EUROPEAN
TELECOMMUNICATION
STANDARD

ETS 300 579

May 1996

Fourth Edition

Source: ETSI TC-SMG

Reference: RE/SMG-020510PR3

ICS: 33.060.50

Key words: Digital cellular telecommunications system, Global System for Mobile communications (GSM)

GLOBAL SYSTEM FOR
MOBILE COMMUNICATIONS

Digital cellular telecommunications system (Phase 2); Radio subsystem synchronisation (GSM 05.10)

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Foreword

This European Telecommunication Standard (ETS) has been produced by the Special Mobile Group (SMG) Technical Committee (TC) of the European Telecommunications Standards Institute (ETSI).

This ETS defines the requirements for synchronisation of the Radio sub-system within the Digital cellular telecommunications system (Phase 2). This ETS does not define the synchronisation algorithms implemented in the Mobile Station (MS) and Base Station System (BSS).

This third edition of the ETS is a result of further work carried out by TC-SMG and correspond to GSM technical specification, GSM 05.10 version 4.7.0.

The specification from which this ETS has been derived was originally based on CEPT documentation, hence the presentation of this ETS is not in accordance with the ETSI/PNE rules.

Reference is made within this ETS to GSM Technical Specifications (GSM-TSs) (NOTE).

NOTE: TC-SMG has produced documents which give the technical specifications for the implementation of the Digital cellular telecommunications system. Historically, these documents have been identified as GSM Technical Specifications (GSM-TSs). These TSs may have subsequently become I-ETSs (Phase 1), or ETSs (Phase 2), whilst others may become ETSI Technical Reports (ETRs). GSM-TSs are, for editorial reasons, still referred to in GSM ETSs.

Transposition dates	
Date of adoption of this ETS:	30 April 1996
Date of latest announcement of this ETS (doa):	20 August 1996
Date of latest publication of new National Standard or endorsement of this ETS (dop/e):	18 February 1997
Date of withdrawal of any conflicting National Standard (dow):	18 February 1997

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1.1 Scope

This European Telecommunications Standard (ETS) defines the requirements for synchronization on the GSM radio sub-system. (However, it does not define the synchronization algorithms to be used in the Base Station (BS) and Mobile Station (MS). These are up to the manufacturer to specify.)

1.2 Normative references

This ETS incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETS only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

[1] GSM 01.04 (ETR 100): "Digital cellular telecommunication system (Phase 2); Abbreviations and acronyms".

[2] GSM 04.08 (ETS 300 557): "Digital cellular telecommunication system (Phase 2); Mobile radio interface layer 3 specification".

[3] GSM 05.02 (ETS 300 574): "Digital cellular telecommunication system (Phase 2); Multiplexing and multiple access on the radio path".

[4] GSM 05.05 (ETS 300 577): "Digital cellular telecommunication system (Phase 2); Radio transmission and reception".

[5] GSM 05.08 (ETS 300 578): "Digital cellular telecommunication system (Phase 2); Radio subsystem link control".

[6] GSM 03.30 (ETR 103): "Digital cellular telecommunication system (Phase 2); Radio network planning aspects".

1.3 Definitions and abbreviations

In addition to those below, Abbreviations used in this ETS are listed in GSM 01.04.

BS Base Station

Timing Advance: A signal sent by the BS to the MS which the MS uses to advance its timings of transmissions to the BS so as to compensate for propagation delay

Quarter bit number: The timing of quarter bit periods (12/13 μs) within a timeslot

Timeslot number: The timing of timeslots within a TDMA frame

TDMA frame number: The count of TDMA frames relative to an arbitrary start point

Current Serving BS: The BS on one of whose channels (TCH, DCCH or CCCH) the MS is currently operating

Timebase counters: A set of counters which determine the timing state of signals transmitted by a BS or MS

MS timing offset: The delay of the received signal relative to the expected signal from an MS at zero distance under static channel conditions with zero timing advance. This is accurate to ± 1 bit, and reported once per SACCH or after a RACH as. required (ie at the same rate as timing advance). For example, for an MS with a round trip propagation delay of P bits, but with a timing advance of T bits, the reported timing offset will be P-T quantized to the nearest bit.

2 General description of synchronization system

This clause gives a general description of the synchronization system. Detailed requirements are given in clauses 3 to 6.

The BS sends signals on the BCCH to enable the MS to synchronize itself to the BS and if necessary correct its frequency standard to be in line with that of the BS. The signals sent by the BS for these purposes are:

a) Frequency correction bursts;

b) Synchronization bursts.

The timings of timeslots, TDMA frames, TCH frames and control channel frames are all related to a common set of counters which run continuously whether the MS and BS are transmitting or not. Thus, once the MS has determined the correct setting of these counters, all its processes are synchronized to the current serving BS.

The MS times its transmissions to the BS in line with those received from the BS. The BS sends to each MS a "timing advance" parameter according to the perceived round trip propagation delay BS-MS-BS. The MS advances its timing by this amount, with the result that signals from different MS's arriving at the BS and compensated for propagation delay. This process is called "adaptive frame alignment".

Additionally, synchronisation functions may be implemented in both the MS and the BS to support the so-called pseudo synchronisation scheme. The support of this scheme is optional except that MS shall measure and report the Observed Timing Difference (OTD), which is a mandatory requirement. The detailed specifications of the pseudo-synchronisation scheme are included in Annex A.

3 Timebase Counters

3.1 The timing state of the signals transmitted by a BS or MS is defined by the following counters:

- Quarter bit number QN (0 - 624)- Bit number BN (0 - 156)
- Timeslot number TN (0 - 7)
- TDMA frame number FN (0 to (26 x 51 x 2048) - 1 = 2715647)

3.2 The relationship between these counters is as follows:

* QN increments every 12/13 μs
* BN = Integer part of QN/4
* TN increments whenever QN changes from count 624 to 0
* FN increments whenever TN changes from count 7 to 0

4 Timing of Transmitted Signals

The timing of signals transmitted by the MS and BS are defined in GSM 05.02.

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

QN is set by the timing of the training sequence
TN = 0 when the synch burst is received
FN = 51 ((T3-T2) mod (26)) + T3 + 51 x 26 x T1 when the synch burst is received,
(where T3 = (10 x T3') + 1, T1, T2 and T3' being contained in information fields in synchronization burst)

Thereafter, the timebase counters are incremented as in section 3.2.

(When adjacent BS's are being monitored for handover purposes, the MS may choose to store the values of QN, TN and FN for all the BS's whose synchronization bursts have been detected relative to QN, TN and FN for its current serving BS).

5 BS Requirements for Synchronization

The conditions under which the requirements of sections 5.4 and 5.6 must be met shall be 3 dB below the reference sensitivity level in GSM 05.05 and 3 dB less carrier to interference ratio than the reference interference ratios in GSM 05.05.

5.1 The BS shall use a single frequency source of absolute accuracy better than 0.05 ppm for both RF frequency generation and clocking the timebase. The same source shall be used for all carriers of the BS.

5.2 It is optional whether the timebase counters of different BS's are synchronized together.

5.3 The channels of different carriers transmitted by a BS shall be synchronized together, ie controlled by the same set of counters. The timing difference between the different carriers shall be less than 1/4 bit periods, measured at the BS antenna.

5.4 When the BS detects a random access CCCH transmission or a message with a long guard time (eg handover acknowledgement) on a TCH, it shall measure the delay of this signal relative to the expected signal from an MS at zero distance under static channel conditions. This delay, called the timing advance, shall be rounded to the nearest bit period and included in a response from the BS when applicable.

5.5 The maximum timing advance value shall be 63. If the BS measures a value larger than this, it shall set the timing advance to 63. (GSM 03.30 defines how the PLMN deals with MS's where the delay exceeds timing advance value 63.)

5.6 The BS shall thereafter continuously monitor the delay from the MS. If the delay changes by more than one bit period, the timing advance shall be advanced or retarded 1 and the new value signalled to the MS. The delay shall be assessed in such a way that the assessment error (due to noise and interference) is less than 1/2 bit periods for stationary MS. For MS moving at a speed up to 500 km/h the additional error shall be less then 1/4 bit period.

The control loop for the timing advance shall be implemented in such a way that it will cope with MSs moving at a speed up to 500 km/h.

Restricting the change in timing advance to 1 bit period at a time gives the simplest implementation of the BS. However the BS may use a larger change than this but great care must then be used in the BS design.

5.7 Optionally, the BS may use a timeslot length of 157 bit periods on timeslots with TN = 0 and 4, and 156 bit periods on timeslots with TN = 1, 2, 3, 5, 6, 7, rather than 156.25 bit periods on all timeslots.

5.8 The timing advance shall be in the range 0 to 63. The value 0 corresponds to no timing advance, ie. the MS transmissions to the BS are 468.75 bits periods behind (see section 6.4). The value 63 corresponds to maximum timing advance, ie. the MS transmissions are 405.75 bit periods behind.

6 MS Requirements for Synchronization

The MS shall only start to transmit to the BS if the requirements of sections 6.1 to 6.4 are met.

The conditions under which the requirements of sections 6.1 to 6.4 must be met shall be 3 dB below the reference sensitivity level in GSM 05.05 and 3 dB less carrier to interference ratio than the reference interference ratios in GSM 05.05.

In discontinuous reception (DRX), the MS should meet the requirements of sections 6.1 to 6.3 during the times when the receiver is required to be active.

6.1 The MS carrier frequency shall be accurate to within 0.1 ppm, or accurate to within 0.1 ppm compared to signals received from the BTS (these signals will have an apparent frequency error due to BTS frequency error and Doppler shift). In the latter case the signals from the BTS must be averaged over sufficient time that errors due to noise or interference are allowed for within the above 0.1 ppm figure. The MS shall use the same frequency source for both RF frequency generation and clocking the timebase.

6.2 The MS shall keep its internal timebase in line with that of signals received from the BTS. If the MS determines that the timing difference exceeds 2 µ seconds, it shall adjust its timebase in steps of 1/4 bit period. This adjustment shall be performed at intervals of not less than 1 second and not greater than 2 seconds until the timing difference is less than 1/2 bit periods.

6.3 In determining the timing of signals from the BTS, the timings shall be assessed in such a way that the timing assessment error is less than 1/2 bit periods. The assessment algorithm must be such that the requirements of 6.2 can be met.

6.4 The MS shall time its transmissions to the BTS according to signals received from the BTS. The MS transmissions to the BTS, measured at the MS antenna, shall be 468.75-TA bit periods (i.e. 3 timeslots-TA) behind the transmissions received from the BTS, where TA is the last timing advance received from the current serving BTS. The tolerance on these timings shall be ±1 bit period. The MS shall signal the used TA to the BTS.

6.5 When the MS receives a new value of TA from the BTS on the SACCH, it shall implement the new value of TA at the first TDMA frame belonging to the next reporting period (as defined in GSM 05.08), after the SACCH frame containing the new TA value.

6.6 When the MS accesses a new BTS, random access, or the serving BTS is changed, handover, the MS shall change the TA as follows:

Random access:

The MS shall use a TA value of 0 for the Random Access burst sent. When a TA is received from the BTS that TA shall be used.

Synchronised handover:

After the Handover Access bursts which shall be sent with a TA value of 0 the MS shall use a TA calculated as specified in Annex A using a value of RTD equal to 0. When a TA is received from the new BTS that TA shall be used. The transmission of the Handover Access burst is optional if so indicated by the BS.

Non-synchronised handover:

The MS shall use a TA value of 0 for the Handover Access bursts sent. When a TA is received in a physical information message that TA shall be used. Before a TA is received from the new BTS no valid "used TA" shall be signalled to the new BTS.

Pseudo synchronised handover:

After the Handover Access bursts which shall be sent with a TA value of 0 the MS shall use a TA as specified in Annex A. The transmission of the Handover Access burst is optional if so indicated by the BS.

Pre-synchronised handover:

After the Handover Access bursts which shall be sent with a TA value of 0 the MS shall use a TA as specified in the HO command by the old BTS, or a default value of 1, if the old BTS did not provide a TA value. The transmission of the Handover Access burst is optional if so indicated by the BS.

6.7 During a temporary total loss of signal, of up to 64 SACCH block periods, the MS shall update its timebase with a clock which is accurate to within 0.2 ppm, or to within 0.2 ppm of the signals previously received from the BTS.

6.8 When the MS receives an intracell channel change command or a handover command (see GSM 04.08), it shall be ready to transmit on the new channel within 120 ms of the last timeslot of the message block containing the command, unless the access is delayed to an indicated starting time, in which case it shall be ready to transmit on the new channel at the designated starting time, or within 120 ms, whichever is the later. The time between the end of the last complete speech or data frame or message block sent on the old channel and the time the MS is ready to transmit on the new channel shall be less than 20 ms.

6.9 When the MS receives a new TA value in response to a handover access burst, the MS shall be ready to transmit using the new TA value within 40 ms of the end of the last timeslot of the message block containing the new TA value.

6.10 The phrase "ready to transmit within x ms" means that the MS shall transmit no later than:

- the first burst of the first TCH or control channel block that occurs after the x ms, in case of an intracell channel change,

- the first burst of the TCH or control channel that occurs after the x ms, in case of a handover.

NOTE: The MS shall keep the timings of the neighbour BS's that it is monitoring (according to GSM 05.08) to an accuracy of ±1 bit periods.

Annex A (normative): Additional requirements for pseudo-synchronisation, synchronised handovers and pseudo-synchronised handovers.

A.1 General descriptions and definitions

A.1.1 Conventions

The following conventions are adopted in this annex:

- the modulating bit period is denoted T = 48/13 µs

- all timing values are considered for descriptive purposes as real numbers modulo the largest period defined in the system i.e. 3394560000T. When transmitted over the air interface, such a value shall be rounded to the nearest integer multiple of a 1/2 bit period T/2 and that integer shall be reduced mod some integer multiple of 256. Considering the allocated coding space (see GSM 04.08), the modulo to be used is 256 (calculated in 1/2 bit period T/2).

- the Timing Advance (TA) value, when the distance between the base station and the mobile station is equal to or less than 35 km, represents the estimated two way propagation delay in T units. For the purpose of this annex it is convenient to consider timing values representing the estimated one way propagation delay in T/2 units rather than twice the delay in T units, although this is purely a matter of conventions.

A.1.2 Definitions

Assuming that some MS has to perform handover from BTS 0 (the "current" or "old" BTS) to BTS 1 (the "new" BTS), the following quantities are defined.

- t_0 (resp. t_1) denotes the one way line of sight propagation delay between the MS and BTS 0 (resp. BTS 1)

- RTD (Real Time Difference) denotes the value of the local GSM time in BTS 0 minus that of BTS 1

- OTD (Observed Time Difference) denotes the timing difference between BTS 0 and BTS 1 as measured by the MS with the same sign conventions as for RTD

All these four values are slowly time-varying due to the MS movement and oscillators drift in the BTS's, but they are defined here just prior handover execution.

A.1.3 Details of operations

The following relation holds:

$$OTD = RTD + t_1 - t_0$$

Synchronised and pseudo synchronised handovers work as follows:

For the pseudo synchronised handover, it is assumed that RTD is known to BTS 0 and MS supports the scheme, BTS 0 may order pseudo-synchronised handover to BTS 1, including RTD in the "HANDOVER COMMAND" message.

For the synchronised handover, BTS 0 may order synchronised handover to BTS 1, and the MS sets RTD equal to 0.

Under normal operating conditions, t_0 should be closely related to the latest received Timing Advance sent by BTS 0 to the MS; since the MS must have got synch to BTS 1 before performing handover, OTD, RTD and t_0 are available to the MS, hence the value of t_1 that can be used to set the new Timing Advance parameter without receiving it from BTS 1.

After successful handover, either synchronised, non-synchronised or pseudo-synchronised, the MS shall provide to BTS 1 the value of OTD + t_0 in the "HANDOVER COMPLETE" message, allowing BTS 1 to obtain a non biased estimate of RTD given the transmitted OTD + t_0 and it's estimated value to t_1. In practice, additional processing will be required to mitigate the effects of estimation errors and quantisation effects; this matter is left unspecified.

A.2 BTS requirements

A.2.1 The pseudo-synchronisation scheme

If the pseudo-synchronisation scheme is supported, the BTS shall comply with the following requirements, in addition to those of the main part of the recommendations.

A.2.1.1

The BTS shall maintain for each of a set of neighbouring BTS a time difference estimate modulo some integer multiple of 128T. These time differences can be updated when a MS supporting the pseudo-synchronisation scheme enters the cell via a handover: the MS provides the observed time difference corrected for the propagation time with the previous BTS but not corrected for the propagation to the current BTS. When the adaptive frame alignment process in the new BTS has assessed the propagation time, it is used to correct the observed time difference given by the MS and the result is used (possibly after some unspecified processing) to update the value of the time difference with the previous BTS. Other means for maintaining the time difference estimates may be used.

A.2.1.2

The reception epoch criterion used for evaluating the MS time shift (cf 5.6) shall be as close as possible to line of sight path reception epoch, so that with MS supporting the pseudo-synchronisation scheme the timing advance for stationary MS is as close as possible to the double propagation delay.

A.2.1.3

When a handover is requested, if the MS supports pseudo-synchronisation, it may be chosen to order a pseudo-synchronised handover. In that case, the time difference between the two BTS, memorized as specified in A2.1 and encoded as specified in A1.1 must be sent to the MS.

A.2.2 The synchronisation scheme

If the synchronisation scheme is supported, the BTS shall comply with the following requirements, in addition to those of the main part of the specifications.

The BTS shall maintain synchronisation with a set of neighbouring BTS. In this context, synchronisation means that the timing of the TDMA frame at the BTSs is the same, ie. the timeslot zeros from the BTS transmitted are synchronous with the timeslot zeros of the carriers on the set of neighbouring BTSs. All timings are to be referenced at the BTS.

A.3 MS requirements

The MS shall comply to the following requirements.

A.3.1

The reception epoch criterion used for clocking the timebase shall be as close as possible to line of sight path reception epoch so that the timing advance when the MS is stationary is as close as possible to the double propagation delay. However the quantisation mentioned in A1.1 does not impose any additional requirement on the resolution of the measurement.

A.3.2

After each successful handover the MS shall give to the new BTS the modulo 256 sum of the observed time difference encoded as in A1.1 and the last timing advance value received from the old BTS,if required by the BTS.

A.3.3

When a synchronised or a pseudo synchronised handover occurs, the MS shall synchronize to the new BTS and shall use as initial timing advance value the value calculated from the observed time difference between the two BTS, the real time difference and the last timing advance value received from the previous BTS, according to A1.3. The Real Time Difference (RTD) is in the case of pseudo synchronised handover given with the handover command and in the case of synchronised handover set to 0 by the MS. If the initial timing advance value calculated is outside the range 0 to 63 the MS shall do as follows:

- if the initial timing advance value calculated is greater than 63, the MS shall, if it attempts to transmit on the new cell, use a timing advance value of 63 as the initial timing advance value and memorize that the cell is out of range. Whether the MS transmits on the new cell or not depends on the NCI bit as specified in TS GSM 04.08.

- if the initial timing advance value calculated is less than 0, the MS shall use a timing advance value of 0 as the initial timing advance value.

In the case where the mobile station calculates the timing advanced in calculations modulo the value X, then shall values of the timing advance in the interval 0.9 X to X - 1 be regarded as negative, e.g in the case of a timing advance calculated modulo 128 (equivalent to 256 calculated in 1/2 bit period T/2) the timing advances in interval 115 to 127 be regarded as negative.

History

Document history			
September 1995	First Edition		
March 1995	Unified Approval Procedure (Second Edition)	UAP 26:	1995-03-06 to 1995-06-30
May 1995	Unified Approval Procedure (Third Edition)	UAP 29:	1995-05-22 to 1995-09-15
July 1995	Second Edition		
September 1995	Third Edition		
December 1995	Unified Approval Procedure (Fourth Edition)	UAP 40:	1995-12-04 to 1996-04-12
May 1996	Fourth Edition		

ISBN 2-7437-0742-9 - Edition 4
(ISBN 2-7437-0289-3 - Edition 3)
(ISBN 2-7437-0191-9 - Edition 2)
Dépôt légal : Mai 1996