CCITT SGXV
Working Party XV/1
Experts Group for ATM Video Coding

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SOURCE : UK
TITLE : Description of a compatible coding approach for MPEG1 and MPEG2.
PURPOSE : Information

1. General Description

A compatible coding scheme is presented here to code CIF/SIF * sized pictures and CCIR601 sized pictures.

The compatability is at the bitstream level where the bitstreams for the SIF pictures and the CCIR601 pictures are separable.

The approach adopted is to introduce a second layer of coding to the existing coding of the SIF pictures (MPEG1/H261) as shown in figure 1.

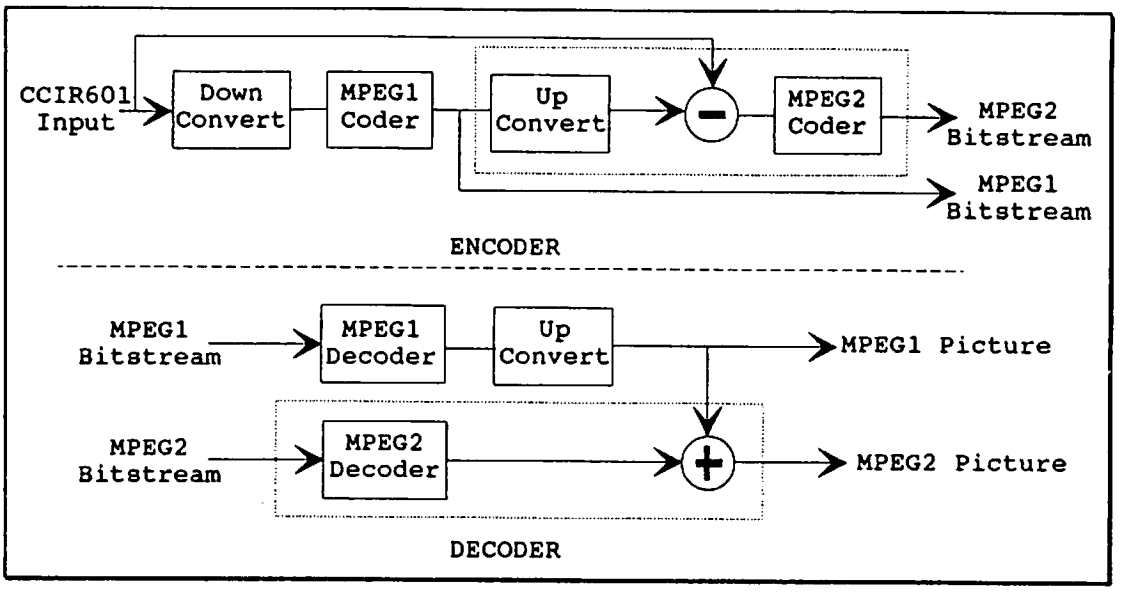

Figure 1: Block diagram of compatible coding for MPEG2/1

The second layer coding uses the pictures produced by the SIF coder as its prediction. This means that the second layer coder (MPEG2/H26X) can be used with any coding scheme used for the SIF pictures.

If the base layer is switched off then the second layer can code the input source pictures instead of the difference pictures. This provides a non-compatible mode if required.

Section 2 describes the down and up conversion between CCIR601 pictures and SIF pictures. Section 3 details the parameters for the MPEG1/H261 coding of the SIF pictures.

2. SIF Conversion

The SIF consists of 288 luminance and 144 chrominance lines per field, non-interlaced, with 360 luminance samples per line and 180 chrominance samples per line. The field rate is 25Hz.

The luminance and chrominance sample positions interleave as shown in figure 2 so that transform blocks of luminance and chrominance samples coincide at their edges.

It should be noted that the up conversion will have to be standardized. This is not the case for the down conversion.

* CIF Common Intermediate Format
SIF Source Input Format

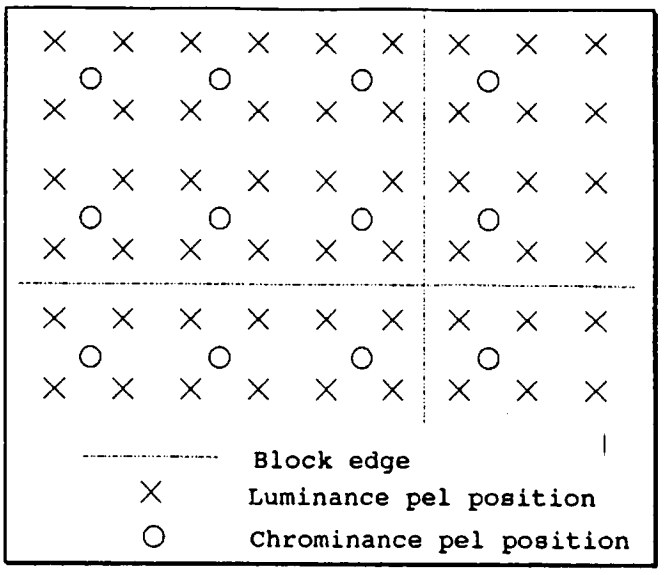

Figure 2: Spatial positions of luminance and chrominance samples.

2.1 Down Conversion

Lines are first shifted up and down by a quarter line pitch in alternate fields. A 5-tap interpolator is used [1]. This gives 50Hz fields with lines at the same spatial positions. Adjacent fields are then averaged on a running basis.

Conversion from 50Hz to 25Hz is then achieved by subsampling.

The pictures are filtered in the horizontal direction with a sharp cut off low pass filter before subsampling.

2.2 Up Conversion

The field rate is converted from 25Hz to 50Hz by interpolating output fields from the two nearest input fields, figure 3a. The constant 'K' changes from field to field, figure 3b.

Interpolating back to 576 lines using 5-tap interpolators to give +/- quarter line shifts re-introduces the interlace.

For these simulations horizontal interpolation of the pels is performed by a 22-tap interpolator.

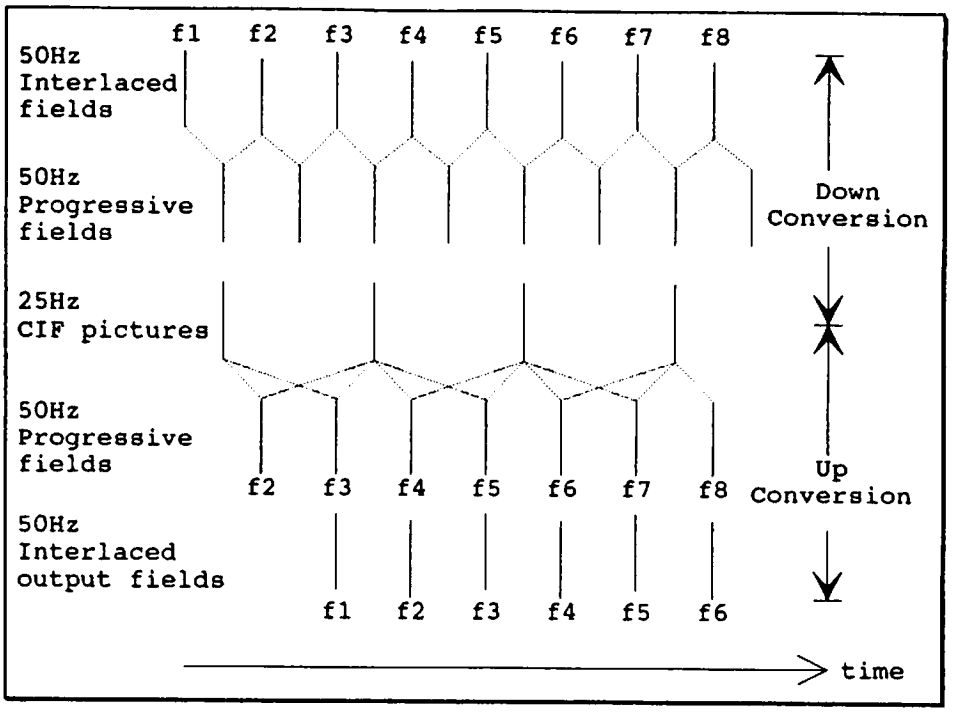

Figure 3a: Temporal interpolation

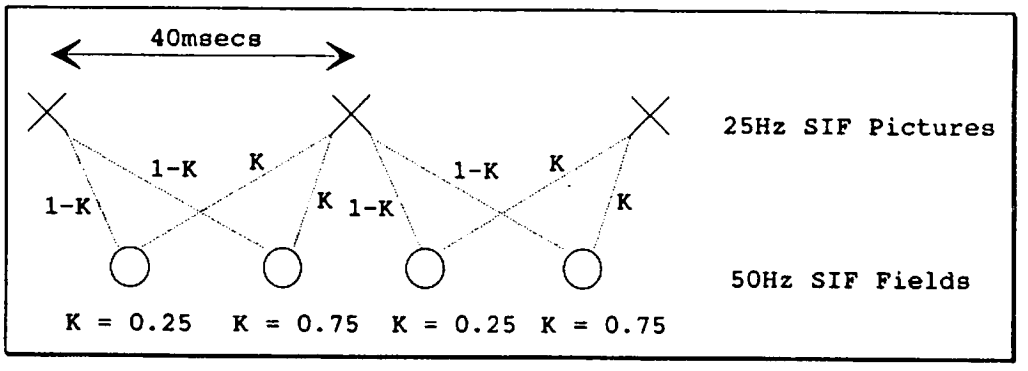

Figure 3b: 'K' factor for temporal interpolation

3. MPEG1 Coding

The MPEG1 coding of the SIF pictures is as the SM3 reference model [2]. The essential coding parameters are as follows:

horizontal picture size 360 pels (352 active),
vertical picture size 288 lines,
picture rate 25 pictures per second,
video bitrate 1.15Mbits/s,
the intra picture interval is 10 pictures,
there are 2 interpolated pictures between predicted pictures (M=3).

4. Difference Picture

The difference picture which is coded in the second layer is formed from the subtraction of the MPEG1 coded picture (up converted to CCIR601 size) and the CCIR601 source input picture.

Both the CCIR601 input picture and the MPEG1 coded picture have 8 bit pel resolution. To maintain accuracy through the subtraction process a 9 bit pel output would be required. In order to save bits a scaling factor is introduced into the subtraction process.

diff_pel = (CCIR601_pel - MPEG1_pel)/2

The difference picture is then represented by 8 bit pels in the range +/- 127.

In the reconstruction of the CCIR601 coded output picture the opposite scaling is introduced.

CCIR601_recon_pel = MPEG1_pel + (2*diff_pel)

5. MPEG2 Coding

The coding of the difference picture produced from the subtraction of the MPEG1 coded picture and the CCIR601 input picture is a combination of intra and inter coding.

The sequence of pictures is coded in a similar manner to MPEG1 in that there are intra pictures interspersed with inter pictures. The intra pictures occur at the same points in time as the MPEG1 intra coded pictures.

The difference pictures are interlaced pictures and the first step is to separate out the fields and to code them individually, figure 4.

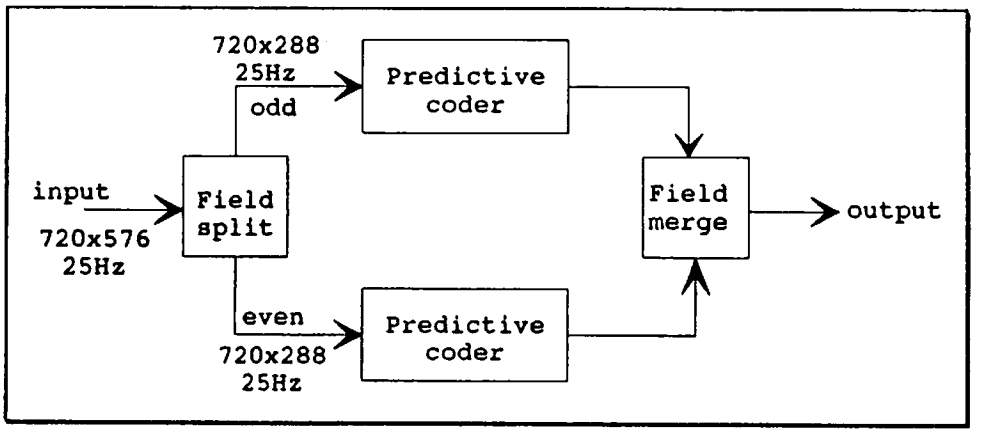

Figure 4: Separation of fields before coding.

This is realized by using a delay of two fields rather than one in the predictor loop.

A functional block diagram of the MPEG2 predictive coder is shown in figure 5.

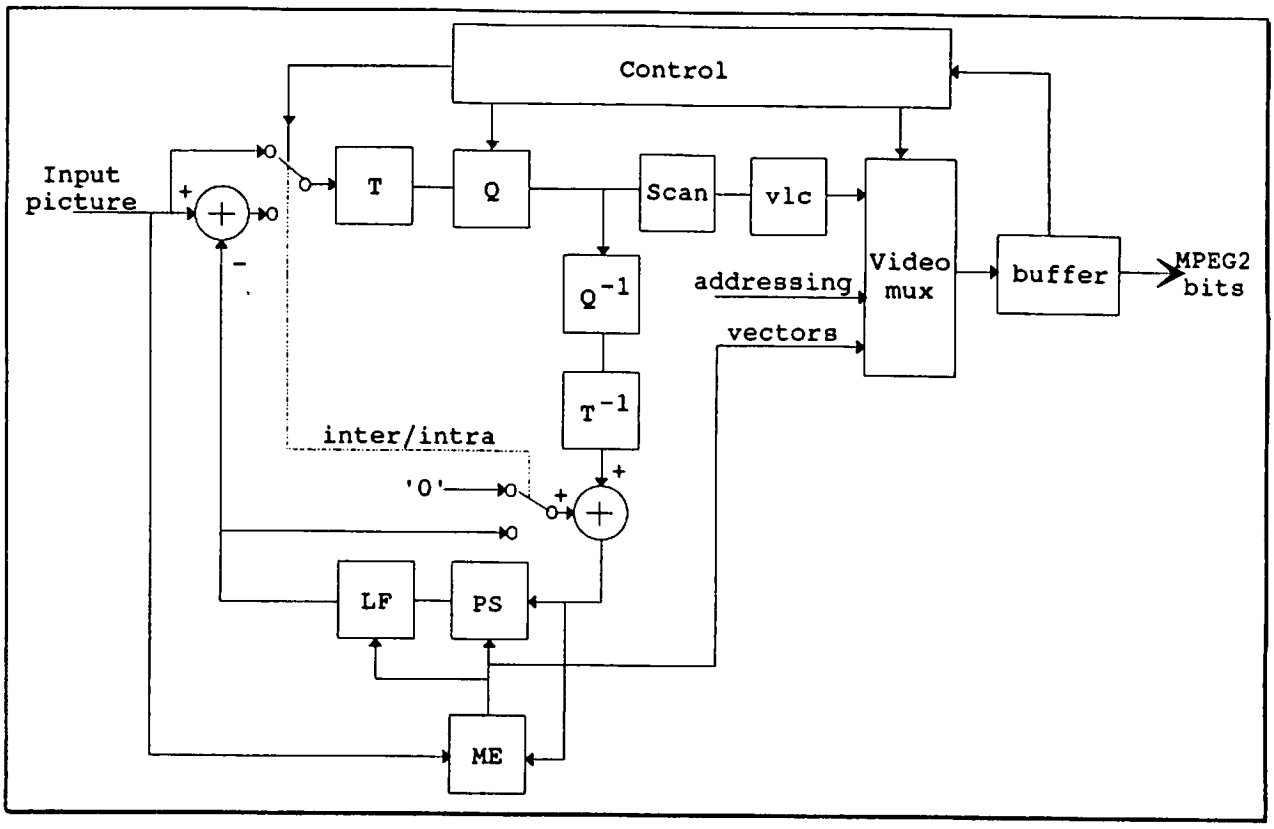

Figure 5: MPEG2 predictive coder.

T	Forward transform (DCT)
T^{-1}	Reverse transform
Q	Quantizer
Q^{-1}	Inverse quantizer
LF	Loop filter
PS	Picture store
ME	Motion estimation.

Intra pictures are first transformed from the pel to the coefficient domain, using the block based DCT. The block size is 8 by 8 for both luminance and chrominance. The resulting block of coefficients are then quantized with a linear quantizer. For the intra DC the stepsize is fixed at 8 with a half dead zone.

Input Level	Output Level
0	0
1	0
2	0
3	0
4	1
4	1
.	.
.	.
11	1
12	2

The remaining coefficients in the intra block are coded with a half stepsize. For instance if the buffer control determined a normal stepsize of 12, then for the intra picture a stepsize of 6 would be used. The quantizer is fixed for both fields of an intra picture.

In the case of an inter coded picture a prediction picture is formed from the previous coded picture using motion estimation to improve the prediction. The motion estimation is performed over a search area of +/- 7 pels by +/- 7 lines. A full search is carried out. For macro blocks that are motion compensated a horizontal filter is applied to pels within

the individual blocks of the macro block. This filter is a non-recursive filter with coefficients of 1/4, 1/2, 1/4. At block edges where filter taps fall outside of the block then the filter is changed to have coefficients of 0, 1, 0.

The prediction error is then coded as for intra blocks except that the quantizer does not use the half stepsize nor apply a different quantizer to the DC coefficient.

7. Simulations

Simulations have been done on the MPEG2 test sequences Table Tennis, Flower Garden, and Mobile and Calendar.

The coding parameters used for the two layers are listed below.

7.1 MPEG1 Pictures

The MPEG1 pictures were coded using the SM3 reference model (kindly supplied by PRL). The coding parameters were set to:

bit rate	1150kbits/s
intra interval	10 pictures (N=10)
Number of B pics between I and P pics	2 pictures (M=3)
picture width	352 active pels
picture height	288 lines
picture rate	25Hz.
buffer size	SM3

7.2 MPEG2 Pictures

The difference pictures were coded at a bit rate of 28500kbits/s and 7850kbits/s giving total bit rates of 4000kbits/s and 9000kbits/s for the MPEG2 coding. The picture size was 704 pels by 576 lines.

The difference pictures, obtained by subtracting the up-converted MPEG1 pictures from the CCIR601 source pictures, were coded with the following coding parameters:

bit rate	2850kbits/s and 7850kbits/s
intra interval	10 pictures (N=10)
no B pictures	
picture width	704 active pels
picture height	576 lines
picture rate	25Hz
buffer size	5 pictures (1/5th bit rate)
vector limit for motion estimation	+/-7.

Note: The intra pictures are coincident with the intra pictures of the MPEG1 coded pictures.

8. Results

Tables 1 through to 6 summarize the results obtained for the sequences Flower Garden, Mobile and Calendar, and Table Tennis at total bit rates of 4000kbits/s and 9000kbits/s.

Figures 1 through to 6 show plots of luminance SNR curves for all three sequences at both bit rates.

9. Conclusion

The coding scheme offers both forwards and backwards compatibility between MPEG1 and MPEG2. Similarly for H.261 and H.26X. It can also be used in a non-compatible mode. Preliminary simulation results have been obtained. Many aspects of the coding scheme have yet to be optimized.

10. References

[1] CCITT SGXV Working Party XV/1 Document #55,"Standards conversion to and from single mode 288, 29.97 format".

[2] MPEG 90/041,"MPEG video simulation model three (SM3)".

			intra pictures		interpolated	predicted pictures		mean seq	
			MPEG1	MPEG2	MPEG1	MPEG1	MPEG2	MPEG1	MPEG2
SNR for luminance (Y)			29.58	35.22	28.04	29.82	30.01	28.61	30.53
SNR for chrominance (U)			33.90	35.50	32.87	32.90	31.84	32.91	32.21
SNR for chrominance (V)			34.51	36.12	33.51	33.48	32.98	33.53	33.30
Number bits per picture	Overheads		6260	3169	4305	7927	14216	5501	13111
		Y	163488	819446	7962	70042	202557	32806	264246
		U	16003	99074	75	3007	13785	1560	22314
		V	15229	75513	76	2828	8541	1478	15238
		Total	194750	994033	8113	75877	224883	35844	301798
	Total		201010	997202	12418	83804	239099	41345	314909

Table 1: Results for Mobile and Calendar at a total bit rate of 9000kbits/s, MPEG1 pictures are coded at 1150kbits/s.

			intra pictures		interpolated	predicted pictures		mean seq	
			MPEG1	MPEG2	MPEG1	MPEG1	MPEG2	MPEG1	MPEG2
SNR for luminance (Y)			29.58	29.91	28.04	29.82	27.37	28.61	27.63
SNR for chrominance (U)			33.90	31.55	32.87	32.90	31.09	32.91	31.14
SNR for chrominance (V)			34.51	32.58	33.51	33.48	32.61	33.53	32.61
Number bits per picture	Overheads		6260	3169	4305	7927	9490	5501	8859
		Y	163488	392473	7962	70042	64184	32806	97013
		U	16003	38529	75	3007	1571	1560	5266
		V	15229	30571	76	2828	770	1478	3750
		Total	194750	461573	8113	75877	66525	35844	106029
	Total		201010	464742	12418	83804	76015	41345	114888

Table 2: Results for Mobile and Calendar at a total bit rate of 4000kbits/s, MPEG1 pictures are coded at 1150kbits/s.

			intra pictures		interpolated	predicted pictures		mean seq	
			MPEG1	MPEG2	MPEG1	MPEG1	MPEG2	MPEG1	MPEG2
SNR for luminance (Y)			32.40	36.18	28.56	31.01	31.79	29.37	32.23
SNR for chrominance (U)			34.67	36.39	32.89	33.20	33.17	33.04	33.49
SNR for chrominance (V)			36.94	36.17	35.51	35.37	33.50	35.52	33.77
Number bits per picture	Overheads		6289	3169	5485	7931	14887	6275	13716
		Y	186778	691246	3519	73169	213004	31711	260828
		U	15891	90556	171	2796	16663	1554	24052
		V	10584	74144	107	805	9666	704	16114
		Total	213253	855946	3797	76770	239333	33969	300994
	Total		219542	859116	9282	84701	254220	40244	314710

Table 3: Results for Flower Garden at a total bit rate of 9000kbits/s, MPEG1 pictures are coded at 1150kbits/s.

			intra pictures		interpolated	predicted pictures		mean seq	
			MPEG1	MPEG2	MPEG1	MPEG1	MPEG2	MPEG1	MPEG2
SNR for luminance (Y)			32.40	31.66	28.56	31.01	28.21	29.37	28.55
SNR for chrominance (U)			34.67	32.79	32.89	33.20	30.67	33.04	30.88
SNR for chrominance (V)			36.94	32.95	35.51	35.37	32.23	35.52	32.30
Number bits per picture	Overheads		6289	3169	5485	7931	11731	6275	10875
		Y	186778	365203	3519	73169	63512	31711	93681
		U	15891	42639	171	2796	2764	1554	6751
		V	10584	29984	107	805	518	704	3465
		Total	213253	437826	3797	76770	66794	33969	103897
	Total		219542	440994	9282	84701	78525	40244	114772

Table 4: Results for Flower Garden at a total bit rate of 4000kbits/s, MPEG1 pictures are coded at 1150kbits/s.

			intra pictures		interpolated	predicted pictures		mean seq	
			MPEG1	MPEG2	MPEG1	MPEG1	MPEG2	MPEG1	MPEG2
SNR for luminance (Y)			36.20	38.51	34.67	36.07	33.89	35.14	34.38
SNR for chrominance (U)			41.64	39.26	40.60	40.93	37.05	40.74	37.29
SNR for chrominance (V)			41.34	39.85	39.27	40.04	37.51	39.57	37.76
Number bits per picture	Overheads		6290	3169	7369	9906	17620	388106	16082
		Y	154686	881762	9503	60374	189254	31002	262925
		U	8672	74352	306	2180	10709	1221	17480
		V	12863	74411	539	4044	15369	2115	21650
		Total	176221	1030525	10348	66598	215332	34338	302055
	Total		182511	1033694	17717	76504	232952	42444	318137

Table 5: Results for Table Tennis at a total bit rate of 9000kbits/s, MPEG1 pictures are coded at 1150kbits/s.

			intra pictures		interpolated	predicted pictures		mean seq	
			MPEG1	MPEG2	MPEG1	MPEG1	MPEG2	MPEG1	MPEG2
SNR for luminance (Y)			36.20	33.97	34.67	36.07	32.60	35.14	32.75
SNR for chrominance (U)			41.64	36.36	40.60	40.93	36.34	40.74	36.34
SNR for chrominance (V)			41.34	37.04	39.27	40.04	36.00	39.57	36.11
Number bits per picture	Overheads		6290	3169	7369	9906	11936	388106	11004
		Y	154686	388898	9503	60374	56007	31002	91421
		U	8672	27543	306	2180	2610	1221	5262
		V	12863	33362	539	4044	5136	2115	8139
		Total	176221	449803	10348	66598	63753	34338	104822
	Total		182511	452972	17717	76504	75689	42444	115826

Table 6: Results for Table Tennis at a total bit rate of 4000kbits/s, MPEG1 pictures are coded at 1150kbits/s.

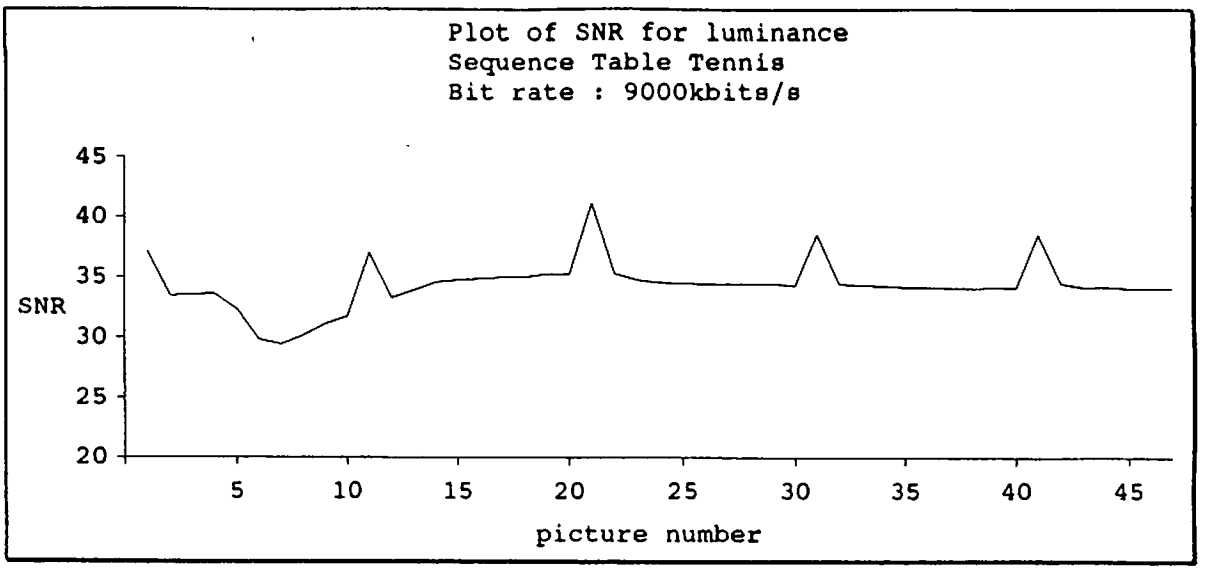

Figure 1: Table Tennis coded at a total bit rate of 9000kbits/s

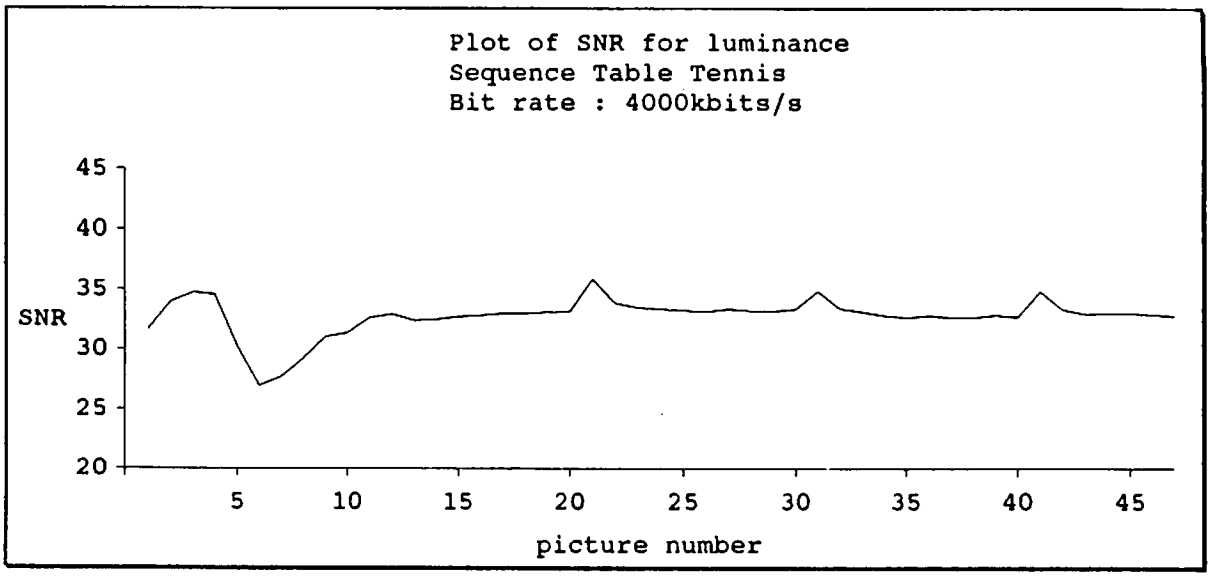

Figure 2: Table Tennis coded at a total bit rate of 4000kbits/s

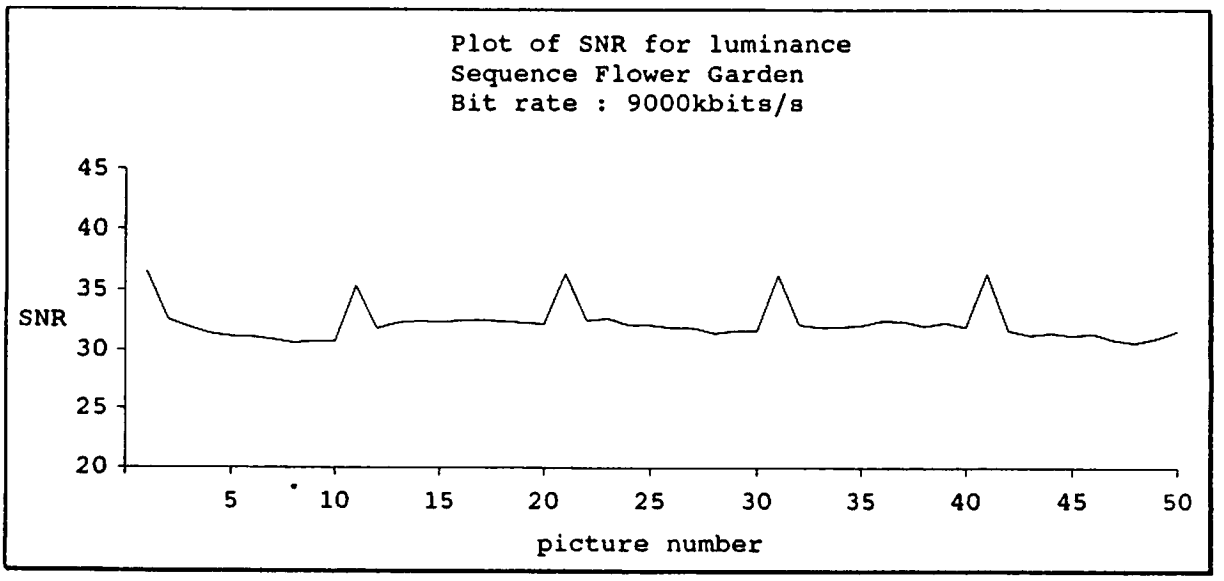

Figure 3: Flower Garden coded at a total bit rate of 9000kbits/s

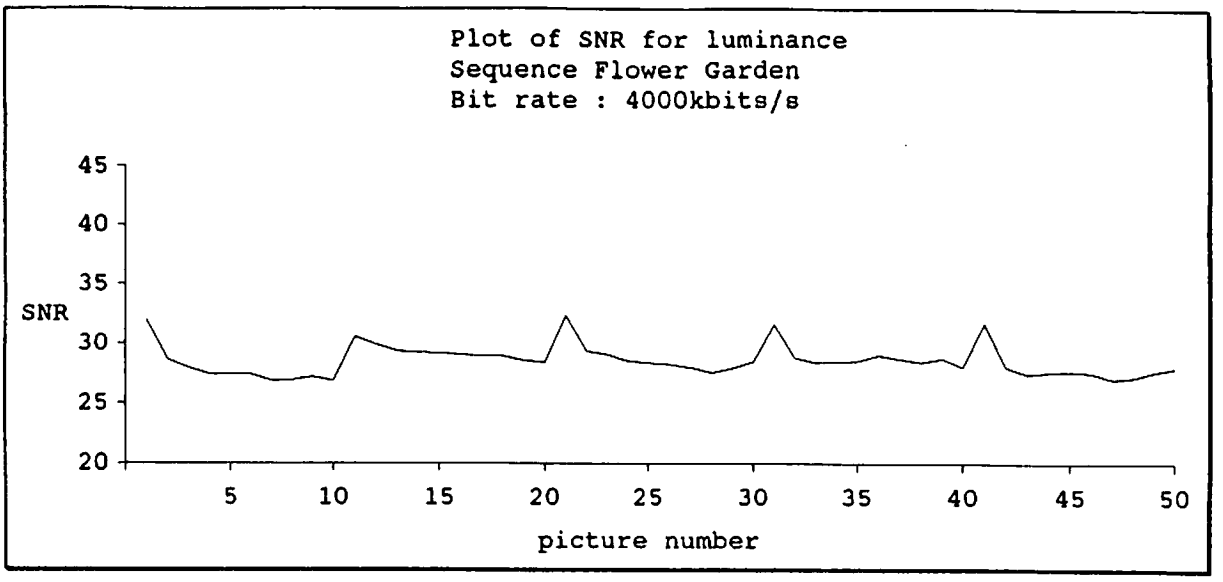

Figure 4: Flower Garden coded at a total bit rate of 4000kbits/s

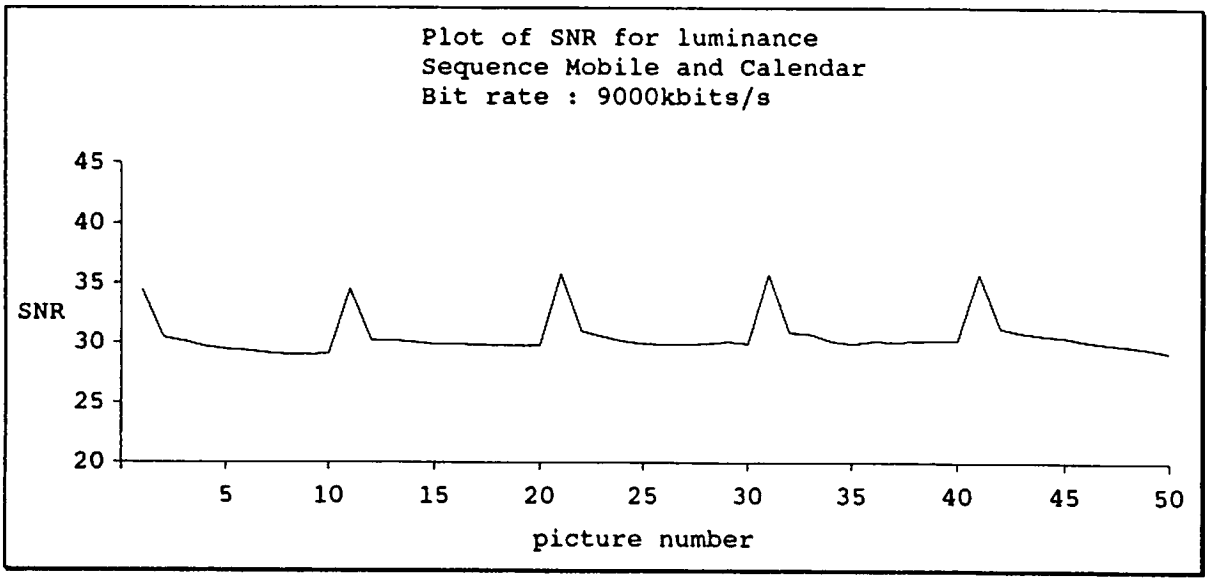

Figure 5: Mobile and Calendar coded at a total bit rate of 9000kbits/s

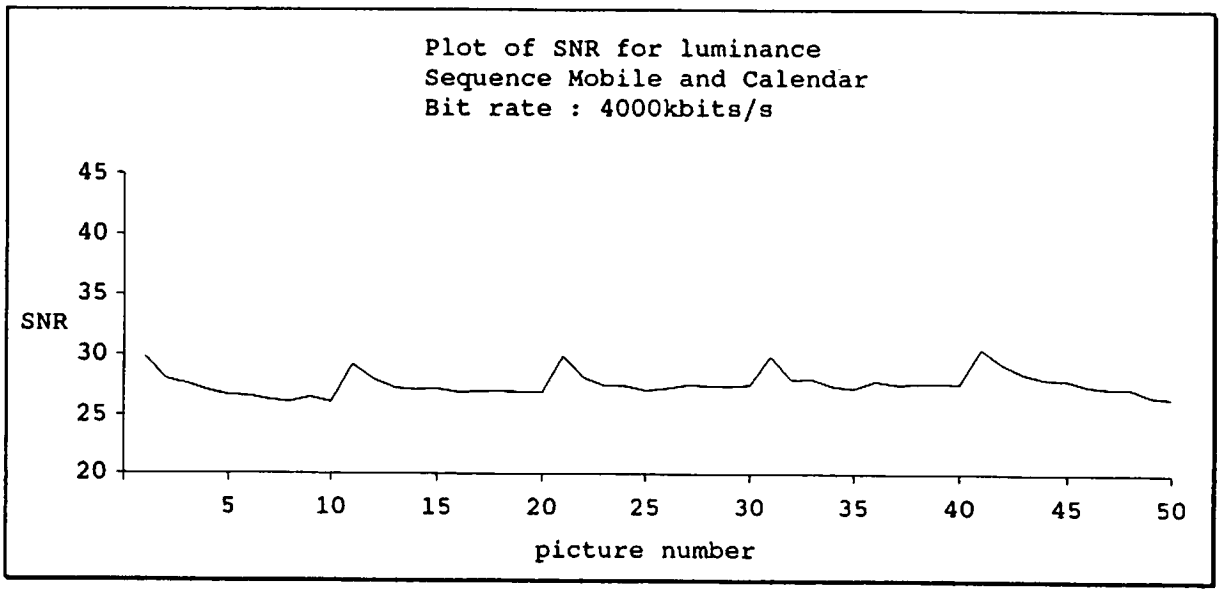

Figure 6: Mobile and Calendar coded at a total bit rate of 4000kbits/s