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**Digital cellular telecommunications system (Phase 2+);
Radio subsystem synchronization
(GSM 05.10 version 5.2.1 Release 1996)**

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Foreword

This draft European Telecommunication Standard (ETS) has been produced by the Special Mobile Group (SMG) Technical Committee of the European Telecommunications Standards Institute (ETSI), and is now submitted for the One-step Approval Procedure phase of the ETSI standards approval procedure.

This ETS defines the requirements for synchronization on the GSM radio sub-system of the digital mobile cellular and personal communication systems operating in the 900 MHz and 1 800 MHz band (GSM 900 and DCS 1 800).

The contents of this ETS are subject to continuing work within SMG and may change following formal SMG approval. Should SMG modify the contents of this ETS it will then be re-submitted for approval by ETSI with an identifying change of release date and an increase in version number as follows:

Version 5.x.y
where:

- 5 indicates GSM Phase 2+ Release 1996
- x the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- y the third digit is incremented when editorial only changes have been incorporated in the specification.

Proposed transposition dates	
Date of latest announcement of this ETS (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this ETS (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

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1 Scope

This European Telecommunication 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 Transceiver Station (BTS) 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 350): "Digital cellular telecommunications system (Phase 2+); Abbreviations and acronyms".
- [2] GSM 03.60: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Service Description Stage 2".
- [3] GSM 03.64: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); GPRS Radio Interface Stage 2".
- [4] GSM 04.08 (ETS 300 940): "Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification".
- [5] GSM 04.60: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Mobile Station (MS) - Base Station System (BSS) interface; Radio Link Control (RLC) and Medium Access Control (MAC) Layer Specification".
- [6] GSM 05.02 (ETS 300 908): "Digital cellular telecommunications system (Phase 2+); Multiplexing and multiple access on the radio path".
- [7] GSM 05.05 (ETS 300 910): "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception".
- [8] GSM 05.08 (ETS 300 911): "Digital cellular telecommunications system (Phase 2+); Radio subsystem link control".
- [9] GSM 03.30 (ETR 364): "Digital cellular telecommunications system; 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.

BTS	Base Transceiver Station
Timing Advance:	A signal sent by the BTS to the MS which the MS uses to advance its timings of transmissions to the BTS so as to compensate for propagation delay
Quarter bit number:	The timing of quarter bit periods (12/13 μ s) 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 BTS:	The BTS 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 BTS 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 (i.e. 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 BTS sends signals on the BCCH to enable the MS to synchronize itself to the BTS and if necessary correct its frequency standard to be in line with that of the BTS. The signals sent by the BTS 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 BTS 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 BTS.

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

Additionally, synchronization functions may be implemented in both the MS and the BTS to support the so-called pseudo synchronization 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-synchronization scheme are included in annex A.

3 Timebase counters

3.1 Timing state of the signals

The timing state of the signals transmitted by a BTS 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 $(26 \times 51 \times 2048) - 1 = 2715647$).

3.2 Relationship between counters

The relationship between these counters is as follows:

- QN increments every 12/13 μ s;
- 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 BTS 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 = $51 ((T3-T2) \bmod (26)) + T3 + 51 \times 26 \times T1$ when the synch burst is received,
 (where $T3 = (10 \times T3') + 1$, T1, T2 and T3' being contained in information fields in synchronization burst).

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

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

5 BTS Requirements for Synchronization

The conditions under which the requirements of subclauses 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 Frequency source

The BTS 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 BTS.

5.2 Timebase counters

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

5.3 Internal BTS carrier timing

The channels of different carriers transmitted by a BTS shall be synchronized together, i.e. 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 BTS antenna.

5.4 Timing advance estimation

When the BTS detects a random access CCCH transmission or a message with a long guard time (e.g. 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 BTS when applicable.

5.5 Maximum timing advance value

The maximum timing advance value shall be 63. If the BTS 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 Delay tracking

The BTS 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 than 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 BTS. However the BTS may use a larger change than this but great care must then be used in the BTS design.

5.7 Timeslot length

Optionally, the BTS 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 Range of Timing advance

The timing advance shall be in the range 0 to 63. The value 0 corresponds to no timing advance, i.e. the MS transmissions to the BTS are 468,75 bits periods behind (see subclause 6.4). The value 63 corresponds to maximum timing advance, i.e. the MS transmissions are 405,75 bit periods behind.

6 MS Requirements for Synchronization

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

The conditions under which the requirements of subclauses 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 subclauses 6.1 to 6.3 during the times when the receiver is required to be active.

6.1 MS carrier frequency

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 Internal timebase

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 Assessment of BTS timing

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 Timing of transmission

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.

In case of a multislots configuration, the MS shall use a common timebase, derived from the main channel, for transmission of all channels. The TA values received on other channels shall be neglected. In this case, the MS may optionally use a timeslot length of 157 bit periods on timeslots $TN = 0$ and 4, and 156 bit periods on timeslots with $TN = 1, 2, 3, 5, 6$ and 7, rather than 156,25 bit periods on all timeslots.

6.5 Application of Timing Advance

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. On channels used for a voice group call, the TA value sent by the BTS applies only to an MS currently allocated the uplink.

6.6 Access to a new BTS

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.

Synchronized or Pseudo Synchronized 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. 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 BTS.

Non-synchronized 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.

Pre-synchronized 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 BTS.

6.7 Temporary loss of signal

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 Timing of intracell channel change

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 Application of new Timing Advance value

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 Definition of "ready to transmit within x ms"

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 BTS's that it is monitoring (according to GSM 05.08) to an accuracy of ± 1 bit periods.

Annex A (normative): Additional requirements for pseudo-synchronization, synchronized handovers and pseudo-synchronized 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 $T = 48/13 \mu\text{s}$;
- 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 as defined in GSM 04.08;
- the Timing Advance (TA) value, when the distance between the base station and the MS is equal to or less than 35 km, represents the estimated two way propagation delay in T units. For the purpose of the calculations in this annex the timing advance values are considered to represent the estimated one way propagation delay in $T/2$ units which is equivalent to twice the delay in T units.

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:

$$\text{OTD} = \text{RTD} + t_1 - t_0$$

Synchronized and pseudo synchronized handovers work as follows:

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

For the synchronized handover, BTS 0 may order synchronized 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 synchronized, non-synchronized or pseudo-synchronized, 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 its estimated value to t_1 . In practice, additional processing will be required to mitigate the effects of estimation errors and quantization effects; this matter is left unspecified.

A.2 BTS requirements

A.2.1 The pseudo-synchronization scheme

If the pseudo-synchronization 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 BTS a time difference estimate

The BTS shall maintain for each of a set of neighbouring BTS a time difference estimate encoded as in A 1.1. These time differences can be updated when a MS supporting the pseudo-synchronization 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

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-synchronization scheme the timing advance for stationary MS is as close as possible to the double propagation delay.

A.2.1.3 Pseudo-synchronized handover

When a handover is requested, if the MS supports pseudo-synchronization, it may be chosen to order a pseudo-synchronized handover. In that case, the time difference between the two BTS, memorized as specified in A.2.1 and encoded as specified in A.1.1 must be sent to the MS.

A.2.2 The synchronization requirement

If the pseudo-synchronization 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 synchronization with a set of neighbouring BTS. In this context, synchronization means that the timing of the TDMA frame at the BTSs is the same, i.e. 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 Provision of time difference information

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 quantization mentioned in A.1.1 does not impose any additional requirement on the resolution of the measurement.

A.3.2 After each successful handover

After each successful handover the MS shall give to the new BTS the sum of the observed time difference and the last timing advance value received from the old BTS, if required by the BTS encoded as A 1.1.

A.3.3 Synchronized or a pseudo synchronized handover

When a synchronized or a pseudo synchronized handover occurs, the MS shall synchronize to the new BTS and shall use as initial timing advance value the value calculated modulo 256 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 A.1.3. Calculated values between 230 and 255 shall be regarded as negative timing advance. The Real Time Difference (RTD) is in the case of pseudo synchronized handover given with the handover command and in the case of synchronized handover set to $2500 * \text{INT}(\text{OTD}/2500 + 0,5)$ 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 cell shall be considered as out of range. 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. Whether the MS transmits on the new cell or not depends on the NCI bit as specified in 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.

Annex B (informative): Change Request History

SM G#	TDoc	CR	SPEC	VERS	NEW_ VERS	SUBJECT
S18	336/96	A004	05.10	4.8.0	5.0.0	Addition of ASCI features
S20	602/96	A008	05.10	5.0.0	5.1.0	Introduction of high speed circuit switched data
S23	97-640	A011	05.10	5.1.0	5.2.0	Introduction of the new Timing Advance Procedure for GPRS

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