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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Special Mobile Group (SMG).

The present document specifies the relevant procedures for link adaptation implemented in the Mobile Station (MS) and Base Station System (BSS) of the digital mobile cellular and personal communication systems operating in the 900 MHz, 1 800 MHz and 1 900 MHz band (GSM 900, DCS 1 800 and PCS 1 900).

The contents of the present document are subject to continuing work within SMG and may change following formal SMG approval. Should SMG 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:

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where:

7 indicates release 1998 of GSM Phase 2+

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.

National transposition dates	
Date of adoption of this EN:	3 December 1999
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1 Scope

The present document has been produced by Technical Committee Special Mobile Group (SMG), and is now submitted for the ETSI standards One-step Approval Procedure.

The requirements described in the present document are mandatory for implementation in all GSM MSs and BSSs capable of supporting the adaptive multi rate speech traffic channel.

Unless otherwise specified, references to GSM include GSM at any frequency band.

1.1 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.
- For this Release 1998 document, references to GSM documents are for Release 1998 versions (version 7.x.y).

[1] GSM 01.04: "Digital cellular telecommunications system (Phase 2+); Abbreviations and acronyms".

[2] GSM 04.08: "Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification".

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

[4] GSM 05.03: "Digital cellular telecommunications system (Phase 2+); Channel Coding".

[5] GSM 05.05: "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception".

[6] GSM 08.08: "Digital cellular telecommunications system (Phase 2+); Mobile-services Switching Centre - Base Station System (MSC - BSS) interface, Layer 3 specification".

1.2 Abbreviations

Abbreviations used in the present document are listed in GSM 01.04.

2 General

The present document gives the detailed requirements for the correct operation of in call service specific link adaptation and control for GSM services implemented in GSM Mobile Stations (MS)s and Base Station Systems (BSS)s.

For the adaptive multi-rate (AMR) speech service, the detailed description and requirements for the associated inband signaling, AMR codec mode adaptation, and AMR codec setup are given.

An inband signaling channel is defined for AMR which enables the MS and the BTS to exchange messages on applied or requested speech and channel codec modes. Codec mode adaptation for AMR is based on received channel quality estimation in both MS and BTS, followed by a decision on the most appropriate speech and channel codec mode to apply at a given time.

The overall operation of AMR, in terms of used codec modes as well as general adaptation behaviour is controlled by the network at call setup.

3 Adaptive Multi-Rate inband control and link adaptation

3.1 General operation

A high-level block diagram of the complete AMR system is depicted in figure 1. The system consists of the major components TRAU and BTS on the network side and the MS. On the network side, speech encoder (SPE) and channel encoder (CHE) as well as channel decoder (CHD) and speech decoder (SPD) are connected via the serial A-bis interface. For each link, quality information is derived by estimating the current channel state. Based on the channel state, and also taking into consideration possible constraints from network control, the codec mode control, which is located on the network side, selects the codec modes to be applied.

The channel mode to use (TCH/AFS or TCH/AHS) is controlled by the network. Uplink and downlink always apply the same channel mode.

For codec mode adaptation the receiving side performs link quality measurements of the incoming link. The measurements are processed yielding a Quality Indicator. For uplink adaptation, the Quality Indicator is directly fed into the UL mode control unit. This unit compares the Quality Indicator with certain thresholds and generates, also considering possible constraints from network control, a Mode Command indicating the codec mode to be used on the uplink. The Mode Command is then transmitted inband to the remote side where the incoming speech signal is encoded in the corresponding codec mode. For downlink adaptation, the DL Mode Request Generator compares the DL Quality indicator with certain thresholds and generates a Mode Request indicating the preferred codec mode for the downlink. The Mode Request is transmitted inband to the network side where it is fed into the DL Mode Control unit. This unit generally grants the requested mode. However, considering possible constraints from network control, it may also override the request. The resulting codec mode is then applied for encoding of the incoming speech signal. Both for uplink and downlink, the presently applied codec mode is transmitted inband as codec Mode Indication together with the coded speech data. At the decoder, the codec mode indication is decoded and applied for decoding of the received speech data.

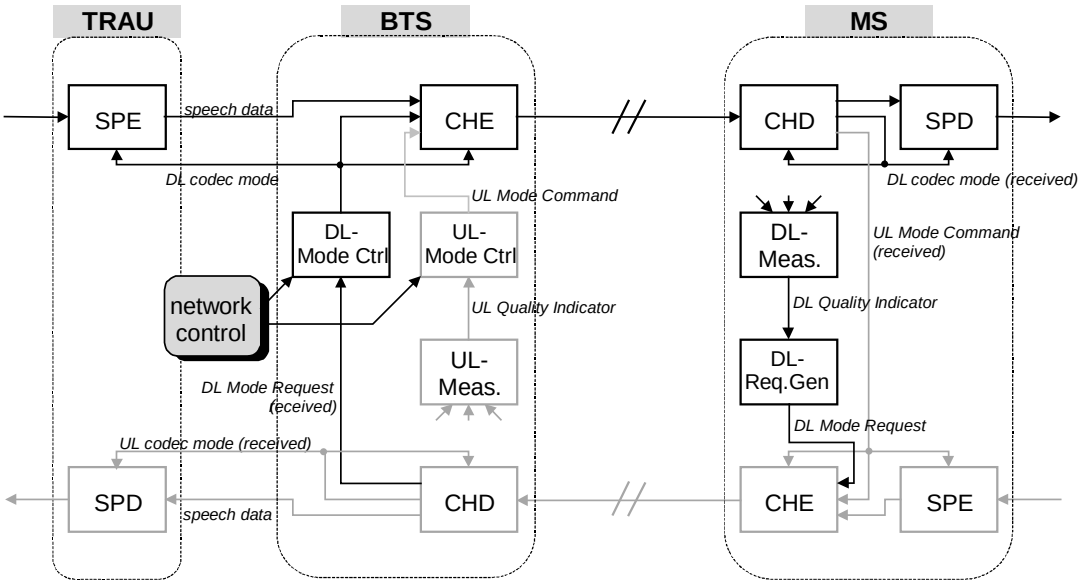

Figure 1: High level AMR block diagram

3.2 Inband signalling

3.2.1 General

The codec mode information, which has to be transmitted on each link, consists of Mode Indications and Mode Commands in the downlink, or Mode Indications and Mode Requests in the uplink. Mode Indications inform the receiver about the currently applied codec mode. Mode Commands inform the other end about the codec mode to be applied on the other link. Mode Requests inform the other end about the preferred codec mode on the other link.

Codec mode information is transmitted inband in the speech TCH, using parts of the transmission capacity dedicated to speech data transmission. The coding of codec modes in the inband signalling is given in subclause 3.4.1.

3.2.2 Operation without DTX enabled

Codec modes are constrained to change only every second speech frame. Mode Commands or Mode Requests are sub-sampled such that they occur only every second frame. Mode Indications and Mode Commands/Mode Requests shall be transmitted in alternating order.

Channel coding of codec mode information is specified in GSM 05.03 [4].

3.2.3 Operation with DTX enabled

For SPEECH frames, codec modes are constrained to change only every second speech frame. Mode Commands or Mode Requests are sub-sampled such that they occur only every second frame. Mode Indications and Mode Commands/Mode Requests shall be transmitted in alternating order.

For SID_FIRST frames, the Mode Indication or Mode Command/Mode Request in phase with the alternating transmission shall be transmitted.

For SID_UPDATE frames, both Mode Indication and Mode Command/Mode Request shall be transmitted in the same SID frame.

For ONSET frames, Mode Indication indicating the Codec Mode in the following SPEECH frame shall be transmitted.

Channel coding of codec mode information is specified in GSM 05.03 [4].

3.2.3 Transmitter/Receiver Synchronisation at Call Setup

Alternating transmission of codec mode information requires synchronisation of transmitting and receiving ends, such that Mode Indications and Mode Commands/Requests are decoded as such in correct order. In order to ensure proper synchronisation at call setup, codec mode information is transmitted aligned to the multi frame structure of the GSM system. For TCH/AFS, the transmission phase shall be such that Mode Indications are sent starting with TDMA frame 0 as defined in GSM 05.02 [3]. For TCH/AHS, the transmission phase shall be such that Mode Indications are sent starting with TDMA frame 0 or 1 depending on subchannel as defined in GSM 05.02 [3].

3.3 Codec mode adaptation

3.3.1 Channel quality measure

Codec mode adaptation is based on a normalized one-dimensional measure of the channel quality, called the Quality Indicator. For reference purposes, the Quality Indicator is defined as an equivalent carrier to interferer ratio, C/I_{norm}. The MS and BSSs shall continously update the Quality Indicator estimates.

The Quality Indicator may be derived from an estimate of the current carrier to interferer ratio, C/I_{est} , or an estimate of the current raw bit error rate (BER_{est}). A fixed normalization factor may be applied between the the estimate (C/I_{est} or BER_{est}) and the Quality Indicator to compensate for higher receiver performance.

A second normalization factor should be applied to normalize the estimate with respect to different channel types, such that, with given C/I_{norm} and given codec mode, the FER after channel decoding becomes independent of channel type.

An example of link quality measuring for the case of an ideal FH channel in a typical urban environment is given in Annex A.

3.3.2 Generation of Mode Commands and Mode Requests

For codec mode adaptation, the channel Quality Indicators are mapped to Mode Commands/Requests, by quantizing the channel measurements (Quality Indicators). The output values of the quantizer shall represent the different codec modes.

Hysteresis in the mapping from Quality Indicators to Mode Commands/Requests should be used to prevent undesirable fast switching of Mode Commands and Mode Requests.The hysteresis in the mapping is defined in the following way. The previously sent Mode Command MC', or Mode Request MR' is used as the current state of the adaptation logic. For each state, lower and upper thresholds THR_MC_Dn(MC') and THR_MC_Up(MC') for the downlink, and THR_MR_Dn(MR') and THR_MR_Up(MR') for the uplink are defined. If the measure falls below the lower threshold, the next lower Mode Command/Request commanding/requesting a more robust codec mode shall be generated. If the measure exceeds the upper threshold, then the next higher Mode Command/Request commanding/requesting a less robust codec mode shall be issued. Otherwise, the previous Mode Command/Request shall be repeated.

The degree of hysteresis is controlled by appropriately setting the upper and lower decision thresholds. The thresholds are defined by layer 3 signaling, as described in subclause 3.4.2. An example of decision threshold for the case of an ideal FH channel in a typical urban environment is given in Annex B.

For reasons of channel error robustness of the codec mode information, both Mode Commands and Requests shall be restricted to change at maximum to their nearest neighbours. This means that mode switches to modes that are not direct neighbours to the previous transmitted mode are prohibited.

3.3.3 Performance requirements

3.3.3.1 MS response to the Mode Command

The MS shall at the reception of a Mode Command apply the corresponding mode. The MS shall apply the signalled mode for the speech frame transmitted 8 TDMA frames after the reception of the last TDMA frame containing the Mode Command.

3.3.3.2 BTS response to the Mode Request

The BTS should apply the requested mode for the earliest possible speech frame, unless the BTS intends to override the MS Mode Request.

3.3.3.3 Performance of the Mode Request

For TU50 channel conditions with ideal frequency hopping without DTX activated, the MS shall produce Mode Requests with the following accuracy.

- When a carrier to interferer ratio 4 dB higher than a defined upper threshold is applied to the antenna connector, the MS shall request a higher mode with a probability exceeding 90%. This shall be measured immediately after a settling-time of 200 ms.
- When a carrier to interferer ratio 4 dB lower than a defined lower threshold is applied to the antenna connector, the MS shall request a lower mode with a probability exceeding 90%. This shall be measured immediately after a settling-time of 200 ms.

3.4 Setup procedures

3.4.1 Definition of AMR codec mode sets

AMR codec mode adaptation is done within a set of up to four codec modes. The codec mode set to be used is defined during call setup and/or handover by layer 3 signaling defined in GSM 04.08 [2].

The following convention applies for the coding of the codec modes for the inband signalling (Mode Indications, Mode Commands, and Mode Requests).

00	CODEC_MODE_1	represents the lowest codec mode (lowest bit-rate)
01	CODEC_MODE_2	represents the second lowest mode, if the codec mode set includes more than one mode
10	CODEC_MODE_3	represents the third lowest mode, if the codec mode set includes more than two modes
11	CODEC_MODE_4	represents the highest mode, if the codec mode set includes four modes

If less than 4 Codec Modes are used, the unused codec Mode Indications and Mode Commands/Mode Requests shall not be signalled. Unused codec modes shall not be detected by the inband signalling decoder.

3.4.2 Definition of Mode Command and Mode Request decision thresholds

The Mode Command and Mode Request decision thresholds are defined at call setup and/or handover by layer 3 signaling as defined in GSM 04.08 [2]. For each pair of neighboring codec modes in the codec mode set, a threshold and a hysteresis value in terms of normalized carrier to interference ratio (C/I_{norm}), is defined. The lower decision threshold for switching from mode j to mode j-1 is given by the signalled threshold. The threshold is referred to as THR_MC_Dn(j) or, THR_MR_Dn(j) in subclause 3.3.2.

The sum of the signalled threshold and hysteresis constitutes the upper threshold between the codec modes, referred to as THR_MC_Up(j-1) or, THR_MR_Up(j-1). The figure below illustrates the definition of the decision thresholds, and the operational range of the Codec Modes.

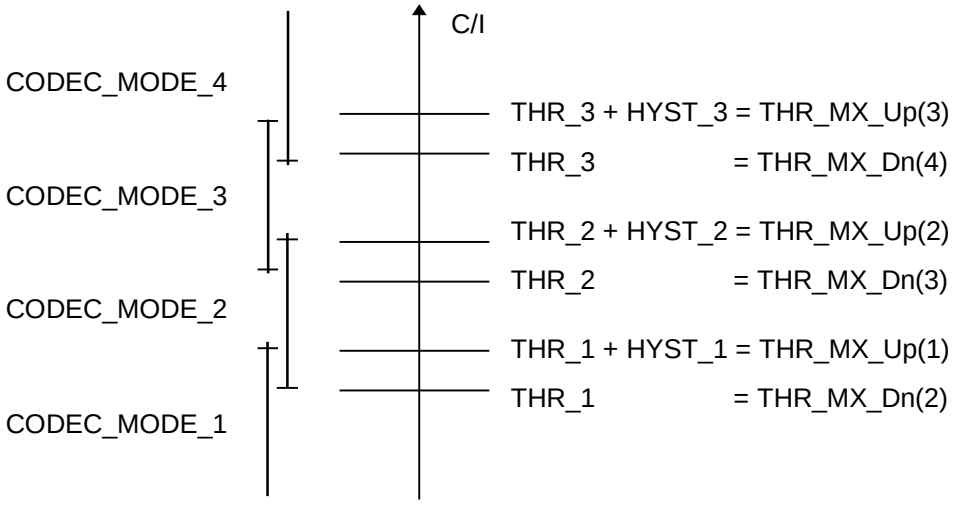

Figure 2: Definition of Threshold and Hysteresis for codec mode adaptation

The switching thresholds shall be given by the network in a consistent order. I.e., such that:

- THR_1 ≤ THR_2 ≤ THR_3; and

- THR_1 + HYST_1 ≤ THR_2 + HYST_2 ≤ THR_3 + HYST_3.

Parameter name	Description	Range	Bits
THR_1/2/3	Lower thresholds for switching between between mode j and j-1	0-63	6
HYST_1/2/3	Hysteresis values to obtain the higher thresholds for switching between mode j and j+1	0-15	4

A threshold (THR) is given as an absolute value in 0.5 dB steps. . The THR values between 0 and 63 shall be mapped to normalized C/I as follows.

THR 1/2/3	0	=	0.0 dB
THR 1/2/3	1	=	0.5 dB
THR 1/2/3	2	=	1.0 dB
		:	
		:	
THR 1/2/3	62	=	31.0 dB
THR 1/2/3	63	=	31.5 dB

NOTE: The threshold for codec mode j should be set to such a normalized C/I value that codec mode j starts to degrade and that a FER of less than 1 % is observed.

The hysteresis range is defined in 0,5 dB steps. The HYST values between 0 and 15 shall be mapped to C/I as follows.

HYST 1/2/3	0	=	0.0 dB
HYST 1/2/3	1	=	0.5 dB
HYST 1/2/3	2	=	1.0 dB
		:	
		:	
HYST 1/2/3	14	=	7.0 dB
HYST 1/2/3	15	=	7.5 dB

3.4.3 Initial Codec Mode Selection at Call Setup and Handover

The Initial Codec mode to start the speech coding operation with at call setup and after handover may be signalled by layer 3 signalling, in which case it shall be used.

If the Initial Codec mode is not signalled, the Initial Codec mode which shall be used is given by the following rule. If the codec mode set contains.

1 mode, then it is the Initial Codec mode.

2 or 3 modes, then the Initial Codec mode is the most robust mode of the set with lowest bit rate.

4 modes, then the Initial Codec mode is the second most robust mode of the set with second lowest bit rate.

Annex A (informative): Example Solution for Link quality estimation

Link adaptation is based on a normalized measure C/I_{norm} of the carrier to interferer ratio. This measure is composed of an estimate of the actual carrier to interferer ratio C/I_{est} (or equivalently the actual C/N). For ideal FH-hopping channels in a typical urban environment no further adjustment or normalization is required, as described in section 3.3.1.

C/I estimates are derived by taking C and I measurements burst by burst from the equaliser algorithm. Intermediate processing results of the equaliser are estimates of the "useful" received signal and the received noise or interference signal. Taking the ratio of the energies of both signals gives a C/I estimate for the present burst.

The further processing of the burst-wise C/I estimates is as follows.

- The C/I estimates are converted to dB.
- Then FIR filtering is done with non-adaptive filters of order 100 for FR and 50 for HR channels (Filter coefficients are given in Table 1 and Table 2, which is read left to right line by lineTable 2). The purpose of the filter is smoothing and prediction such that the filter output is an estimate of the expected C/I at the time instant for which the link adaptation operation, i.e. the codec mode selection, becomes effective.

Table 1: Filter coefficients of C/I measuring filter for TCH/AFS

0.02737	0.02692	0.02643	0.02573	0.02527	0.02499	0.02448	0.02393	0.02335	0.02286
0.02240	0.02203	0.02158	0.02106	0.02072	0.02032	0.01993	0.01956	0.01923	0.01877
0.01825	0.01782	0.01743	0.01715	0.01682	0.01642	0.01614	0.01566	0.01520	0.01489
0.01465	0.01422	0.01382	0.01340	0.01303	0.01273	0.01236	0.01205	0.01178	0.01141
0.01102	0.01068	0.01031	0.00998	0.00958	0.00928	0.00909	0.00882	0.00854	0.00827
0.00800	0.00784	0.00757	0.00729	0.00693	0.00659	0.00629	0.00601	0.00586	0.00565
0.00540	0.00510	0.00491	0.00473	0.00464	0.00443	0.00424	0.00397	0.00385	0.00360
0.00351	0.00311	0.00290	0.00269	0.00232	0.00204	0.00180	0.00165	0.00137	0.00119
0.00098	0.00073	0.00052	0.00031	0.00006	-0.00018	-0.00027	-0.00034	-0.00043	-0.00064
-0.00079	-0.00104	-0.00107	-0.00122	-0.00146	-0.00162	-0.00183	-0.00195	-0.00208	-0.00232
-0.00253									

Table 2: Filter coefficients of C/I measuring filter for TCH/AHS

0.03998	0.03903	0.03781	0.03650	0.03513	0.03406	0.03296	0.03223	0.03116	0.03036
0.02911	0.02832	0.02756	0.02682	0.02585	0.02524	0.02441	0.02368	0.02277	0.02194
0.02118	0.02032	0.01923	0.01837	0.01788	0.01712	0.01636	0.01544	0.01474	0.01431
0.01370	0.01297	0.01263	0.01221	0.01181	0.01135	0.01080	0.00974	0.00919	0.00836
0.00790	0.00748	0.00681	0.00647	0.00613	0.00558	0.00534	0.00494	0.00436	0.00403
0.00351									

Annex B (informative): Example Definition of Mode Command/Request decision thresholds

Following Table 3 gives an example definition of Mode Command/Request decision thresholds for the TCH/AFS traffic channel employing a codec mode set which contains the 12.2 kbit/s, the 7.95 kbit/s, and the 5.9 kbit/s codec modes. Table 4 gives an example definition of Mode Command/Request decision thresholds for the TCH/AHS traffic channel employing a codec mode set which contains the 7.95 kbit/s, the 6.7 kbit/s, the 5.9 kbit/s, and the 5.15 kbit/s codec modes.

Table 3: MC/MR decision thresholds for TCH/AFS

MC'/MR'	THR_MC_Dn(MC')/ THR_MR_Dn(MR')	THR_MC_Up(MC')/ THR_MR_Up(MR')
12,2 kbit/s	11,5 dB	+ ∞
7,95 kbit/s	6,5 dB	13,5 dB
5,9 kbit/s	– ∞	8,5 dB

Table 4: MC/MR decision thresholds for TCH/AHS

MC'/MR'	THR_MC_Dn(MC')/ THR_MR_Dn(MR')	THR_MC_Up(MC')/ THR_MR_Up(MR')
7,95 kbit/s	15,0 dB	+ ∞
6,7 kbit/s	12,5 dB	17,0 dB
5,9 kbit/s	11,0 dB	15,0 dB
5,15 kbit/s	– ∞	13,0 dB

History

Document history		
V7.0.1	July 1999	One-step Approval Procedure OAP 9952: 1999-07-28 to 1999-11-26
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