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Technical Specification

**GEO-Mobile Radio Interface Specifications (Release 3);**
**Third Generation Satellite Packet Radio Service;**
**Part 5: Radio interface physical layer specifications;**
**Sub-part 4: Modulation;**
**GMR-1 3G 45.004**

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# Foreword

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where:

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- the second digit (m) is incremented for all other types of changes, i.e. technical enhancements, corrections, updates, etc.

The present document is part 5, sub-part 4 of a multi-part deliverable covering the GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service, as identified below:

Part 1: "General specifications":

Part 2: "Service specifications";

Part 3: "Network specifications";

Part 4: "Radio interface protocol specifications";

**Part 5: "Radio interface physical layer specifications";**

Sub-part 1: "Physical Layer on the Radio Path: General Description; GMR-1 3G 45.001";

Sub-part 2: "Multiplexing and Multiple Access; Stage 2 Service Description; GMR-1 3G 45.002";

Sub-part 3: "Channel Coding; GMR-1 3G 45.003";

**Sub-part 4: "Modulation; GMR-1 3G 45.004";**

Sub-part 5: "Radio Transmission and Reception; GMR-1 3G 45.005";

Sub-part 6: "Radio Subsystem Link Control; GMR-1 3G 45.008";

Sub-part 7: "Radio Subsystem Synchronization; GMR-1 3G 45.010";

Part 6: "Speech coding specifications";

Part 7: "Terminal adaptor specifications".

# Introduction

GMR stands for GEO (Geostationary Earth Orbit) Mobile Radio interface, which is used for Mobile Satellite Services (MSS) utilizing geostationary satellite(s). GMR is derived from the terrestrial digital cellular standard GSM and supports access to GSM core networks.

The present document is part of the GMR Release 3 specifications. Release 3 specifications are identified in the title and can also be identified by the version number:

- Release 1 specifications have a GMR 1 prefix in the title and a version number starting with "1" (V1.x.x).
- Release 2 specifications have a GMPRS 1 prefix in the title and a version number starting with "2" (V2.x.x).
- Release 3 specifications have a GMR-1 3G prefix in the title and a version number starting with "3" (V3.x.x).

The GMR release 1 specifications introduce the GEO Mobile Radio interface specifications for circuit mode Mobile Satellite Services (MSS) utilizing geostationary satellite(s). GMR release 1 is derived from the terrestrial digital cellular standard GSM (phase 2) and it supports access to GSM core networks.

The GMR release 2 specifications add packet mode services to GMR release 1. The GMR release 2 specifications introduce the GEO Mobile Packet Radio Service (GMPRS). GMPRS is derived from the terrestrial digital cellular standard GPRS (included in GSM Phase 2+) and it supports access to GSM/GPRS core networks.

The GMR release 3 specifications evolve packet mode services of GMR release 2 to 3rd generation UMTS compatible services. The GMR release 3 specifications introduce the GEO-Mobile Radio Third Generation (GMR-1 3G) packet radio service. Where applicable, GMR-3G is derived from the terrestrial digital cellular standard 3GPP and it supports access to 3GPP core networks.

Due to the differences between terrestrial and satellite channels, some modifications to the GSM or 3GPP standard are necessary. Some GSM and 3GPP specifications are directly applicable, whereas others are applicable with modifications. Similarly, some GSM and 3GPP specifications do not apply, while some GMR specifications have no corresponding GSM or 3GPP specification.

Since GMR is derived from GSM and 3GPP, the organization of the GMR specifications closely follows that of GSM or 3GPP as appropriate. The GMR numbers have been designed to correspond to the GSM and 3GPP numbering system. All GMR specifications are allocated a unique GMR number. This GMR number has a different prefix for Release 2 and Release 3 specifications as follows:

- Release 1: GMR n xx.zyy.
- Release 2: GMPRS n xx.zyy.
- Release 3: GMR-1 3G xx.zyy.

where:

- xx.0yy (z = 0) is used for GMR specifications that have a corresponding GSM or 3GPP specification. In this case, the numbers xx and yy correspond to the GSM or 3GPP numbering scheme.
- xx.2yy (z = 2) is used for GMR specifications that do not correspond to a GSM or 3GPP specification. In this case, only the number xx corresponds to the GSM or 3GPP numbering scheme and the number yy is allocated by GMR.
- n denotes the first (n = 1) or second (n = 2) family of GMR specifications.

A GMR system is defined by the combination of a family of GMR specifications and GSM and 3GPP specifications as follows:

- If a GMR specification exists it takes precedence over the corresponding GSM or 3GPP specification (if any). This precedence rule applies to any references in the corresponding GSM or 3GPP specifications.

NOTE: Any references to GSM or 3GPP specifications within the GMR specifications are not subject to this precedence rule. For example, a GMR specification may contain specific references to the corresponding GSM or 3GPP specification.

- If a GMR specification does not exist, the corresponding GSM or 3GPP specification may or may not apply. The applicability of the GSM or 3GPP specifications is defined in TS 101 376-1-2 [2].

# 1 Scope

The present document defines the modulation used within the GMR-1 Mobile Satellite System. It includes the various modulation formats that are required for different physical channel types. It also defines the concept of the transmission burst and the mapping of modulated symbols to the burst, describes the required transmit filtering in general terms, and specifies the modulation accuracy.

# 2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

## 2.1 Normative references

The following referenced documents are necessary for the application of the present document.

*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 Release 7 or to the latest version of that document in the latest release less than 7.*

*In the case of a reference to a GMR-1 3G document, a non-specific reference implicitly refers to the latest version of that document in the same Release as the present document.*

[1] ETSI TS 101 376-1-1: "GEO-Mobile Radio Interface Specifications (Release 2) General Packet Radio Service; Part 1: General specifications; Sub-part 1: Abbreviations and acronyms; GMPRS-1 01.004".

NOTE: This is a reference to a GMR-1 Release 2 specification. See the introduction for more details.

[2] ETSI TS 101 376-1-2: "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 1: General specifications; Sub-part 2: Introduction to the GMR-1 family; GMR-1 3G 41.201".

[3] ETSI TS 101 376-5-2: "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 5: Radio interface physical layer specifications; Sub-part 2: Multiplexing and Multiple Access; Stage 2 Service Description; GMR-1 3G 45.002".

[4] ETSI TS 101 376-5-4: "GEO-Mobile Radio Interface Specifications (Release 1); Part 5: Radio interface physical layer specifications; Sub-part 4: Modulation; GMR-1 05.004".

NOTE: This is a reference to a GMR-1 Release 1 specification. See the introduction for more details.

## 2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

Not applicable.

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TS 101 376-1-2 [2] apply.

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TS 101 376-1-1 [1] apply.

# 4 Burst structure

## 4.1 Signal representation

Same as clause 4.1 in TS 101 376-5-4 [4].

## 4.2 Modulating symbol rate

Same as clause 4.2 in TS 101 376-5-4 [4].

## 4.3 Start and stop of the burst

Same as clause 4.3 in TS 101 376-5-4 [4].

## 4.4 Data bits and data symbols

Same as clause 4.4 in TS 101 376-5-4 [4].

## 4.5 Packet burst structure

### 4.5.1 Modulating symbol rate

Packet Normal Bursts (PNBs) are modulated at a symbol rate of $23,4 \times m$ ksps, where $m$ is an integer $m = 1, 2, 4$ or 5. The symbol period time for PNB($m$,$n$), PNB2(m,n), and PNB3(m,n), where $m$ is the bandwidth factor and $n$ is the duration of the burst in timeslots, is defined as $1/(23,4 \times m)$ seconds, where {$m$ = 4 or 5; and $n$ = 3} or {$m$ = 1 or 2; and $n$ = 6} or {$m$ = 5; and $n$ = 12} or {$m$ = 10; and $n$ = 3}.

Packet Access Burst (PAB) and PAB3 are modulated at a symbol rate of 23,4 ksps.

## 4.5.2 Start and stop of the burst

For packet normal bursts, the time interval [0, 39*nT*] is the burst time window, where *n* = 3, *n* = 6, *n* = 8, and *n* = 12 for the burst types defined in TS 101 376-5-2 [3] and T is as defined in clause 4.2. The time window of the active part of different burst types is listed in table 4.1. The content of the active part of the burst corresponds to data symbols, i.e. reference and free symbols. The remaining time corresponds to the guard intervals (see TS 101 376-5-2 [3]). These guard intervals correspond to the transition from no signal to a continuous carrier and vice versa.

**Table 4.1: Useful Duration For Different Packet Normal Burst Types**

| Burst | Direction | Active Part of Burst |
|---|---|---|
| PNB(1,6) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB(2,6) | D | [2,5T/*m*, 39*n*T-2,5T/*m*] |
| PNB(4,3) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB(5,3) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB2(5,3) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB2(5,12) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB3(1,3) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB3(1,6) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB3(1,8) | U/D | [2,5*T*, 39*nT*-2,5*T*] |
| PNB3(2,6) | U | [2,5*T*, 39*nT*-2,5*T*] |
| PNB3(2,6) | D | [2,5T/*m*, 39*n*T-2,5T/*m*] |
| PNB3(5,3) | U | [2,5*T*, 39*nT*-2,5*T*] |
| PNB3(5,3) | D | [2,5T/*m*, 39*n*T-2,5T/*m*] |
| PNB3(5,12) | U | [2,5*T*, 39*nT*-2,5*T*] |
| PNB3(5,12) | D | [2,5T/*m*, 39*n*T-2,5T/*m*] |
| PNB3(10,3) | D | [2,5T/*m*, 39*n*T-2,5T/*m*] |

## 4.5.3 Data bits and data symbols

### 4.5.3.1 QPSK modulation

For π/4-CQPSK (Coherent Quadrature Phase-Shift Keying) modulated packet normal bursts, there are 78*mn* binary data bits defined in {0,1} in each burst, including header and payload (as defined in TS 101 376-5-2 [3]). For π/4-CQPSK, the burst bits are represented by $[b_0\ b_1\ b_2\ b_3 \ldots b_{78mn-2}\ b_{78mn-1}]$, where $b_0$ to $b_{5m-1}$ and $b_{78mn-5m}$ to $b_{78mn-1}$ are guard bits for *m* = 1, 4, and 5, and where $b_0$ to $b_4$ and $b_{78mn-5}$ to $b_{78mn-1}$ are guard bits for *m* = 2. When modulating these bits, we want to avoid grouping one guard bit with one information bit. Thus, for π/4-CQPSK with *m* = 1, 2, and 5, the mapping rule from data bits to data symbols shall be:

$$d_k = (b_{2k-1} b_{2k}), \quad k = 0,1,...,39mn$$

which results in 39*mn* + 1 different symbols being transmitted during 39*nT* (39*mn* symbol duration). However, the signals contained in the first and the last half-symbol duration are not actually transmitted according to the burst window definition in clause 4.5.2. To generate the first and the last symbols, one needs to use two dummy bits, which are represented by $b_{-1}$ and $b_{78mn}$. The dummy bits can be either of the two binary values {0,1}.

For π/4-CQPSK with *m* = 4, the mapping rule from data bits to data symbols shall be:

$$d_k = (b_{2k} b_{2k+1}), \quad k = 0,\ 1,...,39mn\text{-}1$$

which results in 39*mn* different symbols being transmitted during 39*nT* (39*mn* symbol duration) as shown in figure 4.1.

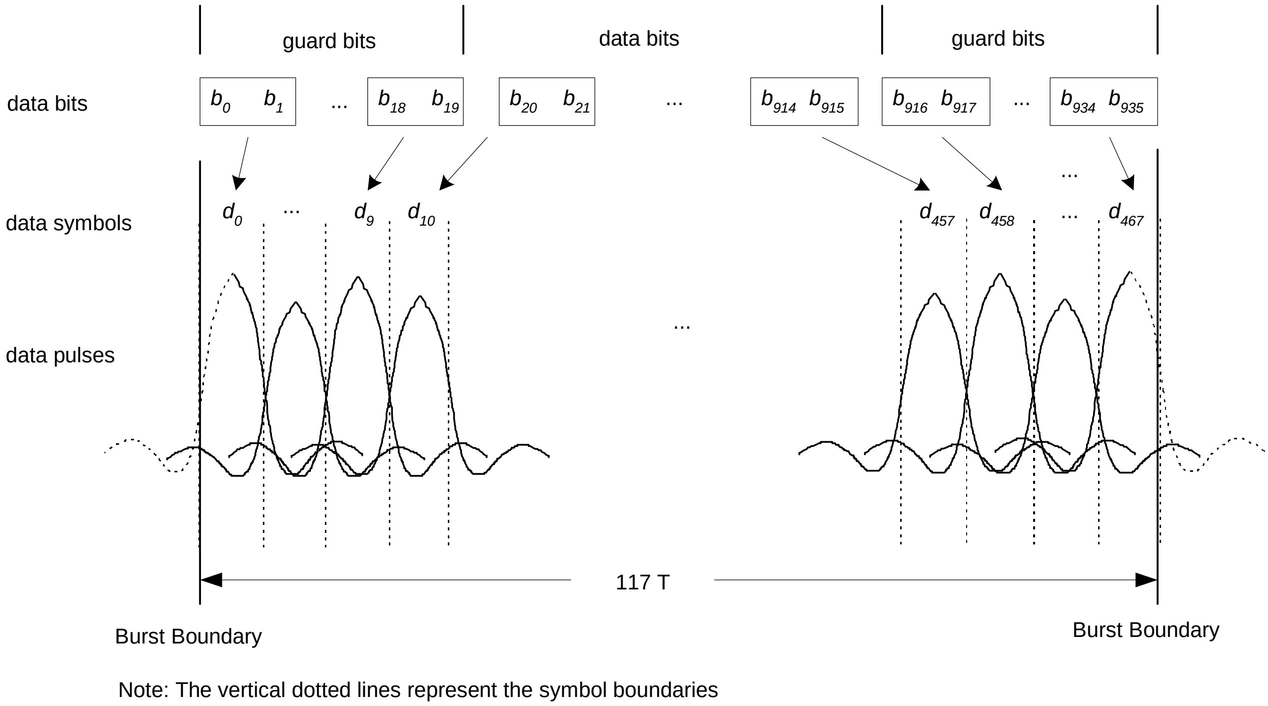


**Figure 4.1: Relationship of data bits, data symbols, burst timing, and symbol timing for PNB(4,3)**

For Packet Access Burst (PAB), there are 234 binary data bits defined {0,1} in each burst.

Finally, the mapping of $\{d_k\}$ to the constellation points is defined in clause 5.3.

### 4.5.3.2 BPSK modulation

For π/2-CBPSK (Coherent Binary Phase-Shift Keying) modulated packet normal bursts, there are 39*mn* binary data bits defined in {0,1} in each burst. The burst bits are represented by $[b_0\ b_1\ b_2\ b_3\ \dots\ b_{38mn-2}\ b_{39mn-1}]$, where $b_0$ to $b_{3m-1}$ and $b_{39mn-2}$ to $b_{39mn-1}$ are guard bits (total 5*m* guard bits). For π/2-CBPSK, the mapping rule from data bits to data symbols shall be:

$$d_k = b_k, \quad k = 0,1,\dots,39mn$$

where $b_{39mn}$ is considered to be a dummy bit. Figure 4.2 clearly illustrates the relationship of data bits, dummy bits, data symbols, burst boundary, and symbol boundary for a π/2-CBPSK modulated burst.

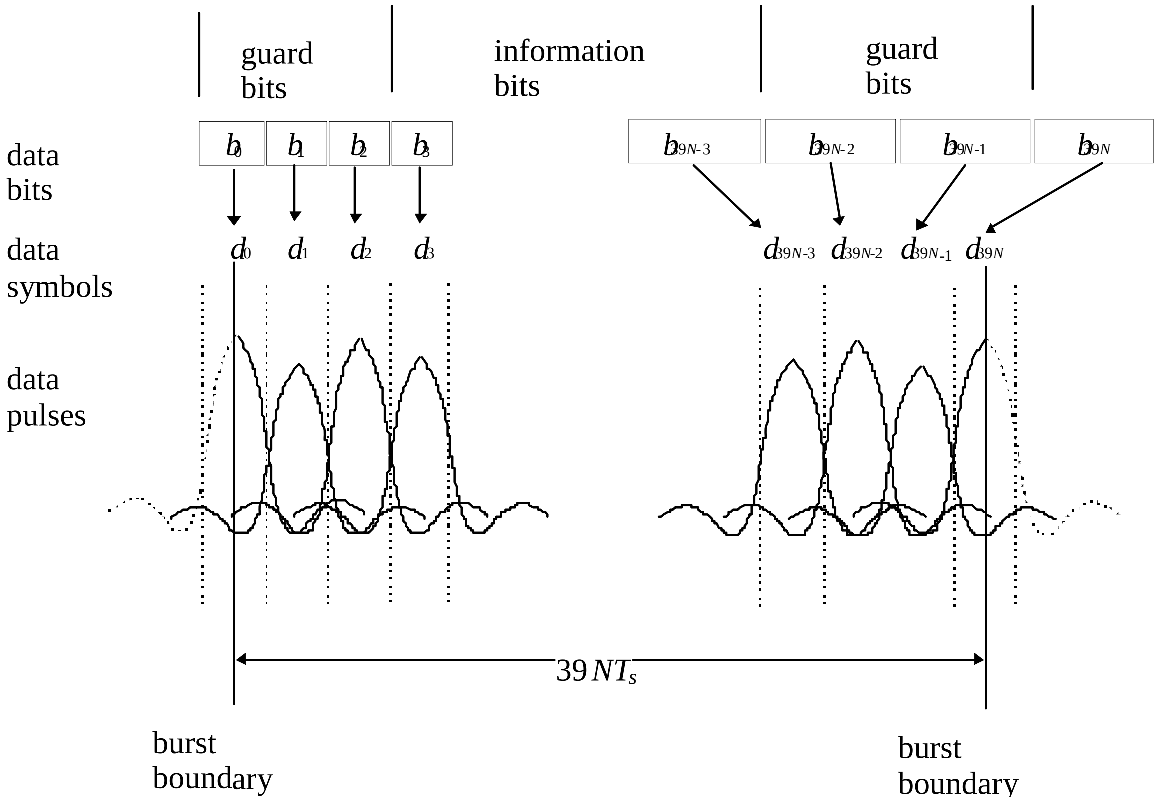


**Figure 4.2: Relationship of data bits, data symbols, burst timing, and symbol timing for BPSK (the vertical dotted lines represent the symbol boundaries)**

# 5 Normal burst

Same as clause 5 in TS 101 376-5-4 [4].

## 5.1 π/4-CQPSK modulation

Same as clause 5.1 in TS 101 376-5-4 [4].

### 5.1.1 Filtering

Same as clause 5.1.1 of TS 101 376-5-4 [4].

### 5.1.2 Power ramp

Same as clause 5.1.2 of TS 101 376-5-4 [4].

## 5.2 π/4-CBPSK modulation

Same as clause 5.2 of TS 101 376-5-4 [4].

# 5.2a π/2-CBPSK modulation

The complex envelope of the π/2-CBPSK (coherent binary phase-shift keying) modulated signal in a burst is expressed as:

$$x(t) = \left\{ \sum_{k=0}^{N-1} \alpha_k \cdot e^{jk\frac{\pi}{2}} \cdot h\left(t - kT_s\right) \right\}$$

where $N$ is the number of symbols in a burst, $h(t)$ is the square root raised cosine pulse-shaping filter, $T_s$ is the symbol period and $\alpha_k \in \{\exp(j \cdot \pi \cdot l); l = 0,1\}$ is the BPSK symbol.

# 5.3 PNB modulation

PNBs are modulated by π/2-CBPSK, π/4-CQPSK, 16-APSK or 32-APSK. The complex envelope of the transmitted signal is defined as follows:

$$x(t) = p(t)\left[ e^{j\varphi_o} \sum_{k=-\infty}^{\infty} \alpha_k h(t - kT) \right]$$

where $\varphi_o$ is a random phase, $h(t)$ is the impulse response of a shaping filter defined in clause 5.1.1, $p(t)$ is the ramp function as defined in clause 5.1.2, and $\{\alpha_k\}$ is the modulating symbol, defined as follows:

$$\begin{cases} \mathrm{k} < 0: & \alpha_\mathrm{k} = 0 \\ 0 \le \mathrm{k} \le 39\mathrm{mn}: & \text{see tables 5.1} \\ \mathrm{k} > 39\mathrm{mn}: & \alpha_\mathrm{k} = 0 \end{cases} \text{ for different modulation schemes}$$

where {*m* = 4 or 5; and *n* = 3} and {*m* = 1 or 2; and *n* = 6}, or {*m* = 5; and *n* = 12} depending on the type of the burst. For PNB(5,12), the PRI can be modulated either in π/4-CQPSK, 16 APSK, and 32 APSK. The modulating symbols for π/4-CQPSK are derived from the data symbols (free and reference symbols) according to table 5.1a.

**Table 5.1a: π/4-CQPSK bits-to-symbols mapping**

| $a_{k-1}$ | $a_k$ | Modulating symbols |
|---|---|---|
| 0 | 0 | (1 + j0) exp(jkπ/4) |
| 0 | 1 | (0 + j1) exp(jkπ/4) |
| 1 | 1 | (-1 + j0) exp(jkπ/4) |
| 1 | 0 | (0 - j1) exp(jkπ/4) |

**Table 5.1b: QPSK bits-to-symbols mapping**

| $a_{k-1}$ | $a_k$ | Modulating symbols |
|---|---|---|
| 0 | 0 | (1 + j0) |
| 0 | 1 | (0 + j1) |
| 1 | 1 | (-1 + j0) |
| 1 | 0 | (0 - j1) |

The constellation points for APSK modulation can be written as:

$$\begin{cases} r_1 \exp\left\{ j\left(\frac{2\pi}{n_1}k+\theta_1\right)\right\} \text{ for } k = 0,\ 1,\ ...,n_1\text{-}1 \\ r_2 \exp\left\{ j\left(\frac{2\pi}{n_2}k+\theta_2\right)\right\} \text{ for } k = 0,\ 1,\ ...,n_2\text{-}1 \\ ... \\ r_N \exp\left\{ j\left(\frac{2\pi}{n_N}k+\theta_N\right)\right\} \text{for } k = 0,\ 1,\ ...,n_N\text{-}1 \end{cases}$$

The parameters for 16-APSK and 32-APSK are listed in table 5.1c.

**Table 5.1c: 16 APSK and 32 APSK constellation parameters**

| | $n_1$ | $n_2$ | $n_3$ | $r_1$ | $r_2 / r_1$ | $r_3 / r_1$ | $\theta_1$ | $\theta_2$ | $\theta_3$ |
|---|---|---|---|---|---|---|---|---|---|
| 16 APSK | 4 | 12 | N/A | 0,4182 | 2,7 | N/A | $\pi/4$ | $\pi/12$ | N/A |
| 32 APSK | 4 | 12 | 16 | 0,2637 | 2,7 | 4,8 | $\pi/4$ | $\pi/12$ | $\pi/8$ |

The mapping of π/4-CQPSK modulating symbols to data bits is defined in table 5.1a. The mapping of QPSK modulating symbols to data bits is defined in table 5.1b. The mapping of the 16 APSK modulating symbols to data bits is defined in table 5.1d. The mapping of the 32 APSK modulating symbols to data bits is defined in table 5.1e. The mapping of π/2-CBPSK modulating symbols to data bits is defined in table 5.1f.

**Table 5.1d: 16 APSK bits-to-symbols mapping (r1 = 0,4182 and r2 =1,1292)**

| $a_{k-3}$ | $a_{k-2}$ | $a_{k-1}$ | $a_k$ | Modulating symbols |
|---|---|---|---|---|
| 1 | 1 | 0 | 0 | $r_1 \cdot \exp\left\{ j(\frac{2\pi}{4}\cdot 0+\frac{\pi}{4})\right\}$ |
| 1 | 1 | 1 | 0 | $r_1 \cdot \exp\left\{ j(\frac{2\pi}{4}\cdot 1+\frac{\pi}{4})\right\}$ |
| 1 | 1 | 1 | 1 | $r_1 \cdot \exp\left\{ j(\frac{2\pi}{4}\cdot 2+\frac{\pi}{4})\right\}$ |
| 1 | 1 | 0 | 1 | $r_1 \cdot \exp\left\{ j(\frac{2\pi}{4}\cdot 3+\frac{\pi}{4})\right\}$ |
| 0 | 1 | 0 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12}\cdot 0+\frac{\pi}{12})\right\}$ |
| 0 | 0 | 0 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12}\cdot 1+\frac{\pi}{12})\right\}$ |
| 1 | 0 | 0 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12}\cdot 2+\frac{\pi}{12})\right\}$ |
| 1 | 0 | 1 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12}\cdot 3+\frac{\pi}{12})\right\}$ |
| 0 | 0 | 1 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12}\cdot 4+\frac{\pi}{12})\right\}$ |

| $a_{k-3}$ | $a_{k-2}$ | $a_{k-1}$ | $a_k$ | Modulating symbols |
|---|---|---|---|---|
| 0 | 1 | 1 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 5 + \frac{\pi}{12}) \right\}$ |
| 0 | 1 | 1 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 6 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 1 | 1 | $r_2 \cdot \exp\left\{ (j\frac{2\pi}{12} \cdot 7 + \frac{\pi}{12}) \right\}$ |
| 1 | 0 | 1 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 8 + \frac{\pi}{12}) \right\}$ |
| 1 | 0 | 0 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 9 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 0 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 10 + \frac{\pi}{12}) \right\}$ |
| 0 | 1 | 0 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 11 + \frac{\pi}{12}) \right\}$ |

**Table 5.1e: 32 APSK bits-to-symbols mapping (r1 =0,2637, r2 =0,7120 and r3= 1,2658)**

| $a_{k-4}$ | $a_{k-3}$ | $a_{k-2}$ | $a_{k-1}$ | $a_k$ | Modulating symbols |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1 | $r_1 \cdot \exp\left\{ j(\frac{2\pi}{4} \cdot 0 + \frac{\pi}{4}) \right\}$ |
| 1 | 0 | 1 | 0 | 1 | $r_1 \cdot \exp\left\{ j(\frac{2\pi}{4} \cdot 1 + \frac{\pi}{4}) \right\}$ |
| 1 | 0 | 1 | 1 | 1 | $r_1 \cdot \exp\left\{ (j\frac{2\pi}{4} \cdot 2 + \frac{\pi}{4}) \right\}$ |
| 1 | 0 | 0 | 1 | 1 | $r_1 \cdot \exp\left\{ j(\frac{2\pi}{4} \cdot 3 + \frac{\pi}{4}) \right\}$ |
| 1 | 0 | 0 | 0 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 0 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 0 | 0 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 1 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 0 | 0 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 2 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 1 | 0 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 3 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 1 | 0 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 4 + \frac{\pi}{12}) \right\}$ |

| $a_{k-4}$ | $a_{k-3}$ | $a_{k-2}$ | $a_{k-1}$ | $a_k$ | Modulating symbols |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 5 + \frac{\pi}{12}) \right\}$ |
| 1 | 0 | 1 | 1 | 0 | $r_2 \cdot \exp j\left\{ (\frac{2\pi}{12} \cdot 6 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 1 | 1 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 7 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 1 | 1 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 8 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 0 | 1 | 1 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 9 + \frac{\pi}{12}) \right\}$ |
| 0 | 0 | 0 | 1 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 10 + \frac{\pi}{12}) \right\}$ |
| 1 | 0 | 0 | 1 | 0 | $r_2 \cdot \exp\left\{ j(\frac{2\pi}{12} \cdot 11 + \frac{\pi}{12}) \right\}$ |
| 0 | 1 | 0 | 0 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 0 + \frac{\pi}{8}) \right\}$ |
| 1 | 1 | 0 | 0 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 1 + \frac{\pi}{8}) \right\}$ |
| 0 | 1 | 0 | 0 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 2 + \frac{\pi}{8}) \right\}$ |
| 0 | 1 | 1 | 0 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 3 + \frac{\pi}{8}) \right\}$ |
| 1 | 1 | 1 | 0 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 4 + \frac{\pi}{8}) \right\}$ |
| 0 | 1 | 1 | 0 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 5 + \frac{\pi}{8}) \right\}$ |
| 1 | 1 | 1 | 0 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 6 + \frac{\pi}{8}) \right\}$ |
| 1 | 1 | 1 | 1 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 7 + \frac{\pi}{8}) \right\}$ |
| 0 | 1 | 1 | 1 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 8 + \frac{\pi}{8}) \right\}$ |

| $a_{k-4}$ | $a_{k-3}$ | $a_{k-2}$ | $a_{k-1}$ | $a_k$ | Modulating symbols |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 9 + \frac{\pi}{8}) \right\}$ |
| 0 | 1 | 1 | 1 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 10 + \frac{\pi}{8}) \right\}$ |
| 0 | 1 | 0 | 1 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 11 + \frac{\pi}{8}) \right\}$ |
| 1 | 1 | 0 | 1 | 1 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 12 + \frac{\pi}{8}) \right\}$ |
| 0 | 1 | 0 | 1 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 13 + \frac{\pi}{8}) \right\}$ |
| 1 | 1 | 0 | 1 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 14 + \frac{\pi}{8}) \right\}$ |
| 1 | 1 | 0 | 0 | 0 | $r_3 \cdot \exp\left\{ j(\frac{2\pi}{16} \cdot 15 + \frac{\pi}{8}) \right\}$ |

**Table 5.1f: BPSK bits-to-symbols mapping**

| Information bits $(b_k)$ | Modulating symbols $\alpha_k$ |
|---|---|
| 0 | $\exp(j \cdot \pi \cdot 0) = (1 + j \cdot 0)$ |
| 1 | $\exp(j \cdot \pi \cdot 1) = (-1 + j \cdot 0)$ |

Figures 5.1, 5.2, and 5.3 illustrate the symbol constellations and bit mapping for QPSK, 16 APSK, and 32 APSK, respectively.

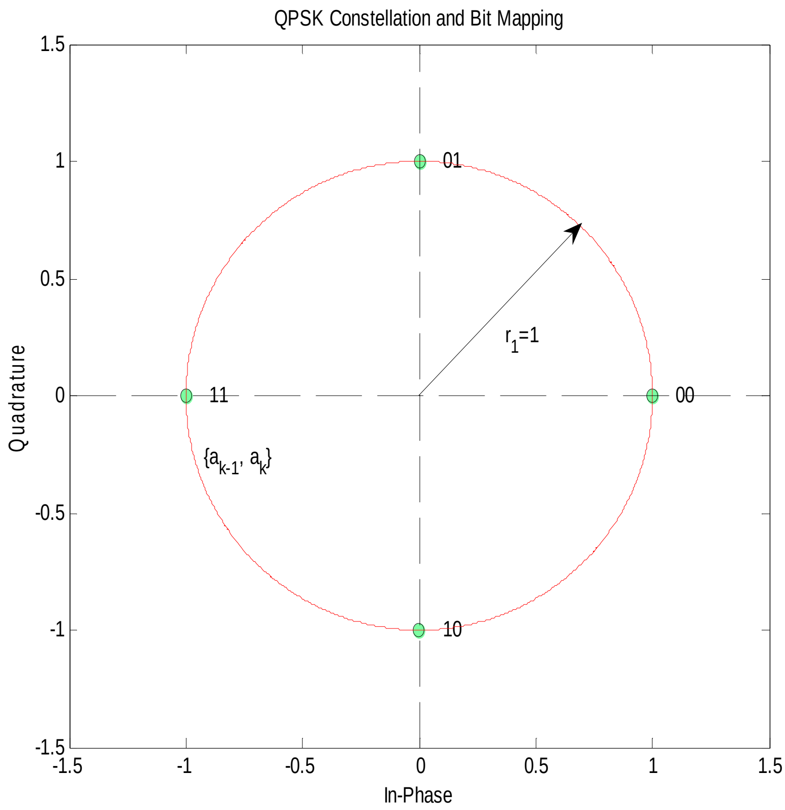


**Figure 5.1: QPSK Constellation and Bit Mapping**

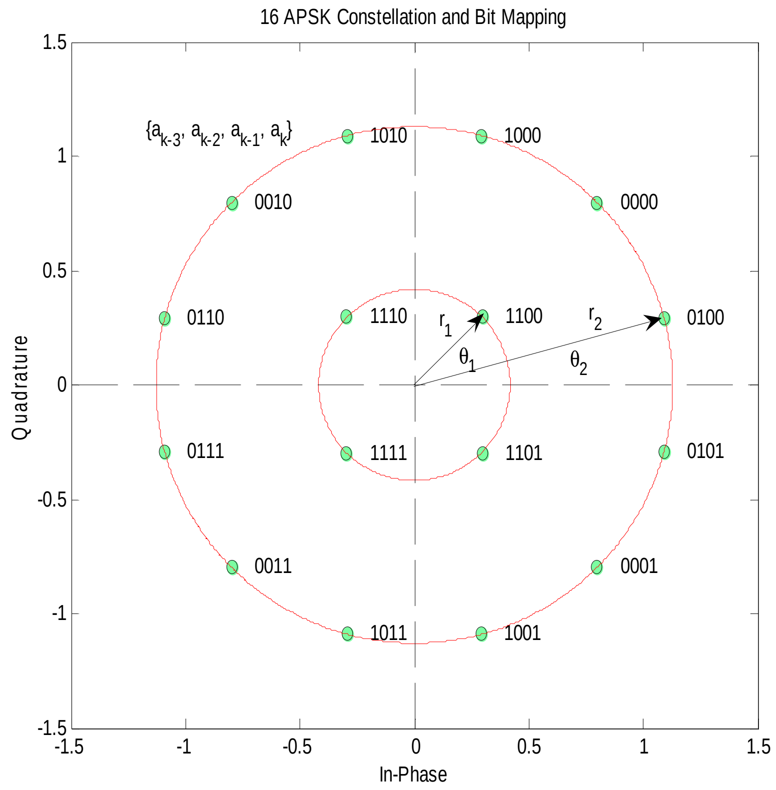


**Figure 5.2: 16 APSK Constellation and Bit Mapping**

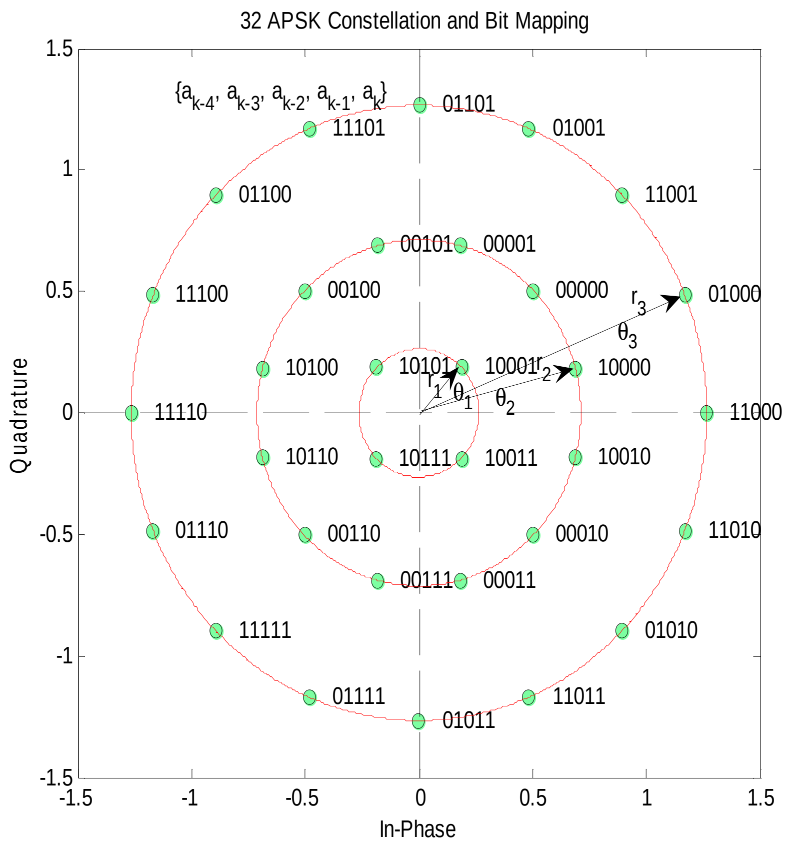


**Figure 5.3: 32 APSK Constellation and Bit Mapping**

# 6 DKABs (A/Gb mode only)

## 6.1 π/4-DBPSK modulation

Same as clause 6.1 of TS 101 376-5-4 [4].

# 7 BACH

Same as clause 7 of TS 101 376-5-4 [4].

## 7.1 Modulation format

Same as clause 7.1 of TS 101 376-5-4 [4].

## 7.2 BACH3

The Alert channel (BACH3) data consists of a 36-bit message that addresses the intended terminal notifying the user of a call attempt. The message bits are encoded to output 60 coded bits (i.e. 15 RS encoded symbols, each symbol containing 4 coded bits). Each BACH3 burst of six slots carries three RS symbols (i.e. 3 x 4 coded bits). Five BACH3 bursts are required to transmit a complete alerting message.

### 7.2.1 Modulation format

BACH3 bursts are π/2-BPSK modulated. The complex envelope of the transmitted signal is defined as follows:

$$x(t) = p(t)\left[ e^{j\varphi_o} \sum_{k=-\infty}^{\infty} \alpha_k \cdot e^{jk\frac{\pi}{2}} \cdot h(t - kT) \right]$$

where $\varphi_o$ is a random phase, $h(t)$ is the impulse response of a shaping filter defined in clause 5.1.1, $p(t)$ is the ramp function as defined in clause 5.1.2, and $\{\alpha_k\}$ are the modulating symbols defined as follows:

$$\begin{cases} k < 3: & \alpha_k = 0 \\ 3 \le k \le 231: & \text{see table 7.1}a \\ k > 231: & \alpha_k = 0 \end{cases}$$

The modulating symbols are derived from BACH3 sequences $\{v_k\}$ according to table 7.1a.

**Table 7.1a: Mapping between sequence value and modulation symbol**

| Sequence values ($v_k$) | Modulating symbols $\alpha_k$ |
|---|---|
| 0 | $\exp(j \cdot \pi \cdot 0) = (1 + j \cdot 0)$ |
| 1 | $\exp(j \cdot \pi \cdot 1) = (-1 + j \cdot 0)$ |

The sequence value $v_k$ is uniquely defined by concatenation of three sequences $S_j$ , $S_l$ , $S_m$ as follows:

$$v_k = \begin{cases} S_j(k-3), & j \in \{0, 1, ..., 15\};\ k = 3, 4, ..., 78. \\ S_l(k-79), & l \in \{0, 1, ..., 15\};\ k = 79, 80, ..., 154 \\ S_m(k-155), & m \in \{0, 1, ..., 15\};\ k = 155, 156, ..., 230 \end{cases}$$

Each sequence can take one of the 16 sequences $S_j$ in table 7.2a as follows:

**Table 7.2a: Definition of 16 BACH3 sequences**

| Sequences | Sequence elements (76 per each sequence) |
|---|---|
| $S_0$ | 0001001100001111001100000000111111001111111100111111000000001100111100001100 |
| $S_1$ | 0011000100110000111100110000000011111100111111110011111100000000110011110000 |
| $S_2$ | 0000001100010011000011110011000000001111110011111111001111110000000011001111 |
| $S_3$ | 0011110000110001001100001111001100000000111111001111111100111111000000001100 |
| $S_4$ | 0011001111000011000100110000111100110000000011111100111111110011111100000000 |
| $S_5$ | 0000001100111100001100010011000011110011000000001111110011111111001111110000 |
| $S_6$ | 0000000000110011110000110001001100001111001100000000111111001111111100111111 |
| $S_7$ | 0011110000000011001111000011000100110000111100110000000011111100111111110011 |
| $S_8$ | 1111000000111111110011000011110011101100111100001100111111110000001100000000 |
| $S_9$ | 1100001100000011111111001100001111001110110011110000110011111111000000110000 |
| $S_{10}$ | 1100000000110000001111111100110000111100111011001111000011001111111100000011 |
| $S_{11}$ | 1100110000000011000000111111110011000011110011101100111100001100111111110000 |
| $S_{12}$ | 1100000011000000001100000011111111001100001111001110110011110000110011111111 |
| $S_{13}$ | 1111110000001100000000110000001111111100110000111100111011001111000011001111 |
| $S_{14}$ | 1111111111000000110000000011000000111111110011000011110011101100111100001100 |
| $S_{15}$ | 1111001111111100000011000000001100000011111111001100001111001110110011110000 |

The sequence $v_k\big|_{k=3}^{k=230}$ is further scrambled by adding srambling pattern $u_k$ in modulo 2 in bit-wise, which operation is equivalent to:

$$v_k = \left[v_k + u_{k-3}\right] \bmod 2, \text{where } k = 3, 4, ..., 230$$

and $u_k\big|_{k=0}^{k=227}$ is given by:

[00010011000110111100010000100101000011111000110000010101111011111100110101101010111011001001100
1011011100010001101101000011110110110000010100100100000011000111000000010000101111111110000011010
101011111101100110010101001000100011 0 ].

The first bit in the above array corresponds to $u_{k=0}$ and the last bit corresponds to $u_{k=227}$ .

The mapping from the 4 coded bits (i.e. one RS symbol) to one of the 16 sequences $S_j$ is defined in table 7.3a.

**Table 7.3a: Coded bits to $S_j$ mapping**

| Coded bits | Sequences $S_j$ |
|---|---|
| 0000 | $S_0$ |
| 0001 | $S_1$ |
| 0010 | $S_2$ |
| 0011 | $S_3$ |
| 0100 | $S_4$ |
| 0101 | $S_5$ |
| 0110 | $S_6$ |
| 0111 | $S_7$ |
| 1000 | $S_8$ |
| 1001 | $S_9$ |
| 1010 | $S_{10}$ |
| 1011 | $S_{11}$ |
| 1100 | $S_{12}$ |
| 1101 | $S_{13}$ |
| 1110 | $S_{14}$ |
| 1111 | $S_{15}$ |

# 8 Frequency correction burst

## 8.1 Modulation format

Same as clause 8.1 of TS 101 376-5-4 [4].

## 8.2 FCCH3

### 8.2.1 L-band FCCH3

The L-band frequency correction burst (FCCH3) is a real chirp signal spanning twelve slots. The complex envelope of the transmitted burst is defined as follows:

$$x(t) = p(t)\left[e^{j\varphi_o}\sqrt{2}\cos\left(0{,}64\pi(t-234T)^2/(468T^2)\right)\right]$$

where $\varphi_o$ is a random phase and $p(t)$ is the ramp function as defined in clause 5.1.2 of TS 101 376-5-4 [4]. This signal defines the chirp sweeping range as (-7,488 kHz to 7,488 kHz).

### 8.2.2 S-band FCCH3

The S-band frequency correction burst (FCCH3) is a real chirp signal spanning twelve slots. The complex envelope of the transmitted burst is defined as follows:

$$x(t) = p(t)\left[e^{j\varphi_o}\sqrt{2}\cos\left(0{,}32\pi(t-234T)^2/(468T^2)\right)\right]$$

where $\varphi_o$ is a random phase and $p(t)$ is the ramp function as defined in clause 5.1.2 of TS 101 376-5-4 [4]. This signal defines the chirp sweeping range as (-3,744 kHz to 3,744 kHz).

# 9 Modulation accuracy

Same as clause 9 of TS 101 376-5-4 [4]. For the burst carrying more than one modulation type, the rms vector error measurement shall be applied to each modulation type, separately. Then the measurements are averaged across the multiple type modulation types with weights proportional to the number of associated symbols for each modulation type divided by total number of symbols within the burst.

# Annex A (informative): Bibliography

GMR-1 3G 45.005 (ETSI TS 101 376-5-5): "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 5: Radio interface physical layer specifications; Sub-part 5: Radio Transmission and Reception".

# History

| Document history | | |
|---|---|---|
| V3.1.1 | July 2009 | Publication |
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