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# UMTS XX.04 V1.0.0 (1999-02)

*Technical Report*

## UMTS Terrestrial Radio Access Network (UTRAN); UTRA FDD, multiplexing, channel coding and interleaving description (UMTS XX.04 version 1.0.0)

UMTS

Universal Mobile Telecommunications System

Reference

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# Contents

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# Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Special Mobile Group (SMG).

The present document describes multiplexing, channel coding and interleaving for UTRA Physical Layer FDD mode.

The contents of the present document 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.

# 1 Scope

This Technical Report 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.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, 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.

[1] Reference 1.

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document the following terms and definitions apply:
**Definition 1:** to be completed

## 3.2 Abbreviations

For the purposes of the present document the following abbreviations apply:

| | |
|---|---|
| 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 |

# 4 Status of the present document

## 4.1 General

## 4.2 Transport channel coding/Multiplexing

- Working assumption.

### 4.2.1 CRC calculation

- Study item.

### 4.2.2 Channel coding

1. For medium bit rate services and medium quality
   a) Working assumption for channel coding schemes based on rate 1/2 and 1/3 convolutional code.
   b) Details of channel coding and interleaving to be designed for final concept depending on layer 1 services as defined by Layer 2 group, service multiplexing aspects and slotted mode aspects.
2. For high bit rate service and high quality
   1) These two schemes are under consideration:
      - Eight state Parallel concatenated convolutional code (PCCC);
      - Four state Serial concatenated convolutional code (SCCC),

      as candidate scheme for final decision on the base of a complete set of simulation results regarding also the complexity of both schemes.
   2) The following interleaver schemes:
      - 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),

      which should be include in the simulation environment of point 1)

### 4.2.3 1st interleaving

- working assumption on the values of interleaver span (10, 20, 40, 80 ms). The maximum interleaver span and the exact interleaver still as a study item. Also the interleaver in case of single service is a study item.

### 4.2.4 Rate matching

- Working assumption;
- Whether additional rate matching should be applied also before 1st interleaving, when blind rate detection is applied in downlink, is a study item.

### 4.2.5 Downlink discontinuous transmission

- Working assuption.

### 4.2.6 Transport channel multiplexing

- Working assumption.

### 4.2.7 2nd interleaving

- Working assumption based on 10ms intra-frame interleaving.

## 4.3 Automatic Repeat Request

- Still to be decided whether it is within the layer 1 scope.

## 4.4 Coding for layer 1 control

- Working assumption.

## 4.5 Slotted mode

- Working assumption.

# 5 Multiplexing, channel coding and interleaving

## 5.1 General

## 5.2 Transport-channel coding/multiplexing

Figure 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}.
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.

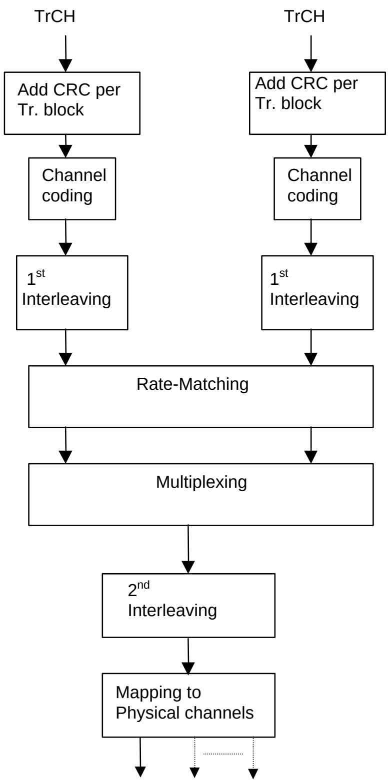


**Figure 1: Coding and multiplexing of transport channels**

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 1, resulting in several data stream, each mapped to one or several physical channels.

## 5.2.1 CRC calculation

[No text available].

## 5.2.2 Channel coding

The following options are available for the transport-channel specific coding, see also Figure 2:

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

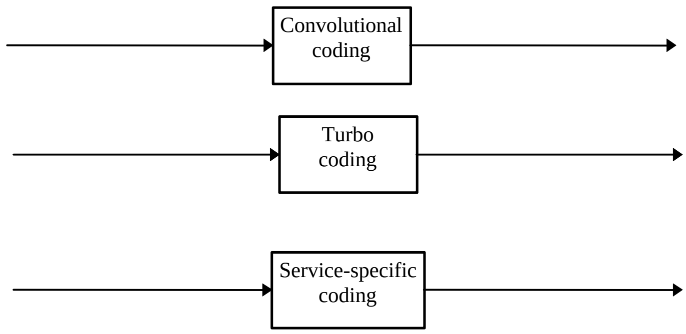


**Figure 2: Channel coding in UTRA/FDD**

### 5.2.2.1 Convolutional coding

Convolutional coding is applied for services that require a BER in the order of $10^{-3}$. Turbo coding is applied to services that require a BER in the order of $10^{-6}$, see also section Turbo coding.
Table 1 lists the possible parameters for the convolutional coding.

**Table 1: Generator polynomials for the convolutional codes**

| Rate | Constraint length | Generator polynomial 1 | Generator polynomial 2 | Generator polynomial 3 |
|---|---|---|---|---|
| 1/3 | 9 | 557 | 663 | 711 |
| 1/2 | 9 | 561 | 753 | N/A |

### 5.2.2.2 Turbo coding

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 3: Structure of the 8 state PCCC encoder**

The SCCC is a rate 1/3 SCCC, The outer code of the SCCC is a rate 2/3 obtained by puncturing a rate 1/2 code with generating matrix.

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

The rate 2/3 is obtained by puncturing every other parity-check bit. The inner code is a rate 1/2 systematic recursive convolutional code with the same previous generating matrix.

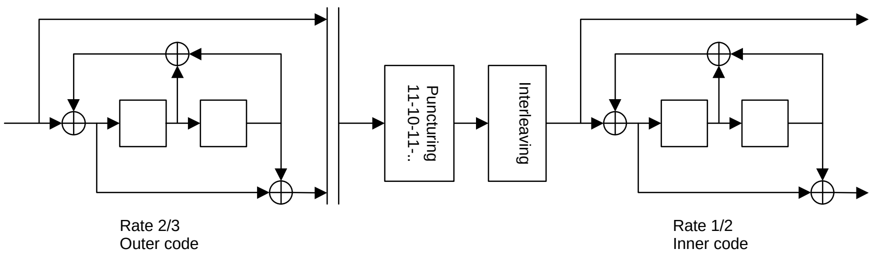


**Figure 4: Structure of the 4 state SCCC encoder**

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.
Interleaver is TBD. Good performance interleaver proposals as listed in section 6 are available. The complexity and flexibility of the interleaver proposals are for further study.
Turbo coding should be used for high data rate (above 32 kbps), high quality services. Code rates for the turbo code will be adapted to layer 2 requirements. Code rates around 1/3 and 1/2 are recommended. Puncturing patterns for turbo codes including rate compatible puncturing are for further study.

### 5.2.2.3 Service specific coding

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.

## 5.2.3 1st interleaving

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.

## 5.2.4 Rate matching

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

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.

### 5.2.4.1 Rate matching algorithm

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)

The rate matching rule is as follows:

```
find Ni and Ni+1 so that Ni ≤ NC < Ni+1
    if (Ni/NC > 1 - P)
?
?
        ?  y = NC-Ni
             ?
        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 = Ni+1-NC
        ?
        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
```

## 5.2.5 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.

### 5.2.6 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 5.

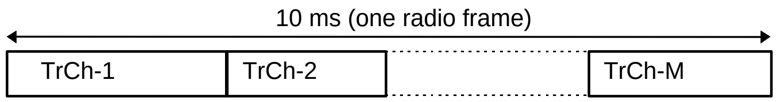


**Figure 5: Transport channel multiplexing**

### 5.2.7 2nd interleaving

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

## 5.3 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.

## 5.4 Coding for layer 1 control

### 5.4.1 Coding of Transport-format-combination indicator (TFCI)

According to current working assumption, the number of TFCI bits is variable and is set during a call via higher level signalling. If the number of TFCI bits is up to 6 or up to 10 the coding shall be as follows. For improve TFCI detection reliability, repetition is used by increasing the number of TFCI bits within a slot.

#### 5.4.1.1 Coding of default TFCI word

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 6.

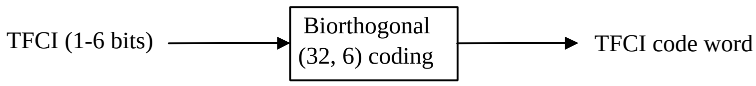


**Figure 6: Channel coding of TFCI bits**

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 6 of the code three of OVSF codes defined in document XX.05. The code words, $C_6(I)$, $I$ = 0, …, 31, form an orthogonal set, $S_{C_6} = \{C_6(0), C_6(1), \ldots, C_6(31)\}$, of 32 code words of length 32 bits. By taking the binary complements of the code words of $S_{C_6}$, another set, $\overline{S}_{C_6} = \{\overline{C}_6(0), \overline{C}_6(1), \ldots, \overline{C}_6(31)\}$ 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 Figure 7.

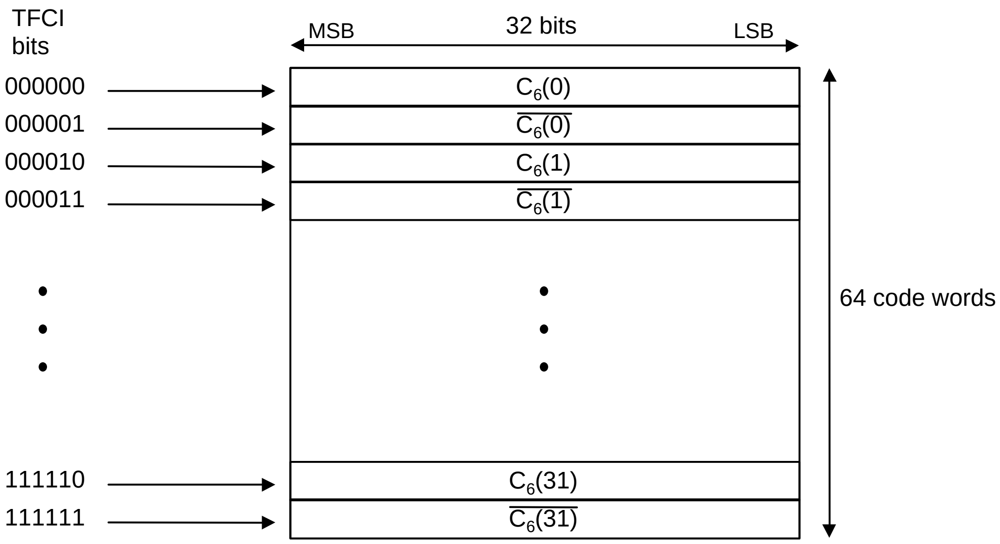


**Figure 7: Mapping of TFCI bits to biorthogonal code words**

### 5.4.1.2 Coding of extended TFCI word

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 Figure 8.

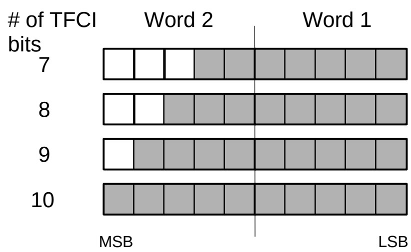


**Figure 8: Mapping of TFCI bits to two words**

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, $S_{C_5} = \{C_5(0), C_5(1), \ldots, C_5(15)\}$ and its binary complement, $\overline{S}_{C_5} = \{\overline{C}_5(0), \overline{C}_5(1), \ldots, \overline{C}_5(15)\}$. Words of set $S_{C_5}$ are from the level 5 of the code three of OVSF codes defined in document XX.05. The mapping of information bits to code words is shown in Table 2.

**Table 2: Mapping of information bits to code words for biorthogonal (16, 5) code**

| Information bits | Code word |
|---|---|
| 00000 | $C_5(0)$ |
| 00001 | $\overline{C_5(0)}$ |
| 00010 | $C_5(1)$ |
| ... | ... |
| 11101 | $\overline{C_5(14)}$ |
| 11110 | $C_5(15)$ |
| 11111 | $\overline{C_5(15)}$ |

## 5.4.2 Interleaving of TFCI words

### 5.4.2.1 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 9. Within a slot the more significant bit is transmitted before the less significant bit.

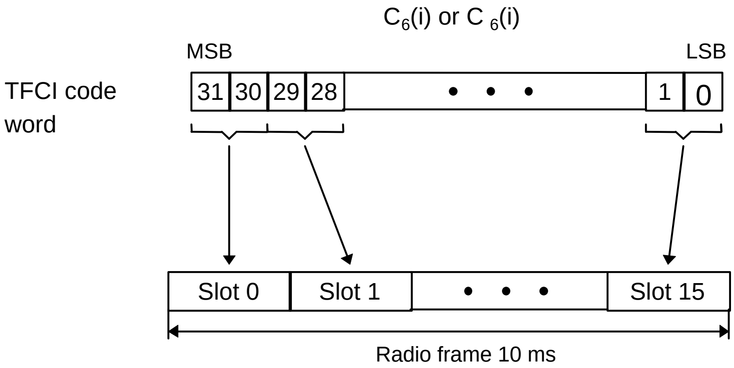


**Figure 9: Time multiplexing of code words of (32, 6) code to the slots of the radio frame**

### 5.4.2.2 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 Figure 10.

NOTE: $b_{1,i}$ and $b_{2,i}$ denote the bit *i* of code word 1 and code word 2, respectively.

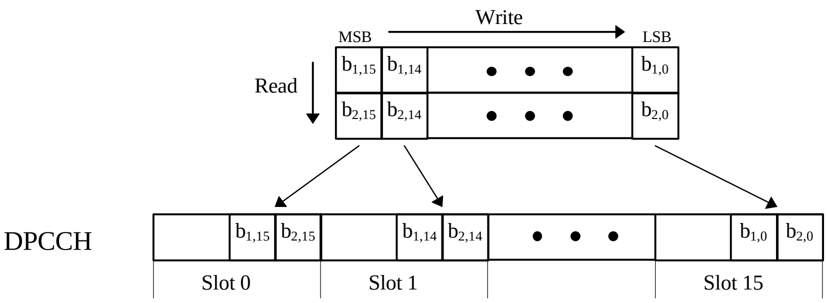


**Figure 10: Interleaving of TFCI code words**

## 5.5 Slotted mode

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 in Figure 12. When in slotted mode, the information normally transmitted during a 10 ms frame is compressed in time. The mechanism provided for achieving this is the reduction of the spreading factor by a factor of two, or changing the code rate, giving a maximum idle period of 5 ms in one 10 ms frame.

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. Decrease of the spreading factor could involve change of the scrambling code, but when such an option could be used is for further study. As illustrated in Figure 11, 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.

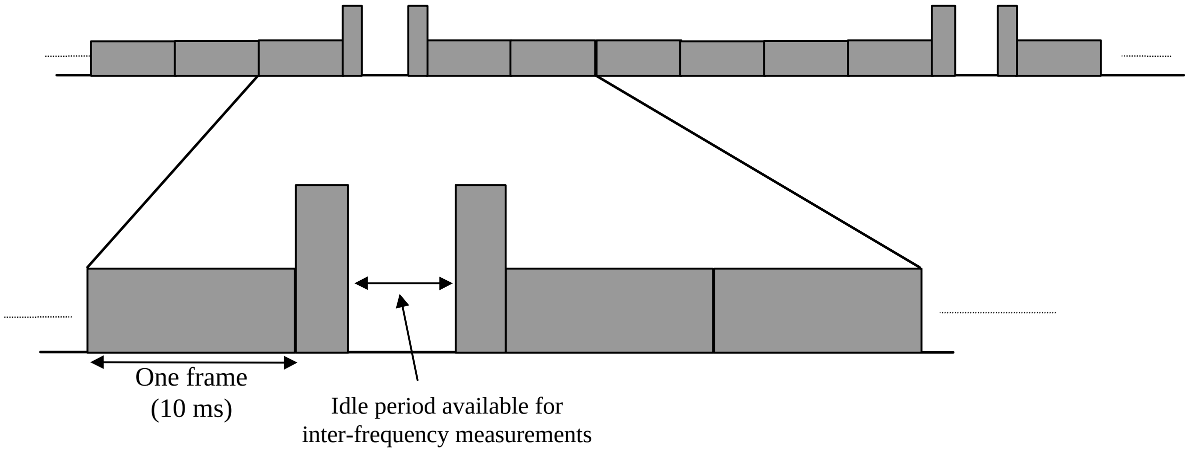


**Figure 11: Downlink slotted transmission**

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

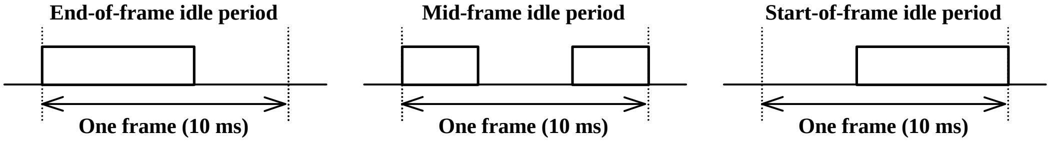


**Figure 12: Possible idle period positions**

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 in Figure 13.

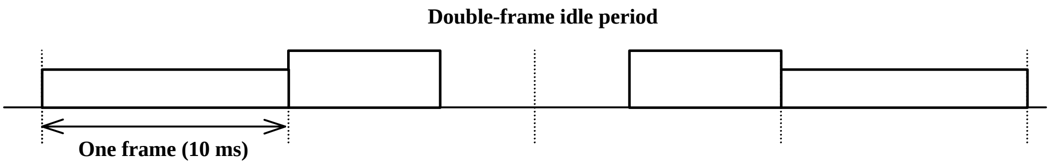


**Figure 13: Double-frame idle period**

When in slotted mode, slotted frames can occur periodically, as illustrated in Figure 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 clause xx.
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 14.

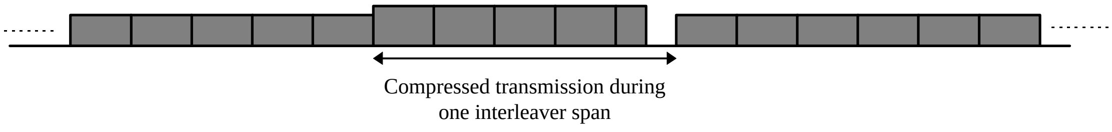


**Figure 14: Multi-frame compressed mode for long-delay services**

# History

| Document history | | |
|---|---|---|
| v0.1 | 1998-04-24 | Document created based on the documents Tdoc SMG2 UMTS-L1 36/98 and Tdoc SMG 905/97. (Tdoc SMG2 UMTS-L1 56/98) |
| v0.2 | 1998-05-20 | Updated with additions and modifications agreed upon at the UMTS-L1 meeting in Bocholt, May 18-20. (Tdoc SMG2 UMTS-L1 161/98) |
| v0.2.1 | 1998-05-26 | Many editorial changes. Also tried to reflect the decisions in Bocholt to better extent, following comments from various persons. Section 3 still not in line with discussion in Bocholt. (Tdoc SMG2 219/98) |
| v0.3 | 1998-05-29 | New sections 3 and 5, plus some editorial changes. (Tdoc SMG2 UMTS-L1 163/98, Tdoc SMG2 258/98) |
| v0.3.1 | 1998-06-10 | Editorial changes only, provided to UMTS-L1 meeting in Turin. (Tdoc SMG2 UMTS-L1 176/98) |
| v0.4 | 1998-06-24 | Added text according to the decisions at the UMTS-L1 meeting in Turin. (Tdoc SMG2 UMTS-L1 221/98) |
| v0.5 | 1998-09-03 | 'UTRA Physical Layer Description, FDD part' was split into several subdocuments xx.xx. This new subdocument xx.04 contains chapter 3 of the former FDD master document v0.4. It is updated with modifications agreed upon at the L1 meeting in Turin 15-17.6, and comments via e-mail about moving slotted mode description here into this section. |
| v.0.6 | 1998-09-17 | The revision marks accepted at the UMTS-L1meeting in Helsinki removed, provided to SMG2 meeting in Marseille. |
| v.0.6.1 | 1998-11-05 | Status of this document was added here from xx.18. |
| v.0.6.2 | 1998-12-09 | Revision marks accepted at the UMTS-L1 meeting in Sophia Antipolis removed. |
| v.0.7.0 | 1999-01-07 | Added text according to the decisions at the UMTS-L1 meeting in Espoo, December 1998 (Tdoc SMG2 UMTS-L1 719/98, Tdoc SMG2 UMTS-L1 755/98, Tdoc SMG2 UMTS-L1 758/98). |
| v.0.7.1 | 1999-01-19 | Chapters 7.4 and 7.5 updated based on text proposals Tdoc 567 and Tdoc 531 taking into account comments raised in plenary discussion 18.1.99 |
| v. 0.8.0 | 1999-01-21 | Turbo-coding description updated. Revision marks accepted at the UMTS-L1 meeting in Espoo 18-20.1.99 |
| Editor for UTRA FDD, multiplexing, channel coding and interleaving description, is:<br><br>Anu Virtanen<br>Nokia Telecommunications<br>Email: anu.virtanen @ ntc.nokia.com<br><br>The present document is written in Microsoft Word 97. | | |

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