TSG-RAN Working Group1 meeting #15 **TSGR1#15(00)1134**
Berlin, Germany, August 22 – 25, 2000

**Agenda item:**

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

**Title:** **Revised CRs on Turbo code internal interleaver**

**Document for:** **Decision**

---

## Introduction

This document includes revised versions of approved CRs: 25.212 CR 085 and 25.222 CR 041 in [1]. A few editorial corrections (commented with /*…*/ below) were made for the description errors that were accidentally made during editing the previous CR and some additional minor corrections are also made to improve describing. These corrections should be adopted for both 25.212 and 25.222 commonly. The major revisions indicated with underlines are as follows:

Section 4.2.3.2.3

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

…

| | | |
|---|---|---|
| $\underline{q_i}$ | Minimum prime integers | /*"$q_j$" *was replaced by* "$q_i$"*/ |
| $\underline{r_i}$ | Permuted prime integers | /*"$r_j$" *was replaced by* "$r_i$"*/ |
| … | | |
| $\underline{k}$ | Index of bit sequence | /*"k" *was replaced by* "$k$"*/ |

Section 4.2.3.2.3.1

(2) Determine <u>the prime number to be used in the intra-permutation, *p*, and</u> the number of columns of rectangular matrix, *C*, such that:

if (481 $\leq K \leq$ 530) then

$p$ = 53 and $C = p$.

else

Find minimum prime <u>number</u> $p$ <u>from table 2</u> such that

$K \leq R \times (p+1)$,

and determine $C$ such that

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

<u>end if</u> /* *deleting "end if" was cancelled* */

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

$$\begin{bmatrix} y_1 & y_2 & y_3 & \cdots & y_C \\ y_{(C+1)} & y_{(C+2)} & y_{(C+3)} & \cdots & y_{2C} \\ \vdots & \vdots & \vdots & \ldots & \vdots \\ y_{((R-1)C+1)} & y_{((R-1)C+2)} & y_{((R-1)C+3)} & \cdots & y_{R\times C} \end{bmatrix}$$

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

Section 4.2.3.2.3.2

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 stepwise by using the following algorithm with steps (1) – (6):
(1) Select a primitive root $v$ from table 2 in section 4.2.3.2.3.1, which is indicated on the right side of the prime number $p$.

The following attached CRs: 25.212 CR 085r1 and 25.222 CR 041r1 will supersede the original CRs: 25.212 CR 085 and 25.222 CR 041 respectively.

## Reference

[1] NTT DoCoMo, Nokia and Nortel Networks, "Editorial corrections in Turbo code internal interleaver section", TSGR1#15(00)0858

**3GPP RAN WG1 Meeting #15**
**Berlin, Germany, 22 - 25 August 2000**

***Document* R1-00-1134**
*e.g. for 3GPP use the format TP-99xxx*
*or for SMG, use the format P-99-xxx*

# CHANGE REQUEST

*Please see embedded help file at the bottom of this page for instructions on how to fill in this form correctly.*

**25.212 CR 085r1** 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
*list expected approval meeting # here ↑*

| | | | | |
|---|---|---|---|---|
| for approval | X | Strategic | | *(for SMG use only)* |
| 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:** (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:** 24-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 | |
| A | Corresponds to a correction in an earlier release | | |
| B | Addition of feature | | |
| C | Functional modification of feature | | |
| D | Editorial modification | | |

**Release:**

| | |
|---|---|
| Phase 2 | |
| Release 96 | |
| Release 97 | |
| Release 98 | |
| 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.

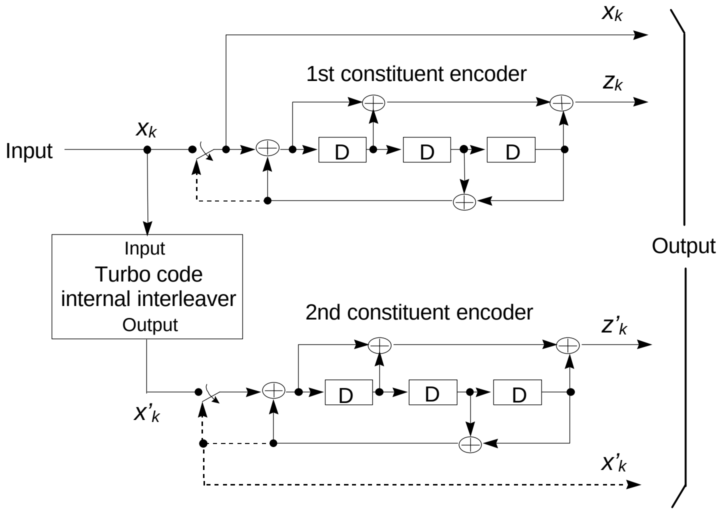


**Figure 4: Structure of rate 1/3 Turbo coder (dotted lines apply for trellis termination only)**

### 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 $40 \le K \le 5114$. 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
~~$q_j$~~ $q_i$ Minimum prime integers
~~$r_j$~~ $r_i$ 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 prime number to be used in the intra-permutation, $p$, and 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 number $p$ from table 2 such that

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

and determine $C$ such that

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

~~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.

**Table 2: List of prime number *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 | | |

(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 $y_k = x_k$ for $k$ = 1, 2, …, $K$ and if $R \times C > K$, the dummy bits are padded such that $y_k = 0 \text{ or } 1$ 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 stepwise by using the following algorithm with steps (1) – (6):~~.~~

(1) Select a primitive root $v$ from table 2 in section 4.2.3.2.3.1, which is indicated on the right side of the prime number $p$.

(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 to 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 integers ~~$\{q_j\}$~~ 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~~{~~($q_{\cancel{j}i}$, $p$ - 1~~}~~) = 1, $q_{\cancel{j}i} > 6$, and $q_{\cancel{j}i} > q_{(\cancel{j}i-1)}$~~,~~ 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

$r_{T(\cancel{j}i)} = q_{\cancel{j}i}$, ~~$j$~~$i$ = 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 $K$.

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

~~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 <$T(0)$, $T(1)$, …, $T(R - 1)$> |
|---|---|---|
| $(40 \le K \le 159)$ | 5 | <4, 3, 2, 1, 0> |
| $(160 \le K \le 200)$ or $(481 \le K \le 530)$ | 10 | <9, 8, 7, 6, 5, 4, 3, 2, 1, 0> |
| $(2281 \le K \le 2480)$ or $(3161 \le K \le 3210)$ | 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

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

where $U_{\cancel{j}i}(\cancel{i}j)$ 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

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

where $U_{\cancel{j}i}(\cancel{i}j)$ 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

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

where $U_{\cancel{j}i}(\cancel{i}j)$ 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 for the rectangular matrix based on the pattern ~~$T(j)$ ($j$ = 0, 1, 2, …, $R$ - 1)~~ $\langle T(i) \rangle_{i \in \{0,1,\cdots,R-1\}}$,

where $T(\cancel{j}i)$ 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:

$R \times C - K$.

**3GPP RAN WG1 Meeting #15**
**Berlin, Germany, 22 - 25 August 2000**

***Document* R1-00-1134**
*e.g. for 3GPP use the format TP-99xxx*
*or for SMG, use the format P-99-xxx*

# CHANGE REQUEST

*Please see embedded help file at the bottom of this page for instructions on how to fill in this form correctly.*

| | | | | |
|---|---|---|---|---|
| **25.222** | **CR** | **041r1** | 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:** (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:** 24-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.
To align mathematical notations with preferred notations shown in TS25.201 Annex A.

**Clauses affected:** 4.2.3.2.3 of TS25.222

| **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:**

where $x_1$, $x_2$, …, $x_K$ 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 $z_1$, $z_2$, …, $z_K$ and $z'_1$, $z'_2$, …, $z'_K$ are the bits output from first and second 8-state constituent encoders, respectively.

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

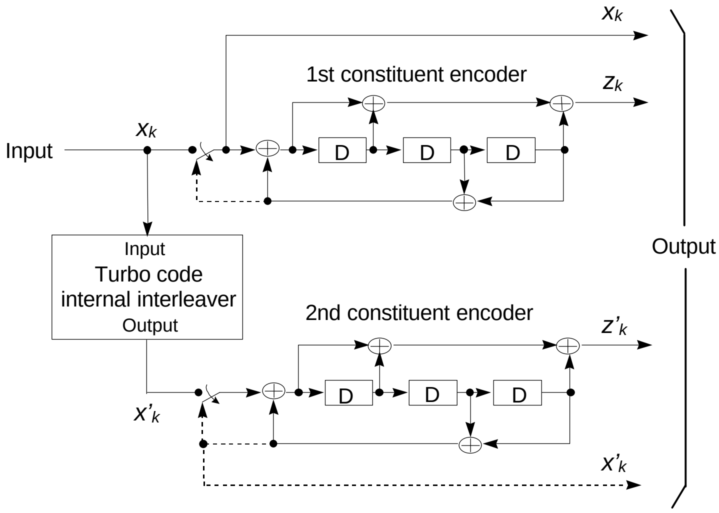


**Figure 3: Structure of rate 1/3 Turbo coder (dotted lines apply for trellis termination only)**

### 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 $40 \le K \le 5114$. 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 |
| ~~$q_j$~~ $q_i$ | Minimum prime integers |
| ~~$r_j$~~ $r_i$ | 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 prime number to be used in the intra-permutation, $p$, and 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 number $p$ from table 2 such that

~~($p$ + 1) - $K/R$ ≥ 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 ($p$ - $K/R$ ≥ 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.

**Table 2: List of prime number *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 | | |

(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 $y_k = x_k$ for $k = 1, 2, \ldots, K$ and if $R \times C > K$, the dummy bits are padded such that $y_k = 0 \text{ or } 1$ 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 stepwise by using the following algorithm with steps (1) – (6).

(1) Select a primitive root $v$ from table 2 in section 4.2.3.2.3.1, which is indicated on the right side of the prime number $p$.

(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 × s(i - 1)] mod 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 to 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 integers ~~$\{q_j\}$~~ 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~~{~~($q_{\cancel{j}i}$, $p$ - 1~~}~~) = 1, $q_{\cancel{j}i} > 6$, and $q_{\cancel{j}i} > q_{(\cancel{j}i-1)}$~~,~~ 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

$r_{T(\cancel{j}i)} = q_{\cancel{j}i}$, ~~j~~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 $K$.

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

~~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 $U_{\cancel{j}i}(p - 1) = 0$,

where $U_{\cancel{j}i}$(~~$i$~~$j$) 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)~~.~~, $U_{\cancel{j}i}(p - 1) = 0$, and $U_{\cancel{j}i}(p) = p$,

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

if ($K$ = ~~$C$ ×~~ $R$×$C$) 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 $U_{\cancel{j}i}(\cancel{i}j)$ 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 for the rectangular matrix based on the pattern ~~$T(j)$ ($j$ = 0, 1, 2, …, $R$ - 1)~~ $\langle T(i)\rangle_{i\in\{0,1,\cdots,R-1\}}$,

where $T(\cancel{j}i)$ 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 $y'_k$:

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

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:

$R \times C - K.$