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**Satellite Earth Stations and Systems (SES);
Satellite Component of UMTS/IMT-2000;
Part 4: Physical layer procedures;
Sub-part 3: G-family enhancements
(S-UMTS-G enhanced 25.214)**

Reference

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Contents

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Foreword

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

The present document is specifying the Satellite Radio Interface referenced as SRI Family G at ITU-R, in the frame of the modification of ITU-R Recommendation M.1457 [i.5]. This modification has been approved at SG8 meeting in November 2005.

The present document is part 4, sub-part 3 of a multi-part deliverable covering Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; G-family enhancements, as identified below:

Part 1: "Physical channels and mapping of transport channels into physical channels";

Part 2: "Multiplexing and channel coding";

Part 3: "Spreading and modulation";

Part 4: "Physical layer procedures";

Sub-part 1: "G-family (S-UMTS-G 25.214)";

Sub-part 2: "A-family (S-UMTS-A 25.214)";

Sub-part 3: "G-family enhancements (S-UMTS-G enhanced 25.214)";

Part 5: "UE Radio Transmission and Reception";

Part 6: "Ground stations and space segment radio transmission and reception".

Introduction

S-UMTS stands for the Satellite component of the Universal Mobile Telecommunication System. S-UMTS systems will complement the Terrestrial UMTS (T-UMTS) and inter-work with other IMT-2000 family members through the UMTS core network. S-UMTS will be used to deliver 3rd generation Mobile Satellite Services (MSS) utilizing either low (LEO) or medium (MEO) earth orbiting, or geostationary (GEO) satellite(s). S-UMTS systems are based on terrestrial 3GPP specifications and will support access to GSM/UMTS core networks.

NOTE 1: The term T-UMTS will be used in the present document to further differentiate the Terrestrial UMTS component.

Due to the differences between terrestrial and satellite channel characteristics, some modifications to the terrestrial UMTS (T-UMTS) standards are necessary. Some specifications are directly applicable, whereas others are applicable with modifications. Similarly, some T-UMTS specifications do not apply, whilst some S-UMTS specifications have no corresponding T-UMTS specification.

Since S-UMTS is derived from T-UMTS, the organization of the S-UMTS specifications closely follows the original 3rd Generation Partnership Project (3GPP) structure. The S-UMTS numbers have been designed to correspond to the 3GPP terrestrial UMTS numbering system. All S-UMTS specifications are allocated a unique S-UMTS number as follows:

S-UMTS-n xx.yyy

Where:

- The numbers xx and yyy correspond to the 3GPP-numbering scheme.
- n (n = A, B, C, etc.) denotes the family of S-UMTS specifications.

An S-UMTS system is defined by the combination of a family of S-UMTS specifications and 3GPP specifications, as follows:

- If an S-UMTS specification exists it takes precedence over the corresponding 3GPP specification (if any). This precedence rule applies to any references in the corresponding 3GPP specifications.

NOTE 2: Any references to 3GPP specifications within the S-UMTS specifications are not subject to this precedence rule.

EXAMPLE: An S-UMTS specification may contain specific references to the corresponding 3GPP specification.

- If an S-UMTS specification does not exist, the corresponding 3GPP specification may or may not apply. The exact applicability of the complete list of 3GPP specifications shall be defined at a later stage.

The present document is part of the S-UMT sub-part 3 specifications. Sub-part 3 specifications are identified in the title and can also be identified by the specification number:

- Sub-part 1 specifications have a S-UMTS-G prefix in the title and a sub-part number of "1" (TS 101 851-x-1).
- Sub-part 2 specifications have a S-UMTS-A prefix in the title and a sub-part number of "2" (TS 101 851-x-2).
- Sub-part 3 specifications have a S-UMTS-G enhanced prefix in the title and a sub-part number of "3" (TS 101 851-x-3).

The sub-part 1 specifications introduce the WCDMA satellite radio interface (ITU-R G-family) specifications for the third generation (3G) wireless communication systems. It is also based on the WCDMA UTRA FDD radio interface already standardized in 3GPP. Mobile satellite systems intending to use this interface will address user equipment fully compatible with 3GPP UTRA FDD WCDMA, with adaptation for agility to the Mobile Satellite Service (MSS) frequency band.

The sub-part 2 specifications introduce the SW-CDMA satellite radio interface (ITU-R A-family) specifications for third generation (3G) wireless communication systems. SW-CDMA is based on the adaptation to the satellite environment of terrestrial WCDMA. The intention is to reuse the same core network and reuse the radio interface specifications for the Is and Cu interface. Only the Uu interface is adapted to the satellite environment. SW-CDMA operates in FDD mode with RF channel bandwidth of either 2,350 MHz or 4,700 MHz for each transmission direction.

The sub-part 3 specifications introduce the WCDMA satellite radio interface enhancement (G enhance-family). It considers G-family as radio interface basis, adding option selected enhancing features from ITU-R A and C-family in order to optimize the radio interface over satellite. It is based on the results of the TR 102 278 [i.6] identifying a way to achieve harmonization between A, C and G-family satellite radio interfaces for IMT-2000 in ITU-R. The G-family enhancements made of A, C and G features are described in annex E.

The sub-parts 1 and 2 will be withdrawn if the A and C family will be removed from the satellite radio interface list of IMT-2000 in ITU-R Recommendation M.1850 [i.7] and then, the sub-part 3 will be revised.

1 Scope

The present document specifies the characteristics of the physical layer procedures used for family G enhanced of the satellite component of UMTS (S-UMTS-G).

It is based on the FDD mode of UTRA defined by TS 125 211 [4], TS 125 212 [i.1], TS 125 213 [i.2], TS 125 215 [i.3], TS 125 214 [5], TS 125 331 [i.4] and TS 125 433 [6] and adapted for operation over satellite transponders.

Furthermore, it specifies enhancing features optimizing the basic G family radio interface performances over satellite and new functions.

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.

[1] ETSI TS 101 851-1-3: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 1: Physical channels and mapping of transport channels into physical channels; Sub-part 3: G-family enhancements (S-UMTS-G enhanced 25.211)".

[2] ETSI TS 101 851-2-3: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 2: Multiplexing and channel coding; Sub-part 3: G-family enhancements (S-UMTS-G enhanced 25.212)".

[3] ETSI TS 101 851-3-3: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 3: Spreading and modulation; Sub-part 3: G-family enhancements (S-UMTS-G enhanced 25.213)".

[4] ETSI TS 125 211: "Universal Mobile Telecommunications System (UMTS); Physical channels and mapping of transport channels onto physical channels (FDD) (3GPP TS 25.211)".

[5] ETSI TS 125 214: "Universal Mobile Telecommunications System (UMTS); Physical layer procedures (FDD) (3GPP TS 25.214)".

[6] ETSI TS 125 433: "Universal Mobile Telecommunications System (UMTS); UTRAN Iub interface Node B Application Part (NBAP) signalling (3GPP TS 25.433)".

[7] ETSI TS 125 101: "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (FDD) (3GPP TS 25.101)".

[8] ETSI TS 125 133: "Universal Mobile Telecommunications System (UMTS); Requirements for support of radio resource management (FDD) (3GPP TS 25.133)".

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.

[i.1] ETSI TS 125 212: "Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (FDD) (3GPP TS 25.212)".

[i.2] ETSI TS 125 213: "Universal Mobile Telecommunications System (UMTS); Spreading and modulation (FDD) (3GPP TS 25.213)".

[i.3] ETSI TS 125 215: "Universal Mobile Telecommunications System (UMTS); Physical layer; Measurements (FDD) (3GPP TS 25.215)".

[i.4] ETSI TS 125 331: "Universal Mobile Telecommunications System (UMTS); Radio Resource Control (RRC); Protocol specification (3GPP TS 25.331)".

[i.5] ITU-R Recommendation M.1457 (2006): "Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)".

[i.6] ETSI TR 102 278: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Considerations on possible harmonization between A, C and G family Satellite Radio Interface features".

[i.7] ITU-R Recommendation M.1850: "Detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)".

[i.8] ETSI TS 101 851-1-1: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 1: Physical channels and mapping of transport channels into physical channels; Sub-part 1: G-family (S-UMTS-G 25.211)".

[i.9] ETSI TS 101 851-1-2: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 1: Physical channels and mapping of transport channels into physical channels; Sub-part 2: A-family (S-UMTS-A 25.211)".

[i.10] ETSI TS 101 851-2-1: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 2: Multiplexing and channel coding; Sub-part 1: G-family (S-UMTS-G 25.212)".

[i.11] ETSI TS 101 851-2-2: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 2: Multiplexing and channel coding; Sub-part 2: A-family (S-UMTS-A 25.212)".

[i.12] ETSI TS 101 851-3-1: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 3: Spreading and modulation; Sub-part 1: G-family (S-UMTS-G 25.213)".

[i.13] ETSI TS 101 851-3-2: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 3: Spreading and modulation; Sub-part 2: A-family (S-UMTS-A 25.213)".

[i.14] ETSI TS 101 851-4-1: " Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 4: Physical layer procedures; Sub-part 1: G-family (S-UMTS-G 25.214)".

[i.15] ETSI TS 101 851-4-2: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Part 4: Physical layer procedures; Sub-part 2: A-family (S-UMTS-A 25.214)".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

L1 combining period: interval of contiguous radio frames when S-CCPCH clusters may be soft combined

S-CCPCH cluster: one or more S-CCPCHs on different RLs, all containing identical physical channel bits

NOTE: S-CCPCHs in an S-CCPCH cluster are synchronized such that the delay between the earliest and latest arriving S-CCPCH at the UE is no more than 296 chips.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3rd Generation Partnership Project
AI	Acquisition Indicator
AICH	Acquisition Indicator CHannel
ASC	Access Service Class
BCH	Broadcast CHannel
BPSK	Binary Phase Shift Keying
BSDT	Beam Selection Diversity Transmission
CCPCH	Common Control Physical CHannel
CCTrCH	Coded Composite Transport CHannel
CFN	Connection Frame Number
CLPC	Closed Loop Power Control
CPICH	Common PIlot CHannel
CRC	Cyclic Redundancy Check
DL	DownLink
DPCCH	Dedicated Physical Control CHannel
DPCH	Dedicated Physical CHannel
DPDCH	Dedicated Physical Data CHannel
DTX	Discontinuous Transmission
FBI	FeedBack Indicator
FDD	Frequency Division Duplexing
GEO	Geostationary Earth Orbit
HPPICH	High Penetration Paging Indicator CHannel
ID	Identity
ISCP	Interference on Signal Code Power
ITP	Initial Transmit Power mode
LEO	Low Earth Orbit
MAC	Medium Access Control
MEO	Medium Earth Orbit
MICH	MBMS Indicator Channel
ML	Maximum Likelihood
MSS	Mobile Satellite Services
OLPC	Open Loop Power Control
PCA	Power Control Algorithm
P-CCPCH	Primary Common Control Physical CHannel
P-CPICH	Primary Common PIlot CHannel
PICH	Paging Indicator CHannel
PRACH	Physical Random Access CHannel
RACH	Random Access CHannel
RAT	Radio Access Technology
RF	Radio Frequency
RF	Radio Frequency
RL	Radio Link
RPL	Recovery Period Length
RPP	Recovery Period Power control
RRC	Radio Resource Control
RSCP	Received Signal Code Power
S-CCPCH	Secondary Common Control Physical CHannel
SCH	Synchronization CHannel
SFN	System Frame Number
SIR	Signal-to-Interference Ratio
SSDT	Site Selection Diversity Transmission
S-UMTS	Satellite Universal Mobile Telecommunication System

SW-CDMA	Satellite Wideband Code Division Multiple Access
TFC	Transport Format Combination
TFCI	Transport Frame Combination Indicator
TPC	Transmit Power Control
TrCH	Transport CHannel
TTI	Transmission Time Interval
T-UMTS	Terrestrial Universal Mobile Telecommunication System
TX	Transmission
UE	User Equipment
UL	UpLink
USRAN	UMTS Satellite Radio Access Network
UTRA	UMTS Terrestrial Radio Access
UW	Unique Word
WCDMA	Wideband Code Division Multiple Access

4 Synchronization procedures

4.1 Spot search

During the spot search, the UE searches for a satellite beam and determines the downlink scrambling code and common channel frame synchronization of that satellite beam. How spot search is typically done is described in annex B.

4.2 Common physical channel synchronization

The radio frame timing of all common physical channels can be determined after spot search.

4.2.1 P-CCPCH radio frame timing

The P-CCPCH radio frame timing is found during spot search and the radio frame timing of all common physical channel are related to that timing as described in TS 101 851-1-3 [1].

4.2.2 S-CCPCH soft combining timing

Higher layers will provide additional timing information when S-CCPCH clusters can be soft combined. The timing information allows the UE to determine the L1 combining period that applies to each S-CCPCH cluster. The information also identifies the S-CCPCHs and the RLs in each cluster as well as which S-CCPCH clusters can be soft combined. The set of S-CCPCH clusters that can be combined does not change during an L1 combining period. When S-CCPCH clusters can be soft combined, all S-CCPCHs in the clusters shall contain identical bits in their data fields, although the TFCI fields of S-CCPCH in different clusters may be different. (TFC detection when S-CCPCH clusters may be soft combined is discussed in TS 101 851-2-3 [2].) An L1 combining period shall contain only complete TTIs. The maximum delay between S-CCPCH clusters that the UE may combine is set by UE performance requirements.

4.3 DPCCH/DPDCH synchronization

4.3.1 Synchronization primitives

4.3.1.1 General

For the dedicated channels, synchronization primitives are used to indicate the synchronization status of radio links, both in uplink and downlink. The definition of the primitives is given in the following clauses.

4.3.1.2 Downlink synchronization primitives

Layer 1 in the UE shall every radio frame check synchronization status of the downlink dedicated channels. Synchronization status is indicated to higher layers using the CPHY-Sync-IND and CPHY-Out-of-Sync-IND primitives.

The criteria for reporting synchronization status are defined in two different phases.

The first phase starts when higher layers initiate physical dedicated channel establishment (as described in TS 125 331 [i.4]) or whenever the UE initiates synchronization procedure A (as described in clause 4.3.2.1) and lasts until 160 ms after the downlink dedicated channel is considered established by higher layers (physical channel establishment is defined in TS 125 331 [i.4]). During this time out-of-sync shall not be reported and in-sync shall be reported using the CPHY-Sync-IND primitive if the following criterion is fulfilled:

- The UE estimates the DPCCH quality over the previous 40 ms period to be better than a threshold Q_{in}. This criterion shall be assumed not to be fulfilled before 40 ms of DPCCH quality measurements have been collected. Q_{in} is defined implicitly by the relevant tests in TS 125 101 [7].

The second phase starts 160 ms after the downlink dedicated channel is considered established by higher layers. During this phase both out-of-sync and in-sync are reported as follows.

Out-of-sync shall be reported using the CPHY-Out-of-Sync-IND primitive if any of the following criteria is fulfilled:

- The UE estimates the DPCCH quality over the previous 160 ms period to be worse than a threshold Q_{out}. Q_{out} is defined implicitly by the relevant tests in TS 125 101 [7].

- The 20 most recently received transport blocks with a non-zero length CRC attached, as observed on all TrCHs using non-zero length CRC, have been received with incorrect CRC. In addition, over the previous 160 ms, all transport blocks with a non-zero length CRC attached have been received with incorrect CRC. In case no TFCI is used this criterion shall not be considered for the TrCH(s) not using guided detection if they do not use a non-zero length CRC in all transport formats. If no transport blocks with a non-zero length CRC attached are received over the previous 160 ms this criterion shall not be assumed to be fulfilled.

In-sync shall be reported using the CPHY-Sync-IND primitive if both of the following criteria are fulfilled:

- The UE estimates the DPCCH quality over the previous 160 ms period to be better than a threshold Q_{in}. Q_{in} is defined implicitly by the relevant tests in TS 125 101 [7].

- At least one transport block with a non-zero length CRC attached, as observed on all TrCHs using non-zero length CRC, is received in a TTI ending in the current frame with correct CRC. If no transport blocks are received, or no transport block has a non-zero length CRC attached in a TTI ending in the current frame and in addition over the previous 160 ms at least one transport block with a non-zero length CRC attached has been received with a correct CRC, this criterion shall be assumed to be fulfilled. If no transport blocks with a non-zero length CRC attached are received over the previous 160 ms this criterion shall also be assumed to be fulfilled. In case no TFCI is used this criterion shall not be considered for the TrCH(s) not using guided detection if they do not use a non-zero length CRC in all transport formats.

How the primitives are used by higher layers is described in TS 125 331 [i.4]. The above definitions may lead to radio frames where neither the in-sync nor the out-of-sync primitives are reported.

4.3.1.3 Uplink synchronization primitives

Layer 1 in the satellite gateway shall every radio frame check synchronization status of all radio link sets. Synchronization status is indicated to the RL Failure/Restored triggering function using either the CPHY-Sync-IND or CPHY-Out-of-Sync-IND primitive. Hence, only one synchronization status indication shall be given per radio link set.

The exact criteria for indicating in-sync/out-of-sync is not subject to specification, but could e.g. be based on received DPCCH quality or CRC checks. One example would be to have the same criteria as for the downlink synchronization status primitives.

4.3.2 Radio link establishment and physical layer reconfiguration for dedicated channels

4.3.2.1 General

Two synchronization procedures are defined in order to obtain physical layer synchronization of dedicated channels between UE and USRAN:

- Synchronization procedure A: This procedure shall be used when at least one downlink dedicated physical channel and one uplink dedicated physical channel are to be set up on a frequency and none of the radio links after the establishment/reconfiguration existed prior to the establishment/reconfiguration which also includes the following cases:
    - the UE was previously on another RAT i.e. inter-RAT handover;
    - the UE was previously on another frequency i.e. inter-frequency hard handover;
    - the UE has all its previous radio links removed and replaced by other radio links i.e. intra-frequency hard-handover;
    - after it fails to complete an inter-RAT, intra- or inter-frequency hard-handover TS 125 133 [8], the UE attempts to re-establish TS 125 331 [i.4] all the dedicated physical channels which were already established immediately before the hard-handover attempt. In this case only steps c) and d) of synchronization procedure A are applicable.
- Synchronization procedure B: This procedure shall be used when one or several radio links are added to the active set and at least one of the radio links prior to the establishment/reconfiguration still exists after the establishment/reconfiguration.

For existing radio links, the reconfiguration of downlink phase reference from P-CPICH or S-CPICH to dedicated pilots is not supported. For all other physical layer reconfigurations not listed above, the UE and USRAN shall not perform any of the synchronization procedures listed above.

The two synchronization procedures are described in clauses 4.3.2.3 and 4.3.2.4 respectively.

4.3.2.2 Satellite gateway radio link set state machine

In the satellite gateway, each radio link set can be in three different states: initial state, out-of-sync state and in-sync state. Transitions between the different states are shown in figure 1. The state of the satellite gateway at the start of radio link establishment is described in the following clauses. Transitions between initial state and in-sync state are described in clauses 4.3.2.3 and 4.3.2.4 and transitions between the in-sync and out-of-sync states are described in clause 4.3.3.2.

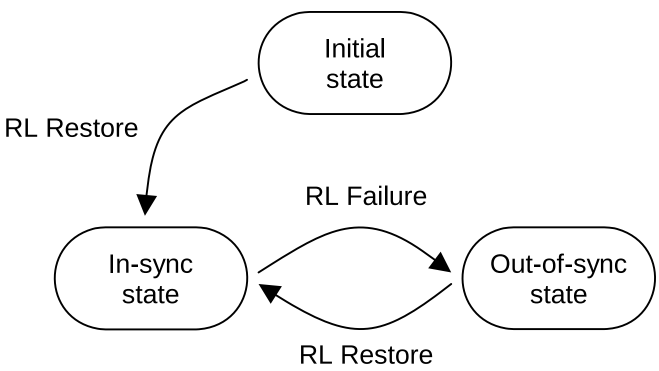


Figure 1: Satellite gateway radio link set states and transitions

4.3.2.3 Synchronization procedure A

The synchronization establishment procedure, which begins at the time indicated by higher layers (either immediately at receipt of upper layer signalling, or at an indicated activation time), is as follows:

a) Each satellite gateway involved in the procedure sets all the radio link sets which are to be set-up for this UE in the initial state.

b) USRAN shall start the transmission of the downlink DPCCH and may start the transmission of DPDCH if any data is to be transmitted. The initial downlink DPCCH transmit power is set by higher layers TS 125 433 [6]. Downlink TPC commands are generated as described in clause 5.1.2.2.1.2.

c) The UE establishes downlink chip and frame synchronization of DPCCH, using the P-CCPCH timing and timing offset information notified from USRAN. Frame synchronization can be confirmed using the frame synchronization word. Downlink synchronization status is reported to higher layers every radio frame according to clause 4.3.1.2.

d) The UE shall not transmit on uplink until higher layers consider the downlink physical channel established. If no activation time for uplink DPCCH has been signalled to the UE or if the UE attempts to re-establish the DPCH after an inter-RAT, intra- or inter-frequency hard-handover failure TS 125 331 [i.4], uplink DPCCH transmission shall start when higher layers consider the downlink physical channel established. If an activation time has been given, uplink DPCCH transmission shall not start before the downlink physical channel has been established and the activation time has been reached. Physical channel establishment and activation time are defined in TS 125 331 [i.4]. The initial uplink DPCCH transmit power is set by higher layers TS 125 331 [i.4]. In case the UE attempts to re-establish the DPCH after an inter-RAT, intra- or inter-frequency hard-handover failure TS 125 331 [i.4] the initial uplink DPCCH power shall be the same as the one used immediately preceding the inter-RAT, intra- or inter-frequency hard-handover attempt. In case of physical layer reconfiguration the uplink DPCCH power is kept unchanged between before and after the reconfiguration except for inner loop power control adjustments. A power control preamble shall be applied as indicated by higher layers. The transmission of the uplink DPCCH power control preamble shall start N_{pcp} radio frames prior to the start of uplink DPDCH transmission, where N_{pcp} is a higher layer parameter set by USRAN TS 125 331 [i.4]; in case the UE attempts to re-establish the DPCH after an inter-RAT, intra- or inter-frequency hard-handover failure TS 125 331 [i.4] the UE shall use the value of N_{pcp} as specified in TS 125 331 [i.4] for this case. Note that the transmission start delay between DPCCH and DPDCH may be cancelled using a power control preamble of 0 length. The starting time for transmission of DPDCHs shall also satisfy the constraints on adding transport channels to a CCTrCH, as defined in TS 101 851-2-3 [2], independently of whether there are any bits mapped to the DPDCHs. During the uplink DPCCH power control preamble, independently of the selected TFC, no transmission is done on the DPDCH.

e) USRAN establishes uplink chip and frame synchronization. Frame synchronization can be confirmed using the frame synchronization word. Radio link sets remain in the initial state until N_INSYNC_IND successive in-sync indications are received from layer 1, when the satellite gateway shall trigger the RL Restore procedure indicating which radio link set has obtained synchronization. When RL Restore has been triggered the radio link set shall be considered to be in the in-sync state. The parameter value of N_INSYNC_IND is configurable, see TS 125 433 [6]. The RL Restore procedure may be triggered several times, indicating when synchronization is obtained for different radio link sets.

   The total signalling response delay for the establishment of a new DPCH shall not exceed the requirements given in TS 125 331 [i.4].

4.3.2.4 Synchronization procedure B

The synchronization procedure B, which begins at the time indicated by higher layers (either immediately at receipt of upper layer signalling, or at an indicated activation time) is as follows:

a) The following applies to each satellite gateway involved in the procedure:

   - New radio link sets are set up to be in initial state.

   - If one or several radio links are added to an existing radio link set, this radio link set shall be considered to be in the state the radio link set was prior to the addition of the radio link, i.e. if the radio link set was in the in-sync state before the addition of the radio link it shall remain in that state.

b) USRAN starts the transmission of the downlink DPCCH/DPDCH for each new radio link at a frame timing such that the frame timing received at the UE will be within $T_0 \pm 148$ chips prior to the frame timing of the uplink DPCCH/DPDCH at the UE. Simultaneously, USRAN establishes uplink chip and frame synchronization of each new radio link. Frame synchronization can be confirmed using the frame synchronization word. Radio link sets considered to be in the initial state shall remain in the initial state until N_INSYNC_IND successive in-sync indications are received from layer 1, when the satellite gateway shall trigger the RL Restore procedure indicating which radio link set has obtained synchronization. When RL Restore is triggered the radio link set shall be considered to be in the in-sync state. The parameter value of N_INSYNC_IND is configurable, see TS 125 433 [6]. The RL Restore procedure may be triggered several times, indicating when synchronization is obtained for different radio link sets.

c) The UE establishes chip and frame synchronization of each new radio link. Layer 1 in the UE keeps reporting downlink synchronization status to higher layers every radio frame according to the second phase of clause 4.3.1.2. Frame synchronization can be confirmed using the frame synchronization word.

4.3.3 Radio link monitoring

4.3.3.1 Downlink radio link failure

The downlink radio links shall be monitored by the UE, to trigger radio link failure procedures. The downlink radio link failure criteria is specified in TS 125 331 [i.4], and is based on the synchronization status primitives CPHY-Sync-IND and CPHY-Out-of-Sync-IND, indicating in-sync and out-of-sync respectively.

4.3.3.2 Uplink radio link failure/restore

The uplink radio link sets are monitored by the satellite gateway, to trigger radio link failure/restore procedures. Once the radio link sets have been established, they will be in the in-sync or out-of-sync states as shown in figure 1 in clause 4.3.2.2. Transitions between those two states are described below.

The uplink radio link failure/restore criteria are based on the synchronization status primitives CPHY-Sync-IND and CPHY-Out-of-Sync-IND, indicating in-sync and out-of-sync respectively. Note that only one synchronization status indication shall be given per radio link set.

When the radio link set is in the in-sync state, the satellite gateway shall start timer T_RLFAILURE after receiving N_OUTSYNC_IND consecutive out-of-sync indications. the satellite gateway shall stop and reset timer T_RLFAILURE upon receiving successive N_INSYNC_IND in-sync indications. If T_RLFAILURE expires, the satellite gateway shall trigger the RL Failure procedure and indicate which radio link set is out-of-sync. When the RL Failure procedure is triggered, the state of the radio link set change to the out-of-sync state.

When the radio link set is in the out-of-sync state, after receiving N_INSYNC_IND successive in-sync indications the satellite gateway shall trigger the RL Restore procedure and indicate which radio link set has re-established synchronization. When the RL Restore procedure is triggered, the state of the radio link set change to the in-sync state.

The specific parameter settings (values of T_RLFAILURE, N_OUTSYNC_IND, and N_INSYNC_IND) are configurable, see TS 125 433 [6].

4.3.4 Transmission timing adjustments

During a connection the UE may adjust its DPDCH/DPCCH transmission time instant.

If the receive timing for any downlink DPCCH/DPDCH in the current active set has drifted, so the time between reception of the downlink DPCCH/DPDCH in question and transmission of uplink DPCCH/DPDCH lies outside the valid range, L1 shall inform higher layers of this, so that the network can be informed of this and downlink timing can be adjusted by the network.

The maximum rate of uplink TX time adjustment, and the valid range for the time between downlink DPCCH/DPDCH reception and uplink DPCCH/DPDCH transmission in the UE are defined by the requirements specified in TS 125 133 [8].

5 Power control

5.1 Uplink power control

5.1.1 PRACH

5.1.1.1 General

The power control during the physical random access procedure is described in clause 5.2.5. The setting of power of the message control and data parts is described in clause 5.1.1.2.

5.1.1.2 Setting of PRACH control and data part power difference

The message part of the uplink PRACH channel shall employ gain factors to control the control/data part relative power similar to the uplink dedicated physical channels. Hence, clause 5.1.2.5 applies also for the RACH message part, with the differences that:

- β_c is the gain factor for the control part (similar to DPCCH);
- β_d is the gain factor for the data part (similar to DPDCH);
- no inner loop power control is performed.

5.1.2 DPCCH/DPDCH

It is not recommended in normal operations to activate DPCH inner loop power control for geo-stationary constellations. Inner loop power control may be activated for LEO constellations.

5.1.2.1 General

5.1.2.1.1 Normal operations

The following shall apply in all modes, except optional mode C.

The initial uplink DPCCH transmit power is set by higher layers. Subsequently the uplink transmit power control procedure simultaneously controls the power of a DPCCH and its corresponding DPDCHs (if present). The relative transmit power offset between DPCCH and DPDCHs is determined by the network and is computed according to clause 5.1.2.5 using the gain factors signalled to the UE using higher layer signalling.

The operation of the inner power control loop, described in clause 5.1.2.2.1, adjusts the power of the DPCCH and DPDCHs by the same amount, provided there are no changes in gain factors. Additional adjustments to the power of the DPCCH associated with the use of compressed mode are described in clause 5.1.2.3.1.

Any change in the uplink DPCCH transmit power shall take place immediately before the start of the pilot field on the DPCCH. The change in DPCCH power with respect to its previous value is derived by the UE and is denoted by Δ_{DPCCH} (in dB). The previous value of DPCCH power shall be that used in the previous slot, except in the event of an interruption in transmission due to the use of compressed mode, when the previous value shall be that used in the last slot before the transmission gap.

During the operation of the uplink power control procedure the UE transmit power shall not exceed a maximum allowed value which is the lower out of the maximum output power of the terminal power class and a value which may be set by higher layer signalling.

Uplink power control shall be performed while the UE transmit power is below the maximum allowed output power.

The provisions for power control at the maximum allowed value and below the required minimum output power (as defined in TS 125 101 [7]) are described in clause 5.1.2.6.

5.1.2.1.2 Operations in Optional mode C

In optional mode C, the following shall apply:

The initial uplink DPCCH transmit power is set by higher layers. Subsequently the uplink transmit power control procedure simultaneously controls the power of a DPCCH and its corresponding DPDCHs (if present). The relative transmit power offset between DPCCH and DPDCHs is determined by the network and is computed according to clause 5.1.2.5 using the gain factors signalled to the UE using higher layer signalling.

The operation of the inner power control loop, described in clause 5.1.2.2.2, adjusts the power of the DPCCH and DPDCHs by the same amount, provided there are no changes in gain factors. Additional adjustments to the power of the DPCCH associated with the use of compressed mode are described in clause 5.1.2.3.2.

Any change in the uplink DPCCH transmit power shall take place immediately before the start of the frame on the DPCCH. The change in DPCCH power with respect to its previous value is derived by the UE and is denoted by Δ_{DPCCH} (in dB). The previous value of DPCCH power shall be that used in the previous frame.

During the operation of the uplink power control procedure the UE transmit power shall not exceed a maximum allowed value which is the lower out of the maximum output power of the terminal power class and a value which may be set by higher layer signalling.

Uplink power control shall be performed while the UE transmit power is below the maximum allowed output power.

The provisions for power control at the maximum allowed value and below the required minimum output power (as defined in [7]) are described in clause 5.1.2.6.

5.1.2.2 Ordinary transmit power control

5.1.2.2.1 Normal operation

The following shall apply in all modes, except optional mode C.

5.1.2.2.1.1 General

The uplink inner-loop power control adjusts the UE transmit power in order to keep the received uplink Signal-to-Interference Ratio (SIR) at a given SIR target, SIR_{target}.

The serving spots (spots in the active set) should estimate signal-to-interference ratio SIR_{est} of the received uplink DPCH. The serving spots should then generate TPC commands and transmit the commands once per frame according to the procedure specified in the present document.

Upon reception of one or more TPC commands in a frame, the UE shall derive a single TPC command, TPC_cmd, for each frame, combining multiple TPC commands if more than one is received in a frame. This is also valid when SSDT transmission is used in the downlink. Two algorithms shall be supported by the UE for deriving a TPC_cmd. Which of these two algorithms is used is determined by a UE-specific higher-layer parameter, "PowerControlAlgorithm", and is under the control of the USRAN. If "PowerControlAlgorithm" indicates "algorithm1", then the layer 1 parameter PCA shall take the value 1 and if "PowerControlAlgorithm" indicates "algorithm2" then PCA shall take the value 2.

If PCA has the value 1, Algorithm 1, described in clause 5.1.2.2.1.2, shall be used for processing TPC commands.

If PCA has the value 2, Algorithm 2, described in clause 5.1.2.2.1.3, shall be used for processing TPC commands.

The step size Δ_{TPC} is a layer 1 parameter which is derived from the UE-specific higher-layer parameter "TPC-StepSize" which is under the control of the USRAN. If "TPC-StepSize" has the value "dB1", then the layer 1 parameter Δ_{TPC} shall take the value 1 dB and if "TPC-StepSize" has the value "dB2", then Δ_{TPC} shall take the value 2 dB. The parameter "TPC-StepSize" only applies to Algorithm 1 as stated in TS 125 331 [i.4]. For Algorithm 2 Δ_{TPC} shall always take the value 1 dB.

After deriving of the combined TPC command TPC_cmd using one of the two supported algorithms, the UE shall adjust the transmit power with a step of $\pm\Delta_1^{PC}$ or $\pm\Delta_2^{PC}$ dB according to the TPC command. The change of transmitter power shall apply at the beginning of a new frame.

The relationship between the TPC symbol and the transmitter power control command is presented in table 1.

Table 1: TPC Bit Pattern

TPC Bit Pattern	Transmitter power control command
00	Reduce large power step
01	Reduce small power step
10	Increase small power step
11	Increase large power step

5.1.2.2.1.1.1 Out of synchronization handling

After 160 ms after physical channel establishment (defined in TS 125 331 [i.4]), the UE shall control its transmitter according to a downlink DPCCH quality criterion as follows:

- The UE shall shut its transmitter off when the UE estimates the DPCCH quality over the last 160 ms period to be worse than a threshold Q_{out}. Q_{out} is defined implicitly by the relevant tests in TS 125 101 [7].
- The UE can turn its transmitter on again when the UE estimates the DPCCH quality over the last 160 ms period to be better than a threshold Q_{in}. Q_{in} is defined implicitly by the relevant tests in TS 125 101 [7]. When transmission is resumed, the power of the DPCCH shall be the same as when the UE transmitter was shut off.

5.1.2.2.1.1.2 TPC command generation on downlink during RL initialization

When commanded by higher layers the TPC commands sent on a downlink radio link from satellite gateways that have not yet achieved uplink synchronization shall follow a pattern as follows:

If higher layers indicate by "First RLS indicator" that the radio link is part of the first radio link set sent to the UE and the value "n" obtained from the parameter "DL TPC pattern 01count" passed by higher layers is different from 0 then:

- the TPC pattern shall consist of n instances of the pair of TPC commands ("0","1"), followed by one instance of TPC command "1", where ("0","1") indicates the TPC commands to be transmitted in 2 consecutive slots;
- the TPC pattern continuously repeat but shall be forcibly re-started at the beginning of each frame where CFN mod 4 = 0;

else

- the TPC pattern shall consist only of TPC commands "1".

The TPC pattern shall terminate once uplink synchronization is achieved.

5.1.2.2.1.2 Algorithm 1 for processing TPC commands

5.1.2.2.1.2.1 Derivation of TPC_cmd when only one TPC command is received in each frame

When a UE is not in soft handover, only one TPC command will be received in each frame. In this case, the value of TPC_cmd shall be derived as follows:

- If the received TPC command is equal to 0 then TPC_cmd for that frame is -1.
- If the received TPC command is equal to 1, then TPC_cmd for that frame is 1.

5.1.2.2.1.2.2 Combining of TPC commands from radio links of the same radio link set

When a UE is in soft handover, multiple TPC commands may be received in each frame from different spots in the active set. In some cases, the UE has the knowledge that some of the transmitted TPC commands in a frame are the same. This is the case when the radio links are in the same radio link set. For these cases, the TPC commands from the same radio link set shall be combined into one TPC command, to be further combined with other TPC commands as described in clause 5.1.2.2.1.2.3.

5.1.2.2.1.2.3 Combining of TPC commands from radio links of different radio link sets

This clause describes the general scheme for combination of the TPC commands from radio links of different radio link sets.

First, the UE shall conduct a soft symbol decision W_i on each of the power control commands TPC_i, where $i = 1, 2, \ldots, N$, where N is greater than 1 and is the number of TPC commands from radio links of different radio link sets, that may be the result of a first phase of combination according to clause 5.1.2.2.1.2.2.

Finally, the UE derives a combined TPC command, TPC_cmd, as a function γ of all the N soft symbol decisions W_i:

- TPC_cmd = γ (W_1, W_2, … W_N), where TPC_cmd can take the values 1 or -1 (2, 1, -1 or -2 for optional mode C).

The function γ shall fulfil the following criteria:

If the N TPC_i commands are random and uncorrelated, with equal probability of being transmitted as "0" or "1", the probability that the output of γ is equal to 1 shall be greater than or equal to $1/(2^N)$, and the probability that the output of γ is equal to -1 shall be greater than or equal to 0,5. Further, the output of γ shall equal 1 if the TPC commands from all the radio link sets are reliably "1" , and the output of γ shall equal -1 if a TPC command from any of the radio link sets is reliably "0".

5.1.2.2.1.3 Algorithm 2 for processing TPC commands

NOTE: Algorithm 2 makes it possible to emulate smaller step sizes than the minimum power control step specified in clause 5.1.2.2.1.1, or to turn off uplink power control by transmitting an alternating series of TPC commands.

5.1.2.2.1.3.1 Derivation of TPC_cmd when only one TPC command is received in each frame

When a UE is not in soft handover, only one TPC command will be received in each frame. In this case, the UE shall process received TPC commands on a 5-frames cycle, where the sets of 5 frames shall be aligned to the frame boundaries and there shall be no overlap between each set of 5 frames.

The value of TPC_cmd shall be derived as follows:

- For the first 4 frames of a set, TPC_cmd = 0.
- For the fifth frame of a set, the UE uses hard decisions on each of the 5 received TPC commands as follows:
  - If all 5 hard decisions within a set are 1 then TPC_cmd = 1 in the 5^{th} frame.
  - If all 5 hard decisions within a set are 0 then TPC_cmd = -1 in the 5^{th} frame.
  - Otherwise, TPC_cmd = 0 in the 5^{th} frame.

5.1.2.2.1.3.2 Combining of TPC commands from radio links of the same radio link set

When a UE is in soft handover, multiple TPC commands may be received in each frame from different spots in the active set. In some cases, the UE has the knowledge that some of the transmitted TPC commands in a frame are the same. This is the case when the radio links are in the same radio link set. For these cases, the TPC commands from radio links of the same radio link set shall be combined into one TPC command, to be processed and further combined with any other TPC commands as described in clause 5.1.2.2.1.2.3.

5.1.2.2.1.3.3 Combining of TPC commands from radio links of different radio link sets

This clause describes the general scheme for combination of the TPC commands from radio links of different radio link sets.

The UE shall make a hard decision on the value of each TPC_i, where i = 1, 2, …, N and N is the number of TPC commands from radio links of different radio link sets, that may be the result of a first phase of combination according to clause 5.1.2.2.1.3.2.

The UE shall follow this procedure for 5 consecutive frames, resulting in N hard decisions for each of the 5 frames.

The sets of 5 frames shall be aligned to the frame boundaries and there shall be no overlap between each set of 5 frames.

The value of TPC_cmd is zero for the first 4 frames. After 5 frames have elapsed, the UE shall determine the value of TPC_cmd for the fifth frame in the following way:

The UE first determines one temporary TPC command, TPC_temp_i, for each of the N sets of 5 TPC commands as follows:

- If all 5 hard decisions within a set are "1", TPC_temp_i = 1.
- If all 5 hard decisions within a set are "0", TPC_temp_i = -1.
- Otherwise, TPC_temp_i = 0.

Finally, the UE derives a combined TPC command for the fifth frame, TPC_cmd, as a function γ of all the N temporary power control commands TPC_temp_i:

TPC_cmd(5th frame) = γ (TPC_temp_1, TPC_temp_2, …, TPC_temp_N), where TPC_cmd(5th frame) can take the values 1, 0 or -1, and γ is given by the following definition:

- TPC_cmd is set to -1 if any of TPC_temp_1 to TPC_temp_N are equal to -1.
- Otherwise, TPC_cmd is set to 1 if $\frac{1}{N}\sum_{i=1}^{N} TPC\_temp_i > 0,5$.
- Otherwise, TPC_cmd is set to 0.

5.1.2.2.2 Operation in optional mode C

In optional mode C, the following shall apply.

5.1.2.2.2.1 General

The uplink inner-loop power control adjusts the UE transmit power in order to keep the received uplink signal-to-interference ratio (SIR) at a given SIR target, SIR_{target}.

The serving spots should estimate signal-to-interference ratio SIR_{est} of the received uplink DPCH. The serving spots should then generate TPC commands and transmit the commands once per radio frame according to the following rule:

Define the variable:

- $\Delta_\varepsilon = SIR_{est} - SIR_{target}$;
- $\Delta_p(i)$ = power control step whose value is determined to be one of $\{-\Delta_L, -\Delta_S, \Delta_S\ \Delta_L\}$ according to the *i*th frame's TPC cmd (TPC command), where the step sizes Δ_S, Δ_L are layer 1 parameters which are derived from the UE-specific higher-layer parameter "TPC-SmallStepSize" and "TPC-LargeStepSize" which are under the control of the USRAN; and

- N_{frame} = loop delay expressed in frames.

And then, $\Delta_p(i)$ is generated by using Δ_ε and the past N_{frame} power control steps $\Delta_p(k)$, k=i-N_{frame}, …, i-1 as follows:

- Compute $\Delta_{\varepsilon,c} = \Delta_\varepsilon + \chi \sum_{k=i-N_{frame}}^{i-1} \{\Delta_p(k) - \alpha\Delta_p(k-1)\}$ where the loop delay compensation indicator χ is set to "1" when a UE is in soft handover and "0" when a UE is not in soft handover, The accumulation reduction factor, α ($0 < \alpha < 1$) is the higher layer parameter and is identical for all UEs in the same spot.

- if $|\Delta_{\varepsilon,c}| < \varepsilon_T$ and $\Delta_{\varepsilon,c} < 0$, $\Delta_p(i) = \Delta_S$

- if $|\Delta_{\varepsilon,c}| < \varepsilon_T$ and $\Delta_{\varepsilon,c} > 0$, $\Delta_p(i) = -\Delta_S$

- if $|\Delta_{\varepsilon,c}| > \varepsilon_T$ and $\Delta_{\varepsilon,c} < 0$, $\Delta_p(i) = \Delta_L$

- if $|\Delta_{\varepsilon,c}| > \varepsilon_T$ and $\Delta_{\varepsilon,c} > 0$, $\Delta_p(i) = -\Delta_L$

For the case of a three-level power control strategy, simply set $\Delta_S = 0$. The two levels power control corresponds to $\varepsilon_T = \infty$.

The UE adjusts the transmit power of the uplink DPCCH with a step of Δ_{DPCCH} (in dB) using two most recently received power control steps, $\Delta_p(i)$ and $\Delta_p(i-1)$ as follows:

- When a UE is not in soft handover

$$\Delta_{DPCCH} = \Delta_p(i) - \alpha\Delta_p(i-1)$$

where α is identical to that used in the serving spot and is signalled by the higher layer.

- When a UE is in soft handover

$$\Delta_{DPCCH} = \kappa\,\Delta_p(i)$$

where κ is the power control step reduction factor signalled by the higher layer.

The relationship between $\Delta_p(i)$ and the transmitter power control command TPC_cmd is presented in table 1a.

Table 1a: Relationship between $\Delta_p(i)$ and TPC_cmd

TPC_cmd	$\Delta_p(i)$
-2	$-\Delta_L$
-1	$-\Delta_S$
1	Δ_S
2	Δ_L

5.1.2.2.2.1.1 Out of synchronisation handling

After 160 ms after physical channel establishment (defined in [5]), the UE shall control its transmitter according to a downlink DPCCH quality criterion as follows:

- The UE shall shut its transmitter off when the UE estimates the DPCCH quality over the last 160 ms period to be worse than a threshold Q_{out}. Q_{out} is defined implicitly by the relevant tests in [7].

- The UE can turn its transmitter on again when the UE estimates the DPCCH quality over the last 160 ms period to be better than a threshold Q_{in}. Q_{in} is defined implicitly by the relevant tests in [7]. When transmission is resumed, the power of the DPCCH shall be the same as when the UE transmitter was shut off.

5.1.2.2.2.1.2 TPC command generation on downlink during RL initialisation

When commanded by higher layers the TPC commands sent on a downlink radio link from Node Bs that have not yet achieved uplink synchronisation shall follow a pattern as follows:

If higher layers indicate by "First RLS indicator" that the radio link is part of the first radio link set sent to the UE and the value "n" obtained from the parameter "DL TPC pattern 0110 count" passed by higher layers is different from 0 then

- the TPC pattern shall consist of n instances of the pair of TPC commands ("01" ,"10"), followed by one instance of TPC command "10", where ("01" ,"10") indicates the TPC commands to be transmitted in 2 consecutive frames,

else

- The TPC pattern shall consist of all "10".

The TPC pattern shall terminate once uplink synchronisation is achieved.

5.1.2.2.2.2 Algorithm for processing TPC commands

5.1.2.2.2.2.1 Derivation of TPC_cmd when only one TPC command is received in each frame

When a UE is not in soft handover, only one TPC command will be received in each radio frame. In this case, the value of TPC_cmd shall be derived as follows:

- If the received TPC command is equal to 00, then TPC_cmd for that frame is -2.
- If the received TPC command is equal to 01, then TPC_cmd for that frame is -1.
- If the received TPC command is equal to 10, then TPC_cmd for that frame is 1.
- If the received TPC command is equal to 11, then TPC_cmd for that frame is 2.

5.1.2.2.2.2.2 Combining of TPC commands from radio links of the same radio link set

When a UE is in soft handover, multiple TPC commands may be received in each radio frame from different spots in the active set. In some cases, the UE has the knowledge that some of the transmitted TPC commands in a radio frame are the same. This is the case when the radio links are in the same radio link set. For these cases, the TPC commands from the same radio link set shall be combined into one TPC command, to be further combined with other TPC commands as described in clause 5.1.2.2.2.2.3.

5.1.2.2.2.2.3 Combining of TPC commands from radio links of different radio link sets

This clause describes the general scheme for combination of the TPC commands from radio links of different radio link sets.

First, the UE shall conduct a soft symbol decision W_i on each of the power control commands TPC_i, where i = 1, 2, …, N, where N is greater than 1 and is the number of TPC commands from radio links of different radio link sets, that may be the result of a first phase of combination according to clause 5.1.2.2.2.2.2.

Finally, the UE derives a combined TPC command, TPC_cmd, as a function γ of all the N soft symbol decisions W_i:

- TPC_cmd = γ (W_1, W_2, … W_N), where TPC_cmd can take the values 2, 1, -1 or -2.

The function γ shall fulfil the following criteria:

If the N TPC commands are random and uncorrelated, with equal probability of being transmitted as "00", "01", "10" or "11", the probability that the output of γ is greater than or equal to 1 shall be greater than or equal to $1/(2^N)$, and the probability that the output of γ is smaller than or equal to -1 shall be greater than or equal to 0,5. Further, the output of γ shall equal to 2 if the TPC commands from all the radio link sets are reliably "11" , and the output of γ shall equal to -2 if a TPC command from any of the radio link sets is reliably "00".

5.1.2.3 Transmit power control in compressed mode

5.1.2.3.1 Normal operation

The following shall apply in all modes, except optional mode C.

In compressed mode, one or more transmission gap pattern sequences are active. Therefore some frames are compressed and contain transmission gaps. The uplink power control procedure is as specified in clause 5.1.2.2.1, using the same USRAN supplied parameters for Power Control Algorithm and step size (Δ_{TPC}), but with additional features which aim to recover as rapidly as possible a signal-to-interference ratio (SIR) close to the target SIR after each transmission gap.

The serving spots (spots in the active set) should estimate signal-to-interference ratio SIR_{est} of the received uplink DPCH. The serving spots should then generate TPC commands and transmit the commands once per spot, except during downlink transmission gaps, according to the following rule: if $SIR_{est} > SIR_{cm\_target}$ then the TPC command to transmit is "0", while if $SIR_{est} < SIR_{cm\_target}$ then the TPC command to transmit is "1".

- SIR_{cm_target} is the target SIR during compressed mode and fulfils;
- $SIR_{cm\_target} = SIR_{target} + \Delta SIR_{PILOT} + \Delta SIR1\_coding + \Delta SIR2\_coding$,

where ΔSIR1_coding and ΔSIR2_coding are computed from uplink parameters DeltaSIR1, DeltaSIR2, DeltaSIRafter1, DeltaSIRafter2 signalled by higher layers as:

- ΔSIR1_coding = DeltaSIR1 if the start of the first transmission gap in the transmission gap pattern is within the current uplink frame.
- ΔSIR1_coding = DeltaSIRafter1 if the current uplink frame just follows a frame containing the start of the first transmission gap in the transmission gap pattern.
- ΔSIR2_coding = DeltaSIR2 if the start of the second transmission gap in the transmission gap pattern is within the current uplink frame.
- ΔSIR2_coding = DeltaSIRafter2 if the current uplink frame just follows a frame containing the start of the second transmission gap in the transmission gap pattern.
- ΔSIR1_coding = 0 dB and ΔSIR2_coding = 0 dB in all other cases.

ΔSIR_{PILOT} is defined as: $\Delta SIR_{PILOT} = 10Log_{10} (N_{pilot,N}/N_{pilot,curr\_frame})$,

where $N_{pilot,curr\_frame}$ is the number of pilot bits per slot in the current uplink frame, and $N_{pilot,N}$ is the number of pilot bits per slot in a normal uplink frame without a transmission gap.

In the case of several compressed mode pattern sequences being used simultaneously, ΔSIR1_coding and ΔSIR2_coding offsets are computed for each compressed mode pattern and all ΔSIR1_coding and ΔSIR2_coding offsets are summed together.

In compressed mode, compressed frames may occur in either the uplink or the downlink or both. In uplink compressed frames, the transmission of uplink DPDCH(s) and DPCCH shall both be stopped during transmission gaps.

Due to the transmission gaps in compressed frames, there may be missing TPC commands in the downlink. If no downlink TPC command is transmitted, the corresponding TPC_cmd derived by the UE shall be set to zero.

Compressed and non-compressed frames in the uplink DPCCH may have a different number of pilot bits per slot. A change in the transmit power of the uplink DPCCH would be needed in order to compensate for the change in the total pilot energy. Therefore at the start of each slot the UE shall derive the value of a power offset Δ_{PILOT}. If the number of pilot bits per slot in the uplink DPCCH is different from its value in the most recently transmitted slot, Δ_{PILOT} (in dB) shall be given by:

$$\Delta_{PILOT} = 10Log_{10} (N_{pilot,prev}/N_{pilot,curr});$$

where $N_{pilot,prev}$ is the number of pilot bits in the most recently transmitted slot , and $N_{pilot,curr}$ is the number of pilot bits in the current slot. Otherwise, including during transmission gaps in the downlink, Δ_{PILOT} shall be zero.

Unless otherwise specified, in every slot during compressed mode the UE shall adjust the transmit power of the uplink DPCCH with a step of Δ_{DPCCH} (in dB) which is given by:

$$\Delta_{DPCCH} = \Delta_{TPC} \times TPC\_cmd + \Delta_{PILOT}.$$

At the start of the first slot after an uplink or downlink transmission gap the UE shall apply a change in the transmit power of the uplink DPCCH by an amount Δ_{DPCCH} (in dB), with respect to the uplink DPCCH power in the most recently transmitted uplink slot, where:

$$\Delta_{DPCCH} = \Delta_{RESUME} + \Delta_{PILOT}.$$

The value of Δ_{RESUME} (in dB) shall be determined by the UE according to the Initial Transmit Power mode (ITP). The ITP is a UE specific parameter, which is signalled by the network with the other compressed mode parameters (see TS 125 215 [i.3]). The different modes are summarized in table 2.

Table 2: Initial Transmit Power modes during compressed mode

Initial Transmit Power mode	Description
0	$\Delta_{RESUME} = \Delta_{TPC} \times TPC\_cmd_{gap}$
1	$\Delta_{RESUME} = \delta_{last}$

In the case of a transmission gap in the uplink, TPC_cmd_{gap} shall be the value of TPC_cmd derived in the first slot of the uplink transmission gap, if a downlink TPC_command is transmitted in that slot. Otherwise TPC_cmd_{gap} shall be zero.

δ_{last} shall be equal to the most recently computed value of δ_i. δ_i shall be updated according to the following recursive relations, which shall be executed in all slots in which both the uplink DPCCH and a downlink TPC command are transmitted, and in the first slot of an uplink transmission gap if a downlink TPC command is transmitted in that slot:

$$\delta_i = 0{,}9375\delta_{i-1} - 0{,}96875 TPC\_cmd_i \Delta_{TPC} k_{sc}$$
$$\delta_{i-1} = \delta_i$$

where: TPC_cmd_i is the power control command derived by the UE in that slot;

k_{sc} = 0 if additional scaling is applied in the current slot and the previous slot as described in clause 5.1.2.6 and k_{sc} = 1 otherwise.

δ_{i-1} is the value of δ_i computed for the previous slot. The value of δ_{i-1} shall be initialized to zero when the uplink DPCCH is activated, and also at the end of the first slot after each uplink transmission gap, and also at the end of the first slot after each downlink transmission gap. The value of δ_i shall be set to zero at the end of the first slot after each uplink transmission gap.

After a transmission gap in either the uplink or the downlink, the period following resumption of simultaneous uplink and downlink DPCCH transmission is called a recovery period. RPL is the recovery period length and is expressed as a number of slots. RPL is equal to the minimum value out of the transmission gap length and 7 slots. If a transmission gap is scheduled to start before RPL slots have elapsed, then the recovery period shall end at the start of the gap, and the value of RPL shall be reduced accordingly.

During the recovery period, 2 modes are possible for the power control algorithm. The Recovery Period Power control mode (RPP) is signalled with the other compressed mode parameters (see TS 125 215 [i.3]). The different modes are summarized in table 3.

Table 3: Recovery Period Power control modes during compressed mode

Recovery Period power control mode	Description
0	Transmit power control is applied using the algorithm determined by the value of PCA, as in clause 5.1.2.2 with step size $\Delta_{TPC.}$
1	Transmit power control is applied using algorithm 1 (see clause 5.1.2.2.1.2) with step size Δ_{RP-TPC} during RPL slots after each transmission gap.

For RPP mode 0, the step size is not changed during the recovery period and ordinary transmit power control is applied (see clause 5.1.2.2.1), using the algorithm for processing TPC commands determined by the value of PCA (see clauses 5.1.2.2.1.2 and 5.1.2.2.1.3).

For RPP mode 1, during RPL slots after each transmission gap, power control algorithm 1 is applied with a step size Δ_{RP-TPC} instead of Δ_{TPC}, regardless of the value of PCA. Therefore, the change in uplink DPCCH transmit power at the start of each of the RPL + 1 slots immediately following the transmission gap (except for the first slot after the transmission gap) is given by:

$$\Delta_{DPCCH} = \Delta_{RP\text{-}TPC} \times TPC\_cmd + \Delta_{PILOT.}$$

Δ_{RP-TPC} is called the recovery power control step size and is expressed in dB. If PCA has the value 1, Δ_{RP-TPC} is equal to the minimum value of 3 dB and $2\Delta_{TPC}$. If PCA has the value 2 , Δ_{RP-TPC} is equal to 1 dB.

After the recovery period, ordinary transmit power control resumes using the algorithm specified by the value of PCA and with step size Δ_{TPC}.

If PCA has the value 2 , the sets of slots over which the TPC commands are processed shall remain aligned to the frame boundaries in the compressed frame. For both RPP mode 0 and RPP mode 1, if the transmission gap or the recovery period results in any incomplete sets of TPC commands, TPC_cmd shall be zero for those sets of slots which are incomplete.

5.1.2.3.2 Operations in Optional mode C

In optional mode C, the following shall apply:

In compressed mode, one or more transmission gap pattern sequences are active. Therefore some frames are compressed and contain transmission gaps. The uplink power control procedure is as specified in clause 5.1.2.2.2, using the same USRAN supplied parameters for power control thresholds and step sizes, but with additional features which aim to compensate the target SIR variation.

The serving spots (spots in the active set) should estimate signal-to-interference ratio SIR_{est} of the received uplink DPCH. The serving spots should then generate TPC commands and transmit the commands once per frame, according to the same rule as specified in clause 5.1.2.2.2.2, except using SIR_{cm_target} instead of SIR_{target} as the SIR target. SIR_{cm_target} is the target SIR during compressed mode and fulfils:

$$SIR_{cm\_target} = SIR_{target} + \Delta SIR_{PILOT} + \Delta SIR1\_coding + \Delta SIR2\_coding,$$

where ΔSIR1_coding and ΔSIR2_coding are computed from uplink parameters DeltaSIR1, DeltaSIR2, DeltaSIRafter1, DeltaSIRafter2 signalled by higher layers as:

- ΔSIR1_coding = DeltaSIR1 if the start of the first transmission gap in the transmission gap pattern is within the current uplink frame.
- ΔSIR1_coding = DeltaSIRafter1 if the current uplink frame just follows a frame containing the start of the first transmission gap in the transmission gap pattern.
- ΔSIR2_coding = DeltaSIR2 if the start of the second transmission gap in the transmission gap pattern is within the current uplink frame.
- ΔSIR2_coding = DeltaSIRafter2 if the current uplink frame just follows a frame containing the start of the second transmission gap in the transmission gap pattern.

- ΔSIR1_coding = 0 dB and ΔSIR2_coding = 0 dB in all other cases.

ΔSIR_{PILOT} is defined as: $\Delta SIR_{PILOT} = 10Log_{10} (N_{pilot,N}/N_{pilot,curr\_frame})$,

where $N_{pilot,curr\_frame}$ is the number of pilot bits per slot in the current uplink frame, and $N_{pilot,N}$ is the number of pilot bits per slot in a normal uplink frame without a transmission gap.

In the case of several compressed mode pattern sequences being used simultaneously, ΔSIR1_coding and ΔSIR2_coding offsets are computed for each compressed mode pattern and all ΔSIR1_coding and ΔSIR2_coding offsets are summed together.

In compressed mode, compressed frames may occur in either the uplink or the downlink or both. In uplink compressed frames, the transmission of uplink DPDCH(s) and DPCCH shall both be stopped during transmission gaps.

In compressed frame, the UE shall adjust the transmit power of the uplink DPCCH with a step of $\Delta_{DPCCH,cmp}$ (in dB) which is given by

$$\Delta_{DPCCH,cmp} = \Delta_{DPCCH,}$$

where Δ_{DPCCH} is the same as described in clause 5.1.2.2.2.2.

5.1.2.4 Transmit power control in the uplink DPCCH power control preamble

An uplink DPCCH power control preamble is a period of uplink DPCCH transmission prior to the start of the uplink DPDCH transmission. The downlink DPCCH shall also be transmitted during an uplink DPCCH power control preamble.

The length of the uplink DPCCH power control preamble is a higher layer parameter signalled by the network as defined in TS 125 331 [i.4]. The uplink DPDCH transmission shall commence after the end of the uplink DPCCH power control preamble.

During the uplink DPCCH power control preamble the change in uplink DPCCH transmit power shall be given by:

$$\Delta_{DPCCH} = \Delta_{TPC} \times \text{TPC\_cmd}.$$

During the uplink DPCCH power control preamble TPC_cmd is derived according to algorithm 1 as described in clause 5.1.2.2.1.1, regardless of the value of PCA.

Ordinary power control (see clause 5.1.2.2), with the power control algorithm determined by the value of PCA and step size $\Delta_{TPC,}$ shall be used after the end of the uplink DPCCH power control preamble.

5.1.2.5 Setting of the uplink DPCCH/DPDCH power difference

5.1.2.5.1 General

The uplink DPCCH and DPDCH(s) are transmitted on different codes as defined in TS 101 851-3-3 [3]. The gain factors β_c and β_d may vary for each TFC. There are two ways of controlling the gain factors of the DPCCH code and the DPDCH codes for different TFCs in normal (non-compressed) frames:

- β_c and β_d are signalled for the TFC; or
- β_c and β_d is computed for the TFC, based on the signalled settings for a reference TFC.

Combinations of the two above methods may be used to associate β_c and β_d values to all TFCs in the TFCS. The two methods are described in clauses 5.1.2.5.2 and 5.1.2.5.3 respectively. Several reference TFCs may be signalled from higher layers.

The gain factors may vary on radio frame basis depending on the current TFC used. Further, the setting of gain factors is independent of the inner loop power control.

After applying the gain factors, the UE shall scale the total transmit power of the DPCCH and DPDCH(s), such that the DPCCH output power follows the changes required by the power control procedure with power adjustments of Δ_{DPCCH} dB, subject to the provisions of clause 5.1.2.6.

The gain factors during compressed frames are based on the nominal power relation defined in normal frames, as specified in clause 5.1.2.5.4.

5.1.2.5.2 Signalled gain factors

When the gain factors β_c and β_d are signalled by higher layers for a certain TFC, the signalled values are used directly for weighting of DPCCH and DPDCH(s). The variable A_j, called the nominal power relation is then computed as:

$$A_j = \frac{\beta_d}{\beta_c}.$$

5.1.2.5.3 Computed gain factors

The gain factors β_c and β_d may also be computed for certain TFCs, based on the signalled settings for a reference TFC.

Let $\beta_{c,ref}$ and $\beta_{d,ref}$ denote the signalled gain factors for the reference TFC. Further, let $\beta_{c,j}$ and $\beta_{d,j}$ denote the gain factors used for the j:th TFC. Also let L_{ref} denote the number of DPDCHs used for the reference TFC and $L_{,j}$ denote the number of DPDCHs used for the j:th TFC.

Define the variable

$$K_{ref} = \sum_i RM_i \cdot N_i \quad ;$$

where RM_i is the semi-static rate matching attribute for transport channel i (defined in TS 101 851-2-3 [2]), N_i is the number of bits output from the radio frame segmentation block for transport channel i (defined in TS 101 851-2-3 [2]), and the sum is taken over all the transport channels i in the reference TFC.

Similarly, define the variable

$$K_j = \sum_i RM_i \cdot N_i \quad ;$$

where the sum is taken over all the transport channels i in the j:th TFC.

The variable A_j, called the nominal power relation is then computed as:

$$A_j = \frac{\beta_{d,ref}}{\beta_{c,ref}} \times \sqrt{\frac{L_{ref}}{L_j}} \sqrt{\frac{K_j}{K_{ref}}} .$$

The gain factors for the j:th TFC are then computed as follows:

- If $A_j > 1$, then $\beta_{d,j} = 1{,}0$ and $\beta_{c,j}$ is the largest quantized β -value, for which the condition $\beta_{c,j} \leq 1 / A_j$ holds. Since $\beta_{c,j}$ may not be set to zero, if the above rounding results in a zero value, $\beta_{c,j}$ shall be set to the lowest quantized amplitude ratio of 1/15 as specified in TS 101 851-3-3 [3].
- If $A_j \leq 1$, then $\beta_{d,j}$ is the smallest quantized β -value, for which the condition $\beta_{d,j} \geq A_j$ holds and $\beta_{c,j} = 1{,}0$.

The quantized β-values are defined in TS 101 851-3-3 [3].

5.1.2.5.4 Setting of the uplink DPCCH/DPDCH power difference in compressed mode

The gain factors used during a compressed frame for a certain TFC are calculated from the nominal power relation used in normal (non-compressed) frames for that TFC. Let A_j denote the nominal power relation for the j:th TFC in a normal frame. Further, let $\beta_{c,C,j}$ and $\beta_{d,C,j}$ denote the gain factors used for the j:th TFC when the frame is compressed. The variable $A_{C,j}$ is computed as:

$$A_{C,j} = A_j \times \sqrt{\frac{15 \times N_{pilot,C}}{N_{slots,C} \times N_{pilot,N}}};$$

where $N_{pilot,C}$ is the number of pilot bits per slot when in compressed mode, and $N_{pilot,N}$ is the number of pilot bits per slot in normal mode. $N_{slots,C}$ is the number of slots in the compressed frame used for transmitting the data.

The gain factors for the j:th TFC in a compressed frame are computed as follows:

- If $A_{C,j} > 1$, then $\beta_{d,C,j} = 1{,}0$ and $\beta_{c,C,j}$ is the largest quantized β -value, for which the condition $\beta_{c,C,j} \leq 1 / A_{C,j}$ holds. Since $\beta_{c,C,j}$ may not be set to zero, if the above rounding results in a zero value, $\beta_{c,C,j}$ shall be set to the lowest quantized amplitude ratio of 1/15 as specified in TS 101 851-3-3 [3].

- If $A_{C,j} \leq 1$, then $\beta_{d,C,j}$ is the smallest quantized β -value, for which the condition $\beta_{d,C,j} \geq A_{C,j}$ holds and $\beta_{c,C,j} = 1{,}0$.

The quantized β-values are defined in TS 101 851-3-3 [3].

5.1.2.6 Maximum and minimum power limits

5.1.2.6.1 Normal operation

The following shall apply in all modes, except optional mode C.

In the case that the total UE transmit power (after applying DPCCH power adjustments and gain factors) would exceed the maximum allowed value, the UE shall apply additional scaling to the total transmit power so that it is equal to the maximum allowed power. This additional scaling shall be such that the power ratio between DPCCH and DPDCH remains as required by clause 5.1.2.5.1. Any scaling shall only be applied or changed at a DPCCH slot boundary.

When transmitting on a DPCH the UE is not required to be capable of reducing its total transmit power below the minimum level required in TS 125 101 [7]. However, it may do so, provided that the power ratio between DPCCH and DPDCH remains as specified in clause 5.1.2.5.1. Some further regulations also apply as follows: In the case that the total UE transmit power (after applying DPCCH power adjustments and gain factors) would be at or below the total transmit power in the previously transmitted slot and also at or below the required minimum power specified in TS 125 101 [7], the UE may apply additional scaling to the total transmit power, subject to the following restrictions:

- The total transmit power after applying any additional scaling shall not exceed the required minimum power, nor the total transmit power in the previously transmitted slot.

- The magnitude of any reduction in total transmit power between slots after applying any additional scaling shall not exceed the magnitude of the calculated power reduction before the additional scaling.

In the case that the total UE transmit power in the previously transmitted slot is at or below the required minimum power specified in TS 125 101 [7] and the DPCCH power adjustment and gain factors for the current slot would result in an increase in total power, then no additional scaling shall be used (i.e. power control shall operate as normal).

If the UE applies any additional scaling to the total transmit power as described above, this scaling shall be included in the computation of any DPCCH power adjustments to be applied in the next transmitted slot.

5.1.2.6.2 Operation in Optional mode C

In optional mode C, the following shall apply.

In the case that the total UE transmit power (after applying DPCCH power adjustments and gain factors) would exceed the maximum allowed value, the UE shall apply additional scaling to the total transmit power so that it is equal to the maximum allowed power. This additional scaling shall be such that the power ratio between DPCCH and DPDCH remains as required by clause 5.1.2.5.2.

When transmitting on a DPCH the UE is not required to be capable of reducing its total transmit power below the minimum level required in [7]. However, it may do so, provided that the power ratio between DPCCH and DPDCH remains as specified in clause 5.1.2.5.2. Some further regulations also apply as follows: In the case that the total UE transmit power (after applying DPCCH power adjustments and gain factors) would be at or below the total transmit power in the previously transmitted frame and also at or below the required minimum power specified in [7], the UE may apply additional scaling to the total transmit power, subject to the following restrictions:

- The total transmit power after applying any additional scaling shall not exceed the required minimum power, nor the total transmit power in the previously transmitted frame.
- The magnitude of any reduction in total transmit power between frames after applying any additional scaling shall not exceed the magnitude of the calculated power reduction before the additional scaling.

In the case that the total UE transmit power in the previously transmitted frame is at or below the required minimum power specified in [7] and the DPCCH power adjustment and gain factors for the current frame would result in an increase in total power, then no additional scaling shall be used (i.e. power control shall operate as normal).

If the UE applies any additional scaling to the total transmit power as described above, this scaling shall be included in the computation of any DPCCH power adjustments to be applied in the next transmitted frame.

5.2 Downlink power control

The transmit power of the downlink channels is determined by the network. In general the ratio of the transmit power between different downlink channels is not specified and may change with time. However, regulations exist as described in the following clauses.

Higher layer power settings shall be interpreted as setting of the total power, i.e. the sum of the power from the two antennas in case of transmit diversity.

5.2.1 DPCCH/DPDCH

5.2.1.1 General

The downlink transmit power control procedure controls simultaneously the power of a DPCCH and its corresponding DPDCHs. The power control loop adjusts the power of the DPCCH and DPDCHs with the same amount, i.e. the relative power difference between the DPCCH and DPDCHs is not changed.

The relative transmit power offset between DPCCH fields and DPDCHs is determined by the network The TFCI, TPC and pilot fields of the DPCCH are offset relative to the DPDCHs power by PO1, PO2 and PO3 dB respectively. The power offsets may vary in time. USRAN may use the SSDT operation as specified in clause 5.2.2 to determine what power offset to use for TFCI in hard split mode with respect to the associated downlink DPDCH. The method for controlling the power offsets within USRAN is specified in TS 125 433 [6].

5.2.1.2 Ordinary transmit power control

5.2.1.2.1 Normal operations

The following shall apply in all modes, except optional mode C.

5.2.1.2.1.1 UE behaviour

The UE shall generate TPC commands to control the network transmit power and send them in the TPC field of the uplink DPCCH.

An example on how to derive the TPC commands in given in clause B.2.

The UE shall check the downlink power control mode (DPC_MODE) before generating the TPC command:

- if DPC_MODE = 0: the UE sends a unique TPC command in each slot and the TPC command generated is transmitted in the first available TPC field in the uplink DPCCH;
- if DPC_MODE = 1: the UE repeats the same TPC command over 3 frames and the new TPC command is transmitted such that there is a new command at the beginning of the frame.

The DPC_MODE parameter is a UE specific parameter controlled by the USRAN.

The UE shall not make any assumptions on how the downlink power is set by USRAN, in order to not prohibit usage of other USRAN power control algorithms than what is defined in clause 5.2.1.2.1.2.

5.2.1.2.1.2 USRAN behaviour

Upon receiving the TPC commands USRAN shall adjust its downlink DPCCH/DPDCH power accordingly. For DPC_MODE = 0, USRAN shall estimate the transmitted TPC command TPC_{est} to be 0 or 1, and shall update the power every frame. If DPC_MODE = 1, USRAN shall estimate the transmitted TPC command TPC_{est} over three frames to be 0 or 1, and shall update the power every three frames.

After estimating the *k*:th TPC command, USRAN shall adjust the current downlink power $P(k\text{-}1)$ [dB] to a new power $P(k)$ [dB] according to the following formula:

$$P(k) = P(k - 1) + P_{TPC}(k) + P_{bal}(k),$$

where $P_{TPC}(k)$ is the *k*:th power adjustment due to the inner loop power control, and $P_{bal}(k)$ [dB] is a correction according to the downlink power control procedure for balancing radio link powers towards a common reference power. The power balancing procedure and control of the procedure is described in TS 125 433 [6].

$P_{TPC}(k)$ is calculated according to the following.

If the value of *Limited Power Increase Used* parameter is "Not used", then

$$\mathrm{P_{TPC}}(k) = \begin{cases} +\Delta_{\mathrm{TPC}} & \text{if } \mathrm{TPC_{est}}(k) = 1 \\ -\Delta_{\mathrm{TPC}} & \text{if } \mathrm{TPC_{est}}(k) = 0 \end{cases}, \text{ [dB].} \qquad (1)$$

If the value of *Limited Power Increase Used* parameter is "Used", then the *k:*th inner loop power adjustment shall be calculated as:

$$P_{TPC}(k) = \begin{cases} +\Delta_{TPC} & \text{if } \mathrm{TPC_{est}}(k) = 1 \text{ and } \Delta_{sum}(k) + \Delta_{TPC} < \text{Power\_Raise\_Limit} \\ 0 & \text{if } \mathrm{TPC_{est}}(k) = 1 \text{ and } \Delta_{sum}(k) + \Delta_{TPC} \geq \text{Power\_Raise\_Limit} \\ -\Delta_{TPC} & \text{if } \mathrm{TPC_{est}}(k) = 0 \end{cases}, \text{ [dB]} \qquad (2)$$

where

$$\Delta_{sum}(k) = \sum_{i = k - \text{DL\_Power\_Averaging\_Window\_Size}}^{k-1} P_{TPC}(i)$$

is the temporary sum of the last *DL_Power_Averaging_Window_Size* inner loop power adjustments (in dB).

For the first (*DL_Power_Averaging_Window_Size* - 1) adjustments after the activation of the limited power increase method, formula (1) shall be used instead of formula (2). *Power_Raise_Limit* and *DL_Power_Averaging_Window_Size* are parameters configured in the USRAN.

The power control step size Δ_{TPC} can take four values: 0,5 dB, 1 dB, 1,5 dB or 2 dB. It is mandatory for USRAN to support Δ_{TPC} of 1 dB, while support of other step sizes is optional.

In addition to the above described formulas on how the downlink power is updated, the restrictions below apply.

In case of congestion (commanded power not available), USRAN may disregard the TPC commands from the UE.

The average power of transmitted DPDCH symbols over one timeslot (over radio frame in optional mode C) shall not exceed Maximum_DL_Power (dB), nor shall it be below Minimum_DL_Power (dB). Transmitted DPDCH symbol means here a complex QPSK symbol before spreading which does not contain DTX. Maximum_DL_Power (dB) and Minimum_DL_Power (dB) are power limits for one channelization code, relative to the primary CPICH power TS 125 433 [6].

5.2.1.2.2 Operation in Optional mode C

In optional mode C, the following shall apply.

5.2.1.2.2.1 UE behaviour

The UE shall generate TPC commands to control the network transmit power, encode them according to TPC coding method in [2], and send the coded bits in the TPC field of the uplink DPCCH.

The UE shall not make any assumptions on how the downlink power is set by USRAN, in order to not prohibit usage of other USRAN power control algorithms than what is defined in clause 5.2.1.2.2.2.

The downlink inner-loop power control adjusts the network transmit power in order to keep the received downlink SIR at a given SIR target, SIR_{target}. A higher layer outer loop adjusts SIR_{target} independently for each connection.

The UE should estimate the received downlink DPCCH/DPDCH power of the connection to be power controlled. Simultaneously, the UE should estimate the received interference and calculate the signal-to-interference ratio, SIR_{est}. SIR_{est} can be calculated as RSCP/ISCP, where RSCP refers to the received signal code power on one code and ISCP refers to the non-orthogonal interference signal code power of the received signal on one code.

The obtained SIR estimate SIR_{est} is then used by the UE to generate TPC commands according to the following rule:

- if $| SIR_{est} - SIR_{target} | > \varepsilon_T$ and $SIR_{est} > SIR_{target}$, then the TPC command to transmit is "00"
- if $| SIR_{est} - SIR_{target} | < \varepsilon_T$ and $SIR_{est} > SIR_{target}$, then the TPC command to transmit is "01"
- if $| SIR_{est} - SIR_{target} | > \varepsilon_T$ and $SIR_{est} < SIR_{target}$, then the TPC command to transmit is "10"
- if $| SIR_{est} - SIR_{target} | < \varepsilon_T$ and $SIR_{est} < SIR_{target}$, then the TPC command to transmit is "11"

When the UE is in soft handover and BSDT is not activated, the UE should estimate SIR_{est} from the downlink signals of all spots in the active set.

When BSDT is activated, the UE should estimate SIR_{est} from the downlink signals of the primary spot. If the state of the spots (primary or non-primary) in the active set is changed and the UE sends the coded ID in uplink frame j, the UE should change the basis for the estimation of SIR_{est} at the beginning of downlink frame ($j+1+T_{os}$), where T_{os} is defined as a constant and is under the control of Satellite-RAN.

The UE may employ prediction algorithm which estimates the future SIR value after the round trip delay. Prediction for the SIR variation can be implemented by observing the trace of the past SIR variations of the CPICHs in the active set. In order to support UEs which employ the prediction algorithm, a nominal round trip delay of the spot to which the UE belongs is signalled by higher layers.

When the UE employs prediction algorithm, the predicted SIR variation after round trip delay, Δ_{pred} is used by the UE to generate TPC commands according to the following rule:

Define $SIR_{est.pred}=SIR_{est}+\Delta_{pred}$, then

- if $| SIR_{est.pred} - SIR_{target} | > \varepsilon_T$ and $SIR_{est,pred} > SIR_{target}$, then the TPC command to transmit is "00"
- if $| SIR_{est,pred} - SIR_{target} | < \varepsilon_T$ and $SIR_{est,pred} > SIR_{target}$, then the TPC command to transmit is "01"
- if $| SIR_{est,pred} - SIR_{target} | > \varepsilon_T$ and $SIR_{est,pred} < SIR_{target}$, then the TPC command to transmit is "10"
- if $| SIR_{est,pred} - SIR_{target} | < \varepsilon_T$ and $SIR_{est,pred} < SIR_{target}$, then the TPC command to transmit is "11"

5.2.1.2.2.2 USRAN behaviour

Upon receiving the TPC commands USRAN shall adjust its downlink DPCCH/DPDCH power accordingly. USRAN shall estimate the transmitted TPC command TPC_{est}, and shall update the power every frame.

After estimating the k:th TPC command, USRAN shall adjust the current downlink power $P(k-1)$ [dB] to a new power $P(k)$ [dB] according to the following formula:

$$P(k) = P(k - 1) + P_{TPC}(k) + P_{bal}(k),$$

where $P_{TPC}(k)$ is the k:th power adjustment due to the inner loop power control, and $P_{bal}(k)$ [dB] is a correction according to the downlink power control procedure for balancing radio link powers towards a common reference power. The power balancing procedure and control of the procedure is described in [6].

$P_{TPC}(k)$ is calculated according to the following.

If the value of *Limited Power Increase Used* parameter is "Not used", then

$$\mathrm{P}_{\mathrm{TPC}}(k) = \begin{cases} -\Delta_L & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 00 \\ -\Delta_\mathrm{S} & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 01 \\ +\Delta_\mathrm{S} & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 10 \\ +\Delta_\mathrm{L} & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 11 \end{cases}, \text{ [dB]} \tag{3}$$

If the value of *Limited Power Increase Used* parameter is "Used", then the *k:*th inner loop power adjustment shall be calculated as:

$$P_{TPC}(k) = \begin{cases} -\Delta_L & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 00 \\ -\Delta_S & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 01 \\ 0 & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 10 \text{ or } 01 \text{ and } \Delta_{sum}(k) + \Delta_{TPC} > \text{Power\_Raise\_Limit} \\ +\Delta_S & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 10 \text{ and } \Delta_{sum}(k) + \Delta_{TPC} < \text{Power\_Raise\_Limit} \\ +\Delta_L & \text{if } \mathrm{TPC}_{\mathrm{est}}(k) = 11 \text{ and } \Delta_{sum}(k) + \Delta_{TPC} < \text{Power\_Raise\_Limit} \end{cases}, \text{ [dB]} \tag{4}$$

where

$$\Delta_{sum}(k) = \sum_{i=k-\text{DL\_Power\_Averaging\_Window\_Size}}^{k-1} P_{TPC}(i)$$

is the temporary sum of the last *DL_Power_Averaging_Window_Size* inner loop power adjustments (in dB).

For the first (*DL_Power_Averaging_Window_Size* - 1) adjustments after the activation of the limited power increase method, formula (3) shall be used instead of formula (4). *Power_Raise_Limit* and *DL_Power_Averaging_Window_Size* are parameters configured in the Satellite-RAN.

In addition to the above described formulas on how the downlink power is updated, the restrictions below apply.

In case of congestion (commanded power not available), USRAN may disregard the TPC commands from the UE.

The average power of transmitted DPDCH symbols over one radio frame shall not exceed Maximum_DL_Power (dB), nor shall it be below Minimum_DL_Power (dB). Transmitted DPDCH symbol means here a complex QPSK symbol before spreading which does not contain DTX. Maximum_DL_Power (dB) and Minimum_DL_Power (dB) are power limits for one channelization code, relative to the primary CPICH power [6].

5.2.1.3 Power control in compressed mode

The aim of downlink power control in uplink or/and downlink compressed mode is to recover as fast as possible a signal-to-interference ratio (SIR) close to the target SIR after each transmission gap.

The UE behaviour is the same in compressed mode as in normal mode, described in clause 5.2.1.2, except that the target SIR is offset by higher layer signalling. However due to transmission gaps in uplink compressed frames there may be incomplete sets of TPC commands when DPC_MODE = 1.

USRAN behaviour is as stated in clause 5.2.1.2.2 except for DPC_MODE = 1 where missing TPC commands in the UL may lead the USRAN to changing its power more frequently than every 3 slots.

In compressed mode, compressed frames may occur in either the uplink or the downlink or both. In compressed frames, the transmission of downlink DPDCH(s) and DPCCH shall be stopped during transmission gaps.

The power of the DPCCH and DPDCH in the first slot after the transmission gap should be set to the same value as in the slot just before the transmission gap.

During compressed mode except during downlink transmission gaps, USRAN shall estimate the k:th TPC command and adjust the current downlink power $P(k - 1)$ [dB] to a new power $P(k)$ [dB] according to the following formula:

$$P(k) = P(k - 1) + P_{TPC}(k) + P_{SIR}(k) + P_{bal}(k),$$

where $P_{TPC}(k)$ is the k:th power adjustment due to the inner loop power control, $P_{SIR}(k)$ is the k-th power adjustment due to the downlink target SIR variation, and $P_{bal}(k)$ [dB] is a correction according to the downlink power control procedure for balancing radio link powers towards a common reference power. The power balancing procedure and control of the procedure is described in TS 125 433 [6].

Due to transmission gaps in uplink compressed frames, there may be missing TPC commands in the uplink.

For DPC_MODE = 0 if no uplink TPC command is received, $P_{TPC}(k)$ derived by the satellite gateway shall be set to zero. Otherwise, $P_{TPC}(k)$ is calculated the same way as in normal mode (see clause 5.2.1.2.1.2) but with a step size Δ_{STEP} instead of Δ_{TPC}.

For DPC_MODE = 1, the sets of slots over which the TPC commands are processed shall remain aligned to the frame boundaries in the compressed frame. If this results in an incomplete set of TPC commands, the UE shall transmit the same TPC commands in all slots of the incomplete set.

The power control step size $\Delta_{STEP} = \Delta_{RP\text{-}TPC}$ during RPL slots after each transmission gap and $\Delta_{STEP} = \Delta_{TPC}$ otherwise, where:

- RPL is the recovery period length and is expressed as a number of slots. RPL is equal to the minimum value out of the transmission gap length and 7 slots. If a transmission gap is scheduled to start before RPL slots have elapsed, then the recovery period shall end at the start of the gap, and the value of RPL shall be reduced accordingly.

- $\Delta_{RP\text{-}TPC}$ is called the recovery power control step size and is expressed in dB. $\Delta_{RP\text{-}TPC}$ is equal to the minimum value of 3 dB and $2\Delta_{TPC}$.

The power offset $P_{SIR}(k) = \delta P_{curr} - \delta P_{prev}$, where δP_{curr} and δP_{prev} are respectively the value of δP in the current slot and the most recently transmitted slot and δP is computed as follows:

$$\delta P = \max(\Delta P1\_compression, \ldots, \Delta Pn\_compression) + \Delta P1\_coding + \Delta P2\_coding$$

where n is the number of different TTI lengths amongst TTIs of all TrChs of the CCTrCh, where ΔP1_coding and ΔP2_coding are computed from uplink parameters DeltaSIR1, DeltaSIR2, DeltaSIRafter1, DeltaSIRafter2 signalled by higher layers as:

- ΔP1_coding = DeltaSIR1 if the start of the first transmission gap in the transmission gap pattern is within the current frame.
- ΔP1coding = DeltaSIRafter1 if the current frame just follows a frame containing the start of the first transmission gap in the transmission gap pattern.
- ΔP2_coding = DeltaSIR2 if the start of the second transmission gap in the transmission gap pattern is within the current frame.
- ΔP2_coding = DeltaSIRafter2 if the current frame just follows a frame containing the start of the second transmission gap in the transmission gap pattern.
- ΔP1_coding = 0 dB and ΔP2_coding = 0 dB in all other cases.

and ΔPi_compression is defined by:

- ΔPi_compression = 3 dB for downlink frames compressed by reducing the spreading factor by 2.
- ΔPi_compression = 10 log $(15 \times F_i / (15 \times F_i - TGL_i))$ if there is a transmission gap created by puncturing method within the current TTI of length F_i frames, where TGL_i is the gap length in number of slots (either from one gap or a sum of gaps) in the current TTI of length F_i frames.
- ΔPi_compression = 0 dB in all other cases.

In case several compressed mode patterns are used simultaneously, a δP offset is computed for each compressed mode pattern and the sum of all δP offsets is applied to the frame.

For all time slots except those in transmissions gaps, the average power of transmitted DPDCH symbols over one timeslot shall not exceed Maximum_DL_Power (dB) by more than δP_{curr}, nor shall it be below Minimum_DL_Power (dB). Transmitted DPDCH symbol means here a complex QPSK symbol before spreading which does not contain DTX. Maximum_DL_Power (dB) and Minimum_DL_Power (dB) are power limits for one channelization code, relative to the primary CPICH power TS 125 433 [6].

5.2.1.4 Spot selection diversity transmit power control

5.2.1.4.1 General

Spot Selection Diversity Transmit power control (SSDT) is another macro diversity method in soft handover mode. This method is optional in USRAN.

Operation is summarized as follows. The UE selects one of the spots from its active set to be "primary", all other spots are classed as "non-primary". The main objective is to transmit on the downlink from the primary spot, thus reducing the interference caused by multiple transmissions in a soft handover mode. A second objective is to achieve fast spot selection without network intervention, thus maintaining the advantage of the soft handover. In order to select a primary spot, each spot is assigned a temporary IDentification (ID) and UE periodically informs a primary spot ID to the connecting spots. The non-primary spots selected by UE switch off the transmission power. The primary spot ID is delivered by UE to the active spots via uplink FBI field. SSDT activation, SSDT termination and ID assignment are all carried out by higher layer signalling.

SSDT is only supported when the P-CPICH is used as the downlink phase reference.

5.2.1.4.1.1 Definition of temporary spot identification

Each spot is given a temporary ID during SSDT and the ID is utilized as site selection signal. The ID is given a binary bit sequence. There are three different lengths of coded ID available denoted as "long", "medium" and "short". The network decides which length of coded ID is used. Settings of ID codes for 1-bit and 2-bit FBI are exhibited in tables 4 and 5, respectively.

In optional mode C, settings of ID codes for only 1 bit FBI are considered.

Table 4: Settings of ID codes for 1 bit FBI

ID label	ID code		
	"long"	"medium"	"short"
a	000000000000000	(0)0000000	00000
b	101010101010101	(0)1010101	01001
c	011001100110011	(0)0110011	11011
d	110011001100110	(0)1100110	10010
e	000111100001111	(0)0001111	00111
f	101101001011010	(0)1011010	01110
g	011110000111100	(0)0111100	11100
h	110100101101001	(0)1101001	10101

Table 5: Settings of ID codes for 2 bit FBI

ID label	ID code (Column and Row denote slot position and FBI-bit position)		
	"long"	"medium"	"short"
a	(0)0000000 (0)0000000	(0)000 (0)000	000 000
b	(0)0000000 (1)1111111	(0)000 (1)111	000 111
c	(0)1010101 (0)1010101	(0)101 (0)101	101 101
d	(0)1010101 (1)0101010	(0)101 (1)010	101 010
e	(0)0110011 (0)0110011	(0)011 (0)011	011 011
f	(0)0110011 (1)1001100	(0)011 (1)100	011 100
g	(0)1100110 (0)1100110	(0)110 (0)110	110 110
h	(0)1100110 (1)0011001	(0)110 (1)001	110 001

The ID code bits shown in tables 4 and 5 are transmitted from left to right. In table 5, the first row gives the first FBI bit in each slot, the second row gives the 2nd FBI bit in each slot. The ID code(s) are transmitted aligned to the radio frame structure (i.e. ID codes shall be terminated within a frame). If FBI space for sending the last ID code within a frame cannot be obtained, the first bit(s) from that ID code are punctured. The bit(s) to be punctured are shown in brackets in tables 4 and 5.

The alignment of the ID codes to the radio frame structure is not affected by transmission gaps resulting from uplink compressed mode.

5.2.1.4.2 TPC procedure in UE

The UE shall generate TPC commands to control the satellite transmit power and send them in the TPC field of the uplink DPCCH based on the downlink signals from the primary spot as selected by the UE. An example on how to derive the TPC commands is given in clause B.2.

In optional mode C, the UE shall generate TPC commands to control the network transmit power, encode them according to TPC coding method in [2], and send the coded bits in the TPC field of the uplink DPCCH based on the downlink signals from the primary spot only. How to derive the TPC commands in given in clause 5.2.1.2.2.1.

5.2.1.4.3 Selection of primary spot

The UE selects a primary spot periodically by measuring the RSCP of P-CPICHs transmitted by the active spots. The spot with the highest P-CPICH RSCP is detected as a primary spot.

5.2.1.4.4 Delivery of primary spot ID

The UE periodically sends the ID code of the primary spot via portion of the uplink FBI field assigned for SSDT use (FBI S field). A spot recognizes its state as non-primary if the following conditions are fulfilled simultaneously:

- The received ID code does not match with the own ID code.
- The received uplink signal quality satisfies the following:

$$SIR_{estIDcode} > SIR_{target} + Qth \text{ [dB]}$$

Where $SIR_{estIDcode}$ is the average of estimated signal-to-interference ratio of the received uplink DPCH SIR_{est}, described in clause 5.1.2.2.1.1, over the uplink slots containing the received spot ID code; SIR_{target} is the target SIR of the uplink, described in clause 5.1.2.2.1.1; and Qth is uplink quality threshold which corresponds to the uplink DPCH quality level relative to the SIR_{target}. Qth parameter is signalled via higher layer signalling.

- If uplink compressed mode is used, and less than $\lfloor N_{ID}/3 \rfloor$ bits are lost from the ID code (as a result of uplink compressed mode), where N_{ID} is the number of bits in the ID code (after puncturing according to clause 5.2.1.4.1.1, if puncturing has been done).

Otherwise the spot recognizes its state as primary.

The state of the spots (primary or non-primary) in the active set is updated synchronously. If a spot receives the last portion of the coded ID in uplink slot j, the state of spot is updated in downlink slot $(j + 1 + T_{os})$ mod 15, where T_{os} is defined as a constant of 2 time slots. The updating of the spot state is not influenced by the operation of downlink compressed mode.

In optional mode C, the state of the spots (primary or non-primary) in the active set is updated synchronously. If a spot receives the last portion of the coded ID in uplink frame j, the state of spot is updated in downlink frame $(j+1+T_{os})$, where T_{os} is provided by higher layers. The updating of the spot state is not influenced by the operation of downlink compressed mode.

At the UE, the primary ID code to be sent to the spots is segmented into a number of portions. These portions are distributed in the uplink FBI S-field. The spot in SSDT collects the distributed portions of the primary ID code and then detects the transmitted ID. The period of the primary spot update depends on the settings of the code length and the number of FBI bits assigned for SSDT use as shown in table 6. However, SSDT is only applicable with DPC_MODE = 0.

Table 6: Period of primary spot update

code length	The number of FBI bits per slot assigned for SSDT	
	1	2
"long"	1 update per frame	2 updates per frame
"medium"	2 updates per frame	4 updates per frame
"short"	3 updates per frame	5 updates per frame

In optional mode C, at the UE, the primary ID code to be sent to the spots is segmented into a number of portions. These portions are distributed in the uplink FBI field. In non-compressed frame the primary ID code of 15-bit length is distributed in the FBI fields of 15 slots in a radio frame. In compressed frame the primary ID code of 5-bit length is distributed in the FBI field of the first 5 slots in a radio frame and is repeated in remaining slots. The last repeated code may not be completed in the radio frame. The spot in SSDT collects the distributed portions of the primary ID code and then detects the transmitted ID. The primary spot is updated once per radio frame regardless of the uplink compressed mode.

5.2.1.4.5 TPC procedure in the network

In SSDT, a non-primary spot can switch off its DPDCH output (i.e. no transmissions).

The spot manages two downlink transmission power levels, P1, and P2. Power level P1 is used for downlink DPCCH transmission power level and this level is updated in the same way with the downlink DPCCH power adjustment specified in clauses 5.2.1.2.2 (for normal mode) and 5.2.1.3 (for compressed mode) regardless of the selected state (primary or non-primary). The actual transmission power of TFCI, TPC and pilot fields of DPCCH is set by adding P1 and the offsets PO1, PO2 and PO3, respectively, as specified in clause 5.2.1.1. P2 is used for downlink DPDCH transmission power level and this level is set to P1 if the spot is selected as primary, otherwise P2 is switched off. The spot updates P1 first and P2 next, and then the two power settings P1 and P2 are maintained within the power control dynamic range. Table 7 summarizes the updating method of P1 and P2.

Table 7: Updating of P1 and P2

State of spot	P1 (DPCCH)	P2 (DPDCH)
non-primary	Updated in the same way with the downlink DPCCH power adjustment specified in clauses 5.2.1.2.2 and 5.2.1.3.	Switched off
primary		= P1

5.2.1.5 Open Loop power control

Open loop power control can be activated continuously after DPCCH/DPDCH link establishment. This is configured by higher layers (RRC).

In optional mode C, the open loop power control used to adjust the transmit power of the DPCH. It can reduce H/W complexity compared with the closed power control. The UE should measure the received power of the downlink P-CCPCH before the transmission of a DPCH. The transmit power of DPCH is determined by the and uplink SIR.

The UE shall perform continuously the OLPC procedure as follows:

- Step 1: If the UE receives the data from Satellite-RAN in idle state, then it checks the pilot field of DPCCH and/or CPICH and/or S-CCPCH.
- Step 2: The UE takes CSI from channel estimation.
- Step 3: The UE estimates the received SIR of downlink DPCCH/DPDCH.
- Step 4: The UE compares the target SIR with the received SIR.
- Step 5: The UE determines transmit power of DPCH as follows:

$$P_{DPCH}(i) = P_{DPCH}(i-1) \pm \Delta_{\varepsilon}(i-1), \text{ (dBm)}$$

Where $\Delta_{\varepsilon}(i) = SIR_{est}(i) - SIR_{target}(i)$

5.2.2 AICH

The UE is informed about the relative transmit power of the AICH (measured as the power per transmitted acquisition indicator) compared to the primary CPICH transmit power by the higher layers.

5.2.3 PICH

The UE is informed about the relative transmit power of the PICH (measured as the power over the paging indicators) compared to the primary CPICH transmit power by the higher layers.

5.2.4 S-CCPCH

The TFCI and pilot fields may be offset relative to the power of the data field. The power offsets may vary in time.

5.2.5 MICH

The UE is informed about the relative transmit power of the MICH (measured as the power over the notification indicators) compared to the primary CPICH transmit power by the higher layers.

6 Random access procedure

6.1 Physical random access procedure

The physical random access procedure described in this clause is initiated upon request from the MAC sublayer.

Before the physical random-access procedure can be initiated, Layer 1 shall receive the following information from the higher layers (RRC):

- The preamble scrambling code.
- The message length in time, either 10 ms or 20 ms.
- The AICH_Transmission_Timing parameter [0 or 1].
- The set of available signatures and the set of available RACH sub-channels for each Access Service Class (ASC). Sub-channels are defined in clause 6.1.1.
- The power-ramping factor Power Ramp Step [integer > 0].
- The parameter Preamble Retrans Max [integer > 0].
- The initial preamble power Preamble_Initial_Power.
- The Power offset $P_{p\text{-}m} = P_{message\text{-}control} - P_{preamble}$, measured in dB, between the power of the last transmitted preamble and the control part of the random-access message.
- The set of Transport Format parameters. This includes the power offset between the data part and the control part of the random-access message for each Transport Format.

Note that the above parameters may be updated from higher layers before each physical random access procedure is initiated.

At each initiation of the physical random access procedure, Layer 1 shall receive the following information from the higher layers (MAC):

- The Transport Format to be used for the PRACH message part.
- The ASC of the PRACH transmission.
- The data to be transmitted (Transport Block Set).

The physical random-access procedure shall be performed as follows:

1) Derive the available uplink access slots, in the next full access slot set, for the set of available RACH sub-channels within the given ASC with the help of clauses 6.1.1 and 6.1.2. Randomly select one access slot among the ones previously determined. If there is no access slot available in the selected set, randomly select one uplink access slot corresponding to the set of available RACH sub-channels within the given ASC from the next access slot set. The random function shall be such that each of the allowed selections is chosen with equal probability.

2) Randomly select a signature from the set of available signatures within the given ASC. The random function shall be such that each of the allowed selections is chosen with equal probability.

3) Set the Preamble Retransmission Counter to Preamble Retrans Max.

4) Set the parameter Commanded Preamble Power to Preamble_Initial_Power.

5) In the case that the Commanded Preamble Power exceeds the maximum allowed value, set the preamble transmission power to the maximum allowed power. In the case that the Commanded Preamble Power is below the minimum level required in TS 125 101 [7], set the preamble transmission power to a value, which shall be at or above the Commanded Preamble Power and at or below the required minimum power specified in TS 125 101 [7]. Otherwise set the preamble transmission power to the Commanded Preamble Power. Transmit a preamble using the selected uplink access slot, signature, and preamble transmission power.

6) If no positive or negative acquisition indicator ($AI \neq + 1$ nor $- 1$) corresponding to the selected signature is detected in the downlink access slot corresponding to the selected uplink access slot:

   6.1) Select the next available access slot in the set of available RACH sub-channels within the given ASC.

   6.2) Randomly select a new signature from the set of available signatures within the given ASC. The random function shall be such that each of the allowed selections is chosen with equal probability.

   6.3) Increase the Commanded Preamble Power by ΔP_0 = Power Ramp Step [dB]. If the Commanded Preamble Power exceeds the maximum allowed power by 6dB, the UE may pass L1 status ("No ack on AICH") to the higher layers (MAC) and exit the physical random access procedure.

   6.4) Decrease the Preamble Retransmission Counter by one.

   6.5) If the Preamble Retransmission Counter > 0 then repeat from step 5. Otherwise pass L1 status ("No ack on AICH") to the higher layers (MAC) and exit the physical random access procedure.

7) If a negative acquisition indicator corresponding to the selected signature is detected in the downlink access slot corresponding to the selected uplink access slot , pass L1 status ("Nack on AICH received") to the higher layers (MAC) and exit the physical random access procedure.

8) Transmit the random access message three or four uplink access slots after the uplink access slot of the last transmitted preamble depending on the AICH transmission timing parameter. Transmission power of the control part of the random access message should be P_{p-m} [dB] higher than the power of the last transmitted preamble. Transmission power of the data part of the random access message is set according to clause 5.1.1.2.

9) Pass L1 status "RACH message transmitted" to the higher layers and exit the physical random access procedure.

In optional mode C, the physical random-access procedure shall be performed as follows:

1) Derive the available uplink access frame, in the next full access frame set for the set of available RACH sub-channels within the given ASC with the help of clauses 6.1.1 and 6.1.2. Randomly select one access frame among the ones previously determined. If there is no access frame available in the selected set, randomly select one uplink access frame corresponding to the set of available RACH sub-channels within the given ASC from the next access slot set. The random function shall be such that each of the allowed selections is chosen with equal probability. When sub-access frames are used for the PRACH, the UE randomly selects a sub-access frame from the even and odd sub-access frames within the selected access frame. The random function shall be such that each of the allowed selections is chosen with equal probability.)

2) Randomly select a signature from the set of available signatures within the given ASC. The random function shall be such that each of the allowed selections is chosen with equal probability.

3) Set the Preamble Retransmission Counter to Preamble Retrans Max.

4) Set the parameter Commanded Preamble Power to Preamble_Initial_Power.

5) Randomly select a transmission offset time, τ_{off}, in range of $-\tau_{off,max}$ to $\tau_{off,max}$ chips. The random function shall be such that each of the allowed selections is chosen with equal probability.

6) In the case that the Commanded Preamble Power exceeds the maximum allowed value, set the preamble transmission power to the maximum allowed power. In the case that the Commanded Preamble Power is below the minimum level required in TS 125 101 [7], set the preamble transmission power to a value, which shall be at or above the Commanded Preamble Power and at or below the required minimum power specified in TS 125 101 [7]. Otherwise set the preamble transmission power to the Commanded Preamble Power. Transmit a preamble part and a message part using the selected access frame (or sub-access frame), transmission offset time, signature, and preamble transmission power.

7) If no positive or negative acquisition indicator (AI ≠ + 1 nor - 1) corresponding to the selected signature is detected in the downlink access frame or sub-access frame corresponding to the selected uplink access frame:

   7.1) Select the next available access frame in the set of available RACH sub-channels within the given ASC. When sub-access frames are used for the PRACH, the UE randomly selects a sub-access frame from the even and odd sub-access frames within the selected access frame. The random function shall be such that each of the allowed selections is chosen with equal probability.

   7.2) Randomly select a new signature from the set of available signatures within the given ASC. The random function shall be such that each of the allowed selections is chosen with equal probability.

   7.3) Increase the Commanded Preamble Power by ΔP_0 = Power Ramp Step [dB]. If the Commanded Preamble Power exceeds the maximum allowed power by 6dB, the UE may pass L1 status ("No ack on AICH") to the higher layers (MAC) and exit the physical random access procedure.

   7.4) Decrease the Preamble Retransmission Counter by one.

   7.5) If the Preamble Retransmission Counter > 0 then repeat from step 5. Otherwise pass L1 status ("No ack on AICH") to the higher layers (MAC) and exit the physical random access procedure. (In the MAC layer, UE repeats exit the retransmission cycle in the next TTI.)

8) If a negative acquisition indicator corresponding to the selected signature is detected in the downlink access frame corresponding to the selected uplink access frame or sub-access frame, pass L1 status ("Nack on AICH received") to the higher layers (MAC) and exit the physical random access procedure.

9) Pass L1 status "RACH message transmitted" to the higher layers and exit the physical random access procedure.

If the response message corresponding to the transmitted RACH message is received in the highlayer at any time during the random access procedure, UE should stop the RACH procedure. In the transmission of the RACH preamble and message, UE may use a Doppler pre-compensation technique, based on the Doppler shift estimation on the downlink carrier.

6.1.1 RACH sub-channels

A RACH sub-channel defines a sub-set of the total set of uplink access slots. There are a total of 12 RACH sub-channels. RACH sub-channel #i (i = 0, …, 11) consists of the following uplink access slots:

- Uplink access slot #i leading by τ_{p-a} chips the downlink access slot #i contained within the 10 ms interval that is time aligned with P-CCPCH frames for which SFN mod 8 = 0 or SFN mod 8 = 1.
- Every 12th access slot relative to this access slot.

The access slots of different RACH sub-channels are also illustrated in table 8.

Table 8: The available uplink access slots for different RACH sub-channels

SFN modulo 8 of corresponding P-CCPCH frame	Sub-channel number											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
0	0	1	2	3	4	5	6	7				
1	12	13	14						8	9	10	11
2				0	1	2	3	4	5	6	7	
3	9	10	11	12	13	14						8
4	6	7					0	1	2	3	4	5
5			8	9	10	11	12	13	14			
6	3	4	5	6	7					0	1	2
7						8	9	10	11	12	13	14

In optional mode C, a RACH sub-channel defines a set of uplink access frames that are time-aligned with P-CCPCH frames. There are a total of 8 RACH sub-channels. RACH sub-channel #i (i = 0, …, 7) is also illustrated in table 8a.

Table 8a: RACH sub-channels

RACH sub-channel number	0	1	2	3	4	5	6	7
SFN modulo 16 of corresponding P-CCPCH frame	0, 1	2, 3	4, 5	6, 7	8, 9	10, 11	12, 13	14, 15
Corresponding AICH frame number	0	1	2	3	4	5	6	7
Corresponding RACH access frame number	0	1	2	3	4	5	6	7

6.1.2 RACH access slot sets

The PRACH contains two sets of access slots as shown in figure 2. Access slot set 1 contains PRACH slots 0 - 7 and starts τ_{p-a} chips before the downlink P-CCPCH frame for which SFN mod 2 = 0. Access slot set 2 contains PRACH slots 8 - 14 and starts (τ_{p-a} - 2 560) chips before the downlink P-CCPCH frame for which SFN mod 2 = 1.

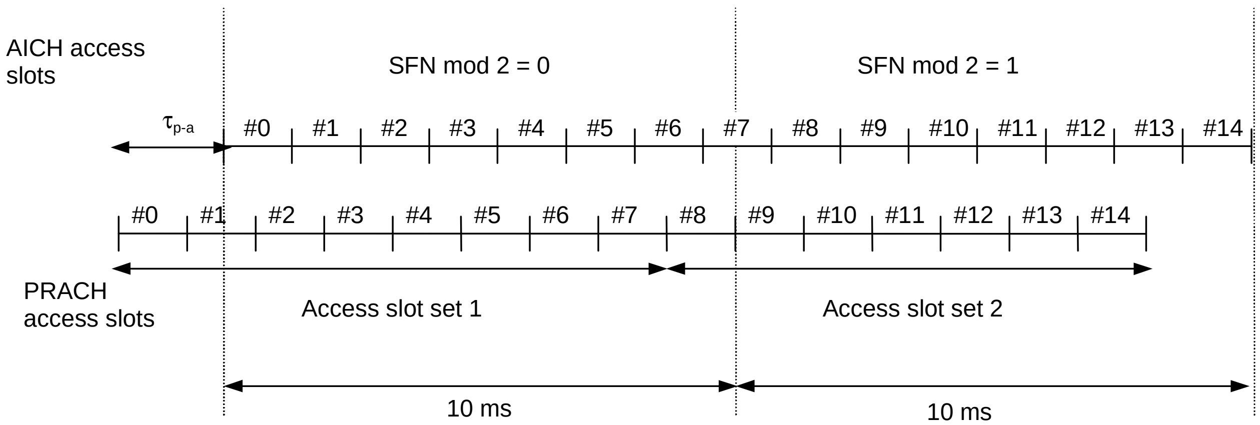


Figure 2: PRACH access slot and downlink AICH relation (τ_{p-a} = 7 680 chips)

In optional mode C, the PRACH access frame starts τ_{p-a} chips before the downlink AICH frame, as shown in figure 2a.

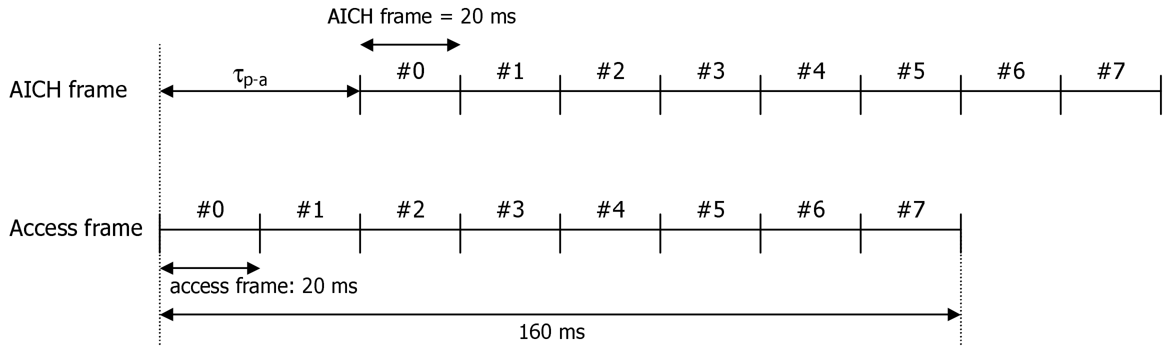


Figure 2a: PRACH access frames and downlink AICH frames ($\tau_{p\text{-}a}$ = 153 600 chips)

Annex A (informative): Power control

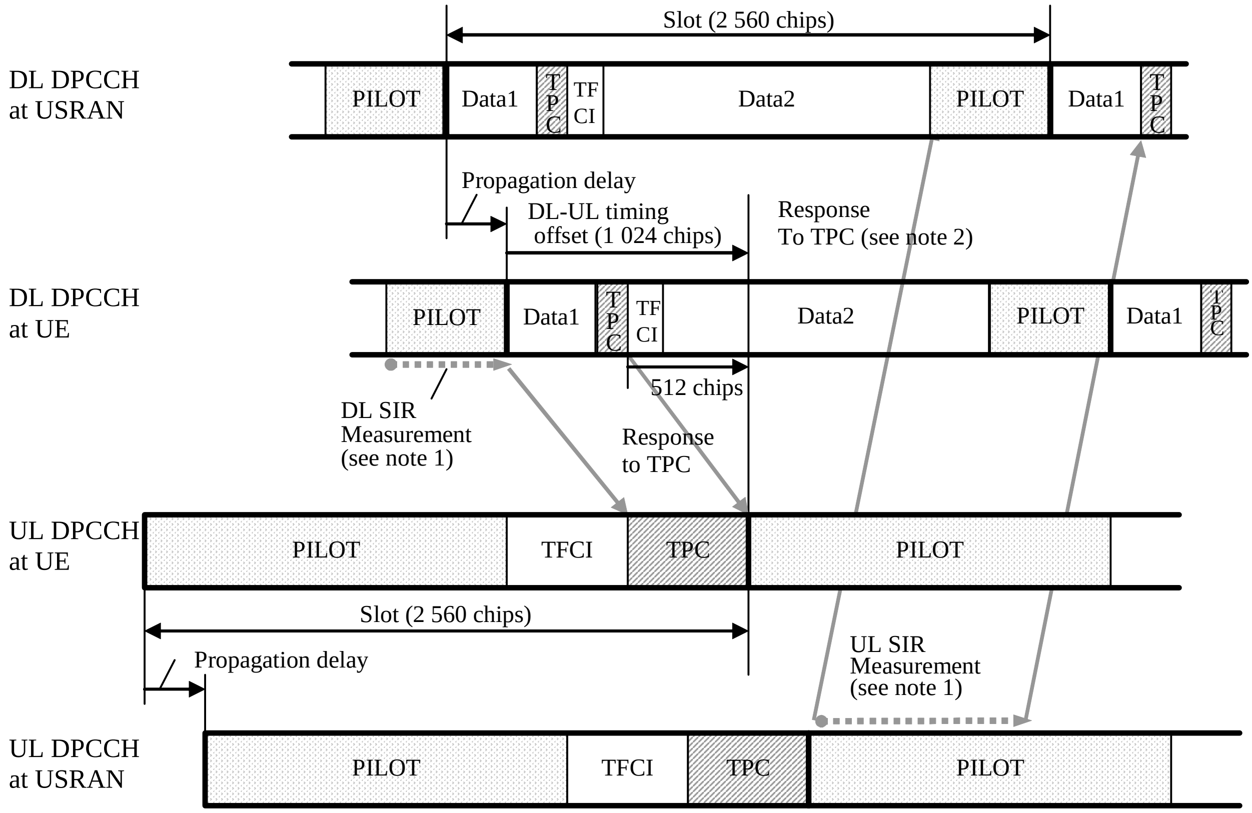
A.1 Downlink power control timing

The power control timing described in this annex should be seen as an example on how the control bits have to be placed in order to permit a short TPC delay.

In order to maximize the spot radius distance within which one-slot control delay is achieved, the frame timing of an uplink DPCH is delayed by 1 024 chips from that of the corresponding downlink DPCH measured at the UE antenna.

Responding to a downlink TPC command, the UE change its uplink DPCH output power at the beginning of the first uplink pilot field after the TPC command reception. Responding to an uplink TPC command, the USRAN access point change its DPCH output power at the beginning of the next downlink pilot field after the reception of the whole TPC command. Note that in soft handover, the TPC command is sent over one frame when DPC_MODE is 0 and over three frames when DPC_MODE is 1. Note also that the delay from the uplink TPC command reception to the power change timing is not specified for USRAN. The UE decide and send TPC commands on the uplink based on the downlink SIR measurement. The TPC command field on the uplink starts, when measured at the UE antenna, 512 chips after the end of the downlink pilot field. The USRAN access point decide and send TPC commands based on the uplink SIR measurement. However, the SIR measurement periods are not specified either for UE nor USRAN.

Figure A.1 illustrates an example of transmitter power control timings.



NOTE 1: The SIR measurement periods illustrated here are examples. Other ways of measure are allowed to achieve accurate SIR estimation.

NOTE 2: If there is not enough time for USRAN to respond to the TPC, the action can be delayed until next frame.

Figure A.1: Transmitter power control timing

Annex B (informative): Spot search procedure

During the spot search, the UE searches for a spot and determines the downlink scrambling code and frame synchronization of that spot. The spot search is typically carried out in three steps.

Step 1: Slot synchronization

During the first step of the spot search procedure the UE uses the SCH's primary synchronization code to acquire slot synchronization to a spot. This is typically done with a single matched filter (or any similar device) matched to the primary synchronization code which is common to all spots. The slot timing of the spot can be obtained by detecting peaks in the matched filter output.

Step 2: Frame synchronization and code-group identification

During the second step of the spot search procedure, the UE uses the SCH's secondary synchronization code to find frame synchronization and identify the code group of the spot found in the first step. This is done by correlating the received signal with all possible secondary synchronization code sequences, and identifying the maximum correlation value. Since the cyclic shifts of the sequences are unique the code group as well as the frame synchronization is determined.

Step 3: Scrambling-code identification

During the third and last step of the spot search procedure, the UE determines the exact primary scrambling code used by the found spot. The primary scrambling code is typically identified through symbol-by-symbol correlation over the CPICH with all codes within the code group identified in the second step. After the primary scrambling code has been identified, the Primary CCPCH can be detected and the system- and spot specific BCH information can be read.

If the UE has received information about which scrambling codes to search for, steps 2 and 3 above can be simplified.

Annex C (normative): Description of G-family enhancements

C.1 Definition of the optional modes A and C

The following two optional modes are defined in the G-family enhancements.

- Optional mode A: Operation with G-family features and A-family optional features which are identified in clause C.2 for performance enhancement.
- Optional mode C: Operation with G-family feature and C-family optional features which are identified in clause C.3 for performance enhancement.

In order to keep backward compatibility with G family, the G-family enhancements system should support G basic terminals as well as G enhanced terminals and the G enhanced terminals should be operated in the G family system. For this, the following terminal types are considered in the G-family enhancements system.

- Terminal type 1 including only G-family interface
- Terminal type 2 including G-family interface as well as optional mode A
- Terminal type 3 including G-family interface as well as optional mode C
- Terminal type 4 including G-family interface as well as both optional modes A and C

The information which types of terminals are supported in the targeted frame and/or the considered Base Station could be sent via broadcasting channel.

C.2 Description of Optional mode A

The following new features of SRI-A family are considering for the standardization of SRI-G-family enhancements. They are based on a synthetic view of SW-CDMA and WCDMA identified in TR 102 278 [i.6].

Table C.1: Description of A-family optional features

Features	Description
HPPICH	- Additional paging channel - Unspread BPSK signal packet of length 10 ms - Channel rate = 15 k symbol/s - Packet = preamble (24bits) +UW (12 bits) + data (114 bits)
Downlink data scrambling	- For downlink when interference mitigation is used - Prior to physical channel mapping - By a ML sequence with polynomial $1+X^{14}+X^{15}$ - Rate: 30 kbit/s

C.3 Description of Optional mode C

The following new features of SRI-C family are considering for the standardization of SRI-G-family enhancements.

Table C.2: Description of C-family optional features

Features	Description
Uplink random access	- Transmission of both preamble and message, together - Access frame: 2 radio frames
FBI/TPC bits generation and transmission	- TPC field: the reduction of the half of TPC field - FBI field: removal of 2 bits FBI filed
Power control	- CLPC: a delay compensation power control scheme + prediction algorithm - SIR estimation from CPICH and S-CCPCH - 2-bit TPC command - OLPC algorithm using pilot diversity in option
Synchronization codes for downlink SCH in LEO constellation	- One so-called generalized hierarchical Golay sequence

Annex D (informative): Bibliography

ETSI TS 125 321: "Universal Mobile Telecommunications System (UMTS); Medium Access Control (MAC) protocol specification (3GPP TS 25.321)".

ETSI TS 125 306: "Universal Mobile Telecommunications System (UMTS); UE Radio Access capabilities (3GPP TS 25.306)".

Annex E (informative): Change history

This annex describes the differences relevant to TS 101 851-1-1 [i.8], TS 101 851-1-2 [i.9], TS 101 851-2-1 [i.10], TS 101 851-2-2 [i.11], TS 101 851-3-1 [i.12], TS 101 851-3-2 [i.13], TS 101 851-4-1 [i.14] and TS 101 851-4-2 [i.15].

E.1 A-family optional features

The following tables present summary on changes for TS 101 851-1-3 [1] to TS 101 851-4-3 (the present document) of SRI-G family, considering the harmonization with SRI-A family.

Table E.1: TS 101 851-1-3 [1]; Physical channels and mapping of transport channels into physical channels

Item Reference	Item	Actions
3.2 Abbreviations	- HPPICH for optional mode A	- To add HPPICH for high penetration paging
5.3.2.8 High penetration page indication channel	- HPICCH for optional mode A	- To define HPPICH for high penetration paging + Unspread BPSK signal packet of length 10 ms + Channel rate = 15 ksymbol/s + Packet = Preamble (24 bits) + UW (12 bits) + data (114 bits)

Table E.2: TS 101 851-2-3 [2]; Multiplexing and channel coding

Item Reference	Item	Actions
4.2 General coding/multiplexing of TrCHs	- Downlink data scrambling for optional mode A	- To add downlink data scrambling step between 2nd interleaving and physical mapping
4.2.15 Downlink data scrambling	- Downlink data scrambling for optional mode A	- To define downlink data scrambling + A ML sequence with polynomial 1+X14+X15 + Rate: 30 kbit/s

E.2 C-family optional features

The following tables present summary on changes for TS 101 851-1-3 [1] to TS 101 851-4-3 (the present document) of SRI-G family, considering the harmonization with SRI-C family.

Table E.3: TS 101 851-1-3 [1]; Physical channels and mapping of transport channels into physical channels

Item Reference	Item	Actions
5.2.1 Dedicated uplink physical channels	- FBI/TPC field generation for the optional mode C	- Addition of statement related to deletion of FBI field for closed-loop transmit diversity and reduction as 1 bit for only SSDT - Reduction of the number of slot formats: Deletion of 2 bits FBI - Reduction of TPC field and extension of pilot field - Identification of new pilot patterns
5.2.2 Common uplink physical channels	- Uplink random access for the optional mode C	- Addition of modified structure of random-access transmission: transmission of both a preamble and a message - Identification of access frame - Based on ALOHA approach with fast acquisition indication - Optional RACH preamble: Np repetition of a sub-preamble and conjugation in the final sub-preamble
6.3.1 Dedicated downlink physical channels	- FBI/TPC field generation for the optional mode C	- Modification of TPC duration as one radio frame - Reduction of the TPC field as 1/2 and extension of the Data2 field
6.3.2 Common downlink physical channels	- Uplink random access for the optional mode C	- Identification on transmission of AI only on the first and 9th access slots
8.1 Timing relation between physical channels	- Uplink random access for the optional mode C	- Identification on AICH sub-access frame
8.3 PRACH/AICH timing relation	- Uplink random access for the optional mode C	- Identification of modified PRACH/AICH timing relation in order to consider long round trip delay of satellite system and transmission of both preamble and message parts

Table E.4: TS 101 851-2-3 [2]; Multiplexing and channel coding

Item Reference	Item	Actions
4.5 TPC command coding	- FBI/TPC field generation for the optional mode C	- Identification of a new coding method of TPC command: 8 repetition of 2 bits TPC command - Identification of mapping of TPC words

Table E.5: TS 101 851-3-3 [3]; Spreading and modulation

Item Reference	Item	Actions
5.3.3 PRACH preamble codes	- Uplink random access transmission for the optional mode C	- Addition of new code construction: Nsp repetition of a sub-preamble and conjugation in the final sub-preamble - Identification of usage of other codes in order to distinguish even and odd sub-access frames
6.2.3 Synchronization codes	- Synchronization codes for downlink SCH in LEO constellation	- Identification of a new code generation method for LEO based mobile satellite system - Addition of modified synchronization codes as two hierarchical Golay sequences with 128 chip length

Table E.6: TS 101 851-4-3; Physical layer procedure

Item Reference	Item	Actions
5.1 Uplink power control	- Power control method for the optional mode C	- Identification of one power control per one frame duration - Identification of a new closed-loop power control with delay compensation algorithm in order to optimize the basic power control loop parameters, including the power control rate, power control step size, and the number of control levels - Identification of a new open-loop power control algorithm considering pilot diversity
5.2 Downlink power control	- Synchronization codes for downlink SCH in LEO constellation for the optional mode C	- Identification of one power control per one frame duration - Identification of a new closed-loop power control with delay compensation and prediction algorithms in order to optimize the basic power control loop parameters, including the power control rate, power control step size, and the number of control levels - Deletion of ID codes for 2 bit FBI in spot selection diversity transmit power control
6.1 Random access procedure	- Uplink random access transmission for the optional mode C	- Identification of access frame, even access frame and odd access frame - Identification of a new PRACH procedure with addition to selection of sub-access frame
6.1.1 RACH sub-channels	- Uplink random access transmission for the optional mode C	- Identification of a RACH sub-channel as a set of access frame
6.1.2 RACH access frame sets	- Uplink random access transmission for the optional mode C	- Identification of a new RACH access frame sets

History

Document history		
V3.1.1	September 2011	Publication