

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Helical-scan digital video cassette recording system using 12,65 mm (0,5 in) magnetic tape – Format HD-D5 –
Part 2: Compression format**

**Système de magnétoscope numérique à cassette à balayage hélicoïdal sur bande magnétique de 12,65 mm (0,5 in) – Format HD-D5 –
Partie 2: Format de compression**



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PRICE CODE
CODE PRIX



ICS 33.160.40; 35.240.99

ISBN 978-2-83220-461-0

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HELICAL-SCAN DIGITAL VIDEO CASSETTE RECORDING SYSTEM USING 12,65 mm (0,5 in) MAGNETIC TAPE – FORMAT HD-D5 –

Part 2: Compression format

FOREWORD

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International Standard IEC 62330-2 has been prepared by Technical Area 6: Higher data rate storage media and equipment of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This bilingual version (2012-11) corresponds to the monolingual English version, published in 2003-05.

It was submitted to the national committees for voting under the Fast Track Procedure as the following documents:

CDV	Report on voting
100/505/CDV	100/604/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

IEC 62330 consists of the following parts, under the general title *Helical-scan digital video cassette recording system using 12,65 mm (0,5 in) magnetic tape – Format HD-D5*.

Part 1: VTR specifications

Part 2: Compression format

Part 3: Data stream format

Part 1 describes the VTR specifications which are tape, magnetization, helical recording, modulation method and basic system data for high definition video compressed data on 29,97 or 59,94 frame rate.

This part 2 describes the specifications for encoding process and data format for 1080i and 720p systems.

Part 3 describes the specifications for transmission of HD-D5 compressed video and audio data stream over 360 Mb/s serial digital interface.

HELICAL-SCAN DIGITAL VIDEO CASSETTE RECORDING SYSTEM USING 12,65 mm (0,5 in) MAGNETIC TAPE – FORMAT HD-D5 –

Part 2 – Compression format

1 Scope

This part of IEC 62330 defines the encoding process of the HD-D5 video compression and its data format for the 1 080/59,94i system (hereinafter referred to as the 1 080i system) and the 720/59,94p system (hereinafter referred to as the 720p system).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ITU-R BT.1543, *1 280 × 720, 16 × 9 progressively-captured image format for production and international programme exchange in the 60 Hz*

ITU-R BT.709, *Parameter values for the HDTV standards for production and international programme exchange*

3 Acronyms

BUF	Buffer memory
C	Colour difference signal
C3RMB	Compressed data of 3 RMBs
C(t, u)	The value of the DCT coefficient at frequency (t, u)
C _B /C _R	Colour difference signal
CC0 ~ CC2	Categories for C DCT block
Ccoef()	C DCT CG
CG	Coefficient group
CGNR	CG number of one Y/C DCT coefficient block in one RMB
CGNS	CG number of one Y/C DCT coefficient block in one SMB
CN	C3RMB number in one RMBG
CRcoef()	Rearranged C DCT CG
CS	C DCT block number in one SMB
CY0 ~ CY3	Categories for Y DCT block
DCT	Discrete cosine transform
DIF	Digital interface
DIF(n)	DIF block numbered n
DN	DIF block number
EOB	“End of block” code
EOM	“End of 3 RMBs” code

exnor	Logical exclusive nor
f()	Offset value table for SMBG distribution
FCB	Category flag of C_B DCT block
FCB'	Category flag of C_B DCT block
FCR	Category flag of C_R DCT block
FCR'	Category flag of C_R DCT block
FFL	Field number flag
FMB	Category flag of the MB
FMB'	Category flag of the MB
FYa ~ FYd	Category flags of the four DCT blocks (Ya ~ Yd) of the MB
FYa' ~ FYd'	Category flags of the four DCT blocks (Ya ~ Yd) of the MB
H	The horizontal SMB position number in one video field (1 080i system) or one video frame (720p system)
HR	The column position number of RMB
HS	The column position number of SMB in one SMBG
IDCT	Inverse discrete cosine transform
int (A)	Integer part of A
LEN	The byte length of C3RMB
MB	Macro block
mod	Modulus operator
N.A.	Not applicable
Offset()	Offset value for RMB shuffling
P(r, s)	The value of the pixel at the position (r, s) in Y/C DCT block
Qno	Quantization number
Qstep	Quantization step value
r	The horizontal pixel position number in Y/C DCT block
Rg	The RMBG number within the RMBs
RMB	Rearranged macro block
RMBG	Rearranged macro block group
Rn	The number of RMB coding order in each RMBG
s	The vertical pixel position number in Y/C DCT block
SA	The starting address of the remainder data in buffer memory
SABM	One byte data of SA (two bytes)
Sg	The SMBG number in one video field (1 080i system) or one video frame (720p system)
SMB	Super macro block
SMBG	Super macro block group
t	The horizontal frequency number in Y/C DCT coefficient block
TableCY0 ~ 3	Set up value tables for Y weighting function
TableCC0 ~ 2	Set up value tables for C weighting function
u	The vertical frequency number in Y/C DCT coefficient block
V	The vertical position number of SMB in one video field (1 080i system) or one video frame (720p system)
VLC	Variable length coding

VR	The row position number of RMB
VS	The row position number of SMB in one SMBG
$W(t, u)$	Weighting value at frequency (t, u)
Y	Luminance signal
$Y_a \sim Y_d$	Four Y DCT blocks in one MB
$Y_{coef}()$	Y DCT CG
YR	The Y DCT coefficient block number in one RMB
$YR_{coef}()$	Rearranged Y DCT CG
YS	The Y DCT block number in one SMB
Z	The row position number of the RMB after RMB shuffling
ZRL	Code of 15 successive zero coefficients followed by a coefficient of zero amplitude

4 Video processing

4.1 Overview

Luminance (Y) and colour difference components (C_B and C_R) from 1 080i or 720p video signal are sampled by 74,25/1,001 MHz and 37,125/1,001 MHz respectively.

After discarding samples in vertical and horizontal blanking periods, active video samples are divided into four super macro block groups (SMBG) per field (1 080i) or per frame (720p). Each SMBG consists of 1 080 super macro blocks (SMB).

Each SMB consists of two MBs. Each MB consists of four luminance DCT blocks (8×4 pixel matrix) and one each of C_B DCT block (8×8 pixel matrix) and C_R DCT block (8×8 pixel matrix).

As described later, two horizontally adjacent luminance DCT blocks are overlapped by one pixel column at their junction. Two horizontally adjacent chrominance DCT blocks are overlapped by one pixel column at their junction when they are formed into SMB.

Each DCT block is transformed to represent DC and AC coefficients. Coefficients are weighted through the prearranged categories prior to shuffling, then formed into rearranged MBs (RMB).

DCT coefficients within one rearranged MB group (RMBG) are quantized, and made into a fixed length data set through VLC.

The VLC output code words from one RMBG are formed into 360 DIF blocks.

The compressed video data for one 1 080i field or one 720p frame consists of 5 760 DIF blocks.

The block diagram of the outline about video processing is shown in Figure 1.

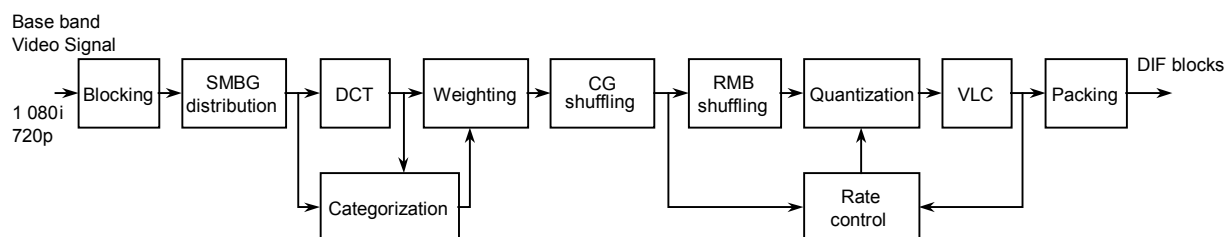


Figure 1 – Block diagram of outline about video processing

4.2 Video signal

4.2.1 Sampling process

The sampling structure is defined in ITU-R BT.709 and ITU-R BT.1543. Sampling structures of the luminance (Y) and the two colour difference signals (C_B/C_R) are described in Table 1.

4.2.1.1 Line structure in one field (1 080i system) or frame (720p system)

For the 1 080i system, 540 lines for Y, C_B and C_R signals from each field shall be transmitted. For the 720p system, 720 lines for Y, C_R and C_B signals from each frame shall be transmitted. The transmitting lines on a television frame are defined in Table 1.

Table 1 – The construction of video signal sampling

		1 080i system		720p system	
Sampling frequency	Y	74,25 MHz / 1,001			
	C _B /C _R	37,125 MHz / 1,001			
Total number of pixels per line	Y	2 200		1 650	
	C _B /C _R	1 100		825	
The number of active pixels per line	Y	1 920		1 280	
	C _B /C _R	960		640	
Total number of lines per frame		1 125		750	
The number of active lines per frame		1 080		720	
The active line numbers		Field 1	21 to 560	Frame	26 to 745
		Field 2	584 to 1 123		
Quantization		Each sample is linearly quantized to 10 bits for Y, C _B and C _R			
The relation between video signal level and quantized level	Scale	4 to 1 019			
	Y	Quantized level:		877	
		Video signal level of white:		940	
		Video signal level of black:		64	
	C _B /C _R	Quantized level:		897	
Video signal level of gray:		512			

4.2.1.2 Pixel structure in one field (1 080i) / in one frame (720p)

– 1 080i system

All sampled pixels, 1 920 luminance pixels per line and 960 colour difference pixels, are retained for processing as shown in Figure 2. The sampling process starts simultaneously for both luminance and colour difference signals.

– 720p system

All sampled pixels, 1 280 pixels per line and 640 colour difference pixels, are retained for processing as shown in Figure 3. Sampling processes start simultaneously for both luminance and colour difference signals.

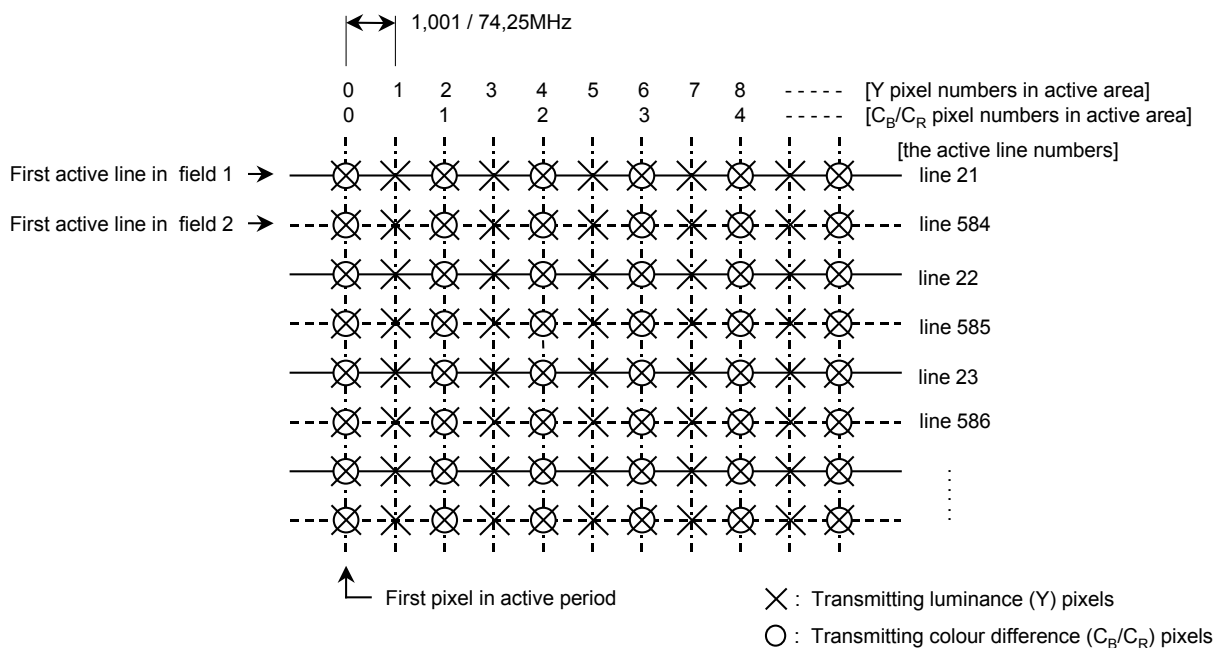


Figure 2 – Transmitting samples of 1 080i system

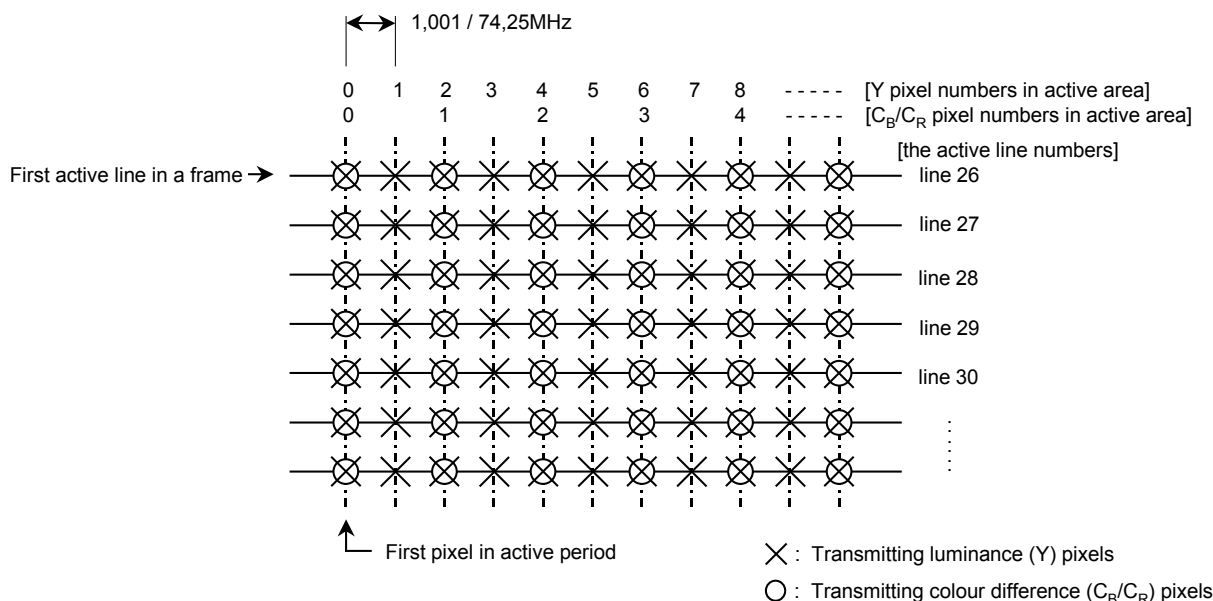


Figure 3 – Transmitting samples of 720p system

4.3 Block formation

4.3.1 DCT block, macro block (MB) and super macro block (SMB)

4.3.1.1 DCT block

The Y pixels in a field (1 080i system) and in a frame (720p system) shall be divided into rectangular areas of 15 horizontal pixels and 4 lines. Two Y DCT blocks (one Y DCT block pair) are made from each one of the rectangular areas as shown in Figure 4. In each Y DCT block pair, the rightmost pixel in the left DCT block is overlapped with the leftmost pixel in the right DCT block (overlapped blocking).

The C_B/C_R pixels in a field (1 080i) and in a frame (720p) shall be divided into rectangular areas of 15 horizontal pixels and 8 lines. Two C DCT blocks (one C DCT block pair) are made from each one of the rectangular areas as shown in Figure 5. In each C DCT block pair, the rightmost pixel in the left block is overlapped with the leftmost pixel in the right block (overlapped blocking). Overlapped blocking is used for the robustness of error (see Annex A).

Let r be the horizontal pixel position number in Y/C DCT block

$$r = 0, 1, 2, \dots, 7.$$

Let s be the vertical pixel position number in Y/C DCT block

$$\text{For Y block } s = 0, 1, 2, 3$$

$$\text{For C block } s = 0, 1, 2, \dots, 7.$$

Let $P(r, s)$ be the value of the pixel at the position (r, s)

4.3.1.2 Macro block (MB)

Each macro block (MB) in the 1 080i system and the 720p system consists of two Y DCT block pairs, one C_B DCT block and one C_R DCT block. Two Y DCT block pairs are vertically adjacent. C_B DCT block and C_R DCT block spatially correspond to the two Y DCT block pairs. Four Y DCT blocks (Y_a, Y_b, Y_c, Y_d), one C_B DCT block and one C_R DCT block are shown in Figure 6.

4.3.1.3 Super macro block (SMB)

As shown in Figure 7, each super macro block (SMB) in the 1 080i system and the 720p system consists of two macro blocks which are horizontally adjacent. Two C DCT blocks of C_B/C_R in one super macro block are one C DCT block pair of C_B/C_R .

Let YS be the Y DCT block number in each SMB as shown in Figure 7.

YS = 0, 1, 2, ..., 7.

Let CS be the C DCT block number in each SMB as shown in Figure 7.

CS = 0, 1.

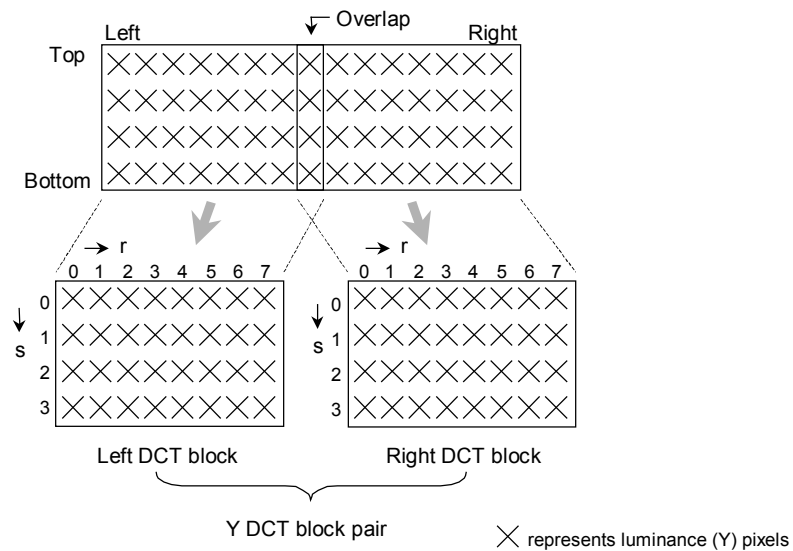


Figure 4 – Overlapped blocking of luminance (Y) pixels

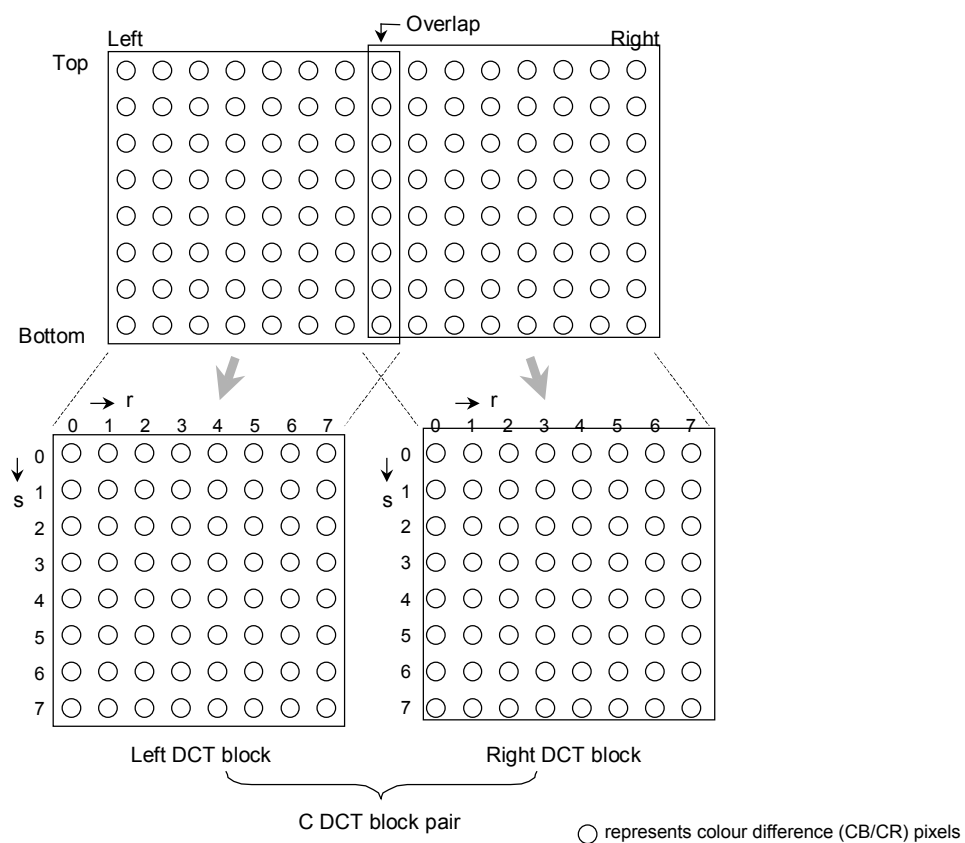


Figure 5 – Overlapped blocking of colour difference C_B/C_R pixels

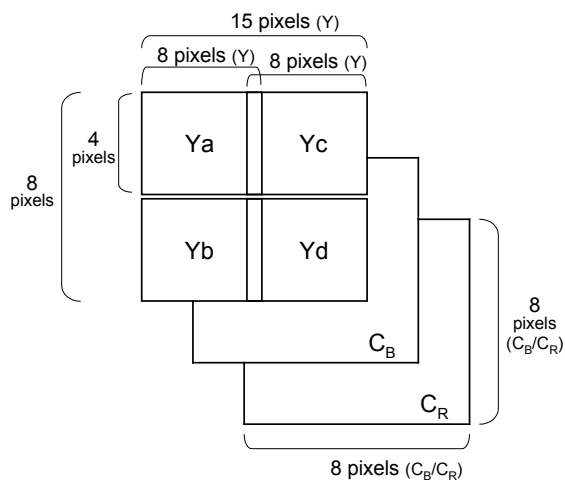


Figure 6 – Macro block structure in 1 080i system and 720p systems

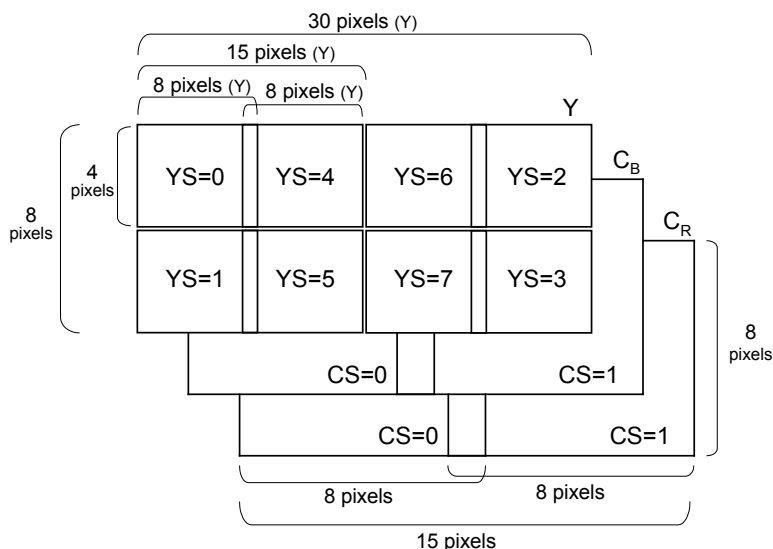


Figure 7 – Super macro block structure in 1 080i system and 720p systems

4.3.2 Super macro block arrangement

4.3.2.1 1 080i system

The vertical field dimension, 540 pixel long, is not divisible into an integer by the vertical dimension of the SMB, 8 pixels long.

In order to place all SMBs within the 1 920 × 540 pixel matrix of the 1 080i field, removal and attachments of half height SMBs are required as shown in Figure 8.

1) Y pixels

- Pixels in four rectangular areas of the horizontal pixel position number from $(480 \times N)$ to $(59 + 480 \times N)$ and from $(360 + 480 \times N)$ to $(419 + 480 \times N)$ in the active area and line position number from 536 to 539 in the active area shall be moved horizontally 1 020 pixel positions to the right, vertically 4 lines to the bottom ($N = 0, 1$).
- Pixels in two rectangular areas of the horizontal pixel position number from $(240 + 480 \times N)$ to $(359 + 480 \times N)$ in the active area and line position number from 536 to 539 in the active area shall be moved horizontally 840 pixel positions to the right, vertically 4 lines to the bottom ($N = 0, 1$).
- Pixels in four rectangular areas of the horizontal pixel position number from $(960 + 480 \times N)$ to $(1 019 + 480 \times N)$ and from $(1 320 + 480 \times N)$ to $(1 379 + 480 \times N)$ in the active area and line position number from 536 to 539 in the active area shall be moved horizontally 900 pixel positions to the left, vertically 4 lines to the bottom ($N = 0, 1$).
- Pixels in two rectangular areas of the horizontal pixel position number from $(1 200 + 480 \times N)$ to $(1 319 + 480 \times N)$ in the active area and line position number from 536 to 539 in the active area shall be moved horizontally 1 080 pixel positions to the left, vertically 4 lines to the bottom ($N = 0, 1$).

2) C_B/C_R pixels

C_B/C_R pixels occupy the positions held by the even numbered Y horizontal pixel numbers. The half height SMB replacement operation, identical to the Y pixels as described above, is performed for C_B/C_R pixels.

The arrangement of the SMBs in one field is shown in Figure 9. The same horizontal arrangement of 64 SMBs is repeated with 67 SMBs in the vertical direction from top, and there are 32 SMBs in the horizontal direction at the bottom. The number of SMBs in one field is 4 320 as described below:

$$(\text{vertical } 67 \text{ SMBs} \times \text{horizontal } 64 \text{ SMBs}) + 32 \text{ SMBs} = 4\,320 \text{ SMBs}$$

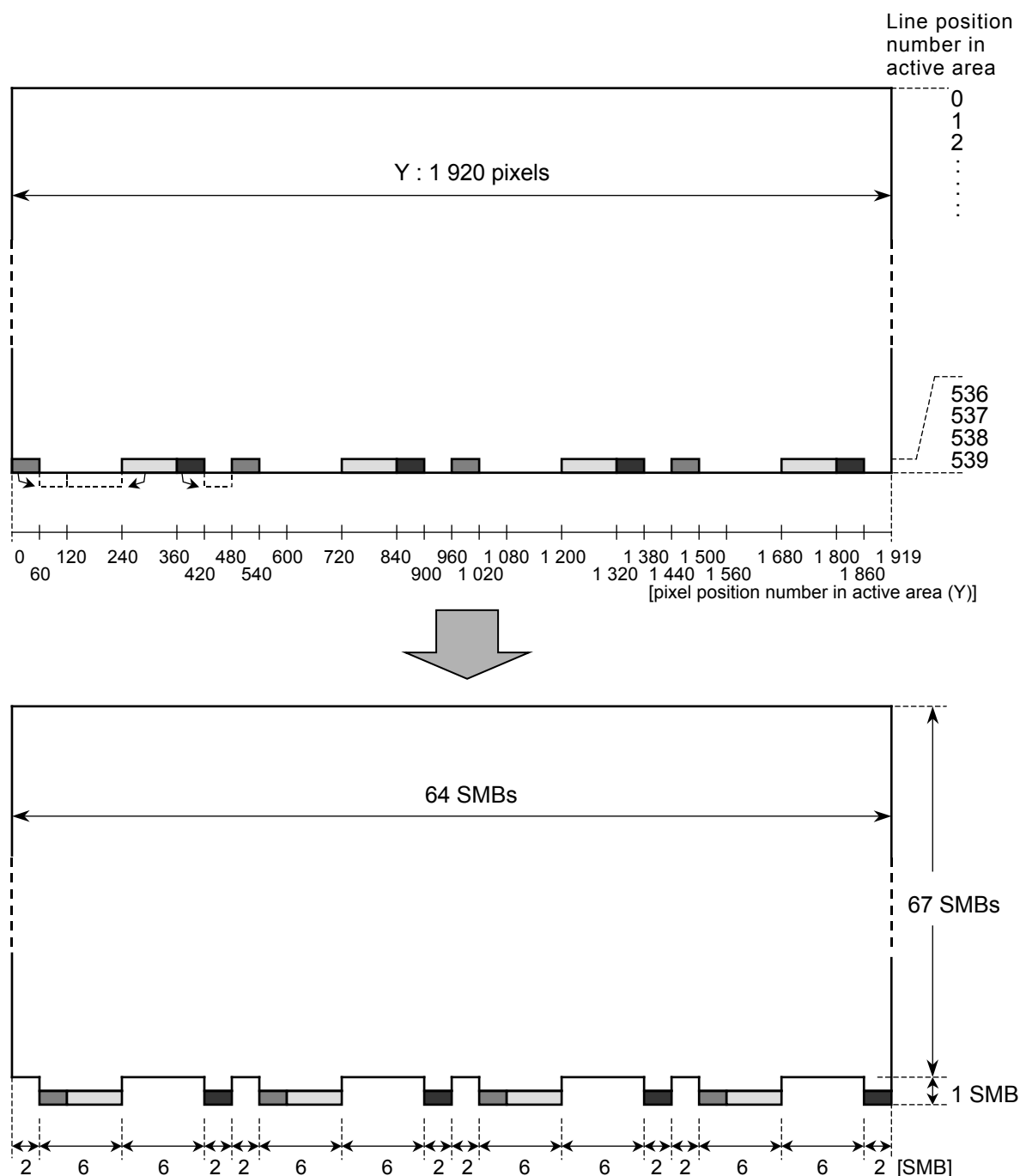


Figure 8 – Pixel arrangement for blocking of 1 080i system

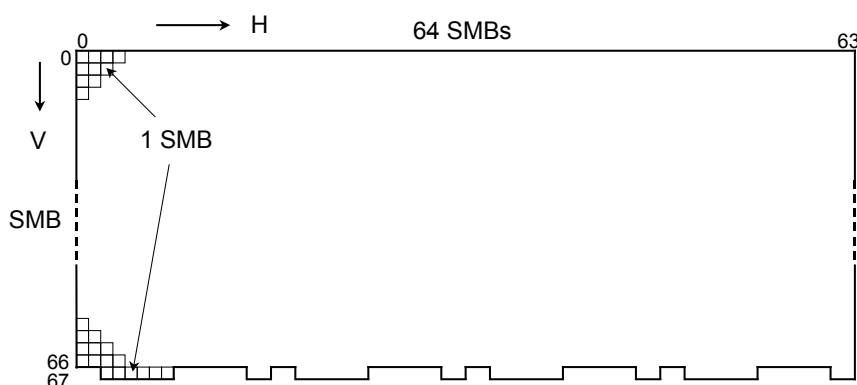


Figure 9 – The arrangement of SMBs in one field for 1 080i system

4.3.2.2 720p system

As the first step of block formation, 160 dummy of Y pixels and 80 dummy of C_B/C_R pixels are added as rightmost pixels in each line. The value of dummy shall be “040h” for Y and “200h” for C.

The arrangement of SMBs in one frame for the 720p system is shown in Figure 10. The same horizontal arrangement of 48 SMBs is repeated with 90 SMBs in the vertical direction from top to bottom. The number of SMBs in one frame is 4 320 as described below:

$$\text{vertical 90 SMBs} \times \text{horizontal 48 SMBs} = 4\,320 \text{ SMBs}$$

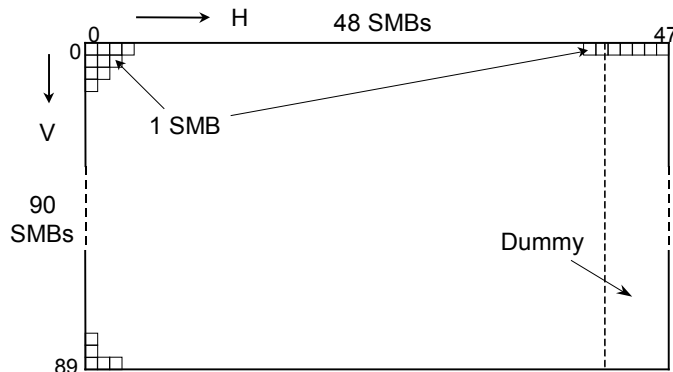


Figure 10 – The arrangement of SMBs in one frame for 720p system

4.4 SMBG distribution

4.4.1 1 080i system

4 320 SMBs in one field are divided into four SMBGs as shown in Figure 11.

Let H be the horizontal position number of SMB within the video field

$$H = 0, 1, 2, \dots, 63.$$

Let V be the vertical position number of SMB within the video field

$$V = 0, 1, 2, \dots, 67.$$

Let HS be the column position number of SMB within one SMBG

$$HS = 0, 1, 2, \dots, 5.$$

Let VS be the row position number of SMB within one SMBG

VS = 0, 1, 2, ..., 179.

Let Sg be the SMBG number in one field

Sg = 0, 1, 2, 3.

The distribution method is described as follows:

$$V = (\text{int} (VS / 8)) \times 3 + \text{int} (((VS \bmod 8) \times 6 + HS) / 16)$$

$$H = ((f(h, v) + ((\text{int} (VS / 8)) - Sg) \times 8) \bmod 32) \times 2 + ((\text{int} (VS / 8)) \bmod 2) \times \text{nor} (HS \bmod 2)$$

$$\text{where } v = \text{int} (((VS \bmod 8) \times 6 + HS) / 16)$$

$$h = \text{int} ((((VS \bmod 8) \times 6 + HS) \bmod 16) / 2)$$

xnor: exclusive nor

Value of f(h, v)

v \ h	0	1	2	3	4	5	6	7
0	1	2	0	19	20	21	15	14
1	15	10	9	11	30	29	28	24
2	24	25	5	7	6	20	19	18

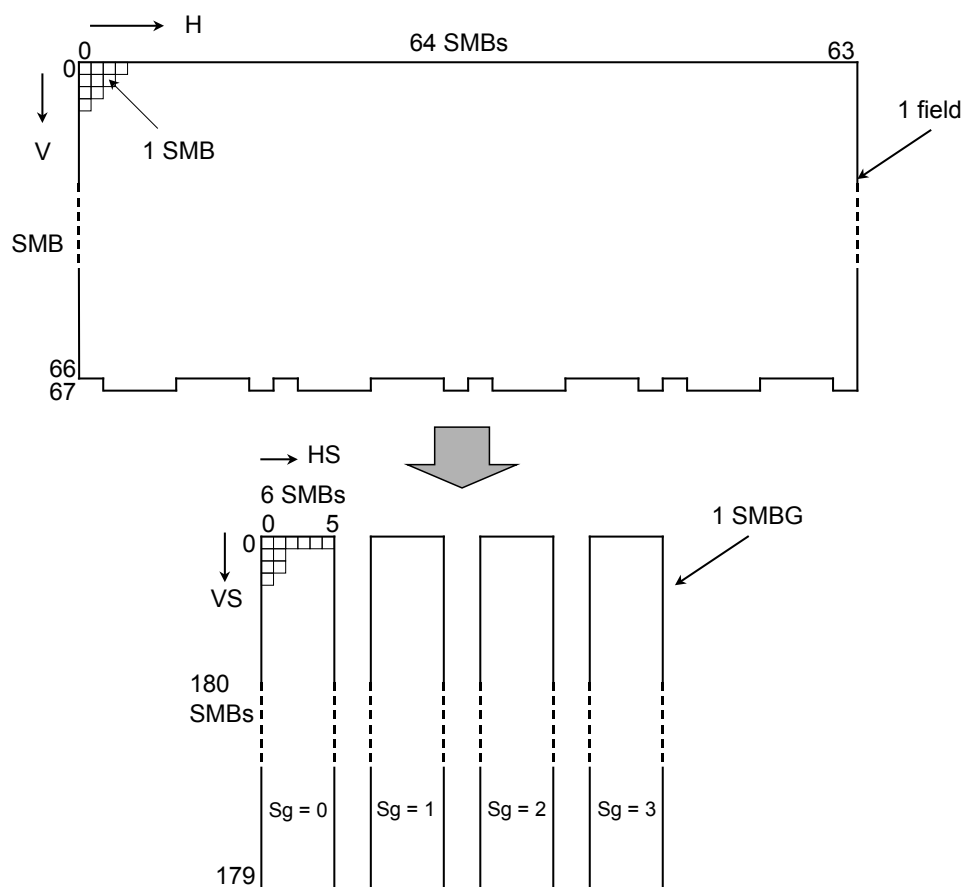


Figure 11 – SMBG distribution in 1 080i system

4.4.2 720p system

4 320 SMBs in one frame are divided into four SMBGs as shown in Figure 12.

Let H be the horizontal position number of SMB within video frame

$$H = 0, 1, 2, \dots, 47.$$

Let V be the vertical position number of SMB within video frame

$$V = 0, 1, 2, \dots, 89.$$

Let HS be the column position number of SMB within one SMBG

$$HS = 0, 1, 2, \dots, 5.$$

Let VS be the row position number of SMB within one SMBG

$$VS = 0, 1, 2, \dots, 179.$$

Let Sg be the SMBG number in one frame

$$Sg = 0, 1, 2, 3.$$

The distribution method is described as follows:

$$V = \text{int} (VS / 2)$$

$$H = (VS \bmod 2) \times 24 + ((Sg + f ((\text{int} (VS / 2)) \bmod 4)) \bmod 4) \times 6 + ((HS - \text{int} (VS / 2)) \bmod 6)$$

where $f(0) = 0, f(1) = 1, f(2) = 3, f(3) = 2$

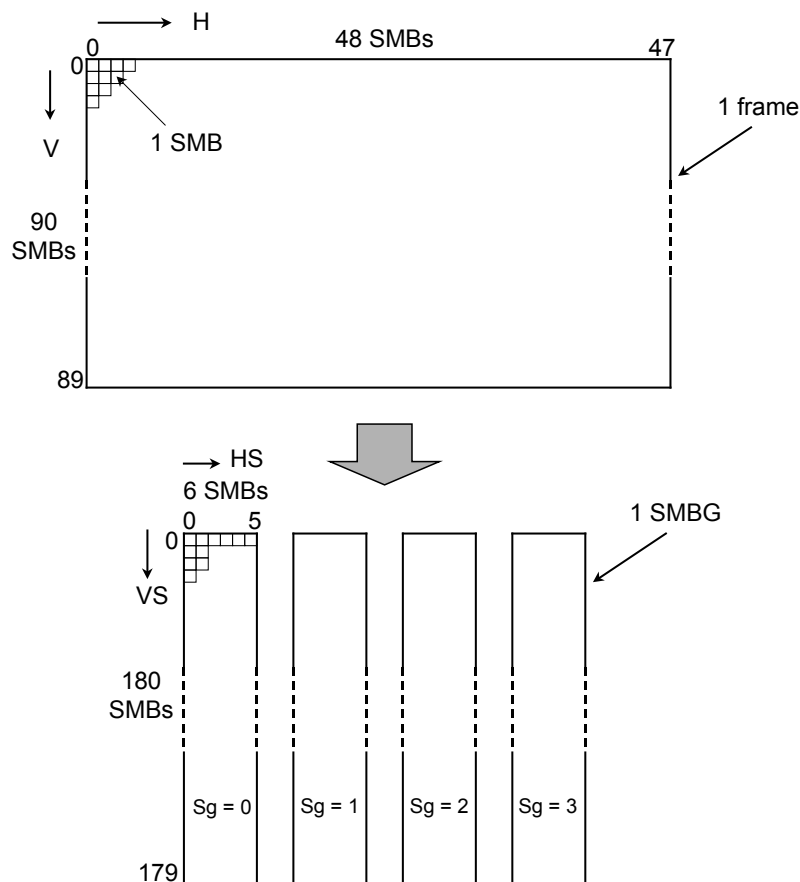


Figure 12 – SMBG distribution in 720p system

4.5 DCT

The maximum excursion of all pixel value is changed to fall between –511 and +511 by the subtraction of 512 from the original sampled value. 8×4 pixels $P(r, s)$ of each Y DCT block and 8×8 pixels $P(r, s)$ of each C_B/C_R DCT block are transformed into 8×4 Y DCT coefficients and 8×8 C DCT coefficients respectively.

Let t be the horizontal frequency number in Y/C DCT coefficient block as shown in Figure 13.

$$t = 0, 1, 2, \dots, 7.$$

Let u be the vertical frequency number in Y/C DCT coefficient block

For Y DCT coefficient block $u = 0, 1, 2, 3$

For C DCT coefficient block $u = 0, 1, 2, \dots, 7$.

Let $C(t, u)$ be the value of the DCT coefficient at frequency (t, u) .

The coefficient of $t = 0$ and $u = 0$ is called as DC coefficient. Other coefficients are called as AC coefficients.

4.5.1 DCT/IDCT for Y

DCT/IDCT for the Y signal are defined as shown below:

DCT:

$$C(t, u) = \sqrt{2} \times C1(t) \times C2(u) \sum_{s=0}^3 \sum_{r=0}^7 (P(r, s) \times \cos(\pi u(2s+1)/8) \times \cos(\pi t(2r+1)/16))$$

IDCT:

$$P(r, s) = (1/\sqrt{2}) \sum_{u=0}^3 \sum_{t=0}^7 (C1(t) \times C2(u) \times C(t, u) \times \cos(\pi u(2s+1)/8) \times \cos(\pi t(2r+1)/16))$$

$$\begin{aligned} \text{where } C1(t) &= 1/2\sqrt{2} & \text{for } t = 0 \\ C1(t) &= 1/2 & \text{for } t = 1 \text{ to } 7 \\ C2(u) &= 1/2 & \text{for } u = 0 \\ C2(u) &= 1/\sqrt{2} & \text{for } u = 1 \text{ to } 3 \end{aligned}$$

The structure of the Y DCT coefficient block is shown in Figure 13 a). DCT coefficients $C(t, u)$ of the Y DCT coefficient block are divided into 6 DCT coefficient groups (CGs).

Let CGNS be the CG number as shown in Figure 13 a)

$$CGNS = 0, 1, 2, 3, 4, 5.$$

4.5.2 DCT/IDCT for C

DCT/IDCT for C (C_B/C_R) signal are defined as shown below:

DCT:

$$C(t, u) = C3(t) \times C4(u) \sum_{s=0}^7 \sum_{r=0}^7 (P(r, s) \times \cos(\pi u(2s+1)/16) \times \cos(\pi t(2r+1)/16))$$

IDCT:

$$P(r, s) = \sum_{u=0}^7 \sum_{t=0}^7 (C3(t) \times C4(u) \times C(t, u) \times \cos(\pi u(2s + 1)/16) \times \cos(\pi t(2r + 1)/16))$$

$$\begin{aligned} \text{where } C3(t) &= 1 / 2\sqrt{2} & \text{for } t = 0 \\ C3(t) &= 1 / 2 & \text{for } t = 1 \text{ to } 7 \\ C4(u) &= 1 / 2\sqrt{2} & \text{for } u = 0 \\ C4(u) &= 1 / 2 & \text{for } u = 1 \text{ to } 7 \end{aligned}$$

The structure of the C DCT coefficient block is shown in Figure 13 b). DCT coefficients $C(t, u)$ of the C DCT coefficient block are divided into 6 DCT coefficient groups (CGs).

Let CGNS be the CG number as shown in Figure 13 b)

CGNS = 0, 1, 2, 3, 4, 5.

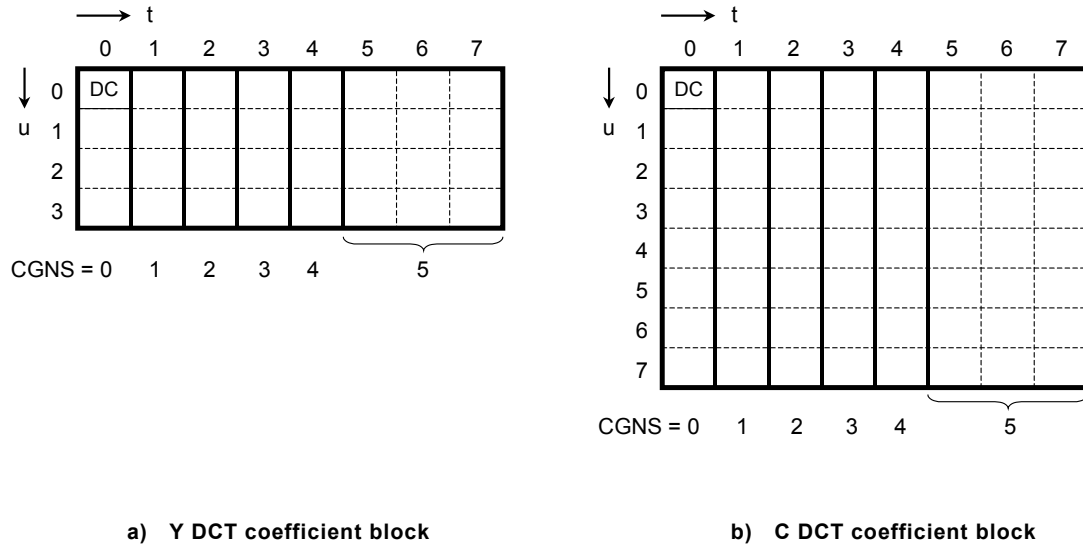


Figure 13 – The structure of DCT coefficient block

4.6 Categorization and weighting

Each MB is categorized into one of the categories and weighting is performed by multiplying all AC coefficients of the subject MB by a weighting function $W(t, u)$ selected by the category. The DC coefficient is not weighted.

There are four categories (CY0, CY1, CY2, CY3) for the Y DCT block, and three categories (CC0, CC1, CC2) for the C_B/C_R DCT block. Each category has its own weighting function. The weighting functions are selectively used to optimize the data compression process by categorization.

4.6.1 Categorization

MB categorization is identified by category flags of FMB, FYa, FYb, FYc, FYd, FCB and FCR. FYa, FYb, FYc, and FYd correspond to the Y DCT blocks of Ya, Yb, Yc, Yd in Figure 6 respectively. If the value of the quantized DC coefficient (–255, ..., 0, ..., 255, decimal) of C_B DCT block is less than 24, then FCB is set to 0, else FCB is set to 1. If the value of quantized DC coefficient (–255, ..., 0, ..., 255) of the C_R DCT block is less than 44, then FCR is set to 0, else FCR is set to 1.

Categories of CY0, CY1, CY2, and CY3 for the Y signal and categories of CC0, CC1, and CC2 for C signal are expressed by the flags as shown in Tables 2 to 4.

Table 2 – Categorization of Y signal

Flag				Category
FMB	FYa, FYb, FYc, FYd	FCB	FCR	
1	-	-	-	CY0
0	1	-	-	CY1
0	0	1	-	CY2
0	0	-	1	CY2
0	0	0	0	CY3

where -: arbitrary

Table 3 – Categorization of C_B signal

Flag		Category
FMB	FCB	
1	-	CC0
0	1	CC1
0	0	CC2

where -: arbitrary

Table 4 – Categorization of C_R signal

Flag		Category
FMB	FCR	
1	-	CC0
0	1	CC1
0	0	CC2

where -: arbitrary

4.6.2 Weighting

Weighting function $W(t, u)$ in each category is defined below:

4.6.2.1 For Y signal**Category CY0**

$$W(t, u) = \text{TableCY0}(t, u) \times \cos(0,045\pi t) \times \cos(0,060\pi u) / \sqrt{2}$$

Table 5 – Table CY0(t, u)

$\begin{matrix} t \\ u \end{matrix}$	0	1	2	3	4	5	6	7
0	-	0,25	0,25	0,125	0,125	0,125	0,125	0,125
1	0,25	0,25	0,25	0,125	0,125	0,125	0,062 5	0,062 5
2	0,25	0,25	0,125	0,125	0,125	0,062 5	0,062 5	0,062 5
3	0,125	0,125	0,125	0,125	0,125	0,062 5	0,062 5	0,062 5

where -: N.A.

Category CY1

$$W(t, u) = \text{TableCY1}(t, u) \times \cos(0,045\pi t) \times \cos(0,0585\pi u) / \sqrt{2}$$

Table 6 – Table CY1(t, u)

$\begin{matrix} t \\ u \end{matrix}$	0	1	2	3	4	5	6	7
0	-	0,5	0,5	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
1	0,5	0,5	0,5	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
2	0,5	0,5	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
3	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$

where -: N.A.

Category CY2

$$W(t, u) = \text{Table CY2}(t, u) \times \cos(0,045\pi t) \times \cos(0,0585\pi u) / \sqrt{2}$$

Table 7 – Table CY2(t, u)

$\begin{matrix} t \\ u \end{matrix}$	0	1	2	3	4	5	6	7
0	-	1	1	0,5	0,5	0,5	0,5	0,5
1	1	1	0,5	0,5	0,5	0,5	0,5	0,5
2	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
3	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5

where -: N.A.

Category CY3

$$W(t, u) = \text{TableCY3}(t, u) \times \cos(0,045\pi t) \times \cos(0,0585\pi u) / \sqrt{2}$$

Table 8 – Table CY3(t, u)

$\begin{matrix} t \\ u \end{matrix}$	0	1	2	3	4	5	6	7
0	-	0,5	0,5	0,5	0,5	0,5	0,5	0,5
1	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
2	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
3	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5

where -: N.A.

4.6.2.2 For C_B/C_R signal

Category CC0

$$W(t, u) = \text{TableCC0}(t, u) \times \cos(0,065\pi t) \times \cos(0,065\pi u)$$

Table 9 – Table CC0(t, u)

$\begin{matrix} t \\ u \end{matrix}$	0	1	2	3	4	5	6	7
0	-	0,25	0,25	0,125	0,125	0,125	0,125	0,125
1	0,25	0,25	0,125	0,125	0,125	0,125	0,125	0,062 5
2	0,25	0,125	0,125	0,125	0,125	0,125	0,062 5	0,062 5
3	0,125	0,125	0,125	0,125	0,125	0,062 5	0,062 5	0,062 5
4	0,125	0,125	0,125	0,125	0,062 5	0,062 5	0,062 5	0,062 5
5	0,125	0,125	0,125	0,062 5	0,062 5	0,062 5	0,062 5	0,062 5
6	0,125	0,125	0,062 5	0,062 5	0,062 5	0,062 5	0,062 5	0,062 5
7	0,125	0,062 5	0,062 5	0,062 5	0,062 5	0,062 5	0,062 5	0,062 5

where -: N.A.

Category CC1

$$W(t, u) = \text{TableCC1}(t, u) \times \cos(0,065\pi t) \times \cos(0,065\pi u)$$

Table 10 – Table CC1(t, u)

$\begin{matrix} t \\ u \end{matrix}$	0	1	2	3	4	5	6	7
0	-	1	1	1/	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
1	1	1	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
2	1	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
3	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
4	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
5	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
6	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$
7	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$

where -: N.A.

– Category CC2

$$W(t, u) = \text{TableCC2}(t, u) \times \cos(0,065\pi t) \times \cos(0,065\pi u)$$

Table 11 – Table CC2(t, u)

$\begin{matrix} t \\ u \end{matrix}$	0	1	2	3	4	5	6	7
0	-	0,5	0,5	0,5	0,5	0,5	0,5	0,5
1	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
2	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
3	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
4	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
6	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
7	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5

where -: N.A.

4.7 CG shuffling

In order to improve data robustness against error, weighted DCT CGs are shuffled within the same CGNSs of the 6 SMBs to 12 RMBs as shown in Figures 14 and 15. Each RMB comprises 4 Y shuffled DCT coefficient blocks, one shuffled C_B DCT coefficient block and one shuffled C_R DCT coefficient block.

Let Ycoef(HS, VS, YS, CGNS) be the DCT CG which is referred by CGNS, YS, VS, and HS.

Let HR be the column position number of RMB

HR = 0, 1, 2, ..., 11.

Let VR be the row position number of RMB

VR = 0, 1, 2, ..., 179.

Let YR be the Y DCT coefficient block number within one RMB

YR = 0, 1, 2, 3.

Let CGNR be the DCT CG number of one Y DCT coefficient block or one C_B/C_R DCT coefficient block within one RMB

CGNR = 0, 1, 2, ..., 5.

Let YRcoef(HR, VR, YR, CGNR) be the DCT CG which is referred by CGNR, YR, VR, and HR.

The shuffling method of Y DCT CGs is described in the following equations.

For HR = 0 to 5

$$\text{YRcoef}(\text{HR}, \text{VR}, \text{YR}, \text{CGNR}) = \text{Ycoef}((\text{CGNR} - \text{HR} - \text{int}(\text{VR} / 32)) \bmod 6, \text{VR}, \\ \text{YR} + 4 \times \text{int}(((\text{CGNR} - \text{HR}) \bmod 6) / 3), \text{CGNR})$$

For HR = 6 to 11

$$\text{YRcoef}(\text{HR}, \text{VR}, \text{YR}, \text{CGNR}) = \text{Ycoef}((1 - (\text{CGNR} + \text{HR} + \text{int}(\text{VR} / 32))) \bmod 6, \text{VR}, \\ \text{YR} + 4 \times \text{int}(((4 - (\text{CGNR} + \text{HR})) \bmod 6) / 3), \text{CGNR})$$

Let Ccoef(HS, VS, CS, CGNS) be the DCT CG which is referred by CGNS, CS, VS, and HS.

Let CRcoef(HR, VR, CGNR) be the DCT CG which is referred by CGNR, VR, and HR.

The shuffling method of C_B/C_R DCT CGs is described in the following equations.

For HR = 0 to 5

$$\text{CRcoef}(\text{HR}, \text{VR}, \text{CGNR}) = \text{Ccoef}((\text{CGNR} - \text{HR} - \text{int}(\text{VR} / 32)) \bmod 6, \text{VR}, \\ \text{int}(((\text{CGNR} - \text{HR}) \bmod 6) / 3), \text{CGNR})$$

For HR = 6 to 11

$$\text{CRcoef}(\text{HR}, \text{VR}, \text{CGNR}) = \text{Ccoef}((1 - (\text{CGNR} + \text{HR} + \text{int}(\text{VR} / 32))) \bmod 6, \text{VR}, \\ \text{int}((4 - (\text{CGNR} + \text{HR}) \bmod 6) / 3), \text{CGNR})$$

1 SMB (8 Y DCT blocks)

YS = 0	YS = 4	YS = 6	YS = 2
YS = 1	YS = 5	YS = 7	YS = 3

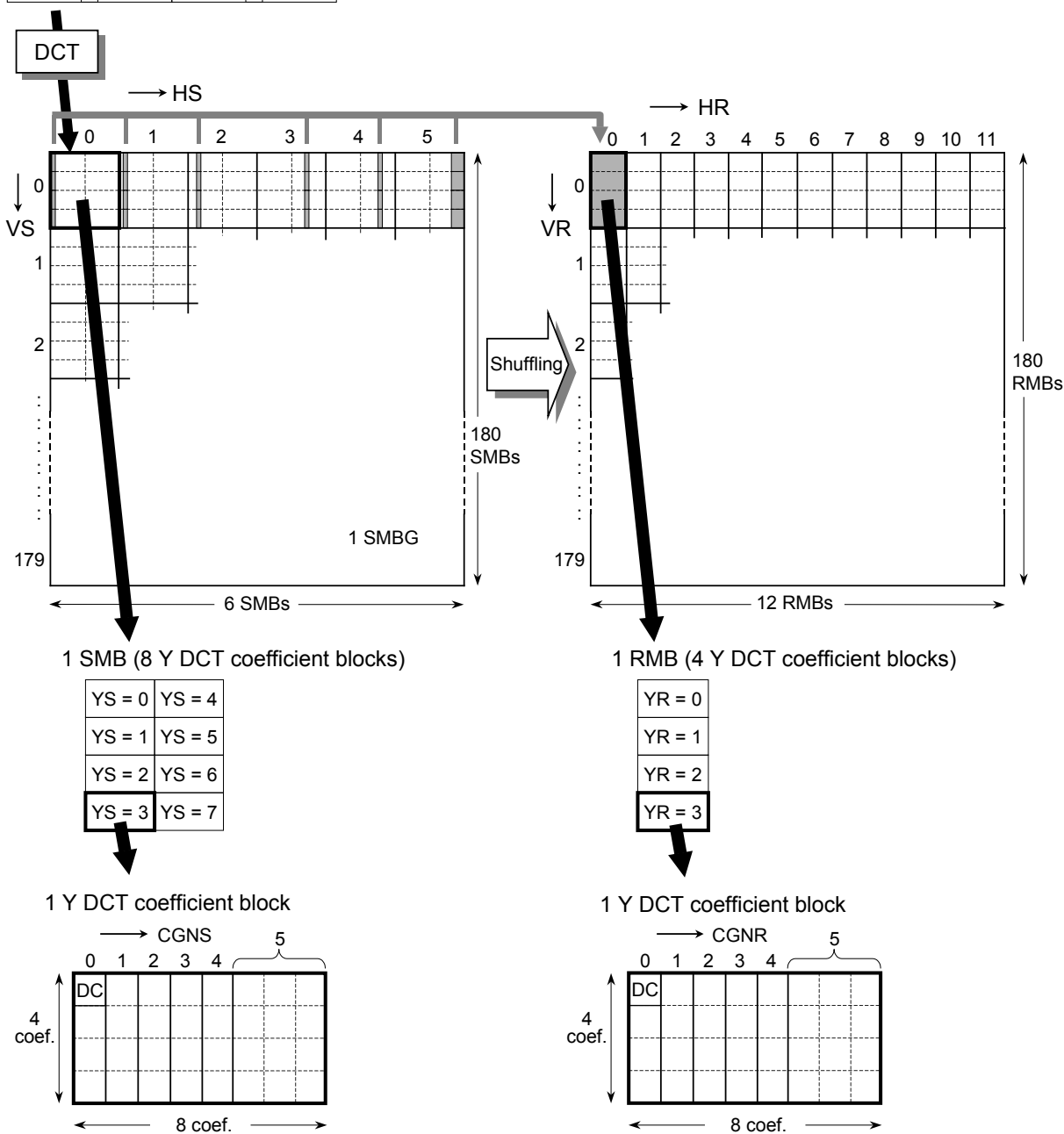


Figure 14 – CG shuffling for Y

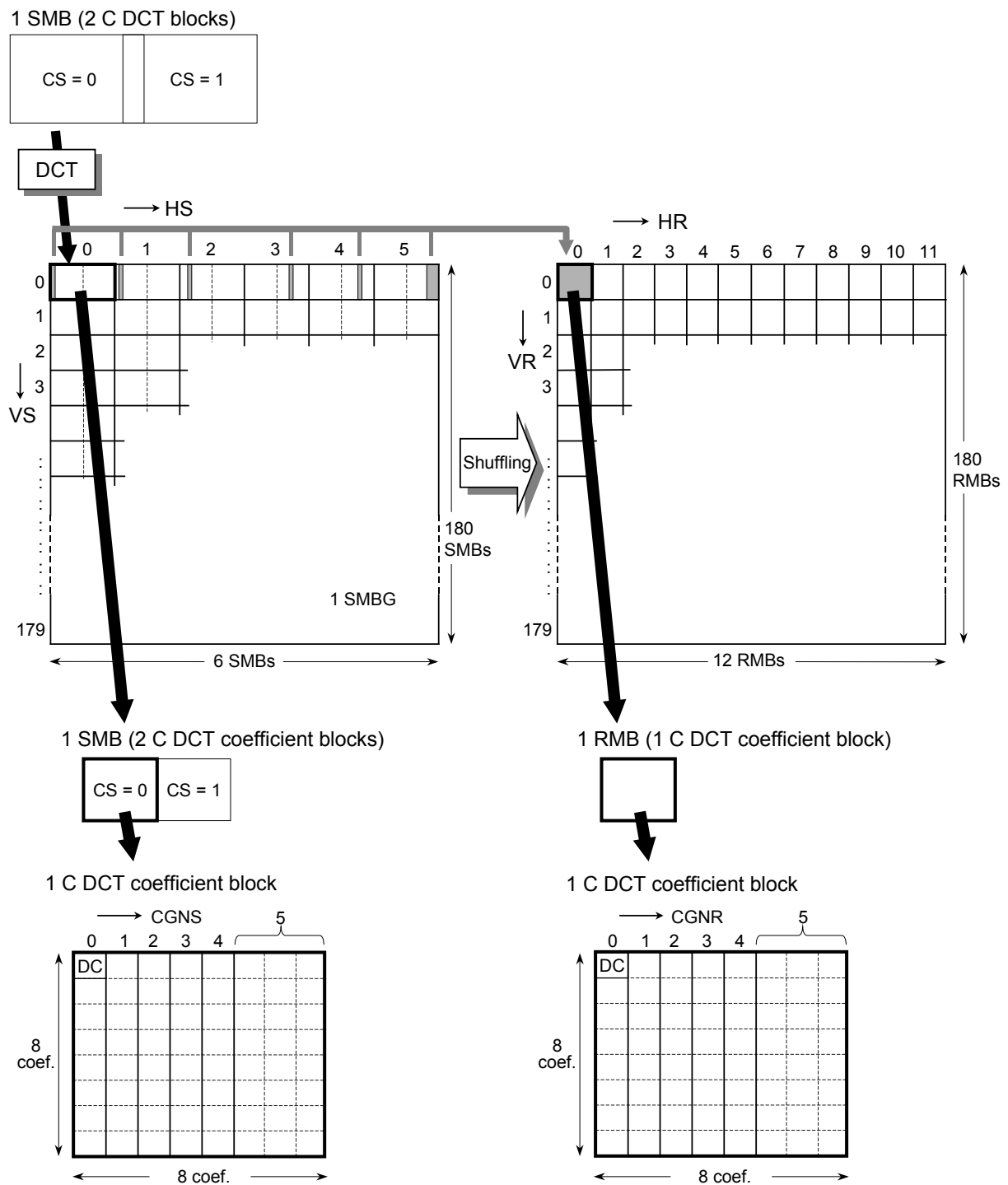


Figure 15 – CG shuffling for C

4.8 RMB shuffling

In order to improve data robustness against error, RMBs are shuffled within the column of 180 RMBs as shown in Figure 16.

Let Z be the row position number of the RMB after RMB shuffling.

$Z = 0, 1, 2, \dots, 179$.

The method of RMB shuffling is described in the following equation:

$$Z = (17 \times (VR - \text{Offset}(HR))) \bmod 180$$

where value of $\text{Offset}(HR)$

HR	Offset(HR)
0	0
1	165
2	150
3	135
4	120
5	105
6	90
7	75
8	60
9	45
10	30
11	15

Then, the RMBs corresponding to one SMBG are divided into 4 RMB Groups (RMBGs). There are 540 RMBs in each RMBG.

Let R_g be the RMBG number within the RMBs as shown in Figure 16

$R_g = 0, 1, 2, 3$.

Let R_n be the number of RMB coding order in each RMBG

$R_n = 0, 1, 2, \dots, 539$.

The dividing method is described in the equation:

$$R_g = HR \bmod 4$$

$$R_n = Z + 180 \times \text{int} (HR / 4)$$

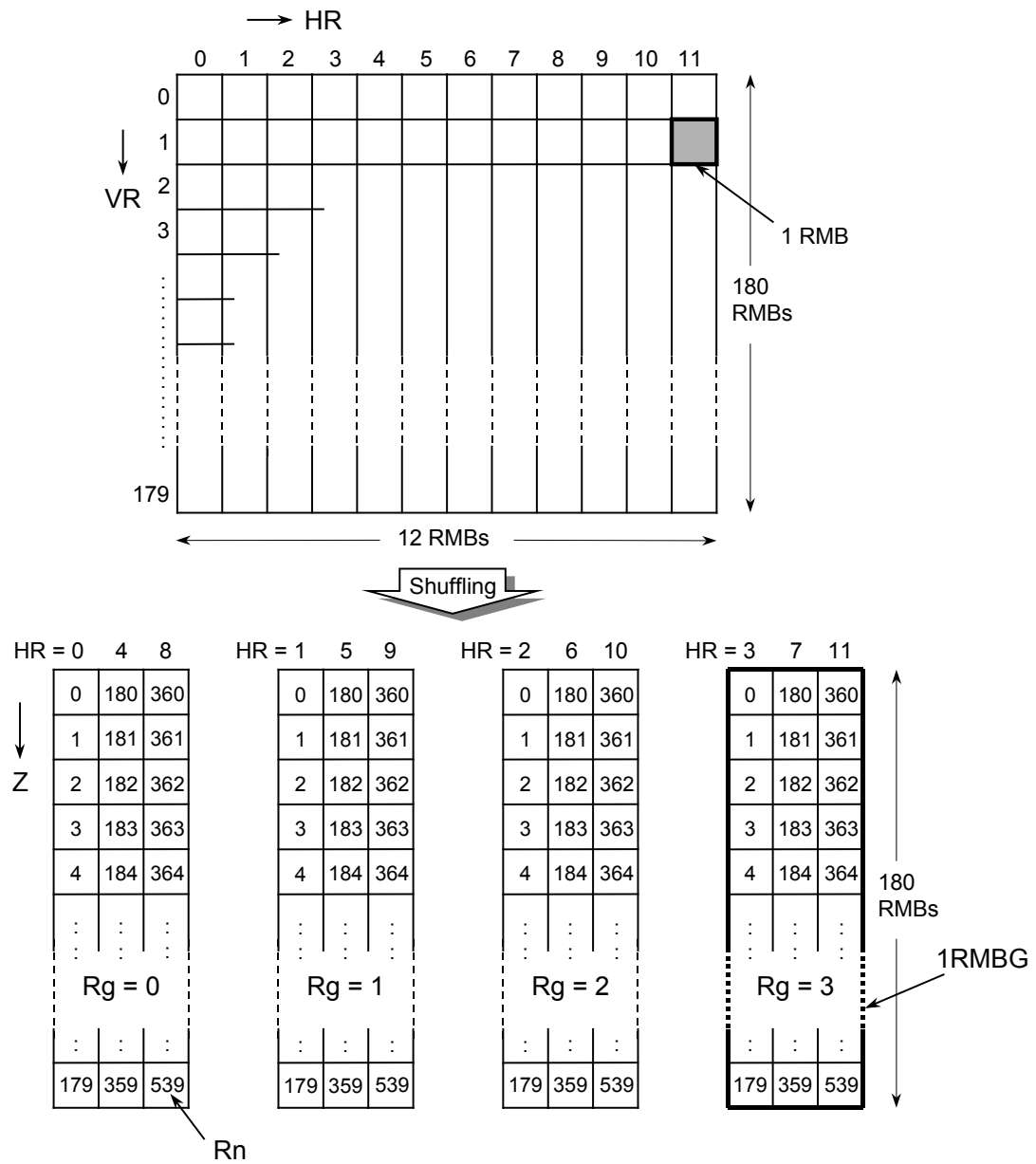


Figure 16 – RMB shuffling