**Summary of revision**

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| **Radiocommunication Study Groups** |  |
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| Source: Document 4/58  Subject: Recommendation ITU-R M.1850-1 | **Document 4/BL/7-E** |
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| Radiocommunication Study Group 4 | |
| Draft revision of Recommendation ITU-R M.1850-1 | |
| **Detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)** | |
| Interface H specifications update (section 4.3.7) | |

Recommendation ITU-R M.1850 identifies the IMT-2000 satellite radio interface specifications, originally based on the key characteristics identified in the output of activities outside ITU. The satellite radio interface for 3rd generation mobile satellite systems has continued to develop at a fast rate. The latest version was published by ETSI in December, 2012. This revision updates section 4.3.7 (Satellite radio interface H specifications) to bring the Recommendation   
ITU-R M.1850 to be consistent with the Geo-Mobile-Radio-1 (GMR-1) specifications currently in force. No self-evaluation form is required with this submission as none of the changes effect   
the answers to the form presented with the current version of the Recommendation.

The updates include two new sub-sections and expanded text that describe key features of the newer releases as well as updated figures and tables to better describe the current standard. These modifications cover the topics of efficient multicast implementation, flexible beam coverage, new PDTCH variants, and control channels implementation. ETSI documents references are updated throughout the text. Other minor editorial changes have also been performed.

**Attachment:** 1

ATTACHMENT

Draft Revision of Recommendation ITU-R M.1850-1

**Detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)**

…

### 4.3.7 Satellite radio interface H specifications

SRI-H air interface is an evolutionary third generation (3G) mobile satellite system air interface that was first published as the GMR-1 (Geo-Mobile Radio-1) mobile satellite air interface specification by both ETSI (ETSI TS 101 376) and TIA (S‑J-STD-782) in 2001. The ETSI version has been updated several times with improvements, additional features and routine maintenance including a Release 2 and Release 3. The latest version of Release 3, version 3.3.1 has been published by ETSI in December, 2012. This section is a brief summary of the air interface. For a fuller description, please see the published specification.

The GMR-1 development and standardization path follows the evolution of GSM/EDGE Radio Access Network or GERAN as shown in Fig. 77.

GMR-1 air interface specifications based on TDMA were first standardized in ETSI in 2001 (GMR‑1 Release 1) based on GSM protocol architecture with satellite specific optimizations and use of A interface with core Network (see Fig. 78). GMR-1 Release 1 radio interface supports compatible services to GSM and reuses the GSM network infrastructure. It is designed to be used with dual-mode terminals (satellite/terrestrial) allowing the user to roam between GMR-1 satellite networks and GSM terrestrial networks. Features include spectrally efficient voice, delay tolerant fax, reliable non-transparent data services up to 9.6 kbit/s, Short Message Service (SMS), cell broadcast services, position‑based services, subscriber identity module (SIM) roaming, high penetration alerting and single-satellite hop terminal-to-terminal calls. Systems based on GMR-1 Release 1 are being used today in Europe, Africa, Asia and Middle East.

FIGURE 77



FIGURE 78



The circuit switched specification (Release 1) has been updated two additional times in the ETSI satellite earth stations and systems (SES) technical committee, in 2002 (Version 1.2.1) and again in 2005 (Version 1.3.1).

GMR-1 uses time division multiplex on the forward link and time division multiple access on the return link.

In 2003, GMR-1 was enhanced with the addition of a packet switched data capability and published as GMPRS-1 (Geo-Mobile Packet Radio System) or GMR-1 Release 2. GMPRS-1 provides IP data services to transportable terminals using GPRS technology with a Gb interface to core network. Figures 79 and 80 illustrate protocol architecture of GMR-1 air interface for user plane and control plane using Gb interface towards core network. A number of satellite specific enhancements were introduced at PHY and MAC layers of the protocol stack to provide improved throughputs and better spectral efficiencies.

FIGURE 79



FIGURE 80



GMPRS-1 Version 2.1.1 supports bidirectional packet data rates up to 144 kbit/s, QoS differentiation across users, and dynamic link adaptation. GMPRS-1 Version 2.2.1, published in 2005, supports narrow band packet data services to handheld terminals that permit up to 28.8 kbit/s in uplink and 64 kbit/s in downlink. Wideband packet service is expanded to 444 kbit/s on the forward link and 202 kbit/s on the return link for A5 size transportable terminals in Version 2.3.1 published in 2008. The system also permits achieving up to 400 kbit/s in uplink with an external antenna.   
This latest set of specifications uses the state-of‑the art techniques in the physical layer such as LDPC codes and 32-APSK modulation and can provide bidirectional streaming services.

A system, using GMR-1, Release 2 specifications, has been successfully deployed in the field and is being used in Europe, Africa, Asia and Middle East.

GMR-1 3G Release 3.1.1 was first published by ETSI in July, 2009. It has been updated twice since as Release 3.2.1 (in February, 2011) and Release 3.3.1 (in December, 2012). GMR-1 3G is based on the adaptation to the satellite environment of the ETSI TDMA EDGE radio air interface (see Recommendation [ITU‑R M.1457-6](http://www.itu.int/rec/R-REC-M.1457/en), IMT-2000 TDMA Single-Carrier). GMR-1 3G is therefore the satellite equivalent to EDGE. The protocol architecture is based on 3GPP Release 6 and beyond, but the air interface is TDMA. In line with ETSI 3GPP specifications, the satellite base-station is therefore equivalent to a GERAN. GMR-1 3G is designed to meet the requirements of the satellite component of the third generation (3G) wireless communication systems.

Systems based on GMR-1 3G air interface specifications are currently being developed for MSS operators around the world operating in the MSS bands at both L-band and S-band frequencies   
as defined in ETSI TS 101 376-5-5.

#### 4.3.7.1 Key features of GMR-1 3G

The GMR-1 3G specification uses the Iu-PS interface between radio network and core network. The objective is to allow MSS operators to provide forward-looking IP Multimedia System (IMS) based services. Key features included in this air interface are:

– Spectrally efficient multi-rate VoIP with zero byte header compression.

– V.44 data compression.

– TCP/IP, UDP/IP and RTP/UDP/IP header compression.

– Robust waveforms for link closure with terrestrial form-factor MESs.

– Up to 590 kbit/s throughput.

– Multiple carrier bandwidth operation.

– Multiple terminal types - Hand-held terminals, PDA, vehicular, portable, fixed, maritime and aeronautical.

– IP multimedia services.

– Differentiated QoS across users and applications.

– Dynamic link adaptation.

– IPv6 compatibility.

– Terrestrial/Satellite handovers.

– Beam-to-beam handovers.

– Unmodified non-access stratum (NAS) protocols and core network.

– High penetration alerting.

– GPS assist including either Earth-Centered Earth-Fixed coordinates or Keplerian coordinates.

– Cell broadcast.

– Capability to multiplex support multiple VOIP sessions for one MES.

– Resource efficient multicast.

– Resource and delay efficient push-to-talk.

– Regional beams and spot beam operation with or without overlay.

– Flexible traffic-only beam support.

Figures 81 and 82 illustrate protocol architecture of GMR-1 3G air interface for user plane and control plane using Iu-PS interface towards core network.

FIGURE 81



FIGURE 82



End-to-end architectures depicting the use of GMR-1 3G air interface with different core network interfaces are depicted in Fig. 83. A given operator may choose an individual architecture option (A, Gb, Iu-PS) or a combination thereof.

In this description, the term “GMR-1” is used to refer to attributes of the air interface and system that uses A interface and Gb interface. Where a particular attribute is only applicable to A-interface or Gb-interface, it will be referred to as GMR-1 (A mode) or GMR-1 (Gb mode), respectively.   
The term GMR-1 3G is used to refer to attributes of the air interface and system that uses the Iu-PS interface, and will be referred to as GMR-1 3G (Iu mode). If no interface is referenced the attribute is common to all interfaces.

FIGURE 83



GMR-1 3G operates in FDD mode with RF channel bandwidths from 31.25 kHz up to 312.5 kHz. Provides finer spectrum granularity yielding an easier spectrum sharing among different systems.

GMR-1 3G provides a wide range of bearer services from 1.2 up to 592 kbit/s. High-quality telecommunication service can be supported including voice quality telephony and data services in a global coverage satellite environment.

The implementation of efficient multicast is shown in Fig. 84. Terminals use Internet Group Management Protocol (IGMPv2) (see IETF RFC 2236) to join multicast sessions. The core network functions as defined in 3GPP specifications. The SBSS merges the multiple streams onto a single multicast TFI stream per beam. Details are provided in ETSI TS 101 376-4-14 and   
ETSI TS 101 376-4-12.

FIGURE 84



An example of flexible beam coverage support is shown in Fig. 85. GMR-1 3G is deployed in systems which use a variety of beam types in the same system. Fig. 85 shows a regional beam overlay, a spot beam overlay and flexible traffic-only beams superimposed on the same coverage area. In this example, regional beams might be large with relatively low G/T and e.i.r.p. properties suitable for support of aeronautical terminals with high-gain antennas. Spot beam might be very small with much higher G/T and e.i.r.p. designed to support high capacity and very small handheld terminals with electrically small, low gain antennas. Traffic-only beams might be stationary or steerable and configured to support spot traffic needs. With the advances in satellite/ground technology including ground based beam formers, steerable antennas and array architectures, the GMR-1 3G air interface does not constrain satellite or system design.

FIGURE 85



#### 4.3.7.2 Frame structure

The time reference structure (ETSI TS 101 376-5-2 and ETSI TS 101 376-5-7) is shown in   
Fig. 86.

GMR-1 uses Frequency Division Duplex (FDD) of the forward and return links, with time division multiplex (TDM) on the forward link and Time Division Multiple Access (TDMA) on the return link.

The air interface frame structure is shown in Fig. 86. The same frame structure is used on both the forward link and the return link: in this description all references to "TDMA Frames" apply equally to TDM frames on the forward link and TDMA frames on the return link.

The timeslots within a TDMA frame are numbered from 0 to 23 and a particular timeslot is referred to by its Timeslot Number (TN). TDMA frames are numbered by a Frame Number (FN). The frame number is cyclic and has a range of 0 to FN\_MAX = (16 × 4 × 4 896) - 1 = 313 343. The frame number is incremented at the end of each TDMA frame. The complete cycle of TDMA frame numbers from 0 to FN\_MAX is defined as a hyperframe. Other combinations of frames include:

– Multiframes: A multiframe consists of 16 TDMA frames. Multiframes are aligned so that the FN of the first frame in a multiframe, modulo 16, is always 0.

– Superframes: A superframe consists of four multiframes. Superframes are aligned so that the FN of the first frame in a superframe, modulo 64, is always 0.

– System information cycle: The system information cycle has the same duration as a superframe. However, the first frame of the system information cycle is delayed an integer number of frames (0 to 15) from the start of a superframe. The actual delay is intentionally varied from spot beam to spot beam to reduce the satellite’s peak power requirements. The FCCH and BCCH are used to achieve system information cycle synchronization at the MES.

FIGURE 86



#### 4.3.7.3 Channels

The radio subsystem is required to support a certain number of logical channels described in ETSI TS 101 376‑5-2 that can be separated into two overall categories:

**–** traffic channels (TCHs);

**–** control channels (CCHs).

##### 4.3.7.3.1 Traffic channels

Circuit switched or A-mode traffic channels include those listed in Table 58. These traffic channels are bidirectional.

TABLE 58

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Channel type | User information capability | Gross data transmission rate | Modulation | Channel coding |
| TCH3 | Encoded speech | 5.85 kbit/s | π/4 CQPSK | Convolutional code |
| TCH6 | User data: 4.8 kbit/s Fax: 2.4 or 4.8 kbit/s | 11.70 kbit/s | π/4 CQPSK | Convolutional code |
| TCH9 | User data: 9.6 kbit/s Fax: 2 kbit/s; 4 kbit/s;  4.8 kbit/s or 9.6 kbit/s | 17.55 kbit/s | π/4 CQPSK | Convolutional code. |

Packet channels are defined which provide data rates between 8.8 kbit/s and 587.2 kbit/s.

A packet data traffic channel (PDTCH) corresponds to the resource allocated to a single MES on one physical channel for user data transmission. Different logical channels may be dynamically multiplexed on to the same PDTCH. The PDTCH uses π/2 BPSK, π/4 QPSK, 16 APSK, or 32 APSK modulation. All packet data traffic channels are unidirectional, either uplink (PDTCH/U), for a mobile-originated packet transfer or downlink (PDTCH/D) for a mobile-terminated packet transfer.

PDTCHs are used to carry packet data traffic in either Gb or Iu mode. Those applicable to Gb mode are listed in Table 59 and those applicable to Iu mode are listed in Table 3. Different PDTCHs are defined by the suffix (*m*, *n*) where m indicates the bandwidth of the physical channel in which the PDTCH is mapped, *m* × 31.25 kHz, and *n* defines the number of timeslots allocated to this physical channel. Tables 59 and 60 summarize different types of packet traffic data channels, PDTCH (*m*, 3), (*m* = 1, 4, 5 and 10), where the burst duration is 5 ms, PDTCH (*m*, 6), (*m* = 1, 2), where the burst duration is 10 ms, and PDTCH (*m*, 12), (*m* = 5), where the burst duration is 20 ms.

A dedicated traffic channel (DTCH) is used to carry user traffic when a dedicated channel (DCH) is allocated to the mobile earth station (MES) in packet dedicated mode. A DTCH is unidirectional. DTCH/U is used for the uplink and a DTCH/D is used for the downlink. A DTCH may support either 2.45 or 4.0 kbit/s encoded speech. Table 60 summarizes different types of packet traffic data channels, DTCH (*m*, 3), (*m* = 1, 4, 5 and 10), where the burst duration is 5 ms , DTCH (*m*, 6), (*m* = 1, 2), where the burst duration is 10 ms, and DTCH(*m*, 8), (*m* = 1), where the burst duration is 13.333 ms.

TABLE 59

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Channels | Direction (U: uplink,  D: downlink) | Transmission symbol rate (ksymbol/s) | Channel coding | Modulation | Transmission bandwidth (kHz) | Peak payload transmission rate (without CRC)  (kbit/s) | Peak payload transmission rate (with CRC) (kbit/s) |
| PDTCH(4,3) | U/D | 93.6 | Conv. | π/4‑QPSK | 125.0 | 113.6 | 116.8 |
| PDTCH(5,3) | U/D | 117.0 | Conv. | π/4‑QPSK | 156.25 | 145.6 | 148.8 |
| PDTCH(1,6) | U/D | 23.4 | Conv. | π/4‑QPSK | 31.25 | 27.2 | 28.8 |
| PDTCH(2,6) | D/D | 46.8 | Conv. | π/4‑QPSK | 62.5 | 62.4 | 64.0 |
| PDTCH2(5,12) | D | 117.0 | LDPC | π/4‑QPSK | 156.25 | 199.2 | 199.6 |
| PDTCH2(5,12) | D | 117.0 | LDPC | 16‑APSK | 156.25 | 354.8 | 355.2 |
| PDTCH2(5,12) | D | 117.0 | LDPC | 32‑APSK | 156.25 | 443.6 | 444.0 |
| PDTCH2(5,12) | U | 117.0 | LDPC | π/4‑QPSK | 156.25 | 199.2 | 199.6 |
| PDTCH2(5,12) | U | 117.0 | LDPC | 16‑APSK | 156.25 | 399.2 | 399.6 |
| PDTCH2(5,3) | U/D | 117.0 | LDPC | π/4‑QPSK | 156.25 | 169.6 | 171.2 |
| PDTCH2(5,3) | U/D | 117.0 | LDPC | 16‑APSK | 156.25 | 342.4 | 344.0 |
| PDTCH2(5,3) | U/D | 117.0 | LDPC | 32‑APSK | 156.25 | 380.8 | 382.4 |

TABLE 60

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Channels | Direction (U: uplink,  D: downlink) | Transmission  symbol rate (ksymbol/s) | Channel coding | Modulation | Transmission bandwidth (kHz) | Peak payload transmission rate (without CRC) (kbit/s) | Peak payload transmission rate (with CRC) (kbit/s) |
| DTCH(1,3) | U/D | 23.4 | Conv. | π/4‑QPSK | 31.25 | 28.8 | 32.0 |
| DTCH(1,6) | U/D | 23.4 | Conv. | π/2‑BPSK | 31.25 | 14.4 | 16.0 |
| DTCH(1,6) | U/D | 23.4 | Conv. | π/4‑QPSK | 31.25 | 8.8 | 10.4 |
| DTCH(1,8) | U/D | 23.4 | Conv. | π/2‑BPSK | 31.25 | 10.8 | 12.0 |
| PDTCH(1,6) | U/D | 23.4 | Conv. | π/4‑QPSK | 31.25 | 27.2 | 28.8 |
| PDTCH3(2,6) | U/D | 46.8 | Conv. | π/4‑QPSK | 62.5 | 62.4 | 64.0 |
| PDTCH3(2,6) | U/D | 46.8 | Turbo | π/4‑QPSK | 62.5 | 62.4 | 64.0 |
| PDTCH3(5,3) | U/D | 117.0 | Turbo | π/4‑QPSK | 156.25 | 156.80 | 160.00 |
| PDTCH3(5,3) | D | 117.0 | Turbo | 16‑APSK | 156.25 | 252.80 | 256.0 |
| PDTCH3(5,12) | U/D | 117.0 | Turbo | π/4‑QPSK | 156.25 | 185.2 | 186.0 |
| PDTCH3(5,12) | U/D | 117.0 | Turbo | 16‑APSK | 156.25 | 257.6 | 259.2 |
| PDTCH3(5,12) | D | 117.0 | Turbo | 16‑APSK | 156.25 | 295.2 | 296.0 |
| PDTCH3(10,3) | D | 234.0 | Turbo | π/4‑QPSK | 312.50 | 344.0 | 347.20 |
| PDTCH3(10,3) | D | 234.0 | Turbo | 16‑APSK | 312.50 | 587.20 | 590.40 |

A complete list of supported modulation and coding schemes is found in ETSI TS 101 376-4-12.

###### 4.3.7.3.1.1 Cell broadcast channels

Traffic can be broadcast on a per spot beam basis using the Cell Broadcast CHannel (CBCH). This channel is downlink only and used to broadcast Short Message Service Cell Broadcast (SMSCB) information to MESs. When the FCCH is used the CBCH is broadcast using a DC6 burst structure and when the FCCH3 is used the CBCH is broadcast using a DC12 burst structure.

##### 4.3.7.3.2 PUI and PRI

A MAC/RLC block consists of PUI (Public User Information) and PRI (Private User Information) as shown in Fig. 85. Downlink blocks may include an extended PUI which contains an uplink allocation mapping or ULMAP. This field allows multiple uplink assignments to different MES using the same downlink burst. See ETSI TS 101 376-4-12 and ETSI TS 101 376-5-2 for more detailed information.

FIGURE 87



The payload is the Private Information (PRI) delivered to the physical layer by the link layer. The PRI includes the MAC header and the other higher layer overhead. The peak payload transmission rate (without CRC) is defined as the maximum attainable PRI data rate with continuous transmission, i.e. using all 24 timeslots in a frame. The above peak-rates are achieved with rate 3/4 coding for PDTCH (4,3) and PDTCH (5,3) and are achieved with rate 4/5 for PDTCH (1,6) and PDTCH (2,6). The peak rates of LDPC coded PDTCH2 (5,12) and LDPC coded PDTCH2 (5,3) are achieved for different modulation schemes with the following coding rate combinations:

– Downlink: 32 APSK Rate 4/5, 16 APSK Rate 4/5, π/4 QPSK Rate 9/10.

– Uplink: 16 APSK Rate 9/10, π/4 QPSK Rate 9/10.

The peak rates of Turbo coded PDTCH3 (5,12) and PDTCH3 (5,3) are achieved for different modulation schemes with the following coding rate combinations:

– Downlink: 16 APSK Rate 2/3, π/4 QPSK Rate 5/6.

– Uplink: π/4 QPSK Rate 5/6, for PDTCH3 (5,3), and

– Uplink: 16 APSK Rate 4/7 for PDTCH3 (5,12).

The peak rates of Turbo coded PDTCH3 (10,3) are achieved for different modulation schemes with the following coding rate combinations:

– Downlink: 16 APSK Rate 2/3, π/4 QPSK Rate 5/6.

##### 4.3.7.3.3 Control channels

Control channels (ETSI TS 101 376-5-2) are intended to carry signalling or synchronization data. Three categories of control channels are defined: broadcast, common and dedicated. Specific channels within these categories are defined. As with traffic channels, some control channels are applicable to A, Gb and Iu modes and some are specific to a subset of modes. Where no mode is indicated, the control channel is applicable to both. Two sets of control channels are defined. Depending on available satellite e.i.r.p. one set may be preferred over the other. All broadcast and common control channels are transmitted on a 31.25 kHz carrier.

###### 4.3.7.3.3.1 Broadcast control channels

4.3.7.3.3.1.1 FCCH or FCCH3

The Frequency Correction CHannel (FCCH or FCCH3) carries information for frequency correction of the mobile earth station (MES). This frequency correction is only required for operation of the radio subsystem. The FCCH is also used for system information cycle synchronization of the MES. The FCCH is downlink only.

The FCCH burst is a real chirp signal spanning three slots. The complex envelope of the transmitted burst is defined as follows (ETSI TS 101 376-5-4):



where ϕ0 is a random phase and p(t) is the ramp function as defined in the published specification. This signal defines the chirp sweeping range as (−7.488 kHz, 7.488 kHz).

The FCCH3 burst is a real chirp signal spanning twelve slots. The complex envelope of the transmitted burst is defined as follows:



where ϕ0 is a random phase and *p*(*t*) is the ramp function as defined in the specification. This signal defines the chirp sweeping range as (−3.744 kHz to 3.744 kHz).

4.3.7.3.3.1.2 GBCH or GBCH3

The GPS Broadcast Control CHannel (GBCH or GBCH3) carries global positioning system (GPS) time information and GPS satellite ephemeris information to the MESs. (The PCH described below may also contain almanac data). The GBCH is downlink only.

Each GBCH burst contains 108 bits of information and is broadcast using the two-slot DC2 burst. The DC2 burst uses π/4 CQPSK modulation is encoded using a convolutional code. The GBCH3 contains the same information as the GBCH but is formatted to fit a DC12 burst structure. The DC12 burst structure uses π/2 BPSK modulation and convolutional coding. Each GBCH3 burst contains 192 bits of information.

4.3.7.3.3.1.3 BCCH

The Broadcast Control CHannel (BCCH) broadcasts system information to the MESs and is downlink only. The BCCH system information parameters are described in (ETSI TS 101 376-4-8). Each BCCH burst contains 192 bit of information. The BCCH is broadcast using either the BCCH burst structure or the DC12 burst structure. The BCCH burst structure is six-slot long and is broadcast using π/4 CQPSK modulation is encoded using a convolutional code.

###### 4.3.7.3.3.2 Common control channels

The Common Control CHannel (CCCH) includes the following common control-type channels.

4.3.7.3.3.2.1 PCH

The Paging CHannel (PCH): downlink only, used to page MESs. Each PCH burst contains 192 bits of information and is broadcast using either the six-slot DC6 burst or the DC12 burst. The DC6 burst is broadcast using π/4 CQPSK modulation is encoded using a convolutional code.

4.3.7.3.3.2.2 RACH or RACH3

The Random Access CHannel (RACH): uplink only, used to request the allocation of traffic channel resources.

4.3.7.3.3.2.3 AGCH

The Access Grant CHannel (AGCH): downlink only, used to allocate traffic channel resources to the user terminal or MES. Each AGCH burst contains 192 bits of information and is broadcast using either the six-slot DC6 burst or the DC12 burst.

4.3.7.3.3.2.4 BACH

The Basic Alerting CHannel (BACH): downlink only, used to alert MESs. The BCCH system information parameters are described in ETSI TS 101 376-4-8. Each BCCH burst contains 192 bit of information. The BCCH is broadcast using either the BCCH burst structure or the DC12 burst structure. The BCCH burst structure is six-slot long and is broadcast using /4 CQPSK modulation is encoded using a convolutional code.

#### 4.3.7.4 FEC

GMR-1 3G adopts various state-of‑the-art FEC schemes (ETSI TS 101 376-5-3). Table 61 lists the FEC schemes supported by GMR-1 3G.

TABLE 61

|  |  |  |
| --- | --- | --- |
| FEC Code | FEC block size  (Information bits) | Comments |
| Convolutional Code | Between 20-1 000 bits | Constraint length K = 5, 6, 7, and 9. Mother code of rate 1/4, 1/3, and 1/2. Various rates by puncturing. Tail biting for small FEC block |
| Turbo Code | Between 200-6 000 bits | Turbo code. Various Rates by puncturing |
| Reed Solomon Code | Blocks of 9 information symbols of 4 bits | Systematic (15,9) Reed-Solomon |
| Extended Golay Code | 12 bit information bits | (12,24) extended Golay code |
| LDPC (Low Density Parity Check) Code | Between 500-9 000 bits | Optimized for small FEC block size |
| CRC (Cyclic Redundancy Check) Code | Between 20-9 000 bits | 3, 5, 8, 12, 16 bit CRC for error detection |

The FEC coded bits are additionally punctured, interleaved and scrambled before modulation. Details can be found in ETSI TS 101 376-5-3.

#### 4.3.7.5 Modulation

GMR-1 3G adopts power and spectrally efficient modulations as specified in ETSI TS 101 376-5-4. The specified modulation schemes are:

– Dual Chirp

– π/2-BPSK, π/4-QPSK, 16 APSK and 32 APSK.

Dual chirp is a constant envelope frequency modulated signal that is used for MES initial timing and frequency acquisition of Frequency Correction Channel (FCCH). The dual chirp waveform is shown in Fig. 88.

FIGURE 88



Control channels use either π/2-BPSK or π/4-QPSK, and traffic channels use π/2-BPSK, π/4‑QPSK, 16 APSK or 32 APSK depending on data rate. The signal constellations for π/2-BPSK and π/4-QPSK are shown in Fig. 89 and for 16 APSK and 32 APSK in Fig. 90.

FIGURE 89



FIGURE 90



The modulated signal is pulse-shaped by the square root raised cosine (SQRC) filter with a roll-off factor 0.35. As an example, the Power Spectral Density (PSD) of π/4-QPSK modulated PNB3(5,3) is shown in Fig. 91.

FIGURE 91



Table 62 lists the Peak-to-Average-Power-Ratio (PAPR) for different modulation schemes. The adopted GMR-1 3G modulation schemes such as π/2-BPSK, π/4-QPSK, or 16-APSK have much smaller PAPR than conventional BPSK, QPSK and 16-QAM.

TABLE 62

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Modulation | π/2-BPSK | BPSK | QPSK | π/4- QPSK | 16-QAM | 16-APSK | 32-APSK |
| PAPR (dB) | 1.84 | 3.86 | 3.86 | 3.17 | 6.17 | 4.72 | 5.91 |

#### 4.3.7.6 Power control and link adaptation

##### 4.3.7.6.1 General

GMR-1 3G supports power control and link adaptation, as specified in ETSI TS 101 376-5-6. The power control and link adaptation allows the system to manage the radio resources optimally according to the MES receive and transmit channel quality.

The objective of the modulation-code rate adaptation is:

– to adjust the transmission throughput according to each user’s unique channel environment while maintaining a reliable transmission.

For the mobile return link, the objectives of power control are to:

– reduce co-channel interference at the satellite receiver by ensuring that all signals from different UTs are received at approximately the same level at the satellite;

– minimize MES power drain by using the minimum equivalent isotropically radiated power (e.i.r.p.) necessary to close the link for a given channel condition.

##### 4.3.7.6.2 Link adaptation

Packet data services use coding rate and modulation scheme control procedures both over the forward and return link (ETSI TS 101 376-5-6).

The network selects the coding rate/modulation scheme for both the forward and return directions based on the signal quality and power level information available at the network or reported by the terminals.

The terminal identifies the coding rate and modulation selected by the network by reading the Physical Layer Header (PUI) on each forward burst.

##### 4.3.7.6.3 Power control

Dedicated channels utilize power control for both return and forward link (ETSI TS 101 376-5-6). In packet data service, power control is used in the return direction. The transmit power at the MES is regulated so as to achieve expected, but not excessive, signal quality at the network end. The power transmitted by the terminal can be changed over a range of 24 dB below the maximum power with 0.4 dB resolution.

Both closed loop and open loop power control are supported.

In the closed-loop power control, the MES’s transmit power is controlled based upon measurements of the received signal quality made at the network. Due to the round trip time, for the closed-loop, the reaction speed to channel variation is slow. Closed‑loop control is intended to mitigate shadowing events. The network makes the selection of the terminal power control based on signal quality measurement made by the network physical layer over the transmitted bursts from MES.

In the open loop power control, the measurements of received signal quality at the MES are processed and are used to quickly adjust the MES’s transmit power should the signal quality suddenly deteriorate. This approach assumes that there is some degree of statistical correlation between the receive and transmit shadowing. This approach is used at the UTs to speed the power control response to abrupt shadowing events.

#### 4.3.7.7 Control channel organization

A mobile satellite system may use either the three-slot FCCH or the twelve-slot FCCH3 burst for synchronization (ETSI TS 101 376-5-2). The choice would depend on the available e.i.r.p. for the satellite. Table 63 lists the burst types used for the broadcast and common control channels for the cases where the FCCH is used and Table 64 lists the burst types used for the broadcast and common control channels for the case where the FCCH3 is used.

An MES would scan for either the FCCH or the FCCH3 and would be able to receive the other control channels depending on which version of the frequency correction channel it received.

TABLE 63

|  |  |
| --- | --- |
| Control channel | Burst type |
| FCCH | FCCH |
| BCCH | BCCH |
| GBCH | DC2 |
| PCH | DC6 |
| AGCH | DC6 |
| BACH | BACH |

TABLE 64

|  |  |
| --- | --- |
| Control channel | Burst type |
| FCCH3 | FCCH3 |
| BCCH | DC12 |
| GBCH3 | DC12 |
| PCH | DC12 |
| AGCH | DC12 |
| BACH | BACH |

The organization of control channel broadcast on the 31.25 kHz BCCH/CCCH channel when the FCCH is used is shown in Fig. 92. Note that the FCCH is a three-slot burst and the BCCH and PCH are six-slot bursts. When the FCCH is used 6 out of the 24 time slots in each frame are dedicated to broadcast of the control channels. The twenty four-slot frame is shown in Fig. 93. Note the GBCH is broadcast two time slots later than the BCCH/CCCH within each frame. The unused time slots from time slot 12 to time slot 23 within the frame may be used for traffic. The Physical Channel Relative Timeslot Number (PCRTN) and the System Information relative frame number are described in ETSI TS 101 376-5-2. The number after PCH and BACH refer to the paging and alerting groups. This is described in ETSI TS 101 376-5-2.

FIGURE 92



FIGURE 93



Figure 94 shows the organization of control channel broadcast on the 31.25 kHz BCCH/CCCH channel when the FCCH3 is used is shown in Fig. 96. Note that the FCCH3, BCCH, PCH and AGCH are all twelve-slot bursts. As can be seen from Fig. 93, the first twelve time slots of the twenty-four time slot frame are used to transmit the control channels and the remaining twelve time slots are available for traffic.

The return link allocation in both Fig. 95 and Fig. 97 show a 12-slot RACH window. In very large spot or regional beams where the timing uncertainty is large, GMR-1 3G allows the RACH window to be extended arbitrarily up to the full 24 time slots leaving the remainder for traffic. The forward link traffic can accommodate broadcast, multicast or dedicated traffic depending on the needs of the system.

FIGURE 94

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S I R | PC6d PCRTN | | | | | |  | S I R | PC6d PCRTN | | | | | |  | S I R | PC6d PCRTN | | | | | |  | S I R | PC6d PCRTN | | | | | |
| F N | 0 | 1 | 2 | 3 | 4 | 5 |  | F N | 0 | 1 | 2 | 3 | 4 | 5 |  | F N | 0 | 1 | 2 | 3 | 4 | 5 |  | F N | 0 | 1 | 2 | 3 | 4 | 5 |
| 0 | FCCH | | | CICH | | |  | 16 | FCCH | | | CICH | | |  | 32 | FCCH | | | CICH | | |  | 48 | FCCH | | | CICH | | |
| 1 | BACH #0 | | BACH #0 | | BACH #0 | |  | 17 | BACH #0 | | BACH #0 | | BACH #0 | |  | 33 | BACH #0 | | BACH #0 | | BACH #0 | |  | 49 | BACH #0 | | BACH #0 | | BACH #0 | |
| 2 | BCCH | | | | | |  | 18 | BCCH | | | | | |  | 34 | BCCH | | | | | |  | 50 | BCCH | | | | | |
| 3 | BACH #4 | | BACH #4 | | BACH #4 | |  | 19 | BACH #4 | | BACH #4 | | BACH #4 | |  | 35 | BACH #4 | | BACH #4 | | BACH #4 | |  | 51 | BACH #4 | | BACH #4 | | BACH #4 | |
| 4 | PCH#0 | | | | | |  | 20 | PCH#0 | | | | | |  | 36 | PCH#0 | | | | | |  | 52 | PCH#0 | | | | | |
| 5 | BACH #0 | | BACH #0 | | BACH #0 | |  | 21 | BACH #1 | | BACH #1 | | BACH #1 | |  | 37 | BACH #2 | | BACH #2 | | BACH #2 | |  | 53 | BACH #3 | | BACH #3 | | BACH #3 | |
| 6 | BACH #1 | | BACH #1 | | BACH #1 | |  | 22 | BACH #1 | | BACH #1 | | BACH #1 | |  | 38 | BACH #1 | | BACH #1 | | BACH #1 | |  | 54 | BACH #1 | | BACH #1 | | BACH #1 | |
| 7 | BACH #5 | | BACH #5 | | BACH #5 | |  | 23 | BACH #5 | | BACH #5 | | BACH #5 | |  | 39 | BACH #5 | | BACH #5 | | BACH #5 | |  | 55 | BACH #5 | | BACH #5 | | BACH #5 | |
| 8 | FCCH | | | CICH | | |  | 24 | FCCH | | | CICH | | |  | 40 | FCCH | | | CICH | | |  | 56 | FCCH | | | CICH | | |
| 9 | BACH #2 | | BACH #2 | | BACH #2 | |  | 25 | BACH #2 | | BACH #2 | | BACH #2 | |  | 41 | BACH #2 | | BACH #2 | | BACH #2 | |  | 57 | BACH #2 | | BACH #2 | | BACH #2 | |
| 10 | BCCH | | | | | |  | 26 | BCCH | | | | | |  | 42 | BCCH | | | | | |  | 58 | BCCH | | | | | |
| 11 | BACH #6 | | BACH #6 | | BACH #6 | |  | 27 | BACH #6 | | BACH #6 | | BACH #6 | |  | 43 | BACH #6 | | BACH #6 | | BACH #6 | |  | 59 | BACH #6 | | BACH #6 | | BACH #6 | |
| 12 | PCH#1 | | | | | |  | 28 | PCH#1 | | | | | |  | 44 | PCH#1 | | | | | |  | 60 | PCH#1 | | | | | |
| 13 | BACH #7 | | BACH #7 | | BACH #7 | |  | 29 | BACH #7 | | BACH #7 | | BACH #7 | |  | 45 | BACH #7 | | BACH #7 | | BACH #7 | |  | 61 | BACH #7 | | BACH #7 | | BACH #7 | |
| 14 | BACH #3 | | BACH #3 | | BACH #3 | |  | 30 | BACH #3 | | BACH #3 | | BACH #3 | |  | 46 | BACH #3 | | BACH #3 | | BACH #3 | |  | 62 | BACH #3 | | BACH #3 | | BACH #3 | |
| 15 | BACH #4 | | BACH #4 | | BACH #4 | |  | 31 | BACH #5 | | BACH #5 | | BACH #5 | |  | 47 | BACH #6 | | BACH #6 | | BACH #6 | |  | 63 | BACH #7 | | BACH #7 | | BACH #7 | |

FIGURE 95



FIGURE 96

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S I R | PC12d PCRTN | | | | | | | | | | | |  | S I R | PC12d PCRTN | | | | | | | | | | | |  | S I R | PC12d PCRTN | | | | | | | | | | | |  | S I R | PC12d PCRTN | | | | | | | | | | | |
| F N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |  | F N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |  | F N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |  | F N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 0 | FCCH3 | | | | | | | | | | | |  | 16 | FCCH3 | | | | | | | | | | | |  | 32 | FCCH3 | | | | | | | | | | | |  | 48 | FCCH3 | | | | | | | | | | | |
| 1 | GBCH3 | | | | | | | | | | | |  | 17 | GBCH3 | | | | | | | | | | | |  | 33 | GBCH3 | | | | | | | | | | | |  | 49 | GBCH3 | | | | | | | | | | | |
| 2 | BCCH | | | | | | | | | | | |  | 18 | BCCH | | | | | | | | | | | |  | 34 | BCCH | | | | | | | | | | | |  | 50 | BCCH | | | | | | | | | | | |
| 3 | PCH#0 | | | | | | | | | | | |  | 19 | PCH#0 | | | | | | | | | | | |  | 35 | PCH#0 | | | | | | | | | | | |  | 51 | PCH#0 | | | | | | | | | | | |
| 4 | BACH#4 | | | | | | BACH#2 | | | | | |  | 20 | BACH#4 | | | | | | BACH#2 | | | | | |  | 36 | BACH#4 | | | | | | BACH#2 | | | | | |  | 52 | BACH#4 | | | | | | BACH#2 | | | | | |
| 5 | GBCH3 | | | | | | | | | | | |  | 21 | GBCH3 | | | | | | | | | | | |  | 37 | GBCH3 | | | | | | | | | | | |  | 53 | GBCH3 | | | | | | | | | | | |
| 6 | BACH#0 | | | | | | BACH#6 | | | | | |  | 22 | BACH#0 | | | | | | BACH#6 | | | | | |  | 38 | BACH#0 | | | | | | BACH#6 | | | | | |  | 54 | BACH#0 | | | | | | BACH#6 | | | | | |
| 7 |  | | | | | | | | | | | |  | 23 |  | | | | | | | | | | | |  | 39 |  | | | | | | | | | | | |  | 55 |  | | | | | | | | | | | |
| 8 | FCCH3 | | | | | | | | | | | |  | 24 | FCCH3 | | | | | | | | | | | |  | 40 | FCCH3 | | | | | | | | | | | |  | 56 | FCCH3 | | | | | | | | | | | |
| 9 | GBCH3 | | | | | | | | | | | |  | 25 | GBCH3 | | | | | | | | | | | |  | 41 | GBCH3 | | | | | | | | | | | |  | 57 | GBCH3 | | | | | | | | | | | |
| 10 | BCCH | | | | | | | | | | | |  | 26 | BCCH | | | | | | | | | | | |  | 42 | BCCH | | | | | | | | | | | |  | 58 | BCCH | | | | | | | | | | | |
| 11 | PCH#1 | | | | | | | | | | | |  | 27 | PCH#1 | | | | | | | | | | | |  | 43 | PCH#1 | | | | | | | | | | | |  | 59 | PCH#1 | | | | | | | | | | | |
| 12 | BACH#1 | | | | | | BACH#5 | | | | | |  | 28 | BACH#3 | | | | | | BACH#7 | | | | | |  | 44 | BACH#1 | | | | | | BACH#5 | | | | | |  | 60 | BACH#1 | | | | | | BACH#5 | | | | | |
| 13 | GBCH3 | | | | | | | | | | | |  | 29 | GBCH3 | | | | | | | | | | | |  | 45 | GBCH3 | | | | | | | | | | | |  | 61 | GBCH3 | | | | | | | | | | | |
| 14 | BACH#3 | | | | | | BACH#7 | | | | | |  | 30 | BACH#1 | | | | | | BACH#5 | | | | | |  | 46 | BACH#3 | | | | | | BACH#7 | | | | | |  | 62 | BACH#3 | | | | | | BACH#7 | | | | | |
| 15 | BACH#1 | | | | | | BACH#5 | | | | | |  | 31 | BACH#3 | | | | | | BACH#7 | | | | | |  | 47 | BACH#0 | | | | | | BACH#6 | | | | | |  | 63 | BACH#4 | | | | | | BACH#2 | | | | | |

FIGURE 97



#### 4.3.7.8 MAC/RLC layer design

MAC layer design (ETSI TS 101 376-4-12 and ETSI TS 101 376-4-14) for SRI-H air interface is based on GPRS/EDGE MAC with satellite specific optimizations to mitigate impacts of long delay. These optimizations are geared to improve throughput by minimizing chattiness of protocols and maximally utilizing bandwidth provided by the physical layer.

The MAC provides the following functions:

– Configuring the mapping between logical channels and basic channels.

– Selecting logical channels for signalling radio bearer.

– Selecting logical channels for user radio bearer.

– Assignment, reconfiguration and release of shared resources for a TBF.

– MES measurement reporting and control of reporting.

– Broadcasting/listening of BCCH and CCCH.

– Ciphering and deciphering for Transparent Mode in Iu Mode.

– Identification of different traffic flows of one or more MESs on the shared channel.

– Multiplexing/demultiplexing of higher layer PDUs.

– Multiplexing/demultiplexing of multiple TBFs on the same PDTCH.

– Scheduling of RLC/MAC data and control PDUs delivered to the physical channel on a shared channel.

– Splitting/recombining RLC/MAC PDUs onto/from several shared logical channels.

– Mapping multicast bearers to shared TFIs.

The RLC operates in Acknowledge mode (AM) or UnAcknowledged mode (UM). Functions include:

**–** Segmentation of upper layer PDUs into RLC data blocks.

– Concatenation of upper layer PDUs into RLC data blocks.

– Padding to fill out RLC data block.

– Reassembly of RLC data blocks into upper layer PDU.

– In-sequence delivery of upper layer PDUs.

– Link Adaptation.

– Ciphering and deciphering in Iu Mode.

– Sequence number check to detect lost RLC blocks.

For Iu mode of operation, RLC can also operate in Transparent Mode for carrying spectrally efficient VoIP.

In addition to the above, RLC provides the following functions when operating in ACK mode:

– Backward Error Correction (BEC) procedure enabling the selective retransmission of RLC data blocks.

– Discard of RLC SDUs not yet segmented into RLC PDUs, according to the delay requirements of the associated Radio Bearers.

#### 4.3.7.9 RRC layer design

Radio Resource Control (RRC) layer design for SRI-H is based on ETSI GERAN Iu mode RRC specifications (ETSI TS 101 376-4-13) specifications with satellite specific optimizations to cater to long delay environments and achieve better spectral efficiency.

RRC state model is based on RRC states defined in ETSI TS 101 376-4-13 and is illustrated in Fig. 98.

FIGURE 98



RRC functions include:

– Assignment, reconfiguration, and release of radio resources for the RRC connection.

– Establishment, reconfiguration, and release of Radio Bearers.

– Release of signalling connections.

– Paging.

– Routing of higher layer PDUs.

– Control of requested QoS.

– Control of Ciphering.– Integrity Protection.

– Support for Location Services.

– Timing advance control.

Satellite specific enhancements in RRC layer includes:

– Enhancements to Cell Update procedure to reduce number of round-trips.

– Fast RRC Connection Setup using RACH.

– Fast GRA Update using RACH/PRACH.

– Fast RRC Connection Reject/Connection Release using AGCH.

– RAB Binding procedure to identify PTT bearers.

– RAB Binding procedure to identify multicast bearer.

– RB Reconfiguration procedure for intra-beam carrier relocation.

#### 4.3.7.10 PDCP layer design

Packet Data Convergence Protocol (PDCP) layer design is defined in ETSI TS 101 376-4-15 with satellite specific enhancements. The PDCP structure is shown in Fig. 99.

FIGURE 99



The PDCP performs the following functions:

– Header compression and decompression of IP data streams (e.g. TCP/IP and RTP/UDP/IP headers for IPv4 and IPv6) at the transmitting and receiving entity, respectively.

– Transfer of user data. This function is used for conveyance of data between users of PDCP services.

– Maintenance of PDCP sequence numbers.

– Data compression using V.44.

PDCP uses the services provided by the Radio Link Control (RLC) sublayer.

Satellite specific optimizations include:

– Early context establishment procedures.

– Zero byte header compression.

– Efficient handling of RTCP packets.

– Efficient handling of IPv6 RTP/UDP/IP headers.

– Interaction with TCP Performance Enhancing Proxy.

Benefits of PDCP layer functions include:

– Improve spectral efficiency and decrease satellite power usage.

– Improve capacity.

– Improve MES battery life.

– Improve interactive response time.

– Reduce packet loss rate.

#### 4.3.7.11 Terminal types

GMR-1 3G supports a wide range of terminal types from small handheld terminals to large high gain fixed or transportable terminals. Both 2.45 kbit/s and 4 kbit/s voice rates are supported using zero-byte header compression, as well as IP data traffic with bandwidths dependent on terminal type. The following terminal characteristics are supported.

– GMR-1 3G terminal type identifier (signalling code point).   
See ETSI TS 101 376-5-2.

– Multislot class (limitations on burst transmissions for small terminals).   
See ETSI TS 101 376-5-2.

– Power class. See ETSI TS 101 376-5-5.

– Supported channel types (FCCH and/or FCCH3).   
See ETSI TS 101 376-5-2.

– Supported traffic channel types based on terminal capability.

– Transmission capability (half or full duplex).

– Mode of use (handheld, fixed, etc.).

– Antenna type (internal or external, linearly or circularly polarized, etc.).

– Network interfaces supported (A, Gb or Iu mode).

– Operating band (S-band, L-band).   
See ETSI TS 101 376-5-5.

#### 4.3.7.12 Conclusion

GMR-1 3G comprises three releases of an ETSI and TIA standard for mobile satellite communications to support IMT-2000 services. GMR-1 is currently used in mobile satellite systems covering Europe, Africa, Asia and Middle East. GMR-1 3G is currently being deployed in North America.

GMR-1 3G provides IMT-2000 services to a wide variety of terminals and supports packet data throughputs from 2.45 to 592 kbit/s.

GMR-1 3G supports spectrally efficient zero-byte header compressed voice.

GMR-1 3G is currently available as a published air interface specification from ETSI (ETSI TS 101 376) and TIA (S-J-STD-782).

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