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CE8: Conditional joint deblocking-debanding filter
(JCTVC-D043/ m18790)

Keiichi Chono, Kenta Senzaki, Hirofumi Aoki
Junji Tajime, and Yuzo Senda
NEC Corporation

Summary

- Banding-noise in video coding
- Conditional joint deblocking-debanding filter
- Issues of conditional joint deblocking-debanding filter
- Simulation results
  - Negligible impacts on BD-rates
    - Intra: HE 0.07%, LC 0.50%, and HE w/o ALF 0.51%
    - Random access: HE 0.00 %, LC 0.01%, and HE w/o ALF 0.12%
    - Low delay: HE 0.07%, LC 0.08%, and HE w/o ALF 0.06%
  - Negligible impacts on encode and decode times
    - Encode time increase: up to 1%.
    - Decode time increase: up to 3%.
  - Significant banding-noise reduction in Kimono sequence

Banding-noise in video coding

Banding-noise

- Signal-dependent noise
- Appear in areas of low detail with subtle pixel-intensity changes even when input video is encoded at high bit rates

Solutions

- Use high precision arithmetic operations in encoding
- Mask banding-noise with signal independent noise by in-loop processing and/or post processing (JCTVC-C091)

Banding-noise example: Kimono1 144th frame (1/5)

Original image

Banding-noise example: Kimono1 144th frame (2/5)

Cropped and zoomed original image

Banding-noise example: Kimono1 144th frame (3/5)

(Color enhanced) Cropped and zoomed original image

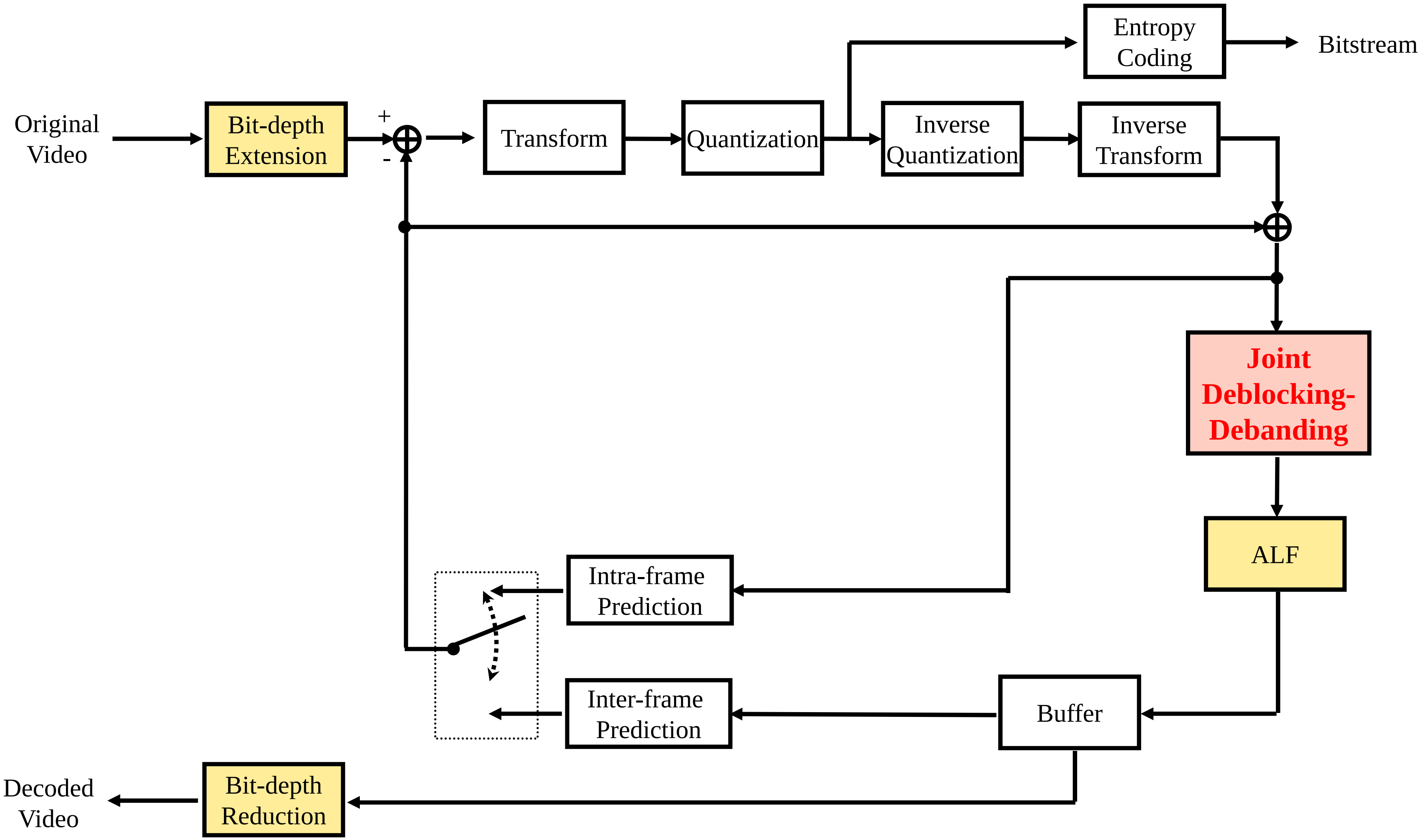
Banding-noise example: Kimono1 144th frame (4/5)

(Color enhanced) TMuC0.9 HE Random Access Anchor QP=22

Banding-noise example: Kimono1 144th frame (5/5)

(Color enhanced) Proposal HE Random Access Anchor QP=22

Conditional joint deblocking-debanding filter



Random quantization effect on the IBDI output image

Conditional joint deblocking-debanding filter (Cont.)

In-loop debanding

- Conditional comfort noise injection in deblocking process for intra coded blocks
  - Non-recursive processing
  - Comfort noise is loaded from LUT in a pixel-position associated way
- Systematic noise shaping with the help of ALF and IBDI

Several advantages over post debanding

- No need for extra frame buffer in the decoder
- Efficient banding-noise detection by using coded information
- Consistent comfort noise in temporal direction due to motion-compensated prediction

Issues of conditional joint deblocking-debanding filter

● Pseudo-noise can generate particular noise pattern in specific sequences

⇐ The issue can be solved by introducing a syntax in SPS/PPS that controls pseudo-noise injection

● Definition of pseudo-noise table takes many pages as that of VLC

⇐ The issue can be solved by using a linear feedback register as used in our original design

●Pseudo-noise may degrade coding efficiency significantly if ALF is not used

⇐ Additional simulation results show that such degradation does not happen.

Simulation

- Coding conditions

  - JCTVC-C500 and JCTVC-C508 compliant: High Efficiency, Low Complexity, and High Efficiency w/o ALF.

- Computing platform

  - Windows 7 64-bit Professional on Xeon 3.33GHz and Memory 32GB
  - Up to 12 processes of encoding and decoding ran at the same time

BD-rate and run-time results

Intra coding results

	HE Intra			LC Intra			HE w/o ALF Intra		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	0.02	0.00	0.00	0.24	0.00	0.00	0.23	0.00	0.00
Class B	0.09	-0.01	-0.01	0.62	0.00	0.00	0.62	0.00	0.00
Class C	0.02	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.00
Class D	0.02	0.01	0.01	0.05	0.00	0.00	0.05	0.00	0.00
Class E	0.23	-0.05	-0.05	1.56	0.00	0.00	1.65	0.00	0.00
All	0.07	-0.01	-0.01	0.50	0.00	0.00	0.51	0.00	0.00
Enc Time[%]	101%			101%			100%		
Dec Time[%]	105%			103%			102%		

Random access coding results

	HE Random access			LC Random access			HE w/o ALF Random access		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	0.01	0.11	0.15	0.09	0.09	0.08	0.12	0.03	-0.05
Class B	0.02	-0.02	-0.09	0.18	0.07	0.08	0.22	0.07	0.03
Class C	0.02	-0.06	0.00	0.05	0.09	-0.05	0.06	0.09	0.12
Class D	-0.04	-0.03	0.03	0.01	-0.17	0.03	0.06	0.18	0.11
Class E									
All	0.00	-0.01	0.00	0.09	0.01	0.03	0.12	0.10	0.06
Enc Time[%]	100%			101%			100%		
Dec Time[%]	101%			102%			101%		

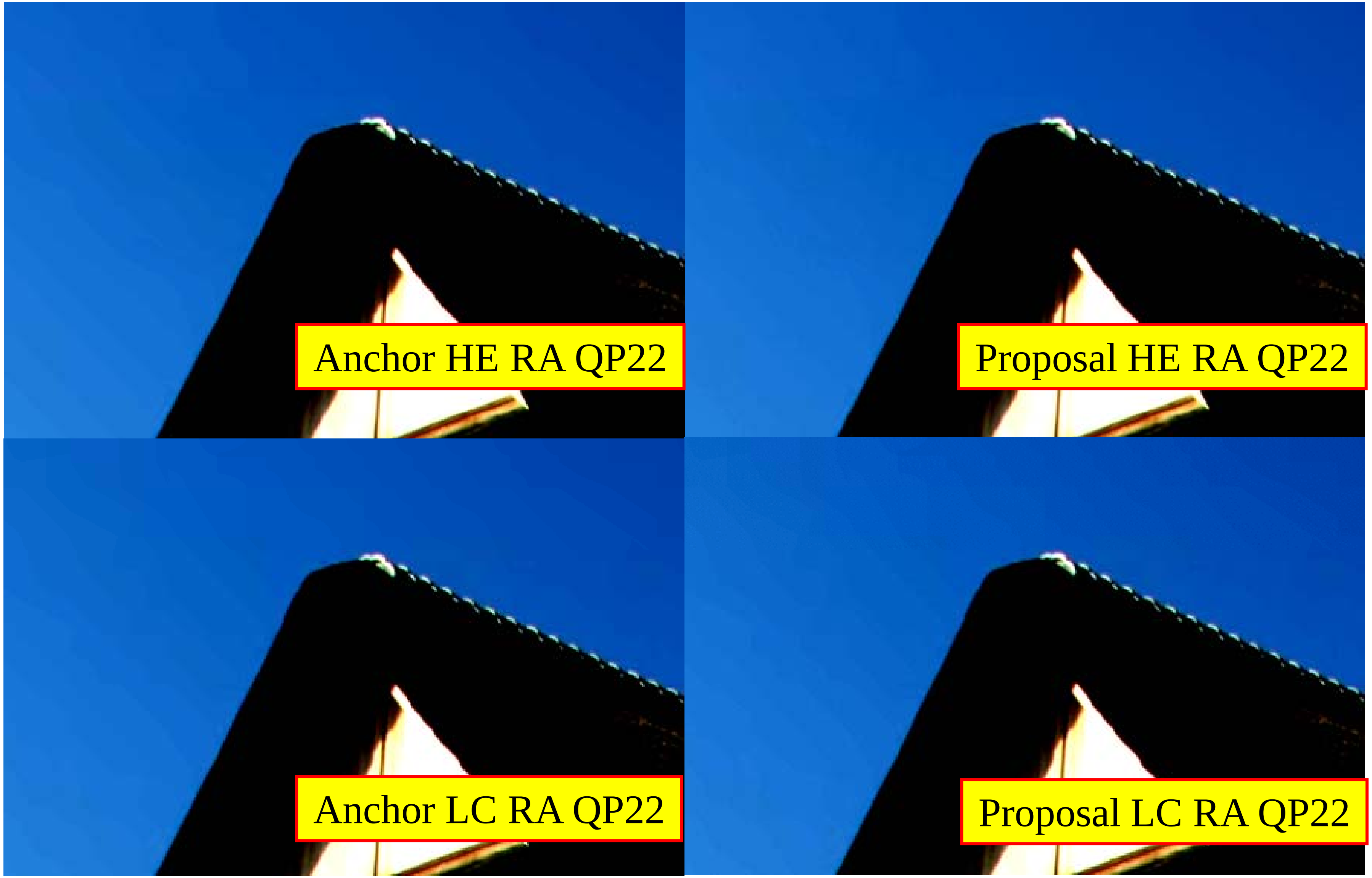
BD-rate and run-time results (Cont.)

Low delay coding results

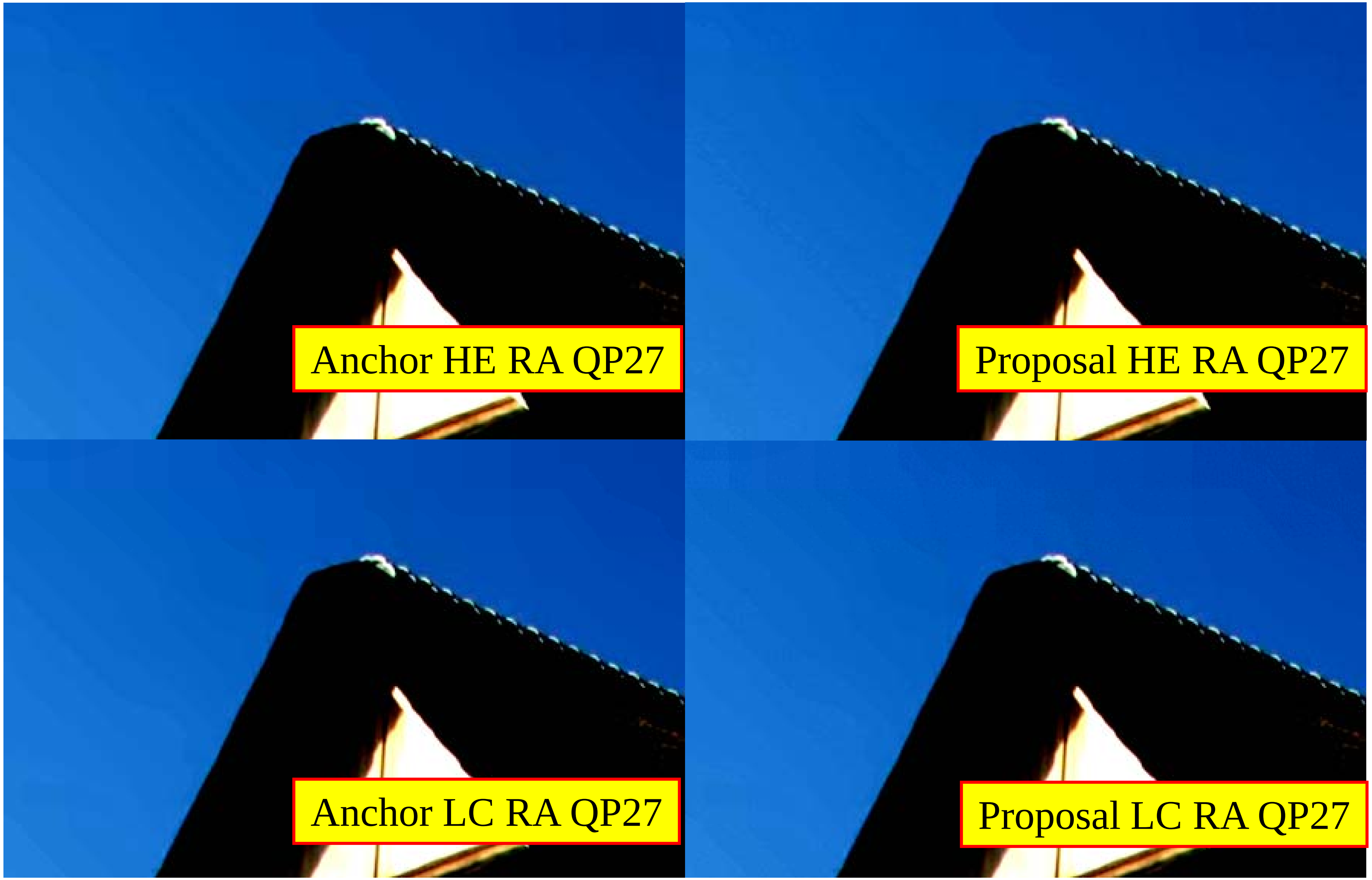
	HE Low delay			LC Low delay			HE w/o ALF Low delay		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A									
Class B	0.03	-0.01	0.11	0.04	-0.04	0.08	0.08	0.15	-0.17
Class C	0.07	-0.09	-0.13	0.06	-0.09	0.01	0.01	0.02	-0.12
Class D	0.07	-0.28	0.26	-0.04	0.15	-0.04	0.01	-0.05	-0.27
Class E	0.13	-0.24	0.18	0.32	0.39	-0.21	0.18	-0.14	0.34
All	0.07	-0.14	0.10	0.08	0.08	-0.02	0.06	0.01	-0.09
Enc Time[%]	100%			100%			100%		
Dec Time[%]	100%			101%			101%		

- Slight impacts on BD-rate in intra coding results of LC and HE w/o ALF cases
- Negligible impacts on BD-rate in other results
- Insignificant impacts on encode and decode times

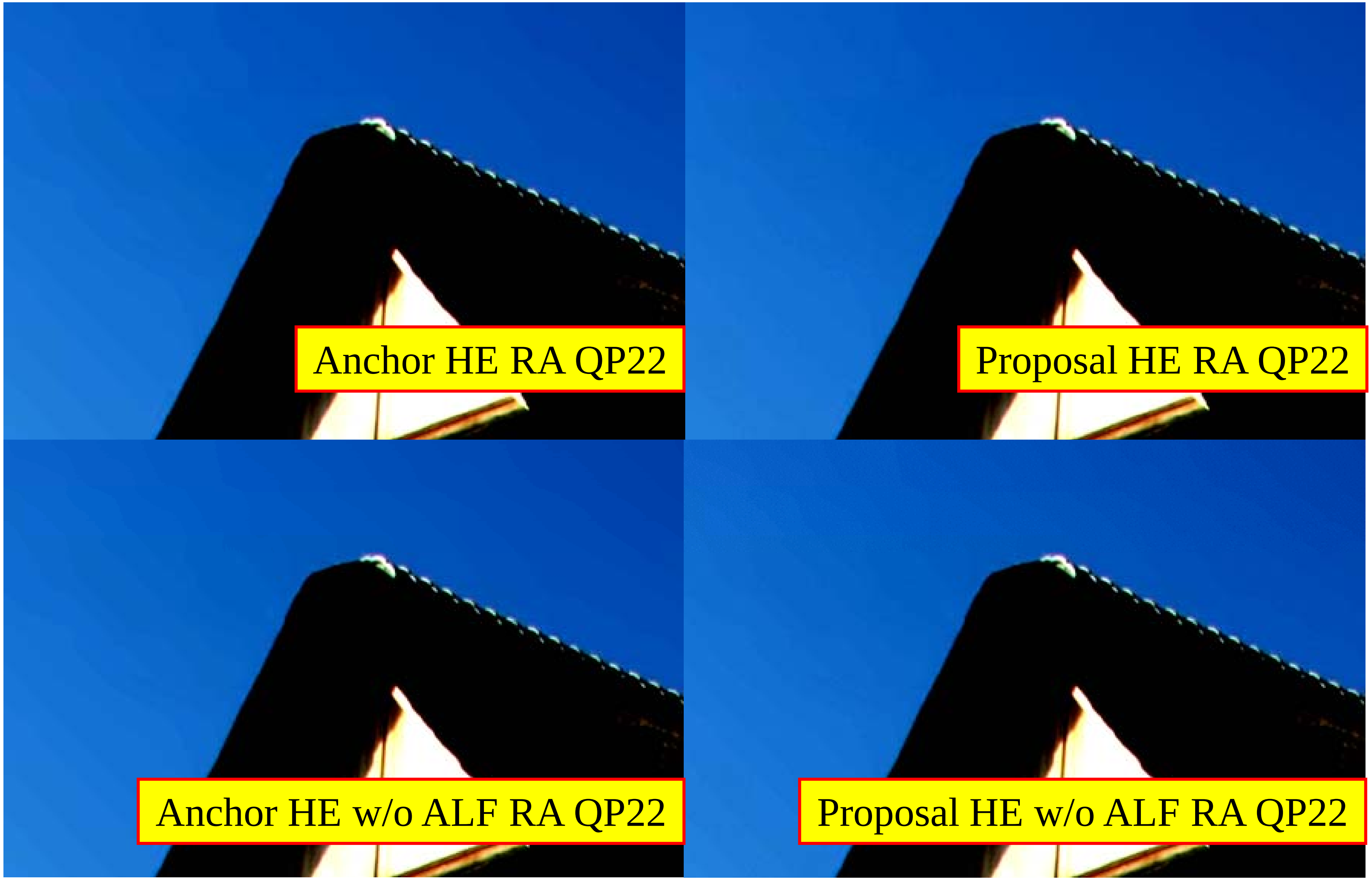
Compressed Kimono with QP=22 (Color enhanced)



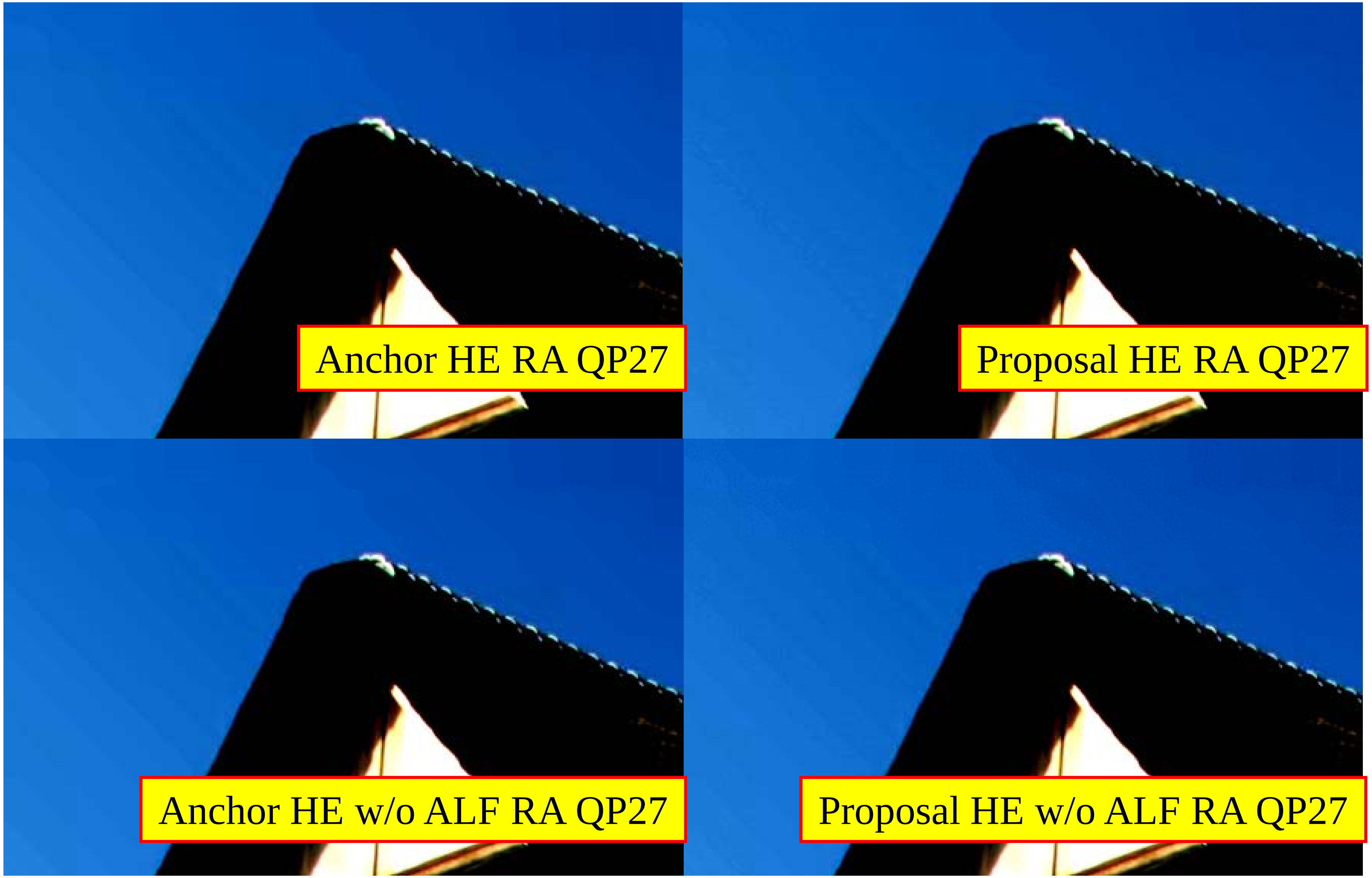
Compressed Kimono with QP=27 (Color enhanced)



Compressed Kimono with QP=22 (Color enhanced)



Compressed Kimono with QP=27 (Color enhanced)



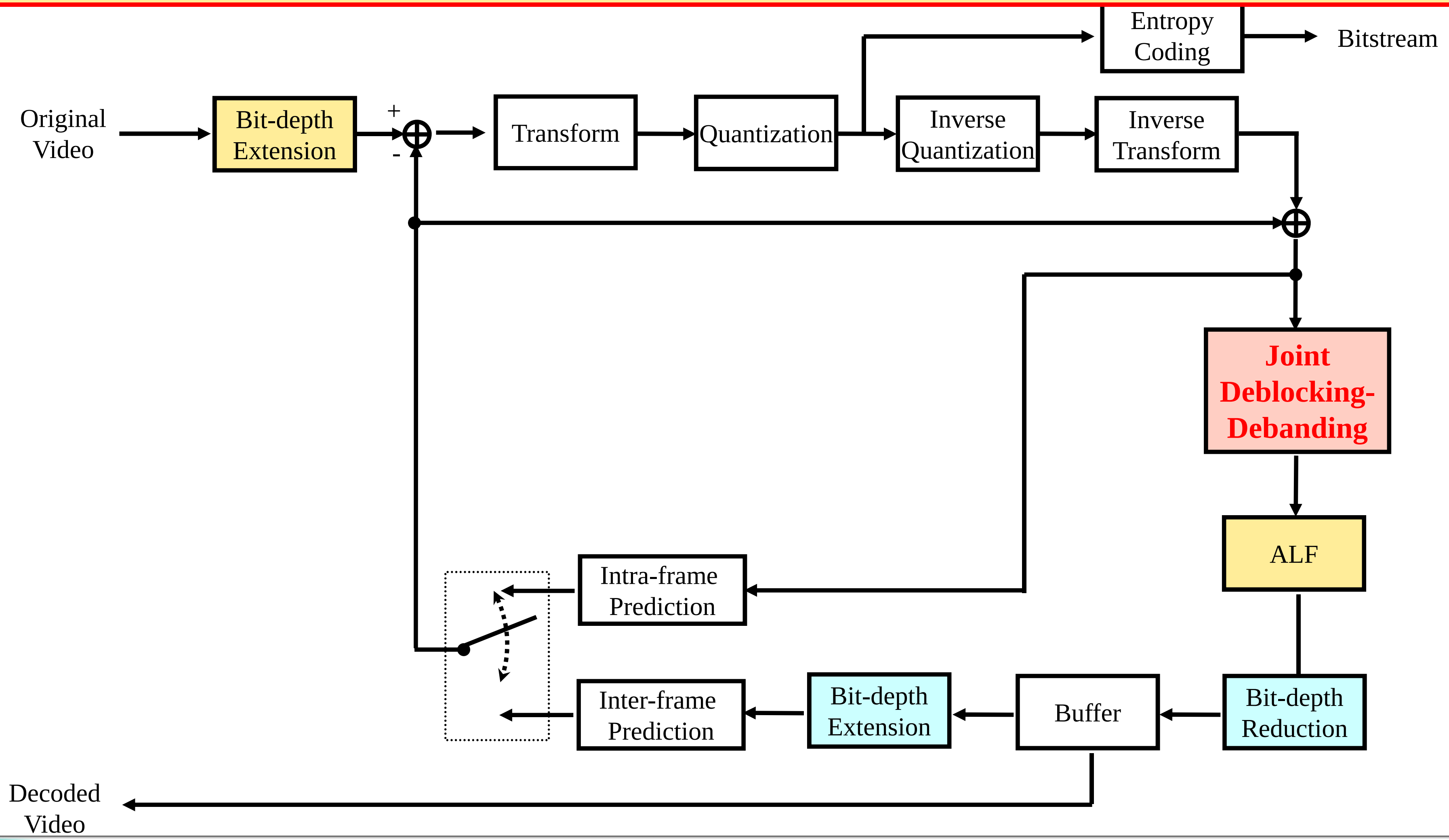
Visual quality improvements

- Banding-noise reduction is observed in low QP Intra and Random access results of Kimono
  - No banding-noise in HE results
  - No banding-noise in HE w/o ALF results
  - Moderate banding-noise in LC results

The major benefit of Proposal is in reducing banding-noise associated with fixed rounding in IBDI encoding.

IBDI encoding using in-loop fixed rounding

Proposal can be further studied as a visual quality enhancement tool in HEVC codec when it uses in-loop fixed rounding



Conclusions

- Banding-noise in video coding
- Debanding by pseudo-noise based in-loop processing
  - Several advantages over post filtering
- Simulation results
  - Significant banding-noise reduction with a negligible impact on coding performance
- Recommend studying conditional joint deblocking-debanding filter as a visual quality enhancement tool in HEVC codec when it uses in-loop fixed rounding for reducing picture memory storage

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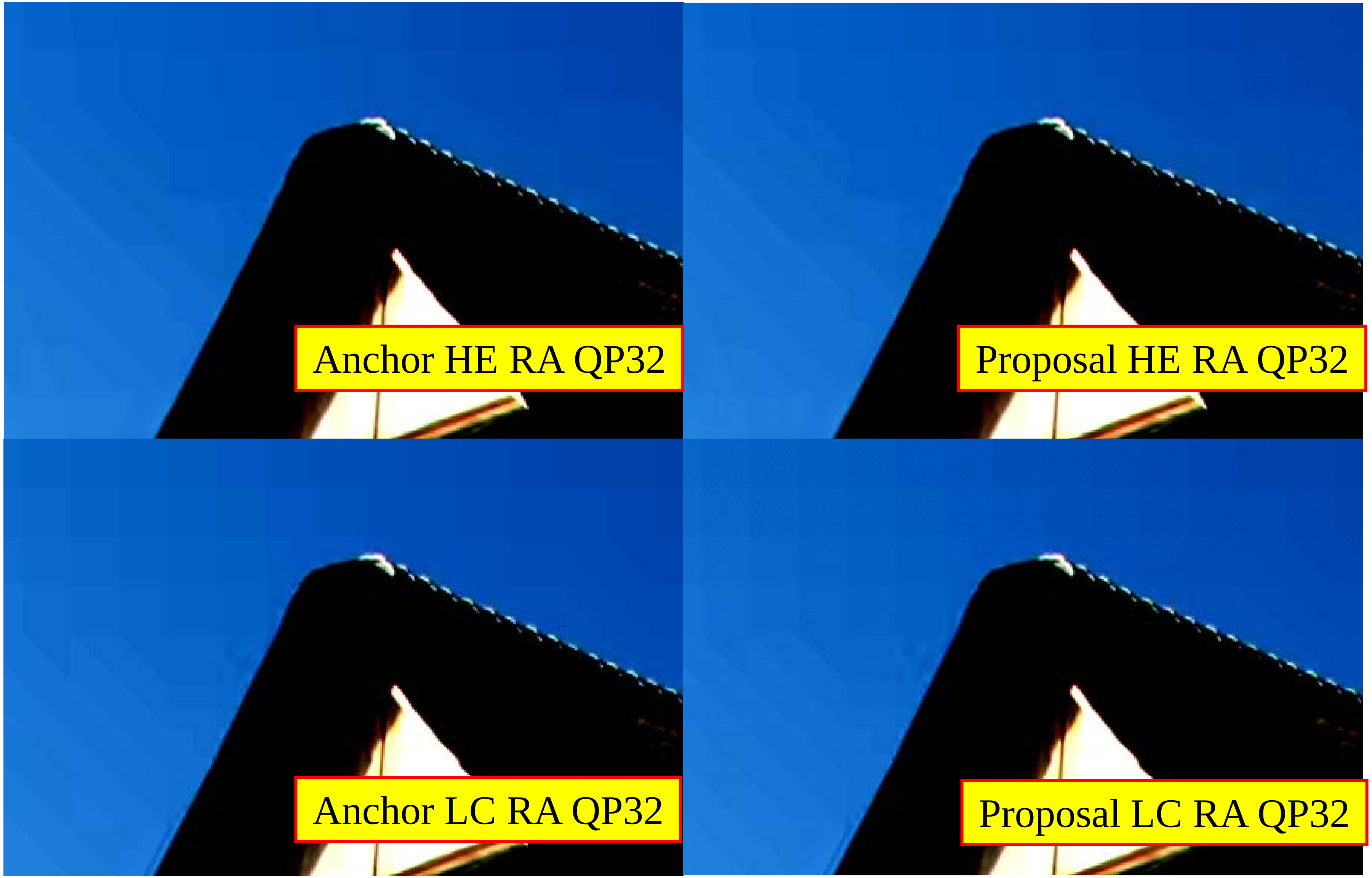
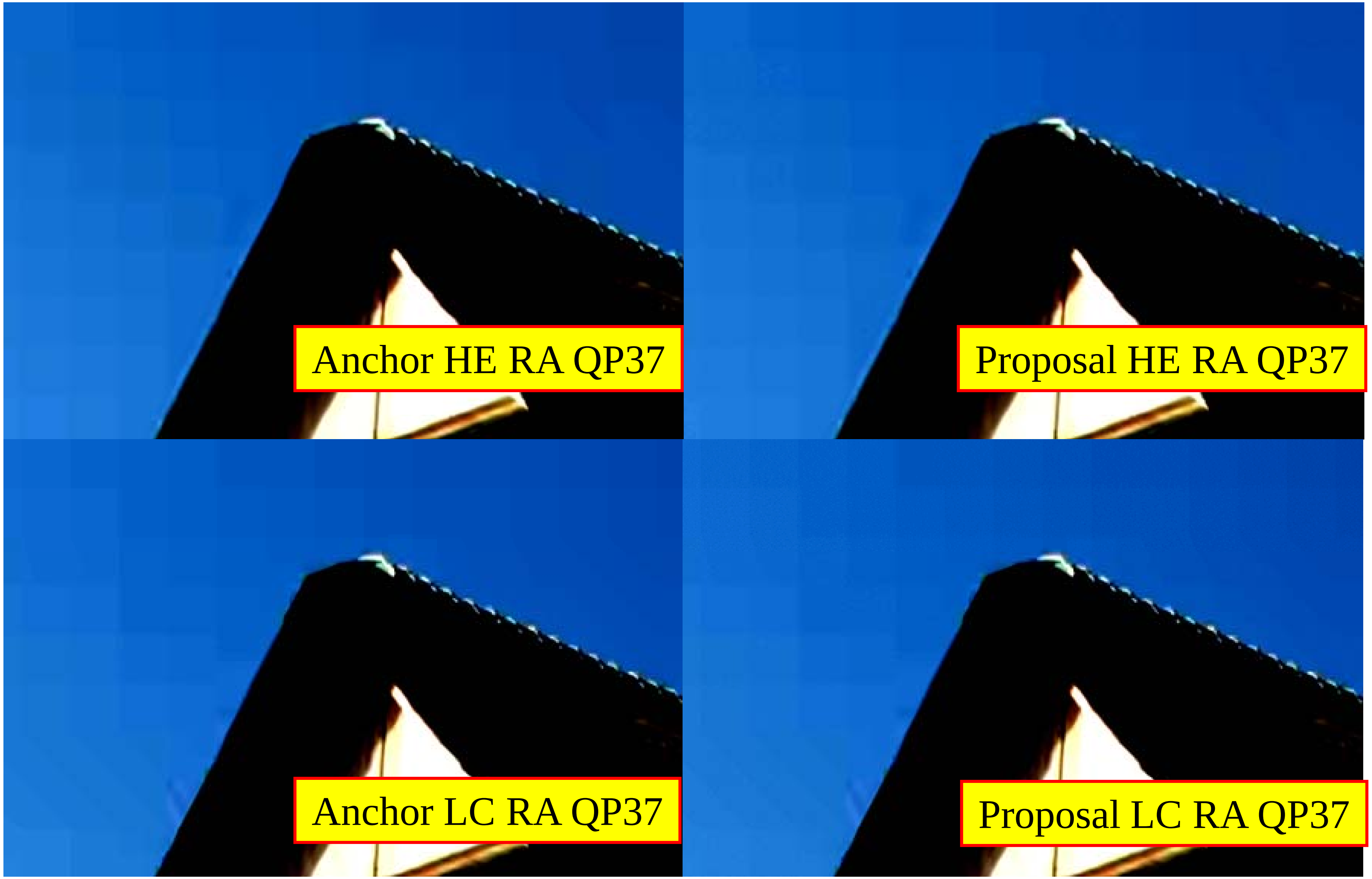
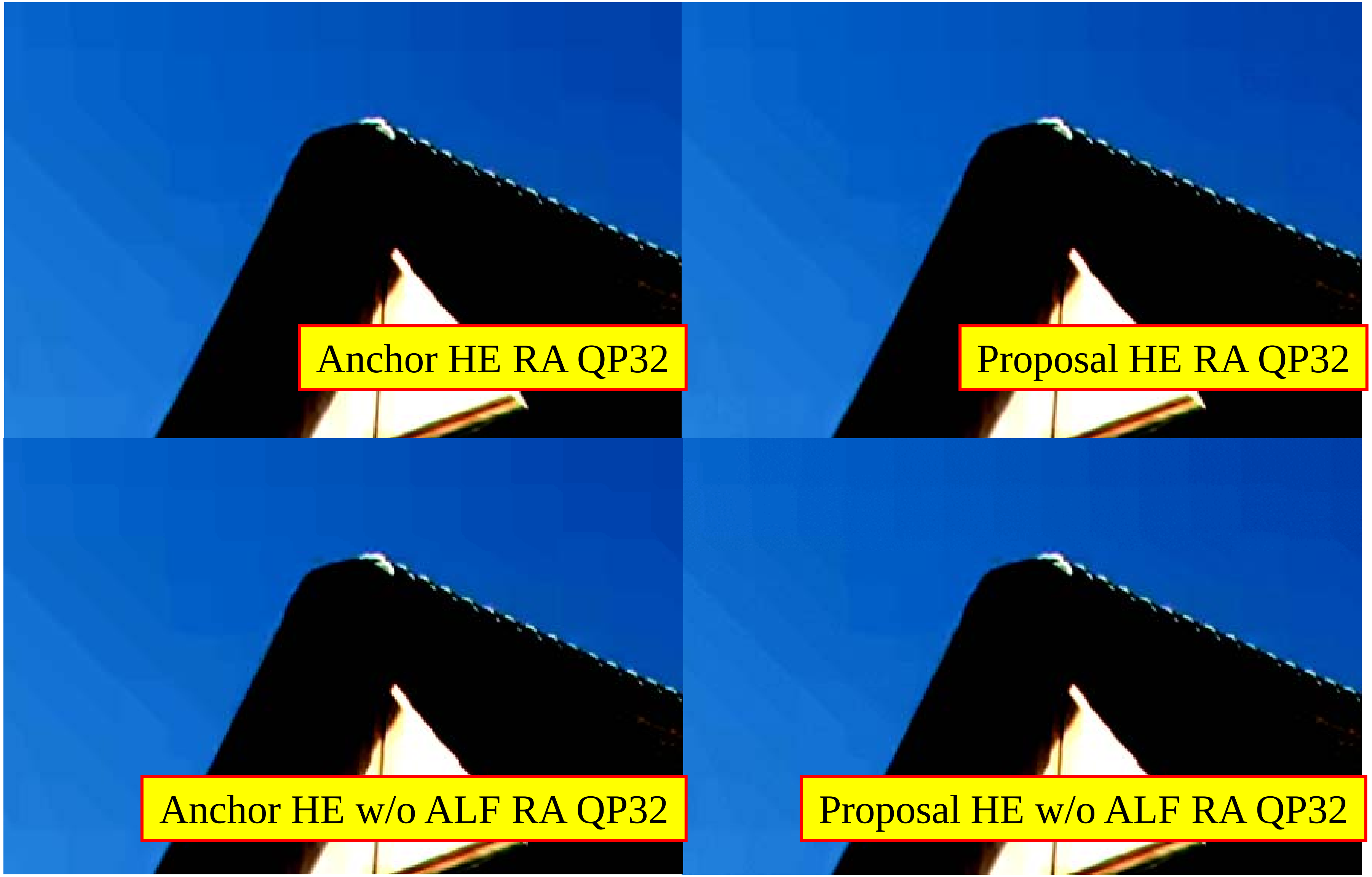
Compressed Kimono with QP=32 (Color enhanced)



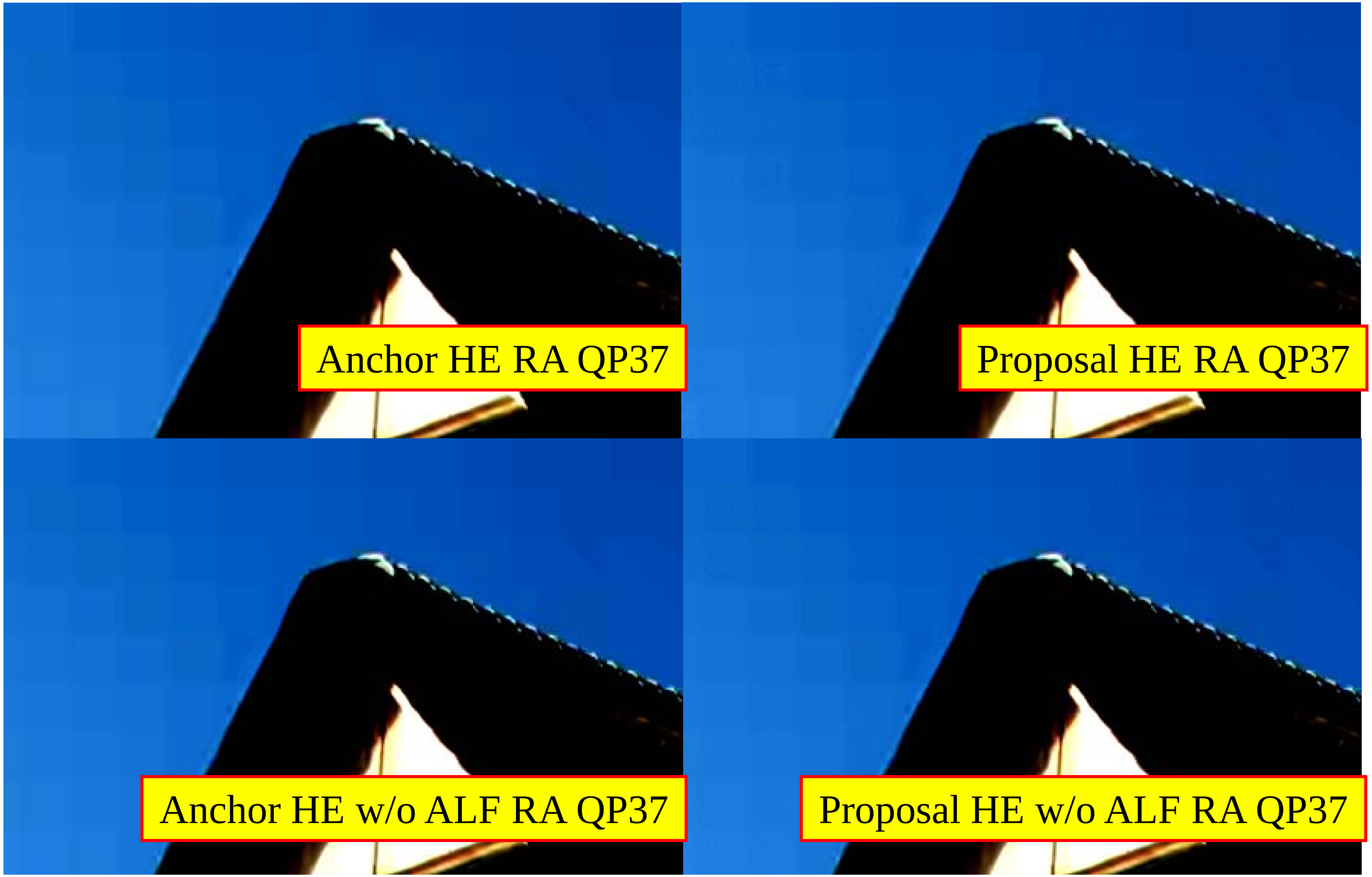
Compressed Kimono with QP=37 (Color enhanced)



Compressed Kimono with QP=32 (Color enhanced)

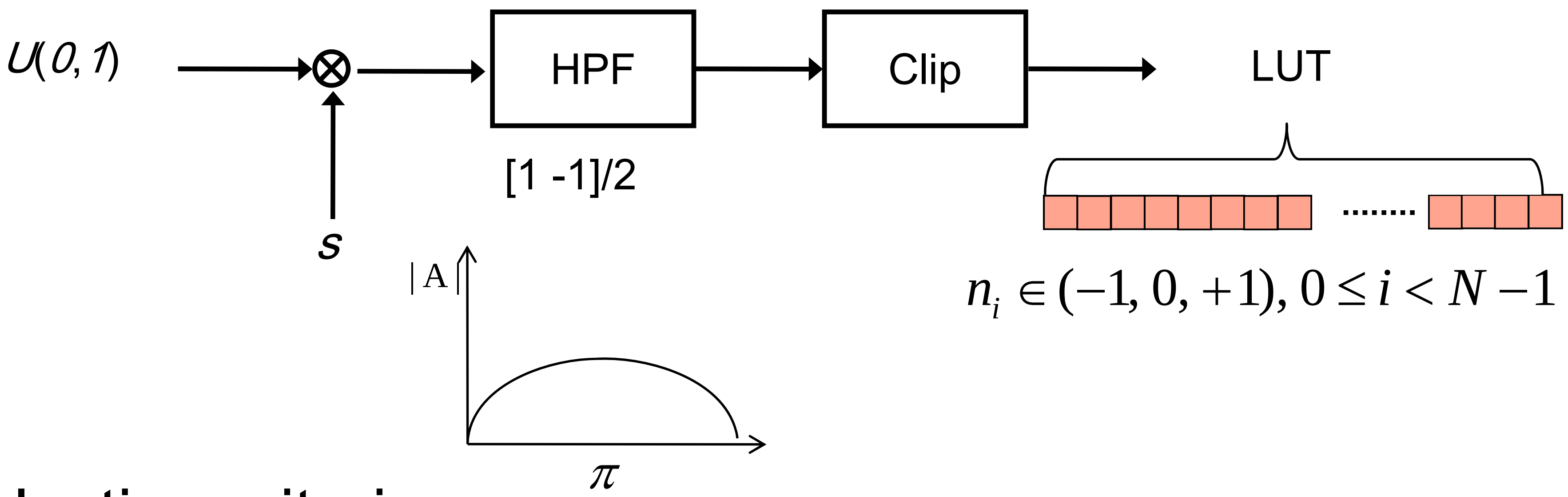


Compressed Kimono with QP=37 (Color enhanced)



Pseudo-noise in LUT

Procedure



$$n_i \in (-1, 0, +1), 0 \le i < N - 1$$

Selection criteria

$$N = 4096$$

$$P(+1) = 0.125$$

$$P(-1) = 0.125$$

$$P(0) = 0.75$$

The LUT size is about 1KB.
(= 2 * 4096 / 8)
The maximum MSE increase is 0.5.
(= 0.25 * 1 * 2)

Conditional joint deblocking-debanding filter

(Step1) Load pseudo-noise from LUT

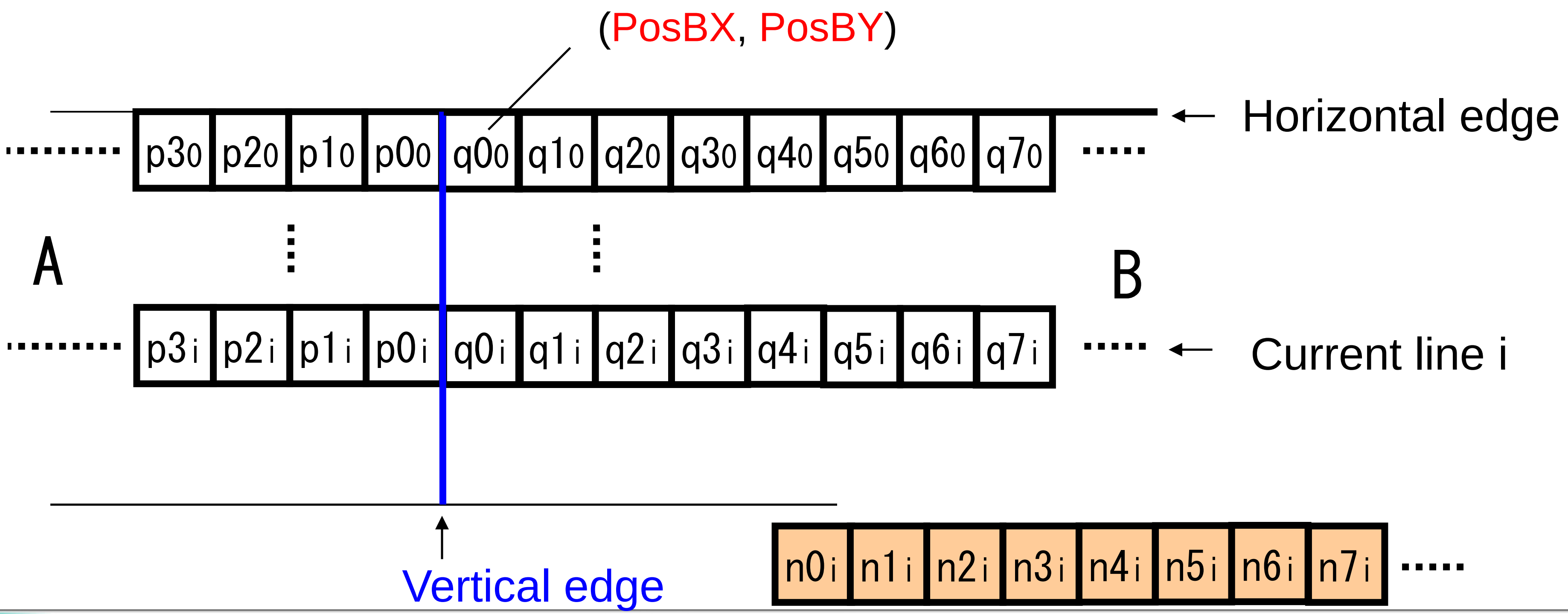
(Step2) Apply strong filtering

(Step3) Conditionally inject pseudo-noise

(Step1) Load pseudo-noise from LUT

- Pseudo-noise is associated with its pixel position.

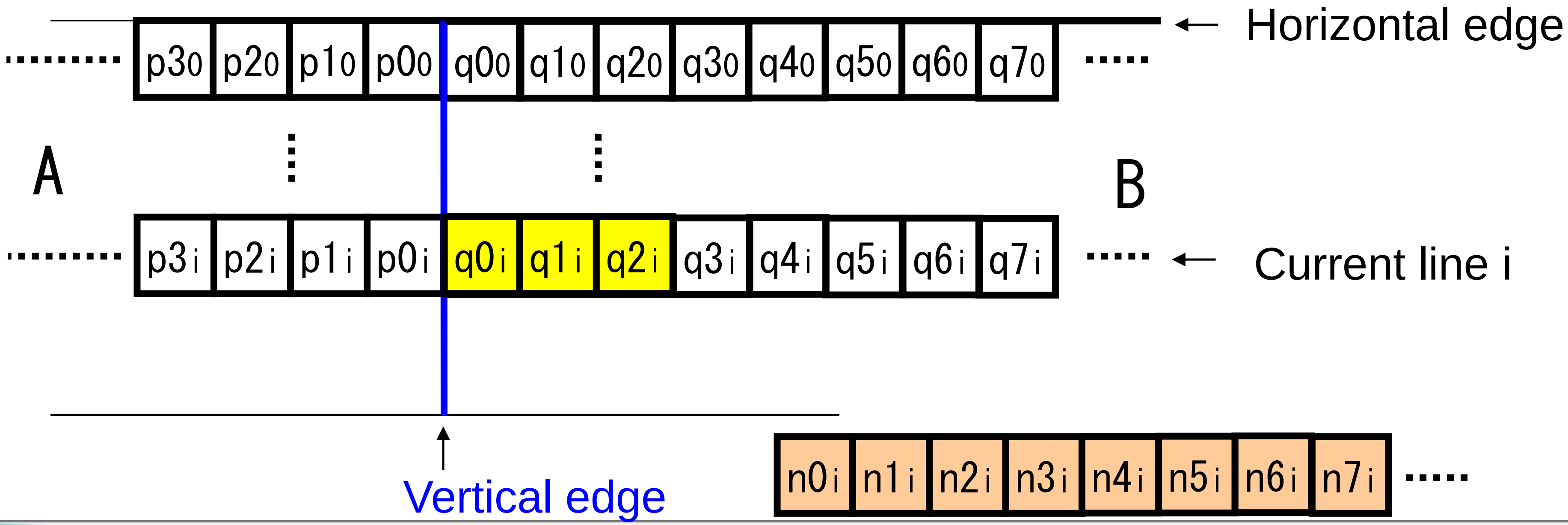
nj_i =LUT [(idxOffset + (i<<4) + j) & 4095];
idxOffset = ((PosBY + (PosBX<<4)) & 4095);



(Step2) Strong filtering

- Boundary three pixels are filtered by conventional filter as in TMuC

q0i=(p1i + 2*p0i + 2*q0i + 2*q1i + q2i + 4)>>3;
q1i=(p0i + q0i + q1i + q2i +2)>>2;
q2i=(p0i + q0i + q1i + 3*q2i + 2*q3i + 4)>>3;



(Step3) Conditional pseudo-noise injection

- Add pseudo-noise if the area is supposed to be very smooth.

If all of the following conditions are true,

- q_0 is an intra block with TUsizeB >= 16x16
- $| p_1 - q_0 | <= 1$
- $| q_0 - q_3 | <= 1$

the pseudo-noise is added as

$qj_i = \mathrm{Clip}_{0\text{-}255}(qj_i + nj_i);$ for j=0, … max(3, TUWidthB-9)