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

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

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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

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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.

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- [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.

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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.

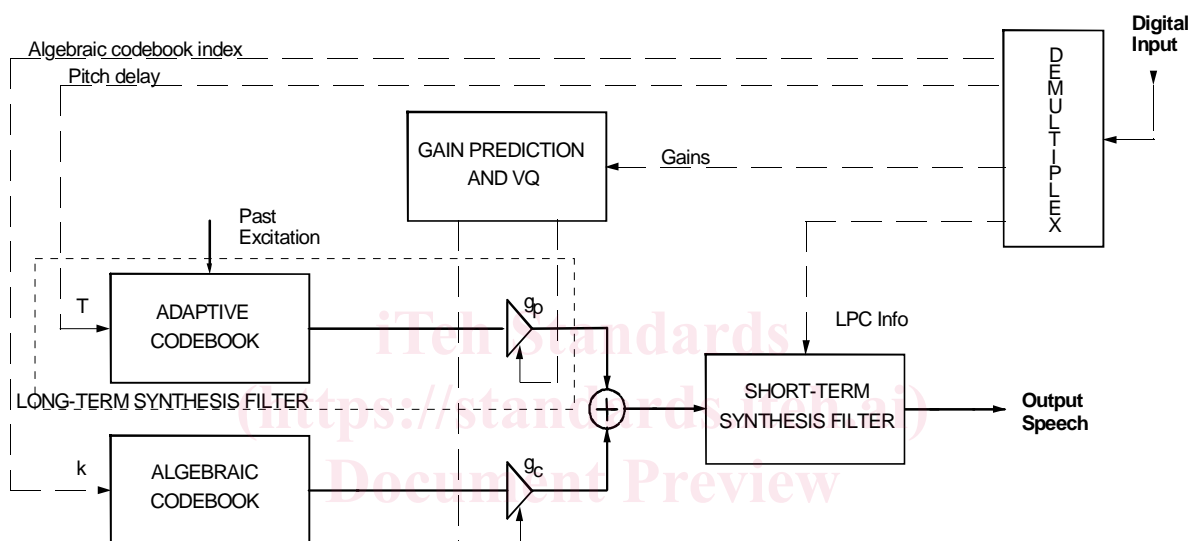


Figure 1: High level block diagram of the TETRA speech synthesizer

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.

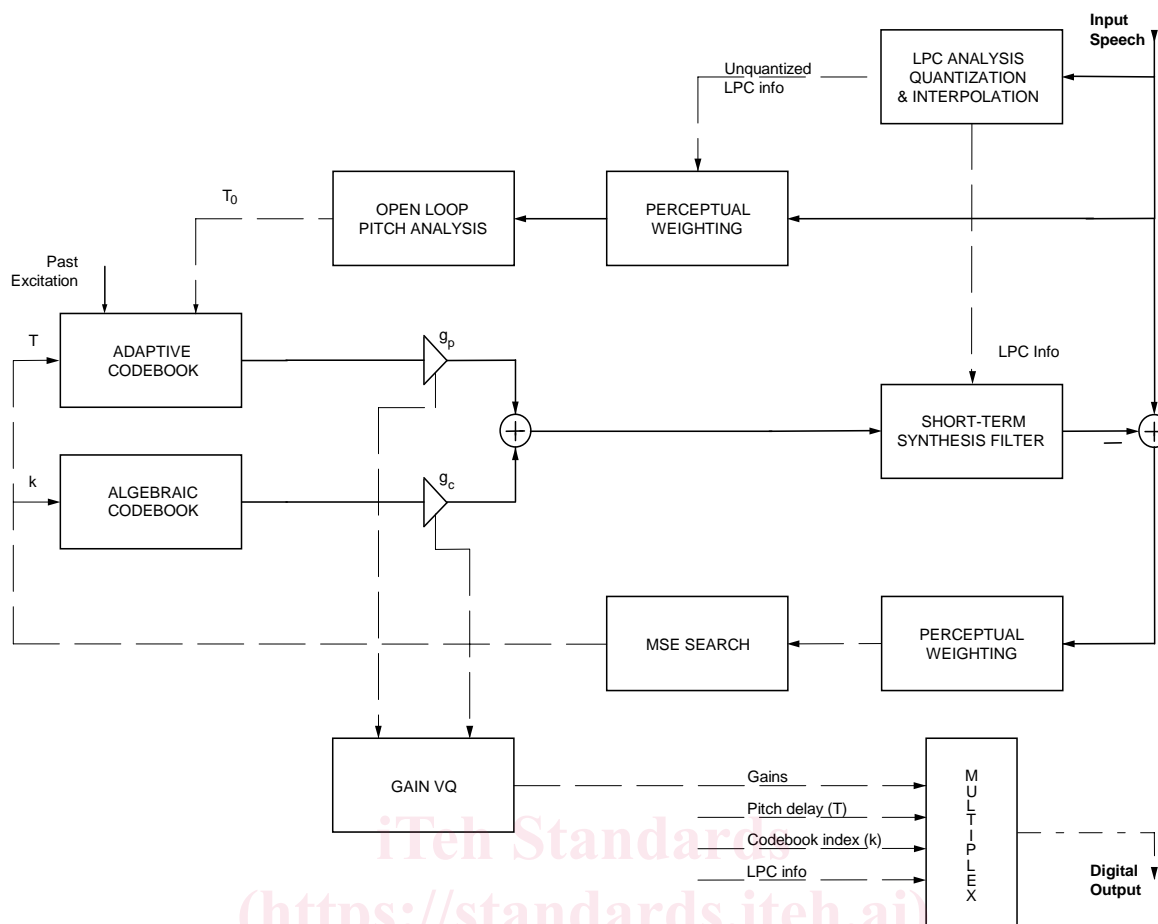


Figure 2: High level block diagram of the TETRA speech encoder

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.