AVC-160

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ORGANISATION INTERNATIONALE DE NORMALISATION
ISO/IEC JTC1/SC2/WG11
CODING OF MOVING PICTURES AND ASSOCIATED AUDIO

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SOURCE : Olivier PONCIN (RTT)
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TITLE : Algorithm description (proposal # 30)
PURPOSE : Information
SUBGROUP : Video

1. INTRODUCTION

This document describes the algorithm we propose for the Kurihama tests. This proposal is submitted by PONCIN Olivier (RTT Belgium), DELOGNE Paul (UCL) and has been developed in the framework of the European VADIS/COST collaboration.

Its preregistration number is 30.

Annexes contain statistics.

2. PICTURE FORMAT

The picture format throughout this coding method is the 625-line version of the 4:2:2 level of CCIR Rec 601-2. No pre or post processing is performed. The whole format is coded.

3. GENERAL CODEC OUTLINE

This scheme is based on hybrid DCT coding with motion compensation based on the previous picture. It is the first layer of a compatible coding scheme we are designing for SDTV/HDTV.

The first step of this scheme consists of merging the two fields of each frame to compose a pseudo-progressive frame. The core of the algorithm is applied to this "progressive" frame. So, the core of this algorithm is suitable for coding pictures of both input formats (interlaced or progressive).

Each frame is divided into 72 slices (collecting 8 video frame lines).

Each slice is divided into 45 MacroBlocks (MB) (collecting 2 luminance blocks and 2 chrominance blocks).

Motion estimation/compensation is performed only on the previous frame.No interpolation technique is applied; this allows to reduce processing delay, hardware complexity and memory cost.

Each block (inter or intra) is transformed using DCT, quantized using an adaptive quantizer and coded using what we call the U-VLC (for *"Universal Variable Length Coder"*). Due to its self-adaptability property, the U-VLC allows to code efficiently all kinds of pictures in a wide range of quality levels.

4. LAYERED STRUCTURE OF VIDEO DATA

1- BLOCK layer

A block consists of an array of 8 pixels x 8 lines of either luminance or one of the colour difference signals. The scan sequence is from left to right and then from top to bottom. Each block is frame based. Transformation and quantization is performed at the block level.

2- MACROBLOCK layer

A macroblock consists of 2 luminance blocks (16 pixels x 8 lines) and the co-sited single 8x8 CB block and single 8x8 CR block. The scan sequence is Y0, Y1, CB, CR. Determination of MB type (inter or intra) is done on the MB level. Motion estimation/compensation is also performed at the MB level.

3- SLICE layer

A slice consists of a row of 45 MB across the complete width of the picture frame (720 pixels x 8 lines). Variable Length Coding is performed at the slice level. Adjustment of quantization (buffer regulation) is done on the slice level.

4- PICTURE layer

A picture consists of 72 slices (720 pixels x 576 lines).

5- GROUP OF PICTURE (GOP) layer

A GOP consists of 10 pictures. The first is intra coded; the 9 following ones may be predicted from the previous one. So it is possible to retrieve pictures from the stream of data with the time resolution of one GOP and it also assures a total refresh of data every GOP to prevent errors from spreading.

5. MOTION ESTIMATION AND COMPENSATION

Motion compensated prediction technique is used to exploit temporal redundancy. No "interpolation technique" is applied in this scheme.

Motion Estimation is based on the 16 pixels x 8 lines of luminance samples of each macroblock. Motion vectors are calculated on decoded pictures.

The range of motion vectors is +/- 16 pixels and +/- 8 lines (frame lines). The accuracy of the prediction is half pel in both directions.

A bi-linear filter is applied in both directions in order to provide half-pel accuracy.

The vector chosen is the one which gives the minimum value to the total of the 16 x 8 absolute differences.

Motion compensated prediction is carried out on both the luminance and chrominance samples within each macroblock. The vertical component of the vector used for chrominance has the same value as that used for luminance. The horizontal component is half the value (truncated at half pel) of that used for luminance.

6. PICTURE TYPE - MACROBLOCK TYPE

There are two types of picture frame :

1. Intra frame : all the macroblocks are intra coded.
2. Predicted frame : macroblocks may be intra coded or inter coded by using the motion compensated prediction from the previous picture frame. The chosen mode is the one which gives the minimum value to the total of the 16 x 8 absolute values of luminance samples.

7. TRANSFORMATION

For each component (Y, CB or CR), the Discrete Cosine Transform (DCT) is applied to each block (as in the MPEG1 or H261 standards) [ref. 1-2].

8. QUANTIZATION

The quantization algorithm is close to the quantizer of the CMTT/2 standard for contribution [ref. 3]. For each transform coefficient, the quantization is achieved in two steps :

1. multiplication by a scaling factor : $C_1 = C_{IN} \times 2^{\frac{-n}{16}}$
2. linear quantization : $C_{OUT} = round(\frac{C_1}{4})$

Each scaling factor (n) is expressed in terms of $2^{\frac{-n}{16}}$ where $n = n_w + n_q$:

- n_q is a linear function of the block criticallity (4 criticallity classes) [ref. 4] and the transmission factor (TxF) coming from the buffer regulation. TxF is linearly related to the buffer occupancy; therefore the real quantization stepsize is increasing logarithmically according to the buffer occupancy. The same scaling factor is applied to luminance and chrominances coefficients.
  The criticallity is an image of the block resistance to the quantization noise. It is computed on luminance blocks only; that information is also used for quantization of the co-sited chrominance blocks.
- n_w is the weighting factor; it is function of the coefficient order, the block criticallity and the component (Y or C). Weighting factors are relaxed for critical blocks. The same factors are applied to intra and non-intra blocks. Tables of weighting factors are given below.

Then a linear quantization is performed at the end of the quantizer. The DCT coefficients are rounded on 9 bits+s.

No variable thresholding or clipping is used.

0	6	18	30	39	47	53	59
0	11	21	32	40	47	53	59
6	15	24	33	41	48	54	59
14	21	28	35	43	49	55	60
21	26	32	38	44	50	55	60
28	31	36	41	46	52	56	61
33	36	39	44	49	53	57	62
38	41	43	47	51	55	59	63

Luminance weighting factors

16	28	35	43	50	57	62	68
29	34	40	46	53	59	64	68
36	40	44	50	55	60	65	70
45	47	50	54	59	63	67	71
52	54	56	59	62	66	69	73
59	60	61	64	66	69	72	75
64	65	66	68	70	72	75	78
70	70	71	72	74	76	78	79

Chrominances weighting factors

9. VARIABLE LENGTH CODING

1- CODING OF TRANSFORM COEFFICIENTS

Tansform coefficients are coded by the Universal Variable Length Coder (U-VLC) [ref. 5].

A. Principle of the UVLC

The efficiency of the UVLC is based on some elementary observations, which may be considered valid in a first approximation, namely :

- the probability distribution function of DCT coefficients is decreasing about zero, with standard deviations decreasing with the coefficient order ;
- DCT coefficients of a given order taken in successive blocks are uncorrelated. Indeed if it were not so, the DCT scheme would be inefficient. Thus it is possible to use adaptive codes, which calculate the coded data after some on line estimation of the statistics of

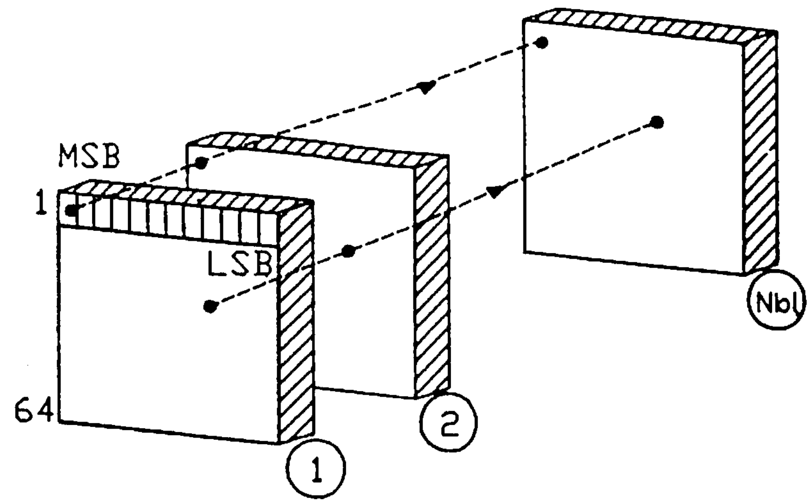


Figure 1: Information reorganization

a sequence of uncorrelated coefficients having the same probability distribution. Such codes are called universal when their coding efficiency tends to unity when the length of the sequence increases indefinitely. They are called quasi-universal when the efficiency tends to a value close to unity.

- when the amplitude of a coefficient is analyzed from the MSB to the LSB, the probability for the next bit being zero remains very high as long a no bit equal to one is met. However, when the first non-zero bit (MSNZB : most significant non zero bit) has been met, the probabilities of following bits to be zero or one are roughly equal. Therefore, the entropy of these bits is close to one and little is gained by coding them.

The UVLC uses these properties by coding the positions of the MSNZB bits with a quasi-universal code and by transmitting the remaining bits uncoded. Some further refinements have been added to increase the coding efficiency. The VLC words are generated in two steps :

- storing all the blocks of transform coefficients of a stripe of 90 blocks into a two-dimensional table (64×90 coefficients of 12 bits) : this is the *reorganization step*;
- encoding sequences of 90 DCT coefficients of the same order taken in this table by a run-length coding of their MSNZB and by sending the less significant bits uncoded : this is the *skip step*.

A.1 The reorganization step

The UVLC processes groups of blocks of transform coefficients belonging to a stripe. At the reorganization step, the blocks of a stripe of 8 lines are grouped into a stack. The binary representation of the transform coefficients in this stack is the sign and magnitude representation. The Figure 1 shows the three-dimensional array of bits corresponding to such a stack of blocks. The array consists of :

- 64 rows, corresponding to coefficients orders;
- 12 columns corresponding to bit levels from the MSB to the LSB + the sign bit;
- 12×64 lines, made of the 90 bits of the same level, belonging to bits of the same level, belonging to the coefficients of the same order.

A.2 The skip step

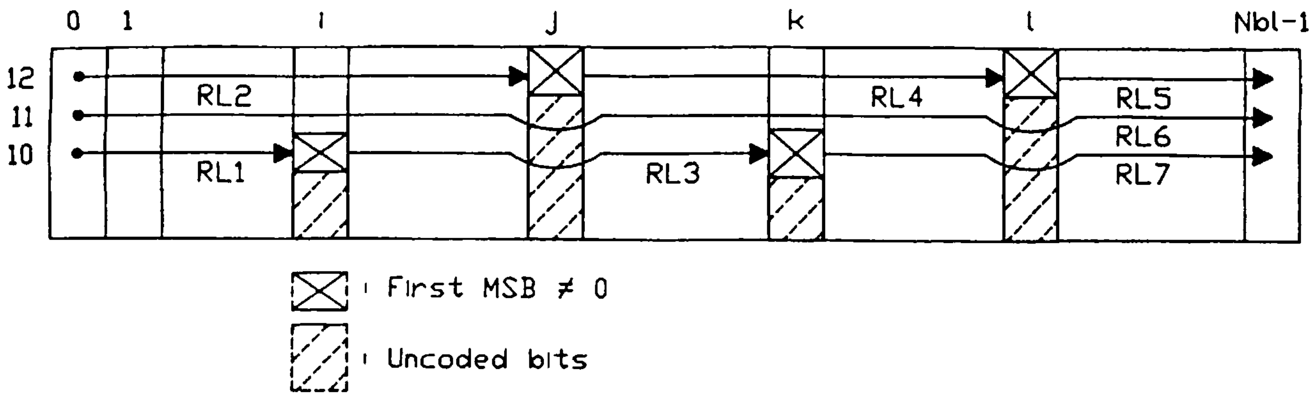


Figure 2: Skip coding

In the skip step, sequences of coefficients of the same order are proceesed at the bit level. Such sequences correspond to horizontal slices in the tridimensional table illustrated on Figure 1. Figure 2 illustrates such a slice considered at the bit level as well as the analysis process. The coefficients of a given order are encoded by a run-length coding of their lines of bits from the MSB to the LSB (the sign bit is placed after the LSB) : when a non-zero bit is encountered, the other less significant bits are sent uncoded and the whole non-zero coefficient is removed from the stack. Therefore, the non-zero coefficients are encoded by giving the position of their most significant non-zero bit (MSNZB), and by sending the less significant bits uncoded. As the encoded coefficients are removed from the table, the lines to encode become progressively shorter when the process runs from the MSB line to the LSB line. Obviously the MSNZB is never met for zero coefficients and very few MSNZB's will be met for high-order DCT coefficients.

B. **Principle of the MSNZB coding**

The adaptive truncated run-length coding (ATRL) proposed by Tanaka and Leon-Garcia [ref. 6] has been used for encoding the positions of the MSNZB. This scheme is robust with respect to the statistical fluctuations of the pictures and allows a very simple implementation. For a DCT coefficient of a given order, the ATRL code is applied successively to the lines of the table shown on Figure 2, from the MSB to the LSB. Each time a MSNZB is met, the corresponding coefficient is removed from the table, which makes the latter progressively narrower.

The zero run length encoding is limited to a length $M = 2^m$ (truncation). The truncated run length code encodes two types of patterns :

- runs of length 0 to $M - 1$ consecutive zeroes terminated by a one;
- M consecutive zeros.

The M consecutive zeros are coded by one bit set to 0. The run length terminated by a one are coded by one bit set to 1 followed by the position of the one coded on $m = \log_2(M)$ bits (see Figure 3). The TRL is made adaptive by changing the value of m in function of the probability of a bit to be a one and of the length L of the line to encode. Thus the encoder operates in the two steps :

- first, count the number of ones in the line to code in order to determine the corresponding optimum value of m

source	code-word
00000000	0
1	1000
01	1001
001	1010
0001	1011
00001	1100
000001	1101
0000001	1110
00000001	1111

Figure 3 : Truncated Run-Length for M=8, m=3

- secondly, send a prefix value giving the number of ones into the line and generate the code words.

The decoding algorithm consists in simply writing ones sequentially as the run-lengths are arriving. The prefix indicating the number of ones has to be used in order to know which m value has to be used and to determine when the block transmission is achieved.

2- CODING OF MOTION VECTORS

Motion vectors are coded differentially within a slice. Thanks to the universality of the U-VLC, the 90 differential motion vectors are also coded by this algorithm.

10. VIDEO MULTIPLEX LAYER

1- PICTURE LAYER

The video framing at the picture layer consists of :

- Picture Start Code (PSC) [48 bits]
- Buffer Occupancy (BO) [8 bits]
- Bit Rate Flag (BRF) [1 bit]
- Picture Type (PT) [2 bits]

- The information of 72 slice layers

2- SLICE LAYER

The video framing at the slice layer consists of :

- Slice Start Code (SSC) [32 bits]
- Slice Number (SN) [7bits]
- Transmission Factor (TxF) [8bits]

- 45 × MB types [45 bits]
- 90 × criticallity classes [180 bits]
- Motion vectors [VLC]
- Coded transform coefficients [VLC]

11. BUFFER REGULATION

The buffer size corresponds to 200 ms (0.8 Mbit at 4 Mbit/s and 1.8 Mbit at 9 Mbit/s). The buffer is divided in three areas as illustrated on Figure 4. The top and the bottom areas are reached during abnormal situations (extremely complex or extremely simple sequences).

The quantization parameter (TxF : Transmission Factor) is computed at the end of each slice. It is related to the BO (Buffer Occupancy) by a linear relation. TxF_0, ...,TxF_3 are function of the output bitrate; BO_0, ...,BO_3 are fixed [ref. 7].

The Transmission Factor is maintained constant during all the stripes of a intra picture.

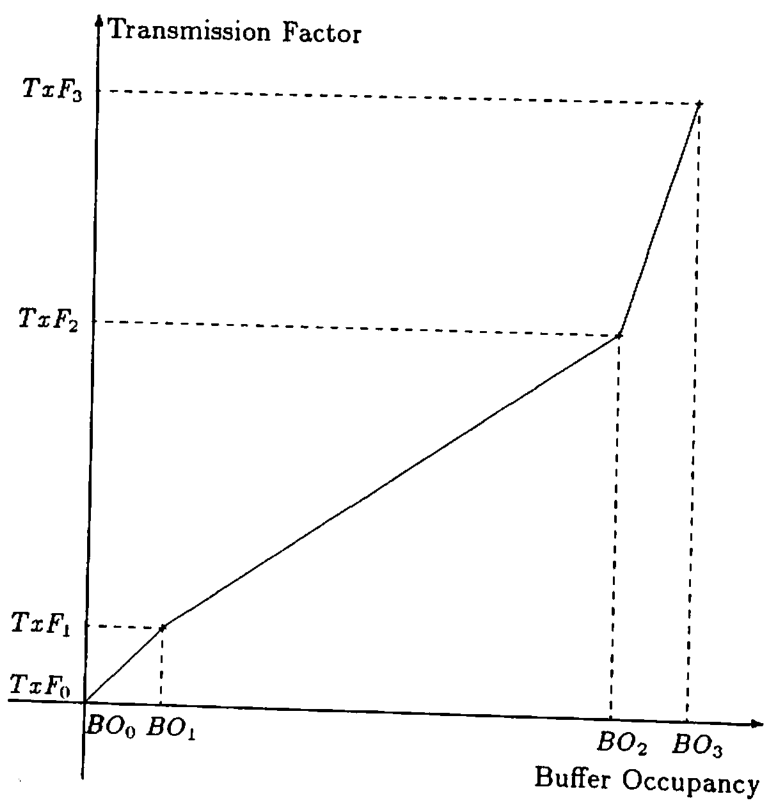


Figure 4 : Buffer design

13. COMPATIBILITY FEATURE

We are convinced that the way of designing the most efficient compatible scheme between two or more applications implies the simultaneous study of all the applications together. That is the raison why we are defining a compatible scheme for SDTV and HDTV. As mentionned at the beginning of this text, the algorithm presented here is the first layer of this general compatible scheme.

14. RANDOM ACCESS FEATURE

Random access feature is achieved by forcing intra mode coding at the first frame of each group of pictures. That means a intra frame each 40 ms.

15. CODING/DECODING DELAY

Coding/decoding delay is generated by buffering and processing :

- buffering delay : 200 msec
- processing delay :
  . field merging : 1 field + 1 slice (20.55 msec)
  . VLC : 1 slice (0.55 msec)
  . VLD : 1 slice (0.55 msec)
  . field "demerging" : 1 field (20 msec) *[display buffer]*

For applications requiring low delay (as conversationnal services), buffer size may be reduced without debasing significantly picture quality.

16. CELL LOSS RESILIENCE

The mechanism of the protection against cell losses and bit errors developed by RTT for the Belgian Broadband Experiment has been presented within the Experts Group for ATM Video Coding of CCITT SGXV [ref. 8]. That method using a bi-directionnal correction allows to increase the time error free from 0.1 sec up to 1.8 min at 9 Mbit/sec for a 10^{-3} CLR. The bitrate overhead needed by that is 3.1 %.

17. CONCLUSIONS

The main objective of our work was to define a coding scheme being a good compromise between picture quality and hardware complexity. Only two picture types (intra or predicted) and two macroblock types (intra or inter) are used.

The main characteristics are the following ones :

- **frame based coding** to improve spatial decorrelation technique.
- **forward prediction only** to reduce processing delay.
- design of a **quantizer** self-adapted to picture content by defining 4 criticallity classes. The logarithmic relation between buffer occupancy and quantization stepsize is also suitable.

- full advantage of high <u>VLC</u> efficiency is needed for critical picture material and also when the intra mode is selected. This is the case when switching to the intra mode is due to the sequence itself, like at scene cuts or for which inter prediction is poor. On the other hand, the intra mode is forced at some rate for refreshing purposes; this is a strong requirement for storage and retrieval applications.
  A self-adaptive or universal VLC is also a key point when designing a generic coding scheme devoted to several applications for a lot of picture kinds.
  The mechanism of the U-VLC consisting of coding coefficients of the same order together is also suitable for the design of layered coding schemes.

18. REFERENCES

-1. CD of MPEG I

-2. CCITT recommendation H261

-3. CCIR recommendation : video codec for contribution applications at 34-45 Mbit/sec.

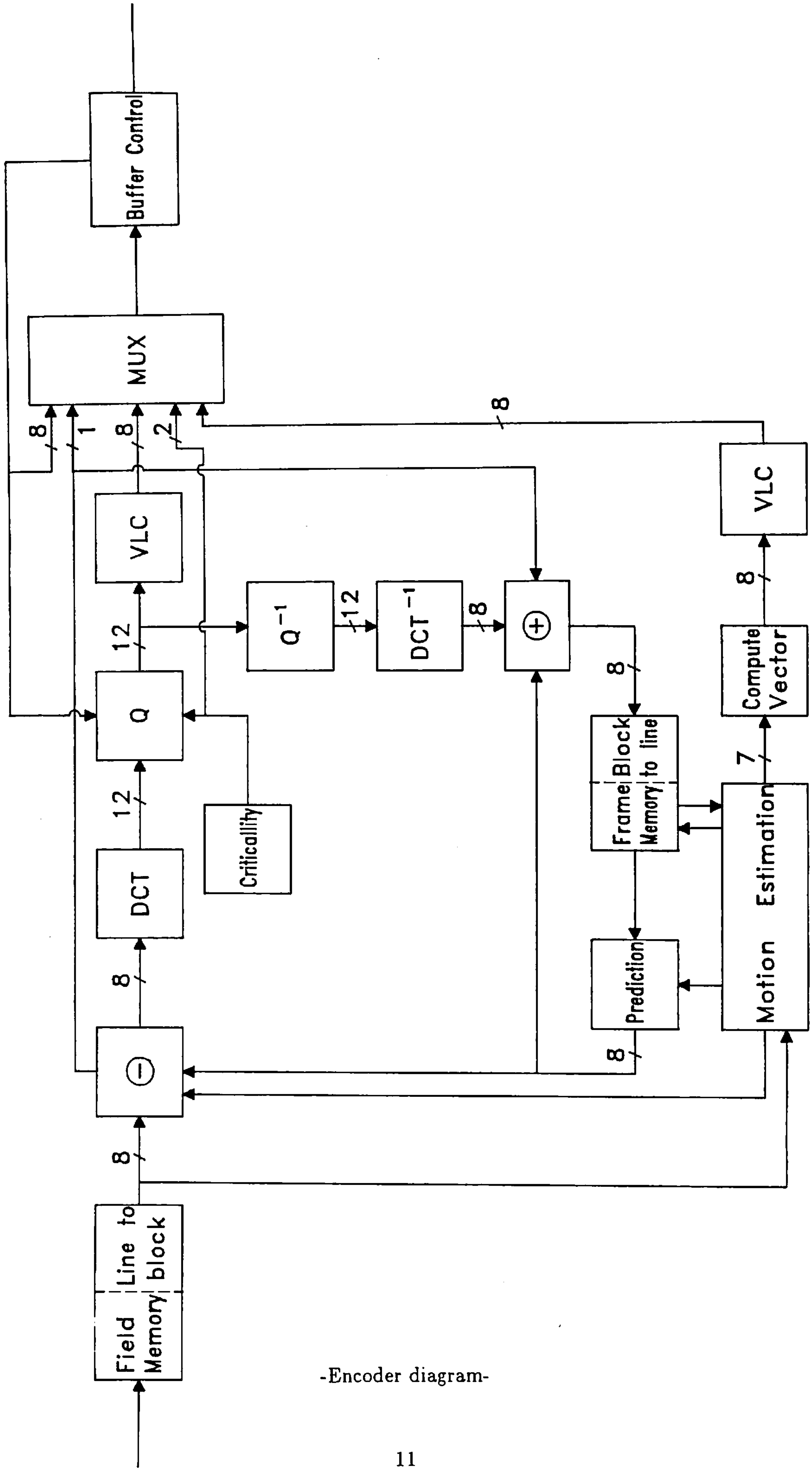
-4. O. Poncin : "Quantization algorithm for universal video codec in the ATM Belgian Broadband Experiment", Packet Video 90, Morristown, pp. C9.1, C9.5.

-5. B. Macq : "A universal entropy coder", PCS 90, Boston, pp. 12.1-1, 12.1-2.

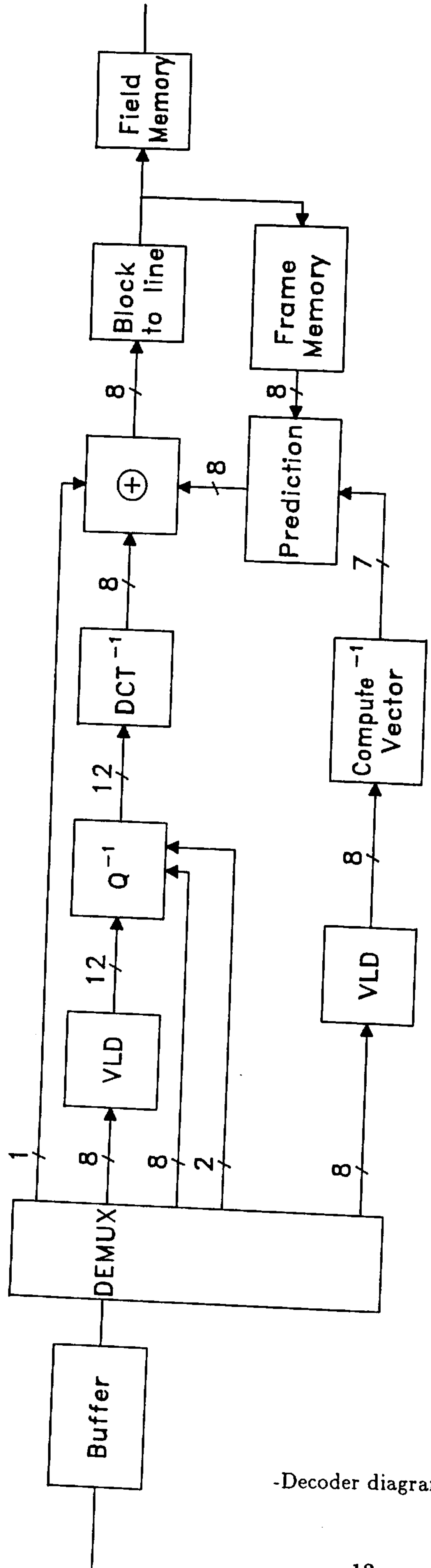
-6. H. Tanaka and A. Leon Garcia : "Efficient run-length encodings", IEEE Trans. on Information Theory, vol IT-28,pp. 880-890, November 1982.

-7. JP. Leduc : "Buffer Regulation for universal video codec in the ATM Belgian Broadband Experiment", Packet Video 90, Morristown, pp. C10.1, C10.6.

-8. RTT Belgium : "CLR and BER protection for enhanced end-to-end users QOS", CCITT SGVX - WPXV/1 AVC-69.



-Encoder diagram-



-Decoder diagram-

Size of coded bit stream file

```
-rw-r--r--  1 poncin    2521424 Sep 26 21:24 codeflower4
-rw-r--r--  1 poncin    2565036 Sep 28 10:32 codemobcal4
-rw-r--r--  1 poncin    2504312 Sep 29 17:14 codetable4
-rw-r--r--  1 poncin    5672760 Aug 21 18:39 codeflower9
-rw-r--r--  1 poncin    5668848 Aug 20 08:27 codemobcal9
-rw-r--r--  1 poncin    5712292 Aug 24 22:29 codepopple9
-rw-r--r--  1 poncin    5639904 Aug 23 20:06 codetable9
```


Average statistics

```
SEQUENCE : flower
BIT RATE :   4Mbit/s

  Global overhead      :  0.4 Mbit/s
  Lum. Counter         :  3.1 Mbit/s
  Chrom. Counter       :  0.6 Mbit/s
  ---------------------------------
  TOTAL                :  4.0 Mbit/s

  Overhead (excl. MV)  :  0.1 Mbit/s
  MV Counter           :  0.2 Mbit/s

===================================

SEQUENCE : mobcal
BIT RATE :   4Mbit/s

  Global overhead      :  0.3 Mbit/s
  Lum. Counter         :  3.1 Mbit/s
  Chrom. Counter       :  0.6 Mbit/s
  ---------------------------------
  TOTAL                :  4.0 Mbit/s

  Overhead (excl. MV)  :  0.1 Mbit/s
  MV Counter           :  0.2 Mbit/s

===================================

SEQUENCE : table
BIT RATE :   4Mbit/s

  Global overhead      :  0.4 Mbit/s
  Lum. Counter         :  3.0 Mbit/s
  Chrom. Counter       :  0.6 Mbit/s
  ---------------------------------
  TOTAL                :  4.0 Mbit/s

  Overhead (excl. MV)  :  0.1 Mbit/s
  MV Counter           :  0.2 Mbit/s

===================================
```

```
SEQUENCE : flower
BIT RATE :    9Mbit/s

  Global overhead      :  1.0 Mbit/s
  Lum. Counter         :  6.9 Mbit/s
  Chrom. Counter       :  1.2 Mbit/s
  ---------------------------------
  TOTAL                :  9.0 Mbit/s

  Overhead (excl. MV)  :  0.5 Mbit/s
  MV Counter           :  0.5 Mbit/s

===================================

SEQUENCE : mobcal
BIT RATE :    9Mbit/s

  Global overhead      :  0.9 Mbit/s
  Lum. Counter         :  6.9 Mbit/s
  Chrom. Counter       :  1.3 Mbit/s
  ---------------------------------
  TOTAL                :  9.0 Mbit/s

  Overhead (excl. MV)  :  0.5 Mbit/s
  MV Counter           :  0.4 Mbit/s

===================================

SEQUENCE : popple
BIT RATE :    9Mbit/s

  Global overhead      :  1.3 Mbit/s
  Lum. Counter         :  6.0 Mbit/s
  Chrom. Counter       :  1.9 Mbit/s
  ---------------------------------
  TOTAL                :  9.1 Mbit/s

  Overhead (excl. MV)  :  0.5 Mbit/s
  MV Counter           :  0.8 Mbit/s

===================================
```



```
SEQUENCE : table
BIT RATE :    9Mbit/s

  Global overhead      :  0.9 Mbit/s
  Lum. Counter         :  6.9 Mbit/s
  Chrom. Counter       :  1.2 Mbit/s
  ---------------------------------
  TOTAL                :  9.0 Mbit/s

  Overhead (excl. MV)  :  0.5 Mbit/s
  MV Counter           :  0.5 Mbit/s
```

0.4 sec basis statistics

SEQUENCE : flower
BIT RATE : 4Mbit/s

Fr. Number	Cum. Bit Count
10	1792384
20	3332960
30	4944256
40	6522112
50	8172736
60	9767552
70	11288224
80	12967712
90	14601216
100	16202048
110	17829152
120	19338880
125	20171392

SEQUENCE : mobcal
BIT RATE : 4Mbit/s

Fr. Number	Cum. Bit Count
10	2113088
20	3713088
30	5311008
40	6918272
50	8518944
60	10121344
70	11722976
80	13321632
90	14922336
100	16522464
110	18125088
120	19731040
125	20520288

Annex 3

SEQUENCE : table
BIT RATE : 4Mbit/s

Fr. Number	Cum. Bit Count
10	1686464
20	3212768
30	4804992
40	6423136
50	8046944
60	9594304
70	11192288
80	12793472
90	14396704
100	15996992
110	17598848
120	19195776
125	20034496

SEQUENCE : flower
BIT RATE : 9Mbit/s

Fr. Number	Cum. Bit Count
10	4044576
20	7458496
30	11098496
40	14648448
50	18397408
60	21963072
70	25355520
80	29136096
90	32852096
100	36476704
110	40169760
120	43507200
125	45382080

SEQUENCE : mobcal
BIT RATE : 9Mbit/s

Fr. Number	Cum. Bit Count
10	3957664
20	7536896
30	11027296
40	14579136
50	18305568
60	21952032
70	25574304
80	29143264
90	32649792
100	36243808
110	39899744
120	43460992
125	45350784

SEQUENCE : popple
BIT RATE : 9Mbit/s

Fr. Number	Cum. Bit Count
10	3608832
20	7207168
30	10810560
40	14432448
50	18233408
60	21881280
70	25419104
80	28990976
90	32780416
100	36544768
110	40283712
120	43883968
125	45698336

SEQUENCE : table
BIT RATE : 9Mbit/s

Fr. Number	Cum. Bit Count
10	3889696
20	7259712
30	10843008
40	14503808
50	18121088
60	21617760
70	25216640
80	28819520
90	32425472
100	36028416
110	39645440
120	43229856
125	45119232

Annex 4

Frame basis statistics

SEQUENCE : flower
BIT RATE : 4Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	242656	27	25	30
2	213312	28	26	31
3	185984	28	26	31
4	180192	28	26	31
5	169472	28	26	31
6	156256	28	26	31
7	163360	28	26	31
8	165312	27	26	31
9	161120	27	26	31
10	154720	28	26	31
11	252448	27	25	30
12	124192	27	25	30
13	125632	27	25	30
14	129696	27	26	31
15	141344	28	26	31
16	147232	28	26	31
17	145344	28	26	31
18	153056	28	27	31
19	152704	28	27	31
20	168928	28	27	31
21	255264	27	25	30
22	137344	27	25	30
23	138208	27	26	30
24	154336	28	26	31
25	156512	28	26	31
26	140512	28	26	31
27	145504	28	26	31
28	179072	28	26	31
29	163552	28	26	31
30	140992	28	26	31
31	258848	27	25	30
32	140448	27	25	30
33	148384	27	25	30
34	144960	27	25	31
35	133632	28	26	31
36	147936	28	26	31
37	141216	28	26	31
38	153248	28	27	31
39	163328	28	27	31
40	145856	28	27	31
41	261216	27	25	30

42	145952	27	25	30
43	168992	27	25	30
44	153632	27	25	30
45	149120	27	25	30
46	159424	27	25	30
47	155008	27	26	30
48	174432	27	25	30
49	154784	27	25	30
50	128064	27	26	30
51	263328	26	24	30
52	114080	27	25	30
53	153920	27	25	30
54	149248	27	25	30
55	141664	27	25	30
56	152832	27	26	30
57	155360	27	26	30
58	153184	27	26	30
59	159328	27	26	30
60	151872	28	26	30
61	260672	26	25	30
62	114880	27	25	30
63	125440	27	25	30
64	127872	28	26	30
65	149216	28	26	31
66	138048	28	26	31
67	169824	28	27	31
68	139200	28	27	31
69	148448	28	27	31
70	147072	29	27	31
71	259552	26	24	30
72	156960	27	25	30
73	133408	27	26	30
74	138784	28	26	30
75	144320	28	26	31
76	157920	28	27	31
77	185248	28	26	31
78	168320	28	26	31
79	160768	28	26	31
80	174208	28	26	31
81	259552	26	24	30
82	120224	27	25	30
83	135616	27	25	30
84	166112	27	25	30
85	158752	27	25	30
86	158304	27	25	30
87	137504	27	26	30
88	149184	27	26	30
89	170080	27	26	30
90	178176	27	25	30

91	259040	26	24	30
92	129440	26	24	30
93	136800	26	24	30
94	152096	27	25	30
95	154080	27	25	30
96	151296	27	25	30
97	143904	27	25	30
98	146368	27	25	30
99	167872	27	25	30
100	159936	27	25	30
101	260576	26	24	30
102	117856	26	24	30
103	134720	27	25	30
104	152800	27	25	30
105	162016	27	25	30
106	159616	27	25	30
107	158464	27	25	30
108	162720	27	25	30
109	161760	27	25	30
110	156576	27	25	30
111	261088	26	24	30
112	117120	26	24	30
113	130816	26	24	30
114	133984	27	25	30
115	133792	27	25	30
116	131488	27	25	30
117	139424	28	26	30
118	162336	28	26	30
119	158880	28	26	31
120	140800	28	26	31
121	260608	26	24	30
122	149984	27	25	30
123	146336	27	25	30
124	121472	27	25	30
125	154112	27	26	30

SEQUENCE : mobcal
BIT RATE : 4Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	363904	27	25	31
2	295424	25	23	28
3	229888	23	21	26
4	200416	22	21	26
5	183936	22	20	25
6	175680	22	20	24
7	168896	21	20	24
8	167072	21	20	24
9	164096	21	20	23
10	163776	21	20	23
11	130976	23	21	28
12	165312	23	21	26
13	165536	22	20	26
14	164768	22	20	25
15	164992	22	20	25
16	162784	21	20	24
17	161472	21	20	24
18	161024	21	20	23
19	161120	21	20	23
20	162016	21	20	23
21	129344	23	21	28
22	162688	23	21	26
23	166080	22	21	26
24	164896	22	20	25
25	163872	22	20	25
26	164384	21	20	24
27	161856	21	20	24
28	161824	21	20	23
29	161440	21	20	23
30	161536	21	20	23
31	129088	23	21	27
32	162976	23	21	26
33	167168	22	20	26
34	166080	22	20	25
35	166496	22	20	24
36	164032	21	20	24
37	162656	21	20	24
38	162176	21	20	23
39	163776	21	20	23
40	162816	21	19	23
41	126880	23	21	27
42	164320	23	21	26
43	166112	22	21	25

44	166080	22	20	25
45	164896	22	20	24
46	163008	21	20	24
47	162720	21	20	23
48	162688	21	20	23
49	163168	21	20	23
50	160800	21	20	23
51	128384	23	21	27
52	164416	23	21	26
53	166176	22	21	25
54	166496	22	20	25
55	164096	22	20	24
56	163232	21	20	24
57	164032	21	20	23
58	162496	21	20	23
59	161952	21	20	23
60	161120	21	19	23
61	129312	23	21	27
62	165280	23	21	26
63	168032	22	20	25
64	165120	22	20	24
65	163360	21	20	24
66	164480	21	20	24
67	162112	21	20	23
68	161024	21	19	23
69	161600	21	19	23
70	161312	21	19	22
71	128000	23	21	27
72	163776	23	21	26
73	166656	22	20	25
74	165792	22	20	24
75	164832	21	20	24
76	164992	21	20	23
77	162208	21	20	23
78	160896	21	20	23
79	160224	21	19	22
80	161280	21	19	22
81	129472	23	21	27
82	163712	23	21	26
83	167520	22	20	25
84	166176	22	20	24
85	163840	21	20	24
86	163712	21	20	23
87	161888	21	20	23
88	161856	21	20	23
89	161024	21	19	22
90	161504	21	19	22
91	129728	23	21	27
92	163360	23	21	26

93	168032	22	21	25
94	164992	22	20	24
95	164384	21	20	24
96	163776	21	20	23
97	161952	21	20	23
98	161824	21	19	23
99	161216	21	20	22
100	160864	21	19	22
101	129376	23	21	27
102	164224	23	21	26
103	168928	22	20	25
104	164576	22	20	24
105	165120	21	20	24
106	162976	21	20	23
107	161280	21	20	23
108	161664	21	19	23
109	161824	21	19	22
110	162656	21	19	22
111	130048	23	21	27
112	164800	23	21	26
113	167392	22	20	25
114	166336	22	20	24
115	164544	21	20	24
116	162464	21	20	23
117	163360	21	20	23
118	162688	21	19	22
119	163008	21	19	22
120	161312	20	19	22
121	128960	23	21	26
122	164832	22	21	25
123	166432	22	20	25
124	166176	22	20	24
125	162848	21	20	23

SEQUENCE : table
BIT RATE : 4Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	177536	25	23	34
2	229888	27	25	34
3	130112	27	25	35
4	137376	27	25	35
5	144096	28	25	35
6	194144	28	25	34
7	201888	28	25	34
8	186912	30	29	34
9	149152	31	29	35
10	135360	32	30	35
11	123872	31	29	35
12	158848	32	30	35
13	145600	32	31	35
14	147264	33	31	36
15	151936	33	31	36
16	154720	33	31	36
17	159264	33	32	36
18	161536	33	32	35
19	161504	33	32	35
20	161760	33	32	35
21	135488	31	30	34
22	184512	33	31	35
23	151232	33	32	35
24	158496	33	32	35
25	160288	33	32	35
26	160448	33	32	34
27	160736	33	32	34
28	160320	33	32	34
29	160576	33	32	34
30	160128	33	32	34
31	159808	30	29	32
32	184064	32	31	33
33	152672	32	31	33
34	152608	32	31	34
35	159040	32	31	34
36	161376	32	31	33
37	163776	32	31	33
38	159808	32	31	34
39	162368	32	31	34
40	162624	32	31	33
41	169728	30	28	32
42	185760	31	30	33
43	155936	32	30	33

44	158624	32	31	33
45	159104	32	31	33
46	160256	32	31	33
47	160800	32	31	33
48	159616	32	31	33
49	158048	32	31	33
50	155936	32	31	33
51	180704	30	28	32
52	169600	31	30	32
53	148224	31	30	33
54	269664	30	28	34
55	95200	30	28	34
56	113120	30	28	34
57	126816	31	29	34
58	135968	31	29	34
59	150976	31	29	34
60	157088	31	30	34
61	205824	29	27	34
62	171360	31	29	35
63	122080	31	29	35
64	143904	31	29	35
65	156768	32	30	35
66	159040	32	30	35
67	160160	32	30	36
68	161120	32	30	36
69	158496	32	31	36
70	159232	32	31	36
71	207328	29	27	34
72	168704	31	29	35
73	120320	31	29	35
74	148224	31	30	35
75	157504	32	30	35
76	158944	32	30	36
77	158944	32	31	36
78	160032	33	31	36
79	160832	33	31	36
80	160352	33	31	36
81	207936	29	27	34
82	170528	31	29	35
83	292480	29	26	34
84	99968	29	27	34
85	112992	29	27	34
86	124736	30	27	34
87	134720	30	28	35
88	143040	30	28	35
89	158240	31	29	35
90	158592	31	29	35
91	213568	28	26	34
92	173312	30	27	35

93	120864	30	28	35
94	135168	30	28	35
95	157952	31	29	35
96	158848	31	29	36
97	158912	32	30	36
98	159872	32	29	36
99	160896	31	29	35
100	160896	31	29	35
101	213984	28	26	34
102	181856	30	27	35
103	137728	30	28	35
104	151584	30	28	35
105	150624	30	28	35
106	152608	30	28	35
107	148736	31	28	35
108	149280	31	29	35
109	155296	31	29	35
110	160160	31	29	35
111	211040	28	26	34
112	180352	30	27	35
113	146016	30	27	35
114	144160	30	28	35
115	152896	30	28	35
116	141504	30	28	35
117	144064	31	29	35
118	158688	31	29	35
119	158560	31	29	35
120	159648	31	29	35
121	211776	28	25	34
122	185280	30	27	35
123	142624	30	28	35
124	149312	30	28	35
125	149728	30	28	35

SEQUENCE : flower
BIT RATE :   9Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	621056	31	29	33
2	381408	31	29	33
3	416128	31	29	33
4	412768	30	29	33
5	391360	30	29	33
6	349216	30	29	33
7	374496	30	29	33
8	383840	30	28	33
9	368896	30	28	33
10	345408	30	28	32
11	642944	31	29	33
12	246496	30	28	33
13	261664	30	28	33
14	272512	30	29	33
15	299808	30	29	33
16	319968	31	29	33
17	319552	31	29	33
18	333920	31	30	33
19	343584	31	30	33
20	373472	31	30	33
21	652480	31	29	33
22	259488	30	29	33
23	297408	31	29	33
24	342912	31	29	33
25	347904	31	29	33
26	316576	31	29	33
27	324928	31	30	33
28	408544	31	29	33
29	368992	31	29	33
30	320768	31	29	33
31	657824	31	29	33
32	274112	30	28	33
33	326304	30	28	33
34	323296	30	29	33
35	294272	31	29	33
36	327744	31	29	33
37	313856	31	30	33
38	342560	31	30	33
39	360384	31	30	33
40	329600	31	30	33
41	657152	31	29	33
42	285280	30	29	33
43	385856	30	28	32

44	348704	30	29	32
45	332064	30	29	32
46	358112	30	29	32
47	346816	30	29	32
48	399168	30	28	32
49	352384	30	28	32
50	283424	30	29	32
51	661376	30	29	32
52	212576	30	28	32
53	335264	30	28	32
54	330752	30	28	32
55	307008	30	28	32
56	333824	30	28	32
57	350848	30	29	32
58	337952	30	29	32
59	359072	30	29	32
60	336992	30	29	32
61	654912	30	29	33
62	215008	30	28	32
63	255488	30	29	32
64	274144	31	29	33
65	328960	31	29	33
66	316096	31	30	33
67	378688	31	30	33
68	314048	31	30	33
69	328320	31	30	33
70	326784	31	30	33
71	658144	30	29	32
72	293152	30	29	32
73	293248	31	29	33
74	309504	31	30	33
75	316032	31	30	33
76	361280	31	30	33
77	412448	31	29	33
78	379776	31	29	33
79	360672	31	29	33
80	396320	30	29	33
81	658432	30	29	32
82	231072	30	29	32
83	292992	30	29	32
84	383680	30	28	32
85	365120	30	28	32
86	356032	30	28	32
87	307328	30	29	32
88	326144	30	29	32
89	381952	30	29	32
90	413248	30	28	32
91	657120	30	29	33
92	279392	29	27	32

93	302048	29	27	32
94	340736	29	27	32
95	351456	29	28	32
96	337440	29	28	32
97	311968	29	28	32
98	313504	30	28	32
99	374624	30	28	32
100	356320	30	28	32
101	661920	30	29	32
102	231360	30	28	32
103	275712	30	28	32
104	333344	30	28	32
105	368672	30	28	32
106	365504	29	28	32
107	362048	29	28	32
108	373088	29	28	32
109	366048	29	28	32
110	355360	29	28	32
111	663168	30	29	33
112	247776	29	27	32
113	272096	29	27	32
114	281600	29	28	32
115	278624	30	28	32
116	283360	30	29	32
117	300288	30	29	32
118	350560	31	29	32
119	345184	31	29	32
120	314784	31	30	32
121	665088	31	29	33
122	296192	30	29	32
123	312256	30	29	32
124	263520	30	29	32
125	337824	30	29	32

SEQUENCE : mobcal
BIT RATE : 9Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	730528	31	29	34
2	332576	31	29	34
3	357440	31	29	34
4	358592	31	29	34
5	364352	31	29	34
6	371488	31	29	34
7	366176	30	29	34
8	367488	30	29	34
9	358752	30	29	34
10	350272	30	29	33
11	738400	31	29	34
12	213696	30	28	33
13	267008	30	28	33
14	294176	30	28	33
15	317184	30	29	33
16	328544	30	29	33
17	334336	31	29	33
18	337952	31	29	33
19	366784	31	29	33
20	381152	31	29	33
21	741632	31	29	33
22	216896	30	28	33
23	268736	30	28	33
24	297568	30	29	33
25	306112	31	29	33
26	311296	31	29	33
27	319776	31	30	33
28	338208	31	30	34
29	336224	31	30	34
30	353952	32	30	34
31	740256	31	30	33
32	224928	30	29	33
33	275328	31	29	33
34	298656	31	29	33
35	336096	31	29	34
36	345632	31	30	34
37	329184	31	30	34
38	333856	31	30	34
39	338816	32	30	34
40	329088	32	30	34
41	733152	31	29	34
42	212896	31	29	34
43	281408	31	29	34
44	321952	31	29	34
45	332480	31	30	34
46	349408	31	30	34
47	360128	31	30	34
48	370976	31	30	34
49	384320	31	30	34
50	379712	31	30	34
51	732512	31	29	33
52	237664	30	28	33
53	306880	30	28	33
54	333728	30	28	33
55	354208	30	28	33
56	347648	30	28	33
57	348416	30	28	33
58	338208	30	28	33
59	326144	30	29	33
60	321056	30	29	33
61	738272	31	29	33
62	204864	30	28	33
63	278464	30	28	33
64	317408	30	28	33
65	337760	30	28	33
66	340736	30	29	33
67	336736	30	29	33
68	360800	30	29	33
69	358048	30	29	33
70	349184	30	29	33
71	738560	31	29	33
72	215840	30	28	33
73	276000	30	28	33
74	303040	30	28	33
75	326464	30	28	33
76	331136	30	29	33
77	335552	30	29	33
78	345056	30	29	33
79	346976	30	29	33
80	350336	31	29	33
81	744704	31	29	33
82	212736	30	28	33
83	262432	30	28	33
84	292672	30	29	33
85	314240	30	29	33
86	335424	31	29	33
87	341888	31	29	33
88	328096	31	29	33
89	332192	31	30	33
90	342144	31	30	33
91	733664	31	29	33
92	217280	30	29	33

93	274976	31	29	33
94	299328	31	29	33
95	309408	31	30	33
96	315200	31	30	34
97	342304	32	30	34
98	360256	32	30	34
99	373152	32	30	34
100	368448	32	30	34
101	739168	31	29	33
102	243744	30	28	33
103	303840	30	28	33
104	320000	30	29	33
105	330304	30	29	33
106	333376	30	29	33
107	342624	31	29	33
108	346624	31	29	33
109	348896	31	29	33
110	347360	31	29	33
111	753312	31	29	33
112	213504	30	28	33
113	287392	30	28	33
114	309536	30	28	33
115	321728	30	29	33
116	324704	30	29	33
117	329120	31	29	33
118	349792	31	29	33
119	340000	31	29	33
120	332160	31	30	33
121	755776	31	29	33
122	221632	30	28	33
123	280800	30	28	33
124	298592	30	29	33
125	332992	30	29	33

SEQUENCE : popple
BIT RATE : 9Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	480032	33	31	35
2	342496	34	32	36
3	321184	34	32	36
4	333664	34	33	36
5	343040	34	33	36
6	350560	34	33	36
7	361280	34	33	36
8	358304	34	33	36
9	359264	34	33	36
10	359008	34	33	36
11	473856	33	31	35
12	339424	34	32	36
13	327296	34	32	36
14	331104	34	33	36
15	345984	34	33	36
16	346432	34	33	36
17	355136	34	33	36
18	359232	34	33	36
19	363456	34	33	36
20	356416	34	33	36
21	484448	33	31	36
22	335264	33	32	36
23	329120	34	32	36
24	337984	34	32	36
25	340704	34	33	36
26	344928	34	33	36
27	352960	34	33	36
28	357984	34	33	36
29	361856	34	33	36
30	358144	34	33	36
31	476704	33	31	35
32	335200	33	32	36
33	333216	34	32	36
34	341184	34	32	36
35	348480	34	33	36
36	350656	34	33	36
37	350528	34	33	36
38	361088	34	33	36
39	363328	34	33	36
40	361504	34	33	36
41	478432	33	31	36
42	333312	33	32	36
43	346720	34	32	36

44	365536	34	32	36
45	374304	34	32	36
46	365504	33	32	36
47	353120	33	32	36
48	369312	33	32	36
49	410944	33	32	36
50	403776	33	31	36
51	477952	33	31	36
52	330368	33	31	35
53	326112	33	31	35
54	333792	33	31	35
55	357600	33	31	35
56	370880	33	31	35
57	345216	33	32	35
58	359872	33	32	34
59	369888	33	32	34
60	376192	33	32	34
61	388576	33	32	35
62	353504	33	32	34
63	353920	33	32	34
64	348000	33	32	34
65	346720	33	32	34
66	343328	33	33	34
67	346624	33	33	34
68	349824	33	33	34
69	351712	34	33	34
70	355616	33	33	34
71	356992	34	33	35
72	354336	34	33	34
73	356224	34	34	34
74	352576	34	34	34
75	355552	34	34	34
76	357632	34	34	34
77	363968	34	34	33
78	358752	34	34	33
79	354368	33	34	33
80	361472	33	34	33
81	359680	34	34	34
82	364512	34	34	33
83	372320	33	34	33
84	377696	33	33	32
85	383296	33	33	32
86	390400	32	33	31
87	390464	32	33	31
88	390368	32	32	31
89	387680	31	32	30
90	373024	31	32	30
91	460960	32	33	32
92	339296	31	32	31

93	359872	30	31	30
94	360512	31	31	30
95	369440	30	31	29
96	373440	30	31	29
97	370112	30	31	29
98	381536	29	30	29
99	370944	30	30	29
100	378240	29	30	28
101	537376	32	32	31
102	317248	29	29	29
103	346592	29	29	28
104	347456	29	29	28
105	364352	28	29	28
106	361440	28	29	28
107	369056	28	29	28
108	367616	28	29	28
109	361856	28	29	28
110	365952	28	29	27
111	568416	32	33	31
112	298048	28	29	28
113	323744	28	29	27
114	331584	28	29	28
115	346624	28	29	27
116	340832	28	29	28
117	342976	28	29	27
118	353600	28	29	27
119	339776	28	29	28
120	354656	28	29	27
121	571968	32	33	31
122	276320	29	29	28
123	313984	28	29	28
124	314528	28	29	28
125	337568	28	29	28

SEQUENCE : table
BIT RATE :   9Mbit/s

Fr. Number	Bit Count	Mean SNR,Lum.	SNR,Chr.	SNR
1	595776	30	28	36
2	296512	31	28	36
3	310432	31	29	36
4	311136	31	29	36
5	333792	31	29	36
6	431072	31	29	36
7	513024	31	29	36
8	439776	33	31	36
9	339680	33	31	36
10	318496	34	32	37
11	416416	34	33	37
12	283744	34	33	37
13	309312	35	33	37
14	319552	35	33	37
15	332256	35	34	37
16	331968	35	34	37
17	334656	36	34	37
18	343936	36	35	37
19	351936	36	35	37
20	346240	36	35	37
21	410080	35	34	37
22	337952	36	35	37
23	344896	36	35	37
24	339104	36	35	37
25	354304	36	35	37
26	353536	36	35	37
27	358656	36	35	37
28	360096	36	35	37
29	362496	35	35	36
30	362176	35	35	36
31	459360	34	33	35
32	340160	35	34	36
33	343328	35	34	36
34	348352	35	34	36
35	359008	35	34	36
36	362688	35	34	36
37	363392	35	34	36
38	358368	35	34	36
39	361408	35	34	36
40	364736	35	34	36
41	471648	34	33	35
42	333952	34	33	36
43	340992	34	34	36
44	346816	34	34	35
45	352992	35	34	35
46	353280	35	34	35
47	352608	34	34	35
48	358656	34	34	35
49	353568	34	34	35
50	352768	34	34	35
51	493888	34	33	35
52	311648	34	33	35
53	324544	34	33	35
54	563488	33	31	36
55	227104	33	31	36
56	269280	33	32	36
57	290048	34	32	36
58	312544	34	32	36
59	347584	34	33	36
60	356544	34	33	37
61	541024	33	31	36
62	277696	34	32	36
63	290112	34	32	37
64	334368	34	33	37
65	356864	35	33	37
66	358912	35	33	37
67	361216	35	33	37
68	363168	35	33	37
69	356544	35	33	37
70	358976	35	33	37
71	540704	33	31	36
72	268672	34	32	36
73	285024	34	32	37
74	349504	35	33	37
75	357344	35	33	37
76	359008	35	34	37
77	359680	35	34	38
78	359776	35	34	38
79	362016	35	34	38
80	361152	35	34	38
81	540832	33	31	36
82	271712	34	32	37
83	628160	32	30	36
84	234688	32	30	36
85	263904	33	31	36
86	293120	33	31	36
87	301664	33	31	36
88	355008	34	32	37
89	357408	34	32	37
90	359456	34	33	37
91	581312	32	30	36
92	260032	33	31	36

93	278944	33	31	37
94	322176	34	32	37
95	357408	34	32	37
96	358432	34	33	37
97	359392	34	33	37
98	361152	34	32	37
99	362912	34	32	37
100	361184	34	32	37
101	582240	32	30	36
102	283232	33	31	36
103	323200	33	31	36
104	346720	33	31	36
105	346112	33	32	37
106	347424	33	32	37
107	340640	34	32	37
108	342240	34	32	37
109	340992	34	32	37
110	364224	34	32	37
111	572864	32	30	36
112	288032	33	31	37
113	332288	33	31	37
114	324928	33	31	37
115	339200	33	31	37
116	320448	34	32	37
117	331008	34	32	37
118	363456	34	32	37
119	354528	34	32	37
120	357664	34	32	37
121	584192	33	30	36
122	306912	33	31	36
123	319680	33	31	37
124	338400	33	31	37
125	340192	33	32	37