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Technical Report

UMTS Terrestrial Radio Access Network (UTRAN);
UTRA TDD;
Spreading and modulation
(UMTS XX.11 version 1.0.1)

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Universal Mobile Telecommunications System

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Foreword

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

The present document has been elaborated by the Layer 1 expert group of SMG2 "Radio aspects", as a part of the work in defining and describing Layer 1 of the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA).

The present document describes the spreading and modulation in UTRA/TDD.

1 Scope

This Technical Report establishes the characteristics of the spreading and modulation in the TDD mode of UTRA. The main objectives of the document are to be a part of the full description of the UTRA Layer 1, and to serve as a basis for the drafting of the actual technical specification (TS).

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, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:
<defined term>: <definition>.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

3.3 Abbreviations

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

CDMA Code Division Multiple Access
PN Pseudo Noise
QPSK Quadrature Phase Shift Keying
RACH Random Access Channel

4 General

< Documentation status: A chip rate equal to the FDD mode, 4.096 Mcps, is to be considered as working assumption.>
In the following, a separation between the data modulation and the spreading modulation has been made. The data modulation is defined in clause 5 and the spreading modulation in clause 6.

Table 1: Basic modulation parameters

Chip rate	same as FDD basic chiprate, 4.096 Mchip/s
Carrier spacing	5.0 MHz
Data modulation	QPSK
Chip modulation	same as FDD chip modulation, root-raised cosine roll-off $\alpha = 0.22$
Spreading characteristics	Orthogonal Q chips/symbol, where $Q = 2^p$, $0 <= p <= 4$

5 Data modulation

< Documentation status: Everything in this clause is to be considered as working assumption, except otherwise explicitly stated. >

5.1 Symbol rate

The symbol rate and duration are indicated below:

$T_s = Q \times T_c$, where $T_c = \frac{1}{chiprate} = 0.24414$ µs, reflecting the dependence of the symbol time T_s upon the spreading factor Q.

5.2 Mapping of bits onto signal point constellation

A certain number K of CDMA codes can be assigned to either a single user or to different users who are simultaneously transmitting bursts in the same time slot and the same frequency. The maximum possible number of CDMA codes, which is smaller or equal to 16, depends on the individual spreading factors, the actual interference situation and the service requirements. In UMTS XX.09 examples of bodies of such spread bursts associated with a particular user are shown. Each user burst has two data carrying parts, termed data blocks:

$$\underline{\mathbf{d}}^{(k,i)} = (\underline{d}_1^{(k,i)}, \underline{d}_2^{(k,i)}, \ldots, \underline{d}_{N_k}^{(k,i)})^{\mathrm{T}} \quad \mathrm{i} = 1, 2; \mathrm{k} = 1,\ldots,\mathrm{K}. \tag{1}$$

N_k is the number of symbols per data field for the user k. This number is linked to the spreading factor Q_k as described in table 1 of XX.09.

Data block $\underline{\mathbf{d}}^{(k,1)}$ is transmitted before the midamble and data block $\underline{\mathbf{d}}^{(k,2)}$ after the midamble. Each of the N_k data symbols $\underline{d}_n^{(k,i)}$; i=1, 2; k=1,...,K; n=1,...,N_k; of equation 1 has the symbol duration $T_s^{(k)} = Q_k . T_c$ as already given.

The data modulation is QPSK, thus the data symbols $\underline{d}_n^{(k,i)}$ are generated from two interleaved and encoded data bits

$$b_{l,n}^{(k,i)} \in \{0,1\} \qquad l = 1,2;\ k = 1,\ldots K;\ n = 1,\ldots, N_k;\ i = 1,2 \tag{2}$$

using the equation

$$\begin{aligned} \mathrm{Re}\{\underline{d}_n^{(k,i)}\} &= \frac{1}{\sqrt{2}}(2b_{1,n}^{(k,i)} - 1) \\ \mathrm{Im}\{\underline{d}_n^{(k,i)}\} &= \frac{1}{\sqrt{2}}(2b_{2,n}^{(k,i)} - 1) \quad \mathrm{k} = 1,\ldots,\mathrm{K};\ \mathrm{n} = 1,\ldots,\mathrm{N_k};\ \mathrm{i} = 1, 2. \end{aligned} \tag{3}$$

Equation 3 corresponds to a QPSK modulation of the interleaved and encoded data bits $b_{l,n}^{(k,i)}$ of equation 2.

5.3 Pulse shape filtering

< Documentation status: The use of root-raised cosine pulse shaping is the working assumption. Another proposal exist in Tdoc SMG2 UMTS-L1 17/98. >

The pulse shape filtering is applied to each chip at the transmitter. In this context the term chip represents a single element $\underline{c}_q^{(k)}$ with k=1,...,K; q=1,...,Q_k; of a spreading code $\underline{\mathbf{c}}^{(k)}$; see also subclause 6.2.

The impulse response of the above mentioned chip impulse filter $Cr_0(t)$ shall be a root-raised cosine. The corresponding raised cosine impulse $C_0(t)$ is defined as

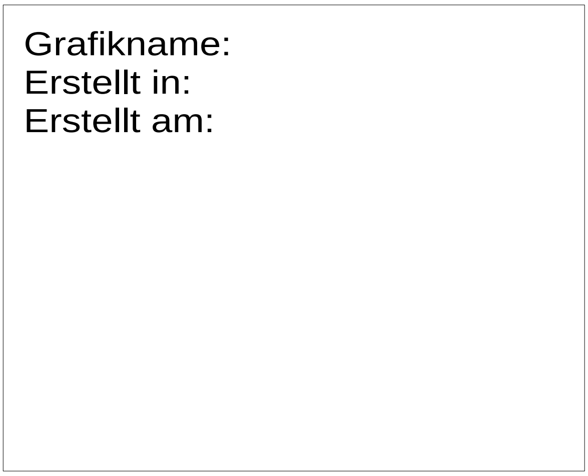
$$C_0(t) = \frac{\sin \pi \frac{t}{T_c}}{\pi \frac{t}{T_c}} \cdot \frac{\cos \alpha\pi \frac{t}{T_c}}{1 - 4\alpha^2 \frac{t^2}{T_c^2}} \tag{4}$$

The roll-off factor shall be $\alpha = 0.22$. T_c is the chip duration:

$$T_c = \frac{1}{chiprate} = 0.24414 \mu s$$

The impulse response $C_0(t)$ according to equation 4 and the energy density spectrum $\Phi_{C0}(f)$ of $C_0(t)$ are depicted in figure 1 below:

$C_0(t)$



$\Phi_{C0}(f)$ in dB

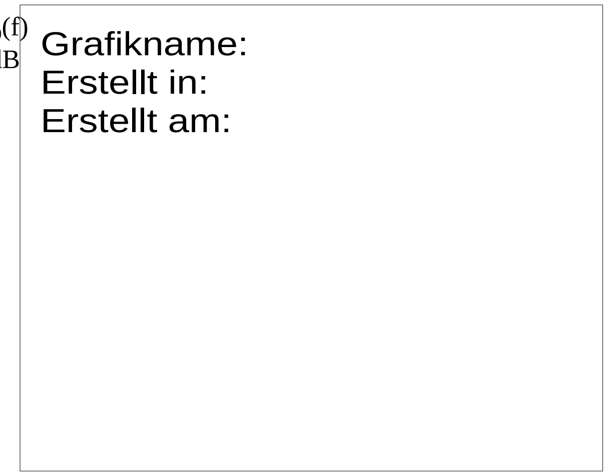


Figure 1: Basic impulse $C_0(t)$ and the corresponding energy density spectrum $\Phi_{C0}(f)$ of $C_0(t)$

6 Spreading modulation

< Documentation status: Everything in this clause is to be considered as working assumption, except otherwise explicitly stated. >

6.1 Basic spreading parameters

Each data symbol $\underline{d}_n^{(k,i)}$ of equation 1 is spread with a spreading code $\underline{\mathbf{c}}^{(k)}$ of length $Q_k \in \{1,2,4,8,16\}$. The resulting sequence is then scrambled by a sequence ν of length 16.

6.2 Spreading codes

The elements $\underline{c}_q^{(k)}$; k=1,...,K; q=1,...,Q_k; of the spreading codes $\underline{\mathbf{c}}^{(k)}=(\underline{c}_1^{(k)},\underline{c}_2^{(k)},...,\underline{c}_{Q_k}^{(k)})$; k=1,...,K; shall be taken from the complex set

$$\underline{V}_c = \{1, j, -1, -j\}. \qquad (5)$$

In equation 5 the letter j denotes the imaginary unit. A spreading code $\underline{\mathbf{c}}^{(k)}$ is generated from the binary codes $\mathbf{a}_{Q_k}^{(k)} = \left(a_1^{(k)}, a_2^{(k)}, ..., a_{Q_k}^{(k)}\right)$ of length Q_k shown in Figure 2 allocated to the k^{th} user. The relation between the elements $\underline{c}_q^{(k)}$ and $\underline{a}_q^{(k)}$ is given by:

$$\underline{c}_q^{(k)} = (j)^q \cdot a_q^{(k)} \quad a_q^{(k)} \in \{1,-1\}; \; q = 1,...,Q_k. \qquad (6)$$

Hence, the elements $\underline{c}_q^{(k)}$ of the CDMA codes $\underline{\mathbf{c}}^{(k)}$ are alternating real and imaginary.

The $\mathbf{a}_{Q_k}^{(k)}$ are Orthogonal Variable Spreading Factor (OVSF) codes, allowing to mix in the same timeslot channels with different spreading factors while preserving the orthogonality. The OVSF codes can be defined using the code tree of Figure 2.

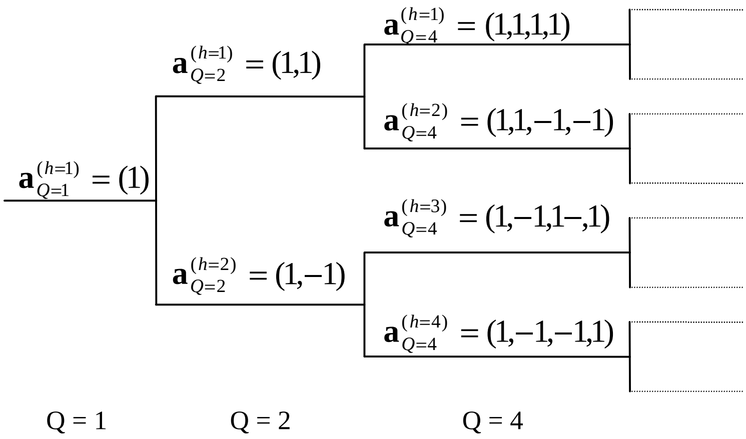


Figure 2: Code-tree for generation of Orthogonal Variable Spreading Factor (OVSF) codes

Each level in the code tree defines a spreading factors indicated by the value of Q in the figure. All codes within the code tree cannot be used simultaneously in a given timeslot. A code can be used in a timeslot if and only if no other code on the path from the specific code to the root of the tree or in the sub-tree below the specific code is used in this timeslot. This means that the number of available codes in a slot is not fixed but depends on the rate and spreading factor of each physical channel.
The spreading factor goes up to Q_{MAX}=16.

6.3 Scrambling codes

The spreading of data by a code $\mathbf{c}^{(k)}$ of length Q_k is followed by a cell specific scrambling sequence ν=(ν1, ν2, … ν_{QMAX}). The length matching is obtained by concatenating Q_{MAX}/Q_k spread words before the scrambling. The scheme is illustrated in Figure 3 below and is described in more detail in subclause 6.4

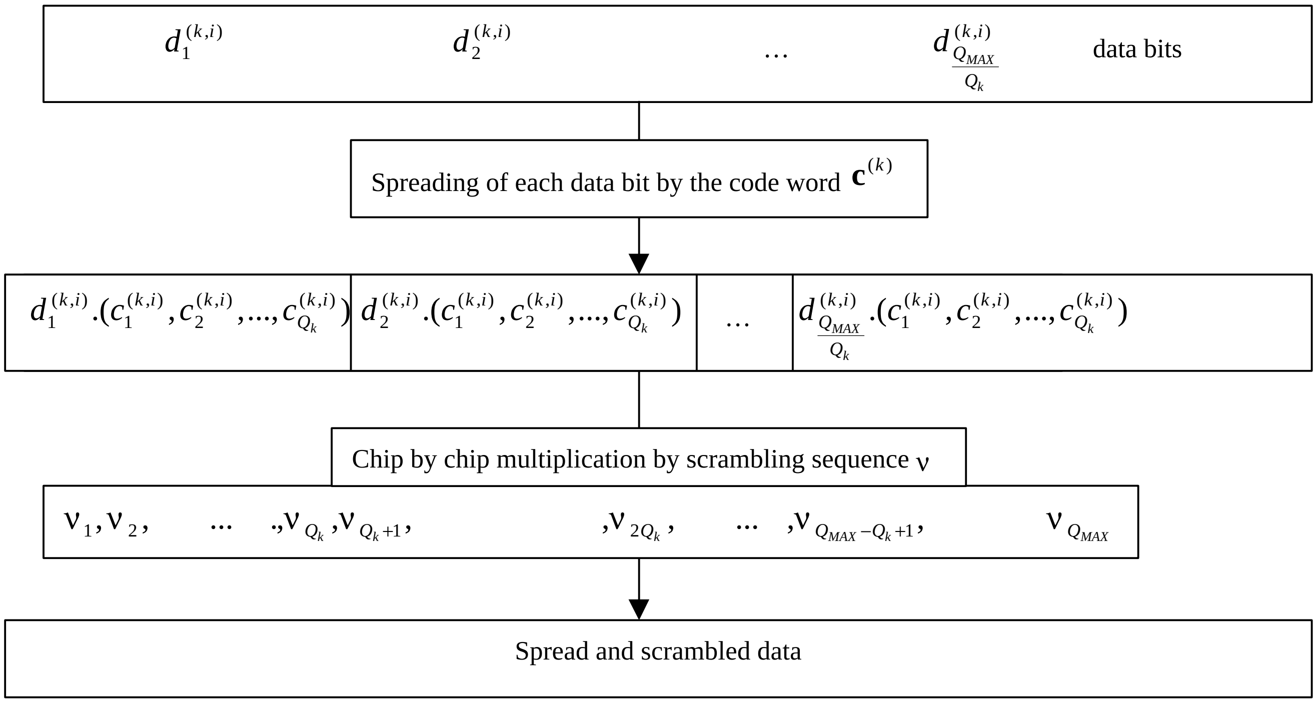


Figure 3: Spreading and subsequent scrambling of data bits

6.4 Spread and scrambled signal of data symbols and data blocks

The combination of the spreading and cell specific scrambling codes can be seen as a user and cell specific spreading code $\mathbf{s}^{(k)} = \left(s_p^{(k)}\right)$ with $s_p^{(k)} = c^{(k)}_{1+[(p-1)\bmod Q_k]} \cdot \nu_{1+[(p-1)\bmod Q_{MAX}]}$, k=1,…,K, p=1,…,$N_kQ_k$.

With the root raised cosine chip impulse filter $Cr_0(t)$ the transmitted signal belonging to the data block $\underline{\mathbf{d}}^{(k,1)}$ of equation 1 transmitted before the midamble is:

$$\underline{d}^{(k,1)}(t) = \sum_{n=1}^{N_k} \underline{d}_n^{(k,1)} \sum_{q=1}^{Q_k} s^{(k)}_{(n-1)Q_k+q} \cdot Cr_0(t-(q-1)T_c-(n-1)Q_kT_c) \qquad (7)$$

and for the data block $\underline{\mathbf{d}}^{(k,2)}$ of equation 1 transmitted after the midamble

$$\underline{d}^{(k,2)}(t) = \sum_{n=1}^{N_k} \underline{d}_n^{(k,2)} \sum_{q=1}^{Q_k} s^{(k)}_{(n-1)Q_k+q} \cdot Cr_0(t-(q-1)T_C-(n-1)Q_kT_c-N_kQ_kT_c-L_mT_c). \qquad (8)$$

where L_m is the number of midamble chips.

History

Document history		
V0.0.1	1998-08-17	Created document from UTRA/TDD L1 description, v0.2.1
V0.1.0	1998-09-17	Includes changes from Helsinki UMTS-L1 meeting.
V0.2.0	1998-09-23	Includes variable spreading factor concept, also agreed in Helsinki but missing in V0.1.0
V0.3.0	1998-10-26	Added documentation status.
V0.3.1	1998-11-15	Changed title of document, added changes agreed at Sophia Antipolis UMTS-L1 meeting.
V1.0.0	1998-12-09	As agreed by SMG2 # 28 in Dresden.
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