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Technical Specification

GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 5: Radio interface physical layer specifications; Sub-part 7: Radio Subsystem Synchronization; GMR-1 3G 45.010

Reference

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Contents

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Foreword

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

The present document is part 5, sub-part 7 of a multi-part deliverable covering the GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service, as identified below:

Part 1: "General specifications";

Part 2: "Service specifications";

Part 3: "Network specifications";

Part 4: "Radio interface protocol specifications";

Part 5: "Radio interface physical layer specifications":

Sub-part 1: "Physical Layer on the Radio Path: General Description";

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 3 specifications. Release 3 specifications are identified in the title and can also be identified by the version number:

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

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

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

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

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

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

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

where:

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

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

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

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

- If a GMR specification does not exist, the corresponding GSM or 3GPP specification may or may not apply. The applicability of the GSM and 3GPP specifications is defined in GMR 1 3G 41.201 [8].

1 Scope

The present document presents the requirements for synchronizing timing and frequency between the MES and the Gateway Station (GS) in the GMR-1 3G Mobile Satellite System for circuit switch and packet switch modes of operation.

2 References

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

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

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

2.1 Normative references

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

In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document.*

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

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

[2] GMR-1 3G 44.008 (ETSI TS 101 376-4-8): "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 4: Radio interface protocol specifications; Sub-part 8: Mobile Radio Interface Layer 3 Specifications".

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

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

[5] GMR-1 3G 45.008 (ETSI TS 101 376-5-6): "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 5: Radio interface physical layer specifications; Sub-part 6: Radio Subsystem Link Control".

[6] GMR-1 05.010 (ETSI TS 101 376-5-7) (V1.3.1): "GEO-Mobile Radio Interface Specifications (Release 1); Part 5: Radio interface physical layer specifications; Sub-part 7: Radio Subsystem Synchronization".

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

[7] GMR-1 3G 44.060 (ETSI TS 101 376-4-12): "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 4: Radio interface protocol specifications; Sub-part 12: Mobile Earth Station (MES) - Base Station System (BSS) interface; Radio Link Control/Medium Access Control (RLC/MAC) protocol".

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

[9] GMR-1 3G 44.118 (ETSI TS 101 376-4-13): "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 4: Radio interface protocol specifications; Sub-part 13: Radio Resource Control (RRC) protocol; Iu Mode".

2.2 Informative references

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

Not applicable.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in GMR-1 3G 41.201 [8] and the following apply:

Frequency Correction (FC): in-call frequency correction sent over FACCH channel

frequency offset: frequency correction sent over AGCH channel

guard time violation: message to indicate the violation of Rx/Tx burst guard time

MAC_FORWARD_TS_OFFSET: offset in number of timeslots of MAC-slot 0 or D-MAC-slot 0 relative to the start of the downlink frame

MAC_RETURN_TS_OFFSET: offset in number of timeslots of MAC-slot 0 or D-MAC-slot 0 relative to the start of the uplink frame

Precorrection Indication (PI): timing delay pre-compensated by the MES in the RACH transmission

RACH_TS_OFFSET: RACH window offset relative to the start of BCCH window within the same frame, measured in number of timeslots

RACH_SYMBOL_OFFSET: RACH timing offset in symbols

NOTE: The offset between RACH window and the start of the reference frame seen from the MES. Measured in number of symbols.

SA_BCCH_STN: BCCH window offset relative to the start of the frame, in number of timeslots

SA_FREQ_OFFSET: twice of the downlink beam centre Doppler due to satellite motion only

SA_SIRFN_DELAY: within each multiframe, the first FCCH channel frame number relative to the start of the multiframe

SB_FRAME_TS_OFFSET: offset between downlink frame N and uplink frame N + 7 at the spot-beam centre, measured in number of timeslots

SB_SYMBOL_OFFSET: additional offset between downlink frame N and uplink frame N + 7 at the spot beam centre, measured in number of symbols

Timing Correction (TC): in-call timing correction sent over FACCH channel

timing offset: timing correction sent over AGCH channel

USF Delay Value: if an MES receives a USF in its receive downlink frame N, it applies the USF (i.e. transmits corresponding to the received USF grant) on the uplink frame numbered (N + USF Delay Value)

NOTE: USF Delay Value is decoded from USF_DELAY and USF_DELAY Adjustment parameters in BCCH System Information, and it can take values of 6, 7, 8, 9 or 10.

3.2 Abbreviations

For the purposes of the present document, the abbreviations defined in GMPRS-1 01.004 [1] apply.

4 General description of synchronization system

Same as clause 4 in GMR-1 05.010 [6], with addition of following at the end of the first paragraph.

The description above also applies to S-band.

4.1 System timing structure

Same as clause 4.1 in GMR-1 05.010 [6].

4.2 Timebase counter

Same as clause 4.2 in GMR-1 05.010 [6].

4.3 General requirement

4.3.1 Timing and frequency reference point

Same as clause 4.3.1 in GMR-1 05.010 [6].

4.3.2 MES requirement

Same as clause 4.3.2 in GMR-1 05.010 [6], with the addition of the following:

- MES receiver's time and frequency search ranges (apertures) shall be large enough to accommodate the variations (specified in clause 4.3.3) in the network transmit time and frequency in addition to the satellite-MES relative motion induced time and frequency shifts (see annex A for an informative description), MES oscillator drifts, etc. The MES receiver, operating with such values of time and frequency apertures, shall achieve the performance requirements (i.e. BER, FER, time and frequency estimation accuracies, etc.) specified in GMR-1 3G 45.005 [4].

4.3.3 Network requirement

Same as clause 4.3.3 in GMR-1 05.010 [6], with the addition of the following:

- The network shall ensure that the maximum variation between the transmit time of a CCCH burst and the transmit time of a PDCH burst does not exceed 12 µs. Similarly, the maximum burst-to-burst variation in the PDCH transmit time shall not exceed 4 µs. Burst-to-burst variations in the network transmit frequency shall not exceed 10 Hz.

4.3.4 Measurement conditions

Same as clause 4.3.4 in GMR-1 05.010 [6].

5 Timing synchronization, TtG/GtT call

Same as clause 5 in GMR-1 05.010 [6], except for the addition of the next paragraph, which follows the second paragraph.

For the case in which the MES operates in the packet mode, shared or dedicated, receive timing shall be corrected by monitoring BCCH, PCH, PDCH, or DCH and transmission timing shall be corrected with factors provided by the Gateway Station (GS). The GS provides correction factors via AGCH, PACCH, or DACCH based on the MES mode and situation, which is explained here.

5.1 General description

Same as clause 5.1 in GMR-1 05.010 [6], except for the addition of the next paragraph, which follows the fifth paragraph.

If packet transfer mode is initiated via the RACH then the procedure is identical to that described for circuit switched service in clause 5.3.1. Packet switched time and frequency synchronization for the PDCH and the PRACH is described in clause 5.6.

5.2 Timing of forward link common channels

Same as clause 5.2 in GMR-1 05.010 [6], except for the addition of the following text.

When the FCCH3 is used, the timing of forward link common channels is defined in GMR-1 3G 45.002 [3]. An outline is given below for convenience.

The BCCH/CCCH bursts occupy twelve consecutive timeslots. In each spot beam, a set of common channels are defined: FCCH3, BCCH, PCH, GBCH3 and AGCH. These channels follow a fixed repetition pattern with repetition duration equal to one multiframe. The position of the BCCH and FCCH3 between neighbouring beams shall be offset in frames as well as in timeslots to facilitate MES fast timing/frequency acquisition and satellite power spread in time.

5.2.1 FCCH/BCCH timing

Same as clause 5.2.1 in GMR-1 05.010 [6], except for the addition of the following text.

For FCCH3/BCCH timing, refer to GMR-1 3G 45.002 [3].

5.2.2 CCCH timing

Same as clause 5.2.2 in GMR-1 05.010 [6], except for the addition of the following text.

When the FCCH3 is used, CCCH timing, is described in GMR-1 3G 45.002 [3].

5.3 Idle mode timing synchronization

5.3.1 Initial timing acquisition

Same as clause 5.3.1 in GMR-1 05.010 [6] except for the addition of the following text.

The specification applies identically when the FCCH3 is used except that reference should be made to GMR-1 3G 45.008 [5].

5.3.2 Paging mode

Same as clause 5.3.2 in GMR-1 05.010 [6] except for the addition of the following text.

The specification applies identically when the FCCH3 is used except that reference should be made to GMR-1 3G 45.005 [4] and GMR-1 3G 45.008 [5].

5.3.3 Alerting mode

Same as clause 5.3.3 in GMR-1 05.010 [6] except for the addition of the following text.

The specification applies identically when the FCCH3 is used except that reference should be made to GMR-1 3G 45.002 [3] and GMR-1 3G 45.005 [4].

5.4 Synchronization at initial access

5.4.1 Synchronization process

Same as clause 5.4.1 in GMR-1 05.010 [6], with the following addition.

The synchronization process also applies to RACH3.

5.4.2 RACH timing pre-correction

Same as clause 5.4.2 in GMR-1 05.010 [6], with the following additions.

When transmitting RACH/RACH3 the MES shall not apply any pre-correction unless explicitly indicated by the network. The MES shall always offset the transmission RACH/RACH3 with respect to the received control channel reference frame, assuming that the MES located at the beam centre.

The network may send on the AGCH the Immediate Assignment Reject (IAR) message with a reject cause that indicates that the class-2 information bits of the RACH burst are incorrect (e.g. if the RACH burst from the MES does not entirely fit within the RACH window at the network). The IAR message shall contain Timing Correction and Frequency Correction fields (see clauses 5.6.2 and 6.6, and GMR-1 3G 44.008 [2]).

The MES shall retransmit RACH when it receives the IAR message with the reject cause indicating incorrect class-2 bits.

The MES shall apply entire value of the received Frequency Correction to the re-transmitted RACH/RACH3.

All MES Terminal Types except Terminal type C shall apply entire value of the received Timing Correction to the re-transmitted RACH.

An MES of Terminal Type C shall retransmit RACH, in response to an IAR with reject cause indicating incorrect Class-2 bits, with a new value of Precorrection Indication that is derived from the received Timing Correction, as described below:

- The MES of Terminal Type C shall select one of the seven (non-reserved) values of Precorrection Indication shown in the Compensation column of table 5.2 of GMR-1 05.010 [6] such that the selected value, in symbols, is the one closest to one-half of the received Timing Correction converted to units of a symbol (the received Timing Correction is in units of $T_{SB}/40$, whereas the Precorrection Indication is in units of T_{SB} (i.e. 1/23400 seconds)). Equivalently, the selected value of Precorrection Indication, in symbols, shall be the one which is the closest to $(1/80)^{th}$ of the received Timing Correction in units of $T_{SB}/40$. The selected value shall be used as the new value of Precorrection Indication in calculation of RACH_SYMBOL_OFFSET (refer to clause 5.4.3 of GMR-1 05.010 [6]). Furthermore, the MES shall send, in the retransmitted RACH, the applied value of Precorrection Indication by converting it to one of the seven (non-reserved) values of the three-bit code shown in table 5.2 of GMR-1 05.010 [6].

5.4.3 Description of parameters

Same as clause 5.4.3 in GMR-1 05.010 [6], with the following additions for MES of Terminal Type C.

For a retransmitted RACH resulting from receipt of Immediate Assignment Reject message from the network indicating invalid Class-2 RACH information, the MES of Type C shall apply transmit timing offset based on computation of RACH_SYMBOL_OFFSET derived as described in clause 5.4.2. For all other RACH transmissions, an MES of Terminal Type C shall apply transmit timing offset based on computation of RACH_SYMBOL_OFFSET as described in clause 5.4.3 of GMR-1 05.010 [6]. This offset is relative to the start of timeslot 0 of the received TDMA frame in the forward direction.

5.4.4 Timing accuracy

Same as clause 5.4.4 in GMR-1 05.010 [6].

5.5 Dedicated mode synchronization

Same as clause 5.5 in GMR-1 05.010 [6], with the following addition.

Timing synchronization for packet dedicated mode refers to clause 5.6.

5.5.1 In-call timing relationship

Same as clause 5.5.1 in GMR-1 05.010 [6].

5.5.2 In-call synchronization scenario

Same as clause 5.5.2 in GMR-1 05.010 [6].

5.5.3 Transmission timing drift rate

Same as clause 5.5.3 in GMR-1 05.010 [6].

5.5.4 RX/TX guard time violation

Same as clause 5.5.4 in GMR-1 05.010 [6] except for the following changes.

For a terminal type C MES in the packet data mode, the available RX/TX guard time shall be monitored at least once every 15 s. If the guard time is found to be smaller than a predefined threshold of 2 200 µs, the MES shall abort the TBF and send RACH for requesting new packet resource.

For a terminal type E or above MES, the available RX/TX guard time shall be monitored at least once every 15 s. If the guard time is found to be smaller than a predefined threshold of 1 000 µs, the MES shall abort the TBF and send RACH3 for requesting new packet resource.

5.6 Packet transfer mode synchronization

In packet transfer mode, either the PDCH/PDCH3 channels, or the PRACH/PRACH3 channels are used. The synchronization scheme addressed below applies to these channels.

5.6.1 Packet transfer mode timing relationship

The uplink and downlink frame timing relationship described in clause 5.5.1 shall apply to packet transfer mode. The time between the start of receive frame N and the start of transmit frame N + 7 at the MES is given by, ΔT_{OF} .

To interpret the Uplink State Flag (USF) in the downlink PUI (see GMR-1 3G 44.060 [7]), the MES shall apply the following rule. If the MES receives a USF in its receive downlink frame N, it shall apply the USF to the uplink frame numbered (N + USF DELAY Value), where the USF Delay Value is decoded from the USF_DELAY and USF_DELAY_Adjustment parameters that are contained in System Information (see GMR-1 3G 44.008 [2]). The USF Delay Value, after adjustment if any, decodes to values of 6, 7, 8, 9 or 10.

Thus the MES response time is defined as the time measured from the end of the time slot in which the MES received a PNB(m,3), PNB2(m,3), PNB2(m,12), or PNB3(m,n) containing the USF assigned to the MES and the start of the time slot in which the MES is granted uplink access by the USF (see GMR-1 3G 44.060 [7]).

For terminals assigned carrier type PDTCH(4,3), PDTCH(5,3), PDTCH2(5,3), PDTCH3(5,3) or PDTCH3(10,3) the response time is given by:

$$T_{RESP\text{-}1} = \Delta T_{OF} - TS \times MAC\_FORWARD\_TS\_OFFSET + TS \times MAC\_RETURN\_TS\_OFFSET - 5\ ms + (USF\ Delay\ Value - 7) \times 40\ ms.$$

For terminals receiving PDTCH2(5,12) or PDTCH(5,12), the response time is given by:

$$T_{RESP\text{-}1} = \Delta T_{OF} - TS \times MAC\_FORWARD\_TS\_OFFSET + TS \times MAC\_RETURN\_TS\_OFFSET - 20\ ms + (USF\ Delay\ Value - 7) \times 40\ ms.$$

An MES receiving a PDTCH2(5,12) shall decode additional USF values in the Extended PUI. Refer to GMR-1 3G 44.060 [7] for $T_{RESP\text{-}1}$ calculation for the USF values assigned through the Extended PUI.

An MES receiving a PDTCH3(m,n) shall decode additional USF values in the ULMAP. Refer to GMR-1 3G 44.060 [7] for $T_{RESP\text{-}1}$ calculation for the USF values assigned through ULMAP.

For terminals assigned carrier type PDTCH(2,6) and PDTCH(1,6) or receiving PDTCH3(1,6) or PDTCH3(2,6) the response time is given by:

$$T_{RESP\text{-}2} = \Delta T_{OF} - TS \times MAC\_FORWARD\_TS\_OFFSET + TS \times MAC\_RETURN\_TS\_OFFSET - 10\ ms + (USF\ Delay\ Value - 7) \times 40\ ms$$

The range of values for MAC_FORWARD_TS_OFFSET and MAC_RETURN_TS_OFFSET is given in GMR-1 3G 44.008 [2].

The MES shall be able to transmit a PNB in the assigned time slot and frame provided the response time, $T_{RESP\text{-}2}$, is greater than or equal to 40 ms.

The value of $T_{RESP\text{-}2}$ may be such that the terminal type C MES can only partially receive PNB(2,6) when it transmits PNB(1,6) on the uplink. Consider a value $T_{RESP\text{-}2}$ such that the terminal type C MES can receive burst-header of downlink PNB(2,6), but not the PRI. For such values of $T_{RESP\text{-}2}$, the MES of terminal type C shall receive, decode and interpret the burst header of PNB(2,6) (see also GMR-1 3G 45.002 [3] and GMR-1 3G 44.060 [7]).

The GS shall determine USF_DELAY and USF_DELAY Adjustment (if applicable) values for a spot beam such than for every MES within the boundary of the spot beam, the above requirement shall be satisfied.

During the packet transfer mode, the value of $2[T_U - T_0]$ may be updated via PTCCH/D or PACCH messages to compensate for any timing drift caused by MES oscillator and MES-satellite relative motion as described in clause 5.6.2.

5.6.2 Time synchronization for Packet switched channels

The MES receiver timing shall be derived from its internal timebase, but frequently corrected by timing detection of the received PDCH and PDCH3 bursts during packet transfer mode. The task of receiver timing correction has to be performed often enough to handle the worst case timing drift rate specified in clause 4.3.2. The target timing accuracy is to achieve demodulation performances specified by GMR-1 3G 45.005 [4].

In the uplink, a closed-loop synchronization scheme is used. The synchronization process is detailed below:

The GS shall perform the scheduled timing advance mechanism for all MES working in packet transfer mode on a PDCH for which a PTCCH/U is assigned. The GS shall not assign a PTCCH/U on a PDCH3 packet channel. Therefore the GS shall monitor the delay of the PNB bursts sent by the MES on PTCCH/U, if assigned to the MES and respond with timing advance values for all MES performing the procedure on that PDCH. These timing advance values shall be sent via a downlink signalling message on PTCCH/D (see GMR-1 3G 1 44.060 [7]), if assigned to the MES. These are scheduled timing corrections.

The PTCCH/U and PTCCH/D shall be transmitted using the most conservative modulation and coding rate supported by the MES for the shortest duration PDCH burst. The MCS values to be used for different terminal types are defined in table 5.4. For MCS definitions, refer to GMR-1 3G 44.060 [7].

Table 5.4: MCS values and burst types for PTCCH/U and PTCCH/D

Downlink Channel type PDTCH	Terminal type	MCS for PTCCH/D (binary) (see note)	PTCCH/D burst	MCS for PTCCH/U (binary) (see note)	PTCCH/U burst
(2,6)	C	000	PDCH(2,6)	000	PDCH (1,6)
(4,3)	A	0000	PDCH(4,3)	0000	PDCH(4,3)
(5,3)	A	0000	PDCH(5,3)	0000	PDCH(5,3)
(5,3)	D	0011	PDCH(5,3)	0011	PDCH(5,3)
NOTE: MCS coding (3 bits or 4 bits) is dependent on channel type, see GMR-1 3G 44.060 [7].					

The GS shall update the timing advance values for a MES in the next downlink signalling message addressed to that MES following the reception of a packet access burst from the MES. These are initial timing corrections.

The GS may also monitor the delay of the packet normal bursts sent by the MES on PDTCH and PACCH. Whenever an updating of Timing Advance (TA) is needed, the GS may send the new TA value in a link synchronization message (see GMR-1 3G 44.060 [7]). This is unsolicited timing correction.

If the GS does not assign a PTCCH/U to the MES, the GS shall use the unsolicited timing correction mechanism described above.

An MES transmitting PDCH(4,3) or PDCH(5,3) shall apply the received timing correction to all transmitted bursts within T_{RESP-1} of the end of the downlink burst in which the timing correction was received. An MES transmitting PDCH(1,6) or PDCH(2,6) shall apply the received timing correction to all transmitted bursts within T_{RESP-2} of the end of the downlink burst in which the timing correction was received.

The adjustment shall be applied to the MES transmission in such a way: if the Control Flag associated with the Timing Correction message is 1, then this message overrides all previous messages; Otherwise, if the Control Flag is 0, the adjustment shall be made in addition to any previous messages. Refer to GMR-1 3G 44.060 [7] for further description on the timing correction message.

During an active TBF the network should not send to the MES a new timing correction message with control flag set to 0 within 2 seconds of sending a prior timing correction message with control flag set to 0.

The MES shall ignore a Timing Correction message with Control Flag set to 0 if a previous Timing Correction message with Control Flag set to 0 was received within two seconds of the latest message.

The range of the timing adjustment sent by the network shall be from -0,4 ms to +0,4 ms or -375 T_{SB}/40 to +375 T_{SB}/40, with a unit of T_{SB}/40.

In the initial, unsolicited or scheduled correction, the network sends the timing offset of the signal received from the MES. Therefore, the MES shall apply negative of the received value in the timing correction message from the network.

EXAMPLE: If the timing correction value received from the network is +10, the MES shall change the time of the start of the uplink frame relative to the start of the downlink frame by $-10 \times \frac{T_{SB}}{40}$.

Refer to annexes E and F for a description of timer T3202 and for derivation of assigned PTCCH/U and PTCCH/D, respectively.

5.6.3 Transmission timing drift rate

In packet transfer mode, to reduce the number of PTCCH and PRACH messages and to improve timing accuracy and stability of MES transmission, the MES timing drift rate shall be used for transmission timing correction. This timing drift rate R shall be derived from the Frequency Correction message received from AGCH channel as well as PACCH according to clause 5.5.3.

5.6.4 Packet transfer mode timing relationship for handover to dedicated packet channel - Iu mode

This clause only applies to MES operation in Iu mode.

For handover onto a Dedicated packet CHannel (DCH) a MES shall first acquire the FCCH3 and a subsequent BCCH burst to obtain initial frequency and timing synchronization and to derive its receive reference timing within the spot beam.

As part of the signalling prior to handover the MES shall receive a Radio Bearer Reconfiguration message (see GMR-1 3G 44.118 [9]) that includes a Physical Information IE that specifies the assigned physical channel description as well as Handover Reference IE that provides information needed for transmit timing synchronization. The MES transmit timing shall be pre-calculated by the network based on the prior known MES position. This timing pre-correction shall be of sufficient accuracy to allow the MES to transmit a Handover Access message (see GMR-1 3G 44.060 [7]) using a Packet Access Burst (PAB3) on the assigned dedicated channel without MES impact to other user transmissions. This network provided information allows the MES to immediate enter packet transfer mode on the assigned channel without having to read the spot beam BCCH and without the MES having to initiate RACH or PRACH access.

The uplink and downlink frame timing relationship described in clause 5.5.1 shall apply to packet transfer mode being entered as a result of handover onto a dedicated channel within the spot beam. The time between the start of receive frame N and the start of transmit frame N + 7 at the MES is given by ΔT_{OF} .

Following BCCH acquisition, the MES uplink transmit time is defined as the time measured from the start of the absolute frame time to the start of the uplink transmission Return MAC-slot in which the MES is granted its uplink DCH assignment. The uplink transmission time for a handover dedicated channel occurs each frame and is given by:

$$T_{TX\text{-}HO} = \Delta T_{OF} + (\text{TS} \times \text{MAC\_RETURN\_TS\_OFFSET}) + (\text{TS} \times \text{Return\_TimeSlot\_Allocation}).$$

Where *TS* is the TDMA frame timeslot (0, ..., 23) and *Return_TimeSlot_Allocation* specifies the starting timeslot of the MES DCH transmission assignment within the return link frame. For PNB3(1,3) or PNB3(1,6) dedicated channel bursts the starting timeslot is derived from the Return *MAC-slot Allocation*. For PNB3(1,8) bursts the starting timeslot is derived from the Return *Slot Allocation* (see GMR-1 3G 44.060 [7]).

The value of *MAC_RETURN_TS_OFFSET* for the spot beam is as given in GMR-1 3G 44.008 [2] and shall be directly provided to the MES as part of the Radio Bearer Reconfiguration message (see GMR-1 3G 44.118 [9]) sent in the handover initiation message.

The absolute frame time shall be derived from the receipt of the FCCH3/BCCH3 burst following handover where (*TS* × *SA_BCCH_STN*) gives the start of the BCCH3 (and FCCH3) burst relative to the start of the absolute frame time. The value of *SA_BCCH_STN* shall be directly provided to the MES as part of the Radio Bearer Reconfiguration message.

For a given MES the delta Timing Offset ΔT_{OF} , is given by:

$$\Delta T_{OF} = \Delta T_{OFC} - 2[T_U - T_O] = SB\_FRAME\_TS\_OFFSET * 39 + SB\_SYMBOL\_OFFSET - 2[T_U - T_O].$$

The delta Timing Offset shall be calculated by the MES based on the values of *SB_FRAME_TS_OFFSET*, *SB_SYMBOL_OFFSET*, and *Timing Correction*, $2[T_U - T_O]$ (derived from the position of the MES at the time of the handover initiation) that are directly provided to the MES as information elements within the handover Radio Bearer Reconfiguration message.

In response to the receipt of the Handover message from the MES sent using the PAB3, the GS shall transmit a Physical Information message on the MES assigned downlink channel. The Physical Information message includes packet link synchronization parameters that provide fine timing adjustment for the subsequent MES transmission (see GMR-1 3G 44.060 [7]). The network shall use the received PAB3 transmission to derive the link synchronization and frequency and timing correction specified to the MES for subsequent transmissions on the dedicated channel.

Once the MES initial frequency and timing has been corrected, the MES shall continue to operate in on the dedicated uplink channel in accordance with the time relationship specified in clause 5.6.1.

5.6.5 Packet transfer mode timing for handover to shared packet channel - Iu mode

This clause only applies to MES operation in Iu mode.

For handover onto a shared packet channel (PDCH3) a MES shall first acquire the FCCH3 and a subsequent DC12 (BCCH) burst to obtain initial frequency and timing synchronization and to derive its receive reference timing within the spot beam.

As part of the handover signalling prior to handover the MES shall receive a Radio Bearer Reconfiguration message (see GMR-1 3G 44.118 [9]) that includes a Physical Information IE that specifies the assigned physical channel description as well as Handover Reference IE that provides information needed for transmit timing synchronization. The MES transmit timing shall be pre-calculated by the network based on the prior known MES position. This timing pre-correction shall be of sufficient accuracy to allow the MES to transmit a Packet Channel Request Type 2, Handover Access message (see GMR-1 3G 44.060 [7]) using a Packet Access Burst (PAB3) on the PRACH associated with the MES shared channel assignment. The network provided information allows the MES to immediate initiate the packet access procedure on the assigned channel without the MES having to read the spot beam BCCH.

The MES shall identify PRACH channel transmit opportunities by monitoring the downlink channels on the carrier on which the shared channel assigned has been allocated.

In response to the receipt of the Packet Channel Request Type 2 Handover message from the MES sent using the PAB3, the network shall transmit a Physical Information message on the MES assigned downlink shared channel. The Physical Information message includes packet link synchronization parameters that provide fine timing adjustment for the subsequent MES transmission. The network shall use the received PAB3 transmission to derive the link synchronization and frequency and timing correction specified to the MES for subsequent transmissions when a TBF assignment is made.

6 Frequency synchronization, TtG/GtT call

Same as clause 6 in GMR-1 05.010 [6], except add the following sentence at the end of the clause.

In the case of data service, PDCH frequency is corrected with corrective factors given over the AGCH. During packet transfer mode, frequency correction shall be provided to the MES by the GS through the PTCCH in the same way as timing correction when a PTCCH/U is assigned.

Whenever a PTCCH/U is not assigned or when the PDCH3 is used, the GS shall provide frequency correction using the same mechanism as the unsolicited timing correction mechanism.

6.1 General description

Same as clause 6.1 in GMR-1 05.010 [6].

6.2 Frequency of common channels

The FCCC/BCCH/CCCH or FCCC3/BCCH/CCCH carrier leaves the satellite with its nominal frequency. After experiencing a Doppler drift due to user-satellite relative motion, frequency of the received signal can be off its nominal value by 495 Hz in L-band, worst case, 264 Hz due to satellite motion, and 231 Hz due to user motion. The offset from the value is 661 Hz in S-band, worst case, 335 Hz due to satellite motion, and 326 Hz due to user motion.

6.3 Idle mode frequency synchronization

6.3.1 Initial frequency acquisition

Same as clause 6.3.1 in GMR-1 05.010 [6].

6.3.2 Paging mode

Same as clause 6.3.2 in GMR-1 05.010 [6].

6.3.3 Alerting mode

Same as clause 6.3.3 in GMR-1 05.010 [6].

6.4 Synchronization at initial access

Same as clause 6.4 in GMR-1 05.010 [6].

6.4.1 Frequency compensation strategy

Same as clause 6.4.1 in GMR-1 05.010 [6], except add PDCH to the last bullet item in the clause.

6.4.2 Parameter description

Same as clause 6.4.2 in GMR-1 05.010 [6], except for the addition of the next paragraph, which follows the second paragraph.

For packet switched service, receiving the frequency correction from the AGCH, the MES shall adjust its frequency of PDCH transmission to an accuracy better than 10 Hz 1-sigma under the conditions defined in GMR-1 3G 45.005 [4].

6.5 Dedicated mode synchronization

Same as clause 6.5 in GMR-1 05.010 [6].

6.6 Frequency synchronization for the packet switched channels

Packet transfer mode synchronization is maintained in the same way as for dedicated mode as described in clause 6.5 with the following modifications.

The MES receiver frequency shall be derived from its internal oscillator, which shall be disciplined by frequency detection of the received PDCH bursts during packet transfer mode. The MES shall maintain the receiver frequency lock so as to handle the worst case frequency drift rate specified in clause 4.3.2. The target frequency accuracy is to achieve demodulation performances specified by GMR-1 3G 45.005 [4].

In the uplink, a closed-loop frequency synchronization scheme is used. The frequency synchronization process is detailed below:

- The GS shall perform the scheduled frequency correction mechanism for all MES working in packet transfer mode for which a PTCCH/U is assigned. Therefore the GS shall monitor the frequency offset of the PNB bursts sent by the MES on PTCCH/U and respond with frequency correction values for all MES performing the procedure on that PDCH. These frequency correction values shall be sent via a downlink signalling message on PTCCH/D (see GMR-1 3G 44.060 [7]). These are scheduled frequency corrections.

- The GS shall update the frequency correction values for a MES in the next downlink signalling message addressed to that MES following the reception of a packet access burst from the MES. These are initial frequency corrections.

- The GS may also monitor the frequency offset of the packet normal bursts sent by the MES on PDTCH and PACCH. Whenever a frequency correction is needed, the GS may send the frequency correction value in a link synchronization message (see GMR-1 3G 44.060 [7]). This is unsolicited frequency correction. The GS shall use the unsolicited frequency correction mechanism for operation on a PDCH3 or DCH and if a PTCCH/U is not assigned to the MES for operation on a PDCH.

As described in clause 6.5 these solicited and unsolicited Frequency Corrections shall be relative to the currently used frequency offset.

The adjustment shall be applied to the MES transmission in such a way: if the Control Flag (CF) associated with the Frequency Correction message is 1, then this message overrides all previous messages. Otherwise, if the Control Flag is 0, the adjustment shall be made in addition to any previous messages. Refer to GMR-1 3G 44.060 [7] for further description on the Frequency Correction (FC) message.

During active TBF the network should not send to the MES a new frequency correction message with control flag set to 0 within two seconds of sending a prior frequency correction message with control flag set to 0.

The MES shall ignore a Frequency Correction (FC) message with Control Flag (CF)set to 0 if a previous Frequency Correction message with Control Flag (CF)set to 0 was received within two seconds of the latest message.

The Frequency Correction shall have a range from -2 048 Hz to +2 047 Hz, with accuracy better than 1 Hz. For both uplink and downlink signals, the MES tracking loop needs to handle the worst case Doppler frequency change.

An MES transmitting PDCH/PDCH2/PDCH3 shall apply the received Frequency Correction value within T_{RESP-1} after the end of the burst in which it received the correction. An MES transmitting PDCH(1,6) or PDCH(2,6) shall apply the received frequency correction to all transmitted bursts within T_{RESP-2} of the end of the downlink burst in which the frequency correction was received.

An MES receiving DCH and transmitting DCH shall apply the received Frequency Correction as per clause 6.5. An MES receiving PDCH3(5,n) or PDCH(10,m) shall apply the received Frequency Correction within T_{RESP-1} or before the next transmit time slot. An MES receiving PDCH(2,6) shall apply the received Frequency Correction within T_{RESP-2} or before the next transmit time slot.

In the initial, unsolicited or scheduled correction, the network sends the frequency offset of the signal received from the MES. Therefore, the MES shall apply negative of the received value in the frequency correction message from the network.

EXAMPLE: If the frequency correction value received from the network is +100 Hz, the MES shall change its transmit frequency by -100 Hz.

7 Frame and message synchronization, TtG/GtT call

7.1 Frame synchronization

7.1.1 Frame number definition

Same as clause 7.1.1 in GMR-1 05.010 [6].

7.1.2 Frame synchronization scenario

Same as clause 7.1.2 in GMR-1 05.010 [6].

7.2 Message synchronization

7.2.1 Power control message synchronization

Same as clause 7.2.1 in GMR-1 05.010 [6], with the following addition for DCH power control message synchronization.

During a call over DCH, each power control (PC) message takes 6 contiguous frames (240 ms) for transmission, with the messages being sent continuously. That is, PC messages are sent back-to-back (no gaps) over consecutive bursts on the assigned channel. The PC message synchronization is described in clauses 7.2.1.1 and 7.2.1.2.

7.2.1.1 DCH power control message synchronization in forward direction

In the forward direction, synchronization is based on the frame number. The procedure is outlined below:

- The GS shall always start its PC message transmission at a frame whose frame number meets:

  FN mod 6 = 0.

- The GS shall send a PC message at the first timing opportunity to do so, independent of actual PC message reception from the MES.
- The MES shall receive the PC messages by receiving the six consecutive bursts beginning with the frame whose frame number meets FN mod 6 = 0.

7.2.1.2 DCH power control message synchronization in return direction

In the return direction, synchronization is based on GS designating the first frame number carrying PC message. This procedure is outlined below:

There shall be a guard time, denoted as Tgt , between the expected completion of the last burst of the received PC message to the beginning of the first burst of the transmit PC message. This guard time includes the maximum allowed MES processing time for PC messages, such that there is no PC "message slip" between the reception of a PC message and the transmission of the response at the return link. The MES shall start sending a PC message at the designated timing opportunity, independent of actual PC message reception from the GS.

Suppose frame N is the last frame carrying forward link PC message. GS shall derive and then pass a value of K to MES for a return link frame number N + K. The value of K is selected such that the restriction of Tgt is satisfied. A default value is K = 8. Then the first frame carrying return link PC message is frame N + K. Once in synchronization, GS shall use the position (N + K) mod 6 as timing reference for PC message. If K changes, the timing reference shall also be updated.

The value of the Power Control Synch Offset, K, shall be provided to the MES by the GS as part of the dedicated channel (DCH) assignment (see GMR-1 3G 44.118 [9]).

7.2.2 SACCH message synchronization, TCH6/TCH9 call

Same as clause 7.2.2 in GMR-1 05.010 [6].

8 Synchronization for TtT call

Same as clause 8 in GMR-1 05.010 [6].

9 Aeronautical terminal synchronization scheme

9.1 MES special features

9.1.1 Speed

Same as clause 9.1.1 in GMR-1 05.010 [6].

9.1.2 Worst-case delay and Doppler features

Same as clause 9.1.2 in GMR-1 05.010 [6], with the following additional text for S-band Doppler features:

The following assumes that nominal frequency S-band in the mobile uplink is 2,020 GHz. In the mobile downlink, nominal frequency is 2,200 GHz. The maximum user velocity is 1 000 km/h, moving directly to the satellite. The time required for an aircraft to completely turn is 1 minute.

Table 9.2a: Doppler features, user contribution (S-band)

Item	Value
Maximum Doppler (uplink)	1,870 kHz
Maximum Doppler (downlink)	2,037 kHz
Maximum Doppler rate of change (uplink)	62 Hz/s
Maximum Doppler rate of change (downlink)	68 Hz/s

9.1.3 Frequency offset

Same as clause 9.1.3 in GMR-1 05.010 [6].

9.2 Frequency synchronization

9.2.1 Frequency synchronization general description

Same as clause 9.2.1 in GMR-1 05.010 [6].

9.2.2 Idle mode frequency synchronization

Same as clause 9.2.2 in GMR-1 05.010 [6].

9.2.3 Synchronization at initial access

Same as clause 9.2.3 in GMR-1 05.010 [6].

9.2.4 Dedicated mode synchronization

Same as clause 9.2.4 in GMR-1 05.010 [6].

9.3 Timing synchronization

Same as clause 9.3 in GMR-1 05.010 [6].

Annex A (informative): Worst-case delay and Doppler features

A.1 L-band

L-band is the same as annex A in GMR-1 05.010 [6].

A.2 S-band

Addition for S-band is as follows.

In calculating the worst case delay and Doppler features, the following assumptions are taken into account:

The maximum satellite inclination angle is 6°. Both time delay and satellite motion are approximately sinusoidal with a period of 24 h. The worst-case user has an elevation of 20° when the satellite is on equator.

The maximum user velocity is 160 km/h, moving directly to the satellite. For accelerating user, its velocity is increased from 0 km/h to 160 km/h in 10 s.

In the mobile uplink, nominal frequency is 2,02 GHz. In the mobile downlink, nominal frequency is 2,20 GHz.

Table A.5: Time delay features (S-band)

Item	Value
Minimum Delay	129,89 ms
Maximum Delay	134,03 ms
Maximum Rate of Delay Change (satellite contribution)	0,1516 µs/s
Maximum rate of delay change (user contribution)	0,1482 µs/s
Maximum rate of delay change (overall value)	0,2998 µs/s

Table A.6: Doppler features, satellite contribution (S-band)

Item	Value
Maximum Doppler (uplink)	308 Hz
Maximum Doppler (downlink)	335 Hz
Maximum Doppler rate of change (uplink)	0,0231 Hz/s
Maximum Doppler rate of change (downlink)	0,0251 Hz/s

Table A.7: Doppler features, user contribution (S-band)

Item	Value
Maximum Doppler (uplink)	299 Hz
Maximum Doppler (downlink)	326 Hz
Maximum Doppler rate of change (uplink)	29,9 Hz/s
Max. Doppler rate of change (downlink)	32,6 Hz/s

Table A.8: Doppler features, overall values (S-band)

Item	Value
Maximum Doppler (uplink)	607 Hz
Maximum Doppler (downlink)	661 Hz
Maximum Doppler rate of change (uplink)	29,9 Hz/s
Maximum Doppler rate of change (downlink)	32,6 Hz/s

Annex B (informative): Range of timing correction factor

Same as annex B in GMR-1 05.010 [6].

Annex C (informative): Differential Doppler frequency

Same as annex C in GMR-1 05.010 [6].

Annex D (informative): SACCH message synchronization, TtG/GtT call

Same as annex D in GMR-1 05.010 [6].

Annex E (normative): Timer T3202 for packet mode of operation

After every reception of a scheduled timing correction, an unsolicited timing correction or an initial timing correction, the MES shall restart a timer, T3202 = PACKET_RANDOM_ACCESS_TIMER. For random access, the MES may use a PAB in any PRACH or a RACH burst in any RACH provided its timer T3202 has not expired. There are procedures requiring to use RACH to access the network even if T3202 is not expired (see GMR-1 3G 44.008 [2]).

If an MES transitions to the circuit-switched operation from packet data operation, it shall continue running timer T3202 during the circuit-switched call duration. After reverting back to the packet mode after the close of the circuit-switched call, if the timer T3202 has not expired, the MES may use a PAB in any PRACH or a RACH burst in any RACH.

For random access after T3202 has expired, the MES shall use a RACH burst in a RACH. The GS shall broadcast the value of PACKET_RANDOM_ACCESS_TIMER in system information (see GMR-1 3G 44.008 [2] and GMR-1 3G 44.060 [7]).

Annex F (normative): PTCCH/U and PTCCH/D scheduling

The MES shall derive its assigned PTCCH/U from the TAI value (see GMR-1 3G 44.060 [7]) and the value of PKT_TIMING_CORR_CYCLE parameter broadcast by the GS in system information. (see GMR-1 3G 44.008 [2]). Using:

$$P = TAI \bmod 4$$

$$RMF = INT(TAI/4).$$

The MES shall have an assigned PTCCH/U in every uplink frame number, UFN, which satisfies the following equations.

$$RMF = INT(UFN/16) \bmod (PKT\_TIMING\_CORR\_CYCLE)$$

and

$$UFN \bmod 16 = 15.$$

For an MES transmitting PTCCH/U on a PDCH(4,3) or PDCH(5,3), the MES shall calculate the MAC-slot number for its assigned PTCCH/U from the following equations:

$$\text{MAC-slot number} = 2 \times P + (RMF \bmod 2).$$

For an MES transmitting PTCCH/U on a PDCH(1,6) or PDCH(2,6), the MES shall calculate the D-MAC-slot number for its assigned PTCCH/U from the following equation:

$$\text{D-MAC-slot number} = P.$$

The MES shall transmit a PNB in every assigned PTCCH/U.

The GS shall transmit timing and frequency corrections in every downlink frame number, DFN = UFN + 10 in timeslot number equal to 0.

On the PDCH downlink burst corresponding to an assigned PTCCH/U timeslot, the GS shall set the USF to the reserved value (see GMR-1 3G 44.060 [7]). In order to send the PTCCH/U burst, the MES shall confirm that the received USF value is set to the reserved value on the PDCH downlink timeslot which corresponds to the PTCCH/U timeslot. If the MES receives two consecutive downlink bursts in the PDCH corresponding to its assigned PTCCH/U time slot in which the USF is set to another value than reserved, the MES shall declare the link dead (see GMR-1 3G 45.008 [5]).

On the PDCH downlink burst corresponding to an assigned PTCCH/U timeslot, the GS shall set the USF to the reserved value (see GMR-1 3G 44.060 [7]). In order to send the PTCCH/U burst, the MES shall confirm that the received USF value is set to the reserved value on the PDCH downlink timeslot which corresponds to the PTCCH/U timeslot. If the MES receives a downlink burst in the PDCH corresponding to its assigned PTCCH/U time slot in which the USF is set to in-use, the MES shall not transmit on that time slot. If the MES receives two consecutive downlink bursts in the PDCH corresponding to its assigned PTCCH/U time slot in which the USF is set any value other than either reserved or in-use, the MES shall declare the link dead (see GMR-1 3G 45.008 [5]).

The GS shall not reassign any Timing Advance Indicator (TAI) (see GMR-1 3G 44.060 [7]) value which it has assigned to an MES before completion of at least three timing correction cycles or three PKT_TIMING_CORR_CYCLE multiframes.

A network supporting multiplexing of terminal type A and D on a PDCH-Carrier shall assign TAIs such that all TAIs that map to the same RMF value are assigned to MESs belonging to the same terminal type. This ensures that all MESs addressed in a PTCCH/D message are of the same terminal type.

Refer to GMR-1 3G 45.002 [3] for PTCCH/D scheduling rules.

Annex G (informative): Bibliography

GMR-1 3G 45.003 (ETSI TS 101 376-5-3): "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 5: Radio interface physical layer specifications; Sub-part 3: Channel Coding".

History

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