ETSI TS 101 376-5-7 V3.4.1 (2015-10)

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

Reference

RTS/SES-00374-5-7

Keywords

3G, GMPRS, GMR, GPRS, GSM, GSO, interface, MES, mobile, MSS, radio, satellite, S-PCN, synchronization, terminal, user

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Contents

Intellectual Property Rights ... 6
Foreword ... 6
Modal verbs terminology ... 7
Introduction ... 7
1 Scope ... 9
2 References ... 9
2.1 Normative references ... 9
2.2 Informative references ... 10
3 Definitions and abbreviations ... 10
3.1 Definitions ... 10
3.2 Abbreviations ... 11
4 General description of synchronization system ... 11
4.0 Overview ... 11
4.1 System timing structure ... 11
4.2 Timebase counter ... 12
4.3 General requirement ... 12
4.3.1 Timing and frequency reference point ... 12
4.3.2 MES requirement ... 12
4.3.3 Network requirement ... 13
4.3.4 Measurement conditions ... 13
5 Timing synchronization, TtG/GtT Session ... 13
5.0 Overview ... 13
5.1 General description ... 13
5.2 Timing of forward link common channels ... 14
5.2.0 General ... 14
5.2.1 FCCH/BCCH timing ... 14
5.2.2 CCCH timing ... 14
5.3 Idle mode timing synchronization ... 15
5.3.1 Initial timing acquisition ... 15
5.3.2 Paging mode ... 15
5.3.3 Alerting mode ... 15
5.4 Synchronization at initial access ... 15
5.4.1 Synchronization process ... 15
5.4.2 RACH timing pre-correction ... 16
5.4.3 Description of parameters ... 18
5.4.4 Timing accuracy ... 19
5.5 Dedicated mode synchronization (A/Gb mode only) ... 19
5.5.0 General ... 19
5.5.1 In-call timing relationship (A/Gb mode only) ... 19
5.5.2 In-call synchronization scenario (A/Gb mode only) ... 20
5.5.3 Transmission timing drift rate (A/Gb mode only) ... 21
5.5.4 RX/TX guard time violation (A/Gb mode only) ... 22
5.6 Packet transfer mode synchronization ... 22
5.6.0 General ... 22
5.6.1 Packet transfer mode timing relationship ... 22
5.6.2 Time synchronization for Packet switched channels ... 24
5.6.3 Transmission timing drift rate ... 27
5.6.4 RX/TX guard time violation ... 27
5.6.5 Packet transfer mode timing relationship for handover to dedicated packet channel (Iu mode only) ... 27
5.6.6 Packet transfer mode timing for handover to shared packet channel (Iu mode only) ... 28
6 Frequency synchronization, TtG/GtT call ... 29
6.0 Overview ... 29
6.1 General description ... 29

6.2 Frequency of common channels ... 29
6.3 Idle mode frequency synchronization ... 29
6.3.1 Initial frequency acquisition ... 29
6.3.2 Paging mode ... 29
6.3.3 Alerting mode ... 30
6.4 Synchronization at initial access ... 30
6.4.0 General ... 30
6.4.1 Frequency compensation strategy ... 30
6.4.2 Parameter description ... 31
6.5 Dedicated mode synchronization (A/Gb mode only) ... 32
6.6 Frequency synchronization for the packet switched channels ... 33

7 Frame and message synchronization, TtG/GtT call ... 35
7.1 Frame synchronization ... 35
7.1.1 Frame number definition ... 35
7.1.2 Frame synchronization scenario ... 36
7.2 Message synchronization ... 36
7.2.1 Power control message synchronization ... 36
7.2.1.0 General ... 36
7.2.1.1 Synchronization in master-to-slave direction (A/Gb mode only) ... 37
7.2.1.2 Synchronization in slave-to-master direction (A/Gb mode only) ... 37
7.2.1.3 DCH power control message synchronization in forward direction ... 38
7.2.1.4 DCH power control message synchronization in return direction ... 38
7.2.2 SACCH message synchronization, TCH6/TCH9 call (A/Gb mode only) ... 38

8 Synchronization for TtT call (A/Gb mode only) ... 38
8.0 General ... 38
8.1 Timing synchronization ... 40
8.1.1 General description ... 40
8.1.2 Initial access ... 40
8.1.2.0 General ... 40
8.1.2.1 Synchronization procedure ... 40
8.1.2.2 Basic requirement ... 41
8.1.3 TtG channel synchronization ... 41
8.1.3.0 General ... 41
8.1.3.1 Basic requirement ... 42
8.1.4 Transition from TtG-to-TtT channel ... 42
8.1.4.0 General ... 42
8.1.4.1 Synchronization procedure ... 42
8.1.4.2 Basic requirement ... 42
8.1.5 TtT channel synchronization ... 42
8.1.5.0 General ... 42
8.1.5.1 Synchronization procedure ... 43
8.1.5.2 Basic requirement ... 43
8.1.6 Effect of the half symbol offset (TtT call) ... 43
8.2 Frequency synchronization ... 44
8.2.1 General description ... 44
8.2.2 Synchronization at initial access ... 45
8.2.2.0 General ... 45
8.2.2.1 Synchronization procedure ... 45
8.2.2.2 Basic requirement ... 46
8.2.3 TtG channel synchronization ... 46
8.2.3.0 General ... 46
8.2.3.1 Basic requirement ... 46
8.2.4 Transition from TtG-to-TtT channel ... 46
8.2.4.0 General ... 46
8.2.4.1 Synchronization procedure ... 46
8.2.4.2 Basic requirement ... 47
8.2.5 TtT channel synchronization ... 47
8.2.5.0 General ... 47
8.2.5.1 Synchronization procedure ... 47
8.2.5.2 Basic requirement ... 47

8.3 Frame synchronization 47

9 Aeronautical terminal synchronization scheme.....48
9.1 MES special features 48
9.1.1 Speed 48
9.1.2 Worst-case delay and Doppler features 48
9.1.3 Frequency offset 49
9.2 Frequency synchronization.....49
9.2.1 Frequency synchronization general description.....49
9.2.2 Idle mode frequency synchronization.....49
9.2.2.1 Initial frequency acquisition.....49
9.2.2.2 Paging mode.....50
9.2.2.3 Alerting mode 50
9.2.3 Synchronization at initial access.....50
9.2.3.1 Frequency compensation strategy 50
9.2.3.2 Parameter description.....50
9.2.4 Dedicated mode synchronization.....51
9.2.4.0 General.....51
9.2.4.1 Frequency compensation strategy 51
9.2.4.2 Parameter description.....51
9.3 Timing synchronization.....52
9.3.1 Timing synchronization general description.....52
9.3.2 Idle mode timing synchronization 52
9.3.2.1 Initial timing acquisition 52
9.3.2.2 Paging mode.....52
9.3.2.3 Alerting mode 52
9.3.3 Synchronization at initial access.....52
9.3.4 Dedicated mode synchronization.....53
9.3.4.1 Doppler-based timing adjustment 53
9.3.4.2 Standard timing synchronization procedure.....53
9.3.4.3 Parameter description.....53

Annex A (informative): Worst-case delay and Doppler features 54

A.1 L-band 54

A.2 S-band.....54

Annex B (informative): Range of timing correction factor 56

Annex C (informative): Differential Doppler frequency.....57

Annex D (informative): SACCH message synchronization, TtG/GtT call (A/Gb mode only) 58

D.0 General 58

D.1 SACCH message synchronization scenario 58

D.2 SACCH message-round trip delay 58

Annex E (normative): Timer T3202 for packet mode of operation.....61

Annex F (normative): PTCCH/U and PTCCH/D scheduling (A/Gb mode only) 62

Annex G (informative): Bibliography.....63

History 64

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://ipr.etsi.org).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

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 will then be republished by ETSI with an identifying change of release date and an increase in version number as follows:

Version 3.m.n

where:

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

Part 1: "General specifications";

Part 2: "Service specifications";

Part 3: "Network specifications";

Part 4: "Radio interface protocol specifications";

Part 5: "Radio interface physical layer specifications":

Sub-part 1: "Physical Layer on the Radio Path: General Description; GMR-1 3G 45.001";

Sub-part 2: "Multiplexing and Multiple Access; Stage 2 Service Description; GMR-1 3G 45.002";

Sub-part 3: "Channel Coding; GMR-1 3G 45.003";

Sub-part 4: "Modulation; GMR-1 3G 45.004";

Sub-part 5: "Radio Transmission and Reception; GMR-1 3G 45.005";

Sub-part 6: "Radio Subsystem Link Control; GMR-1 3G 45.008";

Sub-part 7: "Radio Subsystem Synchronization; GMR-1 3G 45.010";

Part 6: "Speech coding specifications";

Part 7: "Terminal adaptor specifications".

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Introduction

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

The present document is part of the GMR Release 3 specifications. Release 3 specifications are identified in the title and can also be identified by the version number:

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

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

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

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

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

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

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

where:

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

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

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

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

- If a GMR specification does not exist, the corresponding GSM or 3GPP specification may or may not apply. The applicability of the GSM and 3GPP specifications is defined in ETSI TS 101 376-1-2 [8].

1 Scope

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

2 References

2.1 Normative 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.

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

In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document in Release 7 or to the latest version of that document in the latest release less than 7.

In the case of a reference to a GMR-1 3G document, a non-specific reference implicitly refers to the latest version of that document in the same Release as the present document.

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

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

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

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

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

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

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

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

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

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

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

2.2 Informative 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.

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

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

Not applicable.

3 Definitions and abbreviations

3.1 Definitions

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

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

frequency offset: frequency correction sent over AGCH channel

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

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

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

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

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

RACH_SYMBOL_OFFSET: RACH timing offset in symbols

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

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

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

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

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

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

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

timing offset: timing correction sent over AGCH channel

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

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

3.2 Abbreviations

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

4 General description of synchronization system

4.0 Overview

The GEO-Mobile Radio 1 (GMR-1) satellite system is a multi-spot beam, multicarrier, synchronous system where the timing and frequency on the satellite serve as the reference to synchronize the TDMA transmissions for the MESs, the network GSs and other network elements.

For A/Gb mode only, the satellite may include a switch designed to provide single-hop, TtT connectivity. Such a TDMA satellite switch permits the selection of connection patterns between any slot in the TDMA frame of a return carrier in one spot beam to any other slot in the TDMA frame of a forward carrier in the same spot beam or any other spot beam.

Synchronization in the GMR-1 system is composed of four major tasks:

- timing synchronization;
- frequency synchronization;
- frame synchronization;
- message synchronization.

A master oscillator onboard the GMR-1 spacecraft is the primary reference for all synchronization processes. The fundamental goal of synchronization is to have gateways and mobile earth stations alike operate such that all bursts arrive at the satellite synchronized in timing and frequency.

The above description applies to S and L band mobile link operations.

4.1 System timing structure

The GMR-1 satellite system is a TDMA system. Timing configuration in the system is composed of hyperframe, superframe, multiframe, frame, timeslot, symbol and bit. A hyperframe is the longest repetition time period and 1/40 symbol duration is the smallest measurable and adjustable unit in the system.

A hyperframe has a duration of 3 h 28 min 53 s 760 ms, it contains 4 896 superframes, 19 584 multiframes or 313 344 TDMA frames. One superframe equals to 2,56 s, including four multiframes or 64 TDMA frames. One multiframe includes 16 TDMA frames and each TDMA frame has 24 timeslots. The TDMA frame duration is 40 ms, one timeslot duration is approximately 1,67 ms. In each timeslot, there are 39 symbols, each symbol corresponds to 2 bits. The complete timeframe structure can be seen from the graph shown in ETSI TS 101 376-5-2 [3].

A superframe always starts from the frame that meets FN mod 64 = 0. Within the superframe, the first frame is also the beginning of the first multiframe with multiframe number 00.

4.2 Timebase counter

The timing state of the signals transmitted by the MES and satellite is defined by the following counters:

- bit counter BN (0 to 77);
- timeslot counter TN (0 to 23);
- TDMA frame counter FN (0 to 313 343).

The relationship between these counters is as follows:

- BN increments every 5 000/234 µs;
- TN increments whenever BN changes from count 77 to 0;
- FN increments whenever TN changes from count 23 to 0.

The MES can use the timing of the receipt of the BCCH burst to set up its timebase counters as follows:

- BN is set by the timing of the FCCH timing acquisition;
- TN is set by the timeslot number that is contained in the information fields of the BCCH burst;
- FN is set by the frame number derived from the information fields of the BCCH bursts.

The frame number field definition is given in ETSI TS 101 376-4-8 [2].

4.3 General requirement

4.3.1 Timing and frequency reference point

The satellite is selected to be the reference point for both timing and frequency. For downlink signals, the reference point is the output of the satellite forward link antenna. For uplink signals, the reference point is the input of the satellite return link antenna.

4.3.2 MES requirement

The following requirements shall apply to the MES side:

- Both transmitter and receiver timing shall be derived from the same timebase.
- Both transmitter and receiver frequency shall be derived from the same frequency source.
- The MES shall use the same source for both RF frequency generation and clicking the timebase.
- All return link signals (control channel and traffic channel) transmitted from the MESs shall achieve frame/timeslot alignment on the satellite timing reference point, i.e. input of satellite antenna.
- In various operation modes, synchronization shall be maintained under the worst case timing and frequency drift rate due to MES-satellite relative motion and MES master oscillator stability. The MES oscillator long term stability shall be better than 5 ppm. The MES oscillator short-term stability shall maintain all timing offset, frequency offset and symbol rate requirement specified in ETSI TS 101 376-5-5 [4] in the absence of received signal up to 5 s. The maximum timing drift rate due to MES-satellite relative motion is 0,32 µs/s. The maximum frequency drift rate due to MES acceleration is 24,6 Hz/s.
- MES receiver's time and frequency search ranges (apertures) shall be large enough to accommodate the variations (specified in clause 4.3.3) in the network transmit time and frequency in addition to the satellite-MES relative motion induced time and frequency shifts (see annex A for an informative description), MES oscillator drifts, etc. The MES receiver, operating with such values of time and frequency apertures, shall achieve the performance requirements (i.e. BER, FER, time and frequency estimation accuracies, etc.) specified in ETSI TS 101 376-5-5 [4].

4.3.3 Network requirement

The following requirements shall apply to the network side:

- All forward link signals (control channel and traffic channel) transmitted from the network shall achieve frame/timeslot alignment on the satellite timing reference point, i.e. output of satellite antenna.
- Both forward and return link signals shall be adjusted by the network to maintain a fixed frame and slot relative timing on the satellite timing reference point. This adjustment shall be capable of handling the worst case timing and frequency drift caused by satellite motion and user motion.
- Forward and return link timeslots shall be assigned by the network to meet the follows: A 1,0 ms guard time shall be left for the MES to switch between transmit and receive frequencies. A 1,0 ms guard time shall be left for the MES to switch between two different receive frequencies.
- At the initial call setup, the network shall be able to estimate the RACH signal arrival to the accuracy better than 12,6 Hz 1-sigma in frequency, 3,6 μs 1-sigma in timing, under the condition of AWGN channel.
- The network shall ensure that the maximum variation between the transmit time of a CCCH burst and the transmit time of a PDCH burst does not exceed 1,1 μs. Similarly, the maximum burst-to-burst variation in the PDCH transmit time shall not exceed 1,1 μs. Burst-to-burst variations in the network transmit frequency shall not exceed 10 Hz.

4.3.4 Measurement conditions

- In the following, all timing and frequency related parameters are defined under the condition of AWGN channel, with $E_b / N_0 = -0{,}5\ dB$.
- In the following, unless specifically specified, all timing and frequency related parameters are defined as 1-sigma value.

5 Timing synchronization, TtG/GtT Session

5.0 Overview

The general requirement for MES timing synchronization is that the MES shall transmit signals that are time aligned and frame number aligned with the system timing on the satellite reference point.

The MES timing alignment is achieved by correcting transmission timing with factors provided by a Gateway Station (GS). RACH timing is setup by factors provided over the BCCH. The GS transmits a frame number on the BCCH which is received and used by the MES to establish its local frame numbering process.

For the case in which the MES operates in A/Gb dedicated mode, TCH or SDCCH timing is corrected with corrective factors given over the AGCH. During a call, timing correction is provided by FACCH (TCH3) or SACCH (TCH6/TCH9).

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

5.1 General description

The whole system is synchronized on the satellite. The network adjusts FCCH/FCCH3 and BCCH transmission so that each of these channels leaves from the satellite antenna at the predefined system timing. An MES derives its local timing reference from the signals received from the satellite. By listening to the FCCH/FCCH3, both timing and frequency synchronization can be achieved for CCCH channels.

From a cold start, MESs initially search for and acquire the FCCH/FCCH3 sent in each spot beam. The MES's frame timing is then synchronized to system timing.

In idle mode, after initial timing acquisition, the MES needs to track system timing continuously in order to compensate the timing drift caused by its local oscillator frequency uncertainty and the relative motion between the satellite and the user.

At initial access, an MES accesses the network using a RACH/RACH3 offset pre-calculated for the spot beam centre. This RACH offset is distributed from the network in each spot beam and it is available at the MES soon after it decodes the BCCH. The round trip delay variation caused by the difference of MES position relative to the beam centre shall be detected from the network, and this value shall be passed to the MES as a Timing Correction. After the RACH process, the MES shall be able to transmit such that timing of burst arrival on the satellite is nominal.

At the beginning of a packet transfer mode session, to achieve frame/timeslot synchronization on the satellite, a transmission frame offset relative to the start of downlink reference frame is provided from the network. During the packet transfer mode, both MES transmitter and receiver adjust their burst timing to maintain the frame/timeslot synchronization. For the MES transmitter, a closed loop synchronization scheme is adopted. Any transmission timing drift at the MES shall be detected from the network by comparing the actual burst arrival with the expected arrival, and a timing correction is passed to the MES if the difference exceeds a threshold defined by the network.

If packet transfer mode is initiated via the RACH/RACH3 then the procedure is identical to that described for circuit switched service in clause 5.3.1. Packet switched time and frequency synchronization for the PDCH/PDCH3 and the PRACH/PRACH3 is described in clause 5.6.

Time and frequency advisements are sent by the GS to the MES in Packet Link Control or Packet Uplink Ack/Nack Type 2 message specified in ETSI TS 101 376-4-12 [7]. These advisements are provided periodically, and additionally, as and when needed (e.g. when the measured time and frequency offsets at the GS exceed their respective configurable thresholds).

To reduce the number of timing corrections due to satellite motion, Doppler frequency corrections received from the GS on the AGCH and subsequently in the Packet Link Control or Packet Uplink Ack/Nack Type 2 messages are used by the MES to determine the timing drift rate. During the packet switched connected mode, this timing drift rate is used to correct transmission timing.

The following symbolic definitions apply to the rest of the clauses. T_F : frame duration, T_S : timeslot duration, T_{SB} : symbol duration, T_0 : propagation delay from the satellite to the beam centre, T_U : propagation delay from the satellite to the MES.

5.2 Timing of forward link common channels

5.2.0 General

The timing of forward link common channels is defined in ETSI TS 101 376-5-2 [3]. An outline is given below for convenience.

When the FCCH is used, the BCCH/CCCH bursts occupy six consecutive timeslots. In each spot beam, a set of common channels are defined: FCCH, BCCH, PCH, BACH, GBCH and AGCH. These channels follow a fixed repetition pattern with repetition duration equals to one superframe. Position of BCCH and FCCH between neighbouring beams shall be offset in frames as well as in timeslots to facilitate MES fast timing/frequency acquisition and satellite power spread in time.

When the FCCH3 is used, the BCCH/CCCH bursts occupy twelve consecutive timeslots. In each spot beam, a set of common channels are defined: FCCH3, BCCH, PCH, BACH3, GBCH3 and AGCH. These channels follow a fixed repetition pattern with repetition duration equal to one multiframe. The position of the BCCH and FCCH3 between neighbouring beams shall be offset in frames as well as in timeslots to facilitate MES fast timing/frequency acquisition and satellite power spread in time.

5.2.1 FCCH/BCCH timing

For FCCH/BCCH and FCCH3/BCCH timing, refer to ETSI TS 101 376-5-2 [3].

5.2.2 CCCH timing

CCCH timing is described in ETSI TS 101 376-5-2 [3].

5.3 Idle mode timing synchronization

5.3.1 Initial timing acquisition

The MES shall keep its internal timebase in line with the system timing derived from the BCCH control carrier. For initial timing acquisition, the MES looks for one control carrier with the highest BCCH signal level. Though FCCH/FCCH3 acquisition procedure, the MES is then locked to this carrier in both frequency and timing.

The initial timing acquisition procedure has been given in ETSI TS 101 376-5-6 [5].

5.3.2 Paging mode

In entering paging mode, the timing synchronization in the MES has already been achieved from the FCCH/FCCH3 channel detection. The MES shall track the system timing by listening to either PCH or BCCH channel periodically.

In case of losing synchronization, the MES shall make use of the stored information (frequency, timing) in order to re-establish synchronization as quickly as possible. This process is described in ETSI TS 101 376-5-6 [5].

In paging mode, the MES receiver timing relative to the received signal shall be accurate enough so that demodulation performances specified by ETSI TS 101 376-5-5 [4] can be achieved. The MES tracking loop shall be able to handle the worst case timing drift rate due to MES-satellite relative motion and MES oscillator stability, their maximum values are specified in clause 4.3.2.

5.3.3 Alerting mode

When the MES can no longer demodulate BCCH or PCH information from its serving beam or from any one of the neighbouring beams, the MES shall enter alerting mode. To achieve alerting mode synchronization, the MES shall use the timing information derived from the FCCH/FCCH3 channel to estimate the timing of the BACH/BACH3 channel.

In alerting mode, the MES shall track the system timing by listening to the FCCH/FCCH3 channel periodically. The derived system timing shall be used to update its internal timebase.

Table 5.1: Void

Refer to ETSI TS 101 376-5-2 [3] for a description of the BACH and BACH3 channels and alerting groups.

5.4 Synchronization at initial access

5.4.1 Synchronization process

The synchronization process at initial access is performed according to several different steps: RACH/RACH3 burst transmission, network measurement and return link timing correction. The timing relationship is shown in figure 5.1. These procedures are outlined below.

- The common signalling channel leaves the satellite antenna at the system timing. This signal arrives at the spot beam centre after a propagation delay T_0, and arrives at the MES after T_U.
- The MES offsets its RACH/RACH3 transmission relative to the start of the received control channel reference frame by RACH_SYMBOL_OFFSET. RACH_SYMBOL_OFFSET is calculated at the MES based on parameters received from the BCCH channel.
- Because of the difference between the MES position and the spot beam centre, the RACH/RACH3 signal arrives at the satellite antenna with a timing error, $2[T_U - T_0]$ the round-trip differential delay from the user to the beam centre.
- The GS measures the difference between the actual RACH/RACH3 burst arrival and the expected arrival if the MES is located at the beam centre, $2[T_U - T_0]$. This difference is then passed to the MES in the Timing Offset of the "IMMEDIATE ASSIGNMENT" signalling message via AGCH channel.
- The MES offsets its PDCH/PDCH3 transmission by $2[T_U - T_0]$. Mobile uplink timing synchronization is achieved at this point.

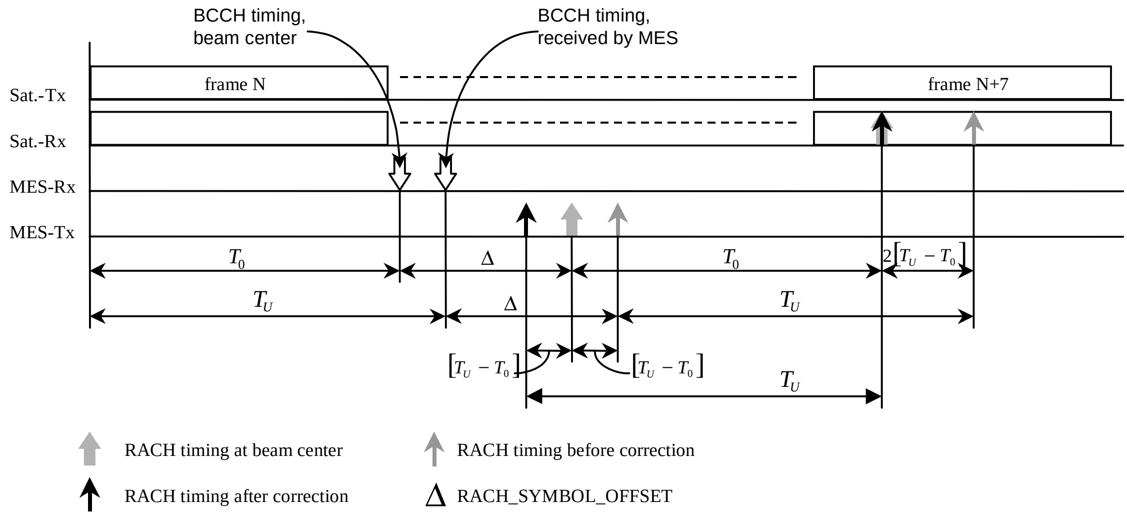

Figure 5.1: Initial timing synchronization process

The RACH/RACH3 burst has a length of 9 TS. To fit this 9 TS burst into a 12, 18 or 24 TS RACH window, ±1,5 TS, ±4,5 TS or ±7,5 TS is left to accommodate user position variation within a spotbeam.

After receiving the RACH/RACH3 signal, the GS shall measure the difference between the actual burst arrival and the expected arrival. This difference nominally (i.e. when the measurement error is zero) equals $dT_2 = 2 \times (T_U - T_0)$. The value of dT_2 shall be passed to the MES via AGCH. The GS shall also calculate MES-satellite propagation delay T_U according to the following equation:

$$T_u = T_0 + \frac{dT_2}{2}$$

where T_0 is the beam centre propagation delay.

The MES shall offset its PDCH/PDCH3 transmission relative to its RACH/RACH3 transmission timing by Timing Offset dT_2 received from AGCH.

5.4.2 RACH timing pre-correction

The RACH burst has a length of 9 TS. To fit this 9 TS burst into a 12, 18 or 24 TS RACH window, ±1,5 TS, ±4,5 TS or ±7,5 TS is left to accommodate user position variation within a spotbeam. For most of the spotbeams, propagation delay variation is far beyond this range, therefore the MES shall pre-compensate part of the delay variation to fit RACH burst into the RACH window. The MES shall be able to estimate its differential delay relative to spotbeam centre with reasonable accuracy and compensate this differential delay in its RACH transmission. With this compensation, the RACH window shall be able to accommodate the whole range of delay variation. For more details on the differential delay measurement, see ETSI TS 101 376-5-6 [5].

A parameter Precorrection Indication shall be included in the RACH transmission burst. This is half of the actual timing value the MES compensates in its RACH transmission. The goal is to inform the GS about its pre-compensation so that the measurement of absolute propagation delay is made possible at the GS.

The parameter Precorrection Indication has 3 bits. Its coding is shown in table 5.2.

Table 5.2: Coding of the parameter Precorrection Indication

Code	Compensation	Code	Compensation
000	Reserved (see ETSI TS 101 376-4-8 [2])	100	+141 symbols
001	-47 symbols	101	+94 symbols
010	-94 symbols	110	+47 symbols
011	-141 symbols	111	0 symbols

The value of this parameter shall be derived at the MES based on one way differential delay measurement relative to spotbeam centre. The differential delay measurement is first converted into the number of symbols, then the closest value of Precorrection Indication is selected from all seven possible correction levels shown in table 5.2.

If dt_0 is the one-way propagation differential delay relative to beam centre measured in the unit of ms (see ETSI TS 101 376-5-6 [5]), then dT_0, the same differential delay but in the unit of symbol can be converted as:

$$dT_0 = round\left(\frac{117}{5} \times dt_0\right).$$

This differential delay dT_0 is then graded into the closest level of Precorrection Indication, denoted as dT_1. The actual value of MES pre-correction is $2 \times dT_1$. Converting from dT_0 to dT_1 is based on the following:

$$dT_1 = 47 \times round\left(\frac{dT_0}{47}\right).$$

If Timing Offset received from AGCH is dT_2, then the MES shall offset its SDCCH/TCH transmission by $2 \times dT_1 + dT_2$ relative to its RACH transmission timing.

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

The network may send on the AGCH the Immediate Assignment Reject (IAR) message with a reject cause that indicates that the class-2 information bits of the RACH burst are incorrect (e.g. if the RACH burst from the MES does not entirely fit within the RACH window at the network). The IAR message shall contain Timing Correction and Frequency Correction fields (see clauses 5.6.2 and 6.6, and ETSI TS 101 376-4-8 [2]).

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

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

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

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

- The MES of Terminal Type C shall select one of the seven (non-reserved) values of Precorrection Indication shown in the Compensation column of table 5.2 of ETSI TS 101 376-5-7 (Release 1) [6] such that the selected value, in symbols, is the one closest to one-half of the received Timing Correction converted to units of a symbol (the received Timing Correction is in units of $T_{SB}/40$, whereas the Precorrection Indication is in units of T_{SB} (i.e. 1/23 400 seconds)). Equivalently, the selected value of Precorrection Indication, in symbols, shall be the one which is the closest to $(1/80)^{th}$ of the received Timing Correction in units of $T_{SB}/40$. The selected value shall be used as the new value of Precorrection Indication in calculation of RACH_SYMBOL_OFFSET. Furthermore, the MES shall send, in the retransmitted RACH, the applied value of Precorrection Indication by converting it to one of the seven (non-reserved) values of the three-bit code shown in table 5.2.

After receiving the RACH signal, the GS shall measure the difference between the actual burst arrival and the expected arrival, denoted as dT_2, and decode the parameter Precorrection Indication to obtain the value of dT_1. The value of dT_2 shall be passed to the MES via AGCH. Both dT_1 and dT_2 shall be used by the GS to calculate MES-satellite propagation delay T_U according to the following equation:

$$T_u = T_0 + dT_1 +' \frac{dT_2}{2'}$$

If the MES has applied a timing precorrection of dT_1 and it receives on AGCH a Timing Offset of dT_2, the MES shall offset its PDCH transmission by $2 \times dT_1 + dT_2$ relative to its RACH transmission timing.

5.4.3 Description of parameters

Figure 5.2 shows the time offset between the transmit and received frame for an MES experiencing an overall delay of between 119,37 ms and 140 ms. The 5-bit parameter SB_FRAME_TS_OFFSET indicates to the MES, the offset, in slots, between the forward link timeslot 0 in FN = N and the return link timeslot 0 in FN = N + 7 nominally at the centre of the spot beam. The value of this parameter varies between 0 and 31. In addition to SB_FRAME_TS_OFFSET, a 6-bit parameter SB_SYMBOL_OFFSET indicates to the MES, an additional offset in symbol periods nominally at the centre of the spot beam. The SB_SYMBOL_OFFSET varies between -32 to +31 symbols. The parameter RACH_TS_OFFSET indicates to the MES the start of RACH window relative to the start of the BCCH window, ranges from 0 to 23. All of these parameters are broadcast from the BCCH. Based on these parameters, the MES can calculate the offset between forward and return frames to within 1 symbol period if it is at the centre of the spot beam.

To accommodate satellite diurnal motion, the two parameters SB_FRAME_TS_OFFSET and SB_SYMBOL_OFFSET shall be calculated dynamically at the GS based on satellite and beam centre instantaneous relative distance. These values are periodically updated though BCCH so that the RACH burst sent by MES is always centred at the middle of the RACH window if the MES is located at beam centre.

The MES shall calculate the start of the RACH burst transmission referenced to the start of timeslot 0 on the forward channel in units of symbol periods, RACH_SYMBOL_OFFSET, using the following formula:

RACH_SYMBOL_OFFSET = SB_SYMBOL_OFFSET + 2 × PRECORRECTION_INDICATION +
39 × (SB_FRAME_TS_OFFSET + SA_BCCH_STN + RACH_TS_OFFSET + R)

This is the number of symbols that an MES shall delay the start of a RACH burst in frame number M relative to the start of the received frame number N. This transmission shall be in the return link timeslot (SA_BCCH_STN + RACH_TS_OFFSET + R) mod 24, where *R* is set to 1,5.

If the value of (SA_BCCH_STN + RACH_TS_OFFSET + R) < 24, the MES shall use frame number M = N + 7. If the value of (SA_BCCH_STN + RACH_TS_OFFSET + R) ≥ 24, the MES shall use frame number M = N + 8. Therefore if the RACH burst crosses the uplink frame boundary, the frame number used by the RACH burst is determined by the start of RACH transmission. During the initial access, timing correction $2[T_U - T_0]$ is provided from the network via AGCH. To handle spot beams with large delay variation, ±17 ms is considered to be the worst case differential delay from beam edge to beam centre. This requires 15 bits to inform the MES, with unit of T_{SB}/40 (1,075 µs), and a range from -15 912 to +15 912.

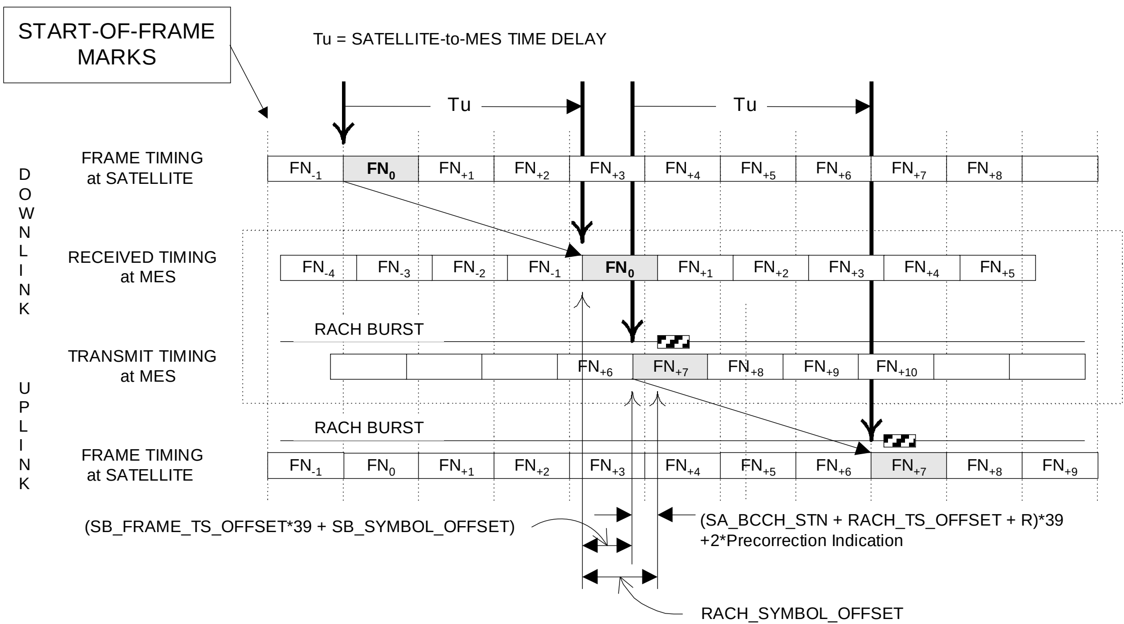

Figure 5.2: RACH burst timing

Table 5.3: Range of parameters at initial access

Parameter	Unit	Range
SB_FRAME_TS_OFFSET	TS	0 to 31
SB_SYMBOL_OFFSET	Symbol	-32 to +32
SA_BCCH_STN	TS	0 to 23
RACH_TS_OFFSET	TS	0 to 23
M - N	Frame	7 to 8
RACH_SYMBOL_OFFSET	Symbol	(-32 + R × 39) to (2 956 + R × 39)

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

5.4.4 Timing accuracy

From the MES, BCCH timing is used as timing reference for RACH burst transmission. The timing error is dominated by several factors: BCCH signal timing error, BCCH timing detection error introduced by the MES, timing drift due to MES oscillator stability and differential delay from the MES to beam centre. The network shall be able to measure the overall timing error to the accuracy better than 3,6 μs 1-sigma. After receiving the timing correction from the AGCH, the MES shall adjust its transmission timing to the accuracy better than 4,6 μs 1-sigma relative to the system timing.

5.5 Dedicated mode synchronization (A/Gb mode only)

5.5.0 General

In call in A/GB mode, to accurately maintain the correct time alignment at the satellite, the MES advances or retards the transmission of bursts relative to the start of its reference frame to synchronize their arrival at the reference point of the satellite.

The forward and return frames are offset relative to each other at the MES. This offset is provided to meet the following basic system requirements:

- Achieve time synchronization of the forward and return frames and slots at the satellite reference point.
- Permit a low-complexity MES implementation that eliminates the need for a frequency diplexer (an MES is not required to transmit and receive at the same time), which also allows simple synthesizers to switch frequencies in the proper time intervals.
- Allow MESs to monitor the assigned TTCH channel during a TtT call.

In dedicated mode, either voice channel or SDCCH channel is used. Synchronization scheme addressed below applies to both of these two channels.

5.5.1 In-call timing relationship (A/Gb mode only)

Figure 5.3 shows the relationship between receive frame number N and transmit frame number N + 7. An MES shall synchronize its transmit frame number N + 7 with receive frame number N, by offsetting its transmit frame N + 7 by ΔT_{OF} relative to receive frame number N to achieve frame synchronization at the satellite. K_D and K_U are the forward and return link burst positions, the values of K_D and K_U are allocated by the network at the beginning of the call, they are all numbered from 0 to 23.

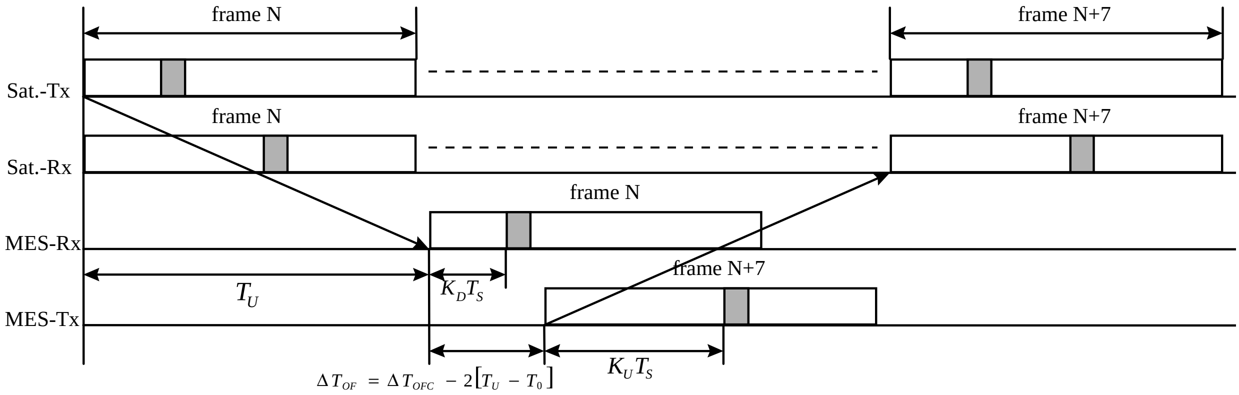

Figure 5.3: Frame and burst timing on the satellite and the MES

The offset between frame N + 7 uplink and frame N downlink shall be calculated from:

$$\begin{aligned}\Delta T_{OF} &= \Delta T_{OFC} - 2[T_U - T_0] \\ &= SB\_FRAME\_TS\_OFFSET \times 39 + SB\_SYMBOL\_OFFSET - 2[T_U - T_0],\end{aligned}$$

where the parameter SB_FRAME_TS_OFFSET and SB_SYMBOL_OFFSET are as defined in clause 5.4.3.

After initial access, the MES shall derive the frame offset ΔT_{OF} based on the corrective factor $2[T_U - T_0]$ received from the AGCH. During the call, the value of $2[T_U - T_0]$ is updated via FACCH messages (TCH3) or SACCH message (TCH6/TCH9) to compensate any timing drift caused by MES oscillator, MES-satellite relative motion.

5.5.2 In-call synchronization scenario (A/Gb mode only)

In the downlink, an open-loop synchronization scheme is used. The MES receiver timing is still derived from its internal timebase, but frequently corrected by timing detection of the received TCH or DKAB bursts during the call. The task of receiver timing correction shall be performed often enough to handle the worst case timing drift rate specified in clause 4.3.2. The target timing accuracy is to achieve demodulation performances specified by ETSI TS 101 376-5-5 [4].

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

- After RACH process, the MES transmitter has already synchronized to system timing. If T_a is the expected burst arrival time on the satellite, then the MES shall start its burst transmission at T_a - T_u.
- Sometime later, because of the user motion and its oscillator stability, the MES receiver timing is offset by $\Delta T_U = \Delta T_{U1} + \Delta T_{U2}$ from its original timing, where ΔT_{U1} is due to its internal oscillator drift and timing tracking error, ΔT_{U2} is due to a change of the MES position.
- Since the MES transmitter uses receiver timing as reference, then the MES transmission timing also offsets by $\Delta T_U = \Delta T_{U1} + \Delta T_{U2}$. Burst transmission timing becomes $T_a - T_U + \Delta T_{U1} + \Delta T_{U2}$.
- After experiencing an uplink propagation delay $T_U + \Delta T_{U2}$, the signal arrives on the satellite at $T_a + \Delta T_{U1} + 2\Delta T_{U2}$, offsets from the nominal timing by $\Delta T_{U1} + 2\Delta T_{U2}$.
- At the GS, difference between the actual burst arrival and expected arrival shall be monitored. If the GS has detected that the difference $\Delta T_{U1} + 2\Delta T_{U2}$ exceeds a predefined threshold of 10 µs, it shall pass the difference to the MES though a Link Correction message via FACCH3, SACCH6/9 or SDCCH.

- After receiving the Timing Correction, the MES shall offset its transmission by $\Delta T_{U1} + 2\Delta T_{U2}$ in timing. This timing adjustment shall be achieved gradually. The adjustment shall be made at a rate of 2 µs/s ±0,2 µs/s, the RMS error between the actual transmission timing and the 2 µs/s profile shall be less than 0,5 µs over the duration of adjustment. This rate of change shall be made in addition to the Doppler-related rate-of-change which is applied to the MES transmission timing continuously.
- The adjustment shall be applied to the MES transmission in such a way: if the Control Flag associated with the Link Correction message is 1, then this message overrides all previous messages; Otherwise, if the Control Flag is 0, the adjustment shall be made in addition to any previous messages. Refer to ETSI TS 101 376-4-8 [2] for further clarification regarding use of the Control Flag (CF).
- After this adjustment, the MES transmission timing becomes $T_a - T_U - \Delta T_{U2}$. With an uplink propagation delay $T_U + \Delta T_{U2}$, the burst arrives on the satellite at nominal timing Ta.

The task of transmission timing correction shall be performed often enough to cope with the worst-case timing drift specified in clause 4.3.2. As the maximum timing drift rate in the mobile's downlink is 0,32 µs/s, the transmission timing drift rate can be up to 0,64µs/s. With this correction, a transmission timing accuracy relative to the system timing specified by ETSI TS 101 376-5-5 [4] shall be achieved.

In the FACCH or SACCH channel, the Timing Correction shall be provided by the network relative to the currently used transmission timing value, this is different from the correction transmitted over AGCH. The range of the timing adjustment shall be from -32 T_{SB}/40 to +31 T_{SB}/40, with a unit of T_{SB}/40, which requires 6 bits. When the MES receives a new value of Timing Correction, it shall apply the change within 80 ms after receiving the message. Suppose this message has been successfully received and has been applied to the MES transmitter, the GS shall be able observe this adjustment sometime later.

When the GS instructs an MES to switch from one channel to another (i.e. from SDCCH to TCH), a Timing Correction shall be provided to the MES. Then the MES shall apply the new TC to the new channel.

In the initial Timing Offset over AGCH or subsequent Timing Correction over FACCH or SACCH , the network sends the timing offset of the signal received from the MES. Therefore, the MES shall apply the negative of the received value in the Timing Offset or Timing Correction message from the network.

For example, if the Timing Correction value received from the network is +10, the MES shall change the time of the start of the uplink frame relative to the start of the downlink frame by $-10 \times \frac{T_{SB}}{40}$.

5.5.3 Transmission timing drift rate (A/Gb mode only)

In call, to reduce the number of FACCH messages and to improve timing accuracy and stability of MES transmission, the MES timing drift rate shall be used for transmission timing correction. This timing drift rate R shall be derived from the Frequency Correction received from AGCH channel as well as FACCH (SACCH) according to the following.

The drift rate of timing depends on the exact carrier frequency being used. In using the following equations, the terminal shall presume *drift_factor* to be either of the following values:

- the value of the current transmit frequency expressed in GHz; or
- 1,6345.

The former choice is preferable; however, the latter choice is an acceptable compromise value. The total error in the determination of R (assuming the frequency adjustments are correct) should not exceed 8 ns per second from this. Note that transmit timing is limited by the quantization of the hardware and errors in the estimators and tracking loops. Therefore, conformance to this requirement should be tested using periods of several minutes. For example, the error after 1 000 s should be less than 8 µs.

After the RACH process, the value of Frequency Correction received from AGCH is ΔF_1, ΔF_0 is the round trip Doppler experienced by a stationary MES located at beam centre, it is broadcast though BCCH and therefore available by the MES prior to each call. Then the timing drift rate R is:

$$R = \frac{\Delta F_1 + \Delta F_0}{drift\_factor}(ns/s).$$

During a call, after an MES has received a Frequency Correction ΔF_2 from the FACCH or SACCH channel, this message shall be used to calculate the delta value of timing drift rate, denoted as ΔR. This delta value shall be calculated as:

$$\Delta R = \frac{\Delta F_2}{drift\_factor}(ns/s).$$

The timing drift rate R shall be adjusted as:

$$R = [R + \Delta R] \ (ns/s).$$

The accumulated frequency offset is equal to the offset being applied (in Hz) to the transmitter at any time (based on the estimated received frequency). Therefore, the MES does not need to separately accumulate the values it has received via the BCCH, AGCH, and control messages.

The MES shall apply this new timing drift rate to its transmission timing within 80 ms after the Frequency Correction is received. The adjustment shall be made relative to receive timing.

5.5.4 RX/TX guard time violation (A/Gb mode only)

A guard time of 2,2 ms is required by the terminal to switch from one receive frequency to another transmission frequency. Due to MES-satellite relative motion, the RX burst and TX burst move relative to each other so that the RX/TX guard time may finally violate the minimum required guard time limitation. In the worst case, the relative moving speed between the two bursts is 0,64 µs/s, twice the rate of propagation delay change.

From the MES, the available RX/TX guard time shall be monitored at least once every 15 s. If the guard time is found to be smaller than a predefined threshold 2 200 + Tgt µs, where Tgt is the additional guard time left for signalling exchange, a GUARD_TIME_VIOLATION message shall be sent from the MES to the network notifying about this violation. The value of Tgt is 15 µs.

5.6 Packet transfer mode synchronization

5.6.0 General

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

5.6.1 Packet transfer mode timing relationship

Figure 5.3 shows the relationship between receive frame number N and transmit frame number N + 7. An MES shall synchronize its transmit frame number N + 7 with receive frame number N, by offsetting its transmit frame N + 7 by ΔT_{OF} relative to receive frame number N to achieve frame synchronization at the satellite. The forward and return link burst positions, MAC_FORWARD_TS_OFFSET and MAC_RETURN_TS_OFFSET respectively, are determined by the network, and broadcast in BCCH and in AGCH (refer to ETSI TS 101 376-5-6 [5]).

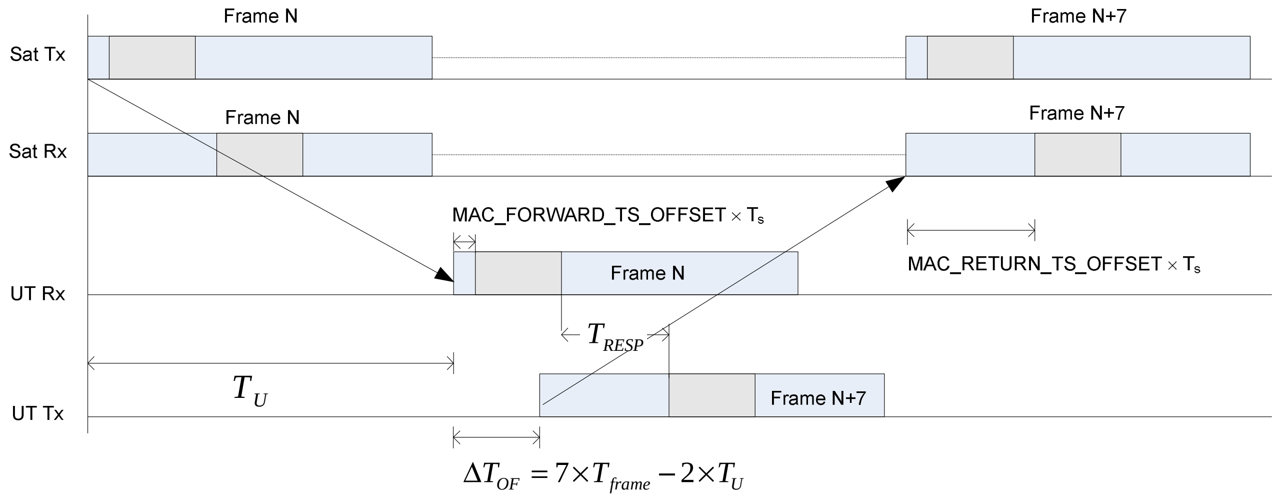

Figure 5.3a: Frame and burst timing on the satellite and the MES in the Connected Mode

The offset between frame N + 7 uplink and frame N downlink shall be calculated as follows:

$$\begin{aligned}\Delta T_{OF} &= \Delta T_{OFC} - 2[T_U - T_0] \\ &= SB\_FRAME\_TS\_OFFSET \times 39 + SB\_SYMBOL\_OFFSET - 2[T_U - T_0],\end{aligned}$$

where the parameter SB_FRAME_TS_OFFSET and SB_SYMBOL_OFFSET are as defined in clause 5.4.3.

After initial access, the MES shall derive the frame offset ΔT_{OF} based on the corrective factor $2[T_U - T_0]$ received from the AGCH. During the packet transfer connected mode, the value of $2[T_U - T_0]$ is updated via Packet Link Control or Packet Uplink Ack/Nack Type 2 message specified in ETSI TS 101 376-4-12 [7]. This mechanism compensates for any timing drift caused by MES oscillator, MES-satellite relative motion.

The MES response time T_{RESP} is defined as the time measured from the end of the time slot in which the MES received a PNB(m,3), PNB2(m,3), PNB2(m,12), or PNB3(m,n) containing the USF assigned to the MES and the start of the time slot in which the MES is granted uplink access by the USF (see ETSI TS 101 376-4-12 [7]). As described next, the MES response time is a function of MAC_FORWARD_TS_OFFSET, MAC_RETURN_TS_OFFSET and USF Delay Value.

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

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

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

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

The range of values for MAC_FORWARD_TS_OFFSET and MAC_RETURN_TS_OFFSET is given in ETSI TS 101 376-4-8 [2].

To interpret the Uplink State Flag (USF) in the downlink PUI (see ETSI TS 101 376-4-12 [7]), the MES shall apply the following rule. If the MES receives a USF in its receive downlink frame N, it shall apply the USF to the uplink frame numbered (N + USF DELAY Value), where the USF Delay Value is decoded from the USF_DELAY and USF_DELAY_Adjustment parameters that are contained in System Information (see ETSI TS 101 376-4-8 [2]). The USF Delay Value, after adjustment if any, decodes to values of 6, 7, 8, 9 or 10.

An MES receiving a PDTCH2(5,12) shall decode additional USF values in the Extended PUI. Refer to ETSI TS 101 376-4-12 [7] for T_{RESP-1} calculation for the USF values assigned through the Extended PUI.

An MES receiving a PDTCH3(m,n) shall decode additional USF values in the ULMAP. Refer to ETSI TS 101 376-4-12 [7] for T_{RESP-1} calculation for the USF values assigned through ULMAP.

For an MES with terminal type identifier values of either 0x3D, 0x3E, 0x3F, or 0x40 (refer to ETSI TS 101 376-5-2 [3] for a detailed listing of the terminal types) assigned to transmit on the uplink, the following shall apply.

1) The MES shall be able to differentiate between the two possible scenarios shown in figure 5.4; its scheduled uplink transmission may either be after the end of a downlink burst or it may be during a downlink burst. MES may be able to differentiate between these two scenarios using the downlink carrier bandwidth and the burst duration information, if present, in the PUI.

2) In the former case (i.e. when the MES' scheduled uplink transmission is after the end of a downlink burst), the MES shall be able to receive, decode and interpret both the burst header and the burst data fields of the downlink burst provided the scheduled uplink transmission starts no earlier than ΔT_{Rx-Tx} ms after the end of the downlink burst (here, ΔT_{Rx-Tx} is the time required by MES' synthesizer to switch from receive to transmit, refer to ETSI TS 101 376-5-5 [4]).

3) In the latter case (i.e. when the MES' scheduled uplink transmission is during a downlink burst), if the MES' scheduled uplink transmission starts no earlier than 5 + ΔT_{Rx-Tx} ms after the start of the downlink burst (either 10 ms PNB(1,6) or PNB3(2,6) or 20 ms PNB3(5,12)), the MES shall receive, decode, interpret the burst header (PUI, USF or ULMAP) of the downlink burst and apply either the USF or the ULMAP, if present.

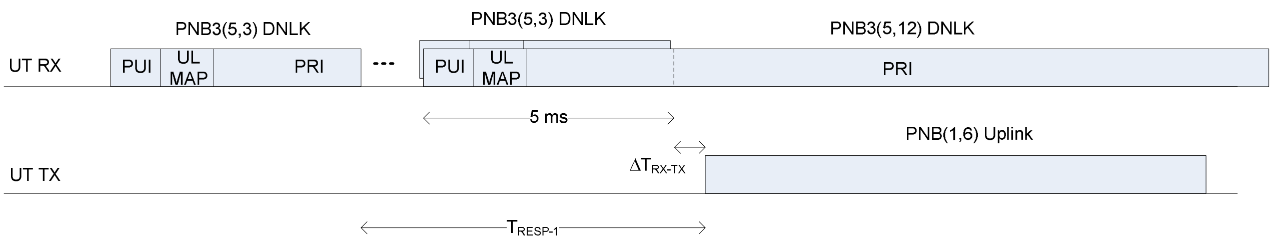

Figure 5.4: Terminal can receive either a 5 ms or a 20 ms burst on the downlink prior to the start of its scheduled transmission on the uplink

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

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

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

The value of T_{RESP-2} may be such that the terminal type C MES can only partially receive PNB(2,6) when it transmits PNB(1,6) on the uplink. Consider a value T_{RESP-2} such that the terminal type C MES can receive burst-header of downlink PNB(2,6), but not the PRI. For such values of T_{RESP-2}, the MES of terminal type C shall receive, decode and interpret the burst header of PNB(2,6) (see also ETSI TS 101 376-5-2 [3] and ETSI TS 101 376-4-12 [7]).

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

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

5.6.2 Time synchronization for Packet switched channels

The MES receiver timing shall be derived from its internal timebase, but frequently corrected by timing detection of the received PDCH and PDCH3 bursts during packet transfer mode. The task of receiver timing correction has to be performed often enough to handle the worst case timing drift rate specified in clause 4.3.2. The target timing accuracy is to achieve demodulation performances specified by ETSI TS 101 376-5-5 [4].

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

- After RACH process, the MES receives the timing correction in the Immediate Assignment message from the network via AGCH.
- The network uses the Timing Offset IE (see ETSI TS 101 376-4-8 [2]) to send the timing correction to the MES.
  - The MES shall apply the negative of the received timing correction value to the transmission timing offset used for its RACH transmission. The entire offset shall be applied all at one time. The MES shall transmit the first burst of the new channel at the resultant transmission timing.
- Thus, after RACH process, the MES transmitter is already synchronized to system timing. If Ta is the expected burst arrival time on the satellite, then the MES shall start its burst transmission at Ta - Tu.
- Sometime later, because of the user motion and its oscillator stability, the MES receiver timing is offset by $\Delta T_U = \Delta T_{U1} + \Delta T_{U2}$ from its original timing, where ΔT_{U1} is due to its internal oscillator drift and timing tracking error, ΔT_{U2} is due to a change of the MES position.
- Since the MES transmitter uses receiver timing as reference, then the MES transmission timing also offsets by $\Delta T_U = \Delta T_{U1} + \Delta T_{U2}$. Burst transmission timing becomes to be $T_a - T_U + \Delta T_{U1} + \Delta T_{U2}$.
- After experiencing an uplink propagation delay $T_U + \Delta T_{U2}$, the signal arrives on the satellite at $T_a + \Delta T_{U1} + 2\Delta T_{U2}$, offsets from the nominal timing by $\Delta T_{U1} + 2\Delta T_{U2}$.
- At the GS, timing difference between the actual burst arrival and expected arrival shall be monitored. The observed difference is sent to the MES either as an initial correction following the reception of a packet access burst from the MES, as a periodically scheduled timing correction message, as a timing correction on an as-needed basis, or at beam to beam handover. This is described next.
  - *Timing correction after reception of a packet access burst from the MES, when the MES does not have an active uplink TBF:*
    - When the MES does not have an active uplink TBF, and if its PACKET_RANDOM_ACCESS_TIMER (timer T3202) has not expired (timer T3202 counts the time since the last timing and frequency correction message received from the GS; see annex E) and if it requires a new uplink assignment, the MES transmits PRACH on the packet access burst. Following the reception of a packet access burst from the MES, the GS shall send the timing advance values in the next downlink signalling message addressed to that MES.
    - The MES shall apply the negative of the timing correction value to the transmission timing offset used for its PRACH transmission.. The entire offset shall be applied all at one time.
  - *Timing correction after reception of a packet access burst from the MES, when the MES already has at least one active uplink TBF:*
    - If the MES transmits PRACH on the packet access burst when it has at least one active uplink TBF (e.g. to request the activation of another uplink TBF), the GS may also respond with a signaling message containing a timing correction.
    - The MES shall apply any timing correction received in this case gradually, at an (absolute) rate of 5 µs/s ± 1 µs/s.
  - *Periodically scheduled timing corrections:* The GS shall perform the scheduled timing advance mechanism for all MES working in packet transfer mode on a PDCH for which a PTCCH/U is assigned (on a PDCH3 channel, the GS shall not assign a PTCCH/U). The GS shall monitor the delay of the PNB bursts sent by the MES on PTCCH/U, if assigned to the MES, and respond with timing advance values for all the MESs on that PDCH. The timing advance values shall be sent via a downlink signalling message on PTCCH/D (see ETSI TS 101 376-4-12 [7]), if assigned to the MES.

   - The PTCCH/U and PTCCH/D shall be transmitted using the most conservative modulation and coding rate supported by the MES for the shortest duration PDCH burst. The MCS values to be used for different terminal types are defined in table 5.4. For MCS definitions, refer to ETSI TS 101 376-4-12 [7].

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

Downlink Channel type PDTCH	Terminal type	MCS for PTCCH/D (binary) (see note)	PTCCH/D burst	MCS for PTCCH/U (binary) (see note)	PTCCH/U burst
(2,6)	C	000	PDCH(2,6)	000	PDCH (1,6)
(4,3)	A	0000	PDCH(4,3)	0000	PDCH(4,3)
(5,3)	A	0000	PDCH(5,3)	0000	PDCH(5,3)
(5,3)	D	0011	PDCH(5,3)	0011	PDCH(5,3)
NOTE: MCS coding (3 bits or 4 bits) is dependent on channel type, see ETSI TS 101 376-4-12 [7].					

- *Unsolicited timing corrections sent on an as-needed basis:* If the GS detects that the difference $\Delta T_{U1} + 2\Delta T_{U2}$ measured using the packet normal bursts sent by the MES on PDTCH and PACCH exceeds a predefined threshold, it shall pass the difference to the MES though a link synchronization message (see ETSI TS 101 376-4-12 [7]). The GS shall use the unsolicited timing correction mechanism when a PTCCH/U is not assigned to the MES.

- *Timing correction applied by the MES at the beam to beam handover:* When the GS instructs an MES to switch from one beam to another, the MES transmission timing on the new beam shall be based on the last received Timing Correction from the GS.

- For the periodically scheduled and the unsolicited timing corrections, the MES shall apply the negative of the timing correction value to the prior value of the transmission timing offset.

   - The MES shall apply the timing offset gradually. The adjustment shall be made at an (absolute) rate of 5 μs/s ± 1 μs/s.

   - The transmission timing change in either of the above two cases shall be made in addition to the Doppler-related rate-of-change which is applied to the MES transmission timing continuously.

- After receiving the Timing Correction, the MES shall offset its transmission by $\Delta T_{U1} + 2\Delta T_{U2}$ in timing. An MES transmitting PDCH(4,3) or PDCH(5,3) shall apply the received timing correction to all transmitted bursts within T_{RESP-1} of the end of the downlink burst in which the timing correction was received. An MES transmitting PDCH(1,6) or PDCH(2,6) shall apply the received timing correction to all transmitted bursts within T_{RESP-2} of the end of the downlink burst in which the timing correction was received. After this adjustment, the MES transmission timing becomes $T_a - T_U - \Delta T_{U2}$. With an uplink propagation delay $T_U + \Delta T_{U2}$, the burst arrives on the satellite at nominal timing Ta.

- The MES may implement the timing correction received from the network based on either the Control Flag associated with the timing correction or autonomously (i.e. without reading the Control Flag).

   - In the former case (i.e. when MES implements timing correction based on the Control Flag received from network), the adjustment shall be applied to the MES transmission in the following way: if the Control Flag associated with the Timing Correction message is 1, then the timing correction received in this message overrides the unapplied residual (due to the gradual ±5 μs/s application rate), if any, of the previous timing correction; Otherwise, if the Control Flag is 0, the timing correction received in this message is applied after the MES completes the residual (due to the gradual ±5 μs/s application rate), if any, of the previous timing correction. Refer to ETSI TS 101 376-4-12 [7] for further description on the timing correction message.

   - In the latter case (i.e. if the MES does not read the Control Flag received from the network), the MES shall implement the timing correction as if the Control Flag is 1. Thus, the MES shall replace unapplied residual (due to the gradual ±5 μs/s application rate), if any, of the previous timing correction with the new value of the received timing correction.

- During an active TBF the network should not send to the MES a new timing correction message within 2 seconds of sending a prior timing correction message. The MES shall ignore a Timing Correction message if a previous Timing Correction message was received within two seconds of the latest message.
- The range of the timing adjustment sent by the network shall be from -0,4 ms to +0,4 ms or -375 T_{SB}/40 to +375 T_{SB}/40, with a unit of T_{SB}/40.
- In the initial, unsolicited or scheduled correction, the network sends the timing offset of the signal received from the MES. Therefore, the MES shall apply negative of the received value in the timing correction message from the network.
  - EXAMPLE: If the timing correction value received from the network is +10, the MES shall change the time of the start of the uplink frame relative to the start of the downlink frame by $-10 \times \frac{T_{SB}}{40}$.

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

5.6.3 Transmission timing drift rate

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

5.6.4 RX/TX guard time violation

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

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

5.6.5 Packet transfer mode timing relationship for handover to dedicated packet channel (Iu mode only)

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

As part of the signalling prior to handover the MES shall receive a Radio Bearer Reconfiguration message (see ETSI ETSI TS 101 376-4-13 [9]) that includes a Physical Information IE that specifies the assigned physical channel description as well as Handover Reference IE that provides information needed for transmit timing synchronization. The MES transmit timing shall be pre-calculated by the network based on the prior known MES position. This timing pre-correction shall be of sufficient accuracy to allow the MES to transmit a Handover Access message (see ETSI TS 101 376-4-12 [7]) using a Packet Access Burst (PAB3) on the assigned dedicated channel without MES impact to other user transmissions. This network provided information allows the MES to immediate enter packet transfer mode on the assigned channel without having to read the spot beam BCCH and without the MES having to initiate RACH or PRACH access.

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

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

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

Where *TS* is the TDMA frame timeslot (0, ..., 23) and *Return_TimeSlot_Allocation* specifies the starting timeslot of the MES DCH transmission assignment within the return link frame. For PNB3(1,3) or PNB3(1,6) dedicated channel bursts the starting timeslot is derived from the Return *MAC-slot Allocation*. For PNB3(1,8) bursts the starting timeslot is derived from the Return *Slot Allocation* (see ETSI TS 101 376-4-12 [7]).

The value of *MAC_RETURN_TS_OFFSET* for the spot beam is as given in ETSI TS 101 376-4-8 [2] and shall be directly provided to the MES as part of the Radio Bearer Reconfiguration message (see ETSI TS 101 376-4-13 [9]) sent in the handover initiation message.

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

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

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

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

In response to the receipt of the Handover message from the MES sent using the PAB3, the GS shall transmit a Physical Information message on the MES assigned downlink channel. The Physical Information message includes packet link synchronization parameters that provide fine timing adjustment for the subsequent MES transmission (see ETSI ETSI TS 101 376-4-12 [7]). The network shall use the received PAB3 transmission to derive the link synchronization and frequency and timing correction specified to the MES for subsequent transmissions on the dedicated channel.

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

5.6.6 Packet transfer mode timing for handover to shared packet channel (Iu mode only)

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

As part of the handover signalling prior to handover the MES shall receive a Radio Bearer Reconfiguration message (see ETSI TS 101 376-4-13 [9]) that includes a Physical Information IE that specifies the assigned physical channel description as well as Handover Reference IE that provides information needed for transmit timing synchronization. The MES transmit timing shall be pre-calculated by the network based on the prior known MES position. This timing pre-correction shall be of sufficient accuracy to allow the MES to transmit a Packet Channel Request Type 2, Handover Access message (see ETSI TS 101 376-4-12 [7]) using a Packet Access Burst (PAB3) on the PRACH associated with the MES shared channel assignment. The network provided information allows the MES to immediate initiate the packet access procedure on the assigned channel without the MES having to read the spot beam BCCH.

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

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

6 Frequency synchronization, TtG/GtT call

6.0 Overview

Both forward and return link signals are required to align their nominal frequencies on the satellite. The task of frequency synchronization is to precompensate the transmission signal to align the nominal frequency on the satellite and to track the received signal in frequency to achieve effective demodulation.

The MES frequency alignment is achieved by correcting transmission frequency with messages provided by a network. RACH frequency is set up by messages provided over the BCCH.

In A/Gb mode, the SDCCH/TCH frequency is corrected with corrective factors given over the AGCH. During a call, frequency correction is provided though FACCH (TCH3) or SACCH (TCH6/TCH9).

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

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

6.1 General description

Frequency error introduced by MES oscillator: The MES oscillator has an accuracy better than 5 ppm long term. Without any compensation, the first order frequency error can be up to ±7,5 kHz. After initial frequency acquisition, this uncertainty can be reduced by several orders of magnitude. In this case, the MES receiver and transmitter frequency tolerance under various environmental conditions has been defined in ETSI TS 101 376-5-5 [4].

Doppler frequency introduced by satellite motion: Due to the satellite motion, a stationary user shall experience a maximum Doppler frequency drift ±264 Hz downlink, ±282 Hz uplink.

Doppler frequency introduced by user motion: Due to the user motion, additional Doppler is generated. In the worst case, this frequency error is ±231 Hz downlink, ±246 Hz uplink.

6.2 Frequency of common channels

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

6.3 Idle mode frequency synchronization

6.3.1 Initial frequency acquisition

In the initial frequency acquisition, an MES looks for one control carrier with the highest signal level. After FCCH/FCCH3 acquisition process described in ETSI TS 101 376-5-6 [5], the MES shall use the BCCH frequency as its frequency reference and locked to the BCCH carrier.

6.3.2 Paging mode

In paging mode, the frequency synchronization in the MES has already been derived from the FCCH/FCCH3 channel detection. The MES shall track the frequency of the control carrier by listening to either PCH channel or BCCH channel.

6.3.3 Alerting mode

Based on ETSI TS 101 376-5-5 [4], in alerting mode, the frequency synchronization in the MES is derived from the FCCH/FCCH3 channel detection. The MES shall track the control carrier frequency by listening to the FCCH/FCCH3 channel periodically.

In both paging and alerting mode, the MES tracking loop needs to handle the worst case Doppler frequency rate of change specified in clause 4.3.2. The tracking loop shall be implemented in such a way that demodulation performances specified in ETSI TS 101 376-5-5 [4] can be achieved.

6.4 Synchronization at initial access

6.4.0 General

Prior to the RACH process, the MES shall receive the RACH frequency and the round-trip L-band Doppler at the beam centre from the BCCH channel. The round-trip beam centre Doppler has a range from -635 Hz to +640 Hz. This requires 8 bits to inform the MES, with stepsize better than 5 Hz. At initial access, the MES accesses the network using the beam centre Doppler as its Doppler precompensation. The MES round trip Doppler variation relative to the beam centre is detected from the network, and this value is passed to the MES as a Frequency Correction. After the RACH process, the MES shall be able to compensate its frequency drift and Doppler variation to the accuracy of 17,6 Hz 1-sigma (with 12,6 Hz RACH detection error and 5 Hz quantization error) relative to nominal frequency.

6.4.1 Frequency compensation strategy

In general, the frequency compensation strategy shall align the nominal frequencies for both uplink and downlink signals on the satellite, this is shown in figure 6.1. Nominal BCCH receiving frequency is F_B, RACH transmission frequency is F_{RH}, MES traffic channel Tx/Rx frequencies are F_T and F_R, the ratio between F_{RH} and F_B is $\varepsilon = F_{RH} / F_B \doteq F_T / F_R$, so that $F_{RH} = \varepsilon \cdot F_B$, $F_T \doteq \varepsilon \cdot F_R$. In the downlink, Doppler frequency at beam centre due to satellite motion is dF_0, Doppler perceived by the MES is dF_U. In the uplink, Doppler received by the satellite is $\varepsilon \cdot dF_U$. The value of dF_U can have two components: one is due to satellite motion, the other is due to MES motion.

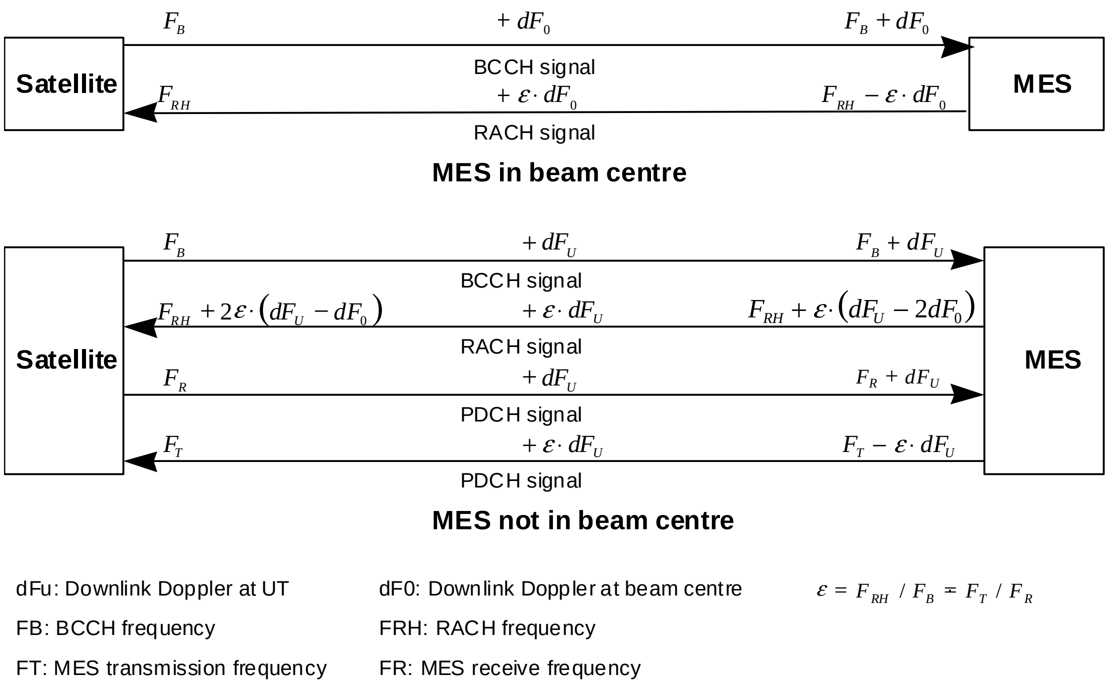

Figure 6.1: Frequency compensation strategy at initial access

where $\doteq$ represents approximately equal to.

MES frequency compensation scheme is outlined below:

- The GS calculates the mobile downlink beam centre Doppler frequency dF_0, broadcasts the RACH frequency F_{RH} and the value of $2 \cdot dF_0$, which is twice of the downlink beam centre Doppler, to the MES though the BCCH channel.
- The BCCH signal is received by the MES after experiencing a Doppler shift dF_U, received frequency is then $F_B + dF_U$. For a stationary MES located at beam centre, $dF_U = dF_0$, received frequency is $F_B + dF_0$.
- The MES generates its RACH transmission frequency F_{RH} by multiplying a factor $\varepsilon = F_{RH} / F_B$ from the receiving frequency $F_B + dF_U$, and pre-compensates it RACH Tx frequency by an amount $2 \cdot \varepsilon \cdot dF_0$, resulting in a radiated RACH signal transmission of $F_{RH} + \varepsilon \cdot (dF_U - 2dF_0)$. The MES shall calculate $\varepsilon = F_{RH} / F_B$ in order to apply the precorrection. (For a stationary MES at beam centre, the radiated transmission frequency is simply $F_{RH} - \varepsilon \cdot dF_0$).
- After experiencing Doppler shift $\varepsilon \cdot dF_U$ in the uplink, the RACH signal arrives at the satellite with frequency $F_{RH} + 2\varepsilon \cdot (dF_U - dF_0)$.
- The GS searches for and acquires the MES RACH burst, measures its frequency offset from nominal frequency F_{RH}, and passes a measurement of the quantity $2\varepsilon \cdot (dF_U - dF_0)$ to the MES though AGCH as a FREQUENCY OFFSET.
- The MES switches to the allocated channel (with nominal frequencies F_T and F_R) and offsets its transmission signal by the FREQUENCY OFFSET (approximately $2\varepsilon \cdot (dF_U - dF_0)$) and therefore starts its SDCCH/TCH/PDCH transmission with frequency $F_T - \varepsilon \cdot dF_U$. After experiencing a Doppler $\varepsilon \cdot dF_U$ on the mobile uplink, the signal arrives in the satellite with nominal frequency F_T.

With this frequency compensation scenario, both forward and return link nominal frequencies take place on the reference point of the satellite.

6.4.2 Parameter description

From the MES, the BCCH carrier is used as frequency reference for RACH transmission. The accuracy of the RACH transmission frequency is influenced by several factors: BCCH carrier frequency error, BCCH frequency detection error introduced by the MES, frequency drift due to MES oscillator stability, differential Doppler from MES to beam centre and Doppler produced by the MES motion.

The network shall be able to measure the above mentioned overall frequency error, the measurement shall be made to the accuracy better than 12,6 Hz 1-sigma. Receiving the frequency correction from the AGCH, the MES shall adjust its frequency of SDCCH/TCH transmission to the accuracy better than 17,6 Hz 1-sigma (with 5 Hz AGCH quantization error) under the condition defined in ETSI TS 101 376-5-5 [4].

After receiving the frequency correction from the AGCH, the MES shall adjust its frequency of PDCH transmission to the accuracy better than 10 Hz 1-sigma under the condition defined in ETSI TS 101 376-5-5 [4].

Beam centre Doppler $2 \cdot dF_0$: The maximum downlink beam centre Doppler dF_0 can be up to ±264 Hz, taking place at the centre of an edge beam. Therefore $2 \cdot dF_0$ is up to ±528 Hz. To accommodate satellite diurnal motion, the beam centre Doppler shall be calculated dynamically at the GS based on satellite velocity relative to beam centre, the value is periodically updated though BCCH so that the RACH burst arrival on the satellite is always nominal if a stationary MES is located at beam centre.

Frequency correction factor $2\varepsilon \cdot (dF_U - dF_0)$: This factor has two components, one is the user position two way differential Doppler relative to beam centre, the other is the two way Doppler frequency due to mobile user's motion. From annexes A and C, the maximum value of $2\varepsilon \cdot (dF_U - dF_0)$ measured from the network is around ±600 Hz. Again, to leave enough margin, a range of -2 047 Hz to +2 048 Hz is considered. This Frequency Correction factor on the AGCH requires 12 bits to inform the MES, with an accuracy better than 1 Hz.

6.5 Dedicated mode synchronization (A/Gb mode only)

In call, the accurate receiver frequency is maintained by using its internal frequency reference. Meanwhile, frequency detection technique is used to monitor any possible frequency drift caused by the MES oscillator stability, MES frequency tracking error and Doppler frequency due to MES-satellite relative motion. The MES receiver shall maintain its frequency accuracy relative to the received signal so that demodulation performances specified in ETSI ETSI TS 101 376-5-5 [4] can be achieved.

In the uplink, a closed-loop synchronization scheme is used. The frequency correction procedure is detailed below, figure 6.2 is used as reference.

- After RACH process, MES receive frequency is $F_R + dF_U$, transmission frequency is $F_T - \varepsilon \cdot dF_U$, so that both forward/return link signal frequencies seen from the satellite are nominal: F_R and F_T.
- Sometime later, frequency of the MES receiver is offset by $\Delta dF_U = \Delta dF_{U1} + \Delta dF_{U2}$, where ΔdF_{U1} is due to its internal oscillator drift and receiver's tracking error, ΔdF_{U2} is due to a change of downlink Doppler frequency.
- Since the MES transmitter uses receive frequency as reference, then transmission frequency also offset by $\Delta dF_U = \Delta dF_{U1} + \Delta dF_{U2}$, and becomes to be $F_T' = F_T - \varepsilon \cdot dF_U + \Delta dF_{U1} + \Delta dF_{U2}$.
- After experiencing an uplink Doppler $\varepsilon \cdot (dF_U + \Delta dF_{U2})$, the signal arrives on the satellite with frequency $F_T + \Delta dF_{U1} + (1+\varepsilon)\Delta dF_{U2}$, offsets from the nominal frequency by $dF = \Delta dF_{U1} + (1+\varepsilon)\Delta dF_{U2}$.
- At the GS, dF, the difference between actual signal arrival and expected arrival shall be monitored. If the GS detects that the frequency offset dF exceeds a predefined threshold of 40 Hz, it shall pass the value of dF to the MES in a Link Correction message via FACCH3, SACCH6/9 or SDCCH. This Frequency Correction shall be relative to the currently used frequency offset, different from the Frequency Offset sent over AGCH channel.
- After receiving the Frequency Correction, the MES shall adjust its transmission to $F_T' - dF$ in frequency, so that MES transmission frequency becomes to be $F_T - \varepsilon \cdot (dF_U + \Delta dF_{U2})$. This frequency adjustment shall be achieved gradually. The adjustment shall be made at a rate of 20 Hz/s ±2 Hz/s, the RMS error between the actual transmit frequency and the 20 Hz/s profile shall be less than 1 Hz over the duration of adjustment.
- The adjustment shall be applied to the MES transmission in such a way: if the Control Flag associated with the Link Correction message is 1, then this message overrides all previous messages; otherwise, if the Control Flag is 0, the adjustment shall be made in addition to any previous messages. Refer to ETSI ETSI TS 101 376-4-8 [2] for further clarification regarding use of the Control Flag.
- After experiencing an uplink Doppler $\varepsilon \cdot (dF_U + \Delta dF_{U2})$, the signal arrives on the satellite with nominal frequency F_T.

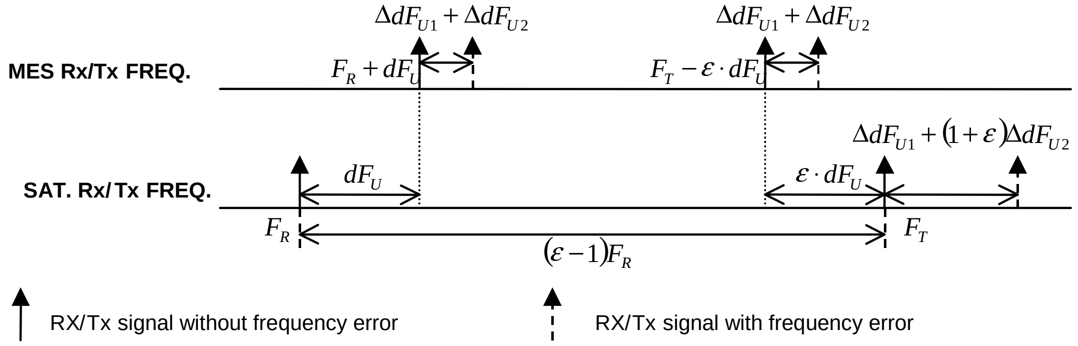

Figure 6.2: In call frequency correction

With the frequency correction technique, accuracy of the MES transmission frequency shall meet the requirement defined in ETSI TS 101 376-5-5 [4]. The same correction scheme shall be applied to both voice and DKAB transmission. The in-call Frequency Correction shall have a range from -2 048 Hz to +2 047 Hz, this requires 12 bits to inform the MES, with accuracy better than 1 Hz. For both uplink and downlink signals, the MES tracking loop needs to handle the worst case Doppler frequency change. The maximum Doppler rate of change due to the mobile's acceleration is 23,1 Hz/s downlink, 49,2 Hz/s uplink.

When the MES receives a new value of Frequency Correction, it shall apply the change within 80 ms after receiving the message. After this message has been successfully received and has been applied to the MES transmitter, the GS shall be able to observe this adjustment sometime later.

When the GS instructs an MES to switch from one channel to another (i.e. from SDCCH to TCH), a Frequency Correction shall be provided to the MES. The MES then shall apply the new FC to the new channel.

In the initial Frequency Offset over AGCH or subsequent Frequency Correction over FACCH or SACCH, the network sends the frequency offset of the signal received from the MES. Therefore, the MES shall apply the negative of the received value in the Frequency Offset or Frequency Correction message from the network.

For example, if the Frequency Correction value received from the network is +20 Hz, the MES shall change the MES shall change the transmit frequency by -20 Hz.

6.6 Frequency synchronization for the packet switched channels

In call, the accurate receiver frequency is maintained by using its internal frequency reference. Meanwhile, frequency detection technique is used to monitor any possible frequency drift caused by the MES oscillator stability, MES frequency tracking error and Doppler frequency due to MES-satellite relative motion. The MES receiver shall maintain its frequency accuracy relative to the received signal so that demodulation performances specified in ETSI TS 101 376-5-5 [4] can be achieved.

In the uplink, a closed-loop synchronization scheme is used. The frequency correction procedure is detailed below, figure 6.2 is used as reference.

- After RACH process, MES receives the frequency correction in the Immediate Assignment message from the network via AGCH.
- The network uses the Frequency Offset IE (see ETSI TS 101 376-4-8 [2]) to send the frequency correction to the MES.
    - The MES shall apply the negative of the received frequency correction value to the transmission frequency offset used for its RACH transmission. The entire offset shall be applied all at one time. The MES shall transmit the first burst of the new channel at the resultant transmission frequency.
- Thus, after RACH process, the MES receives frequency is $F_R + dF_U$, transmission frequency is $F_T - \varepsilon \cdot dF_U$, so that both forward/return link signal frequencies seen from the satellite are nominal: F_R and F_T.
- Sometime later, frequency of the MES receiver is offset by $\Delta dF_U = \Delta dF_{U1} + \Delta dF_{U2}$, where ΔdF_{U1} is due to its internal oscillator drift and receiver's tracking error, ΔdF_{U2} is due to a change of downlink Doppler frequency.
- Since the MES transmitter uses receive frequency as reference, then transmission frequency also offset by $\Delta dF_U = \Delta dF_{U1} + \Delta dF_{U2}$, and becomes to be $F_T' = F_T - \varepsilon \cdot dF_U + \Delta dF_{U1} + \Delta dF_{U2}$.
- After experiencing an uplink Doppler $\varepsilon \cdot \left(dF_U + \Delta dF_{U2}\right)$, the signal arrives on the satellite with frequency $F_T + \Delta dF_{U1} + (1+\varepsilon)\Delta dF_{U2}$, offsets from the nominal frequency by $dF = \Delta dF_{U1} + (1+\varepsilon)\Delta dF_{U2}$.

- At the GS, frequency difference between the actual burst arrival and expected arrival shall be monitored. The observed difference is sent to the MES either as an initial correction following the reception of a packet access burst from the MES, as a periodically scheduled timing correction message, in an as-needed basis, or at beam to beam handover. This is described next.
  - *Frequency correction after reception of a packet access burst from the MES, when the MES does not have an active uplink TBF:*
    - When the MES does not have an active uplink TBF, and if its PACKET_RANDOM_ACCESS_TIMER (timer T3202) has not expired (timer T3202 counts the time since the last timing and frequency correction message received from the GS; see annex E) and if it requires a new uplink assignment, the MES transmits PRACH on the packet access burst. Following the reception of a packet access burst from the MES, the GS shall send the frequency correction value in the next downlink signalling message addressed to that MES.
    - The MES shall apply the negative of the frequency correction value to the transmission frequency offset used for its PRACH transmission. The entire offset shall be applied all at one time.
  - *Frequency correction after reception of a packet access burst from the MES, when the MES already has at least one active uplink TBF:*
    - If the MES transmits PRACH on the packet access burst when it has at least one active uplink TBF (e.g. to request the activation of another uplink TBF), the GS may also respond with a signaling message containing a frequency correction.
    - The MES shall apply any frequency correction received in this case gradually, at an absolute rate of 20 Hz/s ± 4 Hz/s.
  - *Periodically scheduled frequency corrections:* The GS shall perform the scheduled frequency correction mechanism for all MES working in packet transfer mode on a PDCH for which a PTCCH/U is assigned (on a PDCH3 channel, the GS shall not assign a PTCCH/U). The GS shall monitor the received frequency of the PNB bursts sent by the MES on PTCCH/U, if assigned to the MES, and respond with frequency correction values for all the MESs on that PDCH. The frequency correction values shall be sent via a downlink signalling message on PTCCH/D (see ETSI TS 101 376-4-12 [7]), if assigned to the MES.
  - *Unsolicited frequency corrections sent on an as-needed basis:* If the GS detects that the difference $dF = \Delta dF_{U1} + (1+\varepsilon)\Delta dF_{U2}$ measured using the packet normal bursts sent by the MES on PDTCH and PACCH exceeds a predefined threshold, it shall pass the difference to the MES though a link synchronization message (see ETSI TS 101 376-4-12 [7]). The GS shall use the unsolicited frequency correction mechanism when a PTCCH/U is not assigned to the MES.
  - *Frequency correction at beam to beam handover:* When the GS instructs an MES to switch from one beam to another, the MES' transmission frequency on the new beam shall be derived by:
    - (i) scaling the downlink frequency received at the MES antenna on the new beam by the ratio $\varepsilon = F_T / F_R$ of the transmit frequency to the received frequency on the new beam, and
    - (ii) applying a correction to the resultant frequency that equals the last received Frequency Correction (from the GS) scaled by the ratio of the assigned (i.e. nominal) transmit frequency on the new (handed-over) beam to the assigned transmit frequency on the prior beam.
  - For the periodically scheduled and the unsolicited frequency corrections, the MES shall apply the negative of the frequency correction value to the prior value of the transmission frequency offset.
    - The MES shall apply the frequency offset gradually. The adjustment shall be made at an absolute rate of 20 Hz/s ± 4 Hz/s.
    - The transmission frequency change in either of the above two cases shall be made in addition to the Doppler-related rate-of-change which is applied to the MES transmission frequency continuously.

- The solicited and unsolicited Frequency Corrections shall be relative to the currently used frequency offset. After receiving the Frequency Correction, the MES shall offset its transmission to $F_T' - dF$ in frequency, so that MES transmission frequency becomes to be $F_T - \varepsilon \cdot (dF_U + \Delta dF_{U2})$ in frequency. An MES transmitting PDCH(4,3) or PDCH(5,3) shall apply the received frequency correction to all transmitted bursts within T_{RESP-1} of the end of the downlink burst in which the frequency correction was received. An MES transmitting PDCH(1,6) or PDCH(2,6) shall apply the received frequency correction to all transmitted bursts within T_{RESP-2} of the end of the downlink burst in which the frequency correction was received. After experiencing an uplink Doppler $\varepsilon \cdot (dF_U + \Delta dF_{U2})$, the signal arrives on the satellite with nominal frequency F_T.

- The MES may implement the frequency correction received from the network based on either the Control Flag associated with the frequency correction or autonomously (i.e. without reading the Control Flag):

  - In the former case (i.e. when MES implements frequency correction based on the Control Flag received from network), the adjustment shall be applied to the MES transmission in such a way: if the Control Flag associated with the Frequency Correction message is 1, then the frequency correction received in this message overrides the unapplied residual (due to the gradual ±20 Hz/s application rate), if any, of the previous frequency correction; Otherwise, if the Control Flag is 0, frequency correction received in this message is applied after the MES completes the residual (due to the gradual ±20 Hz/s application rate), if any, of the previous frequency correction. Refer to ETSI TS 101 376-4-12 [7] for further description on the frequency correction message.

  - In the latter case (i.e. if the MES does not read the Control Flag received from the network), the MES shall implement the frequency correction as if the Control Flag is 1. Thus, the MES shall replace unapplied residual (due to the gradual ±20 Hz/s application rate), if any, of the previous frequency correction with the new value of the received frequency correction.

- During an active TBF the network should not send to the MES a new frequency correction message within 2 seconds of sending a prior frequency correction message. The MES shall ignore a Frequency Correction message if a previous Frequency Correction message was received within two seconds of the latest message.

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

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

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

7 Frame and message synchronization, TtG/GtT call

7.1 Frame synchronization

7.1.1 Frame number definition

Definition of FN is based on the absolute system timing. On the satellite, both forward and return link frames are aligned on the satellite reference point and the same FN is shared by the two frames in both directions. The frame numbering is cycled in a hyperframe duration, $T_{HYP} = 3$ h 28 min 53 s 760 ms, or 313 344 TDMA frames. If the absolute system timing relative to the start of the system operation is denoted as T in ms, then FN can be given as a function of time T:

$$FN = floor\left[\frac{T \mod T_{HYP}}{40}\right]$$

If a traffic burst wraps across the boundary between two frames, frame number applied to the burst is the number of the first frame, i.e. the one with smaller number.

7.1.2 Frame synchronization scenario

The MES frame numbering for both uplink and downlink is purely based on parameters received from the GS.

Idle Mode

In entering idle mode, the MES frame number has been acquired by demodulating parameter Superframe number, Multiframe number and MFFN from the BCCH channel. This parameter is the frame number relative to the start of the hyperframe, its configuration has been introduced in ETSI TS 101 376-4-8 [2].

In idle mode, the MES RX frame number is maintained by its internal frame counter.

Initial Access

The RACH signal can be transmitted in any frame in the mobile's uplink.

At initial access, the MES first looks for an Rx frame with frame number FN = N as its reference frame. The RACH signal transmission frame number M is then calculated at the MES based on the parameter RACH_TS_OFFSET and SA_BCCH_STN received from the BCCH channel. This task is performed according to the following:

- If the value of SA_BCCH_STN + RACH_TS_OFFSET + R < 24, the MES shall use M = N + 7 as its RACH TX frame number.
- If the value of SA_BCCH_STN + RACH_TS_OFFSET + R ≥ 24, the MES shall use M = N + 8 as its RACH TX frame number.

Definition of R has been given in clause 5.4.3.

To meet the frame number requirement, the MES shall offset its RACH transmission burst relative to the start of the downlink reference frame by RACH_SYMBOL_OFFSET in the unit of symbols. The parameter RACH_SYMBOL_OFFSET is calculated according to clause 5.4.3.

Dedicated Mode

In call, the MES Rx FN is obtained from its internal frame counter, the MES TX FN is calculated based on the Rx FN and transmission frame offset relative to the start of the reference frame, i.e. given in clause 5.5.1. For frame number synchronization purpose, the system requires that the offset between transmission burst with FN N + 7 and receive burst with FN N equals to. This has been shown in figure 5.3.

The frame number for any RX/TX burst is decided by the start time of the burst. If $T(N)$ is the start time of the Rx frame with FN = N and $T(N+1)$ is the start time of the Rx frame with FN = N + 1, T_R is the start of an Rx burst, T_T is the start of a TX burst, then the frame number of each burst can be given as:

The Rx burst belongs to frame number N if:

$$T(N) \le T_R < T(N+1).$$

The TX burst belongs to frame number N + 7 if:

$$T(N) + \Delta T_{OF} \le T_T < T(N+1) + \Delta T_{OF} .$$

7.2 Message synchronization

7.2.1 Power control message synchronization

7.2.1.0 General

During a call, each power control message takes 6 contiguous frames (240 ms) for transmission, with the messages being sent back-to-back (no gaps).

For message synchronization purpose, one of the two entities involved in the call functions as master and the other one functions as slave. Both shall know their own positions. For TtG or GtT call, the GS functions as master, the MES functions as slave. For TtT calls, the originating MES functions as master, the terminating MES functions as slave. Two different schemes are used to achieve the PC message synchronization. One is applied in the master-to-slave direction, the other is applied to the slave-to-master direction.

Note that for the initial PC message transmissions described below, where PC messages have not yet been received, the transmit PC message shall contain the appropriate value for PAN in the PAN field, and a NULL code in the PAR field. This is true for both master and slave. See ETSI TS 101 376-4-8 [2] for specification.

During a call over DCH, each power control (PC) message takes 6 contiguous frames (240 ms) for transmission, with the messages being sent continuously. That is, PC messages are sent back-to-back (no gaps) over consecutive bursts on the assigned channel. The PC message synchronization is described in clauses 7.2.1.1, 7.2.1.2, 7.2.1.3 and 7.2.1.4.

7.2.1.1 Synchronization in master-to-slave direction (A/Gb mode only)

In the master-to-slave direction, synchronization is based on the frame number. The procedure is outlined below.

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

  FN mod 6 = 0.

- The master shall send a PC message at the first timing opportunity to do so, independent of actual PC message reception from the slave.
- The slave entity shall always receive the PC message beginning with the frame whose frame number meets FN mod 6 = L. For a TtG or GtT call, L = 0. For a TtT call, L is the number of frames slipped on the satellite, either 0 or 1.

7.2.1.2 Synchronization in slave-to-master direction (A/Gb mode only)

In the slave-to-master direction, synchronization is based on the detection of error-free Golay coding bits. This procedure is outlined below.

Slave entity:

The PC transmit position is determined at call setup as follows:

1) During call setup, the slave entity shall determine and then maintain transmit PC message synchronization by selecting one of the six possible burst positions for the beginning of the PC messages.
2) This position shall be the earliest burst (modulo 6) that meets the following restriction: There shall be a guard time of at least Tgt ms between the expected completion of the last burst of the receive PC message to the beginning of the first burst of the transmit PC message. (Note that this determination is dependent on the timeslot assignments.)
3) The value of Tgt shall equal Tp + 26 ms, where Tp is the maximum allowed MES processing time for power control messages, such that there is no PC "message slip" between the reception of a PC message and the transmission of the response. The 26 ms is used as a margin to provide for MES-satellite relative motion. Tp shall be 132,8 ms worst case.
4) The MES shall send a PC message at the first timing opportunity to do so, independent of actual PC message reception from the master.

Master entity:

Two correctly received PC messages are required to declare PC message synchronization, as follows:

1) For initial synchronization, the master entity shall continuously observe the most recent six bursts. It shall verify the 24 bits obtained as being a correct Golay message. The master entity shall re-encode the first 12 bits of the PC message, result is compared with the last 12 bits of the received PC message. Any single bit error shall cause declaration of message decoding error. This verification of the Golay message shall be performed every 40 ms, i.e. the 24-bit window is shifted by 4 bits each time. These comparison results are recorded on a per-burst basis (from 7 to 13 results, depending on channel conditions).

2) For initial synchronization, the master entity shall continuously examine the previously recorded results. It shall declare synchronization if it finds a sequence of *DFFFFFD* or *DFFFFFXFFFFFD* (where *D* corresponds to the detection of an error-free message, *F* corresponds to failure of detection, and *X* corresponds to a failure of detection at an expected *D* location).

3) Once in synchronization, Golay Decoding shall use this "D" position (modulo 6) as the current timing reference for end of the PC messages and shall decode and pass on the PC messages. This decoding shall be done even when the above sequences fail for this timing reference.

4) Re-sync: During a call, the master entity may continuously verify the status of synchronization as in Item 2, above. If the one of the expected patterns appears in a different timing position (modulo 6) than the current reference, then this new position is taken as the current timing reference - to be used for Item 3.

7.2.1.3 DCH power control message synchronization in forward direction

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

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

  FN mod 6 = 0.

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

7.2.1.4 DCH power control message synchronization in return direction

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

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

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

The value of the Power Control Synch Offset, K, shall be provided to the MES by the GS as part of the dedicated channel (DCH) assignment (see ETSI TS 101 376-4-13 [9]).

7.2.2 SACCH message synchronization, TCH6/TCH9 call (A/Gb mode only)

For SACCH message synchronization scheme, refer to annex D.

8 Synchronization for TtT call (A/Gb mode only)

8.0 General

The TtT call in the GMR-1 network can be established in two different modes: single-hop mode and double-hop mode. The following clause addresses synchronization procedure in a single-hop TtT call. For a double-hop TtT call, synchronization procedure for each communication link is the same as that described for TtG/GtT call.

From a synchronization point of view, each MES involved in the TtT call performs a number of procedures. This is shown in figure 8.1.

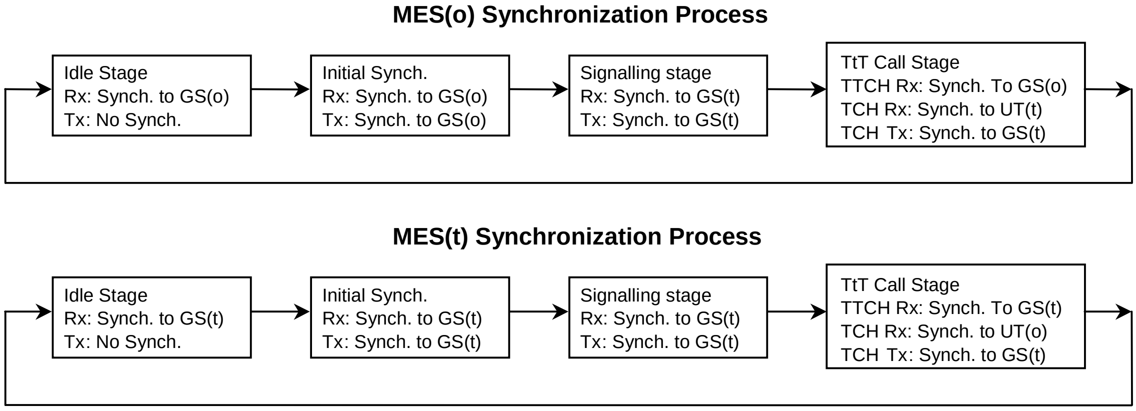

Figure 8.1: MES synchronization process for TtT call

The general TtT call synchronization scenario is outlined below.

- In idle stage, both MESs synchronize their receivers to the BCCH signal (in frequency and timing) received from their registered GSs. For MES(o), the BCCH signal comes from the originating GS, denoted as GS(o). For MES(t), the BCCH signal comes from the terminating GS, denoted as GS(t).
- In the initial synchronization stage, the originating MES(o) performs a RACH procedure with the GS(o). The MES(o) is then synchronized with the GS(o) in both frequency and timing.
- In the signalling stage, the MES(o) corrects its transmission signal to GS(t) using frequency and timing corrections received from the GS(o) and starts its signalling transmission/reception with the GS(t) in the allocated TtG channel. MES(o)-GS(t) synchronization is achieved at this point.
- On the terminating side, after receive a paging message from the GS(t), the MES(t) performs another RACH procedure to synchronize its transmission with the GS(t). After that a TtG channel is assigned and signalling exchange can be performed between the MES(t) and the GS(t).
- During the signalling stage, frequency and timing synchronization follows the same scenario described for normal TtG call.
- At appropriate time, both MESs simultaneously switch from their TtG channels to the allocated TtT channels. Meanwhile, their transmission signals are corrected by timing and frequency corrections provided from the network. Terminal-to-terminal voice call starts from this point.
- During the TtT call, both TTCH and TCH signals are used by the MES as frequency and timing reference. In the downlink, the TTCH reception is used to control the terminal's perspective of timing and frequency. This reference is also used for voice transmission. In addition, the received TCH burst is separately tracked using offset relative to the TTCH-based observation. In the uplink, MES transmission is corrected by Link Correction messages received from the TTCH channel.

As a result, there are two transition processes throughout a TtT call. One is transition from initial synchronization to signalling stage. The other is transition from signalling to TtT call stage. One task of synchronization is to provide smooth transition between different stages.

Two types of channels are involved for each terminal: TtG channel and TtT channel. The TtG channel is used by the MES for signalling exchange with the network, the TtT channel is used by the MES for voice message transmission/reception. Therefore another task of synchronization is to maintain timing and frequency synchronization accuracy in the usage of both channels.

Synchronization requirement addressed below takes the most general case as prototype, i.e. the two MESs are registered at two different GSs before a TtT call is initiated. The MES(o) is registered at GS(o), the MES(t) is registered at GS(t). Within the GS(t), two GSCs are involved during a call. The GSC(t1) is the GSC dealing with the MES(o) during the call, the GSC(t2) is the GSC dealing with the MES(t) during the call.

8.1 Timing synchronization

8.1.1 General description

The timing synchronization during a TtT call has several tasks: synchronization at initial access, synchronization of TtG channel, synchronization during the transition from TtG to TtT channel and synchronization of TtT channel.

Timing synchronization of the TtG channel: In the forward link, synchronization is performed at the MES by tracking signals received from the network. In the return link, the network keeps tracking signal arrivals transmitted from the MES, any transmission timing drift is then corrected by TC message received from the network.

Timing synchronization of the TtT channel: In the downlink, the MES maintains an independent tracking loop for both TtT signal and TTCH signal. In the uplink, TTCH-based observation is used as reference for transmission. Meanwhile, the network monitors signal arrivals transmitted from each MES, MES timing drift is then corrected by messages received from the TTCH.

The following symbolic definitions apply to the rest of the clauses. T_{01} and T_{02} : propagation delay from the satellite to the originating beam centre and terminating beam centre, T_{U1} and T_{U2} : mobile link propagation delay seen from MES(o) and MES(t). K_{U1} and K_{D1} : uplink and downlink burst position allocated to MES(o), K_{U2} and K_{D2} : uplink and downlink burst position allocated to MES(t). The burst positions are all ranged from 0 to 23.

8.1.2 Initial access

8.1.2.0 General

To synchronize terminal transmission, each terminal performs a RACH procedure to the currently registered GS. After that, on the originating side, a timing correction is provided from GS(o) to MES(o). On the terminating side, the timing correction is provided from GS(t) to MES(t). This is shown in figure 8.2.

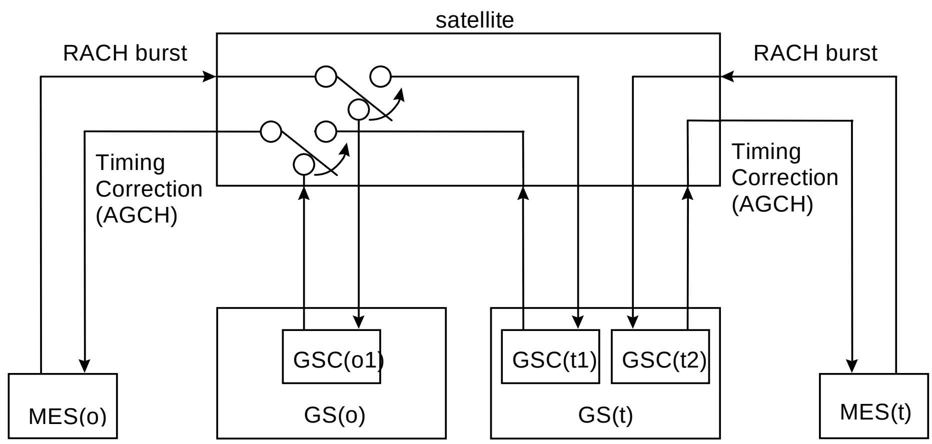

Figure 8.2: Initial timing synchronization for a TtT call

8.1.2.1 Synchronization procedure

The initial synchronization process for both MESs is outlined below:

- Before the TtT call, both MES(o) and MES(t) shall synchronize their receiver timing to the BCCH timing received from their registered GS. The MES(o) is synchronized to the BCCH timing received from GS(o), the MES(t) is synchronized to the BCCH timing received from GS(t).

- To synchronize MES transmitter with the system timing, the MES(o) shall send its RACH burst to the GS(o). Calculation of the RACH offset RACH_SYMBOL_OFFSET follows the same procedure introduced in clause 5.4.

- The GS(o) detects the MES(o)'s round trip differential delay $2[T_{U1} - T_{01}]$ relative to the originating beam centre, and passes the value of Timing Offset to the MES(o) via the AGCH channel of the originating beam.

- The MES(o) shall switch its TX/RX frequency to the allocated TtG channel, offset its TCH transmission by, and start signalling exchange with the GSC(t1) of the GS(t). At this point, the MES(o) is known as synchronized with the GS(t) using timing information obtained from GS(o).
- Sometime later, the GSC(t2) of the GS(t) starts to page the MES(t). The MES(t) shall perform a similar RACH procedure and receive a timing correction factor $2[T_{U2} - T_{02}]$ from the GSC(t2) via the AGCH channel of the terminating spot beam.
- The MES(t) shall switch its TX/RX frequency to the allocated TtG channel, offset its TCH transmission by $2[T_{U2} - T_{02}]$, and start signalling exchange with the GSC(t2) of the GS(t). At this point, both MES(o) and MES(t) are known as synchronized with the GS(t).

After initial access, the frame offset between transmission frame N + 7 and receive frame N at each MES is ΔT_{OF1} or ΔT_{OF2}, they are given as:

$$\Delta T_{OF1} = \Delta T_{OFC1} - 2[T_{U1} - T_{01}]$$
$$\Delta T_{OF2} = \Delta T_{OFC2} - 2[T_{U2} - T_{02}]$$

ΔT_{OFC1} and ΔT_{OFC2} are frame offsets between transmission frame N + 7 and receive frame N at originating and terminating beam centre, these information is broadcast over BCCH channel. For details, see clause 5.4.

8.1.2.2 Basic requirement

The GS shall be able to measure the RACH burst arrival to the accuracy better than 3,6 μs 1-sigma. After receiving the Timing Offset from the AGCH, the MES shall adjust its voice transmission timing to the accuracy better than 4,6 μs 1-sigma (with 1 μs quantization error) relative to system timing. The details of this Timing Offset message has been addressed in clause 5.4.2.

8.1.3 TtG channel synchronization

8.1.3.0 General

Two TtG channels are established for signalling message transmission at the beginning of a TtT call. One is between MES(o) and GSC(t1), the other is between MES(t) and GSC(t2). This is shown in figure 8.3.

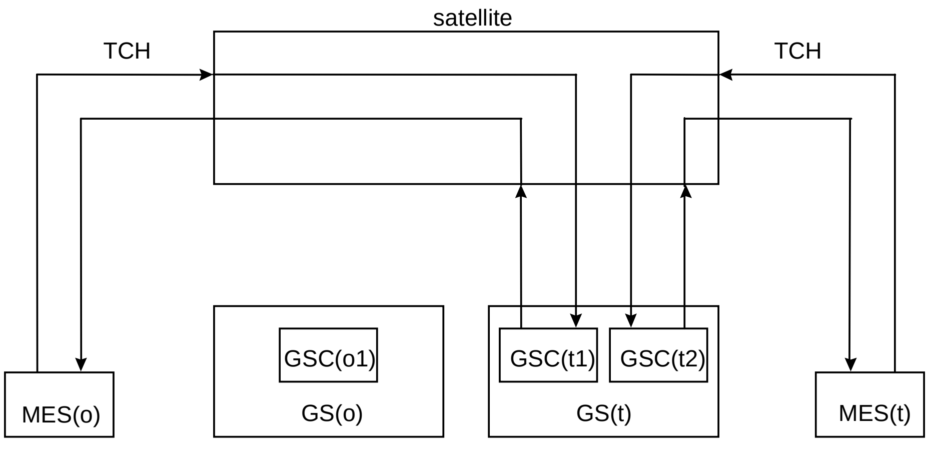

Figure 8.3: Signalling connections at the beginning of TtT call

Timing synchronization in the signalling stage is similar to that of normal TtG call. In case of a timing drift due to MES-satellite relative motion or MES master oscillator drift, both MESs shall compensate their receivers by tracking signals received in the downlink. In the uplink, transmission timing is corrected by TC messages received from the network. For MES(o), the TC message comes from GSC(t1). For MES(t), the TC message comes from GSC(t2). To perform smooth transition from TtG channel to TtT channel, a TC message shall be passed from the network to each MES before the L-to-L connection is activated.

8.1.3.1 Basic requirement

The MES tracking loop shall be implemented to accommodate the worst case timing drift shown in clause 4.3.2. Meanwhile, the TCH channel based observation shall be used as timing reference for transmission. In the signalling stage, timing synchronization requires the same accuracy as that required for normal TtG call. The Timing Correction shall have the same range and format as those described in clause 5.5.2.

8.1.4 Transition from TtG-to-TtT channel

8.1.4.0 General

After the signalling stage, both MESs switch from their corresponding TtG channels to the allocated TtT channels. From synchronization point of view, the transition stage has two major tasks: one is to setup a TtT link between the two MESs, the other is to setup a TTCH link for each MES. For MES(o), the TTCH in use is from GS(o). For MES(t), the TTCH in use is from GS(t). This is shown in figure 8.4.

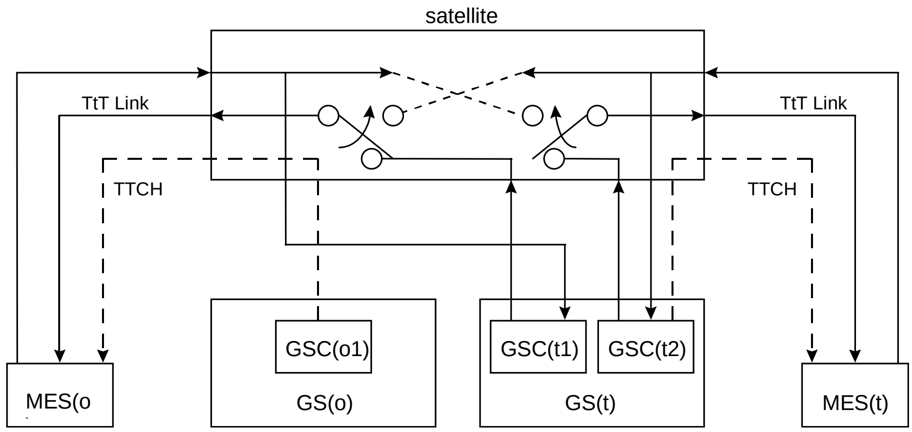

Figure 8.4: Two major tasks in the transition stage

8.1.4.1 Synchronization procedure

- A Timing Correction is provided from the network to the MES via GtT channel. For MES(o), the TC factor is provided by the GSC(t1). For MES(t), the TC factor is provided by the GSC(t2).
- Each MES receiver uses the time base established from the GtT channel (signalling) observation as timing reference, switches to the allocated TtT channel and start their TtT message reception in the downlink.
- Each MES transmitter uses the time base established from the GtT channel (signalling) observation as timing reference, switches to the allocated TtT channels using the received TC factor as precorrection, and starts TtT message transmissions in the uplink.

8.1.4.2 Basic requirement

After transition stage, MES transmission timing error relative to system timing shall meet requirements defined in ETSI TS 101 376-5-5 [4]. The Timing Correction shall have the same range and format as those described in clause 5.5.2.

8.1.5 TtT channel synchronization

8.1.5.0 General

During the TtT call, the two terminals follow the same synchronization procedure. Various transmission paths are shown in figure 8.5.

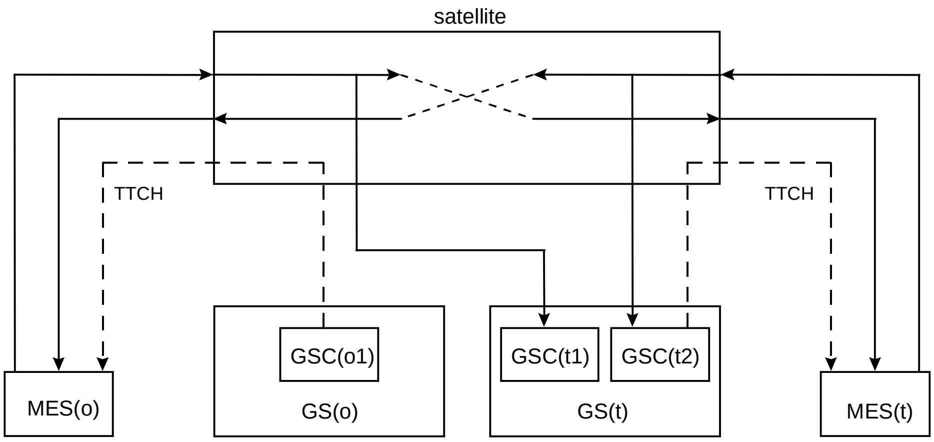

Figure 8.5: Transmission path during the TtT call

8.1.5.1 Synchronization procedure

In general, the MES timing reference is established using TTCH-based timing observation. This timing reference shall be used as TTCH reception and TCH signal transmission. A separate tracking loop shall be used to track the timing offset between TTCH signal and downlink TCH signal. In addition, any timing drift of terminal transmitter is corrected by Link Correction messages received from the TTCH channel. The timing synchronization procedure during a TtT call is outlined below.

- Within each MES, a timing reference is established though TTCH channel observation. The MES keeps monitoring the timing of TTCH burst arrival, the derived TTCH timing shall be used to update the terminal's internal timebase. This timing reference shall be used by the MES for both TTCH signal receive and TCH signal transmission.

- For MES(o), the TTCH timing received from GS(o) shall be taken as its timing reference. For MES(t), the TTCH timing received from GS(t) shall be taken as its timing reference.

- To synchronize MES receiver with downlink TCH signal, a separate tracking loop shall be provided for downlink TCH signal observation. The TCH burst arrival is monitored and the derived timing shall be used to update the receive burst timing offset relative to its internal timebase.

- For transmission timing synchronization purpose, the terminal uplink signal is monitored by the network. In figure 8.5, the MES(o) transmission signal is monitored by GSC(t1), the MES(t) transmission signal is monitored by GSC(t2).

- On the network, the actual time of TCH burst arrival is monitored. If the timing error is found to be over 10 µs, this error shall be passed to the MES as a TC message though its corresponding TTCH channel. The TC shall be made relative to the MES current transmission timing, same as that for normal TtG/GtT call described in clause 5.5.2. MES(o) receives the TC message from the TTCH transmitted from the GS(o), MES(t) receives the TC factor from the TTCH transmitted from the GS(t).

- After receiving the TC factor, the MES shall advance/retard its burst transmission by TC µs and start transmission according to the new timing within 80 ms after reception of the TC message. This adjustment shall be made in the same way as that described in clause 5.5.2.

8.1.5.2 Basic requirement

Each MES shall time its burst transmission to the accuracy specified in ETSI TS 101 376-5-5 [4]. The tracking loop of the MES receiver shall be implemented in such a way that performances for both TTCH and TCH demodulation specified in ETSI TS 101 376-5-5 [4] can be achieved. A maximum timing drift rate specified in clause 4.3.2 shall be handled for both TTCH and TCH tracking loops. The TC message shall have the same range and format as those described in clause 5.5.2.

8.1.6 Effect of the half symbol offset (TtT call)

During the initial part of a TtT call when each party is talking to a GS, the half symbol offset operation is identical to the one described in clause 5.6.

When the reassignment is made to the L-to-L channel, the GS shall inform each MES involved in the call of the offset to be used on both the forward and return links. The GS shall assign both MESs with the same offset, so that the uplink channel offset used by each MES is the same as the downlink channel offset used by the peer MES.

The GS shall never offset the TTCH channel.

8.2 Frequency synchronization

8.2.1 General description

From frequency synchronization point of view, a number of procedures are involved during a TtT call.

- Prior to the TtT call, both MESs shall lock their receivers to the BCCH carriers received from their corresponding spot beams.
- To synchronize MES transmission frequency, both MESs perform a RACH procedure to synchronize with their registered GSs in frequency. The MES(o) is then synchronized with GS(o), the MES(t) is synchronized with GS(t).
- During signalling stage using TtG channel, the MES receiver tracks signals received from the GS(t). The derived frequency is used as reference for transmission. In the uplink, any transmission frequency drift is corrected by messages received from the network.
- During the TtT call using L-to-L link, independent tracking loops are provided for TtT signal and TTCH signal. In the uplink, TTCH-based observation is used as frequency reference for transmission. Meanwhile, the network monitors signal arrivals transmitted from each MES, MES frequency drift is then corrected by FC factors received from the TTCH.

The frequency synchronization during a TtT call has several tasks: synchronization at initial access, synchronization of TtG channel, synchronization during the transition from TtG-to-TtT channel and synchronization of TtT channel.

The following symbolic definitions apply to the rest of the clauses. MES traffic channel TX/RX frequencies are F_T and F_R, the ratio between F_{RH} and F_B is $\varepsilon = F_{RH} / F_B \doteq F_T / F_R$, so that $F_{RH} = \varepsilon \cdot F_B$, $F_T \doteq \varepsilon \cdot F_R$, where $\doteq$ represents approximately equal to. In the downlink, Doppler frequency at beam centre is dF_0, Doppler received by the MES is dF_U. In the uplink, beam centre Doppler is $\varepsilon \cdot dF_0$, Doppler produced by the MES is $\varepsilon \cdot dF_U$.

8.2.2 Synchronization at initial access

8.2.2.0 General

The frequency compensation strategy at initial access is the same as that for normal TtG call. Both terminals involved in the TtT call shall align their RX/TX nominal frequencies on the satellite, this is shown in figure 8.6.

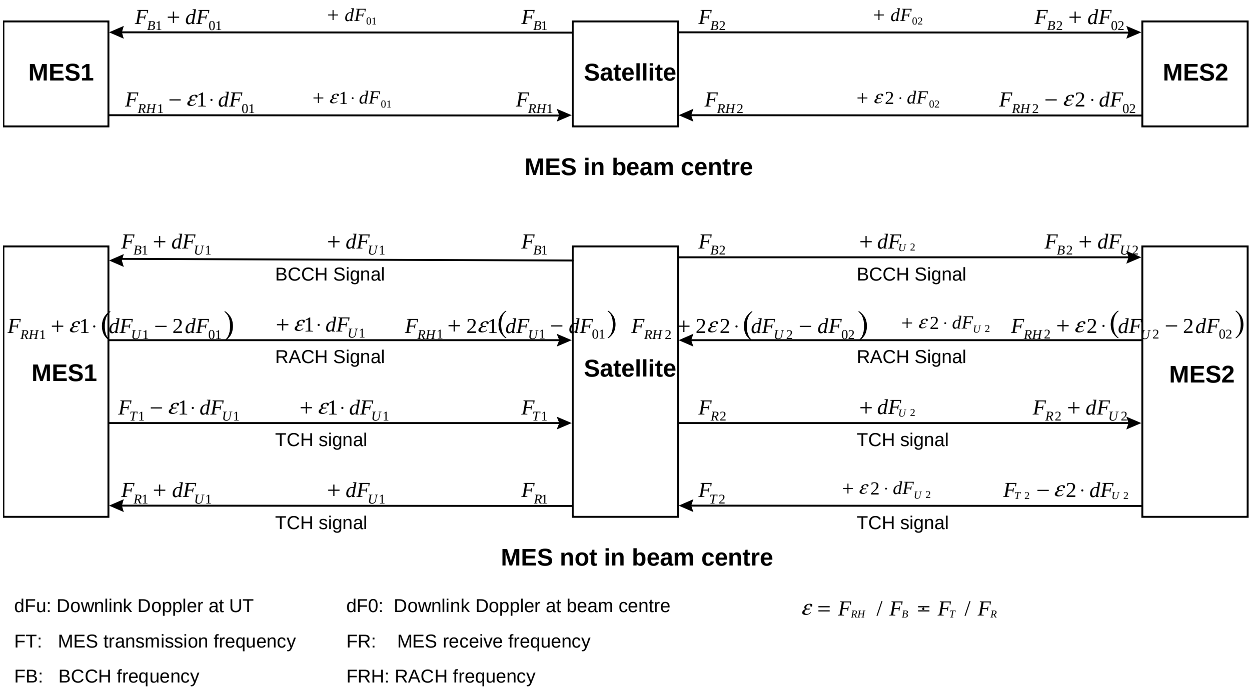

Figure 8.6: Doppler compensation scenario, TtT call

To synchronize terminal transmission frequency, each terminal performs a RACH procedure to the currently registered GS. After that, on the originating side, an FC factor is provided from GS(o) to MES(o). On the terminating side, a FC is provided from GS(t).

8.2.2.1 Synchronization procedure

The initial synchronization process for both MESs is outlined below:

- Before the TtT call, both MES(o) and MES(t) lock their receivers to the BCCH carrier received from their registered GS. The BCCH carrier used by MES(o) is received from the GS(o), the BCCH carrier used by MES(t) is received from GS(t).
- To synchronize MES transmitter in frequency, the MES(o) sends its RACH burst to the GS(o). The transmission frequency is generated using downlink BCCH frequency as reference, with $2 \cdot \varepsilon \cdot dF_{01}$ as pre-compensation. The value of $2 \cdot dF_{01}$ is twice the downlink beam centre Doppler due to satellite motion, it is received from the BCCH channel and has been detailed in clause 4.4. ε is the ratio between RACH frequency and BCCH frequency, and is calculated by the MES.
- The GS(o) detects the MES(o)'s round-trip differential Doppler $2\varepsilon \times [dF_{U1} - dF_{01}]$ relative to the originating beam centre, and passes this value to the MES(o) via the AGCH channel of the originating beam as FREQUENCY OFFSET. This message shall have the same range and format as those described in clause 4.4.2.
- The MES(o) uses downlink BCCH frequency F_{B1} as reference, switches its Tx/Rx frequencies to the allocated TtG channel, offsets its TCH transmission by the FREQUENCY OFFSET (approximately $2\varepsilon[dF_{U1} - dF_{01}]$), and starts signalling exchange with the GSC(t1) of the GS(t). At this point, the MES(o) is known as synchronized with the GS(t) in frequency using information obtained from GS(o).

- Sometime later, the GSC(t2) of the GS(t) starts to page the MES(t). The MES(t) performs a similar RACH procedure and receives a FREQUENCY OFFSET (approximately $2\varepsilon \cdot \left[dF_{U2} - dF_{02}\right]$) from the GSC(t2) via the AGCH channel of the terminating spot beam.
- The MES(t) uses downlink BCCH frequency F_{B2} as reference, switches its TX/RX frequencies to the allocated TtG channel, offsets its TCH transmission by the FREQUENCY OFFSET, and starts signalling exchange with the GSC(t2) of the GS(t).
- At this point, both MES(o) and MES(t) are known as synchronized with the GS(t) in frequency. On the satellite reference point, signal frequencies transmitted to both MESs are all nominal, signal frequencies received from both MESs are also nominal.

8.2.2.2 Basic requirement

After the RACH process, the MES shall adjust its transmission frequency to the accuracy better than 17,6 Hz 1-sigma (with 12,6 Hz RACH detection error and 5 Hz quantization error) relative to nominal frequency. This accuracy shall be met under the channel conditions specified in ETSI TS 101 376-5-5 [4].

8.2.3 TtG channel synchronization

8.2.3.0 General

As was shown in figure 8.3, there are two TtG channels at signalling message transmission stage. One is between MES(o) and GSC(t1), the other is between MES(t) and GSC(t2).

Frequency synchronization scheme in the signalling stage is similar to that of normal TtG call. In case of any frequency drift due to a change of MES-satellite relative velocity or MES master oscillator drift, both MESs shall compensate their receivers by tracking the TCH signals received from the network. In the uplink, transmission frequency is corrected by FC messages received from the network. For MES(o), the FC message comes from GSC(t1). For MES(t), the FC message comes from GSC(t2). To perform smooth transition from TtG channel to TtT channel, a FC message shall be passed from the network to each MES before the L-to-L connection is activated.

8.2.3.1 Basic requirement

The MES tracking loop shall be implemented to accommodate the worst case frequency drift shown in clause 4.3.2. Meanwhile, the TCH channel based observation shall be used as frequency reference for transmission. In the signalling stage, frequency synchronization requires the same accuracy as that required for normal TtG call. The Frequency Correction shall have the same range and format as those described in clause 6.4.2.

8.2.4 Transition from TtG-to-TtT channel

8.2.4.0 General

After the signalling stage, both MESs switch from their corresponding TtG channels to the allocated TtT channels. Again, from frequency synchronization point of view, the transition stage has two major tasks: one is to set up a TtT link between the two MESs, the other is to set up a TTCH link for each MES. For MES(o), the TTCH in use is from GS(o). For MES(t), the TTCH in use is from GS(t). This has been shown in figure 8.4.

8.2.4.1 Synchronization procedure

- A Frequency Correction (FC) shall be provided from the network to the MES via GtT channel. For MES(o), the FC factor is provided by the GSC(t1). For MES(t), the FC factor is provided by the GSC(t2).
- Both MES receivers shall use their downlink GtT channel as frequency reference, switch to the allocated TtT channel and start their TtT message reception in the downlink.
- Both MES transmitters shall use their current TtG channel downlink frequency as reference, switch to the allocated TtT channels, use the received FC factors as precorrection, and start TtT message transmissions on the new channels.

8.2.4.2 Basic requirement

After the L-to-L cross link is activated, each of the two MES receivers is required to receive two signals, one is TCH signal, the other is TTCH signal. But the MES transmitter only transmits signals to the other MES. MES transmission frequency error shall be better than 15 Hz 1-sigma relative to nominal frequency, under channel conditions specified in ETSI TS 101 376-5-5 [4]. The Frequency Correction shall have the same range and format as those described in clause 6.4.2.

8.2.5 TtT channel synchronization

8.2.5.0 General

During a TtT call, the two terminals follow the same synchronization procedure. Various transmission paths have been shown in figure 8.5.

8.2.5.1 Synchronization procedure

In general, the MES frequency reference is established using TTCH-based frequency observation. This frequency reference shall be used as TTCH reception and TCH signal transmission. A separate tracking loop shall be used to track the frequency offset between TTCH signal and downlink TCH signal. In addition, any frequency drift of terminal transmitter shall be corrected by Frequency Correction (FC) messages received from the TTCH channel. The frequency synchronization procedure during a TtT call is outlined below.

- Within each MES, a frequency reference shall be established though TTCH channel observation. The MES keeps monitoring the frequency of TTCH burst arrival, the derived TTCH frequency shall be used to update the terminal's internal frequency reference. This reference shall be used by the MES for both TTCH signal receive and TCH signal transmission.

- For MES(o), the TTCH frequency received from GS(o) shall be taken as its frequency reference. For MES(t), the TTCH frequency received from GS(t) shall be taken as its frequency reference.

- To synchronize MES receiver with downlink TCH signal, a separate tracking loop shall be provided for downlink TCH signal observation. The TCH burst arrival is monitored and the derived frequency shall be used to update the TCH frequency offset relative to the TTCH-based frequency reference.

- For transmission frequency synchronization purpose, the terminal uplink signal is monitored by the network. In figure 8.5, the MES(o) transmission signal is monitored by GSC(t1), the MES(t) transmission signal is monitored by GSC(t2).

- On the network, the actual frequency of TCH burst arrival is monitored. If the frequency error is found to be over a predefined threshold 40 Hz, this error shall be passed to the MES as a FC factor though its corresponding TTCH channel. MES(o) receives the FC factor from the TTCH transmitted from the GS(o), MES(t) receives the FC factor from the TTCH transmitted from the GS(t).

- After receiving the FC factor, the MES shall adjust its burst transmission by FC Hz and start transmission according to the new frequency within 80 ms after reception of the Link Correction message. This frequency adjustment shall be made in the same way as that described in clause 6.5.

8.2.5.2 Basic requirement

During a TtT call, the TTCH-based frequency observation shall be used as reference for TTCH reception and TCH transmission. Transmission frequency accuracy relative to nominal frequency shall meet requirement defined in ETSI TS 101 376-5-5 [4]. The downlink TCH-based frequency observation shall be used as frequency reference for TCH signal reception. The MES receiver frequency error shall be small enough so that demodulation performances specified by ETSI TS 101 376-5-5 [4] can be achieved. The Frequency Correction shall have the same range and format as those described in clause 6.4.2.

8.3 Frame synchronization

The frame number variation on the satellite L-to-L connection is given as follows: Lot is the frame number variation for signal from MES(o) to MES(t), Lto is the frame number variation for signal from MES(t) to MES(o). The value of Lot and Lto is either 0 or 1. At the beginning of the call, the MES(t) shall be informed with the value of Lot, the MES(o) shall be informed with the value of Lto.

For ciphering purpose, the frame synchronization has two different stages for each MES. In the first stage, frame synchronization is established between each MES and the GS(t), the channel in use is GtT channel. In the second stage, frame synchronization is established between the two MESs, the channel in use is TtT channel.

Originating MES Side: MES(o)

The signalling message "Cipher Mode Command" stands for the beginning of ciphering process in the GtT channel. If the "Cipher Mode Command" is received in frame N, in the uplink, ciphering process shall be started beginning from frame N + 9. In the downlink, deciphering process shall be started beginning from frame N + 3. If a message is transmitted in frame K, the ciphering algorithm shall use frame number K. If a message is received from frame K, the deciphering algorithm shall also use frame number K.

The signalling message "Assignment Command 2" stands for the beginning of ciphering process in the TtT channel. If the "Assignment Command 2" is received in frame M, in the uplink, ciphering process to the TtT channel shall be started beginning from frame M + 9. In the downlink, deciphering process from the TtT channel shall be started beginning from frame M + 3. If a message is transmitted in frame K, the ciphering algorithm shall use frame number K. If a message is received in frame K, the deciphering algorithm shall use frame number K-Lto.

Terminating MES Side: MES(t)

The signalling message "Cipher Mode Command" stands for the beginning of ciphering process in the GtT channel. If the "Cipher Mode Command" is received in frame N, in the uplink, ciphering process shall be started beginning from frame N + 9. In the downlink, deciphering process shall be started beginning from frame N + 3. If a message is transmitted in frame K, the ciphering algorithm shall use frame number K. If a message is received from frame K, the deciphering algorithm shall also use frame number K.

The signalling message "Assignment Command 2" stands for the beginning of ciphering process in the TtT channel. If the "Assignment Command 2" is received in frame M, in the uplink, ciphering process to the TtT channel shall be started beginning from frame M + 9. In the downlink, deciphering process from the TtT channel shall be started beginning from frame M + 3. If a message is transmitted in frame K, the ciphering algorithm shall use frame number K. If a message is received in frame K, the deciphering algorithm shall use frame number K-Lot.

9 Aeronautical terminal synchronization scheme

9.1 MES special features

9.1.1 Speed

Commercial aircraft fly at speeds less than about 1 000 km/h. This is over six times the speed of vehicular-mounted terminals. The time required for an aircraft to completely turnabout is typically 1 to 2 minutes. These characteristics imply timing, Doppler, and their rate-of-change as described in the following clauses.

9.1.2 Worst-case delay and Doppler features

The following assumes that nominal frequency in the mobile uplink is 1,6605 GHz. In the mobile downlink, nominal frequency is 1,5590 GHz. The maximum user velocity is 1 000 km/h, moving directly to the satellite. The time required for an aircraft to completely turn is 1 minute.

Table 9.1: Time delay features

Item	Value
Maximum timing drift rate (user contribution)	1,11 μs/s
Maximum timing drift rate (satellite contribution)	0,17 μs/s
Maximum timing drift rate (total)	1,28 μs/s

Table 9.2: Doppler features, user contribution

Item	Value
Maximum Doppler (uplink)	1,538 kHz
Maximum Doppler (downlink)	1,444 kHz
Maximum Doppler rate of change (uplink)	51 Hz/s
Maximum Doppler rate of change (downlink)	48 Hz/s

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

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

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

9.1.3 Frequency offset

Due to the large Doppler and rate-of-change of Doppler, the method used in ground-based terminals to measure and correct Doppler shall not suffice here. Therefore, extra effort shall be made in the aircraft to combat these effects. The principal method is to incorporate a higher stability frequency reference into the aircraft terminal that can be used to derive the absolute frequency offset the air terminal is experiencing and compensate for it in the return direction. The net effect shall be an aircraft terminal that emulates a slowly moving vehicular terminal. The degree of precision required shall be better than $2{,}5\times10^{-7}$. The long-term frequency drift of the oscillator shall be adjusted based on the standard frequency control loops in the existing infrastructure.

9.2 Frequency synchronization

9.2.1 Frequency synchronization general description

Due to the MES high speed and its variation, Doppler frequency can be very large and its rate of change can be much higher than that of a ground-based terminal. In the downlink, this results in the Doppler rate of change being out of the range which a ground-based terminal tracking loop can handle. In the uplink, the large Doppler variation results in frequent message correction from the network to the MES. For this reason, upgrade from a ground-based terminal shall be done in the following two aspects. First, an aeronautical terminal shall be equipped with a high stability frequency source from which nominal frequency can be derived with high accuracy. The MES shall use this source as its frequency reference for both transmission and receive. In addition, the MES shall be able to derive absolute Doppler frequency caused by MES-satellite relative motion. This is done by comparing the derived downlink carrier frequency with its nominal value. This Doppler frequency is then applied to MES transmitter so that MES transmission signal seen from the satellite is close to nominal.

The overall frequency error caused by MES oscillator and Doppler observation all together shall be better than 0,25 ppm.

9.2.2 Idle mode frequency synchronization

9.2.2.1 Initial frequency acquisition

At initial acquisition, the MES shall tune its receiver to the BCCH nominal frequencies based on its internal frequency reference. To acquire frequency synchronization to the selected control carrier, the MES frequency search range shall cover the range of frequency offset caused by aircraft motion (±1,5 kHz) as well as frequency offset caused by satellite motion (±264 Hz). After frequency acquisition, the MES receiver frequency accuracy relative to the received signal shall meet demodulation performances specified by ETSI TS 101 376-5-5 [4].

9.2.2.2 Paging mode

In paging mode, the MES tunes its receiver to the frequency of downlink control carrier based on its internal frequency reference and control channel frequency offset. Similar to a ground-based terminal, to maintain synchronization, the control channel frequency offset is adjusted based on the standard tracking procedure. The MES receiver frequency tracking is based on either a PCH channel or a BCCH channel.

9.2.2.3 Alerting mode

In alerting mode, the MES again tunes its receiver to the frequency of downlink control carrier based on its internal frequency reference and control channel frequency offset. To maintain synchronization, the control channel frequency offset is adjusted based on the standard tracking procedure of the FCCH channel.

In both paging and alerting mode, the MES receiver frequency tracking loop needs to handle the worst-case Doppler frequency rate of change specified in clause 9.1.2. The tracking loop shall be implemented in such a way that demodulation performances specified in ETSI TS 101 376-5-5 [4] can be achieved.

9.2.3 Synchronization at initial access

9.2.3.1 Frequency compensation strategy

The RACH process for an aeronautical MES differs from that of a ground-based terminal in such a way that prior to the RACH process, the MES already knows the Doppler frequency caused by MES-satellite relative motion. To send a RACH signal, the MES simply offsets its transmission by this Doppler value, then a nominal frequency can be expected on the satellite.

On the network side, an aeronautical terminal is treated in the same way as that for a ground-based terminal. The GS measures the frequency difference between the actual burst arrival and the expected arrival, a Frequency Correction is then passed to the MES via AGCH channel. As the MES is equipped with an accurate frequency reference, and the uplink Doppler has already been compensated, the transmission of an aeronautical terminal always behaves like that from a stationary terminal, which is located close to spot beam centre.

The above description can be symbolically expressed as follows. If nominal RACH transmission frequency is F_{RH0}, nominal BCCH carrier frequency is F_{B0}, due to the Doppler effect, receive frequency measured by the MES is F_B (therefore Doppler frequency observed by the MES is $F_B - F_{B0}$). Then the MES shall adjust its RACH transmission to frequency F_{RH} , and

$$F_{RH} = F_{RH0} - \varepsilon(F_B - F_{B0}) .$$

After a Frequency Correction ΔF is received from the AGCH, the MES shall adjust its transmission so that transmission frequency becomes to be:

$$F_{RH} = F_{RH0} - \varepsilon(F_B - F_{B0}) - \Delta F .$$

Since the MES internal reference and Doppler observation are both accurate enough, the value of this correction ΔF is always close to zero.

9.2.3.2 Parameter description

The aeronautical terminal shall achieve the same transmission and receive performances specified for ground-based terminal. After the RACH process, the MES transmission frequency error seen from the satellite shall be smaller than 17,6 Hz 1-sigma relative to nominal frequency.

The Frequency Correction in the AGCH channel shall have the same format and step size as those described for ground-based terminal.

9.2.4 Dedicated mode synchronization

9.2.4.0 General

During the packet transfer connected mode, both MES transmitter and receiver shall use its internal frequency source as reference. The uplink signal shall be corrected by downlink signal-based Doppler frequency observation. In addition, residual transmission frequency error is compensated further by Link Correction messages received from the GS.

9.2.4.1 Frequency compensation strategy

In the downlink, the frequency tracking loop of the MES receiver shall be able to accommodate the large rate of frequency change caused by the variation of MES-satellite relative speed. The maximum rate of frequency change has been given in clause 9.1.2. Though this tracking procedure, the MES receiver shall be able to maintain its frequency accuracy relative to the received signal to meet the demodulation performances specified in ETSI TS 101 376-5-5 [4].

In the uplink, the MES uses its internal frequency source as reference to decide the nominal transmission frequency. This frequency is then corrected by downlink signal based frequency offset observation. Assuming nominal MES transmission frequency is F_{T0}, nominal receive frequency is F_{R0} due to the Doppler effect, downlink receive frequency measured by the MES is F_R (therefore Doppler frequency observed by the MES is $F_R - F_{R0}$). Then the MES shall adjust its transmission to frequency F_T, and

$$F_T = F_{T0} - \varepsilon(F_R - F_{R0}).$$

During the packet transfer connected mode, the downlink signal frequency is constantly monitored by the MES. If the frequency of the received signal changes from F_R to $F_R + \Delta F$, this change shall be immediately applied to its transmission. The updated transmission frequency equals:

$$F_T = F_{T0} - \varepsilon(F_R + \Delta F - F_{R0}).$$

Due to this adjustment, the MES shall achieve the same transmission performances specified for a ground-based terminal. As a result, from the network, the aeronautical terminal looks like a normal ground-based terminal in terms of its transmission frequency.

If the MES receiver frequency tracking loop cannot completely follow the frequency change of the downlink signal without any error, a frequency error is introduced to the uplink transmission signal. This remaining transmission frequency error shall be detected on the GS. A Link Correction message is then passed to the MES in the same way as that used for ground-based terminal, as described in clause 6.6. The MES shall use this message to update its PDCH transmission frequency.

In A/Gb mode, when the GS instructs an MES to switch from one channel to another (i.e. from SDCCH to TCH), a Frequency Correction shall be provided to the MES. The MES then shall switch to the new channel and apply the received value to both of its transmitter and receiver.

9.2.4.2 Parameter description

In terms of frequency accuracy, an aeronautical terminal shall achieve the same transmission and receive performances specified for a ground-based terminal. The same Link Synchronization Information Element shall be used by the GS to send the frequency corrections to the MES for both the ground-based terminals and the Aeronautical terminals.

In A/Gb mode, the Link Correction message in the FACCH (TCH3) or SACCH (TCH6/TCH9) channel shall have the same format and step size as those described for a ground-based terminal.

9.3 Timing synchronization

9.3.1 Timing synchronization general description

Timing synchronization of an aeronautical terminal differs from that of a ground-based terminal in two different ways. First, due to the large timing drift rate caused by the aircraft motion, it is crucial to use Doppler frequency to estimate the timing drift rate. This timing drift rate shall be used to adjust both receive and transmission timing. In addition, due to the large timing drift rate, relative motion between uplink and downlink bursts at the reference point of an aeronautical MES is much faster than that of a ground-based terminal. This makes it very difficult to separate the RX/TX burst timing and to maintain enough guard time for all users throughout the call. As a result, an aeronautical terminal shall be equipped with a diplexer, which allows simultaneous transmit and receive.

The MES shall calculate the current timing drift rate R based on the following if ΔF is the one-way Doppler frequency measured in the unit of Hz, F is the downlink signal nominal frequency measured in the unit of GHz. Then R shall be calculated as:

$$R = \frac{\Delta F}{F}\,(ns/\mathrm{s})$$

For an aeronautical terminal moving with a speed up to 1 000 km/h, the range of R can be up to ±0,926 μs/s. The Doppler frequency shall be always calculated from the downlink signal based observation, i.e. the difference between downlink signal frequency measurement and nominal receive frequency. In idle mode (paging or alerting mode), the downlink signal refers to BCCH signal. During the packet transfer mode, the downlink signal refers to the PDCH signal.

The rest of the synchronization scheme is similar to that of a ground-based terminal. In idle mode, BCCH timing is used as MES timing reference, i.e. this timing is used to update MES internal time base. During the packet transfer mode, the derived timing from the downlink signal (PDCH) is used as reference for its transmission. In addition, to maintain synchronization, the MES transmission timing shall be corrected by the timing corrections received from the GS. RACH timing is still set up by messages provided over the BCCH. PDCH timing is corrected by corrective messages given over the AGCH and in the link synchronization messages transferred during the packet transfer mode.

For A/Gb mode, TCH or SDCCH timing is corrected by corrective messages given over the AGCH. In a call, timing the corrections is provided by FACCH (TCH3) or SACCH (TCH6/TCH9).

9.3.2 Idle mode timing synchronization

9.3.2.1 Initial timing acquisition

Same as ground-based terminal.

9.3.2.2 Paging mode

Same as ground-based terminal.

9.3.2.3 Alerting mode

Same as ground-based terminal.

In both paging and alerting mode, the downlink signal-based Doppler frequency observation shall be used to calculate MES timing drift rate. This timing drift rate is then used by the MES to adjust its internal time base in order to compensate MES-satellite relative motion. The timing drift rate shall be proportionally applied to the adjustment, once every Ts. Then ΔT , the value of the adjustment each time is $\Delta T = T \cdot R$ ns.

9.3.3 Synchronization at initial access

At initial access, an aeronautical terminal uses the same RACH procedure as that described for ground-based terminal.

9.3.4 Dedicated mode synchronization

9.3.4.1 Doppler-based timing adjustment

During a call or during the packet transfer mode, both MES-receive and MES-transmission timing are adjusted by the Doppler based timing drift rate R. Each time the MES shall apply a fraction of R to the adjustment, the adjustment shall be made once every Ts.

To align MES receiver with downlink signal in time, the MES internal timing reference shall be incremented by ΔT ns once every Ts. Notice ΔT can be either positive or negative; therefore, the adjustment can be made in both directions. Each time a change of frequency measurement of the received signal results in an update of the timing drift rate R. The new value of R (and therefore new value of ΔT) shall be applied to the MES timing reference in the next update period immediately following this change.

Since the MES transmission timing uses the received timing as reference, the transmission timing drift rate is doubled compared with the receive direction. To correct MES transmission timing, the adjustment shall be applied to the parameter ΔT_{OF} , the offset between uplink frame N + 7 and downlink frame N, which has been defined before.

If the MES RX timing reference is adjusted by ΔT ns once every Ts, then ΔT_{OF} shall be adjusted by $2 \times \Delta T$ ns in the opposite direction, with Ts as adjustment interval. This can be expressed as:

$$\Delta T_{OF} = \Delta T_{OF} - 2 \times \Delta T .$$

9.3.4.2 Standard timing synchronization procedure

Though the Doppler-based timing adjustment procedure, the MES itself shall be able to compensate most of the timing drift without any correction received from the network. However, if the application of timing drift rate is still not enough to compensate all timing error (due to Doppler measurement error), the GS shall be able to correct the remaining timing error by providing a Timing Correction message as described in clause 5.6.

9.3.4.3 Parameter description

In terms of timing accuracy, an aeronautical terminal shall achieve the same transmission and receive performances specified for a ground-based terminal. The Timing Correction message in the Link Synchronization IE shall have the same format and step size as those described for a ground-based terminal.

In A/Gb mode, the Timing Correction in the FACCH (TCH3) or SACCH (TCH6/TCH9) channel shall have the same format and step size as those described for a ground-based terminal.

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

A.1 L-band

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

The maximum satellite inclination angle is 6,7°. Both time delay and satellite motion are approximately sinusoidal with a period of 24 h. The worst-case user has an elevation of 20° when the satellite is on equator.

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

In the mobile uplink, nominal frequency is 1,6605 GHz. In the mobile downlink, nominal frequency is 1,5590 GHz.

Table A.1: Time delay features

Item	Value
Minimum Delay	129,66 ms
Maximum Delay	134,33 ms
Maximum Rate of Delay Change (satellite contribution)	0,1696 μs/s
Maximum rate of delay change (user contribution)	0,1482 μs/s
Maximum rate of delay change (overall value)	0,3178 μs/s

Table A.2: Doppler features, satellite contribution

Item	Value
Maximum Doppler (uplink)	282 Hz
Maximum Doppler (downlink)	264 Hz
Maximum Doppler rate of change (uplink)	0,0204 Hz/s
Maximum Doppler rate of change (downlink)	0,0192 Hz/s

Table A.3: Doppler features, user contribution

Item	Value
Maximum Doppler (uplink)	246 Hz
Maximum Doppler (downlink)	231 Hz
Maximum Doppler rate of change (uplink)	24,6 Hz/s
Max. Doppler rate of change (downlink)	23,1 Hz/s

Table A.4: Doppler features, overall values

Item	Value
Maximum Doppler (uplink)	528 Hz
Maximum Doppler (downlink)	495 Hz
Maximum Doppler rate of change (uplink)	24,6 Hz/s
Maximum Doppler rate of change (downlink)	23,1 Hz/s

A.2 S-band

Addition for S-band is as follows.

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

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

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

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

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

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

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

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

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

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

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

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

Annex B (informative): Range of timing correction factor

The maximum round-trip differential delay relative to beam centre $2 \times [T_U - T_0]$ is calculated for 0,7° nominal beam angle and 50 % beam angle extension. Calculation results are given in figure B.1 under various elevation angles seen from the furthest corner of the spot beam. From this graph, the value of $2 \times [T_U - T_0]$ varies from 0 ms to 9,73 ms.

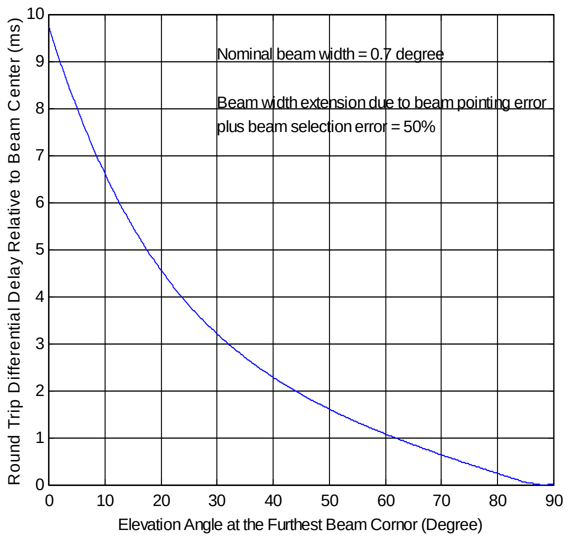

Figure B.1: Maximum round-trip differential delay within spot beams

Annex C (informative): Differential Doppler frequency

The maximum beam differential Doppler frequency relative to beam centre for a stationary MES located on the beam edge is calculated for various spot beam elevation angles, result is given in figure C.1. From this graph, the differential Doppler is less than ±11 Hz worst case.

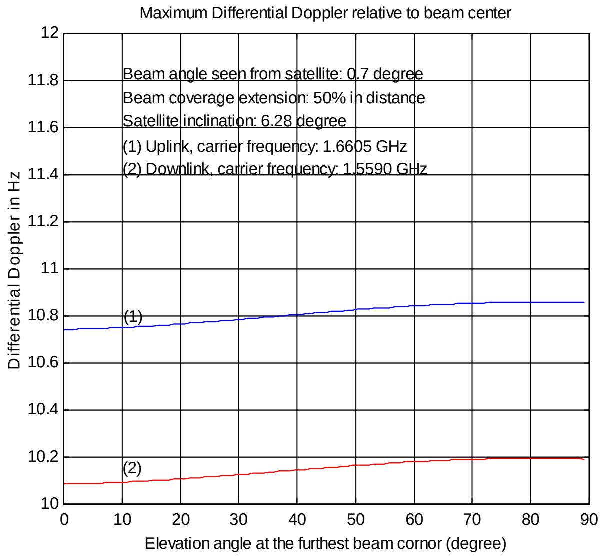

Figure C.1: Maximum differential Doppler, stationary MES on beam edge

Annex D (informative): SACCH message synchronization, TtG/GtT call (A/Gb mode only)

D.0 General

Baseline design: The MES uses a fixed SACCH message transmission frame offset relative to the frame number of the received SACCH message. One SACCH frame offset will be applicable to all users in the system.

D.1 SACCH message synchronization scenario

With a single frame offset, the available MES processing time between message receive and transmission depends on MES position and burst position. Two extremes are considered: The smallest processing time and the largest processing time.

The smallest processing time: MES with the lowest elevation, forward link burst in position 23, 0, 1, return link burst position in 0, 1, 2. For minimum processing time = 120 ms, first TX frame = N + 11. See figure D.1.

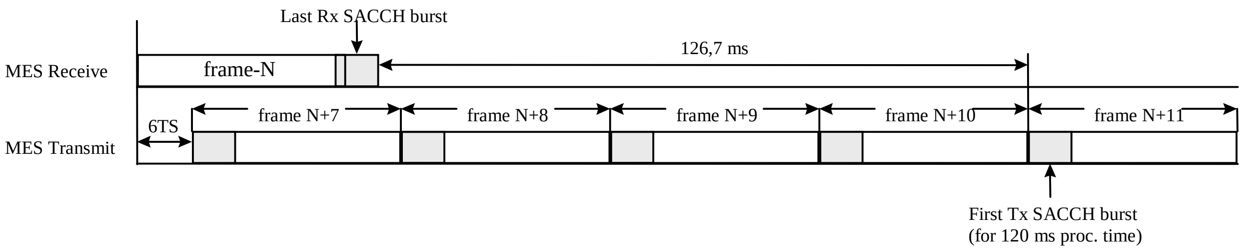

Figure D.1: The worst-case available at processing time, MES with the lowest elevation, for SACCH message

The largest processing time: MES on subsatellite point, forward link burst in position 0, 1, 2, return link burst position in 23, 0, 1. For minimum processing time = 120 ms, TX frame number = N + 11, there is a maximum 240 ms processing interval. This is the penalty of the SACCH transmission algorithm. See figure D.2.

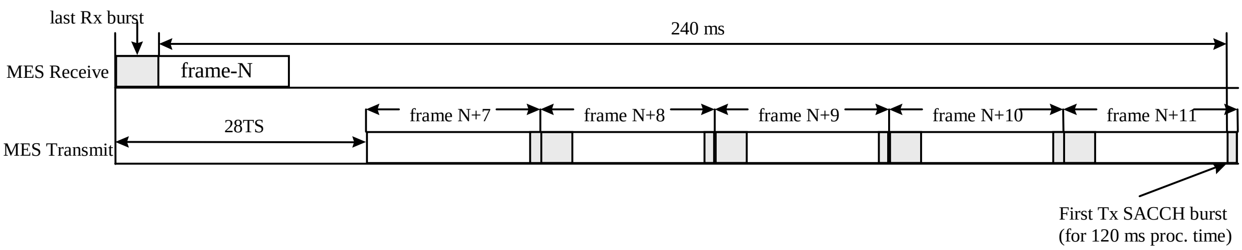

Figure D.2: The longest available MES processing time, MES on subsatellite point, for SACCH message

D.2 SACCH message-round trip delay

The round-trip SACCH message delay is defined to be the interval from the beginning of the first SACCH message burst transmitted from the network to the arrival of the last response burst received from the MES. See figure D.3.

T_N : feeder link delay,: T_U service link delay, dT : interval between the last received frame (frame N) and the first transmitted frame (frame N + 11) at the position of MES.

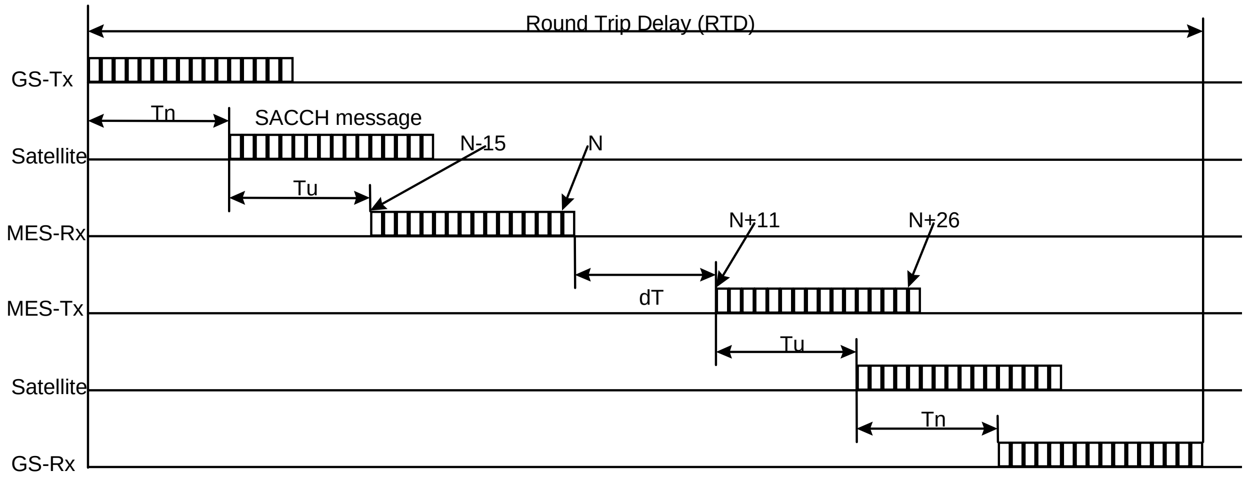

Figure D.3: Timing relationship for SACCH message round-trip transmission

Interval dT :

$$dT = 10T_F - 2T_U$$

RTD calculation, assuming satellite delay is zero:

$$\begin{aligned} RTD &= 32T_F + 2T_N + 2T_U + dT - K_D T_S - (T_F - K_U T_S - T_{CH}) \\ &= 41T_F + 2T_N + (K_U - K_D + X)T_S \end{aligned}$$

For TCH6, X = 6. For TCH9, X = 9. Let

$$W = 2T_N + (K_U - K_D)T_S$$

then

$$RTD = 41T_F + W + X \times T_S$$

and

$$\begin{aligned} W_{\min} &\le W \le W_{\max} \\ W_{\min} &= 2T_{N\min} - 23T_S \\ W_{\max} &= 2T_{N\max} + 23T_S \end{aligned}$$

The RTD is calculated as a function of W, results are given in figure D.4.

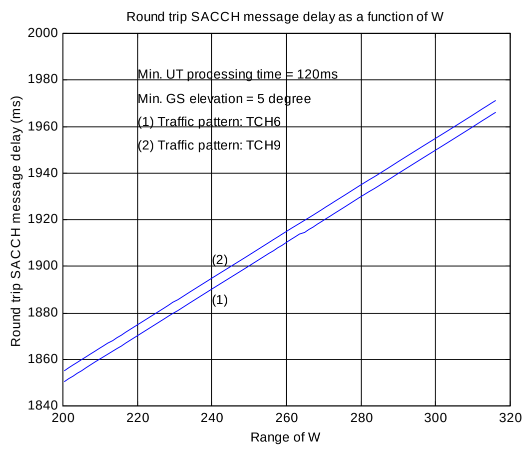

Figure D.4: Round-trip SACCH message transmission delay (ms)

From this graph, the earliest response message takes about 1 850 ms to arrive at the GS, the latest response message takes about 1 970 ms to arrive at the GS. This is shown in figure D.5.

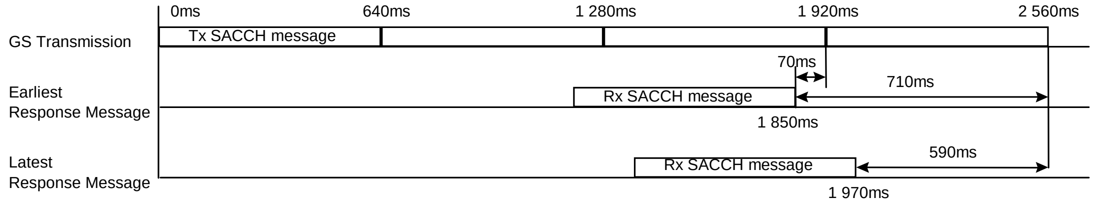

Figure D.5: SACCH message transmission/reception at the GS

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

After every reception of a scheduled timing correction, an unsolicited timing correction or an initial timing correction, the MES shall restart a timer, T3202 = PACKET_RANDOM_ACCESS_TIMER. For random access, the MES may use a PAB in any PRACH or a RACH burst in any RACH provided its timer T3202 has not expired. There are procedures requiring to use RACH to access the network even if T3202 is not expired (see ETSI TS 101 376-4-8 [2]).

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

For random access after T3202 has expired, the MES shall use a RACH burst in a RACH. The GS shall broadcast the value of PACKET_RANDOM_ACCESS_TIMER in system information (see ETSI TS 101 376-4-8 [2] and ETSI TS 101 376-4-12 [7]).

Annex F (normative): PTCCH/U and PTCCH/D scheduling (A/Gb mode only)

The MES shall derive its assigned PTCCH/U from the TAI value (see ETSI TS 101 376-4-12 [7]) and the value of PKT_TIMING_CORR_CYCLE parameter broadcast by the GS in system information. (see ETSI TS 101 376-4-8 [2]). Using:

$$P = TAI \bmod 4$$

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

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

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

and

$$UFN \bmod 16 = 15.$$

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

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

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

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

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

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

On the PDCH downlink burst corresponding to an assigned PTCCH/U timeslot, the GS shall set the USF to the reserved value (see ETSI TS 101 376-4-12 [7]). In order to send the PTCCH/U burst, the MES shall confirm that the received USF value is set to the reserved value on the PDCH downlink timeslot which corresponds to the PTCCH/U timeslot. If the MES receives two consecutive downlink bursts in the PDCH corresponding to its assigned PTCCH/U time slot in which the USF is set to another value than reserved, the MES shall declare the link dead (see ETSI TS 101 376-5-6 [5]).

On the PDCH downlink burst corresponding to an assigned PTCCH/U timeslot, the GS shall set the USF to the reserved value (see ETSI TS 101 376-4-12 [7]). In order to send the PTCCH/U burst, the MES shall confirm that the received USF value is set to the reserved value on the PDCH downlink timeslot which corresponds to the PTCCH/U timeslot. If the MES receives a downlink burst in the PDCH corresponding to its assigned PTCCH/U time slot in which the USF is set to in-use, the MES shall not transmit on that time slot. If the MES receives two consecutive downlink bursts in the PDCH corresponding to its assigned PTCCH/U time slot in which the USF is set any value other than either reserved or in-use, the MES shall declare the link dead (see ETSI TS 101 376-5-6 [5]).

The GS shall not reassign any Timing Advance Indicator (TAI) (see ETSI TS 101 376-4-12 [7]) value which it has assigned to an MES before completion of at least three timing correction cycles or three PKT_TIMING_CORR_CYCLE multiframes.

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

Refer to ETSI TS 101 376-5-2 [3] for PTCCH/D scheduling rules.

Annex G (informative): Bibliography

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

History

Document history		
V1.1.1	March 2001	Publication
V1.2.1	April 2002	Publication
V1.3.1	February 2005	Publication
V2.1.1	March 2003	Publication
V2.2.1	March 2005	Publication
V2.3.1	August 2008	Publication
V3.1.1	July 2009	Publication
V3.2.1	February 2011	Publication
V3.3.1	December 2012	Publication
V3.4.1	October 2015	Publication