CCITT SGXV
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Title : Precision for Inverse DCT Calculation and Refresh Cycle

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1. Introduction

In Doc.#255, it has been shown that mismatch error accumulates when there is accuracy difference in inverse DCT at the coder and decoder. Therefore, a countermeasure is needed if different algorithm and/or calculation accuracy are employed at coder and decoder in the inverse DCT(IDCT) specification. In this document, suggestion is made on how to decide a refresh cycle as a countermeasure.

2. Modeling of Mismatch Error Accumulation

Symbols are defined as follows. (See Fig.1)

$X(i)$: original signal in the ith frame
$\hat{X}(i)$: local decoded signal in the ith frame (coder)
$\tilde{X}(i)$: decoded signal in the ith frame (decoder)
$E1(i)$: DCT calculation error in the ith frame
$E2(i)$: IDCT calculation error in coder
$E3(i)$: IDCT calculation error in decoder
$Q(i)$: quantize error in the ith frame
$e1$: mean of $E1(i)^2$
$e2$: mean of $E2(i)^2$
$e3$: mean of $E3(i)^2$
$e4$: mean of $(E3(i)-E2(i))^2$
q : mean of $Q(i)^2$

The decoded signals in the coder and the decoder are shown as follows.

$$\begin{aligned}\hat{X}(i) &= (X(i)-\hat{X}(i-1)) + E1(i) + Q(i) + E2(i) + \hat{X}(i-1) \\ &= X(i) + E1(i) + Q(i) + E2(i) \qquad (2.1)\end{aligned}$$

$$\tilde{X}(i) = (X(i)-\hat{X}(i-1)) + E1(i) + Q(i) + E2(i) + \tilde{X}(i-1) \qquad (2.2)$$

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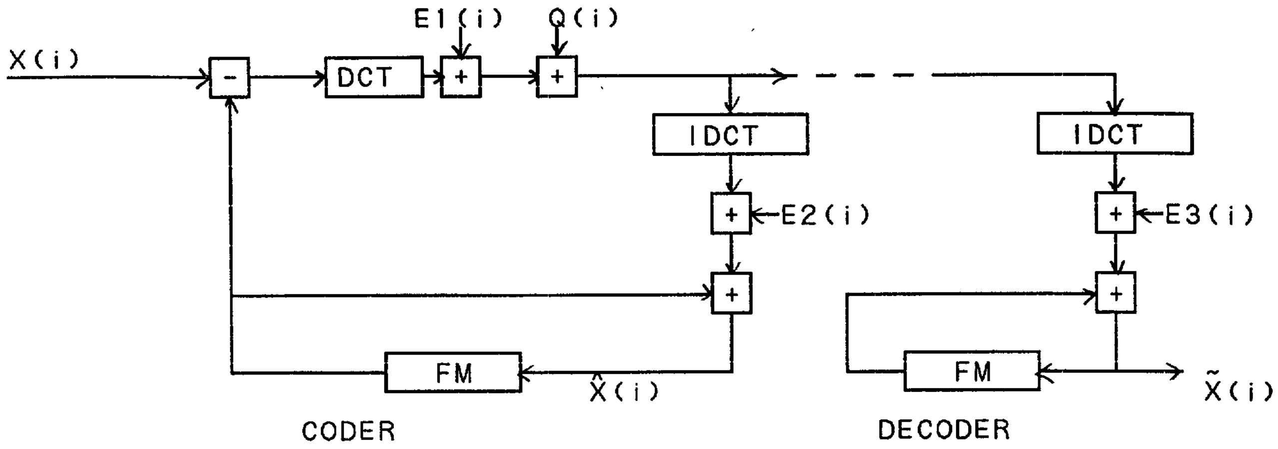

Fig.1 Model of the Calculation Error

Therefore, the error between these two decoded signals is given by

$$\tilde{X}(i) - \hat{X}(i) = \tilde{X}(i-1) - \hat{X}(i-1) + E3(i) - E2(i)$$
$$= \sum_{i} (E3(i) - E2(i)). \qquad (2.3)$$

The error between the original signal and the decoded signal is

$$\tilde{X}(i) - X(i) = E1(i) + Q(i) + E2(i) + \sum_{i} (E3(i) - E2(i)). \qquad (2.4)$$

If there are no correlation between E1(i), E2(i), E3(i) and Q(i), the mean square of these errors are

$$\overline{(\tilde{X}(i) - \hat{X}(i))^2} = (e2 + e3)*i \qquad (2.5)$$

$$\overline{(\tilde{X}(i) - X(i))^2} = e1 + q + e2(i-1) + e3*i$$
$$\fallingdotseq q + (e2 + e3)*i. \qquad (2.6)$$

In Eq.(2.6), $e1 \fallingdotseq e2$ is assumed. If there are some correlation between E2(i) and E3(i), the mean values given by Eq.(2.5) and (2.6) should be modified as follows.

$$\overline{(\tilde{X}(i) - \hat{X}(i))^2} = e4*i \qquad (2.7)$$
$$\overline{(\tilde{X}(i) - X(i))^2} = q + e4*i \qquad (2.8)$$

The equations (2.5) (2.6) or (2.7) (2.8) show that the mismatch error accumulates in the decoded picture.

3. Refresh Cycle

Degradation of decoded picture quality can be estimated if e2,e3 or e4 are calculated as shown in Fig.2. The relationship between Eqs.(2.5) and (2.6) or (2.7) and (2.8) are shown in this figure. The refresh cycle will be decided from the view point of subjectively tolerable degradation shown in the vertical axis.

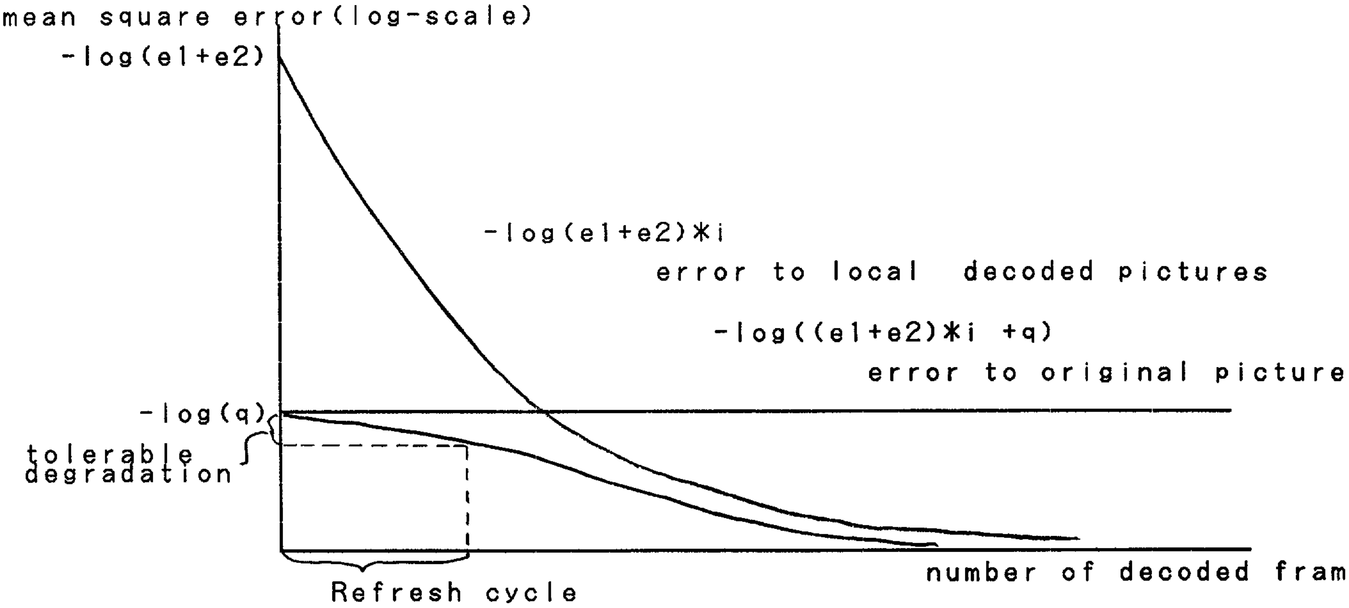

Fig.2 Degradation Curve

The values of e2,e3 or e4 depend on the the accuracy of IDCT at the coder and the decoder. Moreover, these values depend on the number of significant DCT coefficients which are supplied to IDCT. There is no error accumulation effect for zero level coefficients. Further discussion is needed regarding the estimation of e2,e3 or e4.

4. Simulation

Simulation was carried out to confirm the model described in Chapters 2 and 3 under the following conditions.

*Reference Model 4

*matrix algorithm for DCT

*'CHECKED JACKET'(monochrome,frame rate 2:1, starting with an original picture in the frame memories)

*quantize step size = 8, dead-zone = 8

*rounded 12-bit data between the vertical and the horizontal transform (See Doc.#222)

*rounded 16-bit data for the multiplication result in the coder (See Doc.#222)

To evaluate the mismatch error accumulation, the accuracy was varied as follows in IDCT of the decoder.

*simulation 1: rounded 17-bit data for the multiplication result in the decoder

*simulation 2: rounded 15-bit data for the multiplication result in the decoder

The simulation results are shown in Fig.3. The curve of the error value between two decoded signals in the coder and the decoder looks like an exponential function of decoded frame number as shown in Fig.2. Moreover, the curve of the degradation of decoded signal against original signal is masked by quantiziation error.

If rounded 17-bit data is employed for the multiplication result in the decoder, the decoded signal is much less affected by the mismatch error. However, if 15-bit accuracy is employed, decoded signal degrades rapidly. Required refresh cycle time is apparently longer for 17-bit accuracy. Consequently, the required accuracy will preferably be 16-bit or higher for this sequence.

Generally, if a coarse quantizer is used, the mismatch effect slowly appears. Two reasons can be mentioned. One is that, if the value of q in Eq.(2.6) or (2.8) is larger, the mismatch error e4 is masked by quantization error q. The second reason is that, the value of e2,e3 or e4 is small, since the number of significant coefficients is small.

5. Conclusion

The decision method of the refresh cycle has been discussed. If the value of e4 in Eq.(2.6) or (2.8) can be estimated, the required refresh cycle time can be decided.

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The value of e4 depends on the IDCT algorithm, calculation accuracy and the number of significant coefficients (quantizer and picture). Evaluation of the e4 is left for further study.

If accuracy is at least one-bit higher than more than the specification in Doc.#222, significant mismatch error cannot be subjectively detected in the sequence 'CHECKED JACKET'.

quantize step size = 8
quantize dead zone = 8

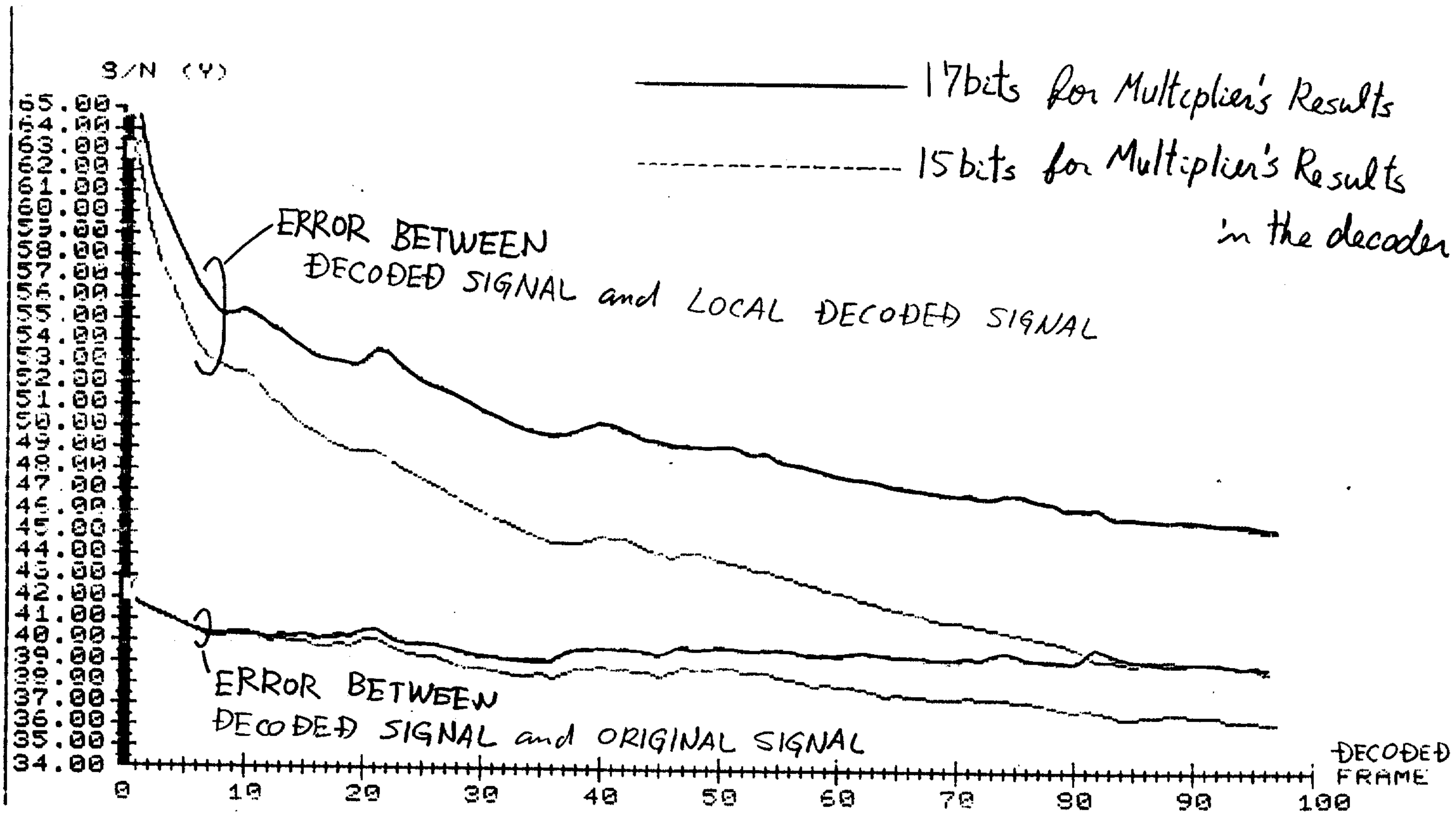

FIG.3 Simulation Result