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

Document # 112
June 1986

SOURCE : NTT, KDD, NEC and FUJITSU

TITLE : MOTION COMPENSATION FOR CHROMINANCE SIGNALS

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1. Introduction

Concerning motion compensation for chrominance signals, the following three methods are listed in Section 9/Document # 103R :

(a) derived from luminance
(b) none
(c) independent

This document describes the results of comparative experiments among these three methods.

2. Motion Compensation for Chrominance Signals

In this section, three methods to perform motion compensation for chrominance signals are briefly explained. Some comments on each method are also presented.

(a) derived from luminance

Motion compensation for chrominance signals is performed using the motion vectors derived from those for luminance signals. A block of chrominance pels consisting of 8 x 8 pels is divided into 4 subblocks, each of which consists of 4 x 4 pels. For each subblock, motion compensation is performed using the motion vector v of the corresponding block in luminance signal. Since the numbers of sampling points in both horizontal and vertical directions for chrominance signals are half of those for luminance signal, the motion vector v is halved. Fractional value of halved vector is truncated.

[Comments] If the best matching vectors for luminance and chrominance signals are the same (or almost the same), this method may work well. This method has a merit in the point that it can perform motion compensation for chrominance signals under the above condition without transmitting motion vectors for them. However, it requires its own motion compensation circuit, because motion compensation is performed in different block sizes for luminance and chrominance signals.

(b) none

Only interframe differences are transmitted for chrominance signals. In other words, motion vectors for chrominance signals are always forced to zero.

[Comments] This method requires no information about motion vectors. No extra hardware is required. However, the amount of generated information may increase for movements of colored objects.

(c) independent

Motion vectors for chrominance signals are detected independently on luminance signals.

[Comments] Motion detection and motion compensation can be carried out using the same hardware for luminance signals. Though this method requires transmission of motion vectors for chrominance signals, the amount of generated information in transformed coefficients may decrease.

3. Conditions on Experimental Simulation

Experimental simulation has been carried out in two manners in order to compare the performance of above three methods.

(1) Using an original image as a previous decoded image (without coding errors in the previous frame)

Simulation which uses an original image as a previous decoded image is carried out in order to compare each method without the effect of feedbacked errors in the coding process.

Coding algorithm and parameters are as follows :

- The smallest rectangle which covers the all transformed coefficients above the certain threshold is detected to limit the number of transformed coefficients. The total number of such rectangles is 64 and 6 bit/block is assigned to each significant block as a class index.
- Motion detection
  - Block size: 8 x 8 pels for both luminance and chrominance signals,
  - Search method: three steps method (coarse-to-fine),
  - Search range: $\pm 12 \times \pm 12$ pels
  - The following condition is applied in order to reduce the improper motion detection in still area ; if S/N ratio of prediction errors with $\mathbf{V} = 0$ is greater than 43 dB, then the motion vector for that block is forced to zero.

(2) Coding of sequences (with coding errors in the previous frames)

(2.1) The same algorithm and parameters described in the above (Section 3 (1)) are applied to the image sequences. Coding control is carried out in order to keep the generated information at the appropriate bit rate, that is, 20 [kbit/coded frame] for Checked Jacket and Miss America sequences, and 30 [kbit/coded frame] for Split-Trevor sequence.

(2.2) The reference model with the following conditions is used in the simulation.
- Coding control is not carried out. (open loop)
- Quantizer for the transformed coefficients is fixed on step size 8.

4. Simulation Results

4.1. Using an original image as a previous decoded image

By varying the quantization parameters, the amount of generated information for R-Y and B-Y signals and S/N ratio are calculated. Figure 1 - 4 show the results for the following image pairs :

Figure 1 : Checked Jacket, #1 - #3 and #37 - #39
Figure 2 : Miss America, #1 - #3 and #57 - #59
Figure 3 : Split, #1 - #4 and #28 - #31
Figure 4 : Trevor, #97 - #100

Figure 5 shows the differences of bit assignment for each transmitted information among three methods.

4.2. Coding of sequences

Table 1 summarizes the simulation results based on the coding process described in Section 3 (2.1) (with coding control). Average amount of bits per coded frame and average S/N ratio of decoded images are listed for three methods.

Table 2 summarizes the simulation results based on the coding process described in Section 3 (2.2) (without coding control / with fixed quantizer). Amount of bits and S/N ratio of specified frame are listed for three methods. In the table, C means the total of R-Y and B-Y signals.

5. Discussion

As shown in the above simulation results, the performance of three methods is varied depending on contents of images, movement of colored objects and so on. If three methods are compared with measure of amount of bits vs. S/N ratio of decoded images, it is impossible to give the first priority to any of three methods.

In the simulation results under the condition of bit rate control, i.e. Table 1, the following features are observed for Checked Jacket and Split sequences.
- Generated information and S/N ratio for the total of luminance and chrominance signals are almost the same for three methods.
- Method (c) requires more bits for chrominance signals than other methods, but gives better S/N ratio to them.
- Method (a) assigns more bits to luminance signal and gives better S/N ratio to it.
- Method (b) shows medium performance between methods (a) and (c).

For Miss America sequence, method (b) shows the better results than other two methods.

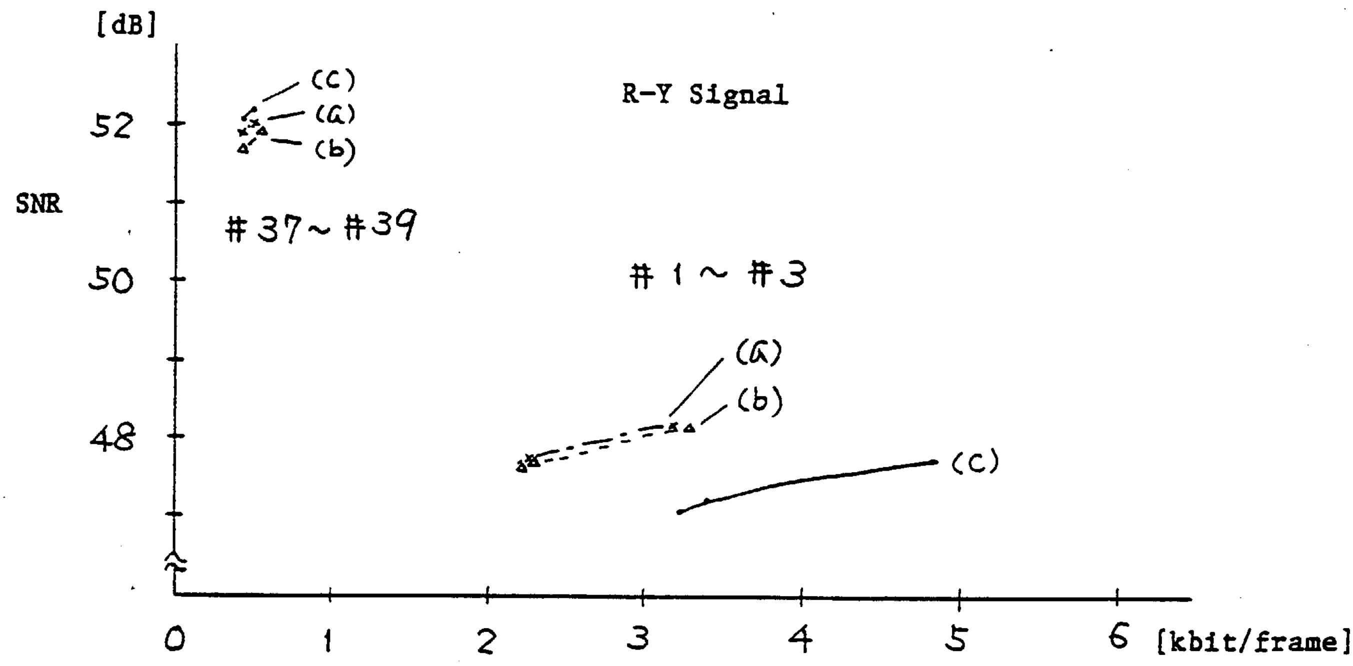
Considering above discussion and comments mentioned in Section 2, method (b), i.e. no motion compensation for chrominance signals, is preferable, because it requires no extra hardware and no transmission of motion vectors for chrominance signals.

6. Conclusion

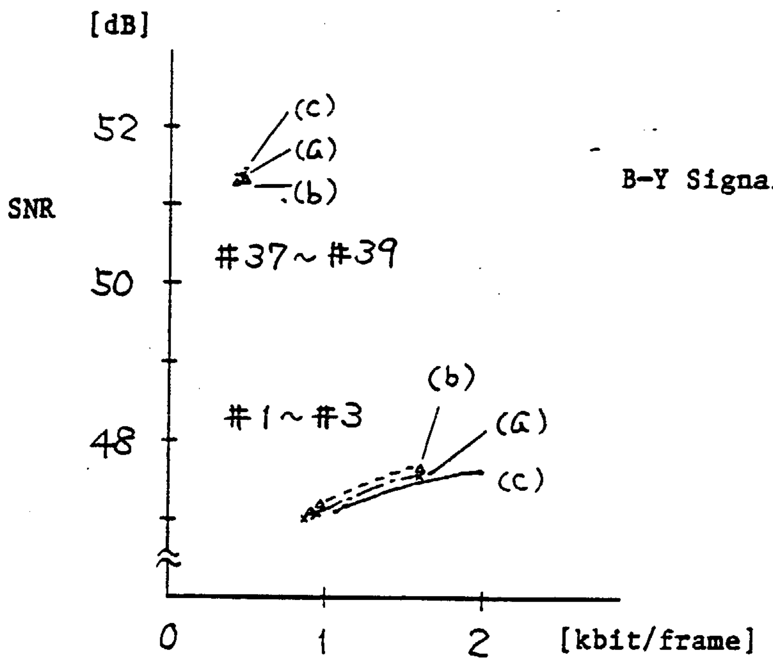
This document has described the results of comparison of motion compensation techniques for chrominance signals.

As the conclusion, method (b), i.e. no motion compensation for chrominance signals, seems to be preferable, since it is the simplest method and its performance is not bad compared to other two methods.

Checked Jacket #1 — #3, #37 — #39



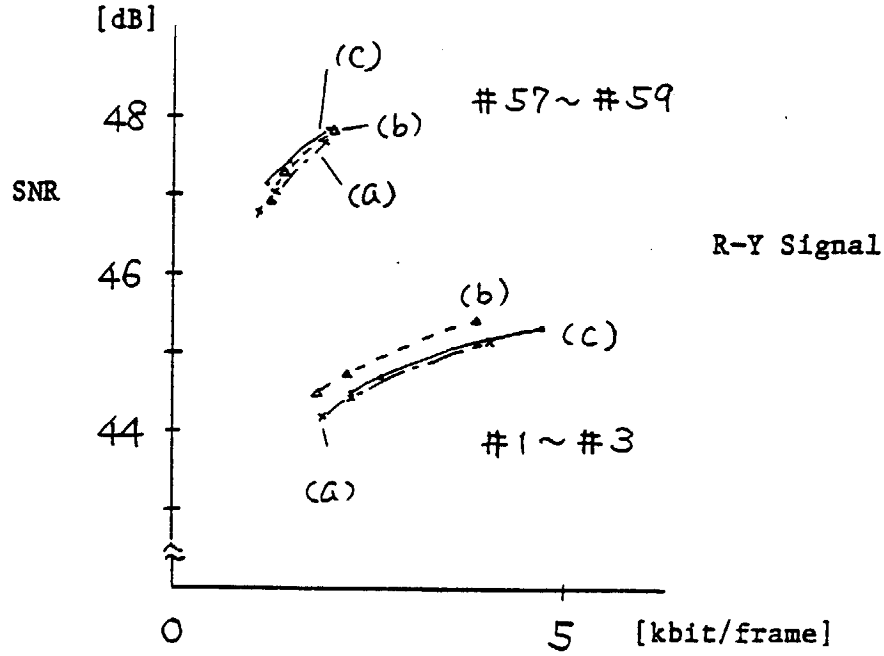
Generated Information for R-Y Signal



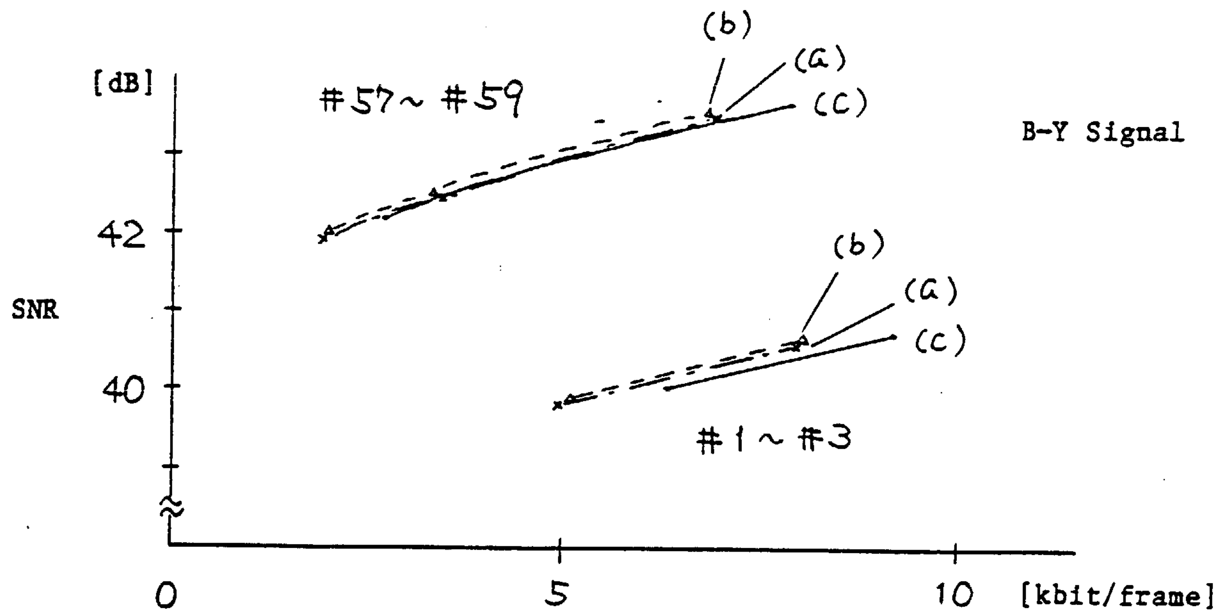
Generated Information for B-Y Signal

Figure 1. Comparison among three methods.
(Using an original image as a previous decoded image)
(a) derived from luminance
(b) none
(c) independent.

Miss America #1 -- #3, #57 -- #59



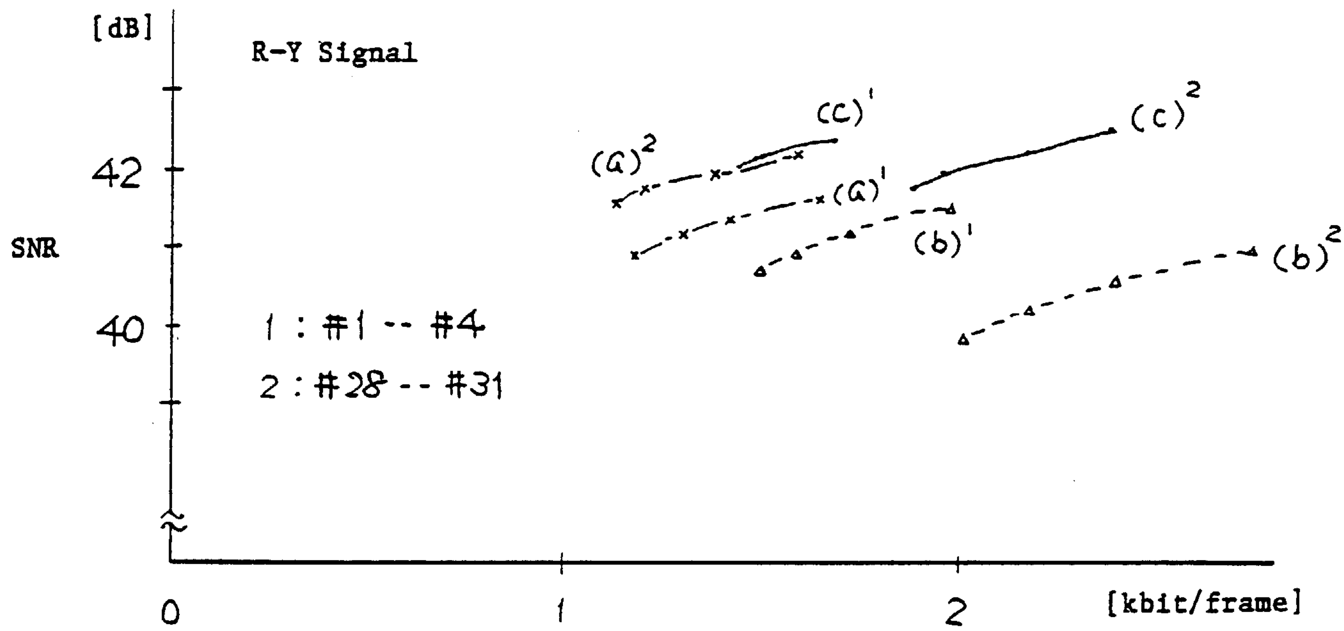
Generated Information for R-Y Signal



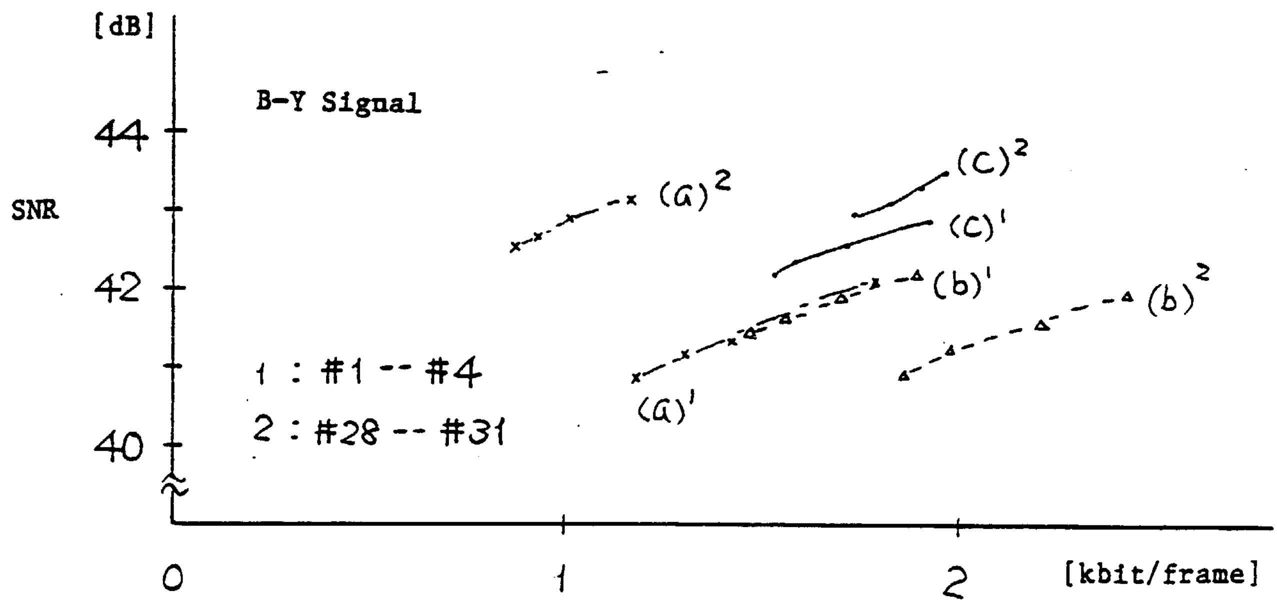
Generated Information for B-Y Signal

Figure 2. Comparison among three methods.
(Using an original image as a previous decoded image)
(a) derived from luminance
(b) none
(c) independent.

Split #1 — #4, #28 — #31



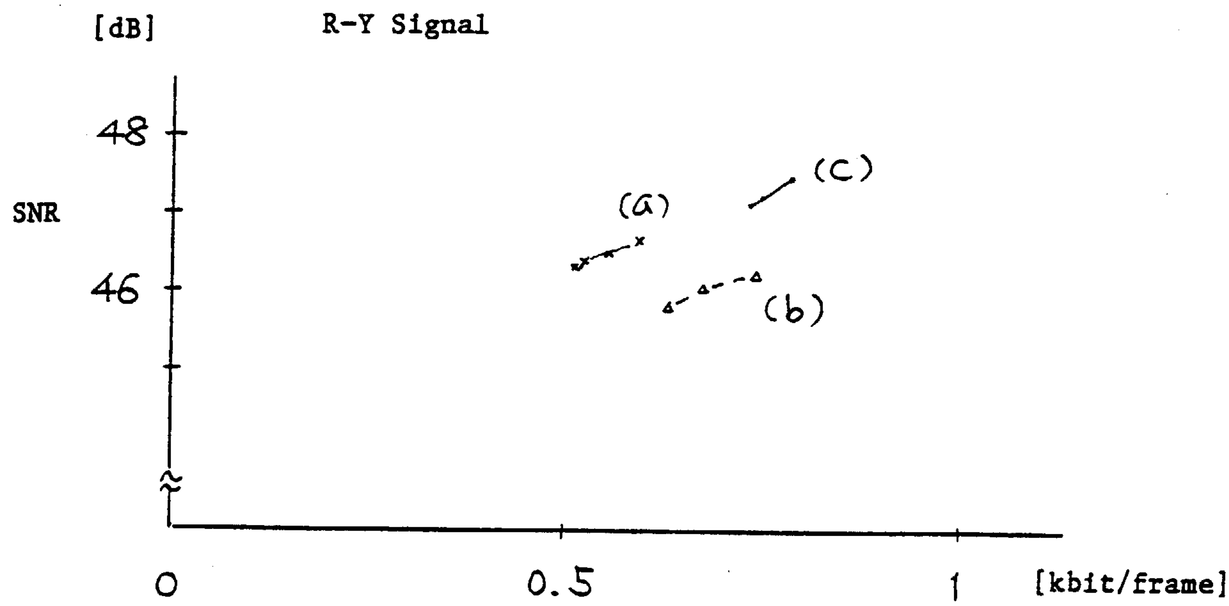
Generated Information for R-Y Signal



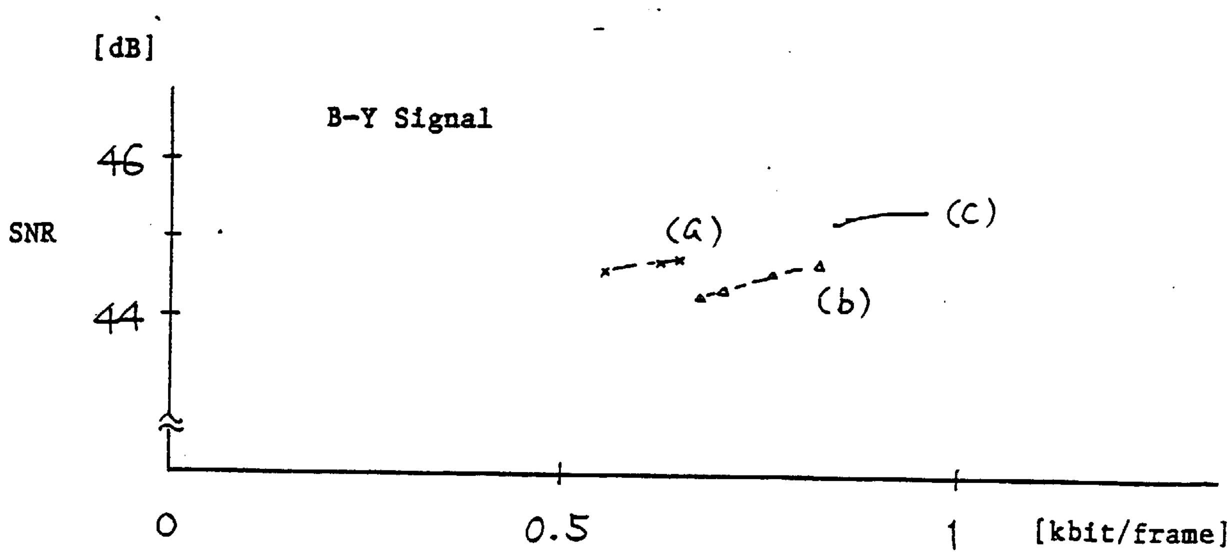
Generated Information for B-Y Signal

Figure 3. Comparison among three methods.
(Using an original image as a previous decoded image)
(a) derived from luminance
(b) none
(c) independent.

Trevor #97 — #100



Generated Information for R-Y Signal



Generated Information for B-Y Signal

Figure 4. Comparison among three methods.
(Using an original image as a previous decoded image)
(a) derived from luminance
(b) none
(c) independent.

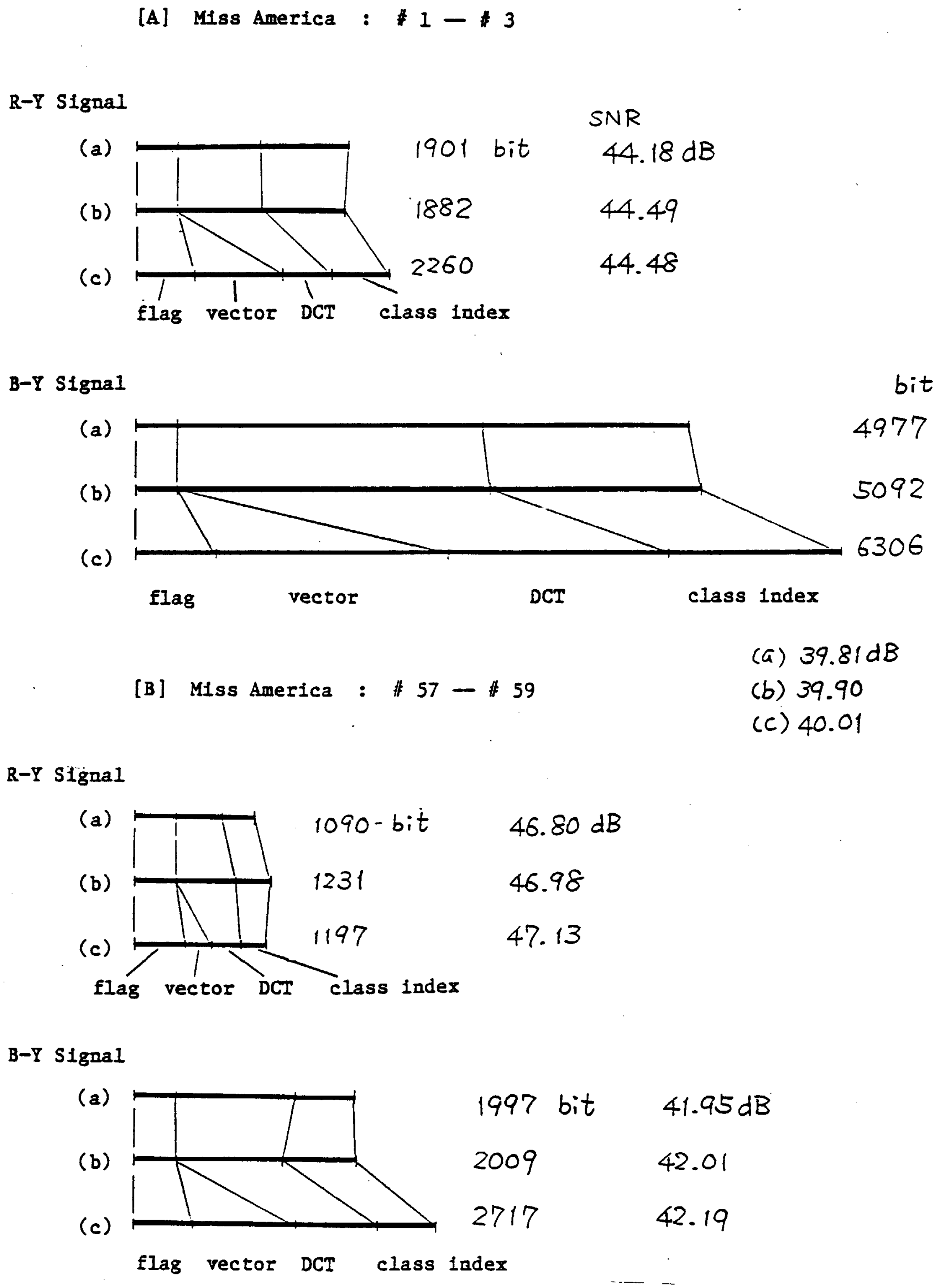
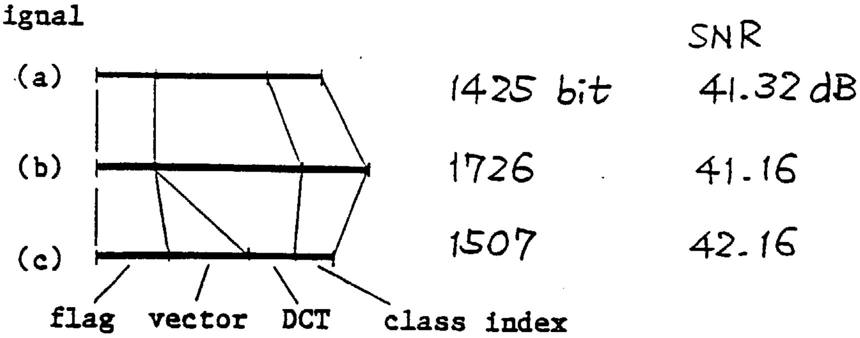


Figure 5. Bit assignment for each transmitted information. (Using an orginal image as a previous decoded image)

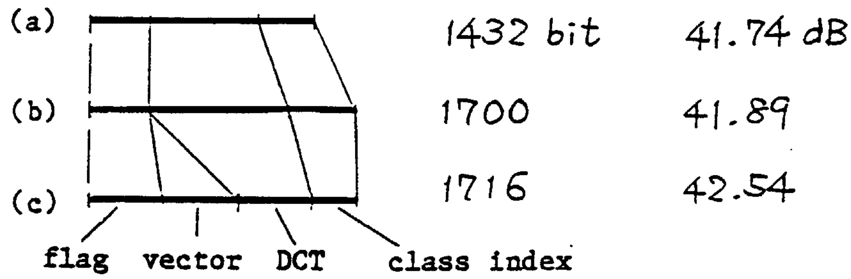
(a) derived from luminance
(b) none

[C] Split : # 1 — # 4

R-Y Signal

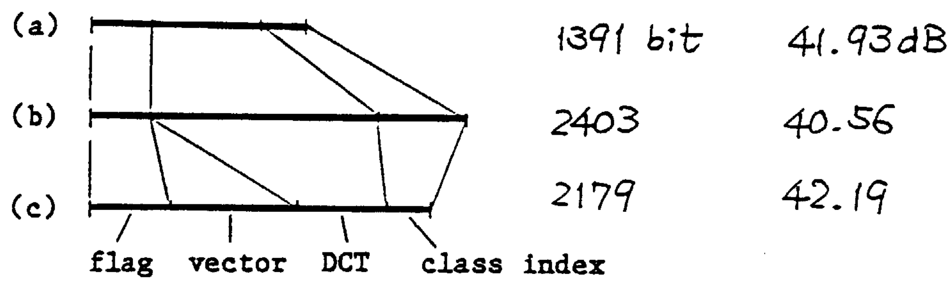


B-Y Signal



[D] Split : # 28 — # 31

R-Y Signal



B-Y Signal

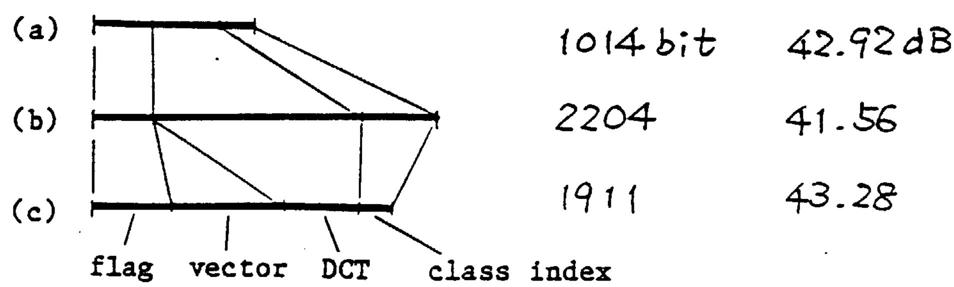


Figure 5 (continued). Bit assignment for each transmitted information.
(using an orginal image as a previous decoded image)

Table 1. Comparison among three methods. Coding algorithm described in Section 3 (2.1) has been used. (With coding control)
Average amount of bits per coded frame and average SNR of decoded images are shown below.

[A] Checked Jacket : # 15 — # 59

	(a) derived from Y		(b) none		(c) independent	
	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]
R-Y	994.8	42.71	1001.3	43.18	1161.3	43.46
B-Y	747.2	43.35	763.1	43.86	846.7	44.41
Y	17485.0	40.26	17021.5	40.21	16612.5	40.10
Total	19227.0	41.00	18785.8	41.05	18620.6	41.04

[B] Miss America : # 10 — # 100

	(a) derived from Y		(b) none		(c) independent	
	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]
R-Y	2048.9	41.18	2528.5	43.00	2299.0	42.67
B-Y	3220.3	39.76	3181.8	41.33	3703.3	40.98
Y	14920.0	41.91	15225.7	41.97	14877.5	41.89
Total	20189.2	41.34	20936.0	42.01	20879.8	41.84

[C] Split : # 20 — # 59

	(a) derived from Y		(b) none		(c) independent	
	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]
R-Y	1719.8	34.70	2252.4	35.24	2643.7	37.11
B-Y	1602.6	35.34	2006.8	36.38	2522.8	38.23
Y	25244.9	33.05	25094.6	32.82	24226.9	32.55
Total	28567.3	33.60	29353.8	33.60	29393.4	33.68

Table 2. Comparison among three methods. Coding algorithm described in Section 3 (2.2) has been used. (Without coding control / with fixed quantizer)

[A] Checked Jacket : # 39

	(a) derived from Y		(b) none		(c) independent	
	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]
C	1602	38.54	1641	39.09	1541	39.02
Y	19104	35.17	19104	35.17	19104	35.17
Total	20706	36.03	20475	36.14	20645	36.12

[B] Miss America : # 39

	(a) derived from Y		(b) none		(c) independent	
	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]
C	4777	36.43	4261	37.24	4454	36.65
Y	13003	36.32	13003	36.32	13003	36.32
Total	17780	36.36	17264	36.61	17457	36.43

[C] Split - Trevor

	(a) derived from Y		(b) none		(c) independent	
	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]	Amount of bits [bit/frame]	SNR [dB]
# 39						
C	5239	36.33	5789	37.69	4760	36.93
Y	38123	33.82	38123	33.82	38123	33.82
Total	43362	34.51	43912	34.77	42883	34.63
# 119*						
C	2245	38.67	2674	39.90	2369	39.52
Y	34599	34.67	34599	34.67	34599	34.67
Total	36844	35.64	37273	35.83	36968	35.77

* Coding process starts at # 81 frame.

Annex / Document # 112

Motion Compensation for Chrominance Signals

--- VTR Demonstration of Simulation Results ---

Simulation results obtained by the coding process described in Section 3 (2.1) (with coding control) will be demonstrated on VTR at the meeting.

Contents of VTR are as follows :

- Miss America sequence (40 frames)*
  (1) derived from luminance
  (2) none
  (3) independent

- Split sequence (42 frames)
  (4) derived from luminance
  (5) none
  (6) independent

* Since the frame dropping rate is varied from 2:1 to 3:1 three times in the sequence and decoded images are displayed under the condition of 2:1 frame dropping rate, slight jerkiness is observed.