ETSI TS 101 376-5-4 V1.1.1 (2001-03)

Technical Specification

GEO-Mobile Radio Interface Specifications;
Part 5: Radio interface physical layer specifications;
Sub-part 4: Modulation;
GMR-1 05.004

Reference

DTS/SES-001-05004

Keywords

GMR, MSS, MES, satellite, GSO, S-PCN, GSM, interface, mobile, modulation, radio

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Contents

Intellectual Property Rights

The information pertaining to essential IPRs is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://www.etsi.org/ipr).

The attention of ETSI has been drawn to the Intellectual Property Rights (IPRs) listed below which are, or may be, or may become, Essential to the present document. The IPR owner has undertaken to grant irrevocable licences, on fair, reasonable and non-discriminatory terms and conditions under these IPRs pursuant to the ETSI IPR Policy. Further details pertaining to these IPRs can be obtained directly from the IPR owner.

The present IPR information has been submitted to ETSI and pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

IPRs:

Project	Company	Title	Country of Origin	Patent n°	Countries Applicable
TS 101 376 V1.1.1	Digital Voice Systems Inc		US	US 5,226,084	US
TS 101 376 V1.1.1	Digital Voice Systems Inc		US	US 5,715,365	US
TS 101 376 V1.1.1	Digital Voice Systems Inc		US	US 5,826,222	US
TS 101 376 V1.1.1	Digital Voice Systems Inc		US	US 5,754,974	US
TS 101 376 V1.1.1	Digital Voice Systems Inc		US	US 5,701,390	US

IPR Owner: Digital Voice Systems Inc
One Van de Graaff Drive Burlington,
MA 01803
USA

Contact: John C. Hardwick
Tel.: +1 781-270-1030
Fax: +1 781-270-0166

Project	Company	Title	Country of Origin	Patent n°	Countries Applicable
TS 101 376 V1.1.1	Ericsson Mobile Communication	Improvements in, or in relation to, equalisers	GB	GB 2 215 567	GB
TS 101 376 V1.1.1	Ericsson Mobile Communication	Power Booster	GB	GB 2 251 768	GB
TS 101 376 V1.1.1	Ericsson Mobile Communication	Receiver Gain	GB	GB 2 233 846	GB
TS 101 376 V1.1.1	Ericsson Mobile Communication	Transmitter Power Control for Radio Telephone System	GB	GB 2 233 517	GB

IPR Owner: Ericsson Mobile Communications (UK) Limited
The Keytech Centre, Ashwood Way
Basingstoke
Hampshire RG23 8BG
United Kingdom

Contact: John Watson
Tel.: +44 1256 864821

Project	Company	Title	Country of Origin	Patent n°	Countries Applicable
TS 101 376 V1.1.1	Hughes Network Systems		US	Pending	US

IPR Owner: Hughes Network Systems
11717 Exploration Lane
Germantown, Maryland 20876
USA

Contact: John T. Whelan
Tel: +1 301-428-7172
Fax: +1 301-428-2802

Project	Company	Title	Country of Origin	Patent n°	Countries Applicable
TS 101 376 V1.1.1	Lockheed Martin Global Telecommunic. Inc	2.4-to-3 KBPS Rate Adaptation Apparatus for Use in Narrowband Data and Facsimile Communication Systems	US	US 6,108,348	US
TS 101 376 V1.1.1	Lockheed Martin Global Telecommunic. Inc	Cellular Spacecraft TDMA Communications System with Call Interrupt Coding System for Maximizing Traffic ThroughputCellular Spacecraft TDMA Communications System with Call Interrupt Coding System for Maximizing Traffic Throughput	US	US 5,717,686	US
TS 101 376 V1.1.1	Lockheed Martin Global Telecommunic. Inc	Enhanced Access Burst for Random Access Channels in TDMA Mobile Satellite System	US	US 5,875,182	
TS 101 376 V1.1.1	Lockheed Martin Global Telecommunic. Inc	Spacecraft Cellular Communication System	US	US 5,974,314	US
TS 101 376 V1.1.1	Lockheed Martin Global Telecommunic. Inc	Spacecraft Cellular Communication System	US	US 5,974,315	US
TS 101 376 V1.1.1	Lockheed Martin Global Telecommunic. Inc	Spacecraft Cellular Communication System with Mutual Offset High-argin Forward Control Signals	US	US 6,072,985	US
TS 101 376 V1.1.1	Lockheed Martin Global Telecommunic. Inc	Spacecraft Cellular Communication System with Spot Beam Pairing for Reduced Updates	US	US 6,118,998	US

IPR Owner: Lockheed Martin Global Telecommunications, Inc.
900 Forge Road
Norristown, PA. 19403
USA

Contact: R.F. Franciose
Tel.: +1 610.354.2535
Fax: +1 610.354.7244

Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

The contents of the present document are subject to continuing work within TC-SES and may change following formal TC-SES approval. Should TC-SES modify the contents of the present document, it will then be republished by ETSI with an identifying change of release date and an increase in version number as follows:

Version 1.m.n

where:

- the third digit (n) is incremented when editorial only changes have been incorporated in the specification;
- 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, 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 05.001";

Sub-part 2: "Multiplexing and Multiple Access; Stage 2 Service Description; GMR-1 05.002";

Sub-part 3: "Channel Coding; GMR-1 05.003";

Sub-part 4: "Modulation; GMR-1 05.004";

Sub-part 5: "Radio Transmission and Reception; GMR-1 05.005";

Sub-part 6: "Radio Subsystem Link Control; GMR-1 05.008";

Sub-part 7: "Radio Subsystem Synchronization; GMR-1 05.010";

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.

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

Since GMR is derived from GSM, the organization of the GMR specifications closely follows that of GSM. The GMR numbers have been designed to correspond to the GSM numbering system. All GMR specifications are allocated a unique GMR number as follows:

GMR-n xx.zyy

where:

- xx.0yy (z = 0) is used for GMR specifications that have a corresponding GSM specification. In this case, the numbers xx and yy correspond to the GSM numbering scheme.
- xx.2yy (z = 2) is used for GMR specifications that do not correspond to a GSM specification. In this case, only the number xx corresponds to the GSM 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 specifications as follows:

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

NOTE: Any references to GSM 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 specification.

- If a GMR specification does not exist, the corresponding GSM specification may or may not apply. The applicability of the GSM specifications is defined in GMR-1 01.201 [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

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 and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

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

[2] GMR-1 01.201 (ETSI TS 101 376-1-2): "GEO-Mobile Radio Interface Specifications; Part 1: General specifications; Sub-part 2: Introduction to the GMR-1 Family; GMR-1 01.201".

[3] GMR-1 05.002 (ETSI TS 101 376-5-2): "GEO-Mobile Radio Interface Specifications; Part 5: Radio interface physical layer specifications; Sub-part 2: Multiplexing and Multiple Access; Stage 2 Service Description; GMR-1 05.002".

[4] GMR-1 05.005 (ETSI TS 101 376-5-5): "GEO-Mobile Radio Interface Specifications; Part 5: Radio interface physical layer specifications; Sub-part 5: Radio Transmission and Reception; GMR-1 05.005".

3 Definitions and abbreviations

For the purposes of the present document, the definitions and the abbreviations given in GMR-1 01.004 [1] apply.

4 Burst structure

4.1 Signal representation

All transmitted signals s(t) are represented as baseband complex signals x(t). The actual transmitted signal may be derived from its baseband representation as follows:

$$s(t) = \Re e\left(x(t)e^{j2\pi ft}\right)$$

where f is the carrier frequency, and $\Re e$ represents the real part of a complex number.

4.2 Modulating symbol rate

The modulating symbol rate is 23,4 ksps for all burst types, except for the Broadcasting Alert Channel (BACH). The symbol period T is defined as 1/23,4 msec. For BACH, the symbol rate is 300 sps (1 200 bps).

4.3 Start and stop of the burst

The time interval [0, $N(39T)$] is the burst time window where N = 2, 3, 4, 6, 9, corresponding to the burst types defined in GMR-1 05.002 [3]. The time interval [2,5T, $N(39T)$-2,5T] is the burst time window corresponding to the active part of this burst. The content of this part corresponds to data symbols, i.e., reference and free symbols. The remaining time corresponds to the guard intervals (see GMR-1 05.002 [3]). These guard intervals correspond to the transition from no signal to a continuous carrier and vice-versa.

4.4 Data bits and data symbols

There are 78N binary data bits defined in {0,1} in each burst for π/4-CQPSK (Coherent Quadrature Phase-Shift Keying) modulation and 39N binary bits for π/4-DBPSK (Differential Binary Phase-Shift Keying) and π/4-CBPSK (Coherent Binary Phase-Shift Keying) modulation. For π/4-CQPSK, the burst bits are represented by [b_0 b_1 b_2 b_3 … b_{78N-2} b_{78N-1}], where b_0 to b_4 and b_{78N-5} to b_{78N-1} are guard bits. For π/4-DBPSK and π/4-CBPSK, the burst bits are denoted by [b_0 b_1 b_2 b_3 … b_{39N-2} b_{39N-1}] and b_0 to b_2 and b_{39N-2} to b_{39N-1} are guard bits (total 5 guard bits). When modulating these bits, we want to avoid grouping 1 guard bit with 1 information bit. Thus for π/4-CQPSK, the mapping rule from data bits to data symbols shall be:

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

which results in 40N different symbols being transmitted during 39NT (39N 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 4.3. To generate the first and the last symbols, one needs to use 2 dummy bits, which are represented by b_{-1} and b_{78N} The dummy bits can be either of the two binary values {0,1}. Figure 4.1 clearly illustrates the relationship of data bits, dummy bits, data symbols, burst boundary, and symbol boundary for a π/4-CQPSK modulated burst. Similarly, figure 4.2 shows the relationship of the π/4-DBPSK and π/4-CBPSK bursts. According to figure 4.2, the mapping rule from data bits to data symbols for π/4-DBPSK and π/4-CBPSK bursts is:

$$d_k = b_k, \quad k = 0,1,...,39N$$

where b_{39N} is considered to be a dummy bit.

Finally, the mapping of $\{d_k\}$ to the constellation points is defined in clauses 5.1 and 6.1.

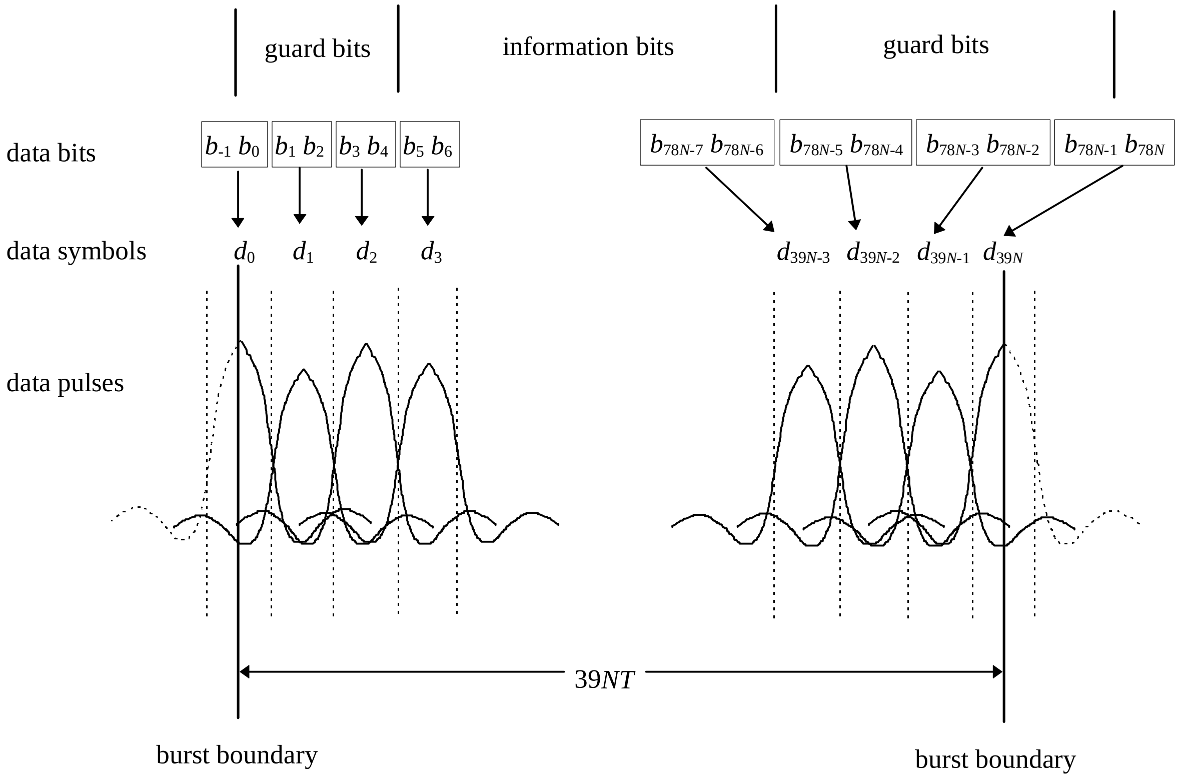

Figure 4.1: Relationship of data bits, data symbols, burst timing, and symbol timing for QPSK (the vertical dotted lines represent the symbol boundaries)

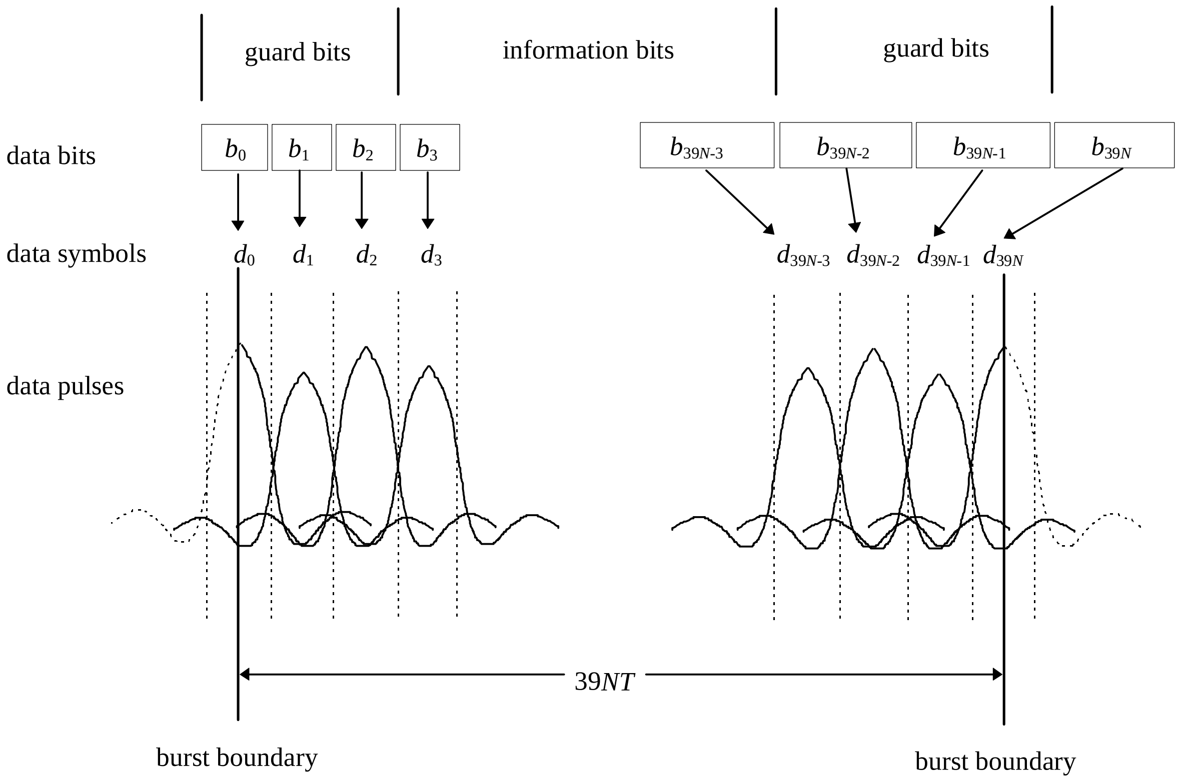

Figure 4.2: Relationship of data bits, data symbols, burst timing, and symbol timing for BPSK (the vertical dotted lines represent the symbol boundaries)

5 Normal burst

All traffic and control channel bursts except for DKAB, BACH, and FCCH are called normal bursts. They can be uplink or downlink bursts.

5.1 π/4-CQPSK modulation

Normal bursts are π/4-CQPSK (coherent quadrature phase shift keying) modulated. The complex envelope of the transmitted signal is defined as follows:

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

where φ_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:

$$\begin{cases} k < 0: & \alpha_k = 0 \\ 0 \le k \le 39N: & \text{see table 5.1} \\ k > 39N: & \alpha_k = 0 \end{cases}$$

where N = 2, 3, 4, 6, 9 depending on the type of the burst. The modulating symbols are derived from the data symbols (free and reference symbols) according to table 5.1.

Table 5.1: π/4-CQPSK modulation

Data Symbols (d_k)	Modulating Symbols α_k
0 0	$(1+j0)e^{jk\pi/4}$
0 1	$(0+j1)e^{jk\pi/4}$
1 1	$(-1+j0)e^{jk\pi/4}$
1 0	$(0-j1)e^{jk\pi/4}$

5.1.1 Filtering

The pulse shaping filter is the root raised cosine filter with a rolloff factor of 0,35. Its frequency response $H(f)$ is defined by the following function:

$$|H(f)| = \begin{cases} 1 & \text{for } 0 < |f| < \frac{0{,}325}{T} \\ \sqrt{\frac{1}{2}\left\{1 - \sin\left[\frac{\pi(2|f|T-1)}{0.7}\right]\right\}} & \text{for } \frac{0{,}325}{T} \le |f| \le \frac{0{,}675}{T} \\ 0 & \text{for } |f| > \frac{0{,}675}{T} \end{cases}$$

The impulse response $h(t)$, the inverse Fourier transform of $H(f)$, is written as:

$$h(t) = \frac{\frac{5}{7}T^2}{\pi\left[\left(\frac{5}{7}T\right)^2 - t^2\right]}\left(\cos\frac{1{,}35\pi t}{T} + \frac{5T}{7t}\sin\frac{0{,}65\pi t}{T}\right)$$

5.1.2 Power ramp

The power ramp function shall meet the GMR-1 05.005 [4] specification.

NOTE: An approach to meeting the GMR-1 05.005 [4] specification is the convolution of a Blackman window of appropriate duration x (the duration may be different for different types of bursts) and a rectangular-shaped function of duration $(T_b - x)$ msec., where T_b is the burst length in msec.
An alternative approach is to set all the guard modulating symbols (α_0, α_1, α_2, α_{3N-2}, α_{3N-1}, α_{3N}) to zero. In this way, the ramp effect is achieved by the filter response defined in clause 5.1.1.

5.2 π/4-CBPSK modulation

Some of the normal bursts are π/4-CBPSK (coherent binary phase-shift keying) modulated. The complex envelope of the transmitted signal is defined as for the π/4-CQPSK case. π/4-CBPSK bursts are considered as a special case of π/4-CQPSK with the following correspondence.

Table 5.2: π/4-CBPSK modulation

Data Symbols (d_k)	Modulating Symbols α_k
0	$(1 + j0)e^{jk\pi/4}$
1	$(-1 + j0)e^{jk\pi/4}$

6 DKABs

6.1 π/4-DBPSK modulation

Dual Keep-Alive Bursts (DKABs) are π/4-DBPSK modulated. The complex envelope of the transmitted signal is defined as follows:

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

where φ_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 1.2, and $\{\alpha_k\}$ are the modulating symbols defined as follows:

$$\begin{cases} k < 3+q/2: & \alpha_k = 0 \\ k = 3+q/2: & \alpha_k = 1 \\ 3+q/2 < k \le 7+q/2: & \text{see table 6.1} \\ 7+q/2 < k < 62+q/2: & \alpha_k = 0 \\ k = 62+q/2: & \alpha_k = 1 \\ 62+q/2 < k \le 66+q/2: & \text{see table 6.1} \\ k > 66+q/2: & \alpha_k = 0 \end{cases}$$

where q shall be even and $0<q<95$ as explained in GMR-1 05.002 [3]. The modulating symbols are derived from the data symbols (free and reference symbols) according to table 6.1.

Table 6.1: π/4-DBPSK modulation

Data Symbols d_k	Modulating Symbols α_k
0	$\alpha_{k-1} e^{j\pi/4}$
1	$\alpha_{k-1} e^{-j3\pi/4}$

$\alpha_{3+q/2}$ and $\alpha_{62+q/2}$ represent the first and the second reference symbols respectively.

7 BACH

The Alert channel (BACH) 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. Each BACH burst of two slots carries 4 coded bits. 15 BACH bursts are required to transmit a complete alerting message.

7.1 Modulation format

BACH bursts are 6PSK modulated. The complex envelope of the transmitted signal is defined as follows:

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

where φ_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:

$$\begin{cases} k < 0: & \alpha_k = 0 \\ 0 \le k \le 78: & \text{see table 7.1} \\ k > 78: & \alpha_k = 0 \end{cases}$$

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

Table 7.1: HPSK modulation

Sequence Values (v_k)	Modulating Symbols α_k
0	e^{j0}
1	$e^{j2\pi/3}$
2	$e^{-j2\pi/3}$
3	$e^{j\pi}$
4	$e^{j\pi/3}$
5	$e^{-j\pi/3}$

The sequence value v_k is uniquely defined by one of the 16 sequences S_j in table 7.2 as follows:

$$v_k = \begin{cases} \{\text{any of } (0,1,2,3,4,5)\}, & k = 0,1,2. \\ S_j(i), & j = 0, 1,\ldots,15; k = 3,4,\ldots,74. \\ \{\text{any of } (0,1,2,3,4,5)\}, & k = 75,76,77,78. \end{cases}$$

where I is computed by:

$$i = \left\lfloor \frac{k-3}{4} \right\rfloor$$

and $\lfloor x \rfloor$ takes the integer part of x. i takes numbers from {0, 1, …, 17} for the range of k values.

Table 7.2: Definition of 16 BACH sequences

Sequences	Sequence elements (18 per each sequence)
S_0	0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3
S_1	0 0 1 1 2 2 0 0 1 1 2 2 0 0 1 1 2 2
S_2	0 3 1 5 2 4 0 3 1 5 2 4 0 3 1 5 2 4
S_3	0 0 2 2 1 1 0 0 2 2 1 1 0 0 2 2 1 1
S_4	0 3 2 4 1 5 0 3 2 4 1 5 0 3 2 4 1 5
S_5	0 0 0 0 0 0 1 1 1 1 1 1 2 2 2 2 2 2
S_6	0 3 0 3 0 3 1 5 1 5 1 5 2 4 2 4 2 4
S_7	0 0 1 1 2 2 1 1 2 2 0 0 2 2 0 0 1 1
S_8	0 3 1 5 2 4 1 5 2 4 0 3 2 4 0 3 1 5
S_9	0 0 2 2 1 1 1 1 0 0 2 2 2 2 1 1 0 0
S_{10}	0 3 2 4 1 5 1 5 0 3 2 4 2 4 1 5 0 3
S_{11}	0 0 0 0 0 0 2 2 2 2 2 2 1 1 1 1 1 1
S_{12}	0 3 0 3 0 3 2 4 2 4 2 4 1 5 1 5 1 5
S_{13}	0 0 1 1 2 2 2 2 0 0 1 1 1 1 2 2 0 0
S_{14}	0 3 1 5 2 4 2 4 0 3 1 5 1 5 2 4 0 3
S_{15}	0 0 2 2 1 1 2 2 1 1 0 0 1 1 0 0 2 2

From the above equation, v_k for k = 0, 1, 2 and k = 75, 76, 77, 78 also belongs to {0, 1, 2, 3, 4, 5}. The specific sequence patterns can be arbitrarily defined.

The mapping from the 4 coded bits to one of the 16 sequences S_j is defined in table 7.3.

Table 7.3: Coded bits to S_j mapping

Coded bits	Sequences Sj
0000	*S0*
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

Frequency correction burst is a real chirp signal spanning three slots. The complex envelope of the transmitted burst is defined as follows:

$$x(t) = p(t)\left[e^{j\varphi_o}\sqrt{2}\cos\left(0{,}64\pi(t-58{,}5T)^2/(117T^2)\right)\right]$$

where φ_o is a random phase and $p(t)$ is the ramp function as defined in clause 5.1.2. This signal defines the chirp sweeping range as (-7,488 kHz, 7,488 kHz).

9 Modulation accuracy

Modulation accuracy is defined as the difference between the actual transmitted signal and the theoretical signal defined in previous clauses.

Modulation accuracy is measured in terms of the error vector magnitude from the transmitted symbol to the theoretical point in the constellation at the optimum symbol sampling points.

The transmit accuracy requirements are:

- the root-mean-square (rms) error vector magnitude over the entire burst shall be less than 0,09;
- the rms error vector magnitude over the first eight symbols of the burst shall be less than 0,18.

The rms error vector magnitude, the measure of modulation accuracy, shall be computed as follows:

Observing an ideal transmitter through an ideal square root raised-cosine receiver filter at the correct sampling instants one symbol apart would result in the sequence of values given (for π/4-CQPSK) by:

$$S(k) = S_R e^{j[k\pi/4 + B(k)\pi/2]}$$

where S_R is a reference symbol position defined by the transmitted sync pattern and k = 0, 1, ..., 39N, $|S(k)|$ = 1 and $B(k)$ = 0, 1, 2, 3 according to table 9.1.

For π/4-DBPSK,

$$S(k) = S(k-1)e^{j[\pi/4 + B(k)\pi/2]}$$

where k = 0, 1, ..., 39N, $|S(k)|$ = 1 and $B(k)$ = 0, 2 according to table 9.2.

Table 9.1: Derivation of B(k) for π/4-CQPSK

Data Symbols (d_k)	$B(k)$
0 0	0
0 1	1
1 1	2
1 0	3

Table 9.2: Derivation of B(k) for π/4-DBPSK

Data Symbols (d_k)	$B(k)$
0	0
1	2

The ideal transmit and receive filters in cascade form a raised cosine Nyquist filter having an impulse response going through zero at symbol period intervals so there is no intersymbol interference at the ideal sampling points. Therefore, the ideal signal samples take on one of the eight values defined above, at the output of the receive filter.

Let $Z(k)$ be the complex vectors produced by observing the real transmitter through an ideal measuring receiver filter at instants k, one symbol period apart. With $S(k)$ defined as above, the transmitter is modelled as:

$$Z(k) = \{C_0 + C_1[S(k) + E(k)]\}W^k$$

where:

1) $W = e^{dr + jd\sigma}$ accounts for both a frequency offset giving "$d\sigma$" radians per symbol phase rotation and an amplitude change of "dr" nepers per symbol;
2) C_0 is a constant origin offset representing carrier feedthrough at the transmitter;
3) C_1 is a complex constant representing the arbitrary phase and output power of the transmitter; and
4) $E(k)$ is the residual vector error on sample $S(k)$.

The sum square vector error is then:

$$\sum_{k=MIN}^{MAX} |E(k)|^2 = \sum_{k=MIN}^{MAX} \left| \frac{[Z(k)W^{-k} - C_0]}{C_1} - S(k) \right|^2$$

C_0, C_1, and W will be chosen to minimize this expression and are then used to compute the individual vector errors $E(k)$ on each symbol. The symbol timing phase of the receiver output samples used to compute the vector error will also be chosen to give the lowest value.

The values of *MAX* and *MIN* are the last and first maximum effect points in the (segment of the) burst under measurement.

The rms vector error is then computed as the square root of the sum-square vector divided by the number of symbols in the segment under measurement. The result is then normalized relative to the symbol magnitude.

The above requirements shall be satisfied over the extreme set of environmental conditions specified in annex B of GMR-1 05.005 [4]. If the MES is operated outside the range of extreme environmental conditions, the EVM of the whole burst shall not exceed 0,12, and the EVM of the first eight symbols of the burst shall not exceed 0,24.

Annex A (informative): Bibliography

GMR-1 05.001 (ETSI TS 101 376-5-1): "GEO-Mobile Radio Interface Specifications; Part 5: Radio interface physical layer specifications; Sub-part 1: Physical Layer on the Radio Path: General Description; GMR-1 05.001".

History

Document history		
V1.1.1	March 2001	Publication