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Part 3: Specific operating features

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Project Terrestrial Trunked Radio (TETRA).

The present document is part 3 of a multi-part deliverable covering speech codec for full-rate traffic channel, as identified below:

Part 1: "General description of speech functions";

Part 2: "TETRA codec";

Part 3: "Specific operating features";

Part 4: "Codec conformance testing".

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1 Scope

The present document describes all the functions associated with the TETRA speech codec, except the specification of the codec by itself which is entirely defined in EN 300 395-2 [1].

Clause 4 of the present document provides a description of the functions associated with the speech encoder, while clause 5 is its counterpart for the speech decoder.

Clause 6 describes the contents and the format of the signalling data block included in a stolen frame when used for transferring information relevant to the codec in a U-plane signalling message.

In addition, annex A provides indications and preferred solutions for the implementation of optional features.

2 References

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

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

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

[1] ETSI EN 300 395-2: "Terrestrial Trunked Radio (TETRA); Speech codec for full-rate traffic channel; Part 2: TETRA codec".

[2] ETSI EN 300 392-7: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 7: Security".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in EN 300 392-2, clause 3 apply.

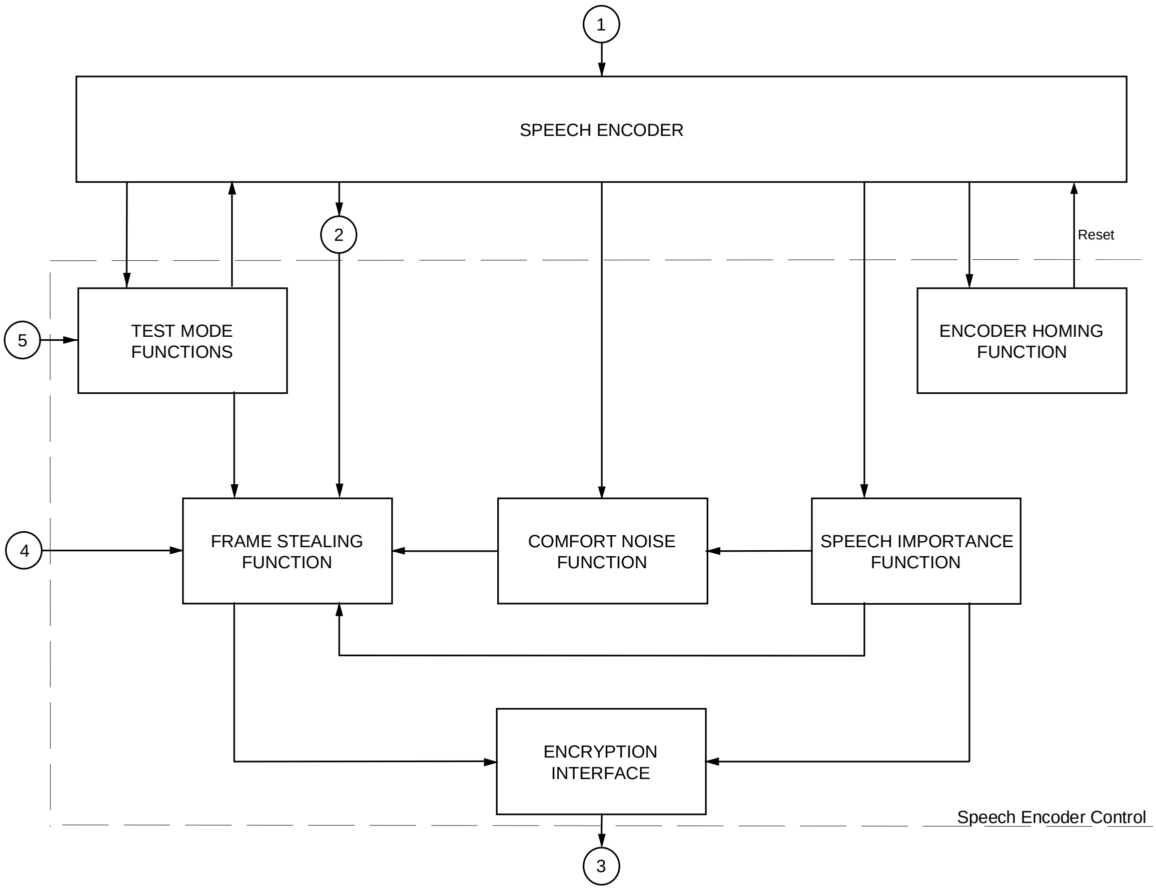
3.2 Abbreviations

For the purposes of the present document, the abbreviations given in EN 300 392-2, clause 3 and the following apply:

AMR	Adaptive Multi-Rate
BFI	Bad Frame Indicator
CNF	Comfort Noise Frame
DTX	Discontinuous Transmission
LTP	Long Term Predictor
MAC	Medium Access Control
MFG	Missing Frame Generation
PCM	Pulse Coded Modulation
RMS	Root Mean Square
VAD	Voice Activity Detector

4 TETRA Speech encoder

A diagram of the speech encoder and associated functions is given in figure 1. A more general overview is given in EN 300 395-1. The speech encoder is defined in EN 300 395-2 [1] and the other functions form the speech encoder control unit. The speech encoder control unit shall have access to all the internal data and functions of the speech encoder (including the input speech).



1) 16-bit uniform PCM, 8 000 samples/s.
2) Encoded speech frame 30 ms, 137 bits/frame.
3) Encoded speech frame in "TMD_UNITDATA_request" message.
4) Stolen indication in "TMD_REPORT_indication" message.
5) Test mode control.

Figure 1: Overview of speech encoder specific operating features

The speech encoder as defined in EN 300 395-2 [1] shall receive speech in the form of 16-bit uniform PCM at a rate of 8 000 samples per second.

The coded data corresponding to each 30 ms speech frame shall be output from the speech encoder control unit via the encryption interface to the encryption unit (or directly to the MAC if encryption is not used). The interfaces with the encryption unit, namely interface points 3 and 4 in figure 1, shall be as defined in EN 300 392-7 [2], clause 7. Message "TMD_UNITDATA_ request" is the means of conveying half-slots from the U-plane to the MAC, while "TMD_REPORT_indication" enables the MAC to pass control information to the U-plane.

Comfort noise parameters may be generated and their presence in the coded speech data shall be indicated by a U-plane signalling message conveyed using the frame stealing mechanism.

A speech importance indication shall be provided.

The presence of a homing sequence in the input speech shall be recognized and the encoder reset to a defined state.

All functions necessary to support conformance testing shall be implemented.

An appropriate U_device destination address shall be set for each half slot of coded speech data to allow correct routing at the receiver.

4.1 Encoder homing function

4.1.1 Definition of encoder homing frame

The encoder homing frame shall consist of 240 identical samples (corresponding to a 30 ms speech frame), each 16 bits long with the value 0x0008.

NOTE: 0x0008 is a number represented in hexadecimal notation.

4.1.2 Encoder homing

Whenever the speech encoder receives at its input an encoder homing frame exactly aligned with its internal speech frame segmentation, the following events shall take place:

Step 1: the speech encoder performs its normal operation and produces a speech parameter frame at its output which is in general unknown;

Step 2: the speech encoder shall be reset and placed in its home state by executing the reset functions "Init_Coder_Tetra( )" and "Init_Pre_Process( )" as defined in EN 300 395-2 [1];

Step 3: the speech encoder is now in its home state and any further consecutive encoder homing frames shall result in an output speech parameter frame identical to the decoder homing frame.

Applying a sequence of N encoder homing frames to the speech encoder input shall cause at least N-1 decoder homing frames at the output of the speech encoder control unit.

4.2 Speech importance function

This function shall compute an importance parameter for each speech frame. This may be done on the basis of the likely degradation in speech quality which would result from stealing that frame. The importance parameter shall take one of the values:

- NO_IMPORTANCE;
- LOW;
- MEDIUM; or
- HIGH.

Even in the case of speech frames marked "NO_IMPORTANCE" there may be some benefit in terms of speech quality from transmission to the end user.

4.3 Comfort noise function

This function may compute speech parameters which can be used for comfort noise generation at the receiver.

A Comfort Noise Frame (CNF) shall have the same format as a normal speech frame.

The comfort noise function may also determine when a CNF should be transmitted.

If Discontinuous Transmission (DTX) is employed on an uplink, then at least a CNF, or some other data, should be transmitted frequently enough that the receiving base station does not drop the connection.

4.4 Frame stealing function

Clause 6 hereafter defines the format of the signalling messages inserted by the frame stealing function used in conjunction with the codec. The following describes the normal use of these messages.

SPEECH_ON is used to signal the start of active speech in the next half slot. This may be used particularly to end DTX. An alternative method of ending DTX is to recommence transmission of speech frames without specific signalling.

SPEECH_OFF is used to signal the end of active speech. This may be used particularly to start or maintain the channel during a period of DTX.

CNF_COMMAND signals that the second half slot contains CNF. It might be used normally to signal three conditions:

- to signal the end of active speech and to start comfort noise in the receiver;

- to maintain the channel during a period of DTX;

- to update the CNF.

MUTE signals the receiver to mute the speech decoder output.

NOTE: U-plane frame stealing shall be disabled when required by test mode functions.

4.5 Test mode functions

The test mode control input to the speech encoder control shall determine when the codec conformance test mode is active.

When the codec conformance test mode is active, the following shall apply:

- the frame stealing function shall not carry out U-plane frame stealing;
- the frame stealing function shall pass the encoded speech data to the encryption interface without any modification;
- the speech importance function shall indicate HIGH importance for all input speech data;
- encryption shall be disabled.

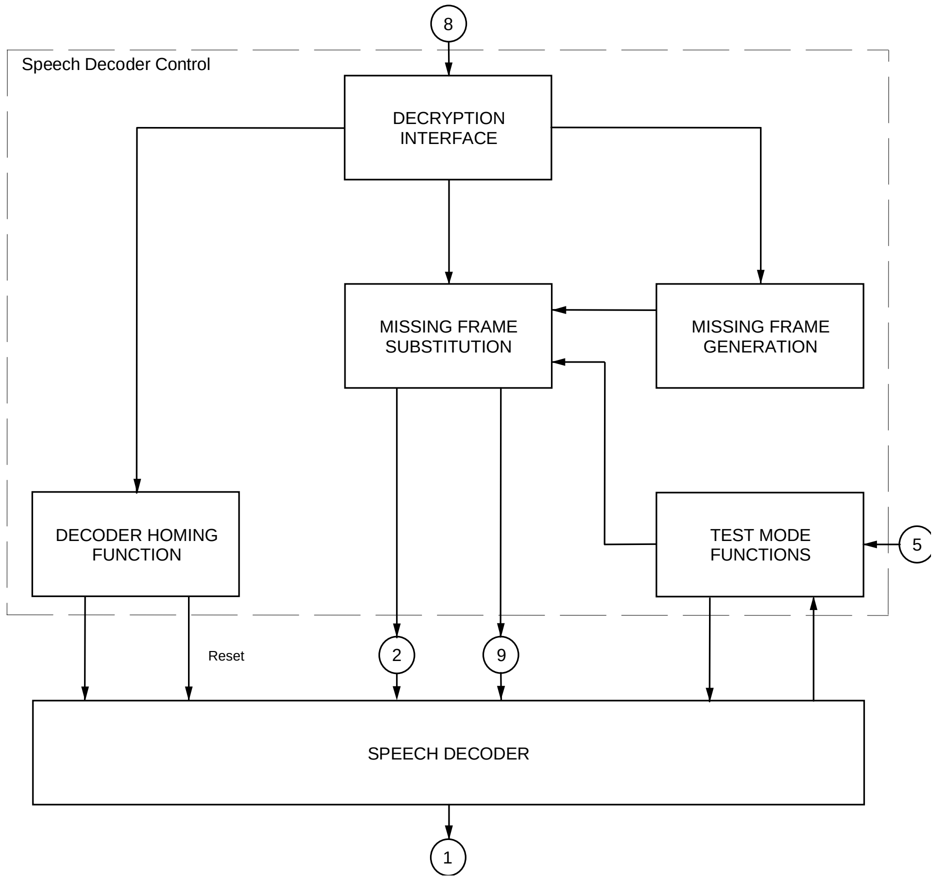
4.6 Encryption interface

This function assembles the parameters for the message "TMD_UNITDATA_request" for passing to the encryption unit (or directly to the MAC if encryption is not used).

The parameters of this message shall each be set to one of their allowed values.

5 TETRA Speech decoder

A diagram of the speech decoder and associated functions is given in figure 2. A more general overview is given in EN 300 395-1. The speech decoder is defined in EN 300 395-2 [1] and the other functions form the speech decoder control unit. The speech decoder control unit shall have access to all the internal data and functions of the speech decoder.



1) 16-bit uniform PCM, 8 000 samples/s.
2) Encoded speech frame 30 ms, 137 bits/frame.
5) Test mode control.
8) Encoded speech frame in "TMD_UNITDATA_indication" message.
9) Bad frame indicator.

Figure 2: Overview of speech decoder specific operating features

The interfaces from the encryption unit (or MAC) to the speech decoder control unit, namely interface point 8 in figure 2 shall be as defined in EN 300 392-7 [2], clause 7. Message "TMD_UNITDATA_indication" is used to convey half-slots from the MAC to the U-plane. The coded data corresponding to each 30 ms speech frame shall be received from the encryption unit via the encryption interface.

Each received half_slot will have a U_device destination address to allow routing to appropriate device at the receiver.

The speech decoder as defined in EN 300 395-2 [1] shall output synthesized speech in the form of 16-bit uniform PCM at a rate of 8 000 samples per second.

5.1 Encryption interface

This function receives the parameters in the message "TMD_UNITDATA_indication" from the encryption unit (or directly from the MAC if encryption is not used).

5.2 Decoder homing function

5.2.1 Definition of decoder homing frame

The decoder homing frame is a fixed set of parameters as described in table 1. It is the natural response of the speech encoder, starting from its home state, to an encoder homing frame. This condition occurs if at least two encoder homing frames are input to the encoder consecutively. As for any 30 ms speech frame, the decoder homing frame is an encoded block of 137 bits. Table 1 shall be read as follows: bit 1 appears on line 1 column 1, bit 2 on line 1 column 2 and bit 137 on the last line, last column. Only for the convenience of the reader, those 137 bits are split by strings of 8 in table 1.

Table 1: Values of the 137 bits in the decoder homing frame (bit 1 in upper left side)

10111111	01110011	11010100	11000011	01110100	11110011	10000000
00111111	00111000	01100000	00000100	11100111	10001000	00000111
00101000	01100011	11100100	1			

5.2.2 Decoder homing

Whenever the speech decoder control unit receives at its input a decoder homing frame, then the following events shall take place:

Step 1: the speech decoder performs its normal operation and produces a speech frame at its output which is in general unknown, except if the speech decoder was in its home state at the start of the frame, the resulting speech frame is replaced by the encoder homing frame;

Step 2: the speech decoder is reset, placing it in its home state, by executing the reset function "Init_Decod_Tetra( )" as defined in EN 300 395-2 [1].

Applying a sequence of N decoder homing frames to the input of the speech decoder control unit shall cause at least N-1 encoder homing frames at the output of the speech decoder.

5.3 Missing frame generation

This function may generate half slots of coded speech data to replace those missing due to failure of the radio link, frame stealing, or DTX.

If comfort noise is generated using the data in a CNF, successive values of the codebook index, sign and shift shall be randomized.

5.4 Missing frame substitution

This function may replace missing half slots of information by those produced by the Missing Frame Generation (MFG) function.

Encoded speech frames shall be passed to the speech decoder at an average rate of one every 30 ms.

The Bad Frame Indicator (BFI) shall not be set if the half_slot_condition is "GOOD" and the stolen indication is "Not Stolen" in the "TMD_UNITDATA_indication".

5.5 Test mode functions

The test mode control input to the speech decoder control shall determine when the codec conformance test mode is active.

When the codec conformance test mode is active, the following shall apply:

- decryption shall be disabled;
- the missing frame substitution function shall not replace any missing half slots, unless the stolen indication is "Stolen by C-plane" or "Stolen by U-plane" or the half_slot_condition is "BAD" or "NULL", in which case the BFI shall also be set.

NOTE: If frame stealing occurs or bad frames are received during the codec conformance test, then the test will almost certainly fail.

6 Signalling data block format

The requirements of this clause are applicable to stealing mode both for the TETRA codec and the optional AMR codec.

As described in EN 300 392-7 [2], clause 7.4.1, in the messages "TMD_UNITDATA_indication" and "TMD_UNITDATA_request", the presence of a half slot stolen by the U-plane shall be indicated by the stolen indication "Stolen by U-plane". In this case the format of the stolen half slot shall be as defined in table 2 (extracted from EN 300 392-7 [2], clause 7.4.5), knowing that the stealing channel STCH/E allows 121 bits of data.

Table 2: Stolen half slot format

Information Element	Element Length
Half Slot Stolen by Encryption unit (HSSE)	1
Stolen Half Slot Identifier (SHSI)	1
Signalling data block	119

If HSSE is 0 and SHSI is 0, the format of the signalling data block shall be as defined in table 3. The other combinations of HSSE and SHSI are not used in the present document.

Table 3: Signalling data block format

Information Element	Element Length
Signalling message	6
Signalling data	113

The coding of the signalling message information element (64 values allowed) shall be as follows.

Table 4: Information element coding

Value	Message Name	Description	Remarks
0	NULL	No message	
1	SPEECH_ON	Next half slot contains active speech	If muted, speech decoder is unmuted.
2	SPEECH_OFF	End of active speech	
3	CNF_COMMAND	Second half slot contains CNF and marks end of current period of active speech	- If muted, speech decoder is unmuted, - May be repeated to either update CNF or to maintain the channel.
4	MUTE	Mute speech decoder output	
5-31	Reserved	For definition within TETRA standard	
32-63	User defined	For use by manufacturers and system implementers	

NOTE 1: As indicated in table 4, the MUTE message is intended to mute the speech codec output. On receipt of the MUTE message, and to avoid the possibility of permanently and erroneously de-activating the codec, the speech decoder output shall be muted for a maximum of 100 speech frames (corresponding to 3 seconds) after the last MUTE message.

NOTE 2: All the codec defined signalling messages in table 4 may appear in either the first or the second half slot, excepted CNF_COMMAND which shall be inserted in the first half slot, the second half slot carrying the CNF.

7 AMR speech encoder and decoder

The optional AMR speech encoder and decoder function is described in the 26-series of the 3GPP specifications, as referenced by EN 300 395-2 [1].

Annex A (informative): Implementation of optional features

A.1 Speech importance calculation

The speech frame importance is intended to indicate the degradation in quality likely to be caused by stealing that speech frame. Therefore the degradation due to frame stealing can be minimized by preferentially stealing frames of lower importance.

As an example, the speech importance could be related directly to the RMS energy of the input speech.

If means are not provided for calculation of importance all speech frames could be labelled with importance "HIGH".

A.2 Voice Activity Detection (VAD)

VAD may be implemented by the speech importance function. Active speech could correspond to all speech frames labelled with other that "NO_IMPORTANCE".

A.3 Discontinuous Transmission (DTX)

DTX may be implemented within the MAC or other part of the transmission system. For example, speech frames marked "NO_IMPORTANCE" need not be transmitted over the air interface.

Gaps in the transmission can be filled at the receiver by inserting comfort noise.

As an example, a CNF could be placed at the end of a period of active speech. This would be indicated by the U-plane signalling message "CNF_COMMAND" and the subsequent half slots marked "NO_IMPORTANCE" until the start of the next period of active speech.

A.4 CNF computation

For best subjective speech quality the CNF parameters should be estimated using periods of no input speech activity.

To minimize possible disturbing periodic noises, it may for example, be desirable to transmit the smallest possible energy value for the LTP parameter.

A.5 Missing Frame Generation (MFG)

A.5.1 Error concealment

The speech decoder carries out error concealment action if the Bad Frame Indicator (BFI) is set at its input, but implementation of improved error concealment may be possible within the speech decoder control unit.

As an example, appropriate replacement data could be calculated for half slots marked "BAD" or "NULL", and in this case the BFI could then be set to "GOOD".

A.5.2 Comfort noise generation

Comfort noise can be generated using a recently received CNF. In this case successive values of the speech parameters codebook index, sign and shift shall be randomized.

If a half slot containing a CNF is marked "BAD", then the previous good CNF may be used.

If a CNF is not available at the receiver, then comfort noise parameters may be computed in some other way, for example by estimation from received speech parameters or using a pre-defined CNF.

A.6 Setting BFI

In the missing frame substitution function the BFI should be set if error concealment action by the speech decoder is appropriate.

For example the BFI could be set if the stolen_indication is "Stolen by C-plane" or "Stolen by U-plane", or the half_slot_condition is "BAD" or "NULL".

A.7 U-plane frame stealing

In general frame stealing will degrade the speech quality and should therefore be used as infrequently as possible. A rate of less than one frame per second is desirable.

Since it may be possible that the speech encoder can be informed that U-plane frame stealing has occurred before the next speech frame is processed it may be possible for the encoder to take some action to minimize the degradation in speech quality at the receiver.

A.8 Receiver muting

The speech decoder may be muted by substituting its input data for coded frames corresponding to silence.

A.9 Response to U-plane signalling

The action to be carried out on receipt of signalling messages and data is optional. However, ignoring signalling messages is likely to reduce the perceived communications quality.

Annex B (informative): Bibliography

ETSI EN 300 395-1: "Terrestrial Trunked Radio (TETRA); Speech codec for full-rate traffic channel; Part 1: General description of speech functions".

ETSI EN 300 392-2: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".

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