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Physical Layer on the Radio Path: General Decsription

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Physical Layer on the Radio Path:

General Description

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PREFATORY NOTE

ETSI has constituted stable and consistent documents which give specifications for the implementation of the European Cellular Telecommunications System. Historically, these documents have been identified as "GSM recommendations".

Some of these recommendations may subsequently become Interim European Telecommunications Standards (I-ETSs) or European Telecommunications Standards (ETSs), whilst some continue with the status of ETSI-GSM Technical Specifications. These ETSI-GSM Technical Specifications are for editorial reasons still referred to as GSM recommendations in some current GSM documents.

The numbering and version control system is the same for ETSI-GSM Technical Specifications as for "GSM recommendations".

GSM Recommendation:05.01

Title: PHYSICAL LAYER ON THE RADIO PATH: GENERAL DESCRIPTION

Date : January 1991

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Number of pages: 11

RECOMMENDATION 05.01
PHYSICAL LAYER ON THE RADIO PATH
GENERAL DESCRIPTION

1. SCOPE:

This recommendation is an introduction to the 05 series of the GSM recommendations. It is not of a mandatory nature, but consists in a general description of the organization of the physical layer with reference to the recommendations where each part is specified in details. It introduces furthermore, the reference configuration that will be used throughout this series of recommendations.

2. SET OF CHANNELS:

The radio subsystem provides a certain number of logical channels that can be separated into two categories according to Rec.04.03:

1) the traffic channels (TCH): they are intended to carry two types of user information streams: encoded speech and data. Two types of traffic channels are defined: Bm or full-rate (TCH/F) and Lm or half-rate (TCH/H) traffic channels. For the purpose of this series of recommendations, the following traffic channels are distinguished:

   - full rate speech TCH (TCH/FS)
   - half rate speech TCH (TCH/HS)
   - 9.6 kbit/s full rate data TCH (TCH/F9.6)
   - 4.8 kbit/s full rate data TCH (TCH/F4.8)
   - 4.8 kbit/s half rate data TCH (TCH/H4.8)
   - ≤ 2.4 kbit/s full rate data TCH (TCH/F2.4)
   - ≤ 2.4 kbit/s half rate data TCH (TCH/H2.4)
   - cell broadcast channel (CBCH)

2) the signaling channels: these can be sub-divided into BCCH (broadcast control channel), CCCH (common control channel), SDCCH (stand-alone dedicated control channel) and ACCH (associated control channel). An associated control channel is always allocated in conjunction with, either a TCH, or a SDCCH. Two types of ACCH are defined: continuous stream (slow ACCH) and burst stealing mode (fast ACCH). For the purpose of this series of recommendations, the following signalling channels are distinguished:

   - stand-alone dedicated control channel, four of them mapped on the same basic physical channel as the CCCH (SDCCH/4)
   - stand-alone dedicated control channel, eight of them mapped on a separate basic physical channel (SDCCH/8)
   - full rate fast associated control channel (FACCH/F)
   - half rate fast associated control channel (FACCH/H)
   - slow, TCH/F associated, control channel (SACCH/TF)
   - slow, TCH/H associated, control channel (SACCH/TH)
   - slow, SDCCH/4 associated, control channel (SACCH/C4)
   - slow, SDCCH/8 associated, control channel (SACCH/C8)
   - broadcast control channel (BCCH)
   - random access channel (ie uplink CCCH) (RACH)

- paging channel (part of downlink CCCH) (PCH)
- access grant channel (part of downlink CCCH) (AGCH)

When there is no need to distinguish between different sub-categories of the same logical channel, only the generic name will be used, meaning also all the sub-categories (SACCH will mean all categories of SACCHs, SACCH/T will mean both the slow, TCH associated, control channels,..).

The logical channels mentioned above are mapped on physical channels that are described in this set of recommendations. The different physical channels provide for the transmission of information pertaining to higher layers according to a block structure.

3. REFERENCE CONFIGURATION:

For the purpose of elaborating the physical layer specification, a reference configuration of the transmission chain is used as shown in annex 1. This reference configuration also indicates which parts are dealt with in details in which recommendation. It shall be noted that only the transmission part is specified, the receiver being specified only via the overall performance requirements. With reference to this configuration, the recommendations in the 05 series address the following functional units:

- Rec.05.02: burst building, and burst multiplexing;
- Rec.05.03: coding, reordering and partitioning, and interleaving;
- Rec.05.04: differential encoding, and modulation;
- Rec.05.05: transmitter, antenna, and receiver (overall performance).

This reference configuration defines also a number of points of vocabulary in relation to the name of bits at different levels in the configuration. It must be outlined, in the case of the encrypted bits, that they are named only with respect to their position after the encryption unit, and not to the fact that they pertain to a flow of information that is actually encrypted.

4. THE BLOCK STRUCTURES:

The different block structures are described in more detail in Rec. 05.03 (Channel coding). A summarised description appears in the table below, in terms of net bit rate, length and recurrence of blocks.

Notes:

1) for full rate speech, the block is divided into two classes according to the importance of the bits (182 bits for class I and 78 bits for class II).
2) the half rate speech TCH is envisaged for future evolution.
3) for data services, the net bit rate is the adaptation rate as defined in Rec.04.21, necessary to transmit control information to modems.
4) on SACCH, 16 bits are reserved for control information on layer 1, and 168 bits are used for higher layers.
5) CCCH channels are common to all users of a cell; the total number of blocks (n, p, r) per recurrence period is adjustable on a cell by cell basis and depends upon the parameters (BS_CC_CHANS, BS_BCCH_SDCCH_COMB and BS_AG_BLKS_RES) broadcast on the BCCH and specified in 05.02 and 04.08.

Type of channel	net bit rate (kbit/s)	block length (bits)	block recurrence (ms)
full rate speech TCH[1]	13,0	182 + 78	20
half rate speech TCH[2]	tbd	tbd	tbd
data TCH (9,6 kbit/s)[3]	12,0	60	5
data TCH (4,8 kbit/s)[3]	6,0	60	10
data TCH (≤2,4 kbit/s)[3]	3,6	72	20
full rate FACCH	9,2	184	20
half rate FACCH	4,6	184	40
SDCCH	598/765(~0,782)	184	3060/13 (~235)
SACCH (with TCH) [4]	115/300(~0,383)	168 + 16	480
SACCH (with SDCCH) [4]	299/765(~0,391)	168 + 16	6120/13 (~471)
BCCH	598/765(~0,782)	184	3060/13 (~235)
AGCH [5]	n*598/765(~0,782)	184	3060/13 (~235)
PCH [5]	p*598/765(~0,782)	184	3060/13 (~235)
RACH [5]	r*26/765(~0,034)	8	3060/13 (~235)

5. MULTIPLE ACCESS AND TIME SLOT STRUCTURE:

The access scheme is Time Division Multiple Access (TDMA) with 8 basic physical channels per carrier. The carrier separation is 200 kHz. A physical channel is therefore defined as a sequence of TDMA frames, a time slot number (modulo 8) and a frequency hopping sequence.

The basic radio resource is a time slot lasting ~ 576.9 µs (15/26 ms) and transmitting information at a modulation rate of ~ 270.833 kbit/s (1625/6 kbit/s). This means that the time slot duration, including guard time, is 156.25 bit durations.

We shall describe successively the time frame structures, the time slot structures and the channel organization. The appropriate specifications will be found in Rec.05.02 (multiplexing and multiple access).

5.1 Hyperframes, superframes and multiframes:

A diagrammatic representation of all the time frame structures is in figure 1. The longest recurrent time period of the structure is called hyperframe and has a duration of 3h 28mn 53s 760ms (or 12533.76 s). The TDMA frames are numbered modulo this hyperframe (TDMA frame number, or FN, from 0 to 2715647). This long period is needed to support cryptographic mechanisms defined in 03.20.

One hyperframe is subdivided in 2048 superframes which have a duration of 6.12 seconds. The superframe is the least common multiple of the time frame structures. The superframe is itself subdivided in multiframes; two types of multiframes exist in the system:

- a 26-frame multiframe (51 per superframe) with a duration of 120 ms, comprising 26 TDMA frames. This multiframe is used to carry TCH (and SACCH/T) and FACCH.

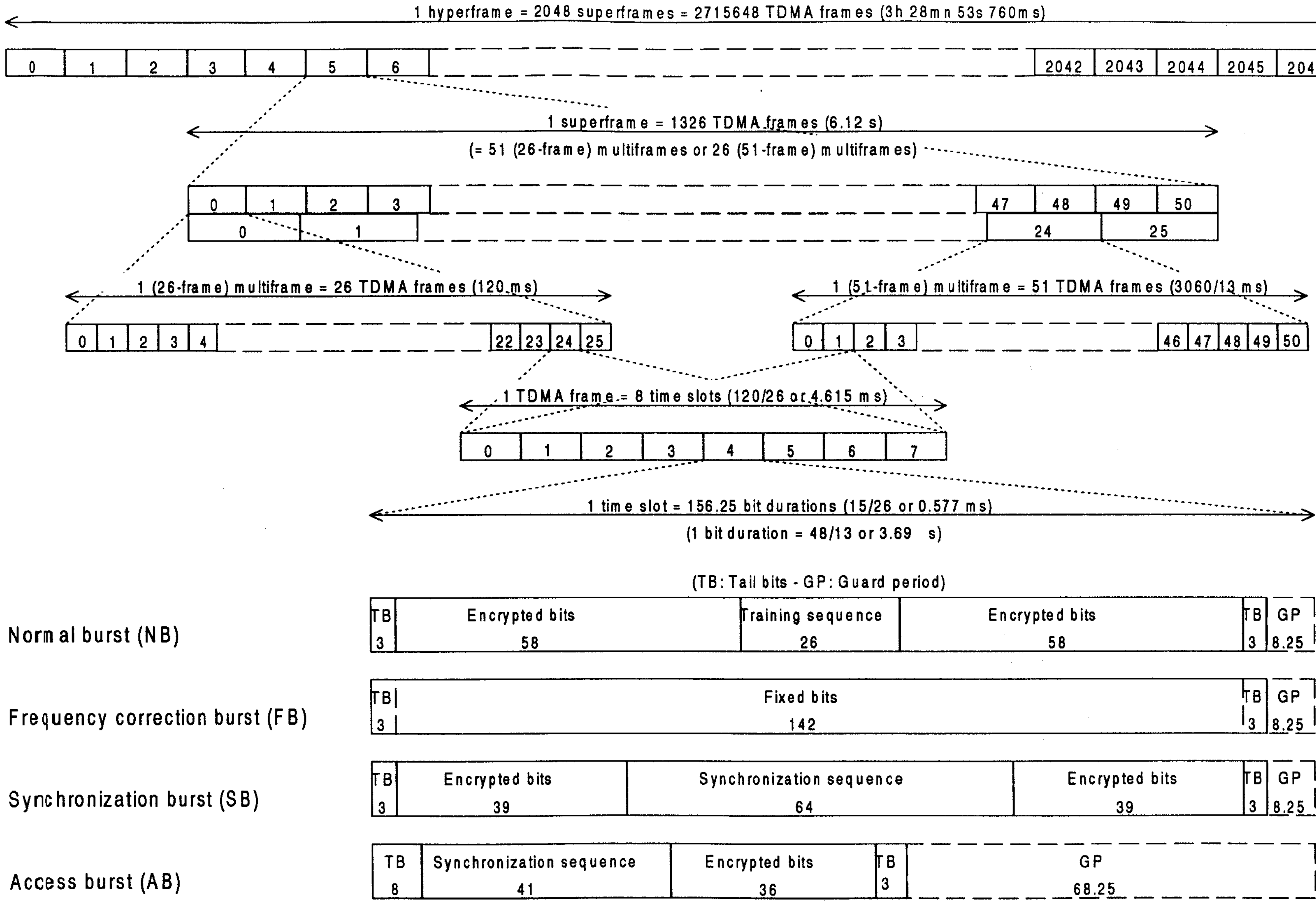


Figure 1: Time frames, time slots and bursts

- a 51-frame multiframe (26 per superframe) with a duration of ~ 235.4 ms (3060/13 ms), comprising 51 TDMA frames. This multiframe is used to carry BCCH, CCCH (AGCH, PCH and RACH) and SDCCH (and SACCH/C).

A TDMA frame, comprising 8 time slots has a duration of ~ 4.62 (60/13) ms.

5.2 Time slots and bursts:

The time slot is a time interval of ~ 576.9 μs (15/26 ms), that is 156.25 bit durations, and its physical content is called a burst. Four different types of bursts exist in the system. A diagram of these bursts appears in figure 1.

- normal burst (NB): this burst is used to carry information on traffic and control channels, except for RACH. It contains 116 encrypted bits and includes a guard time of 8.25 bit durations (~ 30.46 μs).

- frequency correction burst (FB): this burst is used for frequency synchronization of the mobile. It is equivalent to an unmodulated carrier, shifted in frequency, with the same guard time as the normal burst. It is broadcast together with the BCCH. The repetition of FBs is also named frequency correction channel (FCCH).

- synchronization burst (SB): this burst is used for time synchronization of the mobile. It contains a long training sequence and carries the information of the TDMA frame number (FN) and base station identity code (BSIC, see Rec.03.03). It is broadcast together with the frequency correction burst. The repetition of synchronization bursts is also named synchronization channel (SCH).

- access burst (AB): this burst is used for random access and is characterized by a longer guard period (68.25 bit durations or 252 μs) to cater for burst transmission from a mobile which does not know the timing advance at the first access (or after handover). This allows for a distance of 35 km. This burst is used in the RACH and after a handover. In exceptional cases of cell radii larger than 35 km, some possible measures are described in Rec.03.30.

5.3 Channel organization:

The channel organization for the traffic channels (TCH), FACCHs and SACCH/T uses the 26-frame multiframe. It is organized as described in the following figure, where only one time slot per TDMA frame is considered.

(a)	T	T	T	T	T	T	T	T	T	T	T	T	A	T	T	T	T	T	T	T	T	T	T	T	T	–

← 26 frames = 120 ms →

(b)	T	t	T	t	T	t	T	t	T	t	T	t	A	t	T	t	T	t	T	t	T	t	T	t	T	a

(a) case of one full rate TCH (b) case of two half rate TCHs

T, t: TDMA frame for TCH –: idle TDMA frame A, a: TDMA frame for SACCH/T

The FACCH is transmitted by preempting half of the information bits of the bursts (on 8 consecutive T or t frames) of the TCH to which it is associated.

The channel organization for the control channels (except FACCHs and SACCH/T) uses the 51-frame multiframe. It is organized in the downlink and uplink as described in figure 2.

6. FREQUENCY HOPPING CAPABILITY:

The frequency hopping capability is optionally used by the network operator on all or part of its network. The main advantage of this feature is to provide diversity on one transmission link (especially to increase the efficiency of coding and interleaving for slowly moving mobile stations) and also to average the quality on all the communications through interferers diversity. It is implemented on all mobile stations.

The principle of slow frequency hopping is that every mobile transmits its time slots according to a sequence of frequencies that it derives from an algorithm. The frequency hopping occurs between time slots and, therefore, a mobile station transmits (or receives) on a fixed frequency during one time slot (~ 577 μs) and then must hop before the time slot on the next TDMA frame. Due to the time needed for monitoring other base stations the time allowed for hopping is approximately 1 ms, according to the receiver implementation. The receive and transmit frequencies are always duplex frequencies.

The frequency hopping sequences are orthogonal inside one cell (ie no collisions occur between communications of the same cell), and independent from one cell to an homolog cell (ie using the same set of RF channels, or cell allocation). The hopping sequence is derived by the mobile from parameters broadcast at the channel assignment, namely, the mobile allocation (set of frequencies on which to hop), the hopping sequence number of the cell (which allows different sequences on homolog cells) and the index offset (to distinguish the different mobiles of the cell using the same mobile allocation). The non-hopping case is included in the algorithm as a special case. The different parameters needed and the algorithm are specified in Rec.05.02.

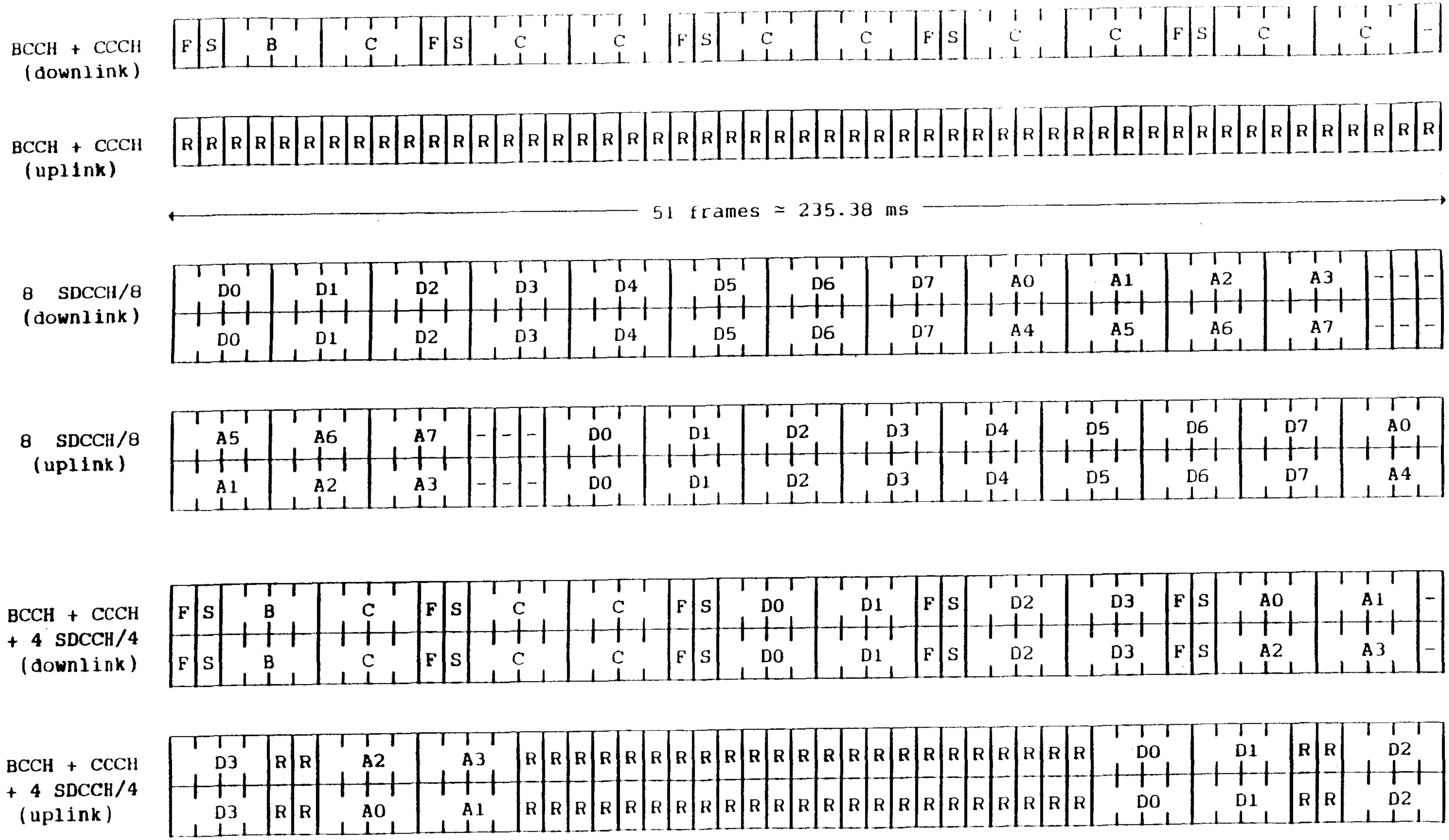
It must be noted that the basic physical channel supporting the BCCH does not hop.

7. CODING AND INTERLEAVING:

A brief description of the coding schemes that are used for the logical channels mentioned in section 2, plus the synchronization channel (SCH, see 5.2), is made in the following table. For all the types of channels the following operations are made in this order:

- external coding (block coding)
- internal coding (convolutional coding)
- interleaving

After coding the different channels (except RACH and SCH) are constituted by blocks of 464 bits, that is, 456 coded information bits plus 8 bits of coded header (the purpose of the header is to distinguish between TCH and



F: TDMA frame for frequency correction burst S: TDMA frame for synchronisation burst
B: TDMA frame for BCCH C: TDMA frame for CCCH R: TDMA frame for RACH
D: TDMA frame for SDCCH A: TDMA frame for SACCH/C

FIGURE 2: Channel organisation in the 51-frame multiframe

FACCH blocks). These blocks are interleaved over a number of interleaved blocks which is channel dependent. All these operations are specified in Rec.05.03.

Type of channel	bits/block data+parity+tail[1]	convolutional code rate	coded bits per block	interleaving depth
TCH/FS			456	8
class I[(2]	182 + 3 + 4	1/2	(378)	
class II	78 + 0 + 0	-	(78)	
TCH/HS	tbd	tbd	tbd	tbd
TCH/F9.6	4*60 + 0 + 4	244/456	456	19
TCH/F4.8	60 + 0 + 16	1/3	228	19
TCH/H4.8	4*60 + 0 + 4	244/456	456	19
TCH/F2.4	72 + 0 + 4	1/6	456	8
TCH/H2.4	72 + 0 + 4	1/3	228	19
FACCHs	184 + 40 + 4	1/2	456	8
SDCCHs SACCHs	184 + 40 + 4	1/2	456	4
BCCH AGCH PCH	"	"	"	"
RACH	8 + 6 + 4	1/2	36	1
SCH	25 + 10 + 4	1/2	78	1

Notes:

1) The tail bits mentioned here are the tail bits of the convolutional code.
2) The 3 parity bits for TCH/FS detect an error on 50 bits of class I.

8. MODULATION:

The modulation scheme is gaussian MSK (GMSK) with BT = 0.3. As already mentioned the modulation rate is 1625/6 kbit/s (≈ 270.83 kbit/s). This scheme is specified in detail in Rec. 05.04 (Modulation and demodulation).

9. TRANSMISSION AND RECEPTION:

The modulated stream is then transmitted on a radio frequency carrier. The overall frequency band available is the band 890-915 MHz (mobile transmit) and 935-960 MHz (base transmit). The RF channel spacing is 200 kHz, allowing for 124 radio frequency channels in the entire band, thus leaving a guard band of 200 kHz at each end of the subbands.

The specific RF channels, together with the requirements on the transmitter and the receiver will be found in Rec. 05.05 (Transmission and reception). In the radio subsystem, provision has been made for the possible use of extended bands in the future. Together with the GSM bands, three different frequency bands are allowed on a national basis.

In order to allow for low power consumption for different classes of mobiles (eg. vehicle mounted, hand-held, ..), 5 different power classes have been defined. The maximum power class is 20 W peak output power (ca 2.5 W mean output power) and the minimum is 0.8 W peak output power. Those classes are specified in Rec.05.05.

The requirements on the overall transmission quality together with the measurement conditions are also in Rec.05.05.

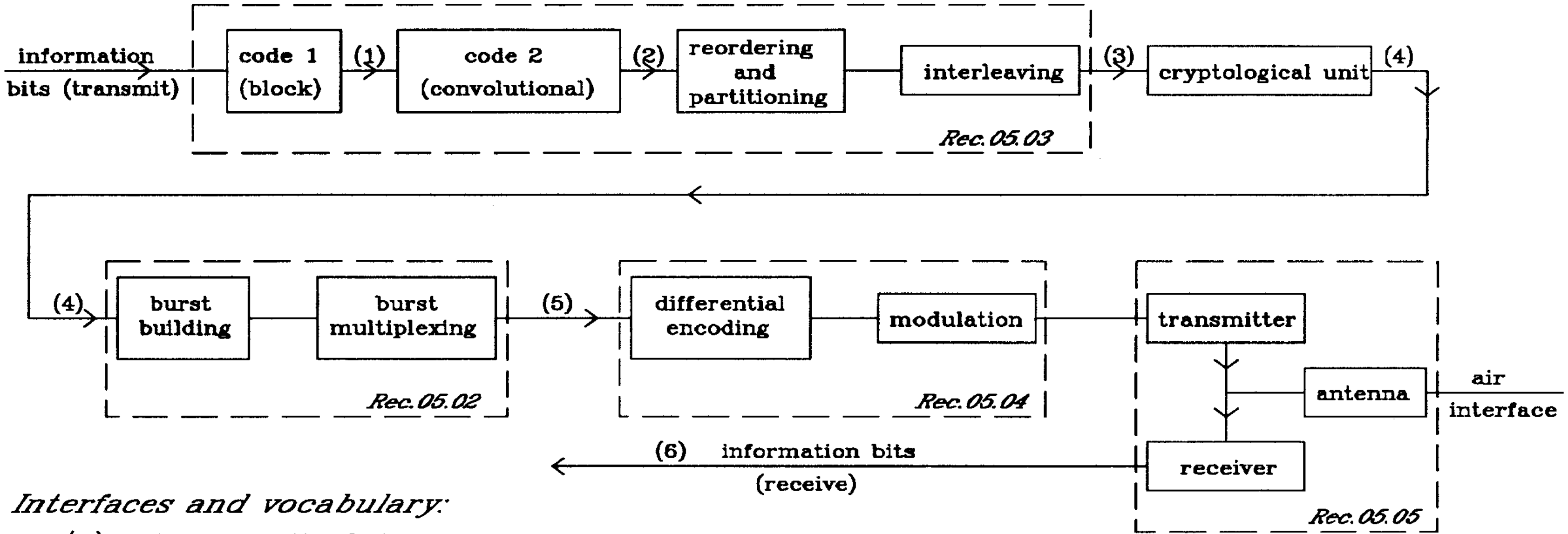
10 OTHER LAYER 1 FUNCTIONS:

The transmission involves other functions. These functions may necessitate the handling of specific protocols between BS and MS. Relevant topics for these cases are:

1) the power control mechanisms which adjust the output level of the mobile station (and optionally of the base station) in order to ensure that the required quality is achieved with the less possible radiated power. Sixteen power levels, with 2 dB steps, have been defined for that purpose. This is described in Rec.05.08 (radio subsystem link control) and Rec.05.05.
2) the synchronisation of the receiver with regard to frequency and time (time acquisition and time frame alignment). The synchronisation problems are described in Rec.05.10 (synchronisation aspects).
3) the hand-over and quality monitoring which are necessary to allow a mobile to continue a call during a change of physical channel. This can occur either because of degradation of the quality of the current serving channel, or because of the availability of another channel which can allow communication at a lower Tx power level, or to prevent a MS from grossly exceeding the planned cell boundaries.
   The choice of the new channel is done by the network (base station control and MSC) based on measurements (on its own and on adjacent base stations) that are sent on a continuous basis by the mobile station via the SACCHs. The requirements are specified in Rec. 05.08 (radio subsystem link control).
4) the strategy of first selection or reselection of a base station by a mobile, together with the idle mode activity (listening to CCCH, sleep mode,..) are specified in Rec.05.08 (radio subsystem link control).

11 PERFORMANCE:

Under typical urban fading conditions (ie multipath delays no greater than 5 µs), the quality threshold for full-rate speech is reached at a C/I value of approximately 9 dB and the maximum sensitivity is approximately -104 dBm for mobile and base stations and -102 dBm for hand-helds.



Interfaces and vocabulary:

(1) info + parity bits
(2) coded bits
(3) interleaved bits
(4) encrypted bits
(5) modulating bits
(6) information bits (receive)

REFERENCE CONFIGURATION

TABLE 1: RELATIONS BETWEEN RECOMMENDATIONS