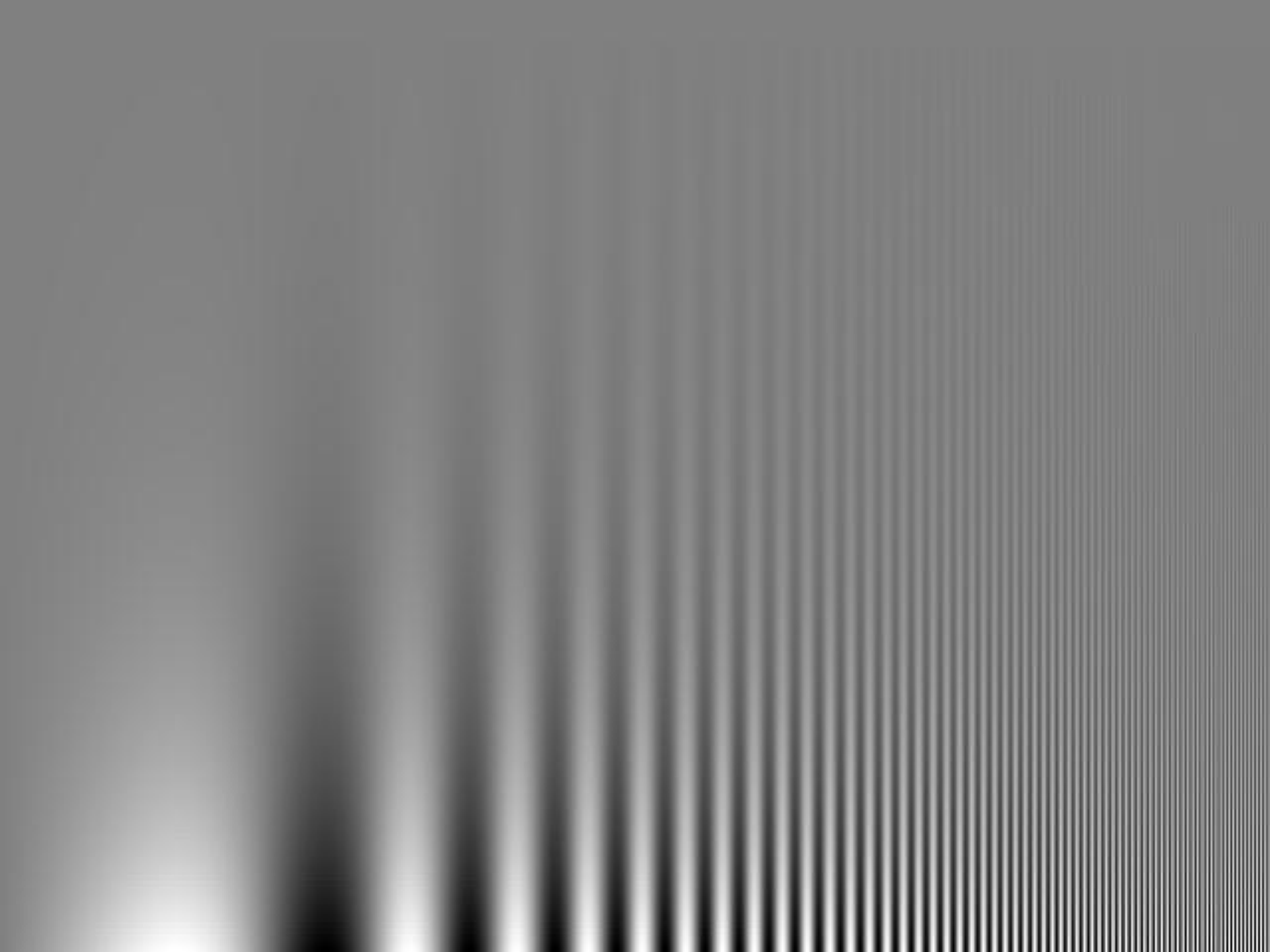
[JPEG Standard, Annex K]

Contrast sensitivity of human vision

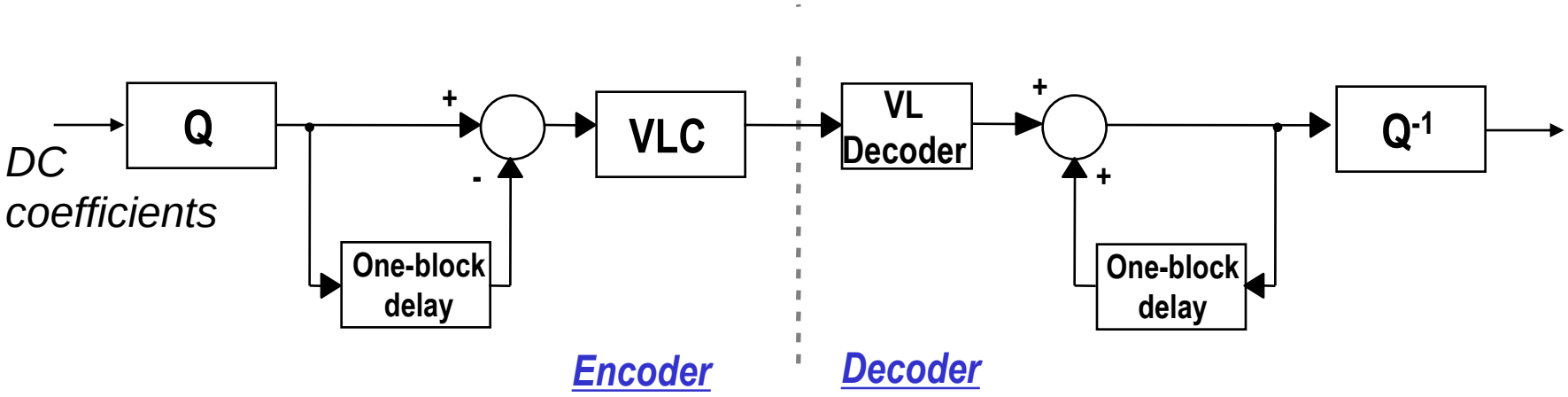


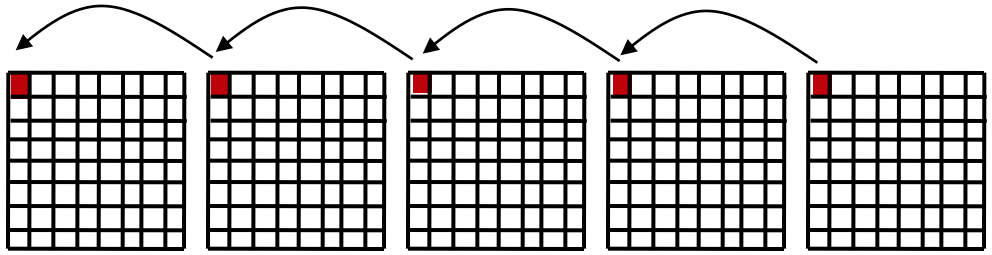


contrast ratio $\frac{L_2 - L_1}{L_2 + L_1}$



Differential coding of DC coefficients





DC difference categories

Range	DC Difference Category
0	0
−1, 1	1
−3, −2, 2, 3	2
−7, …, −4, 4, …, 7	3
−15, …, −8, 8, …, 15	4
−31, …, −16, 16, …, 31	5
−63, …, −32, 32, …, 63	6
−127, …, −64, 64, …, 127	7
−255, …, −128, 128, …, 255	8
−511, …, −256, 256, …, 511	9
−1023, …, −512, 512, …, 1023	A
−2047, …, −1024, 1024, …, 2047	B
−4095, …, −2048, 2048, …, 4095	C
−8191, …, −4096, 4096, …, 8191	D
−16383, …, −8192, 8192, …, 16383	E
−32767, …, −16384, 16384, …, 32767	F

Suggested Huffman code for DC differences

JPEG Standard, Table K3 - Luminance

Category	Code length	Code word
0	2	00
1	3	010
2	3	011
3	3	100
4	3	101
5	3	110
6	4	1110
7	5	11110
8	6	111110
9	7	1111110
10	8	11111110
11	9	111111110

JPEG run-level coding

- $RRRR$ – four bits value specifying ac coefficient zero-run of length 0…15
- $SSSS$ – four bits specifying a range of magnitudes of the following coefficient (“category”)
- Joint Huffman encoding for 8-bit value $RRRRSSSS$
- Append bits for sign and exact magnitude

JPEG coefficient coding categories

Range	DC Difference Category	AC Category
0	0	N/A
−1, 1	1	1
−3, −2, 2, 3	2	2
−7, . . . , −4, 4, . . . , 7	3	3
−15, . . . , −8, 8, . . . , 15	4	4
−31, . . . , −16, 16, . . . , 31	5	5
−63, . . . , −32, 32, . . . , 63	6	6
−127, . . . , −64, 64, . . . , 127	7	7
−255, . . . , −128, 128, . . . , 255	8	8
−511, . . . , −256, 256, . . . , 511	9	9
−1023, . . . , −512, 512, . . . , 1023	A	A
−2047, . . . , −1024, 1024, . . . , 2047	B	B
−4095, . . . , −2048, 2048, . . . , 4095	C	C
−8191, . . . , −4096, 4096, . . . , 8191	D	D
−16383, . . . , −8192, 8192, . . . , 16383	E	E
−32767, . . . , −16384, 16384, . . . , 32767	F	N/A

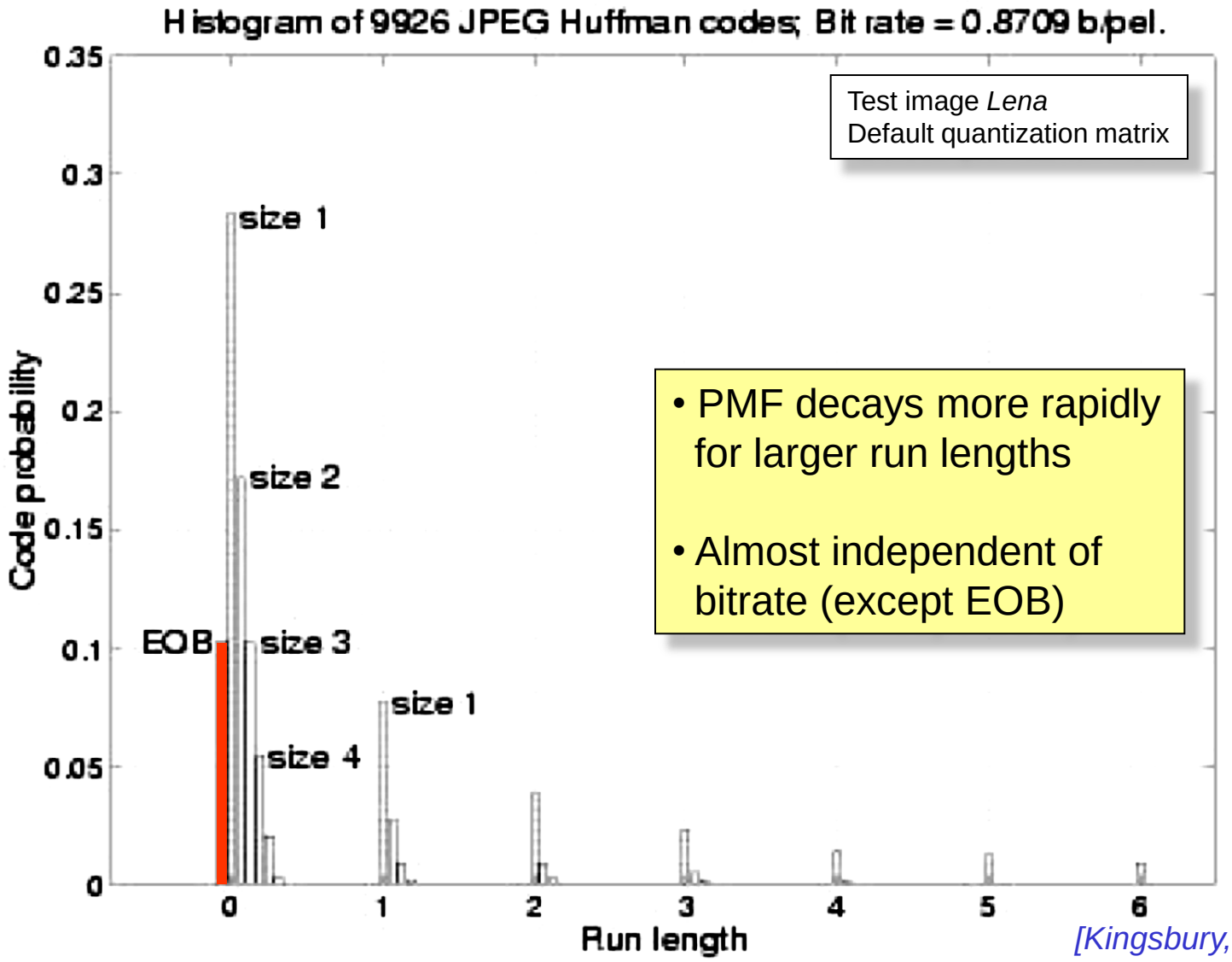
JPEG suggested AC code for luminance

Run/ Category	Base Code	Length	Run/ Category	Base Code	Length
0/0	**1010 (= EOB)**	**4**			
0/1	00	3	8/1	11111010	9
0/2	01	4	8/2	111111111000000	17
0/3	100	6	8/3	1111111110110111	19
0/4	1011	8	8/4	1111111110111000	20
0/5	11010	10	8/5	1111111110111001	21
0/6	111000	12	8/6	1111111110111010	22
0/7	1111000	14	8/7	1111111110111011	23
0/8	1111110110	18	8/8	1111111110111100	24
0/9	1111111110000010	25	8/9	1111111110111101	25
0/A	1111111110000011	26	8/A	1111111110111110	26
1/1	1100	5	9/1	111111000	10
1/2	111001	8	9/2	1111111110111111	18
1/3	1111001	10	9/3	1111111111000000	19
1/4	111110110	13	9/4	1111111111000001	20
1/5	11111110110	16	9/5	1111111111000010	21
1/6	1111111110000100	22	9/6	1111111111000011	22
1/7	1111111110000101	23	9/7	1111111111000100	23
1/8	1111111110000110	24	9/8	1111111111000101	24
1/9	1111111110000111	25	9/9	1111111111000110	25
1/A	1111111110001000	26	9/A	1111111111000111	26
2/1	11011	6	A/1	111111001	10
2/2	11111000	10	A/2	1111111111001000	18
2/3	1111110111	13	A/3	1111111111001001	19
2/4	1111111110001001	20	A/4	1111111111001010	20
2/5	1111111110001010	21	A/5	1111111111001011	21
2/6	1111111110001011	22	A/6	1111111111001100	22
2/7	1111111110001100	23	A/7	1111111111001101	23

JPEG suggested AC code for luminance (cont.)

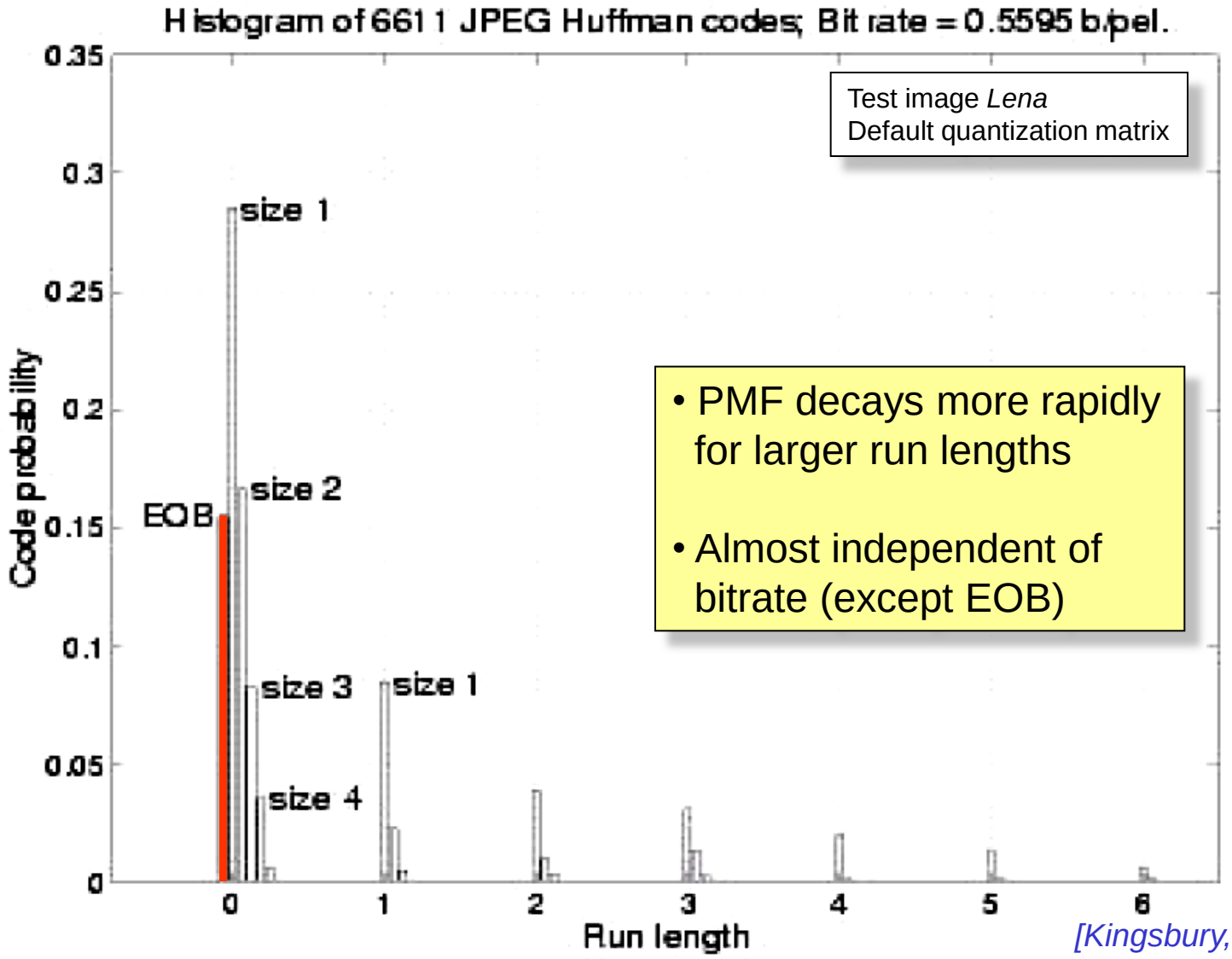
2/8	1111111110001101	24	A/8	1111111111001110	24
2/9	1111111110001110	25	A/9	1111111111001111	25
2/A	1111111110001111	26	A/A	1111111111010000	26
3/1	111010	7	B/1	111111010	10
3/2	111110111	11	B/2	1111111111010001	18
3/3	11111110111	14	B/3	1111111111010010	19
3/4	1111111110010000	20	B/4	1111111111010011	20
3/5	1111111110010001	21	B/5	1111111111010100	21
3/6	1111111110010010	22	B/6	1111111111010101	22
3/7	1111111110010011	23	B/7	1111111111010110	23
3/8	1111111110010100	24	B/8	1111111111010111	24
3/9	1111111110010101	25	B/9	1111111111011000	25
3/A	1111111110010110	26	B/A	1111111111011001	26
4/1	111011	7	C/1	1111111010	11
4/2	1111111000	12	C/2	1111111111011010	18
4/3	1111111110010111	19	C/3	1111111111011011	19
4/4	1111111110011000	20	C/4	1111111111011100	20
4/5	1111111110011001	21	C/5	1111111111011101	21
4/6	1111111110011010	22	C/6	1111111111011110	22
4/7	1111111110011011	23	C/7	1111111111011111	23
4/8	1111111110011100	24	C/8	1111111111100000	24
4/9	1111111110011101	25	C/9	1111111111100001	25
4/A	1111111110011110	26	C/A	1111111111100010	26

AC coefficient probabilities



[Kingsbury, 2006]

AC coefficient probabilities (cont.)



- PMF decays more rapidly for larger run lengths
- Almost independent of bitrate (except EOB)

[Kingsbury, 2006]

JPEG compression results

231 kb, uncompressed, 320x240x3x8 bit

JPEG compression results

74 kb, compressed 3.24:1

JPEG compression results

51 kb, compressed 4.53:1

JPEG compression results

38 kb, compressed 6.08:1

JPEG compression results

31 kb, compressed 7.45:1

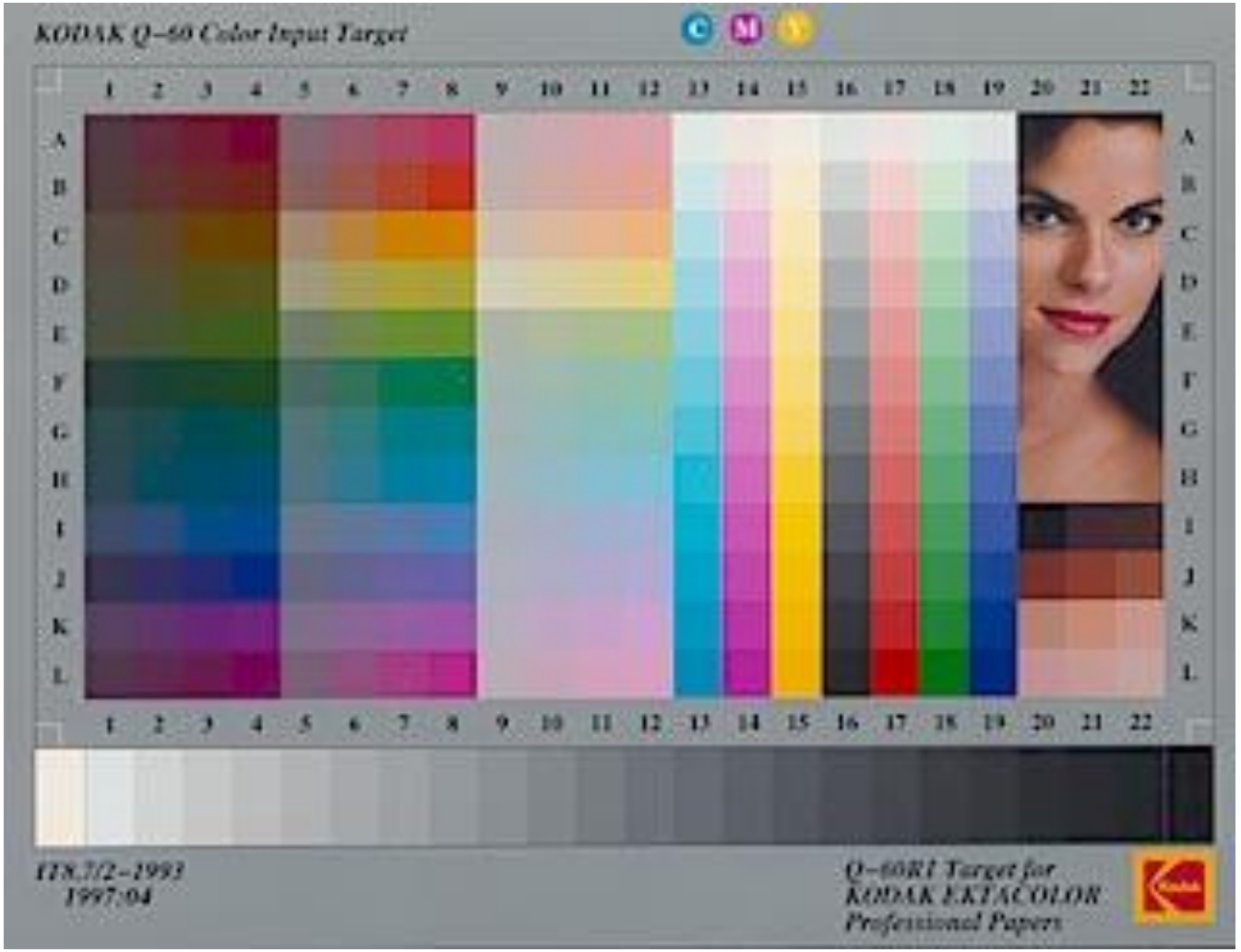
JPEG compression results

26 kb, compressed 8.88:1

JPEG compression results

22 kb, compressed 10.5:1

JPEG compression results

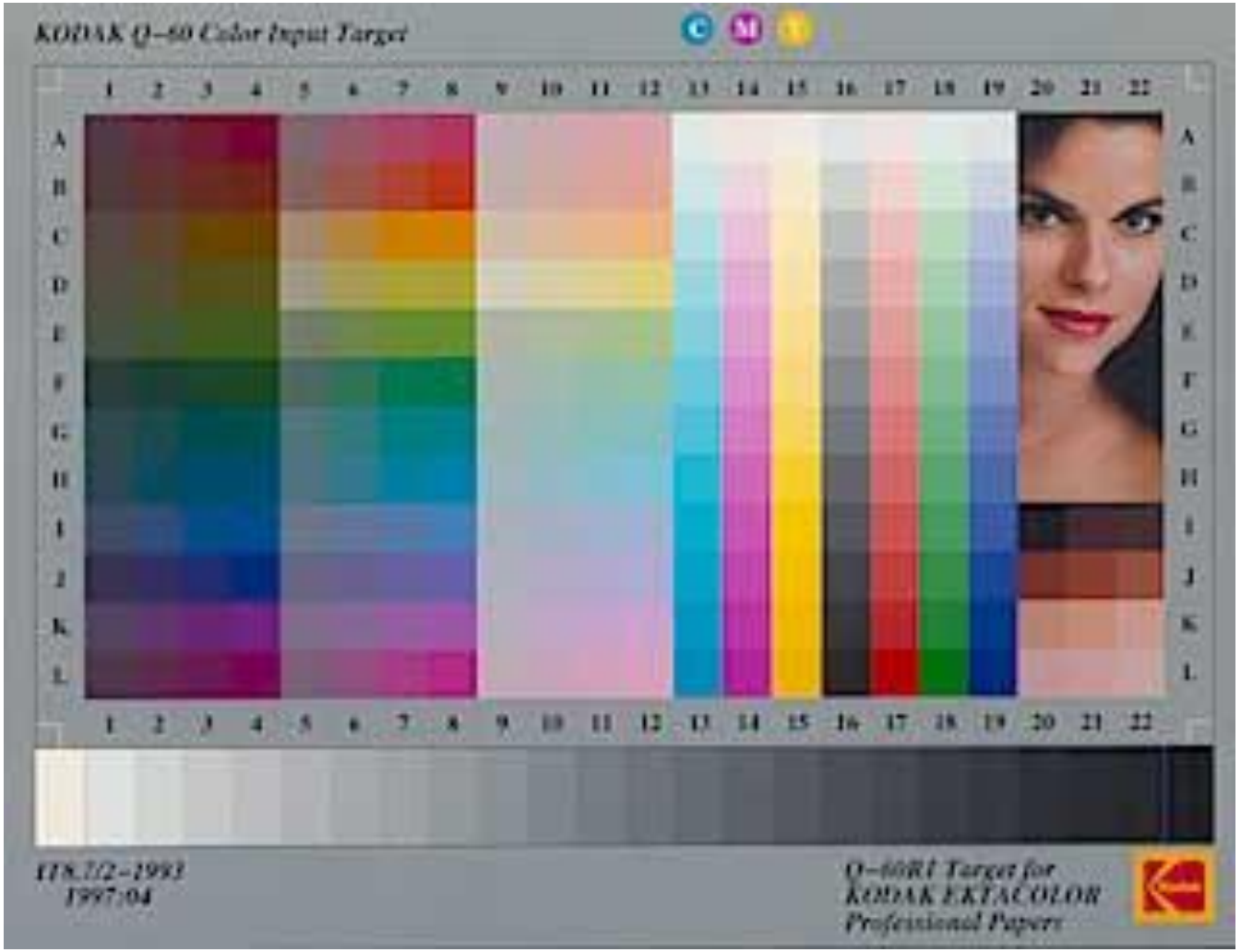


21 kb, compressed 11:1

JPEG compression results

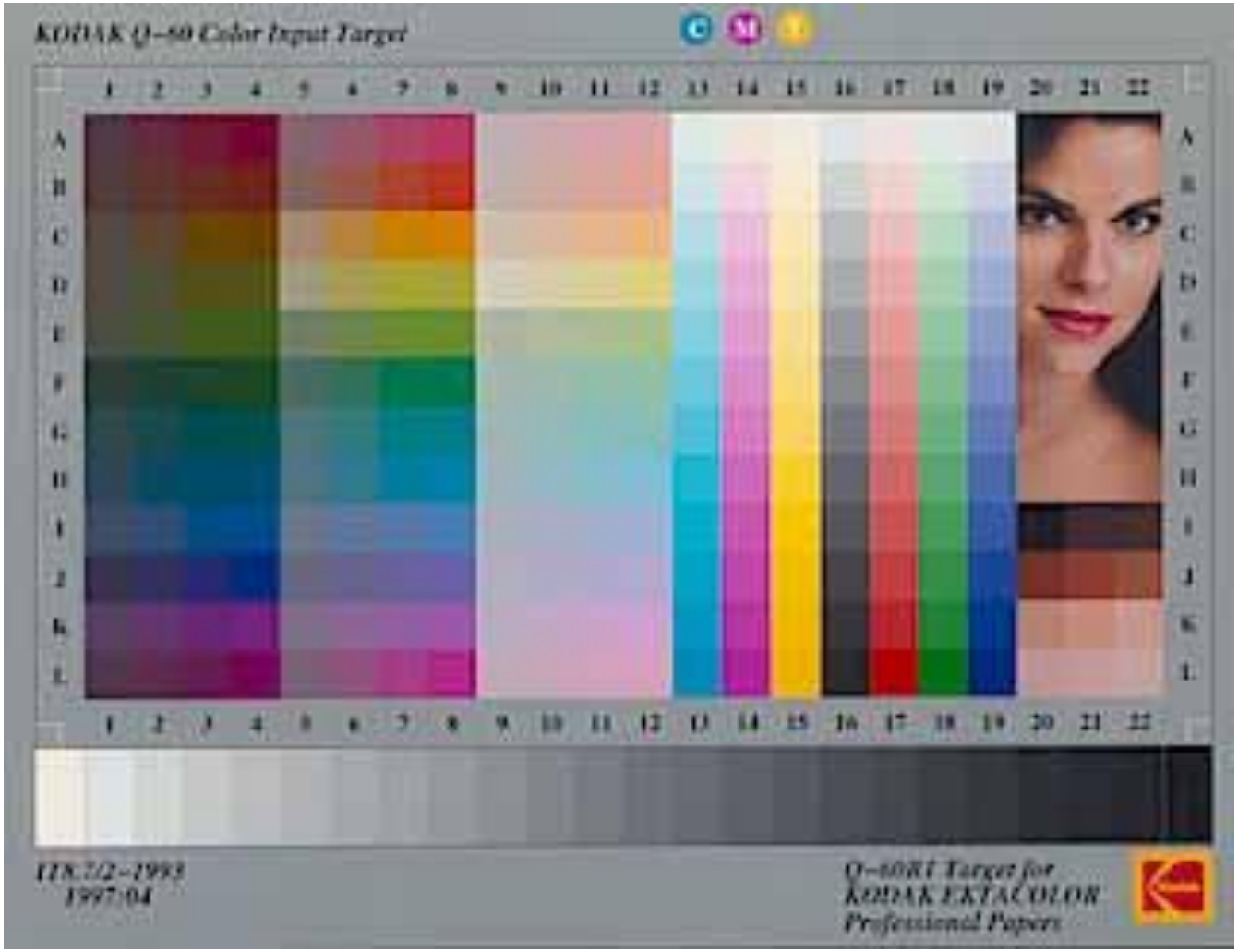
18 kb, compressed 12.83:1

JPEG compression results



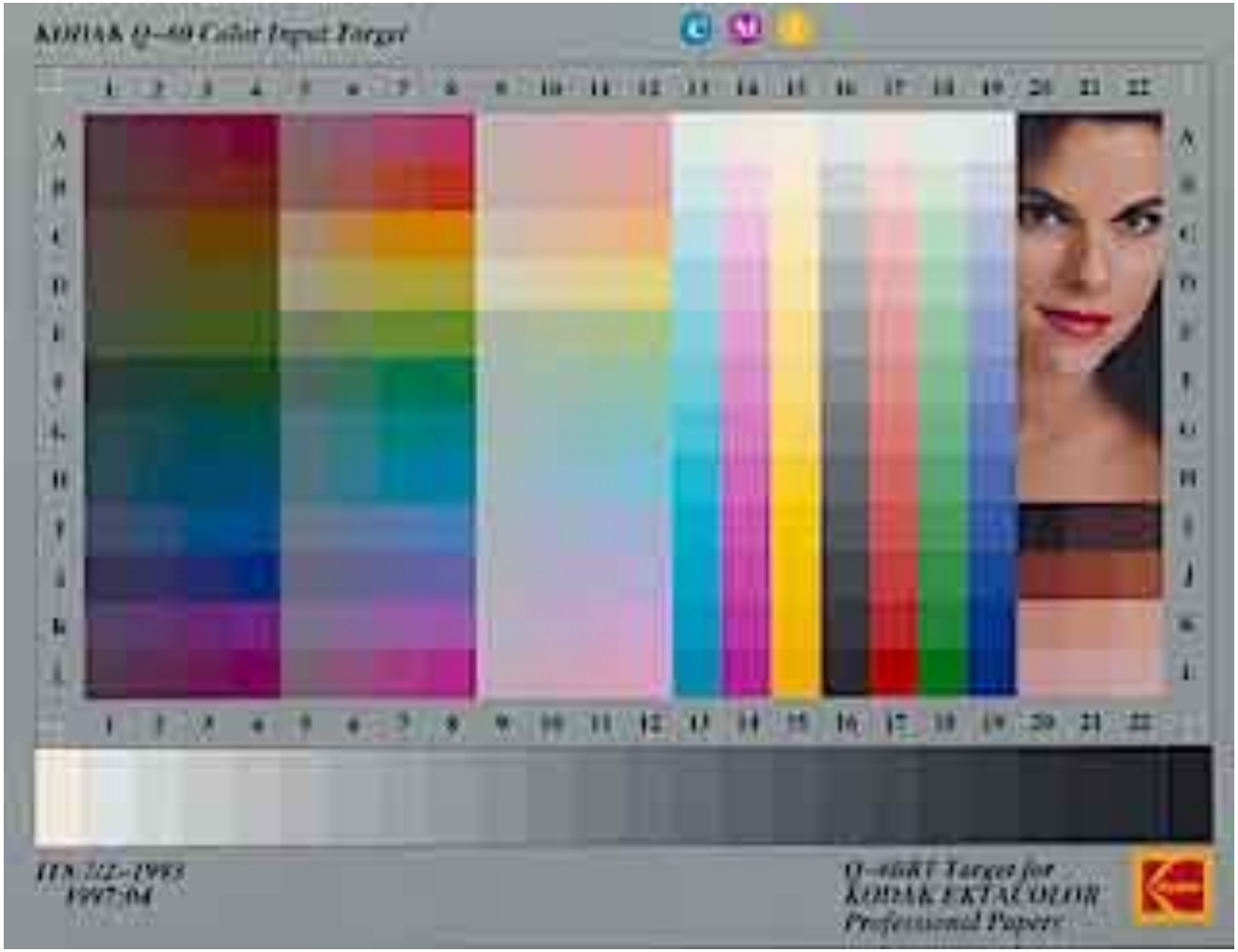
17 kb, compressed 13.59:1

JPEG compression results



15 kb, compressed 15.4:1

JPEG compression results



13 kb, compressed 17.77:1

JPEG compression results

11 kb, compressed 21:1

JPEG compression results

11 kb, compressed 21:1

Beyond Baseline JPEG

- Huffman code tables can be optionally replaced by arithmetic coder (rarely supported)
- Hierarchical mode for progressive image transmission
- No predefined color spaces: up to 255 image components
- Lossless mode: prediction with Huffman coding of residual (not to be confused with JPEG-LS)
- Additional information (e.g. date/time, camera, exposure, aperture etc.) may be embedded into JPEG file (e.g., EXIF, DCF used by digital cameras)

Reading

- Taubman, Marcellin, Chapter 19
- G. K. Wallace, “The JPEG still picture compression standard,” IEEE Trans. Consumer Electronics, vol. 38, no. 1, pp. xviii-xxxiv, Feb. 1992.
- ITU-T Rec. T.81