4 LAYERED STRUCTURE OF VIDEO DATA

4.1 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. Quantization is performed at the block level.

4.2 MACROBLOCK layer

A macroblock consists of 4 luminance blocks (16 pixels x 16 lines) and the co-sited single 8x8 CB block and single 8x8 CR block. The scan sequence is Y0, Y1, Y2, Y3, CB, CR. Determination of MB type (inter or intra) is done on the MB level. Motion compensation is also performed at the MB level.

4.3 SLICE layer

A slice consists of a row of 90 blocks 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 is done on the slice level.

4.4 PICTURE layer

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

4.5 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 16 lines of luminance samples of each macroblock. Motion vectors are calculated on decoded pictures.

The range of motion vectors is +/- 16 pixels and +/- 16 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 16 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 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 16 absolute values of luminance samples.

7 TRANSFORMATION

7.1 Subband Filters :

The coding scheme is based on a multiresolution transform of which the key-element is the two-band filter bank for analysis and synthesis.

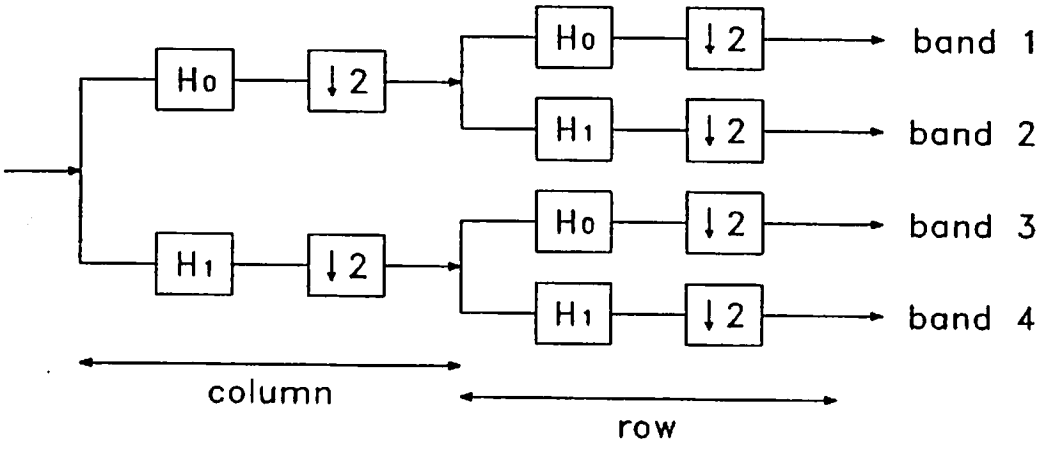
Such a transform is consistent with the scale-space nature of the human visual perception : the artefacts produced by the reconstruction errors will be less anoying than in the case of the DCT.

Furthermore, the decorrelative properties of such a transform seem to be very attractive because the finest decorrelation can be achieved in the low frequencies.

Subband splitting is done according to a hierarchocal tree-structured scheme : the primary cell is the following one : it splits its input spectrum into four rectangular bands using a separable approach where first the columns are treated and then the rows.

Ho and H1 are respectively a low-pass(LP) and a high-pass(HP) filter, having the same even length L. Each filtering operation is directly followed by a subsampling by 2.

A primary cell produces then four bands :



The coefficients h1(n) are deduced from Ho as :

$$h1(n) = (-1)^{L-n} * h0(L-1-n),\ n = 0\ to\ L-1$$

Ho is chosen as a new class of Quadrature Mirror Filter (QMF) of even order. QMF structure has been investigated because they can be implemented with efficient computationnel schemes (the so-called polyphase structures). Moreover, the QMF of even order have a symetrical impulse response at the low-pass branch and an antisymetrical response at the high-pass branch. This class of filters yields to less anoying quantization artefacts around edges.

Classically, the design of those filters is based on the minimization of a weighted sum of the low-pass filter energy in the [pi/2,pi] band and the integral of the reconstruction error.

We propose a new approach of even order QMF. Their design is based on the following specifications :

- the filters have to be unitary
- there will be perfect reconstruction of the DC component
- the bounded reconstruction error should be minimized
- the coding gain should be maximized

The optimization was based on a numerical method avoiding convergence on a local optimum.

For our simulations, we have used a fixed 8-taps Ho filter optimized for some typical sequences(Fig.1). Its coeffiecients are listed here below :

h(0)=0.0068359375=h(7)
h(1)=-0.0812988281=h(6)
h(2)=0.0908203125=h(5)
h(3)=0.483642578=h(4)

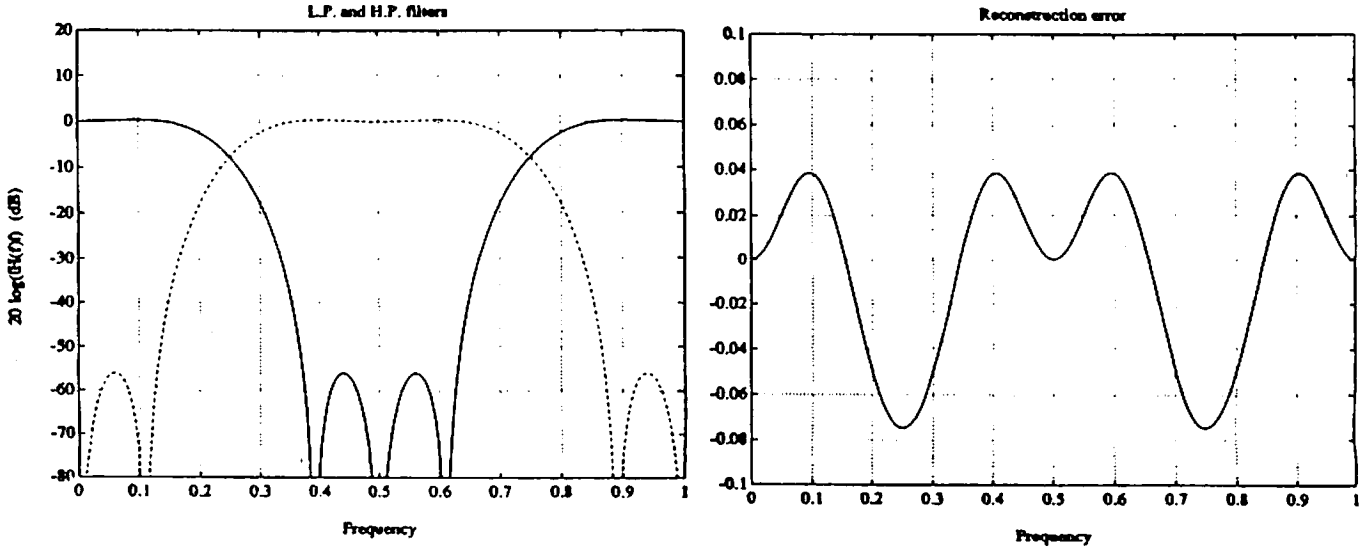
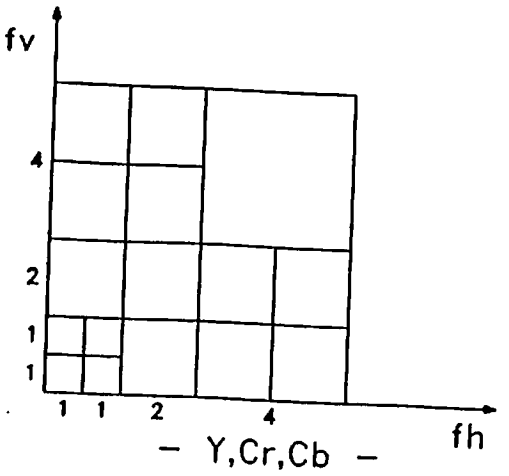


Figure 1: Signal adapted filter and reconstruction error for the 'Mobcal' sequence

7.2 Splitting :

The splitting is done hierarchically according to the following tree-structured scheme :



This splitting is done on both luminance and chrominance signals in the same way.

7.3 Organisation into blocks :

After the subband decomposition, the information is reorganised into 8x8 blocks.

The luminance input image, once transformed into progressive, is supposed to be divided into adjacent NxN blocks, N=8 for the Kurihama tests.

Each block of this input signal corresponds to one block in every subband whose size is divided according to the subsampling factor of the considered band :

- the first pass will correspond to subband-block size of 4x4
- the second pass will produce 2x2 subband-block size
- the third pass will produce 1x1 subband-block size

Finally, we obtain an 8x8 subband-block consisting of coefficients from every subband produced during the three passes.

8 QUANTIZATION

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

1. multiplication by a scaling factor,

2. linear quantization.

Each scaling factor is expressed in terms of 2**(-n/16) where n=nw+nq :

- nq is function of the transmission factor (deltahdi) coming from the buffer regulation. deltahdi is linearly related to the buffer occupancy; therefore the real quantization stepsize is increasing logarithmically according to the buffer occupancy.

- nw is the weighting factor; This factor depends on the distance of the observer from the screen, the sampling parameters of the picture, the decimation factor of the considered subband and the equivalent synthesis filter [ref.3]. It is then function of the subband order. The same factors are applied to intra and non-intra blocks, and either on chrominance or luminance blocks.

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

No variable thresholding or clipping is used.

0	10	22	22	37	37	37	37
0	19	22	22	37	37	37	37
4	4	31	31	37	37	37	37
4	4	31	31	37	37	37	37
13	13	13	13	46	46	46	46
13	13	13	13	46	46	46	46
13	13	13	13	46	46	46	46
13	13	13	13	46	46	46	46

Weighting factors

9 VARIABLE LENGTH CODING

9.1 CODING OF TRANSFORM COEFFICIENTS

Tansform coefficients are coded by the Universal Variable Length Coder (U-VLC) [ref. 4].

9.1.1 PRINCIPLE OF THE U-VLC.

The efficiency of the U-VLC is based on some elementary observations :

- the probability distribution function of transform coefficients is decreasing around zero with standard deviations decreasing with the coefficient scanning order;

- subband coefficients of a given order taken in successive blocks are uncorrelated. Thus it is possible to use adaptive codes, which calculate the coded data after some on line estimation of the statistics of 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.

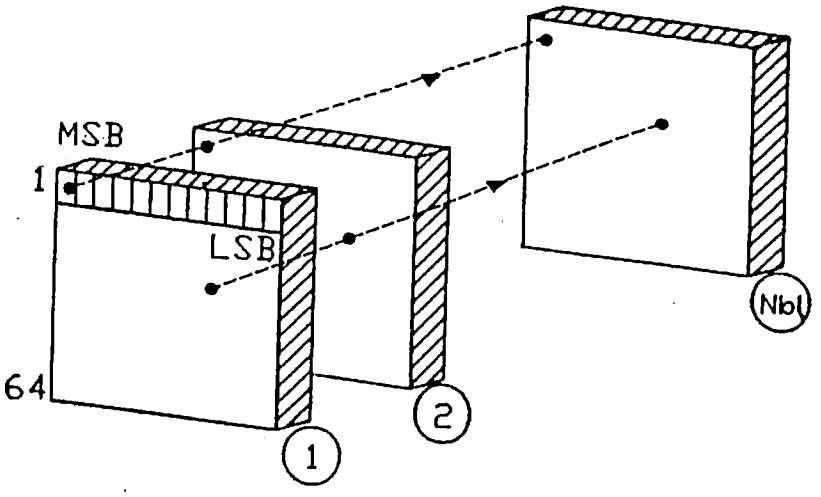


Figure 2: Information Organisation

- 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 as 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 U-VLC uses these properties by coding the positions of the MSNZB 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 90 blocks of transform coefficients of a slice into a two-dimensional table (64x90 coefficients of 12 bits) : this is the "reorganization step";

- encoding sequences of 90 subband coefficients of the same subband location 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".

9.1.2 The reorganization step :

The U-VLC processes groups of blocks of coefficients belonging to a slice; those blocks are grouped into a stack. A three-dimensional array of bits corresponds to such a stack; this array consists of :

```
.64 rows, corresponding to coefficients scanning orders,
.12 columns, corresponding to bits levels (MSB -> LSB)
.12x64 lines, made of the 90 bits of the same level,
belonging to bits of the same level, belonging to
the coefficients of the same subband location.
```

9.1.3 The skip step :

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 subband coefficients.

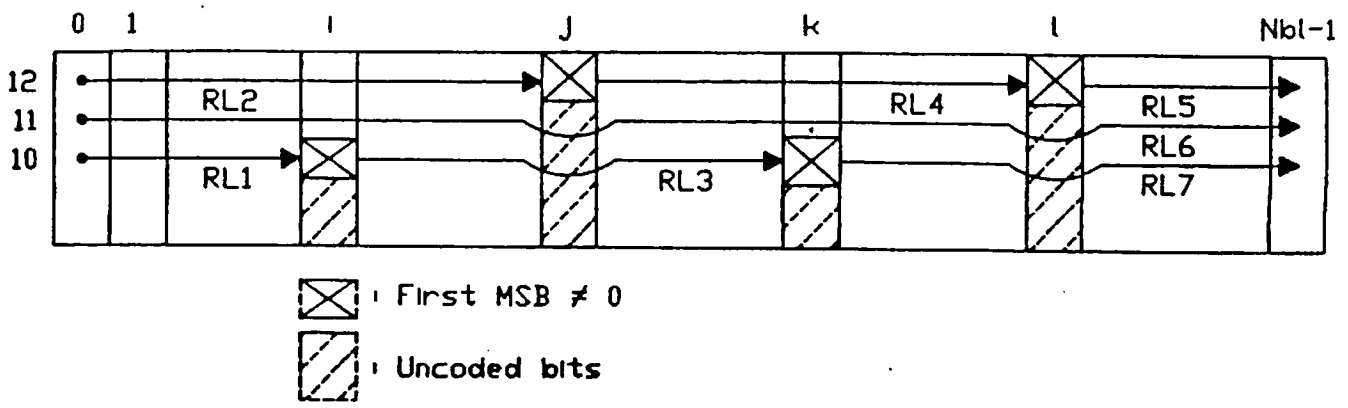


Figure 3: Skip coding

9.1.4 Principle of the MSNZB coding :

The adaptive truncated run-length coding (ATRL) proposed by Tanaka and Leon-Garcia [ref. 5] 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 subband 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
- 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.

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

Figure 4: Truncated run-lengths

9.2 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

10.1 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

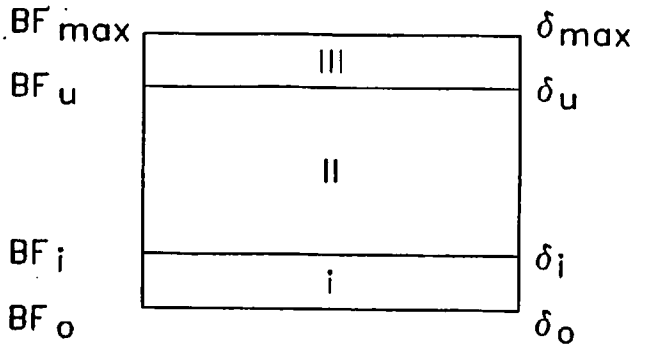
10.2 SLICE LAYER

The video framing at the slice layer consists of :

-Slice Start Code (SSC) [32 bits]
-Slice Number (SN) [7bits]
-Transmission Factor (deltahdi) [8bits]
-45 x MB types [45 bits]
-Motion vectors [VLC]
-Coded transform coefficients [VLC]

11 BUFFER EGULATION

The quantization level variations should be as slow as possible [ref.6].



The buffer is divided in three areas as illustrated on Figure 3. The middle one (II) is the normal area. The top and the bottom areas are reached during abnormal situations (extremely complex or extremely simple sequences).

The quantization parameter (δ) used in the normal area at any time is given by a linear relation with the buffer fullness delimitors BF_u and BF_l and is computed after each slice coding :

$$\delta = \delta_l + (BF - BF_l)\frac{\delta_u - \delta_l}{BF_u - BF_l}$$

The security areas are designed in order to avoid buffer overflow and underflow.

For the Kurihama tests, the coding starts with a buffer fullness of 10 % of its size. The buffer size corresponds to 200 ms. The quantization parameter is fixed for all the slices of an intra picture.

12 COMPATIBILITY FEATURE

Most of the Subband schemes are non-compatible but they all can be design for. We could switch between a DCT-MPEG1 coder and a Subband-MPEG2 coder for the compatible part of the signal. The described scheme can then be defined eather to be a simulcast or switchable scheme.

13 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.

14 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)

. frame "demerging" : 1 frame (40 msec) *[display buffer]*

15 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. 7]. 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 %.

16 CONCLUSION

The purpose of our work was to make a proposal that suits to the MPEG2 coding requirements.

The targets were both a good picture quality and a low hardware complexity.

The proposed scheme is frame based, includes a simple forward prediction loop with synthesis and analysis filters as key-elements for the multiresolution transform of the picture. This leads to very attractive decorrelative properties.

Finally, the U-VLC scheme on slice basis has an excellent cosing performance. When using U-VLC it is still possible to code hierarchically, the error sensitivity is comparable to Huffman codes and the complexity is only slightly higher. The real advantage of the univerality of the U-VLC is its efficiency in the coding of critical pictures, especially the intra mode ones.

17 REFERENCES

-1. P. Delsarte, B. Macq, D. T. Slock : "Efficient multiresolution signal coding via a signal-adapted perfect reconstruction filter pyramid", in Proc. Int. Conf. Acoust. Speech Signal Process., Toronto, 1991.

-2. CCIR recommendation : video codec for contribution applications at 34-45 Mbit/sec.

-3 L. Vandendorpe : "Hierarchical Coding of Digital Moving Pictures", Thesis, Oct.91, UCL

-4. B. Macq : "A universal entropy coder", PCS 90, Boston, pp. 12.1-1, 12.1-2.

-5. H. Tanaka and A. Leon Garcia : "Efficient run-length encodings", IEEE Trans. on Information Theory, vol IT-28,pp. 880-890, November 1982.

-6 Choffray J.P., Delogne P., Poncin O., Van Caillie B. : "Bit Rate Regulation for Digital Television Coding", PCS 90, Boston.

-7 RTT Belgium : "CLR and BER protection for enhanced end-to-end users QOS", CCITT SGVX - WPXV/1 AVC-69.

AVC-165

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

ISO/IEC JTC1/SC2/WG11
MPEG91/229
NOVEMBER 1991

SOURCE : Beatrice VAN CAILLIE (UCL)
TITLE : Algorithm description (proposal # 37)
PURPOSE : Information
SUBGROUP : Video

1 INTRODUCTION

This document gives a short description of the algorithm we propose for the Kurihama tests. This proposal is submitted by VAN CAILLIE (UCL), and has been developed in the framework of the European VADIS/COST collaboration. Its preregistration number is 37.

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 subband coding with motion compensation based on the previous picture.

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.

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

A subband decomposition is then applied on each (inter or intra) frame.

After reorganisation into 8x8 subband blocks, the frame is divided into 72 slices (collecting 8 video frame lines).

Each slice will consist in 90 blocks.

Each subband block is quantized using an adaptive quantizer and coded using the U-VLC.

ANNEX A : Coded Bit Stream Files

```
-rw-r-----  1 nobody    2779408 Oct 14 09:37 flower4
-rw-r-----  1 nobody    5680384 Oct 14 15:37 flower9
-rw-r-----  1 nobody    2863960 Oct 14 16:07 mobcal4
-rw-r-----  1 nobody    5680624 Oct 12 13:05 mobcal9
-rw-r-----  1 nobody    5743528 Oct 14 11:53 popple9
-rw-r-----  1 nobody    2580048 Oct 13 20:26 tabten4
-rw-r-----  1 nobody    5643008 Oct 12 18:42 tabten9
```

ANNEX B : Frame Based Statistics

SEQUENCE : table tennis
BIT RATE : 4Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	305536	17	14	30
2	554592	21	19	31
3	143328	21	18	30
4	149600	21	18	30
5	155392	21	18	30
6	195200	20	18	30
7	239136	19	16	29
8	175840	23	21	30
9	158304	23	21	30
10	179232	25	22	31
11	135776	24	22	30
12	155296	25	23	30
13	156128	25	23	30
14	157536	25	23	30
15	157248	25	23	30
16	156192	25	23	30
17	157632	25	23	30
18	163616	25	23	30
19	167392	25	23	30
20	191328	26	24	31
21	136864	26	23	30
22	159648	26	23	30
23	160896	25	23	29
24	159424	25	23	29
25	162112	25	23	29
26	162144	25	23	29
27	160544	25	23	29
28	160608	25	23	28
29	161248	24	22	28
30	235552	25	23	29
31	92192	22	20	26
32	159296	25	23	28
33	160416	25	23	28
34	159264	24	22	28
35	160320	24	22	28
36	160352	24	22	28
37	159616	24	22	28
38	160256	24	22	28

39	159328	24	22	28
40	246432	25	23	29
41	82112	22	20	26
42	158816	24	22	28
43	160096	24	22	28
44	161216	24	22	28
45	159488	24	22	28
46	160192	24	22	28
47	159488	23	22	27
48	159072	23	21	27
49	157504	23	21	27
50	260768	24	23	28
51	80544	21	19	25
52	157920	24	22	27
53	159040	24	22	27
54	175968	19	17	25
55	142912	21	19	27
56	126880	22	20	27
57	129056	22	20	27
58	136640	23	20	28
59	142688	23	21	28
60	270784	23	21	29
61	87872	24	21	29
62	124928	24	22	30
63	132928	25	22	30
64	137376	25	23	30
65	143776	25	23	30
66	149248	25	23	30
67	157024	25	23	30
68	159584	25	23	30
69	151136	25	23	30
70	272608	23	21	29
71	133504	24	22	30
72	126656	25	22	30
73	140032	25	23	30
74	144800	25	23	30
75	147136	26	23	30
76	150208	26	23	31
77	153184	26	24	31
78	154336	26	24	31
79	159776	26	24	31
80	271840	23	21	29
81	156160	25	22	30
82	131008	25	22	30
83	304352	21	19	28
84	125184	22	20	28
85	117088	23	20	28
86	135200	23	21	29
87	140448	23	21	29

88	144000	24	21	29
89	148288	24	21	29
90	274240	22	20	29
91	101824	23	21	30
92	134304	24	21	30
93	132640	24	22	30
94	142848	24	22	30
95	149088	25	22	30
96	150752	25	23	30
97	153120	25	23	30
98	169216	25	23	30
99	175520	25	23	30
100	274880	23	20	29
101	124896	23	21	30
102	147072	24	21	30
103	148128	24	21	30
104	162048	24	21	30
105	166432	24	21	30
106	168160	23	21	29
107	168416	23	21	29
108	166912	23	21	29
109	165408	23	20	29
110	269152	23	20	29
111	69536	22	20	29
112	135264	23	21	29
113	150240	23	21	29
114	171232	23	21	29
115	157120	23	20	29
116	146304	23	21	29
117	151872	23	21	29
118	167360	23	21	29
119	177280	23	20	29
120	302080	22	20	29
121	58240	19	16	28
122	165984	21	18	28
123	156416	22	19	28
124	159872	22	20	29
125	154848	22	20	29

==========

SEQUENCE : table tennis

BIT RATE : 9Mbit/s

==========

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	788128	23	21	31
2	681248	27	25	32
3	362880	26	23	32
4	352544	26	23	32
5	363200	26	23	31
6	465728	25	22	31
7	560544	22	20	31
8	374080	25	23	31
9	357344	25	23	31
10	441408	27	24	33
11	298784	26	23	32
12	316000	26	24	32
13	335648	27	24	32
14	343232	27	24	32
15	348064	27	25	32
16	348608	27	25	32
17	351680	27	25	32
18	361056	27	25	32
19	368000	27	25	32
20	438144	28	26	33
21	321888	28	25	32
22	340864	27	25	32
23	354048	27	25	31
24	352448	27	25	31
25	361920	27	25	31
26	362656	27	25	31
27	361472	27	25	31
28	362080	27	25	31
29	365312	27	25	31
30	512320	28	26	31
31	298304	27	25	31
32	322176	27	25	31
33	346656	27	25	30
34	353504	26	24	30
35	355264	26	24	30
36	357888	26	24	30
37	364096	26	24	30
38	358432	26	24	30
39	365440	26	24	30
40	534976	27	25	31

41	281024	26	24	30
42	318560	26	24	30
43	339616	26	24	30
44	353152	26	24	30
45	346528	26	24	30
46	352992	26	24	30
47	360864	26	24	29
48	360864	26	24	29
49	352896	26	24	29
50	559616	27	26	30
51	261248	26	24	29
52	296864	26	24	29
53	328832	26	24	29
54	550016	24	22	28
55	154976	24	22	28
56	248256	25	23	29
57	283168	25	23	29
58	306816	26	24	30
59	322016	26	24	30
60	566912	27	25	32
61	216608	27	25	32
62	285536	27	25	32
63	309344	28	26	32
64	321696	28	26	32
65	334944	28	26	32
66	349536	28	26	32
67	358368	28	26	32
68	366400	28	26	32
69	351136	28	26	32
70	573696	27	25	31
71	272096	27	25	32
72	302112	28	26	32
73	323008	28	26	33
74	335136	28	26	33
75	342368	29	26	33
76	351168	29	27	33
77	352768	29	27	33
78	354656	29	27	33
79	364064	29	27	33
80	569536	27	25	32
81	314304	28	25	32
82	307040	28	26	32
83	739360	26	23	30
84	198944	26	24	30
85	277344	26	24	30
86	310976	26	24	31
87	318912	27	25	31
88	335072	27	25	31
89	340256	27	25	31

90	595776	26	24	31
91	226720	27	24	31
92	306528	27	25	32
93	306016	28	26	32
94	327424	28	26	32
95	349920	28	26	32
96	347808	28	26	32
97	354304	28	26	32
98	379648	28	26	32
99	393536	28	26	32
100	595840	26	24	31
101	264704	27	24	31
102	334112	27	25	31
103	340000	27	25	31
104	370240	27	25	31
105	381312	27	25	31
106	380672	27	25	31
107	379520	27	24	31
108	376096	26	24	31
109	373088	26	24	31
110	587424	26	24	31
111	187072	26	23	31
112	285440	26	24	31
113	341952	27	25	31
114	401408	26	24	31
115	351872	26	24	31
116	325600	26	24	31
117	347168	27	24	31
118	376992	26	24	31
119	394944	26	24	31
120	633536	26	24	30
121	258560	25	22	30
122	332992	25	23	30
123	325408	25	23	30
124	340928	25	23	30
125	340480	26	23	30

SEQUENCE : mobcal
BIT RATE : 4Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	425344	20	18	26
2	448544	23	21	28
3	179744	23	20	27
4	169984	22	20	27
5	166496	22	20	27
6	167408	22	20	27
7	168992	21	20	27
8	169600	21	20	26
9	169168	21	20	26
10	457824	24	21	28
11	61376	24	20	27
12	174272	23	20	27
13	177744	23	20	27
14	173856	22	20	27
15	175264	22	20	26
16	175008	22	19	26
17	169504	22	20	26
18	168144	22	20	26
19	168320	22	20	26
20	457152	24	22	27
21	62064	23	21	26
22	178112	23	21	26
23	176816	23	21	26
24	172384	22	21	26
25	167954	22	21	26
26	164048	21	20	26
27	166992	21	20	26
28	165282	21	20	26
29	161378	20	20	26
30	458432	23	21	28
31	69394	23	21	27
32	173248	22	20	27
33	175672	22	20	26
34	172448	22	20	26
35	171280	22	20	26
36	176672	21	20	26
37	179632	21	19	26
38	170268	22	19	26
39	171456	21	19	26
40	423168	23	21	28

41	66624	20	18	26
42	171456	23	20	28
43	166112	22	20	27
44	171616	22	19	27
45	170528	21	19	27
46	174816	21	18	27
47	171584	20	18	26
48	167616	20	17	26
49	164832	20	18	26
50	425664	23	21	27
51	63360	19	18	26
52	200416	21	19	27
53	177504	19	17	26
54	164896	18	16	26
55	161920	18	15	25
56	160056	18	16	25
57	160408	18	16	25
58	160360	18	16	25
59	161216	18	15	25
60	483840	22	21	27
61	64496	20	19	26
62	172944	21	20	26
63	176496	21	19	26
64	171664	21	19	26
65	169808	21	19	26
66	167408	21	19	26
67	169552	21	18	26
68	168584	21	18	26
69	163920	21	19	26
70	435936	23	21	27
71	61504	20	18	26
72	192256	21	18	27
73	176224	20	17	26
74	162336	19	16	26
75	161216	18	16	26
76	160800	18	16	25
77	160192	18	16	25
78	160288	18	16	25
79	159876	19	16	25
80	435872	23	21	27
81	63152	21	18	26
82	183648	21	19	27
83	170400	21	18	27
84	177408	20	18	26
85	165984	20	17	26
86	163808	20	17	26
87	160224	19	17	26
88	158688	19	17	26
89	153072	20	18	26

90	379008	21	19	27
91	64608	19	17	26
92	160128	21	18	26
93	155424	21	18	26
94	156832	21	18	26
95	160608	22	19	27
96	162432	21	19	27
97	168224	21	19	26
98	170304	21	18	26
99	179264	20	18	26
100	597824	22	20	27
101	70976	23	20	27
102	199072	22	19	27
103	184256	21	18	26
104	174336	20	17	26
105	161856	19	17	26
106	161184	19	16	25
107	160896	18	16	25
108	160096	18	16	25
109	158296	19	16	26
110	565088	22	20	26
111	64512	19	16	26
112	162560	19	16	25
113	163840	18	16	25
114	160192	18	16	25
115	158624	19	16	25
116	157504	19	16	25
117	158208	19	17	25
118	159872	19	17	25
119	152832	20	18	26
120	559904	22	20	26
121	52064	20	18	26
122	171168	20	18	26
123	166240	20	18	26
124	164448	20	17	26
125	164384	20	17	26

SEQUENCE : mobcal
BIT RATE : 9Mbit/s

Fr. Number,Bit Count,Mean SNR,Lum. SNR,Chr. SNR

1	882016	25	23	29
2	683680	27	25	30
3	459008	25	23	29
4	419840	24	22	29
5	399104	24	21	28
6	389696	23	21	28
7	381408	23	20	28
8	376512	22	20	28
9	370272	22	20	27
10	845728	25	23	28
11	72480	20	17	28
12	263968	21	18	28
13	322176	21	19	27
14	351136	22	19	27
15	344320	22	19	27
16	361536	22	19	27
17	359168	22	19	27
18	358272	21	19	27
19	364064	21	19	27
20	845856	25	23	28
21	76832	19	16	27
22	268864	21	18	27
23	310016	21	19	27
24	341312	22	19	27
25	354848	22	19	27
26	353984	22	19	27
27	352992	22	20	27
28	358432	22	19	27
29	352192	22	19	27
30	847680	25	23	28
31	68736	19	17	27
32	260896	21	19	27
33	322464	21	19	27
34	342208	22	19	27
35	322624	22	20	27
36	327808	22	20	28
37	324384	23	21	28
38	336096	23	21	28
39	340960	23	21	28
40	833152	25	23	28

41	111360	23	20	28
42	214496	23	21	28
43	291904	24	22	28
44	333504	24	22	28
45	347232	24	22	28
46	363168	24	22	28
47	372192	24	22	28
48	379520	23	21	28
49	387456	23	21	28
50	837920	25	23	28
51	121568	20	18	28
52	292896	21	19	27
53	332032	21	19	27
54	358880	21	19	27
55	363648	21	19	27
56	369856	21	19	27
57	357856	21	19	26
58	352160	21	19	26
59	339872	21	19	26
60	851712	25	23	28
61	80064	19	16	27
62	272096	21	18	27
63	303840	21	19	27
64	346272	22	19	27
65	354720	22	19	27
66	357280	21	19	27
67	361408	21	19	27
68	368512	21	19	27
69	357152	21	19	27
70	850464	25	23	28
71	82080	19	17	27
72	271776	21	18	27
73	312544	21	19	27
74	336544	21	19	27
75	341248	22	19	27
76	358400	22	19	27
77	358048	22	19	27
78	353568	22	19	27
79	349920	22	19	27
80	852672	25	23	28
81	76448	20	18	27
82	255552	21	18	27
83	285152	22	19	27
84	322752	22	20	27
85	332544	23	20	27
86	350272	23	21	27
87	349728	23	21	27
88	342336	23	21	27
89	339680	23	21	28

90	841280	25	23	28
91	107232	22	20	28
92	237024	23	21	28
93	297248	23	21	28
94	318816	24	22	28
95	328096	24	22	28
96	336832	24	22	28
97	358560	24	22	28
98	372512	24	22	28
99	377984	24	22	28
100	841056	25	23	28
101	122656	22	20	28
102	276544	22	20	27
103	323904	22	20	27
104	348320	22	20	27
105	349120	22	20	27
106	361088	22	20	27
107	356928	22	20	27
108	362752	22	20	27
109	370432	22	20	27
110	857088	25	23	28
111	73152	19	17	27
112	288864	20	18	27
113	310560	21	19	27
114	334080	21	19	27
115	322688	22	19	27
116	323680	22	20	27
117	326656	22	20	27
118	348256	23	20	27
119	338496	23	21	27
120	855584	25	23	28
121	95424	22	19	28
122	235392	22	20	27
123	313536	22	20	27
124	331712	23	20	27
125	350496	23	21	27

SEQUENCE : flower
BIT RATE : 4Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	362816	23	21	25
2	544128	25	23	26
3	223296	23	21	26
4	162976	21	19	24
5	160160	20	18	24
6	159072	20	18	24
7	160160	20	18	24
8	161216	20	18	24
9	159328	20	18	24
10	341088	22	21	25
11	91424	21	19	25
12	160960	21	19	25
13	159840	21	19	25
14	160064	21	19	24
15	160352	21	19	24
16	160800	21	19	24
17	160064	21	19	24
18	160320	21	19	24
19	160192	21	19	24
20	349056	22	21	25
21	92480	21	19	25
22	160864	21	19	24
23	160192	21	19	24
24	160288	21	19	24
25	160768	21	19	24
26	159968	21	19	24
27	159584	21	19	24
28	160896	20	18	24
29	159616	20	18	24
30	352704	22	20	25
31	93504	21	19	25
32	159104	21	19	24
33	161024	21	19	24
34	160000	21	19	24
35	160192	21	19	24
36	161024	21	19	24
37	159808	21	19	24
38	159872	21	19	24
39	160224	20	19	24
40	354848	22	21	25

41	94720	20	18	24
42	158944	21	19	24
43	161824	20	18	24
44	160544	20	18	24
45	159936	20	18	24
46	160288	20	18	24
47	158720	20	18	24
48	160960	19	17	23
49	160032	19	17	23
50	358272	22	20	25
51	92864	21	19	24
52	162176	21	19	24
53	161184	20	18	24
54	159744	20	18	24
55	159296	20	18	24
56	159680	20	18	24
57	160192	20	18	24
58	159936	20	18	24
59	159328	20	18	23
60	353280	22	20	25
61	91840	21	19	24
62	160960	21	19	24
63	161152	21	20	24
64	160032	21	20	24
65	161920	21	19	24
66	159360	21	19	24
67	160544	21	19	24
68	160640	21	19	24
69	159808	21	19	24
70	359840	22	20	25
71	94240	20	19	24
72	160864	21	19	24
73	160640	21	19	24
74	159744	21	19	24
75	160320	21	19	24
76	159232	21	19	24
77	160640	20	18	24
78	160000	20	18	24
79	159648	20	18	24
80	361664	22	20	25
81	93120	20	18	24
82	160416	21	19	24
83	160384	21	19	24
84	161664	20	18	24
85	160832	20	18	23
86	159680	20	18	23
87	158656	20	18	24
88	160096	20	18	24
89	160928	20	18	23

90	355008	22	20	25
91	95360	20	17	24
92	160448	20	18	24
93	159360	20	18	24
94	160480	20	18	23
95	160288	19	17	23
96	159648	19	17	23
97	158720	20	18	23
98	159232	20	18	23
99	162048	20	18	23
100	361696	22	20	25
101	91872	20	18	24
102	162208	20	18	24
103	159520	20	19	24
104	161408	20	18	24
105	160736	20	18	23
106	160128	19	17	23
107	160032	19	17	23
108	160928	19	17	23
109	160352	19	17	23
110	363680	22	20	25
111	93056	20	17	24
112	161984	20	17	24
113	159264	20	18	24
114	160032	20	18	24
115	159456	20	18	24
116	160576	20	19	24
117	158976	21	19	24
118	161184	20	19	24
119	160032	20	18	23
120	368480	22	21	25
121	91936	21	19	24
122	162688	20	18	24
123	159808	20	18	24
124	158432	21	19	24
125	161152	20	19	24

SEQUENCE : flower
BIT RATE : 9Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	756864	25	24	27
2	234556	22	20	25
3	345666	22	20	25
4	367834	22	20	25
5	358582	23	20	25
6	369824	23	21	25
7	373732	23	21	26
8	376626	23	21	26
9	379868	23	21	26
10	742534	25	23	27
11	198282	21	19	25
12	297912	22	20	25
13	324336	22	20	25
14	332498	22	20	25
15	338282	23	21	25
16	347928	23	21	25
17	351322	24	22	25
18	358784	24	22	25
19	362256	24	22	25
20	768224	27	26	28
21	237648	25	24	27
22	485568	26	24	28
23	415488	25	23	27
24	414432	24	23	27
25	401568	24	22	26
26	356288	24	22	26
27	355200	24	22	26
28	398208	23	22	26
29	417136	25	24	27
30	775552	27	26	28
31	297552	25	24	27
32	470400	26	24	27
33	451264	24	23	27
34	407040	24	22	26
35	366592	24	22	26
36	370784	24	22	26
37	360928	24	22	26
38	368288	24	22	26
39	340240	24	22	26
40	745504	25	24	27

41	235040	23	21	26
42	308128	23	21	26
43	374336	23	21	26
44	358752	23	21	26
45	354976	23	21	26
46	357600	23	21	25
47	344064	23	21	25
48	384064	22	21	25
49	379900	22	21	25
50	754080	25	24	27
51	148000	22	20	26
52	296902	23	20	26
53	358004	23	21	26
54	362964	23	21	26
55	368580	23	21	26
56	364404	24	21	26
57	370028	24	22	25
58	373980	24	22	25
59	379814	24	22	25
60	780352	25	24	27
61	825568	27	26	28
62	474688	26	25	28
63	415520	25	24	27
64	397088	25	23	27
65	403648	24	23	27
66	386496	24	23	26
67	396416	24	23	26
68	361632	24	23	26
69	358824	24	23	26
70	758176	25	24	27
71	172864	22	20	26
72	309984	23	21	25
73	356976	23	21	25
74	359820	23	21	25
75	362560	23	21	25
76	366992	23	21	25
77	371002	23	21	25
78	375344	23	21	25
79	358904	24	21	25
80	756122	25	23	27
81	217710	23	21	25
82	347152	23	21	25
83	351280	23	21	25
84	356744	23	21	25
85	360856	23	21	25
86	363272	23	21	25
87	369296	23	21	25
88	365560	24	21	25
89	362384	24	22	26

90	732704	26	26	27
91	197584	24	23	27
92	385536	24	23	26
93	393712	23	22	26
94	401232	23	21	26
95	394240	22	21	25
96	366592	22	20	25
97	339776	22	20	25
98	337824	22	21	25
99	331264	22	21	25
100	718400	24	23	26
101	183840	22	20	25
102	324576	22	21	25
103	327040	23	21	25
104	357920	23	21	25
105	376096	23	21	25
106	363264	22	20	25
107	358976	22	20	25
108	378464	22	20	25
109	372736	23	21	25
110	723392	24	23	26
109	181472	21	19	25
111	312736	22	20	25
112	327424	22	20	25
113	310336	22	20	25
114	330176	22	21	25
115	337568	23	21	25
116	340672	23	21	26
117	353312	23	21	26
118	365120	23	22	25
119	368816	23	21	25
120	726784	25	23	26
121	173984	22	21	26
122	341600	23	21	25
123	337888	23	21	25
124	317184	23	21	25
125	359552	23	22	25

SEQUENCE : popple
BIT RATE : 9Mbit/s

Fr. Number	Bit Count	Mean SNR	Lum. SNR	Chr. SNR
1	589760	26	24	29
2	800992	30	28	33
3	449600	28	26	31
4	412800	27	25	30
5	391200	27	25	30
6	380320	26	24	30
7	374176	26	24	29
8	369344	26	24	29
9	363264	26	24	29
10	561184	26	24	30
11	257664	25	23	29
12	316224	26	24	29
13	333024	26	24	29
14	343776	26	24	29
15	352928	26	24	29
16	355424	26	24	29
17	352768	26	24	29
18	357184	26	24	29
19	359168	26	24	29
20	563232	26	24	29
21	257184	25	23	29
22	313888	26	24	29
23	338720	26	24	29
24	347296	26	24	29
25	351136	26	24	29
26	355104	26	24	29
27	359360	26	24	29
28	361696	26	24	29
29	362784	26	24	29
30	566400	26	24	30
31	256096	25	23	29
32	317600	26	24	29
33	339008	26	24	29
34	348480	26	24	29
35	354528	26	24	29
36	353344	26	24	29
37	355360	26	24	29
38	360736	26	24	29
39	362496	26	24	29

40	561984	26	24	30
41	252032	25	23	29
42	315840	26	24	29
43	345568	26	24	29
44	364992	26	24	29
45	371712	26	24	29
46	366080	25	23	29
47	353056	25	23	29
48	369184	25	23	29
49	431296	25	23	29
50	559584	26	24	30
51	311264	24	22	29
52	326912	24	22	28
53	345312	24	22	28
54	351424	24	22	28
55	357440	24	22	28
56	362400	24	22	28
57	360896	24	22	28
58	356000	24	22	28
59	359584	24	22	28
60	546944	27	25	30
61	349984	26	24	29
62	329376	26	24	29
63	336896	26	24	29
64	390368	25	24	28
65	371328	25	23	28
66	355360	25	23	28
67	354848	25	23	28
68	357408	25	23	28
69	361536	26	24	28
70	448928	27	26	30
71	296480	26	24	28
72	348448	26	24	28
73	350112	26	24	28
74	350880	25	24	28
75	354624	25	24	28
76	354656	25	24	28
77	357728	25	24	28
78	354400	25	24	28
79	364704	25	24	28
80	447712	27	26	29
81	294656	26	24	28
82	356128	25	24	28
83	368320	25	24	27
84	372480	25	23	27
85	380320	24	23	26
86	386400	24	22	26
87	385952	24	22	26
88	383552	23	22	26

89	331008	23	22	25
90	556576	27	25	29
91	272288	24	22	26
92	371072	23	21	25
93	355392	22	21	25
94	361152	22	21	24
95	371840	22	20	24
96	368128	22	20	24
97	373344	21	20	24
98	379200	21	20	24
99	379976	21	21	25
100	457504	24	24	24
101	297504	23	23	24
102	367222	23	23	24
103	372854	23	23	24
104	376988	22	22	24
105	380762	22	22	24
106	386544	22	22	24
107	386674	22	22	23
108	384200	22	21	23
109	387580	21	21	23
110	553422	25	24	28
111	273986	24	25	27
112	335866	24	25	27
113	364432	23	25	27
114	368478	23	25	27
115	372628	24	25	27
116	375598	23	25	27
117	379042	23	25	27
118	372260	23	25	26
119	374352	23	25	26
120	472480	24	22	28
121	288560	23	22	27
122	381872	23	22	27
123	379184	22	21	25
124	376288	22	20	24
125	373296	21	20	23

ANNEX C : 0.4 second Based Statistics

```
==================================================
SEQUENCE : table tennis
BIT RATE :   4Mbit/s
==================================================
:
Fr. Number,Cum. Bit Count
-------------------------

        10          2256160
        20          3854304
        30          5513344
        40          7130816
        50          8749568
        60         10272000
        70         11788480
        80         13369952
        90         15045920
       100         16630112
       110         18316736
       120         19945024
       125         20640384


==================================================
SEQUENCE : table tennis
BIT RATE :   9Mbit/s
==================================================


Fr. Number,Cum. Bit Count
-------------------------

        10          4747104
        20          8256320
        30         11951328
        40         15608064
        50         19234176
        60         22553280
        70         26020544
        80         29587456
        90         33325440
       100         36913184
       110         40700352
       120         44346336
       125         45944704
```

SEQUENCE : mobcal
BIT RATE : 4Mbit/s

Fr. Number	Cum. Bit Count
10	2523104
20	4423744
30	6297206
40	8180444
50	10031292
60	11925268
70	13786076
80	15616640
90	17392032
100	19367680
110	21363736
120	23261744
125	23980048

SEQUENCE : mobcal
BIT RATE : 9Mbit/s

Fr. Number	Cum. Bit Count
10	5207264
20	8850240
30	12467392
40	15946720
50	19585472
60	23325952
70	26977760
80	30594560
90	34090304
100	37665664
110	41394496
120	44916512
125	46243072

SEQUENCE : flower
BIT RATE : 4Mbit/s

Fr. Number	Cum. Bit Count
10	2434240
20	4157312
30	5884672
40	7614272
50	9348512
60	11076192
70	12812288
80	14549280
90	16280064
100	18017344
110	19758208
120	21501248
125	22235264

SEQUENCE : flower
BIT RATE : 9Mbit/s

Fr. Number	Cum. Bit Count
10	6212448
20	10020512
30	15754560
40	19794592
50	24008160
60	28071904
70	33497472
80	37153472
90	40922560
100	44573312
110	48294336
120	51931776
125	53376384

SEQUENCE : popple
BIT RATE : 9Mbit/s

Fr. Number	Cum. Bit Count
10	4692640
20	8284032
30	11897600
40	15507232
50	19236676
60	22914752
70	26570784
80	30150528
90	33965920
100	37655816
110	41549566
120	45238688
125	47037888

ANNEX D : Sequence Average Based Statistics

SEQUENCE : table tennis
BIT RATE : 4Mbit/s

Global overhead	:	0.2 Mbit/s
Lum. Counter	:	3.2 Mbit/s
Chrom. Counter	:	0.7 Mbit/s
TOTAL	:	4.1 Mbit/s
Overhead (excl. MV)	:	0.1 Mbit/s
MV Counter	:	0.1 Mbit/s

SEQUENCE : table tennis
BIT RATE : 9Mbit/s

Global overhead	:	0.2 Mbit/s
Lum. Counter	:	7.2 Mbit/s
Chrom. Counter	:	1.8 Mbit/s
TOTAL	:	9.2 Mbit/s
Overhead (excl. MV)	:	0.1 Mbit/s
MV Counter	:	0.1 Mbit/s

SEQUENCE : mobcal
BIT RATE : 4Mbit/s

Global overhead	:	0.2 Mbit/s
Lum. Counter	:	3.3 Mbit/s
Chrom. Counter	:	0.6 Mbit/s
TOTAL	:	4.1 Mbit/s
Overhead (excl. MV)	:	0.1 Mbit/s
MV Counter	:	0.1 Mbit/s

```
=====================================================
SEQUENCE : mobcal
BIT RATE :   9Mbit/s
=====================================================

  Global overhead      :  0.2 Mbit/s
  Lum. Counter         :  7.8 Mbit/s
  Chrom. Counter       :  1.3 Mbit/s
  ---------------------------------
  TOTAL                :  9.2 Mbit/s

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


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

  Global overhead      :  0.2 Mbit/s
  Lum. Counter         :  3.8 Mbit/s
  Chrom. Counter       :  0.4 Mbit/s
  ---------------------------------
  TOTAL                :  4.4 Mbit/s

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


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

  Global overhead      :  0.2 Mbit/s
  Lum. Counter         :  7.4 Mbit/s
  Chrom. Counter       :  1.6 Mbit/s
  ---------------------------------
  TOTAL                :  9.2 Mbit/s

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



```
=====================================================
SEQUENCE : popple
BIT RATE :   9Mbit/s
=====================================================

  Global overhead      :  0.3 Mbit/s
  Lum. Counter         :  7.0 Mbit/s
  Chrom. Counter       :  1.8 Mbit/s
  ---------------------------------
  TOTAL                :  9.1 Mbit/s

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