RAN WG1 meeting #7bis **TSG R1#7b(99) f32**

(revision of e61)

Place : Corea
Date : (4-5 October)
Title : Text proposal for corrections in the RM sections
Source : Mitsubishi Electric
Paper for : Decision

1 Introduction

During e-mail discussion several problems in the rate matching section of [1] have been noticed. These problems are more "bugs" than really problems on the content.
Inside the text proposal <Mitsubishi Note>s are included to provide motivation for the changes. These note are not part of the proposal and shall be deleted during incorporation of this new material to 25.212

2 References

[1] TS25.212 v2.2.0 FDD Multiplexing and channel coding

3 Conclusion

We propose that the proposed corrections be included in [1].

-------------------------------- Text proposal --------------------------------

4.2.7 Rate matching

<Editors' note: Rate matching for Turbo codes is a working assumption.>

Rate matching means that bits on a transport channel are repeated or punctured. Higher layers assign a rate-matching attribute for each transport channel. This attribute is semi-static and can only be changed through higher layer signalling. The rate-matching attribute is used when the number of bits to be repeated or punctured is calculated.
The number of bits on a transport channel can vary between different transmission time intervals. In the downlink the transmission is interrupted if the number of bits is lower than maximum. When the number of bits between different transmission time intervals in uplink is changed, bits are repeated or punctured to ensure that the total bit rate after second multiplexing is identical to the total channel bit rate of the allocated dedicated physical channels.
Notation used in Section 0 and subsections:

N_{ij}: For uplink: Number of bits in a radio frame before rate matching on TrCH i with transport format combination j .

For downlink : An intermediate calculation variable (not a integer but a multiple of 1/8).

N_{il}^{TTI} : Number of bits in a transmission time interval before rate matching on TrCH i with transport format l. Used in downlink only.

ΔN_{ij} : For uplink: If positive - number of bits that should be repeated in each radio frame on TrCH i with transport format combination j.

If negative - number of bits that should be punctured in each radio frame on TrCH i with transport format combination j.

For downlink : An intermediate calculation variable (not integer but a multiple of 1/8).

ΔN_{il}^{TTI} : If positive - number of bits to be repeated in each transmission time interval on TrCH *i* with transport format *j*.
If negative - number of bits to be punctured in each transmission time interval on TrCH *i* with transport format *j*.
Used in downlink only.

RM_i: Semi-static rate matching attribute for transport channel *i*. Signalled from higher layers.

PL: Puncturing limit for uplink. This value limits the amount of puncturing that can be applied in order to avoid multicode or to enable the use of a higher spreading factor. Signalled from higher layers.

$N_{data,j}$: Total number of bits that are available for the CCTrCH in a radio frame with transport format combination *j*.

I: Number of TrCHs in the CCTrCH.

Z_{ij}: Intermediate calculation variable.

F_i: Number of radio frames in the transmission time interval of TrCH *i*.

n_i: Radio frame number in the transmission time interval of TrCH *i* ($0 \leq n_i < F_i$).

q: Average puncturing distance. Used in uplink only.

$I_F(n_i)$: The inverse interleaving function of the 1st interleaver (note that the inverse interleaving function is identical to the interleaving function itself for the 1st interleaver). Used in uplink only.

$S(n_i)$: The shift of the puncturing pattern for radio frame n_i. Used in uplink only.

$TF_i(j)$: Transport format of TrCH *i* for the transport format combination *j*.

TFS(i) The set of transport format indexes *l* for TrCH *i*.

TFCS The set of transport format combination indexes *j*.

e_{ini} Initial value of variable *e* in the rate matching pattern determination algorithm of section 4.2.7.3.

e_{plus} Increment of variable *e* in the rate matching pattern determination algorithm of section 4.2.7.3.

e_{minus} Decrement of variable *e* in the rate matching pattern determination algorithm of section 4.2.7.3.

X: Systematic bit in section **Error! Reference source not found.**.

Y: 1st parity bit (from the upper Turbo constituent encoder) in section **Error! Reference source not found.**.

Y': 2nd parity bit (from the lower Turbo constituent encoder) in section **Error! Reference source not found.**.

Note: Time index t in section **Error! Reference source not found.** is omitted for simplify the rate matching description.

The * (star) notation is used to replace an index *x* when the indexed variable X_x does not depend on the index *x*. In the left wing of an assignment the meaning is that "$X_* = Y$" is equivalent to "**for all** *x* **do** $X_x = Y$". In the right wing of an assignment, the meaning is that "$Y = X_*$" is equivalent to "**take any** *x* **and do** $Y = X_x$"

The following relations, defined for all TFC *j*, are used when calculating the rate matching parameters:

$$Z_{0,j} = 0$$

$$Z_{ij} = \left\lfloor \frac{\sum_{m=1}^{i} RM_m \cdot N_{mj}}{\sum_{m=1}^{I} RM_m \cdot N_{mj}} \cdot N_{data,j} \right\rfloor$$ for all *i* = 1 .. *I, where* ⌊ ⌋ *means round downwards*

$$\Delta N_{ij} = Z_{ij} - Z_{i-1,j} - N_{ij} \qquad \text{for all } i = 1 \;..\; I$$

4.2.7.1 Determination of rate matching parameters in uplink

In uplink puncturing can be used to avoid multicode or to enable the use of a higher spreading factor when this is needed because the UE does not support SF down to 4. The maximum amount of puncturing that can be applied is signalled from higher layers and denoted by *PL*. The number of available bits in the radio frames for all possible spreading factors is given in [2]. Denote these values by N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, and N_4, where the index refers to the spreading factor. The possible values of N_{data} then are { N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, $2N_4$, $3N_4$, $4N_4$, $5N_4$, $6N_4$}.Depending on the UE capabilities, the supported set of N_{data} , denoted SET0, can be a subset of { N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, $2N_4$, $3N_4$, $4N_4$, $5N_4$, $6N_4$}. $N_{data,\,j}$ for the transport format combination j is determined by executing the following algorithm:

SET1 = { N_{data} in SET0 such that $N_{data} - \sum_{x=1}^{I} \frac{RM_{x,}}{\min_{1 \le y \le I}\{RM_y\}} \cdot N_{x,j}$ is non negative }

If SET1 is not empty and the smallest element of SET1 requires just one PhCH then

$N_{data,j}$ = min SET1

else

SET2 = { N_{data} in SET0 such that $N_{data} - PL \cdot \sum_{x=1}^{I} \frac{RM_x}{\min_{1 \le y \le I}\{RM_y\}} \cdot N_{x,j}$ is non negative }

Sort SET2 in ascending order

N_{data} = min SET2

While N_{data} is not the max of SET2 and the follower of N_{data} requires no additional PhCH do

N_{data} = follower of N_{data} in SET2

End while

$N_{data,j}$ = N_{data}

End if

The number of bits to be repeated or punctured, DN_{ij}, within one radio frame for each TrCH *i* is calculated with the relations given in Section 4.2.74.2.7 for all possible transport format combinations *j* and selected every radio frame.

If DN_{ij} = 0 then the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.3 does not need to be executed.

OtherwiseAdditionally, for determining e_{ini}, e_{plus}, e_{minus}, and N the following parameters are needed:

For convolutional codes,

~~*a*=2 for the rate matching algorithm in section 4.2.7.3.~~< Mitsubishi Note : This sentence is moved downwards>

$q = ëN_{ij}/(ô DN_{ij} ô)û$

if *q* is even

then $q' = q - gcd(q, F_i)/F_i$ -- where $gcd(q, F_i)$ means greatest common divisor of *q* and F_i

-- note that q' is not an integer, but a multiple of 1/8

else

$q' = q$

endif

for x = 0 to F_i-1

$S(I_F$ (éx*q'ù mod F_i)) = (éx*q'ù div F_i)

end for

$DN = DN_{i,j}$

$a = 2$

For each radio frame, the rate-matching pattern is calculated with the algorithm in Section 4.2.7.3, where :

~~$DN = DN_{i,j}$~~

$N = N_{i,j}$., and

e_{ini} = (a·$S(n_i)$·|DN| + N) mod a·N, if e_{ini} = 0 then e_{ini} = a·N.

$e_{plus} = a \cdot N$

$e_{minus} = a \cdot |DN|$

puncturing for DN<0, repeating otherwise.

For turbo codes,

if repetition is to be performed, such as $DN_{i,j}$>0, parameters for turbo codes are the same as parameter for convolutional codes.

If puncturing is to be performed, parameters are as follows.

a=2 for Y ~~parity~~ sequence, and

a=1 for Y' ~~parity~~ sequence.

<Mitsubishi note : this sentence is put just before listing the four parameters N , e_{ini}, e_{plus}, and e_{minus} >

~~For each radio frame, the rate-matching pattern is calculated with the algorithm in section 4.2.7.3, where:~~

$$DN = \begin{cases} \lfloor DN_{i,j} / 2 \rfloor \text{for Y sequence} \\ \lceil DN_{i,j} / 2 \rceil \text{for Y' sequence} \end{cases}$$

N = ë$N_{i,j}$/3û ,

q = ëN/|DN| û

if($q \leq 2$)

for x=0 to F_i-1

if(Y sequence)

$S[I_F[(3x+1) \bmod F_i]] = x \bmod 2;$

if(Y' sequence)

$S[I_F [(3x+2) \bmod F_i]] = x \bmod 2;$

end for

else

if q is even

then $q' = q - gcd(q, F_i)/ F_i$ -- where $gcd(q, F_i)$ means greatest common divisor of q and F_i
-- note that q' is not an integer, but a multiple of 1/8

else $q' = q$

endif

for x=0 to F_i -1

$r = \lceil x*q' \rceil \bmod F_i;$

if(Y sequence)

$S[I_F[(3r+1) \bmod F_i]] = \lceil x*q' \rceil \operatorname{div} F_i;$

if(Y' sequence)

$S[I_F[(3r+2) \bmod F_i]] = \lceil x*q' \rceil \operatorname{div} F_i;$

endfor

endif

For each radio frame, the rate-matching pattern is calculated with the algorithm in section 4.2.7.3, where:

N is as above,

$e_{ini} = (a \cdot S(n_i) \cdot |\Delta N| + N) \bmod a \cdot N$, if $e_{ini} = 0$ then $e_{ini} = a \cdot N$.

$e_{plus} = a \cdot N$

$e_{minus} = a \cdot |\Delta N|$

puncturing for $\Delta N<0$, repeating otherwise.

4.2.7.2 Determination of rate matching parameters in downlink

For downlink $N_{data,j}$ does not depend on the transport format combination j. $N_{data,*}$ is given by the channelization code(s) assigned by higher layers.

4.2.7.2.1 Determination of rate matching parameters for fixed positions of TrCHs

First an intermediate calculation variable $N_{i,*}$ is calculated for all transport channels i by the following formula :

$$N_{i,*} = \frac{1}{F_i} \cdot \max_{l \in TFS(i)} N_{i,l}^{TTI}$$

The computation of the $\Delta N_{i,l}^{TTI}$ parameters is then performed in for all TrCH i and all TF l by the following formula, where $\Delta N_{i,*}$ is derived from $N_{i,*}$ by the formula given at section 4.2.74.2.7:

$$\Delta N_{i,*}^{TTI} = F_i \cdot \Delta N_{i,*}$$

~~Note : the order in which the transport format combinations are checked does not change the final result.~~

If $\Delta N_{i,*}^{TTI} = 0$ then, for TrCH i, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.3 does not need to be executed.

Otherwise, for determining e_{ini}, e_{plus}, e_{minus}, and N the following parameters are needed:

~~For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in Section 0. The following parameters are used as input:~~

For convolutional codes,

$$\Delta N = \Delta N_{i,*}^{TTI}$$

$a=2$

$$N_{max} = \max_{l \in TFS(i)} N_{il}^{TTI}$$

For each transmission time interval of TrCH i with TF l, the rate-matching pattern is calculated with the algorithm in Section 4.2.7.3. The following parameters are used as input:

$$N = N_{il}^{TTI}$$

$$e_{ini} = \max_{l \in TFS(i)} N_{il}^{TTI} \quad e_{ini} = N_{max}$$

$$e_{plus} = a \cdot N_{max}$$

$$e_{minus} = a \cdot |\Delta N|$$

a=2 for the rate matching algorithm.

Puncturing if $\Delta N < 0$, repetition otherwise.

For turbo codes, if repetition is to be performed, such as $\Delta N_{i,*}^{TTI} > 0$ $\Delta N>0$, parameters for turbo codes are the same as parameter for convolutional codes. If puncturing is to be performed, parameters are as follows.

$a=2$ for Y sequence,

$a=1$ for Y' sequence.

Systematic The X bits shouldall not be punctured. <Mitsubishi note : I replaced systematic by X, because the Y and Y' bits can comprise some tail systematic bits>

$$\Delta N = \begin{cases} \lfloor \Delta N_{i,*}^{TTI} / 2 \rfloor & \text{for Y sequence} \\ \lceil \Delta N_{i,*}^{TTI} / 2 \rceil & \text{for Y' sequence} \end{cases}$$

$$N = \lfloor N_{il}^{TTL} / 3 \rfloor$$

$$N_{max} = \max_{l \in TFS(i)} \lfloor N_{il}^{TTI} / 3 \rfloor \quad \max_{l \in TFS(i)} \lfloor N_{il}^{TTL} / 3 \rfloor$$

$$e_{ini} = \max_{l \in TFS(i)} \lfloor N_{il}^{TTL} / 3 \rfloor \bmod a \cdot \max_{l \in TFS(i)} \lfloor N_{il}^{TTL} / 3 \rfloor$$

For each transmission time interval of TrCH i with TF l, the rate-matching pattern is calculated with the algorithm in Section 4.2.7.3. The following parameters are used as input:

$$N = \lfloor N_{il}^{TTI} / 3 \rfloor$$

$$e_{ini} = N_{max}$$

$$e_{plus} = a \cdot N_{max}$$

$$e_{minus} = a \cdot |\Delta N|$$

Puncturing if $\Delta N < 0$, repetition otherwise.

4.2.7.1.2 4.2.7.2.2 Determination of rate matching parameters for flexible positions of TrCHs

First an intermediate calculation variable N_{ij} is calculated for all transport channels i and all transport format combinations j by the following formula :

$$N_{i,j} = \frac{1}{F_i} \cdot N_{i,TF_i(j)}^{TTI}$$

Then rate matching ratios RF_i are calculated for each the transport channel i in order to minimise the number of DTX bits when the bit rate of the CCTrCH is maximum. The RF_i ratios are defined by the following formula :

$$RF_i = \frac{N_{data,*}}{\max_{j \in TFCS} \sum_{i=1}^{i=I} (RM_i \cdot N_{i,j})} \cdot RM_i$$

The computation of $\Delta N_{i,l}^{TTI}$ parameters is then performed in two phases. In a first phase, tentative temporary values of $\Delta N_{i,l}^{TTI}$ are computed, and in the second phase they are checked and corrected. The first phase, by use of the RF_i ratios, ensures that the number of DTX indication bits inserted is minimum when the CCTrCH bit rate is maximum, but it does not ensure that the maximum CCTrCH bit rate is not greater than $N_{data,*}$. per 10ms. The latter condition is ensured through the checking and possible corrections carried out in the second phase.
At the end of the second phase, the latest value of $\Delta N_{i,l}^{TTI}$ is the definitive value.

The first phase defines the tentative temporary $\Delta N_{i,l}^{TTI}$ for all transport channel i and any of its transport format l by use of the following formula :

$$\Delta N_{i,l}^{TTI} = F_i \cdot \left\lceil \frac{RF_i \cdot N_{i,l}^{TTI}}{F_i} \right\rceil - N_{i,l}^{TTI}$$

The second phase is defined by the following algorithm :

for all j in *TFCS* do -- for all TFC

$$D = \sum_{i=1}^{i=I} \frac{N_{i,TF_i(j)}^{TTI} + \Delta N_{i,TF_i(j)}^{TTI}}{F_i}$$ -- CCTrCH bit rate (bits per 10ms) for TFC *l*

  if $D > N_{data,*}$ then

    for i = 1 to I do -- for all TrCH

      $\Delta N = F_i \cdot \Delta N_{i,j}$ -- $\Delta N_{i,j}$ is derived from $N_{i,j}$ by the formula given at section 0

      if $\Delta N_{i,TF_i(j)}^{TTI} > \Delta N$ then

        $\Delta N_{i,TF_i(j)}^{TTI} = \Delta N$

      end-if

    end-for

  end-if

end-for

Note : the order in which the transport format combinations are checked does not change the final result.

If $\Delta N_{i,l}^{TTI} = 0$ then, for TrCH *i* at TF *l*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.3 does not need to be executed.

Otherwise, for determining e_{ini}, e_{plus}, e_{minus}, and N the following parameters are needed:

~~For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in Section 4.2.7.3. The following parameters are used as input:~~

For convolutional codes,

$$\Delta N = \Delta N_{il}^{TTI}$$

a=2

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in Section 4.2.7.3. The following parameters are used as input:

$N = N_{il}^{TTI}$

$e_{ini} = N$ ~~$e_{ini} = N_{il}^{TTI}$~~

~~*a*=2 for the rate matching algorithm.~~

$e_{plus} = a \cdot N$

$e_{minus} = a \cdot |\Delta N|$

puncturing for $\Delta N < 0$, repeating otherwise.

For turbo codes, if repetition is to be performed, such as $\Delta N_{il}^{TTI} > 0$ ~~*DN>0*~~, parameters for turbo codes are the same as parameter for convolutional codes. If puncturing is to be performed, parameters are as follows.

a=2 for *Y* sequence,

a=1 for *Y'* sequence.

~~Systematic~~ *X* bits sh~~ould~~all not be punctured.

$$DN = \begin{cases} \lfloor DN_{il}^{TTI} / 2 \rfloor & \text{for Y sequence} \\ \lceil DN_{il}^{TTI} / 2 \rceil & \text{for Y' sequence} \end{cases}$$

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in Section 4.2.7.3. The following parameters are used as input:

$N = \lfloor N_{il}^{TTI} / 3 \rfloor$,

$e_{ini} = N$ ~~N_{il}^{TTI} mod a. N_{il}^{TTI}~~,

$e_{plus} = a \cdot N$

$e_{minus} = a \cdot |\Delta N|$

puncturing for $\Delta N < 0$, repeating otherwise.

4.2.6.1. Bit separation for rate matching

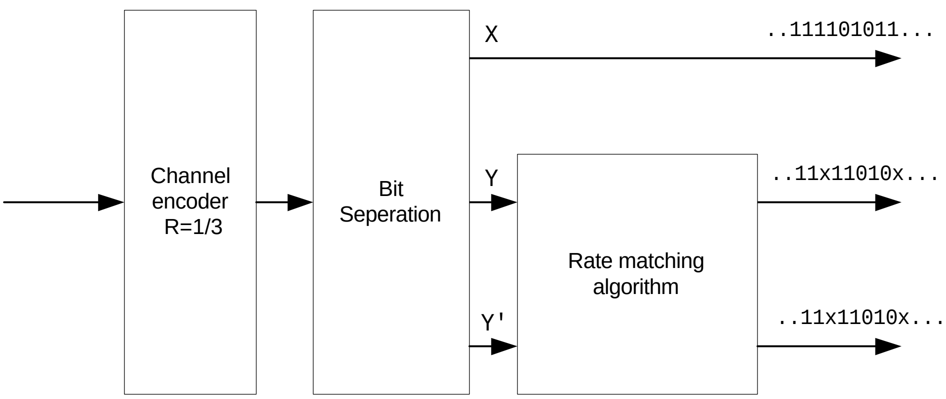

Figure 1: Overall rate matching block diagram before first interleaving where x denotes punctured bit.

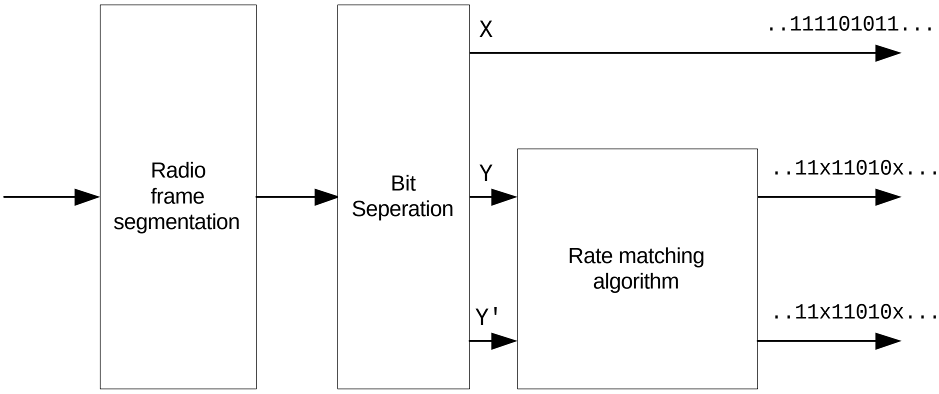

Figure 2: Overall rate matching block diagram after first interleaving where x denotes punctured bit.

Rate matching puncturing for Turbo codes in uplink is applied separately to *Y* and *Y'* sequences. No puncturing is applied to *X* sequence. Therefore, it is necessary to separate *X*, *Y*, and *Y'* sequences before rate matching is applied.
For uplink, there are two different alternation patterns in bit stream from radio frame segmentation according to the TTI of a TrCH as shown in Table 1.

Table 1: Alternation patterns of bits from radio frame segmentation in uplink

TTI (msec)	Alternation patterns
10, 40	… *X,Y,Y',…*
20, 80	… *X,Y',Y,…*

In addition, each radio frame of a TrCH starts with different initial parity type. Table 2 shows the initial parity type of each radio frame of a TrCH with TTI = {10, 20, 40, 80} msec.

Table 2: Initial parity type of radio frames of TrCH in uplink

TTI (msec)	Radio frame indexes (n_i)							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
10	*X*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
20	*X*	*Y*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
40	*X*	*Y'*	*Y*	*X*	*NA*	*NA*	*NA*	*NA*
80	*X*	*Y*	*Y'*	*X*	*Y*	*Y'*	*X*	*Y*

Table 1 and Table 2 defines a complete output bit pattern from radio frame segmentation.

Ex. 1. TTI = 40 msec, n_i = 2

Radio frame pattern: *Y, Y', X, Y, Y', X, Y, Y', X, …*

Ex. 2 TTI = 40 msec, n_i = 3

Radio frame pattern: *X, Y, Y', X, Y, Y', X, Y, Y', X, …*

Therefore, bit separation is achieved with the alternative selection of bits with the initial parity type and alternation pattern specified in Table 1 and Table 2 according to the TTI and n_i of a TrCH.

Rate matching puncturing for Turbo codes in downlink is applied separately to Y and Y's sequences. No puncturing is applied to X sequence. Therefore, it is necessary to separate X, Y, and Y' sequences before rate matching is applied.

For downlink, output bit sequence pattern from Turbo encoder is always X, Y, Y', X, Y, Y', …. Therefore, bit separation is achieved with the alternative selection of bits from Turbo encoder.

4.2.7.3 Rate matching pattern determination

Denote the bits before rate matching by:

$x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iN}$, where *i* is the TrCH number and *N* is the parameter given in section 4.2.7.2.

The rate matching rule is as follows:

```
if puncturing is to be performed
        ~~y = -DN~~
        e = e_ini                   -- initial error between current and desired puncturing ratio
        m = 1                       -- index of current bit
        do while m <= N
                e = e – e_minus ~~a * y~~          -- update error
                if e <= 0 then              -- check if bit number m should be punctured
                        puncture bit x_i,m
                        e = e + ~~a*N~~e_plus      -- update error
                end if
                m = m + 1                          --  next bit
        end do
else
        ~~y = DN~~
        e = e_ini                           -- initial error between current and desired puncturing
        ratio
        m = 1                               -- index of current bit
        do while m <= N
                e = e ~~– a * y~~e_minus            -- update error
                do while e <= 0             -- check if bit number m should be repeated
                        repeat bit x_i,m
                        e = e +  ~~a*N~~e_plus     -- update error
                end do
                m = m + 1                          --  next bit
        end do
end if
```

A repeated bit is placed directly after the original one.

4.2.7.4 Relation between input and output of the rate matching block in uplink

The bits input to the rate matching are denoted by $e_{i1}, e_{i2}, e_{13}, \ldots, e_{iN_i}$, where *i* is the TrCH.

Hence, $x_{ik} = e_{ik}$ and $N = N_{ij} = N_i$.

The bits output from the rate matching are denoted by $f_{i1}, f_{i2}, f_{13}, \ldots, f_{iV_i}$, where *i* is the TrCH number and $V_i = N + DN = N_{ij} + DN_{ij}$.

Note that the transport format combination number *j* for simplicity has been left out in the bit numbering.

4.2.7.5 Relation between input and output of the rate matching block in downlink

The bits input to the rate matching are denoted by $c_{i1}, c_{i2}, c_{13}, \ldots, c_{iE_i}$, where *i* is the TrCH number and *l* the transport format number. Hence, $x_{ik} = e_{ik}$ and $N = N_{il}^{TTI} = E_i$.

The bits output from the rate matching are denoted by $g_{i1}, g_{i2}, g_{13}, \ldots, g_{iG_i}$, where *i* is the TrCH number and $G_i = N + \Delta N = N_{il}^{TTI} + \Delta N_{il}^{TTI}$.

Note that the transport format number *l* for simplicity has been left out in the bit numbering.