Low Complexity Communication Codec

***Bluetooth*® Specification**

- **Revision:** v1.0
- **Revision Date:** 2020-09-15
- **Group Prepared By:** Hearing Aid Working Group

Abstract:

This specification defines a Low Complexity Communication Codec (LC3), which is an efficient codec for audio applications, including hearing aid applications, speech, and music. This version supports frame intervals of 7.5 ms and 10 ms.

Revision History

Revision Number	Date	Comments
v1.0	2020-09-15	Adopted by the Bluetooth SIG Board of Directors.

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1 Introduction

The Low Complexity Communication Codec (LC3) specification defines an efficient Bluetooth Audio Codec for use in audio profiles. This codec can encode speech and music at a variety of bitrates.

The LC3 can be incorporated in any Bluetooth audio profile. To deliver satisfactory audio quality under all channel conditions, it is strongly recommended that some form of Packet Loss Concealment (PLC) should be implemented on the receiving ends of audio connections. The purpose of packet loss concealment is to conceal the effect of unavailable or corrupted frame data for decoding. The example PLC algorithm provided in the Appendix B of this specification may be used. The audio quality of this example PLC under typical packet loss conditions is considered satisfactory. If implementations choose to modify or implement an alternate PLC scheme, the performance of any such alternate PLC should meet or exceed the performance of the example PLC provided in Appendix B.

Reference executables of both the encoder and the decoder of the LC3 codec are available in [1].

Note: LC3 source code—whether for the encoder or decoder—is not available as part of the specification.

1.1 Conformance

If conformance to this specification is claimed, all capabilities indicated as mandatory for this specification shall be supported in the specified manner (process-mandatory). This also applies for all optional and conditional capabilities for which support is indicated.

1.2 Bluetooth specification release compatibility

This specification shall be used with any profile that includes the LC3 as a mandatory or optional codec.

1.3 Language

1.3.1 Language conventions

The Bluetooth SIG has established the following conventions for use of the words ***shall***, ***must***, ***will***, ***should***, ***may***, ***can***, ***is***, and ***note*** in the development of specifications:

shall	is required to – used to define requirements.
must	is used to express: a natural consequence of a previously stated mandatory requirement. OR an indisputable statement of fact (one that is always true regardless of the circumstances).
will	it is true that – only used in statements of fact.
should	is recommended that – used to indicate that among several possibilities one is recommended as particularly suitable, but not required.
may	is permitted to – used to allow options.
can	is able to – used to relate statements in a causal manner.
is	is defined as – used to further explain elements that are previously required or allowed.

note	Used to indicate text that is included for informational purposes only and is not required in order to implement the specification. Each note is clearly designated as a “Note” and set off in a separate paragraph.

For clarity of the definition of those terms, see Core Specification Volume 1, Part E, Section 1.

1.3.2 Reserved for Future Use

Where a field in a packet, Protocol Data Unit (PDU), or other data structure is described as "Reserved for Future Use" (irrespective of whether in uppercase or lowercase), the device creating the structure shall set its value to zero unless otherwise specified. Any device receiving or interpreting the structure shall ignore that field; in particular, it shall not reject the structure because of the value of the field.

Where a field, parameter, or other variable object can take a range of values, and some values are described as "Reserved for Future Use," a device sending the object shall not set the object to those values. A device receiving an object with such a value should reject it, and any data structure containing it, as being erroneous; however, this does not apply in a context where the object is described as being ignored or it is specified to ignore unrecognized values.

When a field value is a bit field, unassigned bits can be marked as Reserved for Future Use and shall be set to 0. Implementations that receive a message that contains a Reserved for Future Use bit that is set to 1 shall process the message as if that bit was set to 0, except where specified otherwise.

The acronym RFU is equivalent to Reserved for Future Use.

1.3.3 Prohibited

When a field value is an enumeration, unassigned values can be marked as “Prohibited.” These values shall never be used by an implementation, and any message received that includes a Prohibited value shall be ignored and shall not be processed and shall not be responded to.

Where a field, parameter, or other variable object can take a range of values, and some values are described as “Prohibited,” devices shall not set the object to any of those Prohibited values. A device receiving an object with such a value should reject it, and any data structure containing it, as being erroneous.

“Prohibited” is never abbreviated.

2 LC3 description

This section provides an overview of the LC3 and the design principles of the LC3.

2.1 Overview

The LC3 is a block-based transform audio codec that has a low algorithmic delay, offers low complexity implementations, and provides a very wide range of usable bitrates. The encoder and decoder both work at a frame interval of 10 ms and 7.5 ms at the sampling frequencies of 8 kHz, 16 kHz, 24 kHz, 32 kHz, and 48 kHz. When the sampling frequency of the input signal is 44.1 kHz, the same frame length is used as for 48 kHz, resulting in the slightly longer actual frame duration of 10.884 ms for the 10 ms frame interval and of 8.16 ms for the 7.5 ms frame interval.

The Total Codec Algorithmic Delay of LC3 is the sum of the frame duration and the duration of encoder side MDCT (Modified Discrete Cosine Transform) look ahead. For 10 ms frame interval, the Total Codec Algorithmic Delay at the sampling frequencies of 8 kHz, 16 kHz, 24 kHz, 32 kHz, and 48 kHz is 12.5 ms, while for a 44.1 kHz signal the Total Codec Algorithmic Delay is 13.605 ms, because of the 48 kHz frame size. For 7.5 ms frame interval, the Total Codec Algorithmic Delay at the sampling frequencies of 8 kHz, 16 kHz, 24 kHz, 32 kHz, and 48 kHz is 11.5 ms, while for a 44.1 kHz signal the Total Codec Algorithmic Delay is 12.517 ms, because of the 48 kHz frame size.

Based on an externally set bitrate, the LC3 encoder algorithm compresses single PCM (Pulse Code Modulation) frames per channel and provides source-encoded bits for each channel (the payload) without adding any transport channel error protection on top of this payload. The size of the payload for a single channel ranges from 20 bytes to 400 bytes for each frame and corresponds to an overall compressed bitrate range of 16,000 bps to 320,000 bps for 10 ms frames and to an overall compressed bitrate range of 21,334 bps to 426,667 bps for 7.5 ms frames. For 10.884 ms duration frames, which are used for the 44.1 kHz sampling frequency, the corresponding bitrate range is 14,700 bps to 294,000 bps for the 10 ms frame size and 19,600 bps to 392,000 bps for the 7.5 ms frame size. The LC3 can be operated at a constant bitrate or at an externally controlled variable bitrate.

To decode the received payload, the LC3 decoder relies on an externally determined Bad Frame Indication (BFI) flag and a payload size parameter for each channel. The BFI flag is used to signal a lost payload or the presence of any detected bit error in the received payload to the decoder. This specification also defines internal fields in the payload, which allow external applications to signal a corrupt payload to the decoder. If the payload bits are flagged as corrupt the LC3 decoder will skip reading payload bits, and instead activate a PLC algorithm to produce the uncompressed output PCM signal. The payload size parameter enables the LC3 decoder to parse each received payload correctly. The LC3 payload does not contain any timing information such as time stamps or sequence numbers.

This specification is written using equations and integer pseudocode to enable efficient implementation of the codec on many different architectures. Examples include a power-restricted hearing aid device with a limited 24-bit accumulator and a device with an efficient floating-point unit.

2.2 Encoder interfaces

Table 2.1 provides a high-level description of the session parameters that the LC3 encoder requires to be configured before commencing frame-by-frame encoding.

Session Configuration Parameter	Description/Value range
{Sampling frequency F_s, N_f } The sampling frequency and frame size pair for the input PCM signal	F_s = [8, 16, 24, 32, 44.1, 48] kHz Corresponding frame size for 10 ms frame duration: N_f = [80, 160, 240, 320, 480, 480] samples Corresponding frame size for 7.5 ms frame duration: N_f = [60, 120, 180, 240, 360, 360] samples (Identical {F_s, N_{ms}, N_f} triple to the decoder) Note: For both the 44.1 kHz operation and the 48 kHz operation, the input sample buffer size is 480 samples for the 10 ms frame duration and 360 samples for the 7.5 ms frame duration.
N_c The number of audio channels	N_c = [1 … $N_{c,max}$] N_{c_max}, the maximum number of audio channels, shall be set by the profile (the maximum number is not limited by this specification, but will be determined by the profile or the implementation.)
bits_per_audio_sample_enc The bits per audio sample for the input PCM signal	[16, 24, or 32] (bits per sample) The bits_per_audio_sample_enc value may differ from the decoder output PCM setting bits_per_audio_sample_dec.

Table 2.1: Encoder session configuration (identical for all encoded frames in a session)

Table 2.2 provides a description of the frame parameters that the LC3 encoder requires to be available before it can commence encoding of an input signal.

Encoder Frame Input Parameters	Description/Value range
byte_count[Nc] External byte count values to be used for the frame encoding of each audio channel.	byte_count controls the rate for the session configured frame size NF. The byte count value range is [20, …. 400] (bytes per channel) For mono use cases, byte_count has only one value. In this case it is equal to nbytes.
InputPCM[N_C] PCM data for Nc channels	The input audio data for a frame. The total size is specified by the session configured number of channels N_C, the frame size in samples NF and the configured encoder PCM bits per audio sample bits_per_audio_sample_enc

Table 2.2: Encoder frame level inputs required for every frame to compress

Table 2.3 provides a description of the frame output that the LC3 encoder produces after encoding a frame of input audio data.

Encoder Frame Output	Description
payloadTX[NC]	Size: [20, …, 400] bytes for a frame and NC channels, corresponding to byte_count[NC]

Table 2.3: Encoder frame level output produced for every compressed frame

2.3 LC3 high-level operation description

This section provides a high-level overview of how LC3 operates. Full details are provided in Section 3 of this document.

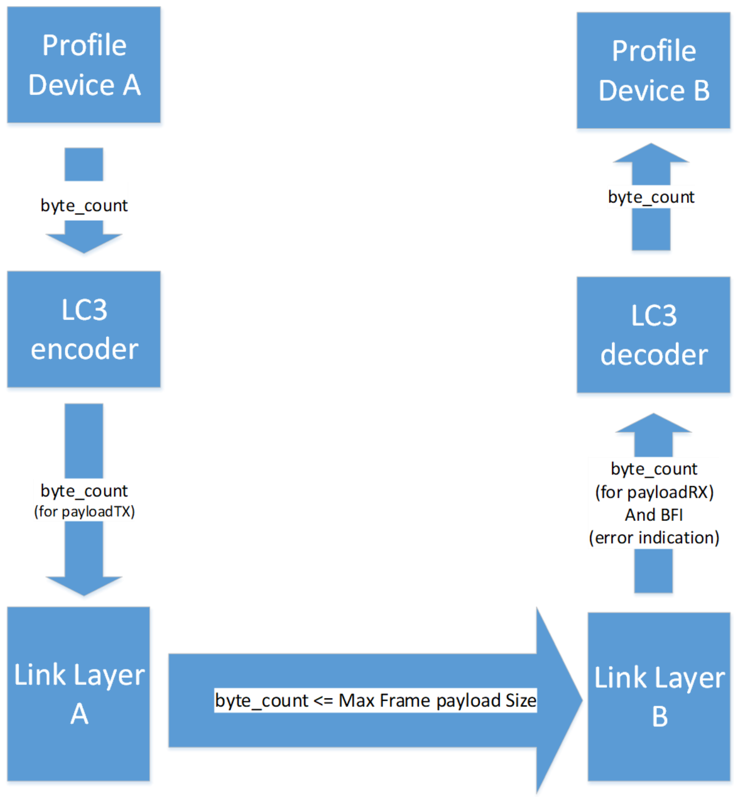

Figure 2.1: Overview of LC3 rate-related parameters from profile to link-layer for a mono stream

Figure 2.1 shows the rate-related parameters communicated between the link layer and the LC3 encoder/decoder for an example profile. The profile in Device A defines a byte_count in bytes that the LC3 encoder will use to generate the compressed payloadTX for an audio frame. (The resulting size of the payloadTX will be exactly byte_count.) As long as the byte_count is less than or equal to the link's maximum frame size, the link layer in Device A can transmit the payload to Device B.

When Device B receives an encoded payload, a BFI flag shall be generated and forwarded to the LC3 decoder.

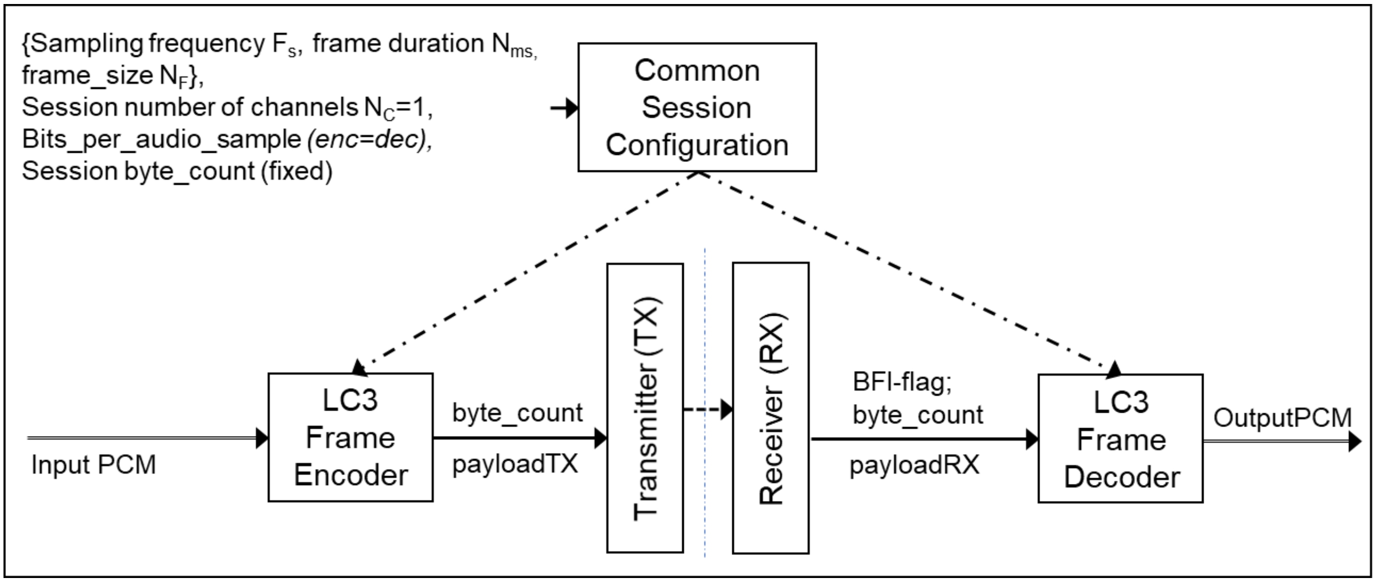

Figure 2.2: High-level basic operation of LC3 using a single fixed bitrate for a mono stream

Figure 2.2 shows fixed rate, mono-channel operation using LC3 where the encoded bitrate is the same for all frames and the encoder and decoder are using the same number of bits per audio sample resolution (bits_per_audio_sample). The actual bitrate in kbps is determined by the byte_count (in bytes) and the parameter tuple {FS, Nms}, where FS is the sampling frequency and Nms is the frame duration (in milliseconds). The encoder and decoder shall in this case be configured and initialized with all these common session parameters. They shall be identical between encoder and decoder except the bits_per_audio_sample parameter, which can differ between encoder and decoder. For every frame the LC3 frame encoder receives an InputPCM signal composed in a buffer of size (NF x bits_per_audio_sample/8) bytes. The LC3 frame encoder produces a buffer payloadTX of size byte_count. In this application, the byte_count is fixed by the Session byte_count parameter.

The Transmitter transmits the payloadTX over the air interface and the Receiver receives the transmitted information as payloadRX of size byte_count. If the receiver identifies that there are bit errors in payloadRX, the BFI flag is set to a value other than 0; otherwise it is set to 0 for an assumed correct payloadRX. For a good frame with BFI=0, the LC3 frame decoder receives the payloadRX of size byte_count. If the frame is bad, with BFI!=0, the LC3 frame decoder will not use the information in payloadRX; the implementation or profile will determine how the bad frame is handled. For every good frame, the LC3 frame decoder produces an OutputPCM signal composed in a buffer of size (N_F x bits_per_audio_sample/8) bytes.

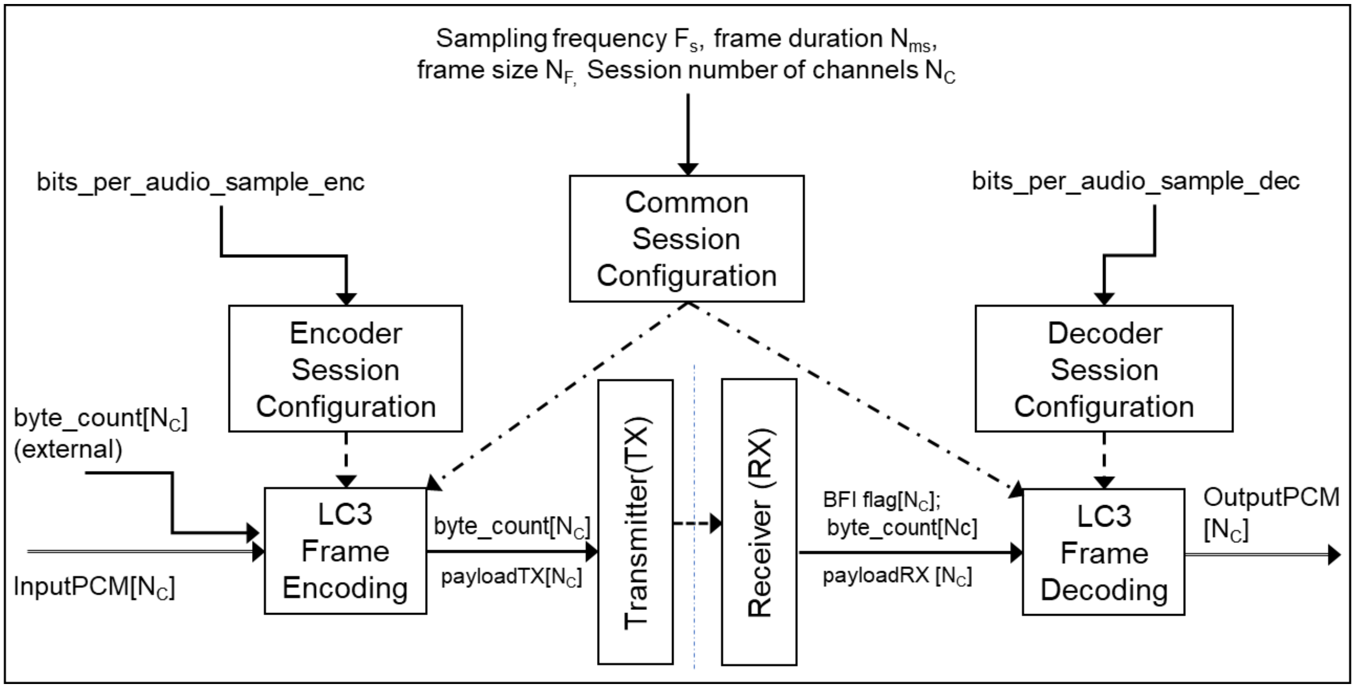

Figure *2.3*: Full capability operation of LC3, using external rate control over several audio channels

Figure 2.3 shows external rate (non-fixed rate), multi-channel operation using the LC3 where the encoded bitrate may vary for any audio channel and for any frame, based on an external rate control input. External rate control (on a frame and audio channel basis) may be specified by a profile using LC3, for example to support Content Augmentation and/or codec re-configuration without the need to tear down streams. The encoder and decoder may use different bits per audio sample resolution (bits_per_audio_sample_enc, bits_per_audio_sample_dec) for the session. The number of audio channels is indicated by N_C and is fixed throughout the session. For multi-channel operation, all channels are expected to have the same number of bits per audio sample; therefore, not all configuration parameters are independent.

The actual bitrate in kbps for a given audio channel k in a frame is determined by the byte_count[k] (in bytes) and the session parameter triple $\{F_S, N_{ms}, N_F\}$, where F_S is the sampling frequency, N_{ms} is the frame duration in milliseconds and N_F is the frame size in samples. The total bitrate for a frame is given by the sum of the N_C channel bitrates. The session parameter triple $\{F_S, N_{ms}, N_F\}$ and the number of channels N_C is always common between encoder and decoder and may be configured during encoder and decoder initialization.

For every frame of PCM audio input data, the LC3 encoder receives a multichannel InputPCM signal composed in a buffer of size of N_C x N_F x bits_per_audio_sample_enc/8 bytes. The LC3 frame encoder produces a compressed buffer payloadTX [N_C], where the total buffer size for a frame is given by the sum of elements in byte_count [N_C]. The exact payload format for the transmitted packets is defined in the upper audio profiles, e.g., Basic Audio Profile.

The transmitter transmits the payloadTX over the air interface and the receiver receives the transmitted information as payloadRX [N_C] with individual channels of size byte_count [N_C]. If the receiver identifies that there are bit errors for a channel k payload (payloadRX [k]), the BFI [k] flag is set to a value other than 0 for that channel. Otherwise, the flag is set to 0 for an assumed correct payloadRX [k]. For a good frame with BFI [k]=0, the LC3 frame decoder receives the payloadRX [k] of size byte_count [k]. If the frame is marked bad by BFI [k] !=0, the LC3 frame decoder will not use the information in payloadRX [k]; the implementation or profile will determine how the bad frame is handled. For every good frame, the LC3 frame decoder produces an OutputPCM [N_C] signal composed in a buffer of size (N_C x N_F x bits_per_audio_sample_dec/8) bytes. Multi-channel implementations should handle the BFI flags jointly for all channels, so that muting or concealment is applied consistently.

Allowing different audio sample resolutions between encoder and decoder allows decoders with limited capability to decode 24-bits and 32-bits per audio sample encoded LC3 audio payloads into 16 bits per audio sample output PCM.

2.4 Decoder interfaces

Table 2.4 provides a high-level description of the session parameters that the LC3 decoder requires to be configured before commencing frame-by-frame decoding.

Decoder Session Configuration Parameter	**Value range**
{Fs, N_{ms}, Nf} The sampling frequency and frame size pair for the output PCM signal	Fs = [8, 16, 24, 32, 44.1, 48] kHz N_{ms}= [7.5, 10] ms Corresponding frame size for 10 ms frame duration: N_f = [80, 160, 240, 320, 480, 480] samples Corresponding frame size for 7.5 ms frame duration: N_f = [60, 120, 180, 240, 360, 360] samples (Identical {Fs, N_{ms}, Nf} triple in the encoder) Note: For both the 44.1 kHz operation and the 48 kHz operation, the output sample buffer size is 480 samples for the 10 ms frame duration and 360 samples for the 7.5 ms frame duration.
Nc, The number of audio channels	Nc = [1 … Nc,max] Nc_max, the maximum number of audio channels required to be set by the profile
bits_per_audio_sample_dec Bits per audio sample for the output PCM signal	[16, 24, or 32] (bits per sample) (may differ from encoder input PCM setting bits_per_audio_sample_enc)
byte_count_max_dec Maximum allowed payload byte_count for a single channel	When using and allowing external rate control, the maximum byte count for the session may be used to configure the session buffers without a need to dynamically reallocate memory during the session.

Table 2.4: Decoder session configuration (identical for all decoded frames in a session)

Table 2.5 provides a description of the frame parameters that the LC3 decoder needs to be supplied before decoding a compressed payload.

Decoder Frame Input Parameters	**Description/Value range**
BFI[NC] Bad Frame Indication flags	A vector of decoder external binary flags for each audio channel k, where: "0" signifies that no bit errors were detected in payloadRX[k] "1" signifies a corrupt payload packet was detected in payloadRX[k]

Decoder Frame Input Parameters	**Description/Value range**
byte_count[NC] byte_count to be used for decoding the received frame payload	Values: [20, ..., 400] bytes per channel
Decoder Frame Payload	**Description/Value range**
payloadRX[NC]	Size: [20, … , 400] bytes for a frame and NC channels Note: If BFI[k] does not equal 0 for the channel k, the information in the payloadRX[k] is corrupt.

Table 2.5: Decoder frame level inputs required for every frame to uncompress

Table 2.6 provides a description of the frame output that the LC3 decoder produces after decoding a frame.

Decoder Frame Output	**Description/Value range**
OutputPCM[N_C], PCM data (for N_c channels)	The output audio data for a frame, total size as specified by: The session configured number of channels N_C The frame size in samples N_F The configured decoder PCM bits per audio sample bits_per_audio_sample_dec

Table 2.6: Decoder output produced for every uncompressed frame

3 Technical specification

3.1 General codec description

3.1.1 Introduction

This section describes the technical specification of the Low Complexity Communication Codec (LC3). The LC3 is an audio codec that was initially designed for Bluetooth Hearing Aid applications but is also suitable for hands-free communication and other general audio applications.

Table 3.1 shows the main features of LC3 coding one audio channel.

Feature	Supported Range
Frame duration	10 ms (10.88 ms @ 44.1 kHz) and 7.5 ms (8.163 ms @ 44.1 kHz)
Look ahead delay	2.5 ms (2.72 ms @ 44.1 kHz) for 10 ms frame duration 4 ms (4.35 ms @ 44.1 kHz) for 7.5 ms frame duration
Total algorithmic delay	12.5 ms (13.6 ms @ 44.1 kHz) for 10 ms frame duration 11.5 ms (12.52 ms @ 44.1 kHz) for 7.5 ms frame duration
Supported sampling rates	8, 16(HA-SQ), 24(HA-HQ), 32, 44.1, and 48 kHz
Supported bitrate	20–400 bytes per frame and audio channel
Supported bits per audio sample	No restriction by the algorithm; however, optimized for 16-, 24-, and 32-bit depth input. See the limitation described in Section 3.2.3.

Table 3.1: Feature summary

The source code for the encoder and decoder are not part of the specification. The algorithmic description uses both floating point and integer data format representations, assuming that implementations on platforms with 16-, 24-, 32-, and 64-bit word length using fixed or floating point ALU (Arithmetic Logic Unit) can be achieved with adequate precision. For a limited number of equations of this technical specification, intermediate input and output values are provided as guidance to implementers in Appendix C.

3.1.2 Mathematical symbols

Symbol	Description
f_{scal}	Scale factor used for 44.1 kHz
f_s	Sampling rate
$x_b(n)$	Time domain sample of block b and index n
$X_b(k)$	Frequency domain coefficient in block b at frequency index k
$nbytes$	Number of bytes per frame

Symbol	Description
$nbits$	Number of bits per frame ($nbytes * 8$)
N_F	Number of samples processed in a single uncompressed audio frame (also known as frame size)
N_b	Number of bands (also known as number of entries in $I_{f_s} - 1$)
N_{bw}	Number of bandwidth sections
N_E	Number of encoded spectral lines
N_{ms}	Frame duration parameter in milliseconds (either 10 ms or 7.5 ms; note that the actual frame duration is longer by a factor of 480/441 if the sampling rate is 44100). The variable N_{ms} only takes the values of 10 ms or 7.5 ms. For the case of 44.1 kHz the value is corrected to match the frame duration.
$I_{f_s}(n)$	Band indices in dependency of sampling rate
D	Algorithmic delay of the codec
D_{MDCT}	Delay because of the MDCT look ahead
$E_B(b)$	Energy per band
w_N	Low Delay MDCT window
$X(k)$	Frequency coefficients
Z	Number of leading zeros in MDCT window

Table 3.2: Symbol definitions

Note: The variables in Table 3.2 are global and are used throughout the specification.

3.1.3 Operators

Symbol	Description
$\{x \mid condition(x)\}$	Defines the quantity of x where x fulfills a certain condition
$\boldsymbol{x}^{\boldsymbol{T}}$, $\boldsymbol{X}^{\boldsymbol{T}}$	The transpose of vector x and matrix X respectively
a | *b*	Set construction operator with elements a such that b is fulfilled
argmax X	Returns the position of the first occurrence of the maximum value of array X
argmin X	Returns the position of the first occurrence of the minimum value of array X
$nint(x)$ or $\lfloor x \rceil$	Round x to nearest integer, e.g., $\lfloor -4.5 \rceil = -5, \lfloor -3.2 \rceil = -3, \lfloor 3.2 \rceil = 3, \lfloor 4.5 \rceil = 5,$ Note: Rounding might be platform dependent. However, the overall performance is unlikely to be affected

Symbol	Description
$\lfloor x \rfloor$	Round x to next lower integer, e.g., $\lfloor -4.5 \rfloor = -5, \lfloor -3.2 \rfloor = -4, \lfloor 3.2 \rfloor = 3, \lfloor 4.5 \rfloor = 4$
$\lceil x \rceil$	Round x to next higher integer, e.g., $\lceil -4.5 \rceil = -4, \lceil -3.2 \rceil = -3, \lceil 3.2 \rceil = 4, \lceil 4.5 \rceil = 5$
$\{a, b, ..\}$	Ordered sequence of values. Indexing starts with 0, if not specified otherwise.
$a(n..m)$	Sequence of values indexed from n to m,i.e., $\{a(n), a(n+1), \dots, a(m)\}$
$x \leftarrow y$	Reading from y and storing in x. Defines in-place operations with formulas, e.g., $x(n) \leftarrow x(n+1)$ shifts samples in x by one.

Table 3.3: Operator definitions

3.2 General codec parameters

3.2.1 Audio channels

The algorithm describes only the coding of a single audio channel. Any stereo or multi-channel coding shall be supported by coding of multiple mono streams.

3.2.2 Sampling rates

The codec supports the sampling rates f_s of 8,000 Hz, 16,000 Hz, 24,000 Hz, 32,000 Hz, 44,100 Hz, and 48,000 Hz. For the 44,100 Hz mode, all configurations, e.g., frame size, shall be identical to the 48,000 Hz mode.

A sampling rate index is defined as follows

$$f_s^{ind} = \min\left(4, \frac{f_s}{8{,}000} - 1\right) \tag{1}$$

Table 3.4 provides the sampling rate index for the relevant sampling frequencies.

f_s	8,000	16,000	24,000	32,000	44,100/48,000
f_s^{ind}	0	1	2	3	4

Table 3.4: Sampling rate index function

For easier parameter mapping when $f_s = 44100$, f_{scal} is defined by

$$f_{scal} = \begin{cases} \frac{48{,}000}{44{,}100}, & for\ f_s = 44{,}100\ Hz \\ 1, & otherwise \end{cases} \tag{2}$$

3.2.3 Bits per sample

The codec algorithm itself has the restriction that the sample resolution is limited to a minimum of 16 bits per audio sample and to a maximum of 32 bits per audio sample of the input and output audio samples. Typical values are 16, 24, or 32 bits per audio sample.

3.2.4 Frame size and delay

The codec works at a frame duration N_{ms} of either 7.5 ms or 10 ms, except when $f_s = 44{,}100\ Hz$. For all f_s, the frame size in samples is defined as $N_F = \frac{f_s \cdot f_{scal} \cdot N_{ms}}{1{,}000}$.

The algorithmic delay of the codec D in ms is therefore $D = \frac{1{,}000 \cdot (2 \cdot N_F - 2 \cdot Z)}{f_s}$ with

$$Z = \begin{cases} \frac{7}{30} N_F, & for\ N_{ms} = 7.5\ ms \\ \frac{3}{8} N_F, & for\ N_{ms} = 10\ ms \end{cases} \tag{3}$$

meaning

- For $N_{ms} = 7.5\ ms$, the delay is equal to 11.5 ms for all sampling rates except 44,100 Hz where the delay is about 12.5 ms.
- For $N_{ms} = 10\ ms$, the delay is equal to 12.5 ms for all sampling rates except 44,100 Hz where the delay is about 13.6 ms.

For more information about the transformation delay see Appendix A.

3.2.5 Bit budget and bitrate

The number of bytes available in one frame is denoted $nbytes$. The number of bytes $nbytes$ to use for encoding a single channel is a required external input to each single channel LC3 encoder. The same number of bytes (now to be used for decoding) is also a required external input to each single channel LC3 decoder. The corresponding number of bits available in one frame is thus $nbits = 8 * nbytes$. And the bitrate of the codec in bits per second is then $bitrate = \left\lceil \frac{nbits}{frame\_duration} \right\rceil = \left\lceil \frac{nbits * f_s}{N_F} \right\rceil = \left\lceil \frac{8 * nbytes * f_s}{N_F} \right\rceil = \left\lceil \frac{8{,}000 \cdot nbytes}{N_{ms} \cdot f_{scal}} \right\rceil$ with N_{ms} being the frame duration in milliseconds (either 10 ms or 7.5 ms) and $nbytes$ being the number of available bytes per frame. The codec works on a byte boundary, i.e. the variable $nbytes$ shall be an integer number. A certain $bitrate$ can be converted to a number of bytes $nbytes$ with the following formula $nbytes = \left\lfloor \frac{bitrate \cdot N_{ms} \cdot f_{scal}}{8{,}000} \right\rfloor$ where the number of bytes is rounded to the nearest lower integer.

The algorithm is verified from the bitrate corresponding to $nbytes = 20$ up to the bitrate corresponding to $nbytes = 400$ per channel for all sampling rates. This specification does not specify nor recommend what bitrate to use for encoding a frame of audio samples. This bitrate is specified by the profiles making use of the LC3.

3.3 Encoding process

3.3.1 Encoder modules

A high-level overview of the encoding modules is given in Figure 3.1. The coder is a spectral transform coder which converts a segment of the time domain into a spectral representation (using an LD-MDCT (Low Delay Modified Discrete Cosine Transform)). The corresponding frequency components are processed by a Spectral Noise Shaping (SNS) module to reduce perceived spectral quantization noise. The SNS module contains a vector quantizer, where the first stage is a split VQ (Vector Quantizer) and the second stage is a low complexity algorithmic Pyramid VQ. Next, a Temporal Noise Shaping (TNS) module is used to reduce perceived temporal quantization noise. The SNS and TNS shaped components are quantized by a spectral quantizer module. For the spectral coefficients that are quantized to 0, the decoder will substitute these zero values by noise to reduce artifacts. The Noise Level module computes the proper level to be used by the decoder. Afterwards, the spectral coefficients are entropy encoded and multiplexed into the bitstream.

Two additional modules are included in the encoder. A BW (Bandwidth) Detector module is used to determine if the signal is oversampled and contains high frequency spectral coefficients without energy. This information is shared with the TNS and Noise Level estimator to restrict their usage to the active signal region. The decoder uses a pitch-based postfilter (LTPF), and the associated pitch is determined in the encoder and transmitted to the decoder.

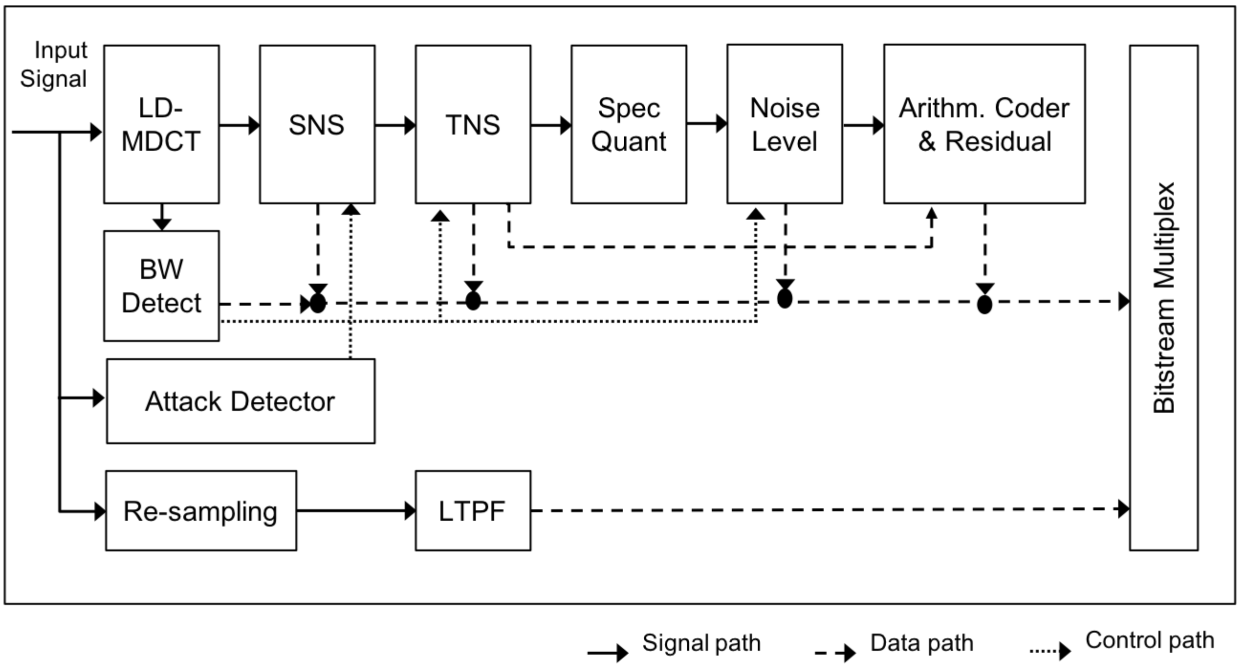

Figure 3.1: Encoder high-level overview

3.3.2 Input signal

The input signal $x_b(n)$ of the current frame b consists of N_F audio samples, $x_b(0), \dots, x_b(N_F - 1)$ where the newest one is located at $x_b(N_F - 1)$. Audio samples of past frames are accessed by negative indexing, e.g., $x_b(-1)$ shall be the most recent sample of the previous frame.

The input signal $x(n)$ is typically retrieved in Pulse-Code-Modulation (PCM) format consisting of integer values in the range of $[-2^{s-1}, 2^{s-1} - 1]$, where s is the bit depth of the PCM input signal, e.g., 16, 24, or 32 bits per sample.

Note: If other audio formats are used it is likely that some level of conversion will need to be applied to match value scaling and data format.

3.3.3 Input signal scaling

The input signal shall be first scaled to the range of $[-32{,}768, 32{,}768]$ but without reducing input precision according to

$$x_{s0}(n) = x_b(n) \cdot 2^{-(s-1)+15}, \tag{4}$$

where s is the smallest integer such that $x_{s0}(n)$ fits this range. For example, for integer PCM format s equals the bit-depth and for floating point PCM format s is equal to 1. The scaled signal shall then be clipped according to

$$x_s(n) = \begin{cases} 2^{15}-1, & x_{s0}(n) > 2^{15}-1 \\ -2^{15}, & x_{s0}(n) < -2^{15} \\ x_{s0}(n), & otherwise \end{cases} . \quad (5)$$

to fit the native 16-bit PCM range $[-32{,}768, 32{,}767]$.

3.3.4 Low Delay MDCT analysis

3.3.4.1 Overview

The Low Delay MDCT (LD-MDCT) converts the audio input time domain samples into spectral coefficients and corresponding energy values grouped into bands. Figure 3.2 outlines the processing blocks.

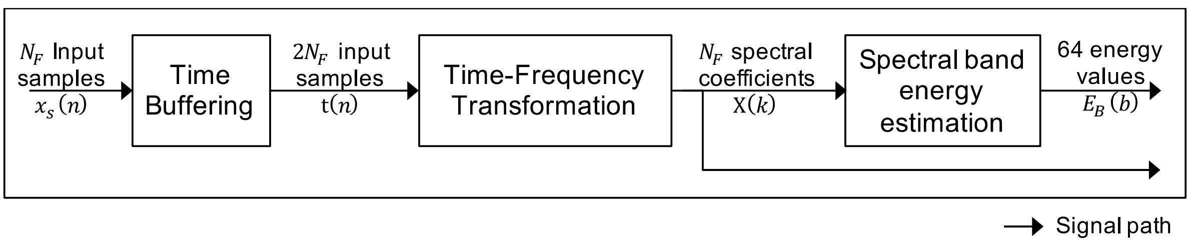

Figure 3.2: Low Delay MDCT overview

3.3.4.2 Update time buffer

The time input buffer for the MDCT t shall be updated according to

$$t(n) = x_s(Z - N_F + n)\, , for \quad n = 0 \dots 2 \cdot N_F - 1 - Z \quad (6)$$

$$t(2N_F - Z + n) = 0\, , \quad for \quad n = 0 \dots Z - 1 \quad (7)$$

where the latter initialization may be jointly optimized with the subsequent Time-Frequency Transformation.

3.3.4.3 Time-Frequency Transformation

A block of N_F time samples shall be transformed to the frequency coefficients $X(k)$ using the following equation:

$$X(k) = \sqrt{\frac{2}{N_F}} \sum_{n=0}^{2 \cdot N_F - 1} w_{N_{ms\_}N_F}(n) \cdot t(n) \cdot \cos\left[\frac{\pi}{N_F} \cdot \left(n + \frac{1}{2} + \frac{N_F}{2}\right) \cdot \left(k + \frac{1}{2}\right)\right], \qquad for \;\; k = 0 \dots N_F - 1\, , \quad (8)$$

where $w_{N_{ms\_}N_F}(n)$ is the Low Delay MDCT window chosen for the frame duration and frame size. The windows have been optimized for $F_S = 48$ kHz. The windows for all other frame sizes and different sample rates have been generated by means of interpolation so that all windows are compatible for the same frame duration, allowing sample rate conversion. All window coefficients given in Section 3.7.2 shall be used for implementation.

The window shape is the result of an optimization algorithm; therefore, there is no mathematical formula to calculate the coefficients. The optimization focused on exploiting the advantages of an asymmetric shape while keeping the temporal envelope close to one and providing a high stop-band attenuation. The result is given in the Figure 3.3. The window shows two sections with an amplitude higher than one, which needs to be considered for fixed-point implementations. The plot also shows the leading zeros Z at the right side of the window.

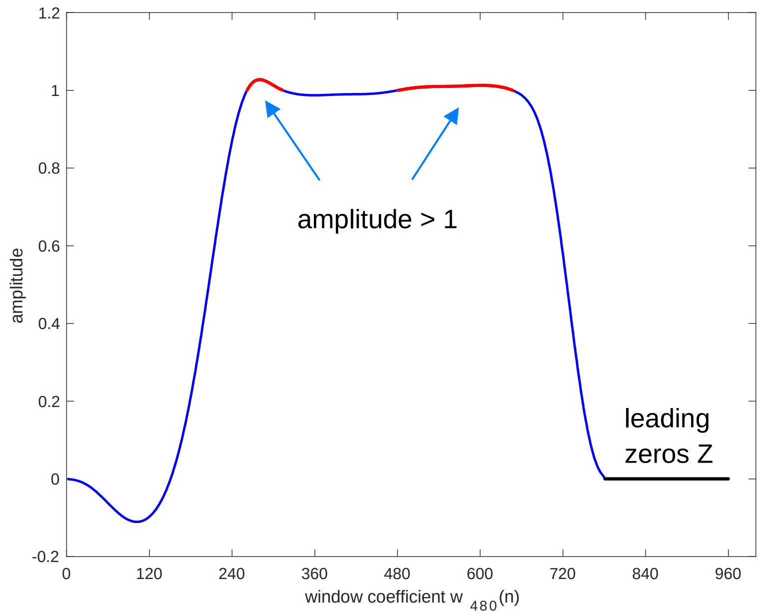

Figure 3.3: Plot of low delay MDCT window w_{10_480}. Sections where the amplitude is greater than one are marked in red; leading zeroes are marked in black.

For $N_F = 480$, only the frequency coefficients $X(0..399)$ shall be used and for $N_F = 360$, only the frequency coefficients $X(0..299)$ shall be used, which corresponds to a maximum audio bandwidth of 20 kHz (about 18.4 kHz at $f_s = 44{,}100\ Hz$). The number of encoded frequency coefficients shall be

$$N_E = \begin{cases} 400 & if\ N_F = 480 \\ 300 & if\ N_F = 360 \\ N_F & otherwise \end{cases} . \tag{9}$$

3.3.4.4 Energy estimation per band

The energy per band $E_B(b)$ shall be computed as follows:

$$E_B(b) = \sum_{k=I_{f_s}(b)}^{I_{f_s}(b+1)-1} \frac{X(k)^2}{I_{f_s}(b+1) - I_{f_s}(b)},\ \ for\ \ b = 0 \ldots N_b - 1\,, \tag{10}$$

where $X(k)$ are the MDCT coefficients computed in Section 3.3.4.3, N_b is the number of bands and $I_{f_s}(b)$ are the band indices given in Section 3.7.1 for the 10 ms frame duration or in Section 3.7.2 for the 7.5 ms frame duration. N_b is 64 except when $N_{ms} = 7.5ms$ and $fs = 8{,}000$, then $N_b = 60$.

3.3.4.5 Near Nyquist detector

The near Nyquist detector is used to identify signals with comparatively high energy in the range close to the Nyquist frequency. The near Nyquist detector is active only for sample rates $f_s <= 32{,}000\ Hz$. The

Aliasing-like structures in these signals can wrongly trigger TNS and lead to distortions. To identify such signals the detector compares the energy of the upper and lower bands and sets the near_nyquist_flag to 1 if the following condition is fulfilled:

$$\sum_{n=nn\_idx}^{n<N_B} E_B(n) > NN_{thres} \cdot \sum_{n=0}^{n<nn\_idx} E_B(n) \tag{11}$$

where nn_idx is the highest band index of the considered energy bands as listed in Table 3.5 and NN_thresh is 30. The near_nyquist_flag is handed over to the TNS module to deactivate TNS in case of a near Nyquist signal.

N_{ms}	**10 ms**	**7.5 ms**
nn_idx	$N_B - 2$	$N_B - 4$

Table 3.5: nn_idx as function of N_{ms}

3.3.5 Bandwidth detector

3.3.5.1 Algorithm

This tool detects bandlimited signals coded at higher sampling rates, e.g., an NB (Narrow Band) telephone call coded at 8 kHz but upsampled to a higher sampling rate. The detector provides guidance to the TNS (see Sections 3.3.8, 3.4.6) and noise filling tool (see Sections 3.3.12, 3.4.4) to avoid any spreading or smearing of noise into the empty upper spectrum. The quantization of the spectrum is not controlled by the BW detector to avoid any hard cut-offs in the spectrum in case of uncertain detections.

The detector can detect the commonly used speech bandwidths in voice communication, i.e., NB (0-4 kHz), WB (Wide Band) (0-8 kHz), SSWB (Semi Super Wide Band) (0-12 kHz), SWB (Super Wide Band) (0-16 kHz) and FB (Full Band) (0-20 kHz). The definitions for NB, WB, SWB and FB correspond to those of the 3GPP EVS codec, where an audio bandwidth up to the Nyquist frequency (up to a maximum of 20 kHz) is assumed. For the LC3, SSWB is defined in this document as a 24 kHz sampled signal with an audio bandwidth up to the Nyquist frequency.

The bandwidth detector works as a two-stage classifier on the band energies E_B, as defined in Section 3.3.4.4. The first stage detects active bands. To achieve this, a sequence of low-energy flags $F_Q(k)$ shall be calculated for $k = 0 \ldots N_{bw} - 1$ as

$$F_Q(k) = \begin{cases} 1 \quad , \quad if \displaystyle\sum_{n=I_{bw\,start}(k)}^{I_{bw\,stop}(k)} \frac{E_B(n)}{I_{bw\,stop}(k) - I_{bw\,start}(k) + 1} < T_Q(k) \\ 0 \quad , \quad otherwise \end{cases} . \tag{12}$$

$F_Q(-1)$ is defined to be 0. The values of $I_{bw\,start}(k)$ and $I_{bw\,stop}(k)$ are given in Table 3.6 and define frequency regions above the cut-off frequencies for the bandwidths in question. The quietness thresholds are given by $T_Q = \{20, 10, 10, 10\}$. The first stage classifier outputs a bandwidth index bw_0 which is the largest index between 0 and N_{bw} (with 0 and N_{bw} included) such that $F_Q(bw_0 - 1) = 0$.

The second stage determines the final bandwidth index bw. If $bw_0 = N_{bw}$, then bw shall be set to bw_0. Otherwise, the second stage classifier aims at detecting an energy drop above the cut-off frequency of the candidate bandwidth bw_0. This shall be done by testing the condition

$$\max_{I_{bw\,start}(bw_0)-L(bw_0)+1 \leq n \leq I_{bw\,start}(bw_0)+1} \left(10log_{10} \left(10^{-31} + \frac{E_B\left(n - L(bw_0)\right)}{E_B(n)} \right) \right) > T_C(bw_0)\,, \tag{13}$$

where $T_C = \{15, 23, 20, 20\}$ and $L = \{4, 4, 3, 1\}$ for 10 ms frame duration and $L = \{4, 4, 3, 2\}$ for 7.5 ms frame duration. If this condition holds then bw shall be set to bw_0 and otherwise it shall be set to N_{bw}. The parameter P_{bw} stores the final value bw.

The bandwidth information (NB, WB, …) shall be retrieved by mapping P_{bw} to the bandwidth column in Table 3.6. The bandwidth information is used to control the TNS and the Noise Level Estimation. The parameter P_{bw} shall be stored in the bitstream using the number of bits $nbits_{bw}$ as outlined in Table 3.6.

Note: The parameter P_{bw} is not a constant session parameter and may change in every processed frame depending on the bandwidth that has been detected.

3.3.5.2 Parameters

Table 3.6 lists the parameters used to detect the active bandwidth for a given sampling rate f_s.

N_{ms}	f_s	N_{bw}	$I_{bw\,start}$	$I_{bw\,stop}$	**Bandwidth(P_{bw})**	$nbits_{bw}$
10 ms	8,000	0	–	–	{NB}	0
10 ms	16,000	1	{53, 0, 0, 0}	{63, 0, 0, 0}	{NB, WB}	1
10 ms	24,000	2	{47, 59, 0, 0}	{56, 63, 0, 0}	{NB, WB, SSWB}	2
10 ms	32,000	3	{44, 54, 60, 0}	{52, 59, 63, 0}	{NB, WB, SSWB, SWB}	2
10 ms	44,100, 48,000	4	{41, 51, 57, 61}	{49, 55, 60, 63}	{NB, WB, SSWB, SWB, FB}	3
7.5 ms	8,000	0	–	–	{NB}	0
7.5 ms	16,000	1	{51, 0, 0, 0}	{63, 0, 0, 0}	{NB, WB}	1
7.5 ms	24,000	2	{45, 58, 0, 0}	{55, 63, 0, 0}	{NB, WB, SSWB}	2
7.5 ms	32,000	3	{42, 53, 60, 0}	{51, 58, 63, 0}	{NB, WB, SSWB, SWB}	2
7.5 ms	44,100, 48,000	4	{40, 51, 57, 61}	{48, 55, 60, 63}	{NB, WB, SSWB, SWB, FB}	3

Table 3.6: Parameter table bandwidth detector

Note: When $f_s = 8{,}000$, the bandwidth detector is not needed and we have $P_{bw} = 0$ and $nbits_{bw} = 0$, i.e., the parameter P_{bw} is not stored in the bitstream.

3.3.6 Time domain attack detector

3.3.6.1 Overview

The time domain attack detector shall be active only for higher bitrates and sampling rates $f_s \geq 32{,}000$. Specifically, transient detection shall be carried out if and only if one of the following conditions is satisfied:

1. $N_{ms} = 10$ and $f_s = 32{,}000$ and $nbytes\ > 80$.
2. $N_{ms} = 10$ and $f_s\ \geq 44{,}100$ and $nbytes\ \geq 100$.
3. $N_{ms} = 7.5$ and $f_s = 32{,}000$ and $nbytes\ \geq 61$ and $nbytes < 150$.
4. $N_{ms} = 7.5$ and $f_s\ \geq 44{,}100$ and $nbytes\ \geq 75$ and $nbytes < 150$.

If active, the transient detector outputs a flag $F_{att}(k)$ for each frame k, which takes a value of 1, indicating that an attack was detected, or 0, indicating that no attack was detected in this frame. If not active, $F_{att}(k)$ shall be set to 0. In the remainder of Section 3.3.6, the start-up frame index is denoted k_0.

3.3.6.2 Downsampling and filtering of input signal

The first step is a downsampling of the input signal $x_s(n), n = 0 \dots N_F - 1$, which shall be performed as

$$x_{att}^{(k)}(n) = \sum_{m=0}^{\frac{N_F}{M_F}-1} x_s\left(\frac{N_F}{M_F} \cdot n + m\right), for\ n = 0 \dots M_F - 1, \tag{14}$$

where $M_F = 16 \cdot N_{ms}$.

Next, the downsampled signal shall be high pass filtered according to

$$x_{hp}^{(k)}(n) = \ 0.375 \cdot\ x_{att}^{(k)}(n) - 0.5\ \cdot x_{att}^{(k)}(n-1) + 0.125\ \cdot x_{att}^{(k)}(n-2), for\ n = 0 \dots M_F - 1\ , \tag{15}$$

where *k* is the current frame index.

As in the case for the input signal, samples at negative indices correspond to samples from previous frames, i.e., $x_{att}^{(k)}(-1)$ and $x_{att}^{(k)}(-2)$ hold the values $x_{att}^{(k-1)}(M_F - 1)$ and $x_{att}^{(k-1)}(M_F - 2)$. The values $x_{att}^{(k_0)}(-1)$ and $x_{att}^{(k_0)}(-2)$ shall be zero.

3.3.6.3 Energy calculation

The attack detector operates on block wise energies on N_{blocks} blocks of 40 samples

$$E_{att}^{(k)}(n) = \sum_{l=40n}^{40n+39} x_{hp}^{(k)}(l)^2, for\ n = 0 \dots N_{blocks} - 1\ , \tag{16}$$

where $N_{blocks} = N_{ms}/2.5$. The energy values are compared to a delayed long time temporal envelope which shall be computed inductively by

$$A_{att}^{(k)}(n) = \max\left\{0.25\ \cdot A_{att}^{(k)}(n-1),\ E_{att}^{(k)}(n-1)\right\}, for\ n = 0 \dots N_{blocks} - 1\ , \tag{17}$$

where the values at index -1 correspond again to the values at index $N_{blocks} - 1$ in frame $k-1$. The values $A_{att}^{(k_0)}(-1)$ and $E_{att}^{(k_0)}(-1)$ shall be zero.

3.3.6.4 Attack detection

An attack is detected if

$$E_{att}^{(k)}(n) > 8.5 \cdot A_{att}^{(k)}(n) \tag{18}$$

holds for any n between 0 and $N_{blocks} - 1$. Furthermore, in this case the attack position $P_{att}(k)$ shall be set to the largest n such that the inequality holds. Otherwise, $P_{att}(k)$ shall be set to -1. The value $P_{att}(k_0 - 1)$ shall be defined to be -1.

The attack flag for frame k shall be computed as:

$$F_{att}(k) = \begin{cases} 1 & if\ P_{att}(k) \geq 0\ or\ P_{att}(k-1) \geq T_{att}, \\ 0 & else, \end{cases} \tag{19}$$

where $T_{att} = \left\lfloor \frac{N_{blocks}}{2} \right\rfloor$.

The attack flag is then used in Section 3.3.7.2.7.

3.3.7 Spectral Noise Shaping (SNS)

3.3.7.1 Overview

Spectral Noise Shaping (SNS) applies a set of scale factors to the MDCT spectrum. These scale factors shape the quantization noise introduced in the frequency domain by the spectral quantization. The noise shaping is performed in such a way that the quantization noise is minimally perceived by the human ear, maximizing the perceptual quality of the decoded output.

The SNS encoder performs the following four steps. A set of 16 scale factors shall be estimated as described in Section 3.3.7.2. These 16 scale factors shall then be quantized and encoded as described in Section 3.3.7.3. The quantized scale factors shall then be interpolated as described in Section 3.3.7.4. Finally, the MDCT spectrum shall be shaped using the 64 interpolated scale weights as described in Section 3.3.7.5. Figure 3.4 outlines the processing steps.

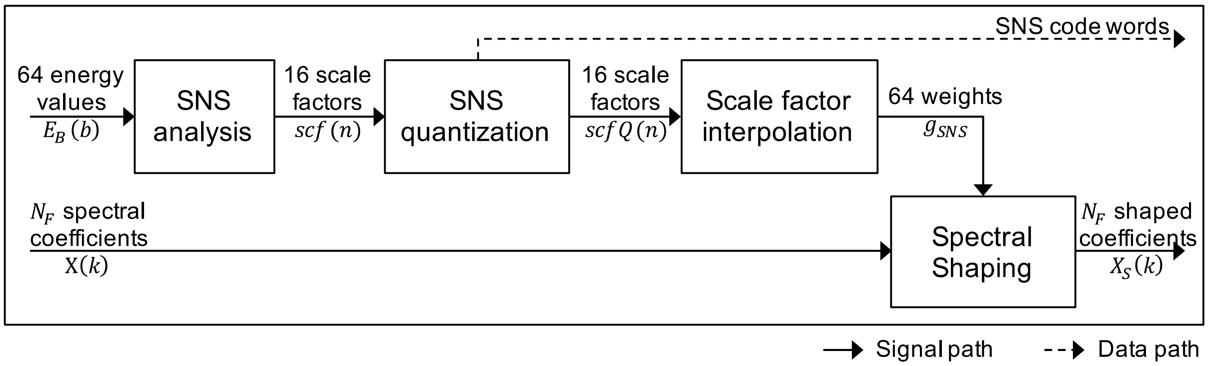

Figure 3.4: SNS encoder overview

3.3.7.2 SNS analysis

In the first step of the SNS encoder, a set of 16 scale factors are estimated. These scale factors shall be derived from the energies per band $E_B(b)$ (see Section 3.3.4.4).

3.3.7.2.1 Padding

In the case where the configuration of the codec results in a number of bands $N_B < 64$, the energy array $E_B(b)$ is extended by repeating the entries, starting from the lowest ones, until the vector has reached its dedicated size of 64 as described by the following C-style pseudocode:

```
n2 = 64 - N_B;

for (i=0; i < n2; i++)
{
    for (i2=0; i2 < 2; i2++)
    {
        E_B2(i * 2 + i2) = E_B(i);
    }
}

for (i=0; i < N_B - n2; i++)
{
    E_B2(n2 * 2 + i) = E_B(n2 + i);
}

for (i=0; i < 64; i++)
{
    E_B(i) = E_B2(i);
}
```

3.3.7.2.2 Smoothing

The energy per band $E_B(b)$ shall be first smoothed using

$$E_S(b) = \begin{cases} 0.75 \cdot E_B(0) + 0.25 \cdot E_B(1) & , if\ b = 0 \\ 0.25 \cdot E_B(62) + 0.75 \cdot E_B(63) & , if\ b = 63 \\ 0.25 \cdot E_B(b-1) + 0.5 \cdot E_B(b) + 0.25 \cdot E_B(b+1) & , otherwise. \end{cases} \tag{20}$$

3.3.7.2.3 Pre-emphasis

The smoothed energy per band $E_S(b)$ shall then be pre-emphasized using

$$E_P(b) = E_S(b) \cdot 10^{\frac{b \cdot g_{tilt}}{630}}\ ,\ for\ b = 0 \ldots 63 \tag{21}$$

with g_{tilt} given in Table 3.7.

f_s	g_{tilt}
8,000	14
16,000	18
24,000	22
32,000	26

f_s	g_{tilt}
44,100, 48,000	30

Table 3.7: Pre-emphasis tilt factor table

3.3.7.2.4 Noise floor

A noise floor at -40 dB relative to the average energy per band shall be added to $E_P(b)$ using

$$E_{P2}(b) = \max(E_P(b), noiseFloor)\,, \quad for\ \ b = 0 \dots 63 \tag{22}$$

with the noise floor being calculated by

$$noiseFloor = \max\left(\frac{\sum_{b=0}^{63} E_P(b)}{64} \cdot 10^{-\frac{40}{10}}, 2^{-32}\right). \tag{23}$$

3.3.7.2.5 Logarithm

A transformation into the logarithm domain shall then be performed using

$$E_L(b) = \frac{\log_2\left(10^{-31} + E_{P2}(b)\right)}{2}\,, \quad for\ \ b = 0 \dots 63\,. \tag{24}$$

3.3.7.2.6 Band energy grouping

The vector $E_L(b_1)$, with $b_1 = 0 \dots 63$ shall then be grouped and downsampled by a factor of 4 using

$$E_4(b_2) = \begin{cases} w(0) \cdot E_L(0) + \sum_{k=1}^{5} w(k) \cdot E_L(4 \cdot b_2 + k - 1) & , if\ b_2 = 0 \\ \sum_{k=0}^{4} w(k) \cdot E_L(4 \cdot b_2 + k - 1) + w(5) \cdot E_L(63) & , if\ b_2 = 15\,. \\ \sum_{k=0}^{5} w(k) \cdot E_L \cdot (4 \cdot b_2 + k - 1) & , otherwise \end{cases} \tag{25}$$

with $b_2 = 0\ \dots 15$ and

$$w(k) = \left\{\frac{1}{12}, \frac{2}{12}, \frac{3}{12}, \frac{3}{12}, \frac{2}{12}, \frac{1}{12}\right\} \tag{26}$$

3.3.7.2.7 Mean removal and scaling, attack handling

Mean removal and scaling shall be performed according to

$$scf_0(b_2) = 0.85 \cdot \left(E_4(b_2) - \frac{\sum_{b=0}^{15} E_4(b)}{16}\right), \quad for\ \ b_2 = 0 \dots 15\,. \tag{27}$$

If the attack detection is not active or if it is active and $F_{att}(k) = 0$ (computed in Section 3.3.6.4), then the final scale factors shall be

$$scf(n) = scf_0(n)\,, for\ n = 0 \dots 15\,. \tag{28}$$

Otherwise, if attack detection is active and $F_{att}(k) = 1$, a second smoothing shall be applied to the scale factors according to

$$scf_1(0) = \frac{1}{3} \cdot \left(scf_0(0) + scf_0(1) + scf_0(2)\right), \tag{29}$$

$$scf_1(1) = \frac{1}{4} \cdot (scf_0(0) + scf_0(1) + scf_0(2) + scf_0(3)), \tag{30}$$

$$scf_1(n) = \frac{1}{5} \cdot \sum_{m=-2}^{2} scf_0(n+m) \quad for\ n = 2 \ldots 13, \tag{31}$$

$$scf_1(14) = \frac{1}{4} \cdot (scf_0(12) + scf_0(13) + scf_0(14) + scf_0(15)), \tag{32}$$

And

$$scf_1(15) = \frac{1}{3} \cdot \left(scf_0(13) + scf_0(14) + scf_0(15)\right). \tag{33}$$

From these values the final scale factors shall be computed as

$$scf(n) = f_{att} \cdot \left(scf_1(n) - \frac{\sum_{b=0}^{15} scf_1(b)}{16}\right), \quad for\ \ n = \ 0 \ldots\ 15, \tag{34}$$

where $f_{att} = 0.5$ if $N_{ms} = 10$, and $f_{att} = 0.3$ if $N_{ms} = 7.5$.

3.3.7.3 SNS quantization

3.3.7.3.1 General

The SNS scale factors $scf(n)$ (obtained in Section 3.3.7.2) are quantized using a two-stage vector quantizer that uses a total of 38 bits (R = 2.375 bits/coefficient). The first stage is a 10 bit split VQ and the second stage is a low complexity algorithmic Pyramid Vector Quantizer (PVQ). To further maintain low overall VQ complexity, the Pyramid VQ is analyzed in a gain/shape manner in a transformed domain that enables an efficient shape-only search, followed by a low complexity total MSE evaluation in a combined gain and shape determination step. In general, PVQ quantizers are a family of L1-norm based algorithmic vector quantizers that require minimal storage space and use an algorithmic structure that enables efficient search procedures.

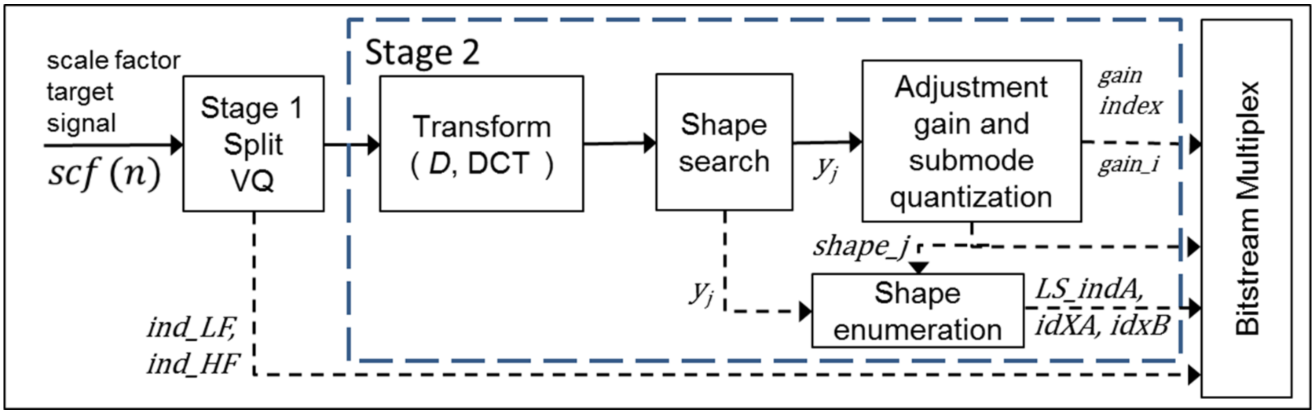

Figure 3.5: High-level overview of Encoder SNS VQ analysis

3.3.7.3.2 Stage 1

The first stage is a split VQ that uses two off-line trained stochastic codebooks called $LFCB$ and $HFCB$. Each codebook row has dimension 8 and the number of codebook columns is 32, requiring 5 bits for each split for transmission. The MSE distortions for the two code books shall be:

$$dMSE\_LF_i = \sum_{n=0}^{7} \left(scf(n) - LFCB_i(n)\right)^2, \qquad for\ i = 0 \dots 31, \tag{35}$$

$$dMSE_{HF_i} = \sum_{n=0}^{7} \left(scf(n+8) - HFCB_i(n)\right)^2, \qquad for\ i = 0 \dots 31,. \tag{36}$$

The best index for the low-frequency split shall be calculated according to:

$$ind\_LF = \underset{i=[\,0\ \dots\ 31]}{\operatorname{argmin}}\ dMSE\_LF_i\ . \tag{37}$$

The best index for the high-frequency split shall be calculated according to:

$$ind\_HF = \underset{i=[\,0\ \dots\ 31]}{\operatorname{argmin}}\ dMSE\_HF_i\ . \tag{38}$$

Codebooks $LFCB$ and $HFCB$ (available in Section 3.7.3.2) can be searched in any order.

The first stage vector shall be composed as:

$$st1(n) = LFCB_{ind\_LF}(n), \qquad for\ n = 0 \dots 7, \tag{39}$$

$$st1(n+8) = HFCB_{ind\_HF}(n), \qquad for\ n = 0 \dots 7, \tag{40}$$

The first stage residual signal shall be calculated as:

$$r1(n) = scf(n) - st1(n), \qquad for\ n = 0 \dots 15, \tag{41}$$

3.3.7.3.3 Stage 2

3.3.7.3.3.1 General

On a high level the overall mean square error (MSE) that is minimized by the second stage shall be:

$$dMSE(shape\_j, gain\_i, LSindices, MPVQindices) = \sum_n \left(r1_n - G_{gain\_i,shape\_j} \cdot \left[x_{q,shape_j,n}(LSindices, MPVQindices) \cdot \boldsymbol{D^T}\right]\right)^2, \quad (42)$$

where $G_{gain\_i,shape\_j}$ is a scalar value (as in Table 3.11), $\boldsymbol{D}$ is a16-by-16 rotation matrix (realizing an IDCT (Inverse Discrete Cosine Transform) rotation) and $x_{q,shape\_j}$ is a unit energy normalized vector of length 16 and $r1(n)$ is the first stage residual signal computed in Equation 41. The $shape\_j, gain\_i, LSindices, MPVQindices$ are vector quantization sub-indices that result in a total of $\boldsymbol{2^{28}}$ possible gain-shape combinations. The target of the second stage SNS VQ search is to find the set of indices that results in a minimum $dMSE$ distortion value.

Depending on the selected shape index $\boldsymbol{shape\_j}$ the number of leading sign indices $\boldsymbol{LSindices}$ shall be one $\{\boldsymbol{LS\_indA}\}$ or two $\{\boldsymbol{LS\_indA, LS\_indB}\}$, and similarly, depending on the selected shape index $\boldsymbol{shape\_j}$ the number of $\boldsymbol{MPVQindices}$ shall be one $\{\boldsymbol{idxA}\}$ or two $\{\boldsymbol{idxA, idxB}\}$.

3.3.7.3.3.2 Transform

The second stage uses a 16-dimensional DCT-rotation using a 16-by-16 matrix D**.** The **D**-matrix has been determined off-line for efficient scale factor quantization and has the property that $D^T \cdot D = I$ (the identity matrix). To reduce the encoder side search complexity the reverse(analysis) transform $D\ (= DCT)$ can be used before the shape and gain determination, while on the decoder side only the forward(synthesis) transform $D^T\ (= IDCT)$ is required. The coefficients of the full D *rotation* matrix are listed in Section 3.7.3.2. The equivalent conventional DCT (realized as the orthogonalized DCT-II) and the corresponding $IDCT$ functions can also be used to perform these transformations.

3.3.7.3.3.3 Stage 2 target preparation

The shape search target preparation consists of a 16x16 dimensional matrix analysis rotation. An orthogonalized DCT-II can be implemented using matrix multiplication with 16x16 matrix $\boldsymbol{D}$, where the DCT base vectors are stored column wise as:

$$t2_{rot}(n) = \sum_{row=0}^{15} r1(row) \cdot \boldsymbol{D}(n + row \cdot 16) \ , \qquad where\ n = [0 \ldots 15] \quad (43)$$

3.3.7.3.3.4 Shape candidates

There are four different 16-dimensional unit energy normalized shape candidates evaluated, where the normalization is always performed over 16 coefficients. The pulse configurations for two sets $(A\ and\ B)$ of scale factors for each candidate shape index ($\boldsymbol{shape\_j}$) are given in Table 3.8 .

Shape index (*shape_j*)	Shape name	Scale factor set A	Scale factor set B	Pulse configuration, Set A, PVQ(N_A, K_A)	Pulse configuration, Set B, PVQ(N_B, K_B)
0	'regular'	{0,1,2,3,4,5,6,7,8,9}	{10,11,12,13,14,15}	PVQ(10, 10)	PVQ(6, 1)
1	'regular_lf'	{0,1,2,3,4,5,6,7,8,9}	{10,11,12,13,14,15}	PVQ(10, 10)	*Zeroed*

Shape index (*shape_j*)	**Shape name**	**Scale factor set A**	**Scale factor set B**	**Pulse configuration, Set A, PVQ(N_A, K_A)**	**Pulse configuration, Set B, PVQ(N_B, K_B)**
2	'outlier_near'	{0,1,2,3,4,5,6,7,8,9, 10,11,12,13,14,15}	Empty set	PVQ(16, 8)	*Empty*
3	'outlier_far'	{0,1,2,3,4,5,6,7,8,9, 10,11,12,13,14,15}	Empty set	PVQ(16, 6)	*Empty*

Table 3.8: SNS VQ second stage shape candidate pulse configurations

The shape index $shape\_j=0$ pulse configuration is a hybrid PVQ shape configuration, with K_A=10 over N_A=10 scale factors and K_B=1 over the remaining N_B=6 scale factors. For shape index 0, the two sets of unit pulses shall be unit energy normalized over the full target dimension $N=N_A+N_B$=16, even though the PVQ integer pulse and sign enumeration is performed separately for each scale factor set.

3.3.7.3.3.5 Stage 2 shape search

The goal of the $PVQ(N, K)$ shape search procedure is to find the best normalized vector $x_q(n)$. In vector notation $x_q(n)$ shall be:

$$\boldsymbol{x_q} = \frac{\boldsymbol{y}}{\sqrt{\boldsymbol{y^T y}}} \ , \qquad (44)$$

where $y = y_{N,K}$ belongs to $PVQ(N, K)$ and this integer vector is a deterministic point on the surface of an N-dimensional hyperpyramid with K unit pulses. The L1-norm of $y_{N,K}$ is K, in other words, $y_{N,K}$ is an integer shape code vector of dimension N according to:

$$\boldsymbol{y_{N,K}} = \left\{ \boldsymbol{e} \quad | \quad \sum_{n=0}^{N-1} |\boldsymbol{e}_n| = K \right\} \ . \qquad (45)$$

As a result of the definition, x_q is a unit energy normalized version of the integer vector $y_{N,K}$, a deterministic point on the N-dimensional non-integer unit energy hypersphere. A high K value leads to a better shape approximation over dimension N but also has a higher cost, in terms of bitrate, for transmitting the location of the K unit pulses in the vector of dimension N.

The best integer $\boldsymbol{y}$ vector is the one minimizing the mean squared shape error between the second stage target vector $t2_{rot}(n) = x(n)$ and the normalized quantized output vector x_q. The shape search is achieved by minimizing a distortion measure according Equation 46, where the shape distortion measure $d_{PVQ-shape}$ shall be obtained by assuming an optimal gain in Equation 42.

$$d_{PVQ-shape} = -\boldsymbol{x^T x_q} = -\frac{(\boldsymbol{x^T y})}{\sqrt{\boldsymbol{y^T y}}} \ . \qquad (46)$$

By squaring the numerator and denominator in Equation 46 one can also maximize the quotient $Q_{PVQ\text{-}shape}$:

$$Q_{PVQ-shape} = \frac{(\boldsymbol{x^T y})^2}{\boldsymbol{y^T y}} = \frac{\left(corr_{xy}\right)^2}{energy_y} \ , \qquad (47)$$

where $corr_{xy}$ is the correlation between vector x and vector y. One can also use an efficient iterative search method in the all positive hyperoctant in N-dimensional space. In such a search in the all positive hyperoctant for the best (in an MSE sense) always positive integer vector $\boldsymbol{y}$, the correlation $corr_{xy}$ and $energy_y$ terms can always be evaluated as vector products ($|\boldsymbol{x}|^T\boldsymbol{y}$) and $\boldsymbol{y}^T\boldsymbol{y}$, respectively. However, with the unit pulse iterative approach**,** the search for the optimal (in an MSE sense) PVQ vector shape $y(n)$ with L1-norm K, can be simplified using iterative updates of the $Q_{PVQ\text{-}shape}$ variables for each unit pulse position candidate n_c (from 0 to $N\text{-}1$) according to:

$$corr_{xy}(k, n_c) = \ corr_{xy}(k-1) + 1 \cdot |x(n_c)| \tag{48}$$

$$energy_y(k, n_c) = \ energy_y(k-1) + 2 \cdot 1^2 \cdot y(k-1, n_c) + 1^2\,, \tag{49}$$

where $corr_{xy}(k\text{-}1)$ signifies the correlation achieved so far by placing the previous $k\text{-}1$ positive unit pulses, $energy_y(k\text{-}1)$ signifies the accumulated energy achieved so far by placing the previous $k\text{-}1$ positive unit pulses, and $y(k\text{-}1, n_c)$ signifies the amplitude of y at position n_c from the previous placement of a total of $k\text{-}1$ unit pulses. When no previous pulses have been placed, $\boldsymbol{y}$ is an all zero vector and therefore $\boldsymbol{corr_{xy}}$ is initialized to zero, and therefore $\boldsymbol{energy_y}$ is also initialized to zero.

$$Q_{PVQ-shape}(k, n_c) = \frac{\left(corr_{xy}(k, n_c)\right)^2}{energy_y(k, n_c)}. \tag{50}$$

The best position n_{best} for the kth unit pulse shall be iteratively updated by increasing n_c from 0 to $N\text{-}1$:

$$n_{best} = n_c, \quad if\ Q_{PVQ-shape}(k, n_c) > \ Q_{PVQ-shape}(k, n_{best})\,. \tag{51}$$

where n_{best} is initialized to zero before performing the search.

To avoid divisions (which is especially important in fixed point arithmetic) the $Q_{PVQ\text{-}shape}$ maximization update decision can be performed using a cross-multiplication of a saved best squared correlation numerator $bestCorrSq$ so far and the saved best energy denominator $bestEn$ so far.

$$\left.\begin{array}{lcl} n_{best} & = & n_c \\ bestCorrSq & = & corr_{xy}(k, n_c)^2 \\ bestEn & = & energy_y(k, n_c) \end{array}\right\}, if\ \ corr_{xy}(k, n_c)^2 \cdot bestEn > \ bestCorrSq \cdot energy_y(k, n_c)\,. \tag{52}$$

The pulse search methodology has to increase the number of pulses for each unit pulse addition loop. That is, at least one update of n_{best} over the positions 0 to $N\text{-}1$ in Equation 51 or in the cross-multiplied version Equation 52 shall be performed.

The iterative maximization in the all positive hyperoctant of $Q_{PVQ\text{-}shape}$ can start from a zero number of initially placed unit pulses ($y_{start}(n) = 0$, for n=0…15) or alternatively from a low-cost pre-placement number of unit pulses based on a projection to an integer valued point below the K'th-pyramid's surface, which results in an undershoot of unit pulses in the target L1 norm K. Such a projection can be made as follows:

$$proj_{fac} = \frac{K-1}{\sum_{n=0}^{n=15}|t2_{rot}(n)|}\,, \tag{53}$$

$$y_{start}(n) = \lfloor |t2_{rot}(n)| \cdot \ proj_{fac} \rfloor, \qquad for\ n = 0 \ldots 15\,. \tag{54}$$

If a projection is used in combination with an iterative positive unit pulse search approach, then, before starting the unit pulse search addition iterations, calculate $corr_{xy}(k-1)$ as $(|\boldsymbol{x}|^{\boldsymbol{T}}\boldsymbol{y}_{\boldsymbol{start}})$ and $energy_y(k-1)$ as $\boldsymbol{y}_{\boldsymbol{start}}{}^{\boldsymbol{T}}\boldsymbol{y}_{\boldsymbol{start}}$.

Four signed integer pulse configuration vectors y_j shall be established by using the distortion measure $d_{PVQ-shape}$ and then their corresponding unit energy shape vectors $x_{q,j}$ shall be computed according to Equation 44.

In the $j=0$ search, the set B positions only contain a single non-stacked unit pulse with a fixed energy contribution. This means that the search for the single pulse in set B can be simplified to search only for the maximum absolute value in the six set B locations.

For the $j=0,1$ normalization each total pulse configuration y_j always spans 16 coefficients. Therefore, the energy normalization shall always be performed over dimension 16, even though two shorter position sets are used for enumeration of the y_0 integer vector and one position set (set A) of dimension 10 for the y_1 integer vector.

An efficient overall unit pulse search (for all four shape candidates) can be achieved by searching the shapes in the order from shape $j=3$ to shape $j=0$, then making a first projection to a point on or below the pyramid $K=6$, updating the correlation and energy terms, and then sequentially adding unit pulses and saving intermediate shape results until K is correct for each of the four shape candidates with a higher number of unit pulses K. Because the regular set A shapes ($j=0,1$) span different allowed scale factor dimensions/regions than the two outlier shapes ($j=2,3$), one will need to handle the search start pulse configuration for the two regular shapes by removing any unit pulses that are not possible to index in the regular shape set A($j=0,1$). Because the iterative pulse search is performed in the all positive hyperoctant, a final step of setting the signs of the non-zero entries in $y_j(n)$ based on the corresponding sign in target vector $x(n)=t2_{rot}(n)$ shall be performed.

A step-by-step example of a search procedure is shown in Table 3.9 and an example of the resulting vectors are shown in Table 3.10.

Search step	Related shape index (j)	Description of search step	Resulting vector
1	3	Project to or below pyramid $N=16$, $K=6$, (and update energy $energy_y$ and correlation $corr_{xy}$ terms to reflect the pulses present in $y_{3,start}$)	$y_{3,start}$
2	3	Add unit pulses until you reach $K=6$ over $N=16$ samples, save y_3	$y_3 = y_{2,start}$
3	2	Add unit pulses until you reach $K=8$ over $N=16$ samples, save y_2	$y_2 = y_{1,pre\text{-}start}$
4	1	Remove any unit pulses in $y_{1,pre\text{-}start}$ that are not part of set A to yield $y_{1,start}$	$y_{1,start}$
5	1	Update energy $energy_y$ and correlation $corr_{xy}$ terms to reflect the pulses present in $y_{1,start}$	$y_{1,start}$ (unchanged)

Search step	Related shape index (j)	Description of search step	Resulting vector
6	1	Add unit pulses until you reach *K=10* over *N=10* samples (in set A), save y_1	$y_1 = y_{0,start}$
7	0	Add unit pulses to $y_{0,start}$ until you reach *K=1* over *N=6* samples (in set B), save y_0	y_0
8	3,2,1,0	Add signs to non-zero positions of each y_j vector from the target vector *x*, save y_3, y_2, y_1, y_0 as shape vector candidates (and for subsequent indexing of one of them)	y_3, y_2, y_1, y_0
9	3,2,1,0	Unit energy normalize each y_j vector to candidate vector $x_{q\,j}$	$x_{q,3}, x_{q,2}, x_{q,1}, x_{q,0}$

Table 3.9: Example of a PVQ search strategy for the described PVQ based shapes

Shape index (j)	Example Integer vector y_j	Corresponding unit energy normalized vector $x_{q,j}$ (Important: listed here in very low precision)
0	$y_0 = [-10,0,0,0,0,0,0,0,0,0, \ 0,0,0,0,0, 1]$	$x_{q,0} = [-0.995, 0, 0,0,0,0,0,0,0,0,0, 0,0,0,0,0.100]$
1	$y_1 = [0,0,0,0,0,0,0,0,0, 10, \ 0,0,0,0,0,0]$	$x_{q,1} = [0,0,0,0,0,0,0,0,0,1.0, \ 0,0,0,0,0,0]$
2	$y_2 = [0,0,0,0,0,0,0,0,0, 1, \ 0,0,0,0,0,-7]$	$x_{q,2} = [0,0,0,0,0,0,0,0,0,0.141, \ 0,0,0,0,0,-0.990]$
3	$y_3 =$ $[0,0,0,0,0,0,0,0,0,0, \ -1, 1,-1, 1,-1, 1]$	$x_{q,3} =$ $[0,0,0,0,0,0,0,0,0,0,-0.408,0.408,-0.408,0.408,-0.408,0.408]$

Table 3.10: Example of potentially available integer vectors yj and their corresponding unit energy normalized vectors $x_{q,j}$, after completing the PVQ shape search

3.3.7.3.3.6 Adjustment gain candidates

There are four different adjustment gain candidate sets, one set corresponding to each overall shape candidate j. The adjustment gain configuration ($G_{i,j}$) for each of the shapes is provided in Table 3.11.

Gain set index (same as Shape index = j)	Corresponding Shape name	Number of gain levels	Adjustment Gain set values ($G_{i,j}$) See Section 3.7.3.2	Start adjustment gain index $Gminind_j$	End adjustment gain index $Gmaxind_j$
0	'regular'	2	sns_vq_reg_adj_gains[2]	0	1
1	'regular_lf'	4	sns_vq_reg_lf_adj_gains[4]	0	3
2	'outlier_near'	4	sns_vq_near_adj_gains[4]	0	3
3	'outlier_far'	8	sns_vq_far_adj_gains[8]	0	7

Table 3.11: SNS VQ Second Stage Adjustment Gain sets

3.3.7.3.3.7 Shape and gain combination determination

The best possible shape and gain shall be determined among the possible shape candidates and each corresponding gain set. To minimize complexity the Mean Square Error (MSE) versus the target can be evaluated in the rotated domain, i.e., the same domain in which the shape search was performed.

$$dMSE(j,i) = \sum_{n=0}^{15} (t2_{rot}(n) \quad - \quad G_{i,j}\, x_{q,j}(n))^2\,, \qquad for\; j = 0 \dots 3, i = 0 \dots Gmaxind_j \tag{55}$$

Out of the total $18(2+4+4+8)$ possible gain-shape combinations, the shape_index $shape\_j$ and adjustment gain index $gain\_i$ that results in the minimum MSE shall be selected for subsequent enumeration and multiplexing.

$$\{shape_j = j\,, gain_i = i\} = \underset{j=0\,\dots\,3,\quad i=0\dots Gmaxind_j}{\operatorname{argmin}} dMSE(j,i)\,. \tag{56}$$

3.3.7.3.3.8 Enumeration of the selected PVQ pulse configurations

The pulse configuration(s) of the selected shape shall be enumerated using an efficient scheme that separates each $PVQ(N, K)$ pulse configuration into two short codewords: a leading sign index bit and an integer MPVQ (Modular Pyramid Vector Quantizer)-index codeword. The MPVQ-index bit-space is typically fractional (i.e., a non-power of 2 total number of pulse configurations). The indexing step is also referred to as enumeration.

The largest MPVQ integer shape index ($shape\_j=2$, ‘outlier_near’) fits within a 24-bit unsigned word, enabling fast implementations of MPVQ enumeration and de-enumeration on platforms supporting unsigned integer arithmetic of 24 bits or higher.

The enumeration scheme uses an indexing offsets table $MPVQ\_offsets(n, k)$, which is given as a table of unsigned integer values in Section 3.7.3.2. The offset values in $MPVQ\_offsets$ (dimension n, L1-norm k) shall be defined recursively as:

$$MPVQ\_offsets(n,k) \;=\; MPVQ\_offsets(n-1,k-1) \;+ MPVQ\_offsets(n,k-1) \;+ MPVQ\_offsets(n-1,k), \tag{57}$$

with initial conditions MPVQ_offsets (n, k=0) = 0 for n>=0, MPVQ_offsets (n=0, k) =1 for k>0.

The actual enumeration of a signed integer vector y(=vec_in) with an L1 norm of K(=k_val_in) over dimension N(=dim_in) into an MPVQ shape index and a leading sign index $lead\_sign\_ind$ is shown in C-style pseudocode below:

```
[ index, lead_sign_ind ] =
MPVQenum ( dim_in,      /* i :  dimension of vec_in                   */
           k_val_in,    /* i :  number of pulses in vec_in (redundant) */
           vec_in[N]    /* i :  PVQ integer pulse train               */
         )
{
    /*  init    */
    next_sign_ind  =  0x80000000U;  /* sentinel for first sign  */
    k_val_acc = 0;
    pos       = dim_in;
    index     = 0;
    n         = 0;
    row_ptr   = &(MPVQ_offsets[n]);
```

```
    /* MPVQ-index composition loop */
    tmp_h_row = row_ptr[0];
    for (pos--; pos >= 0; pos--) {
        tmp_val                = vec_in[pos];
        [index, next_sign_ind] = encPushSign(tmp_val, next_sign_ind, index);
        index                 += tmp_h_row;
        k_val_acc             += abs(tmp_val);

        if ( pos != 0 ) {
           n += 1;       /* switch row in offset table MPVQ_offsets(n, k) */
        }
        row_ptr   = &(MPVQ_offsets[n]);
        tmp_h_row = row_ptr[k_val_acc];
    }
    lead_sign_ind = next_sign_ind;

    return [ index, lead_sign_ind ] ;
}


[ index, next_sign_ind ] =
encPushSign( val, next_sign_ind_in, index_in)
{
    index = index_in;
    if ((next_sign_ind_in & 0x80000000U) == 0) && (val != 0) {
        index = 2*index_in + next_sign_ind_in;
    }
    next_sign_ind = next_sign_ind_in;
    if ( val < 0 ) {
        next_sign_ind = 1;
    }
    if ( val > 0 ){
        next_sign_ind = 0;
    }
    /* if val==0, there is no new sign information to "push",
       i.e. next_sign_ind is not changed */
    return [ index, next_sign_ind ];
}
```

The `MPVQ_enum()` function above implements a PVQ-enumeration method that passes through all the possible combinations of signed elements given the input signed integer PVQ-vector `vec_in`, while sequentially pushing one bit of sign information from the end of the vector(`pos= dim_in-1`) towards the front(`pos=0`). The function `encPushSign`() stores the information about the other non-leading signs in the larger of two codewords. This PVQ-enumeration method enables a separation of a large total PVQ-index into two shorter separate codewords.

Table 3.12 lists the MPVQ enumeration calls for a selected *shape_j*:

Shape index (*shape_j*)	**Shape name**	**Scale factor set A enumeration**	**Scale factor set B enumeration**
0	'regular'	$[idxA, LS\_indA] =$ MPVQenum($10, 10, y_0$)	$z(n-10) = y_0(n)$, for $n=10...15$ $[idxB, LS\_indB] =$ MPVQenum($6, 1, z$);
1	'regular_lf'	$[idxA, LS\_indA] =$ MPVQenum($10, 10, y_1$)	n/a
2	'outlier_near'	$[idxA, LS\_indA]$ = MPVQenum($16, 8, y_2$)	n/a
3	'outlier_far'	$[idxA, LS\_indA]$ = MPVQenum($16, 6, y_3$)	n/a

Table 3.12: Scale factor VQ second stage shape enumeration of integer vector y shape_j into MPVQ shape indices{idxA, idxB}, and leading signs indices{LS_indA, LS_indB} for each possible selected shape index shape_j

3.3.7.3.4 Multiplexing of SNS VQ codewords

The SNS VQ Stage 1 codewords shall be multiplexed in the following order: ind_LF (5 bits) followed by ind_HF (5 bits).

The second stage SNS VQ codeword multiplexing is performed differently depending on the selected shape $shape\_j$. To efficiently use the available 38 bits for the second stage SNS scale factor quantizer, the fractional sized MPVQ-indices, the LSB (Least Significant Bit) of shape index j, the second stage shape codewords, and potentially an LSB of the gain codeword shall be jointly encoded. The overall parameter encoding order for the second stage multiplexing components is shown in Table 3.13.

SNS-VQ Multiplexing order	**Stage 2 parameter description**	**Parameter**
0	Stage 2 submode bit	$shape\_j>>1$, (as the submodeMSB bit)
1	Gain index $gain\_i$ or MSBs of the adjustment gain index $gain\_i$	$gain\_i$, (the gain index), for even(*shape_j*) (or $gain\_i>>1$; for odd (*shape_j*)
2	Leading sign of shape in set A	LS_indA
3	A joint shape index (for set A and set B) and possibly an LSB gain bit	Joint composition of : $(idxA, LS\_indB, idxB, LSB_{submode}, LSB_{gain})$ The LSB submode bit shall be encoded as a bitspace section inside the overall joint shape codeword $index_{joint}$.

Table 3.13: Multiplexing order and parameters for the second stage

As shown in Table 3.14, in the multiplexing of leading signs LS_indA and/or LS_indB, each leading sign shall be multiplexed as 1 if the leading sign is negative and multiplexed as 0 if the leading sign is positive.

Shape index (*shape_j*)	Shape name	Submode bit value (regular/ outlier)	SZ_{MPVQ} Set A (excl. LS_indA)	SZ_{MPVQ} Set B (excl. LS_indB)	Number of LSB gain index code points	Adjustment gain index bit separation {MSBs, LSB}
0	'regular'	0	$SZ_{shapeA,0}$ = 2,390,004 (~21.1886 bits)	$SZ_{shapeB,0}$ = 6 (~2.585 bits)	0	{1, 0}
1	'regular_lf'	0	$SZ_{shapeA,1}$ = $SZ_{shapeA,0}$	$SZ_{shapeB,1}$ = 1 (0 bits)	2	{1, 1}
2	'outlier_near'	1	$SZ_{shapeA,2}$ = 15,158,272 (~23.8536 bits)	n/a	0	{2, 0}
3	'outlier_far'	1	$SZ_{shapeA,3}$ = 774,912 (~19.5637 bits)	n/a	2	{2, 1}

Table 3.14: Submode bit values, sizes of the various second stage MPVQ shape indices, and the adjustment gain separation sections for each shape index (=shape_j)

3.3.7.3.4.1 Encoding of gain or MSBs of gains:

For a selected shape with shape index ***shape_j***=0 and ***shape_j***=2, *submodeLSB* shall be set to 0, and the selected gain index shall be sent without modification as index *gain_i*, for gain value $G_{gain\_i\,,shape\_j}$, requiring 1 bit for ***shape_j***=0 and 2 bits for ***shape_j***=2.

For a selected shape with shape index *shape_j*=1 and *shape_j*=3, *submodeLSB* shall be set to 1, and for a selected gain value $G_{gain\_i\,,shape\_j}$ with gain index i , the MSB part of the gain index shall first be obtained by a removal of the LSB_{gain} bit. i.e., $gain\_i_{\,MSBs} = gain\_i >> 1$; $LSB_{gain} = gain\_i \,\&0x1$. The multiplexing of $gain\_i_{\,MSBs}$ will require 1 bit for ***shape_j***=1 and 2 bits for ***shape_j***=3. The LSB_{gain} bit shall be multiplexed into the joint index.

3.3.7.3.4.2 Joint index composition:

Joint index for a selected shape index of *shape_j*=0 ('regular') and *submodeLSB*=0

$$index_{joint,0} = (2 \cdot idxB + LS\_indB + 2) \cdot SZ_{shapeA,0} + idxA \,, \tag{58}$$

where the range of *idxB* shall be from 0 to ($SZ_{shapeB,0}$ -1) .

Joint index for a selected shape index of *shape_j*=1 ('regular_lf') and *submodeLSB*=1

$$index_{joint,1} = LSB_{gain} \cdot SZ_{shapeA,1} + idxA \,, \tag{59}$$

as $log2(SZ_{shapeB,1}) = 0$ bits are required for set B, *idxB* shall not be multiplexed into $index_{joint,1}$.

Joint index for a selected shape index of *shape_j*=2 ('outlier_near') and *submodeLSB*=0

$$index_{joint,2} = idxA\,. \tag{60}$$

Joint index for a selected shape index of $shape\_j$=3 (‘outlier_far’) and $submodeLSB$=1

$$index_{joint,3} = SZ_{shapeA,2} + LSB_{gain} + (2 \cdot idxA) \tag{61}$$

3.3.7.3.4.3 Synthesis of the Quantized SNS scale factor vector:

The quantized first stage vector $st1$, the quantized second stage unit energy shape vector $x_{q,shape\_j}$, the quantized adjustment gain $G_{gain\_i,shape\_j}$ (with gain index $gain\_i$) , and the rotation matrix $\boldsymbol{D}$ (now used to implement the synthesis IDCT transform) shall be used to establish the quantized scale factor vector $scfQ(n)$ as follows:

$$scfQ(n) = st1(n) \quad + \quad G_{gain\_i\,,shape\_j} \cdot \sum_{col=0}^{15} \left[x_{q,shape\_j}(col) \cdot \boldsymbol{D}(col + n \cdot 16\,) \right], for\ n = 0 \ldots 15 \tag{62}$$

3.3.7.4 SNS scale factors interpolation

The quantized scale factors $scfQ(n)$ (obtained in Section 3.3.7.3) shall be interpolated using

$$\begin{gathered}
scfQint(0) = scfQ(0) \\
scfQint(1) = scfQ(0) \\
scfQint(4 \cdot n + 2) = scfQ(n) + \frac{1}{8} \cdot \big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n =\ 0 \ldots 14 \\
scfQint(4 \cdot n + 3) = scfQ(n) + \frac{3}{8} \cdot \big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n =\ 0 \ldots 14 \\
scfQint(4 \cdot n + 4) = scfQ(n) + \frac{5}{8} \cdot \big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n =\ 0 \ldots 14 \\
scfQint(4 \cdot n + 5) = scfQ(n) + \frac{7}{8} \cdot \big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n =\ 0 \ldots 14 \\
scfQint(62) = scfQ(15) + \frac{1}{8} \cdot \big(scfQ(15) - scfQ(14)\big) \\
scfQint(63) = scfQ(15) + \frac{3}{8} \cdot \big(scfQ(15) - scfQ(14)\big)
\end{gathered} \tag{63}$$

In cases where the codec is configured to operate on a number of bands $N_B < 64$, the number of scale factors will need to be reduced using the following C-style pseudocode:

```
n2 = 64 - N_B;

for (i=0; i < n2; i++)
{
   sum = 0;
   for (i2=2*i; i2 < 2*i+2; i2++)
   {
      sum+= 0.5 * scfQint(i2);
   }

   tmp(i) = sum;
}

for (i=n2; i < N_B; i++)
{
   tmp(i) = scfQint(n2 + i)
```

```
}

for (i=0; i < N_B; i++)
{
    scfQint(i) = tmp(i);
}
```

The scale factors are then transformed back into the linear domain using

$$g_{SNS}(b) = 2^{-scfQint(b)}, \; for \; b = 0 \ldots N_B - 1. \tag{64}$$

3.3.7.5 Spectral shaping

The SNS scale factors $g_{SNS}(b)$ shall be applied to the MDCT frequency coefficients for each band separately to generate the shaped spectrum $X_s(k)$ as outlined by the following code.

```
for b=0 to N_B − 1 do
    for k=I_fs(b) to I_fs(b + 1) − 1
        X_s(k) = X(k)· g_SNS(b)
```

3.3.8 Temporal Noise Shaping (TNS)

3.3.8.1 Overview

Temporal Noise Shaping (TNS) is used to control the temporal shape of the quantization noise within each window of the transform. If TNS is active in the current frame, up to two filters per MDCTspectrum will be applied. The processing steps are outlined in Figure 3.6.

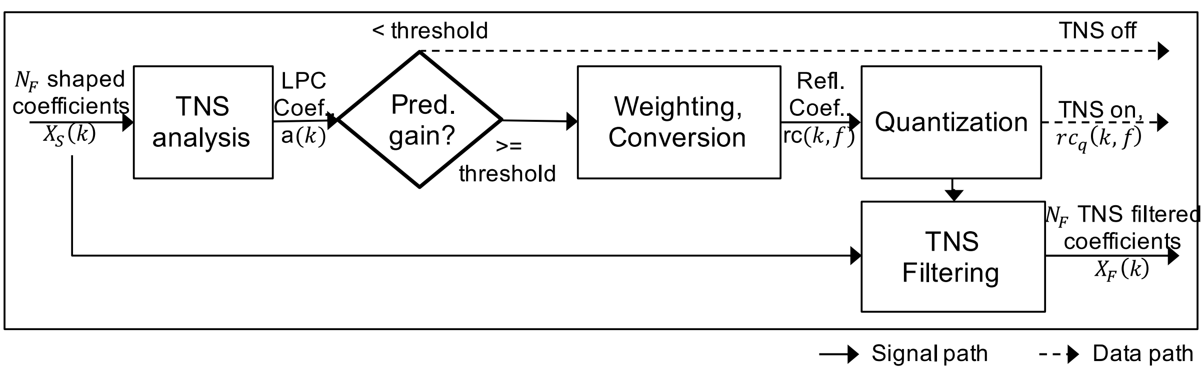

Figure 3.6: TNS overview for the encoder

The number of filters for each configuration, the start and the stop frequency of each filter, and the start and stop frequencies of the subdivisions are given in Table 3.15.

N_{ms}	Bandwidth	num_tns_filters	start_freq(f)	stop_freq(f)	sub_start(f,s)	sub_stop(f,s)
10 ms	NB	1	{12}	{80}	{{12,34,57}}	{{34,57,80}}
10 ms	WB	1	{12}	{160}	{{12,61,110}}	{{61,110,160}}
10 ms	SSWB	1	{12}	{240}	{{12,88,164}}	{{88,164,240}}

N_{ms}	**Bandwidth**	**num_tns_filters**	**start_freq(f)**	**stop_freq(f)**	**sub_start(f,s)**	**sub_stop(f,s)**
10 ms	SWB	2	{12,160}	{160,320}	{{12,61,110}, {160,213,266}}	{{61,110,160}, {213,266,320}}
10 ms	FB	2	{12,200}	{200,400}	{{12,74,137}, {200,266,333}}	{{74,137,200}, {266,333,400}}
7.5 ms	NB	1	{9}	{60}	{{9,26,43}}	{{26,43,60}}
7.5 ms	WB	1	{9}	{120}	{{9,46,83}}	{{46,83,120}}
7.5 ms	SSWB	1	{9}	{180}	{{9,66,123}}	{{66,123,180}}
7.5 ms	SWB	2	{9,120}	{120,240}	{{9,46,82}, {120,159,200}}	{{46,82,120}, {159,200,240}}
7.5 ms	FB	2	{9,150}	{150,300}	{{9,56,103}, {150,200,250}}	{{56,103,150}, {200,250,300}}

Table 3.15: TNS encoder parameters

The TNS encoding steps are described in Sections 3.3.8.1 through 3.3.8.4. First, an analysis estimates a set of reflection coefficients for each TNS Filter. Then, these reflection coefficients are quantized. Finally, the MDCTspectrum is filtered using the quantized reflection coefficients.

3.3.8.2 TNS analysis

The complete TNS analysis described below shall be repeated for every TNS filter f, with $f = 0 \ldots \text{num\_tns\_filters-1}$ (num_filters is given in Table 3.15).

The normalized autocorrelation function shall be calculated as follows, for each $k = 0 \ldots 8$

$$r(k) = \begin{cases} r_0(k) & \text{, if } \prod_{s=0}^{2} e(s) = 0 \\ \sum_{s=0}^{2} \frac{\sum_{n=\text{sub\_start}(f,s)}^{\text{sub\_stop(f,s)-1-k}} X_s(n) \cdot X_s(n+k)}{e(s)} & \text{, otherwise} \end{cases} \quad (65)$$

where

$$r_0(k) = \begin{cases} 3 & , if\ k = 0 \\ 0 & , otherwise \end{cases} \quad (66)$$

and

$$e(s) = \sum_{n=\text{sub\_start}(f,s)}^{\text{sub\_stop(f,s)-1}} X_s(n)^2 \,, \quad for\ \ s = 0 \ldots 2 \quad (67)$$

with $\text{sub\_start}(f,s)$ and $\text{sub\_stop}(f,s)$ given in Table 3.15.

The normalized autocorrelation function shall be lag-windowed using

$$r_w(k) = r(k) \cdot \exp\left[-\frac{1}{2} \cdot (0.02 \cdot \pi \cdot k)^2\right], \quad for \;\; k = 0 \dots 8\,. \tag{68}$$

The Levinson-Durbin recursion shall be used to obtain LPC (Linear Predictive Coding) coefficients $a(k), k = 0 \dots 8$ and a prediction error err. It is described by the following pseudocode.

$err = r_w(0)$
$a(0) = 1$
for $k = 1$ to 8 do
  $rc = \frac{-\sum_{n=0}^{k-1} a(n) r_w(k-n)}{err}$
  $\mathrm{tmp}(0) = 1$
  for $n = 1$ to $k - 1$ do
    $\mathrm{tmp}(n) = a(n) + rc \cdot a(k-n)$
  $\mathrm{tmp}(k) = rc$
  for $n = 0$ to k do
    $a(n) = \mathrm{tmp}(n)$
  $err = (1 - rc^2) \cdot err$

where $a(k), k = 0 \dots 8$ is the estimated LPC coefficients and err is the prediction error.

The decision to turn the TNS filter f on or off in the current frame shall be based on the prediction gain.

If predGain > 1.5 and the *near_nyquist_flag* obtained in Section 3.3.4.5 is 0, then turn on the TNS filter f and the prediction gain shall be computed by

$$\mathrm{predGain} = \frac{r_w(0)}{err} \tag{69}$$

The additional steps described below shall be performed only if the TNS filter f is turned on.

The weighting factor shall be computed by

$$\gamma = \begin{cases} 1 - (1 - 0.85) \cdot \dfrac{2 - \mathrm{predGain}}{2 - 1.5} & \text{, if tns\_lpc\_weighting} = 1 \text{ and predGain} < 2 \\ 1 & \text{, otherwise} \end{cases} \tag{70}$$

and

$$\text{tns\_lpc\_weighting} = \begin{cases} 1 & \text{, if nbits} < 48 \cdot N_{ms} \\ 0 & \text{, otherwise} \end{cases}\,. \tag{71}$$

The LPC coefficients shall be weighted using the factor γ

$$a_w(k) = \gamma^k \cdot a(k)\,, \quad for \;\; k = 0 \dots 8\,. \tag{72}$$

The weighted LPC coefficients shall be converted to reflection coefficients using the following algorithm.

$\mathrm{tmp1}(k) = a_w(k), k = 0, \dots, 8$
for $k = 8$ to 1 do
  $rc(k-1) = \mathrm{tmp1}(k)$
  $e = (1 - rc(k-1)^2)$
  for $n = 1$ to $k - 1$ do
    $\mathrm{tmp2}(n) = \frac{\mathrm{tmp1}(n) - rc(k-1)\mathrm{tmp1}(k-n)}{e}$

```
    for n = 1 to k − 1 do
        tmp1(n) = tmp2(n)
```

with $rc(k,f) = rc(k), k = 0 \ldots 7$ are the final estimated reflection coefficients for the TNS filter f.

If the TNS filter f is turned off, then the reflection coefficients shall be set to 0: $rc(k,f) = 0,\ \ k = 0 \ldots 7$.

3.3.8.3 Quantization

For each TNS filter f, the reflection coefficients obtained in Section 3.3.8.2 shall be quantized using scalar uniform quantization in the arcsine domain

$$rc_{int}(k,f) = \text{nint}\left[\frac{\arcsin\big(rc(k,f)\big)}{\Delta}\right] + 8\,,\quad for\ \ k = 0 \ldots 7 \tag{73}$$

and

$$rc_q(k,f) = \sin\left(\Delta \cdot (rc_{int}(k,f) - 8)\right),\ \ for\ \ k = 0 \ldots 7 \tag{74}$$

with $\Delta = \frac{\pi}{17}$ and $\text{nint}[.]$ is the rounding-to-nearest-integer function.
$rc_i(k,f)$ are the quantizer output indices and $rc_q(k,f)$ are the quantized reflection coefficients.

The order of the quantized reflection coefficients shall be calculated using

```
k = 7
while  k ≥ 0  and  rc_q(k,f) = 0
    k = k − 1
rc_order(f) = k + 1
```

The total number of bits consumed by TNS in the current frame shall then be computed as follows

$$nbits_{TNS} = \sum_{f=0}^{\text{num\_tns\_filters}-1} \left\lceil \frac{2{,}048 + nbits_{TNS_{order}}(f) + nbits_{TNS_{coef}}(f)}{2{,}048} \right\rceil \tag{75}$$

with

$$nbits_{TNS_{order}}(f) = \begin{cases} \text{ac\_tns\_order\_bits}[\text{tns\_lpc\_weighting}][rc_{order}(f) - 1] & , if\ rc_{order}(f) > 0 \\ 0 & , otherwise \end{cases} \tag{76}$$

and

$$nbits_{TNS_{coef}}(f) = \begin{cases} \displaystyle\sum_{k=0}^{rc_{order}(f)-1} \text{ac\_tns\_coef\_bits}[k][rc_i(k,f)] & , if\ rc_{order}(f) > 0 \\ 0 & , otherwise \end{cases} \tag{77}$$

The tables ac_tns_order_bits and ac_tns_coef_bits are provided in Section 3.7.5.

3.3.8.4 Filtering

The MDCT spectrum $X_s(n)$ computed in Section 3.3.7.5 shall be analysis filtered using the following algorithm.

$$
\begin{aligned}
&\texttt{for } k = 0 \texttt{ to } (N_E - 1) \texttt{ do } \{\\
&\qquad X_f(k) = X_s(k)\\
&\}\\
&\\
&st(0) = st(1) = \cdots = st(7) = 0\\
&\texttt{for } f = 0 \texttt{ to } \mathrm{num\_tns\_filters\text{-}1} \texttt{ do } \{\\
&\quad \texttt{if } (rc_{order}(f) > 0) \{\\
&\qquad \texttt{for } n = \mathrm{start\_freq}(f) \texttt{ to } \mathrm{stop\_freq}(f) - 1 \texttt{ do } \{\\
&\qquad\quad t = X_s(n)\\
&\qquad\quad st\_save = t\\
&\qquad\quad \texttt{for } k = 0 \texttt{ to} (rc_{order}(f) - 2) \texttt{ do} \{\\
&\qquad\qquad st\_tmp = rc_q(k,f) \cdot t + st(k)\\
&\qquad\qquad t = t + rc_q(k,f) \cdot st(k)\\
&\qquad\qquad st(k) = st\_save\\
&\qquad\qquad st\_save = st\_tmp\\
&\qquad\quad \}\\
&\qquad\quad t = t + rc_q(rc_{order}(f) - 1, f) \cdot st(rc_{order}(f) - 1)\\
&\qquad\quad st(rc_{order}(f) - 1) = st\_save\\
&\qquad\quad X_f(n) = t\\
&\qquad \}\\
&\quad \}\\
&\}
\end{aligned}
$$

where $X_f(n)$ is the TNS filtered MDCT spectrum. The initial condition for $st^k(n-1)$ for the first TNS filter *(f = 0)* shall be 0, and for the second TNS filter *(f = 1)* shall be carried over from the first TNS filter *(f = 0)*.

Note: If $\mathrm{num\_tns\_filters} > 1$ and ($rc_{order}(0) < rc_{order}(1)$), some of the lattice states st^x for the second filter will be starting off from zero.

3.3.9 Long Term Postfilter

3.3.9.1 Overview

A Long Term Postfilter (LTPF) module controls a pitch-based postfilter on the decoder side which perceptually shapes quantization noise in spectral valleys. Figure 3.7 outlines the processing steps of the LTPF encoder. The steps defined in Sections 3.3.9.3, 3.3.9.4, 3.3.9.5, 3.3.9.6, 3.3.9.7 and 3.3.9.8 shall be performed.

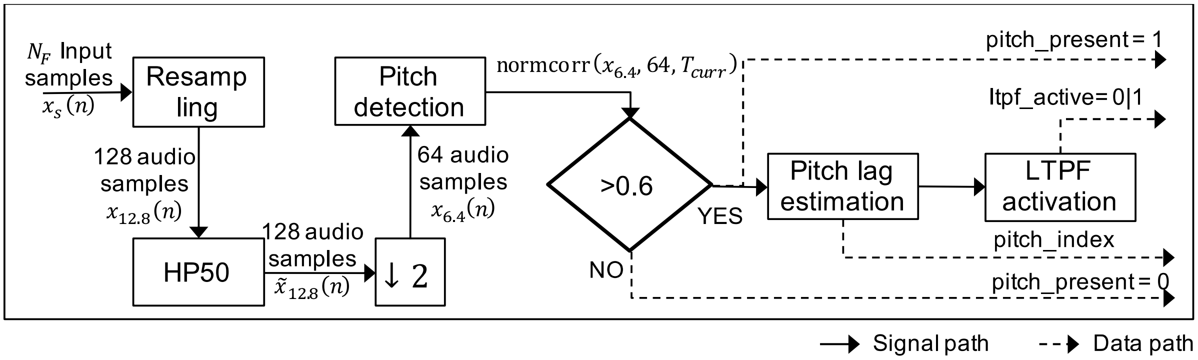

Figure 3.7: LTPF encoder overview

Note: The processing of the LTPF decoder (Section 3.4.9) depends on the bitrate of the current frame. At high bitrates (see Section 3.4.9.4 for exact parameters), the coefficients C_{num} and

C_{den} are set to zero, meaning that the transition handling (Section 3.4.9.2) has no effect on the input data. However, the pitch information computed in Section 3.3.9.7 is very valuable for a packet loss concealment algorithm and is therefore calculated and encoded into the bitstream on the encoder side regardless of the bitrate of the current frame.

3.3.9.2 Time domain signals

Several time domain signals are computed in the LTPF encoder. The signals are processed with filters that contain a memory and therefore operate on audio samples that were computed in the previous frames. For simplicity, audio samples of past frames are accessed by negative indexing, e.g., $x_s(-1)$ is the most recent sample of the signal x_s in the previous frame.

3.3.9.3 Resampling

The input signal at sampling rate f_s shall be resampled at a fixed sampling rate of 12.8 kHz for input sampling rates of 8, 16, 24, 32, and 48 kHz and to 11.76 kHz for input sampling rate of 44.1 kHz. The resampling shall be performed using an upsampling+low-pass-filtering+downsampling approach that can be formulated as a polyphase implementation as follows

$$x_{12.8}(n) = res_{fac} \cdot P \cdot \sum_{k=-\frac{120}{P}}^{\frac{120}{P}} x_s\left(\left\lfloor \frac{15n}{P} \right\rfloor + k - \frac{120}{P}\right) \cdot h_{12.8}(P \cdot k - 15 \cdot n \cdot \ (\mathrm{mod}\ P)) \qquad for \quad n = 0 \dots len_{12.8} - 1\,, \tag{78}$$

where $x_s(n)$ is the scaled input signal, $x_{12.8}(n)$ is the resampled signal at 12.8kHz, $P = \frac{192kHz}{f_s}$ is the upsampling factor ($P = 4$ for $f_s = 44.1kHz$), and $h_{12.8}$ is the impulse response of a FIR (Finite Impulse Response) low-pass filter given by

$$h_{12.8}(n) = \begin{cases} \text{tab\_resamp\_filter}[n + 119] & \text{, if} -120 < n < 120 \\ 0 & \text{, otherwise} \end{cases} \tag{79}$$

with the table tab_resamp_filter values provided in Section 3.7.6 and the length of the resampled signal defined as:

$$len_{12.8} = \frac{N_{ms} \cdot 128}{10} \tag{80}$$

$$len_{6.4} = \frac{len_{12.8}}{2} \tag{81}$$

and

$$res_{fac} = \begin{cases} 0.5 & \text{, if } f_s == 8\ kHz \\ 1 & \text{, otherwise} \end{cases} \tag{82}$$

3.3.9.4 High-pass filtering

The resampled signal shall be high-pass filtered using a 2-order IIR (Infinite Impulse Response) filter with a cut-off frequency of 50 Hz and a transfer function given by

$$H_{50}(z) = \frac{0.9827947082978771 - 1.965589416595754z^{-1} + 0.9827947082978771z^{-2}}{1 - 1.9652933726226904z^{-1} + 0.9658854605688177z^{-2}} \tag{83}$$

The high-pass filtered signal is denoted as $\tilde{x}_{12.8}(n)$ in the following. The high-pass filtered signal shall be further delayed by D_{LTPF} samples:

$$\tilde{x}_{12.8\_D}(n) = \tilde{x}_{12.8}(n - D_{LTPF}) \quad for\ \ n = 0 \ldots len_{12.8} + 1\,, \tag{84}$$

where a negative index of $\tilde{x}_{12.8}$ means that the sample has been taken from the previous processed frame (the last D_{LTPF} values of the previously processed frame). $D_{LTPF} = 24$ samples for $N_{ms} = 10$ ms and $D_{LTPF} = 44$ samples for $N_{ms} = 7.5$ ms. At start-up, these values shall be set to zero.

Note: Only 129 out of 130 values of $\tilde{x}_{12.8\_D}$ are provided as intermediate values because the last (130th) value is multiplied with zero in the further processing (Equation 104).

3.3.9.5 Pitch detection algorithm

The delayed 12.8 kHz signal $\tilde{x}_{12.8\_D}(n)$ shall be downsampled by a factor of 2 to 6.4 kHz using:

$$x_{6.4}(n) = \sum_{k=0}^{4} \tilde{x}_{12.8\_D}(2 \cdot n + k - 3) \cdot h_2(k)\ ,\ \ for\ \ n = 0 \ldots len_{6.4} - 1 \tag{85}$$

with the FIR filter coefficients given by

```
h2[5]  = {
0.1236796411180537, 0.2353512128364889, 0.2819382920909148,
0.2353512128364889, 0.1236796411180537}
```

A two stage downsampler is used here because the 12.8 kHz downsampled signal $\tilde{x}_{12.8\_D}(n)$ is used in Equation 97 to calculate the pitch-lag.

The autocorrelation of $x_{6.4}(n)$ shall be computed by

$$R_{6.4}(k) = \sum_{n=0}^{len_{6.4}-1} x_{6.4}(n) \cdot x_{6.4}(n-k)\,,\ \ for\ \ k = k_{min} \ldots k_{max} \tag{86}$$

with $k_{min} = 17$ and $k_{max} = 114$ as the minimum and maximum lags. A negative index of $x_{6.4}$ means that the sample has been taken from the previous processed frame. At start-up, these values shall be set to zero.

The autocorrelation shall be weighted using

$$R_{6.4}^{w}(k) = R_{6.4}(k) \cdot w(k)\,, \qquad for\ \ k = k_{min} \ldots k_{max}\,, \tag{87}$$

where $w(k)$ is defined as follows

$$w(k) = 1 - 0.5 \cdot \frac{(k - k_{min})}{(k_{max} - k_{min})}\ , \qquad for\ \ k = k_{min} \ldots k_{max}\,. \tag{88}$$

The first estimate of the pitch-lag T_1 shall be the lag that maximizes the weighted autocorrelation

$$T_1 = \underset{k=k_{min} \ldots k_{max}}{\operatorname{argmax}} R_{6.4}^{w}(k)\ . \tag{89}$$

The second estimate of the pitch-lag T_2 shall be the lag that maximizes the non-weighted autocorrelation in the neighborhood of the pitch-lag estimated in the previous frame

$$T_2 = \underset{k=k'_{min}\dots k'_{max}}{\operatorname{argmax}} R_{6.4}(k) \tag{90}$$

with $k'_{min} = \max(k_{min}, T_{prev} - 4)$, $k'_{max} = \min(k_{max}, T_{prev} + 4)$ and T_{prev} is the final pitch-lag estimated in the previous frame ($T_{prev} = k_{min}$ in the first frame). If more than one lag maximizes the (non-weighted) autocorrelation, the smallest lag shall be chosen.

The final estimate of the pitch-lag in the current frame is then given by

$$T_{curr} = \begin{cases} T_1 & \text{if } \operatorname{normcorr}(x_{6.4}, corr_{len}, T_2) \leq 0.85 \cdot \operatorname{normcorr}(x_{6.4}, corr_{len}, T_1) \\ T_2 & \text{otherwise} \end{cases} \tag{91}$$

where $\operatorname{normcorr}(x, L, T)$ is the normalized correlation of the signal x of length L at lag T

$$\operatorname{normcorr}(x, L, T) = max\left(0, \frac{\sum_{n=0}^{L-1} x(n) \cdot x(n-T)}{\sqrt{\sum_{n=0}^{L-1} x^2(n) \cdot \sum_{n=0}^{L-1} x^2(n-T)}}\right). \tag{92}$$

and

$$corr_{len} = \begin{cases} 64, & N_{ms} = 10 \\ 48, & N_{ms} = 7.5 \end{cases} \tag{93}$$

A negative index of x means that the sample has been taken from the previous processed frame. At start-up, these values shall be set to zero.

3.3.9.6 LTPF Bitstream

The first bit of the LTPF bitstream signals the presence of the pitch-lag parameter in the bitstream. It shall be obtained by

$$\text{pitch\_present} = \begin{cases} 1 & \text{if } \operatorname{normcorr}(x_{6.4}, corr_{len}, T_{curr}) > 0.6 \\ 0 & \text{otherwise} \end{cases}. \tag{94}$$

If pitch_present is 0, no more bits shall be encoded, resulting in an LTPF bitstream of only one bit.

If pitch_present is 1, two more parameters shall be encoded, one pitch-lag parameter encoded using 9 bits, and one bit to signal the activation of LTPF. In that case, the LTPF bitstream is composed of 11 bits.

$$nbits_{LTPF} = \begin{cases} 1 & , if \ \text{pitch\_present} = 0 \\ 11 & , otherwise \end{cases}. \tag{95}$$

The pitch-lag parameter and the activation bit shall be obtained as described in Sections 3.3.9.7 and 3.3.9.8.

3.3.9.7 LTPF pitch-lag parameter

The integer part of the LTPF pitch-lag parameter shall be

$$\text{pitch\_int} = \underset{k=k''_{min}\dots k''_{max}}{\operatorname{argmax}} R_{12.8}(k) \tag{96}$$

with

$$R_{12.8}(k) = \sum_{n=0}^{len_{12.8}-1} \tilde{x}_{12.8\_D}(n) \cdot \tilde{x}_{12.8\_D}(n-k)\,, \;\; for\ k = (k''_{min} - 4) \ \dots (k''_{max} + 4) \qquad (97)$$

and $k''_{min} = \max(32, 2T_{curr} - 4)$, $k''_{max} = \min(228, 2T_{curr} + 4)$.

A negative index of $\tilde{x}_{12.8\_D}$ means that the sample has been taken from the previous processed frame. At start-up, these values shall be set to zero.

The fractional part of the LTPF pitch-lag shall be

$$\text{pitch\_fr} = \begin{cases} 0 & \text{if pitch\_int} \geq 157 \\ \underset{d=-2,0,2}{\text{argmax}}\, interp(d) & \text{if } 157 > \text{pitch\_int} \geq 127 \\ \underset{d=-3\dots3}{\text{argmax}}\, interp(d) & \text{if } 127 > \text{pitch\_int} > 32 \\ \underset{d=0\dots3}{\text{argmax}}\, interp(d) & \text{if pitch\_int} = 32 \end{cases} \qquad (98)$$

with

$$interp(d) = \sum_{m=-4}^{4} R_{12.8}(\text{pitch\_int} + m) \cdot h_4(4m - d) \qquad (99)$$

and h_4 is the impulse response of a FIR low-pass filter given by

$$h_4(n) = \begin{cases} \text{tab\_ltpf\_interp\_R}(n + 15) & \text{, if } -16 < n < 16 \\ 0 & \text{, otherwise} \end{cases} \qquad (100)$$

with tab_ltpf_interp_R provided by the table in Section 3.7.6.

If $\text{pitch\_fr} < 0$ then both pitch_int and pitch_fr shall be modified according to

$$\begin{aligned} \text{pitch\_int} &\leftarrow \text{pitch\_int} - 1 \\ \text{pitch\_fr} &\leftarrow \text{pitch\_fr} + 4 \end{aligned} . \qquad (101)$$

Finally, the pitch-lag parameter index that is later written to the output bitstream shall be

$$\text{pitch\_index} = \begin{cases} \text{pitch\_int} + 283 & \text{if pitch\_int} \geq 157 \\ 2 \cdot \text{pitch\_int} + floor\left(\frac{\text{pitch\_fr}}{2}\right) + 126 & \text{if } 157 > \text{pitch\_int} \geq 127 \\ 4 \cdot \text{pitch\_int} + \text{pitch\_fr} - 128 & \text{if } 127 > \text{pitch\_int} \end{cases} . \qquad (102)$$

3.3.9.8 LTPF activation bit

A normalized correlation shall first be computed as

$$nc = \frac{\sum_{n=0}^{len_{12.8}-1} x_i(n, 0) \cdot x_i(n - \text{pitch\_int,pitch\_fr})}{\sqrt{\sum_{n=0}^{len_{12.8}-1} {x_i}^2(n, 0) \cdot \sum_{n=0}^{len_{12.8}-1} {x_i}^2(n - \text{pitch\_int,pitch\_fr})}} \qquad (103)$$

with

$$x_i(n, d) = \sum_{k=-2}^{2} \tilde{x}_{12.8\_D}(n - k) \cdot h_i(4k - d) \qquad (104)$$

and h_i is the impulse response of a FIR low-pass filter given by

$$h_i(n) = \begin{cases} \text{tab\_ltpf\_interp\_x12k8}(n+7) & \text{, if } -8 < n < 8 \\ 0 & \text{, otherwise} \end{cases} \tag{105}$$

where tab_ltpf_interp_x12k8 is given in Section 3.7.6.

The LTPF activation bit shall then be set according to

```
if (gain_ltpf != 0)
{
    if (
        (mem_ltpf_active==0 && (Nms == 10 || mem_mem_nc > 0.94) && mem_nc>0.94
&& nc>0.94) ||
     (mem_ltpf_active==1 && nc>0.9) ||
     (mem_ltpf_active==1 && abs(pitch-mem_pitch)<2 && (nc-mem_nc)>-0.1 &&
nc>0.84)
   )
    {
        ltpf_active = 1;
    }
    else
    {
        ltpf_active = 0;
    }
} else
{
    ltpf_active = 0;

}
```

where mem_ltpf_active is the value of ltpf_active in the previous frame (it is 0 if pitch_present=0 in the previous frame), mem_nc is the value of nc in the previous frame (it is 0 if pitch_present=0 in the previous frame), mem_mem_nc is the value of nc in the penultimate frame, pitch=pitch_int+pitch_fr/4, mem_pitch is the value of pitch in the previous frame (it is 0 if pitch_present=0 in the previous frame), and gain_ltpf is a global parameter of the LTPF obtained in Section 3.4.9.4.

The LTPF shall be disabled for signals with a comparatively high energy in the range close to the Nyquist frequency; therefore, the value of ltpf_active is set to 0 if the near_nyquist_flag in Section 3.3.4.5 is 1.

3.3.10 Spectral quantization

The MDCT spectrum after TNS filtering ($X_f(n)$, see Section 3.3.8.4) is quantized using dead-zone plus uniform threshold scalar quantization and the quantized MDCT spectrum $X_q(n)$ is then encoded using arithmetic encoding. A global gain gg controls the step size of the quantizer. This global gain is quantized with 8 bits and the quantized global gain index gg_{ind} is then an integer between 0 and 255. The global gain index is chosen such that the number of bits needed to encode the quantized MDCT spectrum is as close as possible to the available bit budget.

3.3.10.1 Bit budget

The number of bits available for coding the spectrum shall be

$$nbits_{spec} = nbits - nbits_{bw} - nbits_{TNS} - nbits_{LTPF} - nbits_{SNS} - nbits_{gain} - nbits_{nf} - nbits_{ari} \tag{106}$$

with $nbits$ given in Section 3.2.5, $nbits_{bw}$ given in Section 3.3.5, $nbits_{TNS}$ given in Section 3.3.8.3, $nbits_{LTPF}$ given in Section 3.3.9.6, $nbits_{SNS} = 38$, $nbits_{gain} = 8$, $nbits_{nf} = 3$ and

$$nbits_{ari} = \begin{cases} \left\lceil \log_2 \left(\frac{N_E}{2} \right) \right\rceil + 3 & \text{, if } nbits \le 1{,}280 \\ \left\lceil \log_2 \left(\frac{N_E}{2} \right) \right\rceil + 4 & \text{, if } 1{,}280 < nbits \le 2{,}560 \\ \left\lceil \log_2 \left(\frac{N_E}{2} \right) \right\rceil + 5 & \text{, otherwise} \end{cases} \tag{107}$$

3.3.10.2 First global gain estimation

An offset shall first be computed using

$$nbits_{offset} = \begin{cases} 0.8 \cdot nbits_{offset}^{old} + 0.2 \cdot \min\left(40, \max\left(-40, nbits_{offset}^{old} + nbits_{spec}^{old} - nbits_{est}^{old}\right)\right) & \text{, if } reset_{offset}^{old} = 0 \\ 0 & \text{, otherwise} \end{cases} \tag{108}$$

where $nbits_{offset}^{old}$ is the value of $nbits_{offset}$ in the previous frame, $nbits_{spec}^{old}$ is the value of $nbits_{spec}$ in the previous frame, $nbits_{est}^{old}$ is the value of $nbits_{est}$ in the previous frame ($nbits_{est}$ is computed in Section 3.3.10.4), and $reset_{offset}^{old}$ is the value of $reset_{offset}$ in the previous frame ($reset_{offset}$ is computed at the end of this section).

$nbits_{offset}^{old}$, $nbits_{spec}^{old}$, $nbits_{est}^{old}$ and $reset_{offset}^{old}$ shall be initialized to zero before the first frame is processed. If the spectrum was re-quantized in the previous frame, $nbits_{est}^{old}$ shall be set to the value prior to re-quantization.

This offset shall then be used to adjust the number of bits available for coding the spectrum

$$nbits'_{spec} = \mathrm{nint}\left(nbits_{spec} + nbits_{offset}\right) \tag{109}$$

A global gain index is then estimated such that the number of bits needed to encode the quantized MDCT spectrum is as close as possible to the available bit budget. This estimation is based on a low-complexity bisection search that roughly approximates the number of bits needed to encode the quantized spectrum. The following algorithm shall be used:

Compute the quantized gain index offset gg_{off} by

$$gg_{off} = -\min\left(115, \left\lfloor \frac{nbits}{10 \cdot (f_s^{ind} + 1)} \right\rfloor\right) - 105 - 5 \cdot (f_s^{ind} + 1) \tag{110}$$

and the energy E[k] (in dB) of blocks of 4 MDCT coefficients given by

$$E(k) = 10 * \log_{10}\left(2^{-31} + \sum_{n=0}^{3} X_f(4 \cdot k + n)^2\right), \quad for \quad k = 0 \ldots \frac{N_E}{4} - 1\,. \tag{111}$$

Note: The value of 2^{-31} in the calculation of the energies E[k] is added to prevent taking the logarithm of zero which is undefined.

Then conduct the following steps:

```
fac = 256;
gg_ind = 255;
for (iter = 0; iter < 8; iter++)
{
   fac >>= 1;
   gg_ind -= fac;
   tmp = 0;
   iszero = 1;
   for (i = N_E/4-1; i >= 0; i--)
   {
      if (E[i]*28/20 < (gg_ind+gg_off))
      {
         if (iszero == 0)
         {
            tmp += 2.7*28/20;
         }
      }
      else
      {
         if ((gg_ind+gg_off) < E[i]*28/20 - 43*28/20)
         {
            tmp += 2*E[i]*28/20 – 2*(gg_ind+gg_off) - 36*28/20;
         }
         else
         {
            tmp += E[i]*28/20 – (gg_ind+gg_off) + 7*28/20;
         }
         iszero = 0;
      }
   }
   if (tmp > nbits'_spec*1.4*28/20 && iszero == 0)
   {
      gg_ind += fac;
   }
}
```

Finally, the quantized gain index shall be limited such that the quantized spectrum stays within the range [-32,768, 32,767]

```
if (gg_ind < gg_min || X_f^max == 0)
{
   gg_ind = gg_min;
   reset_offset = 1;
}
else
{
   reset_offset = 0;
}
```

with

$$gg_{min} = \begin{cases} \left\lceil 28 * \log 10 \left(10^{-31} + \frac{X_f^{max}}{32{,}768 - 0.375} \right) \right\rceil - gg_{off} & \text{, if } X_f^{max} > 0 \\ 0 & \text{, otherwise} \end{cases} \tag{112}$$

and

$$X_f^{max} = \max_{0 \le n < N_E} |X_f(n)| \tag{113}$$

3.3.10.3 Quantization

The quantized global gain index found in Section 3.3.10.2 shall first be unquantized using

$$gg = 10^{\frac{gg_{ind}+gg_{off}}{28}} \tag{114}$$

The spectrum $X_f(n)$ (computed in Section 3.3.8.4) shall then be quantized using

$$X_q(n) = \begin{cases} \left\lfloor \frac{X_f(n)}{gg} + 0.375 \right\rfloor & \text{, if } X_f(n) \ge 0 \\ \left\lceil \frac{X_f(n)}{gg} - 0.375 \right\rceil & \text{, otherwise} \end{cases} \quad , \quad for \quad n = 0 \ldots N_E - 1 \, . \tag{115}$$

3.3.10.4 Bit consumption

The number of bits $nbits_{est}$ needed to encode the quantized MDCT spectrum $X_q(n)$ shall be estimated using the algorithm below.

Two bitrate flags shall be computed using

```
if (nbits > (160 + f_s^ind * 160))
{
   rateFlag = 512;
}
else
{
   rateFlag = 0;
}
if (nbits >= (480 + f_s^ind * 160))
{
   modeFlag = 1;
}
else
{
   modeFlag = 0;
}
```

Then the index of the last non-zeroed 2-tuple shall be obtained by

```
lastnz = N_E;
while (lastnz>2 && X_q[lastnz-1] == 0 && X_q[lastnz-2] == 0)
{
   lastnz -= 2;
}
```

The number of bits $nbits_{est}$ shall then be computed as follows

```
nbits_est = 0;
nbits_trunc = 0;
```

```
nbits_lsb = 0;
lastnz_trunc = 2;
c = 0;
for (n = 0; n < lastnz; n=n+2)
{
   t = c + rateFlag;
   if (n > N_E/2)
   {
      t += 256;
   }
   a = abs(X_q[n]);
   b = abs(X_q[n+1]);
   lev = 0;
   while (max(a,b) >= 4)
   {
      pki = ac_spec_lookup[t+lev*1024];
      nbits_est += ac_spec_bits[pki][16];
      if (lev == 0 && modeFlag == 1)
      {
         nbits_lsb += 2;
      }
      else
      {
         nbits_est += 2*2048;
      }
      a >>= 1;
      b >>= 1;
      lev = min(lev+1,3);
   }
   pki = ac_spec_lookup[t+lev*1024];
   sym = a + 4*b;
   nbits_est += ac_spec_bits[pki][sym];
   a_lsb = abs(X_q[n]);
   b_lsb = abs(X_q[n+1]);
   nbits_est += (min(a_lsb,1) + min(b_lsb,1)) * 2048;
   if (lev > 0 && modeFlag == 1)
   {
      a_lsb >>= 1;
      b_lsb >>= 1;
      if (a_lsb == 0 && X_q[n] != 0)
      {
         nbits_lsb++;
      }
      if (b_lsb == 0 && X_q[n+1] != 0)
      {
         nbits_lsb++;
      }
   }

   if ((X_q[n] != 0 || X_q[n+1] != 0) && (nbits_est <= nbits_spec*2048))
   {
      lastnz_trunc = n + 2;
      nbits_trunc = nbits_est;
   }
   if (lev <= 1)
```

```
    {
        t = 1 + (a+b)*(lev+1);
    }
    else
    {
        t = 12 + lev;
    }
    c = (c&15)*16 + t;
}
nbits_est = ceil(nbits_est/2048) + nbits_lsb;
nbits_trunc = ceil(nbits_trunc/2048);
```

with ac_lookup and ac_bits determined by the tables in Section 3.7.7.

3.3.10.5 Truncation

The quantized spectrum X_q[k] shall be truncated such that the number of bits needed to encode it is within the available bit budget.

```
for (k = lastnz_trunc; k < lastnz; k++)
{
    X_q[k] = 0;
}
```

with lastnz and lastnz_trunc given in Section 3.3.10.4.

A flag that allows the truncation of the LSBs in the arithmetic encoding/decoding shall be obtained using

```
if (modeFlag == 1 && nbits_est > nbits_spec)
{
    lsbMode = 1;
}
else
{
    lsbMode = 0;
}
```

3.3.10.6 Global gain adjustment

The number of bits $nbits_{est}$ (computed in Section 3.3.10.4) shall be compared with the available bit budget $nbits_{spec}$ (computed in Section 3.3.10.1). If they are far from each other (as defined by the conditions given below), then the quantized global gain index gg_{ind} shall be adjusted and the spectrum shall be requantized using Sections 3.3.10.3, 3.3.10.4 and 3.3.10.5. The algorithm used to adjust the quantized global gain index gg_{ind} is given below. The global gain adjustment process should not be run more than one time for each processed frame. The value of $nbits_{est}^{old}$ shall not be updated if requantization is carried out.

```
if ((gg_ind < 255 && nbits_est > nbits_spec) ||
     (gg_ind > 0 && nbits_est < nbits_spec – delta2))
{
    if (nbits_est < nbits_spec – delta2)
    {
        gg_ind -= 1;
    }
```

```
    else if (gg_ind == 254 || nbits_est < nbits_spec + delta)
    {
        gg_ind += 1;
    }
    else
    {
        gg_ind += 2;
    }
    gg_ind = max(gg_ind, gg_min);
}
```

where the delta values shall be obtained using

```
if (nbits_est < t1[fs_ind])
{
    delta = (nbits_est+48)/16;
}
else if (nbits_est < t2[fs_ind])
{
    tmp1 = t1[fs_ind]/16+3;
    tmp2 = t2[fs_ind]/48;
    delta = (nbits_est-t1[fs_ind])*(tmp2-tmp1)/(t2[fs_ind]-t1[fs_ind]) + tmp1;
}
else if (nbits_est < t3[fs_ind])
{
    delta = nbits_est/48;
}
else
{
    delta = t3[fs_ind]/48;
}
delta = nint(delta);
delta2 = delta + 2;
```

and the three tables t1, t2 and t3 below:

```
t1[5] = {80, 230, 380, 530, 680};
t2[5] = {500, 1025, 1550, 2075, 2600};
t3[5] = {850, 1700, 2550, 3400, 4250};
```

3.3.11 Residual coding

Residual coding uses the remaining non-used bits to refine the non-zero quantized coefficients. It shall be performed only when `lsbMode` is 0.

First, the maximum number of bits available for residual coding shall be calculated using

```
nbits_residual_max = nbits_spec - nbits_trunc + 4;
```

Then, the residual bits shall be computed using

```
k = 0;
nbits_residual = 0;
while (k < N_E && nbits_residual < nbits_residual_max)
```

```
{
   if (X_q[k]!= 0)
   {
      if (X_f[k] >= X_q[k]*gg)
      {
         res_bits[nbits_residual] = 1;
      }
      else
      {
         res_bits[nbits_residual] = 0;
      }
      nbits_residual++;
   }
   k++;
}
```

3.3.12 Noise level estimation

The noise level estimator controls the noise filling in the decoder. In the encoder, the noise level parameter is estimated, quantized, and transmitted in the bitstream.

3.3.12.1 Relevant spectral lines

The noise level shall be estimated based on the spectral coefficients that have been quantized to zero, i.e., $X_q(k) == 0$. The indices for the relevant spectral coefficients shall be given by

$$I_{NF}(k) = \begin{cases} 1 & \text{if } NF_{start} \le k < bw_{stop} \; and \; X_q(i) == 0 \; for \; all \; i = k - NF_{width} \ldots \min\left(bw_{stop} - 1, k + NF_{width}\right) \\ 0 & \text{otherwise} \end{cases} \quad (116)$$

where bw_stop depends on the bandwidth detected by the bandwidth detector (see Section 3.3.5), as defined in Table 3.16,

	Bandwidth(P_{bw})				
	NB	WB	SSWB	SWB	FB
bw_stop	$80 \cdot \frac{N_{ms}}{10}$	$160 \cdot \frac{N_{ms}}{10}$	$240 \cdot \frac{N_{ms}}{10}$	$320 \cdot \frac{N_{ms}}{10}$	$400 \cdot \frac{N_{ms}}{10}$

Table 3.16: Mapping table bw_stop according to bandwidth

and the tuning parameters NF_{start} and NF_{width} are given in Table 3.17.

N_{ms}	NF_{start}	NF_{width}
$10\ ms$	24	3
$7.50\ ms$	18	2

Table 3.17: Tuning parameters NF_{start} and NF_{width}

3.3.12.2 Noise level calculation

For the identified indices, the mean level of the missing coefficients shall be estimated based on the spectrum after TNS filtering ($X_f(k)$, see Section 3.3.8.4) and normalized by the global gain.

$$L_{NF} = \frac{\sum_{k=0}^{N_E-1} I_{NF}(k) \cdot \frac{|X_f(k)|}{gg}}{\sum_{k=0}^{N_E-1} I_{NF}(k)} \quad , \tag{117}$$

where N_E is defined in Section 3.3.4.3. The final noise level shall be quantized to eight steps:

$$F_{NF} = min(max(\lfloor 8 - 16 \cdot L_{NF} \rfloor, 0), 7) \tag{118}$$

3.3.13 Bitstream encoding

3.3.13.1 Overview

The bitstream of an encoded audio frame consists of four parts:

- Initial side information (Sections 3.3.13.2 and 3.3.13.3)
- A dynamic data block that is arithmetically coded (Section 3.3.13.4.2)
- A dynamic data block with signs and least significant bits of the encoded spectrum
- Residual data

An overview of the bitstream structure and layout is provided in Section 3.5. The remainder of this section (Sections 3.3.13.2 to 3.3.13.6) defines the exact payload writing process for all codec elements.

3.3.13.2 Initialization

```
bp = 0;
bp_side = nbytes - 1;
mask_side = 1;
c = 0;
nlsbs = 0;
```

3.3.13.3 Side information

```
/* Bandwidth */
if (nbits_bw > 0)
{
   write_uint_backward(bytes, &bp_side, &mask_side, P_bw, nbits_bw);
}

/* Last non-zero tuple */
write_uint_backward(bytes, &bp_side, &mask_side, (lastnz_trunc >> 1) - 1,
ceil(log2(N_E/2)));
/* LSB mode bit */
write_bit_backward(bytes, &bp_side, &mask_side, lsbMode);

/* Global Gain */
write_uint_backward(bytes, &bp_side, &mask_side, gg_ind, 8);

/* TNS activation flag */
for (f = 0; f < num_tns_filters; f++)
{
   write_bit_backward(bytes, &bp_side, &mask_side, min(rc_order(f), 1));
```

```
}

/* Pitch present flag */
write_bit_backward(bytes, &bp_side, &mask_side, pitch_present);

/* Encode SCF VQ parameters - 1st stage (10 bits) */
write_uint_backward(bytes , &bp_side, &mask_side, ind_LF, 5);
write_uint_backward(bytes, &bp_side, &mask_side, ind_HF, 5);

/* Encode SCF VQ parameters - 2nd stage side-info (3-4 bits) */
write_bit_backward(bytes, &bp_side, &mask_side, shape_j>>1 )
submode_LSB = (shape_j & 0x1); /* shape_j is the stage2 shape_index [0…3] */
submode_MSB = (shape_j>>1);
gain_MSBs   = gain_i;     /* where gain_i is the SNS-VQ stage 2 gain_index */

gain_MSBs   = (gain_MSBs >> sns_gainLSBbits[shape_j]);
write_uint_backward(bytes,&bp_side,&mask_side,gain_MSBs,
sns_gainMSBbits[shape_j]);
write_bit_backward(bytes, &bp_side, &mask_side, LS_indA);

/* Encode SCF VQ parameters - 2nd stage MPVQ data   */
if (submode_MSB == 0) {
   if (submode_LSB == 0) {
      tmp =  index_joint_0;  /*  Eq. 58 */
   } else {
      tmp =  index_joint_1;  /*  Eq. 59 */
   }
   write_uint_backward(bytes, &bp_side, &mask_side, tmp, 13)
   write_uint_backward(bytes, &bp_side, &mask_side, tmp>>13, 12);
} else {
   if (submode_LSB == 0) {
       tmp = index_joint_2;     /* Eq. 60 */
    } else {
       tmp = index_joint_3;     /* Eq. 61 */
    }
    write_uint_backward(bytes, &bp_side, &mask_side, tmp, 12);
    write_uint_backward(bytes, &bp_side, &mask_side, tmp>> 12, 12);
}

/* LTPF data */
if (pitch_present != 0)
{
   write_uint_backward(bytes, &bp_side, &mask_side, ltpf_active, 1);
   write_uint_backward(bytes, &bp_side, &mask_side, pitch_index, 9);
}

/* Noise Factor */
write_uint_backward(bytes, &bp_side, &mask_side, F_NF, 3); /* Section 3.3.12.2
*/
```

3.3.13.4 Arithmetic encoding

3.3.13.4.1 Overview

The TNS data (if TNS is active) and the quantized spectral coefficients X_q are noiselessly encoded. X_q is encoded starting from the lowest-frequency coefficient, progressing to the highest-frequency coefficient. They are encoded by groups of two coefficients a and b resulting in a 2-tuple {a,b}.

Each frequency coefficient 2-tuple {a,b} is split into three parts: MSB, LSB, and the sign. The sign is coded independently from the magnitude using uniform probability distribution and a and b may have different signs. Signs are only coded for non-zero values of a and b. The magnitude itself is further divided into two parts. The two most significant bits (MSBs) of the 2-tuple {a,b} are combined and coded with an arithmetic encoder, and the remaining least significant bitplanes (LSBs, if applicable) are encoded individually using uniform probability distribution. For 2-tuples for which the magnitude of one of the two spectral coefficients is higher than 3, one or more escape symbols are transmitted first for signaling any additional bitplane.

The relation between a 2-tuple, the individual spectral values *a* and *b* of a 2-tuple, the most significant bitplanes *m* and the remaining least significant bitplanes *r,* are illustrated in the example in Figure 3.8. In this example three escape symbols are sent before the actual value m, indicating three transmitted least significant bitplanes.

Note: `lsbMode==1` is a special case used for high-bitrate modes where the first bitplane (lev=0) is encoded separately as residual bits.

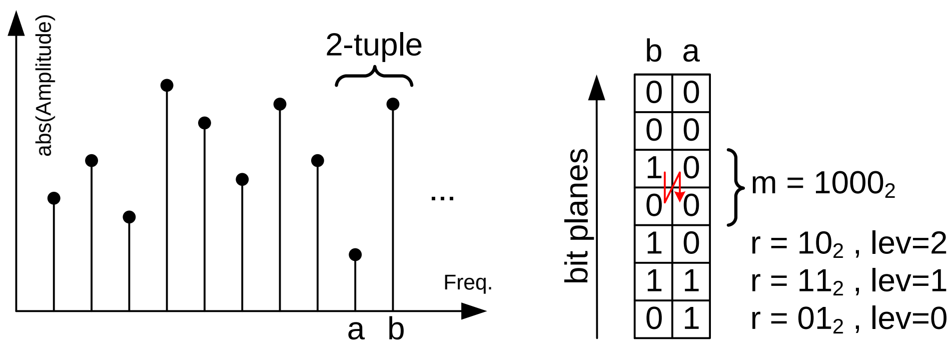

Figure 3.8: Example of a coded pair (2-tuple) of spectral values a and b and their representation as m and r

3.3.13.4.2 Pseudocode implementation

```
/* Arithmetic Encoder Initialization */
ac_enc_init(&st);

c = 0;

/* TNS data */
for (f = 0; f < num_tns_filters; f++)
{
   if (rc_order(f) > 0)
   {
      ac_encode(bytes, &bp, &st,
                ac_tns_order_cumfreq[tns_lpc_weighting][rc_order(f)-1],
                ac_tns_order_freq[tns_lpc_weighting][rc_order(f)-1]);
      for (k = 0; k < rc_order(f); k++)
      {
         ac_encode(bytes, &bp, &st, ac_tns_coef_cumfreq[k][rc_i(k,f)],
                   ac_tns_coef_freq[k][rc_i(k,f)]);
      }
   }
}
```

```
/* Spectral data */
for (k = 0; k < lastnz_trunc; k += 2)
{
   t = c + rateFlag;
   if (k > N_E/2)
   {
      t += 256;
   }
   a = abs(X_q[k]);
   b = abs(X_q[k+1]);
   lev = 0;
   while (max(a,b) >= 4)
   {
      pki = ac_spec_lookup[t+min(lev,3)*1024];
      ac_encode(bytes, &bp, &st, ac_spec_cumfreq[pki][16],
                ac_spec_freq[pki][16]);
      if (lsbMode == 1 && lev == 0)
      {
         lsb0 = a & 1;
         lsb1 = b & 1;
      }
      else
      {
         write_bit_backward(bytes, &bp_side, &mask_side, a & 1);
         write_bit_backward(bytes, &bp_side, &mask_side, b & 1);
      }
      a >>= 1;
      b >>= 1;
      lev++;
   }
   pki = ac_spec_lookup[t+min(lev,3)*1024];
   sym = a + 4*b;
   ac_encode(bytes, &bp, &st, ac_spec_cumfreq[pki][sym],
ac_spec_freq[pki][sym]);
   a_lsb = abs(X_q[k]);
   b_lsb = abs(X_q[k+1]);
   if (lsbMode == 1 && lev > 0)
   {
      a_lsb >>= 1;
      b_lsb >>= 1;
      lsbs[nlsbs++] = lsb0;
      if (a_lsb == 0 && X_q[k] != 0)
      {
         lsbs[nlsbs++] = X_q[k]>0?0:1;
      }
      lsbs[nlsbs++] = lsb1;
      if (b_lsb == 0 && X_q[k+1] != 0)
      {
         lsbs[nlsbs++] = X_q[k+1]>0?0:1;
      }
   }
   if (a_lsb > 0)
   {
      write_bit_backward(bytes, &bp_side, &mask_side, X_q[k]>0?0:1);
```

```
    }
    if (b_lsb > 0)
    {
       write_bit_backward(bytes, &bp_side, &mask_side, Xq[k+1]>0?0:1);
    }
    lev = min(lev,3);
    if (lev <= 1)
    {
       t = 1 + (a+b)*(lev+1);
    }
    else
    {
       t = 12 + lev;
    }
    c = (c&15)*16 + t;
}
```

3.3.13.5 Residual data and finalization

```
/* Residual bits */
nbits_side = nbits - (8 * bp_side + 8 - log2(mask_side));
nbits_ari = bp * 8;
nbits_ari += 25 - floor(log2(st->range));
if (st->cache >= 0)
{
   nbits_ari += 8;
}
if (st->carry_count > 0)
{
   nbits_ari += st->carry_count * 8;
}
nbits_residual_enc = nbits - (nbits_side + nbits_ari);
if (lsbMode == 0)
{
   nbits_residual_enc = min(nbits_residual_enc, nbits_residual);
   for (k = 0; k < nbits_residual_enc; k++)
   {
      write_bit_backward(bytes, &bp_side, &mask_side, res_bits[k]);
   }
}
else
{
   nbits_residual_enc = min(nbits_residual_enc, nlsbs);
   for (k = 0; k < nbits_residual_enc; k++)
   {
      write_bit_backward(bytes, &bp_side, &mask_side, lsbs[k]);
   }
}

/* Arithmetic Encoder Finalization */
ac_enc_finish(bytes, &bp, &st);
```

where res_bits and nbits_residual are given in Section 3.3.11.

3.3.13.6 Functions

```
write_bit_backward(bytes[], *bp, *mask, bit)
{
    if (bit == 0)
    {
      bytes[*bp] &= ~*mask;
    }
    else
    {
      bytes[*bp] |= *mask;
    }
    if (*mask == 0x80)
    {
      *mask = 1;
      *bp -= 1;
    }
    else
    {
      *mask <<= 1;
    }
}

write_uint_backward(bytes[], *bp, *mask, val, numbits)
{
    for (k = 0; k < numbits; k++)
    {
        bit = val & 1;
        write_bit_backward(bytes, bp, mask, bit);
        val >>= 1;
    }
}

write_uint_forward(bytes[], bp, val, numbits)
{
    mask = 0x80;
    for (k = 0; k < numbits; k++)
    {
        bit = val & mask;
        if (bit == 0)
        {
          bytes[bp] &= ~mask;
        }
        else
        {
          bytes[bp] |= mask;
        }
        mask >>= 1;
    }
}

ac_enc_init(*st)
{
   st->low = 0;
```

```
    st->range = 0x00ffffff;
    st->cache = -1;
    st->carry = 0;
    st->carry_count = 0;
}

ac_shift(bytes[], *bp, *st)
{
    if (st->low < 0x00ff0000 || st->carry == 1)
    {
        if (st->cache >= 0)
        {
            bytes[(*bp)++] = st->cache + st->carry;
        }
        while (st->carry_count > 0)
        {
            bytes[(*bp)++] = (st->carry + 0xff) & 0xff;
            st->carry_count -=  1;
        }
        st->cache = st->low >> 16;
        st->carry = 0;
    }
    else
    {
        st->carry_count += 1;
    }
    st->low <<= 8;
    st->low &= 0x00ffffff;
}

ac_encode(bytes[], *bp, *st, cum_freq, sym_freq)
{
    r = st->range >> 10;
    st->low += r * cum_freq;
    if ((st->low >> 24) != 0)
    {
        st->carry = 1;
    }
    st->low &= 0x00ffffff;
    st->range = r * sym_freq;
    while (st->range < 0x10000)
    {
        st->range <<= 8;
        ac_shift(bytes, bp, st);
    }
}

ac_enc_finish(bytes[], *bp, *st)
{
    bits = 1;
    while ((st->range >> (24-bits)) == 0)
    {
      bits++;
    }
    mask = 0x00ffffff >> bits;
    val  = st->low + mask;
```

```
    over1 = val >> 24;
    val &= 0x00ffffff;
    high = st->low + st->range;
    over2 = high >> 24;
    high &= 0x00ffffff;
    val = val & ~mask;
    if (over1 == over2)
    {
        if (val + mask >= high)
        {
            bits += 1;
            mask >>= 1;
            val  = ((st->low + mask) & 0x00ffffff) & ~mask;
        }
        if (val < st->low)
        {
            st->carry = 1;
        }
    }
    st->low = val;
    for (; bits > 0; bits -= 8)
    {
        ac_shift(bytes, bp, st);
    }
    bits += 8;
    if (st->carry_count > 0)
    {
        bytes[(*bp)++] = st->cache;
        for (; st->carry_count > 1; st->carry_count--)
        {
            bytes[(*bp)++] = 0xff;
        }
        write_uint_forward(bytes, *bp, 0xff>>(8-bits), bits);
    }
    else
    {
        write_uint_forward(bytes, *bp, st->cache, bits);
    }
}
```

3.4 Decoding process

3.4.1 Decoder modules

A high-level overview of all decoder modules is given in Figure 3.9. The decoder is reversing the encoding process and essentially transforms the spectral coefficients into a time domain signal. First, the transmitted parameters are decoded and the spectral coefficients are restored. The Noise Filling module inserts noise for the coefficients that are zero and are in-band as indicated by the BW info. The coefficients are processed by the Temporal Noise Shaping (TNS) and Spectral Noise Shaping (SNS) decoders, which have taken their respective parameters from the received bitstream. The reconstructed spectral coefficients are transformed to the time domain using an Inverse LD-MDCT. Finally, the time domain signal is filtered by the Long-term Postfilter (LTPF), which uses the transmitted pitch information to define its filter.

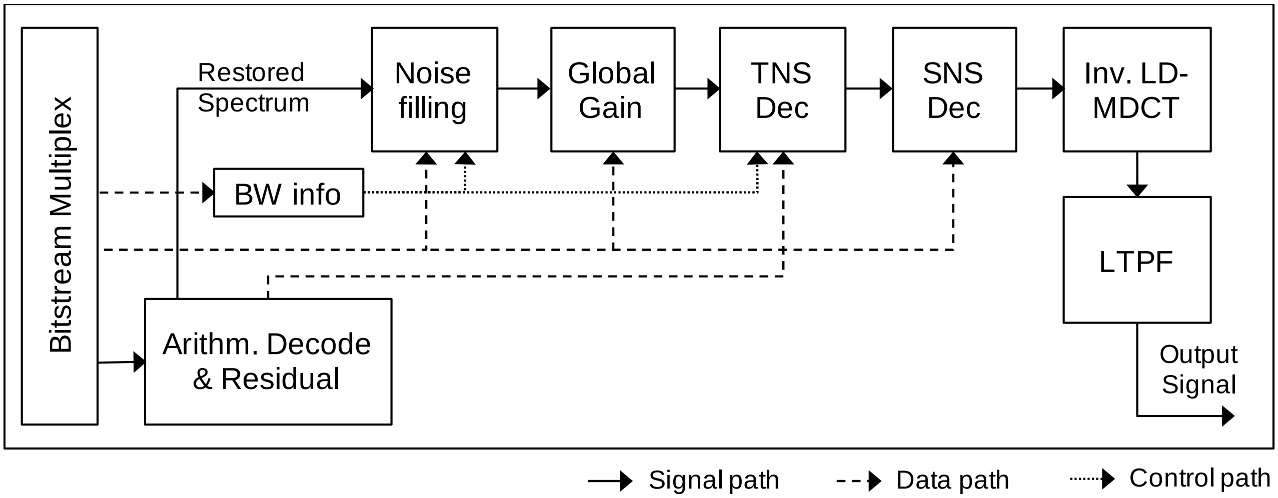

Figure 3.9: Decoder high-level overview

The LC3 decoder shall accept the BFI flag. When BFI is 0 for the frame, an assumed error-free payload (payloadRX) of size byte_count is forwarded to the LC3 decoder. When BFI is not 0, it indicates that there are identified bit errors in the received payloadRX, so the payload should not be decoded. In this case, the payload is considered corrupt. A substitute for the PCM (Pulse Code Modulation) audio frame shall be generated, e.g., by a packet loss concealment algorithm (an example concealment algorithm is described in Appendix B).

3.4.2 Bitstream decoding

3.4.2.1 Overview

The bitstream of a coded audio frame consists of four parts:

- Side information (Sections 3.4.2.2 and 3.4.2.3)
- A dynamic data block that is arithmetically coded (Section 3.4.2.5)
- A dynamic data block with signs and least significant bits of the encoded spectrum (Section 3.4.2.5)
- Residual data (Section 3.4.2.6)

An overview of the bitstream structure and layout is provided in Section 3.5. The remainder of this section (Sections 3.4.2.2 to 3.4.2.7) defines the exact payload reading process for all codec elements and the order in which they shall be performed.

In some cases, the decoder can detect bit error conditions (BEC) in the bitstream. This section outlines possible locations in the bitstream where bit errors can be detected and marked as `BEC_detect=1`. In the case of a positive BEC detection the decoder shall stop parsing and may apply a packet loss concealment.

3.4.2.2 Initialization

```
bp = 0;
bp_side = nbytes - 1;
mask_side = 1;
```

```
c = 0;
BEC_detect = 0;
if (nbits > (160 + f_s^ind * 160))
{
   rateFlag = 512;
}
else
{
   rateFlag = 0;
}
```

3.4.2.3 Side information

```
/* Bandwidth */
if (nbits_bw > 0)
{
   P_bw = read_uint(bytes, &bp_side, &mask_side, nbits_bw);
   if (f_s^ind < P_bw)
   {
      BEC_detect = 1;
   }
}
else
{
   P_bw = 0;
}

/* Last non-zero tuple */
nbits_lastnz = ceil(log2(N_E/2));
tmp_lastnz = read_uint(bytes, &bp_side, &mask_side, nbits_lastnz);
lastnz = (tmp_lastnz + 1) << 1;
if (lastnz > N_E)
{
   /* consider this as bit error (BEC) */
   BEC_detect = 1;
}

/* LSB mode bit */
lsbMode = read_bit(bytes, &bp_side, &mask_side);

/* Global Gain */
gg_ind = read_uint(bytes, &bp_side, &mask_side, 8);

/* TNS activation flag */
if (P_bw < 3)
{
   num_tns_filters = 1;
}
else
{
   num_tns_filters = 2;
}
for (f = 0; f < num_tns_filters; f++)
{
```

```
    rc_order(f) = read_bit(bytes, &bp_side, &mask_side);
}

/* Pitch present flag */
pitch_present = read_bit(bytes, &bp_side, &mask_side);

/* SNS-VQ integer bits */
/* Read 5+5 bits of SNQ VQ stage 1 according to Section 3.4.7.2.1 */
/* Read 28 bits of SNQ VQ stage 2 according to Section 3.4.7.2.2 */

/* LTPF data */
if (pitch_present != 0)
{
    ltpf_active = read_uint(bytes, &bp_side, &mask_side, 1);
    pitch_index = read_uint(bytes, &bp_side, &mask_side, 9);
}
else
{
    pitch_index = 0;
    ltpf_active = 0;
}

/* Noise Level */
F_NF = read_uint(bytes, &bp_side, &mask_side, 3);
```

3.4.2.4 Bandwidth interpretation

Depending on the transmitted parameter P_{bw} (see Section 3.4.2.3) and the sample frequency f_s, the bandwidth information can be interpreted as outlined in Table 3.6 in Section 3.3.5.2.

3.4.2.5 Arithmetic decoding

```
/* Arithmetic Decoder Initialization */
ac_dec_init(bytes, &bp, &st);

/* TNS data */
for (f = 0; f < num_tns_filters; f++)
{
    if (rc_order(f) > 0)
    {
        rc_order(f) = ac_decode(bytes, &bp, &st,
                          ac_tns_order_cumfreq[tns_lpc_weighting],
                          ac_tns_order_freq[tns_lpc_weighting], 8,
                          &BEC_detect);
        rc_order(f) = rc_order(f)  + 1;
        for (k = 0; k < 8; k++)
        {
            rc_i(k,f) = 8;
        }
        for (k = 0; k < rc_order(f); k++)
        {
            rc_i(k,f) = ac_decode(bytes, &bp, &st, ac_tns_coef_cumfreq[k],
                          ac_tns_coef_freq[k], 17, &BEC_detect);
        }
    }
```

```
}

/* Spectral data */
for (k = 0; k < lastnz; k += 2)
{
   t = c + rateFlag;
   if (k > N_E/2)
   {
      t += 256;
   }
   X̂q[k] = X̂q[k+1] = 0;
   for (lev = 0; lev < 14; lev++)
   {
      pki = ac_spec_lookup[t+min(lev,3)*1024];
      sym = ac_decode(bytes, &bp, &st, ac_spec_cumfreq[pki],
                      ac_spec_freq[pki], 17, &BEC_detect);
      if (sym < 16)
      {
         break;
      }
      if (lsbMode == 0 || lev > 0)
      {
         bit = read_bit(bytes, &bp_side, &mask_side);
         X̂q[k] += bit << lev;
         bit = read_bit(bytes, &bp_side, &mask_side);
         X̂q[k+1] += bit << lev;
      }
   }
   if (lev == 14)
   {
      BEC_detect = 1;
   }
   if (lsbMode == 1)
   {
      save_lev[k] = lev;
   }
   a = sym & 0x3;
   b = sym >> 2;
   X̂q[k] += a << lev;
   X̂q[k+1] += b << lev;
   if (X̂q[k] > 0)
   {
      bit = read_bit(bytes, &bp_side, &mask_side);
      if (bit == 1)
      {
         X̂q[k] = -X̂q[k];
      }
   }
   if (X̂q[k+1] > 0)
   {
      bit = read_bit(bytes, &bp_side, &mask_side);
      if (bit == 1)
      {
         X̂q[k+1] = -X̂q[k+1];
      }
```

```
    }
    lev = min(lev,3);
    if (lev <= 1)
    {
        t = 1 + (a+b)*(lev+1);
    }
    else
    {
        t = 12 + lev;
    }
    c = (c&15)*16 + t;
    if (bp - bp_side > 3)
    {
        BEC_detect = 1;
    }
}
```

3.4.2.6 Residual data and finalization

```
for (k = lastnz; k < N_E; k++)
{
    X̂_q[k] = 0;
}

/* Number of residual bits */
nbits_side = nbits - (8 * bp_side + 8 - log2(mask_side));
nbits_ari = (bp - 3) * 8;
nbits_ari += 25 - floor(log2(st->range));
nbits_residual = nbits - (nbits_side + nbits_ari);
if (nbits_residual < 0)
{
    BEC_detect = 1;
}

/* Decode residual bits */
if (lsbMode == 0)
{
    nResBits = 0;
    for (k = 0; k < N_E; k++)
    {
        if (X̂_q[k] != 0)
        {
            if (nResBits == nbits_residual)
            {
                break;
            }
            resBits[nResBits++] = read_bit(bytes, &bp_side, &mask_side);
        }
    }
}
else
{
    for (k = 0; k < lastnz; k+=2)
    {
        if (save_lev[k] > 0)
```

```
    {
        if (nbits_residual == 0)
        {
            break;
        }
        bit = read_bit(bytes, &bp_side, &mask_side);
        nbits_residual--;
        if (bit == 1)
        {
            if (X̂q[k] > 0)
            {
                X̂q[k] += 1;
            }
            else if (X̂q[k] < 0)
            {
                X̂q[k] -= 1;
            }
            else
            {
                if (nbits_residual == 0)
                {
                    break;
                }
                bit = read_bit(bytes, &bp_side, &mask_side);
                nbits_residual--;
                if (bit == 0)
                {
                    X̂q[k] = 1;
                }
                else
                {
                    X̂q[k] = -1;
                }
            }
        }
        if (nbits_residual == 0)
        {
            break;
        }
        bit = read_bit(bytes, &bp_side, &mask_side);
        nbits_residual--;
        if (bit == 1)
        {
            if (X̂q[k+1] > 0)
            {
                X̂q[k+1] += 1;
            }
            else if (X̂q[k+1] < 0)
            {
                X̂q[k+1] -= 1;
            }
            else
            {
                if (nbits_residual == 0)
                {
```

```
                    break;
                }
                bit = read_bit(bytes, &bp_side, &mask_side);
                nbits_residual--;
                if (bit == 0)
                {
                    X̂q[k+1] = 1;
                }
                else
                {
                    X̂q[k+1] = -1;
                }
            }
        }
    }
}
}

/* Noise Filling Seed */
tmp = 0;
for (k = 0; k < NE; k++)
{
    tmp += abs(X̂q[k]) * k;
}
nf_seed = tmp & 0xFFFF; /* Note that both tmp and nf_seed are 32-bit int*/

/* Zero frame flag */
if (lastnz == 2 && X̂q[0] == 0 && X̂q[1] == 0 && gg_ind == 0 && F_NF == 7)
{
    zeroFrameFlag = 1;
}
else
{
    zeroFrameFlag = 0;
}
```

3.4.2.7 Functions

```
read_bit(bytes[], *bp, *mask)
{
    if (bytes[*bp] & *mask)
    {
        bit = 1;
    }
    else
    {
        bit = 0;
    }
    if (*mask == 0x80)
    {
        *mask = 1;
        *bp -= 1;
    }
    else
    {
```

```
        *mask <<= 1;
    }
    return bit;
}

read_uint(bytes[], *bp, *mask, numbits)
{
    value = read_bit(bytes, bp, mask);
    for (i = 1; i < numbits; i++)
    {
        bit = read_bit(bytes, bp, mask);
        value += bit << i;
    }
    return value;
}

ac_dec_init(bytes[], *bp, *st)
{
    st->low = 0;
    st->range = 0x00ffffff;
    for (i = 0; i < 3; i++)
    {
        st->low <<= 8;
        st->low += bytes[(*bp)++];
    }
}

ac_decode(bytes[], *bp, *st, cum_freq, sym_freq, numsym, *BEC_detect)
{
    tmp = st->range >> 10;
    if (st->low >= (tmp<<10))
    {
        *BEC_detect = 1;
    }
    val = numsym-1;
    while (st->low < tmp * cum_freq[val])
    {
        val--;
    }
    st->low -= tmp * cum_freq[val];
    st->range = tmp * sym_freq[val];
    while (st->range < 0x10000)
    {
        st->low <<= 8;
        st->low &= 0x00ffffff;
        st->low += bytes[(*bp)++];
        st->range <<= 8;
    }
    return val;
}
```

3.4.3 Residual decoding

Residual decoding shall be performed only when `lsbMode` is 0.

```
k = n = 0;
while (k < N_E && n < nResBits)
{
    if (X̂q[k] != 0)
    {
        if (resBits[n++] == 0)
        {
            if (X̂q[k] > 0)
            {
                X̂q[k] -= 0.1875;
            }
            else
            {
                X̂q[k] -= 0.3125;
            }
        }
        else
        {
            if (X̂q[k] > 0)
            {
                X̂q[k] += 0.3125;
            }
            else
            {
                X̂q[k] += 0.1875;
            }
        }
    }
    k++;
}
```

3.4.4 Noise filling

Noise filling shall be performed only when `zeroFrame`Flag is 0.

The indices for the relevant spectral coefficients shall be:

$$I_{NF}(k) = \begin{cases} 1 & \text{if } NF_{start} \leq k < bw\_stop \text{ } and \text{ } \widehat{X_q}(i) == 0 \text{ } for \text{ } all \text{ } i = k - NF_{width} \ldots \min(bw\_stop - 1, k + NF_{width}) \\ 0 & \text{otherwise} \end{cases} \quad (119)$$

where bw_stop depends on the bandwidth information (see Section 3.4.2.4) as defined in Table 3.18.

	Bandwidth(P_{bw})				
	NB	WB	SSWB	SWB	FB
bw_stop	$80 \cdot \frac{N_{ms}}{10}$	$160 \cdot \frac{N_{ms}}{10}$	$240 \cdot \frac{N_{ms}}{10}$	$320 \cdot \frac{N_{ms}}{10}$	$400 \cdot \frac{N_{ms}}{10}$

Table 3.18: Mapping table bw_stop according to bandwidth

and the tuning parameters NF_{start} and NF_{width} are given in Table 3.17.

N_{ms}	NF_{start}	NF_{width}
$10\ ms$	24	3
$7.50\ ms$	18	2

Table 3.19: Tuning parameters NF_{start} and NF_{width}

The noise filling shall be applied on the identified relevant spectral lines $I_{NF}(k)$ using the transmitted noise factor F_{NF} given in Section 3.4.2.3 and the random seed (`nf_seed`) given in Section 3.4.2.6.

```
L̂_NF = (8-F_NF)/16;
for k=0..bw_stop-1
  if I_NF(k)==1
    nf_seed = (13849+nf_seed*31821) & 0xFFFF;
    if nf_seed<0x8000
      X̂_q(k) = L̂_NF;
    else
      X̂_q(k) = -L̂_NF;
```

3.4.5 Global gain

The global gain shall be applied to the spectrum after noise filling has been applied using the following formula:

$$\widehat{X_f}(k) = \widehat{X_q}(k) \cdot 10^{\left(\frac{gg_{ind}+gg_{off}}{28}\right)}, \quad for\ k = 0 \dots N_E - 1 \tag{120}$$

where gg_{ind} is the global gain index retrieved in the side information described in Section 3.4.2.3 (and previously calculated by the encoder in Section 3.3.10.2) and gg_{off} shall be defined by:

$$gg_{off} = -\min\left(115, \left\lfloor \frac{nbits}{10 * (f_s^{ind} + 1)} \right\rfloor\right) - 105 - 5 * (f_s^{ind} + 1) \tag{121}$$

3.4.6 TNS decoder

The quantized reflection coefficients shall be obtained for each TNS filter f using

$$rc_q(k,f) = \sin[\Delta \cdot (rc_i(k,f) - 8)]\ , \quad for\ k = 0 \dots 7 \tag{122}$$

with $rc_i(k,f)$ the quantizer output indices and $\Delta = \frac{\pi}{17}$.

The TNS parameters depend on the transmitted bandwidth information (see Section 3.4.2.4) as shown in Table 3.20 (see also Section 3.3.8 for the TNS encoder side operation).

N_{ms}	**Bandwidth**	**num_tns_filters**	**start_freq(f)**	**stop_freq(f)**
10 ms	NB	1	{12}	{80}
10 ms	WB	1	{12}	{160}
10 ms	SSWB	1	{12}	{240}

N_{ms}	Bandwidth	num_tns_filters	start_freq(f)	stop_freq(f)
10 ms	SWB	2	{12,160}	{160,320}
10 ms	FB	2	{12,200}	{200,400}
7.5 ms	NB	1	{9}	{60}
7.5 ms	WB	1	{9}	{120}
7.5 ms	SSWB	1	{9}	{180}
7.5 ms	SWB	2	{9,120}	{120,240}
7.5 ms	FB	2	{9,150}	{150,300}

Table 3.20: TNS decoder parameters

The MDCT spectrum $\widehat{X_f}(n)$ as generated in Section 3.4.5 shall be then synthesis filtered using the following algorithm:

```
for k = 0 to N_E − 1 do {
    X̂_s(k) = X̂_f(n)
}

s^0 = s^1 = s^2 = s^3 = s^4 = s^5 = s^6 = s^7 = 0
for f = 0 to num_tns_filters-1 do {
     if (rc_order(f) > 0)
     {
          for n = start_freq(f) to stop_freq(f) − 1 do {
             t = X̂_f(n) − rc_q(rc_order(f) − 1 , f) · s^(rc_order(f)−1)
             for k = rc_order(f) − 2 to 0 do {
                 t = t − rc_q(k, f) · s^k
                 s^(k+1) = rc_q(k, f) · t + s^k
             }
            X̂_s(n) = t
            s^0 = t
          }
     }
}
```

where $\widehat{X_s}(n)$ is the output of the TNS decoder.

> Note: If $rc_{order}(0)$ is less than $rc_{order}(1)$ some of the lattice states s^x for the second filter will be starting off from zero.

3.4.7 SNS decoder

3.4.7.1 Overview

The SNS decoder performs three steps. First, a set of 16 quantized scale factors shall be decoded as described in Section 3.4.7.2.

Note: These quantized scale factors are the same as the quantized scale factors as determined by the encoder (See Section 3.3.7.3).

Second, the quantized scale factors shall be interpolated as described in Section 3.4.7.3, similarly to the encoder (see Sections 3.3.7.4 and 3.3.7.5). Third, these interpolated scale factors are then used to shape the MDCT spectrum as described in Section 3.4.7.4.

3.4.7.2 SNS scale factor decoding

Figure 3.10 provides an overview of the SNS scale factor decoding.

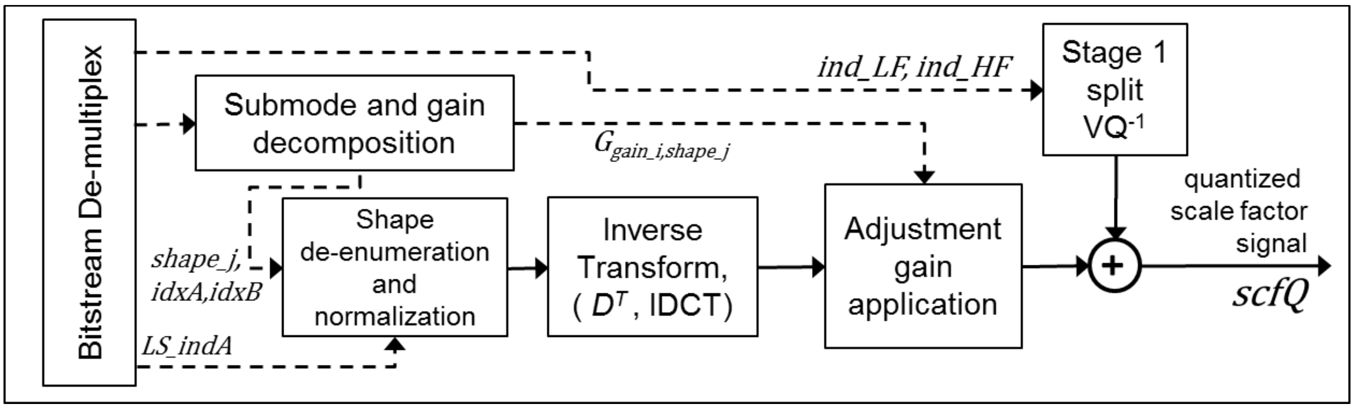

Figure 3.10: High-level overview of Decoder SNS scale factor synthesis

3.4.7.2.1 Stage 1 SNS VQ decoding

The first stage parameters shall be decoded as follows:

```
    ind_LF = read_uint(bytes, &bp_side, &mask_side, 5); /* stage1 LF  */
    ind_HF = read_uint(bytes, &bp_side, &mask_side, 5); /* stage1 HF  */
```

The first stage indices ind_LF and ind_HF shall be converted into signal $st1(n)$ according to Equations 39 and 40 in Section 3.3.7.3.2.

3.4.7.2.2 Stage 2 SNS VQ decoding

To efficiently use the available total bit space for the scale factor quantizer (38 bits) in combination with the fractional sized MPVQ-indices, the shape selection LSB, the second stage shape codewords, and the adjustment gain least significant bit were jointly encoded as described in Table 3.14 and the subsequent paragraph in Section 3.3.7.3.4.

On the decoder/receiver side, the reverse process takes place.

The second stage MSB submode bit, initial gain index, and the Leading Sign index shall first be read from the decoded bitstream as follows:

```
submodeMSB = read_bit(bytes, &bp_side, &mask_side);
if( submodeMSB == 0 ){
   Gind        = read_uint(bytes, &bp_side, &mask_side, 1);
} else {
   Gind        = read_uint(bytes, &bp_side, &mask_side, 2);
}
LS_indA     = read_bit(bytes, &bp_side, &mask_side); /*  LS_indA 1 bit */
```

If *submodeMSB* equals 0, corresponding to one of the shapes (*shape_j =0* or *shape_j =1*), the following demultiplexing procedure shall be applied:

```
/* 'regular'/'regular_lf' demultiplexing, establish if shape_j is 0 or 1 */

tmp =   read_uint(bytes, &bp_side, &mask_side, 13) ;
tmp |= (read_uint(bytes, &bp_side, &mask_side, 12)<<13) ;
[ BEC_detect, submodeLSB, idxA, idxBorGainLSB ] =
    dec_split_st2VQ_CW(tmp,4780008U>>1,14);

if(  submodeLSB != 0 ) {
   Gind    = (Gind<<1) + idxBorGainLSB; /* for regular_lf   */
} else {
   idxB    = idxBorGainLSB>>1;          /* for regular */
   LS_indB = idxBorGainLSB&0x1);
}
```

with function `dec_split_st2VQ_CW` defined as:

```
[BEC_detect, submodeLSB, idxA, idxBorGainLSB ] =
 dec_split_st2VQ_CW(cwRx, szA, szB )
{
    if( cwRx  >=    szB * szA) {
        idxA                 = 0;
        idxBorGainLSB        = 0;
        submodeLSB           = 0;
        BEC_detect           = 1;
        return;
    }

    idxBorGainLSB  =   floor( cwRx / szA );
    idxA           =   cwRx - idxBorGainLSB*szA;

    submodeLSB    = 0;
    idxBorGainLSB =  idxBorGainLSB - 2 ;
    if( idxBorGainLSB < 0 ) {
         submodeLSB = 1;
    }
    idxBorGainLSB  =  idxBorGainLSB + 2*submodeLSB ;

    BEC_detect     = 0;

    return;
}
```

If *submodeMSB* equals 1, ('outlier_near' or 'outlier_far' submodes) the following demultiplexing procedure shall be applied:

```
/* outlier_* demultiplexing, establish if shape_j is 2 or 3 */

tmp =   read_uint(bytes, &bp_side, &mask_side, 12);
tmp |= ( read_uint(bytes, &bp_side, &mask_side, 12)<<12 );

idxA       = tmp;
submodeLSB = 0;
BEC_detect = 0;

if ( tmp  >=   ((30316544U>>1)  +  1549824U) ) {
   BEC_detect = 1;
} else {
   tmp             -= (30316544U>>1);
   if( tmp >= 0 )  {
      submodeLSB     = 1;
      Gind           = (Gind<<1) + (tmp&0x1);
      idxA           = tmp>>1;
   }
}
```

Finally, the decombined/demultiplexed second stage indices $shape\_j$ and $gain\_i$ shall be determined as follows:

```
shape_j    = (submodeMSB<<1) + submodeLSB;
gain_i     = Gind;
```

3.4.7.2.2.1 De-enumeration of the shape indices

If $shape\_j$ is 0, the two shapes A and B, (where shape A is a function of LS_indA and $idxA$, and shape B is a function of LS_indB and $idxB$) shall be de-enumerated into signed integer vectors, otherwise ($shape\_j$ is not 0) only one shape shall be de-enumerated. The setup of the four possible shape configurations is described in Table 3.8.

The actual de-enumeration of a leading sign index LS_ind and an MPVQ shape index $MPVQ\_ind$ into a signed integer PVQ vector y(=vec_out) with an L1 norm of K(=k_val_in) over dimension N(=dim_in) is shown in C-style pseudocode below.

```
MPVQdeenum( dim_in,       /* i :  dimension of vec_out     */
            k_val_in,     /* i :  number of unit pulses    */
            LS_ind,       /* i :  leading sign index       */
            MPVQ_ind,     /* i :  MPVQ shape index         */
            *vec_out      /* o :  PVQ integer pulse train  */
{
  for (i=0; i < dim_in; i++){
     vec_out[i] = 0;
  }

  leading_sign = 1;
  if ( LS_ind != 0 ){
        leading_sign = -1;
  }

  mind2vec_tab ( dim_in,
                 k_val_in,
                 leading_sign,
                 MPVQ_ind,
```

```
                  vec_out,
                  MPVQ_offsets );
  return;
}
```

with:

```
mind2vec_tab ( short        dim_in,        /* i:  dimension         */
               short        k_max_local,   /* i:  nb unit pulses    */
               short        leading_sign,  /* i:  leading sign      */
               unsigned int ind,           /* i:  MPVQ-index        */
               short        *vec_out,       /* o:  pulse train       */
               unsigned int  MPVQ_offsets [][11]     /* i:  offset matrix
*/
)
{
    /* init */
    h_row_ptr = &(MPVQ_offsets[(dim_in-1)][0]);
    k_acc     = k_max_local;

    /* loop over positions */
    for (pos = 0; pos < dim_in; pos++) {

        if (ind != 0) {
            k_acc          = k_max_local;;
            UL_tmp_offset = h_row_ptr[k_acc];

            wrap_flag    = (ind < UL_tmp_offset ) ;
            UL_diff      =  ind - UL_tmp_offset;

            while (wrap_flag != 0) {
                k_acc--;
                wrap_flag = (ind <  h_row_ptr[k_acc]);
                UL_diff   =  ind -  h_row_ptr[k_acc];
            }

            ind      = UL_diff;
            k_delta = k_max_local - k_acc;
        } else {
            mind2vec_one(k_max_local, leading_sign, &vec_out[pos]);
            break;
        }

        k_max_local = setval_update_sign(
                      k_delta,
                      k_max_local,
                      &leading_sign,
                      &ind,
                      &vec_out[pos]);
        h_row_ptr -= 11;      /* reduce dimension in MPVQ_offsets table */
    }
    return;
}
```

with:

```
mind2vec_one( short  k_val_in,      /* i:  nb unit pulses  */
              short  leading_sign,  /* i: leading sign  -1, 1 */
              short *vec_out        /* o:  updated pulse train   */
)
{
```

```
    amp =  k_val_in;
    if ( leading_sign < 0 )
    {
        amp = -k_val_in ;
    }
    *vec_out = amp;

    return;
}
```

with:

```
[ k_max_local_out ] = setval_update_sign (
    short k_delta,          /* i   */
    short k_max_local_in,   /* i   */
    short *leading_sign,    /* i/o */
    short *ind_in,          /* i/o */
    short *vec_out          /* i/o */
)
{
    k_max_local_out = k_max_local_in;
    if  (k_delta != 0) {
        mind2vec_one(k_delta, *leading_sign, vec_out);
        *leading_sign      = get_lead_sign( ind_in );
        k_max_local_out   -=  k_delta ;
    }
    return k_max_local_out;
}
```

with:

```
[ leading_sign ] =  get_lead_sign(unsigned int  *ind )
{
    leading_sign     =  +1;
    if ( ((*ind)&0x1 ) != 0 ) {
        leading_sign =  -1;
    }
    (*ind) = (*ind >> 1);

    return leading_sign;
}
```

The `MPVQdeenum()` function above uses a table-based approach to decompose the two input indices into a signed integer PVQ vector with L1 norm of `k_val_in` and a leading sign for the first non-zero element according to the `LS_ind` index. Because the encoder side enumeration was performed from the end of the vector to the start of the vector, the de-enumeration takes place from the start(0) to the end(`dim_in-1`) of the vector.

Table 3.21 shows the MPVQ de-enumeration calls that are made for the demultiplexed *shape_j*.

Shape index (*shape_j*)	**Shape name**	**Scale factor set A de-enumeration**	**Scale factor set B de-enumeration (or initialization)**
0	'regular'	MPVQdeenum(*10, 10, LS_indA, idxA*, y_0)	MPVQdeenum(*6,1, LS_indB, idxB, z*); $y_0(n) = z(n\text{-}10)$, for $n=10...15$
1	'regular_lf'	MPVQdeenum(*10, 10, LS_indA, idxA*, y_1)	$y_1(n) = 0$, for $n=10...15$

Shape index (*shape_j*)	Shape name	Scale factor set A de-enumeration	Scale factor set B de-enumeration (or initialization)
2	'outlier_near'	MPVQdeenum(*16, 8, LS_indA, idxA,* y_2)	n/a
3	'outlier_far'	MPVQdeenum(*16, 6, LS_indA, idxA,* y_3)	n/a

Table 3.21: SNS VQ second stage shape de-enumeration into integer vector y_{shape_j} for each possible received shape index shape_j

3.4.7.2.3 Unit energy normalization of the received shape

The de-enumerated signed integer vector y_{shape_j} shall be normalized to a unit energy vector $x_{q,\ shape\_j}$ over dimension 16 according to Equation 44.

3.4.7.2.4 Reconstruction of the quantized SNS scale factors

The adjustment gain value $G_{gain\_i\ ,shape\_j}$ for gain index $gain\_i$ and shape index $shape\_j$ shall be determined based on table lookup (see Table 3.11).

Finally, the synthesis of the quantized scale factor vector $scfQ(n)$ shall be performed in the same way as on the encoder side in Section 3.3.7.3.

3.4.7.3 SNS scale factors interpolation

The quantized scale factors $scfQ(n)$ (obtained in Section 3.4.7.2) shall be interpolated using

$$\begin{gathered}
scfQint(0) = scfQ(0) \\
scfQint(1) = scfQ(0) \\
scfQint(4\cdot n+2) = scfQ(n) + \frac{1}{8}\cdot\big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n = \ 0 \ldots 14 \\
scfQint(4\cdot n+3) = scfQ(n) + \frac{3}{8}\cdot\big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n = \ 0 \ldots 14 \\
scfQint(4\cdot n+4) = scfQ(n) + \frac{5}{8}\cdot\big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n = \ 0 \ldots 14 \\
scfQint(4\cdot n+5) = scfQ(n) + \frac{7}{8}\cdot\big(scfQ(n+1) - scfQ(n)\big),\ \ for\ \ n = \ 0 \ldots 14 \\
scfQint(62) = scfQ(15) + \frac{1}{8}\cdot\big(scfQ(15) - scfQ(14)\big) \\
scfQint(63) = scfQ(15) + \frac{3}{8}\cdot\big(scfQ(15) - scfQ(14)\big)
\end{gathered} \tag{123}$$

If the configuration of the codec results in a number of bands $N_B < 64$, the number of scale factors shall be reduced as described by the following C-style pseudocode:

```
n2 = 64 - N_B;

for (i=0; i < n2; i++)
{
    sum = 0;
    for (i2=2*i; i2 < 2*i+2; i2++)
    {
        sum+= 0.5 * scfQint(i2);
    }
```

```
    tmp(i) = sum;
}

for (i=n2; i < N_B; i++)
{
    tmp(i) = scfQint(n2 + i);
}

for (i=0; i < N_B; i++)
{
    scfQint(i) = tmp(i);
}
```

The scale factors are then transformed back into the linear domain using

$$g_{SNS}(b) = 2^{scfQint(b)}, \quad for \;\; b = 0 \dots N_B - 1. \tag{124}$$

3.4.7.4 Spectral Shaping

The SNS scale factors $g_{SNS}(b)$ shall be applied on the TNS filtered MDCT frequency lines for each band separately to generate the shaped spectrum $\hat{X}(k)$ as outlined by the following code.

```
for (b=0; b<N_b; b++) {
    for (k=I_fs(b); k< I_fs(b+1); k++) {
        X̂(k) = X̂_S(k) · g_SNS(b)
    }
}
```

3.4.8 Low delay MDCT synthesis

The reconstructed spectrum $\hat{X}(k)$ shall be transformed to the time domain by the following steps:

1. Generation of time domain aliasing buffer $\hat{t}(n)$

$$\hat{t}(n) = \sqrt{\frac{2}{N_F}} \sum_{k=0}^{N_F-1} \hat{X}(k) \cdot \cos\left[\frac{\pi}{N_F} \cdot \left(n + \frac{1}{2} + \frac{N_F}{2}\right) \cdot \left(k + \frac{1}{2}\right)\right], \qquad for \;\; n = 0 \dots 2N_F - 1 \tag{125}$$

2. Windowing of time-aliased buffer

$$\hat{t}(n) = w_N(2 \cdot N - 1 - n) \cdot \hat{t}(n), \qquad for \;\; n = 0 \dots 2 \cdot N_F - 1 \tag{126}$$

3. Conduct overlap-add operation to get reconstructed time samples $\hat{x}(n)$

$$\hat{x}(n) = mem_{ola_{add(n)}} + \hat{t}(Z + n), \qquad for \;\; n = 0 \dots N_F - Z - 1 \tag{127}$$

$$\hat{x}(n) = \hat{t}(Z + n), \qquad for \;\; n = N_F - Z \dots N_F - 1 \tag{128}$$

$$mem_{ola_{add(n)}} = \hat{t}(N_F + Z + n), \qquad for \;\; n = 0 \dots N_F - Z - 1 \tag{129}$$

with $mem\_ola\_add(n)$ initialized to 0 before decoding the first frame.

Also see Section 3.3.3 regarding any definition related to the MDCT operation.

3.4.9 Long Term Postfilter

3.4.9.1 Overview

The decoded signal after MDCT synthesis is postfiltered in the time domain using an IIR filter whose parameters depend on the LTPF bitstream data pitch_index and ltpf_active. Because the filter coefficients are a pre-defined set, the result of the IIR filter is always stable. To avoid any discontinuity when the parameters change from one frame to the next, a transition mechanism is applied on the first quarter of the current frame.

Note: If the codec settings are such that gain_ltpf is zero, the LTPF processing will not change the MDCT synthesis buffer but will only update the LTPF buffers.

For simplicity, audio samples of past frames are accessed by negative indexing, e.g., $x(-1)$ is the most recent sample of the signal x in the previous frame.

The LTPF sharpens the harmonic structure of the signal by attenuating the quantization noise in the spectral valleys. An example of an LTPF frequency response for a speech signal is given in Figure 3.11.

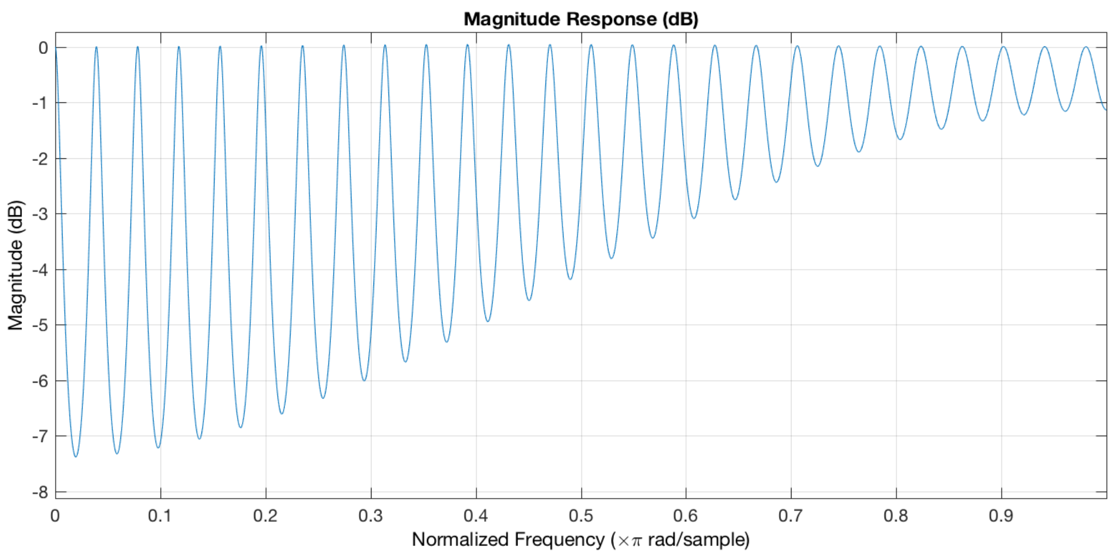

Figure 3.11: Example of LTPF frequency response for a speech signal: The harmonic structure is sharpened by attenuation of the spectral valleys and quantization noise is perceptually optimized.

3.4.9.2 Transition handling

The transition corresponds to the first 2.5 ms samples of the current frame ($n = 0 \ldots \frac{f_s \cdot f_{scal}}{400} - 1$).

Five different cases shall be considered:

1. First case: ltpf_active = 0 and mem_ ltpf_active = 0

$$\widehat{x_{ltpf}}(n) = \hat{x}(n) \tag{130}$$

2. Second case: ltpf_active = 1 and mem_ ltpf_active = 0

$$\widehat{x_{ltpf}}(n) \leftarrow \hat{x}(n) - \frac{n}{norm} \cdot \left[\sum_{k=0}^{L_{num}} c_{num}(k) \cdot \hat{x}(n-k) - \sum_{k=0}^{L_{den}} c_{den}(k, p_{fr}) \cdot \widehat{x_{ltpf}}\left(n - p_{int} + \frac{L_{den}}{2} - k\right) \right] \quad (131)$$

3. Third case: ltpf_active = 0 and mem_ ltpf_active = 1

$$\widehat{x_{ltpf}}(n) \leftarrow \hat{x}(n) - \left(1 - \frac{n}{norm}\right) \cdot \left[\sum_{k=0}^{L_{num}} c_{num}^{mem}(k) \cdot \hat{x}(n-k) - \sum_{k=0}^{L_{den}} c_{den}^{mem}(k, p_{fr}^{mem}) \cdot \widehat{x_{ltpf}}\left(n - p_{int}^{mem} + \frac{L_{den}}{2} - k\right) \right] (132)$$

4. Fourth case: ltpf_active = 1 and mem_ltpf_active = 1 and $p_{int} = p_{int}^{mem}$ and $p_{fr} = p_{fr}^{mem}$

$$\widehat{x_{ltpf}}(n) \leftarrow \hat{x}(n) - \sum_{k=0}^{L_{num}} c_{num}(k) \cdot \hat{x}(n-k) + \sum_{k=0}^{L_{den}} c_{den}(k, p_{fr}) \cdot \widehat{x_{ltpf}}\left(n - p_{int} + \frac{L_{den}}{2} - k\right) \quad (133)$$

5. Fifth case: ltpf_active = 1 and mem_ltpf_active = 1 and ($p_{int} \neq p_{int}^{mem}$ or $p_{fr} \neq p_{fr}^{mem}$)

$$\widehat{x_{ltpf}}(n) \leftarrow \hat{x}(n) - \left(1 - \frac{n}{norm}\right) \cdot \left[\sum_{k=0}^{L_{num}} c_{num}^{mem}(k) \cdot \hat{x}(n-k) - \sum_{k=0}^{L_{den}} c_{den}^{mem}(k, p_{fr}^{mem}) \cdot \widehat{x_{ltpf}}\left(n - p_{int}^{mem} + \frac{L_{den}}{2} - k\right) \right] (134)$$

$$\widehat{x_{ltpf}}'(m) \leftarrow \widehat{x_{ltpf}}(m), \quad m = -L_{num} \dots norm - 1 \quad (135)$$

$$\widehat{x_{ltpf}}(n) \leftarrow \widehat{x_{ltpf}}'(n) - \frac{n}{norm} \cdot \left[\sum_{k=0}^{L_{num}} c_{num}(k) \cdot \widehat{x_{ltpf}}'(n-k) - \sum_{k=0}^{L_{den}} c_{den}(k, p_{fr}) \cdot \widehat{x_{ltpf}}\left(n - p_{int} + \frac{L_{den}}{2} - k\right) \right] \quad (136)$$

where $norm = \frac{N_F}{4} \cdot \frac{10}{N_{ms}}$.

mem_ ltpf_active corresponds to the value of ltpf_active in the previous frame (it is initialized to zero before the first frame is processed), $\hat{x}(n)$ is the filter input signal (i.e., the decoded signal after MDCT synthesis), $\widehat{x_{ltpf}}(n)$ is the filter output signal, the filter parameters c_{num}, c_{den}, p_{int} and p_{fr} are given in the Section 3.4.9.4, and c_{num}^{mem}, c_{den}^{mem}, p_{int}^{mem} and p_{fr}^{mem} are the filter parameters computed in the previous frame.

3.4.9.3 Remainder of the frame

The remainder of the frame corresponds to the remaining samples of the current frame ($n = \frac{f_s \cdot f_{scal}}{400} \dots N_F - 1$).

Two different cases shall be considered:

1. First case: ltpf_active = 0

$$\widehat{x_{ltpf}}(n) = \hat{x}(n) \quad (137)$$

2. Second case: ltpf_active = 1

$$\widehat{x_{ltpf}}(n) \leftarrow \hat{x}(n) - \sum_{k=0}^{L_{num}} c_{num}(k) \cdot \hat{x}(n-k) + \sum_{k=0}^{L_{den}} c_{den}(k, p_{fr}) \cdot \widehat{x_{ltpf}}\left(n - p_{int} + \frac{L_{den}}{2} - k\right) \quad (138)$$

3.4.9.4 Filter parameters

The filter parameters shall be computed in the case ltpf_active = 1. The integer part p_{int} and the fractional part p_{fr} of the LTPF pitch-lag (pitch_index recovered from the bitstream in Section 3.4.2.3) are computed as follows. First the pitch-lag at 12.8 kHz (see Section 3.3.9) shall be recovered using

$$\text{pitch\_int} = \begin{cases} \text{pitch\_index} - 283 & \text{if pitch\_index} \geq 440 \\ \left\lfloor \frac{\text{pitch\_index}}{2} \right\rfloor - 63 & \text{if } 440 > \text{pitch\_index} \geq 380 \\ \left\lfloor \frac{\text{pitch\_index}}{4} \right\rfloor + 32 & \text{if } 380 > \text{pitch\_index} \end{cases} \tag{139}$$

$$\text{pitch\_fr} = \begin{cases} 0 & \text{if pitch\_index} \geq 440 \\ 2 * \text{pitch\_index} - 4 * \text{pitch\_int} - 252 & \text{if } 440 > \text{pitch\_index} \geq 380 \\ \text{pitch\_index} - 4 * \text{pitch\_int} + 128 & \text{if } 380 > \text{pitch\_index} \end{cases} \tag{140}$$

$$\text{pitch} = \text{pitch\_int} + \frac{\text{pitch\_fr}}{4} \tag{141}$$

The pitch-lag shall then be scaled to the output sampling rate f_s and converted to integer and fractional parts using

$$\text{pitch}_{f_s} = \text{pitch} \cdot \frac{8000 \cdot ceil\left(\frac{f_s}{8{,}000}\right)}{12{,}800} \tag{142}$$

$$p_{up} = \text{nint}\left(\text{pitch}_{f_s} \cdot 4\right) \tag{143}$$

$$p_{int} = \left\lfloor \frac{p_{up}}{4} \right\rfloor \tag{144}$$

$$p_{fr} = p_{up} - 4 \cdot p_{int} \tag{145}$$

The filter coefficients $c_{num}(k)$ and $c_{den}(k, p_{fr})$ shall be computed as follows

$$c_{num}(k, gaind\_ind) = 0.85 \cdot gain_{ltpf} \cdot \text{tab\_ltpf\_num\_fs[gain\_ind]}[k]\,, \quad for\ k = 0 \ldots L_{num} \tag{146}$$

$$c_{den}(k, p_{fr}) = gain\ _{ltpf} \cdot \text{tab\_ltpf\_den\_fs}[p_{fr}][k]\,, \quad for\ k = 0 \ldots L_{den} \tag{147}$$

with

$$L_{den} = \max\left(4, ceil\left(\frac{f_s}{4{,}000}\right)\right) \tag{148}$$

$$L_{num} = L_{den} - 2 \tag{149}$$

and $gain\_ltpf$ and $gain\_ind$ shall be obtained according to

```
/* correction table for smaller frame sizes */
If (N_ms == 7.5)
{
```

```
   t_nbits = round(nbits * 10 / 7.5);
} else {
   t_nbits = nbits;
}

/* Tuning lookup */
fs_idx = min(4,(fs/8000-1));
if (t_nbits < 320 + fs_idx*80)
{
   gain_ltpf = 0.4;
   gain_ind = 0;
}
else if (t_nbits < 400 + fs_idx*80)
{
   gain_ltpf = 0.35;
   gain_ind = 1;
}
else if (t_nbits < 480 + fs_idx*80)
{
   gain_ltpf = 0.3;
   gain_ind = 2;
}
else if (t_nbits < 560 + fs_idx*80)
{
   gain_ltpf = 0.25;
   gain_ind = 3;
}
else
{
   gain_ltpf = 0;
}
```

The tables for $\mathrm{tab\_ltpf\_num\_fs}[\mathrm{gain\_ind}][k]$ and $\mathrm{tab\_ltpf\_den\_fs}[p_{fr}][k]$ are provided in Section 3.7.6.

3.4.10 Output signal scaling and rounding

The LTPF output signal $\widehat{x_{ltpf}}(n)$ for all samples with index $n = 0 \ldots N_F - 1$ shall be clipped to upper integer value range

$$\widehat{x_{clip}}(n) = \begin{cases} 2^{15} - 1, & \widehat{x_{ltpf}}(n) > 2^{15} - 1 \\ -2^{15}, & \widehat{x_{ltpf}}(n) < -2^{15} \\ \widehat{x_{ltpf}}(n), & otherwise \end{cases} . \tag{150}$$

Afterwards, the signal $\widehat{x_{clip}}(n)$ shall be scaled to the proper range using

$$x_o(n) = nint\left(\widehat{x_{clip}}(n) \cdot 2^{-15+s-1}\right). \tag{151}$$

The output signal $x_o(n)$ is in the PCM integer format using s bits per sample.

3.5 Frame structure

The frame structure of the codec consists of the following four parts:

- Side information containing static bits about the configuration of the frame data. This data block starts at the end of the frame and is read backwards. It includes information about audio bandwidth, global gain, noise level, TNS activity, LTPF, SNS data, the index of the last non-zero spectral line, and parts of the quantized spectrum. An exact bitstream definition can be found in Section 3.4.2.3.

- A dynamic data block that is arithmetically coded and contains TNS and fractional parts of the quantized spectrum. This block is read from the beginning of the frame towards the end. The decoding of this block is described in Section 3.4.2.5.

- A dynamic data block with signs and the least significant bits part of the quantized spectrum. This block is read backwards from the end of the static side information bits. The decoding of this dynamic data block is described in Section 3.4.2.5; the encoding is described in Section 3.3.13.4.2.

- The residual data, which is located between the two dynamic data blocks and contains refinements of the quantized spectrum. It is read backwards starting immediately after the dynamic data block with spectrum signs and spectrum LSBs. The residual data is described according to Section 3.4.2.6.

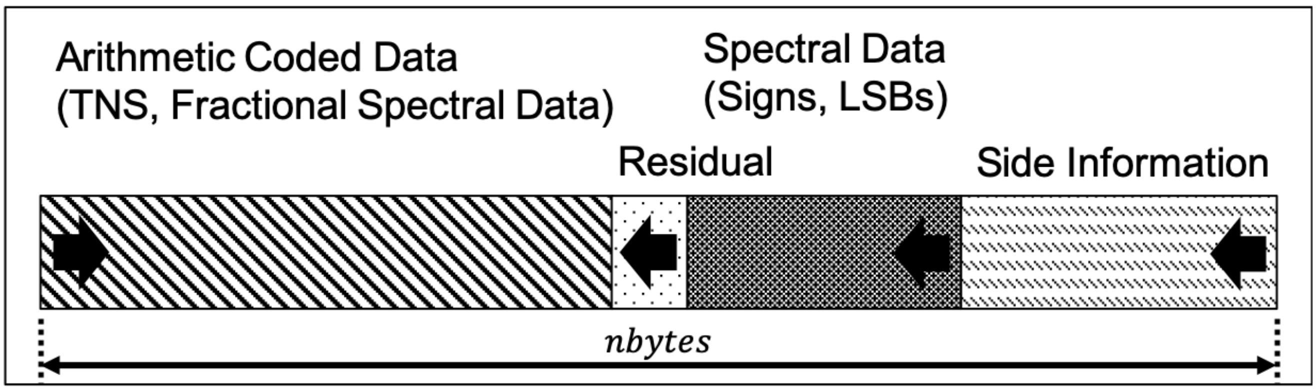

Figure 3.12: Frame structure

3.6 External rate adaptation

The LC3 encoder can change the length of a compressed audio frame (*nbytes*) in a seamless manner. To enable this, the encoder receives an external command to change the compressed frame size, which is applied to the current frame and subsequent frames. The decoder shall determine the bitrate from the received packet size.

Whenever the bitrate (*nbytes*) is changed, the variables describing the bitrate defined in Section 3.2.5 shall be updated. These variables control the tuning parameter for the TNS (Section 3.3.8 and Section 3.4.6), LTPF (Section 3.3.9 and Section 3.4.9) and the Time Domain Attack Detector (Section 3.3.6.1) modules.

3.7 Tables and constants

3.7.1 Band tables index I_{fs} for 10 ms frame duration

```
int I_8000[65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28
```

```
,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,51,53,55,57,5
9,61,63,65,67,69,71,73,75,77,80};


int I_16000[65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28
,30,32,34,36,38,40,42,44,46,48,50,52,55,58,61,64,67,70,73,76,80,84,88,92,96,1
01,106,111,116,121,127,133,139,146,153,160};

int I_24000[65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,25,27,29,31,33
,35,37,39,41,43,46,49,52,55,58,61,64,68,72,76,80,85,90,95,100,106,112,118,125
,132,139,147,155,164,173,183,193,204,215,227,240};

int I_32000[65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,22,24,26,28,30,32,34,36
,38,41,44,47,50,53,56,60,64,68,72,76,81,86,91,97,103,109,116,123,131,139,148,
157,166,176,187,199,211,224,238,252,268,284,302,320};

int I_48000[65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,22,24,26,28,30,32,34,36,39
,42,45,48,51,55,59,63,67,71,76,81,86,92,98,105,112,119,127,135,144,154,164,17
5,186,198,211,225,240,256,273,291,310,330,352,375,400};
```

3.7.2 Band tables index I_{fs} for 7.5 ms frame duration

```
int I_8000_7.5ms[61] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28
,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,5
4,55,56,57,58,59,60};

int I_16000_7.5ms [65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28
,29,30,31,32,33,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,65,68,71,74,77,8
0,83,86,90,94,98,102,106,110,115,120};

int I_24000_7.5ms [65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,29
,31,33,35,37,39,41,43,45,47,49,52,55,58,61,64,67,70,74,78,82,86,90,95,100,105
,110,115,121,127,134,141,148,155,163,171,180};

int I_32000_7.5ms [65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,26,28,30,32
,34,36,38,40,42,45,48,51,54,57,60,63,67,71,75,79,84,89,94,99,105,111,117,124,
131,138,146,154,163,172,182,192,203,215,227,240};

int I_48000_7.5ms [65] =
{0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,24,26,28,30,32,34
,36,38,40,43,46,49,52,55,59,63,67,71,75,80,85,90,96,102,108,115,122,129,137,1
46,155,165,175,186,197,209,222,236,251,266,283,300};
```

3.7.3 Low delay MDCT windows

3.7.3.1 10 ms Frame Duration

3.7.3.1.1 w_{10_80}

```
double w_N80[160] = {
-7.078546706512391e-04, -2.098197727900724e-03, -4.525198076002370e-03,
-8.233976327300612e-03, -1.337713096257934e-02, -1.999721557401502e-02,
-2.800909464274782e-02, -3.721502082245055e-02, -4.731768261606175e-02,
-5.794654834034055e-02, -6.867606753531441e-02, -7.904647440788692e-02,
-8.859705468085925e-02, -9.688303623049199e-02, -1.034961241263523e-01,
-1.080766457616878e-01, -1.103242262600913e-01, -1.099809851424550e-01,
-1.068172142230882e-01, -1.006190418791648e-01, -9.116452506492527e-02,
-7.820617483254730e-02, -6.146688124166948e-02, -4.063362855701623e-02,
-1.536329520788766e-02, +1.470155068746303e-02, +4.989736509080558e-02,
+9.050369257152079e-02, +1.366911019414417e-01, +1.884686389218322e-01,
+2.456456803467095e-01, +3.077789078889820e-01, +3.741642373060188e-01,
+4.438114799213576e-01, +5.154735456539700e-01, +5.876661722564289e-01,
+6.587619767809000e-01, +7.270576699841359e-01, +7.908752989295335e-01,
+8.486643364959733e-01, +8.991320235484349e-01, +9.413348145272842e-01,
+9.747634827941575e-01, +9.994114730415857e-01, +1.015760373791603e+00,
+1.024736164069697e+00, +1.027634294456205e+00, +1.025991493983836e+00,
+1.021427210603284e+00, +1.015439859549357e+00, +1.009366925499550e+00,
+1.003508162416449e+00, +9.988898206257559e-01, +9.953133902427869e-01,
+9.925943919208190e-01, +9.905771957917731e-01, +9.891371616557014e-01,
+9.881790747212391e-01, +9.876249269174586e-01, +9.874056275509585e-01,
+9.874524849192456e-01, +9.876951134084213e-01, +9.880640617030884e-01,
+9.884926873551375e-01, +9.889230031022089e-01, +9.893074965384659e-01,
+9.896146331889107e-01, +9.898319269347060e-01, +9.899693102025342e-01,
+9.900603352632121e-01, +9.901575015155720e-01, +9.903255289051605e-01,
+9.906303787150326e-01, +9.911298894709990e-01, +9.918665491182922e-01,
+9.928619727154252e-01, +9.941156069136238e-01, +9.956033775539884e-01,
+9.972793109558521e-01, +9.990784840729244e-01, +1.000922365901945e+00,
+1.002728111386909e+00, +1.004416038098237e+00, +1.005919224127911e+00,
+1.007189345025525e+00, +1.008200146369426e+00, +1.008949493525753e+00,
+1.009458241425143e+00, +1.009768980817384e+00, +1.009940336228694e+00,
+1.010039453539107e+00, +1.010132323996401e+00, +1.010272524848519e+00,
+1.010494354532353e+00, +1.010808068774316e+00, +1.011201071127927e+00,
+1.011641272406023e+00, +1.012080125934687e+00, +1.012458183122033e+00,
+1.012706955800289e+00, +1.012755013843985e+00, +1.012530134411619e+00,
+1.011962331100864e+00, +1.010982135506986e+00, +1.009512438049510e+00,
+1.007460860286395e+00, +1.004708677491086e+00, +1.001111413242302e+00,
+9.965041017623596e-01, +9.907199995730845e-01, +9.823765865983288e-01,
+9.708821747608998e-01, +9.546732976073705e-01, +9.321553861564006e-01,
+9.018003682081348e-01, +8.623984077953557e-01, +8.132817365236141e-01,
+7.544551974836834e-01, +6.866580716267418e-01, +6.113488038789190e-01,
+5.306181649316597e-01, +4.471309850999502e-01, +3.639114681156236e-01,
+2.841647033392408e-01, +2.110209448747969e-01, +1.472287968327703e-01,
+9.482665349502291e-02, +5.482436608328477e-02, +2.701461405056264e-02,
+9.996743588367519e-03, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
```

```
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00};
```

3.7.3.1.2 w_{10_160}

```
double w_N160[320] = {
-4.619898752628163e-04, -9.747166718929050e-04, -1.664473096973725e-03,
-2.597106916737789e-03, -3.806285163352241e-03, -5.324608721716763e-03,
-7.175885277771099e-03, -9.382480860899108e-03, -1.195270300743193e-02,
-1.489528159506296e-02, -1.820666399965468e-02, -2.187570925786862e-02,
-2.588471937157619e-02, -3.020862738245264e-02, -3.481597793538342e-02,
-3.967067992672979e-02, -4.472698045914417e-02, -4.994225863256500e-02,
-5.526334794593565e-02, -6.063717235243996e-02, -6.600961519440657e-02,
-7.131966266443390e-02, -7.651178225890490e-02, -8.152964005319532e-02,
-8.631137544905677e-02, -9.080411291245728e-02, -9.495377758870335e-02,
-9.870736514214426e-02, -1.020202684361974e-01, -1.048438825017798e-01,
-1.071382314127799e-01, -1.088690135027248e-01, -1.099969655786929e-01,
-1.104898474883336e-01, -1.103225838568563e-01, -1.094621746650760e-01,
-1.078834293141886e-01, -1.055612509762041e-01, -1.024650162703341e-01,
-9.857014566194629e-02, -9.384684920715425e-02, -8.826309993000785e-02,
-8.178792716809512e-02, -7.438785600211463e-02, -6.602189797715241e-02,
-5.665655641133161e-02, -4.624456893420224e-02, -3.474585776145929e-02,
-2.211581608120528e-02, -8.310425696208936e-03, +6.717697635290676e-03,
+2.300642061077823e-02, +4.060106462625085e-02, +5.953239090915557e-02,
+7.983354189816511e-02, +1.015233140203748e-01, +1.246171387327525e-01,
+1.491152519299797e-01, +1.750067399059861e-01, +2.022699854906251e-01,
+2.308655379767671e-01, +2.607365124918583e-01, +2.918144694729168e-01,
+3.240095704645023e-01, +3.572175180786021e-01, +3.913146885756875e-01,
+4.261571642320424e-01, +4.615925445090212e-01, +4.974471592901086e-01,
+5.335326819631583e-01, +5.696546730080154e-01, +6.056083823929643e-01,
+6.411830842823245e-01, +6.761653499550255e-01, +7.103400549562944e-01,
+7.434943718765665e-01, +7.754281892901473e-01, +8.059437233154637e-01,
+8.348589373399948e-01, +8.620108336276733e-01, +8.872599706865123e-01,
+9.104863121445679e-01, +9.315962496426278e-01, +9.505220861927248e-01,
+9.672366712325431e-01, +9.817397501303696e-01, +9.940557180662704e-01,
+1.004247514102417e+00, +1.012407428282884e+00, +1.018650990561848e+00,
+1.023118841384460e+00, +1.025972450969440e+00, +1.027397523939210e+00,
+1.027585830688143e+00, +1.026738673647482e+00, +1.025061777648234e+00,
+1.022756514615106e+00, +1.020009139549275e+00, +1.016996499560845e+00,
+1.013915946100629e+00, +1.011044869639164e+00, +1.007773858455400e+00,
+1.004848753962734e+00, +1.002245009135684e+00, +9.999393169239009e-01,
+9.979055415627330e-01, +9.961203379971326e-01, +9.945597525471822e-01,
+9.932031606606762e-01, +9.920297273323891e-01, +9.910230654424902e-01,
+9.901668953434221e-01, +9.894488374513719e-01, +9.888556356037892e-01,
+9.883778520531268e-01, +9.880051626345804e-01, +9.877295459610343e-01,
+9.875412739766566e-01, +9.874329809802893e-01, +9.873949921033299e-01,
+9.874197049003676e-01, +9.874973205882319e-01, +9.876201238703241e-01,
+9.877781920433015e-01, +9.879637979933339e-01, +9.881678007807095e-01,
+9.883835200189653e-01, +9.886022219397892e-01, +9.888182771263505e-01,
+9.890247977602895e-01, +9.892178658748239e-01, +9.893923680007577e-01,
+9.895463342815009e-01, +9.896772011542693e-01, +9.897859195209235e-01,
+9.898725363809847e-01, +9.899410789223559e-01, +9.899945557067980e-01,
+9.900394023736973e-01, +9.900814722948890e-01, +9.901293790312005e-01,
```

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+9.901902265696609e-01, +9.902734448815004e-01, +9.903862280081246e-01,
+9.905379830873822e-01, +9.907348826312993e-01, +9.909842592301273e-01,
+9.912905118607647e-01, +9.916586940166509e-01, +9.920906151219310e-01,
+9.925887208794144e-01, +9.931516528513824e-01, +9.937790866568735e-01,
+9.944668184371617e-01, +9.952116634297566e-01, +9.960068616185641e-01,
+9.968461329825753e-01, +9.977203369515556e-01, +9.986213520769593e-01,
+9.995382582242990e-01, +1.000461955079660e+00, +1.001380551217109e+00,
+1.002284871786226e+00, +1.003163845364970e+00, +1.004009147462043e+00,
+1.004811375053364e+00, +1.005563968008037e+00, +1.006259855360867e+00,
+1.006895570408563e+00, +1.007466616298057e+00, +1.007972441990187e+00,
+1.008411468616852e+00, +1.008786009787269e+00, +1.009097763850333e+00,
+1.009351762546296e+00, +1.009552401900961e+00, +1.009707093778162e+00,
+1.009822090220407e+00, +1.009906958448099e+00, +1.009969021400474e+00,
+1.010017890428877e+00, +1.010060809299530e+00, +1.010106564965965e+00,
+1.010161131093372e+00, +1.010231078494249e+00, +1.010319484524512e+00,
+1.010430470494512e+00, +1.010564099281000e+00, +1.010721360243234e+00,
+1.010899655674578e+00, +1.011096993993037e+00, +1.011308167670753e+00,
+1.011529185153809e+00, +1.011753008569803e+00, +1.011973876511603e+00,
+1.012182837094955e+00, +1.012373028737774e+00, +1.012535058602453e+00,
+1.012660975529858e+00, +1.012740575296603e+00, +1.012765922449960e+00,
+1.012726958954961e+00, +1.012615904116265e+00, +1.012422888521601e+00,
+1.012140460211194e+00, +1.011758810583150e+00, +1.011269960947744e+00,
+1.010663676735228e+00, +1.009930754807923e+00, +1.009058249873833e+00,
+1.008034308295421e+00, +1.006843352506855e+00, +1.005470005637052e+00,
+1.003894772403371e+00, +1.002098854400575e+00, +1.000060686758758e+00,
+9.977600196406868e-01, +9.951746430061121e-01, +9.922861082472264e-01,
+9.890757868707590e-01, +9.847362453480265e-01, +9.798613526271561e-01,
+9.741378617337759e-01, +9.673331975559332e-01, +9.592539757044516e-01,
+9.496984081652284e-01, +9.384634163826711e-01, +9.253567968750328e-01,
+9.101986790930605e-01, +8.928338316495705e-01, +8.731437835983047e-01,
+8.510420440685049e-01, +8.264839911291133e-01, +7.994681492797084e-01,
+7.700431275216928e-01, +7.383028603058783e-01, +7.043814340356083e-01,
+6.684616478236647e-01, +6.307755329382612e-01, +5.915799587176216e-01,
+5.511703155400274e-01, +5.098915423728179e-01, +4.681017110047964e-01,
+4.261772971493010e-01, +3.845172335531009e-01, +3.435228672445613e-01,
+3.036004651973099e-01, +2.651434678028531e-01, +2.285283969438072e-01,
+1.941021906320984e-01, +1.621735416384830e-01, +1.330015240938615e-01,
+1.067840430193724e-01, +8.365057236623041e-02, +6.365188111381356e-02,
+4.676538412257621e-02, +3.288072750732215e-02, +2.183057564646270e-02,
+1.336381425803019e-02, +6.758124889697787e-03, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
```

```
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00};
```

3.7.3.1.3 w_{10_240}

```
double w_N240[480] = {
-3.613496418928369e-04, -7.078546706512391e-04, -1.074443637110903e-03,
-1.533478537964509e-03, -2.098197727900724e-03, -2.778420871815740e-03,
-3.584129920673041e-03, -4.525198076002370e-03, -5.609327243712055e-03,
-6.843234536105624e-03, -8.233976327300612e-03, -9.785314755557023e-03,
-1.149880303071551e-02, -1.337713096257934e-02, -1.542181679511618e-02,
-1.762979910961727e-02, -1.999721557401502e-02, -2.252080561390149e-02,
-2.519406300389030e-02, -2.800909464274782e-02, -3.095765092956728e-02,
-3.402996266948349e-02, -3.721502082245055e-02, -4.050053247568393e-02,
-4.387219218706189e-02, -4.731768261606175e-02, -5.082325342672667e-02,
-5.437166635159518e-02, -5.794654834034055e-02, -6.153426201732499e-02,
-6.511708163113709e-02, -6.867606753531441e-02, -7.219447805250771e-02,
-7.565695975592170e-02, -7.904647440788692e-02, -8.234442557322251e-02,
-8.553324579905185e-02, -8.859705468085925e-02, -9.152091100798199e-02,
-9.428847446755965e-02, -9.688303623049198e-02, -9.929123258537813e-02,
-1.015008467688577e-01, -1.034961241263523e-01, -1.052637003544443e-01,
-1.067939984687745e-01, -1.080766457616878e-01, -1.090997300590506e-01,
-1.098524491515805e-01, -1.103242262600913e-01, -1.105084619148789e-01,
-1.103977408741932e-01, -1.099809851424550e-01, -1.092492774392824e-01,
-1.081974227416502e-01, -1.068172142230882e-01, -1.050995803285455e-01,
-1.030360111111103e-01, -1.006190418791648e-01, -9.784120023411771e-02,
-9.469304216883027e-02, -9.116452506492527e-02, -8.724644532866996e-02,
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+4.820662943337458e-01, +4.681017110048007e-01, +4.541216995958746e-01,
+4.401421815729068e-01, +4.261772971493010e-01, +4.122417888542512e-01,
+3.983499612526493e-01, +3.845172335531009e-01, +3.707583717376236e-01,
+3.570886786795506e-01, +3.435228672445627e-01, +3.300763764703638e-01,
+3.167640325043893e-01, +3.036004651973109e-01, +2.905996158436682e-01,
+2.777758503744847e-01, +2.651434678028531e-01, +2.527161881181577e-01,
+2.405069849650012e-01, +2.285283969438072e-01, +2.167933432162879e-01,
+2.053139897833021e-01, +1.941021906320988e-01, +1.831680872008943e-01,
+1.725221947208913e-01, +1.621735416384834e-01, +1.521320683467849e-01,
+1.424052801149985e-01, +1.330015240938615e-01, +1.239260664828526e-01,
+1.151858295527293e-01, +1.067840430193724e-01, +9.872637505002878e-02,
+9.101379000888035e-02, +8.365057236623055e-02, +7.663508305536153e-02,
+6.997033405748826e-02, +6.365188111381365e-02, +5.768176015814392e-02,
+5.205244216987966e-02, +4.676538412257621e-02, +4.180950541438362e-02,
+3.718640251368464e-02, +3.288072750732215e-02, +2.889548499582958e-02,
+2.520980565928884e-02, +2.183057564646272e-02, +1.872896194002638e-02,
+1.592127815153420e-02, +1.336381425803020e-02, +1.108558877807282e-02,
+8.943474189364638e-03, +6.758124889697787e-03, +3.504438130619497e-03,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
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+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
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+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00,
+0.000000000000000e+00, +0.000000000000000e+00, +0.000000000000000e+00};
```

3.7.3.2 7.5 ms Frame Duration

3.7.3.2.1 $w_{7.5\_60}$

```
double w_N60[120] = {
2.950608593187313e-03, 7.175411316438510e-03, 1.376953735371754e-02,
2.309535564877266e-02, 3.540362298325999e-02, 5.082893035710152e-02,
6.946962925951473e-02, 9.138842778133426e-02, 1.166045748296231e-01,
1.450735459839195e-01, 1.767111740534608e-01, 2.113429529554800e-01,
2.487686144599148e-01, 2.887011017469859e-01, 3.308238711499938e-01,
3.748145444067251e-01, 4.203080130472308e-01, 4.669049179648736e-01,
5.141853413578332e-01, 5.617100406669413e-01, 6.090263461524341e-01,
6.556710162134097e-01, 7.012183842298189e-01, 7.452406787622362e-01,
7.873692060484326e-01, 8.272238334368036e-01, 8.645136750188277e-01,
8.989774146126214e-01, 9.304075179845523e-01, 9.585999373974852e-01,
9.834477193784226e-01, 1.004882833289021e+00, 1.022853807278541e+00,
```

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1.037404947967044e+00, 1.048597914202596e+00, 1.056561843427440e+00,
1.061493706243562e+00, 1.063625783716980e+00, 1.063259727973876e+00,
1.060745048351166e+00, 1.056435897894500e+00, 1.050695001011264e+00,
1.043924345068839e+00, 1.036477246028582e+00, 1.028728673666003e+00,
1.021064859918030e+00, 1.014006582262175e+00, 1.007274550102931e+00,
1.001722497437142e+00, 9.973095916665831e-01, 9.939851582601669e-01,
9.916833348089591e-01, 9.903253250249126e-01, 9.898226125376152e-01,
9.900747339893667e-01, 9.909753143689592e-01, 9.924128512256524e-01,
9.942731493578623e-01, 9.964391574315900e-01, 9.987916157534086e-01,
1.001209846205687e+00, 1.003573567479612e+00, 1.005759836364722e+00,
1.007645153692818e+00, 1.009106872290545e+00, 1.010024764464639e+00,
1.010282031682720e+00, 1.009769188700535e+00, 1.008386412173240e+00,
1.006051238984656e+00, 1.002697666156926e+00, 9.982804644584213e-01,
9.927779867939798e-01, 9.861868921689572e-01, 9.776341643922554e-01,
9.674472695701162e-01, 9.551297254161167e-01, 9.403898774115922e-01,
9.229592799642977e-01, 9.026073499372684e-01, 8.792026885629480e-01,
8.526417497265664e-01, 8.228812716163106e-01, 7.899717151715774e-01,
7.540303276706357e-01, 7.152557417328465e-01, 6.739369112409073e-01,
6.304147162292445e-01, 5.850788579084674e-01, 5.383985182966198e-01,
4.908337531732809e-01, 4.428858232573716e-01, 3.950910240537553e-01,
3.480043431985102e-01, 3.021967102409465e-01, 2.582274305805284e-01,
2.166414164389013e-01, 1.779221215201146e-01, 1.424805471287674e-01,
1.106521943353717e-01, 8.269959669528287e-02, 5.883345162013132e-02,
3.920308484545646e-02, 2.386291074479415e-02, 1.269762234246248e-02,
5.356653610215987e-03, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00};
```

3.7.3.2.2 $w_{7.5\_120}$

```
double w_N120[240] = {
2.208248743046650e-03, 3.810144195090351e-03, 5.915524734289813e-03,
8.583614568030036e-03, 1.187597226083452e-02, 1.583353014097089e-02,
2.049186515516006e-02, 2.588835928921542e-02, 3.204158944817544e-02,
3.896167212395468e-02, 4.667421691393490e-02, 5.518493372761350e-02,
6.450383844383757e-02, 7.464110714806732e-02, 8.560001618878993e-02,
9.738467025048170e-02, 1.099936025389733e-01, 1.234192774722812e-01,
1.376554565476283e-01, 1.526904374639564e-01, 1.685133626404965e-01,
1.850931046131430e-01, 2.024104194879864e-01, 2.204503651331880e-01,
2.391679406203077e-01, 2.585261682883327e-01, 2.784985387736362e-01,
2.990384315995911e-01, 3.201048623655521e-01, 3.416586222430363e-01,
3.636600340252121e-01, 3.860626951895035e-01, 4.088152724594432e-01,
4.318710458458660e-01, 4.551769877048139e-01, 4.786765926352632e-01,
5.023248131381035e-01, 5.260609162248473e-01, 5.498312828850233e-01,
5.735768827770059e-01, 5.972413384410342e-01, 6.207702424193973e-01,
6.440996624336124e-01, 6.671763816763950e-01, 6.899588537658654e-01,
7.123799800931302e-01, 7.343963718694788e-01, 7.559666880505324e-01,
7.770369811015168e-01, 7.975581136897942e-01, 8.174908555311138e-01,
8.367969496408532e-01, 8.554473095679163e-01, 8.734007983991156e-01,
8.906357189698083e-01, 9.071287701238782e-01, 9.228487835702877e-01,
9.377633225341820e-01, 9.518602062527468e-01, 9.651306001536289e-01,
9.775565405467248e-01, 9.891262086779957e-01, 9.998469191683163e-01,
1.009700729703874e+00, 1.018682286908352e+00, 1.026814550859190e+00,
1.034089812751720e+00, 1.040511956629397e+00, 1.046108368522362e+00,
```

```
1.050885649534276e+00, 1.054862887578656e+00, 1.058072205849552e+00,
1.060534138670111e+00, 1.062276617517642e+00, 1.063338150260194e+00,
1.063755566766962e+00, 1.063566320618061e+00, 1.062821557530121e+00,
1.061559958917576e+00, 1.059817091581481e+00, 1.057658760384513e+00,
1.055120057365395e+00, 1.052239850719546e+00, 1.049087785713381e+00,
1.045698595146235e+00, 1.042108306824389e+00, 1.038380985588667e+00,
1.034552762539362e+00, 1.030671997181282e+00, 1.026791666942681e+00,
1.022955584022344e+00, 1.019207332137853e+00, 1.015872887197225e+00,
1.012210174593533e+00, 1.008845591036958e+00, 1.005778512486221e+00,
1.003002618498964e+00, 1.000514601809148e+00, 9.983092287560527e-01,
9.963786013745719e-01, 9.947181322797367e-01, 9.933162157118496e-01,
9.921669569649387e-01, 9.912586027088507e-01, 9.905811038723256e-01,
9.901231181863754e-01, 9.898737119947000e-01, 9.898187066647253e-01,
9.899468001787191e-01, 9.902431753677082e-01, 9.906955635514434e-01,
9.912885401035934e-01, 9.920094690635668e-01, 9.928426927501408e-01,
9.937750666306635e-01, 9.947903979828719e-01, 9.958755336221258e-01,
9.970143670156726e-01, 9.981928706842119e-01, 9.993945064762333e-01,
1.000605860368296e+00, 1.001810400944408e+00, 1.002994573682287e+00,
1.004141548053574e+00, 1.005236884099094e+00, 1.006263925890636e+00,
1.007208903587772e+00, 1.008054893814649e+00, 1.008788016348394e+00,
1.009391822060050e+00, 1.009852958217732e+00, 1.010155293011166e+00,
1.010286018304889e+00, 1.010229878703309e+00, 1.009975407736885e+00,
1.009508455280294e+00, 1.008818483155921e+00, 1.007894884001199e+00,
1.006728757854175e+00, 1.005309913983530e+00, 1.003634560818982e+00,
1.001693634792953e+00, 9.994856628696702e-01, 9.970063702291652e-01,
9.942546868773952e-01, 9.912319673936767e-01, 9.879371153343368e-01,
9.843751246861034e-01, 9.798909633127684e-01, 9.752698788428587e-01,
9.701804980040253e-01, 9.645800268203278e-01, 9.584255335155275e-01,
9.516840138455831e-01, 9.443202322315050e-01, 9.362906241698766e-01,
9.275805069442316e-01, 9.181534137230351e-01, 9.079765240138057e-01,
8.970500584793123e-01, 8.853513603848177e-01, 8.728579265043998e-01,
8.595798186504622e-01, 8.455026150386550e-01, 8.306199433014801e-01,
8.149466481575340e-01, 7.984893775294407e-01, 7.812624496601451e-01,
7.632917692550881e-01, 7.445908434203883e-01, 7.251992870809165e-01,
7.051536683608545e-01, 6.844905446038185e-01, 6.632452099313783e-01,
6.414771616618185e-01, 6.192353336355413e-01, 5.965591325427860e-01,
5.735199893648143e-01, 5.501738510234542e-01, 5.265685382300127e-01,
5.027811586638018e-01, 4.788608890561979e-01, 4.548778943490807e-01,
4.308981228989757e-01, 4.069939642056274e-01, 3.832340305827807e-01,
3.596800983344559e-01, 3.364081000913040e-01, 3.134964181526467e-01,
2.910105654938709e-01, 2.690195851087463e-01, 2.475843475618672e-01,
2.267884333851992e-01, 2.066777706538489e-01, 1.873103432384193e-01,
1.687396441250691e-01, 1.510123820588979e-01, 1.341718422797088e-01,
1.182546623256353e-01, 1.032907339774596e-01, 8.931173602725516e-02,
7.634297866041775e-02, 6.440772914585903e-02, 5.352437147393933e-02,
4.370844528199230e-02, 3.496670991534089e-02, 2.729846292648297e-02,
2.068958080348781e-02, 1.511251252352759e-02, 1.052287538118900e-02,
6.855473143120779e-03, 4.023511190940974e-03, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
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0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
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0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00,
0.000000000000000e+00, 0.000000000000000e+00, 0.000000000000000e+00};
```

3.7.3.2.3 $w_{7.5\_180}$

```
double w_N180[360] = {
1.970849076512990e-03, 2.950608593187313e-03, 4.124477213467950e-03,
5.526886639437362e-03, 7.175411316438510e-03, 9.087577304291669e-03,
1.128191051703656e-02, 1.376953735371754e-02, 1.656002661605294e-02,
1.966508945492317e-02, 2.309535564877266e-02, 2.686128938982976e-02,
3.096325597431720e-02, 3.540362298325999e-02, 4.019156101100901e-02,
4.533314033337320e-02, 5.082893035710152e-02, 5.668154478534839e-02,
6.289353044640154e-02, 6.946962925951473e-02, 7.641063136809326e-02,
8.371600156519982e-02, 9.138842778133426e-02, 9.942940076792395e-02,
1.078347249723074e-01, 1.166045748296231e-01, 1.257365027864348e-01,
1.352268113395951e-01, 1.450735459839195e-01, 1.552738186648721e-01,
1.658221942341435e-01, 1.767111740534608e-01, 1.879287758848813e-01,
1.994731798188807e-01, 2.113429529554800e-01, 2.235245540318082e-01,
2.360030996517997e-01, 2.487686144599148e-01, 2.618138107489893e-01,
2.751291608544314e-01, 2.887011017469859e-01, 3.025140336309949e-01,
3.165588052366450e-01, 3.308238711499938e-01, 3.452955666730954e-01,
3.599639915662127e-01, 3.748145444067251e-01, 3.898318165532388e-01,
4.050010096015846e-01, 4.203080130472308e-01, 4.357395152859960e-01,
4.512778173547499e-01, 4.669049179648736e-01, 4.826090405673480e-01,
4.983754662664123e-01, 5.141853413578332e-01, 5.300214783136831e-01,
5.458693517886994e-01, 5.617100406669413e-01, 5.775281514417204e-01,
5.933046964262578e-01, 6.090263461524341e-01, 6.246741889386914e-01,
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3.7.4 SNS quantization

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-2.186107070099790e+00, -1.971521356752276e+00, -1.787186196810059e+00,
-1.918658956855768e+00, -1.793991218365963e+00, -1.357384042572884e+00,
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+8.300458594009102e-01, -2.755691738882634e-02,

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+2.195268374585677e+00, +2.026596138366193e+00,

+2.463757462771289e-01, +9.556217733930993e-01, +1.520467767417663e+00,
+1.976474004194571e+00, +1.940438671774617e+00, +2.233758472826862e+00,
+1.988359777584072e+00, +1.272326725547010e+00
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double HFCB[32][8] = {
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+1.343273586282854e+00, +8.229788368559223e-01, +2.158767985156789e-01,
-4.049257530802925e-01, -1.070256058705229e+00,

-8.262659539826793e-01, -6.711812327666034e-01, -2.284955927794715e-01,
+5.189808525519373e-01, +1.367218963402784e+00, +2.180230382530922e+00,
+2.535960927501071e+00, +2.201210988600361e+00,

+1.410083268321729e+00, +7.544419078354684e-01, -1.305505849586310e+00,
-1.871337113509707e+00, -1.240086851563054e+00, -1.267129248662737e+00,
-2.036708130039070e+00, -2.896851622423807e+00,

+3.613868175743476e-01, -2.199917054278258e-02, -5.793688336338242e-01,
-8.794279609410701e-01, -8.506850234081188e-01, -7.793970501558157e-01,
-7.321829272918255e-01, -8.883485148212548e-01,

+4.374692393303287e-01, +3.054404196059607e-01, -7.387865664783739e-03,
-4.956498547102520e-01, -8.066512711183929e-01, -1.224318919844005e+00,
-1.701577700431810e+00, -2.244919137556108e+00,

+6.481003189965029e-01, +6.822991336406795e-01, +2.532474643329756e-01,
+7.358421437884688e-02, +3.142167093890103e-01, +2.347298809236790e-01,
+1.446001344798368e-01, -6.821201788801744e-02,

+1.119198330913041e+00, +1.234655325360046e+00, +5.891702380853181e-01,
-1.371924596531664e+00, -2.370957072415767e+00, -2.007797826823599e+00,
-1.666885402243946e+00, -1.926318462584058e+00,

+1.418474970871759e-01, -1.106600706331509e-01, -2.828245925436287e-01,
-6.598134746141936e-03, +2.859292796272158e-01, +4.604455299529710e-02,
-6.025964155778858e-01, -2.265687286325748e+00,

+5.040469553902519e-01, +8.269821629590972e-01, +1.119812362918282e+00,
+1.179140443327336e+00, +1.079874291972597e+00, +6.975362390675000e-01,
-9.125488173710808e-01, -3.576847470627726e+00,

-5.010760504793567e-01, -3.256780060814170e-01, +2.807981949470768e-02,
+2.620545547631326e-01, +3.605908060857668e-01, +6.356237220536995e-01,
+9.590124671781544e-01, +1.307451566886533e+00,

+3.749709827096420e+00, +1.523426118470452e+00, -4.577156618978547e-01,
-7.987110082431923e-01, -3.868193293091003e-01, -3.759010622312032e-01,
-6.578368999305377e-01, -1.281639642436027e+00,

-1.152589909805491e+00, -1.108008859062412e+00, -5.626151165124718e-01,
-2.205621237656746e-01, -3.498428803366437e-01, -7.534327702504950e-01,
-9.885965933963837e-01, -1.287904717914711e+00,

+1.028272464221398e+00, +1.097705193898282e+00, +7.686455457647760e-01,
+2.060819777407656e-01, -3.428057350919982e-01, -7.549394046253397e-01,
-1.041961776319998e+00, -1.503356529555287e+00,

+1.288319717078174e-01, +6.894393952648783e-01, +1.123469050095749e+00,
+1.309345231065936e+00, +1.355119647139345e+00, +1.423113814707990e+00,
+1.157064491909045e+00, +4.063194375168383e-01,

+1.340330303347565e+00, +1.389968250677893e+00, +1.044679217088833e+00,
```

```
+6.358227462443666e-01, -2.747337555184823e-01, -1.549233724306950e+00,
-2.442397102780069e+00, -3.024576069445502e+00,

+2.138431054193125e+00, +4.247112673031041e+00, +2.897341098304393e+00,
+9.327306580268148e-01, -2.928222497298096e-01, -8.104042968531823e-01,
-7.888680987564828e-01, -9.353531487613377e-01,

+5.648304873553961e-01, +1.591849779587432e+00, +2.397716990151462e+00,
+3.036973436007040e+00, +2.664243503371508e+00, +1.393044850326060e+00,
+4.038340235957454e-01, -6.562709713281135e-01,

-4.224605475860865e-01, +3.261496250498011e-01, +1.391713133422612e+00,
+2.231466146364735e+00, +2.611794421696881e+00, +2.665403401965702e+00,
+2.401035541057067e+00, +1.759203796708810e+00
}
```

```
double sns_vq_reg_adj_gains[2]    =
{8915.0,12054.0}/4096.0;
double sns_vq_reg_lf_adj_gains[4] =
{6245.0,15043.0,17861.0,21014.0}/4096.0;
double sns_vq_near_adj_gains[4]   =
{7099.0,9132.0,11253.0,14808.0}/4096.0;
double sns_vq_far_adj_gains[8]    =
{4336.0,5067.0,5895.0,8149.0,10235.0,12825.0,16868.0,19882.0}/4096.0;

int   sns_gainMSBbits[4]={1,1,2,2};
int   sns_gainLSBbits[4]={0,1,0,1};

unsigned int MPVQ_offsets[16][1+10]= {
/* k=0, k=1, k=2,...                , k=10 */
0,1,1,1,1,1,1,1,1,1,1,                                        /* n=0*/
0,1,3,5,7,9,11,13,15,17,19,                                   /* n=1*/
0,1,5,13,25,41,61,85,113,145,181,
0,1,7,25,63,129,231,377,575,833,1159,
0,1,9,41,129,321,681,1289,2241,3649,5641,
0,1,11,61,231,681,1683,3653,7183,13073,22363,
0,1,13,85,377,1289,3653,8989,19825,40081,75517,
0,1,15,113,575,2241,7183,19825,48639,108545,224143,
0,1,17,145,833,3649,13073,40081,108545,265729,598417,
0,1,19,181,1159,5641,22363,75517,224143,598417,1462563,
0,1,21,221,1561,8361,36365,134245,433905,1256465,3317445,
0,1,23,265,2047,11969,56695,227305,795455,2485825,7059735,
0,1,25,313,2625,16641,85305,369305,1392065,4673345,14218905,
0,1,27,365,3303,22569,124515,579125,2340495,8405905,27298155,
0,1,29,421,4089,29961,177045,880685,3800305,14546705,50250765,   /* n=14*/
0,1,31,481,4991,39041,246047,1303777,5984767,24331777,89129247,  /* n=15*/
}

double D[16][16] = {
/* D is a rotation matrix                                        */
/* D consists of the base vectors of the DCT (orthogonalized DCT-II)*/
/* (the DCT base vector are stored in column-wise in this table)    */
```

```
/* first row results in the first coeff in fwd synthesis (dec+(enc))*/
/* first column results in the first coeff in the analysis(encoder) */
+2.500000000000000e-01, +3.518509343815957e-01, +3.467599613305369e-01,
+3.383295002935882e-01, +3.266407412190941e-01, +3.118062532466678e-01,
+2.939689006048397e-01, +2.733004667504394e-01, +2.500000000000001e-01,
+2.242918965856591e-01, +1.964237395967756e-01, +1.666639146194367e-01,
+1.352990250365493e-01, +1.026311318805893e-01, +6.897484482073578e-02,
+3.465429229977293e-02,

+2.500000000000000e-01, +3.383295002935882e-01, +2.939689006048397e-01,
+2.242918965856591e-01, +1.352990250365493e-01, +3.465429229977286e-02,
-6.897484482073579e-02, -1.666639146194366e-01, -2.500000000000001e-01,
-3.118062532466678e-01, -3.467599613305369e-01, -3.518509343815956e-01,
-3.266407412190941e-01, -2.733004667504394e-01, -1.964237395967756e-01,
-1.026311318805893e-01,

+2.500000000000000e-01, +3.118062532466678e-01, +1.964237395967756e-01,
+3.465429229977286e-02, -1.352990250365493e-01, -2.733004667504394e-01,
-3.467599613305369e-01, -3.383295002935882e-01, -2.500000000000001e-01,
-1.026311318805894e-01, +6.897484482073574e-02, +2.242918965856590e-01,
+3.266407412190941e-01, +3.518509343815957e-01, +2.939689006048397e-01,
+1.666639146194367e-01,

+2.500000000000000e-01, +2.733004667504394e-01, +6.897484482073575e-02,
-1.666639146194366e-01, -3.266407412190941e-01, -3.383295002935882e-01,
-1.964237395967755e-01, +3.465429229977288e-02, +2.500000000000001e-01,
+3.518509343815957e-01, +2.939689006048397e-01, +1.026311318805893e-01,
-1.352990250365493e-01, -3.118062532466679e-01, -3.467599613305369e-01,
-2.242918965856590e-01,

+2.500000000000000e-01, +2.242918965856591e-01, -6.897484482073575e-02,
-3.118062532466678e-01, -3.266407412190941e-01, -1.026311318805894e-01,
+1.964237395967755e-01, +3.518509343815957e-01, +2.500000000000001e-01,
-3.465429229977282e-02, -2.939689006048397e-01, -3.383295002935882e-01,
-1.352990250365493e-01, +1.666639146194367e-01, +3.467599613305369e-01,
+2.733004667504394e-01,

+2.500000000000000e-01, +1.666639146194366e-01, -1.964237395967756e-01,
-3.518509343815956e-01, -1.352990250365493e-01, +2.242918965856591e-01,
+3.467599613305369e-01, +1.026311318805894e-01, -2.500000000000001e-01,
-3.383295002935882e-01, -6.897484482073574e-02, +2.733004667504394e-01,
+3.266407412190941e-01, +3.465429229977289e-02, -2.939689006048397e-01,
-3.118062532466677e-01,

+2.500000000000000e-01, +1.026311318805894e-01, -2.939689006048397e-01,
-2.733004667504393e-01, +1.352990250365493e-01, +3.518509343815957e-01,
+6.897484482073579e-02, -3.118062532466678e-01, -2.500000000000001e-01,
+1.666639146194366e-01, +3.467599613305369e-01, +3.465429229977293e-02,
-3.266407412190941e-01, -2.242918965856591e-01, +1.964237395967756e-01,
+3.383295002935882e-01,

+2.500000000000000e-01, +3.465429229977287e-02, -3.467599613305369e-01,
-1.026311318805893e-01, +3.266407412190941e-01, +1.666639146194366e-01,
-2.939689006048397e-01, -2.242918965856591e-01, +2.500000000000001e-01,
+2.733004667504393e-01, -1.964237395967756e-01, -3.118062532466678e-01,
```

```
+1.352990250365493e-01, +3.383295002935882e-01, -6.897484482073578e-02,
-3.518509343815956e-01,

+2.500000000000000e-01, -3.465429229977287e-02, -3.467599613305369e-01,
+1.026311318805893e-01, +3.266407412190941e-01, -1.666639146194366e-01,
-2.939689006048397e-01, +2.242918965856591e-01, +2.500000000000001e-01,
-2.733004667504393e-01, -1.964237395967756e-01, +3.118062532466678e-01,
+1.352990250365493e-01, -3.383295002935882e-01, -6.897484482073578e-02,
+3.518509343815956e-01,

+2.500000000000000e-01, -1.026311318805894e-01, -2.939689006048397e-01,
+2.733004667504393e-01, +1.352990250365493e-01, -3.518509343815957e-01,
+6.897484482073579e-02, +3.118062532466678e-01, -2.500000000000001e-01,
-1.666639146194366e-01, +3.467599613305369e-01, -3.465429229977293e-02,
-3.266407412190941e-01, +2.242918965856591e-01, +1.964237395967756e-01,
-3.383295002935882e-01,

+2.500000000000000e-01, -1.666639146194366e-01, -1.964237395967756e-01,
+3.518509343815956e-01, -1.352990250365493e-01, -2.242918965856591e-01,
+3.467599613305369e-01, -1.026311318805894e-01, -2.500000000000001e-01,
+3.383295002935882e-01, -6.897484482073574e-02, -2.733004667504394e-01,
+3.266407412190941e-01, -3.465429229977289e-02, -2.939689006048397e-01,
+3.118062532466677e-01,

+2.500000000000000e-01, -2.242918965856591e-01, -6.897484482073575e-02,
+3.118062532466678e-01, -3.266407412190941e-01, +1.026311318805894e-01,
+1.964237395967755e-01, -3.518509343815957e-01, +2.500000000000001e-01,
+3.465429229977282e-02, -2.939689006048397e-01, +3.383295002935882e-01,
-1.352990250365493e-01, -1.666639146194367e-01, +3.467599613305369e-01,
-2.733004667504394e-01,

+2.500000000000000e-01, -2.733004667504394e-01, +6.897484482073575e-02,
+1.666639146194366e-01, -3.266407412190941e-01, +3.383295002935882e-01,
-1.964237395967755e-01, -3.465429229977288e-02, +2.500000000000001e-01,
-3.518509343815957e-01, +2.939689006048397e-01, -1.026311318805893e-01,
-1.352990250365493e-01, +3.118062532466679e-01, -3.467599613305369e-01,
+2.242918965856590e-01,

+2.500000000000000e-01, -3.118062532466678e-01, +1.964237395967756e-01,
-3.465429229977286e-02, -1.352990250365493e-01, +2.733004667504394e-01,
-3.467599613305369e-01, +3.383295002935882e-01, -2.500000000000001e-01,
+1.026311318805894e-01, +6.897484482073574e-02, -2.242918965856590e-01,
+3.266407412190941e-01, -3.518509343815957e-01, +2.939689006048397e-01,
-1.666639146194367e-01,

+2.500000000000000e-01, -3.383295002935882e-01, +2.939689006048397e-01,
-2.242918965856591e-01, +1.352990250365493e-01, -3.465429229977286e-02,
-6.897484482073579e-02, +1.666639146194366e-01, -2.500000000000001e-01,
+3.118062532466678e-01, -3.467599613305369e-01, +3.518509343815956e-01,
-3.266407412190941e-01, +2.733004667504394e-01, -1.964237395967756e-01,
+1.026311318805893e-01,

+2.500000000000000e-01, -3.518509343815957e-01, +3.467599613305369e-01,
-3.383295002935882e-01, +3.266407412190941e-01, -3.118062532466678e-01,
+2.939689006048397e-01, -2.733004667504394e-01, +2.500000000000001e-01,
-2.242918965856591e-01, +1.964237395967756e-01, -1.666639146194367e-01,
```

```
+1.352990250365493e-01, -1.026311318805893e-01, +6.897484482073578e-02,
-3.465429229977293e-02 };
```

3.7.5 Temporal noise shaping

```
short ac_tns_order_bits[2][8] =
{{17234,13988,11216,8694,6566,4977,3961,3040},
{12683,9437,6874,5541,5121,5170,5359,5056}};

short ac_tns_order_freq[2][8] = {{3,9,23,54,111,190,268,366},
{14,42,100,157,181,178,167,185}};

short ac_tns_order_cumfreq[2][8] = {{0,3,12,35,89,200,390,658},
{0,14,56,156,313,494,672,839}};

short ac_tns_coef_bits[8][17] =
{{20480,15725,12479,10334,8694,7320,6964,6335,5504,5637,6566,6758,8433,11348,
15186,20480,20480},
{20480,20480,20480,20480,12902,9368,7057,5901,5254,5485,5598,6076,7608,10742,
15186,20480,20480},
{20480,20480,20480,20480,13988,9368,6702,4841,4585,4682,5859,7764,12109,20480
,20480,20480,20480},
{20480,20480,20480,20480,18432,13396,8982,4767,3779,3658,6335,9656,13988,2048
0,20480,20480,20480},
{20480,20480,20480,20480,20480,14731,9437,4275,3249,3493,8483,13988,17234,204
80,20480,20480,20480},
{20480,20480,20480,20480,20480,20480,12902,4753,3040,2953,9105,15725,20480,20
480,20480,20480,20480},
{20480,20480,20480,20480,20480,20480,12902,3821,3346,3000,12109,20480,20480,2
0480,20480,20480,20480},
{20480,20480,20480,20480,20480,20480,15725,3658,20480,1201,10854,18432,20480,
20480,20480,20480,20480}};

short ac_tns_coef_freq[8][17] =
{{1,5,15,31,54,86,97,120,159,152,111,104,59,22,6,1,1},
{1,1,1,1,13,43,94,139,173,160,154,131,78,27,6,1,1},
{1,1,1,1,9,43,106,199,217,210,141,74,17,1,1,1,1},
{1,1,1,1,2,11,49,204,285,297,120,39,9,1,1,1,1},
{1,1,1,1,1,7,42,241,341,314,58,9,3,1,1,1,1},
{1,1,1,1,1,1,13,205,366,377,47,5,1,1,1,1,1},
{1,1,1,1,1,1,13,281,330,371,17,1,1,1,1,1,1},
{1,1,1,1,1,1,5,297,1,682,26,2,1,1,1,1,1}};

short ac_tns_coef_cumfreq[8][17] =
{{0,1,6,21,52,106,192,289,409,568,720,831,935,994,1016,1022,1023},
{0,1,2,3,4,17,60,154,293,466,626,780,911,989,1016,1022,1023},
{0,1,2,3,4,13,56,162,361,578,788,929,1003,1020,1021,1022,1023},
{0,1,2,3,4,6,17,66,270,555,852,972,1011,1020,1021,1022,1023},
{0,1,2,3,4,5,12,54,295,636,950,1008,1017,1020,1021,1022,1023},
{0,1,2,3,4,5,6,19,224,590,967,1014,1019,1020,1021,1022,1023},
{0,1,2,3,4,5,6,19,300,630,1001,1018,1019,1020,1021,1022,1023},
{0,1,2,3,4,5,6,11,308,309,991,1017,1019,1020,1021,1022,1023}};
```

3.7.6 Long Term Postfiltering

```
double tab_resamp_filter[239] = {
-2.043055832879108e-05, -4.463458936757081e-05, -7.163663994481459e-05,
-1.001011132655914e-04, -1.283728480660395e-04, -1.545438297704662e-04,
-1.765445671257668e-04, -1.922569599584802e-04, -1.996438192500382e-04,
-1.968886856400547e-04, -1.825383318834690e-04, -1.556394266046803e-04,
-1.158603651792638e-04, -6.358930335348977e-05, +2.810064795067786e-19,
+7.292180213001337e-05, +1.523970757644272e-04, +2.349207769898906e-04,
+3.163786496265269e-04, +3.922117380894736e-04, +4.576238491064392e-04,
+5.078242936704864e-04, +5.382955231045915e-04, +5.450729176175875e-04,
+5.250221548270982e-04, +4.760984242947349e-04, +3.975713799264791e-04,
+2.902002172907180e-04, +1.563446669975615e-04, -5.818801416923580e-19,
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+3.922117380894736e-04, +3.163786496265269e-04, +2.349207769898906e-04,
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-1.825383318834690e-04, -1.968886856400547e-04, -1.996438192500382e-04,
-1.922569599584802e-04, -1.765445671257668e-04, -1.545438297704662e-04,
-1.283728480660395e-04, -1.001011132655914e-04, -7.163663994481459e-05,
-4.463458936757081e-05, -2.043055832879108e-05};

double tab_ltpf_interp_R[31] = {
-2.874561161519444e-03, -3.001251025861499e-03, +2.745471654059321e-03
+1.535727698935322e-02, +2.868234046665657e-02, +2.950385026557377e-02
+4.598334491135473e-03, -4.729632459043440e-02, -1.058359163062837e-01
-1.303050213607112e-01, -7.544046357555201e-02, +8.357885725250529e-02
+3.301825710764459e-01, +6.032970076366158e-01, +8.174886856243178e-01
+8.986382851273982e-01, +8.174886856243178e-01, +6.032970076366158e-01
+3.301825710764459e-01, +8.357885725250529e-02, -7.544046357555201e-02
-1.303050213607112e-01, -1.058359163062837e-01, -4.729632459043440e-02
+4.598334491135473e-03, +2.950385026557377e-02, +2.868234046665657e-02
+1.535727698935322e-02, +2.745471654059321e-03, -3.001251025861499e-03
-2.874561161519444e-03};

double tab_ltpf_interp_x12k8[15] = {
+6.698858366939680e-03, +3.967114782344967e-02, +1.069991860896389e-01
+2.098804630681809e-01, +3.356906254147840e-01, +4.592209296082350e-01
+5.500750019177116e-01, +5.835275754221211e-01, +5.500750019177116e-01
+4.592209296082350e-01, +3.356906254147840e-01, +2.098804630681809e-01
+1.069991860896389e-01, +3.967114782344967e-02, +6.698858366939680e-03};

double tab_ltpf_num_8000[4][3] = {
{6.023618207009578e-01,4.197609261363617e-01,-1.883424527883687e-02},
{5.994768582584314e-01,4.197609261363620e-01,-1.594928283631041e-02},
{5.967764663733787e-01,4.197609261363617e-01,-1.324889095125780e-02},
{5.942410120098895e-01,4.197609261363618e-01,-1.071343658776831e-02}};

double tab_ltpf_num_16000[4][3] = {
{6.023618207009578e-01,4.197609261363617e-01,-1.883424527883687e-02},
```

```
{5.994768582584314e-01,4.197609261363620e-01,-1.594928283631041e-02},
{5.967764663733787e-01,4.197609261363617e-01,-1.324889095125780e-02},
{5.942410120098895e-01,4.197609261363618e-01,-1.071343658776831e-02}};

double tab_ltpf_num_24000[4][5] = {
{3.989695588963494e-01,5.142508607708275e-01,1.004382966157454e-01,-
1.278893956818042e-02,-1.572280075461383e-03},
{3.948634911286333e-01,5.123819208048688e-01,1.043194926386267e-01,-
1.091999960222166e-02,-1.347408330627317e-03},
{3.909844475885914e-01,5.106053522688359e-01,1.079832524685944e-01,-
9.143431066188848e-03,-1.132124620551895e-03},
{3.873093888199928e-01,5.089122083363975e-01,1.114517380217371e-01,-
7.450287133750717e-03,-9.255514050963111e-04}};

double tab_ltpf_num_32000[4][7] = {
{2.982379446702096e-01,4.652809203721290e-01,2.105997428614279e-
01,3.766780380806063e-02,-1.015696155796564e-02,-2.535880996101096e-03,-
3.182946168719958e-04},
{2.943834154510240e-01,4.619294002718798e-01,2.129465770091844e-
01,4.066175002688857e-02,-8.693272297010050e-03,-2.178307114679820e-03,-
2.742888063983188e-04},
{2.907439213122688e-01,4.587461910960279e-01,2.151456974108970e-
01,4.350104772529774e-02,-7.295495347716925e-03,-1.834395637237086e-03,-
2.316920186482416e-04},
{2.872975852589158e-01,4.557148886861379e-01,2.172126950911401e-
01,4.620088878229615e-02,-5.957463802125952e-03,-1.502934284345198e-03,-
1.903851911308866e-04}};

double tab_ltpf_num_48000[4][11] = {
{1.981363739883217e-01,3.524494903964904e-01,2.513695269649414e-
01,1.424146237314458e-01,5.704731023952599e-02,9.293366241586384e-03,-
7.226025368953745e-03,-3.172679890356356e-03,-1.121835963567014e-03,-
2.902957238400140e-04,-4.270815593769240e-05},
{1.950709426598375e-01,3.484660408341632e-01,2.509988459466574e-
01,1.441167412482088e-01,5.928947317677285e-02,1.108923827452231e-02,-
6.192908108653504e-03,-2.726705509251737e-03,-9.667125826217151e-04,-
2.508100923165204e-04,-3.699938766131869e-05},
{1.921810055196015e-01,3.446945561091513e-01,2.506220094626024e-
01,1.457102447664837e-01,6.141132133664525e-02,1.279941396562798e-02,-
5.203721087886321e-03,-2.297324511109085e-03,-8.165608133217555e-04,-
2.123855748277408e-04,-3.141271330981649e-05},
{1.894485314175868e-01,3.411139251108252e-01,2.502406876894361e-
01,1.472065631098081e-01,6.342477229539051e-02,1.443203434150312e-02,-
4.254449144657098e-03,-1.883081472613493e-03,-6.709619060722140e-04,-
1.749363341966872e-04,-2.593864735284285e-05}};

double tab_ltpf_den_8000[4][5] = {
{0.000000000000000e+00, 2.098804630681809e-01, 5.835275754221211e-01,
2.098804630681809e-01, 0.000000000000000e+00},
{0.000000000000000e+00, 1.069991860896389e-01, 5.500750019177116e-01,
3.356906254147840e-01, 6.698858366939680e-03},
{0.000000000000000e+00, 3.967114782344967e-02, 4.592209296082350e-01,
4.592209296082350e-01, 3.967114782344967e-02},
{0.000000000000000e+00, 6.698858366939680e-03, 3.356906254147840e-01,
5.500750019177116e-01, 1.069991860896389e-01}};
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```
double tab_ltpf_den_16000[4][5] = {
{0.000000000000000e+00, 2.098804630681809e-01, 5.835275754221211e-01,
2.098804630681809e-01, 0.000000000000000e+00},
{0.000000000000000e+00, 1.069991860896389e-01, 5.500750019177116e-01,
3.356906254147840e-01, 6.698858366939680e-03},
{0.000000000000000e+00, 3.967114782344967e-02, 4.592209296082350e-01,
4.592209296082350e-01, 3.967114782344967e-02},
{0.000000000000000e+00, 6.698858366939680e-03, 3.356906254147840e-01,
5.500750019177116e-01, 1.069991860896389e-01}};

double tab_ltpf_den_24000[4][7] = {
{0.000000000000000e+00, 6.322231627323796e-02, 2.507309606013235e-01,
3.713909428901578e-01, 2.507309606013235e-01, 6.322231627323796e-02,
0.000000000000000e+00},
{0.000000000000000e+00, 3.459272174099855e-02, 1.986515602645028e-01,
3.626411726581452e-01, 2.986750548992179e-01, 1.013092873505928e-01,
4.263543712369752e-03},
{0.000000000000000e+00, 1.535746784963907e-02, 1.474344878058222e-01,
3.374259553990717e-01, 3.374259553990717e-01, 1.474344878058222e-01,
1.535746784963907e-02},
{0.000000000000000e+00, 4.263543712369752e-03, 1.013092873505928e-01,
2.986750548992179e-01, 3.626411726581452e-01, 1.986515602645028e-01,
3.459272174099855e-02}};

double tab_ltpf_den_32000[4][9] = {
{0.000000000000000e+00, 2.900401878228730e-02, 1.129857420560927e-01,
2.212024028097570e-01, 2.723909472446145e-01, 2.212024028097570e-01,
1.129857420560927e-01, 2.900401878228730e-02, 0.000000000000000e+00},
{0.000000000000000e+00, 1.703153418385261e-02, 8.722503785537784e-02,
1.961407762232199e-01, 2.689237982237257e-01, 2.424999102756389e-01,
1.405773364650031e-01, 4.474877169485788e-02, 3.127030243100724e-03},
{0.000000000000000e+00, 8.563673748488349e-03, 6.426222944493845e-02,
1.687676705918012e-01, 2.587445937795505e-01, 2.587445937795505e-01,
1.687676705918012e-01, 6.426222944493845e-02, 8.563673748488349e-03},
{0.000000000000000e+00, 3.127030243100724e-03, 4.474877169485788e-02,
1.405773364650031e-01, 2.424999102756389e-01, 2.689237982237257e-01,
1.961407762232199e-01, 8.722503785537784e-02, 1.703153418385261e-02}};

double tab_ltpf_den_48000[4][13] = {
{0.000000000000000e+00, 1.082359386659387e-02, 3.608969221303979e-02,
7.676401468099964e-02, 1.241530577501703e-01, 1.627596438300696e-01,
1.776771417779109e-01, 1.627596438300696e-01, 1.241530577501703e-01,
7.676401468099964e-02, 3.608969221303979e-02, 1.082359386659387e-02,
0.000000000000000e+00},
{0.000000000000000e+00, 7.041404930459358e-03, 2.819702319820420e-02,
6.547044935127551e-02, 1.124647986743299e-01, 1.548418956489015e-01,
1.767122381341857e-01, 1.691507213057663e-01, 1.352901577989766e-01,
8.851425011427483e-02, 4.499353848562444e-02, 1.557613714732002e-02,
2.039721956502016e-03},
{0.000000000000000e+00, 4.146998467444788e-03, 2.135757310741917e-02,
5.482735584552816e-02, 1.004971444643720e-01, 1.456060342830002e-01,
1.738439838565869e-01, 1.738439838565869e-01, 1.456060342830002e-01,
1.004971444643720e-01, 5.482735584552816e-02, 2.135757310741917e-02,
4.146998467444788e-03},
{0.000000000000000e+00, 2.039721956502016e-03, 1.557613714732002e-02,
4.499353848562444e-02, 8.851425011427483e-02, 1.352901577989766e-01,
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1.691507213057663e-01, 1.767122381341857e-01, 1.548418956489015e-01,
1.124647986743299e-01, 6.547044935127551e-02, 2.819702319820420e-02,
7.041404930459358e-03}};
```

3.7.7 Spectral data

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unsigned char ac_spec_lookup[4096] =
{
0x01,0x27,0x07,0x19,0x16,0x16,0x1C,0x16,
0x16,0x16,0x16,0x1C,0x1C,0x1C,0x22,0x1F,
0x1F,0x28,0x2B,0x2E,0x31,0x34,0x0E,0x11,
0x24,0x24,0x24,0x26,0x00,0x39,0x26,0x16,
0x00,0x08,0x09,0x0B,0x2F,0x0E,0x0E,0x11,
0x24,0x24,0x24,0x26,0x3B,0x3B,0x26,0x16,
0x16,0x1A,0x2E,0x1D,0x1E,0x20,0x21,0x23,
0x24,0x24,0x24,0x26,0x00,0x3B,0x17,0x16,
0x2E,0x2E,0x2D,0x2F,0x30,0x32,0x32,0x12,
0x36,0x36,0x36,0x26,0x3B,0x3B,0x3B,0x16,
0x00,0x3E,0x3F,0x03,0x21,0x02,0x02,0x3D,
0x14,0x14,0x14,0x15,0x3B,0x3B,0x27,0x1C,
0x1C,0x3F,0x3F,0x03,0x21,0x02,0x02,0x3D,
0x26,0x26,0x26,0x15,0x3B,0x3B,0x27,0x1C,
0x1C,0x06,0x06,0x06,0x02,0x12,0x3D,0x14,
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0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,
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0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,
0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00
};

short ac_spec_cumfreq[64][17] = {
{    0,    1,    2,  177,  225,  226,  227,  336,  372,  543,  652,  699,
719,  768,  804,  824,  834 },
{    0,   18,   44,   61,   71,   98,  135,  159,  175,  197,  229,  251,
265,  282,  308,  328,  341 },
{    0,   71,  163,  212,  237,  318,  420,  481,  514,  556,  613,  652,
675,  697,  727,  749,  764 },
{    0,  160,  290,  336,  354,  475,  598,  653,  677,  722,  777,  808,
823,  842,  866,  881,  890 },
{    0,   71,  144,  177,  195,  266,  342,  385,  411,  445,  489,  519,
539,  559,  586,  607,  622 },
{    0,   48,  108,  140,  159,  217,  285,  327,  354,  385,  427,  457,
478,  497,  524,  545,  561 },
{    0,  138,  247,  290,  308,  419,  531,  584,  609,  655,  710,  742,
759,  780,  807,  825,  836 },
{    0,   16,   40,   62,   79,  103,  139,  170,  195,  215,  245,  270,
290,  305,  327,  346,  362 },
{    0,  579,  729,  741,  743,  897,  970,  980,  982,  996, 1007, 1010,
1011, 1014, 1017, 1018, 1019 },
{    0,  398,  582,  607,  612,  788,  902,  925,  931,  956,  979,  987,
990,  996, 1002, 1005, 1007 },
{    0,   13,   34,   52,   63,   83,  112,  134,  149,  163,  183,  199,
211,  221,  235,  247,  257 },
{    0,  281,  464,  501,  510,  681,  820,  857,  867,  902,  938,  953,
959,  968,  978,  984,  987 },
{    0,  198,  362,  408,  421,  575,  722,  773,  789,  832,  881,  905,
915,  928,  944,  954,  959 },
{    0,    1,    2,   95,  139,  140,  141,  213,  251,  337,  407,  450,
475,  515,  551,  576,  592 },
{    0,  133,  274,  338,  366,  483,  605,  664,  691,  730,  778,  807,
822,  837,  857,  870,  878 },
{    0,  128,  253,  302,  320,  443,  577,  636,  659,  708,  767,  799,
814,  833,  857,  872,  881 },
{    0,    1,    2,   25,   42,   43,   44,   67,   85,  105,  126,  144,
159,  174,  191,  205,  217 },
{    0,   70,  166,  229,  267,  356,  468,  533,  569,  606,  653,  685,
705,  722,  745,  762,  774 },
```

```
{     0,   55,  130,  175,  200,  268,  358,  416,  449,  488,  542,  581,
606,  628,  659,  683,  699 },
{     0,    1,    3,    5,    7,    9,   11,   13,   15,   17,   19,   21,
23,   25,   27,   29,   31 },
{     0,   34,   85,  123,  147,  196,  265,  317,  352,  386,  433,  470,
497,  518,  549,  574,  593 },
{     0,   30,   73,  105,  127,  170,  229,  274,  305,  335,  377,  411,
436,  455,  483,  506,  524 },
{     0,    9,   24,   38,   51,   65,   87,  108,  126,  139,  159,  177,
193,  204,  221,  236,  250 },
{     0,   30,   74,  105,  125,  166,  224,  266,  294,  322,  361,  391,
413,  431,  457,  478,  494 },
{     0,   15,   38,   58,   73,   95,  128,  156,  178,  196,  222,  245,
263,  276,  296,  314,  329 },
{     0,   11,   28,   44,   57,   74,  100,  123,  142,  157,  179,  199,
216,  228,  246,  262,  276 },
{     0,  448,  619,  639,  643,  821,  926,  944,  948,  971,  991,  998,
1000, 1005, 1010, 1012, 1013 },
{     0,  332,  520,  549,  555,  741,  874,  903,  910,  940,  970,  981,
985,  991,  998, 1002, 1004 },
{     0,    8,   21,   34,   45,   58,   78,   96,  112,  124,  141,  157,
170,  180,  194,  207,  219 },
{     0,  239,  415,  457,  468,  631,  776,  820,  833,  872,  914,  933,
940,  951,  964,  971,  975 },
{     0,  165,  310,  359,  375,  513,  652,  707,  727,  774,  828,  856,
868,  884,  904,  916,  923 },
{     0,    3,    8,   13,   18,   23,   30,   37,   44,   48,   55,   62,
68,   72,   78,   84,   90 },
{     0,  115,  237,  289,  311,  422,  547,  608,  635,  680,  737,  771,
788,  807,  832,  849,  859 },
{     0,  107,  221,  272,  293,  399,  521,  582,  610,  656,  714,  749,
767,  787,  813,  831,  842 },
{     0,    6,   16,   26,   35,   45,   60,   75,   89,   98,  112,  125,
137,  145,  157,  168,  178 },
{     0,   72,  160,  210,  236,  320,  422,  482,  514,  555,  608,  644,
665,  685,  712,  732,  745 },
{     0,   45,  108,  153,  183,  244,  327,  385,  421,  455,  502,  536,
559,  578,  605,  626,  641 },
{     0,    1,    2,    9,   16,   17,   18,   26,   34,   40,   48,   55,
62,   68,   75,   82,   88 },
{     0,   29,   73,  108,  132,  174,  236,  284,  318,  348,  391,  426,
452,  471,  500,  524,  543 },
{     0,   20,   51,   76,   93,  123,  166,  200,  225,  247,  279,  305,
326,  342,  365,  385,  401 },
{     0,  742,  845,  850,  851,  959,  997, 1001, 1002, 1009, 1014, 1016,
1017, 1019, 1020, 1021, 1022 },
{     0,   42,   94,  121,  137,  186,  244,  280,  303,  330,  366,  392,
410,  427,  451,  470,  484 },
{     0,   13,   33,   51,   66,   85,  114,  140,  161,  178,  203,  225,
243,  256,  275,  292,  307 },
{     0,  501,  670,  689,  693,  848,  936,  952,  956,  975,  991,  997,
999, 1004, 1008, 1010, 1011 },
{     0,  445,  581,  603,  609,  767,  865,  888,  895,  926,  954,  964,
968,  977,  986,  991,  993 },
{     0,  285,  442,  479,  489,  650,  779,  818,  830,  870,  912,  930,
937,  949,  963,  971,  975 },
```

```
{     0,  349,  528,  561,  569,  731,  852,  883,  892,  923,  953,  965,
970,  978,  987,  992,  994 },
{     0,  199,  355,  402,  417,  563,  700,  750,  767,  811,  860,  884,
894,  909,  926,  936,  942 },
{     0,  141,  275,  325,  343,  471,  606,  664,  686,  734,  791,  822,
836,  854,  877,  891,  899 },
{     0,  243,  437,  493,  510,  649,  775,  820,  836,  869,  905,  923,
931,  941,  953,  960,  964 },
{     0,   91,  197,  248,  271,  370,  487,  550,  580,  625,  684,  721,
741,  761,  788,  807,  819 },
{     0,  107,  201,  242,  262,  354,  451,  503,  531,  573,  626,  660,
680,  701,  730,  751,  765 },
{     0,  168,  339,  407,  432,  553,  676,  731,  755,  789,  830,  854,
866,  879,  895,  906,  912 },
{     0,   67,  147,  191,  214,  290,  384,  441,  472,  513,  567,  604,
627,  648,  678,  700,  715 },
{     0,   46,  109,  148,  171,  229,  307,  359,  391,  427,  476,  513,
537,  558,  588,  612,  629 },
{     0,  848,  918,  920,  921,  996, 1012, 1013, 1014, 1016, 1017, 1018,
1019, 1020, 1021, 1022, 1023 },
{     0,   36,   88,  123,  145,  193,  260,  308,  340,  372,  417,  452,
476,  496,  525,  548,  565 },
{     0,   24,   61,   90,  110,  145,  196,  237,  266,  292,  330,  361,
385,  403,  430,  453,  471 },
{     0,   85,  182,  230,  253,  344,  454,  515,  545,  590,  648,  685,
706,  727,  756,  776,  789 },
{     0,   22,   55,   82,  102,  135,  183,  222,  252,  278,  315,  345,
368,  385,  410,  431,  448 },
{     0,    1,    2,   56,   89,   90,   91,  140,  172,  221,  268,  303,
328,  358,  388,  412,  430 },
{     0,   45,  109,  152,  177,  239,  320,  376,  411,  448,  499,  537,
563,  585,  616,  640,  658 },
{     0,  247,  395,  433,  445,  599,  729,  771,  785,  829,  875,  896,
905,  920,  937,  946,  951 },
{     0,  231,  367,  408,  423,  557,  676,  723,  742,  786,  835,  860,
872,  889,  909,  921,  928 }
};

short ac_spec_freq[64][17] = {
{     1,    1,  175,   48,    1,    1,  109,   36,  171,  109,   47,   20,
49,   36,   20,   10,  190 },
{    18,   26,   17,   10,   27,   37,   24,   16,   22,   32,   22,   14,
17,   26,   20,   13,  683 },
{    71,   92,   49,   25,   81,  102,   61,   33,   42,   57,   39,   23,
22,   30,   22,   15,  260 },
{   160,  130,   46,   18,  121,  123,   55,   24,   45,   55,   31,   15,
19,   24,   15,    9,  134 },
{    71,   73,   33,   18,   71,   76,   43,   26,   34,   44,   30,   20,
20,   27,   21,   15,  402 },
{    48,   60,   32,   19,   58,   68,   42,   27,   31,   42,   30,   21,
19,   27,   21,   16,  463 },
{   138,  109,   43,   18,  111,  112,   53,   25,   46,   55,   32,   17,
21,   27,   18,   11,  188 },
{    16,   24,   22,   17,   24,   36,   31,   25,   20,   30,   25,   20,
15,   22,   19,   16,  662 },
```

```
{   579,  150,   12,    2,  154,   73,   10,    2,   14,   11,    3,    1,
3,    3,    1,    1,    5 },
{   398,  184,   25,    5,  176,  114,   23,    6,   25,   23,    8,    3,
6,    6,    3,    2,   17 },
{    13,   21,   18,   11,   20,   29,   22,   15,   14,   20,   16,   12,
10,   14,   12,   10,  767 },
{   281,  183,   37,    9,  171,  139,   37,   10,   35,   36,   15,    6,
9,   10,    6,    3,   37 },
{   198,  164,   46,   13,  154,  147,   51,   16,   43,   49,   24,   10,
13,   16,   10,    5,   65 },
{     1,    1,   93,   44,    1,    1,   72,   38,   86,   70,   43,   25,
40,   36,   25,   16,  432 },
{   133,  141,   64,   28,  117,  122,   59,   27,   39,   48,   29,   15,
15,   20,   13,    8,  146 },
{   128,  125,   49,   18,  123,  134,   59,   23,   49,   59,   32,   15,
19,   24,   15,    9,  143 },
{     1,    1,   23,   17,    1,    1,   23,   18,   20,   21,   18,   15,
15,   17,   14,   12,  807 },
{    70,   96,   63,   38,   89,  112,   65,   36,   37,   47,   32,   20,
17,   23,   17,   12,  250 },
{    55,   75,   45,   25,   68,   90,   58,   33,   39,   54,   39,   25,
22,   31,   24,   16,  325 },
{     1,    2,    2,    2,    2,    2,    2,    2,    2,    2,    2,    2,
2,    2,    2,    2,  993 },
{    34,   51,   38,   24,   49,   69,   52,   35,   34,   47,   37,   27,
21,   31,   25,   19,  431 },
{    30,   43,   32,   22,   43,   59,   45,   31,   30,   42,   34,   25,
19,   28,   23,   18,  500 },
{     9,   15,   14,   13,   14,   22,   21,   18,   13,   20,   18,   16,
11,   17,   15,   14,  774 },
{    30,   44,   31,   20,   41,   58,   42,   28,   28,   39,   30,   22,
18,   26,   21,   16,  530 },
{    15,   23,   20,   15,   22,   33,   28,   22,   18,   26,   23,   18,
13,   20,   18,   15,  695 },
{    11,   17,   16,   13,   17,   26,   23,   19,   15,   22,   20,   17,
12,   18,   16,   14,  748 },
{   448,  171,   20,    4,  178,  105,   18,    4,   23,   20,    7,    2,
5,    5,    2,    1,   11 },
{   332,  188,   29,    6,  186,  133,   29,    7,   30,   30,   11,    4,
6,    7,    4,    2,   20 },
{     8,   13,   13,   11,   13,   20,   18,   16,   12,   17,   16,   13,
10,   14,   13,   12,  805 },
{   239,  176,   42,   11,  163,  145,   44,   13,   39,   42,   19,    7,
11,   13,    7,    4,   49 },
{   165,  145,   49,   16,  138,  139,   55,   20,   47,   54,   28,   12,
16,   20,   12,    7,  101 },
{     3,    5,    5,    5,    5,    7,    7,    7,    4,    7,    7,    6,
4,    6,    6,    6,  934 },
{   115,  122,   52,   22,  111,  125,   61,   27,   45,   57,   34,   17,
19,   25,   17,   10,  165 },
{   107,  114,   51,   21,  106,  122,   61,   28,   46,   58,   35,   18,
20,   26,   18,   11,  182 },
{     6,   10,   10,    9,   10,   15,   15,   14,    9,   14,   13,   12,
8,   12,   11,   10,  846 },
{    72,   88,   50,   26,   84,  102,   60,   32,   41,   53,   36,   21,
20,   27,   20,   13,  279 },
```

```
{   45,   63,   45,   30,   61,   83,   58,   36,   34,   47,   34,   23,
19,   27,   21,   15,  383 },
{    1,    1,    7,    7,    1,    1,    8,    8,    6,    8,    7,    7,
6,    7,    7,    6,  936 },
{   29,   44,   35,   24,   42,   62,   48,   34,   30,   43,   35,   26,
19,   29,   24,   19,  481 },
{   20,   31,   25,   17,   30,   43,   34,   25,   22,   32,   26,   21,
16,   23,   20,   16,  623 },
{  742,  103,    5,    1,  108,   38,    4,    1,    7,    5,    2,    1,
2,    1,    1,    1,    2 },
{   42,   52,   27,   16,   49,   58,   36,   23,   27,   36,   26,   18,
17,   24,   19,   14,  540 },
{   13,   20,   18,   15,   19,   29,   26,   21,   17,   25,   22,   18,
13,   19,   17,   15,  717 },
{  501,  169,   19,    4,  155,   88,   16,    4,   19,   16,    6,    2,
5,    4,    2,    1,   13 },
{  445,  136,   22,    6,  158,   98,   23,    7,   31,   28,   10,    4,
9,    9,    5,    2,   31 },
{  285,  157,   37,   10,  161,  129,   39,   12,   40,   42,   18,    7,
12,   14,    8,    4,   49 },
{  349,  179,   33,    8,  162,  121,   31,    9,   31,   30,   12,    5,
8,    9,    5,    2,   30 },
{  199,  156,   47,   15,  146,  137,   50,   17,   44,   49,   24,   10,
15,   17,   10,    6,   82 },
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18,   23,   14,    8,  125 },
{  243,  194,   56,   17,  139,  126,   45,   16,   33,   36,   18,    8,
10,   12,    7,    4,   60 },
{   91,  106,   51,   23,   99,  117,   63,   30,   45,   59,   37,   20,
20,   27,   19,   12,  205 },
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21,   29,   21,   14,  259 },
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13,   16,   11,    6,  112 },
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21,   30,   22,   15,  309 },
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18,   27,   23,   18,  553 },
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21,   29,   20,   13,  235 },
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17,   25,   21,   17,  576 },
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30,   30,   24,   18,  594 },
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22,   31,   24,   18,  366 },
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15,   17,    9,    5,   73 },
{  231,  136,   41,   15,  134,  119,   47,   19,   44,   49,   25,   12,
17,   20,   12,    7,   96 }
```

```
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9168,11485,13988,12479,12109,13988,15725, 7804 },
{  4400, 5965, 9508,12479, 6009, 6360, 9105,11781, 9300,
8982,10970,13138,12109,11629,13138,14731, 6994 }
};
```

4 Acronyms and abbreviations

Acronym/Abbreviation	Meaning
ALU	Arithmetic Logic Unit
BEC	Bit Error Condition
BFI	Bad Frame Indication
BW	Bandwidth
DCT	Discrete Cosine Transform
FB	Full Band (20 kHz audio bandwidth)
FIR	Finite Impulse Response
HFCB	High Frequency Code Book (part of SNS VQ)
HQA	High Quality Audio
IDCT	Inverse DCT
IIR	Infinite Impulse Response
LC3	Low Complexity Communication Codec
LD-MDCT	Low Delay Modified Discrete Cosine Transform
LFCB	Low Frequency Code Book (part of SNS VQ)
LPC	Linear Predictive Coding
LSB	Least Significant Bit
LTPF	Long Term Postfilter
MDCT	Modified Discrete Cosine Transform
MPVQ	Modular Pyramid Vector Quantizer index (a partial PVQ index)
MSB	Most Significant Bit
MSE	Mean Square Error
NB	Narrow Band (4 kHz audio bandwidth)
PCM	Pulse Code Modulation
PDU	Protocol Data Unit
PLC	Packet Loss Concealment

Acronym/Abbreviation	Meaning
PVQ	Pyramid Vector Quantizer
SNS	Spectral Noise Shaping
SSWB	Semi Super Wide Band (12 kHz audio bandwidth)
SWB	Super Wide Band (16 kHz audio bandwidth)
TNS	Temporal Noise Shaping
VQ	Vector Quantizer
WB	Wide Band (8 kHz audio bandwidth)

Table 4.1: List of Abbreviations

5 References

[1] LC3 executables: https://www.bluetooth.org/DocMan/DocInfo.aspx?doc_id=497700

Appendix A High-level timing diagram for the LD-MDCT

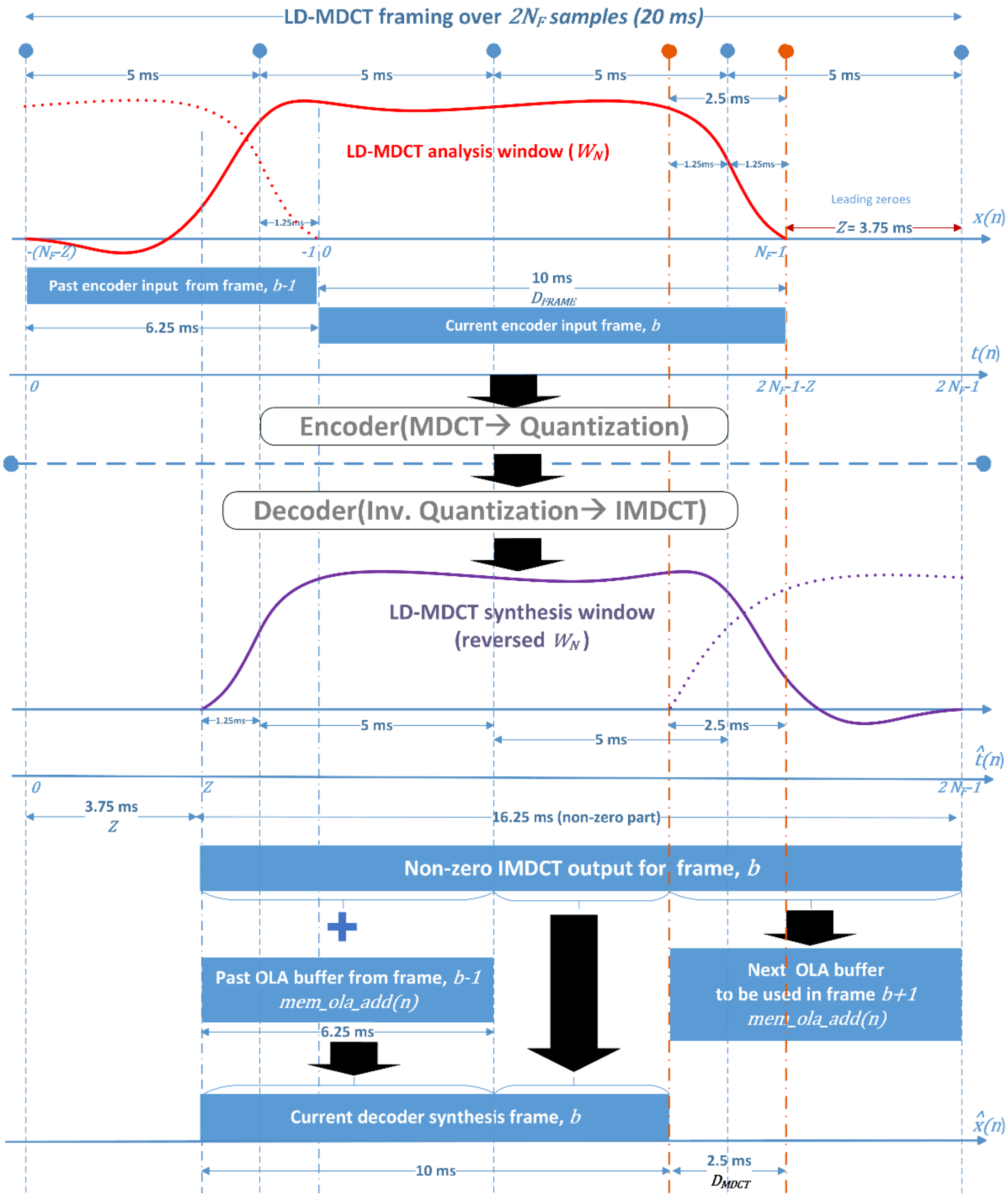

Figure A.1: Low Delay MDCT timing figure for $N_{ms} = 10\ ms$

Appendix B Packet Loss Concealment

B.1 General consideration

The purpose of packet loss concealment (PLC) is to conceal the effect of unavailable or corrupted frame data for decoding.

To deliver satisfactory audio quality under all channel conditions, it is strongly recommended that some form of PLC should be implemented on the receiving ends of audio connections. The example PLC algorithm provided here may be used. The audio quality of this example PLC under typical packet loss conditions is considered satisfactory. If implementations choose to modify or implement an alternate PLC scheme, the performance of any such alternate PLC should meet or exceed the performance of this example PLC.

B.2 Concealment trigger

The decoder should apply a packet loss concealment algorithm for the following two events:

a) The decoder receives an externally determined Bad Frame Indicator (BFI) flag signaling a lost frame or the presence of any detected bit error in the received channel payload to the decoder.

b) The decoder detects a bit error marked with `BEC_detect=1` as described in Section 3.4.2.

A receiver generates a BFI flag for each frame indicating its integrity. If the frame is error-free, BFI for that frame shall be set to 0. If bit errors are identified or an expected frame is missing, BFI shall be set to a value other than 0. How the flag is generated is implementation specific.

B.3 Low complexity concealment

The shaped spectrum of the concealed frame $\hat{X}(k)$ shall be derived by sign scrambling of the last received shaped spectrum $\hat{X}_{lastGood}(k)$:

```
for k=0..N_F − 1
  plc_seed = (16831 + plc_seed*12821) & 0xFFFF;
  if plc_seed<0x8000
    X̂(k)  = X̂_lastGood(k);
  else
    X̂(k)  = −X̂_lastGood(k);
```

with the initial value of `plc_seed=24,607`. This value is initialized only once at codec start-up and is not reset after the appearance of an error-free frame.

The spectrum $\hat{X}(k)$ fades out to zero. The fade out speed is controlled by an attenuation factor, α, which is dependent on the previous attenuation factor, α_{-1}, and the number of consecutive erased frames, $nbLostCmpt$. The following algorithm shall be used to compute the attenuation factor, α.

```
if (nbLostCmpt < 4)
   α = α_-1
else if (nbLostCmpt < 8)
   α = 0.9·α_-1
else
   α = 0.85·α_-1
```

where $\alpha_{-1} = 1$ for $nbLostCmpt == 1$.

The Long Term Postfilter in Section 3.4.9 shall be limited to cases 1 and 3 by setting ltpf_active =0.

Appendix C Intermediate verification of input and output

The sections within this appendix provide an intermediate output of a limited set of equations and pseudocode output used within this specification. The data is provided for a sinusoid signal sampled at 16 ksps and coded with 32 kbps.

C.1 Format of provided data

For each variable, the type of the variable is given within the description in the respective table. The subsequent rows contain the respective name, the size in square brackets followed by a colon, and the value of each variable in the respective format. The values are all separated by a new line. Empty variables are identified with the symbol #. In the case of an array, the values are separated with a comma and are still stored within one row.

An example output could contain the following information:

```
frameN[1]:1

P_bw[1]:1

Lastnz[1]:150

lsbMode[1]:0
```

rc_{order}`[2]:1,0`

Arrays are indicated with square brackets after the variable name in this document. For example:

```
bytes []
```

For floating point values that are provided in HEX format, the IEEE 754 standard is used for conversion.

C.2 Buffer initialization

If not explicitly mentioned, all buffers in the first frame of the test vectors are initialized according to the specification for handling the first frame. For the second frame, buffers are updated and used from the previous frame according to the specification.

C.3 Encoder intermediate output

C.3.1 Modules and data type overview

C.3.1.1 PCM Input

Variable Name	Type
x_s	Integer16

C.3.1.2 MDCT

Variable Name	Type
$X[]$	Double as HEX

C.3.1.3 12.8 kHz resampler

The test vectors provide only 129 samples for the resampler output. The last (130th) sample is not provided because it is multiplied with zero in all cases and therefore has no effect on the LTPF. (See `x_tilde_12.8D in C.3.3.`)

Variable Name	Type
$x_{12.8D}[]$	Double as HEX

C.3.1.4 Pitch analysis

The value for normcorr2 is set to the value of normcorr1 if T_1 matches T_2.

Variable Name	Type
T_{curr}	Integer16
normcorr	Float
T_1	Integer16
T_2	Integer16
normcorr1	Float
normcorr2	Float

C.3.1.5 LTPF encoder

Variable Name	Type
pitch_present	Integer16
pitch_index	Integer16
ltpf_active	Integer16
nc_ltpf (corresponding to nc in pseudocode	Float

C.3.1.6 Per-band energy

Variable Name	Type
$E_B[]$	Double as HEX

C.3.1.7 Bandwidth detector

Variable Name	Type
P_{bw}	Integer16

C.3.1.8 SNS gains

Variable Name	Type
$scf[]$	Double as HEX

C.3.1.9 SNS quantization: stage 2

Variable Name	Type
$t2_{rot}[]$	Double as HEX
$y_0[]$	Integer16
$y_1[]$	Integer16
$y_2[]$	Integer16
$y_3[]$	Integer16
$x_{q,0}[]$	Double as HEX
$x_{q,1}[]$	Double as HEX
$x_{q,2}[]$	Double as HEX
$x_{q,3}[]$	Double as HEX

C.3.1.10 SNS quantized gains

Variable Name	Type
ind_LF	Integer16
ind_HF	Integer16
submodeMSB	Integer16
Gind	Integer16
LS_indA	Integer16
idxA	integer32
idxB	Integer16
scfQ	Double as HEX

C.3.1.11 SNS interpolation

Variable Name	Type
g_sns[]	Double as HEX

C.3.1.12 SNS shape_j==3

Additional vectors are provided for the case when shape_j==3.

C.3.1.13 Spectral shaping

Variable Name	Type
X_s	Double as HEX

C.3.1.14 TNS coder

Variable Name	Type
X_f[]	Double as HEX
rc_{order}[]	Integer16
$rc_{i,1}$[]	Integer16
$rc_{i,2}$[]	Integer16
$rc_{q,1}$[]	Double as HEX
$rc_{q,2}$[]	Double as HEX
num_tns_filters	Integer16
tns_lev_a[]	Double as HEX
tns_lev_e	Float
tns_lev_rc[]	Double as HEX
nbits_tns	Integer16

C.3.1.15 Global gain estimation

Variable Name	Type
gg_{off}	Integer16
gg_{ind}	Integer16
gg_{min}	Integer16
gg	Float
$nbits_{offset}$	Float

C.3.1.16 Quantization

Note: The value of nbits_trunc is provided only if requantization occurs and is stored in the variable nbits_trunc_req.

Variable Name	Type
X_Q	Integer16
lastnz	Integer16
$nbits_{est}$	Integer16
lsbmode	Integer16
nbits_spec	Integer16

C.3.1.17 Global gain adjustment

Variable Name	Type
gg_{ind} (_adj)	Integer16
gg (_adj)	Float

C.3.1.18 Requantization

Variable Name	Type
X_Q (_req)	Integer16
Lastnz (_req)	Integer16
$nbits_{est}$ (_req)	Integer16
$nbits_{trunc}$ (_req)	Integer16
Lsbmode (_req)	Integer16

C.3.1.19 Residual coding

Variable Name	Type
res_bits	Integer16

C.3.1.20 Noise factor

Variable Name	Type
F_{NF}	Integer16

C.3.1.21 Side information encoding

Variable Name	Type
bytes_side_info[]	Integer16

C.3.1.22 Arithmetic encoding

Variable Name	Type
bytes_ari[]	Integer16

C.3.1.23 Attack detector intermediate data

For the attack detector module, two frames with a separate input test vector sampled at 48 ksps and coded with 88 kbps are provided in addition to the attack flag of the respective frame.

Variable Name	Type
x_s[480] (pcm input data)	Integer16
F_att	Integer16

C.3.2 Intermediate data for 10 ms frame duration

The data values are provided below. The following box provides the intermediate data for the attack detector module:

```
x_s[480]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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,0,0,0,0,0,0,0,0,0,0,0,0,0,27852,29491,27852,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
F_att[1]:1
x_s[480]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
F_att[1]:1
```

The intermediate data for all other modules is provided below:

```
x_s[160]:0,3212,6392,9512,12539,15446,18205,20788,23170,25328,27244,28898,30272,31357
,32137,32609,32767,32609,32138,31356,30272,28898,27245,25330,23169,20787,18205,15446,
12539,9511,6393,3212,0,-3212,-6393,-9512,-12540,-15446,-18204,-20787,-23170,-25329,-
27245,-28898,-30273,-31356,-32137,-32610,-32766,-32609,-32137,-31356,-30272,-28898,-
```

27244,-25329,-23171,-20787,-18204,-15446,-12539,-9511,-6393,-3212,-
1,3212,6393,9512,12540,15446,18204,20788,23169,25329,27245,28898,30273,31356,32137,32
609,32767,32609,32137,31356,30273,28898,27245,25330,23170,20787,18204,15446,12540,951
2,6393,3212,0,-3212,-6393,-9512,-12539,-15447,-18204,-20787,-23170,-25330,-27244,-
28898,-30272,-31356,-32137,-32609,-32767,-32609,-32137,-31356,-30273,-28898,-27244,-
25330,-23169,-20787,-18204,-15446,-12540,-9511,-6393,-
3212,0,3212,6392,9511,12539,15446,18205,20787,23169,25329,27245,28898,30273,31356,321
37,32609,32767,32610,32137,31356,30273,28898,27244,25329,23170,20787,18204,15446,1254
0,9511,6392,3211

X[160]:c0826f406dde3989,40df81a78a4f75b5,c0daf8c06ebb7a2c,40f73ca25afe9232,c0fbe0488f
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b39deb,c08e77af160aedbb,407d85c08136279a,c0a57bedebdfe234,40a34d212827b442,c0a581d9b1
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107fa9,c075560b649c76d8,407e6e6bd3bf5c4a,c0814bb53a8a1545,408039c1eefcbd14,c07a2152d8
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8065df

x_tilde_12.8D[129]:0000000000000000,0000000000000000,0000000000000000,000000000000000
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0,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000000
0,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000000
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6,c0c47bfbe3401986,c0cbb02febb3a033,c0d13efe815913ce,c0d46800f3bd59d2,c0d742706a7a9d4
c,c0d9c2de88f32995,c0dbe2db4ee61926,c0dd9b325ab2cc8e,c0dede896a78ab4b,c0dfabf596a1678
5,c0e000cbe7a99645,c0dfdeae9fb741a1,c0df3cb1138e1b46,c0de2403a749c136,c0dc98f56e2c0a4
6,c0daa0de243426e4,c0d83d98901f6550,c0d57ec747a2e008,c0d26eb02f824b3a,c0ce2ca2f01b02c
8

T_curr[1]:25

normcorr[1]:0.677220

T1[1]:25

T2[1]:21

normcorr1[1]:0.677220

normcorr2[1]: 0.276293

pitch_index[1]:76

pitch_present[1]:1

ltpf_active[1]:0

nc_ltpf[1]:0.690317

E_B[64]:41153d56862bdeb7,41cf0541ee3242a7,41c6bbc65f2a32b6,4200df9c46dae720,4208489e6
9c8ee96,422767e4ec100c34,41530cd7d9ef07ad,41b786fd2a331732,41aec638e198f576,4114a4590
8405949,41ad7805c6a12049,416ec29c51771a7e,419843893e021604,414b97b6b945a160,4170c94f0
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P_bw[1]:1

scf[16]:400c020435f6210b,4011fa204e9143a7,40027522f5bd96d4,3ff33c6fcfd46f29,3fe3f4b81
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2438723,bff36795aab84dd1,bff77c3572f9fca7,bffa9feea0452449,bffd6dc03304405b,bffee45b2
ddffa29,bffebab5f70bcd85

ind_LF[1]:25

ind_HF[1]:8

submodeMSB[1]:0

Gind[1]:0

LS_indA[1]:1

idxA[1]:865837

idxB[1]:1

scfQ[16]:400d4d38126557d8,401070a4f1ca321d,4003cbfe3d106d26,3ff2fe1dd23651be,3fe0ebbe
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ca86593d,c00036bd6c653caf

```
t2rot[16]:bfd85bcd1f7895d5,3fd1f84864d9b805,bfe592b62254c86b,bfdc313c09b87796,bfa9f2c
c921a1009,3ff4b6c71398748e,bfa055ec5fd6e21d,bfeadff5ac5b1e6f,bf9f4ea71f8fc65a,bfc5fdc
def46bddf,bfd4596060160a41,bfe22d2c6c086cfd,bfd60dd5e0dedb9f,bfab45b6a4851848,bfb01ba
d70eae474,bfcab2685e93826b
sns_Y0[16]:-1,1,-2,-1,0,3,0,-2,0,0,0,-1,0,0,0,0
sns_Y1[10]:-1,1,-2,-1,0,3,0,-2,0,0
sns_Y2[16]:-1,0,-1,-1,0,2,0,-1,0,0,0,-1,-1,0,0,0
sns_Y3[16]:0,0,-1,-1,0,2,0,-1,0,0,0,-1,0,0,0,0
sns_XQ0[16]:bfcbee9056fb9c39,3fcbee9056fb9c39,bfdbee9056fb9c39,bfcbee9056fb9c39,80000
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00000000000,8000000000000000,bfcbee9056fb9c39,8000000000000000,8000000000000000,80000
00000000000,8000000000000000
sns_XQ1[10]:bfcc9f25c5bfedd9,3fcc9f25c5bfedd9,bfdc9f25c5bfedd9,bfcc9f25c5bfedd9,80000
00000000000,3fe5775c544ff263,8000000000000000,bfdc9f25c5bfedd9,8000000000000000,80000
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sns_XQ2[16]:bfd43d136248490f,0000000000000000,bfd43d136248490f,bfd43d136248490f,80000
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sns_XQ3[16]:8000000000000000,0000000000000000,bfd6a09e667f3bcc,bfd6a09e667f3bcc,80000
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g_sns[64]:3fb436d4269e6456,3fb436d4269e6456,3fb3721ca551016c,3fb1fed3fc8dc2f9,3fb0a73
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c75d0e31
```

```
rc_order[2]:6,0
```

```
rc_i_1[8]:13,9,4,9,8,9,8,8
```

```
rc_i_2[8]:8,8,8,8,8,8,8,8
```

```
rc_q_1[8]:3fe9895b6c9a05f6,3fc7851aacd6c6b4,bfe58eea2a9d6da3,3fc7851aacd6c6b4,0000000
000000000,3fc7851aacd6c6b4,0000000000000000,0000000000000000
```

```
rc_q_2[8]:0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000
000000000,0000000000000000,0000000000000000,0000000000000000
```

```
tns_lev_a[9]:3ff0000000000000,3fe71cf765e37e07,bfe2ecb8af097134,bfe2c1a678d610b2,3fbe
5a6fd718c3d3,3f9df8c25b008585,3fb48d3c22d5ffdb,3fa3af52a68a710d,3fa66a878cf023e1
```

```
tns_lev_e[1]:0.412635
tns_lev_rc[8]:3feaceded68aad6e,3fc5f38e9dae2665,bfe6a471b7410399,3fc85b4ce494c040,bf8
d1624bba2bded,3fb9f8444ec7ba02,3f7c0173bfb5d55c,3fa66a878cf023e1
num_tns_filters[1]:1
nbits_TNS[1]:24
gg_off[1]:-131
gg_ind[1]:191
gg_min[1]:121
gg[1]:138.949549
nbits_offset[1]:0.000000
X_q[160]:0,18,-15,48,-53,-97,-1,-13,-13,1,-23,7,-23,-10,1,-2,1,-3,0,-2,1,-2,1,-1,1,-
1,0,1,-1,0,-1,0,0,0,1,-1,1,-1,0,0,0,0,-1,1,-1,1,0,0,0,0,0,-1,1,-1,0,0,0,0,-
1,0,0,1,0,0,0,0,0,-1,0,0,0,0,0,0,-
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0
lastnz[1]:108
nbits_est[1]:231
lsbMode[1]:0
nbits_spec[1]:225
gg_ind_adj[1]:192
gg_adj[1]:1.508591e+02
X_q_req[160]:0,17,-14,44,-49,-89,-1,-12,-12,0,-21,7,-21,-10,1,-2,1,-3,0,-2,1,-2,1,-
1,1,-1,0,1,-1,0,-1,0,0,0,1,-1,1,-1,0,0,0,0,-1,1,-1,1,0,0,0,0,0,-1,1,-1,0,0,0,0,-
1,0,0,0,0,0,0,0,0,-
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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0,0,0,0,0,0,0,0
lastnz_req[1]:68
nbits_est_req[1]:206
nbits_trunc_req[1]:206
lsbMode_req[1]:0
res_bits[23]:0,1,1,0,0,1,1,0,1,0,0,1,1,1,1,0,0,1,1,1,1,1,0
F_NF[1]:3
bytes_side_info[40]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,25,
48,195,141,241,136,207,128,67
bytes_ari[40]:167,28,42,53,175,105,14,249,190,241,203,46,135,95,5,19,215,142,60,242,2
05,213,173,86,182,94,225,143,193,190,128,153,48,195,141,241,136,207,128,67
x_s[160]:0,-3211,-6393,-9512,-12539,-15446,-18204,-20788,-23170,-25329,-27245,-
28898,-30273,-31356,-32137,-32609,-32767,-32609,-32138,-31356,-30273,-28898,-27245,-
25329,-23170,-20788,-18205,-15447,-12539,-9512,-6392,-
3211,0,3211,6393,9512,12539,15446,18204,20787,23170,25329,27244,28897,30273,31356,321
37,32609,32767,32609,32137,31356,30273,28897,27244,25330,23170,20787,18205,15446,1253
9,9512,6393,3213,0,-3212,-6393,-9512,-12540,-15447,-18205,-20787,-23169,-25329,-
27245,-28897,-30273,-31356,-32138,-32609,-32767,-32609,-32138,-31356,-30273,-28898,-
27244,-25330,-23170,-20787,-18205,-15446,-12540,-9513,-6392,-
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38,32609,32767,32609,32138,31356,30273,28898,27244,25330,23170,20787,18204,15446,1254
0,9512,6392,3211,0,-3211,-6393,-9512,-12539,-15446,-18205,-20786,-23170,-25329,-
27245,-28898,-30272,-31356,-32137,-32609,-32766,-32609,-32137,-31356,-30273,-28898,-
27245,-25329,-23170,-20787,-18204,-15446,-12539,-9511,-6393,-3212
```

X[160]:c0b88c5b2132b117,c0cc91b58442929d,40b37426cfc48129,c0f12c8f76c2d1ff,40f4e3c53d
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x_tilde_12.8D[129]:c0ce2ca2f01b02c8,c0c7002bbad49212,c0beff12f76f77cc,c0af0eaf19e7611
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7,c0dfa0617dc955b2,c0df3c5be12f34f0,c0de607ad881c4e0,c0dd09e82b64ee5a,c0db440f43bfdae
a,c0d915b64ae86c98,c0d68608be74597a,c0d39a51e6ec2a3b,c0d0651b9864e187,c0c9e0e3c64e587
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2,40c4075e837905d2,40cb510efc5d2084,40d119c27254e498,40d44cfab31700f1,40d730b133679cb
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b,40e011def53a5270,40e00446b46b715b,40df6dae6b62917b,40de5bf53fee6357,40dcd7dae2b5fcb
c,40dae615b95a8437,40d888f486916eda,40d5d01da1502cd3,40d2c5b577b627a8,40cee5fe2bf3fa4
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T_curr[1]:26
normcorr[1]:0.992748
T1[1]:26
T2[1]:26
normcorr1[1]:0.992748
normcorr2[1]:0.992748
pitch_index[1]:76
pitch_present[1]:1
ltpf_active[1]:0
nc_ltpf[1]:0.998707
E_B[64]:4182d4f050320a23,41a981952078be37,4177a72760957982,41f26f2cf6718c0d,41fb46178
eba3bd0,422f180b56019069,41d278d2dad3ec8e,41e63f4eb44d58db,419df944af4b15d9,41b4ce81d
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c44b77f,404ccab955ac4037,40a5c20db927597e,40ad112979148773,40bb2d3292715d84,409e3edd8
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c083921,3fe642063075e2b4,3fe3b06e6679a1ba,3fc7d938b0fdcb63,3fddbec9d4ad266e
P_bw[1]:1
scf[16]:400df2262f5b30e5,4016c555b6f732b5,400a214629996f9d,3ff728eee824de90,bfdc7bca5
1ca4360,bff3ef1b430af0cf,bff3ef1b430af0cf,bff3ef1b430af0cf,bff3ef1b430af0cf,bff3ef1b4
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30af0cf,bff3ef1b430af0cf
ind_LF[1]:25
ind_HF[1]:9
submodeMSB[1]:0
Gind[1]:0
LS_indA[1]:1
idxA[1]:1023911
idxB[1]:1
scfQ[16]:400e88cee80fadc8,401476fd672e11f4,400bd88a7cffcc57,3ff33230297ea402,bfcc43cd
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t2rot[16]:bfe65b29df6547cf,3fe7c7f7f8917731,3fc5802300712417,3ffbb5af9b5b5180,3fca4aa
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38ca8832c,bfd545ff85617f28,bfdf0002bd99d087,bfdb21eacf8bd056,bfd72faca0f92e56,bfcdb7c
c95b11715,bfcd0962c5160e40
sns_Y0[16]:-1,1,0,3,0,0,-1,-2,-1,-1,0,-1,0,0,0,0
sns_Y1[10]:-1,1,0,3,0,0,-1,-2,-1,-1
sns_Y2[16]:-1,1,0,2,0,0,-1,-1,-1,0,0,-1,0,0,0,0
sns_Y3[16]:-1,1,0,2,0,0,0,-1,-1,0,0,0,0,0,0,0
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sns_XQ0[16]:bfcd5d7ea914b936,3fcd5d7ea914b936,0000000000000000,3fe6061efecf8ae8,0000000000000000,8000000000000000,bfcd5d7ea914b936,bfdd5d7ea914b936,bfcd5d7ea914b936,bfcd5d7ea914b936,8000000000000000,bfcd5d7ea914b936,8000000000000000,8000000000000000,8000000000000000,8000000000000000

sns_XQ1[10]:bfce2b7dddfefa67,3fce2b7dddfefa67,0000000000000000,3fe6a09e667f3bcd,0000000000000000,8000000000000000,bfce2b7dddfefa67,bfde2b7dddfefa67,bfce2b7dddfefa67,bfce2b7dddfefa67

sns_XQ2[16]:bfd43d136248490f,3fd43d136248490f,0000000000000000,3fe43d136248490f,0000000000000000,8000000000000000,bfd43d136248490f,bfd43d136248490f,bfd43d136248490f,8000000000000000,8000000000000000,bfd43d136248490f,8000000000000000,8000000000000000,8000000000000000,8000000000000000

sns_XQ3[16]:bfd6a09e667f3bcc,3fd6a09e667f3bcc,0000000000000000,3fe6a09e667f3bcc,0000000000000000,8000000000000000,8000000000000000,bfd6a09e667f3bcc,bfd6a09e667f3bcc,8000000000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000

g_sns[64]:3fb22a97eb80b319,3fb22a97eb80b319,3fb03b68345ec6dc,3fa9eb32fc7584ab,3fa4b16b5ec2550b,3fa0855c695057ae,3fa1025283060782,3fa694fc10577e94,3fadfb152285e820,3fb3e6e24e9c6505,3fbbf1482f4ec4ee,3fc4be8271954a64,3fceccea58768457,3fd6ddaa520dc1f2,3fdf8302e39266a5,3fe4274e9c6a8fb9,3fe9c75569a27ff2,3ff07ca50db3ac87,3ff3fae3897d6278,3ff6f0c2aeb8ed8b,3ffa56ecff97d166,3ffe3e05f1f04042,40004509dce5d1bd,4000678b00b88200,40008a5551b5dfe9,4000ad696b0ee350,4000d4652a0755bb,4000ff6284e5e88a,40012acdafd24ea4,400156a7c34de626,4001aa42b28bcb2c,400227d92014057a,4002a8ec66edee5b,40032d9552b19bbf,40037b8283a3b9bd,40039004007 8bd02,4003a49b1287adab,4003b947d087fe8f,40039977a201ab55,400346278dfcd371,4002f4399ea2074a,4002a3a7f29007e0,4002999aa38b18ba,4002d59fde7eebb0,40031266c78ae5ce,40034ff1cfab97f8,4002a7bc295537ea,400130d14fc3cdff,3fffaeaa7e998ca5,3ffd31f0e7dabaf2,3ffc7fe7e3aa874b,3ffd78c16a99e7ae,3ffe7a17d1eb5d3a,3fff8435367c91f1,4000951fbdfdb4b0,4001c1ceaa5e413a,400303c9be65a182,40045c93278c8ab8,40048b8bb44a00b0,40038891c474bff2,400292584b4c7148,4001a83e8b6846d8,4000c9abb18a6afc,3fffec1ce1b742ab

X_S[160]:c07bdf400a7f25b2,c09037fcfa7485b2,4073bc61d18ba693,c0abd2155eed007a,40ab045a712d9105,40c0490dd577de8d,c092469d063587fa,40a2d43440a8134b,c08484776213a9ac,4096b1fe25f6b013,4068a07189e31b7c,4091deafa13919b0,40734b6f6ce03483,4096d96bb1776aa0,408261e896908205,408e5c0b3b047495,407e5f9132eb7c2e,4084d5d28a779f32,406887c0bd52faf5,406313e96b72a436,c028fc0018c88b1f,c058eff21a4bad56,c05f03285cbdf28b,c065612c7174b0eb,c056bdc81b5864ba,c05198b7af68499a,c03967710162cdf9,c018e55c453385d1,4026b4f893fc4f79,403f1e45657ba4fd,40378cf99cbe3d39,4033eb34175078f0,401b087d0032bbca,400c5018857c7b3c,c00449ec8af869cd,c028a33539526dcd,c0256be5d7ffc470,c0249e780ed3c191,c0134276af1af7a3,bff02284e940bcc7,3ff8b8c39af43dde,401b005a0d0dbb58,40216feaebfa2200,401a01c5ed21ce27,400af8aaa3fbb083,400aec23c24ae5ac,3fc42276a8c31911,c00612dbde08fc97,c01510a3470884e9,c014c9764d961b8c,c00590ad2715efde,c00a4d5ba07bd3a0,c00735d388fbaa66,3fd7b37c184e341e,40036a2c38af7663,4012bc9195247a9f,4011b18f99099146,4007338ff29632bd,401019262e3f7b6e,400187117d6b9ef0,bfe9035e751578c8,c00e313dd488a0be,bffaec2e2991dc5d,c0138103957c2110,c01c0ef39ba48fe4,c0110b47c6c5c527,bffec1b547e23b89,bf6fd34de1f4525e,3ffeac8be5ff703b,4000fb94a42fbd13,4010004afd7080a1,40035edd198116c0,4016257107103332,4000bd5a6a6840ab,400a490e84f0c50d,3fce787def553883,c0053330438fbd42,bff96761562a8569,c002e93c3d8e7f81,c0099346f9b0e4b7,c01205103b3cb5d9,3fdfb727cfd1527b,bfe0d15783994db7,3fd256e92ca88387,bfdfe67e05b5f1c9,3ff507fc59b7dfd8,3ffd8a34450c8b53,3ff3d34908d64cd1,3fc78a85b7506667,3ff5d08c8b171cd0,bf9f4f1dca0a8922,bff3c7085ccb9130,3fc708f8ab4970ac,c001420e52cbfe7e,c00290a5dc0aec29,c00142988ae3b8d2,bff643324833c82b,c0017c72a0abf98b,3fd221566192a681,3fed125e622190d1,3ff8fca07461945a,40082c664750fb47,40102e603436a4dd,4009b160eecf4440,3ff982fcac5ae80f,3fcc4d3667b8788b,bff4bb5f5dd7dfcf,bfd93de3655c3025,bffbffd5285ecd93,bffdedca0ccf504d,bfcfe66b41b3aa24,3fd9df4d7ac0c260,c008510e78531ea8,bfff32d61a3d5099,3fb1a986e865713e,40057c8a8e8f3b6c,400f7e0c419c3816,3ff741660022750b,400478dfd8391679,3fff639923a7a555,bfd45c185c316577,3fd790a62942f577,bf981a0f6aebef04,3fd8f75e1904f99f,c0132a49f222c0e8,c00ad7cb44b0c136,c005852f2d923729,bff83700f0f1e9b1,bfefe62f66a81717,bfe41e6dc79c7cdc,3ffd608343ac67ea,3ff721279183b443,3fee7338f9112609,3ff196f8c878b5b5,4001ebd4dd82ef92,4003c97457b64d5e,3fce3f8e2d86afb8,c00037272c6209ac,c003911cb38f25ae,bff38797

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X_f[160]:c07bdf400a7f25b2,c09037fcfa7485b2,4073bc61d18ba693,c0abd2155eed007a,40ab045a
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12721284

rc_order[2]:6,0

rc_i_1[8]:4,7,9,9,9,9,8,8

rc_i_2[8]:8,8,8,8,8,8,8,8

rc_q_1[8]:bfe58eea2a9d6da3,bfc7851aacd6c6b4,3fc7851aacd6c6b4,3fc7851aacd6c6b4,3fc7851
aacd6c6b4,3fc7851aacd6c6b4,0000000000000000,0000000000000000

rc_q_2[8]:0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000
000000000,0000000000000000,0000000000000000,0000000000000000

tns_lev_a[9]:3ff0000000000000,bfe1f2d1628505b0,bfcdddbb7d985903,3fc0f89a04290272,bfb2
7ddec95327e5,3fbe169221930ca2,3fc958eb3c1d4d8c,bfaf5f7dce174448,3f96fe7885e65076

tns_lev_e[1]:1.396833

tns_lev_rc[8]:bfe5a964ebb177c2,bfb992c3c4395c7b,3fccfec8a37dcc02,3fba181c5c99df6b,3fc
a7fa3331ffaec,3fc6984462b7afb9,bfa8efe065b1017a,3f96fe7885e65076

num_tns_filters[1]:1

nbits_TNS[1]:18

gg_off[1]:-131

gg_ind[1]:166
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gg_min[1]:115
gg[1]:17.782794
nbits_offset[1]:-1.200000
X_q[160]:-25,-58,18,-200,194,469,-66,135,-37,82,11,64,17,74,-12,14,-7,11,-
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lastnz[1]:34
nbits_est[1]:250
lsbMode[1]:0
nbits_spec[1]:231
gg_ind_adj[1]:168
gg_adj[1]:2.096180e+01
X_q_req[160]:-21,-49,15,-170,165,398,-56,115,-31,69,9,54,15,63,-10,11,-6,10,-
3,10,3,5,4,3,4,2,1,0,-1,-
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,0,0,0
lastnz_req[1]:30
nbits_est_req[1]:237
nbits_trunc_req[1]:229
lsbMode_req[1]:0
res_bits[6]:0,0,1,1,0,0
F_NF[1]:7
bytes_side_info[40]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,57,
48,197,247,107,137,207,80,29
bytes_ari[40]:126,85,255,133,53,134,247,1,248,140,170,26,30,66,67,214,38,2,55,92,120,
255,26,85,221,210,129,46,104,221,196,249,48,197,247,107,137,207,80,29
```

C.3.3 SNS shape_j==3 vectors

```
E_B[64]:3fd19241233381e1,3f9b1988a896eb7a,3fb4b6459237988a,3febc552e01c4cb2,3f9b60918
0a70b09,3fbb21681c2f36a1,3ff019a2495ae9b2,3f4f93cdbe9f1ff8,3fa915032285bca3,3fd8b582b
15246f2,3fa1e7afdd6649ec,3f86df0651faddd9,3fc75a21d0bc5814,3f75217cb65ec4be,3fc91017f
70d40c4,3ff0f819d2100645,3fc750e60c4c7b4e,3f7a14cb73340322,3fd0879f3ffbad71,3faeb7d48
4429319,4005b63cda33838e,3fc4a1aa6899b6b5,3fb18e27d21a8305,3fa79ae46622db30,4003556c4
b0e5ff5,3fce7040e8871962,3fd98369d90857e4,3fed1e4de8caddec,3fdf1e3d844430cc,3fdf69632
175313c,3fd2581dd8dec698,3fd2e9f7b8f8170f,3fb58d4260f06fe4,3fb0e4782751ec39,3fe27e298
1e1c77e,3fd58753fff2035e,3fc7ff173f07ad93,3fe478059d98c4c2,3fb224ca727bdacd,3fa209fd1
1c001bf,3fe025a37d112775,3ff55f8d7b77c2d4,3fdc3a0c454a0fd1,3fe3d857f9bc5d79,3fd8f54ab
ddf145d,3fe7915e3d123935,3fcd263fd0f5ee11,3ffdf064e2c6ef63,3ff15736775a24de,3fdf11d27
89e9596,3fd891c4b5728b32,3fe32581b73750a8,3fee91be7677c676,3fea255c74fbddae,3fd535ada
905203e,3fe1bdcc57f4d7b2,3feec12946551475,3fd8105b3812d232,3ff6a5868757c3c5,3fd27337c
1f4a434,3fd5254692229e6d,3fe124b05b385420,3fbf7fdb58806c2d,3fe167262cf76dcd
P_bw[1]:1
scf[16]:bff90a0a71ecf085,bff2a64da2b1ceb2,bff8ffeca2159827,bff24206904209a2,bfe7fe12c
b3e1364,bfcf8ea5154c4c4d,3fc152f3068332f3,bfbce98c839a4540,bfc5ac97a5238fad,3fad80d60
0d97953,3fe57db5c77cfed9,3fee08fabbb443f3,3ff1519da18d3e3d,3ff34ace509f9bc4,3ff67c516
0d2926c,3ff374da66adca89
ind_LF[1]:4
```

```
ind_HF[1]:27
shape_j[1]:3
submodeMSB[1]:1
submodeLSB[1]:1
Gind[1]:3
LS_indA[1]:1
idxA[1]:61886
scfQ[16]:bff4dc7a80df520a,bff5180e65c91a5e,bff717e6b347417c,bff4d7617f4ecec0,bfe72b98
3159f1a3,bfb21bfc088f5950,3fd3c54744f32060,3fbc716ac1d41f9b,bfce7f5eec6313a8,3fcd2bf1
88b66226,3fe84e8326169ee2,3ff0347500978b3d,3ff16b0c1519d43c,3ff54f7ac4bf246a,3ff6fcba
cc436a08,3ff03c03e8ed6dd2
t2rot[16]:bff08f373905faf4,bfec1fd4f73c9c94,3fc87541501f3d07,bfed11419f82c67b,3fe8684
d55205d01,3fe15084621f75d8,3fe80d409ddf34e1,bfb42f49a0102b3c,3fc24dd2368b5da9,bfc3e61
2254786c6,bfb0fa6e32c591d5,bfb27fef2ba732cf,bfc0aa0c5d54b2dc,bfced76b78aad39b,bfc57c3
236a0f889,3fb23d1697e9859c
sns_Y0[16]:-2,-2,0,-2,2,1,1,0,0,0,0,0,0,-1,0,0
sns_Y1[10]:-2,-2,0,-2,2,1,1,0,0,0
sns_Y2[16]:-2,-1,0,-2,1,1,1,0,0,0,0,0,0,0,0,0
sns_Y3[16]:-1,-1,0,-1,1,1,1,0,0,0,0,0,0,0,0,0
sns_XQ0[16]:bfdd5d7ea914b936,bfdd5d7ea914b936,0000000000000000,bfdd5d7ea914b936,3fdd5
d7ea914b936,3fcd5d7ea914b936,3fcd5d7ea914b936,8000000000000000,0000000000000000,80000
00000000000,8000000000000000,8000000000000000,8000000000000000,bfcd5d7ea914b936,80000
00000000000,0000000000000000
sns_XQ1[10]:bfde2b7dddfefa67,bfde2b7dddfefa67,0000000000000000,bfde2b7dddfefa67,3fde2
b7dddfefa67,3fce2b7dddfefa67,3fce2b7dddfefa67,8000000000000000,0000000000000000,80000
00000000000
sns_XQ2[16]:bfe279a74590331d,bfd279a74590331d,0000000000000000,bfe279a74590331d,3fd27
9a74590331d,3fd279a74590331d,3fd279a74590331d,8000000000000000,0000000000000000,80000
00000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,80000
00000000000,0000000000000000
sns_XQ3[16]:bfda20bd700c2c3f,bfda20bd700c2c3f,0000000000000000,bfda20bd700c2c3f,3fda2
0bd700c2c3f,3fda20bd700c2c3f,3fda20bd700c2c3f,8000000000000000,0000000000000000,80000
00000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,80000
00000000000,0000000000000000
g_sns[64]:4003c02a2eede437,4003c02a2eede437,4003c68a762f86a3,4003d351323477ea,4003e02
02f5579c3,4003ecf772e7c164,40042aff88859144,40049c04bc9afa05,40050f834d068a7a,4005858
9171b38be,40057e00ccb0ed8b,4004f96e15df2cc6,4004780d23977e8e,4003f9ca41825776,4002c4d
42164ceba,4000fa8242238914,3ffeb7d0574255f7,3ffbc9b49fd430bc,3ff8f990e077785a,3ff64d3
25d63072b,3ff3ea15273f22a4,3ff1c861e22f0d55,3ff042a378e5f1eb,3fee7330fd1ed3a1,3fec82d
b6d528d9d,3feab2201c0b1243,3fea474aff9854a2,3feb31e366d1d30c,3fec24aa1a26accc,3fed1fe
821f5c46a,3fee89e64f3bd4aa,3ff038e93c144622,3ff13c1921f9ee25,3ff24f761d88cb98,3ff2204
3bab414ea,3ff0b829abd5553b,3feed80330309f74,3fec7340a51a9aec,3fea1804bf34a1c4,3fe7cc1
158f41d35,3fe5b3ddc3350511,3fe3cadbf7c9a964,3fe27dbc116d7359,3fe1b28247f202f8,3fe0f00
20851e414,3fe035db6effb5a9,3fdf826e25d21f34,3fdf192197da65cb,3fdeb134edd3c0b0,3fde4aa
38fc9e83b,3fdd772d881a4269,3fdc3fcd21a155aa,3fdb1547328e4689,3fd9f713e6eedafe,3fd9319
c132ef784,3fd8bd8ab473b2f1,3fd84b900f4cf1e7,3fd7dba284400541,3fd885d952ecd7cf,3fda623
085490783,3fdc62ac542ee947,3fde8a0acdac9a3b,3fe06d9fa263e54c,3fe1acbb2e1b8c70
```

C.3.4 Intermediate data for 7.5 ms frame duration

Attack detector data:

```
x_s[360]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,27852,29491,27852,0,0,0,0,0,0,0,0,0
F_att[1]:1
x_s[360]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
F_att[1]:1
```

The intermediate data for all other modules is provided below:

```
x_s[120]:0,3212,6392,9512,12539,15446,18205,20788,23170,25328,27244,28898,30272,31357
,32137,32609,32767,32609,32138,31356,30272,28898,27245,25330,23169,20787,18205,15446,
12539,9511,6393,3212,0,-3212,-6393,-9512,-12540,-15446,-18204,-20787,-23170,-25329,-
27245,-28898,-30273,-31356,-32137,-32610,-32766,-32609,-32137,-31356,-30272,-28898,-
27244,-25329,-23171,-20787,-18204,-15446,-12539,-9511,-6393,-3212,-
1,3212,6393,9512,12540,15446,18204,20788,23169,25329,27245,28898,30273,31356,32137,32
609,32767,32609,32137,31356,30273,28898,27245,25330,23170,20787,18204,15446,12540,951
2,6393,3212,0,-3212,-6393,-9512,-12539,-15447,-18204,-20787,-23170,-25330,-27244,-
28898,-30272,-31356,-32137,-32609,-32767,-32609,-32137,-31356,-30273,-28898,-27244,-
25330
X[120]:c0db280e0e0f71f2,40de70fc62705035,c0f998c7e29545a6,c103aa4bc74ab9a6,40bbbe0dab
93eec5,40ee0b38d5e66bed,c0b0ef42720e0ede,409a5d17868740bd,40c037155e8f23ad,c0bf9a66fa
283fa3,40a6a55792157da0,40997830199ddad1,c0aed07f403831da,40aa11ebfcf6145d,c0878921ee
62727c,c0987a3e40c6ceac,40a27574dbf7e795,c098f34195b8a947,c03d7451b308facc,4094945168
e18979,c097c899c8d40302,40879817138b2ace,4075bf692ed669c2,c090c2663bcebab8,408f0d73fc
ebf3c6,c072577ae4207be6,c07da92e09d99b82,408aa8cc2b690c80,c083ca22c42599ee,4036dfe3b7
ed886b,407fb0824583d176,c0849c8b1a6d28ea,4077826c85b48d02,40610ea3f7c7e3d2,c07e9b36c3
875d8c,407ec920b9407479,c06780cfc7dfbf23,c06c7c44b2c1b32e,407bb0d2be3b410b,c075d3f6e1
0ad257,4049593ca87827b2,40710a4625d524d3,c077f18afde6c064,406c5b718eea4709,40485cc2c6
af8756,c071e4c56ac4e38c,4073aee89f71b961,c05f3bb3fc84cbdd,c05da3c9676237c8,4071641fdd
751b78,c06e86ff87be56f0,4043e04fd922dc86,40647a4a6627279f,c06f94628d0e8e51,4065ce3a5a
e58aaa,403ad569e798e0bf,c06776a5d343b19f,406b34f33dd11be5,c05b91adc4f33273,c053bdc540
2a12a3,406877aa8ef65127,c065fffb7b9e95de,4048d703ccdc09d2,405cb5c39ff99237,c0679f654c
f819a5,40605d71ebb47597,3fe71c76f6f70564,c0613c8e243f9e53,4065a6c7e188b412,c055496c87
da3d6b,c045f2cebb219af1,40628c8d6482260a,c062a4dd240b42d8,40448a2f432569b1,4053739792
8083b9,c062887ba766b779,405de2a3c46ab955,bfee732911211d13,c059b2aeccc05c3b,406179c2ff
00ad01,c05578e7aaa36350,c0413b9e3c69c209,405dcf1ec88a89cd,c05eab51369b92cd,404982f614
5db9f6,40500547e3bc4130,c05f8886d5395cc2,4058fa3635b82cbc,c030828bbcf91e18,c055bec7e9
47e198,405ef621842226ba,c0525ceb89cb8f46,c02eb5a4c747b686,40599d2af393d6e3,c05c9d120f
0d7462,4046c03332ce132d,4045ef18b3ccfb5b,c05bcde5dcb1b0a0,405912037c9b712f,c02e567a41
d2827a,c0515c61339e165e,405bed544af65bd2,c053da41f5f17941,c02d98e7f775cd4b,4055e4108d
41e25e,c05a466677e319da,404bb12f31da2e58,4044c41389c9ef7a,c0592ca65f32decf,40571b67c4
e0fa70,c03bd921749bbf20,c0501d92033035fe,405a91fb3a782346,c052bea4e9173651,3fc4e27621
```

```
b60af6,4054e6608cf4147a,c05a675336991fb9,404a64d7f53838d6,403b19f623debd34,c0587b0360
4c3300
x_tilde_12.8D[97]:0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000000000000
,0000000000000000,c005b5914c6c7278,c00541883af8b6d5,c0206b6ef56342ac,40045917b94a58fd
,c029628ca941907a,4009e8323f877cd3,c04584ed7e565d21,40649836bf6c518e,40ae78911f1147e8
,40be09c9813dd3ec,40c5d003dcd6c390,40cc1a3b6b4e97e8,40d0d33707324b60,40d33b5c4c025217
,40d5398d7a4fa943,40d6cb5bda161453,40d7e2abf48653de,40d880e05588b5a2,40d8a57276a6988a
,40d850afb7e9cf7b,40d77e1f8ed9f23f,40d6379c9c6630a8,40d482b57cccbbf2,40d26562680fa419
,40cfc7c3a164fd08,40ca1df0156e6aa0,40c3e0fab5ecce6c,40ba4e8c2293d214,40a81bd2ed8fbc60
,c0858a1859558830,c0b1babd8466ba44,c0c06e661c4f29e1,c0c7ec60c66124c8,c0cf32278109b523
,c0d313e91cb24ec4,c0d65b6df17cd208,c0d95e6689290f1a,c0dc103be724b602,c0de692b268fd233
,c0e030abf9e23cba,c0e0f52d78affa67,c0e180816600e1fc,c0e1d1388e6e74b3,c0e1e6361e2aafc8
,c0e1bbad37ddfeaa,c0e154afb1c60fc0,c0e0b2de93d3a17e,c0dfb0f649e94079,c0dd8a8adaf42f49
,c0db01cfc015db44,c0d81f03bbd5f9ed,c0d4eb80d00db5d1
T_curr[1]:22
normcorr[1]:0.473429
T1[1]:22
T2[1]:21
normcorr1[1]:0.473429
normcorr2[1]:0.000000
pitch_index[1]:0
pitch_present[1]:0
ltpf_active[1]:0
nc_ltpf[1]:0.000000
E_B[64]:41c70bc9dae36339,41ccf568270a382d,42047991c1d2574e,42182b88850352e2,41880d1fd
3e4f6a0,41ec350e80880b03,4171ec7eb63f71d9,4145b8550b6b06f3,41906ee86024e9d6,418f36108
5212114,416006aeb8dfaf4b,4144458e910f12be,416dac3d10a63e40,41653d298498f9bb,41214f6c7
15aaa21,4142b9305c513d6f,41554ba52f545405,4143741b8d2d4d70,408b1c7ae5a2ddf3,413a782a6
9e65cb9,4141ad4695e22bd0,4121657407625bc3,40fd8f65fce48c01,41318e066955060b,412e22166
1eb11b5,40f506b2cd69dbad,410b7e21e064b0ab,412635c62b692d0a,41187a0c3ffd8e08,408059f79
10e97cc,410f61ca01be653b,411a8d575f4d923b,4101458f9361ee5e,40d22f29d40ab973,410d72028
409a110,40e54f460052cceb,41036cf2619185e0,40e2c67ee65082be,40f8329a074a412c,40e4974c0
f3e2128,40ec06640f0d318d,40e655bab0ace38d,40dde4e0d5964380,40e6226facdea94c,40ce6bbe2
930882b,40e42afc300ab656,40c1f71608e55281,40e0ea9c9040423e,40d0b8d94a95abec,40c789d17
8a464b8,40c981e490a616df,40cdeb04be3340a5,40cb8e68253b8b3d,40c39ac193d036fd,40bdaa0a0
9b402d0,40bc552d8d18f355,40c07838d2d40fa7,40beba7a20e04642,40bcc5f419fba3df,40baf0e61
89a8ddd,40b8a597bea532bc,40b6ecd344cee582,40b111ac58e8a978,40b86a9e3276c5ca
P_bw[1]:1
scf[16]:40119e8ccf5bdaca,400c4fba6ce20f6a,3ff86d617d68a589,3fe9650e6df3a213,3fd397ffd
81df8be,bfa0d3fd57faf066,bfd1d2866537221e,bfddad6f56b46c03,bfe5f03178a10334,bfec24735
7d9e9de,bff18feb8b6b0aca,bff3a86320930235,bff635235afcff3a,bff80b18fddd3989,bff81d79b
eeb4689,bff8189c3be1c088
ind_LF[1]:17
ind_HF[1]:8
shape_j[1]:1
```

```
submodeMSB[1]:0
submodeLSB[1]:1
Gind[1]:0
LS_indA[1]:0
idxA[1]:1025681
scfQ[16]:4011865433eddfbd,4009aa7557a2ef9d,3ffc73abbaeb8fa1,3fe4cb391389ca1f,3fc9e222
41ae43bc,3fb2014e9f17b238,bfd258fb6e312ba2,bfeb6c91a3feca2e,bfe3d4267b92e86c,bfe9a72c
25052f46,bff0d3c1e09e99ce,bff5904638bf2587,bff66802b35f72b2,bff8e810e4d45b4e,bff9b202
77fa20ba,bff8ba4d08a6b893
t2rot[16]:3fe1c34b72fc7a77,3fd89f1a175b3a10,3fa4f7312b4d5ddc,bfe8026d002f0cf9,bfef527
dca23bc3a,3fdfcf3b77995c83,bfb508f688cfbfa4,bfdbdeb553c12f4d,3fc8360f9b0b4d0b,bfc955a
56e2ac942,bfcfbcbde46194ad,bfd28f60de55d217,bfcd5925ae9dbae7,bfb4f6cad576fd55,bfbb78c
55ad044bc,bfcc9ba2a703e8b1
sns_Y0[16]:1,1,0,-2,-3,1,0,-1,0,-1,0,-1,0,0,0,0
sns_Y1[10]:1,1,0,-2,-3,1,0,-1,0,-1
sns_Y2[16]:1,1,0,-1,-2,1,0,-1,0,0,0,-1,0,0,0,0
sns_Y3[16]:1,0,0,-1,-2,1,0,-1,0,0,0,0,0,0,0,0
sns_XQ0[16]:3fcd5d7ea914b936,3fcd5d7ea914b936,0000000000000000,bfdd5d7ea914b936,bfe60
61efecf8ae8,3fcd5d7ea914b936,8000000000000000,bfcd5d7ea914b936,0000000000000000,bfcd5
d7ea914b936,8000000000000000,bfcd5d7ea914b936,8000000000000000,8000000000000000,80000
00000000000,8000000000000000
sns_XQ1[10]:3fce2b7dddfefa67,3fce2b7dddfefa67,0000000000000000,bfde2b7dddfefa67,bfe6a
09e667f3bcd,3fce2b7dddfefa67,8000000000000000,bfce2b7dddfefa67,0000000000000000,bfce2
b7dddfefa67
sns_XQ2[16]:3fd43d136248490f,3fd43d136248490f,0000000000000000,bfd43d136248490f,bfe43
d136248490f,3fd43d136248490f,8000000000000000,bfd43d136248490f,0000000000000000,80000
00000000000,8000000000000000,bfd43d136248490f,8000000000000000,8000000000000000,80000
00000000000,8000000000000000
sns_XQ3[16]:3fd6a09e667f3bcc,0000000000000000,0000000000000000,bfd6a09e667f3bcc,bfe6a
09e667f3bcc,3fd6a09e667f3bcc,8000000000000000,bfd6a09e667f3bcc,0000000000000000,80000
00000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,80000
00000000000,8000000000000000
g_sns[64]:3fa891e439a05cb3,3fa891e439a05cb3,3fab32bbb5ccd5b9,3fb0aa055179d18a,3fb46b8
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62708b977,3ffc63f437791abb,3ffb3f153068b43c,3ffa26035f7fd82f,3ff91845066b3795,3ff8f98
95935374d,3ff9c666c3378ac7,3ffa99d4a8acc38d,3ffb7408e2603ba4,3ffc801c7b6b4af3,3ffdc33
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7d2c8c0de,4007b8ddecc156d8,4007798ec3c5ec5e,40073ae8902c9272,4006fce98f0b6b5f
X_S[120]:c094d9d9b886df9a,40975f865d4a5520,c0b5c17d85bc13a2,c0c47b43b5cbbaea,4081b400
b17c6ba7,40b77e284250a39c,c0809790661d7d11,40708c048e9feb5e,409a141454da5ee7,c0a0479d
d30a5bf0,408d1efc863a88c5,4083e9a9833ed355,c09d4b6de305e590,409e2309b3018efe,c07f3020
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5f44a839,c095e37aa54b08fe,4086375577dfb41c,40755d1708c61508,c091839b2c20d366,409142ce
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329c06db,408806e9b4788356,c072ee5ad3c39058,c076f1b20e9b100a,408704c8af97ae7b,c0822527
```

```
1a8f025c,4055bf35b3a9b686,407d3cea52a4a659,c085533519d3d780,4079418a60aa94fd,4056a8ab
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393a2a1c,40613906853e0d97,40609abaf5c148d5,c0750c60db50392f,4072c7e732c059cd,c046ba12
afa8ad1f,c06a02cdcae3c7e8,4074ebc03da90bba,c06d6f202489bdc0,c045f0e332a8173b,40703a63
15bc2216,c0737a64abf633fe,4064508b71f5be75,405e77a034184559,c07277b8b9aa9999,4070f379
4cdc8c16,c0543753fc1db99f,c06765d753dd118b,407349d64373a7da,c06b37109a1d8a12,3fde526e
4c912195,406e072248338e9c,c072f7b79b34492c,4062f5ef4182439e,4053780b79318120,c071960d
b9e9c3d0
```

```
X_f[120]:c094d9d9b886df9a,40975f865d4a5520,c0b5c17d85bc13a2,c0c47b43b5cbbaea,4081b400
b17c6ba7,40b77e284250a39c,c0809790661d7d11,40708c048e9feb5e,409a141454da5ee7,c0a0479d
d30a5bf0,c081de84a5d9c7f6,40735cc0d589b54e,c06abdfdd88beaf0,405f4deadbddf5c6,40746d8e
8b2c794f,c0667e437eeb6dba,c0690683f7901caa,402138ee1d065908,c06f0a8e913b332b,40658460
6d7b57c7,3ff69c538ddcfc8c,c055526e8c44aa83,4066507bab4ec6e7,c06de7457471660d,4058d408
98f118d2,40565f84e8ad8ce9,c06b19082a7a774b,4071c74486c5df56,c05a770b8083cd67,c0654394
91a2e3eb,406a27d491edf5b9,c045d44c990279e7,c04aa71d67604b5d,4057c4310c35b9ab,c038f59e
63fb399e,c033e1ea6fc6bc8a,404ff9a4d5da0185,c066d16a4df7f6ff,406296c45e6ad606,c03dec98
73c84c70,c0432de390212b4e,406113ed3f6f5ae6,c056e06c43ccb76a,c04244b5657c4b66,404eb09d
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b95a838c,c04a402787a21814,c05622b8c04782fb,4055cf1ff29b7128,c051cf8968dbe4c7,40417592
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57afb7aa,c0250e751a98ebd0,4041559613fd3087,c0587b66bf68169d,404b6bb6afa6fa44,404344c5
4de2456d,c044d583559bdabd,40574e70271f2077,c0423dccf3ab3586,c04c5c1f288522e9,4048a94f
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f16d1c64,4055c3ba92c031ff,c049dba34ec4c589,bfe718db458d26d8,402de47078c77b5e,c05560c0
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8421ed02,c041464433acd5a3,404122ee71f3932b,c051d8f7e92b1c91,4032a1bbcf387dc4,404a25e0
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2c952709,c04223bc832994cd,3ff5342ba5afdc18,40521cb6ef589d20,c043beccb6ea84d0,402d383b
b7bb79ba,4022a87d5af9b104,c0520ec567f20002,4042a1f4ee4c82d2,400921bd8b1610a2,c032dbf7
5d4e9610,4051c8e13f3dd2ed,c03fd9521d94c1a8,c035da0094f77625,403a92c826cf2e62,c0517ddf
58e070c7
```

```
rc_order[2]:8,0
```

```
rc_i_1[8]:12,13,6,9,7,9,7,9
```

```
rc_i_2[8]:8,8,8,8,8,8,8,8
```

```
rc_q_1[8]:3fe58eea2a9d6da3,3fe9895b6c9a05f6,bfd71e955d8e7cdc,3fc7851aacd6c6b4,bfc7851
aacd6c6b4,3fc7851aacd6c6b4,bfc7851aacd6c6b4,3fc7851aacd6c6b4
```

```
rc_q_2[8]:0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000
000000000,0000000000000000,0000000000000000,0000000000000000
```

```
tns_lev_a[9]:3ff0000000000000,3fe0ecc1c2b664e3,3fe158892bd17778,bfdcb5ba5ed18b51,3fd7
02c4799591fe,bfc88c983e0474d7,3fc757f1df454cac,bfbea3e315478191,3fc54f9e48ee9621
```

```
tns_lev_e[1]:0.397854
```

```
tns_lev_rc[8]:3fe3676a52d291ca,3feaa067f362f434,bfda207694c55026,3fcc223e23fb9bd5,bfc
3c6c9412859c7,3fcce28435fe0c7d,bfcb59813cfae2ea,3fc54f9e48ee9621
```

```
num_tns_filters[1]:1
```

```
nbits_TNS[1]:24
gg_off[1]:-127
gg_ind[1]:189
gg_min[1]:114
gg[1]:163.789371
nbits_offset[1]:0.000000
X_q[120]:-8,9,-34,-64,3,37,-3,1,10,-13,-3,2,-1,1,2,-1,-1,0,-1,1,0,0,1,-1,0,0,-1,2,-
1,-1,1,0,0,0,0,0,0,-1,1,0,0,1,0,0,0,-1,0,0,0,0,0,0,0,0,1,0,0,0,-
1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
lastnz[1]:64
nbits_est[1]:164
lsbMode[1]:0
nbits_spec[1]:156
gg_ind_adj[1]:190
gg_adj[1]:1.778279e+02
X_q_req[120]:-7,8,-31,-59,3,34,-3,1,9,-12,-3,2,-1,1,2,-1,-1,0,-1,1,0,0,1,-1,0,0,-
1,1,0,-1,1,0,0,0,0,0,0,-1,1,0,0,1,0,0,0,-1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
lastnz_req[1]:60
nbits_est_req[1]:147
nbits_trunc_req[1]:147
lsbMode_req[1]:0
res_bits[13]:0,1,0,1,1,0,1,1,1,1,0,0,0
F_NF[1]:4
bytes_side_info[30]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,4,7,211,72,132,69,190
,59
bytes_ari[30]:254,134,219,162,144,120,84,177,93,27,31,59,36,98,175,181,149,156,176,16
0,111,190,172,7,211,72,132,69,190,59
x_s[120]:-23169,-20787,-18204,-15446,-12540,-9511,-6393,-
3212,0,3212,6392,9511,12539,15446,18205,20787,23169,25329,27245,28898,30273,31356,321
37,32609,32767,32610,32137,31356,30273,28898,27244,25329,23170,20787,18204,15446,1254
0,9511,6392,3211,0,-3211,-6393,-9512,-12539,-15446,-18204,-20788,-23170,-25329,-
27245,-28898,-30273,-31356,-32137,-32609,-32767,-32609,-32138,-31356,-30273,-28898,-
27245,-25329,-23170,-20788,-18205,-15447,-12539,-9512,-6392,-
3211,0,3211,6393,9512,12539,15446,18204,20787,23170,25329,27244,28897,30273,31356,321
37,32609,32767,32609,32137,31356,30273,28897,27244,25330,23170,20787,18205,15446,1253
9,9512,6393,3213,0,-3212,-6393,-9512,-12540,-15447,-18205,-20787,-23169,-25329,-
27245,-28897,-30273,-31356,-32138,-32609
X[120]:40adc8628fab7480,c0d583f6a794a367,40ee56c99e07de16,c10f3b2664a343f3,c0e3ac3739
e07553,c0c6a3d301434ce7,40c385521cfb344a,c0b63d28319bee39,c095eadcb6b40fca,c055344549
012528,c064ddbce2d9807f,4042bbe090b12cab,4063d86f2e5da099,405b45cc9d73e6e3,c028e4b5b0
359884,c05381065694ff8d,c04dd52612b1c9e3,40312689a5957720,4044b7b62e126b33,402ce4b4bd
dceb5c,c00eb0fb7553ad59,c022073da669edb5,c027cfc1ec4bc545,c027842365af977f,4003c1b448
d5ca84,40306bf2ece97449,4031f572442807c7,bff02e21d2020ece,c03146b1a7a23fa6,c02d288c8b
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a0dd99,c0159c6ea96b225c,c01caa3d839dc697,c01516d5dc2cd90e,4001cf1002aca2ba,402452e37b
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x_tilde_12.8D[97]:c0d4eb80d00db5d1,c0d16fb7bc0026f9,c0cb7cb0ffa4ec84,c0c3c9015b5be4d1,c0b7b5a0bc49a996,c09e813ef256c400,40a0be89b64cd466,40b8183543a9c46f,40c3ada7dcb216c9,40caf0933223cf3e,40d0db4ba9949e41,40d3f5c9d3f1b058,40d6beafc1634196,40d9261bdaba8941,40db24383accff48,40dcb4e3478fa22f,40ddd2dad090086c,40de73a90f1465db,40de99aa214cc8b2,40de4607c43c423f,40dd7a49d0642a8f,40dc330f34dfbbab,40da7c5878dab2e0,40d85ce2592c5415,40d5db8f23c6730b,40d2fdf8eb37efaf,40cfac2a94ee5ab4,40c8dd62e8944696,40c1a654eecabae2,40b4406663b330e0,409398ff5973ec90,c0a5202049b39b9c,c0b9f044fa1b2786,c0c47bfbe3401986,c0cbb02febb3a033,c0d13efe815913ce,c0d46800f3bd59d2,c0d742706a7a9d4c,c0d9c2de88f32995,c0dbe2db4ee61926,c0dd9b325ab2cc8e,c0dede896a78ab4b,c0dfabf596a16785,c0e000cbe7a99645,c0dfdeae9fb741a1,c0df3cb1138e1b46,c0de2403a749c136,c0dc98f56e2c0a46,c0daa0de243426e4,c0d83d98901f6550,c0d57ec747a2e008,c0d26eb02f824b3a,c0ce2ca2f01b02c8,c0c7002bbad49212,c0beff12f76f77cc,c0af0eaf19e76114,404c1b3cb16f3b00,40affd9e48cecda2,40bf8212771548da,40c7486a15461893,40ce7d4601a03e2f,40d29ee82de51842,40d5b70d33f8c764,40d87df5a4c476b8,40daeab17a609911,40dcee4c24e22ca7,40de83ed5360b4bb,40dfa6f7ab29f7dd,40e02a3763c90ed4,40e0415bcc418788,40e01b460884b62a,40df721f173c55c5,40de3820c4726dc2,40dc86adcab9e056,40da6bd5aca8b522,40d7eed78ef248af,40d517b940993a70,40d1edf282f89e13,40cd0811f72a1a9e,40c5caa6befc266c,40bc779eeede1862,40a9d8360570c184,c085ec80ce3a2de0,c0b251282c2d7248,c0c0ceeaf68f8d60,c0c8300b456338a6,c0cf2b7c8e926f4f,c0d2d526d8683836,c0d5ccc9518c7f26,c0d86c0617476cd9,c0daa9c7b3ddef16,c0dc7f55ac309f1f,c0dde7eb93ae2ff4,c0ded6eecacfa35b,c0df4d238e1430c3,c0df49fdc3456de5,c0dece3740a49b25

T_curr[1]:25

normcorr[1]:0.952099

T1[1]:25

T2[1]:25

normcorr1[1]:0.952099

normcorr2[1]:0.952099

pitch_index[1]:72

pitch_present[1]:1

ltpf_active[1]:0

nc_ltpf[1]: 0.963121

E_B[64]:416bb819759a34d7,41bceea7ddb8b6d8,41ecc3a568f67702,422e7b07b8bd7df2,41d83040cd900f38,41a00488d4c8c005,4197d0f9eb9bd5b8,417ee9184b4c0cbb,413e05fae35d64be,40bc19e0a3298ff1,40db365931d05943,4095ef576314aa72,40d89d77cb06d135,40c73e618936f3ff,40635d732966f5ac,40b7c67f83d8844c,40abcfe0c4e8692c,4072624152504d6b,409ad384d2a649fb,406a169edfd10457,402d6faa51bf77b9,4054504dfd4d7f32,4061b7eb9d2530fe,40614814865a7a1c,4018653542484ec5,4070dabe295be74f,407428480f6c66d2,3ff05cc8a6c3267e,4072a771de6826b0,406a91b21e9fa18c,3fb847a4933877dc,40285d91b86e6d20,4053e9a60c1ab5f6,405bc8e65777b385,40409fdfb1e59a51,40630912e5ef1a6b,404ca62f82ce0133,403e7321623667ba,403e35ca9e03b4e4,4049b03984c0f31c,405986728ed55adb,40119fbef91aaf2e,404422e1a597f4db,40306058331f5dd0,4054409ca6871087,402f54e6e97bf936,40393a32650b687a,4011f57c0dee4d59,40467cd951d280e4,4033d2305

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P_bw[1]:1

scf[16]:4015ac48d30a5ffa,401159618f275898,3fd426e8b70c5da3,bfe8c9e7f4b2c3f9,bfe8c9e7f
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ind_LF[1]:17

ind_HF[1]:25

shape_j[1]:0

submodeMSB[1]:0

submodeLSB[1]:0

Gind[1]:0

LS_indA[1]:0

idxA[1]:2213651

LS_indB[1]:1

idxB[1]:1

scfQ[16]:401753911fe7e9f3,400fde45d3b283e4,3febab7db4064d5d,bfee8ab7695a25f6,bfe9f9be
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t2rot[16]:bfc87efaa08dd13b,bfc19a12b096b423,3fdc9ce5b8440376,3fd9d6e6efd8cf2e,3ffa9af
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sns_Y0[16]:0,0,1,1,3,1,1,1,-1,-1,0,-1,0,0,0,0

sns_Y1[10]:0,0,1,1,3,1,1,1,-1,-1

sns_Y2[16]:0,0,0,0,2,0,1,1,0,-1,-1,-1,-1,0,0,0

sns_Y3[16]:0,0,0,0,2,0,1,1,0,-1,0,-1,0,0,0,0

sns_XQ0[16]:8000000000000000,8000000000000000,3fcf0b6848d2af1c,3fcf0b6848d2af1c,3fe74
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sns_XQ1[10]:8000000000000000,8000000000000000,3fd0000000000000,3fd0000000000000,3fe80
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sns_XQ2[16]:8000000000000000,8000000000000000,0000000000000000,0000000000000000,3fe43
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sns_XQ3[16]:8000000000000000,8000000000000000,0000000000000000,0000000000000000,3fe6a
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g_sns[64]:3f91fb1aefcfa377,3f91fb1aefcfa377,3f951a76422a8944,3f9d11b867a9d6d1,3fa4055
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X_S[120]:4050bc29336bf3fb,c0782de0785e1531,4094020af2485ac2,c0bc5ee630e25499,c0989dde
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X_f[120]:4050bc29336bf3fb,c0782de0785e1531,4094020af2485ac2,c0bc5ee630e25499,c0989dde
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rc_order[2]:8,0
rc_i_1[8]:5,13,8,10,9,9,7,9
rc_i_2[8]:8,8,8,8,8,8,8,8
rc_q_1[8]:bfe0d8884363dd7f,3fe9895b6c9a05f6,0000000000000000,3fd71e955d8e7cdc,3fc7851
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rc_q_2[8]:0000000000000000,0000000000000000,0000000000000000,0000000000000000,0000000
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tns_lev_a[9]:3ff0000000000000,bfecfcf3a6e63fc0,3fefa1bae963f3a7,bfc24c23ae5730ab,3fd0
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tns_lev_e[1]:0.665554
tns_lev_rc[8]:bfe19251a15afc9a,3fe8e6404522d65d,bf6241e8461c6ea8,3fd62cea112e526d,3fc
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num_tns_filters[1]:1
nbits_TNS[1]:24
gg_off[1]:-127
gg_ind[1]:162
gg_min[1]:109
gg[1]:17.782794
nbits_offset[1]:-1.600000
X_q[120]:4,-22,72,-408,-88,-35,46,-45,-19,-2,-4,5,3,3,-1,2,0,4,-1,0,-
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lastnz[1]:22
nbits_est[1]:140
lsbMode[1]:0
nbits_spec[1]:146
gg_ind_adj[1]:162
gg_adj[1]:1.778279e+01
res_bits[10]:0,1,1,0,0,0,1,0,0,1
F_NF[1]:6
bytes_side_info[30]:0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,24,144,108,15,107,140,1
99,162,21
bytes_ari[30]:218,82,99,87,248,102,55,207,133,225,212,50,70,194,54,109,237,169,82,88,
23,24,144,108,15,107,140,199,162,21
```

C.4 Decoder intermediate output

C.4.1 Modules and data type overview

C.4.1.1 Side information

Before the arithmetic decoding is processed, the side information needed to initialize the decoder is read from the input bitstream. The input arguments to read the side information are provided in the table below.

Variable Name	Type
nbytes	integer16

Variable Name	Type
bytes_ari [nbytes]	unsigned integer8
fs_idx	integer16

The implementer should initialize the variable N_E indicating the number of encoded spectral lines. Table C.1 gives an overview of the variables provided after decoding the side information.

Variable Name	Type
BEC_detect	integer16
lastnz	integer16
P_{bw}	integer16
lsbMode	integer16
gg_ind	integer16
num_tns_filters	integer16
$rc_{order}[2]$	integer16
pitch_index	integer16
pitch_present	integer16
ltpf_active	integer16
F_{NF}	integer16
ind_LF	Integer16
ind_HF	Integer16
submodeMSB	Integer16
Gind	Integer16
LS_indA	Integer16
idxA	integer32
idxB	Integer16

Table C.1: Variables provided after decoding the side information

C.4.1.2 Arithmetic decoding

Input:

Variable Name	Type
nbytes	integer16

Variable Name	Type
bytes [nbytes]	unsigned integer8
tns_lpc_weighting	integer16
num_tns_filters	integer16
$rc_{order}[2]$	integer16
lsbMode	integer16
lastnz	integer16
F_{NF}	integer16
gg_ind	integer16
fs_idx	integer16

Output:

Variable Name	Type
tns_lpc_weighting	integer16
$rc_{order}[2]$_ari	integer16
$rc_i[]$	integer16
nbits_residual	integer16
resBits	integer16
zeroFrame	integer16
$\hat{X}_q\_ari$ []	integer16
BEC_detect	integer16
nf_seed	Integer32

C.4.1.3 Residual decoding

Variable Name	Type
$\hat{X}_q\_residual$ []	double as HEX

C.4.1.4 Noise filling

Variable Name	Type
$\hat{X}_q$ []_nf	double as HEX

C.4.1.5 Global gain

Variable Name	Type
gg_{off}	integer16

C.4.1.6 TNS

Variable Name	Type
rc_i_tns[8]	integer16
X_s_tns[]	double as HEX

Additional intermediate data is provided for one frame where two TNS filters are active and the order of the TNS filters is not equal.

Variable Name	Type
rc_i_tns_filter1[8]	integer16
rc_i_tns_filter2[8]	integer16
rc_order[2]	integer16
X_f_hat[] (TNS input)	double as HEX
X_s_tns[] (TNS output)	double as HEX

C.4.1.7 Spectral shaping

Variable Name	Type
$\hat{X}$[] _ss	double as HEX

C.4.1.8 MDCT

Variable Name	Type
$\hat{x}\_mdct$[] (corresponding to equations 125 and 126	double as HEX
$\hat{t}\_mdct$[] corresponding to equations 127 and (128)	double as HEX

C.4.1.9 LTPF

Variable Name	Type
$\widehat{x_{ltpf}}$[]	double as HEX

Additional intermediate data is provided to trigger all five LTPF transition cases.

Note: c_num, c_den, c_num_mem, and c_den_mem are zero if they are not used in the current frame.

Variable Name	Type
$input\_ltpf\_transition\_case\_x[]$	double as HEX
$\widehat{X_{ltpf}}\_transition\_case\_x[]$	double as HEX
c_num_case_x[]	double as HEX
c_den_case_x[]	double as HEX
c_num_mem_case_x[]	double as HEX
c_den_mem_case_x[]	double as HEX
pitch_index_prev	Integer16
pitch_index_current	Integer16
nbits_case_x	Integer16
mdct_synt_output_prev_frame_case_x[]	double as HEX
$\widehat{X_{ltpf}}\_prev\_prev\_transition\_case\_x[]$	double as HEX
$\widehat{X_{ltpf}}\_prev\_transition\_case\_x[]$	double as HEX

C.4.1.10 Output signal clipping

The clipped signal $\widehat{x_{clip}}$ is provided.

Variable Name	Type
$\widehat{x_{clip}}[]$	double as HEX

C.4.2 Bitstream input data

The bitstream input data values are provided below. The raw input data is provided for both frames in the following block:

```
frameN[1]:1
nbytes[1]:40
bytes_ari[40]:please see encoder intermediate output data (bytes_ari[40] array)
frameN[1]:2
nbytes[1]:40
bytes_ari[40]:please see encoder intermediate output data (bytes_ari[40] array)
```

C.4.3 Intermediate data for 10 ms frame duration

The intermediate output of the two respective frames is provided within the following block:

```
frameN[1]:1
nbytes[1]:40
fs_idx[1]:1
```

```
BEC_detect[1]:0
lastnz[1]:68
P_BW[1]:1
lsbMode[1]:0
gg_ind[1]:192
num_tns_filters[1]:1
rc_order[2]:1,0
pitch_index[1]:76
pitch_present[1]:1
ltpf_active[1]:0
F_NF[1]:3
ind_LF[1]:25
ind_HF[1]:8
submodeMSB[1]:0
Gind[1]:0
LS_indA[1]:1
idxA[1]:865837
idxB[1]:1
tns_lpc_weighting[1]:1
rc_order_ari[2]:6,0
rc_i[16]:13,9,4,9,8,9,8,8,8,8,8,8,8,8,8,8
nbits_residual[1]:21
resBits[21]:0,1,1,0,0,1,1,0,1,0,0,1,1,1,1,0,0,1,1,1,1
zeroFrame[1]:0
X_hat_q_ari[160]:0,17,-14,44,-49,-89,-1,-12,-12,0,-21,7,-21,-10,1,-2,1,-3,0,-2,1,-
2,1,-1,1,-1,0,1,-1,0,-1,0,0,0,1,-1,1,-1,0,0,0,0,-1,1,-1,1,0,0,0,0,0,-1,1,-1,0,0,0,0,-
1,0,0,0,0,0,0,0,0,-
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0
nf_seed[1]:2660
X_hat_q_residual[160]:0000000000000000,4030d00000000000,c02ba00000000000,404628000000
0000,c048a80000000000,c056540000000000,bfea000000000000,c027a00000000000,c028a0000000
0000,0000000000000000,c034d00000000000,401b400000000000,c035500000000000,c023a0000000
0000,3ff5000000000000,bffd000000000000,3ff5000000000000,c00a800000000000,000000000000
0000,c002800000000000,3ff5000000000000,bffd000000000000,3ff5000000000000,bfea00000000
0000,3ff0000000000000,bff0000000000000,0000000000000000,3ff0000000000000,bff000000000
0000,0000000000000000,bff0000000000000,0000000000000000,0000000000000000,000000000000
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0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
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0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
```

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0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
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0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000

X_hat_q_nf[160]:0000000000000000,4030d00000000000,c02ba00000000000,4046280000000000,c
048a80000000000,c056540000000000,bfea000000000000,c027a00000000000,c028a00000000000,0
000000000000000,c034d00000000000,401b400000000000,c035500000000000,c023a00000000000,3
ff5000000000000,bffd000000000000,3ff5000000000000,c00a800000000000,0000000000000000,c
002800000000000,3ff5000000000000,bffd000000000000,3ff5000000000000,bfea000000000000,3
ff0000000000000,bff0000000000000,0000000000000000,3ff0000000000000,bff0000000000000,0
000000000000000,bff0000000000000,0000000000000000,0000000000000000,0000000000000000,3
ff0000000000000,bff0000000000000,3ff0000000000000,bff0000000000000,0000000000000000,0
000000000000000,0000000000000000,0000000000000000,bff0000000000000,3ff0000000000000,b
ff0000000000000,3ff0000000000000,0000000000000000,0000000000000000,0000000000000000,0
000000000000000,0000000000000000,bff0000000000000,3ff0000000000000,bff0000000000000,0
000000000000000,0000000000000000,0000000000000000,0000000000000000,bff0000000000000,0
000000000000000,0000000000000000,0000000000000000,bfd4000000000000,bfd4000000000000,0
000000000000000,0000000000000000,0000000000000000,bff0000000000000,0000000000000000,0
000000000000000,0000000000000000,3fd4000000000000,bfd4000000000000,bfd4000000000000,b
fd4000000000000,bfd4000000000000,3fd4000000000000,bfd4000000000000,bfd4000000000000,3
fd4000000000000,3fd4000000000000,3fd4000000000000,3fd4000000000000,3fd4000000000000,b
fd4000000000000,3fd4000000000000,3fd4000000000000,3fd4000000000000,3fd4000000000000,3
fd4000000000000,3fd4000000000000,3fd4000000000000,3fd4000000000000,bfd4000000000000,b
fd4000000000000,bfd4000000000000,bfd4000000000000,bfd4000000000000,bfd4000000000000,b
fd4000000000000,bfd4000000000000,bfd4000000000000,3fd4000000000000,bfd4000000000000,b
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fd4000000000000,3fd4000000000000,3fd4000000000000,3fd4000000000000,bfd4000000000000,b
fd4000000000000,3fd4000000000000,3fd4000000000000,3fd4000000000000,bfd4000000000000,b
fd4000000000000,3fd4000000000000,3fd4000000000000,bfd4000000000000,bfd4000000000000,b
fd4000000000000,bfd4000000000000,bfd4000000000000,3fd4000000000000,bfd4000000000000,b
fd4000000000000

gg_off[1]:-131

rc_i_tns[8]:13,9,4,9,8,9,8,8

X_s_tns[160]:0000000000000000,40a3d0a2e1c8544f,c0a0477b59600ff8,40ba1cf14cc20e09,c0bd
0f3ce918f1a6,c0ca50cce5e80748,c05ea4abf387a597,c09bd81752351a28,c09d05cf2a57db9a,0000
000000000000,c0a8878242535a17,40900ee8e0d98bb3,c0a91e5e2e64bad0,4087c73ab709ba56,c09e
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edd61bcb6b5d,4090c776e0fddfdb,c092d0f92766b3b8,409435f31fe0192c,c0911b3efd99cfbd,4083
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```

```
b7b259c259c8,c0842afbe06ae502,40888123b1336ed0,c08cc2862ab32c1a,408a7a3849a619a0,c086
7af2dd5a05a8,407d1e5e7f7fac1f,c050386f5bdab0b0,c070893111ea903e,4081913732 3b161e,c084
e11315469d97,4084b21b4e07f91c,c08475fd210d6c79,408060c88da63439,c07916ccdf3d28f6,404f
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4f0cb0f173f6,c0487363d00c1226,4058e6885bd25fb7,c04f5d1cd4566b65,404452ccb95bbce3,c043
6b783a292fdc,404bcf31985b9e08,402f37d15de18e3c,403a69fad458e7d5,c02b52f15ccac02a,c035
ef64b669dff7,4051a6b1b4922474,c04201c6a34d5748,c0150388b3153734,c033188867b22f14,c04d
bb29be4debc2,c0347974b90e1052,c0549d44f60933da,40509d5079cae1a9,c06161de92a08455,4046
7efa56353fda
```

```
X_hat_ss[160]:0000000000000000,40df5e39778ac3c1,c0daca0628dd9eed,40f737aecc46de7d,c0f
beb6a6bd8d3af,c10b522e8ffb00a2,c09cb3b2eaf9318d,c0d3a4e8e5a5770b,c0ced87506205df5,000
0000000000000,c0ce7c8805b8ba96,40afef0b4322f3f0,c0c3fb284b660072,409e43b80b315681,c0b
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5b950f2a2004f,40a138e603790286,c096e6433242f365,4088e1e9934e9719,406248c9e7122492,c08
561b45d7c5cba,40937d24276619bc,c0953e391bbd0786,4094f70e59b92dc1,c0904dec42704a69,408
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982fb17c7dae6,c0782d8fd822f82e,407d607450b69e02,c07fe32a45008c2d,407d5b520a81fdce,c07
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321451b565a53,407322d9f329f1df,c072eb438c764b11,406e90e89faf8052,c067695f5d1ba3a0,403
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2d1732750379c,3ff150e50d6faf60,c021e288641cf347,403b325fb9d99550,c04202f24e308c69,404
4eabda4aa5c78,c036ff1168d06d9c,4009376f904d0ace,4038737a0b32d59f,c037a9c48896b001,404
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```

ec926326d66f3,c0153362070b8c1b,c03558777c2c5265,4031343088acf201,c041ffb788b939a6,402
74b433909e358

x_hat_mdct[160]:3fe3b022c408e712,3ffb6360984e3ac1,bfc4bc8f0c69c8e2,c000e2d368dec200,3
fed52e55156e352,402184451d748799,402c956a7d5924b5,402d3b57c75005fe,4033500f1764b54e,4
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resBits[3]:0,0,1
zeroFrame[1]:0
X_hat_q_ari[160]:-21,-49,15,-170,165,398,-56,115,-31,69,9,54,15,63,-10,11,-6,10,-
3,10,3,5,4,3,4,2,1,0,-1,-
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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,0,0,0
nf_seed[1]:8298
X_hat_q_residual[160]:c035500000000000,c048a80000000000,402ea00000000000,c06540000000
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0000,4051400000000000,4022000000000000,404b000000000000,402e000000000000,404f80000000
0000,c024000000000000,4026000000000000,c018000000000000,4024000000000000,c00800000000
0000,4024000000000000,4008000000000000,4014000000000000,4010000000000000,400800000000
0000,4010000000000000,4000000000000000,3ff0000000000000,0000000000000000,bff000000000
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0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
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0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
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0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
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0000,0000000000000000
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```
X_hat_q_nf[160]:c035500000000000,c048a80000000000,402ea00000000000,c065400000000000,4
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0240000000000000,4026000000000000,c018000000000000,4024000000000000,c008000000000000,4
0240000000000000,4008000000000000,4014000000000000,4010000000000000,4008000000000000,4
0100000000000000,4000000000000000,3ff0000000000000,0000000000000000,bff0000000000000,b
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fb0000000000000,3fb0000000000000,3fb0000000000000,bfb0000000000000,3fb0000000000000,3
fb0000000000000
```

```
gg_off[1]:-131
```

```
rc_i_tns[8]:4,7,9,9,9,9,8,8
```

```
X_s_tns[160]:c07bebf949452e8f,c09026b70c8a8d3b,40740fa4175d3f7b,c0abd70310c01966,40ab
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```

```
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X_hat_ss[160]:c0b8978ff0f7648d,c0cc73484eb39a3d,40b3c6385e599657,c0f12f9a534e4683,40f
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```

```
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```

```
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C.4.4 Additional intermediate data for TNS decoder

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rc_order[2]:4,5

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rc_i_tns_filter2[8]:4,9,11,9,9,8,8,8

X_s_tns[400]:408d895fa2816cac,408319d8e6438bba,40a4fcde6727e066,c08cca8cde33dc9a,40ae
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C.4.5 Additional intermediate data for LTPF decoder transition cases 2-5

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c_num_case2[3]:3fca36fc3e722260,3fc2449b5a7b66e3,bf7a3ab4ef4b7f3f

c_den_case2[4]:3f903fd243fe90c8,3fc78319bedc78c0,3fc78319bedc78c0,3f903fd243fe90c8
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c_num_mem_case2[1]:0.000000

c_den_mem_case2[1]:0.000000

pitch_index_prev_case2[1]:60

pitch_index_curr_case2[1]:56

nbits_case2[1]:320

mdct_synt_output_prev_frame_transition_case2[160]:40a068f5c1436f73,40a024166818d1d2,4
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c_num_case3[1]:0.000000

c_den_case3[1]:0.000000

c_num_mem_case3[3]:3fca36fc3e722260,3fc2449b5a7b66e3,bf7a3ab4ef4b7f3f

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pitch_index_prev_case3[1]:56

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x_hat_ltpf_prev_prev_transition_case3[160]:4050043be40481c7,4058acf7d00ce4bd,40613c49
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c_num_case4[3]:3fca36fc3e722260,3fc2449b5a7b66e3,bf7a3ab4ef4b7f3f

c_den_case4[4]:3f903fd243fe90c8,3fc78319bedc78c0,3fc78319bedc78c0,3f903fd243fe90c8

c_num_mem_case4[3]:3fca36fc3e722260,3fc2449b5a7b66e3,bf7a3ab4ef4b7f3f

c_den_mem_case4[4]:3f903fd243fe90c8,3fc78319bedc78c0,3fc78319bedc78c0,3f903fd243fe90c
8

pitch_index_prev_case4[1]:56

pitch_index_curr_case4[1]:56

nbits_case4[1]:320

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c_num_case5[3]:3fca36fc3e722260,3fc2449b5a7b66e3,bf7a3ab4ef4b7f3f

c_den_case5[4]:3fa5e9d6c3f68035,3fcc29f16cb77c64,3fc12ff6d38bca60,3f65f368e15d1dd2

c_num_mem_case5[3]:3fca36fc3e722260,3fc2449b5a7b66e3,bf7a3ab4ef4b7f3f

c_den_mem_case5[4]:3f903fd243fe90c8,3fc78319bedc78c0,3fc78319bedc78c0,3f903fd243fe90c
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pitch_index_prev_case5[1]:56

pitch_index_curr_case5[1]:52

nbits_case5[1]:320

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05147f42e214936,4014980e3b228e58,c04cfcb5fc5084e6,c05cd48bc1790a4b,c06561f5f9cfded5,c
06bae454ee2cad4,c070ba2e60708766,c07385bcd6988eb9,c07623efb29a57fa,c078a3526c0b6789,c
07aca0b5cf7c790,c07cfeef6be36896,c07f4978df671be0,c0809429c7a46f4b,c081a4fcc77a4b86,c
082aab007458833,c083911ec6ba4354,c0846fa5d6aac876,c08524623a664c33,c0858c7c13b2be30,c
08592e98fbbbdbf,c08560ccc2e8bfec,c084ddc7963b63ff,c0840a87c47512d5,c082e1e54457faae,c
08171982177a25e,c07f4dbae2308836,c07b1dc44df81c9d,c0764fa2ba89a001,c0711885ac2ad164,c
0666ec55e550e90,c054f9433459cef4,402bbd97db96b64c,405d272253b566c6,406b249c24b38b3d,4
073f2b4b188a6f7,4079ea9481016ac6,407fc12a38715098,4082a7f6ac9e8cc0,408517726 2b29483,4
087502f32061214,4089368cc5a1fcc8,408a9cf797e06084,408b6a900193649f,408bc01969a61c98,4
08b6ab4c4ccba25,408ac8e79bbb49f8,40899b2ce9e15ce0,408811a0d3837da2,40865145f00c9c57,4
084332fca417704,4081f1c85757dd08,407f1d27149b835c,4079e002b6b515d2,4074ce8d3c9f67af,4
06f9740e58bbb88,40655e289958712c,4057ab82e50281b9,4033370015d705db,c0478503241ecd36,c
05ce6bf7541a3b0,c066032c23ba3c35,c06d4cde79b83c5a,c071f8772ee9acd8,c07511dbc758f408,c
077ebc2e3254160,c07a9eaaf871e296,c07cff9a775ae7a8,c07f64cf420ac30e,c080a6a840fe0930,c
0819234c619eb74,c0827a414d4cb826,c083258dfba877d4,c083f1b254febefe,c084749fee18ab9c,c
084f1fd19e7989a,c085326528a243c8,c08526067eff99ca,c084c4689109152d,c0841a3de6a553ea,c
0834a44d180e399,c082138e10221229,c080af5c17922038,c07ddda0c2ddf21c,c079df4e9215de34,c
0753567678c8c77,c0702262eb0d27cd,c0658aea5dcd6f56,c053f72f12ed7fab,402f6c58c5ad5baa,4
05b9eb740b55626,406a286214e02fca,40730d1dcf0f436e,407905de42a56a82,407eb2e1f0202a5e,4
081f2573213d662,40845647fed572a0
```

C.4.6 Intermediate data for 7.5 ms frame duration

The intermediate output of the two respective frames is provided within the following block:

```
frameN nbytes fs_idx BER_detect lastnz P_BW lsbMode gg_ind num_tns_filters rc_order
pitch_index pitch_present ltpf_active F_NF ind_LF ind_HF submodeMSB submodeLSB
```

```
shape_j Gind LS_indA idxA LS_indB idxB tns_lpc_weighting rc_order_ari rc_i
nbits_residual resBits zero_frame X_hat_q_ari nf_seed X_hat_q_residual X_hat_q_nf
gg_off rc_q_tns X_s_tns X_hat_ss x_hat_mdct t_hat_mdct x_hat_ltpf



frameN[1]:1
nbytes[1]:30
fs_idx[1]:1
BER_detect[1]:0
lastnz[1]:60
P_BW[1]:1
lsbMode[1]:0
gg_ind[1]:190
num_tns_filters[1]:1
rc_order[2]:1,0
pitch_index[1]:0
pitch_present[1]:0
ltpf_active[1]:0
F_NF[1]:4
ind_LF[1]:17
ind_HF[1]:8
submodeMSB[1]:0
submodeLSB[1]:1
shape_j[1]:1
Gind[1]:0
LS_indA[1]:0
idxA[1]:1025681
tns_lpc_weighting[1]:1
rc_order_ari[2]:8,0
rc_i_1[8]:12,13,6,9,7,9,7,9
rc_i_2[8]:8,8,8,8,8,8,8,8
nbits_residual[1]:10
resBits[10]:0,1,0,1,1,0,1,1,1,1
zero_frame[1]:0
X_hat_q_ari[120]:-7,8,-31,-59,3,34,-3,1,9,-12,-3,2,-1,1,2,-1,-1,0,-1,1,0,0,1,-1,0,0,-
1,1,0,-1,1,0,0,0,0,0,0,-1,1,0,0,1,0,0,0,-1,0,0,0,0,0,0,0,0,0,0,0,0,-
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
nfseed[1]:1184
X_hat_q_residual[120]:c01d400000000000,4020a00000000000,c03f500000000000,c04d68000000
0000,400a800000000000,4040e80000000000,c006800000000000,3ff5000000000000,4022a0000000
0000,c027a00000000000,c008000000000000,4000000000000000,bff0000000000000,3ff000000000
0000,4000000000000000,bff0000000000000,bff0000000000000,0000000000000000,bff000000000
0000,3ff0000000000000,0000000000000000,0000000000000000,3ff0000000000000,bff000000000
0000,0000000000000000,0000000000000000,bff0000000000000,3ff0000000000000,000000000000
0000,bff0000000000000,3ff0000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,bff0000000000000,3ff000000000
0000,0000000000000000,0000000000000000,3ff0000000000000,0000000000000000,000000000000
0000,0000000000000000,bff0000000000000,0000000000000000,0000000000000000,000000000000
```

```
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,bff0000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000,0000000000000000,0000000000000000,0000000000000000,000000000000
0000,0000000000000000
```

```
X_hat_q_nf[120]:c01d400000000000,4020a00000000000,c03f500000000000,c04d680000000000,4
00a800000000000,4040e80000000000,c006800000000000,3ff5000000000000,4022a00000000000,c
027a00000000000,c008000000000000,4000000000000000,bff0000000000000,3ff0000000000000,4
000000000000000,bff0000000000000,bff0000000000000,0000000000000000,bff0000000000000,3
ff0000000000000,0000000000000000,0000000000000000,3ff0000000000000,bff0000000000000,0
000000000000000,0000000000000000,bff0000000000000,3ff0000000000000,0000000000000000,b
ff0000000000000,3ff0000000000000,0000000000000000,0000000000000000,3fd0000000000000,b
fd0000000000000,0000000000000000,0000000000000000,bff0000000000000,3ff0000000000000,0
000000000000000,0000000000000000,3ff0000000000000,0000000000000000,0000000000000000,0
000000000000000,bff0000000000000,0000000000000000,0000000000000000,bfd0000000000000,3
fd0000000000000,3fd0000000000000,3fd0000000000000,bfd0000000000000,3fd0000000000000,3
fd0000000000000,3fd0000000000000,bfd0000000000000,0000000000000000,0000000000000000,b
ff0000000000000,0000000000000000,0000000000000000,3fd0000000000000,3fd0000000000000,b
fd0000000000000,bfd0000000000000,3fd0000000000000,3fd0000000000000,3fd0000000000000,b
fd0000000000000,bfd0000000000000,3fd0000000000000,bfd0000000000000,3fd0000000000000,b
fd0000000000000,3fd0000000000000,bfd0000000000000,bfd0000000000000,bfd0000000000000,b
fd0000000000000,bfd0000000000000,bfd0000000000000,3fd0000000000000,bfd0000000000000,3
fd0000000000000,3fd0000000000000,bfd0000000000000,bfd0000000000000,3fd0000000000000,b
fd0000000000000,3fd0000000000000,3fd0000000000000,bfd0000000000000,bfd0000000000000,3
fd0000000000000,bfd0000000000000,3fd0000000000000,bfd0000000000000,3fd0000000000000,3
fd0000000000000,3fd0000000000000,3fd0000000000000,3fd0000000000000,bfd0000000000000,b
fd0000000000000,bfd0000000000000,3fd0000000000000,3fd0000000000000,3fd0000000000000,3
fd0000000000000,3fd0000000000000,bfd0000000000000,bfd0000000000000,bfd0000000000000,3
fd0000000000000,3fd0000000000000,3fd0000000000000,bfd0000000000000,3fd0000000000000,3
fd0000000000000
```

```
gg_off[1]:-127
```

```
rc_i_tns[8]:12,13,6,9,7,9,7,9
```

```
X_s_tns[120]:c09451779f4aeefe,409718c76f0f29ee,c0b5c03cc66c1d62,c0c46d40bd68994b,4082
6870c0740678,40b77ccea846c238,c07f4241e15f9710,406d2cc6058c6adc,4099e0173ed364de,c0a0
692f631efc1c,408eb286f601076e,408475c352a28128,c09d66a5834f0967,409f3e05228c3ec8,c080
66a4fb796d68,c091a675ed836ac8,409d8ed283a2609e,c095fdef91f25018,40527165ff4a2400,4092
22e9930119c9,c096e5eb011b64c0,408c3a511ff66b46,40677cfaffc1a0c4,c0900f799f808ff1,4090
9bae731d3f84,c080c2c47c5c92fa,c074484e56f3681b,408c30a3b47feaec,c089156c1358aa29,405e
b1735dd8d4e8,408156ca75a1a440,c0856ec77480d684,407a3035ab35b6fa,405231eab386cc5c,c07b
29b8ec2a3fba,407c354de51cb94c,c06af9363978917b,c06ec914887386dc,4080cc8907e9c484,c077
d78021dffb09,40410c802774dff8,407c3b2de9b0c475,c07f9c0ecf1280f9,40710ca2a8f07a09,4057
9f9220ced6aa,c0807a2b99942cb6,407f10b5847e5392,c0695d0589097811,c06b6e006f6d7e4e,407c
f2a67542aad2,c0767e2b49409bf0,4063319881211d62,40563e287f7690ff,c06a78b2fc28c582,4072
563179189b23,c0640515ee2a5728,c03e1384b633bc80,4061da5a771e0c4a,c066c1103c03b397,c043
1e691aa32c14,40543f4f6f4cfc76,c050fa52c382b23c,4046f03c62cbe2a8,404d149a90106b14,c05e
59fc72b3a941,403e860a0f220fee,405971cf4941146d,c051f14675325144,40516ca041f96b22,c046
```

2bdac9af78a2,c053591aed5d10ea,4063f517ec392520,c06355b23cdcf42c,40543dca45326582,4017
e5f8ded49198,c053b8fc9be13a46,4057735bff6f05b4,c0607893e9f0d88f,403f56306cd18c80,3fe2
c3cef0782e60,c05b5a97105028fc,4055149d4ea929b6,c0247663ab000f74,c05313f90c59f054,4060
3ee43ce50078,c03b9c30ea8f0190,c0564c332bf244d5,405383e6a57a6606,4018afb6bb31bc70,c057
fd1ac8db4eff,4060c1db0204b421,c029012defb70978,c060f0d509292ed6,405de16de3f64dda,c019
ec3bbc8bca60,c05e5b6c6f56a17d,4066a4f0970eb587,c061d284cbdeb656,403f39aa0a207c30,4064
0aa1f9f0c0ef,c064a3c77a5c587e,40630d093c7da409,402946ade7d41ce8,c0649634a2a0eed1,4061
c1bad292f702,c05d1aa331c17138,4047f77e4493e852,405821068e59f78c,c05c43dfef2a94b3,4061
6dab19ef005e,c0393ded841cfda0,c05761f3eb302643,40561bb7dd6704ee,c05b65e993e6670a,4055
d21a6406294d,4043fd26d7553ddd,c0519a5dd59828ce,4044e3e32b2ab21a,402d061d60d615b2,403f
2025c9e6e185

X_hat_ss[120]:c0da766dae748521,40de14d893fccbd9,c0f9974e829035ee,c1039cd7c40332c5,40b
cd8d0c15efc40,40ee097edca030ff,c0afe778f53061ae,40973ddc8e557690,40c016c1fc034767,c0b
fdb9143f5cda8,40a7df276e71b5bd,409a2b626d540c5c,c0aeed205ae3b571,40ab06b772ad9cd9,c08
8c0eb9a016cc2,c098a6a9370f7748,40a319b5b6a8a191,c09a4d26011fceda,4054fa13980b4b6b,409
4297dfdfe2259,c098e169fb371f3c,408dfa87478d393a,4067e9144549328e,c08ebc9bb3c67b98,408
de0cb93fb3e0c,c07c5808eb3bcb2a,c06fa6b53559a3d1,4083ecfbbd1bc76c,c0800fc5d847d930,405
1cdd59ccfba52,40738b2341ff71ef,c0792c09961acbd3,4070063d36c6ce2f,4047339c17b484c1,c07
166e1a1e09988,4072124e932f9aaa,c060be745b95d7dd,c0631c3b2877ce64,40743566a857c511,c06
cae4eea90d636,4033df568fb59250,40707410304bf3b9,c071bed7240d6e61,406324918a3ad176,404
96639647b8fb5,c071b74a4ed8b64d,406ffc0377e8c977,c05a1d230e176acd,c05b0b332afa390d,406
c8a6147187469,c06526cd3c31a589,40520c9764d33c11,4043dedb9839ba16,c057a5f137dc850a,405
f1fb31b77bf12,c050fd89b5a71a61,c0283fa7577e00f6,404cc998a3ad192c,c051cca0ecf71c5b,c02
de94271b46e62,403f639066c2ef79,c03a5200b8089b51,40319e707815c424,4036562b1bc40940,c04
75017dbdcf7e5,40273b665862ddab,40435dc5cdfd0143,c03b500aa98c6964,403a0c4e079cfd60,c03
0927d9ef7af15,c03cec864d99302d,404d09ac617fdc69,c04c21c091bb1795,403d73723a0a2be4,400
0ebe3163e190d,c03bedf6ca03e92e,40409abc025d3e31,c046b3a7626d9f94,4025987064a46594,3fc
9dd06aa25f848,c0428499197736f5,403c8ac6c301d302,c00bb48becaa66d9,c0399c6d77935a98,404
5cf0d281c39e7,c022884d481d85f1,c03dadb6302a1646,4039f9a12ebb7a28,40006dd2d564fa32,c03
fedea4fedc869,40461d4beb03594c,c0107fcc8e0fbbec,c0465b4a9848adbd,4043b773f3ede011,c00
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ac0d253b46bfe,c04b8d414adb6403,40496e4c6402b113,40110c5092b27575,c04bc53fcdf6f089,404
7f3f781cced26,c043a145c3c4886e,403055d5d4bdfcac,404072249896b9cf,c04343d597bc1c2b,404
7c1f9ed99c82b,c02162b9b140a930,c0401ae469d49bc6,403e74639614a141,c042dee9350f2871,403
e0efb85b0ba08,402bd34038c6a1d4,c0388104552420a0,402d14715c845600,4014337cc6b4f43f,402
5a9f7ae99d1b4

x_hat_mdct[120]:3fecec2bcd9ab6f9,4006d9c386e81f6d,4000b0c6cd81c6e3,400a158f573dc4a6,3
ffd2b6cb955d2ae,c0052dad46081bfc,c01ef7e14bf7bd13,c030f8c42ddb9d82,c011aaf6c27f2065,4
012fd465c186987,401ff3fde089c77c,4000df631ae3641c,401bca73103b91b3,401e848ae7da8f9a,4
0120714ecf7f820,3ff20f9bfd39eb2d,3fe1b252c25e9d98,bff3b699ff7e24ae,402964d8950c5ef7,4
031ff855a80e2b6,4033ff542e44003b,40374f90b0c2bcc8,40410eef138101ad,403f9e8552e0d32e,4
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0480db1ffee8a6d,c051c7ca9070017c,c0554134f1dda178,c050213f81155b7a,c04ed355812f4b8a,c
04f0036c7eca67f,c04886ecadf55706,4015712ac0b4069d,c005c71f67a28d7d,c01947c6e2bec526,c
03cdfb2c53e5b19,c04c2836e6cdcfe8,c04dc6a4baa7a721,c0352f02316e1f66,c057c07cccac9adc,c
050eb3135b28a32,405322f3b08d5b68,4076b8e6f1debb16,406a22b36f9d8b98,4057129bee0e2556,c
0551d05f01d4d17,c06a0377511bc67f,c0680b49875ec88e,c079658850d8a2cb,c06b83d51ed19cbd,4
083a9a301912114,40a898552416b8e6,40b85a55c8cd12dc,40c25d1a9ef215f3,40c87439ac2f581d,4
0cde890cd0bdba7,40d1b43f0cf45bbe,40d4469d15f4d211,40d68b3258b53cb6,40d8aef63edcfaa1,4
0da75dfb0340377,40dbfe5342a9a08a,40dd63a7dc08099e,40de7882f9e46600,40df41ab6a9bd0b6,4
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0d428d6acc75188,40d1a7c695bbc382,40cdfc6d1d8283eb,40c85e5d27138ea1,40c262cc4ea79db2,4
0b896d267bdcd6c,40a83a186a1dd7e2,c056b97557bc2c83,c0aa14bc1546c5e9,c0b96d5bcf0a470b,c
0c2cab49c4b9d90,c0c8af4ff62f4780,c0ce6663c77204cd,c0d1dc4f374f60b5,c0d4636ecee72ad1,c

0d6ba9f94638aae,c0d8dc273dff06b9,c0dabb12c0a8e635,c0dc56927898d9ba,c0ddafe1012861b8,c
0debc8fdae12abb,c0df7551d4f6cf55,c0dfebb1445d174f,c0e00884af774444,c0dfe3d8b9d42ef9,c
0df687fb60152db,c0dea0e49ce32700,c0dd962e61e17426,c0dc376d166e3287,c0da96aa3994798d,c
0d8b5c129c61959

t_hat_mdct[240]:8000000000000000,8000000000000000,8000000000000000,8000000000000000,8
000000000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,8
000000000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,8
000000000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,8
000000000000000,8000000000000000,8000000000000000,8000000000000000,8000000000000000,8
000000000000000,8000000000000000,8000000000000000,8000000000000000,3fecec2bcd9ab6f9,4
006d9c386e81f6d,4000b0c6cd81c6e3,400a158f573dc4a6,3ffd2b6cb955d2ae,c0052dad46081bfc,c
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03826a000cc16e2,40318fdb419e83f6,40382b01b46c34d3,4035de46dc0659d7,40280b09faa310f0,4
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0554134f1dda178,c050213f81155b7a,c04ed355812f4b8a,c04f0036c7eca67f,c04886ecadf55706,4
015712ac0b4069d,c005c71f67a28d7d,c01947c6e2bec526,c03cdfb2c53e5b19,c04c2836e6cdcfe8,c
04dc6a4baa7a721,c0352f02316e1f66,c057c07cccac9adc,c050eb3135b28a32,405322f3b08d5b68,4
076b8e6f1debb16,406a22b36f9d8b98,4057129bee0e2556,c0551d05f01d4d17,c06a0377511bc67f,c
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frameN[1]:2
nbytes[1]:30
fs_idx[1]:1
BER_detect[1]:0
lastnz[1]:22
P_BW[1]:1
lsbMode[1]:0
gg_ind[1]:162
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num_tns_filters[1]:1
rc_order[2]:1,0
pitch_index[1]:72
pitch_present[1]:1
ltpf_active[1]:0
F_NF[1]:6
ind_LF[1]:17
ind_HF[1]:25
submodeMSB[1]:0
submodeLSB[1]:0
shape_j[1]:0
Gind[1]:0
LS_indA[1]:0
idxA[1]:2213651
LS_indB[1]:1
idxB[1]:1
tns_lpc_weighting[1]:1
rc_order_ari[2]:8,0
rc_i_1[8]:5,13,8,10,9,9,7,9
rc_i_2[8]:8,8,8,8,8,8,8,8
nbits_residual[1]:7
resBits[7]:0,1,1,0,0,0,1
zero_frame[1]:0
X_hat_q_ari[120]:4,-22,72,-408,-88,-35,46,-45,-19,-2,-4,5,3,3,-1,2,0,4,-1,0,-
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nfseed[1]:2998
X_hat_q_residual[120]:400e800000000000,c035d00000000000,4052140000000000,c07985000000
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X_hat_q_nf[120]:400e800000000000,c035d00000000000,4052140000000000,c079850000000000,c
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gg_off[1]:-127

rc_i_tns[8]:5,13,8,10,9,9,7,9

X_s_tns[120]:4050f30073603454,c0783e31f4c34f0b,409417ac566963ce,c0bc5cefe6d77b3d,c098
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X_hat_ss[120]:40ae29fbc488fffd,c0d5927bec8e0b02,40ee77963772b1cd,c10f38fd7674f47e,c0e
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