CCITT SGXV
WORKING PARTY XV/1
Specialists Group on Coding for Visual Telephony

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SOURCE: NTT, KDD, NEC and Fujitsu
TITLE: Precision for IDCT Calculation and Refresh Cycle

1.Introduction

In Doc.#281 and #284, it is described that IDCT mismatch error occurs when different algorithms and/or calculation accuracy are employed between coder and decoder. If the difference i permitted, refresh process should be operated to suppress the mismatch error accumulation which degrades picture quality. In this case, a specification about refresh interval should be described along with IDCT accuracy.

In this document it is discussed how to decide the maximum refresh interval and how to estimate mismatch error.

2.Maximum Refresh Interval

Suggestion has been made on a specification about refresh interval as follows.

*Interframe coding mode must not be repeated n times at any significant blocks.

With this specification, intraframe mode must be operated more than once during n frames. Any refresh pattern is allowed, if it satisfies the above specification (Doc.#281, #284). The value of n should be decided not to significantly degrade coding efficiency.

	n=30	n=60	n=120	n=180
frame rate 2:1	2sec	4sec	8sec	12sec
frame rate 3:1	3sec	6sec	12sec	18sec
maximum increase number of intra-frame mode block	79.2block	39.6block	19.8block	13.2block

Table.1 Maximum refresh interval n and increase number of intraframe mode block

Cyclic refresh is carried out in the first Flexible Hardwar implemented in Japan, and its interval is 120 frames. Moreover, the is no visible degradation when n=60 in reference model(Doc.#281). Therefore, n may be settled from 60 to 120. A suitable value for n will be 120.

3.Estimation of Mismatch Error

Estimation of mismatch error is needed to make specification. Mismatch error accumulates as time passes by, as described in Doc.#255. If mean square mismatch error is represented by Em, accumulated mismatch error is n x Em after n-decoded frames. Maximum value of n is decided from the refresh interval.

First, IDCT error power must be estimated. IDCT error power is defined by mean square difference between two transformed results, with and without calculation error. It can be calculated theoretically. For example, IDCT error can be calculated in case of matrix algorithm as shown in Annex 1 and Table 2.

Then, mismatch error power Em can be expressed as a function of IDCT error power. Em can be represented as Em(E1,E2), where E1 and E2 is IDCT error power in coder and decoder. Eq(3.1) can be obtained using a very simplified model(Annex 2).

$$Em(E1,E2) = \sqrt{2/3} \cdot \sqrt{E1 + E2 - 1/6}$$

$$= \sqrt{2/3} \cdot \sqrt{(E1 - 1/12) + (E2 - 1/12)} \qquad (3.1)$$

In this equation, main factors are E1-1/12 and E2-1/12. Since results of IDCT are rounded in the same manner, mean square error is 1/12.

If IDCT error power is limited within Et, mismatch error would be less than Em(Et,Et) as shown in Fig.1. Therefore, the value of threshold Et may be necessary in the specification.

4.Experiment and Simulation

An experiment of mismatch error has been carried out using Japanese first Flexible Hardware. A computer simulation has been also carried out under the same condition.

The condition is shown as follows,

*IDCT in coder loop follows the flexible hardware specification.
*In decoder, IDCT accuracy is reduced.
  CASE-1: results of the first transform are truncated to 15bits
  CASE-2: results of the first transform are truncated to 14bits
  CASE-3: results of IDCT are truncated to 9bits

It takes more than 10 seconds until picture quality degradation become visible regarding CASE-1 and CASE-2. In this case, normal refresh with about ten-second refresh interval is enough to suppress the degradation. On the other hand, in Case-3, fast refresh is needed(Annex 3, VTR demo.).

Computer simulation has been carried out regarding CASE-1 and CASE-2 in order to measure mismatch error power. Results are shown in Table 3.

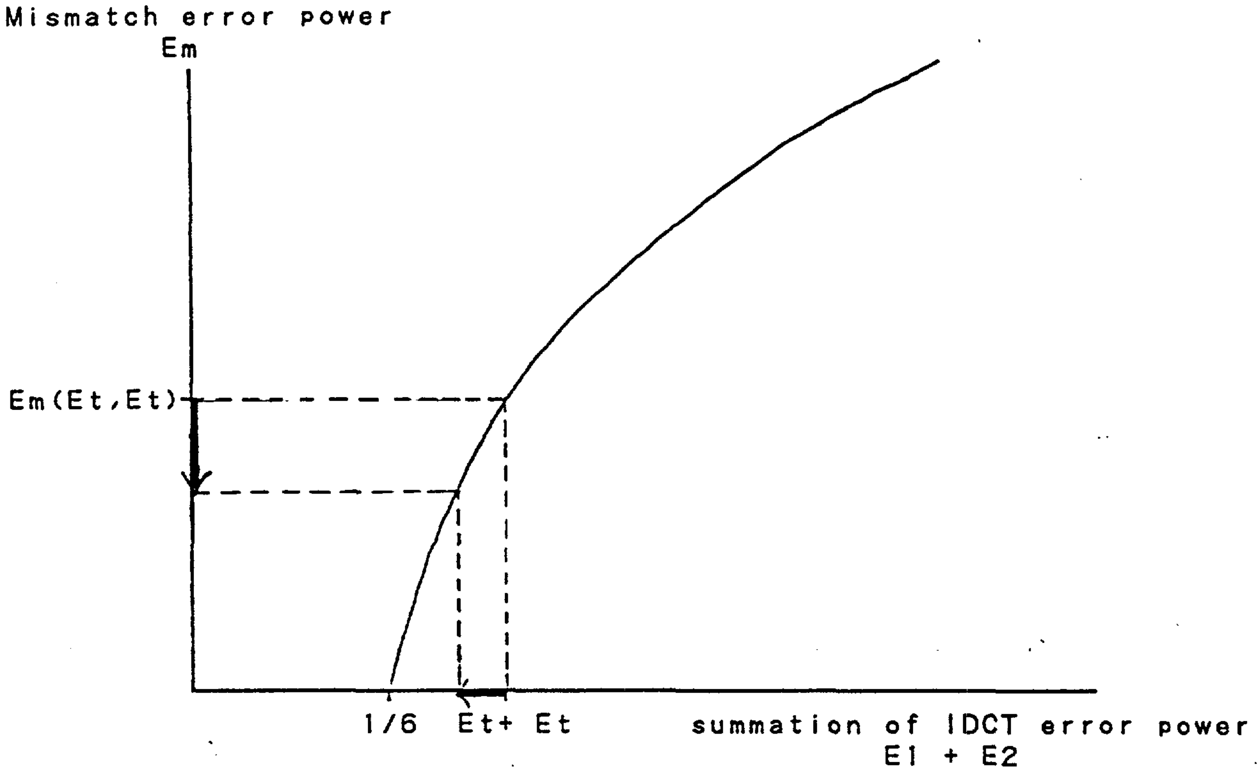


Fig.1 Relation between mismatch error Em and summation of IDCT error power E1 + E2

5.Discussion and Conclusion

IDCT error power which is calculated for the worst case is shown in Table 2. The three cases described in the experiment above are included in this table. Mismatch error power is shown in the Table 3. This table shows the value which is calculated using Eq.(3.1) as worst case and the measured value in the computer simulation.

The experimental and simulation results show that the Flexible Hardware with CASE-2 approximation produces no visible degradation. Therefore, Eq.(5.1) is obtained from Table 3 and Eq.(3.1).

$$(E1 - 1/12) + (E2 - 1/12) < 0.0055 \quad (5.1)$$

If sum of E1 and E2 is equal to 2Et,

$$(Et - 1/12) + (Et - 1/12) < 0.0055.$$

$$Et - 1/12 < 0.0027 \quad (5.2)$$

Values of E●¿- 1/12 are used instead of E●¿ to make a difference clear between acceptable and unacceptable mismatch.

result of multiplier in the first 1-D transform	(12,a)bits
result of the first 1-D transform	(11,b)bits
result of multiplier in the second 1-D transform	(11,c)bits
result of IDCT	(9,d)bits

	a	b	c	d	E1	E1 - 1/12
FH	--	5(t)	--	0	0.0836	0.00033
CASE-1	--	4(t)	--	0	0.0846	0.00130
CASE-2	--	3(t)	--	0	0.0885	0.00521
CASE-3	--	5(t)	--	0(t)	0.3337	-------
CASE-4	4	1	5	0	0.1074	0.02409(Doc.#255)
CASE-5	--	1	--	0	0.1042	0.02083

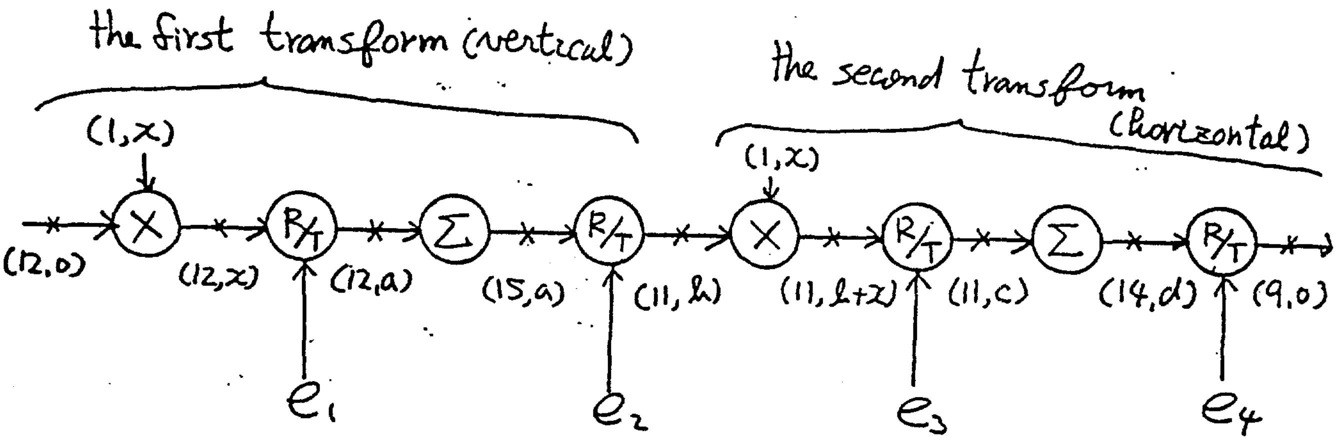
(t):truncation

Table 2: IDCT error power when matrix algorithm is applied

	E1 + E2	E1-1/12 + E2-1/12	value of Eq.(3.1)	simulation result
CASE-1	0.1683	0.00163	0.0329	0.006 - 0.021
CASE-2	0.1722	0.00554	0.0607	0.012 - 0.040

Table 3: Summation of IDCT power and mismatch power against Flexible Hardware

Annex 1. Estimation of the worst case IDCT error power in matrix algorithm



Calculation of Matrix

e1, e2, e3 and e4 are error power

	e1	e2	e3	e4
R:round off	$(1/12)\times2^{-2a}$	$(1/12)\times2^{-2b}$	$(1/12)\times2^{-2c}$	$(1/12)\times2^{-2}$
T:truncate	$(1/3)\times2^{-2a}$	$(1/3)\times2^{-2b}$	$(1/3)\times2^{-2c}$	$(1/3)\times2^{-2}$

There is another error which occurs from an approximation of transform matrix component. However, it can be neglected if x is more than 10.

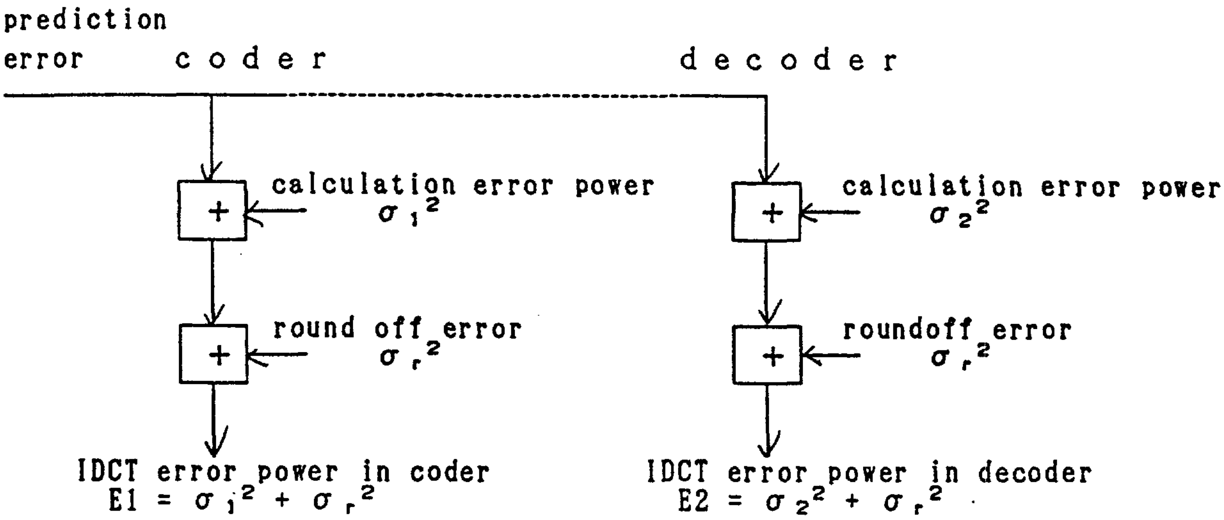
In the worst case, e1 and e3 occurs 64x8 times per one block, e2 and e4 does 64 times.

Error power per sample can be estimated as follows.

$$(1/64)(\ 64\times8(e1+e3)\ +\ 64(e2+e4)\ )$$
$$=\ 8(e1+e3)\ +\ (e2+e4)$$

Annex 2. Relation of mismatch error and IDCT error (on the simplified model) Doc.#321

In this model, the last round off is devided from calculation error as follows, because this round off is generally common.



The round off error $\sigma_r^2 = 1/12$.
If probability density function of error is

$$p(x) = 1/a, \quad -a/2 \leqq x \leqq a/2,$$

calculation error power is

$$\sigma_1^2 = \sigma_2^2 = (1/12)\cdot a^2 .$$

Therefore, summation of IDCT error power is

$$E1 + E2 = (1/6)\cdot a^2 + (1/6) . \qquad (A2.1)$$

On the other hand, mean square mismatch error Em can be calculated.

$$Em = (1/3)\cdot a \qquad (A2.2)$$

From (A2.1) and (A2.2),

$$Em^2 = (2/3)\cdot(E1 + E2 - (1/6)),$$

$$Em = \sqrt{(2/3)\cdot(E1 + E2 - (1/6))}. \qquad (A2.3)$$

Eq.(A2.3) is shown in Fig.A1. Simulation result is also shown with cross marks.

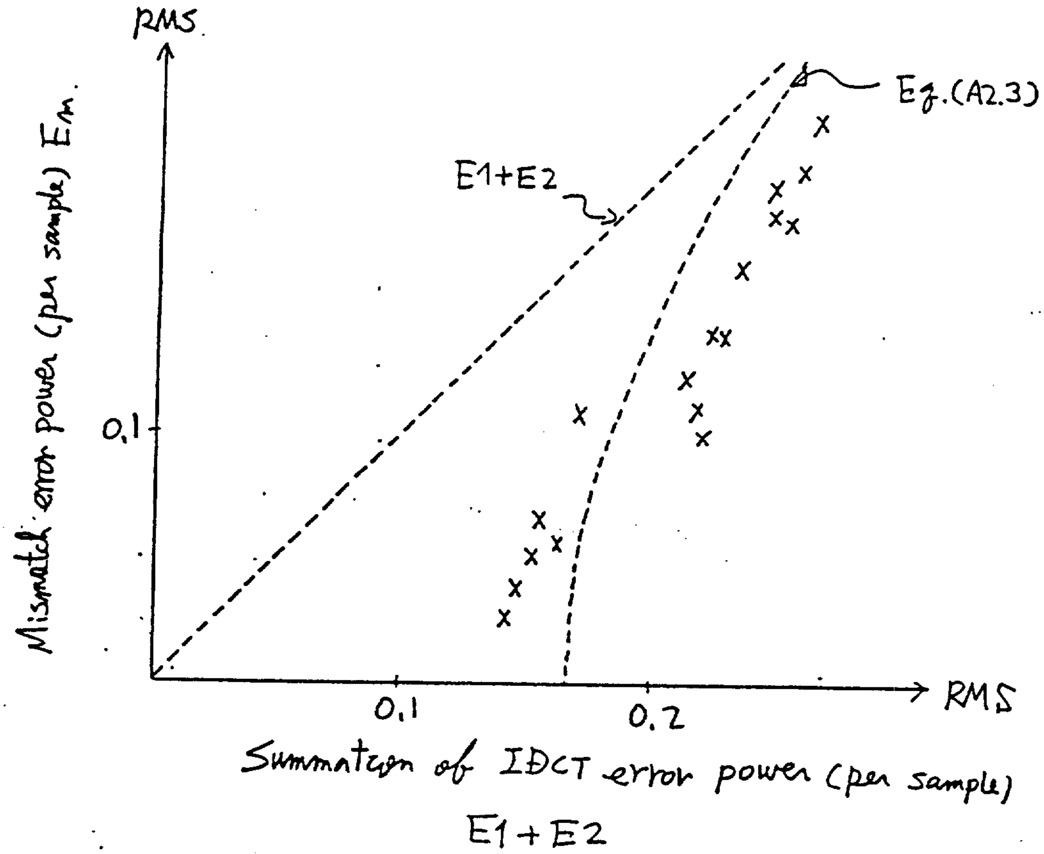


Fig.A1. Relation of mismatch error and IDCT error.

IDCT in coder is normal, but it is modified in decoder to make mismatch error.

CASE-1:Truncate transfer data to 15bits
CASE-2:Truncate transfer data to 14bits
CASE-3:Truncate IDCT result to 9bits

	CASE-3	0:00 - 1:20
controlled (384kbit/sec)	CASE-2	1:20 - 2:45
	CASE-1	2:45 - 4:10
	CASE-3	4:10 - 5:30
step size = 4 dead zone = 4	CASE-2	5:30 - 6:55
	CASE-1	6:55 - 8:30

Each case include color bar and teleconference scene.