GSM
TECHNICAL
SPECIFICATION

GSM 05.03

March 1996

Version 5.0.0

Source: ETSI TC-SMG

Reference: TS/SMG-020503Q

ICS: 33.060.50

Key words: Digital cellular telecommunications system, Global System for Mobile communications (GSM)

GLOBAL SYSTEM FOR
MOBILE COMMUNICATIONS

Digital cellular telecommunications system (Phase 2+);
Channel coding
(GSM 05.03)

ETSI

European Telecommunications Standards Institute

ETSI Secretariat

Postal address: F-06921 Sophia Antipolis CEDEX - FRANCE
Office address: 650 Route des Lucioles - Sophia Antipolis - Valbonne - FRANCE
X.400: c=fr, a=atlas, p=etsi, s=secretariat - **Internet:** secretariat@etsi.fr

Tel.: +33 92 94 42 00 - Fax: +33 93 65 47 16

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Foreword

This Global System for Mobile communications Technical Specification (GTS) has been produced by the Special Mobile Group (SMG) Technical Committee (TC) of the European Telecommunications Standards Institute (ETSI).

This GTS specifies the data blocks given to the encryption unit. It includes the specification of encoding, reordering, interleaving and the stealing flag within the digital cellular telecommunications system (Phase 2/Phase 2+).

This GTS is a TC-SMG approved GSM technical specification version 5, which contains GSM Phase 2+ enhancements/features to the version 4 GSM technical specification. The ETS from which this Phase 2+ GTS has evolved is Phase 2 GSM ETS 300 575 edition 2 with Amendment 1 (GSM 05.03 version 4.3.0).

GTS are produced by TC-SMG to enable the GSM Phase 2+ specifications to become publicly available, prior to submission for the formal ETSI standards approval procedure to become European Telecommunications Standards (ETS). This ensures the earliest possible access to GSM Phase 2+ specifications for all Manufacturers, Network operators and implementors of the Global System for Mobile communications.

The contents of this GTS are subject to continuing work within TC-SMG and may change following formal TC-SMG approval. Should TC-SMG modify the contents of this GTS it will then be republished by ETSI with an identifying change of release date and an increase in version number as follows:

Version 5.x.y

where:

- y the third digit is incremented when editorial only changes have been incorporated in the specification;

- x the second digit is incremented for all other types of changes, i.e. technical enhancements, corrections, updates, etc.

The specification from which this GTS has been derived was originally based on CEPT documentation, hence the presentation of this GTS may not be entirely in accordance with the ETSI rules.

Reference is made within this GTS to GSM-TSs (note).

NOTE: TC-SMG has produced documents which give the technical specifications for the implementation of the digital cellular telecommunications system. Historically, these documents have been identified as GSM Technical Specifications (GSM-TSs). These TSs may have subsequently become I-ETSs (Phase 1), or ETSs/ETSI Technical Reports (ETRs) (Phase 2). TC-SMG has also produced ETSI GSM TSs which give the technical specifications for the implementation of Phase 2+ enhancements of the digital cellular telecommunications system. These version 5.x.x GSM Technical Specifications may be referred to as GTSs.

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1 Scope

A reference configuration of the transmission chain is shown in GSM 05.01. According to this reference configuration, this technical specification specifies the data blocks given to the encryption unit.

It includes the specification of encoding, reordering, interleaving and the stealing flag. It does not specify the channel decoding method.

The definition is given for each kind of logical channel, starting from the data provided to the channel encoder by the speech coder, the data terminal equipment, or the controller of the MS or BS. The definitions of the logical channel types used in this technical specification are given in GSM 05.02, a summary is in annex 1.

1.2 Normative references

This GTS incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this GTS only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

[1] GSM 01.04 (ETR 100): "Digital cellular telecommunication system (Phase 2); Abbreviations and acronyms".

[2] GSM 04.08 (ETS 300 557): "Digital cellular telecommunication system (Phase 2); Mobile radio interface layer 3 specification".

[3] GSM 04.21 (ETS 300 562): "Digital cellular telecommunication system (Phase 2); Rate adaption on the Mobile Station - Base Station System (MS - BSS) interface ".

[4] GSM 05.01 (ETS 300 573): "Digital cellular telecommunication system (Phase 2); Physical layer on the radio path General description".

[5] GSM 05.02 (ETS 300 574): "Digital cellular telecommunication system (Phase 2); Multiplexing and multiple access on the radio path".

[6] GSM 05.05: (ETS 300 577): "Digital cellular telecommunication system (Phase 2); Radio Transmission and Reception".

[7] GSM 06.10 (ETS 300 580-2): "Digital cellular telecommunication system (Phase 2); Full rate speech transcoding".

[8] GSM 06.20 (ETS 300 581-2): "Digital cellular telecommunication system; Half rate speech Part 2: Half rate speech transcoding".

1.3 Abbreviations

Abbreviations used in this specification are listed in GSM 01.04.

2. General

2.1 General Organization

Each channel has its own coding and interleaving scheme. However, the channel coding and interleaving is organized in such a way as to allow, as much as possible, a unified decoder structure.

Each channel uses the following sequence and order of operations:

- The information bits are coded with a systematic block code, building words of information + parity bits.

- These information + parity bits are encoded with a convolutional code, building the coded bits.

- Reordering and interleaving the coded bits, and adding a stealing flag, gives the interleaved bits.

All these operations are made block by block, the size of which depends on the channel. However, most of the channels use a block of 456 coded bits which is interleaved and mapped onto bursts in a very similar way for all of them. Figure 1 gives a diagram showing the general structure of the channel coding.

This block of 456 coded bits is the basic structure of the channel coding scheme. In the case of full rate speech TCH, this block carries the information of one speech frame. In case of control channels, it carries one message.

In the case of half rate speech TCH, the information of one speech frame is carried in a block of 228 coded bits.

In the case of FACCH, a coded message block of 456 bits is divided into eight sub-blocks. The first four sub-blocks are sent by stealing the even numbered bits of four timeslots in consecutive frames used for the TCH. The other four sub-blocks are sent by stealing the odd numbered bits of the relevant timeslot in four consecutive used frames delayed 2 or 4 frames relative to the first frame. Along with each block of 456 coded bits there is, in addition, a stealing flag (8 bits), indicating whether the block belongs to the TCH or to the FACCH. In the case of SACCH, BCCH or CCCH, this stealing flag is dummy.

Some cases do not fit in the general organization, and use short blocks of coded bits which are sent completely in one timeslot. They are the random access messages of the RACH on uplink and the synchronization information broadcast of the SCH on downlink.

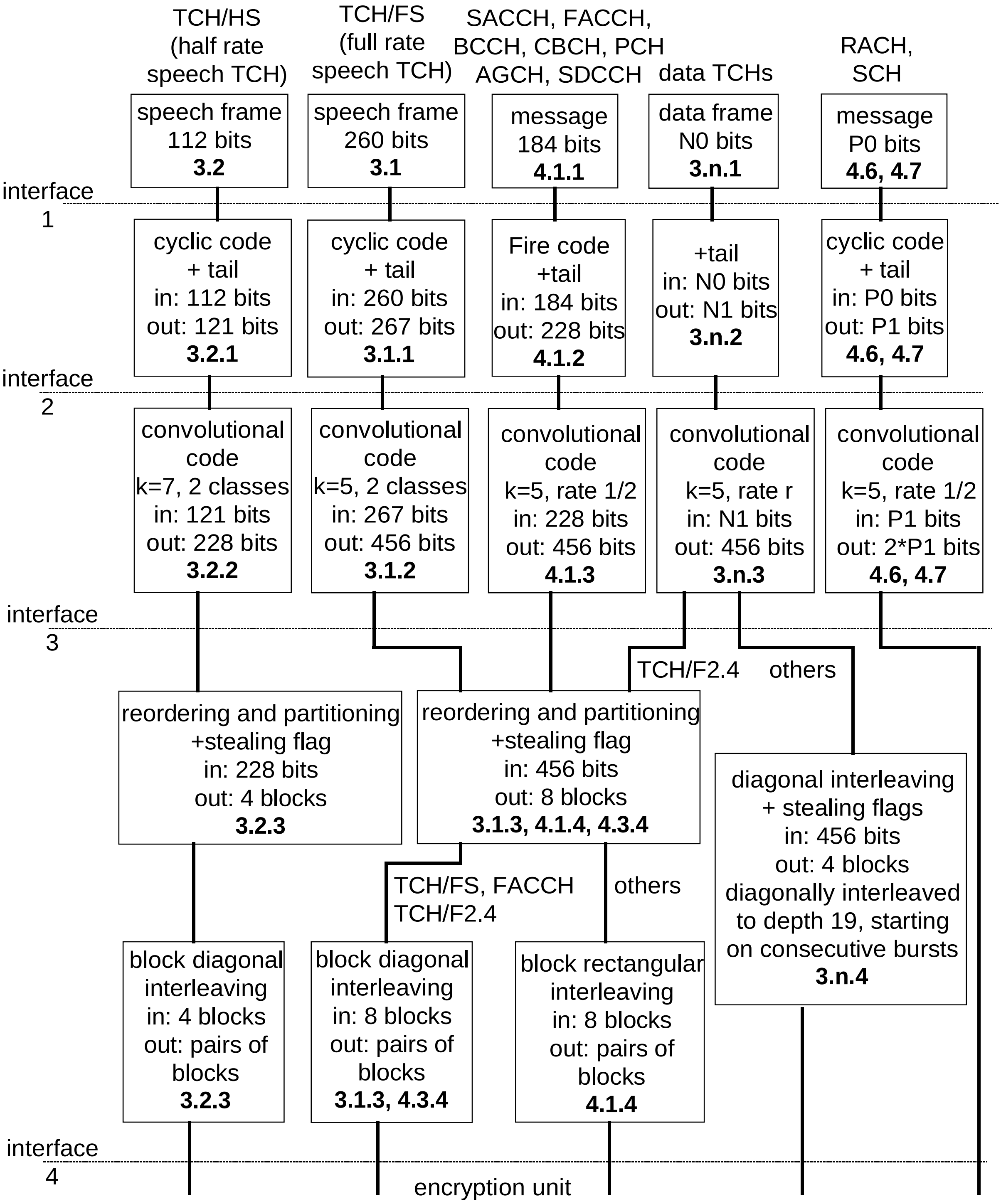

Figure 1: Channel Coding and Interleaving Organisation

In each box, the last line indicates the chapter defining the function. In the case of RACH, P0=8 and P1=18; in the case of SCH, P0=25 and P1=39. In the case of data TCHs, N0, N1 and n depend on the type of data TCH.

Interfaces:

1) information bits (d)
2) information + parity + tail bits (u)
3) coded bits (c)
4) interleaved bits (e)

2.2 Naming Convention

For ease of understanding a naming convention for bits is given for use throughout the technical specification:

- General naming

"k" and "j" for numbering of bits in data blocks and bursts.

"K_x" gives the amount of bits in one block, where "x" refers to the data type

"n" is used for numbering of delivered data blocks where

"N" marks a certain data block

"B" is used for numbering of bursts or blocks where

"B_0" marks the first burst or block carrying bits from the data block with n = 0 (first data block in the transmission)

- Data delivered to the encoding unit (interface 1 in figure 1):

  d(k) for $k = 0,1,...,K_d-1$

- Data after the first encoding step (block code, cyclic code; interface 2 in figure 1):

  u(k) for $k = 0,1,...,K_u-1$

- Data after the second encoding step (convolutional code ; interface 3 in figure 1):

  c(n,k) or c(k) for $k = 0,1,...,K_c-1$
  $n = 0,1,...,N,N+1,...$

- Interleaved data:

  i(B,k) for $k = 0,1,...,K_i-1$
  $B = B_0, B_0+1,....$

- Bits in one burst (interface 4 in figure 1):

  e(B,k) for $k = 0,1,...,114,115$
  $B = B_0, B_0 + 1,....$

3 Traffic Channels (TCH)

Two kinds of traffic channel are considered: speech and data. Both of them use the same general structure (see fig.1), and in both cases, a piece of information can be stolen by the FACCH.

3.1 Speech channel at full rate (TCH/FS)

The speech coder delivers to the channel encoder a sequence of blocks of data. In case of a full rate speech TCH, one block of data corresponds to one speech frame. Each block contains 260 information bits, including 182 bits of class 1 (protected bits), and 78 bits of class 2 (no protection), (see Table 2).

The bits delivered by the speech coder are received in the order indicated in GSM 06.10 and have to be rearranged according to Table 2 before channel coding as defined in 3.1.1 to 3.1.4. The rearranged bits are labelled {d(0),d(1),...,d(259)}, defined in the order of decreasing importance.

3.1.1 Parity and tailing for a speech frame

a) Parity bits:

The first 50 bits of class 1 are protected by three parity bits used for error detection. These parity bits are added to the 50 bits, according to a degenerate (shortened) cyclic code (53,50,2), using the generator polynomial:

$$g(D) = D^3 + D + 1$$

The encoding of the cyclic code is performed in a systematic form, which means that, in GF(2), the polynomial:

$$d(0)D^{52} + d(1)D^{51} + \ldots + d(49)D^3 + p(0)D^2 + p(1)D + p(2)$$

where p(0), p(1), p(2) are the parity bits, when divided by g(D), yields a remainder equal to:

$$1 + D + D^2$$

b) Tailing bits and reordering:

The information and parity bits of class 1 are reordered, defining 189 information + parity + tail bits of class 1, {u(0),u(1),...,u(188)} defined by:

u(k) = d(2k) and u(184-k) = d(2k+1)		for k = 0,1,...,90
u(91+k) = p(k)		for k = 0,1,2
u(k) = 0		for k = 185,186,187,188 (tail bits)

3.1.2 Convolutional encoder

The class 1 bits are encoded with the 1/2 rate convolutional code defined by the polynomials:

$$G0 = 1 + D^3 + D^4$$
$$G1 = 1 + D + D^3 + D^4$$

The coded bits {c(0), c(1),..., c(455)} are then defined by:

- class 1 :	c(2k)	= u(k) + u(k-3) + u(k-4)	
	c(2k+1)	= u(k) + u(k-1) + u(k-3) + u(k-4)	for k = 0,1,...,188 u(k) = 0 for k < 0
- class 2 :	c(378+k)	= d(182+k)	for k = 0,1,....,77

3.1.3 Interleaving

The coded bits are reordered and interleaved according to the following rule :

i(B,j) = c(n,k), for
k = 0,1,...,455
n = 0,1,...,N,N+1,...
$B = B_0 + 4n + (k \bmod 8)$
$j = 2((49k) \bmod 57) + ((k \bmod 8) \operatorname{div} 4)$

See table 1. The result of the interleaving is a distribution of the reordered 456 bits of a given data block, n = N, over 8 blocks using the even numbered bits of the first 4 blocks ($B = B_0 + 4N + 0, 1, 2, 3$) and odd numbered bits of the last 4 blocks ($B = B_0 + 4N + 4, 5, 6, 7$). The reordered bits of the following data block, n = N+1, use the even numbered bits of the blocks $B = B_0 + 4N + 4, 5, 6, 7$ ($B = B_0 + 4(N+1) + 0, 1, 2, 3$) and the odd numbered bits of the blocks $B = B_0 + 4(N+1) + 4, 5, 6, 7$. Continuing with the next data blocks shows that one block always carries 57 bits of data from one data block (n = N) and 57 bits of data from the next block (n = N+1), where the bits from the data block with the higher number always are the even numbered data bits, and those of the data block with the lower number are the odd numbered bits.

The block of coded data is interleaved "block diagonal", where a new data block starts every 4th block and is distributed over 8 blocks.

3.1.4 Mapping on a Burst

The mapping is given by the rule :

e(B,j) = i(B,j) and e(B,59+j) = i(B,57+j) for j = 0,1,...,56

and

e(B,57) = hl(B) and e(B,58) = hu(B)

The two bits, labelled hl(B) and hu(B) on burst number B are flags used for indication of control channel signalling. For each TCH/FS block not stolen for signalling purposes:

hu(B) = 0	for the first 4 bursts	(indicating status of even numbered bits)
hl(B) = 0	for the last 4 bursts	(indicating status of odd numbered bits)

For the use of hl(B) and hu(B) when a speech frame is stolen for signalling purposes see section 4.2.5.

3.2 Speech channel at half rate (TCH/HS)

The speech coder delivers to the channel encoder a sequence of blocks of data. In case of a half rate speech TCH, one block of data corresponds to one speech frame. Each block contains 112 bits, including 95 bits of class 1 (protected bits), and 17 bits of class 2 (no protection), see Tables 3a and 3b.

The bits delivered by the speech coder are received in the order indicated in GSM 06.20 and have to be arranged according to either Table 3a or Table 3b before channel encoding as defined in sections 3.2.1 to 3.2.4. The rearranged bits are labelled {d(0),d(1),...,d(111)}. Table 3a has to be taken if parameter Mode=0 (which means that the speech encoder is in unvoiced mode), while Table 3b has to be taken if parameter Mode=1, 2 or 3 (which means that the speech encoder is in voiced mode)

3.2.1 Parity and tailing for a speech frame

a) Parity bits:

The most significant 22 class 1 bits d(73),d(74),...,d(94) are protected by three parity bits used for error detection. These bits are added to the 22 bits, according to a cyclic code using the generator polynomial:

$$g(D) = D^3 + D + 1$$

The encoding of the cyclic code is performed in a systematic form, which means that, in GF(2), the polynomial:

$$d(73)D^{24} + d(74)D^{23} + ... + d(94)D^3 + p(0)D^2 + p(1)D + p(2)$$

where p(0), p(1), p(2) are the parity bits, when divided by g(D), yields a remainder equal to:

$$1+D+D^2.$$

b) Tail bits and reordering:

The information and parity bits of class 1 are reordered, defining 104 information + parity + tail bits of class 1, {u(0),u(1),...,u(103)} defined by:

u(k) = d(k)	for k = 0,1,...,94
u(k) = p(k-95)	for k = 95,96,97
u(k) = 0	for k = 98,99,...,103 (tail bits)

3.2.2 Convolutional encoder

The class 1 bits are encoded with the punctured convolutional code defined by the mother polynomials:

$G4 = 1 + D^2 + D^3 + D^5 + D^6$

$G5 = 1 + D + D^4 + D^6$

$G6 = 1 + D + D^2 + D^3 + D^4 + D^6$

and the puncturing matrices:

(1,0,1) for {u(0),u(1),...,u(94)} (class 1 information bits);
and {u(98),u(99),...,u(103)} (tail bits).

(1,1,1) for {u(95),u(96),u(97)} (parity bits)

In the puncturing matrices, a 1 indicates no puncture and a 0 indicates a puncture.

The coded bits {c(0),c(1),...,c(227)} are then defined by:

class 1 information bits:

c(2k) = u(k)+u(k-2)+u(k-3)+u(k-5)+u(k-6)
c(2k+1) = u(k)+u(k-1)+u(k-2)+u(k-3)+u(k-4)+u(k-6) for k = 0,1,...,94;u(k) = 0 for k<0

parity bits:

c(3k-95) = u(k)+u(k-2)+u(k-3)+u(k-5)+u(k-6)
c(3k-94) = u(k)+u(k-1)+u(k-4)+u(k-6)
c(3k-93) = u(k)+u(k-1)+u(k-2)+u(k-3)+u(k-4)+u(k-6) for k = 95,96,97

tail bits:

c(2k+3) = u(k)+u(k-2)+u(k-3)+u(k-5)+u(k-6)
c(2k+4) = u(k)+u(k-1)+u(k-2)+u(k-3)+u(k-4)+u(k-6) for k = 98,99,...,103

class 2 information bits:

c(k+211) = d(k+95) for k = 0,1,...,16

3.2.3 Interleaving

The coded bits are reordered and interleaved according to the following rule:

i(B,j) = c(n,k) for k = 0,1,...,227
n = 0,1,...,N,N+1,...
B = B0 + 2n + b

The values of b and j in dependance of k are given by Table 4.

The result of the interleaving is a distribution of the reordered 228 bits of a given data block, n=N, over 4 blocks using the even numbered bits of the first 2 blocks (B=B0+2N+0,1) and the odd numbered bits of the last 2 blocks (B=B0+2N+2,3). The reordered bits of the following data block, n=N+1, use the even numbered bits of the blocks B=B0+2N+2,3 (B=B0+2(N+1)+0,1) and the odd numbered bits of the blocks B=B0+2(N+1)+2,3. Continuing with the next data blocks shows that one block always carries 57 bits of data from one data block (n=N) and 57 bits from the next block (n=N+1), where the bits from the data block with the higher number always are the even numbered data bits, and those of the data block with the lower number are the odd numbered bits. The block of coded data is interleaved "block diagonal", where a new data block starts every 2nd block and is distributed over 4 blocks.

3.2.4 Mapping on a burst

The mapping is given by the rule:

e(B,j) = i(B,j) and e(B,59+j) = i(B,57+j) for j = 0,1,...,56

and

e(B,57) = hl(B) and e(B,58)=hu(B)

The two bits, labelled hl(B) and hu(B) on burst number B are flags used for indication of control channel signalling. For each TCH/HS block not stolen for signalling purposes:

hu(B) = 0	for the first 2 bursts (indicating status of the even numbered bits)
hl(B) = 0	for the last 2 bursts (indicating status of the odd numbered bits)

For the use of hl(B) and hu(B) when a speech frame is stolen for signalling purposes, see section 4.3.5.

3.3 Data channel at full rate, 12.0 kbit/s radio interface rate (9.6 kbit/s services (TCH/F9.6))

The definition of a 12.0 kbit/s radio interface rate data flow for data services is given in GSM 04.21.

3.3.1 Interface with user unit

The user unit delivers to the encoder a bit stream organized in blocks of 60 information bits (data frames) every 5 ms. Four such blocks are dealt with together in the coding process {d(0),...,d(239)}. For non-transparent services those four blocks shall align with one 240-bit RLP frame.

3.3.2 Block code

The block of 4 * 60 information bits is not encoded, but only increased with 4 tail bits equal to 0 at the end of the block.

u(k) = d(k)	for k = 0,1,...,239
u(k) = 0	for k = 240,241,242,243 (tail bits)

3.3.3 Convolutional encoder

This block of 244 bits {u(0),...,u(243)} is encoded with the 1/2 rate convolutional code defined by the following polynomials:

$G0 = 1 + D^3 + D^4$
$G1 = 1 + D + D^3 + D^4$

resulting in 488 coded bits {C(0), C(1),..., C(487)} with

C(2k) = u(k) + u(k-3) + u(k-4)
C(2k+1) = u(k) + u(k-1) + u(k-3) + u(k-4) for k = 0,1,...,243 ; u(k) = 0 for k < 0

The code is punctured in such a way that the following 32 coded bits:

{C(11+15j) for j = 0,1,...,31} are not transmitted.

The result is a block of 456 coded bits, {c(0),c(1),..., c(455)}

3.3.4 Interleaving

The coded bits are reordered and interleaved according to the following rule :

i(B,j) = c(n,k) for k = 0,1,...,455
n = 0,1,...,N,N+1,...
B = B_0 +4n + (k mod 19) + (k div 114)
j = (k mod 19) + 19 (k mod 6)

The result of the interleaving is a distribution of the reordered 114 bit of a given data block, n = N, over 19 blocks, 6 bits equally distributed in each block, in a diagonal way over consecutive blocks.

Or in other words the interleaving is a distribution of the encoded, reordered 456 bits from four given input data blocks, which taken together give n=N, over 22 bursts, 6 bits equally distributed in the first and 22nd bursts, 12 bits distributed in the second and 21st bursts, 18 bits distributed in the third and 20th bursts and 24 bits distributed in the other 16 bursts.

The block of coded data is interleaved "diagonal", where a new block of coded data starts with every fourth burst and is distributed over 22 bursts.

3.3.5 Mapping on a Burst

The mapping is done as specified for TCH/FS in section 3.1.4. On bitstealing by a FACCH, see section 4.2.5.

3.4 Data channel at full rate, 6.0 kbit/s radio interface rate (4.8 kbit/s services (TCH/F4.8))

The definition of a 6.0 kbit/s radio interface rate data flow for data services is given in GSM 04.21.

3.4.1 Interface with user unit

The user unit delivers to the encoder a bit stream organized in blocks of 60 information bits (data frames) every 10 ms, {d(0),d(1),...,d(59)}.

In the case where the user unit delivers to the encoder a bit stream organised in blocks of 240 information bits every 40 ms (e.g. RLP frames), the bits {d(0),d(1),...,d(59),d(60),...,d(60+59), d(2*60),...,d(2*60+59), d(3*60),...,d(3*60+59)} shall be treated as four blocks of 60 bits each as described in the remainder of this section. To ensure end-to-end synchronisation of the 240 bit blocks, the resulting block after coding of the first 120 bits {d(0),d(1),...,d(60+59)} shall be transmitted in one of the transmission blocks B0, B2, B4 of the channel mapping defined in GSM 05.02.

3.4.2 Block code

Sixteen bits equal to 0 are added to the 60 information bits, the result being a block of 76 bits, {u(0),u(1),...,u(75)}, with:

u(19k+p) = d(15k+p) for k = 0,1,2,3 and p = 0,1,...,14;
u(19k+p) = 0 for k = 0,1,2,3 and p = 15,16,17,18.

Two such blocks forming a block of 152 bits {u'(0),u'(1),...,u'(151)} are dealt with together in the rest of the coding process

u'(k) = u1(k), k=0,1,...,75 (u1 = 1st block)
u'(k+76) = u2(k), k=0,1,...,75 (u2 = 2nd block)

3.4.3 Convolutional encoder

This block of 152 bits is encoded with the convolutional code of rate 1/3 defined by the following polynomials:

$G1 = 1 + D + D^3 + D^4$
$G2 = 1 + D^2 + D^4$
$G3 = 1 + D + D^2 + D^3 + D^4$

The result is a block of 3 * 152 = 456 coded bits, {c(0),c(1),...,c(455)},

c(3k) = u'(k) + u'(k-1) + u'(k-3) + u'(k-4)
c(3k+1) = u'(k) + u'(k-2)+ u'(k-4)
c(3k+2) = u'(k) + u'(k-1) + u'(k-2) + u'(k-3)+u'(k-4) for k = 0,1,...,151 ;
u'(k) = 0 for k < 0

3.4.4 Interleaving

The interleaving is done as specified for the TCH/F9.6 in section 3.3.4

3.4.5 Mapping on a Burst

The mapping is done as specified for the TCH/FS in section 3.1.4. On bitstealing for signalling purposes by a FACCH, see section 4.2.5.

3.5 Data channel at half rate, 6.0 kbit/s radio interface rate (4.8 kbit/s services (TCH/H4.8))

The definition of a 6.0 kbit/s radio interface rate data flow for data services is given in GSM 04.21.

3.5.1 Interface with user unit

The user unit delivers to the encoder a bit stream organized in blocks of 60 information bits (data frames) every 10 ms. Four such blocks are dealt with together in the coding process, {d(0),d(1),...,d(239)}.

For non-transparent services those four blocks shall align with one complete 240-bit RLP frame.

3.5.2 Block code

The block encoding is done as specified for the TCH/F9.6 in section 3.3.2.

3.5.3 Convolutional encoder

The convolutional encoding is done as specified for the TCH/F9.6 in section 3.3.3.

3.5.4 Interleaving

The interleaving is done as specified for the TCH/F9.6 in section 3.3.4.

3.5.5 Mapping on a Burst

The mapping is done as specified for the TCH/FS in section 3.1.4. On bitstealing for signalling purposes by a FACCH, see section 4.3.5.

3.6 Data channel at full rate, 3.6 kbit/s radio interface rate (2.4 kbit/s and less services (TCH/F2.4))

The definition of a 3.6 kbit/s radio interface rate data flow for data services is given in GSM 04.21.

3.6.1 Interface with user unit

The user unit delivers to the encoder a bit stream organized in blocks of 36 information bits (data frames) every 10 ms. Two such blocks are dealt with together in the coding process, {d(0),d(1),...,d(71)}.

3.6.2 Block code

This block of 72 information bits is not encoded, but only increased with four tail bits equal to 0 at the end of the block.

u(k) = d(k) , k = 0,1,...,71
u(k) = 0 , k = 72,73,74,75 (tail bits);

3.6.3 Convolutional encoder

This block of 76 bits {u(0),u(1),...,u(75)} is encoded with the convolutional code of rate 1/6 defined by the following polynomials:

$G1 = 1 + D + D^3 + D^4$
$G2 = 1 + D^2 + D^4$
$G3 = 1 + D + D^2 + D^3 + D^4$
$G1 = 1 + D + D^3 + D^4$
$G2 = 1 + D^2 + D^4$
$G3 = 1 + D + D^2 + D^3 + D^4$

The result is a block of 456 coded bits:

{c(0), c(1),...,c(455)}, defined by

c(6k) = c(6k+3) = u(k) + u(k-1) + u(k-3) + u(k-4)
c(6k+1) = c(6k+4) = u(k) + u(k-2) + u(k-4)
c(6k+2) = c(6k+5) = u(k) + u(k-1) + u(k-2) + u(k-3) + u(k-4), for k = 0,1,...,75;
u(k) = 0 for k < 0

3.6.4 Interleaving

The interleaving is done as specified for the TCH/FS in section 3.1.3

3.6.5 Mapping on a Burst

The mapping is done as specified for the TCH/FS in section 3.1.4.

3.7 Data channel at half rate, 3.6 kbit/s radio interface rate (2.4 kbit/s and less services (TCH/H2.4))

The definition of a 3.6 kbit/s radio interface rate data flow for data services is given in GSM 04.21

3.7.1 Interface with user unit

The user unit delivers to the encoder a bit stream organized in blocks of 36 information bits (data frames) every 10 ms. Two such blocks are dealt with together in the coding process, {d(0),d(1),...,d(71)}.

3.7.2 Block code

The block of 72 information bits is not encoded, but only increased with 4 tail bits equal to 0, at the end of the block.

Two such blocks forming a block of 152 bits {u(0),u(1),...,u(151)} are dealt with together in the rest of the coding process.

u(k)	= d1(k),	k = 0,1,...,75 (d1 = 1st information block)
u(k+76)	= d2(k),	k = 0,1,...,75 (d2 = 2nd information block)
u(k)	= 0,	k = 72,73,74,75,148,149,150,151 (tail bits)

3.7.3 Convolutional encoder

The convolutional encoding is done as specified for the TCH/F4.8 in section 3.4.3.

3.7.4 Interleaving

The interleaving is done as specified for the TCH/F9.6 in section 3.3.4.

3.7.5 Mapping on a Burst

The mapping is done as specified for the TCH/FS in section 3.1.4. On bit stealing for signalling purposes by a FACCH, see section 4.3.5.

4. Control Channels

4.1 Slow associated control channel (SACCH)

4.1.1 Block constitution

The message delivered to the encoder has a fixed size of 184 information bits {d(0),d(1),...,d(183)}. It is delivered on a burst mode.

4.1.2 Block code

a) Parity bits:

The block of 184 information bits is protected by 40 extra bits used for error correction and detection. These bits are added to the 184 bits according to a shortened binary cyclic code (FIRE code) using the generator polynomial :

$$g(D) = (D^{23} + 1)*(D^{17} + D^3 + 1)$$

The encoding of the cyclic code is performed in a systematic form, which means that, in GF(2), the polynomial:

$$d(0)D^{223} + d(1)D^{222}+...+d(183)D^{40} + p(1)D^{38}+...+p(38)D + p(39)$$

where {p(0),p(1),...,p(39)} are the parity bits , when divided by g(D) yields a remainder equal to:

$$1 + D + D^2 +...+ D^{39}.$$

b) Tail bits

Four tail bits equal to 0 are added to the information and parity bits, the result being a block of 228 bits .

u(k) = d(k)	for k= 0,1,...,183
u(k) = p(k-184)	for k = 184,185,...,223
u(k) = 0	for k = 224,225,226,227 (tail bits)

4.1.3 Convolutional encoder

This block of 228 bits is encoded with the 1/2 rate convolutional code (identical to the one used for TCH/FS) defined by the polynomials:

$$G0 = 1 + D^3 + D^4$$
$$G1 = 1 + D + D^3 + D^4$$

This results in a block of 456 coded bits: {c(0),c(1),...,c(455)} defined by

c(2k) = u(k) + u(k-3) + u(k-4)
c(2k+1) = u(k) + u(k-1) + u(k-3) + u(k-4)   for k = 0,1,...,227 ; u(k) = 0 for k < 0

4.1.4 Interleaving

The coded bits are reordered and interleaved according to the following rule

i(B,j) = c(n,k)   for   k = 0,1,...,455
n = 0,1,...,N,N+1,...
$B = B_0 + 4n + (k \bmod 4)$
j = 2((49k) mod 57) + ((k mod 8) div 4)

See table 1.The result of the reordering of bits is the same as given for a TCH/FS (section 3.1.3) as can be seen from the evaluation of the bit number-index j, distributing the 456 bits over 4 blocks on even numbered bits and 4 blocks on odd numbered bits. The resulting 4 blocks are built by putting blocks with even numbered bits and blocks with odd numbered bits together into one block.

The block of coded data is interleaved "block rectangular" where a new data block starts every 4th block and is distributed over 4 blocks.

4.1.5 Mapping on a Burst

The mapping is given by the rule

e(B,j) = i(B,j) and e(B,59+j) = i(B,57+j) for j = 0,1,...,56

and

e(B,57) = hl(B) and e(B,58) = hu(B)

The two bits labelled hl(B) and hu(B) on burst number B are flags used for indication of control channel signalling. They are set to "1" for a SACCH.

4.2 Fast associated control channel at full rate (FACCH/F)

4.2.1 Block constitution

The message delivered to the encoder has a fixed size of 184 information bits. It is delivered on a burst mode.

4.2.2 Block code

The block encoding is done as specified for the SACCH in section 4.1.2.

4.2.3 Convolutional encoder

The convolutional encoding is done as specified for the SACCH in section 4.1.3.

4.2.4 Interleaving

The interleaving is done as specified for the TCH/FS in section 3.1.3.

4.2.5 Mapping on a Burst

A FACCH/F frame of 456 coded bits is mapped on 8 consecutive bursts as specified for the TCH/FS in section 3.1.4. As a FACCH is transmitted on bits which are stolen in a burst from the traffic channel, the even numbered bits in the first 4 bursts and the odd numbered bits of the last 4 bursts are stolen.

To indicate this to the receiving device the flags hl(B) and hu(B) have to be set according to the following rule :

hu(B) = 1 for the first 4 bursts (even numbered bits are stolen)
hl(B) = 1 for the last 4 bursts (odd numbered bits are stolen)

The consequences of this bitstealing by a FACCH/F is for a

- speech channel (TCH/FS) and data channel (TCH/F2.4):
  One full frame of data is stolen by the FACCH.

- Data channel (TCH/F9.6):
  The bitstealing by a FACCH/F disturbs a maximum of 96 coded bits generated from an input frame of four data blocks. A maximum of 24 of the 114 coded bits resulting from one input data block of 60 bits may be disturbed.

- Data channel (TCH/F4.8):
  The bit stealing by FACCH/F disturbs a maximum of 96 coded bits generated from an input frame of two data blocks. A maximum of 48 of the 228 coded bits resulting from one input data block of 60 bits may be disturbed.

NOTE: In the case of consecutive stolen frames, a number of bursts will have both the even and the odd bits stolen and both flags hu(B) and hl(B) must be set to 1.

4.3 Fast associated control channel at half rate (FACCH/H)

4.3.1 Block constitution

The message delivered to the encoder has a fixed size of 184 information bits. It is delivered on a burst mode.

4.3.2 Block code

The block encoding is done as specified for the SACCH in section 4.1.2.

4.3.3 Convolutional encoder

The convolutional encoding is done as specified for the SACCH in section 4.1.3.

4.3.4 Interleaving

The coded bits are reordered and interleaved according to the following rule:

$i(B,j) = c(n,k)$ for $k=0,1,\ldots,455$
$n=0,1,\ldots,N,N+1,\ldots$
$B= B_0 + 4n + (k \bmod 8) - 4((k \bmod 8) \text{ div } 6)$
$j= 2((49k) \bmod 57) + ((k \bmod 8) \text{ div } 4)$

See table 1. The result of the reordering of bits is the same as given for a TCH/FS (section 3.1.3) as can be seen from the evaluation of the bit number-index j, distributing the 456 bits over 4 blocks on even numbered bits and 4 blocks on odd numbered bits. The 2 last blocks with even numbered bits and the 2 last blocks with odd numbered bits are put together into 2 full middle blocks.

The block of coded data is interleaved "block diagonal" where a new data block starts every 4th block and is distributed over 6 blocks.

4.3.5 Mapping on a Burst

A FACCH/H frame of 456 coded bits is mapped on 6 consecutive bursts by the rule:

$e(B,j)=i(B,j)$ and $e(B,59+j)=i(B,57+j)$ for $j=0,1,\ldots,56$

and

$e(B,57)=hl(B)$ and $e(B,58)=hu(B)$

As a FACCH/H is transmitted on bits which are stolen from the traffic channel, the even numbered bits of the first 2 bursts, all bits of the middle 2 bursts and the odd numbered bits of the last 2 bursts are stolen.

To indicate this to the receiving device the flags hl(B) and hu(B) have to be set according to the following rule:

hu(B) = 1 for the first 2 bursts (even numbered bits are stolen)

hu(B) = 1 and hl(B) = 1 for the middle 2 bursts (all bits are stolen)

hl(B) = 1 for the last 2 bursts (odd numbered bits are stolen)

The consequences of this bitstealing by a FACCH/H is for a

- speech channel (TCH/HS):

  Two full consecutive speech frames are stolen by a FACCH/H.

- data channel (TCH/H4.8):

  The bitstealing by FACCH/H disturbes a maximum of 96 coded bits generated from an input frame of four data blocks. A maximum of 24 out of the 114 coded bits resulting from one input data block of 60 bits may be disturbed.

- data channel (TCH/H2.4):

  The bitstealing by FACCH/H disturbes a maximum of 96 coded bits generated from an input frame of four data blocks. A maximum of 24 out of the 114 coded bits resulting from one input data block of 36 bits may be disturbed.

  NOTE: In the case of consecutive stolen frames, two overlapping bursts will have both the even and the odd numbered bits stolen and both flags hu(B) and hl(B) must be set to 1.

4.4 Broadcast, Paging, Access grant and Cell broadcast channels (BCCH, PCH, AGCH, CBCH)

The coding scheme used for the broadcast, paging, access grant and cell broadcast messages is the same as for the SACCH messages, specified in section 4.1.

4.5 Stand-alone dedicated control channel (SDCCH)

The coding scheme used for the dedicated control channel messages is the same as for SACCH messages, specified in section 4.1.

4.6 Random access channel (RACH)

The burst carrying the random access uplink message has a different structure. It contains 8 information bits d(0),d(1),...,d(7).

Six parity bits p(0),p(1),...,p(5) are defined in such a way that in GF(2) the binary polynomial $d(0)D^{13} + \ldots + d(7)D^6 + p(0)D^5 + \ldots + p(5)$, when divided by $D^6 + D^5 + D^3 + D^2 + D + 1$ yields a remainder equal to $D^5 + D^4 + D^3 + D^2 + D + 1$.

The six bits of the BSIC, {B(0),B(1),...,B(5)}, of the BS to which the Random Access is intended, are added bitwise modulo 2 to the six parity bits, {p(0),p(1),...,p(5)}. This results in six colour bits, C(0) to C(5) defined as C(k) = b(k) + p(k) (k = 0 to 5) where

b(0) = MSB of PLMN colour code
b(5) = LSB of BS colour code.

This defines {u(0),u(1),..., u(17)} by:

u(k)	= d(k)	for k = 0,1,...,7
u(k)	= C(k-8)	for k = 8,9,...,13
u(k)	= 0	for k = 14,15,16,17 (tail bits)

The bits {e(0),e(1),..., e(35)} are obtained by the same convolutional code of rate 1/2 as for TCH/FS, defined by the polynomials:

$G0 = 1 + D^3 + D^4$
$G1 = 1 + D + D^3 + D^4$

and with

e(2k) = u(k) + u(k-3) + u(k-4)
e(2k+1) = u(k) + u(k-1) + u(k-3) + u(k-4) for k = 0,1,...,17 ; u(k) = 0for k < 0

4.7 Synchronization channel (SCH)

The burst carrying the synchronization information on the downlink BCCH has a different structure. It contains 25 information bits {d(0),d(1),..., d(24)}, 10 parity bits {p(0),p(1),..., p(9)} and 4 tail bits. The precise ordering of the information bits is given in GSM 04.08.

The ten parity bits {p(0),p(1),,...,p(9)} are defined in such a way that in GF(2) the binary polynomial:

$d(0)D^{34} +...+ d(24)D^{10} + p(0)D^{9} +...+ p(9)$, when divided by:

$D^{10} + D^{8} + D^{6} + D^{5} + D^{4} + D^{2} + 1$, yields a remainder equal to:

$D^{9} + D^{8} + D^{7} + D^{6} + D^{5} + D^{4} + D^{3} + D^{2} + D+1$.

Thus the encoded bits {u(0),u(1),...,u(38)} are:

u(k) = d(k) for k = 0,1,...,24
u(k) = p(k-25) for k = 25,26,...,34
u(k) = 0 for k = 35,36,37,38 (tail bits)

The bits {e(0),e(1),..., e(77)} are obtained by the same convolutional code of rate 1/2 as for TCH/FS, defined by the polynomials:

$G0 = 1 + D^{3} + D^{4}$
$G1 = 1 + D + D^{3} + D^{4}$

and with

e(2k) = u(k) + u(k-3) + u(k-4)
e(2k+1) = u(k) + u(k-1) + u(k-3) + u(k-4) for k = 0,1,....,77 ; u(k) = 0 for k < 0

4.8 Access Burst on channels other than RACH

The encoding of this burst is as defined in section 4.6 for the random access channel (RACH). The BSIC used shall be the BSIC of the BTS to which the burst is intended.

Table 1: Reordering and partitioning of a coded block of 456 bits into 8 sub-blocks

k mod 8=	0	1	2	3
j= 0	k = 0	57	114	171
2	64	121	178	235
4	128	185	242	299
6	192	249	306	363
8	256	313	370	427
10	320	377	434	35
	384	441	42	99
	448	49	106	163
	56	113	170	227
	120	177	234	291
20	184	241	298	355
	248	305	362	419
	312	369	426	27
	376	433	34	91
	440	41	98	155
30	48	105	162	219
	112	169	226	283
	176	233	290	347
	240	297	354	411
	304	361	418	19
40	368	425	26	83
	432	33	90	147
	40	97	154	211
	104	161	218	275
	168	225	282	339
50	232	289	346	403
	296	353	410	11
	360	417	18	75
	424	25	82	139
	32	89	146	203
60	96	153	210	267
	160	217	274	331
	224	281	338	395
	288	345	402	3
	352	409	10	67
70	416	17	74	131
	24	81	138	195
	88	145	202	259
	152	209	266	323
	216	273	330	387
80	280	337	394	451
	344	401	2	59
	408	9	66	123
	16	73	130	187
	80	137	194	251
90	144	201	258	315
	208	265	322	379
	272	329	386	443
	336	393	450	51
	400	1	58	115
100	8	65	122	179
	72	129	186	243
	136	193	250	307
	200	257	314	371
	264	321	378	435
110	328	385	442	43
112	392	449	50	107

k mod 8=	4	5	6	7
j= 1	228	285	342	399
3	292	349	406	7
5	356	413	14	71
7	420	21	78	135
9	28	85	142	199
11	92	149	206	263
	156	213	270	327
	220	277	334	391
	284	341	398	455
	348	405	6	63
21	412	13	70	127
	20	77	134	191
	84	141	198	255
	148	205	262	319
	212	269	326	383
31	276	333	390	447
	340	397	454	55
	404	5	62	119
	12	69	126	183
	76	133	190	247
41	140	197	254	311
	204	261	318	375
	268	325	382	439
	332	389	446	47
	396	453	54	111
51	4	61	118	175
	68	125	182	239
	132	189	246	303
	196	253	310	367
	260	317	374	431
61	324	381	438	39
	388	445	46	103
	452	53	110	167
	60	117	174	231
	124	181	238	295
71	188	245	302	359
	252	309	366	423
	316	373	430	31
	380	437	38	95
	444	45	102	159
81	52	109	166	223
	116	173	230	287
	180	237	294	351
	244	301	358	415
	308	365	422	23
91	372	429	30	87
	436	37	94	151
	44	101	158	215
	108	165	222	279
	172	229	286	343
101	236	293	350	407
	300	357	414	15
	364	421	22	79
	428	29	86	143
	36	93	150	207
111	100	157	214	271
113	164	221	278	335

Table 2: Subjective importance of encoded bits for the full rate speech TCH (Parameter names and bit indices refer to GSM 06.10)

Importance class	Parameter name	Parameter number	Bit index	Label	Class
1	Log area ratio 1	1	5	d0	1 with parity check
	block amplitude	12,29,46,63	5	d1,d2,d3,d4	
2	Log area ratio 1	1	4		
	Log area ratio 2	2	5		
	Log area ratio 3	3	4		
3	Log area ratio 1	1	3		
	Log area ratio 2	2	4		
	Log area ratio 3	3	3		
	Log area ratio 4	4	4		
	LPT lag	9,26,43,60	6		
	block amplitude	12,29,43,63	4		
	Log area ratio 2,5,6	2,5,6	3		
	LPT lag	9,26,43,60	5		
	LPT lag	9,26,43,60	4		
	LPT lag	9,26,43,60	3		
	LPT lag	9,26,43,60	2		
4	block amplitude	12,29,43,63	3		
	Log area ratio 1	1	2		
	Log area ratio 4	4	3		
	Log area ratio 7	7	2		
	LPT lag	9,26,43,60	1	...d48,d49	
	Log area ratio 5,6	5,6	2	d50	1 with parity check
	LPT gain	10,27,44,61	1		
	LPT lag	9,26,43,60	0		
	Grid position	11,28,45,62	1		
5	Log area ratio 1	1	1		
	Log area ratio 2,3,8,4	2,3,8,4	2		
	Log area ratio 5,7	5,7	1		
	LPT gain	10,27,44,61	0		
	block amplitude	12,29,43,63	2		
	RPE pulses	13..25	2		
	RPE pulses	30..42	2		
	RPE pulses	47..59	2		
	RPE pulses	64..76	2		
	Grid position	11,28,45,62	0		
	block amplitude	12,29,43,63	1		
	RPE pulses	13..25	1		
	RPE pulses	30..42	1		
	RPE pulses	47..59	1		
	RPE pulses	64..67	1	...d181	
	RPE pulses	68..76	1	d182	2
6	Log area ratio 1	1	0		
	Log area ratio 2,3,6	2,3,6	1		
	Log area ratio 7	7	0		
	Log area ratio 8	8	1		
	Log area ratio 8,3	8,3	0		
	Log area ratio 4	4	1		
	Log area ratio 4,5	4,5	0		
	block amplitude	12,29,43,63	0		
	RPE pulses	13..25	0		
	RPE pulses	30..42	0		
	RPE pulses	47..59	0		
	RPE pulses	64..67	0		
	Log area ratio 2,6	2,6	0	...d259	

Table 3a: Subjective importance of encoded bits for the half rate speech TCH for unvoiced speech frames (Parameter names and bit indices refer to GSM 06.20)

Parameter name	Bit index	Label	Class
R0	1	d0	
LPC 3	7	d1	
GSP 0-1	2	d2	
GSP 0-2	2	d3	
GSP 0-3	2	d4	
GSP 0-4	2	d5	
LPC 1	0	d6	
LPC 2	5...1	d7...d11	
LPC 3	6...1	d12...	
Code 1-2	0		
Code 2-2	6...0		
Code 1-3	6...0		1
Code 2-3	6...3		
LPC3	0		without
R0	0		parity
INT-LPC	0		check
Code 1-2	1...6		
Code 2-1	0...6		
Code 1-1	0...6		
GSP 0-4	0		
GSP 0-3	0		
GSP 0-2	0		
GSP 0-1	0		
LPC 2	0		
GSP 0-4	1		
GSP 0-3	1		
GSP 0-2	1		
GSP 0-1	1		
LPC 1	1...4	...d72	
LPC 1	5	d73...	
GSP 0-4	3		
GSP 0-3	3		
GSP 0-2	3		
GSP 0-1	3		
LPC2	6...8		1
GSP 0-4	4		
GSP 0-3	4		with
GSP 0-2	4		parity
GSP 0-1	4		check
LPC 1	6...9		
R0	2		
LPC 1	10		
R0	3,4		
Mode	0,1	...d94	
Code 2-4	0...6	d95...	
Code 1-4	0...6		2
Code 2-3	0...2	...d111	

Table 3b: Subjective importance of encoded bits for the half rate speech TCH for voiced speech frames (Parameter names and bit indices refer to GSM 06.20)

Parameter name	Bit index	Label	Class
LPC 1	2,1	d0, d1	
LPC 2	6...4	d2...	
GSP 0-1	4		
GSP 0-2	4		
GSP 0-3	4		
GSP 0-4	4		
GSP 0-1	3		
GSP 0-2	3		
GSP 0-3	3		
GSP 0-4	3		
GSP 0-1	2		
GSP 0-2	2		
GSP 0-3	2		
GSP 0-4	2		
Code 1	8...0		
Code 2	8...5		
Code 2	2...0		
Code 3	8		
Code 2	4,3		
GSP 0-1	1		
GSP 0-2	1		
GSP 0-3	1		
GSP 0-4	1		1
GSP 0-1	0		
GSP 0-2	0		without
GSP 0-3	0		parity
GSP 0-4	0		check
INT-LPC	0		
LPC 2	0		
LPC 3	0		
LAG 4	0		
LPC 3	1		
LPC 2	1		
LAG 4	1		
LAG 3	0		
LAG 2	0		
LAG 1	0		
LAG 4	2		
LAG 3	1		
LAG 2	1		
LAG 1	1		
LPC 3	2...4		
LPC 2	2		
LPC 3	5,6		
LPC 2	3		
R0	0		
LPC 3	7		
LPC 1	0		
LAG 4	3		
LAG 3	2		
LAG 2	2		
LAG 1	2		
R0	1	...d72	

Parameter name	Bit index	Label	Class
LAG 3	3	d73...	
LAG 2	3		
LAG 1	3,4		1
LPC 2	7,8		
LPC 1	3...6		with
R0	2		parity
LAG 1	5...7		check
LPC 1	7...10		
R0	3,4		
Mode	0,1	...d94	
Code 4	0...8	d95...	2
Code 3	0...7	...d111	

Table 4: Reordering and partitioning of a coded block of 228 bits into 4 sub-blocks for TCH/HS

b=	0	1
i=0	k=0	150
2	38	188
4	76	226
6	114	14
8	152	52
10	190	90
	18	128
	56	166
	94	204
	132	32
20	170	70
	208	108
	8	146
	46	184
	84	222
30	122	10
	160	48
	198	86
	28	124
	66	162
40	104	200
	142	30
	180	68
	218	106
	4	144
50	42	182
	80	220
	118	6
	156	44
	194	82
60	22	120
	60	158
	98	196
	136	24
	174	62
70	212	100
	12	138
	50	176
	88	214
	126	2
80	164	40
	202	78
	34	116
	72	154
	110	192
90	148	26
	186	64
	224	102
	16	140
	54	178
100	92	216
	130	20
	168	58
	206	96
	36	134
110	74	172
112	112	210

b=	2	3
i=1	k=1	151
3	39	189
5	77	227
7	115	15
9	153	53
11	191	91
	19	129
	57	167
	95	205
	133	33
21	171	71
	209	109
	9	147
	47	185
	85	223
31	123	11
	161	49
	199	87
	29	125
	67	163
41	105	201
	143	31
	181	69
	219	107
	5	145
51	43	183
	81	221
	119	7
	157	45
	195	83
61	23	121
	61	159
	99	197
	137	25
	175	63
71	213	101
	13	139
	51	177
	89	215
	127	3
81	165	41
	203	79
	35	117
	73	155
	111	193
91	149	27
	187	65
	225	103
	17	141
	55	179
101	93	217
	131	21
	169	59
	207	97
	37	135
111	75	173
113	113	211

Annex A (informative): Summary of Channel Types

TCH/FS:	full rate speech traffic channel
TCH/HS:	half rate speech traffic channel
TCH/F9.6:	9.6 kbit/s full rate data traffic channel
TCH/F4.8:	4.8 kbit/s full rate data traffic channel
TCH/H4.8:	4.8 kbit/s half rate data traffic channel
TCH/F2.4:	≤ 2.4 kbit/s full rate data traffic channel
TCH/H2.4:	≤ 2.4 kbit/s half rate data traffic channel

SACCH:	slow associated control channel
FACCH/F:	fast associated control channel at full rate
FACCH/H:	fast associated control channel at half rate
SDCCH:	stand-alone dedicated control channel
BCCH:	broadcast control channel
PCH:	paging channel
AGCH	access grant channel
RACH:	random access channel
SCH:	synchronization channel
CBCH:	cell broadcast channel

Annex B (informative): Summary of Polynomials Used for Convolutional Codes

$G0 = 1 + D^3 + D^4$	TCH/FS, TCH/F9.6, TCH/H4.8, SDCCH, BCCH, PCH,SACCH,FACCH, AGCH, RACH, SCH
$G1 = 1 + D + D^3 + D^4$	TCH/FS, TCH/F9.6, TCH/H4.8, SACCH, FACCH, SDCCH, BCCH,PCH, AGCH, RACH, SCH, TCH/F4.8,TCH/F2.4,TCH/H2.4
$G2 = 1 + D^2 + D^4$	TCH/F4.8, TCH/F2.4, TCH/H2.4
$G3 = 1 + D + D^2 + D^3 + D^4$	TCH/F4.8, TCH/F2.4, TCH/H2.4
$G4 = 1 + D^2 + D^3 + D^5 + D^6$	TCH/HS
$G5 = 1 + D + D^4 + D^6$	TCH/HS
$G6 = 1 + D + D^2 + D^3 + D^5 + D^6$	TCH/HS

History

Document history	
February 1996	Creation of Version 5.0.0
March 1996	Publication of Version 5.0.0

ISBN 2-7437-0585-X
Dépôt légal : Mars 1996