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3 Foreword

This Technical Report (TR) has been produced by the Special Mobile Group (SMG) of the European Telecommunications Standards Institute (ETSI).

This TR describes multiplexing, channel coding and interleaving for UTRA Physical Layer FDD mode.

The contents of this TR are subject to continuing work within SMG2 and SMG2 UMTS layer 1 expert group and may change following approval by either of these two groups

4 Scope

This European Telecommunication Report (ETR) describes multiplexing, channel coding and interleaving for UTRA Physical Layer FDD mode.

Text without revision marks has been approved in the previous SMG2 Layer 1 expert group meetings, while text with revision marks is subject to approval.

5 References

References may be made to:

a) specific versions of publications (identified by date of publication, edition number, version number, etc.), in which case, subsequent revisions to the referenced document do not apply;

b) publications without mention of a specific version, in which case the latest version applies.

A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

6 Definitions and abbreviations

ARQ	Automatic Repeat Request
BCCH	Broadcast Control Channel
BER	Bit Error Rate
BLER	Block Error Rate
BS	Base Station
CCPCH	Common Control Physical Channel
DCH	Dedicated Channel
DL	Downlink (Forward link)
DPCH	Dedicated Physical Channel
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel

DS-CDMA	Direct-Sequence Code Division Multiple Access
FACH	Forward Access Channel
FDD	Frequency Division Duplex
FER	Frame Error Rate
Mcps	Mega Chip Per Second
MS	Mobile Station
ODMA	Opportunity Driven Multiple Access
OVSF	Orthogonal Variable Spreading Factor (codes)
PCH	Paging Channel
PG	Processing Gain
PRACH	Physical Random Access Channel
PUF	Power Up Function
RACH	Random Access Channel
RX	Receive
SCH	Synchronisation Channel
SF	Spreading Factor
SIR	Signal-to-Interference Ratio
TDD	Time Division Duplex
TFCI	Transport Format Combination Indicator
TFI	Transport-Format Indicator
TPC	Transmit Power Control
TX	Transmit
UL	Uplink (Reverse link)
VA	Voice Activity

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8 Status of this document

8.1 General

8.2 Transport channel coding/Multiplexing

- Under study in Ad Hoc 4, currently combined from ETSI xx.04 and ARIB Volume 3.

8.2.1 CRC calculation

- Currently only input from ARIB Volume 3.

8.2.2 Channel coding

- Under study in AdHoc 5, currently a combination of ETSI and ARIB original sources.

8.2.3 1st interleaving

- Under study in AdHoc 5.

8.2.4 Rate matching

- A combination of ETSI xx.10 and ARIB Volume 3.

8.2.5 Downlink discontinuous transmission

- A combination of ETSI xx.10 and ARIB Volume 3.

8.2.6 Transport channel multiplexing

- Under study in AdHoc 4.

8.2.7 2nd interleaving

- Under study in AdHoc 5.

8.2.8 Multirate transmission

- ARIB Volume 3

8.2.9 Rate detection

- ARIB Volume 3

8.2.10 Coding procedure

- ARIB Volume 3

8.2.11 Bit transmission sequence

- ARIB Volume 3

8.3 Coding for layer 1 control

- Contents are same between ETSI and ARIB. Only wordings are changed.

8.4 Coding of slotted mode

- A combination of ETSI xx.10 and ARIB Volume 3.

Annex A: Blind rate detection

- ARIB Volume 3

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10 Multiplexing, channel coding and interleaving

10.1 General

<Editor's note: Taken from ARIB Volume 3 section 3.2.3.1>

Data stream from/to MAC and higher layers (Transport block / Transport block set) is encoded/decoded to offer transport services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting (including rate matching), and interleaving and transport channels mapping onto/splitting from physical channels.

Editor's note: The following overview is taken from ARIB Volume 3 section 3.2.3.1 and its contents are based on the RIB specification.>

yclic Redundancy Check is applied as an error detection scheme. For forward error correction, either convolutional oding or Turbo coding is applied. Common transport channels employ only convolutional coding. However, for edicated transport channels, convolutional coding is used when maximal coding unit size is less than 320 bits while urbo coding is used when maximal coding unit size is more than or equal to 320 bits. To offer efficient transmission, te-matching scheme, such as repetition or puncturing, is applied.

or interleaving, Multi-stage Interleaving method (MIL) is applied to ensure higher performance both with onvolutional coding and Turbo coding.

s for Broadcast channel (BCH), SFN information is combined with data stream from MAC layer. PI part is attached to aging message (MUI) in Paging channel (PCH).

recise channel coding processes for some of transport channels are given as examples in Annex-D.

10.2 Transport-channel coding/multiplexing

<Editor's note: The following is taken from ETSI specs. Description referring to Figure 7-1 was removed because this figure is referred in the next paragraph.>

~~Figure 7-1 illustrates the overall concept of transport-channel coding and multiplexing.~~ Data arrives to the coding/multiplexing unit in form of transport block sets, once every transmission time interval. The transmission time interval is transport-channel specific from the set {10 ms, 20 ms, 40 ms, 80 ms}.

<Editor's note: The following is taken from ARIB specs.>

When two or more services having different Quality of Service (QoS) requirements are multiplexed into one or more physical channels using a common physical channel mapping unit, as shown in [Figure Error! ***Style not defined.-Error! Bookmark not defined.***][Figure Error! ***Style not defined.-Error! Bookmark not defined.***], service specific rate matching shall be used to adjust the channel symbol rates (i.e., symbol rate after channel coding and service specific rate matching) to an optimum level, where minimum QoS requirement of each service is fulfilled with the same channel symbol energy. The service specific rate matching uses the same algorithm that is used in the physical channel-mapping unit, and described in section Rate matching. The symbol rates after service specific rate matching shall be signaled to physical layer via Layer 3 messages.

The following coding/multiplexing steps can be identified:

- Add CRC to each transport block
- Channel coding. This may include interleaving for turbo code
- Interleaving (two steps)
- Transport-channel multiplexing
- Mapping to physical channels

The different steps are described in detail below.

<Editor's note: The following figure is taken from ETSI specs.>

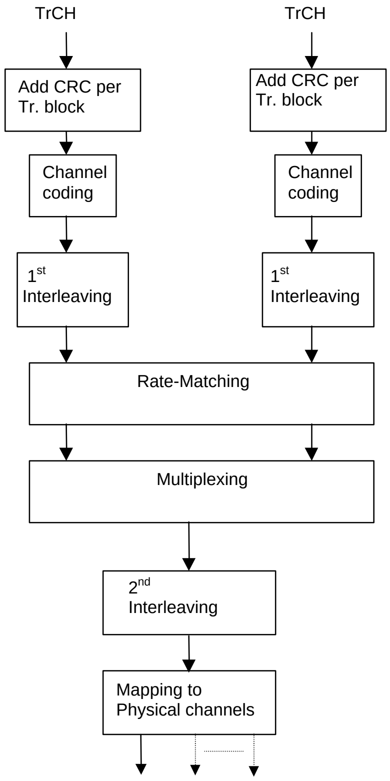

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Coding and multiplexing of transport channels.*

<Editor's note: The following figure is taken from ARIB specs.>

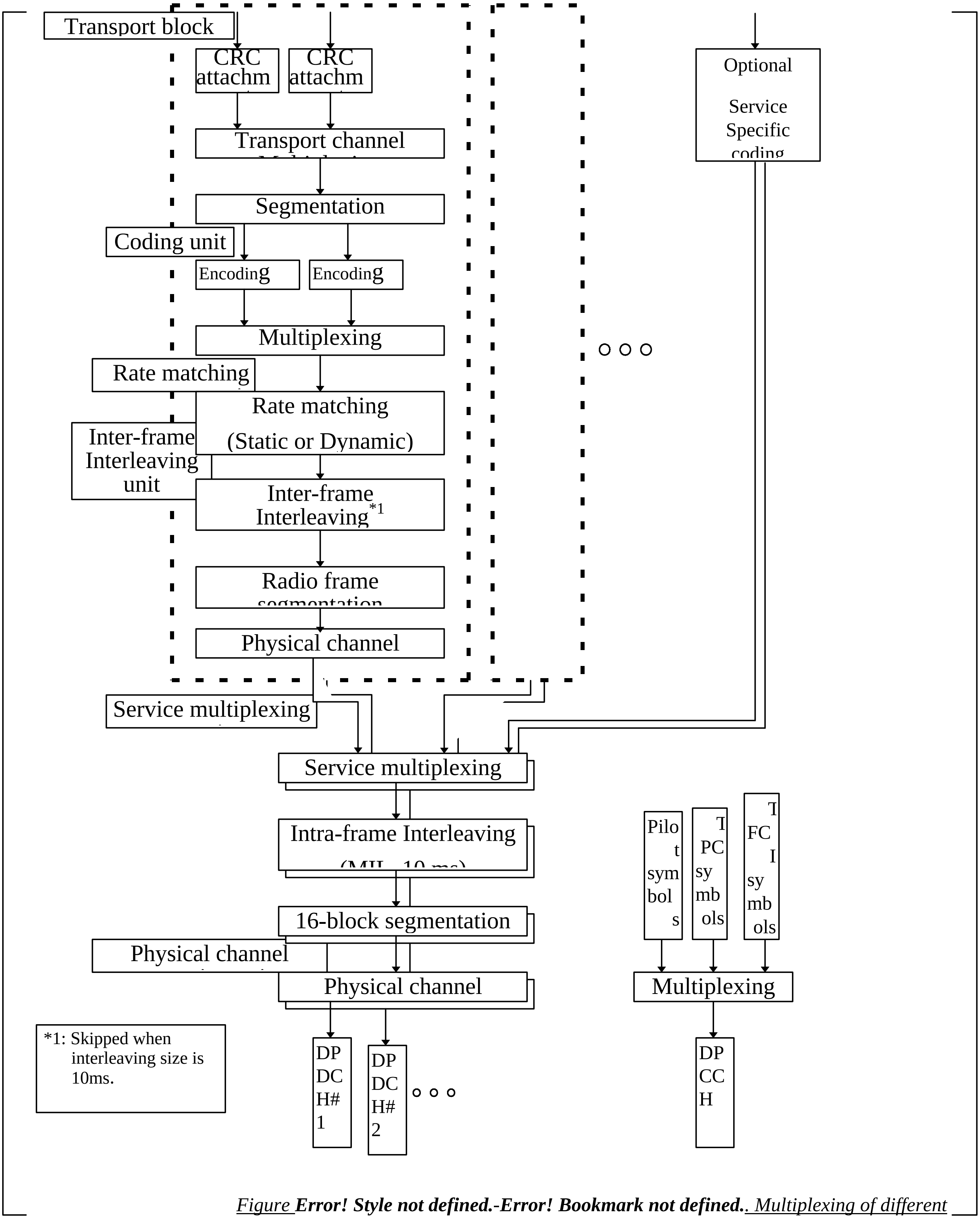

Figure **Error! Style not defined.-Error! Bookmark not defined.**. *Multiplexing of different QoS services.*

<Editor's note: The following is taken from ETSI specs. Use of code multiplexing is specified only in ETSI specs.>

Primarily, transport channels are multiplexed as described above, i.e. into one data stream mapped on one or several physical channels. However, an alternative way of multiplexing services is to use code multiplexing, which corresponds to having several parallel multiplexing chains as in Figure Error! ***Style not defined.-Error! Bookmark not defined.***, resulting in several data stream, each mapped to one or several physical channels.

10.2.1 CRC calculation

<Editor's note: In ETSI specs, no text is available on this issue and it is for further study. The contents are taken from ARIB specs.>

10.2.1.1 Generator Polynomial

Cyclic Redundancy Check is applied as an error detection scheme of transport blocks. A 16-bit CRC code is applied to each transport block of all logical channels. Generator Polynomial is as follows:

$G_{CRC16}(X)= X^{16}+X^{12}+X^{5}+1$

10.2.1.2 CRC Arithmetic Application Range

CRC for each transport block: overall Transport block

10.2.1.3 Usage of CRC Check Results

- CRC for each transport block: judgement of retransmission required/not required in the retransmission protocol (layer2, layer 3 retransmission) of higher layer.
- CRC for each DCH selective combining units: (i) outer-loop transmitter power control, (ii) reliability information for selective combining.
- CRC for each DCH inner coding units: outer-loop transmitter power control
- Inner coding units of RACH: layer 1 retransmission.

[Editor's note: Description on Retransmission function shall be harmonised with MAC specification

- Inner coding units of DCH: (i) outer-loop transmitter power control.
- CRC for RACH inner coding units: Invalidate data of inner coding units.
- The initial value of the CRC arithmetic calculator shall be "all 0".

10.2.1.4 CRC Transmission order

- Output to the convolutional coder or Turbo coder shall be done from the higher ones.

10.2.2 Channel coding

The following options are available for the transport-channel specific coding, see also Figure Error! **Style not defined.-Error! Bookmark not defined.**:

- Convolutional coding
- Turbo coding
- Service-specific coding, e.g. unequal error protection for some types of speech codecs.

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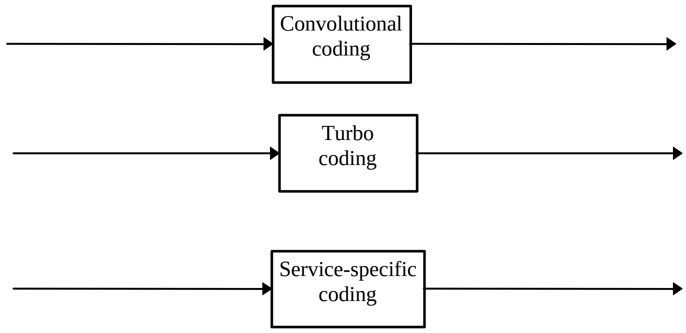


Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Channel coding ~~in UTRA/FDD~~.*

<Editor's note: There is difference in the application of convolutional/Turbo coding. This issue is a study item of AdHoc 5. The following is taken from ETSI specs.>

Convolutional coding is applied for services that require a BER in the order of 10^{-3}.

Turbo coding should be used for high data rate (above 32 kbps), high quality services that require a BER in the order 10^{-6}. Code rates for the turbo code will be adapted to layer 2 requirements. Code rates around 1/3 and ½ are recommended. Puncturing patterns for turbo codes including rate compatible puncturing are for further study.

<Editor's note: There is difference in the application of convolutional/Turbo coding. This issue is a study item of AdHoc 5. The following is taken from ARIB specs.>

Convolutional coding is applied for common transport channels and for dedicated transport channels whose maximal coding unit size is less than 320 bits.

Turbo coding is used when maximal coding unit size is more than or equal to 320 bits.

Table ***Error! Style not defined.-Error! Bookmark not defined.****. Error Correction Coding Parameters*

Transport channel type (Maximal coding unit size)	Coding scheme (constraint length)	Coding rate
BCH	Convolutional code (K=9)	1/2
PCH		
FACH		
RACH		
DCH (less than 320 bits)		1/3 /(1/2 in compressed mode using Method A*)
DCH (equal or more than 320 bits)	Turbo code (K=3)	

* See 7.4.1

[Editor's note: Combined or segmented mode with Turbo coding is F.F.S.]

10.2.2.1 Convolutional coding

<Editor's note: The following is taken from ARIB specs.The output order and the initial value of the shift register are specified only in ARIB specs.>

- The configuration of the convolutional coder is presented in Figure **Error! Style not defined.-Error! Bookmark not defined.**.
- The output from the convolutional coder shall be done in the order starting from output0, output1 and output2. (When coding rate is 1/2, output is done up to output 1).
- The initial value of the shift register of the coder shall be "all 0".

<Editor’s note: Table 7-1 of ETSI xx.04 contains the same information which is shown in Figure Error! **Style not defined.-Error! Bookmark not defined.** that is taken from ARIB specs. ARIB figure is taken.>

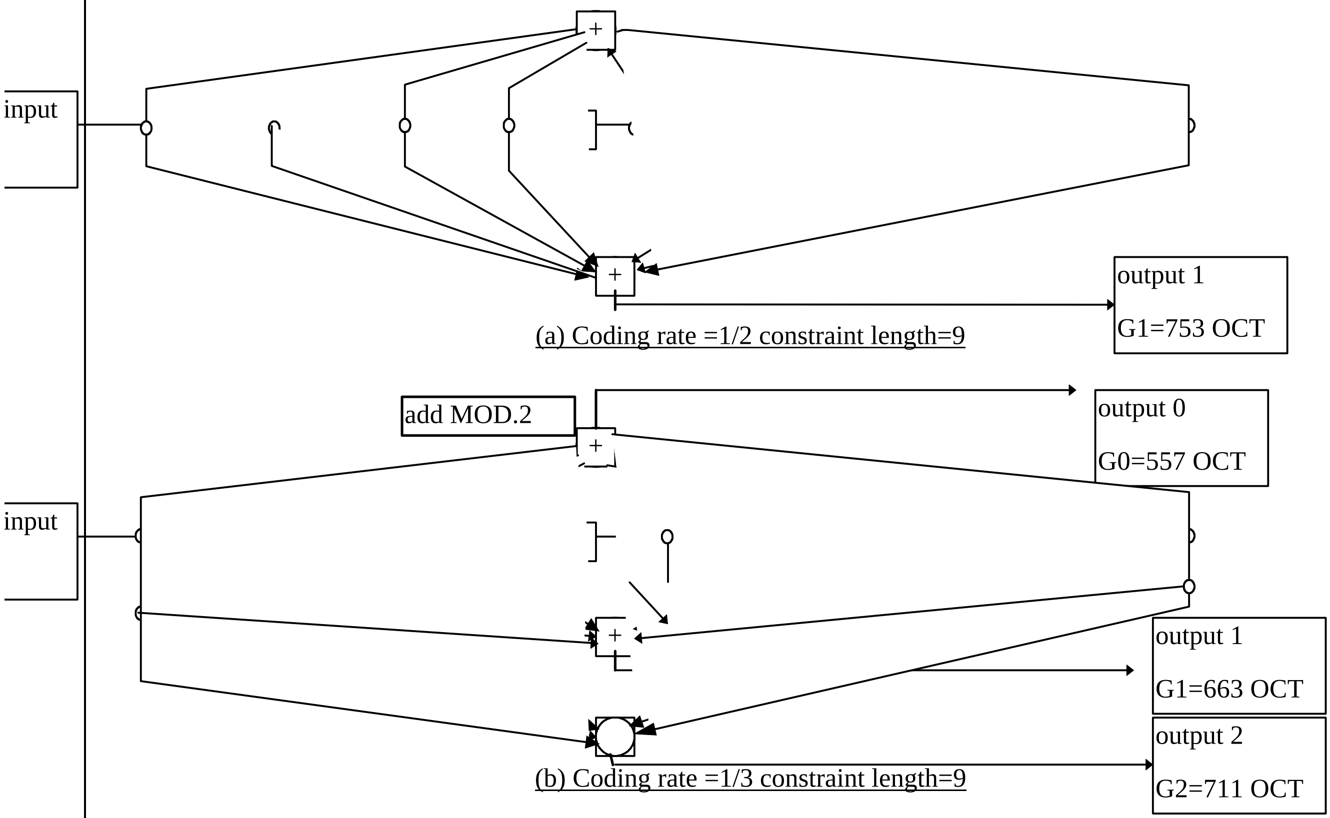


Figure ***Error! Style not defined.-Error! Bookmark not defined.*** *Convolutional Coder*

10.2.2.2

10.2.2.3 Turbo coding

<Editor’s note: Turbo coding schemes of ETSI and ARIB are different. This issue is a study item of Ad Hoc 5. The following is taken from ETSI specs.>

The parallel concatenated convolutional code (PCCC) with 8-state constituent encoders is described below. SCCC will be further evaluated equally with the 8-state PCCC.

The transfer function of the 8-state constituent code for PCCC is

$$G(D)=\left[1, \frac{n(D)}{d(D)}\right]$$

where,

$$d(D)=1+D^2+D^3$$

$$n(D)=1+D+D^3.$$

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Structure of the 8 state PCCC encoder* he SCCC is a rate 1/3 SCCC, The outer code of the SCCC is a rate 2/3 obtained by puncturing a rate ½ code with enerating matrix

$$G^{(o)}(Z) = (1, (1+Z^2)/(1+Z+Z^2))$$

he rate 2/3 is obtained by puncturing every other parity-check bit.
he inner code is a rate ½ systematic recursive convolutional code with the same previous generating matrix

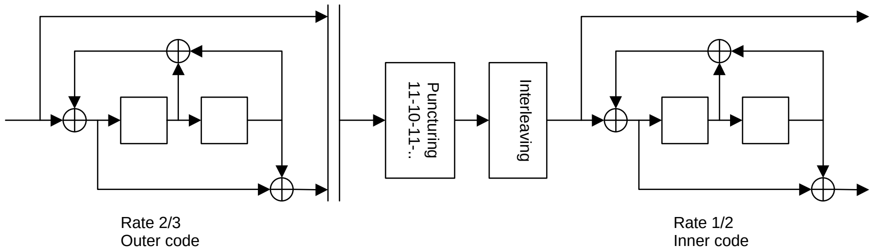
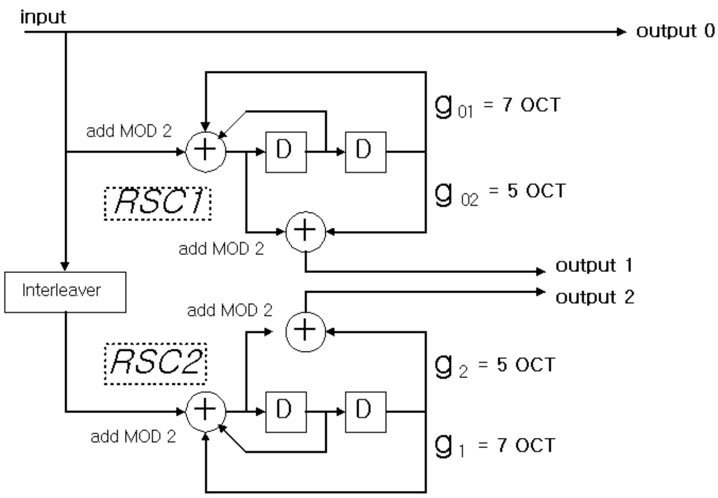


*Figure **Error! Style not defined.-Error! Bookmark not defined.**. Structure of the 4 state SCCC encoder*

- *<Editor's note: Turbo coding schemes of ETSI and ARIB are different. This issue is a study item of Ad Hoc 5. The following is taken from ARIB specs.>*

The configuration of Turbo coder is presented in Figure **Error! Style not defined.-Error! Bookmark not defined.**
The initial value of the shift registers of the coder shall be "all 0".
The output of the Turbo encoder is a sequence taken from output0, output1 and output2 using the puncturing pattern given in Table **Error! Style not defined.-Error! Bookmark not defined.**.

In the case of coding rate=1/3, the output pattern from the Turbo encoder shall be:
output0, output1, output2, output0, output1, output2,. ...
In the case of coding rate=1/2, the output pattern from the Turbo encoder shall be:
output0, output1, output0, output2, output0, output1, output0, output2, ...



Constraint length=3

*Figure **Error! Style not defined.-Error! Bookmark not defined.**. Turbo Coder*

*Table **Error! Style not defined.-Error! Bookmark not defined.**. Puncturing patterns for Turbo coder*

(1: output, 0: punctured)

output 0	1	1
output 1	1	1
output 2	1	1

(a) Coding rate = 1/3

output 0	1	1
output 1	1	0
output 2	0	1

(b) Coding rate = 1/2

10.2.2.3.1 [Trellis termination] [Catalytic Bit Processing (CBP) in Turbo code]

<Editor's note: Termination schemes are different between ETSI and ARIB. This issue is a study item of Ad Hoc 5. The following is the text taken from ETSI specs.>

The conventional method of trellis termination is used in which the tail bits are taken from the shift register feedback after all information bits are encoded. Tail bits are added after the encoding of information bits.

The following is the text taken from ARIB specs.>

The 12 bits are inserted in the pre-determined -positions of the turbo encoder input. Then 12 bits at the pre-determined -positions of the input (output0 in Figure Error! Style not **defined.-Error! Bookmark not defined..** Turbo Coder) are punctured after turbo encoding. Thus, the 12 inserted bits are actually not transmitted.

In terms of the decoder, the pre-determined 12 bits pattern is reinserted to the punctured positions that are the same place of the pre-determined -positions of the turbo encoder output.

Finally, the Turbo decoded bits are transferred to the source decoder after 12 inserted bits are deleted.

- Appendix-C shows a process CBP in Turbo code.

10.2.2.3.2

10.2.2.3.3 Turbo code internal interleaver

Editor's note: Interleaving schemes of ETSI and ARIB are different. This issue is a study item of Ad Hoc 5. The llowing is taken from ETSI specs.>

terleaver is TBD. Good performance interleaver proposals as listed in section 6 are available. The complexity and exibility of the interleaver proposals are for further study.

he following interleaver schemes are under study.

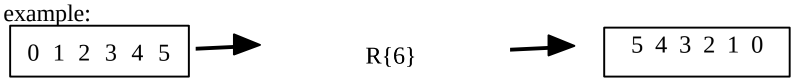
- Multiple stage interleaver (MIL)
- Galois field interleaver (GF)
- 2 dimensional algebraic interleaver (AL-N)
- 1 dimensional algebraic interleaver (AL-C) (single padding and matching constituent encoders)

he following is taken from ARIB specs.>

- The turbo code internal interleaver has the interleaving pattern obtained by using MIL. Table Error! ***Style not defined.-Error! Bookmark not defined.*** is the interleaving pattern for DTCHs.
- Appendix-B shows a process to make the interleaving pattern by using MIL.

Definition2: R{A} ... reverse the ordering of a sequence of bits (A bits).

example:



Definition3: L[N1xM1, N2xM2, ...] ... permute the ordering of a sequence of bits (L bits) using corresponding

example:

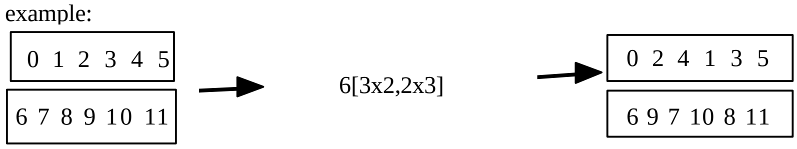


Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Turbo Code Internal Interleaving*

Table ***Error! Style not defined.-Error! Bookmark not defined.****. Turbo code Internal Interleaver (for DTCH)*

Channel	Number of bits	Interleaving pattern
DCH(32kbps, 10msec DTCH)	348	[R{7[3xR{3}]} x 50[10[4[2xR{2}]xR{3[2x2]}]x5[2x3], 8[4[2x2]x2]x7[3x3[2x2]], 5[2x3]x11[3x5[3x2]], 4[2xR{2}]x13[2x7[3x3[2x2],3[3x1,2xR{2}, 2xR{2}]x3[R{3}x1,R{3}x1,3x1]]], R{3[2x2]}x17[4[2x2,4x1,4x1,4x1,4x1]x5[3x2]], R{2}x37[7[3x3]x6[3x2]], R{2}x43[4[2x2]x11[3x5[3x2]]]]]
DCH(32kbps, 80msec DTCH)	2784	[R{7[3xR{3}]} x 398[80[10[4[2xR{2}]xR{3[2x2]}]x8[4[2x2]x2]]x5[2x3], 57[9[R{2}x5[2x3]]x7[3x3[2x2]]]x7[3x3[2x2]], 37[7[3x3]x6[3x2]]x11[3x5[3x2]], 31[7[3x3[2x2]]x5[2x3]]x 13[2x7[3x3[2x2],3[3x1,2xR{2}, 2xR{2}]x3[R{3}x1,R{3}x1,3x1]]], 24[8[4[2x2]x2]xR{3[2x2]}]x17[4[2x2,4x1,4x1, 4x1,4x1]x5[3x2]], 11[3x5[3x2]]x37[7[3x3]x6[3x2]], 10[4[2xR{2}]xR{3[2x2]}]x43[4[2x2]x11[3x5[3x2]]]]]
DCH(64kbps, 10msec DTCH)	668	R{7[3[xR{3}]} x 96[20[4[2xR{2}]x5[2x3]]x5[2x3], 14[5[2x3]xR{3[2x2]}]x7[3x3[2x2]], 9[R{2}x5[2x3]]x11[3x5[3x2]], 8[4[2x2]x2]x13[2x7[3x3[2x2],3[3x1,2xR{2}, 2xR{2}]x3[R{3}x1,R{3}x1,3x1]]], 6[3x2]x17[4[2x2,4x1,4x1,4x1,4x1]x5[3x2]], R{3[2x2]}x37[7[3x3]x6[3x2]], R{3[2x2]}x43[4[2x2]x11[3x5[3x2]]]]]
DCH(64kbps, 80msec DTCH)	5344	[R{7[3x3[2x2]]} x 764[110[13[2x7[3x3[2x2],3[3x1,2xR{2}, 2xR{2}]x3[R{3}x1,R{3}x1,3x1]]] x9[R{2}x5[2x3]]]x7[3x3[2x2]], 59[9[R{2}x5[2x3]]x7[3x3]]x13[2x7[3x3[2x2], 3[3x1,2xR{2},2xR{2}]x3[R{3}x1,R{3}x1,3x1]]], 45[9[R{2}x5[2x3]]x5[2x3]]x17[4[2x2,4x1,4x1, 4x1,4x1]x5[3x2]], 27[6[3x2]x5[2x3]]x29[5[3x2]x7[3x3[2x2]]], 21[7[3x3[2x2]]xR{3[2x2]}]x37[7[3x3]x6[3x2]], 18[6[3x2]xR{3[2x2]}]x43[4[2x2]x11[3x5[3x2]]], 13[2x7[3x3[2x2],3[3x1,2xR{2}, 2xR{2}]x3[R{3}x1,R{3}x1,3x1]]] x59[9[R{2}x5[2x3]]x7[3x3]]]]

Jote: “R” shall be processed after “L[NxM]”.

10.2.2.3.4 Adaptive QoS processing in Turbo code

<Editor's note: This content is described only in ARIB specs. This issue is a study item in Ad Hoc 5.>

- In high-speed data mode (e.g. N x 64kbps mode), the turbo encoder/decoder can process combined frames, where the number of frames "J" in a combined (super) frame can be varied from 1 to 8 (i.e. 10ms to 80 ms).
- In very high-speed data mode where the size of frame is very long, the turbo encoder/decoder can process segmented frame in order to reduce the decoder complexity. The number of segmented (sub) frames is denoted by "I"

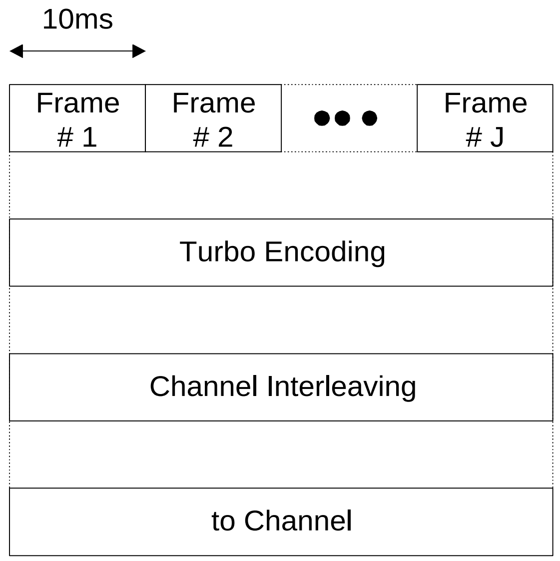


Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Frame Combining*

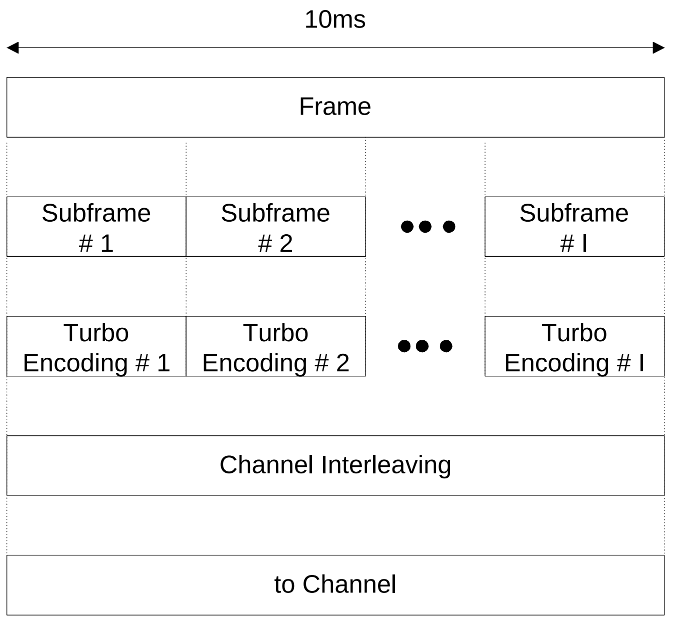


Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Frame Segmentation*

10.2.2.4 Service specific coding

<Editor's note: Both of ETSI and ARIB text are almost same. The text is taken from ARIB specs.>

In addition to standard channel coding options a service specific encoder can be used. In the simplest case it can mean that there is no channel coding at all. A more typical example is an optimized channel code for a specific speech codec. The service-specific coding option allows for additional flexibility of the UTRA layer 1 by allowing for additional coding schemes, in addition to the standard coding schemes listed above. One example is the use of unequal-error-protection coding schemes for certain speech-codecs.

10.2.3 1st interleaving

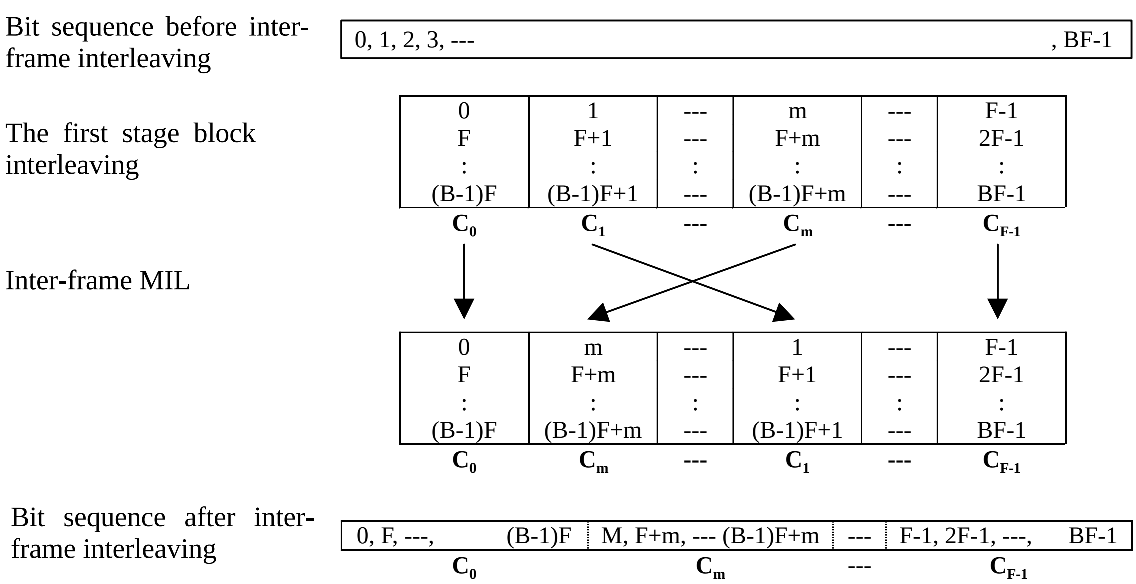
<Editor's note: In ETSI, the exact interleaver structure is for further study. However, ARIB MIL interleaver is the only channel interleaver proposal offered thus far in ETSI. So that, text from ARIB is taken.>

1st interleaving is carried out on a per-transport-channel basis. The span of the 1st interleaving is the same as the transmission time interval of the transport channel. The exact interleaver structure is TBD. Also the interleaver in case of single service is TBD.

The channel interleaver has the interleaving pattern obtained by using Multi-stage Interleaving Method (MIL). The channel MIL consists of two-step interleaving process; inter-frame MIL and intra-frame MIL. In the transmitter side, the inter-frame MIL is processed in advance of the intra frame MIL as shown in Figure Error! ***Style not defined.-Error! Bookmark not defined.***.

10.2.3.1 Inter-frame MIL

Inter-frame MIL pattern corresponds to interleaving size [frames]. Overview of the inter-frame MIL is shown in Figure Error! **Style not defined.-Error! Bookmark not defined.**.Table Error! **Style not defined.-Error! Bookmark not defined.** shows the inter-frame MIL pattern for each interleaving size [frames].



F: the number of radio frames corresponding to interleaving size
B: the number of bits in a radio frame for a inter-frame interleaving unit

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Overview of the inter-frame MIL*

Table ***Error! Style not defined.-Error! Bookmark not defined.****. Inter-frame MIL pattern for each interleaving size [frames]*

Interleaving size [frames]	Interleaving pattern of the inter-frame MIL
1	**C_0**
2	**C_0, C_1**
4	**C_0, C_2, C_1, C_3**
8	**C_0, C_4, C_2, C_6, C_1, C_5, C_3, C_7**

10.2.4 Rate matching

The rate matching applies repetition and puncturing of the different transport channels.

<Editor’s note: The following is taken from ARIB.>

Static rate matching is applied to forward link channels. In this scheme, ratio of rate matching is determined by the size of each transport blocks and mapping position of each transport channels to a radio frame is settled even when the rate of the other transport channels are varied. When rate of a transport channel is reduced from its maximum rate, this lead some punctured bits (not transmitted bits) in a radio frame.

Dynamic rate matching means service specific rate matching as described Transport-channel coding/multiplexing. In this case, ratio of each rate matching is varied with size of each transport blocks and rate of the other transport channels. Mapping position of each transport channels to a radio frame is varied according to the share of each transport channels in a radio frame so as to fulfill a radio frame with valid data bits.

For each combination of rates of the different transport channels, a puncturing/repetition factor is assigned to each transport channel. The set of puncturing/repetition factors is determined based on following criteria:

- desired transmission quality requirements of each transport channel is fulfilled and not significantly exceeded. This means that required transmission power to meet quality requirements for all transport channels is as low as possible.
- on the uplink, the total bit rate after transport channel multiplexing is identical to the total channel bit rate of the dedicated physical channels allocated
- on uplink and downlink, the total allocated code resource should be minimised
- the puncturing factors should not exceed a certain maximum puncturing factor, specific for each transport channel.

<Editor’s note: The content of the following text is a study item of Ad Hoc 4.>

- For downlink transport channel combinations that use blind rate detection (no explicit TFCI) additional rate matching may also be applied before 1st interleaving. Whether this option is to be kept is ~~ffs~~FFS.

10.2.4.1 Rate matching algorithm

<Editor’s note: This is the same algorithm in ETSI and ARIB except for the value of P. Values are taken from ARIB specs as tentative ones.>

Let’s denote:

$S_N = \{N_1, N_2, \ldots, N_L\}$ = ordered set (in ascending order from left to right) of allowed number of bits per block

N_C = number of bits per matching block

$S_0 = \{d_1, d_2, \ldots, d_{N_C}\}$ = set of N_C data bits

P = maximum amount of puncturing allowed ~~(tentatively 0.2, for further study)~~

$P = \begin{cases} 0.2\text{: for forward-link} \\ 0.0\text{: for reverse-link} \end{cases}$

The rate matching rule is as follows:

find N_i and N_{i+1} so that $N_i \le N_C < N_{i+1}$

$if\ (\frac{N_i}{N_C} > 1 - P)$

?

?

? $y = N_C - N_i$

?

```
e = NC              -- initial error between current and desired puncturing ratio
                    -- this offset is flexible, e.g. e = 2Nc
m = 1               -- index of current bit
do while m <= NC
        e = e – 2 * y           -- update error
        if e <= 0 then          -- check if bit number m should be punctured
            puncture bit m from set S0
            e = e + 2*NC        -- update error
        end if
        m = m + 1               --  next bit
end do
```

? else

? $y = N_{i+1} - N_C$

?

```
e = NC              -- initial error between current and desired puncturing ratio
                    -- this offset is flexible, e.g. e = 2Nc
m = 1               -- index of current bit
do while m <= NC
        e = e – 2 * y           -- update error
        do while e <= 0         -- check if bit number m should be repeated
            repeat bit m from set S0
            e = e +  2*NC       -- update error
        enddo
        m = m + 1               --  next bit
end do
```

end if

10.2.5 Downlink discontinuous transmission

On the downlink, if the total bit rate after transport channel multiplexing is not identical to the total channel bit rate of the allocated dedicated physical channels, discontinuous transmission is used, i..e. dummy channel bits with zero power are inserted.

<Editor's note: The following is taken from ARIB specs.>

10.2.5.1 Transmission

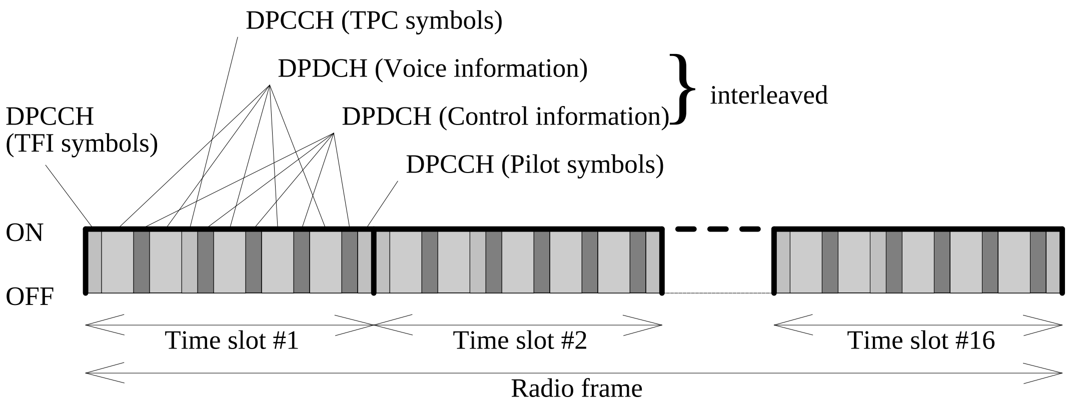
- If transport data is less than the number of DPDCH bits in a radio frame, the DPDCH transmission can be turn off for data absent. This situation can be occurred when the DPDCH carries DCH(s) to which a DTCH for voice information and/or a DCCH(s) are mapped. (Although Rate matching described in Rate matching can be applied to fulfil the DPDCH, the forward link transmission is not need to be continuous.)
- The transmission of the DPDCH symbols shall be ON, only if there is data to transmit. If there is no data, the transmission shall be OFF. An example of the transmission patterns in forward link is represented in Figure Error! **Style not defined.-Error! Bookmark not defined.**.
- Pilot and TPC symbols are always transmitted regardless of the data existence.
- The information to notify whether voice and/or control information exist or not shall not be transmitted.

10.2.5.2 Receive

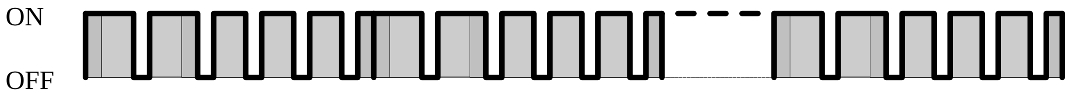
- When the DPDCH carries DCH(s) to which DCCH(s) are mapped, there is no need to judge whether there is data or not, and the ordinary processing shall be performed.
- When the DPDCH carries DCH(s) to which a DTCH for voice information is mapped, the method shown in Table Error! **Style not defined.-Error! Bookmark not defined.** shall be performed to judge whether there is voice and/or control information. The symbol average received power in Table Error! **Style not defined.-Error! Bookmark not defined.** is the received power average value of all corresponding symbols within the radio frame.

Table ***Error! Style not defined.-Error! Bookmark not defined.****. Decision Method for With/Without Voice Information/ Control Information*

information type	with information	without information
Voice information	(At least one) CRC in DCH transport block is OK, or the power ratio of Pilot & TPC symbol average received power to the average symbol received power for DCH is less than P_{DTX} dB.	(At least one) CRC in DCH transport block is NG, and the power ratio of the Pilot & TPC symbol average received power to the average symbol received power for DCH is P_{DTX} dB or more.
Control information	(At least one) CRC in DCH transport block is OK.	(At least one) CRC in DCH transport block is NG.



(i) The whole DPDCH is power-on.



(ii) DPDCH only for voice information is power-on (no contol information).

(iii) DPDCH only for control information is power-on (no voice information).

(iv) The whole DPDCH is power-off (no voice and no control information).

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Discontinuous transmission pattern examples in forward link*

10.2.6 Transport-channel multiplexing

The coded transport channels are serially multiplexed within one radio frame. The output after the multiplexer (before the 2nd interleaver) will thus be according to Figure Error! **Style not defined.-Error! Bookmark not defined.**.

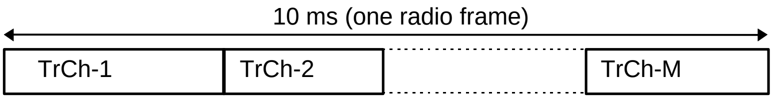


Figure ***Error! Style not defined.-Error! Bookmark not defined.****.   Transport channel multiplexing.*

<Editor's note: The following is taken from ARIB specs.>

When more than one transport channel has been allocated to one user the following multiplexing principles must be followed:

1. Transport channels with same E_b/N_o requirement are multiplexed into one physical code channel. Only when the aggregate bit rate of the transport channels exceeds the transmission capability of the one physical code channel multicode transmission is used.
2. Transport channels that use turbo coding with 10-80 ms channel interleaving (target BER $\leq 10^{-6}$) are multiplexed with transport channels that utilize convolutional coding and 10 ms channel interleaving (target BER $\leq 10^{-3}$) into one physical code channel. Only when the aggregate bit rate of the transport channels exceeds the transmission capability of the one physical code channel multicode transmission is used.

10.2.7 2nd interleaving

<Editor's note: In ETSI, the exact interleaver structure is for further study. However, ARIB MIL interleaver is the only channel interleaver proposal offered thus far in ETSI. So that, text from ARIB is taken.>

The 2nd interleaving is carried out over one radio frame (10 ms) and is applied to the multiplexed set of transport channels.

Intra-frame MIL pattern corresponds to physical channel [symbol rate]. Table Error! **Style not defined.-Error! Bookmark not defined.** shows the intra-frame MIL pattern for each interleaving size [frames].

Table ***Error! Style not defined.-Error! Bookmark not defined.****. Intra-frame MIL pattern for each physical channel [symbol rate]*

Physical channel	Link	Symbol rate [ksps]	TFCI bits in a frame [bits]	DATA bits in a frame [bits]	Interleaving pattern of the intra-frame MIL
Perch CH	Forward	16	0	160	160[10[5[3x2]x2]x16[4[2x2]x4[2x2]]]
CCPCH	FACH	64	0	1152	1152[72[9[3x3]x8[4[2x2]x2]]x16[4[2x2]x4[2x2]]]
	PCH	64	0	272	272[17[4[2x2,4x1,4x1,4x1,4x1]x5[3x2]]x16[4[2x2]x4[2x2]]]
	Reverse	32	0	320	320[20[4[2x2]x5[3x2]]x16[4[2x2]x4[2x2]]]
		128	0	1280	1280[80[10[5[3x2]x2]x8[4[2x2]x2]]x16[4[2x2]x4[2x2]]]
DPCH	Forward	8	0	64	64[4[2x2]x16[4[2x2]x4[2x2]]]
			32	32	32[2x16[4[2x2]x4[2x2]]]
		16	0	160	160[10[5[3x2]x2]x16[4[2x2]x4[2x2]]]
			32	128	128[8[4[2x2]x2]x16[4[2x2]x4[2x2]]]
		32	0	480	480[30[6[3x2]x5[2x3]]x16[4[2x2]x4[2x2]]]
			32	448	448[28[7[3x3[2x2]]x4[2x2]]x16[4[2x2]x4[2x2]]]
		64	0	1120	1120[70[10[5[3x2]x2]x7[3x3[2x2]]]x16[4[2x2]x4[2x2]]]
			128	992	992[62[9[3x3]x7[3x3[2x2]]]x16[4[2x2]x4[2x2]]]
		128	0	2400	2400[150[15[5[2x3]x3]x10[5[3x2]x2]]x16[4[2x2]x4[2x2]]]
			128	2272	2272[142[13[2x7[3x3[2x2],3[3x1,2xR{2},2xR{2}]x3[R{3}x1,R{3}x1,3x1]]]x11[3x5[3x2]]]x16[4[2x2]x4[2x2]]]
		256	0	4832	4832[302[19[5[2x3]x4[2x2]]x16[4[2x2]x4[2x2]]]x16[4[2x2]x4[2x2]]]
			128	4704	4704[294[19[5[2x3]x4[2x2]]x16[4[2x2]x4[2x2]]]x16[4[2x2]x4[2x2]]]
		512	0	9952	9952[622[32[8[4[2x2]x2]x4[2x2]]x20[4[2x2]x5[3x2]]]x16[4[2x2]x4[2x2]]]
			128	9824	9824[614[31[7[3x3[2x2]]x5[2x3]]x20[4[2x2]x5[3x2]]] x16[4[2x2]x4[2x2]]]
		1024	0	20192	20192[1262[40[8[4[2x2]x2]x5[2x3]]x32[8[4[2x2]x2]x4[2x2]]]x16[4[2x2]x4[2x2]]]
			128	20064	20064[1254[40[8[4[2x2]x2]x5[2x3]]x32[8[4[2x2]x2]x4[2x2]]] x16[4[2x2]x4[2x2]]]
		2048	0	40416	40416[2526[79[10[5[3x2]x2]x8[4[2x2]x2]]x32[8[4[2x2]x2]x4[2x2]]]x16[4[2x2]x4[2x2]]]
			128	40288	40288[2518[79[10[5[3x2]x2]x8[4[2x2]x2]]x32[8[4[2x2]x2]x4[2x2]]] x16[4[2x2]x4[2x2]]]
		4096	0	81376	81376[5086[80[10[5[3x2]x2]x8[4[2x2]x2]]x64[8[4[2x2]x2]x8[4[2x2]x2]]]x16[4[2x2]x4[2x2]]]
			128	81248	81248[5078[80[10[5[3x2]x2]x8[4[2x2]x2]]x64[8[4[2x2]x2]x8[4[2x2]x2]]]x16[4[2x2]x4[2x2]]]

Table Error! Style not defined.-Error! Bookmark not defined.. Intra-frame MIL pattern for each physical channel [symbol rate] *(Cont')*

Physical channel	Link	Symbol rate [ksps]	TFCI bits [bits]	DATA bits in a frame [bits]	Interleaving pattern of the intra-frame MI
DPCH	Reverse	16	0, 32	160	160[10[5[3x2]x2]x16[4[2x2]x4[2x2]]]
		32	0, 32	320	320[20[4[2x2]x5[3x2]]x16[4[2x2]x4[2x2]]]
		64	0, 32	640	640[40[8[4[2x2]x2]x5[2x3]]x16[4[2x2]x4[2x2]]]
		128	0, 32	1280	1280[80[10[5[3x2]x2]x8[4[2x2]x2]]x16[4[2x2]x4[2x2]]]
		256	0, 32	2560	2560[160[16[4[2x2]x4[2x2]]x10[5[3x2]x2]]x16[4[2x2]x4[2x2]]]
		512	0, 32	5120	5120[320[20[4[2x2]x5[3x2]]x16[4[2x2]x4[2x2]]]x16[4[2x2]x4[2x2]]]
		1024	0, 32	10240	10240[640[32[8[4[2x2]x2]x4[2x2]]x20[4[2x2]x5[3x2]]]x16[4[2x2]x4[2x2]]]
		2048	0, 32	20480	20480[1280[40[8[4[2x2]x2]x5[2x3]]x32[8[4[2x2]x2]x4[2x2]]]x16[4[2x2]x4[2x2]]]
		4096	0, 32	40960	40960[2560[80[10[5[3x2]x2]x8[4[2x2]x2]]x32[8[4[2x2]x2]x4[2x2]]]x16[4[2x2]x4[2x2]]]

Definition: L[NxM] ... NxM block interleaver as shown the following figure:

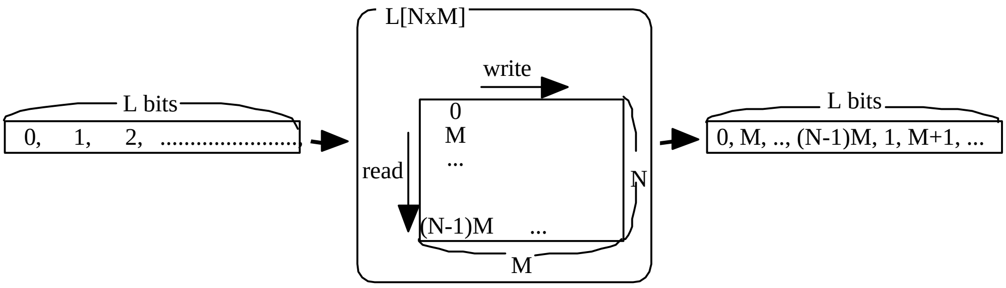


Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Channel Interleaving*

10.2.8 Multirate transmission

<Editor's note: This section is taken from ARIB specs.>

10.2.8.1 Variable Rate Transmission

10.2.8.1.1 Forward-link

- The timing of each variable rate DCH on physical channel is determined on the basis of the highest data rate case by Layer-3 negotiation. The head bit position of each variable rate DCH is fixed during the data rate changes. (See Physical Channel Mapping)
- Rate matching is always performed using the common rule which is done by assuming that all variable rate DCHs are the highest data rate. (See Rate matching Rate matching)
- Discontinuous transmission according to the data rate is applied for forward-link-DPDCH. (See Downlink discontinuous transmission Downlink discontinuous transmission (DTX) [needs changes/supplements concerned with the case of multiple variable rate DCH])

- Rate detection is performed either by use of blind rate detection using CRC (See Blind Rate Detection Blind Rate Detection), or by use of explicit Transport Format Combination Indicator (TFCI). Independent blind rate detection can be performed for each variable rate DCH. (The rate detection scheme (blind detection or TFCI) of each variable rate DTCH can be selected independently according to the required service quality.)

10.2.8.1.2 Reverse-link

- The transmission order of the variable rate DCH and its mapping on service rate combinations (SRCs) are determined by Layer-3 negotiation in advance. (See Physical Channel Mapping)
- Rate matching (See Rate matching Rate matching) is performed for each SRC. Before rate matching, all data bits including in a SRC are mapped from the head of the frame closely.
- Continuous transmission is applied for reverse-link-DPDCH at all times. The modulated BPSK symbol sequence is multiplied by power coefficient (this is necessary to reduce the transmit power for lower rates). (See Power control in S1.14 [needs supplements concerned with the frame transmit power control according to the SRC, See xx])
- Rate detection is performed either by use of blind rate detection, or by use of explicit transport format combination indicator (TFCI, See Explicit Rate Detection Explicit rate detection). TFCI can be used for all variable rate DCH. Blind rate detection can be used for DCH for DCCH + primary variable rate DCH.

10.2.8.2 Multicode Transmission

10.2.8.2.1 Forward-link

- When 1 Radio Link consists of multiple dedicated physical channels (spreading codes), transmission shall be performed as described below, and pilot aided coherent detection and transmitter power control, etc. shall be performed comprehensively for all the dedicated physical channels in 1 Radio Link. When multiple Radio Links were allocated for one MS, pilot aided coherent detection and transmitter power control shall be performed independently for each Radio Link.
- The frame timing and scrambling code phase shall be matched at all dedicated physical channels in one Radio Link. Also, the symbol rate of the multiple physical channels designated within one Radio Link shall all be the same.
- In all of the dedicated physical channels within one Radio Link, the spreading codes used at one particular dedicated physical channel shall be used only for the pilot symbol and the TPC symbol part. (See Figure Error! **Style not defined.-Error! Bookmark not defined.**)
- Transmission power of pilot symbols and TPC symbols in 1 Radio Link might be transmitted at a different transmission power from that multiplied by the number of dedicated physical channels in 1 Radio Link for the transmission power by symbols other than the pilot symbols and TPC symbols. (See Figure Error! **Style not defined.-Error! Bookmark not defined.**)
- Generally, δ shall be settled around the value which sets the power of DPCCH part to be one-N th of the DPDCH part, where N is the number of dedicated physical channels in a radio link. But basically, there is no regulation about the difference δ of transmission power.
- Mobile Station should reflect the difference δ in target received SIR for forward-link closed-loop transmission power control.

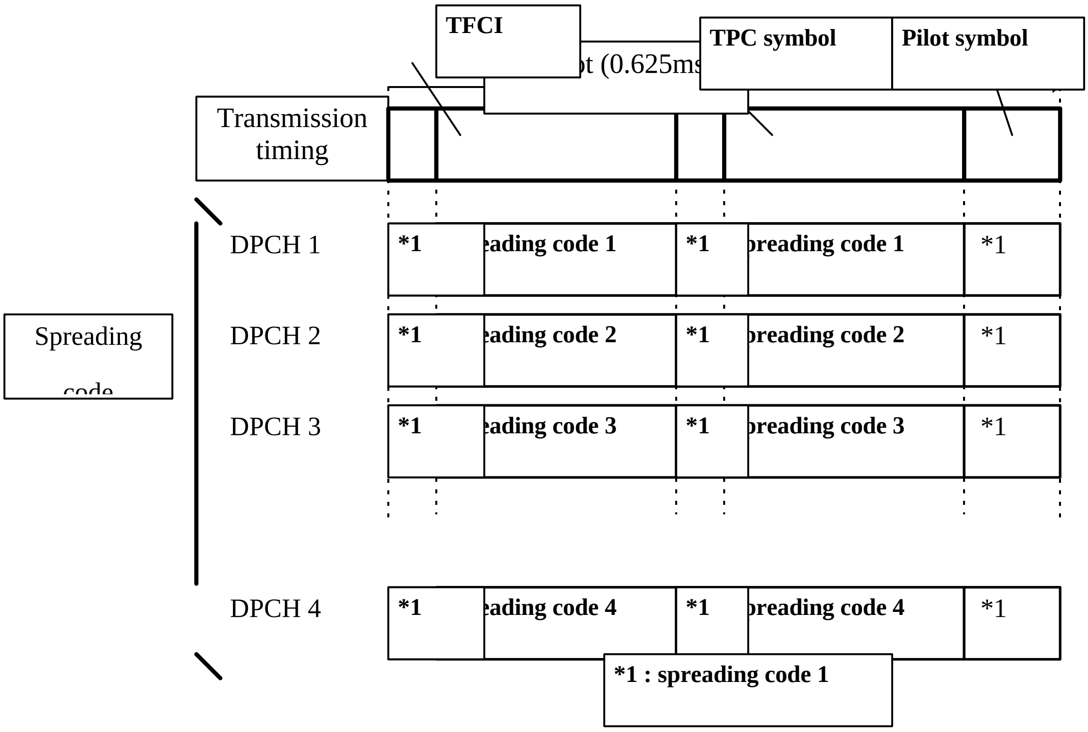


Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Spreading code in multi-code transmission*

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Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Transmission power in multi-code transmission*

10.2.8.2.2 Reverse-link

For multi-code transmission in one reverse link radio link, each additional reverse link DPDCH may be transmitted on either the I or the Q branch, sharing a single common DPCCH. Each DPDCH branch shall use its own spreading code, Multiple DPDCHs on different branches may share a common scrambling code. When multiple radio links are allocated for one MS, pilot aided coherent detection and transmit power control shall be performed independently for each radio link.

10.2.9 Rate detection

<Editor's note: This section is taken from ARIB specs.>

Two kinds of rate detection can be employed; explicit rate detection and blind rate detection. In the explicit rate detection, transmitter side transmits Transport Format Combination Indicator (TFCI), and receiver side detects transport format combination using TFCI. In the blind rate detection, transmitter side does not transmit TFCI, and receiver side detect transport format combination using some information, e.g. received power ratio of DPDCH to DPCCH, CRC check results.

For reverse-link, the blind rate detection is an operator option. For forward-link, services to be applied blind rate detection shall be specified.

10.2.9.1 Blind Rate Detection

Two kinds of blind rate detection are employed. Examples of these methods are given in Annex A.

10.2.9.2 Explicit Rate Detection

10.2.9.2.1 Transport Format Combination Indicator

Transport Format Combination Indicator (TFCI) informs the receiver of the number of bits in each frame of each of the services currently in use. As soon as a certain bit-rate is known, the number of code channels, the spreading factor and the puncturing/repetition rate is immediately known from the rules described in section 7.2.4.

This document therefore only explains the mapping from TFCI bits to TFCI service rate combinations.

A connection may in general include the variable-rate services S_1, S_2, …, S_K. Each service S_i has a set of possible transport format combination indicators $TF_{i,1}$,$TF_{i,2}$,…$TF_{i,Li}$:

S_1: $TF_{1,1}$, … , $TF_{1,L1}$

S_2: $TF_{2,1}$, … , $TF_{2,L2}$

…

S_K: $TF_{K,1}$, … , $TF_{K,LK}$

This gives L=L1xL2x…xLK service rate combinations, and thus it is required that L is less than or equal to 64 with the default TFCI word or 1024 with the extended TFCI word.

These service rate combinations shall be mapped to a certain service rate combination number, *m*, in the following way:

```
For j=K:-1:1,
  SRC[j]= m MOD L[j];
  m = m DIV L[j];
End;
```

From this pseudo-code, given a service rate combination number, i.e. a certain combination of TFCI bits, *m*, SRC contains the rates of each of the K services. The integer values used for *m* shall be consecutive, starting from 0. Note that this code gives the mapping rule from *m* to SRC, i.e. the rule used in the receiving side. The mapping rule from SRC to *m*, i.e. the transmitting side rule, is [TBD].

10.2.10 Coding Procedure

<Editor's note: PI part bit configuration is described only in ARIB specs. Other contents will also be described in S1.11.>

10.2.10.1 SFN(System Frame Number)

- SFN indicates reverse link scrambling code phase and super frame synchronisation. It is broadcasted in BCH. (See S1.11)

10.2.10.2 PI part

- Applied to: PCH
- An identifier to instruct whether there is termination information to the MS, and the necessity to receive BCH. When there arises the need to make the MS receives BCH, the necessity of reception shall be notified to the MS by PI1 and PI2.
- The bit configuration is presented in Table **Error! Style not defined.-Error! Bookmark not defined.**.

*Table **Error! Style not defined.-Error! Bookmark not defined.**. PI part bit configuration*

Bit	identified content
All 0	There is no termination information and not necessary to receive BCH
All 1	There is termination information or necessary to receive BCH

10.2.11 Bit transmission Sequence

<Editor's note: This content is described only in ARIB specs.>

- DCH shall be transmitted in the order it was input. Other various information shall be transmitted from the MSB side.
- Tail bits shall all transmit "0".
- CRC bits shall be transmitted from the higher number bits to the lower ones.
- Dummy bit shall always be "0".
- Dummy is the subject of CRC coding.

.

~~10.3 Automatic Repeat Request (ARQ)~~

~~The details of the UTRA ARQ schemes are not yet specified. Therefore, the impact on layer 1, e.g. if soft combining of retransmitted packets is to take place, is not yet fully specified.~~

<Editor's note: It is proposed to delete this ARQ section for the time being from here, since there is no contents defined.>

10.4 Coding for layer 1 control

10.4.1 Coding of Transport-format-combination indicator (TFCI)

<Editor's note: Only wording is changed, not technical contents, except that TFCI bit repetition is mentioned to be done only in downlink, since in uplink it it not needed.>

~~According to current working assumption, t~~The number of TFCI -bits is variable and is set ~~during~~ at the beginning of the ~~a~~ call via higher layer ~~level~~ signalling. ~~If the number of TFCI bits is up to 6 or up to 10 the coding shall be as follows.~~ Encoding of the TFCI bits depends on the number of them. If there are at most 6 bits of TFCI, the channel encoding is done as described in section Coding of default TFCI word. Correspondingly, if the TFCI word is extended to 7-10 bits the channel encoding is done as explained in the section Coding of extended TFCI word. For improved -TFCI detection reliability, in downlink, repetition is used by increasing the number of TFCI bits within a slot.

10.4.1.1 -Coding of default TFCI word

<Editor's note: the definition of OVSF codes has been corrected C6(I)=>C32,I, no other changes.>

If the number of TFCI bits is up to 6, the TFCI bits are encoded using biorthogonal (32, 6) block code. The coding procedure is as shown in Figure Error! **Style not defined.-Error! Bookmark not defined.**.

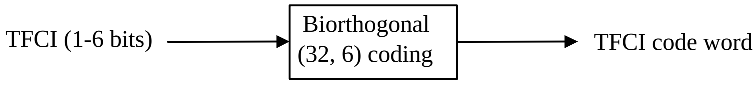

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Channel coding of TFCI bits.*

If the TFCI consist of less than 6 bits, it is padded with zeros to 6 bits, by setting the most significant bits to zero. The receiver can use the information that not all 6 bits are used for the TFCI, thereby reducing the error rate in the TFCI decoder. The length of the TFCI code word is 32 bits. Thus there are 2 bits of (encoded) TFCI in every slot of the radio frame. The code words of the biorthogonal block code are from the level 326 of the code three of OVSF codes defined in document xx.05S1.13. The code words, $C_6(I)$, $I = 0, \ldots, 31$, $C_{32,I}$, $I = 1,\ldots,32$, form an orthogonal set, $S_{C_6} = \{C_6(0), C_6(1), \ldots, C_6(31)\}$,, $S_{C_{32}} = \{C_{32,1}, C_{32,2}, \ldots, C_{32,32}\}$, of 32 code words of length 32 bits. By taking the binary complements of the code words of S_{C_6} , $S_{C_{32}}$, another set, $\bar{S}_{C_6} = \{\bar{C}_6(0), \bar{C}_6(1), \ldots, \bar{C}_6(31)\}$ $\bar{S}_{C_{32}} = \{\bar{C}_{32,1}, \bar{C}_{32,2}, \ldots, \bar{C}_{32,32}\}$ is formed. These two sets are mutually biorthogonal yielding total of 64 different code words.

Mapping of the TFCI bits to the code words is done as shown in the Figure Error! **Style not defined.-Error! Bookmark not defined.**.

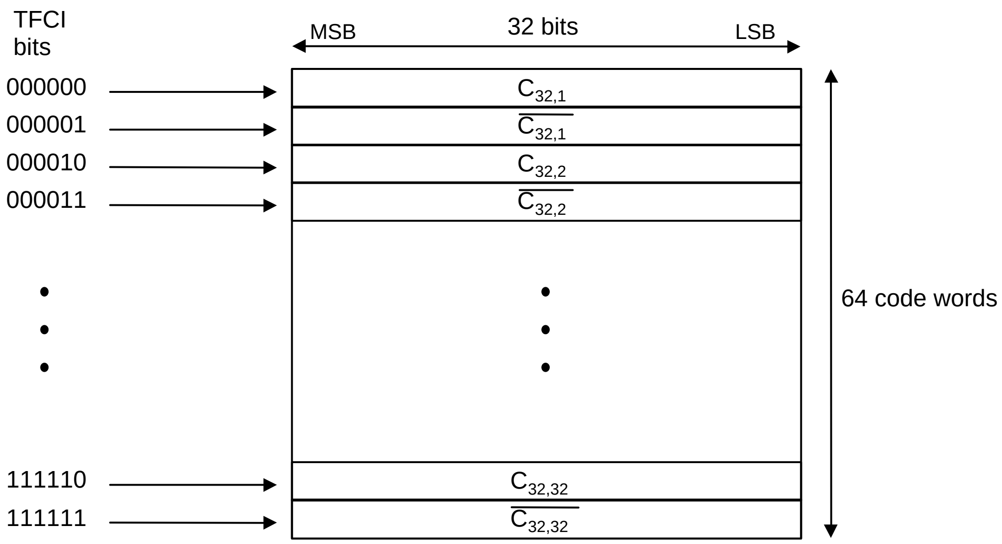

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Mapping of TFCI bits to biorthogonal code words.*

10.4.1.2 Coding of extended TFCI word

<Editor's note: the definition of OVSF codes has been corrected C5(I)=>C16,I, no other changes.>

If the number of TFCI bits is 7-10 the TFCI information field is split into two words of length 5 bits as shown in the Figure Error! **Style not defined.-Error! Bookmark not defined.**.

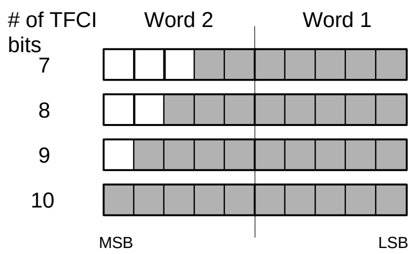

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Mapping of TFCI bits to two words*

Both of the words are encoded using biorthogonal (16, 5) block code. The code words of the biorthogonal (16, 5) code are from two mutually biorthogonal sets, $S_{C_5} = \{C_5(0), C_5(1), \ldots, C_5(15)\}$ $S_{C_{16}} = \{C_{16,1}, C_{16,2}, ..., C_{16,16}\}$ and its binary complement, $\overline{S}_{C_5} = \{\overline{C}_5(0), \overline{C}_5(1), \ldots, \overline{C}_5(15)\}$ $\overline{S}_{C_{16}} = \{\overline{C}_{16,1}, \overline{C}_{16,2}, ..., \overline{C}_{16,16}\}$. Words of set S_{C_5} $S_{C_{16}}$ are from the level ~~5~~ 16 of the code three of OVSF codes defined in document ~~xx.05~~ S1.13. The mapping of information bits to code words is shown in the Table Error! **Style not defined.-Error! Bookmark not defined.**.

Table ***Error! Style not defined.-Error! Bookmark not defined.****. Mapping of information bits to code words for biorthogonal (16, 5) code.*

Information bits	Code word
00000	$C_5(0)$ $C_{16,1}$
00001	$\overline{C_5(0)}$ $\overline{C}_{16,1}$
00010	$C_5(1)$ $C_{16,2}$
...	...
11101	$\overline{C_5(14)}$ $\overline{C}_{16,15}$
11110	$C_5(15)$ $C_{16,16}$
11111	$\overline{C_5(15)}$ $\overline{C}_{16,16}$

10.4.2 Interleaving of TFCI words

10.4.2.1 Interleaving of default TFCI word

As only one code word for TFCI of maximum length of 6 bits is needed no channel interleaving for the encoded bits are done. Instead, the bits of the code word are directly mapped to the slots of the radio frame as depicted in the Figure Error! **Style not defined.-Error! Bookmark not defined.**. Within a slot the more significant bit is transmitted before the less significant bit.

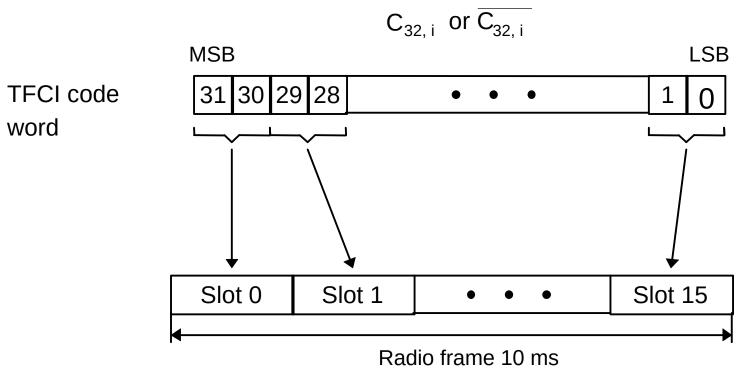

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Time multiplexing of code words of (32, 6) code to the slots of the radio frame.*

10.4.2.2 Interleaving of extended TFCI word

After channel encoding of the two 5 bit TFCI words there are two code words of length 16 bits. They are interleaved and mapped to DPCCH as shown in the Figure Error! **Style not defined.-Error! Bookmark not defined.**. Note that $b_{1,i}$ and $b_{2,i}$ denote the bit *i* of code word 1 and code word 2, respectively.

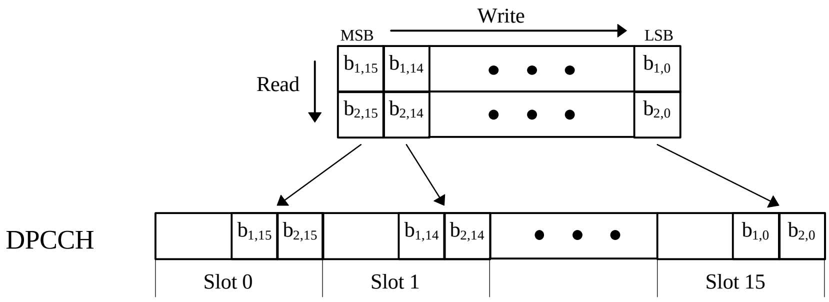

Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Interleaving of TFCI code words.*

10.5 Coding of Slotted mode

<Editor's note: No major change in technical contents, except that uplink slotted mode possibility is adopted from ETSI, it was not mentioned in ARIB text. Some sentences from initial ETSI text have been moved to following subsections. >

~~With slotted downlink transmission, it is possible for a single-receiver mobile station to carry out measurements on other frequencies without affecting the ordinary data flow. Slotted mode can also be used in uplink transmission when making measurements at frequencies close to the FDD uplink band. The principle of slotted transmission is illustrated inFigure 7-12.~~ .

~~Note that the idle slot is created without any loss of data as the number of information bits per frame is kept constant, while the processing gain is reduced by decreasing the spreading factor or increasing the code rate.~~

To support interfrequency measurements downlink transmission may, on network command, enter slotted mode. Uplink transmission may also enter slotted mode, on network command, if measurements will be made at frequencies close to FDD uplink band.

In slotted mode, slots N_{first} to N_{last} are not used for transmission of data. As illustrated in Figure **Error! Style not defined.-Error! Bookmark not defined.**, which shows the example of fixed idle position with single frame method (see section Position of Idle Period), the instantaneous transmit power is increased in the slotted frame in order to keep the quality (BER, FER, etc.) unaffected by the reduced processing gain. The amount of power increase depends on the transmission time reduction method (see section Transmission Time Reduction Method).

What frames are slotted, are decided by the network. When in slotted mode, slotted frames can occur periodically, as illustrated in Figure **Error! Style not defined.-Error! Bookmark not defined.**, or requested on demand (see section xx). The rate of and type of slotted frames is variable and depends on the environment and the measurement requirements.

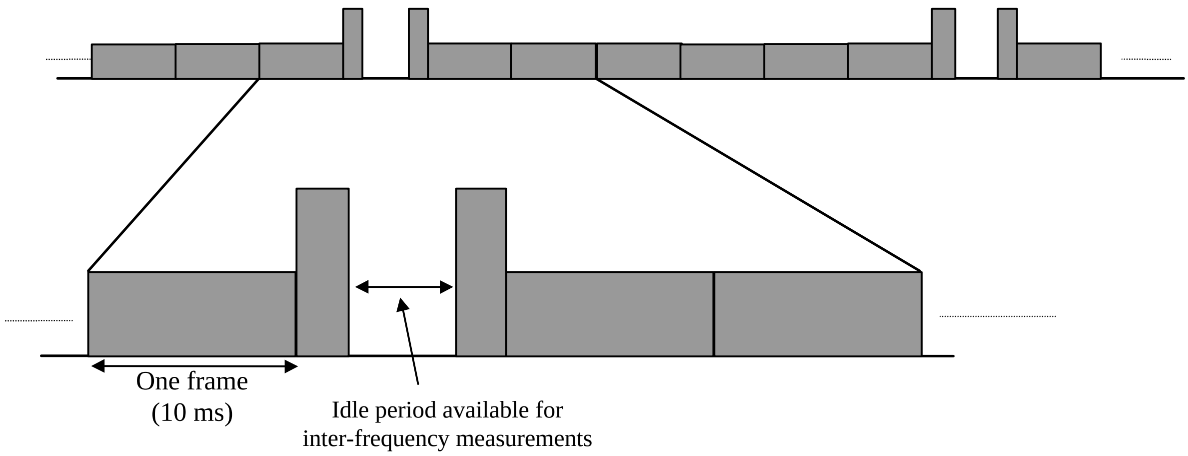

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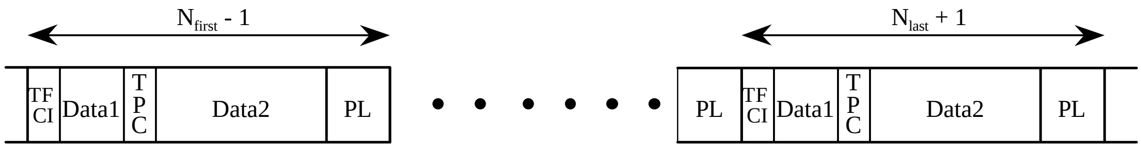
*Figure **Error! Style not defined.-Error! Bookmark not defined.**. ~~Downlink s~~Slotted mode transmission.*

10.5.1 Frame structure types in downlink

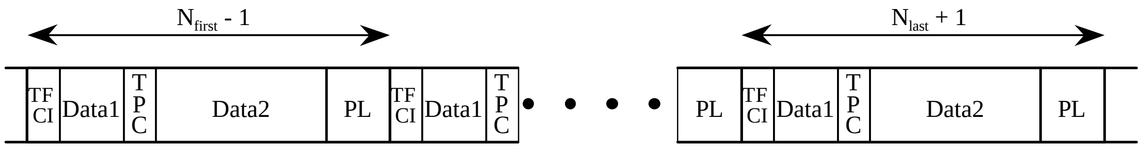
<Editor's note: This contents is from ARIB, and editor's opinion is that it could be adopted, since it makes sense; there is good argumentation behind it. However, it should be kept in mind, that if uplink slotted mode is also needed, there is a time offset between downlink and uplink frame, and for that reason it should be thought about how these downlink frame structures, A and B, affect to the corresponding uplink frame structures. Naturally the idle slot in downlink and uplink has to have the same timing.>

There are two different types of frame structures defined for downlink slotted transmission. Type A is the basic case, which maximises the idle slot duration. Type B, which is more optimised for power control, can be used if the requirement of the idle slot duration allows that.

- With frame structure of type A, BTS transmission is off from the beginning of TFCI field in slot N_{first}, until the end of Data2 field in slot N_{last} (Figure **Error! Style not defined.-Error! Bookmark not defined.**(a)).
- With frame structure of type B, BTS transmission is off from the beginning of Data2 field in slot N_{first}, until the end of Data2 field in slot N_{last} (Figure **Error! Style not defined.-Error! Bookmark not defined.**(b)) Dummy bits are transmitted in the TFCI and Data1 fields of slot N_{first}, and BTS and MS do not use the dummy bits. Thus BTS and MS utilize only the TPC field of N_{first}.



(a) Frame structure type A



(b) Frame structure type B

Figure **Error! Style not defined.-Error! Bookmark not defined.**. Frame structure types in downlink slotted transmission

10.5.2 Transmission Time Reduction Method

<Editor's note: The maximum idle slot duration was 5 ms per 10 frame in both ARIB and ETSI.>

When in slotted mode, the information normally transmitted during a 10 ms frame is compressed in time. The mechanism provided for achieving this is either changing the code rate, which means puncturing in practice, or the reduction of the spreading factor by a factor of two.~~, or changing the code rate, giving a- m~~The maximum idle period is defined to be ~~of~~ 5 ms ~~in~~ per one 10 ms frame.

10.5.2.1 Method A1: by Puncturing, basic case

<Editor's note1: The contents are taken from ARIB specs, but 2 ideas are clarified / added there by editor: a) puncturing means always pure puncturing, and not changing coding polynomials. Otherwise it is not easy/possible to define the procedure explicitly together with rate matching parameters. b) initial rate matching conditions corresponding to non-slotted case have to be taken into account. The main point is that the maximum limit for total puncturing is the amount of bits that corresponds to code rate ½.>

<Editor's note2: However, if the variable rate connection is on , and the target is to have periodical slotted mode pattern, this kind of rule does not work, because it corresponds to variable number of timeslots depending on the rate matching conditions. In that case it should be defined so that either the rate is not allowed to be changed during slotted mode or the maximum limit for the slotted period length has to be limited to 2 time slots (=worst case) in all cases. So here some decision from 3GPP W1 is needed.>

During slotted mode, rate matching (puncturing) is applied for making short idle periods in one frame. Algorithm of rate matching (puncturing) described in Rate matching is used. The maximum idle period length allowed to be achieved with this method is the case where the code rate is increased from 1/3 to 1/2 by puncturing, which corresponds to 2 - 5 time slots per 10 ms frame, depending on the rate matching conditions that would be used in the non-slotted frame case. The explanation of the rate matching conditions are given below:

Example 1: If rate matching conditions in the non-slotted frame case would be such that maximum puncturing =0.2 would be used, then during slotted mode further puncturing of 1-(2/(3*(1-0.2))) =0.17 is allowed which corresponds to 0.17*16=2.7 => 2 time slots.

Example 2: If rate matching conditions in the non-slotted frame case would be such that no puncturing would be used, then during slotted mode puncturing of 1-(2/3)=0.33 is allowed which corresponds to 0.33*16=5.3 => 5 time slots.

10.5.2.2 Method A2: By puncturing, for services that allow larger delay

< Editor's note: This has been an option in ETSI. However, editor's opinion is that this is not possible, or at least it will be very difficult to specify it clearly, since combined rate matching for several transport channels has to be done at 10 ms intervals. This means that there can be another, maybe delay sensitive, service to be multiplexed in the slotted frame, which may require certain room for data transmission and will make the concept quite complicated. So editor's proposal is to delete this option >

Other methods of supporting slotted mode may be considered as options. For example, with services that allows for a larger delay, e.g. data services with interleaving over several frames, multiple frames might be compressed together in order to create a short measurement slot. As an example, for a 2 Mbps service, with interleaving of 5 frames (50 ms), a 5 ms idle slot can be created by puncturing only 10% of 5 frames, as illustrated in Figure **Error! Style not defined.-Error! Bookmark not defined.**.

*Figure **Error! Style not defined.-Error! Bookmark not defined.**. Multi-frame compressed mode for long-delay services.*

10.5.2.3 Method B: by Reducing the Spreading Factor by 2

<Editor's note: The same contents is basically in ARIB and ETSI. ARIB has, however, defined it more clearly that for small idle period lengths, method A should be used, and only if that method is not possible, then use method B. Editor supports this, and thinks that a table like in section Parameters for Slotted Mode *should be defined in the future, so that in every case it is explicitly defined what is the coding procedure.>*

<Editor's note: The second scrambling code possibility was defined only in ETSI, and not in ARIB, but editor thinks that this should be adopted from ETSI..>

During slotted mode, the spreading factor (SF) can be reduced by 2 to enable the transmission of the information bits in the remaining time slots of a compressed frame. This can accommodate up to 50% idle slots per frame which is the maximum compression factor required. Additional rate matching is required if there are less than 50% idle slots. Reducing the spreading factor will normally be used if rate matching alone is not sufficient to transmit all information bits in compressed mode. Decrease of the spreading factor could involve change of the scrambling code, but when such an option could be used is for further study.

10.5.3 Position of Idle Period

<Editor's note: The same kind of idea has been in ETSI and ARIB. Since ARIB had more detailed text, which does make sense, it was adopted here. >

Idle period can be placed at both fixed position and adjustable position for each purpose such as interfrequency power measurement, acquisition of control channel of other system/carrier, and actual handover operation.

10.5.3.1 Fixed Idle Position

Idle period can be placed on fixed positions. The fixed idle positions are located on the center of a frame or on the center of two connected frames as shown in Figure Error! ***Style not defined.-Error! Bookmark not defined.***. Table Error! ***Style not defined.-Error! Bookmark not defined.*** shows the parameters for the fixed idle position case.

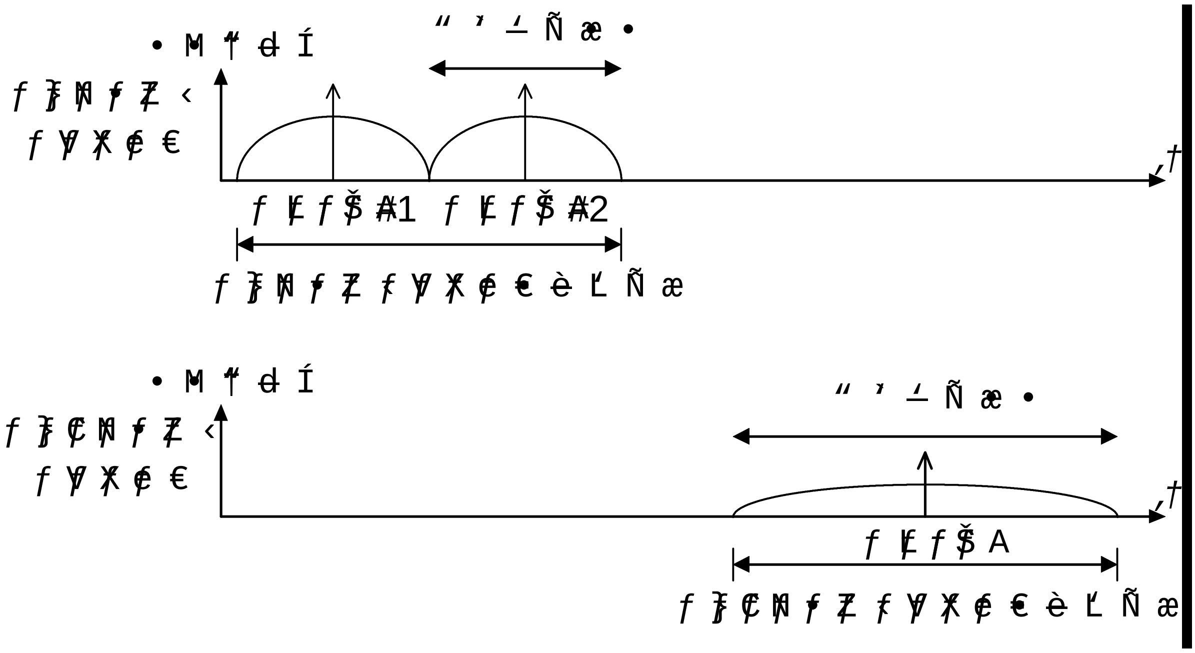


Figure **Error! Style not defined.-Error! Bookmark not defined.**. *Fixed Idle Position*

Table **Error! Style not defined.-Error! Bookmark not defined.**. *Parameters for Fixed idle position*

	Single-frame method		Double-frame method	
Idle slots	N_{first}	N_{last}	N_{first}	N_{last}
2	8	9	16 in first frame	1 in second frame
3	8	10	16 in first frame	2 in second frame
4	7	10	15 in first frame	2 in second frame
5	7	11	15 in first frame	3 in second frame
6	6	11	14 in first frame	3 in second frame
8	5	12	13 in first frame	4 in second frame
10	N.A.	N.A.	12 in first frame	5 in second frame
16	N.A.	N.A.	9 in first frame	8 in second frame

10.5.3.2 Adjustable Idle Position

Position of idle period can be adjustable/relocatable for some purpose e.g. data acquisition on certain position as shown in Figure Error! ***Style not defined.-Error! Bookmark not defined.***. Parameters of the adjustable idle positions are calculated as follows:

N_{idle} is the number of consecutive idle slots during Compressed Mode, as shown in Table Error! ***Style not defined.-Error! Bookmark not defined.***,

N_{idle} = 2,3,4,5,6,8,10,16.

N_{first} specifies the starting slot of the consecutive idle slots,

N_{first} = 1,2,3,…,16.

N_{last} shows the number of the final idle slot and is calculated as follows;

If $N_{first} + N_{idle} <= 17$, then $N_{last} = N_{first} + N_{idle} - 1$ (in the same frame),

If $N_{first} + N_{idle} > 17$, then $N_{last} = N_{first} + N_{idle} - 17$ (in the next frame).

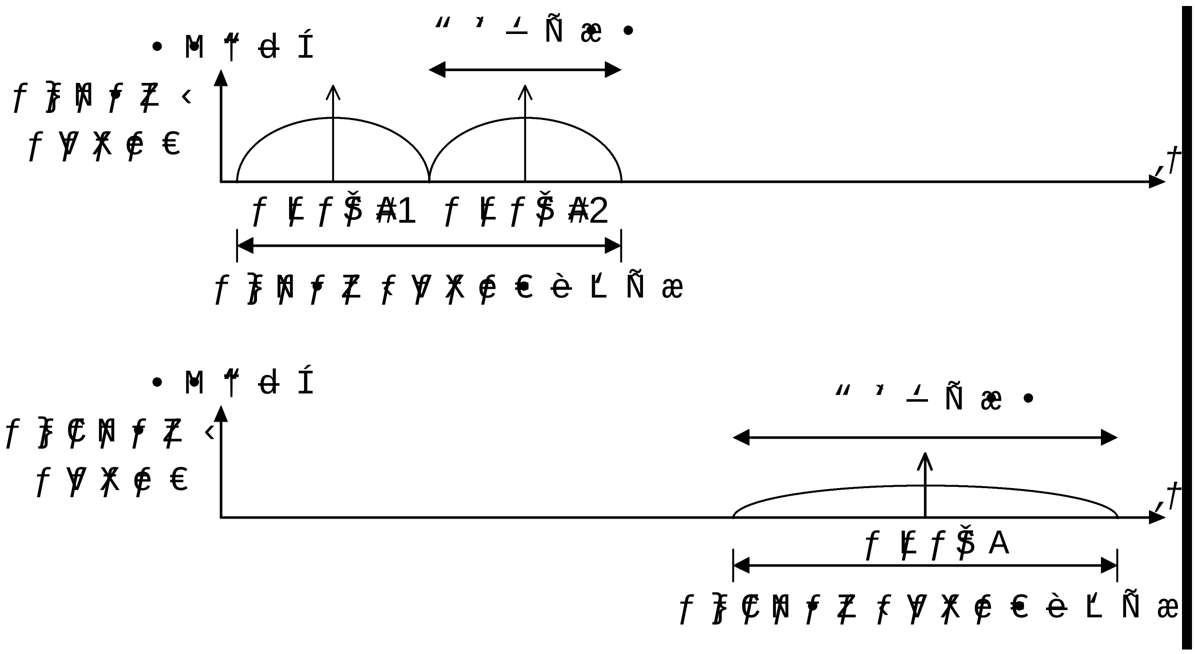


Figure ***Error! Style not defined.-Error! Bookmark not defined.****. Concept of Adjustable Idle Position*

Although Figure 7-11 shows slotted transmission with a mid-frame idle-period, there are in general three types of possible slotted transmission mechanisms, as illustratedin Figure 7-12.

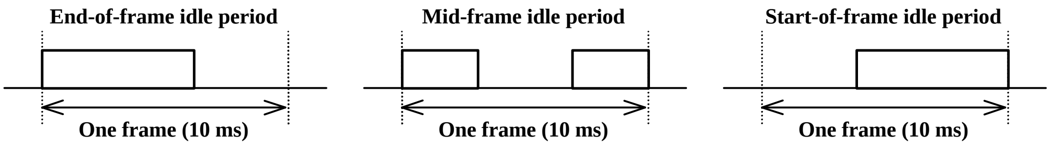


Figure7-12.Possible idle period positions.

The default position is the mid-frame idle period. The start-of-frame and end-of-frame idle are supported in order to be able to create an even longer double-frame idle period, as illustrated inFigure 7-13.

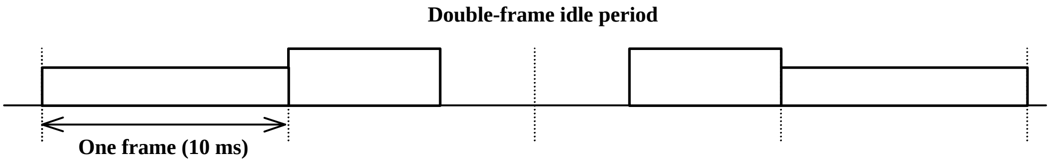


Figure 7-13. Double-frame idle period.

When in slotted mode, slotted frames can occur periodically, as illustrated inFigure 7-11, or requested on demand. The rate of and type of slotted frames is variable and depends on the environment and the measurement requirements.

For UTRA-to-GSM inter-frequency handover considerations, see section xx.

10.5.3.3

10.5.3.4 Parameters for Slotted Mode

< Editor's note 1: This contents is from ARIB specs. Editor's opinion is that maybe this section should be revisited after a) spreading factors have been defined, b) other sections in this coding of slotted mode chapter has been accepted. However, editor's opinion is that this kind of table should be defined, and is very important, since the coding procedure for each possible case should be defined clearly and explicitly>

< Editor's note 2:Editor would like to emphasize that we should really think about how the idle slot periods are placed in that case, where both uplink and downlink slotted mode is on at the same time, since there is always certain time offset between uplink frame and downlink frame, and this affects the frame structure optimisation during slotted mode (pilot bits, power control bits etc. in uplink and downlink). And since the idle period has to occur at the same time in uplink and downlink. >

[*Table* ***Error! Style not defined.-Error! Bookmark not defined.*** shows the detailed parameters for each number of idle slots. Each number of idle slots are classified for three cases:

Case 1 - Power measurement : Number of idle slots = 2, 3, 4, 5, 6.

Case 2 - Acquisition of control channels : Number of idle slots = 3, 4, 5, 6, 8, 10.

Case 3 - Actual handover operation : Number of idle slots = 10, 16.

Table ***Error! Style not defined.-Error! Bookmark not defined.****. Parameters for Slotted Mode*

Number of idle slots	Mode	Spreading Factor	Idle time [ms]	Transmission time reduction method	Idle frame combining
2	A	512 - 256	1.00 - 1.00	Puncturing	(S)/(D)
	B	128 - 1	1.00 - 1.12		
3	A	512 - 256	1.63 - 1.63		
	B	128 - 1	1.63 - 1.75		
4	A	512 - 256	2.25 - 2.25	Puncturing (D) Coding rate reduction:R=1/3->1/2 (S)	
	B	128 - 1	2.25 - 2.37		
5	A	512 - 256	2.87 - 2.87		
	B	128 - 1	2.87 – 2.99		
6	A	512 - 256	3.50 - 3.50	Puncturing (D)Spreading factor reduction by 2 (S)	
	B	128 - 2/1	3.50 - 3.62		
8	A	512 - 256	4.75 - 4.75	R=1/3->1/2(D) Spreading factor reduction by 2 (S)	
	B	128 - 2/1	4.75 - 4.87		
10	A	512 - 256	6.00 - 6.00	Coding rate reduction: R=1/3->1/2	(D)
	B	128 - 1	6.00 - 6.12		
16	A	512 - 256	9.75 - 9.75	Spreading factor reduction by 2	
	B	128 - 2	9.75 - 9.87		

(S): Single-frame method as shown in Figure Error! ***Style not defined.-Error! Bookmark not defined.*** (1).

(D): Double-frame method as shown in Figure Error! ***Style not defined.-Error! Bookmark not defined.*** (2).

SF="2/1": "2" is for (S) and "1" is for (D).]

Annex A (informative): Blind rate detection

A.1 Blind Rate Detection using Received Power Ratio

- This method is used for dual transport format case (the possible data rates, 0 and full rate, and only transmitting CRC for full rate).
- The rate detection is done using average received power ratio of DPDCH to DPCCH.
  Pc: Received Power per bit of DPCCH calculated from all pilot and TPC bits per slot over 10ms frame.
  Pd: Received Power per bit of DPDCH calculated from *X* bits per slot over 10ms frame.
  X: the number of DPDCH bits per slot when transport format corresponds to full rate.
  T: Threshold of average received power ratio of DPDCH to DPCCH for rate detection.

If *Pd/Pc >T* then

"TX_ON"

else

"TX_OFF"

A.2 Blind Rate Detection using CRC

- This method is used for multiple transport format case (the possible data rates: 0, …, (full rate)/r, …, full rate, and always transmitting CRC for all transport formats).
- At the transmitter, the variable-rate DCH data to be transmitted is block-encoded using a cyclic redundancy check (CRC) and then convolutionally encoded [Turbo-encoded]. It is necessary that the CRC parity bits are mapped on the head position (or certain position) in a frame as shown in Figure A-1.
- The receiver knows only the possible transport formats (or the possible end bit position $\{n_{end}\}$ by Layer-3 negotiation (See Figure A-1). The receiver performs Viterbi-decoding [Turbo-decoding] on the soft decision sample sequence. The correct trellis path of the Viterbi-decoder [Turbo-decoder] ends at the zero state at the correct end bit position.
- Blind rate detection method by using CRC traces back the surviving trellis path ending at the zero state (hypothetical trellis path) at each possible end bit position to recover the data sequence. Each recovered data sequence is then error-detected by CRC and if there is no error, the recovered sequence is declared to be correct.
- The following variable is defined:

$$s(n_{end}) = - 10 \log ((a_0(n_{end}) – a_{min}(n_{end})) / (a_{max}(n_{end})-a_{min}(n_{end}))) \text{ [dB]} \qquad \text{(Eq. 1)}$$

  where $a_{max}(n_{end})$ and $a_{min}(n_{end})$ are, respectively, the maximum and minimum path-metric valuse among all survivors at end bit position n_{end}, and $a_0(n_{end})$ is the path-metric value at zero state.

- In order to reduce the probability of false detection (this happens if the selected path is wrong but the CRC misses the error detection), a path selection threshold D is introduced. D determines whether the hypothetical trellis path connected to the zero state should be traced back or not at each end bit position n_{end}. If the hypothetical trellis path connected to the zero state that satisfies

$$s(n_{end}) =< D \qquad \text{(Eq. 2)}$$

  is found, the path is traced back to recover the frame data, where D is the path selection threshold and a design parameter.

- If more than one end bit positions satisfying Eq. 2 are found, the end bit position which has minimum value of $s(n_{end})$ is declared to be correct.
- If no path satisfying Eq. 2 is found even after all possible end bit positions have been exhausted, the received frame data is declared to be in error.

Figure A-2 shows the procedure of blind rate detection using CRC.

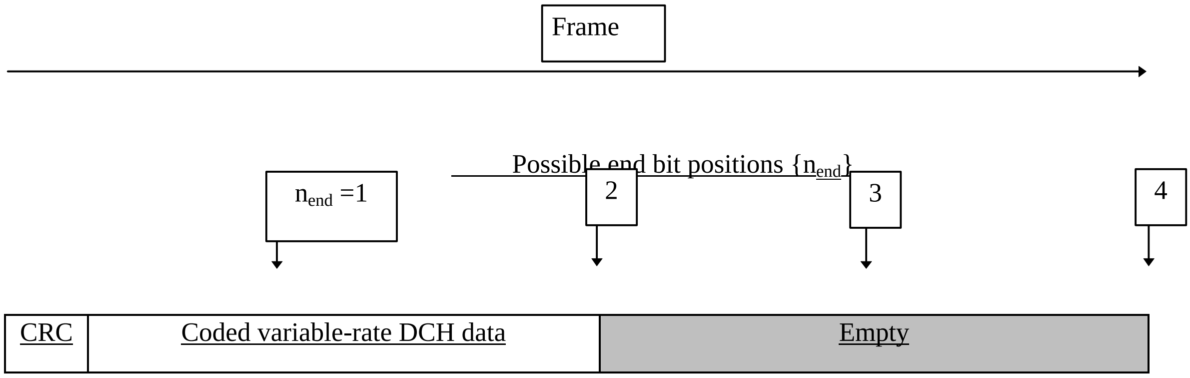


Figure A-1. An example of variable rate data format

(Number of possible transport formats = 4, transmitted end bit position n_{end} = 2)

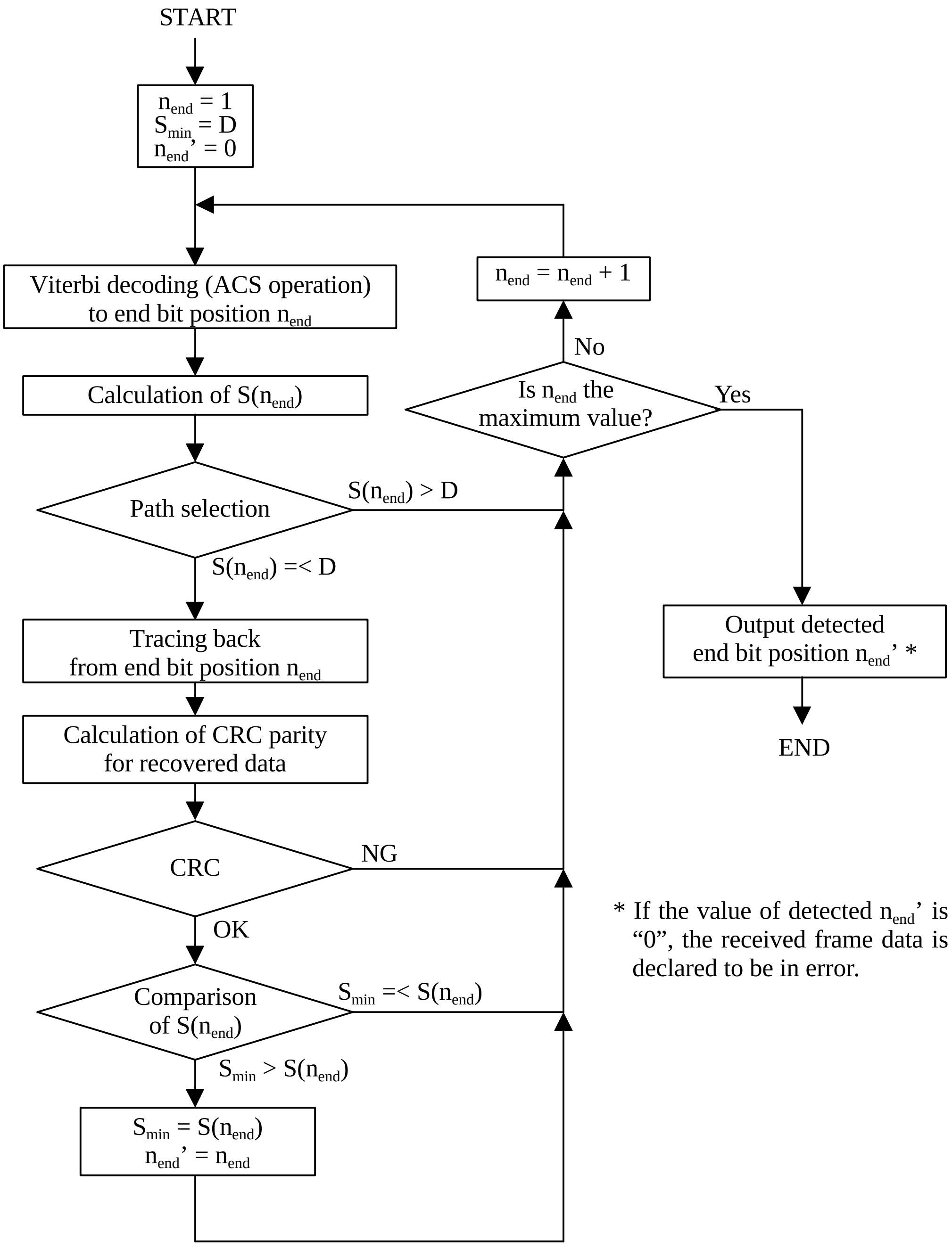


Figure A-2.Basic processing flow of blind rate detection

11 History

Document history		
V0.0.1	1999-02-12	First version created by the editor on the basis of XX.04 and the Volume 3 of the ARIB specification.

1st temporary editor for S1.12, multiplexing, channel coding and interleaving description, is:

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This document is written in Microsoft Word 97.