ETSI EN 300 959 V7.1.1 (2000-06)

European Standard (Telecommunications series)

Digital cellular telecommunications system (Phase 2+);
Modulation
(GSM 05.04 version 7.1.1 Release 1998)
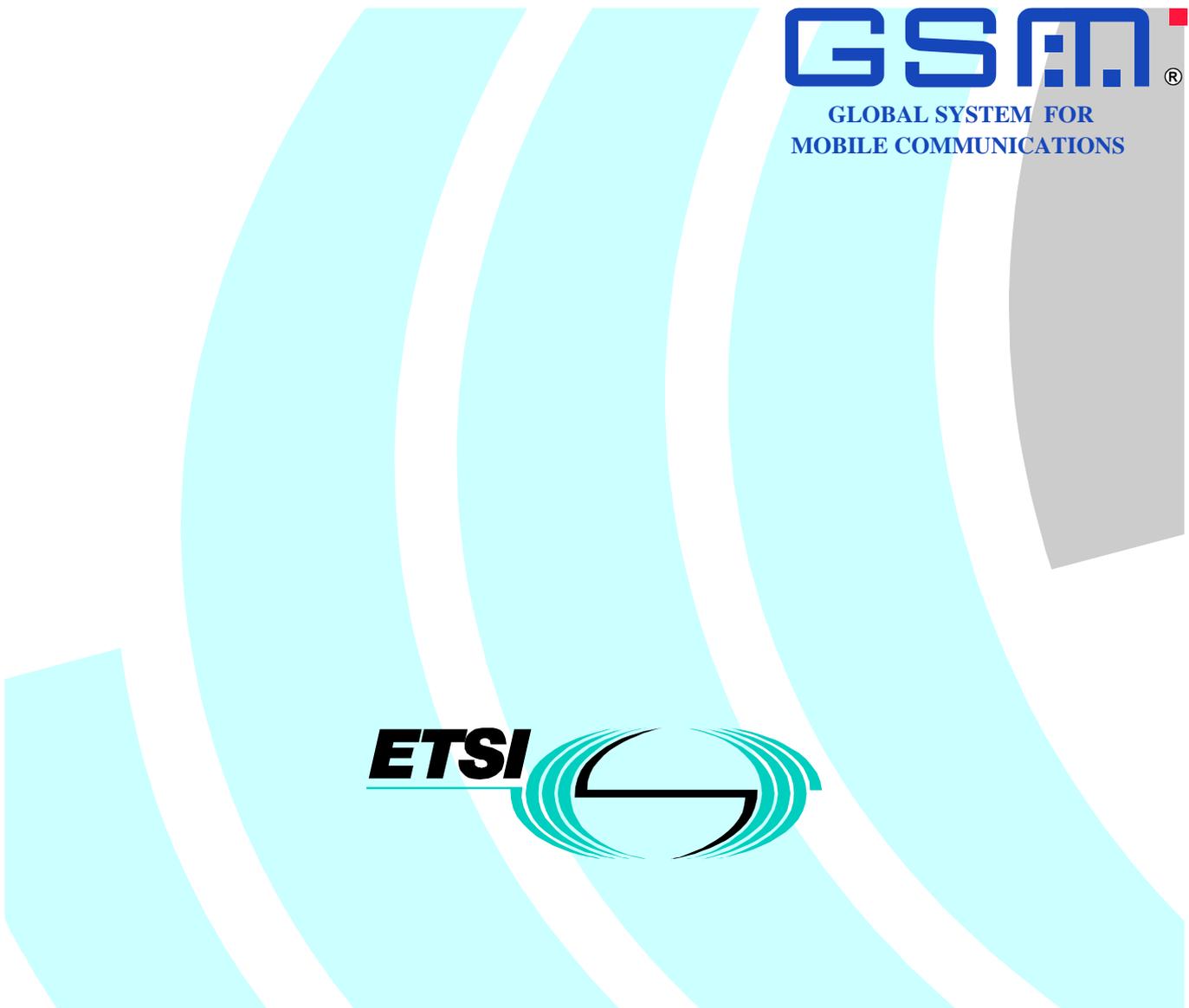
GLOBAL SYSTEM FOR
MOBILE COMMUNICATIONS

ETSI
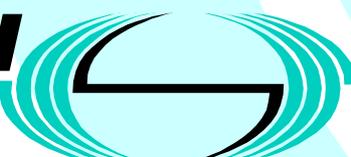
Reference

REN/SMG-020504Q7R1

Keywords

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

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Foreword

This European Standard (Telecommunications series) has been produced by the Special Mobile Group (SMG).

The present document specifies the modulation format used within the digital cellular telecommunications system.

The contents of the present document may be subject to continuing work within SMG and may change following formal SMG approval. Should SMG modify the contents of the present document it will then be re-submitted for formal approval procedures by ETSI with an identifying change of release date and an increase in version number as follows:

    Version 7.x.y

    where:

        7   indicates release 1998 of GSM Phase 2+.

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

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

National transposition dates	
Date of adoption of this EN:	12 May 2000
Date of latest announcement of this EN (doa):	31 August 2000
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	28 February 2001
Date of withdrawal of any conflicting National Standard (dow):	28 February 2001

1 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].

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.

- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

- For this Release 1998 document, references to GSM documents are for Release 1998 versions (version 7.x.y).

[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".

1.2 Abbreviations

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

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.

dummy bits	3 tail bits		3 tail bits	dummy bits
.......111111	000.......		000	111111.......

Output phase

The useful part

1/2 bit

The active part

1/2 bit
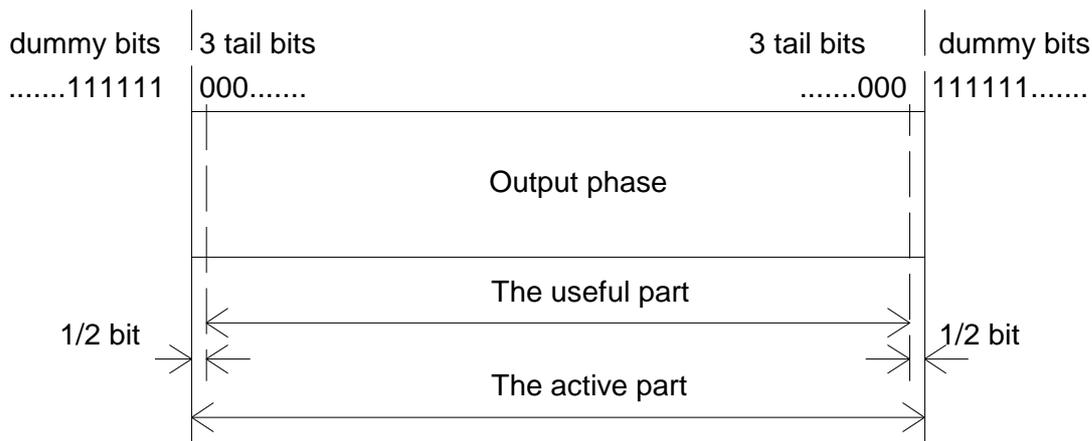
**Figure 1: Relation between active part of burst, tail bits and dummy bits.
For the normal burst the useful part lasts for 147 modulating bits**

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 $\oplus$ 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 $h(t)$, 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:

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

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

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*1 625/6 kbit/s (i.e. 812.5 kbit/s),

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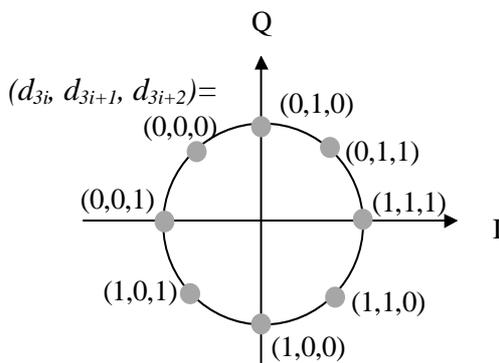
Figure 2: Symbol mapping of modulating bits into 8PSK symbols

3.3   Start and stop of the burst

Before the first bit of the bursts as defined in 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.
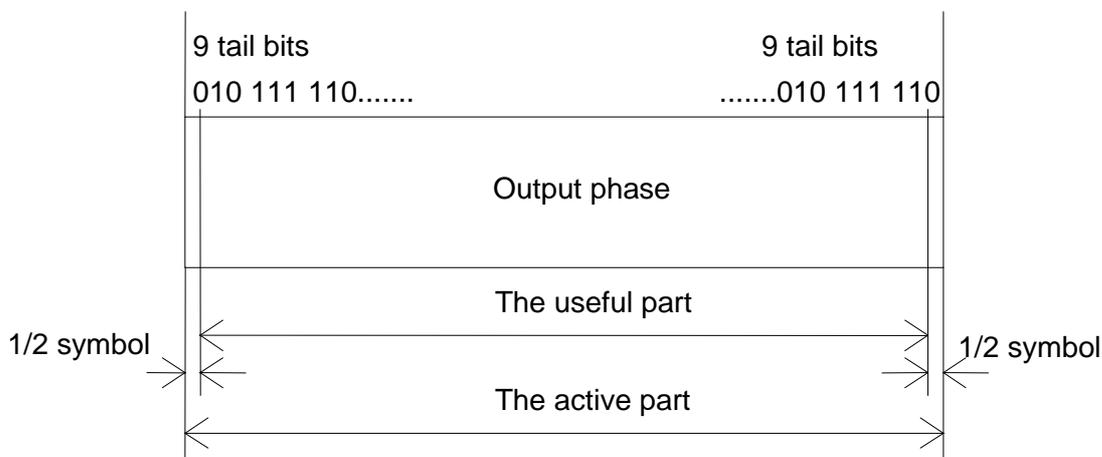
Figure 3: Relation between active part of burst and tail bits.
For the normal burst the useful part lasts for 147 modulating symbols

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

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

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

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

where

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

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

and

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

T is the symbol period.

The base band signal is

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

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 φ_0 is a random phase and is constant during one burst.

Annex A (informative):
Change control history

SMG	SPEC	VERS	NEW_VE	PHA	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		Upgrade to Release 1998
S30b		7.0.0	7.1.0		Correction of mistake for range alpha-sub-i in Clause 2.3
S30b		7.0.0	7.1.0		Specification of 8-PSK modulation for LCS compatibility
		7.1.0	7.1.1		Upgrade to version 7.1.1 for publication

History

Document history			
V7.0.0	August 1999	One-step Approval Procedure	OAP 9956: 1999-08-25 to 1999-12-24
V7.0.1	January 2000	Publication	
V7.1.0	January 2000	One-step Approval Procedure	OAP 200019: 2000-01-12 to 2000-05-12
V7.1.1	June 2000	Publication	