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Proposal Document for MPEG phase−2 Video Coding algorithm

Title: Hybrid Multi−Resolution Representation Coding

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(Main proposer: NEC corp.)

MPEG91/220

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1 Introduction

Hybrid coding which is a combination of prediction coding and transform coding is one of the most popular techniques, and it is adopted to many international standards. (ISO/MPEG phase−1, CCITT/H.261, CCIR−CCITT/CMTT/R.723) In this algorithm, redundancy for time axis is reduced with Motion Compensated Interframe Coding(MC), and transform coding (most commonly DCT) is used to reduce spatial redundancy. The hybrid schemes are powerful methods, and therefore we start with SM3 which belongs to one of these hybrid coding schemes.

In this algorithm, operations such as MC and DCT are carried out by block by block basis, so blocking effect can be observed at lower bit rate. To avoid this blocking effect, we propose to replace DCT with Multi−Resolution Representation(MRR) Transform. MRR transform is a kind of sub−band coding, in which the lowest band is divided repeatedly. If the same filter bank is used at every stage and satisfy regularity condition[Daubechies:1], this transform is "Wavelet Transform"[Mallat:1,2]. MRR or Wavelet transforms do not produce blocking effect, since its transform bases are overlapped each other. Moreover, transform bases for higher frequencies become shorter in MRR, and mosquito noise is reduced by adopting MRR instead of DCT.

In most cases, MRR has been applied out of coding loop, but in this proposal, we set it inside the loop to keep the general architecture of SM3. Therefore, our proposal preserves most part of the elements in SM3.

For prediction part, there are two issues. These are how to deal with interlace signal and how to reduce blocking effects due to motion compensation by block matching technique. For the former, we add interfield prediction to SM3. Obviously, the interfield coding is more effective than field independent codings. To prevent increase of the number of prediction modes, we put some restriction for macro−block type. Allowable prediction mode is 1, 4, 7 for I, P, B−field, respectively. This concept is based on an idea from Mr.Nishikawa et al., Mitsubishi corp. (It was only presented in Japanese[Nishikawa:1].)

The prediction mode is selected for each macro block in SM3, so blocking effect appears both on prediction and prediction error pictures. This reduces coding efficiency of MRR whose transform basis span several prediction blocks. Therefore, we use "overlapped prediction" method. The method does not produce blocking effect, and it is suitable for MRR transform[Ohta:1].

Another technique we use is adaptive quantization for macro block. Quantization scale is controlled by AC power of original picture. The idea is from Mr.Katayama, GCT.

Features of our algorithm can be summarized as follows:

1. Conventional hybrid scheme (SM3 like),
2. Multi Resolution Represent Transform(MRR) is adopted for transform,
3. Overlapped prediction ,
4. Intra−field mode is added to SM3,
5. Adaptive quantization for macro−block.

2 Algorithm

2.1 Total System

A block diagram of the proposed system is shown in Figure 1. The outline is the same as that of SM3. Basically, an interfield prediction coding reduces temporal redundancy. In the coding loop, transform(MRR) is applied to reduce spatial redundancy.

Motion vectors are estimated and used for prediction. Variable Length Coder(VLC) encodes quantized transform coefficients and the motion vectors.

Source format is CCIR Rec.601. No sub−sampling is performed, and the picture size is 704pel*240lines/field for luminance, 352pel*240line/field for chrominance.

2.2 Prediction Mode

I,P,B picture are defined in SM3, where I,P and B means "Intra","Predictive", and "Bidirectional", respectively. I pictures appear cyclically for random accesability, and its interval is 12 frames. This means N=12 in terms of SM3. P pictures appear in every two frames, so M=2. In our proposal, odd field and even field are coded in different manners, so it is useful to consider six types of fields, namely I−odd, I−even, P−odd, P−even, B−odd and B−even field.

Basically, prediction mode for each Macro−block is the same as that of SM3, but some additional modes are available. These modes are interfield prediction and average prediction. For example, interfield prediction can be selected for I−even field, and interfield prediction and average prediction of inter−field and frame is added to P−picture. These modes are shown at Table.1 and Figure.2.

Table.1: Prediction Modes

I−odd field:

```
Intra field mode(I)
```

I−even field:

```
Intra field mode(I)
Inter field in frame mode(f)
```

P−odd field:

```
Intra field mode(I)
Forward inter frame mode(F)
Inter field over frame mode(Fx)
Average of F and Fx mode(AFF)
```

P−even field:

```
Intra field mode(I)
Forward inter frame mode(F)
Inter field in frame mode(f)
Average of F and f mode(AFf)
```

B−odd field:

```
Intra field mode(I)
Forward inter frame mode(F)
Backward inter frame mode(B)
Forward inter field mode(Fx)
Average of F and B mode(A)
Average of Fx and B mode(Ax)
```

B–even field:

```
Intra field mode(I)
Forward inter frame mode(F)
Backward inter frame mode(B)
Backward inter field mode(Bx)
Average of F and B mode(A)
Average of Bx and F mode(Ax)
```

2.3 Overlapped Prediction

In conventional coding, prediction is carried out by block–by–block basis. However, it is not appropriate for overlapped transforms such as LOT, MDCT, subband coding , wavelet coding and MRR. For these blockless transforms, blockless prediction is required.

In our proposal, an overlapped prediction is adopted. Prediction blocks are overlapped with each other, and predicted signals are multiplied with a window function.(See Figure 3.)

2.4 Transform

Prediction error picture is transformed by MRR (Multi Resolution Representation). It is well known that MRR is realized with a subband filter bank as is shown in Figure 4, where the lower subband is divided iteratively. In terms of transform coding, MRR means overlapped transform coding in which block size becomes larger for lower frequency. If the same filters are applied in each filter bank, and if they satisfy satisfies some mathematical conditions, this MRR is called "Wavelet transform" [Mallat:1,2,Daubechies:1].

In our proposal, transform is carried out in four stages. In each stage, the signal is divided both horizontally and vertically except for the first stage where only horizontal division is performed. Daubechies' four tap filters(D4) are used in a filter bank, but in the last stage, H2(two taps Hadamard filter) is applied instead of D4(See Figure 5). For chrominance signals, the first stage is eliminated.

The filter bank shown in Figure 5 means spatial frequency division as shown in Figure 6. Each subband has a different resolution, and transform coefficients are considered as tree structured data. (See Figure 7.) Each luminance tree has 128 coefficients and chrominance has 64.

2.5 Quantizer

Quantization is done after the transform. The quantizer characteristic is linear and its step size is defined weighting factor(wf), macro block adaptive Q scale(M_Q), and field Q scale(F_Q).

```
step size = wf * M_Q * f_Q
```

The weighting factor, wf, is shown in Table 7. M_Q is defined by the AC power of original picture.(See Table 6.) F_Q is controlled by buffer controller.

2.6 Macro–block

In our proposal, macro block is defined as in Figure 9. 16*8 of luminance and 8*8 of chrominance pels make up a macro block. This block size coincides with the number of transform coefficients of tree structured data.

For each macro block, an appropriate prediction mode and motion vectors are chosen.

2.7 VLC/VLD

Basically, VLC and VLD is the same as in SM3, though there are two points that differ. Firstly, the number of macro_block_type increases. Secondly, methods of coefficients scanning is quite different.

A macro block header includes "prediction mode", "motion vectors" and "Coded/Non_coded flag" whose code table are shown in Table 3,4 and 5. For skipped macro blocks in B–field, Macro block address increment code is used.(See Table 2.)

As described in section 2.4, transform coefficients can be considered as a tree structured data. Scanning order is defined from lower layer to higher as shown in Figure 8. Zero–run–length and quantized index are encoded mutually and independently. For the last zero–run, EOT(End of Tree) code is allocated. The code tables of the zero run length and quantized index are switched for each layer. The code tables are shown in Table 8,9.

3 Functionality

3.1 Compatibility

Our algorithm does not have a compatibility, but can be embedded in a compatible codec.

3.2 Random Access

Random access is realized by using I–fields which appear in every 24 fields.

3.3 Encoding and Decoding Delay

Delay times for each part of the codec are shown as follows. (See Figure 1.)

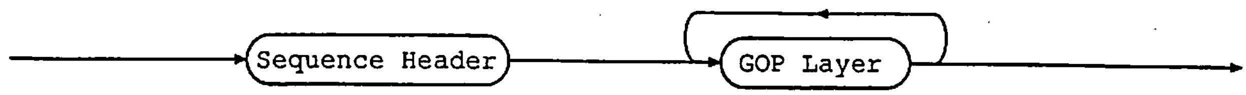
Delay time(1+12)	Pre&Post–process(Re–ordering), 70msec (two frames delay)
Delay time(2)	Negligible
Delay time(3)	Transform, 1msec (15 lines delay)
Delay time(4)	Quantizer, negligible
Delay time(5)	VLC, negligible
Delay time(6+7)	Transmission buffer(encoder+decoder) 4Mbps...250msec, 9Mbps...167msec
Delay time(8)	VLD, negligible
Delay time(9)	Dequantizer, negligible
Delay time(10)	Transform, 1msec (15 lines delay)
Delay time(11)	Negligible
Delay time(12)	Post–process
Total	4Mbps...about 330msec 9Mbps...about 240msec

4 Syntax

The video multiplex is arranged in a hierarchical structure with five layers. From the top to the bottom the layers are:

- Sequence layer
- Group of Pictures(GOP) layer
- Picture layer
- Slice layer
- Macroblock layer

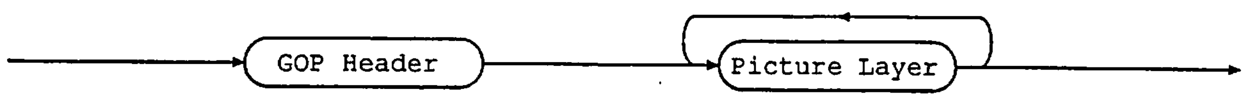
Sequence Layer:



Sequence Header:

Same as SM3.

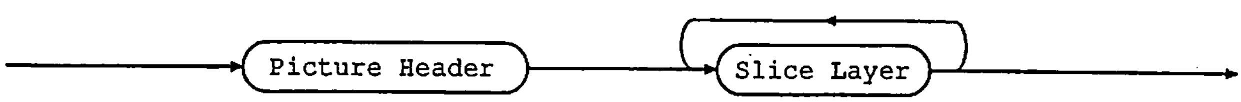
GOP Layer:



GOP Header:

Same as SM3.

Picture Layer:

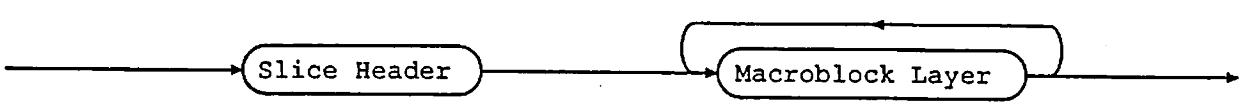


Picture Header:

Same as SM3 except the picture type. In our proposal, there are 6 picture types: I-odd, I-even, P-odd, P-even, B-odd and B-even field. (See 2.2)

Slice Layer:

Each picture is divided into macroblock slices, each of which consists of a series of macroblocks.

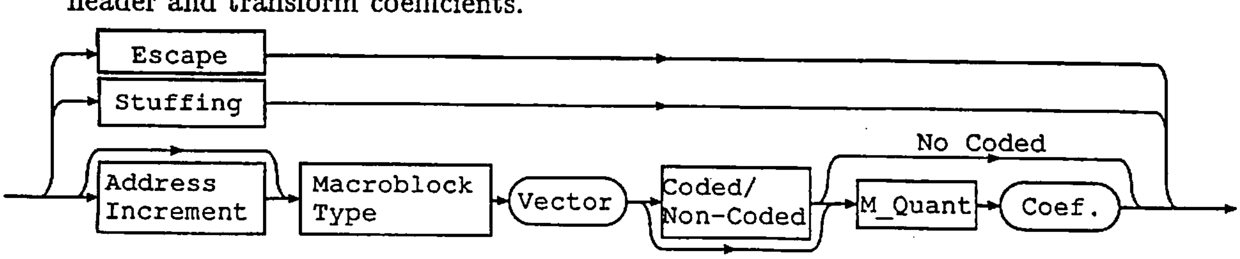


Slice Header:

Same as SM3 except the q_scale. The q_scale is extended with five extra bits to indicate the fractional value of the quantization parameter.

Macroblock Layer:

Each slice is divided into 44 macroblocks. Each macroblock consists of a macroblock header and transform coefficients.



Escape, Stuffing:

Same as SM3.

Address Increment

Same as SM3 except two differences.

- Address Increment is only present in B-odd, B-even pictures.
- Variable-length codes are extended to provide a large-valued address.

The variable-length codes are given in Table 2.

Macroblock Type:

Macroblock Type indicates macroblock prediction mode. It consists of a variable-length codeword. The variable-length codes are given in Table 3.

Vector:

Same as SM3.

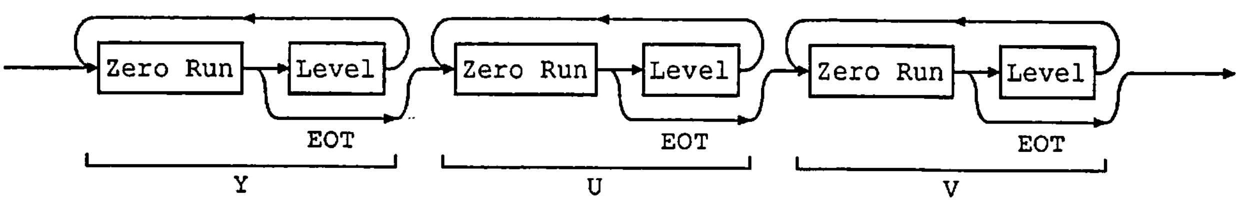
Coded/Non-Coded:

If all the coefficients of a macroblock are zero after quantization, the macroblock is declared "Non-Coded." Coded/Non-Coded is only present in B-odd, B-even pictures and expressed by a fixed-length codeword. The fixed-length codes are given in Table 5.

M_Quant:

M_Quant is used to define quantization step size(See 2.5) and defined by a fixed-length codeword. The fixed-length codes are given in Table 6.

Coef.:



5 Implementation

5.1 Picture Buffer

In our proposal, coding parameter M is fixed to two. Therefore, reordering of picture frame is required at pre−process and post−process. Frame memory for the reordering must have size of two frames. With the frame memory, motion estimation and prediction mode decision are performed.

For the predicter, P−picture requires two reference fields, in other word one reference frame, B−picture four fields (two frames). As a result, two frame buffer is needed.

For transmission buffer, it was confirmed with our simulation that 900kbit and 1500kbit are enough for transmission rate of 4Mbps and 9Mbps, respectively. These buffer sizes are required in both the encoder and the decoder.

```
Encoder
        4 frame memories and
        1500kbit transmission buffer
Decoder
         4 frame memories and
         1500kbit transmission buffer
```

Some smaller buffers are required in MRR transform, which will be mentioned at 5.2.4.

5.2 Implementation for each module

5.2.1 Pre & Post Process

Same to SM3. In our proposal M is fixed to two, so memory size is smaller than the case of M=3.

5.2.2 Motion Estimater

In SM3, each macro block requires two motion vectors, which are forward and backward vectors, at most. In our proposal, each one requires three at most. Therefore, calculation and memory access per pel become 3/2 times as SM3.

5.2.3 Prediction Mode Decision

Basically, same to SM3, but prediction mode increases. For B−frames, prediction mode is six, while it was four in SM3. Therefore calculation per pel become 3/2 times as SM3. Memory access does also 3/2 times.

5.2.4 MRR & IMRR (Transform)

As shown in Figure 5, MRR is realized of a combination of FIR filters, subsampler, upsampler and delay line. A couple of lowpass filter and highpass filter with sub(up)sampler is an element of MRR, and can be realized as in Figure 12. With the element, required multiplier, adder and buffer can be estimated.

Luminance

Multiplier

```
4+(4+4)/2+(4+4)/8+(2+2)/32 = about 9 Mul/pel,
16bit*9Mul/pel
```

Adder

```
3+(3+3)/2+(3+3)/8+(1+1)/32 = about 6.8 Mul/pel,
16bit*6.8Mul/pel
```

line buffer

```
16bit*720word*4 (on chip)
16bit*360word*4 (on chip)
16bit*180word*4 (on chip)
16bit* 90word*2 (on chip)
```

delay line

```
16bit*360word*10 (10 lines delay, onchip)
16bit*180word*8*3 ( 8 lines delay, on chip)
16bit* 90word*4*3 ( 4 lines delay, on chip)
```

Chrominance

Multiplier

```
(4+4)/2+(4+4)/8+(2+2)/32 = about 5 Mul/pel,
16bit*5Mul/pel
```

Adder

```
(3+3)/2+(3+3)/8+(1+1)/32 = about 3.8 Mul/pel,
16bit*3.8Mul/pel
```

line buffer

```
16bit*360word*4 (on chip)
16bit*180word*4 (on chip)
16bit* 90word*2 (on chip)
```

delay line

```
16bit*180word*8*3 (8 lines delay, on chip)
16bit* 90word*4*3 (4 lines delay, on chip)
```

5.2.5 Quantizer & Dequantizer

As shown in Figure 10, the quantizer and the dequantizer require two multipliers and a ROM table. Number of M_Q and layer are 4 and 11.

```
Multiplier  16bit * 2 Mul/pel
ROM table   16bit * 44word
```

5.2.6 Predicter

As shown Figure 11, thepredicter have to calculate an averaging and overlapping. Every pels are belongs to four expanded macro blocks (32*16), and every expanded macro blocks require two memory access per pel at the worst case of average prediction. Therefore, memory access must be performed 8*fs HZ, where fs is sample clock.

```
Memory access  1+8 = 9/pel (write and read)
Adder          8+4 =12 add/pel
```

5.2.7 VLC & VLD

Almost same to SM3, though the code table of coefficients is changed. In our proposal, Zero run length and quantize index are encoded independently and mutually. (See Table 8 and 9.)

```
Memory size of Code Table
       Zero run length  20bit * 256words * 4tables
       Quantize Index   24bit * 512words * 4tables
       Total            70kbit(on chip)

Memory size of code length table
       Zero run length  5bit * 256words * 4tables
       Quantize Index   5bit * 512words * 4tables
       Total            15kbit(on chip)
```

5.2.8 Transmission Buffer

It was confirmed with our simulation that 900kbit and 1500kbit are enough for transmission rate of 4Mbps and 9Mbps, respectively. These buffer sizes are required in both the encoder and the decoder.

6 Statistics

Bit amount, buffer ocupancy and SNR are shown in Figure 13 and Table 10.

7 Reference

[Daubechies:1]
Ingrid Daubechies, "Orthonormal Bases Compactly Supported Wavelets," Communications on Pure and Applied Mathematics, 1988,vol.XLI,pp.909−996.

[Mallat:1]
Stephane G.Mallat, "A Theory for Multiresolution Signal Decomposition: The Wavelet Representation," IEEE Trans. on Patern Analysis and Machine Intelligence, 1989,Vol.11, No.7, July, pp.674–693.

[Mallat:2]
Stephane G.Mallat, "Multifrequency Channel Decompositions of Images and Wavelet Model," IEEE Trans. on Acoustics, Speech and Signal Processing, 1989,Vol.37, No.12, Dec., pp.2091–2110.

[Ohta:1]
Mutsumi Ohta, "Entropy Coding for Wavelet Transform of Image, ––And Its Applicationfor Motion Picture Coding––," SPIE/Visual Communication and Image Processing '91, 1991,Nov.,Boston,No.1605–151.

[Nishikawa:1]
Hirofumi Nisikawa et al, "A Study on Moving Picture Coding....,"(in Japanese) proc. of the 1991 ITE Anual Convention. 1991,July,Tokyo,16–1,pp.313–314.

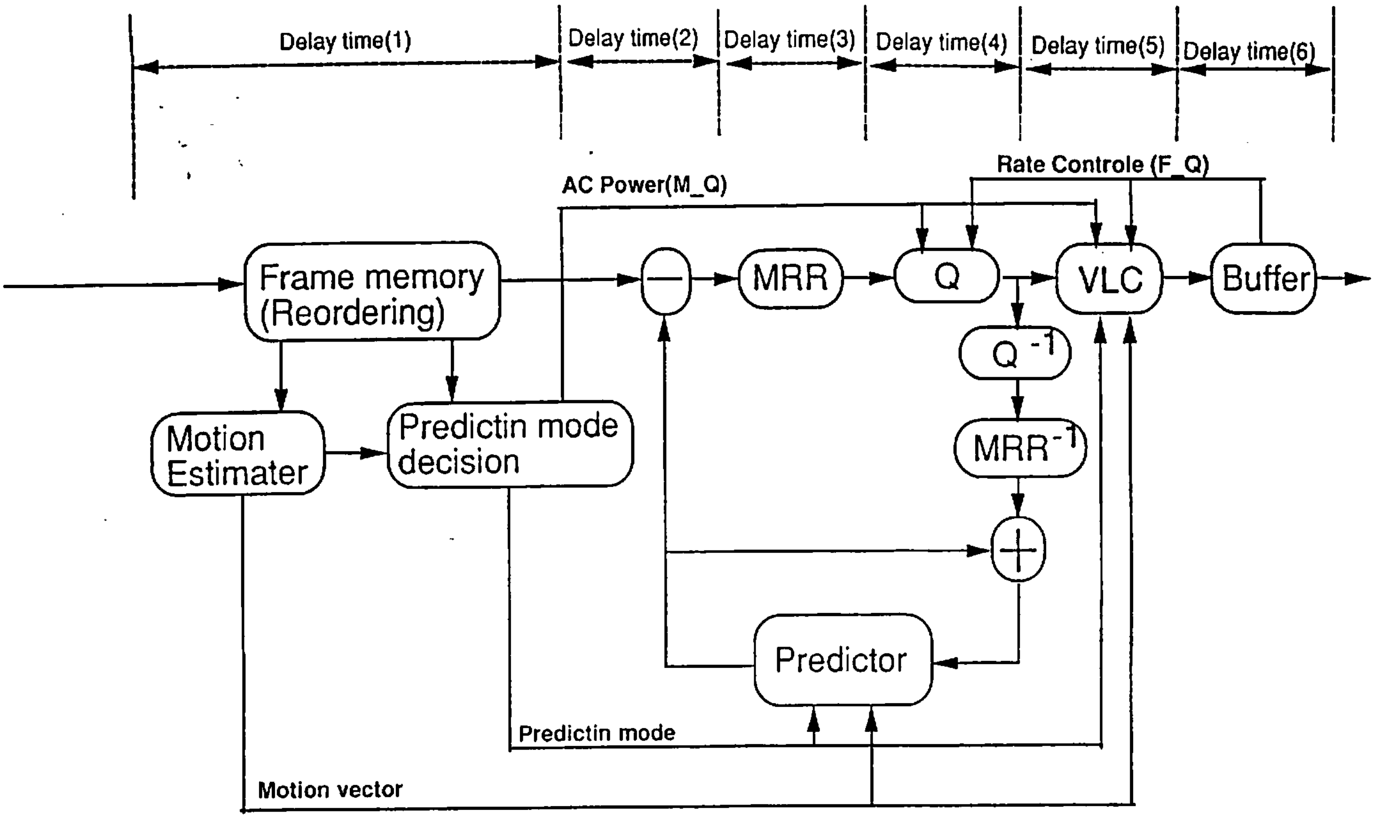


Fig.1(a) Block Diagram of Encoder

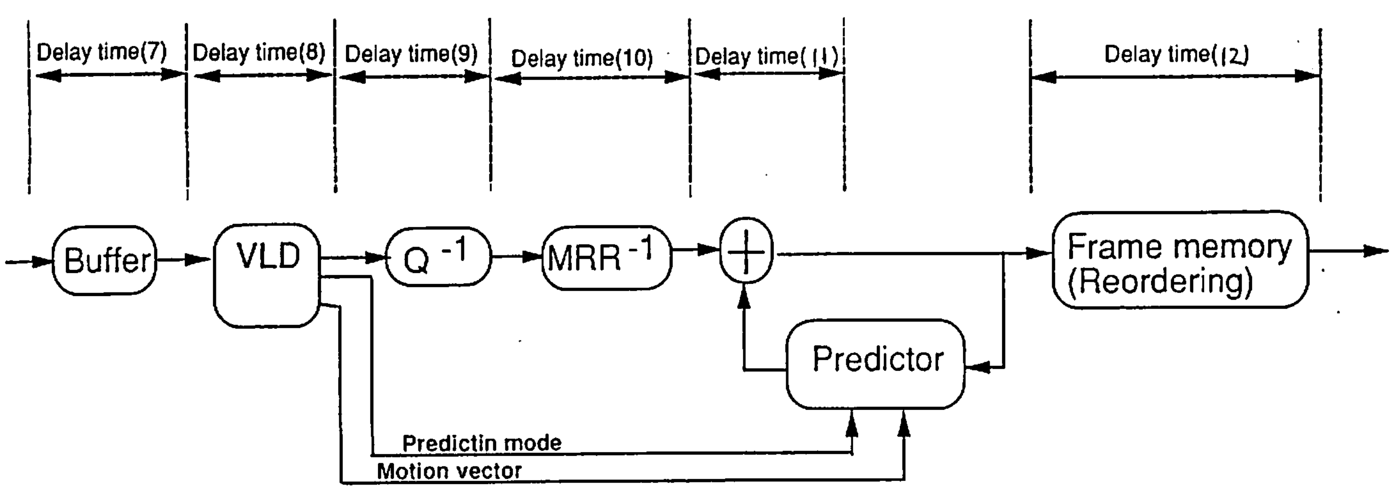


Fig.1(b) Block Diagram of Decoder

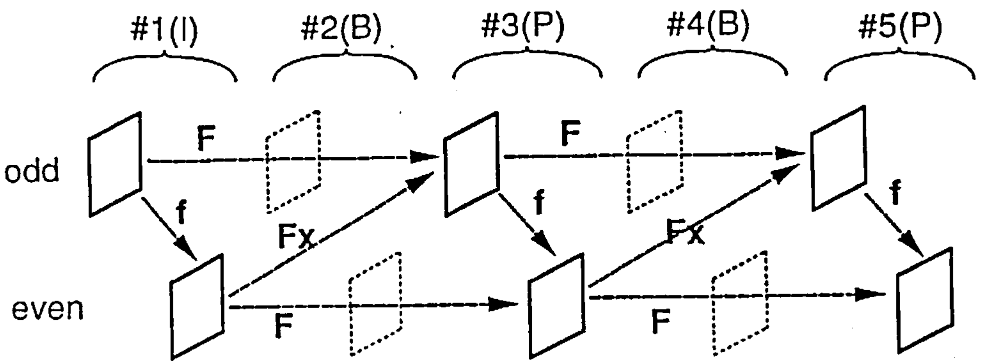


Fig. 2(a) Prediction Mode for I & P-frame

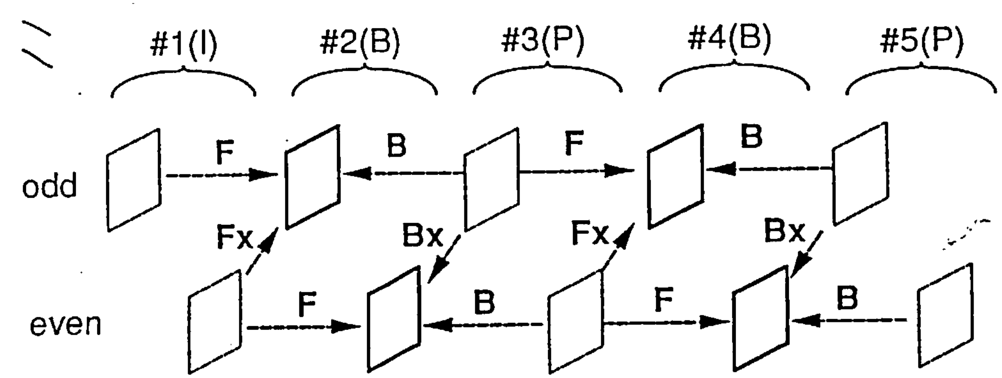


Fig. 2(b) Prediction Mode for B-frame

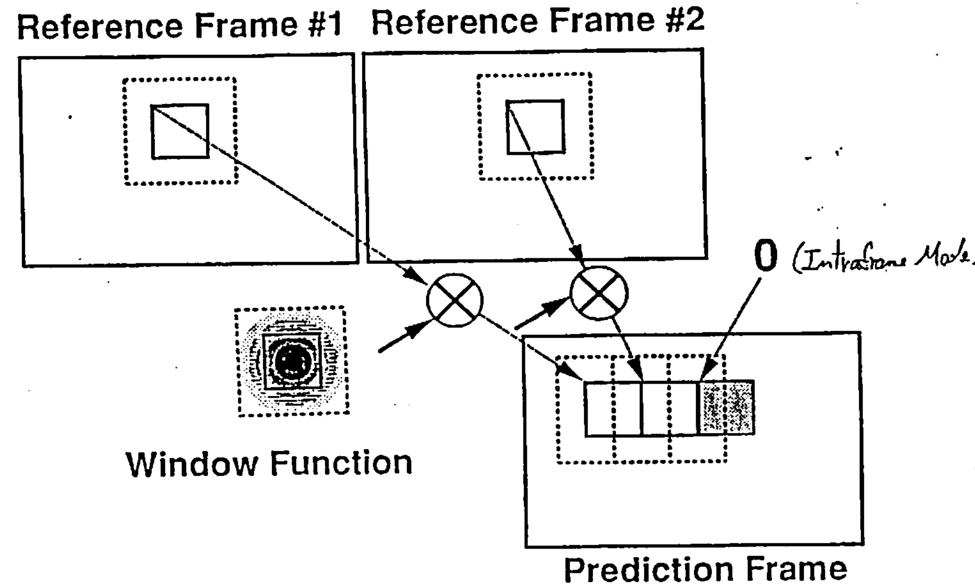


Fig. 3 Overlapped Prediction

LPF: Lowpass\ filter

HPF: Highpass filter

⇩ : Subsampler

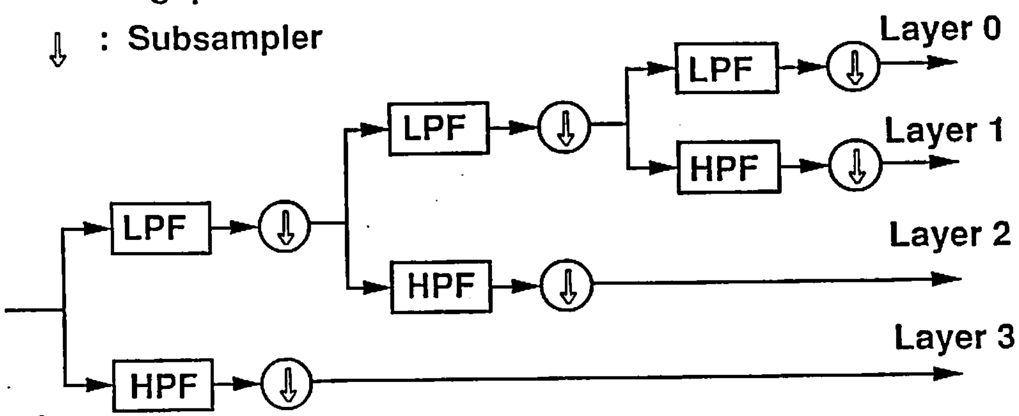


Fig. 4 Filter Bank for MRR

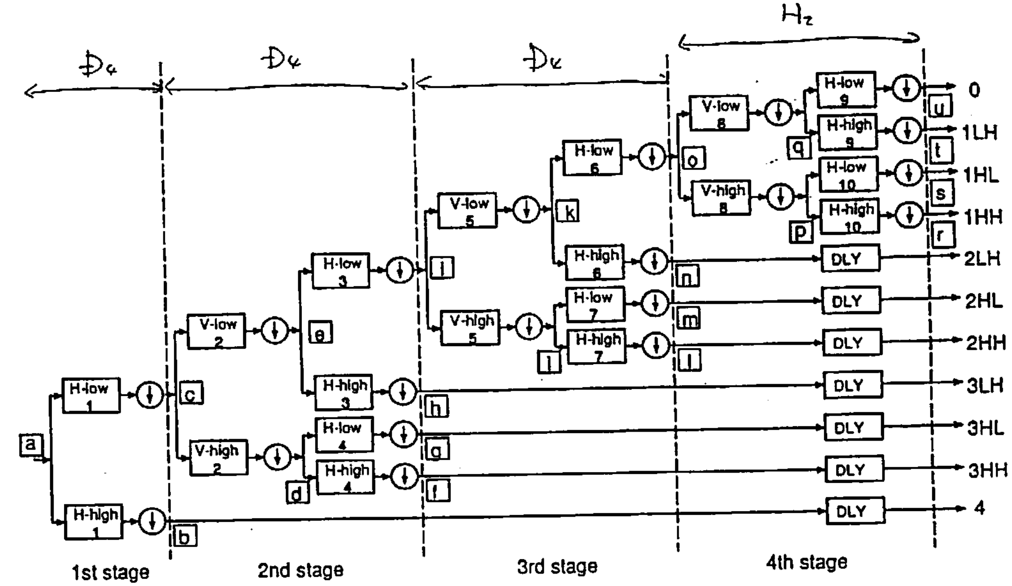
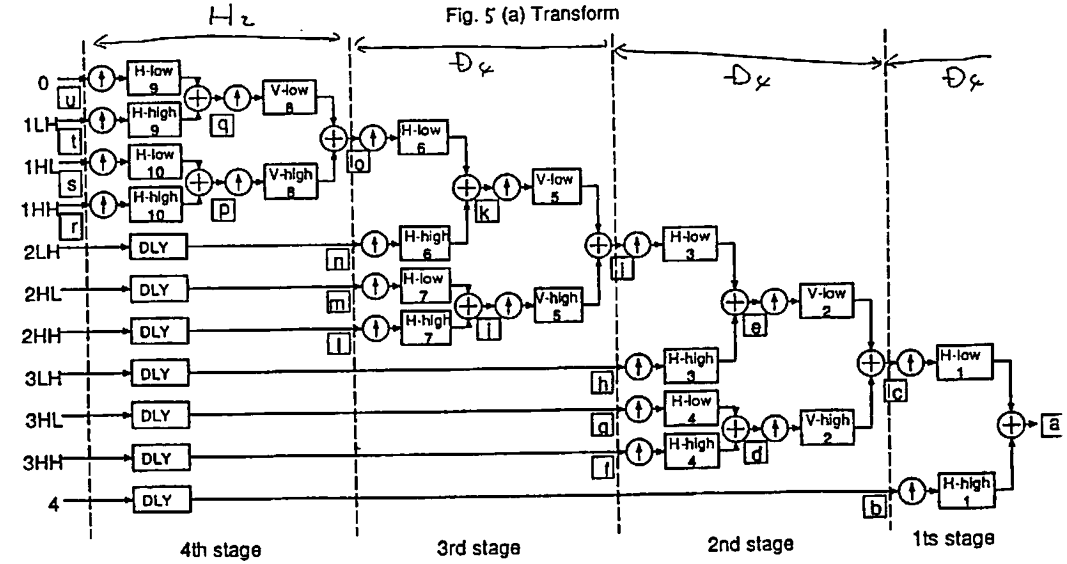


Fig. 5 (a) Transform



H-low Hollzontal Lowpass Filter
H-high Hollzontal Highpass Filter
2-to-1 Down-sampler
V-low Vertical Lowpass Filter
V-high Vertical Highpass Filter
2-to-1 Up-sampler
DLY Delay Line .

Fig. 5 (b) Inverse Transform

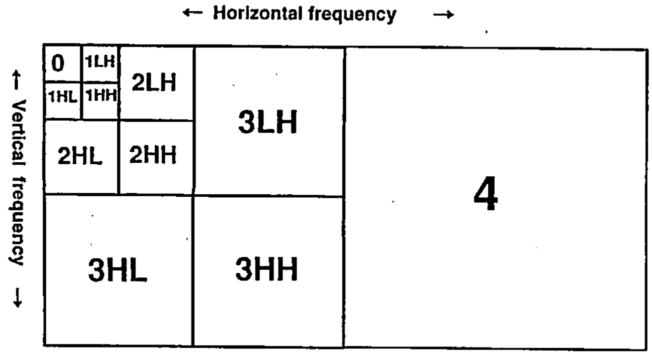


Fig. 6(a) Division in Frequency Domain for Luminance

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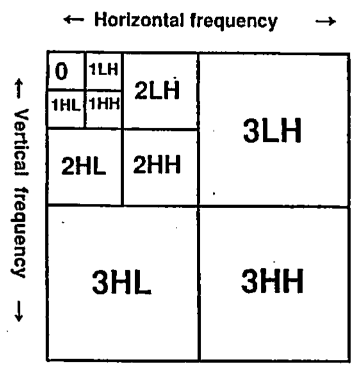

Fig. 6(b) Division in Frequency Domain for Chrominance

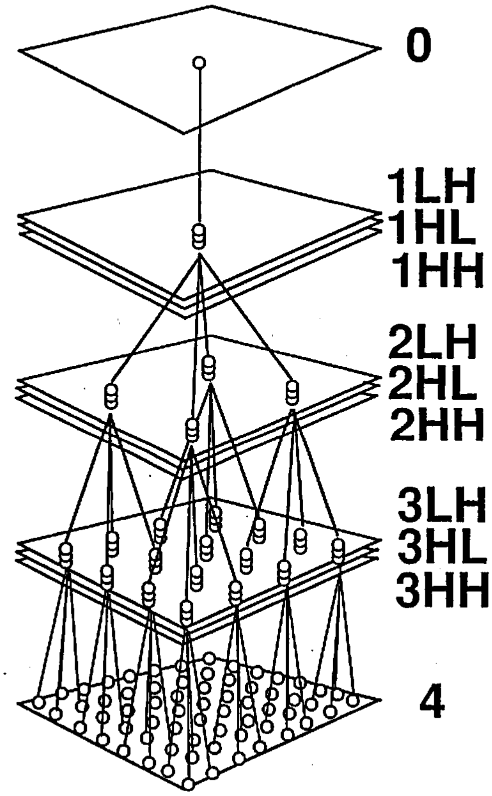

Fig. 7 Structure of Transform Coefficients

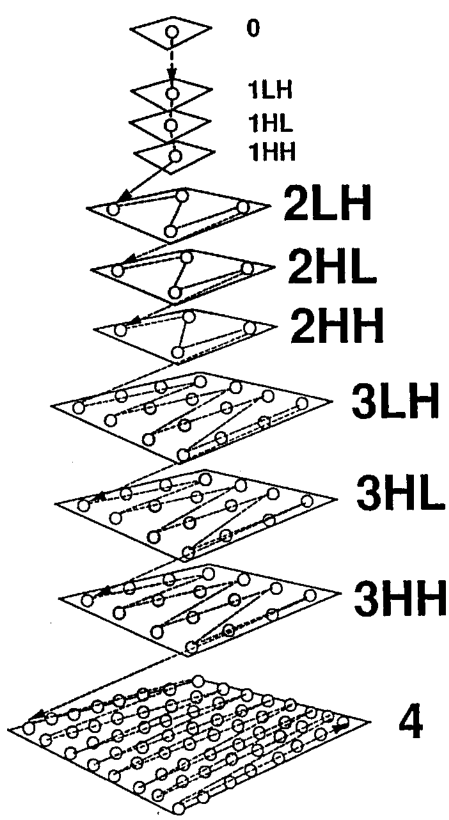

Fig. 8 Scanning Order

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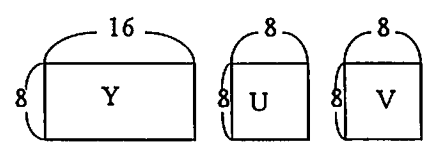

Fig. 9 Macro block

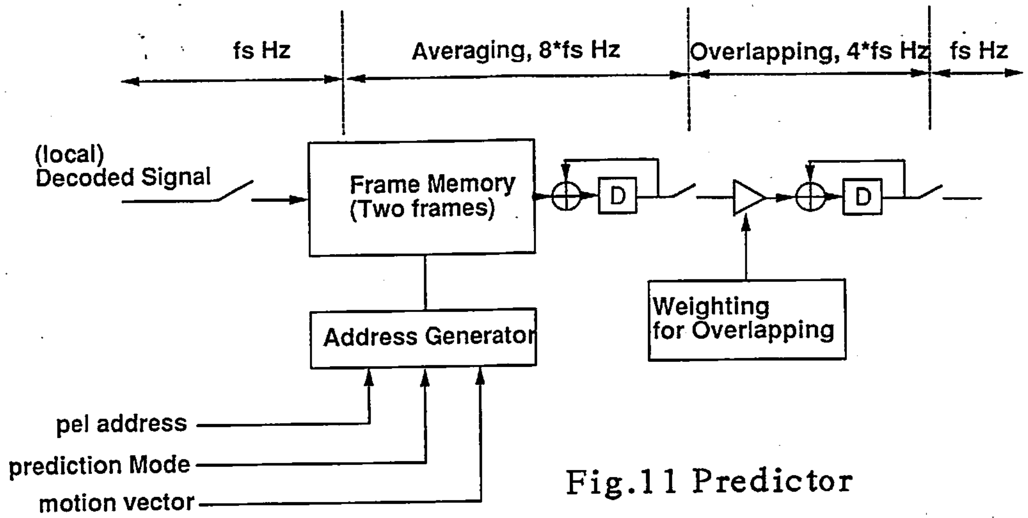

Fig.11 Predictor

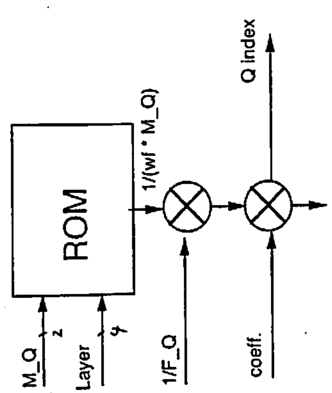

Fig. 10(a) Block diagram of Quantizer

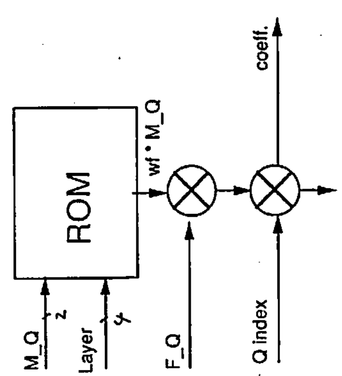

Fig. 10(b) Block diagram of Dequantizer

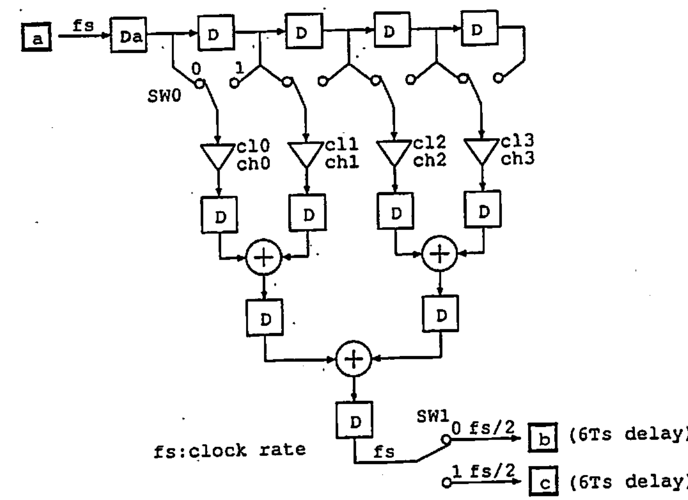

Fig 12 (a) Filter Bank Architecture of 1st-stage for Y (f=fs)

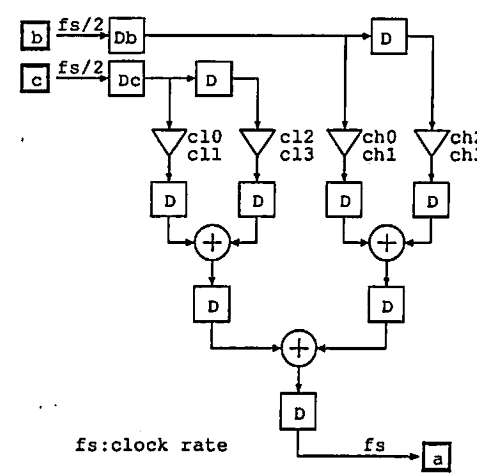

Fig 12(b) Filter Bank Architecture of Inverse Wavelet 1st-stage for Y (f=fs)

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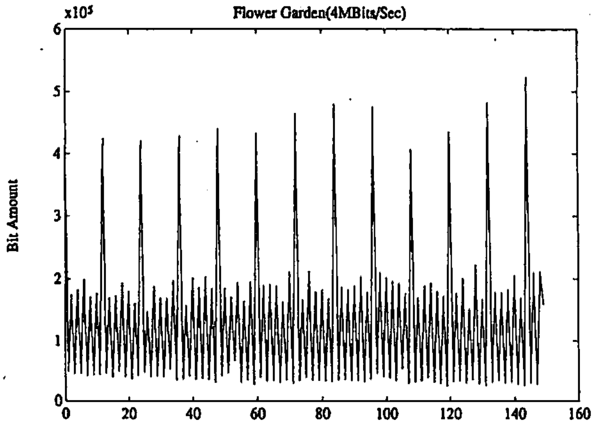

Fig.13-1a Frame Number

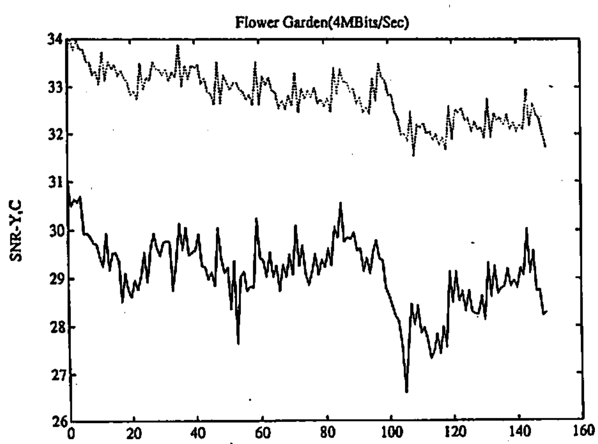

Fig. 13-1b Frame Number

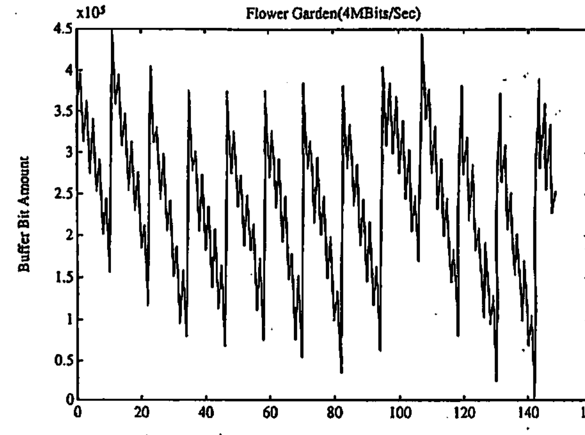

Fig 13-1c Sequence Number

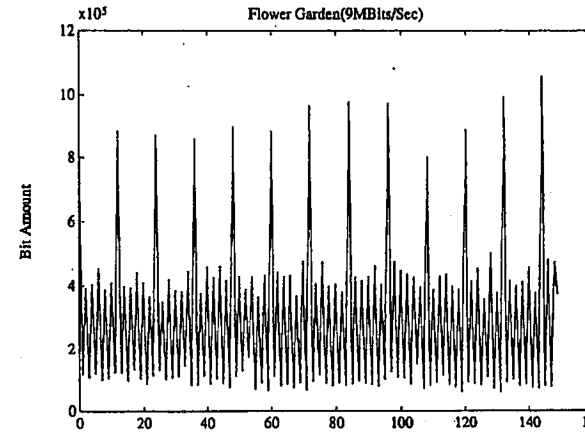

Fig. 13-2a Frame Number

18

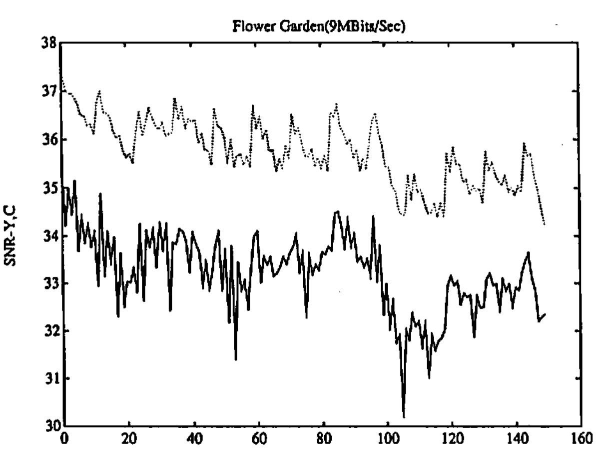

Fig.13-2b Frame Number

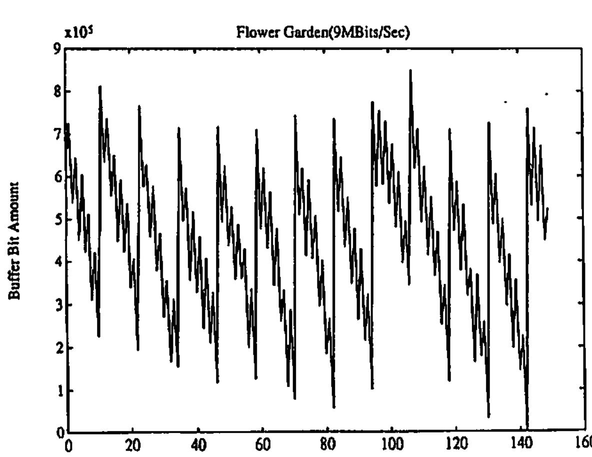

Fig.13-2c Sequence Number

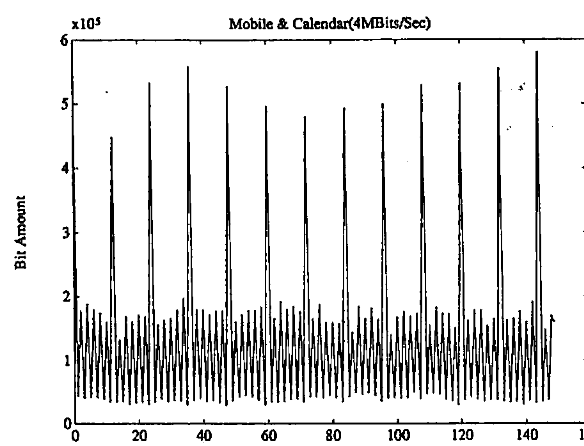

Fig.13-3a Frame Number

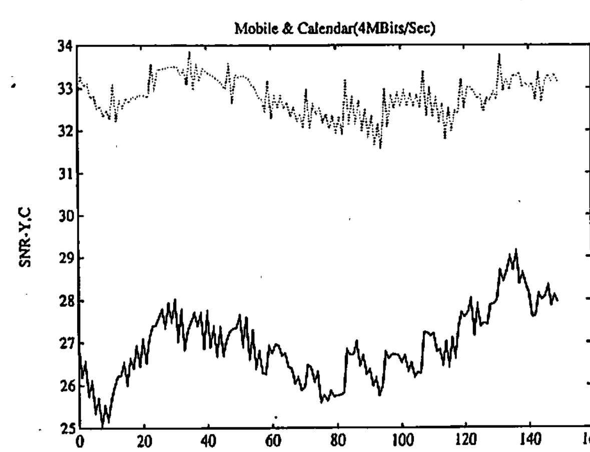

Fig.13-3b Frame Number

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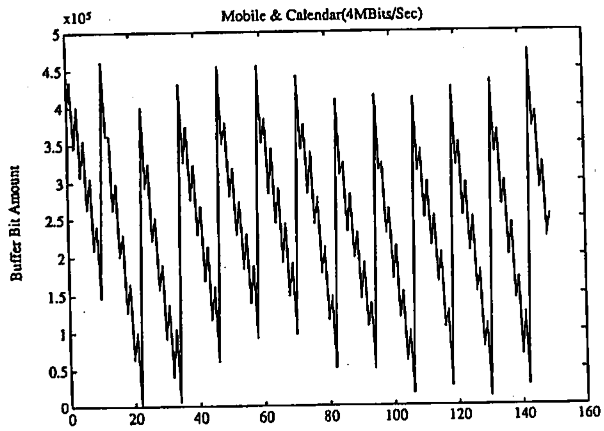

Fig. 13-3c

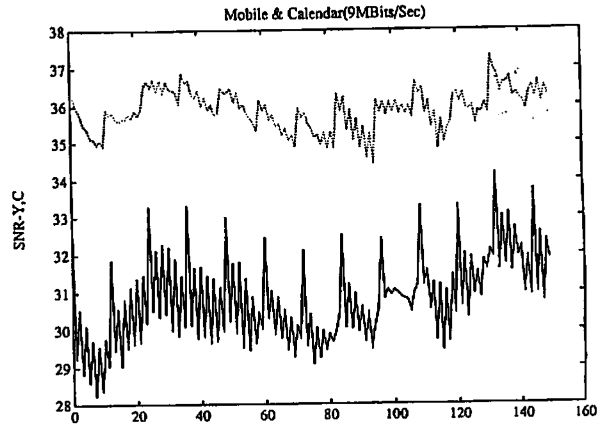

Fig. 13-4b

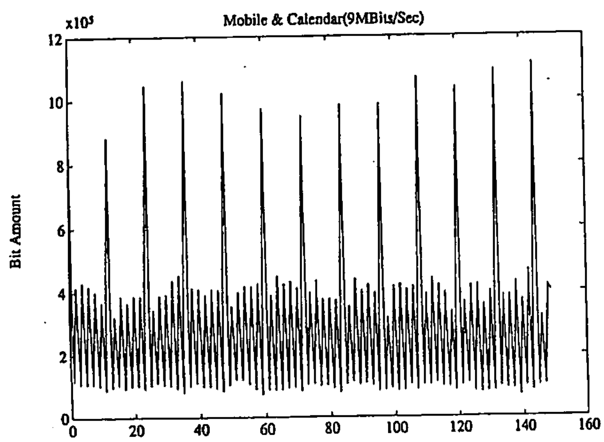

Fig. 13-4a

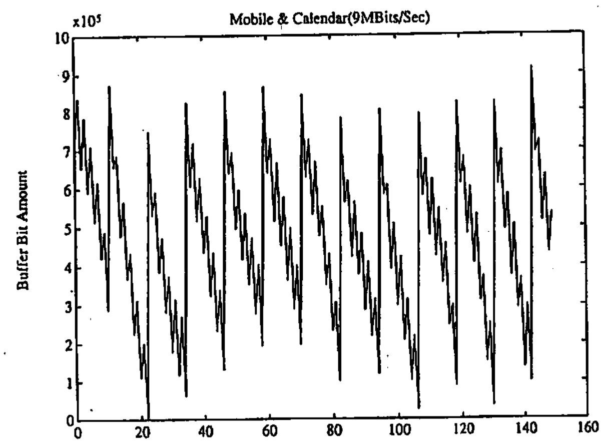

Fig. 13-4c

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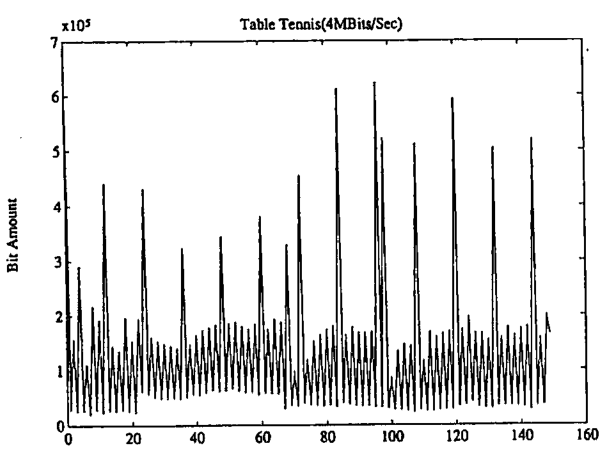

Fig. 13-5a

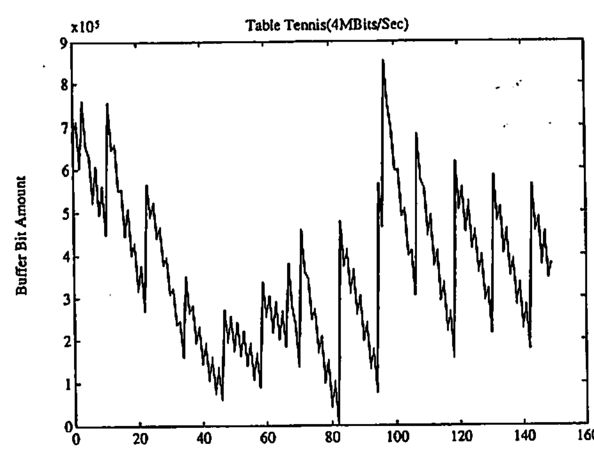

Fig. 13-5c

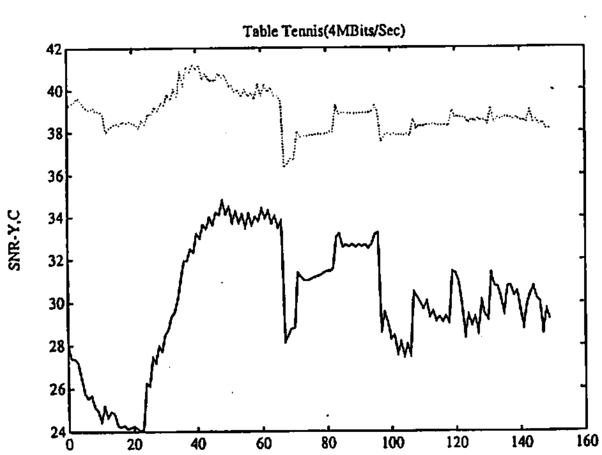

Fig. 13-5b

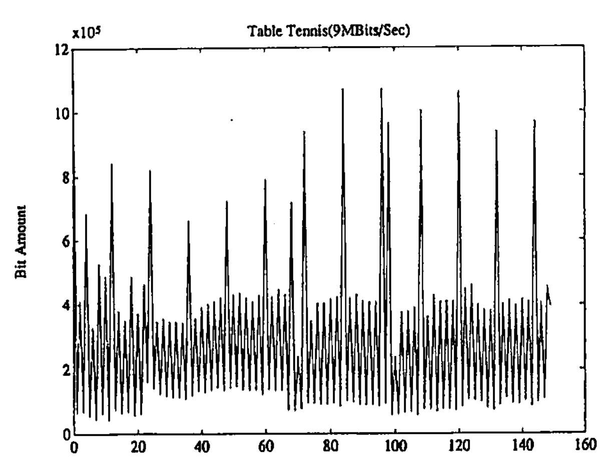

Fig. 13-6a

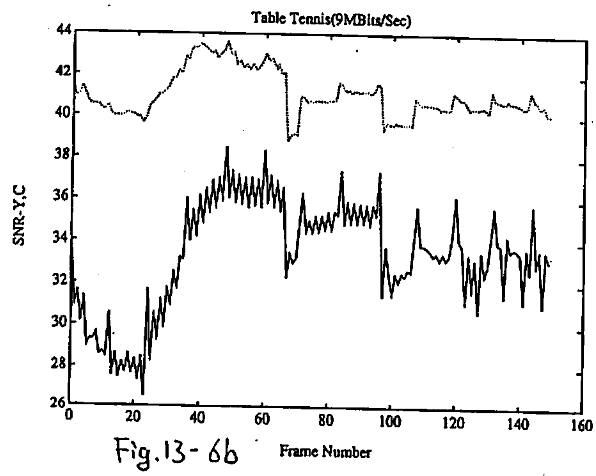

Fig.13-6b

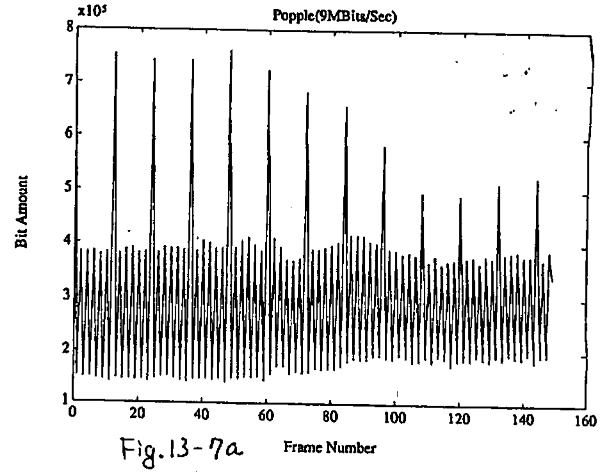

Fig.13-7a

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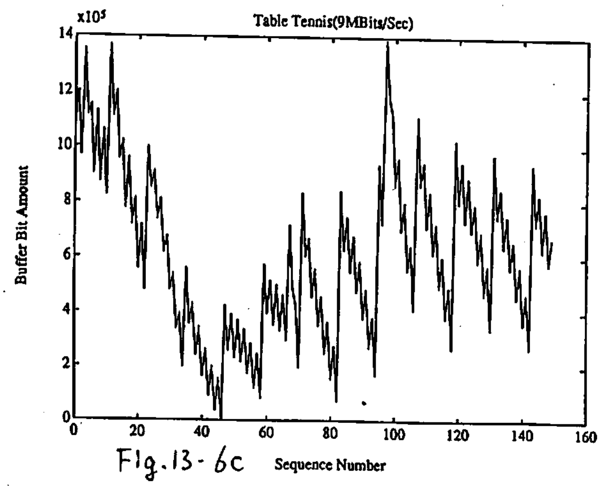

Fig.13-6c

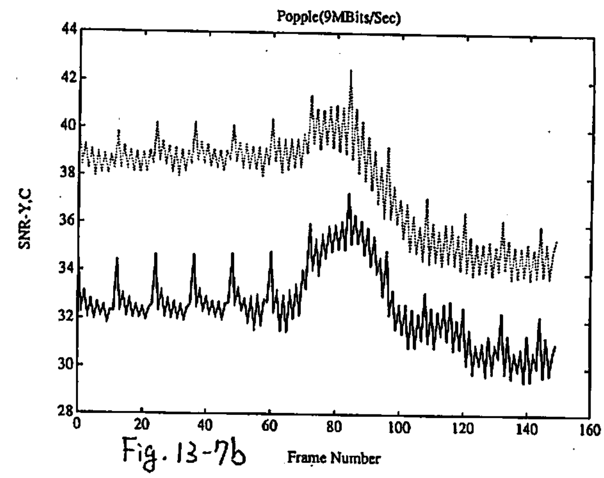

Fig.13-7b

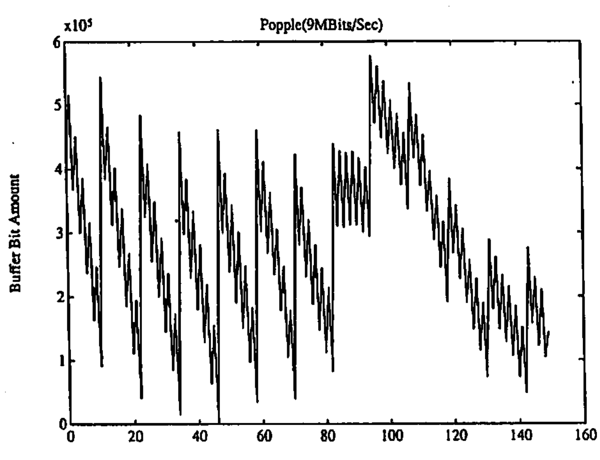

Fig.13-7c

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Table 2. Code Length of Macro Block Address Increment(for B-Picture only)

Increment Count	Code Length
1	1
2–3	3
4–5	4
6–7	5
8–9	7
10–15	8
16–21	10
22–33	11
34–49	15

Table 3. Code Length of Macro Block Prediction Mode

Field	Prediction Mode Code Length									
	I	F	B	A	f	Fx	Bx	Ax	AFF	AfF
I-Picture Odd-Field	0									
I-Picture Even-Field	2				1					
P-Picture Odd-Field	4	2				3			1	
P-Picture Even-Field	4	2			3					1
B-Picture Odd-Field	5	5	5	1		3		2		
B-Picture Even-Field	5	5	5	1			3	2		

Prediction Mode	
Abbreviation	Prediction Method
I	Intraframe
F	Forward Interframe
B	Backward Interframe
A	Average of F and B
f	Interfield in Frame
Fx	Forward Interfield over Frame
Bx	Backward Interfield over Frame
Ax	Average of F and Bx or Fx and B
AFF	Average of F and Fx
AfF	Average of f and F

Table 4. Code Length of Motion Vector

Field Distance≤2		2<Field Distance≤4	
Differential Motion Vector	Code Length	Differential Motion Vector	Code Length
0	1	0	1
±1	3	±(1–2)	4
±2	4	±(3–4)	5
±3	5	±(5–6)	6
±4	7	±(7–8)	8
±(5–7)	8	±(9–14)	9
±(8–10)	10	±(15–20)	11
±(11–16)	11	±(21–32)	12

Table 5. Code Length of Coded/Non-Coded Macro Block(for B-Picture only)

Block Type	Code Length
Coded Block	1
Non-Coded Block	1

Table 6. Code Length of Macro Block Adaptive Quantization Scale(M_Q)

Quantization Scale	Code Length
0.5	2
0.87	2
1.12	2
1.32	2

Table 7. Weighting Factor(wf)

Y/C	Layer										
	0	1LH	1HL	1HH	2LH	2HL	2HH	3LH	3HL	3HH	4
Y	5	5	5	8	5	5	8	6	6	12	18
C	5	5	5	8	5	5	8	12	12	32	

Table 8. Code Length of Zero Run Length(A,B,C)

Field	Y/C	Layer										
		0	1LH	1HL	1HH	2LH	2HL	2HH	3LH	3HL	3HH	4
I-Picture Odd-Field	Y	-	A	A	A	A	A	A	A	A	B	B
	C	A	A	A	A	A	A	C	C	C	C	
I-Picture Even-Field	Y	A	A	A	A	A	A	A	A	A	B	B
	C	B	B	B	B	B	B	C	C	C	C	
P-Picture	Y	B	A	A	B	B	B	B	B	B	C	C
	C	C	B	B	C	C	C	C	C	C	C	
B-Picture	Y	C	B	B	C	B	B	B	C	C	C	C
	C	C	C	C	C	C	C	C	C	C	C	

VLC Type	Zero Run Length	Code Length
A	EOT	5
	0	1
	1	2
	2-3	4
	4	5
	5–8	7
	9–12	8
	13–16	9
	17–24	11
	25–32	12
	33–40	13
	41–48	14
	49+16n–64+16n	16+n
B	EOT	4
	0-1	2
	2-4	4
	5-8	5
	9-16	7
	17-24	8
	25-32	9
	33-40	10
	41-48	11
	49-52	12
	53+16n–68+16n	14+n
C	EOT	1
	0–1	3
	2–5	5
	6–13	7
	14–21	8
	22–29	9
	30–37	10
	38–45	11
	46–53	12
	54–61	13
	62–69	14
	70–77	15
	78–85	16
	86+16n–101+16n	18+n

Table 9. Code Length of Quantize Index(A,B,C,D)

Field	Y/C	Layer										
		0	1LH	1HL	1HH	2LH	2HL	2HH	3LH	3HL	3HH	4
I-Picture Odd-Field	Y	A	B	B	C	C	C	D	D	D	D	D
	C	B	C	C	D	D	D	D	D	D	D	
I-Picture Even-Field	Y	D	D	D	D	D	D	D	D	D	D	D
	C	D	D	D	D	D	D	D	D	D	D	
P-Picture	Y	D	D	D	D	D	D	D	D	D	D	D
	C	D	D	D	D	D	D	D	D	D	D	
B-Picture	Y	D	D	D	D	D	D	D	D	D	D	D
	C	D	D	D	D	D	D	D	D	D	D	

VLC Type	Level	Code Length
A	0	7
	±(1–16)	6
	±(17–32)	7
	±(33–47)	8
	±(48+16n–63+16n)	9+n
B	±(1–4)	4
	±(5–8)	5
	±(9–16)	7
	±(17–24)	8
	±(25–32)	9
	±(33+16n–48+16n)	11+n
C	±(1)	2
	±(2–3)	4
	±(4–5)	5
	±(6–7)	6
	±(8–9)	7
	±(10–11)	8
	±(12–13)	9
	±(14–17)	11
	±(18–21)	12
	±(22–25)	13
	±(26–29)	14
	±(30–33)	15
	±(34–37)	16
	±(38–41)	17
	±(42+16n–57+16n)	20+n
D	±(1)	2
	±(2)	3
	±(3)	4
	±(4)	5
	±(5)	6
	±(6)	7
	±(7–8)	9
	±(9–10)	10
	±(11–12)	11
	±(13–16)	13
	±(17–20)	14
	±(21–24)	15
	±(25–32)	17
	±(33–40)	18
	±(41–48)	19
	±(49+16n–64+16n)	21+n

Table 10-1. Flower Gargen 4MBits/Sec

Flower Garden(4MBits/Sec)	
Frame	Bit Amount
0–11	1619763
12–23	1558311
24–35	1555816
36–47	1584498
48–59	1603187
60–71	1580361
72–83	1584460
84–95	1632172
96–107	1700255
108–119	1505096
120–131	1544275
132–143	1575284

	Flower Garden(4MBits/Sec)						
	Field Type						
	I0	I1	P0	P1	B0	B1	Total
RMSE & SNR(dB)							
RMS for Luminance	9.18	8.20	9.06	9.25	8.90	8.92	9.00
SNR for Luminance	28.87	29.85	28.99	28.81	29.14	29.12	29.05
SNR for Chrominance	32.18	32.95	32.68	32.60	32.95	32.91	32.77
SNR for Lum.&Chro.	30.22	31.13	30.46	30.30	30.64	30.62	30.52
Macro Block Prediciton Mode(%)							
I	100.00	0.78	0.60	0.05	0.00	0.01	4.51
F	0.00	0.00	27.21	28.29	6.16	6.07	14.67
B	0.00	0.00	0.00	0.00	6.78	8.30	3.72
A	0.00	0.00	0.00	0.00	66.27	68.11	33.15
f	0.00	99.22	0.00	14.92	0.00	0.00	7.43
Fx	0.00	0.00	14.16	0.00	3.87	0.00	3.93
Bx	0.00	0.00	0.00	0.00	0.00	4.38	1.08
Ax	0.00	0.00	0.00	0.00	16.91	13.14	7.41
AFF	0.00	0.00	58.03	0.00	0.00	0.00	12.19
AfF	0.00	0.00	0.00	56.74	0.00	0.00	11.92
Bit Amount(Bits/Field)							
Macro Block Addess Increment	0.00	0.00	0.00	0.00	1389.76	1391.51	686.05
Macro Block Type	0.00	1330.31	2076.75	2089.17	1843.62	1851.39	1843.93
Motion Vectors	0.00	6405.23	12407.11	10901.38	8467.57	8283.73	9304.33
Coded Block Pattern	0.00	0.00	0.00	0.00	917.31	908.49	450.36
Macro Block Adaptive Quantization	2640.00	2640.00	2640.00	2640.00	494.24	477.70	1577.35
Zero Run(Luminance)	73154.46	64319.15	40926.56	42220.10	3926.22	3722.81	25304.75
Level(Luminance)	125414.00	64904.00	22034.48	22971.62	1241.51	1156.76	18289.97
Zero Run(Chrominance)	37176.31	25605.69	9234.03	8359.68	618.11	597.49	6715.08
Level(Chrominance)	37087.77	9776.08	2962.22	2381.97	54.82	54.01	3179.89
Total	275472.54	174980.46	92281.14	91563.92	18953.16	18443.89	67351.70

Table 10-2. Flower Gargen 9MBits/Sec

Flower Garden(9MBits/Sec)	
Frame	Bit Amount
0–11	3584160
12–23	3556645
24–35	3531215
36–47	3556832
48–59	3598254
60–71	3552149
72–83	3596314
84–95	3662698
96–107	3813888
108–119	3364487
120–131	3510646
132–143	3579519

	Flower Garden(9MBits/Sec)						
	Field Type						
	I0	I1	P0	P1	B0	B1	Total
RMSE & SNR(dB)							
RMS for Luminance	5.41	4.81	5.47	5.55	5.79	5.80	5.62
SNR for Luminance	33.46	34.48	33.37	33.25	32.88	32.86	33.14
SNR for Chrominance	35.75	36.46	35.58	35.40	35.87	35.77	35.70
SNR for Lum.&Chro.	34.46	35.36	34.34	34.19	34.13	34.08	34.23
Macro Block Prediciton Mode(%)							
I	100.00	0.53	0.56	0.04	0.00	0.01	4.48
F	0.00	0.00	29.54	30.63	5.67	5.75	15.45
B	0.00	0.00	0.00	0.00	6.22	7.35	3.35
A	0.00	0.00	0.00	0.00	68.38	68.23	33.70
f	0.00	99.47	0.00	14.95	0.00	0.00	7.45
Fx	0.00	0.00	13.55	0.00	3.75	0.00	3.77
Bx	0.00	0.00	0.00	0.00	0.00	4.58	1.13
Ax	0.00	0.00	0.00	0.00	15.99	14.09	7.42
AFF	0.00	0.00	56.35	0.00	0.00	0.00	11.83
AfF	0.00	0.00	0.00	54.38	0.00	0.00	11.42
Bit Amount(Bits/Field)							
Macro Block Addess Increment	0.00	0.00	0.00	0.00	1405.09	1409.41	694.24
Macro Block Type	0.00	1327.00	2089.71	2120.44	2019.43	2084.82	1954.02
Motion Vectors	0.00	6446.31	12138.00	10564.98	9061.08	8920.31	9482.38
Coded Block Pattern	0.00	0.00	0.00	0.00	1104.78	1108.95	546.05
Macro Block Adaptive Quantization	2640.00	2640.00	2640.00	2640.00	1645.86	1649.84	2150.54
Zero Run(Luminance)	115027.23	98143.15	80396.33	82285.06	20615.64	20413.08	53520.89
Level(Luminance)	267533.23	148079.23	66673.11	68764.32	8524.32	8319.16	50606.46
Zero Run(Chrominance)	82053.54	63871.92	31092.27	31103.13	3245.72	3268.28	20991.26
Level(Chrominance)	94043.77	35625.54	13859.51	12901.67	695.08	699.24	11582.78
Total	561297.77	356133.15	208888.94	210379.60	48317.01	47873.09	151528.63

Table 10-3. Mobile & Calendar 4MBits/Sec

Mobile & Calendar(4MBits/Sec)	
Frame	Bit Amount
0–11	1612598
12–23	1449689
24–35	1605034
36–47	1654206
48–59	1632321
60–71	1608854
72–83	1554203
84–95	1599027
96–107	1570523
108–119	1600647
120–131	1593640
132–143	1611049

	Mobile & Calendar(4MBits/Sec)						
	Field Type						
	I0	I1	P0	P1	B0	B1	Total
	RMSE & SNR(dB)						
RMS for Luminance	11.71	10.70	11.41	11.54	11.71	11.75	11.58
SNR for Luminance	26.76	27.54	26.99	26.89	26.76	26.73	26.86
SNR for Chrominance	32.09	32.93	32.56	32.69	32.89	33.05	32.78
SNR for Lum.&Chro.	28.65	29.45	28.94	28.89	28.82	28.83	28.88
	Macro Block Prediciton Mode(%)						
I	100.00	1.57	0.81	0.16	0.03	0.04	4.62
F	0.00	0.00	47.91	52.73	7.70	6.69	24.69
B	0.00	0.00	0.00	0.00	8.64	9.47	4.47
A	0.00	0.00	0.00	0.00	69.26	69.84	34.31
f	0.00	98.43	0.00	9.50	0.00	0.00	6.26
Fx	0.00	0.00	8.77	0.00	2.75	0.00	2.52
Bx	0.00	0.00	0.00	0.00	0.00	2.66	0.66
Ax	0.00	0.00	0.00	0.00	11.61	11.30	5.65
AFF	0.00	0.00	42.50	0.00	0.00	0.00	8.93
AfF	0.00	0.00	0.00	37.61	0.00	0.00	7.90
	Bit Amount(Bits/Field)						
Macro Block Addess Increment	0.00	0.00	0.00	0.00	1352.72	1352.09	667.19
Macro Block Type	0.00	1340.77	2216.08	2273.17	1916.61	1897.81	1941.73
Motion Vectors	0.00	6652.23	8757.03	7914.48	6342.68	6319.18	6912.54
Coded Block Pattern	0.00	0.00	0.00	0.00	879.19	873.51	432.33
Macro Block Adaptive Quantization	2640.00	2640.00	2640.00	2640.00	662.65	655.41	1662.72
Zero Run(Luminance)	93726.46	79983.69	38577.62	39503.73	5159.36	5108.31	26457.22
Level(Luminance)	127617.00	68788.08	18357.95	18352.57	1600.81	1592.86	17007.87
Zero Run(Chrominance)	42553.62	29122.54	11404.14	10069.08	847.84	853.89	8035.10
Level(Chrominance)	49409.38	12424.92	4210.35	3216.92	85.28	92.68	4283.11
Total	315946.46	200952.23	86163.17	83969.95	18847.14	18745.74	67399.81

Table 10-4. Mobile & Calendar 9MBits/Sec

Mobile & Calendar(9MBits/Sec)	
Frame	Bit Amount
0–11	3603091
12–23	3315055
24–35	3651618
36–47	3672738
48–59	3653291
60–71	3612650
72–83	3498808
84–95	3620560
96–107	3510570
108–119	3661602
120–131	3542916
132–143	3667188

	Mobile & Calendar(9MBits/Sec)						
	Field Type						
	I0	I1	P0	P1	B0	B1	Total
	RMSE & SNR(dB)						
RMS for Luminance	5.80	5.76	7.05	7.14	8.03	8.03	7.47
SNR for Luminance	32.86	32.92	31.17	31.06	30.04	30.03	30.66
SNR for Chrominance	35.94	36.53	35.65	35.67	35.94	35.99	35.86
SNR for Lum.&Chro.	34.13	34.36	32.86	32.78	32.06	32.06	32.52
	Macro Block Prediciton Mode(%)						
I	100.00	1.19	0.75	0.12	0.02	0.04	4.58
F	0.00	0.00	55.40	58.45	5.71	4.90	26.53
B	0.00	0.00	0.00	0.00	7.03	7.97	3.70
A	0.00	0.00	0.00	0.00	75.22	75.25	37.12
f	0.00	98.81	0.00	9.03	0.00	0.00	6.18
Fx	0.00	0.00	9.05	0.00	2.49	0.00	2.51
Bx	0.00	0.00	0.00	0.00	0.00	2.25	0.56
Ax	0.00	0.00	0.00	0.00	9.53	9.59	4.72
AFF	0.00	0.00	34.80	0.00	0.00	0.00	7.31
AfF	0.00	0.00	0.00	32.39	0.00	0.00	6.80
	Bit Amount(Bits/Field)						
Macro Block Addess Increment	0.00	0.00	0.00	0.00	1404.26	1405.28	693.02
Macro Block Type	0.00	1335.69	2319.98	2334.84	1965.55	1961.16	2003.98
Motion Vectors	0.00	6674.69	8179.65	7494.00	7098.68	7079.59	7078.01
Coded Block Pattern	0.00	0.00	0.00	0.00	1087.47	1085.35	535.96
Macro Block Adaptive Quantization	2640.00	2640.00	2640.00	2640.00	1796.16	1798.59	2224.31
Zero Run(Luminance)	136624.38	125277.85	83727.79	86619.35	21591.81	21386.85	57723.40
Level(Luminance)	267727.54	158023.92	54924.59	55848.02	8535.12	8467.20	45905.38
Zero Run(Chrominance)	89309.85	68414.00	32895.46	31258.35	3645.41	3706.64	22120.50
Level(Chrominance)	113560.31	40706.77	15667.79	13623.19	839.96	868.58	13257.45
Total	609862.08	403072.92	200355.27	199817.75	47964.42	47759.26	151542.02

Table 10-5. Table Tennis 4MBits/Sec

Table Tennis(4MBits/Sec)	
Frame	Bit Amount
0–11	1793918
12–23	1456101
24–35	1479595
36–47	1513679
48–59	1622729
60–71	1626872
72–83	1462034
84–95	1675651
96–107	1818952
108–119	1458118
120–131	1658940
132–143	1560614

Table Tennis(4MBits/Sec)							
	Field Type						
	I0	I1	P0	P1	B0	B1	Total
RMSE & SNR(dB)							
RMS for Luminance	8.51	8.07	9.16	9.11	9.10	9.05	9.04
SNR for Luminance	29.53	29.99	28.89	28.94	28.95	29.00	29.01
SNR for Chrominance	38.66	38.91	38.66	38.72	38.85	38.90	38.79
SNR for Lum.&Chro.	32.04	32.48	31.47	31.52	31.54	31.58	31.59
Macro Block Prediciton Mode(%)							
I	87.47	6.77	3.84	0.47	0.09	0.08	5.03
F	0.00	0.00	29.22	29.63	5.09	3.98	14.60
B	0.00	0.00	0.00	0.00	10.67	11.24	5.41
A	0.00	0.00	0.00	0.00	53.67	56.35	27.14
f	12.53	93.23	0.66	17.28	0.00	0.00	8.35
Fx	0.00	0.00	10.85	0.17	4.85	0.03	3.52
Bx	0.00	0.00	0.00	0.00	0.05	6.15	1.53
Ax	0.00	0.00	0.00	0.00	25.58	22.15	11.77
AFF	0.00	0.00	55.42	0.00	0.00	0.00	11.64
AfF	0.00	0.00	0.00	52.45	0.00	0.00	11.01
Bit Amount(Bits/Field)							
Macro Block Addess Increment	0.00	0.00	0.00	0.00	1407.68	1411.70	695.45
Macro Block Type	0.00	1409.31	2135.51	2183.70	2163.30	2161.45	2034.87
Motion Vectors	0.00	7147.62	12056.27	10602.05	9119.09	9024.84	9543.48
Coded Block Pattern	0.00	0.00	0.00	0.00	992.64	987.69	488.48
Macro Block Adaptive Quantization	2640.00	2640.00	2640.00	2640.00	453.54	442.49	1558.62
Zero Run(Luminance)	97067.00	86137.77	41807.81	39329.76	3371.58	3277.11	26617.77
Level(Luminance)	122506.69	73098.85	21801.29	17868.21	1117.54	1088.69	17351.04
Zero Run(Chrominance)	32130.46	25418.62	8403.97	6888.57	667.92	643.69	6028.76
Level(Chrominance)	31609.15	11374.92	3832.98	1983.62	114.49	106.50	3138.64
Total	285953.31	207227.08	92677.83	81495.90	19407.77	19144.15	67457.11

Table 10-6. Table Tennis 9MBits/Sec

Table Tennis(9MBits/Sec)	
Frame	Bit Amount
0–11	3953117
12–23	3371459
24–35	3266093
36–47	3428485
48–59	3669632
60–71	3671863
72–83	3482400
84–95	3696684
96–107	3814087
108–119	3469746
120–131	3671222
132–143	3543848

Table Tennis(9MBits/Sec)							
	Field Type						
	I0	I1	P0	P1	B0	B1	Total
RMSE & SNR(dB)							
RMS for Luminance	4.56	4.49	5.85	5.83	6.45	6.43	6.05
SNR for Luminance	34.95	35.09	32.78	32.82	31.94	31.96	32.50
SNR for Chrominance	41.20	41.45	40.84	40.88	40.92	40.96	40.94
SNR for Lum.&Chro.	37.03	37.20	35.16	35.20	34.44	34.46	34.93
Macro Block Prediciton Mode(%)							
I	87.47	2.47	3.62	0.32	0.07	0.06	4.76
F	0.00	0.00	27.68	27.08	3.97	3.05	13.23
B	0.00	0.00	0.00	0.00	7.15	7.00	3.49
A	0.00	0.00	0.00	0.00	58.82	59.72	29.24
f	12.53	97.53	0.62	17.06	0.00	0.00	8.48
Fx	0.00	0.00	9.57	0.13	4.30	0.02	3.10
Bx	0.00	0.00	0.00	0.00	0.02	6.17	1.53
Ax	0.00	0.00	0.00	0.00	25.68	23.98	12.25
AFF	0.00	0.00	58.51	0.00	0.00	0.00	12.29
AfF	0.00	0.00	0.00	55.40	0.00	0.00	11.63
Bit Amount(Bits/Field)							
Macro Block Addess Increment	0.00	0.00	0.00	0.00	1400.96	1405.07	692.15
Macro Block Type	0.00	1352.54	2073.05	2139.00	2168.57	2175.19	2014.60
Motion Vectors	0.00	7916.85	12231.68	10681.59	9806.18	9725.51	9972.67
Coded Block Pattern	0.00	0.00	0.00	0.00	1137.62	1142.22	562.36
Macro Block Adaptive Quantization	2640.00	2640.00	2640.00	2640.00	1769.78	1773.76	2211.67
Zero Run(Luminance)	151346.38	141528.00	101047.94	97406.41	19983.49	19806.24	64181.44
Level(Luminance)	249251.46	163524.15	67251.11	59607.94	7468.64	7348.53	48182.24
Zero Run(Chrominance)	58404.54	52118.54	21868.41	19615.43	2990.97	2961.26	14969.16
Level(Chrominance)	66875.31	30923.85	11741.11	8265.11	614.12	590.20	8736.34
Total	528517.69	400003.92	218853.30	200355.48	47340.32	46927.97	151522.63

Table 10-7. Popple 9MBits/Sec

Popple(9MBits/Sec)	
Frame	Bit Amount
0–11	3557857
12–23	3550063
24–35	3574305
36–47	3583465
48–59	3637085
60–71	3621644
72–83	3656330
84–95	3832996
96–107	3631987
108–119	3455620
120–131	3489661
132–143	3566186

Popple(9MBits/Sec)							
	Field Type						
	I0	I1	P0	P1	B0	B1	Total
RMSE & SNR(dB)							
RMS for Luminance	5.04	4.97	6.00	5.89	6.57	6.61	6.20
SNR for Luminance	34.07	34.20	32.57	32.73	31.78	31.73	32.20
SNR for Chrominance	38.54	39.02	37.46	37.87	36.44	36.43	37.09
SNR for Lum.&Chro.	35.76	35.98	34.36	34.58	33.52	33.47	34.05
Macro Block Prediciton Mode(%)							
I	99.98	1.51	2.49	0.57	0.35	0.37	5.22
F	0.00	0.00	15.52	10.66	5.77	4.39	8.01
B	0.00	0.00	0.00	0.00	3.81	6.44	2.53
A	0.00	0.00	0.00	0.00	35.43	35.67	17.54
f	0.02	98.49	0.00	28.09	0.00	0.00	10.17
Fx	0.00	0.00	16.54	0.00	14.26	0.00	6.99
Bx	0.00	0.00	0.00	0.00	0.00	13.84	3.41
Ax	0.00	0.00	0.00	0.00	40.39	39.28	19.65
AFF	0.00	0.00	65.45	0.00	0.00	0.00	13.74
AfF	0.00	0.00	0.00	60.68	0.00	0.00	12.74
Bit Amount(Bits/Field)							
Macro Block Addess Increment	0.00	0.00	0.00	0.00	1327.61	1326.70	654.73
Macro Block Type	0.00	1339.92	2060.14	2224.76	2915.89	2951.46	2405.17
Motion Vectors	0.00	15559.23	30520.83	27680.14	28698.46	28517.31	27009.66
Coded Block Pattern	0.00	0.00	0.00	0.00	1297.34	1296.16	639.73
Macro Block Adaptive Quantization	2640.00	2640.00	2640.00	2640.00	1522.95	1530.57	2090.80
Zero Run(Luminance)	96091.85	92656.54	58412.71	54489.67	16649.03	16878.76	40197.78
Level(Luminance)	121861.08	80040.08	40481.71	33239.44	7807.68	7932.76	28113.13
Zero Run(Chrominance)	57376.85	51581.54	40952.30	35148.38	14651.42	14654.28	27931.41
Level(Chrominance)	85464.69	40803.62	32616.60	23774.86	8525.81	8546.12	21524.91
Total	364334.46	284620.92	207684.30	179197.25	83396.18	83634.12	150567.33

Table 10-8. Coded Bit Stream Files

```
-rw-r--r--   1 NEC      MPEG2    20205510 Oct 18 00:00 FlowerGarden.4M
-rw-r--r--   1 NEC      MPEG2    45458588 Oct 18 00:00 FlowerGarden.9M
-rw-r--r--   1 NEC      MPEG2    20219943 Oct 18 00:00 Mobile&Calendar.4M
-rw-r--r--   1 NEC      MPEG2    45462607 Oct 18 00:00 Mobile&Calendar.9M
-rw-r--r--   1 NEC      MPEG2    20237132 Oct 18 00:00 TableTennis.4M
-rw-r--r--   1 NEC      MPEG2    45456788 Oct 18 00:00 TableTennis.9M
-rw-r--r--   1 NEC      MPEG2    45170200 Oct 18 00:00 Popple.9M
```