CCITT SGXV
Working party XV/1
Specialists Group on Coding
for Visual Telephony

Document no. 267
Oct 1987

Title : The evaluation of filtering inside the hybrid DPCM/Transform coding loop

Source : The Netherlands

1 Introduction

This document deals with the evaluation of various filters embedded in a hybrid DPCM/transform coding configuration. The influence of motion compensation in both cases (with and without filter) is also considered.

One could wonder why?

- Is the choice of the filter not appropriate?
- Is the displacement compensation using integer displacement not adequat?
- Is the switching criterion correctly chosen?

1.1 Why filtering?

- Reduction of quantization noise
- Reduction of high frequency artifacts introduced by displacement estimation

1.2 Constraints optimization

- Closed Loop i.e. noise is adaptive to coder control
- Non-optimal prediction

2 Used configurations

- Pixel domain processing
- Transform domain processing

See figure 1a and figure 1b.

The coding strategy is based on :

- Displacement compensation
- Macro block approach reducing the overhead
- Block type discrimination
- 2-D Discrete Cosine Transform

- Uniform quantizer with a variable stepsize adaptive to the buffer status
- Adaptive scanning of the quantized coefficients
- 2-D Variable length coding

For the simulation following input format is used:

Frame rate	:	10 Hz
Spatial resolution	:	352 x 288 for Y
		176 x 144 for U, V

2.1 Used filters

- Pixel domain
  - FIR filter 3 and 5 taps
  - Hysteresis
- Transform domain
  - Separable
  - Non Separable

Example filters

Pixel domain filter

Truncated convolution

$$
\begin{pmatrix}
10 & 5 & 1 & & & & & \\
5 & 6 & 4 & 1 & & & & \\
1 & 4 & 6 & 4 & 1 & & & \\
 & 1 & 4 & 6 & 4 & 1 & & \\
 & & 1 & 4 & 6 & 4 & 1 & \\
 & & & 1 & 4 & 6 & 4 & 1 \\
 & & & & 1 & 4 & 6 & 5 \\
 & & & & & 1 & 5 & 10
\end{pmatrix}
$$

Transform domain

Frequency Weighting

$$
P(u,v) = \begin{pmatrix}
100. & 96 & 85 & 69 & 50 & 31 & 15 & 4 \\
96. & 93 & 82 & 67 & 48 & 30 & 14 & 4 \\
85 & 82 & 73 & 59 & 43 & 26 & 13 & 3 \\
69. & 67 & 59 & 48 & 35 & 21 & 10 & 3 \\
50. & 48 & 43 & 35 & 25 & 15 & 7 & 2 \\
31. & 30 & 26 & 21 & 15 & 10 & 5 & 1 \\
15. & 14 & 13 & 10 & 7 & 5 & 2 & 1 \\
4. & 4 & 3 & 3 & 2 & 1 & 1 & 0
\end{pmatrix}
$$

Then the filtered elements become:

$$F^{*}\left(q(u,v)\right) = P(u,v)\ F\ \left(q(u,v)\right)$$

with	$F(q(u,v))$	: *coefficients*
	$F^*(q(u,v))$	: *filtered coefficients*
	$P(u,v)$	: *weighting coefficients*
	u, v	: *coordinates of coefficients*

Comparison of coding performance:

	NoDE	*DE*
Nofilter	*case* 1	*case* 2
filter	*case* 3	*case* 4

- Displacement estimation
  WITH and WITHOUT filtering
  (case 4 - 2)

- Filtering
  WITH and WITHOUT
  displacement estimation
  (case 4 - 3)

RESULTS

Figure 1 comparison filters

Figure 2 comparison case 4 -2

Displacement estimation WITH and WITHOUT filtering (case 4 - 2)

Figure 3 comparison case 4 -3

Filtering WITH and WITHOUT displacement estimation (case 4 - 3)

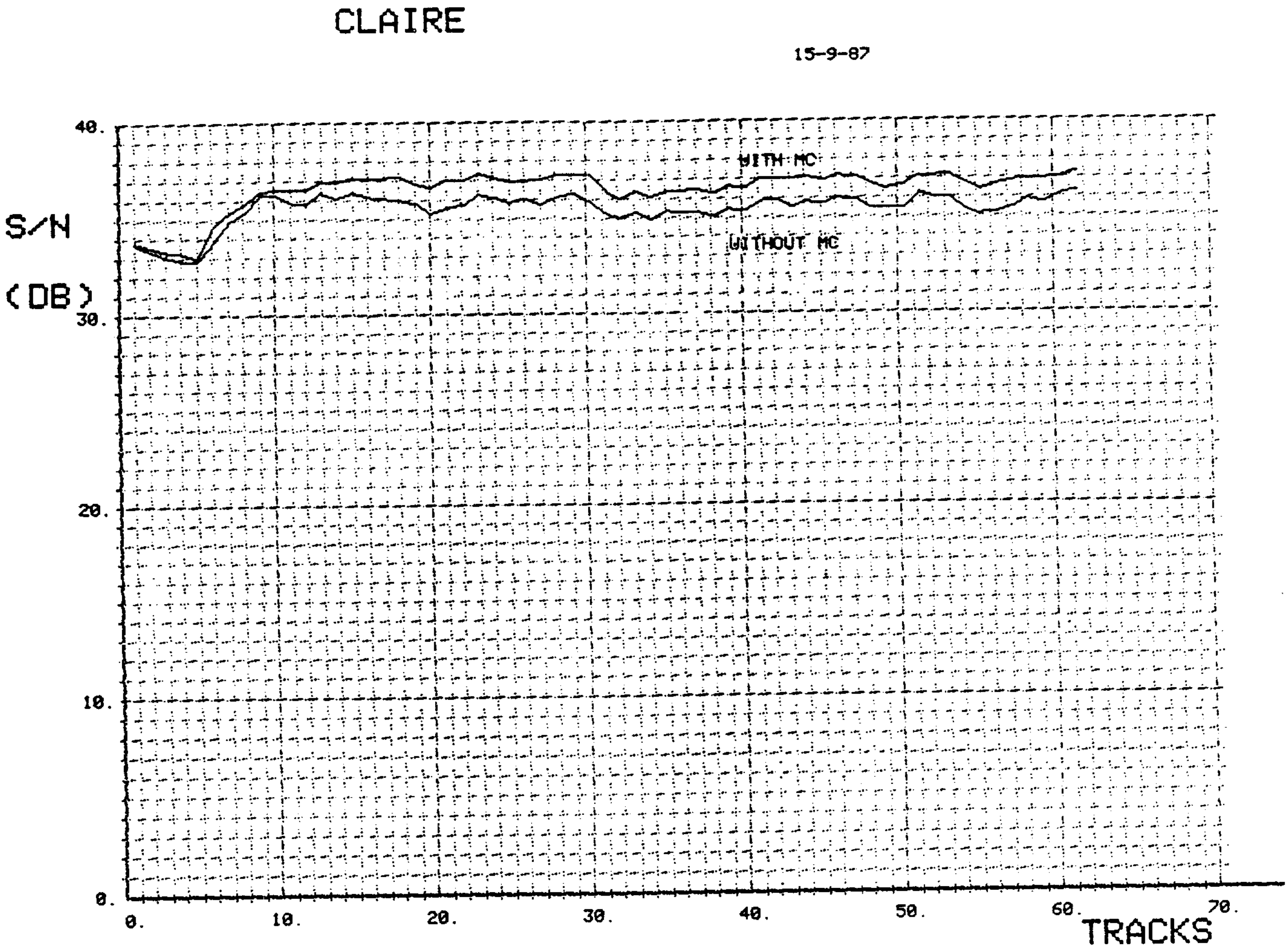

Figure 3 comparison case 4 -3

Filtering WITH and WITHOUT displacement estimation (case 4 - 3)

CONCLUSION

- Including a filter in the loop improves the performance with approximately 3-4 dB.
- In the case of pixel domain processing a simple 3 tab filter seems to be sufficient.
- In the case of transform domain processing filtering is preformed implicitely by scaling of the transform domain coefficients.
- The loss in performance in the case of No Displacement Estimation and filtering versus Displacement Estimation with filtering is approx. 1.5 dB.
- The high frequency noise components cannot be further reduced by MC due to integer displacement (method 2 with implicite filtering could be a solution)

3 Appendix A explananation Hysteresis filter

The standard hysteresis filter is an edge preserving filter which only smooths small fluctuations (see figure). The description of the 1-dimensional standard hysteresis filter is formulated with :

```
initialisation  : Y(0)=X(0)

     Y(k)  <  X(k+1)  -  T/2          --->      Y(k+1)  =  X(k+1)  -  T/2

X(k+1)-T/2  <  Y(k)  <  X(k+1)  +T/2   --->      Y(k+1)  =  Y(k)

      X(k+1)  +  T/2  <  Y(k)          --->      Y(k+1)  =  X(k+1)  +  T/2

with  :
               T          threshold
               X(k)       original, non-filtered value
               Y(k)       filtered value
               k          pixel number
```

figure 1 : Example of standard hysteresis filter

Relative extremes with maximum T are being removed. A disadvantage of this filter is a shifting of the input signal rightwards. Besides the filtering is not commutative, i.e. leftwards filtering results in another output signal than rightwards filtering.
The symmetric hysteresis filter doesn't have these disadvantages. The algorithm has two states, i.e. up and down (see figure 2).

```
algorithm up    :
```

```
Initialisation :   Y(0) = X(0)

Y(k)         < X(k+1) - T          --->    Y(k+1) = X(k+1) - T
X(k+1) - T < Y(k) < X(k+1)         --->    Y(k+1) = Y(k)
Y(k)         > X(k+1)              --->    Y(k+1) = X(k+1)
```

The condition for switching to the down-state is : $X(k+2) < X(k)$

algorithm down :

```
Initialisation :   Y(0) = X(0)

Y(k)         > X(k+1) + T          --->    Y(k+1) = X(k+1) + T
X(k+1)       < Y(k) < X(k+1) + T   --->    Y(k+1) = Y(k)
Y(k)         < X(k+1)              --->    Y(k+1) = X(k+1)
```

The condition for switching to the up-state is : $X(k+2) > X(k)$

figure 2 : Example of symmetric hysteresis filter

A : The state (up) is not changed
B : The state (up) is changed to down-state

In the figures the filtering of the same signal for three different thresholds for the standard and symmetric hysteresis filter are given.

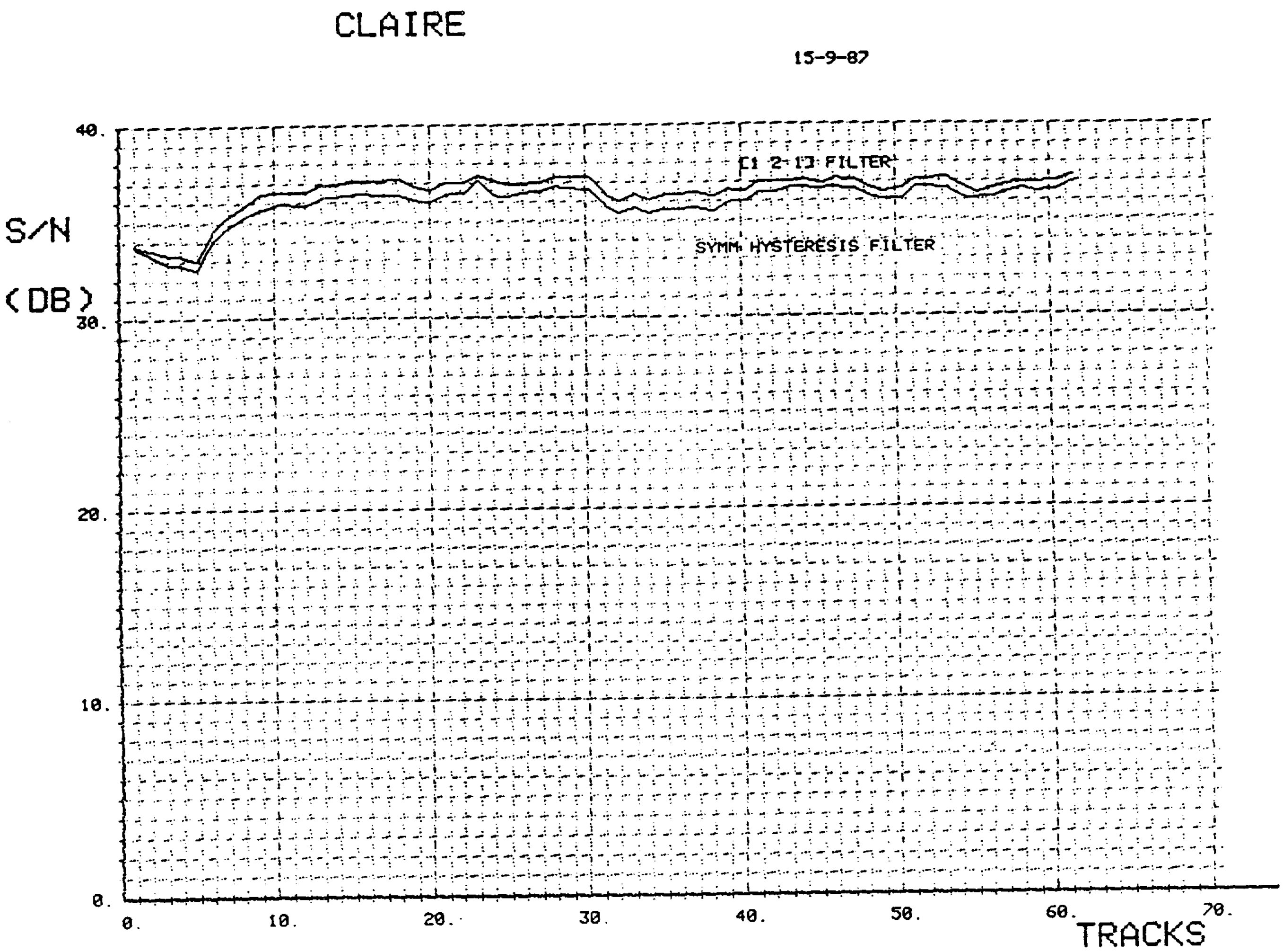

Figure 1 comparison filters

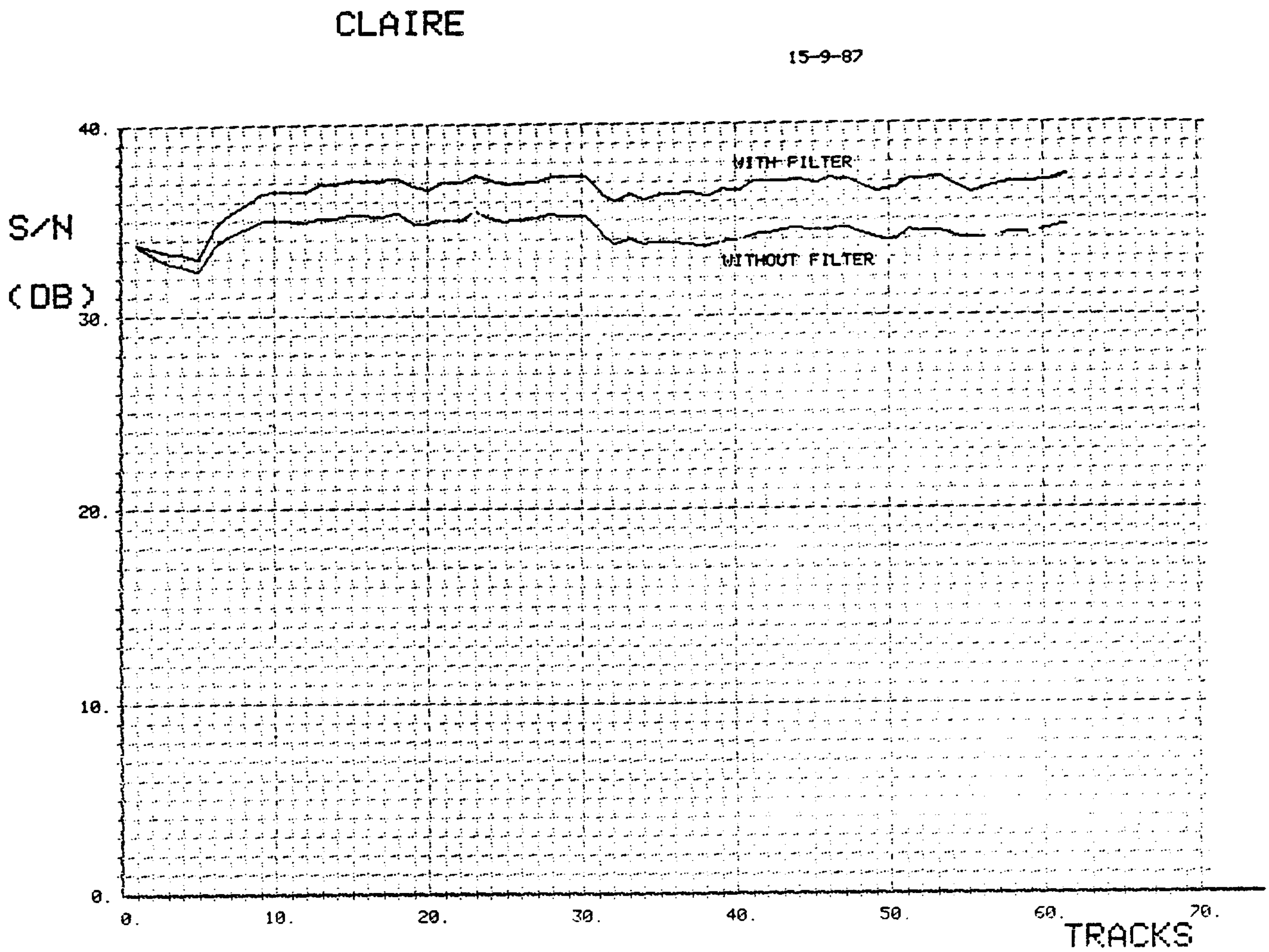

Figure 2 comparison case 4 -2

Displacement estimation
WITH and WITHOUT filtering
(case 4 - 2)

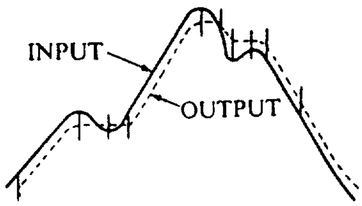

figure 1 : Example of standard hysteresis filter

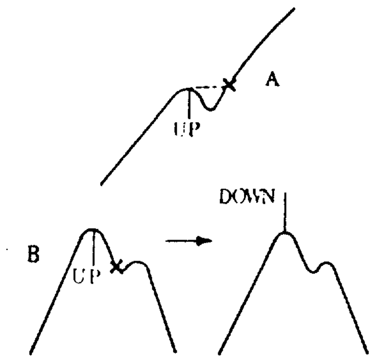

figure 2 : Example of symmetric hysteresis filter

Annex : hysteresis filter characteristics

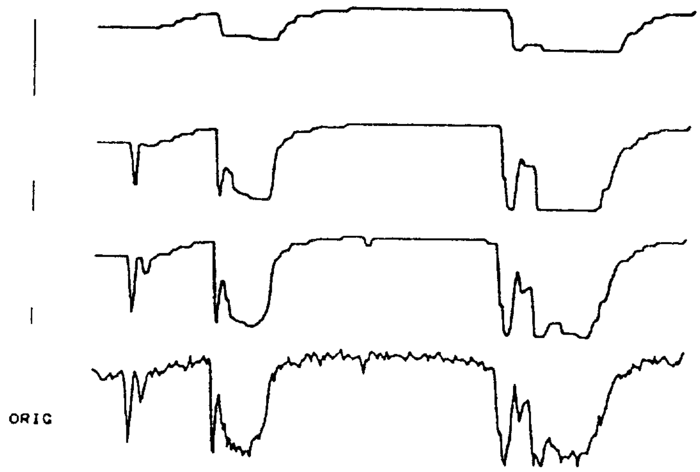

figure 3 : Standard hysteresis filtering

figure 4 : Symmetric hysteresis filtering