

# ETSI EN 300 395-2 V1.3.3 (2025-02)



**TETRA and Critical Communications Evolution (TCCE);  
Speech codec for full-rate traffic channel;  
Part 2: TETRA codec**

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# Contents

|                                                                                        |    |
|----------------------------------------------------------------------------------------|----|
| Intellectual Property Rights .....                                                     | 7  |
| Foreword.....                                                                          | 7  |
| Modal verbs terminology.....                                                           | 8  |
| 1 Scope .....                                                                          | 9  |
| 2 References .....                                                                     | 9  |
| 2.1 Normative references .....                                                         | 9  |
| 2.2 Informative references.....                                                        | 9  |
| 3 Definition of terms, symbols and abbreviations.....                                  | 10 |
| 3.1 Terms.....                                                                         | 10 |
| 3.2 Symbols.....                                                                       | 10 |
| 3.3 Abbreviations .....                                                                | 10 |
| 4 Full rate codec .....                                                                | 11 |
| 4.1 Structure of the codec.....                                                        | 11 |
| 4.2 Functional description of the codec.....                                           | 13 |
| 4.2.1 Pre- and post-processing.....                                                    | 13 |
| 4.2.2 Encoder .....                                                                    | 13 |
| 4.2.2.0 General .....                                                                  | 13 |
| 4.2.2.1 Short-term prediction .....                                                    | 14 |
| 4.2.2.2 LP to LSP and LSP to LP conversion .....                                       | 15 |
| 4.2.2.3 Quantization and interpolation of LP parameters.....                           | 17 |
| 4.2.2.4 Long-term prediction analysis.....                                             | 18 |
| 4.2.2.5 Algebraic codebook: structure and search.....                                  | 20 |
| 4.2.2.6 Quantization of the gains .....                                                | 23 |
| 4.2.2.7 Detailed bit allocation .....                                                  | 24 |
| 4.2.3 Decoder.....                                                                     | 25 |
| 4.2.3.0 General .....                                                                  | 25 |
| 4.2.3.1 Decoding process .....                                                         | 25 |
| 4.2.3.1.0 General .....                                                                | 25 |
| 4.2.3.1.1 Decoding of LP filter parameters .....                                       | 25 |
| 4.2.3.1.2 Decoding of the adaptive codebook vector.....                                | 26 |
| 4.2.3.1.3 Decoding of the innovation vector .....                                      | 26 |
| 4.2.3.1.4 Decoding of the adaptive and innovative codebook gains.....                  | 26 |
| 4.2.3.1.5 Computation of the reconstructed speech.....                                 | 26 |
| 4.2.3.2 Error concealment .....                                                        | 26 |
| 5 Channel coding for speech .....                                                      | 27 |
| 5.1 General .....                                                                      | 27 |
| 5.2 Interfaces in the error control structure .....                                    | 27 |
| 5.3 Notations .....                                                                    | 29 |
| 5.4 Definition of sensitivity classes and error control codes .....                    | 29 |
| 5.4.1 Sensitivity classes .....                                                        | 29 |
| 5.4.2 CRC codes .....                                                                  | 29 |
| 5.4.3 16-state RCPC codes .....                                                        | 31 |
| 5.4.3.0 General .....                                                                  | 31 |
| 5.4.3.1 Encoding by the 16-state mother code of rate 1/3.....                          | 31 |
| 5.4.3.2 Puncturing of the mother code .....                                            | 31 |
| 5.5 Error control scheme for normal speech traffic channel.....                        | 32 |
| 5.5.0 General.....                                                                     | 32 |
| 5.5.1 CRC code.....                                                                    | 32 |
| 5.5.2 RCPC codes.....                                                                  | 32 |
| 5.5.2.0 General .....                                                                  | 32 |
| 5.5.2.1 Puncturing scheme of the RCPC code of rate 8/12 (equal to 2/3).....            | 33 |
| 5.5.2.2 Puncturing scheme of the RCPC code of rate 8/18 .....                          | 33 |
| 5.5.3 Matrix Interleaving .....                                                        | 33 |
| 5.6 Error control scheme for speech traffic channel with frame stealing activated..... | 34 |

|                                                                              |                                                                                        |           |
|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-----------|
| 5.6.0                                                                        | General.....                                                                           | 34        |
| 5.6.1                                                                        | CRC code.....                                                                          | 34        |
| 5.6.2                                                                        | RCPC codes.....                                                                        | 35        |
| 5.6.2.0                                                                      | General.....                                                                           | 35        |
| 5.6.2.1                                                                      | Puncturing scheme of the RCPC code of rate 8/17 .....                                  | 36        |
| 5.6.3                                                                        | Interleaving.....                                                                      | 36        |
| 6                                                                            | Channel decoding for speech .....                                                      | 36        |
| 6.1                                                                          | General .....                                                                          | 36        |
| 6.2                                                                          | Error control structure .....                                                          | 36        |
| 7                                                                            | Codec performance.....                                                                 | 37        |
| 8                                                                            | Bit exact description of the TETRA codec.....                                          | 37        |
| 9                                                                            | AMR speech codec.....                                                                  | 39        |
| 10                                                                           | Channel coding for AMR speech .....                                                    | 39        |
| 10.1                                                                         | General .....                                                                          | 39        |
| 10.2                                                                         | Interfaces in the error control structure .....                                        | 39        |
| 10.3                                                                         | Notations .....                                                                        | 39        |
| 10.4                                                                         | Definition of sensitivity classes and error control codes .....                        | 39        |
| 10.4.1                                                                       | Sensitivity classes .....                                                              | 39        |
| 10.4.2                                                                       | CRC codes .....                                                                        | 39        |
| 10.4.3                                                                       | 16-state RCPC codes .....                                                              | 41        |
| 10.4.3.0                                                                     | General .....                                                                          | 41        |
| 10.4.3.1                                                                     | Encoding by the 16-state mother code of rate 1/3.....                                  | 41        |
| 10.4.3.2                                                                     | Puncturing of the mother code .....                                                    | 41        |
| 10.5                                                                         | Error control scheme for normal AMR speech traffic channel.....                        | 42        |
| 10.5.0                                                                       | General.....                                                                           | 42        |
| 10.5.1                                                                       | CRC code.....                                                                          | 42        |
| 10.5.2                                                                       | RCPC codes.....                                                                        | 42        |
| 10.5.2.0                                                                     | General .....                                                                          | 42        |
| 10.5.2.1                                                                     | Puncturing scheme of the RCPC code of rate 8/12 (equal to 2/3).....                    | 43        |
| 10.5.2.2                                                                     | Puncturing scheme of the RCPC code of rate 8/18 .....                                  | 43        |
| 10.5.3                                                                       | Matrix Interleaving .....                                                              | 43        |
| 10.6                                                                         | Error control scheme for AMR speech traffic channel with frame stealing activated..... | 44        |
| 10.6.0                                                                       | General.....                                                                           | 44        |
| 10.6.1                                                                       | Speech frames in stealing mode.....                                                    | 44        |
| 10.6.2                                                                       | CRC code.....                                                                          | 44        |
| 10.6.3                                                                       | RCPC codes.....                                                                        | 45        |
| 10.6.3.0                                                                     | General .....                                                                          | 45        |
| 10.6.3.1                                                                     | Puncturing scheme of the RCPC code of rate 14/8 .....                                  | 46        |
| 10.6.4                                                                       | Interleaving.....                                                                      | 46        |
| 11                                                                           | Channel decoding for AMR speech .....                                                  | 46        |
| 11.1                                                                         | General .....                                                                          | 46        |
| 11.2                                                                         | Error control structure .....                                                          | 46        |
| 12                                                                           | Bit exact description of the AMR codec FEC .....                                       | 47        |
| <b>Annex A (informative): Implementation of speech channel decoding.....</b> |                                                                                        | <b>48</b> |
| A.0                                                                          | General .....                                                                          | 48        |
| A.1                                                                          | Algorithmic description of speech channel decoding .....                               | 48        |
| A.1.1                                                                        | Definition of error control codes .....                                                | 48        |
| A.1.1.1                                                                      | 16-state RCPC codes .....                                                              | 48        |
| A.1.1.1.0                                                                    | General .....                                                                          | 48        |
| A.1.1.1.1                                                                    | Obtaining the mother code from punctured code .....                                    | 48        |
| A.1.1.1.2                                                                    | Viterbi decoding of the 16-state mother code of the rate 1/3.....                      | 48        |
| A.1.1.2                                                                      | CRC codes .....                                                                        | 49        |
| A.1.1.3                                                                      | Type-4 bits .....                                                                      | 49        |
| A.1.2                                                                        | Error control scheme for normal speech traffic channel.....                            | 49        |
| A.1.2.0                                                                      | General.....                                                                           | 49        |

|                               |                                                                                     |           |
|-------------------------------|-------------------------------------------------------------------------------------|-----------|
| A.1.2.1                       | Matrix Interleaving .....                                                           | 49        |
| A.1.2.2                       | RCPC codes .....                                                                    | 49        |
| A.1.2.2.0                     | General .....                                                                       | 49        |
| A.1.2.2.1                     | Puncturing scheme of the RCPC code of rate 8/12 (equal to 2/3) .....                | 50        |
| A.1.2.2.2                     | Puncturing scheme of the RCPC code of rate 8/18 .....                               | 50        |
| A.1.2.3                       | CRC code .....                                                                      | 50        |
| A.1.2.4                       | Speech parameters .....                                                             | 50        |
| A.1.3                         | Error control scheme for speech traffic channel with frame stealing activated ..... | 50        |
| A.1.3.0                       | General .....                                                                       | 50        |
| A.1.3.1                       | Interleaving .....                                                                  | 50        |
| A.1.3.2                       | RCPC codes .....                                                                    | 51        |
| A.1.3.2.0                     | General .....                                                                       | 51        |
| A.1.3.2.1                     | Puncturing scheme of the RCPC code of rate 8/17 .....                               | 51        |
| A.1.3.3                       | CRC code .....                                                                      | 51        |
| A.1.3.4                       | Speech parameters .....                                                             | 51        |
| A.2                           | C Code for speech channel decoding .....                                            | 51        |
| <b>Annex B (informative):</b> | <b>Indexes .....</b>                                                                | <b>52</b> |
| B.1                           | Index of C code routines .....                                                      | 52        |
| B.2                           | Index of files .....                                                                | 55        |
| <b>Annex C (informative):</b> | <b>Codec performance .....</b>                                                      | <b>56</b> |
| C.1                           | General .....                                                                       | 56        |
| C.2                           | Quality .....                                                                       | 56        |
| C.2.1                         | Subjective speech quality .....                                                     | 56        |
| C.2.1.1                       | Description of characterization tests .....                                         | 56        |
| C.2.1.2                       | Absolute speech quality .....                                                       | 56        |
| C.2.1.3                       | Effect of input level .....                                                         | 56        |
| C.2.1.4                       | Effect of input frequency characteristic .....                                      | 56        |
| C.2.1.5                       | Effect of transmission errors .....                                                 | 57        |
| C.2.1.6                       | Effect of tandeming .....                                                           | 57        |
| C.2.1.7                       | Effect of acoustic background noise .....                                           | 57        |
| C.2.1.8                       | Effect of vocal effort .....                                                        | 57        |
| C.2.1.9                       | Effect of frame stealing .....                                                      | 57        |
| C.2.1.10                      | Speaker and language dependency .....                                               | 57        |
| C.2.2                         | Comparison with analogue FM .....                                                   | 57        |
| C.2.2.0                       | General .....                                                                       | 57        |
| C.2.2.1                       | Analogue and digital systems results .....                                          | 57        |
| C.2.2.2                       | All conditions .....                                                                | 58        |
| C.2.2.3                       | Input level .....                                                                   | 58        |
| C.2.2.4                       | Error patterns .....                                                                | 59        |
| C.2.2.5                       | Background noise .....                                                              | 59        |
| C.2.3                         | Additional tests .....                                                              | 59        |
| C.2.3.0                       | General .....                                                                       | 59        |
| C.2.3.1                       | Types of signals .....                                                              | 59        |
| C.2.3.2                       | Codec behaviour .....                                                               | 59        |
| C.3                           | Performance of the channel coding/decoding for speech .....                         | 60        |
| C.3.0                         | General .....                                                                       | 60        |
| C.3.1                         | Classes of simulation environment conditions .....                                  | 60        |
| C.3.2                         | Classes of equipment .....                                                          | 60        |
| C.3.3                         | Classes of bits .....                                                               | 61        |
| C.3.4                         | Channel conditions .....                                                            | 61        |
| C.3.5                         | Results for normal case .....                                                       | 61        |
| C.4                           | Complexity .....                                                                    | 62        |
| C.4.0                         | General .....                                                                       | 62        |
| C.4.1                         | Complexity analysis .....                                                           | 62        |
| C.4.1.1                       | Measurement methodology .....                                                       | 62        |
| C.4.1.2                       | TETRA basic operators .....                                                         | 62        |

|                               |                                                                                         |           |
|-------------------------------|-----------------------------------------------------------------------------------------|-----------|
| C.4.1.3                       | Worst case path for speech encoder .....                                                | 64        |
| C.4.1.4                       | Worst case path for speech decoder .....                                                | 65        |
| C.4.1.5                       | Condensed complexity values for encoder and decoder .....                               | 66        |
| C.4.2                         | DSP independence .....                                                                  | 67        |
| C.4.2.0                       | General .....                                                                           | 67        |
| C.4.2.1                       | Program control structure .....                                                         | 67        |
| C.4.2.2                       | Basic operator implementation .....                                                     | 67        |
| C.4.2.3                       | Additional operator implementation .....                                                | 67        |
| C.5                           | Delay .....                                                                             | 67        |
| <b>Annex D (informative):</b> | <b>Results of the TETRA codec characterization listening and complexity tests .....</b> | <b>68</b> |
| D.1                           | Characterization listening test .....                                                   | 68        |
| D.1.1                         | Experimental conditions .....                                                           | 68        |
| D.1.2                         | Tables of results .....                                                                 | 69        |
| D.2                           | TETRA codec complexity study .....                                                      | 77        |
| D.2.1                         | Computational analysis results .....                                                    | 77        |
| D.2.1.1                       | TETRA speech encoder .....                                                              | 77        |
| D.2.1.2                       | TETRA speech decoder .....                                                              | 85        |
| D.2.1.3                       | TETRA channel encoder and decoder .....                                                 | 88        |
| D.2.2                         | Memory requirements analysis results .....                                              | 90        |
| D.2.2.1                       | TETRA speech encoder .....                                                              | 90        |
| D.2.2.2                       | TETRA speech decoder .....                                                              | 91        |
| D.2.2.3                       | TETRA speech channel encoder .....                                                      | 91        |
| D.2.2.4                       | TETRA speech channel decoder .....                                                      | 91        |
| <b>Annex E (informative):</b> | <b>Description of attached computer files .....</b>                                     | <b>92</b> |
| E.0                           | General .....                                                                           | 92        |
| E.1                           | Directory C-WORD .....                                                                  | 92        |
| E.2                           | Directory C-CODE .....                                                                  | 92        |
| E.3                           | Directory AMR-Code .....                                                                | 92        |
| <b>Annex F (informative):</b> | <b>Bibliography .....</b>                                                               | <b>93</b> |
| History                       | .....                                                                                   | 94        |

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# Foreword

This European Standard (EN) has been produced by ETSI Technical Committee TETRA and Critical Communications Evolution (TCCE).

The present document is part 2 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".

Clause 4 provides a complete description of the full rate speech source encoder and decoder, whilst clause 5 describes the speech channel encoder and clause 6 the speech channel decoder.

Clause 7 describes the codec performance.

Clause 8 introduces the bit exact description of the codec. This description is given as an ANSI C code, fixed point, bit exact. The whole C code corresponding to the TETRA codec is given in computer files attached to the present document, and are an integral part of this multi-part deliverable.

Clause 9 describes the optional AMR codec.

Clause 10 describes the AMR speech channel encoder.

Clause 11 describes the AMR speech channel decoder.

Clause 12 introduces the AMR speech channel encoder and decoder. This description is given as an ANSI C code.

In addition to these clauses, five informative annexes are provided.

Annex A describes a possible implementation of the speech channel decoding function.

Annex B provides comprehensive indexes of all the routines and files included in the C code associated with the present document.

Annex C describes the actual quality, performance and complexity aspects of the codec.

Annex D reports detailed results from codec characterization listening and complexity tests.

Annex E contains instructions for the use of the attached electronic files.

Annex F lists informative references relevant to the speech codec.

| National transposition dates                                                           |                 |
|----------------------------------------------------------------------------------------|-----------------|
| Date of adoption of this EN:                                                           | 7 January 2025  |
| Date of latest announcement of this EN (doa):                                          | 30 April 2025   |
| Date of latest publication of new National Standard or endorsement of this EN (dop/e): | 31 October 2025 |
| Date of withdrawal of any conflicting National Standard (dow):                         | 31 October 2025 |

## 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](https://standards.iteh.ai/) (Verbal forms for the expression of provisions).

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# 1 Scope

The present document contains the full specification of the speech codecs for use in the Terrestrial Trunked Radio (TETRA) system.

The TETRA codec specified in clauses 4 to 8 is mandatory for all TETRA mobiles and networks. The AMR codec specified in clauses 9 to 12 is optional. If the AMR codec is implemented, all clauses from 9 to 12 applies.

---

## 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 referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found in the [ETSI docbox](#).

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.

- [1] [ETSI EN 300 392-2](#): "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".
- [2] [ETSI TS 126 073](#): "Universal Mobile Telecommunications System (UMTS); ANSI-C code for the Adaptive Multi Rate speech codec (3GPP TS 26.073 Release 4)".
- [3] [ETSI TS 126 074](#): "Universal Mobile Telecommunications System (UMTS); Mandatory speech codec speech processing functions; AMR speech codec test sequences (3GPP TS 26.074 Release 4)".
- [4] [ETSI TS 126 090](#): "Universal Mobile Telecommunications System (UMTS); Mandatory Speech Codec speech processing functions AMR Speech Codec - Transcoding functions (3GPP TS 26.090 Release 4)".

### 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 referenced 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.

- [i.1] Recommendation ITU-T P.48 (1988): "Specification for an intermediate reference system".
- [i.2] ETSI ETR 300-1: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Designers' guide; Part 1: Overview, technical description and radio aspects".

## 3 Definition of terms, symbols and abbreviations

### 3.1 Terms

Void.

### 3.2 Symbols

Void.

### 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

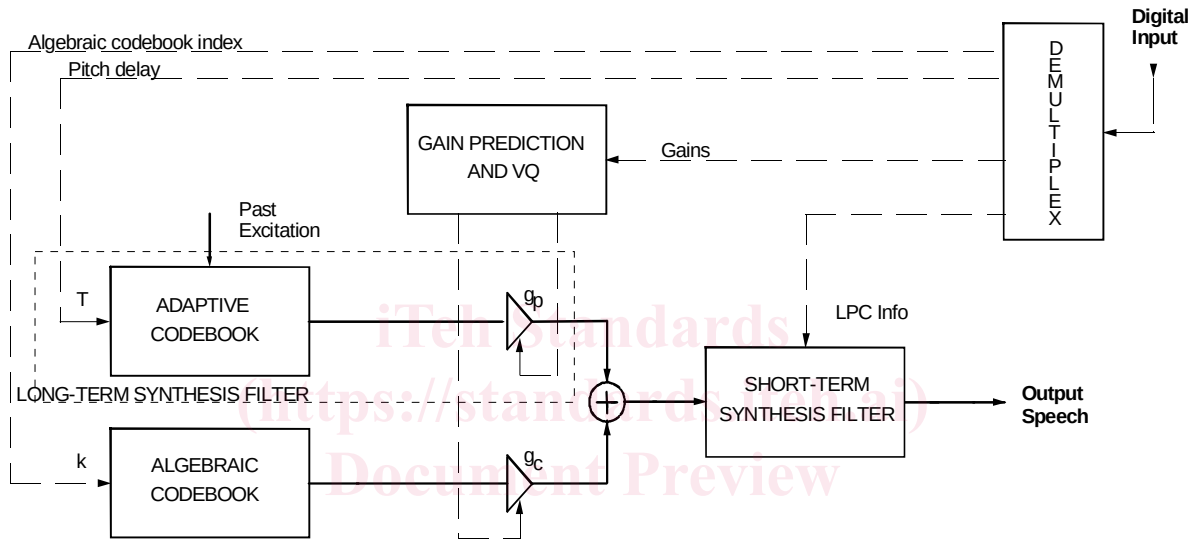
|       |                                             |
|-------|---------------------------------------------|
| ACELP | Algebraic CELP                              |
| AMR   | Adaptive Multi-Rate                         |
| ANSI  | American National Standards Institute       |
| BER   | Bit Error Ratio                             |
| BFI   | Bad Frame Indicator                         |
| BS    | Base Station                                |
| CELP  | Code-Excited Linear Predictive              |
| CRC   | Cyclic Redundancy Code                      |
| DSP   | Digital Signal Processor                    |
| DTMF  | Dual Tone Multiple Frequency                |
| EP    | Error Pattern                               |
| EQ    | Equalizer test                              |
| FEC   | Forward Error Correction                    |
| FIR   | Finite Impulse Response                     |
| FM    | Frequency Modulation                        |
| GSM   | Global System for Mobile communications     |
| HT    | Hilly Terrain                               |
| IRS   | Intermediate Reference System               |
| LP    | Linear Prediction                           |
| LPC   | Linear Predictive Coding                    |
| LSB   | Least Significant Bit                       |
| LSF   | Line Spectral Frequency                     |
| LSP   | Line Spectral Pair                          |
| MAC   | Media Access Control                        |
| MER   | Message Error Rate                          |
| MNRU  | Multiplicative Noise Reference Unit         |
| MOPS  | Million of Operations per Second            |
| MOS   | Mean Opinion Score                          |
| MS    | Mobile Station                              |
| MSB   | Most Significant Bit                        |
| MSE   | Mean Square Error                           |
| PCM   | Pulse Code Modulation                       |
| PDF   | Probability Density Function                |
| PUEM  | Probability of Undetected Erroneous Message |
| RAM   | Random Access Memory                        |
| RCPC  | Rate-Compatible Punctured Convolutional     |
| RF    | Radio Frequency                             |
| ROM   | Read-Only Memory                            |
| SCR   | Source Controlled Rate                      |
| SNR   | Signal to Noise Ratio                       |
| STCH  | STealing CHannel                            |
| TCH/S | Speech Traffic Channel                      |
| TDM   | Time Division Multiplex                     |
| TU    | Typical Urban                               |

|      |                     |
|------|---------------------|
| UPCM | Uniform PCM         |
| V+D  | Voice + Data        |
| VQ   | Vector Quantization |

## 4 Full rate codec

### 4.1 Structure of the codec

The TETRA speech codec is based on the Code-Excited Linear Predictive (CELP) coding model. In this model, a block of  $N$  speech samples is synthesized by filtering an appropriate innovation sequence from a codebook, scaled by a gain factor  $g_c$ , through two time varying filters. A simplified high level block diagram of this synthesis process, as implemented in the TETRA codec, is shown in figure 1.



**Figure 1: High level block diagram of the TETRA speech synthesizer**

The first filter is a long-term prediction filter (pitch filter) aiming at modelling the pseudo-periodicity in the speech signal and the second is a short-term prediction filter modelling the speech spectral envelope.

The long-term or pitch, synthesis filter is given by:

$$\frac{1}{B(z)} = \frac{1}{1 - g_p z^{-T}} \quad (1)$$

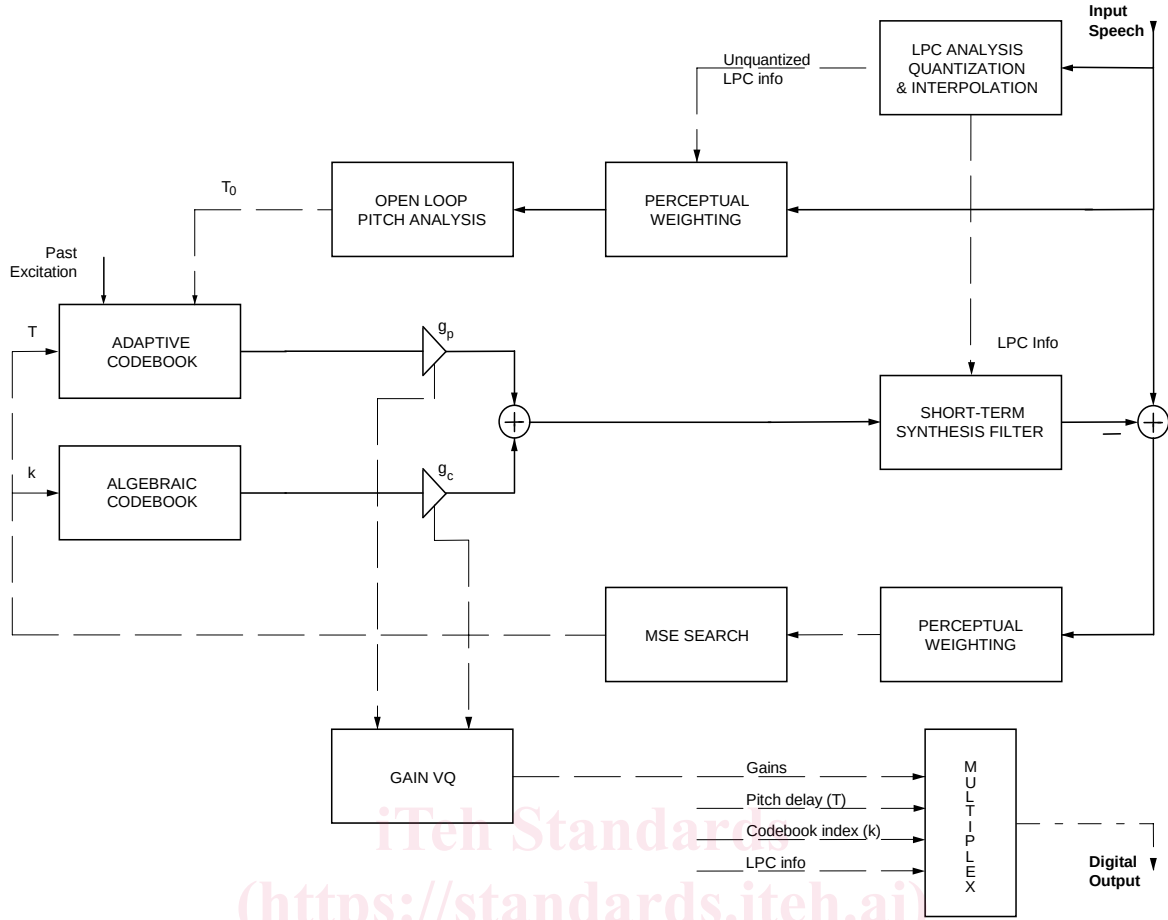
where  $T$  is the pitch delay and  $g_p$  is the pitch gain. The pitch synthesis filter is implemented as an adaptive codebook, where for delays less than the sub-frame length the past excitation is repeated.

The short-term synthesis filter is given by:

$$H(z) = \frac{1}{A(z)} = \frac{1}{1 + \sum_{i=1}^p a_i z^{-i}} \quad (2)$$

where  $a_i, i = 1, \dots, p$ , are the Linear Prediction (LP) parameters and  $p$  is the predictor order. In the TETRA codec  $p$  shall be 10.

The TETRA encoder uses an analysis-by-synthesis technique to determine the pitch and excitation codebook parameters. The simplified block diagram of the TETRA encoder is shown in figure 2.



**Figure 2: High level block diagram of the TETRA speech encoder**

In this analysis-by-synthesis technique, the synthetic speech is computed for all candidate innovation sequences retaining the particular sequence that produces the output closer to the original signal according to a perceptually weighted distortion measure. The perceptual weighting filter de-emphasizes the error at the formant regions of the speech spectrum and is given by:

$$W(z) = \frac{A(z)}{A(z/\gamma)} \quad (3)$$

where  $A(z)$  is the LP inverse filter (as in Equation (2)) and  $0 < \gamma \leq 1$ . The value  $\gamma_1 = 0,85$  shall be used.

Both the weighting filter,  $W(z)$ , and formant synthesis filter,  $H(z)$ , shall use the quantized LP parameters.

In the Algebraic CELP (ACELP) technique, special innovation codebooks having an algebraic structure are used. This algebraic structure has several advantages in terms of storage, search complexity, and robustness. The TETRA codec shall use a specific dynamic algebraic excitation codebook whereby the fixed excitation vectors are shaped by a dynamic shaping matrix (see annex F). The shaping matrix is a function of the LP model  $A(z)$ , and its main role is to shape the excitation vectors in the frequency domain so that their energies are concentrated in the important frequency bands. The shaping matrix used is a Toeplitz lower triangular matrix constructed from the impulse response of the filter:

$$F(z) = \frac{A(z/\gamma_1)}{A(z/\gamma_2)} \quad (4)$$

where  $A(z)$  is the LP inverse filter. The values  $\gamma_1 = 0,75$  and  $\gamma_2 = 0,85$  shall be used.

In the TETRA codec, 30 ms speech frames shall be used. It is required that the short-term prediction parameters (or LP parameters) are computed and transmitted every speech frame. The speech frame shall be divided into 4 sub-frames of 7,5 ms (60 samples). The pitch and algebraic codebook parameters have also to be transmitted every sub-frame.

Table 1 gives the bit allocation for the TETRA codec. 137 bits shall be produced for each frame of 30 ms resulting in a bit rate of 4 567 bit/s.

**Table 1: Bit allocation for the TETRA codec**

| Parameter      | 1 <sup>st</sup> subframe | 2 <sup>nd</sup> subframe | 3 <sup>rd</sup> subframe | 4 <sup>th</sup> subframe | Total per frame |
|----------------|--------------------------|--------------------------|--------------------------|--------------------------|-----------------|
| LP filter      |                          |                          |                          |                          | 26              |
| Pitch delay    | 8                        | 5                        | 5                        | 5                        | 23              |
| Algebraic code | 16                       | 16                       | 16                       | 16                       | 64              |
| VQ of 2 gains  | 6                        | 6                        | 6                        | 6                        | 24              |
| Total          |                          |                          |                          |                          | 137             |

More details about the sequence of bits within the speech frame of 137 bits per 30 ms, with reference to the speech parameters, can be found in clause 4.2.2.7, table 3.

## 4.2 Functional description of the codec

### 4.2.1 Pre- and post-processing

Before starting the encoding process, the speech signal shall be pre-processed using the offset compensation filter:

$$H_p(z) = \frac{1}{2} \left( \frac{1 - z^{-1}}{1 - \alpha z^{-1}} \right) \quad (5)$$

where  $\alpha = 32\,735/32\,768$ . In the time domain, this filter corresponds to:

$$s'(n) = s(n)/2 - s(n-1)/2 + \alpha s'(n-1) \quad (6)$$

where  $s(n)$  is the input signal and  $s'(n)$  is the pre-processed signal. The purpose of this pre-processing is firstly to remove the dc from the signal (offset compensation), and secondly, to scale down the input signal in order to avoid saturation of the synthesis filtering.

At the decoder, the post-processing consists of scaling up the reconstructed signal (multiplication by 2 with saturation control).

### 4.2.2 Encoder

#### 4.2.2.0 General

Figure 3 presents a detailed block diagram of the TETRA encoder illustrating the major parts of the codec as well as signal flow. On this figure, names appearing at the bottom of the various building blocks correspond to the C code routines associated with the present document.

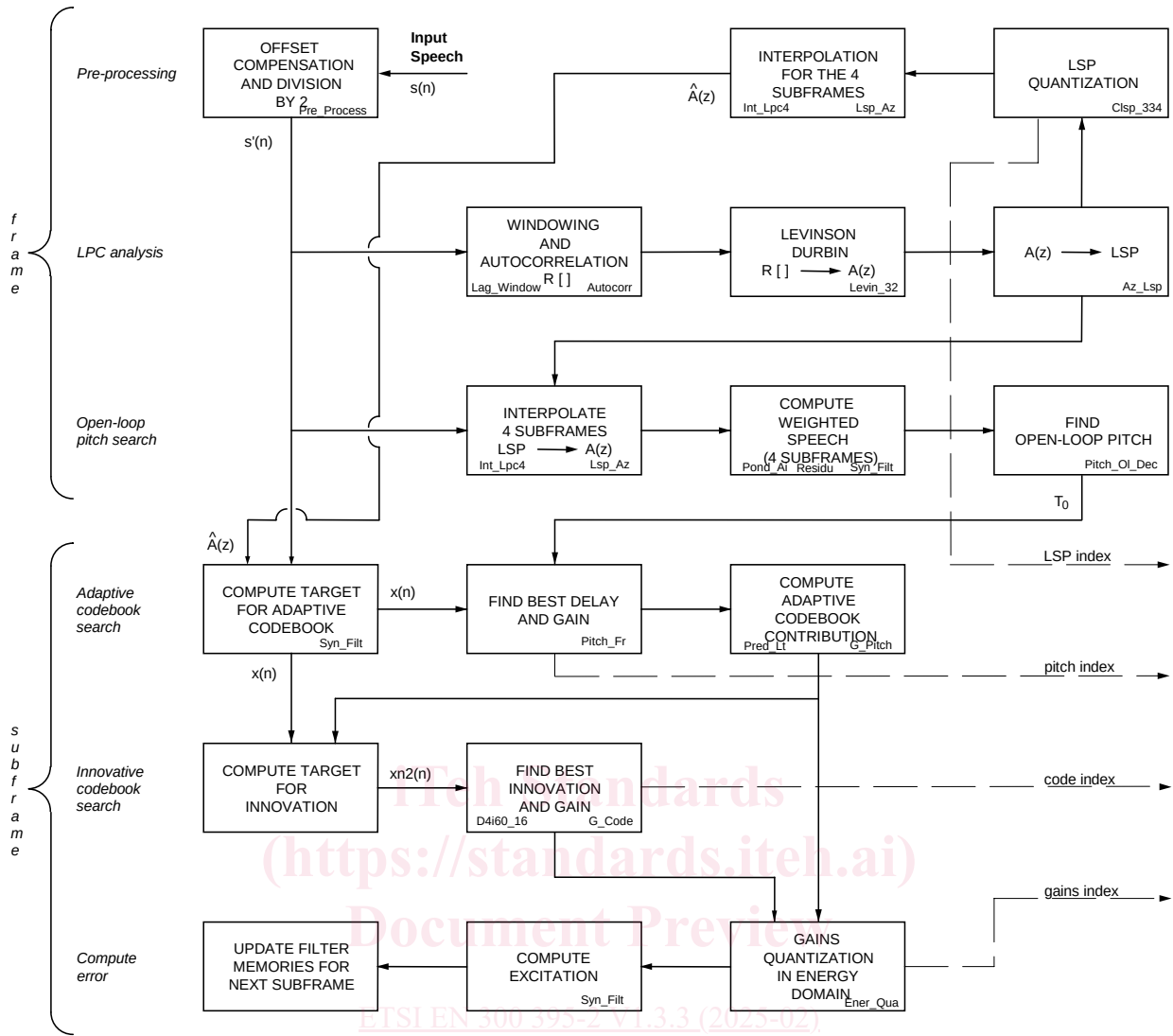


Figure 3: Signal flow at the encoder

#### 4.2.2.1 Short-term prediction

Short-term prediction (LP or LPC analysis) shall be performed every 30 ms. The auto-correlation approach shall be used with an asymmetric analysis window. The LP analysis window consists of two halves of Hamming windows with different lengths. This window is given by:

$$\begin{aligned}
 w(n) &= 0,54 - 0,46 \cos\left(\frac{\pi n}{L_1 - 1}\right), & n = 0, \dots, L_1 - 1 \\
 &= 0,54 + 0,46 \cos\left(\frac{\pi(n - L_1)}{L_2 - 1}\right), & n = L_1, \dots, L_1 + L_2 - 1
 \end{aligned} \tag{7}$$

A 32 ms analysis window (corresponding to 256 samples with the sampling frequency of 8 kHz) shall be used with values  $L_1 = 216$  and  $L_2 = 40$ . The window shall be positioned such that 40 samples are taken from the future frame (look-ahead of 40 samples).