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Technical Specification

GEO-Mobile Radio Interface Specifications;
Part 5: Radio interface physical layer specifications;
Sub-part 6: Radio Subsystem Link Control;
GMR-1 05.008

Reference

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IPRs:

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

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

IPR Owner: Ericsson Mobile Communications (UK) Limited
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Project	Company	Title	Country of Origin	Patent n°	Countries Applicable
TS 101 376 V1.1.1	Hughes Network Systems		US	Pending	US

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

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Foreword

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

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

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- the third digit (n) is incremented when editorial only changes have been incorporated in the specification;
- the second digit (m) is incremented for all other types of changes, i.e. technical enhancements, corrections, updates, etc.

The present document is part 5, sub-part 6 of a multi-part deliverable covering the GEO-Mobile Radio Interface Specifications, as identified below:

Part 1: "General specifications";

Part 2: "Service specifications";

Part 3: "Network specifications";

Part 4: "Radio interface protocol specifications";

Part 5: "Radio interface physical layer specifications";

Sub-part 1: "Physical Layer on the Radio Path: General Description; GMR-1 05.001";

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

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

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

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

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

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

Part 6: "Speech coding specifications";

Part 7: "Terminal adaptor specifications".

Introduction

GMR stands for GEO (Geostationary Earth Orbit) Mobile Radio interface, which is used for mobile satellite services (MSS) utilizing geostationary satellite(s). GMR is derived from the terrestrial digital cellular standard GSM and supports access to GSM core networks.

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

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

GMR-n xx.zyy

where:

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

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

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

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

- If a GMR specification does not exist, the corresponding GSM specification may or may not apply. The applicability of the GSM specifications is defined in GMR-1 01.201 [10].

1 Scope

The present document specifies several control aspects for the radio link between the Mobile Earth Station (MES) and the Gateway Station (GS) in the GMR-1 Mobile Satellite System. It specifies the operation of power control and defines dead link detection. It makes requirements for DTX operation.

The present document also defines requirements for the MES for monitoring system information, as prerequisites to system access, and upon exit from dedicated mode. It makes requirements for spot beam selection and reselection. It defines the nature of the measurements that the MES uses to implement these processes.

Timing and frequency control aspects of link control are to be found in GMR-1 05.010 [9], and messages for timing and frequency control are defined in GMR-1 04.008 [4].

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

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

[2] GMR-1 03.022 (ETSI TS 101 376-3-10): "GEO-Mobile Radio Interface Specifications; Part 3: Network specifications; Sub-part 10: Functions related to Mobile Earth station (MES) in idle mode; GMR-1 03.022".

[3] GMR-1 04.006 (ETSI TS 101 376-4-6): "GEO-Mobile Radio Interface Specifications; Part 4: Radio interface protocol specifications; Sub-part 6: Mobile earth Station-Gateway Station Interface Data Link Layer Specifications; GMR-1 04.006".

[4] GMR-1 04.008 (ETSI TS 101 376-4-8): "GEO-Mobile Radio Interface Specifications; Part 4: Radio interface protocol specifications; Sub-part 8: Mobile Radio Interface Layer 3 Specifications; GMR-1 04.008".

[5] GMR-1 04.022 (ETSI TS 101 376-4-11): "GEO-Mobile Radio Interface Specifications; Part 4: Radio interface protocol specifications; Sub-part 11: Radio Link Protocol (RLP) for Data Services; GMR-1 04.022".

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

[7] GMR-1 05.003 (ETSI TS 101 376-5-3): "GEO-Mobile Radio Interface Specifications; Part 5: Radio interface physical layer specifications; Sub-part 3: Channel Coding; GMR-1 05.003".

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

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

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

3 Definitions and abbreviations

3.1 Definitions

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

Average Power Used (APU): at the beginning of each call, the MES shall start a running power-averaged PAS setting, expressed in dB. This parameter shall be transmitted upon receipt of an INFORMATION REQUEST message from the network, with a power control request code.

BCCH_FULL_LIST: list of all the broadcast control channel (BCCH) numbers used by the network.

BCCH_NEIGHBOR_LIST: list of the neighboring spot beams' BCCH numbers, starting timeslots, and system information cycle offsets.

Call Quality Metric (CQM): at the beginning of each call, the MES shall start a running average of the percentage of post-FEC burst errors occurring for the call. This parameter shall be transmitted upon receipt of an INFORMATION REQUEST message from the network, with a power control request code.

Criterion C1: this criterion is used by the MES for detecting the presence of frequency control channel (FCCH) and switching out of the frequency search state. The C1 is the minimum usable threshold on the received LQI that shall be satisfied at the MES before it camps on the system.

Link Margin: link margin is the difference (in dB) between the SQI at the receiver corresponding to the maximum transmit power level and the SQT.

Link Quality Indication (LQI): LQI is the amount of available link margin with respect to SQT, expressed in dB. A positive value indicates the amount of additional link margin in reserve. A negative value indicates that power control is at saturation and that the SQT is not being met by the indicated value.

Open Loop Threshold and Gain (Olthresh and Olgain): parameter Olthresh is the threshold on the LQI estimate before activating open loop power control. Parameter Olgain is the loop gain for open loop control.

Power Attenuation Notification (PAN): attenuation in dB, used by the transmitter in the power control loop, relative to the maximum transmit power level.

Power Attenuation Request (PAR): attenuation in dB, requested by the receiver in the power control loop, relative to the maximum transmit power level.

Power Control Loop Gain (GainDn and GainUp): power control loop gain is a number by which the difference between SQT and SQI is multiplied to derive the power correction value. If the difference is negative, GainDn is used as the loop gain; otherwise, GainUp is used as the loop gain. The loop gain is a unitless number with a default value of 1.0.

Power Control Topped-Out (PCTO): at the beginning of each call, the MES shall start a running average of the percentage of messages for which the calculated PAS is less than PASmin. This parameter shall be transmitted upon receipt of an INFORMATION REQUEST message from the network, with a power control request code.

Radio Link Failure Counter S: counter whose value of zero determines the failure of the radio link.

RADIO_LINK_TIMEOUT: maximum value of the radio link failure counter S.

Received Signal Strength Indication (RSSI): RSSI is the root mean squared (rms) value of the signal received at the receiver antenna. The RSSI estimate is compensated for all the time-varying processes (such as automatic gain control) that affect the estimation procedure for obtaining a relative measure to use in comparing the strength of signals received at different times.

Reserve Link Margin: reserve link margin is the difference (in dB) between the SQI corresponding to the maximum transmit power level and the actual SQI at the receiver.

SB_RESELECT_HYSTERESIS: value in dB by which a nonserving beam's BCCH power measurement shall exceed the serving beam's BCCH power before the MES switches to the nonserving beam.

SB_RESELECTION_TIMER: maximum time interval between consecutive spot beam reselection procedures.

SB_SELECTION_POWER: during the spot beam selection and reselection, the MES selects only those BCCH carriers whose receive power is within SB_SELECTION_POWER dB of the strongest BCCH carrier.

Signal Quality Indication (SQI): estimate of the ratio of signal power to the noise and the interference power S/(N+I) formed at the receiver in the power control loop. This estimate, averaged over one burst, is denoted here as SQIj (estimate for jth burst). For the power control algorithm, this estimate is averaged over six frames and it is denoted as $\overline{SQI6}$.

Signal Quality Target (SQT): SQT is the desired receive signal quality, and it is defined as the targeted value for the ratio of the signal power to the noise and interference power. The SQT is derived from a reference threshold and an allowance for fading and Doppler shift.

3.2 Abbreviations

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

4 General

The radio subsystem link control aspects that are addressed are as follows:

- RF power control;
- RF frequency control;
- Radio link failure;
- Spot beam selection and reselection in idle mode.

Adaptive control of the RF transmit power from an MES or a GS is implemented in order to optimize the downlink and the uplink performance and minimize the effects of cochannel interference in the GMR-1 system.

Adaptive frequency control is necessary to maintain the receive and transmit frequencies in the presence of instabilities introduced by oscillators and Doppler frequency shifts caused by the movement of the satellite and the MES.

The criteria for determining radio link failure are specified in order to ensure that calls that fail, either from loss of radio coverage or unacceptable interference, are satisfactorily handled by the network. Radio link failure may result in the release of the call in progress.

The procedures for spot beam selection and reselection while the MES is in the idle mode (i.e., not actively processing a call) are specified in order to ensure that an MES is camped on the spot beam control channel with which it can reliably communicate on both the radio uplink and downlink.

5 RF power control

The power control in the GMR-1 system is performed for all the active traffic channels in the gateway station-to-mobile earth station (GS-to-MES) direction (the MES downlink), the MES-to-GS direction (the MES uplink) and in the MES-to-MES configuration.

5.1 Objective

RF power control is employed to minimize the transmit power required at the MES or the GS while maintaining the quality of the radio links. By minimizing the transmit power levels, the unnecessary power source drain at the satellite and the MES is prevented, and the cochannel interference due to the signals received from different MESs is reduced.

The power control aims at a fast transient response to mitigate sudden shadowing events, a steady-state condition that accurately achieves the designated received signal quality, and a robust operation with respect to the error conditions.

5.2 Overall process

The power control mechanism has two ends. One of the two power control ends is an MES. The other end is either a GS or an MES.

5.2.1 Open loop power control

In the open-loop power control mechanism, each power control end increases the transmit power if the quality of the received signal suddenly deteriorates by a designated amount. The use of open loop power control assumes a useful degree of statistical correlation between the receive and the transmit links.

5.2.2 Closed loop power control

In closed loop power control, the receiver end estimates the quality of the signal received from the transmitter end and, based on the estimated signal quality, conveys to the transmit end a request for attenuation relative to the maximum transmit power level.

Closed loop power control is performed in both the downlink (the control of the GS transmit power based on the received signal quality measurement at the MES) and in the uplink (the control of the MES transmit power based on the signal quality measurement at the GS).

5.2.3 Message error response

The message error response procedures define the steps to be performed when the power control messages are corrupted.

5.2.4 Power control parameters

Power control is governed by many different parameters, e.g., target signal quality, power control loop gain, etc. These parameters provide the capability to adjust the power control response for different channel conditions, terminal types, operation policies, etc.

The power control parameters are initialized prior to the start of the dedicated channel power control. The power control operates on the basis of the values assigned to these parameters, but it does not modify them. Refer to clauses 3 and 11.1 for the list of these parameters.

The MES shall store the power control parameters received most recently on the broadcast channel in its non-volatile memory, to be available for immediate use after subsequent power on cycles.

5.2.5 The Scope of the power control

There is no power control for the common control channels. The MES shall transmit the RACH at the full power. Similarly, there is no power control for SDCCH. The SDCCH is also transmitted at the maximum power.

The power control is active for the dedicated traffic channels only. The power control is active during discontinuous transmission (DTX).

5.3 Power control message

In closed loop power control, each power control end regularly exchanges a power control message with the other end. The power control message is composed of two variables, as described in the following clauses.

5.3.1 Power Attenuation Notification (PAN)

The power control mechanism requires the transmit end to notify the other end of the actual transmit power level used. The transmit end accomplishes this requirement by specifying the attenuation from the maximum transmit power.

The PAN is defined as the difference, in dB, between the maximum (nonbacked-off) transmit power level and the actual transmit power level at the transmitter. The PAN is originated at the transmitter end.

$$\text{PAN (dB)} = P_{tx\text{-}max}\ \text{(dBW)} - P_{tx\text{-}actual}\ \text{(dBW)}.$$

The PAN is an explicit attenuation that results in an output power that is independent of the previous settings. For example, if setting PAN to 0 for a particular MES produces an output power of +4 dBW, then a PAN of 10 dB shall produce a nominal value of -6 dBW.

5.3.2 Power Attenuation Request (PAR)

The closed loop power control requires the receive end to request the other end to transmit at a specific power level. The receive end accomplishes this by sending a PAR value to the transmit end.

Specifically, PAR is a request for the transmit end to use a PAN value that equals the PAR. The receive end calculates a value for PAR from the receive PAN value and the difference between the estimated received signal quality and the desired signal quality. Based on the defined control procedures, the transmitter may choose to transmit at some other power level than the PAR it receives.

SQI is an important power control variable that influences the PAR value. It is an estimate of the received signal quality. Annex B describes a procedure for estimating the SQI.

5.3.3 Message coding

The MES and the GS shall quantize each of the PAR and the PAN values to 6-bit integer words. The 6-bit field permits 64 codes. Codes 0 to 60 represent power levels (see table 5.1), and the remaining three codes represent escape sequences.

The quantization coding scheme is shown here, with the term "value" representing the unquantized PAR or PAN value.

If value $< 0{,}0$ dB, code = 0.

If value $> 24{,}0$ dB, code = 60.

If $0{,}0 \le \text{value} \le 24{,}0$ dB, code = $\lfloor (\text{value}/0{,}4)+0{,}5 \rfloor$,

where $\lfloor x \rfloor$ represents the largest integer less than or equal to x.

The decoding of the coded field shall be as follows:

Decoded value = $0{,}4 \cdot \text{code}$, where $0 \le \text{code} \le 60$.

This is summarized in table 5.1. Refer to GMR-1 05.005 [8] for specification on the power setting accuracy and the attenuation control ranges.

Table 5.1: Power control message coding

Code	Value (dB)
0	0,00
1	0,40
2	0,80
3	1,20
4	1,60
5	2,00
6	2,40
…	…
59	23,60
60	24,00
61	Escape 1
62	Escape 2
63	Escape 3

5.3.4 Format of encoded message

The two 6-bit fields resulting after the quantization of the PAR and the PAN values shall be grouped to form a 12-bit field with the PAR code in the first 6 bits and the PAN code in the last 6 bits. The escape codes defined in table 5.1 shall form the first 6 bits (normally PAR). The interpretation of the second 6-bit field when the escape code is in the first 6-bit field is left to implementation. The 12-bit field shall be encoded using a systematic Golay (24, 12) code.

Refer to GMR-1 05.003 [7] for the specification on the message coding. For the traffic channels, the coded 24 bits shall be transmitted over a duration of six bursts, i.e., one power control message block. Each burst in the power control message block has a 4-bit power control field. The 4-bit power control field is present in all the traffic and the keep-alive bursts.

5.3.5 Timing

The transmit power of a channel shall change synchronously with the transmission of the power control messages. Specifically, the transmit power shall change with the first burst of the first transmit power control message that follows the reception of a requested power change. This actual power shall also be coded as the PAN value of the transmit power control message.

5.4 Implementation

The core of the power control implementation is described in this clause. Annex A, provides a complete specification on the power control implementation.

1) Power Control Initialization:

   1.1) PANlast = PANinit, (the parameter PANinit is conveyed to the MES on BCCH; refer to clause 11.1).

   1.2) PARsave = PANinit.

   1.3) Power_step_increase = 0.

2) The power control end (either an MES or a GS) is synchronized to receive the power control message block. Refer to GMR-1 05.010 [9] for power control message block synchronization.

3) The power control message block is decoded, and the PAR and PAN values are extracted. Refer to clauses 5.3.3 and 5.3.4.

4) Calculation of PAR for closed loop power control:

   4.1) If the power control message is decoded successfully and if the decoder output is a valid PAN code, PANuse = decoded PAN code, and PANlast = decoded PAN code; otherwise PANuse = PANlast.

   4.2) The power control end updates the parameter SQI. Refer to clause 10.3.2.

   4.3) The value of PAR is computed as follows: PAR = PANuse – (GAIN) × (SQT – SQI), where GAIN is the closed loop gain factor whose value equals GainDn if SQT < SQI; otherwise its value is equal to GainUp.

This calculated value of PAR is then coded and used to form the power control message block. Refer to clauses 5.3.3 and 5.3.4.

5) Calculation of PAN using closed loop power control and message error response:

   5.1) If the power control message is decoded successfully into a numeric value, then:

      5.1.1) PANbasic = Minimum of the decoded PAR value and previous value of PARsave;

      5.1.2) PARsave = decoded value of PAR; and

      5.1.3) Power_step_increase = 0.

   5.2) If the power control message is decoded successfully but yields an escape code, then:

      5.2.1) Power_step_increase = 0.

   5.3) If power control message is not decoded successfully, then:

      5.3.1) Power_step_increase = Power_step_increase + step_size; and

      5.3.2) PANbasic = PARsave.

   5.4) PAN_closed_loop = PANbasic – Power_step_increase.

6) Update of PAN through open loop power control:

   6.1) LQI_avg = Average of LQI over the previous n1th update to n2th update.

   6.2) Open_loop power_deficit = LQI_avg – LQI.

   6.3) If open_loop_power_deficit >= open_loop_threshold, then PAN = PAN_closed_loop -(open_loop up_gain×open_loop_power_deficit + open_loop_step).

   6.4) If open_loop_power_deficit < open_loop_threshold, PAN = PAN_closed_loop-(open_loop dn_gain×open_loop_power_deficit + open_loop_step).

7) Quantize and limit check PAN using PANstep, PANmin, and PANmax.

8) Set the transmit power level according to this quantized PAN value.

9) This value of PAN is then coded and used to form the power control message block. Refer to clauses 5.3.3 and 5.3.4.

5.5 Power control diagnostic

At the beginning of a call, the MES shall start a running average of the three following call statistics relating to power control:

1) Call Quality Metric (CQM), which shall be a running average of the percentage of the post-FEC burst error occurring for the call.

2) Power Control Topped-Out (PCTO), which shall be a running average of the percentage of messages from which the calculated PAS was less than PASmin.

3) Average Power Used (APU), which shall be calculated as a running power-averaged PAS setting, expressed in dB.

The running average shall be stopped at the end of the call, and CQM, PCTO, and APU shall be reset to zero.

Upon receipt of an INFORMATION REQUEST message from the network with a power control request code, the MES shall send to the network an INFORMATION RESPONSE POWER CONTROL containing CQM, PCTO, and APU. In addition, the MES shall include in the INFORMATION RESPONSE POWER CONTROL the time at which the estimate of its position is formed. (The MES reports the position estimate in the INFORMATION RESPONSE position message. If the MES does not report the position information, the time field in the INFORMATION RESPONSE POWER CONTROL shall be set to a null value).

The MES shall quantize each of the CQM and PCTO values to a 4-bit code as shown in table 5.2. These codes shall be stored in the INFORMATION RESPONSE message fields CQM and PCTO.

Table 5.2: CQM and PCTO message coding

Code	Level (%)
0000	0,1
0001	0,2
0010	0,5
0011	1,0
0100	1,5
0101	2,0
0110	3,0
0111	5,0
1000	10
1001	15
1010	20
1011	40
1100	60
1101	80
1110	100
1111	NULL

The MES shall use the same scheme described in clause 5.3.3 to quantize the APU value to a 6-bit code.

6 Radio link failure

This clause specifies the radio link failure detection during the dedicated mode.

The radio link failure criterion is based on a radio link failure counter S and the system information parameter RADIO_LINK_TIMEOUT.

1) At the assignment of a dedicated channel, the MES shall initialize the radio link failure counter S to a value of (RADIO_LINK_TIMEOUT*25).

2) The MES shall never set the counter S to a value greater than (RADIO_LINK_TIMEOUT*25). This restriction shall be a limitation on all following paragraphs of this clause.

3) For the dedicated voice traffic channel (NT3), and FACCH is not detected, the power control Golay code shall provide the criterion for judging the quality of the radio link. The Golay decoder, besides decoding the power control field, shall also perform error detection check. If this check passes, the counter S shall be incremented by 6, otherwise the counter S shall be decremented by 6. The MES shall have a full block of 6 consecutive frames to either increment or decrement S. In the event that the power control message framing has not been determined (i.e., synchronization is not achieved), a Golay decoding failure shall be assumed every 240 ms.

4) For the dedicated voice traffic channel (NT3), if the FACCH is detected, the FACCH CRC shall be used. If the FACCH CRC passes, the counter S shall be incremented by the lesser of (RADIO_LINK_TIMEOUT * 25) and 250. If the FACCH CRC fails, the counter shall be decremented by 4.

5) For the dedicated control channel (SDCCH), the counter S shall be decremented by one each frame. The counter S shall be incremented by the lesser of (RADIO_LINK_TIMEOUT *25) and 250 when the detected SDCCH burst sync pattern exactly matches any of the four possible SDCCH sync patterns.

6) For the dedicated data traffic channels (NT6, NT9), the received cyclic redundancy check (CRC) code in the slow associated control channel (SACCH) shall provide the criterion for judging the quality of the radio link. If the CRC fails, the counter S shall be decremented by 20, else the counter S shall be incremented by 20.

7) If S reaches 0, radio link failure shall be declared by the MES (the GS). In case of radio link failure, the MES (the GS) shall be required to perform the standard call setup procedures described in GMR-1 03.022 [2] before the next dedicated channel assignment.

8) The counter S shall be reinitialized to (RADIO_LINK_TIMEOUT * 25) at channel reassignment.

7 Idle mode tasks

7.1 Introduction

While in idle mode, an MES shall implement the spot beam selection and reselection procedures described in GMR-1 03.022 [2], GMR-1 04.006 [3], and GMR-1 05.002 [6]. These procedures make use of measurements and procedures described in this clause.

This clause makes use of terms defined in GMR-1 03.022 [2].

These procedures ensure that the MES is camped on a spot beam:

- from which it can reliably decode downlink data and with which it has a high probability of communications on the return link; and
- that is the optimum or close to optimum beam for communication.

The MES shall not make use of the discontinuous reception (DRX) mode of operation (i.e., powering itself down between reception of paging messages from the network) during the spot beam selection defined in GMR-1 03.022 [2]. Use of the DRX is permitted at all other times in idle mode.

For the purposes of spot beam selection and reselection, the MES shall be capable of detecting and synchronizing to a BCCH carrier and reading the BCCH data at reference sensitivity and reference interference levels as specified in GMR-1 05.005 [8].

For the purposes of spot beam selection and reselection, the MES is required to obtain an average of the received signal strength for all the monitored frequencies. These quantities, termed as the "receive level averages", shall be an unweighted average of the received signals' strengths measured in dBm.

The times shown throughout clause 7 refer to internal processes in the MES that are required to ensure that the MES camps as quickly as possible on the most appropriate spot beam signal.

The tolerance on all the timing requirements in this clause is ±10%.

7.2 Measurements for stored list spot beam selection

The MES shall store BCCH_FULL_LIST(s) when switched off as detailed in GMR-1 03.022 [2].

A BCCH_FULL_LIST contains the carrier number for at least one BCCH carrier in every spot beam of GMR-1 system. There may multiple satellites in each GMR-1 system but there is only one BCCH_FULL_LIST per GMR-1 system. The MES may have more than one BCCH_FULL_LIST.

The MES shall search for the frequency control channel (FCCH) to acquire frequency and timing synchronization. To minimize camp-on time, the MES shall first scan BCCH_FULL_LISTs, if available. The MES shall order its scan of stored lists by PLMN priority order GMR-1 03.022 [2]. The MES may also scan stored carriers (that might or might not be in a BCCH_FULL_LIST) in an implementation dependent manner to accelerate spot beam selection.

7.3 All LMSS band carrier spot beam search

It may be necessary to scan all potential BCCH carriers. (See GMR-1 03.022 [2]).

The RF channels in the GMR-1 systems are denoted by their respective carrier numbers N as described in GMR-1 05.005 [8]. There are a total of 1 087 RF channels in the GMR-1 system, i.e., $1 \leq$ RF channel number $N \leq 1\ 087$. The MES shall first search the RF channel N = 4; it shall continue searching RF channels by incrementing N in steps of five until N = 1 084; the MES shall measure channel number N = 5 and proceed in steps of five until N = 1 083, then N = 5 with steps of 5 until N = 1 085, then N = 2 with steps of 5 until N = 1 087, and N = 1 with steps of 5 until N = 1 086.

If the MES finds a BCCH carrier, it shall attempt to load System Information and scan the BCCH_FULL_LIST, if not already done so, as described in the previous clause. It should then perform spot beam selection, before resuming the full LMSS band scan.

7.4 Criteria for Spot Beam Selection and Reselection

The network shall synchronize the FCCH and the BCCH transmissions in neighboring spot beams so that they are orthogonal in time. (They do not overlap, and allow time for synthesizer tuning. See GMR-1 05.002 [6]). The MES shall be able to schedule measurements for at least six neighboring BCCH broadcasts so that they can be measured concurrently with the selected BCCH broadcast. An example is shown in figure 7.1.

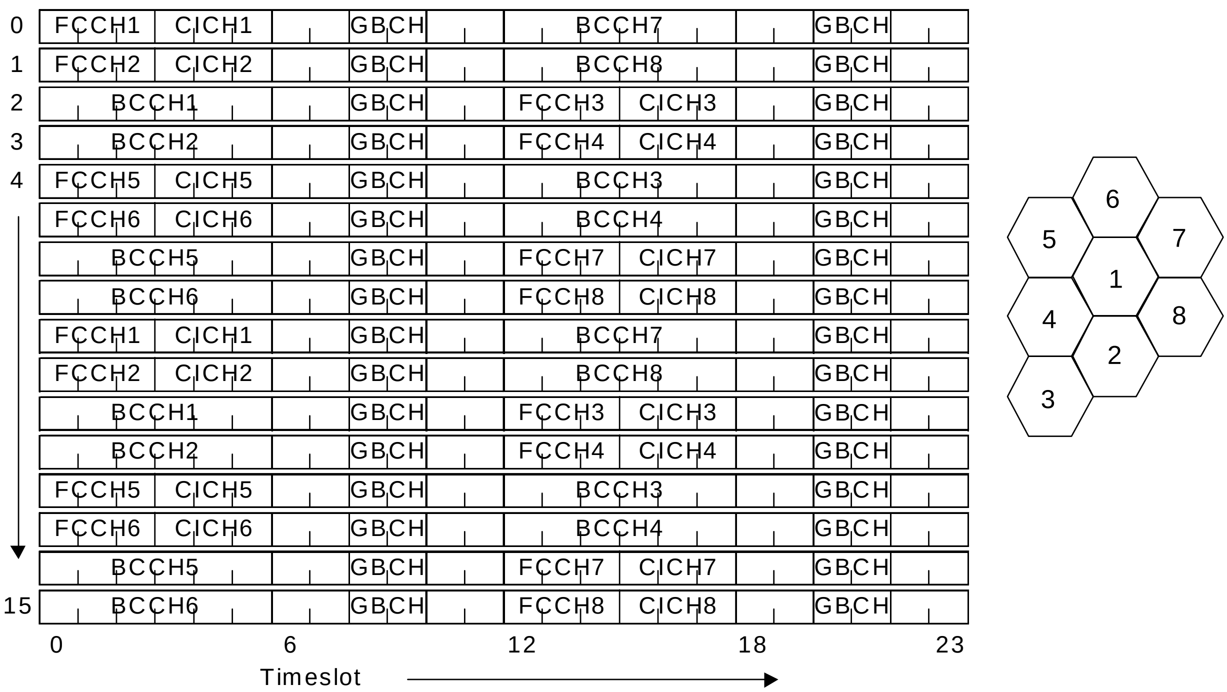

Figure 7.1: Scheduled FCCH and BCCH measurements for neighboring spot beams

After selecting a candidate spot beam, the MES shall schedule the relative RSSI measurements for its BCCH and the BCCHs in the BCCH_NEIGHBOR_LIST of the candidate spot beam. These measurements shall be averaged using the dB scale and shall be used to rank order the neighboring BCCHs.

The MES may also optionally measure CICHs to improve relative RSSI measurements.

The algorithm used for spot beam selection shall be defined by:

i) Measure consecutively the BCCH relative power (dB) of beam 1, 2, …, 7 at measurement iteration j as $b_1^j, b_2^j, \ldots, b_7^j$. Repeat until j = 15.

ii) Calculate the mean power, m_i for beam *I*, in dB for the j measurement cycles as:

$$m_i = \frac{1}{j}\sum_{k=1}^{j} p_i^k$$

iii) If the strongest spot beam is different from the candidate spot beam and was not a previous candidate, go back to step (I) with the strongest spot beam as the candidate spot beam.

iv) Otherwise, select that spot beam and all the spot beams that are within SB_SELECTION_POWER dB of the strongest spot beam, and provided that C1 > 0 for each selected spot beam. If SB_SELECTION_POWER is configured to a value of 0, then only the strongest spot beam shall be selected.

If multiple spot beams meet these selection criteria, the MES shall select among them according to the rules in GMR-1 03.022 [2]. If spot beam(s) contain more than one BCCH carrier, the MES shall select among the BCCH carriers according to the rules in GMR-1 03.022 [2].

The path loss criterion C1 is defined by:

$$C1 = A$$

where:

A	=	Receive Level Average – RXLEV_SELECT_MIN
Receive Level Average	=	Apparent (measured) flux density at the MES antenna
RXLEV_SELECT_MIN	=	Adjustment for minimum received level at the MES required for selecting a spot beam. This parameter shall be received from System Information on a BCCH from the candidate spot beam (centre spot beam) of the previous clause. If neighbor beam(s) also meet the requirement for selection of the previous clause, the MES shall use the RXLEV_SELECT_MIN of the candidate beam for the C1 criterion check for the neighbor beam(s).

7.5 Minimum Signal Strength for Transmission Via the RACH

The MES shall predict a frame error rate of less than 1% on the BCCH, the PCH, the AGCH, or any combination of these channels, before sending a CHANNEL REQUEST message with Establishment Cause of "Location Update", "IMSI Detach", or "In Response to Alerting".

The MES shall send a CHANNEL REQUEST message with Establishment Cause of "Emergency Call" as soon as possible and provided only that emergency calls are not blocked by ACCESS_CLASS or CELL_BAR_ACCESS.

7.6 Position determination procedure

Once a spot beam has been selected, the MES shall use the seven relative power measurements of clause 5.4 to estimate its position.

The MES shall obtain the location of the centre of the seven spot beams and the satellite from the BCCH system information parameters SAT_POS and BEAM_CENTER_POS. The first of the two parameters contains the satellite position (latitude = 8 bits, longitude = 12 bits). The latter parameter contains the main beam centre position (latitude = 11 bits, longitude = 12 bits) and the six neighboring beam centre positions as offsets from the main beam centre position (latitude = 9 bits, longitude = 9 bits for each neighbor beam centre offset). With this information and the measured BCCH relative signal strength from three spot beams at a time, the MES shall calculate the limits of the region in which its location is possible. From the relative power measured from each of these three beams, the MES shall then calculate its approximated location within that region. The MES shall calculate approximated locations for different combinations of three spot beams depending on the number of neighbors in the cluster. The MES shall then average these approximated locations to get the final averaged approximate location.

The MES may compare this approximate location with valid GPS position if available to check the accuracy of the spot beam selection. This check may trigger a new spot beam selection procedure.

With this approximate location or using valid GPS position if available, the MES shall calculate the delay difference, in milliseconds, between the satellite and the approximated location and the satellite and the selected spot beam centre. This result shall then be matched to one of seven possible fixed levels (0, ±47, ±94, ±141) symbols and stored in a parameter called RACH_CORRECTION GMR-1 05.010 [9].

Annex C shows an algorithm for the MES position determination.

7.7 Spot beam reselection

The MES shall perform spot beam reselection at least every SB_RESELECTION_TIMER seconds to ensure that the serving spot beam is acceptable. If the MES moves to alerting mode from paging mode, it shall continue to update the SB_RESELECTION_TIMER counter. If the MES reverts back to the paging mode from the alerting mode, and if the SB_RESELECTION_TIMER counter is expired, it shall immediately perform the spot beam reselection. The MES shall also perform the spot beam reselection immediately after returning to paging mode from the dedicated mode.

Spot beam reselection consists of the following steps:

1) The MES shall perform the procedure described in clause 7.4, with the currently camped-on BCCH as the candidate spot beam, and determine the strongest spot beam.

2) If the MES is not camped on a BCCH carrier of the strongest spot beam, the MES shall then check whether the calculated value of the RSSI of the nonserving spot beam exceeds the value of the RSSI for the serving spot beam by at least SB_RESELECT_HYSTERESIS dB. If this condition is satisfied, the MES then selects the spot beams that are within SB_SELECTION_POWER dB of the strongest spot beam and for which C1 > 0.

3) Spot beam selection among multiple beams, and BCCH selection among multiple BCCH carriers, is performed according to GMR-1 03.022 [2].

Once a spot beam has been selected, the relative power measurements for up to seven beams shall be stored in the MES for diagnostic purposes. Once a spot beam has been selected, the MES shall also start a timer TRSSI used for diagnostic purposes.

7.8 Spot beam diagnostics

The network can request diagnostic information from the MES by sending an INFORMATION REQUEST message to the MES. The diagnostic message from the network contains a request for specific information GMR-1 04.008 [4]. Two request codes are related to spot beam selection/reselection:

- Spot Beam Selection: Upon receipt of an INFORMATION REQUEST message from the network with a spot beam selection request code, the MES shall send to the network an INFORMATION RESPONSE SPOT BEAM SELECTION message containing the following:
  - The relative power measurements of the current beam and all defined neighbor beams of the most recent spot beam selection or reselection.
  - The time difference between the last spot beam selection or reselection (TRSSI) and the time at which the GPS position that shall be or has been reported in the INFORMATION RESPONSE POSITION message, in response to the other request code in the same INFORMATION REQUEST message, was measured. Otherwise, this time shall be set to a null value.
- Current Beam: Upon receipt of an INFORMATION REQUEST message from the network with a current beam request code, the MES shall start measuring the signal strength of the spot beam that the MES is currently camped on. A total of 15 measurements shall be taken averaged in dB. Once the measurements are completed, the MES shall send to the network an INFORMATION RESPONSE CURRENT BEAM message containing the signal strength of the spot beam that the MES is currently camped on and the time at which the GPS position that shall be or has been reported in the INFORMATION RESPONSE POSITION message, in response to the other request code in the same INFORMATION REQUEST message, was measured. Otherwise, this time shall be set to a null value.

7.9 Release of TCH and SDCCH

When the MES releases a TCH or SDCCH and returns to idle mode, it shall, as quickly as possible, camp on the BCCH carrier upon which it was most recently camped. The MES shall then attempt to decode the new BCCH data. The MES shall also monitor the frames assigned to its paging group on the appropriate CCCH carrier. If the MES receives a page before having decoded the full BCCH data for the spot beam, the MES shall respond to the page, provided that the spot beam is not barred and the MES's access class is allowed.

7.10 BCCH read operation

The MES shall decode the full BCCH data immediately after final selection of a BCCH after power on or after a change of selected BCCH. The MES shall attempt to decode the new BCCH data of the selected BCCH at least every 30 seconds in paging mode and immediately after returning to paging mode from alerting mode. New BCCH data shall consist of Class I system information and all other system information classes which have changed since the last time the MES read them.

7.11 Abnormal cases and emergency calls

When in the limited service state GMR-1 03.022 [2], the aim is to gain normal service rapidly, and the following tasks shall be performed, depending on the conditions, as given in the table below.

a) The MES shall conduct an All LMSS Band Spot Beam Search. When a suitable carrier is found, the MES shall camp on that spot beam, irrespective of the PLMN identity.

b) The MES shall monitor the signal strength of all RF channels in its BCCH_FULL_LISTs. This information shall be processed according to the PLMN selection algorithm defined in GMR-1 03.022 [2].

c) The MES shall perform spot beam reselection, except that a zero value SB_SELECTION_POWER shall be used and a small but non-zero value of SB_RESELECT_HYSTERESIS shall be used.

In this mode, only emergency calls may be made. Powering down of the MS is permitted.

Table 7.1: Schedule of tasks for emergency and abnormal calls

Condition			Tasks To Be Performed as a Minimum:		
SIM Present	**Other**	**MES camped on a spotbeam**	**a)**	**b)**	**c)**
X	In Manual PLMN selection mode only	No	Yes	No	No
No	X	Yes	No	No	Yes
Yes	"IMSI Unknown", illegal MES	Yes	No	No	Yes
Yes	No suitable spot beam of selected PLMN or "PLMN not allowed"	Yes	No	Yes	note
X = "Don't care" state. NOTE: Perform normal reselection.					

8 Network prerequisites

8.1 BCCH Carriers

The BCCH carrier shall transmit two three-timeslot FCCHs into every multiframe on a PC6d physical channel. The six-timeslot BCCH shall be transmitted once every eight frames in the second frame, following the FCCH. All other control channels, e.g., the PCH, BACH, AGCH, and CBCH are time multiplexed onto this physical channel.

The BCCH carriers in adjacent spot beams shall have their transmission of FCCH and BCCH offset in time, either on different timeslots or on the same timeslot, but offset in frame number to facilitate the signal strength and quality measurements at the MES for spot beam selection and reselection. The neighboring beams' BCCH carrier identification and the timing shall be broadcast in the BCCH.

9 Aspects of Discontinuous Transmission (DTX)

When DTX is employed on a TCH, a dual keep-alive burst (DKAB) is transmitted on TDMA frames during periods of voice inactivity, as determined by the vocoder. The structure of a DKAB burst is described in GMR-1 05.002 [6]. The DKAB bursts essentially carry the equivalent to the silence descriptor (SID) frames of GSM, but in a time-multiplexed fashion. A total of 26 DKAB bursts, each carrying 4 SID bits, forms an SID frame. The 104 bits every 26 TDMA (time division multiple access) frames are dealt with as a single 20 msec voice frame from the point of view of channel decoding and voice decoding. The SID frames contain a description of the background noise on the encoder side. Background noise parameters are carried at an information rate of 100 bps and are updated every 1,04 seconds. Based on a received background noise update, the voice decoder generates noise (called comfort noise) every 20 msec until the next update occurs or speech activity begins. If speech activity begins before an entire SID frame is received, then the partial SID frame is ignored and active speech processing is resumed. Although the vocoder declares voice activity on a 20 msec basis, from a transmission point of view, DTX is invoked if both 20 msec intervals belonging to the current TDMA frame have been declared inactive and at least one of the two 20 msec speech frames in the previous TDMA frame have been declared inactive. This innovation shall allow comfort noise to be generated during the first 1,04 sec of an inactive voice interval.

When FACCH, SACCH, or Short Message is to be transmitted during an inactive voice interval in place of a DKAB burst, the 4 SID bits are still transported across air interface by appropriately puncturing the encoded bit stream. From a physical layer processing point of view, FACCH, SACCH, and SMS messages are encoded and punctured in the same manner.

Transmission of DKABs is applicable on a speech traffic channel. The transparent facsimile traffic channel does not allow for DTX operation. For a nontransparent data traffic channel, when DTX is invoked, NULL frames (in ADM mode) and receive ready (RR) or receive not ready (RNR) frames (in asynchronous balance mode (ABM) are transmitted GMR-1 04.022 [5], hence DKABs are not transmitted.

For the common control channels, e.g., the BCCH, paging channel (PCH), access grant channel (AGCH), broadcast alerting channel (BACH), and cell broadcast channel (CBCH), the signal transmission is stopped when there is no information to be transmitted.

9.1 Rules of burst transmission

This clause summarizes the rules of burst transmission for different channel types.

1) The GS transmits the AGCH burst carrying either a traffic channel or an SDCCH assignment. The GS may also send the traffic channel assignment from the SDCCH.

2) The GS shall begin dedicated channel transmission after a maximum delay of 160 ms from the last transmitted bit of the burst carrying the channel assignment message. The MES shall begin dedicated channel transmission within 320 ms from the receipt of last bit of burst with channel assignment message.

3) For the NT3 channel type, the discontinuous transmission (DTX) mode shall be supported in VOICE mode and shall be supported in SIGNALLING mode according to the following limitations. DTX mode shall be supported by use of DKABs. Upon assignment of a new NT3 channel, the DTX mode shall be initiated only after the GS (or the MES) receives data link layer acknowledgement from the MES (or the GS). This acknowledgement shall be conveyed by setting the Link Status Flag associated with the PH-EMPTY-FRAME-REQUEST primitive. (Refer to GMR-1 04.006 [3]). Prior to receiving this acknowledgement, the GS (or the MES) shall transmit the bursts with 100% duty cycle, using fill frames (refer to GMR-1 04.006 [3]) if necessary.

   If the NT3 channel is assigned by an ASSIGNMENT COMMAND 2 message, the transition to DTX mode shall occur after establishment of the SAPI 0 link if the MES has been assigned the terminal role, and the transition to DTX mode shall occur after establishment of the SAPI 2 link if the MES has been assigned the network role (refer to GMR-1 04.008 [4]). In all other cases, the transition to DTX mode shall occur after establishment of the SAPI 0 link.

   After the NT3 channel enters the DTX mode but before the start of the voice activity, frames shall be transmitted with a minimum duty cycle as follows. A fill frame shall be transmitted as FACCH if less than 8 out of the last 49 bursts are transmitted and if no new messages are waiting in the FACCH queue.

   Once the fill frame transmission starts, it shall continue for four frames.

4) For the SDCCH, the DTX mode shall not be supported. In absence of information, the bursts shall be transmitted with fill frames. Once the fill frame transmission starts, it shall continue for two frames.

5) For the dedicated channels carrying data traffic, NT6 and NT9, the DTX mode shall not be supported. In absence of information, the bursts shall be transmitted with fill frames.

6) For the dedicated control channel TACCH/2 for terminal to terminal calls, the discontinuous transmission mode shall not be supported. In absence of information, the bursts shall be transmitted with fill frames.

10 Radio link measurements

The MES shall make radio link measurements for the RF power control, radio link failure criterion, idle mode beam selection/reselection procedures, idle mode selection criteria, and user strength indication.

The GS shall make radio link measurements for RF power control, radio link failure criterion, and time and frequency synchronization processes.

10.1 Received Signal Strength Indication (RSSI)

10.1.1 General

The MES shall measure the RSSI as the criterion for rank ordering the BCCHs during the spot beam selection and reselection procedures and for signal quality estimation. The MES shall not be required to report this parameter to the network.

10.1.2 Physical parameter

The MES shall measure the RSSI as the RMS value of the signal received at the antenna. In the estimation of the RSSI, the MES shall compensate for all the time-varying processes (such as automatic gain control) that affect the estimation procedure to obtain a relative measure for comparing the strength of signals received at different times. Refer to annex B for one approach for estimating RSSI.

10.1.3 Statistical parameter

Refer to clause 7.8 of GMR-1 05.005 [8] for the accuracy requirement on the RSSI estimate.

10.1.4 Range of the parameter

Refer to annex B of GMR-1 05.005 [8] for the range of the RSSI estimate.

10.2 Signal Quality Indication (per Burst)

10.2.1 General

The SQI_j, estimated for each received burst (j^{th} burst), shall be used to determine the LQI. The parameter LQI is used for the power control, for the transition between the idle modes, and for the user strength indication.

10.2.2 Physical parameter

The SQI_j is defined as an estimate of the ratio of the desired signal power to the noise and interference power in the received burst. The SQI_j estimate shall be formed for each received burst. Refer to annex B for an approach for estimating SQI_j.

10.2.3 Range of parameter

The MES and the GS shall be able to estimate SQI_j in a range from -5 dB to 20 dB.

10.2.4 Accuracy of the parameter

The accuracy of SQI_j for TCH3 channel is specified in terms of its average over six bursts. For the k^{th} nonoverlapping block of six TCH3 bursts (where k is a positive integer), the average SQI is defined as:

$$\overline{SQI\,6_k} = \frac{1}{6} \cdot \left(\sum_{j=6\cdot k+1}^{6\cdot(k+1)} SQI_j \right).$$

The sample mean and the standard deviation of the SQI estimator are defined as follows:

$$\left\langle \overline{SQI\,6_k} \right\rangle_{N_{avg}} = \frac{1}{N_{avg}} \times \sum_{k=1}^{N_{avg}} \left(\overline{SQI\,6_k} \right), \text{ and}$$

$$\sigma\left\{ \overline{SQI\,6_k} \right\}\Big|_{N_{avg}} = \sqrt{\frac{1}{N_{avg}} \times \sum_{k=1}^{N_{avg}} \left(\overline{SQI\,6_k} - \left\langle \overline{SQI\,6_k} \right\rangle_{N_{avg}} \right)^2}.$$

The SQI estimation accuracy for the TCH3 channel is specified in table 10.1A.

Table 10.1A: SQI_j estimation accuracy for TCH3 nonfading channels

Metric	Range of Input Signal Quality	
	$0 < E_b/N_o$, dB < 5	$5 < E_b/N_o$, dB < 12
$\left\lvert \left\langle \overline{SQI6_k} \right\rangle_{N_{avg}} - E_b/N_o \right\rvert$	2 dB	0,2 dB
Range of $\sigma\{\overline{SQI6_k}\}\rvert_{N_{avg}}$	Less than 0,5 dB	Less than 0,3 dB

The range of $\sigma\{\overline{SQI6_k}\}\rvert_{N_{avg}}$ for all other channels, except FCCH, shall be adjusted from the value in table 10.1A by factor $\sqrt{\frac{L_{TCH3}}{L_{CH-TYPE}}}$, where CH-TYPE is the channel under observation, $L_{CH\text{-}TYPE}$ is the number of symbols per burst (except guard symbols) for the channel under observation, and L_{TCH3} is the number of symbols per TCH3 burst (L_{TCH3} is equal to 112 since guard symbols are ignored in SQI estimation).

The SQI estimation accuracy for the FCCH is as specified in table 10.1B.

Table 10.1B: SQI_j estimation accuracy for FCCH

Metric	Range of input signal quality	
	$-15 < E_b/N_o$, dB < 5	$5 < E_b/N_o$, dB < 20
$\left\lvert \left(\overline{SQI_j}\rvert_{N_{avg}} \right) - E_b/N_o \right\rvert$	2 dB	0,2 dB
Range of $\sigma\{SQI_j\}\rvert_{N_{avg}}$	Less than 5 dB	Less than 0,5 dB

The following is the definition of the mean and the standard deviation of the signal quality estimates:

$$\overline{SQI_j}\Big\rvert_{N_{avg}} = \frac{1}{N_{avg}} \times \sum_{j=1}^{N_{avg}} SQI_j \text{, and}$$

$$\sigma\{SQI_j\}\Big\rvert_{N_{avg}} = \sqrt{\frac{1}{N_{avg}} \times \sum_{j=1}^{N_{avg}} \left(SQI_j - \left[\overline{SQI_j}\Big\rvert_{N_{avg}} \right] \right)^2} .$$

The GS informs the MES of the number of averaged samples N_{avg} in tables 10.1A and 10.1B through BCCH (refer to clause 11.3).

10.2.5 Implementation

Refer to annex B for an informative procedure for the SQI estimation.

10.3 Link Quality Indication (LQI)

10.3.1 General

The LQI shall be employed as criterion for radio link failure, for idle mode selection criteria, and for user strength indication. The LQI is the amount of reserve link margin, with respect to the target signal quality, SQT, expressed in dB. A negative value of LQI indicates that the target signal quality is not being met by the indicated value.

10.3.2 Physical parameter

The LQI calculation methods for the control channels in the absence of power control and for the dedicated channels operating under power control are different, as shown in the following paragraphs.

In the absence of power control, as when monitoring BCCH or a PCH, the LQI for the j^{th} received burst shall be calculated as follows:

$$LQI_j = SQI_j - SQT - CCH\_POWER\_ADVANTAGE,$$

where all quantities are expressed in dB. The parameters SQI and SQT are defined in clause 3. The parameter CCH_POWER_ADVANTAGE is the transmit power level difference between the common control channel and the dedicated traffic channel.

During power control, as for the dedicated traffic channel, the LQI is calculated as follows:

1) Set power control message block index k to 1.

2) Calculate the mean and the variance of the six SQIj estimates in kth power control message block:

$$\overline{SQI\,6_k} = \frac{1}{6}\cdot\left(\sum_{j=6\cdot k+1}^{6\cdot(k+1)} SQI_j\right),\quad \sigma^2\{SQI\,6_k\} = \frac{1}{6}\cdot\left(\sum_{j=6\cdot k+1}^{6\cdot(k+1)} \left(SQI_j - \overline{SQI\,6_k}\right)^2\right).$$

3) If k is equal to one, initialize averaged variance of SQI estimate $\sigma^2\{\overline{SQI\,6}\} = \sigma^2\{\overline{SQI\,6_k}\}$.

4) If k is greater than one, update the averaged variance of SQI estimates using a first order filter as shown in the following two steps:

   - If the averaged SQI variance is greater than the variance of the SQI for the k^{th} block, use VarDn as the filter coefficient, else use VarUp as the filter coefficient, i.e., if $\sigma^2\{\overline{SQI\,6_k}\} < \sigma^2\{\overline{SQI\,6}\}$, fltr = VarDn, else fltr = VarUp.

   - Filter $\sigma^2\{\overline{SQI\,6}\}$ using the first order IIR filter, $\sigma^2\{\overline{SQI\,6}\} = fltr\cdot\left(\sigma^2\{\overline{SQI\,6_k}\}\right) + (1 - fltr)\cdot\left(\sigma^2\{\overline{SQI\,6}\}\right)$.

5) Update the mean of SQI estimate using the running average of the SQI variance:

$$\overline{SQI\,6_k} = \overline{SQI\,6_k} - \{SQIfactor \times \sigma\{\overline{SQI\,6}\}\}.$$

6) If the power control message is decoded successfully, and if the decoder output is a valid PAN code, PANuse = decoded PAN code, PANlast = decoded PAN code; otherwise PANuse = PANlast.

7) LQI = PANuse + $\overline{SQI\,6_k}$ - SQT.

10.3.3 Range and accuracy of the parameter

LQI is the sum of 3 values: SQI, PAN, and -SQT. Its value is not transmitted across the air interface, and thus the method of internal representation is implementation dependent.

The range of values is defined by the range of values of each of the constituents, summarized in table 10.2, yielding a range of LQI from -18,6 to 44 dB (typically the value shall lie in a much narrower range, for example, 0 to 15 dB).

Table 10.2: Range of LQI Values

Parameter	Min. Value [dB]	Max. Value [dB]
SQI	-6	20
PAN	0	24
-SQT	-12,6	0
Total Range	-18,6	44

The accuracy of LQI is dictated by the accuracy of the constituent values. Both PAN and SQT are fixed values, in that they are defined externally. The only error in their representation is quantization, which should be negligible. Hence, the accuracy of SQI is dominated by the accuracy of the SQI, defined in clause 10.2.4, tables 10.1A and 10.1B.

10.4 Receive time and frequency offsets

Refer to GMR-1 05.010 [9] for the description of these parameters.

11 Control parameters

The following are the lists of the radio link control parameters. Refer to GMR-1 04.008 [4] for the details of the parameter messaging and the parameter encoding.

11.1 Power control parameters

These parameters shall be conveyed over BCCH, AGCH, SDCCH, SACCH, or FACCH from the GS to the MES.

Parameter	Description	Range	Resolution	Bits	Default
SQT	Target signal quality, in dB	0 to 12,6 dB (note 1)	0,1	7	8 dB
PANinit	Initial value of PAN, in dB	0 to 24,0 dB	0,4	6	0 dB
PANmin	Minimum value of PAN, in dB	0 to 24,0 dB	0,4	6	0 dB
PANmax	Maximum value of PAN, in dB	0 to 24,0 dB	0,4	6	24 dB
GainUp	The power control loop gain used if SQI is less than SQT	0 to 3,1	0,1	5	1,0
GainDn	The power control loop gain used if SQI is greater than SQT	0 to 1,0	0,1	5	1,0
Olthresh	Threshold for activating open loop control, dB	0 to 6,0 dB (note 2)	0,2	5	0,0 dB
OlupGain	The open loop control gain for power increases	0 to 3,1	0,1	5	1,0
OldnGain	The open loop control gain for power decreases	0 to 3,1	0,1	5	0,4
VarUp	IIR filter coefficient for filtering SQI estimate increases	0 to 1,0	0,05	5	0,2
VarDn	IIR filter coefficient for filtering SQI estimate decreases	0 to 1,0	0,05	5	1,0
Mestep	Message error power gain step size, dB	0 to 3,0 dB	0,2	4	0,0 dB
SQIfactor	The constant factor by which the estimation variance is weighed in the calculation of SQI	0 to 3,1	0,1	5	1
LQIn1	The LQI filter beginning point	0 to 15	1	4	3
LQIn2	The LQI filter ending point	0 to 15	1	4	6
NOTE 1: A code of 127 implies a null value (no assignment). NOTE 2: A code value of 31 implies the open-loop function is to be disabled.					

11.2 Parameters for idle mode tasks

These parameters shall be conveyed over BCCH by the GS to MES.

Parameter	Description	Unit	Range	Default	Resolution	#Bits
BEAM_CENTER_ POS_main Latitude	Latitude of the centre of the main beam	Deg	±64		0,1	11
BEAM_CENTER_ POS_main Longitude	Longitude of the centre of the main beam	Deg	128		0,1	12
BCCH_NEIGHBOR_LIST ARFCN	List of RF channels corresponding to the BCCH carriers in the six neighbor spot beams		0 to 1 087			11×6 = 66
BCCH_NEIGHBOR_LIST RELATIVE_FRAME_OFFSET	The frame number relative to start of the system information cycle for the six neighbor beams		0 to 7			3×6 = 18
BCCH_NEIGHBOR_LIST SA_BCCH_STN	Starting timeslot of the physical channel hosting BCCH		0 to 23			5×6 = 30
BEAM_CENTER_POS_neighbor Latitude	Latitude of the centre of the six neighbor beams expressed as offset from the main beam centre	Deg	±15		0,1	9×6 = 54
BEAM_CENTER_POS_neighbor Longitude	Longitude of the centre of the six neighbor beams expressed as offset from the main beam centre	Deg	±15		0,1	9×6 = 54
BCCH_FULL_LIST	List of BCCH carriers used systemwide		1 to 1 087			11
Satellite Position Latitude	Satellite latitude position	Deg	-12,8 to 12,7		0,1	8
Satellite Position Longitude	Satellite longitude position	Deg	0 to 360		0,1	12
SB_SELECTION_POWER	Minimum power level for selecting spot beam	dB	0 to 6,0		0,54	4
SB_RESELECTION_HYSTERESIS (see note)	Receive level hysteresis required for spot beam reselection	dB	0 to 6,0		0,54	4
SB_RESELECTION_TIMER	Time interval between consecutive neighbor BCCH power measurements for the spot beam reselection	Minute	0 to 252		4	6
RXLEV_SELECT_MIN	Spot beam selection criterion	dB	0 to 15,5		0,5	5
NOTE: If all four bits in SB_RESELECTION_HYSTERESIS parameters are set to one, the MES shall consider this parameter to be infinite and remain in the same spot beam.						

11.3 Miscellaneous parameters

Parameter	Description	Unit	Range	Step	#Bits	Channel
RADIO_LINK_TIMEOUT	Maximum value of the radio link failure counter		0 to 255	1	8	BCCH, SACCH, FAACH (GS to MES)

Annex A (informative): Pseudocode for power control

This annex is normative in the sense that the product code that is to be implemented shall produce the same results - in particular, the same PAS, PAN, and PAR values - as implied by the pseudocode.

There are (at least) three processes to consider: initialization, transmit a frame, and receive a frame. Upon setup (or reset) of a call that is to have power control active, a call is made to `pc_alg_init`. Then the transmit and receive power control processes are enabled. The power control parameters are read-only by the power control algorithm. They are initialized at call setup, and generally remain fixed during the call.

PC_ALG16.FOR

This pseudocode contains definitions of the mechanisms being specified for the product.

SUBROUTINE pc_alg_init

This subroutine is executed at call setup and call reset.

This quantization and range check may be done in any of several places.

```
Call quantize(PASinit, PARstep, PARmin, PARmax)
```

Initialize transmit variables

```
call set_PAR(<null msg>)          ! null code value for PAR used on initial transmission
call set_PAS(PASinit)             ! initial attenuation for transmit level
```

PC_ALG variables

```
init = true                       ! used to initialize some local variables
PANlast =  PASinit
PARsave =  PASinit
END
```

PROCESS Transmit_frame

PAS and PAN values shall be held until proper transmission time, therefore, the ENTRYs.

At GSs, these entries shall be messages that are asynchronous to the transmit process.

For MESs, these may just be global variables.

This process is performed for every transmit frame time (e.g., 40 msec).

See GMR-1 05.010 [9] for timing and synchronization of PC messages.

```
If(a PC message is about to start)
     <Set new transmit level according to PAShold>
     PAN = PAShold
     PAR = PAR_hold
     Golay_Encode_PC_message(PAN, PAR)
send_frame(PC_message)                ! the PC message gets sent over six frames
return
```

ENTRY set_PAS(val)

```
PAShold = val              ! note: this entry does not immediately change the transmit power
return
```

ENTRY set_PAR(val)

```
PAR_hold = val
END
```

PROCESS Receive_frame

`constant nbpm=6`

This process is activated upon the reception of a frame.

See GMR-1 05.010 [9] for timing and synchronization of PC messages.

```
If(<PC message is not in sync>) then   <re-sync PC message>
< The receiver determines if this burst is the beginning of PC message, BOM >
< If the beginning of this current message has been received then continue>
< The receiver calculates SQIburst, in dB>

The average and the variance are calculated on the fly.

If (BOM) them
     Average=0.0
     Variance=0.0
Average = average+SQIburst
Variance=variance+SQIburst^2
< The receiver determines if this burst was the end-of-message, EOM >
```

```
if(not EOM) return

SQImean = average/nbpm
Msg_var = variance / nbpm – SQImean^2
```

End-of-message processing

< The Golay Decoder determines if msgOK, and recovers PAN and PAR>

```
call control_algorithm(SQI_sav, msgOK, PAN, PAR)
END
```

SUBROUTINE control_algorithm(SQImean, msg_var, PAN, PAR, msgOK)

Runs when PC message is complete

Calculate the SQM for each message, including its variance offset

```
If (init) SQIvar = msg_var
If (msg_var >= SQIvar) fltr = VarUp
else                       fltr = VarDn
SQIvar = fltr*msg_var + (1.0 – fltr)*SQIvar
SQM = SQImean – SQIfactor*SQRT(SQIvar)
```

Now do the PC actions

```
LQI = closed_loop(SQM, PAN, msgOK)     ! calculate and transmit PAR
call open_loop(LQI, PAR, msgOK)! Calculate PAS and set transmit level
init = false                           ! cancel PC message initializations
END
```

FUNCTION closed_loop(SQM, PAN, msgOK)

Calculates transmit PAR based upon received PAN and measured SQM

Returns LQI for open_loop use

Process PAN. Determine LQI for open loop use.

```
ValOK = (PAN != <an escape code>)
if(msgOK .and. valOK) PANuse =  PAN
                      PANlast = PAN
  else                PANuse =  PANlast
LQI = PANuse + SQM – SQT
```

```
PAR message calculation for transmit
   PCI = SQT – SQM                        ! power correction indication
   if(PCI > 0.0)  PCV = GainUp * PCI      ! power correction value
     else         PCV = GainDn * PCI
   PARtx = PANuse – PCV             ! attenuation is negative to power
   call quantize(PARtx, PARstep, PARmin, PARmax)
   call set_PAR(PARtx)                    ! command this end to transmit PAR msg
   return LQI
   END
```

SUBROUTINE open_loop(LQI, PAR, msgOK)

This routine calculates the PAS value to use for the transmit level.
(It is based upon STATE2.TXT 19-May)

Examine PAR code.

```
   PARok = msgOK and (PAR value != <escape code>) ! Only <null code> is used so far
   <possible future processing of PAR escape codes>
```

Basic PAR to PAS calculation -------------------------------

```
   if(msgOK) step = 0.0
   else      step = step + Mestep
   if(PARok) then
        PASin =   min(PAR, PARsave)        ! Delay power decreases by one msg
        PARsave = PAR
   PAS = PASin – step
```

Open-Loop Processing ---

Filter LQI against negative glitches

```
LQIref =  LQIave(LQI)
deficit =   LQIref – LQI
```

Is there a deficit requiring an OL action ?

```
Olaction =  absolute(deficit) > Olthresh
```

If so, calculate an OL correction and reduce PAS (increase power)

```
if(Olaction)  then
     if (deficit>=0) Olcorr = OlupGain * deficit
     else      Olcorr = Oldngain * deficit
     PAS = PAS – Olcorr
Flag = PAS < PARmin
If (flag)
     <accumulate condition and report as a call statistic>

call quantize(PAS, PARstep, PARmin, PARmax)
```

Set transmit power level to PAS

```
If (<power control is enabled>) call set_PAS(PAS)
END
```

SUBROUTINE quantize(x, step, a, b)

Quantize – to resolution of "step" within range of a <= x <= b

```
if(x < a) x = a
if(x > b) x = b
if(step > 0.0)  x = int(x/step+0.5) * step
END
```

```
FUNCTION  LQIave(LQI)
C   This function returns the average of LQI over the last n1 through n2 values,
inclusively.
C   LQIn1 and LQIn2 are integer parameters: max >= LQIn2 >= LQIn1 >= 0.
Parameter max = 12
Real last(0:max)
If (init)
Do I=0, max
  Last(I)=LQI
  Flag = false
RETURN LQI

Shift by one and insert new LQI at position '0'
Do I=max, 1, -1
Last(I)=last(I-1)
Last(0)=LQI

Calculate average from LQIn1 to LQIn2, inclusive
Sum = 0.0
Do I=LQIn1, LQIn2
  Sum = sum + last(I)

Average = sum / (1.0+LQIn1-LQIn2)
RETURN average
END
```

Annex B (informative): Per-burst SQI estimation

This annex is informative. The approaches for the per burst SQI (SQI_j) estimation are summarized. The SQI_j estimation results, irrespective of the method used, shall satisfy the accuracy and the variance requirements specified in clause 10.2.4.

B.1 Time Domain Method

The time domain SQI_j estimation scheme is suitable for TCH power control during the call, and also for the idle mode state transition when the FCCH is not available.

The SQI_j, for j^{th} burst, is estimated either by the received signal strength indication ($RSSI_j$) or by error vector magnitude (EVM_j). These are expressed as:

$$RSSI_j = 10 \cdot \log_{10}\left\{\frac{1}{N}\cdot\sum_{n=0}^{N-1}\mu^2(n)\right\} AGC\_VALUE, \text{ and}$$

$$EVM_j = -10 \cdot \log_{10}\left\{\frac{1}{N}\cdot\sum_{n=0}^{N-1}\frac{\sigma^2(n)}{\mu^2(n)}\right\},$$

where N is the number of symbols in one measurement block, AGC_VALUE is the gain introduced by the automatic gain controller. $\mu(n)$ is the mean and $\sigma(n)$ is the standard deviation of the signal level for n^{th} symbol after the modulation is removed (for example, by squaring the BCCH signal symbol, or by raising the QPSK signal symbol to the power of four).

The results generated by the above equations are biased over a certain range of the input signal-to-noise ratio. For example, the error vector magnitude (EVM) exhibits a large error relative to the SNR when the true SNR is less than 0 dB. The RSSI is required to be calibrated to remove fixed offsets before it can be used as a reliable SQI estimator. An approach to use RSSI based SQI estimation is to calibrate RSSI using the EVM when the true SNR is high (i.e., when the EVM is an unbiased estimate of SNR).

At low SNR, both EVM and RSSI exhibit significant bias relative to the true SNR. One approach to reduce the bias is to use brute-force method as described here.

$$SQI_j = f_1\{RSSI_j\} \text{ or}$$

$$SQI_j = f_2\{EVM_j\},$$

where f_1 and f_2 are two nonlinear functions of RSSI and EVM, respectively. The nonlinear functions should be designed offline to map the RSSI and EVM estimates to the true SNR over the range of interest.

B.2 Frequency domain method

The goal of the signal quality estimator is to provide an estimate of the Signal-to-Noise ratio (SNR), so that transitions to/from states (e.g., paging and alerting) can be made. The estimate of the SNR is based on calculating the Error Vector Magnitude over the FCCH burst. As EVM estimation implies knowledge of the location of constellation points, which in turn imply knowledge of the channel's phase, these estimates are coherent.

Let the received waveform be $S_a(n)$ and the reference waveform be $S_h(n)$. The received waveform $S_a(n)$ should be corrected as follows to attempt to minimize the differences between it and the reference waveform.

The phase and gain difference between $S_a(n)$ and $S_h(n)$ is removed, as follows:

$$Corr = \frac{\sum_{n=0}^{m} S_a(n).S_h^*(n)}{\sum_{n=0}^{m} S_h^2(n)},$$

$$S_{a1}(n) = \frac{S_a(n)}{Corr}$$

If the FCCH signal is received without noise, $S_{a1}(n)$ is identical to $S_h(n)$. Hence, the EVM can be calculated as follows.

$$EVM = \sqrt{\frac{1}{m}\sum_{n=0}^{m}[S_{a1}(n) - S_h(n)]^2} .$$

This is an estimate of the Noise-to-Signal Ratio. The signal to noise ratio or the SQI is then calculated as:

$$\text{SNR} = -20*\log_{10}(\text{EVM}).$$

Annex C (informative): Position determination at the MES

```
/*

INPUT:

1. FROM THE SPOT BEAM SELECTION ALGORITHM:

→ Store in increasing order the spot beam relative power (dB) :
max_power_level[in] for in=0,1,2,3,4,5,6 where 0 is the strongest and 6
is the weakest

→ Store the spot beam number :  max_spotbeam[in] for in=0,1,2,3,4,5,6.

The spot beam number is a temporary number based on beam position with
respect to the centre beam (beam 0) of the cluster. The frequency and
timing of neighbor BCCHs broadcast in the BCCH_NEIGHBOR_LIST and used
in the spot beam selection algorithm are broadcast following a defined
order based on position. The neighbors are ordered in a clockwise
fashion around the centre beam starting with beam 1 positioned at the
northernmost location.

2. FROM THE PARAMETERS BROADCAST IN THE BCCH SYSTEM INFORMATION

→ Get the beam centre position of the seven spot beams broadcast in SI
in latitude and longitude in degree in the parameter BEAM_CENTER_POS.

The beam centre positions are broadcast by the network in a clockwise
order around the centre beam (beam 0) starting with beam 1 positioned
at the northernmost location.

Store the centre of the cluster in lat_pos_spot[0], long_pos_spot[0].

The six neighbors latitude and longitude are expressed as an offset
from the beam centre cluster.

Add this offset to the beam centre cluster latitude and longitude and
store in lat_pos_spot[I], long_pos_spot[I] for I=1,2,3,4,5,6

Convert these values in meters and store in:

x_pos_beam[in] =
(elevation_sat+radius_earth)*cos(lat_pos_spot[max_spotbeam[in]]*pi/180)
*sin(long_pos_spot[max_spotbeam[in]]*pi/180);

y_pos_beam[in] =
(elevation_sat+radius_earth)*cos(lat_pos_spot[max_spotbeam[in]]*pi/180)
*cos(long_pos_spot[max_spotbeam[in]]*pi/180);

z_pos_beam[in] =
(elevation_sat+radius_earth)*sin(lat_pos_spot[max_spotbeam[in]]*pi/180)
; for in=0,1,2,3,4,5,6

→ Get the satellite position broadcast in SI in latitude and longitude
in degree in the parameter SAT_POS, convert in meters, and store in:

x_pos_sat =
(elevation_sat+radius_earth)*cos(sat_lat*pi/180)*sin(sat_long*pi/180);

y_pos_sat =
(elevation_sat+radius_earth)*cos(sat_lat*pi/180)*cos(sat_long*pi/180);

z_pos_sat = (elevation_sat+radius_earth)*sin(sat_lat*pi/180);
```

```
OUTPUT:

1. Averaged estimated position (avg_lat_new, avg_long_new) required for
GPS fast-acquisition

2. Precorrection factor in milliseconds that may be added to the
RACH_SYMBOL_OFFSET in order to fit the RACH burst in its window

*/

/* Constants */
MAX_SPOTBEAM = 7;
radius_earth = 6378000;
elevation_sat = 35787000;
pi = 3.14159265359;
aperture = 4.5;
tol = 0.00001;

/* Initialize variables */
count_nb_neighbors = 0;
for (I=0; I<MAX_SPOTBEAM; I++)
    {
     store_valid_neighbors[I] = 0;
    }
for(I=0; I<12; I++)
    {
     valid_in1[I] = 0;
     valid_in2[I] = 0;
    }
count_valid_combin = 0;


/* Find satellite beamwidth between beam1 & beam2, beam1 & beam3, beam1 & beam4, …, beam1 & beam7 */
dist_sat_beam0 = sqrt(((x_pos_sat-x_pos_beam[0])*(x_pos_sat-x_pos_beam[0]))+((y_pos_sat-
y_pos_beam[0])*(y_pos_sat-y_pos_beam[0]))+((z_pos_sat-z_pos_beam[0])*(z_pos_sat-z_pos_beam[0])));

for (in=1; in<MAX_SPOTBEAM; in++)
    {
     if ((lat_pos_spot[(MAX_SPOTBEAM-(in+1))]!= lat_pos_spot[MAX_SPOTBEAM-
1])||(long_pos_spot[(MAX_SPOTBEAM-(in+1))]!= long_pos_spot[MAX_SPOTBEAM-1]))
        {
     dist_sat_beamx = sqrt(((x_pos_sat-x_pos_beam[in])*(x_pos_sat-x_pos_beam[in]))+((y_pos_sat-
y_pos_beam[in])*(y_pos_sat-y_pos_beam[in]))+((z_pos_sat-z_pos_beam[in])*(z_pos_sat-z_pos_beam[in])));
     dist_beam0_beamx = sqrt(((x_pos_beam[0]-x_pos_beam[in])*(x_pos_beam[0]-
x_pos_beam[in]))+((y_pos_beam[0]-y_pos_beam[in])*(y_pos_beam[0]-y_pos_beam[in]))+((z_pos_beam[0]-
z_pos_beam[in])*(z_pos_beam[0]-z_pos_beam[in])));
         beamwidth_beam0x = acos((dist_sat_beam0*dist_sat_beam0 + dist_sat_beamx*dist_sat_beamx –
dist_beam0_beamx*dist_beam0_beamx) / (2*dist_sat_beam0*dist_sat_beamx));

     /* Calculate the minimum power level in dB between each neighbor beam centre and the centre of the
cluster, i.e. the selected spot beam */
     if (beamwidth_beam0x == 0.0)
         minimum_power_level[in-1] = 0.0;
     else
         minimum_power_level[in-1] =
(10*log((sin(2*pi*aperture*5*sin(beamwidth_beam0x))/(2*pi*aperture*5*sin(beamwidth_beam0x)))*(sin(2*pi*
aperture*5*sin(beamwidth_beam0x))/(2*pi*aperture*5*sin(beamwidth_beam0x)))))/log(10);
        }
     else
        minimum_power_level[in-1] = -100.0;


/*
Step 1:  Identify the number of neighbors in the current cluster.
Step 2:  Identify the beams that are aligned.
Step 3:  Store the list of valid combination that shall be used for the position determination
algorithm and start position determination
The position determination is performed by comparing the relative power level of three spot beams at a
time. In a cluster of seven spot beams, there is a maximum of 15 combinations of three beams. However,
only 12 out of these 15 combinations in this cluster are useful because the position determination
algorithm performs well only when the three beams are not aligned.
*/

/*
Step 1: Check number of neighbor beams by looking at number of beams with latitude != centre beam
latitude and longitude != centre beam longitude degree. If # of neighbors < 6, edge beam. If # of
neighbors = 6, centre beam of cluster
```

```
*/
for (I=1; I<MAX_SPOTBEAM; I++)
    {
     if ((lat_pos_spot[(MAX_SPOTBEAM-(I+1))]!= lat_pos_spot[MAX_SPOTBEAM-
1])||(long_pos_spot[(MAX_SPOTBEAM-(I+1))]!= long_pos_spot[MAX_SPOTBEAM-1]))
        {
         store_valid_neighbors[count_nb_neighbors] = I;
         count_nb_neighbors++;
        }
        }

/*
Step 2: Find all the good combinations that can be used out of the 15 possible combinations
Beams are broadcast in a given way, i.e., ordered in a clockwise fashion around the centre beam (beam
0) starting with beam 1 positioned at the northernmost location. The three combinations to avoid shall
always be the pairs of beams 1-4, 2-5, and 3-6, based on that order.
*/
for (I=1; I<(count_nb_neighbors+1); I++)
    {
     for (j=I+1; j<(count_nb_neighbors+1); j++)
        {
    if ((((max_spotbeam[I]!=2)&&(max_spotbeam[I]!=5))||((max_spotbeam[j]!=2)&&(max_spotbeam[j]!=5))) &&
\
(((max_spotbeam[I]!=3)&&(max_spotbeam[I]!=6))||((max_spotbeam[j]!=3)&&
(max_spotbeam[j]!=6))) && \

    (((max_spotbeam[I]!=1)&&(max_spotbeam[I]!=4))||((max_spotbeam[j]!=1)&&(max_spotbeam[j]!=4))))
            {
             valid_in1[count_valid_combin]=I;
             valid_in2[count_valid_combin]=j;
            }
        }
    }

/*Step 3: Start estimating user's position for each combination */

/* Initialization */

for (in=0; in<MAX_SPOTBEAM; in++)
    {
     /* Calculate different vectors required in future formulas */
     diff_xc_sat[in] = x_pos_beam[in] – x_pos_sat;
     diff_yc_sat[in] = y_pos_beam[in] – y_pos_sat;
     diff_zc_sat[in] = z_pos_beam[in] – z_pos_sat;
     H[in] =
sqrt((diff_xc_sat[in]*diff_xc_sat[in])+(diff_yc_sat[in]*diff_yc_sat[in])+(diff_zc_sat[in]*diff_zc_sat[i
n]));
    }

 for (combin_num=0; combin_num<count_valid_combin; combin_num++)
    {
     in_v[0] = valid_in1[combin_num];
     in_v[1] = valid_in2[combin_num];
     for (I=0; I<2; I++)
        {
         if (max_power_level[in_v[I]] >= minimum_power_level[(in_v[I]-1)])
            {
             latu[I] = ((lat_pos_spot[(MAX_SPOTBEAM-(in_v[I]+1))] – lat_pos_spot[MAX_SPOTBEAM-1])/2) +
lat_pos_spot[MAX_SPOTBEAM-1];
             longu[I] = ((long_pos_spot[(MAX_SPOTBEAM-(in_v[I]+1))] – long_pos_spot[MAX_SPOTBEAM-1])/2)
+ long_pos_spot[MAX_SPOTBEAM-1];
            }
         else
            {
             latu[I] =  lat_pos_spot[MAX_SPOTBEAM-1] – ((lat_pos_spot[(MAX_SPOTBEAM-(in_v[I]+1))] –
lat_pos_spot[MAX_SPOTBEAM-1])/2);
             longu[I] =  long_pos_spot[MAX_SPOTBEAM-1] – ((long_pos_spot[(MAX_SPOTBEAM-(in_v[I]+1))] –
long_pos_spot[MAX_SPOTBEAM-1])/2);
            }

         increment1 = 0.0;
         increment = 1.0;
         diff_power = 100.0;

/*
1. Find 2 points with calculated relative power (dB) equal to measured relative power (dB). Those
points are called latu[I], longu[I]
*/
```

```
        while (max_power_level[in_v[I]] != diff_power)
            {
             latu[I] = latu[I] + (lat_pos_spot[(MAX_SPOTBEAM-(in_v[I]+1))] – lat_pos_spot[MAX_SPOTBEAM-1])*increment1;
             longu[I] = longu[I] + (long_pos_spot[(MAX_SPOTBEAM-(in_v[I]+1))] – long_pos_spot[MAX_SPOTBEAM-1])*increment1;
             tempx_latlongu = radius_earth*cos(latu[I]*pi/180)*sin(longu[I]*pi/180);
             tempy_latlongu = radius_earth*cos(latu[I]*pi/180)*cos(longu[I]*pi/180);
             tempz_latlongu = radius_earth*sin(latu[I]*pi/180);
             diff_x0c_user = x_pos_beam[0] – tempx_latlongu;
             diff_y0c_user = y_pos_beam[0] – tempy_latlongu;
             diff_z0c_user = z_pos_beam[0] – tempz_latlongu;
             diff_x1c_user = x_pos_beam[in_v[I]] – tempx_latlongu;
             diff_y1c_user = y_pos_beam[in_v[I]] – tempy_latlongu;
             diff_z1c_user = z_pos_beam[in_v[I]] – tempz_latlongu;
             diff_xsat_user = x_pos_sat – tempx_latlongu;
             diff_ysat_user = y_pos_sat – tempy_latlongu;
             diff_zsat_user = z_pos_sat – tempz_latlongu;
             H_fixed = sqrt((diff_xsat_user*diff_xsat_user)+(diff_ysat_user*diff_ysat_user)+(diff_zsat_user*diff_zsat_user));
             delta0 = sqrt((diff_x0c_user*diff_x0c_user)+(diff_y0c_user*diff_y0c_user)+(diff_z0c_user*diff_z0c_user));
             delta1 = sqrt((diff_x1c_user*diff_x1c_user)+(diff_y1c_user*diff_y1c_user)+(diff_z1c_user*diff_z1c_user));
             delta_phi_acos0 = ((H[0]*H[0])+(H_fixed*H_fixed)-(delta0*delta0))/(2*H[0]*H_fixed);
             delta_phi_acos1 = ((H[in_v[I]]*H[in_v[I]])+(H_fixed*H_fixed)-(delta1*delta1))/(2*H[in_v[I]]*H_fixed);

             delta_phi0 = acos(delta_phi_acos0);
             delta_phi1 = acos(delta_phi_acos1);
             if (delta_phi0 == 0.0)
                deltaD0 = 0.0;
             else
                deltaD0 = (10*log((sin((2*pi*aperture*5.0)*sin(delta_phi0))*sin((2*pi*aperture*5.0)*sin(delta_phi0)))/((2*pi*aperture*5.0)*sin(delta_phi0)*(2*pi*aperture*5.0)*sin(delta_phi0))))/log(10);
             if (delta_phi1 == 0.0)
                delta1 = 0.0;
             else
                 deltaD1 = (10*log((sin((2*pi*aperture*5.0)*sin(delta_phi1))*sin((2*pi*aperture*5.0)*sin(delta_phi1)))/((2*pi*aperture*5.0)*sin(delta_phi1)*(2*pi*aperture*5.0)*sin(delta_phi1))))/log(10);
             old_diff_power = diff_power;
             diff_power = deltaD1 – deltaD0;

             if (diff_power > max_power_level[in_v[I]])
                increment1 = -1/(4*increment);
             else
                increment1 = 1/(4*increment);
             increment = 2*increment;
             if ((max_power_level[in_v[I]] > (diff_power – tol))&&(max_power_level[in_v[I]] < (diff_power + tol)))
                diff_power = max_power_level[in_v[I]];
             if ((diff_power > old_diff_power – 0.0000001)&&(diff_power < old_diff_power + 0.0000001))
                 diff_power = max_power_level[in_v[I]];
            }
        }

/*
Draw two lines :
1. at point (latu[0], longu[0]) perpendicular to line joining centre of beam1 and beam2
2. at point (latu[1], longu[1]) perpendicular to line joining centre of beam1 and beam3
The intersection of these two lines is the user estimated position (y_new_prime3, z_new_prime3)
*/
     lat0 = lat_pos_spot[MAX_SPOTBEAM-1];
     long0 = long_pos_spot[MAX_SPOTBEAM-1];
     lat1 = lat_pos_spot[(MAX_SPOTBEAM-(in_v[0]+1))];
     long1 = long_pos_spot[(MAX_SPOTBEAM-(in_v[0]+1))];
     lat2 = lat_pos_spot[(MAX_SPOTBEAM-(in_v[1]+1))];
     long2 = long_pos_spot[(MAX_SPOTBEAM-(in_v[1]+1))];
     if (lat1 == lat0)
        {
         z_new_prime3 = longu[0];
         y_new_prime3 = latu[1] – ((longu[0]-longu[1])*((long2-long0)/(lat2-lat0)));
        }
     else if (lat2 == lat0)
        {
         z_new_prime3 = longu[1];
```

```
         y_new_prime3 = latu[0] – ((longu[1]-longu[0])*((long1-long0)/(lat1-lat0)));
        }
     else if (long1 == long0)
        {
         y_new_prime3 = latu[0];
         z_new_prime3 = longu[1] + (((lat2-lat0)/(long2-long0))*(latu[1]-latu[0]));
        }
     else if (long2 == long0)
        {
         y_new_prime3 = latu[1];
         z_new_prime3 = longu[0] + (((lat1-lat0)/(long1-long0))*(latu[0]-latu[1]));
        }
     else
        {
         y_new_prime3 = (((long1-long0)*(lat2-lat0)*latu[1]) + (longu[1]*(long1-long0)*(long2-long0)) –
((lat1-lat0)*(long2-long0)*latu[0]) – (longu[0]*(long1-long0)*(long2-long0)))/(((long1-long0)*(lat2-
lat0)) – ((lat1-lat0)*(long2-long0)));
         z_new_prime3 = (((lat1-lat0)/(long1-long0))*(latu[0] – y_new_prime3)) + longu[0];
        }

     x_new_prime2 = radius_earth*cos(y_new_prime3*pi/180)*sin(z_new_prime3*pi/180);
     y_new_prime2 = radius_earth*cos(y_new_prime3*pi/180)*cos(z_new_prime3*pi/180);
     z_new_prime2 = radius_earth*sin(y_new_prime3*pi/180);

     x_new[combin_num] = x_new_prime2;
     y_new[combin_num] = y_new_prime2;
     z_new[combin_num] = z_new_prime2;
    }

/*
Take the average position estimate from results obtained from all the valid combinations of three spot
beams
*/

/* Initialization */
 avg_x_new = 0.0;
 avg_y_new = 0.0;
 avg_z_new = 0.0;
 for (I=0; I<count_valid_combin; I++)
    {
     avg_x_new += x_new[I];
     avg_y_new += y_new[I];
     avg_z_new += z_new[I];
    }
 avg_x_new = avg_x_new/count_valid_combin;
 avg_y_new = avg_y_new/count_valid_combin;
 avg_z_new = avg_z_new/count_valid_combin;

/* INPUT FOR GPS FAST ACQUISITION: avg_lat_new, avg_long_new */
 avg_lat_new = (atan(avg_z_new/(sqrt((avg_x_new*avg_x_new)+(avg_y_new*avg_y_new)))))*180/pi;
 if (((avg_x_new>0)&&(avg_y_new>0))||((avg_x_new<0)&&(avg_y_new>0)))
    avg_long_new = (atan(avg_x_new/avg_y_new))*180/pi;
 else
    avg_long_new = (atan(avg_x_new/avg_y_new) + pi)*180/pi;

/*
Calculate the precorrection factor that needs to be applied to RACH_SYMBOL_OFFSET parameter in order to
fit the RACH burst in its window
*/
 centre_delay_fromsat = (sqrt(((x_pos_sat-x_pos_beam[0])*(x_pos_sat-x_pos_beam[0]))+((y_pos_sat-
y_pos_beam[0])*(y_pos_sat-y_pos_beam[0]))+((z_pos_sat-z_pos_beam[0])*(z_pos_sat-
z_pos_beam[0]))))/300000000.0;
 estimated_delay_fromsat = (sqrt(((x_pos_sat-avg_x_new)*(x_pos_sat-avg_x_new))+((y_pos_sat-
avg_y_new)*(y_pos_sat-avg_y_new))+((z_pos_sat-avg_z_new)*(z_pos_sat-avg_z_new))))/300000000.0;
 correction_factor = (estimated_delay_fromsat-centre_delay_fromsat)*1000.0; /* correction_factor in
msec */
```

History

Document history		
V1.1.1	March 2001	Publication