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Digital cellular telecommunications system (Phase 2+) (GSM); Modulation (3GPP TS 45.004 version 13.2.0 Release 13)

A GLOBAL INITIATIVE

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Contents

Foreword

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1 Scope

The modulator receives the bits from the encryption unit, see 3GPP TS 45.001, and produces an RF signal. The filtering of the Radio Frequency (RF) signal necessary to obtain the spectral purity is not defined, neither are the tolerances associated with the theoretical filter requirements specified. These are contained in 3GPP TS 45.005.

1.1 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.
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[1] 3GPP TR 21.905: 'Vocabulary for 3GPP Specifications'.

[2] 3GPP TS 45.001: 'Physical Layer on the Radio Path (General Description)'.

[3] 3GPP TS 45.002: 'Multiplexing and multiple access on the radio path'.

[4] 3GPP TS 45.005: 'Radio transmission and reception'.

[5] 3GPP TS 45.010: 'Radio subsystem synchronization'.

[6] 3GPP TS 44.060: 'Radio Link Control/ Medium Access Control (RLC/MAC) protocol'.

[7] 3GPP TS 43.064: 'General Packet Radio Service (GPRS)'.

[8] 3GPP TS 45.003: 'Channel Coding'.

1.2 Abbreviations

Abbreviations used in this specification are listed in 3GPP TR 21.905. In addition to abbreviations in 3GPP TR 21.905 the following abbreviation apply:

AQPSK Adaptive Quadrature Phase Shift Keying

2 Modulation format for GMSK

2.1 Modulating symbol rate

The modulating symbol rate is the normal symbol rate which is defined as 1/T = 1 625/6 ksymb/s (i.e. approximately 270.833 ksymb/s), which corresponds to 1 625/6 kbit/s (i.e. 270.833 kbit/s). T is the normal symbol period (see 3GPP TS 45.010).

2.2 Start and stop of the burst

Before the first bit of the bursts as defined in 3GPP TS 45.002 enters the modulator, the modulator has an internal state as if a modulating bit stream consisting of consecutive ones ($d_i = 1$) had entered the differential encoder. Also after the last bit of the time slot, the modulator has an internal state as if a modulating bit stream consisting of consecutive ones ($d_i = 1$) had continued to enter the differential encoder. These bits are called dummy bits and define the start and the stop of the active and the useful part of the burst as illustrated in figure 1. Nothing is specified about the actual phase of the modulator output signal outside the useful part of the burst. In case of EC operation when using blind physical layer transmissions, the phase during the useful part of contiguous bursts within a TDMA frame has a fixed relation, see subclause 2.6 and 2.7.

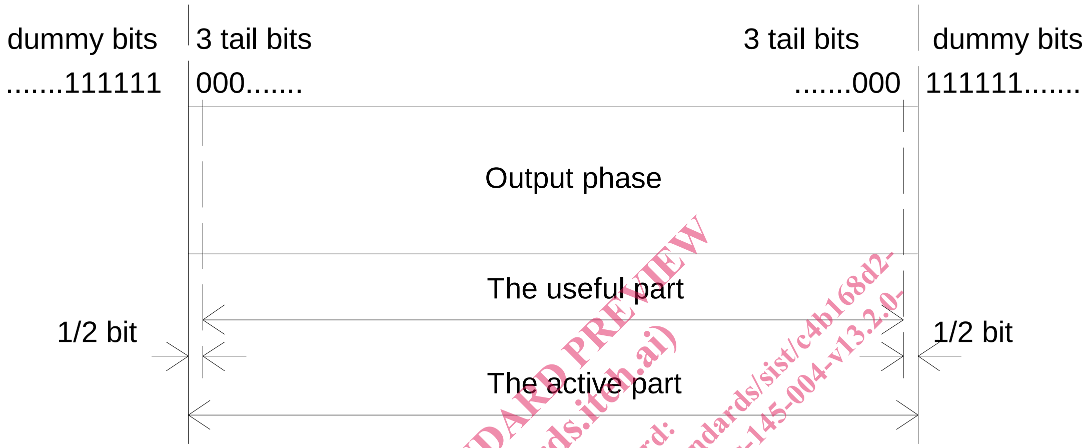

Figure 1: Relation between active part of burst, tail bits and dummy bits. For the normal burst the useful part lasts for 147 modulating bits

2.3 Differential encoding

Each data value $d_i = [0,1]$ is differentially encoded. The output of the differential encoder is:

$$\hat{d}_i = d_i \oplus d_{i-1} \qquad (d_i \in \{0,1\})$$

where ⊕ denotes modulo 2 addition.

The modulating data value α_i input to the modulator is:

$$\alpha_i = 1 - 2\hat{d}_i \qquad (\alpha_i \in \{-1,+1\})$$

2.4 Filtering

The modulating data values α_i as represented by Dirac pulses excite a linear filter with impulse response defined by:

$$g(t) = h(t) * rect\left(\frac{t}{T}\right)$$

where the function $rect(x)$ is defined by:

$$rect\left(\frac{t}{T}\right) = \frac{1}{T} \qquad for\ |t| < \frac{T}{2}$$

$$rect\left(\frac{t}{T}\right) = 0 \qquad otherwise$$

and * means convolution. *h(t)* is defined by:

$$h(t) = \frac{\exp\left(\frac{-t^2}{2\delta^2 T^2}\right)}{\sqrt{(2\pi)}\ .\ \delta T}$$

where $\delta = \frac{\sqrt{\ln(2)}}{2\pi BT} \qquad and\ \ BT = 0.3$

where B is the 3 dB bandwidth of the filter with impulse response *h(t)*. This theoretical filter is associated with tolerances defined in 3GPP TS 45.005.

2.5 Output phase

The phase of the modulated signal is:

$$\varphi(t') = \sum_i \alpha_i \pi h \int_{-\infty}^{t'-iT} g(u)du$$

where the modulating index h is 1/2 (maximum phase change in radians is π/2 per data interval).

The time reference $t' = 0$ is the start of the active part of the burst as shown in figure 1. This is also the start of the bit period of bit number 0 (the first tail bit) as defined in 3GPP TS 45.002.

2.6 Modulation

The modulated RF carrier, except for start and stop of the TDMA burst may therefore be expressed as:

$$x(t') = \sqrt{\frac{2E_c}{T}}\ .\ \ \cos(2\pi f_0 t' + \varphi(t') + \varphi_0)$$

where E_c is the energy per modulating bit, f_0 is the centre frequency and φ_0 is a random phase and is constant during one burst.

In case of EC operation when using blind physical layer transmissions (see 3GPP TS 43.064 [7]) the modulated RF carrier, except for start and stop of the burst may, for each blind physical layer transmission of a burst for which phase coherency is required (see 3GPP TS 45.005 [4]), be expressed as:

$$x(t') = \sqrt{\frac{2E_c}{T}}\ .\cos(2\pi f_0(t'+t_0) + \varphi(t') + \varphi_{157} + \varphi_0)$$

where

- t_0 is a burst-specific time offset, constant during one burst, and is defined as the time difference between time instant $t' = 0$ for the current burst and $t' = 0$ for the first transmission of the same burst in the current TDMA frame.

- φ_{157} is a phase shift of either 0 or πh, and is constant during one burst.

- φ_0 is a random phase and is constant during all blind physical layer transmissions of the same burst within the same TDMA frame.

For EC-GSM_IoT, only integer timeslot lengths are allowed (see 3GPP TS 45.010 [5]). If any blind physical layer transmission is transmitted in the uplink on timeslot 0 or timeslot 4, which are 157 symbols long, all following blind physical layer transmissions of the same burst in that TDMA frame shall be shifted in phase by πh, i.e. φ_{157} = πh, otherwise φ_{157} = 0. For the downlink this phase shift shall not be applied, i.e. φ_{157} = 0.

2.7 Overlaid CDMA

In the case of Overlaid CDMA the modulated RF carrier may be expressed with an additional term compared to subclause 2.6 representing the Overlaid CDMA code:

$$x(t') = \sqrt{\frac{2E_c}{T}} \, . \cos(2\pi f_0 (t'+t_0) + \varphi(t') + \varphi_{157} + \varphi_0 + OC \cdot \pi)$$

where *OC* equals 0 or 1 in accordance with the applied Overlaid CDMA code (see 3GPP TS 45.002 [3]) and is constant during one burst. For each blind physical layer transmission within a TDMA frame, *OC* equals its respective Overlaid CDMA code element. For example for Overlaid CDMA code 0,0,1,1, *OC* equals 0 for the first two blind physical layer transmissions and 1 for the last two blind physical layer transmissions within a TDMA frame.

3 Modulation format for 8PSK

3.1 Modulating symbol rate

The modulating symbol rate is the normal symbol rate which is defined as 1/T = 1 625/6 ksymb/s (i.e. approximately 270.833 ksymb/s), which corresponds to 3*1 625/6 kbit/s (i.e. 812.5 kbit/s). T is the normal symbol period (see 3GPP TS 45.010).

3.2 Symbol mapping

The modulating bits are Gray mapped in groups of three to 8PSK symbols by the rule

$$s_i = e^{j2\pi l/8}$$

where l is given by table 1.

Table 1: Mapping between modulating bits and the 8PSK symbol parameter *l*.

Modulating bits $d_{3i}, d_{3i+1}, d_{3i+2}$	Symbol parameter l
(1,1,1)	0
(0,1,1)	1
(0,1,0)	2
(0,0,0)	3
(0,0,1)	4
(1,0,1)	5
(1,0,0)	6
(1,1,0)	7

This is illustrated in figure 2.

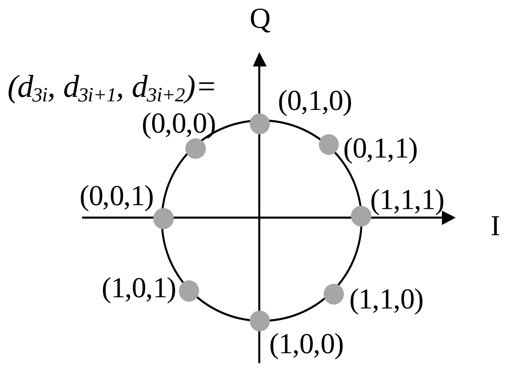

Figure 2: Symbol mapping of modulating bits into 8PSK symbols.

3.3 Start and stop of the burst

Before the first bit of the bursts as defined in 3GPP TS 45.002 enters the modulator, the state of the modulator is undefined. Also after the last bit of the burst, the state of the modulator is undefined. The tail bits (see 3GPP TS 45.002) define the start and the stop of the active and the useful part of the burst as illustrated in figure 3. Nothing is specified about the actual phase of the modulator output signal outside the useful part of the burst.

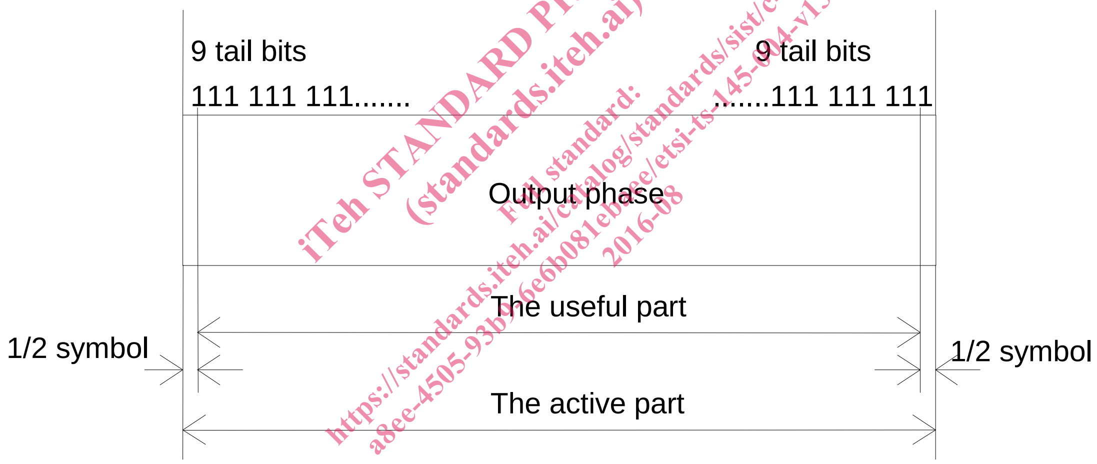

Figure 3: Relation between active part of burst and tail bits. For the normal burst the useful part lasts for 147 modulating symbols

3.4 Symbol rotation

The 8PSK symbols are continuously rotated with 3π/8 radians per symbol before pulse shaping. The rotated symbols are defined as

$$\hat{s}_i = s_i \cdot e^{ji3\pi/8}$$

3.5 Pulse shaping

The modulating 8PSK symbols $\hat{s}_i$ as represented by Dirac pulses excite a linear pulse shaping filter. This filter is a linearised GMSK pulse, i.e. the main component in a Laurant decomposition of the GMSK modulation. The impulse response is defined by: