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Title: Additional Simulation Results for EZW-structured DCT Coding
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Purpose: Proposal

ABSTRACT

This document presents the additional simulation results and the several features for the EZW-Structured DCT (WS-DCT; Wavelet Structured-DCT) coding of Q-15-22.doc[4]. Coding performance is compared with the results of various option modes in H.263+. In addition, a modified WS-DCT coding method, which adds the preprocessing of the restructured DCT coefficients, is presented to improve the zerotree coding efficiency of the motion compensated residual.

1. INTRODUCTION

In ITU-T Seoul meeting, we have presented an efficient DCT-based embedded video coder using wavelet structure of DCT. Especially, it is designed for I (intra)-frame and motion compensated residual (e.g. DFD) coding. Briefly summarizing, the proposed coder rearranges the DCT transformed image into 2-level wavelet pyramid structure and makes use of embedded zerotree coding. The proposed rearranged structure is well coupled with an EZW-style coding. The resulting design was presented as offering enhancements in coding efficiency, rate control precision, scalability, and error robustness. Significant gains in coding performance were reported in both INTRA and INTER coding performance.

This document does not describe the detailed WS-DCT coding algorithm. For further details of the WS-DCT coding, please refer Q-15-22.doc[4].

2. REVIEW OF THE WS-DCT CODER AND MODIFICATIONS

The overall structure of the modified WS-DCT coder is shown in Figure1. To improve the zerotree coding efficiency of DFD, (band-adaptive or band-fixed) preprocessing of the restructured DCT coefficients can be made by using the scale factor. This method is to design a scale factor based on the actual statistics of the each band. This process results in finer quantizing to lower band and coarser quantizing to higher subband by reducing the total magnitude of higher subband by scale factor. The number of scale factor equals to the number of 2-level wavelet pyramid-like subband (e.g. 7). This method is flexible in that it works with any wavelet subband-based decomposition. In current works, we identified the improvements of rate-distortion performance and visual quality in very low bit rate (e.g. QP=15, 25). But this process needs more experiments for optimizing the performance.

In DCT, traditionally the blocks used are 8 x 8 in size. But any block size of power of two (e.g. 16 x 16, 32 x 32, 64 x 64). In 8 x 8 block DCT, the DC and three AC coefficients make up the lowest frequency subband. Other coefficients respectively assembled into vertical, horizontal, and diagonal subbands. The number of level, NL, is

$$NL = \log_2 N - 1$$

related to the N x N block size by

(e.g. 8 x 8 -> 2-level, 16 x 16 -> 3-level, 32 x 32 -> 4-level, 64 x 64 -> 5-level)

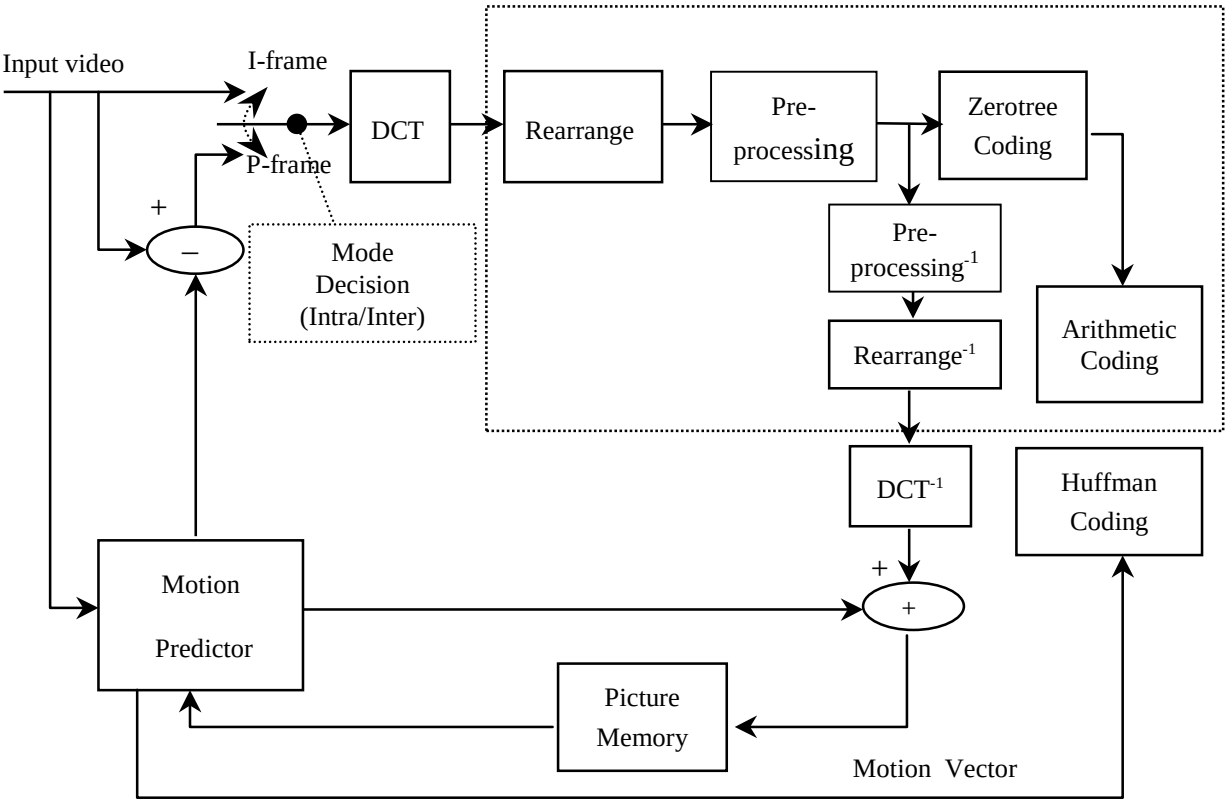

Figure 1. The modified WS-DCT coder

3. FEATURES OF THE WS-DCT SATISFYING THE REQUIREMENT OF H.26L

The proposed algorithm is based on DCT, which has been used in most still image and video coding standards. By rearrangement of DCT coefficients, selection of the appropriate embedded zerotree coding, and the use of an adaptive arithmetic coding, an embedded DCT-based (WS-DCT) video coder is achieved. The following is the features of the WS-DCT satisfying the requirements of H.26L.

Briefly, The WS-DCT coder has:

Enhanced Coding Performance: The algorithm offers the performance superior to the current standard (H.263+) with various option mode at various bit rate. The results will be showed in following section.

Fully Embedded Bitstream : Produces a completely embedded bitstream, therefore supporting SNR scalability. The decoder can cut the bitstream at any point and reconstruct an image that would be the same as if the encoder had coded the image at that bitrate)

Adaptable Rate Control: Notice that the proposed embedded video coder does not require any rate control mechanism, since rate control is inherent to the algorithm. Furthermore, since our coder can achieve precise bitrate without any iterative procedures or trial-and-error experiments, we can easily adjust coding bit rates according to algorithm and application. Therefore, it is suitable for applications that require a single compression algorithm to operate at varying bit rates or with different degrees of image quality.

Scalable functionality: The algorithm is inherently scalable. In practice, SNR scalability is achieved without introducing any more complexity in the algorithm. The proposed algorithm provides for the efficient delivery of image data in many applications such as WWW applications.

Blocking Artifacts: Due to the block based DCT structure of the algorithm, the well known blocking artifacts appear at high compression ratios. However, it has been shown that those artifacts can be reduced by the use of simple post-filtering. Although post-filtering increases the complexity of the decoder, the use of simple post-filters can result in a significant improvement of the visual quality of the image. Furthermore, The proposed WS-DCT algorithm reflects more mid and high frequencies, any deblocking filter can be applied effectively.

4. SIMULATION RESULTS

Coding performance is compared with the results of various option modes in H.263+ TMN-3.0 codec provided by UBC[3] about three representative sequence Hall Objects, News, Foreman. The H.263+ coders were run with QP_{intra} =10 and QP_{inter} having 4 to 25 for all frames. Frame rates is 10Hz. WS-DCT baseline represents the WS-DCT coder by using block-matching estimation for 16x16 block of pels. WS-DCT DF is WS-DCT coder by using Unrestricted Motion Vector Mode(ANNEX D) and Advanced Prediction Mode(ANNEX F) of H.263+. Referring Figure 5, Figure 6 and Figure 7, it can be realized immediately that WS-DCT DF is better than the WS-DCT baseline using the conventional block motion estimation. DFD coding will have to sacrifice much of their coding efficiency by coding the artificial high frequency information at the block boundaries of motion compensated P-frames. As a result, the better motion estimation and compensation is, the better our proposed texture coding method is. Table 1 and Figure 2, 3, 4 shows the comparison of WS-DCT baseline with H.263+ with ANNEX I or ANNEX J. Table 2 shows the comparison of WS-DCT baseline with H.263+ with ANNEX I at same bit rate. As you know, since our coder is embedded coder, we can easily adjust the coding bit rates to be the same as that of H263+ for each frame. In most of the plots, the proposed coder shows a consistent PSNR gain over H.263+ baseline and H.263+ with ANNEX I for the majority of bit rate. In case of ANNEX J deblocking filter mode, WS-DCT coder don't use the deblocking filter. But rate distortion performance show the improved results.

Table 3. shows the improved coding performances of WS-DCT coder than those of WS-DCT coder previously proposed in Seoul meeting. We make a parameter tuning of INTRA/INTER MODE Decision, approximation value, and etc. Especially, in case of Hall and News sequence, the performance is improved at very low bit rate than previous coder.

Table 4, Figure 5, Figure 6, Figure 7 shows the comparison of WS-DCT DF with H.263+ with ANNEX DFIT and ANNEX DFJIT. Average PSNR calculated over the entire coded sequences shows that our new coder achieves the promising performance to the H.263+. It can be seen that the proposed coder has a comparable average PSNR than H.263+ in nearly all the cases.

The reconstructed sequences are not given in this document. It can be seen by D1 device in ITU-T Monterey Meeting. Our coding strategy allows residual bits to be concentrated in the areas where motion compensation fails, as are the complex and fast regions or scene change. The proposed coder provides the reconstructed image with the reduced blocking artifacts. We will demonstrate that the proposed coder outperforms the H.263+ standard in visual quality.

5. CONCLUSION AND FUTHER STUDIES

A WS-DCT coding for INTRA and INTER was proposed to satisfy the requirements for H.26L.

Summarizing, the properties of the proposed WS-DCT algorithm are:

- Provides the enhanced coding performance.
- It is an embedded video coder and inherently scalable.
- Can operate precisely at any target bit rate according to algorithm or applications.
- It allows for backward compatibility with the current H.263 without significant modifications.

The following issues are currently identified as important for future research:

- Avoid the coding of the resulting bits after embedded zerotree coding by adaptive arithmetic coder. This will not affect the results significantly, but give a speed improvement. Investigate the possibility of using Huffman coding instead of arithmetic coding.
- Check if the use of larger block sizes gives significant improvement such as 16x16, 32x32, 64x64 DCT.
- Study better de-blocking filters suitable for proposed WS-DCT algorithm.
- More band adaptive preprocessing for improving the coding performance of DFD coding.
- Core experiments for combination with other motion estimation and compensation.

Seq.	QP	WS-DCT Baseline		H.263+ with ANNEX I		H.263+ with ANNEX .	
		Rate	Y PSNR	Rate	Y PSNR	Rate	Y PSNR
Hall QCIF	25	9.08	30.90	8.82	30.49	9.15	30.22
	15	14.75	32.50	14.57	32.29	14.30	31.81
	10	22.83	33.99	22.48	33.60	21.96	33.15
	7	37.43	36.18	36.81	35.21	35.97	35.04
	5	57.61	37.72	57.33	37.53	55.23	37.31
	4	70.73	39.34	70.47	38.84	67.34	38.66
News QCIF	25	13.38	28.93	13.28	28.87	13.93	28.63
	15	23.36	30.46	23.42	30.89	23.16	30.65
	10	37.63	32.56	37.54	32.59	36.70	32.35
	7	59.34	35.03	58.94	34.45	57.32	34.42
	5	87.33	36.93	87.06	36.73	84.26	36.77
	4	108.84	39.12	107.79	37.93	103.78	37.93
Foreman QCIF	25	28.56	27.56	29.46	27.59	30.40	27.63
	15	48.57	29.70	49.75	30.02	48.70	30.03
	10	76.97	32.11	78.63	32.09	74.54	32.13
	7	120.68	34.70	121.57	34.32	114.04	34.39
	5	178.47	36.92	179.23	36.49	168.17	36.53
	4	222.77	38.61	224.11	37.58	209.03	37.59

Table 1 Comparison of WS-DCT baseline with H.263+ with ANNEX I, J

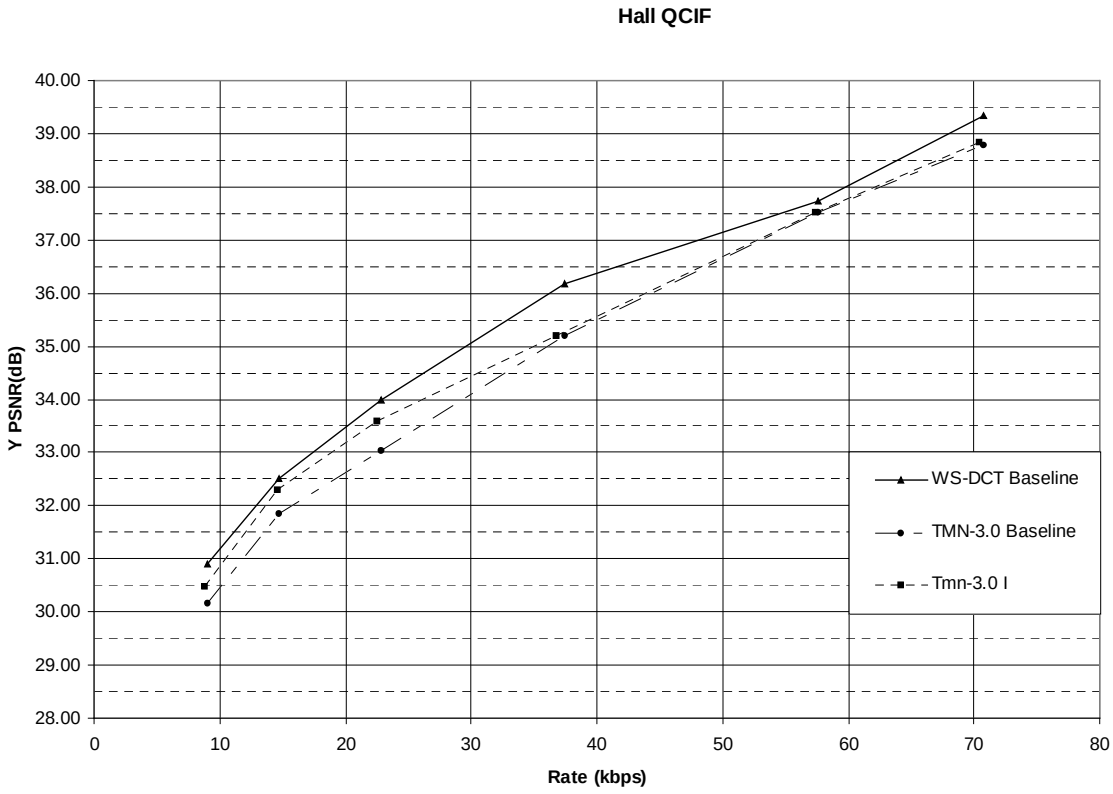

Figure 2. R-D performance among the WS-DCT baseline, H.263 baseline, and H.263+ with ANNEX I

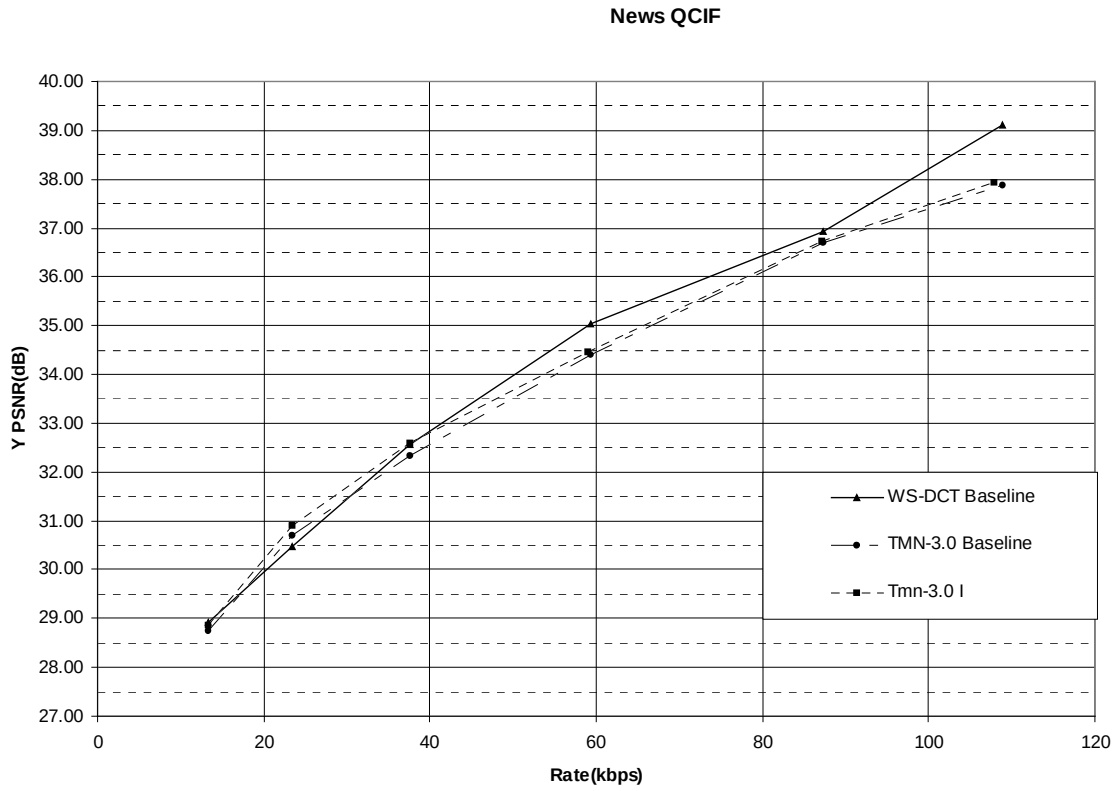

Figure 3. R-D performance among the WS-DCT baseline, H.263 baseline, and H.263+ with ANNEX I

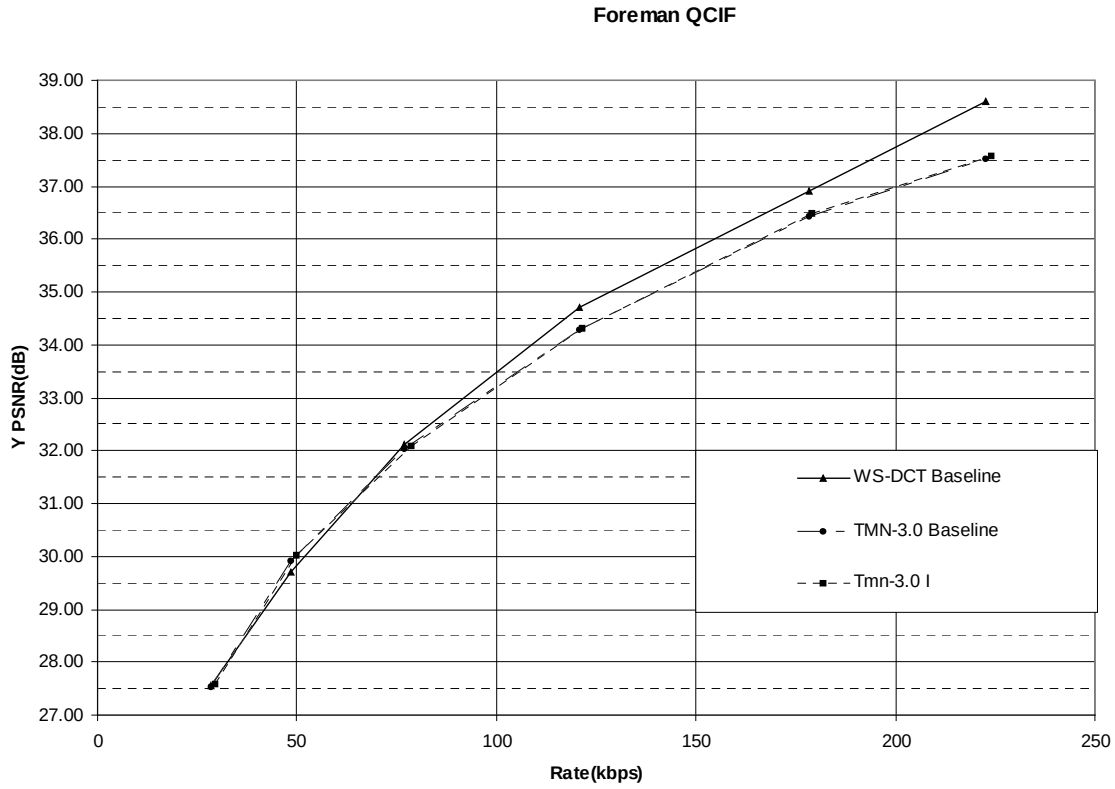

Figure 4. R-D performance among the WS-DCT baseline, H.263 baseline, and H.263+ with ANNEX I

Rate	QP	ANNEX I	WS-DCT_Mon
70.47	4	38.84	39.19
57.33	5	37.53	37.20
36.81	7	35.21	35.76
22.48	10	33.60	33.68
14.57	15	32.29	32.21
8.82	25	30.49	30.68

Hall Object

Rate	QP	ANNEX I	WS-DCT_Mon
107.79	4	37.93	38.88
87.06	5	36.73	36.65
58.94	7	34.45	34.86
37.54	10	32.59	32.53
23.42	15	30.89	30.48
13.28	25	28.87	28.93

News

Rate	QP	ANNEX I	WS-DCT_Mon
224.11	4	37.58	38.65
179.23	5	36.49	36.93
121.57	7	34.32	34.76
78.63	10	32.09	32.21
49.75	15	30.02	29.80
29.46	25	27.59	27.58

Foreman

Table 2. Comparison of WS-DCT baseline with H.263+ with ANNEX I at same bit rate

Rate	QP	baseline	WS-DCT_Seoul	WS-DCT_Mon
70.73	4	38.79	39.68	39.34
57.61	5	37.52	37.66	37.72
37.43	7	35.19	36.07	36.18
22.83	10	33.04	33.80	33.99
14.75	15	31.84	32.10	32.50
9.08	25	30.17	30.05	30.90

Hall Objects

Rate	QP	baseline	WS-DCT_Seoul	WS-DCT_Mon
108.84	4	37.88	39.05	39.12
87.33	5	36.69	36.86	36.93
59.34	7	34.39	34.84	35.03
37.63	10	32.34	32.51	32.56
23.36	15	30.70	30.34	30.46
13.38	25	28.74	28.52	28.93

News

Rate	QP	baseline	WS-DCT_Seoul	WS-DCT_Mon
222.77	4	37.52	38.08	38.61
178.47	5	36.44	36.89	36.92
120.68	7	34.28	34.69	34.7
76.97	10	32.02	32.08	32.11
48.57	15	29.92	29.68	29.70
28.56	25	27.54	27.47	27.56

Foreman

Table 3. Improved coding performance of WS-DCT coder

WS-DCT DF		H.263+ with ANNEX DFIT		H.263+ with ANNEX DFJIT	
Rate	Y PSNR	Rate	Y PSNR	Rate	Y PSNR
9.09	30.98	9.01	30.47	9.06	30.33
14.23	32.37	14.31	32.31	14.33	32.1
21.75	33.96	21.65	33.58	21.75	33.49
35.61	36.15	35.2	35.23	35.71	35.12
55.03	37.65	54.6	37.55	54.74	37.24
68.40	39.58	67.82	38.85	67.12	38.61
13.85	29.04	14.54	28.91	14.90	28.56
23.15	30.51	23.78	30.95	24.10	30.69
36.51	32.54	36.94	32.61	37.18	32.42
57.25	34.89	57.74	34.45	58.20	34.39
84.33	36.77	84.41	36.73	84.51	36.67
104.98	38.9	104.73	37.90	104.51	37.84
27.79	27.79	27.02	27.77	28.23	27.64
43.32	29.83	43.02	30.14	44.98	30.07
65.76	32.08	66.07	32.18	68.23	32.15
101.71	34.58	104.12	34.38	104.58	34.37
152.07	36.7	151.58	36.5	152.3	36.52
192.49	38.35	190.96	37.57	191.29	37.59

Table 4. Comparison of WS-DCT DF with H.263+ with ANNEX DFIT and ANNEX DFJIT

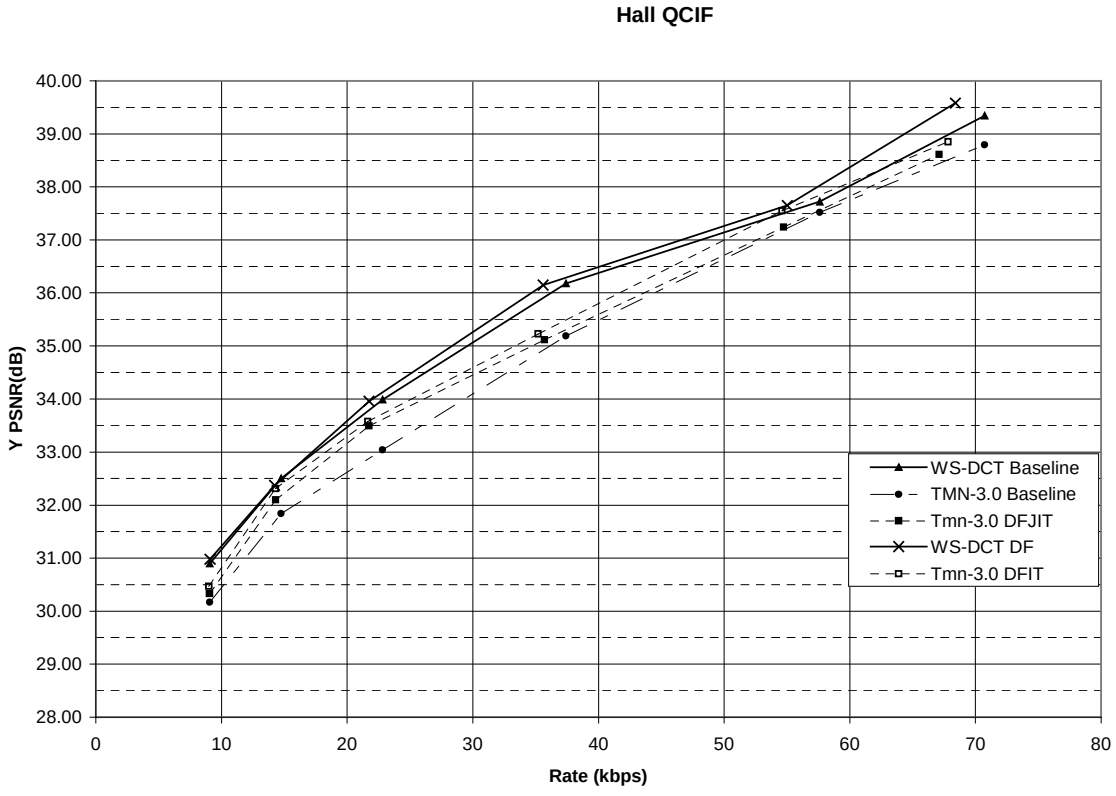

Figure 5. R-D performance among the WS-DCT baseline, WS-DCT DF, H.263 baseline, and H.263+ with ANNEX DFIT, DFJIT

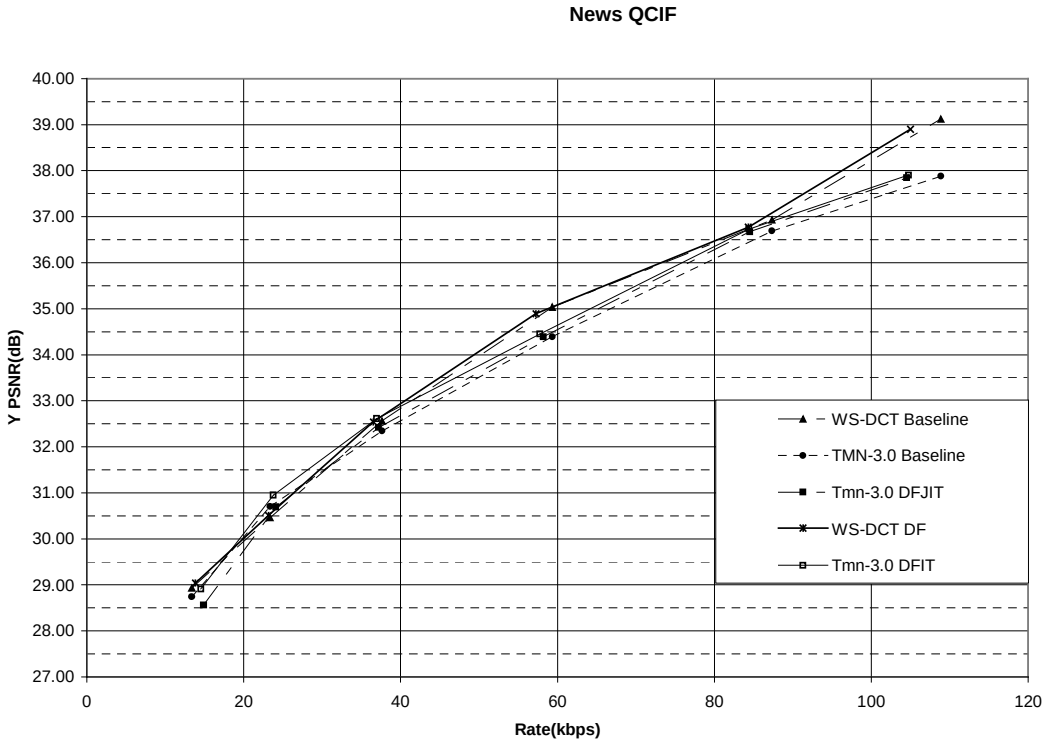

Figure 6. R-D performance among the WS-DCT baseline, WS-DCT DF, H.263 baseline, and H.263+ with ANNEX DFIT, DFJIT

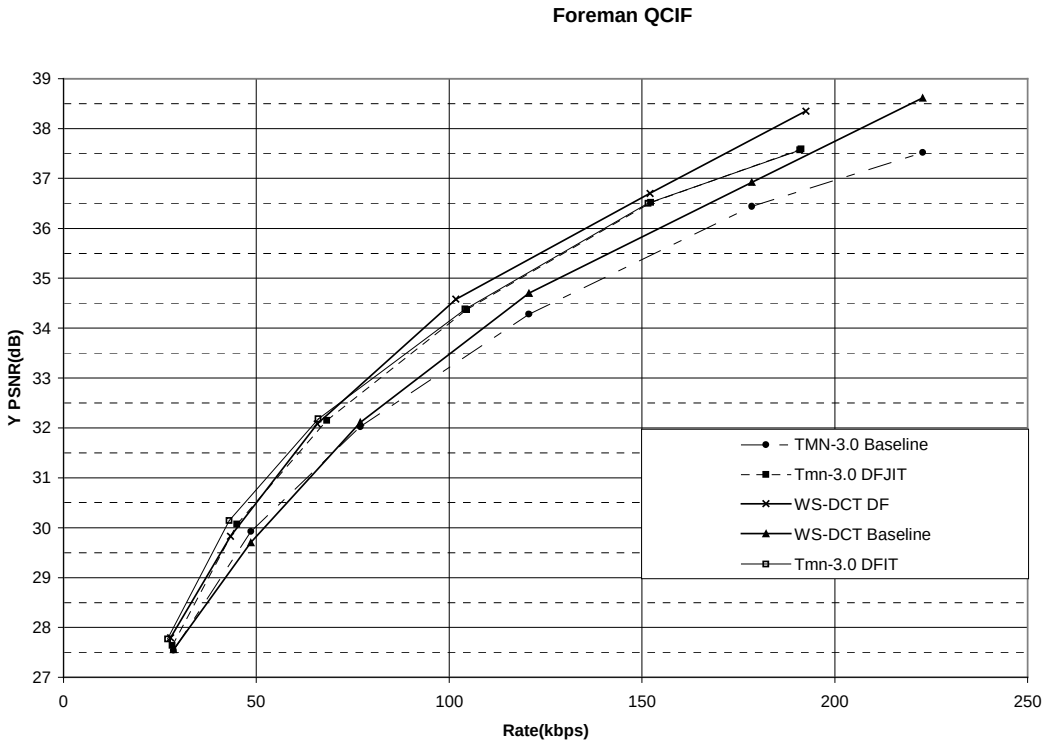

Figure 7. R-D performance among the WS-DCT baseline, WS-DCT DF, H.263 baseline, and H.263+ with ANNEX DFIT, DFJIT

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