ETSI TS 145 004 V13.0.0 (2016-01)

Digital cellular telecommunications system (Phase 2+); Modulation (3GPP TS 45.004 version 13.0.0 Release 13)

3GPP A GLOBAL INITIATIVE

GSM® GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS

Reference
RTS/TSGG-0145004vd00

Keywords
GSM

ETSI

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Contents

Foreword

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

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.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[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'.

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.

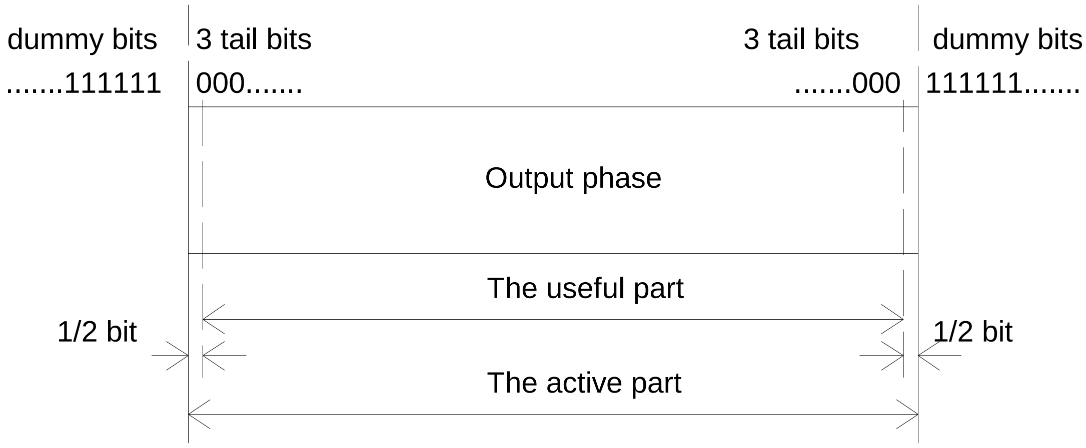

Figure 1: Relation between active part of burst, tail bits and dummy bits. For the normal burst the useful part lasts for 147 modulating bits

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 $\pi/2$ 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.

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.

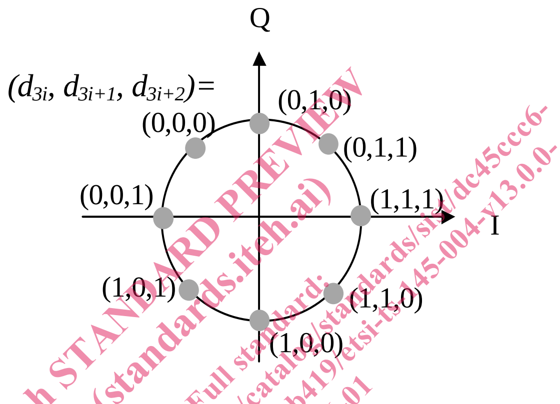

Figure 2: Symbol mapping of modulating bits into 8PSK symbols.

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.

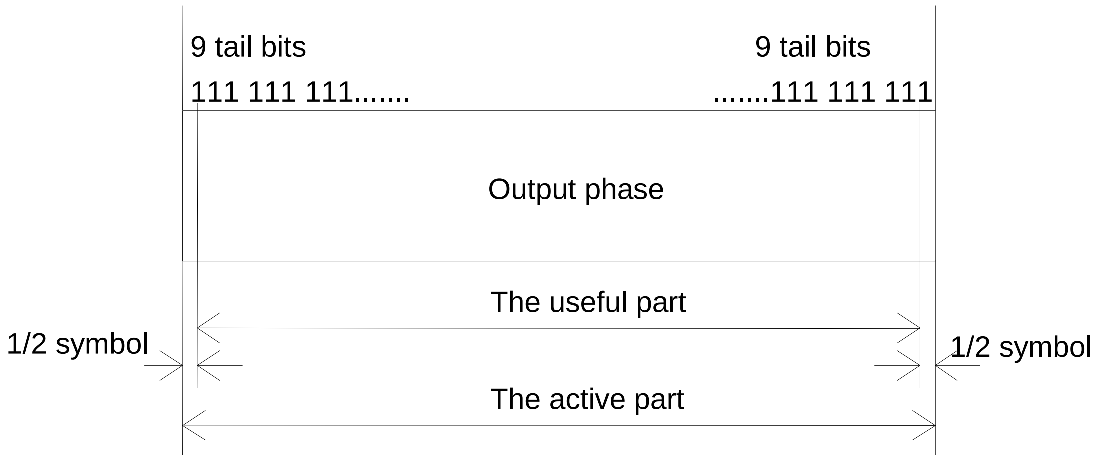

Figure 3: Relation between active part of burst and tail bits. For the normal burst the useful part lasts for 147 modulating symbols

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:

$$c_0(t) = \begin{cases} \prod_{i=0}^{3} S(t+iT), \; for \; 0 \le t \le 5T \\ 0, \; else \end{cases}$$

where

$$S(t) = \begin{cases} \sin\left(\pi \int_0^t g(t')dt'\right), \; for \; 0 \le t \le 4T \\ \sin\left(\frac{\pi}{2} - \pi \int_0^{t-4T} g(t')dt'\right), \; for \; 4T < t \le 8T \\ 0, \; else \end{cases}$$

$$g(t) = \frac{1}{2T}\left(Q\left(2\pi \cdot 0.3 \frac{t-5T/2}{T\sqrt{\log_e(2)}}\right) - Q\left(2\pi \cdot 0.3 \frac{t-3T/2}{T\sqrt{\log_e(2)}}\right) \right)$$

and

$$Q(t) = \frac{1}{\sqrt{2\pi}} \int_t^{\infty} e^{-\frac{\tau^2}{2}} d\tau .$$

The base band signal is

$$y(t') = \sum_i \hat{s}_i \cdot c_0(t' - iT + 2T)$$

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

3.6 Modulation

The modulated RF carrier during the useful part of the burst is therefore:

$$x(t') = \sqrt{\frac{2E_s}{T}} \operatorname{Re}\left[y(t') \cdot e^{j(2\pi f_0 t' + \varphi_0)} \right]$$

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