TSG-RAN Working Group1 meeting #15
Berlin, Germany, August 22 – 25, 2000

TSGR1#15(00)0858

Agenda item:

Source: **NTT DoCoMo, Nokia and Nortel Networks**

Title: **Editorial corrections in Turbo code internal interleaver section**

Document for: **Decision**

Introduction

This document includes CRs on editorial corrections in Turbo code internal interleaver section to clarify the correct interleaving function and to align mathematical notations with preferred notations shown in TS25.201 Annex A. The interleaving algorithm itself is not changed through these corrections at all. The major corrections, which should be applied for both 25.212 and 25.222 identically, are as follows:

Section 4.2.3.2.3 Turbo code internal linterleaver

- Align the mathematical notations with preferred notations.

Section 4.2.3.2.3.1 Bits-input to rectangular matrix

- Add the explicit description about the dummy bits padding: the previous description has included the implicit padding function corresponding to the explicit pruning function. However, both functions should be described explicitly to indicate the correct bit operation. The specific value should not be specified for dummy bits since the value will not affect the interleaving function itself.

- Align the mathematical notations with preferred notations.

Section 4.2.3.2.3.2 Intra-row and inter-row permutations

- Align the mathematical notations with preferred notations.

Section 4.2.3.2.3.3 Bits-output from rectangular matrix with pruning

- Add the explicit description about the dummy bits padded in bits-input.

- Align the mathematical notations with preferred notations.

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25.212	**CR**	**085**	Current Version:	3.3.0

GSM (AA.BB) or 3G (AA.BBB) specification number ↑ *↑ CR number as allocated by MCC support team*

For submission to:	RAN #9	for approval	X	Strategic		(for SMG use only)
list expected approval meeting # here ↑		For information		non-strategic		

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Proposed change affects: (U)SIM [ ] ME [X] UTRAN / Radio [X] Core Network [ ]
(at least one should be marked with an X)

Source: NTT DoCoMo, Nokia and Nortel Networks **Date:** 17-August-2000

Subject: Editorial corrections in Turbo code internal interleaver section

Work item:

Category: *(only one category shall be marked with an X)*

F	Correction	X	**Release:**	Phase 2	
A	Corresponds to a correction in an earlier release			Release 96	
B	Addition of feature			Release 97	
C	Functional modification of feature			Release 98	
D	Editorial modification			Release 99	X
				Release 00	

Reason for change: To clarify bits padding and pruning for rectangular matrix.
To align mathematical notations with preferred notations shown in TS25.201 Annex A.

Clauses affected: 4.2.3.2.3 of TS25.212

Other specs affected:

Other 3G core specifications		→ List of CRs:
Other GSM core specifications		→ List of CRs:
MS test specifications		→ List of CRs:
BSS test specifications		→ List of CRs:
O&M specifications		→ List of CRs:

Other comments:

The initial value of the shift registers of the 8-state constituent encoders shall be all zeros when starting to encode the input bits.

Output from the Turbo coder is

$$x_1, z_1, z'_1, x_2, z_2, z'_2, \ldots, x_K, z_K, z'_K,$$

where $x_1, x_2, \ldots, x_K$ are the bits input to the Turbo coder i.e. both first 8-state constituent encoder and Turbo code internal interleaver, and K is the number of bits, and $z_1, z_2, \ldots, z_K$ and $z'_1, z'_2, \ldots, z'_K$ are the bits output from first and second 8-state constituent encoders, respectively.

The bits output from Turbo code internal interleaver are denoted by $x'_1, x'_2, \ldots, x'_K$, and these bits are to be input to the second 8-state constituent encoder.

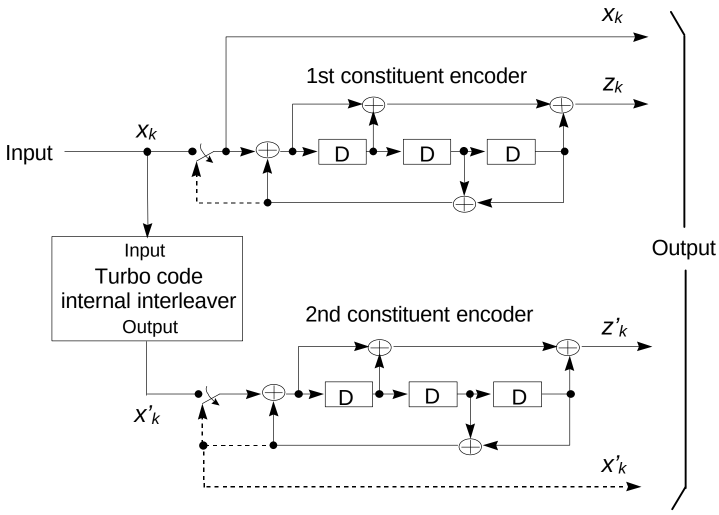

Figure 4: Structure of rate 1/3 Turbo coder (dotted lines apply for trellis termination only)

4.2.3.2.2 Trellis termination for Turbo coder

Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded. Tail bits are padded after the encoding of information bits.

The first three tail bits shall be used to terminate the first constituent encoder (upper switch of figure 4 in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of figure 4 in lower position) while the first constituent encoder is disabled.

The transmitted bits for trellis termination shall then be:

$$x_{K+1}, z_{K+1}, x_{K+2}, z_{K+2}, x_{K+3}, z_{K+3}, x'_{K+1}, z'_{K+1}, x'_{K+2}, z'_{K+2}, x'_{K+3}, z'_{K+3}.$$

4.2.3.2.3 Turbo code internal interleaver

The Turbo code internal interleaver consists of bits-input to a rectangular matrix with padding, intra-row and inter-row permutations of the rectangular matrix, and bits-output from the rectangular matrix with pruning. The bits input to the Turbo code internal interleaver are denoted by $x_1, x_2, x_3, \ldots, x_K$, where K is the integer number of the bits and takes one value of $40 \leq K \leq 5114$. The relation between the bits input to the Turbo code internal interleaver and the bits input to the channel coding is defined by $x_k = o_{irk}$ and $K = K_i$.

The following subclause specific symbols are used in subclauses 4.2.3.2.3.1 to 4.2.3.2.3.3:

~~K~~K	Number of bits input to Turbo code internal interleaver
~~R~~R	Number of rows of rectangular matrix

~~C~~ C	Number of columns of rectangular matrix
~~p~~ p	Prime number
~~v~~ v	Primitive root
~~s(i)~~ $\langle s(j) \rangle_{j\in\{0,1,\cdots,p-2\}}$	Base sequence for intra-row permutation
~~q_i~~ q_i	Minimum prime integers
~~r_i~~ r_i	Permuted prime integers
~~T(j)~~ $\langle T(i) \rangle_{i\in\{0,1,\cdots,R-1\}}$	Inter-row permutation pattern
~~U_j(i)~~ $\langle U_i(j) \rangle_{j\in\{0,1,\cdots,C-1\}}$	Intra-row permutation pattern of i-th row
~~i~~ i	Index of row number of rectangular matrix
~~j~~ j	Index of column number of rectangular matrix
~~k~~ k	Index of bit sequence

4.2.3.2.3.1 Bits-input to rectangular matrix with padding

The bit sequence $x_1, x_2, x_3, \ldots, x_K$ input to the Turbo code internal interleaver ~~x_k~~ is written into the rectangular matrix as follows:

(1) Determine the number of rows ~~R~~ of the rectangular matrix, R, such that:

$$R = \begin{cases} 5, \text{if } (40 \le K \le 159) \\ 10, \text{if } ((160 \le K \le 200) \text{ or } (481 \le K \le 530)) \\ 20, \text{if } (K = \text{any other value}) \end{cases} .$$

~~where t~~The rows of rectangular matrix are numbered 0, 1, 2, …, R - 1 from top to bottom.

(2) Determine the number of columns ~~C~~ of rectangular matrix, C, such that:

if (481 ≤ K ≤ 530) then

p = 53 and C = p.

else

Find minimum prime p such that

~~$(p + 1) - K/R \geq 0$~~ $K \le R \times (p+1)$,

and determine C such that

$$C = \begin{cases} p-1 & if \quad K \le R\times(p-1) \\ p & if \quad R\times(p-1) < K \le R\times p \\ p+1 & if \quad R\times p < K \end{cases} .$$

~~if (p - K/R ≥ 0) then~~

~~if (p - 1 - K/R ≥ 0) then~~

~~C = p - 1.~~

~~else~~

~~C = p.~~

~~end if~~

~~else~~

~~C = p + 1~~

~~end if~~

~~end if~~

~~where t~~The columns of rectangular matrix are numbered 0, 1, 2, …, C - 1 from left to right.

(3) Write the input bit sequence ~~x_k~~ $x_1, x_2, x_3, \ldots, x_K$ into the $R \times C$ rectangular matrix row by row starting with bit ~~x~~y_1 in column 0 of row 0:

$$\begin{bmatrix} x_1 & x_2 & x_3 & \cdots x_C \\ x_{(C+1)} & x_{(C+2)} & x_{(C+3)} & \cdots x_{2C} \\ \vdots & \vdots & \vdots & \cdots \vdots \\ x_{((R-1)C+1)} & x_{((R-1)C+2)} & x_{((R-1)C+3)} & \cdots x_{RC} \end{bmatrix} \begin{bmatrix} y_1 & y_2 & y_3 & \cdots y_C \\ y_{(C+1)} & y_{(C+2)} & y_{(C+3)} & \cdots y_{2C} \\ \vdots & \vdots & \vdots & \cdots \vdots \\ y_{((R-1)C+1)} & y_{((R-1)C+2)} & y_{((R-1)C+3)} & \cdots y_{R\times C} \end{bmatrix}$$

where if $R \times C > K$, the dummy bits are padded such that $y_k = 0 or 1$ for $k = K + 1, K + 2, \ldots, R \times C$. These dummy bits are pruned away from the output of the rectangular matrix after intra-row and inter-row permutations.

4.2.3.2.3.2 Intra-row and inter-row permutations

After the bits-input to the $R \times C$ rectangular matrix, the intra-row and inter-row permutations for the $R \times C$ rectangular matrix are performed by using the following algorithm.

(1) Select a primitive root v from table 2 on the right side of the value of the prime p.

Table 2: Table of prime *p* and associated primitive root *v*

p	v	p	v	p	v	p	v	p	v
7	3	47	5	101	2	157	5	223	3
11	2	53	2	103	5	163	2	227	2
13	2	59	2	107	2	167	5	229	6
17	3	61	2	109	6	173	2	233	3
19	2	67	2	113	3	179	2	239	7
23	5	71	7	127	3	181	2	241	7
29	2	73	5	131	2	191	19	251	6
31	3	79	3	137	3	193	5	257	3
37	2	83	2	139	2	197	2		
41	6	89	3	149	2	199	3		
43	3	97	5	151	6	211	2		

(2) Construct the base sequence ~~$s(i)$~~ $\langle s(j) \rangle_{j\in\{0,1,\cdots,p-2\}}$ for intra-row permutation as:

~~$s(i) = [v \times s(i-1)] \bmod p$~~ $s(j) = (v \times s(j-1)) \bmod p$, ~~$i$~~$j$ = 1, 2,…, (p - 2)~~.~~, and $s(0)$ = 1.

(3) ~~Let~~Assign q_0 = 1 be the first prime integer in ~~$\{q_j\}$~~the sequence $\langle q_i \rangle_{i\in\{0,1,\cdots,R-1\}}$, and ~~select~~determine the ~~consecutive minimum~~ prime integer~~s~~ ~~$\{q_j\}$~~ in the sequence $\langle q_i \rangle_{i\in\{0,1,\cdots,R-1\}}$ ~~(j = 1, 2, …, R - 1)~~ to be a least prime integer such that~~:~~

g.c.d~~{~~(q_i, p - 1~~}~~) = 1, $q_i > 6$, and $q_i > q_{(i-1)}$~~,~~ for each i = 1, 2, …, R – 1.

Here ~~where~~ g.c.d. is greatest common divisor.

(4) Permute ~~$\{q_j\}$~~the sequence $\langle q_i \rangle_{i\in\{0,1,\cdots,R-1\}}$ to make ~~$\{r_j\}$~~the sequence $\langle r_i \rangle_{i\in\{0,1,\cdots,R-1\}}$ such that

$r_{T(ji)} = q_{ji}$, ji = 0, 1, …, R - 1,

where ~~$T(j)$ (j = 0, 1, 2, …, R - 1)~~ $\langle T(i) \rangle_{i \in \{0,1,\cdots,R-1\}}$ is the inter-row permutation pattern defined as the one of the ~~following~~ four kind of patterns, which are shown in table 3,~~: Pat_1, Pat_2, Pat_3 and Pat_4~~ depending on the number of input bits K.

$$\{T(0),T(1),T(2),\ldots,T(R-1)\} = \begin{cases} Pat_4 & \text{if } (40 \le K \le 159) \\ Pat_3 & \text{if } (160 \le K \le 200) \\ Pat_1 & \text{if } (201 \le K \le 480) \\ Pat_3 & \text{if } (481 \le K \le 530) \\ Pat_1 & \text{if } (531 \le K \le 2280) \\ Pat_2 & \text{if } (2281 \le K \le 2480) \\ Pat_1 & \text{if } (2481 \le K \le 3160) \\ Pat_2 & \text{if } (3161 \le K \le 3210) \\ Pat_1 & \text{if } (3211 \le K \le 5114) \end{cases},$$

~~where Pat_1, Pat_2, Pat_3 and Pat_4 have the following patterns respectively.~~

~~Pat_1: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11}~~

~~Pat_2: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10}~~

~~Pat_3: {9, 8, 7, 6, 5, 4, 3, 2, 1, 0}~~

~~Pat_4: {4, 3, 2, 1, 0}~~

Table 3: Inter-row permutation patterns for Turbo code internal interleaver

Number of input bits K	Number of rows R	Inter-row permutation patterns <$T(0)$, $T(1)$, …, $T(R - 1)$>
(40 ≤ K ≤ 159)	5	<4, 3, 2, 1, 0>
(160 ≤ K ≤ 200) or (481 ≤ K ≤ 530)	10	<9, 8, 7, 6, 5, 4, 3, 2, 1, 0>
(2281 ≤ K ≤ 2480) or (3161 ≤ K ≤ 3210)	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10>
K = any other value	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11>

(5) Perform the ji-th (ji = 0, 1,~~2,~~ …, R - 1) intra-row permutation as:

if ($C = p$) then

~~$U_j(i) = s([i \times r_j] \mathrm{mod}(p-1))$~~ $U_i(j) = s((j \times r_i) \mathrm{mod}(p-1))$, ij = 0, 1,~~2,~~ …, (p - 2)~~., ,~~ and $U_{ji}(p - 1) = 0$,

where $U_{ji}(ij)$ is the ~~input~~original bit position of ij-th ~~output after the permutation~~permuted bit of ji-th row.

end if

if ($C = p + 1$) then

~~$U_j(i) = s([i \times r_j] \mathrm{mod}(p-1))$~~ $U_i(j) = s((j \times r_i) \mathrm{mod}(p-1))$, ij = 0, 1,~~2,~~ …, (p - 2).~~,~~ $U_{ji}(p - 1) = 0$, and $U_{ji}(p) = p$,

where $U_{ji}(ij)$ is the ~~input~~original bit position of ij-th ~~output after the permutation~~permuted bit of ji-th row, and

if (K = ~~$C \times$~~ $R \times C$) then

Exchange $U_{R-1}(p)$ with $U_{R-1}(0)$.

end if

end if

if ($C = p$ - 1) then

~~$U_j(i) = s([i \times r_j] \mathrm{mod}(p-1)) - 1$~~ $U_i(j) = s((j \times r_i) \mathrm{mod}(p-1)) - 1$, ~~$i$~~$j$ = 0, 1,~~ 2,~~ …, (p - 2),

where $U_{\sout{j}i}$(~~i~~j) is the ~~input~~ original bit position of ~~i~~j-th ~~output after the permutation~~permuted bit of ~~j~~i-th row.

end if

(6) Perform the inter-row permutation based on the pattern ~~$T(j)$ (j = 0, 1, 2, …, R - 1)~~ $\langle T(i) \rangle_{i \in \{0,1,\cdots,R-1\}}$,

where T(~~j~~i) is the original row position of the ~~j~~i-th permuted row.

~~**Table 2: Table of prime *p* and associated primitive root *v***~~

~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~v~~
~~7~~	~~3~~	~~47~~	~~5~~	~~101~~	~~2~~	~~157~~	~~5~~	~~223~~	~~3~~
~~11~~	~~2~~	~~53~~	~~2~~	~~103~~	~~5~~	~~163~~	~~2~~	~~227~~	~~2~~
~~13~~	~~2~~	~~59~~	~~2~~	~~107~~	~~2~~	~~167~~	~~5~~	~~229~~	~~6~~
~~17~~	~~3~~	~~61~~	~~2~~	~~109~~	~~6~~	~~173~~	~~2~~	~~233~~	~~3~~
~~19~~	~~2~~	~~67~~	~~2~~	~~113~~	~~3~~	~~179~~	~~2~~	~~239~~	~~7~~
~~23~~	~~5~~	~~71~~	~~7~~	~~127~~	~~3~~	~~181~~	~~2~~	~~241~~	~~7~~
~~29~~	~~2~~	~~73~~	~~5~~	~~131~~	~~2~~	~~191~~	~~19~~	~~251~~	~~6~~
~~31~~	~~3~~	~~79~~	~~3~~	~~137~~	~~3~~	~~193~~	~~5~~	~~257~~	~~3~~
~~37~~	~~2~~	~~83~~	~~2~~	~~139~~	~~2~~	~~197~~	~~2~~		
~~41~~	~~6~~	~~89~~	~~3~~	~~149~~	~~2~~	~~199~~	~~3~~		
~~43~~	~~3~~	~~97~~	~~5~~	~~151~~	~~6~~	~~211~~	~~2~~		

4.2.3.2.3.3 Bits-output from rectangular matrix with pruning

After intra-row and inter-row permutations, the bits of the permuted rectangular matrix are denoted by y'_k:

~~$$\begin{bmatrix} y'_1 & y'_{(R+1)} & y'_{(2R+1)} & \cdots y'_{((C-1)R+1)} \\ y'_2 & y'_{(R+2)} & y'_{(2R+2)} & \cdots y'_{((C-1)R+2)} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ y'_R & y'_{2R} & y'_{3R} & \cdots & y'_{CR} \end{bmatrix}$$~~

$$\begin{bmatrix} y'_1 & y'_{(R+1)} & y'_{(2R+1)} & \cdots y'_{((C-1)R+1)} \\ y'_2 & y'_{(R+2)} & y'_{(2R+2)} & \cdots y'_{((C-1)R+2)} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ y'_R & y'_{2R} & y'_{3R} & \cdots & y'_{C \times R} \end{bmatrix}$$

The output of the Turbo code internal interleaver is the bit sequence read out column by column from the intra-row and inter-row permuted $R \times C$ rectangular matrix starting with bit y'_1 in row 0 of column 0 and ending with bit y'_{CR} in row R - 1 of column C - 1. The output is pruned by deleting dummy bits that were ~~not present~~padded ~~in~~to the input ~~bit sequence~~of the rectangular matrix before intra-row and inter row permutations, i.e. bits y'_k that corresponds to bits ~~x~~y_k with $k > K$ are removed from the output. The bits output from Turbo code internal interleaver are denoted by x'_1, x'_2, …, x'_K, where x'_1 corresponds to the bit y'_k with smallest index k after pruning, x'_2 to the bit y'_k with second smallest index k after pruning, and so on. The number of bits output from Turbo code internal interleaver is K and the total number of pruned bits is:

$R \times C - K$.

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25.222	**CR**	**041**	Current Version:	3.3.0

GSM (AA.BB) or 3G (AA.BBB) specification number ↑ *↑ CR number as allocated by MCC support team*

For submission to:	RAN #9	for approval	X	Strategic		*(for SMG use only)*
list expected approval meeting # here ↑		For information		non-strategic		

Form: CR cover sheet, version 2 for 3GPP and SMG The latest version of this form is available from: ftp://ftp.3gpp.org/Information/CR-Form-v2.doc

Proposed change affects: *(at least one should be marked with an X)*	(U)SIM		ME	X	UTRAN / Radio	X	Core Network

Source: NTT DoCoMo, Nokia and Nortel Networks **Date:** 17-August-2000

Subject: Editorial corrections in Turbo code internal interleaver section

Work item:

Category:				**Release:**		
	F	Correction	X		Phase 2	
	A	Corresponds to a correction in an earlier release			Release 96	
(only one category	B	Addition of feature			Release 97	
shall be marked	C	Functional modification of feature			Release 98	
with an X)	D	Editorial modification			Release 99	X
					Release 00	

Reason for change: To clarify bits padding and pruning for rectangular matrix.
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Other specs affected:			
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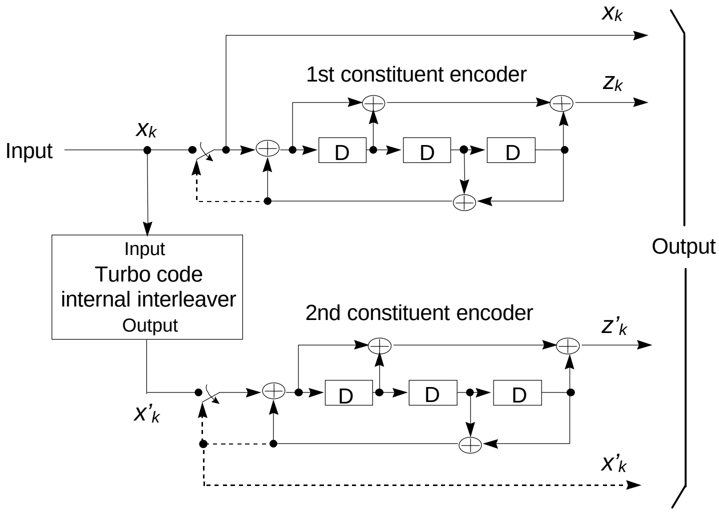
Other comments:

where $x_1, x_2, \ldots, x_K$ are the bits input to the Turbo coder i.e. both first 8-state constituent encoder and Turbo code internal interleaver, and K is the number of bits, and $z_1, z_2, \ldots, z_K$ and $z'_1, z'_2, \ldots, z'_K$ are the bits output from first and second 8-state constituent encoders, respectively.

The bits output from Turbo code internal interleaver are denoted by $x'_1, x'_2, \ldots, x'_K$, and these bits are to be input to the second 8-state constituent encoder.



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4.2.3.2.2 Trellis termination for Turbo coder

Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded. Tail bits are padded after the encoding of information bits.

The first three tail bits shall be used to terminate the first constituent encoder (upper switch of figure 4 in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of figure 4 in lower position) while the first constituent encoder is disabled.

The transmitted bits for trellis termination shall then be:

$$x_{K+1}, z_{K+1}, x_{K+2}, z_{K+2}, x_{K+3}, z_{K+3}, x'_{K+1}, z'_{K+1}, x'_{K+2}, z'_{K+2}, x'_{K+3}, z'_{K+3}.$$

4.2.3.2.3 Turbo code internal interleaver

The Turbo code internal interleaver consists of bits-input to a rectangular matrix with padding, intra-row and inter-row permutations of the rectangular matrix, and bits-output from the rectangular matrix with pruning. The bits input to the Turbo code internal interleaver are denoted by $x_1, x_2, x_3, \ldots, x_K$, where K is the integer number of the bits and takes one value of $40 \leq K \leq 5114$. The relation between the bits input to the Turbo code internal interleaver and the bits input to the channel coding is defined by $x_k = o_{irk}$ and $K = K_i$.

The following subclause specific symbols are used in subclauses 4.2.3.2.3.1 to 4.2.3.2.3.3:

~~K~~ K	Number of bits input to Turbo code internal interleaver
~~R~~ R	Number of rows of rectangular matrix
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~~p~~ p	Prime number
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~~s(i)~~ $\langle s(j) \rangle_{j\in\{0,1,\cdots,p-2\}}$	Base sequence for intra-row permutation
~~qi~~ q_i	Minimum prime integers
~~ri~~ r_i	Permuted prime integers

~~T(j)~~ $\langle T(i) \rangle_{i \in \{0,1,\cdots,R-1\}}$ Inter-row permutation pattern

~~$U_j(i)$~~ $\langle U_i(j) \rangle_{j \in \{0,1,\cdots,C-1\}}$ Intra-row permutation pattern of *i*-th row

~~i~~ *i* Index of row number of rectangular matrix

~~j~~ *j* Index of column number of rectangular matrix

~~k~~ k Index of bit sequence

4.2.3.2.3.1 Bits-input to rectangular matrix with padding

The bit sequence $x_1, x_2, x_3, \ldots, x_K$ input to the Turbo code internal interleaver ~~x_k~~ is written into the rectangular matrix as follows:

(1) Determine the number of rows ~~*R*~~ of the rectangular matrix, *R*, such that:

$$R = \begin{cases} 5, \text{if } (40 \le K \le 159) \\ 10, \text{if } ((160 \le K \le 200) \text{ or } (481 \le K \le 530)) \\ 20, \text{if } (K = \text{any other value}) \end{cases} .$$

~~where t~~The rows of rectangular matrix are numbered 0, 1, 2, …, *R* - 1 from top to bottom.

(2) Determine the number of columns ~~*C*~~ of rectangular matrix, *C*, such that:

if (481 ≤ *K* ≤ 530) then

p = 53 and *C* = *p*.

else

Find minimum prime *p* such that

~~$(p + 1) - K/R \geq 0$~~ $K \le R \times (p+1)$,

and determine *C* such that

$$C = \begin{cases} p-1 & \text{if} \quad K \le R \times (p-1) \\ p & \text{if} \quad R \times (p-1) < K \le R \times p \\ p+1 & \text{if} \quad R \times p < K \end{cases} .$$

~~if ($p - K/R \geq 0$) then~~

~~if ($p - 1 - K/R \geq 0$) then~~

~~$C = p - 1$.~~

~~else~~

~~$C = p$.~~

~~end if~~

~~else~~

~~$C = p + 1$~~

~~end if~~

~~end if~~

~~where t~~The columns of rectangular matrix are numbered 0, 1, 2, …, *C* - 1 from left to right.

(3) Write the input bit sequence ~~x_k~~ $x_1, x_2, x_3, \ldots, x_K$ into the $R \times C$ rectangular matrix row by row starting with bit ~~x~~ y_1 in column 0 of row 0:

$$\begin{bmatrix} x_1 & x_2 & x_3 & \cdots x_C \\ x_{(C+1)} & x_{(C+2)} & x_{(C+3)} & \cdots x_{2C} \\ \vdots & \vdots & \vdots & \cdots \vdots \\ x_{((R-1)C+1)} & x_{((R-1)C+2)} & x_{((R-1)C+3)} & \cdots x_{RC} \end{bmatrix} \begin{bmatrix} y_1 & y_2 & y_3 & \cdots y_C \\ y_{(C+1)} & y_{(C+2)} & y_{(C+3)} & \cdots y_{2C} \\ \vdots & \vdots & \vdots & \cdots \vdots \\ y_{((R-1)C+1)} & y_{((R-1)C+2)} & y_{((R-1)C+3)} & \cdots y_{R\times C} \end{bmatrix}$$

where if $R \times C > K$, the dummy bits are padded such that $y_k = 0 or 1$ for $k = K + 1, K + 2, \ldots, R \times C$. These dummy bits are pruned away from the output of the rectangular matrix after intra-row and inter-row permutations.

4.2.3.2.3.2 Intra-row and inter-row permutations

After the bits-input to the $R \times C$ rectangular matrix, the intra-row and inter-row permutations for the $R \times C$ rectangular matrix are performed by using the following algorithm.

(1) Select a primitive root v from table 2 on the right side of the value of the prime p.

Table 2: Table of prime p and associated primitive root v

p	v	p	v	p	v	p	v	p	v
7	3	47	5	101	2	157	5	223	3
11	2	53	2	103	5	163	2	227	2
13	2	59	2	107	2	167	5	229	6
17	3	61	2	109	6	173	2	233	3
19	2	67	2	113	3	179	2	239	7
23	5	71	7	127	3	181	2	241	7
29	2	73	5	131	2	191	19	251	6
31	3	79	3	137	3	193	5	257	3
37	2	83	2	139	2	197	2		
41	6	89	3	149	2	199	3		
43	3	97	5	151	6	211	2		

(2) Construct the base sequence ~~$s(i)$~~ $\langle s(j) \rangle_{j \in \{0,1,\cdots,p-2\}}$ for intra-row permutation as:

~~$s(i) = [v \times s(i-1)] \bmod p$~~ $s(j) = (v \times s(j-1)) \bmod p$, ~~$i$~~$j$ = 1, 2,…, (p - 2)~~.~~, and $s(0)$ = 1.

(3) ~~Let~~Assign q_0 = 1 be the first prime integer in ~~$\{q_j\}$~~the sequence $\langle q_i \rangle_{i \in \{0,1,\cdots,R-1\}}$, and ~~select~~determine the ~~consecutive minimum~~ prime integer~~s~~ ~~$\{q_j\}$~~ in the sequence $\langle q_i \rangle_{i \in \{0,1,\cdots,R-1\}}$ ~~(j = 1, 2, …, R - 1)~~ to be a least prime integer such that~~:~~

g.c.d~~{~~(q_i, p - 1~~}~~) = 1, $q_i > 6$, and $q_i > q_{(i-1)}$~~,~~ for each $i = 1, 2, \ldots, R - 1$.

Here ~~where~~ g.c.d. is greatest common divisor.

(4) Permute ~~$\{q_j\}$~~the sequence $\langle q_i \rangle_{i \in \{0,1,\cdots,R-1\}}$ to make ~~$\{r_j\}$~~the sequence $\langle r_i \rangle_{i \in \{0,1,\cdots,R-1\}}$ such that

$r_{T(i)} = q_i$, i = 0, 1, …, R - 1, where ~~$T(j)$ (j = 0, 1, 2, …, R - 1)~~ $\langle T(i) \rangle_{i \in \{0,1,\cdots,R-1\}}$ is the inter-row permutation pattern defined as the one of the ~~following~~ four kind of patterns, which are shown in table 3, ~~: Pat_1, Pat_2, Pat_3 and Pat_4~~ depending on the number of input bits K.

$$\sout{\{T(0), T(1), T(2), \ldots, T(R-1)\} =} \begin{cases} Pat_4 & \text{if } (40 \le K \le 159) \\ Pat_3 & \text{if } (160 \le K \le 200) \\ Pat_1 & \text{if } (201 \le K \le 480) \\ Pat_3 & \text{if } (481 \le K \le 530) \\ Pat_1 & \text{if } (531 \le K \le 2280) \\ Pat_2 & \text{if } (2281 \le K \le 2480) \\ Pat_1 & \text{if } (2481 \le K \le 3160) \\ Pat_2 & \text{if } (3161 \le K \le 3210) \\ Pat_1 & \text{if } (3211 \le K \le 5114) \end{cases}$$

~~where Pat_1, Pat_2, Pat_3 and Pat_4 have the following patterns respectively.~~

~~Pat_1: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11}~~

~~Pat_2: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10}~~

~~Pat_3: {9, 8, 7, 6, 5, 4, 3, 2, 1, 0}~~

~~Pat_4: {4, 3, 2, 1, 0}~~

Table 3: Inter-row permutation patterns for Turbo code internal interleaver

Number of input bits K	Number of rows R	Inter-row permutation patterns <$T(0)$, $T(1)$, …, $T(R$ - 1)>
(40 ≤ K ≤ 159)	5	<4, 3, 2, 1, 0>
(160 ≤ K ≤ 200) or (481 ≤ K ≤ 530)	10	<9, 8, 7, 6, 5, 4, 3, 2, 1, 0>
(2281 ≤ K ≤ 2480) or (3161 ≤ K ≤ 3210)	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10>
K = any other value	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11>

(5) Perform the ~~j~~i-th (~~j~~i = 0, 1, ~~2,~~ …, R - 1) intra-row permutation as:

if (C = p) then

~~$U_j(i) = s([i \times r_j] \bmod (p-1))$~~ $U_i(j) = s((j \times r_i) \bmod (p-1))$, ~~i~~$j$ = 0, 1, ~~2,~~ …, (p - 2)~~., ,~~ and $U_{\sout{j}i}(p-1) = 0$,

where $U_{\sout{j}i}$(~~i~~j) is the ~~input~~original bit position of ~~i~~j-th ~~output after the permutation~~permuted bit of ~~j~~i-th row.

end if

if (C = p + 1) then

~~$U_j(i) = s([i \times r_j] \bmod (p-1))$~~ $U_i(j) = s((j \times r_i) \bmod (p-1))$, ~~i~~$j$ = 0, 1, ~~2,~~ …, (p - 2)~~.,~~ $U_{\sout{j}i}(p-1) = 0$, and $U_{\sout{j}i}(p) = p$,

where $U_{\sout{j}i}$(~~i~~j) is the ~~input~~original bit position of ~~i~~j-th ~~output after the permutation~~permuted bit of ~~j~~i-th row, and

if (K = ~~$C \times$~~ $R \times C$) then

Exchange $U_{R-1}(p)$ with $U_{R-1}(0)$.

end if

end if

if (C = p - 1) then

~~$U_j(i) = s([i\times r_j]\mathrm{mod}(p-1)) - 1$~~ $U_i(j) = s((j\times r_i)\bmod(p-1))-1$, ~~i~~j = 0, 1, ~~2,~~ …, (p - 2),

where U~~$_j$~~$_i$(~~i~~j) is the ~~input~~ original bit position of ~~i~~j-th ~~output after the permutation~~permuted bit of ~~j~~i-th row.

end if

(6) Perform the inter-row permutation based on the pattern ~~T(j) (j = 0, 1, 2, …, R - 1)~~ $\langle T(i)\rangle_{i\in\{0,1,\cdots,R-1\}}$,

where T(~~j~~i) is the original row position of the ~~j~~i-th permuted row.

~~**Table 2: Table of prime *p* and associated primitive root *v***~~

~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~v~~
~~7~~	~~3~~	~~47~~	~~5~~	~~101~~	~~2~~	~~157~~	~~5~~	~~223~~	~~3~~
~~11~~	~~2~~	~~53~~	~~2~~	~~103~~	~~5~~	~~163~~	~~2~~	~~227~~	~~2~~
~~13~~	~~2~~	~~59~~	~~2~~	~~107~~	~~2~~	~~167~~	~~5~~	~~229~~	~~6~~
~~17~~	~~3~~	~~61~~	~~2~~	~~109~~	~~6~~	~~173~~	~~2~~	~~233~~	~~3~~
~~19~~	~~2~~	~~67~~	~~2~~	~~113~~	~~3~~	~~179~~	~~2~~	~~239~~	~~7~~
~~23~~	~~5~~	~~71~~	~~7~~	~~127~~	~~3~~	~~181~~	~~2~~	~~241~~	~~7~~
~~29~~	~~2~~	~~73~~	~~5~~	~~131~~	~~2~~	~~191~~	~~19~~	~~251~~	~~6~~
~~31~~	~~3~~	~~79~~	~~3~~	~~137~~	~~3~~	~~193~~	~~5~~	~~257~~	~~3~~
~~37~~	~~2~~	~~83~~	~~2~~	~~139~~	~~2~~	~~197~~	~~2~~		
~~41~~	~~6~~	~~89~~	~~3~~	~~149~~	~~2~~	~~199~~	~~3~~		
~~43~~	~~3~~	~~97~~	~~5~~	~~151~~	~~6~~	~~211~~	~~2~~		

4.2.3.2.3.3 Bits-output from rectangular matrix with pruning

After intra-row and inter-row permutations, the bits of the permuted rectangular matrix are denoted by y'_k:

$$\begin{bmatrix} y'_1 & y'_{(R+1)} & y'_{(2R+1)} & \cdots y'_{((C-1)R+1)} \\ y'_2 & y'_{(R+2)} & y'_{(2R+2)} & \cdots y'_{((C-1)R+2)} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ y'_R & y'_{2R} & y'_{3R} & \cdots & y'_{CR} \end{bmatrix}
\begin{bmatrix} y'_1 & y'_{(R+1)} & y'_{(2R+1)} & \cdots y'_{((C-1)R+1)} \\ y'_2 & y'_{(R+2)} & y'_{(2R+2)} & \cdots y'_{((C-1)R+2)} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ y'_R & y'_{2R} & y'_{3R} & \cdots & y'_{C\times R} \end{bmatrix}$$

The output of the Turbo code internal interleaver is the bit sequence read out column by column from the intra-row and inter-row permuted $R \times C$ rectangular matrix starting with bit y'_1 in row 0 of column 0 and ending with bit y'_{CR} in row R - 1 of column C - 1. The output is pruned by deleting dummy bits that were ~~not present~~padded ~~in~~to the input ~~bit sequence~~of the rectangular matrix before intra-row and inter row permutations, i.e. bits y'_k that corresponds to bits ~~x~~y_k with $k > K$ are removed from the output. The bits output from Turbo code internal interleaver are denoted by x'_1, x'_2, …, x'_K, where x'_1 corresponds to the bit y'_k with smallest index k after pruning, x'_2 to the bit y'_k with second smallest index k after pruning, and so on. The number of bits output from Turbo code internal interleaver is K and the total number of pruned bits is:

$R \times C - K$.