INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

J.81
(ex CMTT.723)
(09/93)

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

TELEVISION AND SOUND TRANSMISSION

TRANSMISSION OF COMPONENT-CODED DIGITAL TELEVISION SIGNALS FOR CONTRIBUTION-QUALITY APPLICATIONS AT THE THIRD HIERARCHICAL LEVEL OF ITU-T RECOMMENDATION G.702

ITU-T Recommendation J.81

(Formerly Recommendation ITU-R CMTT.723)

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation J.81 (formerly Recommendation ITU-R CMTT.723) was revised by the former ITU-R Study Group CMTT and was approved under the CCIR Resolution 97 procedure on 8 September 1993. See Note 1 below.

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector (ITU-R).

Conforming to a joint decision by the World Telecommunication Standardization Conference, Helsinki, March 1993, and the Radiocommunication Assembly, Geneva, November 1993, the ITU-R Study Group CMTT was transferred to ITU-T as Study Group 9, except for the satellite news gathering (SNG) study area which was transferred to ITU-R Study Group 4.

2 In this Recommendation, the expression “Administration” is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

CONTENTS

Recommendation J.81[1)]

TRANSMISSION OF COMPONENT-CODED DIGITAL TELEVISION SIGNALS FOR CONTRIBUTION-QUALITY APPLICATIONS AT THE THIRD HIERARCHICAL LEVEL OF ITU-T RECOMMENDATION G.702

(1990; revised 1993)

The ITU-R,

considering

(a) that for contribution-quality application, transmission should be based on component-coded digital video signals conforming with Recommendation ITU-R BT.601;

(b) that such transmission would satisfy user requirements for contribution-quality codecs at about 34 or 45 Mbit/s, as specified by Radiocommunication Study Group 11;

(c) that according to these user requirements such transmission should preserve the picture quality inherent to the 4:2:2 encoding process based on Recommendation ITU-R BT.601 to the maximum extent possible, taking into account the bit rate available to the user;

(d) that such transmission should similarly preserve the down stream processing capabilities by maintaining the spatial and temporal resolution of the 4:2:2 signals as given by Recommendation ITU-R BT.601;

(e) that additional transmission capacity should be provided for stereo sound-channels, ancillary signals (e.g. Teletext, test signals) and accompanying error-protection data;

(f) that through the use of appropriate bit-rate reduction techniques it is likely that these objectives can be reached at an acceptable level of complexity and cost for transmission at bit rates of about 34 or 45 Mbit/s,

recommends

1 that for the transmission of component-coded digital video signals according to Recommendation ITU-R BT.601 at the Recommendation ITU-T G.702 third hierarchical level bit rates, the bit-rate reduction codec should be characterized as given in Annex A.

Annex A

Digital coding of component television signals for contribution-quality applications at about 34 or 45 Mbit/s

(This annex forms an integral part of this Recommendation)

A.1 Scope

This annex constitutes a common standard for the coding and transmission of component television signals at bit rates of about 34 or 45 Mbit/s in the format specified by Recommendation ITU-R BT.601 [1]. The standard embraces the coding algorithm needed for digital picture coding at about 34 and 45 Mbit/s, and their interfaces with the transmission network.

1) Formerly Recommendation ITU-R CMTT.723.

The video coding algorithms are based on a hybrid predictive/transform scheme incorporating arrangements for variable word-length coding (VLC), synchronization and video framing. Provision is made for the transmission of audio and Teletext services to accompany the video and for the application of scrambling for conditional access.

Network adaptation is specified to both plesiochronous and synchronous digital hierarchies.

A.2 Recommendations and standards

A list of the ITU Recommendations, ISO Standards and IEC Publications referred to in the text is given in A.13.

A.3 Definitions, symbols and abbreviations

A.3.1 Arithmetic operators

+	Addition
–	Subtraction or negation
×	Multiplication
/	Integer division
Σ	Summation
LCM	Lowest common multiple
XOR	Exclusive OR binary operation (modulo-2 addition)

A.3.2 Relational operators

=	Equal
≠	Not equal
>	Greater than
<	Less than
≥	Greater than or equal to
≤	Less than or equal to

A.3.3 General abbreviations and usage

For the purposes of this Recommendation, the following abbreviations apply:

Binary	Number system with base 2
Hexadecimal	Number system with base 16. In written form, equivalents of the decimal numbers 10 to 15 are replaced by the letters A to F
XY hex	Values expressed in hexadecimal notation
Bit	Contraction of the words “binary digit”
Word	Group or sequence of bits treated together
Octet	Sequence of 8 bits operated on as a data group or word
MSB	Most significant bit of a word or octet of bits
LSB	Least significant bit of a word or octet of bits
Y	Luminance signal or sample
R	Red chrominance signal
B	Blue chrominance signal
C_R	Scaled colour difference signal or sample Y-R
C_B	Scaled colour difference signal or sample Y-B
PLL	Phase locked loop
FEC	Forward error correction
ATM	Asynchronous transfer mode

SDH	Synchronous digital hierarchy
PDH	Plesiochronous digital hierarchy
PAL	Acronym for phase alternate line – a composite analogue colour transmission system
SECAM	Acronym for sequential colour with memory – a composite analogue colour transmission system
NTSC	Acronym for the National Television System Committee which developed the composite analogue colour transmission system that is used in the majority of countries using 525-line 60 Hz scanning parameters
MAC	Acronym for Multiplexed Analogue Components. An analogue component colour transmission system. Usually prefixed with letters and/or numbers denoting the variant
FSW	Frame synchronization word
VLC	Variable length (word) coding
CIW	Container identification word
CW	Control word
ECM	Entitlement control message
ECW	Even control word
EMM	Entitlement management message
PRG	Pseudo-random (sequence) generator
IW	Initialization word loaded into pseudo-random sequence generators for descrambling
OCW	Odd control word
PPI	Phase parity identifier indicating which CW must be used for descrambling

Other abbreviations and specialized terminology are noted where they occur in this annex.

A.4 Summary specification of component TV codecs for about 34 or 45 Mbit/s

See Table A.1.

A.5 Video coding and discrete cosine transformation (DCT)

A.5.1 Coding modes

Two processing modes are used.

A.5.1.1 Intra-field mode

See Figure A.1.

A.5.1.2 Inter-field and inter-frame mode

See Figure A.2.

A.5.1.3 Definition of the different modules

DCT	Discrete cosine transformation (DCT) (for 8×8 blocks).
IDCT	Inverse DCT (for 8×8 blocks).
Q	Quantization (see A.6).

TABLE A.1/J.81

Summary specification of component TV codecs for about 34 or 45 Mbit/s

Video input/output	Standard	525-line or 625-line digital video component form. Manual or automatic selection of the video standard is at the manufacturer's discretion (Note 1)
	Coding	4:2:2 level of Recommendation ITU-R BT.601[a)]
	Interfaces	Bit-serial (10-bit, 270 Mbit/s serial interface). Recommendation ITU-R BT.656[a)] [9] bit-parallel interfaces shall also be provided
Signal pre-processing	Horizontal	Full digital active line of 720 samples for luminance (Y) and 360 samples for each colour-difference (C_R, C_B)
	Vertical	525-line: 248 lines per field (Note 2) Field 1: lines 16 to 263 Field 2: lines 278 to 525 625-line: 288 lines per field Field 1: lines 23 to 310 Field 2: lines 336 to 623
	Numerical representation	Digital input samples of Y, C_R, and C_B conform to the Recommendation ITU-R BT.601[a)] numerical range. These samples are converted to an 8-bit 2s complement representation for the purposes of processing within the codec
Coding	Modes	Three modes (intra-field, inter-field and motion compensated inter-frame) are used. The following three processing operations are applied either on 8×8 intra-field blocks (intra-field mode) or on differential blocks obtained by difference between the current 8×8 intra-field block and a reference block taken in the previous field (inter-field mode) or in the field with the same parity in the previous frame (inter-frame mode) (see A.5.1)
	DCT	Discrete cosine transform applied on rectangular blocks of 8 lines of 8 samples for the three components Y, C_R, C_B (see A.5.2)
	Prediction of the block	For each block processed according to inter-field mode, the reference block is determined with pixels for the previous field without motion compensation. For each block processed according to inter-frame mode, the reference block is taken from the position of the current block by application of a displacement vector (see A.5.3)
	Motion compensation	Motion compensation is applied to "macro-blocks". Each macro-block (two adjacent 8×8 blocks for Y and the two co-positioned C_R, and C_B blocks) is assigned a single displacement vector with half-pel accuracy (see A.5.4)
	Quantization	A different quantization characteristic is used for each coefficient. Its parameters are adapted to the buffer occupancy, the type of block (luminance/chrominance), and the criticality of the block. The shape of the characteristic is nearly uniform (see A.6)
	Variable length coding	VLCs are used to encode the quantized DCT coefficients and motion information (see A.7)
Buffer memory capacity		1 572 864 bits
Video framing		(See A.8)
Video data error protection		Reed Solomon (255,239) (interleaving factor 6) (see A.8.2)

TABLE A.1/J.81 (*end*)

Summary specification of component TV codecs for about 34 or 45 Mbit/s

Service multiplex	(See A.10) This combines: – a video channel – 2048 kbit/s (or 1544 kbit/s) audio channels (Note 3) – 384 kbit/s Teletex channel(s) (see A.9.3) – 128 kbit/s test-line channel (see A.9.4) – 8 kbit/s supervision channels (see A.9.2) – two 8 kbit/s conditional access channels – two 8 kbit/s time code channels (see A.9.5)
Network adaptation	Adaptation to Recommendations ITU-T G.751 [2], ITU-T G.752[b)] [3] and to SDH Recommendations ITU-T G.707 [4], ITU-T G.708 [5], ITU-T G.709[b)] [6] (see A.11)
Scrambling for conditional access	(See A.12)

a) Former CCIR Recommendations 601 and 656.

b) Former CCITT Recommendations G.751, G.752, G.707, G.708 and G.709.

NOTES

1 This codec can accommodate the transmission of PAL/SECAM/NTSC by optional decoders and encoders.

2 Only 244 lines per field are significant; lines 16, 17, 18, 19 and 278, 279, 280, 281 are encoded but not displayed.

3 Neither the coding nor the error protection of the audio channels is covered by this Recommendation.

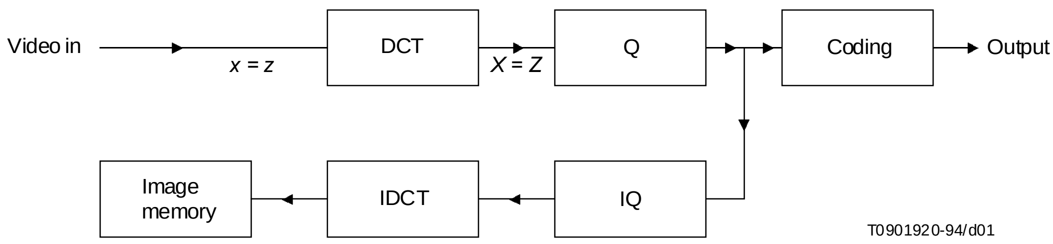

FIGURE A.1/J.81

Intra-field mode

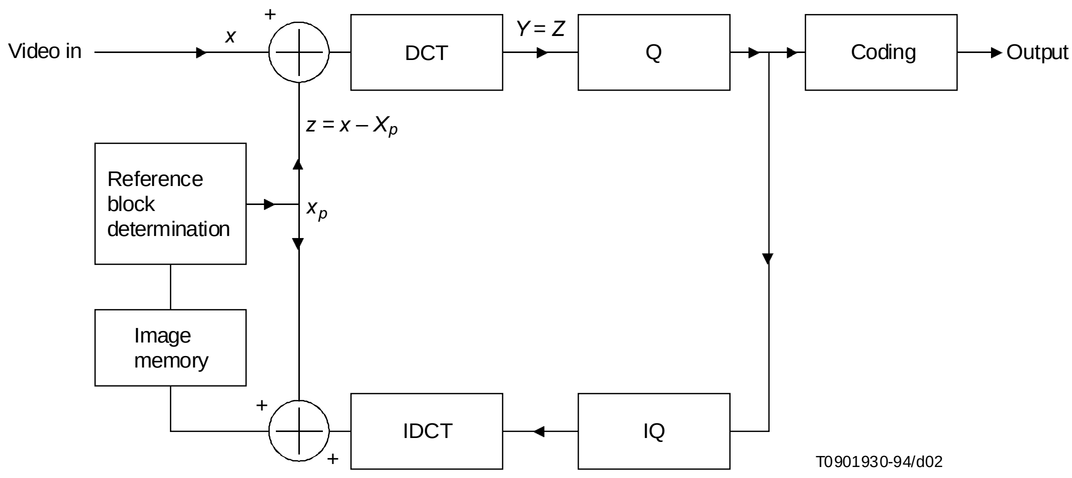

FIGURE A.2/J.81

Inter-field and inter-frame mode

IQ — The IQ module builds a DCT-coefficients block from the corresponding transmitted information, by assigning to the coefficients the reconstruction values corresponding to the transmitted quantization levels (see A.6).

Coding — (See A.7).

Image memory — Provides storage for:

- The decoded current field. This field is used as reference for coding the next image.
- The two last previously decoded fields, which are used to determine the current reference block.

For the inter-field mode — The reference block is computed with pixels of the previous field according to the interpolation process described in A.5.3.

For the inter-frame mode — The reference block is taken in the field of the previous frame with the same parity as the current field. Its position is obtained from the position of the current block by a translation given by a motion vector. The specification of the motion vector is given in A.5.4, the exact computation of the reference block for the inter-frame mode is presented in A.5.3.

A.5.1.4 Notations

$x(i, j)$ — 8×8 pixels block

$x_p(i, j)$ — 8×8 reference block

$z(i, j)$ — $= x(i, j)$ for the intra-field mode

$= x(i, j) - x_p(i, j)$ for the inter-frame or inter-field mode

$X(k, l)$ — 8×8 DCT coefficients block in intra-field mode

$Y(k, l)$ — 8×8 DCT coefficients block in inter-frame or inter-field mode

$Z(k, l)$ — $= X(k, l)$ for intra-field mode

$= Y(k, l)$ for inter-frame or inter-field mode

(i, j)	Coordinates in the image domain:
	i : line index (range: 0 to 7 from left to right)
	j : column index (range: 0 to 7 from top to bottom)
(k, l)	Coordinates in the transform domain:
	k : line index (range: 0 to 7)
	l : column index (range: 0 to 7)

A.5.1.5 Mode choice

The chosen mode (intra-field, inter-field or inter-frame) is coded and transmitted for each processed macro-block (see A.8.1). No specification is given for the mode choice as it concerns only the coder side.

The inter-field and the inter-frame scheme presented in Figure A.2 allows the use of *a priori* choice (decision done before coding steps) or *a posteriori* choice (decision done after having coded the blocks according to both modes).

In the inter modes, the $z(i, j)$ elements must be in the range (–128, 127); the mode decision is forced, when necessary, in order to satisfy this constraint.

To avoid the temporal propagation of transmission error effects it is recommended to use an intra-field refreshing processing. This processing concerns only the coder and is not specified.

A.5.2 Discrete cosine transform

For each component (Y, C_R, C_B), the discrete cosine transformation is applied to blocks composed of eight lines of eight samples. The data to be processed are, for each block, the samples of the present field or the differences between the present field samples and those obtained from a reference block (see A.5.3). The direct transformation is computed according to the formula:

$$Z(k; l) = \frac{1}{4} C_k C_l \sum_{i=0}^{7} \sum_{j=0}^{7} z(i; j) \cos\frac{\pi(2i + 1)k}{16} \cos\frac{\pi(2j + 1)l}{16}$$

and the inverse transformation is given by:

$$z(i, j) = \frac{1}{4} \sum_{k=0}^{7} \sum_{l=0}^{7} C_k C_l Z(k; l) \cos\frac{\pi(2i + 1)k}{16} \cos\frac{\pi(2j + 1)l}{16}$$

with the terms as defined in A.5.1.4:

$$C_k = \frac{1}{\sqrt{2}} \quad \text{for } k = 0 \qquad C_l = \frac{1}{\sqrt{2}} \quad \text{for } l = 0$$

$$= 1 \quad \text{elsewhere} \qquad = 1 \quad \text{elsewhere}$$

Z(0,0) is called the DC coefficient; the other coefficients are AC coefficients.

The input to the DCT is expressed as 2s complement integers of 8 bits (including sign). The output of the DCT is expressed as 12-bit 2s complement numbers, of which the integer part is 11 bits (including sign).

The accuracy of the performance of the inverse DCT computation is in accordance with that specified in Recommendation H.261 [7].

A.5.3 Prediction of the block

A.5.3.1 Inter-field mode

The reference block x_p for the current block x in field N is computed with pixels of field $N - 1$ with the interpolation scheme illustrated in Figure A.3.

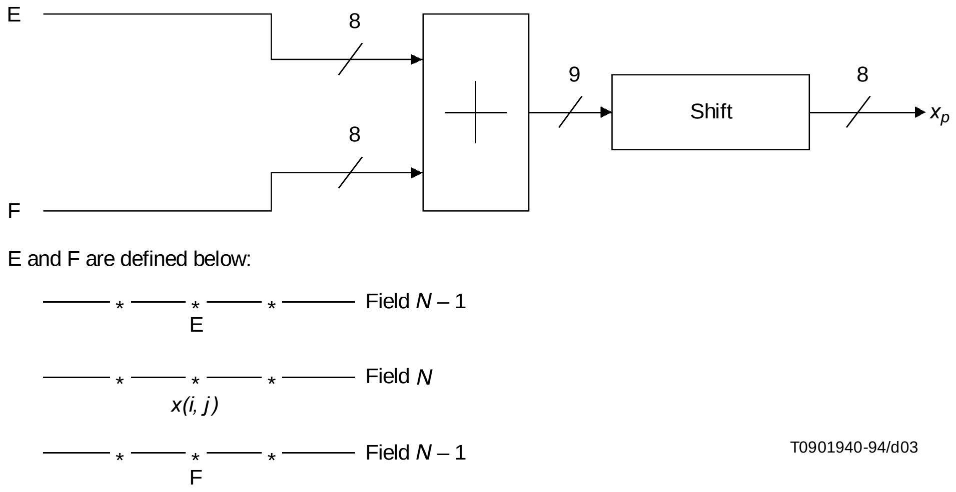

FIGURE A.3/J.81

Definition of E and F for inter-field mode interpolation

A.5.3.2 Inter-frame mode

The position of the reference block is obtained from the position of the currently processed block by a translation. For motion compensation, the translation vector (x, y) is as described in A.5.4.

There is no ambiguity in the definition of the reference block when the coordinates (x, y) are integers. If one of the coordinates has a non-zero fractional part, an interpolation scheme has to be used to build the reference block.

This scheme is described below for ½ pel accuracy for luminance and ¼ pel accuracy for colour difference:

A+ U. P. X. +B

Q. V. R. Y. .S

C+ W. T. Z. +D

A, B, C, D — Reconstituted pixels of the previous frame (in the field of the same parity). Integer coordinates.

P, Q, R, S, T
U, V, W, X, Y, Z — Interpolated pixels of the previous frame (in the field of the same parity).

The values assigned to interpolated pixels are:

P = [(A+B)/2]

Q = [(A+C)/2]

R = [(A+B+C+D)/4]

U = [(3A+B)/4]

V = [(3A+B+3C+D)/8]

as illustrated in Figure A.4.

A.5.3.3 Video level outside active picture

In the definition of the reference block given in the two previous subclauses, the pixels outside the active picture must be set to zero, expressed in 2s complement (8 bits), as shown in Figure A.5.

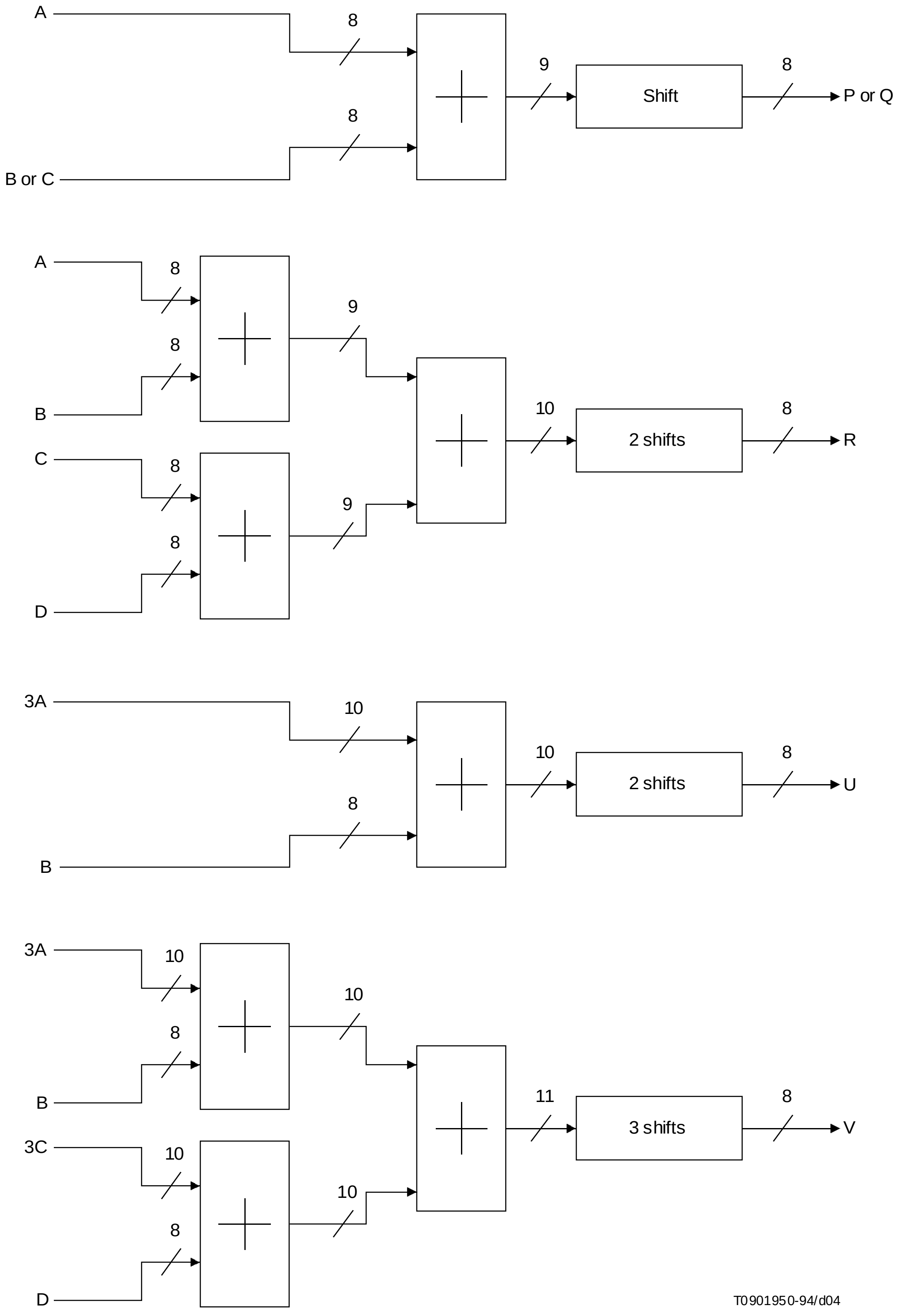

FIGURE A.4/J.81

Interframe mode interpolated pixel values

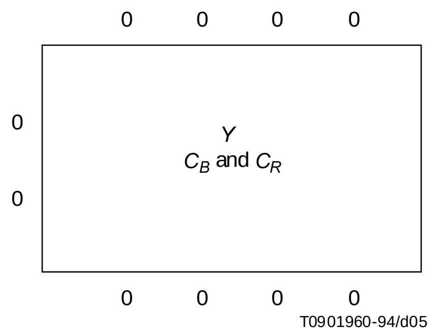

FIGURE A.5/J.81

Video levels outside active picture area

A.5.4 Motion compensation

Only one motion vector is used for the blocks belonging to a macro-block. The parameters of the motion compensation are given in Table A.2:

TABLE A.2/J.81

Motion compensation parameters

Search areas	± 14 pels and ± 7 lines
Resolution	½ pel and ½ line
Number of possible vectors	1653 (all vectors within the search area are permitted)

The method of estimation is not specified since it concerns only the coder side.

The motion vector points to the pixel in the previous frame that is used in the inter-frame prediction.

If the vector components are defined as:

– x increasing from left to right, from –14 to +14;

– y increasing from top to bottom, from –7 to +7.

The x component of the vector is expressed as a 6-bit 2s complement number, the integer part of which is 5 bits (including sign). The y component is expressed as a 5-bit 2s complement number, the integer part of which is 4 bits (including sign). It is coded by differential variable-length coding as described in A.7.

The motion vector which applies to the C_R, C_B blocks is derived from the macro-block luminance motion vector in the following way:

– the vertical coordinate is identical to that of the luminance vector;

– the horizontal coordinate is equal to half that of the luminance vector.

Chrominance samples at quarter-pixel points are obtained by interpolation as is described in A.5.3.

A.6 Quantization of DCT coefficients

Subclauses A.6.1 and A.6.2 give information on the method of computation of the parameters necessary for the operation of the inverse quantizer which is specified in A.6.3.

The quantizer parameters signalled to the decoder are the transmission factor and the criticality. The transmission factor is related to the buffer occupancy and it is provided at stripe level, i.e. for all the macro-blocks belonging to each group of 8 video lines.

The criticality is provided at macro-block level and allows a different quantization precision for blocks belonging to a single stripe. The criteria for criticality selection concern only the coder side and are not specified.

A.6.1 AC coefficient quantization

A different quantization characteristic is used for each coefficient. The quantization is achieved in two steps.

A.6.1.1 Computation of relative coefficients

$$C\ (k, l) = 2Z\ (k, l)\ /\ [S\ (k, l, m, f)]$$

where

$S(k, l, m, f)$: transmission threshold for (k, l) coefficients and is of the form:

$S(k, l, m, f) = 2^{n(k, l, m, f)/16}$

where

$n(k, l, m, f)$: an integer

$m = 0, 1, 2, 3$ according to the block criticality (criticality factor)

f: transmission factor.

A.6.1.2 Quantization of relative coefficients

A.6.1.2.1 Quantization characteristic

Table A.3 defines the quantization levels for the nearly-linear law for luminance and chrominance information. The quantization law is symmetric, and the characteristic is given for positive input values only.

TABLE A.3/J.81

Nearly-linear quantizer characteristic

Imput values $C\ (k, l)$ or intervals	Quantizer levels	Quantized values $C'\ (k, l)$ [a]
0	0	0
1	1	1
2	2	2
:	:	:
255	255	255
256:257	256	256
258:259	257	:
:	:	:
510:511	383	510
512:515	384	513
516:519	385	:
:	:	:
1020:1023	511	1021
1024:1031	512	1027
1032:1039	513	:
:	:	:
2040:2047	639	2043

[a] Outputs of the inverse quantizer.

A.6.1.2.2 Determination of transmission threshold matrix

The *S* matrix for each component depends on the relative visibility matrix defined in Figures A.6 and A.7 for both components and buffer factor *f* which is sent before each stripe of the DCT blocks and the criticality factor *m* which is sent for each macro-block.

$p_0\,(k, l)$	0	1	2	3	4	5	6	7
0	0	0	2	8	12	18	22	28
1	0	6	6	10	16	18	22	34
2	0	6	10	14	18	20	24	38
3	2	6	12	16	18	20	26	40
4	6	12	14	16	20	22	28	42
5	10	14	14	18	22	24	30	42
6	14	16	16	18	22	24	34	44
7	14	18	18	20	24	30	38	44

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FIGURE A.6/J.81

Relative visibility matrix for luminance

The value of *f* is computed according to the buffer occupancy in order to provide a mean rate not greater than the bit rate available for video in the transmission multiplex. Different values of *f* may be transmitted for luminance and chrominance components of a stripe, as shown in Figure A.9.

The value of *m* is coded with two bits per macro-block.

The modules which realize the computation of *f* and the choice of the value for *m* are only in the coder and the corresponding information is sent to the decoder.

Referring to Figures A.8, A.9 and A.10, the scalar control parameter $n(k, l, m, f)$ for each component is obtained in the following way:

$$p\,(k, l, m) = \text{Min}\,[p_0\,(k, l) + Tr\,(m), Th\,(m)]$$

where

$p_0(k, l)$: defined in Figures A.6 and A.7; and

p: integer between 0 and 52.

$Tr(m)$ and $Th(m)$ are parameters depending on criticality (m) and are defined in Table A.4.

$p_0(k, l)$	1	2	3	4	5	6	7	8
0	0	0	3	4	6	8	8	11
1	0	1	2	3	6	8	9	13
2	2	2	3	4	7	9	10	16
3	3	4	5	5	8	10	12	16
4	5	6	6	7	9	11	13	17
5	8	7	9	9	11	14	16	21
6	10	11	11	11	14	16	19	24
7	12	12	12	12	17	18	20	26

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FIGURE A.7/J.81

Relative visibility matrix for chrominance

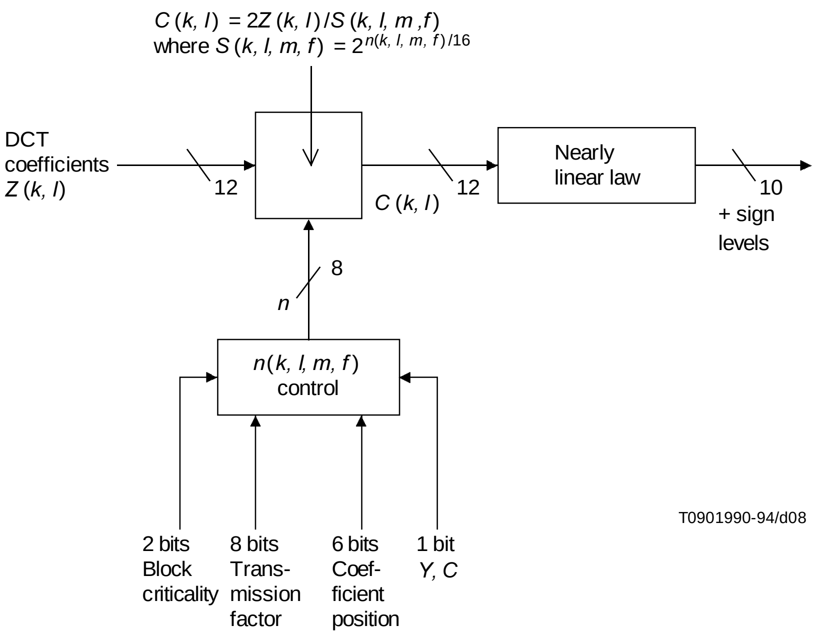


FIGURE A.8/J.81

Overview of quantizer

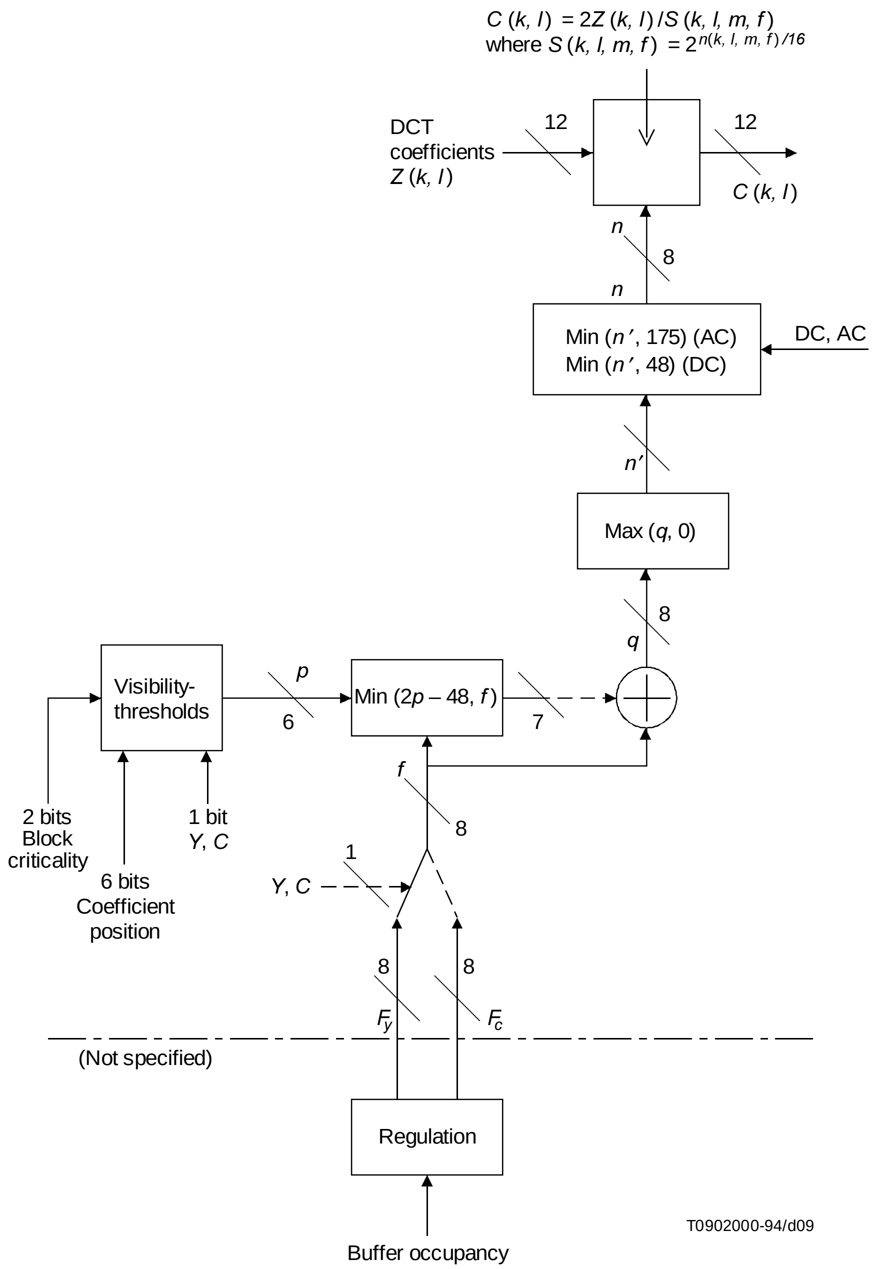


FIGURE A.9/J.81

Overview of calculation of the scalar control parameter *n(k, l, m, f)*

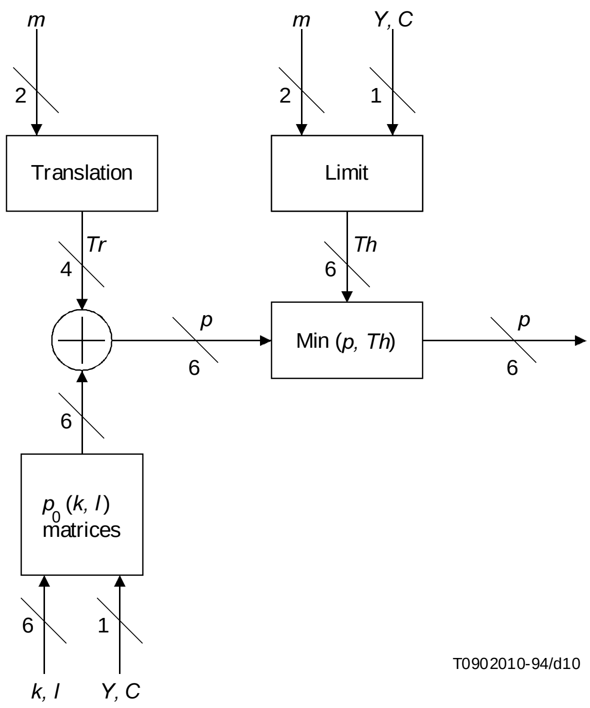


FIGURE A.10/J.81

Computation of *p*(*k*, *l*, *m*)

TABLE A.4/J.81

***Tr* (*m*) and *Th* (*m*) parameters**

Criticality (*m*)	Translation *Tr* (*m*) [*Y* or C_R C_B coefficients]	Limit for *Y* *Th* (*m*)	Limit for C_R C_B *Th*(*m*)
0	+8	No (i.e. 44 + 8)	No (i.e. 26 + 8)
1	+2	No (i.e. 44 + 2)	No (i.e. 26 + 2)
2	0	34	16
3	0	24	9

Then the scalar control parameter $n(k, l, m, f)$ is given by:

$$n\ (k, l, m, f) = \mathrm{Min}[n'(k, l, m, f), 175]$$

where

$$q\ (k, l, m, f) = \mathrm{Min}[2p(k, l, m) - 48, f] + f$$

$$n'\ (k, l, m, f) = \mathrm{Max}[q(k, l, m, f), 0]$$

A.6.1.2.3 Data accuracy

See Table A.5.

TABLE A.5/J.81

Coefficient data bits

Data	Total (including sign bit) (bits)
AC – DCT coefficients $Z(k, l)$	12
Relative coefficients $C(k, l)$	12
Quantized coefficients	11

A.6.1.2.4 Ranges of quantization parameters

See Table A.6.

TABLE A.6/J.81

Quantization parameter range

Information	Range
Transmission threshold $n(k, l, m, f)$	0 to 175
Transmission factor f	0 to 175
Relative visibility $p_0(k, l)$	0 to 44

The transmission factors are transmitted for each stripe of blocks and are each coded with 8 bits.

A.6.2 DC-coefficient quantization

The DC coefficient $Z(0, 0)$ is quantized using the same process as the AC coefficients but the scaling factor $n(0, 0, m, f)$ of the DC coefficient is limited to the range (0, 48).

A.6.3 Inverse quantization

The reconstructed DCT coefficients are given by the following formula:

$$Z'(k, l) = C'(k, l) \cdot S(k, l, m, f) \cdot ½$$

where

$S(k, l, m, f) = 2^{n(k, l, m, f)/16}$ as defined in A.6.1

$C'(k, l)$: quantized value corresponding to the transmitted quantizer level

$n(k, l, m, f)$ may be expressed as:

$n(k, l, m, f) = 16\,q + r$

where q (quotient) and r (remainder) are integers, $0 \le r < 16$

so that

$$Z'(k, l) = C'(k, l) \cdot 2^{q-1} \cdot 2^{r/16}$$

The 12-bit values for $2^{r/16}$ are given in Table A.7. The same set of values may be used in the quantizer.

$C'(k, l) \cdot 2^{q-1}$ is obtained by a binary left shift of $q - 1$ bits performed on the 12-bit value $C'(k, l)$. Only the 12 bits furthest on the right of the result are significant and are used in the following multiplication.

$Z'(k, l)$ is the result of the multiplication of $C'(k, l)2^{q-1}$ by $2^{r/16}$, truncated to 12 bits.

TABLE A.7/J.81

Values of $2^{r/16}$

r	$2^{r/16}$	$2048 \times 2^{r/16}$
0	1.00000000000	2048
1	1.00001011011	2139
2	1.00010111001	2233
3	1.00100011100	2332
4	1.00110000011	2435
5	1.00111101111	2543
6	1.01001100000	2656
7	1.01011010110	2774
8	1.01101010000	2896
9	1.01111010001	3025
10	1.10001010110	3158
11	1.10011100010	3298
12	1.10101110100	3444
13	1.11000001101	3597
14	1.11010101100	3756
15	1.11101010010	3922

A.7 Variable length coding for DCT coefficients and motion vector differences

A.7.1 Scanning path for quantized DCT values

Non-zero DCT coefficients are quantized and VLC coded. Runs of zeros, according to the scanning path shown in Figure A.11 are coded as run-lengths.

0	2	6	12	20	28	36	44
1	5	11	19	27	35	43	51
3	7	13	21	29	37	45	52
4	10	18	26	34	42	50	57
8	14	22	30	38	46	53	58
9	17	25	33	41	49	56	61
15	23	31	39	47	54	59	62
16	24	32	40	48	55	60	63

a) Scanning path for luminance

0	2	3	9	10	20	21	35
1	4	8	11	19	22	34	36
5	7	12	18	23	33	37	48
6	13	17	24	32	38	47	49
14	16	25	31	39	46	50	57
15	26	30	40	45	51	56	58
27	29	41	44	52	55	59	62
28	42	43	53	54	60	61	63

b) Scanning path for chrominance

FIGURE A.11/J.81

The transmission of the last run length of zeros in a block is avoided by anticipating the end of the block (EOB). The decoder assumes that the last coefficients in a block are all zeros when less than 64 coefficients are decoded.

If there is one or more coefficients +1 between two runs of zeros, or between a run of zeros and the EOB, one of them is not transmitted and the decoder reinserts it.

A.7.2 Assignment of codewords to quantized values and run lengths

The words at the output of the variable length coder have the following structure:

$$\left| 1\,X_i \right| \ldots \left| 1\,X_1 \right| \; \left| 0\,X_0 \right| \;,\; i = 0\,..\,8,\, X_i \;\in \{\, 0, 1 \,\}$$

$$\left| 1\,X_8 \right| \ldots \left| 1\,X_1 \right| \; \left| 1\,X_0 \right| \;, \qquad X_i \;\in \{\, 0, 1 \,\}$$

where | | corresponds to a pair of bits, and where $\in$ indicates a mapping.

The first bit is the continuation bit and if this is 0 the present pair is the last one except for the words having length 18; the second bit of each pair, and both the bits of the last pair, if the word length is 18, is the information bit and can assume the value 0 or 1. The length of the available words can vary from 2 to 18, as indicated in Table A.8, and the words having less than 18 bits end with a $|0\ X_0|$ pair.

TABLE A.8/J.81

Available word lengths

i	Word length (bit)	Word structure	Number of words
0	2	$0\ X_0$	2
1	4	$1\ X_1\ 0\ X_0$	4
2	6	.	8
3	8	.	16
4	10	.	32
5	12	.	64
6	14	.	128
7	16	$1\ X_7 \ldots\ 0\ X_0$	256
8	18	$1\ X_8 \ldots\ 0\ X_0$	512
	18	$1\ X_8 \ldots\ 1\ X_0$	512

The total number of words is 1534 of which 66 are used to code the run length of zeros, the special words EOB_0 and EOB_1, indicating the end of each block (see A.8.1.4), and the word NULL (used in case of underflow). In order to avoid underflow, the zero values can be coded using the NULL word. In this case, a run length of *n* zeros can be coded with *n* NULL words.

It is allowed to mix the NULL words and run length of zeros to obtain the desired length of *n*.

The NULL word is considered as a normal value, so a "+1" must be transmitted between two NULL words.

The codes 11 11 11 11 11 11 11 11 11 and 10 10 10 10 10 10 10 10 10 are reserved.

The remaining 1466 words are available to code the quantized levels from –733 to +733.

Two assignment tables for the values of X (quantized levels) lower than 17 and greater than –17 and for the run lengths up to 28 zeros are used. In Table A.9 the value of luminance or chrominance coefficients assigned to codewords differ in 20 cases, thus two different assignment tables are required to specify the luminance or the chrominance coefficients. The assignments of EOB_0 and EOB_1 are fixed for all the tables.

TABLE A.9/J.81

Assignment for luminance (*Y*) and chrominance (*C*) coefficients

Codeword	*Y*		*C*	Codeword	*Y*		*C*
0 1		1		0 0		–1	
1 1 0 0		2		1 0 0 1		–2	
1 1 0 1		0*1		1 0 0 0		0*2	
1 1 1 0 0 0		0*3		1 0 1 1 0 1		0*4	
1 1 1 0 0 1	3		0*5	1 0 1 1 0 0	–3		0*6
1 1 1 1 0 0	4		0*7	1 0 1 0 0 1	–4		0*8
(1 1 1 1 0 1	reserved, EOB$_1$)			(1 0 1 0 0 0	reserved, EOB$_0$)		
1 1 1 0 1 0 0 0	0*5		3	1 0 1 1 1 1 0 1	0*6		–3
1 1 1 0 1 0 0 1	0*7		4	1 0 1 1 1 1 0 0	0*8		–4
1 1 1 0 1 1 0 0		0*9		1 0 1 1 1 0 0 1		0*10	
1 1 1 0 1 1 0 1		0*11		1 0 1 1 1 0 0 0		0*12	
1 1 1 1 1 0 0 0		5		1 0 1 0 1 1 0 1		–5	
1 1 1 1 1 0 0 1	6		0*13	1 0 1 0 1 1 0 0	–6		0*14
1 1 1 1 1 1 0 0	7		0*15	1 0 1 0 1 0 0 1	–7		0*16
1 1 1 1 1 1 0 1	8		0*17	1 0 1 0 1 0 0 0	–8		0*18
1 1 1 0 1 0 1 0 0 0	0*13		6	1 0 1 1 1 1 1 1 0 1	0*14		–6
1 1 1 0 1 0 1 0 0 1	0*15		7	1 0 1 1 1 1 1 1 0 0	0*16		–7
1 1 1 0 1 0 1 1 0 0	0*17		8	1 0 1 1 1 1 1 0 0 1	0*18		–8
1 1 1 0 1 0 1 1 0 1		0*19		1 0 1 1 1 1 1 0 0 0		0*20	
1 1 1 0 1 1 1 0 0 0		0*21		1 0 1 1 1 0 1 1 0 1		0*22	
1 1 1 0 1 1 1 0 0 1		0*23		1 0 1 1 1 0 1 1 0 0		0*24	
1 1 1 0 1 1 1 1 0 0		0*25		1 0 1 1 1 0 1 0 0 1		0*26	
1 1 1 0 1 1 1 1 0 1		0*27		1 0 1 1 1 0 1 0 0 0		0*28	
1 1 1 1 1 0 1 0 0 0		9		1 0 1 0 1 1 1 1 0 1		–9	
1 1 1 1 1 0 1 0 0 1		10		1 0 1 0 1 1 1 1 0 0		–10	
1 1 1 1 1 0 1 1 0 0		11		1 0 1 0 1 1 1 0 0 1		–11	
1 1 1 1 1 0 1 1 0 1		12		1 0 1 0 1 1 1 0 0 0		–12	
1 1 1 1 1 1 1 0 0 0		13		1 0 1 0 1 0 1 1 0 1		–13	
1 1 1 1 1 1 1 0 0 1		14		1 0 1 0 1 0 1 1 0 0		–14	
1 1 1 1 1 1 1 1 0 0		15		1 0 1 0 1 0 1 0 0 1		–15	
1 1 1 1 1 1 1 1 0 1		16		1 0 1 0 1 0 1 0 0 0		–16	

NOTE – 0*n refers to a run-length of n zeros.

The information bits for the positive values and the corresponding negative values are complemented. Similarly, the information bits for EOB_0 and EOB_1 are also complemented.

The assignments for run lengths of zeros from 29 up to 63 and for the codeword NULL are shown in Table A.10.

TABLE A.10/J.81

Assignments for run length of zeros

Codeword						Run of zeros	Codeword						Run of zeros
1 1	1 0	1 0	1 0	1 0	0 0	0*29	1 0	1 1	1 1	1 1	1 1	0 0	0*30
1 1	1 0	1 0	1 0	1 0	0 1	0*31	1 0	1 1	1 1	1 1	1 1	0 1	0*32
1 1	1 0	1 0	1 0	1 1	0 0	0*33	1 0	1 1	1 1	1 1	1 0	0 0	0*34
1 1	1 0	1 0	1 0	1 1	0 1	0*35	1 0	1 1	1 1	1 1	1 0	0 1	0*36
1 1	1 0	1 0	1 1	1 0	0 0	0*37	1 0	1 1	1 1	1 0	1 1	0 0	0*38
1 1	1 0	1 0	1 1	1 0	0 1	0*39	1 0	1 1	1 1	1 0	1 1	0 1	0*40
1 1	1 0	1 0	1 1	1 1	0 0	0*41	1 0	1 1	1 1	1 0	1 0	0 0	0*42
1 1	1 0	1 0	1 1	1 1	0 1	0*43	1 0	1 1	1 1	1 0	1 0	0 1	0*44
1 1	1 0	1 1	1 0	1 0	0 0	0*45	1 0	1 1	1 0	1 1	1 1	0 0	0*46
1 1	1 0	1 1	1 0	1 0	0 1	0*47	1 0	1 1	1 0	1 1	1 1	0 1	0*48
1 1	1 0	1 1	1 0	1 1	0 0	0*49	1 0	1 1	1 0	1 1	1 0	0 0	0*50
1 1	1 0	1 1	1 0	1 1	0 1	0*51	1 0	1 1	1 0	1 1	1 0	0 1	0*52
1 1	1 0	1 1	1 1	1 0	0 0	0*53	1 0	1 1	1 0	1 0	1 1	0 0	0*54
1 1	1 0	1 1	1 1	1 0	0 1	0*55	1 0	1 1	1 0	1 0	1 1	0 1	0*56
1 1	1 0	1 1	1 1	1 1	0 0	0*57	1 0	1 1	1 0	1 0	1 0	0 0	0*58
1 1	1 0	1 1	1 1	1 1	0 1	0*59	1 0	1 1	1 0	1 0	1 0	0 1	0*60
1 1	1 1	1 0	1 0	1 0	0 0	0*61	1 0	1 0	1 1	1 1	1 1	0 0	0*62
1 1	1 1	1 0	1 0	1 0	0 1	0*63	1 0	1 0	1 1	1 1	1 1	0 1	Null

NOTE – 0**n* refers to a run-length of *n* zeros.

Examples of the use of run lengths and end of blocks are given below:

Example 1:

Coefficients:	–2	0 0 0	+1	+1	0 0	+2	0 0 0 0	End of block
Codewords:	1001	111000	01	01	1000	1100	101101	111101
Transmitted:	1001	111000	01		1000	1100		111101

+1 is not transmitted because there are two +1s between two runs of zeros, and a run of four zeros is not transmitted because the EOB is anticipated.

Example 2:

Coefficients:	–2	0 0 0 0 0 0 0 0 0	+1	End of block
Codewords:	1001	11101100	01	111101
Transmitted:	1001	11101100		111101

+1 is not transmitted because it is between a run of nine zeros and the EOB.

The assignments for values of quantized levels X are made in two's-complement using the following rules:

Range of x rules

–733 ... –479	Add +1501, then generate nine info bits, set continuation bit of last pair to one (see example 1).
–478 ... –17	Add –34, then generate up to nine info bits, not considering all the leading bits equal to one (see example 2).
–16 ... +16	Use Table A.9 for assignment.
+17 ... +478	Add +33, then generate up to nine info bits, not considering all the leading bits equal to 0 (see example 3).
+479 ... +733	Add +34, then generate nine info bits, set continuation bit of last pair to one (see example 4).

Example 1: from –733 to –479

X = –733   –733 + 1501 = 768 = $(001\ 100000000)_2$ =
(|1 1|1 0|1 0|1 0|1 0|1 0|1 0|1 0|1 0|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

X = –479   –479 + 1501 = 1022 = $(001\ 111111110)_2$ =
(|1 1|1 1|1 1|1 1|1 1|1 1|1 1|1 1|1 0|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

Example 2: from –478 to –17

X = –478   –478 –34 = –512 = $(111\ 000000000)_2$ =
(|1 0|1 0|1 0|1 0|1 0|1 0|1 0|1 0|0 0|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

X = –403   –403 –34 = –437 = $(111\ 001001011)_2$ =
(|1 0|1 0|1 1|1 0|1 0|1 1|1 0|1 1|0 1|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

X = –23   –23 –34 = –57 = $(111111\ 000111)_2$ =
(|1 0|1 0|1 0|1 1|1 1|0 1|)VLC
(X_5 X_4 X_3 X_2 X_1 X_0)VLC

Example 3: from +17 to +478

X = 23   23 + 33 = 56 = $(000000\ 111000)_2$ =
(|1 1|1 1|1 1|1 0|1 0|0 0|)VLC
(X_5 X_4 X_3 X_2 X_1 X_0)VLC

X = 403   403 + 33 = 436 = $(000\ 110110100)_2$ =
(|1 1|1 1|1 0|1 1|1 1|1 0|1 1|1 0|0 0|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

X = 478   478 + 33 = 511 = $(000\ 111111111)_2$ =
(|1 1|1 1|1 1|1 1|1 1|1 1|1 1|1 1|0 1|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

Example 4: from +479 to +733

X = 479   479 + 34 = 513 = $(001\ 000000001)_2$ =
(|1 0|1 0|1 0|1 0|1 0|1 0|1 0|1 0|1 1|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

X = 733   733 + 34 = 767 = $(001\ 011111111)_2$ =
(|1 0|1 1|1 1|1 1|1 1|1 1|1 1|1 1|1 1|)VLC
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)VLC

A.7.3 Coding of the motion vectors

Predictive encoding of the motion vectors is performed along a stripe of blocks. The components of the prediction error on the horizontal (MV_x) and vertical (MV_y) directions are VLC coded according to Table A.11. The prediction for the motion vector of a macro-block is the motion vector of the previous macro-block of the stripe. The prediction for the first macro-block of a stripe and for a macro-block following an intra-field or inter-field encoded macro-block is 0 for both coordinates of the motion vector.

The motion vector differences MV_x and MV_y are only sent:

– if the macro-block is inter-frame encoded; and

– if the motion vector difference (MV_x, MV_y) is different from (0,0).

The corresponding macro-blocks are identified by MI = "10".

A.8 Video framing and forward error correction

A.8.1 Video framing

A single stream is produced for variable length coded (VLC) and fixed length coded (FLC) data. All data are transmitted MSB first.

A.8.1.1 General structure

Even fields are organized as follows:

FSW 00 FCP BOF

FSW 01 FCP BOF

FSW 10 FCP BOF

SSW SN_0 BO_0 TFY_0 TFC_0 $(MI_j\ CT_j\ VLC_j)_0$ [STUFF]CRC_0

:

SSW SN_i BO_i TFY_i TFC_i $(MI_j\ CT_j\ VLC_j)_i$ [STUFF]CRC_i

:

SSW SN_{m-1} BO_{m-1} TFY_{m-1} TFC_{m-1} $(MI_j\ CT_j\ VLC_j)_{m-1}$ [STUFF]CRC_{m-1}

m = 36 for a 50 Hz system

m = 31 for a 60 Hz system

i varies from 0 to m – 1 for each stripe and j varies from 1 to 45 (position of the macro-block in the stripe).

VLC_j are VLC data for the jth macro-block, and have the form :

$$[MV_x, MV_y]\ VLC_{y1}\ EOB\ VLC_{cb}\ EOB\ VLC_{y2}\ EOB\ VLC_{cr}\ EOB$$

Odd fields are organized in a similar manner where i varies from m to $2m$–1.

TABLE A.11/J.81

Codewords for the motion vector differences

Codeword	MV_x or MV_y	Codeword	MV_x or MV_y
01	0	00	–0.5
11 00	+0.5	10 01	–1
11 01	+1	10 00	–1.5
11 10 00	+1.5	10 11 01	–2
11 10 01	+2	10 11 00	–2.5
11 11 00	+2.5	10 10 01	–3
(11 11 01 reserved.	EOB_1)	(10 10 00 reserved.	EOB_0)
11 10 10 00	+3	10 11 11 01	–3.5
11 10 10 01	+3.5	10 11 11 00	–4
11 10 11 00	+4	10 11 10 01	–4.5
11 10 11 01	+4.5	10 11 10 00	–5
11 11 10 00	+5	10 10 11 01	–5.5
11 11 10 01	+5.5	10 10 11 00	–6
11 11 11 00	+6	10 10 10 01	–6.5
11 11 11 01	+6.5	10 10 10 00	–7
11 10 10 10 00	+7	10 11 11 11 01	–7.5
11 10 10 10 01	+7.5	10 11 11 11 00	–8
11 10 10 11 00	+8	10 11 11 10 01	–8.5
11 10 10 11 01	+8.5	10 11 11 10 00	–9
11 10 11 10 00	+9	10 11 10 11 01	–9.5
11 10 11 10 01	+9.5	10 11 10 11 00	–10
11 10 11 11 00	+10	10 11 10 10 01	–10.5
11 10 11 11 01	+10.5	10 11 10 10 00	–11
11 11 10 10 00	+11	10 10 11 11 01	–11.5
11 11 10 10 01	+11.5	10 10 11 11 00	–12
11 11 10 11 00	+12	10 10 11 10 01	–12.5
11 11 10 11 01	+12.5	10 10 11 10 00	–13
11 11 11 10 00	+13	10 10 10 11 01	–13.5
11 11 11 10 01	+13.5	10 10 10 11 00	–14
11 11 11 11 00	+14	10 10 10 10 01	–14.5
11 11 11 11 01	+14.5	10 10 10 10 00	–15
11 10 10 10 10 00	+15	10 11 11 11 11 01	–15.5
11 10 10 10 10 01	+15.5	10 11 11 11 11 00	–16
11 10 10 10 11 00	+16	10 11 11 11 10 01	–16.5
11 10 10 10 11 01	+16.5	10 11 11 11 10 00	–17
11 10 10 11 10 00	+17	10 11 11 10 11 01	–17.5
11 10 10 11 10 01	+17.5	10 11 11 10 11 00	–18
11 10 10 11 11 00	+18	10 11 11 10 10 01	–18.5
11 10 10 11 11 01	+18.5	10 11 11 10 10 00	–19
11 10 11 10 10 00	+19	10 11 10 11 11 01	–19.5
11 10 11 10 10 01	+19.5	10 11 10 11 11 00	–20
11 10 11 10 11 00	+20	10 11 10 11 10 01	–20.5
11 10 11 10 11 01	+20.5	10 11 10 11 10 00	–21
11 10 11 11 10 00	+21	10 11 10 10 11 01	–21.5
11 10 11 11 10 01	+21.5	10 11 10 10 11 00	–22
11 10 11 11 11 00	+22	10 11 10 10 10 01	–22.5
11 10 11 11 11 01	+22.5	10 11 10 10 10 00	–23
11 11 10 10 10 00	+23	10 10 11 11 11 01	NULL
11 11 10 10 10 01	+23.5	10 10 11 11 11 00	–23.5
11 11 10 10 11 00	+24	10 10 11 11 10 01	–24
11 11 10 10 11 01	+24.5	10 10 11 11 10 00	–24.5
11 11 10 11 10 00	+25	10 10 11 10 11 01	–25
11 11 10 11 10 01	+25.5	10 10 11 10 11 00	–25.5
11 11 10 11 11 00	+26	10 10 11 10 10 01	–26
11 11 10 11 11 01	+26.5	10 10 11 10 10 00	–26.5
11 11 11 10 10 00	+27	10 10 10 11 11 01	–27
11 11 11 10 10 01	+27.5	10 10 10 11 11 00	–27.5
11 11 11 10 11 00	+28	10 10 10 11 10 01	–28

A.8.1.2 Detailed content

FSW	Field synchronization word (47 "1"s + "0") (see Note 1)	48 bits
00 01 10	are used to identify the threefold of FSW, FCP and BOF	2 bits
FCP	Field coding parameters (see A.8.1.3)	30 bits
BOF	Buffer occupancy at the field level (measured at the beginning of the active field just before the first FSW is inserted into the buffer) (see Note 2)	16 bits
SSW	Stripe synchronization word ("0" + 46 "1"s + "0")	48 bits
BO	Buffer occupancy (indicates the buffer occupancy at the coder just before the SSW of the current stripe is inserted into the buffer) (see Note 2)	16 bits
SN_i	Stripe number for the i^{th} stripe range is from 0 to 71 {50 Hz system}: 0 to 35 {even field} 36 to 71 {odd field} the MSB is set to "0" range is from 0 to 61 {60 Hz system}: 0 to 30 {even field} 31 to 61 {odd field} the two MSB's are set to "0"	8 bits
TFY_i	Transmission factor for luminance in the i^{th} stripe (from 0 to 175)	8 bits
TFC_i	Transmission factor for chrominance in the i^{th} stripe (from 0 to 175)	8 bits
CRC_i	Cyclic redundancy code for the i^{th} stripe (to be applied to all bits of the encoded stripex cluding SSW) excluding SSW) The generator polynomial is $1 + x^2 + x^{15} + x^{16}$	16 bits
MI_j	Mode identification 00 intra-field mode 01 inter-field mode 10 inter-frame mode with motion compensation [motion vector difference ≠(0,0)] 11 inter-frame mode with motion compensation [motion vector difference = (0,0)]	2 bits
CT_j	Criticality (from 0 to 3)	2 bits
MV_x	VLC codeword associated with the motion prediction error in the horizontal direction (see Table A.11 in A.7) (see Note 4)	variable
MV_y	VLC codeword associated with the motion prediction error in the vertical direction (see Table A.11 in A.7) (see Note 4)	variable

VLC_y1	VLC words for first Y block in the macro-block	variable
VLC_{cb}	VLC words for C_B block in the macro-block	variable
VLC_{y2}	VLC words for second Y block in the macro-block	variable
VLC_{cr}	VLC words for C_R block in the macro-block	variable
[STUFF]	Stuffing bits (see Note 3)	2, 4, 6, 8, 10, 12 or 14 bits
EOB	End-of-block code (see A.8.1.4)	6 bits

(EOB_0 = "10 10 00", EOB_1 = "11 11 01")

NOTES

1 The stream of video data is organized in 16-bit words. In order to ensure easy synchronization, FSW and SSW are aligned at the beginning of these words.

2 Minimum coder buffer occupancy equals 128 kbit/s. Maximum coder buffer occupancy is 1 572 864 kbit/s minus 128 kbit/s. The buffer occupancy at the coder is measured in bits and is 21 bits long. The empty condition is equal to "zero" and only the 16 most significant bits are transmitted.

3 In order to ensure that the number of coded bits corresponding to a stripe is an integer multiple of 16 bits, stuffing bits are inserted between the last coded macro-block of the stripe and the CRC, if needed. As the number of coded bits is even, the possible configurations for the stuffing bits are: (00)*n where n = 1, 2, 3, 4, 5, 6 or 7 and (00)*n means n times repetition.

4 MV_x and MV_y are transmitted only when mode MI_j = 10.

A.8.1.3 Definition of the data for phase information and status in the video multiplex

Field coding parameters (FCP)

MSB	r	VF	AR	r	ST	VA	FS	SL	BA	SCP	LSB
	2	3	1	3	1	1	3	1	7	8	

r Reserved bits, set to "0", ignored by the receiver

VF Video format

000 = 4:2:2, 001 = PAL, 010 = NTSC
011 = SECAM, 100 = MAC

AR Aspect ratio

0 = 4:3
1 = 16:9

ST System type

0 = 50 Hz, 1 = 60 Hz

VA V-axis switch (PAL)

VA = 1 for positive phase on the first line of each field

FS Field sequence

Field sequence	Frame	Field
000	1	1
001	1	2
010	2	3
011	2	4
.	.	.
.	.	.
.	.	.
111	4	8

SL Sub-carrier/line frequency relationship

0 = correct

BA Burst amplitude (for PAL and NTSC only)

The amplitude of the sub-carrier burst is quantized as a Recommendation ITU-R BT.601 luminance signal, with the MSB omitted

SCP Sub-carrier phase (for PAL and NTSC only)

Phase of the reference sub-carrier at the field-synchronization datum with respect, to field start as defined in Recommendation ITU-R BT 470 [8], MSB first.

Scale: 0 = ([360°/256] × 0)

1 = ([360°/256] × 1)

... = ...

255 = ([360°/256] × 255)

A.8.1.4 Generation of the EOB sequence

Two VLC words are assigned to the end-of-block event: EOB_0 and EOB_1. At the coder a pseudo-random sequence is generated, the repetition of which is equal to the number of blocks (180) in a video stripe of blocks. The pseudo-random generator is reset at the beginning of each stripe. At the end of each block, the pseudo-random generator steps forward one bit and the output of the generator, 0 or 1 determines which of the two EOB words, EOB_0 and EOB_1 is inserted as delimiter of the block.

The pseudo-random generator is based on the following polynomial:

$$g(x) = 1 + x^5 + x^9$$

and corresponds to the feedback shown in Figure A.12.

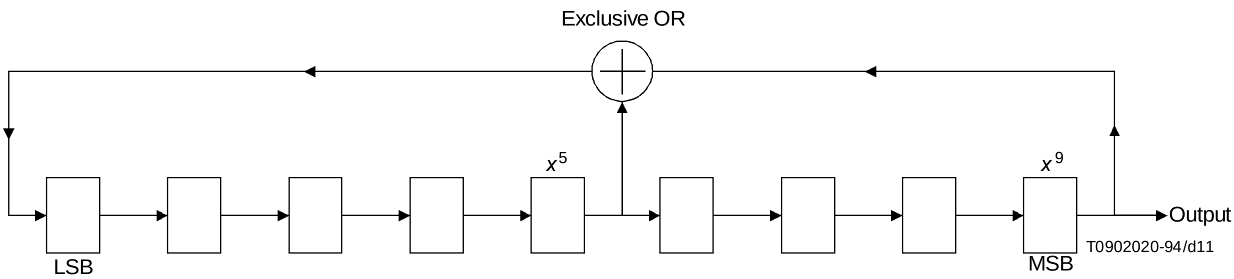


FIGURE A.12/J.81

Pseudo-random generator feedback arrangement

EOB_0 and EOB_1 correspond respectively to one “0” and “1” at the output of the pseudo-random generator.

The initial value of the shift register at the beginning of each stripe is:

LSB → 100111000

With the configuration, the initial value at the beginning of a stripe may also be obtained by simply inverting the LSB of the contents of the shift register at the end of the previous stripe.

The successive states of the pseudo-random generator are:

State 1	100111000 (beginning of a stripe)
State 2	110011100
State 3	111001110
.	.
.	.
.	.
State 180	001110001 (end of stripe)
Following state	000111000
State 1	100111000 (beginning of the following stripe)

A.8.2 Forward error protection and correction

The transmission signal is protected from transmission errors by a Reed Solomon (255,239) code which is used to correct 8-octet errors and has 2-octet interleaving.

The generator polynomial of the Reed Solomon (RS) code is given by

$$\prod_{i=0}^{15} (x + \alpha^i)$$

where α is a root of the binary primitive polynomial $x^8 + x^4 + x^3 + x^2 + 1$.

A data octet (d_7, d_6, ..., d_1, d_0) is identified with the element $d_7\alpha^7 + d_6\alpha^6 + ... + d_1\alpha + d_0$ in Galois Field (GF) (256), the finite field with 256 elements.

The redundancy of the forward error coding is 6.69%. The data stream is interleaved in a two-stage operation as follows:

First stage

The data stream at the output of the video encoder is arranged in a matrix of 16 rows of 239 columns. Each column corresponds to one 16-bit word of video data. The first column is reserved and ignored by the decoder.

The RS (255,239) code is computed on each of the 2 rows of octets and the 16-octet error control group is added to the corresponding row. The write sequence is performed from column 1 to column 238 with the sequence shown in Figure A.13.

Second stage

Three successive blocks formed in the first stage are interlaced column by column to form the superblock shown in Figure A.14. Numbers refer to the sequence of video-data octets passed from the video framing layer to the first stage of error protection. Transmission is performed reading octets column by column.

A.9 Additional services

A.9.1 Audio

A maximum of two separate channels is provided for the transport of audio services through the codec. These appear in the multiplex as octets A and A′, where A is the primary and A′ is the supplementary audio data channel. By varying the frequency of occurrence of A and A′ octets in the multiplex, channel rates of 2048 kbit/s or 1544 kbit/s can be accommodated either singly, or as a pair. Any data capacity not used for audio is reutilized for video data. The A and A′ channels can be used synchronously or asynchronously, and are intended for use with appropriate audio codecs having their own data protection mechanisms.

A.9.2 Supervision channel

A.9.2.1 Overview

The supervision channel is intended to carry information related to the operation of the encoder and to the management of the transmission.

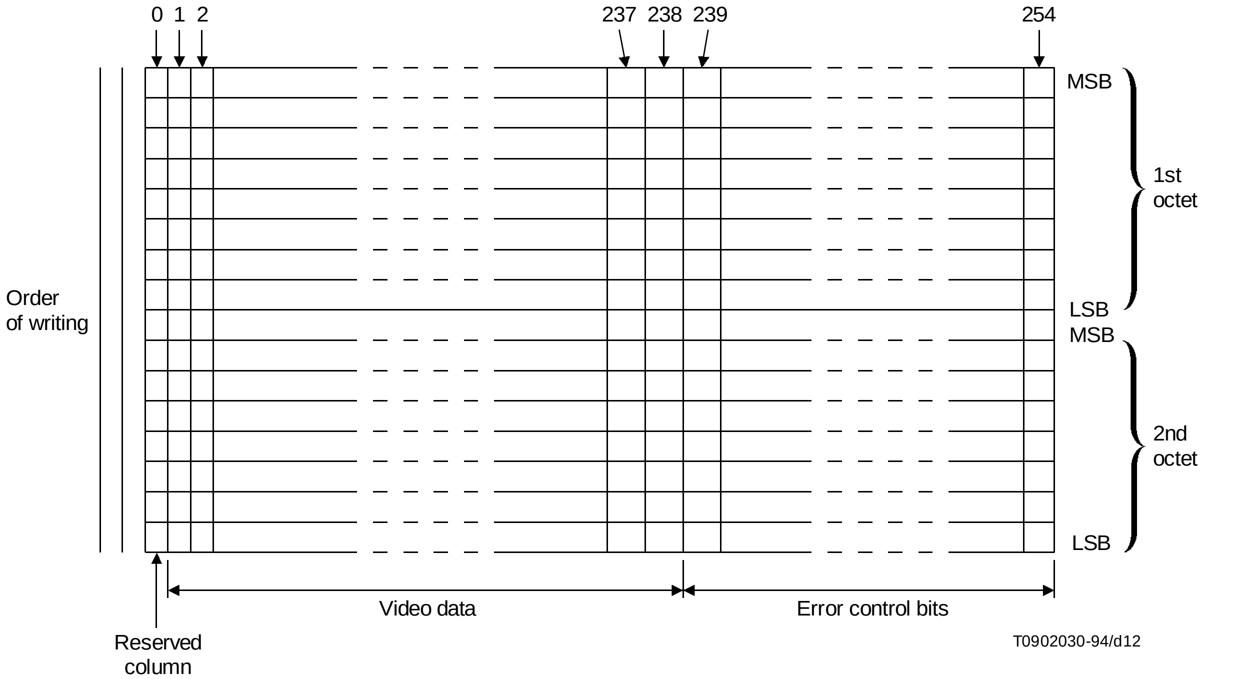


FIGURE A.13/J.81

Bit stream matrix

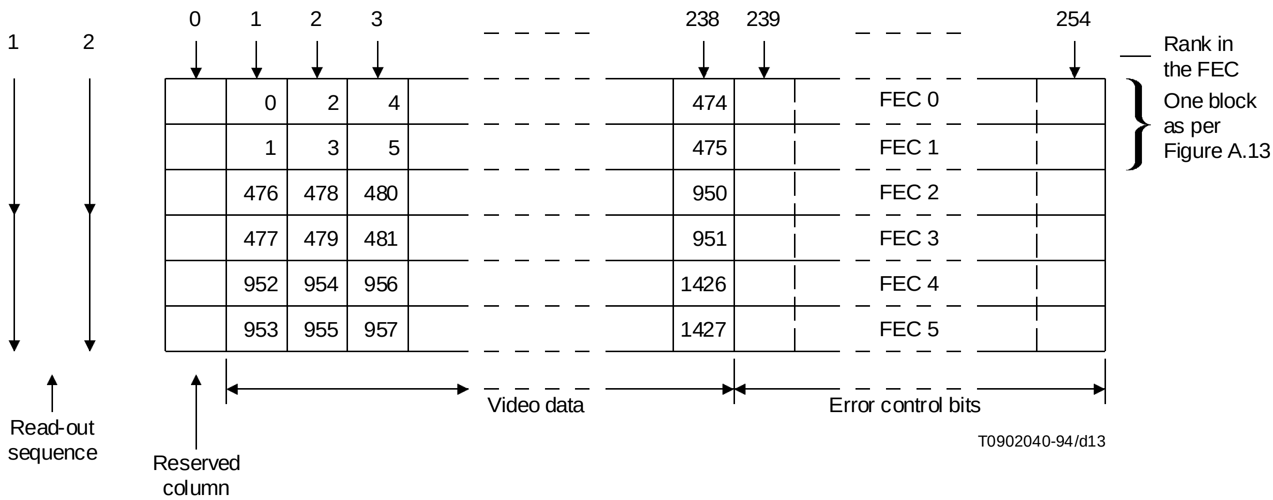


FIGURE A.14/J.81

Superblock configuration

Part of this information is directly related to the codec and is specified in A.9.2. Other information may be defined at a later stage.

The requirement that various types of messages are serially inserted in the channel necessitates a protocol which will accommodate potentially long user-messages yet which guarantees a sufficiently short transmission time for urgent service messages such as alarms.

To this effect, the organization of the supervision channel complies with the rules developed for the formatting of user data in the Recommendation ITU-R BT.656 digital audio interface [9].

For transmission of necessary fundamental codec messages only that part of the format described below need be implemented. The parameters introduced to maintain full compatibility with the complete format are noted between square brackets [ ].

The definition of the supervision channel comprises the following sections:

- Message definition;
- Packet structure;
- Frame structure;
- Channel management;
- Extension rules.

A.9.2.2 Message definition

A.9.2.2.1 Alarms (mandatory, address FE hex, priority 3)

Alarms indication message. The alarm condition is logic "zero". It is comprised of:

Octet 0: Alarms related to the encoder itself

- bit 0 (LSB) power supply fault
- bit 1 time-base error in the multiplexer
- bit 2 fault in the video processing chain
- bit 3 fault in the audio processing chain
- bits 4-7 reserved (set to logic "one")

Octet 1: Alarms related to the video input

- bit 0 (LSB) no input signal (analogue interface); junction fault (digital interface)
- bit 1 time-base error
- bit 2 out-of-specification input signal (the encoder cannot work properly)
- bit 3 out-of-specification input signal (the encoder can still work, possibly with reduced quality)
- bits 4-7 reserved (set to logic "one")

Octet 2: Alarms related to the auxiliary signals in the video field blanking interval

- bits 0-7 reserved (set to logic "one")

Octet 3: Alarms related to the audio input(s)

- bit 0 (LSB) junction fault (digital interface only)
- bit 1 time-base error
- bit 2 out-of-specification input signal (the encoder cannot work properly)
- bit 3 out-of-specification input signal (the encoder can still work, possibly with reduced quality, e.g. saturation of analogue inputs)
- bits 4-7 reserved (set to logic "one")

A.9.2.2.2 Multiplex structure (mandatory, address FD hex, priority 2)

This message provides information related to the multiplex structure for use by network supervision equipment, if necessary.

Octet 0: Copy of the 8-bit word carried by bit m_2 in octet J4 of the multiplex. LSB corresponds to the bit carried in frame 0, MSB to the bit carried in frame 7

Octet 1: Copy of bits carried through bit m_3

Octet 2: Copy of bits carried through bit m_4

Octet 3: Video format, as specified in the FCP field of the video multiplex

- bit 0 (LSB) system type
- bit 1 aspect ratio
- bits 2-4 video format
- bits 5-7 reserved (set to logic "one")

Octet 4: Sound encoding method

- 00 not specified
- 01 according to Recommendation ITU-R CMTT.724 [10]
- others reserved (set to logic "one")

A.9.2.2.3 Source identification (optional, address FC hex, priority 2)

User-defined alphanumeric string of up to 15 ASCII characters. MSB is set to "0". Non-printing control characters (codes 01 hex to 1F hex and 7F hex) are not permitted.

A.9.2.2.4 Destination identification (optional, address FB hex, priority 2)

User-defined alphanumeric string of up to 15 ASCII characters. MSB is set to "0". Non-printing control characters (codes 01 hex to 1F hex and 7F hex) are not permitted.

A.9.2.2.5 Identification of the encoder (optional, address FA hex, priority 2)

User-defined alphanumeric string of up to 15 ASCII characters. It may be used to distinguish each of the coders on the network. MSB is set to "0". Non-printing control characters (codes 01 hex to 1F hex and 7F hex) are not permitted.

A.9.2.2.6 Other messages

The present list of messages may be extended, provided that they comply with the requirements of the extended system. In particular, messages longer than 15 octets will be segmented in order to limit the length of packets.

A.9.2.2.7 Header

Each message is preceded by the following header octet:

- bits 0-3 Message length in octets, excluding the header (LSB is bit 0).
- bit 4 Set to "0" ["1" indicates the encoding of lengths above 15 octets].
- bits 5-7 3-bit continuity index of messages sent with a given address. Not incremented in case of repetition of the previous message.

A.9.2.3 Packet structure

Messages preceded by the header described above [and segmented if necessary, in the case of the extended mode] are inserted in packets.

A packet consists of:

An address octet – Identifies the nature of the message. This address is specified in A.9.2.2 for the messages already defined (in the case of an extended system, an address extension octet may be added).

A control octet – Structured as follows:

– bits 0 and 1 Priority index [used to manage resource sharing when needed]. See A.9.2.2 for the messages already defined.

– bits 2 to 4 Continuity index referring to packets sent with a given address. Not incremented in case of repetition of the previous message. For single segment messages, this index may be equal to the message repetition index.

– bit 5 "0" [used for software address extension].

– bits 6 and 7 b6 = "0", b7 = "1" [used to link segmented messages].

– the message [or message segment].

A.9.2.4 Frame structure

The packets defined above (19 octets maximum) are transmitted within HDLC (high-level data link control) frames [11] on the 8 kHz supervision channel provided by bit s of the container.

An HDLC frame comprises:

– a beginning flag: "01111110";

– a packet;

– a 16-bit error-detecting CRC (FCS: frame check sequence);

– an ending flag, identical to the beginning one.

To avoid the imitation of flags by data, HDLC defines a method of suppressing long strings of ones in the data or CRC areas.

All messages received incorrectly will be ignored according to the HDLC rules. Furthermore, messages sent to addresses which are not recognized by the receiver should also be ignored.

A.9.2.5 Channel management

HDLC frames are organized in blocks starting every 800 ± 1 bits (10 Hz repetition rate).

Each block starts with the transmission of the alarm message (address FE hex), followed by other HDLC frames in any order. The "idle" mode should be avoided between transmission of successive HDLC frames.

When all frames to be transmitted in a block have been sent, the channel is filled with "ones" ("idle" mode) until the start of the new block.

This procedure is compatible with the extended system and allows, if needed, downstream insertion of other data.

To prevent channel saturation, it is recommended that the encoder should send messages defined with priority 2 every two or three blocks and with an approximately even distribution over successive blocks.

A.9.2.6 Extension rules

Extension to the transmission of other messages, if necessary, will be based on the protocol under study in AES for the transmission of user data across the professional digital audio interface.

However, it should be recognized that the reduced bit rate available will have implications on the real-time performance of the system and on the definition of priority levels.

Address field 00 to 7F hex is allocated for user-defined applications. All undefined addresses in the field 80 hex to FF hex are reserved.

A.9.3 Transmission frame for Teletext and other digital data inserted during field blanking intervals

This subclause concerns the use of a 384 kbit/s channel to carry Teletext and other signals found in the vertical blanking interval (VBI) of a television signal. Teletext is normally present only for distribution but this may not be true in future or where "Teletext" coding is used to enable data to be transmitted during contribution, e.g. ancillary data carried in the 4:2:2 interface.

A.9.3.1 Introduction

The frame is optimized for the transmission of the various Teletext systems described in Recommendation ITU-R BT.653 [12], but it may also be used for other forms of messages. Up to 4.096 messages may be defined, among which Teletext messages form a particular class.

Each message comprises a type identifier, a length indicator and the data field itself.

Each frame has a fixed length and consists of a synchronization word, a frame status, a 46-octet field carrying one (possibly 2) message(s) and protection bits.

When the allocated transmission bit rate exceeds the required data bit rate, dummy data fields are transmitted. Thus, there is no need to justify the frames in the transmission multiplex.

A.9.3.2 Frame structure

The frame is composed of the following information (see Figure A.15). In all fields MSB are sent first:

- a 10-bit synchronization word — 010011011X (see Note 1 of Table A.13)
- a 4-bit frame header including:
  - a system type identifier — 0: 625/50 1: 525/60
  - a reserved bit — fixed to 0
  - a frame status — 2 bits, see A.9.3.3
- a 24-bit message header including:
  - a 12-bit message type-identifier
  - a field identifier (see Note 2 of Table A.13) — 0: first field
1: second field
2: third field
3: fourth field
  - a 6-bit message length indicator
  - a 4-bit interleaved parity word: BIP-4 (even parity computed over the frame header and the message header)
- depending on the frame status, either
- a 43-octet data field for a single message; or
  - a 20-octet data field for a first message
  - a second message header (the BIP-4 applies also to the frame header)
  - a second 20-octet data field for a second message
- an 18-bit error protecting code, BCH (390,372), computed over the full frame, synchronization word excepted (see Note 3 of Table A.13)

A.9.3.3 Data field allocation

Messages of length 43 octets or less are inserted in the appropriate data field. If the message length is less than the data field capacity, the last remaining octets are set to zero. The length indicator is in the range 1 to 43 (or 1 to 20).

Single data field frames are indicated by a status equal to 0.

Double data field frames are indicated by a status equal to 1.

If messages longer than 43 octets are to be transmitted, they are split into 43-octet segments. These segments are sent in successive frames bearing the same message type-identifier. The length indicator of the last segment describes the number of useful octets in this segment. The length indicator of other segments starts from 48 and is increased by one from frame to frame (63 is updated to 48).

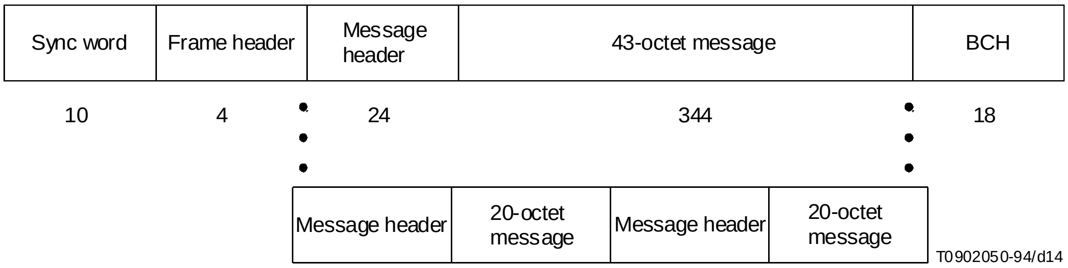


FIGURE A.15/J.81

Frame structure

The frame status is encoded as follows:

- 0: frame with a single 43-octet data field (message of length up to 43 octets);
- 1: frame with two 20-octet data fields;
- 2: frames of a segmented message, except the last one;
- 3: last frame of a segmented message.

Unused data fields are marked with a message type-identifier equal to zero. Data field is set to all zeros.

A.9.3.4 Teletext messages

Teletext messages are formed by the complete data unit specified for the system. For system B Teletext in 525/60 systems, a dummy octet, set to zero, is added at the end of the data unit. The message lengths are shown in Table A.12.

TABLE A.12/J.81

Teletext message lengths

Teletext system	Message length (625/50)	Message length (525/60)
A	38	
B	43	36
C	34	34
D		35

The message type identified is in the form 1111000XXXXX. The 5 LSBs form a line identifier (U) which indicates the line-number (see Note 4 of Table A.13) as shown in Table A.13.

A.9.4 Transmission format of test lines in a 128 kbit/s channel

A.9.4.1 Introduction

In intervals of 5 fields a test line is digitized according to the sampling structure defined in A.9.4.2. The data are given to a transmission buffer and then transmitted in a format (described in A.9.4.3) by a channel with a bit rate of 128 kbit/s.

If 3 test lines per field are in use, they are sampled sequentially. Thus the lines have to be repeated 15 times when re-inserting them at the decoder.

TABLE A.13/J.81

Line identifiers (LI)

(LI)		625/50		(LI)		525/60	
0	=	line	1/314	0	=	line	1/264
1	=	line	2/315	1	=	line	2/265
2	=	line	3/316	2	=	line	3/266
.				.			
.				.			
.				.			
20	=	line	21/334	20	=	line	21/284
21	=	line	22/335	21	=	line	260/523
22	=	line	311/624	22	=	line	261/524
23	=	line	312/625	23	=	line	262/525
24	=	line	313	24	=	line	263
25 to 31		unused		25 to 31		unused	

NOTES

1 *X* alternates between "0" and "1". The beginning of the synchronization word coincides with the start of a new octet in the container (see A.10).

2 Field numbering is in accordance with Recommendation ITU-R BT.470 [8]. The code corresponds to the field number from which the current data unit is extracted.

3 The code is a shortened BCH (511,492) with the generator polynomial:

$$g_x = (x^9 + x^4 + 1)\,(x^9 + x^6 + x^4 + x^3 + 1)$$

4 Line numbering is in accordance with Recommendation ITU-R BT.470. The code corresponds to the line number from which the current data unit is extracted.

In order to keep the phase consistency for the sub-carrier in composite lines, the test lines have to be re-inserted in the fields with the same field number (1 to 8 for PAL). That means 8 times the number of test lines used per field has to be stored.

A.9.4.2 Sampling of the test lines

Test line sampling is in accordance with Recommendation ITU-R BT.601 luminance sampling with the following differences:

– 10 bit scale used, with range 0 ... 1023;

– black corresponds to 288 (32 + 256);

– 100% white corresponds to 726.

This sampling structure permits values below black level (composite signals) with double resolution. It corresponds to Recommendation ITU-R BT.601 with 9 bits resolution, scale extension and scale shift by 256.

A.9.4.3 Format

The transmission of a test line starts after sampling of a test line and has the following format:

00	S	R	FS	L	E	D1	D2		Dn	00

Field start, modulo 5 fields

S synchronization word [32 "1" + "00010010"]

[The beginning of the synchronization word coincides with the start of a new octet in the container (see A.10)].

R reserved bits, 3 bits (normally = 0)

FS field status, 3 bits

0	0	0	field one
0	0	1	field two
.	.	.	.
.	.	.	.
.	.	.	.
1	1	1	field eight

L line identifier, 5 bits. Same assignment as for Teletext (see Table A.13)

E error protection, 5 bits

R, FS and L are protected by an extended Hamming code (16,11)

[(15,11) code + even parity] generated with the polynomial $x^4 + x + 1$ + even parity bit

Dn data word + parity, 12 bits

d0 = MSB

d9 = LSB

d10 = Reserve (e.g. higher resolution) else = 0

p = Parity bit, even parity over d0, d1, d2, d3, d4.

Pairs of consecutive words are interleaved as follows (′ denotes the second sample):

d0	d′0	d5	d′5	followed by
d1	d′1	d6	d′6	followed by
d2	d′2	d7	d′7	followed by
d3	d′3	d8	d′8	followed by
d4	d′4	d9	d′9	followed by
p	p′	d10	d′10	

The first sample, D1, corresponds with the first sample of the digital line (resp. after the active video timing reference code) defined in Recommendation ITU-R BT.656 [9].

The number, *n*, of data words is 864 for the 625 lines system and 858 for the 525 lines system, respectively.

The number of remaining octets until the data of the next test line depends on the system type and should be filled with octets of zeros.

A.9.5 Transmission of 80-bit serial time code in a dedicated 8 kHz channel

The time code, which is defined in IEC Publication 461 [13] is first demodulated and then justified in successive transmission frames of 9-bit length.

Each frame contains 2 or 3 bits of time code data, the justification indication and error correction redundancy. It is constituted as follows (d0 transmitted first):

– d0: 1st time code data bit;
– d1: 2nd time code data bit;
– d2: 3rd time code data bit (or justification bit);

– *ij*: justification indication (“1” if d2 is used);

– p0: exclusive OR of (d0, d1, *ij*);

– p1: exclusive OR of (d1, d2, *ij*);

– p2: exclusive OR of (d0, d1, d2,) complemented;

– p3: exclusive OR of (d0, d2, *ij*);

– *ij′*: repetition of *ij*.

NOTES

1 p0-p3 are complemented and form a Hamming extended code protecting d0, d1, d2 and *ij*. In case of double error detection, *ij′* may be used instead of *ij*.

2 In case of sync loss on reception, all code words received are detected in error.

3 The precise timing between time code and video components may be guaranteed in the decoder by controlling the time of emission of the time code sync word.

A.10 Service multiplex

A.10.1 Introduction

The service multiplex is based on a set of two compatible TV containers, organized according to an octet-oriented 8 kHz structure.

It permits multiplexing of:

– a video channel;

– zero, one or two channels for audio (1544 kbit/s or 2048 kbit/s) (see Notes 1, 2, 3 and 7);

– zero, one or two 384 kbit/s channels for Teletext/auxiliary applications (see Notes 6 and 7);

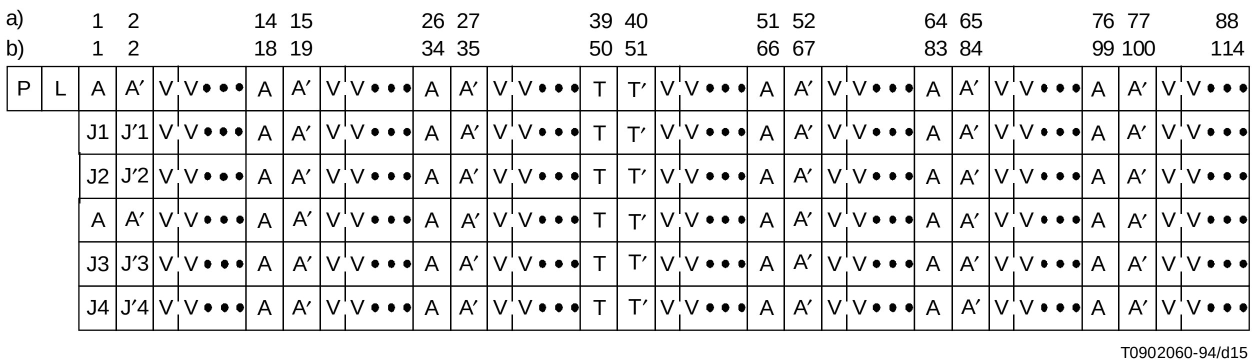
– a 128 kbit/s channel for test lines (see Note 7);

– an 8 kbit/s channel for supervision;

– two 8 kbit/s channels for conditional access;

– two 8 kbit/s channels for time codes.

The structure is arranged in 6 rows (see Figure A.16) giving 384 kbit/s per column. The multiplex structure is indicated by a special channel and gives the flexibility needed to allocate the above channels. Changes in capacity are made in steps of a number of columns ($n \times 384$ kbit/s).



a) 34 Mbit/s column allocation

b) 45 Mbit/s column allocation

FIGURE A.16/J.81

Container structure (125 µs)

For error monitoring a bit-interleaved parity check is provided. An appropriate pointer permits the synchronization of the FEC block.

The service multiplex does not provide error correction for the channels. Therefore, for random bit errors, the contributory channels will have the same bit error ratios as that of the received data stream.

A.10.2 TV container

A.10.2.1 General structure

Data are transmitted row after row.

The container defined for 34 Mbit/s (530 octets in length) is compatible with five SDH TU-2 containers concatenated (TU2-5c), a SDH VC-3 container and fits into the 34 368 kbit/s G.751 transmission frame.

The container defined for 45 Mbit/s (686 octets) is compatible with a SDH VC-3 container, seven SDH TU-2 containers concatenated and fits into the 44 736 kbit/s G.752 transmission frame.

Interworking between 34 and 45 Mbit/s levels is possible by the mapping of one container in the other as described in A.10.2.4.

A.10.2.2 Column allocation

Octets J, which indicate the use of other columns, are always transmitted in column 1.

Columns 14, 26, 51, 64 and 76 (18, 34, 66, 83 and 99 at 45 Mbit/s) are used to carry channel A (2048 kbit/s or 1544 kbit/s if column 76 (99) is not used).

Column 39 (50) is used for channel T.

Columns 2, 15, 27, 52, 65 and 77 (2, 19, 35, 67, 84 and 100) are used to carry a second channel A′ (2048 kbit/s or 1544 kbit/s if column 77 (100) is not used). Column 2 is active only when channel A′ is active, otherwise it carries video data.

Column 40 (51) is used for a second channel T′.

All other columns, plus columns for A, A′, T and T′ if not in use (but never column 2), are allocated to video data.

A.10.2.3 Definitions

V Octet for video data. The first octet in the container belongs to FEC 0 of a superblock (see A.8.2).

P Bit interleaved parity code using even parity (BIP-8, as defined for SDH); the P refers to the previous container, excluding its P. It is computed after scrambling, if applied.

L = [l_1, l_2, l_3, ... l_8]. Pointer for FEC block synchronization.

L indicates the rank of the first V octet of a container within FEC 0 of a superblock (see Figure A.14).

l_1 = MSB.

L = 0 when the first V octet of the container corresponds to the first octet of the FEC 0, L = 254 for the last octet of FEC 0.

A, A′ Octets for 2048 kbit/s or 1544 kbit/s channels (synchronous or asynchronous mode, see Notes 1, 2 and 3). Channel A is the primary audio channel.

T, T′ Octets for Teletext/auxiliary applications. Channel T is the primary channel for data formatted according to A.9.3. T′ is the primary channel for data not formatted according to A.9.3.

J, J′ Octets containing justification, video clock recovery and frame usage bits, as follows (transmitted from left to right):

J1	aj	vj	ca1	r	b_0	b_1	b_2	b_3
J2	aj	vj	ca2	vitc	b_4	b_5	b_6	b_7
J3	aj*	vj	s	ltc	b_0	b_1	b_2	b_3
J4	m_1	m_2	m_3	m_4	b_4	b_5	b_6	b_7
J′1	a′j	r	r	r	r	r	r	r
J′2	a′j	r	r	r	r	r	r	r
J′3	a′j*	r	r	r	r	r	r	r
J′4	r	r	r	r	r	r	r	r

ca1 Channel for the key management of the conditional access system.

ca2 Synchronization channel for the conditional access system.

s Bit for 8 kbit/s supervision channel.

ltc Channel for the 80 bits longitudinal time code (see A.9.5).

vitc Reserved for transmission of Vertical Insertion Time Code.

b_0 to b_7 Bits for test line transmission of 128 kbits, organized in octets (b_0 is the MSB).

m_1 Bit sequence defining a multiframe of length 8.

m_2, m_3 Channel defining the frame usage in a bit-serial (see Table A.14).

m_4 Format.

aj, aj* Positive/negative justification bits for channel A. The justification is made on two successive 8 kHz frames.

aj* in the first frame (even frame) and bits aj in both frames transmit the justification indication, repeated 5 times.

aj* in the second frame (odd frame) is available for positive justification of channel A. For negative justification, the first bit of the next A octet has to be used. Position justification is indicated by aj/aj* = 1.

a′j, a′j* Same definition as aj, aj* for A′ channel.

vj Bit for video clock transmission (positive/negative) (repeated three times – see Note 4).

r Bits reserved for future applications.

TABLE A.14/J.81

m_i bit sequence

Frame number	Parity	m_1	Frame usage defined by m_2	m_3	m_4
0	Even	1	"1" if T-channel T in use	"1" if T′-channel in use	Scrambling update flag (see A.12.7.3)
1	Odd	1	"1" if A-channel in use	"1" if A′-channel in use	Scrambling operation mode (see A.12.7.3)
2	Even	1	"1" if A-channel A is synchronous (Note 2)	"1" if A′-channel is synchronous (Note 2)	Scrambling operation mode (see A.12.7.3)
3	Odd	0	"1" if A-channel is 1544 kbit/s (Note 3)	"1" if A-channel is 1544 kbit/s (Note 3)	Reserved
4	Even	1	"0" if T-channel is formatted as in A.9.3 "1" if T-channel is used for auxiliary purposes	"0" if T′-channel est formatted as in A.9.3 "1" if T′-channel is used for auxiliary purposes	Reserved
5	Odd	0	**Error!**	Reserved	Reserved
6	Even	0		Reserved	Reserved
7	Odd	0		Reserved	Reserved

a) Frame 5 carries the MSB.

A.10.2.4 34/45 Mbit/s interworking

For interworking between 34 and 45 Mbit/s networks, the following procedure is recommended:

Encoding is performed at the bit rate defined by the 530-octet container. This container is carried on 34 Mbit/s-based networks by means of the corresponding network adaptation layers.

For transmission on 45 Mbit/s-based networks, this container is mapped into the 686-octet container, carried by the corresponding network adaption layer.

The mapping of the 530-octet container in the 686-octet one is achieved by filling each field in the 686-octet container with the corresponding data in the 530-octet container followed by the necessary stuffing octets, set to "all ones", in columns 14 to 17, 30 to 33, 47 to 49, 62 to 65, 79 to 82, 95 to 98 and 112 to 114.

NOTES FOR A.10 (SERVICE MULTIPLEX)

1 If channel A or A′ is used to transmit 1544 kbit/s, the last column is left for video data. The two A or A′ octets in column 1 are unused with the exception of the first bit in the first octet.

2 A synchronous mode is provided for A and/or A′ channels. The first A or A′ octet in the container frame corresponds to time slot 0 of the 2048 kbit/s frame or to the framing bit of the 1544 kbit/s frame.

3 If both A and A′ channels are in use, they must have the same bit rates.

4 The 13.5 MHz clock used for video sampling in the encoder is compared to a network-related 8 kHz reference. A 13.5 MHz clock is used to drive a counter which is reset at the end of each 8 kHz clock period; the count reached before resetting can be either 1687 or 1688.

Each frame of the transmission multiplex carries a video clock recovery bit, repeated three times for error protection, and defined as follows:

– "0" if 1687 clock pulses;

– "1" if 1688 clock pulses.

The original 8 kHz reference is reconstructed in the decoder by division of the local 13.5 MHz clock and compared with a local 8 kHz network-related reference. The phase difference is used to adjust the frequency of the local oscillator.

The generation of the block sequence should be controlled by the encoder in such a way that, in the absence of jitter at the input of the encoder, the phase jitter requirement defined by Recommendation ITU-R BT.601 is met when the PLL in the decoder has a bandwidth of 3 Hz or less. The use of dithering or of an equivalent technique is necessary.

The system should be able to tolerate an error on the video clock sampling frequency of up to 10^{-5}.

5 In order to permit the proper compensation of any difference in sound or vision delay resulting from different implementations of encoders or decoders, the delays needed to synchronize sound and vision components should be divided equally between both ends.

For each end, the sound and vision delay should be zero ± 1 ms.

The sound delay is defined as the average delay between the input of a sound signal to the sound encoder and the time of transmission of the corresponding data bits in the container.

The vision delay is defined as the delay between the time of reception by the encoder of the first pixel of the first active line and the time of transmission of the FSW, when the BOF sent in the FSW corresponds to 50% of the specified buffer capacity.

Sound and vision delays should include any delay associated with a possible pre-processing of sound or vision components (e.g. filtering).

6 The format for Teletext use is defined in A.9.3. The same format may also be used for transmission of auxiliary data.

Alternatively, the channels formed by the T′ and T octets may be used as transparent 384 kbit/s channels. The data format is not specified for this application.

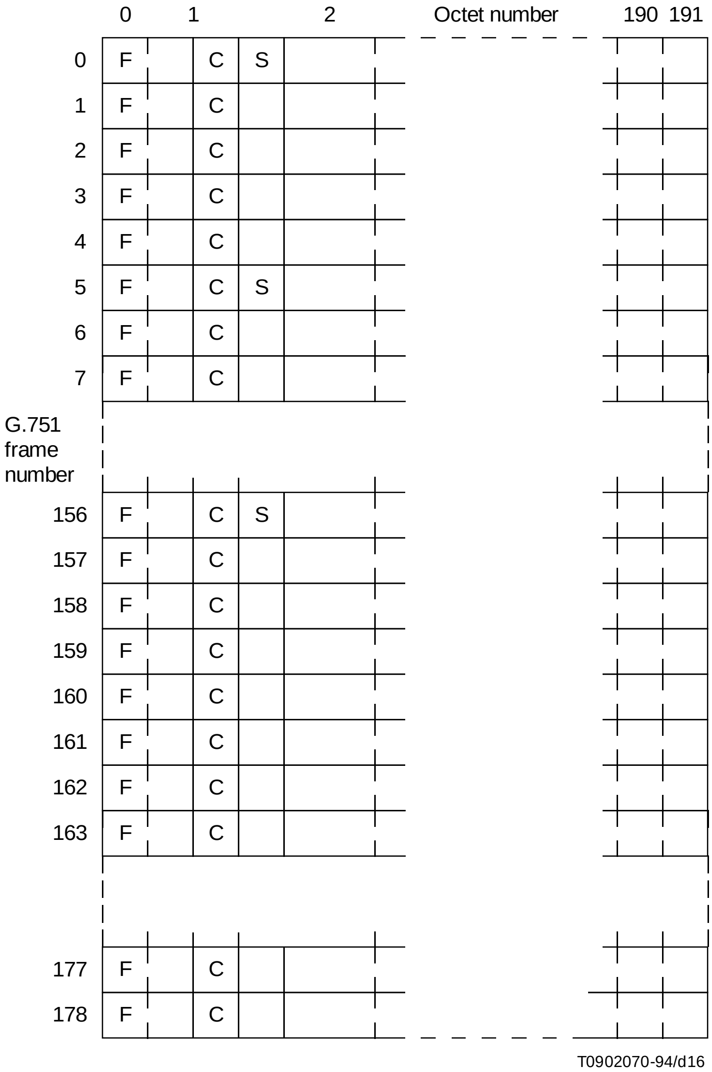
7 As a consequence of the framing structure, the burst error length is normally limited to 8 bits for the 2048 kbit/s, 1544 kbit/s and 384 kbit/s channels (i.e. audio, Teletext/auxiliary) and to 4 bits for the 128 kbit/s channel (test lines). The appropriate error protection, which is to be provided by these tributaries, should take due account of these characteristics.

A.11 Network adaptation

A.11.1 Network adaptation to 34 368 kbit/s G.751 frame

If the framing structure of Recommendation G.751 [2] is used for transmission, the TV container is first mapped into blocks of 532 octets comprising two reserved octets followed by 530 octets of data. These blocks are then mapped into a G.751 frame by using a multiframe structure. As is shown in Figure A.17 the same multiframe structure may also be used for mapping ATM or DQDB (distributed queue dual bus) cells.

Payload capacity:	34 048 kbit/s
Block length:	532 octets
Multiframe:	179 G.751 frames carrying 64 blocks; the first bit after the 2 stuffing bits in frame 0 is the first bit of one block of 532 octets.



F (12 bits) Frame alignment (10 bits) plus alarm bit and national bit
C (2 bits) Chain code
S (2 bits) Stuffing bits (every 6th frame, from frame 0 to frame 56)

FIGURE A.17/J.81

Structure of the 8 ms multiframe (179 G.751 frames)

Two C bits are assigned to every frame. These bits are obtained from a pseudo-random generator based on the polynomial:

$$g(x) = 1 + x^5 + x^9$$

and corresponds to the feedback shown in Figure A.18:

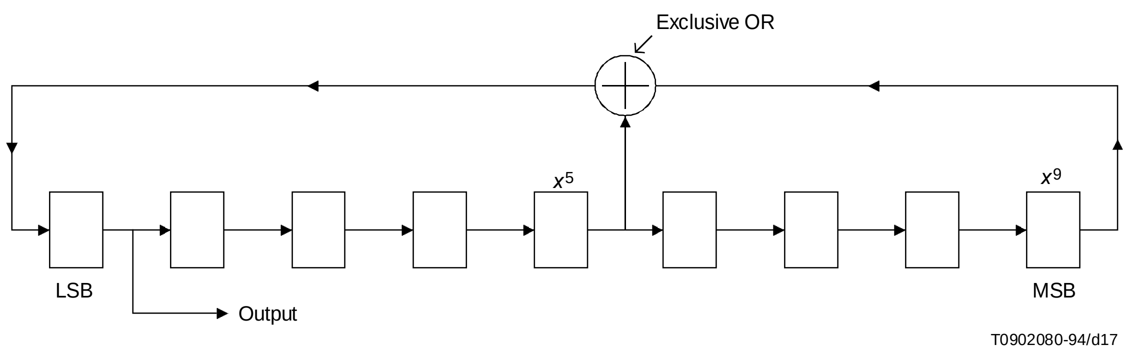


FIGURE A.18/J.81

Pseudo-random generator feedback arrangement

The initial value at the beginning of the first frame is:

LSB – 01111101

and is updated twice every frame.

With this configuration, the initial value at the beginning of the first frame may also be obtained by simply inverting the LSB of the contents of the shift register at the end of the last frame.

The successive states of the pseudo-random generator are:

	LSB MSB		First Second
State 0	001111101	Frame 0	transmitted bits 0,0
State 1	000111110		
State 2	100011111	Frame 1	transmitted bits 1,0
State 3	010001111		
State 4	101000111	Frame 2	transmitted bits 1,1
State 5	110100011		
.	. . . .	. . .	. . .
.	. . . .	. . .	. . .
State 354	111010110	Frame 177	transmitted bits 1,1
State 355	111101011		
State 356	111110101	Frame 178	transmitted bits 1,0
State 357	011111010		
Following state	101111101 ↓		
State 0	001111101	Frame 0	transmitted bits 0,0
State 1	000111110		

A.11.2 Network adaptation of 686 octet containers to 44 736 kbit/s G.752 frame

If the framing structure of Recommendation G.752 [2] is used for transmission, the appropriate 125 µs information block is mapped into this frame by using a multiframe structure. In this case, the block is equivalent to the TV container for 45 Mbit/s.

Payload capacity: 43 904 kbit/s

Block length: 686 octets

Multiframe: 699 G.752 frames, carrying 595 blocks; the first bit after the 6 kbits in the first frame of the multiframe is the first bit of one TV container.

This frame is repeated 699 times to make up one multiframe.

Structure of the 9398 kHz (G.752) frame

- L (10 bit) G.752 frame number (MSB first) starting from 0 and extending to 698
- K (6 bit) indicates the frames where S is a stuffing octet according to the 14 + J*15 law with J having values between 0 and 45

  K = 111111 for frames 14, 29, 45, etc.

  K = 000000 for all other frames
- S (8 bit) video stuffing octet
- R (16 bit) reserved

X* Service function bit (repeated once)

C* Control channel

P* Parity bit for the preceding multiframe (repeated once)

F_0*, F_1* Subframe alignment bits

M_0*, M_1* Frame alignment bits

* Defined or present in Recommendation G.752.

Bit number

0					85		170		255		340		425		510		595	
X	L	K			F_1		C		F_0		C		F_0		C		F_1	
X					F_1		C		F_0		C		F_0		C		F_1	
P	R	R			F_1		C		F_0		C		F_0		C		F_1	
P					F_1		C		F_0		C		F_0		C		F_1	
M_0					F_1		C		F_0		C		F_0		C		F_1	
M_1					F_1		C		F_0		C		F_0		C		F_1	
M_0	S				F_1		C		F_0		C		F_0		C		F_1	

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FIGURE A.19/J.81

Structure of one G.752 frame

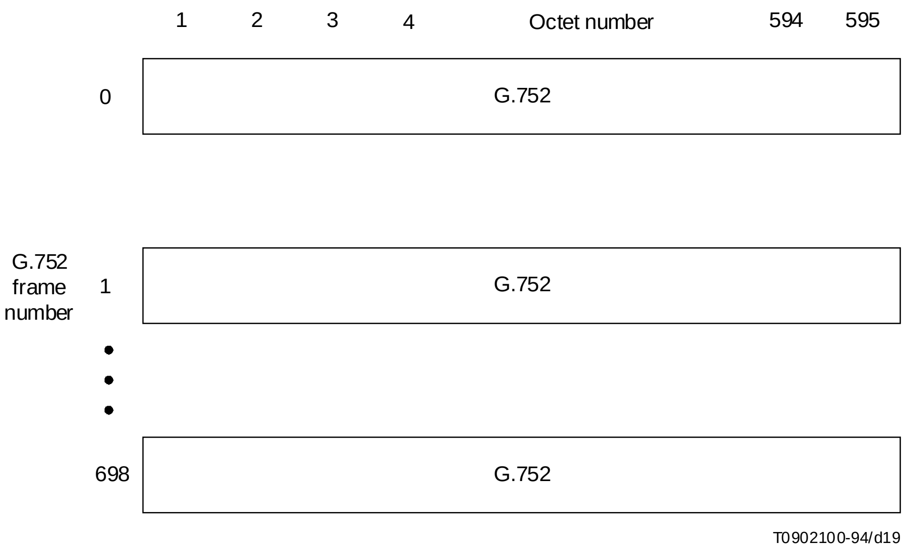

FIGURE A.20/J.81

Structure of the 74.375 ms multiframe

A.11.3 Network adaptation to SDH

The 8 kHz structure of the television container is particularly convenient for mapping into SDH VC3 or VC2-5c containers. The most appropriate mapping is still being studied. It is expected that it will be given in Recommendation G.709.

A.12 Scrambling for conditional access of transmitted data

A.12.1 General description of the access control system

Figures A.21 and A.22 provide the functional block diagram of an encoder and a decoder with an access control system for one channel. The source information may be any one of the programme components (video, audio, or Teletext) or all components together, considered as a unique service. Only the audio, Teletext and Video octets (V, A, A′, T, T′) may be scrambled. The auxiliary channels such as the supervision channel are not scrambled.

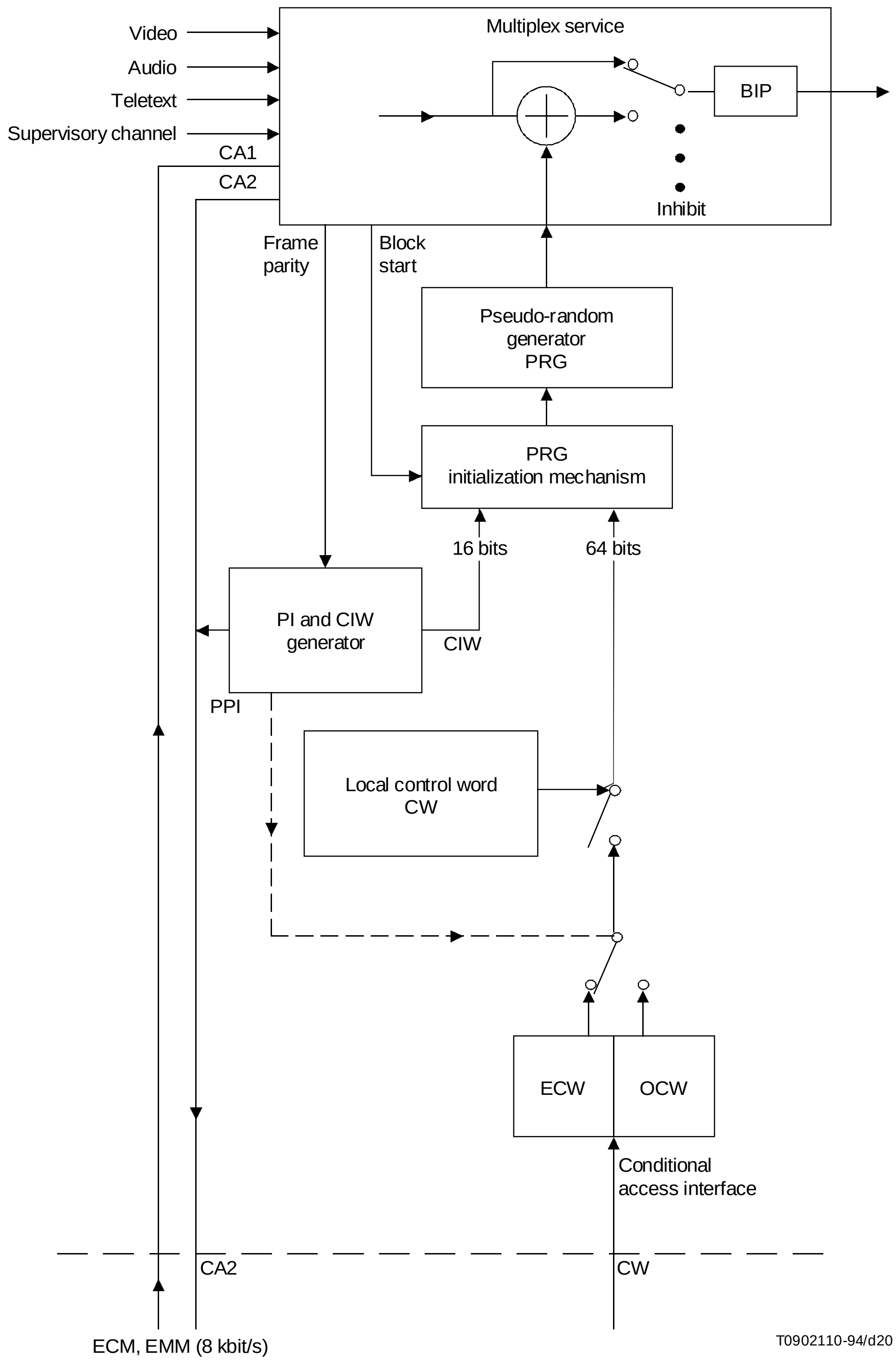

FIGURE A.21/J.81

Scheme of the encoder

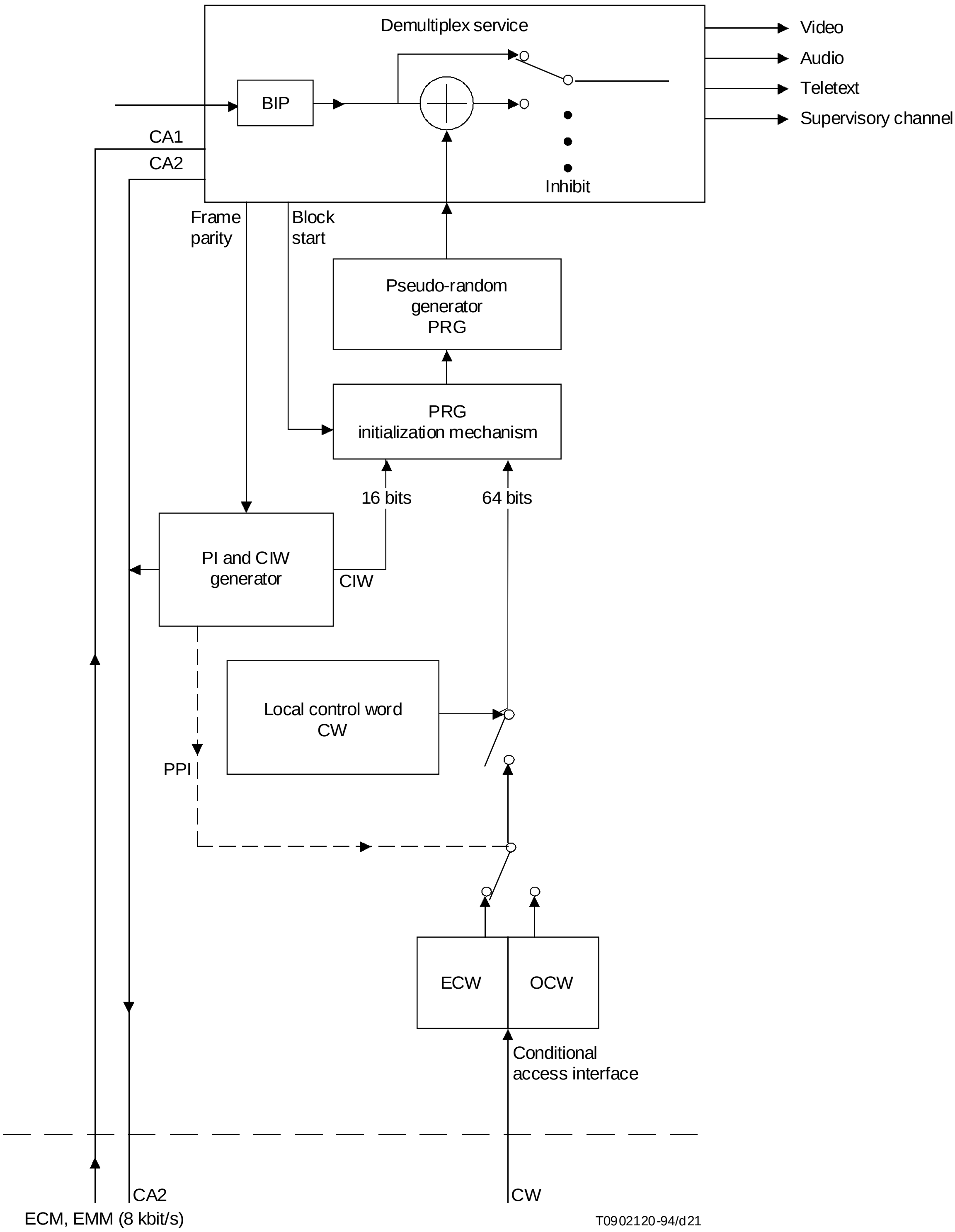

FIGURE A.22/J.81

Scheme of the encoder

The main features of the scrambling system are:

- Scrambling is done at the level of the service multiplex. Therefore, it is applied to audio, Teletext and video after forward error correction.

  NOTE – Calculation of bit interleave parity is done after scrambling as specified in A10.

- Scrambling is achieved by means of an “Exclusive Or” operation between information octets (A, T, V) and sequential octets produced by a pseudo-random generator (PRG). Octets P, L, J1, J2, J3, J4, J′1, J′2, J′3, J′4 are never scrambled.
- The scrambling sequence generator is a pseudo-random generator with a very long cycle time. Its output is made unpredictable by the use of a control word (CW) and a cyclic 16-bit container identification word (CIW). A combination of these words initializes the PRG at the beginning of each container, every 125 µs.
- The length of the cyclic sequence giving the CIW is 65 534. CWs are changed at the beginning of each new CIW sequence, i.e. every 8.2 s (125 µs * 65 534).
- The cryptograms are sent in entitlement control messages (ECM) containing two encrypted control words (the current CW and the next CW) and also data concerning the administration of the control word. To allow faster locking for receivers connected during an 8.2 s period, cryptograms of CWs may be transmitted more frequently. ECMs are sent through the 8 kbit/s channel carried in bit CA1.
- The descrambling system must be synchronized between the source and the receiver. The scrambled source component, the CIW generator and the synchronizing signal are derived from the multiplex structure. For instance, the validity period of a new control word begins when the CIW equals a specific value.

Moreover, the service operator can choose to send the signal scrambled or in the clear.

If scrambled, the service operator can use either a local control word which is constant and stored in the receiver or a regenerated control word transmitted in the ECM.

When the different programme components are scrambled individually, separate PRGs are used with different CWs. PRGs, which are not used to scramble (and unscramble) an octet at a given time are inhibited (no clock pulse and ignored output). Because of the delay needed for PRG initialization, the last 11 octets of the container are left unscrambled.

A.12.2 The pseudo-random generator

A.12.2.1 Introduction

The pseudo-random generator (PRG) described in this Recommendation can be considered as being defined, at each step, by three variables:

- the internal state: X_n
- the input register: I_n
- the output register: O_n

The relations between these variables are:

$$O_n = f(X_n) \quad \text{and} \quad X_{n+1} = g(X_n, I_n)$$

The functions f and g are described later.

The PRG is based on four irreducible polynomials: Q, R, S, T. Two are defined over the Galois Field GF(31) and the other two over the Galois Field GF(127) as follows:

Polynomial Q $X^5 = 15X^2 + 30$ over GF(31) (the order of the roots of Q is $(31^5 – 1)/15$)

Polynomial R $X^7 = X + 1^5$ over GF(31) (the order of the roots of R is $(31^7 – 1)/3$)

Polynomial S $X^5 = 2X^2 + 125$ over GF(127) (the order of the roots of S is $(127^5 – 1)/9$)

Polynomial T $X^7 = 2X + 125$ over GF(127) (the order of the roots of T is $(127^7 – 1)/9$)

The PRG is synchronized on a container basis (125 µs). The PRG is initialized at the beginning of each container with a 64-bit control word (CW) sent by the conditional access system, and a 16-bit container identifier word (CIW).

A.12.2.2 Description

See Figure A.23.

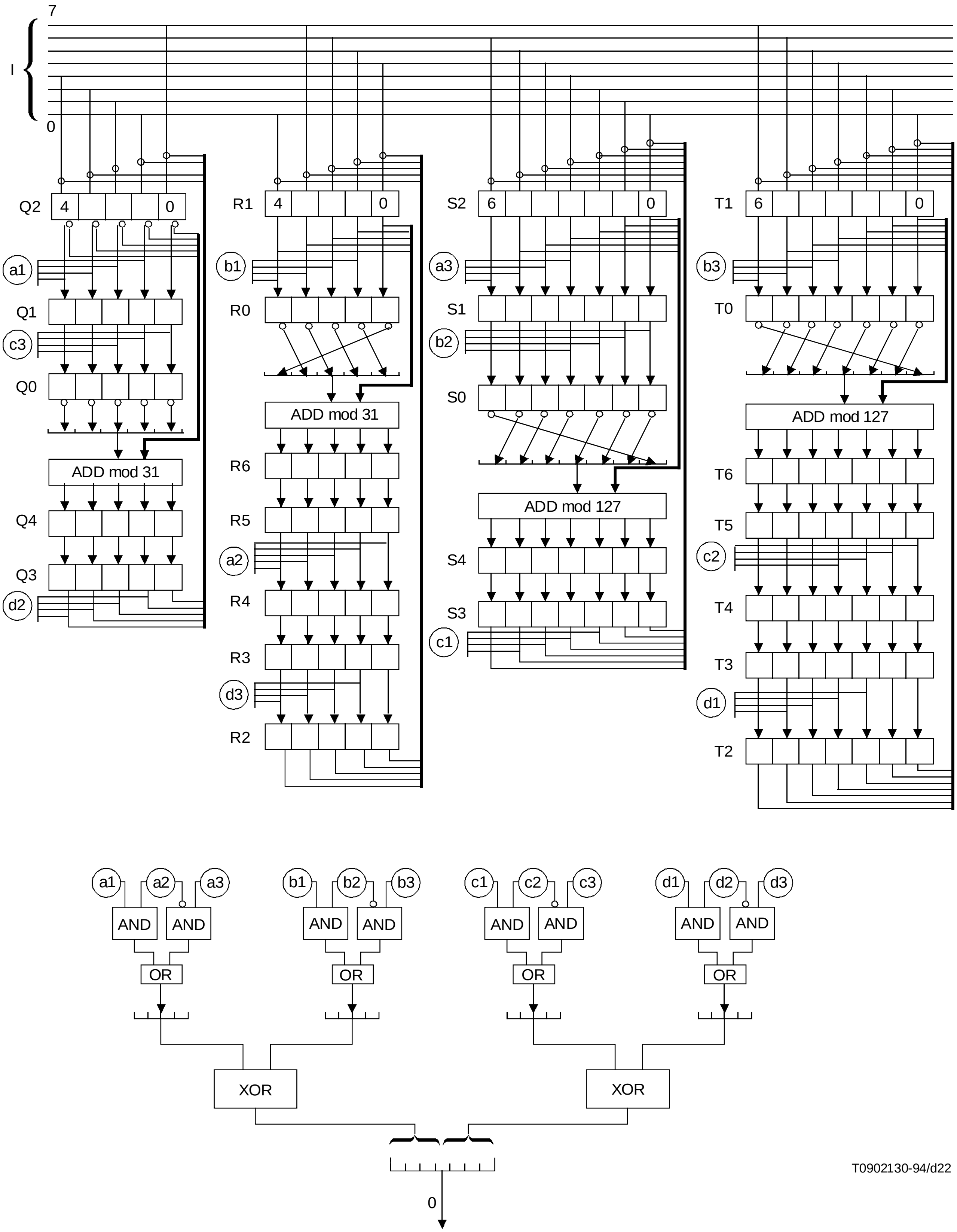

FIGURE A.23/J.81
Pseudo-random generator

The internal state X_n of the PRG is made up of the following registers:

- 5 registers of 5 bits: Q0, Q1, Q2, Q3, Q4;
- 7 registers of 5 bits: R0, R1, R2, R3, R4, R5, R6;
- 5 registers of 7 bits: S0, S1, S2, S3, S4;
- 7 registers of 7 bits: T0, T1, T2, T3, T4 ,T5, T6.

Hence, the size of the internal state is 144 bits.

Four start up registers QI, RI, SI, TI are loaded with a selection of the 8 bits of the input register:

If

I_n = i7, i6, i5, i4, i3, i2, i1, i0 (8bits) (i7 is the MSB)

then

QI = i3, i2, i1, i0, i7 (5 bits)

RI = i0, i7, i6, i5, i4 (5 bits)

SI = i6, i5, i4, i3, i2, i1, i0 (7 bits)

TI = i7, i6, i5, i4, i3, i2, i1 (7 bits)

The evolution of the PRG, after *n* cycles of the clock is described by the following function g:

$$X_{n+1} = g\,(I_n, X_n)$$

$$\text{If } X_n = \begin{cases} \text{Q0, Q1, Q2, Q3, Q4} \\ \text{R0, R1, R2, R3, R4, R5, R6} \\ \text{,S0, S1, S2, S3, S4} \\ \text{T0, T1, T2, T3, T4, T5, T6} \end{cases}$$

$$\text{Then } X_{n+1} = \begin{cases} \text{Q1, Q2, Q3, (XOR) QI, Q4, } (16\ \overline{\text{Q2}} + \overline{\text{Q0}}) \text{ mod } 32^* \\ \text{R1, R2, (XOR) RI, R3, R4, R5, R6, } (\text{R1} + 16\ \overline{\text{R0}}) \text{ mod } 31^* \\ \text{S1, S2, S3, (XOR) SI, S4, } (2\ \text{S2} + 2\ \overline{\text{S0}}) \text{ mod } 127^* \\ \text{T1, T2 (XOR) TI, T3, T4, T5, T6, } (2\ \text{T1} + 2\ \overline{\text{T0}}) \text{ mod } 127^* \end{cases}$$

where (XOR) signifies EXCLUSIVE OR:

NOTE – X mod N* means that N is subtracted from X when X is greater than N (i.e. the result belongs to the interval [0, N]).

The output function f :O_n = f (X_n) is computed thus:

If

O_n = o(7), o(6), o(5), o(4), o(3), o(2), o(1), o(0) (8 bits, where o(7) is the MSB)

then

$$o(0) = [S3(2) \cdot T5(0) + Q1(0) \cdot T5(0),\overline{\qquad}]\ (XOR)\ [T3(2) \cdot Q3(1) + R3(1) \cdot Q3(1),\overline{\qquad}]$$

$$o(1) = [S3(3) \cdot T5(1) + Q1(1) \cdot T5(1),\overline{\qquad}]\ (XOR)\ [T3(3) \cdot Q3(2) + R3(2) \cdot Q3(2),\overline{\qquad}]$$

$$o(2) = [S3(4) \cdot T5(2) + Q1(2) \cdot T5(2),\overline{\qquad}]\ (XOR)\ [T3(4) \cdot Q3(3) + R3(3) \cdot Q3(3),\overline{\qquad}]$$

$$o(3) = [S3(5) \cdot T5(3) + Q1(3) \cdot T5(3),\overline{\qquad}]\ (XOR)\ [T3(5) \cdot Q3(4) + R3(4) \cdot Q3(4),\overline{\qquad}]$$

$$o(4) = [Q2(1) \cdot R5(0) + S2(3) \cdot R5(0),\overline{\qquad}]\ (XOR)\ [R1(1) \cdot S1(0) + T1(3) \cdot S1(0),\overline{\qquad}]$$

$$o(5) = [Q2(2) \cdot R5(1) + S2(4) \cdot R5(1),\overline{\qquad}]\ (XOR)\ [R1(2) \cdot S1(1) + T1(4) \cdot S1(1),\overline{\qquad}]$$

$$o(6) = [Q2(3) \cdot R5(2) + S2(5) \cdot R5(2),\overline{\qquad}]\ (XOR)\ [R1(3) \cdot S1(2) + T1(5) \cdot S1(2),\overline{\qquad}]$$

$$o(7) = [Q2(4) \cdot R5(3) + S2(6) \cdot R5(3),\overline{\qquad}]\ (XOR)\ [R1(4) \cdot S1(3) + T1(6) \cdot S1(3),\overline{\qquad}]$$

where (XOR) signifies EXCLUSIVE OR.

Bit o(7) processes the first transmitted bit of an encrypted octet; bit o(0) processes the last transmitted bit.

A.12.3 PRG initialization parameters

A.12.3.1 CIW Generator

The container identification word (CIW) is a 16-bit word generated at the coder side and regenerated at the decoder side by means of a 15-bit chain-code and a frame parity bit as LSB. The input of the shift register associated with the chain-code is sent in the CA2 channel of the container: it allows the synchronization of the sequences in the coder and in the decoder. This information is sent every two containers (odd frames as defined by bit m_1). A phase parity identifier (PPI) is sent in the same bit of the container during even frames.

The chosen pseudo-random sequence is based on the polynomial

$$g(x) = 1 + x^{14} + x^{15}$$

which is generated using a shift register with the feedback loop shown in Figure A.24.

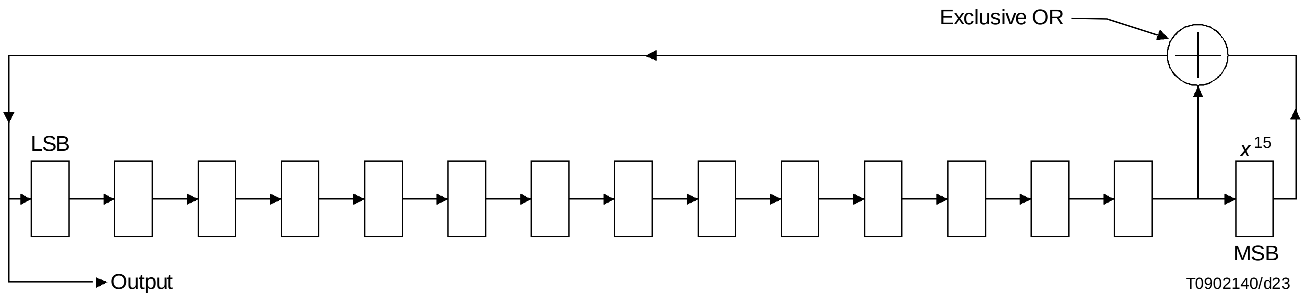

FIGURE A.24/J.81

Pseudo-random generator feedback arrangement

The shift register steps forward one bit at the end of every odd container, and the input of the shift register is sent to the decoder for synchronization purposes. The container identification word is constructed using:

- the contents of the shift register (15 MSBs of CIW);
- the parity of the current frame (LSB of CIW) ("0" for even frames, "1" for odd frames).

The period is $2 \times (2^{15} - 1) = 65\,534$ containers (8.2 s).

The CIW defines blocks of 8.2 s which delimit the period of validity of successive CWs. The first container in a block is identified by a parity bit and all bits of the shift register equal to "0" except for the LSB of the chain code which is set to "1" (CIW = 0000 0000 0000 0010). The phase parity identifier (PPI) is inverted from block to block and is used to identify the CW related to the current block and the one related to the next block. The PRG for the first container of a block is initialized at the end of the previous block with the CW related to that block, as shown in Figure A.25.

A.12.3.2 Control word

The control word may be a local control word for testing or for low security services. The method to introduce and/or change the local control word is left to the manufacturer. For normal usage, the control word is generated at the source by the sender, and sent enciphered to the receiver. The control word changes every 65 534 containers but its cryptogram may be transmitted every second.

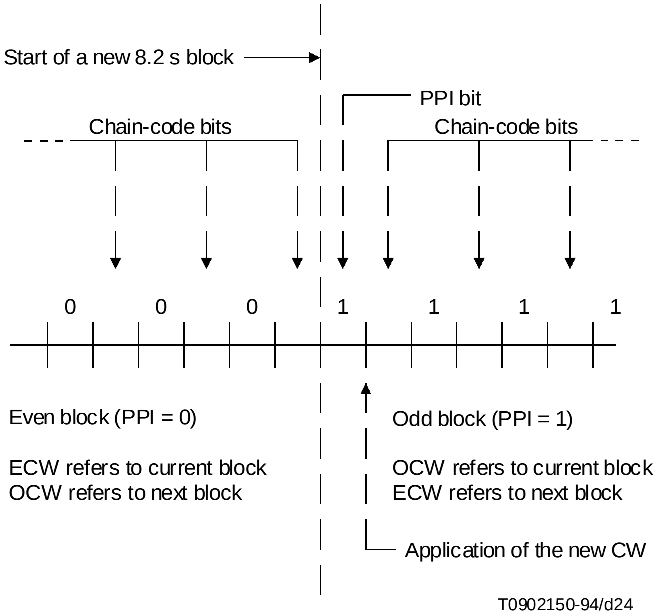

FIGURE A.25/J.81

Block-change mechanism

A.12.3.3 Synchronization

Synchronization is used to prepare and load a new initialization word (IW) in the PRG. This word results from the concatenation of the container identification word CIW, followed by the control word CW and a repetition of the CIW.

Synchronization happens:

- every 125 µs (at each container), corresponding to a CIW change;
- every 8.2 s (every 65 534 containers), corresponding to a CW change.

Two CWs are used, one each for odd 8.2 s blocks (OCW), and for even 8.2 s blocks (ECW). This mechanism is necessary to prepare the next CW before a new synchronization command and also to allow a new receiver to obtain the current CW.

Synchronization makes use of:

- the CIW;
- OCW and ECW;
- the phase parity identifier PPI is used to define the parity of the 8.2 s block and therefore which CW is active.

The synchronization of the PRG should be performed during the last video octets of each container, which are left unscrambled. The CW and CIW defined during a container are therefore used to define the initialization word of the PRG for the next container.

A.12.4 Performance of the PRG

A.12.4.1 Periodicity of sequences

The PRG can produce ($2^{16} \times 2^{64}$) distinct sequences of octets because of its initialization method. The highest periodicity of these sequences can be deducted from the behaviour of the polynomials Q, R, S and T.

Therefore, the PRG, which is a combination of the four polynomials Q, R, S and T, can generate sequences of octets which have a periodicity equal to the least common multiple of Tq, Tr, Ts and Tt:

$$\text{LCM}(Tq, Tr, Ts, Tt) = 1{,}36 \times 10^{37}$$

A.12.4.2 Degenerations

Degenerations occur when one of the groups of registers (Qi, Ri, Si or Ti) remains in the same state. This happens only if all the registers of this group are loaded with 0 or 31 (for Q and R) or with 0 or 127 (for S and T). If only one group of registers is degenerated, it is called a single degeneration. If all the groups of registers are degenerated, it is called a fourfold (or complete) degeneration.

Among the 225 possible states of the registers Q0 to Q4 after the initialization process, it is possible to reference:

- 2^5 states with the registers loaded with 0 or 31;
- $32^5 – 2^5$ states shared out among 15 sequences.

The same arguments can apply to the polynomials R, S and T.

It is now possible to enumerate all the degenerated states of the PRG:

- Number of states leading to a complete degeneration:

  $2^5 \times 2^7 \times 2^5 \times 2^7 = 2^{24}$
- Number of states leading to a threefold degeneration: around 2^{66}

  $(2^5 \times 2^7 \times 2^5 \times (128^7 – 128) + 2^5 \times 2^7 \times (128^5 – 128) \times 2^7 + 2^5 \times (32^7 – 32) \times 2^5 \times 2^7 + (32^5 – 32) \times 2^7 \times 2^5 \times 2^7)$
- Number of states leading to a double degeneration: around 2^{95}
- Number of states leading to a single degeneration: around 2^{124}
- No degeneration: around $2^{144} – 2^{124}$

A.12.5 Generating scrambling sequences with the PRG

Figure A.26 describes how the PRG is initialized before scrambling a container. This initialization requires 13 cycles.

For each session, the PRG works as follows:

- Reset the internal state of the PRG ... $X_0 = 0$.
- Initialization of the PRG by loading the input register with the start-up octets (during this phase, the output is inhibited). Most significant octets are sent first for all words.
- Generation of the scrambling octets delivered by the output register (during this phase, the input register is loaded with the octet 0). The first scrambling octet is obtained when the last initialization octet has been clocked into the PRG.

A.12.6 Conditional access system

Decoders with access control need a security module called the access control system (ACS) which may be buried in the decoder, or be detachable. If so, it is connected via an external codec-ACS interface, specified in the next section. The ACS itself, which embodies (amongst other things) the way of producing the control words CW, is not defined in this annex.

A.12.7 Interface between codec and access control system

A.12.7.1 Interface signals

The interface comprises the following signals.

A.12.7.1.1 Transmitted data (encoder only)

Sends ACS data to the encoder for insertion in the CA1 channel of the multiplex.

A.12.7.1.2 Received data (decoder only)

Sends to the ACS the data extracted by the decoder from the CA1 channel.

A.12.7.1.3 Control words and configuration messages

Transmit even and odd control words produced by the ACS to the pseudo-random generator of the encoder or decoder in HDLC frames (defined in A.12.7.4). Configuration messages are also sent on this line to indicate the scrambling mode (encoder only).

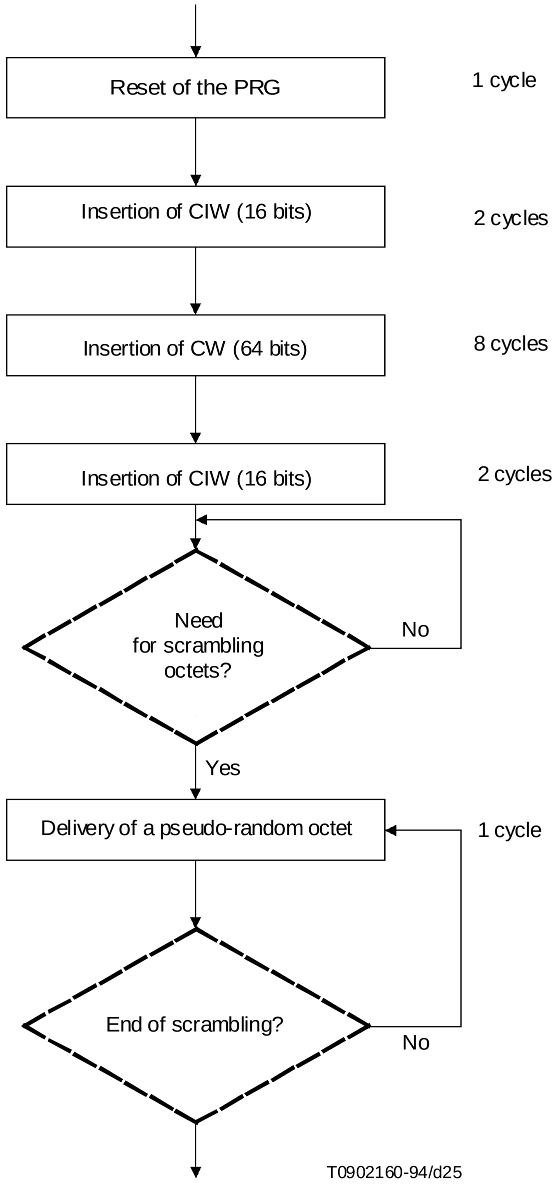

FIGURE A.26/J.81

Initialization of pseudo-random (sequence) generator

A.12.7.1.4 Status

In an encoder, the data sent in the CA2 channel is sent to the ACS. In a decoder, the line is set to logical level "0". This may be used by the ACS to distinguish encoders from decoders.

A.12.7.1.5 Clock

An 8 kHz reference at container repetition rate is used to control data exchange on the serial lines defined above. The cyclic ratio should be about 50%. New data shall appear on the transition from logical "1" to logical "0". Data shall be sampled on the transition from logical "0" to logical "1".

NOTE – Appropriate latches should be provided on the transmission lines to meet the above timing requirements. No specific phase relationship between the clock and the container is specified since the transmission delay between the encoder/decoder and the ACS is not critical.

A.12.7.2 Electrical and physical interface

This interface derives from Recommendation V.24 [14]. The electrical interface should conform to Recommendation V.28 [15]. The connector is the 25-pin connector specified in ISO Standard 2110 [16]. The socket is female on the encoder or decoder, assumed to be a DCE, and male on the ACS, considered as a DTE.

The pin allocation is as follows:

Pin	Circuit	Direction
1	Protective ground	
2	Transmitted data	ACS to encoder
3	Received data	Decoder to ACS
7	Signal ground	
14	Control words	ACS to encoder/decoder
15	Clock	Encoder/decoder to ACS
16	Status	Encoder/decoder to ACS

A.12.7.3 Encryption modes

Four modes of operation are permitted:

- *Mode 0* – No scrambling.
- *Mode 1* – All components are scrambled together by a single PRG. The control word is fixed ("local control word").
- *Mode 2* – Components are scrambled by a single PRG. The control word, changed every block, is provided through the ACS. The ACS also indicates which of the components are subjected to scrambling.
- *Mode 3* – Components are scrambled by more than one PRG. In this optional mode, control words are provided for every block by the ACS with indication of the relevant components.

If present, control words received from the ACS and relating to blocks sent in mode 0 or 1 are not used by the encoder or the decoder.

The mode of operation is described by bit m_4 of octet J4 according to the following:

m_4 in frame 1	m_4 in frame 2	Mode
0	0	0
0	1	1
1	0	2
1	1	3

Changes between these modes are effective only at the boundary between two successive 8.2 s blocks. Such changes are announced by bit m_4 in frame 0 used as an update flag.

Between 0.5 s and 1s before the end of the current block, bit m4 in frame 0 is set to "1". Bits m_4 in the following frames describe the configuration to be introduced for the next block.

Within 0.5 s after the beginning of the new block, bit m_4 in frame 0 should be reset to "0".

The timing of bit m_4 is controlled by the encoder. Changes in modes should be received from the ACS at least 2 s before the beginning of a new block.

A.12.7.4 Format of the CWs and configuration messages

CWs and messages are sent in HDLC frames. They include:

- A start flag.
- An address octet, identifying the type of packet transmitted. Possible values are:
  - "00" the corresponding message is:
    - i) the mode number if the ACS is connected to an encoder;
    - ii) FF hex if the ACS is connected to a decoder;
  - "01" for packets carrying odd control word OCW;
  - "02" for packets carrying even control word ECW;
  - "03" for packets carrying both even and odd control words;
  - "04" for packets transmitting a temporary alternative local control word;
  - "05" for packets loading a new internal local control word;
  - "06" for packets corresponding to "no CW available" (i.e. the access to the corresponding component is not authorized);
  - "07" for packets identifying unscrambled components.

  Other packet types are reserved for future use.
- A control octet with:
  - bits 0 to 5: Indication of the multiplex components concerned with the current packet:

    bit 0 set to "1" if T component is concerned;

    bit 1 set to "1" if A component is concerned;

    bit 2 set to "1" if T′ component is concerned;

    bit 3 set to "1" if A′ component is concerned;

    bit 4 set to "1" if V component is concerned;

    bit 5 reserved for future use.

    In modes 0 and 1, bits 0 to 4 should be ignored by the decoder. They should all be set to "0" in mode 0 and to "1" in mode 1.
  - Bits 6 and 7: Continuity index of messages sent with a given address (not incremented if the same message is repeated).
- The configuration message, which consists of:

  0 octets if the address octet = "06" or "07";

  1 octet containing the mode number if the address octet = "00" (b_0 = LSB of mode, b_1 = MSB of mode, b_2 to b_7 are reserved);

  8 octets for a new local control word;

  8 octets if ECW or OCW are transmitted separately;

  16 octets if ECW and OCW are transmitted together (ECW first);
- 2 CRC octets, as specified by the HDLC format;
- An end flag.

For each transmitted octet, bit 0 is the least significant bit and is sent first according to HDLC specification. However, octets are sent most significant first.

After the end flag, the HDLC line returns to the "idle" mode. Successive frames must be separated by a minimum guard time of 50 ms and a maximum time-out of 1 s. This minimum activity may be obtained by transmission of packets with address "00".

Manufacturers may decide on the most appropriate ways of storing local control words in the codecs and of using the remote CW loading messages (addresses "04" and "05").

Appendix I

(to Annex A)

Guidelines for implementation

I.1 Introduction

In order that a codec should fully satisfy the intended levels of picture quality, error performance and operational convenience, the attention of manufacturers is drawn to the importance of careful design of the following system elements. These elements are not completely defined in the annex because some of their parameters do not influence the video transmission format and can remain as manufacturer options. The choice of these parameters may, however, have a significant impact on overall codec performance.

Users wishing to establish the subjective performance of a codec may employ the methods decided in the ITU Recommendations concerning radiocommunications, while methods are currently under development for the verification of a codec's design with the options discussed below. Such verification methods may operate by comparison of the output of the codec under test with a standard codec which is known to exercise fully the options below. Alternatively, the comparison test may be made on separate encoders or decoders by incorporating them in a codec pair with a standard decoder or encoder respectively.

I.2 Mode choice (see A.5.1)

Subject to the requirement for a refresh strategy, the coder should take full advantage of the increase in coding efficiency offered by the motion-compensated interframe and the interfield modes.

I.3 Refresh strategy (see A.5.1)

Intrafield refreshing is necessary to limit error propagation and recovery time, but attention is also drawn to the effect on coding efficiency of an increase in the proportion of intrafield blocks.

I.4 Motion estimation (see A.5.4)

The use of motion estimation to the full range and accuracy allowed by the specification is recommended.

I.5 Truncation or rounding of coefficients (see A.6)

Attention is drawn to the fact that coding quality may be affected by the manner in which the quantity $C(k, l)$ is converted to an integer prior to quantization.

I.6 Buffer regulation (see A.6)

The method of calculating the transmission factor in terms of buffer occupancy should be such that the full capability of the buffer to absorb variations in bit rate should be exploited for critical picture material.

Depending on the implementation of the encoder, the stripes may be processed at different speeds with possible influences on the exact signification of the BO information sent in each stripe.

The precise synchronization of the decoder should rely on the information sent in the BOF field which should normally lead to timing information consistent from field to field.

It is however recommended that decoders should accept fluctuations of this information as long as they correspond to less than 5000 bits.

I.7 Criticality (see A.6)

The codec should take full advantage of the criticality parameter defined in the Recommendation.

I.8 Error concealment (see A.8.1 and A.8.2)

The CRC and the RS code provide information about uncorrected errors that may be used to control a concealment strategy in the decoder, giving improved performance at high bit error ratios.

I.9 Transmission of composite signals

The composite signal is decoded to Y, C_R, C_B for transmission through the codec. It is recommended that this decoding is of as high a quality as possible to minimize cross-effects which would spoil the performance of the codec.

Appendix II

(to Annex A)

Results of 34 Mbit/s codec tests

In their meetings in November 1991, CCIR Task Group CMTT/2 and Working Party 11B appointed Special Rapporteurs in order to prepare for and carry out – supported by members of these Groups – performance tests on codec hardware as soon as it would become available. The tests were carried out from 6-10 April 1992 in Turin, Italy. The tests performed, the results and the conclusions drawn from the results are described in the following text.

The prototype codec available could be tested with the 34 Mbit/s channel interface only. But it has been stated by members of the test group from 525/60 countries that there is little difference between the coding performance of a bit rate reduction system running on 625/50 and on 525/60 and that the higher bit rate for picture data available at 45 Mbit/s should provide even better picture quality. The conclusion was that taking into account the very limited time available to carry out the tests, the subjective evaluation and the processing of the test results, tests at 525/60 were regarded as not essential.

II.1 Codec tested

There was one 34/45 Mbit/s codec available for the tests working on both systems 625/50 and 525/60 but the 45 Mbit/s channel interface was not yet implemented.

As far as the accordance with the present Recommendation is concerned, most of the features were implemented in the prototype codec. The codec was operated in a mode where 2×2 Mbit/s were allocated to sound and data. This is the worst case condition for the video data rate.

A list of items not in compliance with the present Recommendation and provided by the codec manufacturer is given below:

– *Multiplexer*

  The DS3 mux was not implemented.

– *Encryption*

  Not yet implemented.

– *Motion compensation*

  Fully compliant at the decoder side. At the encoder side motion estimation does not have the full range and accuracy required by the specification.

– *Additional services*

  Not fully implemented.

– The interleaving of Reed-Solomon codes was limited to 2 (instead of 6) as implied by the draft revision to the present Recommendation at that time.

The codec was equipped with serial and parallel 4:2:2 interfaces. Only the parallel input/output was used during the tests.

In addition, a PAL codec was used to produce a PAL signal to be included as "lower anchor" in the subjective tests. The following items could not be tested:

– Sound vision delay

– Interoperability of codecs from different manufacturers.

II.2 Tests carried out and test methods used

II.2.1 Test sequences

Due to the short time available for the production of the subjective test tapes no new test sequences could be provided for the tests. Therefore, it was decided to use the test sequences recorded on codec test tapes produced by the ad hoc Group TPS in 1989 and used for codec tests in 1989 by ad hoc Group BCT.

The sequences used for the tests were:

Basic quality	Downstream CK	Downstream SM	Error case
Diva with noise	Balls of wool	Rotating disc	Blackboard
Tempete	Ciao	Kiel Harbour	Mobile and Calendar
Flower garden	Old Master	Cruising	Popple
Kiel Harbour			
Rotating disc			
Mobile and Calendar			

In a meeting of the test group among other aspects of the test procedures, the question of whether to include the sequence "Diva with noise" in the tests and to use the test results together with the results from other test sequences in the basic quality tests was discussed. It was decided that the sequence should be used for the tests and the results should be processed statistically together with the others to provide an overall mean grade.

II.2.2 Test procedure

The subjective tests were of basic quality (BQ), downstream chroma-key (DCK), downstream slow motion (DSM) and error performance (EP).

The (BQ) (DCK) and (DSM) tests involved the use of two codecs in tandem according to the user requirements as given in Recommendation ITU-R BT.800. This was achieved by passing the signal twice between two D1 recorders with the codec in between. In tests (DCK) and (DSM) the downstream processing was carried out after the first pass through the codec as proposed in the user requirements.

Test (EP) also involved 2 passes with the error generator inserted between coder and decoder during both passes.

The configuration for each of the tests is described below.

Basic quality tests (BQ)

For these tests, test sequences from the codec test tape were recorded after passing the codec twice (with an intermediate recording on a D1 machine). Six test sequences were used for the basic quality tests as given in A.2.1.

The test setup is shown in Figure II.1.

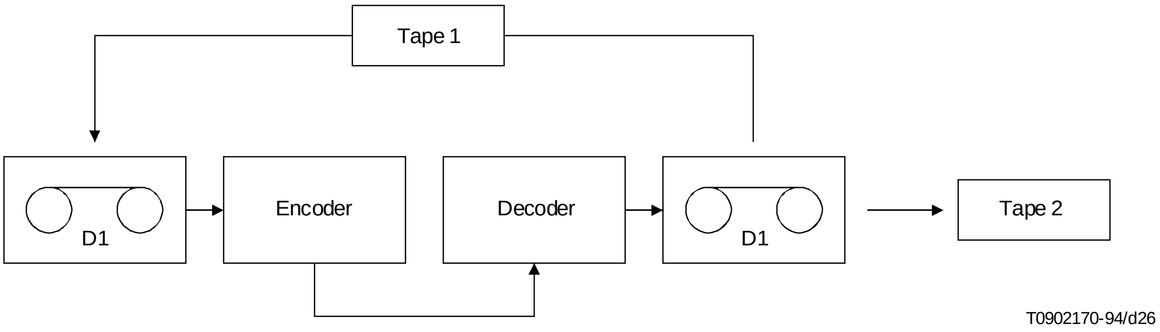

FIGURE II-1/J.81

"Lower anchor quality" for subjective assessment

During the preparation phase of the tests different proposals where made for the choice of a lower anchor quality signal including normal PAL signals, PAL signals sent through the codec using the PAL interfaces of the codec, and MPEGII signals in order to get the coding effects in the same way as in the other test signals.

After some discussion there was support in the test group to choose a PAL coded signal in order to generate the lower anchor sequences needed for the assessment during subjective tests. No further processing was carried out on these lower anchor test sequences.

The test setup is shown in Figure II.2.

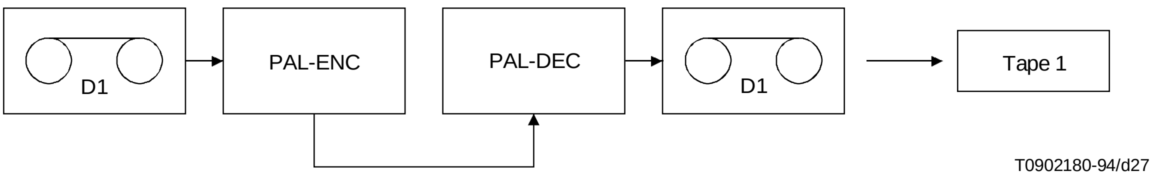

FIGURE II.2/J.81

Quality of downstream processing (DCK) (DSM)

In order to carry out these tests, test sequences from the codec test tape were recorded after the first pass through the codec on a D1 machine for (DCK) and (DSM). For (DCK), the recorded sequences were used as foreground signal for chroma-key with the unprocessed 4:2:2 background signal coming from a second D1. The postprocessed (keyed) sequences were recorded on a D1 machine. After a second pass of the processed sequences through the codec without further postprocessing, the sequences were recorded again on a D1 machine.

For (DSM) the sequences were recorded after the first pass through the codec and expanded by a factor of 10 via a D1 recorder. The expanded sequences were passed again through the codec and recorded on a D1 machine.

The sequences used for these tests are given in II.2.1.

The test setup is shown in Figure II.3.

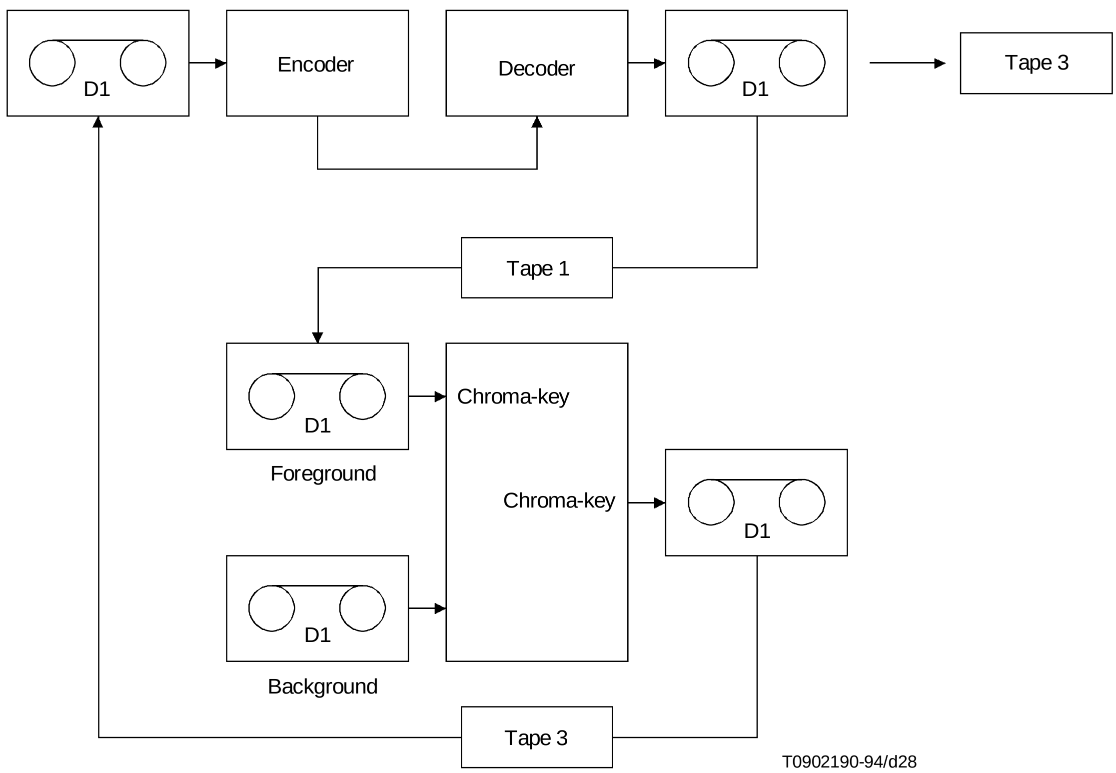

FIGURE II.3/J.81

"Lower anchor quality" for the subjective assessment of the downstream postprocessing quality

In order to get a lower anchor quality signal necessary for subjective assessment, it was proposed to use a PAL signal as foreground signal and a unprocessed 4:2:2 signal as background. In the case of slow motion an unprocessed PAL signal was expanded.

The test setup is shown in Figure II.4.

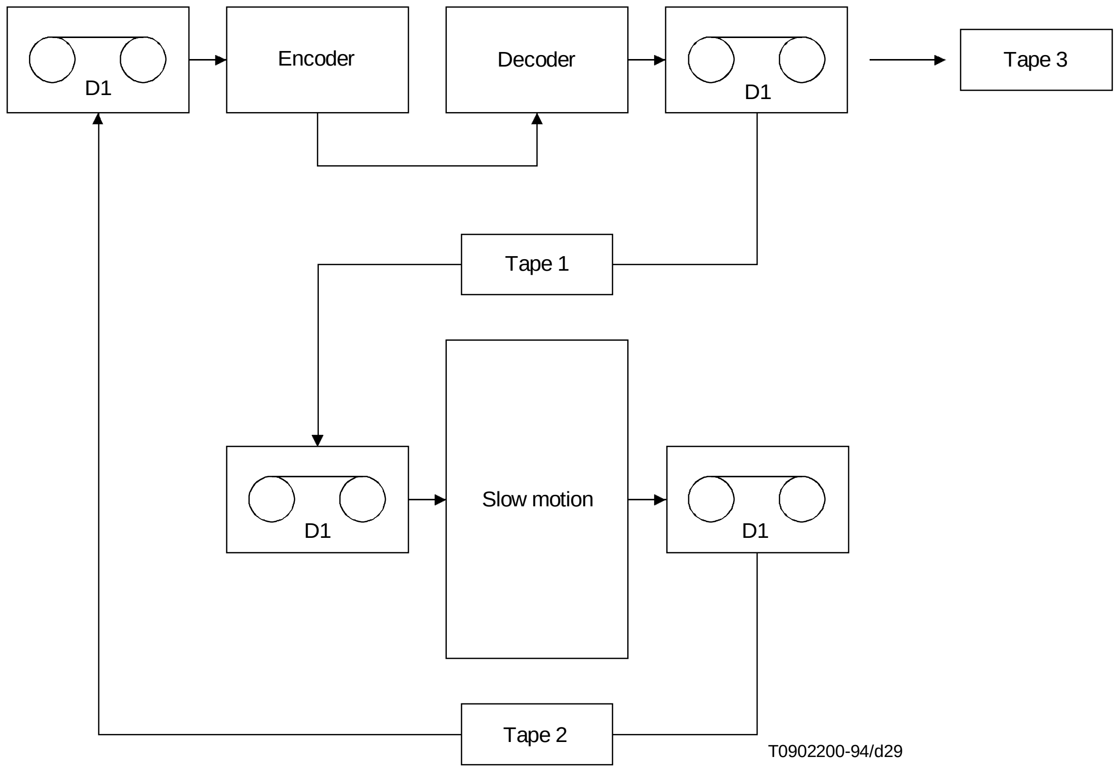

FIGURE II.4/J.81

Error performance tests

For these tests, test sequences were recorded after having been encoded, subjected to errors and decoded (twice, with an intermediate recording on a D1 machine). The sequences, as given in II.2.1 for the error case, were recorded twice for each error condition (7 error rates and 1 burst condition).

The error conditions chosen for the inclusion in the subjective tests (5 error rates and 1 burst condition) were:

Condition 1	BER	6.1×10^{-5}
Condition 2	BER	1.2×10^{-4}
Condition 3	BER	2.4×10^{-4}
Condition 4	BER	4.9×10^{-4}

The test setup is shown in Figure II.5.

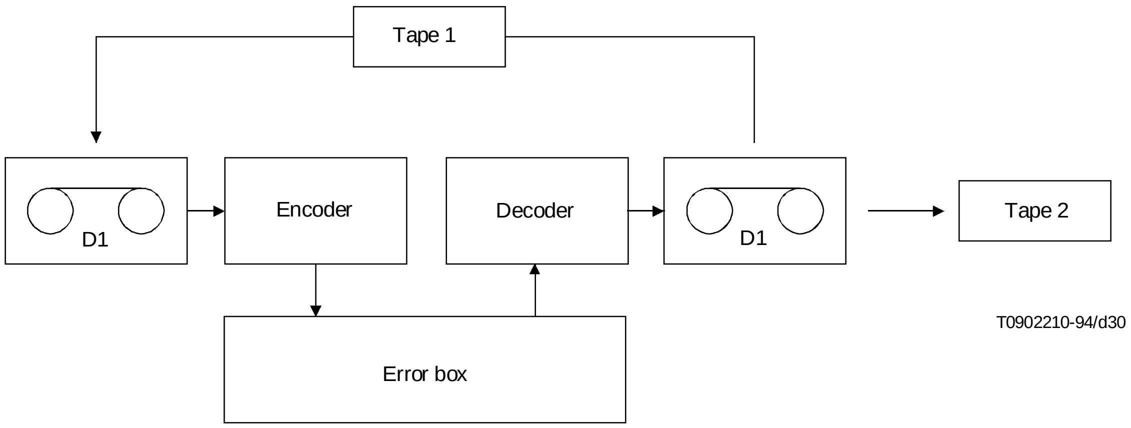

FIGURE II.5/J.81

Recovery from gross disturbances

These tests were not recorded on the D1 output recorder. In these tests, a 50 ms break in the data stream was introduced several times during the codec pass of a test sequence, without errors. The decoded output signal was displayed on a monitor with external studio sync and recorded via a camcorder. The time required to lock up following a break was determined by evaluating the time code visible in the output picture during replay of the camcorder tape.

The test setup is shown in Figure II.6.

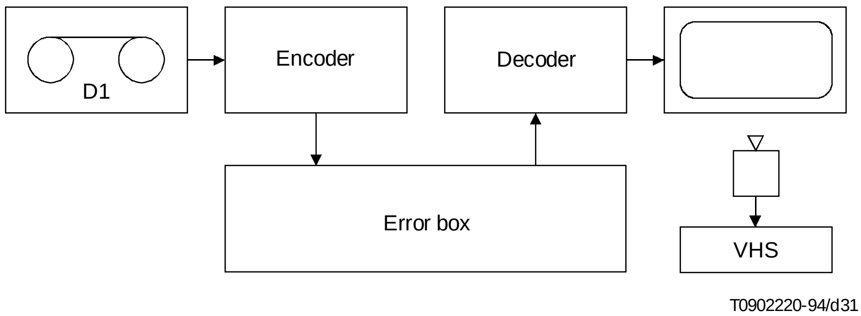

FIGURE II.6/J.81

II.3 Subjective tests

The assessment methods were largely in accordance with Recommendation ITU-R BT.500. They broadly followed those applied to the codec tests carried out previously in 1989.

Tests (BQ) (DCK) and (DSM) used the double stimulus continuous quality scale method, test (EP) used the double stimulus impairment scale method.

II.4 Results of subjective tests

Test results from six laboratories were available for the evaluation of the subjective tests.

II.4.1 Test (BQ) – Basic quality

Mean differences between codec and reference on scale of ± 100, pass mark +12 or less at 6H. Standard deviation of the mean in brackets (standard deviation in the column "average over sequences" was calculated as the mean value of the standard deviation of the mean for all sequences).

Viewing distance 4H

Laboratories: 6

Observers: 74

	Sequences						Average over sequences
	Diva	Tempete	Flower	Kiel	Disc	Mobile	
Codec	45 (1)	1 (1)	0 (1)	0 (1)	3 (1)	3 (1)	9 (1)
PAL	22 (1)	12 (1)	29 (1)	29 (2)	19 (1)	43 (1)	26 (1)

Viewing distance 6H

Laboratories: 6

Observers: 95

	Sequences						Average over sequences
	Diva	Tempete	Flower	Kiel	Disc	Mobile	
Codec	41 (1)	0 (1)	0 (1)	1 (1)	1 (1)	1 (1)	7 (1)
PAL	13 (1)	9 (1)	21 (1)	22 (1)	13 (1)	40 (1)	20 (1)

II.4.2 Test (DCK) – Downstream chroma-key

Mean difference between codec and reference as foreground on a scale of ± 100, pass mark +18 or less at 6H. Standard deviation of the mean in brackets (standard deviation in the column "average over sequences" was calculated as the mean value of the standard deviation of the mean for all sequences).

Viewing distance 4H

Laboratories: 6

Observers: 73

	Sequences			Average over sequences
	Popple	Ciao	Old	
Codec	0 (1)	1 (1)	2 (1)	1 (1)
PAL	49 (2)	38 (2)	42 (1)	43 (2)

Viewing distance 6H

Laboratories: 6

Observers: 97

	Sequences			Average over sequences
	Popple	Ciao	Old	
Codec	0 (0)	0 (1)	0 (1)	0 (1)
PAL	47 (1)	27 (1)	34 (1)	36 (1)

II.4.3 Test (DSM) – Downstream slow motion

Mean difference between codec and reference on a scale of ± 100, pass mark +18 or less at 6H. Standard deviation of the mean in brackets (standard deviation in the column "average over sequences" was calculated as the mean value of the standard deviation of the mean for all sequences).

Viewing distance 4H

Laboratories: 6

Observers: 74

	Sequences			Average over sequences
	Disc	Kiel	Cruising	
Codec	−1 (1)	5 (1)	1 (0)	2 (1)
PAL	20 (2)	42 (1)	14 (1)	25 (2)

Viewing distance 6H

Laboratories: 6

Observers: 97

	Sequences			Average over sequences
	Disc	Kiel	Cruising	
Codec	0 (0)	2 (1)	0 (0)	1 (1)
PAL	16 (1)	39 (1)	5 (1)	20 (1)

II.4.4 Test (EP) – Error performance

Mean scores on a 5-point impairment scale. Pass mark 4.0 at 10^{-4} at 6H. Standard deviation of the mean in brackets (standard deviation in the column "average over sequences" was calculated as the mean value of the standard deviation of the mean for all sequences).

Viewing distance 4H

Laboratories: 6

Observers: 77

	Sequences			Average over sequences
	Backboard	Mobile	Popple	
Condition 1	4.8 (.0)	4.1 (.1)	4.7 (.0)	4.5 (.1)
Condition 2	4.8 (.0)	4.2 (.1)	4.7 (.0)	4.6 (.1)
Condition 3	4.8 (.0)	4.3 (.1)	4.5 (.1)	4.5 (.1)
Condition 4	4.8 (.0)	4.3 (.1)	3.6 (.1)	4.3 (.1)
Condition 5	1.3 (.1)	2.1 (.1)	1.8 (.1)	1.7 (.1)
Burst	4.2 (.1)	2.5 (.1)	1.7 (.1)	2.8 (.1)

Viewing distance 6H

Laboratories: 6

Observers: 95

	Sequences			Average over sequences
	Backboard	Mobile	Popple	
Condition 1	4.9 (.0)	4.5 (.0)	4.8 (.0)	4.7 (.0)
Condition 2	4.9 (.0)	4.7 (.0)	4.8 (.0)	4.8 (.0)
Condition 3	4.9 (.0)	4.6 (.0)	4.6 (.1)	4.7 (.0)
Condition 4	4.9 (.0)	4.7 (.0)	3.9 (.1)	4.5 (.1)
Condition 5	1.5 (.1)	2.4 (.1)	2.2 (.1)	2.0 (.1)
Burst	4.4 (.1)	3.0 (.1)	2.0 (.1)	3.1 (.1)

The 6H random error results are presented in Figure II.7 below:

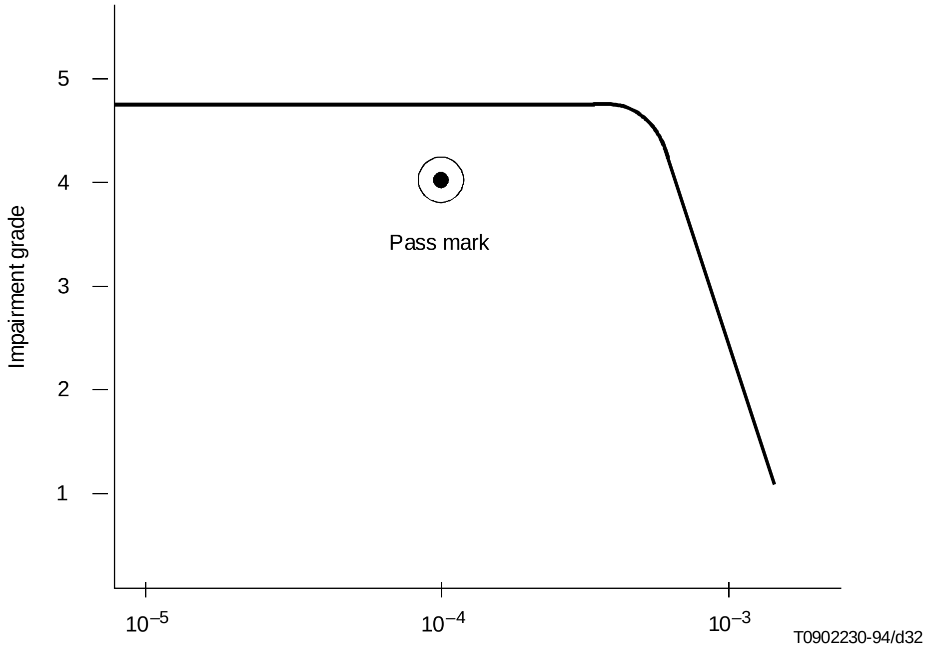

FIGURE II.7/J.81

6H random error results

II.5 Results of tests of codec recovery time

The codec failed the recovery time test. The evaluation of the codec recovery time after a break of 50 ms in transmission led to the result that the mean number of frames the codec took to re-establish a satisfactory output signal was about 16 frames, which means a mean recovery time of about 640 ms. During this time parts of the picture are frozen and/or disturbed. The character of disturbances is varying and can be judged in the range from perceptible to very annoying.

The state of information available and discussions on the subject of recovery time requirements leads to some doubts about the relevance of 160 ms as a user requirement. New consolidated proposals seem to be needed for the definition of the recovery time of a digital codec.

II.6 Additional observations

The quality of the PAL signal generated by the arrangement given in II.2.2 led to a rather poor picture quality for the PAL coded sequences. There was no possibility to change the arrangement within the time available.

The chroma-key equipment available worked in the analogue domain. The set-up of the chroma-key equipment was difficult in the absence of a skilled operator. The results do not seem to represent the best chroma-key quality possible.

II.7 Conclusions

The codec tests were carried out with support of the European Broadcasting Union (EBU) and 9 laboratories from several countries in Australia, Japan and Europe. The subjective tests included more than 90 observers.

The test results show clearly that the codec under test satisfies very well the user requirements for the basic quality as defined in Recommendation ITU-R BT.800 on three of the four sequences. They are not meant for “diva with noise”.

The average results obtained in the chroma-key and slow-motion tests again satisfy very well the criteria laid down in Recommendation ITU-R BT.800. Even using the chroma-key sequences as produced for the tests in 1989, the deviation is quite low.

The error performance tests show that the codec using a powerful error correction together with error concealment satisfies the requirement for random errors up to a bit error ratio of more than 5×10^{-4}.

The codec failed to meet the requirement for error performance under the burst error conditions proposed by the test group and chosen for the test. These conditions include a burst length of 32 bits due to the restrictions in the variation of the burst length allowed by the error box used, which exceeds the burst length (less or equal to 30 bits) mentioned in Recommendation ITU-R BT.800[2)].

The codec failed also the recovery time requirements as given in Recommendation ITU-R BT.800 taking, in the mean, about 16 frames or 640 ms for the re-establishment of a satisfactory output signal. However, it should be mentioned that the definition of the recovery time of digital codecs is under discussion, and new consolidated proposals for the definition of the recovery time are needed.

Sound vision delay and interoperability of codecs from different manufacturers could not yet be tested.

References

[1] Recommendation ITU-R BT.601 *Encoding Parameters of Digital Television for Studios*.

[2] CCITT Recommendation G.751 (1988) *Digital multiplex equipments operating at the third order bit rate of 34 368 kbit/s and the fourth order bit rate of 139 264 kbit/s and using positive justification*.

[3] CCITT Recommendation G.752 (1988) *Characteristics of digital multiplex equipments based on a second order bit rate of 6312 kbit/s and using positive justification*.

[4] CCITT Recommendation G.707 (1988) *Synchronous Digital Hierarchy bit rates*.

[5] CCITT Recommendation G.708 (1988) *Network Node Interface for the Synchronous Digital Hierarchy*.

[6] CCITT Recommendation G.709 (1988) *Synchronous multiplexing structure*.

[7] CCITT Recommendation H.261 (1988) *Codec for audiovisual services at n times 384 kbit/s*.

[8] Recommendation ITU-R BT.470 *Television systems.*

[9] Recommendation ITU-R BT.656 *Interfaces for digital component video signals in 525-line and 625-line television systems.*

[10] Recommendation ITU-R CMTT 724 *Transmission of digital studio quality sound signals over H1 channels*.

[11] ISO Standard 3309-2 (1984) *Information processing systems – Data communication – High-level data link control procedures – Frame structure*.

[12] Recommendation ITU-R BT.653 *Teletext systems.*

[13] IEC Publication 461 (1986) *Timecode and control code for video tape recorders*.

[14] CCITT Recommendation V.24 (1988) *List of definitions for interchange circuits between data terminal equipment and data circuit-terminating equipment*.

[15] CCITT Recommendation V.28 (1988) *Electrical characteristics for unbalanced double-current interchange circuits.*

[16] ISO Standard 2110 (1980) *Data communication – 25-pin DTE/DCE interface connector and pin assignments*.

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2) To overcome this problem, the interleaving depth had been increased to 6 in the present Recommendation.