CCITT SGXV **Doc. #422**
Working Party XV/4
Specialists Group on Coding for Visual Telephony

Source	:	NL,BTRL,F,I,FRG,S,N
Title	:	Loop filter
Purpose	:	Proposal,Information

1 Introduction

This contribution contains a review of the performance, position and the type of the loopfilter [2,3,4,5,6], the outstanding points are studied and annexed to this document. First the outstanding points are mentioned after which the experiments and the results are discussed.

The introduction of a low pass filter after the frame memory could have the following advantages:

- A reduction of high frequency artifacts introduced by MC.
- A reduction of quantization noise in the feedback loop.
- improvement of the prediction.

The filter could be controlled with:

- Displacement vector
- Prediction error

The introduction of a filter before the frame memory could have the following advantages:

- reduction of the quantization noise,
- implicite image enhancement,

The filter could be controlled with:

- displacement vector

- quantizer
- prediction error

From theory [1] it can be shown that two filters are necessary [1], i.e. one filter which tackles the coding noise denoted with h_n the second filter which improves the prediction denoted with h_n. In the case that motion compensation is not used, both filters can be combined and the position is not important.
The introduction of the motion compensation causes for the modeling of the signal a lot of problems. The process can not be seen as a Gaussian process anymore. The influence of the block type discrimination causes a problem for the optimization of the codec.

The decision which filter h_p or h_n increases the performance of the codec is dependant on objective as well as subjective measures.
From [1] and previous work in [3,4] the hybrid coder could be improved by utilize motion compensation only in the low-frequency range and encode the high-frequency rage rather directly. This could be carried out by spatial optimum filtering for motion compensating prediction.
Due to the quantization a second problem occures i.e. the reconstruction and therefore the reconstruction error. This error yield in a quantization noise circulating in the loop. and should be removed by a filter optimized for this process.
Splitting the problem into two parts, one has to identify for each problem the optimum solution. The processes are not independant, so it is not easy to identify the optimum solution.

In RM6 several modifications have been installed, described in doc 396. Due to the introduction of e.g. the variable threshold technique the quantization noise is reduced. This reduction is most visible in stationairy backgrounds, less vissible in the moving areas, this will influence the performance of h_n. The implementations of the different motion estimation algorithms on the otherhand will influence the performance of h_p.
In the proceeding sections

2 Outstanding points from previous CCITT SG XV/1 meeting

- Filtering in loop (Doc #356 and #376). The following topics have to be checked:
  - The number of filters in the loop

[1] under the assumptions of Gaussian sources

- The position of th filter(s); before, after or both sides of the frame memory
- The adaptivity of the filter(s) and how to control it
- The effectiveness of the filter(s) in the loop v.s. outside the loop

3 Draft workplan

1. Subjective picture quality applying filter inside the loop versus filter as post processing
2. The number of filters;
   Do we have to stick to the filter after the frame memory
   (i.e. the 1 2 1) or could we shift the filter in front of the frame memory.
3. The adaptivity rules of the filters
   - Motion vector
   - Prediction error
   - Energy of noise (look up tables)
4. The hardware complexity of the filters
   - using pels inside the block (was only verified for 384kbit/s)
   - using pels of neigbouring blocks
5. The characteristics of the filters
   - Simplified version from doc 356 for h_n[2]
   - Simplified version from doc 376 for h_n
   - Changing filter coefficients of h_n (adaptively without overhead)
6. The implications of the optimized filters for higher bitrates
   - 384 kbit/s
   - 2 Mbit/s
7. Simulations of filter h_{post}.

[2]see annexed figure

4 The possible positions of the loop filter

In figure 4 all mentioned filters are depicted i.e.

- the noise reduction filter h_n
- the prediction filter h_p
- the post processing filter h_pos

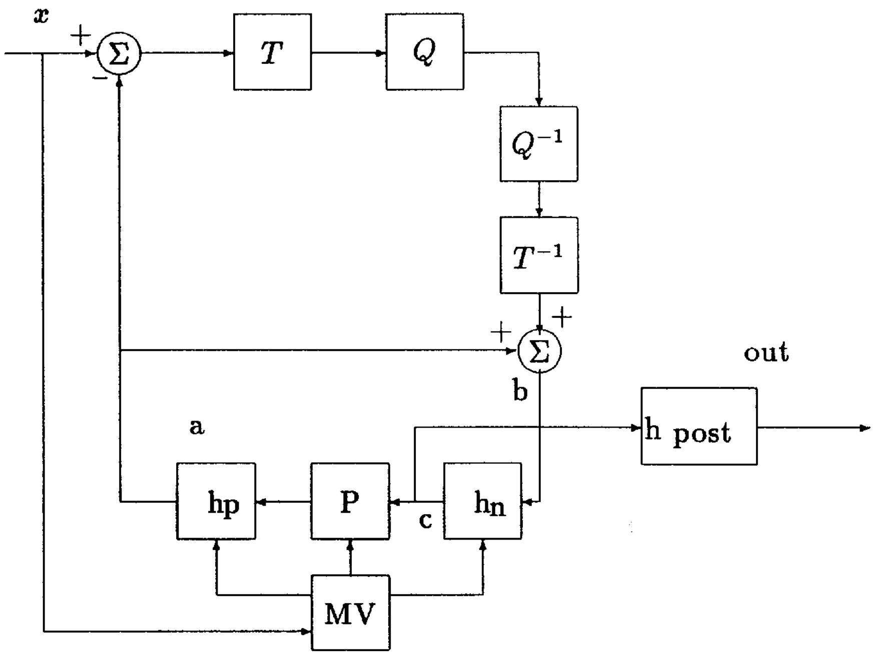


Figure 1: Possible filters inside and outside the loop

5 Evaluation of the different results

In order to reduce the noise a filter in front of the memory is preferable Two measures are to be taken into account:

- Objective measure
- Subjective measure

The objective of this exercise should be to obtain the best picture quality at the lowest complexity.
At the last meeting there was a need of explenation for the position and the number of filters. It was recognized that the adopted filter is insufficient for the universal coding approach. The filter control is not correct, at the moment the filter action is controlled by the motion vector. I.e. in the case of MW = 0 the filter is not active, also for blocks for which the motion vector is forced to zero. This approach is not adequate. Just when a block has changed but the energy does not exceeds the threshold filtering is necessary.

6 Observations

Taking into account the results of the various laboratories:

1. the noise reduction filter h_n should operate inside the block boundaries,
2. the prediction filter h_p could operate inside as well as outside the block boundaries but inside is preferable,
3. the prediction filter h_p should be adaptive, the control mechanisms are under study,
4. the noise reduction filter is for further study, considering:
    - the obtained picture quality
    - the hardware complexity

7 Proposal

From the documents annexed to this contribution and doc 406 entitled — Loop filter in p x 64 kbit/s Flexible hardware — it is difficult to obtain a conclusive answer on the number and the position of the filters.
The subjective difference in quality between adopting h_{post} and h_p is not conclusive. As the meeting agreed upon the Reference Model 6, we therefore propose that the filter maintains after the frame memory but:

- the filter operates inside the block boundaries,
- the adaptation[3] the filter characteristics of the h_p filter has to be verified
- the inclusion of the h_n filter depends on the performance and the complexity.

[3] control mechanisms

- a work plan should be developed to fix the outstanding parameters as soon as possible.

References

[1] Bernd Girod, The efficiency of Motion-Compensating Prediction for Hybrid Coding of Video Sequences, IEEE journal JSAC vol.SAC-5, No.7 pp 1140-1154.

[2] Japan, Loop filter improvement, Document 356

[3] The Netherlands Improvement Reference Model 5 by a noise reduction filter, Document 376

[4] NTT, KDD, NEC and Fujitsu, Filter in the coding loop, Document 286

[5] The Netherlands, The evaluation of filtering inside the hybrid DPCM/Transform coding loop, document 267.

[6] Chairman, Conflicts in the loop filter proposals TD 4 Nurnberg meeting.

8 Tape demonstrations

- Noise filter h_n
- Prediction filter h_p
  - RM6 i.e. non adaptive h_p
  - RM6 directional h_p
  - RM6 post memory filter with edge preserving properties
- Prediction filter h_n
  - RM6 versus RM6 and h_n
  - RM6 and h_n versus RM6 and h_{post}
- Filter(s) operating inside and outside the block boundaries

A Simulation on loop filter, source: Source: Alcatel

La Haye, November 21, 1988

Title : Simulation on loopfilter
Source: ALCATEL CIT (France)

The new loopfilter described on the document # 356 CCITT SGXV has been simulated. This filter is located before the frame memory and the previous loop filter defined in the RM 6 algorithm is not used. This new filter is applied to both luminance and chrominance signals.

We found that there were two errors in the doc # 356 concerning the threshold values. The real values have been confirmed by Japanese people abd are joined in the annex 1.

The statistical results and plots on SNR are given in the figures.

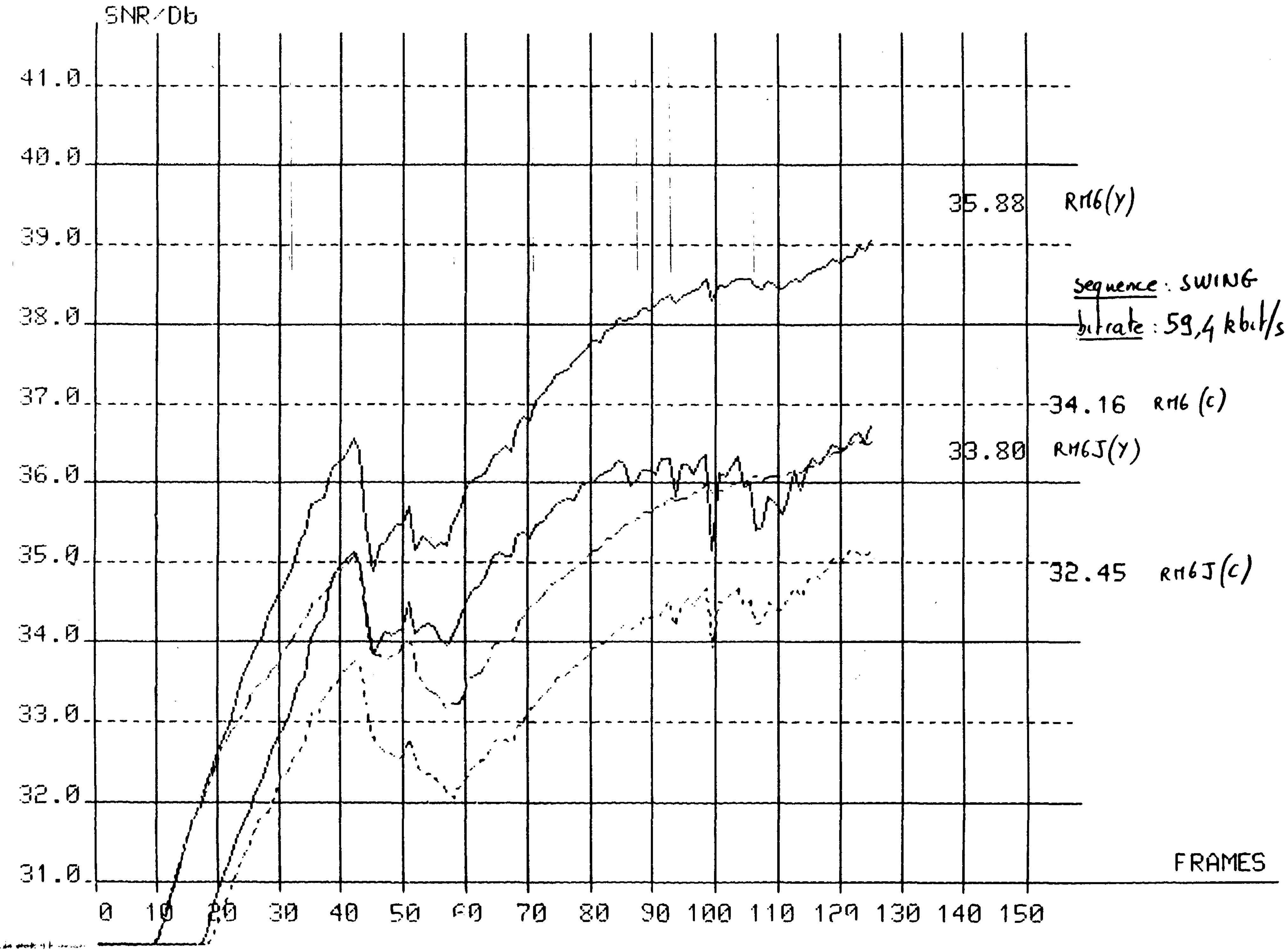
Conclusion

Up to now, using the threshold values given by Japanese people or using other values, we do not find any improvement. In comparison with RM 6 results, we obtain a loss of SNR value about 0,1 dB (CLAIRE) to 2 dB (SWING). About subjective quality picture observed on CLAIRE and BLUE JACKET, the blocking effect is a little reduced involving a slight blurredness and a granular noise on motion, however the picture quality is very closed. Unfortunately we had no time to display other sequencies. Regarding SWING result, this kind of filter seems to be not compatible.

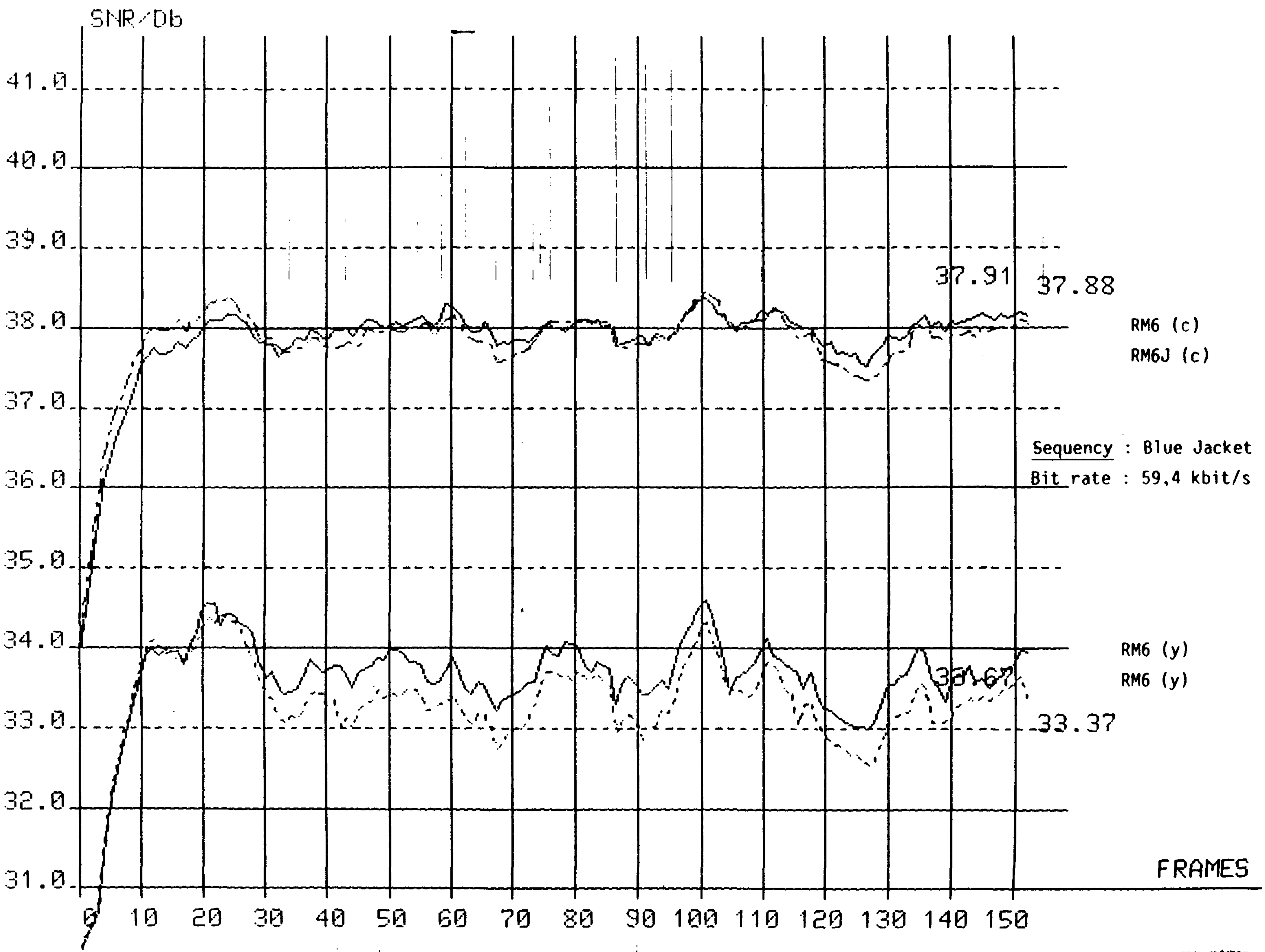
ALGORITHM : RM6J
BIT RATE : 59,4 kbit/s

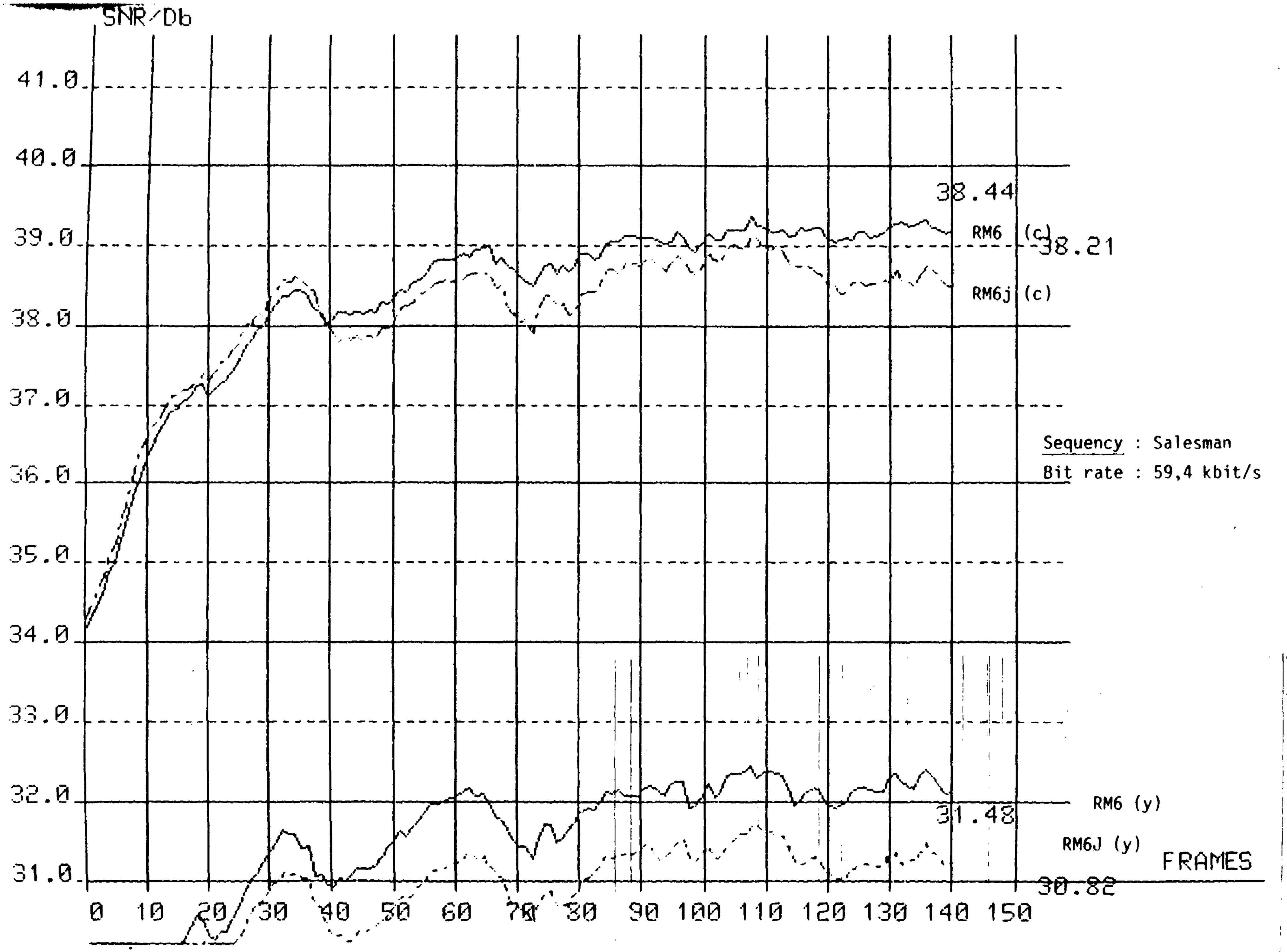
SOURCE : ALCATEL CIT
DATE : 20th November 1988

Sequence		CLAIRE	MISS AMERICA	SALESMAN	BLUE JACKET	SWING
Number of coded pictures		150	50	140	166	125
1) R.M.S. for luminance		3.3094	3.2760	7.3922	5.4486	8.1918
1) R.M.S. for chrominance		2.5778	3.1148	3.1641	3.2466	5.4703
2) SNR for luminance		37.74	37.82	30.76	33.41	29 86
2) SNR for chrominance		39.91	38.26	38.13	37.90	33 37
3) Mean value of the step size		18.94	19.35	26.85	22.39	21.41
4) Mean value of the number of non-zero coefficients		2.70	1.89	2.41	3.06	2.51
5) Mean value of the number of zeros before the last non-zero coefficient		4.39	2.46	7.17	7.17	15.09
4) Mean value of the number of bits per signif block		13.06	8.44	13.11	15.96	16.94
TYPE OF MB	Intra	0	1	3	1	2
	Fixed nf	257	201	239	269	266
	Inter nf	81	103	111	99	115
	Fixed MC f	8	18	8	4	2
	Coded MC f	48	70	32	21	5
TYPE OF LUMI	Intra	2	4	11	3	6
	Fixed nf	1237	1124	1227	1317	1364
	Inter nf	118	96	176	159	164
	Fixed MC f	100	232	88	49	18
	Coded MC f	123	122	75	52	11
TYPE OF CHRO	Intra	1	2	4	2	3
	Fixed nf	656	536	685	705	711
	Inter nf	21	73	16	32	52
	Fixed MC f	86	132	77	41	9
	Coded MC f	25	45	4	9	5
8) Number of bits	Attributs	583	743	680	571	615
	Class. Index	332	571	328	310	342
	EOB words	860	1103	895	773	792
	Motion vectors	332	548	264	157	68
	Coeff. Y	3500	2238	3636	3807	3227
	Coeff. C	305	677	100	295	850
	Coeff. Total	3805	2915	3736	4102	4077
	TOTAL	5912	5880	5903	5913	5894

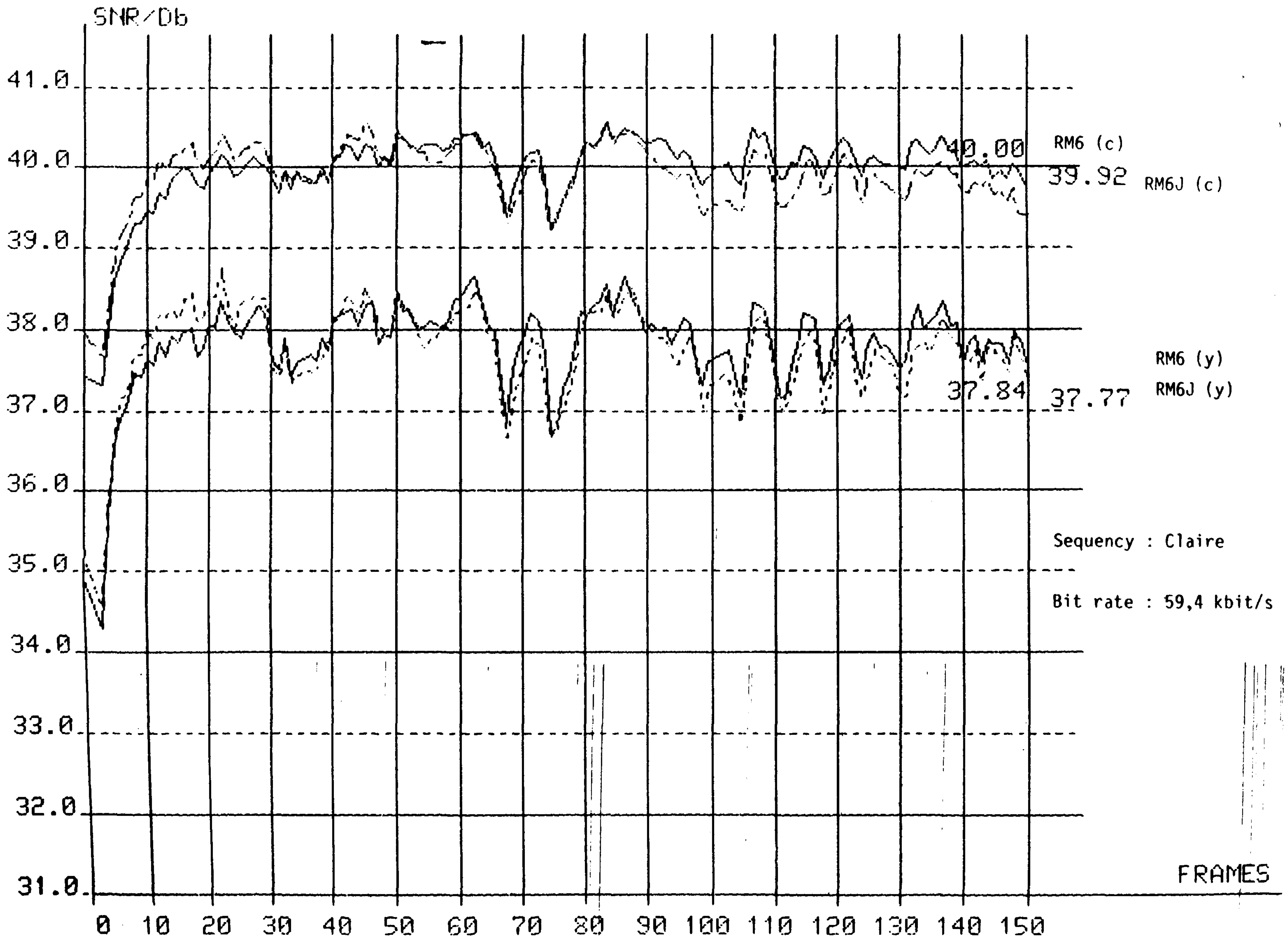


SNR/Db
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
FRAMES
35.88 RM6(Y)
sequence : SWING
bitrate : 59,4 kbit/s
34.16 RM6 (C)
33.80 RM6J(Y)
32.45 RM6J(C)


SNR/Db
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
FRAMES
37.91
37.88
33.37
RM6 (c)
RM6J (c)
Sequency : Blue Jacket
Bit rate : 59,4 kbit/s
RM6 (y)
RM6 (y)



SNR/Db
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
FRAMES
38.44
RM6 (c)
38.21
RM6j (c)
Sequency : Salesman
Bit rate : 59,4 kbit/s
RM6 (y)
31.48
RM6J (y)
30.82


SNR/Db
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
FRAMES
40.00
RM6 (c)
39.92
RM6J (c)
RM6 (y)
37.84
37.77
RM6J (y)
Sequency : Claire
Bit rate : 59,4 kbit/s

A Filtering in the loop, Source: N T A

Source	:	Norway
Subject	:	Improvement of MC prediction by using: FILTER OVER BLOCK EDGES ADAPTIVE DIRECTIONAL LOOPFILTER

1 Introduction

This document deals mainly with twe different methods to make batter prediction for coding of block data. Simulation results are also obtained for loopfilter with and without filter over blockedges and for using one or three scanning classes. In the following section loopfilter is described.

2 Adaptive directional filter

The oidea here is to make the filtering more adapted to the block data to be coded. The 1 2 1 loopfilter is known to give good results concerning noise reduction. On the other hand, this filter removes some of the details in the prediction. This is particularly noticable for reconstruction of edges.

The here proposed approach may be summarized in the following way:

- When the MB is classified as having a well defined 'orientation', one os filter F2 - F5 (fig. 1) is used.
- Otherwise the 'ols' 1 2 1 filter F1 is used as loopfilter.
- The filter is switched oin and off with the motion vector as in RM6

The general effect of this kind of filtering is for instance that predicted edges are not smeared. The effect is often that the block is represented by the prediction only. This gives both an objective saving of bits and a subjectively better reconstructed block with less 'edging'.

2.1 Scanning classes

Having introduces classification of data blocks according to direction, it is natural to investigate the use of different scanning classes connected to the different orientations of the data. The proposed scanning classes are shown in Figure 2. Simulations are shown using both one and three scanning classes together with directional filters.

2.2 How to find direction

The directions are obtained for each MB. At least at 64 kbit/s coding it does not seem useful to define directions for each subblock. Moreover, if the direction information is sent as side information, definition for each subblock would produce too much overhead.

The calculation of direction may be obtained in two waus:

1. On the original data block at the coder
2. On the predicted block. The same calculations are made both at the coder and decoder

Advantages of 1:	More exact directional information is obtained No extra burden on the decoder The method of finding the directionb does not have to be standardized.
Advantages of 2:	No extra overhead bits are needed Slightly better performance

We have used approach 2 in the simulation results to be presented here.

The determination of filter to be used is done according to the method described in [1]. There are listed two 'quality measures' of the direction: S2+S3 and Q. We have used two limits for the two quantities: L1=10000 and L2=0.4. If S2+S3 < L1 or Q < L2 we yse filter F1 and scanning class SC1. Otherwise we use the appropriate directional filter and scanning class.

The direction to be used is signalled for each MB. It is proposed to use a VLC for the coding. A proposal of such a VLC is given in Figure 3. It is based on the statistics of the dirrerent directions from the test sequences CLAIRE, MISS AMERICA and SALESMAN.

3 Conclusions

The following observations could be made.

- Filtering over block boundaries give little SNR gain but reduced blocking
- Adaptive directional transform gives both objective and subjective improvement and should be considered. More work should be cone on a simpler method for filter decision.
- Different scanning classes togehter with directional filtering gives a small saving in bits.

Reference

CCITT SGXV Working Party XV/1, Specialist Group on Coding for Visula Telephony. Doc # 381.

1	2	1	
2	4	2	F1 - used with no direction
1	2	1	

0	0	0	
1	2	1	F2 - used with horizontal orientation.
0	0	0	

0	0	1	
0	2	0	F3 - used with 45 deg orientation.
1	0	0	

0	1	0	
0	2	0	F4 - used with vertical orientation.
0	1	0	

1	0	0	
0	2	0	F5 - used with 135 deg orientation.
0	0	1	

Figure 1. Loopfilters.

ZIG - ZAG SC1

1	2	3	4	8	10	12	18	
5	6	7	9	11	13	16	20	
14	15	17	19	21	22	23	24	
25	26	27	28	29	30	31	32	SC2
33	34	35	36	37	38	39	40	
41	42	43	44	45	46	47	48	
49	50	51	52	53	54	55	56	
57	58	59	60	61	62	63	64	

1	5	14	25	33	41	49	57	
2	6	15	26	34	42	50	58	
3	7	17	27	35	43	51	59	
4	9	19	28	36	44	52	60	SC3
8	11	21	29	37	45	53	61	
10	13	22	30	38	46	54	62	
12	16	23	31	39	47	55	63	
18	20	24	32	40	48	56	64	

Figure 2. Scanning classes. SC2 is used for vertical structures and SC3 for horizontal structures. Otherwise SC1 is used.

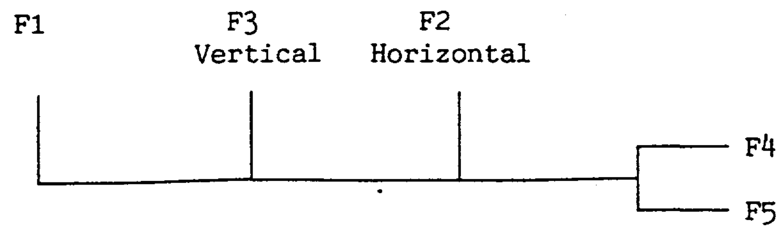


Figure 3. Coding tree forthe VLC to be used to signal which filter to use.

Table 1. SNR gains for the different modifications M1 - M4

	M1	M1+M2	M1+M3	M1+M4	M1+M3+M4
CLAIRE		.3	.38	.03	.63
MISS AMERICA	.1		.24	.05	.26

Table 2. Simulations to be shown in split mode.

CLAIRE

RM6	M1,M3
M1,M2	M1,M3
RM6	M1,M4
RM6	M1,M3

MISS AMERICA

RM6	M1
RM6	M1,M3
RM6	M1,M4
RM6	M1,M3

A Post memory filter with edge preserving properties, Source: BTRL

TITLE: LOOP FILTERS IN RM6
SOURCE: UK
DATE: NOV 88

This paper describes some variants of the standard loop filter configuration in RM6.

Post frame memory filter with edge preserving properties

The existing RM6 filter was modified to give it edge preserving properties. This was done by first calculating the absolute difference between the pixel to be filtered and its filtered value and comparing this difference with a pre-determined threshold. If the difference was greater than the threshold then the pixel examined was not filtered else the pixel was filtered as normal. The filter was additionally modified such that the threshold was set to infinity for the pixels existing on the edges of previous frame blocks with a given block. The situation is illustrated in Figure 1.

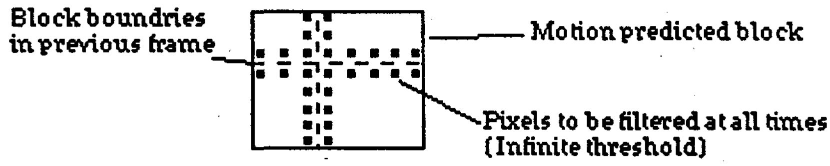


Figure 1. Filter adaptivity illustration

This filter was studied with several threshold values ranging between 0 and 32. Some suprising results were obtained. With a threshold of 32 the codec peformance was almost identical to RM6. Results of thresholds of 0 and 8 are reported in detail. A threshold of 0 implies that only the previous block boundry pixels were filtered. Table 1,2,3 4, 5 and 6 show the results for thresholds of 0 and 8 for MISSA BLUE JACKET and CLAIRE. The results are most significant for CLAIRE with an improvement in SNR of 0.1dBs and a reduction in mean quantiser step size of more than 1 for a threshold of 0. The results indicate the most important part of the block to filter and that the contribution the intra block, block boundry discontinuities have to prediction error is much greater than distributed quantisation error.

Pre and post frame memory filters operating within the block

It has been shown a filter placed before the frame memory which operates across block boundries can lead to good results. A problem with this configuration is that it can be considerably more complex to realise in hardware than a post memory filter operating within a block. A filter configuration is outlined here which has some of the advantages of both the pre and post frame memory filters. The arrangement is shown in Figure 2.

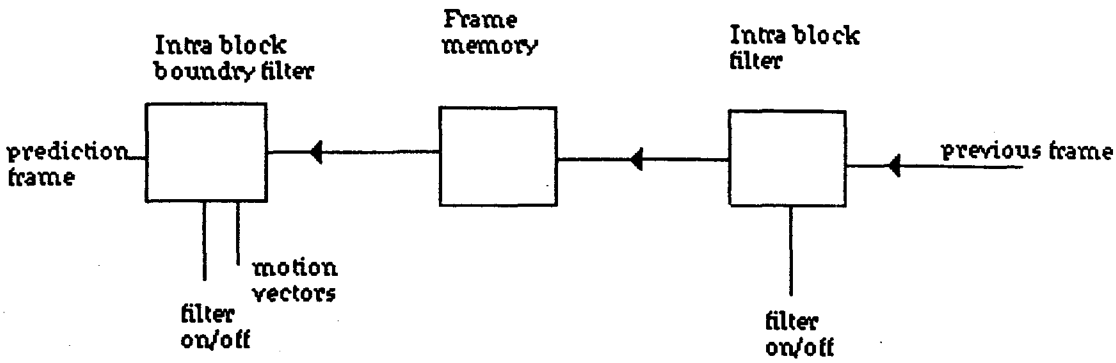


Figure 2.

The pre frame memory filter (FMF) is activated as a function of how the block was coded in the previous frame, and the post frame memory filter is activated if the block was motion compensated, thus no overhead is required for either filter. The pre FMF is a simple spatial filter to reduce distributed quantisation noise. The post FMF is a filter as descibed in the above section. Table 7 illustrates a result where the pre FMF is activated for block which were motion compensated in the previous frame. So far the results are worse than RM6. This may be due to excessive filtering and could be reduced by using a less severe filter for the pre FMF.

THRESHOLD = Ø

```
DETAILS OF REFERENCE FILE

x frame size ..................352
y frame size ..................288
Bitrate .......................15
Number of frames ..............38
Run time control module name...RM6 V1.1 /GGS/Oct 88
Image source file name.........../graham/meiko/img/source/missa
Image sink file name...........gsprb
-----------------------------------------| FRAME 15 |-------------| AVERAGE|----
RMSE value of luminance....................3.18                  3.44
Signal to noise ratio.Y....................38.07                 37.45
Signal to noise ratio.U....................37.96                 37.33
Signal to noise ratio.V....................39.14                 38.06
________________________________________________________________________________
mean quantiser step size...................15.00                 19.84
No of non-zero transmitted coefs...........2.00                  1.68
No of zero transmitted coefs...............1.00                  1.19
________________________________________________________________________________
No of FIXED (NO MC) macro blocks...........223                   212
No of INTRA macro blocks...................1                     2
No of FIXED + MC macro blocks..............9                     31
No of INTER (NO MC) macro blocks...........123                   78
No of INTER + MC...........................40                    69
________________________________________________________________________________
Macro class 0     0 | 0   0 | 0............232                   244
                  0 | 0
Macro class 1     0 | 0   1 | 1............49                    43
                  0 | 0
Macro class 2     0 | 1   0 | 0............23                    23
                  0 | 1
Macro class 3     0 | 1   1 | 1............11                    10
                  0 | 1
Macro class 4     1 | 0   0 | 0............34                    22
                  0 | 0
Macro class 5     1 | 0   1 | 1............7                     10
                  1 | 0
Macro class 6     1 | 1   0 | 0............24                    21
                  1 | 1
Macro class 7     1 | 1   1 | 1............15                    16
                  1 | 1
Macro class 8     (INTRA)..................1                     2
________________________________________________________________________________
Macro attributes...........................923                   844
EOB bits...................................952                   929
Motion vector bits.........................272                   682
Y coef bits................................2773                  2426
Cr coef bits...............................224                   363
Cb coef bits...............................383                   261
________________________________________________________________________________
Total bits per frame.......................5862                  5823
Buffer status..............................1435                  1930
```

THRESH = Ø
TABLE 1

THRESHOLD = Ø

DETAILS OF REFERENCE FILE

```
x frame size ..................352
y frame size ..................288
Bitrate .......................15
Number of frames ..............159
Run time control module name...RM6 V1.1 /GGS/Oct 88
Image source file name........./graham/meiko/img/source/blue
Image sink file name...........gsprb
-------------------------------------------| FRAME 15 |-------------| AVERAGE|----
RMSE value of luminance....................5.23                     5.41
Signal to noise ratio.Y....................33.77                    33.48
Signal to noise ratio.U....................37.11                    37.18
Signal to noise ratio.V....................38.12                    38.29
------------------------------------------------------------------------------
mean quantiser step size...................19.00                    22.61
No of non-zero transmitted coefs...........3.00                     2.66
No of zero transmitted coefs...............3.00                     3.22
------------------------------------------------------------------------------
No of FIXED (NO MC) macro blocks...........296                      289
No of INTRA macro blocks...................3                        2
No of FIXED + MC macro blocks..............2                        5
No of INTER (NO MC) macro blocks...........85                       80
No of INTER + MC...........................10                       17
------------------------------------------------------------------------------
Macro class 0     0 | 0   0 | 0............298                      294
                  0 | 0
Macro class 1     0 | 0   1 | 1............13                       9
                  0 | 0
Macro class 2     0 | 1   0 | 0............28                       23
                  0 | 1
Macro class 3     0 | 1   1 | 1............3                        4
                  0 | 1
Macro class 4     1 | 0   0 | 0............27                       22
                  0 | 0
Macro class 5     1 | 0   1 | 1............0                        3
                  1 | 0
Macro class 6     1 | 1   0 | 0............15                       22
                  1 | 1
Macro class 7     1 | 1   1 | 1............9                        11
                  1 | 1
Macro class 8     (INTRA)..................3                        2
------------------------------------------------------------------------------
Macro attributes...........................512                      530
EOB bits...................................560                      640
Motion vector bits.........................76                       133
Y coef bits................................4089                     4000
Cr coef bits...............................193                      177
Cb coef bits...............................138                      212
------------------------------------------------------------------------------
Total bits per frame.......................5791                     5906
Buffer status..............................1860                     2205
```

THRESH = Ø
TABLE 2

THRESH = Ø   CLAIR2.DAT

DETAILS OF REFERENCE FILE

x frame size 352
y frame size 288
Bitrate 15
Number of frames 79
Run time control module name...RM6 V1.1 /GGS/Oct 88
Image source file name........./graham/meiko/img/source/clair
Image sink file name...........gsprb

	FRAME 15	AVERAGE
RMSE value of luminance	3.31	3.44
Signal to noise ratio.Y	37.73	37.45
Signal to noise ratio.U	38.27	38.35
Signal to noise ratio.V	41.55	41.55
mean quantiser step size	15.00	19.09
No of non-zero transmitted coefs	3.00	2.94
No of zero transmitted coefs	2.00	1.81
No of FIXED (NO MC) macro blocks	259	271
No of INTRA macro blocks	1	2
No of FIXED + MC macro blocks	3	11
No of INTER (NO MC) macro blocks	97	66
No of INTER + MC	36	43

			FRAME 15	AVERAGE
Macro class 0	0 | 0 0 | 0	0 | 0	262	283
Macro class 1	0 | 0 0 | 0	1 | 1	13	5
Macro class 2	0 | 1 0 | 1	0 | 0	34	28
Macro class 3	0 | 1 0 | 1	1 | 1	2	3
Macro class 4	1 | 0 0 | 0	0 | 0	30	26
Macro class 5	1 | 0 1 | 0	1 | 1	5	4
Macro class 6	1 | 1 1 | 1	0 | 0	31	27
Macro class 7	1 | 1 1 | 1	1 | 1	18	14
Macro class 8	(INTRA)		1	2

	FRAME 15	AVERAGE
Macro attributes	667	547
EOB bits	840	724
Motion vector bits	156	318
Y coef bits	3398	3690
Cr coef bits	203	127
Cb coef bits	290	217
Total bits per frame	5824	5879
Buffer status	1489	1857

THRESH = Ø
TABLED

missa. with filter4.c
in worlem 1.
THRESHOLD = 8

DETAILS OF REFERENCE FILE

```
x frame  ize ..................352
y frame size ..................288
Bitrate .......................15
Number of frames ..............38
Run time control module name...RM6 V1.1 /GGS/Oct 88
Image source file name........./graham/meiko/img/source/missa
Image sink file name.........../graham/meiko/img/sink/missa
-------------------------------------------| FRAME 15 |-------------| AVERAGE|----
RMSE value of luminance....................3.21                      3.46
Signal to noise ratio.Y....................38.01                     37.39
Signal to noise ratio.U....................38.03                     37.43
Signal to noise ratio.V....................39.47                     38.28

mean quantiser step size...................15.00                     20.14
No of non-zero transmitted coefs...........2.00                      1.62
No of zero transmitted coefs...............2.00                      1.30

No of FIXED (NO MC) macro blocks...........225                       214
No of INTRA macro blocks...................1                         2
No of FIXED + MC macro blocks..............7                         31
No of INTER (NO MC) macro blocks...........124                       78
No of INTER + MC...........................39                        69

Macro class 0     0 | 0   0 | 0.............232                       246
                  0 | 0
Macro class 1     0 | 0   1 | 1.............35                        40
                  0 | 0
Macro class 2     0 | 1   0 | 0.............27                        24
                  0 | 1
Macro class 3     0 | 1   1 | 1.............12                        11
                  0 | 1
Macro class 4     1 | 0   0 | 0.............38                        22
                  0 | 0
Macro class 5     1 | 0   1 | 1.............10                        10
                  1 | 0
Macro class 6     1 | 1   0 | 0.............23                        22
                  1 | 1
Macro class 7     1 | 1   1 | 1.............18                        15
                  1 | 1
Macro class 8     (INTRA)...................1                         2

Macro attributes...........................908                       833
EOB bits...................................988                       925
Motion vector bits.........................265                       667
Y coef bits................................2932                      2494
Cr coef bits...............................274                       350
Cb coef bits...............................366                       238

Total bits per frame.......................6054                      5824
Buffer status..............................1490                      1958
```

THRESH = 8
TABLE 4

BLUE with filter 4.

THRESHOLD = 8

DETAILS OF REFERENCE FILE

x frame size 352
y frame size 288
Bitrate 15
Number of frames 159
Run time control module name...RM6 V1.1 /GGS/Oct 88
Image source file name........./graham/meiko/img/source/blue
Image sink file name...........gsprb

	FRAME 15	AVERAGE
RMSE value of luminance	5.25	5.43
Signal to noise ratio.Y	33.72	33.46
Signal to noise ratio.U	37.14	37.23
Signal to noise ratio.V	38.25	38.36
mean quantiser step size	19.00	22.72
No of non-zero transmitted coefs	2.00	2.70
No of zero transmitted coefs	3.00	3.23
No of FIXED (NO MC) macro blocks	284	290
No of INTRA macro blocks	3	2
No of FIXED + MC macro blocks	2	4
No of INTER (NO MC) macro blocks	95	80
No of INTER + MC	12	17
Macro class 0 0 | 0 0 | 0 0 | 0	286	295
Macro class 1 0 | 0 1 | 1 0 | 0	16	8
Macro class 2 0 | 1 0 | 0 0 | 1	28	23
Macro class 3 0 | 1 1 | 1 0 | 1	4	4
Macro class 4 1 | 0 0 | 0 0 | 0	25	22
Macro class 5 1 | 0 1 | 1 1 | 0	4	3
Macro class 6 1 | 1 0 | 0 1 | 1	19	23
Macro class 7 1 | 1 1 | 1 1 | 1	11	11
Macro class 8 (INTRA)	3	2
Macro attributes	591	525
EOB bits	660	643
Motion vector bits	84	128
Y coef bits	3959	4023
Cr coef bits	167	169
Cb coef bits	166	206
Total bits per frame	5861	5906
Buffer status	1886	2215

THRESH = 8
TABLES

DETAILS OF REFERENCE FILE

```
x frame size ..................352
y frame size ..................288
Bitrate .......................15
Number of frames ..............38
Run time control module name...RM6 V1.1 /GGS/Oct 88
Image source file name........./graham/meiko/img/source/missa
Image sink file name...........gsprb
-------------------------------------------| FRAME 15 |-------------| AVERAGE|----
RMSE value of luminance....................3.20                      3.48
Signal to noise ratio.Y....................38.03                     37.32
Signal to noise ratio.U....................38.03                     37.39
Signal to noise ratio.V....................39.26                     38.17
-------------------------------------------------------------------------------------
mean quantiser step size...................15.00                     20.62
No of non-zero transmitted coefs...........2.00                      1.49
No of zero transmitted coefs...............2.00                      1.41
-------------------------------------------------------------------------------------
No of FIXED (NO MC) macro blocks...........226                       217
No of INTRA macro blocks...................1                         2
No of FIXED + MC macro blocks..............11                        29
No of INTER (NO MC) macro blocks...........119                       78
No of INTER + MC...........................39                        68
-------------------------------------------------------------------------------------
Macro class 0     0 | 0    0 | 0..............237                    246
                  0 | 0
Macro class 1     0 | 0    1 | 1..............41                     40
                  0 | 0
Macro class 2     0 | 1    0 | 0..............34                     23
                  0 | 1
Macro class 3     0 | 1    1 | 1..............4                      10
                  0 | 1
Macro class 4     1 | 0    0 | 0..............26                     21
                  0 | 0
Macro class 5     1 | 0    1 | 1..............13                     10
                  1 | 0
Macro class 6     1 | 1    0 | 0..............26                     23
                  1 | 1
Macro class 7     1 | 1    1 | 1..............14                     15
                  1 | 1
Macro class 8    (INTRA)...................1                         2
-------------------------------------------------------------------------------------
Macro attributes...........................884                       824
EOB bits...................................928                       922
Motion vector bits.........................286                       656
Y coef bits................................3040                      2542
Cr coef bits...............................222                       349
Cb coef bits...............................255                       220
-------------------------------------------------------------------------------------
Total bits per frame.......................5939                      5827
Buffer status..............................1426                      2008
```

TABLE 7

DETAILS OF REFERENCE FILE

CLAIR with filter4.
THRESHOLD = 3

x frame size 352
y frame size 288
Bitrate 15
Number of frames 79
Run time control module name...RM6 V1.1 /GGS/Oct 88
Image source file name........./graham/meiko/img/source/clair
Image sink file name.........../graham/meiko/img/sink/clair

	FRAME 15	AVERAGE
RMSE value of luminance	3.36	3.49
Signal to noise ratio.Y	37.59	37.30
Signal to noise ratio.U	38.34	38.25
Signal to noise ratio.V	41.60	41.57
mean quantiser step size	16.00	19.51
No of non-zero transmitted coefs	3.00	2.87
No of zero transmitted coefs	3.00	2.01
No of FIXED (NO MC) macro blocks	272	273
No of INTRA macro blocks	1	1
No of FIXED + MC macro blocks	2	9
No of INTER (NO MC) macro blocks	85	65
No of INTER + MC	36	44
Macro class 0 0 | 0 0 | 0 / 0 | 0	274	283
Macro class 1 0 | 0 1 | 1 / 0 | 0	8	5
Macro class 2 0 | 1 0 | 0 / 0 | 1	37	28
Macro class 3 0 | 1 1 | 1 / 0 | 1	2	4
Macro class 4 1 | 0 0 | 0 / 0 | 0	19	25
Macro class 5 1 | 0 1 | 1 / 1 | 0	9	5
Macro class 6 1 | 1 0 | 0 / 1 | 1	29	27
Macro class 7 1 | 1 1 | 1 / 1 | 1	17	14
Macro class 8 (INTRA)	1	1
Macro attributes	606	543
EOB bits	792	732
Motion vector bits	133	309
Y coef bits	3683	3690
Cr coef bits	189	123
Cb coef bits	242	230
Total bits per frame	5925	5881
Buffer status	1574	1898

THRESH = 8
TABLE 6