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CODING OF MOVING PICTURES AND ASSOCIATED AUDIO INFORMATION

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Title : Proposal Package Description for MPEG Phase 2

Purpose: This document describes the proposed MPEG Phase 2 (MPEG-2) video coding algorithm demonstrated at the preselection test in the WG11/MPEG meeting in Kurihama in November 1991

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1. Description of the Algorithm

1.1. Overview

The coding algorithm that has been developed in MPEG Phase 1 (MPEG-1) has proved to be very efficient in a wide range of bit-rates and picture sizes ranging from S.I.F. to HDTV, provided that :

- The number of bits per luminance pel is 0.4 bits or more
- The pel aspect ratio is close to square

MPEG Phase 2 (MPEG-2) must cover all the aspects that have not been covered by MPEG-1, such as coding of interlaced video, and all the transmission aspects such as error robustness, switchable bit-rate, multichannel transmission, etc... This can be achieved in the framework of the MPEG-1 algorithm.

The proposed MPEG-2 algorithm is therefore based on MPEG-1, and in order to demonstrate the claimed performance of the MPEG-1 algorithm at higher bit-rates, legal MPEG-1 bit-stream syntax has been used for the Kurihama test.

The *format* of the coded bit-streams and the *decoding process*, up to — and not including — post-processing, *is totally compliant* with MPEG-1 as approved in Santa Clara in August 91, and, therefore, will *not* be described in this document (see MPEG-1 CD for details).

However, the proposal uses a different pre- and post-processing designed to handle interlaced source material. The method used is usually referred to as *frame coding*, by opposition to *field coding*. It is described in section 1.2.2.

1.2. Pre-processing and Post-processing Functions

The pre-processing function takes as input a source material, and produces a series of *pictures* for input to the encoder.

The post-processing function takes as input a series of *pictures* output by the decoder, and produces the appropriate signal for display on a particular device.

Two specific types of source material have very different characteristics, and are handled differently by the pre- and post-processing functions: *interlaced* material (e.g. video), and *progressive* material (e.g. movie).

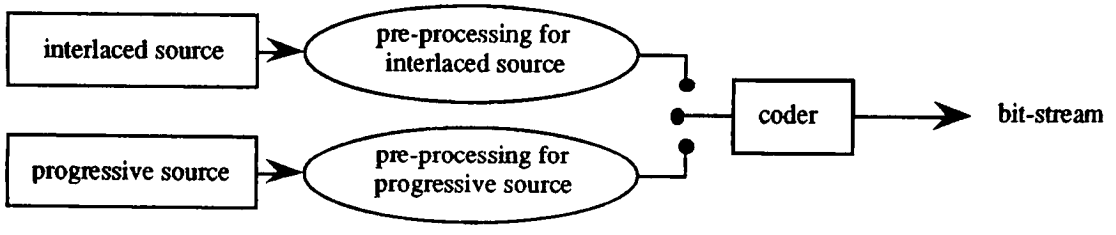

Figure 1 Pre-processing

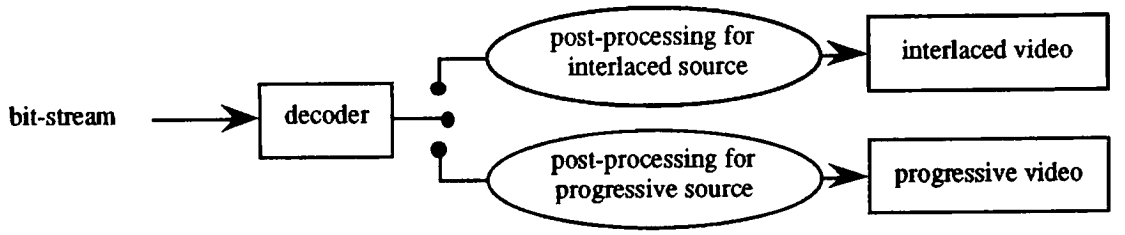

Figure 2 Post-processing

To explain how the pre- and post-processing functions have been adapted to handle interlaced video, we must describe what we mean by *picture*. The term *picture*, in the sense of MPEG-1, can be understood at two levels:

- A logical level: a *picture* is a set of three rectangular matrixes (Y, Cr, Cb) of eight-bit numbers, the Y-matrix having an even number of rows and columns, and the Cr and Cb matrixes being one half the size of the Y-matrix in both horizontal and vertical direction.
- A semantic level: a *picture* is a set of samples of luminance and chrominance that correspond to an image, with a precise spatial and temporal location of the samples.

Only the first level is necessary to understand the decoding process. The second level is necessary to know how to display *pictures*, and is therefore related to the pre- and post-processing functions only.

In MPEG-1, the semantic level of the *picture*, as described in MPEG-1, section 1.6.4., was intended for non-interlaced (i.e. progressive) video format (see MPEG-1 , section 1.1.), and is indeed not suitable for interlaced video.

In order to achieve good performance with interlaced source material, a different semantics is defined for *pictures*. The MPEG-1 semantics of *pictures* is used only when the source material is progressive. In both cases (interlaced and progressive sources), *pictures* have the same logical format and are processed in identical manner by the encoder and the decoder.

1. Progressive Source Material

When the source material is progressive (e.g. movie), all samples in the image have the same temporal location.

In this case, *pictures* in the sense of MPEG-1 are obtained by a spatial sampling of each source image, the position of the samples being described in section 1.6.4. of MPEG-1 CD.

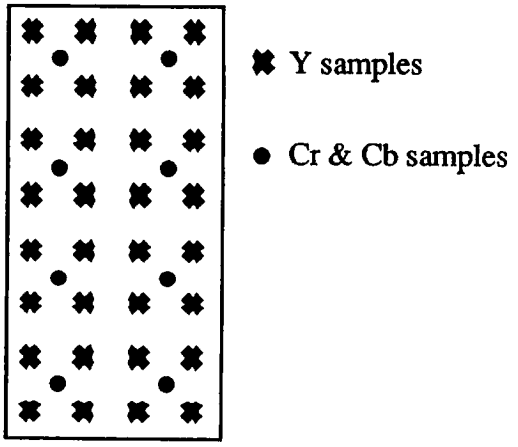

Figure 3-a Picture Format (Progressive Source)

1.2.2 Interlaced Source Material

When the source material is interlaced (e.g. video), we have fields already sampled vertically, and in which the sample vertical positions are shifted down by 1/2 sampling interval (or one scan line) every other field, in order to match the positions scanned by an interlaced display.

In this case, the pre-processing consists of building *pictures* (frames) by merging two consecutive fields. The samples in the *picture* are from two successive temporal locations.

Post-processing is used to reconstruct the two fields from the decoded *picture*.

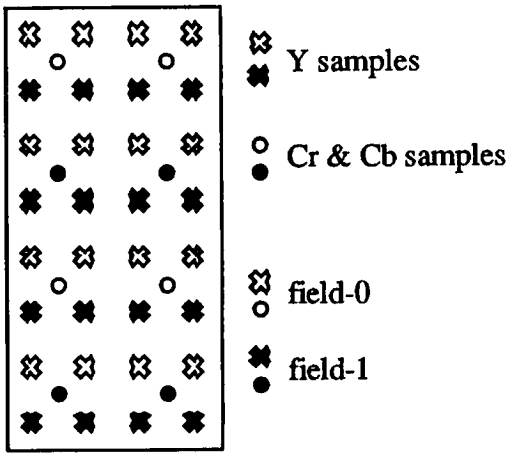

Figure 3-b Picture Format (Interlaced Source)

This method is usually referred to as *frame coding*, by opposition to the *field coding* method in which each *picture* would correspond to only one source field.

The Y-matrix of the *picture* is formed of luminance samples from the two fields 0 and 1: the even lines correspond to field-0 (the first to be displayed), and odd lines correspond to field 1 (the second to be displayed).

The Cr and Cb matrixes of the *picture* are also formed of luminance samples from field-0 and field-1: the even lines of the matrixes correspond to field-0, and odd lines correspond to field-1.

Note that, according to Figure 3-b, the vertical positions of the chroma samples of field-0 correspond almost to every other *odd* vertical positions of luma samples of field-0, and the vertical positions of the chroma samples of field-1 correspond almost to every other *even* vertical positions of luma samples of field-1.

Because of this observation, simple *odd* and *even* filters can be used in pre-processing to decimate vertically the chrominance in each field (cf. section 7).

The sequence header contains additional information to identify the type of post-processing that must be applied. In order to keep total compliance with MPEG-1 bit-stream syntax, this additional information is currently located in the sequence user data. It should normally be in the *sequence extension data* (currently undefined).

2. Decoder

As stated previously, the proposed MPEG-2 decoder is *fully compliant* with MPEG-1. *No additional feature* is added. The only functional difference between the proposed decoder and an MPEG-1 decoder is the ability to decode higher bit-rates and to handle larger *pictures*.

Figure 4 is a simplified block-diagram of an MPEG-1 decoder. A description of the implementation of such a decoder is given in section 9 (Implementation)..

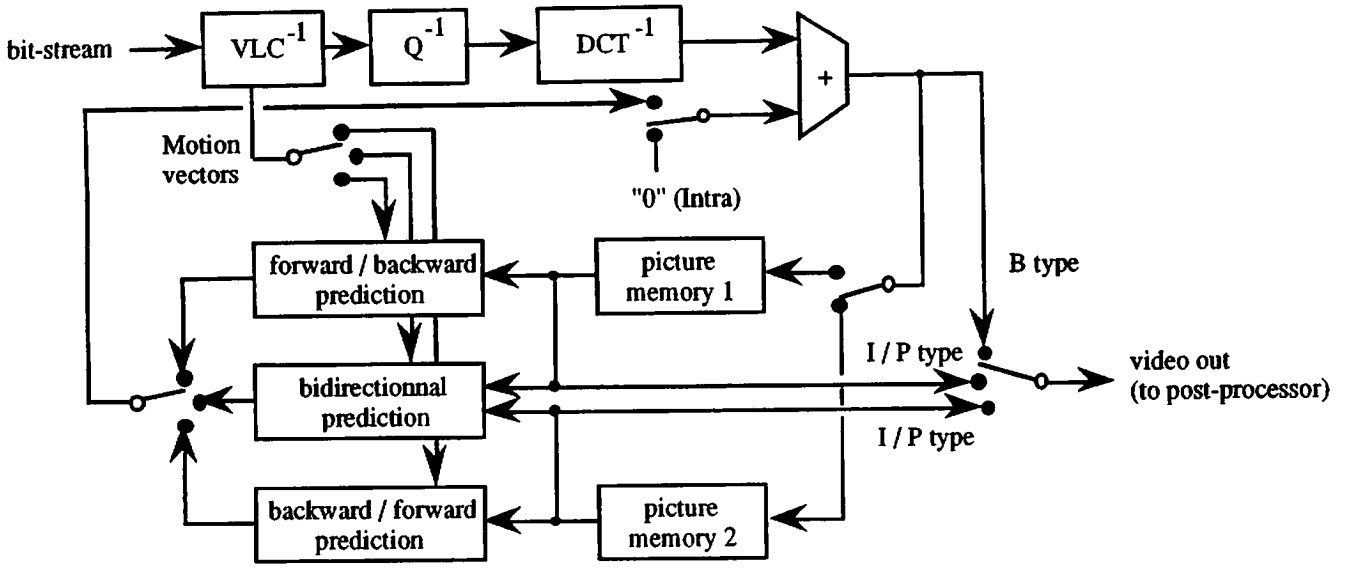

Figure 4 MPEG-1 decoder (simplified block diagram)

3. Compatibility Feature

Upward compatibility and *forward compatibility* are always guaranteed because the proposal is fully compliant with MPEG-1.

Downward compatibility and *backward compatibility* can be easily achieved by simulcast. A more complex method to achieve such compatibility uses layered coding, also submitted to MPEG-2. The performance of the methods at different bit-rate allocations should be subject to evaluation by MPEG.

Simulcast of S.I.F. and CCIR-601 at respectively 1.5 and 7.5 Mbit/s, for a total bit-rate of 9 Mbit/s, will be demonstrated at Kurihama.

4. Random Access Feature

As in MPEG-1, random access is achieved by the periodic introduction of Intra-coded pictures. The total delay after random access also depends on the decoding delay (see next section).

The appropriate interval separating Intra-coded pictures in the bit-stream is application-dependent. In the case of TV broadcasting, Intra pictures must be very frequent in order to have a fast random access decoding delay and to recover from transmission errors.

In the test sequences coded for the Kurihama test, the interval separating Intra-coded pictures is 9 frames at 25 Hz, and 12 frames at 30 Hz.

5. Coding/decoding Delay

As in MPEG-1, the coding/decoding delay depends directly on :

- The number of consecutive Bidirectionaly-coded frames between two Intra or Predictive-coded frames (M). This number is application-dependent.
- The size of the VBV buffer, i.e. the minimum decoder buffer size.
- The various other delays (pre-processing, motion estimation, encoding).

The delay due to pre-processing, motion estimation, and the other operations performed during the process of encoding a picture are quite difficult to estimate, because they may vary according to the implementation (pipeline etc...), but it seems reasonable to consider that these operations will not produce more than 1 picture-period delay.

The minimum delay for conversational services is achieved by having no Bidirectionaly-coded pictures at all (M = 1), and a very small VBV buffer size. In such a case, the minimum coding/decoding delay is the sum of the decoding delay (about 0.5 picture-period), and the VBV buffering delay (about 3.5 picture-periods). Picture quality with these parameters will be demonstrated in Kurihama.

In case of distribution or TV broadcast, the encoding/decoding delay only affects the random access time.

In the test sequences coded for subjective quality assessment in Kurihama, there are two consecutive Bidirectionaly-coded frames between two Intra or Predictive-coded frames (M = 3), and the size of the VBV corresponds to 1/4 of a second at the corresponding bit-rate. This corresponds to a coding/decoding delay of about 330 ms.

6. Repetition of Coding-Decoding

As recommended in the Proposal Package Description for MPEG-2 (MPEG91/100), we have simulated repetition of coding-decoding process. We will demonstrate that the quality of the Table Tennis sequence after five repeated coding-decoding process is not significantly lower than after just one coding-decoding process. For this experiment, we have used 7.5 Mbit/s.

7. Fast Forward and Fast Reverse

During the fast forward and fast reverse performance, intra coded pictures are read from the DSM and subsequently decoded. To code an intra picture requires up to 3 times the amount of bits which is on average available for each picture. To read an intra coded picture from the DSM requires therefore reading data which is read in normal play forward during up to 3 picture periods.

In the demonstration of the fast forward and fast reverse performance it has been assumed that the Digital Storage Medium is read with the same bit-rate at which the sequence has been coded. As a consequence it requires up to 3 picture periods to read an intra coded picture. The time to search for an intra coded picture at the DSM is neglected.

During reading of an intra coded picture, the previously read and decoded picture is displayed. In case of interlaced video input material coded at a picture rate of 50 Hz or 60 Hz, the two fields from a picture are from two successive temporal locations. To display such picture during 3 picture periods results in motion

artefacts. In order to avoid such artefacts, only the first field from the picture is used for display. In that case both fields from the displayed picture are interpolated from the first field of the intra coded picture, using vertical interpolation filters for the two fields of (3/4 1/4), respectively (1/4 3/4). In case of non-interlaced input material e.g. from film on 24 Hz or 25 Hz, the intra coded picture is displayed normally.

The fast forward and fast reverse performance is demonstrated by reading and decoding each intra coded picture, i.e. each 9th picture in case of 50 Hz and each 12th picture in case of 60 Hz. As each intra coded picture is displayed during 3 picture periods, the resulting speed equals three, respectively four times normal speed. By skipping over intra coded pictures, higher speeds can be achieved. Available options are 3*N times normal speed in case of 50 Hz and 4*N times normal speed in case of 60 Hz.

8. Transport and Error Concealment

A cell-relay based approach which can be used for reliable transport of MPEG video data has been developed, and will be described in a separate document. Associated error concealment procedures will also be outlined in the same document.

To be responsive to the Test and Requirements group's desire to see error performance, a bit-stream conforming in both the syntax and semantics of this proposal was passed through a end-to-end simulation of a communications system example. The transport format used in this example is a packet-oriented approach consisting of three distinct sublayers: "data link level", "adaptation level" and "video service level". This data format is based on a cell relay asynchronous time division multiplexing concept similar to that being considered for the CCITT broadband ISDN/ATM standard. (Note that while the example is ATM-like, it is not strictly ATM compatible or designed for the BISDN.)

MPEG video bit-streams are transported in the form of a series of fixed length 128 byte cells, each containing 120 video data bytes and a one-byte synchronization header, a one-byte data-link sublayer header, a four-byte adaptation level header and two-byte cyclic redundancy check (CRC) code for error detection. The data-link header contains generic transport information such as priority indicator, service ID and sequence number to support priority layering, service multiplexing and resequencing.

An MPEG-specific adaptation sublayer has been designed to permit rapid decoder logic resynchronization after error events that result in the loss of one or more cells. Adaptation headers contain information fields which aid error recovery at the video decoder; for MPEG encoded video, these fields include frame type indicators, slice/macroblock IDs and reentry pointers needed to support segmentation, chaining and error control in variable length coded video.

The video service sublayer contains highly service-specific information (e.g., key MPEG parameters), providing a high-level resynchronization mechanism needed for decoder recovery from certain severe error events.

A variety of error concealment approaches may be used as a receiver option in conjunction with the above transport format to limit the effect of packet losses. The transport protocol supports the use of High and Low priority bit-streams, to allow for the possibility of partitioning the MPEG video into subjectively important high and less important low priority data types when appropriate transmission facilities are available.

Demonstration tapes showing MPEG transport and error concealment performance at some relevant cell loss rates are available.

9. Encoder

This section presents an overview of the structure of the *encoder* that has been used for the Kurihama test.

The encoder is fully automatic, and is designed to quickly adapt to any source material in order to achieve highest quality. **No special tuning** has been done neither for any specific sequence, nor for any specific bit-rate.

The encoder takes *pictures* from the output of the pre-processor, and produces a coded bit-stream that is fully compliant with the MPEG-1 syntax.

It contains 6 major functional blocs :

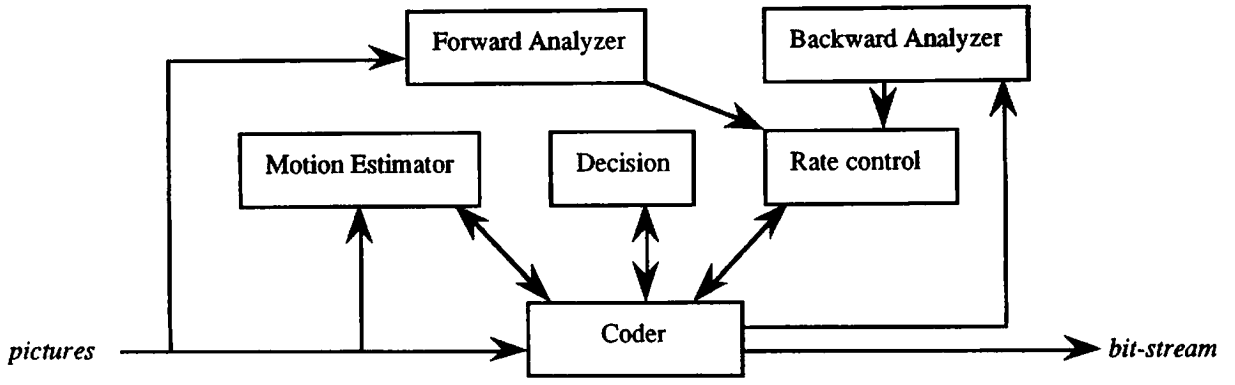

Figure 5 Encoder

9.1. Motion Estimator

The *motion estimator* performs a half-pel accuracy motion vector search for each macro-block.

9.2. Decision

The purpose of the *decision* is :

- To choose the most suitable mode (Intra, Forward, Backward, Interpolated) for each macroblock.
- To eliminate random motion vectors that may occur in flat areas.

9.3. Forward Analyzer

The *forward analyzer* performs a global analysis of the next picture to encode. Results of the analysis are used by the *rate control.*

9.4. Backward Analyzer

The *backward analyzer* observes the result of the encoding of each picture, and provides a feedback to the *rate control.*

9.5. Rate Control

The *rate control* decides what quantizer factor is suitable for each macroblock. The quantizer factor is used as a tool to control the global amount of bits generated by each picture, and to improve the subjective quality of each picture.

9.6. Coder

The *coder* takes no decision. It handles all the other tasks of an encoder, including half-pel interpolation, DCT, inv. DCT, quantizer, dequantizer, zigzag scanning, run-length coding, VLC code generation etc...

10. Kurihama Test

This section describes precisely the pre- and post-processing and the various application-dependent coding parameters used for the test sequences demonstrated in Kurihama (M, N, VBV buffer size etc...). In the proposed MPEG-2 video coding algorithm, all the values indicated correspond to application-dependent parameters.

10.1. Pre-processing

The test sequences demonstrated in Kurihama being interlaced video, pre-processing is of interlaced type and produces *pictures* (frames) as described in section 1.2.2. Pre-processing steps are the following :

- CCIR-601 fields extracted from CCIR-601 frame (field-0 and field-1).
- Luminance samples slightly filtered (horizontal filter only).
- Chrominance horizontally resampled and vertically decimated (conversion from 4:2:2 to 4:2:0).
- *Picture fields* (*field-0* and *field-1*) merged to create a *picture*.

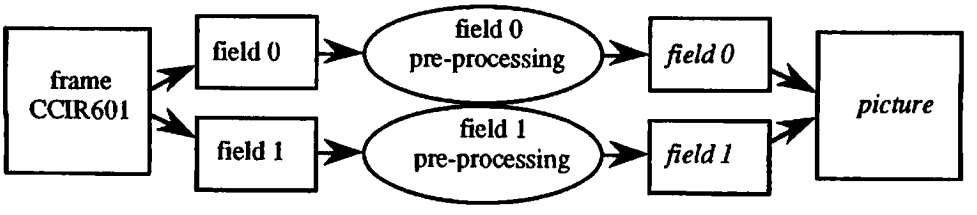

Figure 6 Interlaced Pre-processing

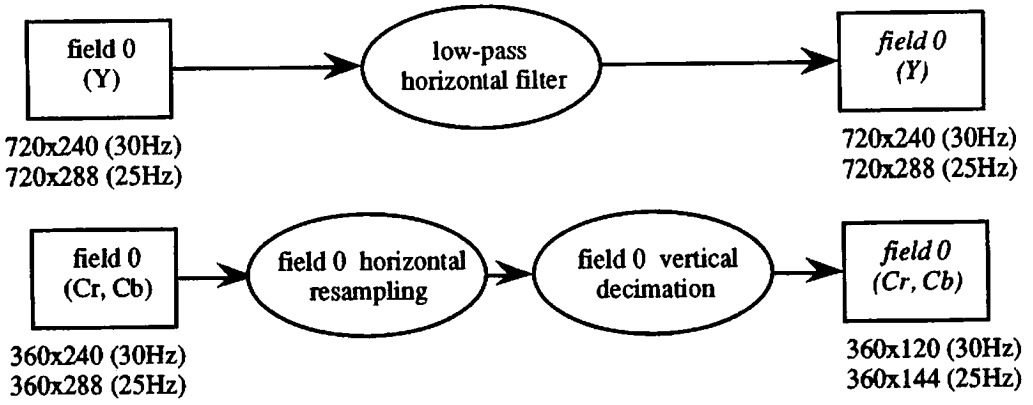

Figure 7 Field-0 Pre-processing

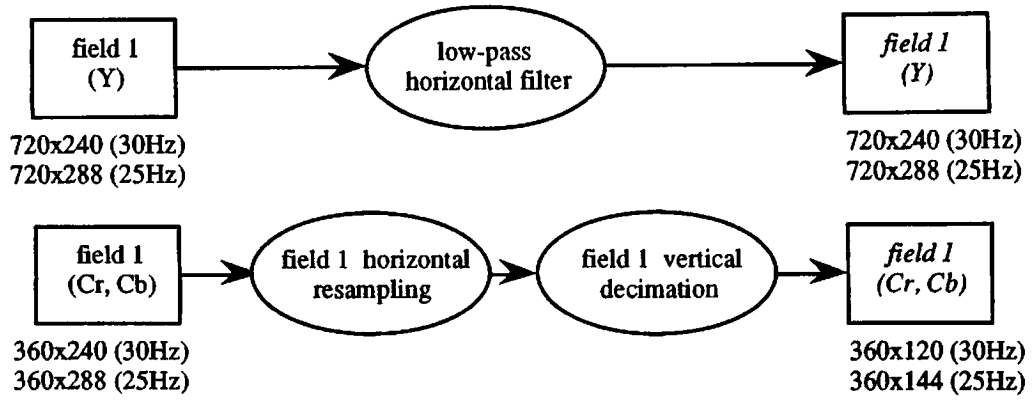

Figure 8 Field-1 Pre-processing

10.1.1 Luminance Pre-processing

A 3-tap horizontal low-pass filter is used : [1 6 1] / 8

10.1.2 Chrominance Pre-processing

Horizontal resampling is not performed (see further note).
A 7-tap vertical filter is used to decimate field-0 :[-29 0 88 138 88 0 -29] / 256.
A 4-tap vertical filter is used to decimate field-1 :[1 7 7 1] / 16.
This filter introduces a phase-shift of pi.

Note : This simple pre-processing does not produce chroma sample *exactly* at the spatial location specified in section 1.2.2. However the phase shift in the chroma, resulting of these simple pre- and post-processing operations, is very small in regard with the chroma resolution and therefore not noticeable.

10.2. Post-processing

The test sequences demonstrated in Kurihama being interlaced video, post-processing is of interlaced type and produces interlaced video (CCIR-601 format) from *interlaced pictures* as described in section 1.2.2. Post-processing steps are the following :

- *Picture fields* (*field-0* and *field-1*) extracted from *picture*.
- Luminance samples are unchanged.
- Chrominance vertically interpolated (conversion from 4:2:0 to 4:2:2 CCIR-601 fields).
- CCIR-601 fields merged to get a CCIR-601 frame.

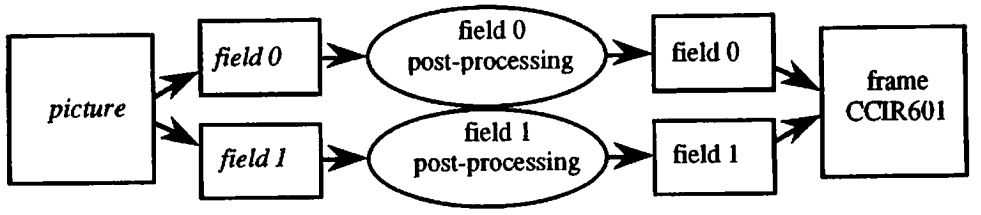

Figure 9 Interlaced Post-processing

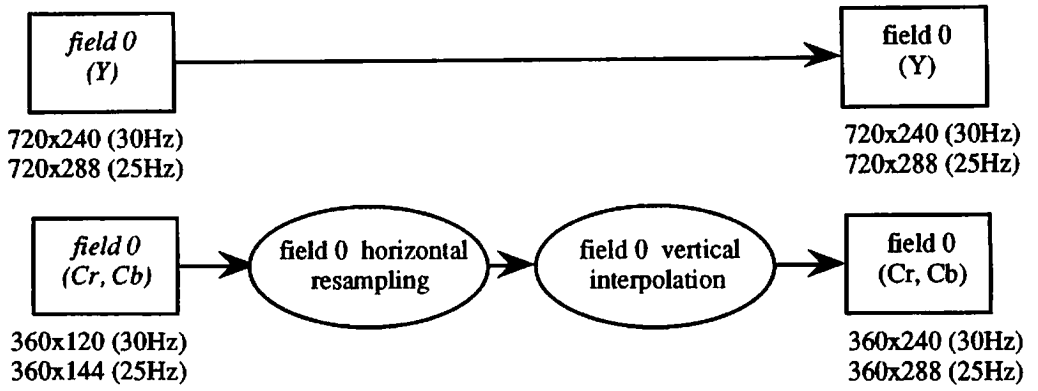

Figure 10 Field-0 Post-processing

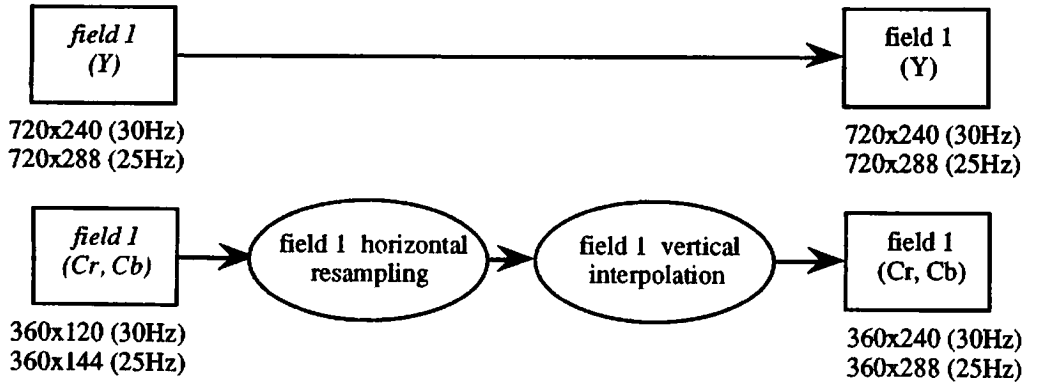

Figure 11 Field-1 Post-processing

10.2.1 Luminance Post-processing

Luminance samples of each *field* are copied directly to the corresponding CCIR-601 field.

10.2.2 Chrominance Post-processing

Horizontal resampling of chroma is not performed, for simplicity reasons (see further note).

Vertical interpolation is done differently in field-0 and field-1, because of the different locations of the chroma samples (see Figure 3-b).

In field-0, chroma samples of even lines are copied from chroma samples of *field-0*. Chroma samples of odd lines are obtained by interpolating chroma samples of *field-0* with a 2-tap filter : [1 1] / 2. This filter introduces a phase-shift of pi, necessary to reconstruct chroma sample at their correct vertical location in CCIR-601 frames.

In field-1, chroma samples of even lines are obtained by interpolating chroma samples of *field-1* with a 2-tap filter : [1 3] / 4, and chroma samples of odd lines are obtained by interpolating chroma samples of *field-1* with the 2-tap filter : [3 1] / 4. These 2 filters introduce a phase-shift of approximately 3/4 pi, necessary to reconstruct chroma sample at their correct vertical location in CCIR-601 frames.

Note : This simple post-processing, when applied to *pictures* (as specified in section 1.2.2.) does not produce chroma sample *exactly* at the spatial location specified in CCIR-601. However the phase shift in the chroma, resulting of these simple pre- and post-processing operations, is very small in regard with the actual chroma resolution and therefore not noticeable.

10.3. Coding Parameters

GOP[1] structure is characterized by the following values :

PAL/NTSC	picture rate	M	N
NTSC	30 Hz	3	12
PAL	25 Hz	3	9

Motion vector search (1/2 pel accuracy) has been performed according to the following table:

picture distance	range	f
1	± 16 pels	2
2	± 32 pels	4
3	± 48 pels	8

The VBV[2] buffer size is equivalent to 1/4 of a second at the used bit-rate. For example, to decode a 9 Mbit/s, the proposed decoder needs about 2.25 Mbit of bit-stream buffer.

[1] GOP = Group Of Pictures, Cf MPEG-1 Draft.

[2] VBV = Video Buffer Verifier. Cf MPEG-1 Draft.

The following quantizer weighting matrixes are used :

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

Intra

16	17	18	19	20	21	22	23
17	18	19	20	21	22	23	24
18	19	20	21	22	23	24	25
19	20	21	22	23	24	26	27
20	21	22	23	25	26	27	28
21	22	23	24	26	27	28	30
22	23	24	26	27	28	30	31
23	24	25	27	28	30	31	33

Non-Intra

11. Implementation

11.1. Purpose

The purpose of this implementation study is to produce a vehicle for establishing the relative complexity of the proposed MPEG-2 algorithm. This implementation study is based on the MPEG document 90/115: Paper design for SM1[1]. This document does not represent optimized designs. However, it is a useful tool for exposing implementation issues.

It must be noted that, since this MPEG-2 proposal is totally compliant with MPEG-1 standard, the hardware complexity is identical to MPEG-1 implementation, except for Memory size and processing speed, which are 4 times higher.

11.2. Decoder

As shown on figure 11, the decoder is composed of seven basic parts: the External Memory, the Memory Interface, the Symbol Decoder, the Parser, the Inverse Transform unit, the Motion Compensation unit and the Post-Processing unit.

11.2.1 External memory

The external memory is the central resource for the storage of predictor frames, the displayed frame and input bit stream.

It is necessary to have storage for two predictor frames to be able to reconstruct B-frames (M>1). To support interlaced display, it is also necessary to store half a reconstructed B-frame. Table 1 shows that at least 12.88 Mbits of external memory is necessary for 60 Hz sequences and 14.95 Mbits for 50 Hz. To be practical, 16 Mbit external memory is used for the decoder. This gives some room to save ancillary data. It also allows to support 3/2 pull down for film sequences with 60 Hz display.

If M is restricted to 1, it is necessary to have external memory to store only a little more than one predictor frame and the input bit stream. In this case the external memory could be implemented in 8 Mbits.

11.2.2 Memory Interface

Because of the economics of Dynamic memory technology, only the use of commodity DRAM parts was considered reasonable for this implementation study. Page mode memory cycles and large data bus (64 bits) are assumed to achieve necessary memory bandwidth. To optimize page mode cycles, burst access with internal FIFOs are assumed. Most of the internal FIFOs work in toggle mode. As soon as the FIFO is half full (write to memory) or empty (read from memory), a memory access is requested. The access has to be served before the second half of the FIFO is respectively full or empty. This allows the processing unit linked to the FIFO to have a constant processing clock.

As shown in the table 1, the maximum memory bandwidth is around 620 Mbit/s. With a 64 bit data bus, it is possible to use standard DRAM if the memory accesses are based on page mode of at least 4 cycles. A

[1] SM1 = Simulation Model 1 (MPEG-1)

possible implementation is to use four 4 Mbit DRAM chips with 256Kx16 data organization and 80 nsec access time.

11.2.3 Bit stream

It is assumed for this study that the decoder accepts a coded input data stream at a maximum fixed rate of 10 Mbit/s. Since the number of bits allocated to each frame varies, while the output frame rate is constant, the decoder must buffer the input data so that an entire frame can be read and decoded in a single frame time. The proposed encoder assumes that the input buffer is equal to the number of bits received in 1/4 of second i.e. 2.5 Mbits for a bit rate of 10 Mbit/s. This input buffer is saved in the external memory. A small internal FIFO of 2*256 bits is used to optimize writes of the input data stream.

To decode a bit stream, a Start Code detector is necessary to start the input buffer update. This detection could be managed by firmware.

11.2.4 Symbol Decoder

The Symbol Decoder reads the input bit stream from the DRAM buffer and translates VLC or FLC coded symbols to their corresponding values. The translated value (a token) is then passed to the Parser and Inverse Transform unit for further processing. A small internal FIFO of 2*256 bits is used to optimize the bit stream read.

Since the symbols are 100% compatible with MPEG-1, the Symbol Decoder has the same complexity than existing MPEG-1 implementation. However, in order to support worst case real time processing, this unit is able to process 20 MVLC/s.

11.2.5 Parser

The Parser works in conjunction with the Symbol Decoder to parse the bit stream. By examining the tokens, and applying the MPEG-1 syntax, the Parser determines what kind of symbol is expected next, and tells the Symbol Decoder the size of the next FLC or which table to use for the next VLC symbol translation.

The Parser digests and interprets all side information tokens. From macro block address tokens, it computes the current macro block address. From block type tokens, it determines the coding mode of a given block and directs the motion compensation unit to apply the appropriate motion compensation mode. It also computes the current motion vector from motion vector data tokens. A micro-coded state machine with a minimum of 2 Kbits of ROM was studied for implementation of the Parser.

11.2.6 Inverse Transform unit

The Inverse Transform unit digests run coded coefficients from the VLD unit. It inverts the quantization, zigzag and DCT transform of the coefficients to produce an 8x8 block in the spatial domain.

Two 64x8 bit tables are used for downloadable quantization weighing. The Inverse transform unit performs two multiply operations per component for inverse quantization and 3 multiply accumulate with four adds per component for inverse DCT.

11.2.7 The Motion Compensation

The Motion Compensation unit generates the predictor block for an inter-coded block. It reads the necessary pixels from frames stored in the external memory, performs the necessary filtering computations for half pixel motion compensation and interpolates blocks for bi-directional blocks. The resulting predictor block is then added to the transformed block to produce a reconstructed 8x8 block which is written back to the external memory.

The worst case computation occurs with B-frames. Two internal FIFOs of 2*360 bits are used to optimize reads of frame predictors. The half pixel filter requires an internal FIFO of 162 bits and 4 adds (two 8 bits, two 9 bits) per sample. The interpolation requires an 8 bit add. Another 8 bits add is necessary to reconstruct every sample. An internal 2*256 bit FIFO is used to optimize writes of the reconstructed picture in the external memory.

11.2.8 Post-processing

In order to display interlaced pictures, a display buffer of at least half a frame is necessary in the external memory. The Post-processing unit reads back the reconstructed fields from the external memory and vertically interpolates the chrominance samples to output CCIR-601 fields. The interpolation uses a 2-tap filter as explained in paragraph 8.2.2.

Two internal FIFOs of 2080 bits are necessary for post-processing as well as 2 adds (one 8 bits and one 9 bits) per chrominance sample. To avoid these large FIFO, it is possible to access twice the external memory. However, this will increase the total external memory bandwidth by 4.15 Mbit/s. Three additional FIFOs of respectively 512, 256 and 256 bits are necessary for Y, U and V display output.

The Post-processing unit produces CCIR-601 output at an average rate of 165.9 Mbit/s and at a peak rate of 216 Mbit/s.

The decoder block diagram (figure 11) that follows shows the overall organization of these units and major computational and memory bandwidths. The diagram is followed by a more detailed derivation of the memory and processing bandwidth (table 1). For the most part, bandwidths were computed by counting the number of operations or transfers per pixel component and multiplying by the component rate. A component is defined as a byte in either a luminance or chrominance block.

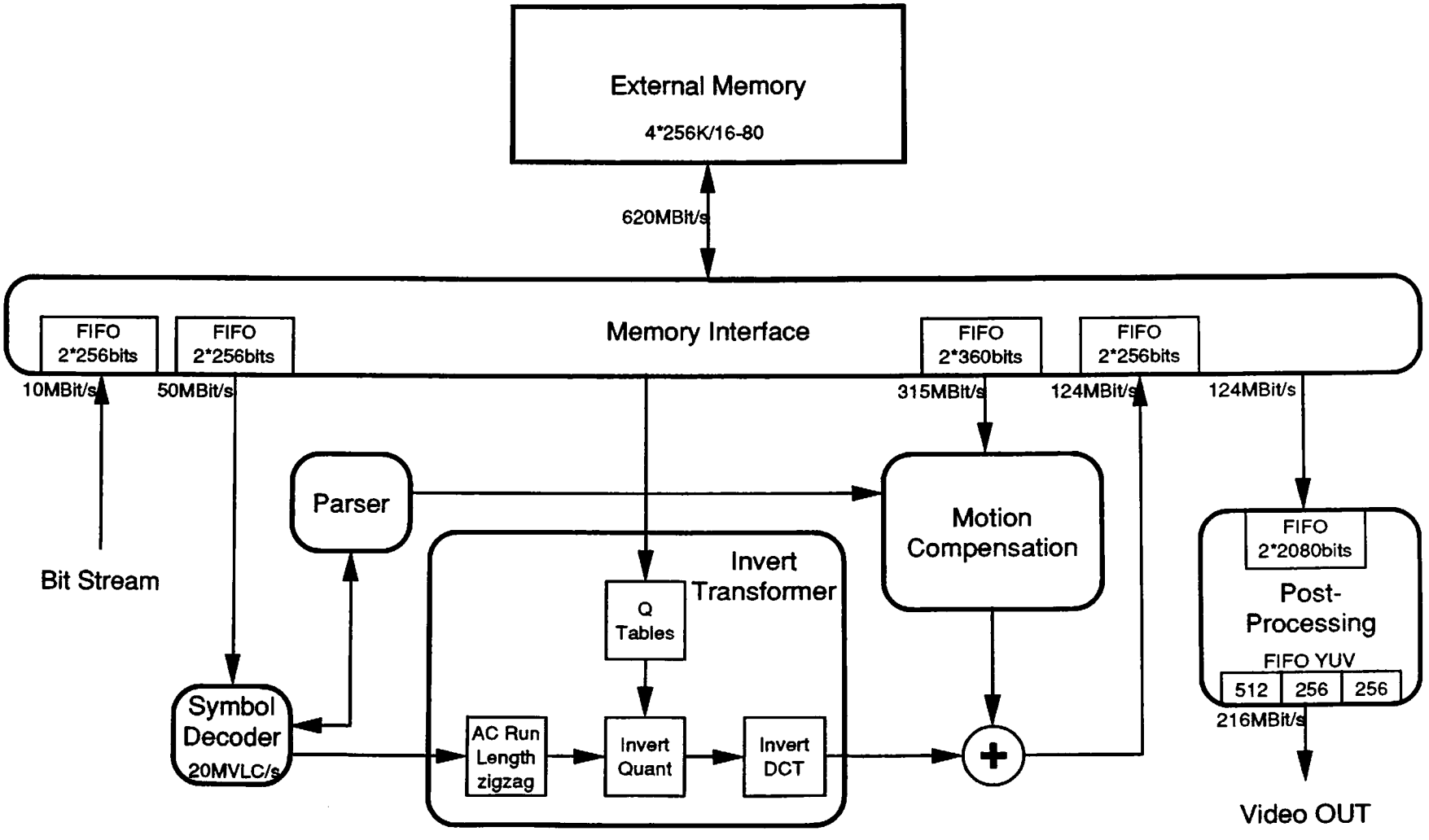

Figure 11: Decoder Block Diagram

Table 1: Decoder

Memory Size

	NTSC	PAL	unit
Picture size	4.15	4.98	Mbit
Bit stream buffer size	2.50	2.50	Mbit
External Memory size M>1	**12.87**	**14.94**	**Mbit**
External Memory size M=1	6.70	7.53	Mbit

Memory Bandwidth

Transfer Operations	Intra	Predicted	Bi-direct	unit
Predictor frame read	0.00	10.13	20.25	Bit/component
Predictor frame write	8.00	8.00	8.00	Bit/component
Display frame read	8.00	8.00	8.00	Bit/component
Bit stream write	0.33	0.33	0.33	Mbit/frame
Bit stream read (worst case)	1.67	0.67	0.33	Mbit/frame

Bandwidth	Intra	Predicted	Bi-direct	unit
Predictor frame read	0.00	157.46	314.93	MBit/sec
Predictor frame write	124.42	124.42	124.42	MBit/sec
Display frame read (peak)	162.00	162.00	162.00	MBit/sec
Bit stream write	10.00	10.00	10.00	MBit/sec
Bit stream read (worst case)	50.00	20.00	10.00	MBit/sec
Total External Memory bandwidth	**346.42**	**473.88**	**621.34**	**MBit/sec**

Computations Bandwidth

Operations/components	Intra	Predicted	Bi-direct	unit
Inverse Quantization	2.00	2.00	2.00	Multiply
Inverse DCT	3.00	3.00	3.00	MAC
Inverse DCT	4.00	4.00	4.00	Add
Half pixel filter	0.00	2.00	4.00	Add
Interpolation	0.00	0.00	1.00	Add
Addition for Inter-blocks	0.00	1.00	1.00	Add
Chrominance Post-processing	2.00	2.00	2.00	Add

Worst case computation bandwidth	Intra	Predicted	Bi-direct	unit (MOP/sec)
Inverse Quantization	31.10	31.10	31.10	Multiply
DCT	46.66	46.66	46.66	MAC
DCT	62.21	62.21	62.21	Add
Half pixel filter	0.00	31.10	62.21	Add
Interpolation	0.00	0.00	15.55	Add
Addition for Inter-blocks	0.00	15.55	15.55	Add
Chrominance Post-processing	20.74	20.74	20.74	Add

11.3. Encoder

The encoder can support various implementation. Compromises have to be made between memory bandwidth, processing power, size of FIFOs, performances and integration.

As shown on figure 12, the encoder consists of 7 basic parts: the Pre-processor, the Motion Estimation unit, the Decision unit, the Coder, the External Memory, the Memory interface and the Rate Control.

11.3.1 Pre-processor

This unit receives CCIR-601 fields at an average bandwidth of 165.9 Mbit/s and a peak bandwidth of 216 Mbit/s. The chrominance samples are vertically decimated, as explained in paragraph 8.1.2. The decimation uses a 4-tap filter (the 7-tap filter used in the simulation is not really necessary). The fields are then merged together. The resulting pictures are then sorted to be in the MPEG-1 process order. This order depends on M. For example, if M=3:

Incoming frames:	0	1	2	3	4	5	6	7	8	9
Process order:	0	-1	-2	3	1	2	6	4	5	9

This unit needs to store half a frame in the external memory to merge the fields and M-1 frames to reorder the pictures. It also needs two FIFOs of 17280 bits for the Chrominance decimation and three adds per chrominance sample.

11.3.2 Motion Estimation

The Motion Estimation Unit contains two basic parts. The first part is the integer Motion estimation block that computes an integer search out of a 16x16 block. The maximum search range in the simulation is 48 integer pixels. Different implementations are possible:

- Full search gives the best results. This requires 96 billion absolute difference operations per second. However with the appropriate FIFOs, it needs a very low memory bandwidth
- Telescopic search requires only 21 billion operations per second but with a very high memory bandwidth
- Coarse searches with successive refinement could also be considered

With two FIFOs of 645 Kbits the peak bandwidth required for full search methods is 166 Mbit/s.

When the best block is found, the 18x18 block around the best match is forwarded to the second part, the half pixel motion estimation.

The 1/2 PEL/interpolate Unit performs the necessary filtering and MAE[1] operations for the half PEL search on the 18x18 block passed from the integer ME block. It also computes the final value for the predictor of inter-coded block.

[1] MAE = Mean Absolute Error

11.3.3 Decision

This unit receives the best match vector set for the Motion Estimation unit and performs a Motion Compensation decision a la SM3[1]. MSEs[2] are computed on luminance macro-blocks for Forward, Backward, Bi-Directional and no MC modes. However, to optimize the hardware implementation, the decision could be done on the MAE generated by the Motion Estimation unit. In this case it is only necessary to compute the MAE for the bi-directional predictor. The intra/non-intra decision is based on a proprietary algorithm which uses 6 adds per luminance sample.

This unit selects for the coder the type of macroblock and the Motion Compensation vector set.

11.3.4 Coder

The coder encodes the data based on the information it receives from the decision unit. It consists of the following processing elements:

- Prediction:

  The prediction consists of the predictor pictures (two for B-frames) saved in the external memory, the half pixel filter and the interpolation adder for Bi-directional predictor. The predictor implementation was already described in the decoder.

  FIFOs are used to optimize the external memory access. They buffer the predictors during the Motion compensation decision.

- DCT:

  process 8*8 blocks with an average of 15.5 Msample/s

- Quantization adjustment:

  To support MPEG-1 double escape limitation, it is necessary to check that the DCT coefficients will not be bigger than +/-255 after quantization. A simple comparison is performed on the first 5 DCT coefficients and the quantizer value (the number of coefficients to test is based on statistics). This unit forces the quantizer value to 4 if necessary (1.2 Mcomparison/s).

- Quantization:

  Two tables of 64*16 bits are used to download the weighing matrices. Two multiplications per coefficient are necessary.

- Invert Quantization: Same as decoder

- Invert DCT: Same as decoder

- Predictor reconstruction:

  In order to optimize memory access, the predictor block is saved in a FIFO to be added to the output of the Invert DCT. The size of this FIFO depends on the total delay for the coding loop.

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1 SM3 = Simulation Model 3 (MPEG-1)

2 MSE = Mean Square Error

- VLC Coder

  The VLC coder performs the final run and VLC coding on the quantized coefficients. Coded data from the VLC coder is multiplexed with symbols from the Side Information Coder to form the final bit stream. The VLC coder requires 32 Kbits of ROM to store the translations of all coefficient VLC codes.

  The Side information coder encodes side information symbols, such as motion vector data, coded block pattern and macroblock type. A microcoded implementation of this unit was studied by the MPEG committee. Its complexity is similar to the one of the parser in the decoder.

11.3.5 External Memory

As in the decoder, the External Memory and Memory interface is the central memory resource for frame storage and coded data buffering. If we assume that M=3, the External Memory will consist at minimum of one incoming picture field, two predictor frames and one bit stream output buffer with the same size as the decoder input buffer.

11.3.6 Rate Control

Finally, the Rate Control Unit provides overall control of the quantization units. This unit will determine the optimum quantization level in order to guarantee the correct bit rate, avoid buffer underflow or overflow and provide the best subjective quality. To do so, it analyzes the buffer fullness as well as overall image quality and keeps track of previous image coding parameters.

The Rate Control is implemented in firmware. However, it uses specific data like the overall image quality. These data are processed with 41 MMul/s and 52 MAdd/s.

The proposed algorithm is 100 % automatic with no manual intervention and no training pass. The only parameters defined for the simulations were: M, N, bit rate, picture resolution, interlace type.

Like the decoder section, a block diagram (figure 13) and bandwidth calculation (table 2) summary follows.

11.4. Encoder complexity

It is possible to have encoders with different complexities. The simplest and cheapest one will be based on M=N=1. This M=N=1 encoder only supports Intra frames. There is no Motion Estimation and no Decision. The quality will not be as good as N>1 and/or M>1, however, this could be of interest for specific applications like real time recorders.

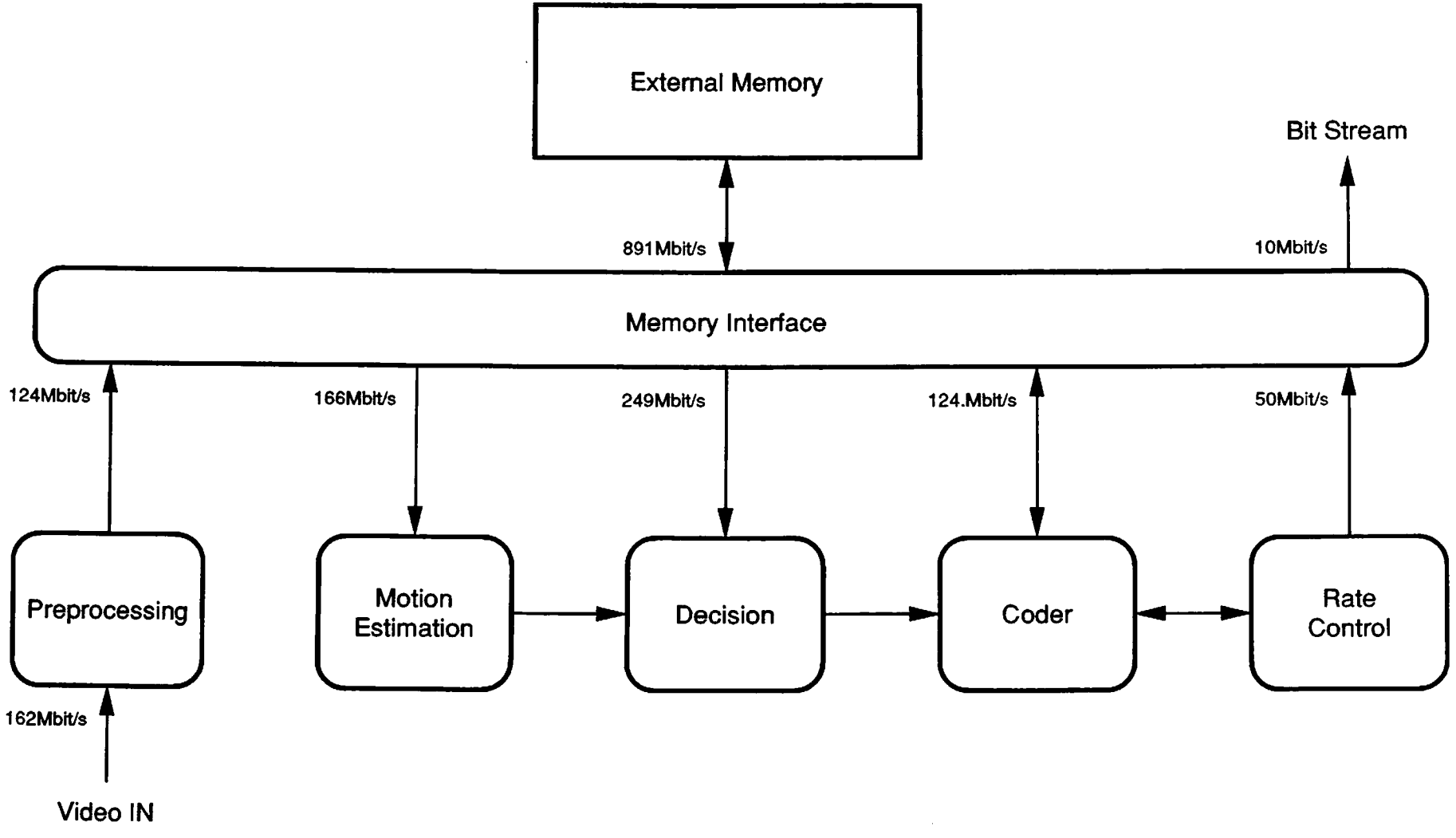

Figure 12: Encoder Block Diagram

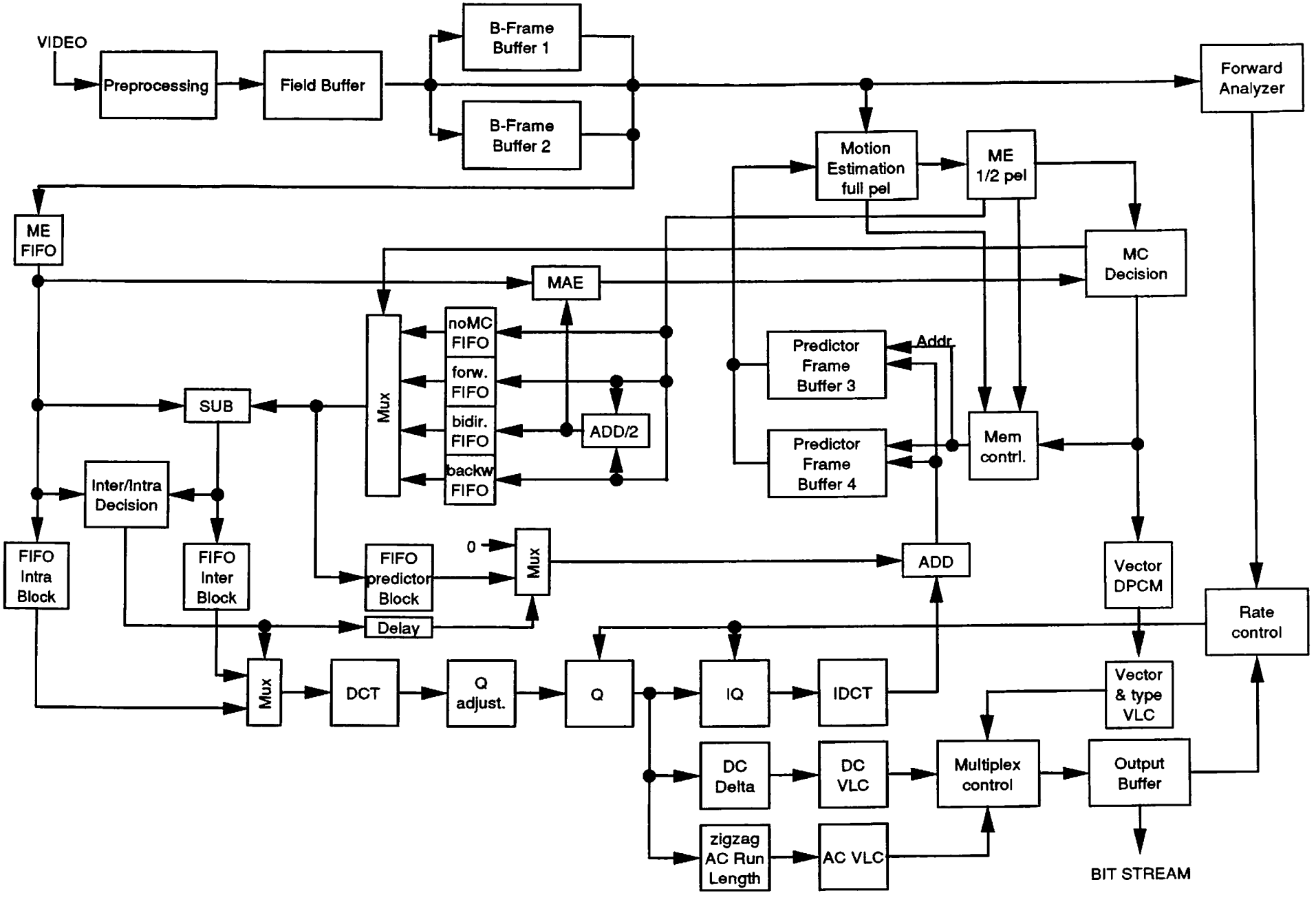

Figure 13: Encoder Detailed Block Diagram

Table 2: Encoder

Memory Size

	NTSC	PAL	unit
Picture size	4.15	4.98	Mbit
Bit stream buffer size	2.50	2.50	Mbit
External Memory size M=3	**21.18**	**24.91**	**Mbit**
External Memory size M=2	17.03	19.93	Mbit
External Memory size M=1	12.88	14.95	Mbit

Memory Bandwidth

Transfer Operations	Intra	Predicted	Bi-direct	unit
Input frame write	8.00	8.00	8.00	Bit/component
Input frame read	8.00	8.00	8.00	Bit/component
Full search integer pel (+/-48)	0.00	8.00	16.00	Bit/luminance
Telescopic Search (+/-16)	0.00	72.00	144.00	Bit/luminance
Half pel search	0.00	10.00	20.00	Bit/luminance
Predictor frame read	0.00	8.00	16.00	Bit/component
Predictor frame write	8.00	8.00	0.00	Bit/component
Bit stream write	1.67	0.67	0.33	Mbit/frame
Bit stream read	0.33	0.33	0.33	Mbit/frame

Bandwidth	Intra	Predicted	Bi-direct	unit
Input frame write	124.42	124.42	124.42	MBit/sec
Input frame read	124.42	124.42	124.42	MBit/sec
Full search integer pel (+/-48)	0.00	82.94	165.89	MBit/sec
Telescopic Search (+/-16)	0.00	746.50	1492.99	MBit/sec
Half pel search	0.00	103.68	207.36	MBit/sec
Predictor frame read	0.00	124.42	248.83	MBit/sec
Predictor frame write	124.42	124.42	0.00	MBit/sec
Bit stream write (worst case)	50.00	20.00	10.00	MBit/sec
Bit stream read	10.00	10.00	10.00	MBit/sec
Total External Memory bandwidth (full searc	433.25	714.29	890.91	MBit/sec

Table 2: Encoder suite

Computations Bandwidth

Operations/components	Intra	Predicted	Bi-direct	unit
Chrominance Pre-processing	8.00	8.00	8.00	Add
Full search integer pel (+/-48)	0.00	9216.00	5120.00	SumAbsDiff
Telescopic Search (+/-16)	0.00	1024.00	2048.00	SumAbsDiff
Half pel search	0.00	13.00	26.00	SumAbsDiff
MC Decision MSE	0.00	2.00	4.00	Sum Square
Inter/Intra Decision	0.00	6.00	6.00	Add
Interpolation	0.00	0.00	1.00	Add
DCT	3.00	3.00	3.00	MAC
DCT	4.00	4.00	4.00	Add
Quantization	2.00	2.00	2.00	Mul
Invert Quantization	2.00	2.00	2.00	Mul
Invert DCT	3.00	3.00	3.00	MAC
Invert DCT	4.00	4.00	4.00	Add
Addition for Inter-blocks	0.00	1.00	1.00	Add
Forward Analyser	4.00	4.00	4.00	Mul
Forward Analyser	5.00	5.00	5.00	Add

Worst case computation bandwidth	Intra	Predicted	Bi-direct	unit (MOP/sec)
Chrominance Pre-processing	82.94	82.94	82.94	Add
Full search integer pel (+/-48)	0.00	95551.49	53084.16	SumAbsDiff
Telescopic Search (+/-16)	0.00	10616.83	21233.66	SumAbsDiff
Half pel search	0.00	134.78	269.57	SumAbsDiff
MC Decision MSE	0.00	20.74	41.47	Sum Square
Inter/Intra Decision	0.00	62.21	62.21	Add
Interpolation	0.00	0.00	15.55	Add
DCT	46.66	46.66	46.66	MAC
DCT	62.21	62.21	62.21	Add
Quantization	31.10	31.10	31.10	Mul
Invert Quantization	31.10	31.10	31.10	Mul
Invert DCT	46.66	46.66	46.66	MAC
Invert DCT	62.21	62.21	62.21	Add
Addition for Inter-blocks	0.00	15.55	15.55	Add
Forward Analyser	41.47	41.47	41.47	Mul
Forward Analyser	51.84	51.84	51.84	Add

12. Statistics

12.1. PAL (50 Hz)

12.1.1 Flower Garden 4 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 20:59:00 PDT 1991
Directory: /usr4/olivier/mpeg50/flower/q4flt
Pictures: 0 to 123 (124 pictures), Bit-stream size: 20160000 bits
Parameters: Bit-rate = 4.00 Mbit/s, Picture-rate = 25.00, M = 3, N = 9

Statistics			All	Intra	Pred	Interp
# of pictures			124	14	28	82
RMS Y			8.3	8.0	8.2	8.4
SNR Y			29.8	30.1	29.9	29.7
SNR U			32.7	32.7	32.3	32.8
SNR V			34.9	35.1	34.6	35.0
QUANT			11.0	10.3	9.0	11.7
# of transmitted coefs per coded bk			4.0	8.4	5.6	2.8
# of zero before eob per coded bk			17.8	14.7	22.5	16.7
% of MB of each type						
Intra	Pred	Interp				
	Skipped	Skipped			10.44	13.30
Intra	MC Coded	I Not Coded		54.24	34.38	19.69
Intra + Q	MC NotCoded	I Coded		45.76	8.90	14.45
	MC Cod + Q	B Not Coded			40.93	5.76
	NoMC Coded	B Coded			1.57	3.97
	Intra	F Not Coded			1.47	4.75
	NoMC Cod Q	F Coded			0.73	2.16
	Intra + Q	Intra			1.58	0.14
		I Coded +Q				24.93
		B Coded +Q				6.79
		F Coded +Q				3.77
		Intra +Q				0.28
# of Coded MB			1439.3	1620.0	1450.8	1404.5
% of Coded Blocks			38.81	100.00	53.62	23.30
% of bits for MB attributes			5.84	1.43	4.44	12.35
Motion Vectors			7.48	0.00	4.88	18.73
CBP			2.52	0.00	2.58	5.40
EOB			4.64	3.61	4.73	5.76
Intra DC			4.83	11.73	1.02	0.41
Y coefs			68.37	74.17	77.34	52.99
U coefs			3.68	5.25	3.62	1.89
V coefs			1.90	3.54	1.33	0.52
Multiplexing			0.74	0.26	0.05	1.96
# of bits per picture			162581	538395	220616	78600
% of bits per type of picture			100.00	37.39	30.64	31.97
% of transmitted coefs == +-1			75.73	68.62	78.58	86.84
% of transmitted coefs with ESC			1.60	0.45	1.62	4.08
# of transmitted coefs			20024	81579	29288	6351

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	513200	31.0	60	213576	29.6	120	208872	30.1
1	73808	29.7	61	53552	31.2	121	75304	29.9
2	150352	30.1	62	56856	31.0	122	75856	29.6
3	222640	30.5	63	525168	29.8	123	276448	29.3
4	133176	29.9	64	76368	30.1			
5	155016	30.1	65	64272	30.5	Frame	#bits(cumul)	
6	191808	30.0	66	250192	31.1	0	513200	
7	118624	29.6	67	46912	31.9	10	2454904	
8	92048	29.6	68	105104	32.2	20	3910152	
9	524408	30.6	69	247112	31.6	30	5265800	
10	76416	30.0	70	76200	32.0	40	7158808	
11	78720	29.7	71	71320	31.6	50	8640000	
12	203408	29.5	72	607472	30.7	60	9964008	
13	66936	30.4	73	63912	31.5	70	12203672	
14	70240	30.5	74	71472	31.0	80	13747392	
15	209200	30.3	75	231080	31.4	90	14944592	
16	66400	31.4	76	80016	29.9	100	16831312	
17	73688	31.3	77	72312	29.4	110	18331840	
18	475216	29.8	78	244736	29.5	120	19614512	
19	79880	30.6	79	66368	29.5			
20	76792	30.4	80	52728	29.6			
21	258176	30.5	81	589776	30.3			
22	76296	30.4	82	61648	29.2			
23	72848	30.4	83	75648	28.4			
24	263960	30.3	84	222672	29.6			
25	70624	30.4	85	49192	29.3			
26	71344	30.2	86	58272	28.9			
27	571000	30.8	87	205736	28.6			
28	60072	30.2	88	74432	28.8			
29	63048	30.2	89	89144	27.7			
30	229576	30.6	90	524032	29.6			
31	73368	29.6	91	84424	27.7			
32	71704	29.4	92	93376	27.6			
33	249056	30.1	93	161952	30.0			
34	55184	30.9	94	94216	27.7			
35	55920	31.1	95	129960	28.8			
36	564864	30.6	96	167904	29.4			
37	57832	30.5	97	87072	29.6			
38	59912	30.2	98	98696	29.2			
39	238280	30.5	99	520760	29.6			
40	81112	29.3	100	80888	29.5			
41	72096	29.1	101	87232	29.0			
42	262656	29.8	102	203896	28.4			
43	84280	28.1	103	98384	28.2			
44	67216	28.8	104	104688	27.5			
45	579608	30.4	105	192160	29.6			
46	71832	28.2	106	63304	29.3			
47	77592	27.8	107	92848	28.6			
48	207128	30.0	108	463944	28.7			
49	38752	30.4	109	108880	27.7			
50	107144	30.8	110	87176	28.2			
51	175544	29.7	111	201912	29.5			
52	109888	29.4	112	66856	29.3			
53	83136	29.8	113	101072	29.3			
54	539544	30.0	114	220232	28.5			
55	79504	29.9	115	71880	30.2			
56	81016	29.4	116	75216	30.0			
57	217344	29.4	117	538544	29.8			
58	65056	29.9	118	55648	30.2			
59	65400	29.8	119	62232	30.2			

12.1.2 Flower Garden 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 21:56:21 PDT 1991
Directory: /usr4/olivier/mpeg50/flower/q9flt
Pictures: 0 to 123 (124 pictures), Bit-stream size: 45360000 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 25.00, M = 3, N = 9

Statistics	All	Intra	Pred	Interp
# of pictures	124	14	28	82
RMS Y	4.9	4.7	4.6	5.0
SNR Y	34.4	34.8	35.0	34.2
SNR U	35.8	35.8	35.6	35.9
SNR V	36.9	37.2	36.8	36.9
QUANT	5.1	4.9	4.2	5.4
# of transmitted coefs per coded bk	7.7	15.5	10.6	5.4
# of zero before eob per coded bk	23.0	18.9	26.2	22.6
% of MB of each type				
Intra / Pred / Interp				
Intra / Skipped / Skipped			3.62	4.74
Intra / MC Coded / I Not Coded		68.03	54.88	6.45
Intra + Q / MC NotCoded / I Coded		31.97	2.63	29.74
Intra + Q / MC Cod + Q / B Not Coded			27.94	4.59
Intra + Q / NoMC Coded / B Coded			7.77	11.07
Intra + Q / Intra / F Not Coded			1.47	3.57
Intra + Q / NoMC Cod Q / F Coded			0.73	7.75
Intra + Q / Intra + Q / Intra			0.97	0.08
Intra + Q / I Coded +Q				19.95
Intra + Q / B Coded +Q				6.87
Intra + Q / F Coded +Q				4.96
Intra + Q / Intra +Q				0.24
# of Coded MB	1556.0	1620.0	1561.4	1543.2
% of Coded Blocks	61.46	100.00	75.77	49.99
% of bits for MB attributes	2.44	0.66	1.50	4.58
Motion Vectors	3.27	0.00	2.10	6.76
CBP	1.62	0.00	1.53	2.93
EOB	3.27	2.04	2.83	4.58
Intra DC	2.11	6.61	0.34	0.12
Y coefs	76.35	76.38	80.57	72.79
U coefs	6.09	7.94	6.69	4.17
V coefs	4.12	6.21	4.42	2.27
Multiplexing	0.75	0.15	0.02	1.81
# of bits per picture	365806	954959	521234	212147
% of bits per type of picture	100.00	29.47	32.17	38.35
% of transmitted coefs == +-1	67.29	60.55	63.74	77.41
% of transmitted coefs with ESC	1.37	0.67	1.32	2.10
# of transmitted coefs	52213	150849	78146	26518

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	1098176	37.0	60	528944	34.7	120	530504	36.0
1	317720	33.0	61	167144	35.7	121	199792	34.7
2	360000	35.1	62	166952	35.5	122	204200	34.8
3	384104	34.5	63	877752	34.0	123	633168	34.7
4	313864	34.1	64	195736	34.3			
5	339928	34.5	65	182480	35.2	Frame	#bits(cumul)	
6	426208	34.5	66	639536	37.0	0	1098176	
7	294104	33.7	67	161736	37.2	10	5245696	
8	251704	33.8	68	248672	37.5	20	8747240	
9	735296	33.6	69	592720	37.3	30	11709592	
10	231072	34.3	70	195408	36.3	40	16065888	
11	223960	34.5	71	190328	35.6	50	19440000	
12	493520	34.3	72	1105440	35.8	60	22335080	
13	197720	35.5	73	177720	36.1	70	27220848	
14	246208	36.2	74	190784	35.5	80	30683712	
15	566416	36.2	75	534808	36.7	90	33354968	
16	209544	36.4	76	208408	34.1	100	37742792	
17	204896	36.1	77	186888	33.5	110	41169256	
18	817088	34.1	78	545744	34.1	120	43993552	
19	208000	35.2	79	169952	33.5			
20	199888	35.1	80	143616	33.9			
21	627824	36.0	81	1114616	35.6			
22	202144	35.1	82	167296	33.4			
23	195280	35.1	83	191912	32.4			
24	617424	35.8	84	557240	35.0			
25	186984	34.9	85	141368	33.3			
26	189280	34.2	86	181128	33.4			
27	1038224	35.7	87	485256	33.5			
28	164408	34.6	88	211952	32.8			
29	177576	34.6	89	232464	31.6			
30	533016	35.6	90	947056	34.3			
31	200528	33.7	91	220256	31.6			
32	187784	33.5	92	248816	31.9			
33	560144	34.9	93	418928	35.1			
34	164224	34.9	94	252432	32.2			
35	168512	35.2	95	309656	33.7			
36	975408	35.2	96	390528	34.2			
37	164872	34.8	97	240976	34.0			
38	169608	35.0	98	247056	33.4			
39	586080	36.0	99	950472	34.4			
40	216872	33.5	100	211456	34.0			
41	191384	33.4	101	215232	33.4			
42	620280	35.2	102	452832	33.1			
43	211896	32.3	103	234208	32.3			
44	185512	32.9	104	247840	31.8			
45	1034560	35.2	105	493888	35.2			
46	204256	32.5	106	209024	33.5			
47	214216	31.8	107	254544	33.0			
48	506240	34.9	108	783280	32.9			
49	141848	35.0	109	273968	31.9			
50	273768	36.0	110	242832	32.5			
51	410432	34.5	111	471648	34.5			
52	264304	33.5	112	205248	34.0			
53	216392	34.1	113	272040	34.5			
54	949720	34.5	114	476240	33.1			
55	218440	34.2	115	201352	34.8			
56	206408	33.6	116	196576	34.4			
57	510872	34.1	117	942336	34.6			
58	175944	34.3	118	152680	34.8			
59	176248	34.6	119	176608	35.2			

12.1.3 Table Tennis 4 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 18:15:17 PDT 1991
Directory: /usr4/olivier/mpeg50/tennis/q4flt
Pictures: 0 to 123 (124 pictures), Bit-stream size: 20160000 bits
Parameters: Bit-rate = 4.00 Mbit/s, Picture-rate = 25.00, M = 3, N = 9

Statistics			All	Intra	Pred	Interp
# of pictures			124	14	28	82
RMS Y			5.0	5.3	4.9	5.0
SNR Y			34.4	33.8	34.6	34.4
SNR U			39.0	39.1	39.0	39.0
SNR V			39.6	39.9	39.7	39.5
QUANT			6.5	7.9	5.2	6.6
# of transmitted coefs per coded bk			4.2	6.8	5.3	3.3
# of zero before eob per coded bk			16.2	11.7	18.7	16.2
% of MB of each type						
Intra	Pred	Interp				
	Skipped	Skipped			1.00	15.07
Intra	MC Coded	I Not Coded		54.27	55.15	20.36
Intra + Q	MC NotCoded	I Coded		45.73	3.66	18.57
	MC Cod + Q	B Not Coded			32.56	5.84
	NoMC Coded	B Coded			2.44	6.65
	Intra	F Not Coded			2.32	3.32
	NoMC Cod Q	F Coded			0.92	3.03
	Intra + Q	Intra			1.96	0.21
		I Coded +Q				18.01
		B Coded +Q				5.71
		F Coded +Q				2.96
		Intra +Q				0.27
# of Coded MB			1454.9	1620.0	1603.9	1375.9
% of Coded Blocks			41.74	100.00	66.25	23.43
% of bits for MB attributes			5.20	1.73	3.46	10.17
Motion Vectors			7.47	0.00	4.62	17.21
CBP			2.76	0.00	2.85	5.19
EOB			4.99	4.37	5.09	5.46
Intra DC			3.98	11.18	1.11	0.38
Y coefs			66.95	74.67	74.63	51.97
U coefs			3.11	3.50	3.55	2.30
V coefs			4.48	4.07	4.65	4.66
Multiplexing			1.06	0.48	0.04	2.66
# of bits per picture			162581	445061	253141	83429
% of bits per type of picture			100.00	30.91	35.16	33.93
% of transmitted coefs == +-1			75.48	71.23	76.38	80.56
% of transmitted coefs with ESC			1.81	0.86	1.63	3.52
# of transmitted coefs			20087	66267	34054	7433

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	480000	29.4	60	266640	36.2	120	244800	34.7
1	143536	29.6	61	68904	36.1	121	73072	33.9
2	160000	30.2	62	66304	36.0	122	71944	34.4
3	176464	29.6	63	562304	35.4	123	244616	35.1
4	122536	30.2	64	65528	35.6			
5	137632	29.7	65	65040	35.5	Frame	#bits(cumul)	
6	230272	29.2	66	258744	36.2	0	480000	
7	123224	31.3	67	62880	35.9	10	2240000	
8	93200	31.7	68	61808	35.9	20	3853144	
9	263656	32.8	69	239856	36.5	30	5194056	
10	86320	33.1	70	64608	36.1	40	7110448	
11	160000	34.1	71	65360	36.1	50	8640000	
12	223160	33.8	72	553968	35.4	60	9928176	
13	123264	34.8	73	69128	35.8	70	12149944	
14	107752	34.8	74	66256	35.8	80	13661280	
15	260936	35.2	75	243600	36.3	90	14761400	
16	99784	35.1	76	62464	36.2	100	16865616	
17	100624	35.0	77	65680	36.2	110	18353288	
18	287080	34.2	78	238168	36.7	120	19627800	
19	94368	35.0	79	69928	36.2			
20	94048	35.2	80	66176	36.2			
21	285288	35.6	81	564576	35.4			
22	98304	35.5	82	141456	31.6			
23	96752	35.5	83	65928	30.8			
24	283632	36.1	84	344808	30.5			
25	91912	35.6	85	25744	32.3			
26	87544	35.4	86	27848	32.5			
27	418608	35.5	87	228048	33.1			
28	84480	35.0	88	34800	32.9			
29	88048	34.9	89	83800	33.2			
30	264160	35.2	90	266288	30.0			
31	88224	34.6	91	69936	34.1			
32	89384	34.6	92	88272	34.3			
33	240408	35.0	93	321792	34.5			
34	90896	34.5	94	67504	35.6			
35	91360	34.5	95	95160	35.8			
36	424072	35.1	96	317336	36.3			
37	90808	34.3	97	79056	35.8			
38	90016	34.2	98	71432	35.3			
39	228080	34.6	99	539592	34.4			
40	90672	34.1	100	75624	34.5			
41	91560	34.1	101	67368	34.8			
42	219944	34.5	102	259912	35.3			
43	91216	34.3	103	68752	34.6			
44	94840	34.4	104	71936	34.2			
45	385808	34.4	105	253320	35.5			
46	95480	34.2	106	62160	35.2			
47	92856	34.2	107	70544	35.0			
48	242112	34.6	108	531520	34.5			
49	92664	34.3	109	70272	34.1			
50	104504	34.4	110	65704	34.4			
51	238512	34.9	111	226096	34.7			
52	107192	33.5	112	73480	33.9			
53	70472	33.6	113	60664	34.5			
54	431328	33.9	114	239304	34.5			
55	70520	34.9	115	66096	34.5			
56	74080	34.9	116	68112	34.5			
57	267944	35.4	117	522056	33.4			
58	73824	35.5	118	71576	34.3			
59	78000	35.5	119	70992	33.9			

12.1.4 Table Tennis 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 19:17:24 PDT 1991
Directory: /usr4/olivier/mpeg50/tennis/q9flt
Pictures: 0 to 123 (124 pictures), Bit-stream size: 45366960 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 25.00, M = 3, N = 9

Statistics			All	Intra	Pred	Interp
# of pictures			124	14	28	82
RMS Y			3.3	3.4	3.1	3.3
SNR Y			38.0	37.7	38.7	37.8
SNR U			41.4	41.5	41.5	41.3
SNR V			42.4	42.6	42.6	42.3
QUANT			3.3	3.9	2.6	3.4
# of transmitted coefs per coded bk			7.0	14.0	10.0	4.8
# of zero before eob per coded bk			21.5	17.9	25.6	20.6
% of MB of each type						
Intra	Pred	Interp				
	Skipped	Skipped			0.29	3.44
Intra	MC Coded	I Not Coded		68.25	67.03	2.19
Intra + Q	MC NotCoded	I Coded		31.75	1.28	45.09
	MC Cod + Q	B Not Coded			24.20	0.91
	NoMC Coded	B Coded			1.77	12.97
	Intra	F Not Coded			2.97	0.48
	NoMC Cod Q	F Coded			1.20	7.78
	Intra + Q	Intra			1.26	0.33
		I Coded +Q				16.93
		B Coded +Q				6.30
		F Coded +Q				3.45
		Intra +Q				0.13
# of Coded MB			1582.0	1620.0	1615.3	1564.2
% of Coded Blocks			69.03	100.00	86.93	57.63
% of bits for MB attributes			2.26	0.76	1.33	4.04
Motion Vectors			3.39	0.00	2.12	6.68
CBP			1.87	0.00	1.45	3.44
EOB			3.67	2.34	3.02	5.08
Intra DC			1.75	5.99	0.48	0.12
Y coefs			75.38	78.89	79.70	69.38
U coefs			5.05	5.83	5.77	3.92
V coefs			5.63	5.70	5.84	5.40
Multiplexing			1.00	0.48	0.30	1.94
# of bits per picture			365863	830500	558911	220615
% of bits per type of picture			100.00	25.63	34.50	39.88
% of transmitted coefs == +-1			71.66	66.93	69.74	77.81
% of transmitted coefs with ESC			1.37	0.76	1.03	2.27
# of transmitted coefs			52239	135991	84709	26853

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	1080000	35.7	60	578128	40.3	120	567144	39.0
1	360000	34.0	61	203568	39.2	121	193120	37.4
2	360112	35.9	62	192256	39.1	122	204144	38.0
3	360000	34.5	63	1003552	39.3	123	561152	39.5
4	258808	34.9	64	197376	38.8			
5	333944	33.8	65	194104	38.7	Frame	#bits(cumul)	
6	491608	32.9	66	547736	40.1	0	1080000	
7	309760	34.3	67	191576	39.0	10	5120712	
8	345960	35.1	68	190336	39.0	20	8679888	
9	419808	34.7	69	535352	40.3	30	11513712	
10	248896	36.2	70	187280	39.3	40	15959248	
11	279288	37.0	71	185064	39.3	50	19449824	
12	551816	37.4	72	1066688	39.8	60	22267048	
13	268168	37.8	73	191792	39.0	70	27200336	
14	262456	37.9	74	191056	39.0	80	30642312	
15	618080	39.2	75	514080	40.3	90	32928984	
16	231896	38.0	76	181744	39.3	100	37807992	
17	231696	38.0	77	190104	39.3	110	41212712	
18	577952	37.6	78	509120	40.5	120	44018784	
19	239304	38.0	79	191704	39.4			
20	233752	38.0	80	186712	39.3			
21	616584	39.3	81	1100600	40.0			
22	221560	38.4	82	255072	35.2			
23	230984	38.4	83	156280	34.5			
24	601912	39.5	84	574392	34.0			
25	225480	38.3	85	90696	37.0			
26	223296	38.2	86	121592	37.3			
27	750856	38.8	87	629072	38.9			
28	235488	37.9	88	191016	37.9			
29	225496	37.7	89	360000	39.1			
30	579736	38.9	90	459568	33.4			
31	219600	37.5	91	261792	38.5			
32	225416	37.6	92	230496	38.4			
33	557744	38.6	93	631392	39.1			
34	227608	37.4	94	207304	39.2			
35	228520	37.4	95	219096	39.3			
36	786368	38.6	96	673872	40.4			
37	230592	37.2	97	190560	38.9			
38	228792	37.2	98	182240	38.5			
39	529272	38.2	99	971728	38.5			
40	226552	37.2	100	189344	38.0			
41	240752	37.4	101	184936	38.3			
42	524088	38.3	102	570168	39.4			
43	242240	37.5	103	178288	37.9			
44	240192	37.5	104	190696	37.6			
45	712480	37.8	105	556352	39.6			
46	238992	37.2	106	195472	38.6			
47	233472	37.2	107	195688	38.4			
48	557600	38.4	108	979560	38.7			
49	231984	37.4	109	200288	37.5			
50	236464	37.5	110	195480	38.0			
51	556400	38.7	111	527960	38.9			
52	244064	36.6	112	190568	37.3			
53	214256	37.1	113	186888	38.1			
54	783664	37.6	114	549344	38.7			
55	205624	38.3	115	189648	37.9			
56	212096	38.4	116	188304	37.9			
57	579392	39.6	117	934176	37.4			
58	206656	38.8	118	198608	37.7			
59	216808	38.9	119	191152	37.2			

12.1.5 Mobile & Calendar 4 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Wed Sep 25 21:50:31 PDT 1991
Directory: /usr4/olivier/mpeg50/mobile/q4flt
Pictures: 0 to 123 (124 pictures), Bit-stream size: 20160000 bits
Parameters: Bit-rate = 4.00 Mbit/s, Picture-rate = 25.00, M = 3, N = 9

Statistics			All	Intra	Pred	Interp
# of pictures			124	14	28	82
RMS Y			7.5	8.2	7.3	7.4
SNR Y			30.7	29.9	30.8	30.8
SNR U			34.7	34.3	34.4	34.8
SNR V			35.8	35.5	35.6	36.0
QUANT			9.6	11.0	7.6	10.0
# of transmitted coefs per coded bk			4.7	8.5	5.9	3.7
# of zero before eob per coded bk			16.8	10.6	20.0	16.7
% of MB of each type						
	Intra	Skipped			2.01	20.23
	Pred	MC Coded		45.99	41.42	18.31
Intra	Interp	MC NotCoded		54.01	7.65	15.97
Intra + Q		MC Cod + Q			43.08	5.64
		NoMC Coded			0.92	3.44
		Intra			2.16	3.07
		NoMC Cod Q			1.01	2.23
		Intra + Q			1.76	0.45
						22.55
						5.23
						2.67
						0.21
# of Coded MB			1395.9	1620.0	1587.4	1292.3
% of Coded Blocks			37.62	100.00	57.52	20.18
% of bits for MB attributes			5.57	1.60	4.38	11.68
Motion Vectors			5.53	0.00	3.46	14.48
CBP			2.74	0.00	3.27	5.50
EOB			4.50	3.67	4.73	5.26
Intra DC			5.14	12.47	1.16	0.54
Y coefs			67.29	69.01	74.51	57.39
U coefs			4.57	6.97	4.62	1.58
V coefs			3.87	5.84	3.82	1.52
Multiplexing			0.80	0.44	0.05	2.05
# of bits per picture			162581	530155	236328	74642
% of bits per type of picture			100.00	36.82	32.82	30.36
% of transmitted coefs == +-1			74.81	68.24	78.20	82.46
% of transmitted coefs with ESC			1.01	0.21	1.11	2.45
# of transmitted coefs			21495	82762	32773	7184

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	480000	29.2	60	210800	30.1	120	232568	31.1
1	128856	29.4	61	72944	30.2	121	69040	31.1
2	160000	30.4	62	75608	30.3	122	92624	31.0
3	191144	29.8	63	473104	29.3	123	241008	32.1
4	137144	30.4	64	70120	30.1			
5	131528	30.2	65	77536	29.9	Frame	#bits(cumul)	
6	211328	29.9	66	241280	29.9	0	480000	
7	107040	30.2	67	77632	30.4	10	2411504	
8	92824	29.9	68	98768	30.5	20	3949856	
9	478904	29.2	69	252224	30.3	30	5257920	
10	76200	29.9	70	85144	30.6	40	7149112	
11	80952	30.0	71	77144	30.3	50	8661312	
12	216536	30.0	72	505792	29.6	60	9958112	
13	81016	30.7	73	67128	30.2	70	12110936	
14	84656	30.7	74	67688	30.2	80	13670528	
15	223112	31.1	75	248416	30.5	90	14945832	
16	76704	31.1	76	79672	30.6	100	16861992	
17	74976	31.4	77	77704	30.4	110	18355104	
18	524544	29.7	78	247208	31.2	120	19640520	
19	81216	30.2	79	72952	30.9			
20	70288	30.1	80	74544	30.9			
21	240888	30.4	81	547136	30.1			
22	71264	31.1	82	65320	30.7			
23	78584	31.0	83	70296	30.6			
24	234896	31.3	84	236344	31.0			
25	69856	31.6	85	66480	31.0			
26	63656	32.1	86	68400	30.7			
27	535808	29.8	87	228216	30.8			
28	68792	31.3	88	56272	31.5			
29	65160	31.1	89	60976	31.5			
30	254000	31.2	90	540248	30.2			
31	62200	32.2	91	59512	31.1			
32	74600	31.9	92	59800	31.0			
33	240536	32.1	93	255280	30.8			
34	72960	31.8	94	52928	31.8			
35	64888	31.9	95	82520	31.7			
36	592952	30.8	96	266880	31.5			
37	59424	31.4	97	77512	31.9			
38	60112	31.1	98	71464	31.5			
39	236920	31.1	99	551832	30.3			
40	55912	31.9	100	70232	30.6			
41	58744	31.7	101	70160	30.3			
42	236736	31.7	102	250952	30.8			
43	63056	32.0	103	67104	30.6			
44	69640	31.8	104	72480	30.3			
45	553016	30.4	105	236696	31.0			
46	68736	30.8	106	66928	30.9			
47	71744	30.6	107	66512	30.9			
48	242600	31.2	108	543032	29.9			
49	77440	30.7	109	61568	30.6			
50	76168	30.3	110	65024	30.6			
51	231056	31.1	111	243608	30.4			
52	80880	30.0	112	73960	30.7			
53	77960	30.1	113	67688	30.5			
54	554600	30.3	114	238936	31.1			
55	73712	29.8	115	61784	31.0			
56	71832	29.5	116	69272	30.8			
57	227016	30.0	117	541208	29.8			
58	58520	30.4	118	55232	30.8			
59	64152	30.1	119	61576	31.0			

12.1.6 Mobile & Calendar 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Wed Sep 25 23:27:01 PDT 1991
Directory: /usr4/olivier/mpeg50/mobile/q9flt
Pictures: 0 to 123 (124 pictures), Bit-stream size: 45360000 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 25.00, M = 3, N = 9

Statistics	All	Intra	Pred	Interp
# of pictures	124	14	28	82
RMS Y	4.5	5.0	4.2	4.6
SNR Y	35.0	34.2	35.7	34.9
SNR U	37.7	37.3	37.8	37.8
SNR V	38.9	38.6	38.9	38.9
QUANT	4.5	5.3	3.6	4.7
# of transmitted coefs per coded bk.	8.1	15.7	10.4	5.9
# of zero before eob per coded bk.	21.0	15.0	23.6	21.1
% of MB of each type				
Intra	Pred	Interp				
	Skipped	Skipped			0.33	7.88
Intra	MC Coded	I Not Coded		53.96	55.83	5.21
Intra + Q	MC NotCoded	I Coded		46.04	1.18	31.53
	MC Cod + Q	B Not Coded			36.57	2.52
	NoMC Coded	B Coded			2.03	7.63
	Intra	F Not Coded			1.47	1.36
	NoMC Cod Q	F Coded			1.40	5.20
	Intra + Q	Intra			1.20	0.21
		I Coded +Q				28.17
		B Coded +Q				6.41
		F Coded +Q				3.75
		Intra +Q				0.12
# of Coded MB	1534.3	1620.0	1614.6	1492.3
% of Coded Blocks	60.70	100.00	81.20	46.99
% of bits for MB attributes	2.64	0.81	1.71	4.86
Motion Vectors	2.52	0.00	1.55	5.32
CBP	1.89	0.00	1.69	3.53
EOB	3.23	2.05	2.96	4.36
Intra DC	2.20	6.98	0.37	0.11
Y coefs	74.60	73.13	78.37	72.45
U coefs	6.69	9.04	7.41	4.24
V coefs	5.25	7.48	5.71	3.13
Multiplexing	0.98	0.52	0.23	1.99
# of bits per picture	365806	947745	533163	209305
% of bits per type of picture	100.00	29.25	32.91	37.84
% of transmitted coefs == +-1	67.88	60.74	67.19	75.40
% of transmitted coefs with ESC	0.92	0.35	0.77	1.61
# of transmitted coefs	53834	152190	82505	27252

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	1080000	35.1	60	503712	34.8	120	514320	36.0
1	360000	31.8	61	213952	34.2	121	197680	35.2
2	360000	35.1	62	215288	34.3	122	218384	35.1
3	360000	32.8	63	796848	33.0	123	564072	37.2
4	294488	34.1	64	210272	34.4			
5	316608	34.1	65	215888	34.1			
6	468904	33.8	66	556720	34.8			
7	264872	33.8	67	210904	34.8			
8	243480	33.4	68	242568	35.0			
9	690952	31.8	69	577560	35.3			
10	223288	33.9	70	219760	34.5			
11	232240	34.2	71	203360	34.1			
12	536216	34.6	72	890472	33.8			
13	229608	35.3	73	198896	34.3			
14	267160	35.6	74	205784	34.3			
15	552184	36.5	75	559400	35.7			
16	232920	35.6	76	218712	34.6			
17	207904	35.8	77	220352	34.6			
18	928232	34.1	78	543912	36.5			
19	222272	34.4	79	213648	34.8			
20	203896	34.4	80	210496	34.9			
21	559296	35.7	81	1008944	34.8			
22	201672	35.6	82	202008	35.1			
23	218496	35.0	83	205224	34.9			
24	529480	36.6	84	492224	35.5			
25	199800	35.8	85	187256	35.2			
26	192648	36.6	86	190368	34.8			
27	1005088	34.7	87	516392	35.3			
28	194384	35.7	88	175640	35.7			
29	190624	35.7	89	179360	35.7			
30	531880	36.9	90	915904	34.1			
31	184104	36.6	91	174680	35.6			
32	204128	35.9	92	172864	35.6			
33	509752	37.5	93	606840	35.8			
34	202800	35.6	94	164528	36.9			
35	193128	35.9	95	200800	36.9			
36	1097512	35.7	96	642176	37.4			
37	192368	36.2	97	193264	36.1			
38	179896	35.7	98	177544	35.6			
39	474824	35.7	99	1029944	35.0			
40	168608	36.6	100	192032	34.6			
41	170912	36.3	101	188424	34.2			
42	531752	36.7	102	566704	35.5			
43	175880	36.2	103	184288	34.5			
44	192872	35.9	104	195008	34.1			
45	945952	34.4	105	546136	36.0			
46	207696	34.9	106	196232	34.6			
47	201360	34.5	107	200512	34.8			
48	550736	35.9	108	952632	34.1			
49	210072	34.6	109	196800	34.9			
50	209032	34.3	110	195360	34.8			
51	541408	35.8	111	530216	35.1			
52	218960	33.5	112	203808	34.6			
53	216880	33.7	113	197048	34.6			
54	979432	34.6	114	555584	36.4			
55	218736	33.5	115	191840	35.3			
56	209456	33.3	116	205584	34.8			
57	506168	34.2	117	946520	33.9			
58	174984	34.5	118	189848	35.4			
59	208288	34.5	119	190216	35.5			

Frame	#bits(cumul)
0	1080000
10	5198808
20	8834520
30	11713584
40	16037464
50	19443384
60	22296728
70	27030232
80	30613736
90	33323112
100	37799488
110	41185096
120	43999800

12.1.7 Popple 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Mon Sep 23 21:34:34 PDT 1991
Directory: /usr4/olivier/mpeg50/popple/q9flt
Pictures: 0 to 123 (124 pictures), Bit-stream size: 45360000 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 25.00, M = 3, N = 9

Statistics			All	Intra	Pred	Interp
# of pictures			124	14	28	82
RMS Y			4.4	4.0	4.1	4.6
SNR Y			35.4	36.2	36.1	35.0
SNR U			37.7	39.2	38.2	37.3
SNR V			38.0	39.5	38.5	37.6
QUANT			4.7	4.4	3.8	5.1
# of transmitted coefs per coded bk			6.6	10.6	8.8	5.1
# of zero before eob per coded bk			23.2	21.5	25.8	22.6
% of MB of each type						
Intra	Pred	Interp				
	Skipped	Skipped			3.09	5.78
Intra	MC Coded	I Not Coded		73.13	25.99	4.93
Intra + Q	MC NotCoded	I Coded		26.87	0.35	35.52
	MC Cod + Q	B Not Coded			21.81	1.82
	NoMC Coded	B Coded			19.86	6.82
	Intra	F Not Coded			23.72	1.09
	NoMC Cod Q	F Coded			1.76	6.30
	Intra + Q	Intra			3.44	10.45
		I Coded +Q				18.72
		B Coded +Q				3.85
		F Coded +Q				3.91
		Intra +Q				0.83
# of Coded MB			1546.8	1620.0	1570.0	1526.3
% of Coded Blocks			70.84	100.00	85.80	60.76
% of bits for MB attributes			2.42	0.87	1.75	3.55
Motion Vectors			4.27	0.00	2.18	7.56
CBP			1.63	0.00	1.19	2.64
EOB			3.76	2.88	3.22	4.52
Intra DC			3.56	7.49	2.53	2.52
Y coefs			63.02	69.80	68.20	56.53
U coefs			10.30	9.59	10.30	10.61
V coefs			10.18	9.15	10.42	10.46
Multiplexing			0.87	0.21	0.21	1.61
# of bits per picture			365806	674258	517789	261248
% of bits per type of picture			100.00	20.81	31.96	47.23
% of transmitted coefs == +-1			72.06	71.19	70.90	73.53
% of transmitted coefs with ESC			2.24	0.93	1.80	3.36
# of transmitted coefs			48356	103351	73770	30289

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	1116192	39.2	60	526968	36.6	120	465768	33.3
1	360000	35.0	61	238448	35.8	121	293256	32.1
2	360000	37.5	62	331824	36.5	122	319160	32.4
3	323808	36.2	63	505216	36.7	123	454384	33.6
4	306232	37.0	64	265032	36.7			
5	346224	37.3	65	272176	37.0	Frame	#bits(cumul)	
6	427544	36.8	66	542792	38.5	0	1116192	
7	290992	36.8	67	270960	37.0	10	5158664	
8	277776	36.7	68	266408	37.0	20	8761408	
9	523680	34.5	69	562168	38.7	30	11508024	
10	281304	36.7	70	260192	36.9	40	16000336	
11	261216	36.5	71	265480	36.8	50	19531640	
12	544912	37.5	72	557072	38.1	60	22237320	
13	246056	36.9	73	271752	36.7	70	26756800	
14	254656	36.9	74	259680	36.7	80	30253776	
15	573560	38.5	75	545728	38.0	90	33089416	
16	230472	36.8	76	262736	36.4	100	37671824	
17	226952	36.7	77	259064	36.3	110	41090384	
18	804536	36.5	78	547040	38.0	120	43718968	
19	236680	36.1	79	256880	36.4			
20	224344	35.9	80	265344	36.2			
21	544272	37.0	81	563272	37.9			
22	215880	36.0	82	270448	36.2			
23	220680	35.9	83	261888	35.9			
24	543496	37.2	84	552216	37.0			
25	225696	36.2	85	273600	35.4			
26	226808	36.1	86	264872	35.1			
27	752352	36.1	87	543248	36.7			
28	232072	35.9	88	267616	34.8			
29	225808	35.9	89	265056	34.5			
30	561704	37.0	90	669368	37.1			
31	220808	36.0	91	275128	34.3			
32	228056	36.0	92	268536	33.7			
33	552792	37.5	93	501792	35.4			
34	233480	36.0	94	281224	33.5			
35	234008	36.1	95	262592	33.2			
36	755448	36.2	96	483824	34.6			
37	238776	35.8	97	284840	32.8			
38	229576	35.7	98	274680	32.9			
39	555136	36.6	99	643504	34.9			
40	220688	35.8	100	289104	32.5			
41	220912	35.8	101	279152	32.1			
42	565664	36.8	102	484512	33.5			
43	239072	35.4	103	280120	31.9			
44	228248	35.4	104	278520	31.7			
45	744128	36.1	105	463544	33.2			
46	243344	34.9	106	268832	31.8			
47	238800	34.7	107	275528	32.1			
48	578032	36.0	108	564128	33.7			
49	250832	34.0	109	278664	31.9			
50	227320	34.1	110	272680	32.1			
51	560616	36.1	111	457392	33.1			
52	218736	34.5	112	280616	32.1			
53	225952	34.6	113	284312	32.0			
54	683952	35.9	114	464688	33.1			
55	253168	34.1	115	286792	32.1			
56	226416	34.3	116	289640	31.9			
57	570488	35.8	117	556768	33.2			
58	219808	34.5	118	282560	32.1			
59	227384	34.8	119	291672	32.0			

12.2. NTSC (60 Hz)

12.2.1 Flower Garden 4 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 15:41:13 PDT 1991
Directory: /usr4/olivier/mpeg60/flower/q4flt
Pictures: 0 to 147 (148 pictures), Bit-stream size: 20245864 bits
Parameters: Bit-rate = 4.00 Mbit/s, Picture-rate = 30.00, M = 3, N = 12

Statistics	All	Intra	Pred	Interp
# of pictures	148	13	37	98
RMS Y	8.1	8.0	8.1	8.1
SNR Y	30.0	30.1	30.0	30.0
SNR U	32.9	32.8	32.5	33.0
SNR V	34.6	34.8	34.3	34.7
QUANT	10.8	10.6	8.8	11.6
# of transmitted coefs per coded bk.	4.0	9.1	6.2	2.5
# of zero before eob per coded bk.	17.0	14.6	21.5	15.6
% of MB of each type				
Intra: Intra		49.91	37.26	20.70
Intra: Intra + Q		50.09	7.18	13.66
Pred: Skipped			4.54	12.80
Pred: MC Coded			45.26	6.32
Pred: MC NotCoded			2.02	3.90
Pred: MC Cod + Q			1.55	4.36
Pred: NoMC Coded			0.60	1.60
Pred: Intra			1.57	0.09
Pred: NoMC Cod Q				25.69
Pred: Intra + Q				6.82
Interp: Skipped				3.93
Interp: I Not Coded				0.13
Interp: I Coded				
Interp: B Not Coded				
Interp: B Coded				
Interp: F Not Coded				
Interp: F Coded				
Interp: Intra				
Interp: I Coded +Q				
Interp: B Coded +Q				
Interp: F Coded +Q				
Interp: Intra +Q				
# of Coded MB	1220.3	1350.0	1288.6	1177.2
% of Coded Blocks	38.36	100.00	61.82	21.32
% of bits for MB attributes	5.99	1.42	3.90	13.83
Motion Vectors	7.53	0.00	4.39	20.04
CBP	2.67	0.00	2.34	5.97
EOB	4.54	3.41	4.48	5.84
Intra DC	3.81	11.15	0.85	0.23
Y coefs	69.51	74.97	79.33	49.67
U coefs	3.25	5.03	3.00	1.71
V coefs	2.07	3.72	1.66	0.91
Multiplexing	0.63	0.30	0.05	1.80
# of bits per picture	136796	474636	223770	59144
% of bits per type of picture	100.00	30.48	40.89	28.63
% of transmitted coefs == +-1	75.00	67.89	76.18	87.37
% of transmitted coefs with ESC	1.28	0.24	1.17	3.83
# of transmitted coefs	17220	73449	31221	4475

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	424296	30.9	60	493664	30.4	120	429992	28.7
1	55704	30.7	61	62400	29.7	121	60936	29.2
2	133328	31.6	62	58200	29.1	122	54728	29.0
3	186672	30.9	63	231840	29.5	123	255616	29.4
4	91624	31.2	64	42952	30.1	124	41000	29.9
5	108272	31.1	65	48760	29.6	125	45600	29.9
6	200104	30.0	66	217360	29.6	126	230344	30.1
7	80888	31.0	67	43536	30.3	127	63584	29.3
8	128112	31.4	68	83512	30.8	128	57424	29.2
9	191000	30.3	69	220176	30.4	129	272864	29.5
10	101472	30.3	70	59584	31.4	130	35896	30.6
11	84896	29.9	71	64256	30.6	131	35440	30.8
12	416424	30.2	72	461376	29.6	132	520768	29.9
13	71376	30.2	73	64968	29.9	133	44096	30.2
14	69832	30.0	74	58776	30.0	134	39112	30.3
15	196800	30.0	75	235192	29.8	135	257304	30.6
16	76464	29.6	76	52096	30.3	136	32616	31.0
17	76600	29.1	77	51648	30.5	137	35976	31.1
18	223248	29.8	78	223752	30.2	138	229168	31.4
19	54712	29.9	79	48768	30.9	139	43600	31.2
20	59792	29.8	80	52728	30.7	140	71864	31.1
21	198856	29.9	81	231000	30.9	141	254152	31.5
22	56544	30.7	82	56136	30.6	142	45616	32.4
23	67352	30.2	83	50296	31.0	143	44016	32.1
24	418584	30.0	84	497792	30.2	144	598376	30.8
25	68008	29.8	85	51136	31.1	145	57936	30.6
26	56672	30.4	86	53024	30.7	146	54304	29.9
27	206680	30.6	87	236752	30.5	147	245664	30.3
28	57904	30.7	88	43992	31.3			
29	59632	30.5	89	48704	31.1			
30	216104	30.7	90	224352	30.9			
31	59584	30.6	91	48096	31.1			
32	74272	30.5	92	53376	30.4			
33	228184	30.6	93	238856	30.3			
34	70488	30.5	94	45544	31.2			
35	57088	30.6	95	52480	30.8			
36	466064	30.5	96	542232	30.7			
37	53584	30.9	97	74936	28.9			
38	59304	30.7	98	63376	28.3			
39	224760	30.9	99	247224	29.1			
40	54456	30.8	100	60488	28.0			
41	59032	30.2	101	64016	27.6			
42	232056	30.2	102	209312	28.3			
43	66440	29.6	103	57096	27.6			
44	61248	29.2	104	66104	27.1			
45	237984	29.7	105	192928	27.9			
46	46120	30.3	106	58632	27.5			
47	44176	30.7	107	54336	28.0			
48	482440	30.2	108	418264	28.6			
49	52512	29.9	109	52304	28.4			
50	52712	29.5	110	54248	28.2			
51	226960	30.3	111	205224	28.2			
52	82648	28.0	112	59168	27.9			
53	66864	28.1	113	51704	28.0			
54	222704	30.5	114	219656	28.5			
55	41032	29.7	115	52840	28.2			
56	55392	29.6	116	71256	28.4			
57	188664	29.1	117	219960	28.6			
58	46016	30.5	118	41800	29.9			
59	46840	30.8	119	46112	30.0			

Frame	#bits(cumul)
0	424296
12	2016424
24	3649056
36	5266056
48	6924936
60	8498384
72	10061352
84	11701912
96	13348864
108	14900632
120	16429952
132	18120728
144	19798328

12.2.2 Flower Garden 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 16:40:22 PDT 1991
Directory: /usr4/olivier/mpeg60/flower/q9flt
Pictures: 0 to 147 (148 pictures), Bit-stream size: 45333920 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 30.00, M = 3, N = 12

Statistics	All	Intra	Pred	Interp
# of pictures	148	13	37	98
RMS Y	4.7	4.5	4.4	4.9
SNR Y	34.8	35.0	35.4	34.5
SNR U	36.3	36.1	36.0	36.4
SNR V	36.9	37.2	36.7	37.0
QUANT	5.0	4.9	4.0	5.4
# of transmitted coefs per coded bk	7.3	16.6	11.2	4.6
# of zero before eob per coded bk	21.0	19.4	24.6	19.9
% of MB of each type				
Intra	Skipped	Skipped	0.73	2.69
Intra + Q	MC Coded	I Not Coded	65.17	60.17	5.60
	MC NotCoded	I Coded	34.83	0.92	33.28
	MC Cod + Q	B Not Coded		29.88	3.26
	NoMC Coded	B Coded		5.23	11.02
	Intra	F Not Coded		1.62	2.48
	NoMC Cod Q	F Coded		0.58	6.61
	Intra + Q	Intra		0.85	0.07
		I Coded +Q			22.48
		B Coded +Q			7.04
		F Coded +Q			5.42
		Intra +Q			0.05
# of Coded MB	1323.5	1350.0	1340.1	1313.7
% of Coded Blocks	63.35	100.00	83.98	50.69
% of bits for MB attributes	2.52	0.65	1.32	5.32
Motion Vectors	3.36	0.00	1.97	7.46
CBP	1.76	0.00	1.38	3.49
EOB	3.35	1.90	2.68	5.20
Intra DC	1.65	6.22	0.29	0.04
Y coefs	77.28	77.14	82.63	70.88
U coefs	5.13	7.47	5.21	3.37
V coefs	4.30	6.45	4.50	2.51
Multiplexing	0.64	0.17	0.02	1.72
# of bits per picture	306310	851827	507952	157816
% of bits per type of picture	100.00	24.43	41.46	34.12
% of transmitted coefs == +-1	65.47	59.15	60.39	79.12
% of transmitted coefs with ESC	1.29	0.49	1.31	2.02
# of transmitted coefs	43558	134749	76441	19046

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	907040	37.2	60	847920	35.1	120	762536	33.5
1	274120	34.3	61	162264	33.6	121	153360	33.2
2	300000	37.2	62	148072	33.5	122	140792	33.3
3	318840	35.2	63	536456	34.9	123	594400	35.1
4	206264	35.7	64	123288	34.7	124	123336	34.6
5	253096	36.2	65	137672	34.5	125	147216	34.9
6	440640	35.2	66	512088	35.1	126	530488	35.9
7	175768	36.0	67	128704	35.1	127	176728	33.6
8	289600	37.0	68	176152	35.8	128	148352	33.6
9	434632	35.9	69	533192	36.5	129	583048	34.6
10	225072	35.0	70	152000	35.9	130	113384	34.7
11	201808	34.3	71	157960	34.9	131	110072	34.9
12	726832	34.9	72	836424	34.6	132	953976	34.9
13	182856	35.0	73	161552	34.1	133	122160	34.1
14	178264	34.9	74	151552	34.1	134	114424	34.6
15	439232	35.3	75	526872	34.9	135	587264	36.0
16	186608	34.2	76	141800	34.7	136	109192	35.1
17	185864	33.5	77	141464	35.2	137	124128	35.6
18	509352	35.1	78	512736	35.7	138	529976	36.9
19	149344	34.7	79	138048	35.7	139	140152	35.5
20	160840	34.7	80	146656	35.7	140	142632	35.0
21	469176	35.4	81	532936	36.8	141	544704	36.7
22	158416	35.2	82	154032	35.1	142	126368	36.2
23	171848	34.6	83	148880	35.3	143	125200	36.0
24	747104	34.8	84	869240	35.0	144	1040848	35.6
25	171032	34.2	85	152704	35.7	145	154256	34.2
26	157336	35.2	86	149536	35.3	146	140072	33.5
27	488464	36.4	87	516528	35.8	147	546984	35.0
28	166368	35.7	88	133480	35.9			
29	165320	35.5	89	141008	36.0			
30	493176	36.5	90	513456	36.6			
31	164968	35.6	91	139824	35.9			
32	187288	35.4	92	149936	35.4			
33	515592	36.3	93	536744	36.0			
34	176680	34.9	94	135984	35.6			
35	153416	35.3	95	144720	34.9			
36	856872	35.8	96	970240	35.9			
37	146256	35.5	97	182832	32.9			
38	155392	35.3	98	150864	32.3			
39	511232	36.5	99	538152	34.1			
40	149888	35.4	100	157240	32.1			
41	150224	34.8	101	163480	31.9			
42	510512	35.4	102	483624	33.6			
43	165896	33.9	103	156664	31.8			
44	150120	33.5	104	172864	31.1			
45	541784	35.0	105	451808	33.1			
46	132688	34.5	106	162448	31.5			
47	130152	34.9	107	160536	32.1			
48	813184	34.6	108	741536	33.4			
49	144120	34.2	109	154512	32.7			
50	141584	34.1	110	149936	32.6			
51	544480	35.8	111	471784	33.5			
52	199744	32.1	112	167448	32.2			
53	167608	32.3	113	141856	32.5			
54	529400	35.7	114	508056	33.8			
55	138512	34.3	115	156120	32.6			
56	163136	34.4	116	150256	32.6			
57	434736	34.2	117	521672	34.0			
58	143800	35.1	118	118632	34.4			
59	140616	35.3	119	129240	34.5			

Frame	#bits(cumul)
0	907040
12	4326832
24	7962352
36	11659032
48	15283616
60	18857696
72	22436424
84	26069240
96	29775608
108	33255376
120	36762536
132	40562104
144	44241040

12.2.3 Table Tennis 4 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 11:36:06 PDT 1991
Directory: /usr4/olivier/mpeg60/tennis/q4flt
Pictures: 0 to 147 (148 pictures), Bit-stream size: 20156432 bits
Parameters: Bit-rate = 4.00 Mbit/s, Picture-rate = 30.00, M = 3, N = 12

Statistics	All	Intra	Pred	Interp
# of pictures	148	13	37	98
RMS Y	5.5	5.8	5.4	5.5
SNR Y	33.8	33.5	34.1	33.8
SNR U	40.9	41.2	40.7	40.9
SNR V	40.4	40.8	40.3	40.4
QUANT	6.5	7.3	5.4	6.9
# of transmitted coefs per coded bk.	4.2	7.8	5.6	3.2
# of zero before eob per coded bk.	18.4	13.4	20.8	18.2
% of MB of each type				
Intra	Skipped	Skipped	0.46	13.65
Intra + Q	MC Coded	I Not Coded	56.77	53.14	19.04
	MC NotCoded	I Coded	43.23	3.78	20.43
	MC Cod + Q	B Not Coded		32.39	7.21
	NoMC Coded	B Coded		3.44	6.23
	Intra	F Not Coded		2.99	3.11
	NoMC Cod Q	F Coded		1.28	3.01
	Intra + Q	Intra		2.51	0.21
		I Coded +Q			18.78
		B Coded +Q			5.43
		F Coded +Q			2.64
		Intra +Q			0.26
# of Coded MB	1226.4	1350.0	1343.7	1165.8
% of Coded Blocks	40.71	100.00	65.28	23.57
% of bits for MB attributes	5.23	1.52	3.42	10.28
Motion Vectors	7.64	0.00	4.54	17.30
CBP	2.83	0.00	2.63	5.26
EOB	4.84	3.97	4.86	5.51
Intra DC	3.21	9.72	1.30	0.39
Y coefs	69.62	77.72	77.31	54.17
U coefs	2.05	2.85	2.14	1.31
V coefs	3.65	3.87	3.76	3.36
Multiplexing	0.92	0.35	0.05	2.41
# of bits per picture	136192	408558	217634	69313
% of bits per type of picture	100.00	26.35	39.95	33.70
% of transmitted coefs == +-1	76.93	72.69	76.94	82.84
% of transmitted coefs with ESC	2.14	0.71	1.84	4.70
# of transmitted coefs	16925	63490	29457	6017

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	400000	28.6	60	318848	35.8	120	608976	36.5
1	90336	28.6	61	79432	35.7	121	57600	35.1
2	133328	29.1	62	79792	35.6	122	51576	35.7
3	176336	28.4	63	211976	35.9	123	199288	36.1
4	93432	29.4	64	80088	35.7	124	60744	34.1
5	117728	29.5	65	80448	35.6	125	50840	34.9
6	188840	28.6	66	208096	36.0	126	198096	34.5
7	95000	28.8	67	97160	33.1	127	62440	33.4
8	106880	28.8	68	65832	32.6	128	52464	33.7
9	198120	28.8	69	265480	32.0	129	195656	34.5
10	82928	28.8	70	35976	34.5	130	52008	34.7
11	74200	29.0	71	33592	34.5	131	60216	34.2
12	352624	27.8	72	377720	34.9	132	452016	33.5
13	74592	28.6	73	30600	34.8	133	58168	33.9
14	70728	28.3	74	27440	34.9	134	63848	33.3
15	230800	28.6	75	248376	35.8	135	201224	34.5
16	59120	28.6	76	33816	35.9	136	59792	33.5
17	63904	28.6	77	85200	36.4	137	60648	34.2
18	224152	29.0	78	272912	37.3	138	192160	34.4
19	61528	29.1	79	65584	37.1	139	60096	34.5
20	60208	29.3	80	102536	37.2	140	81464	33.9
21	249416	29.7	81	231880	37.7	141	196232	34.5
22	66032	28.6	82	74024	37.7	142	72984	34.1
23	77160	28.2	83	56568	37.5	143	69952	34.2
24	331776	28.8	84	589368	37.4	144	477088	33.5
25	76440	28.8	85	52264	36.7	145	71128	33.8
26	73448	29.4	86	53720	36.7	146	69256	33.4
27	215760	30.3	87	198816	37.3	147	196072	34.2
28	67208	30.4	88	53256	37.0			
29	91448	30.8	89	55384	37.1	Frame	#bits(cumul)	
30	196520	31.6	90	190896	37.6	0	400000	
31	76248	31.7	91	55008	37.3	12	1952624	
32	118000	32.4	92	55760	37.3	24	3535976	
33	205752	32.8	93	190128	37.9	36	5022600	
34	96448	33.1	94	56080	37.5	48	6719160	
35	86384	33.4	95	57000	37.5	60	8319824	
36	222608	33.0	96	562744	37.2	72	10032064	
37	79272	34.0	97	121088	31.4	84	11789344	
38	90256	34.5	98	54624	30.8	96	13387912	
39	225032	35.0	99	277648	30.8	108	14780384	
40	89128	35.2	100	24928	32.1	120	16608936	
41	90936	35.3	101	26360	32.1	132	18114096	
42	219936	36.1	102	175016	32.1	144	19677040	
43	93280	35.6	103	24120	33.6			
44	88920	35.5	104	27856	33.7			
45	236792	36.4	105	230440	34.3			
46	85088	35.5	106	34024	34.2			
47	82328	35.6	107	43024	34.1			
48	300176	36.2	108	317312	32.2			
49	79064	35.4	109	45608	34.5			
50	82576	35.3	110	48680	34.8			
51	209344	36.0	111	268448	35.5			
52	83576	35.4	112	41184	36.1			
53	83584	35.4	113	69272	36.1			
54	201200	36.1	114	269344	36.6			
55	85080	35.5	115	60776	36.8			
56	83464	35.6	116	89472	36.8			
57	206512	36.1	117	249744	37.2			
58	82808	35.6	118	67360	37.1			
59	83408	35.6	119	57080	36.8			

12.2.4 Table Tennis 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 12:55:46 PDT 1991
Directory: /usr4/olivier/mpeg60/tennis/q9flt
Pictures: 0 to 147 (148 pictures), Bit-stream size: 45219296 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 30.00, M = 3, N = 12

Statistics	All	Intra	Pred	Interp
# of pictures	148	13	37	98
RMS Y	3.6	3.6	3.3	3.7
SNR Y	37.4	37.5	38.2	37.1
SNR U	43.0	43.3	43.0	42.9
SNR V	43.1	43.5	43.2	43.1
QUANT	3.3	3.6	2.7	3.5
# of transmitted coefs per coded bk.	7.2	15.4	10.7	4.8
# of zero before eob per coded bk.	23.9	18.3	27.1	23.5
% of MB of each type				
Intra / Pred / Interp				
Intra / Skipped / Skipped			0.03	2.34
Intra / MC Coded / I Not Coded		73.94	69.33	2.26
Intra + Q / MC NotCoded / I Coded		26.06	0.34	47.82
MC Cod + Q / B Not Coded			21.16	0.73
NoMC Coded / B Coded			3.32	13.78
Intra / F Not Coded			3.69	0.47
NoMC Cod Q / F Coded			0.90	8.02
Intra + Q / Intra			1.23	0.30
I Coded +Q				16.41
B Coded +Q				5.01
F Coded +Q				2.76
Intra +Q				0.10
# of Coded MB	1329.0	1350.0	1349.6	1318.4
% of Coded Blocks	67.40	100.00	84.17	56.74
% of bits for MB attributes	2.17	0.65	1.22	3.90
Motion Vectors	3.48	0.00	2.13	6.65
CBP	1.82	0.00	1.32	3.28
EOB	3.57	2.20	2.86	5.00
Intra DC	1.39	5.40	0.51	0.11
Y coefs	79.01	81.72	83.43	73.25
U coefs	3.27	4.43	3.72	2.21
V coefs	4.53	5.17	4.79	3.94
Multiplexing	0.77	0.42	0.02	1.67
# of bits per picture	305536	735437	476420	183991
% of bits per type of picture	100.00	21.14	38.98	39.87
% of transmitted coefs == +-1	72.33	67.83	69.28	79.44
% of transmitted coefs with ESC	1.47	0.60	0.99	2.70
# of transmitted coefs	43771	124545	72645	22156

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	900000	35.2	60	585944	39.0	120	903224	39.7
1	292768	32.6	61	202360	38.3	121	169192	38.2
2	300000	34.6	62	196696	38.2	122	170824	38.7
3	307232	32.5	63	476456	39.3	123	461304	40.0
4	209864	33.8	64	190080	38.4	124	169032	37.4
5	271008	34.0	65	193064	38.3	125	167792	38.4
6	419128	33.2	66	476936	39.4	126	460592	38.5
7	208384	32.6	67	194840	37.0	127	160168	36.9
8	259184	32.7	68	184304	37.0	128	166064	37.6
9	432432	33.1	69	498744	36.1	129	476512	39.0
10	203736	32.6	70	134752	38.0	130	167464	38.3
11	197104	32.7	71	117208	37.9	131	166824	37.7
12	653712	32.4	72	657008	38.4	132	774016	37.4
13	190744	32.0	73	94584	38.3	133	170456	37.4
14	178856	31.7	74	154520	38.7	134	169344	36.8
15	485128	33.3	75	640336	41.4	135	480544	38.9
16	172424	32.4	76	150736	39.6	136	169016	37.4
17	180504	32.3	77	183872	40.0	137	179072	38.1
18	488336	34.0	78	565528	42.1	138	469056	39.1
19	181760	33.0	79	183416	40.2	139	174984	38.4
20	180376	33.1	80	216496	40.5	140	185624	37.7
21	505520	34.6	81	499952	42.0	141	456920	39.0
22	186072	31.9	82	177952	40.3	142	176816	37.4
23	207376	31.4	83	166976	40.1	143	177528	37.6
24	641000	33.2	84	985504	41.3	144	856840	37.9
25	202168	31.7	85	174736	39.6	145	180168	37.2
26	200320	32.4	86	168544	39.5	146	175352	36.7
27	424592	33.7	87	452288	41.2	147	451632	38.6
28	187200	33.3	88	158192	39.8			
29	213576	33.8	89	167920	40.0			
30	419496	35.1	90	417496	41.2			
31	203112	34.7	91	167552	40.0			
32	259944	35.5	92	169816	40.1			
33	436944	36.4	93	419016	41.5			
34	227808	35.9	94	179152	40.2			
35	240136	36.5	95	179808	40.2			
36	432056	35.6	96	857048	40.4			
37	206808	36.8	97	233648	35.4			
38	209864	37.2	98	146696	34.9			
39	493168	38.5	99	494336	34.7			
40	213568	37.8	100	95080	36.9			
41	209896	37.9	101	117960	37.2			
42	487016	39.5	102	544040	38.9			
43	214600	38.2	103	112296	38.6			
44	212560	38.2	104	131328	38.6			
45	496552	39.5	105	550168	40.1			
46	201176	38.1	106	142432	39.0			
47	199120	38.2	107	146600	39.0			
48	562728	39.1	108	751600	38.2			
49	203056	38.1	109	149872	38.8			
50	197072	38.0	110	152656	39.0			
51	468936	39.2	111	527992	40.5			
52	195248	38.1	112	153232	39.6			
53	198968	38.2	113	156944	39.3			
54	463792	39.4	114	512760	40.7			
55	203984	38.4	115	153016	39.7			
56	199312	38.4	116	184608	39.7			
57	465456	39.4	117	501200	40.9			
58	199776	38.3	118	167000	39.7			
59	199512	38.3	119	165472	39.5			

Frame	#bits(cumul)
0	900000
12	4253712
24	7859200
36	11232056
48	15006760
60	18588824
72	22258600
84	26185504
96	29683040
108	33219152
120	36903688
132	40411656
144	44057800

12.2.5 Mobile & Calendar 4 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 22:56:06 PDT 1991
Directory: /usr4/olivier/mpeg60/mobile/q4flt
Pictures: 0 to 147 (148 pictures), Bit-stream size: 20198512 bits
Parameters: Bit-rate = 4.00 Mbit/s, Picture-rate = 30.00, M = 3, N = 12

Statistics	All	Intra	Pred	Interp
# of pictures	148	13	37	98
RMS Y	8.1	8.7	7.9	8.1
SNR Y	30.0	29.4	30.2	30.0
SNR U	34.5	34.1	34.3	34.6
SNR V	34.6	34.2	34.4	34.7
QUANT	10.1	11.3	8.0	10.7
# of transmitted coefs per coded bk.	4.9	9.9	5.8	4.0
# of zero before eob per coded bk.	17.5	11.6	20.6	17.1
% of MB of each type				
Intra	Skipped	Skipped		
Intra	MC Coded	I Not Coded	43.26	39.63	16.58
Intra + Q	MC NotCoded	I Coded	56.74	7.31	14.40
	MC Cod + Q	B Not Coded		46.70	6.01
	NoMC Coded	B Coded		0.76	3.47
	Intra	F Not Coded		1.96	2.98
	NoMC Cod Q	F Coded		0.52	1.79
	Intra + Q	Intra		2.08	0.30
		I Coded +Q			22.86
		B Coded +Q			5.92
		F Coded +Q			3.01
		Intra +Q			0.36
# of Coded MB	1147.0	1350.0	1336.0	1048.7
% of Coded Blocks	36.48	100.00	58.37	19.79
% of bits for MB attributes	5.71	1.45	4.49	11.67
Motion Vectors	5.14	0.00	3.19	12.91
CBP	2.84	0.00	3.29	5.30
EOB	4.33	3.21	4.71	5.06
Intra DC	4.34	11.32	1.26	0.64
Y coefs	68.39	70.18	74.18	59.55
U coefs	3.98	6.53	4.03	1.22
V coefs	4.66	7.03	4.79	2.00
Multiplexing	0.61	0.28	0.06	1.64
# of bits per picture	136476	504647	200913	63309
% of bits per type of picture	100.00	32.48	36.80	30.72
% of transmitted coefs == +-1	74.05	66.95	77.87	79.75
% of transmitted coefs with ESC	1.05	0.21	1.16	2.30
# of transmitted coefs	18044	79941	27403	6299

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	405688	27.7	60	526392	29.6	120	518440	29.8
1	67720	27.9	61	55176	29.7	121	63856	30.4
2	125072	28.3	62	55280	29.6	122	58768	30.3
3	201520	28.1	63	199144	29.5	123	202960	30.6
4	98896	28.6	64	59480	29.5	124	66792	30.5
5	105208	28.3	65	57752	29.3	125	61224	30.8
6	195896	28.3	66	211240	29.4	126	202056	31.4
7	86544	28.3	67	58328	29.1	127	62456	31.0
8	116336	28.4	68	57280	29.0	128	58320	30.8
9	197120	28.4	69	210184	29.5	129	195584	31.5
10	86976	29.0	70	57408	29.4	130	56800	31.6
11	75952	28.9	71	57680	29.4	131	63128	30.9
12	412344	27.9	72	475592	28.9	132	547392	30.1
13	62904	28.7	73	61160	29.0	133	52496	30.9
14	62472	28.9	74	60584	28.9	134	57848	30.8
15	198912	28.8	75	224144	29.3	135	178656	30.8
16	61896	29.7	76	62856	28.9	136	56328	31.3
17	65520	29.7	77	61968	28.7	137	60056	31.2
18	209904	30.1	78	202144	29.5	138	184808	31.4
19	66312	30.0	79	56176	29.3	139	58360	31.3
20	74472	30.1	80	75016	29.6	140	85088	31.1
21	222328	30.3	81	195720	30.3	141	190272	31.1
22	61808	30.6	82	63648	30.2	142	65400	31.9
23	57496	30.6	83	67160	29.8	143	63168	31.6
24	508640	29.3	84	474128	29.0	144	568216	30.3
25	50296	30.6	85	60968	29.6	145	56336	31.2
26	52440	30.3	86	65048	29.5	146	55416	31.1
27	219656	30.7	87	198736	29.8	147	190024	31.2
28	52712	30.9	88	69864	29.8			
29	55256	30.8	89	68888	29.7			
30	214104	31.3	90	200512	30.8			
31	63424	30.4	91	73224	29.7			
32	57152	30.5	92	69264	29.8			
33	215448	31.7	93	201128	30.5			
34	63656	30.6	94	62000	30.3			
35	57544	30.9	95	58472	30.4			
36	566296	30.1	96	533600	29.8			
37	60816	30.1	97	50352	29.9			
38	61920	29.9	98	53464	29.9			
39	197088	30.3	99	188208	30.1			
40	58848	30.3	100	54640	30.4			
41	55912	30.3	101	54240	30.3			
42	187192	30.4	102	202928	30.4			
43	60072	30.2	103	53616	30.6			
44	56376	30.0	104	66136	30.5			
45	199688	30.3	105	209768	30.5			
46	56504	30.1	106	65184	30.4			
47	56608	30.1	107	61568	30.4			
48	509872	29.4	108	513816	29.7			
49	50768	29.8	109	59480	29.9			
50	56936	29.6	110	59776	30.0			
51	191264	30.0	111	206968	30.6			
52	63560	29.8	112	64688	30.1			
53	61880	29.6	113	62536	30.1			
54	200032	30.4	114	199800	30.8			
55	64016	29.7	115	57432	30.4			
56	61632	29.5	116	63112	30.2			
57	196904	29.9	117	191744	31.1			
58	58584	30.1	118	55408	31.1			
59	56880	30.1	119	56784	31.4			

Frame	#bits(cumul)
0	405688
12	2012344
24	3708632
36	5374720
48	6943704
60	8530200
72	10085120
84	11674104
96	13346144
108	14913784
120	16524512
132	18156112
144	19768168

12.2.6 Mobile & Calendar 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Tue Sep 24 23:50:40 PDT 1991
Directory: /usr4/olivier/mpeg60/mobile/q9flt
Pictures: 0 to 147 (148 pictures), Bit-stream size: 45282592 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 30.00, M = 3, N = 12

Statistics	All	Intra	Pred	Interp
# of pictures	148	13	37	98
RMS Y	5.0	5.2	4.6	5.1
SNR Y	34.2	33.8	34.9	34.0
SNR U	37.5	37.1	37.5	37.6
SNR V	37.8	37.5	37.8	37.8
QUANT	4.8	5.4	3.9	5.1
# of transmitted coefs per coded bk	8.2	17.6	10.4	6.1
# of zero before eob per coded bk	22.0	15.5	24.4	21.9
% of MB of each type				
Intra	Skipped	Skipped	0.14	7.52
Intra	MC Coded	I Not Coded	50.21	53.19	4.60
Intra + Q	MC NotCoded	I Coded	49.79	0.87	29.69
	MC Cod + Q	B Not Coded		40.56	2.20
	NoMC Coded	B Coded		1.57	7.46
	Intra	F Not Coded		1.63	1.27
	NoMC Cod Q	F Coded		0.45	4.83
	Intra + Q	Intra		1.58	0.22
		I Coded +Q			30.15
		B Coded +Q			7.44
		F Coded +Q			4.37
		Intra +Q			0.26
# of Coded MB	1282.3	1350.0	1348.1	1248.5
% of Coded Blocks	59.60	100.00	81.08	46.13
% of bits for MB attributes	2.78	0.76	1.81	5.04
Motion Vectors	2.39	0.00	1.46	4.86
CBP	1.94	0.00	1.70	3.47
EOB	3.16	1.83	2.96	4.22
Intra DC	1.88	6.44	0.48	0.18
Y coefs	75.48	73.50	78.57	73.86
U coefs	5.67	8.44	6.44	3.10
V coefs	5.95	8.58	6.56	3.63
Multiplexing	0.75	0.45	0.03	1.64
# of bits per picture	305963	887313	443358	176972
% of bits per type of picture	100.00	25.47	36.23	38.30
% of transmitted coefs == +-1	67.97	59.19	68.31	74.80
% of transmitted coefs with ESC	0.92	0.35	0.77	1.54
# of transmitted coefs	44855	142468	68438	23002

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	900000	33.6	60	917328	34.0	120	898088	34.2
1	262600	30.1	61	167096	33.5	121	180424	34.2
2	300000	32.4	62	161848	33.5	122	172552	34.5
3	337400	31.3	63	451456	34.0	123	448376	35.7
4	226200	32.2	64	160800	33.3	124	181576	34.5
5	253560	32.1	65	158896	33.2	125	176208	35.0
6	420240	32.3	66	473440	34.0	126	446400	36.2
7	206768	31.9	67	158320	32.8	127	175032	35.5
8	277816	32.4	68	159336	32.7	128	169248	35.5
9	415416	32.5	69	476016	34.1	129	432528	36.6
10	215384	32.7	70	162216	33.0	130	166312	35.7
11	192888	32.5	71	164728	33.1	131	175312	34.9
12	681616	31.4	72	825960	33.1	132	954808	34.8
13	176984	32.7	73	174064	32.6	133	167392	35.4
14	181864	32.9	74	169040	32.5	134	173688	35.1
15	455848	33.7	75	488624	33.8	135	395160	35.8
16	174440	34.0	76	164688	32.7	136	163392	35.4
17	184016	34.1	77	169376	32.6	137	172208	35.6
18	464856	35.2	78	459800	34.1	138	412824	36.5
19	186312	34.3	79	160320	33.3	139	166752	35.7
20	202712	34.5	80	199088	33.9	140	211312	35.8
21	483080	35.2	81	440888	35.2	141	418416	36.0
22	173432	34.7	82	180816	34.3	142	177448	36.0
23	162160	34.6	83	182992	33.6	143	170928	35.5
24	898416	33.9	84	831832	33.3	144	983880	34.9
25	152392	34.9	85	178480	33.6	145	163944	35.6
26	154720	34.5	86	186072	33.6	146	159216	35.4
27	487352	35.7	87	432112	34.6	147	427176	35.9
28	151800	35.1	88	187600	33.8			
29	156312	35.2	89	187784	33.8			
30	478936	36.2	90	436168	35.4			
31	168752	34.1	91	192824	33.7			
32	168816	34.4	92	187000	33.6			
33	479184	36.9	93	431832	35.0			
34	185000	34.4	94	172720	34.2			
35	176200	34.6	95	168416	34.2			
36	963600	34.6	96	911832	34.0			
37	184376	33.8	97	159608	34.2			
38	179456	33.6	98	159608	34.4			
39	408816	34.8	99	429512	34.8			
40	173176	34.2	100	158792	34.9			
41	165976	34.3	101	154664	34.7			
42	409632	34.6	102	468016	35.4			
43	164784	34.1	103	149768	35.2			
44	156944	33.8	104	169208	35.1			
45	443096	34.7	105	482344	35.8			
46	162856	33.7	106	169168	34.3			
47	166640	33.8	107	163808	34.3			
48	849688	33.4	108	918024	34.3			
49	159648	33.9	109	172432	34.0			
50	166920	33.5	110	170704	34.0			
51	438632	34.6	111	455528	35.4			
52	176616	33.7	112	169048	34.1			
53	174624	33.7	113	171800	34.0			
54	464024	35.3	114	444200	35.5			
55	178624	33.4	115	165912	34.6			
56	176000	33.5	116	175320	34.2			
57	442400	34.6	117	424512	35.9			
58	171128	33.9	118	171144	35.2			
59	165544	33.7	119	170392	35.6			

Frame	#bits(cumul)
0	900000
12	4281616
24	8098416
36	11795872
48	15293016
60	18917328
72	22447168
84	26031832
96	29727344
108	33318024
120	36898544
132	40577232
144	44183880

12.2.7 Popple 9 Mbit/s

Institute: Thomson Consumer Electronics (Los Angeles)
Date: Wed Sep 25 22:21:32 PDT 1991
Directory: /usr4/olivier/mpeg60/popple/q9flt
Pictures: 0 to 147 (148 pictures), Bit-stream size: 45063144 bits
Parameters: Bit-rate = 9.00 Mbit/s, Picture-rate = 30.00, M = 3, N = 12

Statistics	All	Intra	Pred	Interp
# of pictures	148	13	37	98
RMS Y	4.2	3.8	3.8	4.4
SNR Y	35.9	36.9	36.7	35.5
SNR U	37.9	39.4	38.5	37.4
SNR V	38.0	39.4	38.6	37.6
QUANT	4.6	4.5	3.7	5.0
# of transmitted coefs per coded bk.	6.2	10.5	8.3	4.9
# of zero before eob per coded bk.	23.0	22.4	25.0	22.3
% of MB of each type				
Intra / Pred / Interp				
Intra / Skipped / Skipped			1.53	3.31
Intra / MC Coded / I Not Coded		65.06	30.33	4.08
Intra + Q / MC NotCoded / I Coded		34.94	0.26	35.73
MC Cod + Q / B Not Coded			23.46	1.46
NoMC Coded / B Coded			17.01	5.99
Intra / F Not Coded			23.27	0.92
NoMC Cod Q / F Coded			1.47	5.78
Intra + Q / Intra			2.67	9.85
I Coded +Q				22.98
B Coded +Q				3.81
F Coded +Q				4.13
Intra +Q				1.97
# of Coded MB	1315.3	1350.0	1329.4	1305.3
% of Coded Blocks	74.46	100.00	88.34	65.83
% of bits for MB attributes	2.60	0.99	1.82	3.65
Motion Vectors	5.00	0.00	2.59	8.27
CBP	1.83	0.00	1.37	2.73
EOB	3.96	2.91	3.44	4.66
Intra DC	3.36	8.03	2.45	2.48
Y coefs	58.97	65.96	65.67	52.13
U coefs	12.17	11.34	11.46	12.92
V coefs	11.45	10.52	11.16	11.95
Multiplexing	0.65	0.25	0.03	1.21
# of bits per picture	304481	557450	415606	228968
% of bits per type of picture	100.00	16.08	34.12	49.79
% of transmitted coefs == +-1	72.93	72.56	72.19	73.73
% of transmitted coefs with ESC	2.36	0.89	1.70	3.55
# of transmitted coefs	39664	84841	59459	26197

Frame	#bits	SNR	Frame	#bits	SNR	Frame	#bits	SNR
0	923880	40.7	60	569808	37.6	120	482064	34.2
1	293024	35.1	61	205976	36.4	121	263560	32.8
2	300000	37.8	62	206024	36.3	122	263192	32.8
3	283096	36.8	63	471120	37.7	123	346400	33.7
4	212480	37.1	64	205328	36.1	124	262968	32.4
5	283472	37.6	65	200616	36.0	125	255384	32.7
6	404048	37.6	66	463744	37.5	126	333752	33.7
7	226648	36.9	67	203136	36.2	127	260560	32.5
8	287600	37.4	68	204576	36.2	128	259448	32.8
9	385752	37.2	69	463992	37.5	129	346152	33.8
10	231296	36.9	70	201080	36.4	130	262560	32.6
11	214832	36.7	71	203832	36.5	131	260992	32.9
12	593720	37.3	72	497128	37.9	132	472392	33.7
13	212880	36.7	73	202632	37.0	133	260224	32.6
14	205736	36.6	74	207832	37.2	134	258984	32.7
15	425048	37.3	75	458648	38.6	135	359016	33.2
16	202648	36.7	76	206440	37.5	136	253112	32.3
17	204472	36.6	77	232240	37.6	137	249528	32.6
18	452688	38.3	78	461320	39.1	138	351992	33.4
19	201320	36.9	79	216688	37.5	139	253296	32.3
20	201048	36.8	80	239504	37.6	140	252760	32.8
21	463984	38.2	81	443808	39.0	141	367280	33.5
22	201952	36.8	82	233352	37.5	142	253720	32.3
23	204416	36.9	83	229808	37.5	143	246872	32.8
24	577736	37.5	84	467440	39.0	144	484552	33.6
25	204600	36.9	85	226272	37.5	145	257768	32.3
26	201928	36.7	86	230680	37.4	146	242640	32.8
27	459336	38.2	87	437456	38.5	147	365240	33.8
28	202104	36.9	88	228224	37.1			
29	204128	36.8	89	236168	36.9			
30	459968	38.4	90	448128	37.9			
31	203264	36.9	91	231424	36.3			
32	209336	36.9	92	239456	36.0			
33	461560	38.3	93	429632	37.2			
34	206640	36.9	94	235432	35.5			
35	206160	36.8	95	237328	35.2			
36	574384	37.5	96	530056	37.4			
37	206912	36.9	97	248656	34.9			
38	202952	36.8	98	233960	34.5			
39	463224	38.2	99	394352	35.6			
40	199936	36.9	100	244184	34.0			
41	202296	36.9	101	239008	33.9			
42	466224	38.5	102	392256	35.4			
43	199600	37.0	103	247664	33.5			
44	209896	36.8	104	243096	33.5			
45	465376	38.3	105	384856	34.9			
46	203800	36.9	106	246360	33.3			
47	200760	37.0	107	242544	33.3			
48	587112	37.6	108	486584	35.3			
49	205584	36.9	109	250296	33.2			
50	200432	36.9	110	248504	33.6			
51	471080	38.2	111	357976	34.6			
52	205792	36.7	112	260808	33.1			
53	206640	36.6	113	247944	33.3			
54	476880	38.4	114	354896	34.5			
55	201480	36.5	115	252224	33.1			
56	203088	36.5	116	253896	33.2			
57	462608	38.1	117	344536	34.3			
58	204456	36.6	118	261344	32.9			
59	201216	36.7	119	259936	33.2			

Frame	#bits(cumul)
0	923880
12	4193720
24	7787408
36	11374384
48	14990712
60	18598664
72	22125976
84	25667440
96	29368096
108	32955472
120	36497520
132	40082608
144	43696904

12.3. Listing (ls -l) of bit-stream files

```
-rw-rw-r--  1 olivier   2520007 Sep 24 20:58 mpeg50/flower/q4flt/bits
-rw-rw-r--  1 olivier   5670007 Sep 24 21:56 mpeg50/flower/q9flt/bits
-rw-rw-r--  1 olivier   2520007 Sep 25 21:50 mpeg50/mobile/q4flt/bits
-rw-rw-r--  1 olivier   5670007 Sep 25 23:26 mpeg50/mobile/q9flt/bits
-rw-rw-r--  1 olivier   5670007 Sep 23 21:34 mpeg50/popple/q9flt/bits
-rw-rw-r--  1 olivier   2520007 Sep 24 18:15 mpeg50/tennis/q4flt/bits
-rw-rw-r--  1 olivier   5670877 Sep 24 19:17 mpeg50/tennis/q9flt/bits
-rw-rw-r--  1 olivier   2530740 Sep 24 15:41 mpeg60/flower/q4flt/bits
-rw-rw-r--  1 olivier   5666747 Sep 24 16:40 mpeg60/flower/q9flt/bits
-rw-rw-r--  1 olivier   2524821 Sep 24 22:56 mpeg60/mobile/q4flt/bits
-rw-rw-r--  1 olivier   5660331 Sep 24 23:50 mpeg60/mobile/q9flt/bits
-rw-rw-r--  1 olivier   5632900 Sep 25 22:21 mpeg60/popple/q9flt/bits
-rw-rw-r--  1 olivier   2519561 Sep 24 11:36 mpeg60/tennis/q4flt/bits
-rw-rw-r--  1 olivier   5652419 Sep 24 12:55 mpeg60/tennis/q9flt/bits
```