ETSI TS 101 376-5-4 V1.3.1 (2005-02)

Technical Specification

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

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Foreword

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

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where:

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The present document is part 5, sub-part 4 of a multi-part deliverable covering the GEO-Mobile Radio Interface Specifications (Release 1), 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";

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

    Sub-part 3: "Channel Coding";

    Sub-part 4: "Modulation";

    Sub-part 5: "Radio Transmission and Reception";

    Sub-part 6: "Radio Subsystem Link Control";

    Sub-part 7: "Radio Subsystem Synchronization";

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 1 specifications. Release 1 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.).

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.

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. This GMR number has a different prefix for Release 2 specifications as follows:

- Release 1: GMR-n xx.zyy.

- Release 2: GMPRS-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.

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

[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".

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

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

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

[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".

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

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

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

3 Definitions and abbreviations

3.1 Definitions

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

3.2 Abbreviations

For the purposes of the present document, 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 ksymbol/s for all burst types. The symbol period T is defined as 1/23,4 ms.

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-DBIT/SK (Differential Binary Phase-Shift Keying) and π/4-CBIT/SK (Coherent Binary Phase-Shift Keying) modulation. For π/4-CQPSK, the burst bits are represented by
$[b_0\, b_1\, b_2\, b_3\, \ldots\, b_{78N-2}\, b_{78N-1}]$, where b_0 to b_4 and b_{78N-5} to b_{78N-1} are guard bits. For π/4-DBIT/SK and π/4-CBIT/SK, the burst bits are denoted by $[b_0\, b_1\, b_2\, b_3\, \ldots\, b_{39N-2}\, b_{39N-1}]$ 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 39N+1 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-DBIT/SK and π/4-CBIT/SK bursts. According to figure 4.2, the mapping rule from data bits to data symbols for π/4-DBIT/SK and π/4-CBIT/SK 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.

guard bits   information bits   guard bits

data bits $b_{-1}\,b_0$ $b_1\,b_2$ $b_3\,b_4$ $b_5\,b_6$ $b_{78N-7}\,b_{78N-6}$ $b_{78N-5}\,b_{78N-4}$ $b_{78N-3}\,b_{78N-2}$ $b_{78N-1}\,b_{78N}$

data symbols d_0 d_1 d_2 d_3 $d_{39N-3}\;d_{39N-2}\;d_{39N-1}\;d_{39N}$

data pulses

$39NT$

burst boundary   burst boundary
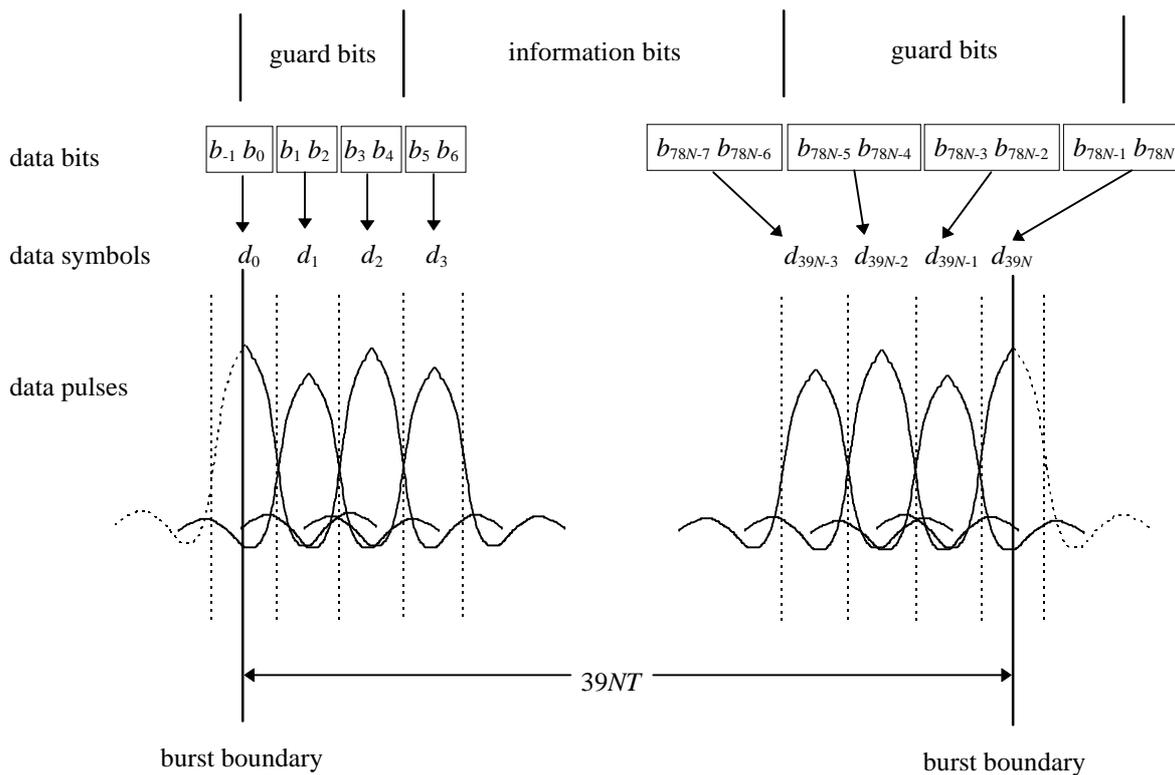
NOTE: The vertical dotted lines represent the symbol boundaries.

Figure 4.1: Relationship of data bits, data symbols, burst timing, and symbol timing for QPSK

guard bits   information bits   guard bits

data bits b_0 b_1 b_2 b_3 b_{39N-3} b_{39N-2} b_{39N-1} b_{39N}

data symbols d_0 d_1 d_2 d_3 $d_{39N-3}\;d_{39N-2}\;d_{39N-1}\;d_{39N}$

data pulses

$39NT$

burst boundary   burst boundary
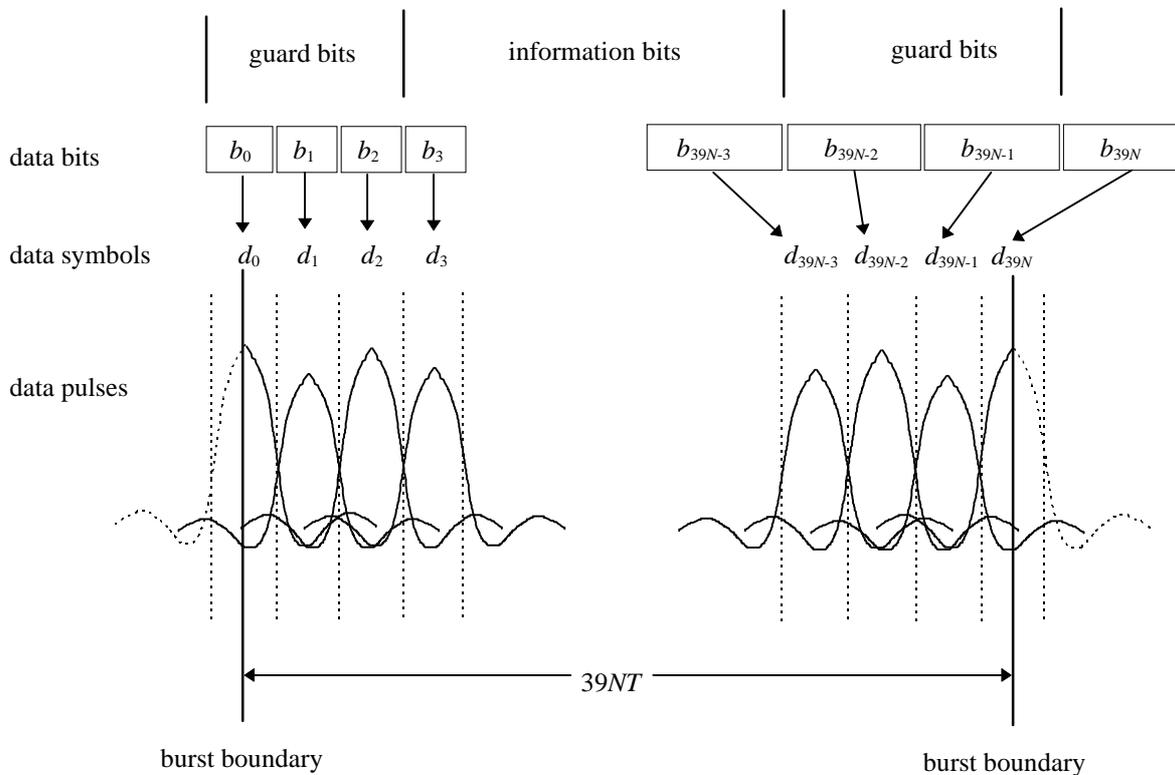
NOTE: The vertical dotted lines represent the symbol boundaries.

Figure 4.2: Relationship of data bits, data symbols, burst timing, and symbol timing for BIT/SK

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:

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

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 roll-off factor of 0,35. Its frequency response $H(f)$ is defined by the following function:

$$|H(f)| = \begin{cases} 1 & \text{for } 0 < |f| < \dfrac{0,325}{T} \\ \sqrt{\dfrac{1}{2}\left\{1 - \sin\left[\dfrac{\pi(2|f|T - 1)}{0,7}\right]\right\}} & \text{for } \dfrac{0,325}{T} \leq |f| \leq \dfrac{0,675}{T} \\ 0 & \text{for } |f| > \dfrac{0,675}{T} \end{cases}$$

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 $(T_b - x)$ ms, where T_b is the burst length in ms.
>
> 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-CBIT/SK modulation

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

Table 5.2: π/4-CBIT/SK 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-DBIT/SK modulation

Dual Keep-Alive Bursts (DKABs) are π/4-DBIT/SK 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:

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

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-DBIT/SK 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 Basic Alerting 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 {α_k} are the modulating symbols defined as follows:

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

The modulating symbols are derived from a set of BACH sequence values {v_k} according to table 7.1. Each sequence value is replicated over 4 successive symbol periods.

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:

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

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.

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

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.

Table 7.3: 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

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 to 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 $\pi/4$-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 $\pi/4$-DBIT/SK:

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

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-DBIT/SK

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:

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

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:

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

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".

Annex B (informative):
Change Record

This annex lists the CRs that have been applied to the present document.

CR	REV	CATEGORY	SUBJECT
CR004	2	Editorial	Suggested improvement to BACH description

History

Document history		
V1.1.1	March 2001	Publication
V1.2.1	April 2002	Publication
V1.3.1	February 2005	Publication