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*Technical Specification*

## Digital cellular telecommunications system (Phase 2+); Modulation (3GPP TS 05.04 version 7.2.0 Release 1998)

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**Reference**

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# Foreword

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## 0 Scope

The modulator receives the bits from the encryption unit, see GSM 05.01 [1], 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 GSM 05.05 [4].

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## 1a 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] GSM 01.04: "Digital cellular telecommunication system (Phase 2+); Abbreviations and acronyms".
- [2] GSM 05.01: "Digital cellular telecommunication system (Phase 2+); Physical layer on the radio path General description".
- [3] GSM 05.02: "Digital cellular telecommunication system (Phase 2+); Multiplexing and multiple access on the radio path".
- [4] GSM 05.05: "Digital cellular telecommunication system (Phase 2+); Radio transmission and reception".

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## 1b Abbreviations

Abbreviations used in the present document are listed in GSM 01.04 [1].

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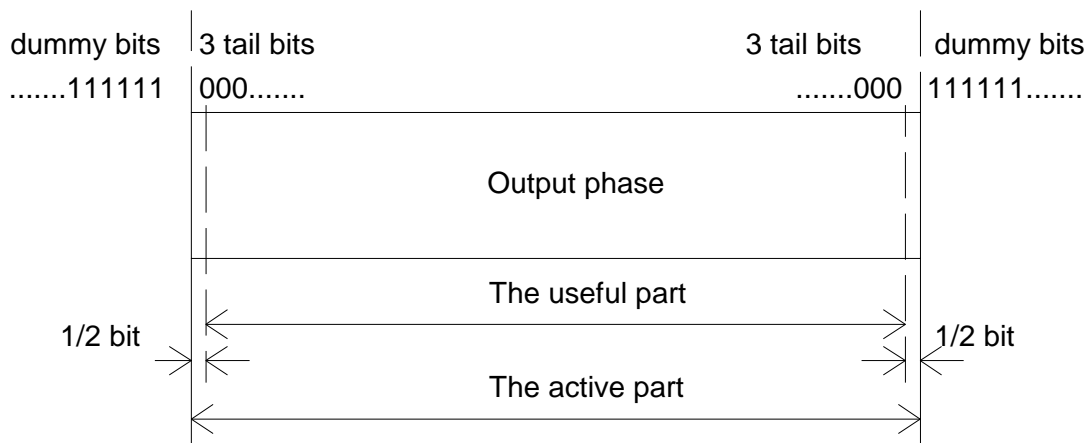
## 2 Modulation format

### 2.1 Modulating bit rate

The modulating bit rate is  $1/T = 1\ 625/6$  kbit/s (i.e. approximately 270,833 kbit/s).

### 2.2 Start and stop of the burst

Before the first bit of the bursts as defined in GSM 05.02 [3] 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:

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

where  $\oplus$  denotes modulo 2 addition.

The modulating data value  $\alpha_i$  input to the modulator is:

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

### 2.4 Filtering

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

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

where the function  $\text{rect}(x)$  is defined by:

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

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

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

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

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

where  $B$  is the 3 dB bandwidth of the filter with impulse response  $h(t)$ , and  $T$  is the duration of one input data bit. This theoretical filter is associated with tolerances defined in GSM 05.05 [4].

## 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 GSM 05.02 [2].

## 2.6 Modulation

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

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

where  $E_c$  is the energy per modulating bit,  $f_0$  is the centre frequency and  $\varphi_0$  is a random phase and is constant during one burst.

# 3 Modulation format for 8PSK

8-PSK modulation is specified here for reference purposes only. 8-PSK modulation is not used in networks supporting Release 98. The modulation is anyway specified here to make sure that Release 98 mobiles supporting E-OTD LCS will be able to do measurements on 8-PSK modulated bursts.

## 3.1 Modulating symbol rate

The modulating symbol rate is  $1/T = 1\ 625/6$  ksymb/s (i.e. approximately 270.833 ksymb/s), which corresponds to  $3 \cdot 1\ 625/6$  kbit/s (i.e. 812.5 kbit/s).  $T$  is the symbol period.

## 3.2 Symbol mapping

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

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

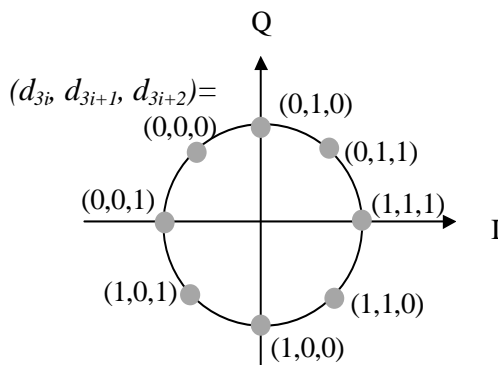
where  $l$  is given by table 1.



**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

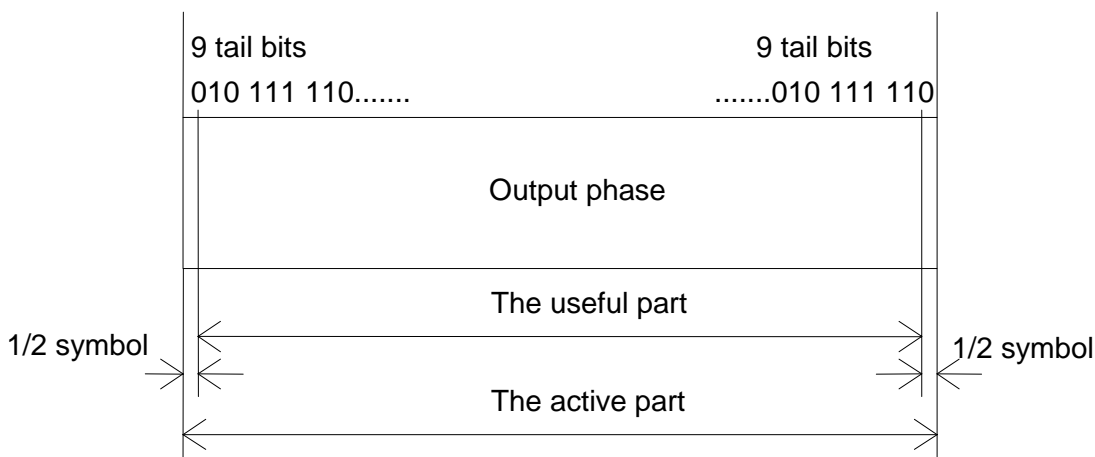
This is illustrated in figure 2.



**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 GSM 05.02 [3] 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 GSM 05.02) 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  $3\pi/8$  radians per symbol before pulse shaping. The rotated symbols are defined as

$$\hat{s}_i = s_i \cdot e^{j3\pi/8}$$

### 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 linearized GMSK pulse, i.e. the main component in a Laurant decomposition of the GMSK modulation. The impulse response is defined by:

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

where

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

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

and

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

The base band signal is

$$y(t') = \sum_i \hat{s}_i \cdot c_0(t'-iT + \frac{5}{2}T)$$

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 bit period of bit number 0 (the first tail bit) as defined in GSM 05.02 [3].

### 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  $\varphi_0$  is a random phase and is constant during one burst.

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## Annex A (informative): Change control history

SMG	SPEC	VERS	NEW_VE	PH	SUBJECT
S27	05.04	5.0.1	6.0.0	R97	conversion to Release 97 EN
		6.0.0	6.0.1		Version update for publication
		6.0.1	7.0.0	R98	Upgrade to Release 1998
S30b		7.0.0	7.1.0	R98	Correction of mistake for range alpha-sub-i in Clause 2.3
S30b		7.0.0	7.1.0	R98	Specification of 8-PSK modulation for LCS compatibility
		7.1.0	7.1.1	R98	Upgrade to version 7.1.1 for publication
G03	05.04	7.1.1	7.2.0	R98	Correction of symbol period notation

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## History

<b>Document history</b>				
V7.0.0	August 1999	One-step Approval Procedure	OAP 9956:	1999-08-25 to 1999-12-24
V7.0.1	January 2000	Publication as EN 300 959		
V7.1.0	January 2000	One-step Approval Procedure	OAP 200019:	2000-01-12 to 2000-05-12
V7.1.1	June 2000	Publication as EN 300 959		
V7.2.0	January 2001	Publication		