ATIS STANDARD

ATIS-0100802.01.2001(R2006)

North American Adaptation for Domestic – International Interfaces of ETSI 300 174 Digital Component Television Signals – Interface and Coding Specifications at DS-3

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Contents

Foreword (This foreword is not part of American National Standard T1.802.01-1996.)

This standard is the North American adaptation for Domestic-International interfaces of ETS 300 174 standard for the coding and transmission of digital component television signals. It addresses the interface characteristic and the coding compatibility characteristic of digital coders/decoders for the transmission of ITU-R 601-2 digital video signals, AES/EBU digital audio signals and ancillary signals used in the production of television material. These signals are formatted to be compatible with time division multiplexing in the North American DS-3 transport media.

This standard has been developed to provide a common framework for encoders and decoders to transmit ITU-R BT.601 television signals between North America and International Telecommunication Networks. Further work is planned to standardize an ISO 13818 (MPEG-2) based system for contribution quality applications.

Equipment performance definitions and measurement methods are provided where appropriate. Interface definitions are provided to facilitate compatibility. This standard has been prepared in consultation with the European Telecommunication Standards Institute (ETSI); Network Aspects (NA) Technical Committee and The Society of Motion Picture and Television Engineers (SMPTE) and by Working Group T1A1.5 of Accredited Standards Committee T1

Signals created or transmitted in accordance with other standards may not necessarily be compatible with the specifications of this standard.

This standard contains three annexes. Annexes A through C are informative and not considered part of the standard.

Suggestions for improvement of this standard are welcome. They should be sent to Alliance for Telecommunications Industry Solutions, Inc., 1200 G Street, NW, Suite 500, Washington, DC 20005.

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee on Telecommunications, T1. Committee approval of this standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the T1 Committee had the following members:

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American National Standard
for Telecommunications –

North American Adaptation for Domestic-International Interfaces of ETSI 300 174 Digital Component Television Signals – Interface and Coding Specifications at DS-3

1 Scope, purpose, and application

1.1 Scope

This standard is the North American adaptation for Domestic-International interfaces of the ETSI ETS 300 174 standard for the coding and transmission of digital component television signal at a bit rate of 45 mbits/s. It provides a detailed description of the digital coding algorithm to be implemented in equipment designed to terminate digital transmission systems when those systems are employed to carry ITU-R 601-2 digital television video signals, AES/EBU digital audio signals and ancillary signals such as SMPTE time-code, and SMPTE machine control. Each television signal is formatted to be compatible with the North American DS-3 transport network. 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.

1.2 Purpose

The purpose of this standard is to provide a common framework for coders and decoders to transmit ITU-R 601-2 television signals between the North American and International telecommunications networks by providing linkage to the ITU-R 723 and ITU-T J.81 recommendations and the ETSI ETS 300 174 standard.

NOTE – It should be recognized that due to the application of this standard for the interworking internationally with ETSI 300 174 it is useful to provide the details of encoder implementation as seen by ETSI and the ITU. In the original development of the coding system structure by ETSI and the ITU there was a pairing of the specifications between the encoder and the decoder. New encoding processes may develop that may be applied to this system approach as long as they interoperate with the original pairing structure. This standard will allow for this new technology. Therefore, normative references in this standard to implementation of encoders are optional, and are not intended as limitations on encoder implementations.

1.3 Application

This standard provides a framework for interoperability of equipment from various manufacturers and various service providers to ensure uniform application of the coding methods. It also provides a common understanding between suppliers and their customers.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this American National Standard. At this time of publication, the editions indicated were valid. All standards are subject to revision, and parties to the agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

ANSI S4.40-1992, *Digital audio engineering – Serial transmission format for two-channel linearly represented digital audio data*

ANSI T1.101-1994, *Telecommunications – Synchronization interface standard*

ANSI T1.102-1993, *Telecommunications – Digital hierarchy – Electrical interfaces*

ANSI T1.105-1995, *Telecommunications – Synchronous optical network (SONET) – Basic description including multiplex structure, rates, and formats*

ANSI T1.107-1995, *Telecommunications – Digital hierarchy – Formats specifications*

ANSI T1.314-1991, *Telecommunications – Digital processing video signals – Video coder/decoder for audiovisual services at 56 to 1,536 kbits*

ANSI T1.404-1994, *Telecommunications – Network-to-customer installation – DS3 metallic interface specification*

ANSI/SMPTE 12M-1986, *Time and control code for video and audio tape for 525 line/60 field television systems*

ANSI/SMPTE 125M-1995, *Television – Component video signal 4:2:2 – Bit parallel digital interface*

ANSI/SMPTE 207M-1992, *Television – Digital control interface – Electrical and mechanical characteristics*

ANSI/SMPTE 259M-1993, *Television – 10-bit 4:2:2 component and* $4f_{sc}$ *NTSC composite digital signals – Serial digital Interface*

ANSI/SMPTE 261M-1993, *Television – 10-bit serial digital television signals: 4:2:2 component and* $4f_{sc}$ *NTSC composite – AMI transmission interface*

ANSI/SMPTE 272M-1994, *Television – Formatting AES/EBU audio and auxiliary data into digital video ancillary data space*

EBU Technical Document 3217 (3rd edition, reissued 1986), *Specification of insertion data signal equipment for international transmissions*[1)]

ETSI 300 174, *European telecommunications standard – Network Aspects (NA); Digital coding of component television signals for contribution quality applications in the range 34-45 Mbit/s*[2)]

IEC 461 (1986), *Time and control code for video tape recorders*[2)]

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1) Available from the European Broadcasting Union, Head of Data and Reference Centre, CP 67, CH-128 Grand Saconnex GE, Switzerland.

2) Available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ISO 2110: 1989, *Data communication – 25-pole DTE/DCE interface connector and contact number assignments*[2)]

ISO/IEC 3309: 1993, *Information technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures – Frame structure*[2)]

ISO/IEC 11172-1: 1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbits/s – Part 1: Systems*[2)]

ISO/IEC 11172-3: 1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbits/s – Part 3: Audio*[2)]

ITU-R Recommendation 601-2, *Encoding parameters of digital television for studios*[2)]

ITU-R Recommendation 723, *Transmission of component coded digital television signals for contribution-quality applications at the third Hierarchical level of ITU-T recommendation G.702*[2)]

ITU-R Recommendation 724, *Transmission of digital studio quality sound signals over H1 channels*[2)]

ITU-R Report 624-4, *Characteristics of television systems*[2)]

ITU-R Report 1206, *Methods for picture quality assessments in relation to impairments from digital coding of television signals*[2)]

ITU-R Report 1235, *Digital transmission of component-coded television signals at 30-34 Mbits/s and 45 Mbit/s*[2)]

ITU-T Recommendation V.24 (1993), *List of definitions for interchange circuits between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE)*[2)]

3 Definitions, symbols, and abbreviations

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)

3.2 Relational operators

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

3.3 General abbreviations and usage

binary	A number system with base 2
hexadecimal	A 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	A contraction of the words "binary digit"
word	A group or sequence of bits treated together
octet	A 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 color difference signal or sample Y-R
C_B	Scaled color 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 color transmission system
SECAM	Acronym for Sequential Color with Memory – a composite analogue color transmission system
NTSC	Acronym for the National Television System Committee that developed the composite analogue color transmission system that is used in the majority of countries using 525-line, 60 Hz scanning parameters
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
SONET	Synchronous Optical Network
VT	Virtual Tributary
SMPTE	Society of Motion Picture and Television Engineers
EBU	European Broadcast Union

Other abbreviations and specialized terminology are noted where occurring in the document.

4 Video

4.1 Video interface specifications

4.1.1 Serial digital video interface specifications

Bit-serial 10-bit, 270 Mbit/s serial interface
Coding 4:2:2 level of ITU-R Recommendation 601-2
525-line or 625-line digital video in component form
Manual or automatic selection of the video standard is at the manufacturer's discretion
The video interface shall conform to ANSI/SMPTE 259M.

Optionally, the serial digital video may be multiplexed or demultiplexed from a serial digital television signal which shall conform to SMPTE 272M.

Optionally, a parallel digital video interface which shall conform to ANSI/SMPTE 125M may be incorporated.

4.1.2 Serial digital video format specifications

Bit-serial 10-bit, 270 Mbit/s serial interface
Coding 4:2:2 level of ITU-R Recommendation 601-2
525-line or 625-line digital video in component form
Manual or automatic selection of the video standard is at the manufacturer's discretion
The video format shall conform to ANSI/SMPTE 261M.

4.2 Video coding specifications

4.2.1 Signal preprocessing

4.2.1.1 Horizontal

Full digital active line of 720 samples for luminance (Y) and 360 samples for each color-difference (C_R, C_B).

4.2.1.2 Vertical

4.2.1.2.1 525 line

248 lines per field
Field 1: lines 16 to 263
Field 2: lines 278 to 525

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

4.2.1.2.2 625 line

288 lines per field
Field 1: lines 23 to 310
Field 2: lines 336 to 623

4.2.1.3 Numerical representation

Digital input samples of Y, C_R, and C_B shall conform to the ITU-R Recommendation 601-2 and ANSI/SMPTE 125M numerical range. As per the methods provided in ANSI/SMPTE 259M, these are converted to an 8-bit 2's complement representation for the purpose of processing within the codec.

4.2.2 Coding summary

4.2.2.1 Modes

Three modes (intra-field, inter-field, and motion compensated inter-frame) are used. The following three processing operations are applied either on 8x8 intra-field blocks (intra-field mode) or on differential blocks obtained by difference between the current 8x8 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 4.3.1).

4.2.2.2 DCT

Discrete Cosine Transform applied on rectangular blocks of 8 lines of 8 samples for the three components Y, C_R, C_B (see 4.3.2).

4.2.2.3 Prediction

For each block processed according to inter-field mode, the reference block is determined with pixels of the previous field without motion compensation. For each block processed according to interframe mode, the reference block is taken from the position of the current block by application of a displacement vector (see 4.3.3).

4.2.2.4 Motion compensation

Motion compensation is applied to "macro-blocks". Each macroblock (two adjacent 8x8 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 4.3.4).

4.2.2.5 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 4.4).

4.2.2.6 Variable length coding

VLCs are used to encode the quantized DCT length coefficients and motion information coding (see 4.5).

4.2.2.7 Buffer memory capacity

1,572,864 bits.

4.2.2.8 Video framing

(See 4.6.)

4.2.2.9 Video data error protection

Video data error protection is provided by Reed Solomon (255, 239) interleaving factor 6 (see 4.6.2). Neither the coding nor the error protection of the audio channels is covered by this standard.

4.2.2.10 Audio service

The system shall provide interfaces for AES/EBU digital audio signals and use ISO/IEC 11172-3 for compressed audio transmission or ITU-R 724 for uncompressed audio transmission.

4.2.2.11 Service multiplex

(See clause 7.) This combines:

- a video channel;
- two 1,544 kbit/s audio channels;
- 384 kbit/s teletext channel (see 6.2);
- 128 kbit/s test–line channel (see 6.3);
- 8 kbit/s supervision channel (see 6.1);
- two 8 kbit/s conditional access channels;
- two 8 kbit/s time code channels (see 6.4.3);
- 384 kbits/s SMPTE machine control channel.

4.2.2.12 Network adaptation

Adaptation to the applicable clauses of ANSI T1.101, ANSI T1.102, ANSI T1.107, and ANSI T1.404 (see clause 8).

4.2.2.13 Scrambling for conditional access

(See clause 9 and informative annex B.)

4.3 Video coding and DCT transformation

4.3.1 Coding modes

Two processing modes are used, intra-field mode (see figure 1), and inter-field and inter-frame mode (see figure 2.)

4.3.1.1 Intra-field mode

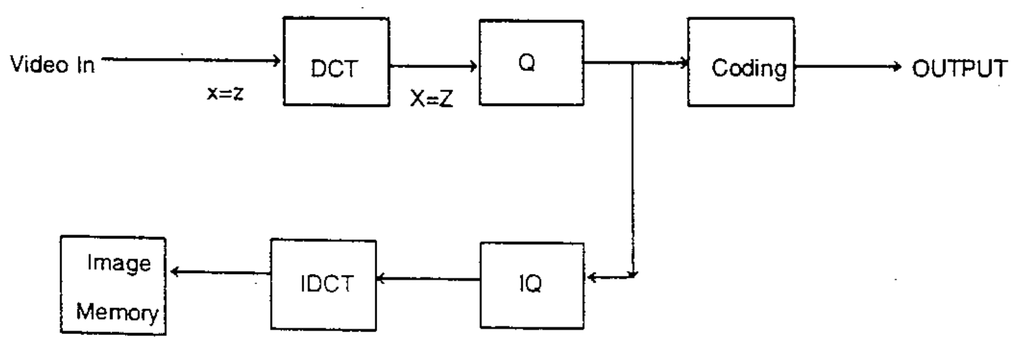

Figure 1 – Intra-field mode

4.3.1.2 Inter-field and inter-frame mode

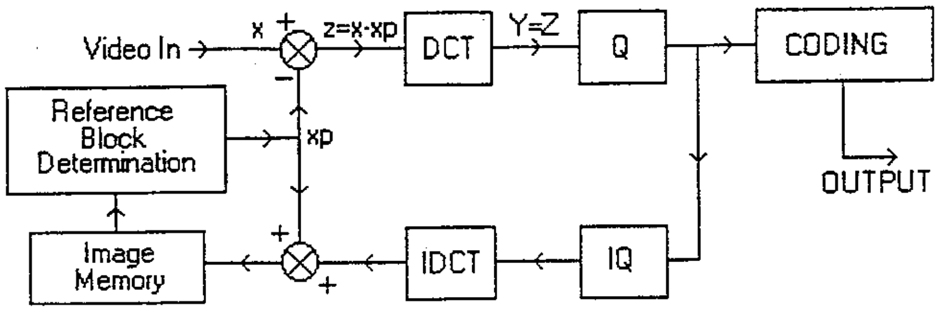

Figure 2 – Inter-field and inter-frame mode

4.3.1.3 Definition of the different modules

DCT	Discrete Cosine Transformation (for 8x8 blocks).
IDCT	Inverse DCT (for 8x8 blocks).
Q	Quantization (see clause 6).
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 4.4).
Coding	See 4.5.

Image memory provides storage for:

a) the decoded current field. This field is used as reference for coding the next image; and

b) 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 4.3.3.

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 4.3.4; the exact computation of the reference block for the inter-frame mode is presented in 4.3.3.

4.3.1.4 Notation

$x(i,j)$	8x8 pixels block.
$xp(i,j)$	8x8 reference block.
$z(i,j)$	$=x(i,j)$ for the intra-field mode.
	$=x(i,j) - xp(i,j)$ for the inter-frame or inter-field mode.
$X(k,l)$	The 8x8 DCT coefficients block in intra-field mode.
$Y(k,l)$	The 8x8 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 is the line index (range: 0 to 7 from left to right);
j is the column index (range: 0 to 7 from top to bottom).

(k,l) Coordinates in the transform domain:
k is the line index (range: 0 to 7);
l is the column index (range: 0 to 7).

4.3.1.5 Mode choice

The chosen mode (intra-field, inter-field or inter-frame) is coded and transmitted for each processed macro-block (see 4.6.1). No specification is given for the mode choice as it concerns only the coder side. Optionally the system may provide a method for using intra-field coding mode only.

The inter-field and the inter-frame scheme presented in figure 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.

4.3.2 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 5.3). The direct transformation is computed according to the formula shown in figure 3.

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

The input to the DCT is expressed as 2's complement integers of 8 bits (including sign). The output of the DCT is expressed as 12-bit 2's 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 ANSI T1.314.

The discrete cosine transformation is given by:

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

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 5.1:

$C_k = \frac{1}{\sqrt{2}}$, for k = 0; $C_l = \frac{1}{\sqrt{2}}$, for l = 0;

$C_k = C_l = 1$, elsewhere.

Figure 3 – Discrete cosine transform formula

4.3.3 Prediction of the block

4.3.3.1 Inter-field mode

The reference block xp for the current block x in field N is computed with pixels of field N-1 with the interpolation scheme shown in figure 4.

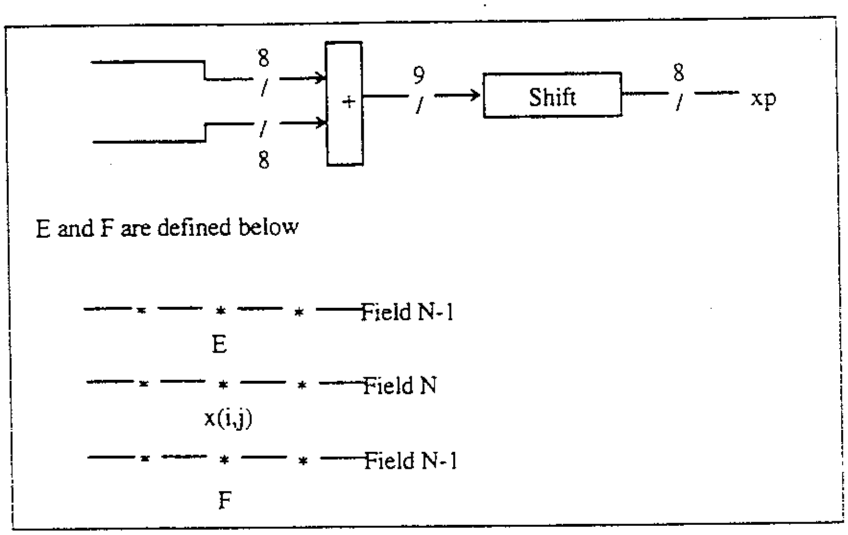

Figure 4 – Interpolation scheme

4.3.3.2 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 4.3.4. There is no ambiguity in the definition of the reference block when the coordinates (x,y) are integer. 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 1/2 pel accuracy for luminance and 1/4 pel accuracy for color difference:

A+	U.	P.	X.	+B
Q.	V.	R.	Y.	S.
C+	W.	T.	Z.	+D

A, B, C, D are 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 are 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 5.

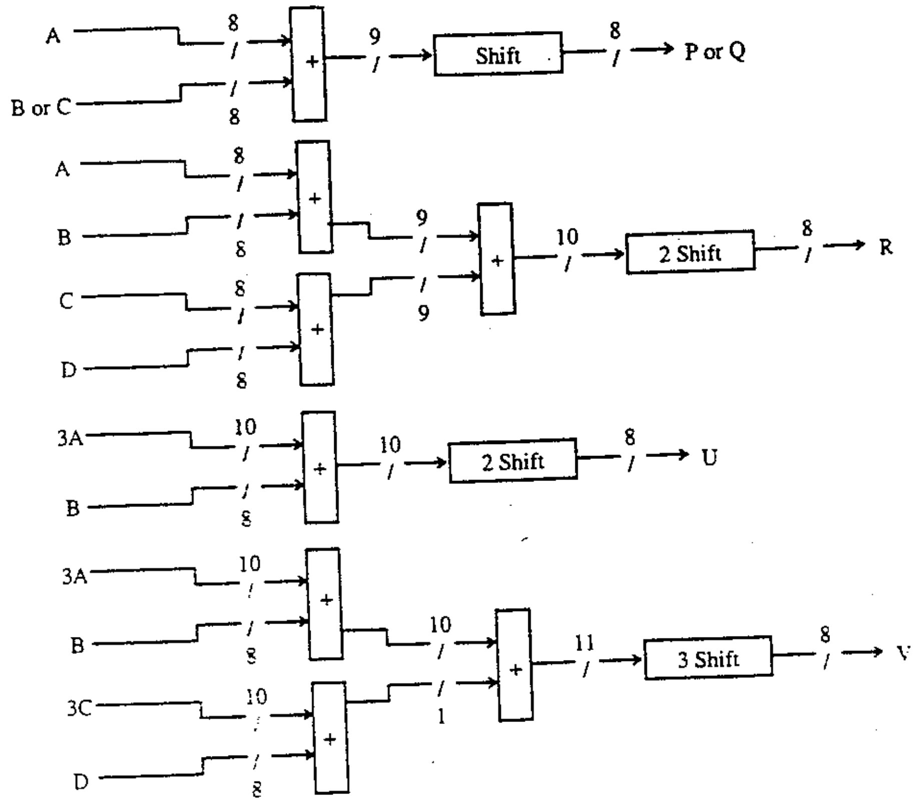

Figure 5 – Values assigned to interpolated pixels

4.3.3.3 Video level outside active picture

In the definition of the reference block given in 4.3.3.1 and 4.3.3.2, the pixels outside the active picture must be set to zero, expressed in 2's complement (8 bits), as illustrated in figure 6.

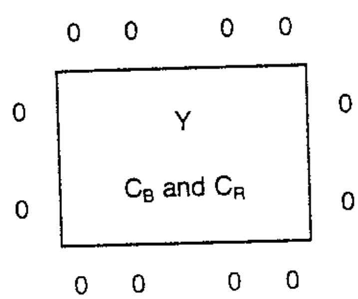

Figure 6 – Definition of the reference block

4.3.4 Motion compensation

Only one motion vector is used for the blocks belonging to a macroblock. The parameters of the motion compensation are given in table 1.

Table 1 – Motion compensation summary

Search area	±14 pels and ±7 lines
Resolution	$^1/_2$ pel and $^1/_2$ line
Number of possible vectors	1653 (all vectors within the search area are permitted)

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

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

Since the vector components are defined as:

a) x increasing from left to right, from -14 to +14; and

b) y increasing from top to bottom, from -7 to +7;

the x component of the vector is expressed as a 6-bit 2's complement number, the integer part of which is 5 bits (including sign). The y component is expressed as a 5-bit 2's complement number, the integer part of which is 4 bits (including sign). It is coded by differential variable-length coding as described in 4.5.

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

a) the vertical coordinate is identical to that of the luminance vector; and

b) 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 4.3.3.

4.4 Quantization of DCT coefficients

Subclauses 4.4.1 and 4.4.2 give information on the computation of parameters necessary for the operation of the inverse quantizer that is specified in 4.4.3.

The quantizer parameters signaled 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 macroblocks 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.

4.4.1 AC coefficient quantization

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

4.4.1.1 Computation of relative coefficients

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

where:

a) S(k,l,m,f) is the 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) is an integer;

b) m = 0,1,2,3 according to the block criticality (criticality factor); and

c) f is the transmission factor.

Care should be taken in the calculation of the relative coefficients in the encoder so that computation of the inverse DCT input in the decoder will not cause overflow.

4.4.1.2 Quantization of relative coefficients

4.4.1.2.1 Quantization characteristic

Table 2 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 2 – Nearly-linear quantizer characteristic

<table>
<tr><th>Input values or intervals C(k,l)</th><th>Quantizer levels</th><th>Quantized values C'(k,l)*</th></tr>
<tr><td>0
1
2
:
255
256:257
258:259
:
510:511
512:515
516:519
:
1020:1023
1024:1031
1032:1039
:
2040:2047</td><td>0
1
2
:
255
256
257
:
383
384
385
:
511
512
513
:
639</td><td>0
1
2
:
255
256
:
:
510
513
:
:
1021
1027
:
:
2043</td></tr>
</table>

* Outputs of the inverse quantizer.

Table 3 – Criticality parameters

Criticality (m)	Translation Tr(m) [Y or C_RC_B coefficients]	Limit for Y Th(m)	Limit for C_RC_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

4.4.1.2.2 Determination of transmission threshold matrix

The S matrix for each component depends on the relative visibility matrix defined in figures 7 and 8 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.

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 9.

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

The modules that 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 9, 10, and 11, the scalar control parameter n(k,l,m,f) for each component is obtained in the following way:

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

where relative visibility $p_0(k,l)$ is defined in figures 7 and 8 and where p is an integer between 0 and 52.

Tr(m) and Th(m) are parameters depending on criticality (m) and are defined in table 3.

Then n(k,l,m,f) is given by:

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

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

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

4.4.1.2.3 Data accuracy

The accuracy of the data coefficients is given in table 4.

Table 4 – Data accuracy

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

4.4.1.2.4 Ranges of quantization parameters

The range of the quantization parameters is given in table 5.

Table 5 – Quantization parameters

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.

$p_0(k,l)$	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

Figure 7 – Relative visibility matrix for luminance

$p_0(k,l)$	1	2	3	4	5	6	7	8
0	0	0	3	4	6	8	8	1
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

Figure 8 – Relative visibility matrix for chrominance

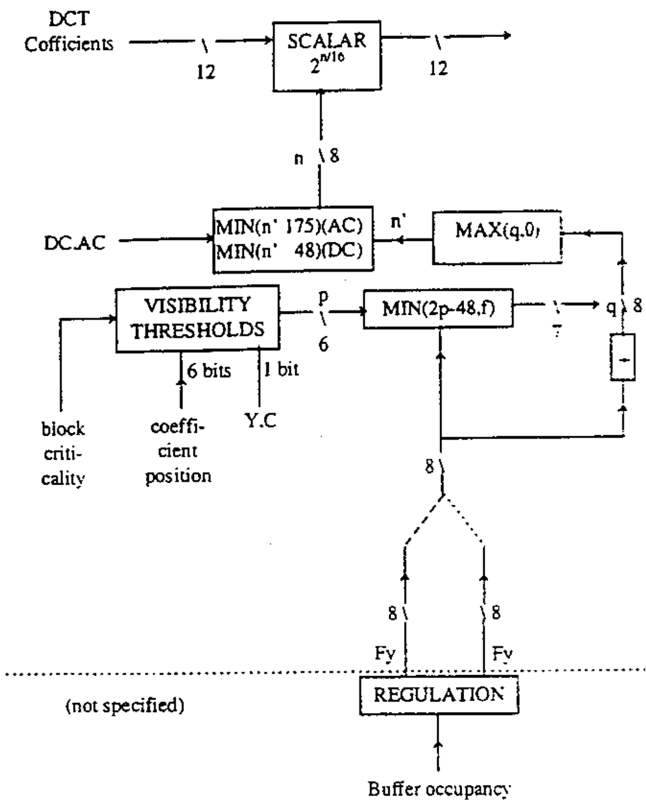

Figure 9 – S(k,l) control

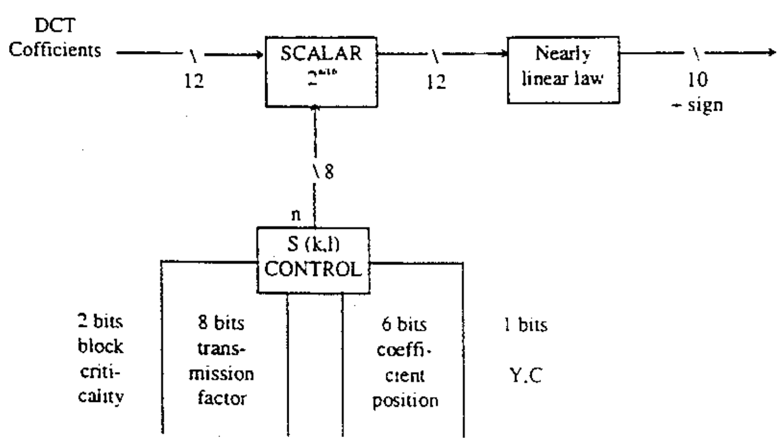

Figure 10 – Scalar control

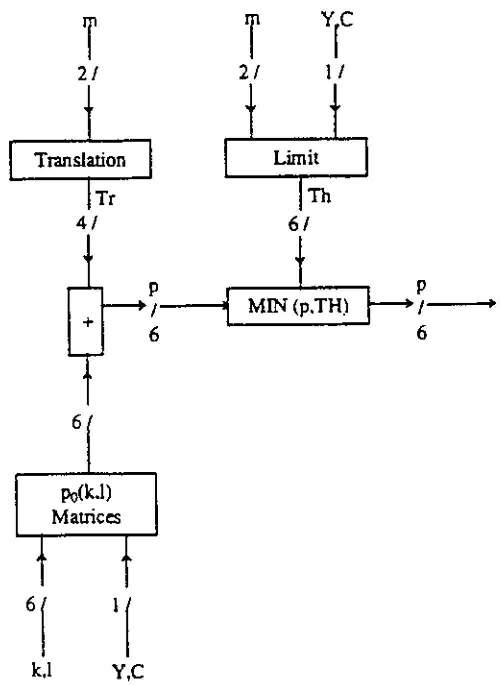

Figure 11 – Computation of p(k,l,m)

4.4.2 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].

4.4.3 Inverse quantization

The reconstructed DCT coefficients are given by the following formula:

$Z'(k,l) = C'(k,l) * S(k,l,m,f) *1/2$

where:

$S(k,l,m,f) = 2^{n(k,l,m,f)/16}$ as defined in 4.4.1;

C'(k,l) is the 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:

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

The 12 bit values for $2^{r/16}$ are given in table 6. The same set of values may be used in the quantizer.

$C'(k,l) * 2^{q-1}$ is obtained by a binary left shift of q-1 bits performed on the 12 bits value C'(k,l). Only the rightmost 12 bits 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 6 – Values of $2^{r/16}$

r	$2^{r/16}$	$2{,}048*2^{r/16}$
0	1.00000000000	2,048
1	1.00001011011	2,139
2	1.00010111001	2,233
3	1.00100011100	2,332
4	1.00110000011	2,435
5	1.00111101111	2,543
6	1.01001100000	2,656
7	1.01011010110	2,774
8	1.01101010000	2,896
9	1.01111010001	3,025
10	1.10001010110	3,158
11	1.10011100010	3,298
12	1.10101110100	3,444
13	1.11000001101	3,597
14	1.11010101100	3,756
15	1.11101010010	3,922

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

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

scanning path for chrominance

Figure 12 – Scanning paths for luminance and chrominance

4.5 Variable length coding for DCT coefficients and motion vector differences

4.5.1 Scanning path for quantized DCT values

DCT coefficients that have non-zero quantized values are VLC coded. The quantized DCT coefficients are scanned according to the scanning path shown as increasing values in figure 12. Runs of zeros along the scanning path are coded as run-lengths.

The transmission of the last run length of zeros in a block is avoided by anticipating the 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 "+1" coefficients between two runs of zeros, or between a run of zeros and the EOB, one of "+1s" is not transmitted and the decoder reinserts it.

4.5.2 Assignment of codewords to quantized values and run lengths

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

$|1\ X_i| \ldots |1\ X_1|\ |0\ X_0|$, $i = 0..8$, $X_i\ \varepsilon\ \{0,1\}$

$|1\ X_8| \ldots |1\ X_1|\ |1\ X_0|$, $X_i\ \varepsilon\ \{0,1\}$

where | | corresponds to a pair of bits, and where ε 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 word 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 8, and the words having less than 18 end with a $|0\ X_0|$ pair.

Table 7 – Assignment for luminance (Y) and chrominance (C) coefficients

<table>
<tr><th>Codeword</th><th>Y</th><th></th><th>C</th><th>Codeword</th><th>Y</th><th></th><th>C</th></tr>
<tr><td>|0 1|</td><td></td><td>1</td><td></td><td>|0 0|</td><td></td><td>-1</td><td></td></tr>
<tr><td>|1 1|0 0|</td><td></td><td>2</td><td></td><td>|1 0|0 1|</td><td></td><td>-2</td><td></td></tr>
<tr><td>|1 1|0 1|</td><td></td><td>0*1</td><td></td><td>|1 0|0 0|</td><td></td><td>0*2</td><td></td></tr>
<tr><td>|1 1|1 0|0 0|</td><td></td><td>0*3</td><td></td><td>|1 0|1 1|0 1|</td><td></td><td>0*4</td><td></td></tr>
<tr><td>|1 1|1 0|0 1|</td><td>3</td><td></td><td>0*5</td><td>|1 0|1 1|0 0|</td><td>-3</td><td></td><td>0*6</td></tr>
<tr><td>|1 1|1 1|0 0|</td><td>4</td><td></td><td>0*7</td><td>|1 0|1 0|0 1|</td><td>-4</td><td></td><td>0*8</td></tr>
<tr><td>(|1 1|1 1|0 1|
reserved, EOB₁)</td><td></td><td></td><td></td><td>(|1 0|1 0|0 0|
reserved, EOB₀)</td><td></td><td></td><td></td></tr>
<tr><td>|1 1|1 0|1 0|0 0|</td><td>0*5</td><td></td><td>3</td><td>|1 0|1 1|1 1|0 1|</td><td>0*6</td><td></td><td>-3</td></tr>
<tr><td>|1 1|1 0|1 0|0 1|</td><td>0*7</td><td></td><td>4</td><td>|1 0|1 1|1 1|0 0|</td><td>0*8</td><td></td><td>-4</td></tr>
<tr><td>|1 1|1 0|1 1|0 0|</td><td></td><td>0*9</td><td></td><td>|1 0|1 1|1 0|0 1|</td><td></td><td>0*10</td><td></td></tr>
<tr><td>|1 1|1 0|1 1|0 1|</td><td></td><td>0*11</td><td></td><td>|1 0|1 1|1 0|0 0|</td><td></td><td>0*12</td><td></td></tr>
<tr><td>|1 1|1 1|1 0|0 0|</td><td></td><td>5</td><td></td><td>|1 0|1 0|1 1|0 1|</td><td></td><td>-5</td><td></td></tr>
<tr><td>|1 1|1 1|1 0|0 1|</td><td>6</td><td></td><td>0*13</td><td>|1 0|1 0|1 1|0 0|</td><td>-6</td><td></td><td>0*14</td></tr>
<tr><td>|1 1|1 1|1 1|0 0|</td><td>7</td><td></td><td>0*15</td><td>|1 0|1 0|1 0|0 1|</td><td>-7</td><td></td><td>0*16</td></tr>
<tr><td>|1 1|1 1|1 1|0 1|</td><td>8</td><td></td><td>0*17</td><td>|1 0|1 0|1 0|0 0|</td><td>-8</td><td></td><td>0*18</td></tr>
<tr><td>|1 1|1 0|1 0|1 0|0 0|</td><td>0*13</td><td></td><td>6</td><td>|1 0|1 1|1 1|1 1|0 1|</td><td>0*14</td><td></td><td>-6</td></tr>
<tr><td>|1 1|1-0|1 0|1 0|0 1|</td><td>0*15</td><td></td><td>7</td><td>|1 0|1 1|1 1|1 1|0 0|</td><td>0*16</td><td></td><td>-7</td></tr>
<tr><td>|1 1|1 0|1 0|1 1|0 0|</td><td>0*17</td><td></td><td>8</td><td>|1 0|1 1|1 1|1 0|0 1|</td><td>0*18</td><td></td><td>-8</td></tr>
<tr><td>|1 1|1 0|1 0|1 1|0 1|</td><td></td><td>0*19</td><td></td><td>|1 0|1 1|1 1|1 0|0 0|</td><td></td><td>0*20</td><td></td></tr>
<tr><td>|1 1|1 0|1 1|1 0|0 0|</td><td></td><td>0*21</td><td></td><td>|1 0|1 1|1 0|1 1|0 1|</td><td></td><td>0*22</td><td></td></tr>
<tr><td>|1 1|1 0|1 1|1 0|0 1|</td><td></td><td>0*23</td><td></td><td>|1 0|1 1|1 0|1 1|0 0|</td><td></td><td>0*24</td><td></td></tr>
<tr><td>|1 1|1 0|1 1|1 1|0 0|</td><td></td><td>0*25</td><td></td><td>|1 0|1 1|1 0|1 0|0 1|</td><td></td><td>0*26</td><td></td></tr>
<tr><td>|1 1|1 0|1 1|1 1|0 1|</td><td></td><td>0*27</td><td></td><td>|1 0|1 1|1 0|1 0|0 0|</td><td></td><td>0*28</td><td></td></tr>
<tr><td>|1 1|1 1|1 0|1 0|0 0|</td><td></td><td>9</td><td></td><td>|1 0|1 0|1 1|1 1|0 1|</td><td></td><td>-9</td><td></td></tr>
<tr><td>|1 1|1 1|1 0|1 0|0 1|</td><td></td><td>10</td><td></td><td>|1 0|1 0|1 1|1 1|0 0|</td><td></td><td>-10</td><td></td></tr>
<tr><td>|1 1|1 1|1 0|1 1|0 0|</td><td></td><td>11</td><td></td><td>|1 0|1 0|1 1|1 0|0 1|</td><td></td><td>-11</td><td></td></tr>
<tr><td>|1 1|1 1|1 0|1 1|0 1|</td><td></td><td>12</td><td></td><td>|1 0|1 0|1 1|1 0|0 0|</td><td></td><td>-12</td><td></td></tr>
<tr><td>|1 1|1 1|1 1|1 0|0 0|</td><td></td><td>13</td><td></td><td>|1 0|1 0|1 0|1 1|0 1|</td><td></td><td>-13</td><td></td></tr>
<tr><td>|1 1|1 1|1 1|1 0|0 1|</td><td></td><td>14</td><td></td><td>|1 0|1 0|1 0|1 1|0 0|</td><td></td><td>-14</td><td></td></tr>
<tr><td>|1 1|1 1|1 1|1 1|0 0|</td><td></td><td>15</td><td></td><td>|1 0|1 0|1 0|1 0|0 1|</td><td></td><td>-15</td><td></td></tr>
<tr><td>|1 1|1 1|1 1|1 1|0 1|</td><td></td><td>16</td><td></td><td>|1 0|1 0|1 0|1 0|0 0|</td><td></td><td>-16</td><td></td></tr>
</table>

In table 7, 0*n refers to a run-length of n zeros.

Table 8 – Length of available words

i	word length (bit)	word structure	no of words
0	2	$0\ X_o$	2
1	4	$1\ X_1 0\ X_o$	4
2	6	.	8
3	8	.	16
4	10	.	32
5	12	.	64
6	14	.	128
7	16	$1\ X_7 \ldots 0\ X_o$	256
8	18	$1\ X_8 \ldots 0\ X_o$	512
	18	$1\ X_8 \ldots 1\ X_o$	512

The total number of words is 1,534. Sixty-six of them are used to code the run length of zeros, the special words EOB_0 and EOB_1, indicating the end of each block (see 4.6.1.4), 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 permissible 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" between two NULL words must be transmitted.

Following are examples of the use of Run Lengths and End of Blocks:

Example 1

Coefficients:	-2	0 0 0	+1	+1	0 0	+2	0 0 0 0	End of Block
Codewords:	1001	11100001	01	01	1000	1100	101101	111101
Transmitted:	1001	11100001	01		1000	1100		111101

+1 is not transmitted because there are two +1s between two runs of zeros, and a run of 4 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 9 zeros and the EOB.

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 1,466 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 8 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.

The information bits for the positive values and the corresponding negative values are complemented. The information bits for EOB0 and EOB1 are complemented.

The assignments for run lengths of zeros from 29 up to 63 and for the codeword NULL are shown in table 9.

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 9 info bits, set continuation bit of last pair to 1 (see Example 3).
-478 ... – 17	Add -34, then generate up to 9 info bits, not considering all the leading bits equal to 1 (see Example 4).
- 16 ... + 16	Use table 7 for assignment.
+ 17 ... +478	Add +33, then generate up to 9 info bits, not considering all the leading bits equal to 0 (see Example 5).
+479 ... +733	Add +34, then generate 9 info bits, set continuation bit of last pair to 1 (see Example 6).

Example 3
from -733 to -479
X=-733→ -733+1501 = 768 =
$(001\ 100000000)_2$ =
(l1 1l1 0l1 0l1 0l1 0l1 0l1 0l1 0l1 0l)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 =
$(001\ 111111110)_2$ =
(l1 1l1 1l1 1l1 1l1 1l1 1l1 1l1 1l1 0l)vlc
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)vlc

Example 4
from -478 to -17
X=-478 → -478-34 = -512 =
$(111\ 000000000)_2$ =
(l1 0l1 0l1 0l1 0l1 0l1 0l1 0l1 0l0 0l)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 =
$(111\ 001001011)_2$ =
(l1 0l1 0l1 1l1 0l1 0l1 1l1 0l1 1l0 1l)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 =
$(111111\ 000111)_2$ =
(l1 0l1 0l1 0l1 1l1 1l0 1l)vlc
(X_5 X_4 X_3 X_2 X_1 X_0)vlc

Example 5:
from +17 to +478
X=23 → 23+33 = 56 =
$(000000\ 111000)_2$ =
(l1 1l1 1l1 1l1 0l1 0l0 0l)vlc
(X_5 X_4 X_3 X_2 X_1 X_0)vlc

X=403 → 403+33 = 436 =
$(000\ 110110100)_2$ =
(l1 1l1 1l1 0l1 1l1 1l1 0l1 1l1 0l0 0l)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 =
$(000\ 111111111)_2$ =
(l1 1l1 1l1 1l1 1l1 1l1 1l1 1l1 1l0 1l)vlc
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)vlc

Example 6:
from +479 to +733
X=479 → 479+34 = 513 =
$(001\ 000000001)_2$ =
(l1 0l1 0l1 0l1 0l1 0l1 0l1 0l1 0l1 1l)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 =
$(001\ 011111111)_2$ =
(l1 0l1 1l1 1l1 1l1 1l1 1l1 1l1 1l1 1l)vlc
(X_8 X_7 X_6 X_5 X_4 X_3 X_2 X_1 X_0)vlc

Table 9 – Assignments for run length of zeros

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

Table 10 – 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

(continued)

Table 10 *(concluded)*

Codeword	MV_x or MV_y	Codeword	MV_x or MV_y
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

4.5.3 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 10. 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:

a) if the macro-block is inter frame encoded; and

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

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

4.6 Video framing and forward error correction

4.6.1 Video framing

A single stream is produced for Variable Length Coded (VLC) and Fixed Length Coded (FLC) data. All data are transmitted MSB first.

4.6.1.1 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 625 system
m = 31 for a 525 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.

4.6.1.2 Detailed content

FSW	Field Synchronization Word (47"1" + "0") (see note 1)	48 bits
00 01 10	Are used to identify the threefold repetition of FSW, FCD, and BOF	2 bits
FCP	Field Coding Parameters (see 4.6.1.3)	30 bits
BOF	Buffer Occupancy Field (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" + "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 ith stripe range is from 0 to 71 {625 system}: 0 to 35 {1st field} 36 to 71 {2nd field} the MSB is set to "0" range is from 0 to 61 {525 system}: 0 to 30 {1st field} 31 to 61 {2nd field} the two MSB's are set to "0"	8 bits
TFY_i	Transmission Factor for luminance in the ith stripe (from 0 to 175)	8 bits
TFC_i	Transmission Factor for chrominance in the ith stripe (from 0 to 175)	8 bits
CRC_i	Cyclic Redundancy Code for the ith stripe (to be applied to all bits of the encoded stripe excluding SSW. The generator polynomial is $1 + x^2 + x^{15} + x^{16}$. The CRC calculation registers are initialized to zero before the start of each stripe.	16 bits
MI_j	Mode Identification 00 intra-field mode 01 inter-field mode 10 inter-frame mode with motion compensation [motion vector difference π (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 10 and note 4)	variable
MV_y	VLC codeword associated with the motion prediction variable error in the vertical direction (see table 10 and note 4)	variable
VLC_{y1}	VLC words for first Y block in the macro- block	variable
VLC_{cb}	VLC words for CB block in the macro- block	variable
VLC_{y2}	VLC words for second Y block in the macro-block	variable
VLC_{cr}	VLC words for CR 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 4.6.1.4) (EOB_0 = "10 10 00" EOB_1 = "11 11 01")	6 bits

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. Maximum coder buffer occupancy is 1,572,864 kbit minus 128 kbit. 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 Mij=10.

4.6.1.3 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	

<table>
<tr><td>r</td><td colspan="4">reserved bits, set to "0", ignored by the receiver.</td></tr>
<tr><td>VF</td><td colspan="4">Video Format
000 = 4:2:2
001 = reserved
010 = reserved</td></tr>
<tr><td>AR</td><td colspan="4">Aspect Ratio
0 = 4:3
1 = 16:9</td></tr>
<tr><td>ST</td><td colspan="4">System Type
0 = 625; 1 = 525</td></tr>
<tr><td>VA</td><td colspan="4">V-Axis switch (625 system)
VA = 1 for positive phase on the first line of each field.</td></tr>
<tr><td rowspan="9">FS (See note)</td><td>Field sequence</td><td>Frame</td><td>Field</td><td>VA</td></tr>
<tr><td>000</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>001</td><td>1</td><td>2</td><td>1</td></tr>
<tr><td>010</td><td>2</td><td>3</td><td>0</td></tr>
<tr><td>011</td><td>2</td><td>4</td><td>0</td></tr>
<tr><td>100</td><td>3</td><td>5</td><td>1</td></tr>
<tr><td>101</td><td>3</td><td>6</td><td>1</td></tr>
<tr><td>110</td><td>4</td><td>7</td><td>0</td></tr>
<tr><td>111</td><td>4</td><td>8</td><td>0</td></tr>
<tr><td>SL</td><td colspan="4">Subcarrier/Line frequency relationship
0 = correct</td></tr>
<tr><td>BA</td><td colspan="4">Burst Amplitude – The amplitude of the subcarrier burst is quantized as an ITU-R Recommendation 601-2 luminance signal, with the MSB omitted</td></tr>
<tr><td>SCP</td><td colspan="4">Subcarrier Phase – Instantaneous phase of the reference subcarrier at the field-synchronization start as defined in ITU-R Report 624-3, MSB first.
Scale: 0=([360°/256] * 0)
1=([360°/256] * 1)
...=...
255=([360°/256] * 255)</td></tr>
</table>

NOTE – This table applies for 625 applications. For 525 applications the 8 field sequence shall be maintained, although 525 applications only use a 4 field sequence. The VA information shall be ignored for 525 applications.

4.6.1.4 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 o blocks (180) in a video stripe of blocks. The pseudo random generator is reset at th beginning of each stripe. At the end of each block, the pseudo random generator step forward one bit and the output of the generator, 0 or 1, determines which of the two EOI words, EOB_0 or 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 13.

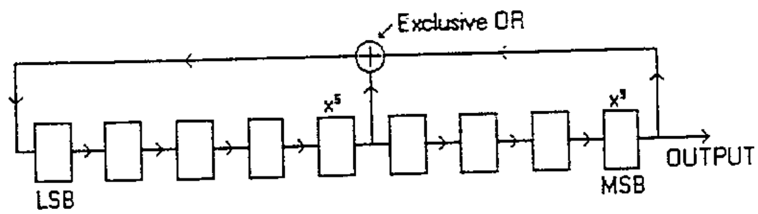

Figure 13 – Pseudo-random generator

EOB0 and EOB1 correspond respectively to one "0" and "1" at the output of the pseuc 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 I 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)

Forward error protection and correction

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

The generator polynomial of the 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 14.

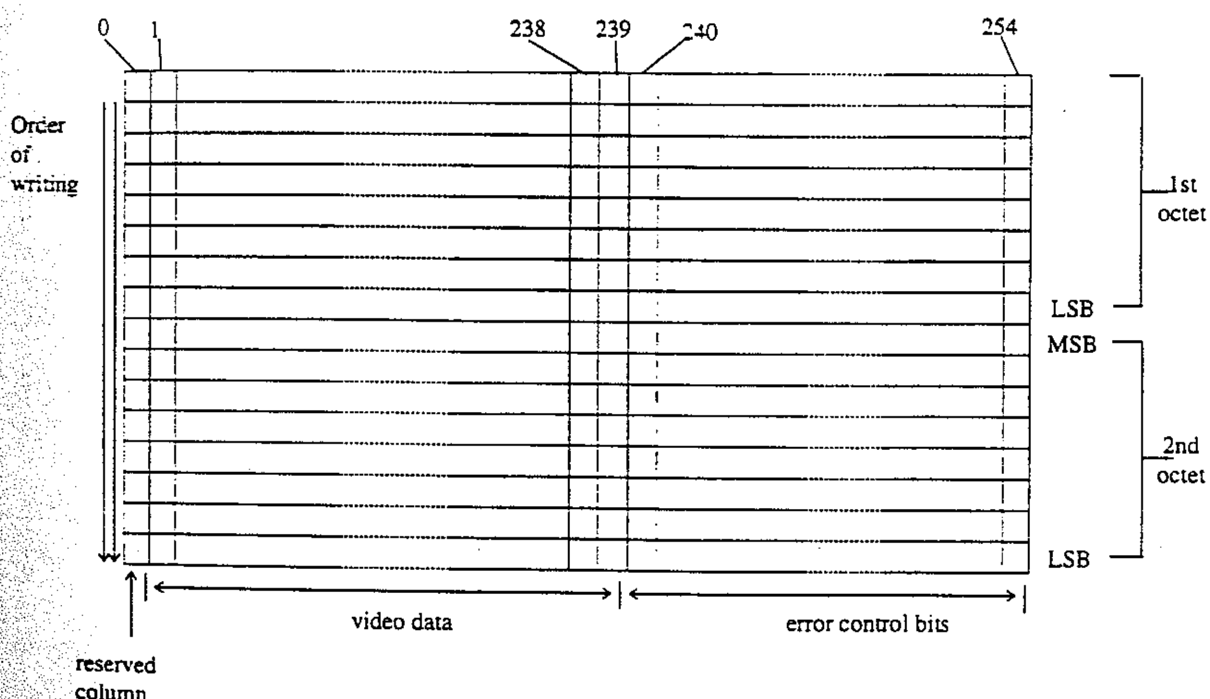

Figure 14 – Write sequence

Second stage

Three successive blocks formed in the first stage are interlaced column by column to form the superblock shown in figure 15. 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.

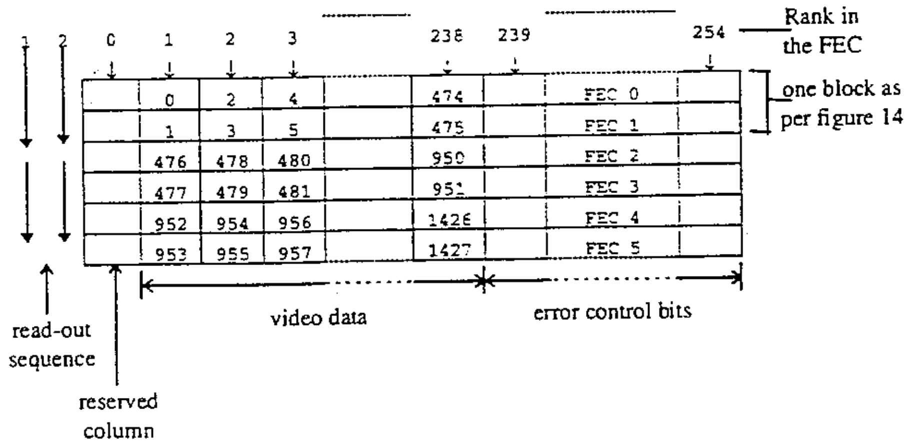

Figure 15 – Superblock configuration

5 Audio

A maximum of two separate allocated blocks of bandwidth are provided for the transport of audio services through the codec. These appear in the multiplex as octet A. Any data capacity not used for audio is reutilized for video data. The A channel can be used synchronously or asynchronously, and is intended for use with appropriate audio codecs having their own data protection mechanisms as defined in 5.2. The coding of the audio signal will allocate the maximum number of audio services which can be transported concurrently within the audio bandwidth A and A'. If the bandwidth is used for uncompressed audio service, a maximum of two digital audio channels is available. If the bandwidth is used for compressed audio service, a maximum of 8 digital audio channels is available per 1,554 kbits/s for a total of 16 digital audio channels when both 1,554 kbit/s channels are used. Since the two methods of transporting audio service have different delay characteristics, care must be taken in the implementation of this standard to ensure that the audio-to-video differential delay shall be within the 2 ms per coding as recommended in ITU-R Report 1235.

5.1 Digital audio interface specifications

The audio interface shall conform to ANSI S4.40.

Optionally, the serial digital audio may be multiplexed or demultiplexed from a serial digital television signal which shall conform to ANSI/SMPTE 272M.

5.2 Audio coding specifications

5.2.1 Compressed audio

The audio coding specification shall meet the applicable clauses of ISO/IEC 11172-3. The compressed audio data from the coding of each digital audio stereo pair shall be multiplexed into an H0 or 384 kbit/s channel within the A or A' octet conforming to ISO/IEC 11172-1.

5.2.2 Uncompressed audio

Up to two channels of uncompressed digital audio service shall optionally be provided by the implementation of the audio coding and H11 multiplexing specification that conforms to ITU-R Recommendation 724.

6 Ancillary signals

6.1 Supervision channel

6.1.1 Overview

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

Part of this information is directly related to the codec and is specified in this clause. 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 that 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 AES/EBU digital audio interface (see ANSI S4.40).

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 braces { }.

The definition of the supervision channel comprises the following subclauses:

6.1.2 message definition;
6.1.3 packet structure;
6.1.4 frame structure;
6.1.5 channel management; and
6.1.6 extension rules.

6.1.2 Message definition

6.1.2.1 Alarms

(mandatory, address FE hex, priority 3)

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

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;
- bit 4-7 reserved (set to logic "one");

Octet 1: Alarms related to the video input:
- bit 0 (LSB) junction fault (digital interface);
- bit 1 time-base error;
- bit 2 out-of-spec input signal (the encoder cannot work properly);
- bit 3 out-of-spec input signal (the encoder can still work, possibly with reduced quality);
- bit 4-7 reserved (set to logic "one");

Octet 2: Alarms related to the auxiliary signals in the video field blanking interval:
bit 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-spec input signal (the encoder cannot work properly);
bit 3 out-of-spec input signal (the encoder can still work, possibly with reduced quality);
bit 4-7 reserved (set to logic "one").

6.1.2.2 Multiplex structure

(mandatory, address FD hex, priority 2)

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

Octet 0: Copy of the 8-bit word carried by bit m2 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 m3.

Octet 2: Copy of bits carried through bit m4.

Octet 3: Video format, as specified in the FCP field of the video mux:
bit 0 (LSB) system type;
bit 1 aspect ratio;
bit 2-4 video format;
bit 5-7 reserved (set to logic "one").

Octet 4: Sound encoding method:
00 not specified;
01 according to ITU-R Recommendation 724;
10 according to ISO/IEC 11172-3
others reserved (set to logic "one").

6.1.2.3 Source identification

(optional, address FC hex, priority 2)

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

6.1.2.4 Destination identification

(optional, address FB hex, priority 2)

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

6.1.2.5 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.

6.1.2.6 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.

6.1.2.7 Header

Each message is preceded by the following header octet:

bit 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};
bit 5-7	3-bit continuity index of messages sent with a given address.

6.1.3 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:

1) an address octet: identifies the nature of the message. This address is specified in 6.1.2 for the messages already defined (in the case of an extended system, an address extension octet may be added);

2) a control octet: structured as follows:

   a) bits 0 and 1: priority index {used to manage resource sharing when needed}. See 6.1.2 for the messages already defined;

   b) 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;

   c) bit 5: "0" {used for software address extension};

   d) bit 6 and 7: b6="0",b7="1" {used to link segmented messages}; the message {or message segment}.

6.1.4 Frame structure

The packets defined above (19 octets maximum) are transmitted within High Level Data Link Control (HDLC) frames (see ISO 3309-2) on the 8 kHz supervision channel provided by bit S of the container. In all packets LSB (bit 0) is sent first.

An HDLC frame comprises:

a) a beginning flag: "01111110";

b) a packet;

c) a 16-bit error-detecting CRC (FCS: Frame Check Sequence);

d) 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 that are not recognized by the receiver should also be ignored.

6.1.5 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.

6.1.6 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.

6.2 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 the 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.

6.2.1 Introduction

The frame is optimized for the transmission of the various teletext systems described in ITU-R Recommendation 653, 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.

6.2.2 Frame structure

The frame is composed of the following information (see figure 16). In all fields MSB are sent first:

1) a 10-bit synchronization word 010011011X (see note 1);
2) a 4-bit frame header including:
   a) a system type identifier:
      i) 0: 625/50
      ii) 1: 525/60
   b) a reserved bit fixed to 0;
   c) a frame status - 2 bits, (see 6.2.3);
3) a 24-bit message header including:
   a) a 12-bit message type-identifier;
   b) a field identifier (see note 2):
      i) 0: first field;
      ii) 1: second field
      iii) 2: third field
      iv) 3: fourth field
   c) a 6-bit message length indicator;
   d) a 4-bit interleaved parity word: BIP-4 (even parity computed over the frame header and the message header);
4) depending on the frame status, either:
   a) a 43-octet data field for a single message; or,
   b) a 20-octet data field for a first message;
   c) a second message header (the BIP-4 applies also to the frame header);
   d) a second 20-octet data field for a second message;
5) an 18-bit error protecting code, BCH (390, 372), computed over the full frame, synchronization word excepted (see note 3).

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 7.2).

2 Field numbering is in accordance with ITU-R Report 624-3. The code corresponds to the field number from which the current data unit is extracted.

3 The code is a shortened BCH (511,493) with the generator polynomial $g(x)=(x^9+x^4+1)(x^9+x^6+x^4+x^3+1)$.

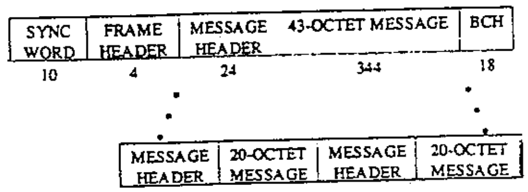

Figure 16 – Frame structure

6.2.3 Data field allocation

Messages of length 43 octets or less are inserted in the appropriate data field. If the message length is less then 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).

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.

6.2.4 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 length is therefore as shown in table 11. First bit after the run-in sequence is MSB of the first octet of the data field.

Table 11 – Teletext message length

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

The message type-identifier is in the form 1111000XXXXX. The 5 LSBs form a Line Identifier (LI) which indicates the line number (see note below) as shown in table 12.

Table 12 – Line identifier

(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	

NOTE – Line numbering is in accordance with ITU-R Report 624-3. The code corresponds to the line number from which the current data unit is extracted.

6.2.5 EBU Tech 3217 data

These biphase coded data, EBU Technical Document 3217, are not decoded. The sampling frequency is thus equal to twice the nominal data frequency (5 MHz). The message type-identifier is 111100011111 (F1F hex). First bit after the run-in sequence is MSB of the first octet of the data field.

6.3 Transmission format of test lines in a 128 kbit/s channel

6.3.1 Introduction

In intervals of 5 fields a testline is digitized according to the sampling structure defined in 6.3.2. The data are given to a transmission buffer and then transmitted in a format (described in 6.3.3) by a channel with a bit-rate of 128 kbit/s.

If 3 testlines per field are in use, they are sampled sequentially. Thus the lines have to b
repeated 15 times when reinserting them at the decoder.

In order to keep the phase consistency for the subcarrier in composite lines, the test line
have to be reinserted in the fields with the same field number (1 to 8 for PAL). Thi
means that 8 times the number of testlines used per field have to be stored.

6.3.2 Sampling of the testlines

Testline sampling is in accordance with ITU-R Recommendation 601-2 luminance samplir
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 with double resolution.
corresponds to ITU-R Recommendation 601-2 with 9 bits resolution, scale extension a
scale shift by 256.

6.3.3 Format

The transmission of a testline starts after sampling of a testline and has the following form

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 synchronizat word coincides with the start of a new octet in the container (see 7.2).

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 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 p
bit.

Dn Data word + parity, 12 bits.
d_0 = MSB
d_9 = LSB
d_{10} = Reserve (e.g., higher resolution), else = 0
p = Parity bit, even parity over d_0, d_1, d_2, d_3, d_4.

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

d_0	d'_0	d_5	d'_5	followed by
d_1	d'_1	d_6	d'_6	followed by
d_2	d'_2	d_7	d'_7	followed by
d_3	d'_3	d_8	d'_8	followed by
d_4	d'_4	d_9	d'_9	followed by
p	p'	d_{10}	d'_{10}	

a) the first sample, D_1, corresponds with the first sample of the digital line (respectively after the active video timing reference code) defined in ITU-R Recommendation 656;

b) the number, n, of data words is 864 for the 625 lines system and 858 for the 525 lines system, respectively;

c) the number of remaining octets until the data of the next testline depends on the system type and should be filled with octets of zeros.

6.4 Time code

6.4.1 Interface specifications

The time code interface shall conform to ANSI/SMPTE 12M and IEC 461.

Optionally, the serial time code may be multiplexed or demultiplexed from a serial digital television signal that shall conform to ANSI/SMPTE 272M.

6.4.2 Transmission of 80-bit serial time code in a dedicated 8kbit/s channel

The time code, which is defined in ANSI/SMPTE 12M and IEC 461 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):

a) d_0 = 1st time code data bit;
b) d_1 = 2nd time code data bit;
c) d_2 = 3rd time code data bit (or justification bit);
d) ij = justification indication ("1" if d_2 is used);
e) p_0 = exclusive OR of (d_0, d_1, ij);
f) p_1 = exclusive OR of (d_1, d_2, ij);
g) p_2 = exclusive OR of (d_0, d_1, d_2) complemented;
h) p_3 = exclusive OR of (d_0, d_2, ij);
i) ij' = repetition of ij.

NOTES

1 P_0 - p_3 are complemented and form a Hamming extended code protecting d_0, d_1, d_2, 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.

6.4.3 Transmission of VITC time code

The VITC time code information, which is defined in IEC 461, is extracted from the vertical blanking information of the incoming composite signal and transferred from encoder to decoder in the supervision channel using the following frame and format description:

$$000000001111111111111111F_1F_0L_4L_3L_2L_1L_0PD_0D_1D_2...D_{89}L'_4L'_3L'_2L'_1L'_0P'000...$$

The 8 0's and the 16 1's are a framing code.

F_1F_0 is the field number in a 4 field sequence.

$L_4L_3L_2L_1L_0$ is the line number of the first VITC line.

P is even parity bit (xor) of F_1 to L_0.

D_0 to D_{89} are the 90 VITC line data bits as defined in IEC 461.

$L'_4L'_3L'_2L'_1L'_0$ is the line number of the last VITC line. It is equal to the first line number if only one line of VITC is detected.

P' is even parity bit (xor) of L'_4 to L'_0.

The space between VITC frames (one per field) is filled with 0s.

6.5 Remote control of television equipment

SMPTE/EBU Esbus digital control information for remote control of, e.g., VTR machines is transferred for the coder to the decoder in the 384 kbits/s T' channel using a transmission format with a modified frame structure compared to what is used with the 384 kbit/s T channel. Same frame length, but short message fields are used in order to minimize the system delay in the communication link between the television equipment.

The Esbus, which is a bidirectional full-duplex four-wire communication channel between the two units, may need to be divided into two separate channels – one for upstream and one for downstream communications.

The unit that controls the television equipment is called the MASTER, while the unit being controlled is called the SLAVE.

6.5.1 Interface specifications

The electrical interface to the MASTER/SLAVE is in accordance with ANSI/SMPTE 207M using balanced signals and a transmission rate of 38.4 kbit/s. Data is transmitted asynchronously, bit serial and word serial.

The data words utilized at this interface are organized into packets of 1 start bit + 8 data bits + 1 parity bit + 1 stop bit.

LSB is transmitted first and odd parity is used.

The interface connector is a 9-pin D-subminiature female with pin assignments as specified in ANSI/SMPTE 207M.

NOTE – The electrical connections may need to be physically divided into Transmit and Receive information due to the separate upstream and downstream transmission paths.

6.5.2 Command block format

The communication between the MASTER and the SLAVE is grouped into blocks of words, composed of the fields CMD1/Data Count, CMDS, Data and Checksum in order, starting from CMD1/Data Count. MSB is transmitted first.

When the Data Count is zero, no Data are transmitted. When it is not zero, the Data corresponding to the value are inserted between CMD2 and Checksum. Thus, the length of the Command Block can vary between 3 and 18 bytes.

The Command Block is shown in figure 17.

MSB LSB

CMD1	Data Count	CMD2	Data1	...	Data N (N = max 15)	Checksum
1 byte		1 byte	1 byte		1 byte	1 byte

Where:

CMD1: Command classification indicating the function and the director of the Data.
Data Count: Number of Data words following CMD2
CMD2: Command to/from the SLAVE
Data 1 to N: Data word content
Checksum: Sum of Data (from CMD1 to Data N)

Figure 17 – Command block format

6.5.3 Transmission format

The Command Blocks described in figure 17 are transmitted from the coder to the decoder byte by byte with start, stop, and parity information originating from the asynchronous interface.

The data for the remote control information is carried in the 384 kbit/s T' channel. The transmission format is similar with the format used for Teletext/Auxiliary data, but shorter message fields are used.

Each frame contains a Synchronization Word and Frame Header plus 24 message fields each comprising a Message Header and Message Data byte. The Message Header contains 3 status bits indicting if the corresponding message contains valid information, followed by 5 error protection bits protecting the data content and the status bits.

The frame structure is shown in figure 18 and described in detail. The length of the frame is 400 bits. In all fields MSB is sent first.

MSB LSB

Sync Word	Frame Header	Message Header 1	Message Data 1	...	Message Header 24	Message Data 24
10 bit	6 bit	8 bit	8 bit		8 bit	8 bit

Figure 18 – Transmission frame structure

The frame is composed of the following information (see figure 18):

1) 10 bit Synchronization word: 010011011x (see note 1)
2) 6 bit frame header: 010000 (specific identifier for remote control)
3) 24 message fields each comprising:
   a) 8 bit for status indications: valid data information: 111
      no data information: 000
   b) 5 bit for error protection: the 3 status bit and the message data are protected by
      an extended Hamming code (16,11) {(15,11) code + even parity} generated with the polonominal $x^4 + x + 1$ +
      even parity bit
   c) 8 bit message data field

The Command Blocks described in 6.5.2 have a length range between 3 and 18 bytes. Immediately after reception of each byte in these blocks, the byte is mapped sequentially into the first available message data field in the T' channel (see note 2).

In order to minimize the system delay, each Command Block is not transmitted as a whole block but is divided into bytes, which are then transmitted in separate message fields. When no Command Blocks are available for transmission, the status indication and the message data bits are set to all zeros (see note 3)

NOTES

1 X alternates between "0" and "1". The beginning of the synchronization word coincides with the start of a new octet in the TV container.

2 The delay in the coder, from reception of a stop bit of a data word at the asynchronous interface until this word has been transmitted at 45 Mbit/s line interface, must be less than 0.2 msec.

3 A short buffer must be incorporated in the decoder in order to secure a continuous transmission of each command block at the asynchronous output interface. However the delay from reception of the word at 45 Mbit/s line interface until the word starts being transmitted at the asynchronous interface must not exceed 0.8 msec.

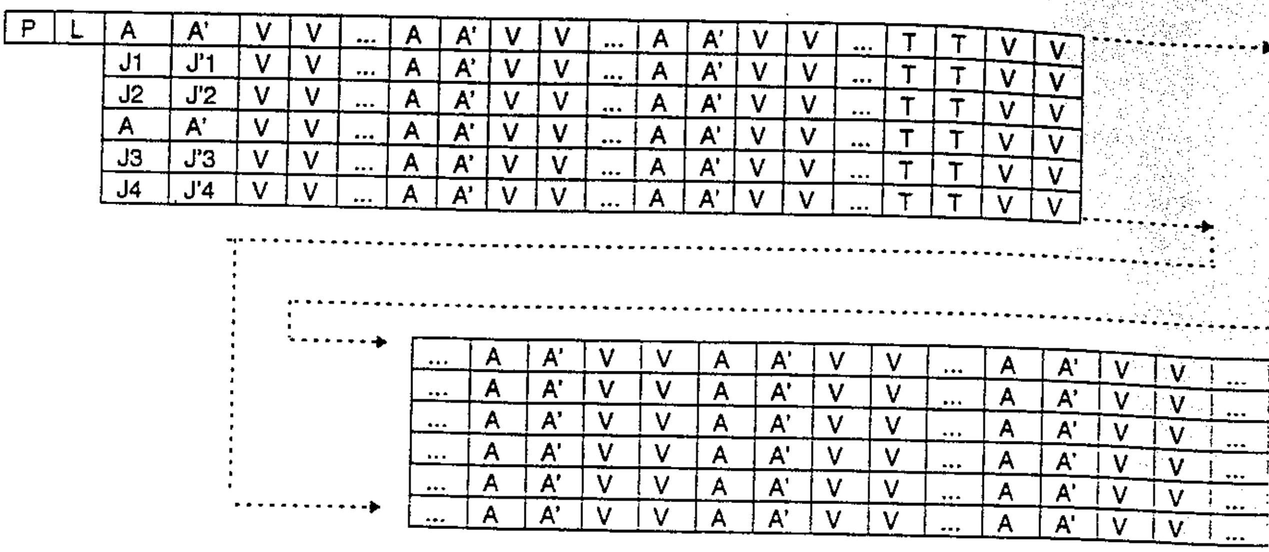

Figure 19 – Container structure (125 μs)

7 Service multiplexing

7.1 Introduction

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

It permits multiplexing of:

a) a video channel;

b) zero, or one or two channels for audio (1,544 kbit/s) (see notes 1, 2, 3 and 7 of 7.2.3);

c) zero, or one 384 kbit/s channels for teletext/vertical interval data applications (see notes 6 and 7 of 7.2.3);

d) a 128 kbit/s channel for testlines (see note 7 of 7.2.3);

e) an 8 kbit/s channel for supervision;

f) two 8 kbit/s channels for conditional access;

g) one 8 kbit/s channel for time codes;

h) zero, or one 384 kbit/s channel for machine control (see notes 6 and 7 of 7.2.3).

The structure is arranged in 6 rows (see figure 19) 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 x 384 kbit/s).

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.

7.2 TV container

7.2.1 General structure

Data are transmitted row after row.

The container defined for 45 Mbit/s (686 octets) is compatible with a SONET STS-1 container, seven SONET VT-6 containers concatenated and fits into the 44,736 kbit/s DS-3 frame as defined in ANSI T1.102 and ANSI T1.107.

7.2.2 Column allocation

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

Columns 18, 34, 66, 83, and 99 at 45 Mbit/s are used to carry channel A at 1,544 kbit/s if column 99 is not used.

Column 50 is used for channel T.

Columns 2, 19, 35, 67, 84, and 100 at 45 Mbits/s are used to carry a second channel A' at 1,544 kbit/s if column 100 is not used. Column 2 is active only when channel A' is active, otherwise it carries video data.

Column 51 is used for a second channel T'.

All other columns (but never column 1), plus columns for A, A', T and T' if not in use, are allocated to video data.

7.2.3 Definitions

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

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

L [l1, l2, l3, ... l8] 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 19). l1 = 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.

L indicates the position of the first two video octets carried at the beginning of the container within the two interleaved error correction blocks (2 x 255 octets). l1= MSB.

L=0 when the first two video octets of the container correspond to the first column of the FEC block, L = 254 for the last column.

A,A' Octets for 1,544 kbit/s channels (synchronous or asynchronous mode, see notes 1, 2, and 3). Channel A is the primary audio.

T,T' Octets for teletext/auxiliary and machine control applications. Channel T is the primary channel for data formatted according to 9.3. T' is the primary channel for machine control data.

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

J_1	aj	vj	ca_1	r	b_0	b_1	b_2	b_3
J_2	aj	vj	ca_2	vitc	b_4	b_5	b_6	b_7
J_3	aj*	vj	s	ltc	b_0	b_1	b_2	b_3
J_4	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

ca_1 Channel for the key management of the conditional access system.

ca_2 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 9.5).

vitc Reserved for transmission of vertical insertion time code.

b_0-b_7 Bits for testline transmission of 128 kbit/s organized in octets (b0 is the MSB).

m_1 Bit sequence defining a multiframe of length 8 (see table 13).

m_2,m_3 & m_4 Channel defining the frame usage in a bit-serial format (see table 13).

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. Positive 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 (pos./neg.) {repeated three times – see note 4}.

r Bits reserved for future applications.

Table 13 – Frame usage

FRAME NUMBER	PARITY	m_1	FRAME USAGE DEFINED BY: m_2	m_3	m_4
0	even	1	"1" if T channel in use	"1" if T' channel in use	Scrambling update flag (see 12.7.3)
1	odd	1	"1" if A channel in use	"1" if A' channel in use	Scrambling operation mode (see 12.7.3)
2	even	1	"1" if A channel is synchronous (see NOTE 2)	"1" if A' channel is synchronous (see NOTE 2)	Scrambling operation mode (see 12.7.3)
3	odd	0	"1" if A channel is 1544 kbit/s (see NOTE 3)	"1" if A' channel is 1544 kbit/s (see NOTE 3)	Reserved
4	even	1	"0" if T channel is formatted as in 9.3 "1" if T channel is used for auxiliary purposes	"0" if T' channel is formatted as in 9.3 "1" if T' channel is used for auxiliary purposes	Reserved
5	odd	0	000 * = Reserved	Reserved	Reserved
6	even	0	001 = single video channel, 45 Mbit/s	Reserved	Reserved
7	odd	0	others reserved	Reserved	Reserved

* Frame 5 carries the MSB

NOTES

1 If channel A or A' is used to transmit 1,544 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 framing bit of the 1,544 kbit/s frame.

3 If both A and A' channels are in use, they must have the same nominal 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 1,687 or 1,688.

Each frame of the transmission multiplex carries a video clock recovery bit, repeated 3 times for error protection, and defined as follows:

"0" if 1,687 clock pulses;

"1" if 1,688 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 ITU-R Recommendation 601-2 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 relative sound and vision delay should be zero ± 2 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 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 1,544 kbit/s and 384 kbit/s channels (i.e., audio, teletext/auxiliary) and to 4 bits for the 128 kbit/s channel (testlines).

The appropriate error protection, which is to be provided by these tributaries, should take due account of these characteristics.

8 Network adaptation of 686 octet containers to 44,736 kbit/s framing structure described in ANSI T1.102 and ANSI T1.107

If the framing structure of ANSI T1.102, ANSI T1.107 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. The structures of one frame (as described in ANSI T1.102 and ANSI T1.107) and the resulting multiframe are shown in figures 20 and 21, respectively.

Payload capacity: 43,904 kbit/s.
Block length: 686 octets.
Multiframe: 699 frames as described in ANSI T1.102 and ANSI T1.107, carrying 595 blocks; the first bit after the 6 'K' bits in the first frame of the multiframe is the first bit of one TV container.

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			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	
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	

Figure 20 – Structure of one frame as described in ANSI T1.102 and ANSI T1.107

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

Structure of the 9,398 kbits/s frame (ANSI T1.102 and ANSI T1.107)

L	(10 bit) ANSI T1.102 and ANSI T1.107 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, 44, 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. The C-Bits (control channel) are application dependent. The relevant applications are mentioned below.
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 ANSI T1.102 and ANSI T1.107.

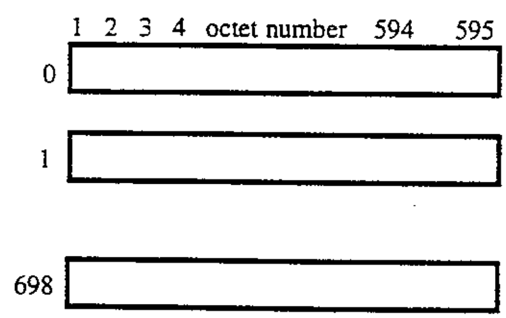

Figure 21 – Structure of the 74,375 ms multiframe

9 Scrambling for conditional access of transmitted data

The use of scrambling is optional but this is the standard method of compliance. Decoders that are optioned for conditional access shall interoperate with encoders that are not optioned for conditional access

9.1 General description of the access control system

Figures 22 and 23 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 program 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.

The main features of the scrambling system are:

1) 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 clause 7.

2) 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. If the A-bytes in column 1 of the TV container are not in use, the A-Bytes in column 1 are not scrambled. In case of 1.5 Mbits/sec in the A-bytes the 2nd A-byte in column 1 is not scrambled, as it is left unused. In case of 1.5 Mbit/s in the A'-bytes the 2nd A'-bytes in column 2 are not scrambled;

3) 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;

4) the length of the cyclic sequence giving the CIW is 65534. CWs are changed at the beginning of each new CIW sequence i.e., every 8.2 sec (125 µs * 65534);

5) the cryptograms are sent in Entitlement Control Messages (ECM) containing 2 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 second period, cryptograms of CWs may be transmitted more frequently. ECMs are sent through the 8 kbit/s channel carried in bit CA1;

6) 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 that is constant and stored in the receiver or a regenerated control word transmitted in the ECM.

When the different program 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.

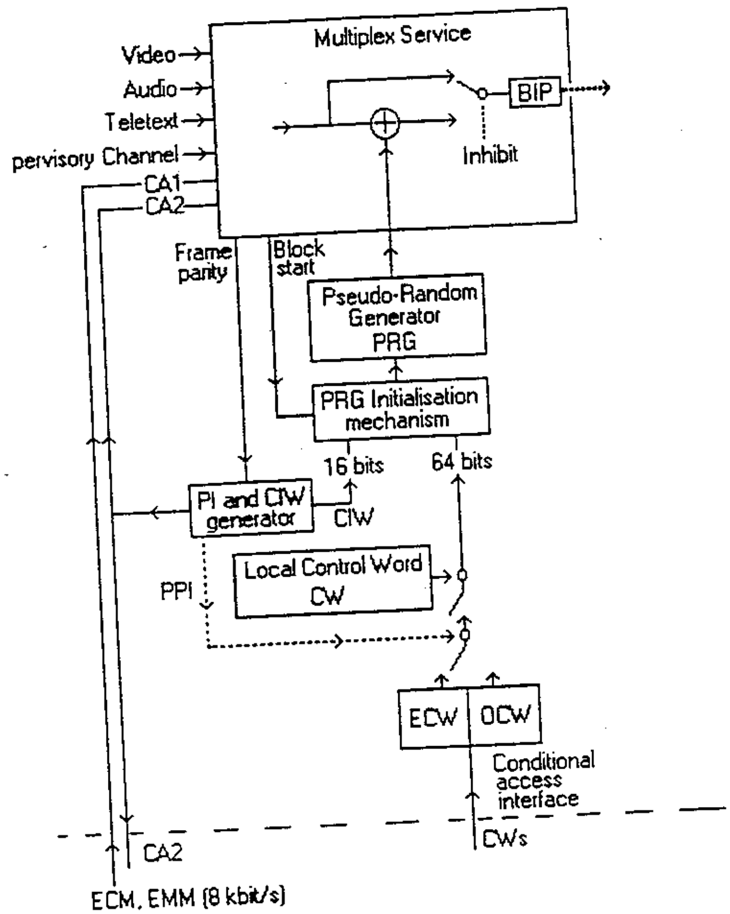

Figure 22 – Scheme of the encoder

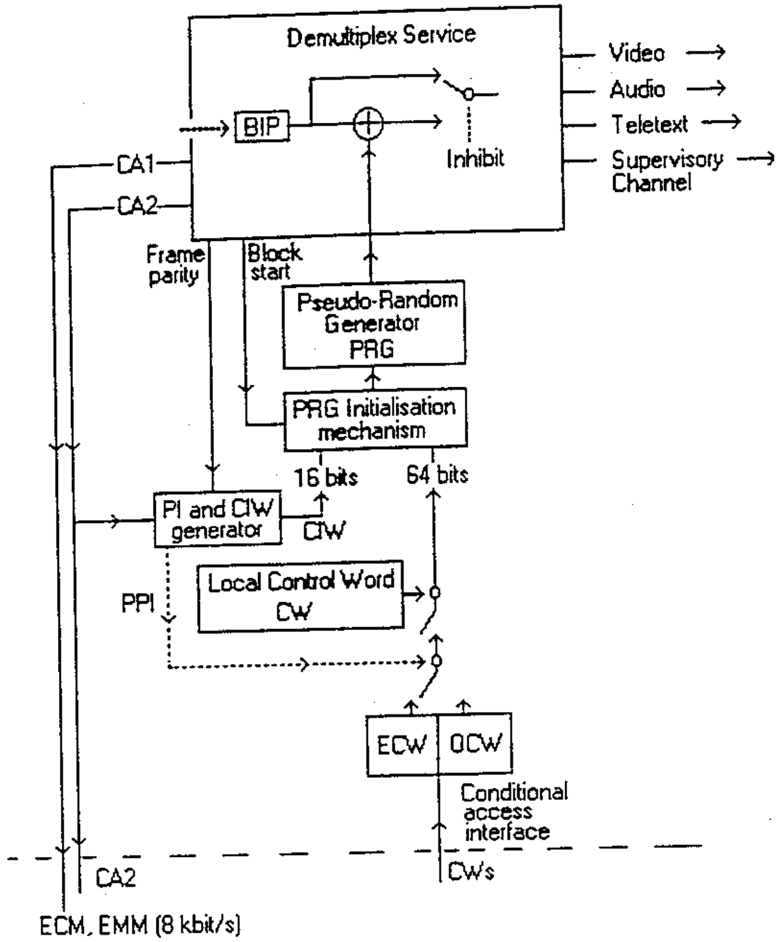

Figure 23 – Scheme of the decoder

9.2 The pseudo-random generator

9.2.1 Introduction

The Pseudo-Random Generator (PRG) described in this standard can be considered as being defined, at each step, by three variables:

a) the internal state: X_n;
b) the input register: I_n;
c) the output register: O_n.

The relations between these variables are:

$O_n = f(X_n)$ and $X_n+1 = g(X_n, I_n)$.

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

Polynomial R $X^7 = X + 15$/ GF(31)
(the order of the roots of R is $(31^7 - 1) / 3$).

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

Polynomial T $X^7 = 2X + 125$/ 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).

9.2.2 Description

The internal state Xn of the PRG is made up of the following registers (see figure 24):

a) 5 registers of 5 bits: Q0, Q1, Q2, Q3, Q4;

b) 7 registers of 5 bits: R0, R1, R2, R3, R4, R5, R6;

c) 5 registers of 7 bits: S0, S1, S2, S3, S4;

d) 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 $I_n = i_7, i_6, i_5, i_4, i_3, i_2, i_1, i_0$ (8 bits) (i_7 is the MSB)

then $QI = i_3, i_2, i_1, i_0, i_7$ (5 bits)

$RI = i_0, i_7, i_6, i_5, i_4$ (5 bits)

$SI = i_6, i_5, i_4, i_3, i_2, i_1, i_0$ (7 bits)

$TI = i_7, i_6, i_5, i_4, i_3, i_2, i_1$ (7 bits)

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

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

$$\text{if } X_n = \begin{cases} Q_0, Q_1, Q_2, Q_3, Q_4 \\ R_0, R_1, R_2, R_3, R_4, R_5, R_6 \\ S_0, S_1, S_2, S_3, S_4 \\ T_0, T_1, T_2, T_3, T_4, T_5, T_6 \end{cases}$$

then

$$X_{n+1} = \begin{cases} Q_1, Q_2, Q_3 (XOR) Q_1, Q_4, (16Q_2 + Q_0) \bmod 31^* \\ R_1, R_2\ (XOR) R_1, R_3, R_4, R_5, R_6, (R_1 + 16R_0) \bmod 31^* \\ S_1, S_2, S_3\ (XOR) S_1, S_4, (2S_2 + 2S_0) \bmod 127^* \\ T_1, T_2\ (XOR) T_1, T_3, T_4, T_5, T_6, (2T_1 + 2(-T_2)) \bmod 127^* \end{cases}$$

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:

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)

$o(0) = [S_3(2).T_5(0) + Q_1(0).\overline{T_5(0)}]\ (XOR)\ [T_3(2).Q_3(1) + R_3(1).\overline{Q_3(1)}]$

$o(1) = [S_3(3).T_5(1) + Q_1(1).\overline{T_5(1)}]\ (XOR)\ [T_3(3).Q_3(2) + R_3(2).\overline{Q_3(2)}]$

$o(2) = [S_3(4).T_5(2) + Q_1(2).\overline{T_5(2)}]\ (XOR)\ [T_3(4).Q_3(3) + R_3(3).\overline{Q_3(3)}]$

$o(3) = [S_3(5).T_5(3) + Q_1(3).\overline{T_5(3)}]\ (XOR)\ [T_3(5).Q_3(4) + R_3(4).\overline{Q_3(4)}]$

$o(4) = [Q_2(1).R_5(0) + S_2(3).\overline{R_5(0)}]\ (XOR)\ [R_1(1).S_1(0) + T_1(3).\overline{S_1(0)}]$

$o(5) = [Q_2(2).R_5(1) + S_2(4).\overline{R_5(1)}]\ (XOR)\ [R_1(2).S_1(1) + T_1(4).\overline{S_1(1)}]$

$o(6) = [Q_2(3).R_5(2) + S_2(5).\overline{R_5(2)}]\ (XOR)\ [R_1(3).S_1(2) + T_1(5).\overline{S_1(2)}]$

$o(7) = [Q_2(4).R_5(3) + S_2(6).\overline{R_5(3)}]\ (XOR)\ [R_1(4).S_1(3) + T_1(6).\overline{S_1(3)}]$

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.

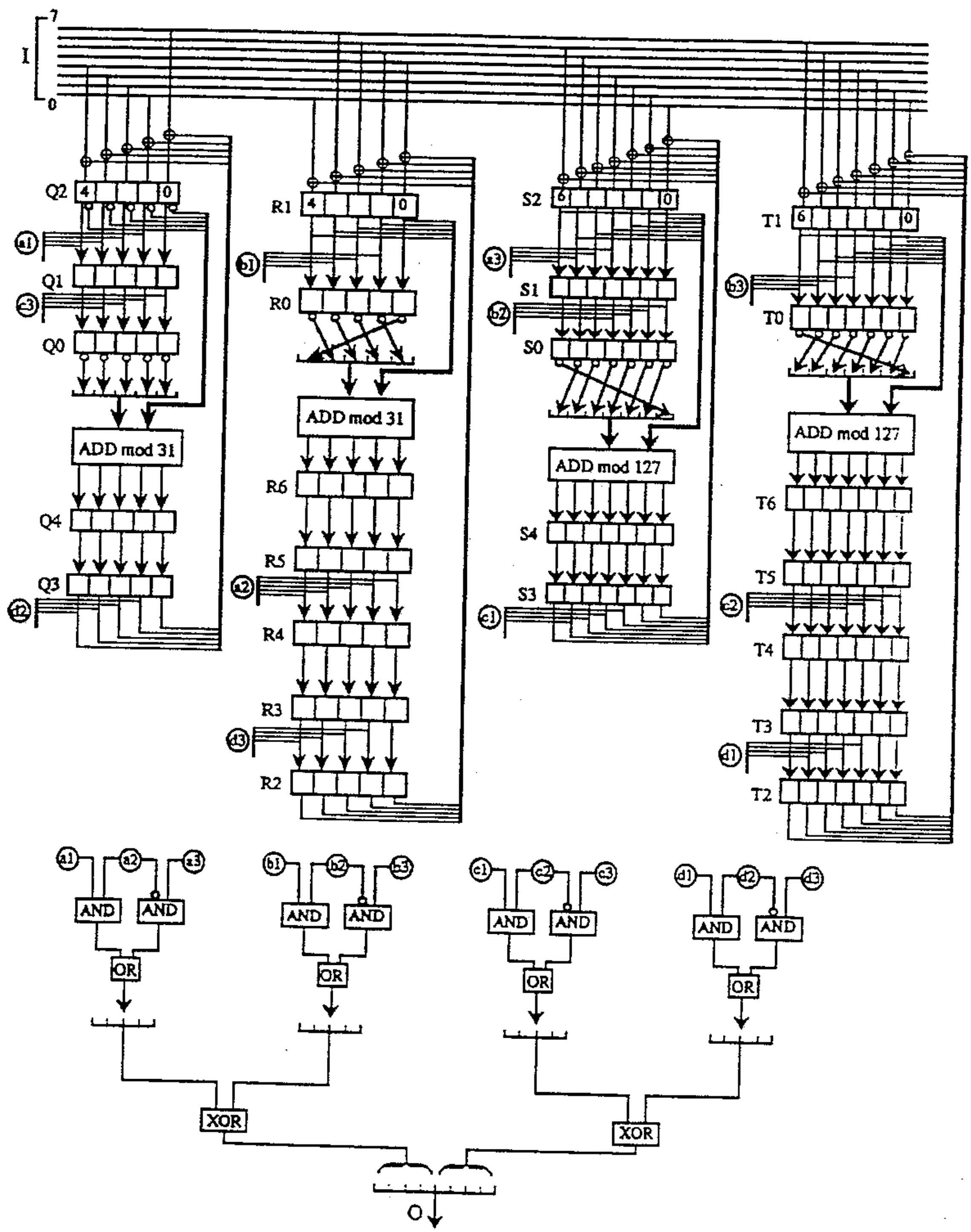

Figure 24 – Pseudo-random generator

9.3 PRG initialization parameters

9.3.1 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 25.

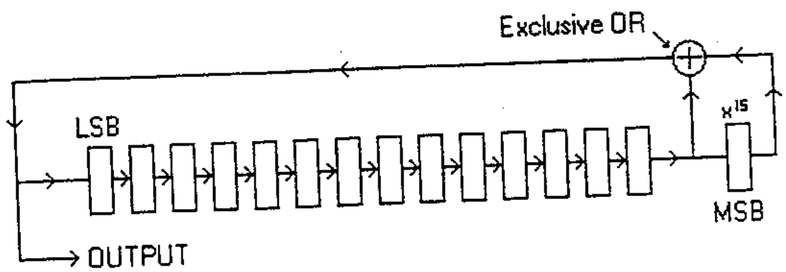

Figure 25 – Shift register

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 CIW is constructed using:

a) the contents of the shift register (15 MSBs of CIW);

b) the parity of the current frame (LSB of CIW) ("0" for even frames, "1" for odd frames).

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

The CIW defines blocks of 8.2 seconds that 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 26.

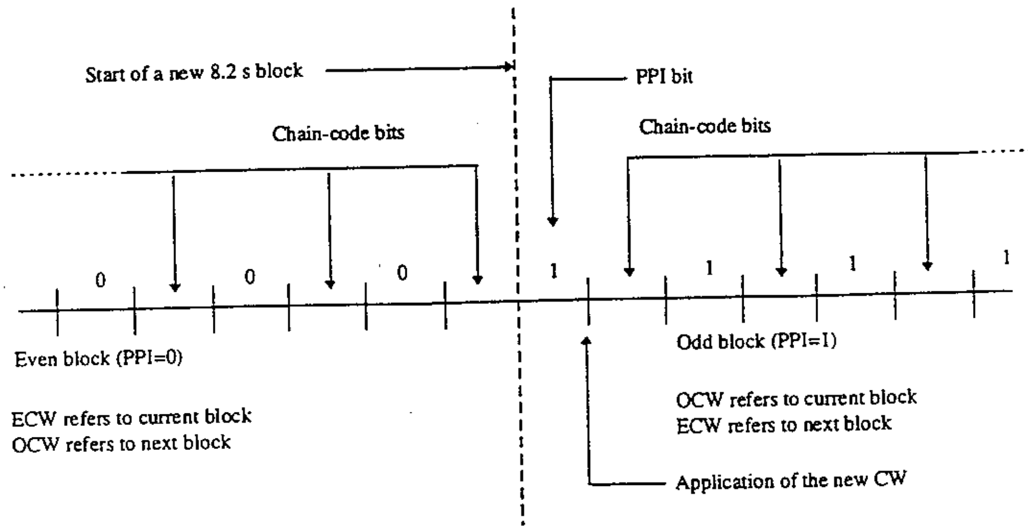

Figure 26 – Block-change mechanism

9.3.2 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.

9.3.3 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:

a) every 125 µs (at each container), corresponding to a CIW change;

b) every 8.2 second (every 65,534 containers), corresponding to a CW change.

Two CWs are used, one each for odd 8.2 second blocks (OCW), and for even 8.2 second 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:

a) the CIW;
b) OCW and ECW;
c) the Phase Parity Identifier (PPI) to define the parity of the 8.2 second 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.

9.4 Performance of the PRG

9.4.1 Periodicity of sequences

The PRG can produce ($2^{16} * 2^{64}$) distinct sequences of octets because of its initialization method. The highest periodicity of these sequences can be deducted from the behavior 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 that have a periodicity equal to the least common multiple of Tq, Tr, Ts, and Tt:

LCM (Tq, Tr, Ts, Tt) = $1.36 * 10^{37}$.

9.4.2 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, we say that we have a single degeneration. If all the groups of registers are degenerated, we call it a fourfold (or complete) degeneration.

Among the 225 possible states of the registers Q0 to Q4 after the initialization process, the following can be referenced:

- 25 states with the registers loaded with 0 or 31;
- 325 – 25 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: $2^5 * 2^7 * 2^5 * 2^7 = 2^{24}$;
- number of states leading to a threefold degeneration: around 2^{66}

  $(2^5 * 2^7 * 2^5 * (128^7 - 128) + 2^5 * 2^7 * (128^5 - 128) * 2^7 + 2^5 * (32^7 - 32) * 2^5 * 2^7 + (32^5 - 32) * 2^7 * 2^5 * 2^7)$;

- 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 $2^{144} - 2^{124}$.

9.5 Generating scrambling sequences with the PRG

Figure 27 describes how the PRG is initialized before scrambling a container. This initialization requires 13 cycles.

For each session, the PRG works as follows:

a) reset the internal state of the PRG ... $X_0 = 0$;

b) 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;

c) 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.

9.6 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 9.7. The ACS itself, which embodies (amongst other things) the way of producing the Control Words (CWs), is not defined in this standard. Informative annex B contains additional information as an example.

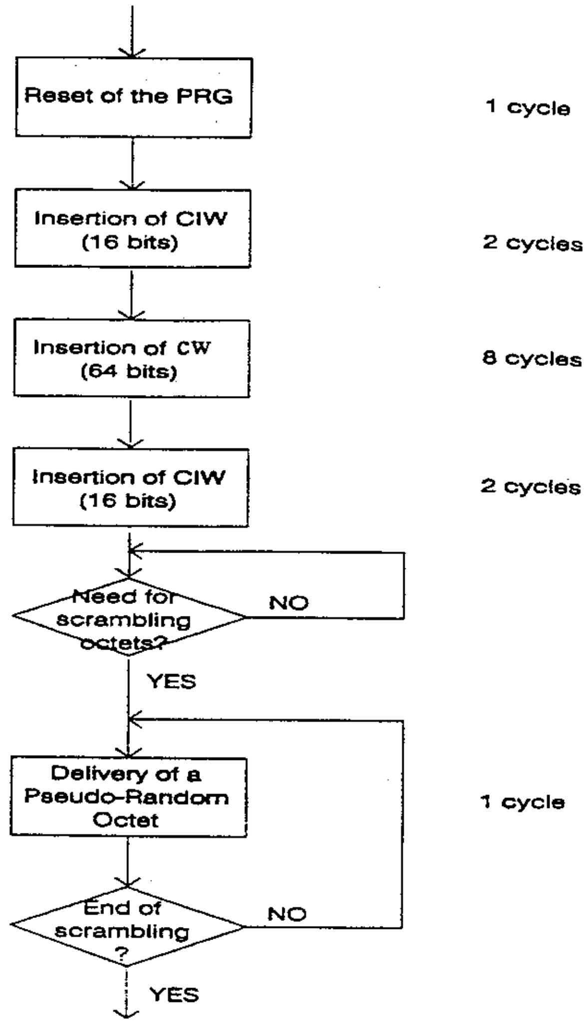

Figure 27 – PRG initialization

9.7 Interface between codec and access control system

9.7.1 Interface signals

The interface comprises the following signals:

transmitted data (encoder only): Sends ACS data to the encoder for insertion in the CA1 channel of the multiplex;

received data (decoder only): Sends to the ACS the data extracted by the decoder from the CA1 channel;

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;

clock: An 8 kbit/s reference at container repetition rate 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 because the transmission delay between the encoder/decoder and the ACS is not critical.

9.7.2 Electrical and physical interface

This interface derives from ITU-T Recommendation V.24. [The electrical interface should conform to ITU-T Recommendation V.28.] The connector is the 25-pin connector specified in ISO 2110. 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

9.7.3 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 indicates also 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 table 14.

Table 14 – Modes of operation

m4 in frame 1	m4 in frame 2	Mode
0	0	0
0	1	1
1	2	2
1	1	3

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

Between 0.5 second and 1 second before the end of the current block, bit m_4 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 second after the beginning of the new block, bit m_4 in frame 0 should be reset to "0".

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

9.7.4 Format of the CWs and configuration messages

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

1) a start flag;
2) an address octet, identifying the type of packet transmitted. Possible values are:
   a) "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;
   b) "01" - for packets carrying odd control word OCW;
   c) "02" - for packets carrying even control word ECW;
   d) "03" - for packets carrying both even and odd control words;
   e) "04" - for packets transmitting a temporary alternative local control word;
   f) "05" - for packets loading a new internal local control word;
   g) "06" - for packets corresponding to "no CW available" (i.e., the access to the corresponding component is not authorized);
   h) "07" - for packets identifying unscrambled components;

NOTE – Other packet types are reserved for future use.

3) a control octet with:
   a) bits 0 to 5: Indication of the multiplex components concerned with the current packet:
      i) bit 0 - set to "1" if T component is concerned;
      ii) bit 1 - set to "1" if A component is concerned;
      iii) bit 2 - set to "1" if T' component is concerned;
      iv) bit 3 - set to "1" if A' component is concerned;
      v) bit 4 - set to "1" if V component is concerned;
      vi) bit 5 - reserved for future use;

NOTE – 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.

   b) bits 6 and 7: continuity index of messages sent with a given address (not incremented if the same message is repeated);
4) the configuration message, which consists of:
   a) 0 octets if the address octet = "06" or "07";
   b) 1 octet containing the mode number if the address octet = "00" (b0 = LSB of mode, b1 = MSB of mode, b2 to b7 are reserved);
   c) 8 octets for a new local control word;
   d) 8 octets if ECW or OCW are transmitted separately;
   e) 16 octets if ECW and OCW are transmitted together (ECW first);
   f) 2 CRC octets, as specified by the HDLC format;
5) 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").

Annex A
(informative)

Recommended features

A.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 by this specification 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 recommended by the ITU-R (see ITU-R Report 1206), 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 that 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.

A.2 Mode choice

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 (see 4.3.1).

A.3 Refresh strategy

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 (see 4.3.1).

A.4 Motion estimation

If motion estimation is used, then the full range and accuracy allowed by this standard is recommended (see 4.3.4).

A.5 Truncation or rounding of coefficients

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 (see 4.4).

A.6 Buffer regulation

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 (see 4.4).

Depending on the implementation of the encoder, the stripes may be processed at different speeds with possible influences on the exact signification of the BOF 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 5 000 bits.

A.7 Criticality

The codec should take full advantage of the criticality parameter defined in this standard (see 4.4).

A.8 Error concealment

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 rates (see 4.6.1 and 4.6.2).

Annex B
(informative)

Access control management

B.1 Introduction

Decoders with access control need a security module called the Access Control System (ACS) which is connected to the rest of the decoder via a decoder-ACS interface.

The Control Word (CW) is sent, encrypted by a session key, in Entitlement Checking Messages (ECM). Data relevant to the conditional access mode are also present in the ECM. The content of the ECM is protected against falsification by a signing procedure. The Session Key (SK) is secret information stored in the ACS security module. If the authorization parameters (called "entitlements") received by the decoder are accepted by the ACS, the session key can be used to decrypt the CW.

The entitlements are updated periodically. The session key is common to all users and can be changed under exceptional circumstances. Both entitlements and session keys may be sent to the users using over-addressing methods in Entitlement Management Messages (EMM). The session keys are sent encrypted with a Distribution Key (DK) specific to the program supplier. The content of the EMM is protected using a signing procedure as for the ECM.

The ECM and EMM messages are sent in the data multiplex. The entitlement management messages are, in most cases, addressed to individual customers (EMM-U), common to specific groups of customers (EMM-S) or even to the entire audience (EMM-C). They are then identified by a customer address that is a unique address for a message to a particular customer or a shared address for a message to a group of customers. In this case, only those EMM packets that have a correct customer address (unique, shared, or collective) cross the decoder-ACS interface. The result of this is that the ACS submits its customer addresses to the decoder's EMM receiving circuit before selection can be implemented.

B.2 Message format

Figure B.1 illustrates the transmission format for ECM and EMM:

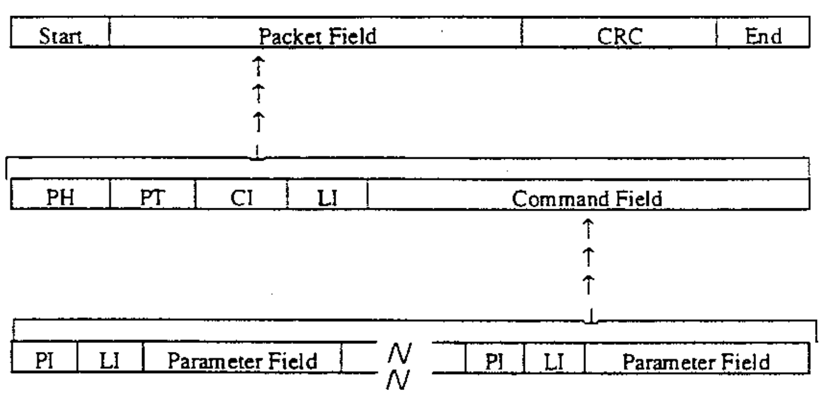

Figure B.1 – ECM format

ECM and EMM are inserted in a transport layer defining the strategy for error transmission. The first two fields, PH and PT, are common to all packets. The Packet Header (PH) contains a field identifying the component concerned with this packet and a 2-bit continuity Index (I) associating packets to the same message. The first packet of a message always has a zero continuity index (I=0), while the subsequent packets have continuity index values in the range [1,3], the value of I being incremented by 1 in modulo 3 sequence each time a packet belonging to the same message is sent (see figure B.2). This index is useful if the size of packets is limited by the transport level.

MSB	Component Indentifying Field (6)	I (2)	LSB

Figure B.2 – Packet Header (PH)

The Component Identifying Field (CIF) is a bit-field, each bit being associated with a component to indicate if the following message concerns this component.

The "Packet Type" (PT) field takes the value 00 hex for ECM packets and the values XX hex, XX hex, XX hex, for EMM-U, EMM-S and EMM-C. After the PT field, packets contain a message field.

Messages are structured as commands. The beginning of each message is introduced by a 1-octet Command Identifier (CI).

This is followed by a Command Length Indicator (CLI) (1 octet) specifying the length of the ECM message parameter field (from 0 to 255 octets). Within the message parameter field of the command, each parameter comprises:

a) a Parameter Identifier (PI) (1 octet);

b) a parameter Length Indicator (LI) (1 octet) specifying the length of the data field associated with the parameter;

c) the parameter data field.

The parameters can be combined into a Group Parameter (PG). The length of the group parameter field is also specified by a group Parameter Length Identifier (PLI), (1 octet).

Within a command field, the codes associated with the PG and with isolated PI parameters (not combined within a PG) must be transmitted in ascending order. Similarly, PI parameters that fall within a PG are also transmitted in ascending order.

All messages containing an unrecognized CI field will be ignored. Unrecognized PI fields will be ignored (as will the associated data field), but this will not cause the entire message to be rejected.

The parameter data fields contain an integer number of octets. The most significant octet is the octet containing the Most Significant Bit (MSB). The least significant octet is the octet containing the Least Significant Bit (LSB). The octets of a parameter data field are transmitted most significant octet first and least significant octet last.

All message octets from and including the CI code are transmitted least significant bit first and most significant bit last.

NOTES

PH Packet Header: this contains the continuity index I (2 bits) and the field describing the data channels concerned with access control messages;

PT Packet Type (2 bits);

CI Command Identifier (8 bits): this specifies the format of the parameter field and the type of crypto-algorithm;

CLI Length Indicator for the data field associated with CI (8 bits);

PI Parameter Identifier (8 bits);

LI Length Indicator for the data field associated with PI (8 bits).

B.3 Control words transfer using ECM

In B.3.2, the length and contents defined for the parameter field correspond to the particular implementation given as an example. For other implementations, the length of the defined parameter fields may be extended or shortened provided those parts of the data field currently specified continue to be used. Further parameters may also be introduced provided that they comply with the following rules:

a) the PPID parameter must be present in all ECM;

b) the HASH parameter must be present in all ECM.

The cryptogram SK(CW) is sent in an Entitlement Control Message (ECM), which is transmitted in the signaling component (J octets of the multiplex). The message also contains data concerning the administration of the control word.

B.3.1 Description of Entitlement Control Messages (ECM)

B.3.1.1 Command Identifier (CI)

The CI identifier comprises 8 bits. It describes the format being used for the parameter field and the type of cryptographic algorithm used for decryption. It is included in all ECM messages and is located in the message synchronizing packet.

It contains (see figure B.3):

a) T (1 bit) is the toggle bit. This is maintained in the same state as long as the OCW/ECW pair of the ECM message remains unchanged. When the contents of the ECM control words change, the toggle bit changes state. The toggle bit is attached to a given crypto-algorithm type; therefore if ECMs corresponding to two different types of crypto-algorithm are sent, the corresponding toggle bits are kept separate;

b) F is the format bit indicating that the following parameter field is either in fixed format without PI LI structure, (F=0), or in variable format with PI LI structure, (F=1). ECMs are in variable format;

c) type of crypto-algorithm (6 bits).

B.3.1.2 Command Length Indicator (CLI)

MSB	Type of crypto-algorithm (6)	F (2)	T (2)	LSB

Figure B.3 – Command Identifier (CI)

The CLI parameter comprises 8 bits. It indicates the number of octets in the ECM message parameter field. It is always included in an ECM message and follows the CI parameter.

B.3.1.3 Parameter Identifier (PI)

The ECM messages convey all the information specifying the conditions of access to a program. The same program can thus be received by customers assigned different entitlements.

Control words are generated by the transmission point and sent encrypted in the ECM messages.

All the parameters listed below are optional within a given ECM message; only those parameters needed to describe the conditions of access to the program are included.

B.3.1.4 List of parameters available in ECM messages

The list below describes the PI parameters available (values expressed in hexadecimal notation):

PI = 90 hex	Program Provider Identifier (PPID) representing the operator generating the ECM. This is used to point to the operation (or management) key of the program provider.
PI = E1 hex	Broadcast Date (CDATE) + program theme/level (THEME/LEVEL); included when the broadcast program is accessible in subscription per theme/level.
PI = E2 hex	Broadcast Date (CDATE) + program class (LINK); included when the program is accessible in subscription per link.
PI = E3 hex	Program Number (PNUMB); included when the program is accessible in pre-booked pay-per-view per program.
PI = E4 hex	Program Number (PNUMB) and program cost (PPV/P); included when the program is accessible in impulse pay-per-view per program.
PI = E5 hex	Program Number (PNUMB) and cost per time unit of the program (PP/T); included when the program is accessible in impulse pay-per-view per time.
PI = E8 hex	Even Control Word cryptogram (ECW); this is used, in conjunction with OCW, in the phase preceding change of key or access criteria. In this case, a PG parameter is also required.
PI = E9 hex	Odd Control Word cryptogram (OCW).
PI = EA hex	Odd and Even Control Word cryptograms (ECW/OCW).
PI = F0 hex	Signature (HASH); guarantees the integrity of all sensitive, clear, or encrypted data contained in the ECM parameter field. The ECM cannot be analyzed and executed by the security processor unless it finds a match between the transmitted signature and the internally generated result of its own message signature computation. It therefore entails a cryptographic redundancy of the sensitive parameters of the ECM, which ensures that no component of the message has been modified.

The PG parameter, encoded 80 hex, is used when several signatures are required in an ECM message. It frames the parameters concerned. It is used, in particular, when the access configuration is changed in controlled access mode. This occurs if the program is accessible under certain access conditions during period T (about 8.2 s) and under different conditions during period T+1.

This list of parameters allows five access control modes:

a) subscription per level and theme with a validity period. The subscription is valid between two dates. The subscription is also characterized by a level, specifying the highest level of services that can be accessed by a customer (each service has a level reference) and a theme specifying the theme of the services that can be accessed (each service also has a theme reference);

b) subscription per link, in which users have access to the service during a period defined by a starting date and an ending date. The subscription is also characterized by a list of classes of services; for each class, the list indicates whether the user is authorized or not (the service is referenced by a class);

c) "pre-booked pay-per-view", in which users have access to one or more service items or set of services defined by an initial service number and by a total number of services (set length);

d) "pay-per-view per service", in which users get a credit. This credit is debited for the cost of the service when it is accessed. Each service is referenced by its service number and its cost. This method is efficient for impulse pay-per-view; it allows a feed-back on the actual service bought by users;

e) "pay-per-view per time", in which users get a credit. This credit is debited on a time basis. Each service is referenced by its service number and its cost. This mode allows a feedback on the actual service bought by the users.

B.3.1.5 Program Provider Identifier (PPID)

PI	=	90 hex.
LI	=	03 hex.
value	=	program provider identifier (see figure B.4).
name	=	PPID.

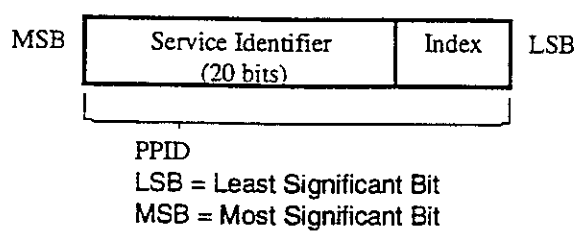

Figure B.4 – Program Provider Identifier (PPID)

This parameter identifies the program provider generating the ECM. This parameter must be included in the ECM message and points to the key used to encrypt the control words and sign the message. The Least Significant Bits (LSBs) of PPID specify the index of the key. This index is used to modify the value of a key and to distinguish the key in current use from the future key to be used. This index can also be used to define two keys for each program provider (an operation key reserved for computing control words and a management key for entering entitlements as well as computing control words). The MSB of the index is used to distinguish a management key from an operation key.

B.3.1.6 Broadcast date CDATE + Theme/Level THEME/LEVEL

PI	=	E1 hex.
LI	=	04 hex.
value	=	broadcast date + theme + level.
name	=	DATE + THEME/LEVEL.

This parameter is included when a program is accessible in subscription per theme/level. The first field, CDATE, describes the current date of transmission of the program covered by subscription. This date is expressed in the form year/month/day. The date is described on two octets; its contents are illustrated in figure B.5.

MSB	Year (7)	Month (4)	Day (5)	LSB

CDATE

00 hex ≤ Year ≤ 7F hex.
01 hex ≤ Month ≤ 0C hex.
01 hex ≤ Day ≤ 1F hex.

Figure B.5 – CDATE parameter

This date is relative to the reference year 1980. For example, January 15, 1988 is encoded (in hexadecimal notation):

CDATE	=	102F hex.
Year	=	0001000 (1980 + 8).
Month	=	0001 (January = month No. 1).
Day	=	01111 (15).

The security processor checks that the current date CDATE falls within one of the validity ranges for the subscription entitlements stored.

The second field comprises 16 bits. The eight most significant bits specify the theme of the program. The eight least significant bits specify the level of the program. The security processor checks that, for the current date, it has a subscription with the same theme and a level LE greater than or equal to the level of the program. If this is not the case, access is barred.

The conditions for accessing a program in subscription per theme/level are therefore:
THEME=TH and LEVEL ≤ LE with TH and LE mandatory valid on the current date, therefore BD ≤ CDATE ≤ FD.

There are a number of special cases associated with the theme:

a) if THEME = FF hex (in the ECM message) the security processor disregards this field and, no matter what the TH value entered in the component, the check on this field will be positive;

b) if TH = FF hex (entitlement entered in the security processor), no matter what the THEME parameter transmitted in the ECM message, this field will be disregarded and the verification will be positive.

The Theme/Level parameter is described in figure B.6:

MSB	CDATE (16)	THEME (8)	LEVEL (8)	LSB

Figure B.6 – CDATE + THEME/LEVEL parameter

B.3.1.7 Broadcast date CDATE + Program class LINK

PI	=	E2 hex.
LI	=	03 hex.
value	=	broadcast date + program class.
name	=	CDATE + LINK.

This parameter is included when a program is accessible in subscription per link. The first field, CDATE, is as described in B.3.1.6. The second parameter field, LINK (8 bits), specifies the class of the program and points to a bit in the list of customer classes (CUSTWD) sent in the EMM messages (see B.1). Each of the bits in the list of classes indicates whether the customer is entitled (bit at 1) or not (bit at 0) to the class concerned. The LINK value specifies the location of the bit in the list of classes; for example, LINK = 0 refers to bit 0, LINK = 1 refers to bit 1, etc. If the LINK value is greater than the CUSTWD length, access is completely barred. Access will be authorized only if the validity period which covers CUSTWD includes CDATE and the bit corresponding to LINK is set to 1 (see figure B.7).

MSB	CDATE (16)	LINK (8)	LSB

Figure B.7 – Program class parameter CDATE + LINK

B.3.1.8 Program Number (PNUMB)

PI	=	E3 hex.
LI	=	03 hex.
value	=	program number.
name	=	PNUMB.

This parameter is included when a program is accessible in pre-booked pay-per-view. It describes the program number PNUMB (3 octets).

In pre-booked pay-per-view mode, access to the program is allowed only if the program number is one of the series of programs stored in the security processor, as follows:

$$INUMB \leq PNUMB \leq FNUMB.$$

The format of this parameter is given in figure B.8.

MSB	Program Number (24) PNUMB	LSB

Figure B.8 – PNUMB parameter

B.3.1.9 Program Number (PNUMB) and Program cost (PPV/P)

PI	=	E4 hex.
LI	=	05 hex.
value	=	program number + program cost.
name	=	PNUMB + PPV/P.

This parameter is included when a program is accessible in impulse pay-per-view per program.

It describes the program number PNUMB (3 octets) and the cost of the program PPV/P (2 octets).

In impulse pay-per-view per program, if the program has not already been purchased, it will not be accessible unless the cost of the program is less than or equal to the remaining credit plus the authorized overdraft. Next, the program number is entered into the security processor and the remaining credit is reduced by the cost of the program. If the program has already been acquired, the program can be accessed.

The structure of this parameter is illustrated in figure B.9.

B.3.1.10 Program Number (PNUMB) + Cost per time unit PPV/T

MSB	Program Number (24) PNUMB	Program Cost (16) PPV/P	LSB

Figure B.9 – PNUMB + PPV/P parameter

PI	=	E5 hex.
LI	=	05 hex.
value	=	program number + cost per time unit.
name	=	PNUMB + PPV/T.

This parameter is included when a program is accessible in impulse per-pay-view per time. It describes the program number PNUMB (3 octets) and the cost per time unit PPV/T (2 octets). The 16 bits of PPV/T (see figure B.10) represent the cost of computing control words, expressed in fractions of units.

In pay-per-view per time, access is granted for a given period provided the remaining credit plus the authorized overdraft is greater than or equal to the total cost of the time unit. The remaining credit is then reduced by this cost.

The customer is asked to confirm purchase in order to open any new counter (new PNUMB) or when the counter value exceeds a maximum cost, COUTMAX, locally defined and stored by the customer. In addition, the PIN code will be needed if the impulse pay-per-view lock is set. The customer can stop a purchase in PPV/T mode at any time.

MSB	Program Number (24) PNUMB	Cost per time unit (16) PPV/T	LSB

Figure B.10 – Cost per time unit parameter PNUMB + PPV/T

B.3.1.11 Even Control Word cryptogram (ECW)

PI = E8 hex.
LI = 08 hex.
value = even control word cryptogram.
name = ECW.

This parameter describes the cryptogram of the even control word ECW (see figure B.11) which is in use when the PPI is set to 0. The control word cryptogram is obtained from the encryption of the control word by the operation key indicated by PPID.

It can be used (in conjunction with OCW) in place of ECW/OCW where there is a change of access conditions from one phase to another (change of PPID, program number, etc.). In this case, a group parameter PG is also needed.

MSB	ECW (64)	LSB

Figure B.11 – Even Control Word cryptogram (ECW)

B.3.1.12 Odd Control Word cryptogram (OCW)

PI = E9 hex.
LI = 08 hex.
value = odd control word cryptogram.
name = OCW.

This parameter describes the cryptogram of the Odd Control Word (OCW) (see figure B.12) which is in use when the PPI is set to 1. The control word cryptogram is obtained from the encryption of the control word by the operation key indicated by PPID.

It can be used (in conjunction with ECW) in place of ECW/OCW when there is a change of access conditions from one phase to another. In this case, a group parameter PG is also needed.

B.3.1.13 Even and Odd Control Word cryptograms (ECW/OCW)

MSB	OCW (64)	LSB

Figure B.12 – Odd Control Word cryptogram (OCW)

PI	=	EA hex.
LI	=	10 hex.
value	=	odd and even control word cryptograms.
name	=	ECW/OCW.

This parameter is composed of two fields containing the cryptograms for two control words (see figure B.13). The first field contains the cryptogram of the control word in use when the PPI set to 0 (ECW). The second field contains the cryptogram of the control in use when the PPI is set to 1 (OCW). The cryptograms are obtained from the encryption of the control words by the service key indicated by PPID.

The cryptograms are 8 octets long.

B.3.1.14 HASH signature

MSB	ECW (64)	OCW (64)	LSB

Figure B.13 – Even and Odd Control Word cryptograms (ECW/OCW)

PI	=	F0 hex.
LI	=	08 hex.
value	=	signature of sensitive parameters in the ECM message.
name	=	HASH.

The presence of this parameter is mandatory in ECM messages (see figure B.14). It gives the signature of the sensitive parameters of the message and assures the security processor that the message has not been modified.

The signature mechanism uses the service key indicated by PPID.

The parameters involved in the signature mechanism are the PI parameters such that D8 hex $\leq$ PI $\leq$ EA hex.

MSB	HASH (64)	LSB

Figure B.14 – Signature parameter

B.3.2 Description of ECM messages with examples

B.3.2.1 Subscription per theme/level

Examples below take no account of PH and PT octets for the estimation of the ECM size because they depend on the needs of the transport layer.

The ECM messages contain:

the program provider identifier:	PPID;
the current date + theme/level of the program:	CDATE + THEME/LEVEL;
the control word cryptograms:	ECW/OCW;
the message signature:	HASH.

The ECM message is 43 octets long. The structure of the ECM message is illustrated in figure B.15.

PH PT	CI 27	PI 03 PPID	PI 04 CDATE + THEME/LEVEL	P1 10 ECW/OCW	P1 08 HASH
8 8	8 8	8 8 24	8 8 32	8 8 128	8 8 64

Length of ECM message = 43 octets   Underlined numbers are in hexadecimal

Figure B.15 – ECM message for subscription per theme/level

B.3.2.2 Impulse pay-per-view per program

The ECM message contains:

the program provider identifier:	PPID;
the program number and program cost:	PNUMB + PPV/P;
the control word cryptograms:	ECW/OCW;
the message signature:	HASH.

The length of the ECM is 44 octets. Its structure is described in figure B.16.

PH PT	CI 28	PI 03 PPID	PI 05 PNUMB + PPV/P	P1 10 ECW/OCW	P1 08 HASH
8 8	8 8	8 8 24	8 8 40	8 8 128	8 8 64

Length of ECM message = 44 octets   Underlined numbers are in hexadecimal

Figure B.16 – ECM message for impulse pay-per-view per program

Annex C
(informative)

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